

### **Technical Specifications for Liquid Nitrogen Bath type Heat Exchanger**

The heat exchanger is required to cool Gaseous Helium at  $22.5^{+0.5}$  MPa from 313 K to 82 K. Gaseous Helium at ambient temperature shall be fed to the heat exchanger through coil pipes which are immersed in LN2 bath kept at 80.22 K at 1.4 bar(a). The LN2 heat exchanger shall be vertical, double walled vacuum insulated cryogenic vessel with 2:1 ellipsoidal dish heads comprising multiple helical wound coils or similar arrangement for cooling helium gas. The Heat Exchanger shall consist of Pressure transmitters (2 numbers), DP type level transmitter (2 numbers), a level gauge, 3-way valve and safety devices for vacuum failure and fire case and rupture of coil for inner vessel and a vacuum safety device of suitable size for outer vessel. The party shall provide a provision for inserting a vertical boom inside a nozzle of size DN100 with a closure flange with separate evacuation port, independent of shell vacuum. Fabrication of boom and mounting of temperature and level sensors shall be in the scope of work of IPRC. The complete details of the type Heat Exchanger is given in Annexure-1.

***Note: The Bath type heat exchanger shall be mounted on a platform with space constraints, hence the max. Envelope size for this heat exchanger shall be limited to outer diameter of 2 m and height of 3.2 m including all nozzle projections from the base of the heat exchanger.***

#### **1. Scope of Work**

The overall scope of Work comprises:

- Design, Detail engineering, sourcing of raw materials and bought-out flow components & instruments including, safety relief valve/Rupture disc with three-way manifold valve and other associated components including provision for inserting a vertical boom for mounting Level/ Temperature sensor.
- Fabrication, testing, in-house inspection engaging Third Party Inspection Agency and ASME 'U' Stamp by Authorized Inspector.
- Transportation of Heat Exchanger to IPRC, Mahendragiri.
- Supervision during Commissioning at IPRC.

#### **2. Design Data**

**Table 1: Specifications of Heat Exchanger**

<b>➤ Design Data for Coils</b>	
Coil Configuration	The heat exchanger shall preferably consist of multiple helical wound coils with specified pitch in transverse and longitudinal direction in which multiple concentric helical coils shall originate from the inlet bottom header and terminate at outlet top header, or any other similar arrangement meeting the specification of overall compactness and technical requirement.
Equipment Tag number	IHX-3703
Operating Fluid for coils	Gaseous Helium
Operating Pressure for coils	$23^{+0.2}$ MPa
Inlet Temperature for coils	313 K
Outlet Temperature for coils	82 K
Design Pressure for coils	30 MPa
Pneumatic Test Pressure for coils	33 MPa
Design Temperature for coils	70 – 350 K

Bath Temperature	80.22 K @ 1.4 bar
Design Flow-rate through coils	0.1 kg/sec
Pressure drop across coils	< 0.2 MPa
Size of tube/ pipe for coils (Diameter, thickness and length)	The tube of size 10 mm and 2 mm thickness shall be preferably used. However, the same be confirmed during Detailed Engineering Review for adequacy in terms of strength, pressure drop and heat transfer area.
<b>Height of concentric coils, length of coils, Minimum outer surface area for coils, Number or turns in coils, No. of coils, Longitudinal and Transverse Pitch, Core diameter of coils, etc.</b>	To be finalized during Detailed Engineering Review
<b>Design Code</b>	
Coil Pipe Strength	ASME B31.3
Coil Pipe Surface Area	To be carried out by vendor during Detailed Engineering Review.
<ul style="list-style-type: none"> <li>• <b>Material</b></li> </ul>	
Coil	SS 304L or dual grade SS304/304L tubes
Coupling/ weldolet	SS 304L or dual grade SS304/304L tubes
<ul style="list-style-type: none"> <li>➤ <b>Design Data for Inner Vessel</b></li> </ul>	
Design, fabrication, inspection and testing Code	ASME Sec. VIII, Div. 1. Thickness as per UG-27, ASME Sec. VIII Div. 1, with allowable stress values as per ASME Sec. II-Part D, without applying note G5.
Orientation	Vertical
Type of Heat Exchanger	Cylindrical with 2:1 Ellipsoidal dish ends
Volume	The minimum volume of inner vessel shall be 1.2 m <sup>3</sup> , including 500 mm level above coil. However, the same shall be discussed and finalized during Detailed Engineering Review to meet the requirement.
Maximum Working Pressure	0.4 MPa(a)
Design Pressure	0.5 MPa(a)
Hydrotest Pressure	0.75 MPa(a)
Pneumatic Test Pressure	0.6 MPa(a)
Design Temperature	350 K (max.), 77 K (min.)
Operating Fluid	Liquid Nitrogen
Operating Temperature	70 - 350 K
Ullage Volume	10% of gross volume of inner vessel. The Volume of Liquid Nitrogen above the coils shall be adequate during the steady state and transient state and coils should always be immersed during steady state operation with reasonable margin. The volume requirement shall be finalized during detailed engineering review by results of calculation. <i>Sufficient shell length of ~500 mm shall be considered above coils to maintain adequate liquid level for design of inner vessel.</i>
Fatigue Life, considering pressure and thermal cycles	8000 cycles
Provision of Nozzle for Ejector	The Ejector shall be connected to the vent nozzle of size DN50. The nozzle size shall be confirmed during Detailed Engineering Review.
Heat Treatment	As per code

