Specification of Superconducting Wavelength Shifter (SWLS)
This document describes the specification for the supply of following item:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Item</th>
<th>Quantity</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Superconducting Wavelength Shifter (SWLS)</td>
<td>1 unit</td>
</tr>
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Specification of Superconducting Wavelength Shifter

1 Introduction

Indus-2 is a 2.5 GeV, 300 mA, Synchrotron Radiation Source (SRS) located at Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India. In this storage ring electron beam is injected at 550 MeV from a booster synchrotron and then the energy is increased to 2.5 GeV in about 400 s. The horizontal beam emittance at 2.5 GeV is approximately 57 nm-rad. The critical energy of synchrotron radiation from its bending magnet is 6.235 keV. A 5 Tesla superconducting wavelength shifter (SWLS) with critical photon energy of about 20.8 keV is required to be installed in one of the straight sections in Indus-2 to extend the usable energy range of the synchrotron to about 80 keV for maximum electron beam energy of 2.5 GeV. This is proposed to be used for the existing Energy dispersive XRD beam line.

2 Scope of the contract

The scope of contract covers design, fabrication, testing, supply, installation and commissioning of a Superconducting Wavelength Shifter (SWLS) in Indus-2 storage ring at RRCAT. The SWLS shall be procured as a single turn-key functioning device and therefore shall include all the necessary components such as magnetic structure, electron beam vacuum chamber, cryostat with vacuum system, cryogenic system, cryogen transfer line, mechanical support structure, current leads, all the required power supplies, quench protection system, control, monitoring and interlock system with necessary instrumentation, software etc. The necessary jacks for precision movement and references (fiducials) for survey and alignment of the SWLS are also included.

i. The supplier shall arrange necessary equipment and measuring instruments required to certify the performance of the device.

ii. The supplier shall be responsible for the detailed design, manufacturing, factory acceptance tests, appropriate packaging of the equipment, purchaser’s Site Acceptance Tests of the SWLS including its installation and commissioning without electron beam in Indus-2 ring.

iii. The supplier shall be responsible to meet the requirements of this specification. The supplier shall also be responsible for all aspects of the performance of the device which covers magnetic, mechanical, cryogenic, vacuum, thermal, as well as safety aspects including respective testing and certification.

3 Bidder Qualification

The original manufacturers or their authorised representatives quoting on behalf of original manufactures are eligible to participate in the bid. However the purchase order shall be placed on the original manufacturer only to keep the original manufacture under direct involvement in technical discussions during project finalization and make the original manufacture responsible for post-contract obligations. In case the bid is from an authorized representative, a valid authorization letter from the original manufacturer shall also be enclosed along with agency agreement showing amount/percentage of commission authorized. Essential qualification criteria for the original manufacturers are as follows:
i. Supplier i.e. original manufacturer must have past experience of fabrication and supply of insertion devices and superconducting magnets for accelerator applications. The offer must accompany supporting documents showing supplier's capability and experience in the field of design, fabrication, testing (including magnetic characterization) of insertion devices and superconducting magnets for accelerator applications.

4 Time Scales

In the offer, supplier shall clearly mention the time schedule for submitting the Preliminary design report (PDR), Final Design Report (FDR), its approval by the purchaser, manufacturing schedule, characterisation, Factory Acceptance Test Schedule and delivery schedule. It is desired that the total time for delivery of SWLS should not exceed 18 months from date of placement of the contract.

The time scales for the purchaser’s site acceptance tests, installation and commissioning in the storage ring shall be decided by the purchaser in consultation with the supplier.

5 Requirements for Subsystems of SWLS

5.1 Magnet System

5.1.1 The SWLS will be installed in the long straight section-4 (LS-4) of Indus-2 storage ring. The maximum length available in the LS-4 for the complete SWLS is 2000 mm. Within this available length of 2000 mm, a fixed source point type wavelength shifter of five (5) poles shall be designed to keep the position of the radiation source point (electron beam position) fixed in the centre of the axis of SWLS at any excitation of magnetic field levels. The nominal on axis peak vertical field at the mid plane of the central pole shall be 5 Tesla. The magnet system shall be designed and tested for a maximum on axis peak vertical magnetic field of 5.5 Tesla. The complete available length of 2000 mm should be utilized optimally and efforts should be given to design the side poles and end poles suitably with lower magnetic field strengths as compared to the central pole to reduce the total radiation heat load.

5.1.2 It has been found in simulation that the integrated octupole and decapole components have significant effect on beam dynamics. Therefore care must be taken to minimize normal and skew integrated octupole within \( \pm 100 \) G/cm\(^2\) and normal and skew decapole components within \( \pm 100 \) G/cm\(^3\) and \( \pm 50 \) G/cm\(^3\) respectively at the design stage. The SWLS must satisfy the following parameters as listed in table 1.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Parameter</th>
<th>Requirement</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Type of Wavelength Shifter</td>
<td>Fixed source point type i.e. the position of radiation point remains fixed in the centre of SWLS axis at any magnetic field levels.</td>
</tr>
<tr>
<td>2.</td>
<td>Number of poles:</td>
<td>5 (1 central pole, 2 side poles and 2 end poles)</td>
</tr>
<tr>
<td>3.</td>
<td>Maximum available length for complete SWLS system</td>
<td>2000 mm</td>
</tr>
</tbody>
</table>
4. Nominal (maximum) on axis peak vertical magnetic field (at the mid plane of the central pole) \( \geq 5 \) Tesla (\( \geq 5.5 \) Tesla)  
The supplier can suitably design two side poles (adjacent to the central pole) and the two extreme end poles with lower field strength than that of the central pole to reduce the total radiation heat load keeping overall length of the whole system limited to 2000 mm. The central pole and the two side poles (adjacent to the central pole) shall be superconducting whereas the extreme two end poles of the wavelength shifter could be either superconducting inside the cryostat or normal conducting room temperature magnets located outside the cryostat within the given length of 2000 mm.

