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Technical Specification

Technical Note of the Absolute Valve

This technical note will be use for the market survey launched jointly with F4E and INDA

Change Log			
Technical Note of the Absolute Valve (65QGKS)			
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v1.0	Signed	03 Nov 2021	first release
v1.1	Signed	15 Nov 2021	Minors corrections taken into account request of clarification from Gilbert
v1.2	Approved	18 Nov 2021	Clarifications agreed with Gilbert Agarici

Absolute Valve Technical Note

For

Market Survey

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1 Scope

The scope of this document is to describe briefly the preliminary design of the Absolute Valve (system, loads and interfaces) and to provide the main requirements of the components in order to launch an international market survey in order to supply the component on ITER project.

2 Abstracts

ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power.
In southern France, 35 nations* are collaborating to build the world's largest tokamak, a magnetic fusion device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy based on the same principle that powers our Sun and stars.
Thousands of engineers and scientists have contributed to the design of ITER since the idea for an international joint experiment in fusion was first launched in 1985. The ITER Members—China, the European Union, India, Japan, Korea, Russia and the United States—are now engaged in a 35-year collaboration to build and operate the ITER experimental device, and together bring fusion to the point where a demonstration fusion reactor can be designed.
ITER will be the first fusion device to produce net energy. ITER will be the first fusion device to maintain fusion for long periods of time. And ITER will be the first fusion device to test the integrated technologies, materials, and physics regimes necessary for the commercial production of fusion-based electricity.

The Neutral Beam system for ITER consists of two heating and current drive (H&CD) NB injectors and a diagnostic neutral beam (DNB) injector. The layout allows a possible third HNB injector to be installed later. These NB injectors will be connected to equatorial ports #4 - #6 for the H&CD NBs. The DNB shares port #4 with the H&CD NB. The injectors will be located outside the cryostat inside a common enclosure, the NB cell, on north side of the Tokamak building in the L1 and the L2 levels. As they are directly coupled to the ITER vacuum vessel, the injectors are extensions of the primary confinement barrier of radioactive materials coming from the vacuum vessel. The NB cell will form the secondary confinement barrier.

