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Report

DNB Vessel Design Description

DNB Vessel Design Description

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1 Purpose

This document describes the design generation of the DNB Vessel to meet the design code requirements as well as other functional specifications like Load Specification Document, System Requirement Document (SRD), Remote Handling Code of Practice (RHCOP) and ITER Vacuum Handbook.

While evolving with design, the various interfaces with the internal components / systems and external components / system have been taken into consideration, keeping in mind various constrains provided by above input documents. These interfaces have also been described in this document.

The load specification document has been revised, post PDR, considering the changes/revisions in the different load and reaction forces.

The most significant changes in the design are the following:

- RCC-MR 2007 Weld compliance
- Implementation of metallic seal (PCR 1112)
- Bolting (Superbolts) arrangement for seal compression
- FRS (frequency response spectrum) for the vessel design

In order to comply the design requirements, chits raised during the PDR have been resolved and worked upon.

Title	Chit Description	Category	Corrections
Lip Seal Welding and RH Compatibility	The design relies largely on welded lip seals. The RCC-MR minimum requirement for the weld penetration is 2 mm. No demonstration has been made that this penetration can be achieved by TIG welding. Recent R&D results have shown that this penetration can be achieved only by Laser welding and not by TIG welding. This	1	PCR 1112 (Additional provision of metallic seal, implemented

	R&D program has demonstrated that lip seals can be maintained with a robotic arm but with hands-on assistance. RH team considers that TIG welding is RH compatible but not laser welding. Therefore, the present design of the BLV cannot be maintained if there is no man access possible in the NB cell		in the revised design)
Deformation of DNB vessel rear wall near HVB flange	The deformation of the rear wall of the DNB vessel is relatively large. The Flange to the HVB must remain flat for the helicoil seal to remain leak tight. Another issue with the deformation is that there will be stresses of cooling water lines that contain in-line ceramic insulators. All these stresses must be verified to be OK.	2	Addressed in the revised design Refer Design Verification Report of DNB Vessel
DNB High Voltage bushing flange deflection	The rear of the DNB vessel deflects when the vessel is evacuated, and that deflection could lead to shear forces on the in-line ceramic breaks in water lines passing through the HV bushing. It should be verified that this does not break the insulators	2	Addressed in the revised design Refer Design Verification Report of DNB Vessel
Interfaces to be clearly defined in the Interface Sheets	The some of the latest update of the interface sheets doesn't reflect well the current status of the design. The Interface Sheets need to be updated. RH features implemented in the component should be described with interface details with the RH tools	2	
Tolerances	Tolerances are an important design driver but are not at all clear from this PDR. The tolerances	2	Updated in the drawings

	for manufacture and for installation of the vessels should be clarified and confirmed to be reasonably achievable.		

2 Abbreviation

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations

ACCC: Active Correction and Compensation Coils
BLC: Beam Line Components
BLK: Blanket
BS: Beam Source
DL: Duct Liner
DNB: Diagnostic Neutral Beam
DT: Drain Tank
EM: Electro Magnetic
FEM: Finite Element Method
FMEA: Failure Modes & Effects Analysis
FRS: Floor Response Spectra
FW: First Wall
HNB: Heating Neutral Beam
HV: High Voltage
HVB: High Voltage Bushing
ICE: Ingress of Coolant Event
LCS1: Local Coordinate System 1
LOCA: Loss of Coolant Accident
LV: Low Voltage
NB: Neutral Beam
NBI: Neutral Beam Injector
NED: Neutralizer Electron Dump
PHTS: Primary Heat Transfer Systems
PMS: Passive Magnetic Shield
PS: Power Supply
RID: Residual Ion Dump
SIC: Safety Important Class
SL: Seismic Level (SL-1 and SL-2)
SMHV: Seismic Maximum Historical Values
ST: Suppression tank

TL: Transmission Line
VMB: Vacuum Measurement Box
VVPSS: Vacuum Vessel Pressure Suppression System

3 Introduction

DNB vessel is rectangular configuration vessel consisting of a main shell and top lid combined with the bolting and sealing provided by a combination of the metallic seal and lip seal arrangements. The DNB vessel assembled with High Voltage Bushing (HVB) and Frond End Components (FECs) forms the primary vacuum boundary for the Diagnostic neutral beam components.

DNB Vessel is fabricated with stainless steel (a non-magnetic material). The boundaries of the vacuum vessel interface with Passive Magnetic Shield (PMS) and Active Compensation Correction Coils (ACCCs).

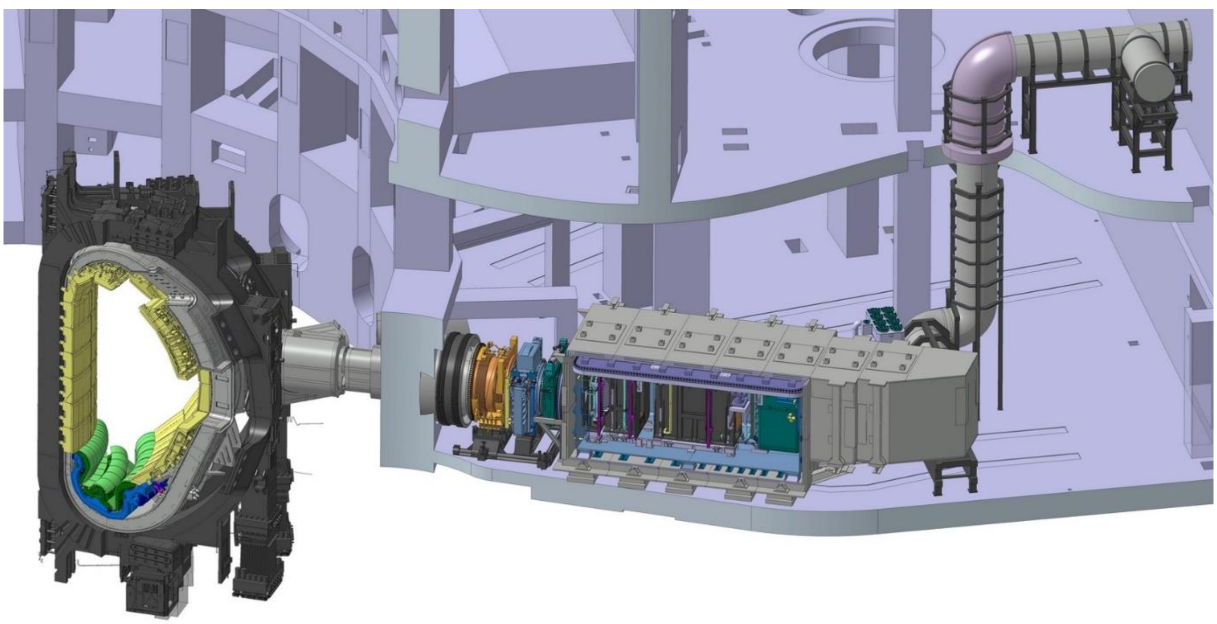

Figure 1: Full view of DNB Injector

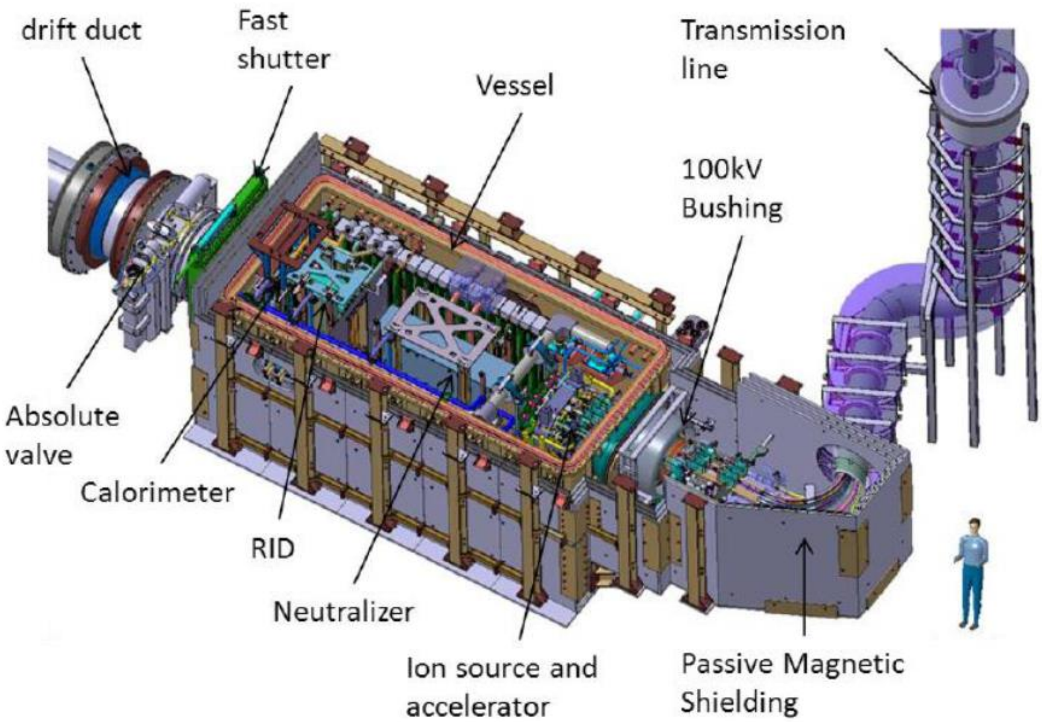

Figure 2: DNB Injector Interfaces

The major load on the DNB vessel during operation is the atmospheric pressure on the outside wall with the internal volume of the vessel under vacuum. In addition, that DNB vessel shall withstand the weight of the beam line components and cryopumps with minimal wall deflection. The vessel design shall also be capable to withstand the over pressure conditions inside and outside the vessel. All these conditions are analysed and presented in the analysis report [1]. The baseline design of the DNB vessel has been documented in the design report presented in the Preliminary Design Review (PDR) [2].

The assembly (handling and positioning of the vessel parts) of the DNB Vessel is documented in the Construction Process Description. The Construction Process Description (CPD) [3] [comprises the description of the Structures, Systems and Components for Construction Work Packages (CWPs) in NB cell and level 3 (HV deck room) for PBS53 assembly activities as per ITER's 4-staged approach. The CPD comprises the description of CWPs and contains information sufficient to describe and demonstrate feasibility for assembly and installation purposes acknowledging interim construction conditions achieved [3].

This Design Report will mainly be focused on the consolidation of the following:

- Design
- Loads specification compliance
- Interfaces evolutions
- Remote Handling Interfaces Requirements

Design and analysis of the DNB Vessel is provided in the design verification report. Manufacturing requirement and compliance with RCC-MR is reported in the feasibility assessment of DNB Vessel manufacturing.

The DNB vessel shall be installed in the Neutral Beam Cell and are manufactured of stainless steel, so no corrosion allowance on the vessels has been considered. Although internal components contain cooling water, however the vessel will not be in contact with water (except for the water circuit feed-through) and will normally remain at full internal vacuum during the whole of the Operational Life, only seeing atmospheric ambient air internally during manufacture and during servicing of the Beam Line components within the vessel. The shape and size of the DNB vessel is bounded by the space between the PMS outside the vessels and the Beam Line Components inside the vessel.

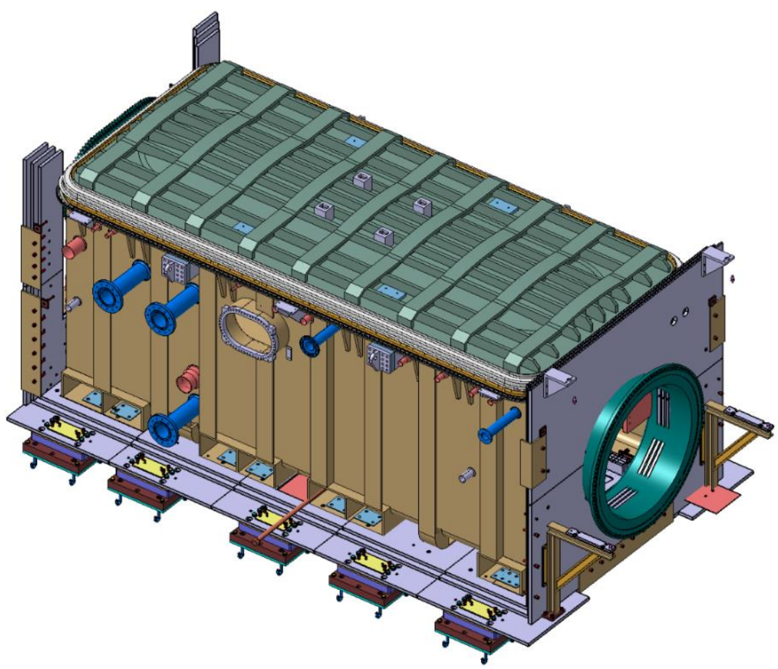

Figure 3: DNB Vessel with PMS

4 Coordinate System of DNB Vessel

The beam reference system used is based on Grounded Grid center (X is horizontal).

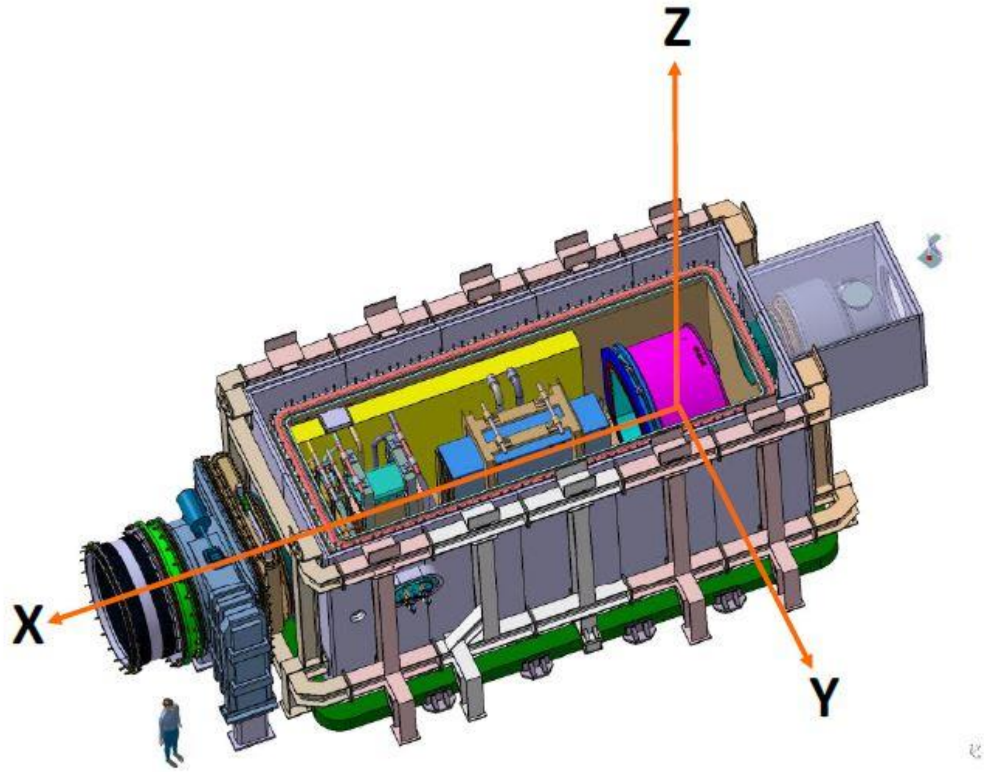

Figure 4: GG coordinate system of DNB Vessel design (for information)

5 System Classification

DNB Vessels consists of main sub-components:

- Vessel
- Top Lid
- Instrumentation Feedthrough Box
- Hydraulic Cooling feedthroughs
- Gas Feedthrough
- High Voltage Feedthrough
- Cryolines feedthrough
- SVS piping
- Draining pipe

DNB vessel comes under the following classifications:

Particulars	**Classified as…**
Remote Handling	RH 2 for Top Lid Vessel - Unclassified
Vacuum Class	VQC 1A
Quality Class	Class 1
Safety Important Class	SIC 1
Seismic Class	1S
Seismic Level	SL-1, SMHV and SL-2
Tritium	1A
Governing Code	RCC-MR 2007
PED requirements	NIL *(Because the pressure 'PS' as defined in ESP and ESPN (see RN-830) for this component is lower than 0.05 MPa relative to atmosphere, this component is not in the scope of ESP or ESPN.)*

6 Materials

The material of the DNB Vessels shall follow the requirements defined in technical specification of DNB Vessel [4].

All the materials for use in vacuum shall respect the requirements from chapter 5 of the Vacuum Handbook [5].

Vessel, Top lid and Feedthrough Box are made of SS304L / EN 1.4307 stainless steel and shall be qualified with all the test and acceptance criteria according to the Section II, RCCMR.

Element	Wt %	Element	Wt %
C	0.03	N	0.11
Mn	2.00	Cu	1.0
Si	1.0	**Co**	**0.05**
Cr	17.5-19.5	**Nb**	**0.01**
Ni	8.0-10.0	**B**	**0.018**
P	0.030	**Ta**	**0.01**
S	0.015	Fe	Balance

The rate of inclusions (as per Section 5-3 of Vacuum Handbook [5] in the steel shall be checked in accordance with ASTM E-45 Method D (or equivalent) to be within the following inclusion limits:

- Inclusion Type A $\leq$ 1.0
- Inclusion Type B $\leq$ 1.0
- Inclusion Type C $\leq$ 1.0
- Inclusion Type D $\leq$ 1.5

Bolting Requirement:

There are different bolts integrated in the DNB Vessel:

- Bolts mounted on systems (beam line components) under vacuum (not in the scope of the report)
- Bolts ensuring sealing system of the Vessel and Top lid (Type SB8 Superbolts tensioner Nord-Lock M36) – 224 bolts.
- Bolts (M20) for ensuring the sealing at the front and rear end of Vessel for FS and HVB mounting – 104 bolts for HVB and 122 bolts for FS
- Bolts (M36) for connecting the PMS plates with the Vessel support structure – 64 bolts

Figure 5: Superbolts M36 tensioner mounted on top lid of DNB Vessel

Based on the loading requirement, bolts mounted on the DNB vessels have been designed in compliance with the RCC-MR 2007 and shall be procured in compliance with the RCC-MR code. The material of the bolts shall be Inconel 718 taken from EN10269. Superbolts (Type SB8 Superbolts tensioner Nord-Lock M36) being the standard product (shown in fig. 5), shall be purchased as the catalogue item.

Seals are Helicoflex® spring energized seals. Their section and materials considered are the same for each flange:

- Spring is made of Inconel 718 alloy.
- Inner Jacket is made of 304L stainless steel.
- Sealing lining is made of pure silver.

As a tritium confinement boundary this component respects the requirement from chapter 4.5 - Material and 4.6 – Plate material of ITER Tritium Handbook [6]. The detailed material specification has been provided in the technical specification.

7 Nuclear safety requirements (in accordance with INB ORDER DATED 7th FEBRUARY 2012)

ITER is a nuclear facility identified in France by the number INB 174. The DNB Vessel is a SIC-1 component since it provides primary vacuum barrier and radiological confinement.

The INDA will ensures that the bidder and its sub-contractors shall follow the following:

- The compliance with the INB-order and must demonstrate in the chain of their bidder and its subcontractors;
- French quality order 7th February 2012 as it is classified as a protection important component (PIC) as per French regulation.
- All Protection Important Activities (PIA) are also subjected to supervision done by Nuclear Operator in application to article II.2.5.4 of the Order 7th February 2012.

For Protection Important Components (PIC), structures and systems of the nuclear facility, the INDA will ensure that bidder shall follow the followings for the tender.

- Bidder shall ensure the generic safety requirements, as described in “Provisions for Implementation of the Generic Safety Requirements by the External Interveners ITER_D_SBSTBM v1.1” shall be complied in entire chain of supplier and subcontractor with a specific stipulated management system to perform protection important activities.

- The (Protection Important Activity) PIA shall be clearly identified in the Manufacturing and Inspection Plan (MIP)/Inspection Plan (IP). The safety functions and associated PIA shall be described in a Quality Plan (QP). These documents (MIP/IP & QP) shall be approved by ITER-India and IO before starting the manufacturing process. Primary list of PIA is described in below table.

Stage of Manufacturing	**Activity**
Material of Construction	Chemical analysis, Mechanical testing
Manufacturing	Weld Data Package (WPS, WPQR, WPQ, NDE)
Final Documentation (acceptance data package)	Acceptance of complete manufacturing file

List of Applicable ITER Documents

Title	ITER IDM Identifier
00 - Nuclear Regulatory Framework for INB ITER	ITER_D_2WBB8P_v3.8

Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN	ITER_D_7M2YKF_v1.7
Overall supervision plan to supplier chain for Protection Important Components, Structures and Systems and Protection Important Activities	ITER_D_4EUQFL_v6.1
Safety Important Function and Components Classification Criteria and Methodology	ITER_D_347SF3_v1.8
Provisions for Implementation of the Generic Safety Requirements by the External Interveners	ITER_D_SBSTBM v1.1
PBS 53 Defined Requirements	ITER_D_M3NUQY_v1.7
Propagation of the Defined Requirements for Protection Important Components Through the Chain External Interveners	ITER_D_BG2GYB_v3.3
Guideline for Identification of the Protection Important Activities (PIA)	ITER_D_SBYJXD_v1.4
List of ITER-INB Protection Important Activities	ITER_D_PSTTZL_v2.2

8 Design Description of DNB Vessel

The DNB vessel is a rectangular enclosure which houses the beam source (BS) and the beam line components (BLC) viz. neutralizer, RID, calorimeter, exit scrapper and the cryopumps.

The rear and front flanges of the DNB vessel interface with the high voltage bushing and a fast shutter respectively. The BS and the BLCs are supported on suitable structures bolted to the floor of the vessel with suitable alignment provisions. The cryopumps are supported with the suitable brackets from the side wall of the DNB vessel.

Vessel has a detachable top lid for insertion as well as removal of internal components during installation and maintenance phases. The vessel has several flanges for ensuring suitable for hydraulic, cryopump and gas feed lines calorimeter movement feedthrough and beam source movement. Ports at appropriate locations will also be provided to provide transition flanges for thermocouples, high voltage feedthroughs for RID and vacuum measurements.

8.1 System Functions

The main functions of DNB vessel are to

- Provide part of the primary vacuum confinement of the DNB system.
- Confinement of radioactive materials in case of accidental over pressurisation.
- Act as ground potential electrode of the high voltage system at -100kV;
- Sustain the weight of the beam source and provide supports to it.
- Sustain the weight of the HV bushing and provide support to it.
- Provide support to all the beam line components and of the cryopumps.
- Provide all the feedthroughs that are necessary for the passage of the vacuum, coolant, cryogens, gas and instrumentation lines and calorimeter movements.
- To allow the access for the beam source and BLCs installation/maintenance and removal of top lid.

8.2 Overall Dimension and Weight

DNB Vessel	Length (L)	Width (W)	Height (H)
Main Shell	9.636 m	5.774 m	3.737 m
Top Lid	8.727 m	4.043 m	0.355 m

DNB Vessel	Weight (ton)
Main Shell	43
Top Lid	25

8.3 Interfaces

The vessel has following main external physical interfaces:

- Connection with the fast shutter on the front opening flange of the DNB vessel.
- Connection with the HV bushing on the rear opening flange of the DNB vessel.
- Connection with the PMS with the vessel supports.
- Connection with hydraulic, gas feed, cryolines, actuators, HV and water drainage.

The vessel has also internal interfaces with BLCs and cryopumps.