<b>• Material</b>	
Shell and Dish end	SS 304L or dual grade SS304/304L
Nozzles	SS 304L or dual grade SS304/304L
Pipe	SS 304L or dual grade SS304/304L
<b>➤ Design Data for Outer Vessel</b>	
Design, fabrication, inspection and testing Code	CGA-341, 2007 or equivalent
Operating Pressure	Vacuum
Allowable internal over-pressure of outer vessel	0.15 MPa(a)
External Overpressure	0.3 MPa (g)
Design Temperature	350 K
Pneumatic Pressure	0.23 MPa(g)
Corrosion Allowance	1.6 mm
Heat Treatment	As per Code
Insulation	Evacuated Multilayer Insulation (Super Insulation)
Vacuum Pressure in the Jacket	better than 1E-02 mbar
Net Evaporation Test	Detailed Calculation for estimation of NER shall be carried out by the party and shall be preferably lesser than 4% per day.
<b>Max. Dimensions* (to be adhered to)</b>	<b>Outer Dia.: 2 m Height: 3.2 m from base upto the top of heat exchanger</b>
Supports	Four legs only. Skirt/saddle design not acceptable.
Heat Treatment	As per Code
<b>• Material</b>	
Shell and Dish end	ASTM A 515 Gr. 70 or ASTM A516 Gr. 70 or equivalent material
Lifting Lug	SA516 Gr. 70 or equivalent material
Name plate/ bracket	SA516 Gr. 70 or equivalent material
Bolts	ASTM A 193 B8
Nuts	ASTM A 194 8

❖ **Specifications for Field Instrumentation items like:**

- Level Transmitters (ILI)
- Pressure Transmitters (IPI)

Specification documents along with their mounting requirements are furnished in **Annexure-3**. Vendor shall study the details & furnish the required information and comply in their Technical bid.

DN100 size nozzle shall be provided in inner vessel for mounting temperature transmitter boom. Mounting of temperature transmitters and level switches shall be in the scope of Department. The party shall provide the arrangement for mounting the boom on inner vessel. Connection from transmitter boom shall be taken through vacuum feed connector (*to be fitted with the Heat Exchanger and supplied by the party*).

❖ **Safety Relief Valves/Burst Disc**

The supplier shall provide two sets of Safety Relief Devices for protection against fire-engulfment & Coil rupture and two sets of safety relief valves sized for Vacuum failure case, for safeguarding the Heat Exchanger IHX-3703 with a flow diverter valve.

**Design Code:** ISO 21013-3\_2016

**Suggested sub- vendors for Safety Relief Valve:**

1. Tyco Sanmar Ltd., Chennai
2. Fainger Lesser Valves Pvt Ltd., Mumbai
3. Anderson Greenwood & Co. Texas, USA
4. Crosby Valve & Engg. Co. Ltd., England

**Suggested sub- vendors for Rupture Disc:**

1. BS&B System (India) Ltd., Chennai
2. Fike Corporation, USA
3. FDC, South Korea

The supplier shall submit the sizing of Safety relief valve/ Rupture Disc for approval of Department.

- Tag number for Safety Relief Valve shall be IVR S-3703 and IVR S-3704.
- Tag number for Rupture Disc shall be IBD S-3703, IBD S-3704.
- The safety block shall be provided with an Excess flow valve IEV S-3703 and IEV S-3704.
- The system shall be designed for Vacuum failure and fire-engulfment case.
- The tentative specification sheet of SRV and Burst Disc is given in Annexure-2.

❖ **Three-way Manifold Valve ITVM-S 3702**

The supplier shall supply a three-way manifold manual valve ITVM-S 3702 for connecting to Safety relief valve/ Rupture Disc set.