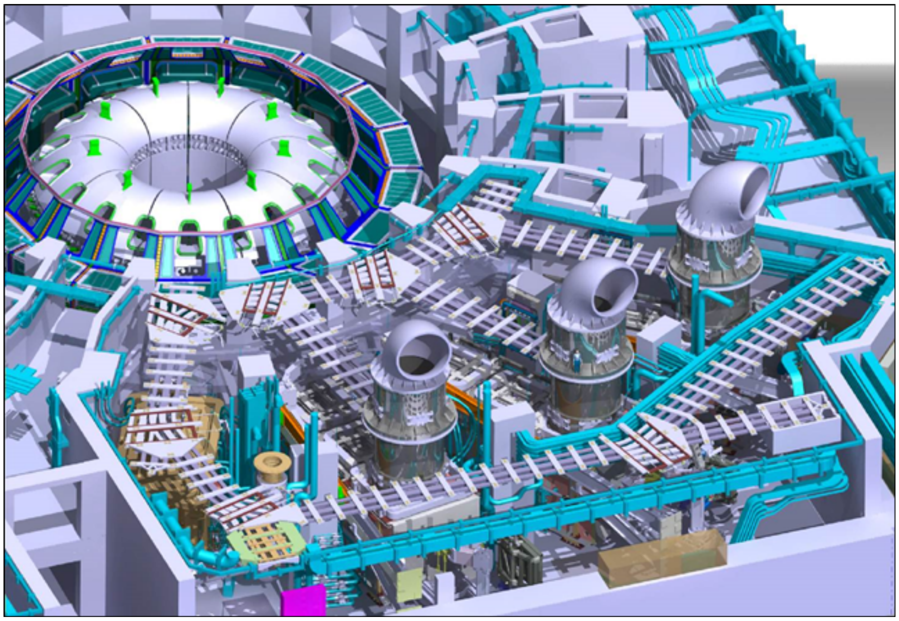


Figure 1: Isometric view of the NB Cell

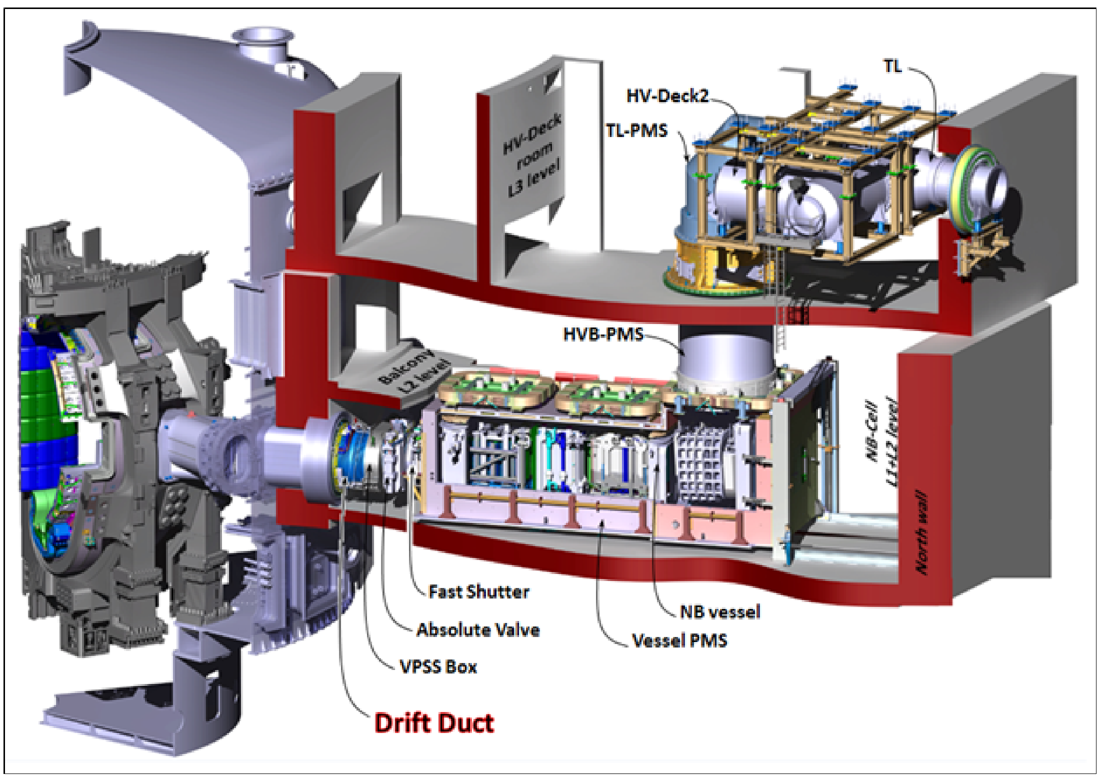


Figure 2: Cross section of one NB Injector

Each NB injectors is connected to the Torus primary vacuum via the Absolute Valve that provides isolation between the ITER VV and the BLV. This component shall provide the primary vacuum containment for this section of the NB system and therefore provides a part of the first confinement barrier of the in-vessel radioactive inventory.

3 Abbreviations

The abbreviations use in this document is explained in the following list:

AAR	Accident Analysis Report
ACCC	Active Compensation Cooled Correction Coils
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
AV	Absolute Valve
BLC	Beam Line Components
BS	Beam Source
BLV	Beam Line Vessel
BSV	Beam Source Vessel
CDR	Conceptual Design Review
DA	Domestic Agency
DD	Drift Duct
DDD	Design Description Document
DOF	Degree Of Freedom
DRS	Design Response Spectra
EM	Electro Magnetic
ESP	French decree dated December 13, 1999 related to the manufacture of pressure equipment (Implementation of the European Pressure Equipment Directive 97/23/EC PED in French law).
ESPN	French order dated December 12, 2005 related to the manufacture of Nuclear Pressure Equipment (NPE)
FEC	Front End Component
FRS	Floor Response Spectra
HNB	Heating Neutral Beam
ICE	Ingress of Coolant Event
kN	Kilo Newton
LOCA	Loss of Coolant Accident
LOFA	Loss of (forced) Flow Accident
LOOP	Loss Of Off-site Power
LOVA	Loss of Vacuum Accident
MD	Major Disruption
MFD	Magnet Fast (current) Discharge
MN	Mega Newton
MPa	Mega Pascal
MQP	Management Quality Program
NBI	Neutral Beam Injector
NRC	Nuclear Regulatory Commission
NSC	Non-Seismic Class
PA	Procurement Arrangement

PR	Project Requirement (Document)
PHTS	Primary Heat Transfer Systems
PRS	Point Response Spectra - Spectra calculated at specific points of a structure (also called "In-Structure Spectra" and "Secondary Spectra
RD	Rupture Disk
RPrS	Preliminary Safety Report (Rapport Préliminaire de Sûreté)
SC	Seismic Class
SIC	Safety Importance Class (-1 or -2)
SL	Seismic Level
SL-1	Seismic Level 1 – Defined by ITER for investment protection
SL-2	Seismic Level 2 – equivalent to Safe Shutdown Earthquake
SMHV	Séismes Maximaux Historiquement Vraisemblables = Maximum Historically Probable Earthquakes
SRD	System Requirement Document
SRSS	Square Root of Sum of Square
SSE	Safe Shutdown Earthquake
ST	Suppression Tank
ST-VS	Suppression Tank Venting System
SVS	Service Vacuum System
TGCS	Tokamak Global Coordinate System
VDE	Vertical Displacement Event
VV	Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System
ZPA	Zero Period Acceleration

4 Functions/ Main requirements

ID	Requirements
R1	Each NB injectors is connected to the Torus primary vacuum via the Absolute Valve that provides isolation between the ITER VV and the BLV. This component shall provide the primary vacuum containment for this section of the NB system and therefore provides a part of the first confinement barrier of the in-vessel radioactive inventory.
R2	The Absolute Valve shall be able to provide isolation of the NB H&CD system during any failure of Internal NB components: Independent vacuum in the BLV can be created when the valve is closed, which allows the independence of the faulted NB system vs. the ITER device itself. This facilitates isolation of the torus vessel vacuum from that of the neutral beam vessel, enabling venting of either Vessels to atmosphere in order to continue ITER operations
R3	The Absolute Valve shall be designed to maintain a maximum leak rate for absolute sealing across two sealing plates and interspace pumping s of 1.10^{-8} $Pa.m^3/s$ for 100 cycles at a pressure difference of one atmosphere.
R4	The maximum single leak rate for absolute sealing across one seal is 1.10^{-5} $Pa.m^3/s$ at a pressure difference of 1 atmosphere and a pumped interspace to 100 Pa.
R5	The valve casing shall provide first confinement functionality in all operational valve states. This functionality is also required under normal, & upset operating conditions and should be maintained during emergency and faulted scenarios to prevent releases in excess of the guidelines established for accidents. The Absolute Valve(overall envelope – casing) must ensure the confinement for tritium
R6	The Absolute Valve shall be capable of maintaining an internal vacuum of better than 10^{-6} Pa (note that this does not refer to the interspace between the valve discs, but to the complete internal environment of the valve). This requirement applies to the valve in both open and closed states.
R7	During maintenance operations, the valve is closed and the neutral beam vessel lid can been removed..
R8	The Absolute Valve, when open, shall maximise the transmission of the beam. The current opening is a rectangular duct of 1457 mm X 597 mm; This is the minimum size allowed.
R9	The Absolute Valve shall operate reliably for absolute sealing for 100 open/close operations.
R10	For low conductance operation (valve closed but not sealed), the maximum leak rate shall be 10^{-2} $Pa.m^3/s$ for 3000 cycles.
R11	For low conductance operation, the capability of the AV shall assume 2400 cycles during the life of ITER.
R12	This component shall be compatible with H^0 and D^0 beams.
R13	Opening and closing times shall be typically less than 10 minutes for each operation for the case of low conduction operation.