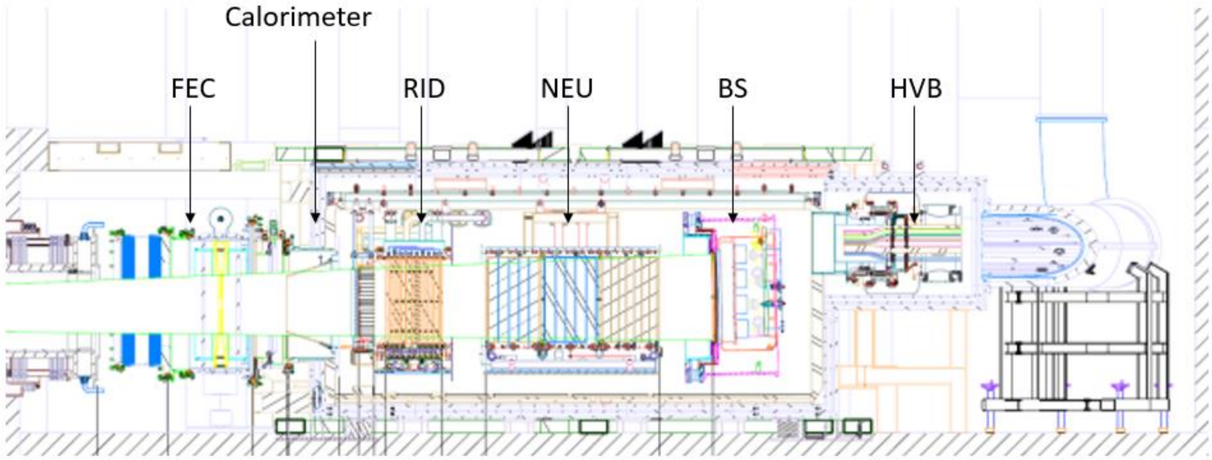

Figure 6: Main vessel mechanical interfaces

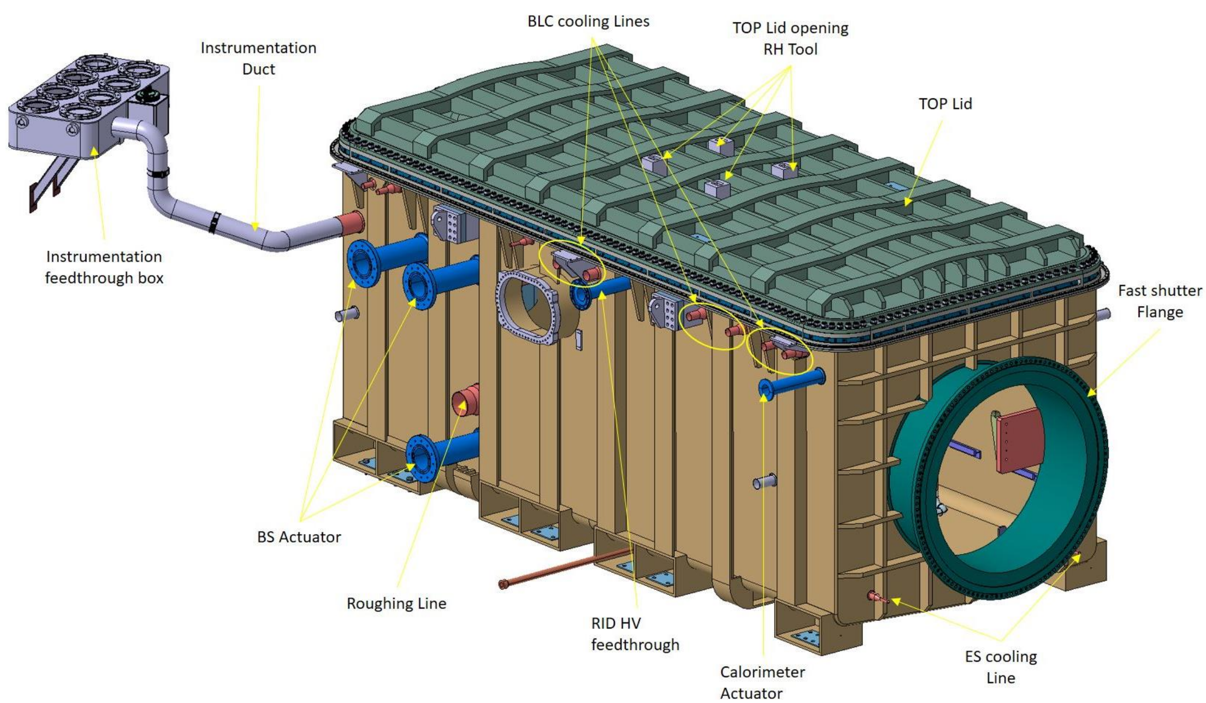

Figure 7: DNB Vessel Interfaces – 1

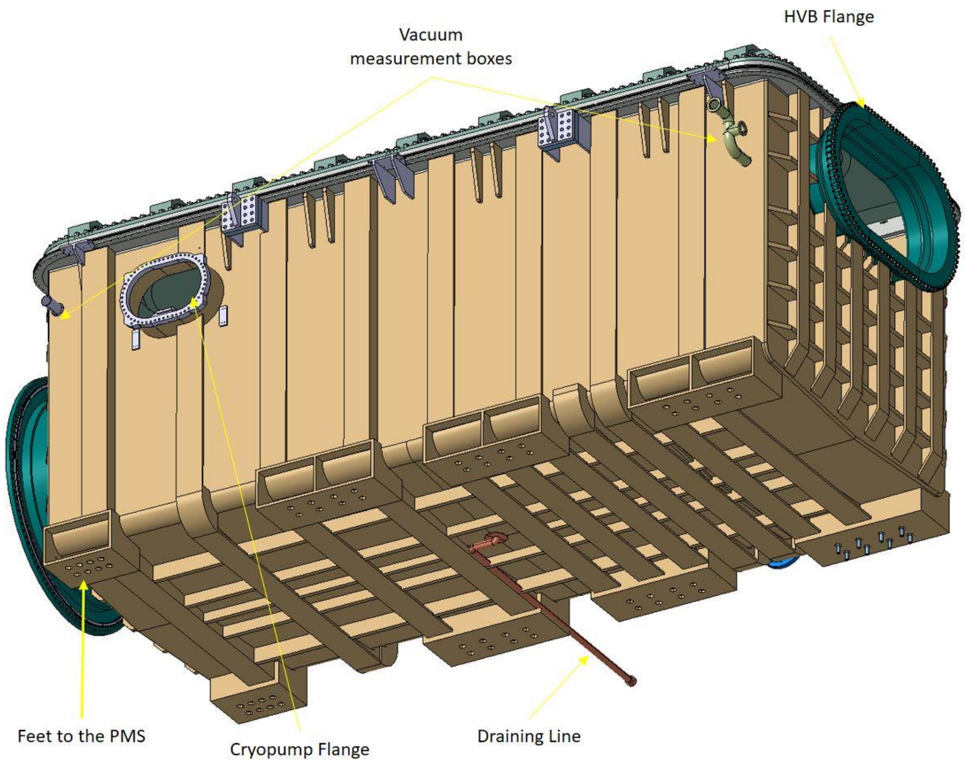

Figure 8: DNB Vessel Interfaces – 2

The vessel is also in interface with the following systems (apart from PBS 53):

Vacuum (PBS 31) https://user.iter.org/default.aspx?uid=UVGSPA https://user.iter.org/default.aspx?uid=UVL2SD https://user.iter.org/default.aspx?uid=UVPY8H https://user.iter.org/default.aspx?uid=UVPYKN https://user.iter.org/default.aspx?uid=UV5WHX	Cryopumps and cryo-feedthroughs, communication with VV, fore pumping, SVS of all flanges, vacuum measurement
Cooling (PBS 26) https://user.iter.org/default.aspx?uid=47PKF6	Cooling circuit for BLC, grounded grid and exit scraper
Remote handling (PBS 23) https://user.iter.org/default.aspx?uid=3244GY https://user.iter.org/default.aspx?uid=2N3XRT https://user.iter.org/default.aspx?uid=2NGAWW	Various interfaces for NB components maintenance
Building (PBS 62) https://user.iter.org/default.aspx?uid=27SB82	Clearance for handling and interface through the PMS

Electricity (PBS 43) https://user.iter.org/?uid=2L98AF	Power supply of the injector and its coils
Gas Distribution (PBS 65) https://user.iter.org/default.aspx?uid=33UP27	Connection through the vessel for neutraliser feeding
CODAC (PBS 45 & 46) https://user.iter.org/?uid=2NKSRL	Signals used by CODAC go through the vessel. Interlock system protect the vessel from energy deposition from the beam.
Diagnostic (PBS 55) https://user.iter.org/default.aspx?uid=2FT2NR https://user.iter.org/default.aspx?uid=27VQD7	Clearance above the DNB vessel is used for diagnostic maintenance.

9 Design Considerations

Metallic Seal Compression Requirement

DNB vessel forms the Primary Vacuum and Confinement boundary. The vacuum sealing arrangements include a combination of metallic and lip seal (PCR 1112).

The integration of double metallic seal has been studied in detail with dedicated research and development [8] [9]. This defines the requirement of metallic seal compression in terms of no. of bolts, preload and compression force required. The design of the top lid and the vessel flange is configured to accommodate metallic seal and lip seal configuration.

In consideration with above, flange configuration has been changed (as compared to PDR design [2]) to match with the Superbolts design. Stiffeners on the top lid are also improved in order to get the required compression of the metallic seal to have the vacuum sealing.

A complete design of the vessel and a remote handling scenario have been developed to integrate the metallic seals and assessed their maintainability. The PCR 1112 covers the manufacturing and testing of metallic seal and the design of RH tools up to the FDR level.

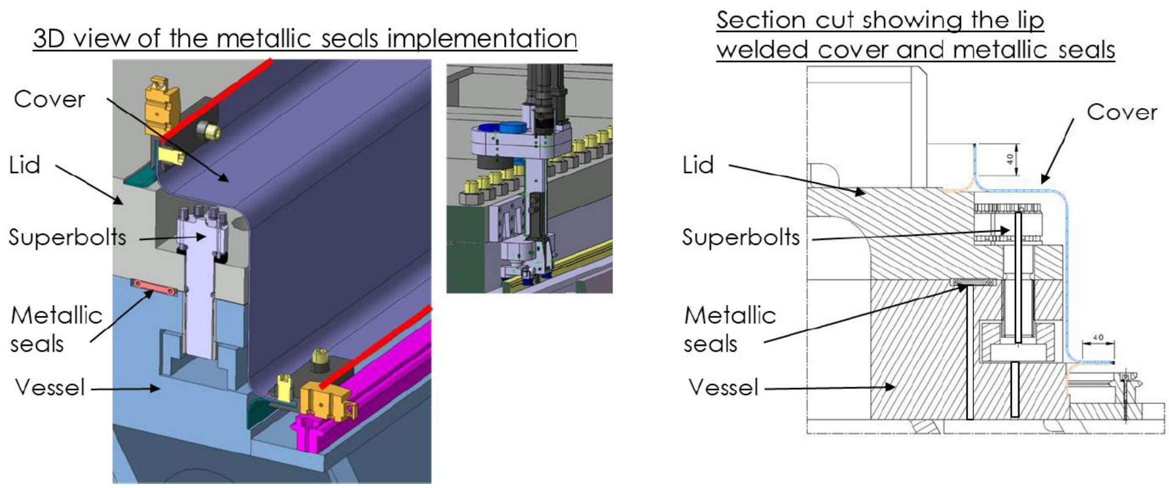

Figure 9: 3D view of metallic seal implementation

9.1 Stress and Deformation Limits targets

As per the RCC-MR Requirements different criteria levels are considered for respective category of loads defined in the load specification document. It is aimed that under worst condition of accident defined in load specification (i.e. criteria level D), the stresses are within the limits so as not to break the vacuum confinement. Considering the nature of stress and the deformation requirements, additional stiffening has been provided on different section of the vessel.

Depending on the space availability, especially the distance between the source support datum lines, dimensions of the stiffeners (width and height), number of stiffeners and distribution of stiffeners have been optimized (as shown in fig 10), so as to meet the stringent deformation requirement of +/- 1mm Max.

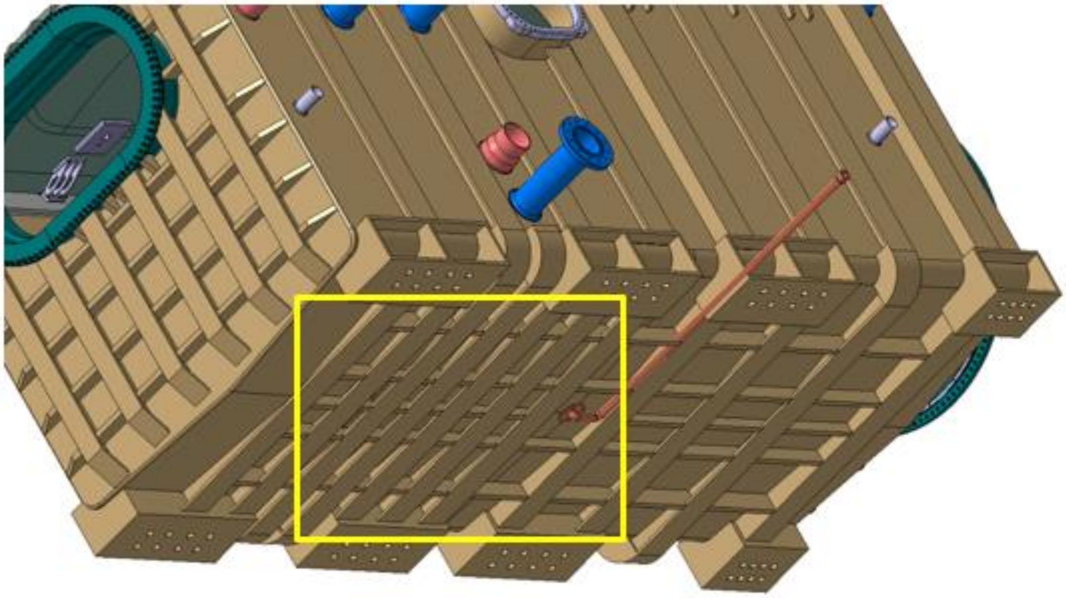

Figure 10: Stiffeners arrangements on bottom plate of DNB Vessel

Deflection Limits under evacuation (In operational condition): (LSD Ref.)

+/- 1mm Max. at Beam Source Support location and BLC datum locations. Whereas at other locations it is +/- 5mm Max.

9.2 Vessel Bottom Plate

It has been designed in angled shape, with the lowest point at centre (i.e. at the location of Water Drain point) so as to facilitate ease the water flow at the time of drainage

Vessel Support

Vessel has 8 nos. of support (four on each side), to be accommodated in the top plate of lower PMS. The bolting of the DNB vessel to the PMS is by 8 M30 bolts. These are passing though Ø76 mm holes giving ± 20.0 mm maximum adjustment of the bolt in the hole to allow for a combination of manufacturing tolerances of the vessel and the PMS and alignment requirements of the vessel on the PMS base-plate.

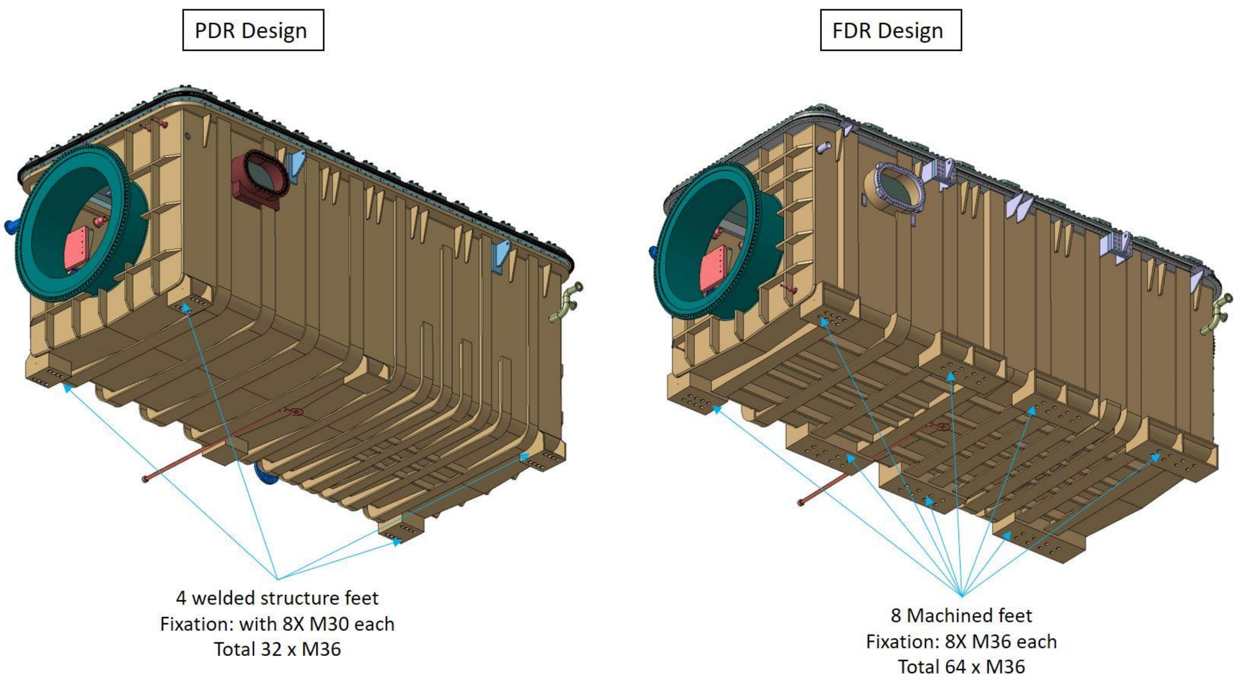

Figure 11: Design changes of DNB vessel support structure from PDR to FDR

9.3 Top Lid

Top Lid has a central dome shape configuration to have an advantage of shape to act against the external loads. 'T' Shaped stiffeners have been provided to limit the deflection and rotation of edges. The vessel top lid is designed to be removed and fitted by a remote handling opening and closing tool. Top lid has provision of 'Twist Lock Pockets' for lifting and handling during the RH maintenance, provision for handling and lifting. It has also provision to support the lid on trolley / stand or pallet.

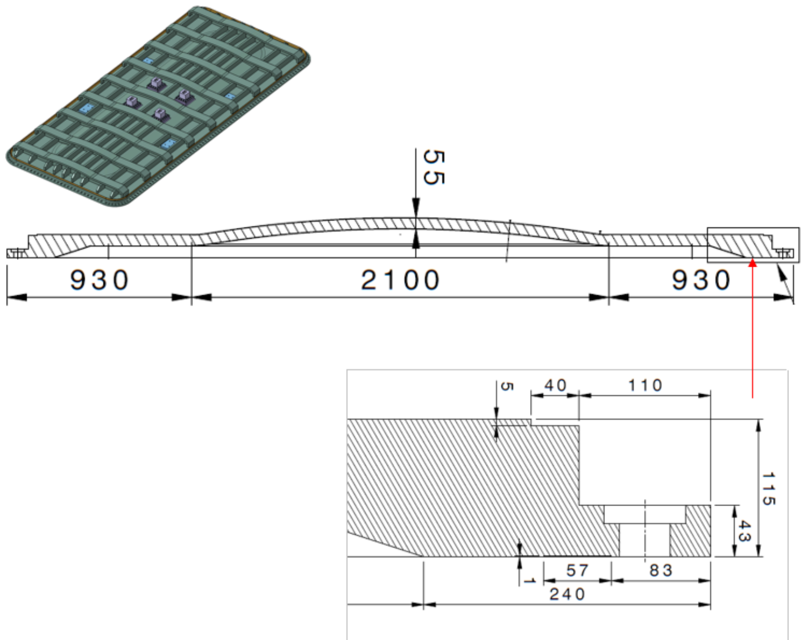

Fig:

Top Lid assembly

Top lid is connected to vessel flange by means of bolting. The bolt size considered is M36 Superbolts. The lid and vessel flange have also provision for the reaction features for RH bolting tool as per the dimensional requirements of RHCOP.

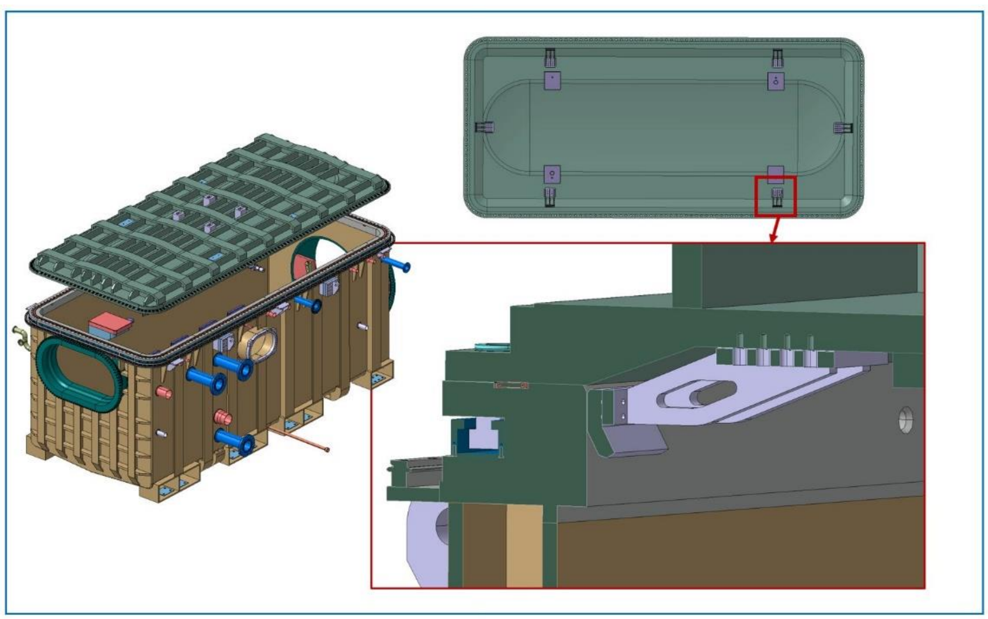

Figure 12: Top lid assembly and their alignment features

Assembly Operation that concern the Top Lid are documented in detail in the CPD [3]. 6 alignment features (as shown in fig. 13) have been implemented on the Top Lid in order to ease the assembly (first assembly and/or RH operations). This will permit a good positioning of the Top lid without damaging the Helicoflex seals. Interface between top lid and RH is shown in the interface document (https://user.iter.org/default.aspx?uid=2NGAWW).

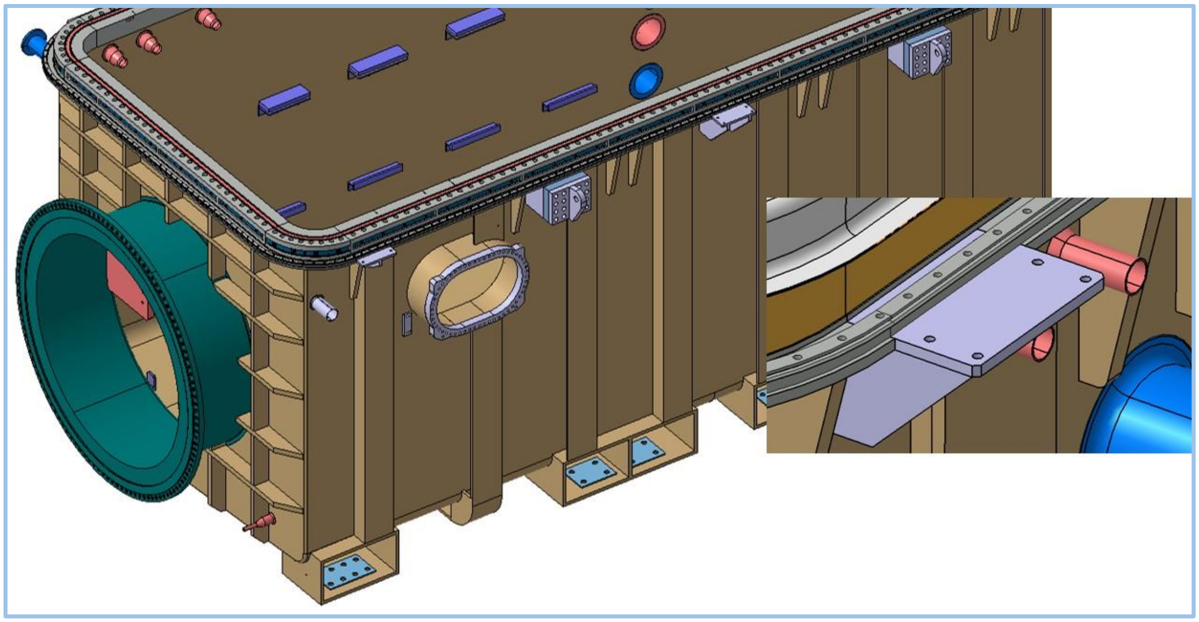

Figure 13: Supporting pads for jacking tools for top lid mounting

Metallic seal will be fixed to the metallic seal lifting frame which in turn will be lifted by the jacking tool. Final alignment of the metallic seal and DNB vessel flange needs to be done by relying on the jacking tool that have the alignment feature for the alignment. Movement of the lifting frame within the NB cell shall be done by monorail crane, lifting features for the same has been provided (as shown in fig 15). Fig. 16 shows the space reservation for the lifting and transportation of the metallic seal in the NBRHS CMM.

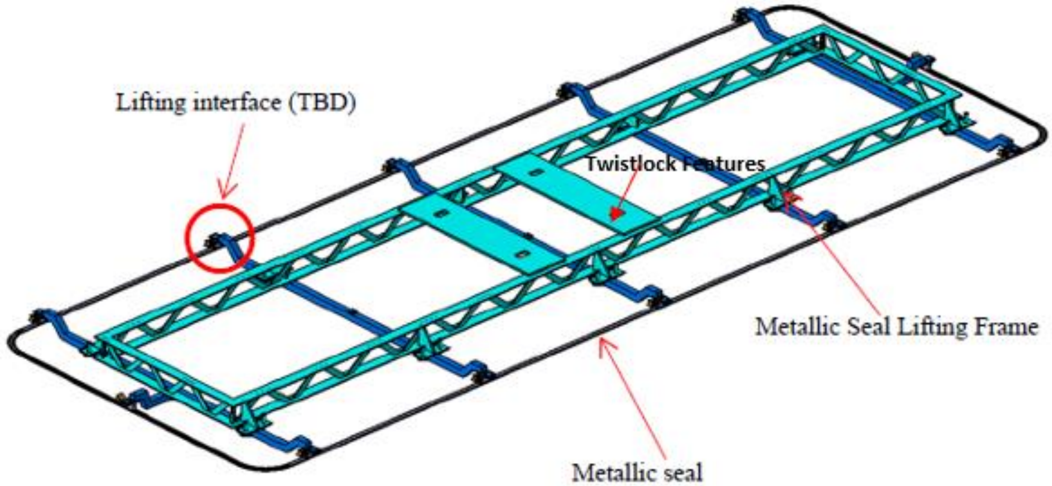

Figure 14: Metallic seal lifting frame

Figure 15: Space reservation for metallic seal lifting frame

The vacuum sealing has to be achieved by metallic seal and the relative movements of vessel and top lid flanges and the required compression of the seal has to be achieved by bolting arrangements. The interspace of the metallic seal shall also be monitored by the service vacuum system.

For next phase of operation, the sealing of vacuum boundary is also supplemented by the Lip Seal weld. The provision for moving the Bolting / unbolting carriage along the periphery of the flange have been considered on the vessel flange.

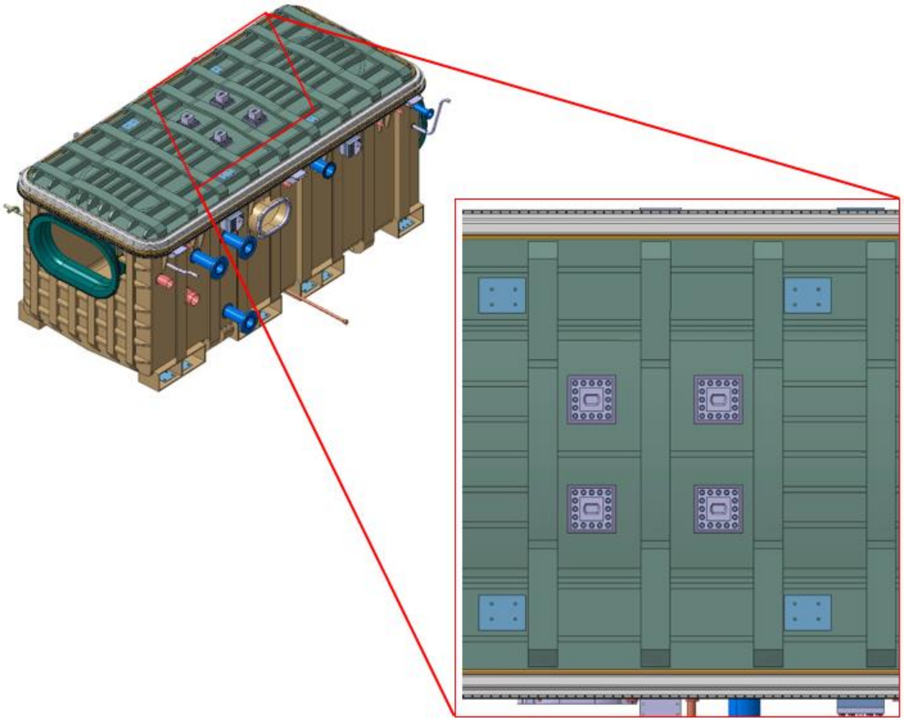

Figure 16: Lifting features for the DNB Vessel lifting

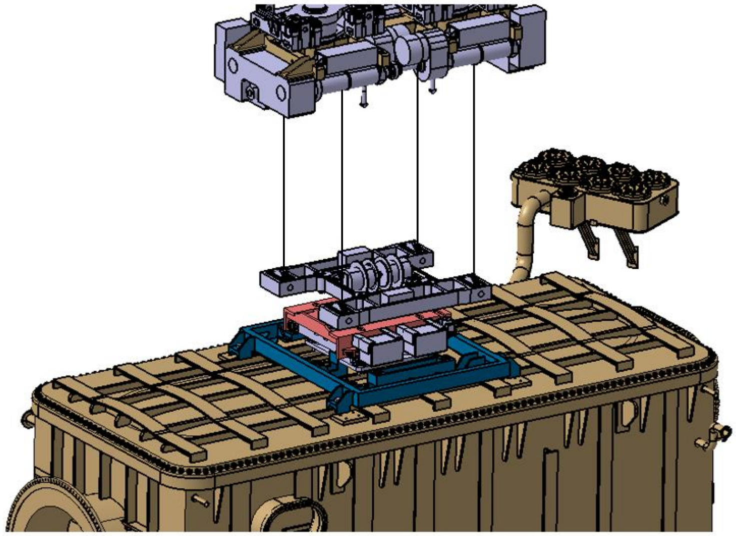

Figure 17: Top Lid lifting with generic adaptor and lifting crane (Illustration purpose only)

10 Interface Description

DNB Vessel has internal and external interfaces with the internal and external components as detailed in following sections.

