

Technical Specifications (In-Cash Procurement)

Pre-matching unit manufacturing technical specification

The present document specifies the requirements for the manufacturing and the testing an Ion Cyclotron Heating and Current Drive system (IC H&CD, PBS-51) pre-matching unit for quarter Antenna prototype.

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1 Preamble

This Technical Specification is to be read in combination with the General Management Specification for Service and Supply (GM3S) – [1] that constitutes a full part of the technical requirements.

In case of conflict, the content of the Technical Specification supersedes the content of [1].

2 Purpose

The present document specifies the requirements for the manufacturing and the testing an Ion Cyclotron Heating and Current Drive system (IC H&CD, PBS-51) pre-matching unit for quarter Antenna prototype.

3 Acronyms & Definitions

3.1 Acronyms

The following acronyms are the main one relevant to this document.

Abbreviation	Description
CRO	Contract Responsible Officer
GM3S	General Management Specification for Service and Supply
IC	Ion Cyclotron
IO	ITER Organization
KOM	Kick-Off-Meeting
MTO	Material Take Off
NDT	Non Destructive Test
PRO	Procurement Responsible Officer
RF	Radio Frequency
SRD	System Requirement Document
UHV	Ultra-High Vacuum

3.2 Definitions

Contractor: shall mean an economic operator who have signed the Contract in which this document is referenced.

4 Applicable Documents & Codes and standards

4.1 Applicable Documents

This is the responsibility of the Contractor to identify and request for any documents that would not have been transmitted by IO, including the below list of reference documents.

This Technical Specification takes precedence over the referenced documents. In case of conflicting information, this is the responsibility of the Contractor to seek clarification from IO.

Upon notification of any revision of the applicable document transmitted officially to the Contractor, the Contractor shall advise within 4 weeks of any impact on the execution of the contract. Without any response after this period, no impact will be considered.

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- [1] General Management Specification for Service and Supply (ITER_D_82MXQK v1.4)
- [2] ITER Vacuum Handbook ITER_D_2EZ9UM v2.5
- [3] Vacuum Handbook Appendices (folder) ITER_D_2FHLMC
- [4] Vacuum Handbook Attachments (folder) ITER_D_2MUS3U
- [5] Codes and Standards for ITER Mechanical Components (25EW4K v5.0)
- [6] Procedure for the management of Deviation Request (2LZJHB v9.1)
- [7] Appendix 13 Cleaning and Cleanliness (ITER_D_2ELUQH v1.2)
- [8] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (ITER_D_7M2YKF v1.7)
- [9] Procedure for Management of Nonconformities (ITER_D_22F53X v10.3)
- [10] Procedure for Inspection and Testing (ITER_D_TVL3Y5 v2.0)
- [11] Quality Management System Audits (ITER_D_2DQTA8 v5.0)
- [12] Specification for CAD data Production in ITER direct contracts (ITER_D_P7Q3J7 v2.0)
- [13] Working Instruction for the Delivery Readiness Review (DRR) (ITER_D_X3NEGB v3.0)
- [14] WP1- Thermo-hydraulic analyses of the Pre-matching unit and the RF window (ITER_D_E7K93G v1.1)
- [15] WP2 - Thermo-structural analyses of the Pre-matching unit, RF window, transmission line and their supports (ITER_D_E7KJJK v1.1)
- [16] QC determination for Antenna prototype pre-matching unit (ITER_D_DCPP3T v1.0)
- [17] ITER_D_EB4ZD3 v1.0- 20250617_PPTF_Prematch_RFlossdensities
- [18] IS-51-58-002 Port Plug Connection to the PPTF Heating System (2BYTUH v2.1)
- [19] MQP L0 ITER Policy on Safety, Security, Quality and Environment Protection (ITER_D_43UJN7 v4.0)
- [20] Decree No. 2012-1248 dated 9 November 2012 authorising IO to create a nuclear facility called « ITER » - EN (ITER_D_CZK7M5 v1.1)
- [21] ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the licensed nuclear facility INB No. 174 called ITER - FR (ITER_D_LYH6QS v1.2)
- [22] Quality Requirements for IO Performers (ITER_D_22MFG4 v6.4)
- [23] Assembly drawing FHY9QZ_v4-075207-075207 - PRE_MATCHING_UNIT_ASSY--C and associated detail drawings in SMDD folder DJNM2B *(some drawings are not approved yet, the applicable versions of the drawings will be confirmed at the KOM)*

4.2 Applicable Codes and Standards

This is the responsibility of the Contractor to procure the relevant Codes and Standards applicable to that scope of work, with respect to the *Codes and Standards for ITER Mechanical Components* [5].

As general requirement, the contractor shall follow the EN 13445. Any deviation shall be identified by the contractor and reviewed by IO.

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5 Scope of Work

This section defines the specific scope of work, in addition to the contract execution requirement as defined in [1].

5.1 Background

5.1.1 System overview

5.1.1.1 Antenna prototype configuration

The quarter antenna prototype is a non-nuclear component representing the final ICRH Antenna, which is already being manufactured. Specific instrumentation has been included in the quarter antenna prototype design in order to validate the behaviour of the quarter antenna prototype during Radio-Frequency (RF) testing. This test configuration is allowing to increase the RF voltage until the design limit of the Antenna (45kV) at two different frequencies (41MHz and 54MHz) in quasi-CW operation (pulses up to 3600s with a duty cycle of 1/4).

A set of specific components must be installed in ITER building 55, to allow the RF power testing of the quarter antenna prototype. The Figure 1 is showing the testing configuration (partial view without supports, main transmission line and power supplies).

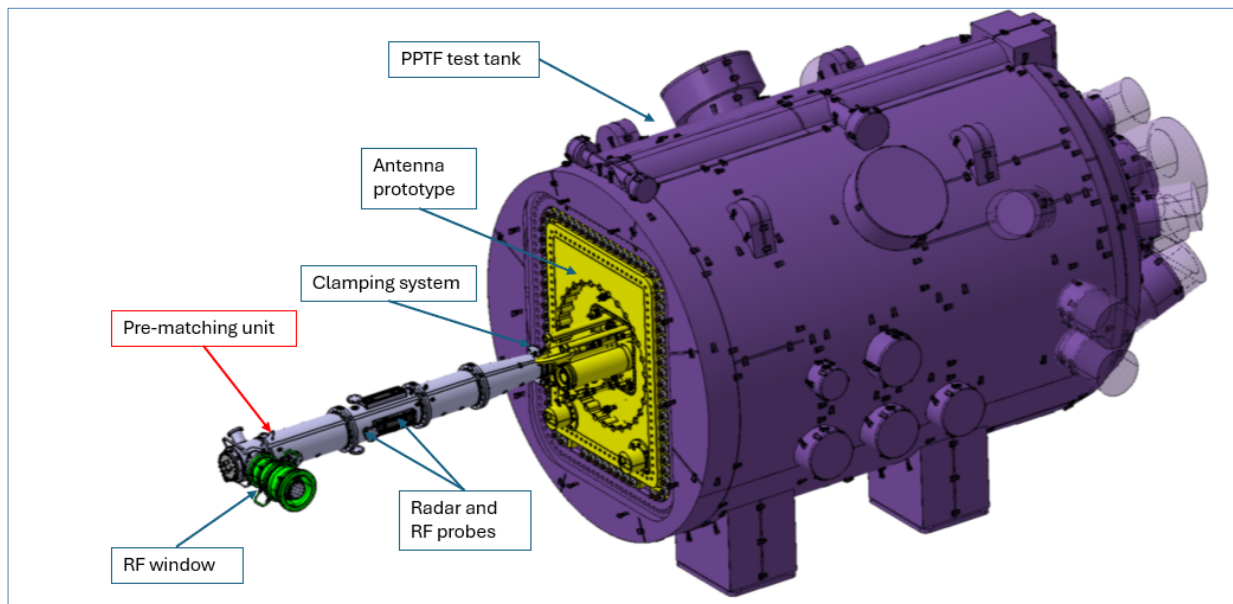


Figure 1: Pre-matching unit within its environment

During this test, only one single port of the quarter antenna prototype is fed with RF.

In order to perform this test, the pre-matching unit, vacuum extension of the quarter antenna prototype, is needed. This is a coaxial line of ~3m length and maximum diameter of DN350, also instrumented, pumped, in stainless steel with copper coating.

During RF testing, the pre-matching unit will be heated up by the RF current and is actively cooled by water. During this test, the water temperature will be around 18°C (<1MPa), see reference [14]. In order to compensate different thermal expansion between inner and outer conductors, two bellows have been implemented on inner conductors (the details of the bellows are given in section 5.3.2.4), see Figure 2:

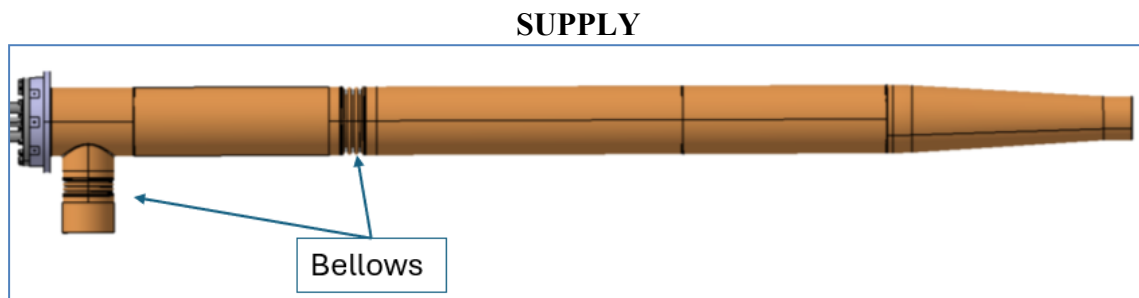


Figure 2: Inner conductor bellows

Note for references [14] and [15]: The initial geometry of the pre-matching unit was with bellows positioned at the lower electric field location. But the thermal calculation concluded that the maximum temperature in the bellows may exceed 200°C , for both tests at $\sim 41\text{MHz}$ and $\sim 54\text{MHz}$, see Figure 3 and Figure 4 respectively.

