TECHNICAL SPECIFICATION

CU_CUPG-01_PTD_Annex No. 1 - Technical Specification_VV

COMPASS-U: Vacuum Vessel and related components

REV. 13/2024

TABLE OF CONTENTS

1. TERMS AND CONDITIONS OF THE SELLER'S BID

This document contains specifications and requirements which must be followed and fulfilled by the Seller during the realization phase of the *Framework Purchase Agreement*, i.e. during the detailed planning and subsequent construction of the "*COMPASS-U: Vacuum Vessel and related components*".

This chapter contains the **minimal technical details, which must be included in the Seller's** Bid. The structure of the Seller's Bid used in this chapter is only recommended, i.e. it is not mandatory. It means that the Seller can organize and structure the technical part of the Bid in a different way, as long as all the required information is provided.

Recommended structure of technical part of the Seller's Bid is as follows:

1. Technical part of the Bid (contains information which must be included in the Bid):
    a. General description of the extent of delivery (≥ 2 pages)
    b. Technical details and parameters - minimum technical data to be included as follows:
        i. Basic overview of the delivered products and services, including description of materials and technologies intended to be used (this includes a brief description of proposed welding technologies).
            - The required extent is at least 1 page for the Item/Task No. 1 according the "Annex No. 3 - Price Schedule and Deliverables", at least short paragraph for Items/Tasks No. 2-5 and at least few sentences for the rest of the Items/Tasks (the rest of the Items/Tasks can be grouped for the purpose of the basic overview).
        ii. Bill of raw material – for need of the Bid (see chapter 7.4.3 for BOM)
        iii. A specific statement that the "*COMPASS-U: Vacuum Vessel and related components*" will fulfil all requirements contained in this entire document (technical specification).
2. Annexes to the technical part of the Bid (the annexes contain the information recommended by the Buyer, i.e. not mandatory):
    a. Seller's Bid Annex No. 1 - Technical details of the proposed manufacturing solutions of delivered products and related services (the extent of the description is left on the discretion of the Seller)
    b. Seller's Bid Annex No. 2 - Material certificates / datasheets of materials intended to be used (the extent of the description is left on the discretion of the Seller)

2. DEFINITIONS OF TERMS AND ABBREVIATIONS

Terms and abbreviations used in this document are grouped according to categories and defined in the following subsections.

2.1. Legal terms and abbreviations

Table 1: List of legal terms and abbreviations

Acronym	Brief description / meaning
Buyer	Generic name for the Institute of the Plasma Physics of the Czech Academy of Sciences.
COMPASS-U tokamak	Device foreseen to be operated at the Buyer's premises. The extent of delivery of this *Framework Purchase Agreement* contributes to the realization of one system of the whole tokamak.
Final design	The design of parts and components provided by the Buyer when an item is ordered. Eventually, design modified by the Seller when agreed with the Buyer.
Final product	All ordered items together after their manufacturing is finished (including post processing, if ordered).
Handover Protocol of the Production and engineering documentation - group no. 1	Document that officially approves taking over of the Production and engineering documentation – group no. 1 by the Buyer.
Handover Protocol of the Manufacturing phase	Document that officially approves successful finishing and taking over of the Manufacturing phase by the Buyer.
Handover Protocol of Acceptance	Document that officially approves taking over of the ordered extent of delivery by the Buyer.
Item / Task	A unique part of the extent of delivery that could be ordered.
Sub-item	A subset (a part) of an item.
IPP	Institute of Plasma Physics of the Czech Academy of Sciences.
PMC	Preliminary Market Consultation.
Seller	Company selected to procure and deliver the extent of delivery.
Transport permission document	Prepared by the Seller when all FAT requirements are met. Once approved by the Buyer, it allows the extent of delivery to be shipped to the Buyer's premises.

2.2. Technical terms and abbreviations

Table 2: Hierarchical ladder of elements composing the extent of delivery.

Acronym	Brief description / meaning
System	Denote the full extent of delivery of this tender documentation, i.e. all items, documentation and related services.
Component	Set of parts fulfilling a given function.
Processed Material / part	Raw material which has been processed during the manufacturing (the processed material is also called part).
Raw material	Input material for the manufacturing process. Raw i.e. as delivered after purchasing from material suppliers.

Table 3: List of items and sub-items.

Acronym	Brief description / meaning
Vacuum Vessel basic configuration	Main item of the extent of delivery. Includes the VV main body weldment, heating/cooling system, VV supports, blank flanges, elastomer seals and jigs sub-items. (item, see 5.1)
Blank flanges	Protective covers of all VV ports needed for vacuum tests, transport, storage and, eventually, for operation. (sub-item, see 5.1.4)
Elastomer seals	Seals to be used together with blank flanges for needs of leak tests, transportation or storage. (sub-item, see 5.1.5)
Heating / cooling system	System of buses and pipes designed to heat up or cool down the VV assembly during the COMPASS-U tokamak operation. (sub-item, see 5.1.2)
Jigs	Jigs which need to be manufactured for manipulation, transport or storage of the individual items, especially the Vacuum Vessel basic configuration. (sub-item, see 5.1.6)
Pads and studs	Interface elements for mounting in-vessel systems. This terminology regroups several items. (sub-items, see 5.6)
Post processing	Treatment(s) of the VV assembly to release the stresses induced during the manufacturing process. (item, see 5.5)
Shear keys	Part of the interface where welded studs are used, avoiding transfer of shear forces to the studs. (item, see 5.6)
Stress relieving heat treatment	Heat treatment of the VV assembly to relieve structural stresses that arise during manufacturing. (sub-item, see 5.5.1)
Stress relieving by vibration (VSR)	Vibration treatment of the VV assembly to relieve structural stresses that arise during manufacturing (Vibration Stress Relief). (sub-item, see 5.5.2)
VV main body weldment	The elementary structure of the VV including all inseparable components and parts. (sub-item, see 5.1.1)
VV support	Main gravity support of the Vacuum Vessel. (sub-item, see 5.1.3)

Table 4: Technical terms and abbreviations.

Acronym	Brief description / meaning
CF	Sealing standard for ultra-high vacuum technology (also ConFlat) according to ISO 3669.
CNC machines	A motorized maneuverable tool controlled by a computer.
CR	Critical Manufacturing Tolerance: deviation on technical dimensions of the part that shall not be exceeded (see 4.2.2).
DE	Desired Manufacturing Tolerance: allowed deviation from technical dimensions of the part that should ideally be respected (see 4.2.2).
DIV	Divertor subsystem to be mounted to the VV, not part of this *Framework Purchase Agreement.*
DUC / DLC	Designation of the center divertor port (Divertor Upper/Lower Center), see Fig. 15.
DUH / DLH	Designation of the horizontal divertor port (Divertor Upper/Lower Horizontal), see Fig. 15.

Acronym	Brief description / meaning
DUX / DLX	Designation of the x-point divertor port (Divertor Upper/Lower X-point), see Fig. 15.
EBW	Electron Beam Welding is a fusion welding process in which a beam of high-velocity electrons is applied to two materials to be *joined.*
Engineering documentation	Provides design overview and technical details of a given product, including general components, assembly / disassembly and eventually maintenance instructions.
FAT	Factory Acceptance Test (key checks before shipping to the Buyer).
HFS	High-field side, machine side where the toroidal magnetic field is the highest, i.e. closer to the central solenoid (see Fig. 2).
High vacuum	Vacuum for which the working pressure is between 10^{-5} Pa and 1 Pa.
ID	Inner diameter.
LFS	Low-field side, machine side where the toroidal magnetic field is the lowest, i.e. further away from the central solenoid (see Fig. 2).
MARC	Magnetic rotating arc welding
MIC	Manufacturing Interim Checks.
Mid-plane	Main plane located in the equatorial plane of the device.
MIG	Metal welding technology using a melted electrode (Metal Inert Gas).
Mill test certificate (MTC)	Material certificate, also known as mill test report (MTR), mill test certificate (MTC) or inspection certificate, is a quality assurance document used in the metals industry that certifies material's technical parameters such as chemistry, mechanical or other physical properties according to EN 10204 (Inspection certificate 3.2).
MMA / MMAW / SMAW	Manual metal arc welding / shielded metal arc welding
MN ports	Narrow port of the VV located on the mid-plane.
MX ports	Wide port of the VV located in the mid-plane.
NC/CNC machine	Motorized tool allowing a numerical controlled automated machining of a processed material offering increased productivity.
OD	Outer diameter.
Outer surface of the VV	Design the exterior boundary of the VV.
Peripheral common bus	Central loop to what all the heating / cooling system is connected, see Fig. 20.
Port stub	Structural shell creating the VV ports.

Acronym	Brief description / meaning
PQR	Procedure Qualification Record.
Production documentation	Provides all detailed dimensions and specifications of a part to be manufactured, so that it can be made with the required precision. It includes the complete dimensions, the surface finish, welding information, bill of material or any other requirements such as the cleaning of the part.
Prototype	A custom product made for qualification of a chosen technology or/and for testing purposes.
Room temperature (RT)	Typical room temperature, for the purpose of this Technical specification 20 - 24 ˚C.
Sample	Material sample cut out of raw material or a prototype to perform given tests (e.g. mechanical properties).
SAT	Site Acceptance Test.
Specimen	Generic term for prototypes and/or samples.
Structural material	Material used for procurement of any item of the extent of delivery.
Testing sample	Sample used to perform given mechanical or other tests.
TIG	Metal welding technology using tungsten electrode (Tungsten Inert Gas).
Tokamak	The tokamak is one of several types of magnetic confinement devices being developed to produce controlled thermonuclear fusion power.
Ultra-high vacuum	Vacuum for which the working pressure is below 10^{-5} Pa.
VV	Stands for Vacuum Vessel. Can also refer to VV main body weldment, according to the context.
VV assembly	Vacuum Vessel assembly made of the VV main body weldment, VV supports (sub-items) and other inseparable items ordered.
VV sector	Angular sector of the VV assembly.
Weld map or weld identification plan	weld map shall show all realized welds on the VV main body weldment including a proper identification of individual welds and additional information.
WPQR	Welding Procedure Qualification Report.
WPS	Welding Procedure Specification.

2.3. Used technical standards

The table in this chapter contains all technical standards used in this Technical specification. Note, that for convenience of the reader, the exactly same table is in the Technical specification – Annex No. 9 – List of used technical standards, so that it can be separately printed as reference material for reading this Technical specification.

The technical standards are listed in this order: 1/ DIN, 2/ ISO, 3/ EN and 4/ EN ISO, followed by alphabetical order of the technical standard number.

In total, there are 82 technical standards required in this Technical specification and listed in the following table. From this number:

1. 22 are complementary (marked by gold background in the table): these are "common" / "automatic" / "auxiliary"
2. 8 are highlighted for the Seller's attention (marked by orange background in the table): the Seller is recommended to pay special attention to these technical standards.

Table 5: List of the key required technical standards

No.	Acronym	Brief description / meaning
1	DIN 17744	Wrought nickel alloys with molybdenum and chromium - Chemical composition.
2	DIN 17750	Strips and sheets of wrought nickel and nickel alloys – Properties.
3	ISO 15510	Stainless steels, chemical composition.
4	ISO 16143-1	Stainless steels for general purposes.
5	ISO 17577	Steel – Ultrasonic testing for steel flat products of thickness equal to or greater than 6 mm.
6	EN 764-5	Pressure equipment - Part 5: Inspection documentation of metallic materials and compliance with the material specification
7	EN 1011-(1-8)	Welding – Recommendations for welding of metallic materials.
8	EN 1518	Non-destructive testing - Leak testing - Characterization of mass spectrometer leak detectors.
9	EN 10204	Metallic products - Types of inspection documents
10	EN 10228-(3, 4)	Non-destructive testing of steel forgings.
11	EN 10296	Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties.
12	EN 13018	Non-destructive testing – Visual testing – General principles
13	EN 13445	Unfired pressure vessels
14	EN 13479	Welding consumables, general product standard for filler metals and fluxes for fusion welding of metallic materials.
15	EN ISO 128	Technical product documentation (TPD) — General principles of representation
16	EN ISO 129	Technical product documentation (TPD) — Presentation of dimensions and tolerances

No.	Acronym	Brief description / meaning
17	EN ISO 148-1	Metallic materials – Charpy pendulum impact test – Part 1: Test method.
18	EN ISO 1101	Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out
19	EN ISO 1779	Non-destructive testing - Leak testing - Criteria for method and technique selection.
20	EN ISO 2768-mK	General tolerances - Part 1: Tolerances for linear and angular dimensions without individual tolerance indications.
21	EN ISO 3274	Geometrical product specifications (GPS) - Surface texture: Profile method - Nominal characteristics of contact (stylus) instruments.
22	EN ISO 3452-(1-6)	Non-destructive testing – Penetrant testing.
23	EN ISO 3506-(1-2)	Mechanical properties of corrosion resistant stainless-steel fasteners.
24	EN ISO 3669	Vacuum technology — Dimensions of knife-edge flanges
25	EN ISO 3834-(1, 2, 5, 6)	Quality requirements for fusion welding of metallic materials - Part 1: Criteria for the selection of the appropriate level of quality requirements. Quality requirements for fusion welding of metallic materials - Part 2: Comprehensive quality requirements. Quality requirements for fusion welding of metallic materials — Part 5: Documents with which it is necessary to conform to claim conformity to the quality requirements of ISO 3834-2, ISO 3834-3 or ISO 3834-4 Quality requirements for fusion welding of metallic materials — Part 6: Guidelines on implementing ISO 3834
26	EN ISO 4063	Welding and allied processes – Nomenclature of processes and reference numbers.
27	EN ISO 4136	Destructive tests on welds in metallic materials - Transverse tensile test.
28	EN ISO 4287	Geometrical product specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters.
29	EN ISO 4288	Geometrical product specifications (GPS) - Surface texture: Profile method - Rules and procedures for the assessment of surface texture.
30	EN ISO 4762	Hexagon socket head cap screws
31	EN ISO 5173	Destructive tests on welds in metallic materials - Bend tests.
32	EN ISO 5178	Destructive tests on welds in metallic materials - Longitudinal tensile test on weld metal in fusion welded joints.
33	EN ISO 5817	Welding, Fusion welded joints in steel, nickel, titanium and their alloys - Quality levels for imperfections.
34	EN ISO 6520-1	Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: Fusion welding.
35	EN ISO 6892-(1, 2)	Metallic materials - Tensile testing - Part 1: Method of test at room temperature.

No.	Acronym	Brief description / meaning
		Metallic materials - Tensile testing - Part 2: Method of test at elevated temperature.
36	EN ISO 6947	Welding and allied processes – Welding positions.
37	EN ISO 8015	Geometrical product specifications (GPS) - Fundamentals - Concepts, principles and rules.
38	EN ISO 9016	Destructive tests on welds in metallic materials - Impact tests - Test specimen location, notch orientation and examination.
39	EN ISO 9606-(1, 4)	Qualification testing of welders - Fusion welding - Part 1: Steels. Qualification testing of welders - Fusion welding - Part 4: Nickel and nickel alloys.
40	EN ISO 9712	Non-destructive testing – Qualification and certification of NDT personnel
41	EN ISO 10012	Measurement management systems - Requirements for measurement processes and measuring equipment
42	EN ISO 10160	Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm.
43	EN ISO 10307	Non-destructive testing - Ultrasonic testing of austenitic and austenitic-ferritic stainless steels flat products of thickness equal to or greater than 6 mm.
44	EN ISO 10675-1	Non-destructive testing of welds – Acceptance levels for radiographic testing – Part 1: Steel, nickel, titanium and their alloys.
45	EN ISO 11666	Non-destructive testing of welds – Ultrasonic testing – Acceptance levels.
46	EN ISO 13588	Non-destructive testing of welds - Ultrasonic testing - Use of automated phased array technology.
47	EN ISO 13715	Technical product documentation - Edges of undefined shape - Indication and dimensioning.
48	EN ISO 13916	Welding - Measurement of preheating temperature, interpass temperature and preheat maintenance temperature.
49	EN ISO 13918	Welding – Studs and ceramic ferrules for arc stud welding.
50	EN ISO 13919-1	Electron and laser-beam welded joints – Requirements and recommendations on quality levels for imperfections – Part 1: Steel, nickel, titanium and their alloys – required quality grade B. *(This standard is required by the Buyer only if the Seller decides to use electron beam welding for manufacturing of the extend of delivery.)*
51	EN ISO 13920	General tolerances for welded constructions – Dimensions for lengths and angles – Shape and position – required tolerance class A for dimensions and angles; tolerance class E for straightness, flatness and parallelism.
52	EN ISO 13925-(1-3)	Non-destructive testing - X-ray diffraction from polycrystalline and amorphous material.

No.	Acronym	Brief description / meaning
53	EN ISO 14172	Welding consumables – Covered electrodes for manual metal arc welding of nickel and nickel alloys – Classification.
54	EN ISO 14175	Welding consumables – Gases and gas mixtures for fusion welding and allied processes.
55	EN ISO 14555	Welding – Arc stud welding of metallic materials.
56	EN ISO 14556	Metallic materials – Charpy V-notch pendulum impact test – Instrumented test method.
57	EN ISO 14732	Welding personnel – Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials.
58	EN ISO 15305	Non-destructive testing – Test method for residual stress analysis by X-ray diffraction.
59	EN ISO 15607	Specification and qualification of welding procedures for metallic materials – General rules.
60	EN ISO 15609-(1, 3)	Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 1: Arc welding. Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 3: Electron beam welding.
61	EN ISO 15611	Specification and qualification of welding procedures for metallic materials – Qualification based on previous welding experience.
62	EN ISO 15613	Specification and qualification of welding procedures for metallic materials – Qualification based on pre-production welding test.
63	EN ISO 15614	Specification and qualification of welding procedures for metallic materials – Welding procedure test
64	EN ISO 16810	Non-destructive testing - Ultrasonic testing - General principles.
65	EN ISO 16827	Non-destructive testing - Ultrasonic testing - Characterization and sizing of discontinuities.
66	EN ISO 17635	Non-destructive testing of welds – General rules for metallic materials
67	EN ISO 17636-(1, 2)	Non-destructive testing of welds - Radiographic testing - Part 1: X- and gamma-ray techniques with film. Non-destructive testing of welds - Radiographic testing - Part 2: X- and gamma-ray techniques with digital detectors.
68	EN ISO 17637	Non-destructive testing of welds - Visual testing of fusion-welded joints.
69	EN ISO 17639	Destructive tests on welds in metallic materials - Macroscopic and microscopic examination of welds.
70	EN ISO 17640	Non-destructive testing of welds – Ultrasonic testing, techniques, testing levels and assessment.
71	EN ISO 17663	Welding - Quality requirements for heat treatment in connection with welding and allied processes.

No.	Acronym	Brief description / meaning
72	EN ISO 18274	Welding consumables – Solid wire electrodes, solid strip, solid wires and solid rods for fusion welding of nickel and nickel alloys – Classification.
73	EN ISO 18563-(1-3)	Non-destructive testing - Characterization and verification of ultrasonic phased array equipment.
74	EN ISO 19285	Non-destructive testing of welds - Phased array ultrasonic testing (PAUT) - Acceptance levels.
75	EN ISO 20484	Non-destructive testing – Leak testing – Vocabulary
76	EN ISO 20485	Non-destructive testing – Leak testing – Tracer gas method.
77	EN ISO 20486	Non-destructive testing – Leak testing – Calibration of reference leaks for gases
78	EN ISO 21920-(1-3)	Geometrical product specifications (GPS) - Surface texture: Profile.
79	EN ISO 22825	Non-destructive testing of welds - Ultrasonic testing - Testing of welds in austenitic steels and nickel-based alloys.
80	EN ISO 23277	Non-destructive testing of welds – Penetrant testing – Acceptance levels.
81	EN ISO 23279	Non-destructive testing of welds – Ultrasonic testing – Characterization of indications in welds.
82	PED 2014/68/EU	Directive of the European parliament and of the council on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

... complementary ... highlighted for the Seller's attention

3. BASIC DESCRIPTION AND THE EXTENT OF DELIVERY

3.1. Basic overview of the extent of delivery

In this section, a brief description of the whole extent of delivery of the *Framework purchase agreement* is given. It provides a general overview of what is expected by the Buyer from the Seller without extensive discussion on technical details. Note that this section is only informative and more technical details are provided in other sections and chapters. All figures shown here are for illustrative purposes only and do not necessarily reflect the final design stage of the shown systems or components.

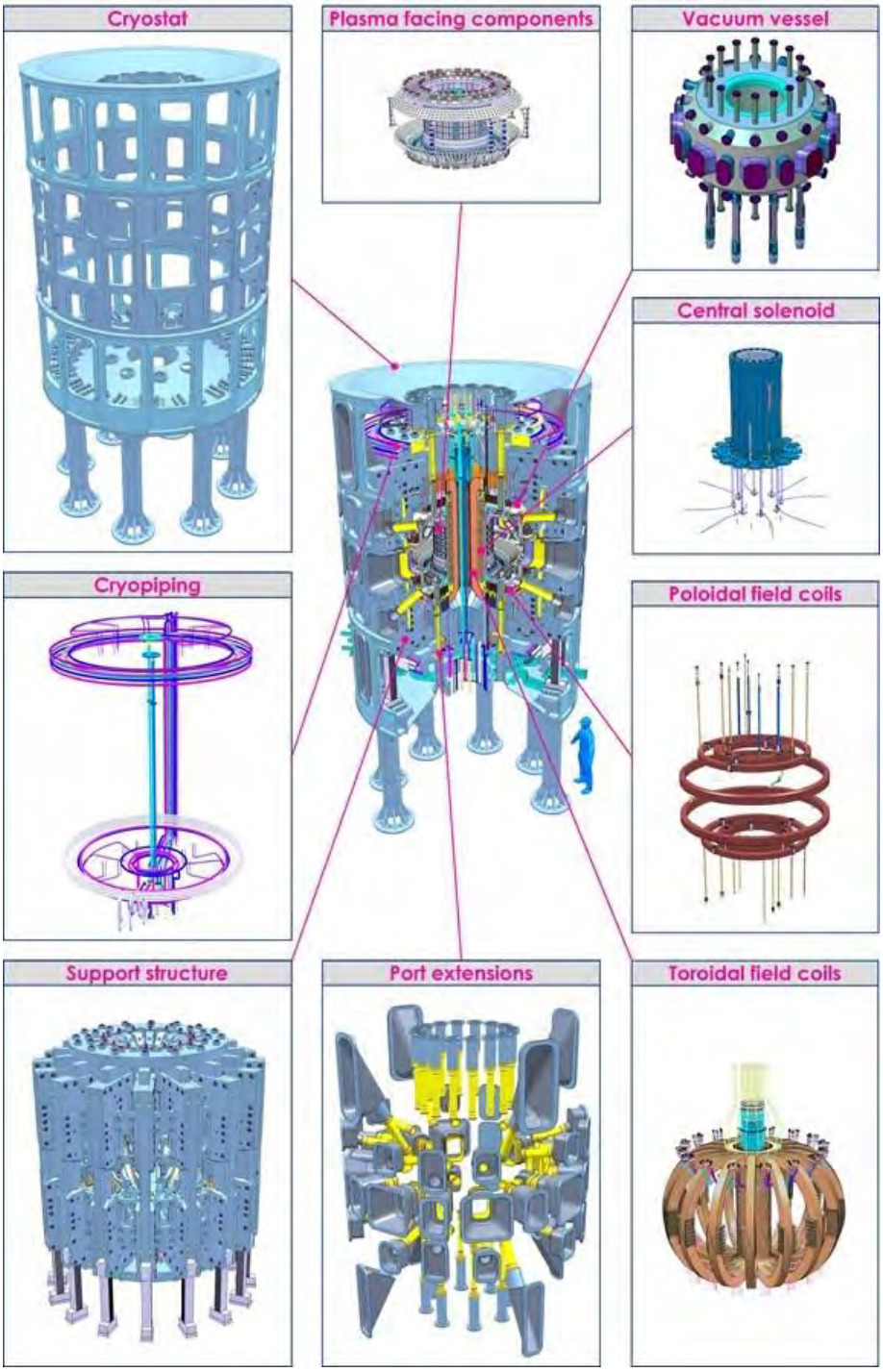


Fig. 1: Overview of the COMPASS-U tokamak main systems (only the vacuum vessel is part of the extent of delivery)

The Vacuum Vessel (VV) assembly and its related components are located in the very core of the COMPASS-U tokamak, as can be seen in Fig. 2. The VV assembly is one of the key systems of the tokamak which should maintain ultra-high vacuum and high operation temperature, serve as a structural boundary and enable the mounting of all related components and systems, including in-vessel diagnostics and plasma facing components (first wall). In particular, during the tokamak operation, the VV assembly must provide ultra-high vacuum down to 10^{-6} Pa with a leak rate of maximum 10^{-9} Pa m^3/s, sustain elevated temperatures up to 500 °C, allow access to diagnostics, control, heating and cooling systems through the ports and feedthroughs, sustain all possible load scenarios coming from EMG forces and enable access for maintenance between the operational campaigns.

An overview of the VV assembly and its related components is shown in Fig. 2 (left). In Fig. 2 (right), a section view of the VV assembly shows more details on the components connected to it. Note that for instance the VV main body weldment forms a structural boundary of the whole VV assembly, while several other components (e.g. ports, heating and cooling system, pads and other interfaces, VV support) will be inseparably joined with the VV by welding.

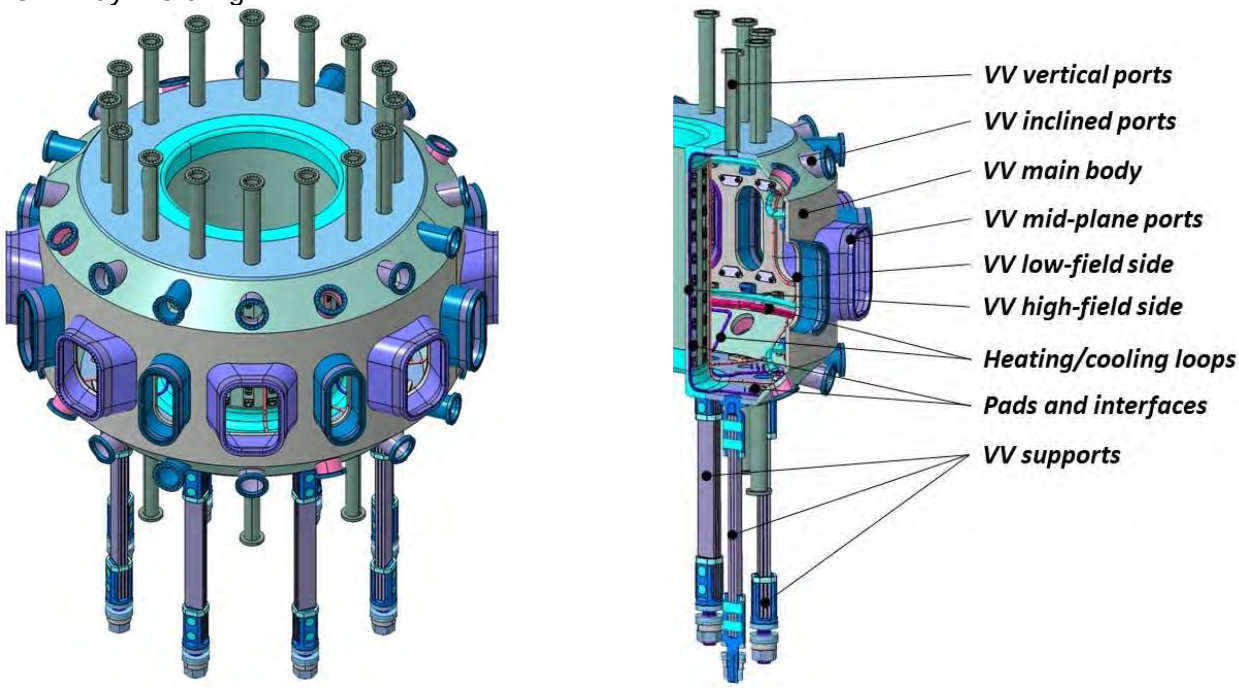


Fig. 2: Left: Overview of the VV assembly. Right: Section of the VV assembly showing its main components

The heating and cooling system is a set of tubes and buses which will serve to heat up (or cool down) the whole VV up to 500 °C (or from 500 °C down to room temperature) using a high-pressure gas. The mounting pads are in most cases welded interfaces that will be used to mount various in-vessel components (not part of the extent of delivery), which will protect the VV from the fusion plasmas. A close-up to these components is shown in Fig. 3.

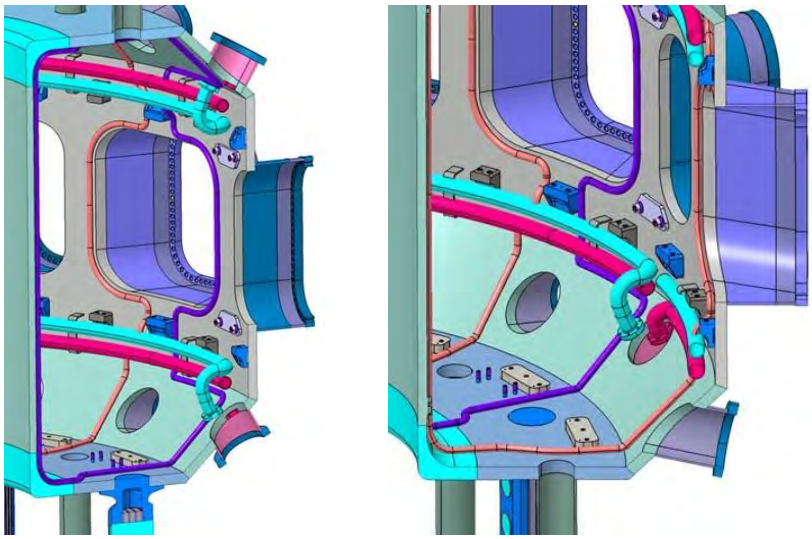


Fig. 3: Left and right: Close-up to welded components (heating and cooling system in red and purple, pads in dark blue and grey) inside the VV assembly

An illustration of the VV supports is shown in Fig. 4. VV supports serve as a gravity support for the VV and, as well, allows thermal expansion of the VV assembly without any harm of the structure.

