PURCHASE DESCRIPTION
FOR
AFPSL
QUANTUM HALL RESISTANCE (QHR) STANDARD MEASUREMENT SYSTEM

1.0 SCOPE: This purchase description identifies performance requirements for the Quantum Hall Resistance (QHR) Standard Measurement System in the U.S. Air Force Primary Standards Laboratory (AFPSL) as an absolute measurement reference for resistance. It shall be a high-performance system such that it may be used to measure very low resistances to very high resistances and make comparisons to a Sample Probe for the Graphene QHR Sample Chip from National Institute of Standards and Technology (NIST). This system shall be capable of measuring a variety of resistive devices in four terminal modes. This system shall have the ability to perform automatic data acquisition, mathematical and graphical data analysis, data display of results, and print data results and data storage of results. This system shall improve and expand the U.S. Air Forces capability to measure the described parameters. The system shall support the Measurement International 4304-1kAF Resistance Standard. This item shall replace the Measurement International 6800C QHR System. Listed in this purchase description are the Air Force minimum functional requirements which are to be satisfied. Proposals offering an item against the requirements of this purchase description will be evaluated for acceptability.

2.0 PERFORMANCE REQUIREMENTS: This measurement system shall have the ability to perform turn-key measurements of resistance devices at any point within the measurement range of 100 mΩ to 13 kΩ. Turn-key measurements represent the ability of the system, after configuration setup, to make a non-stop resistance measurement or measurement sequence of resistors at a single value without the need for manual intervention or additional laboratory equipment. This process will result in a turn-key measurement result. A turn-key measurement result will be displayed on a flat-panel type monitoring device and will be storable and transferable to standard internal memory/storage devices. All equipment necessary to make this system operate as described above must be provided by the contractor. A resistance device will be defined as any electronic device or instrument that exhibits electrical resistance when a Direct Current is applied to it. This would include, but is not limited to, Standard Resistors. These items shall be supportable with this QHR Standard Measurement System without limitation due to lack of capability of the QHR Standard Measurement System. The QHR Standard Measurement System shall be further capable of performing all measurements needed to ensure accuracy of the QHR Sample (the absolute resistance reference relating to the Von Klitzing constant).

2.1.1. GFE EQUIPMENT: The Air Force owns government furnished equipment (GFE) existing in the current 6800C system which may be used in the new system. Listed below is that equipment.

PART NUMBER	DESCRIPTION	QTY
4304-1kAF	Resistance Standard	1
6020Q	QHR Bridge	1
4220A	Scanner, 20 Channel	1
ECODRY 40 PLUS	Vacuum Pump, Turbo	1
IDP-15	Vacuum Pump, Scroll	1
SMS 120C	Magnet Power Supply	1

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MODEL 350	Temperature Controller	1
MODEL 218	Temperature Monitor	1
RGC-150	Vacuum Gauge	1
F-70H	Cryocooler	1

2.2. RESISTANCE:

2.2.1. SYSTEM MEASUREMENT RANGE: Minimum not greater than 0.1 Ω to a maximum not less than 13 kΩ (transferable from the QHR Sample via a resistance ratio bridge provided by the contractor).

2.2.2. SYSTEM MEASUREMENT UNCERTAINTY: 0.1 Ω ±0.02ppm, 1 Ω to 14 kΩs ±0.015 ppm, and 14 kΩ to 100 kΩ ±0.05 ppm, relative to Standard used. Accuracy QHR value to 1 kΩs Standard ±0.015 ppm.

2.2.3. LINEARITY: ±0.005 ppm of full scale. Full scale will be defined here and pertain to all references of such as, the maximum value of each of the ratio ranges noted in paragraph 2.3.1.

2.2.4. REPEATABILITY RESISTANCE TEST CURRENT RANGE: 10 µA to 200 mA, continuously variable. This represents the total range of currents that a Standard or Unknown resistance may be subjected to or measured with using this measurement system.

2.2.5. HYSTERESIS DISSIPATION: This measurement is taken to verify that there is no dissipation in the 2-Deg. When the 2-Deg is quantized V_{xx} should go to 0 and should be less than ±0.02 ppm of V_{xy}.

2.2.6. DRIFT CONTACT RESISTANCE: Less than 1 Ω.

2.2.7. RELIABILITY CURRENT REVERSAL: Test current supplied to the Standard and/or Unknown resistances shall be reversible and switchable throughout the measurement range. Current Reversal shall be selectable from 4 seconds to not less than 1000 seconds. Every attempt should be made to minimize the need for manual intervention to achieve current reversal.