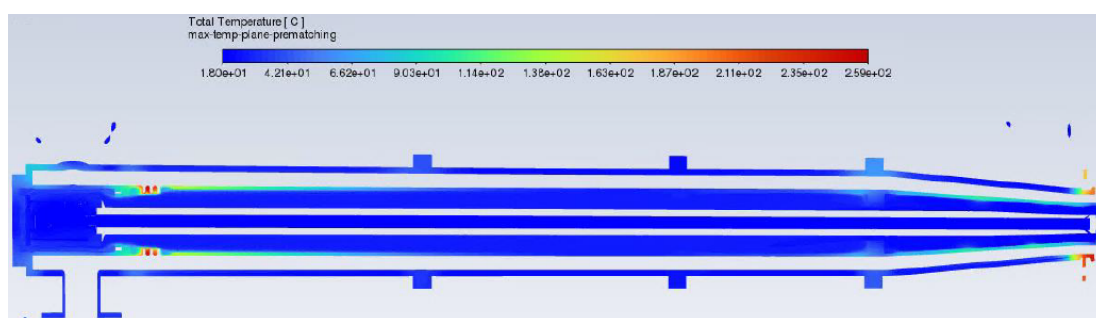


Figure 3: Section view of the thermal maps during RF tests at 41MHz [14]

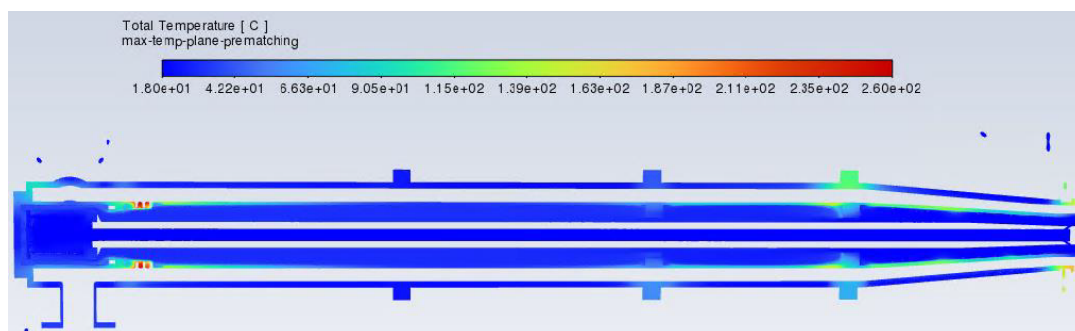


Figure 4: Section view of the thermal maps during RF tests at 54MHz [14]

For this reason, the bellows have been moved (by 600mm) to a cooler location. This is the final design of the pre-matching unit, the one to be manufactured (see thermal map, almost identical for both frequencies, in Figure 5).

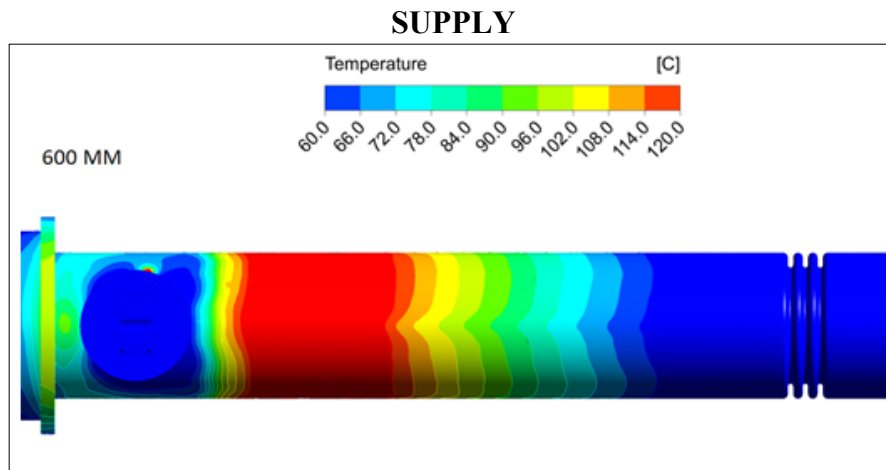


Figure 5: Section view of the thermal maps with the bellows at its final location

In order to reduce the risk of arcing during RF testing, the pre-matching unit shall be baked and outgassed. The pre-matching unit baking is made with water, at hot temperature (around 150°C) with a pressure of 1MPa (absolute pressure), and outgassing is performed in a vacuum environment ($< 1 \times 10^{-4}$ Pa) at 150°C [18].

5.1.1.2 Final Antenna configuration

The pre-matching unit will also be re-used on the final ICH Antenna, which will have a vacuum boundary (front RF windows), see Figure 6. In this configuration, the pre-matching unit will not be vacuum pumped but filled with nitrogen, pressurized at 3 bars (absolute pressure).

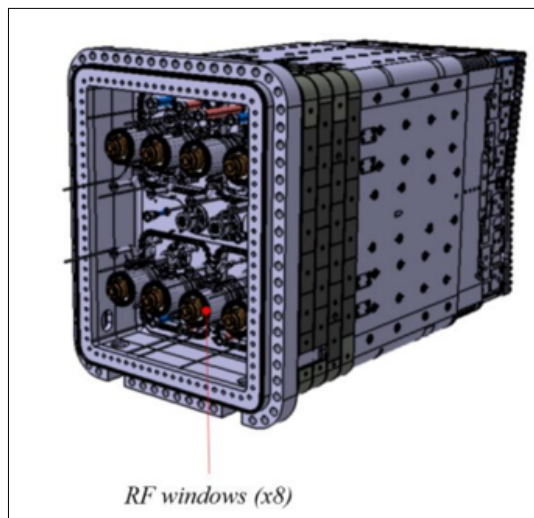


Figure 6: final ICH Antenna (with front RF windows)

5.1.2 Component classification

The pre-matching unit is classified quality class QC3 as per reference [16] and shall follow the ITER vacuum handbook [2] (including appendices [3] and attachments [4]) recommendations for VQC1-A components, except when the present document specifies different requirements.

IO is preparing a justification for the exclusion of the pre-matching unit from French Environmental code Article R557-9. **The contractor shall consider the pre-matching unit as not classified as a Pressure Equipment.**

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5.2 Scope

The contractor shall execute the following activities:

- Review the IO drawings of the pre-matching unit, check the manufacturability and propose optimization if needed
- Produce manufacturing drawings
- Produce the pre-matching unit MIP
- Procure all necessary materials
- Manufacture and clean the pre-matching unit, including assembly and test tools
- Conduct all the inspections specified in the present document
- Perform the Factory Acceptance Tests (FAT)
- Pack and deliver the components on ITER site.

5.3 Scope of Supply

5.3.1 Description and objectives

Prior to start the design of the components, the contractor shall issue the Quality Plan, see section 9.

This activity does not contain PIAs. The contractor shall prepare the manufacturing, carry out the manufacturing activities to procure and test one pre-matching unit.

The aim is to produce one pre-matching unit compliant with the requirements defined in the present technical specification.

IO is providing a current pre-matching unit design (see drawings [23]). The following checks have already been performed:

- Radio frequency performance has been checked in the studies [17]
- Cooling efficiency has been verified in analyses [14]
- Stress assessment is given in [15]

The contractor has to review the design from manufacturing (according to EN 13445) and material procurement aspects. The contractor may refine slightly the design in order to ease the manufacturing, but the changes have to be very limited and without any impact on the radio frequency, thermal and structural behaviour, no analyses update is foreseen. All the modifications will have to be reviewed and approved by IO. The contractor shall then manufacture the pre-matching unit and test it.

The following component are out of scope of the present contract and will be supplied by IO during the execution of the contract in order to check the assembly:

- Clamping system (without seals), useful to perform leak and pressure tests (see section 5.3.9)
- Radars and probes – not used, the contractor has to manufacture and supply caps for this purpose
- RF window, useful to complete the water loop – to be provided by IO

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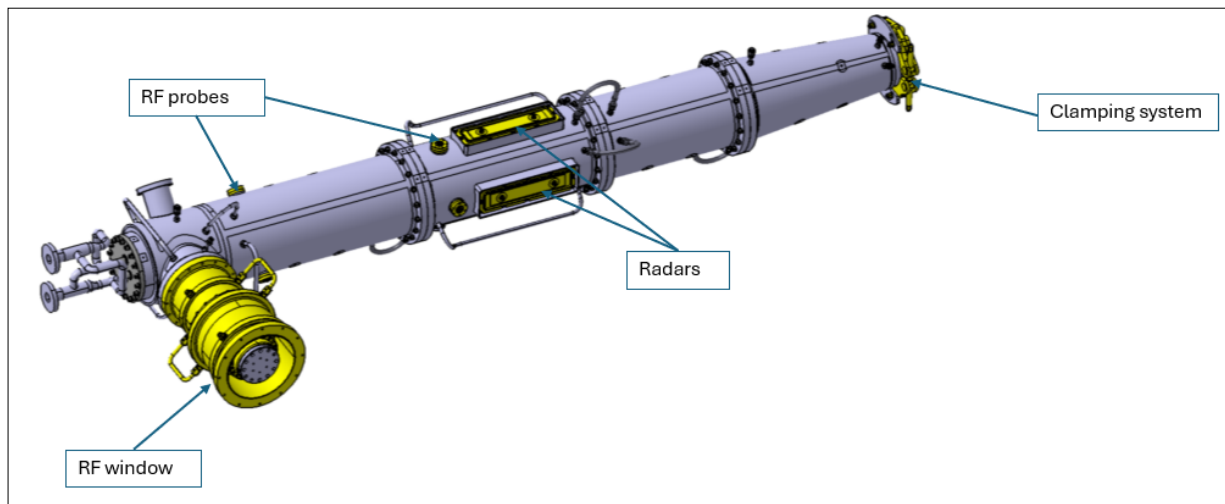


Figure 7: Components out of scope (in yellow)

5.3.2 Design requirements

This section is providing the design description and requirements useful for understanding the pre-matching unit design.