Fig. 4: All eight VV supports

Another component of the extent of delivery is blank flanges for all ports of the VV. All VV ports shall be sealed for several reasons and purposes as follows:

- to perform vacuum leak tests
- for safe and clean transportation or storage of the whole VV assembly
- for the operation of the tokamak (in some cases)

There are six types of blank flanges to seal the MX, MN, vertical, and divertor ports, as shown in Fig. 5.

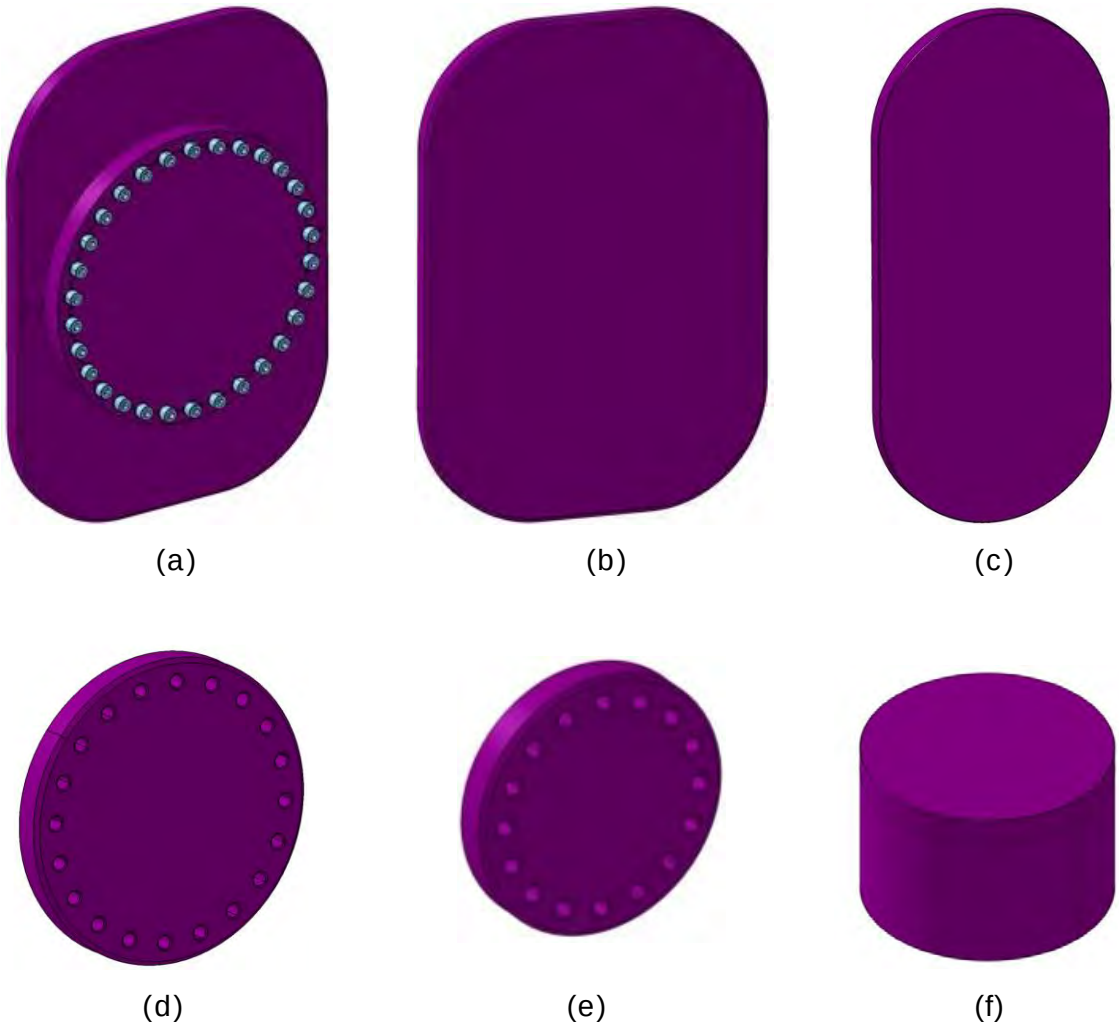


Fig. 5: All six types of blank flanges; (a) MX port with additional CF flange; (b) MX port simple flange; (c) MN port flange; (d) Divertor port flange; (e) Vertical port flange; (f) Divertor port flange – for elevated temperature operation

For safe and reliable transportation and storage of the VV assembly, additional jig(s) are procured by the Seller as part of the extent of delivery. The Seller is responsible for conceptual development and final design as well as procurement of these jigs.

It is expected that all joints or connections of the individual parts or components of the VV assembly (except the blank flanges, jigs, components of the VV supports) will be realised by a specific carefully selected welding technology which is to be chosen by the Seller. Joints on the rest of the mentioned components shall be done according to common industry standards. To release stresses induced by welding, a post processing by heat treatment of the VV (welded) assembly may be needed (if ordered, also to be designed by the Seller).

3.2. Extent of delivery

The "*COMPASS-U: Vacuum Vessel and related components*" extent of delivery includes manufacturing, temporary storage on the Seller's premises and transporting to the Buyer's site of installation of the VV assembly of *the "COMPASS-U tokamak and its related systems"* (as listed below). The extent of delivery (this section) contains a list of all individual items forming the complete "*Vacuum Vessel and related components*" that shall meet all technical specifications and industry standards defined in this document. This includes checks and tests ensuring the quality and reliability of the manufacturing process supported

with appropriate outputs and documentation. All items ordered by the Buyer shall be procured by the Seller.

For the purpose of procurement procedure, the "*COMPASS-U: Vacuum Vessel and related components*" extent of delivery is divided into the following items:

1. Vacuum Vessel basic configuration
2. Item not used
3. Item not used
4. Item not used
5. Post processing of the Vacuum Vessel main body weldment
6. Item not used
7. Item not used
8. Item not used
9. LFS OWL pad
10. Item not used
11. Item not used
12. Item not used
13. Item not used
14. Item not used
15. Item not used
16. Outer DIV four-stud, type 1
17. Item not used
18. Item not used
19. Item not used
20. Item not used
21. Item not used
22. Item not used
23. Outer DIV shear key
24. PSP outer pad
25. PSP LFS pad single
26. PSP LFS combined pad
27. Extra man-hours of project manager / engineer / designer / technician / production worker or assembly worker
28. Extra research and development activities / design activities or service activities
29. Extra machining time on CNC machine (includes work of operator)
30. Extra machining time on conventional / standard machine (includes work of operator)
31. Extra welding time (includes all costs of welding equipment and work of welder)

Throughout this document, the term "*COMPASS-U: Vacuum Vessel and related components*" refers to the entire system, including all the items mentioned above.

An overview of the individual items of the "*COMPASS-U: Vacuum Vessel and related components*" extent of delivery is given below:

1. The *Vacuum Vessel basic configuration* item includes:

    a. The VV main body weldment sub-item: The Seller shall procure the core component of the VV assembly forming its elementary structural boundary, called the VV main

body weldment. The VV main body weldment includes all ports with flanges. It does not include any other items of the extent of delivery and other sub-items of the VV basic configuration mentioned below. More details can be found in chapter 5.1.1. The different parts composing the VV main body weldment will be welded together using a suitable technology selected by the Seller and approved by the Buyer, as described in chapter 4.2.

b. The heating / cooling system sub-item: The Seller shall procure heating/cooling pipes and buses and integrate them inside the VV main body weldment using a suitable technology selected by the Seller and approved by the Buyer. The heating / cooling system shall fulfil all the specifications required by this document and as described in chapter 5.1.2.

c. The VV supports sub-item: The Seller shall procure all the VV support assemblies designed with flexible plates and shall mount them on the VV main body weldment as described in the technical specification given in chapter 5.1.3.

d. The *blank flanges* sub-item: The Seller shall procure blank flanges for all ports of the VV main body weldment for several purposes, as performing vacuum leak tests as part of the FAT and SAT, for safe and clean transportation of the VV assembly, for storage and even for the tokamak operation if needed, as described in chapter 5.1.4.

e. The elastomer seals sub-item: The Seller shall procure a set of elastomer seals for every port of the VV to be used with the blank flanges for storage, transportation and vacuum test purposes. See chapter 5.1.5 for more details.

f. The jigs sub-item (more details can be found in chapter 5.1.6):

- The Seller shall procure a transportation jig to enable safe and reliable transportation of the VV assembly. Eventually, this jig could also serve as a storage jig if it fulfils requirements of the storage jig mentioned below.
- The Seller shall procure a storage jig (if not the same as the transportation jig mentioned above) to enable safe and reliable storage of the VV assembly in the Buyer's premises.

2. Item not used

3. Item not used

4. Item not used

5. The *post processing of the Vacuum Vessel main body weldment item*: In order to reduce any induced stresses that arise during the manufacturing process, the Seller shall perform a heat treatment and, eventually, additional stress relieving process. The post processing shall be performed on the VV main body weldment with or without ports, possibly including also the heating/cooling system or in-vessel interfaces. After the post processing, use some of the welding methods is limited, see chapter 5.5.

   Following treatments are considered:

   a. Stress relieving heat treatment: If the post processing of the Vacuum Vessel main body weldment item is ordered, the Seller shall propose and perform a heat treatment process to relieve the residual stresses of the VV main body weldment or its parts. Performing the heat treatment of the blank flanges or any jigs is not required. More details can be found in chapter 5.5.1.

b. Stress relief by vibration (VSR): Additionally, the Seller can perform a complementary method to relieve the residual stresses in the VV main body weldment, using vibration. Upon agreement with the Buyer, the Seller shall perform the proposed treatment. More details can be found in chapter 5.5.2.

6. Item not used
7. Item not used
8. Item not used
9. *The* LFS OWL pad item: interface elements welded in the VV on outer vertical wall (see chapter 5.6.5)
10. Item not used
11. Item not used
12. Item not used
13. Item not used
14. Item not used
15. Item not used
16. *The* outer DIV four-stud, type 1 item: interface elements welded in the VV on horizontal wall (see chapter 5.6.12)
17. Item not used
18. Item not used
19. Item not used
20. Item not used
21. Item not used
22. Item not used
23. *The* outer DIV shear key item: interface elements welded in the VV on horizontal base together with items 16, 17, (see chapter 5.6.19)
24. *The* PSP outer pad item: interface elements welded in the VV on outer vertical wall (see chapter 5.6.20)
25. *The* PSP LFS pad single item: interface elements welded in the VV on outer vertical wall (see chapter 5.6.21)
26. *The* PSP LFS combined pad item: interface elements welded in the VV on outer vertical wall (see chapter 5.6.22)
27. The extra man-hours of project manager / engineer / designer / technician / production worker or assembly worker item: Additional man-hours covering services that could be ordered in case of significant design changes of any item. For more information, see chapter 4.6 on conditions on design changes.
28. The extra research and development activities / design activities or service activities item: Additional man-hours covering the mentioned services that could be ordered in case of significant design changes of any item. For more information, see chapter 4.6 on conditions on design changes.
29. The extra machining time on NC machines (includes work of operator) item: Additional machine-hours using dedicated NC machines that could be ordered in case of significant design changes of any item. For more information, see chapter 4.6 on conditions on design changes.
30. The extra machining time on conventional / standard machine (includes work of operator) item: Additional machine-hours using standard machines that could be

ordered in case of significant design changes of any item. For more information, see chapter 4.6 on conditions on design changes.

31. The extra welding time (includes all costs of welding equipment + work of welder) item: Additional man-hours covering the welding work that could be ordered in case of significant design changes of any item. For more information, see chapter 4.6 on conditions on design changes.

Every item shall follow a specific procurement process described in chapter 6 and in the Technical specification – Annex No. 1 – Universal Procurement process of an item and is a subject to acceptance tests (see chapter 9). A proper documentation (see chapter 7) shall be delivered with every item as well. A brief overview of the acceptance tests required, documentation and delivery is given below:

1. Acceptance tests include:
    a. Preparation phase of required documentation (see chapter 9.4)
    b. Raw material acceptance prior launching the manufacturing (see chapter 9.5)
    c. Manufacturing phase acceptance (see chapter 9.6) shall be performed by the Seller, where specific technical and quality requirements and progress of the manufacturing process are checked. The manufacturing process cannot continue if specific checks are not performed and approved by the Buyer.
    d. Factory acceptance tests (see chapter 9.7) shall be performed by the Seller and approved by the Buyer before the ordered extent of delivery is transported to the Buyer's premises.
    e. Site acceptance tests (see chapter 9.8) shall be performed by the Seller to validate that the extent of delivery meets quality and specifications as defined in this document, once the extent of delivery is on the Buyer's premises.
2. Documentation: The Seller is obliged to provide technical documentation to the Buyer for all ordered items. This includes:
    a. Production and engineering documentation of all manufactured items (see chapter 7.1),
    b. Any other documentation, certificates or appropriate reports ensuring that the products meet the technical requirements and acceptance tests, as defined in chapter 7.
3. Delivery: The Seller shall secure delivery of all ordered items using the procured jigs to the Buyer's premises, as described in the *Framework Purchase Agreement* and in chapter 4.7.

For the purposes of general tender planning and procurement process definition, the extent of delivery is divided into two following groups of items (see also Technical specification – Annex No. 1 – Universal Procurement process of an item):

- Group no. 1 – first priority group including the VV basic configuration, post processing and LFS OWL interfaces (items no. 1, 5 and 9)
- Group no. 2 – secondary priority group including outer divertor interfaces and PSP interfaces (items no. 16, 18 to 23, and 24 to 26)

4. GENERAL TECHNICAL REQUIREMENTS

This chapter contains all general specifications and requirements necessary for the realization of the tender that shall be strictly followed and fulfilled by the Seller. It aims to provide general requirements for each specific component included in the extent of delivery (see chapter 3.2). Note that some of the specifications are applicable to the complete system, while some are valid for specific items, components or parts only. Each section highlights which requirements are applicable for individual parts of the extent of delivery.

All requirements and specifications are mandatory and subject to approval and verification, as described in chapter 9. In case of any deviation from the required parameters during the manufacturing process, rules provided in chapter 9.9 and in the *Framework Purchase Agreement* shall be strictly followed.

4.1. Material specification

This section defines requirements on input material that is to be used for manufacturing of the individual items of the extent of delivery. Minimum requirements that shall be fulfilled are also discussed. The use of any other material than the material specified in the items' description in chapter 5 and in the preliminary documentation (see chapter 7.1) must be agreed with the Buyer. Any deviations from the required properties of the material shall be reported to and approved by the Buyer.

4.1.1. Overview of the raw material procurement

An overview of the raw material procurement process and acceptance can be found in the Technical specification – Annex No. 1 – Universal Procurement process of an item and chapter 9.5. An overview of key steps that shall be followed by the Seller is provided here.

First, the Seller shall provide all relevant bills of raw material (see chapter 7.4), including preliminary mill test certificates for every batch of raw material planned to be purchased (see chapter 7.4.2). Note that the very first bill of raw material is submitted by the Seller as a part of the bid (mill test certificates are optional in the bid).

The raw material can be ordered and purchased only after the Buyer's approval. In the meantime, the Seller shall propose a general testing plan for raw material samples testing (see 7.5.1).

After the purchased raw material is delivered to the Seller's premises, the bill of raw material, the testing plan, and final mill test certificates shall be updated by the Seller and submitted for approval to the Buyer. The raw material testing can then be started. Every raw material sample shall be identified with a unique marking, see chapter 4.4. Note that for the raw material used for procuring the jigs and blank flanges no tests are required.

On every batch of material (type of the same material, e.g. different thickness) specific required tests shall be performed as described in chapter 9.5. This includes checks of material physical structure for imperfections, destructive and non-destructive tests. Procured material shall be free from surface and internal defects which can impair their intended use. Only when all checks are successfully finished and approved by the Buyer, the manufacturing phase is allowed to start.

At this point a partial payment no. 2 for the raw material needed for the VV main body weldment will be realised (see chapter 9.2 and the *Framework Purchase Agreement* for conditions) and ownership of the raw material passes from the Seller to the Buyer.

The material procurement process shall follow common industry standards, especially the following ones:

DIN 17744 / 17750, ISO 15510, ISO 16143-1, ISO 17577, EN 10228-(3, 4), EN 10296, EN 13445-2, EN 13445-4 and EN 13445-10, EN 13479.

This is not an exhaustive list of all industry standards that shall be followed during the raw material procurement process. All relevant industry standards for any of the selected raw material for procuring any of the items of the extent of delivery shall be respected by the Seller.

4.1.2. Individual requirements for nickel alloy 625

The base structural material required to be used for the VV main body weldment, including welded interfaces, the heating/cooling system and also some of the blank flanges is nickel-based alloy 625. The raw material shall meet all the following individual requirements:

- Designation: Inconel 625, Alloy 625, NiCr22Mo9Nb, NW/NC 6625, 2.4856 or equivalent according to the standards below
- Chemical composition: DIN 17744/17750, UNS N06625/UNS N26625 or ASTM B443
- Minimum required yield strength ($R_{p0.2}$) at RT: 400 MPa
- Treatment of purchased flat material: hot-rolled and annealed condition.

Specific minimum yield strength ($R_{p0.2}$) at RT: 550 MPa is required for finished welded studs, which are to be welded to the VV, as described in chapter 5.6. Note, the required yield strength does not apply to the raw material itself, but to fully finished and treated studs in "as built" condition.

4.1.3. Individual requirements for stainless steel AISI 309(S)/310(S)

Stainless steel according to technical requirements below is required to be used for all VV port flanges and part of the port stubs of the midplane ports MX and MN. The Seller shall decide which type of the steel to be used for these components considering its operational conditions, feasibility, and price.

- Designation: AISI 309(S)/310(S), 1.4828 (1.4833) / 1.4840 (1.4845), UNS S31000 (UNS S31008), UNS S30900 (UNS S30908)
- Chemical composition: ASTM A167, ASTM A240, AMS 5523, ASME SA240, AMS 5521
- Minimum required yield strength ($R_{p0.2}$) at 500 °C: 150 MPa
- Treatment of purchased flat material: hot-rolled and annealed condition
- Magnetic permeability shall not exceed 1.1

4.1.4. Other structural materials requirements

Structural materials other than nickel alloy 625, which will be used to procure some of the items (jigs, some blank flanges etc.) shall be selected by the Seller and approved by the Buyer. All materials shall be selected with respect to technical requirements, service conditions and expected lifetime of the product.

The Seller shall also verify if the selected structural materials are compatible with the main used material (nickel alloy 625 – if used in combination with the VV assembly) and that they meet the following technical and physical properties:

- Magnetic permeability shall not exceed 1.1

- Vacuum compatibility down to 10^{-7} Pa
- Service temperature range from -196 °C to 500 °C

The above-mentioned requirements shall be met for all items of the extent of delivery except jigs and other components used just for transport, storage, testing or maintenance purposes, i.e. not in tokamak operation. For structural materials used to construct jigs only the following requirements apply:

- Structural metal materials shall be selected with respect to required function, service condition and expected life
- The material or its surface finish shall withstand RT, atmospheric pressure condition with standard interior and exterior humidity and any long-term storage

4.2. Manufacturing requirements

This section contains recommended industry standards and technologies that shall be followed during the manufacturing process of any item of the extent of delivery. The list of selected industry standards in this section is not intended to cover all requirements needed to produce the individual items. The Seller will define and choose suitable manufacturing processes of the individual items to meet the technical requirements and related industrial standards. The Seller is responsible to perform his own analyses and research to select the most suitable and reliable production methods and to assess the best practices to meet the required tolerances. Selected processes and technologies shall be discussed and approved by the Buyer.

In addition, the Seller may subcontract the work, but it must be guaranteed that the subcontractor carries out the work in accordance with all requirements of this technical specification. The Seller is responsible for an adequate definition of the subcontracted tasks and for any associated records.

4.2.1. General manufacturing requirements

Any item of the extent of delivery shall be procured in accordance with valid industry standards, namely ČSN, EN, ISO or ASME. The VV assembly shall be procured in compliance with the standard EN 13445.

Manufacturing of every item shall follow the procurement process described in chapter 6. Procurement of any item is a subject to acceptance checks and specific tests performed by the Seller according to the requirements described in chapter 9 and, especially, in chapter 8.

Particular care in every production step must be taken when processing the input material, as material permeability increases with every processing step. This applies to the VV basic configuration and all other ordered items, except of jigs.

Furthermore, since the production process includes a significant amount of machining, forming and, especially, welding, a suitable post-processing might be needed and, thus, possible to be ordered by the Buyer (item no. 5, see chapter 5.5). In this case, the Seller shall propose and perform, after agreement with the Buyer, a post-processing of the VV (welded) assembly and on other items.

The Seller shall check compatibility of any supporting materials used during the procurement process with base materials used for the extent of delivery. The use of materials which can affect the main ones (e.g. corrosion attack during storage, etc.) is absolutely forbidden.

During the manufacturing process, specific vacuum requirements must be also followed as described in the following chapter 4.3 and in Technical specification – Annex No. 3 – Vacuum requirements.

4.2.2. Required manufacturing tolerances

Dimensions and tolerances of all components within the extent of delivery must follow the definition defined in the preliminary documentation (see chapter 7.1), CAD documentation, production documentation and this document (mainly requirements in chapter 5). All not defined dimension tolerances shall follow common industry standards and comply with the standard EN ISO 2768-mK and EN ISO 13920 EA. For some key dimensions indicated in the preliminary documentation provided by the Buyer, different and more stringent tolerances are required.

In general, dimension tolerances are divided into two main groups:

1. Desired manufacturing tolerances
   Refers to precision of any selected dimensions which the Buyer considers desirable to achieve. These tolerances are marked in the provided preliminary documentation as "DE" (desired) and are not strictly binding, but should be followed as closely as possible by the Seller. Any exceeding of the desired tolerances is subject to a contractual penalty (see the *Framework Purchase Agreement*).
2. Critical manufacturing tolerances
   Refers to precision of any selected dimensions which the Buyer considers as critical and necessary to achieve. Any exceeding of the critical tolerances could cause serious issues with function or assembly of the VV assembly and operation of the Tokamak. These tolerances are marked in the provided preliminary documentation as "CR" (critical) and must be satisfied (mandatory) to comply with the technical specification. Otherwise, immediate corrective action is required, as described in chapter 9.9.

Acceptance tests during the manufacturing process, after manufacturing is finished (FAT) at the Sellers premises and at the Buyer's premises after delivery (SAT), are foreseen to check whether all key dimensions and tolerances of the complete extent of delivery comply with the specified technical requirements. Details on the tests and consequences can be found in chapter 9 and *the Framework Purchase Agreement*.

4.2.3. General welding requirements

Since the VV (welded) assembly contains a significant number of welded joints, an outstanding care shall be taken during the welding process. Compliance with the European standards below and other related industry standards for fusion welding technology, its procedures, and checks shall be ensured.

In general, only the following welding methods are allowed to be used:

- Manual metal arc welding (MMA, MMAW, SMAW or stick electrode welding)
- Metal inert gas welding (MIG)
- Tungsten inert gas welding (TIG)
- Electron beam welding (EBW)
- Plasma arc welding
- Magnetic rotating arc welding (MARC, only for studs)

EN 13445, EN 1011-(1-8), EN ISO 3834-2, EN ISO 4063, EN ISO 5817 (quality level B)/EN ISO 13919-1 (quality level B), EN ISO 6520-1, EN ISO 6947, EN ISO 9606-1, EN ISO 9606-4, EN ISO 13916, EN ISO 13920 (Shape and position – required tolerance class A for dimensions and angles; tolerance class E for straightness, flatness and parallelism), EN ISO 14172, EN ISO

14175, EN ISO 14555, EN ISO 14732, EN ISO 15607, EN ISO 15609-1(3), EN ISO 15611, EN ISO 15613, EN ISO 15614, EN ISO 18274.

All welding work shall be done only by qualified welders, its process shall be properly documented and individual WPS, PQR and WPQR documents shall be defined and issued. A specific document, so called "weld map", shall be created by the Seller to document all essential weld joints and their parameters (see chapter 7.7).

For every welding technology used in the manufacturing process of any ordered item, prototypes shall be manufactured and tested before manufacturing starts (see 8.4 and 9.6.1). Manufacturing can be started when all technology tests are successfully finished and approved by the Buyer.

If the welding technology is manual (i.e. performed by a physical person), the Buyer requires that the welds within the VV main structural body (defined in Fig. 13 in chapter 5.1.1) and in the VV supports are performed by the same welder, who performed the welding of the appropriate prototypes. This is not required for the welds between the ports and the VV main structural body, or any other welds (e.g. in-vessel interfaces, heating / cooling loops, ...). If more than one person is to perform welds within the VV main structural body and in the VV supports, each of the persons has to fulfil this requirement, possibly leading to preparation of more prototypes and the subsequent test than strictly necessary for qualification of the welding technology.

If ordered, a suitable post processing of the VV assembly shall be performed to release any induced residual stresses by processing and welding (see chapter 5.5).

All welded joints of the VV assembly shall be vacuum compatible and properly cleaned. For more information on the vacuum compatibility requirements, see 4.3 and 10.3.

For the jigs, some of the above-mentioned industry standards apply, in accordance to selected material and welding technology by the Seller.

4.2.4. Additional welding requirements

The general welding requirements discussed in the previous section (4.2.3) are valid for all items of the extent of delivery. Additional technical requirements are applicable for the VV assembly, where the welding technology and process must be carefully selected and realised by the Seller. The reasons are the use of very specific base materials (nickel alloy 625 and stainless steel), high wall thicknesses, strict quality requirements, and vacuum compatibility.

While there are areas of welding dissimilar materials (nickel alloy 625 and stainless steel), a suitable filler material shall be chosen by the Seller to maintain strong and reliable weld joint. Therefore, the filler material like Ni 6625 acc. to EN ISO 18274 (ERNiCrMo-3) is required to be used.

Full penetration welding is required for all welds.

There are several areas of the VV with specific welding requirements:

1. VV main body weldment (includes ports):
    - TIG, MIG, EBW, manual metal arc welding, or plasma arc welding methods are allowed. Specific requirements when other method than TIG welding is used apply: surfaces of any structural weld must be either covered by the TIG to depth at least 1 mm, or the surfaces must be rewelded by the TIG (without any added material) to the depth at least 1 mm.
    - The root weld can be done by any allowed method chosen by the Seller.

2. Heating / cooling loops:
   - Welding method will be proposed by the Seller, only TIG, MIG, plasma arc welding or brazing are allowed.
3. Pads, shear keys and interfaces:
   - All allowed welding technologies could be used (excl. MARC). Specific requirements when other method than TIG welding is used apply:
     a) The root weld must be done by TIG.
     b) The surface of the weld must be either welded by TIG to depth at least 1 mm, or weld surfaces must be rewelded by the TIG (without any added material) to depth at least 1 mm.
4. Welded studs:
   - Using drawn arc stud welding is required (magnetic rotating arc – MARC – can be used). Use of ceramic ferrules is not allowed for vacuum compatibility reasons.

As specified above, joints of the VV main body weldment shall follow the structure shown in Fig. 6.

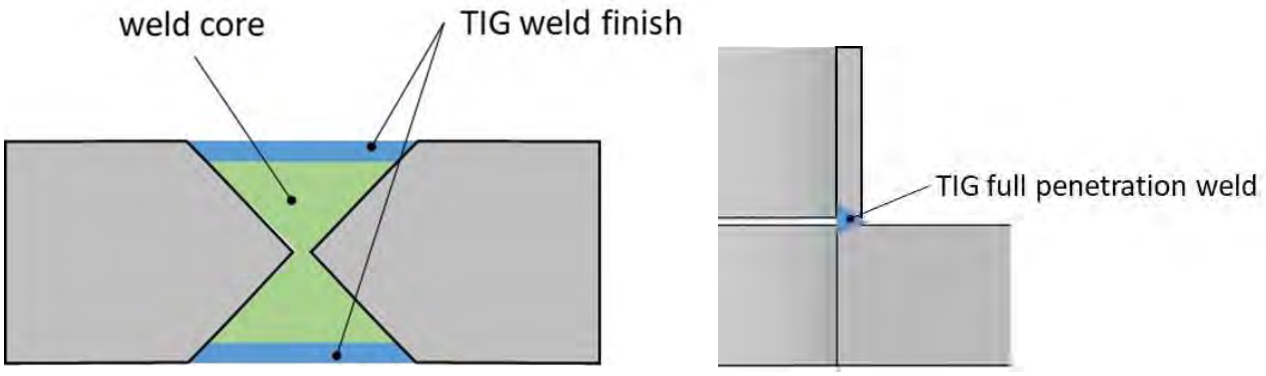


Fig. 6: Left: Structural weld with TIG finish to be used for welding of the VV assembly, Right: Illustration of TIG full penetration weld.

In Fig. 7, main overview of welding methods to be used on the VV main body is shown. The EBW technology might be used to lower induced heat and deformations.

