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## **SECTION-C**

**TENDER NO. IPR/TN/PUR/TPT/ET/20-21/18 DATED 02-03-2021**

# **Technical Specification Document**

**for**

**Fabrication, testing, supply and  
installation of 80K Cryopump and  
accessories along with required vacuum  
equipment**

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## **List of Abbreviations used in document**

AC: After Completing (of activity)  
ASME: American Society of Mechanical Engineers  
ASNT: American Society for Nondestructive Testing  
ASTM: American Society for Testing and Materials  
AOD: Argon Oxygen Decarburization  
CRYOPUMP: 80K Cryopump / Cryopump  
BS: Before Start (of Manufacturing)  
BOM: Bill of Material  
CAD: Computer Aided Design  
CF: ConFlat (CF) Flange  
CS: Carbon Steel  
DM: Demineralization  
DM Water: Demineralized water  
DPT: Differential Pressure Transmitter  
DR: Deviation Requests  
EF: End of the Factory acceptance  
GTAW: Gas Tungsten Arc Welding  
H: Hold Point  
IPR: Institute for Plasma Research  
ISNT: Indian Society for Non-Destructive Testing  
ISO: International Standards Organization  
KOM: Kick of Meeting  
LIGO: Laser Interferometer Gravitational Wave Observatory  
LI-VISTA: LI-Vacuum Integrated System Test Assembly  
LOI: Letter of Intent  
LPT: Liquid Penetration Test  
MSLD: Mass Spectrometer Leak Detector  
MDLR: Minimum Detectable Leak Rate  
N: Notification point  
NDE: Nondestructive Examination  
NDT: Non Destructive Testing  
MIP: Manufacturing and Inspection Plan

OD: Outer Diameter  
OFHC: Oxygen Free High Conductivity (Copper)  
PAW: Plasma Arc Welding  
PQR: Procedure Qualification Record  
PMI: Positive Metal Identification  
PPM: Part Per Million  
PWHT: Post Weld Heat Treatment  
QAP: Quality Assurance Plan  
QP: Quality Plan  
RT: room temperature  
RGA: Residual Gas Analyzer  
RMS: Root Mean Square  
SS: Stainless Steel  
SWP: Shop Weld Plan  
UHV: Ultra High Vacuum  
VOD: Vacuum Oxygen Decarburization  
WDS: Weld Data Sheet  
WOPQ: Welding Operator Performance Qualification  
WPQ: Welder Performance Qualification  
WPS: Welding Procedure Specification

## 1. Introduction

LI-Vacuum Integrated System Test Assembly (LI-VISTA) is a test facility comprising of a long vacuum vessel and a 80K Cryopump. Motivation to setup this facility is to understand the efficacy of condensation cooled Cryopump for trapping of water vapor. The majority of water vapor entering and passing through LI-VISTA length essentially be trapped on the surface of Cryopump placed in the facility.

This document refer the Scope of Work (SoW) and Technical Specifications (TS) covering details of manufacturing drawing preparation, raw material and off the shelf standard parts & equipment procurement, fabrication, inspection, testing, packaging, delivery, assembly & installation of 80K Cryopump along with specified accessories as shown in supplied guideline 2D drawings.

### 1.1 80K Cryopump and its accessories -

80K Cryopump is an assembly of cylindrical metallic shell enclosing double wall reservoir (for storage of liquid nitrogen (LN<sub>2</sub>)) and passive thermal shield. Other accessories and equipments are integrated with it to complete the entire assembly. This assembly perform the following functions:

- Provide Ultra High Vacuum (UHV) ( $10^{-7}$  to  $10^{-10}$  mbar pressure) environment and trap water vapor.
- Sustain self-weight, weight of end covers, nozzles & their flanges, attached accessories and operative loads.
- Provide the openings which are necessary for the attachment of vacuum pump, pressure gauge, Residual Gas Analyzer (RGA), etc. and other control instruments installation requirement

- **The 80K Cryopump comprises of following:**

80K Cryopump assembly as detailed in guide line drawings and Annexure A8 includes

- Outer vacuum vessel, passive thermal shield, LN<sub>2</sub> storage reservoir with demountable end flanges at both ends of outer vacuum vessel
- Other connecting lines – LN<sub>2</sub> inlet, regeneration line, vent line, level control etc.
- Internal supports between outer vacuum vessel and LN<sub>2</sub> reservoir
- Ports in specified sizes with blank offs with UHV compatible seals at joints.
- Bi-metallic Joints
- End flanges with double “O” ring and cover flanges, ports and connecting lines for interspace pumping
- Interfacing cryolines as detailed in guideline drawings
- Support structure to support assembly on ground floor
- **80K Cryopump Equipment & Accessories includes following:**



- Roughing Pump with provision of connection to the cryopump, comprising of bellows with end flanges, ( Annexure A10)
- Total Oil free turbo molecular pumps, with connected backing pumps together with control unit, (Annexure A10)
- Ion pumps with control unit, ( Annexure A10)
- Residual gas analyzer with its control unit ( Annexure A10)
- Isolation gate valves used in ultra-high vacuum application ( Annexure A10)
- Vacuum measuring gauges covering the operating pressure range ( Annexure A10)
- LN<sub>2</sub> Valve, GN<sub>2</sub> Valve, Rupture Disk, Safety valve and Swing Check valve (Annexure A11 Annexure A12 Annexure A13, Annexure A14)
- Differential pressure transmitter (DPT), (Annexure A15)
- Pressure transmitter (Annexure A16)
- Temperature sensors (Annexure A17)
- Instrument rack ( Annexure A18 )
- Respective controllers, Display units, Sensors etc. of the listed accessories herein

## **2. Overall Dimensions of the outer vacuum vessel of Cryopump**

Overall Dimensions of outer vacuum vessel of Cryopump (Refer Annexure A8 and supplied guide line drawings)

- Overall length: 5283 mm,
- ID of the Outer vessel: 2020 mm
- Elevation of Outer vessel center line from the floor in assembled condition: 1778 mm

For detailed dimensions of the Cryopump assembly, vendor may refer attached guideline drawings.

## **3. The Scope of work**

- 3.1 Study & evaluate provided documents, in the form of technical specifications and drawings to assess manufacturing feasibility and fulfilment of functional requirements (related to assembly configuration, dimensions, surface finish & cleanliness, weld joints, locations of support points & lifting lugs) listed in table-1 of section-4.

Vendor shall propose necessary changes from findings of their evaluation to IPR backed up with rational, for review and seek necessary approval, which after approval shall be incorporated to ensure manufacturing feasibility and fulfil the functional requirements. Documents incorporating approved and agreed changes shall be transmitted to IPR.

Vendor shall be responsible to accomplish Cryopump manufacturing and demonstrate functional requirements (section #4) through inspection & testing as specified and defined in subsequent sections (related to surface finish, cleanliness, dimensions,

geometrical tolerances, weld joints, He leak rates and achievement of vacuum etc.) in 80K Cryopump.

- 3.2 Preparation and qualification (where necessary) of manufacturing drawings and documents related to quality, viz. Manufacturing & Inspection Plan (MIP) / Quality Assurance Plan (QAP), Manufacturing sequence with Procedures including process sheet, Welding procedures qualification, Assembly sequence with procedures, Inspection & Test Procedures (ITP), Contamination control, cleaning procedure, Packing specification, transportation details including handling and lifting.
- 3.3 Procurement of essential raw material required, for the Cryopump manufacturing (including material required for sample coupons, testing, pre-qualifications etc.), set of manufacturing tools (jigs & fixtures), and incoming inspection (functional & dimensional) and testing
- 3.4 Manufacture, fabricate, assemble and test the Cryopump as per approved manufacturing & assembly drawings, MIP and QAP and set of associated documents.
- 3.5 Procure, test and supply standard bought out equipment and accessories, included in section #1.1 under heading Cryopump Accessories
- 3.6 Hardware and software necessary for Control and Monitoring of Cryopump and accessories assembly in operation
- 3.7 Establish contamination control plan, setup facility for cleaning (including procurement of the essential equipment(s) if necessary) of manufactured / fabricated and assembled parts of Cryopump
- 3.8 Propose and manufacture necessary tools (jigs & fixtures) required throughout machining, welding, assembly, testing, handling and lifting covering scope of work
- 3.9 Propose, manufacture, test, purpose built transportation structure / fixture with provision for necessary tools for lifting & handling of the Cryopump, at IPR specified delivery site
  - 3.9.1 The design of packing / transportation structure shall be such that it provides access to delivery supplies for lifting by crane at delivery site.
- 3.10 Provide/ arrange vacuum pumping system, gauges, helium leak detector (Helium leak detector is not in the scope of supply) etc. required for leak testing and for demonstration of ultimate vacuum in 80K Cryopump Volume, (Refer Annexure A8 to Annexure A17)
- 3.11 Manufacture / procure and supply of blank off (including ConFlat (CF) / KF) flanges used in vacuum testing / demonstration and seal off for packing and delivery.

3.11.1 Make provision of flanged connections to mount gauges, pumps and other control instruments during Cryopump leak testing, functional testing and vacuum demonstration

3.12 Undertake inspection & testing at identified stages throughout execution of scope of work included in relevant sections of QAP / MIP, appendices and drawings

3.13 Packing, forwarding and loading on transport at factory, unloading and inspection at delivery site.

Loading, transportation, safe delivery to IPR, handling and unloading (shall be done in LIGO Lab) at IPR Gandhinagar. The Cryopump assembly shall be handled safely to prevent damage and distortion, by avoiding additional loads / stresses to Cryopump not included in this specifications.

Vendor shall propose final delivery configuration of the Cryopump, get it approved and ensure its fulfilment during delivery

Delivery configuration details shall include type, placement and location details of necessary gauges to monitor internal pressure of Cryopump, sensors to monitor impact and acceleration subjected to Cryopump during handling, lifting and transport

3.14 Supply specific photographs and edited videos (Recorded video edited to include applicable commentary – sound / text) of overall scope of work covering manufacture, inspection & tests, assembly, packing & forwarding with suitable commentary for IPR records. The content details shall be mutually agreed upon between Vendor and IPR.

The digital records containing photographs and videos shall be delivered to IPR on suitable storage media at the end of scope of work as a part of deliverables.

3.15 Involvement of Third party Inspection (TPI) agency at all respective stages (3.16.1 to 3.16.6) covering activities within India.

3.16 Perform inspection as specified in factory acceptance tests (FAT) and generate reports in accomplishment of the scope of work (as detailed in Annexure A5 Section #5) as a part of FAT, following shall be verified for

- Cryopump

- 3.16.1 Raw Material testing and certification (Annexure A1 Material Specification)

- 3.16.2 Visual and Dimensional inspection (Annexure A5 Specification For Inspection And Testing)

- 3.16.3 Helium leak test of all joints ( bolted and welded) ( As per section 4 mentioned below and Annexure A6 Specification For Helium Leak Testing And Acceptance)

- 3.16.4 Demonstration of specified ultimate vacuum (As per section 4 mentioned below and Annexure A7 Specifications of Vacuum Requirement and as per section 4).

- 3.16.5 Cleaning Inspection (Annexure A4 Specification For Cleaning And Cleanliness)

3.16.6 Packing Inspection (as per section 9)

3.16.7 Inspection reports verified by TPI (3.16.1 to 3.16.6) covering activities within India

- For vacuum equipment and accessories

3.16.8 Inspection and testing shall be as per respective annexures applicable for roughing pumps, TMP, Ion pumps, RGA, UHV gate valves, pressure transmitters, differential pressure transmitters etc.

Request from IPR (or its authorized representative) for “Dispatch Clearance / Shipping Release” certificate by submitting consolidated FAT report

3.17 Perform onsite acceptance inspection and testing at IPR after delivery comprising of following -

3.17.1 Safe unloading of all supplied components

3.17.2 Visual inspection of cryopump, vacuum equipment and all other accessories.

3.17.3 Inspection of pressure gauge readings which are installed on the 80K cryopump

3.17.4 In case of degradation of pressure, sensors, vendor shall identify the cause and take necessary action against observed damage to the delivered equipment

3.17.5 First vent outer vessel to atmospheric pressure and observe internal pressure of LN<sub>2</sub> reservoir to ensure no leak in LN<sub>2</sub> reservoir

3.17.6 Assembly and installation of support structure (excluding civil work) at site

3.17.7 Assembly & Installation of 80K Cryopump and integration of required vacuum equipment and accessories as per Annexure A8.

3.17.8 Vacuum pumpdown of integrated 80K Cryopump assembly

3.17.9 Helium leak testing of integrated 80K Cryopump assembly

3.17.10 Ultimate vacuum demonstration in integrated assembly

3.17.11 Final acceptance subject to satisfactory outcome of above mentioned steps

#### **4. Performance Demonstration requirements of Cryopump**

Demonstration requirements of Cryopump assembly are stated in Table-1 below. Supplier should follow below guidelines described during demonstration of functional compliance of manufactured items in fulfillment of specified functional requirements.

<b>Requirements</b>	<b>Referred Volume</b>	<b>Performance demonstration objective</b>
Pressure and Temperature	Outer vacuum vessel	<ul style="list-style-type: none"><li>• Internal pressure <math>\leq 1 \times 10^{-7}</math> mbar,</li><li>• External pressure - 1 Atmosphere @ room temperature</li></ul>
	LN <sub>2</sub> Reservoir	<ul style="list-style-type: none"><li>• Internal ~1 Atmospheric at 77K</li><li>• External Pressure: Vacuum <math>10^{-7}</math> mbar</li></ul>

Requirements	Referred Volume	Performance demonstration objective
		<ul style="list-style-type: none"> <li>Minimum/ maximum temperature of 77K / 423K (baking temperature)</li> </ul>
Demonstration of vacuum	Outer vacuum vessel	<ul style="list-style-type: none"> <li>Base vacuum <math>\leq 1.0 \times 10^{-7}</math> mbar, in absence of LN<sub>2</sub> in the reservoir</li> </ul>
	LN <sub>2</sub> reservoir	<ul style="list-style-type: none"> <li>Cool down as per cryogenic practice by maintaining not more than 50K temperature difference across the LN<sub>2</sub> inlet and GN<sub>2</sub> outlet</li> <li>LN<sub>2</sub> reservoir will be filled 100% capacity by volume of reservoir / as per standard cryogenic protocols</li> <li>Filled up LN<sub>2</sub> reservoir pressure @ atmospheric.</li> </ul> <p>The Ultimate vacuum in outer vessel shall not degrade.</p>
	Integrated assembly of outer vacuum vessel and LN <sub>2</sub> reservoir	<p>Vacuum Vessel <math>\leq 1.0 \times 10^{-7}</math> mbar, base vacuum,</p> <p>During this check, LN<sub>2</sub> reservoir is filled and is at atmospheric pressure.</p> <p>RGA (Installed on outer vessel) data shall remain unchanged for N<sub>2</sub> in both the states empty reservoir or filled up reservoir</p>
Helium leak testing	Outer vacuum vessel, Internal LN <sub>2</sub> reservoir and integrated assembly	<ul style="list-style-type: none"> <li>Local He leak rate shall be <math>\leq 1 \times 10^{-9}</math> mbar l/s</li> <li>Global leak rate shall be <math>&lt; 5 \times 10^{-7}</math> mbar l/s.</li> </ul>
Interspace vacuum (In between double O- rings)		<ul style="list-style-type: none"> <li>Outer Vessel - <math>\leq 1.0 \times 10^{-7}</math> mbar, base vacuum</li> <li>Interspace Vacuum <math>\leq 1 \times 10^{-5}</math> mbar @ RT</li> </ul> <p>(Testing performed with Cryopump outer vessel is at RT and LN<sub>2</sub> is at 80K)</p>

**Table 1: Design and functional requirement**

## 5. Material Procurement

5.1 The specification requirements for material used in fabrication of Cryopump shall be followed as stated in Table-2 and for as identified in Table-3:

Sr. No.	Part Identification / Name	Remarks
1.	<b>Outer vessel</b>	
	Shell and dish head	ASTM/ASME A240/SA240 - 304L (only Austenite grade) with HRAP mill surface finish
	Port	SS 304L
	Stiffener & lifting lugs	ASTM/ASME, A479/SA479 SS 304
	Standard ConFlat (CF) Flange	ASTM/ASME A240/SA240 - SS 316L
	Large custom flange	ASTM/ASME, A182/SA182, Grade F, SS 304L
2.	<b>LN<sub>2</sub> reservoir</b>	

Sr. No.	Part Identification / Name	Remarks
	Reservoir shell & ends and passive shield	ASTM/ASME B209 / SB209 6061-T6 Al
	Internal Al piping	ASTM/ASME B234/SB234 6061
3.	Internal supports	ASTM/ ASME A276 / SA 479 304L
4.	Annulus tubing & support	ASTM A312 TP 304L SS
5.	External Support Structure	ASME, A36 or A500 Gr B Equivalent Indian standard is IS 2062
6.	Fastener	SS 316 Grade A4-70/A4-80 silver plated
7.	O-ring	Perfluoroelastomer
8.	Copper Gasket	ASTM / ASME B152 / SB152 UNS C10100 Oxygen-Free Electronic (OFE) grade copper
9.	<b>Welding Consumable for</b> Stainless steel to Stainless steel Stainless steel to Carbon steel Aluminum 6061	<b>Filler Material grade</b> Stainless steel – AWS ER 308L Stainless steel – AWS ER 309L Aluminum Alloy AWS ER 5183 / 5356

**Table 2: Material requirement for Cryopump**

- 5.2 Raw material, welding consumable, proprietary items and brought out items including raw material for trials / mock ups, qualifications and test coupons etc., required for manufacture of Cryopump assembly shall be procured and tested in accordance with the specification in Annexure A1 to Annexure A18. The Vendor shall procure identified materials following guidelines of relevant specifications from reputed manufacturers (it is recommended not to procure from agents).