2.2.8. WARM-UP TIME: Time to Stated Accuracy: After a maximum of 8 hours power ON warm-up, in the required operating environment, all parameters shall operate to full specification.

2.2.9. TEMPERATURE COEFFICIENT: Shall be less than ± 0.01 ppm/°C

2.2.10. RESOLUTION: ±0.001 ppm of full scale throughout the measurement range. This parameter shall be selectable from front panel control(s) and from an independent programmable controller.

2.2.11. AUTO BALANCING: This system shall be capable of automatically balancing the current through the primary and secondary of the ratio transformer (resistance) bridge. This

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balance will produce zero flux. This system shall perform this function throughout the measurement range without the need for manual intervention.

2.3. MATRIX SCANNER: In order to speed up total measurements processes, a matrix scanner is required to do multiple Standard and multiple Unknown comparisons. Any error contribution from Matrix Scanner(s) shall be included in the Uncertainty Analysis.

2.3.1. THERMOELECTRIC POTENTIALS: Typically, less than 30 nanovolts, 100 nanovolts maximum

2.3.2. RELAY CONTACT RATINGS:

2.3.3. LIFE: Greater than 10,000,000 cycles.

2.3.4. CONTACT RESISTANCE: Less than 0.05 Ω.

2.3.5. VOLTAGE RATING: The maximum switching voltage shall not be less than 100 volts DC.

2.3.6. CURRENT RATING: The maximum switching current shall not be less than 150 mA.

2.3.7. LEAKAGE RESISTANCE: Greater than 1 part in 10 to the 11th Ωs.

2.3.8. INPUTS: There shall not be less than 10 switchable input channels total. Each input channel will have a minimum of 4 input connectors of insulated binding post type that as a minimum will accept spade lugs and wire. 2 each for "current" and 2 each for "potential", all with equivalent, or better, properties to that of low thermal tellurium copper. The QHR System input channels shall have future expansion capability by addition like Matrix Scanner(s) without the need to re-program the System Controller source code.

2.3.9. OUTPUTS: Four-terminal of insulated binding post type that as a minimum will accept spade lugs and wire, all with equivalent, or better, properties to that of low thermal tellurium copper.

2.3.10. PROTECTION: This scanner shall have internal protection circuits that will prevent damage to the Standard or Unknown resistance as result of improper channel selection.

2.3.11. CHANNEL SELECTION: Channel selection shall be accomplished by manual front panel controls and by independent programming via a standard IEEE-488.2 format interface to a programmable process controller.

2.4. RATIO: This system shall be provided with the ability to make ratio type measurements.

2.4.1. RATIO RANGES: A minimum of the following ratios (Rs:Rx) shall be provided for ratio measurements. 1:1and 10:1. In addition to this, an appropriate ratio of near 13:1 shall be provided that will be suitable for direct comparison of the QHR Sample to a 1 k Ω resistance standard. Any ratio corrections that are required for operation of the system shall be provided by the contractor in table format with an associated ratio correction uncertainty along with a

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(type)written methodology for determination and verification of these corrections and along with a list equipment and specifications required to do so. The contractor shall further recommend a periodic interval to which the verification should be performed. Any error contribution from ratio device(s) shall be included in the Uncertainty Analysis (2.19.4).

2.4.2. RATIO STABILITY: Shall be no worse than ±0.01 ppm/yr.

2.4.3. RATIO UNCERTAINTY: Shall be no worse than ±0.02 ppm.

2.5. DATA ACQUISITION: This system shall have the capability to perform automatic data acquisition throughout the measurement function(s) and range(s). Any additional data and programs not specifically identified hereafter, yet required to perform the stated tasks, will be provided by the contractor. Proposals shall include estimated timelines for start-to-completion of these tasks.

2.5.1. MEASUREMENTS: Whenever possible, the contractor shall maximize the use of single keystrokes to perform multi-layered processes. This system shall have the ability to measure multiple test items against multiple standards in a simultaneous sequence. We refer to this as a N by M measurement scheme. Where N represents a finite number of Standards and M represents a finite number of Unknowns.

2.5.2. MEASUREMENT OPTIONS: The following minimum features shall be available as selectable and programmable options:

1. Time Delays for measurements
2. Number of Test Points to be measured
3. Number of measurements to be made on a Test Point
4. Number of Test Runs
5. Time between Test Runs
6. Number of Standards used
7. Number of Test Items measured
8. Test Currents
9. Test Voltages
10. Standard Uncertainty
11. Test Item Uncertainty
12. Repeat Test Point function
13. Standard Deviation Limit Option (feature used to terminate a measurement sequence, if desired stability is achieved prior to the total Number of Test Points (2) being taken occurs.

