LIQUID NITROGEN DISTRIBUTION SYSTEM FOR INTF CRYOPUMPS

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Acronyms and definitions

Acronym	Definition
CAD	Computer Aided Design
DAQ	Data Acquisition
DNB	Diagnostics Neutral Beam
DN	Nominal Diameter
DR	Deviation Request
FAT	Factory Acceptance Test
FATR	Factory Acceptance Tests Review
FDR	Final Design Review
FE/FT	Cryogenic Flow Meter & Transmitter
FCV	Pneumatic Actuated Flow Control Valve
GN2	Gaseous Nitrogen
INTF	Indian test facility
IRR	Installation Readiness Review
ITP	Inspection and Test Plan
KOM	Kick-off Meeting
LN2	Liquid Nitrogen
LIV	Loss of Insulation Vacuum
LT	Leak testing
MCV	Manual Control Valve
MIP	Manufacturing & Inspection Plan
MLI	Multilayer Insulation
MRR	Manufacturing Readiness Review
NO	Normal Operation
NCR	Non Conformance Request
NDE	Non Destructive Examination
NDT	Non Destructive Test
P&ID	Piping and Instrumentation Diagram
PED	Pressure Equipment Directive
PSV	Pressure Safety Valve
PE/PT	Cryogenic Pressure Sensor & Transmitter
PPT	Pneumatic Pressure Test
PG	Purge
RT	Radiographic Testing
SAT	Site Acceptance Test
SATR	Site Acceptance Tests Review
VCR	Vacuum Coupling Radiation
VT	Visual Testing

1 Introduction to INTF Plus INTF Cryogenics

Indian test facility (INTF) is being developed at IPR which is a full scale prototype to establish and test the performance of the Diagnostic Neutral Beam (DNB) for the International Thermonuclear Experimental Reactor (ITER). The INTF system comprises of a vacuum vessel (~ 180 m^3). The vacuum vessel contains the following major 'internal components' such as the ion source, neutralizer, residual ion dump, calorimeter and the cryo-sorption pumps. It also contains headers and distribution systems for liquid nitrogen and cooling water. The components outside the vacuum vessel are known as the 'external components'. They are the external vacuum pumping system, external nitrogen distribution system, external cooling water distribution system, HV deck etc.

Cryopumps in the vacuum vessel of INTF system are used for maintaining the necessary vacuum of 10^{-6} mbar during the operation of INTF. Cryopumps require supply of liquid nitrogen (LN2) during the operation. The function of INTF Liquid Nitrogen (LN2) Distribution System is to transfer LN2 from a Dewar and to distribute to the chevron radiation shield of the 12 cryo-sorption pumps. The required flow parameters and the relevant physical parameters for operation of INTF LN2 Distribution System are described in section 2. This distribution system will be used for transfer of liquid nitrogen from 6000 ℓ LN2 Dewar to INTF cryopumps during operation.

The present document contains work description of design, fabrication/procurement, testing, supply, installation, commissioning and site acceptance test of INTF LN2 Distribution System.

2 INTF Liquid Nitrogen (LN2) Distribution System Brief Description

- The INTF LN2 Distribution System supplies Liquid Nitrogen to the chevron baffles of cryopumps inside INTF vacuum vessel. The value of mass flow rate from 6000 ℓ LN2 Dewar will be around 200 g/s (± 10%) including all heat loads. LN2 coming from Dewar will first go to the phase separator. From phase separator, LN2 will be entered into the vessel from either sides and will feed the cryopumps which are made of stack of chevron baffles. The mass of the chevron baffles is around 1700 kg (mainly copper) and SS pipes is 400 kg (mainly SS). The total mass of cryopumps is around 2100 kg (1700 + 400). Apart from these, INTF LN2 Distribution System total mass shall be considered. The chevrons baffles which will be maintained at around 85 K during operation (Beam ON) condition receive heat load of around 28 kW (200 g/s – 927 ℓ/hr) from the in-vessel components and vessel walls while in normal (Beam OFF) condition the received heat load is around 18 kW (100 g/s – 463 ℓ/hr). The INTF LN2 Distribution System requires to cooldown the chevron baffles gradually from room temperature to around 80 – 85 K and maintain them at around 85 K during operation. Refer **Figure 11** for overall routing of INTF LN2 Distribution System. Refer P&ID, **Figure 1** for overall process flow, interconnection of process equipment and instrumentation. Refer **Figure 31**, **Figure 32**, **Figure 33**, **Figure 36** for LN2 distribution inside DNB Lab while refer **Figure 41**, **Figure 42** for LN2 distribution outside DNB Lab.

- The 6000 ℓ LN2 Dewar will be filled from transport tanker periodically as per requirement. Dewar will be maintained at ~1.0 bar-g. INTF Cryopumps will be fed LN2 from this Dewar. INTF cryopumps need variable flow of LN2 to maintain uniform temperature during operation. Maximum flow rate, 200 g/s, ± 10% is for design consideration.
- Flow control valves, safety valves, flow meter and transmitter, pressure sensors and transmitters, temperature sensors and monitor are envisaged to control the flow and also for inventory management and diagnostics. Refer **Figure 1**.
- Electrical isolator boxes are required to isolate the INTF vessel and INTF LN2 cryoline electrically. Refer section 5.7.

The technical specifications of individual components are as given in section 5.

2.1 INTF LN2 Distribution System: Main Components

The INTF LN2 Distribution System mainly consists of following. Refer P&ID, **Figure 1** for interconnection of components.

- Vacuum Jacketed Cryogenic line (Rigid)
- Vacuum Jacketed Flexible Cryogenic line
- In-vessel LN2 Supply and Return Manifolds with Flexible hoses and G10 Supports
- Supports for Cryoline, All Instruments, Compressed Air Line and Instruments Cable Tray, Support for Phase Separator
- Phase Separator with dedicated controller associated with Level Sensor, Proportionally Controlled Inlet Fill Valve and other necessary Instrumentation.
- Pneumatic Actuated Flow Control Valves (FCV) with Positioner with Solenoid with Limit Switch
- Manual Control Valves (MCV)
- Pressure Safety Valves (PSV)
- Cryogenic Flow meter and transmitter (FE/FT) with Local Display
- Cryogenic Pressure sensors and transmitters with Local Display (PE/PT)
- Isolator box Assemblies (including Cryogenic Ceramic Isolators Breaks)
- Compressed Air Line for pneumatic operated Flow Control Valves (FCV)
- Temperature sensors
- Temperature monitors
- Feedthroughs
- Data Acquisition (DAQ) junction box including all cabling
- Instruments Cable Tray (For Power and Signal Cable)

Detailed technical specifications for the above are given in section 4 and 5.

2.2 Piping and Instrumentation Diagram (P&ID) – INTF LN2 Distribution System

- The 6000 ℓ LN2 Dewar supplies the liquid nitrogen to 12 nos. of INTF cryopumps through phase separator. Required size of process pipe for transfer of LN2 from Dewar to cryopumps and then vent to atmosphere as well as size of FCVs and PSVs are given in P&ID (refer **Figure 1** below).

- The given value of supply mass flow rate in P&ID is in a range (100 – 200 g/s, ± 10%), one is minimum and the other is maximum value. Maximum flow rate, 200 g/s, ± 10% is for design consideration.
- FCV-1 will be controlled by liquid level in the phase separator and will be a part of phase separator. Considered operating condition as “Normally Open / Fail Open” (fail safe position for instrument air or signal failure) for FCV-1.
- Control logic for FCV-2, FCV-3, FCV-4 and FCV-5 will be semi auto and auto mode. In case of semi auto mode (manual input from SCADA), these FCVs will be controlled by given value of equal percentage closing (considered operating condition as “Normally Open / Fail Open”) (fail safe position for instrument air or signal failure). While in case of auto mode, these FCVs will be controlled by average temperature of cryopump radiation shield during operation. The control logic for operation of valves shall be defined by the ITER-India.
- FCV-6 will be controlled by given value of equal percentage closing (considered operating condition as “Normally Open / Fail Open”) (fail safe position for instrument air or signal failure). The control logic for operation of valve shall be defined by the ITER-India.
- There will be a provision for operating system with “Thermosyphon Flow” or “Without Thermosypon Flow” by controlling FCV-2, FCV-3, FCV-4 and FCV-5. Refer **Figure 1**, **Figure 3**, **Figure 16**, **Figure 17** and **Figure 18**.
- The GN2 vent will be disposed to atmosphere. Under normal operating circumstances, no liquid is foreseen in the vent line.
- Further, **Figure 2** below shows the top view of lab showing overall lab layout and major routing of cryoline from LN2 Dewar to phase separator.

2.3 Data acquisition and control (Hardware and logic)

- All the instruments will be connected to a DAQ junction box located in DNB Lab.
- The control logic for instruments shall be defined by the ITER-India. The control logic for FCV-1 (part of phase separator) shall be defined by the contractor.
- The contractor shall ensure proper supports and mounting scheme for the DAQ junction box, instruments and cables.
- A DAQ junction box is foreseen and is in the scope of contractor and the specifications are given in section 5.10. All the required cabling (signal and power) are in the scope of the contractor.

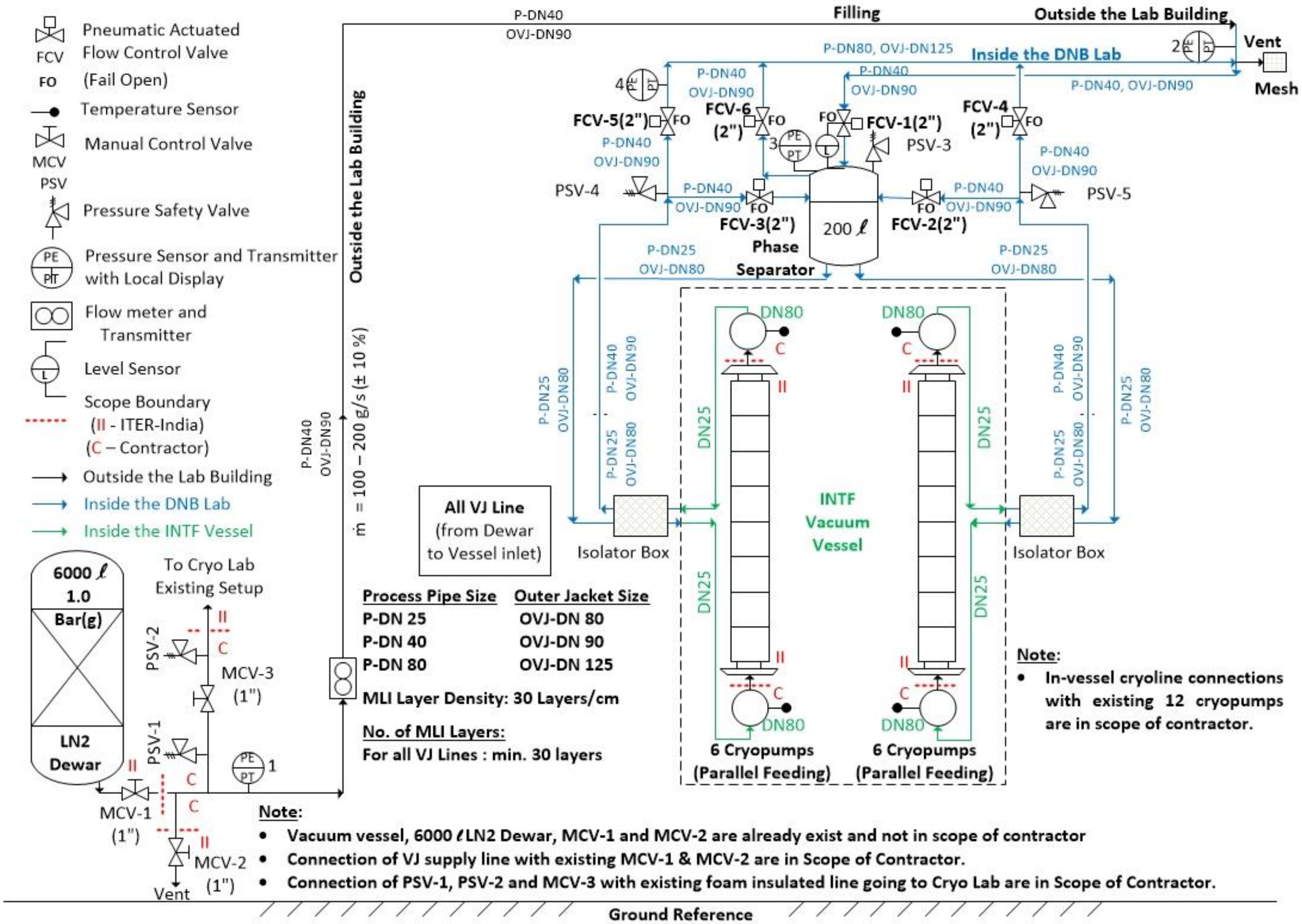


Figure 1: P&ID - INTF LN2 Distribution System

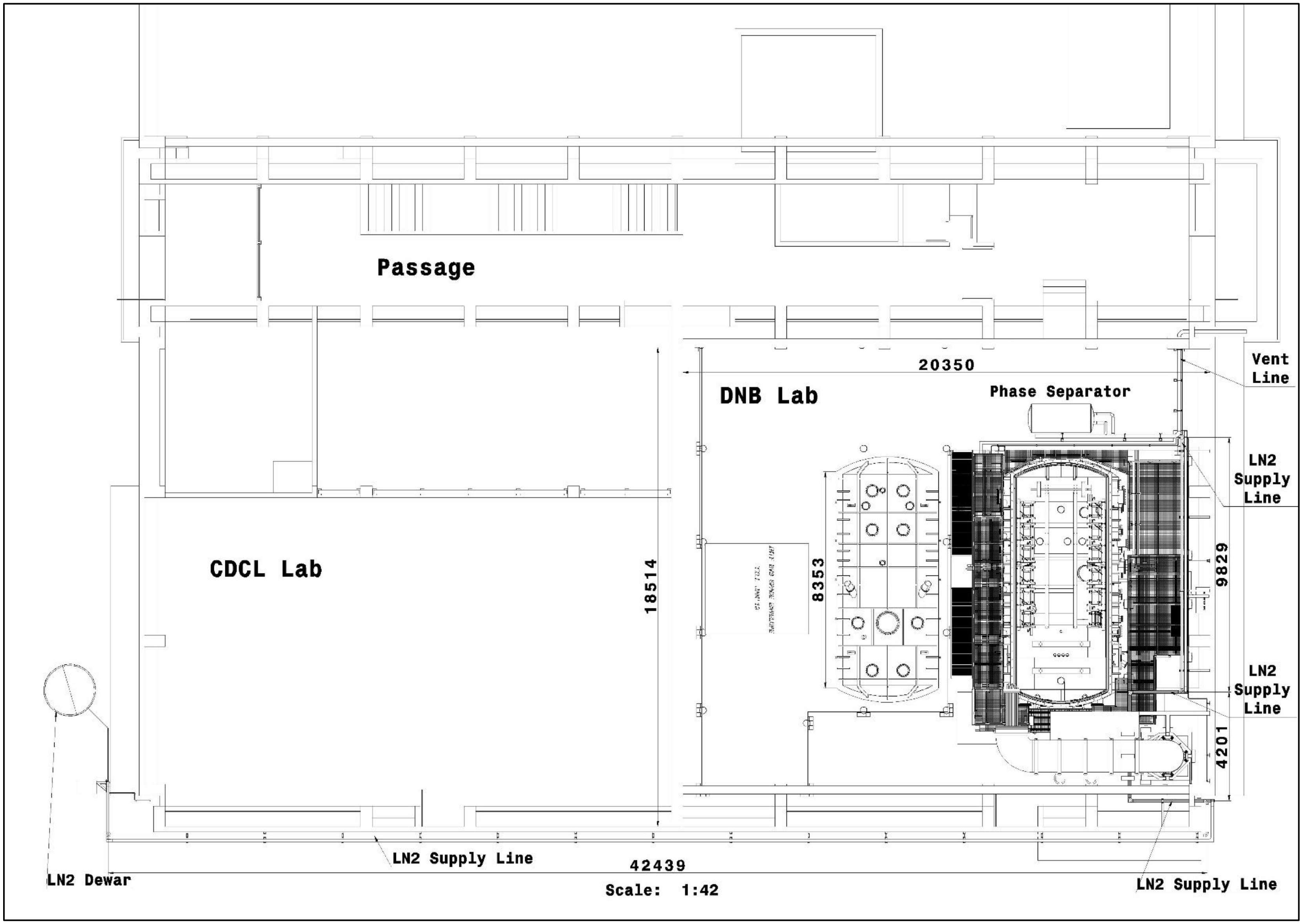


Figure 2: Top view of Lab

2.4 Thermosyphon working principal

In a closed loop, working fluid is partially evaporated at a lower elevation (in the evaporator). By buoyancy, the two-phase mixture reaches the condenser at a higher elevation through the riser. It is cooled down and changes into liquid again, before finally draining into the evaporator through the downcomer. Because the two-phase mixture's density (ρ_m) in the riser is lower than that of the liquid (ρ_l) in the downcomer, gravity sustains the flow, removing the need for mechanical drivers.

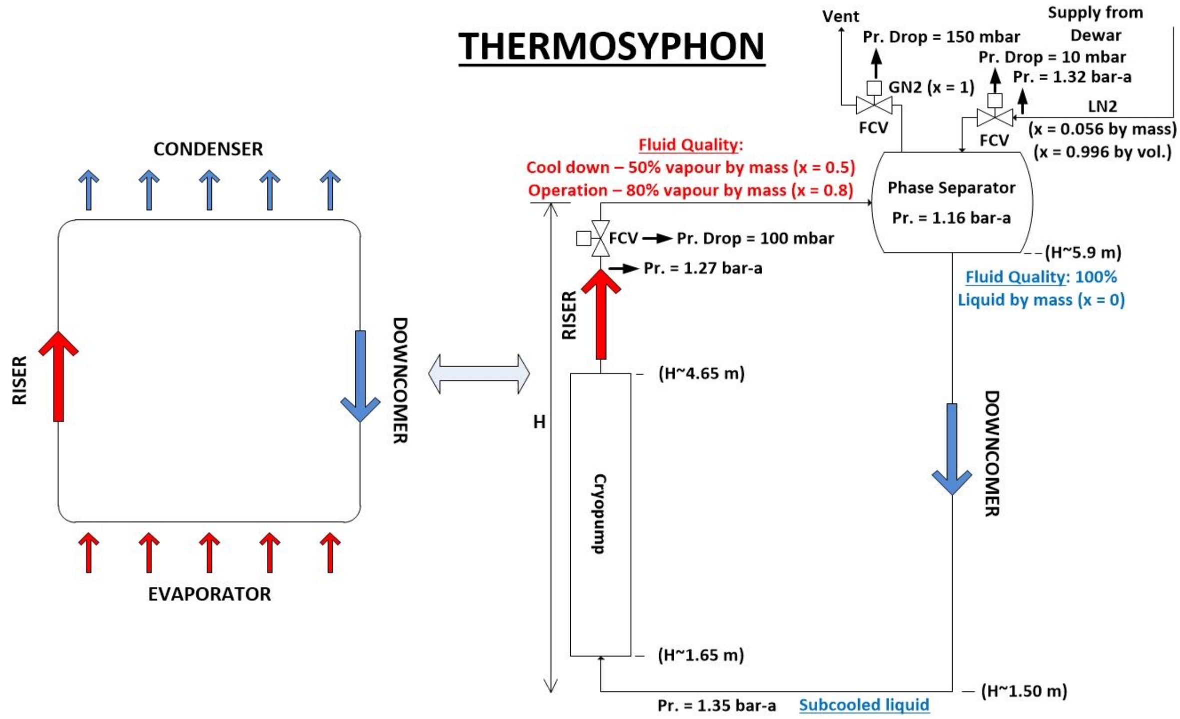


Figure 3: Thermosyphon Circulation

$$\Delta p_{lift} = (\rho_l - \rho_m) \cdot g \cdot H$$

3 INTF Liquid Nitrogen Distribution System: Scope of Work/Supply

The contractor shall visit the site before submitting the quotation

3.1 Contractor's Scope of Work/Supply

The scope of work starting from design (limited scope for design as explained below) (refer section 2 and 4), manufacturing and procurement (refer section 4, 5, 6, 7, 8, 10, 11 and 12) including FAT and SAT (refer section 9). The scope of work of the contractor includes, but not limited to, the following tasks.

- The approx. size of phase separator may be around 200 ℓ. However, design and sizing of phase separator is in scope of contractor. Also, selection of orientation of phase separator (Vertical or Horizontal) is in scope of contractor based on the design.
- Detailed layout (CAD model) preparation based on ITER-India layouts is in scope of contractor. Also, lines shall include compensating bellows. Process pipe size, Outer vacuum jacket size, No. of MLI layers, Valves size and size of PSVs (except PSV-3,

part of phase separator) have been finalized by ITER-India (refer P&ID **Figure 1**). Flexibility and stress analysis of entire piping system is in scope of contractor. Selection of suitable compatible bellows based on flexibility and stress analysis results, design of vacuum barriers, design of spacers (supports between process pipe and outer jacket) are in scope of contractor. The suitable sizing of vacuum pumping port/Evacuation/Seal-off port on OVJ for each spool is in scope of contractor. Design of the field joints for the VJ lines, valves and instruments (field joints shall be vacuum jacketed) are in scope of contractor. Also, design of T-joints for instruments connection are in scope of contractor. Contractor shall submit detail drawings of the valves and PSVs. Design report shall be submitted by contractor for approval.

- External Piping Support Calculations of INTF LN2 Cryolines to withstand the loads from all lines (supply, return, compressed air line and instruments cable tray) and transfer them to the building wall or metal structure is in scope of contractor. The marked location (the building wall or metal structure) is suitable for this work. Design of piping supports, frames and fixtures required for structural integrity is in the scope of contract and subjected to approval by ITER-India.
- Preparation of the P&IDs and fabrication drawings of the INTF LN2 Cryoline, manufacturing, testing at manufacturer's shop/contractor premises, delivery at site (including unloading at site), handling at site (including transportation from storage place to works), fabrication at site, erection/installation, commissioning (carrying out acceptance tests at site) of all the components, equipment at site are in scope of the contractor. Arrangement of all necessary tools, testing equipment, cables, gauges, material, consumables etc. as well as manpower to carry out erection, fabrication and testing work at site are in the scope of the contractor.
- Fabrication and/or procurement of phase separator with necessary seinstrumentation, different segments of LN2 cryolines and its routing from 6000 ℓ LN2 Dewar to Cryopumps are in scope of the contractor.
- Fabrication and/or procurement of compressed air line and its routing from source point to FCVs is in scope of the contractor.
- Fabrication of 02 nos. Isolator box assemblies (refer section 5.7) are in scope of the contractor.
- Procurement of Instruments (Flow Control Valves, Manual control valve, Flow meter and transmitter with local display, Pressure Sensors and transmitters with local display, Safety valves, temperature sensors, temperature monitors and Feedthroughs) are in scope of the contractor. Before procurement, the technical data sheets of instruments shall be submitted for ITER-India approval. Installation of Instruments is under scope of contractor (refer section 5.10).
- Fabrication of Data Acquisition (DAQ) junction box is in scope of the contractor. The contractor shall be responsible for wiring (signal and power cable) of the instruments (refer section 5.10 for detailed scope of work).
- Contractor is responsible for delivery, shifting, loading & unloading, transport and inside lab movement for all the components'/ materials'/ systems' required during

execution of this contract. In-process inspection of critical items (at supplier's site) is required before its delivery to ITER India site.

- Erection and Installation of phase separator, cryogenic lines and instruments are in scope of the contractor. This work includes all necessary civil work including supports.
- Mounting/Fixing of external supports and hangers for the INTF LN2 cryolines, compressed air line and instruments cable tray are in scope of the contractor. Electrical isolation (~ 5 kV) shall be provided between lines (supply, return, compressed air line and instrument cable trays) and supports where support is taken from mezzanine/working platform inside the DNB Lab for avoiding direct contact between lines and mezzanine/working platform.
- Civil work wherever required for the erection of support structures for entire piping layout as per the approved drawings is under scope of contractor. Prior intimation and approval are required for any such work in IPR's premises.
- All necessary arrangement for working at height of around 9 m outside and inside the lab (e.g. support structures, arrangement of mobile crane, scaffolding etc.) with all safety protocols are in scope of contractor.
- Entry and exit of INTF LN2 Cryolines including cable tray in DNB lab shall be through a glass window. Proper cutting of glass window for entry and exit of cryolines including cable tray is a scope of contractor. Proper closing and sealing of glass windows should be done after completion of the work.
- Connection of Vacuum Jacketed (VJ) cryoline with existing LN2 outlet line (Foam Insulated) coming from Dewar is in Contractor's Scope. Approx. 6 m existing foam insulated line coming from Dewar shall be replaced with VJ line. Refer section 6.2.2.
- Interface connection with Cryopumps and vessel will be through flexible lines. (Refer **Figure 22**, **Figure 33**, **Figure 36**)
- Connection and routing from source point compressed air line manifold taping DN 15 SCH 10S SS304L (taping is terminated with shut off valve made of brass) to each Pneumatic Operated Flow Control Valve (FCV) is in the scope of contractor. Refer section 5.8.
- Output signals from all the instruments must be in the range of 4-20 mA /0-10V.
- Contractor has to provide power cabling to the signal conditioning setup from nearest power point available in the DNB lab. Location of power point available in the DNB lab is shown in **Figure 26** as well as in CAD model.
- Arrangement of all hardware, consumables, testing equipment, safety equipment, arrangement of crane, scaffolding and support structures for working at height outside and inside the lab building during installation, commissioning and testing at ITER-India site are in scope of contractor.
- Contractor shall carry out Factory and Site Acceptance tests of INTF LN2 Distribution System as per section 9.
- During Thermal shock test and Performance/Functional testing of the entire LN2 Cryoline system by filling of 6000 ℓ LN2 Dewar at ITER-India Lab, IPR, arrangement of LN2 is in scope of contractor.

- Earthing of all instruments and panels as per industrial practice are in scope of contract.
- Contractor shall submit all quality documents including material test certificates of raw materials and consumables, calibration certificates for all instruments etc. Preparation of Manufacturing Procedures, Inspection and Test Procedures, Cleaning, Packing and Transportation Procedure etc. are in scope of contractor. and submit the same to ITER-India for approval.
- Submit complete documentation including operating manuals (Soft and Hard copies).
- All the necessary spares and tools for future maintenance shall be provided. Refer section 8.
- List of Project Hold Points/Schedule and Documents to be Submitted are mentioned in section 11.
- The site work at ITER-India Lab, IPR will be agreed mutually and ITER-India will give site clearance accordingly.
- The contractor shall follow all safety measures and IPR safety rules during the execution to protect the personnel and investment. The IPR Safety Protocols are given in link provided below.
https://www.ipr.res.in/documents/safety_protocols.html
- **The INTF LN2 Distribution System shall be operated for at least one year from final commissioning and acceptance without any maintenance.**

3.1.1 Scope of Supply: Components Summary

Note 1: Any tools or accessories (viz. fasteners, seal gaskets etc.) which may not be specifically mentioned in the deliverables/specifications list but are necessary for proper and efficient functioning of the systems shall have to be considered as part of scope of supply.

Note 2: The following deliverables as per tables shows an estimated list of quantities based on preliminary design. However, the actual quantities/requirements under the responsibility of contractor.

Note 3: Contractor shall quote for unit price as per APPENDIX-7 Unpriced Bid Templates

Table 3-1: Components Summary (*Refer P&ID,* ***Figure 1*** *for interconnection of components.)*

Name	Quantity	Remark
Vacuum Jacketed LN2 Cryoline	Refer Appendix-7	Details in section 4.1
Vacuum Jacketed LN2 Cryoline Pipe Fittings	Refer Appendix-7	Details in section 4.3
Supports for Cryoline, Compressed Air Line and	Refer Appendix-2	Details in section 4.5

Instruments Cable tray with Wall/Metal Structure		
In-vessel Supply and Return LN2 Manifold with Flexible hoses and G10 Supports	02 sets	Details in section 4.4
Phase Separator with Level Sensor & Proportionally Controlled Inlet Fill Valve (with necessary Instrumentation)	01 No.	Details in section 5.1
Pneumatic Actuated Flow Control Valves (FCV) with Positioner with Solenoid with Limit Switch	06 No.	Details in section 5.2
Manual Control Valve (MCV)	01 No.	Details in section 5.3
Pressure Safety Valves (PSV)	05 No.	Details in section 5.4
Cryogenic Flow meter and transmitter (FE/FT) with Local Display	01 No.	Details in section 5.5
Cryogenic Pressure sensors and transmitters with Local Display (PE/PT)	04 No.	Details in section 5.6
Isolator box Assemblies (including Cryogenic Ceramic Isolators Breaks)	02 Nos.	Details in section 5.7
Compressed Air Line for pneumatic operated Flow Control Valves (FCV)	~ 50 m	Details in section 5.8
Instruments Cable Tray (For Power and Signal cable)	~ 130 m	Details in section 5.11
Temperature Sensors	75 Nos.	Details in section 5.9
Temperature Monitors (8 Channel)	08 No.	Details in section 5.9
Feedthroughs	07 Nos.	Details in section 5.9
Data Acquisition (DAQ) junction box including all cabling	01 No.	Details in section 5.10
USB to 8 port serial converter	01 No.	Details in section 5.10.1
USB to 16 port serial converter	01 No.	Details in section 5.10.1
Spares	01 Lot	Details in section 8
Liquid Nitrogen (LN2)	As per requirement	• LN2 for site welds thermal shock test before He leak testing • LN2 for Performance / Functional testing of the entire LN2 cryoline system from instrumentation point of view by filling 6000 ℓ LN2 Dewar.

		Details in section 9.2

3.2 Utilities and Input Documents Provided by ITER-India (ITER-India Scope)

- Utilities (Water, Electricity, Instrumentation Air, Overhead Crane)
  - Electric supply shall be available @ 230 volts ± 10% single phase and 415 volts ± 10% three phase at 50 Hz supply. The ITER-India shall provide electric power at one point. Distribution to different usage points is in the scope of contractor. Location of power point available in the DNB lab is shown in **Figure 26** a as well as in CAD model.
  - Electric power for control shall be provided from 230 volts ± 10% single phase power supply at one point by the ITER-India. Distribution to different usage points is in the scope of contractor. Shielded twisted pair cable shall be used for instrumentation and control purpose. The contractor shall provide suitable power supply 24V DC for operating different valves, instruments and PLC. Location of power point available in the DNB lab is shown in **Figure 26** as well as in CAD model.
  - Source point of dry compressed air at 5 bars shall be provided by the ITER-India for control purposes at one point in DNB Lab. Distribution of compressed air to different usage points is in the scope of the contractor. Location of dry compressed air source point is shown in **Figure 11** and **Figure 27** as well as in CAD model. Refer section 5.8 for tapping from source point.
  - Inside the DNB lab, there are two overhead cranes available with a capacity of 25 tons and 5 tons. Contractor may use of them with utmost care and by following the safety rules. **Accessibility of both cranes in different locations of DNB lab along with hook approach shall be assessed by contractor by visiting ITER-India Lab before submitting quotations.** Also, refer **Figure 27**. Reference value of hook approach for both cranes are given below.
    - Hook approach (mm) DSL/Other for 25 tones crane: 1500/1950
    - Hook approach (mm) RH/LH for 5 tones crane: 1360/1145
- CAD images
- Reference CAD model of ITER-India building and INTF LN2 Distribution System (Detailed CAD modelling of INTF LN2 Distribution System is the scope of contractor).
- Sample ITP
- DR-NCR format

4 INTF LN2 Distribution System – Technical Specifications

Contractor shall take stage wise approval from ITER-India starting from design, drawing preparation, procurement, fabrication till the completion of work.

4.1 Vacuum Jacketed LN2 Cryoline (Supply and Return Line)

- The whole length of INTF LN2 cryoline shall be divided into number of vacuum compartments depending on transportation feasibility and installation feasibility. Each part shall be prefabricated in spools and tested at factory before shipment. Each section of vacuum jacketed LN2 cryoline shall have an evacuation port with associated seal-off valve. Location of each evacuation port shall be accessible to reach at that location for pumping in future.

- Individual lengths of prefabricated spools shall be determined by the contractor. However, it shall be 3m to 10m (11m). Spools of 3m long is assumed to cope with installation constraints.
- Support and anchors for process lines and the outer vacuum jacket shall be designed by the contractor and reviewed by the ITER-India. Supports for the inner line shall be of a kind that allows for axial movement of the pipe due to thermal contraction resulting from cool down of the equipment as well as it allows minimum heat in leak to process pipe. Direct welding of the supports and anchors with outer jacket should be avoided, However, if it is found necessary, ITER-India's approval shall be taken.
- Compensating bellows shall be used wherever it is required based on flexibility and stress analysis results. Selection of suitable compatible bellows based on flexibility and stress analysis results is in scope of contractor.
- The leak rate for each weld and overall segment is as defined in section 6.1
- Supply LN2 mass flow rate from Dewar: 200 g/s (± 10 %)
- The design pressure for process pipe is 3.54 bar-a.
- Length of Vacuum Jacketed supply & return (LN2) Line: Refer Appendix-7
- Inner Line (Process Pipe)
    - Size of process pipe: Refer **Figure 1**.
    - All process pipes shall be seamless or welded (with 100% radiography) Stainless Steel 304L / 316L for cryogenic application as per suitable international standard (ref. section 7) for dimension tolerances and material identification.
    - Surface roughness (internal) maximum 25 µm (lower value to be confirmed by the supplier)
    - Surface roughness (external) maximum 50 µm (lower value to be confirmed by the supplier).
    - End caps shall be provided at both the ends of the pipe preventing dust and foreign particles to enter and pipes shall be wrapped with polythene to protect the pipes from any dust on the surface.
    - Bellows and/or hoses shall be used on inner line to compensate thermal contraction of process pipe. Inherent flexibility of line due to presence of bends shall be also considered to minimize number of bellows and hoses. Bellows shall be of AISI 321/304L/316L/316Ti stainless steel convolutes with AISI 304L / 316L seamless or welded (with 100% radiography) stainless-steel pipe ends for butt-welding to the process pipe.
    - The bayonet coupling clamp and sealing shall withstand external and internal design pressure. These connections can be used at phase separator. However, selection of connection type (bayonet or simple welded) at phase separator is in scope of contractor.
    - At equipment interfaces, contractor shall provide isolator box as per details given in section 5.7.
    - Supports for inner pipes

    - Internal supports shall be foreseen by the Contractor to support and guide the process pipe, keep internal displacement within admissible values to avoid contacts between the process pipe and the Outer Jacket Pipe while guarantee that the overall stresses in the pipes remain within the acceptable values dictated by the chosen construction code. The support system shall be designed to minimize the heat load and absorb static load of the inner line (process pipe) when partially or completely filled with the cryogenic fluid and withstand loading for shipping, loading/unloading, during installation and flow induced vibration.

- Outer jacket pipe
  - The outer jacket pipe shall be used in internal vacuum and external atmospheric pressure and ambient temperature.
  - Size of outer jacket pipe: Refer **Figure 1**.
  - The jacket pipe shall be seamless or welded (with 100% radiography) Stainless Steel 304L / 316L for cryogenic application as per suitable international standard (ref. section 7) for dimension tolerances and material identification.
  - Surface roughness (internal) maximum 25 µm (lower value to be confirmed by the supplier)
  - Surface roughness (external) maximum 50 µm (lower value to be confirmed by the supplier).
  - End caps shall be provided at both the ends of the pipe preventing dust and foreign particles to enter and pipes shall be wrapped with polythene to protect the pipes from any dust on the surface.
  - Expansion joint/Bellow
    - Expansion joints/bellows shall be installed in the jacket pipe, if required in flexibility and stress analysis. They shall meet the requirements of the EJMA or alternate international code for 0.5 bar-g external pressure with 0 psia internal pressure. They shall withstand an internal pressure of 3.54 bar-a. Normal movement of bellows shall not exceed 75% of the maximum rated movement for a design cycle life of 10000 complete cycles.
    - All bellow assembly shall be of AISI 321/304L/316L/316Ti stainless steel convolutes with AISI 304L / 316L seamless or welded (with 100% radiography) stainless-steel pipe ends for butt-welding to the outer jacket pipe and AISI 304L / 316L braiding on the stainless steel convolutes.
  - Supports with walls/metal structure
    - The outer jacket pipe shall be suitably supported with the building wall/metal structure by supports to absorb loads from the pipe as per load specifications.
    - The material for support and base plate shall be SS304L / SS304 / SS316L / SS316.
    - **During visit to ITER-India lab, attention shall be provided to lab constraints in terms of space, accessibility etc. to decide support locations.**

- Vacuum annulus

  The vacuum annulus has a considerable bearing on the performance and efficiency of the whole system. The contractor has to follow approved cleaning procedure before assembly.