5. Clear horizontal and vertical aperture for electron beam (required during beam injection) \( \geq 84 \) mm (horizontal) and \( \geq 36 \) mm (vertical)

6. Nominal height of the SWLS axis (mid plane) from the ground 1250 mm

7. The roll off of the vertical magnetic field (B_y) at a horizontal distance of \( x = \pm 15 \) mm in the mid plane of all the poles at peak excitation. |\( \Delta B_y/B_y \)| \( \leq 0.07 \) %

8. **Field Integrals:** The values of the first and second integrals of the magnetic fields on the SWLS axis (z-direction).
   a. 1\(^{st}\) vertical field integral \( | \int B_y \, dz \, | \) \( \leq 100 \) G-cm
   b. 2\(^{nd}\) vertical field integral \( | \int \int B_y \, dz \, d\zeta \, | \) \( \leq 100000 \) G-cm\(^2\)
   c. 1\(^{st}\) horizontal field integral \( | \int B_x \, dz \, | \) \( \leq 100 \) G-cm
   d. 2\(^{nd}\) horizontal field integral \( | \int \int B_x \, dz \, d\zeta \, | \) \( \leq 100000 \) G-cm\(^2\)

9. **Integrated Multipoles:**  
   Within the aperture of \( x = \pm 15 \) mm (horizontal) and \( y = \pm 3 \) mm (vertical) w.r.t. central axis.
   a. Absolute value of integrated normal quadrupole and absolute value of integrated skew quadrupole \( \leq 50 \) G
   b. Absolute value of integrated normal sextupole and absolute value of integrated skew sextupole \( \leq 100 \) G/cm

5.1.3 The supplier is free to employ suitable correction strategies e.g. additional corrector magnets/trim coils, shimming etc. to achieve the field integrals and integrated multipole field
components as specified in Sr. 8 and Sr. 9 of table-1 respectively if required. The correction strategy shall be reported in the design report.

5.1.4 The SWLS will be ramped from a minimum magnetic field corresponding to the minimum stable current (typically 5 A) to its maximum magnetic field after the energy of the stored electron beam at 0.55 GeV is increased to 2.5 GeV. Therefore the 1\textsuperscript{st} and 2\textsuperscript{nd} field integrals and integrated multipoles shall stay within the limits as specified in Sr.8 & Sr.9 of table-1 during ramping of the SWLS from minimum current to its maximum value. In case correctors/trim coils are used, a look up table of corrector currents and main coil currents shall be provided by the supplier.

5.1.5 The superconducting wire to be used shall be made of Nb-Ti and Cu. Test reports and data of the wire selected shall be provided. The selection of wire diameter and the ratio of Nb-Ti: Cu shall justify the requirements of operational performance and quench protection. The superconducting wire should be from a reputed manufacturer who has supplied superconducting wire for a working magnet in accelerator.

5.1.6 The magnet core shall preferably be constructed of low carbon steel. The composition details with certificate, B-H curve, and inclusion testing report shall be supplied by the supplier.

5.2 Cryostat and cryogenic system

5.2.1 The SWLS magnets shall be cooled by two-stage cryocoolers with or without liquid helium (LHe) as cooling medium. If magnets are cooled in LHe bath cryostat, the period between refills shall be more than 4 months. The supplier shall design and fabricate the cryostat with a consideration to minimize the static heat in leak to cryostat.

5.2.2 Outer vacuum jacket/vessel for insulating vacuum of helium vessel/bath shall have vacuum pressure of $\leq 10^{-6}$ mbar. Material of construction for outer vessel and helium cryostat shall be non magnetic austenitic stainless steel of suitable grade having relative magnetic permeability of $\geq 1.02$. The supplier shall provide vacuum pumps with all accessories (gauges, controller for gauges and pumps etc.) capable of pumping insulating vacuum space around helium vessel. The pumping system shall be of M/S Pfeiffer Vacuum/Edwards/Varian or equivalent make. The detail of the pumping system with all accessories shall be discussed and decided during preliminary design stage. Vacuum vessel and helium bath/vessel shall be designed in accordance with ASME BP & V code or equivalent as per design requirements.

5.2.3 The cryogenic system with cryocoolers shall be of the design that has demonstrated successful operation under similar/comparable application. The cryogenic system to be offered by the supplier must be highly reliable in order to minimize frequency and time of maintenance and should preferably ensure long term availability of the spare parts and maintenance services for the cryocoolers from its manufacturer. The supplier shall be responsible for the maintenance of the cryogenic system during the period of guarantee.

5.2.4 In the event of a quench, the boiled off cryogen (in case of LHe bath cooled magnet system) shall be safely vented. Supplier shall provide suitable safety features (e.g. relief valves, bursting disks etc.) in helium vessel and vacuum vessel. There is already a helium gas return line in experimental hall outside the tunnel. Purchaser suggests use of the same helium return line for venting by using suitable safety relief valve(s). Connection between cryostat and
helium return line is in purchaser’s scope. Additionally, the bursting /rupture disk may open directly to the atmosphere.

5.2.5 **Liquid cryogen transfer:** In case LHe bath cooled magnet system is provided, supplier shall supply two (02) liquid cryogen (LHe and if needed LN2) filling lines, (i) one with horizontal length of 2 meter and (ii) the other one with horizontal length of 6 meter. Both the filling lines shall be flexible vacuum jacketed type with proper end fittings and necessary associated auxiliary equipment to connect SWLS cryostat with a mobile dewar. The dewar and cryogens are NOT in the scope of supplier.