2.5.3. MEASUREMENT RESULTS: Measurement results shall be displayed in real-time via a Flat-Panel type monitoring device. As a minimum the following parameters will be displayed as measurements results:

1. Test Item Identification (with minimum of Job Control Number (JCN), Part Number (P/N), Serial Number (S/N) and Identification Number (ID))
2. Standard Identification (with minimum of Part Number (P/N), Serial Number (S/N) and Identification Number (ID))
3. Nominal Value (Ωs)
4. Number of Measurements made per test point

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5. Measurement Current
6. Measured Value (Ωs)
7. Deviation from Nominal Value (±ppm)
8. Mean Value of Measured Results (Ωs)
9. Standard Deviation of Measured Results (1-sigma)
10. Real-time calculation of At-Time-of-Measurement Relative Uncertainty in ±ppm of Measured Value (as minimum Root-Square-Sum of Standard Deviation, all other system Type A and all other system Type B uncertainties and displayed in terms of Coverage-Factor of one (K=1))
11. Real-time calculation of At-Time-of Measurement Absolute Uncertainty in ±ppm of Measured Value (as minimum Root-Square-Sum of Reference Standard absolute uncertainty (as automatically retrieved from Reference Standard data file), Standard Deviation, all other system Type A and all other system Type B uncertainties and displayed in terms of Coverage-Factor of two (K=2))
12. Graphical Representation of Accumulated Measurements in the form of an X-Y plot
13. Operator Identification
14. Test Uncertainty Ratio (TUR)

2.5.4. MEASUREMENT INTERFACING: This system shall maximize the use of electronically inter-faceable components. The preferred format of interfacing is the IEEE 488.2 Standard. This system shall also maximize the use of programmable components to perform automated measurements via the programmable system controller, which must be supplied with this system.

2.6. MATHEMATICAL ANALYSIS: This system shall have as minimum the ability to provide trend analysis through the use of Least Squares type of regression analysis. It shall have the ability to predict future characteristic values from a best fit curve. This will be based on the analysis of data stored in historical data files internal to the system and from a CD. The results of mathematical analysis shall be presented in both numerical and graphical forms. The system shall have the ability to crop out sample sets of data from a given data population and display the selected sample data as a Measurement Result. The system shall also have the capability to identify and, if operator desired, remove outliers from the displayed/printed Measurement Result.

2.7. PRINTED RESULTS: As a minimum the following parameters shall be selectively printable to the Flat-Panel type monitoring device and to a laser quality letter and graphical hard copy paper printer. The monitor will be provided with this system.

1. Measurement Results
2. Measurement Data Files
3. Historical Data Files
4. Mathematical Analysis

2.8. STORAGE OF RESULTS: This system shall have the capability to store data to internal memory and transferable media such as CDs. This data shall also be storable in an electrical format that can be imported/exported to MS Excel spreadsheets from the internal memory and from the CDs. Each "Data Element" of a stored "Parameter" shall have some easily understandable unique identifier or label stored in association with it such that, when

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imported/exported and viewed on the monitor device, the user can comprehend what the data represents. This system shall be further capable of performing the import/export function by a single keystroke or action. If necessary, the contractor shall provide an "Interpreter" or raw data "Viewer" utility program function for viewing all stored data. All electronic data "Files" shall have a unique and comprehendible "Filename".

2.8.1. STORABLE PARAMETERS: The following list identifies the minimum provided and storable parameters.

1. Measurement Results (2.4.3, with the addition of the individual element(s) of Type A and Type B uncertainties used to determine real-time Absolute and Relative Uncertainty (at K=1) and the uncertainty of the Reference Standard used, with an associated Coverage-Factor (K=value). All data required for determination of a measured value and its associated uncertainty shall be stored such that, for Quality Assurance and Evaluation purposes, it can be retrieved and hand-calculations can be made to verify these to be the correct result(s))
2. Measurement Data Files (all other)
3. Historical Data Files
4. Mathematical Analysis
5. All associated dates