4.1.1 Absolute Valve specification parameters

Valve overall dimensions (maximum, about beam axis)	Horizontal width ~3250 mm Height ~3000 mm Length (along beam axis from flange to flange) ~1250 mm All numbers including piping See section 7 (interfacing flanges)
Weight conditions	< 10 tons
Duct dimension (Major axis vertical)	Vertical 1457 mm Width 597 mm
Operational conditions	Valve in open position during ITER operational periods, typically many weeks. Valve closed for planned maintenance of the caesium oven. For this planned maintenance it is expected to close the AV ones per year.
Operation of the valve	The valve will be operated and controlled by the vacuum systems . The valve position (open / closed) shall be sent to central vacuum control system. Temperatures of the valve and shield temperatures shall be done.
Opening and closing times	Typically 10 minutes for each operation.
Type of seal	Metallic with metal to metal interface
Maximum leak rate for absolute sealing across absolute valve	Maximum leak rate $\leq 1 \cdot 10^{-8}$ $Pa \cdot m^3/s$ for 100 cycles. (at a pressure difference of 1 atmosphere)

Maximum single leak rate for absolute sealing across one seal	≤ $1\cdot10^{-5}$ $Pa\cdot m^3/s$ (at a pressure difference of 1 atmosphere) and an pumped interspace to 100 Pa
Maximum allowable leak rate of the casing of the AV	1E-10 $Pa.m^3/s$ air equivalent from exterior atmosphere to internal vacuum.
Valve interspace pressure	To be vacuum pumped to <100 Pa so that the overall leak rate will be met with the single leak rates for 100 cycles.
Maximum leak rate for low conductance operation	For low conductance operation a maximum leak rate of 10^{-2} Pam^3/s for about 3000 cycles is required.
Valve interspace surface temperature	Operation: <100ºC
Valve interspace surface area	To be defined during finalization of design
Valve interspace volume	To be defined during finalization of design
Baking temperature	Casing to 200ºC Gate and Seal Protection System to 110 ºC
System replacement period	**≤ 20** years as it is RH class 3
Normal operating temperature	Seal Protection System water cooled with 38 ºC inlet temperature and a ΔT of 50 ºC
Pressure requirements	
Identified operational scenarios call for the valve to sustain a bi-directional maximum pressure differential of 2 bar across the valve, acting as an absolute seal between the ITER duct and the Neutral Beam Vessel.	
Max. design pressure external	0.16 MPa
Max. design pressure internal	0.2 MPa
Radiation	

At the absolute valve	Typically 10 Sv/h during operation but may be reduced due to shielding from ITER vacuum vessel and blanket
Magnetic field	B = 75 mT
Materials	
Overall system	All components to be metallic. Typically stainless steel AISI 316LN. The diaphragm material may require a higher strength material such as INCONEL 718
Heat loads	
Radiation from the plasma	~500 W/m^2, due to Bremsstrahlung, synchrotron and impurity radiation
Nuclear heating	0.008 W/cm^3

Summary of requirements that the Fast Shutter [10] and the Absolute Valve shall fulfil

Requirements	**FS**	**AV**	**AV + FS**
3,000 cycles with low leak rate (10^{-2} $Pa.m^3/s$) during Cryopump regeneration	√	√	√
40,000 cycles OPENING to enable NB pulse (no requirement on leak rate)	√	√	√
10 cycles of VV LOCA event : Protection of the BLV against ingress of Tritium in 5 sec.	√	X	√
10 cycles of BLV LOCA event : Mitigate the loss of vacuum in VV in 5 sec	√	X	√
100 cycles: Absolute sealing (10^{-8} $Pa.m^3/s$) to isolate the BLV from VV vacuum in 15 min	X	√	√

Isolate the NB Vessels from VV in order to enable maintenance operations (VV under depression – no absolute sealing is required)	√	√	√
Failed safe closed and passive closure of the component	√	X	-

5 Classifications

- As part of the first confinement barrier, the casing of this component has Safety Importance Classification (SIC) SIC 1 (**) and shall be designed in accordance with relevant requirements. This statement also applies to any part of the casing which is attached to the internal removable mechanism.
- As part of the first confinement barrier, when the valve is closed, the valve plate and seal have safety important classification SR (Safety Relevant) (**)
- The closure of the AV is not SIC (**)

**:

Systems, structures and components (SSCs) are identified as Safety Importance Class (SIC) based on the consequences of their failure:

Criterion A: Their failure can directly initiate an incident or accident leading to significant risks of exposure or contamination.

Criterion B: Their operation is required to limit the consequences of an incident or accident leading to significant risks of exposure or contamination.

Criterion C: Their operation is required to ensure functioning of SIC components.

- ***SIC-1*** *SSCs are those required to bring and to maintain ITER in a safe state*
- ***SIC-2*** *SSCs are those used to prevent, detect or mitigate incidents or accidents, but not SIC-1 (not required for ITER to reach a safe state)*
- ***SR*** *"Safety Relevant" SSCs have some relevance to safety, but their failure will not impact any safety function.*
- ***Non-SIC*** *All other SSCs.*

- This component shall meet the requirements of vacuum class VQC 1A [5].
- Any coolant piping of this component that is exposed to the primary vacuum has vacuum class VQC 1A [5].
- The component shall be remote handling class 3

RH Class 3: Maintenance Task probability > 10-6 but < 10-1 (in 20 year period) Plant designed to be RH compatible for maintenance/Maintenance equipment and operation sequences designed prior to machine operations.

- This component shall meet the requirements of Quality Class 1[1].

- The casing of this component shall meet the requirements of Seismic Class SC 1(S).
- The mechanism shall meet the requirements of Seismic Class SC 1(SF)

<u>SC1 (SF) - Seismic class one-SF</u>: Structural stability and required functional seismic safety performance maintained in the event of an earthquake, The respect of this level of requirement guarantees the level of safety as throughout the normal operation of the equipment. Nevertheless, while taking into account seismic load characteristics, fatigue is not taken into account.
<u>SC1 (S) - Seismic class one-S</u>: Structural stability maintained in the event of an earthquake, i.e. no rupture of piping, no collapse of structures or equipment, limited plastic strain, limited concrete cracking, structural support functions maintained. With this level of requirement, it is possible that a small level of deformation could occur. Consequently, it could be necessary to inspect equipment before re-using it.