  - Thermal Radiation shielding (MLI)
    - Commercially available Multi-Layer Insulation (MLI) shall be installed in the vacuum space of the cryolines to minimize the heat load by radiation between room temperature at 300K to 77K.
    - The MLI shall be made of Double-aluminized Mylar foils with glass fiber or nylon spacers. If other material were selected for the MLI, they shall be submitted for ITER-India approval.
    - The MLI shall be protected from humidity and dust before, during and after installation. The MLI shall be protected during welding operations to avoid damage and fire.
    - The MLI wrapping around the process pipes shall not create a confined space preventing discharge and evacuation events. The MLI shall be installed such that it will not detach or degrade during evacuation operations.
    - MLI Layer Density: 30 layers/cm
    - No. of MLI Layers:
      - For Supply & Phase Separator Return Line: Minimum 30 layers
      - For Return (Vent) Line: Minimum 30 layers
  - Evacuation port
    - Each section of vacuum annulus shall have an evacuation port with associated seal-off valve. Each Evacuation/Seal-off port shall have a standard KF connection depends on the design. The seal-off port shall be closed using a Seal-off valve/plug. The seal-off valve shall be all stainless-steel construction, equipped with double O-ring seal to prevent vacuum loss from vibration or shock. The valve shall incorporate a poppet which provides relief in the event of an overpressure (Relief Pressure: max. 0.5 to 0.6 bar-g). The seal-off port will be positioned on each spool in an approved location considering safety, accessibility to pump-down devices, and non-interference with neighboring equipment. The vacuum annulus shall be evacuated from seal-off port using seal-off valve operator (plunger). The seal-off valve operator (plunger) shall provide a combination opening with standard KF connections for pump-out and seal-off port. Supply of compatible seal-off valve operators (plunger) are in scope of contractor as a spare item.
    - Each evacuation/seal-off port shall be covered with dust cap.
- Vacuum Jacketed Flexible Cryoline
  - Flexible cryolines shall consist of semi flexible concentric corrugated or bellow pipes and shall be vacuum insulated and thermally insulated by the use of MLI

as per specifications of MLI given above. Flexibles outer corrugated pipe shall be of stainless-steel wire-braided.

- VJ flexible lines shall be used Near entry of cryolines into the INTF vacuum vessel. Refer **Figure 33**, **Figure 36**.
- Flexibles shall be of AISI 321/304L/316L/316Ti stainless steel convolutes with AISI 304L / 316L seamless or welded (with 100% radiography) stainless-steel pipe ends for cryogenic application as per suitable international standard (ref. section 7) for dimension tolerances and material identification.

Table below, shows the exhaustive list of VJ flex cryolines. Appropriate bend radius should be considered based on detailed CAD layout.

Table 4-1: List of VJ Cryoline

Process Pipe Size	Interface Location	Approx. Length (m)
DN25-5S	Supply line – Vessel Port (Refer **Figure 33**, **Figure 36**.)	5 + 5
DN25-5S	Return line – Vessel Port (Refer **Figure 33**, **Figure 36**.)	5 + 5

4.2 Field Joint Connection

Figure 4 below shows, a typical Field Joint Connection for Vacuum Jacketed Cryoline. This includes the joint in between two process pipes of different sections with a sleeve and collar over the outer jacket maintaining the vacuum. Each field joint shall isolate vacuum of two different sections of the lines by using vacuum barrier. Number of field joints shall be as low as reasonably achievable.

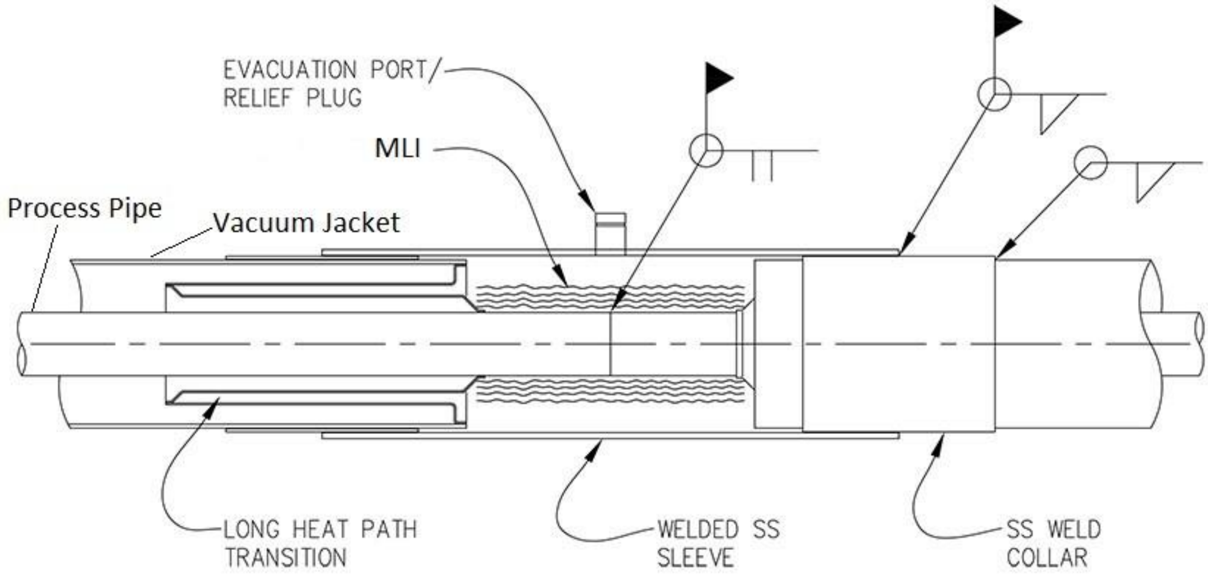


Figure 4: Typical Field Joint Connection for Vacuum Jacketed Cryoline

4.3 Vacuum Jacketed LN2 Cryoline Pipe Fittings

- All LN2 cryoline pipe fittings shall be seamless or welded (with 100% radiography) Stainless Steel 304L / 316L for cryogenic application as per suitable international standard (ref. section 7) for dimension tolerances and material identification.
- Surface roughness (internal) maximum 25 µm (lower value to be confirmed by the supplier)
- Surface roughness (external) maximum 50 µm (lower value to be confirmed by the supplier).
- End caps shall be provided at both the ends preventing dust and foreign particles to enter and shall be wrapped with polythene to protect the fittings from any dust on the surface.
- Each fitting shall be wrapped separately to avoid denting, detritions of surface, scratches on the surface due to rubbing with each other during packing and transits.
- Tentative quantity of Vacuum Jacketed LN2 Cryoline Pipe Fittings: Refer Appendix-7

4.4 In-vessel Supply and Return Manifold with Flexible hoses and G10 Supports

- Manifolds
  - Size of manifolds: DN 80, SCH 5S. Refer **Figure 1** & **Figure 19**.
  - The material shall be seamless or welded (with 100% radiography) Stainless Steel 304L / 316L for cryogenic application as per suitable international standard (ref. section 7) for dimension tolerances and material identification.
  - Surface roughness (internal) maximum 25 µm (lower value to be confirmed by the supplier)
  - Surface roughness (external) maximum 50 µm (lower value to be confirmed by the supplier).
  - During transportation, end caps shall be provided at both the ends of the pipe to prevent the dust and foreign particles to enter and pipes shall be wrapped with polythene to protect the pipes from any dust on the surface.
  - Length of Supply and Return Manifold: ~ 5 m each (Two Supply and Two Return)
  - Rigid-flexible lines shall be used for connections between supply and return lines coming from isolator box to Supply/Return Manifold:
    - Size of rigid-flexible line: DN 25, SCH 5S. Refer **Figure 16**, **Figure 19**.
    - Length of Supply Line: ~ 3 m each (Two supply line)
    - Length of Return Line: ~ 3 m each (Two return line)
  - MLI shall be wrapped on Manifold after installation. No. of MLI layers – 30 layers.
  - Quantum of welding inside the vessel: It should be minimized by doing all possible welding outside the vessel. Welding sequence inside the vessel will be decided by mutual agreement between ITER-India and contractor.
- Flexible Hoses
    - Flexible hose shall be of AISI 321/304L/316L/316Ti stainless steel convolutes with AISI 304L / 316L seamless or welded (with 100% radiography) stainless-

steel pipe ends (Length: ≤ 50 mm) for cryogenic application as per suitable international standard (ref. section 7)

- Size of flexible hoses: DN 20, SCH 5S. Refer **Figure 19**.
- Length: ~ 1 m each
- Quantity: 24 nos.
- MLI shall be wrapped on flexible hoses after installation. No. of MLI layers – 30 layers.
- Quantum of welding inside the vessel: It should be minimized by doing all possible welding outside the vessel. Welding sequence inside the vessel will be decided by mutual agreement between ITER-India and contractor.

- G10 Support
  - Conceptual design is given in **Figure 23**.

Quantity: ~ 12 nos. for Supply Manifold support and ~ 12 nos. for Return Manifold support

4.5 Supports for Cryoline, Compressed Air Line and Instruments Cable tray with Wall/Metal Structure

- External supports and hangers for the INTF LN2 cryolines shall be supplied under the scope of this technical specification. Cryolines shall be supported on external supports and hangers which interface the building in the concrete walls/mezzanine columns and ceilings/mezzanine floor. Load bearing capacity of mezzanine floor is around 0.5 Ton/sq. m.
- The material for support and base plate shall be SS304L/SS304
- Spacing between piping supports should not be more than 3.5m.
- Electrical isolation (~ 5 kV) shall be provided between all lines (supply, return and compressed air line) including instrument cable trays and supports for avoiding direct contact between lines including instrument cable trays and supports.
- The details of INTF LN2 Distribution System supports (Conceptual) are given in Appendix-2. Detailed design is in the scope of contractor.

4.6 Heat Load

- Vacuum jacketed LN2 cryoline shall comply with the following maximum heat load criteria including bend and joints.
  - 6 W/m average for all VJ lines
  - 6 W for all VJ field joints

  Note: No condensation is allowed.

4.7 Mechanical Load Specifications for Flexibility analysis of INTF Liquid Nitrogen Distribution System

- **Table 4-2** below shows the Design parameters INTF LN2 Distribution System

Table 4-2: Design parameters

Description	Temperature	Pressure	Load Case
Process Pipe (PP)	T1 = 77 K	P1 = 2 bar-a	Normal Operation (NO)
Outer Vacuum Jacket (OVJ)	T1 = 333 K	P1 = 0 bar-a	
Process Pipe (PP)	T2 = 77 K	P2 = 3.54 bar-a	Loss of Insulation Vacuum (LIV)
Outer Vacuum Jacket (OVJ)	T2 = 306.22 K	P2 = 0.5 bar (differential)	
Process Pipe (PP)	T3 =333 K	P3 = 4.71 bar-a (1.33 x 3.54 bar-a)	Pneumatic Pressure Test (PPT)
Outer Vacuum Jacket (OVJ)	T3 = 333 K	P3 = 0 bar-a	
Process Pipe (PP)	T4 =333 K	P4 = ~0 bar-a	Purge (PG) (for purge and pumping of process pipes)
Outer Vacuum Jacket (OVJ)	T4 =333 K	P4 = ~0 bar-a	

- Load Combinations for Static Analysis:
  The INTF LN2 Distribution System is to be analyzed for a range of loading conditions for static analysis which include Normal Operation (NO), Loss of Insulation Vacuum (LIV), Pressure Test and Purge. In **Table 4-3** below the load combinations are presented.

Table 4-3: Load Combinations (Static analysis)

Combination Number	Load case name	Load Combination	Service Condition
L1	NO	W+T1+P1	Operating
L2		W+P1	Sustained
L7		L1-L2	Expansion
L3	LIV	W+T2+P2	Operating
L4		W+P2	Sustained
L8		L3-L4	Expansion
L5	PPT	W+T3+P3	Operating
L6	PG	W+T4+P4	Operating

W – Dead weight of process pipes & pipe fittings including fluid weight

- Transportation load: Allowable limit of acceleration during transport is X (1g), Y (1g) and Z (vertical) (4g).

- Load Combinations for Dynamic Analysis:
  The INTF LN2 Distribution System should maintain their mechanical integrity with no excessive deformation or plastic collapse during seismic event. The Design Response Spectrum for seismic Analysis to be used in the dynamic Analysis is summarized in **Table 4-4** below. The load combinations are presented in **Table 4-5**.

Table 4-4: Design Response Spectrum for Seismic Analysis

Frequency (Hz)	(g)
33.00	0.14
25.00	0.14
16.67	0.191
5.26	0.24
4.17	0.41
2.94	0.41
2.17	0.3
1.00	0.3
0.07	0.03

Table 4-5 Load Combinations (Dynamic analysis)

Description	Load Combination
X Response Spectrum	D1
Y Response Spectrum	D2
Z Response Spectrum	D3
NO + SL	W+T1+P1+ D1+D2+D3
LIV + SL	W+T2+P2+D1+D2+D3

5 Technical Specifications of INTF LN2 Distribution System Components

5.1 Technical Specification: Phase Separator with Level Sensor & Proportionally Controlled Inlet Fill Valve (with necessary Instrumentation)

Table 5-1: Phase Separator (PS) Specifications

Particulars	Specifications
Type	• Allows the working pressure to be set at the desired level. (between 1bar-a to 2 bar-a) • Provision of vacuum jacketed one inlet line, two supply lines and two return lines
Quantity	01 No.
Inner and Outer shell Material	Stainless Steel 304L
Insulation	Vacuum Insulated
Net Evaporation Rate (NER)	To be specified by contractor
Max. LN2 inlet flow from Dewar to PS	200 g/s
LN2 supply flow from PS to Cryopumps	185 g/s (two supply lines → 92.5 g/s per line)
Heat load to be handled by LN2 supply flow from PS to the Cryopumps during stand-by and pulse mode	• Stand-by mode (cool down): 18 kW • Pulse mode (Operation): 28 kW
Fluid condition during supply flow ($\dot{m}$ = 185 g/s) from PS to Cryopumps	100% liquid

Fluid condition during return flow ($\dot{m}$ = 185 g/s) from Cryopumps to PS	• Stand-by mode (cool down): 50% vapour by mass • Pulse mode (Operation): 80% vapour by mass
Available space for installation of phase separator	L – 3m X W – 1.7m X H – 2m
Size	~200 ℓ **(design and sizing of phase separator with selection of orientation – Horizontal/Vertical is in the scope of contractor)**
PS shall be supplied with its own dedicated controller for ensuring sufficient level during operation with level fluctuation control. Associated instrumentation such as level sensor and control valves shall be incorporated within the PS controller. The specifications of PS controller are mentioned below. The PS controller needs to be kept in the DAQ Junction box and powered by contractor.	
Phase Separator Controller	• The controller shall have option of accepting external set point for PS level and shall maintain that level using its associated instrumentation and FCV. • Controller must have external communication options such as Ethernet, USB in order to enable remote communication for monitoring of critical parameters related to operation • IP 65 certified
Phase Separator should have mist extractor in gas outlet line / Vent line.	
Phase Separator shall have Level Sensor & Proportionally Controlled Inlet Fill Valve.	
Volume of PS should be such that the LN2 retention time in PS will be minimum 10 minutes in absence of LN2 feed to PS, while 200 g/s LN2 out flow from PS will be maintained.	
Phase Separator fabrication and testing as per standard codes	
Manufacturer of PS should have necessary statutory approval.	
Leak tightness details shall be provided by contractor for approval (refer section 6.1)	

5.2 Technical Specification: Pneumatic Actuated Flow Control Valve (FCV) with Air Filter Regulator with Positioner with Solenoid with Limit Switch

Table 5-2: FCVs Specifications

Valve (Size)*	Operating Condition	Fluid	Type	Heat Leak (Max.)	Flow Characteristics	Control Signal for Valve Operation
FCV-1 (2")	Normally Open (Fail Open) (fail safe position for instrument air or signal failure) $\dot{m}_{max}$ = 200 g/s $\dot{m}_{min}$ = 100 g/s P_{in} = 1.32 bar-a	Liquid N_2 / Two Phase N_2 (x = 5.6 % by mass)	Vacuum Jacketed	(10W)	equal percentage	Phase Separator Liquid Level **(Part of Phase Separator)**

	Allowable ΔP across the valve ≤ 10 mbar at $\dot{m}_{max}$					
FCV-2 (2”) FCV-3 (2”) FCV-4 (2”) FCV-5 (2”)	Normally Open (Fail Open) (fail safe position for instrument air or signal failure) $\dot{m}_{max}$ = 200 g/s $\dot{m}_{min}$ = 100 g/s P_{in} = 1.27 bar-a Allowable ΔP across the valve ≤ 100 mbar at $\dot{m}_{max}$	Vapor N_2 / Two Phase N_2 (x = 50 – 80 % vapor by mass)	Vacuum Jacketed	(15W)	equal percentage	Given value of percentage closing / Average temperature of cryopump radiation shield
FCV-6 (2”)	Normally Open (Fail Open) (fail safe position for instrument air or signal failure) $\dot{m}_{max}$ = 200 g/s $\dot{m}_{min}$ = 100 g/s P_{in} = 1.16 bar-a P_{in} = 1.32 bar-a (When FCV-2,3,4,5 are closed) Allowable ΔP across the valve ≤ 150 mbar at $\dot{m}_{max}$	Vapor N_2	Vacuum Jacketed	(15W)	equal percentage	Given value of percentage closing

Other Technical Specifications:

Particulars	**Specifications**
Valve Size	As per list given above
Valve Body	Stainless Steel 304L / suitable for cryogenic application
Application	Indoor application
Protecting class	IP 65 or better
Valve sealing	Preferably Bellows Sealed type, however, valves without bellow seal are acceptable
Design pressure	3.54 bar-a. Please specify pressure rating of valve along with quotation
Rangeability	100 %
Electropneumatic positioner for pneumatic Actuator shall have 4 – 20 mA set and feedback. Contractor shall give the details of positioner for control valves.	
Pneumatic air supplied to positioner shall pass through solenoid valve and air filter regulator.	
Limit switch shall be provided with each valve.	
Selection of appropriate size Air Filter Regulator compatible with positioner is in scope of contractor.	
Each valve should have local display showing opening/closing condition of the valve	
Leak tightness details shall be given by contractor for approval (refer section 6.1).	
Valves fabrication and testing as per standard codes	
Valve characteristics curve for each valve has to be supplied	

Relevant drawings, Material test certificate, Leak tightness certificate and calibration certificate of valves for full travel shall be provided for approval. Valves C_v value and other technical details shall be provided.
Note: Cryogenic valves shall be installed vertically.

5.3 Technical Specification: Manual Control Valve (MCV) with Limit Switch

Table 5-3: MCV Specifications

Valve	Operating Condition	Fluid	Type	Flow Characteristics
MCV-3 (1”)	$\dot{m}_{max}$ = 200 g/s $\dot{m}_{min}$ = 100 g/s P_{in} = 2 bar-a Allowable ΔP across the valve ≤ 10 mbar at $\dot{m}_{max}$ (For Isolation purpose)	Liquid N_2	Long Stem Non-Jacketed	Isolation Purpose
Other Technical Specifications:				
Particulars	**Specifications**			
Valve Size	As per list given above			
Valve Body	Stainless Steel 304L			
Application	Outdoor application			
Valve sealing	Preferably Bellows Sealed type, however, valves without bellow seal are acceptable			
Design pressure	3.54 bar-a			
Limit switch shall be provided with each valve.				
Leak tightness details shall be given by contractor for approval (refer section6.1)				
Valves fabrication and testing as per standard codes				
Relevant drawings, Material test certificate and Leak tightness certificate shall be provided for approval. Valve C_v value and other technical details shall be provided.				
Note: Cryogenic valves shall be installed vertically.				

5.4 Technical Specification: Cryogenic Pressure Safety Valve (PSV)

Table 5-4: PSV Specifications

Valve	Operation	Fluid	Nominal diameter (DN)	Flow/Orifice diameter (mm)	Type of Process Pipe	Application
PSV-1	Safety	Liquid N_2	Inlet: 15 Outlet: ≥ 20	10.5	Form Insulated	Outdoor application
PSV-2	Safety	Liquid N_2	Inlet: 15 Outlet: ≥ 20	10.5	Form Insulated	Outdoor application
PSV-3	Safety	Vapor N_2 **(Part of Phase Separator)**	Contractor’s Scope	Contractor’s Scope	-	Indoor application
PSV-4	Safety	Vapor N_2 / Two Phase N_2 (x = 50	Inlet: 15 Outlet: ≥ 20	10.5	Vacuum Jacketed	Indoor application

		– 80 % vapor by mass)				
PSV-5	Safety	Vapor N_2 / Two Phase N_2 (x = 50 – 80 % vapor by mass)	Inlet: 15 Outlet: ≥ 20	10.5	Vacuum Jacketed	Indoor application

Other Technical Specifications:	
Particulars	**Specifications**
Type	Self-actuating, Full lift, spring loaded with angular discharge
Valve Body	Stainless Steel
Set Pressure	2.3 bar-g
Valve Size	As per list given above. As the PSV-3 will be a part of phase separator, sizing of PSV-3 is in scope of contractor.
Overpressure	10%
Back pressure	Atmospheric
Seat leakage rate	< 1.0 x 10^{-2} mbar-l/s
Heat inleak from PSV connection (for VJ line)	≤ 6 W
Safety valves shall be from a regular manufacturer	
Safety authorized test certificate shall be provided	
Relevant drawings, Material test certificate, Leak tightness and Set pressure test report for intended pressure shall be provided for approval.	

5.5 Technical Specification: Cryogenic Flow meter and transmitter (FE/FT) with Local Display

Table 5-5: Cryogenic Flow meter and transmitter Specifications

Particulars	**Specifications**
Type	Coriolis mass flow meter / Vortex mass flow meter / Variable Area mass flow meter (any other type subject to ITER-India's approval). Type to be defined by contractor. Type shall be compatible with the application and given inputs.
Size	1.5" OR 2" (Depends on availability of standard size for a given inputs)
Quantity	01 (FE/FT)
Fluid	Liquid Nitrogen (LN_2)
Process Fluid Temperature	LN2
Process Fluid Pressure	1 bar-g
Design Pressure	3.54 bar-a
Ambient Temperature	10 to 50 °C
Mass flow rate	0 to 200 g/s
Allowable ΔP across the flow meter	≤ 100 mbar

Mass flow unit	g/s OR kg/h
Power supply	24V/230VAC
Transmitter output	4 – 20 mA
Communication type	Serial Communication
Local display	Yes
Body material	Stainless Steel
Process connection type	Contractor to specify
Application	Outdoor application
Protecting class	IP 65 or better
Accuracy	± 2.5 % or better for ≥ 100 g/s mass flow rate
Relevant drawings, Material test certificate and calibration certificate shall be provided for approval. It should be traceable to the NABL or equivalent and should be in English language.	

5.6 Technical Specification: Cryogenic Pressure sensor and transmitter with Local Display (PE/PT)

Table 5-6: PE/PT Specifications

Valve	**Application**
PE/PT-1	Outdoor application
PE/PT-2	Indoor application
PE/PT-3	Indoor application (Part of Phase Separator)
PE/PT-4	Indoor application
Other Technical Specifications:	
Particulars	**Specifications**
Type	Suitable for cryogenic application. Type shall be compatible with the application and given inputs. Contractor to specify the type.
Range	0-6 bar-g
Power supply	24V/230VAC
Transmitter output	4 – 20 mA
Local display	Yes
Body material	Stainless Steel
Material of the wetted parts	Stainless steel
Protecting class	IP 65 or better
Display Unit	bar OR mbar OR kPa
Accuracy	± 0.25 % of full-scale value or better
Relevant drawings, Material test certificate and calibration certificate shall be provided for approval.	

5.7 Technical Specification: Isolator Box Assembly

- Contractor has to fabricate 2 numbers of electrical isolator box assemblies. **Detailed engineering drawings of isolator box assembly shall be provided by ITER-India.**

- The purpose of isolator box assembly is to electrically separate high voltage side (INTF vacuum vessel) and INTF cryolines. The construction of isolator boxes is similar to two pipe vacuum jacketed line with ceramic pipe isolators (Cryogenic Ceramic Break) for fluid transfer. Two Isolator box assemblies will be connected to two nos. of NB 400 ports on INTF vacuum vessel. Refer **Figure 20**, **Figure 33**, **Figure 36**.
- Quantity of Isolator box assembly: 02 Nos.
- Material: SS 304L
- O-ring Material: (FKM) fluoroelastomer
- **Cryogenic Ceramic Breaks:**

Table 5-7: Cryogenic Ceramic Breaks Specifications

Particulars	**Specifications**
Quantity	04 Nos. (02 Nos. in each Isolator Box Assembly)
Size	1”
Electrical Isolation	≥ 5 kV
Fluid	LN2
Insulation material	Alumina ceramic
Alumina Content	>99%
Water Absorption/Open Porosity (Maximum)	0%
Bulk Density	>3.7 g/cc
Tube material	Stainless Steel
Leak tightness	< 1.0×10^{-8} mbar-l/s or better

- Isolator box shall be equipped with an evacuation port with associated seal-off valve. Each Evacuation/Seal-off port shall have a standard KF connection. The seal-off port shall be closed using a Seal-off valve/plug. The seal-off valve shall be all-stainless-steel construction, equipped with double O-ring seal to prevent vacuum loss. The valve shall incorporate a poppet which provides relief in the event of an overpressure (Relief Pressure: max. 0.5 to 0.6 bar-g).
- The leak rate for each weld and overall segment is as defined in section 6.1.
- Image of isolator box assembly with overall dimensions are given in **Figure 43**, **Figure 44**.

5.8 Technical Specifications: Compressed Air Lines for Pneumatic Operated Flow Control Valve (FCVs)

- The compressed air line shall be seamless or welded (with 100% radiography) Stainless Steel 304L / 316L as per suitable international standard (ref. section 7) for dimension tolerances and material identification.
- Surface roughness (internal) maximum 25 µm (lower value to be confirmed by the supplier)
- Surface roughness (external) maximum 50 µm (lower value to be confirmed by the supplier).

- During transport end caps shall be provided at both ends of the pipe preventing dust and foreign particles to enter and pipes shall be wrapped with polythene to protect the pipes from any dust on the surface.
- Size of Pipe: DN 15-10S

Figure 5: Compressed Air Line Source Point

- Length: ~ 50 m
- Size of available compressed air line tapping (Source Point): DN 15-10S, SS 304L
- The available tapping is terminated with shut off valve as shown in **Figure 5**.
- Routing and connection of compressed air line from this available tapping (Source Point) to Flow Control Valves (FCVs) with required interface connections are in scope of contractor. Location of dry compressed air source point is shown in **Figure 5**, **Figure 11** and **Figure 27** as well as in CAD model.
- Suitable Shut-Off valves shall be provided in Compressed Air Line near each FCV.
- SS 304L tube (size suitable to FCV) and fittings shall be used for connections between each Shut-Off valve and FCV. Tubes shall be seamless as per suitable international standard (ref. section 7) for dimension tolerances and material identification.

5.9 Technical Specification: Cryogenic Temperature sensors, Monitors and Feed throughs

- **<u>Cryogenic Temperature Sensor</u>**

Table 5-8: Cryogenic Temperature Sensor Specification

Particulars	**Specifications**
Type	Platinum RTD
Range	14K to 325K
Mounting package	• Bobbin type with dimensions: L: ≤ 15 mm, W: ≤ 15 mm, T: ≤ 6 mm with hole suitable for M3 bolt • Cylindrical type with dimensions: ϕ ≤ 2mm, L ≤ 15 mm
Lead Type	**4 wire**, Platinum (ϕ: ≤ 0.3 mm, L: ≥ 10 mm)
Quantity	Total 75 (Bobbin Type: 45 Nos., Cylindrical Type: 30 Nos.) • <u>Calibrated</u>: 4 Nos. (02 Nos. Bobbin Type, 02 Nos. Cylindrical Type) • Calibration range: 14 K to 325 K. • <u>Uncalibrated</u>: 71 Nos.
Accuracy	• <u>Calibrated Sensors</u>: ○ 14 K to 300 K: ± 25 mK or better ○ 300 K to 325 K: ± 50 mK or better

	• <u>Uncalibrated Sensors</u>: ○ 70 K to 325 K: ± 1.5 K or better
Excitation Current	1 mA
Thermal response time	less than 2 s at 77 K or better
Repeatability at 77 K	± 10 mK or better
Calibration reports of calibrated sensors shall be provided for approval. Calibrated sensors shall be provided with calibration curve for temperature range 14 K to 325 K.	
The model number and manufacturer of uncalibrated sensors shall be the same as calibrated sensors.	
<u>Note</u>: • Mounting of 04 sensors inside vacuum vessel and routing of sensors' cables up to DAQ junction box are in scope of contractor. • Location of 04 sensors to be mount: One sensor on each supply and return LN2 manifold inside INTF vessel. There are two supply and two return manifolds inside vacuum vessel.	

- **<u>Cryogenic Temperature Monitor</u>**

Table 5-9: Cryogenic Temperature Monitor Specifications

Particulars	**Specifications**
Number of inputs	8 Channel
Measurement type	4 lead differential
Supported Sensor	RTDs: 100 Ω Platinum
Input Connector	25-pin D-sub
Input Configuration	Constant-Current
Input Range	0 to 500 Ω
Excitation	1 mA ±0.3%
Accuracy	±0.06 Ω ±0.02% RDG OR Better
Resolution	2 mΩ
Other capabilities	• Provision for entering eight user curves. Min. 200 points for each. • Shall have math function to estimate max, minimum and Linear Equation. • Shall have programmable averaging filter with 2 to 64 input points averaging.
Front Panel	LCD display for all 8 reading in various display units (K, C, V, Ω), Keypad for input selection and specific function selection. Sensor unit display resolution shall be 5 digits.
Interface	RS-232C, Max Baud rate 9600, Connector 9 pin D-sub USB, TCP/IP
Software Drivers	LABVIEW®
Alarms	High or low for each input temperature sensor, display annunciator
Data logging	All channels, data log to be sent through serial port interface
Input power requirement	230V AC, 50 Hz Indian power supply condition

Ambient Temperature	15 to 35 °C at rated accuracy
Approval	CE Mark
Size	Standard size half rack
Accessories	Rack mountable kit, Instrument Calibration Certificate, Hard copy of the manual, Input power supply cable
Quantity	8 No. Temperature Monitors

- **Feed through**
    - Type: Subminiature (D-type) Multipin Feedthrough Kit
    - Quantity: (07 Nos.).
    - Mounting Location: On INTF vessel.

Table 5-10 Feed through Specifications

Sr. No.	Particulars	ITER-India Requirement
1.	Type	Subminiature (D-type) Multipin Feedthrough Kit
2.	Number of coaxial pins	(50)
3.	Operating Voltage	100 Volts DC or better
4.	Operating Current	1 Amps per pin or better
5.	Construction	UHV Compatible Construction
6.	Feedthrough flange Mounting	(DN 63 CF)
7.	Flange material	SS304-304L/SS316-316L
8.	Shell material	Stainless Steel
9.	Pins material	Au plated, Ni-Fe alloy/Be-Cu alloy or better
10.	Insulation/seal material	Glass-ceramic
11.	Leak rate	≤ $1X10^{-9}$ mbar-l/sec
12.	Air side connector	Delrin/Plastic/Metallic with Locking Screw (Delrin is an Acetal Homopolymer)
13.	Vacuum side connector	PEEK with Locking Screw (PEEK is a Polyether-Etherketone thermoplastic)
14.	Connector Extension Cables length	19-inch or better at both Vacuum and Air side
15.	Vacuum side cable	Kapton Insulated Vacuum Cable
16.	Vacuum side temperature range	- 50° C to 100° C or better
17.	Air side temperature range	10° C to 35° C or better

5.10 Technical Specifications: DAQ Junction Box including all cabling

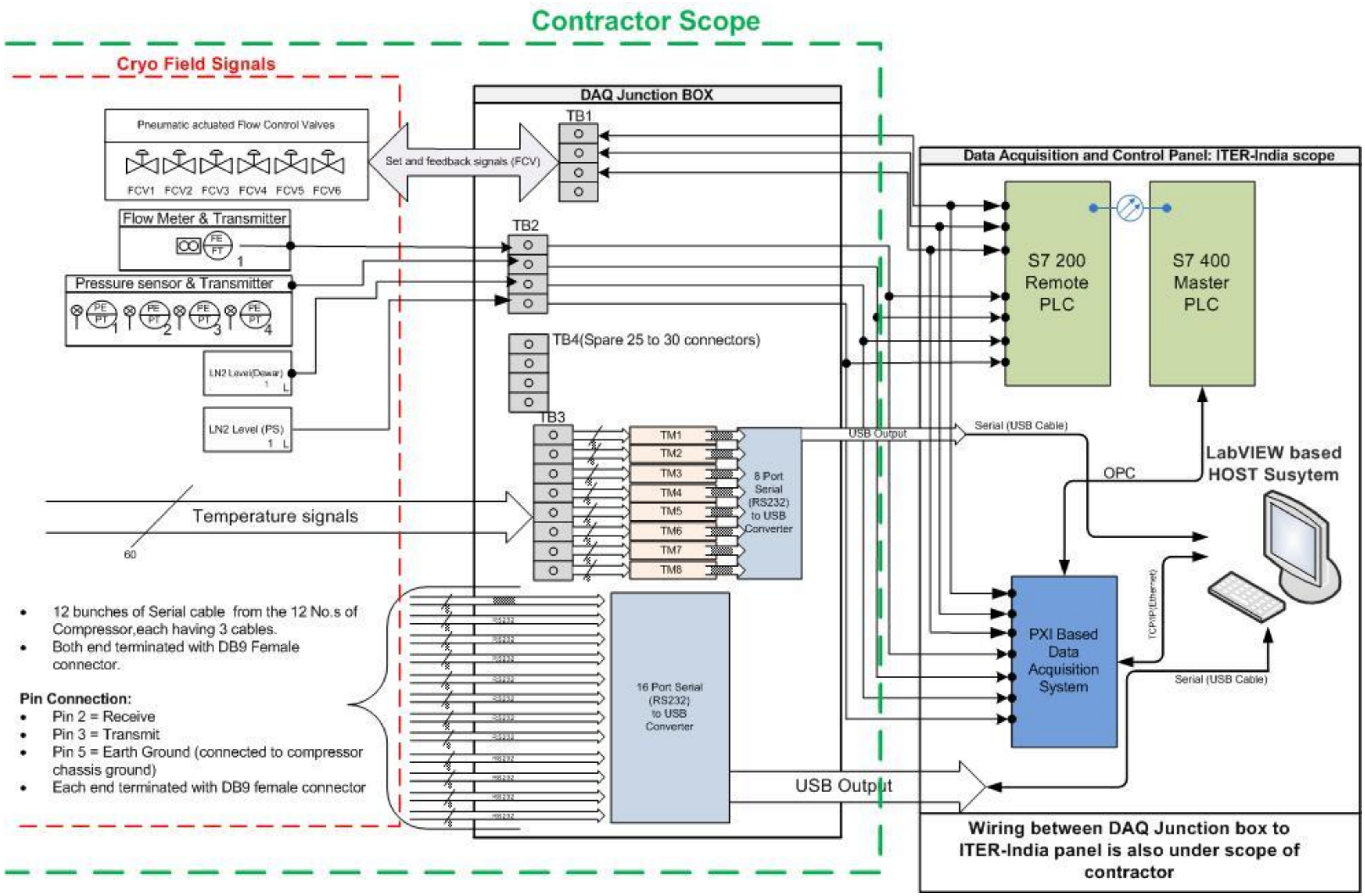


Figure 6: Interface of Cryo signal

Functional Requirements:

- The structural strength of the DAQ junction box shall be such as to withstand its ultimate mechanical load (with all the individual units mounted) without any deformity.
- Top of the DAQ junction box shall be fully covered except for ventilation and/or cable entries, if any.
- There shall be provision of light and fan within DAQ junction box. Door limit switch connection with light and fan shall be there.
- The DAQ junction box shall be designed for easy maintenance & installation. There should be a clear and prominent "DANGER" Marking at the live parts. The DAQ junction box shall conform to IP 54.
- The DAQ junction box shall be accessible for testing and maintenance without any danger of accidental contact with live parts.
- All the signals must be properly tag at both ends for better identification.
- Electric power supply to all instruments in INTF LN2 distribution system shall be provided from DAQ junction box only. Contractor has to select power supplies of appropriate rating in order to ensure required operation of the junction box. Electric power supply to DAQ junction box shall be provided from nearby Cryo Power Supply Box (refer **Figure 26**).
- Approx. dimensions of DAQ junction box is H: 2000 mm, W: 1000 mm, D: 550 mm. However, final dimensions shall be decided by contractor by considering dimensions of individual components to be placed in DAQ junction box.