The source of material procurement shall be intimated to IPR

Material consumed in manufacture shall be marked and traced throughout contract execution time-cycle.

- 5.3 The Vendor shall include the material procurement schedule in the proposed project execution schedule
- 5.4 Vendor shall procure single ply hydro form bellows with required flanges for connection on outer vessel in required quantity, compatible with UHV and low temperature operation to interface LN2 and GN2 lines with the Cryopump as presented in guide line drawings as per specified dimensional details (respective Annexures).
- 5.5 Four numbers of manually operated control valves, four safety valves, two Check valve (NRV) and five rupture disc (complying ASME B16.34 or equivalent) for outer vessel, LN2, GN2 and regeneration lines are included in the scope of supply. LN2, GN2 lines interfaces (which are not included in the attached guide line drawings) with outer vessel and these lines are not in the scope of work, however the interfacing components attached to the Cryopump as included in the guide line drawings are part of the scope of work. Vendor shall be responsible for generation of specification,

selection of valve and rupture disc, following specified operating parameters referring guideline specifications and seek approval from IPR.

- 5.6 Procurement of vacuum equipment including different instrumentations: PFD (Annexure A8– Fig-2 and Figure 3) is provided for identification of required vacuum equipment (roughing pump, turbo molecular pumps with oil free backing pumps, ion pumps, UHV isolation valves, residual gas analyzer, vacuum gauges, sensors, pumping line and associated control and instruments) integrated with Cryopump. Vendor should refer guideline specifications provided in respective Annexures.
- 5.7 Required size anchor fasteners/ foundation bolts shall be used for the anchoring of external support structure to ground. (Civil work is not in scope of work)
- 5.8 MIP/QAP, test procedures, Non Destructive Examination (NDE) procedure etc. submitted by the supplier of raw materials, welding consumables and other brought out items shall be communicated to IPR for information before effecting material delivery.
- 5.9 Material and other standard bought out items should be procured in co-ordination with IPR. The inspection and testing (as covered in relevant Appendices) will be ensured by the Vendor at his cost in a laboratory (NABL certified) agreed upon (wherever necessary) with IPR. This testing may be witnessed by IPR (as covered in QAP/MIP). IPR may ask for the specimen coupons where applicable, for independent testing.
- 5.9.1 The Vendor shall ensure that he procure the material in sufficient quantities & appropriate size in single lot taking into account all the necessary allowances required for qualification tests, coupons and manufacture.
- 5.9.2 Upon receipt of procured material from raw material source, product analysis shall be carried out by Vendor as mentioned in Annexure A1 to ensure its quality and quantity.

Materials meeting the specification and approved by IPR shall only be used for the manufacture of the component.

## **6. Welding**

- 6.1 All welding consumables shall meet the specifications stated in Annexure A3. The average heat input shall be concluded and reported based on qualified welding procedure.
- 6.2 The Vendor shall give details of storage, system for issuance and traceability of welding consumables to IPR.
- 6.3 The Vendor shall submit Shop Weld Plan (SWP) consisting of weld joints indicating seam nos. for respective weld joints, applicable Welding Procedure Specification (WPS), Weld Procedure Qualification Record (PQR) and NDE to be carried out, with corresponding drawing number, for review and approval to the IPR as a part of MIP.
- 6.4 The weld seams shall be staggered as per the design code requirements.
- 6.5 To approve welder and weld samples Vendor shall submit a Procedure Qualification Record (PQR) on welder and weld samples, to IPR prior to starting production welding.
- 6.6 The welding shall be carried out only by qualified (for “6 g” applications) welders. Prior to starting production welding and to approve welder and weld samples, Vendor shall submit a Procedure Qualification Record (PQR) to purchaser. A list of qualified welders

identified for production work assignment shall be submitted for approval to purchaser along with copy of their supporting credentials (qualification, experience, certification etc.).

## **7. Inspection and Testing**

- 7.1 The vendor shall inspect all the machined parts, sub-assemblies, final assemblies etc., in full compliances with Annexure A5, approved drawings and MIP.
- 7.2 All the tolerance dimensions / features of individual parts, sub-assemblies and the assembled Cryopump shall be inspected by applicable procedures. All the threaded fasteners shall be checked by the thread gauges and ensure fasteners shall be interchangeable.
- 7.3 Dimensional check for the individual components and assemblies shall be carried out at a constant temperature as per the approved procedure and shall meet the parameter specified in the approved drawing.
- 7.4 All the dimensions given in the drawing are at 25<sup>0</sup> C. Measurement carried out at other temperature shall be compensated and corrected to 25<sup>0</sup> C before comparing with dimensions in the drawing. Value of co-efficient of thermal expansion at various temperatures shall be obtained from material producer / supplier.
- 7.5 The inspection and testing shall be done as per specifications and in a manner acceptable to IPR. If deemed necessary IPR will have right to specify additional inspection / testing other than specified here in this specification. The records of all the tests and inspection shall be maintained by the Vendor in specific templates and reviewed by IPR.
- 7.6 Quality surveillance as well as quality audit by the IPR or his authorized representative shall not relieve the Vendor from the responsibility of fulfillment of specifications or the inspection duties.
- 7.7 The inspection shall be in compliance with MIP, prepared by the Vendor and approved by the IPR. However depending on the manufacturing procedure, quality assurance system of the company and manufacturing and inspection facilities available with the Vendor, some additional checks may also be necessary on and above approved MIP.
- 7.8 Change request: If Vendor requires raising any deviations from specification provided and approved, for acceptance, he has to get it approved by IPR before implementing, wherever necessary. Change request procedure shall be mutually decided and agreed upon between Vendor and IPR for use.
- 7.9 In case of force majeure conditions like COVID, vendor shall make necessary arrangement of online/ live telecast of inspection/ testing activities covered in MIP / QAP. Vendor shall include the details on online remote testing / inspection activities in their proposal.

## **8. Cleanliness, storage and workmanship**

- 8.1 Surface treatment procedure shall be prepared in line with the Annexure A4 guidelines of this document and submitted to IPR for approval.



- 8.2 Clean condition and good workmanship shall be maintain at all the stages of storing, handling, fabrication, inspection, assembly and packing as acceptable to IPR.
- 8.3 Care should be taken to avoid contact of stainless steel with carbon steel at any time.
- 8.4 SS fabrication area shall be suitably shielded from neighboring areas to prevent contamination from the machining dust, weld spatter & fumes, grinding dust etc.
- 8.5 The raw material, subassemblies and finished components shall be sufficiently and suitably covered to avoid contamination during storage.
- 8.6 Separate storage facility for SS material away from Carbon Steel material shall be used and identification of all material and their cut offs (like heat no, plate no., rolling direction etc.) shall be maintained by transferring the same to other location before cutting.

## **9. Handling, Packing and Delivery**

- 9.1 The Vendor shall provide details of floor space layout, handling facilities available at the place of manufacture, testing and assembly of Cryopump. Vendor shall provide detail of cleanliness class (class 100000 which is ISO 8 equivalent or better) for the area where final clean components are stored, welded, assembled and are prepared for packing before dispatch.
- 9.2 The Vendor shall ensure Cryopump parts & assemblies are protected against surface corrosion & damage during manufacture, inspection, handling, storage and transport.
- 9.3 The packing shall be suitable and rigid enough to ensure safety of Cryopump during shipping to delivery site, loading, stacking and storage. Adequate number of silica gel packets along with a copy of shipping release document shall be kept inside packing.
- 9.4 Openings shall be covered to prevent entrance of dirt and moisture during shipment.
- 9.5 Individual package shall be stenciled in bold character with indelible paint, protected with shellac to indicate shipping mark, package numbers, dimensions and gross weight in kilos, the purchase order number and any other necessary data to identify the equipment and relate it to the technical specifications.
- 9.6 Packing list shall be clearly visible and include package number, package contents, dimensions, net and gross weight of content in each package with handling instructions if any. If more number of items are placed in a package, the net weight for each item shall be specified apart from gross package weight.
- 9.7 The shipment of equipment shall not be effected until and unless written "Shipping Release" is obtained from IPR. The same will be issued by the IPR (or authorized representative) after satisfactory completion of "Factory acceptance test". The Vendor shall dispatch deliverables to IPR site after shipping release certificate is issued.
- 9.8 Transshipment in transit shall be avoided, by arranging specially hired transport for direct delivery to IPR specified delivery site.
- 9.9 The Vendor shall take up the road survey along planned shipment route for transport up to the unloading / installation location. IPR may join Vendor in this activity. Moving supplies up to installation location is responsibility of Vendor.
- 9.10 To obtain necessary clearance from statutory bodies for safe transportation of supplies, if required lies within the scope of the vendor, IPR has no obligation in it.

## **10. Technical documentation and progress reports**

### 10.1 Drawings

All dimensions and measure shall follow metric system manufactured and bought items.

2D guideline drawings are included in tender document for reference input to vendor.

IPR shall supply the CATIA/ SOLIDWORKS 3D Model and 2D drawings derived from them in native CAD / .stp format covering the Cryopump assembly along with support structure.

### 10.2 Preparation of manufacturing drawings -

Preparation of manufacturing drawings (referring 2D drawings / 3D models supplied with tender document) incorporating approved evaluation changes and seek IPR's approval is included in the scope of work for Vendor.

Manufacturing drawings shall include specifying the dimensions with tolerances for each individual component, sub-assemblies and final assemblies. Progressive tolerances shall be implemented at intermediate stages from manufacturing to assembly in order to achieve the final requirements specified in the IPR's assembly drawings. Drawings for jigs, fixtures and tooling required to cover the scope of work, shall be prepared by the Vendor and submitted to the IPR for information & record.

The shop drawings shall also include weld details, method of inspection / examination, surface finish, bill of materials, allowances for cutting, machining including final finish besides other relevant information and details.

If revisions are viewed by IPR / the vendor as significantly affecting interfaces, functionality or costs, a mutually agreed procedure between IPR and the vendor will be adopted.

Evaluation of input information, preparation of 3D model, manufacturing drawings and Bill of Material (BoM) incorporating proposed and approved changes if any -

The Vendor has to carry out evaluation in compliance with specified and applicable design code, manufacturing feasibility, access / effectiveness for inspection, testing and functionality.

The vendor shall incorporate changes proposed if any seeking approval from IPR, in supplied input and prepare 3D model using SOLIDWORKS for review by IPR and obtain approval.

From approved 3D models, the vendor shall prepare manufacturing drawings maintaining design code compliance, manufacturability, fabrication, handling, access / effectiveness of inspection & testing and functional requirements.

2D manufacturing drawings shall be prepared in SOLIDWORKS (compatible with SOLIDWORKS 21) and submitted to IPR for review and approval in CAD & pdf format.

At the end of manufacturing the vendor shall prepare 'as built' 3D model / 2D Drawings of equipment in SOLIDWORKS incorporating dimension reports and submit them to IPR along with in deliverables.

The IPR reserves the right to make changes during the period of contract, such changes shall be considered within the scope of the specified work and shall not be considered extra; the necessary agreement for the quantum of such changes can be mutually agreed upon.

#### 10.3 Applicable code and standards covering scope of work of procurement of Cryopump.

- ASME Boiler and Pressure vessel code Section II Part A
- ASME Boiler and Pressure vessel code Section II Part C
- ASME Boiler and Pressure vessel code Section II Part D
- ASME Boiler and Pressure vessel code Section V
- ASME Boiler and Pressure vessel code Section VIII Div. 1
- ASME Boiler and Pressure vessel code Section VIII Div. 2
- ASME Boiler and Pressure vessel code Section IX
- ASTM E498 / ASME Sec V - Standard Test Methods for Leaks Using the Mass Spectrometer leak Detector
- Standard of Expansion Joint and Manufacturer's Association (EJMA)
- ISO Standard 2861-Flange standard
- ISO Standard 14644-1 for cleanroom

Vendor may also refer additional codes or their equivalent as mentioned below.

- EN 13458: Cryogenic vessels - Static vacuum insulated vessels
- EN 13468: Cryogenic vessels - Safety devices for protection against excessive pressure
- EN 12434: Cryogenic vessels - Cryogenic flexible houses

Latest edition of mentioned codes shall be referred and followed.

#### 10.4 Technical Specifications –

Comprehensive specifications are included in annexures which vendor shall use as guidelines in preparation of documents and in execution of scope of work of this tender. These specifications form the part of Cryopump procurement tender and are listed in table below:

<b>Sr. No.</b>	<b>Description</b>	<b>Annexure No.</b>
1.	Specifications for Material	Annexure A1
2.	Specification for rolling, machining and manufacturing	Annexure A2
3.	Specification for welding and welding qualification of the austenitic stainless steel	Annexure A3
4.	Specification for cleaning and cleanliness	Annexure A4
5.	Specification for inspection and testing	Annexure A5
6.	Specification for Helium leak testing and acceptance	Annexure A6
7.	Specification for Vacuum requirement	Annexure A7
8.	Details & Load specification for Cryopump	Annexure A8
9.	List of deliverables	Annexure A9
10.	Guide line tech specs of off the shelf items	Annexure A10 to Annexure A18

**Table 3: Technical specification annexures list**

10.5 In case of conflict between technical specifications included and other specification stated elsewhere in other places in the tender documents, the Vendor shall contact IPR for guidance and the IPR's decision shall be considered as final.

10.6 Details of documents to be prepared and submitted to IPR for approval shall cover procurement, manufacturing & fabrication, inspection and testing of Cryopump :

\*BS –Before start (of Manufacturing or procedure)

\*AC: After completing of activity

\*EF: End of the factory acceptance

<b>Document to be provided</b>	<b>Provider</b>	<b>Milestone*</b>
Design evaluation report, 3D Model, 2D manufacturing drawing, Bill of Material (BoM)	Vendor	Within 60 days from the Letter of Intent/ Contract
Initial Draft documents (Quality Plan / Manufacturing & Inspection Plan) identifying IPR hold points	Vendor	
Material / welding consumables / Equipment – identification, marking and tracing procedures	Vendor	
Deviation Request (wherever applicable) procedure	Vendor	BS

<b>Document to be provided</b>	<b>Provider</b>	<b>Milestone*</b>
Material procurement (include specifications, incoming inspection, material test & analysis results) with List of Vendor's sub-suppliers / sub-Vendor	Vendor	BS
Welding Data Package (WPS, PQR, WPQ and Shop Weld Plan), welder qualification along with NDE procedures along with the credentials of qualified NDE personnel PWHT – Dimension Stability Procedures (wherever necessary / applicable)	Vendor	BS
Cleanroom specification of the areas used in storage, assembly, testing and packing	Vendor	BS
Forming, machining, fabrication and assembly as applicable procedures	Vendor	BS
Leak Testing Procedures (along with details of equipment & qualified testing personnel credentials)	Vendor	BS
Contamination control plan covering cleaning procedures including cleaning agents/ solvents, equipment used details	Vendor	BS
Packing and Transportation procedures	Vendor	BS
Non Conformance Report (If applicable) (generated throughout contract period and compiled at the end of the period)	Vendor	BS covering scope of work
<b>Documents to be supplied before final acceptance in the factory</b>		
Test & Inspection reports (dimensional check, visual inspection, vacuum leak test (covering magnitude & location of leak), NDE results (Annexure A3 Annexure A4 Annexure A5)	Vendor	AC
Vacuum performance (demonstration of ultimate vacuum as per specification) (Annexure A6 Annexure A7 and Annexure A10)	Vendor	AC
End of manufacturing report (Release Note) including as-built drawings for Cryopump assembly and its parts and support structures.	Vendor	EF

Document to be provided	Provider	Milestone*
The end of manufacturing report file is progressively built up during component manufacture, assembly & testing.		