6 Codes & standards

6.1 First Confinement barrier / Vacuum boundary

For metallic parts which form the first confinement barrier of plasma vacuum chamber it is proposed to use one code. This code shall be used for nuclear pressure and for other components, which are non-pressure equipment. The proposed Code is RCC-MR (edition to be chosen by the supplier).
The supplier may propose other Nuclear code equivalent to RCC-MR code that will subject to IO approval (*).
Using this code has some benefits for licensing of the ITER plasma chamber which provide first confinement. These advantages are:
- Reduction of risk with delay of licensing ITER facility
- Unification of technical procedures for connections of various components
- Simplification of interface requirements

(*) If the supplier encounters technical showstoppers on the design following the RCC-MR code, it shall be clearly identified and justified to IO. IO shall accept the need of deviation to the code with the prerequisite that IO approve the justification of the issue. The deviation will be raised by the supplier. IO shall approve the deviation with the prerequisite that the supplier develop a mitigation/qualification procedure compliant with the regulations

6.2 Non-First Confinement barrier / Vacuum boundary

The Internal, non-first confinement boundary parts of this component shall be designed to SDC-IC [8].

SDC-IC consists of the main Design Criteria document and annexed appendixes.

The main document includes definitions and classifications of different damage and failure modes, type of stresses, joints, thermal creep phenomena, buckling, etc. The other parts of document include design rules for general single layer homogeneous structures at low and elevated temperatures, rules for welded joints and rules for bolts. Design rules for multilayer heterogeneous structures are included also, but they are limited to only low temperature application.

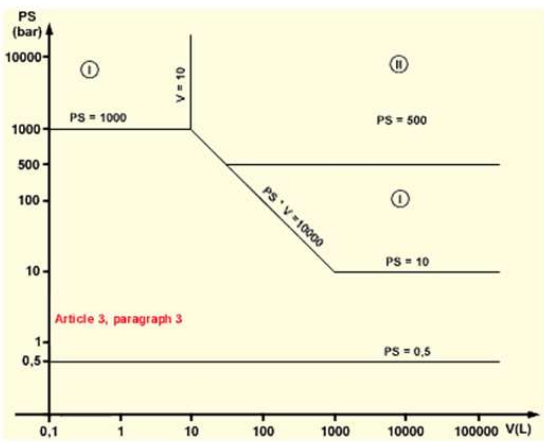
6.3 PED/ESPN Requirements

The design of the AV needs to comply with the requirements of ESP/ESPN. Note that in the context of ESP and ESPN the pressure designation 'PS' is here taken to be equivalent to the Maximum Allowable Working Pressure (MAWP).

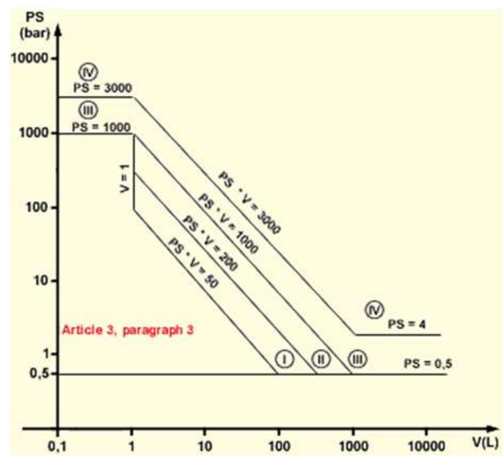
Note that embedded coolant pipes that have a heat exchange function are classed as 'vessels' in the context of ESP/ESPN.

Note that if the coolant temperature exceeds 110˚C, the coolant is classed as a gas.

The graphs below allow the correct classification of the coolant pipework to be determined:



Vessels containing group 2 **liquids**



Vessels containing group 2 **gases**

- The AV shall be designed to be cooled, drained and dried under PED (*) class 0 or max class 1 (*to avoid any requalification/inspection during life time of the valve*)

(*): The Pressure Equipment Directive (PED) was adopted by the European Parliament and the European Council in May 1997. From 29 May 2002 the PED is obligatory throughout the European Union. The directive provides, together with the directives related to simple pressure vessels (87/404/EC), for an adequate legislative framework on European level for equipment subject to a pressure hazard.

Following this European Directive the French Decree 99-1046, 13th December 1999 concerning pressure equipment (Amended by Decree No. 2003-1249 dated 22nd December 2003, by Decree No. 2003-1264 dated 23rd December 2003 and Decree 2007-1557 dated 2nd November 2007 and Decree 2010-882 dated July 27, 2010) and French Order dated 21st December 1999 concerning the classification and evaluation of the conformity of pressure equipment put the PED in force in France. Acronym ESP is proposed to be used for above mentioned documents.

7 Interfaces

7.1 Environment

- This component shall be positioned downstream of the Fast Shutter and upstream of the VVPSS Box - *see figure 3* in the case of HNB