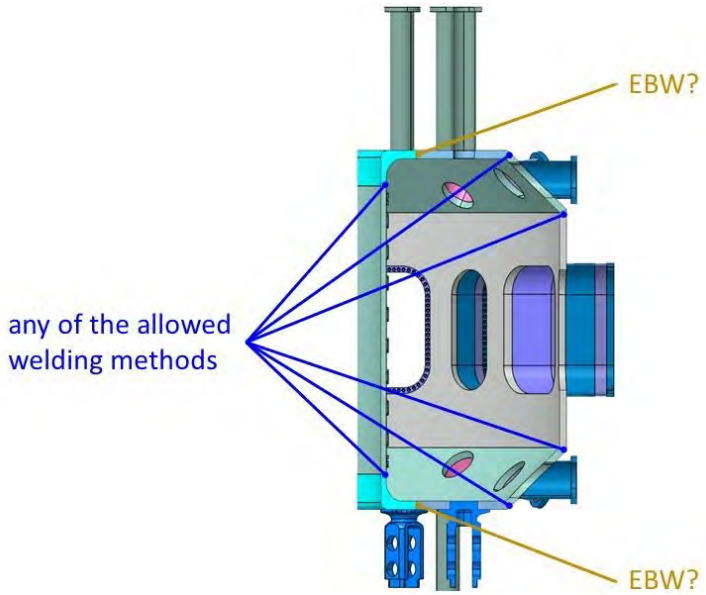


Fig. 7: Welding methods preferred to be used for welding of the VV assembly

Preferred welding methods for the VV joints are also described in the following table:

Weld location	Preferred welding method
VV main body	MIG, TIG, EBW, MMA/MMAW/SMAW, plasma arc welding
Forged rings X horizontal plate	EBW preferred
All port stubs X VV main body	MIG, TIG, EBW, MMA/MMAW/SMAW, plasma arc welding
All port flanges X port stubs	
Heating / cooling loops X VV wall	MIG/TIG, brazing
All in-vessel welded pads or interfaces	MIG, TIG, EBW, MMA/MMAW/SMAW, plasma arc welding
Welded studs	drawn arc stud welding w/o ceramic ferrules

Table 6: Preferred welding method to be used in different location on the VV

4.2.5. Manufacturing prototypes and samples

Before the manufacturing of the VV assembly starts, a certain number of manufacturing prototypes and samples shall be produced by the Seller to prove the technology readiness and compliance with the technical requirements. Note that there are no prototypes needed for the jigs or any additional tools.

The following types of manufacturing prototypes and samples are required by the Buyer:

1. Qualification welding prototypes and samples for each technology used representing the same geometry and size of individual joint that will be realised.
2. Welding prototypes of dissimilar weld
3. Post processing prototypes and samples (if item no. 5 ordered) to demonstrate the feasibility of the selected technology and evaluate possible dimension deviations after processing.

For manufacturing of the prototypes and samples, common industry standards shall be followed, especially the standard EN ISO 13445 (mainly Part 1, 4 and 10). In general, dimensions, shape, and number of prototypes and samples is to be agreed with the Buyer. Every manufacturing prototype and sample shall be identified with a unique marking agreed between the Seller and Buyer, see chapter 4.4.

Qualification welding prototypes and samples

Manufacturing prototypes shall be made for every individual welding technology used for production of the following parts of the VV assembly:

- VV main body primary joints
- Heating/cooling tubes welded to the VV
- Studs welded in the VV

Welding technology used to procure the prototypes shall be the same that is planned to be used for manufacturing of the VV, and under same conditions. Procurement of the welding prototypes shall also comply with the following industry standards: EN ISO 13445, EN ISO 15607, EN ISO 15609, EN ISO 15613, EN ISO 15614 and EN ISO 14555.

Note that there is a requirement that the VV main structural body and the VV supports are welded by the welder, who welded the prototypes (see chapter 4.2.3 for exact requirement).

The Seller shall manufacture and test the following welding prototypes:

- Two welding prototypes (one will be used for performing the tests by the Seller, one for the reference for the Buyer) representing every individual welding technology (in case that more than one is used)
- Two welding prototypes (one will be used for performing the tests by the Seller, one for the reference for the Buyer) representing the thickest weld of the VV main body primary joint (or another weld agreed between the Buyer and Seller)
- Two prototypes (one will be used for performing the tests by the Seller, one for the reference for the Buyer) of material with welded heating / cooling pipes
- Four prototypes of two selected sizes (two will be used for performing the tests by the Seller, two for the reference for the Buyer) of material with three welded studs / bolts

Prototypes shall be made of the same batches used for any item of the extent of delivery.

Each individual prototype shall enable to manufacture a sufficient number of testing samples to perform required tests. Required destructive and non-destructive tests are described in chapter 8.4 and 9.6.1.

Recommended basic dimensions and shape of the prototype for testing the joint between the heating / cooling system and the VV surface are shown in Fig. 8. The diameter and thickness of the tube of the heating / cooling loops are specified in the provided initial CAD documentation or, eventually, could be agreed between the Buyer and the Seller. The length and number of alternating weld paths are to be agreed with the Buyer and shall match the parameters used in the real production process. The welding technology used for procuring of the prototype shall also be the one used in the real production process. The whole prototype shall be made of nickel alloy 625 material (see 4.1.2).

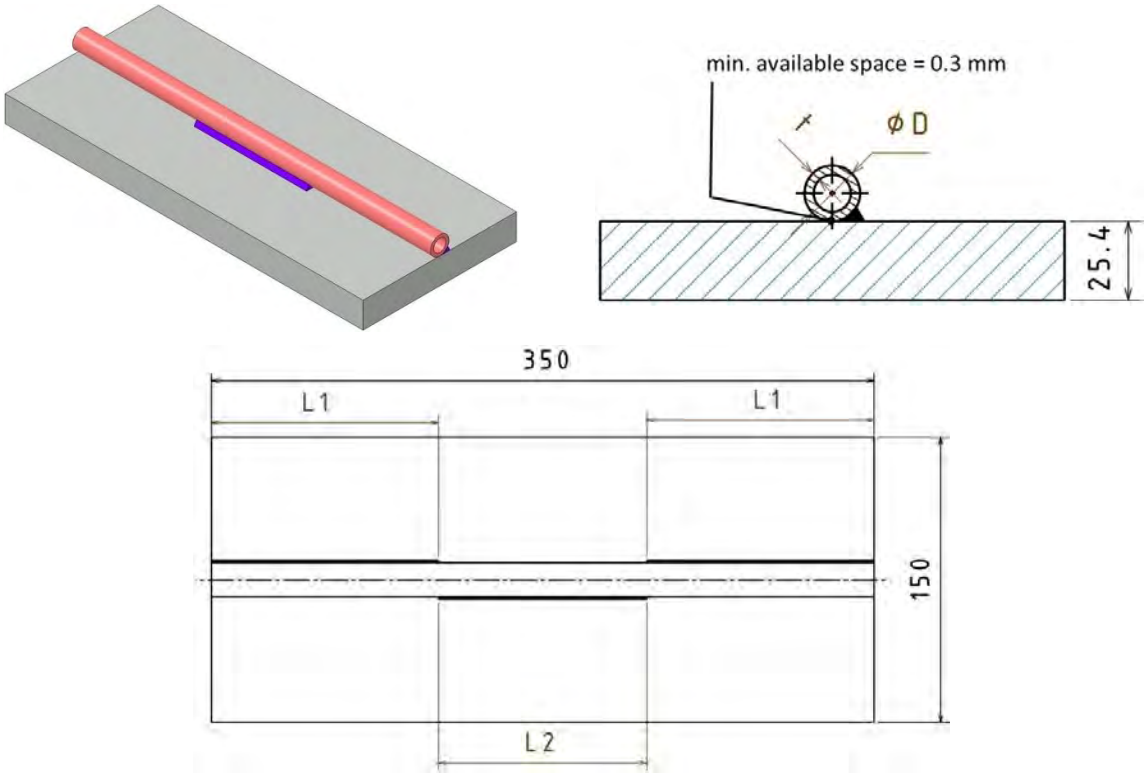


Fig. 8: Heating / cooling system welding prototype and its main dimensions

To test welding studs / bolts on the VV, the prototype shall be made of three studs welded on a thick plate made of nickel alloy 625. The dimensions and type of the studs shall be selected according to EN ISO 13918, if not agreed between the Buyer and the Seller otherwise. The welding procedure shall follow the recommendations of the standard EN ISO 14555 and reflect the real manufacturing process that will be used. Use of ceramic ferrules is not allowed for vacuum compatibility reasons. The prototype and its dimensions are depicted in Fig. 9.

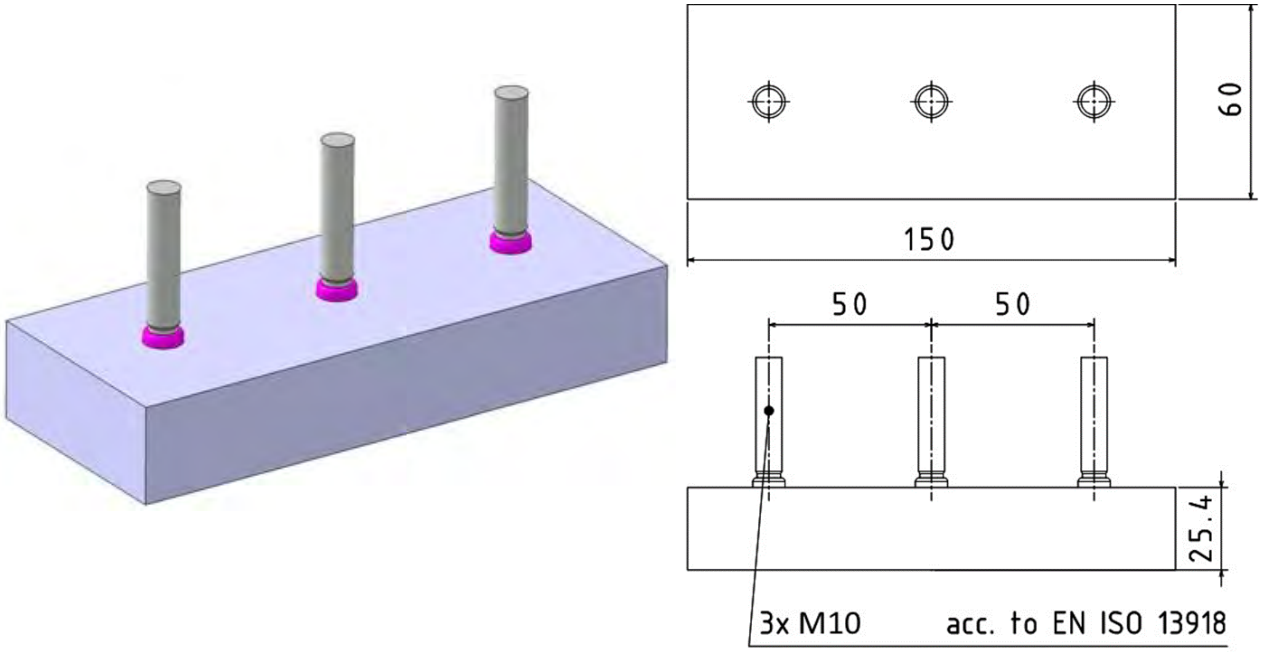


Fig. 9: Prototype for welded studs / bolts and its dimensions

Welding prototypes of dissimilar welds

While the base material of all VV flanges is different from the base material of the vacuum vessel, AISI 309(S)/310(S) versus nickel alloy 625, prototypes are needed to check welding technology and quality of the weld joint.

Welding technology chosen by the Seller has to be qualified already according to the technical requirements in previous section. All mentioned industry standards apply.

Two prototypes (one will be used for performing the tests by the Seller, one for the reference for the Buyer) representing dissimilar weld of nickel alloy 625 and AISI 309(S)/310(S) are required. Shape and material thickness shall represent real welded joint to be used on mid-plane port stubs.

Post-processing prototypes

If the item no. 5 is ordered (see chapter 3.2), a post processing of the extent of delivery shall be performed by the Seller (see chapter 5.5 for more details). Before any post processing is performed, selected process(-es) must be realised on specific prototypes representing the thickest weld of the VV main body primary joint (or another weld agreed between the Buyer and Seller) and relevant tests must be done. The main objectives of these tests are to evaluate:

1. Prove that the residual stress from the welding has been removed (the method will be proposed by the Seller and approved by the Buyer)

2. Possible distortions or cracks caused by the heat treatment
3. Its influence on mechanical properties of the base material

Dimensions of the prototypes are to be agreed between the Seller and the Buyer. Two post-processing prototypes (one will be used for performing the tests by the Seller, one for the reference for the Buyer) shall be manufactured.

The tests that shall be performed on these prototypes are listed in chapter 9.6.4.

4.2.6. Polishing

The outer surfaces of the VV main body weldment and outer surfaces of the VV supports have to be polished to an "Infrared mirror finish" on most of its surface. This requirement is to achieve reasonably low thermal losses due to thermal radiation (that is to reach a low emissivity surface for infrared spectrum). Therefore, the most of the surface must be highly polished, while a small surface area with higher emissivity is permissible as it will not significantly increase the total losses due to thermal radiation.

When measuring the surface roughness of the VV the supplier shall use a profilometer with a tip radius of ≤ 5 μm and a **λc = 0.25 mm gaussian** profile L-filter (important!, as specified in EN ISO 21920-3). Under such measuring conditions, the finished VV surface root mean square roughness Rq (as defined in EN ISO 21920-2) must be lower than 0.08 um on at least 98% of the outer surface of the vacuum vessel. An occasional scratch or an unpolished hard-to-reach weld might be acceptable. For welds that the seller decides not to polish, the seller shall employ an electrolytic weld cleaning process.

Although a full optical mirror finish would be sufficient, it is an unnecessarily strong condition. A sufficiently low Infrared emissivity can also be achieved on surfaces that do not look to the naked eye as a good mirror therefore we require only the above-mentioned condition to be fulfilled.

The Seller shall propose a grinding/polishing process for reaching this and submit it for approval to the Buyer. In the experience of the Buyer to reach the stated surface parameters it is sufficient to grind the surface to a P600 grit equivalent surface finish that will be subsequently polished. Removing the mill scale of the original material by grinding with coarser grits will speed up this process. We advise the Seller to employ a multistep grinding process and single finishing/polishing step. The total number of grinding/polishing/buffing steps should be in the range of 4 to 8.

4.3. Vacuum compatibility and tightness

All items of the extent of delivery shall be ultra-high vacuum compatible (i.e. vacuum below 10^{-5} Pa), except for:

a. High-vacuum compatible items (i.e. vacuum from 1 Pa and down to 10^{-5} Pa):
   - The outer surface of the VV
   - VV supports
   - Divertor blank flanges (made of nickel alloy 625)

b. Not vacuum compatible items:
   - Jigs (part of the basic configuration)

In general, during the production process of the vacuum compatible items, the outer and inner surfaces must be clean of any kind of contaminants, machining fluids or free material particles. Surface roughness, cleanliness and treatment must follow the requirements which

are included in the production documentation and in the Technical specification – Annex No. 3 – Vacuum requirements.

During the manufacturing, letting any kind of contaminants into the heating / cooling system must be fully avoided. A proper sealing all the VV ports and heating / cooling system inlets /outlets during the manufacturing process is therefore necessary. Proper sealing shall also be achieved for any transportation.

4.4. Designation of prototypes and samples

Any prototype or sample (see chapter 2 for exact definition) procured by the Seller shall be properly marked with a unique designation. The designation shall enable to clearly identify at least the following information:

- Type of the prototype or sample
- Material used
- Material batch (if applicable)
- Post processing performed (if any)

The marking shall be permanent, using any of mechanical or non-contact methods (e.g. by laser or mechanically).

The designation shall be used in all related documentation, in particular see chapter 7.9.

4.5. Fasteners requirements

Fasteners shall be delivered by the Seller for the following cases only:

1. Mounting all blank flanges (part of the VV basic configuration) to the VV and interconnecting elements of the blank flanges
2. Fasteners that are part of the jigs (part of the VV basic configuration)
3. Mounting of the heating / cooling loops

In case no. 1 and 2, hexagon socket head cap screws, according to EN ISO 4762 (DIN 912), made of stainless steel better than A2 according to EN ISO 3506-(1-2), are required.

For cases 3 and 4, selected material must be compatible with high vacuum, as stated in chapter 4.3. Therefore, nickel alloy 625 material shall be used.

All delivered fasteners shall comply with common industry standards.

All mounting elements shall be selected in a way to minimize the diversity of types and sizes to simplify assembly and lower the costs.

4.6. Design changes & man-hours

Prior ordering any item, its design could eventually be modified by the Buyer without any extra-cost when the changes imply that the item can be manufactured and delivered within the same time range, dimensions, price cap, complexity and manufacturing and, in general, within all the requirements specified in this technical specification and in the *Framework Purchase Agreement*. In case the changes imply that the item cannot be manufactured and delivered within these limits, any changes would result in a cost increase that will be covered by ordering appropriate extra-services of an appropriate amount, as agreed by both parties. These extra-service items, that can be ordered by the Buyer, are:

- Item 27: Extra man-hours of project manager / engineer / designer / technician / production worker or assembly worker

- Item 28: Extra research and development activities / design activities or service activities
- Item 29: Extra machining time on NC machines (includes work of operator)
- Item 30: Extra machining time on conventional / standard machine (includes work of operator)
- Item 31: Extra welding time (includes all costs of welding equipment + work of welder)

After ordering an item, any change of the final design could also result in a cost-increase that should be covered by an appropriate amount of relevant extra-services, in the same way as specified above. More information on extra services is provided in the *Framework Purchase Agreement*, especially concerning the ordering time plan.

In addition, the final design provided by the Buyer could eventually be modified or optimised by the Seller, as long as it still meets the technical requirements defined in this document, to lower manufacturing costs or, for instance, to increase procuring efficiency. In this case, a thorough description of the proposed modifications and their impact on the design and its cost shall be provided to the Buyer to justify the feasibility of the proposed changes. The proposed modifications are to be approved by the Buyer. Formal decision on approved or rejected design changes is defined in the *Framework Purchase Agreement*.

Any changes made prior the manufacturing phase shall be reflected in the related general testing and manufacturing plans (see chapters 7.5.1 and 7.5.2), as well as in the production and engineering documentation (see chapter 7.2). Any modification done during the manufacturing phase shall be reflected and properly documented in the Complete documentation submitted at FAT and SAT (see chapter 7.5.3).

4.7. Storage, transportation and delivery

Delivery from the Seller's premises to the Buyer's site is allowed after the FAT (see chapter 9.7) is successfully passed and approved by the Buyer. Transportation of the final product shall be realised using suitable jigs, a part of the VV basic configuration, see chapter 5.1.6. Note that the extent of delivery will be unloaded on the Buyer's premises by a crane provided by the Seller (e.g. using mobile crane).

During the transportation and storage of the extent of delivery, no contaminants shall get into the VV and heating / cooling system. A proper sealing all of the VV ports (VV blank flanges, see 5.1.4), heating / cooling system inlets / outlets is therefore required. Individual requirements regarding sealing and packing are described in chapter 4.3 and in Technical specification – Annex No. 3 – Vacuum requirements.

Other conditions on storage, transportation and delivery are described in the *Framework Purchase Agreement*.

4.8. Quality and reliability

The general quality and reliability requirements are defined in the *Framework Purchase Agreement* (i.e. Seller's minimum qualification and certification) and all required and recommended industry standards and technical requirements in this technical specification shall be also considered.

Any unacceptable non-conformances during the procurement process of any item of the extent of delivery must be reported and removed by repair or replacement. Conditions described in chapter 9.9 shall be followed. In case of repair all relevant industry standards and requirements of this documents must be met. In particular, if any weld has to be repaired, relevant industry standards mentioned in chapter 4.2 must be followed, especially

EN ISO 5817, quality level B is required. Welding of the repaired area must be carried out using the same method and welding material as the original weld.

4.9. Warranty

Two-year quality warranty for all items of the extent of delivery applies (see the Framework Purchase Agreement, chapter 7). The Seller shall include instructions and recommendations regarding the use and maintenance of the extent of delivery together with the Complete documentation and Handover Protocol of Acceptance.

After handing over of the ordered items of the extent of delivery, the Vacuum vessel may be equipped with additional interfaces or surface treated, i.e. additional studs or small attaching points may be welded, coated with small layer of metal. This will not compromise the basic structure and properties of the delivered product and shall not lead to withdrawal of the agreed warranty for the extent of delivery given by the Seller.

4.10. Declaration of conformity

According to the pressure equipment directive PED 2014/68/EU, art. 1, part 2(j), the Vacuum Vessel is not required to comply with the directive, because the primary design considerations of the Vacuum Vessel originate from the dynamic loads caused by tokamak plasma disruptions, i.e. the primary design consideration is not the atmospheric pressure.

However, the common buses, part of the heating / cooling system (part of the basic configuration), are considered as a pressure equipment. Thus, the common buses shall comply with the requirements of the PED 2014/68/EU. The conformity evaluation is required for this particular part of the extent of delivery and, therefore, the declaration of conformity (CE) is to be issued for the entire Extent of delivery. The Seller shall issue all relevant documentation needed for the declaration of conformity (CE) according to relevant European standards. The Buyer requires that the declaration of conformity and all relevant documentation shall be issued in English language.

5. **INDIVIDUAL ITEMS'** DESCRIPTION AND REQUIREMENTS

This chapter describes in depth each item of the extent of delivery and provides necessary details and requirements for their procurement. Note that the different items listed in this section are not necessarily independent and cannot always be ordered separately. For instance, the post processing item cannot logically be ordered alone, without ordering the Vacuum Vessel basic configuration item. Note also that some of the items are mutually exclusive – either one will be ordered or the another, but not both simultaneously. In addition, the manufacturing phase of some items could be merged together, if feasible and reasonable. Such solution is to be retained only upon agreement with the Buyer.

Acceptance conditions, test requirements and non-conformities are described in chapter 8 and 9. Relevant documentation is discussed in chapter 7.

5.1. Vacuum Vessel basic configuration (Item no. 1)

This section describes the main item of the extent of delivery, called "Vacuum Vessel basic configuration". A schematic overview of this particular item is given in Fig. 10. The following subsections give technical details on each specific sub-items of this item.

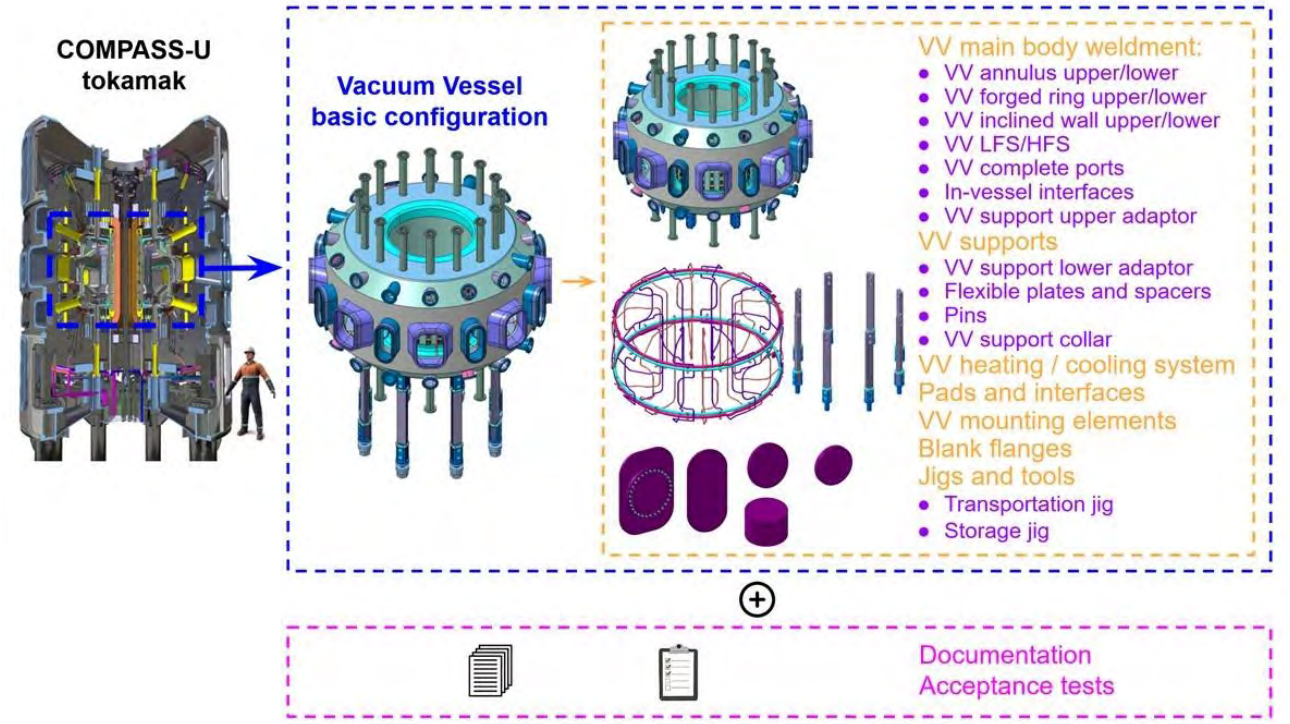


Fig. 10: Schematic of the item's division called Vacuum Vessel basic configuration

5.1.1. Vacuum Vessel main body weldment

General overview

The VV main body weldment forms the elementary structure of the VV assembly (Fig. 2, right). An overview of its main components is shown in Fig. 11. The individual components composing the VV main body weldment will be joined together using a suitable welding technology selected by the Seller and approved by the Buyer (see chapter 4.2).

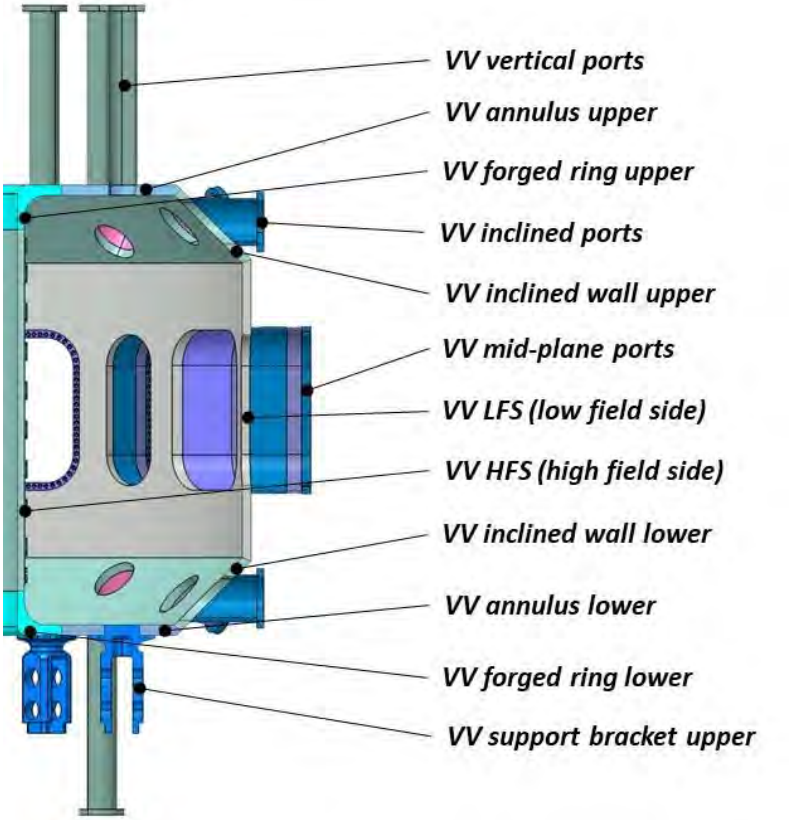


Fig. 11: Overview of the individual (welded) components forming the core of the VV main body weldment

Some basic dimensions and parameters of the VV main body weldment are provided in Table 7 and Fig. 12. More detailed information can be found in CAD documentation and preliminary documentation provided by the Buyer with this technical specification. The base material of the complete VV main body weldment is nickel alloy 625 and stainless steel AISI 309(S)/310(S). More details on the material specification can be found in chapter 4.1.

PARAMETER	VALUE
Outer radius (excl. ports)	1325 mm
Inner radius (excl. ports)	538 mm
Total height (excl. ports)	1520 mm
Wall thickness	23 – 35 mm
Vessel inner surface	~ 10,5 m^2
Vessel outer surface	~ 40 m^2
Total weight VV main body weldment	6102 kg
Base vessel pressure	10^{-6} Pa
Base material	nickel alloy 625 + AISI 309(S)/310(S)
Operating temperature	up to 500 °C

Table 7: VV main body weldment basic dimensions

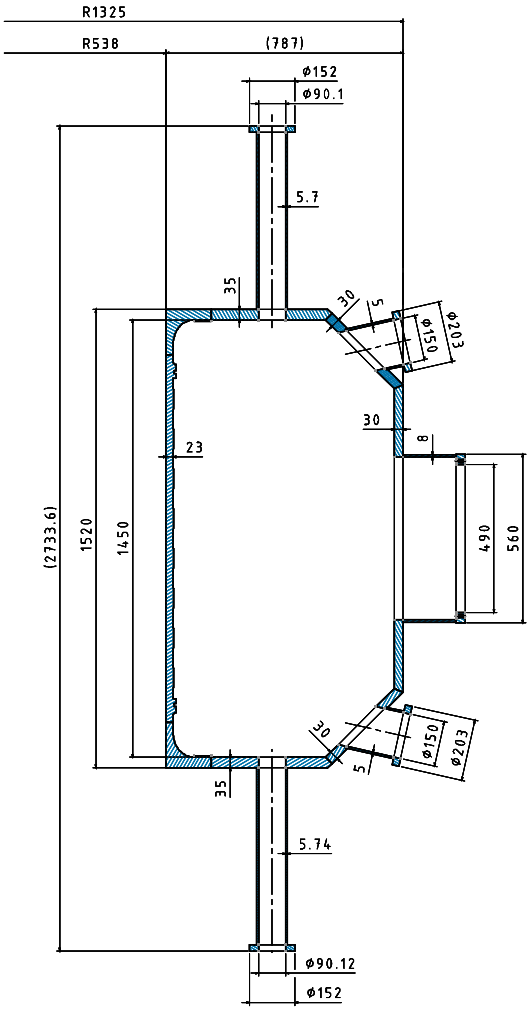


Fig. 12: Basic dimensions and parameters of the VV main body weldment

General technical requirements

The VV main body weldment must provide a reliable structural boundary and support for the whole lifetime of the COMPASS-U tokamak and shall, therefore, be manufactured accordingly. In addition, it has to enable mounting of all related components and systems, including in-vessel diagnostics, and allow an access to diagnostics, control, heating and cooling systems through the ports and feedthroughs. Human maintenance inside the vessel must be also guaranteed using the wide mid-plane ports (MX ports).

In general, procurement of the VV main body weldment shall follow common industry standards, as described in chapter 4, and meet all technical specifications and requirements described in this document. Requirements on procurement process are described in chapter 6.

All threads can be cut or formed according to relevant industry standards while maintaining required vacuum compatibility.