Scope of Work:

- Scope of work shall cover design, manufacture, supply, installation and commissioning of DAQ junction box. **Table 5-11** below details the scope of work between contractor and ITER-India.

Table 5-11: Scope of Work

Contractor's Scope of Work	**ITER-India's Scope of Work**
Submit all the relevant drawings such as Single Line Diagram (SLD) of instrumentations, GA drawing, wiring and loop diagram of the DAQ junction box prior to fabrication for ITER-India's approval.	-
Provide dedicated Terminal box (TB) for all sensors' connection as shown in **Figure 6**. (TB1, TB2 and TB3). Spare TB4 with 25 to 30 connectors shall be provided for future expansion. TB connectors should be 4 SQ.MM 2 Level Screw Clamp Terminal Block.	-
Provide local display with tagging on front in DAQ junction box for following sensors: • 1 no. Dewar LN2 level	-

• 1 no. PS LN2 level • 4 nos. Pressure sensor and transmitter • 1 no. Flow meter and transmitter	
MCB with appropriate rating shall be provided in supply line of electric power to DAQ junction box.	-
Wiring (signal and power cable) of the all instruments used in INTF LN2 distribution system and integrate all of them along with signal conditioning interface in a DAQ junction box. Shielded twisted pair cable shall be used for routing of the signals from field to junction box outside vacuum vessel. While Phosphor-Bronze 4-lead wire, 36 AWG with Polyimide insulation shall be used inside vacuum vessel.	-
Following instruments have been envisaged for wiring (signal and power cable) from instruments location to DAQ junction box. • Flow Control Valves: 06 Nos. • Flow meter and Transmitter: 01 No. • Pressure Sensor and Transmitters: 04 Nos. • Liquid Level Sensor on 6000 ℓ LN2 Dewar: 01 No. • Liquid Level Sensor on PS: 01 No. • Temperature Sensors on LN2 Manifolds inside vacuum vessel: 04 Nos.	-
Supply and Installation of eight temperature monitors (TM) in DAQ junction box as shown in **Figure 6**. Also, provide power connection to all temperature monitors in the junction box. For location of power supply source available in DNB Lab, refer **Figure 26**.	-
Inside Vacuum Vessel: Mounting of 04 Nos. cryogenic temperature sensors on LN2 Manifolds with proper thermal anchoring and routing of them up-to vessel feedthrough.	**Inside Vacuum Vessel:** • Mounting of 56 cryogenic temperature sensors on cryopumps and routing of them up-to vessel feedthrough. • Connections of all 60 (56 + 4) sensor wires with feedthrough pins.
Outside Vacuum Vessel: Cable routing (with cable tray) of all 60 (56 + 4) temperature sensors, each having 4 leads, coming out from vacuum vessel feedthrough to Temperature Monitors in DAQ junction box.	**Outside Vacuum Vessel:** Connections of cables with feedthrough pins and temperature monitors.

Outside Vacuum Vessel: Cable routing (with cable tray) of 12 bunches of serial cable from 12 Nos. of cryocooler compressors to DAQ junction box. End termination of cable shall be DB9 female connector at both end (One at compressor end and anther at USB converter end). Each bunch shall include 3 cables as follow: • Female DB-9 connector: Pin 2 = Receive, Pin 3 = Transmit, Pin 5 = Earth Ground (connected to compressor chassis ground)	-
Outside Vacuum Vessel: Routing and termination of cables from DAQ junction box to control panel of ITER-India. The distance of around 6m can be considered for this work.	**Outside Vacuum Vessel:** Termination plan (for ITER-India panel) will be provided at time of system integration.
Procurement and Installation of 8 port serial (RS232) to USB converter (Specification is given in section 5.10.1) for monitoring the 60 temperature readings (Platinum RTDs) coming from vacuum vessel as shown in **Figure 6**. Also provide power connection to it.	-
Procurement and Installation of 16 port serial (RS232) to USB converter (Specification is given in section 5.10.1) for controlling 12 crycooler compressors. Also provide power connection to it.	-
-	Development of control logic as per process requirements
-	Graphical User interface development of Cryo system.

5.10.1 Technical Specifications: USB to 8 Port and 16 Port Serial Converter

Table 5-12 USB to Serial Converter Specifications

ITER-India Requirements			
Sr. No	**USB to 8 port serial converter**		**USB to 16 port serial converter**
	Parameter	**Value**	**Value**
USB Interface			
1	**Compliance**	USB 1.1/2.0 compliant	USB 1.1/2.0 compliant
2	**Connector**	USB Type B	USB Type B
3	**Speed**	480 Mbps (Hi-Speed USB) and 12 Mbps (Full-Speed USB)	480 Mbps (Hi-Speed USB) and 12 Mbps (Full-Speed USB)
Serial Interface			

4	**Number of Ports**	8	16
5	**Serial Standards**	RS-232 and 422/485(Optional)	RS-232 and 422/485(Optional)
6	**Connector**	DB9 male	DB9 male
Performance			
7	**Baudrate**	50 bps to 921.6 kbps (Configurable)	50 bps to 921.6 kbps (Configurable)
Operating Systems			
8	**Windows Real COM Drivers**	Windows 2000, Windows XP/2003/Vista/2008/7/8/8.1/10 (x86/x64), Windows 2012 (x64), Windows Embedded CE 5.0/6.0	Windows 2000, Windows XP/2003/Vista/2008/7/8/8.1/10 (x86/x64), Windows 2012 (x64), Windows Embedded CE 5.0/6.0
9	**Linux Real TTY Drivers**	Linux 2.4.x, 2.6.x, 3.x or better version	Linux 2.4.x, 2.6.x, 3.x or better version
Environmental Limits			
10	**Operating Temperature**	0 to 55°C	0 to 55°C
Indicators			
11	**LED Indicators**	8 – Port send (Transmitter), 8 – Port receive (Receiver), 1 – Power (Active)	16 – Port send (Transmitter), 16 – Port receive (Receiver), 1 – Power (Active)
Power Requirements			
12	**Input Voltage**	12 to 48 VDC/ USB powered/230 AC- 50Hz	12 to 48 VDC/ USB powered/230 AC- 50Hz
Standards and Certifications			
13	**Safety/EMC/EMI /EMS**	UL 60950-1/EN 55022-24/ CISPR 22, FCC Part 15B Class A/all IEC 61000/RoHS, CRoHS, WEEE	UL 60950-1/EN 55022-24/ CISPR 22, FCC Part 15B Class A/all IEC 61000/RoHS, CRoHS, WEEE
14	**Part number**	Moxa part no.: UPort 1650-8 or equivalent	Moxa part no.: UPort 1650-16 or equivalent
15	**Warranty**	1 Years or more from date of approval of SATR documents	1 Years or more from date of approval of SATR documents
16	**Quantity**	1 Nos.	1 Nos.

5.11 Instruments Cable Tray (For Power and Signal Cable)

- Type: hot-dip GI trunking cable tray with removable cover
- Size: 100 mm x 50 mm (Thickness ≥ 1mm)
- Length: ~ 130 m
- Reference image of Instruments Cable Tray is given below.

Figure 7: Instruments Cable Tray (For Power and Signal Cable)

6 Technical and Manufacturing Requirements of INTF LN2 Cryoline

6.1 Technical Requirements: Leaks and Leak testing

Table 6-1 Requirements for Leaks & Leak Testing

System/ Component	Maximum Leak Rate
Each weld of process pipes and pipe connections (helium pressurized process pipes at 90 % of design pressure or contractor may propose test pressure)	< 1.0 x 10^{-8} mbar-l/s or better
Individual leakage across valve seats (at design pressure and room temperature)	< 5.0 x 10^{-4} mbar-l/s
Leakage from valves and Instrumentation to atmosphere	< 5.0 x 10^{-5} mbar-l/s
Leakage from flange (metal seal) (Near Dewar for connecting VJ line with Dewar)	< 5.0 x 10^{-4} mbar-l/s

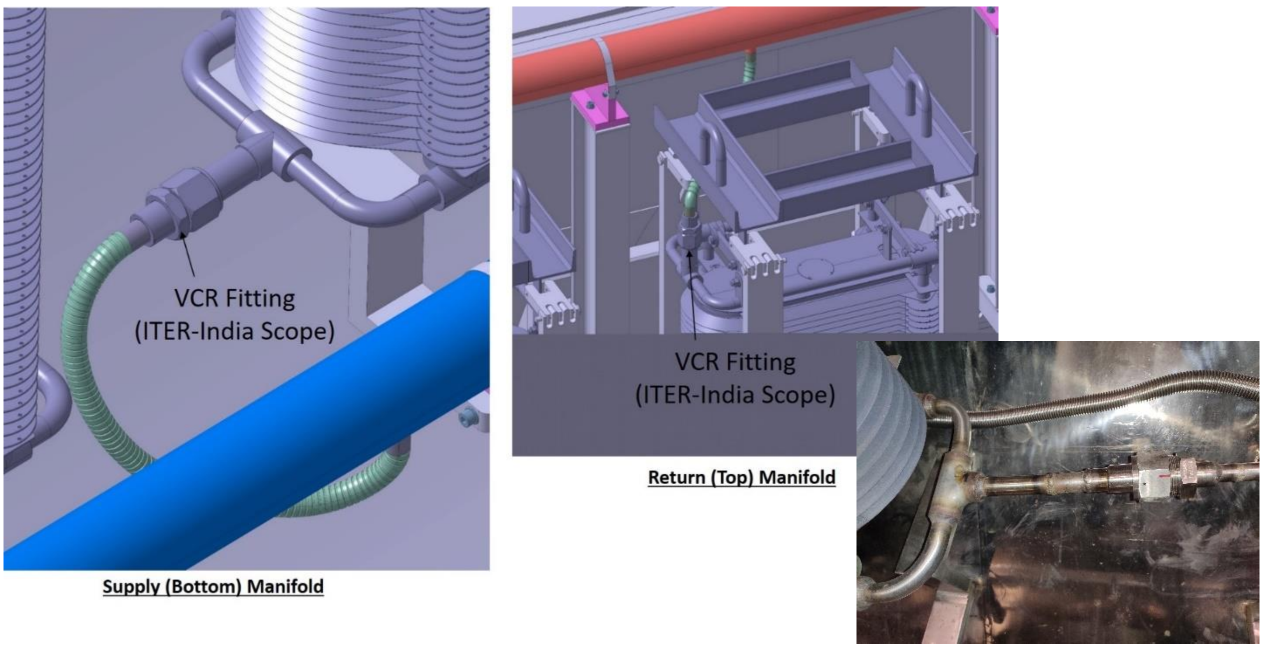
- Helium leak tests shall be performed by the supplier during the final acceptance test after pneumatic pressure test and thermal shock test, for each pre-assembled component/subsystem (to be shipped) within the scope of this technical specification.
- The contractor shall submit a complete leak testing procedure in this regard for ITER-India approval.
- The contractor/sub-contractor shall have experience in leak testing and shall have all the equipment to carry out the leak detection. The arrangement of all tools/items/equipment required in leak detection are in scope contractor.

6.2 Physical Interfaces

INTF LN2 Distribution System will have three basic types of interfaces. At one end it will have an interface with Cryopump Radiation Shields while at another end with 6000 ℓ LN2 Dewar. In between it will have an interface with building wall, mezzanine and working platform.

6.2.1 Physical Interface with Cryopump Radiation Shields

INTF LN2 Distribution System will feed LN2 to 12 nos. of cryopump radiation shields installed in INTF vacuum vessel. Each cryopump radiation shield has one supply and one return header having SA 321 TP 304L, 15NB SCH 5S pipe. Each supply and return cryopump header will be connected to common supply and return LN2 manifold respectively through SS flexible hose by using VCR fittings (SS-16-VCR-3, Swagelok make) as shown in **Figure 8** below. **VCR fittings will be provided by ITER-India.** The contractor shall be responsible for welding of each female part of VCR fitting with cryopump header (DN15, SCH 5S pipe) and male part of VCR fittings with SS flexible hoses (DN20, SCH 5S) Contractor shall ensure proper weld joints preparation for leak tight weld.



Note: In absence of VCR, direct welding to be done. ITER-India will take decision in due course regarding use of VCR or direct welding.

Figure 8: Physical Interface with Cryopump Radiation Shields

6.2.2 Physical Interface with 6000 ℓ LN2 Dewar

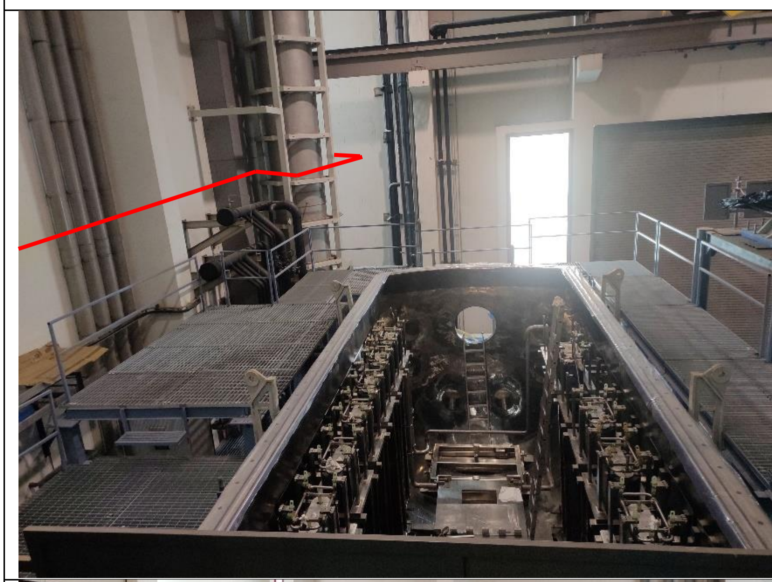
The LN2 comes from 6000 ℓ Dewar through MCV-1 which flows through foam insulated line segment 1,2,3,4 and so on as shown in **Figure 9** below and goes to Cryo Lab existing setup. Contractor shall replace this foam insulated line segments 1,2,3, and 4 having total length approx. 6 m with vacuum jacketed line. INTF LN2 cryoline can be connected in segment 3 or 4. Suitable location for connection and supports shall be decided by contractor. Contractor shall also ensure proper pipe supports for the same. Conceptual support scheme is shown in **Figure 40** as well as in Appendix-2.

Figure 9: Physical Interface with 6000 ℓ LN2 Dewar

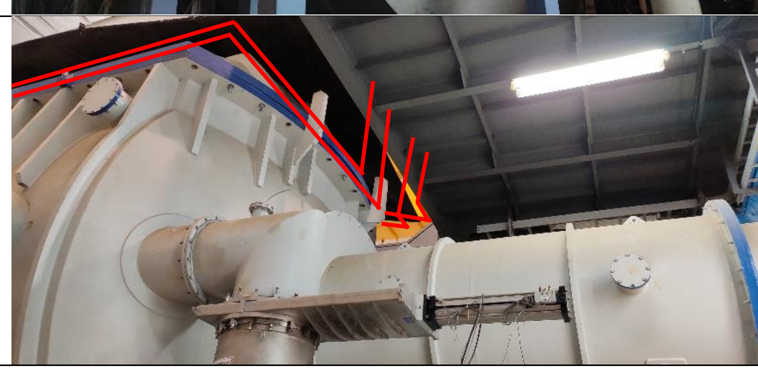
6.2.3 Physical Interface with building wall, mezzanine and working platform

INTF LN2 cryoline will be routed at ~9m height outside the building taking support from wall. It will be entered into the building from back side through glass window. Once entered inside the building, it will be routed at ~9m height taking support from wall then it will be connected to Phase Separator (PS) which will be kept on mezzanine at ~6m height. From PS it will be routed taking support from working platform and entered into the vessel from either side. LN2 exhaust / vent line will be routed taking support from mezzanine and going out from lab through glass window.

6000ℓ
LN2 Dewar



Phase Separator



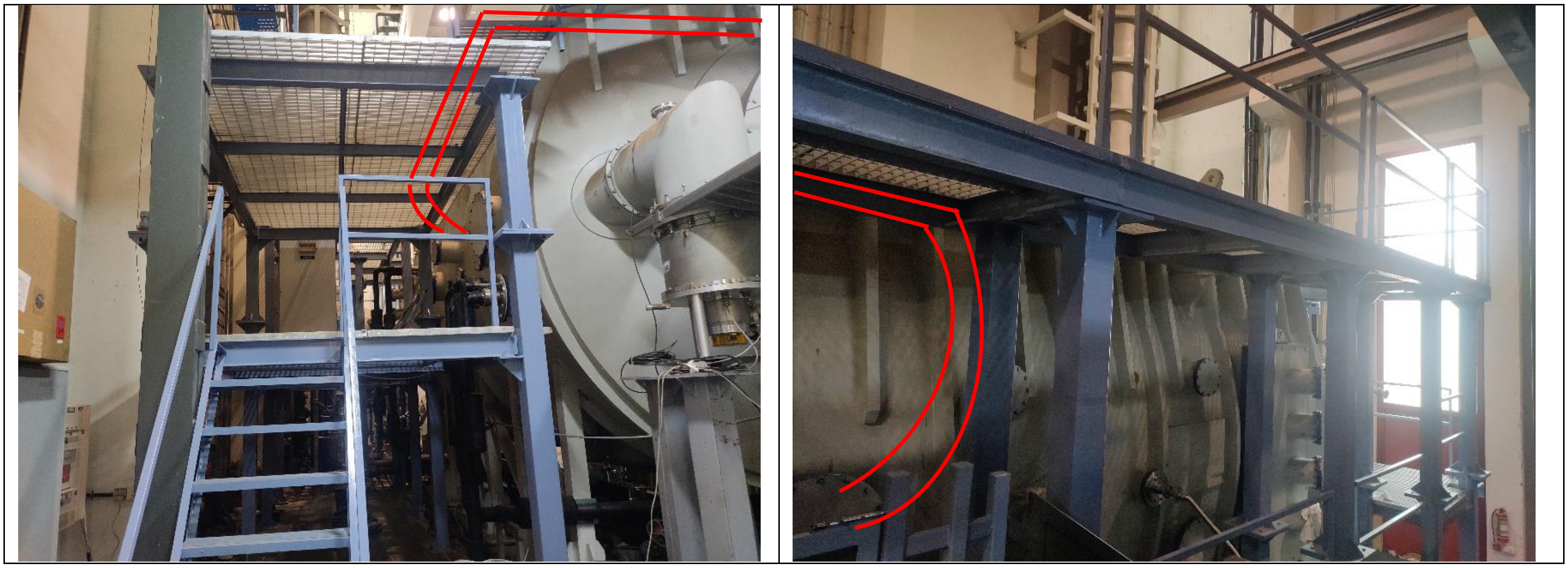


Figure 10 Physical Interface with building wall, mezzanine and working platform

6.3 ITP –Inspection and Test Plan

- In accordance with the ITER-India Quality Program, manufacturing shall be verified by an Inspection and Test Plan (ITP) approved by the ITER-India. Key Hold Points (HP) and Witness Points (WP) within the ITP will need to be agreed and submitted to the ITER-India for approval before the beginning of manufacturing.
- Minimum required Key Points are listed in APPENDIX-3.
- The ITP shall be prepared by the Contractor and sub-contractors for the fabrication phase in agreement with the ITER-India Inspection and Test Plan
- The ITP shall be the common tool used by the supplier in the workshop in terms of quality and project management. ITPs are used to monitor quality control and acceptance tests and shall be produced by the Contractor and each sub-contractor.
- It should be noted that interventions additional to those required in the INTF LN2 Distribution System Contract may be included on the ITP by the ITER-India if justified.
- The Contractor shall ensure that sub-contractors, where appropriate, do not start manufacturing without an ITP in place that has been accepted by the ITER-India.
- Sample ITP template is given in APPENDIX-4.

6.4 Deviation and Non-Conformances

All requirements of the INTF LN2 Distribution System Contract and subsequent changes proposed by either the ITER-India or the Contractor during the course of execution of the Contract are subject to the Deviation Request (DR) process and processed by the Contractor. Sample DR template is given in APPENDIX-5. Any price implications shall be considered only after mutual agreement between ITER-India and the Contractor.

Non-conformance reports (NCR) shall be issued by the Contractor to the ITER-India whenever nonconformities are identified. Sample NCR template is given in APPENDIX-6.

6.5 Fabrication

Workmanship shall conform to the best industry standards worldwide. Utmost care shall be taken at all steps of fabrication considering the application of the components. All materials including process pipes, outer jackets, manifold etc. should be handled vary carefully so that no scratch comes on the surface. The multilayer insulation shall be wrapped in clean dust free environment suitable for high vacuum application. No handling with bare hand is permitted while working with components meant for vacuum.

6.5.1 Welding

All welding shall be appropriately designed for the application. All process pipes must be butt welded. The butt weld shall be full penetration. **All welding shall be carried out with compatible filler material and backing gas purging.** All deviations from butt weld shall be performed with the approval of the ITER-India. The contractor shall prepare detailed weld plans. Every weld shall be identified on the manufacturing drawings and linked to an appropriate weld procedure. All welding shall be performed by welders who have been qualified to procedures and positions for the approved WPS as required by ASME Section IX for the material, temperature, and application intended.

All butt welds shall be 100% radio-graphed. If defects are found in a welded pipe, additional radiography shall be required after repair.

6.5.1.1 Weld Plan

Before fabrication can commence the Contractor shall prepare a Weld Plan and send the same to ITER-India for Approval.

Weld Plan, in conjunction with the following documents as per ASME Section IX shall be submitted to ITER-India before start of welding activity.

1. Welding Procedure Specification
2. Welding Procedure Qualification Record
3. Welder Qualification Record

Contractor shall submit the list of qualified welders. Furthermore, the contractor shall demonstrate that welding equipment and plant is properly maintained and calibrated in accordance with the relevant operation and maintenance schedules.

The existing qualification of welding procedure and welder available with contractor is required to submit to ITER-India for approval prior to start of any welding activity. New qualification of Welding procedure & Welders shall be intimated to ITER-India and the same may be witnessed by ITER-India representative.

6.5.1.2 Acceptable Welding Procedure

The selected welding technique shall produce a clean, pore free weld with minimal oxidation. Suggested welding processes are as below.

1. SS structures - TIG Welding
2. SS Pipe Joints - Manual/Orbital TIG Welding

6.6 General Work Requirement

The Contractor shall visit the site before quotation to understand the space constraints and about the existing system.

1. The INTF LN2 Distribution System will be installed in areas where other equipments have already been installed. The contractor shall take utmost care so that there will not be any damage to existing equipment. The contractor is responsible for such incidents causing the damages.
2. The contractor shall take caution while working in INTF vessel.
3. The contractor shall have experience in handling similar works. The contractor and/or his subcontractor shall have experience in the area for which they are responsible. The contractor shall submit the list of sub-contractors if any for ITER-India approval along with the quotation.
4. In case of any failure of the subassembly/assembly/component to comply with/meet an inspection or test required/specified, the contractor shall notify the ITER-India about it. Without ITER-India's written permission, contractor shall not undertake the repair of the fault.
5. The contractor shall prepare and submit P&IDs and layouts (3D and isometrics) for ITER-India approval.
6. The INTF LN2 Distribution System components shall be suitable for the application and to the environment where they will be installed.
7. ASME or alternate code shall be followed at the various stages of design, fabrication, inspection and testing wherever applicable.
8. The Contractor shall submit a detailed list of codes and standards to be followed for INTF LN2 Distribution System design, fabrication and testing along with the quotation.
9. Qualification of Welding procedures and welders shall be done as per ASME Section IX standard.
10. Welding shall be done on the job, strictly following the approved welding procedures using approved welding consumables and qualified welders.
11. ITER-India reserves the right to carryout stage wise inspection during fabrication.
12. Make sure the measuring tools have been calibrated and within the effective period.
13. Clean up the groove surface and adjacent area before assembly. The surface of welding groove shall be with no oxide scale, rust, oil, grease or other hazardous substance. The

surface of grooves shall be kept dry. Welding activities shall not be performed on wet surfaces.

14. Symmetric tack weld (using the cleats of same base and filler material as that of main welds) is to be adopted during assembly.
15. Tack weld shall have no cracks. Clear away pores and slag inclusions (if any).
16. Both ends of the tack weld fused into the permanent weld shall be easy for joint arc, otherwise repair is required.
17. After tack welding, the spot weld shall be thoroughly cleaned by stainless steel brush or iron-free grinding wheel.
18. Install back protection apparatuses:
    a. The back-protection gas of welding joint shall be inert gas (e.g. argon), to protect the inner surface of root weld and adjacent zone.
19. Temperature of stainless-steel parts to be welded shall not be lower than 10°C. Pre-heat to meet the temperature requirement if the temperature is lower than demand.
20. Piecewise symmetric skip welding is recommended for thin walled pipe welding, to prevent deformation and misalignment.
21. Before the next bead welding, all the welding slag or foreign matters on the weld and adjacent parent metal, and defects such as shrinkage cavity or crack formed due to arc stopping shall be thoroughly eliminated.
22. Stainless steel special tools shall be used for weld repairing or grinding, and shall not be mixed with carbon steel.
23. Weld dimensions and appearance shall be in compliance with the drawings and standards mentioned above.
24. All repair welds shall be re-examined and tested as per the requirements of the original weld and shall meet the requirements and acceptance criteria of the same.
25. Use of LPT is prohibited for the weld joints having vacuum boundary and all vacuum sealing welds shall be 100% leak tested.
26. Suitable sequencing of welds shall be carried out to avoid build-up of residual stresses and distortion. The same shall be displayed in the Contractor’s shop during welding.
27. Shielding and Purging gas required during welding shall be arranged by contractor.
28. The material, fabrication, testing shall comply with all currently available statues, regulations and safety code in the locality where system is fabricated and installed.
29. Ensure human and component safety during assembly and erection Works.

6.7 Cleaning

Each LN2 cryoline spool/section/subassembly shall be cleaned after completion of all welding, machining, threading etc. operations and then sealed and protected against further contamination.

All process lines, vacuum jackets and machined components must be cleaned before wrapping MLI and assembly. The following cleaning procedure is suggested for each process line and vacuum jacket. However, the contractor has the flexibility to suggest alternate procedure agreeable to ITER-India to achieve the required performance which should be clearly mentioned in the offer. Personnel shall be thoroughly trained to follow approved cleaning procedure. It shall be ensured that the cleaning personnel wear required PPEs (Personal Protection Equipments) for safety before starting cleaning operation.

a) Cleaning (water temperature approx. approx. 50°C to 60°C) with mild alkaline cleaning agents.
b) Rinsing in water until all traces of cleaning agents are gone.
c) Rinsing with demineralized hot (approx. 50 °C to 60°C) water having continuous water flow.
d) Cool down the components in dry clean, dust free air.
e) Cleaning with Acetone/Ethanol during final assembly, if necessary.
f) Cloths used in Acetone/Ethanol cleaning operation shall be clean and free of lint.
g) All chemicals used for cleaning shall be chemically pure grade or better

No handling with bare hand is permitted after this cleaning.

6.8 Marking and Spools Identification

Each item supplied must be uniquely identified. Any identification mark must be stamped or engraved on a visible part of the outer surface according to the P&ID tags.

6.9 Sealing

Seal all openings against contamination by appropriate plugs, pipe plugs, blind flanges or by securely taping polyvinyl sheeting at least 200 microns thick.

6.10 Evacuation and bake-out

During the mechanical pump-down phase each section will be heated to an elevated temperature, up to which the insulation can be subjected, to accelerate outgassing of trapped contaminants. The heating operation shall not cause damage to or reduce the effectiveness of the insulation.

6.11 Assembly and tests at works

On completion of spool/component/subassembly fabrication at contractor's site as per approved drawings, contractor shall conduct factory acceptance tests (FAT) as described in section 9.1.

6.12 Metrology inspection

Dimensional controls shall be performed by the contractor on all manufactured elements. The allowable dimensional and geometrical tolerances shall be in agreement with the chosen construction code for metallic piping assemblies and shall be included in the fabrication drawings, and in the welding specification drawings.

6.13 Disassembly, packing and shipment

After completion of all tests at contractor's site to the satisfaction of ITER-India, the contractor shall carefully dismantle all components. Storage shall be done in order to prevent any ingress in components. The fabricated elements shall be entirely enclosed in heat-sealed polyethylene to protect the elements against dust, water and debris during transport. The Contractor shall foresee a rigid structure to fix the packages to the transportation container. Each package shall be clearly marked with contract reference, ITER-India contact person, package weight, up direction, tag number of components inside it, Centre of gravity location, pick-up points for handling etc. as applicable. Provisions to prevent impact or friction of the elements with the supporting structure shall be foreseen. The packing of several elements in the same container is acceptable if a dedicated supporting frame is foreseen by the Contractor to prevent any movements with respect to the container during transport. Interfaces shall be protected with appropriate rigid caps for protection against damages and to maintain cleanliness of the internal components. Proper conditioning (with monitoring) of cryolines shall be done by contractor during transport. The contractor shall also apply adequate protection to all components to ensure against damage during loading, shipment, unloading and storage in a 100% humid atmosphere for six months. Any damage incurred during transport shall be repaired at the cost of the Contractor.

6.14 Assembly and tests at ITER-India site

- After receipt of the material at ITER-India site, the contractor shall unload the material with the help of contractor's personnel. The contractor shall assemble/weld the LN2 Cryolines and its different component/subassembly at ITER-India site as per details on the approved drawings and specifications using appropriately fabricated fixture.
- The contractor shall suggest procedure for assembly, which conforms to the requirement of this specification. Prior approval of the procedure shall be taken from the ITER-India before assembly. The cryogen valves have to be mounted in vertical position according to mounting and assembly instruction from the valve manufacturer. The alignment of valves with process piping has to be ensured while welding and proper closing/sealing of the valves has to be ensured. Required jigs and fixtures for assembly and alignment have to be designed & manufactured by the contractor.
- Cleaning of worksite, workplace mandatory on daily basis after completion of routine works by the contractor.
- Contractor should also keep workplace, surroundings clean and tidy from rubbish, scrap, surplus materials unwanted tools and equipment.

- All passages to entry/exit doors, electrical switches, fire points, first aid boxes etc. shall be kept free by the contractor. Welding and electrical cables shall be routed properly so as to allow safe traffic by all concerned.
- All components shall be fully assembled for the purpose of demonstrating compliance with specification and conduct site acceptance tests (SAT) as described in section 9.2.
- The contractor shall follow all safety measures and IPR safety rules during the execution to protect the personnel and investment. The IPR Safety Protocols are given in link provided below.
  https://www.ipr.res.in/documents/safety_protocols.html

7 Codes and Standards

The material, fabrication, inspection, testing and performance of all the components of the INTF LN2 Distribution System shall be in accordance with all currently available statues, regulations and safety code in the locality where the system is fabricated and installed. The equipment to be used for fabrication shall conform to the latest applicable standards and code of practice. Nothing in this specification shall be construed to relieve contractor from its responsibilities. Contractor may refer the latest version of following standards:

Table 7-1 List of Codes / Standards

Sr. No.	Codes/Standards *	Description
1)	ASME B31.3	Process Piping (Requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of piping)
2)	EJMA	Standard of the expansion joint manufacturer association, Inc.
3)	ASME 36.19	Stainless Steel pipes (Selection of pipe sizes - for dimensions only)
4)	ASME B16.5	Pipe Flanges and Flanged Fittings (All sizes, types and pressure ratings)
5)	ASME B16.9	Factory made wrought butt welding fittings (For selection of fittings, i.e. elbows, Tees, reducers, caps, stub ends etc. (where pipes are as per ASME 36.19)
6)	ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
7)	ASME SEC II	Ferrous, Non-Ferrous & Welding Material Specifications & Properties
8)	ASME SEC V	Non-destructive Examination
9)	ASME SEC VIII Div I	Design, fabrication, inspection, testing and acceptance of pressure vessels

10)	PED-2014-68-EU	The harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment (for Statutory requirement for pressure equipment)
11)	ASME SEC IX	Welding & Brazing Qualifications
12)	API 520	For Sizing, Selection, and Installation of Pressure-Relieving Devices
13)	API 602, API 600	Wall thickness and general valve design
14)	ASME B16.34	Valves—Flanged, Threaded, and Welding End (Pressure – Temperature rating)
15)	API 598	Leak Tightness of Valves
16)	ASTM A380	Practice for Cleaning, Pickling, passivation of SS parts, equipments & systems
	*** Any other alternate International codes will be accepted**	

8 List of Spares

The contractor has to identify a list of spares and shall be submitted along with the quotation. The contractor shall submit a separate price for the spares.

Table 8-1 List of Spares

Item	**Quantity**
Positioner	1 No. for each type of valve
Seal-off valve/plug	4 Nos.
Seal-off valve operator (plunger)	2 Nos.
Cryogenic Ceramic Break	4 Nos.
Dust cap for Evacuation/Seal-off port	1 set (Same quantity as used)
Nuts, bolts, gaskets/seals	1 set (Same quantity as used)
Fittings for Compressed Air line	1 set (Same quantity as used)
MLI	~10 m^2
MLI tape	5 Nos.
Polyimide tape for Cryogenic application	5 Nos.
Vacuum fittings (required for evacuation during operation)	1 set
Vacuum gauge (pirani)	2 Nos.
Cryogenic Pressure Sensor and Transmitter with Local Display (PE/PT)	1 No.
MCV – Size 1” (Parameters similar to MCV-3)	1 No.
FCV – Size 1” (Parameters similar to FCV-1)	1 No.
PSV (Size and parameters similar to PSV-1)	2 No.
VJ rigid line spool (PP-DN 40, OVJ-DN 90), 6 m	1 No.
VJ rigid line spool (PP-DN 80, OVJ-DN 125), 6 m	1 No.

VJ flexible line spool (PP-DN 25, OVJ-DN 80), 6 m	1 No.
Instrument Cable used for LN2 Level, FCVs, Flow meter and Transmitter, Pressure sensor and transmitter, Temperature Sensors (outside vacuum vessel)	5 m for each
Instrument Cable (3 wire serial cable) for Cryocooler Compressor with both ends shall be terminated with DB9 female connector	1 no. (20 m)

9 INTF LN2 Distribution System: Factory and Site Acceptance Tests (FAT and SAT)

The factory acceptance tests listed in the following subsections shall be performed by contractor at the end of the manufacturing process on each spool, after they have been completely assembled in the configuration ready to be shipped. The FAT shall be successfully passed by all of them. Witness of key tests shall be done by ITER-India either in person or remotely. During FAT and SAT, personnel evaluating NDE must be certified according to ASNT Level II.

9.1 INTF LN2 Distribution System Acceptance tests before Shipment (Factory Acceptance Tests - FAT)

- Visual and Dimensional Examination: Visual and dimensional inspection of all manufactured/fabricated elements shall be carried out in accordance with ASME SEC V or alternate international standard. During such examination, the contractor shall arrange sufficient lighting either natural or artificial. External and Internal visual inspection shall be performed for 100% welds without exception. ***Visual and Dimensional Examination procedures shall be submitted by contractor for ITER-India approval.***
- Radiography Test (RT): 100 % groove weld joints of process pipes, jackets in situ welds etc. (except where it is difficult to access) shall be tested for Radiography examination in accordance with the ASME SEC V or alternate international standard. Weld repair (whenever required) shall be performed through approved repair plan. ***Radiography Test procedures shall be submitted by contractor for ITER-India approval.***
- Pneumatic Pressure Tests: Pressure tests of each spool inner pipe shall be performed in accordance with the ASME B 31.3 or alternate international standard. The pressure tests shall be performed at ambient temperature and either using gaseous nitrogen or dry air (dew point shall be checked before pressure test). ***Pressure Test procedures shall be submitted by contractor for ITER-India approval.***
- Thermal Shock Tests: Thermal shock test at LN2 temperature shall be performed on weld samples (per size per welder) followed by RT to qualify it. ***Thermal Shock Test procedures shall be submitted by contractor for ITER-India approval.***

- Helium Leak Tests: Helium leak tests shall be performed after pressure test for each pre-assembled component i.e. process pipe with compensating bellows /subsystem i.e. entire spool (to be shipped) within the scope of this technical specification. All modules shall be checked with a helium mass spectrometer leak detector and shall not have leaks on the level of $1.0x10^{-8}$ mbar-lit/sec or higher (Ref. Section 6.1). ***Helium Leak Test procedures shall be submitted by contractor for ITER-India approval.***
- FAT of DAQ Junction box: Contractor has to complete the wiring of DAQ junction box as per prior submitted and approved GA and wiring diagram. The junction box will be inspected as per the submitted drawings. The junction box will be tested in power on condition for isolation and signal continuity.