Valve Tag no.	Pattern	Type	Port Way	Body and Bonnet Material	Fluid Medium	Working Temp (K)	Size (DN)	MAWP (MPa)	Pressure Rating Class	Minimum Cv
ITVM-S 3702	Globe	BS, ES	3/2	A182 F304L	GN2	70-350	Area=Burst Disc size	1.0	150	Area=Burst Disc size

The size of the Safety Relief Devices shall be confirmed during Detailed Engineering Review, based on sizing of Safety Relief Valve/ Rupture Disc. The valve shall be supplied from a reputed manufacturer, after confirmation from department.

3. **MATERIAL OF CONSTRUCTION**

- Inner vessel** : ASTM A 240 304L or 304/304L DUAL CERTIFIED
- Outer vessel** : ASTM A 515 / 70 or ASTM A516 Gr. 70 or equivalent material
- Coils** : ASTM A 312 TP 304L or dual certified 304/304L
- Nozzle Pipes** : ASTM A 312 TP 304L (Seamless pipe for nominal pipe size  $\leq$  DN250; Longitudinal seam-welded pipe with full radiography for nominal pipe size

	≥ DN300)
<b>Pipe fittings</b>	: ASTM A 403 WP 304L/ 316L
<b>Flanges</b>	: ASTM A 182 F 304L/ 316L/ 321
<b>Bolts</b>	: ASTM A 320 B8
<b>Nuts</b>	: ASTM A 194 8
<b>Lifting Lug</b>	: ASTM A516 Gr.70
<b>Skirt/saddle supports</b>	: ASTM A516 Gr.70
<b>Name plate / bracket</b>	: SA 240 Gr. 304L

**Note:** Cold stretched/ pressure strengthened material should not be used.

#### 4. CONFIGURATION DETAILS

- 1.1 The Overall configuration of Heat Exchanger is given in Annexure-4. The heat exchanger shall be of vertical configuration with cylindrical shell and 2:1 semi-ellipsoidal dish ends.
- 1.2 Heat Exchanger coil shall preferably consist of **multiple helical wound coils** with specified pitch in transverse and longitudinal direction in which multiple concentric helical coils shall originate from the inlet bottom header and terminate at outlet top header, or any other similar arrangement meeting the specification of overall compactness and technical requirement. **The arrangement of coils is essential in order to achieve optimized vessel size and overall compactness. The level of Liquid Nitrogen shall be adequate to cool gaseous helium for duration of at least 3 minutes @ 0.1 kg/sec of helium and this level must be considered beyond 10% ullage volume.**
- 1.3 The inner vessel of the Heat Exchanger shall be designed considering MAWP + Liquid static head and also for vacuum (considering vacuum pressure in the outer jacket).
- 1.4 The Heat Exchanger shall be of vertical configuration with cylindrical shell and 2:1 ellipsoidal ends.
- 1.5 The Heat Exchanger shall be provided with suitable legs for supporting the Heat Exchanger.
- 1.6 The Heat Exchanger shall be provided with suitable lifting lugs for handling.
- 1.7 The fill/ drain port of the Heat Exchanger shall be provided with suitable anti-vortex baffles.
- 1.8 The pressurization and vent ports of the Heat Exchanger shall be provided with diffuser. The flow area of diffuser holes shall of 3 times the inlet pipe area.
- 1.9 All the nozzles of DN 50 and smaller sizes shall be suitably stiffened with gusset plates, as per code requirements.
- 1.10 Suitable earthing bosses shall be provided for protection against lightning and static electricity.
- 1.11 The required size of different nozzles of Heat Exchanger is specified in the Annexure-4: GA Drawing. Blank-off flange for all the nozzle shall be supplied along with metal gasket, with pressure rating suitable for the MAWP of the Heat Exchanger.

**The sizes of nozzles mentioned in Annexure-4 are tentative and its adequacy shall be confirmed during Detailed Engineering Review by the party.**

- 1.12 Filler wire used for welding shall conform to the code requirements.
- 11.13 The outer vessel of Heat Exchanger shall be fitted with a rupture disc device, a vacuum pump-out port cum seal-off valve and a suitable vacuum gauge with portable display.
- 11.14 The Heat Exchanger shall be provided with a name plate made of Stainless steel. The name plate shall be etched with data such as MAWP, fluid medium, U-stamping, date of testing, weight, etc.
- 1.15 All the nozzles in the Heat Exchanger shall be provided with blank off flanges, bolt & nuts and gaskets with pressure rating suitable for MAWP of Heat Exchanger in order to maintain positive pressure. The inner vessel and the coil shall be pressurized and preserved at 0.15 MPa(a) and 0.2 MPa(a) respectively with Gaseous Nitrogen.
- 11.14 Cold stretching of pressure vessel is not allowed.