Required manufacturing tolerances (see chapter 4.2.2) are given by the preliminary documentation (see chapter 7.1) and, later, by the production documentation. The tolerances are in general divided into three groups according to specific areas of importance (see Fig. 13), i.e.:

1. Tolerance area 1 - VV main structural body,

2. Tolerance area 2 - VV ports and
3. Tolerance area 3 - VV inner welded interfaces
   (not part of the VV main body weldment).

Further division of key geometrical tolerances is described in chapter 4.2.2. Specific contractual penalties apply in case of exceeding these tolerances, see *Framework Purchase Agreement* for more information.

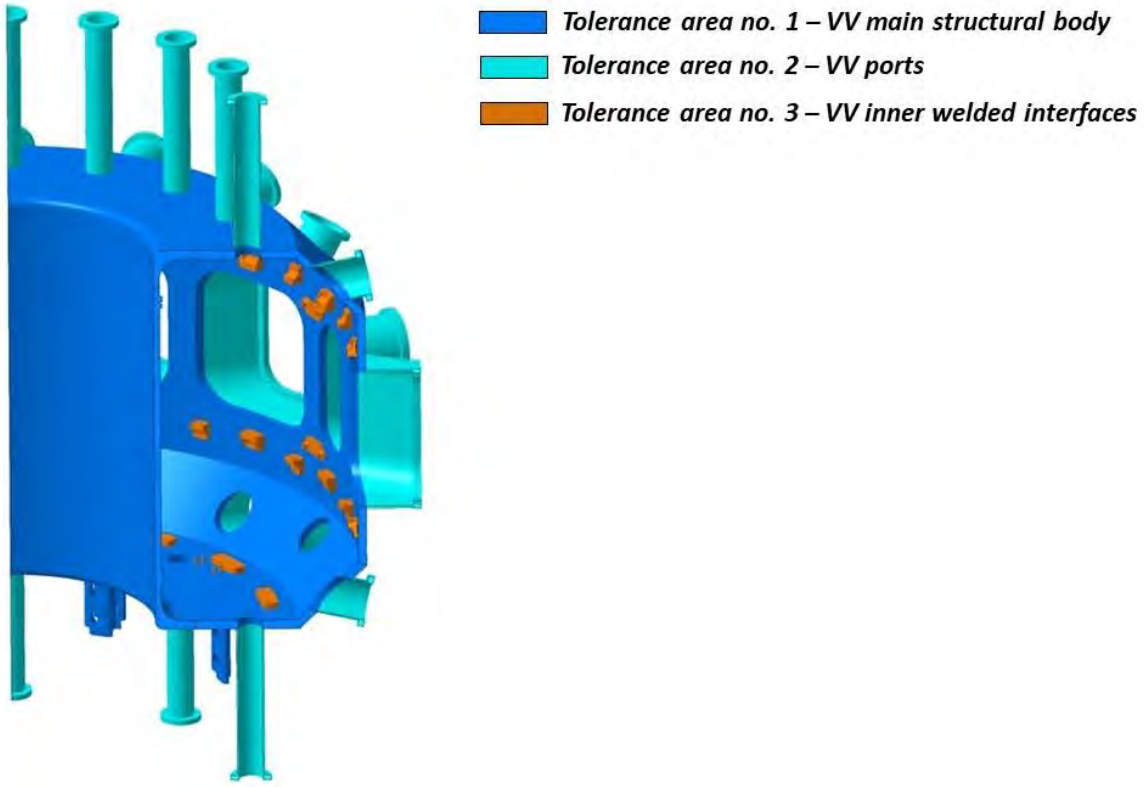


Fig. 13: Overview of the tolerance areas

If the item no. 5 "Post processing" is ordered, appropriate post processing method(s) shall be chosen by the Seller to relieve residual stresses from the VV main body weldment. For more details see chapter 5.5.

The Vacuum Vessel is designed (by the Buyer) to accommodate the mechanical loads originating from the intended use in the COMPASS-U tokamak. The most severe mechanical loads come from the tokamak plasma disruptions – unplanned terminations of the plasma contained within the vacuum vessel. During the plasma disruption, up to 2 MA (mega-amperes) can be induced in the main body of the vacuum vessel in a timeframe of units of microseconds. This induced current, together with the magnetic field originating from the tokamak magnetic coils, creates force loading, which was the primary consideration of the design of the Vacuum Vessel. A brief overview of some of the expected operating scenarios and resulting loads of the VV are enclosed in the Technical specification – Annex No. 4 – Key simulation results. The Buyer requires that the technological process of manufacturing the Vacuum Vessel creates the product (VV), which is compatible with the mechanical loading scenarios described in the Technical specification – Annex No. 4 – Key simulation results. Practically, this requirement may translate to necessity to have high quality welds, locating the welds outside of the high stress areas, lowering residual stress after the welding process (if item no. 5 is ordered), etc.

Welding requirements

The Seller is responsible for choosing a suitable welding technology. Every individual welding technology used must be verified by prototyping prior any manufacturing starts, see chapter 4.2.5.

A specific welding study has been realised by the Buyer covering manufacturing process, welding technology, and expected welding-induced deformations. Results of the study are attached to this document, see Technical specification – Annex No. 2 – Results of the welding study. Conclusions of the study are not mandatory and should serve only as a guide for the Seller. It is expected that the welding induced deformations will not be negligible and must be compensated to meet the required manufacturing tolerances. Therefore, it is highly recommended that the Seller performs a discrete simulation based on the selected welding technology.

All the VV flanges and part of the port stubs of the midplane ports MX and MN are made of stainless steel AISI 309(S)/310(S) (to be selected by the Seller) and therefore specific precautions shall be considered by the Seller. To maintain strong and reliable weld joint compatible filler metal shall be used, see also chapter 4.2.4.

Vacuum compatibility and cleanliness requirements

The VV main body weldment must be able to maintain an ultra-high vacuum down to 10^{-6} Pa with a leak rate of maximum 10^{-9} Pa.m^3/s (for detailed on vacuum requirements see chapter 4.3). The vacuum must be retained for the whole temperature range, i.e. from room temperature (RT) up to 500 °C.

To maintain a high degree of vacuum, the surface roughness of all inner surfaces of the VV main body weldment has to be low enough. Surface finish of all inner surfaces using technology glass bead blasting is required. Detailed vacuum and surface requirements are defined in the initial and production documentation and, especially, in the Vacuum compatibility requirements attached to this technical specification documentation (Technical specification – Annex No. 3 – Vacuum requirements).

The outer surfaces of the VV main body weldment have to be polished to a mirror finish. The requirements for the polishing process and final surface finish are specified in chapter 4.2.6. Note that the same requirement exists for the VV supports (see chapter 5.1.3).

The complete VV main body weldment must meet all vacuum requirements mentioned in chapter 4.3 and in Technical specification – Annex No. 3 – Vacuum requirements. No contaminants shall get inside the VV during the procurement process. During the transportation or storage, all ports shall be sealed with blank flanges. For more details see chapter 4.7 and 5.1.4.

Vacuum Vessel ports layout and design

A basic top-view layout of the VV is shown in Fig. 14. The VV main body is composed of 16 mid-plane ports, 16 upper / lower divertor ports located on inclined walls, 16 upper vertical ports, and 8 lower vertical ports. In principle, there are in total only four different types of ports, regarding the shape of the flange and shell. All ports, except for the mid-plane ones, have a circular form. Layout of divertor ports including its designation is shown in Fig. 15. Inner dimensions of each individual port type are shown in Fig. 16.

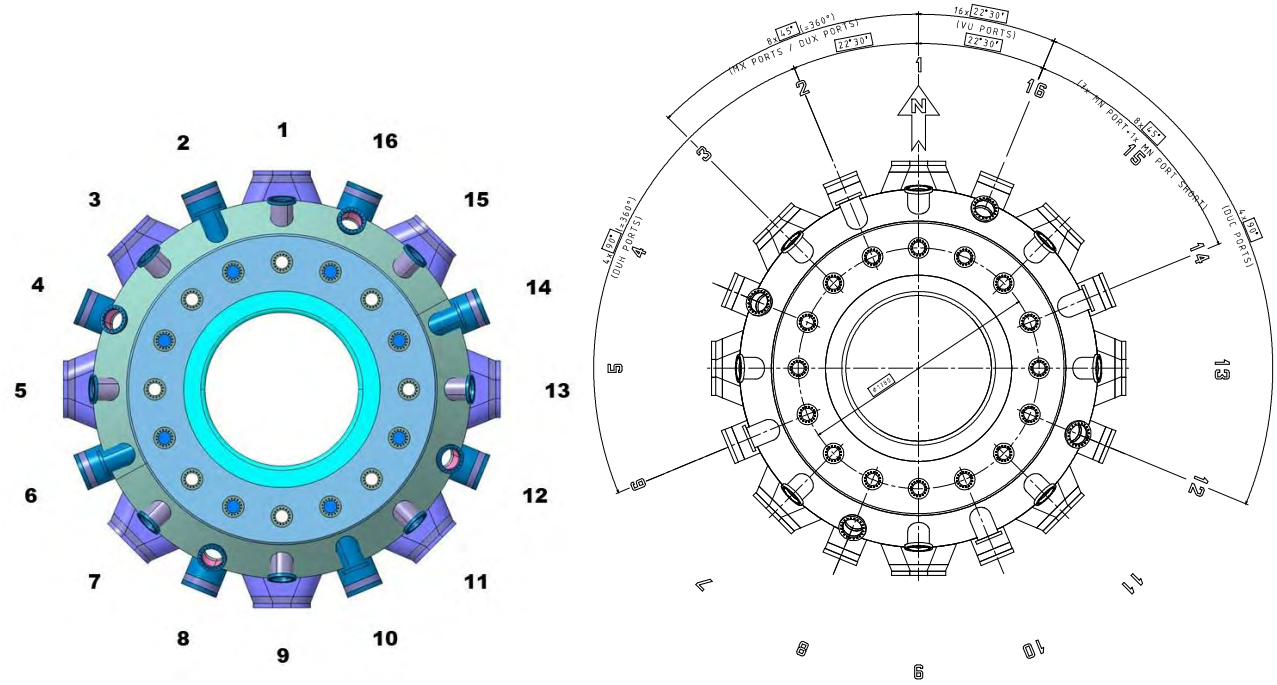


Fig. 14: Left: VV main body weldment top view with numbers representing the different VV sectors. Right: VV ports layout.

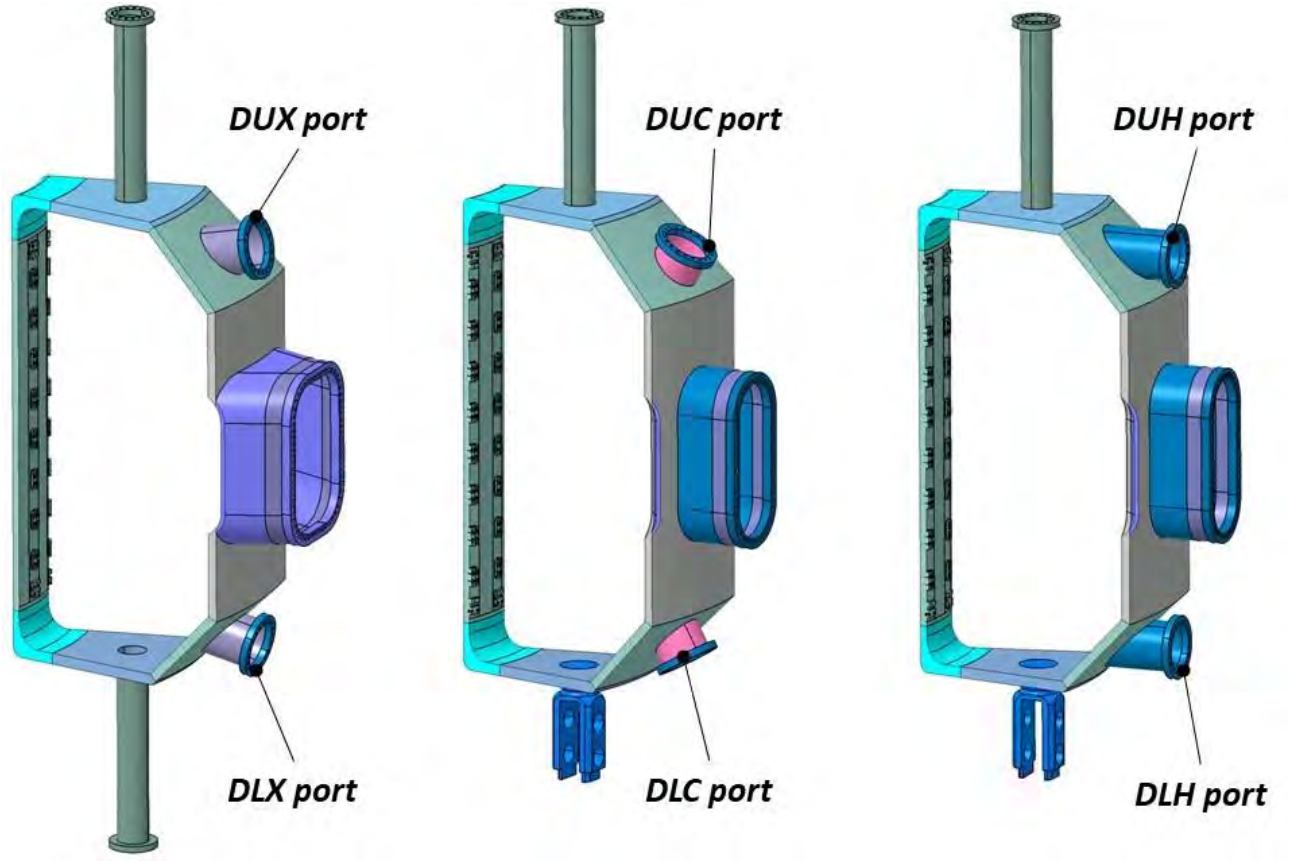


Fig. 15: Overview of the VV ports layout

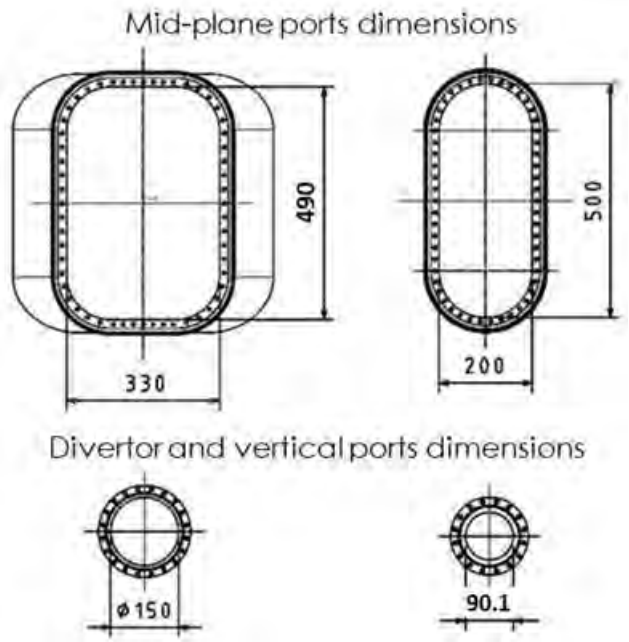


Fig. 16: Schematic overview of inner dimensions of four types of the VV ports

All ports consist of main two parts, a port stub and a flange interface (see Fig. 17). Both parts are joined together by welding. Material of the port flanges and port stubs is different. All the VV port flanges are required to be made of AISI 309(S)/310(S) (to be selected by the Seller). All circular port stubs are required to be made of nickel alloy 625 except of the mid-plane ports, where the stubs are made of combination of both materials. Weld joint of dissimilar materials shall be performed to maintain strong and reliable joint according to the requirements discussed in chapter 4.2.

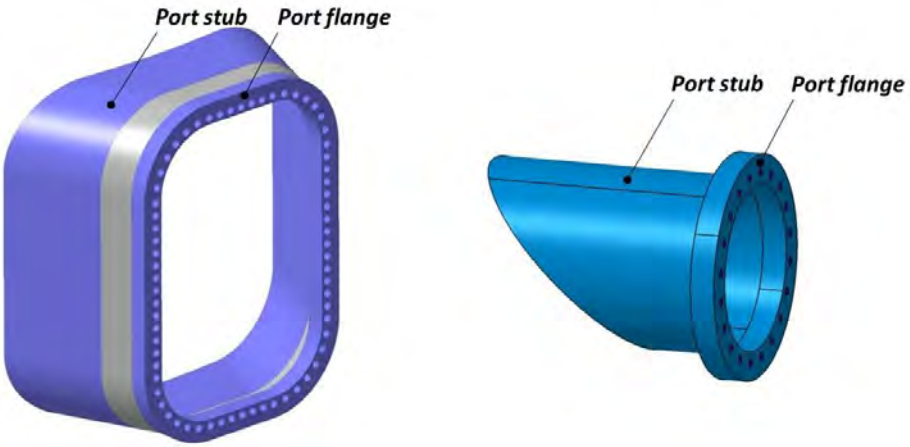


Fig. 17: Components of the VV ports

Dimensions and wall thicknesses of the individual ports are specified by the preliminary documentation and, later, in the production documentation, with related geometrical tolerances. Given dimensions of all circular ports shall be respected. Dimensions of the vertical port stubs were selected in compliance with the industry standard ASTM B444. Dimensions of the divertor port stubs cannot be changed for spatial reasons.

For circular port stubs only seamless tubes according to ASTM B444 shall be used unless they are made by the Seller and Helium leak tested.

Note that metal seals will be used for operation of the COMPASS-U tokamak, so the front surface of all port flanges is flat and with a specific surface roughness. The use of high

temperature resistant and high vacuum compatible resilient metal seals is foreseen. They require applying higher pressure forces and thus suitable size and spacing of fasteners and eventually use of thread inserts in holes in the port flanges. See also 5.1.5 for more details on the seals.

VV high field side wall design

The inner core of the VV consists of the HFS wall including integrated in-vessel interfaces for mounting the in-vessel components, as shown in Fig. 18. The in-vessel surface of the HFS wall has multi-facetted design for easier manufacturing. There are three types of HFS wall interfaces – HFS basic interface pad (192x), HFS divertor lower pad (24x) and HFS divertor upper pad (24x) as shown in Fig. 19. These are distributed in 10 vertical and 24 toroidal patterns.

As the mentioned interfaces need to be fully integrated into the HFS wall (i.e. machined together with the HFS wall from the same piece of metal), the total thickness of raw material used for the HFS wall has to be carefully estimated (by the Seller). Preliminary estimations show that the HFS wall could be manufactured by rolling (rotating) of sheet material and after joining precisely machined. Minimum needed thickness of the raw material could be up to 40 mm. Total thickness includes material allowance needed for machining and to compensate forming imprecision.

Detailed dimensions and required geometrical tolerances are specified by the initial CAD documentation and, later, in the production documentation.

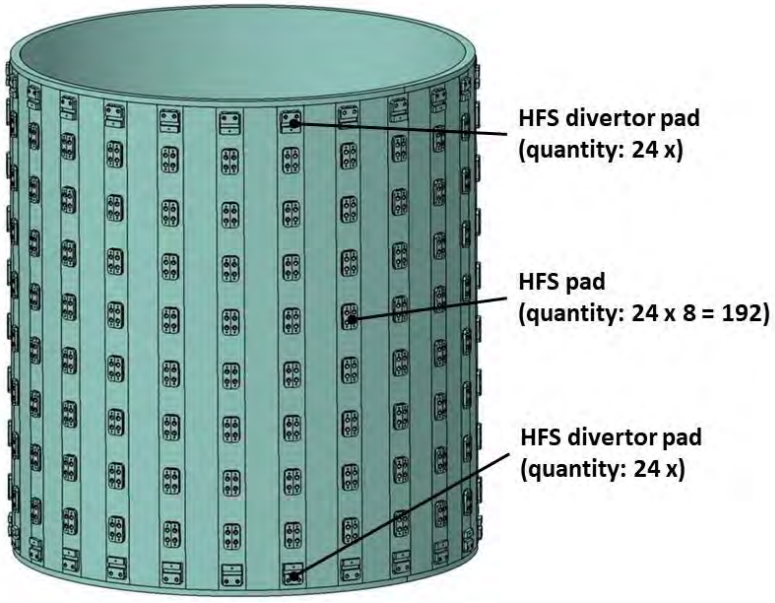


Fig. 18: HFS wall and integrated in-vessel interfaces.

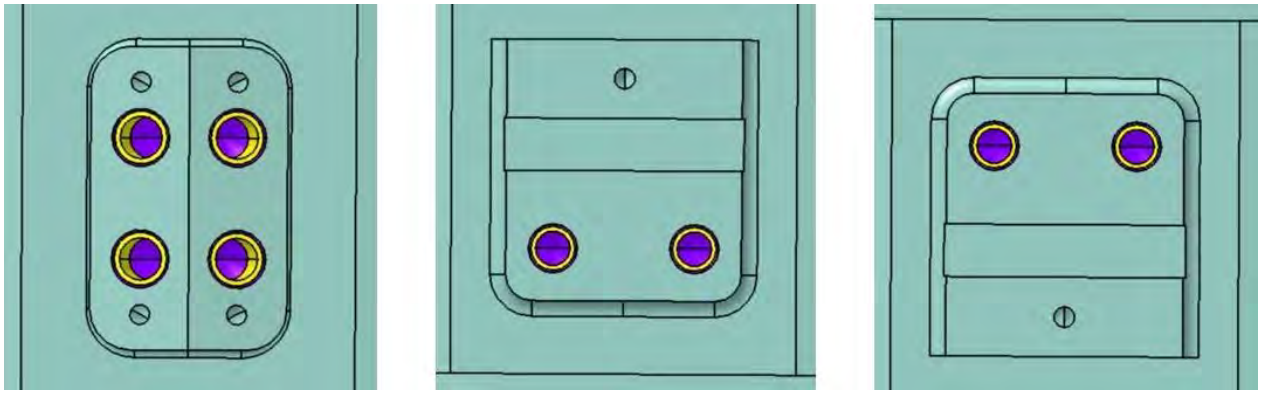


Fig. 19: Three types of the HFS in-vessel interfaces (from left: HFS basic interface, divertor lower, divertor upper)

5.1.2. Heating / cooling system

The goal of the heating/cooling system is to maintain a proper and reliable heating and cooling of the VV using pressurized gas, as a medium, during the operation and between experiments. It shall allow operation of the device at temperatures ranging from RT up to 500 °C, at heating and cooling rates mentioned in the requirements below.

General technical requirements
The system consists of two pairs (one upper and one lower) of peripheral common buses feeding 16 sets of heating / cooling loops, as shown in Fig. 20. Every set of 8 loops is connected to one of the two pairs of the common buses (i.e. upper or lower), allowing redundancy in the system, which is needed in case of failure of one of the loops. The inlets and outlets of the buses are located in sector 16, through the upper and lower DUX ports.

The base material of the heating / cooling system is nickel alloy 625 (see 4.1.2).

The heating / cooling system shall be procured and mounted inside the VV by the Seller according to the preliminary documentation and, later, the production documentation. In case of any design change or optimisation, rules stated in chapter 4.6 apply. Given dimensions of the piping and flanges should be respected and could be eventually changed according to market availability and upon agreement with the Buyer (see required limits on dimensions in section below). Dimensions are recommended to be selected in compliance with the industry standard ASTM B444 or custom made, if necessary. The freedom on the dimensions of the piping and flanges enables the Seller to optimize between the imperial, metric or custom pipes.

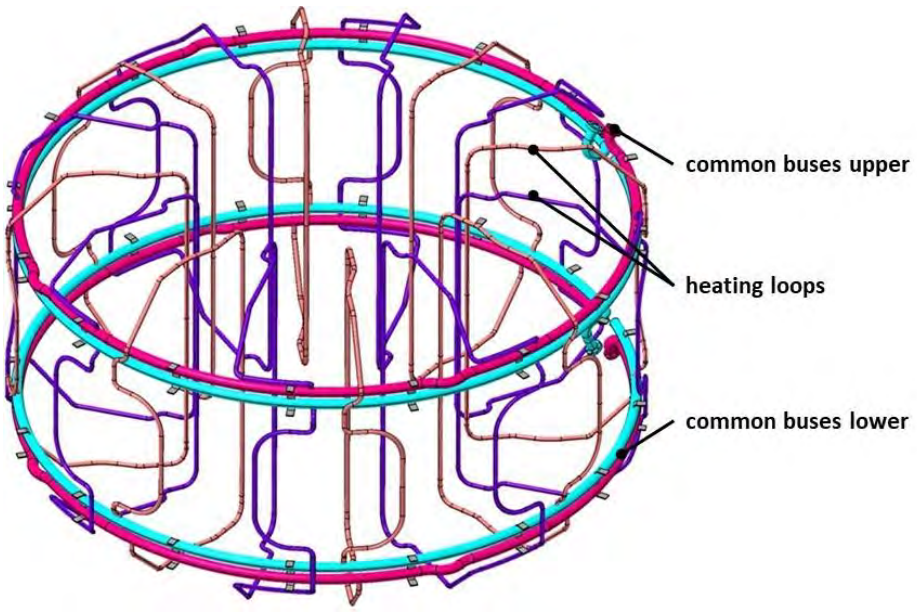


Fig. 20: Overview of the in-vessel heating / cooling system. The peripheral pipping (pink and light blue colors) represents the upper and lower common buses feeding 8 sets of two separated heating and cooling loops.

All 16 heating / cooling loops shall be inseparably mounted to the VV main body weldment. Technology used shall be selected by the Seller and approved by the Buyer according to all technical and operational requirements. Welding requirements are discussed further in this chapter and in chapter 4.2.

The common buses will be attached to the VV main body weldment using specific flexible mounting brackets to allow thermal expansion of the buses. These mounting brackets will be directly welded to the VV main body weldment.

The heating / cooling system basic parameters and requirements are:

- Working gas pressure: 60 bar at 500 °C
- Medium used: helium or CO_2
- Required integral leak rate: no gas leak tolerated (see chapter 8.5)
- Heating rate: 40 °C/h
- Cooling rate: 60 °C/h
- Overall loop length (without common buses): ~ 76 m
- Cumulative length of the common buses: ~ 35 m
- Material of the system components: nickel alloy 625
- Only seamless pipes according to ASTM B444 are allowed

Dimensions of the heating / cooling tubes are not strictly fixed, but must be kept inside the following ranges:

- Loop tube diameter: OD = max. 19 mm, ID = min. 12 mm
- Loop tube thickness: min. 1.5 mm
- Minimum bending radius according to the selected ID

The minimum tube wall thickness is, in particular, critical in case of welding (see below).

Dimensions of the common buses are also not strictly fixed, but must be kept inside the following ranges:

- Common bus diameter: OD = max. 42.5 mm, ID = min. 32 mm
- Common bus thickness: min. 2.5 mm
- Minimum bending radius according to the selected ID

Shape and location tolerance requirements of the heating loops and common buses are defined by the preliminary and production documentation.

Note that this system shall fulfil all relevant requirements of the Pressure equipment directive (PED). For details see chapter 4.10.

Welding / brazing requirements
The heating / cooling loops are to be permanently mounted to the VV main body weldment inner walls, using a suitable fusion welding or brazing technology, compatible with nickel alloy 625 base material of the VV. Note that the physical joint of the heating / cooling loops to the VV is a key element enabling the heat transfer to the VV in the vacuum conditions, leading the Buyer to require weld height and length, specified herein.

The Seller shall choose a suitable technology. The joints must be placed with maximum space density. To avoid trapped volumes between the joints, alternating placement of the joints shall be realised, similarly as what is shown in Fig. 21 (right), with strict requirement that the total length of the joints must be ≥100 %, i.e. for each 1 m of the heating / cooling pipe, there must be ≥ 1 m total length of the joints (for example: 5 x 10 cm joints on one side and 5 x 50 cm joints on the other side, if alternating ratio 50:50 and 10 cm joint length are chosen).

The length and number of alternating joints are to be agreed with the Buyer. In case of welding, the weld type should be corner joint-like, full penetration joint. Joint height shall be at least, a = 6 mm as shown in Fig. 21 (left).

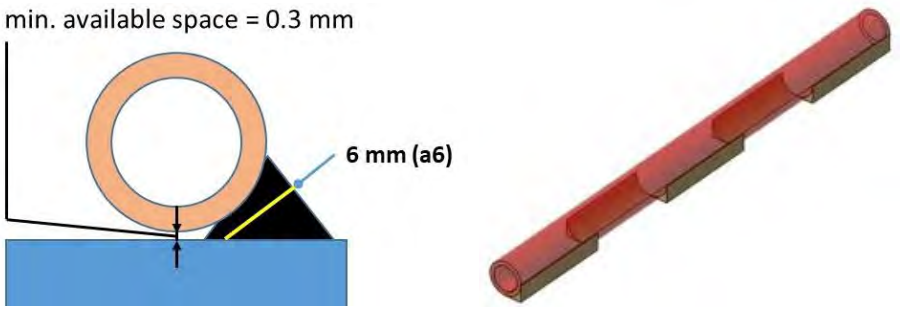


Fig. 21: Left: Joint (weld / brazing) type and minimum joint height (a6). If the shape and spacing of the alternated welds avoid any trapped volume under the loops, min. required available space of 0.3 mm could be neglected Right: Alternating placement of the joints (welding / brazing seams).

In general, the size of the corner joint shall be carefully selected to avoid melting of the tube during the joining (welding / brazing) process, which could pose structural risks. According to analyses performed in the attached welding study (Technical specification – Annex No. 2 – Results of the welding study), there is a significant influence of the tube wall thickness on penetration and overheating of the base material. In Fig. 22, a comparison of the influence of different tube wall thicknesses on heat propagation is shown.