10.1 High Voltage Bushing Interface

High voltage bushing is connected to back flange of vessel by means of bolted flange and metallic seal arrangement for vacuum sealing between vessel and bushing flange. The connection between HV Bushing and vessel forms a primary vacuum boundary.

The Flange assembly is designed to comply with the RH requirements, considering the aspect of Remote handling bolting and unbolting tools. Flange also has the bolted rail structure to provide the path for carriage movement. The interface between HVB and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2LUMWW).

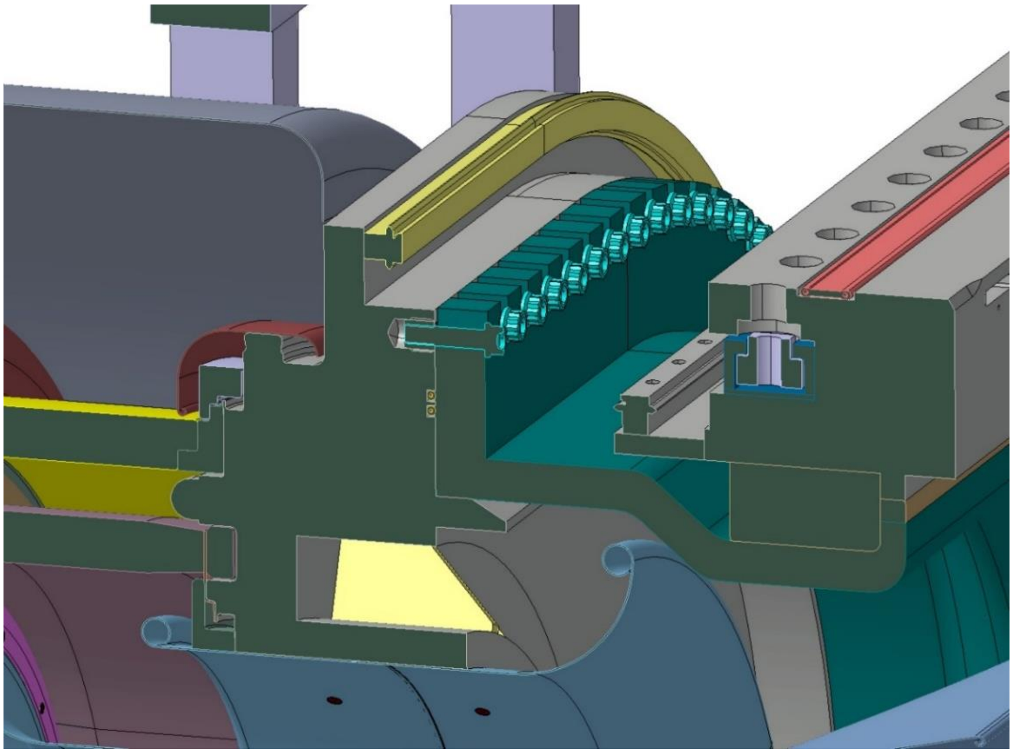

Figure 18: High Voltage Bushing Interface with metallic seal and bolting arrangement

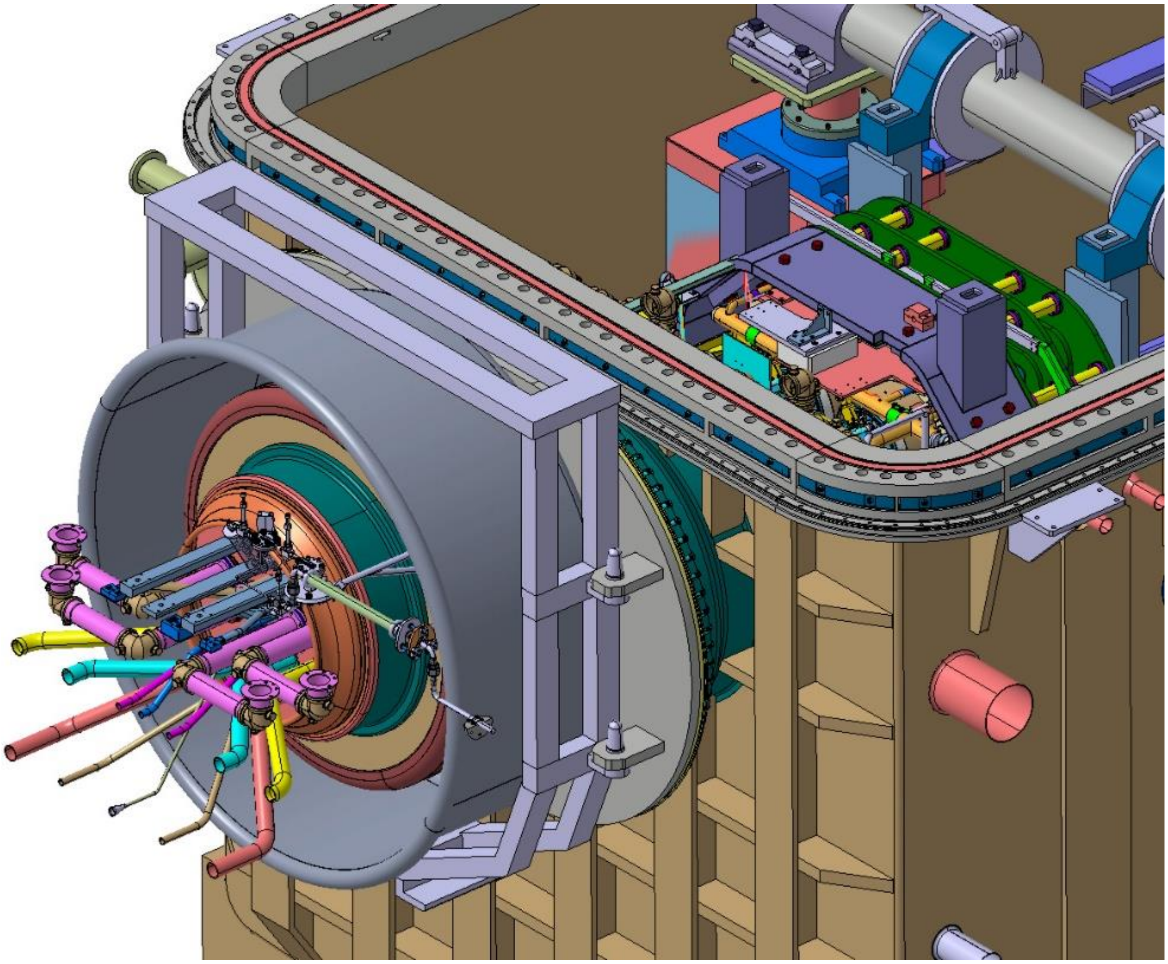

Figure 19: HVB assembly with DNB vessel

10.2 Beam Source Interface

The Beam Source is supported on the L-Shaped beam, which also works as a mechanism for the movement of beam source in lateral direction and rotational movements. The L-Beam is supported on the side walls of the DNB vessel by lateral mounting brackets which are welded to the vessel side walls as shown in fig. 22. The support bracket shall be taking the weight of the beam source and frictional forces imposed by the beam source movement requirements. Positioning system uses two actuators: one for Y translation, the second for Z rotation. The forces generated on the screw are transmitted to the vessel through the screw support.

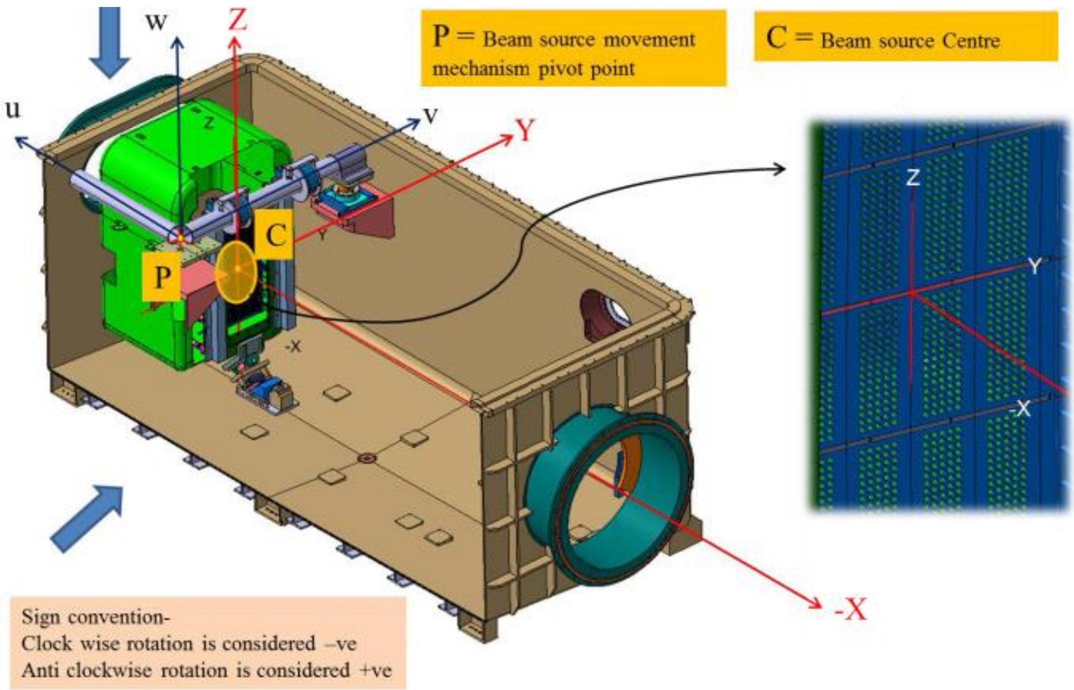

Figure 20: Beam source movement mechanism

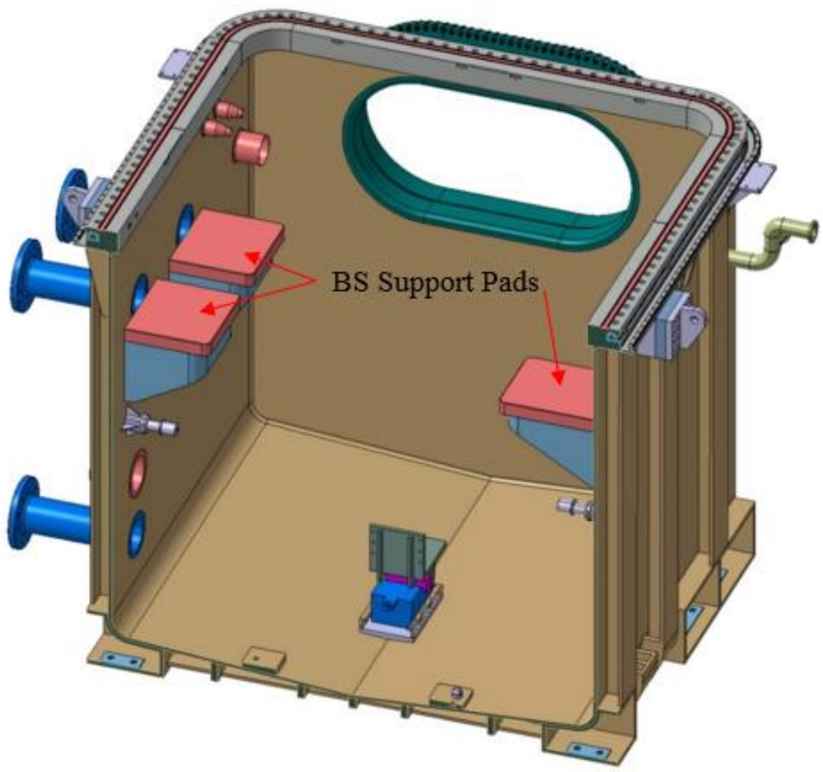

Figure 21: Beam source support pads

The horizontal and translation movement is provided by means of actuators provided on the vessel side wall. Actuator feedthroughs are welded with the vessel wall and as the connection of feedthroughs with vessel forms the primary vacuum boundary, a 'full penetration butt welded' configuration (as shown in fig. 23) has been considered to ensure the 100% volumetric examination. The actuators will be bolted to double-metal O-ring flanges with an interspace monitored by the Service Vacuum System. Similar kind of flange has been provided for actuator of tilting mechanism at the bottom of side wall. The actuation forces generated by the actuators during translation, rotation and tilting movement will be taken by the feedthrough welded on the vessel wall. They have been calculated for various cases as described in "DNB Beam Source Load Sharing and Reaction Force Calculation". The Horizontal and translation actuators will control the position of the Beam Source in various condition. The interface between BS and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2NN82C).

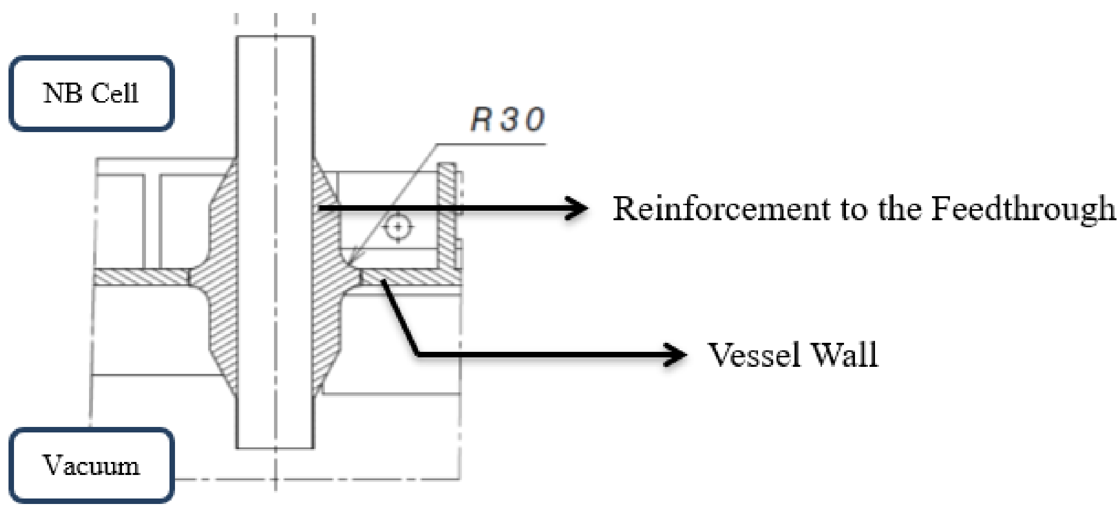

Figure 22: Full Penetration butt weld configuration

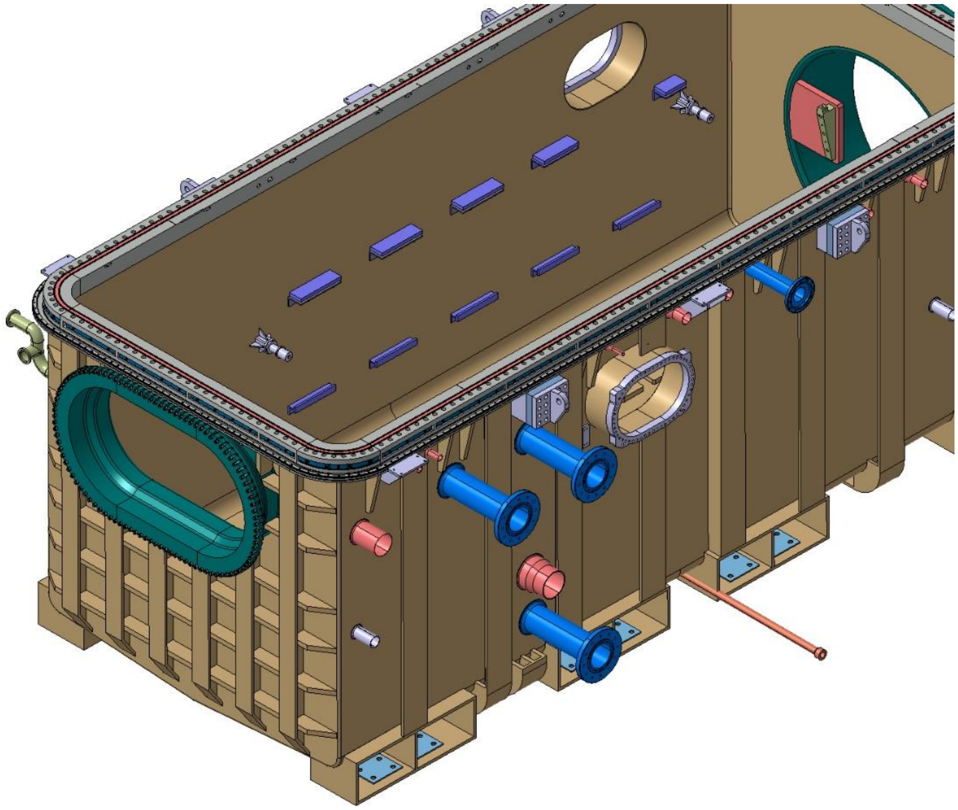

Figure 23: Beam source interface for actuators flanges

Grounded grid hydraulic lines feedthroughs have been provided on the side wall of the vessel. The feedthrough design is based on the recommendation from the RCC-MR code to have gradual transition of thickness and to meet the full penetration requirements of vacuum boundary joints. As this hydraulic feedthrough forms the primary vacuum boundary, it interfaces with vessel as ‘full penetration butt welded’ configuration to ensure the 100% volumetric examination. At the time of RH maintenance, the pipe which connects to the respective component will be cut / welded by RH cutting / welding tools. Space reservation in vessel for the same has been provided in vessel in compliance with the RH interface sheets.

The pipe will be connecting to the NBI PHTS as an external interface. These external joints to the PHTS are never expected to be disturbed once it is welded at the time of initial installation so there are no Remote Handling considerations for these joints. The pipes are long enough to be outside of the PMS when this is installed, as the PHTS cooling pipework will be jointed to these vessel feedthroughs after the PMS is completed around the vessel.

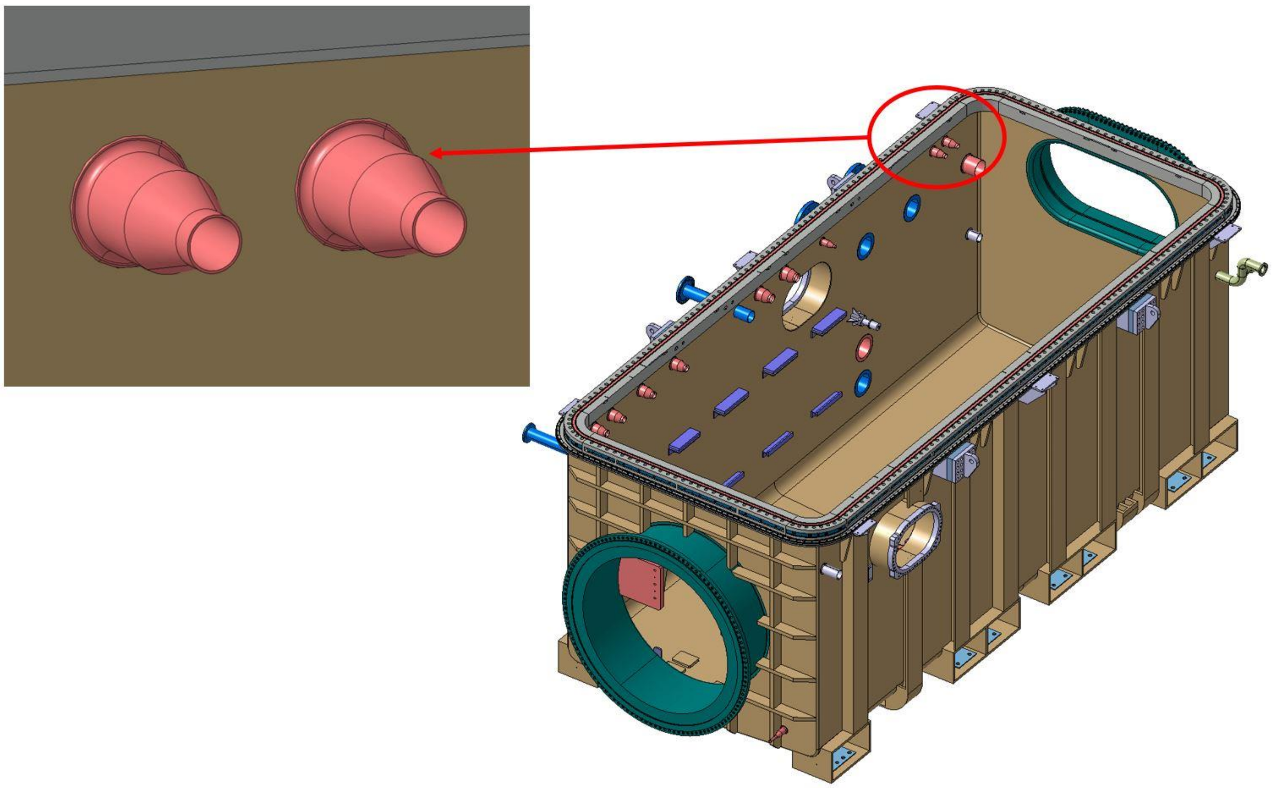

Figure 24: Ground grid PHTS feedthrough connections

10.3 PMS Interface

The DNB vessel is made of non-magnetic material (SS 304L) and is surrounded by the Passive Magnetic Shield (PMS) and Active Correction Compensation Coils (ACCC). ASTM A 36 (Low carbon structural steel) is selected as a construction material for PMS.

The bolting interface between the PMS and the vessel supports the weight of the vessel and the internal Components. This interface is designed to retain the vessel in the event of seismic forces. The interface will locate the vessel on the PMS, allows the flexibility for correct alignment and are of sufficient size to allow for the possible forces of vacuum and mechanical loads in the X axis. The interface between PMS and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2ME5U5).

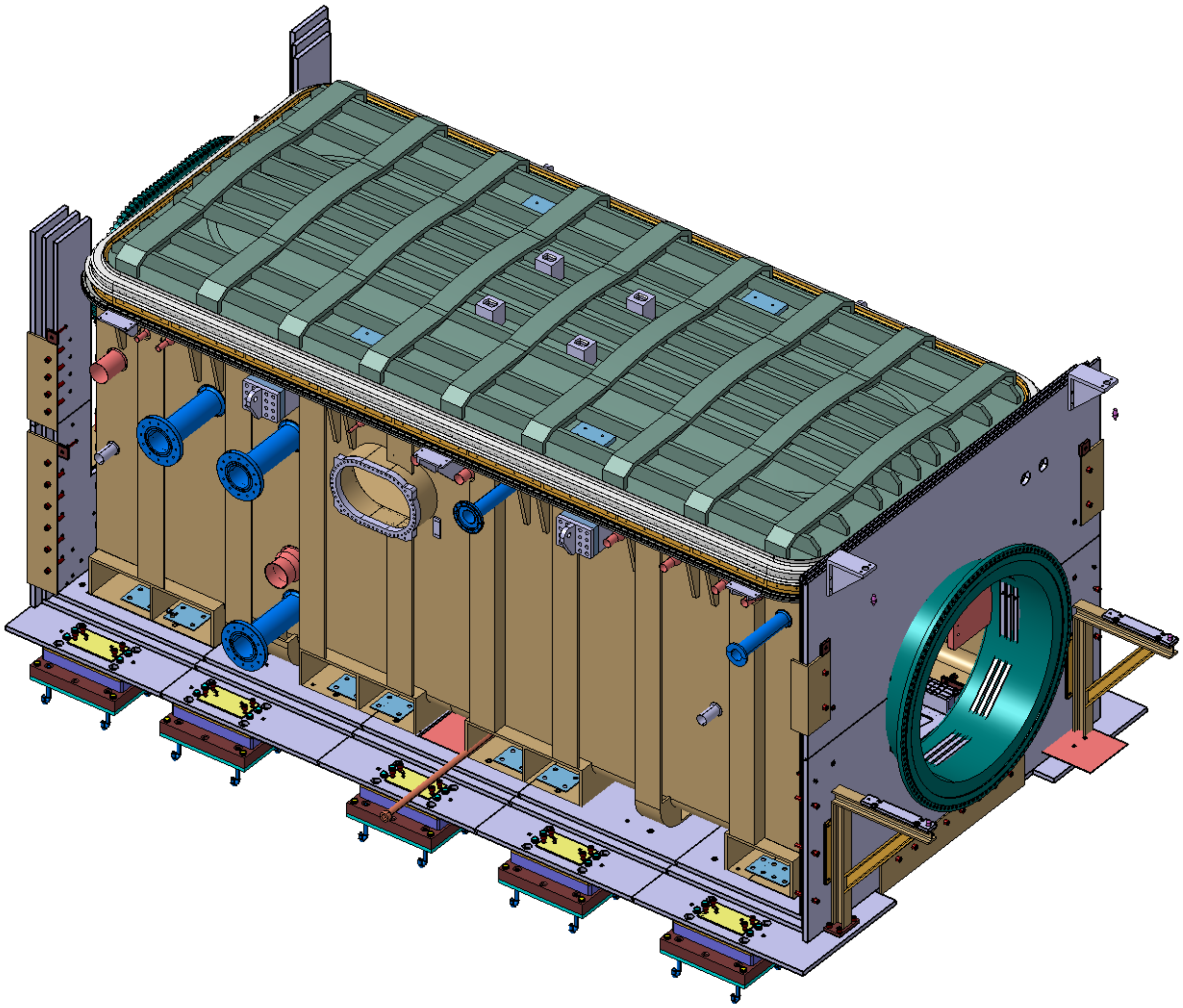

Figure 25: PMS assembly with DNB Vessel

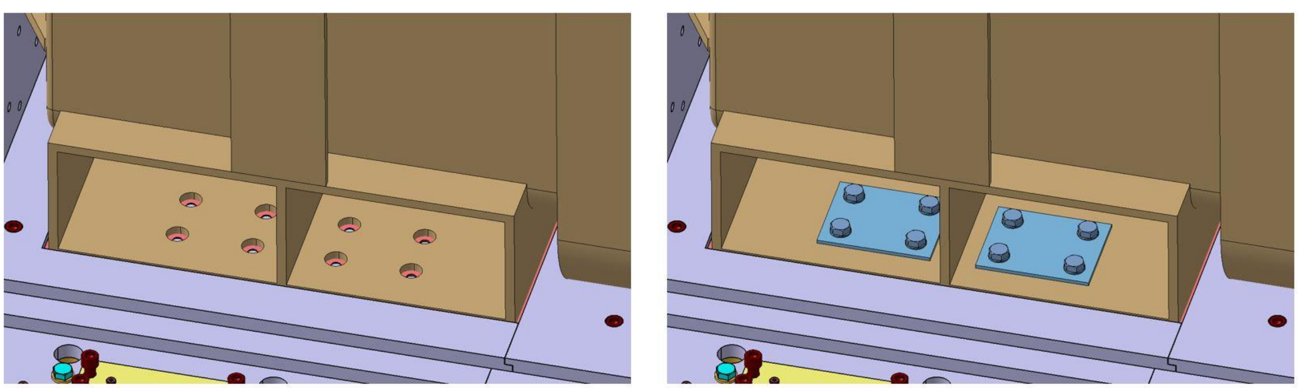

Figure 26: Bolting arrangement between PMS and DNB vessel

10.4 Fast Shutter Interface

The DNB vessel is connected to the Vacuum Vessel (VV) through the NB front end components. The Fast Shutter is mounted on the front flange of the vessel and loads partial weight on the vessel flange. The fast shutter is partially supported by absolute valve at another end.