The contractor has to inform ITER-India about the schedule of tests well in advance.

After completion of the tests, the acceptance test report shall be signed by the contractor and sent to ITER-India prior to shipment.

9.2 INTF LN2 Distribution System: Site Acceptance Tests (SAT) at ITER-India (Installation & Commissioning and Acceptance tests)

The Contractor shall carry out the commissioning of the integrated system and shall carry out the site acceptance tests to demonstrate the performance of INTF LN2 Cryoline.

The following tests have been identified by ITER-India:

- Incoming Inspection: All transported elements to the ITER-India Lab premises shall undergo an inspection by the Contractor and the ITER-India following their delivery to the ITER-India site. The site inspection shall verify that no damage occurred during transport.
- Visual and Dimensional Examination: Visual and Dimensional inspection for INTF LN2 Cryolines and its components after site welds shall be carried out in accordance with ASME SEC V. During such examination, the contractor is responsible to arrange sufficient lighting either natural or artificial. External visual inspection shall be performed for 100% welds without exception. ***Visual and Dimensional Examination procedures shall be submitted by contractor for ITER-India approval.***
- Radiography Testing (RT): Site welds with 100 % groove weld joints of process pipes, field joints, in-vessel joints etc. (except compressed air line and where it is difficult to access) shall be tested for Radiography examination in accordance with the ASME SEC V or alternate international standard. Weld repair (whenever required) shall be performed through approved repair plan. All arrangements for radiography test shall be done by contractor. ***Radiography Test procedures shall be submitted by contractor for ITER-India approval.***
- Pneumatic Pressure Tests: Pressure tests of inner pipe shall be performed in accordance with the ASME B 31.3 or alternate international standard. The pressure

tests shall be performed at ambient temperature and either using gaseous nitrogen or dry air (dew point shall be checked before pressure test). Pressure test shall be performed without connection to LN2 tank and cryopumps for safety reasons. safety valve (with set pressure 10% higher than test pressure) shall be incorporated in pressure test circuit to avoid accidental pressure higher than 1.1 times pressure test. Arrangement of all testing equipment/items require for pressure testing like nitrogen gas cylinders or dry air, pressure gauges, safety valve for pneumatic pressure test, required fittings etc. are in scope of contractor. ***Pressure Test procedures shall be submitted by contractor for ITER-India approval.***

- Thermal Shock Tests: Thermal shock test at LN2 temperature shall be performed on weld samples (per size per welder) followed by RT to qualify it. Arrangement of LN2 for thermal shock tests along with require test setup are in scope of contractor. ***Thermal Shock Test procedures shall be submitted by contractor for ITER-India approval.***
- Helium Leak Tests: Helium leak tests shall be performed after pressure test for each site weld i.e. process pipe joints, field joints, in-vessel joints etc. All these joints shall be checked with a helium mass spectrometer leak detector and shall not have leaks on the level of 1.0×10^{-8} mbar-lit/sec or higher (Ref. section 6.1). Arrangement of all testing equipment/items required for leak testing like helium leak detector, helium gas cylinders, vacuum pumps, gauges, vacuum components and fittings etc. are in scope of contractor. ***Helium Leak Test procedures shall be submitted by contractor for ITER-India approval.***
- Performance/Functional Test: The 6000 ℓ LN2 Dewar will be filled. As an integrated test, LN2 from Dewar will be flowed to INTF LN2 Distribution System for testing of individual components with installed condition of cryopump radiation shields after integrating the whole system from instrumentation point of view. The operation of phase separator and valves; working of flow meter and transmitter, pressure sensor and transmitters, temperature sensors and monitors etc. will be checked functionally. Failing to satisfy the performance requirements, the contractor shall replace the components/equipment with free of cost and the tests shall be repeated. Following two tests of integrated system will be performed.
    1) Thermosyphon Test: During this test, FCV-4 and FCV-5 will be closed. Two-phase liquid return from Cryopumps will be fed to PS through FCV-2 and FCV-3. PS will be at 1.16 bar-a pressure.
    2) Forced Circulation Test: During this test, FCV-2 and FCV-3 will be closed. Two-phase liquid return from Cryopumps will be directly vented to atmosphere through FCV-4 and FCV-5. PS will be at the available pressure of LN2 at PS inlet i.e. 1.3 bar-a.

  Filling of 6000 ℓ LN2 Dewar for this testing is in scope of Contractor. ***Procedures for Performance/Functional Testing shall be submitted by contractor for ITER-India approval***

- SAT of DAQ Junction box: Contractor has to complete the wiring of DAQ junction box as per prior submitted and approved GA and wiring diagram and modifications suggest during FAT (if any). The junction box will be inspected as per the submitted drawings. The junction box will be tested in power on condition for isolation and signal continuity as per cable schedule.

10 Inspection and Test Reports

- ITER-India shall have free access to the Work to witness factory tests. The contractor shall set up a schedule of inspections and a check list acceptable to the ITER-India, copies of which shall be supplied to the ITER-India. Proper records of all inspections and tests shall be maintained and be fully available to the ITER-India. Final acceptance of the material and work under the Contract shall be dependent on visual and dimensional inspection and completion of all tests specified in FAT & SAT in section 9 above.
- The Contractor shall give the ITER-India a minimum of twenty (20) calendar days' notice of its readiness for inspection. If inspections are to be conducted by an outside authority, the date fixed for such an inspection shall also be provided with sufficient notice to the ITER-India. The Contractor shall be responsible for providing tools, equipment, labours and materials that may be necessary to perform all required inspections. All tests and inspections will be carried out at the expense of the Contractor except where indicated otherwise.
- Witness by the ITER-India shall not relieve the Contractor of the responsibility for satisfactory execution of the whole, or any part of the Contract to the requirements of the Contract Documents. Materials or workmanship not conforming to the provisions of the Contract Documents may be rejected at any time if any defects are found during the progress of the Work.

Two copies of all inspection and test reports shall be supplied to the ITER-India for approval.

11 List of Project Hold Points/Schedule and Documents to be Submitted

List of review meetings (hold points) during the contract execution and documents required for the same are summarized below. It is to be noted that all documents shall be submitted to ITER-India in soft copy (preferably pdf) by email or uploaded on INDUS at XXX folder at least 2 weeks before the meeting date for the review and approval. It is expected that all documents are approved before the meeting. In case need arises, in-between progress meetings may be planned based on mutual agreement.

T0 = Purchase Order / Contract award date

List of technical documents to be submitted for various milestones are summarized below.

A. Kick-off Meeting (KOM) (T0+15 calendar days)

1. Quality plan
2. Detailed schedule
3. List of materials, codes and standards, software to be used
4. Design methodology / plan

Approval of these documents by ITER-India will enable start of design phase.

B. Final Design Review (FDR) Meeting (T0+180 calendar days)

1. Updates if any in quality plan, schedule, materials, codes, standards, software etc.
2. P&ID
3. 2D drawings (assembly and details) in pdf format and 3D model of complete system (LN2 and GN2 lines, phase separator, cable trays, compressed air line etc.) in CATIA V5 or neutral (e.g. STEP) format.
4. Sizing calculation report for phase separator.
5. Flexibility analysis report of LN2 and GN2 lines as per ASME B31.3. Analysis shall be done using CAESAR-II or PIPESTRESS or ANSYS or equivalent software. Report shall include 3D model, boundary conditions and other input parameters, various load cases, temperature dependent material properties, final analysis results including max stress and displacement, acceptance criteria for each type of load case etc.
6. Structural analysis report of internal and external supports and vacuum barriers of LN2 and GN2 lines as well as phase separator and its supports. Finite Element Analysis (FEA) shall be done using ANSYS or equivalent software. Report shall include 3D model, boundary conditions and other input parameters, various load cases, temperature dependent material properties, final analysis results including max stress and displacement, acceptance criteria for each type of load case etc.
7. Data sheet of various instruments like FCVs, Flowmeter and transmitters, Pressure sensor and transmitter, temperature sensors and monitors, cables, cable trays, MLI, spares etc. along with BOM.
8. Detailed proposal (2D drawing, type of joint, NDT etc.) for connections to various interfaces (e.g. LN2 tank).
9. Detailed proposal for civil works to be carried out at lab.
10. Technical report on control logic, interlocks etc.
11. Single line diagrams for electrical and signals network.
12. Design report for DAQ junction box including 2D drawings, GA drawing and 3D model. Wiring and loop diagram along with cable schedule and signal list of the DAQ junction box.
13. Design report on electrical isolation (5KV) system for lines, cable trays, supports etc.
14. Detailed proposal on earthing of instruments, panels etc.
15. Deviation requests (if any)

Approval of all FDR documents is necessary to start pre-manufacturing phase (MRR).

C. Manufacturing Readiness Review (MRR) Meeting (T0+210 calendar days)

1. Updates if any in quality plan, schedule, codes, standards, software etc.
2. Inspection and Test Plan (ITP) for manufacturing.
3. Procedures for cleanliness control during manufacturing, leak test, radiographic tests of welds, MLI insulation wrapping, pressure test, visual examination and dimensional control.
4. Manufacturing drawings (assembly and details) showing tolerances, weld details, MOC etc.
5. Qualifications / certifications of welders and NDT personnel.
6. Weld plan (WPS, WPQR and welder qualification record)
7. Deviation requests (if any)

Approval of MRR documents is necessary to start manufacturing and procurement phase. For long lead items, technical specifications shall be submitted well in advance to avoid procurement delays.

D. Factory Acceptance Tests Review (FATR) Meeting (T0+480 calendar days)

Following documents shall be submitted for approval after successful completion of FAT.

1. Updates if any in quality plan, schedule, codes, standards, software etc.
2. Material test certificates from NABL approved lab for materials used in LN2 and GN2 lines (e.g. pipes, fittings, bellows, hoses etc.), phase separator, supports, valves, spares etc.
3. Test certificate of Pressure Safety Valves (PSVs) as per ASME/PED pressure test.
4. Report mentioning surface roughness values (measured) for process pipe inner and outer surface.
5. Calibration certificates of instruments like FCVs and Positioners, Flowmeter and transmitters, Pressure sensor and transmitter, temperature sensors and monitors, gauges etc.
6. Body and seat leak tightness test reports of all valves.
7. Inspection and test reports for leak test, radiographic tests of welds, MLI insulation wrapping, pressure test, dimensional control.
8. DAQ Junction box test report.
9. Signed ITP
10. As built drawings of DAQ junction box including wiring and loop diagram along with cable schedule and signal list.
11. As built drawings and 3D model in CATIA / STEP format.
12. Deviation requests and non-conformance reports (if any).

13. Packing list (including spares as per chapter 8) for transport to ITER-India lab.
14. Material handling instructions for loading, handling and unloading.

Approval of FATR documents is necessary before shipment.

E. Installation Readiness Review (IRR) Meeting (T0+510 calendar days)

This review meeting will be held after approval of all FATR documents.

1. Installation quality plan (including manpower details, tools, equipment and consumables to be used, certificates of welders and NDT personnel for site work).
2. Detailed installation schedule.
3. Inspection and Test Plan (ITP) for Installation.
4. Installation procedures including safety measures to be followed (refer https://www.ipr.res.in/documents/safety_protocols.html for mandatory requirements), material handling equipment details, scaffolding details etc.
5. WPS and WPQR for installation (if different from manufacturing).
6. Installation drawings.

F. Site Acceptance Tests Review (SATR) Meeting (T0+710 calendar days)

This review meeting will be held after successful completion of SAT.

1. Test reports of thermal shock tests of weld samples as well as VT, LT and RT of welds performed at site.
2. Site pressure test reports.
3. Reports of functional tests on site (e.g. valve opening and closing, sensors, gauges, controllers etc.)
4. As installed drawings of DAQ junction box including all the changes with updated wiring and loop diagram along with cable schedule and signal list.
5. As installed drawings and 3D model (CATIA/STEP format).
6. Commissioning report.
7. Deviation requests and non-conformance reports (if any).
8. Calibration certificates of instruments, valves, gauges etc.
9. Certificate of conformance with technical and quality specifications, codes, standards and regulatory requirements.
10. Operation and maintenance manuals.
11. Warranty certificates.

Approval of all SATR documents is necessary before closure of contract and start of warranty period (T0+730 calendar days).

12 Warranty

The contractor warranties that the item and material furnished hereunder will be to the standards specified in the Contract Documents, and be free from defects, and all Manufacturer designed components will conform to the conditions of performance and design specified in the Contract Documents.

The contractor also warranties that he will, at the convenience of and without charge to the ITER-India, replace, repair and install any of the Works or parts or items thereof which prove defective for up to 12 months from the date of final acceptance by ITER-India. The performance shall not be degraded after the replacement and repair.

Latent liability against defects shall be covered by contractors for 2 years from end date of warranty.

APPENDIX – 1: Supporting Figures/Drawings:

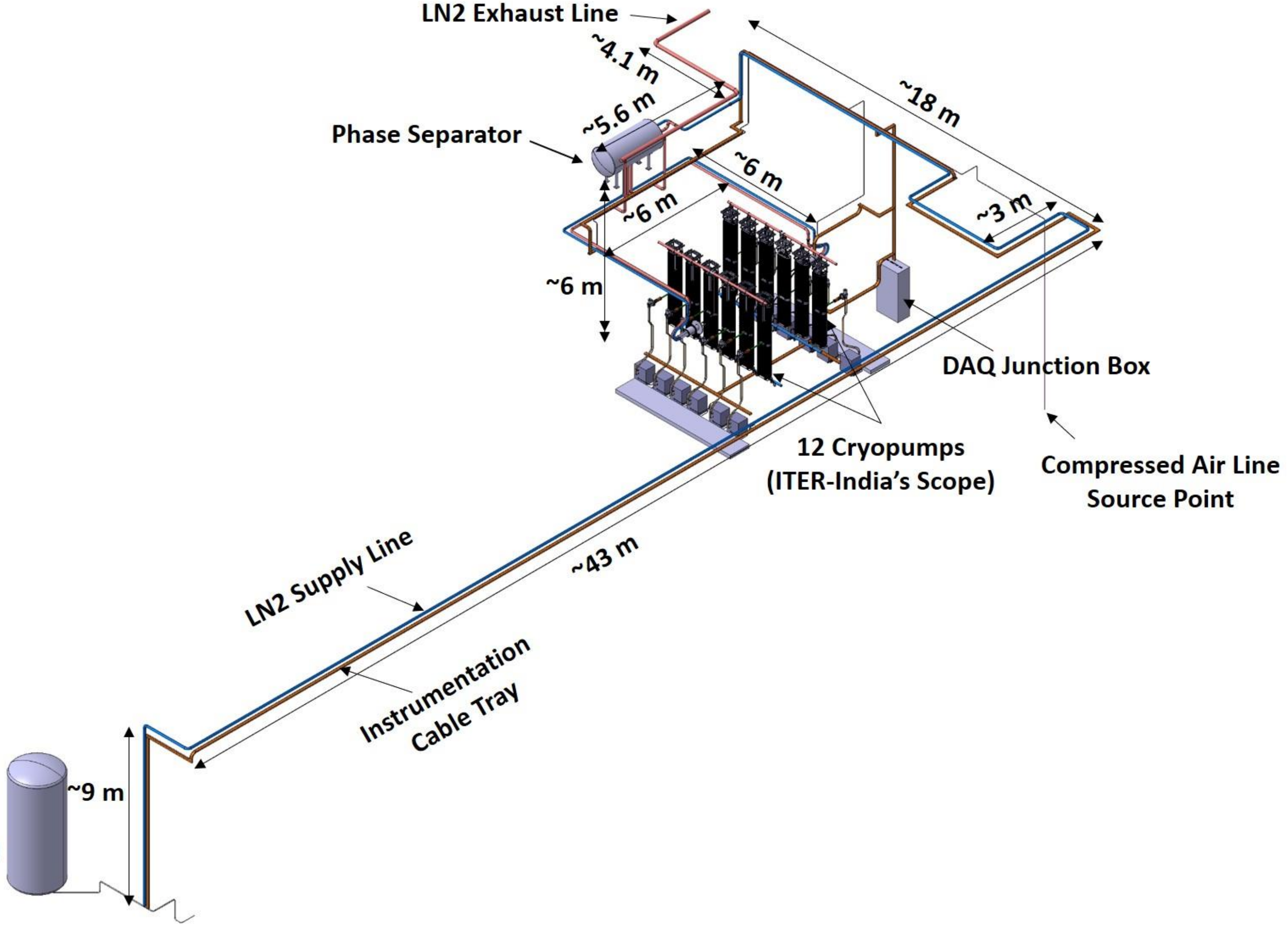


Figure 11: INTF LN2 Distribution System Overall Routing

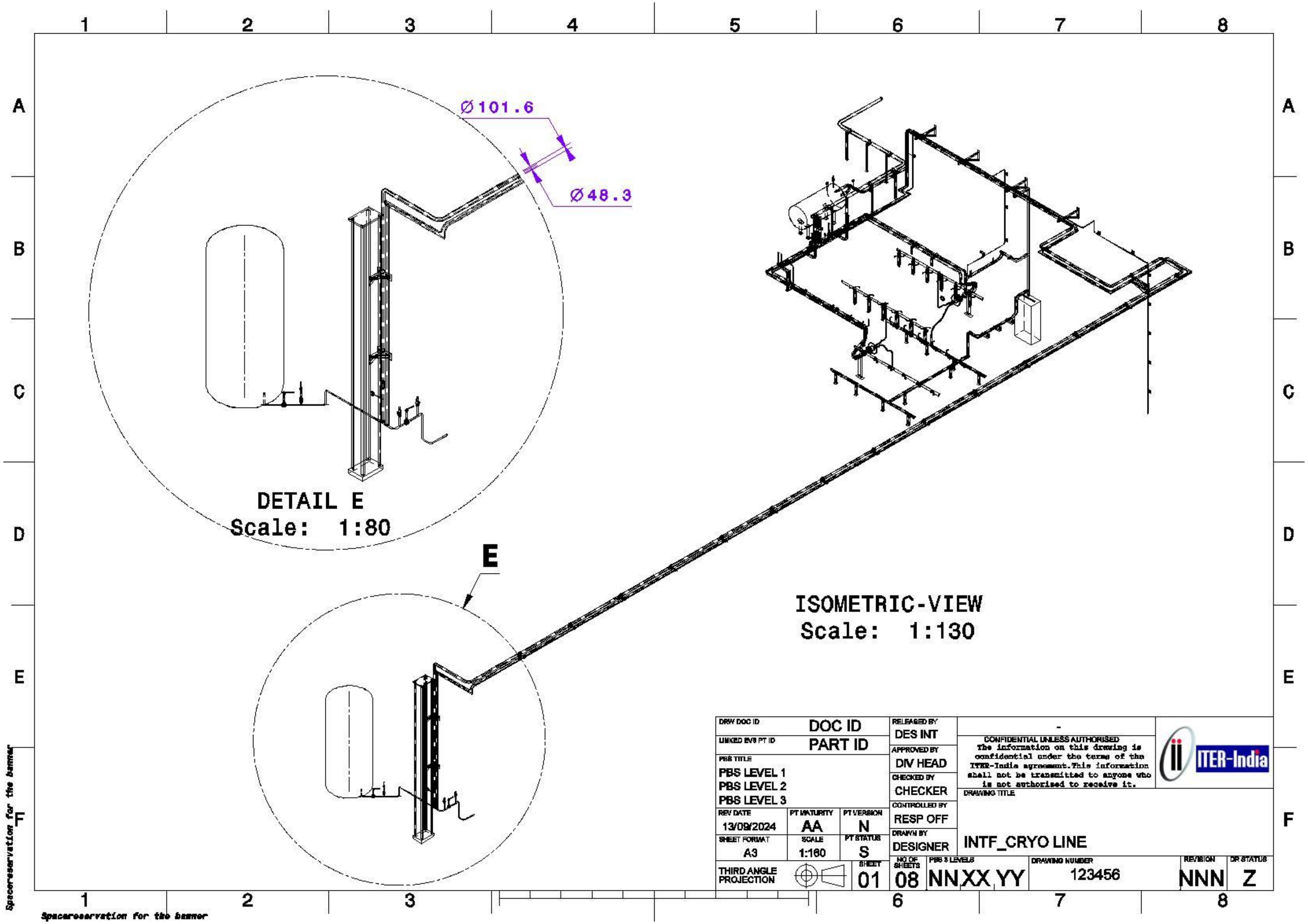


Figure 12: INTF LN2 Distribution System Isometric View

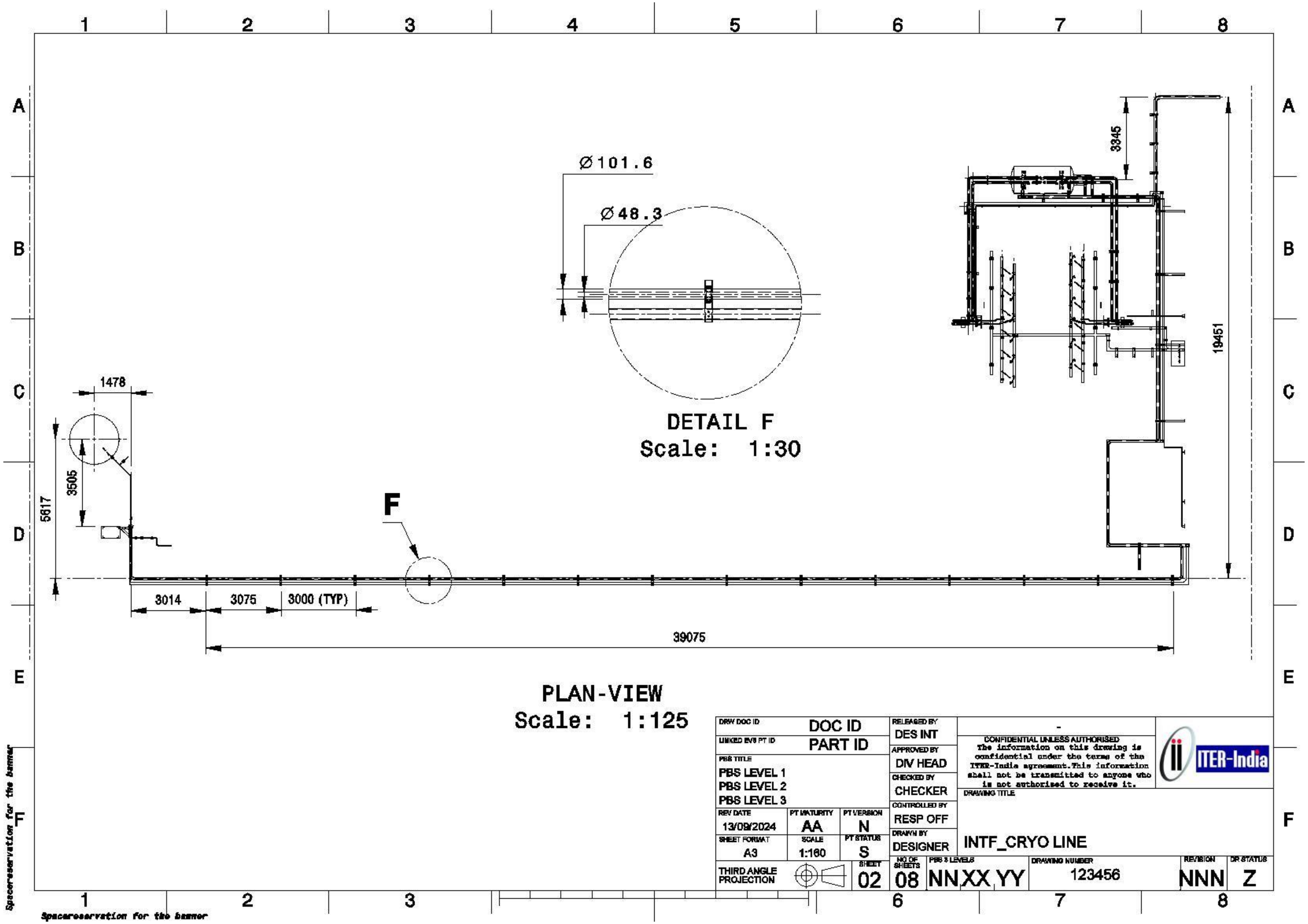


Figure 13: INTF LN2 Distribution System Plan View

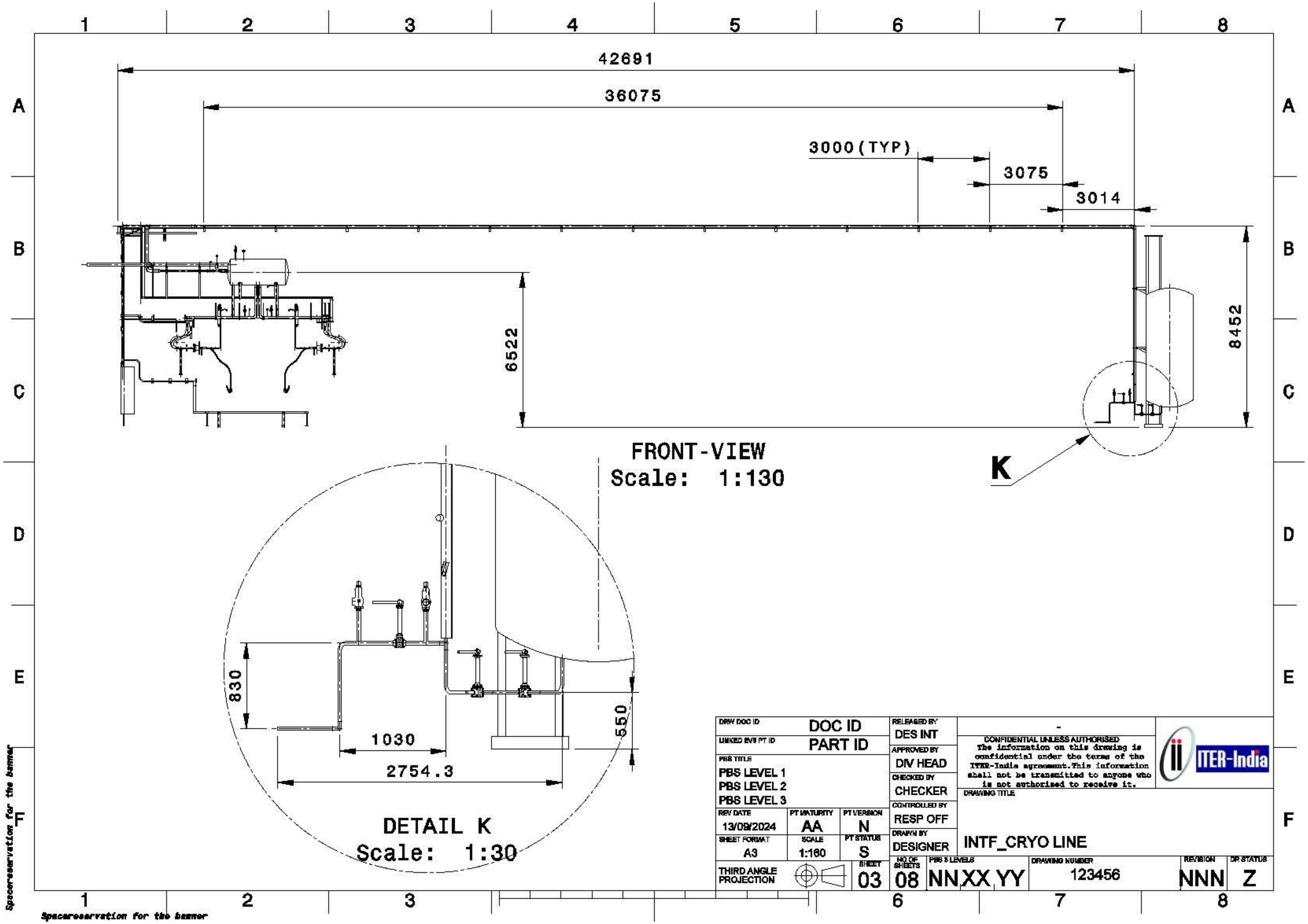


Figure 14: INTF LN2 Distribution System Front View

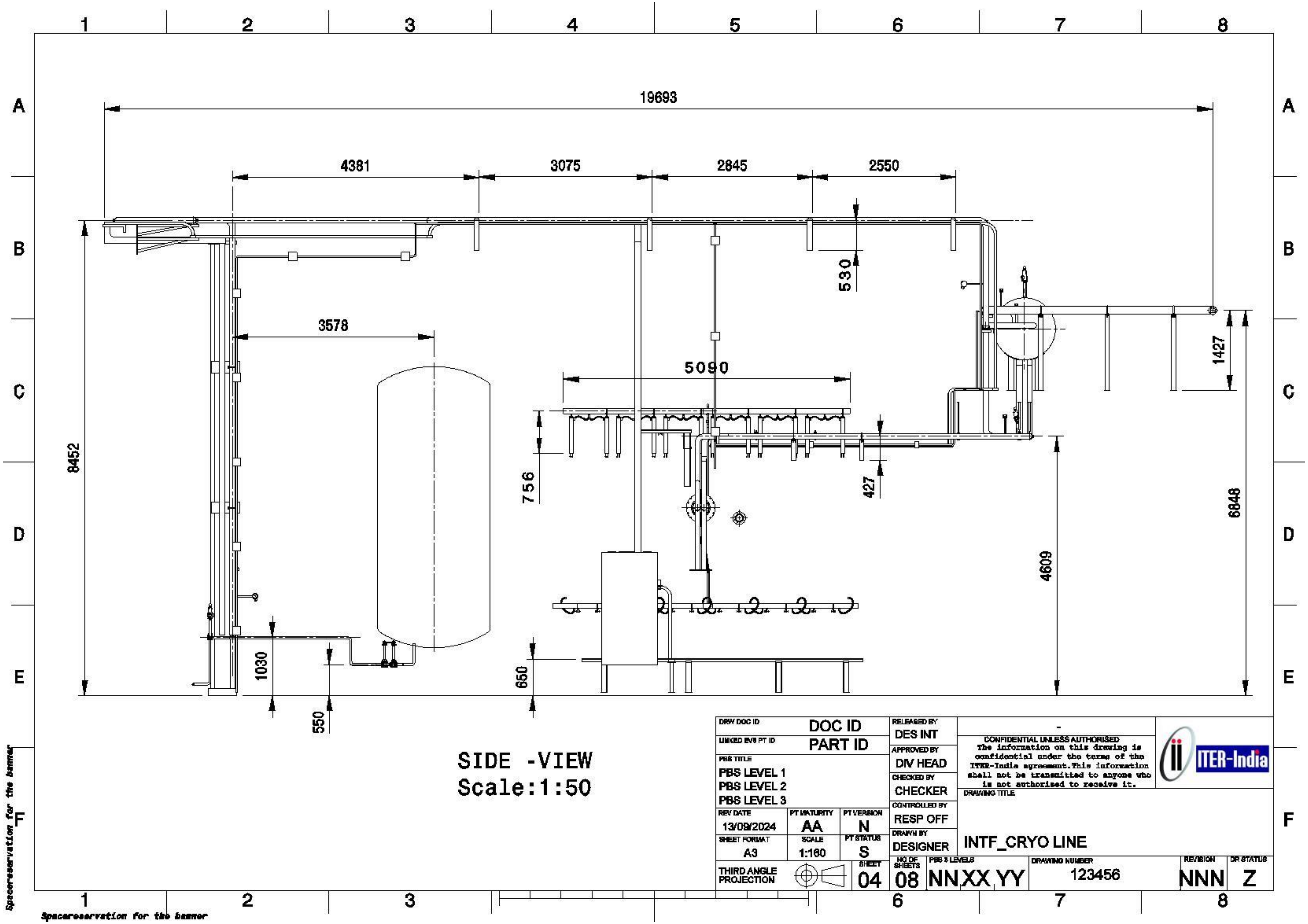


Figure 15: INTF LN2 Distribution System Side View

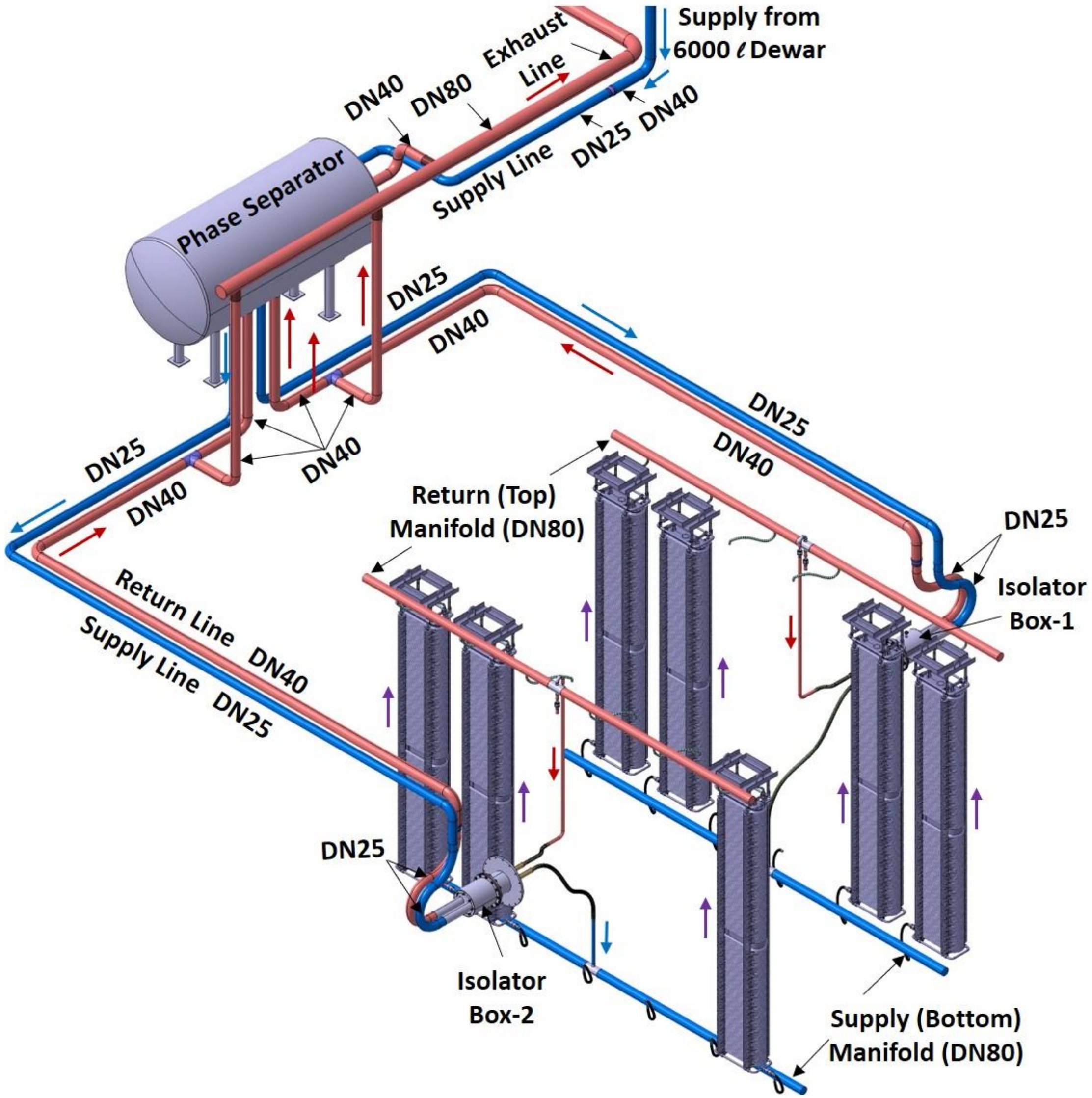


Figure 16: Overview of Thermosyphon

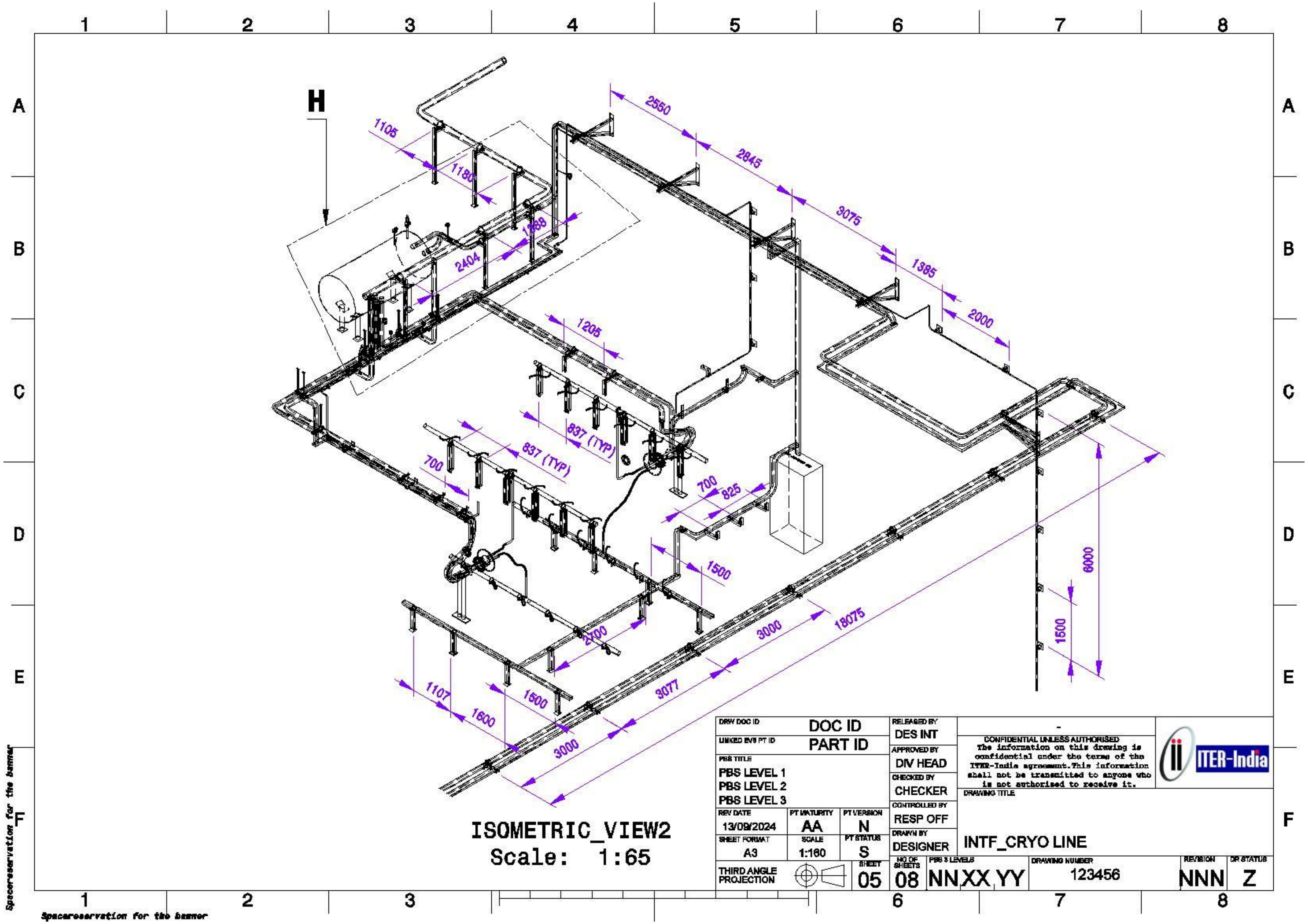


Figure 17: Isometric View (Thermosyphon)