The contractor is not supposed to modify the pre-matching unit design. If an optimization or a design change is required by the contractor, this one shall be submitted to IO for review and acceptance before implementation.

5.3.2.1 Quantity and positions

There is only one single pre-matching unit system.

The pre-matching unit shall be compatible with the two Antenna prototype ports and with the 8 final Antenna ports (see Figure 8).

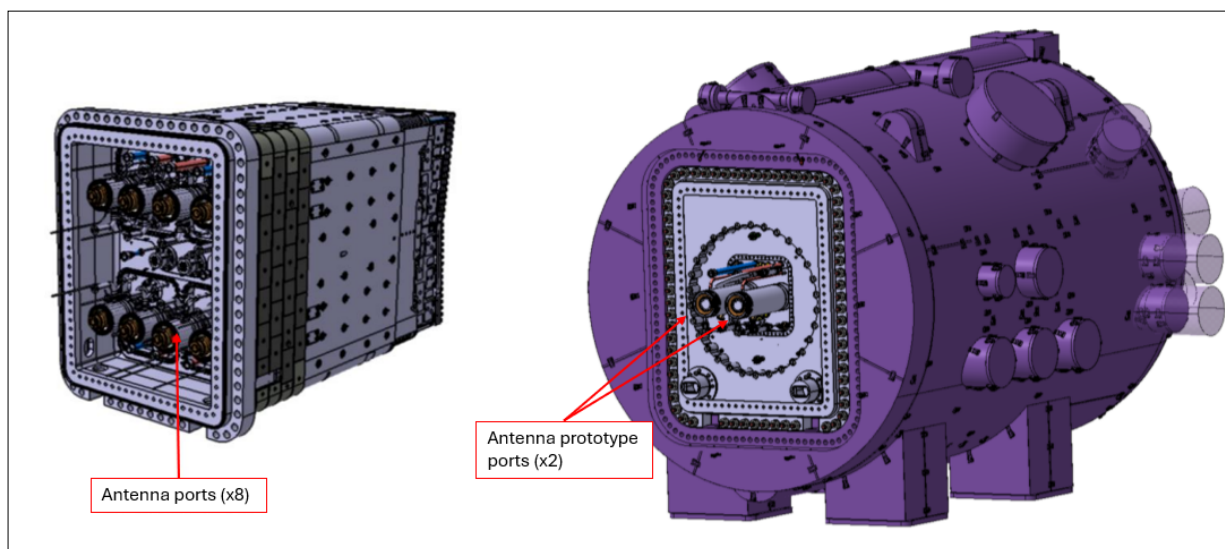


Figure 8: View of 8 Antenna ports and 2 Antenna prototype ports

In order to be compliant with all the possible locations on the Antenna and Antenna prototype, the pre-matching unit shall be used in two different positions, see Figure 10.

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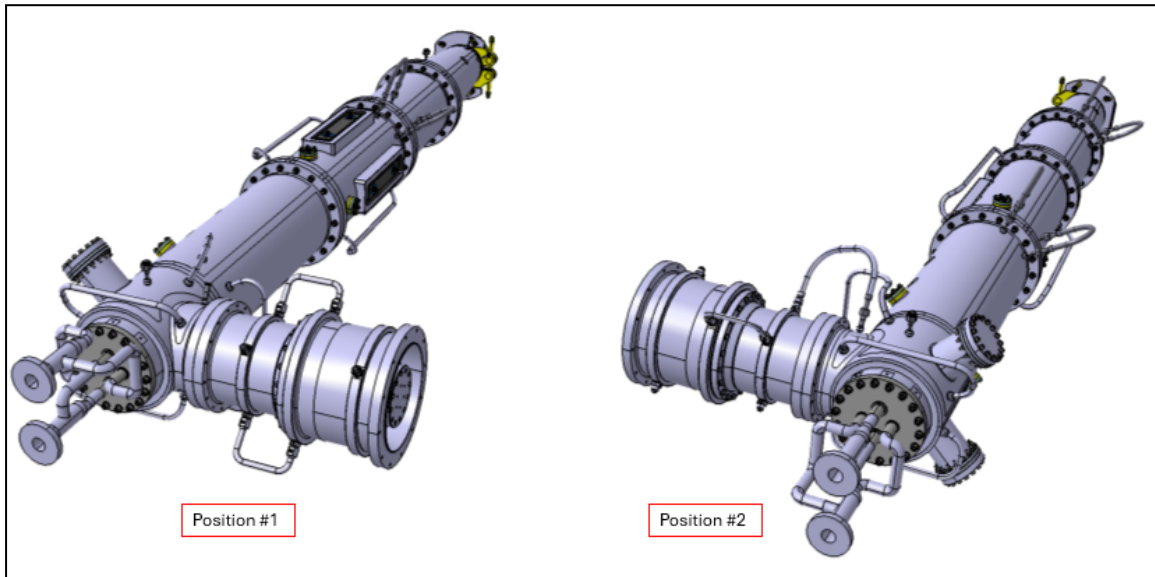


Figure 9: Operation positions of the pre-matching unit

5.3.2.2 RF surfaces

The Radio Frequency (RF) surfaces of the pre-matching unit are the functional surfaces of the component (see Figure 10). They shall not be modified by the contractor. The “RF surfaces” of the pre-matching unit are made of the:

- Internal surface of the outer conductor
- External surface of the inner conductor

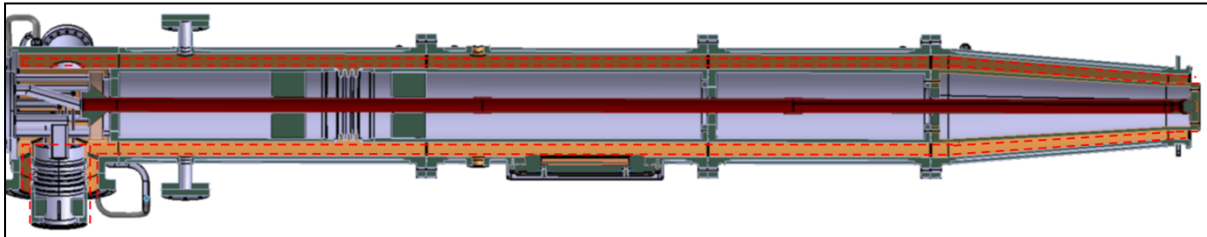


Figure 10: Pre-matching unit RF surfaces (in red dashes)

In order to minimize the RF losses in the conductors, the material of the RF surfaces shall have a high electrical conductivity (very close to the one of copper). In the design prepared by IO, the material for both conductors is Stainless steel with copper coating, see requirements in sections in 5.3.2.5 and 5.3.2.7 for conductors material and copper coating respectively. Silver coating can also be selected instead of copper coating. The high electric conductivity coating thickness shall be of minimum 60 μm (typical).

5.3.2.3 Pre-matching unit water parameters

Due to RF losses in both conductors, the pre-matching unit shall be water cooled.

The cooling water is shared with other sub-systems, so the water parameters are fixed:

- Total flow rate for inner conductor: 0.4kg/s
- Total flow rate for outer conductor: 0.4kg/s
- Water inlet temperature: 18°C min, 34°C max
- Water supply pressure: 1.2 MPa (abs) max
- Water circuit design pressure: 1.85 MPa (abs) max

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In the present configuration, the cooling water flow is based on the following configuration (see Figure 11 and Figure 12):

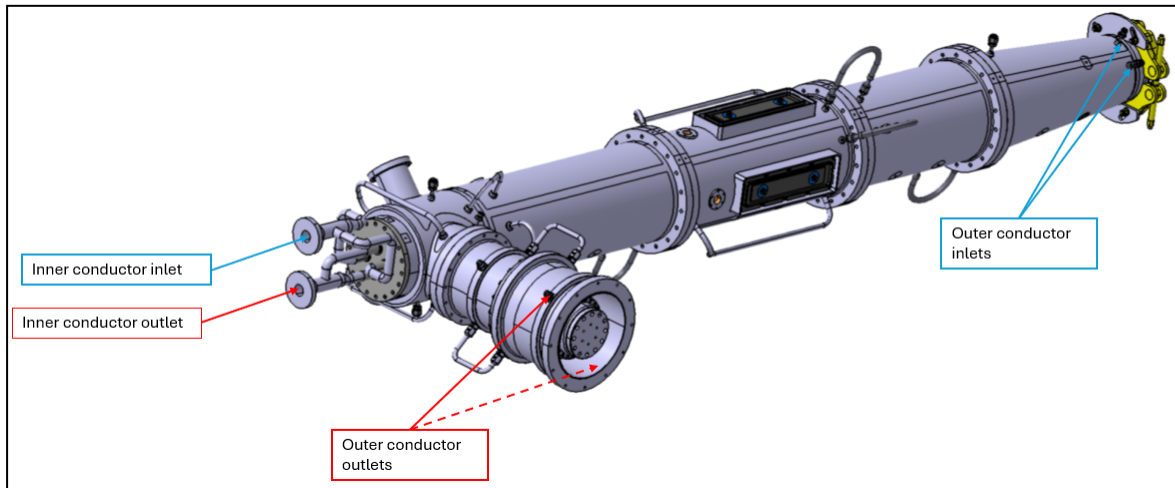


Figure 11: Cooling water inlets and outlets (pre-matching unit + IO window)