#### General Notes:

- a. All flange bolts shall straddle normal to central line of vessel unless otherwise stated.
- b. All flange gasket face machined with 3.2 to 6.4  $\mu\text{m}$  (Ra 125 to 250 AARH).
- c. Appropriate O-rings/ seals instead of serrated gaskets shall be used for vacuum service, wherever required.
- d. Hydro-testing gasket shall be same as gaskets are the same type used in service.
- e. Unless otherwise indicated nozzle projection measured from vessel centre & T.L.
- f. All longitudinal & circumferential seam clear nozzle opening reinforcing pads when the covering of circumferential seam by reinforcing pads is unavoidable, ground the seam flush, examine it, test it prior to welding the reinforcing pads in place.
- g. Coat all machine surface, subject to atmospheric corrosion, with heavy rust preventive grease.
- h. Pickling, passivation shall be done for all SS materials, except bellows, if any.
- i. Fatigue analysis as per ASME Sec. VIII Div. 2 shall be carried out, as referred in Chapter 9.d.

## 5. FABRICATION

The inner vessel shall be designed and constructed in accordance with the Boiler and Pressure Vessel (unfired) code ASME Sec. VIII Div. I or as per equivalent standards, provided minimum requirements specified in ASME Sec. VIII Div. I are complied. Allowable stress values as per ASME Sec. II Part D shall be calculated without applying note G5. Outer vessel shall be designed as per CGA 341.2002 or equivalent.

- 5.1. Forming:** All the forming works of the Heat Exchanger shall be carried out by suitable forming process. After forming, the parts shall be suitably stress-relieved.
- a. **Forming and Heat treatment:** As Per Design Code ASME Sec. VIII Div. 1
  - b. Prior to final inspection, all slag, grit, dirt, weld splatter, oil & other foreign matter to be removed from inside & outside of vessel.
  - c. All sharp corner to be rounded off radius of 3mm.
  - d. All nozzle inside edges except nozzles with inside projection shall be flushed with internal surface of vessel and rounded off with 3mm radius.
  - e. Reinforcing pads shall be provided with 1 No. ¼" NPT Vent hole located at 45° off the longitudinal axis of the vessel. Perform soap solution test with 0.7 bar (Minimum) with 15 bar (Maximum) gauge air prior to performing hydro-static testing.

- f. TOE to TOE gap between nozzles & shell/heads welds are 50mm minimum & 2 times shell/ head thickness for carbon steel material & SS materials respectively.
- g. Minimum distance between the staggered longitudinal seams of two adjacent courses shall be minimum 6 times the shell thickness but not less than 100mm.
- h. Grooves or notches in the base metal while chipping & grinding, gouging & repairing of welds is not allowed. Under cutting at the side of weldments is not allowed.
- i. Fill all tapped holes on the re-pads with corrosion inhabiting grease.
- j. Remove temporary attachments by grinding or thermal cutting. After removal of temporary attachments, remove the remains of the temporary welds by grinding. Examine the area by liquid penetrant method.
- k. The dished ends (if fabricated from plates) shall be solution annealed after forming operation, in-line with the Code requirement.
- l. All the plates used for dished & shell should have original mill heat number.
- m. All the nozzles in the Heat Exchanger shall be provided with blank-off flanges, bolts & nuts and gaskets with pressure ratings suitable for MAWP of Heat Exchanger/ nozzles/ coils.

**5.2. Welding:** It is to be noted that the welding on stainless steel parts of entire inner vessel for the full thickness of the Heat Exchanger shall be carried out by Gas purged Tungsten Argon Welding (GTAW) with Gaseous Argon of 99.995 % purity as the purge medium. All the welding on carbon steel parts of the outer vessel of the Heat Exchanger shall be carried out by Shielded Metal Arc Welding (SMAW)/Gas metal Arc welding (GMAW) process.

- a. Prior to commencement of welding on the Heat Exchanger, welding procedure qualification and welder's performance qualification tests, in accordance with Section IX of ASME BPV code.
- b. No welding is permitted after hydro-test.
- c. The dissimilar thickness to be joined with smooth transition of 1:3 taper (minimum) as per code para UW-9 and UW-33.
- d. Unless otherwise specified, the fillet weld throat size for non-pressure parts to be 0.7 times of least thickness of parts to be joined.
- e. Ensure each layer of weld metal in multiple-layers welding is cleaned of slag and other foreign materials before applying next layer.
- f. **All the welds to be 100% dye penetrate tested for root welds and after completion of final weld.**