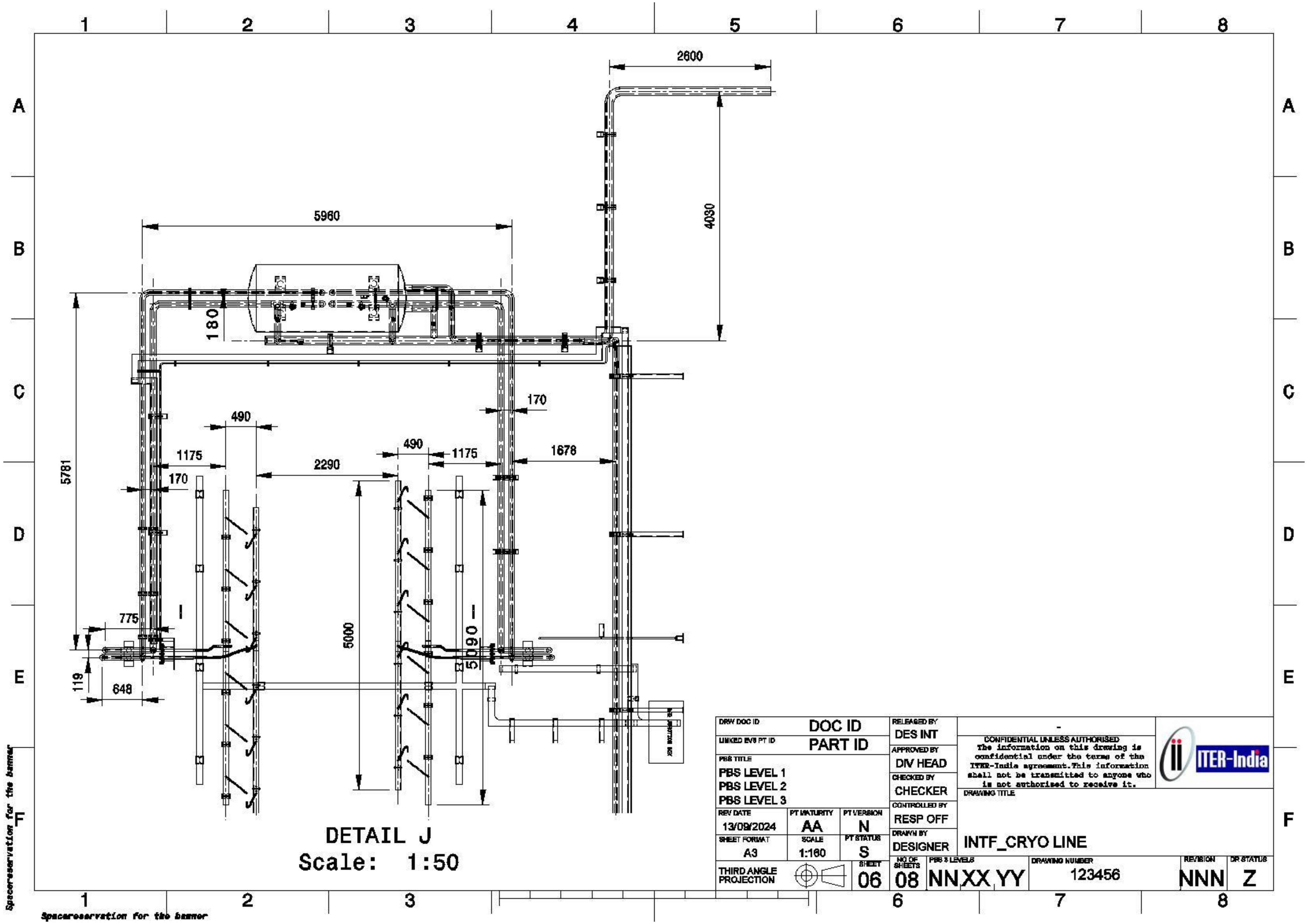


Figure 18: Plan View (Thermosyphon)

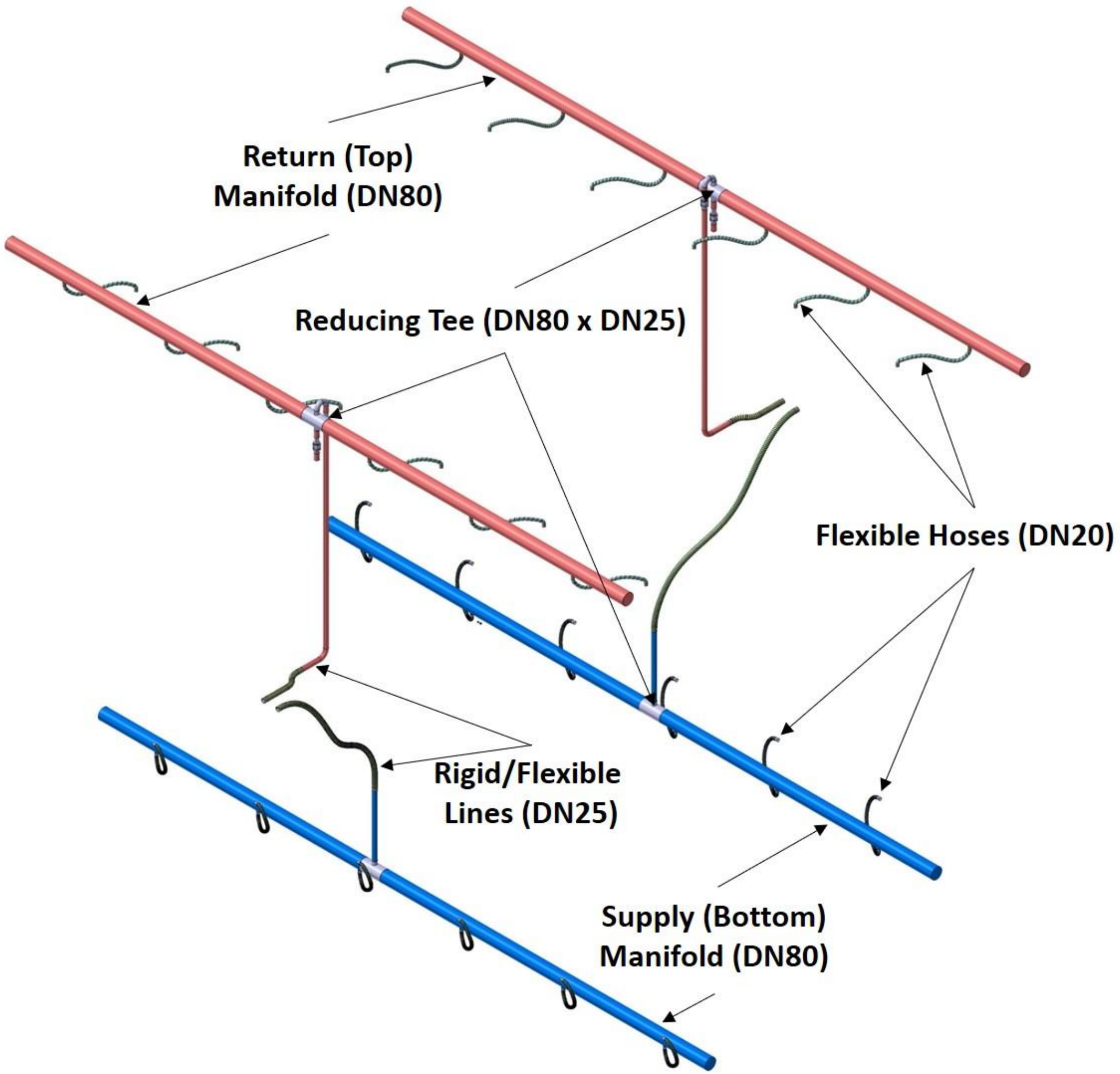
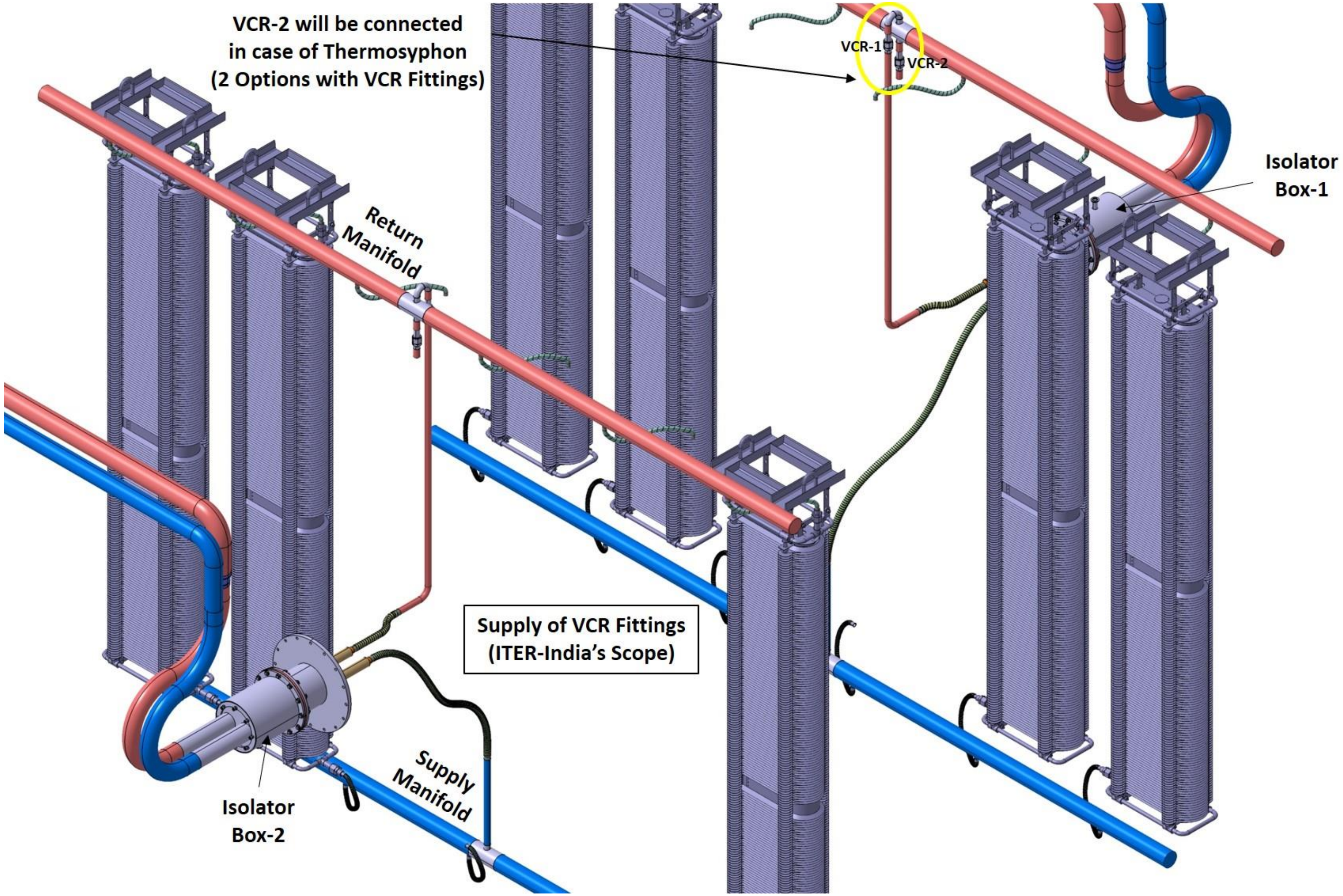
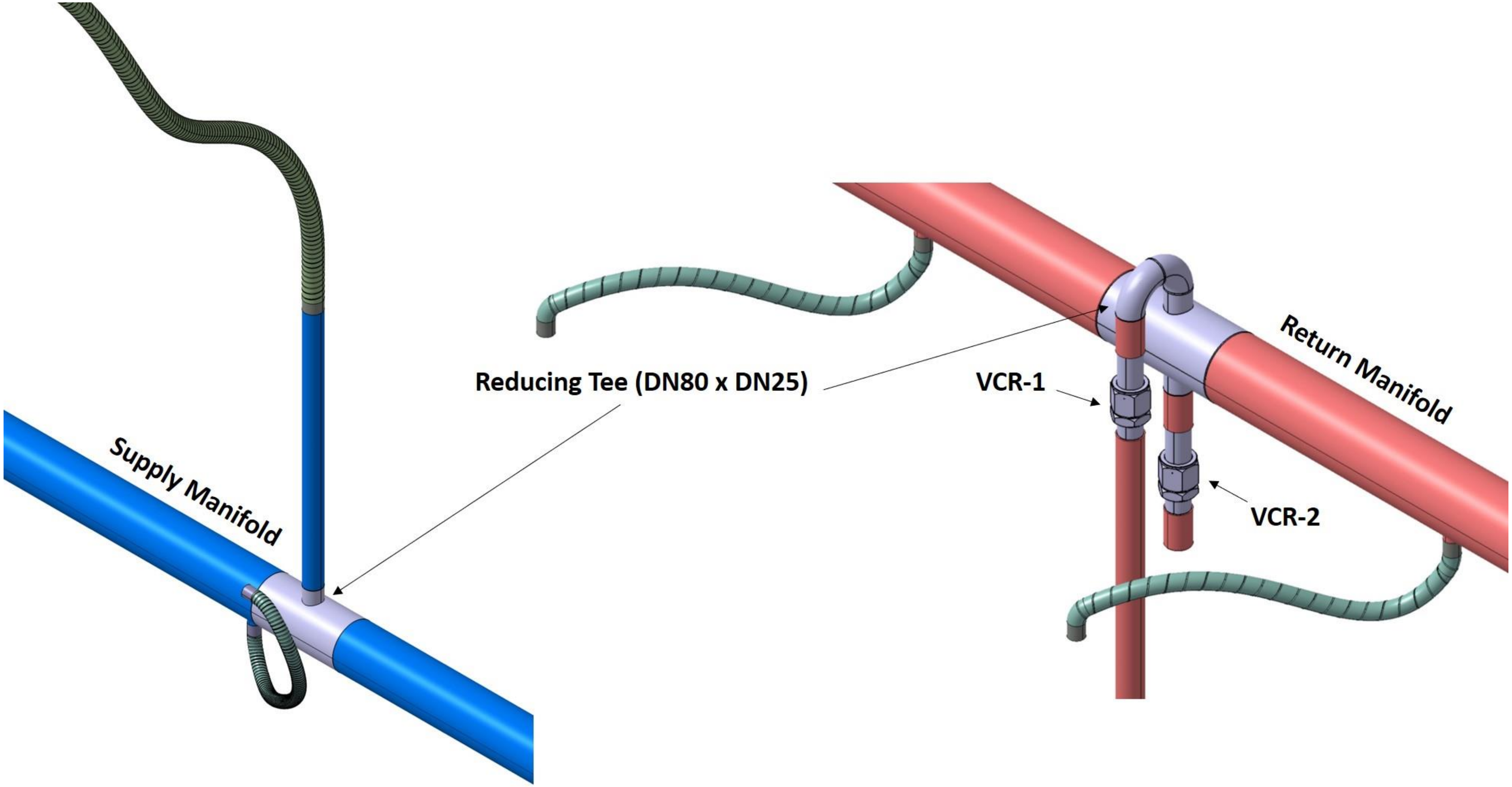


Figure 19: LN2 Manifolds with Flexible lines



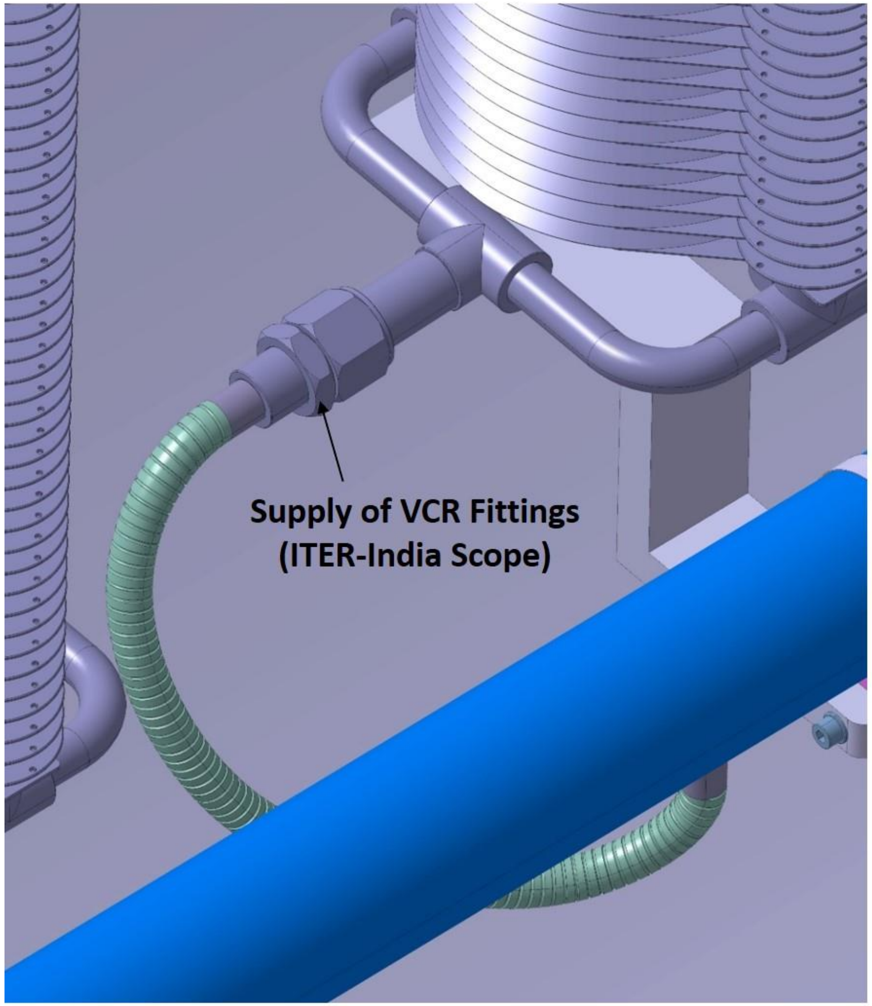
Note: In absence of VCR, direct welding to be done. ITER-India will take decision in due course regarding use of VCR or direct welding.

Figure 20: Connections with LN2 Manifolds

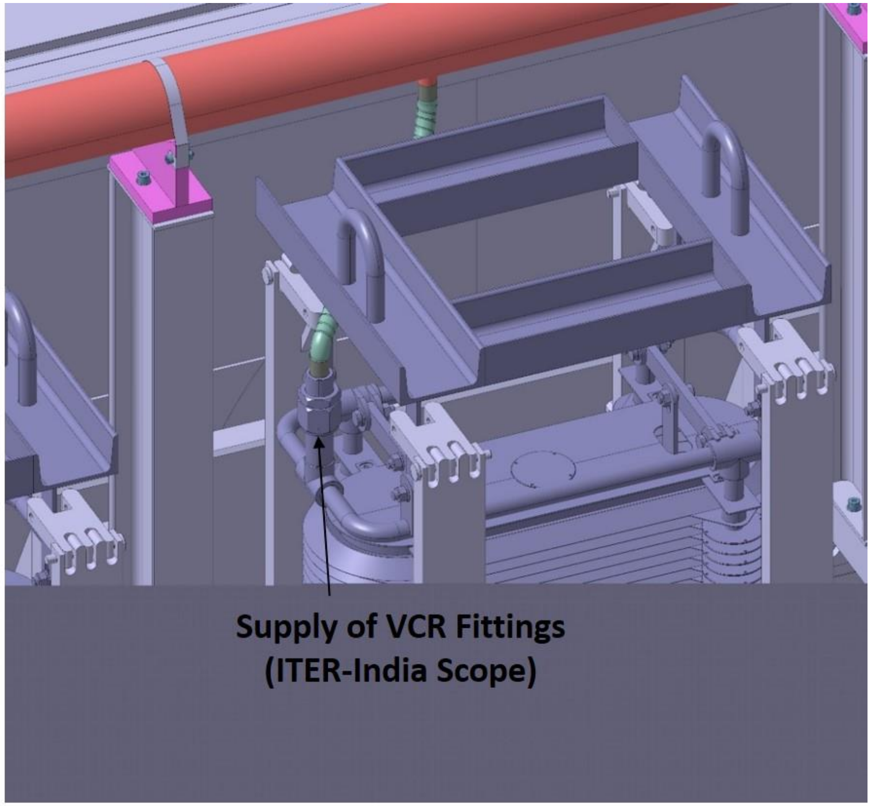


<u>Note</u>: In absence of VCR, direct welding to be done. ITER-India will take decision in due course regarding use of VCR or direct welding.

Figure 21: Connections with LN2 Manifolds (magnified view)



Supply (Bottom) Manifold

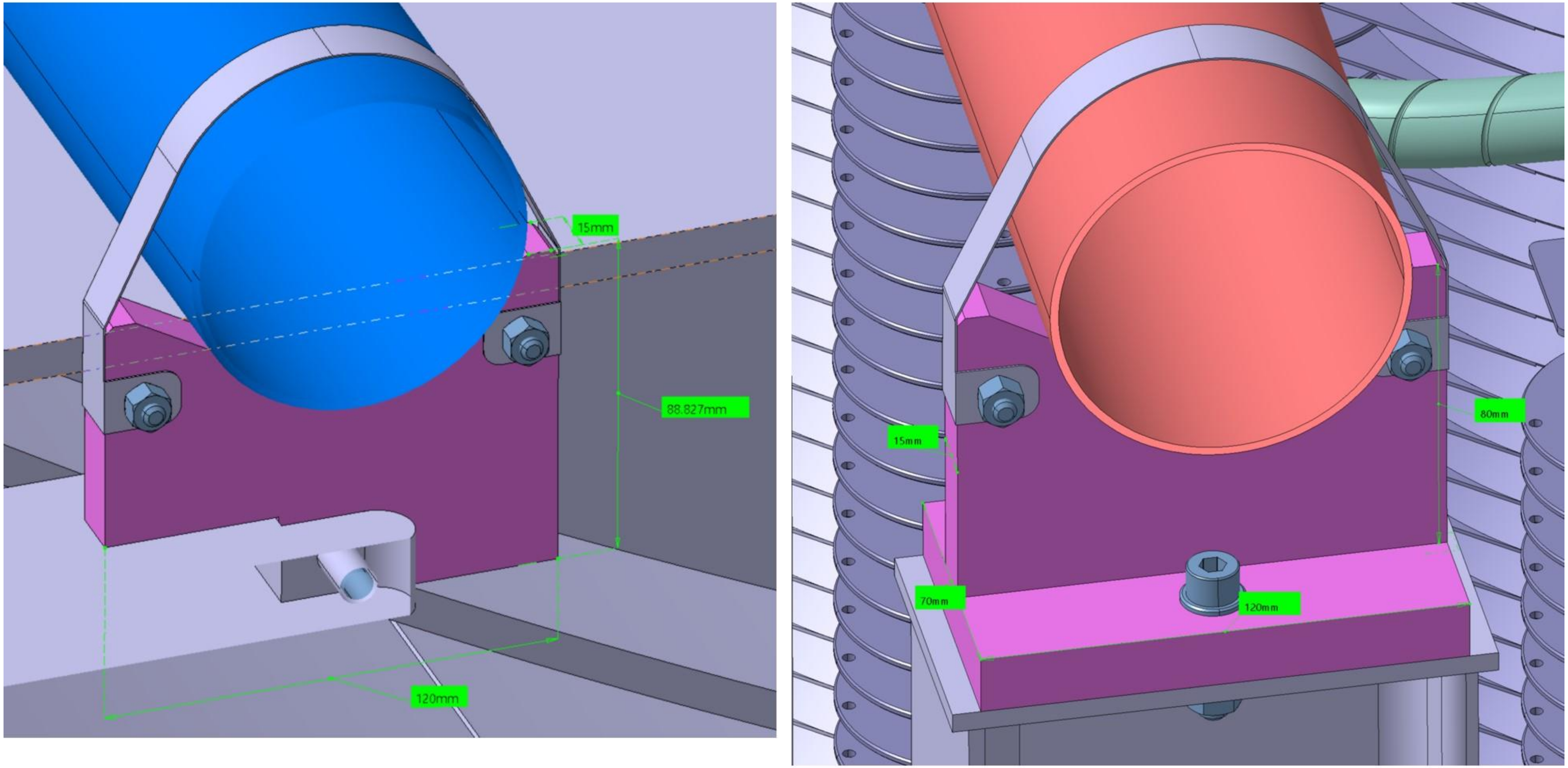


Return (Top) Manifold

Note: In absence of VCR, direct welding to be done. ITER-India will take decision in due course regarding use of VCR or direct welding.

Figure 22: Connections with Cryopump using Flexible Hoses and VCR Fittings

G10 Supports for LN2 Manifolds



Supply (Bottom) Manifold

Return (Top) Manifold

Figure 23: G10 Support for Supply and Return LN2 Manifold

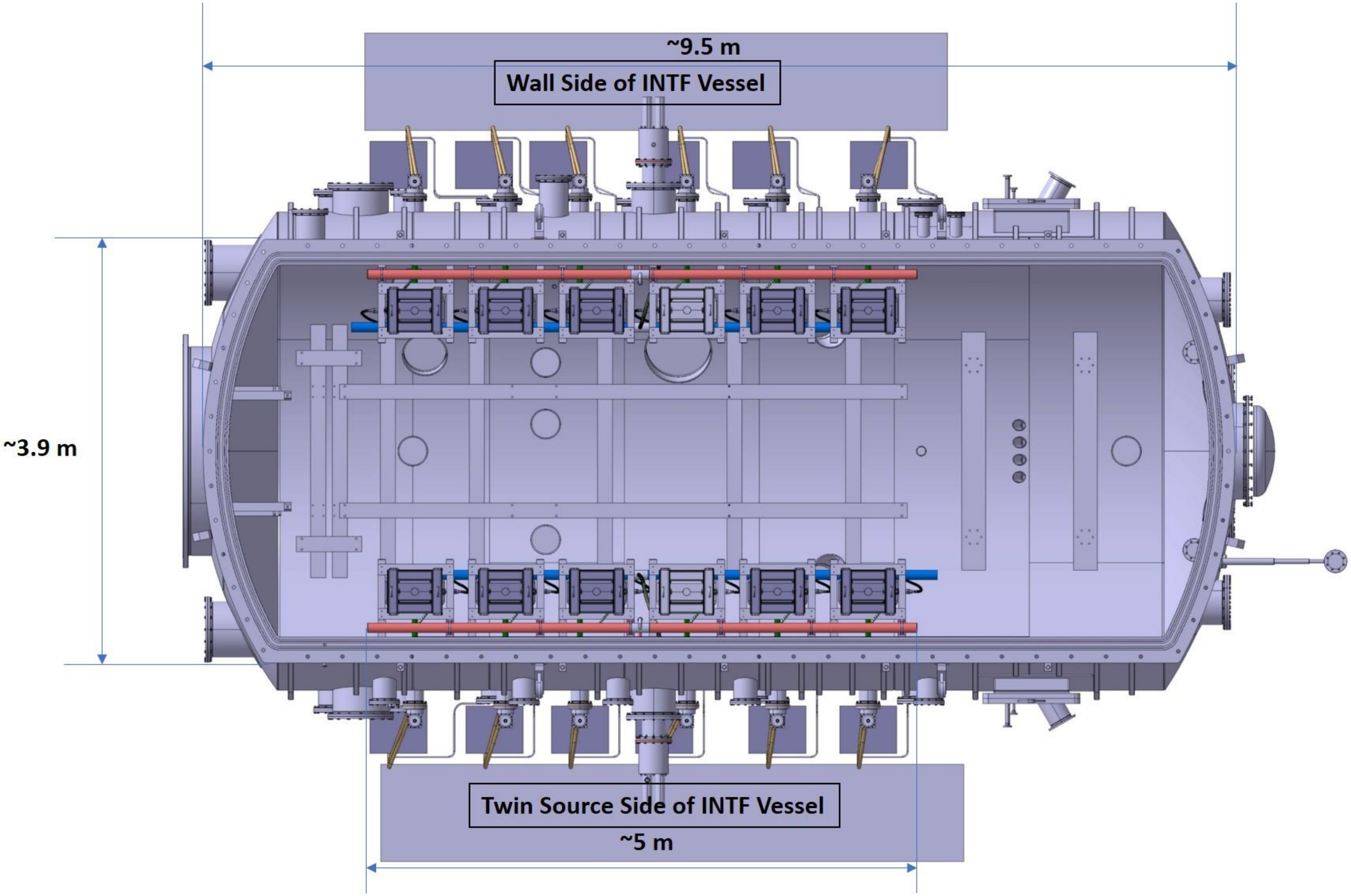


Figure 24: INTF Vessel Overall Dimensions (L x W)

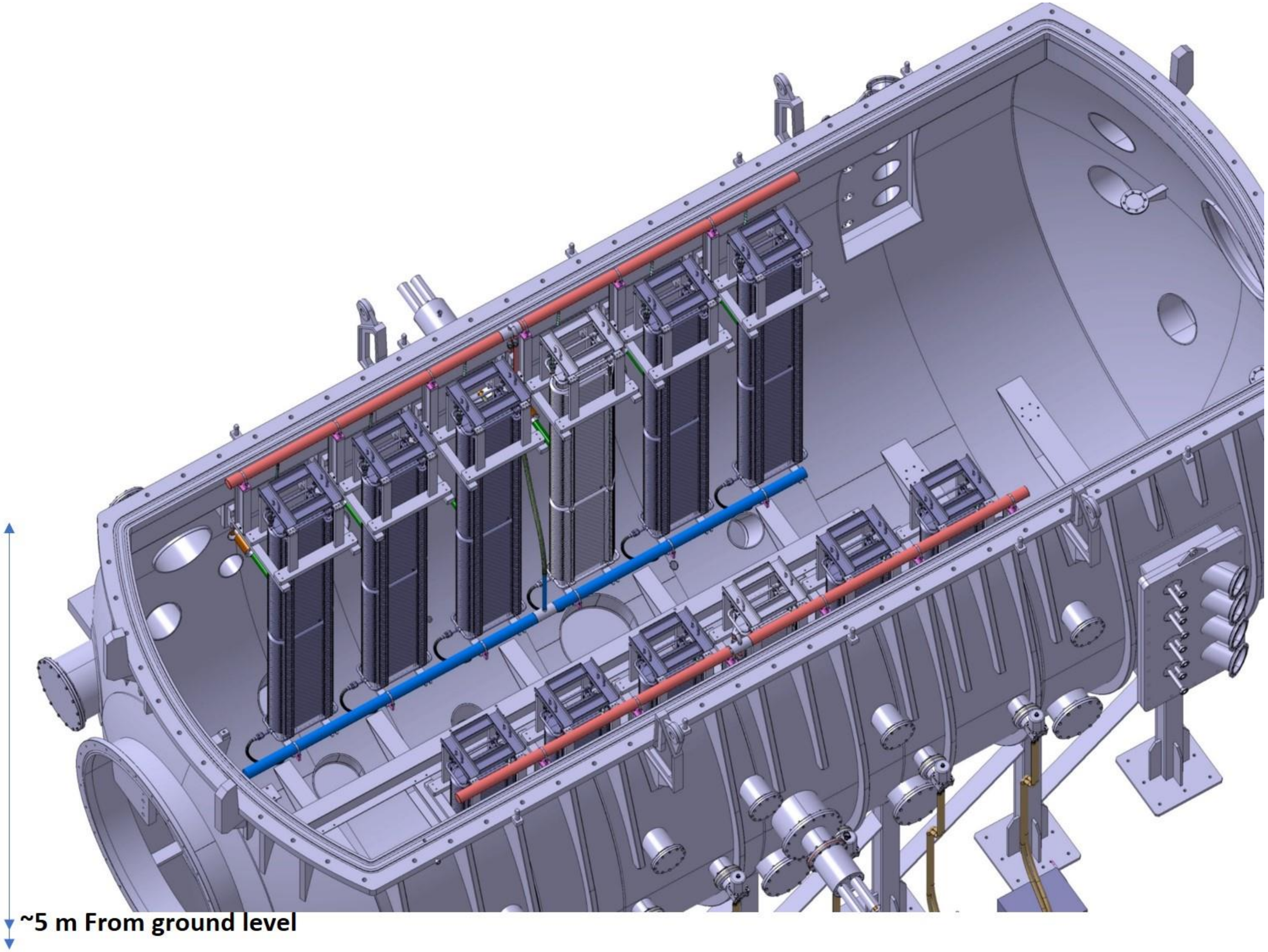


Figure 25: INTF Vessel Overall Dimensions (H)