For the supplier’s understanding and reference, purchaser proposes a layout (see figure 2 and 3) of a 6 meter long vacuum jacketed liquid helium transfer line for the transfer of liquid cryogen to the SWLS cryostat from a mobile dewar positioned at the horizontal distance of 6 meter from the SWLS cryostat located at long straight section -4 (LS-4) inside the Indus-2 ring. A dewar of the capacity of 250 liter may be utilized for the transfer of liquid cryogen considering the dimensions of the ring and availability of space for the movement of dewar. This dewar can be brought inside the ring through a removable door of shielding wall near the location of LS-5 of Indus-2 and can be moved to the two possible locations close to LS-4 both within straight distance of ~6 meter from SWLS centre (as shown in figure 2).

Supplier shall consider both the requirements of initial cool-down and refilling operations (normal refilling as well as after a quench) for transferring liquid to the SWLS cryostat from a mobile dewar. Supplier shall specify the estimated amount of liquid helium to be required for the cool-down (including the amount of liquid nitrogen if required for pre cooling of the system) and refilling of SWLS cryostat, in the offer.

5.2.6 **Helium vapor return line from cryostat:** Mechanism should be provided to recover helium vapor from the cryostat due to boil-off. Purchaser proposes use of existing helium gas return pipeline (header) of ~2 inch diameter (laid by purchaser) in the experimental hall of Indus complex for connecting helium return line from SWLS cryostat. Return line from SWLS cryostat to the existing main header (in experimental hall) shall be in purchaser’s scope. The routing of the return line shall be through trench to avoid interference of component movement inside the ring (see figure 2 and figure 3). In any case provision for handling larger flow rates in accidental condition (e.g. quench, insulation vacuum degradation etc.) shall be considered and implemented by the supplier in the overall system.

5.2.7 **Cryocoolers:** The supplier shall supply the cryocoolers with all the required components or accessories (e.g. compressors, flexible helium lines, interconnecting cables etc.). Cryocooler shall be of M/s Sumitomo/ Cryomech / Leybold make. Long term reliability of the cryocooler should be documented and supplied to the purchaser. The purchaser proposes the location of the water cooled compressors for the cryocoolers in free open space at the centre of the ring (see figure 2). Flexible helium lines of length of 20 m between cryocooler cold heads and compressors may be considered for planning purpose with required interconnecting cables etc. The layout of flexible lines for cryocooler compressors shall be decided in consultation with the purchaser.

5.2.8 All pipelines for gases and liquid helium transfer line shall be designed in accordance with the standard code like ASME B31.3 or equivalent code for process piping. Cryogenic pipe line
should have safety /relief devices for relieving overpressure as per design requirement. The design of relief devices on cryostat shall follow a standard code like CGA or equivalent.

5.2.9 SWLS magnet system should be highly stable. The supplier shall consider to minimize any variations onto the magnet system including temperature variations, vibrations from cryocoolers, and movements due to weight changes during filling with cryogen. The supplier should make provisions to minimize the overall effects of vibration on the SWLS magnet system. The amplitude of the vibration of the magnet system shall be limited to ≤ 5 µm.

5.3 Electron beam vacuum chamber

5.3.1 The vacuum chamber for the electron beam shall have an overall length of ≤ 2000 mm from flange-to-flange in longitudinal direction (e- beam direction). Stainless steel Conflat flanges of size DN160CF shall be used at both ends.

5.3.2 Figure-1 shows the SWLS along with upstream and downstream components and vacuum chamber internal apertures at different locations. Purchaser proposes the shape of the internal aperture of the SWLS electron beam vacuum chamber as race-track type with typical dimensions as shown in reference drawing RRCAT\UHVTDFIND2\LS4-MOD LAY\01 (figure 1) enclosed herewith. The internal aperture in the horizontal and vertical direction shall be 120 mm and 36 mm respectively. The exact design of the SWLS electron beam vacuum chamber shall be made in consultation with the purchaser.

5.3.3 The vacuum chamber shall be designed and constructed for ultra high vacuum (UHV) conditions using UHV compatible materials and techniques and shall be approved by the purchaser. Gaskets shall be silver plated OFE (UNS C10100) Copper. All the fasteners shall have ISO metric thread. All flange bolts shall be of austenitic stainless steel AISI 316 (A4-70) and silver plated. Any other fasteners inside the electron beam vacuum space must also be silver plated. There must be no use of anti seize or thread lubricant.

5.3.4 All parts of the vacuum chamber, and any other material between or near the magnetic poles, shall have relative magnetic permeability of ≤1.02 under all operating conditions. The supplier shall supply adequate data on the properties of the material chosen, in particular the magnetic permeability at LHe temperature and room temperature including the effects of cold working and welding. Supplier shall provide the test reports of the materials procured.

5.3.5 In case bellows are used in line with the electron beam vacuum chamber to accommodate thermal contraction/expansion, they shall be RF shielded for minimizing RF heating.

5.3.6 All parts in contact with the vacuum shall be treated in accordance with the approved (by purchaser) UHV compatible cleaning procedures.

5.3.7 Vacuum chamber shall be designed to reduce the induced heating by the stored electron beam. The inner cross-section of the chamber shall be homogeneous and smooth. The design of vacuum chamber should consider reduction of heating due to high frequencies induced by the bunch structure of the beam. Some of the bunch parameters are given below. Any other parameters may be provided by the purchaser, if required.