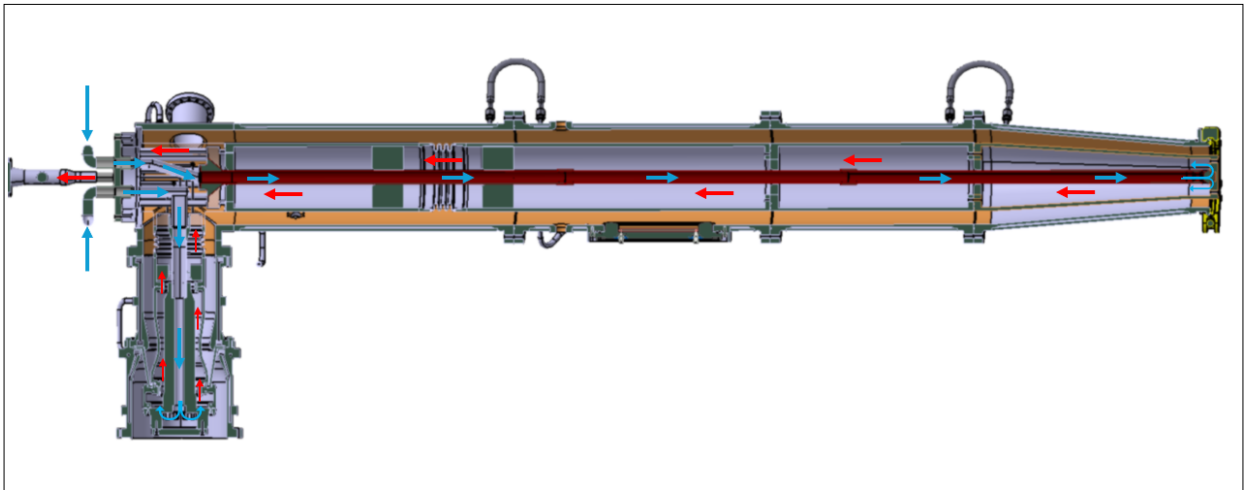


Figure 12: Cooling water flow in inner conductor - blue arrows for water inlet and red arrows for water outlet (pre-matching unit + IO window)

5.3.2.4 Bellows requirements

Two metallic bellows have been implemented on the inner conductors to compensate relative displacements between both inner and outer conductors. IO is strongly recommending to use the design provided in [23].

The bellows shall be compatible with all the following conditions:

- Relative displacement between conductors of 3mm minimum and 1.2mm minimum for 1000 cycles for bellows #1 and #2 respectively (see Figure 13)
- Working temperature between 18°C to 150°C
- Water pressure inside the bellows at 1.85 MPa (abs) as maximum
- Air pressure outside the bellows from 0 to 0.6MPa (abs).

The bellows shall be implemented not to disturb the radio frequency currents. A preliminary study has been performed with bellows manufacturer and implemented in the present design (as per drawings [23], see Figure 13). The study will be disclosed at the KOM by IO, so the

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contractor will be free to re-use or not the existing work. No change on RF surfaces can be performed by the contractor without IO agreement.

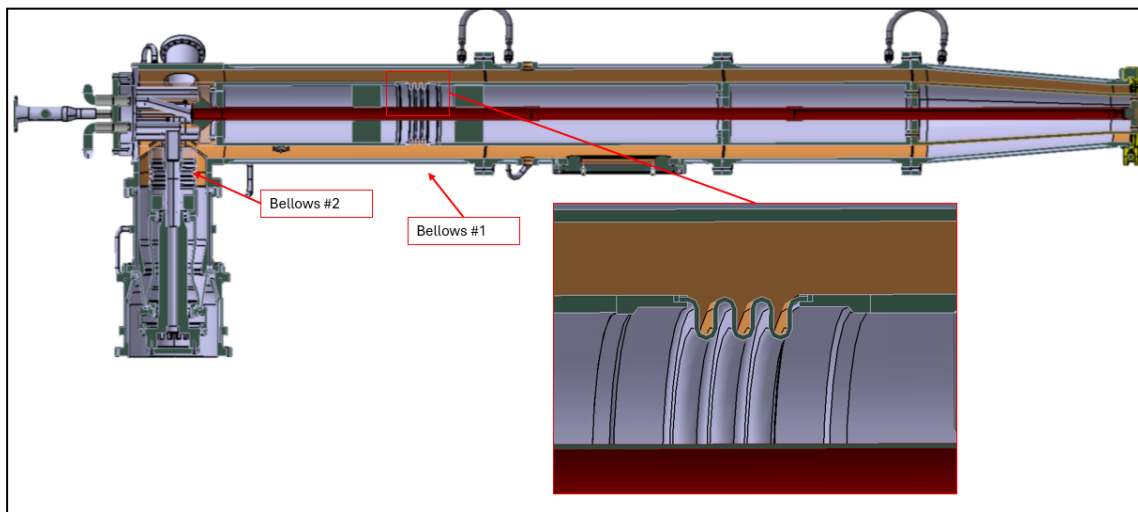


Figure 13: Bellows implementation proposal

5.3.2.5 Material requirements

IO has already selected the materials for the pre-matching unit:

The main body of both internal and external conductors shall be in 316L or 304L (EN grade 1.4404 steel and 1.4307 respectively) with copper (or silver) coating.

The central water pipe shall also be in 316L or 304L (EN grade 1.4404 and 1.4307 respectively).

The bellows may have a different stainless-steel grade.

5.3.2.5.1 Vacuum compatibility

All the metallic material shall be compatible with UHV application. Iter Vacuum Handbook [3] appendix 3 provides the list of acceptable materials for the design of VQC components.

The welding / brazing materials may be subjected to specific acceptance.

The table 5.2 of the ITER vacuum handbook [2] is specifying whether cross-forged material is required or not, according to base material shape (pipe, plate, forging) and to the final thickness.

5.3.2.6 Joint design

5.3.2.6.1 Joint design requirements

The design of welded joints shall be developed on the basis of the EN13445-3, EN13445-4 and EN13445-5.

For joints on the vacuum boundary (to air or water), **full penetration welds are required**. The design of welded joints shall ease the joint inspection.

The requirements for brazed joints are specified in [2]. **Brazed joints in contact with water are not permitted**.

5.3.2.7 Coating

The surfaces carrying RF current shall have low resistivity material, for reducing RF losses. The contractor is free to choose a coating method. The coating shall be carried out with pure copper

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(or silver). The contractor shall complete all the welds prior to execute the coating in order to ensure that 100% of the RF surfaces will be coated without being affected by the welding.

The coating thickness shall be 60µm (+/- 20 µm).

The surface finish of the coated surface shall be compliant with the Ra specified for RF surfaces (Ra 3.2µm maximum). If the coating method cannot achieve such Ra, a polishing phase shall be implemented post coating. The adhesion shall at least be 30MPa (under tension).

5.3.2.8 *Seals*

IO will use TECHNETICS Helicoflex® seals at the boundary of the vacuum volume in the pre-matching unit during its operation:

- Helicoflex® with aluminium cover when the seals are between vacuum and air
- Helicoflex® with silver cover when the seals are between vacuum and water

In addition, IO has implemented alternative grooves where possible to use Elastomer seals when the pre-matching unit will not be under vacuum but with pressurized air (this is the case with the final Antenna, see section 5.1.1.2)

IO will provide the contractor with one set of Helicoflex® seals. The contractor will have to use these seals for the final leak test (see section 5.3.9.6) and for the delivery to IO (see 5.3.10).

The contractor is free to procure Helicoflex® or elastomer seals for all other tests (if needed).

5.3.2.9 *Design assessment by FEA*

No Analysis is expected to be done by the contractor in this contract.

5.3.3 *Interface requirements*

All the interfaces, namely the transmission line connection, the Antenna prototype connection, the water connectors, the ports for vacuum pumping and RF measurements, shall be manufactured as per drawings [23].

100% of the interface dimensions and tolerances shall be controlled by the manufacturer.

5.3.4 *Assembly tools*

In addition of the pre-matching unit, the contractor shall also manufacture and deliver the assembly tools and the tests features necessary to perform the assembly of the pre-matching unit as well as the different tests described in section 5.3.9.

Some parts have been preliminary assessed by IO in the drawings [23]. The contractor may challenge and redefine the different tools with IO agreement.

5.3.4.1 *PEEK fingers*

In order to help the assembly, IO already designed temporary support in PEEK material to support and align the inner conductor. The quantity required is given in the BOM and drawings available in [23].

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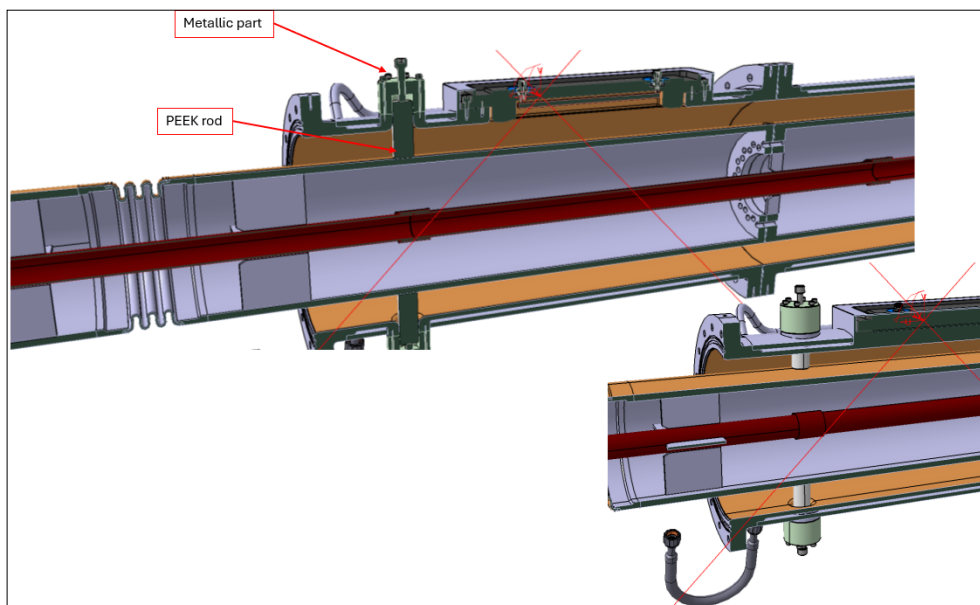


Figure 14: PEEK fingers location

The contractor shall review the design of the fingers, manufacture and then deliver them to IO.