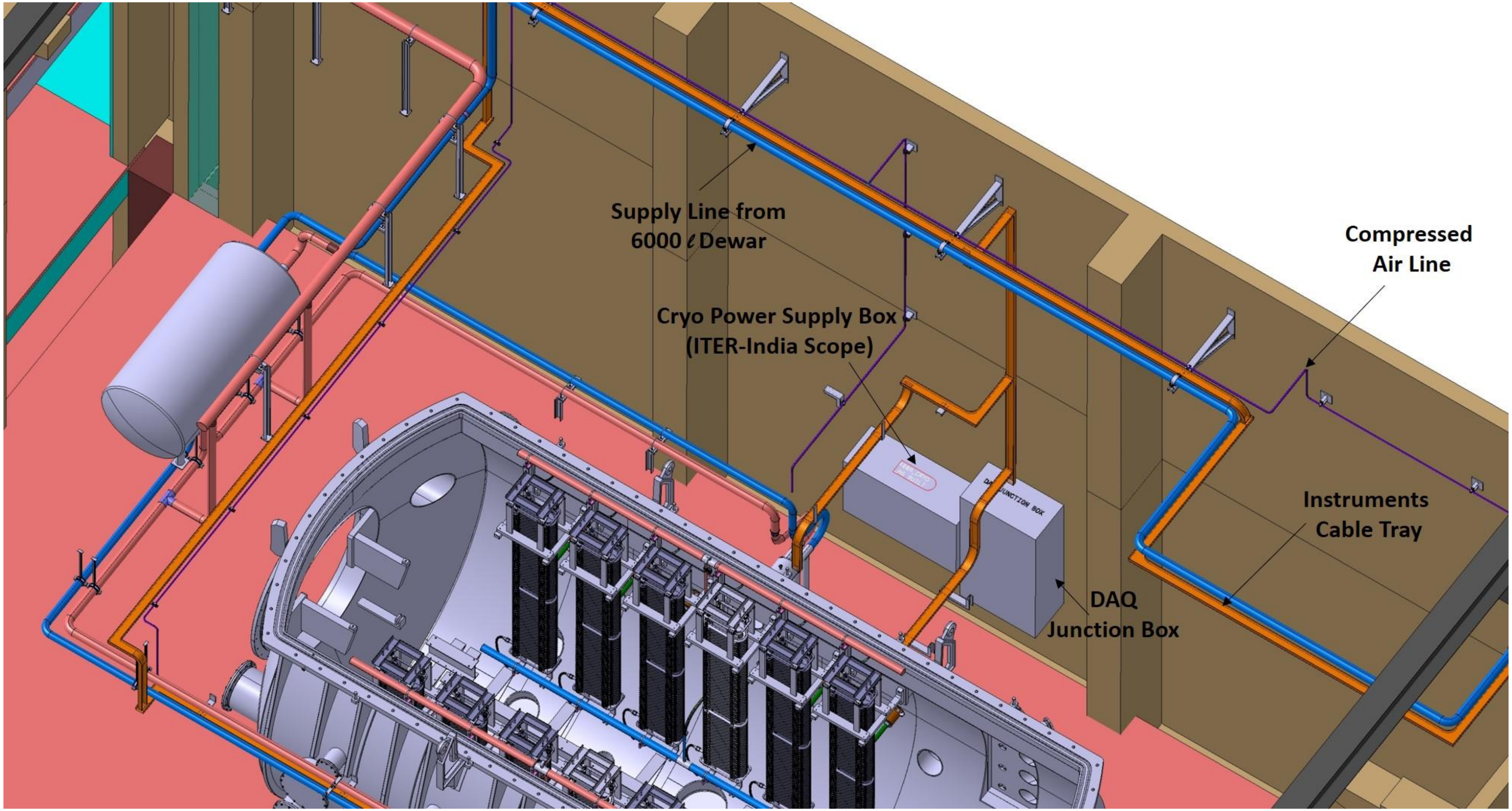


Figure 26: Location of Cryo Power Supply Box in DNB Lab

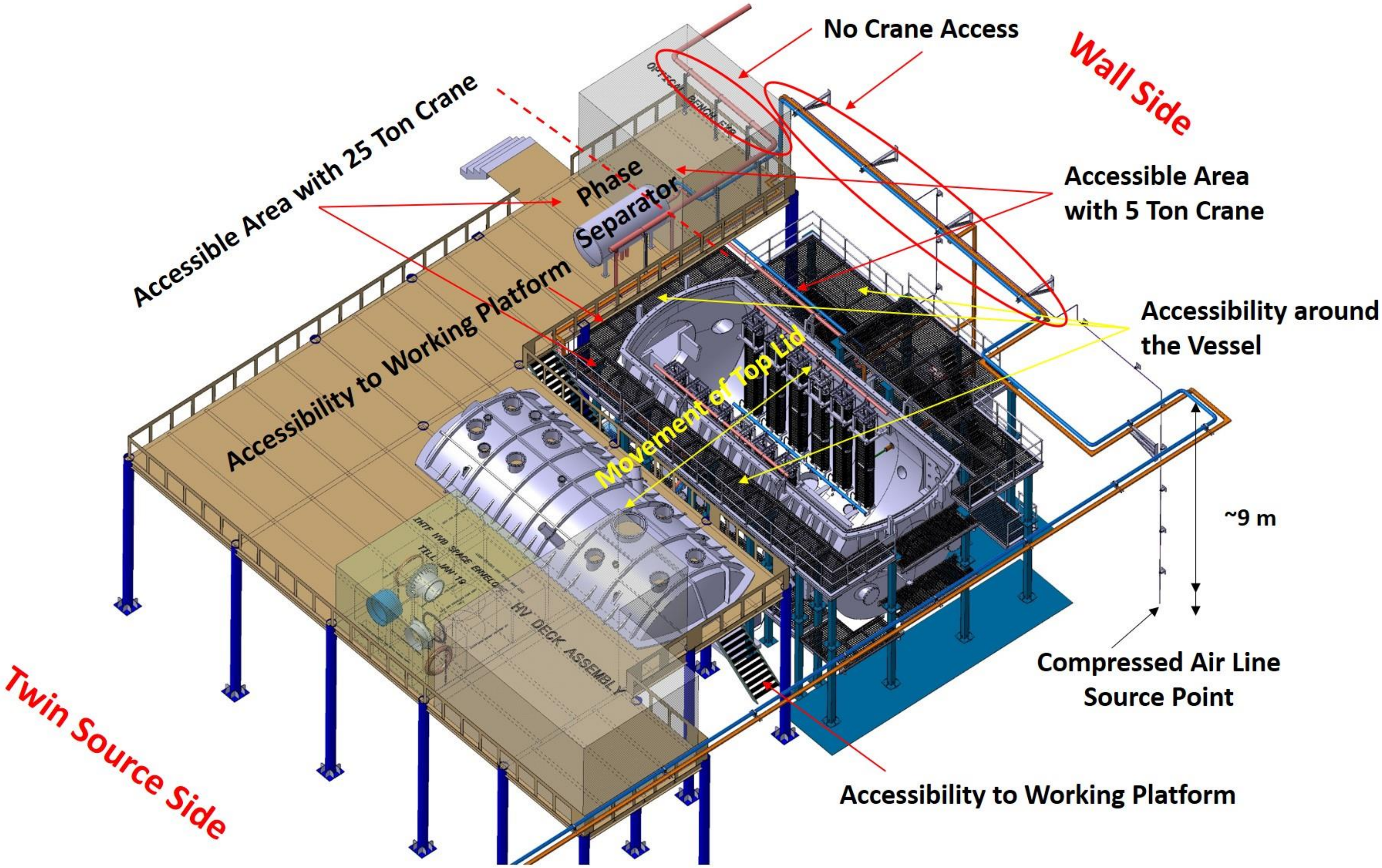


Figure 27: Accessibility for Installation, Maintenance and Repair

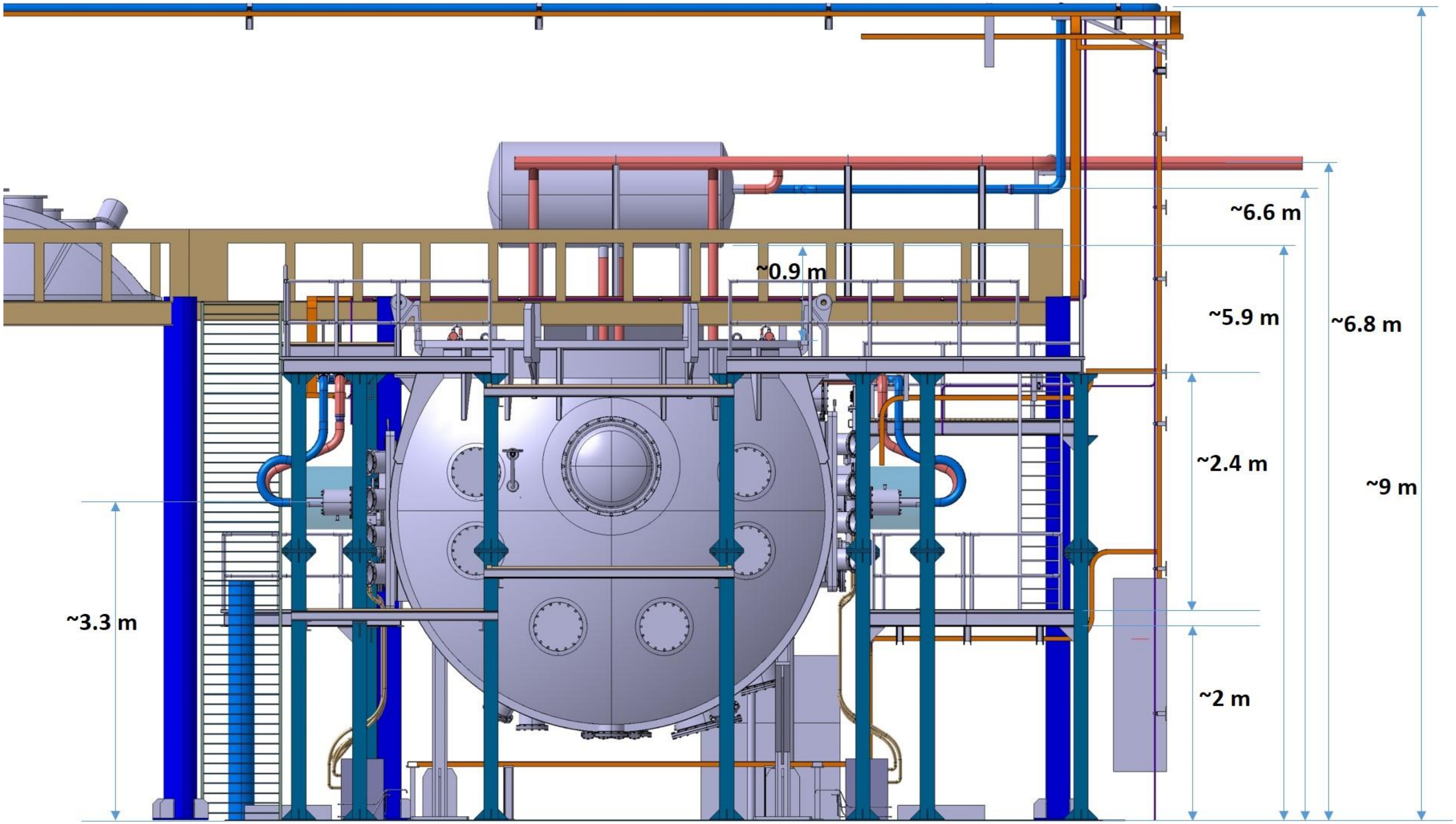


Figure 28: Overall Height Difference

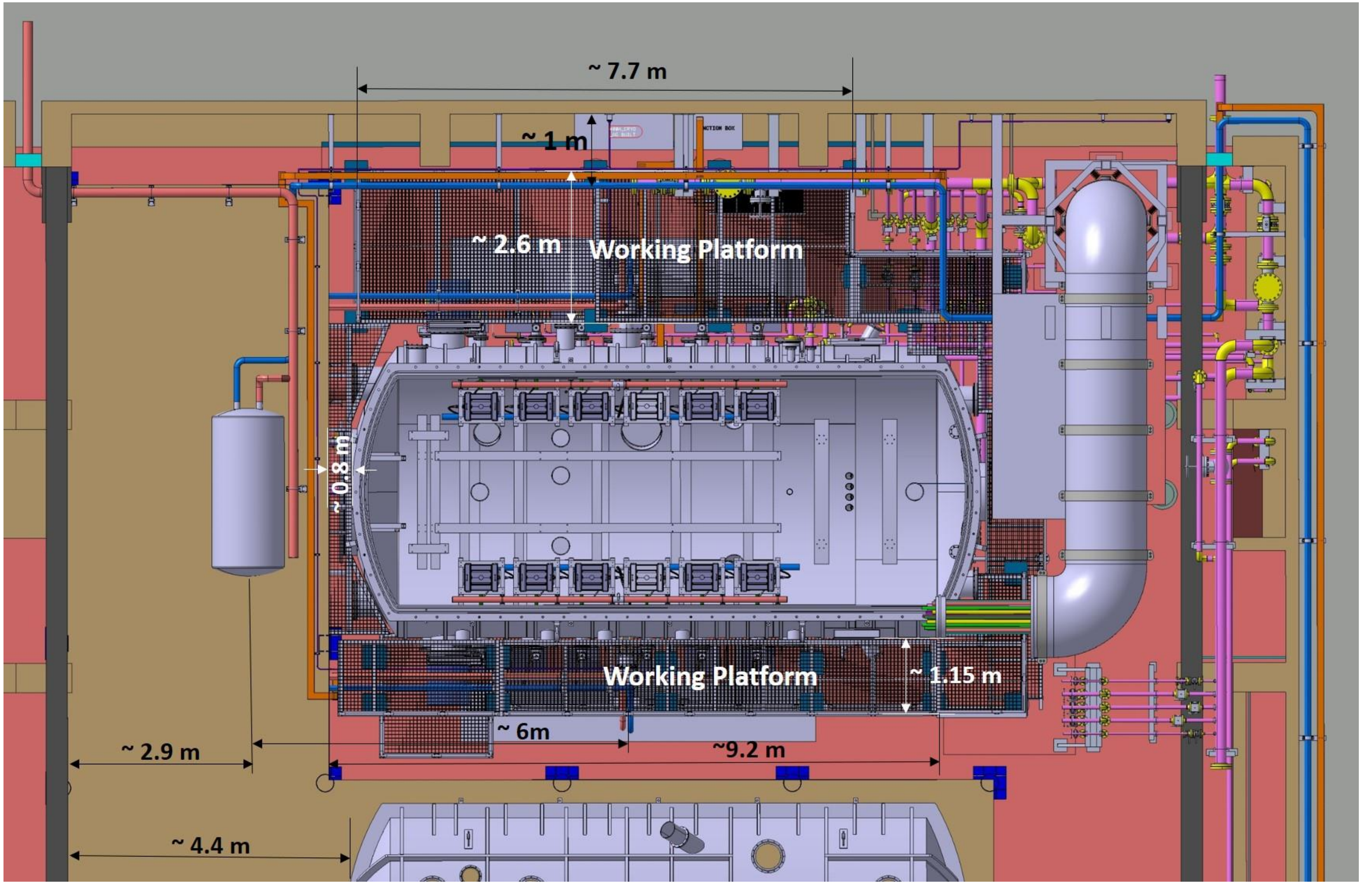


Figure 29: Space Allocation with Dimensions

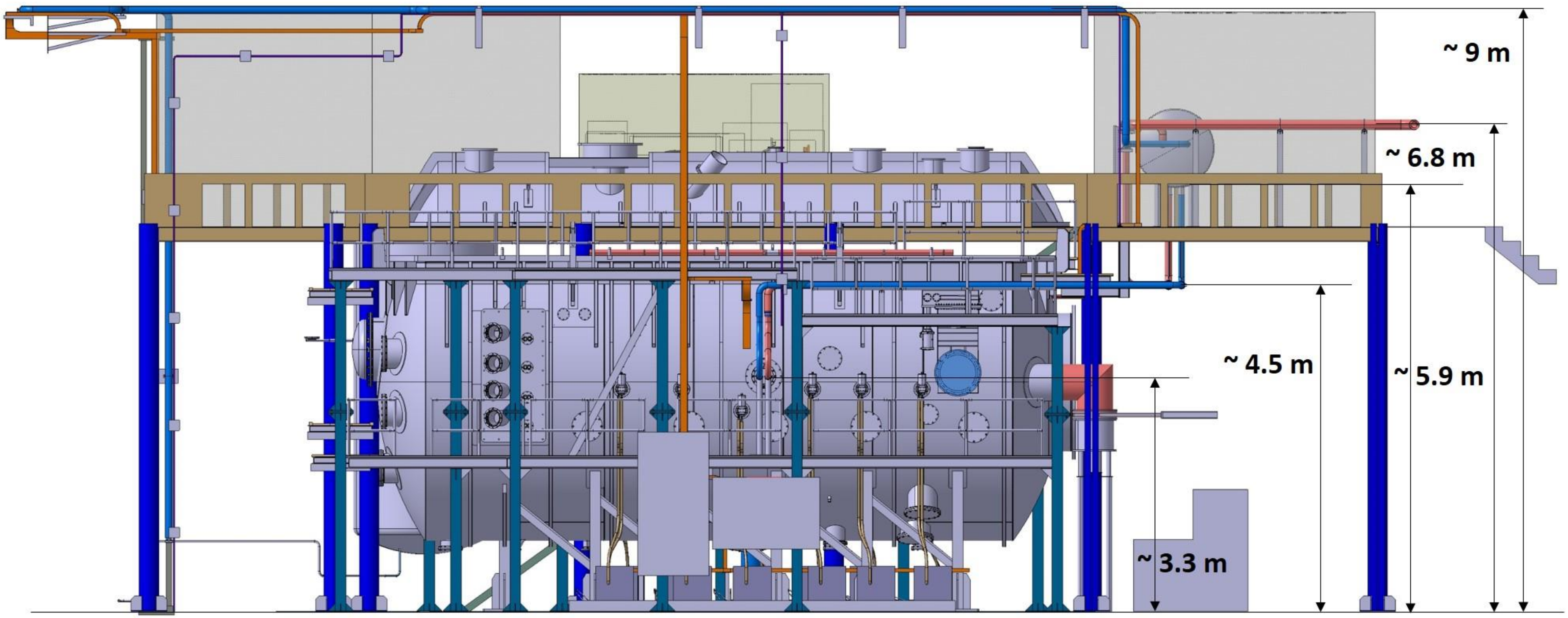


Figure 30: View from Wall Side

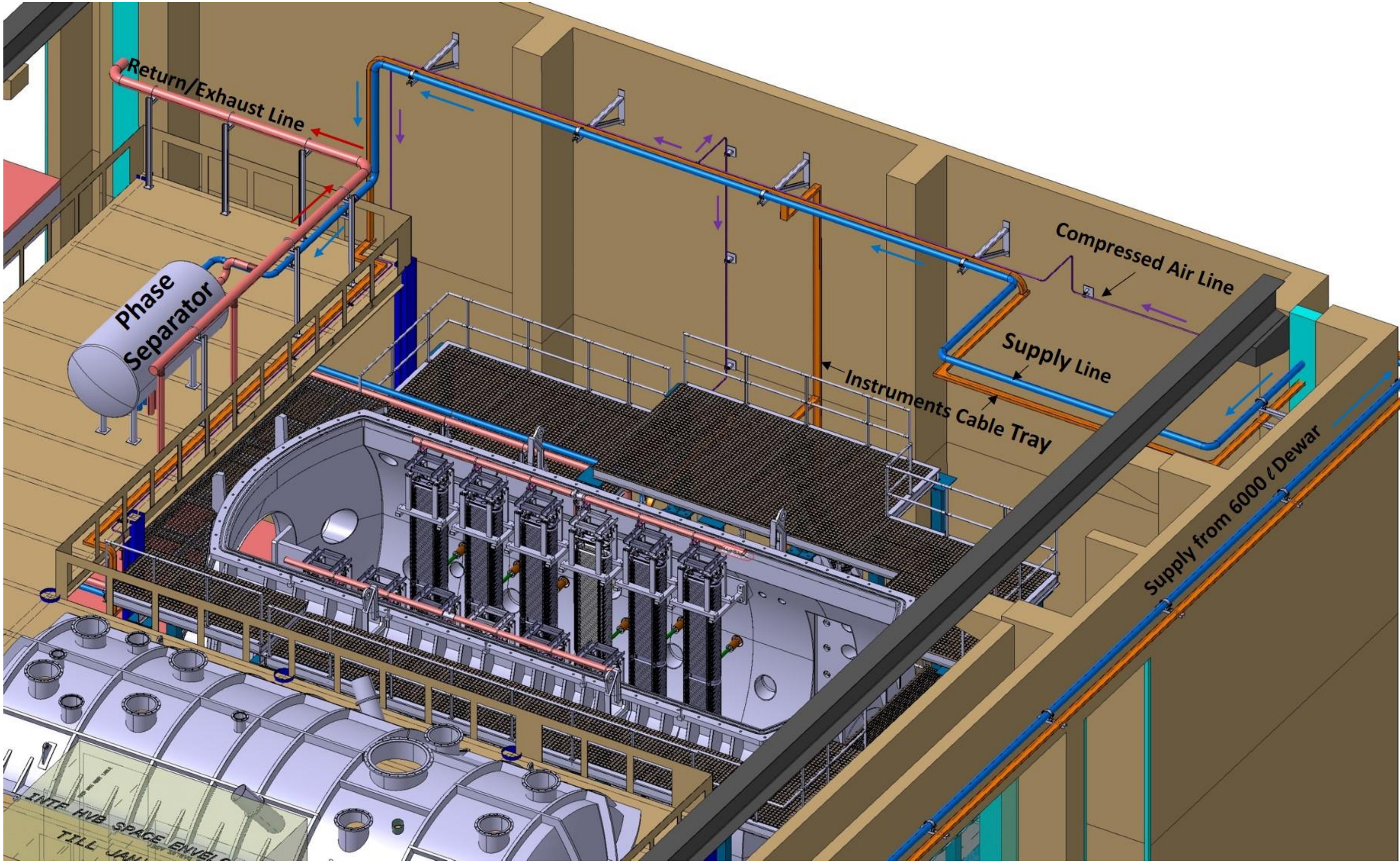


Figure 31: LN2 Distribution Line, Instrumentation Cable Tray and Compressed Air Line Routing Inside DNB Lab

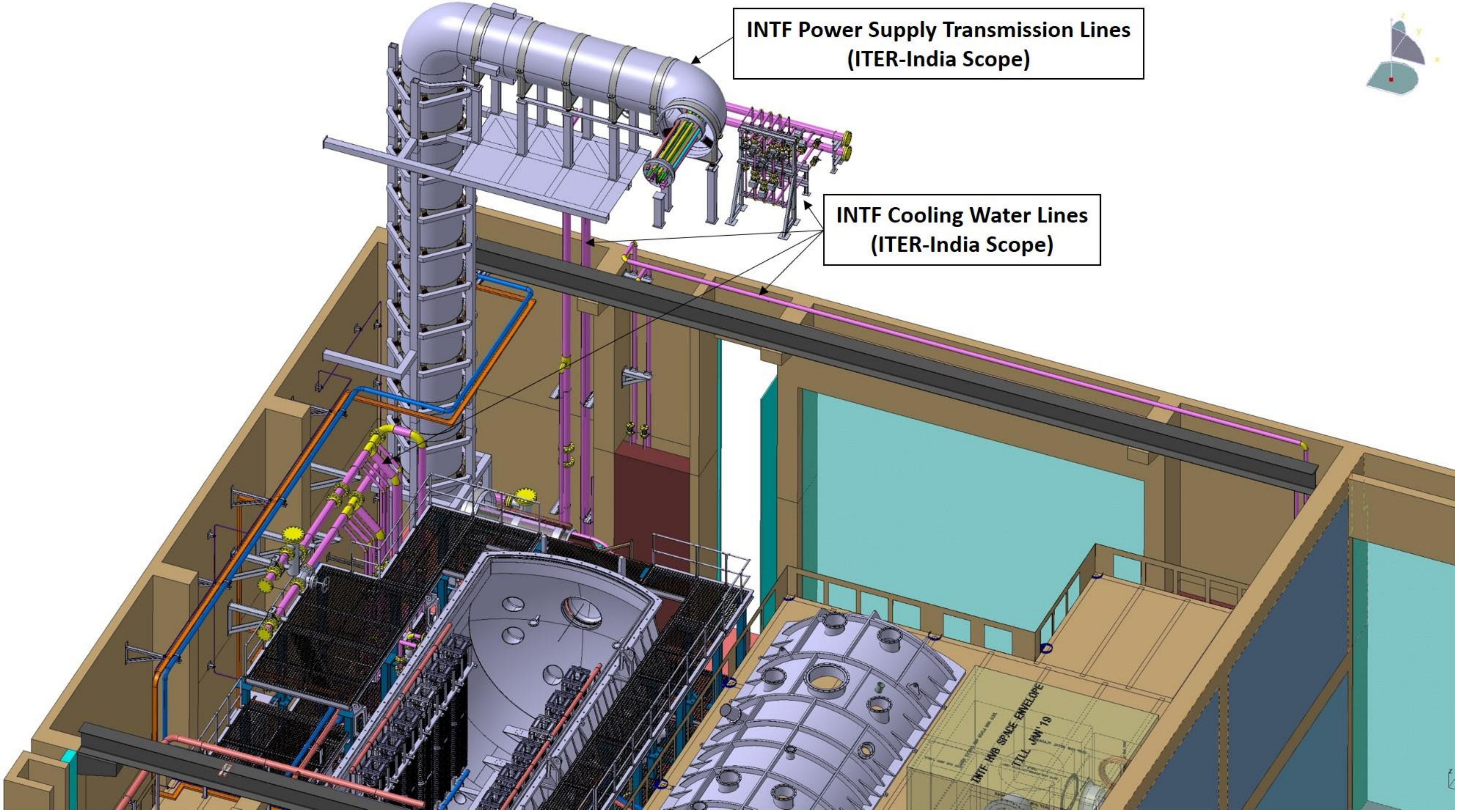


Figure 32: LN2 Distribution Line, Instrumentation Cable Tray and Compressed Air Line Routing Inside DNB Lab (Other View)

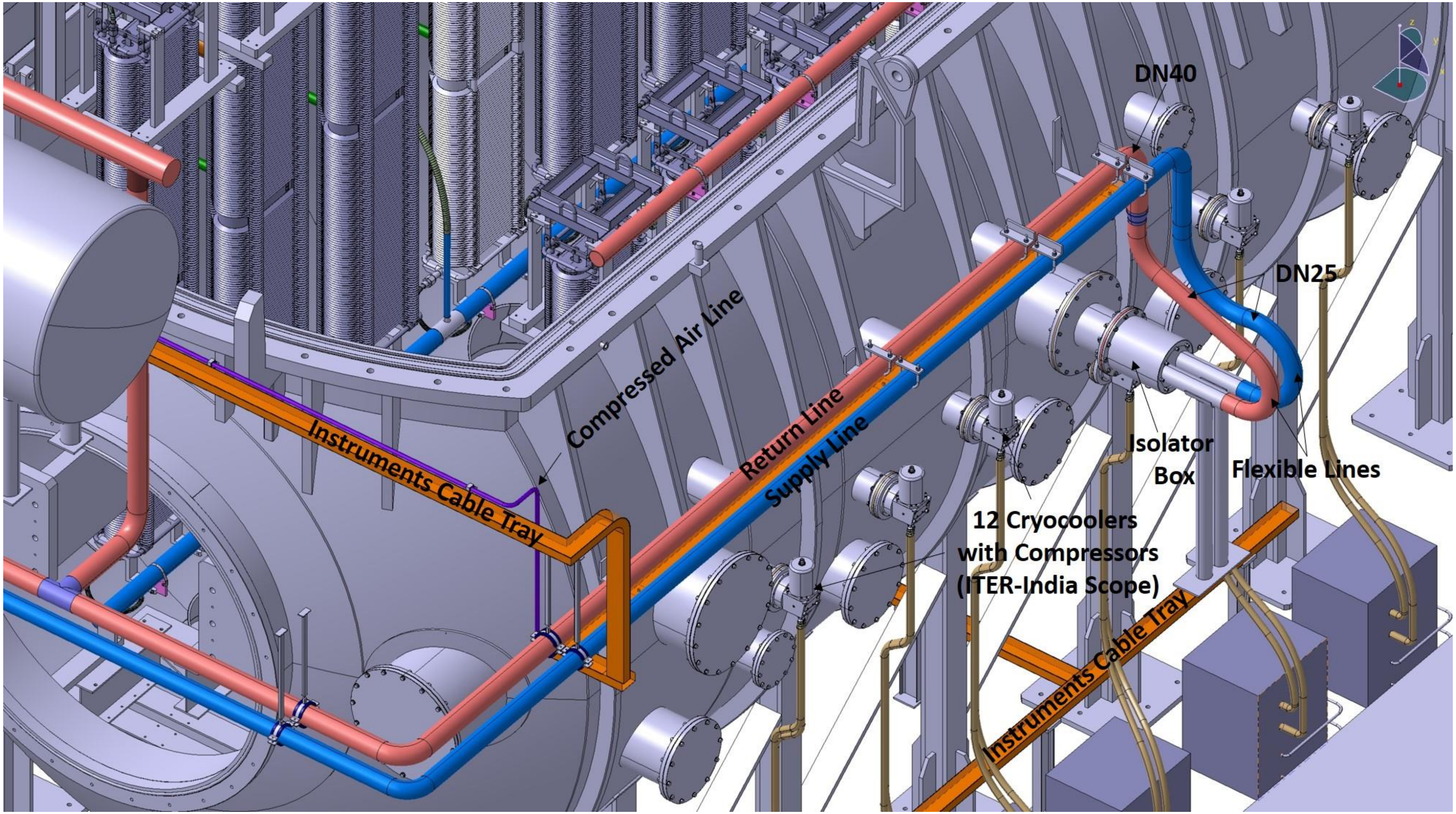


Figure 33: Twin Source Side LN2 Distribution Line Entry into the Vessel

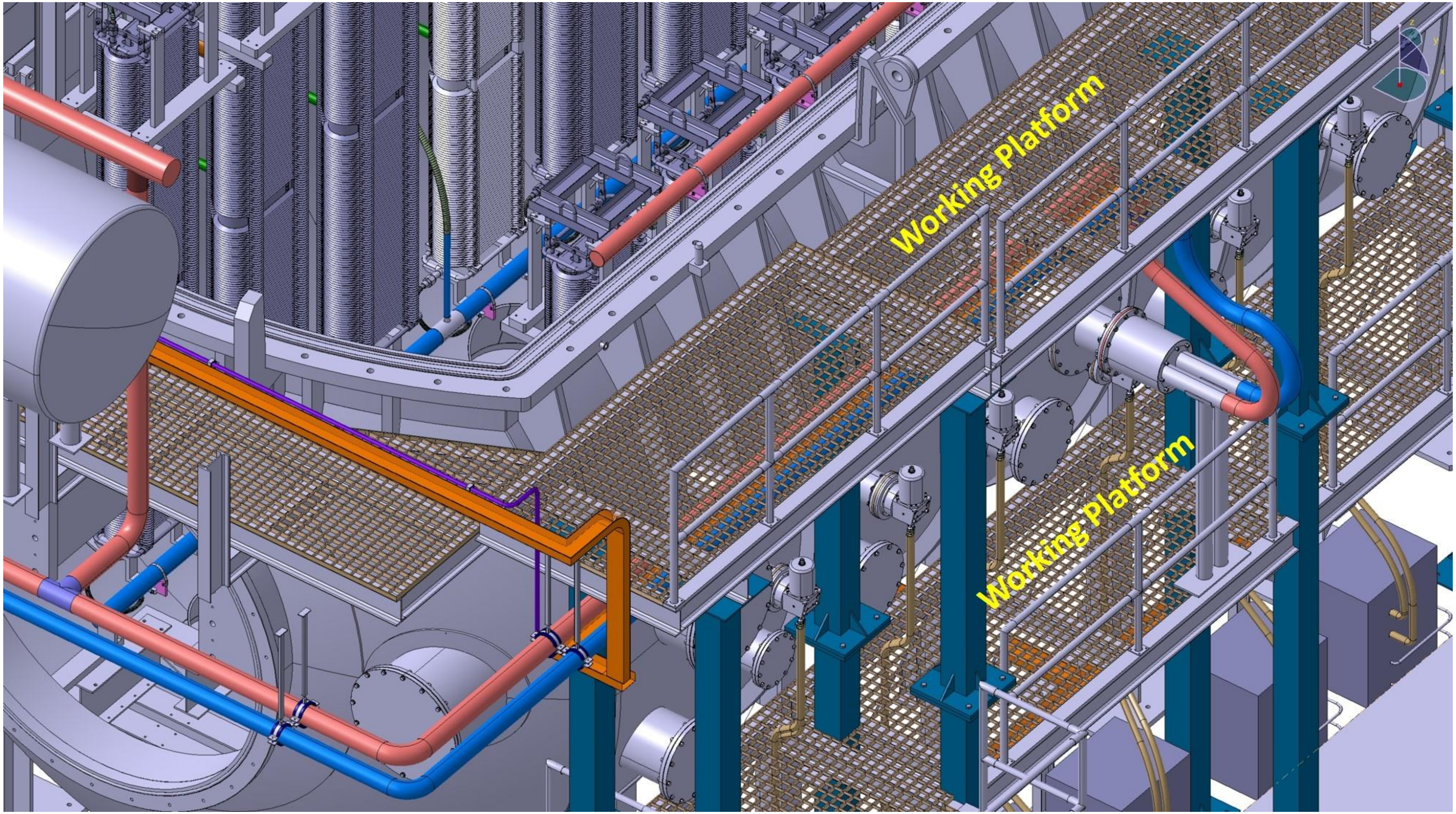


Figure 34: Twin Source Side LN2 Distribution Line Entry into the Vessel (with Working Platform)

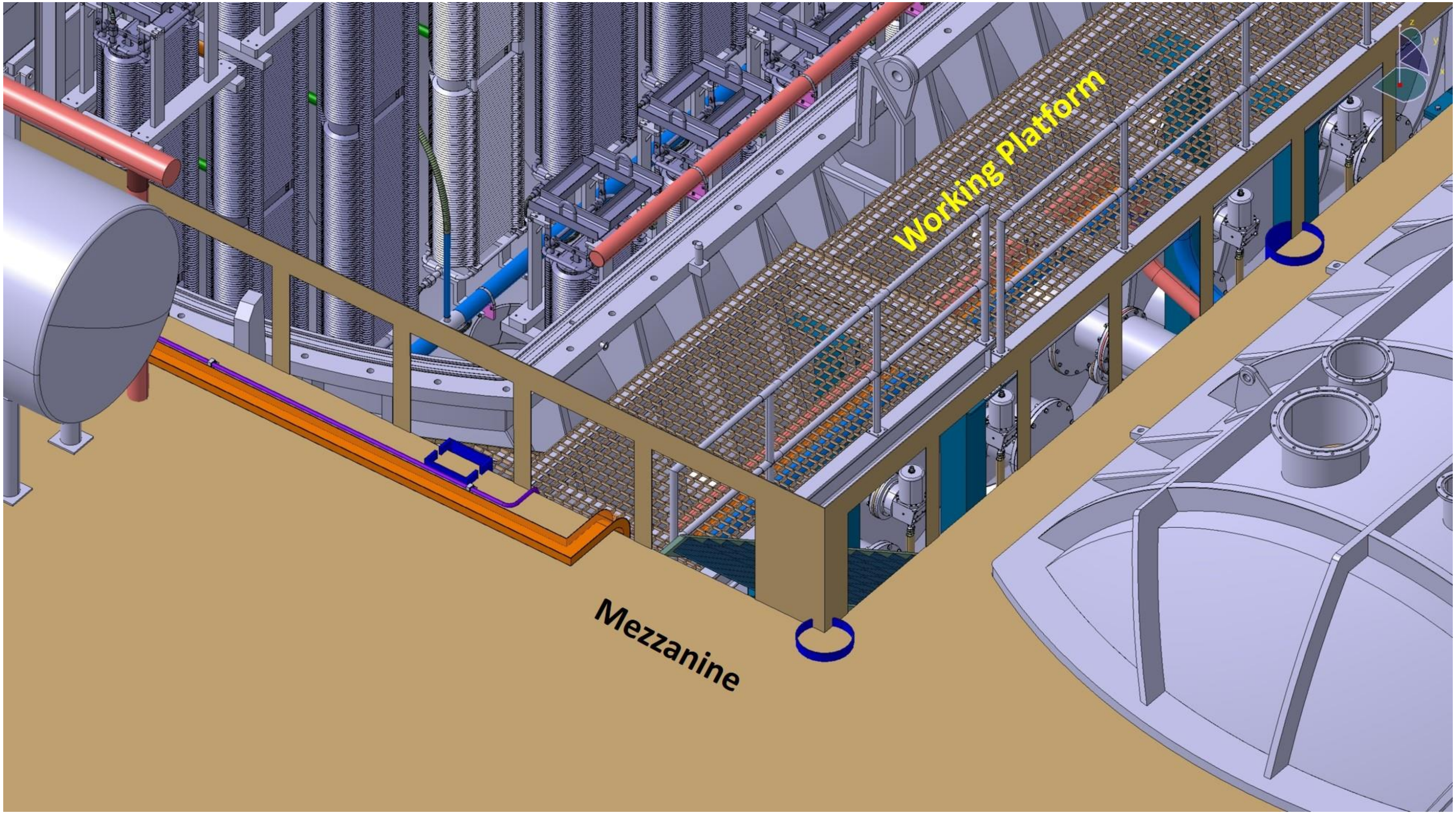


Figure 35: Twin Source Side LN2 Distribution Line Entry into the Vessel (with Working Platform & Mezzanine)