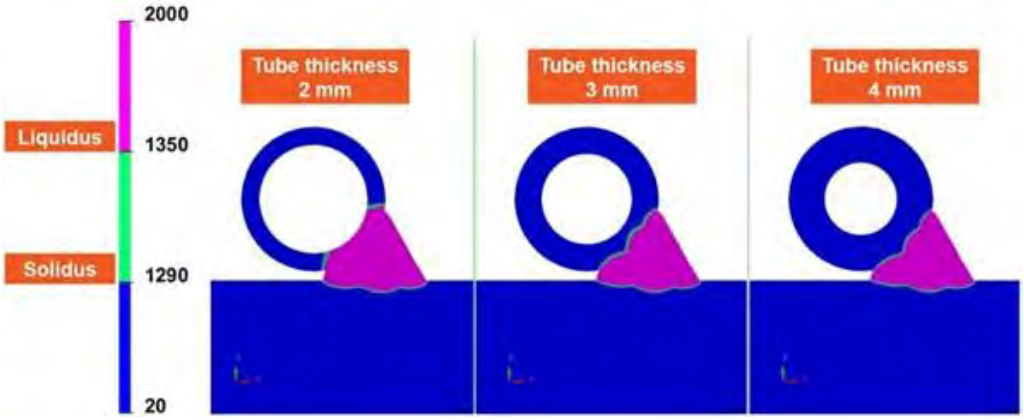


Fig. 22: Influence of the different wall thicknesses during the fusion welding (simulation).

The selected welding / brazing technology used for welding of the heating / cooling loops to the VV wall shall be verified by prototyping prior any manufacturing starts, see chapter 4.2.5.

Vacuum compatibility and cleanliness requirements
The heating / cooling loops and common buses shall meet all vacuum requirements mentioned in chapter 4.3 and in Technical specification – Annex No. 3 – Vacuum requirements. No contaminants shall get into the heating / system during the procurement process and a proper sealing all of the heating and cooling system inlets and outlets is therefore mandatory.

5.1.3. VV supports

The vacuum vessel supports serve as the gravitational support of the VV and to compensate vertical, toroidal and lateral forces that can arise during operation of the COMPASS-U tokamak. At the same time, they must be able to compensate significant thermal expansion of the VV from RT up to 500 °C. The design and dimensions of the supports are driven by expected loads that will arise during the COMPASS-U tokamak operation. More on the expected loading scenarios see the Technical specification – Annex No. 4 – Key simulation results.

In total, eight supports are designed to be flexible in radial direction (direction of the foreseen thermal expansion of the VV) using a set of flexible plates, see Fig. 23. The upper adaptor of the support is directly welded to the VV. The lower part of the support is mounted to the support structure of the COMPASS-U tokamak using a spherical washers (note that the support structure of the COMPASS-U tokamak, is not part of the extent of delivery). In Fig. 23 left, the complete set of the VV supports is shown and, right, the individual components of one of the supports are shown.

All individual mounting elements of the VV supports are inseparable part of the delivery. Amount, size and tolerances are included in the CAD documentation.

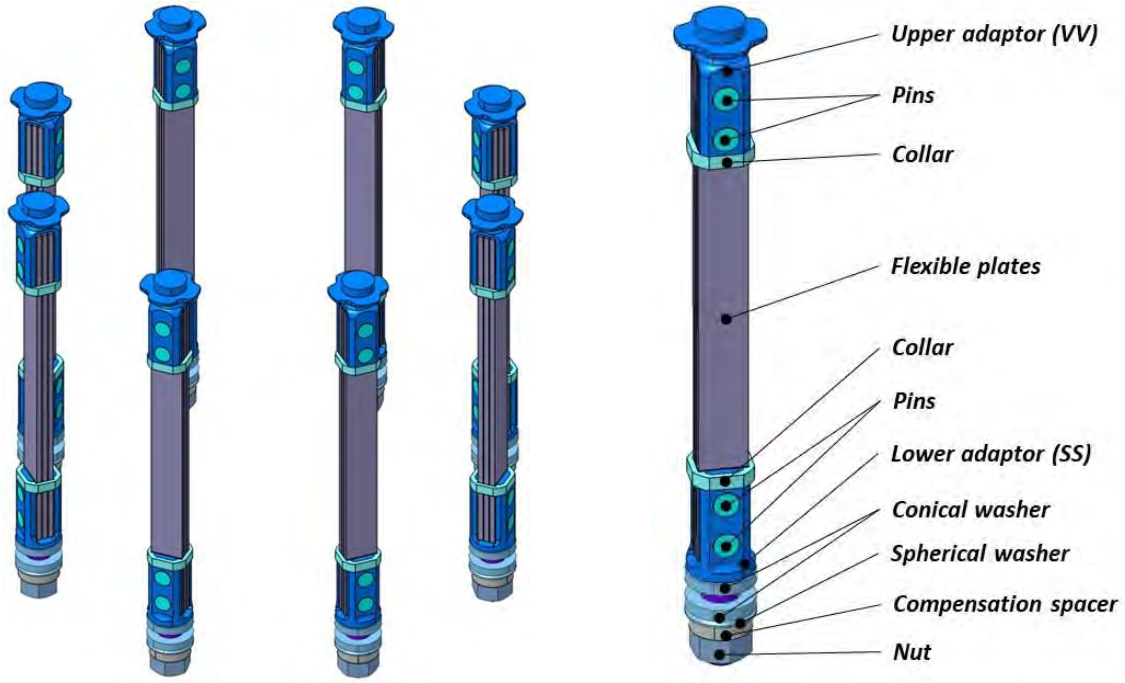


Fig. 23: Left: Set of 8 VV supports. Right: VV support and its components

The base material of the whole VV support is nickel alloy 625. This material was selected to maintain high mechanical strength at elevated temperatures and welding compatibility with the VV.

The outer surfaces of the VV supports have to be polished to a mirror finish. The requirements for the polishing process and final surface finish are specified in chapter 4.2.6. Note that the same requirement exists for the outer surfaces of the VV main body weldment (see chapter 5.1.1).

The Seller shall procure all the VV supports according to preliminary, later production documentation and deliver them mounted to the VV with respect to the required dimension tolerances. For any design change, the conditions discussed in chapter 4.6 apply.

5.1.4. Blank flanges

Blank flanges are required to seal all VV ports. Blank flanges for all ports of the VV shall be procured by the Seller to fulfil the following purposes:

- Safe and clean transportation and storage of the complete VV assembly (see chapter 4.7)
- Perform leak tests as part of the FAT and SAT* (see chapter 9.7 and 9.8)
- Use for machine operation at RT or at elevated temperature

* Note that to perform leak tests of the VV assembly additional tools or modified blank flanges could also be required and shall also be procured by the Seller for testing purposes.

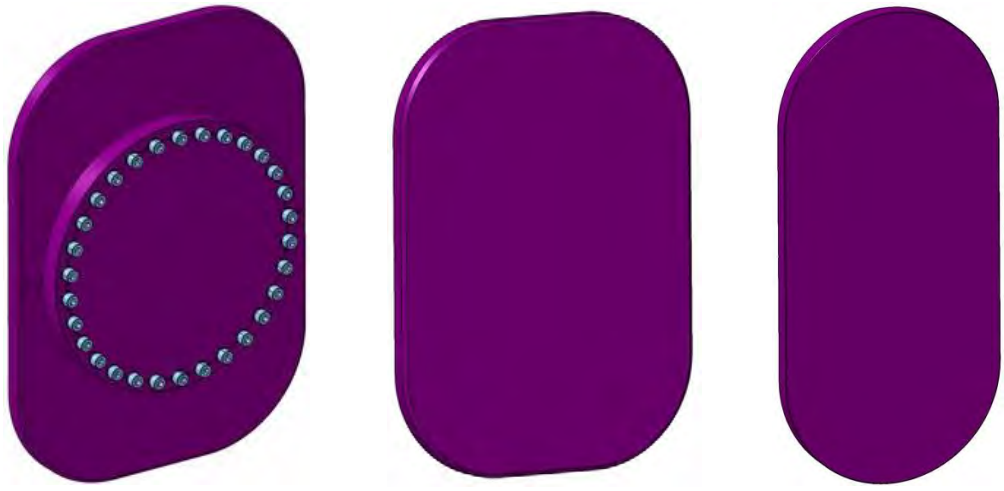
For the cost reasons, three different base materials of the blank flanges are used. AISI 309(S)/310(S) material is required for 25 % of mid-plane blank flanges, i.e. for MX and MN ports and divertor blank flanges for elevated temperature (3 pcs, see Table 8 and Fig. 24, f). Stainless steel AISI 316L is required for the plain MX and MN blank flanges. Aluminium material (T6 or comparable) shall be used for vertical and divertor blank flanges. An overview can be found in Table 8.

Material / Port type	MX (see Fig. 24, b)	MX with CF flange (see Fig. 24, a)	MN	Vertical	Divertor
AISI 309(S)/310(S)	2	-	2	-	3
AISI 316L	4	2	6	-	-
Aluminium (T6 or comparable)	-	-	-	24	32

Table 8: Quantity of the blank flanges according to type and used base material. Note that with exception of the Divertor flanges, the quantity of the flanges is identical with the number of ports (i.e. no reserve flanges are required by the Buyer).

All blank flanges shall be vacuum compatible. All blank flanges shall sustain transportation, storage and leak testing at RT. Blank flanges made of AISI 309(S)/310(S) shall also sustain the tokamak operation at the following temperature range: –200 °C up to 500 °C. For the vacuum compatibility and required leak rates, see the Technical specification – Annex No. 3 – Vacuum requirements.

Design of all six types of the blank flanges is shown in Fig. 24. The MX port blank flange (Fig. 24, a) made of stainless steel accommodates an additional circular CF flange (CF 275) for easier access to fasteners from inside the VV. The MX port blank flange (Fig. 24, b) made of AISI 309(S)/310(S) is rather simple and does not have any additional flange. The MN port blank flange (Fig. 24, c) is a simple flange mounted from the outside for both used materials.



(a) (b) (c)

(d) (e) (f)

Fig. 24: All six types of blank flanges; (a) MX port with additional CF flange; (b) MX port simple flange; (c) MN port flange; (d) Divertor port flange; (e) Vertical port flange; (f) Divertor port flange for elevated temperature

The blank flanges for vertical ports and divertor ports shown in Fig. 24, d) and Fig. 24, e) made of aluminium material are intended to be sealed with standard elastomer seals. The divertor blank flange shown in Fig. 24, f) is to be used with resilient metal (not part of the extent of delivery) seal and elevated temperatures.

For detailed requirements on seals that are to be used, see chapter 5.1.5. The Seller shall deliver all blank flanges already mounted to the VV, including seals.

5.1.5. Elastomer and CF seals

Blank flanges are designed to accommodate two types of seals on the side of the interface to the VV: elastomer and resilient metal seals. Elastomer seals will be used for transportation, storage or leak testing. Resilient metal seals (not part of the extent of delivery) will be used for operation of the COMPASS-U tokamak at the temperature range from –200°C up to 500°C. Standard metal CF seals/gaskets shall be used for the CF flanges used for MX blank flanges. The Seller shall deliver both elastomer and CF seals for all blank flanges.

All types of seals shall fulfil the technical requirements described in the previous section and requirements for performing the leak testing stated in chapter 8.5. The following general technical specification applies for all types of delivered seals:

- Operational temperature range: room temperature
- Vacuum only at one side (in the VV), outside normal atmospheric pressure

Standard elastomer seals
The following technical requirements apply for the standard elastomer seals:

- Type: selected by the Seller, agreed with the Buyer (standard o-ring seal recommended)
- Material: Viton® / FKM / FPM or equivalent
- Working temperature: RT
- Vacuum / pressure requirements: see chapter 8.5

The Seller shall deliver at least the following quantity of seals according to individual port type:

Port type	MX	MN	Vertical	Divertor
Quantity (pcs.)	10	10	30	40

Table 9: Quantity of elastomer seals to be delivered according to the port type

Standard CF seals
The following technical requirements apply for standard CF seals:

- Type: standard CF seal according to EN ISO 3669
- Material: oxygen free copper material (OFHC)
- Working temperature: RT
- Vacuum / pressure requirements: see chapter 8.5

The Seller shall deliver at least the following quantity of seals according to individual port type:

Port type	MX	MN	Vertical	Divertor
Quantity (pcs.)	10	-	-	-

Table 10: Quantity of CF seals to be delivered according to the port type

5.1.6. Jigs

Jigs are an integral part of the item "VV basic configuration" and shall be designed, procured and delivered by the Seller. The extent of the jigs does not contain any tools needed during procurement, manufacturing or testing. The jigs needed to be procured and delivered shall fulfil only the three following functions:

- enable safe and reliable transportation of the complete VV assembly, so-called transportation jig
- enable safe and reliable storage of the complete VV assembly, so-called storage jig

The above-mentioned functions can be fulfilled using two individual jigs or by integrating some of the functions into one jig. It is preferred that only one unique jig is used for transportation and storage purposes.

General technical requirements on all jigs are the following:

- allow fixed and safe position of the complete VV assembly to avoid any damage, deformation or harm of personnel or property
- avoid ground contact of the VV supports or ports during transportation, storage or testing when mounted in the jig
- allow easy operation and maintenance of the jig
- chosen material and surface treatment shall be corrosion and water resistant
- use standard and common market available parts and components
- optimise weight of the jig to be as low as possible

The design of the jig(s) shall be proposed by the Seller and approved by the Buyer.

For the purposes of delivery and further manipulation on the Buyer's premises, an overview and relevant instructions are given in the Technical specification – Annex No. 8 – Shipment unloading area.

Transportation jig
The transportation jig shall be designed and manufactured by the Seller to fulfil the following function: enable safe and reliable transportation of the complete VV assembly from the Seller's to the Buyer's premises.

Specific technical requirements on the transportation jig are the following:

- position of the VV assembly shall be vertical

Storage jig
The storage jig shall be designed and manufactured by the Seller to fulfil the following function: enable safe and reliable storage of the complete VV assembly.

Specific technical requirements on the storage jig are the following:

- position of the VV assembly shall be vertical (along the VV axis)
- human access into the Vacuum Vessel must be possible when the VV is mounted in the Storage jig
- the storage jig must be able to safely carry 15 tonnes, i.e. the VV with additional mounted hardware (plasma facing components inside of the VV)
- the storage jig shall not touch the external walls of the Vacuum Vessel and ports, including the sealing surfaces of the port flanges
- provide at least three hanging points for a crane (all used at once)

5.2. Item not used (Item no. 2)

5.3. Item not used (Item no. 3)

5.4. Item not used (Item no. 4)

5.5. Post processing of VV main body weldment (Item no. 5)

In literature, post processing of welded constructions made of nickel alloys and, especially, nickel alloy 625 is not required according to material manufacturers recommendations and industry standards. However, any mechanical processing or welding of the alloy induce certain residual stresses in the final product, which could limit its operating parameters. Therefore, if any risk of failures due to excessive loads during the operation of the VV in the COMPASS-U tokamak exists, a specific stress relieving procedure shall be considered (if the item no. 5 is ordered).

A post processing by heat treatment is mandatory and shall be performed on the VV main body weldment when this item is ordered. Because the VV main body weldment is made of two dissimilar materials, heat treatment of the entire weldment is not recommended. It is allowed to heat treat the VV main body weldment with or without port flanges and port stubs. Depending on the stage of the manufacturing it may include all inseparably joined items of the extent of delivery that are ordered.

The post processing procedure parameters shall be defined by the Seller in accordance with material manufacturer's recommendations and industry standards, and approved by the Buyer. Before any post processing procedure occurs, post processing prototypes shall be procured and relevant procedure shall be properly tested and evaluated (see chapters 4.2.5 and 9.6.4).

After post processing procedure is finished, the VV main body weldment must still fulfil all required dimensional tolerances and technical requirements of this document.

Two types of post processing procedures are considered in this document, i.e. heat treatment (mandatory if the item no. 5 is ordered) and vibration treatment (optional if the item no. 5 is ordered – use is not required by the Buyer, but it can be proposed by the Seller). Minimum requirements are mentioned in the following sections. Other options could be also envisaged and proposed by the Seller, subsequently approved by the Buyer. Post

processing should be considered also for other sub-items of the VV basic configuration, if meaningful, e.g. VV supports.

5.5.1. Requirements for the heat treatment

Stress relief by heat treatment is applicable after welding or excessive forming. Heat treatment shall be applied during construction process or after all welding work is finished. Therefore, stepwise post processing of the VV main body weldment is allowed if the following is fulfilled:

- Heat treatment shall follow every welding work if electron beam welding method is not used (EBW).
- If EBW is used, it may be performed after the heat treatment.
- It is allowed to perform the heat treatment of the VV main body without port flanges, vertical, divertor, MN, MX ports and holes.

Practically, it means that the Seller is allowed to perform the heat treatment AFTER welding the VV main body weldment, but BEFORE joining parts of the VV main body weldment together by the EBW method (see chapter 4.2.4 for welding requirements). Therefore, it is possible to perform heat treatment BEFORE final machining of the inner parts of the VV main body weldment and BEFORE machining the threads in the inner parts of the VV main body weldment (this requires utilization of the EBW as method of joining two parts of the VV main body weldment together after the heat treatment).

The minimum required temperature for the heat treatment is 870 °C and below 1050 °C, for at least one hour. Other parameters of the heat treatment shall be selected by the Seller and approved by the Buyer. Before any treatment occurs, selected parameters shall be tested and evaluated on prototypes first, see chapters 4.2.5 and 9.6.4.

The heat treatment process shall be performed in accordance with the following industry standards: EN ISO 17663, EN ISO 13445-10.

5.5.2. Requirements for post processing by vibration (VSR)

Stress relief by vibration can be performed as complementary method to the heat treatment. Particular parameters of the treatment shall be defined by the Seller and approved by the Buyer. Before any treatment occurs, selected parameters shall be tested and evaluated on prototype first, see chapter 4.2.5 and 9.6.4.

5.6. In-vessel interfaces

5.6.1. General requirements for pads, studs and shear keys

All pad interfaces, studs and shear keys shall be procured by the Seller (if ordered) and welded to the VV main body weldment. Welding of all the pads, studs and shear keys to the VV main body weldment must be performed according the requirements described in the chapter 4.2.3 and 4.2.4. Additionally, the welds shall not exceed by 2 mm from the ideal shape of the welded object (see an example in Fig. 25). The number of passes as well as the gap between the two objects and the slope of the chamfer are to be proposed by the Seller for an ideal final result.

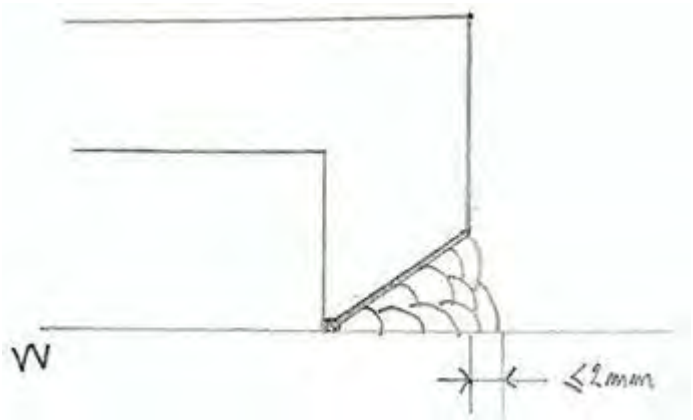


Fig. 25: Schematic view of a full penetration weld of a pad on the VV main body weldment.

Positions of the pads, studs and shear keys on the VV main body are defined by preliminary documentation and production documentation. Related geometrical tolerances in radial, toroidal and vertical/poloidal direction shall also follow the requirements of the preliminary documentation and production documentation. Final dimensions and precise positions will be selected by the Buyer and provided in due time to the Seller (see "Technical specification – Annex No. 1 – Universal Procurement process of an item" for rules for dates).

The front surfaces/functional surfaces of all pads and shear keys are to be machined according to definition in the documentation. The milling shall be realized after the pads and the shear keys are welded to the VV main body weldment. This is not the case of the HFS interfaces where the whole geometry is to be milled at once.

A small conical hole (4 mm in diameter with an apex angle of 45°) shall be drilled in the front surface of each pad, stud and shear key for metrology purposes. These metrology markers shall be drilled in each pad and shear key after they are welded to the VV main body weldment, whilst the markers shall be drilled in each stud before welding.

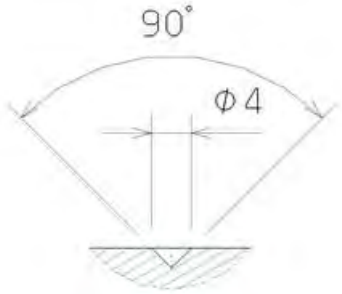


Fig. 26: Metrology marker

For all in-vessel interfaces, the nickel alloy 625 material shall be used as specified in the preliminary documentation and production documentation.

For welded studs, the industry standards EN ISO 13918 and EN ISO 14555 shall be followed, when not agreed otherwise. Specific material properties required are mentioned in chapter 4.1.2. Furthermore, the Buyer requires that the studs shall have rolled threads (i.e. not cut threads).

Note that manufacturing prototypes to verify welding technology used shall be procured and tested, see chapter 4.2.5.

5.6.2. Item not used (Item no. 6)

5.6.3. Item not used (Item no. 7)

5.6.4. Item not used (Item no. 8)

5.6.5. LFS OWL pad (Item no. 9)

The LFS OWL pad is depicted in Fig. 27 and the dimensions, before machining, must be kept inside the following ranges:

- Toroidal length: 100 mm ≤ A ≤ 180 mm
- Poloidal length: 40 mm ≤ B ≤ 80 mm
- Maximum radial thickness: 9 mm ≤ C ≤ 20 mm
- Maximum leg thickness: 8 mm ≤ D ≤ 12 mm

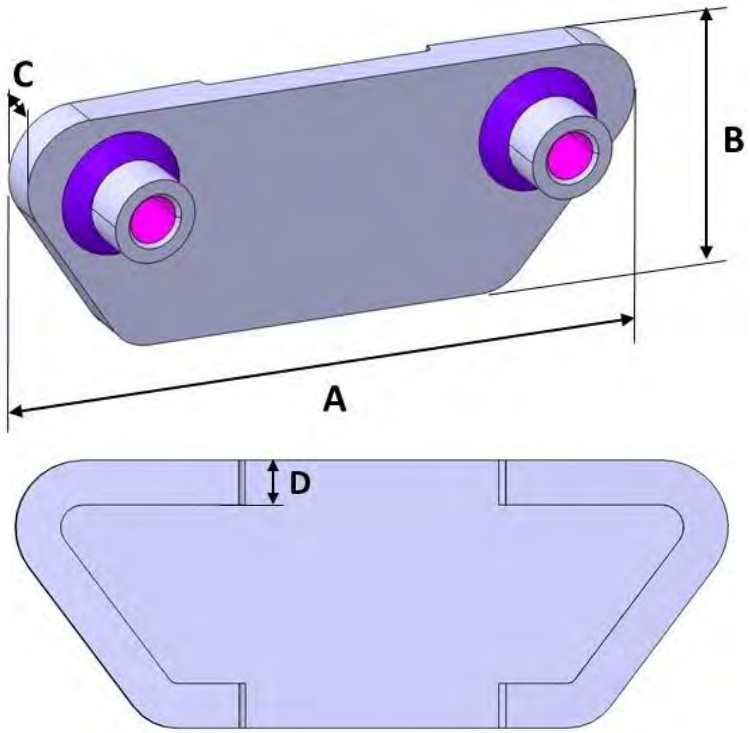


Fig. 27: Schematic view of the LFS OWL pad (left: front view; right: back view) with holes for fixation and the metrology marker.

As shown in Fig. 27, each LFS OWL pad includes two welded nuts for fixation with parameters that must be kept inside the following range:

- Diameter: min. = M12; max. = M16;

The metrology marker in each LFS OWL pad will be drilled after the pad is welded to the VV main body weldment and machined.

5.6.6. Item not used (Item no. 10)

5.6.7. Item not used (Item no. 11)

5.6.8. Item not used (Item no. 12)

5.6.9. Item not used (Item no. 13)

5.6.10. Item not used (Item no. 14)

5.6.11. Item not used (Item no. 15)

5.6.12. Outer DIV four-stud type 1 (Item no. 16)

The outer DIV four-stud type 1 is described in Fig. 28 and the dimensions must be kept inside the following ranges:

- Stud length: 30 mm ≤ L ≤ 50 mm
- Stud diameter: min. = M10; max. = M12
- Thread length: 10 mm ≤ L'

The position of the four studs with respect to each other must be included in a rectangle with (longitudinal, transversal) dimensions (A, B) within the following range:

- Longitudinal stud spacing (axis-to-axis): 80 mm ≤ A ≤ 240 mm
- Transversal stud spacing (axis-to-axis): 25 mm ≤ B ≤ 60 mm

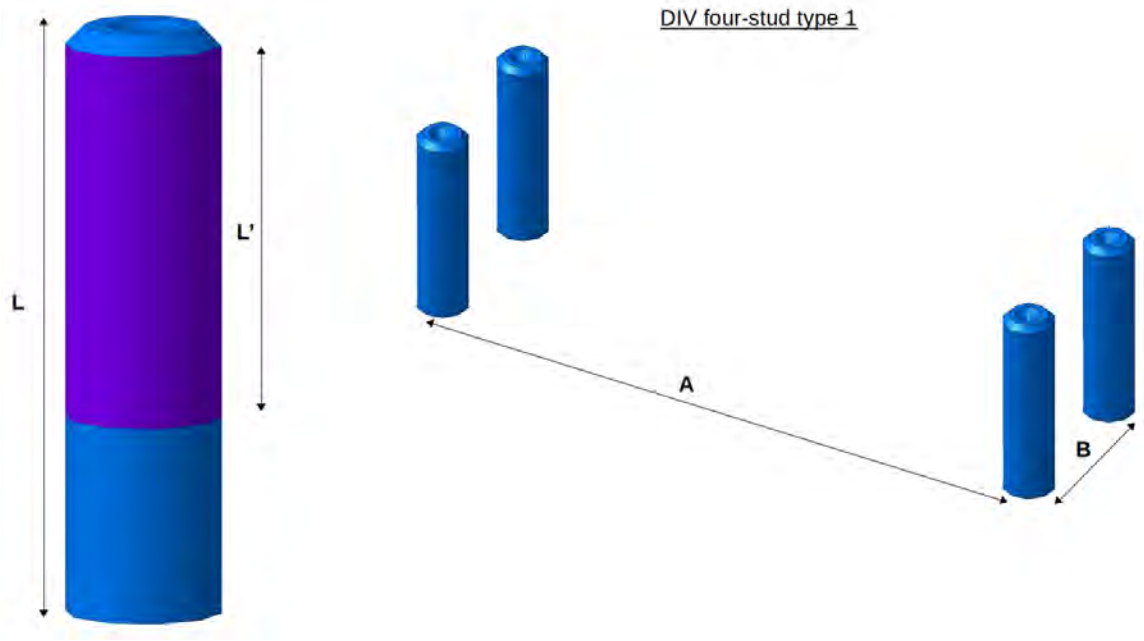


Fig. 28: Schematic view of the outer DIV four-stud type 1 with metrology marker on each stud top surface (opposite to the weld).

Exact dimensions of the stud shall be chosen according to the industry standard EN ISO 13918 when not agreed otherwise. Welding process shall follow the industry standard EN ISO 14555. Use of ceramic ferrules is not allowed for vacuum compatibility reasons.

The metrology marker shall be drilled in the front surface of each stud according to the previously mentioned definition and CAD documentation.

5.6.13. Item not used (Item no. 17)

5.6.14. Item not used (Item no. 18)

5.6.15. Item not used (Item no. 19)

5.6.16. Item not used (Item no. 20)

5.6.17. Item not used (Item no. 21)

5.6.18. Item not used (Item no. 22)

5.6.19. Outer DIV shear key (Item no. 23)

The outer DIV shear key is described in Fig. 29 and the dimensions must be kept inside the following ranges after machining (geometrical tolerances acc. to ISO 2768 – mK):

- Toroidal length: 15 mm ≤ A ≤ 25mm
- Radial length: 40 mm ≤ B ≤ 80 mm
- Maximum height: 5 mm ≤ C ≤ 15 mm
- Maximum leg thickness: 5 mm ≤ D ≤ 10 mm

Fig. 29: Schematic view of the outer DIV shear key with the metrology marker on the front surface (top: side front view; bottom: side back view)

The outer DIV shear key is an individual item but it shall be precisely positioned within the outer DIV four-stud type 1 item (item no. 16). The only information about the Outer DIV shear key is provided in this chapter, the item is not described in the initial CAD documentation and production documentation. The required precision of positing of the Outer DIV shear key: a) positioning with respect to the same datum as item no. 16, b) two times better precision than the item no. 16.

The metrology marker will be drilled after the Outer DIV shear key is welded to the VV main body weldment and machined.

5.6.20. PSP outer pad (Item no. 24)

The outer PSP outer pad is described in Fig. 30 and the dimensions, before machining, must be kept inside the following range:

- Toroidal length: 150 mm ≤ A ≤ 170 mm

- Radial length: 50 mm ≤ B ≤ 70 mm
- Maximum vertical height: 15 mm ≤ C ≤ 25 mm
- Maximum leg thickness: 6 mm ≤ D ≤ 12 mm

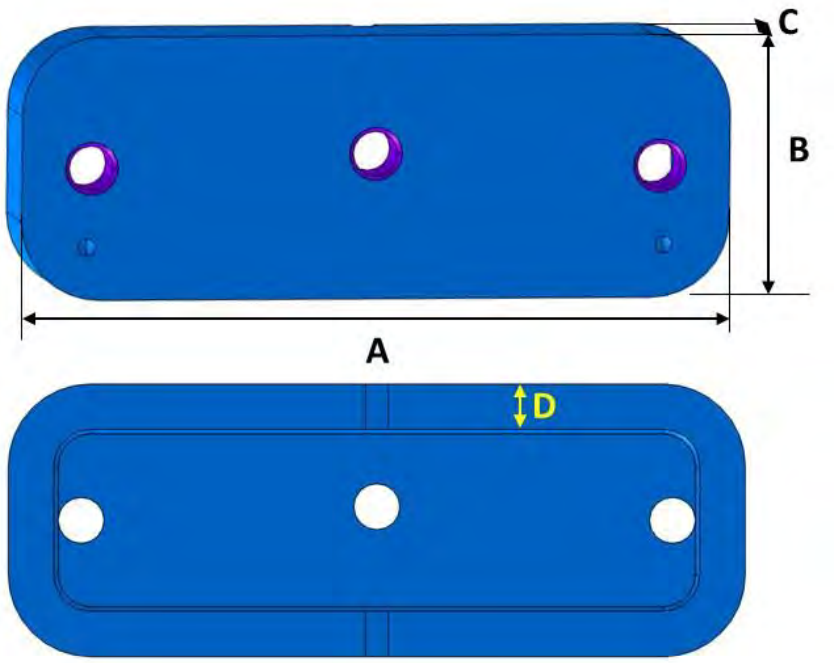


Fig. 30: Schematic view of the PSP outer pad

The fixation holes as well as the metrology marker in each PSP outer pad will be drilled after the pad is welded to the VV main body weldment and machined.