(i) Number of bunches: 291
(ii) Average bunch current: 1.0309 mA
(iii) Bunch length at 2.5 GeV: 11.3 mm
(iv) Revolution frequency: 1.74015 MHz

Vacuum chamber should also be designed to reduce the incident heat load from the synchrotron radiation of SWLS itself.

5.3.8 Supplier can suitably choose the temperature of the inner surface of the vacuum chamber to remove the thermal load incident on the electron beam chamber economically and for achieving ultra high vacuum.

5.3.9 The supplier shall design the chamber ensuring its capability to withstand any forces produced by eddy currents generated in the vacuum chamber during a quench.

5.3.10 The electron beam vacuum chamber must attain static pressure of \( \leq 5 \times 10^{-10} \) mbar. The maximum leak rate for the chamber shall be \( \leq 1 \times 10^{-10} \) mbar l/s at both room temperature and working temperature.

Residual gas analysis from 1 to 100 AMU shall be performed and the cleanliness of the vacuum chamber as measured by residual gas analyzer (RGA) shall meet the following specifications.

1. General Contaminants\(^1\): \( \leq 1 \% \) of the total pressure
2. Chlorine Contaminants\(^2\): \( \leq 0.1 \% \) of the total pressure
3. Hydrocarbon residue\(^3\): \( \leq 0.1 \% \) of the total pressure

\(^1\)The sum of AMUs 39, 41-43, 45 and above, excluding those listed elsewhere.
\(^2\)The sum of AMUs 35 and 37.
\(^3\)The sum of AMUs 69 and 77.

5.3.11 Supplier shall arrange all the necessary vacuum pumps, instruments for factory acceptance test to verify the vacuum specifications as given in Sr.5.3.10 for electron beam vacuum chamber of SWLS. Supplier shall not supply the vacuum pumps and instruments used for factory acceptance test for the electron beam vacuum chamber as the purchaser does not require these as part of SWLS deliverables.

5.3.12 Supplier shall also supply all other necessary accessories/consumables for processing, testing and packing the electron beam vacuum chamber. These includes but not limited to two numbers of blanking flanges (including one blank flange with brazed copper tube of sufficient length for multiple pinch-off at various stages like after cleaning, for \( \text{N}_2 \) filling after helium leak test and ultimate vacuum test), oxygen free electronic grade (OFE) Copper gaskets, fasteners & fixtures etc. Alternatively, O-ring sealed 25 KF right angle valve may be installed on blank flange in place of brazed copper tube.

5.4 Power supplies, current leads and quench protection system

5.4.1 Supplier shall supply all the necessary power supplies to provide currents in the magnet coils of SWLS and for the corrector magnets if included in the design. The main power supply(ies) for the magnet coils of SWLS shall have short and long term stability \( \leq 5 \times 10^{-5} \). Stability is the sum of drift from line, load, time, temperature and ripples. The supplier must purchase the power supplies from a reputed company so that the long term reliable supply of spare parts and possibility of repair becomes feasible.

5.4.2 All the required power supplies shall perform in a stable fashion and exhibit no evidence of
oscillation over their entire operating range. During ramping of SWLS magnet, the stability of the power supplies shall ensure that the field integrals and integrated multipoles remains within the limits as given in Sr.8 and Sr.9 in table-1. Power supplies shall have CE certification and shall meet other standard relevant safety norms.

5.4.3 Supplier shall provide all the necessary current leads for SWLS magnet system. Suitable current leads e.g. combination of normal conducting and HTSc (high temperature superconductor) current leads to minimize the heat load may be chosen.

5.4.4 Supplier shall provide suitable quench protection system for the SWLS. The protection system may consist of quench detector, electromechanical switch, dump resistor or cold diode or a combination of both (dump resistor and cold diode). Estimation of the maximum possible voltage and temperature rise during a quench shall be done. The protection system must be able to prevent damage to the SWLS system.

5.5 Control and interlock system

Purchaser proposes following requirements for the control system. However the detailed specifications of controls and interlock system with addition/modifications of requirements shall be done in agreement with the purchaser during the design stage.

5.5.1 A self sufficient, stand alone local control system shall be provided for SWLS control and monitoring, which shall also be used to test the system at the supplier and purchaser sites. A Process and Instrumentation diagram (PID) shall be provided.

5.5.2 In fault condition, the control system shall trigger interlock signals to protect the SWLS and vacuum chamber from damage. When enabled, the interlock signal shall be used for the protection of SWLS and to trip off RF system to prevent the damage of the vacuum chamber.

5.5.3 Local control system shall be interfaced with storage ring control system over Ethernet 100BaseT or 1000BaseT on TCP/IP. Supplier shall provide complete protocol details for custom software development.

5.5.4 The data update rate for local control system to the storage ring control system shall be decided in consultation with the purchaser and a 10 Hz or better update rate may be required for some parameters/events/processes such as quench etc.

5.5.5 Hard wired safety interlocks must be provided for safe operation. Interlocks and controls shall be designed to be failsafe. A safe state shall be indicated by a potential free closed contact. An unsafe state shall be indicated by open state of potential free contact. On power failure, the system should indicate an unsafe state. All potential free contacts shall be rated for 24 VDC, 0.5 A minimum.

5.5.6 A potential free contact should come from local controller (SWLS control system) to main control system (storage ring control room) as ‘SWLS Healthy’. Close contact will represent ‘SWLS Healthy’. This contact should indicate overall healthiness of system including cryogenics system, power supply system, quench detection and protection system, and vacuum chamber safety etc.

5.5.7 The SWLS magnet system is expected to be ramped up and ramped down several times in a day. Therefore a provision should be made in local control system to execute the instructions
of ramp up and ramp down from storage ring control system. Provision for permission to change power supply (P/S) setting shall be made through potential free contact from main control system.