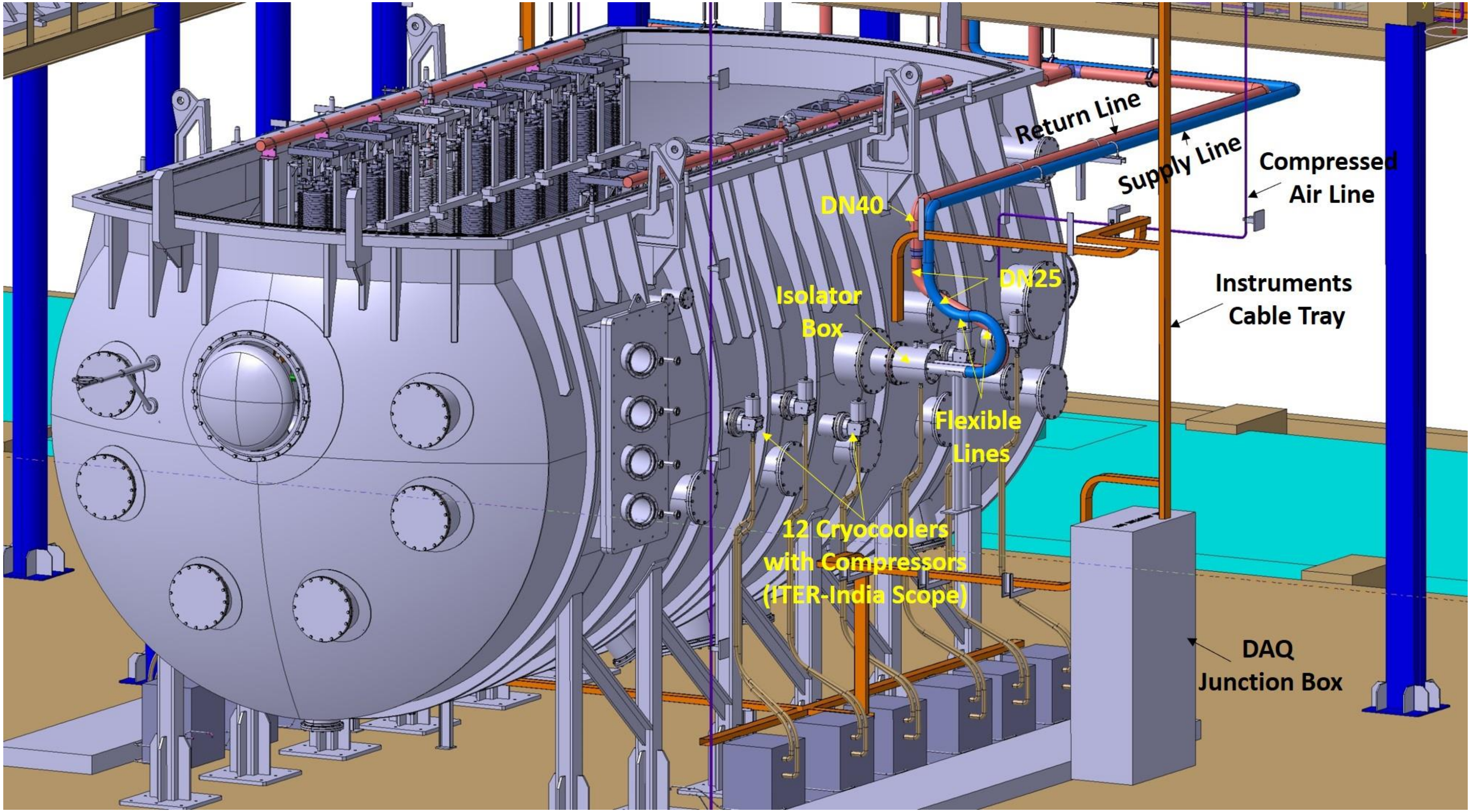


Figure 36: Wall Side LN2 Distribution Line Entry into the Vessel

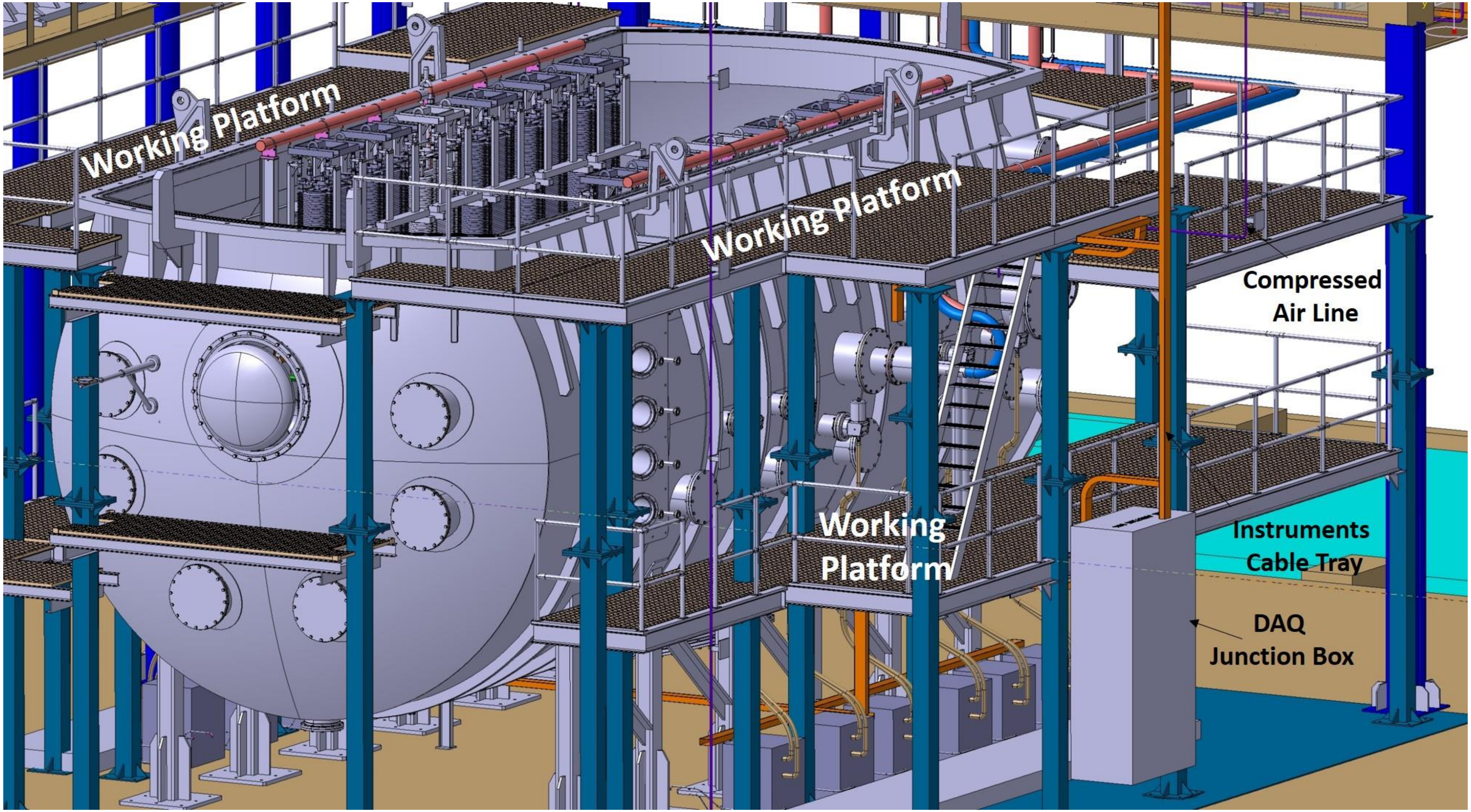


Figure 37: Wall Side LN2 Distribution Line Entry into the Vessel (with Working Platform)

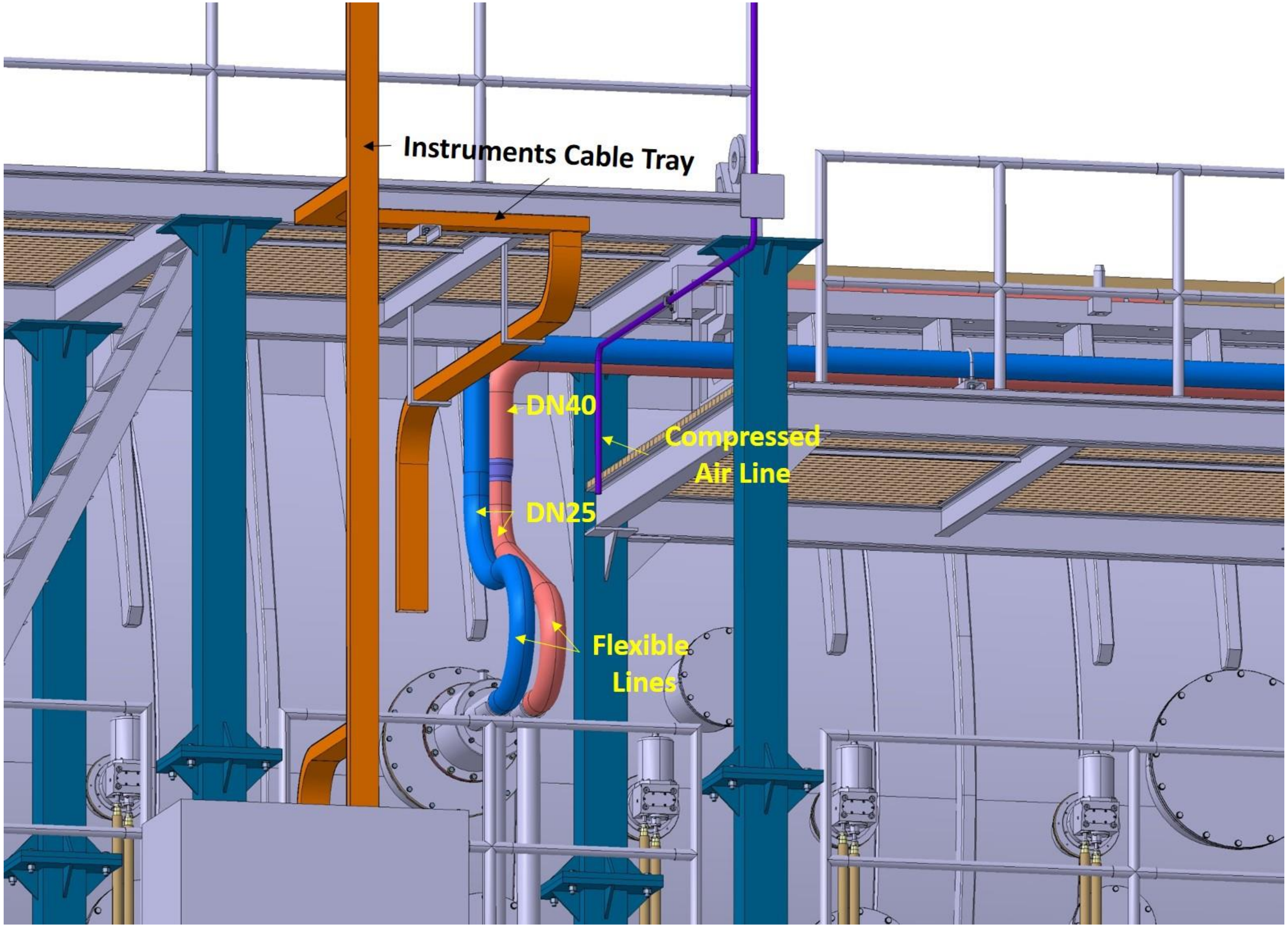


Figure 38 Wall Side LN2 Distribution Line Entry into the Vessel (with Working Platform) (Other view)

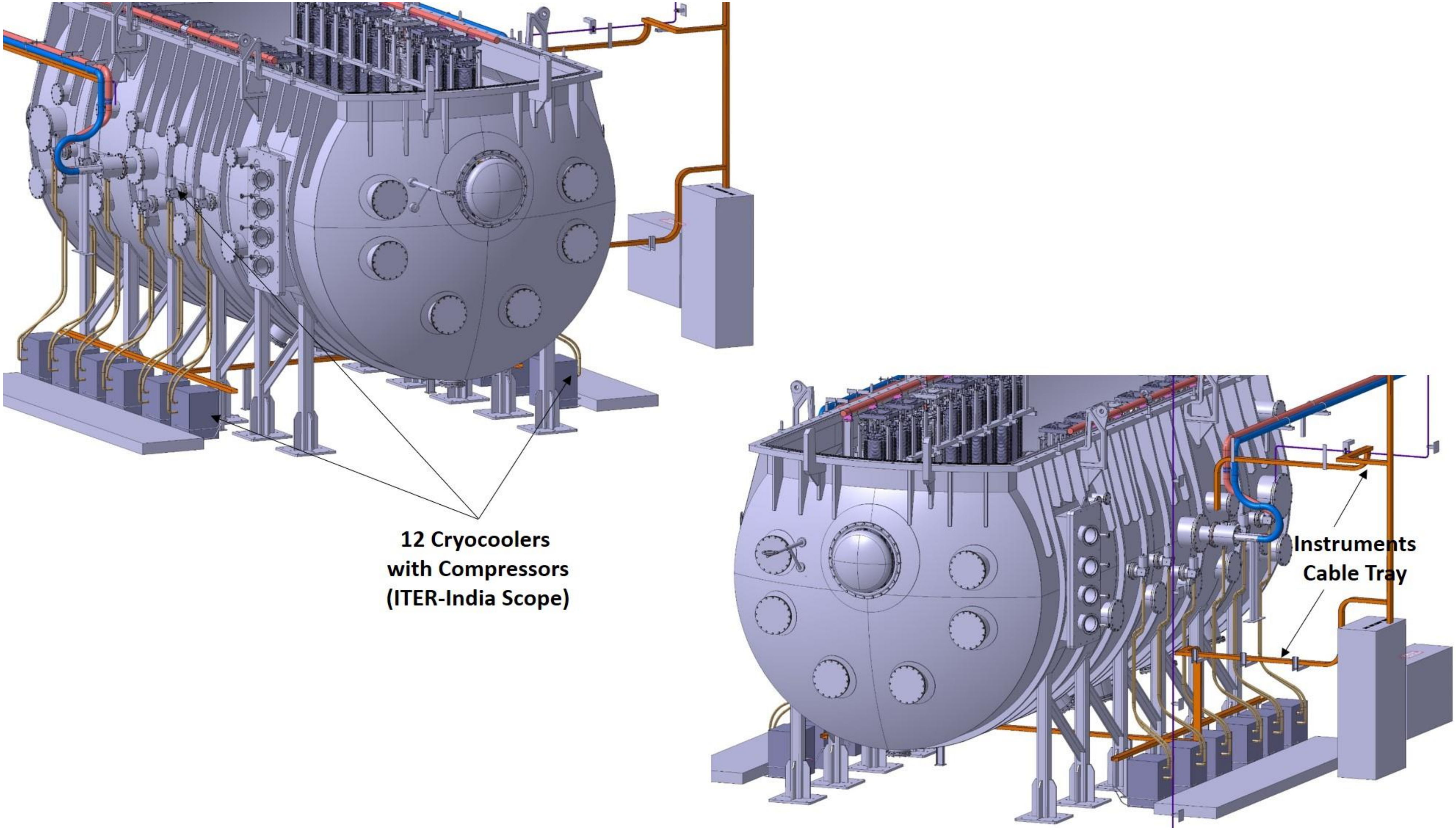


Figure 39: Instruments Cable Tray Routing for 12 Cryocoolers with Compressors

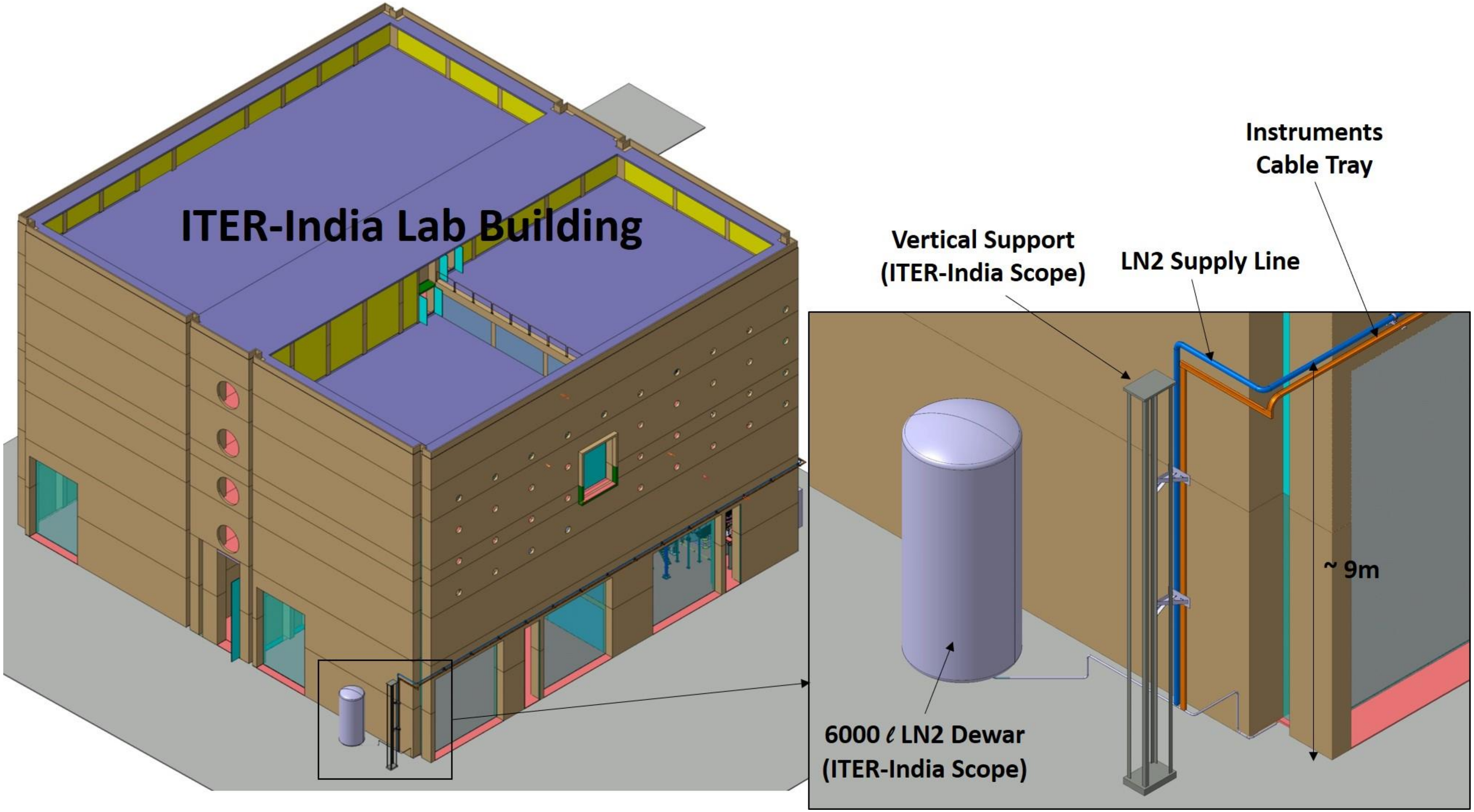
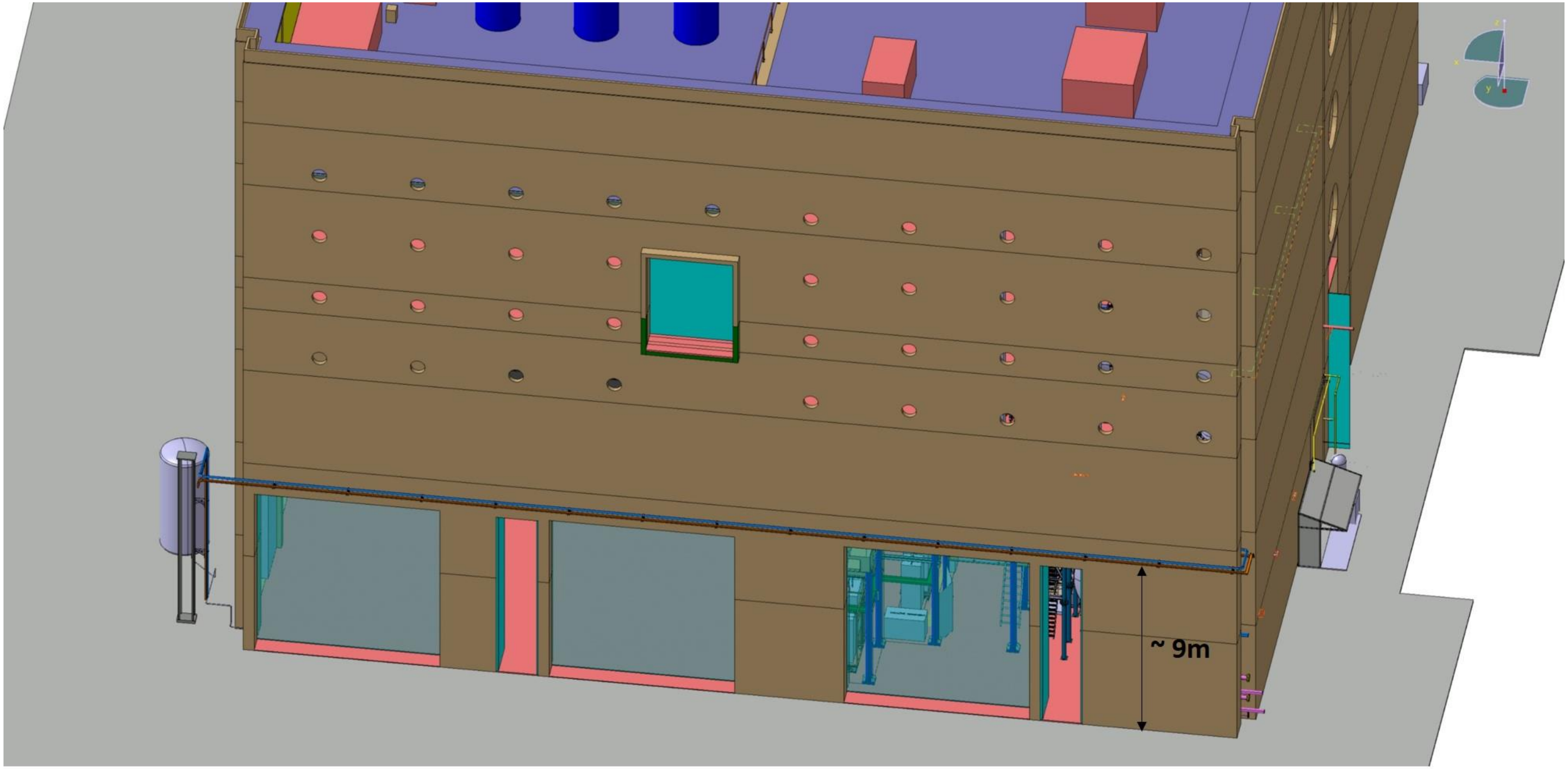


Figure 40: ITER-India Lab Building with 6000 ℓ LN2 Dewar



Shifting and Installation of Cryoline at ~ 9m height with the help of Crane/Scaffolding with Rope

Figure 41: LN2 Distribution Line Routing Outside DNB Lab (Front Side View)

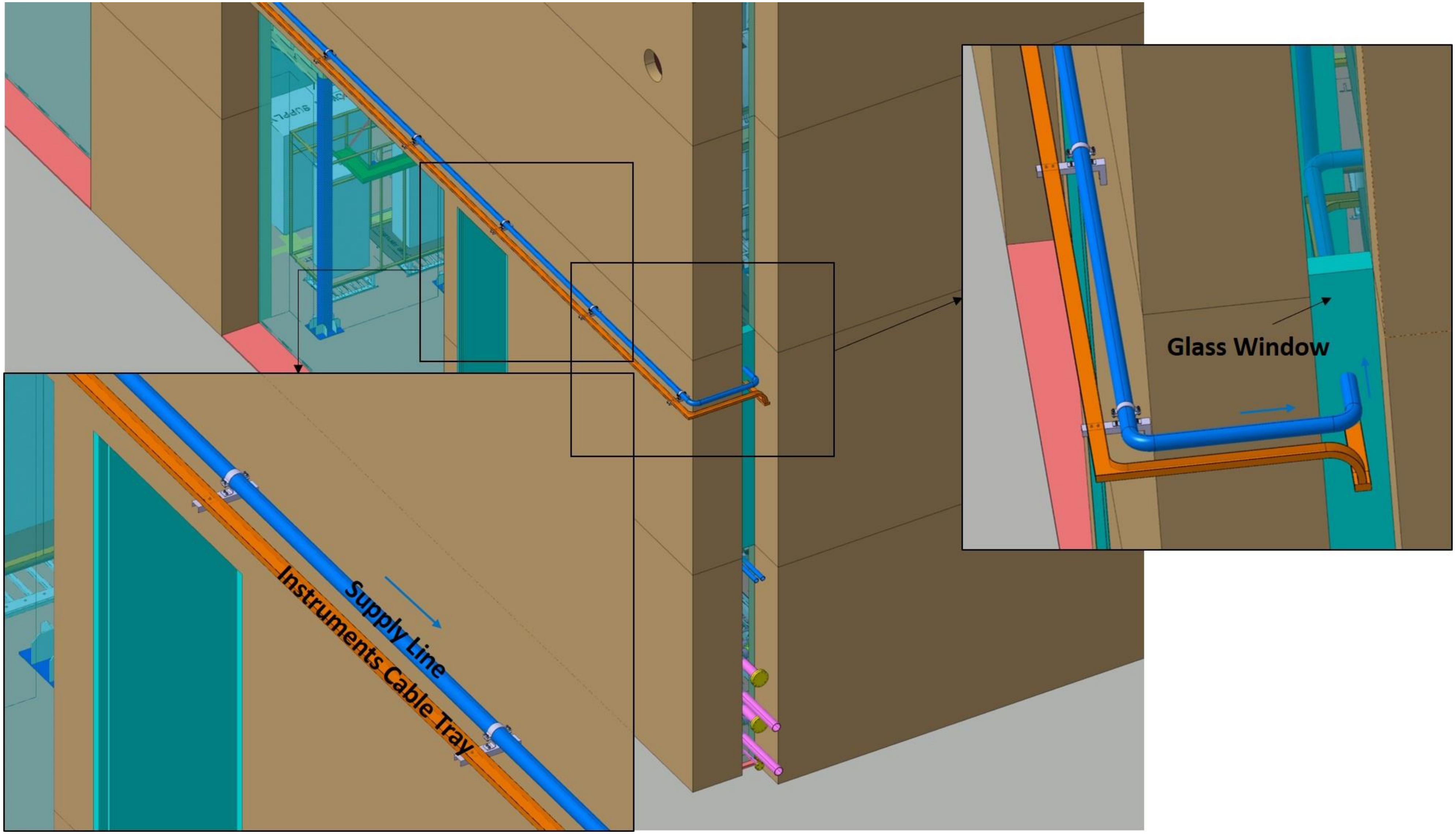


Figure 42: LN2 Distribution Line Routing Outside DNB Lab (Back Side View with Entry into DNB Lab through Glass Window)

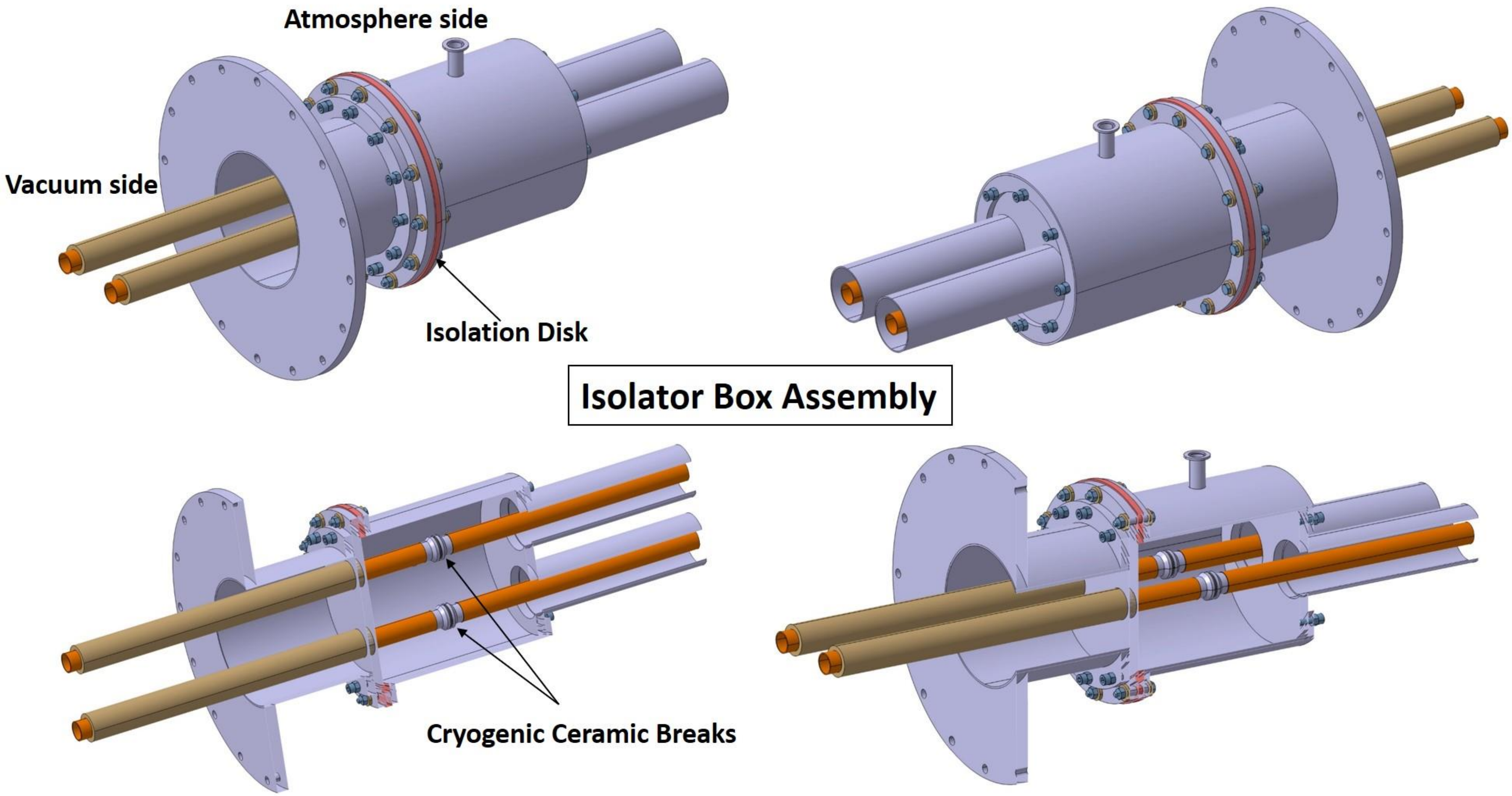


Figure 43: Isolator Box Assembly

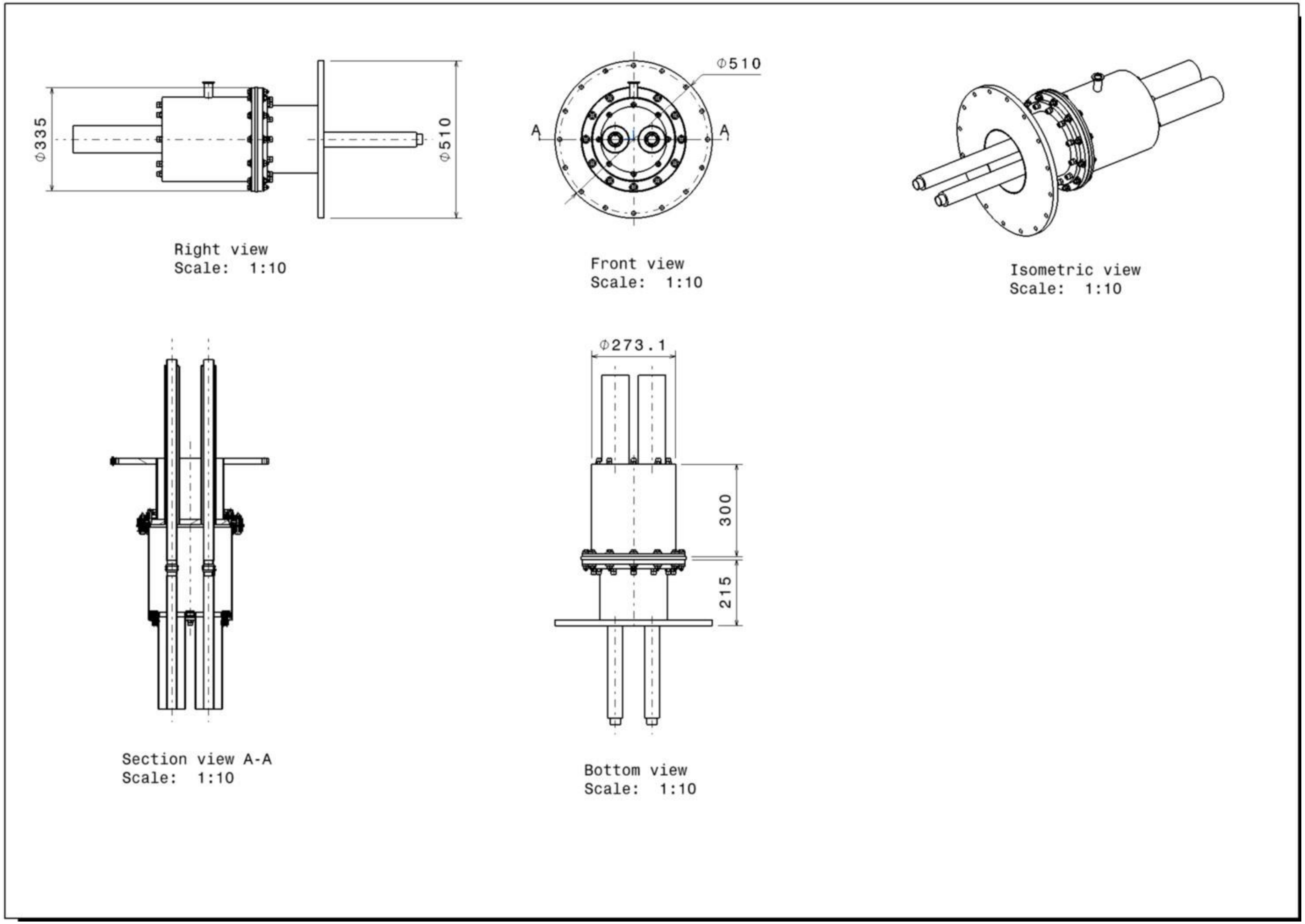
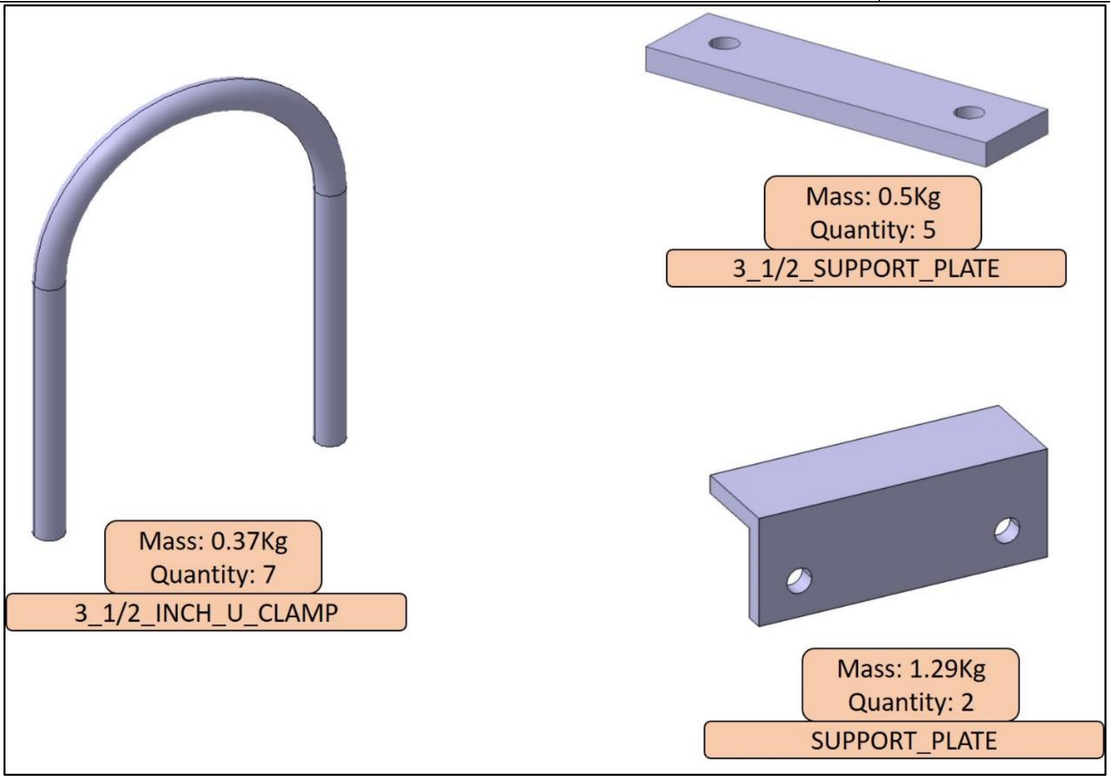