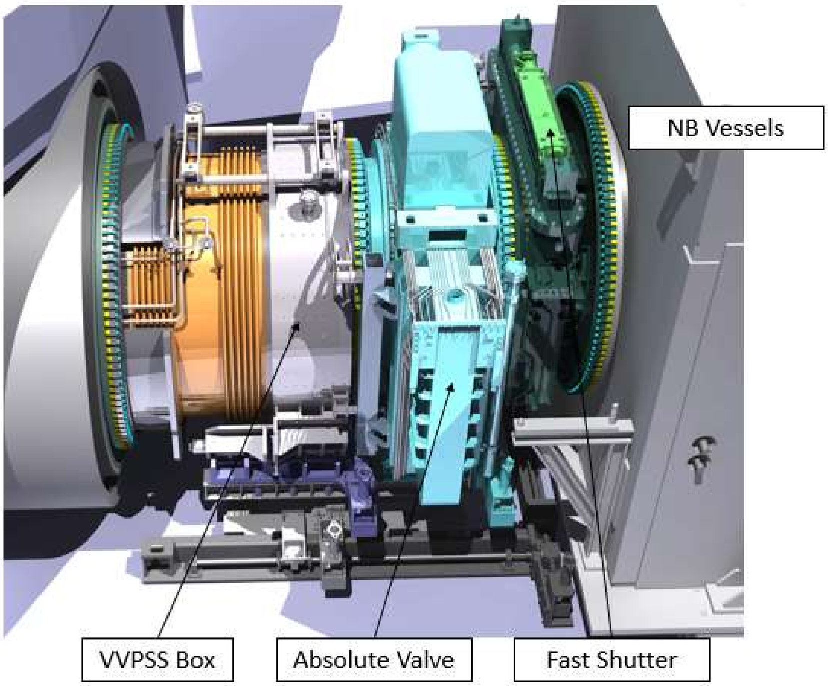


Figure 3: HNB Front End Components integration

- This component shall be positioned downstream of the Fast Shutter and upstream of the Drift Duct - *see figure 4* in the case of DNB

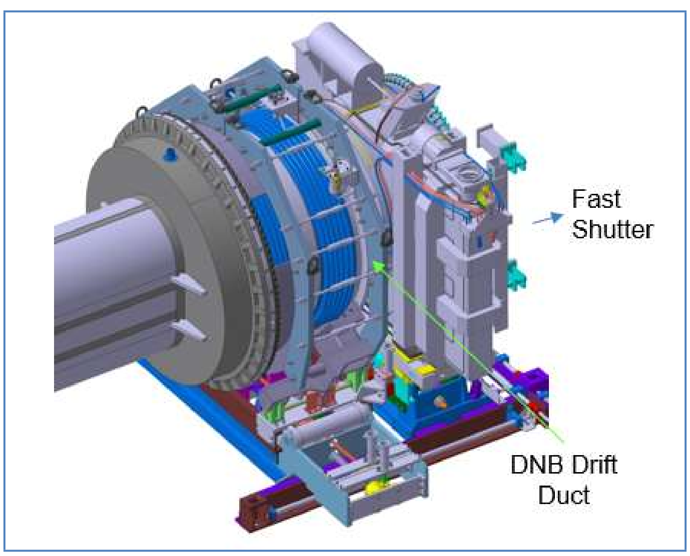


Figure 4: DNB Front End Components integration

- The flanges at either end of this component shall be compatible with the mating interface of the adjacent component.

- The AV services include:
    - coolant from the NBI PHTS (see section 6.4)
    - system, pneumatic actuator "air" lines,
    - Power-electric connections from casing and seal seat ring heating systems connections for C&I systems.

- The AV will be connected to the Service Vacuum System in order to monitored any interspaces used for sealing when needed.

- It is also assumed that the integration of the Absolute Valve in the Beam line will not result in any significant constraint of the casing against thermal expansion

- The flange design has been defined, along with associated remote handling procedures and tooling. The AV flanges shall be compatible with the VVPSS Box flange for the HNB / Drift Duct for the DNB and the Fast Shutter flange taking into account the sealing solution adopted by IO and the RH requirements. The interfaces flanges design have already been frozen. The Fast Shutter shall integrate these interfacing flanges as defined below.

In the current design of the AV, the flanges interface with the 2 neighbouring components are identical.

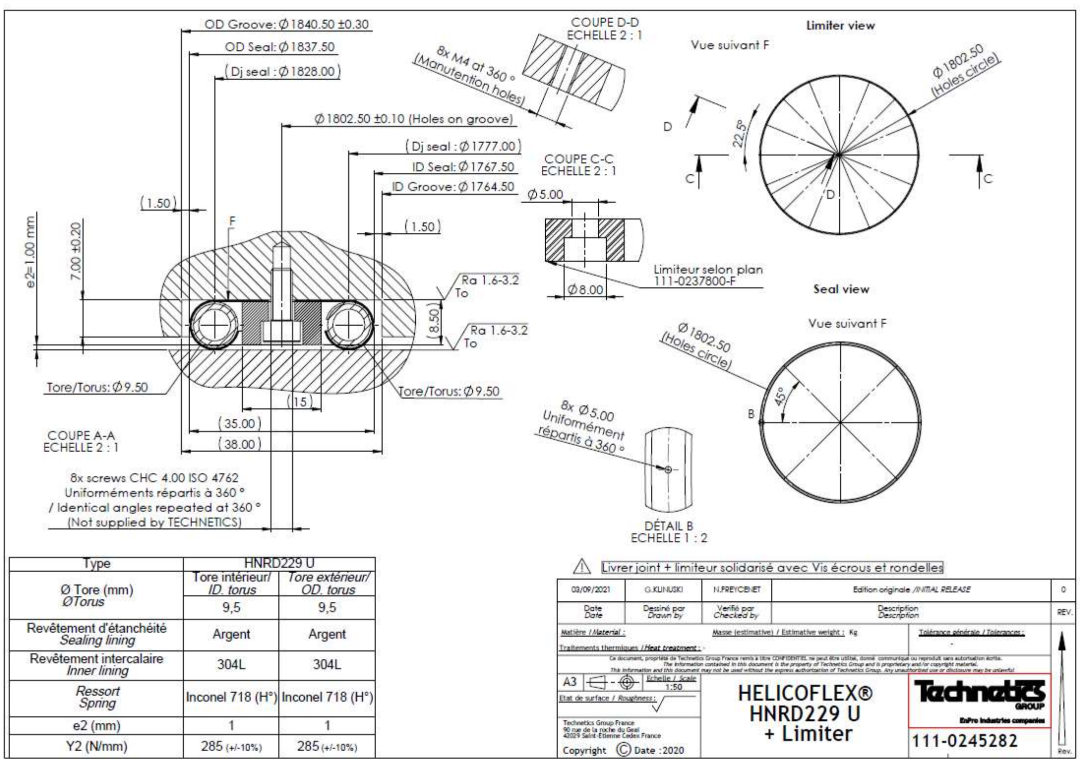


Figure 5: Sealing interface between the Fast Shutter and the VVPSS Box with the Absolute Valve

The flange design has been defined, along with associated remote handling procedures and tooling. The AV flanges shall be compatible with the VVPSS box flange and the Fast Shutter flange taking into account the sealing solution adopted by IO and the RH requirements.
The interfaces flanges design (in colour in the figure below) have already been frozen. The Absolute Valve shall integrate these interfacing flanges.