**Table 4: Document submission list throughout scope of work**

- 10.7 The Vendor shall record all duly approved deviations, necessitated throughout the manufacturing, inspection and testing stages. Approved template formats, in agreement with IPR, shall be used by the vendor to raise Deviation Requests (DRs).
- 10.8 The Vendor shall prepare detailed monthly progress reports on the works performed and submit soft and hard copy for each month to IPR by 7<sup>th</sup> day (mutually agreed) of succeeding month. Content format shall be mutually decided and agreed upon.
- 10.9 Considering this work as prototype development, (Manufacture & assembly of Cryopump), vendor shall prepare and submit a comprehensive note on the manufacturing experience, covering major activities highlighting the salient features. Specific difficulties / difficulties encountered, if any, and the resolution provided shall be included in details. All approved deviation requests shall be part of this note.

## **11. Delivery, Installation and testing**

- Manufacturing drawing shall be submitted within 2 months from the date of Letter of intent (LOI)/Contract issued.
- Scope of work covered in this tender specification document shall be completed within 10 (Ten) months from the date of approval of manufacturing drawings.
- Installation and testing at IPR, which is in the scope of work shall be completed within 1 (one) month from the date of delivery. For testing at IPR, vendor may refer respective annexures including Annexure A6 and Annexure A7.

Deliverables included in this tender shall be supplied at Stores IPR Gandhinagar Gujarat-382428 India.

## **12. Facilities at IPR site**

IPR will arrange following provision for onsite activities covered in scope of work of this tender:

- 230/240 V 50 Hz single-phase and 415 V 50 Hz, three-phase Electric power supply
- 10 tonne capacity overhead crane inside laboratory
- Compressed air for operation of instruments (vendor shall specify need)
- Required GN2, LN2 and helium gas (however vendor shall provide information related to interface requirements, consumption and storage quantity required for test at IPR in advance)

- Space for installation of Cryopump
- MSLD for helium leak detection and helium gas cylinder
- Cooling water if required (vendor shall specify need)

### **13. Warranty requirement**

#### **13.1 Cryopump Assembly (Fabrication)**

Manufactured items shall be covered under warranty for one year from the date of final acceptance at IPR.

#### **13.2 Cryopump Accessories**

Each accessory (pumps, UHV valves, vacuum gauges & RGA) set shall be covered under warranty for one year from the date of final acceptance at IPR.

2 years additional warranty against any manufacturing defects for vacuum equipment covering all for TMP sets, Ion Pumps, roughing pump, UHV gate valves, RGA and vacuum gauges.

### **14. Guidelines to Vendor on Notification/Review/Hold points for IPR**

#### **Manufacturing and Fabrication**

H: Hold Point (Vendor shall proceed to next step after clearance by IPR)

N: Notification Point (Vendor shall notify IPR and proceed)

R: Review

The notification / hold points may be added or deleted by IPR before / during / after manufacturing as per the need and criticality of the activity.

Vendor shall use QAP / MIP and prepare schedule for the execution of scope of work covering these guideline activities to establish the delivery period of contract is achieved

<b>Activity</b>	<b>IPR</b>	<b>Comment</b>
Kick off Meeting between Vendor and IPR	H	<b>Meeting in person or remote</b> MoM to be signed by both the parties
Approval of Procurement related documentation (Manufacturing drawings with BOM, specification of Material used in fabrication)	H	After approval, Vendor will proceed with any procurement related to contract
Manufacturing procedure and Inspection stages & Test results, QAP / MIP,	R	These documents will be reviewed and approved by IPR

<b>Activity</b>	<b>IPR</b>	<b>Comment</b>
<p>Selection of Vendor's sub-suppliers for outsourced tasks / works</p> <p>List of vendors subcontractors with their facility details to take up related manufacturing / fabrication and inspection (of outsourced task)</p>	N	<p>Intimation of sub-Vendor shall be necessary for outsourcing of works related to scope of work of the contract related to fabrication and manufacturing</p> <p>IPR representative may visit subcontractor's facility to assess their capabilities</p>
Material procurement, Procurement of Welding consumables.	N	Vendor shall inform IPR about supplier selection and placement of purchase order
Raw Material receipt inspection Material identification marking	R / H	IPR will verify and review incoming material inspection & test reports and approve
Design of Jigs, fixture, Tooling and manufacturing and fabrication	N	Vendor shall prepare details of Jigs/Fixtures /Tools for use, in agreement with IPR
Marking And Cutting of Material	N	Vendor shall provide layout for material cutout
Machining of parts (as applicable)	N	Relevant applicable documents shall be prepared before commencing the machining of parts
Dimensional inspection of manufactured Parts before taking up for subsequent fabrication, assembly etc.	H	<p>IPR will verify and review the inspection and test report.</p> <p>IPR shall witness inspection in person / remotely.</p>
Welding Qualification (Procedure & Welders)	R	<p>IPR shall witness inspection in person / remotely.</p> <p>IPR will verify and review the inspection and test report.</p>
Commencement of fabrication	R	IPR shall review Manufacturing Procedure and Fabrication Sequence
Visual & Dimensional inspection	H	<p>Inspection reports shall be reviewed by IPR</p> <p>IPR shall witness inspection in person / remotely.</p>
Non Destructive Examination of welds	H	Inspection reports shall be reviewed by IPR



<b>Activity</b>	<b>IPR</b>	<b>Comment</b>
		IPR shall witness inspection in person / remotely
Cleaning of part, subassembly and assembly and cleanliness inspection	R	Inspection reports shall be reviewed by IPR IPR shall witness cleaning, cleanliness inspection in person / remotely.
Leak testing	H	Inspection reports of each leak test stage shall be reviewed by IPR IPR shall witness test in person / remotely
Ultimate Vacuum test	H	Inspection reports shall be reviewed by IPR IPR shall witness test in person / remotely
Factory Acceptance Test	H	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing in person / remotely
Preparation of End of Manufacturing report	N	Vendor shall prepare format / structure for end of manufacturing report, and send it to IPR for review and agreement on the content
Packing & Transportation	R	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing stages in person / remotely
Shipment release clearance by IPR (or IPR's representative)	H	Inspection reports shall be reviewed by IPR before issuing shipment release clearance
Final Site acceptance inspection and testing at IPR specified delivery site	W	IPR shall approve the final acceptance

**Table 5: Guideline on Notification and Hold points for IPR – Cryopump**

**Standard bought out items – (Accessories, Vacuum Equipment, Seals, Fasteners, etc.)**

<b>Activity</b>	<b>IPR</b>	<b>Comment</b>
Approval of Procurement related Specification documentation (With proposed MIP/QAP for supplier.)	H	After approval, Vendor will proceed with any procurement related to contract of standard bought out item with their supplier

<b>Activity</b>	<b>IPR</b>	<b>Comment</b>
(Refer Relevant Annexure)		
Selection of Vendor's suppliers	N	Vendor shall inform IPR about selection of supplier and placement of purchase order
Standard item / equipment receipt inspection	H	IPR will verify and review the inspection and test report for the incoming material and approve
Leak testing	H	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing in person / remotely
Ultimate Vacuum test	H	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing in person / remotely
Factory Acceptance Test - integrated Cryopump and accessories	H	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing in person / remotely
Packing & Transportation	R	Inspection reports shall be reviewed by IPR IPR shall witness inspection of packing stages in person / remotely
Shipment release clearance by IPR (or IPR's representative)	H	Inspection reports shall be reviewed by IPR before issuing shipment releasing clearance

**Table 6 Guideline on Notification and Hold points for IPR - Accessories**

## **A. Specification for Austenitic Stainless Steel SS 304 L plates:**

### **1. Scope:**

This Annexure describes the requirements for the procurement, inspection, testing, packing and supply of austenitic stainless steel plates type 304L.

Any other requirements indicated in ASME Sec II Part A, ASTM A240 SS304L / ASME SA240M SS304L and SA 480 which are not included in the text of this Annexure shall also be applicable.

Material for components used in UHV application, need to comply with requirements for composition as specified in section 6 below. Supplier should source the material that has undergone secondary refining processes (Argon Oxygen Decarburization (AOD) or Vacuum Oxygen Decarburization (VOD) or Vacuum Arc Refining (VAR)).

### **2. General:**

Raw material used in component manufacture shall be firsthand. The Vendor shall procure all the materials from reputed manufacturers with original Certified Material Test Reports (CMTR's) avoiding procurement from agents. In case of pre-qualified material IPR shall recommend source of procurement.

The dimensions provided in supplied 2D drawings are finish dimensions, Vendor shall procure the material in quantities of size accounting essential allowances required for cutting, machining during manufacture, qualification and testing.

### **3. Delivery condition**

The stainless steel plates procured shall be of Hot Rolled, Solution Annealed and pickled (HRAP) condition. The parameters of the heat treatment cycle shall be obtained from the material supplier and shall be made available to the IPR when demanded.

No iron, carbon steel or other contaminants (such as grease, chloride compounds, oil hydrocarbons) to come in contact with the finished material.

### **4. Cleanliness**

Material is intended for use in Ultra High Vacuum (UHV) application. Potential hydrocarbon contamination shall be eliminated, by storing received material wrapped and covered at all times and handling of the material when it is not being processed.

### **5. Testing Details**

Section # 8.0 to 13.0 of this specification are to be followed as guidelines in testing.

### **6. Chemical composition**

- Chemical composition of SS 304L plates as per ASTM A240 / ASME SA240
- The chemical analysis shall be performed on material lot from each heat.

- A lot shall be defined as plates produced from same heat, subjected to same hot work and heat treatment.
- Chemical Analysis shall be performed in accordance to ASME Sec II Part A, SA 751. The results shall be in confirmation with the requirements as per ASME Sec II Part A, SA 240

## 7. Mechanical Properties Requirements;

- Mechanical properties of SS 304L plates Specification as per ASTM A240 / ASME SA240M
- Testing procedure as per ASME Sec II Part A, SA 370.
- Tensile test requirements at room temperature as per ASME Sec II Part A, SA 240/240M
- Additionally % reduction of area shall be recorded for information.
- Hardness test requirements as per ASME Sec II Part A, SA 240/240M

Test reports, submitted to IPR for review, shall include above test parameters

## 8. Failure of mechanical test and retests

### **Case-1:**

If test specimen has a physical defect (not affecting usefulness of the product) or if incorrect mounting of the specimen or testing machine malfunction result in unsatisfactory test outcome, the test shall be repeated on another specimen. If the second test results are satisfactory, the rolled plate shall be accepted; if not, case 2 shall apply.

### **Case-2:**

Where unsatisfactory results cannot be attributed to causes mentioned in Case-1, two retest may be performed for each unsatisfactory result obtained. The second set of test specimens shall be taken close to those which were defective. If the results of the each retest are satisfactory, the plate shall be accepted, if not, it shall be rejected.

## 9. Non-Destructive Examination

### 9.1. Surface Examination

The plates shall be visually examined in accordance with ASME Sec V, Article 9. The products shall show clean surfaces without any undulation. They shall be free from scratches, blowholes, scales, cracks, hairline flaws.

### 9.2. Ultrasonic Examination

All the plates (where applicable) shall be 100% ultrasonically examined with each pass overlapping at least 10% of the previous pass to ensure complete coverage.

Examination shall be carried out with reference to ASME Sec V, Article V and ASME Sec II Part A, SA 578.

Acceptance criteria shall be as per ASME Sec II Part A, SA 578; Acceptance Standard-Level B

## 10. Finish of plate

Final products finish (plates) shall be as per Cl. 13.1.2 of ASME Sec II Part A, SA 480.

The Surface roughness shall not exceed 6.3 microns (RMS value).

## 11. Repairs

Repair by welding is prohibited. Surface grinding (using permissible tools) can be carried out to eliminate surface defects provided the remaining thickness satisfies the tolerance requirements. The resulting depression shall be merged smoothly with the rest of surface.

## 12. Material Test Reports

Each of the following details shall be indicated in Material test report (mill test report).

- Specimen wise Material identification (batch number, heat number etc.)
- Purchase order No.
- Identification of Product
- Identification of Manufacturer
- Melting process
- Heat treatment record (Heat number)
- Chemical Analysis
- Mechanical properties
- Dimensional report
- Non-Destructive Examination report
- Indication from where the specimens have been taken for all specified test

## 13. Marking

Each plate shall be marked as per details given in ASME Sec II, Part A, and SA240. In addition, the following shall also be marked:

- Order Number of item
- Manufacturer name or symbol
- Plate number or unique identification number for traceability of quality history
- Grade of material
- Heat number
- Size
- Direction of Final Rolling (in case plate size is cut from mill finish plate)

## 14. Packing and Transportation

The packing of the delivered material (plates) shall be suitable for repeated handling. Suitable packing material shall be provided in between plates and each plate to prevent damage and contamination. All covered plates shall be packed in wooden crates and protected from dirt and moisture during shipment and storage at site. Each crate shall bear details stenciled in bold letter with indelible paint to indicate shipping details, packing number, dimensions, gross and net weight. Handling locations of the crates shall be identified and clearly visible.

#### 15. Access for inspector

The Vendor shall provide the access to IPR and/ or authorized representative at all reasonable facilities necessary to inspect and ensure that the material is being furnished in accordance with this specification.

### **B. Specification for Austenitic Stainless Steel 304L Forgings**

#### 1. Scope

This section of Annexure prescribes the requirements for the inspection, testing, packing and supply of austenitic stainless steel 304L forgings.

Any other requirements indicated in ASME Sec II Part A, SA 182 which is not covered in this specification shall also be applicable.

#### 2. General

All the material used in manufacture shall be firsthand. The Vendor shall procure all the materials as per relevant applicable specification from reputed manufacturers with original Certified Material Test Reports (CMTRs) and avoid procuring from agents.

The dimensions mentioned in the drawings are final dimensions and the Vendor shall procure the material in appropriate size taking into account all the necessary allowances required for cutting, machining during manufacture, qualification and testing.

#### 3. Melting Process

The steel shall be made using an electric furnace or by any other technically equivalent process.

#### 4. Manufacture

Sufficient discard shall be taken from the ingot to ensure that only sound metal enters the complete forging. Forging shall be as close as practicable to finished shape and size.

No grinding with abrasive wheels, cloths or stones is permitted. No iron carbon steel or other contaminants (such as grease, oil or hydrocarbons) to come in contact with the forging after the cleaning process. Machining fluids shall be water soluble and free of oil, sulfur, and chlorides

#### 5. Delivery condition

The material shall be supplied per the requirements of ASME Sec II Part A, SA 182.

Forged parts shall be delivered in the solution heat treated condition and machined to the as delivered dimension and profile.

Vendor shall propose the details of the treatment whenever it is necessary with details of atmosphere inside oven, temperature, duration of soaking and quench method based on the dimensions of the parts.

## 6. Chemical composition

Chemical analysis shall be performed in accordance with ASME Sec II Part A, SA 751.

Chemical composition of SS 304L forged material as per ASTM A182

## 7. Mechanical Properties Requirements

Specimens shall be tested at ambient temperatures for each lot of material with the same heat.

Testing procedure as per ASME Sec II Part A, SA 370

Tensile & Hardness test requirements at room temperature as per ASME Sec II Part A, SA 182.

Additionally % reduction of area shall be recorded for information.

## 8. Rejection, Rework and Repeated Tests

Conditions mentioned in ASME Sec II A, SA 788 or SA 961.

## 9. Non-Destructive Examination

### 9.1. Surface Examination-Visual Examination

Each forged part shall be visually examined through entire production to machining phase to check the soundness of the metal. The part shall be sound and free from defects like strings, tears, and nicks.

Finish and appearance of the forged component shall meet the requirements of ASME Sec II Part A, SA 961. The maximum Surface roughness shall not exceed 6.3 microns.

### 9.2. Ultrasonic Examination

Examination shall be carried out with reference to ASME Sec V, ASME Sec II Part A, SA388.

## 10. Permissible Variation in dimensions

The dimensions shall be checked in accordance with the requirements of the Approved procurement drawing.

The main dimensions shall be recorded. The values shall be within the tolerances given on the drawing.

## 11. Repairs

Repair by welding is prohibited. Surface grinding can be carried out to eliminate surface defects provided the remaining thickness satisfies the tolerance requirements. The resulting depression shall be merged smoothly with the rest of surface.

## 12. Test Reports (See part A of this Annexure section #11)

## 13. Marking

Marking on the product shall be as per the requirements mentioned in ASME Sec II Part A, SA 182.

## 14. Cleanliness

The forgings are intended for use in a high vacuum application. Potential hydrocarbon contamination shall be eliminated.

## 15. Packing and Transportation

The packing provided on the forging shall be suitable for repeated handling. Corrugated sheets shall be provided in between each forging to prevent scratches etc. All forgings shall be finally covered suitably and packed in wooden crates. Packed material in the crates shall be protected to prevent any entry of dirt and moisture during shipment and storage at site. Each crate shall be stenciled in bold letter with indelible paint to indicate shipping details, packing number, dimensions, gross & net weight and purchase order number.

## 16. Access for inspector

The Vendor shall provide the access to IPR and/ or authorized representative at all reasonable facilities necessary to inspect and ensure that the material is being furnished in accordance with this specification.