5.5.8 Cryostat monitoring and interlocks

5.5.8.1 Sufficient numbers of calibrated temperature sensors and associated electronics for monitoring temperature (with interlocks wherever applicable for safety) of crucial points like at magnet, current leads, thermal shields, electron beam chamber etc. shall be provided by the supplier. Make:- Lake Shore Cryotronics /Oxford Instruments or equivalent.

5.5.8.2 Supplier shall provide liquid helium level sensor and its monitoring with associated electronics for continuously monitoring liquid helium level in the helium bath of SWLS cryostat (if LHe is used for cooling the magnet system). Interlock shall be provided for insufficient helium level. Sensor may be Superconducting liquid level sensor.

5.5.8.3 Supplier shall provide pressure transducer/transmitter to monitor absolute pressure in case magnet system is cooled in LHe bath. The pressure range of the sensor shall be from vacuum to the relief valve setting. Transmitter may be Piezo resistive type sensor / capacitance manometer. (Make: -MKS Inst./Sensortechnics GmbH or equivalent).

5.5.8.4 Standard vacuum gauging system shall be provided to monitor vacuum level of insulating space between liquid helium vessel and room temperature stainless steel vessel. Interlock signal shall be generated in case of vacuum break down. Pressure measurement range:- 1000 mbar to 10⁻⁹ mbar (minimum). Make:- Pfeiffer Vacuum/Varian/ MKS/Edwards or equivalent.

5.5.8.5 Sufficient redundancy for important sensors shall be kept so that in case of failure of any sensor the other one can be used or easy means to replace any sensor shall be provided if required without disassembling the cryostat. The list of these sensors shall be decided during preliminary design phase.

5.5.8.6 Supplier should supply mass flow meter for measuring mass flow rate of helium gas boiled off from helium bath of cryostat in case magnet system is cooled in LHe bath. Make:- MKS Inst./ Bronkhorst High-Tech or equivalent.

5.5.8.7 Voltage taps/sensing leads or temperature sensors shall be provided across each current lead to generate interlock signal to prevent it from overheating.

5.6 Mechanical (General)

5.6.1 Fasteners, fittings and water/air

The entire equipment shall use metric fasteners, nuts and washers throughout. If this is not possible, then each deviation should be approved by the purchaser. The supplier will be required to supply spare fasteners for each case of using non standard fasteners, nuts or washers. The quantities are to be agreed with the purchaser. The entire equipment shall use uniform tube for water, air, etc. throughout. The sizes shall be approved by the purchaser during the design phase.

5.6.2 Mounting and Stands

The SWLS shall have suitable support structure which can be fixed with the concrete floor by...
anchoring and over which SWLS will rest. The jacks/adjustment screws shall be designed to allow movement of the SWLS in all the six degrees of freedom. The minimum linear movement required is ±15 mm in all directions with accuracy better than ±0.1 mm. There should be provision to lock the position of the SWLS after final alignment.

Suitable removable wheels are to be provided in the support structure for easy movement of SWLS from unloading bay area to the Indus-2 tunnel.

Materials that are subject to surface corrosion shall be anodized or painted wherever possible.

5.7 Survey and alignment

5.7.1 To align the Indus-2 storage ring, method of 2-D (horizontal) coordinate measurements along with separate control of elevations has been adopted. A number of reference points are fixed in the tunnel. Coordinates and elevations of these reference points are known in machine coordinate system. The SWLS will be aligned with respect to these reference points. The alignment will be carried out by the purchaser using Leica make theodolite TDA5005 or Laser absolute tracker AT401, optical level and precision electronic/spirit level.

5.7.2 For alignment of the SWLS, minimum four reference fiducial posts are to be fixed by the supplier on the rigid part of the SWLS. These fiducial posts shall be suitable for adopting 1.5 inch/3.5 inch Corner Cube Reflector (CCR) or Taylor-Hobson sphere (T-H sphere) during coordinate measurements. The fiducial post (conical base) along with CCR or T-H sphere will represent one precise point (centre of CCR/T-H sphere). The relationship between the centre of CCR/T-H sphere and SWLS magnetic axis has to be provided by the supplier with accuracy better than 50µm. The supplier shall use instruments having similar accuracy for fiducialization. Also, one level plate (size: 200mmx200mm) parallel to magnetic median plane, has to be provided for direct monitoring of tilt of the SWLS, using precision level or Leica Nivel-20.

5.7.3 The locations and dimensions of fiducial posts and level plate have to be discussed and agreed with the purchaser during the design phase of the SWLS.

5.8 Electrical systems

5.8.1 The electrical system consists of control panels, racks, power distribution, cabling, wiring etc. The control panels, racks supplied by the supplier for the operation of SWLS will be most likely installed in the Equipment Gallery (air conditioned environment, temperature 26°±1°C) of the Indus-2 building (see Figure 3). Without air-conditioning, the ambient temperature in the Equipment Gallery ranges between 20°C to 35°C. The supplier shall be responsible for supplying all the required cables and the work related to the cabling inside the SWLS, control rack, between SWLS to control rack and magnet power supplies, SWLS cryocoolers to compressors etc. The location of the power supplies for SWLS magnets and control rack shall be of purchaser’s choice. The required number of racks/cabinets for the control unit and power supplies and their sizes shall be discussed and decided in consultation with the purchaser during preliminary design stage. One way length of cables for power supplies can be considered around 100 m for planning purpose. However, the final length required for all the cables shall be estimated in consultation with the purchaser during preliminary design stage.