5.3.4.2 Bolting rods

The contractor shall either procure or develop and manufacture tools to perform the bolting of the different inner conductors together. These “bolting rods” can be simple rods, with hexagonal shape welded on their end.

Note: These tools are not listed in drawings [23] but shall be manufactured and delivered by the contractor.

5.3.4.3 Assembly tool for first conductors

Because of the conical shapes of both first conductors, IO is proposing to install both conductors in the same time. For this purpose, a tool is needed to connect the inner conductor to the Antenna prototype while the outer conductor is supported in a “retracted” position, see Figure 15.

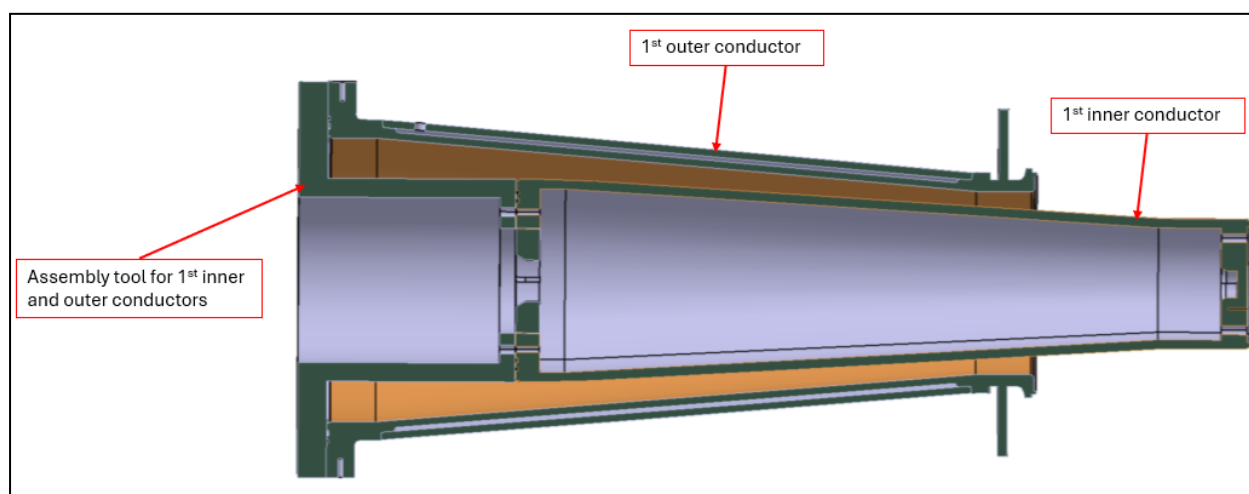


Figure 15: Assembly tool for first conductors

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Once the first inner conductor is connected on the Antenna prototype, this assembly tool shall be disconnected from the outer conductor, and this one shall “slide” on guiding pins (tools to still to be defined) to avoid any contact between the conductors during the connection of the outer conductor on the Antenna prototype.

The contractor shall review the design of the Assembly tool for first conductors, manufacture and then deliver it to IO.

5.3.5 Caps for Antenna prototype second port

During the RF testing of the Antenna prototype, it is also necessary to close the second port of the Antenna prototype. The contractor shall manufacture the two parts needed at this location, see Figure 17.

These parts are included in the drawings [23]. They are in 316L or 304L (EN grade 1.4404 and 1.4307 respectively) and do not need any coating.

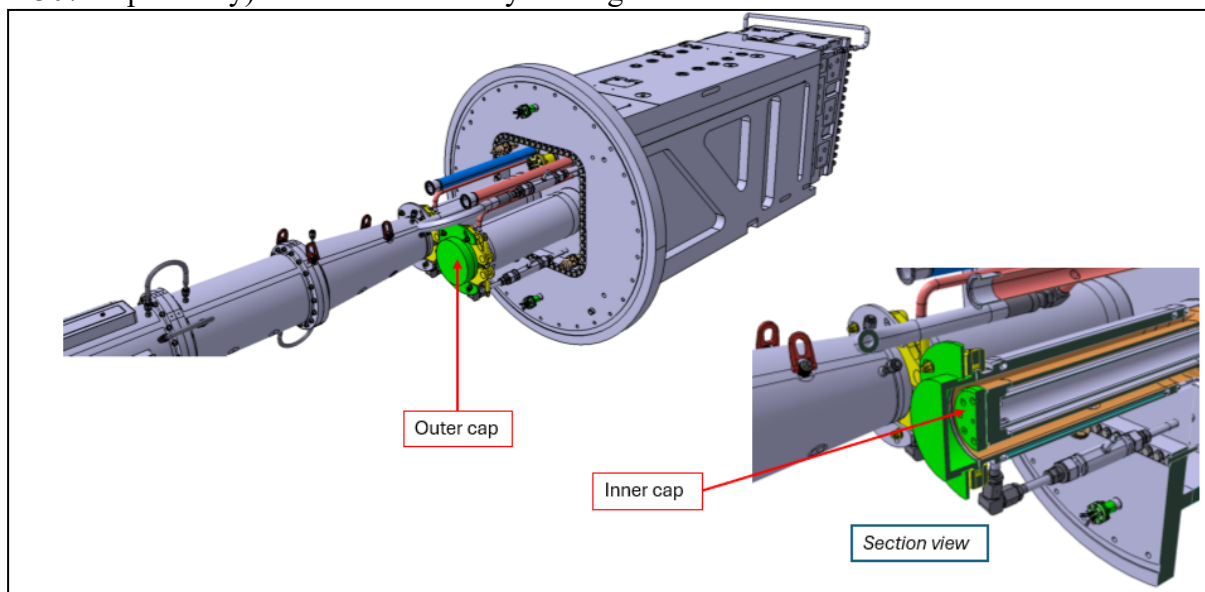


Figure 16: Caps for second port

Since these parts are in vacuum, they shall be manufactured with the same requirements (material, welding, cleanliness) than the pre-matching unit parts (for vacuum compatibility).

5.3.6 Manufacturing requirements

After completion of the Quality Plan, the contractor shall issue the Pre-matching unit manufacturing drawings [DL1] and the Manufacturing & Inspection Plan for the pre-matching unit [DL2] according to requirements available in [22].

In attachment of the Pre-matching unit manufacturing drawings [DL1], the contractor shall deliver the final 3D model of the Pre-matching unit (Catia or Step files).

The contractor shall manufacture all the parts included in the pre-matching unit drawings [23]. All the components that are not tagged “out of scope” or “IO provided” in drawings [23] shall be supplied by the contractor to the IO.

The contractor shall ensure the complete definition and manufacturing of:

- Custom test parts to conduct the tests presented in section 5.3.9
- Transport box needed to transport the pre-matching unit on IO site (see section 5.3.11)
- Assembly tools as per section 5.3.4

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The contractor shall deliver the test and tool parts design package [DL3] made of:

- A detailed presentation of all the tests to be performed and the test sequence.
- The Bill of Materials (BoM), 3D models (native files + STEP files) and the manufacturing drawings of all the components to be manufactured and to be procured
- A description of the transport box for the all the components to be delivered.

The contractor shall follow EN 13445-4 and EN 13445-5 for manufacturing and inspections.

5.3.7 *Material procurement requirements*

5.3.7.1 *Metallic materials*

The contractor shall produce the pre-matching unit material purchase specification. General requirements for materials shall follow EN 13445-2. The contractor is responsible for the conformity of the material used during the prototype manufacturing.

All materials shall be free from surface cracks, fissures and any other tool marks, burns, delamination and other defects, as this would make them incompatible with high vacuum and high frequency environments. The material certificate 3.1 as per EN10204:2004 shall be provided to IO and shall be attached to the MIP [DL2].

5.3.7.2 *Filler material & brazing material*

The contractor shall procure the joining material quantity that covers the present contract. All welding consumables shall be specified in accordance with a standard accepted by IO.

The contractor shall select the filler material in accordance with the EN 13445.

The contractor shall include all data relating to welding and brazing material procurement in the MIP [DL2].

5.3.7.3 *Coating material*

The contractor shall procure the coating material required for the present contract. The coating material shall be specified and certified in accordance with EN ISO 10204:2004. The contractor shall specify all materials required to achieve the coating (i.e. if the process necessitates electrolytic baths or necessitates different layers, such as Nickel layer...). The contractor shall include all data related to coating material procurement in the MIP [DL2].

5.3.8 *Material, welding and fabrication requirements*

5.3.8.1 *Machining requirements*

The contractor shall take care that cutting and machining processes do not introduce contaminants into surfaces which may be difficult to remove later and which might result in degraded vacuum performance. Cutting fluids used for machining shall be water based, oil free, non-halogenated, sulphur and phosphorus free. The contractor can choose from those listed in ITER Vacuum Handbook Appendix 4 [3].

As standard for the machined surfaces used as sealing surfaces, specific surface roughness is required (roughness values defined case by case according to the type of seal, as per drawings [23]). For vacuum seal surfaces the machining marks must be in a circular lay, free from scratches across the lay and be protected at all times from subsequent damage. IO will not accept damaged seal surfaces.

The maximum average surface roughness of surfaces within vacuum shall be 6.3 µm, see Figure 17.

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The RF surfaces shall have a surface roughness of 3.2 μm maximum (RF surfaces have red dashes in Figure 18). The sealing surfaces of the prototype shall be protected with non-permanent covers after manufacture in order to prevent any type of damage during shipment.

