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From: Director, CSIR-NPL
Tender No. 14-VI/PKS(1144)23PB/T-120

Dated: 31.10.2023

CORRIGENDUM

With reference to NPL's Global Tender ID: **2023_CSIR_731681_1**, Pre-Bid Conference (PBC) was concluded on 27.10.2023 for "Quantum Hall Resistance Standard (QHRS) System". Consequent upon the outcome of PBC, **some changes have been made in the technical specification of captioned tender. Revised specifications are as follows:**

QUANTUM HALL RESISTANCE STANDARD (QHRS)

SCOPE OF THE SYSTEM	Fully automated Primary Resistance Standard (Quantum Hall Resistance Standard, QHRS) System with all accessories for doing Quantum Hall Resistance (QHR) and Resistance Ratio measurements having measurement accuracy of 0.015 ppm or better.
TECHNICAL SPECIFICATIONS	The detailed specifications of each item of the Quantum Hall Resistance Standard (QHRS) System are listed below.

S. No.	Item Description
1	**12 Tesla Superconducting Magnet System** with compatible cryostat comprising of the following items **(i)** Solenoid-based 12 Tesla Superconducting Magnet with compatible bipolar four quadrant programmable magnet power supply having quench detection/protection circuit. **(ii)** The magnetic field homogeneity should be better than 0.1 % having uniformity over 1 cm^2. **(iii)** Integratedand compatible LHe level sensor with readout. **(iv)** Variable temperature insert (VTI) having complete wiring for QHR/magnetotransport measurements, temperature sensors, heater, etc., and the compatible cables for connecting to the temperature controller, the LHe level sensor, DCC bridge, etc. It must have **(a)** 12-pin TO8 shocket and provision for plugging in a 12-pin TO8 holder having QHR samples for measurements. **(b)** A compatible heater assembly to vary the temperature in the range 1.3 - 300 K. **(c)** Compatible temperature sensors to cover the complete range from 1.3 - 300 K. **(d)** Provision for doing QHR measurements using a single QHR sample as well as

	intercomparison of two QHR samples. **(e)** Compatible cryogenic temperature controller to control and measure the temperature in the range of 1.3 - 300 K. **(v)** Oil-free/Dry mechanical scroll pump with all accessories/gauges to achieve an operating temperature of ~ 1.3 K at the sample.
2	**Fully Automated Room temperature DCC bridge** with compatible software for various QHR (Vxx, Vxy, R_C, dissipation in micro and nanovolt ranges, etc. and resistance ratio (QHR (i=2 plateau):1 kOhm, 10:1 and 1:1) measurements **(i)** Having measurement ratio for QHR (i=2): 1000 Ohm comparison (from GaAs-AlGaAs based Heterostructure and Graphene-based, QHR devices) directly to 1 kOhm. **(ii)** Having a measurement ratio of 10:1 for scaling up and down in decades in the range of 0.1 Ohm to 100 kOhm **(iii)** Having a measurement ratio 1:1 for measuring the small value of resistors. **(iv)** Having uncertainty ±15 ppb or better. **(v)** Having a self-calibration mechanism for parameters such as ratio error for different winding turns. **(vi)** Compatible software for various measurements. **(vii)** DCC bridge must be calibrated by an NMI(e.g., NIST-USA, PTB-Germany, NRC-Canada, METAS-Switzerland, NPL-UK, etc.). Certificate and details of uncertainty analysis should be provided or mentioned in relevant documentation. Software support and upgradation should be provided for ~ 10 years after installation/commissioning. **(viii)** 12 Nos. of four terminal, low resistance shielded cables of length 5 meters each for doing QHR/ratio measurements.
3	**Automated Low thermal Matrix Scanner** (Min. 10channels and 4 terminals) for scaling of resistors from 0.1 Ohm to 100 kOhm.
4	**QHR devices** with standard 6-8 contacts for transverse and longitudinal measurements. **(i)** GaAs-AlGaAs based Heterostructure, the carrier concentration should be such that (a) perfectly quantized i=2 plateau in resistance quantization appears at B > 7T (e.g., 7-9T) at 1.3 K and (b) corresponding to the center of the plateau the longitudinal resistivity has to be less than or equal to ~20 micro Ohm-cm or less at 2K. **(ii)** Graphene-based, the carrier concentration should be of the order of 2×10^{11} cm^{-2}or lower with mobility of the order of ~ 10^4 $cm^2V^{-1}S^{-1}$ or better such that i=2 plateau in resistance quantization appears at B > 3T at 4.2K and B > 2T at 1.5K. **(iii)** Both QHR devices should be mounted on separate TO8 holders **(iv)** Both the QHR devices must be calibrated by an NMI. The detailed protocol/analysis and data for device characterization, i.e., device type (n or p), carrier concentration, mobility, longitudinal resistance, transverse resistance, dissipation on the plateau, plateau width, measurement temperature, contact resistance (less than 0.1 Ohm), etc. must be provided. The OEM should share the above details prior to the shipment of the QHRS system.
5	**Standard resistors of nominal value** 1 Ohm, 100 Ohm, and 1 kOhm with calibration from an NMI with details of uncertainty.
6	**SS Liquid He-transfer line to transfer LHe** from storage dewar to QHR Dewar with all necessary connections/plugs should also be supplied.
7	**A data acquisition, storage, and analysis system with the latest licensed Windows operating system and licensed** MS Office with QHR measurement and analysis software must be provided. A multifunctional(print, copy, and scan) laser duplex printer having wifi compatibility with a print speed better than 30cpm, scan speed of up to29ppm,and resolution of 4800 x 1200 dpi should be provided with the QHRS system. All compatible interface