### **C. Specification for Aluminum material**

1. This section of Annexure prescribes the requirements for the inspection, testing, packing and supply of Aluminum 6061 plates, tubes and extruded standard structural profiles.
2. All requirements indicated in ASME Sec II Part B, Aluminum SB 209 6061-T6 / T651 in addition to UHV requirement shall be applicable.
3. Required visual, chemical, mechanical test and volumetric examination of plate shall be carried out.

### **D. Specification for Copper gasket**

1. This section of Annexure prescribes the requirements for the inspection, testing, packing and supply of Copper gasket. Following are the requirements for copper gasket used for Conflat flange joints:
  - OFE grade (UNS NO.:C10100) Copper conforming to ASTM: B 152M
  - Temper: 1/4 Hard.
  - Silver plated, free from any surface defects like peeling off or swelling
  - Bake-out temperature ~ 250 °C



- All the gaskets should be cleaned as per standard UHV practices.
- The gaskets should be free of visible defects, debris, scratches, oil marks and finger-prints.

### E. Guide line specifications of Bi-Metallic (AL-SS) Joint

Bi-metallic joint manufacturing	Friction weld / Explosion weld
Material	SS304L / Al 6061-T6
Joint leak rate with helium	
@ Room temperature	$\leq 1 \times 10^{-9}$ mbar l/s
After cold shock @ 80K (min three cycles)	$\leq 1 \times 10^{-9}$ mbar l/s
Design Pressure	~ 14 Bar (Max) at room temperature
Test pressure	~ 21 Bar (Max) at room temperature
Strength of joint at room temperature and 80K	
Tensile	$\geq 80$ MPa (+/- 10%)
Torsional/Shear	$\geq 50$ MPa

- Vendor shall submit the required test certificates for qualification of Bi-metallic joint from original manufacturer/ or any Govt. approved agency.
- In the attached drawing, at this moment Bimetallic joint are shown inside, however, efforts shall be made to bring these joints outside of Cryopump assembly.

## Annexure A2 SPECIFICATION FOR ROLLING, MACHINING AND MANUFACTURING

### 1. Scope

This specification covers the requirements for Stainless Steel / Aluminum (wherever applicable) machining, rolling of shells, dished ends and vacuum components.

The Cryopump assembly is a part of the Ultra High Vacuum assembly.

The Vendor shall be responsible for coordination of sub-contractor's activities to ensure mechanical and application in vacuum compatibility of material and manufactured components.

### 2. General requirements

It shall be the responsibility of the Vendor to call attention to any apparent conflicts between specifications, the Purchase Order, or IPR's drawings and request an interpretation from the IPR. The Vendor shall not assume which instruction shall prevail. In case Vendor find any of IPR's drawings or specifications are in conflict with applicable code requirements, he should seek clarification before proceeding any further.

The components covered in procurement specification are used in ultra-high vacuum service and require stringent controls over cleanliness and contamination throughout the material storage, handling, fabrication and shipping process.

All storage for these components shall be done in the clean and controlled area to prevent contamination from heat, smoke, dust and oily vapors from other manufacturing areas. Material contact with other carbon steel shall be avoided to prevent carbon steel contamination. Same precaution applies to handling of raw material so as not to contaminate with carbon steel, steel forks, hooks of lifting mechanisms.

The material shall be wrapped and covered at all times when it is not being processed to minimize possible exposure to contaminants.

Material identification shall be preserved throughout manufacturing to retain material identity to ensure its traceability.

Finished flange surfaces and rolled shells must be covered and protected throughout all fabrication steps, during shipment between various fabrication shops.

Surface defects shall be removed by grinding with carbide burr cutters only. Abrasive-type wheels and stones are not allowed on vacuum facing metal surfaces.

### 3. Dimensional Stability

Supplier shall ensure dimensional stability by adopting suitable cutting process (preferably laser jet / water jet cutting), balanced welding, suitable welding technique and machining process which shall not introduce residual stresses. The purpose is to minimize distortion and provide dimensional stability to precision stainless steel components with critical tolerances.

### 4. Machining of Parts

#### 4.1. O-Ring Groove and Sealing Surfaces Requirements

O-ring groove and sealing surfaces on flanges, shall meet the following requirements:

- Basic surface finish required: 0.8  $\mu\text{m}$ , concentric lay (finish tolerance  $\pm 0.2 \mu\text{m}$ ) (refer guideline drawings)

The following processes **are not allowed** at any phase: Grinding, honing, lapping, polishing, buffing, sanding, sand blasting, or any other process which can disrupt the concentric machining lay and imbeds material into the surface, or smears the surface.

In addition to out of tolerance dimensions, the following machining problems shall lead to rejection of machined component: ridges, chatter, waviness, scratches or marks along or across the concentric lay, tool marks, dents, gouges, burrs, sharp edges.

#### 4.2. Machining Fluids

Machining, cleaning fluids or any other fluids contacting the raw material or finish component shall be water soluble, and meet the limits as mentioned in below Table

Maximum concentration limits for machining fluids:

<u>Contaminant</u>	<u>Limit</u>
Water Leachable Chlorides	100 ppm
Total Halogens (including Water Leachable Chlorides)	1000 ppm
Total Sulfur	1000 ppm
Hydrocarbons	None Allowed

**Table 7: Maximum contaminant concentration limits for Machining fluid**

#### 5. Tolerance

Tolerances adhered during machining and assembly shall be as per approved drawings. Any deviation from the specification shall be communicated to IPR for review and get it approved.

#### 6. Identification

Parts shall be marked only on outside (of vacuum) surfaces. Marking on vacuum facing surfaces **is not allowed** in any form.

Marking the materials with marking fluids, die stamps, crayons, paints and/or electro-etching is not permitted.

Laser technique or a vibratory tool with a minimum tip radius of 0.1 mm is acceptable for marking only on outside of the rolled / finished shell.

Any other marking method must be approved by the IPR prior to use.

Annexure A3 SPECIFICATION FOR WELDING AND WELDING QUALIFICATIONS FOR AUSTENITIC STAINLESS STEEL / ALUMINUM

1. Scope

Weld quality significantly govern the performance of Cryopump put in UHV service. It's preferred to perform all welding in class 100000 (ISO 8) or better cleanroom areas which is isolated from other areas in machine workshop to ensure contamination free weld quality.

Vendor shall specify, qualify & control following before taking up welding production -

- 1.1 General requirements for welding of the vacuum system components
- 1.2 Requirements for the preparation of Welding Procedure Specification (WPS); qualification of weld procedure & welders by Gas Tungsten Arc Welding (GTAW) used in Cryopump manufacturing.
- 1.3 Requirements for usage and qualification of welding consumable

2. Applicable Specification

Latest edition of the following code / specification shall be referred

ASME Sec IX	: Welding and Brazing Qualification
ASME Sec V	: Non-destructive Examination (NDE)
ASME Sec II Part A, SA 370	: Test methods and definitions for mechanical testing of steel products
ASME Sec II Part C	: Specifications for Welding Rods, Electrodes and Filler metals

**Table 8: Code / specification applicable for welding**

3. Vendor's responsibility

- 3.1. Clause QW-201 and QW 301 of ASME Sec IX shall be applicable.

Welding Procedure Specification (WPS), Procedure Qualification Record (PQR), Welder Performance Qualification (WPQ) and Welding Operator Performance Qualification (WOPQ) shall include weld joint details along with Weld Data Sheet (WDS) and shall get approved by the IPR (or his authorized inspector).

The recommended format shall be:

Clause QW 482 for WPS of ASME Sec IX

Clause QW 483 for PQR of ASME Sec IX

Clause QW 484A for WPQ of ASME Sec IX

Clause QW 484B for WOPQ of ASME Sec IX

4. Welding General Requirements

Production welding shall be accomplished, strictly following the qualified and approved welding procedures using approved welding consumables and qualified welders (welding operators). A list of qualified welders identified for production work assignment shall be submitted for approval to IPR along with copy of their supporting credentials (qualification, experience, certification etc.)

Welds should be regular, continuous and non-porous with attempt to reduce the width of the transition region along each side of the weld. Before commencing welding of assembly parts they shall undergo thorough cleaning procedure.

Sequencing of welds to avoid buildup of residual stress and distortion shall be proposed and submitted for review before it is used during welding. The Vendor shall prepare written procedure for distortion control for each typical joint giving the sequence of welding; heat input etc. and shall submit the same to IPR before taking up work. Reviewed weld procedure shall be displayed in weld shop area during work. The weld fit-up tolerance shall be as indicated in manufacturing drawing.

The shrinkage and distortion of the welded joints shall be measured and recorded. The average heat input as per qualified PQR shall be maintained by suitably controlling voltage, current and welding speed during welding to retain the mechanical and metallurgical properties.

All vacuum boundaries shall be prepared to ensure that they can be examined volumetrically 100% where feasible.

All weld consumables and weld preparation areas shall be clean areas as prescribed to UHV requirement prior to welding. Weld consumables shall be handled only with clean gloves during welding after cleaning.

All penetration (port openings) in the Cryopump shall be welded continuously from inside and stitch welded from outside in accordance with ultra-high vacuum practice. In unavoidable circumstance full penetration welding from atmospheric side shall be used with adequate purging from the backside.

Seam welds of shell shall be from vacuum side with suitable purging from backside.

Where ever it is possible single pass welds should be used. Welds to be smooth but not flush and not ground.

Use of dye penetrant is prohibited on vacuum exposed surface (prior approval is necessary for use in unavoidable circumstances).

All welds at vacuum boundaries shall be compatible with helium leak rate  $< 10^{-9}$  mbar l/s.

## 5. Welding Procedure Qualification (WPQ)

5.1. Procedure qualification test coupons welding shall be reviewed by IPR / authorized inspector

5.2. Weld procedure shall be developed and qualified following latest edition of ASME Sec. IX

5.3. Weld procedures comply both, ASME codes and Ultra high vacuum requirements

5.4. Additional requirements -

5.4.1. Ferrite content -

Ferrite content in weld shall be 3 to 8%

## 6. Qualification for Welders / Welding Operators

6.1 General -

6.1.1 Welder qualification shall be done before he commence work so as to ensure he is certified and qualified to perform satisfactory welding as per qualified weld procedures.

6.2 Technical competence of welder / welding operator -

It is strongly recommended that welding shall be carried out using automatic welding as much as possible considering the dimensional control requirements. Only when automation is not viable manual welding shall be deployed.

6.2.1 Qualification Requirements

- i. Document containing qualification requirements shall be shared with welder
- ii. Qualification tests are performed in presence of the certified welding inspector
- iii. The inspector is entitled to stop the test at any time if it appears obvious that the welder lacks technical competence and operating skill necessary to achieve satisfactory results.
- iv. Test coupon shall be stamped with the identity marks of inspector and welder
- v. The welding equipment used shall be similar to that planned for production
- vi. Any welder / welding operator who has to remove an obviously excess amount of deposited metal by grinding, gouging or other method to avoid leaving defects shall be rejected
- vii. The welder who has qualified the welding procedure shall be automatically qualified.

6.3 Welder shall be qualified as per latest edition of ASME Sec IX, supplemented by addition requirements mentioned in the tender specification document

## 7. Welding Consumable

7.1. Selection of welding consumables shall be in compliance with the used welding method & procedure and Ultra high vacuum requirement.

7.2. Procured welding consumable shall be inspected, tested, packed and stored complying ASME Sec II Part C requirements.

- 7.3. Each batch of welding consumable are required to be qualified by Vendor.
- 7.4. Argon gas of ultra-high purity (99.999% min) with low moisture content [dew point of (-24<sup>0</sup> C) or lower] shall be used for the shielding as well as backside purging.
- 7.5. Ferrite content permissible range in weld consumable (used for stainless steel material) shall be 5 FN to 8 FN.

## 8. Welding repair procedure

### 8.1. For Repairs Not Requiring Welding

- i. Weld defects shall be removed by grinding with Carbide burr cutters only. Abrasive-type wheels and stones are not allowed on the interior or the exterior of welds.
- ii. Visually inspect the area prepared for welding to ensure that the defect has been removed or the indication reduced to an acceptable limit.
- iii. The reduced material thickness shall be checked by a suitable gauge.

### 8.2. For Repair Requiring Welding

- i. Any defect in welding on vacuum exposed side shall be removed before re-welding to minimize the trapped volume and become source for outgassing.
- ii. Remove the defect by grinding (with Carbide burr cutters only) or by chipping and grinding to an acceptable level.
- iii. Visually inspect the area prepared for repair welding.
- iv. Weld as per approved welding procedure.
- v. The repaired area can be left in the as-welded condition or can be blended by grinding. Grinding is restricted to the use of with Carbide burr cutters only. The repaired area shall blend uniformly into the surrounding surface and shall be visually inspected after welding.

### 8.3. For Fillet Weld Repairs Requiring Welding

- i. Remove the unacceptable weld metal by grinding with Carbide burr cutters only.
- ii. If the full fillet weld is not completely removed, visually inspect the area prepared for welding.
- iii. Weld as per approved welding procedure
- iv. Repairs welds shall be visually inspected after welding.

## Annexure A4 SPECIFICATION FOR CLEANING AND CLEANLINESS

### 1. Scope

This specification provide guideline in preparation of cleaning procedures and processes to be used for Cryopump and its components to ensure its compliance with ultra-high vacuum operation. Vendor shall follow these guideline specifications in manufacturing Cryopump to accomplish required cleanliness specifications.

The Vendor can take liberty in deploying alternate practices than those described here in (in consultation with the IPR), while ensuring supplies delivered to IPR comply specified cleanliness requirements detailed herein.

Work scope includes setting up cleaning facility comprising of cleaning equipment, tools, consumable, personnel safety gear and source of supply of dry clean compressed air, steam and DM water necessary to accomplish the cleaning task.

### 2. General requirements

The Vendor shall have clean facilities (as described in this document elsewhere) required for manufacturing Cryopump.

All items (including procured raw material) shall be protected after cleaning to maintain cleanliness throughout storage, testing, handling, transportation and installation. Care shall be taken to minimize exposure to corrosive environment (e.g. such as those containing chloride compounds).

No visible contaminant (viewed with naked eye under both natural and ultraviolet light) of any form shall be left within the vacuum enclosures.

No grinding with abrasive wheels, cloth or stones is allowed on the internal vacuum surface unless specified in this specification. Potential hydrocarbon contamination shall be prevented.

No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) shall come in contact with the Cryopump interior surfaces during handling and assembly. Machining fluids shall be water soluble and free of oil and sulfur (Table 7: Maximum contaminant concentration limits for Machining fluid).

### 3. Cleaning

#### 3.1. Cleaning of components fabricated at shop –

##### 3.1.1. Mechanical Cleaning

The components/assemblies shall be mechanically cleaned for removal of all weld tacks, sharp edges & projections, dust and particles generated during grinding.

##### 3.1.2. Surface Cleaning



- a. This shall be done after mechanical operations (like cutting, bending, grinding etc.) have been completed. The surfaces and edges shall be cleaned of all burrs using SS wire brush. For internal cleaning of SS Pipes / Tubes, such brushes shall be slightly oversized compared to their internal diameters. Brushing shall be alternated with compressed air in the first instance and with jet of DM water afterwards so that the loose scales are removed.
- b. Remove gross contamination from all interior and exterior surfaces (including flange faces) by steam cleaning. Remove temporary markings etc. on the material surfaces with acetone.
- c. Preliminary wash with cleaning solution is followed by UHV compatible cleaning agents (Phosphate free alkaline detergent) & rinsing with DM water.
- d. Handle each piece and component with care by wearing UHV compatible clean gloves during and post cleaning.

### 3.1.3. Precautions in handling the materials

All SS items before surface cleaning, shall be stored in clean racks, shelves / platforms covering suitably to prevent the ingress of extraneous matter. Specific items identified as critical component (e.g. seals) shall always be handled with care so as to avoid scratch, cuts, stains etc. Clean gloves (replaced with new at regular interval) shall be worn while handling materials in order to prevent sweat and finger marks on the surfaces. The surface treatments areas shall be completely dust free.

Personnel involved in cleaning shall wear as a minimum; cleanroom booties or clean boots when walking on/working in the interior surfaces of Cryopump, inside the assembly openings.

### 3.2. Area used during surface cleaning treatment

The Vendor shall arrange exclusive clean area for cleaning, with necessary provisions for handling, exhaust of dust & fumes etc. Arrangements should include provision for disposal of generated waste post cleaning procedures.

### 3.3. Cleanliness assessment

The cleaned surface of assembly parts shall qualify for ultrahigh vacuum requirement. FTIR analysis is used for cleanliness assessment. FTIR analysis is one of the preferred means for cleanliness assessment for presence of Hydrocarbon contamination. This test is carried and cleanliness report is prepared at the end of cleaning process.