2.9. QHR SAMPLE:

2.9.1. PLATEAUS: Shall be able to operate with the plateau present in standard NIST Graphene QHR Chip.

2.9.2. UNCERTAINTY: ±0.015 ppm, absolute.

2.9.3. STABILITY: ±0.01 ppm, absolute.

2.10. SUPER-CONDUCTING MAGNET:

2.10.1. FIELD STRENGTH: As needed to achieve proper QHR Sample operation

2.10.2. CRITICAL TEMPERATURE: As needed to achieve proper QHR Sample operation.

2.10.3. CRITICAL FIELD LEVEL: As needed to achieve proper QHR Sample operation.

2.10.4. CRITICAL CURRENT: As needed to achieve proper QHR Sample operation.

2.11. MAGNET POWER SUPPLY: Characteristics such that the Super-Conducting Magnet should not exceed critical temperature, critical current, critical field levels or to create a magnetic "Quench". Internal system safety measures shall be in place to prevent these conditions from occurring.

2.11.1. CRYOGEN-FREE QHR: Shall have a Sample Probe capable of housing a NIST Graphene QHR Chip.

2.12. CRYOGENICS: Range of cryogen-free magnet systems with sample space temperatures ranging from 3 K to 300 K and magnetic fields up to proper QHR Sample operation.

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2.13. TEMPERATURE SENSOR, MONITOR and CONTROLLER: As needed to measure, monitor and control the QHR Sample temperature shall be provided by the contractor.

2.14. VACUUM PUMP: As needed to achieve proper QHR Sample operation.

2.15. RESISTANCE BRIDGE: As needed to achieve 2.0.

2.16. CRYOCOOLER: As needed to achieve proper QHR Sample operation.

2.17. UNCERTAINTY ANALYSIS: The total Absolute Uncertainty for all functions shall be the worst case Root-Square-Sum of Reference Standard absolute uncertainty, standard-deviation, stability, temperature/power coefficients (where applicable), all other system Type A and all other system Type B uncertainties and displayed in terms of Coverage-Factor of two (K=2)). An uncertainty analysis of the system total Absolute Uncertainty(s) shall be provided by the contractor in accordance with the below format for transfer from the QHR Sample to each of the following decade values, 10k, 1k, 100, 10 and 1 Ω.

Sample Uncertainty Analysis Template

Nominal Resistance(Ω)	1000						
Error Component	Value in ppm	Distribution Type	Divisor	Divisor Value	Adjusted Component	Value (k=1)	Squared Value
TYPE A							
Short Term Repeatability	0.01	Normal	1.0	1.0	0.0100	0.0100	0.0001
Long Term Stability	0.10	Normal	1.0	1.000	0.1000	0.1000	0.0100
Standard Deviation	0.01	Normal	1.0	1.000	0.0100	0.0100	0.0001
TYPE B							
Feed down from QHR Sample (Transfer Standard)	0.02		2.0	2.000	0.0100	0.0100	0.0001
Bridge Resolution	0.001	Rectangular	√(3)	1.732	0.0006	0.0006	0.0000
Temperature Effects (±1 °C)	0.10	Rectangular	√(3)	1.732	0.0577	0.0577	0.0033
Transfer Uncertainty of Bridge	0.02	Rectangular	√(3)	1.732	0.0115	0.0115	0.0001
						Sq-Sum	0.0138
				U = Square-Root-Sum (k=1)			0.1173
		Uncertainty Total (ppm)			Expanded U = (k=2)		0.23

Table 1

(*contains sample data only, not representative of actual system performance, actual data should represent max allowed uncertainty, more, less or different Error Components may be required*)

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3.0 FUNCTIONAL REQUIREMENTS:

3.1. POWER: 120 VAC ±10%, 60 Hz ±3%.

3.1.1. CRYOCOOLER COMPRESSOR:

3.1.1.1. LINE POWER: 3 Phase 200 V, 50/60 Hz 7.5-7.8 kW at 60 Hz 32 Amp rated

3.1.1.2. SETTABLE TEMP RANGE: 5-25 °C (41-77 °F)

3.1.2. COOLING WATER CHILLER: System shall be supplied by a 9-kW chiller at ~19 ºC.

3.2. DIMENSIONS: The complete system shall be capable of fitting on floor space not greater than 3 ft by 6 ft and shall not require being stacked more than 6 ft high. Individual components shall be capable of fitting into standard 19-inch rack width.

3.3. WEIGHT: 1000 lb. maximum.

3.4. RACK MOUNTING: Wherever possible maximum use of rack mounting is required for this system, the system shall be provided with all necessary hardware/accessories to enable maximum allowable rack mounting of its components in a standard 19-inch rack, including rack flanges and handles. The rack shall be portable by means of swivel and lockable caster wheels mounted on the bottom of the rack. Such a rack shall be provided by the contractor. The rack shall have a retractable tray such that the System Controller can be "stowed away" during non-use and will serve as a "desk-top" space for same during normal operation.