5.6.21. PSP LFS pad single (Item no. 25)

The outer PSP LFS pad is described in Fig. 31 and the dimensions, before machining, must be kept inside the following range:

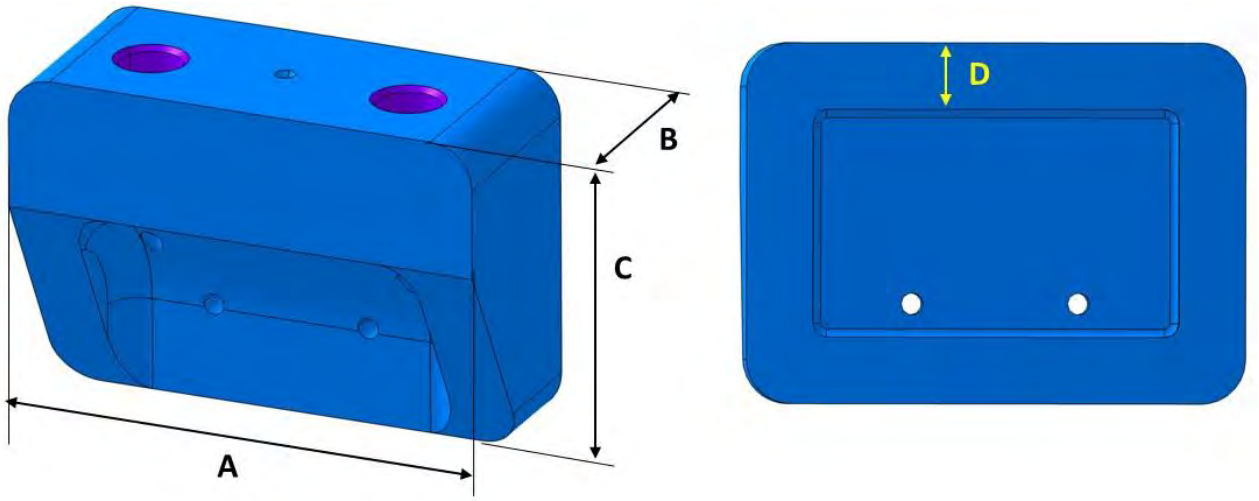


Fig. 31: Schematic view of the PSP LFS pad single

- Toroidal length: 80 mm ≤ A ≤ 100 mm
- Radial length: 30 mm ≤ B ≤ 40 mm
- Maximum vertical height: 30 mm ≤ C ≤ 50 mm

- Maximum leg thickness: 6 mm ≤ D ≤ 12 mm

The fixation holes as well as the metrology marker in each PSP LFS pad single will be drilled after the pad is welded to the VV main body weldment and machined.

5.6.22. PSP LFS combined pad (Item no. 26)

The outer PSP LFS combined pad is described in Fig. 32 and the dimensions, before machining, must be kept inside the following range:

- Toroidal length: 50 mm ≤ A ≤ 70 mm
- Radial length: 40 mm ≤ B ≤ 60 mm
- Maximum vertical height: 50 mm ≤ C ≤ 80 mm
- Maximum leg thickness: 8 mm ≤ D ≤ 14 mm

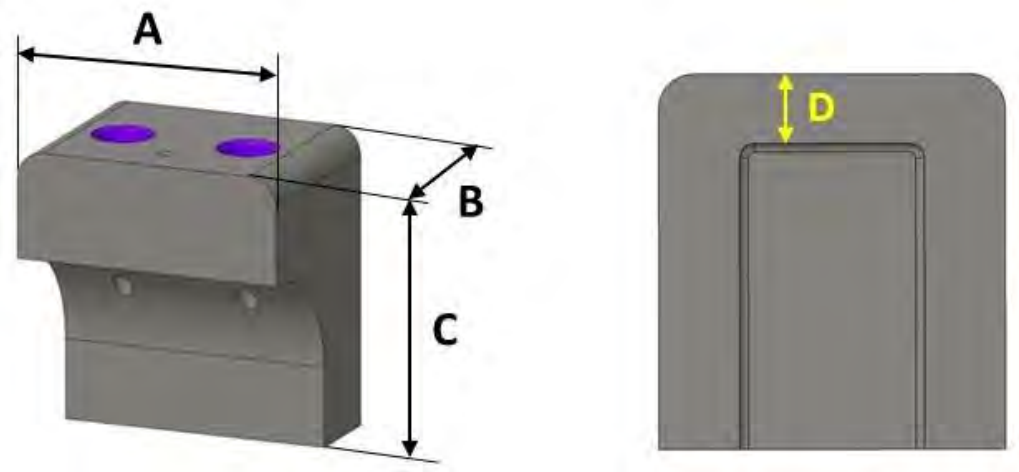


Fig. 32: Schematic view of the PSP LFS combined pad

The fixation holes as well as the metrology marker in each PSP LFS combined pad will be drilled after the pad is welded to the VV main body weldment and machined.

5.7. Vacuum Vessel – delivery state

Vacuum vessel – delivery state represents the real state of the vacuum vessel, including all ordered items of the extent of delivery, delivered by the Seller to the Buyer. In principle, the delivery state consists of the VV main body weldment including all ordered and inseparably joined items on one side, and the rest items / sub-items of the extent of delivery, which are mounted by relevant mounting elements and corresponding accessory. In Fig. 33, the main basic parts of the VV – delivery state are depicted. Table 11 shows weight estimate of the individual main basic parts.

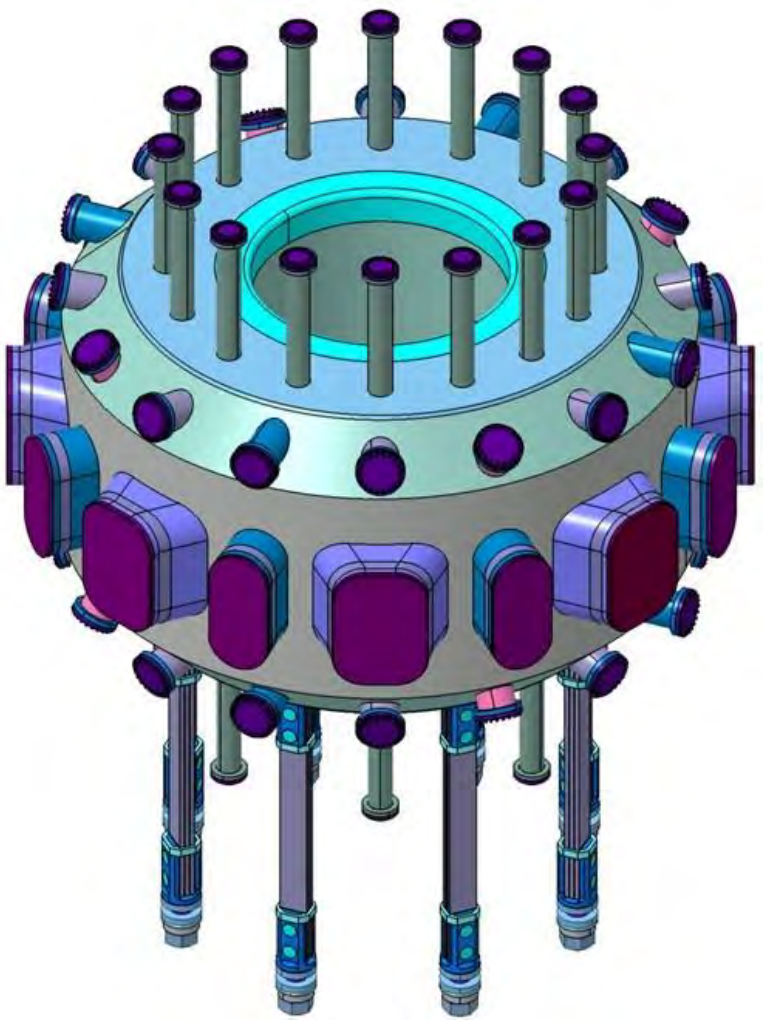


Fig. 33: Vacuum vessel – delivery state

ITEM / SUB-ITEM	WEIGHT (kg)
VV main body weldment	6102
Heating / cooling system	198
In-vessel interfaces	128.5
VV supports (incl. mounting elements)	1141
Blank flanges	579
Elastomer seals	4.3
Bolts	53
TOTAL WEIGHT VV – delivery state	8205.8

Table 11: Summary of weight of the Vacuum vessel – delivery state

6. PROCUREMENT PROCESS

The procurement process of the COMPASS-U: Vacuum Vessel and related components that shall be strictly followed by the Seller, is described by the so-called Universal procurement process of an item (see Technical specification – Annex No. 1 – Universal Procurement process of an item). This chapter complements this document by providing further explanations.

6.1. Procurement general time plan

The procurement general time plan (see file "Universal Procurement process of an item – overview.xlsx", sheet "Procurement General Time plan") shows all essential milestones and duration of procurement of the individual items or group of items. The table is to be read from top to bottom and from left to right. Below, each individual column of the table and its meaning are described.

Group
Items are grouped in two groups as indicated by the first column of the table. These groups will be used for the procurement process as described in the procurement process table overview (see chapter 6.2).

Items
The second column indicates the different items of the extent of delivery.

Planned start
The third column indicates the maximum time the Buyer has to order a particular item from the signature of the *Framework Purchase Agreement*. This time could be shortened but the maximum is considered for illustrative purpose.

Planned duration
The fourth column indicates the possible duration of procurement of each item from ordering, according to the *Framework Purchase Agreement*. This time is strictly bounded to the total duration of the manufacturing of the VV basic configuration, as all the items shall be delivered no later than that.

Percent of lead time
The fifth column indicates the percentage of manufacturing time each item has with respect to the total time needed for manufacturing the VV basic configuration. The latter an item is ordered, the less time there is for manufacturing and delivering.

Months
The last columns show a very general procurement time plan for each individual item of the extent of delivery. The total lead time of 20 months is the maximum allowed by the *Framework Purchase Agreement* for procurement and delivery of all the ordered items. In case of exceeding this range, corresponding contractual penalties according to the *Framework Purchase Agreement* conditions apply.

6.2. Universal procurement process overview

The universal procurement process overview (see file "Universal Procurement process of an item – overview.xlsx", sheet "Universal Procurement Process") describes all necessary steps and required inputs and outputs needed for completion of the individual phases of the procurement process in chronological order. It includes essential information regarding required deadlines, decisions, consequences and also when advance and partial payments or contractual penalties apply.

The table is to be read from top to bottom and from left to right. Below, each individual column of the table and their meaning are described.

Phase
The first column of the table indicates the phases of the procurement process (yellow color). Under each phase, sub-phases (grey color) are listed and correspond to different processes, deliverables and milestones that the Seller shall achieve.

Processes, deliverables and milestones
The second column lists the overview of the activities and outputs of the procurement process. In bold, generic names of the main activities of each phase or sub-phase are provided and are used to label the outputs related to these activities. In plain text, a brief description of the outputs that shall be provided by the Seller is given. For a comprehensive description of the outputs, the Seller is referred to chapters 7 and 9.

Starting point
The third column indicates the starting point of a given sub-phase, i.e. a phase cannot be started until the condition specified in this column is reached. The abbreviation N/A significates that the Seller can start working on the sub-phase whenever most convenient, i.e. there is no constraint on the starting time.

Maximum duration / deadline
The fourth column indicates the maximum time duration of the sub-phase, starting when the condition specified in the starting point column is reached. This maximum duration shall be strictly respected by the Seller. Exceeding will lead to corresponding contractual penalties if these are defined by the *Framework Purchase Agreement* (as described in the "Possible contractual penalties" column). Eventually (starting point N/A), deadlines are provided in the column instead of duration.

Maximum time for decision by the Buyer
The fifth column indicates the maximum time duration that the Buyer has to decide on the outputs of a sub-phase from receiving the documents or inputs from the Seller. The Buyer shall respect this time duration (the Seller can request prolongation of the delivery period of the Object of Purchase if the Buyer is in delay – see *Framework Purchase Agreement*, article 4.3).

Rejection consequences
The sixth column indicates particular consequences for the procurement process in case of rejection of part or all outputs of a sub-phase. In bold, the main consequences are highlighted. The actions that the Seller must undertake for the phase to be approved are given in plain text.

In case of rejection, the Buyer shall provide a list of objections, including references to the Technical specification sections or parts which are either not fulfilled or insufficiently addressed in the documentation submitted by the Seller.

The rejection by the Buyer shall be based only on the Technical specification – it is not allowed to be above or beyond the requirements stated in the Technical specification.

Possible contractual penalties
The seventh column lists if any contractual penalty applies to the delay or rejection of a sub-phase. In bold, the reasons leading to a contractual penalty are mentioned. A summary of the contractual penalty conditions is provided in plain text, but does not substitute for the contractual penalty conditions described in the *Framework Purchase Agreement*.

Delivery format
The eighth column indicates in which format the outputs of a phase or sub-phase shall be submitted (see chapter 7.18 for further explanation on the delivery format of documentation).

Phase completion line (purple)
These lines indicate what actions shall be undertaken by the Seller to finalize a given phase and to continue to the next one, including the necessary documents to be submitted for the phase completion.

6.3. Procurement process interpretation example

It is hereby described how to read the phase 1 from the procurement process table and shall illustrate how the table is to be understood.

Phase 1
The first line of the phase (in yellow) indicates the global name of the phase and its number: phase 1, called preparation phase.

Sub-phase 1.1
The sub-phase 1.1 is specific for the items in group no. 1, as defined in the procurement general time plan table (Technical specification – Annex No. 1 – Universal Procurement process of an item, sheet "Procurement General Time plan"). The Seller is required to provide four main outputs for this group, which are:

- Production and engineering documentation – group no. 1 and no. 2 (further described in chapter 7.1)
- Bill of raw material (further described in chapter 7.4)
- General testing plan (further described in chapter 7.5.1)
- Manufacturing plan (further described in chapter 7.5.2)

The preparation of above-mentioned documents for each item should start when the VV basic configuration and considered items in each group are ordered. The starting time of this sub-phase is set when ordering the VV basic configuration. The Seller has 17 weeks from ordering the VV basic configuration to provide the four mentioned outputs for all items in group no. 1. The Buyer has 3 weeks to approve them after submission. This means, the documents shall be submitted and approved at latest 20 weeks after ordering the VV basic configuration. If the sub-phase is approved, the Seller will receive the advance payment no. 2, as specified in the *Framework Purchase Agreement*.

If any part of the outputs is rejected, the Seller cannot start the manufacturing phase (phase 3) and shall rework the documentation and resubmit for approval. The Buyer has then 2 more weeks for approval. If rejected again, the whole procedure repeats.

The bill of raw material can be approved separately from the other required documents. If so, the Seller can start ordering the raw material accordingly and move to raw material acceptance phase (phase 2) for this group.

If the production and engineering documentation – group no. 1 is not approved in given 20 weeks from ordering the VV basic configuration, contractual penalties apply, as described in the *Framework Purchase Agreement*. The contractual penalties apply until all documents are submitted and approved by the Buyer.

The documentation shall be delivered via the Internet, as specified in chapter 7.18.

Successful completion of the phase is approved by issuing and signing the Handover Protocol of the Production and engineering documentation - group no. 1. Thereafter, the Buyer pays to the Seller the advance payment no. 2, as defined in the *Framework Purchase Agreement*.

Sub-phase 1.2

Here, the handover document, so called "Handover Protocol of the Production and engineering documentation - group no. 1" is signed as a confirmation that the documentation was successfully submitted and approved, and the sub-phases1.1 was finished.

Sub-phase 1.3
The next sub-phase, called sub-phase 1.3, is specific for the items in group no. 2, as defined in the procurement general time plan table (Technical specification – Annex No. 1 – Universal Procurement process of an item). The conditions are very similar to those of sub-phase 1.1, except that the sub-phase starts when all items in the group no. 2 are ordered. The Seller has two months to submit the documents and the Buyer has 2 weeks to approve them. There are no contractual penalties linked to this sub-phase.

Phase completion
To complete the phase 1 and continue to the next phase (phase 2) the Seller shall undertake the following actions:

- The Seller can order the material of a given group once the bill of raw material of the given sub-phase is approved by the Buyer.
- Once all sub-phases 1.1, 1.2 and 1.3 are approved, the Seller shall provide the full documentation of the complete phase 1 on CD (see chapter 7.18 for further explanation on the delivery format) within maximum 2 weeks from approval of the phase.

6.4. Universal procurement process diagram

The procurement process diagram represents a graphical form of the procurement process overview in a simplified and clear way. It includes all essential actions and decisions in the procurement process of an item from signing the contract to delivery and final payment. Individual requirements, inputs and outputs are mentioned in a chronological order.

The diagram can be found attached to this technical specification as the Universal Procurement process of an item – diagram. For more details also see the previous sections.

7. DOCUMENTATION

This chapter contains a detailed description of all types of documentation that shall be produced by the Seller within the procurement process of the extent of delivery. Note that providing the documentation on time is mandatory to fulfill the *Framework Purchase Agreement* conditions. The timeline for the procurement of the documentation can be found in the procurement process table overview of the Technical specification – Annex No. 1 – Universal Procurement process of an item.

As mentioned in chapter 3.2, for the purposes of general tender planning and procurement process definition, the extent of delivery is divided into two groups of items, group no. 1 and group no. 2 (see also Technical specification – Annex No. 1 – Universal Procurement process of an item). This division is used in the preparation phase only and applies to the following documentation:

- Production and engineering documentation (see chapter 7.2)
- Bill of raw material (see chapter 7.4)
- General testing plan (see chapter 7.5.1)
- Manufacturing plan (see chapter 7.5.2)

7.1. Preliminary documentation (provided by the Buyer)

When the tender is published, the preliminary documentation of the current state of the extent of delivery, i.e. the initial 2D and 3D CAD documentation (see 7.3.1) will be provided by the Buyer. This documentation includes the following information:

- Basic dimensions and dimension tolerances
- Materials of individual items
- Required surface treatment
- Bill of material

Missing information or details are to be provided by the Buyer to the Seller as soon as possible or upon agreement, after signing the *Framework Purchase Agreement*.

Based on this preliminary documentation, as the first input, all types of a subsequent documentation in the procurement process are to be created and regularly updated by the Seller.

The preliminary documentation is provided as Technical specification – Annex No. 7 – Preliminary documentation.

7.2. Production and engineering documentation

The Seller shall submit the production and engineering documentation (see chapter 2.2) for all ordered items that are to be manufactured within the extent of delivery based on the preliminary documentation. All necessary modifications and changes according to the manufacturing process and technology shall also be included.

The documentation includes technical drawings, which shall be created according to the following general industry standards: EN ISO 128, EN ISO 129, ISO 2768 – mK, EN ISO 1101, EN ISO 8015, EN ISO 13715 and EN ISO 21920-(1-3). Required form of technical drawings and creation methodology are described in the attachment Technical specification – Annex No. 5 – CAD creation and maintenance methodology.

The type of documentation that needs to be delivered for each item is listed hereafter:

1. VV basic configuration:
   - o VV main body weldment and heating / cooling system – production documentation the individual parts and welded assembly
   - o VV supports – production documentation of the individual parts and support assembly
   - o Blank flanges – engineering documentation
   - o Jigs – engineering documentation
2. Item not used
3. Item not used
4. Item not used
5. Post processing of the VV main body weldment: document with a brief description of the chosen process and its parameters (temperature for heat treatment and/or frequency in case of vibration)
6. Item not used
7. Item not used
8. Item not used
9. LFS OWL pad: production documentation
10. Item not used
11. Item not used
12. Item not used
13. Item not used
14. Item not used
15. Item not used
16. Outer DIV four-stud, type 1: production documentation
17. Item not used
18. Item not used
19. Item not used
20. Item not used
21. Item not used
22. Item not used
23. Outer DIV shear key: production documentation
24. PSP outer pad: production documentation
25. PSP LFS pad: production documentation
26. PSP LFS combined pad: production documentation
27. Extra man-hours of project manager / engineer / designer / technician / production worker or assembly worker: relevant documentation shall be updated
28. Extra research and development activities / design activities or service activities: relevant documentation shall be updated
29. Extra machining time on NC machine (includes work of operator): relevant documentation shall be updated

30. Extra machining time on conventional / standard machine (includes work of operator): relevant documentation shall be updated
31. Extra welding time (includes all costs of welding equipment + work of welder): relevant documentation shall be updated

This documentation is part of the Preparation phase, Manufacturing phase, Factory acceptance test phase and Site acceptance test phase (see Universal Procurement process of an item – diagram).

7.3. CAD documentation

7.3.1. Initial CAD documentation

The initial documentation includes 2D and 3D CAD data of all individual items, assemblies, results or analyses needed to realise the extent of delivery. The first CAD data of the extent of delivery are provided by the Buyer when publishing the tender (see chapter 7.1). The provided documentation has to be followed by the Seller for the procurement of the extent of delivery.

The information included in the CAD models and this technical specification should be enough for a fair price estimate for the Seller's bid and preliminary planning of manufacturing. Note that some of the items are defined within some specific ranges of parameters. Missing information or data will be provided by the Buyer during the realization of the extent of delivery or upon agreement.

The design provided by the Buyer may be modified or optimised by the Seller when needed, e.g. to lower the manufacturing costs or to increase procuring efficiency, provided that the technical requirements defined in this document and other conditions for modifications and changes are met. Rules for any design changes are defined in chapter 4.6 and in the *Framework Purchase Agreement*.

Means, form and quality requirements on the CAD data and documentation are described in the next section and chapter 7.18.

The Initial CAD documentation is provided in the Technical specification – Annex No. 7 – Preliminary documentation.

7.3.2. Revised CAD documentation

The Seller shall take over the CAD data initially provided by the Buyer and maintain, update, extend or, eventually create new data as needed during the procurement process. Final complete CAD data after successfully passing all procurement phases shall be provided by the Seller to the Buyer, as defined in the procurement process requirements (see chapter 6) and acceptance conditions (see chapter 9).

All CAD data shall be created and maintained according to the common ISO industry standards, using CATIA V5 or similar CAD software available.

Submitted 3D CAD data shall fulfil the following criteria:

- Use CATIA V5 native format, interchangeable STEP format or similar
- Follow the Buyer's system breakdown structure and respect naming conventions
- In case of CATIA native format – maintain high structural model quality and integrity, i.e. no missing links, no deactivated features, no hybrid modelling, use only positioned sketches, parametric models with history are desired

Submitted 2D CAD data (technical drawings) shall fulfil the following criteria:

- Use CATIA V5 native format, DXF, DWG or PDF
- Use the Buyer's standard title block and text formatting
- Follow the Buyer's system breakdown structure and respect naming conventions
- Standard language is English
- In case of CATIA native format – no missing links, views directly linked to parts or assemblies

More on CAD data creation and maintenance methodology, see Technical specification – Annex No. 5 – CAD creation and maintenance methodology.

This documentation is part of the Preparation phase, Manufacturing phase, Factory acceptance test phase and Site acceptance test phase.

7.4. Bill of raw material

The bill of raw material document is a stand-alone document that contains an essential information about the input material to be purchased for procuring of the extent of delivery.

There are virtually three types of the bill of raw material related to the individual phases of the procurement process (see Technical specification – Annex No. 1 – Universal Procurement process of an item):

- Bill of raw material – for need of Bid (see 7.4.3)
- Bill of raw material – group no. 1 and no. 2 (see 7.4.4)
- Bill of raw material – final state (see 7.4.5)

This documentation is part of the Preparation phase and Raw material acceptance.

Bill of raw material generally contains two following parts:

- List of purchased material (see next section)
- Mill test certificates (see 7.4.2)

A template of the BOM / list of purchased material is enclosed with the tender assignment and shall be followed.

7.4.1. Lists of purchased material

For each ordered item, the Seller shall provide the Buyer with a list that must include all input material planned to be purchased and used for manufacturing of the item. The list shall include at least following information:

- Full name and designation of material
- Shape and size
- Material thickness
- Quantity
- Supplier of the purchased material

7.4.2. Mill test certificates

Material certificate, also known as mill test report (MTR), mill test certificate (MTC) or inspection certificate, is a quality assurance document used in the metal industry that certifies material's technical parameters according to EN 10204 (Inspection certificate 3.2). The type of inspection documentation shall follow the EN 764-5 norm and include a

declaration of compliance to the material specification. In case of nickel alloy 625 material it should also include the $R_{p1.0}$ value (yield strength at 1% of elongation).

These material certificates must be delivered for each batch of material used in the manufacturing process of all the ordered items, if the nature of the item allows.

Preliminary version of MTC
Prior ordering any batch of material and for approval by the Buyer, the Seller shall provide MTC corresponding to the batch of material foreseen to be purchased.

Final version of MTC
For any batch of material approved and purchased, the Seller shall update the bill of raw material document with the actual MTC corresponding to the purchased batches.

7.4.3. Bill of raw material – for need of the Bid

The Seller shall provide a preliminary bill of raw material as a part of the bid (see chapter 1) containing all foreseen raw materials to be used for the VV main body weldment. The bill shall include both parts, the list of purchased material. Relevant preliminary MTCs (see the previous sections) are not required to be part of the Bid, but may be attached.

A template of the BOM / list of purchased material is enclosed with the tender assignment and shall be followed.

7.4.4. Bill of raw material – group 1 and 2

In the preparation phase (see 9.4), two individual bills of raw material for two different groups of items shall be submitted by the Seller. Group number 1 and group number 2 are defined at the end of the chapter 3.2 - Extent of delivery.

Form of the BOM shall be based on the BOM – for need of the Bid and relevant entries shall be traceable and comparable, if possible (applies mainly to the BOM – group no. 1).

7.4.5. Bill of raw material – final state

The final state of the bill of raw material joins all ordered items of the extent of delivery, i.e. includes BOM – group no. 1 and 2. The final state of the BOM includes final and binding list of input materials and mill test certificates in its latest state. After approval of the BOM by the Buyer testing of the raw material can be started.

7.5. Planning documentation

7.5.1. General testing plan

The general testing plan documentation is a group of documents that includes a detailed plan of all the tests that are to be realised during the procurement and the manufacturing of the VV assembly, i.e. till the FAT. It shall include provisional schedules with clear indications of which tests are to be realized, how and when (test description, test procedure, starting time, duration…).

It shall be regularly updated, following the Technical specification – Annex No. 1 – Universal Procurement process of an item.

It shall include plans for the tests mentioned in chapter 7.6.8, i.e.:

- Plan for the raw material sample testing
- Plan for tests on welding on prototypes
- Plan for test during MIC

- Plan for test during post processing (of prototypes and of the VV assembly)

This documentation is part of the Preparation phase, Raw material acceptance and Manufacturing phase.

7.5.2. Manufacturing plan

The general manufacturing plan shall include an overview of the whole manufacturing timeline, accounting for the manufacturing of all ordered items. The Seller shall also provide individual manufacturing time plans in each relevant phases of the procurement process. Each ordered item should have its own independent manufacturing time plan, if possible. Specific manufacturing plans should also be provided before the procurement of raw material samples, prototypes and before performing welding of the VV assembly and post processing.

The manufacturing plan shall include a detailed overview of all key manufacturing steps intended to be followed. Foreseen duration of each manufacturing steps and activities shall also be estimated and mentioned. Manufacturing plans shall be updated appropriately on regular basis.

This documentation is part of the Preparation phase and Manufacturing phase.

7.5.3. FAT and SAT plan

The Seller shall provide the complete plan for realization of acceptance tests after manufacturing of the VV assembly. This means providing a stand-alone planning document for the FAT and for the SAT, before the respective acceptance tests start. Documents shall contain a detailed plan for the realization of the relevant acceptance tests, including which tests are to be performed, how and when (test description, test procedure, starting time, duration etc.).

This documentation is part of the Factory acceptance test phase and Site acceptance test phase.

7.6. Reporting results

Each measurement report shall contain a detailed description of the measurement procedure that was used to achieve the results. It shall include a description of the means used and standards that were followed (if relevant).

The Seller is strongly encouraged to provide the Buyer with the proposed protocols from the measurements of the results before the actual measurement takes place. This precaution is supposed to prevent possible rejection of insufficient reports by the Buyer.

7.6.1. Raw material sample testing results

To ensure the conformity of the mill test certificates provided by the material supplier, tests of mechanical properties of each material used must be performed by the Seller on material testing samples from randomly selected batches, as specified in chapter 9.5.

Resulting reports shall contain all required information according to EN ISO 6892-1 and EN ISO 6892-2 standards.

This documentation is part of the Raw material acceptance phase.

7.6.2. Welding checks results

In order to supervise the quality of performed welding activities, the Buyer requires the Seller to pass several control checks. The list of all documents that the Seller shall provide to the Buyer to fulfill these checks is listed below.

This documentation is part of the Manufacturing phase.

Welding on prototypes
A document that contains all results of tests performed on welded prototypes, see chapter 9.6.1.

Welding of the VV assembly
A document that contains all results of checks made during the manufacturing (welding) of the VV assembly and relevant items, see chapter 9.6.2.

7.6.3. Dimensional inspection results

This documentation will contain a 3D spatial measurement report of all ordered items (if the nature of the item allows). The measurements shall prove that all ordered items meet the requirements of the technical specification on dimensions and tolerances. The checks to be realised are listed in chapter 9.6.3.1.

