INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

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Detailed Technical Specifications for Closed Cycle 12T superconducting Magnet refrigerator along with Measurement probes

Specifications for various components of the system:

a) VTI, Superconducting Magnet, Magnet Power Supply, temperature controller and basic probe: -

i) **Cryocooler and compressor:** System must have two stage pulse tube cooler with associated compressor, suitable semi-flexible gas lines and power cables. Cold head should be fitted with Cernox sensor on second stage and silicon diode sensor on first stage. Compressor should be water cooled.

ii) **VTI:** Variable-temperature insert with static exchange gas, sample cooling from independent closed-loop cooling circuit. The loop must be independent of sample space to avoid needle valve blockage during sample change process. Temperature range for VTI should be 1.5 K to 300 K and Sample space diameter should be minimum 50mm. Sample space should have relevant pressure gauge. Closed-loop cooling circuit should be fitted with a pressure gauge on the pumping line and auto needle valve or manual Valve for flow control. Cernox sensor and heater should be fitted on VTI heat exchanger

iii) Superconducting magnet and power supply: The system should have Integrated high field superconducting 12T magnet
Central field of magnet - 12 Tesla
Operating current (nominal) <= 120 A
Magnetic field homogeneity <= 0.1% total variation over a 10 mm diameter sphere (dsv)
Persistent mode switch should be fitted
Magnetic field stability in persistent mode <= 1.0 x 10E-4 relative/hour measured at 12 T

Magnet should have Cernox sensor fitted to the magnet assembly along with Magnet quench protection circuit, which should have Integral diode and resistor. Protection circuit should be within the cryostat.
12 Tesla vertical field superconducting solenoid magnet should have Persistent mode switch fitted along with following magnet power supply to run the magnet smoothly.

Magnet power supply must have Persistent mode switch heater control, with intelligent magnet quench detection. Current leads grounding cable with persistence Switch heater cable Configured to suit system magnet should be supplied with system. Magnate power supply should monitor the magnet temperature and the two temperature sensors fitted to the PTR cold head with additional sensor card and without need of additional electronics. Magnet power supply should come with configurational slots for future upgradation.
Magnet power supply should be Bi-polar, four quadrant magnet power supply.

Power supply should be highly accurate and stable, better than 2.8 mA current stability at 120 A at Low noise.
Power supply should have intelligent magnet monitoring and quench protection. Auto rundown allowing the magnet power supply to be programmed to run magnet down safely in event of over temperature or low cryogen levels.

iv) **Temperature controller**: configured with two temperature PID loops for independent control of the sample probe and variable temperature insert heat exchanger. Also should be configured with a pressure PID loop for closed-loop cooling circuit flow control.

Temperature control range 1.5 K to 300 K

Temperature control stability +/- 0.05 K

Temperature range < 378 K

Temperature sensor - Calibrated Cernox
Heater 50 Ω at 300 K

Should be Sample in gas compatible & Vacuum compatible

Temperature controller and magnet power supply should have suitable user interface for easy monitoring,

Temperature controller must be able to measure and control temperatures to below 250 mK with a precision of 0.1 mK.

Temperature controller Heater output should be 60 - 80 W per channel using a true constant voltage source for sensor excitation, preventing self-heating and allowing for high quality measurements at the lowest temperature.

Temperature controller should support all standard cryogenic sensors (ruthenium oxide, cernox, silicon diodes, platinum, thermocouple and RhFe).

Temperature controller should be Expandable and Customisation should be possible through the addition of plug and play expansion cards. The controller should be expandable at least 9 expansion slots (8 multi-function slots and a dedicated GPIB slot) which can be used to extend its capability.

Expansion cards should include additional temperature sensor inputs and heater Outputs, pressure transducer inputs, stepper motor drive allowing gas flow regulation and efficient use of helium flow in cryostats.

Temperature controller should operate at voltage single phase 100-240 VAC 50/60 Hz

v) **Basic sample probe:** The system should be supplied with a basic sample probe to check the performance of system along with probes for sample measurement. The basic sample probe should a sample in exchange gas, which should be electrically isolated from the rest of the system to enable separation of the measurement ground and the cryostat protective ground. Temperature

range probe should be 1.5 K to 300 K, fitted with Cernox temperature sensor and heater on the sample mounting block. Sensor and heater monitored and controlled by the temperature controller. Basic probe should have Experimental wiring of at least 12 twisted pairs of 0.1 mm diameter enamelled constantan wire and wire should terminating at solder pins just above the sample mounting block and 24 pin Fischer connector at the top of the probe.

vi) **Other requirements**: System should take approximately 30-40 hours from room temperature to 4 K with magnet and Standard sample probe cool down should take approximately 2hrs from room temperature to < 5 K.

System should operate uninterrupted for periods of more than four weeks without the need for maintenance operations. There should not be a liquid nitrogen cold trap requirement in the closed-loop cooling circuit.

System cool down from room temperature to < 4 K approximately 48 hours

Pulse Tube Refrigerator cooling power - Nominal second stage cooling power of at least 1.0 W at 4.2 K

Electrical power requirement - Single Phase 220V at 50Hz and Three phases 415 V 50 Hz

b) Mechanical Rotator probe: -

The measurement probe should have come with the sample cells and ceramic sample holders, which allow for maximum interchangeability and modularity whilst allowing for low-noise measurements. The probe should be capable of electrical transport and Hall Effect measurement from DC to midrange AC (few GHz), with facility of de-mountable sample holders for in-plane and out of plane measurements.