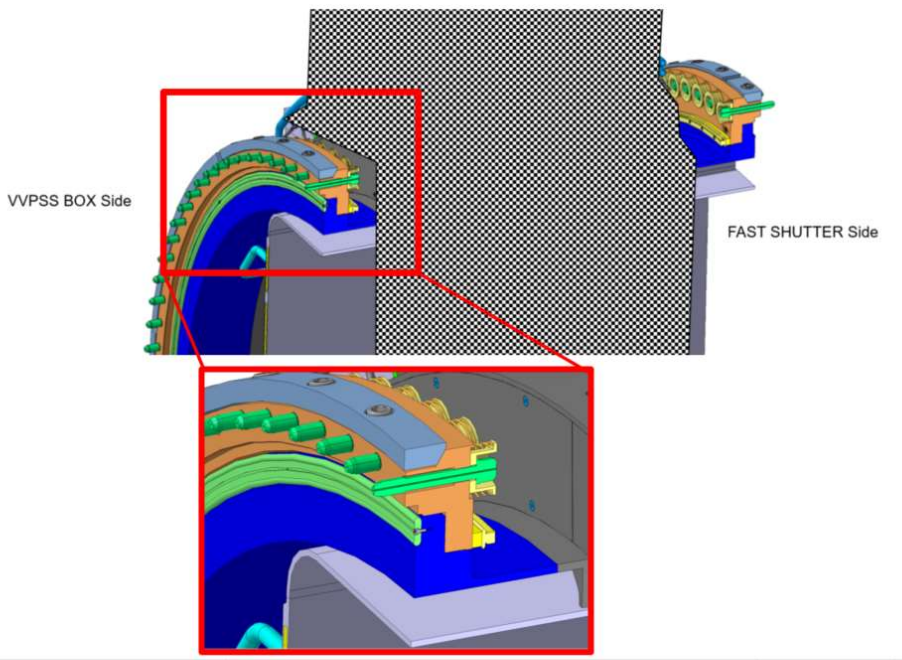


Figure 6: Sealing interface between the Fast Shutter and the VVPSS Box with the Absolute Valve preliminary design

- Design of the flanges at the interfaces will be provided by ITER.

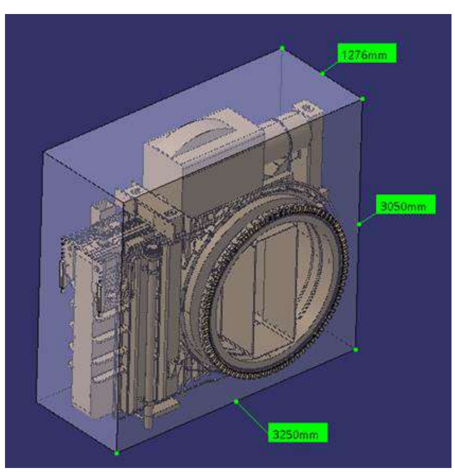


Figure 7: maximum envelope of the Absolute Valve

- The maximum space envelope of the Absolute Valve integrated in the NB cell environment shall be : 3250 mm by 3000mm by 1250mm

- Weight max of the AV : 8 500 kg

7.2 Vacuum

The casing of the AV shall have a maximum allowable leak rate of 1E-10 $Pa.m^3/s$ air equivalent from exterior atmosphere to internal vacuum.

All Interspaces used in vacuum confinement shall be connected to the Service Vacuum System (SVS).

Sealing for the first confinement boundary shall be by either:

- Welding
- metallic seal rings.

All components that have vacuum confinement functions shall comply with the vacuum handbook [3].

7.2.1 Maximum leak rates of the gate valve for different scenarios (*only for information*)

The maximum leak rates for the different scenarios are defined as follows:

A. VV under vacuum the BLV at 0.1 MPa
   Overall maximum leak rate 10^{-8} $Pa\cdot m^3/s$
   Sufficient single leak rate with pumped interspace 10^{-5} $Pa\cdot m^3/s$ at a pressure difference of 0.1 MPa

B. VV at 0.1 MPa the BLV under vacuum
   Overall maximum leak rate 10^{-8} $Pa\cdot m^3/s$
   Sufficient single leak rate with pumped interspace 10^{-5} $Pa\cdot m^3/s$ at a pressure difference of 0.1 MPa

C. Regeneration of the cryopump: VV under vacuum BLV at 2000 Pa
   Overall maximum leak rate 10^{-2} $Pa\cdot m^3/s$
   Sufficient single leak rate with pumped interspace 10 $Pa\cdot m^3/s$ at a pressure difference of 0.1 MPa

7.3 Lifting

The valve shall have at least three lifting points of identical design to the crane twist-lock fittings (design provided by IO). The triangle between the centres encloses the valve centre of gravity.

The maximum height available for components shall be 3,000 mm.

7.4 Support (for information only)

The valve is also supported from beneath by means of a trolley which bears its weight, but with sufficient compliance to accommodate thermal expansion of the valve without transferring significant loads across the flange interfaces. The trolley provides no constraint in the axial or transverse directions. The trolley runs axially on a pair of rails attached to the

NB cell floor with rollers attached to the chassis. The platform allows it to "float" in the transverse direction with a second mechanism to control this movement. The first mechanism also provides vertical compliance and allows fine tuning of the vertical position and rotation about the valve duct axis.

- Intefaces between the AV and the Support trolley will be provided by IO.