3.5. ENVIRONMENTAL:

3.6. OPERATING TEMPERATURE RANGE: The system shall perform to full specifications at 22.8 °C ±3.3 °C.

3.7. OPERATING HUMIDITY RANGE: The system shall perform to full specifications from 20 to 50 % RH.

3.8. STORAGE TEMPERATURE: -20 °C to +60 °C.

3.9. STORAGE HUMIDITY: 15 to 80% RH.

4.0 MECHANICAL & PHYSICAL REQUIREMENTS:

The system of this purchase description shall meet the following requirements:

4.1. COMMERCIAL PARTS: Commercial parts and materials shall have properties consistent with a precision laboratory instrument.

4.2. DESIGN AND CONSTRUCTION: The equipment will be designed and constructed of materials that meet the requirements of this specification and in accordance with the best commercial practices for industry approved equipment. It will be the contractor's responsibility to assure the government that such design objectives as reliability, accuracy of operation,

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maintainability and ease of operation have been given due consideration in the manufacture of this equipment. All parts such as shafts, bearings, regulators, switches, controls, etc. shall have proper clearance and adjustments. They shall so work together that the equipment will supply the rated requirements without unnecessary strains, vibrations and overheating. They shall be able to withstand the conditions met in shipping, storage, installation and services. All material and parts of this equipment shall be capable of withstanding environmental testing requirements of this specification.

4.3. SELECTED COMPONENTS: Matched and selected components shall be kept to an absolute minimum. Use of specially built non-standard components other than switches and similar individual assemblies shall be avoided whenever possible.

4.4. METALS: Metals shall be of corrosion resistant type or suitably treated to resist corrosion due to atmosphere conditions likely to be met in storage, services or transportation. Dissimilar metals in intimate contact should be kept to a minimum.

4.5. INPUT TERMINALS: It is most desirable that all input terminals and connectors be physically located to the rear panel of all system components.

4.6. SELF-TEST: This system shall have the ability to self-test all measurement ranges and functions and verify them to be in or out of specification. This determination shall be displayed and recorded in memory for future reference and comparison. Self-testing shall require no external standards or devices. Program(s) needed to perform system functional test and operational verification shall be provided by the contractor.

4.7. CONTINUOUS OPERATION: After the required warm-up period, the equipment shall meet the specifications of this purchase description and shall not display any intermittent characteristics or overheating for an extended period of not less than 120 hours (5 days) of continuous operation.

4.8. INTERFACE CABLES: The contractor shall provide a minimum of one complete set of interfacing cables that will connect all communicable components simultaneously.

4.9. ANCILLARY/ACCESSORIES: Any-and-All ancillary equipment/items and accessories (not otherwise specified) needed to perform as described shall be provided by the contractor. This would include, but not limited to, special tools, cables, fixtures, programs and Standards.

4.10. LICENSING: Where licensing issues apply to any part of the QHR Standard Measurement System, such licensing and associated documents shall be obtained and provided by the contractor.

5.0 WORKMANSHIP: Workmanship shall be first class of neat general appearance in compliance with standard commercial practices. The standards of workmanship shall be such that the instrument complies with the requirements set forth in this purchase description.

6.0 SAFETY: Equipment shall be designed such that it will not be of any hazard to itself or to any person operating it using reasonable precautionary procedures.

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7.0 WARRANTY & TECHNICAL SUPPORT:

7.1. A warranty & technical support normally offered by the vendor for this product shall be provided with the unit.

8.0 CONTROLLER REQUIREMENTS:

8.1. **CONTROLLER:** A (Laptop or Desktop, specify if needed) controller is required that can efficiently operate under Microsoft Windows 11 Long-Term Servicing Channel (LTSC) 64-bit operating system. All major components of the system shall be commercially available and fully supportable by commercial sources. Where specific brands are identified in this specification, no substitutes are allowed without prior approval from the AFMETCAL. The Controller shall meet or exceed Microsoft Windows 11 LTSC hardware requirements.