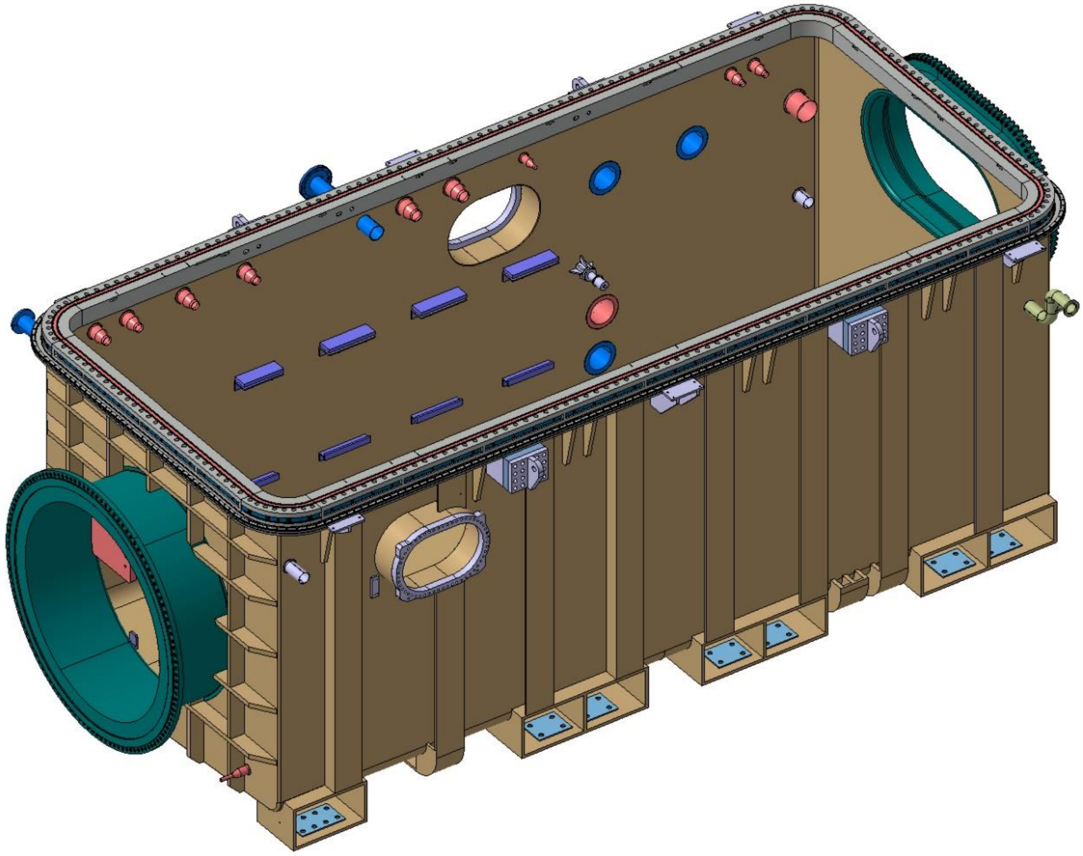

Figure 27: DNB vessel flange for fast shutter connection

The design of this interface has been carried out considering the assembly constraints (positioning, welding, and bolting) and the feasibility of the maintenance scenario with realistic RH tools design. Basically, it is a large circular flange of 304L stainless Steel, 50 mm thick. Inconel 718, 120 X M20 bi-hex bolts have been selected for flanges design. Removable aluminium bronze insert is used in the flange to prevent galling between the Inconel 718 bolt and the stainless flange. The sealing solution implemented is a double metallic seal with a monitored interspace connected to the Service Vacuum System.

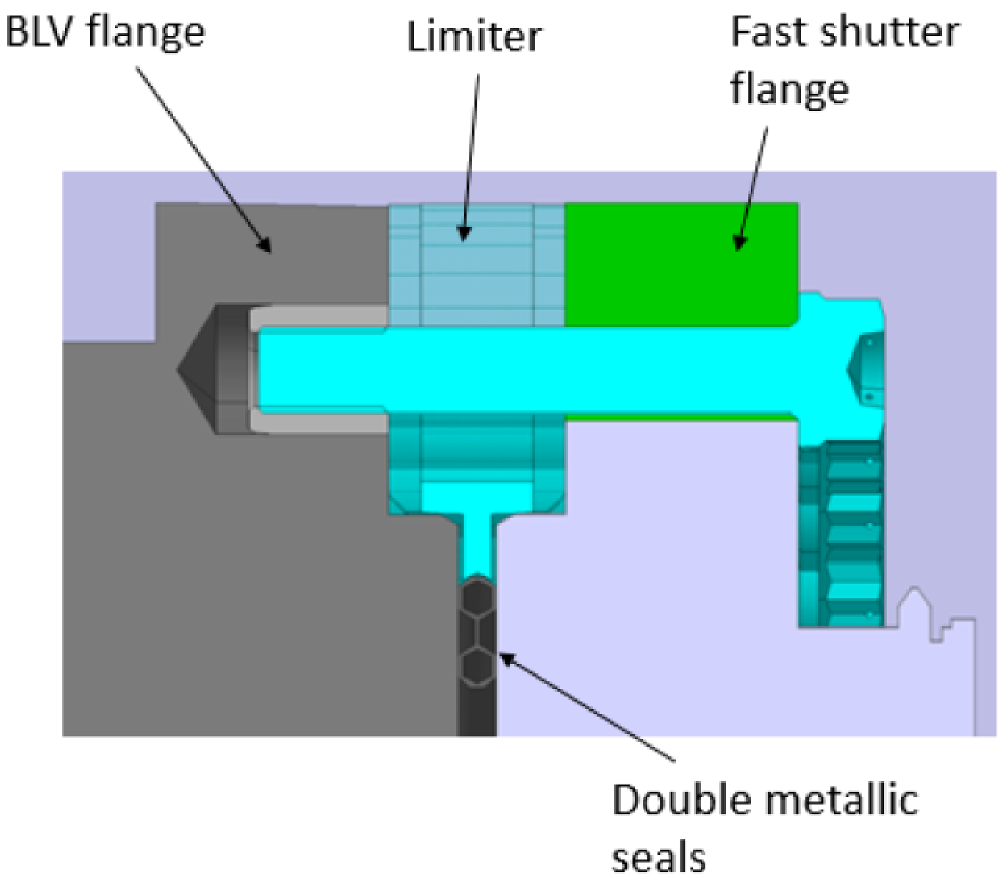

Figure 28: Integration of metallic seal solution between FEC flange

The confinement at this interface must be in compliance with the ITER vacuum requirements and indeed the safety requirements. The Fast Shutter flange diameter (Ø2670mm) corresponds to the type 2 solution; 120 bolts M20. The minimum torque of the bolts shall be 483N.m to ensure the reliability of the metallic seals leak tightness.
The solution developed in collaboration of TECHNETICS is a double HELICOFLEX HN229 mounted on a limiter or seat ring. The FEC consist of three different diameters with a number of bolts associated defined to permit a full efficiency of the sealing. The integration of the seals with the limiter has been finalized in the drawing TECHNECTICS 111-0214207

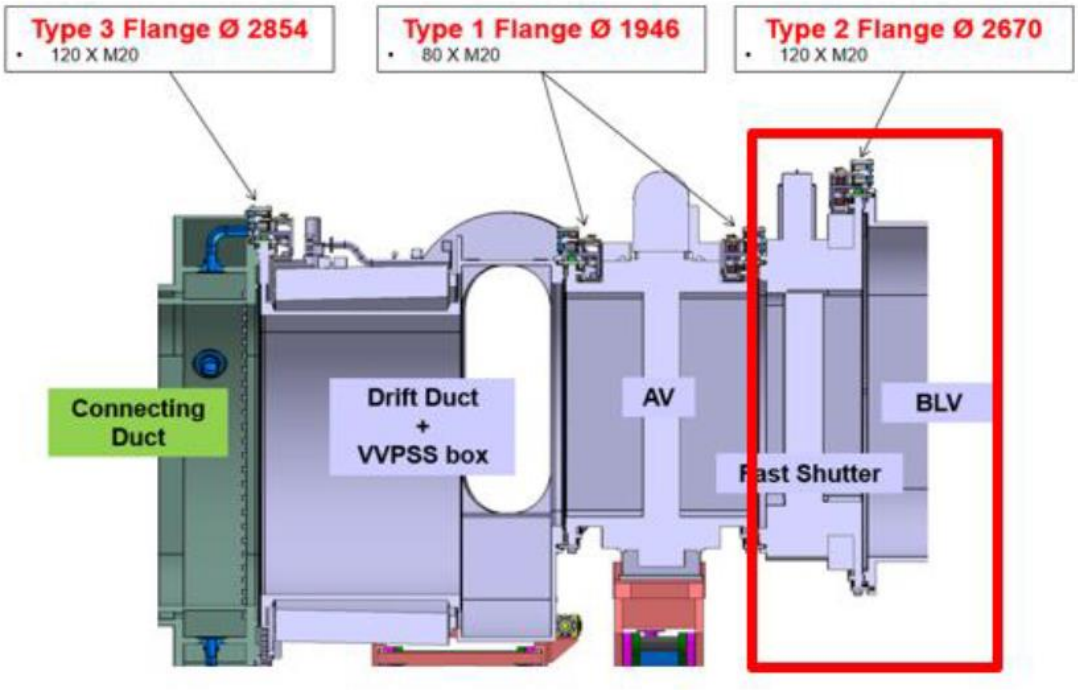

Figure 29: Metallic seal integration of NB FEC

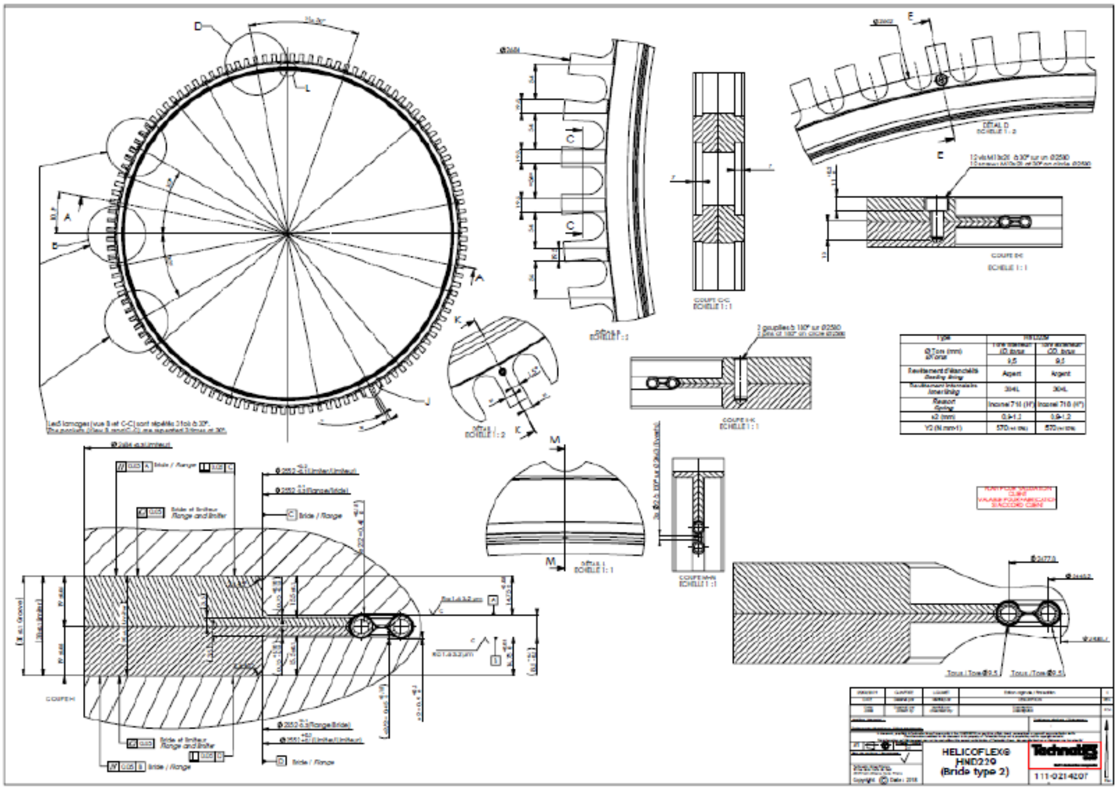

Figure 30: Bolting arrangement for FS (120 M20)

The load acting on the fast shutter is the combination of the different loads coming from the FEC (from DD bellow until FS). It is mainly generated by:

- The spring effect of the DD bellow combined with the VV displacements (thermal expansion)
- The pressure acting on the different surfaces of the components (VV, DNB, NB cell pressures).

The connection details for the fast shutter is shown in https://user.iter.org/default.aspx?uid=UX5WHX and interface between FS and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2NDUF6).

Before the assembly of the Fast Shutter and during Workshop vacuum testing and transportation, the DNB FS interface will be closed by a blank flange which has been analyzed to withstand the loads accordingly. The sealing of this Blanking flange will be done with Viton Seals.

10.5 Interface with Beam Line Components (BLCs)

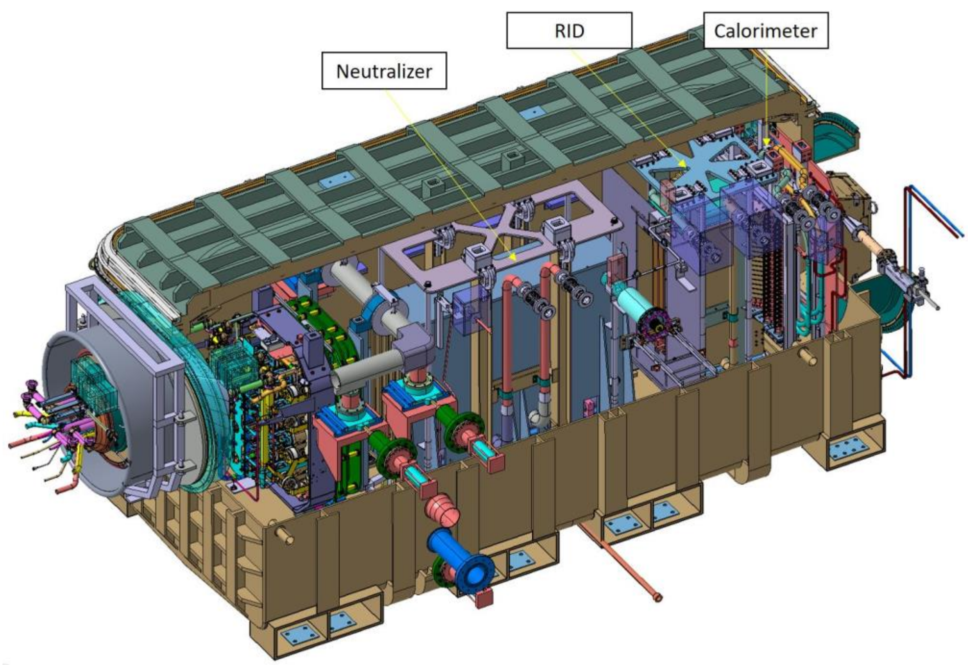

Figure 31: Beam line components inside DNB Vessel

The Beam Line Components (Neutralizer, RID and Calorimeter) are mounted on a combined adjustable bed that interface with pads on the floor of the DNB vessel. There are designated sets of pads for each of the components

This interface is in form of co-planar pad with the provision of dowel and bolting across this plane for ensuring the correct alignment of BLCs under normal operation and at the time of seismic event. As shown in fig 31, DNB vessel has 12 no. of welded pads on the bottom plate for mounting the combined alignment mechanism (CAM). CAM is connected to the vessel bottom plate pads with the help of 4 Nos. of M36 Bolts, there will be through hole in Alignment system & corresponding threaded hole in the vessel pads. Out of 4 pads, 2 diagonally located pads has dowel hole for alignment of bed on the pad. The remaining pads on the vessel plate will work as load sharing member for the distributed weight of combined alignment mechanism and beam line components. Each BLC has four contact points with the combined alignment mechanism.

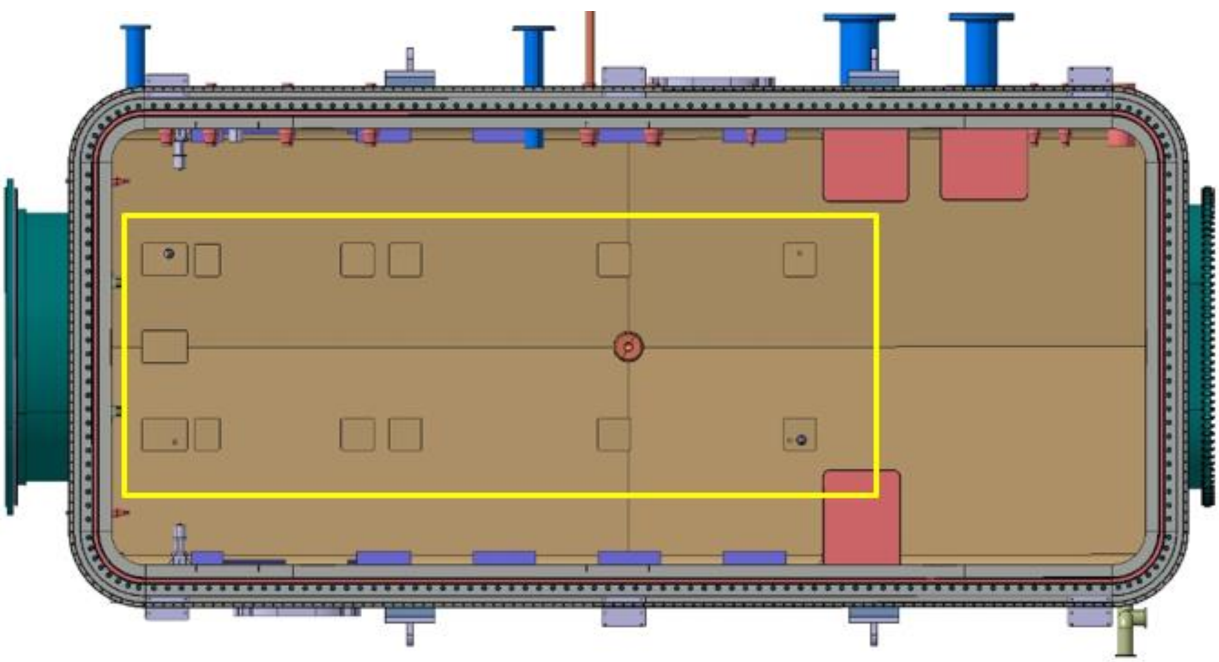

Figure 32: Supporting location for Beam Line components

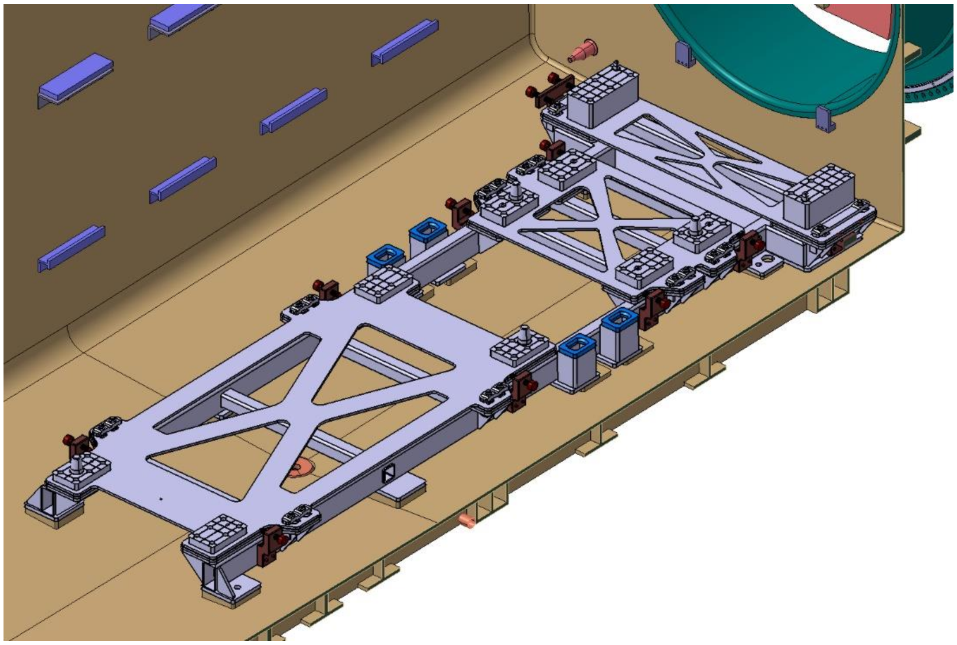

Figure 33: Combined Alignment mechanism interface with DNB Vessel

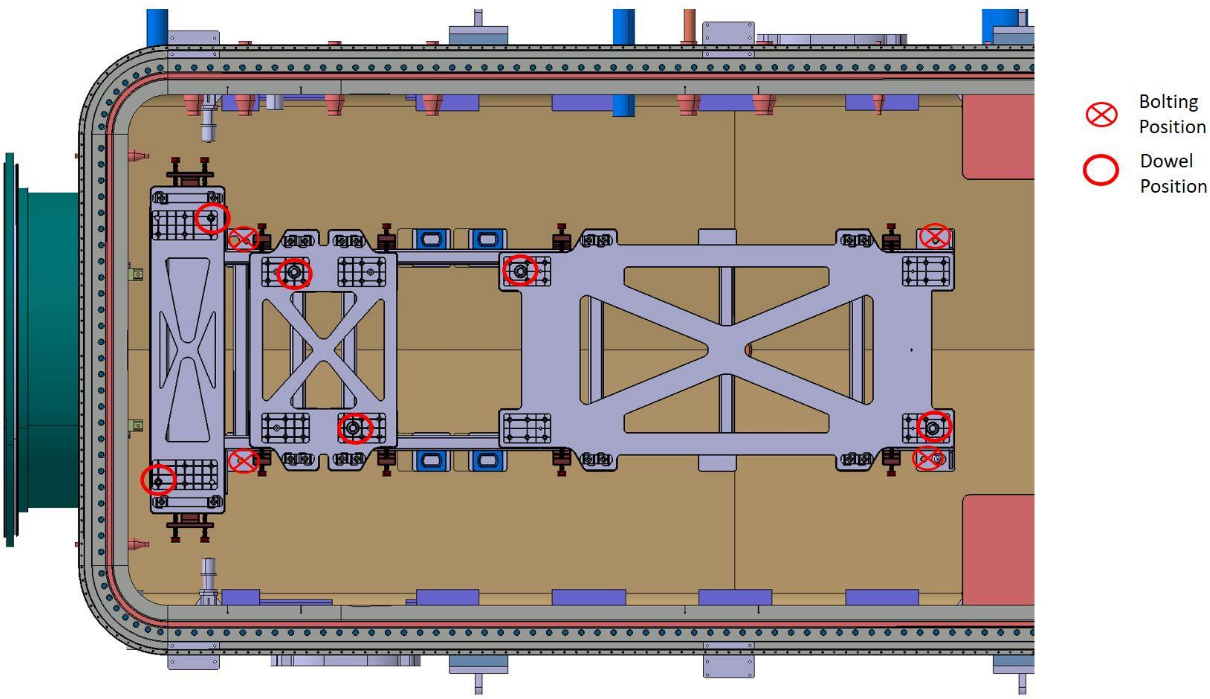

Figure 34: Bolting and dowel position for combined alignment mechanism

10.5.1 Neutraliser (NED) Interfaces

The following interfaces of the NED are identified with the Vessel:

- Adjustable bed / pad support
- Inlet / outlet cooling feedthroughs
- Neutralizer gas supply

The NED panels are supported the structure consisting mainly of the Side Plates and of the Wall Spacers. The Support Structure integrates the RH lifting frame and lugs for the NED lifting/lowering. The NED pads at the Support Structure are interfaced with the Adjustable Bed that allows the NED position adjustment after positioning in the Beam Line Vessel by means of RH crane.

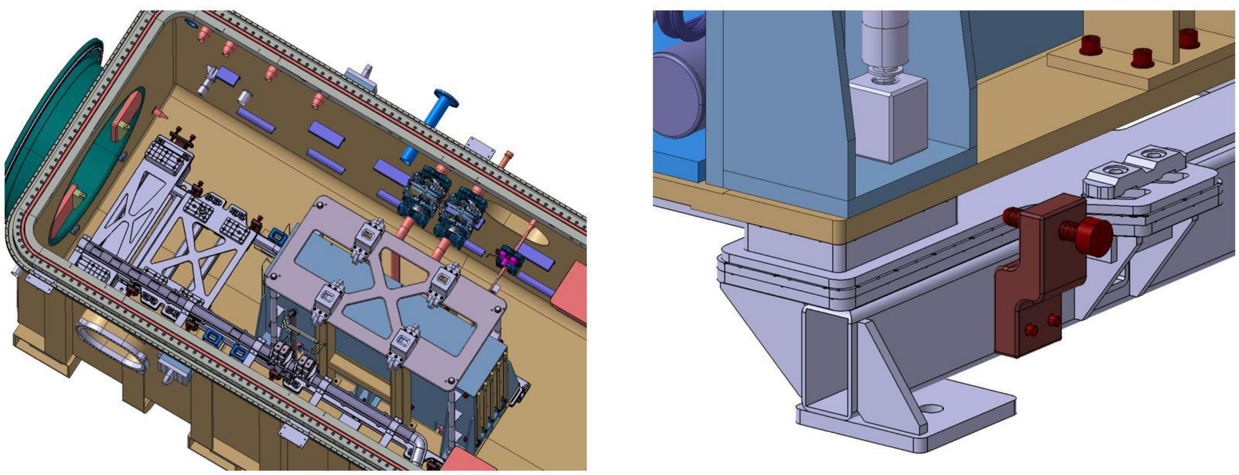

Figure 35: Assembly of NEU inside DNB Vessel and connection with alignment mechanism

Neutraliser hydraulic lines feedthroughs have been provided on the side wall of the vessel. The feedthrough design is based on the recommendation from the RCC-MR code to have gradual transition of thickness and to meet the design requirements of vacuum boundary joints. As this hydraulic and gas feedthrough forms the primary vacuum boundary, it interfaces with vessel as 'full penetration butt welded' configuration to ensure the 100% volumetric examination.

These lines will be welded to the lines coming from the neutraliser inside the vessel, in 'full penetration butt weld' configuration. Space reservation is provided inside the vessel for cutting / welding of these pipes during RH Maintenance.

The pipe will be connecting to the NBI PHTS as an external interface by full penetration butt welding configuration. These external joints to the PHTS are never expected to be disturbed once it is welded at the time of initial installation so there are no Remote Handling considerations for these joints. The pipes are long enough to be outside of the PMS when this is installed, as the PHTS cooling pipework will be jointed to these vessel feedthroughs after the PMS is completed around the vessel.

Also, these feedthroughs must remain leak tight during the SL-2 event. The Neutralizer requires DN 100 schedule 10S penetrations in the vessel.

A similar penetration is provided to supply gas hydrogen into the Neutralizer for the neutralization of the Beam. The gas is fed by gas feeding lines interfaced with the Gas Injection System (GIS) at the ex-vessel side. The interface between NEU and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2M88S4).