FTIR acceptance criteria:

Surface cleanliness from hydrocarbon contamination, prior to bake and vacuum pump-down, shall be verified by an FTIR test to quantify NVR (For surface

acceptance level < 0.05 micrograms / cm<sup>2</sup> and for threaded holes the maximum acceptable NVR level is < 1 microgram/hole).

#### 4. Drying

Drying shall be accomplished by blowing dry clean air over the components after steam / DM water jet cleaning.

Inspect and cover the component (of the Cryopump) as soon after drying as possible and store in clean area. Avoid contamination from unfiltered shop air.

#### 5. Inspection

Inspection shall be done (before removing the piece from the cleaning area) using a procedure which shall be established by Vendor in consultation with IPR and approved by IPR.

The presence of any hydrocarbon or fingerprints on any interior surface or flange face shall be cause for rejection of supplies.

A visual inspection shall be made of exterior surfaces. Visible particulates or actual contamination shall be removed.

Immediately after inspection, cover the components with double wrap of clean, oil-free cover and seal them to preserve the cleanliness established and assessed.

## 1. Scope

This Annexure prescribes the requirements for inspections and tests performed throughout different activities covering scope of work to assess compliance of manufactured parts and fabricated assemblies. Outcome of the inspection and test shall be recorded in specific templates prepared for the purpose and reported in documents. Inspection and test reports will be reviewed and compared with specifications of individual components, sub-assembly, and assembly level to decide acceptance/ rejection.

## 2. Quality assurance, Inspection and surveillance

### 2.1. Quality Assurance Plan (QAP) -

Quality assurance plan aims to achieve quality through examination of the tasks performed, identification of skills required, the selection and training of appropriate personnel, selection and use of suitable tool, equipment & instrument, the select environment to undertake specific activity and assign responsibility to the qualified individual to perform allocated task. QAP shall ensure efficient approach in achieving desired quality and its verification of each task performed while keeping provision for necessary corrective action where necessary where remedy is anticipated. QAP include provision for production of documentary evidence to demonstrate that the required quality has been achieved.

### 2.2. Calibration of Equipment -

Vendor need to ensure following -

Measures shall be in place to ensure that tools, gauges, instruments and other inspection, measuring & testing equipment & devices used in determining conformance to acceptance criterion are of proper range, type, accuracy & precision. Testing & measuring devices used in activities affecting quality shall be controlled, calibrated and adjusted at specified intervals and surrounding environment on or before use to maintain accuracy within limits. Necessary documents in support of the valid calibration shall be accompanying with each of the equipment and made available for inspection when asked by IPR.

### 2.3. Qualification & Certification of personnel engaged in NDE –

Vendor need to ensure following

- 2.3.1. For the NDE inspection ISNT or ASNT level II qualified inspectors in the respective technique shall be employed and certification validity shall comply with applicable ISNT / ASNT standards.
- 2.3.2. The NDE personal shall also be qualified for any special technique or procedures to be followed as per the need mentioned in examination specification or drawing.

2.3.3. Responsibility of necessary Training and certification lies with Vendor.

2.3.4. The air, liquids and other materials to be used at various stages of manufacture, inspection, testing, packing etc. shall be identified, checked to be free from halogen & sulfur contents as limited by the specification for stainless steel components and Vendor shall get it reviewed before initiating work covered in scope of work.

### 3. Documents to be prepared

The following list describe major documents which Vendor shall prepare and submit them to IPR for review and obtain approval where necessary. Description in the document shall be followed by vendor during execution of the work and generate records of gathered data in due course of work scope execution. The Vendor / IPR may prepare additional documents as and when there is need at any stage.

Documents shall be identified by suitable numbering system for ease in identification and reference.

- Drawings for different developments for formed parts with cutting layout of raw materials, shop drawings for parts manufactured in shop, tools used in manufacture, inspection, assembly, testing, packing, transportation etc., essential for execution on the job.
- Manufacturing and Inspection Plan (MIP) covering identified stages of inspection with references to applicable document to cover inspection & testing.
- Internal inspection reports of inspection performed out (to be retained by Vendor and produced when required).
- Non-destructive examination reports covering visual inspection, radiography, UT, vacuum leak test, vacuum demonstration etc. in the format agreed among vendor and IPR.
- Welding qualification for welding procedure and welders covering all the manufacturing weld joints and welding positions.
- Reports of destructive and non-destructive tests done on various test coupons during welder qualifications, procedure qualification complying respective standards and specifications.
- Shop Weld Plan (SWP) with weld joint mapping identifying all the welds by appropriate numbering system, applicable WPS, process used, type of joint with sketch, NDT requirements & welds requiring test coupons.
- Weld data sheets, detailing all the details like joint detail, welding process, welding parameters, inspection & testing prior to, during and after welding etc.
- Compilation of inspection reports of all individual parts and assembly for final acceptance.

- Non-conformances (Vendor to obtain approval by concession request) report and its compilation towards the end of scope of work
- As built drawings after final inspection and acceptance of the parts and assembly
- Compilation of individual Photographs / Videos captured for different significant operations performed through manufacturing to testing.

#### 4. Inspection of Welds

##### 4.1. Weld Data Sheet (WDS)

The Vendor shall identify all the welds by serial numbers in part / assembly drawings. In the Weld Data Sheet welding parameters for individual weld joint shall be filled and submitted to IPR for review and shall be followed by inspectors on shop floor. The format of WDS shall be proposed by Vendor and agreed by IPR.

##### 4.2. Weld Surface –Finish

The welds shall have a regular surface and comply ASME Sec. IX.

##### 4.3. Visual Examination

Visual Examination shall be carried out as per ASME Sec V, by ASNT or ISNT level II inspector.

Weld spatter, surface cracks, surface porosity and such other defects are not permitted.

##### 4.4. Radiographic Examination

Radiography shall be performed on all weld joints where they are applicable.

The radiographic examination shall be carried out as per ASME Sec V.

Radiographic examination Acceptance criteria shall be as per ASME Sec VIII Div. 1/ Div. 2.

##### 4.5. Ultrasonic (UT) Examination

UT shall be performed on weld joints where radiography cannot be performed.

The ultrasonic examination shall be carried out as per ASME Sec V, Reference block with appropriate reference defects shall be made available by supplier.

Ultrasonic examination Acceptance criteria shall be as per ASME Sec VIII Div. 1/ Div. 2.

##### 4.6. Repairs

Any repair welding involving grinding or grinding followed by welding shall be re-examined by non-destructive tests applicable to joint configuration. The repair shall be carried out with prior approval of IPR or his authorized inspector. The procedure and acceptance criteria for repaired weld remain unchanged.

##### 4.7. Liquid Penetration Test (DPT)

Dye/ liquid penetration test is not allowed for welds or repair on welds on vacuum side.

## 5. Factory Acceptance Test

Factory acceptance test shall comprise of verification of inspection and tests performed during execution of scope of work starting from the incoming material inspection stage till the final assembly. In addition to this, test which are performed on the assembly are included in FAT list. FAT covers following -

### 5.1. Incoming Material / equipment / standard parts inspection

Compilation of the Test certificates and reports of incoming raw material, standard bought out parts and equipment is reviewed.

### 5.2. Visual and Dimensional inspection

Vendor shall be required to demonstrate the dimensional control of the component.

The Vendor shall respect the tolerances mentioned on the drawing.

The dimensional verification of parts before assembly, eventual heat treatment, or machining stages shall be performed by the Vendor. The IPR's representative may participate in this verification. The final dimensional check shall be conducted by the Vendor, at Vendor's premises and at IPR's site and reviewed by IPR.

All dimensions indicated on the drawings are in millimetre measured at 25<sup>0</sup> C. The Vendor shall submit to the IPR a report on dimensional check performed. Measurement made at different temperatures of components / assemblies to be matched at site should be corrected to 25<sup>0</sup> C. Later toward the end of scope, vendor shall compile the dimension reports, and prepare "as-built drawing" mentioning all the recorded dimensions in measure values.

### 5.3. Helium Leak test (As detailed in Annexure A6)

### 5.4. Cleanliness inspection (As detailed in Annexure A4)

### 5.5. Ultimate vacuum test (As per Annexure A7)

### 5.6. Vacuum equipment and accessories (as applicable and as per Annexure A10 to Annexure A17)

## Annexure A6 SPECIFICATION FOR HELIUM LEAK TESTING AND ACCEPTANCE

### 1. Scope

This Annexure outlines the Helium leak testing, comprising of test procedure, acceptance criteria, equipment recommended, general instruction and guidelines.

The procedure includes approach for He leak Testing of joints comprising of welded joints, double O-ring seal joints and metal seal joint.

### 2. General

The leak testing methods shall use dry (oil free) Helium Mass Spectrometer Leak Detector (HMSLD). Roughing as well as turbo pump used for pump down shall be OIL-FREE.

Tests shall be performed at ambient temperature of the vessel, with the pressure differential in the same direction as for operation of the vessel. Gases used to back-fill evacuated parts shall be ultra-clean (5N purity N<sub>2</sub>).

Leak test shall be carried by trained and qualified person and shall be witnessed and approved by IPR (or its authorised person). Personnel certified as per SNT-TC-1A only can perform these tests.

Prior to Leak testing it shall be ensured that subassemblies and Cryopump assembly is thoroughly cleaned, dried according to Annexure A4 description guidelines.

100% weld joints and all the sealing joints at vacuum boundaries shall be subjected to He Leak testing.

All other essential test examinations including Non Destructive Examination shall be done prior to cleaning and Final Vacuum Leak testing of parts and assembly.

### 3. Reference Documents

Standard followed in leak testing –

- ASTM E498 - Standard Test Methods for Leaks Using the Mass Spectrometer leak Detector
- ASME Sec. V Article 10 – Non Destructive Examination - Leak Testing

### 4. Equipment Calibration

Equipment used in leak testing shall have valid calibration certificates which shall be submitted to IPR (its representative) before their use and details included in the test report.

### 5. Vendor's responsibilities for hardware for leak testing

- The Vendor is responsible for providing all tools, fixtures, probes / instruments, gas, seals, blank off flanges and vacuum equipment to perform the leak detection test and subsequent quantification across all vacuum boundaries (weld joint, sealed joints, double “O” ring annulus space)

- The Vendor is also responsible for the subsequent removal of tools, seals, and temporary closure plates etc. fitted to facilitate the leak testing.

## 6. Documentation Requirements

- Vendor shall submit the procedure describing how the leak testing will be performed, include configuration diagrams and detail specifications of equipment to be used to IPR for approval. (prior taking up testing)
- Vendor shall prepare leak test report which shall include outcome of leak test and quantum of leak detected along with its location and submit it to IPR for review / acceptance. (after testing)

## 7. Leak Testing Procedure

It is recommended that Vendor follow the procedure as specified in ASTM E498 / ASME Sec V - Standard Test Methods for Leaks Using the Mass Spectrometer leak Detector. However Vendor may propose any other procedure for leak testing and seek approval from IPR before implementing.

Minimum detectable leak rate (MDLR) of MSLD used in leak testing shall be  $\leq 1 \times 10^{-10}$  mbar l / s

### **Leak checking procedure for various type of joints**

#### **Joint Categories:**

##### **Category I**

Welded joint located away from the double O-ring flange assembly.

##### **Category II**

Welded joint located near the double O-ring flange assembly.

##### **Category III**

CF flange joint.

##### **Category IV**

Atmospheric O-ring (O-ring between atmosphere and annulus channel)

##### **Category V**

UHV O-ring. (O-ring between annulus channel and UHV Cryopump)

#### **(a) Leak Checking of Welded Joints**

All weld Joints shall be tested. Acceptance criteria for this category joint shall be He leak rates less than ( $\leq$ )  $1.0 \times 10^{-9}$  mbar l/s.

##### **Category I**

**Welded joint located away from the double O-ring flange assembly.**



These leaks can be detected using standard MSLD leak detection procedures with He as the tracer gas. The leak detector is sensing the Cryopump vacuum and He is sprayed external to the Cryopump.

### **Category II**

#### **Weld joint located near a double O-ring flange assembly.**

The proposed method is to bag the O-ring flanged joint and introduce a pure nitrogen purge into the bag. This will keep the concentration of helium in the bag low in order to minimize permeation or leakage of Helium through the atmospheric O-ring seal. Maintaining a vacuum in the O-ring annulus is required to prevent helium from permeating thru the UHV O-ring and entering the Cryopump vacuum.

#### **(b) Leak Checking of Conflate flange joints**

All Conflates shall be tested with acceptance criteria of He leak rates less than ( $\leq$ )  $1.0 \times 10^{-9}$  mbar l/s at metal gasket seal joint.

### **Category III**

#### **Conflate flanges.**

The conflate flanges can be leak checked using standard Helium MSLD procedures. As in Category II leak detection, nearby O-ring flange assemblies may need covering (enclosing) and nitrogen purging.

#### **(c) Leak Checking O-ring sealed joints**

Annulus space between double O-ring shall be maintained at  $\leq 1 \times 10^{-5}$  mbar.

Individual leak at O-ring seal joint shall be tested with acceptance criteria of He leak rates less than ( $\leq$ )  $1.0 \times 10^{-9}$  mbar l/s.

### **Category IV**

Atmospheric O-ring (O-ring between atmosphere and annulus channel)

### **Category V**

UHV O-ring (O-ring between UHV space and annulus channel)

## **8. Acceptance Criteria**

Acceptance of outcome of leak testing is subject to successfully accomplishment of all stages and following conditions have been met.

- The leak detector has been correctly calibrated and its calibration value is within  $\pm 5\%$  of the standard leak rate value as corrected for the ambient temperature.
- The leak rate value as measured by the leak detector has not increased in value above the measured background to a value greater than the specified leak rate during the entire duration of the individual / global leak testing period
- Movement of the probes are maintained such that the time lag necessary for detection of He leak, at the test location for the detector

- The location and magnitude of all identified leaks shall be recorded

#### 8.1. Acceptable Leak Rate

Individual Leak rate

All Weld Joints and Conflate flanged joint shall be tested for leak and leak rate value  $\leq 1.0 \times 10^{-9}$  mbar l/s.

Global leak rate

Global leak rate value  $\leq 5 \times 10^{-7}$  mbar l/s. (performed by using pressure hood method).

#### 8.2. Vacuum Pump and other equipment leak testing

Independent leak testing of vacuum equipment supplied with the Cryopump (turbo molecular pumping system, backing pump, ion pump, RGA, vacuum gauges etc.) is in the scope of work which shall comply with specifications included in respective appendices attached herewith.

#### 8.3. Helium leak test during cold shock test of LN2 reservoir and associated piping

After perform of three cold shocks of LN2 reservoir and associated piping, they will be tested for helium leak test.

#### 8.4. He Leak test of LN2 reservoir and associated piping at room temperature (RT)

He leak testing shall be performed after thermal shock as described in section 8.1 above

#### 8.5. He Leak Testing of Outer Vessel (of weld joints, prior cryopump assembly at appropriate stage ) at room temperature (RT)

Vendor shall make arrangement for the performing this test with necessary blanks to close the open ends

#### 8.6. He Leak testing of Cryopump Assembly at room temperature (RT)

Vendor shall assemble outer vessel, LN<sub>2</sub> reservoir and other parts of the assembly and make arrangement for the performing this test with necessary blanks to close the open ends

#### 8.7. Cryopump assembly He leak test at 80K at vendor site

**LN2 reservoir at 80K**

Vendor shall make necessary arrangement for measurement of various parameters like temperature, pressure, etc.

- After achieving of ultimate vacuum of  $\leq 1 \times 10^{-7}$  mbar in outer vacuum vessel and satisfactory helium leak rate at RT, LN<sub>2</sub> reservoir shall be cooled down up to 80K with a cool down as per cryogenic practice (Refer Section 4)
- When 80K temp is reached, ensure the reservoir may be filled up with LN<sub>2</sub> only up to 10% of total volume
- System ultimate vacuum at outer vacuum vessel shall not degrade from  $\leq 1 \times 10^{-7}$  mbar after cool down to 80K

- Further, LN<sub>2</sub> reservoir will be pressurized by helium gas up to 0.1bar (g) and outer vacuum vessel will be connected to helium leak detector for leak detection
- Further Outer vessel shall be covered with suitable material bag
- In this condition, bag will be pressurized by helium gas up to 0.1bar (g), to check global leak
- During above mentioned testing, the global He leak rate shall be  $\leq 5 \times 10^{-7}$  mbar l/s
- Fill up the LN<sub>2</sub> reservoir to its full capacity and ensure that vacuum inside the outer vessel shall not degrade
- During the testing, if failure/ damage in Cryopump assembly, pumping systems and instrumentations are observed then vendor shall replace/ repair them in compliance to annexures attached herewith and to the satisfaction of IPR

**After successful tests at room temperature and at 80K, vendor shall dis-assemble vacuum equipment including rupture disc assembly. All the ports of Cryopump shall be covered, sealed and bolted. Cryopump shall be delivered with Nitrogen gas filled @ 1.2 bar (a) internal pressure to IPR.**

**Note: This test shall be repeated at IPR Site also. At IPR site vacuum equipment including rupture disc assembly will retain their position.**

## 9. Test Report

The Leak test report shall contain the following minimum information.