5.8.2 All cable and wiring must be LSZH-FR (Low Smoke, Zero Halogen, Fire Retardant) unless
specifically agreed otherwise, complying with IEC 60754-1 and IEC 60332. The oxygen index must be higher than 28 and acid gas emission less than 4% for the outer sheath. PVC compound must not be used.

5.8.3 Electrical safety issues: Electrical equipments shall be constructed in accordance with best practice and must conform to all applicable CE norms and standards. High voltage components, connectors, wiring terminations, etc. shall be physically separated from low voltage control circuits. Personnel shall not be exposed to high voltages while performing routine service on energized control circuits. The SWLS shall be properly grounded to prevent any damage from high voltage.

5.9 Physical dimensions of the SWLS

Figures 2, 3 & 4 show the space for SWLS inside Indus-2 storage ring. Considering the space restriction, the maximum size of the SWLS is given in table-2 below. The overall size of the SWLS shall not exceed this limit.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Height</td>
<td>The SWLS has to enter in the ring tunnel through a removable shielding door which is having height of 2300 mm. The SWLS shall preferably be made modular type, so that the individual component can easily be brought independently inside the storage ring tunnel and assembled at the desired location. In case modular design is not possible then the total height of the device shall not exceed 2200 mm. However the exact height will be agreed upon during design phase of the SWLS.</td>
</tr>
<tr>
<td>Total width</td>
<td>≤ 1000 mm. This restriction is arising due to space constraint during movement of the SWLS inside the tunnel from entry point to installation location. The exact width will be agreed upon during design phase of the SWLS. (see figure 4)</td>
</tr>
<tr>
<td>Maximum length</td>
<td>≤ 2000 mm</td>
</tr>
<tr>
<td>Height of SWLS axis</td>
<td>1250 mm (nominal)</td>
</tr>
<tr>
<td>Clearance from floor</td>
<td>The clearance between the bottom of the support structure and floor shall be of the order of 100mm. The exact clearance will be agreed upon during the design phase of the SWLS.</td>
</tr>
</tbody>
</table>

Suitable lifting eyes/hooks shall be provided in the structure/cryostat of SWLS for lifting and moving by EOT crane. Also suitable castor wheels are to be provided in the support stand for easy movement of the SWLS through the entry door.

6 Quality Assurance

The supplier shall ensure that all parts/components (e.g. helium and vacuum vessels, cryogenic equipment, power supplies etc.) of the supplied equipment is manufactured and tested following a quality assurance program compliant with ISO-9001 or equivalent.

The equipment must be supplied with a Quality Assurance (QA) document certifying that it conforms to the specification and the supplied engineering drawings along with contents of all material certificates, the results of all inspections and tests and the procedures used.
Purchaser will have right to witness all inspections and tests carried out under the terms and conditions of this contract. The supplier must notify the purchaser at a suitable time in advance of any such inspection and test.

7 Acceptance Tests

Supplier shall make both the Factory Acceptance Test Plan and purchaser’s Site Acceptance Test Plan to be reviewed and accepted by the purchaser. Test plans must include details of how the tests are set up and performed.

The tests at factory and purchaser’s site together must establish that the performance requirements of all the items of the manufactured equipment as described in this specification are completely met.

7.1 Factory Acceptance Tests

Supplier shall have the responsibility to arrange facilities, all the necessary instrumentations and manpower for the tests to be carried out at the site of the factory. The factory acceptance tests shall include at a minimum but not limited to

i. Demonstration of all aspects of the control and interlock system, quench protection system, power supplies, vacuum and diagnostics equipment.

ii. Demonstration of cool-down and warm-up of the SWLS.

iii. Ramping up and down of the magnetic field.

iv. Generation of test quench through excitation of the SWLS above the required maximum on axis field of 5.5 Tesla and/or triggered by the use of quench heater. Field decay time during quench should also be measured.

v. Demonstration of uninterrupted operation of SWLS for 72 hours at the excitation level corresponding to the on axis peak magnetic field of 5 Tesla and demonstration of uninterrupted operation of SWLS for 12 hours at the excitation level corresponding to the on axis peak magnetic field of 5.5 Tesla.

vi. The helium boil off rate shall be quantified. Based on this, the hold time between refills shall be estimated. It shall be shown that the requirement of hold time between refills of 4 months or more is satisfied (in case LHe bath cooled magnet system).

vii. Measurement of remanent field after quench and when SWLS is warmed up to room temperature. The corresponding magnetic field integrals shall be estimated.

viii. Measurement of magnetic field along the longitudinal (z) direction using Hall probe.

ix. Measurement of magnetic field roll off, 1st and 2nd magnetic field integrals for both horizontal and vertical field components by suitable probe or measurement setup. Limits of the magnetic field roll off, field integrals as specified in Sr.7 and Sr.8 of table-1 shall be verified through measurement.

x. Integrated normal and skew multipoles (within the horizontal and vertical zone of ± 15 mm and ± 3mm respectively) as specified in Sr.9 of table-1 shall be verified by measuring field integrals parallel to SWLS axis using suitable measurement setup.

xi. Measurement of field integrals shall also be carried out beyond ± 15 mm (horizontal) within ±32 mm in horizontal direction and maximum possible extent beyond ±3 mm in vertical
direction in consultation with purchaser and the values shall be reported.

xii. The 1st and 2nd field integrals without and with correctors (if end correctors are employed) shall be measured.

xiii. All the above magnetic measurements shall be done at different excitations from minimum to peak magnetic field at intermediate ten steps (atleast).

xiv. The deviations of the electron beam trajectory shall be estimated from the measured data.

 xv. Any manipulation of raw data or processing of raw data and/or use of any necessary formula/method shall be reported in details.

xvi. Measured raw data along with the processed /manipulated data (if any) shall be supplied to the purchaser.

xvii. Demonstration of vacuum pressure of $\leq 10^{-6}$ mbar for outer vacuum vessel for creating insulating vacuum of helium vessel/bath.

xviii. Demonstration of leak tightness of electron beam vacuum chamber better than $1.0 \times 10^{10}$ mbar l/s using helium leak detector.

xix. Supplier shall demonstrate that the electron beam vacuum chamber must attain static pressure of $\leq 5.0 \times 10^{-10}$ mbar and the maximum leak rate for the chamber is $\leq 1.0 \times 10^{-10}$ mbar l/s at working temperature. The cleanliness must satisfy the requirement as specified in 5.3.10 using a residual gas analyzer.