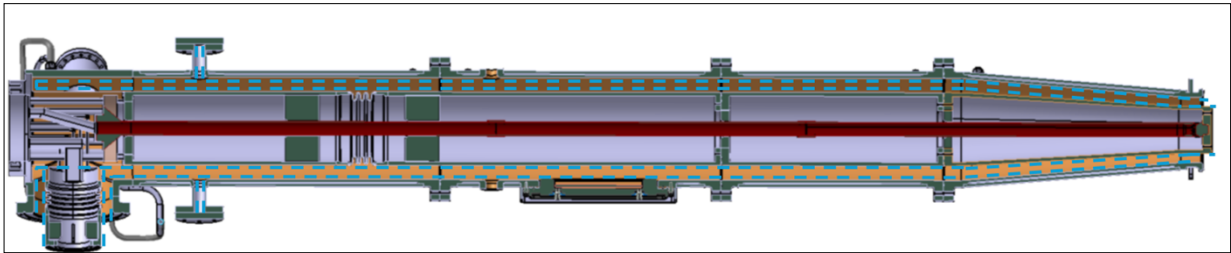


Figure 17: Pre-matching unit vacuum surfaces (in blue dashes)

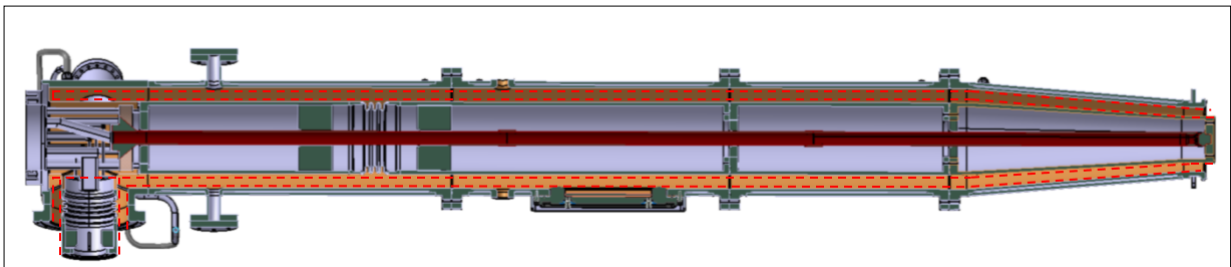


Figure 18: Pre-matching unit RF surfaces (in red dashes)

Machined parts shall be 100% dimensionally controlled. All measurements are recorded in a dimensional report attached to the MIP [DL2]. Roughness measurement of each vacuum sealing and RF surfaces shall be recorded.

5.3.8.2 *Joining requirements*

The contractor is free to choose the fusion joining process, based on his experience. WPS and WPQR shall be produced according to European standards NF EN ISO 15607, 15609 and 15614.

The operator qualifications are required (they shall be attached to the MIP [DL2] in accordance with NF EN ISO 14732 (or equivalent)). The contractor is free to define the post weld heat treatment, as required. Note that the weld seam shall be free from defect, such as:

- Cracks
- Crater
- Surface pore
- Lack of fusion
- Incomplete penetration
- Undercut

The Table 1 (section 5.3.9.1) is providing requirements for inspection methods and associated criteria.

As per the Vacuum handbook, the weld zones can be machined to match the surface finish of the parent material. On RF surfaces (Figure 18), weld beads shall be machined.

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The maximum leak rate for the full pre-matching unit shall be less than 10^{-9} Pa.m³/s air equivalent. The requirements for brazed joints (not permitted in contact with water) are specified in [2].

5.3.8.3 Coating requirements

The selection of the most adequate deposition process and the application of this coating are the responsibility of the contractor. The coating specification is given below:

- Material: copper (or silver)
- Thickness: minimum 60µm (≈ 5 times the skin depth at 40 MHz for copper at 100°C)
- Surface finish: 3.2 µm maximum (as per RF surfaces specified roughness, can be achieved by another operation post plating)
- Adhesion: > 30 MPa under tension

The contractor shall produce the coating procedure specification and shall take into account the provision specified in [2].

The contractor shall execute coating tests as described in paragraph 5.3.9.2.

5.3.8.4 Marking

Each component shall have an identification number implemented on the external surfaces which are not VQC or exposed to RF current. IO will provide the identification number. The components shall be individually marked with a unique identification, which is traceable to the component document package. They shall only be marked by scribing with a clean sharp point or by a laser scribing method.

5.3.8.5 Cleaning requirements

The contractor shall pay attention to the cleanliness throughout the manufacture of the pre-matching unit. The ITER Vacuum Handbook, appendix 13 [3] provides relevant methods. The contractor shall follow the appendix 13 [7] guideline by producing a cleaning plan, which includes all relevant steps for the different parts, before and after the different manufacturing processes. The pre-matching unit cleaning plan shall be delivered to the IO TRO before starting the manufacturing in attachment of the MIP [DL2].

The contractor shall consider the pre-matching unit as VQC1 classified regarding the ITER vacuum handbook [2] and its appendix 13 [7] cleaning requirements.

5.3.8.6 Manufacturing of auxiliary parts and tools

The auxiliary parts, namely test parts, assembly tools, storage support and transport box shall be manufactured. The auxiliary parts are all the parts needed to perform the tests presented in section 5.3.9. It includes the caps for the pre-matching unit interspace volume (see section 5.3.9.1) as well as connectors, caps for water and vacuum ports and caps for radars. It also includes tools for performing the bolting of the inner conductors (see section 5.3.4.2), ensuring the required tightening torques (as per drawings [23]).

The contractor shall identify the applicable standard(s) for the lifting/handling tool(s) and qualify the tools accordingly.

The contractor shall propose standard(s) for auxiliary parts and manufacture them accordingly.

5.3.9 Factory Acceptance Test of the pre-matching unit (FAT)

The following sections are describing the validation process of the pre-matching unit manufactured by the contractor. The FATs are divided in six main sub-tasks (NDT, coating tests, outgassing tests, hydrostatic tests, pressure tests and final leak tests). The successful completion

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of these sub-tasks and consequently of the deliverable [DL4] will clear the FAT Hold Point, which is set up at this stage. The following flow chart (Figure 19) is showing the FAT phase, and the impact of test results if requirements are not met.

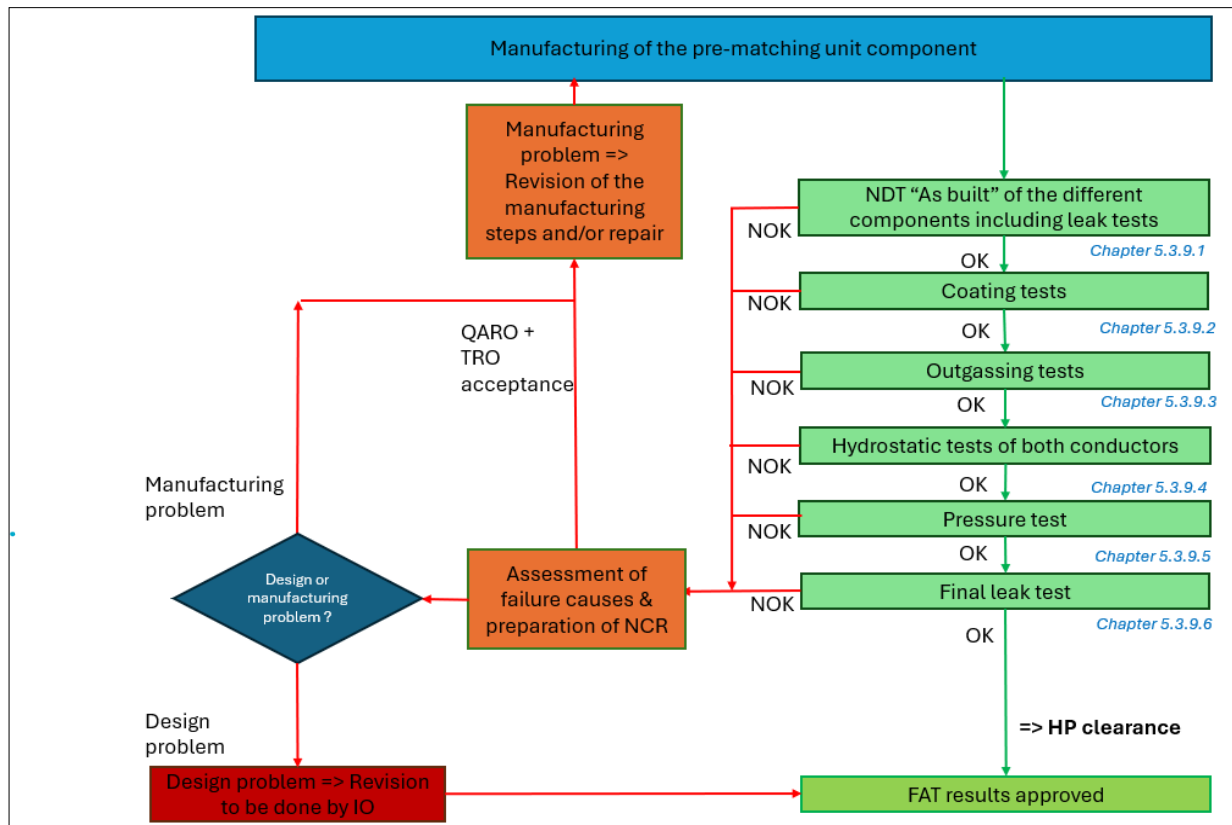


Figure 19: Flow chart for conducting the FAT

Nevertheless, the contractor is free to implement additional NDT all along the manufacturing phase, as required and based on his experience, aiming to limit the risk of issues while the FAT stage is reached. These intermediate NDTs results are not formally requested. In addition, if destructive tests are deemed required by the contractor for risk reduction purpose, the contractor has the freedom to implement these tests.

5.3.9.1 Non-destructive examination of the "As Built" pre-matching unit

The contractor shall control the pre-matching unit during and after the manufacturing. The contractor shall issue procedures for the different NDT tests. The NDT operators shall be qualified and certified according to the NF EN ISO 9712 (or equivalent, the contractor has to select the more relevant standard). The contractor shall produce the pre-matching unit NDT within the FAT package [DL4].