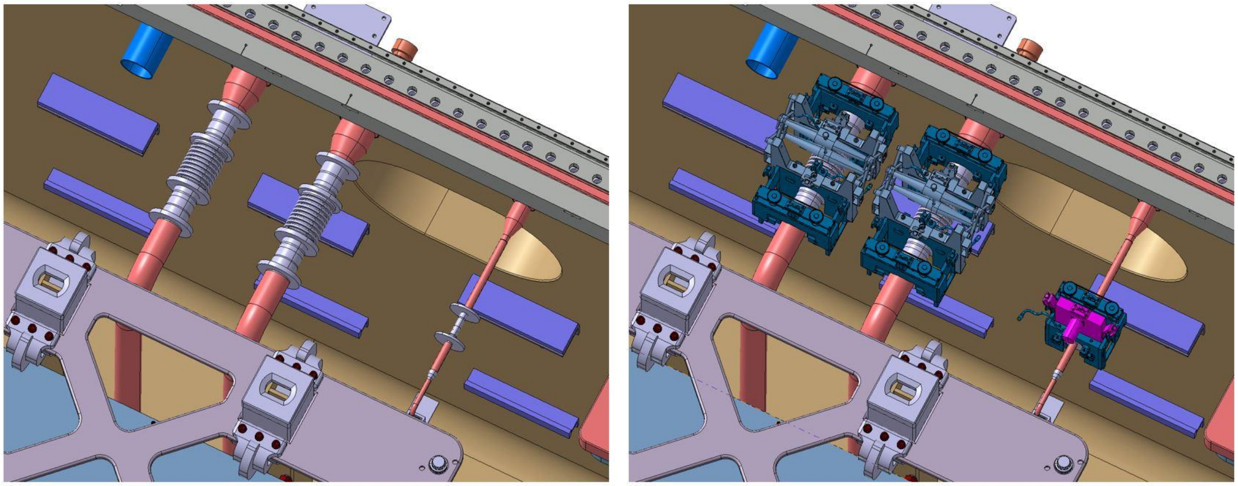

Figure 36: PHTS and gas feed connections and RH tool interface for NEU

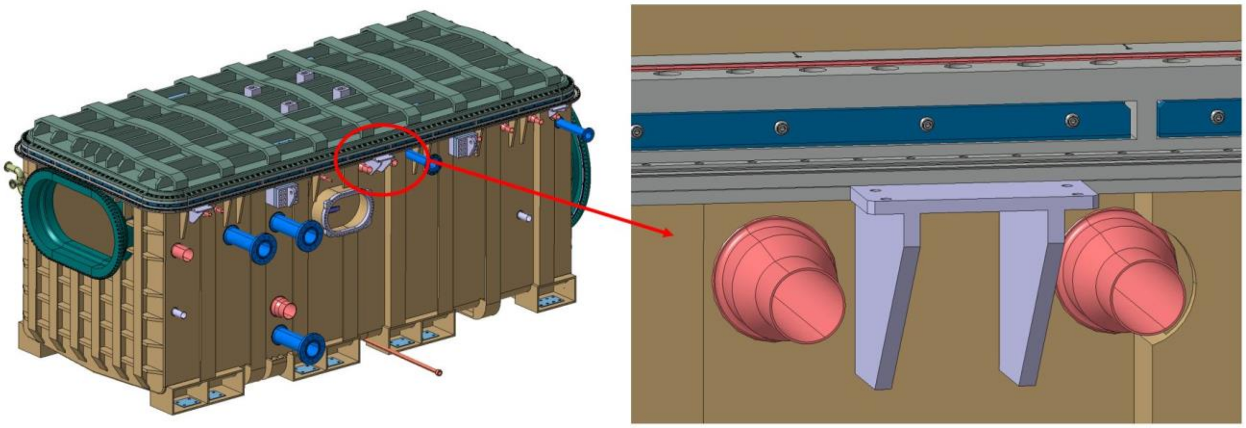

Figure 37: Hydraulic feedthroughs connection with vessel

10.5.2 Residual Ion Dump (RID)

The following interfaces of the RID are identified with the Vessel:

- Adjustable bed / pad support
- Inlet / outlet cooling feedthroughs
- RID HV feedthrough

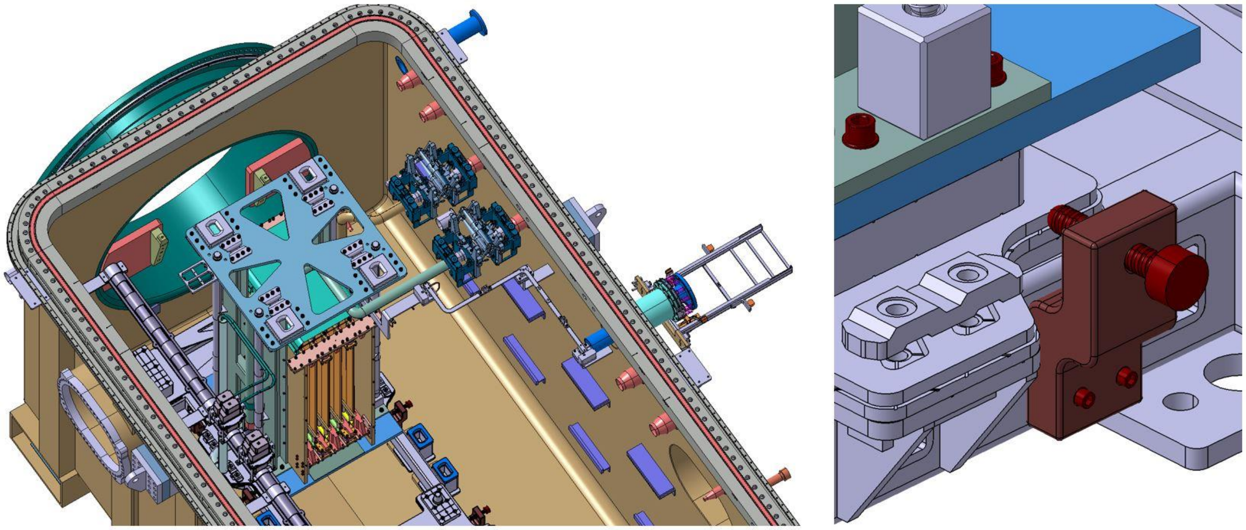

Figure 38: Assembly of RID inside DNB Vessel and connection with alignment mechanism

RID hydraulic lines feedthroughs have been provided on the side wall of the vessel. The feedthrough design is based on the recommendation from the RCC-MR code to have gradual transition of thickness and to meet the design requirements of vacuum boundary joints. As this hydraulic feedthrough forms the primary vacuum boundary, it interfaces with vessel as ‘full penetration butt welded’ configuration to ensure the 100% volumetric examination.

These lines will be welded to the lines coming from the RID inside the vessel, in ‘full penetration butt weld’ configuration. Space reservation is provided inside the vessel for cutting / welding of these pipes during RH Maintenance.

The pipe will be connecting to the NBI PHTS as an external interface by full penetration butt welding configuration. These external joints to the PHTS are never expected to be disturbed once it is welded at the time of initial installation so there are no Remote Handling considerations for these joints. The pipes are long enough to be outside of the PMS when this is installed, as the PHTS cooling pipework will be jointed to these vessel feedthroughs after the PMS is completed around the vessel.

Also, these feedthroughs must remain leak tight during the SL-2 event.

Pipe size: DN80 SCH 10S

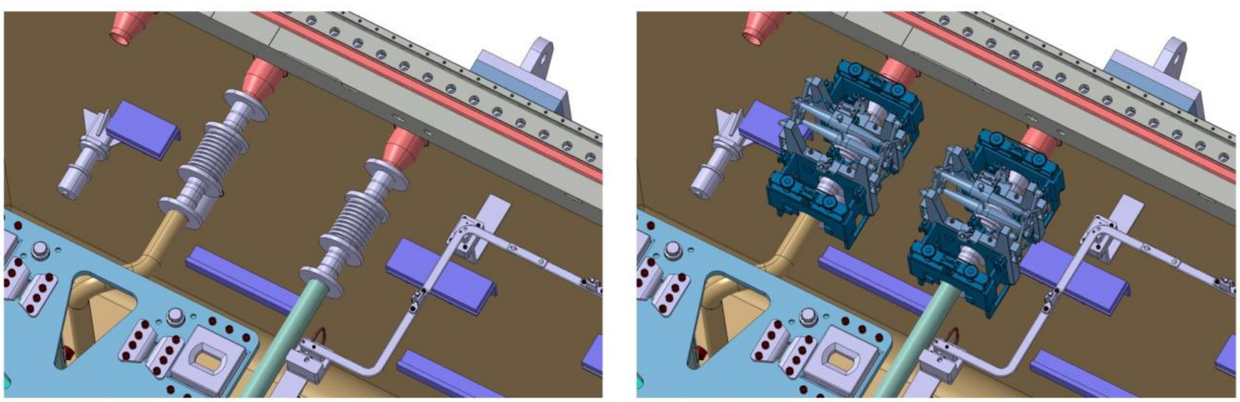

Figure 39: PHTS and HV connections and RH tool interface for RID

The Electrostatic Residual Ion Dump (ERID), requires a High-Voltage feed 12 kV to enable application of the desired voltage and allow for the separation of the un-neutralized particles from the beam onto the ERID plates. The interface of the ERID to HV power supply is established through feedthrough which is required to pass through the wall of the vessel. The design of this Feedthrough is a significant task as it has to avoid issues of voltage tracking and breakdown from high-voltage to ground when there is low pressure gas present in the vessel.

The Feedthrough as a sub assembly is fitted to a flange on a spigot in the wall of the vessel using metal seals and a ring of bolts. This is a part of the Primary Vacuum Boundary of the DNB system. The sealing between the vessel Feedthrough and the HV component is by standard double-metal O-ring with interspace monitoring by the Vacuum Group Service Vacuum System. The design parameters of the interface are to DN 250 standard ITER flange. The interface between RID and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2LDFPT).

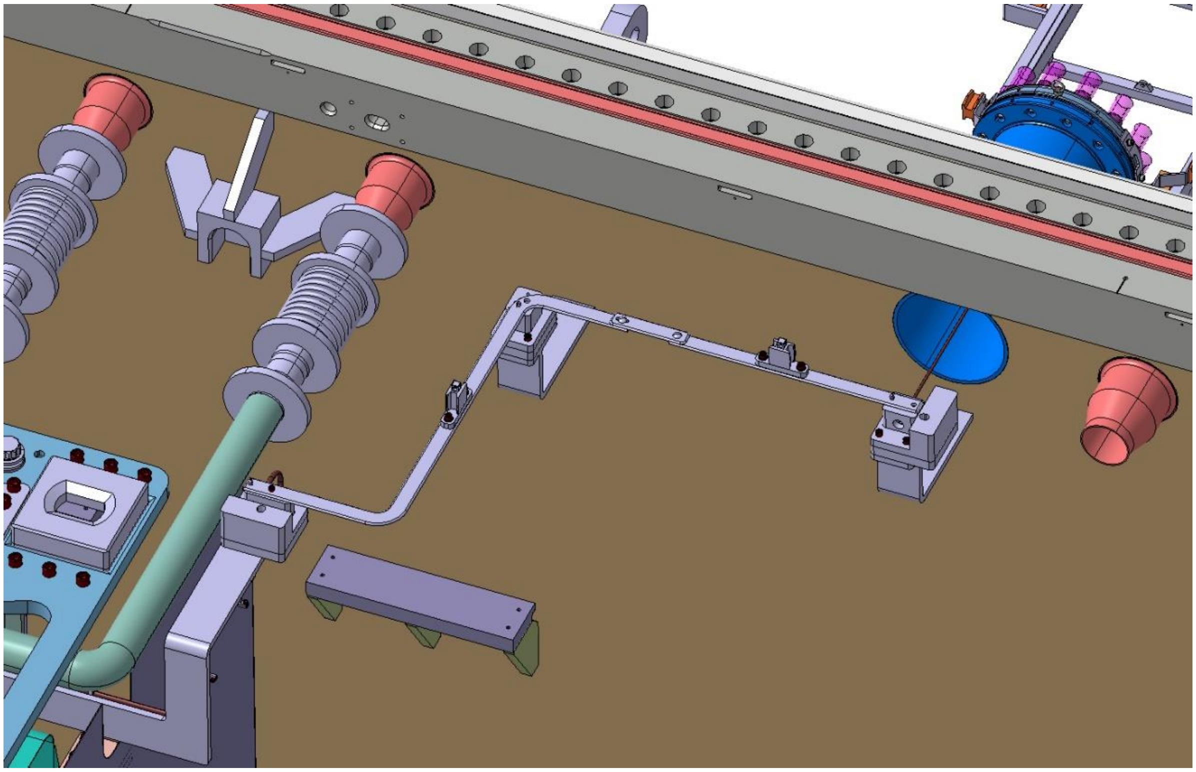

Figure 40: High voltage bushing connections inside the vessel

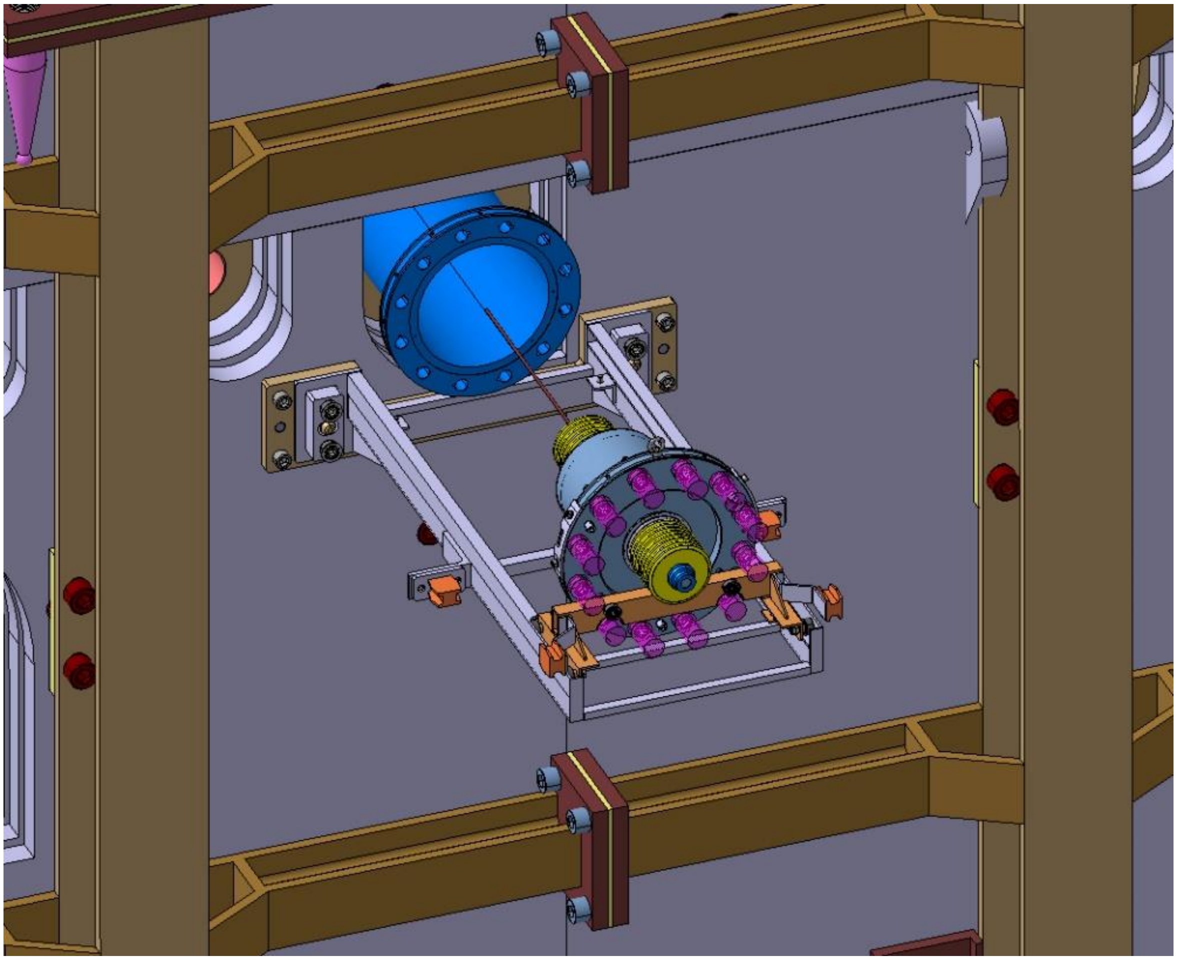

Figure 41: High voltage bushing connections outside the vessel

10.5.3 Calorimeter Interfaces

The following interfaces of the Calorimeter are identified with the Vessel:

- Adjustable bed / pad support
- Inlet / outlet cooling feedthroughs
- Calorimeter actuation

The calorimeter pads at the support structure are interfaced with the Adjustable Bed that allows the calorimeter position adjustment after positioning in the vessel by means of RH crane.

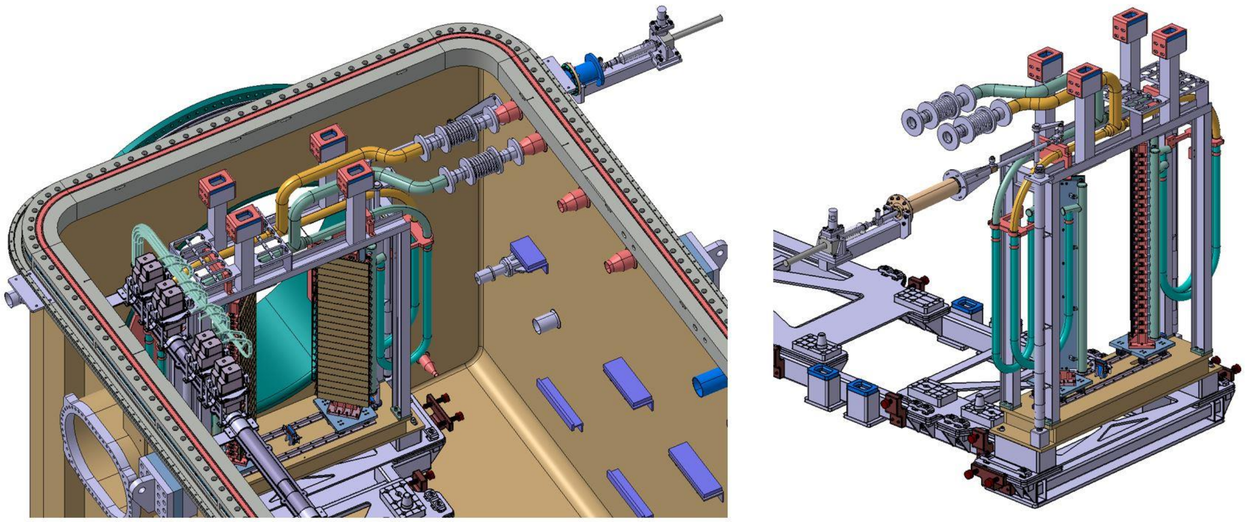

Figure 42: Calorimeter assembly inside the vessel with combined alignment mechanism

Calorimeter hydraulic lines feedthroughs have been provided on the side wall of the vessel. The feedthrough design is based on the recommendation from the RCC-MR code to have gradual transition of thickness and to meet the design requirements of vacuum boundary joints. As this hydraulic feedthrough forms the primary vacuum boundary, it interfaces with vessel as 'full penetration butt welded' configuration to ensure the 100% volumetric examination.

These lines will be welded to the lines coming from the calorimeter inside the vessel, in 'full penetration butt weld' configuration. Space reservation is provided inside the vessel for cutting / welding of these pipes during RH Maintenance.

The pipe will be connecting to the NBI PHTS as an external interface by full penetration butt welding configuration. These external joints to the PHTS are never expected to be disturbed once it is welded at the time of initial installation so there are no Remote Handling considerations for these joints. The pipes are long enough to be outside of the PMS when this is installed, as the PHTS cooling pipework will be jointed to these vessel feedthroughs after the PMS is completed around the vessel.

Also, these feedthroughs must remain leak tight during the SL-2 event.

Pipe size: DN80 SCH 10S

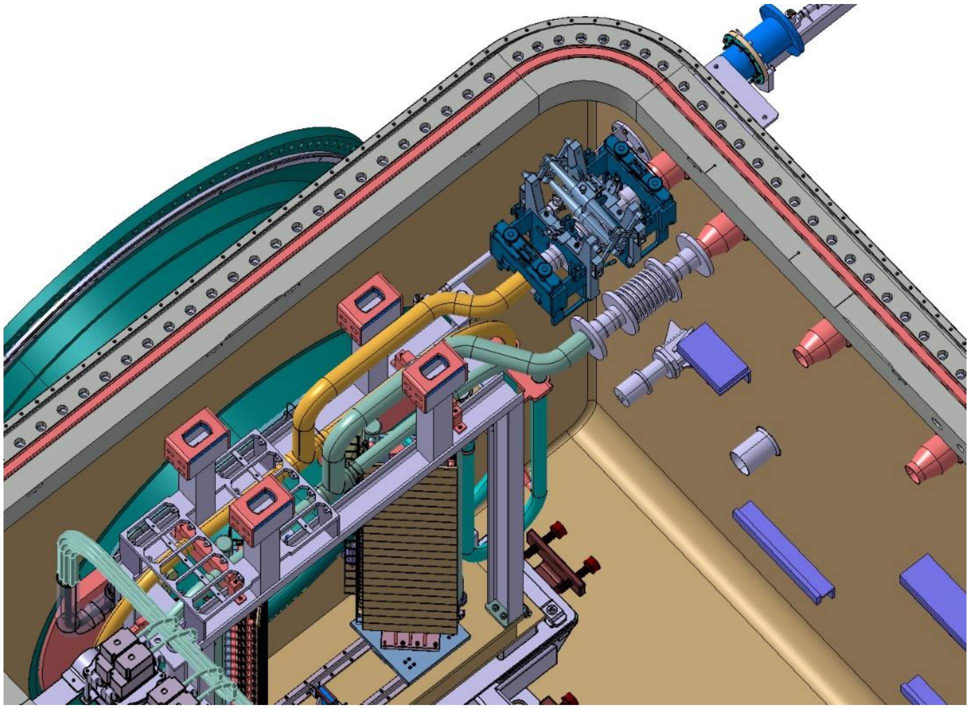

Figure 43: PHTS connections and RH tool interface for calorimeter

The arms of the calorimeter are opened for during beam transport to the tokamak and closed for operation when the calorimeter is used to measure the neutral beam heating power. The actuation of the of the calorimeter arm is achieved by an external actuator to the vessel and a Feedthrough with bellows is included to allow for the actuation movement.

The actuator is mounted on the vessel and extends outwards though the Passive Magnetic Shield (PMS). The actuation mechanism moves the arms between the opening and closing positions. It comprises a rotary air motor driving a screw-jack via a worm gear drive, to produce linear motion of an actuator shaft – these parts are all external to the beamline vessel. The linear motion of the shaft is transferred into the vessel via a replaceable bellows unit, with a double edge-welded bellows arrangement to provide an inter-space for connection to the Service Vacuum System. The interface between calorimeter and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=2LM9PA).

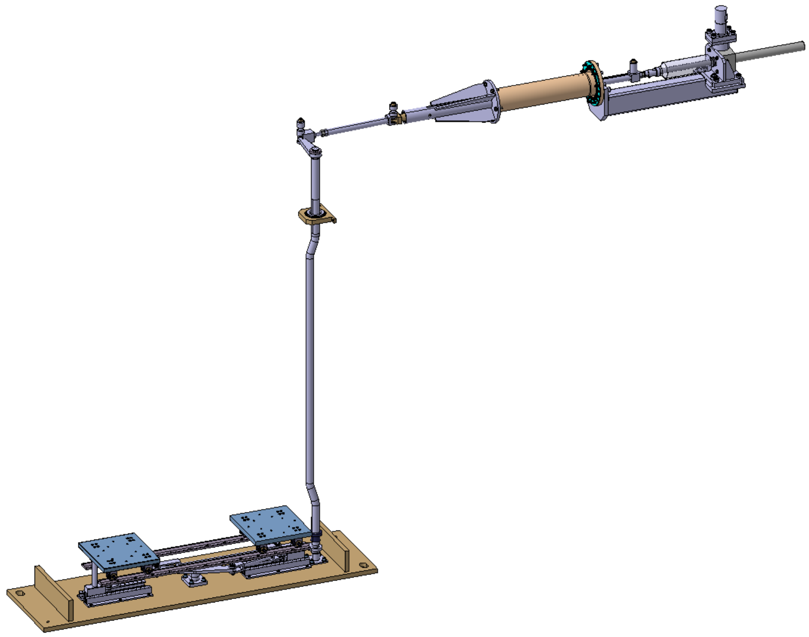

Figure 44: Calorimeter actuator mechanism

There is welded interface between the vessel wall feed through and the actuator nozzle and this will also take the reaction forces generated from the actuation mechanism. Internally to the vessel, the guide and bearing maintain the straight line of the actuator pushrod as the action of the force has an off-set. This guide is mounted on the internal reinforcement ring of the vessel wall with bolts.

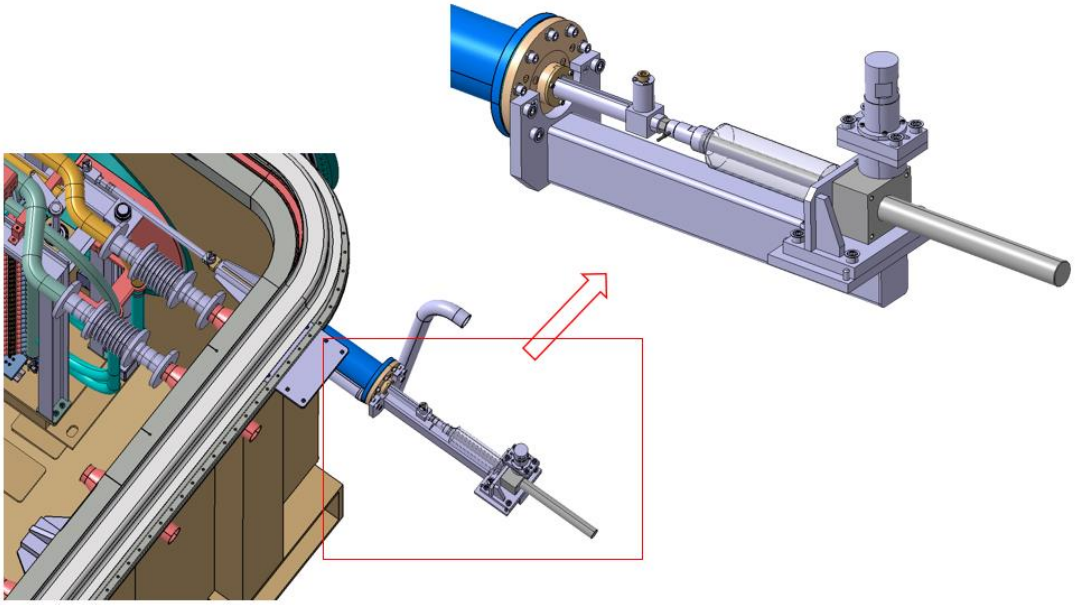

Figure 45: Calorimeter actuator assembly with DNB Vessel

10.6 Interface with Exit Scraper

The Exit Scraper is located inside the vessel. The main flange of ES is fastened using two RH compatible bolts and supported at the front wall of DNB vessel. The dead weight of ES is supported on the brackets of the vessel through a set of alignment plates. The Exit Scraper is required to be able to be removed for maintenance by using Remote Handling. The alignment plates help to align the ES in YZ plane. The verticality is ensured by pads to be fitted on the vessel during the first installation of ES [chapter 9 https://user.iter.org/?uid=WA9CKU]. The rotation of ES (due to its cantilever type installation and position of C.G) is restricted by two supports welded at the bottom of vessel's front wall plate. The interface will provide location to align the Exit Scraper in the beam line in all six degrees of freedom and be of sufficient strength to support the dead-weight of the Exit Scraper assembly. It will also be of sufficient strength to support the seismic forces on the mass of the Exit Scraper assembly. The interface between flanges are in compliance with remote handling requirements as to bolt torques and accessibility for the manipulator. The alignment brackets are of sufficient shape and strength to be used as alignment guides during Remote Handling installation of the Exit Scraper. The interface between ES and RH is shown in the interface document. (https://user.iter.org/default.aspx?uid=BG434N).