- Identification of the purchase order, the equipment and Manufacturer (Vendor)
- Identification of the drawings no, part, assembly, joint subjected to examination
- Test Equipment details along with calibration information
- Reference to approved procedure documents
- Surface condition and cleanliness
- Examination condition and in particular, calibration conditions
- Interpretation of test results
- Name of the inspector with qualification / certification details
- Identification of the sub vendor conducting the examination (if applicable)
- Time / duration of Examination, Date of examination and Inspector's signature.
- Review by QA responsible person with signature

## Annexure A7 SPECIFICATION FOR VACUUM REQUIREMENT

### 1. Vacuum pressure requirement -

1.1 Provide Ultra high vacuum requirement during normal operation in Cryopump.

1.2 Surface treatment / preservation

- All vacuum exposed part / components shall be handled without direct contact with carbon steel and other contaminants
- Storage, Welding, Fitting and Assembly shall be performed in clean space (class 100,000 – ISO 8 equivalent) Vendor shall make necessary arrangement for storage for parts and products (especially for Aluminum) to avoid their oxidation.
- Welding exhaust fumes shall be collected and extracted outside
- No grinding with abrasive tools unless specified in the document, grinding at weld prep area grinding using rotary carbide tools is allowed
- Potential contact with hydrocarbon material (like human hair, oil, grease etc.) to be prevented at all stages.
- Fabricated component to be covered at all times when not in use
- Machining fluids used during machining to be water soluble, free of oil & sulphur.
- Personnel to wear clean boots when walking on the vacuum exposed surfaces
- Smoking not allowed at the manufacturing, fabrication, testing and assembly area
- Clean components shall be handled by wearing clean vacuum compatible gloves
- Independent testing of vacuum equipment supplied with the Cryopump (turbo molecular pumping system, backing pump, ion pump, RGA, vacuum gauges etc.) is in the scope of work which shall comply with specifications included in respective appendices attached herewith.

### 2. Acceptance of vacuum for cryopump -

Vendor shall submit pump-down curve supported with pumping calculations.

Cryopump shall demonstrated achievement of vacuum of  $1 \times 10^{-7}$  mbar in reasonable time duration as estimated in pump-down calculations.

### 3. Pumping system & associated gauges -

The vacuum pumps, vacuum monitoring gauges, leak detector (Leak detector is not in the scope of supply), residual gas analyzer (wherever needed) will be made available by Vendor during leak testing and vacuum pumping.

### 4. Monitoring and control system -

Monitoring and control of the evacuation process of Cryopump is part of vacuum demonstration and it is recorded continuously throughout testing.

Vendor shall make provision of hardware and software for the purpose of necessary monitoring and control of the evacuation process on a single screen

In case of emergency shut down due to power failure, the gate valve shall isolate the Cryopump with vacuum pump to prevent backflow or contamination from the vacuum pump side.

**5. O-ring requirement -**

- Clean O-ring using standard degreasing (Liquinox or equivalent) solution for 10 minutes in an ultrasonic cleaner before their use for sealing flanges.
- Bake for 12 hours at 150° C in air bake oven.

**6. Annulus pumping requirement -**

Annulus space between two “O” rings is to be pumped down to less than  $1 \times 10^{-5}$  mbar pressure using ion / dry-TMP.

**7. Surface (vacuum facing) treatment of vacuum component –**

For any of the components of Cryopump no further surface treatment shall be done other than that mentioned in this Annexure.

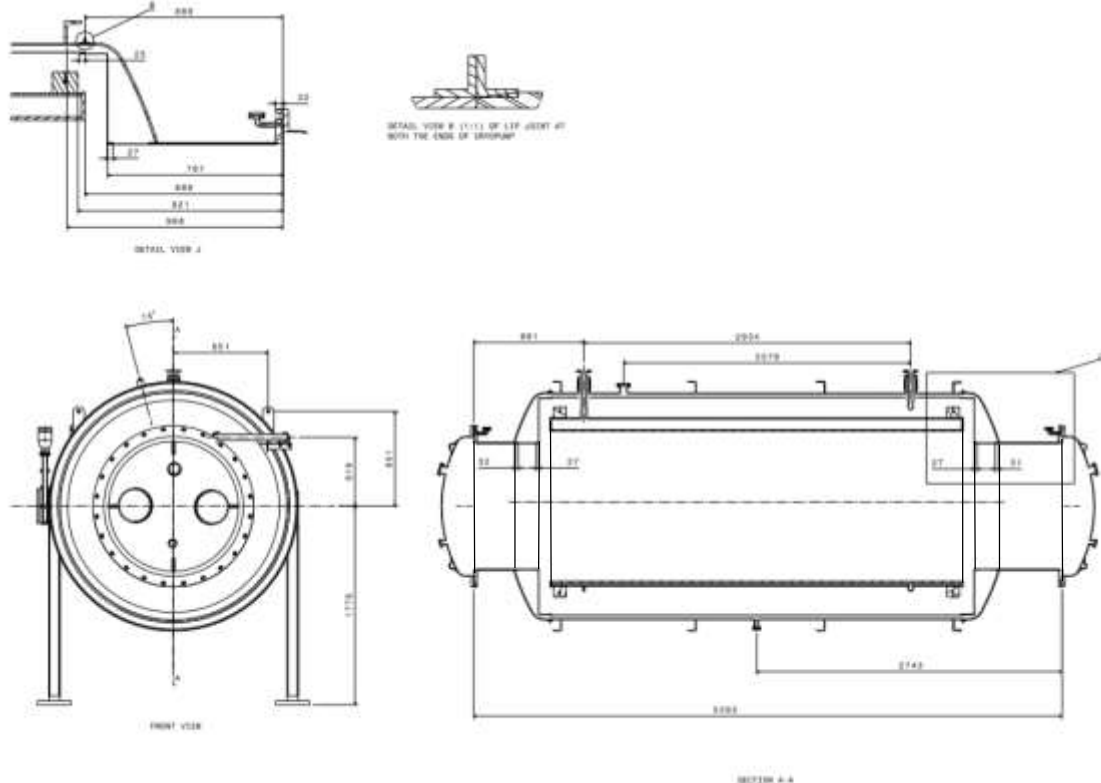
Surface finish of as received HRAP material shall be retained throughout manufacturing and fabrication procedures. Vendor shall obtain prior approval for any changes envisaged to the finish to the vacuum facing surface during manufacturing and fabrication.

## Annexure A8 DETAILS & LOAD SPECIFICATION FOR CRYOPUMP

### 1. Scope:

The aim of this section is to put together all information for constituent part details and the loads applicable to Cryopump assembly.

### 2. Cryopump schematic:



**Figure 1 Cryopump schematic diagram**

### 3. Weight:

Approximate values of empty weight of Cryopump is 4500 kg

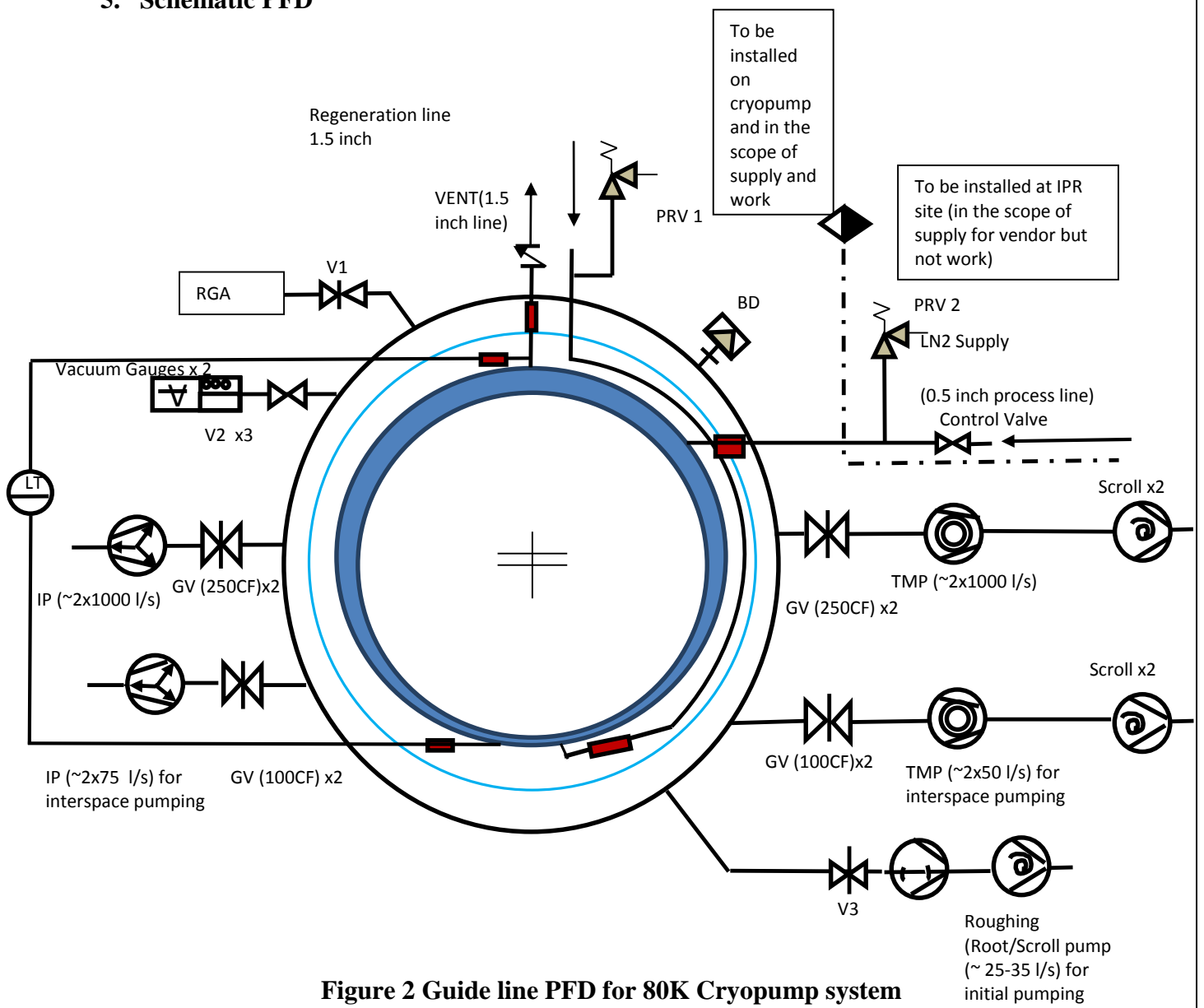
Additional load due to attached pumps with respect to vendor selection of respective vacuum equipment. Vendor shall ensure no deformation on Cryopump due to these attachment and shall provide necessary load bearing structures.

### 4. Type of Loads:

The following types of loads are applied on Cryopump:

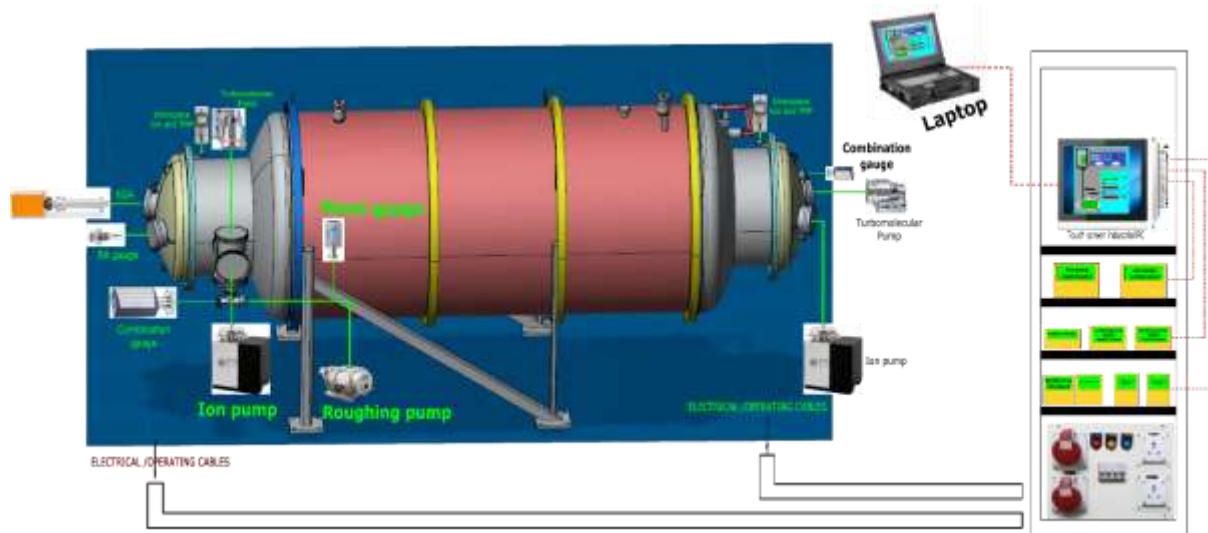
- Self-weight
- Pressure load: due to difference of pressure between atmosphere pressure and inner Cryopump pressure
- Thermal load (baking to 150<sup>0</sup> C temperature before vacuum pumping)

### 5. Schematic PFD



**Figure 2 Guide line PFD for 80K Cryopump system**

Note: For roughing, vendor may opt in between Root or Scroll pump or combination of Root-Scroll pump.



**Figure 3 Schematic diagram of Cryopump with required vacuum equipment and instrumentation rack**



## Annexure A9 LIST OF DELIVERABLES

Section 3 of this document covers the scope of work for successful Vendor of this procurement tender and defines the deliverable. These Annexure detail out the list of deliverables. At the end of the contract, deliverables included herein shall be handed over to IPR. Deliverable are of two categories, A. Digital, which shall be handed over in the form of soft copy including one hard copy, (Table 9: List of Deliverables), B. Physical, manufactured / standard bought out part and equipment (Table 10: List of Deliverables – Cryopump Assembly with Accessories). Below tables list the deliverable.

**Vendor shall give undertaking while bidding** for the tender that he agree to this list and shall comply with the supply of deliverables included herein at the end of completion of scope of work contained in the tender.

### A. Deliverables in the digital form –

Sr. No.	Item (Applicable to Cryopump )	Form of submission Unit / Quantity
1.	Drawings appraisal report with identified proposed changes and their approval status	Report (Set)
2.	Manufacturing drawings (including bill of material (BOM) – Approved for manufacturing	A. Soft copy (Set) B. Hard copy (Set)
3.	Material Testing – Certificates (for procured raw material and standard bought out items)	Original certified Material test reports
4.	Material Testing – Report (for procured raw material)	Complete set  A. Chemical composition B. Mechanical Properties
5.	List of activity for which the special tool / fixture designed and manufactured for -  - Machining - Fabrication - Welding - Handling / Lifting - Cleaning - Testing - Transportation	Set of tool / fixture specifically designed and manufactured to use activity covered in the scope of procurement of CRYOPUMP / -  A. Design report (Set) B. Tool Specification including standard bought

Sr. No.	Item (Applicable to Cryopump )	Form of submission Unit / Quantity
	<ul style="list-style-type: none"> <li>- Temporary support structure to store parts of CRYOPUMP in stable configuration</li> <li>- Temporary support structure to store parts in stable configuration</li> </ul>	<ul style="list-style-type: none"> <li>out items used in tool assembly if any</li> <li>C. Manufacturing Drawings</li> <li>D. Dimension check report</li> <li>E. Tool use procedure</li> </ul>
6.	<p>Procedure / Qualification established –</p> <ul style="list-style-type: none"> <li>- Material traceability procedure</li> <li>- Manufacturing process</li> <li>- Weld Procedure qualification</li> <li>- Welding parameter used</li> <li>- Welding consumable details</li> <li>- Cleaning procedure</li> <li>- Cleaning consumable details</li> <li>- NDE procedure details</li> <li>- Assembly procedure for CRYOPUMP</li> <li>- Assembly procedure for</li> <li>- Dimensional stability control procedure</li> <li>- Packing procedure</li> </ul>	<p>One soft copy and one hard copy of approved procedures and qualifications performed during the scope of work execution</p>
7.	<p>Testing and Inspection report –</p> <ul style="list-style-type: none"> <li>- Dimension check report for individual part of CRYOPUMP /</li> <li>- Dimension check report for assembly of CRYOPUMP /</li> <li>- Visual inspection report</li> <li>- NDE test report</li> </ul>	<p>Report containing each of following covering total scope of procurement of CRYOPUMP</p> <ul style="list-style-type: none"> <li>A. Visual inspection for part/assembly</li> <li>B. Dimension check for parts (Set)</li> <li>C. Dimension check for assembly (Set)</li> <li>D. NDE testing for raw material</li> <li>E. NDE test reports for welding</li> </ul>
8.	<p>Vacuum Leak Testing –</p> <ul style="list-style-type: none"> <li>- List and specifications of equipment and instruments used</li> </ul>	<p>Report containing vacuum leak testing records for parts, weld joint and assembly of CRYOPUMP</p>