Tests that are mutually agreed by the supplier and purchaser shall be carried out/repeated in presence of the purchaser’s representative(s).

7.2 Site Acceptance Tests

After delivery, normal visual inspection and checks of shocks and tilt indicators revealing any mechanical jerk leading to misalignment/damage suffered in transit will be carried out at purchaser site. The following acceptance tests shall be carried out.

i. Measurements of mechanical dimensions of the components of SWLS to verify the requirements as described in the specification.

ii. Helium leak test and ultimate vacuum performance test of the vacuum components.

iii. Any other factory acceptance test deemed necessary by the purchaser to confirm the correct operation of the SWLS. This will be done by the supplier along with the help of purchaser.

8 Installation and Commissioning

Installation and commissioning of SWLS without beam in Indus-2 is the responsibility of the supplier. Before installation commences, the supplier shall supply a full scheme of the installation and the requirements. In case some special toolings / jigs, facilities or specially trained manpower are required for assembly and installation, then those are to be arranged by the supplier. After installation, proper working of the SWLS has to be demonstrated by the supplier. For the purpose of warrantee the final acceptance of the equipment is defined as the successful completion of installation & commissioning of SWLS without beam in Indus-2 ring and completion of the following final acceptance tests:

i. Excitation of SWLS magnet system to the current level corresponding to the maximum on axis peak magnetic field of 5.5 Tesla and demonstration of magnetic field ramp up and down.
ii. Demonstration of proper working of control and interlock system along with instrumentation, power supplies and vacuum system.

iii. Any other acceptance test defined in this document deemed necessary by the purchaser to confirm the correct operation of SWLS.

It will be condition of the final acceptance that the supplier must have provided to the satisfaction of the purchaser, full documentation as noted throughout this specification to cover all systems embodied with in this contract.

9 General Conditions

9.1 Preliminary Design Report (PDR)

In the event of placement of an order, the supplier should carry out the preliminary design of SWLS. The preliminary design report should describe the general design of the SWLS with overall layouts in sufficient detail so that an assessment on the suitability of the design can be done with minimal queries to proceed for the final design of the equipment. The PDR should contain sufficient detail of the equipment in all the aspects: magnetic, mechanical, electrical, cryogenic, vacuum, thermal, as well as safety aspects (control, monitoring and interlock system). The purchaser and the supplier must agree that the design is suitable before proceeding for the final design of the SWLS. The PDR should contain the plan of execution of the contract and also address the area(s) where detailed design and/or building prototype(s) is (are) required.

9.2 Final Design Report (FDR)

The final design review report should contain the detailed final design of the device in all aspects. The report should describe:

i. The detailed design of magnetic, mechanical support structures, electron beam vacuum chamber, cryostat and cryogenic system with design calculations. Any update of data and results of preliminary design.

ii. The design of control and interlock system with list of control, monitoring and interlock parameters with instrumentation, list of display screens and a Process and Instrumentation diagram (PID), interfacing details with Indus-2 control system as agreed upon in PDR or any other as agreed upon in PDR. A detailed electrical schematic of the integration of SWLS, control system and power supplies should be described.

iii. Test results of prototype(s) if agreed in PDR.

iv. General assembly drawings, drawing of the support structures and service manifolds for checking interference with mating components. Assembly sequences in 3D drawings are also preferred.

v. An outline/ draft version of maintenance, operating manual and safety management documents.

vi. Detailed schedules of the fabrication, assembly and testing program.

vii. Detailed plan for the factory acceptance tests, site acceptance tests and final acceptance tests.

The purchaser and the supplier must agree on the final design of the device before proceeding for fabrication. Inclusion of any suggestions/choices of the purchaser in the design and fabrication methods or inclusion of any component chosen by the purchaser or approval of the design and
fabrication methods by the purchaser shall not release the supplier from his responsibilities for the correct performance of the system. In any case, the supplier shall be solely responsible for the final design and manufacturing of the device and for the correct performance of the device in all respects. Any deviation from what is agreed upon in FDR shall not be entertained.

9.3 Approval from the purchaser

9.3.1 Supplier shall proceed for the manufacturing of the equipment only after the final design is approved by the purchaser.

9.3.2 Any non-conformance during manufacturing, testing or installation shall be informed to the purchaser along with the procedure proposed for handling the non-conformance. Approval from purchaser shall be taken before applying the non-conformance handling procedure.

9.3.3 Supplier shall proceed for shipment of the device only after successful completion of all the factory acceptance tests and approval from the purchaser.

9.3.4 Installation shall commence only after successful completion of all the site acceptance tests and approval by the purchaser.

9.4 Safety and hazard management

9.4.1 The supplier shall carry out a safety assessment of the equipment (magnet system, power supplies, cryostat, vacuum etc.) and its operation. This safety assessment shall be fully documented in the corresponding manuals.

9.4.2 Purchaser requires suppliers to employ hazard management techniques to reduce the risk of personnel becoming injured as a result of interaction with the equipment. This has to be addressed in the operation manual. Consideration should be made of hazards that exist at all stages of the life of the equipment, including installation, commissioning, operation, maintenance and repair.