The pre matching unit NDT shall include at least:

- 100% of the welds in vacuum (see Figure 17) shall be controlled by volumetric testing (radiographic or ultrasonic testing)
- Each weld type for other welds (not in vacuum) shall be controlled by volumetric testing at least once
- Radiographic inspection shall be preferred when feasible, where volumetric examination by UT is the only option, the contractor shall provide the method, and shall provide evidence that the method is viable for the present application

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- 100% of the welds not in vacuum shall be controlled by liquid penetrant testing
- 100% of the joints (welded or brazed) shall be Helium leak tested (maximum leak rate is $1 \times 10^{-9} \text{Pa.m}^3/\text{s}$ air equivalent for the full pre-matching unit)
- 100% Visual examination (weld inspection, coating inspection)
- 100% Dimensional control

If a post-weld heat treatment is defined (as per the section 5.3.8.2), the NDT shall be carried out before and after the execution of heat treatment.

The contractor shall reach the weld quality level B according to ISO 5817:2023. Method selection and acceptance criteria shall be in line with corresponding levels defined in ISO 17635:2025, recalled in Table 1 for convenience:

NDT method	Weld quality level in accordance with ISO 5817:2023	Testing method and testing level (if applicable)	Acceptance level and associated standards
VT	B	Method: ISO 17637: 2017 Level: not applicable	Acceptance level B (equal to quality level from ISO 5817:2023)
PT		Method: ISO 3452-1: 2021 Level: not applicable	Acceptance level 2X ISO 23277:2015
RT		Method: ISO 17636-1: 2022 Level: Testing class B	Acceptance level 1 ISO 10675-1:2021
UT		Method: ISO 17640:2018 Level: at least B	Acceptance level 2 ISO 11666:2018

Table 1: NDT Testing methods and level and acceptance criteria for welds

The leak testing of the joints shall be performed in accordance with the NF EN ISO 20485 method (select the method in same direction of the expected leak). The required leak rates for all permanent joints shall be less than $10^{-9} \text{Pa.m}^3/\text{s}$ (air equivalent), as per [2] (VQC3 leak rate, table 25-1).

The contractor shall add the calibration certificate of equipment that will be used for NDT. This certificate shall be attached to [DL2].

The contractor shall perform the leak tests in two steps:

- Step 1: leak testing of the inner conductor (see section 5.3.9.1.1)
- Step 2: leak testing of volume between conductors (see section 5.3.9.1.2).

Prior to perform the leak tests the contractor shall assemble the RF window (provided by IO) on the pre-matching unit. This will allow to ensure the correctness of the assembly and will also close one side of the volume between the conductors.

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5.3.9.1.1 Leak test of the inner conductor:

The Figure 20 is representing an example of leak test configuration for the inner conductor. The contractor is responsible for checking design and manufacturing the tools/caps needed to perform this test.

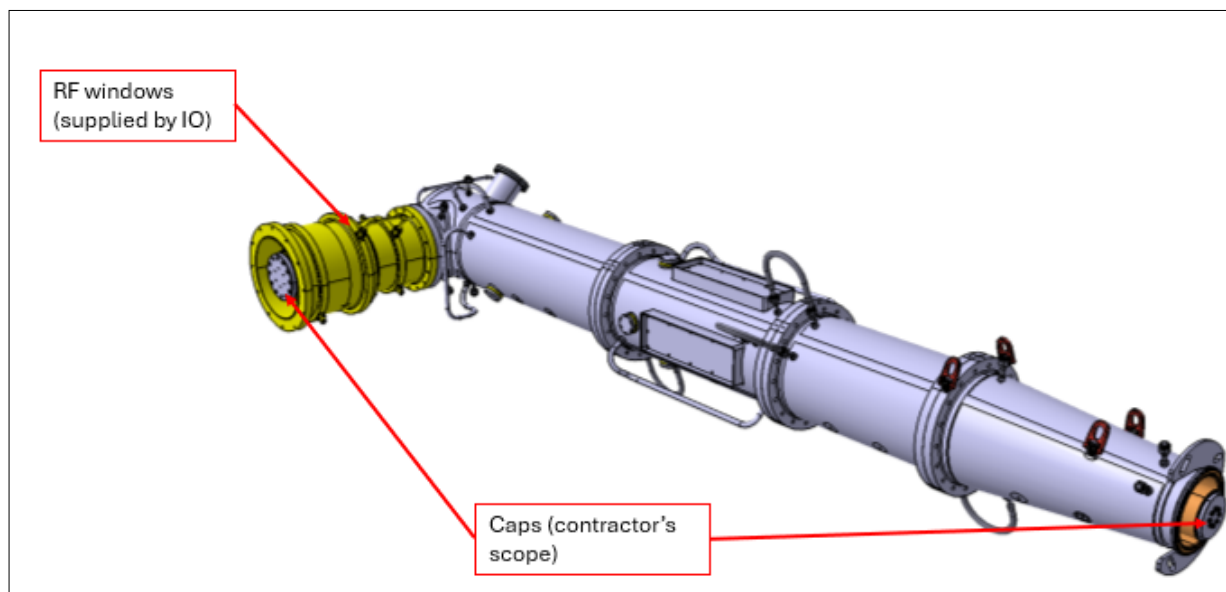


Figure 20: Inner conductor leak test configuration

5.3.9.1.2 Leak test of the volume in between inner and outer conductors

The Figure 21 is representing the leak test configuration for the volume between both conductors. The contractor is responsible for checking design and manufacturing the tools/caps needed to perform this test.

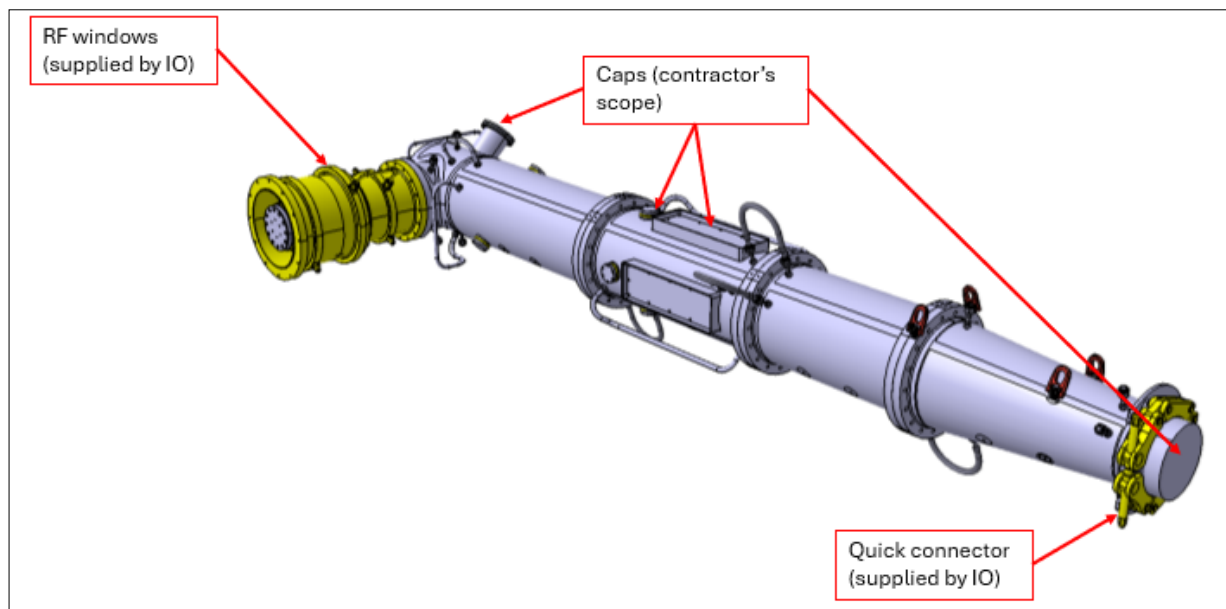


Figure 21: Leak test configuration for the volume between both conductors

Note: IO will supply the quick connector to the contractor to perform this test.

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The leak test of the volume between both conductors shall be done before and after all the other tests (hydrostatic and pressure/pneumatic tests).

Before to perform final leak test, all internal volumes wetted during acceptance testing shall be drained completely and dried by purging with dry air until the purge gas has a water content <4000 ppm before helium leak testing. The water content can be measured at the outlet of the water circuit being dried out. The section 27 of the ITER vacuum handbook [2] is providing requirements for draining and drying.

The final leak test result shall be identical to the result of the leak test done prior to the different test. Hence, the final leak test shall be compliant with ITER vacuum handbook [2] leak rate for VQC3 component.

The final leak test shall be performed with the TECHNETICS Helicoflex® seals provided by IO. The parts shall not be disassembled after the final leak tests.

5.3.9.2 Coating tests

The contractor shall perform the coating on test pieces of the same shape and relevant dimensions and extract test specimens from these test pieces. The following tests shall be carried out as part of the FAT:

- Inspection
 - 100% Visual Examination continuity, uniformity of the coating: no cracks, no flaking, no chipping, no burning, no blistering.
 - Surface roughness measurement
- Destructive tests
 - Macros: with photographs – No pores, no voids, homogenous layers.
 - Thickness measurements of underlayer and final layer coating.
 - Material analysis of deposited layer to identify all constituents.
- Mechanical tests
 - Adhesion check (ASTM B571 or equivalent)
- Thermal tests
 - Bake to 300°C at <50°C/hr under vacuum of <0.01Pa. No cracks, no flaking no blistering.

The tests shall be performed before and after the 300°C baking. The results of the test shall be recorded in a test report part of the FAT package [DL4].

5.3.9.3 Outgassing tests

The contractor shall perform outgassing tests on test pieces that have followed the same manufacturing cycle (machining, cleaning, passivation, welding, heat treatment, coating...) than the real component, according to guidelines of the appendix 17 of [3]. The procedure shall be submitted to the IO TRO prior to the test execution, for review and approval. Visual inspection of the coating shall be carried out after outgassing in order to verify that the coating quality remains identical to the previous verification.