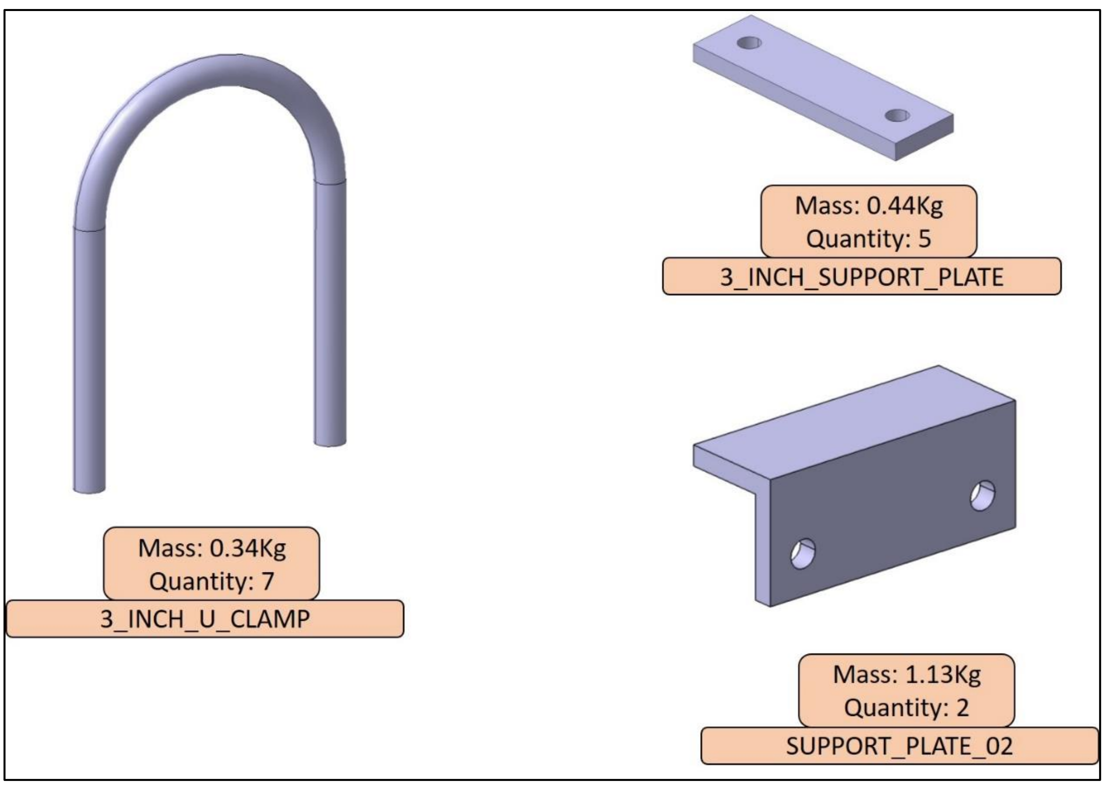
Figure 44: Isolator Box Assembly (Overall Dimensions)

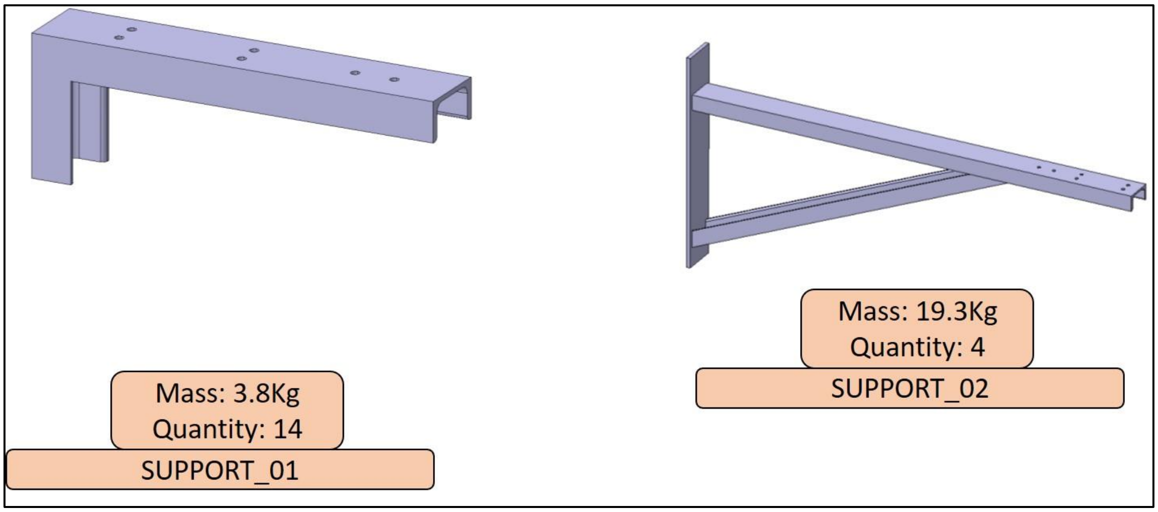
APPENDIX – 2: INTF LN2 Distribution System Supports (Conceptual)

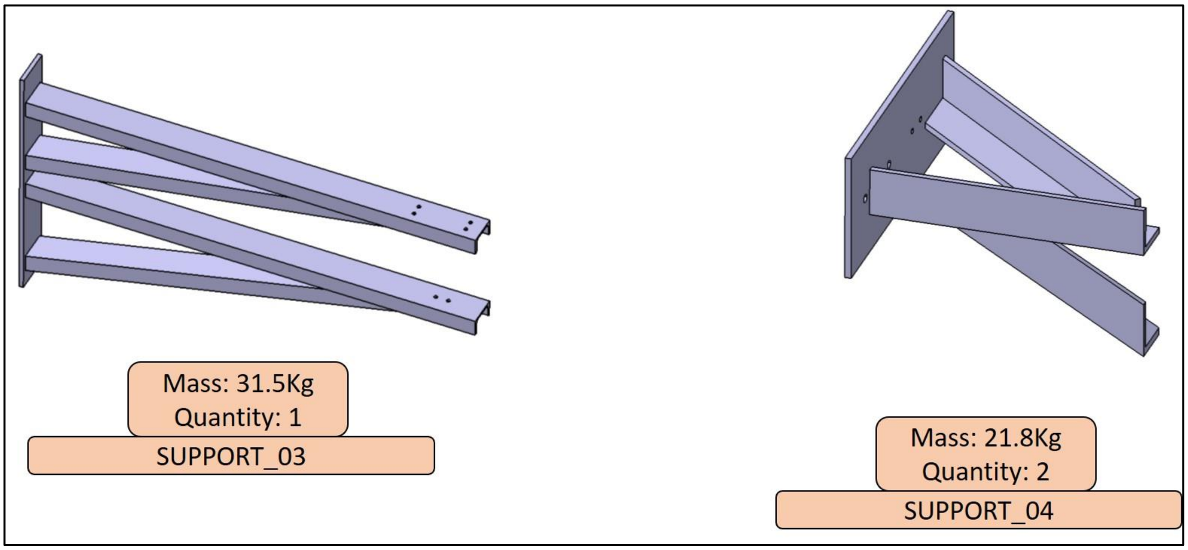
Sr. No.	Component Name	Mass (Kg)	Quantity (Nos.)	Total Mass (Kg)
1)	3_1/2_INCH_U_CLAMP	0.37	7	2.59
2)	3_1/2_SUPPORT_PLATE	0.5	5	2.50
3)	SUPPORT_PLATE	1.29	2	2.58
4)	3_INCH_U_CLAMP	0.34	7	2.38
5)	3_INCH_SUPPORT_PLATE	0.44	5	2.20
6)	SUPPORT_PLATE_02	1.13	2	2.26
7)	SUPPORT_01	3.8	14	53.20
8)	SUPPORT_02	19.3	4	77.20
9)	SUPPORT_03	31.5	1	31.50
10)	SUPPORT_04	21.8	2	43.60
11)	SUPPORT_05	14.1	2	28.20
12)	SUPPORT_06	12.8	4	51.20
13)	SUPPORT_07	5.4	2	10.80
14)	SUPPORT_08	92	2	184.00
15)	SUPPORT_09	2	2	4.00
16)	SUPPORT_10	2.6	2	5.20
17)	SUPPORT_11	4	3	12.00
18)	SUPPORT_12	1.2	1	1.20
19)	SUPPORT_13	7.3	10	73.00
20)	SUPPORT_14	2.9	1	2.90
21)	SUPPORT_15	1.4	1	1.40
22)	SINGLE_PIPE_CLAMP	0.08	24	1.92
23)	PIPE_SUPPORT_PLATE	0.14	24	3.36
24)	C-CHANNEL_SUPPORT	2.56	10	25.60
25)	SINGLE_PIPE_SUPPORT	3	1	3.00
26)	PIPE_CLAMP	1.1	19	20.90
27)	5_INCH_U-CLAMP	1.8	6	10.80
28)	MB_125_I_BEAM	9.9	12	118.80
29)	HANGER_SUPPORT_01	2.1	5	10.50
30)	HANGER_SUPPORT_02	2	5	10.00
31)	CLAMP_1A (G10)	0.228	12	2.74
32)	CLAMP_2A (G10)	0.458	12	5.50

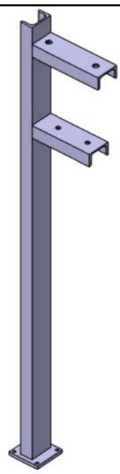
TOTAL MASS OF SUPPORTING COMPONENTS	**807.02**



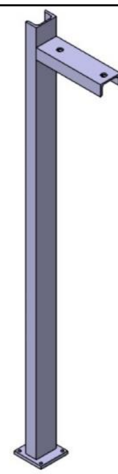



Mass: 3.8Kg
Quantity: 14
SUPPORT_01
Mass: 19.3Kg
Quantity: 4
SUPPORT_02

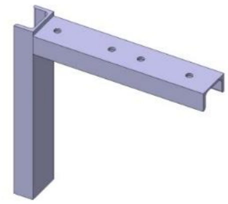

Mass: 31.5Kg
Quantity: 1
SUPPORT_03
Mass: 21.8Kg
Quantity: 2
SUPPORT_04



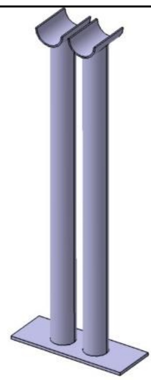
Mass: 14.1Kg
Quantity: 2
SUPPORT_05



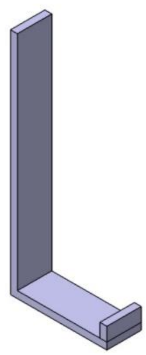
Mass: 12.8Kg
Quantity: 4
SUPPORT_06



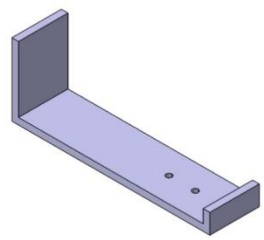
Mass: 5.4Kg
Quantity: 2
SUPPORT_07



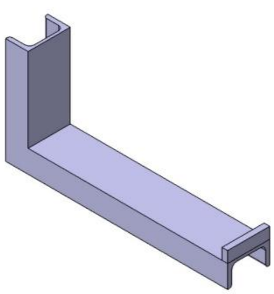
Mass: 92Kg
Quantity: 2
SUPPORT_08



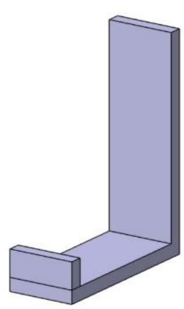
Mass: 2Kg
Quantity: 2
SUPPORT_09



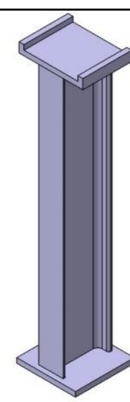
Mass: 2.6Kg
Quantity: 2
SUPPORT_10



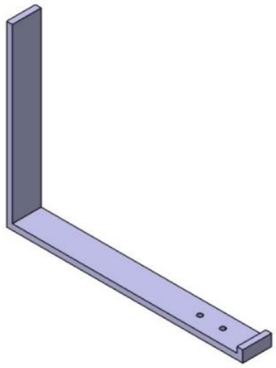
Mass: 4Kg
Quantity: 3
SUPPORT_11



Mass: 1.2Kg
Quantity: 1
SUPPORT_12

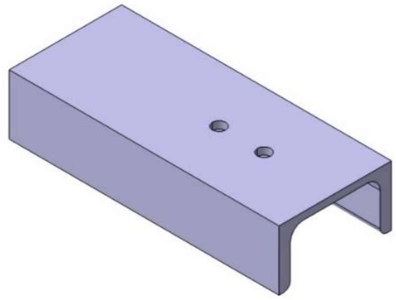


Mass: 7.3Kg
Quantity: 10
SUPPORT_13



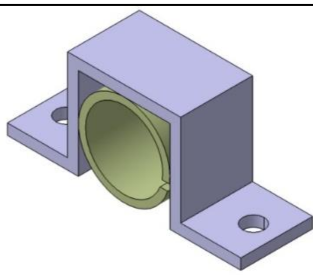
Mass: 2.9Kg
Quantity: 1

SUPPORT_14



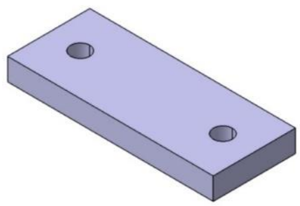
Mass: 1.4Kg
Quantity: 1

SUPPORT_15



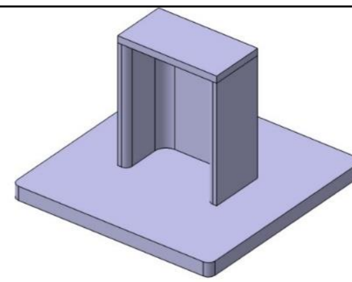
Mass: 0.08Kg
Quantity: 24

SINGLE_PIPE_CLAMP



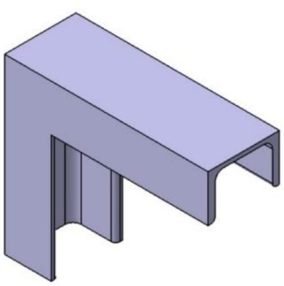
Mass: 0.14Kg
Quantity: 24

PIPE_SUPPORT_PLATE



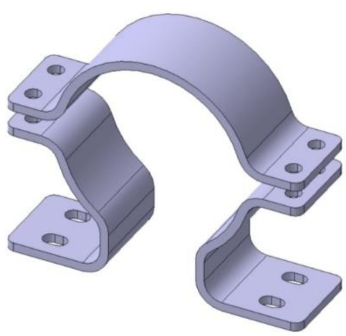
Mass: 2.56Kg
Quantity: 10

C-CHANNEL_SUPPORT



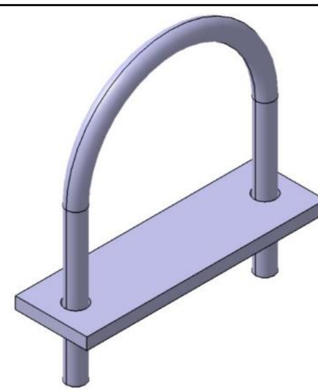
Mass: 3Kg
Quantity: 1

SINGLE_PIPE_SUPPORT



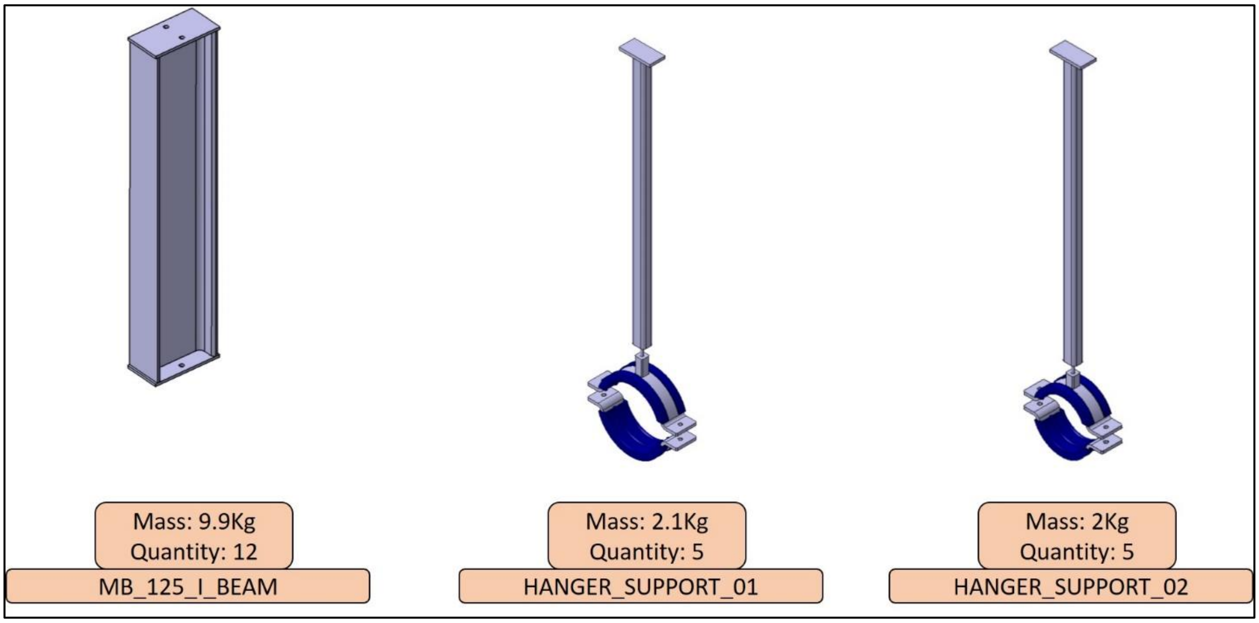
Mass: 1.1Kg
Quantity: 19

PIPE_CLAMP

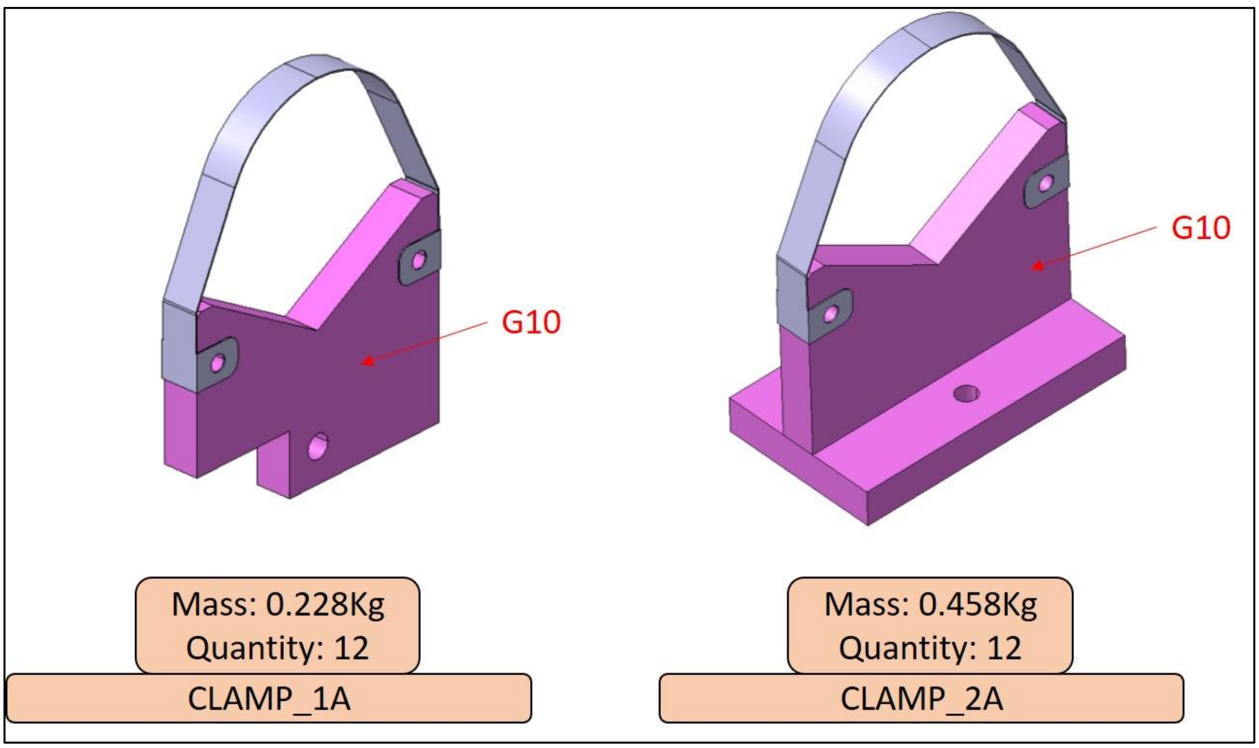


Mass: 1.8Kg
Quantity: 6

5_INCH_U-CLAMP



Mass: 9.9Kg
Quantity: 12
MB_125_I_BEAM
Mass: 2.1Kg
Quantity: 5
HANGER_SUPPORT_01
Mass: 2Kg
Quantity: 5
HANGER_SUPPORT_02



G10
G10
Mass: 0.228Kg
Quantity: 12
CLAMP_1A
Mass: 0.458Kg
Quantity: 12
CLAMP_2A

HP	Hold Point
NP	Notification Point
ATPP	Authorization to Proceed Point
W	Witness of Operation
S1	100% Inspection
S2	Random Inspection
R	Review Report
R&A	Review and Approval
P	Perform

APPENDIX – 3: Minimum required Key Points for the INTF LN2 Cryolines Contract

	Contractor	ITER-India
Tender		
Contract Award for INTF LN2 Cryoline		HP
Kick-off Meeting (KOM)		
Quality plan, Detailed schedule, List of materials, codes and standards, software to be used, Design methodology / plan	R	NP
Design		
P&ID Review	R	R&A
2D drawings (assembly and details), 3D model of complete system (LN2 and GN2 lines, phase separator, cable trays, compressed air line, DAQ Junction box etc.)	R	R&A
Sizing calculation report for phase separator, Flexibility analysis report of LN2 and GN2 lines, Structural analysis report of internal and external supports and vacuum barriers of LN2 and GN2 lines as well as phase separator and its supports. Design report for data acquisition junction box. Wiring and loop diagram along with cable schedule and signal list of the DAQ junction box. Design report on electrical isolation (5KV) system for lines, cable trays, supports etc. Technical report on control logic, interlocks etc.	R	**HP**
Data sheet of various instruments like FCVs, Flowmeter and transmitters, Pressure sensor and transmitter, temperature sensors and monitors, cables, cable trays, MLI, spares etc. along with BOM.	R	R&A
Detailed proposal (2D drawing, type of joint, NDT etc.) for connections to various interfaces (e.g. LN2 tank). Detailed proposal for civil works to be carried out at lab. Detailed proposal on earthing of instruments, panels etc. Single line diagrams for electrical and signals network.	R	R&A
Pre-Manufacturing Activities		
Inspection and Test Plan (ITP) for manufacturing	P	R&A
Procedures for cleanliness control during manufacturing, leak test, radiographic tests of welds, MLI insulation wrapping, pressure test, visual examination and dimensional control.	R	R&A
Manufacturing drawings (assembly and details) showing tolerances, weld details, MOC etc.	R	R&A
Qualifications / certifications of welders and NDT personnel	R/P	R&A
Weld plan (WPS, WPQR and welder qualification record)	R/P	R&A
Incoming Inspection of Materials	P	R&A
Welding Consumables Verification	P	R&A
Workshop Cleanliness Inspection	P	NP
Manufacturing and Acceptance Activities at Factory		
Material test certificates from NABL approved lab for materials used in LN2 and GN2 lines (e.g. pipes, fittings, bellows, hoses etc.), phase separator, supports, valves, spares etc. Test certificate of Pressure Safety Valves (PSVs) as per ASME/PED pressure test. Calibration certificates of instruments like FCVs and Positioners, Flowmeter and transmitters, Pressure sensor and transmitter, temperature sensors and monitors, gauges etc.	R	R&A

Report mentioning surface roughness values (measured) for process pipe inner and outer surface. Body and seat leak tightness test reports of all valves.	P	R&A
Signed Inspection and Test Plan (ITP)	R	R&A
As built drawings and 3D model. As built drawings of DAQ junction box including wiring and loop diagram along with cable schedule and signal list.	R	R&A
Marking and Identification of Pipes, Bellows, Hoses and Fittings	P	R&A
Cleaning of Pipes, Bellows, Hoses and Fittings	P	R&A
MLI Wrapping and Inspection	P	NP
Welding	P	R&A
Dimensional and Visual Inspection of Assembly	P	S2
Radiographic test of Butt Weld Joints of process pipes, jackets in situ welds etc.	P	R&A
Pressure tests of each spool inner pipe	P	W
Thermal Shock of weld samples	P	W
Helium Leak Test of each pre-assembled component i.e. process pipe with compensating bellows / subsystem i.e. entire spool (to be shipped)	P	W
Cleanliness Inspection of Assembly	P	NP
Packing and Shipping		
Packing list (including spares as per chapter 8) for transport to ITER-India lab.	R	R&A
Material handling instructions for loading, handling and unloading.	R	R&A
ITER-India Incoming Inspection	P	R&A
Installation and Acceptance Activities at Site (ITER-India Lab)		
Dimensional and Visual Inspection of Assembly	P	S2
Radiographic test of Butt Weld joints of process pipes, field joints, in-vessel joints, compressed air lines etc.	P	R&A
Pressure test of inner pipe	P	W
Thermal shock tests of weld samples of welds performed at site	P	W
Helium Leak Test of each site weld i.e. process pipe joints, field joints, in-vessel joints etc.	P	W
Reports of functional tests on site (e.g. valve opening and closing, sensors, gauges, controllers etc.)	R	R&A
As installed drawings and 3D model. As installed drawings of DAQ junction box including all the changes with updated wiring and loop diagram along with cable schedule and signal list.	R	R&A
Commissioning report	R	R&A
Calibration certificates of instruments, valves, gauges etc.	R	R&A
Certificate of conformance with technical and quality specifications, codes, standards and regulatory requirements	R	R&A
Operation and maintenance manuals.	R	R&A
Warranty certificates.	R	R&A

APPENDIX – 4: Sample ITP (Inspection and test Plan) Template:

Inspection and Test Plan

Document Number:			Key	
Contract No.			HP	Hold Point
Description of ITP			W	Witness of Operation
Supplier:			NP	Notification Point
Prepared by Contractor	**Reviewed by ITER-India**	**Approved by ITER-India**	ATPP	Authorization to Proceed Point
			R	Review Report Required
			S2	Random Inspection
			S1	100% Inspection

				Inspection Body					**Revision No.:**		
exp. Date	**Activity No.**	**Process**	**Specification, Procedure**	**Sup Contractor**	**Contractor**	**ITER-India**		**Others**	**Record**	**Remarks**	**NCR/DR**

APPENDIX – 5: Deviation Request Template:

Section 1 *To be completed by Contractor* *Report No:*

1. ITER-India contract number:
2. Contract title:
3. Contractor:
4. Item identification / WBS ID:
5. Safety Important Component (SIC): Yes [ ] No [ ]
6. Original requirement:
7. Alternative proposal:
8. Justification:
9. List of attachments: NA

Section 2 *To be completed by Contractor*

Contractor Responsible Officer	Contractor Quality Group
Name: *Date:* *Signature:*	*Name:* *Date:* *Signature:*

Section 3 *To be completed by ITER- India*

ITER India Responsible Officer Accept [ ] Reject [ ]	ITER India Quality Group Comments:
Name: *Date:* *Signature:*	*Name:* *Date:* *Signature:*

APPENDIX – 6: Non Conformance Request Template:

Section 1 *To be completed by Contractor* *Report No:*

1. ITER-India contract number:
2. Contract title:
3. Contractor:
4. Item identification/ WBS ID:
5. Safety Important Component: Yes [ ] No [ ]
6. Requirement:
7. Description of the non-conformance:
8. Non-conformance category: Major [ ] Minor [ ]
9. Proposed remedial action: Use as is [ ] Rework [ ] Repair [ ] Reject [ ]
10. Justification (for Safety Important Components, include safety justification)
11. List of attachments:

Section 2 *To be completed by ITER-India*

ITER-India Responsible Officer Decision:	ITER-India Quality Group Comments:
Name:	*Name:*
Date: *Signature:*	*Date:* *Signature:*

Section 3 *To be completed by Contractor*

Contractor's Responsible Officer Accept [ ] Reject [ ]	Contractor's Quality Group Comments:
Name:	*Name:*
Date: *Signature:*	*Date:* *Signature:*

APPENDIX – 7: Unpriced Bid Templates

A table presented below is a list of preliminary deliverables. The exact quantity will be defined after detailed layout preparation based on ITER-India layouts by contractor. Increase or decrease in quantity during the contract execution will be managed based on unit rates defined in the price bid.

Sr. No.	Name of the Deliverable+	Including (but not limited to)	Est QTY	Unit	HSN code	#Unit rate in ₹ Quoted (Yes/No)	Total in ₹	Remarks (if any) / Make^
+ Deliverable items shall comply with technical specification defined in this tender document - PART A (II) # Please quote "per unit rate" such as "rate per meter length" or "rate per set/nos." etc. ^ Please provide make								
1)	Phase Separator with Level Sensor & Proportionally Controlled Inlet Fill Valve	~200 ℓ	01	Nos.			[redacted]	
2)	VJ Cryoline including Field Joint, Elbow and Tee	DN40-5S	120	Meter			[redacted]	
3)	VJ Cryoline including Field Joint, Elbow and Tee	DN25-5S	25	Meter			[redacted]	
4)	VJ Cryoline including Field Joint, Elbow and Tee	DN80-5S	12	Meter			[redacted]	
5)	VJ Flexible line	DN25-5S	20	Meter			[redacted]	
6)	In-vessel bare Rigid-Flexible connecting line between isolator box and Supply/Return Manifold with MLI wrapping	DN25-5S	12	Meter			[redacted]	
7)	In-vessel Bare Pipe Fittings with MLI wrapping (Reducing Tee)	DN80-5S x DN25-5S	04	Nos.			[redacted]	
8)	In-vessel Bare Pipe Fittings with MLI wrapping (180° Bend)	DN25-5S	2	Nos.			[redacted]	
9)	In-vessel bare pipe with MLI wrapping (Supply and Return Manifold) – 5m each	DN80-5S	04	Nos.			[redacted]	

10)	In-vessel Bare Flexible Hose with MLI wrapping (L: ~ 1 m each) (For connecting Cryopumps with Manifolds)	DN20-5S	24	Nos.			[redacted]	
11)	In-vessel Supply Manifold Supports	G10	12	Nos.			[redacted]	
12)	In-vessel Return Manifold Supports	G10	12	Nos.			[redacted]	
13)	Pneumatic Actuated Flow Control Valve (FCV) with Air Filter Regulator with Positioner with Solenoid with Limit Switch (01 no. is part of PS)	DN50	05 + 01	Nos.			[redacted]	
14)	Manual Control Valve (MCV) with Limit Switch	DN25	01	Nos.			[redacted]	
15)	Cryogenic Pressure Safety Valve (PSV) (01 no. is part of PS)		04 + 01	Nos.			[redacted]	
16)	Cryogenic Flow meter and transmitter (FE/FT) with Local Display	DN40/DN50	01	Nos.			[redacted]	
17)	Cryogenic Pressure sensor and transmitter with Local Display (PE/PT) (01 no. is part of PS)		03 + 01	Nos.			[redacted]	
18)	Isolator Box		02	Nos.			[redacted]	
19)	Compressed Air Lines	DN 15-10S	50	Meter			[redacted]	
20)	Compressed Air line Shut-off valves	Size suitable to Compressed Air line	06	Nos.			[redacted]	
21)	SS 304L connecting tubes with fittings (Connecting line between Shut-Off valves and FCVs)	Tube size suitable to FCVs	15	Meter			[redacted]	

22)	Cryogenic Temperature sensors (Calibrated)	Platinum RTD	04	Nos.			[redacted]	
23)	Cryogenic Temperature sensors (Uncalibrated)	Platinum RTD	71	Nos.			[redacted]	
24)	Cryogenic Temperature Monitors	8 Chanel	08	No.			[redacted]	
25)	Subminiature D-type Multipin Feedthrough Kit (with DN 63 CF Flange mounting)	50 Pin	07	Nos.			[redacted]	
26)	DAQ Junction Box including USB to 8 Port and 16 Port Serial Converter		01	No.			[redacted]	
27)	Instruments Cable (Power and Signal) Tray (hot-dip GI trunking cable tray with removable cover)	100mm x 50mm	130	Meter			[redacted]	
28)	Instrument Cable for LN2 Level in Dewar including power cable		85	Meter			[redacted]	
29)	Instrument Cable for FCVs with Positioners with Solenoids with Limit Switches including power cable	For 6 FCVs	140	Meter			[redacted]	
30)	Instrument Cable for Flow meter and Transmitter including power cable		85	Meter			[redacted]	
31)	Instrument Cable for Pressure sensor and transmitter with Local Display (PE/PT) including power cable	For 4 Nos.	145	Meter			[redacted]	
32)	Instrument Cable for Temperature Sensors (outside vacuum vessel)	For 60 Sensors	540 (30x6 + 30x12) = 540	Meter			[redacted]	
33)	Phosphor-Bronze 4-lead wire, 36 AWG with Polyimide insulation (for using inside vacuum vessel)	For 4 Sensors	20	Meter			[redacted]	

34)	Instrument Cable (3 wire serial cable) for Cryocooler Compressor with both end shall be terminated with DB9 female connector. Each having length of 20m		12	Nos.			[redacted]	
35)	Power cable (including MCB) of appropriate rating for providing electric power to DAQ junction box from Cryo Power Supply Box		2	Meter			[redacted]	
36)	SS supports with fabrication & installation for INTF LN2 Distribution System including electrical isolation (~ 5kV) between lines and supports + G10 Supports	For Supply, Return LN2 cryoline, Instruments cable tray & Compressed Air Line + for In-vessel LN2 Manifolds	Refer Appendix-2				[redacted]	
37)	Spares (section 8)		01	Set			[redacted]	
38)	Design & Documentation Cost						[redacted]	
39)	Fabrication and Assembly at Factory						[redacted]	
40)	Inspection, Testing at Factory and Quality Control						[redacted]	
41)	Packaging and Transport to ITER-India						[redacted]	
42)	ITER-India Site Handling and Installation Activities						[redacted]	
43)	Acceptance Tests at ITER-India Lab						[redacted]	
44)	If any other, specify						[redacted]	

APPENDIX – 8: Technical Compliance Sheet for LN2 Distribution System for INTF Cryopumps

Bidder must check the specification and give his compliance in table given below.

Sr. No.	**ITER-India's requirement**	**Bidder's compliance** (Bidder must check the specification and give his compliance)
1)	INTF Liquid Nitrogen Distribution System: Scope of Work/Supply → Section – 3 (with subsections) of Technical Specifications	
2)	INTF LN2 Distribution System – Technical Specifications → Section – 4 (with subsections) of Technical Specifications	
3)	Technical Specifications of INTF LN2 Distribution System Components → Section – 5 (with subsections) of Technical Specifications	
4)	Technical and Manufacturing Requirements of INTF LN2 Cryoline → Section – 6 (with subsections) of Technical Specifications	
5)	Codes and Standards → Section – 7 of Technical Specifications	
6)	List of Spares → Section – 8 of Technical Specifications	
7)	INTF LN2 Distribution System: Factory and Site Acceptance Tests (FAT and SAT) → Section – 9 (with subsections) of Technical Specifications	
8)	Inspection and Test Reports → Section – 10 of Technical Specifications	
9)	List of Project Hold Points/Schedule and Documents to be Submitted → Section – 11 of Technical Specifications	
10)	Warranty → Section – 12 of Technical Specifications	
11)	Minimum required Key Points for the INTF LN2 Cryolines Contract → APPENDIX-3 of Technical Specifications	