Sr. No.	Item (Applicable to Cryopump )	Form of submission Unit / Quantity
	- Vacuum leak test report with details of magnitude of leak detected and its location	A. Substantiated leak test results with identified location, magnitude with acceptance status B. In case of non-accepted vacuum leak recorded details of repairs and outcome of further leak test record status
9.	Ultimate Vacuum Demonstration –  - List and specifications of equipment and instruments used - Pump down curve covering duration to achieve $1 \times 10^{-7}$ mbar pressure inside Cryopump	Report consisting of  1. List of used equipment 2. Technical specification of equipment 3. Pump down procedure adopted 4. Pump down curve covering vacuum pumping duration until realization of $1 \times 10^{-7}$ mbar ultimate vacuum
10.	End of manufacturing report –  - Digital photograph covering critical operations and manufacturing stages - Video records covering material procurement stage till the demonstration of ultimate cryopu, - Nonconformity report covering duration of entire scope of work - Deviation reports	Report consisting of  1. Nonconformity report 2. Deviation/Change request with their resolution status 3. As Built Drawing set 4. Specified set of digital photographs in soft copies on storage media 5. Specified video in soft copy on storage media
11.	As Built Drawings  (Part of end of manufacturing report)	Complete set of drawings  A. Soft copy B. One set in hard copy

**Table 9: List of Deliverables**

## B. Items in the physical form –

Items listed herein shall be transported and delivered to IPR Gandhinagar after FAT and dispatch clearance in the form of agreed / approved configuration for delivery

Sr. No.	Parts name	Total no required
1.	Cryopump (Assembly of outer vacuum vessel, with LN <sub>2</sub> reservoir, passive thermal shield, external Cryo line, internal Tubing Assembly, Bimetallic joints, bellows etc. included in scope of work)	01 set (As per approved dwg / BOM Set)
2.	End covers (connected to item in sr. no.1)	02
3.	Nut, Bolt, Washer (set) <b>(As specified in approved Manufacturing drawing and BoM )</b>	BOM - Set + additional quantity of 15% (set) as spare packed separately
4.	ConFlat (CF) blank flange of different size with set of fasteners <b>(As specified in BoM in approved Manufacturing drawing and)</b>	BOM + one additional blank flange of each type as spare packed separately
5.	<b>Vacuum Seals –</b> “O” Ring and ConFlat (CF) copper gaskets <b>(As specified in BoM in approved Manufacturing drawing and)</b>	BOM Set + additional 1 set of double “O” rings pair and CF gasket per joint as spare
6.	<b>Brief details of Vacuum equipment -</b> Oil free Roughing Pump set of 25-35 l/s as (specified)	1
	Approx 1000 (+/- 10%) l/s TMP system	2
	Approx 50 l/s TMP system	2
	Approx 1000 (+/- 10%) l/s Ion Pump	2
	Approx 75 (+/- 10%) l/s Ion Pump	2
	100 amu RGA	1
	UHV gate valves 250 CF	4
	UHV gate valves 100 CF	4
	Vacuum gauges (combination)	2
All controller and display units	-	

<b>Sr. No.</b>	<b>Parts name</b>	<b>Total no required</b>
	Suitable isolation valves for isolation of RGA, Vacuum gauges	As required
7.	LN2 and GN2 valves (Specified)	4
8.	Safety valves (Specified)	4
9.	Rupture disc (Specified)	5
10.	Check valve (Specified)	2
11.	Differential pressure transmitter (DPT)	2
12.	Pressure gauge and signal transmitter (PT) (Specified)	2
13.	Temperature sensors, transmitter and display unit(Specified)	6
14.	Laptop with operating system (with in-built software and interfacing for ion pump, TMP controller, RGA, vacuum Gauge etc.) compatible with operation of the control and monitor system of the Cryopump assembly	1
15.	Instrument rack for installation of Controller and all other display unit	1

**Table 10: List of Deliverables – Cryopump Assembly with Accessories**

Vendor shall provide performance guarantee of deliverables listed in Category B, for a period of One (1) year from the date of final acceptance against all sorts of manufacturing defects, faulty material and poor workmanship. However for further details vendor may refer section 13.

For delivery, all openings / ports of Cryopump assembly shall be closed with blank off flanges & vacuum seals, filled with the dry nitrogen (5N purity) gas at 1.2 bar pressure (a). A pressure gauge to continuously monitor internal pressure throughout transport shall be provided with necessary arrangement for its mounting on Cryopump assembly.

## Annexure A10 VACUUM EQUIPMENT SPECIFICATIONS

### 1. Scope:

This Annexure covers details of vacuum equipment requirement for integration with 80K Cryopump (Cryopump) for its operation and demonstration of specified functional requirements. Vacuum equipment details include major specification requirements, minimum acceptance criteria and other associated information. This details will help bidders in selecting right kind of equipment from original manufacturer in procurement.

### 2. General:

Equipments should be procured from original manufacturer and avoid buying from agents. These equipments shall be used in UHV application and need to comply with specified requirements provided in respective sections A, B, etc. below.

- Re-furbished equipment/ items/ components are not acceptable. Vendor shall submit an undertaking on this
- Pumping speed for vacuum pumps is applicable for nitrogen unless specified separately
- Every vacuum equipment shall be oil free and free of any hydrocarbon emissions throughout their operating life
- Combination of TMPs with its foreline pump shall be of same make (Both pumps shall be made of single original equipment manufacturer)
- Equipment shall be compatible with electrical power supply of 230/240 V 50 Hz single-phase or 415 V 50 Hz, three-phase
- Priority for choice of equipment should be to choose air cooled avoiding water cooling option wherever feasible
- Each equipment shall have provision with local display where essential
- Each equipment shall have provision of controller which can be interfaced with computer for local / remote control, monitor and operation of the integrated system
- Computer interface provision in each individual vacuum equipment can be Ethernet (most preferred) / RS 485 / RS 232 in descending order in descending preference order
- Each equipment shall be fitted with cables (power, signal) necessary to discharge corresponding function in required length without any joints. Based on the equipment location in assembly and its distance from the control rack, will determine the cable lengths
- Nominal pumping speed of all pumps (including TMP, Ion, roughing) may vary up to +/- 10% of their specified pumping speed.
- Involvement of Third party Inspection (TPI) at all respective stages for inspection and testing of vacuum equipment covering activities within India.

### 3. Documentation:

For understanding the equipment operation, maintenance and control features available document shall be supplied with each of the equipment.

Below are identified guidelines for the details to be included in the delivered item list.

Literature supplied will be in ENGLISH language.

- Quality plan used by original manufacturer in equipment testing
- Drawings, part list, make of the parts including Spare list
- Catalogue or Brochure, Operation & Maintenance manual
- Safety, operation and control interlocks details with applicable circuit diagrams

#### **4. Integration and demonstration of functional specifications:**

- Vendor shall provide required isolation valve (manual), adapter for interfacing equipment on the Cryopump corresponding port for rough pumping.
- Individual equipment shall be demonstrated for its functional specifications in integrated system.
- Necessary calculations of the pumpdown scenarios of the Cryopump assembly shall be prepared and supplied prior to testing
- Preferable connection flanges for mounting equipment on Cryopump are specified, however, if required, vendor shall make provision of adapter for interfacing, gauges, pumps, UHV gate valves for mounting on Cryopump assembly ports for integration
- Acceptance test details are provided below in subsequent sections providing individual equipment specification details

#### **5. Delivery:**

Each individual equipment with its accessories shall be dismantled after site acceptance test from the integrated assembly and delivered to IPR specified site.

- Each equipment shall be packed in reliable packaging material to avoid damages during transit.

#### **A. Specification Roughing Pump:**

Oil free roughing pump is necessary for initial pumpdown of the vacuum vessel from atmosphere to  $10^{-2}$  mbar range. This pressure after initial pumpdown will help to start turbo molecular pump (TMP) to pump down Cryopump further.

Below table covers guideline for the essential major specification in choosing right pump used in initial rough pumpdown

Vendor shall include these specifications in the details of technical bid of this tender and ensure compliance with the parameters stated herein. Selection of the pump connection flange is wholly at vendor's discretion with due consideration to keep pumpdown duration minimum

To provide necessary pumping speed and ultimate pressure, it may be a set of compatible pumps / individual pump chosen for the purpose, which is at the discretion of the vendor

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

<b>No.</b>	<b>Description</b>	<b>Units</b>	<b>Specification</b>
1.	Quantity	Set	1
2.	Type - Oil free dry		Specify
3.	Nominal Pumping speed	l/s	25-35
4.	Ultimate pressure	mbar	$\leq 5 \times 10^{-2}$ mbar
5.	Inlet Connection flange DN NW		40 Specify if different
6.	Exhaust Connection / Fore line connection flange DN NW		Specify
7.	Gas Ballast NW / DN		Suitable size connection flange Specify flange size
8.	Provision of the port at the inlet (for connection of gauge / MSLD)		Specify type and size
9.	Electrical power requirement	kW	Specify
10.	Cooling System	Air cooling	Specify following if water cooling Inlet temp - Outlet temp - Flow rate -
11.	Ambient Operating temperature	20 - 40 <sup>0</sup> C	Specify
12.	Noise (consider Including silencer to bring down noise level)		Specify
13.	Vibration level		Specify
14.	Foot print dimension	mm x mm	Specify
15.	Operating position		Specify
16.	Portable skid / Support (Preferable Aluminum structure)		Include available details
17.	Make		Specify
18.	Model		Specify
19.	Essential accessories		If essential accessories are necessary for safety and performance enhancement, include recommendation



**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirements refer section 2 of this annexure.

**Acceptance criteria:**

- Test certificates of pump from the original manufacturer.
- Demonstration of ultimate pressure at the pump inlet ( $\leq 5 \times 10^{-2}$  mbar).
- Demonstration of overall operation parameters functional spec of the pump during factory acceptance of the integrated vacuum vessel
- Final acceptance of the pump shall be after testing and satisfactory operation of the pump in integrated Cryopump at IPR site.

**B. Specification Turbo Molecular Pump with fore-line pump (TMP-Set):**

Oil free TMP-Set is necessary to continue pumping after initial pumpdown of the Cryopump. Set consisting of TMP and foreline pump shall be used.

Below table covers guidelines for the essential major specifications in choosing right pump used in bringing internal pressure in UHV region. Turbo pump shall be engaged in operation to take the Cryopump volume to less than  $10^{-6}$  mbar.

Vendor shall include these specifications in the details of technical bid of this tender and ensure compliance with the parameters stated herein.

Ensure combination of TMP and Roughing pump is from the same original manufacturer make. This is necessary for compatibility and cover essential warranty of the equipment.

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

No.	Description	Units	Specification	
1.	Quantity	Set	2	2
2.	Type - Oil free dry, without any hydrocarbon traces		Specify	
3.	Nominal Pumping speed (Approximately)	l/s	1000 (+/- 10%)	50(+/- 10%)
4.	Ultimate pressure	mbar	$< 1 \times 10^{-9}$ mbar	
5.	High vacuum connection flange CFF ConFlat		250 Specify if different	100 Specify if different
6.	Exhaust Connection / Foreline connection flange DN NW		40 Specify if different	
7.	Electrical power requirement	kW	Specify	
8.	Cooling System (Air / Forced air cooling)		Specify following if water cooling Inlet temp - Outlet temp -	

			Flow rate -
9.	Ambient Operating temperature	20-40 <sup>0</sup> C	Specify
10.	Noise level		Specify
11.	Foot print dimension	mm x mm	Specify
12.	Bake out temperature (at inlet flange and neck)	<sup>0</sup> C	150 (+10)
13.	Operating position		Any orientation
14.	Portable skid / Support (Preferable Aluminum structure)		Include if available
15.	Make		Specify Turbo Pump - Foreline Pump -
16.	Model		Specify Turbo Pump - Foreline Pump -
17.	Vibration level		Specify
20.	Essential accessories Splinter Shield Heating pad Vent valve (automatic venting)		Provide details of accessories  (If other essential accessories are necessary for performance enhancement, equipment safety, include recommendation

**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirement refer section 2 of this annexure

**Acceptance criteria:**

- Test certificates from the original manufacturer
- Demonstration of ultimate pressure at the pump inlet  $\leq 10^{-9}$  mbar in standalone mode
- Demonstration of overall operation position, parameters, operation control, venting (auto) during factory acceptance of the integrated vacuum vessel at factory
- Final acceptance of the pump shall be after testing and satisfactory operation in integrated vacuum vessel the pump at IPR site.

**C. Specification Ion Pump (IP):**

Ion pump is necessary to continue pumping vacuum vessel volume beyond  $10^{-6}$  mbar internal pressure to achieve less than ( $<$ )  $10^{-9}$  mbar.

Below table covers guideline for the essential major specifications in choosing right pump used to bring down pressure inside vacuum vessel to less than ( $<$ )  $10^{-9}$  mbar.

Vendor shall include these specifications in the details of technical bid of this tender and ensure compliance with the parameters stated herein.

Prefer to supply both variants of Ion Pumps from the same original manufacturer make, to have manageable essential warranty of these equipment.

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

No.	Description	Units	Specification	
1.	Quantity	Set	2	2
2.	Nominal Pumping speed (Approximately)	l/s	1000 (+/- 10%) Specify	75 (+/- 10%) Specify
3.	Ultimate pressure	mbar	$\leq 1 \times 10^{-10}$ mbar	
4.	UHV Connection flange (System Side) CFF ConFlat		250 Specify if different	100 Specify if different
5.	Additional port DN NW		Specify details	
6.	Recommended starting pressure	mbar	1 X 10 <sup>-6</sup> mbar Specify if different	
7.	Element Material		Titanium Specify if different	
8.	Electrical power requirement	kW	Specify	
9.	Cooling System	-	-	
10.	Ambient Operating temperature	20-40 <sup>0</sup> C	Specify	
11.	Operating life @ 1 X 10 <sup>-6</sup> mbar	hours	specify	
12.	Foot print dimension	mm x mm	Specify	
13.	Bake out temperature (Entire pump assembly)	<sup>0</sup> C	150 (+10)	
14.	Operating position		Any orientation	
15.	Portable skid / Support (Preferable Aluminum structure)		Include details if available	
16.	Make		Specify Large Size - Small Size -	
17.	Model		Specify Large Size - Small Size -	
18.	Vibration level		Specify	
21.	Essential accessories		Provide details of accessories	

	Heater		(If other essential accessories are necessary for performance enhancement, equipment safety, include recommendation)
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**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirements refer section 2 of this annexure

**Acceptance criteria:**

- Test certificates of supply pumps from the original manufacturer
- Calibration curves from the original manufacturer
- Demonstration of ultimate pressure at the pump inlet  $\leq 10^{-10}$  mbar in standalone mode
- Demonstration of overall operation position, parameters, operation control, during factory acceptance testing of the integrated vacuum vessel
- Final acceptance of the pump shall be after testing and satisfactory operation in integrated Cryopump at IPR site.

**D. Specification of Residual Gas Analyzer (RGA):**

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

No.	Description	Units	Specification
1.	Quantity	Set	1
2.	Detectable Mass range	amu	1-100
3.	Number of filaments		Dual filament with built-in degas option (field replaceable)
4.	Resolution	amu	1
5.	Detector type		Faraday cup and electron multiplier
6.	Detectable partial pressure range	mbar	Faraday cup $< 10^{-10}$ mbar Electron multiplier $< 10^{-13}$ mbar
7.	UHV Connection flange CFF ConFlat		35 / 63 Specify
8.	Recommended starting pressure	mbar	$1 \times 10^{-6}$ mbar Specify if different
9.	Element Material		Specify
10.	Electrical power requirement	kW	Specify

11.	Ambient Operating temperature	Deg C	20-40
12.	Gauge head Bake out temperature (reading to be monitored during the baking process)	Deg C	150 (+10) (with controller cable connected)
13.	Operating position		Any orientation
14.	Make		Specify
15.	Model		Specify
16.	Essential accessories		Provide details of accessories

**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirements refer section 2 of this annexure.

**Acceptance criteria:**

- Evaluation of calibration curve /certificates from original manufacturer.
- Test measurement of residual gas mass (for H<sub>2</sub>, He, N<sub>2</sub>, moisture, Ar etc.) at vendor site.
- Demonstration of overall operation parameters, operation control, during factory acceptance testing of the integrated cryopump.
- Final acceptance of RGA shall be after testing and satisfactory operation in integrated Cryopump at IPR site.

**E. Specification of UHV Gate Valve (GV):**

UHV Gate valve is necessary to isolate vacuum equipment from Cryopump assembly to facilitate its maintenance anytime during operation when overall system is in vacuum.