**5.3. Inspection and NDE:**

- a. All welds joints shall be inspected on inside & outside, surfaces as per approved weld book UW-35, all welds shall be continuous.
- b. Water used for hydro testing shall have chloride content <50ppm for ferrite metal & 30ppm for stainless steel materials.
- c. Visual examination (internal & external) after completion of welding to check the compliance to UW-35 shall be performed for both long L seam (CAT.A) & Circumferential seam (CAT.B) welds.
- d. Weldment of lifting lug shall be examined by surface method (magnetic or penetration).
- e. 100% radiography (2-2T sensitivity) examination shall be carried out for all butt joints on the vessel, coils, interconnecting pipelines & nozzles, as per QAP approved by the Department.
- f. DP test shall be carried out for all welds, as per QAP approved by the Department.
- g. Visual inspection shall be carried out for any surface defects for all materials.
- h. 100% ultrasonic testing shall be carried out for all nozzles pipes & plates as per ASTM/ ASME.
- i. Joints alignment & peaking in shell & head shell be considered as per ASME Sec. VIII Div. 2 clause 6.16.1 & 6.1.6.3 respectively.

- j. All weld joints shall be UT tested & weld surface shall PT/MT tested as per UHA-34.

**5.4. Surface Treatment:** The following procedure shall be employed for surface treatment of the Heat Exchanger.

**5.4.1 Cleaning of stainless steel surfaces:** After fabrication, the interior and exterior surfaces of the inner vessel and the interior surfaces of the coils, nozzles, interconnecting pipelines and flow components shall be cleaned for *Oxygen Service*, employing the following procedure:

- a. **Mechanical cleaning:** All the metallic surfaces with scales and newly welded surfaces shall be cleaned by scrubbing with stainless steel metallic wire brush. The loose scales and particles obtained from mechanical cleaning shall be removed by blowing with dry air, sucking with vacuum cleaner or washing with water.
- b. **Degreasing:** The surfaces shall be degreased to *Oxygen service* standard as per CGA G-4.1 (Compressed Gases Association Inc, USA) or MIL-C-52211 or ASTM G-93 or equivalent.
- c. **Pickling:** In order to remove rusts and scales, the surfaces are pickled with a solution containing Hydro-fluoric acid (HF) and Nitric acid (HNO<sub>3</sub>). The composition of pickling solution and duration are to be adjusted after trial test on a sample piece to remove uniformly less than 25 µm thick material. Mostly, the composition is as follows:

HF	: 5 % (by mass)
HNO <sub>3</sub>	: 15 to 20 %
Water	: Remainder

This is followed by rinsing with water.

- d. **Passivation:** In order to form a protective layer, the surfaces are passivated with a solution of the following composition:

HNO <sub>3</sub>	: 25 % (by volume)
Water	: Remainder
Duration	: 2 h (minimum)

This is followed by rinsing with De-Mineralized (DM) water.

**The bellows shall not be subjected to pickling and passivation.**

- e. **Drying:** The surfaces of the Heat Exchanger shall be dried by purging with dry Air or Gaseous Nitrogen until the moisture content in the medium is brought down to 20 ppmv. Before transportation, all the openings shall be kept closed in order to avoid entry of any foreign particle inside the Heat Exchanger and the inner vessel and coils be kept pressurized and preserved with Gaseous Nitrogen.

**5.4.2 Cleaning of carbon steel surfaces**

- The interior and exterior surfaces of the outer vessel shall be sand-blasted and mechanically cleaned.
- Painting:** The exterior surfaces of the outer Heat Exchanger shall be painted with 2 coats of primer (Zinc or Red oxide) and 2 coats of white color Poly Urethane (PU) or Epoxy paint. A color band of 200 mm width shall be painted circumferentially at the middle of the Heat Exchanger. The color scheme shall be green for Heat Exchanger.

**5.5. Materials:**

Materials for all permanent welded attachments to pressure parts shall be of the same grade as the shell materials, all internal welded attachments shall also meet the supplementary requirement applicable to shell plates.



**5.6. Tolerance:**

- a. Codes required tolerances on vessel shall be as per code PARA-UG-80 (Shell) and UG-81 (Head) for out of roundness, UW-33 (alignment) UW-35 (reinforcement) while fabrication & welding. For other tolerance manufactured accepted tolerances shall be used with prior approval of Purchaser.
- b. All STD. blinds & flange shall be procured with min. 1mm over tolerance on thickness

**5.7. Transportation:**

- a. Flanges to be protected with 12.7mm thickness bolted wooden or 3.2mm thickness stainless steel cover & secured with minimum 4 bolts before dispatch.
- b. Coat all thread bolts, studs & nuts with metallic base, rust hinge inhabiting lubricant to prevent galling in used & corrosion during transportation & storage.