8.2. **MEMORY:** Minimum 8 GB system Memory

8.3. **USB:** Minimum of two integrated USB 3.0 ports not being utilized by other components

8.4. External video support

8.5. **DISPLAY PANEL:** 15-inch (diagonal) or larger viewable display

8.6. **HARD DRIVE:** Minimum 120 GB Solid State Drive

8.7. **DVD-ROM:** Internal or External DVD ± RW or Blue-Ray

8.8. **OPERATING SYSTEM AND SOFTWARE:** All software must run under Microsoft Windows 11 LTSC 64-bit operating system. All software shall run Windows 11 as a non-elevated user. All software must run with multiple Windows 11 user accounts. It will be supplied with Microsoft Word and Excel, latest release with a non-renewable license.

8.9. Lenovo brand controller will not be acceptable.

8.10. **ADDITIONAL HARDWARE:** Additional hardware required to make this system function as identified by this purchase description shall be required.

9.0 SOFTWARE/FIRMWARE REQUIREMENTS:

9.1. **SOFTWARE/FIRMWARE IDENTIFICATION:** All software/firmware used in conjunction with instrument shall be identified by Name, Version, and Date; to be displayed upon startup or located in an "About" menu in the software/firmware.

9.2. **SOFTWARE/FIRMWARE WARRANTY:** The contractor shall warrant that the software/firmware product meets this purchase description, is free from defects in design and operation, and will perform to stated specifications within this purchase description for the length of the equipment warranty.

9.2.1. The contractor (at no additional cost) shall update or replace the software/firmware product as necessary to correct any deficiencies identified in the software/firmware. Replacement

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software/firmware shall meet or exceed the requirements in this purchase description, shall not require additional training to operate, and shall be warranted for the remainder of the equipment warranty.

9.2.2. The contractor shall bear transportation costs for all replacement products.

9.2.3. The contractor (at no additional cost) shall provide technical support for normal software/firmware usage, clarification of documentation, and resolution of software/firmware problems. The contractor shall have multiple methods for convenient contact of Technical Support. Contact methods may include but are not limited to on-line or telephone.

9.3. INTERCHANGEABILITY:

9.3.1. When software/firmware upgrade is anticipated by a manufacturer during the life of this contract, the contractor shall contact AFMETCAL for concurrence. If AFMETCAL concurs with the proposed upgrade, all previous units delivered under this contract shall be updated to this upgrade.

9.3.2. All software/firmware provided under this contract shall be at the same version, revision, and revision date at the completion of the contract.

9.3.3. Software/firmware shall be updateable by AFMETCAL through communication protocols with Windows-based PC or external drive. Instructions on how to perform the update and any required communication software shall be provided.

10.0 OPERATOR'S MANUAL: Documentation shall be developed suitable for use as reference material by AFPSL technicians. Documentation shall be separated into general manuals on system operation, theory of operation, troubleshooting, etc., and into specific procedures for calibrating 4304-1kAF standards. Vendor format is acceptable.

11.0 INSTALLATION: Thirty (30) days' notice is required for installation at AFMETCAL. The contractor shall be responsible for setting up the system on site to assure the system is fully functional and meets the requirements of this purchase description. Upon completion of installation the contractor shall demonstrate and fully test the delivered system. AFMETCAL shall perform acceptance testing after installation. Additional documentation to be delivered with the final working system shall include a Troubleshooting Guide, mechanical and electrical schematic diagrams for items designed under this project, and a parts/components list.

12.0 TRAINING: Onsite training shall include any background needed in theory, operation, calculations, etc., and shall include formal objectives below.

12.1. OBJECTIVES: Instruction of successful operation of the system, procedures for calibrating the 4304A-1kAF standard listed in this purchase description, information on maintenance of the system, troubleshooting for common issues and errors, provided training/informational materials in modifiable electronic format, and an in-person demonstration as planned and scheduled for up to ten (10) personnel.

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13.0 ENVIRONMENT, SAFETY, AND OPERATIONAL HEALTH: A combination of the system manual, other documentation, and/or the system itself shall identify potential environment, safety and operational health hazards and how they are mitigated when the design itself cannot mitigate them. This will be accomplished through stating the hazard and accompanying mitigation through the use of safety devices, use of warnings, or use of special operational procedures to counter such hazards.

14.0 TESTING: The item will be inspected and accepted at a destination specified elsewhere in this contract. The item will be checked with test equipment and parameters equal to or better than those required assuring specified performance requirements are met. Test equipment has first echelon certification directly traceable to the International System of Units through the National Institute of Standards and Technology (NIST) or other AFMETCAL approved sources where required. Tests will be performed to ensure the item meets or exceeds all the requirements of this purchase description. Such testing does not relieve the contractor of performing all inspections and quality control checks at the point of fabrication, as necessary, to ensure performance as specified.

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