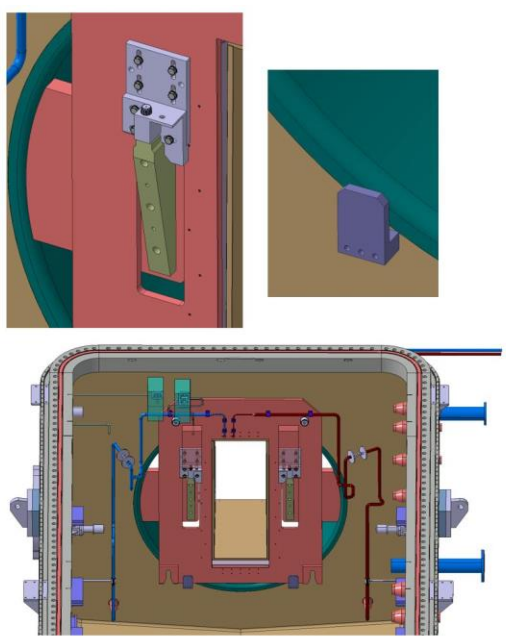

Figure 46: Exit Scraper Interfaces

10.7 Interface with Cryopump

DNB injectors require pumps with very high pumping speed (up to 4700 m3/s for H2). Therefore, two large Cryopumps (8 m long, 3 m high and 0.5 m depth) cooled by liquid nitrogen and helium are integrated in DNB vessel.

Vessel side wall supports the cryopanel on both sides which cryo-pumps the vessel volume before and during operation. The Cryopumps are installed during the first installation and will also be required to be removed for repair / maintenance by RH.

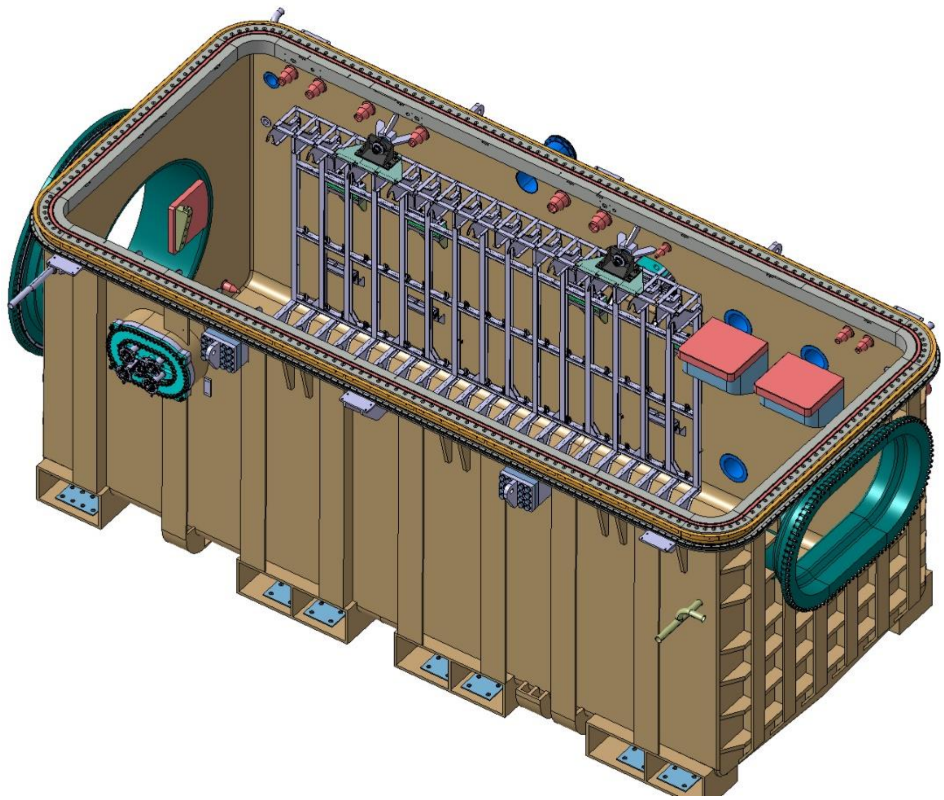

Figure 47: Cryopump assembly with DNB Vessel

Cryopumps and the vessel is part of the ITER primary vacuum system boundary barrier. It will be operated with Tritium and the sealing systems have a confinement function for the radioactive gas. Thus, the sealing connection is considered in term of safety in the highest category. The neutral beam operation and the presence of tritium in the vacuum chamber lead to the activation of the vacuum flange, therefore remote handling operations of this connection have been considered in the design. To control the risk of leakage, double seals are used between the primary vacuum and the atmosphere. The interspace is pumped by the ITER Service Vacuum System.

The cryo supply lines connections pass through the vessel wall through an oval shaped cryo-pump feed-through flange configuration. The sealing of this feed-through to the vessel flange will be by metallic seal and bolting to create the interface. The Cryopanel Cryogenics Connections supply-line Feedthrough is integral with its cryo-panel and so (like the Cryopanel) may need disconnection during the lifetime of ITER. Therefore, the detail design of this joint must comply with the Remote Handling requirements. The flange is set on the vessel wall such that the joint is inside the PMS outer wall but is accessible for Remote Handling without removal of the PMS wall section as there is a sufficiently large aperture through the PMS at this point on each side of the system.

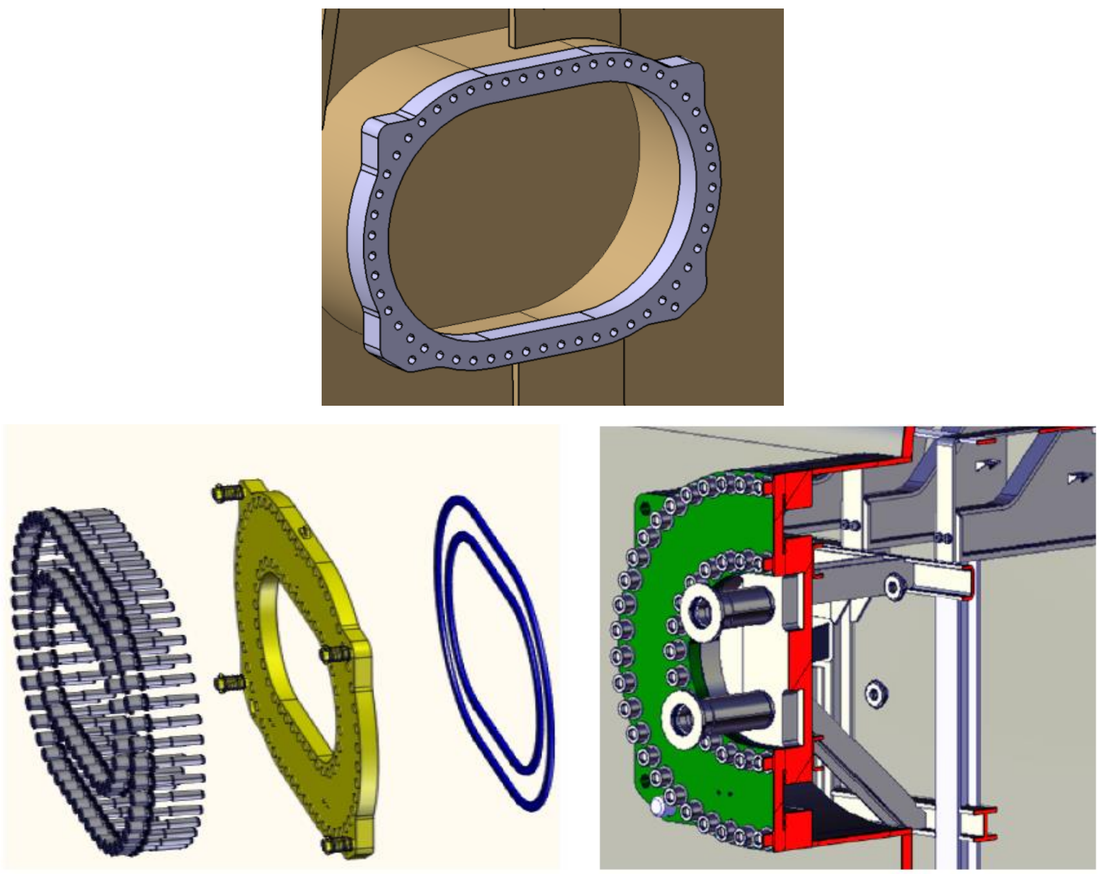

Figure 48: Cryolines flange on vessel and its assembly

The joint between the Cryopanels and the vessel are in two distinct and separate parts. The mechanical positioning and support are completed by the brackets and dowel pins inside the side wall of the vessel stretching almost the entire length of the vessel, and secondly there is a cryogen supply feed-through to each Cryopanel via an oval flange provided on the vessel on both sides.

The support interface consists of alignment dowels and supporting hook-brackets at the upper support and line-contact pressure brackets at the lower support. The support must also be adequate to support and align the Cryopanels under their dead-weight during Operations, and also during SL-1, SMHV and SL-2 seismic events without permanent set, damage or unseating from the mountings.

The Cryopanel supply port will be sealed as part of the Primary Vacuum Boundary utilizing the metallic seal and bolts. The cryogen connection interface consists of bolted and sealed flanges passing through the vacuum supporting wall of the vessel. The joint must be vacuum leak tight. The loading on the vessel feedthrough will be the weight of the Cryopanel Cryogenics Connections and vacuum. The flanged joint must maintain leak tightness even during an SL-2 seismic event. The Cryopanel are to be removed and fitted by Remote Handling. The crane fixture has been designed which seats upon the bracket provided at the level of top surface of vessel top flange. The interface between cryopump and DNB vessel is shown in (https://user.iter.org/default.aspx?uid=UVGSPA).

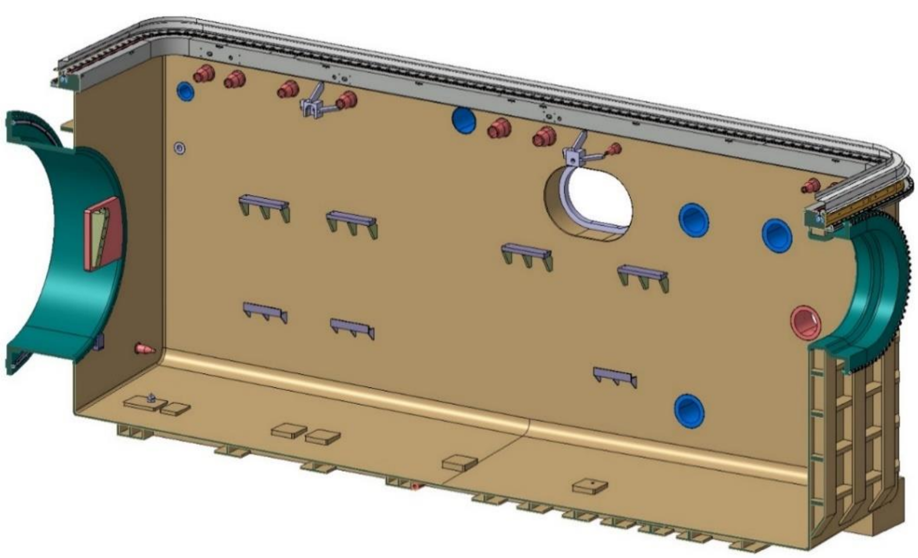

Figure 49: Support location for cryopumps

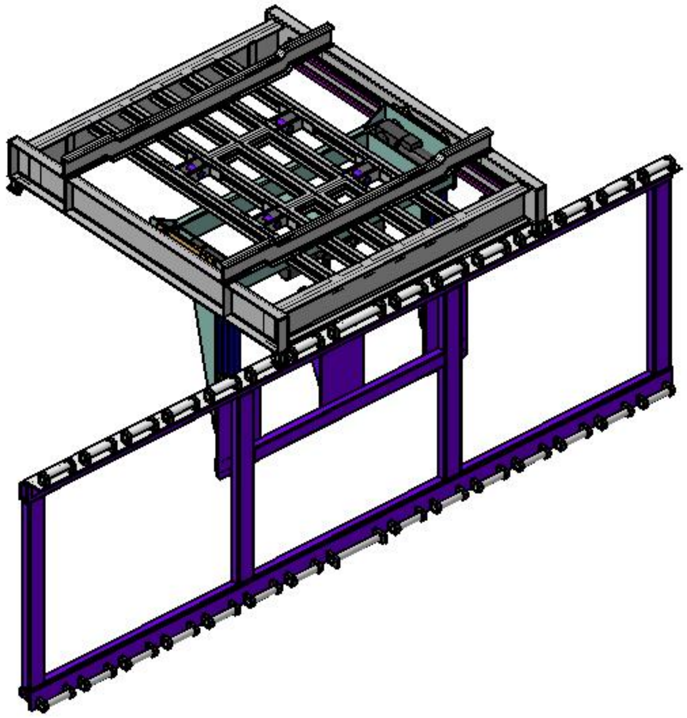

Figure 50: Cryopump RH interfaces

10.8 Interface with Service Vacuum System (SVS)

Components require double confinement and the interspace between the barriers must be connected to the SVS. Services by the SVS include: evacuation, backfilling, pressure monitoring and leak detection. Consistent with the requirements of the Vacuum Handbook, vulnerable components, including feedthroughs for the beamline internal components will have double confinement barriers.

These interspaces will be evacuated via the Service Vacuum System. They will then be partially pressurized and the pressure monitored. The dimensions and connection type of the pipes connecting to the service vacuum system shall be consistent with and as described in the requirements of the ITER Vacuum Handbook.

The connection panel will use Swagelok VCR fittings and the layout should allow easy connections of the pipes to the SVS distribution boxes belonging to PBS 31.

Following interspace is to be monitored by Service vacuum system:

- Top lid and Vessel flange
- Calorimeter actuator flanges
- Calorimeter actuator bellows
- Beam Source actuator flanges
- Cryopanel Feedthroughs
- RID HV feedthrough
- Vacuum instrumentation boxes flanges
- Detritiation flanges

The details of SVS connection for the DNB Vessel is shown in https://user.iter.org/default.aspx?uid=UVPY8H.

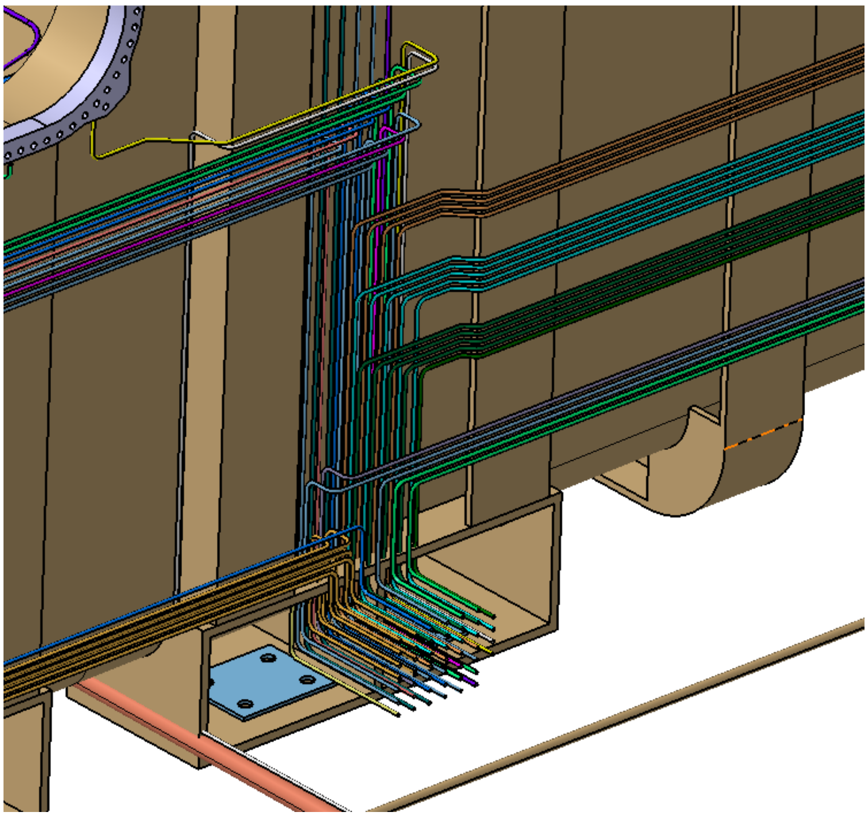

Figure 51: SVS routing for DNB Vessel

10.9 Interface with Vacuum Measurement Boxes

Four vacuum instrumentation boxes, individually isolated by a gate valve are provided on each corner side of the vessel wall. Vessel is provided with welded pipe connection which will interface with vacuum interface box lines through isolation valve. Vessel pipe will have welded connection with the isolation valve. Isolation valve interfaces with vacuum instrumentation box by bolted connection with double metallic sealing with interspace monitoring by service vacuum system. Vacuum instrumentation boxes are to be supported on PMS.

The boxes will feature necessary vacuum instrumentation to cover all operation modes of the vacuum system. The following instruments are foreseen at conceptual level:

- Full range absolute pressure measurement (0.15MPa <10-7Pa)
- Partial pressure analyzer
- Safety and machine protection instrumentation

All vacuum monitoring signals will be available through CODAC for DNB operations.

The details of the vacuum measurement box connection are shown in https://user.iter.org/default.aspx?uid=UVPYKN.

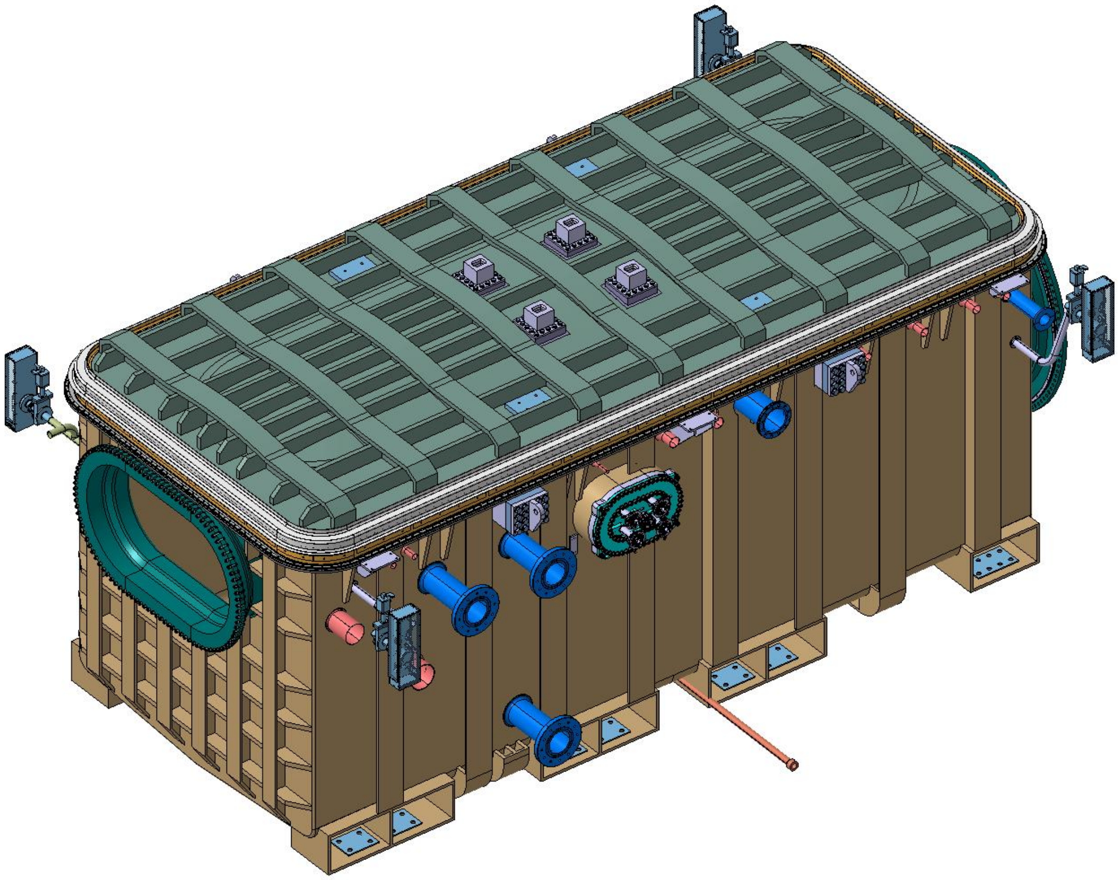

Figure 52: Measurement box assembly on the DNB Vessel

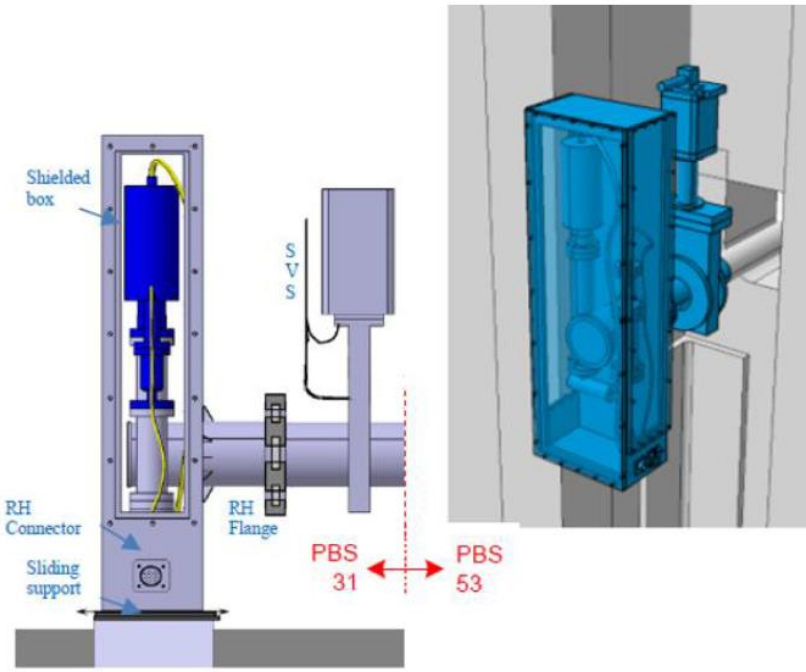

Figure 53: Measurement box assembly

10.10 Interface with Fore Vacuum Pump

The vessel is connected via the fore-lines to the mechanical pumps for roughing the vessels from atmosphere down to the crossover pressure. The fore-lines will also be used for evacuation of the gas from the regeneration of the Cryopumps. The fore line pipe dimensions are: DN250.

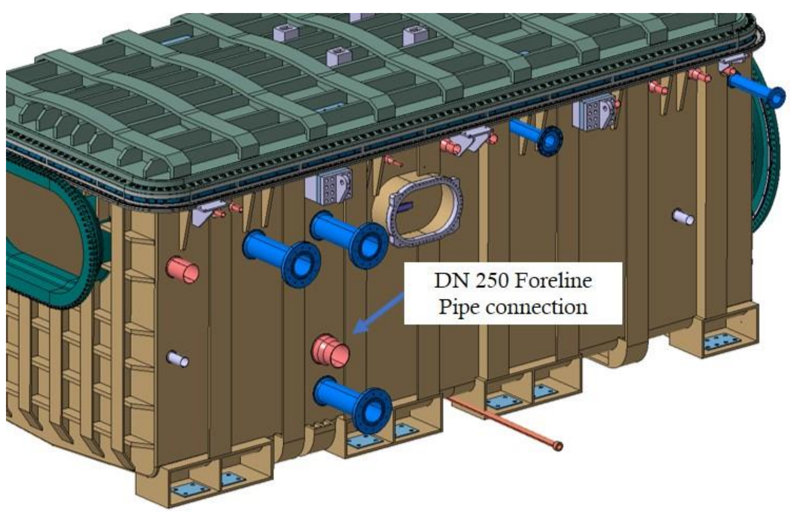

Figure 54: Foreline pipe connection on vessel

The forelines are classified as VQC1A components. The forelines and the isolation valve on the fore line will be provided by PBS-31. The position of the isolation valve on the fore line is in the NB cell at the rear of each box. Isolation valves should be located close to the vessel, but also maintainable in the NB cell. The second isolation valve of the first confinement barrier is located in the HV-deck. The interface sheet for Foreline routing and vacuum valve for the DNB vessel is available at https://user.iter.org/default.aspx?uid=UVL2SD.

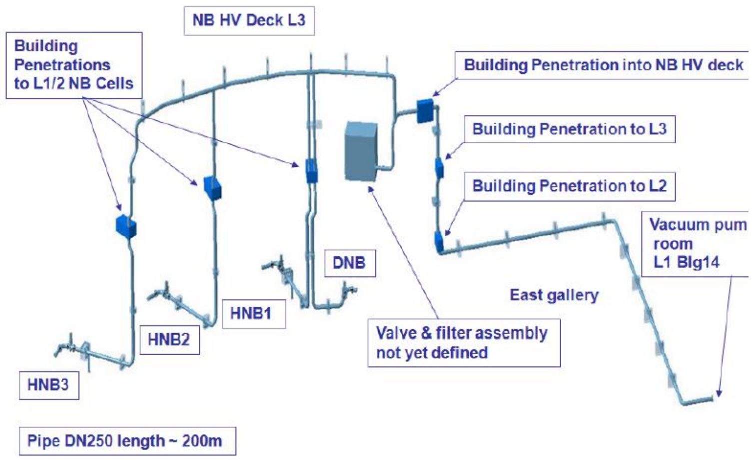

Figure 55: Foreline pumping routing

10.11 Detritiation System Interface

A connection to DS has been integrated in the vessel to pump the DNB vessel in case of any accident. This penetration of the vessel is closed by a standard Vacuum flange of DN 100 size sealed with metallic seals and monitored interspace.

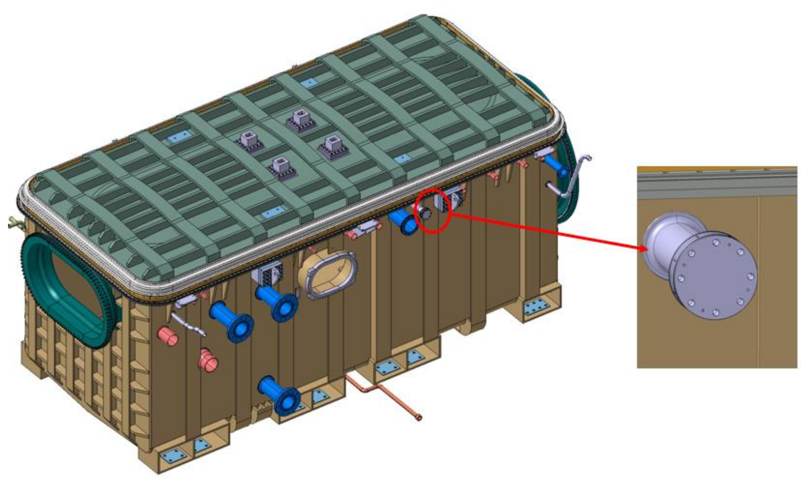

Figure 56: Detritiation system penetration

10.12 DNB Vessel Diagnostic Interface for BLCs

The thermocouple diagnostics lines from the Neutralizer, RID, Calorimeter and Exit Scraper are routed through a demountable connector to wall-mounted sockets in the vessel. From the socket, the signals are routed by a permanently installed cable within the vessel to the multiple vacuum Feedthrough assembly. The plug on the connector and sockets joint have been considered demountable for the removal of the component and this must be designed to be Remote Handling Compatible as this operation of make-and-break the connection shall have to be made under Remote Handling alone during the life of the ITER project.