**6. Vacuum Components and Instruments**

1. The outer vessel of the Heat Exchanger shall be fitted with a vacuum safety device, vacuum pump-out port cum seal-off valve and a suitable vacuum gauge head with portable display with isolation valve. The vacuum safety device shall be set to relieve at an internal pressure of 0.13 MPa(a) to 0.15 MPa(a). However, during normal period, the vacuum safety device shall withstand an external pressure of 0.1 MPa(a) with full vacuum inside.
2. The Heat Exchanger shall be provided with a provision for local level gauges of DP type, alongside the vessel through nozzle. For mounting fluid temperature sensors and level switches, a provision for flanged boom for mounting the instruments shall be provided into the inner vessel (SCOPE OF IPRC) and it shall be sealed with the jacket through proper bellows, through appropriate nozzles. Supply and mounting of Vacuum Feedthrough Connector for level and temperature sensors shall be in the scope of Party.

**7. TESTS**

The following tests are to be performed as per the standards mentioned therein.

- 7.1 **Material certificates:** The material test certificates shall be provided for all the principal and pressure-bearing parts of the Heat Exchanger (including plates, nozzles, interconnecting pipes, flow components, coils, etc.) to ascertain the physical and chemical properties, impact test at 77 K, hydrotest, flattening test, micro and macro structure examination of coils and pipes, etc. in addition to manufacturer's test certificates. The sample from raw material shall be taken by TPI and tested at NABL accredited laboratory.
- 7.2 **Ultrasonic test:** All the plates, tubes, pipes, fittings, flanges, etc. used for the fabrication of inner vessel & outer vessel and the pipes used for the coils, nozzles and interconnection shall be subjected to 100 % ultrasonic test using pulse-echo procedure, as per ASTM standards.
- 7.3 **Radiographic test:** All the (100 % of the) stainless steel butt weld joints on the inner vessel as well the nozzles, interconnecting pipelines, flow components, etc and 10 % of the butt weld joints on the outer vessel shall be subject to radiographic test with X-rays to 2-2T sensitivity.
- 7.4 **DP Test:** All the welds shall be subjected to DP test. It shall include minimum root weld and final weld.
- 7.5 **Hydro-Pneumatic Pressure test of Inner and Outer Vessel:** In lieu of hydraulic test, the vessel (in assembled form) shall be subject to pneumatic pressure test with dry nitrogen at a pressure as specified by the design code, but not lesser than 1.3 times the respective MAWP/ design pressure as per ASME Sec VIII Div.1. After the test, the moisture content in the Heat Exchanger shall be limited <200 ppm.
- 7.6 **Hydro-Pneumatic Testing of Coils of Heat Exchanger:** The coils shall be separately hydro-

tested at 1.5 times the design pressure before integration inside the inner vessel. After the test, heat exchanger coil shall be dried thoroughly by purging with dry nitrogen until the moisture level is less than 20 ppm,v.

7.7 **MSLD Leak test:**

- a. **Inner Vessel and Outer Vessel:** The leak tightness across the inner vessel as well as the outer vessel shall be tested with Gaseous Helium Mass Spectrometer Leak Detector (MSLD) as per Article 10, Section V of ASME BPV code by *hood technique*. While leak-testing the inner vessel and coils, the internal volume shall be charged with a mixture of 75 % Gaseous Nitrogen + 25 % Gaseous Helium and the annular volume between the inner vessel and the outer vessel be evacuated and connected to MSLD. While leak-testing the outer vessel, the exterior surface of the outer vessel shall be shrouded by synthetic bag with 100 % Gaseous Helium and the annular volume between the inner vessel and the outer vessel be evacuated and connected to MSLD. **The leakage rate shall be finer than  $1E-9 Pa.m^3/s$ .**
- b. **Coils:** The coils of Heat Exchanger shall be tested with Gaseous Helium Mass Spectrometer Leak Detector (MSLD) before and after integration inside inner vessel in sniffer mode. The acceptance criterion shall be leakage finer than  $1E-09 Pa.m^3/sec$ .
- c. **Outer Vessel, coils and Inner Vessel:** In Vacuum Mode. **The leakage rate shall be finer than  $1E-9 Pa.m^3/s$ .**

7.8 **Vacuum Retention test:** The vacuum holding (vacuum retention) test shall be conducted at supplier's works. The vacuum level in the vacuum jacket shall be recorded for a minimum duration of 72 hours after achieving stable vacuum and stopping of evacuation of vacuum jacket and sealing of the pump out port. There shall be no appreciable increase in vacuum level and it should stabilize at  $< 10^{-3}$  mbar (at atmospheric temperature).

7.9 **Cold shock test:** The cold shock and MSLD leak test shall be conducted by filling the Heat Exchanger with Liquid Nitrogen and observe for any structural defects or sweating/ frosting on the jacket. MSLD shall be carried out again as per 7.7 after Cold shock test.