7.5 Coolant

The Valve can be served by the NBI PHTS (high resistivity) cooling circuit. It has the following properties:

- Operational Inlet pressure 2.2MPa (+/-0.2MPa) => 2.4 MPa (absolute)

- Max Operational inlet temperature. 38°C

-Max outlet temp. <90°C

-resistivity >5 MΩ.cm

7.6 Compressed air

Compressed air, or other ITER specified gas is required to drive various actuators and mechanisms on the valve.
The Absolute Valve only incorporates air lines and an interface block to connect them to the supply system. It is assumed that all the control valves and systems will be located in a cubicle outside of the NB cell in a location that is easily accessible for maintenance.

7.7 Electrical power

It is assumed that standard 240 V AC will be available and supplied to the valve via the interface defined.

7.8 Control & instrumentation (for information)

Since the instrumentation set for the valve has not yet been defined, the cabling has not been routed yet and no interface is currently included. The I&C connections should either be installed on the interface block or use a separate connector. This work shall be developed during the study.

7.9 Electromagnetic

Subassemblies of this component whose function may be unacceptably affected by electromagnetic fields at their installation location shall be shielded so that their performances are not unacceptably affected by the fields.

The most important fluxes generated by the tokamak will induce loop voltages in the horizontal planes and not in the vertical (radial) ones. This shall be taken into account when tracing cable routes to reduce loop voltages and when designing insulation layout to reduce eddy currents.

8 Preliminary Design (for information)

The preliminary design described in this section is to provide the supplier with information related to the preliminary study of the component. It can be considered as guidelines; the supplier shall not be bounded by the technical solutions to fulfil the requirements and environment described in this document in table 1.

8.1 Preliminary study

The valve is connected to the Fast Shutter and to the VVPSS box. Both these interfaces consist of similar flanges with a bore diameter of 1,600 mm to a standard design compatible with the NB cell RH equipment. The valve is also supported from beneath by means of a trolley which bears its weight, but with sufficient compliance to accommodate thermal expansion of the valve without transferring significant loads across the flange interfaces. The trolley provides no constraint in the axial or transverse directions.

- The preliminary design is a pendulum type valve with a nominal bore dimension of 1600 mm and an axial length of 760 mm between the outer faces of the casing. The overall width of the valve is 3120 mm with edge of the rectangular pocket being 2140 mm from the axis of the valve bore. The overall height is around 3 m. The valve plate is suspended from the pendulum and carries a pair of all-metal seal rings.
- Extra space accessible by the RH manipulator will also be required above the valve for service connections; in particular, flexible pipes connecting to the top end of the pendulum, which provide the water for the valve plate cooling / baking circuit and a duct for pumping the valve body when closed.
- A pair of seal actuators provide the seal load by means of an axial movement driven by gas filled pressure elements
- A sealing system shall be envisaged ~~and~~ an interspace of between 2 metallic seals can be pumped via a DN 100 line. A stub of DN 100 schedule 10 shall be included in the casing of the AV to connect to the interspace.
- Inside the bore of the valve is a system of rectangular section ducting and sliding shutters. This actively cooled by NBI PHTS (see section7.5) liner protects the valve bore from divergent beam energy and re-ionised particles.
- The moveable shutters slide inside the fixed ducts and have internal dimensions equal to those specified for the beam envelope: 1,457 mm high by 597 mm wide.
- Upstream AV Liner duct (opening) is set to have the internal dimensions given in the specification (1457mm high × 597 mm wide).
- Both sliding shutters are the same size and shall overlap the upstream duct.
- The arrangement shall eliminate upstream facing edges and makes some allowance for beam divergence.
- The re-ionised power inside the AV has been defined regarding several potential scenario of the gas profile inside the NB ducts. The results of re-ionization inside the AV will be defined in the LS [5]. The cooling system shall be defined accordingly.
- The valve is rated to sustain a pressure differential of 0.1 MPa across the plate whilst maintaining a leak rate of less than1x10-8Pa.m3/s, but can withstand up to 0.2 MPa without sustaining damage.

8.2 Material

- The use of Halogenated materials, sulphur and phosphorus for the AV that is Tritium Classified shall be avoided. Indeed, these materials lead to potential for oxidation catalyst poisoning and to metallic corrosion due to acid formation.
- All the materials for use in vacuum shall respect the requirements from chapter 5 of the Vacuum Handbook [3].
- The AV Stainless Steel (SS) shall be the X2CrNiMo17-12-2 controlled nitrogen(the X2CrNiMo17-12-2 controlled nitrogen is described in the RCC-MR Code Section A3.1S)
- The chemical composition determined by ladle and product analyses of X2CrNiMo17-12-2 controlled nitrogen shall comply with the requirements given in Table below : Chemical composition of X2CrNiMo17-12-2 controlled nitrogen for the NB Vessels

Chemical composition, X2CrNiMo17-12-2 controlled nitrogen	**Content in Wt. %**
Elements	*Range or Max*
Fe	balance
C	0.030
Mn	1.60 - 2.00
Si	0.50
P	0.030
S	0.015
Cr	17.00 - 18.00
Ni	12.00 – 12.50
Mo	2.30 – 2.70
N	0.060-0.080
Cu	1.00
B	0.0020
Additional ITER specific requirements [6] and [93]:	
Co	0.05
Nb	0.01

Ta	0.01
Ti	0.10

9 Design basis conditions & events

- This component shall be designed to cope with real-time power control of the beam which is designed to vary by +25%/-50%, whilst keeping below the maximum of 16.7MW to ITER, with a maximum frequency of 7 Hz.
- The design of this component shall not preclude pulse lengths of up to 3,600s at all beam powers and energies.
- The design of this component shall provide a thermal fatigue life consistent with the total number of pulses/pulse duration (50 000) foreseen by ITER operation, and by the commissioning and testing of the system as shown below:
- It can also be assumed do not adversely affect fatigue life of this component.
- The design life of this component is 20 years.

- The different states in which the AV will operate during its life are listed below:
  - State 1: transport & handling

The AV will have to be transported on ITER site. No additional load apart should be applied to the FS. The valve shall be equipped with some mechanical locks that stops it moving during handling.

- State 2: leak tests

After manufacturing and welding, the AV leak rate will be helium leak tested on the manufacturing plant following the VHB [5] – Appendix 12 [8].