Below table covers guideline for the essential major specifications in choosing right gate valve.

Vendor shall include these specifications in the details of technical bid of this tender and ensure compliance with the parameters stated herein.

Prefer to supply both variants of gate valve from the same original manufacturer make, to have manageable essential warranty of these equipment.

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

No.	Description	Units	Specification	
1.	Quantity	Set	4	4
2.	Operation		Electro-pneumatically / electrically operated	Electro-pneumatically / electrically operated
3.	Helium leak tightness	mbar-l/s		

	Housing Valve seat		$< 5 \times 10^{-10}$ $< 1 \times 10^{-9}$	$< 5 \times 10^{-10}$ $< 1 \times 10^{-9}$
4.	Operation pressure	mbar	Atmosphere to $1 \times 10^{-10}$ mbar	
5.	Connection flange CFF ConFlat		250	100
6.	Material Housing Bonnet seal Valve Valve Seal		SS 304 Metal SS 304 Viton	
7.	Compressed air requirement		Specify following for each variant Air pressure - Air Flow rate -	
8.	Differential pressure across gate In closed condition While valve is opening		Specify for each variant differential pressure	
9.	Ambient Operating temperature	Deg C	20-40	
10.	Number of cycle before opening for first service	cycle	Specify	
11.	Overall dimension		Specify	
12.	Bake out temperature (Entire pump assembly)	Deg C	150 (+10)	
13.	Operating position		Any orientation	
14.	On / Off position indicator visual and separate switches for open/close for remote status monitoring		Yes Include details	
15.	Make		Specify Large Size - Small Size -	
16.	Model		Specify Large Size - Small Size -	
17.	Vibration level during operation of gate		Specify	
18.	Essential accessories Include set of two O-rings (for each size of valve as spare in the price bid		Provide details of accessories  (If other essential accessories are necessary for performance enhancement, equipment	

			safety, recommendation	include
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**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirements refer section 2 of this annexure.

**Acceptance criteria:**

- Verification of Test certificates for each valve from original manufacturer.
- He Leak detection of the body and gate seals for compliance check of leak tightness.
- Demonstration of overall operation position, parameters, operation control, during factory acceptance testing of the integrated Cryopump.
- Final acceptance of gate valve shall be after testing and satisfactory operation in integrated Cryopump at IPR site.

**F. Combination Gauge (CG):**

Where under specifications heading “specify” is mentioned, vendor shall fill in the parameters obtained from original manufacturer in his bid submission.

No.	Description	Units	Specification
1.	Quantity	Set	2
2.	Pressure measuring range	mbar	Atmosphere to 1 X 10 <sup>-9</sup>
3.	Degas option		Yes
4.	Filament material type (Tungsten material in filament is not acceptable)		Yttria coated Iridium Specify if different
5.	Detectable partial pressure range	mbar	Faraday cup < 10 <sup>-10</sup> mbar Electron multiplier < 10 <sup>-13</sup> mbar
6.	UHV Connection flange CFF ConFlat		35
7.	Set Points		Trip Point relays for safety interlocking
8.	Ambient Operating temperature	Deg C	20-40
9.	Bake out temperature	Deg C	150 (+10) (with controller cable connected)
10.	Operating position		Any orientation
11.	Make		Specify
12.	Model		Specify
13.	Essential accessories		Provide details of accessories

**Note:**

For general information on vacuum equipment regarding scope, testing etc. requirements refer section 2 of this annexure at the top.

**Acceptance criteria:**

- Compliance check of functional specifications by evaluation of calibration curve /certificates received from original manufacturer
- Detection of pressure in integrated Cryopump Assembly at vendor site
- Final acceptance at IPR site



## Annexure A11 GUIDE LINE SPECIFICATIONS FOR LN2/GN2 VALVES

Description	Manual drive cryogenic valve for LN2 application
Qty.	4
fluid service condition	Liquid nitrogen at -196 Deg C to GN2 at 40 Deg C
Mass flow (l/h):	Max 2-phase 1000
Upstream max .pressure p1 (bar):	5
End connection	Butt weld (For size Pl refer Annexure A8, figure 2)53
Material	SS316L
Seat Seal: Cage/Plug/ Seat	316L / PTFE / PCTFE
Room Temperature Gland Sealing	PTFE
Mounting	Directly on the pipe line
Pattern	Straight / Right angle
Stem	Long stem ~350mm
Type	Manual
Handle pattern	Wheel/ Rod
Valve body design pressure (bar)	As per applicable code
Additional requirement	No frosting shall form on hand wheel while operating at LN2 Temperature
Helium Leak rate through seat mbar-l/s (At ambient Temp)	$< 10^{-4}$
Flow characteristics	Linear/ percentage
Valve body insulation	Not required
Additional accessories: (a) Flow control Plug (b)Room temperature gland seal (PTFE) for valves mentioned herein	2 Nos 4Nos

### 2.0 MARKING:

Following markings have to be written clearly on the valves either by embossing/ engraving or any other means which is indelible and not separable.

- Nominal diameter
- Flow direction
- Control marking ( if required)
- Any other detail (like Nominal operating pressure, reference no. etc.)

### 3.0 INSPECTION & TESTING

Vendor shall submit the following test certificates as mentioned below along with the supply.

- Test of welds of body and inset with bellows as per ASME-IX or equivalent.
- Pressure test & helium leak rate testing as mentioned in section 1.0 and as per API598/ applicable equivalent code.
- Performance checking: Performance check of the fully mounted and adjusted valves, test of frictionless

Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.

## Annexure A12 GUIDE LINE SPECIFICATIONS FOR SAFETY RELIEF VALVES

### General

This specification covers the technical (functional & performance) requirements for the supply of Safety Relief Valves. These valves are to be used for relieving the overpressure of outer vessel, Cryo pipings having nitrogen Liquid/ gas.

### Technical & Performance Specifications:

- Qty.: 4
- Design: Self-actuating, Full lift, spring loaded with angular discharge.
- Installation: These safety relief valves are to be mounted vertically on the system.
- Set pressure and quantity refer to TABLE below, and for detailed specification :

### Inspection & Testing

- Following tests shall be carried out:
  - Visual inspection & dimension checks
  - Set pressure test as per ASME Section VIII Div. 1/ API RP 520
  - Seat leakage test as per API 527/ASME Section VIII
  - Hydro-test for body & bonnet as per ASME Section VIII, UG-99 at 1.5 times the maximum allowable working pressure.

**Note:** Vendor shall provide relevant catalogues for the products.

Following data should be filled/marked against the detailed specification sheets for each type of valve:

- Set pressure tolerance values
- Orifice dimensions in sq. in. /sq. cm
- Overpressure and Blow down values.
- Any deviation from the specifications.

Traceability of material test certificates and internal reports should be maintained for each component.

Specification for Safety Relief Valve			
Sr. No.	Description	Requirement	Remark
1.0	Functional specification		
1.1	Set pressure	1.5 bar (a)	+/- 5%
1.2	Operating temperature	Up to 45°C	
1.3	Set Pressure range	1 to 4 bar	
1.4	Superimposed back pressure	Atm.	
1.5	Maximum Pressure	20 bar	
1.6	Orifice	"E" or higher	As per API 526
1.7	Medium	Nitrogen	
1.8	Overpressure	<10%	
1.9	Blowdown	5-7%	Fixed
2.0	Connections		
2.1	Nominal diameter inlet	1/2"	Outlet is open to atmosphere,
2.2	Nominal diameter outlet	1" or higher	
2.3	Connection inlet	BSP 1" Male	
2.4	Pressure rating inlet:	150 lbs	
2.5	Connection outlet	BSP 1" or higher	

Specification for Safety Relief Valve			
3.0	Materials	Stainless Steel 304 or Brass compatible with 80 K	
4.0	Documentation		
4.1	Design/sizing standard according to	ASME Sec. VIII	
4.2	Company test Cert.	Yes	
4.3	Material Certification for	Standard MTC	
5.0	Flow direction marking	Yes	

- Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.

## Annexure A13 GUIDE LINE SPECIFICATIONS FOR RUPTURE DISC ASSEMBLY

The rupture / burst disc is used to protect the LIGO 80K cryopump vacuum chamber shell from overpressure in the event of a break in the liquid nitrogen circuitry within the chamber.

<b>Material</b>	<b>Stainless steel, Compatible for Cryogenic and UHV applications</b>
<b>Nominal size</b>	DN 100/ 4 inch OD (please refer drawing) One end of rupture disc assembly shall have 4” CF flange
<b>Rupture Set Pressure</b>	<b>0.10 bar (g) (+0.05/- 0)</b>
<b>Temperature range</b>	<b>77K to 423K</b>
<b>Fluid Medium</b>	<b>GN<sub>2</sub></b>
<b>Connection</b>	Pl refer schematic PFD (RD connecting pipe/tube/nozzle shall be butt weld with outer shell )
<b>Quantity</b>	1 installed on the Outer vessel at IPR site + <b>4 Spare</b> = 5

Rupture disc shall be certified by the manufacturer for relieving pressure and flow rate, or shall be tested according to the Code part UG127 and a test report included in the Engineering Note.

Calculations notes for safety valve and rupture disc sizing shall be included in the Engineering Note.

Required Documentation –

The following documentation shall be provided prior to shipment –

- Manufacturer's standard QA reports (including final functional test reports).
- A Certificate of Compliance must be furnished for materials used in the construction of the device

Acceptance/ Shop testing –

- The equipment shall be tested in accordance with the manufacturers' standard shop test.

Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.

Annexure A14 GUIDE LINE SPECIFICATIONS SWING CHECK VALVE as per API 600 and ASME 16.34 standard

<b>Material</b>	<b>Stainless steel, Compatible for 80K temperature</b>
<b>Nominal size</b>	1.5 inch OD
<b>Differential Pressure</b>	<b>0.1 bar g (+/- 0.05)</b>
<b>Connection</b>	Welded/ Thread
<b>Quantity</b>	1 installed on the vent line + <b>1 Spare = 2</b>

- Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.
- Acceptance: For back flow test certificates as per manufacturer standard / API 598 or equivalent standard.

Annexure A15 GUIDE LINE SPECIFICATIONS DIFFERENTIAL PRESSURE TRANSMITTER (DPT) ALONG WITH REQUIRED ISOLATION NEEDLE VALVE

Particular	Specifications
Service	Nitrogen gas service
Quantity	1+ 1 (spare) = 2 nos.
Upper range limit	$\geq 500$ mm WC and $\leq 2000$ mm WC
Calibration range	0 to 7500 mm WC
Accuracy	$\leq \pm 0.1\%$ of calibrated span
Turn down ratio	$\geq 10:1$
Sensor Fill Fluid	Silicon oil
Diaphragm material (sensor material)	316L Stainless Steel
Output	Standard, 4-20 mADC with HART protocol
Zero and Span Adjustment	Through HART / local provision on transmitter
HART configurable	Yes
Power supply	24V DC, 2 wire
Local Display	LCD display
Process connection	1/2 inch NPT female connector
Mounting Bracket	L type bracket with clamp for 2" pipe mounting
Wetted part material	316L Stainless Steel
Environment Protection	IP66 / IP67
Calibration certificate	Yes, required
Accessories (Provide price separately)	3-way manifold with PTFE seal between transmitter and the manifold---1 no. 1/4 inch ferrule connection compatible with manifold---2 no.

- Acceptance criteria: Based on evaluation of calibration curve /certificates from original manufacturer.
- Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.

Annexure A16 GUIDE LINE SPECIFICATIONS FOR PRESSURE GAUGE AND SIGNAL TRANSMITTER (PT) ALONG WITH REQUIRED ISOLATION NEEDLE VALVE FOR PRESSURE MEASUREMENT

- Type : Piezo-Resistive Pressure gauge and signal transmitter
  - Quantity : 2 Nos.
  - Calibrated range : 0 - 5 bar (Absolute)
  - Over range protection : 150% or Higher
  - Transmitter power supply : 8 - 28 VDC
  - Signal output / type : 4 - 20 mA DC / 2-Wire
  - Permissible load : Max. 1000 ohms
  - Accuracy (including Non-linearity+ Hysteresis + Repeatability) :  $\pm 0.2\%$  FS
  - Process connection : G 1/4" Male, with Viton-seal
  - Diaphragm Material / Wetted parts : SS 316L
  - Electrical connection : angular connector DIN 175301-803 A
  - Protection : IP 65
  - Individual Display unit for each pressure gauges
  - Operating temperature range : -40°C to 85 °C
  - Calibration certificate : Required
- 
- Acceptance criteria: Based on evaluation of calibration curve /certificates from original manufacturer.
  - Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.

## Annexure A17 GUIDE LINE SPECIFICATIONS FOR TEMPERATURE SENSORS, TRANSMITTER AND DISPLAY UNIT

- Quantity in (Sets): 4 Active + 2 Redundant (Sets)
- Type: Pt-100 sensors (4 wired cryogenic grade class-A with + 0.3% accuracy over full range and maximum 0.2 K resolution) for mounting on LN2/ GN2 line.
- Measuring Temperature range: -196<sup>0</sup> C to 50<sup>0</sup> C.
- Standard for calibration curve: It shall follows IEC751 standard calibration curve over specified range.
- Dimensions and construction:
  - Sensor shall be bare cylinder of ceramic material body with 2 mm diameter and 25 mm length, tolerance in diameter +/- 0.15 mm and tolerance in length ± 1.5 mm.
  - Sensor shall be made with wire wound technique using platinum wire of and strain free element construction with Alumina powder filling inside ceramic tube.
- Connecting Lead material: Pt-Ni with length of ~10 mm.
- Individual Display units: Four channel Pt-100 compatible display unit for display of measured temperature for above range with signal output / type: 4 - 20 mA DC / 2-Wire
- Required Cable: Four (4) core, Total wire Length ~40 meter
  - Single strand silver plated copper conductor 34 SWG wire (0.2337 mm) with PTFE insulation.
  - PTFE insulation thickness shall not be more than 0.15 mm.
  - Total 4 core cable, two core shall be twisted (which makes two pair cable).
  - Twist pitch: For two core wire 3 twist/inch and two pair shall be twisted to each other & 2 twist/inch require.
  - Core wire insulation voltage rating is 250 VDC continue.
  - All 4 core should have distinguished color.
  - Strictly No Jacket insulation and no shielding braid require on this cable.
  - All core shall be individually tested for dielectric test at 1.5 kV for 1 second or more.

Acceptance criteria: Based on evaluation of calibration curve /certificates from original manufacturer.

Vendors shall submit catalogue or Brochure of products (and dimensional drawing if any) for reference.



## Annexure A18 SPECIFICATIONS FOR INSTRUMENT RACK

The Cryopump local instrument control rack shall implement following functional and operational requirements in order to operate and maintain procured Cryo-pump for LI-VISTA facility in stand-alone mode with provision to operate in remote mode.

The supplied Cryo-pump local instrument control rack is a standalone local control unit of LI-VISTA facility at IPR. The Supervisory Vacuum Control and Monitoring System (VCMS) functional at IPR will monitor, operate and control whole LI-VISTA facility from remote using Modbus TCP or equivalent protocol. This VCMS integrates all LI-VISTA local control subsystems including this Cryo-pump local instrument rack in order to operate the whole LI-VISTA from remote console using various operator interfaces.

### **Cryopump Local Instrument Rack :: Functional Requirements**

- It shall implement provision for self-diagnosis of cryo-pump subsystems
- Continuous Monitoring and plotting of all sensors/signals associated with all cryo-pump subsystems
- Interface with Local Control Unit (LCU) of all equipment such as TMP, gauges, roughing pump etc.
- Interlocking of various cryo-pump subsystems with provision for alarm management
- Operator graphical interfaces to support both local and remote operation
- Data archiving (short and long term) and retrieval
- Programmable control panel with local display unit, to input program parameters & display operating parameters of the cryo-pump.
- It shall provide the interface with supervisory control system LI-VISTA at IPR
- It shall provide a hierarchy of operator interface displays as per LI-VISTA subsystems control and monitoring requirements
- Control instrument rack shall provide a for Personal Computer/ Laptop interface via Modbus (TCP/IP) or equivalent protocol for continuous monitoring and plotting of operation parameters on remote unit. All Modbus register addresses to the interface shall be provided in an operating manual.
- Provide programmer and operational manual of the control system

### **Cryopump Local Instrument Rack :: Operational Requirements**

- It shall provide all required interlocks for safe and reliable operation of cryo-pump
- Display Requirement shall be provided as:
  - A window that shall depict the status of various defined subsystems.
  - A summary window shall be provided the vacuum gauge readings and isolation valve status in all section of Vacuum Equipment.
  - A window that shall provide the present status of all vacuum pumps and isolation valves.
  - A diagram showing the system trend with plots.
- Graphical Operator Display to indicate current configuration of cryo-pump
- Interlocks will be provided as per subsystems operational requirements.