This interface is between the brackets under the top flange of the vessel mating to the socket plates that may hold from one to six separate sockets. The design of this interface is common to all the electrical wiring socket-plates for the Beam Line Components. These demountable are disconnected whenever a BLC has to be removed from the vessel. This will be performed under Remote Handling operations. The interface is intended to be a common design for all the similar electronic connection lines for the Beam Line Components. The design of the connections has been finalized in compliance with the RH tools and operations.

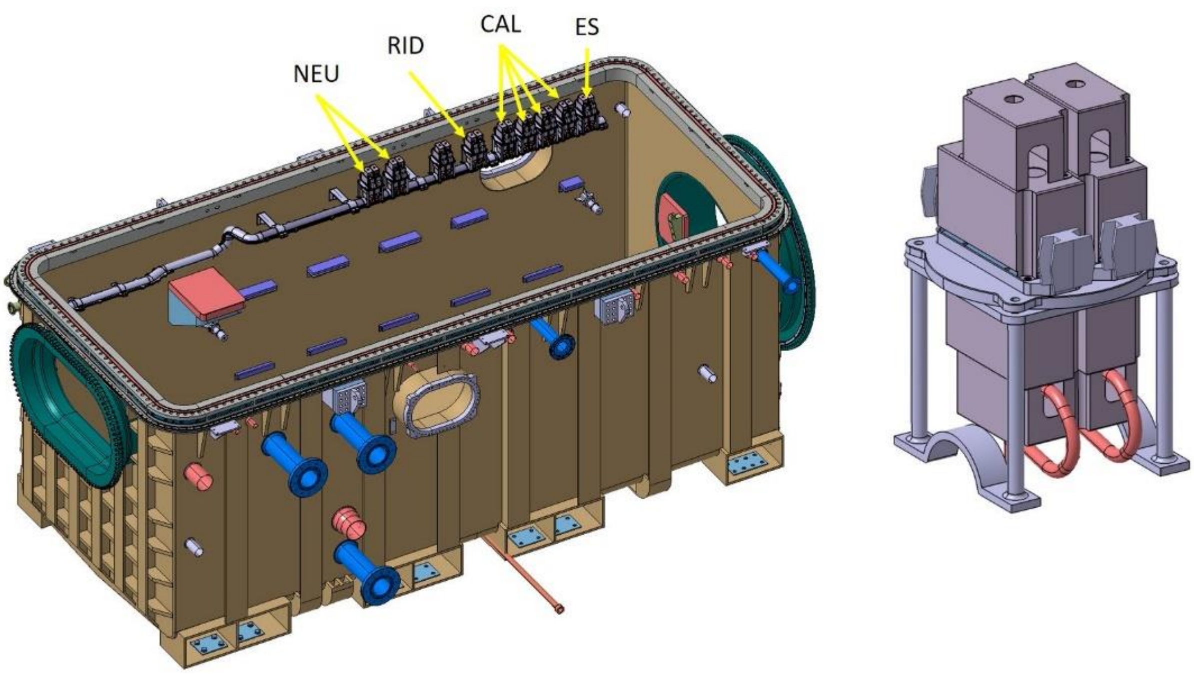

Figure 57: Thermocouple connectors

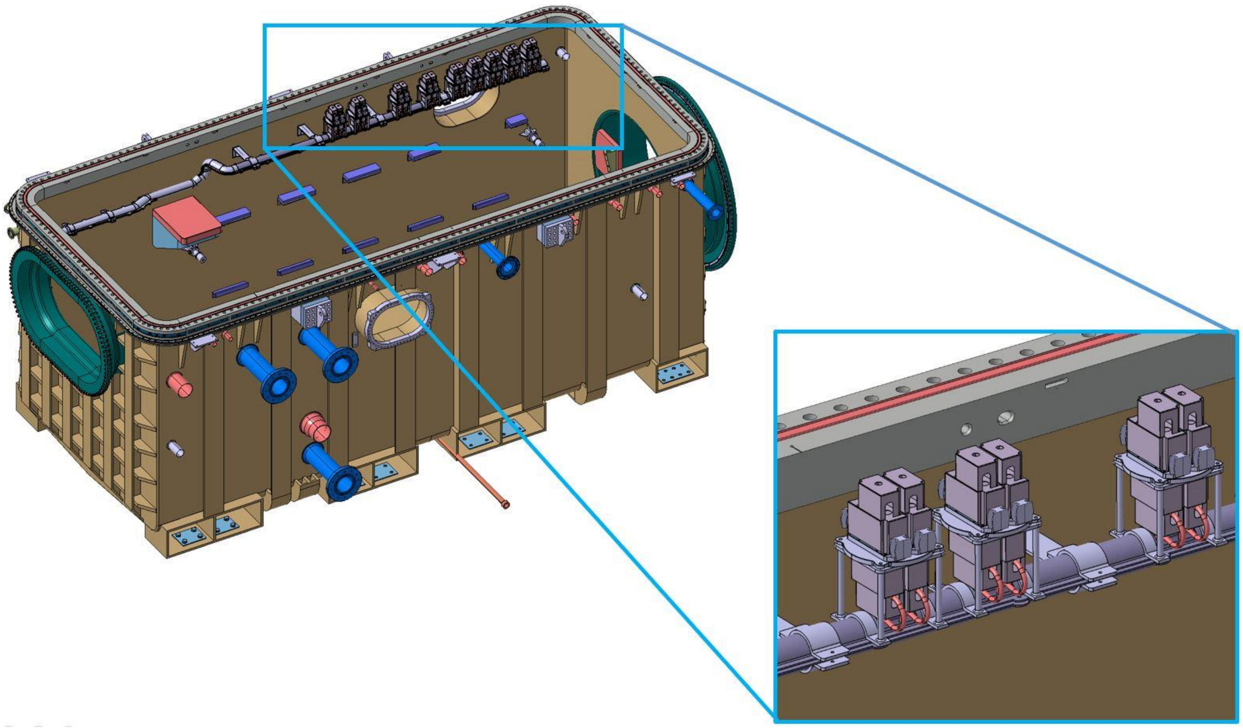

Figure 58: Connector assembly inside the vessel

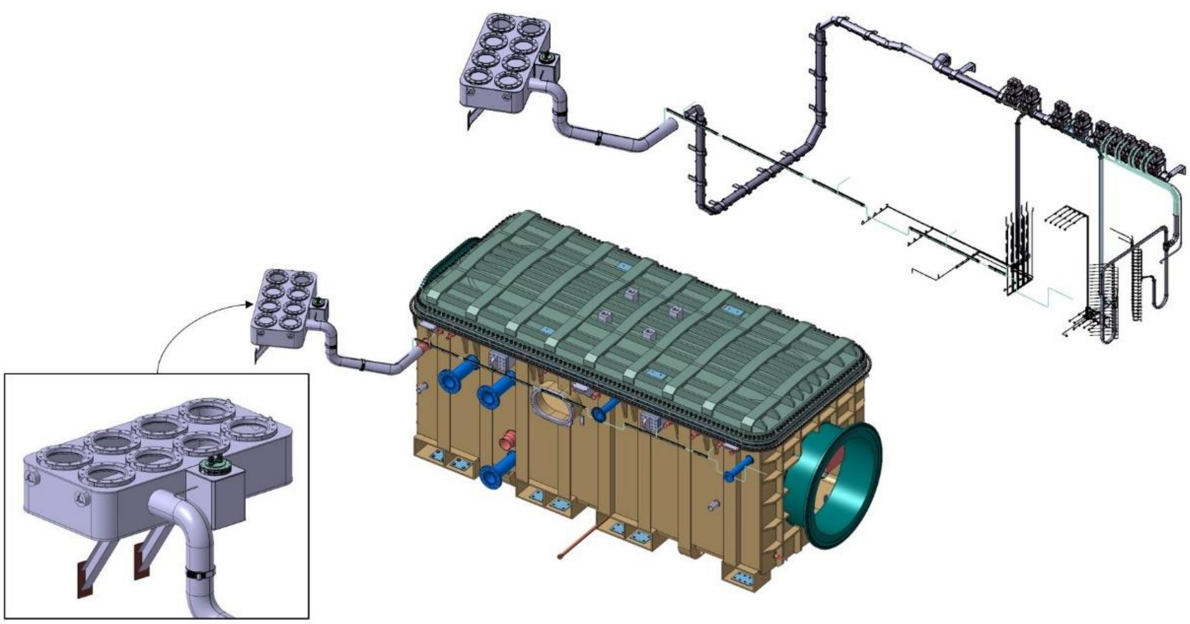

Figure 59: Thermocouple routing inside DNB Vessel

11 Fixation and sealing between Vessel and Top Lid (Ref.)

During the PDR, it was discussed to consider metallic seal instead of the lip seals because of the feasibility of lip seal cutting and welding operation in a fully remote condition which has not been demonstrated with sufficient reliability. In addition, in case of lip seal damage caused by an in-vessel accidental event and failure of RH operations, it could lead to unrecoverable situation and potential risks of loss.

PCR 590 implemented a sealing solution into the baseline for the port plug flanges, which allows the option of lip seal or double Helicoflex to be accommodated by the design. This PCR adopts this baseline solution for the above mentioned NB seals.

VV port flange had similar issues and PCR-590 – "Adjustment of Port/Plug Sealing Interfaces" implemented a sealing solution into the baseline for the port plug flanges, which allows the option of lip seal or double Helicoflex to be accommodated into the design. This PCR adopts this baseline solution for the NBI vessel seals. The sealing scenario will be:

- During the initial assembly: rubber seals will be installed by hands-on.
- During the non-nuclear phase: metallic seals will be installed by hands-on.
- Before going to nuclear phase: lip seals will be installed by hands-on.
- During nuclear phase: metallic seal and lip seal maintenance will be done remotely.

PCR 590 solution has been adapted to the NB seals and is proposed to be adopted under this PCR. The proposed configuration is compatible double Helicoflex seals and also with the implementation of welded lips ensuring welded confinement. It also ensures that the required number of openings can be accommodated.

When assembled with the vessel lid for DNB, the assembly constitutes part of the Primary Vacuum Boundary for the components and is part of the first confinement barrier. The top lid provides the access for repair of the Beam Line Components and DNB Beam Source. There are no routine servicing operations so that this will be an irregular and occasional opening process.

The integration of the double metallic seals was studied in detail within a dedicated R&D [8] [9]. As result of this, the total number of bolts to compress them has been determined as well as the required compression force 655N/mm). The integration of these double metallic seals is compatible with a lip welds integration. It has the benefit to ease the design of the vessels to cope with alignment required for welding operations of lips and maximal allowable deformation of the lips.

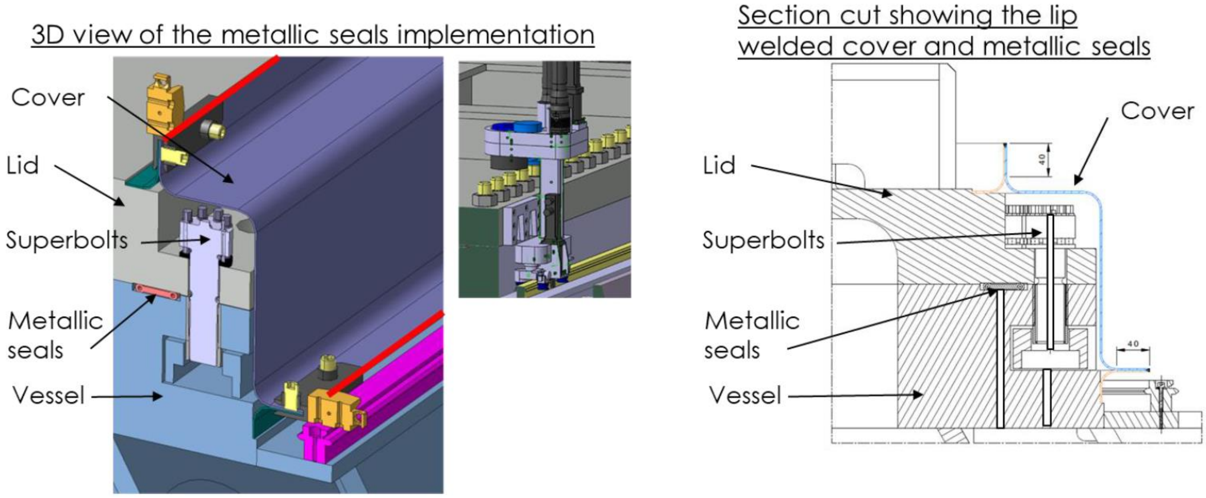

Figure 60: Metallic Seal Solution

A complete design of the vessel and a remote handling scenario have been developed to integrate the metallic seals and the maintainability.

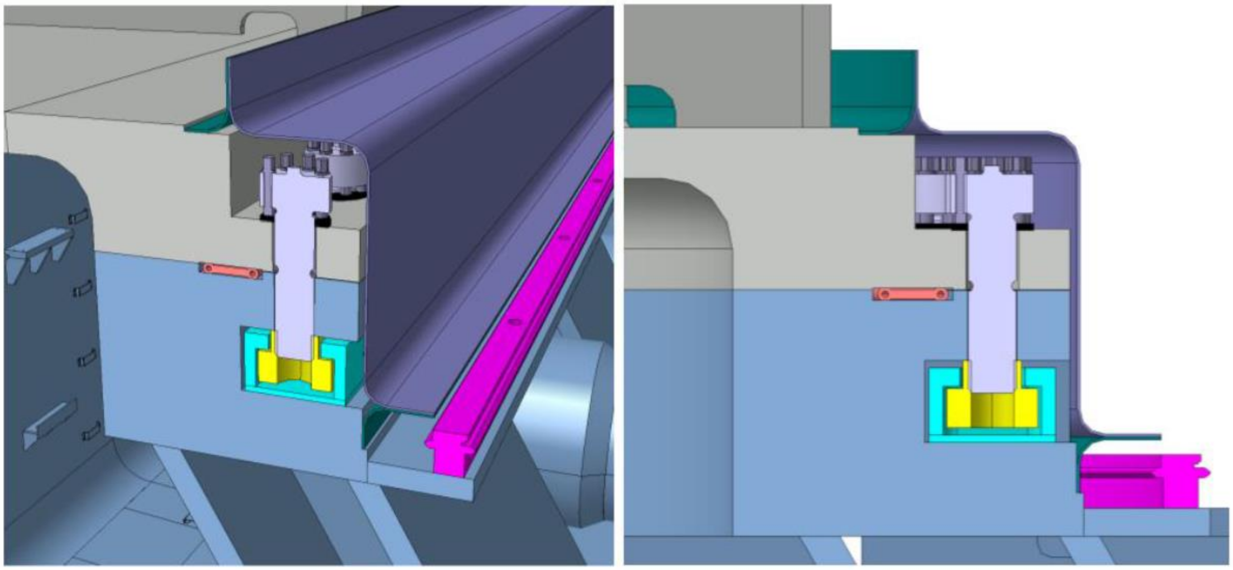

Figure 61: Metallic seal implementation inside the DNB Vessel

12 Interface with RH Tools

The DNB vessel shall comply with the Interface Sheet IS-23-53-0003. The design of the DNB vessel at its interface with RH shall be compliant with the RH code and practice [13] including:

- RH cutting and welding tools
- RH bolting and unbolting tools
- RH generic tools

12.1 Vessel Interface with Crane

The lifting points of the vessel will be used for assembly stage delivery and alignment of empty vessels and without top lid. Lifting lugs have been provided a permanent welded with vessel outside wall. Reinforcement pad have been provided to enhance the strength of the lifting area.

Lifting lug will interface with the lifting crane, and handling will be only in vertical direction (no angled handling is anticipated).

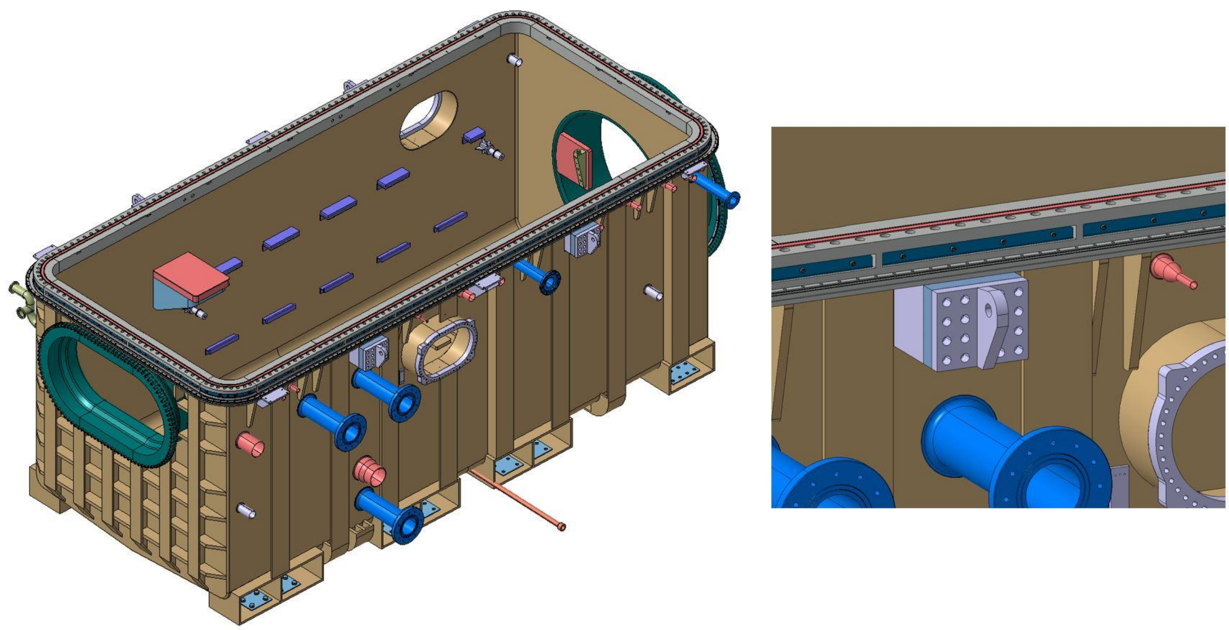

Figure 62: Lifting features for main shell of DNB Vessel

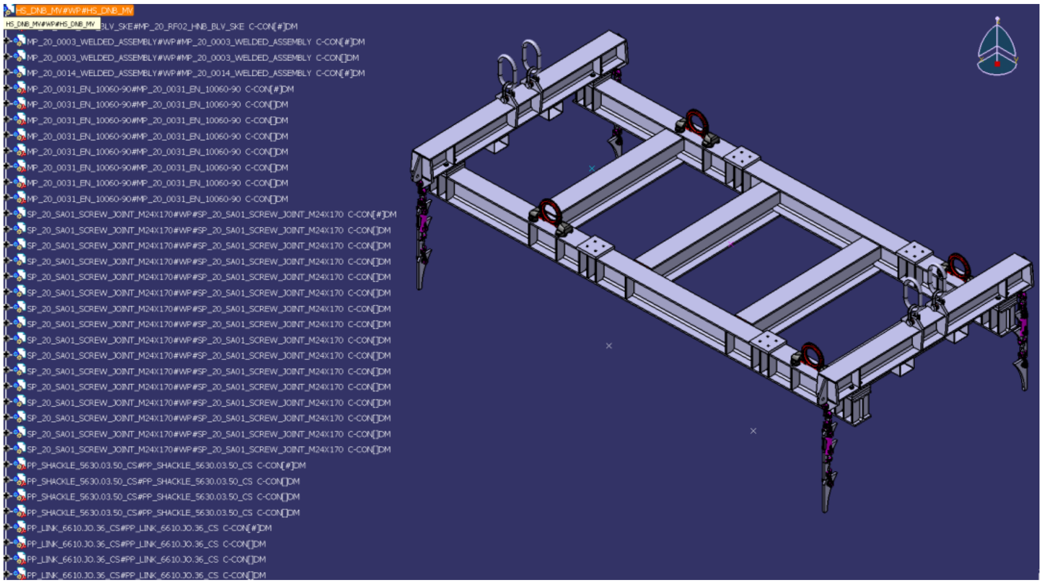

Figure 63: Lifting crane for the main shell

For the fine alignment changes that may be required after the initial positioning of the vessel, an alignment tool is envisaged which employs a small hydraulic ram to allow the vessel to be move minutely on the mounting pads before tightening down. The tool bolts to the PMS base-plate and provides the thrust to move the vessel in a controlled manner.

12.2 Top lid interface with handling equipment

The top Lid is transported into the NB cell using the pallet for transportation and the top lid lifted into position using lifting-fixture for lifting the lid onto the vessel.

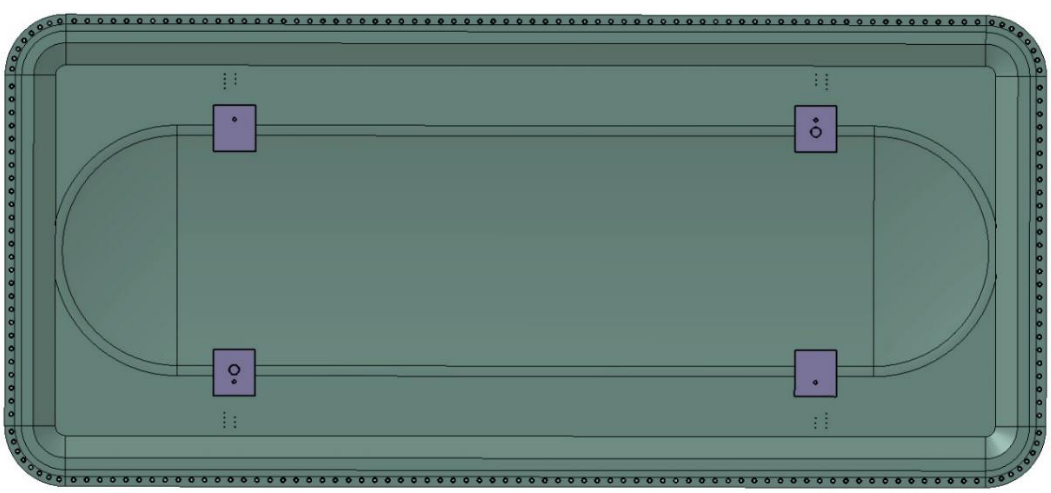

Figure 64: Top lid positional features

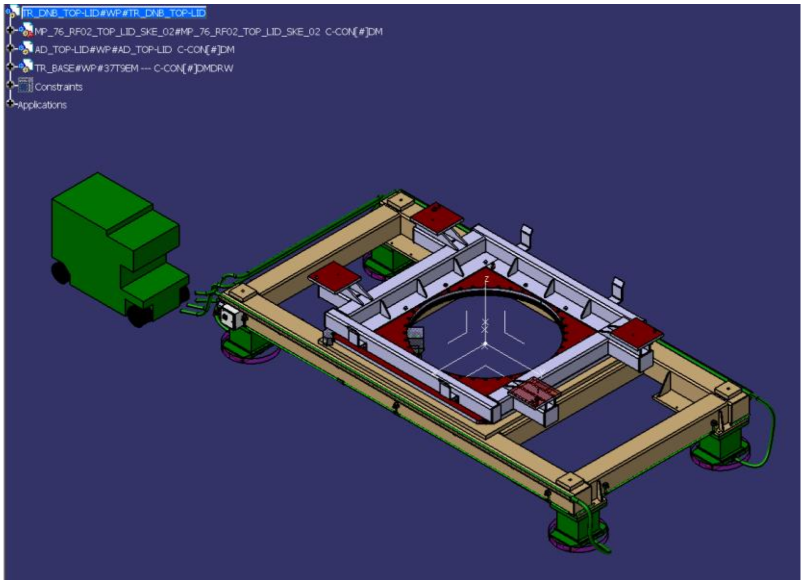

Figure 65: Top lid trolley

The possible options for handling the lid by RH are bolted pads, clevises or Twist-locks per the RHCOP. As per the current recommendation, Twist lock pockets have been provided on the Top Lid considering the requirements of RH monorail crane.

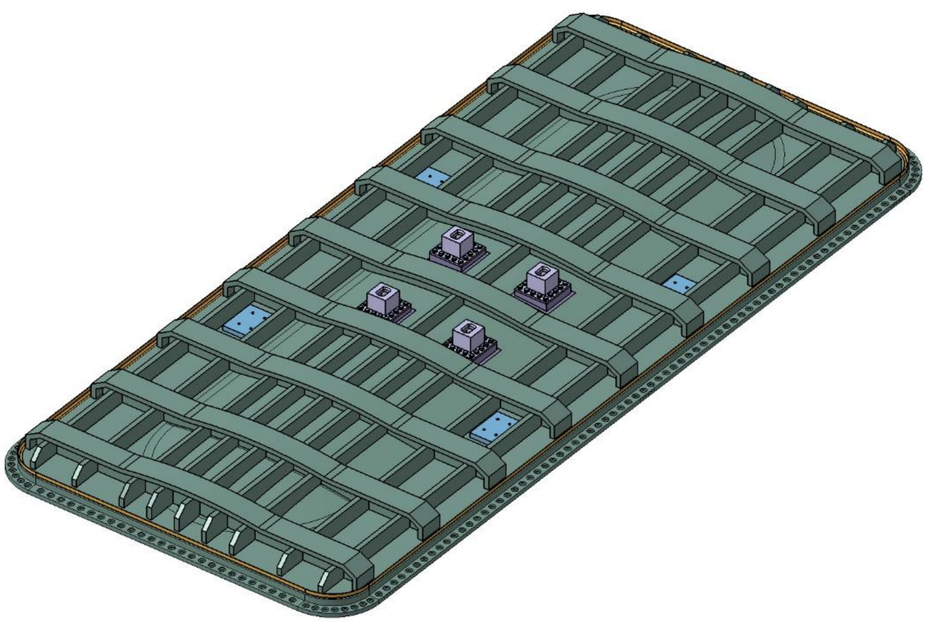

Figure 66: Top Lid lifting fearures

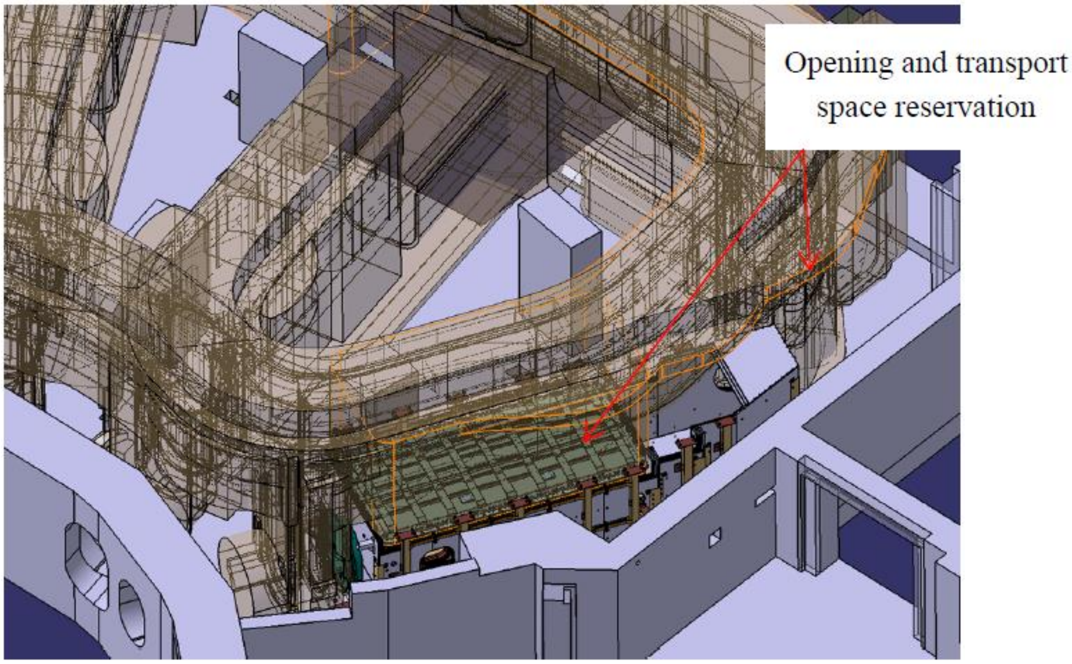

Figure 67: Top lid Opening and Transport space reservation

12.3 BLC Maintenance

Interfaces for guiding features used for the BLC maintenance have been implemented on the DNB Vessel.