7.10 **Performance and Qualification test:** These tests shall be conducted at Suppliers site. The Heat Exchanger shall be filled with Liquid Nitrogen to 80% of its gross volume and the evaporation loss rate be measured by employing a gas flow meter in the vent line for a duration of 24 hours. The evaporation loss rate thus measured shall preferably be less than the 4% per day. The performance test shall also comprise functional check of all flow components and instruments. A detailed Procedure for conducting performance test shall be prepared by the supplier. The procedure shall include the following;

- a) Review of vacuum level in the vacuum jacket.
- b) On the day of performance test the vacuum level in the vacuum jacket shall be measured and recorded before start filling of LN2.
- c) After completion of performance test and draining LN2 & warm up, the vacuum level in the jacket shall be measured and ensure that the vacuum level is not deteriorated.

Moreover, the performance test shall also comprise functional check of all components and instruments. The performance test shall be performed in the presence of Department and TPI. Additionally, the party shall demonstrate the performance of heat exchanger using actual fluids and demonstrate the required temperature of GHe at the outlet of heat exchanger at IPRC (commissioning to be carried out by IPRC and supervised by the party). The supply of actual fluids including Liquid Nitrogen and Gaseous Helium at IPRC is under the scope of IPRC.

## 8. INSPECTION

The in-process (stage) and pre-delivery inspection of the Heat Exchanger shall be carried out by one of the following Third Party Inspection (TPI) agencies:

- Lloyds Register Industrial Services Pvt. Ltd. (LRIS)
- Det-Norske Veritas (DNV)
- Technischer Überwachungs Verein (TUV)
- Bureau Veritas (BV)

It shall be the responsibility of the supplier to arrange for and coordinate with the TPI agency. The scope of inspection shall be as follows.

- 5.1 Review and approval of the design calculations, fabrication drawings and QAP.
- 5.2 Identification of raw materials and review of the material test certificates for compliance with the relevant requirements, including UT for plates.
- 5.3 Review of test and calibration certificates for compliance with the specification and visual examination of the bought-out flow components and instruments.
- 5.4 Witnessing and certification of welding procedure qualification and welder's performance qualification tests. If the welders already possess the performance certificate, the TPI agency shall review and authorize the same.
- 5.5 Review of X-ray films of radiographic tests for possible defects in the weld joints and vacuum retention test results.
- 5.6 Inspection at any stage of fabrication to ensure that the methodology employed for fabrication is in compliance with the requirements of standard codes and practices and the approved documents.
- 5.7 ***Witnessing of pressure test, leak test and cold shock test.***
- 5.8 Issuance of Pre-Delivery Inspection (PDI) certificate and stamping on the Heat Exchanger.

Note: Apart from inspection by the TPI agency, the Purchaser's representative(s) shall also witness any test as may be deemed necessary at their discretion.

## 9. DOCUMENTATION

The following documents (in English) in 2 hard prints/ copies as well as in electronic/ soft copy shall be furnished at different stages specified thereupon.

- 9.1 **Detail engineering review:** Within 8 (eight) weeks from placement/ award of the Purchase order, the Purchaser shall conduct the ***Detail Engineering Review (DER)***. The following documents duly reviewed and approved by the TPI agency for compliance with the requirements of the relevant design codes as specified in the Purchase order and statutory regulations, shall be submitted to the Purchaser during the DER. Before commencement of fabrication of the Heat Exchanger, the supplier is required to submit all the drawings and documents duly approved by TPI agency for approval by the Department. These documents are subject to review by the Purchaser and only upon approval of the same by the Purchaser, the supplier shall proceed with fabrication. However, the Purchaser's approval shall not absolve the Supplier of their responsibility to comply with the specifications of the Purchase order.
  - a. An overall dimensioned General Arrangement (GA) drawing of the Heat Exchanger, coil arrangement, showing the assembled view of coils and nozzles along with all accessories shall be provided. The details of the interconnecting pipelines and their location with respect to the Heat Exchanger shall also be shown in the GA drawing. The interface details for both fluid connections and instrument connections, including the relative positioning among the interfaces, their location with respect to the Heat Exchanger and the end connection/ preparation details for each interface shall also be shown in the GA drawing.