- State 3: **during NB injection pulse**

This state describes normal operation when the beam is launched in the plasma. The Absolute Valve (casing) becomes Vacuum boundary. **The Absolute Valve shall be opened**. As the injector works and Plasma launched, the risk of re-ionization is high. Re-ionised power could appear on the internal side surfaces of the AV.

<u>Re-ionisation</u>: *The re-ionised power inside the AV has been defined regarding several potential scenario of the gas profile inside the NB ducts. A liner actively cooled shall withstand the heating loads when the Absolute Valve is opened.*

- State 4: **between NB injection pulse**

This state describes the period between pulses when the system is waiting for the next NB injection pulse. **The Absolute Valve shall be opened**.

- State 5: **Baking operation**

The AV shall be baked at a temperature greater than 180°C with a pressure of 0.01MPa (vacuum). Baking may be performed up to 500 times in the life of ITER.

All other surfaces exposed to the primary vacuum shall be baked at a temperature greater than 180°C, including the NB port (up to the torus isolation valve) and the VVPSS piping (up to the rupture disk).

The AV shall be capable of being raised from room temperature or operating temperature to the baking temperature within 2 days.

Following baking, the AV shall be capable of being returned to their pre-pulse operating temperature within 24 hours.

All systems shall be designed to accommodate 500 baking cycles from the commissioning phase to the end of life. During D-T pulse operation, the estimated baking cycles are 40.

NB group would suggest a guideline as 200°C ± 20°C for the baking temperature of the AV.

- State 5: Incident and Accident Events

Accident and incident events are pressure loads which are described in the Load Specification document [5]

Upset operating conditions may result in pressure differentials across the gate in excess of 0.1 MPa, up to a maximum design value of 0.2 MPa. The shutter shall withstand these events without any significant permanent deformations. This will be defined in the Load Specification document [5]

During normal operation the pressure in the NB cell is 0.1MPa absolute. During maintenance of a NB internal component the valve will be exposed to the same pressure as in the NB cell. The pressure in the VV can at the same time be between 0 and 0.1 MPa

Tokamak load case of category 4 leads to a pressure in the VV of 0.2 MPa which results into a pressure difference across the closed shutter of 0.1 MPa.

10 Load Specification

The AV design shall be compliant with all loads incident and accident events defined in the Load Specification [5]

11 Assembly

The Absolute valve is design as a stand-alone component and will be manufactured, assembled and tested off-site. It may, therefore, be installed as a module with no further setup required. It is envisaged that the valve will have a transport locking mechanism to prevent movement of the plate while the actuators are not active. This may require some minor intervention to deactivate or remove the mechanism. Ideally the interfaces for first assembly must be the same than for RH lifting in case of maintenance.

12 Maintenance / (Remote Handling interface)

As an RH class 3 component, it is a requirement that the valve continue to function adequately throughout the duration of the ITER experimental programme. As such, no maintenance operations are foreseen. In the event of a failure of the valve or degradation of performance to unacceptable levels, the valve would need to be removed and replaced by a new component. Refurbishment of the valve is not expected.

The operation of maintenance are:

- replacement of the full AV (RH Class3 shall be done Remotely (no human intervention).

The component shall be equipped with RH interfaces during design development. No periodic maintenance (repairing actions) plan is foreseen on the AV, this means that the AV is considered as Remote Handling Class3 on IO.As it is RH class 3, the only way to maintain the AV is to remove the whole component, in this case, the state will be similar to the state 1 ‘’Transport & Handling’’ ensured only with Remote operations

The sequences of this recovery scenario imply to close the AV to avoid the contamination of Tritium dust during the operations. The requirement of the leak tightness is not required, the gate shall just limit the displacement of the dust. All the service pack lines of the AV (cooling, pressurized air, SVS …) shall be cut and disconnected.

13 Manufacturing

The manufacturing feasibility shall be clearly demonstrated. As first confinement barrier, the casing of the AV must be developed and manufactured in accordance of the code and standards defined in the section 6. This component shall be designed to RCC-MR class 2.

In addition to the nuclear manufacturing code to apply, one of the main challenges will be to ensure the vacuum Tightness of the gate valve with metallic seals.

For the manufacturing of the in-vessel components (in the case of the AV, this correspond to the internal system which are not part of the first confinement barrier) generally there are two types of technical procedures:

1) Manufacturing procedures for parts or components which are addressed by conventional Codes and directive requirements. These procedures are typically related to conventional welding, brazing joining, and NDT. The related specifications shall be prescribed in accordance with Code or Directive or Order requirements. To be compatible with ESP and ESPN requirements, the recommended manufacturing Code is EN 13445.

2) Manufacturing procedures for parts or components which are not addressed by conventional Code requirements (e.g. beryllium/Cu joints for first wall, non-metallic material joining, etc.). For the this type of manufacturing procedures ITER specific Technical

Specification Documents shall be prepared or they will be defined in the Procurement technical specification Documents. The justifications shall be supported by R&D.

References:

[1] Quality Classification Determination: ITER_D_24VQES - Quality Classification Determination

[2] Safety Important Components - Abstract for Presentation of Methodology to the French regulator: ITER_D_282VAQ - Safety Important Components - Abstract for Presentation of Methodology to the French regulator

[3] ITER Vacuum Handbook: ITER_D_2EZ9UM - ITER Vacuum Handbook

[4] ITER_D_25EW4K - Codes and Standards for ITER Mechanical Components

[5] ITER_D_44ZMKX - HNB/DNB Absolute Valve Loads Specification

[6] ITER_D_347SF3 - Safety Important Functions and Components Classification Criteria and Methodology

[7] RCC-MR- RCC-MR code, 2007 edition. Design and construction rules for mechanical components of nuclear installations ISBN 2-913638-22-8

[8] ITER_D_222RHC - In-vessel Components, SDC-IC

[9] Vacuum Handbook Appendix 12 Leak Testing link ITER_D_2EYZ5F - Appendix 12 Leak Testing

[10] ITER_D_65QCSD - Technical Note Fast Shutter