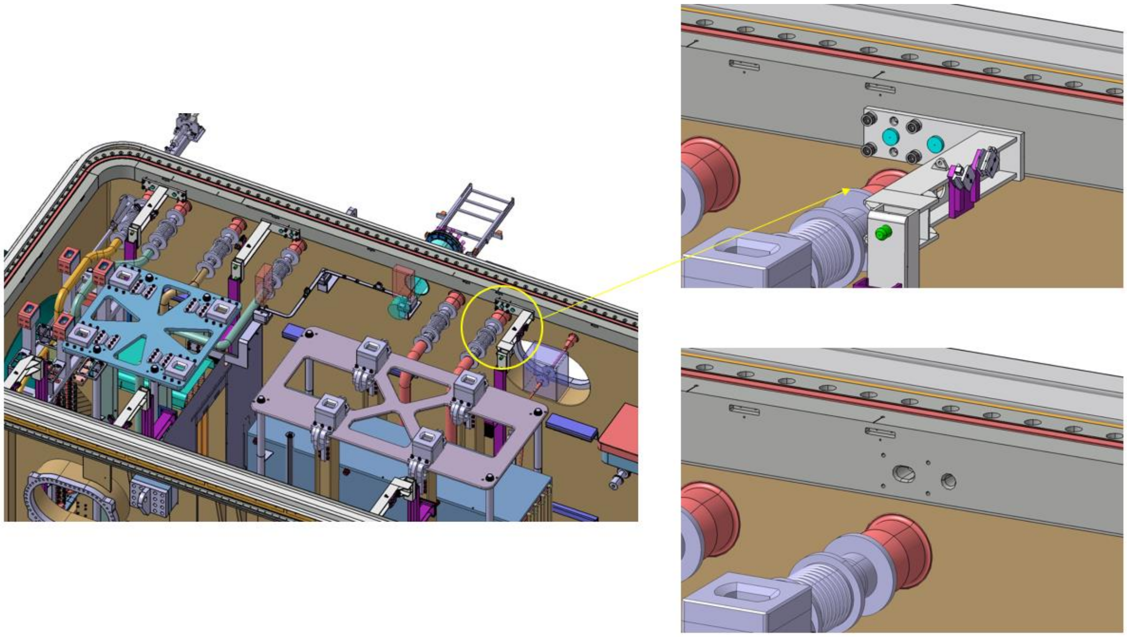

Figure 68: BLCs Guiding features

13 Draining of DNB Vessel

The internal component of vessel contain water for cooling. There is provision to pump away any spilt water inside the vessel due to rupture of a cooling system or during routine opening of a cooling system while the internal component is being exchanged. Therefore, a provision must be made to cross the Primary Vacuum Boundary with the drain pipework. The sealing of this pipework with suitable valves and the removal of the water which may be contaminated is a critical vacuum provision and so is assumed to be under the control of the Vacuum Group.

The water draining interface is provided at the lowest point of vessel where all water will tend to collect so that this water can be removed by opening the suitable valve. The connection of the drain pipe (DN40) with vessel will form a part of primary vacuum boundary and shall comply with the requirements of full penetration butt welding with 100% volumetric inspection. This weld joint is not expected to be disturbed once it is welded at initial installation so requirements for RH is not considered.

The water drain tubing on the vessels passes through the PMS shield prior to joining to the vacuum and drain system pipe-work. Hence the welded joint must be made after installation of the PMS side panels.

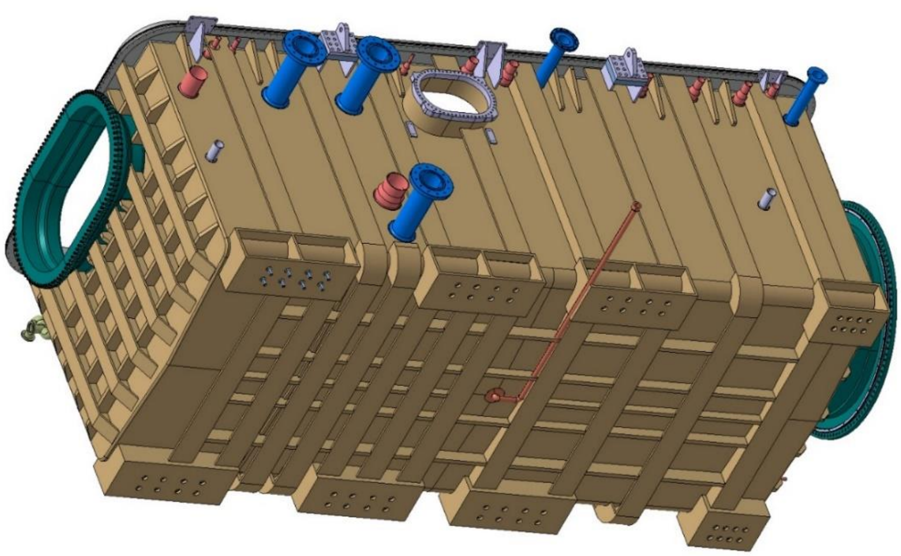

Figure 69: Drain line connection for DNB Vessel

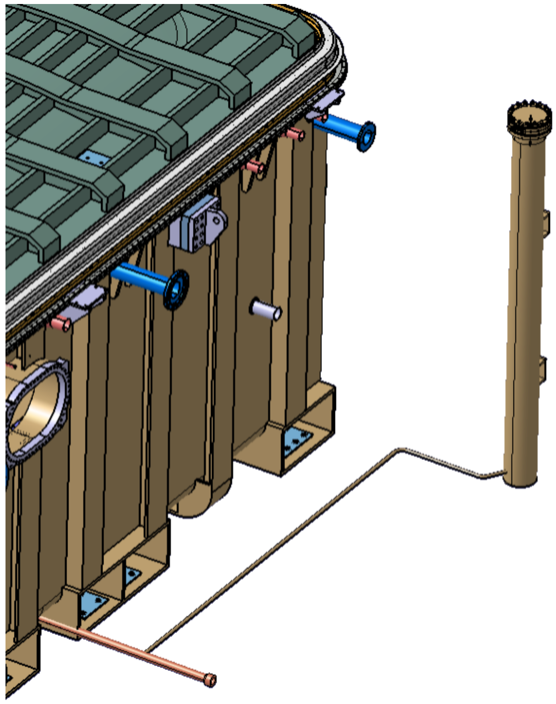

Figure 70: Drain line connection with main header

14 Tests

DNB vessel will be leak tested independently during manufacturing in workshop. This test aims at validating the leak tightness of all the vacuum boundaries.

In order to perform the leak test on the vessel, all penetration will be closed:

- A blank flange has been integrated to close the Fast Shutter interfacing flange and HV bushing flange. The leak tightness of this interface uses double Viton seals with a monitoring interspace.
- All connection pipes (to the Internal components) are closed:
    - For the pipe connections without flange, an extra length shall be foreseen in order to weld a cap.
    - For the pipe connections with flanges, standards blank flanges with Viton seals shall be used to close the penetrations.
- The Top Lid will be mounted on the main shell flange, the leak tightness shall be ensured by the Viton seals with a pumping interspace.
- The Cryopump flanges apertures are blanked by blanks flanges sealed with Viton seals.

Factory and site acceptance test for the DNB vessel shall be carried out as per the technical specification.

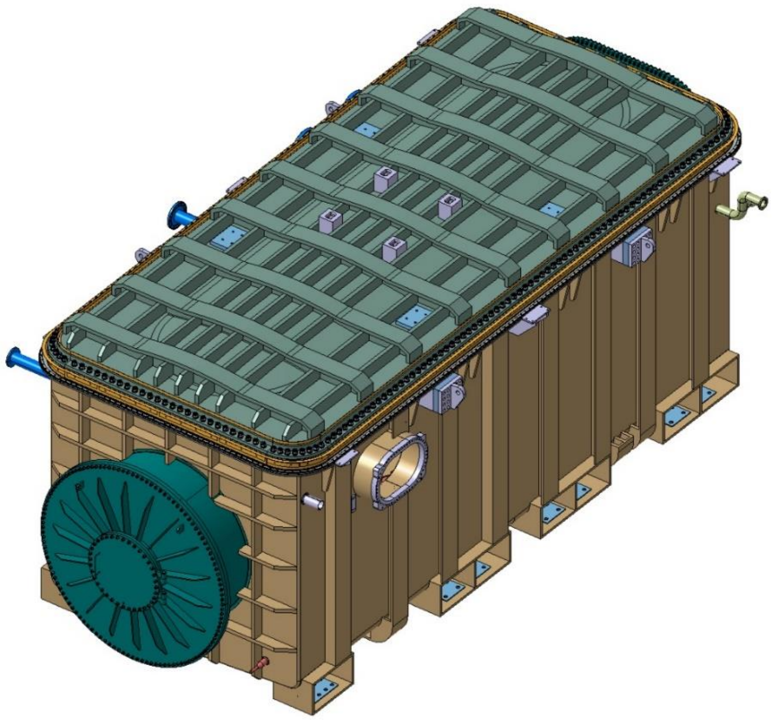

Figure 71: DNB Vessel with Blank Flanges

15 Interface Coordinates

Coordinate positions for all the interfaces have been identified with respect to GG centre as follows:

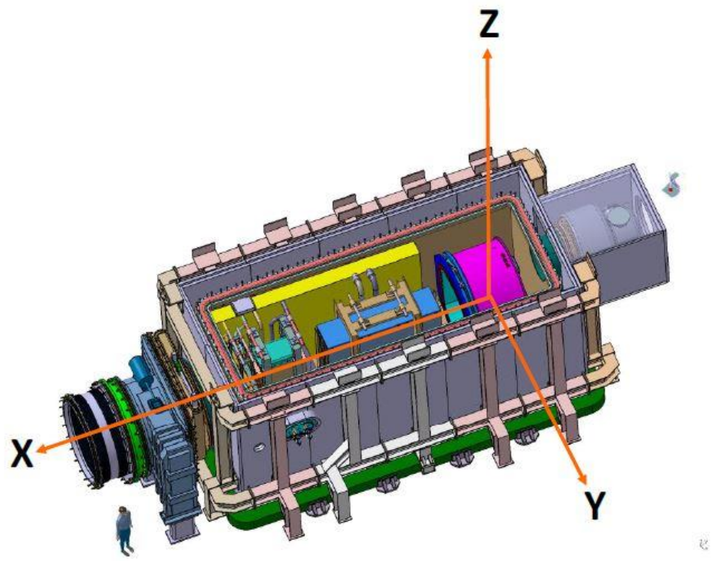

Figure 72: Interface coordinates with GG axis system

Description		Co-ordinate values		
Components	**Interface**	**Position of DNB VESSEL interfaces (w.r.t. GG) (All values in mm)**		
		X	**Y**	**Z**
Exit Scraper	EXIT SCRAPER INLET	1409.98	-6941	1394.3
	EXIT SCRAPER OUTLET	1129.98	-6941	1394.3
	EXIT SCRAPER TOP SUPPORT LH	530	-6517	287.7
	EXIT SCRAPER TOP SUPPORT RH	-530	-6517	287.7

	EXIT SCRAPER BOTTOM SUPPORT LH	530	-6590	-1106.15
	EXIT SCRAPER BOTTOM SUPPORT RH	-530	-6590	-1106.15
Calorimeter	CALORIMETER FLANGE 1 CENTER	-2272	-6318.755	1314.697
	CALORIMETER FLANGE 2 CENTER 1	-2272	-5787.839	1314.697
	CALORIMETER FLANGE 2 CENTER 2	-2272	-5707.839	1314.697
	CALORIMETER PAD 1 RH	-700	-6154.214	-1660.383
	CALORIMETER PAD 1 LH	700	-6154.214	-1660.383
	CALORIMETER MIDDLE PAD	0	-6154.214	-1660.383
RID	RID IN LET	-2099.944	-4853.975	1395.297
	RID OUT LET	-2099.944	-4503.975	1395.297
	RID FEED THROUGH	-2136.07	-4016.549	1395.165
	RID PAD 1 RH	-700	-5813	-1659.8
	RID PAD 2 RH	-695	-4613.038	-1660.1
	RID PAD 1 LH	700	-5813	-1659.8
	RID PAD 2 LH	695	-4613.038	-1660.1
Neutralizer	NEUTRALIZER IN LET	-2099.944	-2756.469	1395.297
	NEUTRALIZER OUT LET	-2099.944	-2241.469	1395.297
	NEUTRALIZER GAS PIPE	-2099.944	-1458.969	1395.297
	NEUTRALIZER PAD 1 RH	-695	-4229.66	-1660.1
	NEUTRALIZER PAD 2 RH	-695	-2561.5	-1660.1

	NEUTRALIZER PAD 3 RH	-695	-1074	-1660.1
	NEUTRALIZER PAD 1 LH	695	-4229.66	-1660.1
	NEUTRALIZER PAD 2 LH	695	-2561.5	-1660.1
	NEUTRALIZER PAD 3 LH	695	-1074	-1660.1
Cryo Pump	CRYO FLANGE CENTER 1 RH	-2150	-1928.625	785
	CRYO FLANGE CENTER 2 RH	-2150	-1628.625	785
	CRYO FLANGE CENTER 1 LH	2150	-5247.389	785
	CRYO FLANGE CENTER 2 LH	2150	-4947.389	785
	CRYO PUMP CONNECTION	-2101	-169.3	-540
	RH BOTTOM ROW SUPPORT 1	-1755.225	-5438.016	-923.5
	RH BOTTOM ROW SUPPORT 2	-1755.225	-4438.016	-923.5
	RH BOTTOM ROW SUPPORT 3	-1755.225	-3438.016	-923.5
	RH BOTTOM ROW SUPPORT 4	-1755.225	-2438.016	-923.5
	RH BOTTOM ROW SUPPORT 5	-1755.225	-1438.016	-923.5
	RH TOP ROW SUPPORT 1	-1703	-5813.015	290.5
	RH TOP ROW SUPPORT 2	-1703	-4401.765	290.5

	RH TOP ROW SUPPORT 3	-1703	-3438.015	290.5
	RH TOP ROW SUPPORT 4	-1703	-2438.015	290.5
	RH TOP ROW SUPPORT 5	-1703	-1438.015	290.5
	LH BOTTOM ROW SUPPORT 1	1755.225	-5438.016	-923.5
	LH BOTTOM ROW SUPPORT 2	1755.225	-4438.016	-923.5
	LH BOTTOM ROW SUPPORT 3	1755.225	-3438.016	-923.5
	LH BOTTOM ROW SUPPORT 4	1755.225	-2438.016	-923.5
	LH BOTTOM ROW SUPPORT 5	1755.225	-1438.016	-923.5
	LH TOP ROW SUPPORT 1	1703	-5813.015	290.5
	LH TOP ROW SUPPORT 2	1703	-4401.765	290.5
	LH TOP ROW SUPPORT 3	1703	-3438.015	290.5
	LH TOP ROW SUPPORT 4	1703	-2438.015	290.5
	LH TOP ROW SUPPORT 5	1703	-1438.015	290.5
	CRYO PUMP LIFTING SUPPORT RH 1	-2108.68	-5230.359	1575
	CRYO PUMP LIFTING SUPPORT RH 2	-2108.68	-915.359	1575
	CRYO PUMP LIFTING SUPPORT LH 1	2108.68	-5230.359	1575

	CRYO PUMP LIFTING SUPPORT LH 2	2108.68	-915.359	1575
	DNB BEAM LINE VESSEL GUIDE RH 1	-1423.5	-6032.014	-50
	DNB BEAM LINE VESSEL GUIDE RH 2	-1423.5	-834.13	-50
	DNB BEAM LINE VESSEL GUIDE LH 1	1423.5	-6032.014	-50
	DNB BEAM LINE VESSEL GUIDE LH 2	1423.5	-834.13	-50
Beam Source	BEAM SUURCE SUPPORT RH PAD 1	-1477.5	-547.503	750
	BEAM SUURCE SUPPORT RH PAD 2	-1480	398.36	750
	BEAM SUURCE SUPPORT LH PAD	1387.5	-582.504	750
	GG IN LET	-2099.944	799.839	1395.297
	GG OUT LET	-2099.944	1099.839	1395.297
	THERMOCOUPLE PIPE OUT LET	-2099.944	1600.693	911.297
	ION SOURCE ACCTUATOR FLANGE 1	-2453.946	-571.69	812.254
	ION SOURCE ACCTUATOR FLANGE 2	-2505.946	378.31	812.254
	ION SOURCE ACCTUATOR FLANGE 3	-2505.946	-624.69	-1187.746
HV Bushing	HV BUSHING FLANGE CENTER 1	-500	2180	900
	HV BUSHING FLANGE CENTER 2	500	2180	900
Fast Shutter	FLANGE COONECTED TO EX COMPONENTS	0	-7405.513	-121.8

DNB Vessel Lifting Eyes & PMS Connections	LIFTING EYE RH 1	-2114.936	-4223	1474
	LIFTING EYE RH 2	-2114.936	310	1474
	LIFTING EYE LH 1	2114.935	-4223	1474
	LIFTING EYE LH 2	2114.935	310	1474
	VESSEL BOTTOM SUPPORT RH 1	-1680	-6355	-1917
	VESSEL BOTTOM SUPPORT RH 2	-1680	-2445	-1917
	VESSEL BOTTOM SUPPORT RH 3	-1680	1465	-1917
	VESSEL BOTTOM SUPPORT LH 1	1680	-6355	-1917
	VESSEL BOTTOM SUPPORT LH 2	1680	-2445	-1917
	VESSEL BOTTOM SUPPORT LH 3	1680	1465	-1917
	DRAIN HOLE PIPE	-3270.31	-2750	-1858.042
Top Lid	RH LIFTING LUG SUPPORT 1	-464.787	-2980.422	2188
	RH LIFTING LUG SUPPORT 2	-464.787	-1900.422	2188
	LH LIFTING LUG SUPPORT 1	465.213	-2980.422	2188
	LH LIFTING LUG SUPPORT 2	465.213	-1900.422	2188

16 References

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7. Sensitivity_analysis_results_UVJEU3_v1_0
8. Qualification plan for the large-scale metallic seals for NBI (2PGZQD v1.0)
9. Load specification of DNB vessel_ITER_D_3R7A9D
10. RCC-MR code, 2007 edition. Design and construction rules for mechanical components of nuclear installations
11. ITER CAD manuals ITER_D_249WHA v5.0.
12. Quality Classification Determination, ITER_D_24VQES
13. ITER Remote Handling Code of Practice (RHCOP) - ITER_D_2E7BC5

Issued by	eboyer	Design number	FT2964V0-Bride2 replaces FT1339V0-Bride2
Date	19-02-202	Customer's name	ITER ORGANIZATION [114635]
Version	0		

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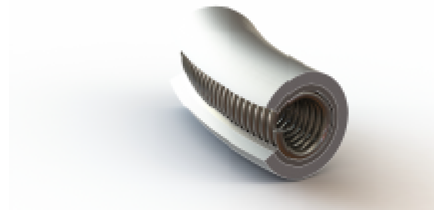
HELICOFLEX® HND229, that consists of 2 seals type HN200:

Seal#1=Outer seal:HELICOFLEX® HN200 - Cross section=9.50 - Outer jacket made of AgU

Seal#2=Inner seal: HELICOFLEX® HN200 - Cross section=9.50 - Outer jacket made of AgU

Seal#1:Ø2468.30 x Ø2487.30 - Seal#2:Ø2438.70 x Ø2457.70

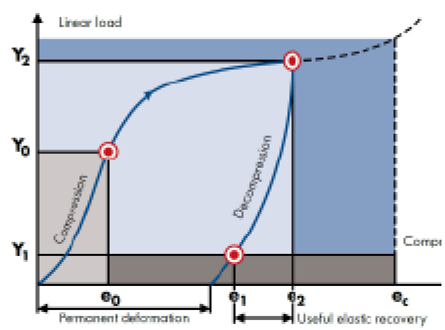
Working Conditions



Application	Vacuum
Media to be sealed	Helium
Working pressure [bar]	1.0
Working or baking temperature T [°C]	240.0
Media side	Internal
Explanation of Operating @ load=Fb1:	Minimum load to be applied to reach the target leak rate
Explanation of Operating @load= Fb2:	Load to ensure the metal-metal contact: this is the recommended tightening load

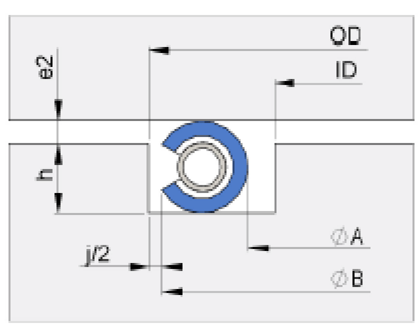
Seal Data

	Seal [#1]	Seal [#2]
Seal style	HN200	HN200
Cross section [mm]	9.50	9.50
Diameter at seal load reaction (DJ) [mm]	2477.80	2448.20
Seal ID (A) [mm]	2468.30	2438.70
Seal OD (B) [mm]	2487.30	2457.70
Sealing material	AgU	AgU
Plating	None	None
Inner material	SS304L	SS304L
Spring material	Alloy_718	Alloy_718
Leak tightness	Helium	Helium
Compression load (Y2) [N/mm]	335 ±10%	335 ±10%



Groove Data

	Seal #1	Seal #2
Groove ID [mm]	2465.80 max	2436.20 max
Groove OD [mm]	2488.00 -0/+0.300	2458.00 -0/+0.300
Groove depth (h) [mm]	8.50 +/-0.100	8.50 +/-0.100
Compression value (e2) [mm]	1.00	1.00
Diametrical clearance (j) [mm]	0.70	0.70
Roughness obtained as per Technetics' specification	Ra1.6 - Ra3.2	Ra1.6 - Ra3.2
Minimum seating load (Fj) [N]	5710454 N	



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EnPro Industries companies

Issued by	eboyer	Design number	FT2964V0-Bride2 replaces FT1339V0-Bride2
Date	19-02-2020		
Version	0	Customer's name	ITER ORGANIZATION [114635]

HELICOFLEX® seal - Loads and torques calculation

Seal Data

	Seal #1	Seal #2		Seal #1	Seal #2
Seal style	HN200	HN200	Compression load (Y2) [N/mm]	335	335
Cross section [mm]	9.50	9.50	Y1 [N/mm]	200	200
Diameter at seal load reaction (DJ) [mm]	2477.80	2448.20	Puθ [bar][20°C,T]	[742,275]	[742,275]
Seal ID (A) [mm]	2468.30	2438.70	Ym [N/mm][20°C,T]	[200,200]	[200,200]
Seal OD (B) [mm]	2487.30	2457.70	Ym=max{Y1;Y2.P/Puθ} if P.DJ≥32.Ym → Ym=Y2		

Bolting Data

Type of bolting	ISO	Material	Unknown
Nominal diameter (ND) [mm]	20	Pitch of the thread [mm]	2.50
Cross-sectional area of one bolt (Sr) [mm²]	225	Quantity of bolts (nb)	120
Effective friction diameter of the bolt head (Dm)	26.00	Friction coefficient (μ)	0.15/0.20/0.25
Young modulus variation (E/ET) [Fb1, Fb2]	[1.084,1.084]	Allowable stress (σbmax) [Fb1,Fb2] given by IO	[315,315]

Working Conditions

	Operating @ Fb1	Operating @ Fb2
Pressure (P) [bar]	1.0	1.0
Temperature [°C]	240.0	240.0
Safety coefficient (k)	1.0	1.0

Loads calculation

	Operating @	Fb1	Fb2
	Loads taken into account	Seating + Hydrostatic + External	
	Metal to metal contact ensured?	NO	YES
Minimum seating load (Fj)	Fj = π.(DJ1+DJ2).Y2.1,1	5710454 N	5710454 N
Hydrostatic end thrust	Ff = π.min(DJ1,DJ2)².P / 4	470743 N	470743 N
Min. working load	Fm = π.(DJ1+DJ2).Ym	3095097 N	3095097 N
External loads (given by IO on october, 2019)	Fext = Fj/2	2855227 N	2855227 N
Min. load @20°C	Fs = Ff + Fm + Fext	6421067 N	6421067 N
Min. load @ working temp.	Fs* = Fs x E / ET	6960437 N	6960437 N
Total load to apply on the seal	**Fb1 = k.Max{Fj; Fs*}**	**6960437 N**	/
	Fb2 = k.max{Fj; [(Ff + Fj + Fext). E / ET]}	/	**9795484 N**

The load above is not the only parameter to take into account to design the assembly.
For instance, the calculations do not take into account any other external load (e.g. Moment on the assembly).
--- In doubt, feel free to reach our engineering department. ---

Stresses and torques

		Operating (Fb1)	Operating (Fb2)
Tensile stress	σ0 = Fb/(nb.Sr)	258 [MPa] ✔	363 [MPa] ✘
Min. torque value [μ=0.15]	C0 = (Fb/nb)(0.16p+μ(0.583d2+Dm/2))	229.4 [N.m]	322.8 [N.m]
Min. torque value [μ=0.20]	C0 = (Fb/nb)(0.16p+μ(0.583d2+Dm/2))	298.2 [N.m]	419.6[N.m]
Min. torque value [μ=0.25]	C0 = (Fb/nb)(0.16p+μ(0.583d2+Dm/2))	366.9 [N.m]	516.4 [N.m]

The friction coefficient depends on the bolting, the lubrication and if there is washers. This is a critical parameter and must be double-checked. Also, the friction depends on the diameter of the bolts.
For information, 0.15 = bolts in really good condition, lubricated, with washers ; 0.20 = bolts in good condition with washers
0.25 = bolts in fairly good condition with washers ; 0.3 = bolts with an elevated friction coefficient.

Assembly according to Technetics Group specification FT921-15 or FT921-45 for UHV application.