- b. The foundation details of the Heat Exchanger, indicating the forces and moments acting on the foundation due to static and dynamic loading of the Heat Exchanger, wind loads, seismic load and load due to external overpressure on the Heat Exchanger shall be provided within 4-Months after placement of order. The calculations for arriving at the forces and moments acting on the foundation due to the aforesaid factors shall also be provided.
  - c. The detailed **FEA of the inner and outer vessel of Heat Exchanger along with nozzles, coils and leg support for the structural and thermal loads at specified external and internal pressure with ANSYS Workbench and Fatigue Analysis** shall be provided. In addition to this, the supplier shall furnish the design calculations of coil length. Flexibility analysis of the piping and coils shall be carried out.
  - d. The detailed **analysis/ calculations to predict fatigue life (8000 cycles)** of the heat exchanger including coils considering temperature and pressure cycling during chill down, filling and expulsion shall be provided.
  - f. A schedule chart, preferably in the form a PERT network, detailing the various activities involved in fabrication and the time required for completing the same, so as to comply with the specified overall delivery period, shall be furnished.
  - g. A detailed Quality Assurance Plan (QAP) shall be provided.
  - h. The make, model number and specifications of the flow components and instruments along with the relevant catalogues shall be provided.
  - i. Detailed procedure for conducting cold shock test and performance test including the methodology of computing evaporation loss rate of actual working fluid from the measured evaporation loss rate of LN2 shall be provided.
- 9.2 **During the course of fabrication:** The details of activities completed by the end of every month shall be sent to the Purchaser. The delay, if any, from the agreed schedule and the reasons, if any, therefore shall be highlighted. The schedule chart shall also be updated in such cases.
- 9.3 **Pre-delivery review:** On completion of fabrication and testing, but prior to delivery of the consignment, the Purchaser shall conduct a pre-delivery review. During the review, the following documents, duly approved by the TPI agency, shall be submitted to the Purchaser. The Purchaser shall review the same to ensure compliance with the specification of the Purchase order. On being satisfied, the Purchaser shall issue a “Purchaser’s delivery clearance”, only upon receipt of which the Supplier shall proceed with delivery of the consignment.
- a. Documents as per QAP & Documentation as per 6.1.
  - b. The certificates of all tests and calibration (including those for the bought-out flow components and instruments) shall be provided. Each page of the certificates shall be duly counter-signed and stamped by the TPI agency.
  - c. Pre-Delivery Inspection certificate by the TPI agency.
  - d. Warranty certificate.
  - e. As-built GA and fabrication drawings.
  - f. Instruction manual for unloading of Heat Exchanger from the transportation trailer, erection, commissioning, operation, trouble-shooting and maintenance.

#### **10. Delivery Period:**

The delivery period to Purchaser’s site shall be 10 months from the data of release/ award of Purchase Order.

#### **11. ERECTION, COMMISSIONING AND SUPERVISION**

After receipt of the heat exchanger at the Purchaser’s site at IPRC, Mahendragiri, the heat exchanger shall be erected by the Purchaser based on the documents to be provided by the Supplier for the same.

The commissioning shall comprise performance test of Heat Exchanger and pressure test up to the MEOP with actual working fluids viz. Liquid Nitrogen in the bath and Gaseous Helium in the coils, including functional check of the flow components and instruments and demonstration of required temperature at the outlet of coils at a flow-rate in-line with the requirement mentioned in technical specifications. The evaporation loss rates measured during commissioning with the respective working fluids shall be preferably better than 4% per day. Though **Commissioning is NOT included under the Vendor's responsibility**, in case any discrepancy or ill-performance is observed during commissioning, it shall be the Supplier's responsibility to rectify/ replace the defective/ ill-performing subsystems or the entire heat exchanger. In case the defective/ ill-performing sub-systems or the entire heat exchanger require rectification/ rework to be carried out at the Supplier's works, it shall be Supplier's responsibility to rectify at site or at their work centre by transporting the same to the Supplier's works, if required and back to the Purchaser's site, at supplier's cost.

**12. Warranty:**

The heat exchanger shall be guaranteed for satisfactory performance over a period of 24 months from the date of dispatch from the Supplier's works or 18 months from the date of commissioning at the Purchaser's site, whichever happens to be earlier, against fabrication, manufacturing and workmanship defects. In case any defect develops in the work due to bad material and / or bad workmanship before the expiry of guarantee period, the Bidder, on notification by Department, shall rectify or remedy the defect or replace items, at their own cost and shall make their own arrangements to provide materials, labour, equipment and any other appliances required in this regard.

**13. SECRECY**

The technical information, drawings, specification and other related documents forming part of enquiry or P.O are the property of the Department and shall not be used for any other purpose, except for execution of this order. All rights, including the rights in the event of grant of a patent and registration of designs are reserved. The technical information, drawings, specifications, records and other documents shall not be copied, transcribed, traced or reproduced in any other form or otherwise in whole and/ or duplicated, modified and/or disclosed to a third party and/or not misused in any other form whatsoever without the Department's consent in writing except to the extent required for the execution of the work. This technical information, drawings, specifications, records and other documents shall be returned to the Department with all approved copies and duplicates, if any, immediately after they have been used for the agreed purpose.