ESD protection must be provided in sample probe. The probe should be configured as sample-in-gas but also should have provision for it to be upgradable for sample-in-vacuum usage.

Heater and sensor should be mounted on probe.

Probe should have sample holder PCB with Sample cell and spring-loaded cold finger to provide additional cooling for the sample carrier. The sample holder's PCB should be made out of ceramics suitable for optimum thermal conduction and should supplied with lead less 20 pin cheap carrier along with ESD protection. A socket for a 20-pin LCC (Leadless Chip Carrier) should be provided.

A Pack of 100 Leadless chip sample carriers with 20 contacts and Seal area and die attach area should be isolated from all leads, gold plating, Non-magnetic, free from Nickel and Chromium and compatible with supplied sample holder should supplied with probe.

Mechanical rotator at least Single-axis, polar axis rotation should include one high-temperature Cernox temperature sensor and one heater on stage.

Sample holder should compatible with vertical sample holders

LCC20 should have 20 contacts non-magnetic with space 5.0 × 5.0 mm2

Temperature range < 378 K with Calibrated Cernox along with Heater50 Ω at 300 K with sample in gas compatible.

Rotation axis single-axis polar rotation

Rotation range 0∘ to 360∘

Rotation backlash < 1∘

Rotation speed < 3.6 ∘/minute at 300 K

Cell material gold-plated copper and polyamide-imide (Torlon)

Measurement wiring should be at least 19 twisted pairs

4 flexible coaxial cables should also be provided

c) Helium 3 Insert:-

Helium-3 sample-in-vacuum insert system should be compatible with 12T cryostat VTI and supplied with He3 gas. Insert diameter should be 50 mm.

The Sample should be accessible by removal of IVC at room temperature IVC should be vacuum sealed by means of a suitable mechanism, for example – by means of silicone sealant.

Insert should have more than 40 mm diameter for experimental wiring and the insert wired at room temperature with Fischer connectors, and temperature sensors like un-calibrated carbon sensor on the helium-3 sorb, un-calibrated ruthenium oxide sensor on the 1 K plate and the helium-3 pot, calibrated Cernox thermometer on the helium-3 pot with un-calibrated ruthenium oxide.

Insert should have at least experimental wiring 24 way Fischer connector and mating plug at room temperature with Nomex woven ribbon cable of 12 twisted pairs (24 wires) 0.1 mm diameter constantan wires with polyester insulation (or appropriate alternative), 25-way miniature D-type connector and plug on bottom of helium-3 pot.

Insert should have Experimental wiring on line-of-sight port as below:

1 off line-of-sight port to the sample space, minimum 6.0 mm clear internal diameter DN16KF flange at room temperature and Line-of-sight port with four S1 coaxial cables, 4 off flexible stainless steel coaxial cables wired to the helium-3 pot with SMB connectors at room temperature and Mating SMB connectors with grounded to insert should be supplied with system and flying leads at helium-3 pot.

Insert should be supplied with temperature controller for helium insert to control the temperature of sorb heater with control of sample temperature from base temperature 300mk to 300 K. temperature controllers should monitors all temperature sensors on independent channels Temperature controller should have capability to Controls auto needle valve on VTI along with connecting leads, Mains power cable, Diagnostic connecting cables.

Insert should be supplied with sliding seal for cold loading insert, clamp for holding sliding seal tube with Basic system spares kit.

Helium 3 Insert should come with universal docking interface attached to the bottom of the 3He pot and piezoelectric drive looms fitted to the insert and terminated at the universal docking interface.

Wirings should terminate at room temperature in a Fisher connector (mating connectors should be included)

Base Temperature: 300 mK for 40 hrs with no applied heat load

Cooling Power < 350 mK for 6 hrs with 50 μW applied

Temperature range: 300 mK to 300 K

For the above specification system should not require more than 3 Litres STP of He3

He should have Chemical purity > 99.99 %, Isotopic enrichment > 99.9 %

Insert should have Weight (kg) < 50 kg, insert length should not more than 1800mm
For sample change ceiling height should not be more than 3.5 - 3.7m

d) Accessories with system:

i) **Gas handling system:** System should be supplied with Manual gas handling system for the closed-loop cooling circuit, including manually operated valves, at least 10 m3/ hour oil-free circulation pump, helium gas storage tank with mechanical pressure gauge (tank should be supplied with helium gas filled) and trap with integrated heater for regeneration. The operation of the manual valves should be required only during initial set-up for system cool-down and for warm-up not all the time. System should be supplied with all thermometry connecting cables at least 10 m long and mains cables.

ii) **Baffle stick:** for variable temperature insert to fit at variable temperature insert when the sample probe is unloaded should be supplied with Basic system spares kit with all manuals and Safety instructions.

iii) **Sample change Kit:** System should be supplied with sample change kit including dry scroll pump and with all necessary fittings.

e) Appropriate Turbo pumping station with rotary backing pump and gauge.

f) Appropriate Water chiller suitable for system.

g) 20KVA UPS to run the system for at least 30 min backup.

Other requirements: -
The cryostat should be able to accommodate a range of ultra-low temperature inserts extending sample base temperatures to as low as 30-25 mK in future, with at least 40mm diameter experimental space.

Warranty: - all system components should have warranty of at least 1 year.