This documentation must include at least:

- Name and type of the measurement tool used
- Date and time of the measurement
- Accuracy of performed measurement relevant to required dimensional tolerances
- Results of the measurement for relevant areas
- Comparison of the real data with 3D CAD model

This documentation is part of the Manufacturing phase, Factory acceptance test phase and Site acceptance test phase.

7.6.4. 3D spatial metrology results

The 3D spatial metrology shall follow requirements described in chapter 8.6.2.

The 3D spatial metrology result shall be provided in the form of the mesh file (.stl or other definition of point cloud) with comparison to the nominal data given by the CAD model. Comparison output shall be one of these possibilities:

- Table form with described points (in the required positions) and their errors to the nominal data. Points positions shall be known and shown in the Vacuum Vessel figures for the sake of clarity (defined in the metrology coordinate system).
- Detailed deviation color map with displayed point deviation labels on the required places.

The metrology output report shall also include information about evaluation conditions such as used equipment, temperature, metrology procedure description, nominal to actual data fitting method and measurement achieved precisions caused by systematic errors of used equipment. For all bolt and pin holes, the metrology output report shall include deviations comparison to tolerances in the CAD model.

Coordinate system for the metrology data is taken from the CAD model coordinate system.

The delivery and acceptance of this document is part of the Factory acceptance test phase.

7.6.5. Surface properties checks results

Measurement and evaluation of the surface properties of the products shall follow the requirements described in chapter 8.6.3 and chapter 9.6.3.1.

Resulting documentation must include at least:

- Name and type of measurement tool used
- Date and time of the measurement
- Results of the measurement for relevant areas as required in the production documentation

This documentation is part of the Manufacturing phase, Factory acceptance test phase and Site acceptance test phase.

7.6.6. Leak test results

The documentation will contain results of leak tests performed on individual items or assemblies, where required. The measurements shall prove that the items meet the requirements of the technical specification on required leak rate. More details regarding the leak tests and report requirements are provided in chapter 8.5 and in Technical specification – Annex No. 3 – Vacuum requirements attached.

This documentation is part of the Factory acceptance test phase and Site acceptance test phase.

7.6.7. Post processing checks results

In case the post processing of the VV assembly is ordered, specific checks have to be performed, as described in chapter 9.6.4. In general, two types of output documents will be required:

1. Results covering tests on the prototypes
2. Results covering the post processing of the VV assembly

This documentation is part of the Manufacturing phase.

Post processing of the prototypes
The report shall include the following information:

- Brief description of post processing type, conditions and equipment
- Particular parameters used
- Comparison and evaluation of key dimensions of the specimen in pre-processing and post-processing conditions
- Results of selected non-destructive tests (NDT) performed after treatment (to be agreed between the Seller and the Buyer)
- Results of selected destructive tests performed after treatment (to be agreed between the Seller and the Buyer)

Post processing of the VV assembly
The report shall include the following information:

- Brief description of post processing type, conditions and equipment
- Particular parameters used
- Comparison and evaluation of key dimensions of the VV in pre-processing and post-processing conditions
- Results of non-destructive tests (NDT) performed after treatment (to be agreed between the Seller and the Buyer)

7.6.8. General testing results

The general testing results documentation is a group of documents that includes a description of all the test results that will be realised during the course of the manufacturing of the extent of delivery, i.e. excluding results from FAT and SAT. Namely, it includes all test results coming from the Preparation phase, Raw material acceptance phase and Manufacturing phase.

This documentation contains the following main parts:

- Raw material sample testing (see chapter 7.6.1)
- Welding on prototypes (see chapter 7.6.2)
- Manufacturing interim checks (MIC)
    - Welding of the VV assembly (see chapter 7.6.2)
    - Key dimensions and surface properties checks (see chapters 7.6.3 and 7.6.5)
- Post processing checks, if ordered (see chapter 7.6.7)

Before realizing any of these tests, a proper planning documentation is to be submitted by the Seller and approved by the Buyer (see chapter 7.5.1).

This documentation is part of the Manufacturing phase.

7.6.9. FAT and SAT results

During FAT (see chapter 9.7) and SAT (see chapter 9.8), several tests have to be performed to ensure that the extent of delivery meets the technical requirements specified in this document. The document describing the results of these tests shall include results on:

- Dimensional inspection of key dimensions (see chapter 7.6.3)
- Surface properties checks (see chapter 7.6.5)
- Vacuum and leak tests (see chapter 7.6.6)

Before realizing any of these tests, a proper planning documentation is to be submitted by the Seller and approved by the Buyer (see chapter 7.5.3).

This documentation is part of the Factory acceptance test phase and Site acceptance test phase.

7.7. Non-conformance and corrective action reporting

Every non-conformance (see chapter 9.9) found in the whole procurement process of the extent of delivery must be reported by the Seller.

7.7.1. Non-conformance report

A non-conformance report shall be created as soon as possible after any non-conformance in the procurement process is found. The report shall include at least the following information:

- Date and time, when non-conformance was found
- Identification of an item
- Identification of a phase
- Detailed description of an issue
- Proposed corrective action

- Foreseen timeline of the corrective action

7.7.2. Corrective action report

A corrective action report shall be created once the non-conformance has been repaired. The report shall include at least the following information:

- Date and time of issuance
- Identification of an item
- Identification of a phase
- Detailed description of a corrective action
- Affected documentation to be updated

7.7.3. Non-conformance summary report

At the end of any individual phase of the procurement process a summary report including all non-conformances solved shall be created by the Seller. The report shall include at least the following information:

- Date and time, when non-conformance was found
- Brief description of an issue
- Identification of an item
- Identification of a phase
- Brief description of a corrective action
- Date and time, when non-conformance was repaired

The report shall include a brief overview of any non-conformances and corrective actions taken during the given phase. The form of the document is up to the Seller, ideally in form of a table.

7.8. Weld map

The Buyer requires the Seller to provide a so-called weld map or "weld identification plan" (see chapter 9.6.2), also required by EN ISO 3834-2, section „Identification and traceability". The weld map shall show all realized welds on the VV main body weldment including a proper identification of individual welds and additional information. Based on the individual welds' identification, the following information shall be provided for every weld:

- Date and time when the welding was realised
- Name of the welder who performed the weld
- Welding method used
- Welding characteristics / parameters (current, voltage, electrode type, atmosphere etc.)
- Schematic representation of the weld shape and its location
- Photos at different angles (at least two) of the welded surfaces before welding
- At least two photos of the welded area after welding from different angles
- Records of quality and testing, as specified in chapter 9.6.2

This documentation is part of the Manufacturing phase.

7.9. Specimen supporting document

A specimen supporting document is a document accompanying any sample or prototype created within the procurement process. It shall include at least the following information:

- General description of the specimen (including designation of the prototypes and samples, see chapter 4.4)
- Type of material
- Specific parameters regarding relevant technology used to create the specimen (if relevant)

There could be one common document created describing each group of specimens with clear identification. All specimen shall be permanently designated, see chapter 4.4.

7.10. Camera surveillance

All key manufacturing steps of the VV main body weldment shall be recorded (see the list below). It means that the whole manufacturing phase 3.3a (see Technical specification – Annex No. 1 – Universal Procurement process of an item) shall be documented.

The Seller agrees that during welding operations of the VV a video recording (time-lapse video), photo documentation and eventually also live streaming of the progress of construction will be taken and stored. No video recording or live streaming is required for jigs and blank flanges.

At least two cameras shall be installed at the Seller's premises directly in production hall to monitor the construction progress. Placement plan of these cameras by the Seller shall be submitted to and approved by the Buyer at the latest prior a particular manufacturing step begins. These records shall be accessible through a remote access or other access otherwise agreed by contract parties during realization. An online live stream shall be accessible and available anytime to the Buyer.

It is required that the access to the live stream is secured by a proper encryption and password (the Buyer has technical expertise and can offer a help to the Seller). The Buyer shall not provide access to the live stream to a third party and shall not distribute or publish records taken without explicit agreement of the Seller. The resolution of the photos and recorded video shall be at least 2 MP (megapixels) and in agreed format. Each working day before start of work activities, the Seller shall check whether the required time-lapse video and online access are functional and available.

Key manufacturing steps of the VV assembly that shall be recorded and documented are following:

- Raw material preparation, machining, rolling and bending (only photographical documentation is required, the video recording or streaming is not required for this step)
- Welding preparation work
- Installation of tooling for welding work
- All welding works
- Post-welding work and cleaning

7.11. Regular approval protocol

Regular approval protocols are intended to serve several purposes in the procurement process of the extent of delivery:

- to confirm a successful completion of each individual procurement phase
- to approve any submitted documentation in the procurement process
- for additional purposes agreed between both parties

Prerequisite for signing and approving any regular approval protocol by the Buyer is fulfilling all requirements and inputs linked to the protocol subject. Form and content of the protocol will be agreed.

7.12. Regular progress reports

To check the progress of the procurement process of the extent of delivery Regular Progress Meetings shall take place (see chapter 9.3). Resulting documents, so called "Regular Progress Reports" shall include at least the following information:

- clear mention of date of the meeting and attendees,
- minutes of meeting summarizing discussions and main points of the meeting,
- updated manufacturing plans that shall contain a summary of what manufacturing steps were achieved the weeks before and what is planned for the next weeks.

7.13. Instructions for transport and maintenance

This documentation will provide all information necessary for a proper transport and maintenance of the ordered items, if the nature of the item allows. It should include any additional information regarding transport and maintenance that could not be included in the engineering documentation.

The documentation shall include at least the following:

- Detailed description of how the ordered items are conserved, packed and secured
- Instructions for handling, transport and maintenance of the individual items and equipment

7.14. Documentation in the preparation phase

For procurement reasons, items are divided into two groups (see end of chapter 3.2). Consequently, in the preparation phase, the below stated documents first includes documentation for items of group no. 1 only, as they will be ordered first. Then, the following updated versions of the documents will always include both groups together, if group no. 2 is already ordered. This concerns the following documents:

- Production and engineering documentation – group no. 1 and no. 2 (see chapter 7.2)
- Bill of raw material (see chapter 7.4)
- General testing plan (see chapter 7.5.1)
- Manufacturing plan (see chapter 7.5.2)

7.15. Updating documents

Update of any document shall be clearly identified with date of the latest change. Previous versions of any document shall be also submitted, so that changes can be easily tracked. Updated documents should be accompanied with a versioning document indicating the changes made since the last submission and the reasoning for these changes. Dates of changes should also be indicated. Specific conditions apply for the production and engineering documentation and CAD documentation, see chapter 7.2 and 7.3.

7.16. Complete documentation

As part of the extent of delivery, the Seller must provide the Buyer with the following individual documents:

- Production and engineering documentation (see chapter 7.2)
- CAD documentation (see chapter 7.3)
- Bill of raw material (see chapter 7.4)
- Planning documentation (see chapter 7.5)
- General testing results documentation (see chapter 7.6.8)
- FAT and SAT results (see chapter 7.6.9)
- Non-conformance and corrective action reports (see chapter 7.7)
- Weld map (see chapter 7.8)
- Specimen supporting documents (see chapter 7.9)
- Camera surveillance documentation (see chapter 7.10)
- Regular approval protocols (see chapter 7.11)
- Regular progress reports (see chapter 7.12)
- Instructions for transport and maintenance (see chapter 7.13)

The so-called Complete documentation consists of all these documents and any other extra relevant documents, if they exist. For all documents, it shall include all the versions which have been produced at the time of delivery of the Complete documentation.

The first version of the Complete documentation is due at the end of the FAT phase, including all the documents which are available so far, while the final version, due at the end of the SAT phase, shall also include the final version of all documents.

7.17. Other documentation

The documentation of all items and its components must be delivered to such an extent that the maintenance and production of spare parts would be possible. Therefore, the Seller is requested to provide any extra documents that would clarify the maintenance and production of these parts.

In addition, the Seller must provide documentation that provide the Buyer with enough information for the necessary on-site preparation for accepting the extend of delivery, e.g. documentation on how to use the standing jig.

Any documentation not specified in this chapter and required by followed standards within the procurement process of the extent of delivery shall be also submitted by the Seller.

7.18. Delivery format of the documentation

There are four different types of delivery formats of the documentation required in the document Technical specification – Annex No. 1 – Universal Procurement process of an item:

- Internet: the documentation shall be delivered to the Buyer via the Internet, as specified later to the Seller by the Buyer (e.g. by e-mail).

- CD: the documentation shall be delivered on a suitable data storage device (e.g. CD/DVD, USB - flash disc…) in two (2) copies by direct delivery, i.e. planned meeting between the Buyer and Seller's representatives or registered post-mail.
- Paper: all required documents shall be delivered in printed form on standard EU paper format. In particular, production and engineering documentation or technical drawings shall be printed and folded as required by relevant industry standards.
- Specimen: in specific cases, material samples or prototypes shall be delivered to the Buyer. The type, number and delivery conditions are described in chapters 9.5 and 9.6.1.

The electronically submitted documents must be handed over in the following data formats:

- General documents: DOC/DOCX, PPT/PPTX, XLS/XLSX, PDF, DWG, DXF
- Photos and videos: Windows compatible file formats or similar should be used – JPEG, TIFF, AVI, MP4
- 3D CAD data: CATIA V5, STEP (see chapter 7.3)

In general, all documents shall be provided by internet, CD and on paper, if not specified otherwise.

For more information on when and in what form the individual documentation shall be delivered, see Technical specification – Annex No. 1 – Universal Procurement process of an item.

7.19. Transport permission document

After the realisation of the FAT, the Buyer and the Seller must sign the transport permission document (hereinafter "Transport Permission") that grants the Seller the permission to deliver the extend of delivery. Only after both parties have signed this document may the transport start. This document is to be prepared by the Seller.

Note that submitting the first version of the Complete documentation to the Buyer is a necessary condition for signing the Transport Permission. However, acceptance of the documentation by the Buyer does not, in any way, release the Seller from the full liability for the correctness, completeness and complete execution of any documentation of information provided or from meeting the rest of parameters and conditions specified within this technical specification document.

For more details regarding this document, please see the *Framework Purchase Agreement*.

7.20. Handover Protocol of the Production and engineering documentation - group no. 1

After the Seller submits the Production and engineering documentation – group no. 1, on assumption that the documentation is submitted without any flaws, the Handover Protocol of the Production and engineering documentation – group no. 1 is approved and signed by the Buyer. The Handover protocol shall be prepared by the Seller.

With singing of this document, the phase 2 (i.e. Raw material acceptance) can be started. In the event not submitting the documentation on time or the documentation is rejected by the Buyer, conditions specified by the *Framework Purchase Agreement* apply.

7.21. Handover Protocol of the Manufacturing phase

When all activities of the manufacturing phase (see 9.6) are successfully finished and approved by the Buyer, the Handover Protocol of the Manufacturing phase can be issued

and signed. In the event of existing open issues, the Handover protocol cannot be signed. The Handover protocol shall be prepared by the Seller. For further details see the Framework Purchase Agreement and chapter 9.9.

7.22. Handover Protocol of Acceptance

After the realisation of the SAT, the Buyer and the Seller will sign the Handover Protocol of Acceptance document (hereinafter "Handover Protocol"). This document officially approves taking over of the ordered extent of delivery by the Buyer. The Handover protocol shall be prepared by the Seller.

Note that submitting of the final version of the Complete documentation to the Buyer is a necessary condition for signing the Handover Protocol. However, acceptance of the documentation by the Buyer does not, in any way, release the Seller from the full liability for the correctness, completeness and complete execution of any documentation of information provided or from meeting the rest of parameters and conditions specified within this technical specification document.

For more details regarding this document, please see the *Framework Purchase Agreement*.

8. COMMON TESTING SPECIFICATION

This chapter contains detailed information regarding checks and tests that the Seller is required to perform in order to pass the individual procurement phases of the extent of delivery, as described in chapter 6 and in the Technical specification – Annex No. 1 – Universal Procurement process of an item. The purpose of the required checks and tests is to control the procurement process, to secure key parameters and to assure the resulting quality of the product. Most of the tests shall follow the general EN ISO industry standards, unless agreed otherwise.

8.1. Non-destructive tests

Specific non-destructive tests are required to check the input raw material, to qualify the welding technology on prototypes and to verify the manufacturing process of the extent of delivery. All required non-destructive tests shall follow the relevant industry standards as described in the following sections. Personnel performing non-destructive tests shall be qualified according to EN ISO 9712.

8.1.1. Visual inspection

Visual inspection is required continuously for any of the individual steps taken during the complete procurement and manufacturing process of the extent of delivery. It applies to the raw material acceptance, manufacturing, FAT and SAT phases.

In general, the visual inspection is required to check any imperfections, surface properties, unwanted deformations or scratches, pollution and cleanliness. Of the most importance is the visual inspection required for checking all welds of the VV assembly. The industry standard EN 13018 shall be followed.

The Seller is required to check all welds according to EN ISO 17637 and to evaluate the imperfections according to EN ISO 5817. Quality level B is required for the VV assembly according to EN ISO 5817. For welds performed on jigs the test according EN ISO 5817 is not required by the Buyer.

8.1.2. Capillary inspection

For capillary inspection of welds the industry standard EN ISO 3452 Part 1 to 6 (Non-destructive testing – Penetrant testing) shall be followed. Results shall be evaluated according to EN ISO 23277 – allowed grade no. 1.

8.1.3. Ultrasonic testing

In general, ultrasonic testing methods shall follow the basic principles according to the industry standard EN ISO 16810 and other related valid standards.

For ultrasonic testing of steel flat products, the industry standard EN ISO 10160 shall be followed. Allowance level at least S3 for internal structure and E3 for edges shall be achieved. Furthermore, the industry standard ISO 17577 shall be followed.

For ultrasonic testing of stainless-steel flat products, the industry standard EN ISO 10307 shall be followed. Allowance level at least S3 for internal structure and E3 for edges shall be achieved.

For ultrasonic testing of steel forgings, the industry standards EN 10228-3 and EN 10228-4 shall be followed.

For ultrasonic testing of welds, the industry standard EN ISO 17640 shall be followed – testing class B. For ultrasonic testing of welds on austenitic steels or Nickel alloys, the industry standard EN ISO 22825 shall be followed.

Results shall be evaluated according to EN ISO 11666 – allowance level 2, EN ISO 23279, EN ISO 16827.

Use of phased array ultrasonic testing method (PAUT) is required for testing of welds on prototypes. The PAUT testing could be performed instead of radiographic testing in selected areas only upon approval of the Buyer.

The following industry standards shall be followed for this method: EN ISO 18563 Part 1-3, EN ISO 13588 and EN ISO 19285. Allowance level of quality according to EN ISO 13588 and EN ISO 19285 grade B and 2 is required, respectively.

It is required that the selected method of testing allows to create a testing record. This record shall be provided to the Buyer in electronic form allowing further data analysis.

8.1.4. Radiographic testing

For radiographic testing of welds the industry standard EN ISO 17636 Part 1 and 2 shall be followed – required technique class B. Results shall be evaluated according to EN ISO 10675-1 with required quality level 1.

The testing records, including images, shall be provided to the Buyer.

8.1.5. X-ray diffraction testing

The X-ray diffraction method used in case of investigation of residual stresses after any mechanical or thermal processing, welding, etc. shall follow relevant industry standards, and especially the following: EN ISO 15305, EN ISO 13925-(1-3).

The testing records shall be provided to the Buyer.

8.1.6. Volumetric defects testing of the raw material

Input raw material for procuring the Vacuum Vessel (i.e. the testing is not required for jigs or blank flanges material) shall be tested by a non-destructive method (e.g. ultrasonic) on presence of internal defects. Ultrasonic testing shall be performed according to requirements in chapter 8.1.3 and according to relevant industry standards.

8.2. Destructive tests

Specific destructive tests are required for qualification of the purchased raw material, to evaluate selected welding technology on the prototypes and to verify the maximum applicable pulling force on welded bolts and interfaces. The destructive tests are not allowed on the extent of delivery.

At least three samples for individual tests are required to reach the minimum statistical relevance. Samples shall be manufactured in a way that the mechanical and thermal influence is minimized.

8.2.1. Standard static tensile test at RT

Standard tensile tests at room temperature (RT) shall be performed according to the industry standard EN ISO 6892-1. Test specimens shall be taken transverse to the rolling direction wherever possible.

8.2.2. Standard static tensile test at elevated temperature

Standard tensile tests at elevated temperature shall be performed according to the industry standard EN ISO 6892-2. The test temperature shall be set to 500 ± 5 °C. Test specimens shall be taken transverse to the rolling direction wherever possible.

8.2.3. Standard static longitudinal tensile test of weld metal

Standard static longitudinal tensile test of weld metal shall be performed according to the industry standard EN ISO 5178. The test shall be performed at two temperatures: RT and 500 ± 5 °C.

8.2.4. Standard static transverse tensile test of weld metal

Standard static transverse tensile test of weld metal shall be performed according to the industry standard EN ISO 4136. The test shall be performed at two temperatures: RT and 500 ± 5 °C.

8.2.5. Standard static transverse tensile test of the whole weld joint

Standard static transverse tensile test of the whole weld joint shall be performed according to the industry standard EN ISO 4136. The test shall be performed at two temperatures: RT and 500 ± 5 °C.

8.2.6. Macroscopic and microscopic examination

Macroscopic and microscopic examination of samples shall be performed according to the industry standard EN ISO 17639.

8.2.7. Charpy pendulum impact test

Charpy pendulum impact test shall be performed according to the industry standard EN ISO 148-1, EN ISO 14556 and EN ISO 9016.

8.2.8. Bend test

Standard bend test of the welded specimen shall be performed according to the industry standard EN ISO 5173.

8.2.9. Testing of the welded studs

Stud interfaces welded to the VV shall be tested and evaluated according to the industry standard EN ISO 14555.

In case of tensile tests, break must not occur in weld, but in area of the stud body. Minimum required yield strength at RT shall not be less than 550 MPa.

8.3. Testing of raw material mechanical properties

Input raw material for procuring of the extent of delivery must be thoroughly tested before it is accepted (see chapter 9.5). The following tests are required:

- Standard tensile test at RT, see chapter 8.2.1
- Standard tensile test at elevated temperature, see chapter 8.2.2

The tests output shall follow the form described in chapter 7.6.1.

8.4. Testing of welds

Every welding technology used in the manufacturing process of the extent of delivery must be qualified and follow general industry standards as discussed in chapter 4 and 9. Testing prototypes and methods shall conform at least to the following standards: EN ISO 15613 and EN ISO 15614. The procedures according to the standard EN ISO 13445 shall be followed.

In case of welded parts of the VV basic configuration and related inseparable items, welding prototypes shall be manufactured by the Seller (see chapter 4.2.5) and specific

destructive and non-destructive tests shall be performed. Note that the destructive tests are required on the welding prototypes only.

8.4.1. Destructive tests

Prior starting the manufacturing process of the VV assembly, the welding prototypes shall be procured, see 4.2.5. The Seller shall perform at least the following destructive tests on the prototypes:

- Standard longitudinal tensile test of weld metal, see chapter 8.2.3
- Standard transverse tensile test of weld metal, see chapter 8.2.4
- Standard transverse tensile test of the whole weld joint, see chapter 8.2.5
- Macroscopic and microscopic examination, see chapter 8.2.6
- Charpy pendulum impact test, see chapter 8.2.7
- Bend test, see chapter 8.2.8
- Welded studs' tests (item no. 16 only), see chapter 8.2.9

The tests must be performed on the same material with the same treatment as the material intended to be used for the VV assembly.

The tests output shall follow the form described in chapter 7.6.2.

8.4.2. Non-destructive tests

Quality checks must be performed for every weld joint of any of the delivered product of the ordered items of the extent of delivery during the manufacturing phase and to pass FAT and SAT. Non-destructive tests of welds shall follow general industry standards, above all EN ISO 17635 and individual standards for relevant inspection method. Quality level B is required for the VV assembly according to EN ISO 5817. For welds performed on jigs the test according EN ISO 5817 is not required by the Buyer.

Any additional non-destructive tests and methods can be performed upon agreement of both parties.

The tests output shall follow the form described in chapter 7.6.2.

8.5. Leak tests

To verify the vacuum tightness, a leak test shall be performed according to the Technical specification – Annex No. 3 – Vacuum requirements. Before testing, the VV must be properly prepared as required in the annex and the following industry standards shall be followed:

EN 1779, EN 1518, ISO 20484, ISO 20485 and ISO 20486.

The leak test is only required for the VV main body weldment including related non-separable items (e.g. not necessary for jigs). Two tests shall be performed:

1. Check the leak tightness of the VV main body weldment
2. Check the leak tightness of the in-vessel heating / cooling system, i.e. heating and cooling loops including the common buses.

The leak test of the VV body weldment shall be performed according to the Annex No. 3 and following additional parameters:

- Testing gas: Helium
- Suggested method according to EN 1779: A2, A3

- Test temperature: room temperature
- Test performed in vented space (air flow must be sufficient to prevent helium accumulation in environment).
- Maximum acceptable single leak rate: <= 10^{-9} Pa.m^3/s
    - This should not include permeation through o-rings. Precautions (testing per parts as specified in EN 1779 A2, wrapping flanges in tape, etc..) must be used.
- The Buyer requires that the Seller additionally demonstrates the leak properties of the vacuum vessel by reaching ultimate pressure: <= 5 × 10^{-5} Pa
    - The Seller must expect this may take several days to reach without baking. This must be accounted for in the time schedule.
    - Expected required pumping speed for this test is 1 - 5 m^3/s.

This value does not have to be kept during the leak test realization.Required parameters for integral leak test of the heating and cooling system:

- Testing gas: Helium
- Suggested method according to EN 1779: B6

  (It is advised to manufacture an additional port blank flange with ability to fill helium to heating/cooling bus from outside)
- Test temperature: room temperature
- Testing gas pressure: > 2 bar
- Maximum acceptable integral leak rate: lower then 10^{-9} Pa.m^3/s

The tests output shall follow the form described in chapter 7.6.6.

8.6. Metrology

Dimensional and surface inspections need to be done to check conformity and quality of the extent of delivery using suitable measurement tools. Required inspections will be performed during the manufacturing phase (MIC), at FAT and SAT by the Seller and approved by the Buyer.

8.6.1. Dimensional inspection

The dimensional inspection shall be performed using standard hand tools, coordinate measurement machine (CMM) or 3D spatial metrology equipment. The dimensional inspection shall be performed by measuring instruments with a valid metrological confirmation according to EN ISO 10012. The Buyer can request the Seller to provide valid calibration certificates. Accuracy of the used equipment shall be such that the measured value, together with its accuracy, fits into the tolerance of the inspected dimension. All in-vessel interfaces may have special metrology markers which could be used for evaluation.

An inspection report indicating all checked dimensions relative to their nominal value shall be provided by the Seller and approved by the Buyer, see also chapter 7.6.3.

A specific dimensional inspection on manufacturing/welding prototypes could be done to evaluate any (un)predicted deformations. Reference values are specified by the Seller or agreed between both sides.

8.6.2. 3D spatial metrology

3D spatial metrology has to be performed on the Vacuum vessel with at least following spatial points density in different areas of the Vacuum Vessel:

1. Inner surfaces of the Vacuum Vessel shall be 3D scanned or measured by another points measuring method with minimum of one point for every square decimeter, with exception of the inner surfaces of the vertical ports.
2. In-vessel interfaces – pads and shear keys - shall be measured with at least six points on each functional surface and at least three points on each non-functional surface.
3. Every metrology marker (see chapter 5.6.1) position shall be measured. This measurement provides also information about the position of every welded stud.
4. Every bolt or pin hole position in every pad shall be measured (i.e. it is not necessary to measure holes in flanges).
5. Ports flanges front (functional) surface measurement – based on at least six points on the front flange surface
6. Vacuum Vessel Support measurement – enough points to describe form and axiality of the upper and lower adaptor, so that the axiality of the whole VV support assembly could be evaluated.
7. Outer surface of the Vacuum Vessel, high field side outer cylinder measurement – based on points measured at the end of the cylinder in the area at least 300 mm from the edge to mid-plane of the VV from both sides of the cylinder (i.e. 300 mm or more of the top and bottom part of the cylinder). Minimum number of points shall be one point per one square decimeter.
8. Outer surface of the Vacuum Vessel without high field side outer cylinder measurement – based on at least one point per 4 square decimeters.

3D scan is suitable for every mentioned 3D spatial metrology requirement. Minimum number of points is defined especially for another points measuring methods (in this case the points have to be positioned approximately evenly). The 3D spatial metrology shall be performed by measuring instruments with a valid metrological confirmation according to EN ISO 10012. The Buyer can request the Seller to provide valid calibration certificates. Minimum accuracy of the metrology shall be according to the 8.6.1.

Note that the Seller may join the procedure of the 3D spatial metrology together with the measurement required in the previous chapter 8.6.1 - Dimensional inspection.

Output of the tests shall follow the form described in chapter 7.6.4.

8.6.3. Surface roughness measurements

The surface roughness of specific selected areas of the individual items of the extent of delivery must be checked. Required surface roughness is defined by the production documentation of any item produced by the Seller. Measurement and evaluation shall be performed according to following industry standards: EN ISO 4287, EN ISO 4288 and EN ISO 3274.

An inspection report indicating all checked surfaces shall be provided by the Seller and approved by the Buyer, see also chapter 7.6.5.

8.7. Cleanliness test

Cleanliness tests are mandatory for all items of the extent of delivery excluding jigs. All inner and outer surfaces of the VV and its components must be vacuum compatible and tested according to the Technical specification – Annex No. 3 – Vacuum requirements.

For vacuum compatibility requirements see also chapter 4.3.

9. ACCEPTANCE AND REPAIRS

The fulfilment of each acceptance step is a mandatory condition to fulfil the *Framework Purchase Agreement* conditions and the Seller shall not proceed in manufacturing or delivery before each step is approved by the Buyer, as defined in chapter 6. Details of the acceptance tests that the Seller shall perform are defined here.