	cables, connectors, and other accessories must be provided with the QHRS System for performing Automatic QHR and Resistance Ratio Measurements. A perennial license for all the software and their backup must be provided.
8	**The following accessories/spares should be supplied with the QHRS system** **(i)** Multistrand wire rolls of different colors similar to that which have been used in the internal wiring of the VTI (QHR probe). **(ii)** TO8 holder (two nos.) similar to that mounted on the QHR probe. **(iii)** 4-terminal low resistance shielded cable of length ~ 50 mts. **(iv)** Spare cable with complete wiring to connect QHR probe to DCC bridge. **(v)** Spare protection fuses for each component (min. 5 each).
9	**(i)** The complete system must be verified by system verification/evaluation by NMI and a duly certified report must be provided. **(ii)** The vendor (OEM/Indian Authorized Distributor) should provide details (PO copies and installation certificates) of at least 2 Nos. of NMIs/ other users where the system has been delivered, and operational for the last 5 years. **(iii)** Detailed method and analysis of measurement uncertainties in accordance with the ISO/IEC 17025:2017 should be provided when the system is used as (i) a primary resistance standard and (ii) a measurement system for an unknown resistor in the range of 0.1 Ohm to 100 kOhm. The source code of the above uncertainty analysis must be provided. **(iv)** OEM must ensure the availability of spares and provide free resistance measurement bridge software upgrades for the next ten years after the expiry of the warranty. **(v)** Pre-shipment operation, maintenance, and training of all measurement capabilities of system at OEM site to one of the user/scientist for 5 working days must be provided. **(vi)** Vendor (OEM/Indian Authorized Distributor) should demonstrate all the quoted capabilities at the NPL site and impart training for operation and maintenance to the users/scientists for 5 days and show all the measurement capabilities for QHR and Resistance Ratio measurements along with uncertainty analysis during commissioning of the System at CSIR-NPL, New Delhi. **(vii)** Complete measurement electronics, e.g., Bipolar four quadrant programmable magnet power supply, Cryogenic temperature controller, LHe level monitor, DCC bridge with low thermal matrix scanner should be rack mounted. **(viii)** All the power cords, connector, plugs, switches, etc. must be as per Indian standard. Manuals, specialized tools, spare parts (e.g. fuses etc.) and essential accessories for the operation and maintenance of the system. **(ix)** All the operation, maintenance and software manuals with supported documents comprising calibration certificates, technical details, literature, pictures and dimensions must be provided both in hard and soft copy for smooth operation and maintenance of the system. **(x)** A minimum five-year warranty should be provided from date of commissioning. **(xi)** All the electrical connections should meet Indian Electrical Standards, i.e., single phase, 220-240 V AC @ 50 Hz.

All other terms & conditions of said tender will remain the same.

Sr. Controller of Stores & Purchase

Minutes of the Meeting

Date: 27th Oct. 2023

Purchase File No. : 14-VI/PKS (1144)23PB/
Sub: Minutes of Pre-Bid meeting
Item: Quantum Hall Resistance Standard (QHRS) System
Venue:2nd Floor, Conference Room, Main Building, CSIR-NPL
Date and Time: Friday27th Oct. 2023 at 4:00 PM

The TSC meeting was held under the Chairmanship of Dr H K Singh, Chief Scientistto finalize the technical specifications for "Quantum Hall Resistance Standard (QHRS) System". The followingTSC members were present:

1. Dr. H. K. Singh, Chief Scientist, CSIR-NPL — Chairman TSC
2. Dr. S. P. Khanna, Sr. Pr. Scientist,CSIR-NPL — Member
3. Dr. T. K. Mandal, Chief Scientist,CSIR-NPL — Member
4. Dr. V. N. Ojha, Ex Chief Scientist, CSIR-NPL — External Expert
5. Dr. P. K. Siwach, Pr. Scientist, CSIR-NPL — Indentor (IO)

The Pre-Bid meeting was attended by Mr Amit Kushwaha and Mr Vinay Kr. Vijay from Measurements International LLP, Delhi representing Measurements International Ltd, Canada **(OEM)**. They presented the technical details of the QHRS System and put forth certain queries reading the specs.

The TSC deliberated over their queries/suggestions and modified the specifications accordingly. The modifications/changes are listed below:

(i) Oil-free/Dry mechanical scroll pump with all accessories/gauges to achieve an operating temperature of ~ 1.3 K at the sample. **[S. No. 1(v)]**

(ii) GaAs-AlGaAs based Heterostructure, the carrier concentration should be such that (a) perfectly quantized i=2 plateau in resistance quantization appears at B > 7T (e.g., 7-9T) at 1.3 K and (b) corresponding to the center of the plateau the longitudinal resistivity has to be less than or equal to ~20 micro Ohm-cm or less at 2K.**[S. No. 4(i)]**

(iii) Graphene-based, the carrier concentration should be of the order of 2×10^{11} cm^{-2} or lower with mobility of the order of ~ 10^4 $cm^2V^{-1}S^{-1}$ or better such that i=2 plateau in resistance quantization appears at B > 3T at 4.2K and B > 2T at 1.5K. **[S. No. 4(ii)]**

(iv) The vendor (OEM/Indian Authorized Distributor) should provide details (PO copies and installation certificates) of at least 2 Nos. of NMIs/ other users where the system has been delivered, and operational for the last 5 years. **[S. No. 9(ii)]**

(v) OEM must ensure the availability of spares and provide free resistance measurement bridge software upgrades for the next ten years after the expiry of the warranty. **[S. No. 9(iv)]**

The modified specifications are attached as **Annexure A**. The purchase section is requested to do the needful and upload the revised specifications.