9.5 Drawings

The supplier shall provide two full sets of paper copies of the final as-built mechanical and electrical drawings. The supplier shall also provide two full sets of electronic copies of the as-built mechanical and electrical drawings (preferably in DWG format) on a CD or DVD. The supplier must note the changes, where deviations from the information or dimensions contained in the manufacturing drawings is authorized by the purchaser during manufacture. The supplier should update all drawings of the final design report according to the production.

9.6 Manuals

Detailed installation, operation and maintenance manuals in English (hard and soft copy) shall be prepared for the systems. Detailed assembly/disassembly and alignment instructions, routine maintenance requirements, fault diagnosis instructions, start-up and conditioning procedures shall be included in the manual. Appropriate mechanical, electrical and controls schematic drawings/diagrams shall also be provided. The software programmer manual shall also be provided.

10 Packing and Delivery

Packaging should be designed for safe handling of the equipment during transportation. It should
have the provision for handling with forklift as well as crane. A detail document containing the design/drawing of the packaging, vapour barrier bag sealing, chemical treatment/fumigation as per international shipment should be prepared by the supplier and send it to the purchaser and prior approval should be obtained before its shipment to the purchaser’s site. Marking with ISO symbols should done on packaging for the safe handling instructions of the packaging during the transit.

Packing cases shall be made suitable for lifting and transportation without damage. Supplier shall also provide any special lifting jigs if required. Shock and tilt indicators must be fitted at suitable location on the packaging unit so that any mishandling during transportation can be detected.

The supplier shall provide guidelines/instructions for safe unloading of the equipment at purchaser’s site. The specific details of delivery and transportation of SWLS system must be discussed with the purchaser and agreed upon in writing.

11  **Spare components and guarantee**

11.1 The SWLS should be designed for reliable operation for a period of about 20 years without any major maintenance. The supplier should separately quote for relevant spares for 5 years of trouble free operation after guarantee period. He shall clearly mention the type of maintenance with schedules required per year to achieve the long term operation of the device. The SWLS is expected to be ramped up and ramped down several times per day and the purchaser expects continuous operation of the device throughout the year. Therefore any maintenance that requires warming up and cooling down of the SWLS in a year shall be mentioned. Quenching of the magnet should not affect the service life of the device.

11.2 The SWLS and all of its associated components/equipment shall be guaranteed against defects or malfunctioning for a period of 24 months from the date of arrival or 18 months from the date of installation and commissioning whichever is earlier. Supplier has to organize any maintenance required during the guarantee period.

12 **Tender Procedure**

This is a two part tender:

**Part-1 - Techno-commercial bid:** This shall contain the detailed technical offer. All the points mentioned in this specification should be adequately addressed to enable the purchaser for making a technical comparison of the offer with this technical specification. Supplier should confirm the acceptance or otherwise of every clause of this specification. The supplier should clearly indicate the specification or condition which cannot be met entirely or partially. This part (Part-1) of the bid must not contain any information on the offered price. However, the commercial terms and conditions of the contract for the supplies to be made and services to be rendered should be mentioned in Part-1 - Techno-commercial bid. Please note that mention of price anywhere in "Part-1 - Techno-commercial bid" will lead to rejection of the bid.

**Part-2 - Price bid:** All price related information shall be given in this part (Part-2).

13 **Facilities and utilities available at the purchaser’s site**

13.1 Crane

There is a 10MT EOT crane installed in the tunnel which is used for moving material from one
place to another in the tunnel. After entry in the tunnel, the SWLS will be moved at its destined location by using this crane. The size of a single component that can be brought in and moved easily in the tunnel is 2.2 m height and 1 m width. The supplier shall try to design the SWLS keeping this dimension in mind. In case if it is not possible to meet this dimension then it has to be discussed and agreed upon during the design phase of the SWLS. But in any case the height of a single component must not exceed 2.2m.

13.2 Cooling water

Water conductivity: <1.0 µSiemens/cm
Temperature: 26°C ±1°C
Maximum inlet pressure: 9 kgf/cm²
Allowed pressure drop: 5 kgf/cm²

13.3 Compressed air

Maximum pressure: 9 kgf/cm²
Humidity: 20%RH

13.4 Electricity supply

Supply type: AC electricity
Frequency: 50 Hz ±3%
Line voltage: 415±10% VAC-3 phase and 240±10% VAC-1 phase

13.5 Ambient conditions

Indus-2 storage ring is located in a circular tunnel of width 5.3 meter and height 6.0 meter. The complete tunnel is air conditioned and during operation, temperature inside the tunnel is maintained within 26°C±1°C. During operation, the radiation level inside the tunnel is of the order of ~100mSv/hr. Therefore all the parts of the SWLS (excluding control racks and power supplies which will be installed outside the tunnel) will be exposed to a radiation level of the same order during its lifetime. In view of this it is mandatory that the components used inside the tunnel should be radiation resistant. When storage ring is not in operation, the ambient temperature in the tunnel varies from 20°C (approx.) in the winter to 35°C (approx.) in the summer.
Figure 2: Top view of location of SWLS in INDUS-2 ring showing layout for helium transfer line and location of compressors for cryocooler.
Figure 3: Cross-sectional view of Indus 2 ring at SWL location showing all the heights of the 10 m TEC crane, SWS helium transfer line & crane hook from the floor level.
Figure 4: Cross-sectional view of SWLS showing the restriction on maximum width as 1080 mm during movement from entry point to installation location (long straight section).

NOTE: - ALL DIMENSIONS ARE IN mm.