Important note: For each phase a proper documentation is to be provided by the Seller to the Buyer and is a necessary condition to fulfil the *Framework Purchase Agreement* conditions (see chapter 7 for details on the required documentation). As a proof of approval of any phase or documentation, regular approval protocols are to be issued and signed by both parties (see chapter 7.11). Specific Handover protocols shall be prepared by the Seller and signed for approval of phases 1, 3, and 5 (see Technical specification – Annex No. 1 – Universal Procurement process of an item and this chapter).

The approval by the Buyer shall be based only on the Technical specification – it is not allowed to go above or beyond the requirements stated in the Technical specification. In case of rejection, the Buyer shall provide a list of objections, including references to the Technical specification sections or parts which are either not fulfilled or insufficiently addressed in the documentation submitted by the Seller.

9.1. Advance payments

Advance payments are made by the Buyer during the procurement process of the extent of delivery closely tied with the VV basic configuration item (item no. 1). There are in total three advance payments possible that will be realised when required conditions are met. For more details on the advance payments and conditions see the Technical specification – Annex No. 1 – Universal Procurement process of an item and the *Framework Purchase Agreement*.

9.2. Partial payments

Partial payments are made by the Buyer during the procurement process of the extent of delivery. There are in total two partial payments possible that will be realised when required conditions are met. For more details on the partial payments and conditions see the Technical specification – Annex No. 1 – Universal Procurement process of an item and the *Framework Purchase Agreement*.

9.3. General progress checks

The Buyer intends to regularly check the procurement progress of the extent of delivery by following the work performed at the Seller's premises. This includes the following checks:

Planning
Prior starting any individual process, the Seller shall provide the Buyer with particular tentative plans, as described in the procurement process table attached in the Technical specification – Annex No. 1 – Universal Procurement process of an item. During the procurement process of the extent of delivery, the Seller shall regularly update the plans. See chapter 7.5 for more details on what the plans shall contain.

Progress checks
The Seller must allow the presence **of the Buyer's personnel** at the manufacturing sites, at any time and without previous notice, and **use of the Buyer's testing equipment** during the realization course of the extent of delivery (including FAT). The Buyer shall be granted the right to make photo and video documentation of the work in progress. Travelling to the Seller's premises is on the Buyer's own expenses. The purpose of the requirements in this

paragraph is to enable the Buyer continuous and unlimited control of the manufacturing process.

The Seller and Buyer shall meet at least once per two weeks to discuss the progress of the realization of the extent of delivery. Form of the Regular Progress Meetings (online or in person) is to be agreed between both sides and shall be organized by the Seller. In exceptional cases, the meeting is allowed to be postponed by one week. The Seller shall summarize the discussion that took place in Regular Progress Reports. The Regular Progress Report of the meeting shall be submitted one week after the meeting took place. See chapter 7.12 on what the report shall contain.

9.4. Preparation phase

The first acceptance step after ordering and approving a group of items (see end of chapter 3.2 for definition of groups) is the so-called preparation phase (as described in chapter 6 and Technical specification – Annex No. 1 – Universal Procurement process of an item). For the phase to be approved, the Seller shall provide the following documents:

- Production and engineering documentation group no. 1 and no. 2 – Provide the first version of the documentation for group no. 1 and 2, see chapter 7.2
- Bill of raw material – Update and extend the document provided during the bid (Bill of raw material – for need of the Bid) for group no. 1 and 2, see chapter 7.4
- General testing plan – Provide the first version (group no 1) and an update (group no. 2), see chapter 7.5.1
- Manufacturing plan – Provide the first version (group no 1) and an update (group no. 2), see chapter 7.5.2
- Handover Protocol of the Production and engineering documentation - group no. 1 – see chapter 7.20

The first version of the production and engineering documentation – group no. 1 shall be submitted by the Seller and approved by the Buyer within 20 weeks from accepting the order of the VV basic configuration (so called "milestone A" according to the *Framework Purchase Agreement*). If not submitted and approved on time, contractual penalty applies, see the *Framework Purchase Agreement*. When this documentation is approved by the Buyer, partial payment no. 1 and advance payment no. 2 are payed, see the *Framework Purchase Agreement*. Handover Protocol of the Production and engineering documentation - group no. 1 shall be prepared the Seller and signed.

In subsequent phases, the production and engineering documentation of group no. 1 and 2 will be joined into one single documentation, covering all ordered items of the extent of delivery.

It is important to note that for a given group of items, the Seller may order the raw material when the bills of raw material of the given group are approved by the Buyer. In this way, the Seller may proceed with the phase while the raw material is being ordered and delivered, avoiding any extra delays.

All documentation shall be provided by the Seller in agreed deadlines and form described in chapter 7.18.

9.5. Raw material acceptance phase

Conditions for accepting the purchased raw material are described here. Only when these steps are approved by the Buyer, may the Seller start the manufacturing process of the individual items. Note that the material requirements described in chapter 4.1 shall also be

fulfilled for the raw material to be accepted. An overview of the raw material acceptance phase timeline is also outlined in Technical specification – Annex No. 1 – Universal Procurement process of an item.

9.5.1. Raw material testing

Once the raw material is received by the Seller, quality (e.g. mechanical properties) of the purchased material shall be verified by several steps, as described below.

Tests of the raw material mechanical properties (as described in chapter 8.3) must be performed by the Seller on material samples from randomly selected batches of the purchased material to ensure conformity of the mill test certificates provided by the material supplier. The batches to be tested will be selected by the Buyer. For each material type (thickness, kind, manufactured process), the number of tested batches must cover at least 25 % of the total number of batches.

Non-destructive volumetric defect testing (as described in chapter 8.1.6) must be performed on 100 % of the raw material which will be used in the Vacuum Vessel (i.e. the testing is not required for jigs or blank flanges material). This testing may be performed by the Seller or by the material supplier.

The approval by the Buyer of all required tests performed on the raw material to be used for the VV main body weldment, accompanied with relevant documentation, is a prerequisite for payment of the raw material of the VV main body weldment (partial payment no. 2) and advance payment no. 3.

9.5.2. Documentation to be provided

A list of the documents to be provided by the Seller as an output of the raw material acceptance phase is described here. More details on conditions and deadlines are provided in the Technical specification – Annex No. 1 – Universal Procurement process of an item.

The following documentation shall be provided by the Seller:

- Bill of raw material - Update after receiving the purchased raw material (includes final version of MTCs), see chapter 7.4
- General testing plan – Update the raw material sample testing part, see chapter 7.5.1
- General testing results – Provide the raw material sample testing results, see chapter 7.6.1
- Specimen supporting documents – Provide relevant information for each provided specimen, see chapter 7.9

All documentation shall be provided by the Seller in agreed deadlines and in form described in chapter 7.18.

9.5.3. Specimen to be provided

As an output of the raw material acceptance phase the following specimen shall be provided by the Seller:

- Testing samples after testing (i.e. remnants of the samples after the destructive testing), see chapter 8.3
- Raw material specimen of each batch:
    - For each batch (i.e. 100 % from the total number of batches for each material type) used for manufacturing of the extent of delivery, the Seller must provide

to the Buyer a number of specimen large enough (surface and volume) such that at least 6 material testing samples could be manufactured and used to perform standard tensile tests, as described in chapter 8.3. The final dimensions must be approved by the Buyer before delivery.

9.6. Manufacturing phase

Conditions for accepting the manufacturing phase of the VV assembly are described here. Note that all the technical requirements described in this document shall also be fulfilled for the phase to be approved.

Duration of the manufacturing phase is denoted in the manufacturing plan provided by the Seller (see chapter 7.5.2 and Technical specification – Annex No. 1 – Universal Procurement process of an item). Successful completion of the manufacturing phase on time is so called **milestone "B"** according to the *Framework Purchase Agreement* and is approved by signing the Handover Protocol of the Manufacturing phase. **Deadline for the milestone "B" is given** by the manufacturing plan approved in the procurement phase 3.1. Delays in fulfilment of the phase are penalized according to the *Framework Purchase Agreement*.

9.6.1. Welding prototypes and samples

To qualify the welding technology and procedures, welding checks must be performed by the Seller on welding prototypes. These checks must be approved by the Buyer prior welding any item of the extent of delivery. The welding technology and procedure used for the testing shall be identical to those foreseen to be used for welding of the VV assembly. More details on procuring the welding prototypes and samples are provided in chapter 4.2.5, including information about specimen to be provided by the Seller to the Buyer.

Note that there is a requirement that the VV main structural body and the VV supports are welded by the same welder, who welded the welding prototypes (see chapter 4.2.3 for exact requirement).

Required tests
The Seller is required to perform at least the following destructive tests on the testing samples:

- Standard longitudinal tensile test of weld metal, see chapter 8.2.3. This test is not required for welding prototypes for heating/cooling tubes, studs, and for dissimilar weld prototype.
- Standard transverse tensile test of weld metal, see chapter 8.2.4. This test is not required for welding prototypes for heating/cooling tubes, studs, and for dissimilar weld prototype.
- Standard transverse tensile test of the whole weld joint, see chapter 8.2.5
- Macroscopic and microscopic examination, see chapter 8.2.6
- Charpy pendulum impact test, see chapter 8.2.7. This test is not required for welding prototypes for heating/cooling tubes and studs.
- Bend test, see chapter 8.2.8. This test is not required for welding prototypes for heating/cooling tubes and studs.

The tests must be performed on the same material with the same treatment as the material intended to be used for the VV assembly. Note that the standard tensile tests are performed at two different temperatures, RT and 500 °C. For more details on technical requirements for testing the welding, see chapter 8.4.

The Seller is required to perform at least the following additional non-destructive tests on the testing samples:

- Visual inspection, see 8.1.1
- Capillary inspection, see 8.1.2
- Ultrasonic testing - phased array ultrasonic testing method (PAUT), see 8.1.3, for all welds with exception of welds of the heating / cooling loops
- Radiographic testing, see 8.1.4

On the prototypes of the welded studs and bolts (items no. 16 only), at least the following specific destructive and non-destructive tests shall be performed:

- Visual inspection, see 8.1.1
- Capillary inspection, see 8.1.2
- Macroscopic examination, see 8.2.6
- Tensile test at RT and 500 °C, see 8.2.1 and 8.2.2

The welding of the VV assembly is allowed only when all above mentioned tests on the prototypes are successfully realised and approved by the Buyer.

9.6.2. Welding of the VV assembly

In order to supervise the quality of the performed welding activities on the VV assembly, the Buyer requires the Seller to pass several control checks which are listed below.

Note that there is a requirement that the VV main structural body and the VV supports are welded by the welder, who welded the prototypes (see chapter 4.2.3 for exact requirement).

Welding checks
After complete welding of any part of the VV assembly, at least the following checks must be performed by the Seller to ensure the quality and reliability of the welding process:

- Visual inspection, see chapter 8.1.1
- Capillary inspection, see chapter 8.1.2. Note that the capillary inspection is explicitly required from both sides of the welds, because both sides of the VV are supposed to be in vacuum.
- Radiographic testing, see chapter 8.1.4. The radiographic testing is required for all welds, with exception of the heating / cooling loops welds and stud welds (i.e. it is required for the VV main structural body, VV supports, MN and MX ports, vertical ports, divertor ports, pads, shear keys). In case the item no. 5 (Post processing of the Vacuum Vessel main body weldment) is ordered, the radiographic testing before post-processing is not compulsory (i.e. radiographic testing may be performed only once - after post processing).
- Ultrasonic testing - phased array ultrasonic testing method (PAUT), see chapter 8.1.3. The PAUT testing could be performed instead of radiographic testing in selected areas only upon approval of the Buyer.

For more details on technical requirements on testing of welds, see chapter 8.4.

Any non-conformance during the welding process must be reported to the Buyer and proper corrective action shall be performed, see chapter 9.9.

Note that the welding must be executed under strict camera surveillance, see chapter 7.10 - Camera surveillance.

Weld map (or welding identification plan)

The Seller shall provide an overview of all welds realised during manufacturing of the VV assembly, so called "weld map". The complete weld map shall be provided at the end of the manufacturing phase.

Further details on what the weld map shall contain are provided in chapter 7.8.

9.6.3. Manufacturing interim checks

During the manufacturing process, several MIC must be realised to ensure that the manufactured equipment qualifies to move to the next steps of the construction. The Seller will propose which tests are to be realised and when as part of the General testing plan. The plan must be approved by the Buyer before being realised. Some tests, required by the Buyer, are listed below.

The results of the MIC will be reviewed and approved by the Buyer as part of the General testing results. If deemed unsatisfactory, the tests of the components must be repeated and/or extended. The manufacturing must not continue if one of the MIC is not satisfactory or not approved by the Buyer.

The Seller must allow the presence of the Buyer's personnel at the manufacturing sites, at any time and without previous notice, and use of the Buyer's testing equipment during the realization course of the extent of delivery (including FAT). The Buyer shall be granted the right to make photo and video documentation of the work in progress. Travelling to the Seller's premises is on the Buyer's own expenses. The purpose of the requirements in this paragraph is to enable the Buyer continuous and unlimited control of the manufacturing process.

9.6.3.1. Dimensional inspection

The Seller shall prove the dimensional conformity of the complete extent of delivery, thus that the products meet all required key dimensions and tolerances as defined in this technical specification document and in the production documentation. For more details on metrology equipment, see chapter 8.6.

The Seller must allow the Buyer to use his own equipment to check relevant parts or areas of in production / delivered products, if requested by the Buyer, without any undue delays.

Any deviations beyond the agreed tolerances must be reported as non-conformance and must be solved according to the rules described in chapter 9.9.

9.6.3.2. Surface roughness measurements

Surface roughness inspection of the key areas of the items of the extent of delivery shall be performed according to roughness definition in the production documentation. Measurement shall be performed as described in chapter 8.6.3.

9.6.4. Post processing checks

Post processing tests on prototypes

The Seller shall perform relevant tests on the prototypes for validation of the post processing method(s) used on the VV assembly. Simulation of deformation and other effects linked to the treatment can also be beneficial. See chapter 4.2.5 for details on manufacturing of the prototypes.

On the prototypes, at least the destructive and non-destructive tests listed below shall be performed. The tests shall be performed before and after the post processing.

- Visual inspection, see 8.1.1
- Capillary inspection, see 8.1.2. Note that the capillary inspection is explicitly required from both sides of the welds, because both sides of the VV are supposed to be in vacuum.
- Ultrasonic testing - phased array ultrasonic testing method (PAUT), see 8.1.3
- Radiographic testing, see 8.1.4
- X-ray diffraction testing, see 8.1.5. The purpose is to determine the change of the residual stress.
- Standard longitudinal tensile test of weld metal, see chapter 8.2.3
- Standard transverse tensile test of weld metal, see chapter 8.2.4
- Standard transverse tensile test of the whole weld joint, see chapter 8.2.5
- Macroscopic and microscopic examination, see chapter 8.2.6
- Charpy pendulum impact test, see chapter 8.2.7
- Bend test, see chapter 8.2.8
- Dimensional inspection, see 8.6.1

If the post processing is ordered, the tests required in the chapter 9.6.1 can be merged together with tests required in this chapter. The prototypes shall be provided to the Buyer as soon as all tests are finished.

Post processing tests of the VV

To evaluate the residual stresses on the VV assembly, after post processing, at least the following non-destructive tests shall be performed:

- Visual inspection, see 8.1.1
- Capillary inspection, see 8.1.2
- Dimensional inspection, see 8.6.1
- Radiographic testing, see chapter 8.1.4. The radiographic testing before post-processing is not compulsory (i.e. radiographic testing may be performed only once - after post processing). The radiographic testing is required for all welds, with exception of the heating / cooling loops welds and stud welds (i.e. it is required for the VV main structural body, VV supports, MN and MX ports, vertical ports, divertor ports, pads, shear keys).
- Ultrasonic testing - phased array ultrasonic testing method (PAUT), see 8.1.3. The PAUT testing could be performed instead of radiographic testing in selected areas only upon approval of the Buyer.

9.6.5. Documentation to be provided

A list of documents to be provided by the Seller as an output of the manufacturing phase is described here. More details on conditions and deadlines are provided in the Technical specification – Annex No. 1 – Universal Procurement process of an item.

The following documentation shall be provided by the Seller:

- Production and engineering documentation – Update the documentation, see chapter 7.1
- CAD documentation – Provide the latest revised CAD documentation, see chapter 7.3
- General testing plan – Update the whole document and, then, the welding on prototypes, MIC, post processing of prototypes and of the VV assembly parts, see chapter 7.5.1
- Manufacturing plan – Update the whole document and, then, the welding of the VV assembly part, see chapter 7.5.2
- General testing results – Update the welding on prototypes, MIC, post processing of prototypes and of the VV assembly parts, see chapter 7.6.8.
- Weld map – Provide an overview of individual welding seams realised on the VV assembly, see chapter 7.8
- Specimen supporting documents – Provide relevant information for each provided specimen, see chapter 7.9
- Camera surveillance documentation – Provide recording captured during the manufacturing phase, see chapter 7.10
- Handover Protocol of the Manufacturing phase – see chapter 7.21

All documentation shall be provided by the Seller in agreed deadlines and in form described in chapter 7.18.

9.6.6. Specimen to be provided

As an output of the manufacturing phase the following specimen shall be provided by the Seller:

- Welding prototypes and samples after testing (i.e. remnants of the samples after the destructive testing), see chapter 9.6.1
- Welding prototype specimen (as defined in the chapter 4.2.5, text ''one (or two) for the reference for the Buyer'')
- Post processing prototypes and samples after testing (i.e. remnants of the samples after the destructive testing), see chapter 4.2.5
- Post processing prototype specimen (as defined in the chapter 4.2.5, text ''one for the reference for the Buyer'')

9.7. Factory acceptance test phase

Every item of the whole extent of delivery is a subject to performance testing at the Seller's premises in order to demonstrate that the required technical specifications have been met before shipping the products to the Buyer's premises. The successful completion and submission of all required documents is a prerequisite for accepting the FAT. The extent of delivery must not be shipped to the Buyer before all results of the FAT are successfully finished and approved by the Buyer, i.e. before signing the *Transport Permission*.

The Seller must allow the presence of the Buyer's personnel at the FAT site for the entire duration of the Factory Acceptance Tests. The Seller is obliged to inform the Buyer about

the date of the FAT at least 2 weeks prior (see Technical specification – Annex No. 1 – Universal Procurement process of an item).

Both parties are allowed to use services of an external company to perform any test within the FAT. Results from such measurements are part of the FAT phase and will be included in the report from the FAT. The results shall be in this case properly documented as required.

Any unacceptable test result(s) must be reported to the Buyer and proper corrective actions shall be agreed and performed, see chapter 9.9 for details. In this case, all related tests shall be repeated and documentation resubmitted.

9.7.1. List of required tests

The following tests shall be performed by the Seller to successfully pass the FAT phase:

1. Dimensional inspection

The Seller must demonstrate that the extent of delivery meets the required key dimensions and tolerances as defined in this technical specification document and in the production documentation, see chapter 8.6.1.

2. 3D spatial metrology

The Seller shall perform the 3D spatial metrology on the extent of delivery, according requirements in chapter 8.6.2. Note that the Seller may join the procedure of the 3D spatial metrology together with the previous point (Dimensional inspection).

3. Non-destructive tests

The Buyer requires that the Seller demonstrates that non-destructive tests were performed for each welded joint after the last manufacturing step, which produced stress in the particular welded joint. Both weld repair and welding in the vicinity (i.e. neighbouring weld) shall be considered as a manufacturing step, which produced stress in the particular welded joint. This means that some of the non-destructive tests performed in the manufacturing phase may be used for the FAT demonstration, but some may have to be repeated.

The non-destructive tests must be performed for every complete weld joint of any of the VV assembly.

At least the following checks shall be performed by the Seller to ensure the quality and reliability of the manufacturing and welding process:

- Visual inspection, see chapter 8.1.1
- Capillary inspection, see chapter 8.1.2
- Radiographic testing, see chapter 8.1.4. The radiographic testing is required for all the welds, with exception of the heating / cooling loops welds and stud welds (i.e. it is required for the VV main structural body, VV supports, MN and MX ports, vertical ports, divertor ports, pads, shear keys).
- Ultrasonic testing - phased array ultrasonic testing method (PAUT), see chapter 8.1.3. The PAUT testing could be performed instead of radiographic testing in selected areas only upon approval of the Buyer.

4. Surface roughness test

Surface roughness inspection of the representative key areas of the items of the extent of delivery shall be performed. Measurement shall be performed as described in chapter 8.6.3.

5. Leak tests

Prior performing any leak test, the Seller shall inform the Buyer on the date of the test and allow his presence at the Seller's premises. Without the presence of the Buyer, tests cannot be started.

The Seller must demonstrate the vacuum tightness of selected items of the extent of delivery. The Seller must perform at least a leak test of the following:

- VV assembly – separate tests of the VV body weldment including all blank flanges
- VV heating / cooling loops including common buses

For more details on the integral leak test methodology, see chapter 8.5.

6. Pressure test

During the FAT, the Seller will perform the pressure test of the heating / cooling system. The required pressure is governed by the pressure equipment directive PED 2014/68/EU (this directive is required in chapter 4.10) and working gas pressure (see chapter 5.1.2).

7. Vacuum cleanliness test

Tissue cleanliness test and Water break test shall be performed on the representative part of the VV according the Technical specification – Annex No. 3 – Vacuum requirements.

9.7.2. Demonstration of the jigs

Flawless function of the jigs included in the extent of delivery (VV basic configuration) must be proved and demonstrated by the Seller. Demonstration of the key features of the following jigs shall be performed by the Seller:

- Transportation jig
- Storage jig

Other tools necessary for assembly, maintenance or cleaning shall also be presented and handed over. Demonstration shall show and verify the intended function and basic parameters of the individual jigs or any additional tools. Function and technical parameters are given in chapter 5.1.6 and by engineering documentation.

9.7.3. Documentation to be provided

A list of the documents to be provided by the Seller as an output of the FAT phase is described here. More details on conditions and deadlines are provided in the Technical specification – Annex No. 1 – Universal Procurement process of an item.

The following documentation shall be provided by the Seller:

1. Production and engineering documentation – Update the documentation, see chapter 7.2
2. FAT plan – Provide particular plans of the FAT phase, see chapter 7.5.3
3. FAT results – Provide documentation of the results obtained for of all FAT tests, see 7.6.9
4. Complete documentation, first version – Provide the whole documentation which was created through the preparation, raw material acceptance, manufacturing and FAT phases, see chapter 7.16.
5. Transport permission document – Provide the document which is to be signed by the Buyer to allow transportation to the Buyer's premises, see chapter 7.19

All documentation shall be provided by the Seller in agreed deadlines and in form described in chapter 7.18.

9.8. Site acceptance test phase

After delivery of the ordered items of the extent of delivery to the Buyer's premises, site acceptance tests are realised by the Seller to ensure that any of the ordered items did not suffer any damage due to transportation and the technical requirements are still met.

For the purposes of delivery and further manipulation on the Buyer's premises, an overview and relevant instructions are given in the Technical specification – Annex No. 8 – Shipment unloading area. The Seller will deliver the extent of delivery to a place specified by the Buyer on the Buyer's premises using a mobile crane provided by the Seller. The Seller is obliged to inform the Buyer about the date of the SAT at least 2 weeks prior (see Technical specification – Annex No. 1 – Universal Procurement process of an item).

Required tests to be realized at the SAT phase by the Seller (if not specified otherwise):

1. Visual inspection

   A visual inspection of the extent of delivery will be performed by the Seller, together with the Buyer.

2. Vacuum cleanliness test

   Tissue cleanliness test and Water break test shall be performed by the Seller on the representative part of the VV according the Technical specification – Annex No. 3 – Vacuum requirements.

3. Limited dimensional inspection

   The Seller will propose to the Buyer a limited set of the key dimensions and tolerances to be measured during the SAT. The limited set will be aimed at parts, which could be damaged during the transportation, e.g. dimensions of the ports, dimensions of the VV supports, overall VV dimensions, etc. The proposal is subjected to approval by the Buyer.

4. 3D spatial scan performed by the Buyer

As a part of the SAT, the Buyer will perform a 3D spatial scan of the extent of delivery with the equipment belonging to the Buyer. The Seller will provide the Buyer with time window at least 5 working days long, announced at least two weeks prior. The output data of the 3D spatial scan will be part of the SAT. The Seller is allowed to be present during the 3D spatial scan and check the procedure.

The Buyer is allowed to perform non-destructive testing of the welds during the SAT. The Buyer is allowed to use services of an external company to perform or repeat any test within the SAT. If any of these two options is used, the resulting measurements shall be part of the SAT outputs.

The final version of the Complete documentation shall also be submitted by the Seller and approved by the Buyer. It contains the same documents (except for the Transport permission document), eventually updated, as in the FAT (see chapter 9.7.3), including additional documentation provided within the SAT.

The extent of delivery will not be accepted by the Buyer if the SAT results are not meeting the technical specification required in this document.

Any unacceptable test result(s) and non-conformities must be reported to the Buyer and a proper corrective action shall be agreed and performed, see chapter 9.9. In this case, all related tests shall be repeated and affected documentation updated and resubmitted.

Once all SAT tests and documentation are approved by the Buyer, the Seller shall prepare and submit the *Handover Protocol of Acceptance* for each item (see chapter 6 and 7.22 for more details) to the Buyer for approval.

9.9. Non-conformances and corrective actions

In case of any deviation from the required technical specification or from the *Framework Purchase Agreement* during the manufacturing process, storage or procurement of any item of the extent of delivery, the Seller must immediately report to the Buyer, see chapter 7.7. This also applies when the Seller cannot follow, or prove that it was followed, a standard specified and requested in this document.

The Seller shall provide a non-conformance report (see chapter 7.7.1) with a complete status on the reason(s) of non-conformance and propose a specific corrective action(s) to remove the defect(s) and relevant time line, as soon as possible. If the proposed corrective action plan is approved by the Buyer, repair can be started. In case the proposal is rejected by the Buyer, the Seller shall propose different corrective action, update the report and submit for approval again.

Any unacceptable imperfections of any item of the extent of delivery must be removed by any means. Whenever any corrective action is performed, all technical requirements of this technical specification shall still be met and relevant acceptance tests and checks shall be repeated. The results of the corrective action shall be approved by the Buyer.

After corrective action is successfully finished, the Seller shall submit a corrective action report including detailed description of the corrective action taken, see chapter 7.7.2.

Every affected documentation (e.g. production or engineering documentation, planning documentation, etc.) shall be updated accordingly.

Every non-conformance from the required technical specification found in any of procurement phase must be corrected on the Sellers own expenses after the Buyer's approval.

10. ANNEXES

This technical specification document includes annexes according to the list below.

10.1. Technical specification – Annex No. 1 – Universal Procurement process of an item

The universal procurement process of an item described in chapter 6 is a fundamental guide for the whole process within this tender. This annex includes a key overview table of the whole procurement process and its visual form described with the diagram. Note that there are more than one sheets in the excel file "CU_CUPG-01_PTD Technical Specification - Annex No. 1 - Universal procurement process of an item – Overview.xlsx".

10.1.1. Universal Procurement process of an item – overview

10.1.2. Universal Procurement process of an item – diagram

10.2. Technical specification – Annex No. 2 – Results of the welding study

The Institute of Plasma Physics asked the MECAS ESI s r.o. company to conduct a feasibility study to investigate the following topics: choosing a suitable manufacturing process and technology of the vacuum vessel, securing the required tolerances, performing preliminary Finite Element Method (FEM) simulations of distortions during the welding and compiling the list of minimum quality and test requirements.

The results can be found in this annex together with a brief summary of the Study. Conclusions of the study are not mandatory and should serve only as a guide for the Seller.

The results can be found in this annex together with a brief summary of the Study. The annex no. 2 has the following structure:

10.2.1. Welding study – Summary

10.2.2. Welding study

10.2.3. Welding study – Annex No. 1 – Arcelor Alloy 625 MTC

10.2.4. Welding study – Annex No. 2 – Boehler Termanit 625 MTC

10.2.5. Welding study – Annex No. 3 – VV Distortions

10.2.6. Welding study – Annex No. 4 – VV Adapters and pipes

10.2.7. Welding study – Annex No. 5 – Welding induced stresses

10.3. Technical specification – Annex No. 3 – Vacuum requirements

This annex summarizes general requirements and guidelines for all components / parts / assemblies that will be placed in vacuum or interface with a vacuum. The Seller must follow these requirements.

10.4. Technical specification – Annex No. 4 – Key simulation results

The Key simulation results included in this annex offer a broader overview of expected operation and load scenarios of the Vacuum vessel in the tokamak. Further, the results of electromagnetic analyses, heating simulations and structural analyses are shown and discussed. All results of key analyses complement the technical requirements in this specification, especially in chapter 4 and 5.

The Buyer requires that the technological process of manufacturing the Vacuum Vessel creates the product (VV), which is compatible with the mechanical loading scenarios described in this annex.

10.4.1. Expected operation and load scenarios overview

10.4.2. Electromagnetic simulations

10.4.3. Heating simulations

10.4.4. Structural analyses

10.5. Technical specification – Annex No. 5 – CAD creation and maintenance methodology

Within the procurement process of individual items, a technical documentation, including CAD documentation is to be created and submitted by the Seller. This annex describes in detail a required methodology of creation and maintenance of such documentation.

10.6. Technical specification – Annex No. 6 – Vacuum vessel breakdown structure

This annex includes an overview of the main structure of the Vacuum vessel assembly, i.e. individual components from the first to the last level of the assembly. This structure shall be followed and eventually updated by the Seller.

10.7. Technical specification – Annex No. 7 – Preliminary documentation

Preliminary documentation, including initial CAD documentation provided by the Buyer is included in this annex. 3D CAD data of the extent of delivery, technical drawings and other additional documents are provided. This documentation is fundamental for the first offering and later the production and engineering documentation will be based on this.

10.8. Technical specification – Annex No. 8 – Shipment unloading area

The annex provides a basic information regarding shipment of the extent of delivery to the Buyer's premises. It includes a basic plan of the IPP campus, spatial constrains and relevant instructions.

10.9. Technical specification – Annex No. 9 – List of used technical standards

The annex contains list of the technical standards used in this Technical specification. The exactly same list is in the chapter 2.3 - Used technical standards.