Acceptance criteria:

- The outgassing rate of material used for ITER vacuum system shall be consistent with the values specified in [2] table 5-1 for VQC3 component, max. $1 \times 10^{-8} \text{Pa.m}^3.\text{s}^{-1}.\text{m}^2$.
- No visible effect on the coating.

The tests and the results shall be detailed in the FAT report [DL4].

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Note: The contractor may investigate the possibility of having the same samples for coating thermal tests (see section 5.3.9.2) and for these outgassing tests.

5.3.9.4 Hydrostatic testing of the pre-matching unit

After completion of the NDTs required for the validation of the manufacturing correctness, the contractor shall perform the assembly of the different components and the hydrostatic test of the pre-matching unit. The contractor shall procure the seals to allow the leak-tightness of the different components. The contractor can perform the hydrostatic tests, the pressure test (see 5.3.9.5) using elastomer seals if preferred, but the seals shall be compatible with vacuum (no grease or material forbidden in vacuum). The final leak test (5.3.9.6) shall be conducted with TECHNETICS Helicoflex® seals supplied by IO.

The contractor shall set up the test stand to perform the hydrostatic tests of the inner and outer conductors cooling circuits with a water pressure of 1.85 MPa absolute as maximum. The contractor shall maintain and monitor the water pressure during at least one hour. The contractor has to propose a hydrostatic test procedure, to be approved by IO before to start the hydrostatic test. The procedure shall be compliant with requirements in EN 13445-5.

Acceptance criteria:

- No visual deformation shall be seen on the pre-matching unit
- No water leak shall be detected

The tests and the results shall be detailed in the FAT report [DL4].

Note: After hydrostatic tests the pre-matching unit shall be drained and dried, see requirements in section 5.3.9.1.2

5.3.9.5 Pneumatic testing of the pre-matching unit interspace

After completion of the hydrostatic tests, the contractor shall perform the pneumatic pressure testing of the pre-matching unit.

The contractor shall set up the test stand to perform the pressure test of the interspace between inner and outer conductors with a pressure (gas to be selected by manufacturer, dry air for example) of 0.4 MPa absolute. The contractor shall maintain and monitor the gas pressure during at least one hour.

The contractor has to propose a pneumatic test procedure, to be approved by IO before to start the pneumatic test. The procedure shall be compliant with requirements in EN 13445-5.

Acceptance criteria:

- No visual deformation shall be seen on the pre-matching unit
- No variation of pressure in the pre-matching unit (at the level of tolerance of the monitoring equipment)

5.3.9.6 Final leak test

Both leak tests described in section 5.3.9.1 shall be repeated.

5.3.10 Cleaning and packing of the pre-matching unit

The contractor shall perform the cleaning of the pre-matching unit after completions of FAT. The cleaning procedure shall issue in accordance with the reference [3] appendix 13.

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The contractor shall then proceed to the pre-matching unit packing and shall install the different components in dedicated transport boxes. The contractor shall design, as part of [DL3], and supply appropriate packaging, adequate to prevent damage during shipping lifting and handling operations. Where appropriate, accelerometers or other sensors shall be fitted to ensure that limits have not been exceeded. When accelerometers are used, they shall be fixed onto each box and shall be capable of recording the acceleration along three perpendicular directions.

Shock absorbing material shall be used.

The Pre-matching unit shall be shipped fully assembled, ready to be performed the leak test on IO site (see SAT in section 5.3.12). The different parts and seals shall not be disassembled after the final leak test (section 5.3.9.6). The packaging shall be performed in accordance with the reference [2] section 29.

5.3.11 Delivery of the pre-matching unit to IO premises

A successful completion of the FAT sequences is required prior to delivery to the IO site. The pre-matching unit shall be prepared in accordance with [2] section 29.

Each shipment shall be accompanied by a Delivery Report shall be prepared by the contractor, stating as a minimum:

- The packing date;
- The full address of the place of delivery and the name of the person responsible to receive the package, as well as of the Contractor's name and full address;
- A manufacturing dossier that compiles all manufacturing documents
- The pre-matching unit FAT package [DL4]
- Bill of Materials
- Security Measures
- Release Note according to instructions in [22];
- Packing List;
- Material Safety Sheet;
- The declaration of integrity of the package;
- The declaration of integrity of the components;
- Any additional relevant information on the status of the components.

Before the shipping, IO will check the availability of the required documentation as specified hereabove.

The pre-matching unit Delivery Report shall be signed by a representative of the IO and its Contractor. Successful completion of the DRR and signature by the IO of the Delivery Report prior to shipment represents a Hold Point that enables the contractor to deliver the pre-matching unit prototype package.

The pre-matching unit [DL5] shall exclusively be delivered to the ITER Site using the ITER Global Logistic Provider (DAHER) under the responsibility of the Contractor.

Before the shipment, a Release Note shall be prepared in accordance with the "Contractor Release Note" (see [22]) and approved by the IO.

Upon receipt of the package, the IO shall open the package and make a visual inspection of its content to check:

- The integrity of the package, including identifying visible damage;
- The number and type of components contained in the shipment;
- The enclosed documentation;
- The reading of the accelerometers or other sensors;

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- The integrity of the components.

5.3.12 SAT & final acceptance

Site acceptance test of the pre-matching unit package [DL5] will be performed by IO representatives. The following points shall be checked before acceptance;

- Checking of backfilled volumes
- Seal face inspection
- Checking the integrity of packing and status of accelerometers
- Cleanliness check
- Leak test (at room temperature)

Successful inspection of the pre-matching is required by IO for the package [DL5] final acceptance.

5.3.13 Delivery Time

All deliverables shall be delivered within the delays detailed in Table 2.

6 Location for Scope of Work Execution

The work is expected to be performed at Contractor's facility. Some tasks can sub-contracted elsewhere.

No work is expected on ITER site.

7 IO Documents & IO Free issue items

7.1 IO Documents:

N/A

7.2 Free issue items:

Under this scope of work, IO will deliver the following equipment/parts by the stated date:

Ref	Equipment / Part Description	Expected date
1	1x Quick connector	Before FAT
2	1x RF window	Before FAT
3	1x set of Helicoflex® seals	Before FAT

8 List of deliverables

The Contractor shall provide IO with the documents and data required in the application of this technical specification, the GM3S [1] and any other requirement derived from the application of the contract.

The due dates are specified on the following main milestones:

- T0: Date of the KoM for Phase 1

Phase	Deliverable (DL)	Type of DL	Due date (in months)
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SUPPLY

1	[DL1] Pre-matching unit manufacturing drawings	docx/pdf + 3D model (native files and step files) + drawings (pdf and dwg/dxf files) (storage in SMDD)	T0+2
	[DL2] Pre-matching unit MIP	docx/pdf	T0+2
	[DL3] Pre-matching unit auxiliary parts, tools and transport box	docx/pdf + 3D model (native files and step files) + drawings (pdf and dwg/dxf files) (storage in SMDD)	T0+3
	[DL4] Pre-matching unit FAT package	docx/pdf	T0+11
	[DL5] Reception of the Pre-matching unit and tools	1x Pre-matching unit + tools + test parts	T0+12

Table 2: Deliverables table

9 Quality Assurance requirements

The Quality class under this contract is QC3, GM3S section 7 [1] applies in line with the defined Quality Class.

The Supplier shall have an ISO 9001 certified quality system or alternatively a QA Program approved by QARO. In addition, the quality management system shall comply with the IO quality requirements as per [22].

All requirements of this Technical Specification and subsequent changes proposed by the Supplier during the course of execution of this Contract are subject to the Deviation Request process described in [6] and Non-Conformities process described in [9].

10 Safety requirements

No specific safety requirement related to PIC and/or PIA and/or PE/NPE components apply.

For Protection Important Components and in particular Safety Important Class components (PIC/SIC), the French Nuclear Regulation shall be observed, in application of the Article 14 of the ITER Agreement.

The Suppliers and Sub-Suppliers (if any) are informed that:

- ITER is a nuclear facility (an “INB”, for Installation nucléaire de base, “Basic nuclear installation” in French regulation) identified in France by the number “INB no. 174”[8].
- The ITER Policy [19] must be circulated, known, understood and applied by all staff of the Suppliers and cascaded down in the managerial lines of the Suppliers and sub-Suppliers.

In application of the ITER agreement, article 14, ITER follows the French Regulation for Nuclear safety. Because of its inventory in nuclear materials, ITER has been classified in France as a nuclear facility “Installation Nucléaire de Base” and in particular numbered as INB no.174 per [20] and the associated ASN Decision [21].

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11 Specific General Management requirements

Requirement for [Ref 1] GM3S section 6 applies completed/amended with the specific requirements detailed in the present section.

11.1 Meeting Schedule

Meetings can be organised face to face or remotely as agreed by the Parties with the exception of the KOM that has to be face to face at IO site (if permitted by sanitary measures). The kick-off meeting will mark the starting date in the contract planning (referred to as time T0). At this meeting, the contractor will have the opportunity to request and receive answer to any outstanding clarification / questions about the project. IO will confirm all applicable document versions.

During the execution of the contract, videoconference meetings shall be held to monitor the project progress. The videoconference software will be defined at the kick off meeting. These meetings shall be organized by the contractor, who will also be responsible to maintain the meeting records (minutes, actions and decisions). The Contractor representative has to provide the MOM to the CRO for review no later than one (1) week after the meeting took place. The meetings will be held bi-weekly unless otherwise agreed during the execution of the different phases.

11.2 Audits and surveillance

Audits, reviews, surveillance and inspection of the contractor's quality assurance arrangements and the compliance with the French 2012 INB order will be carried out as required by IO appointed representatives according to [10] and [11]. These activities may be extended to cover sub-contractors. In respect of any deficiencies revealed, the contractor shall implement, or ensure that every sub-contractor implements, corrective actions in accordance with an agreed timescale. IO shall inform the contractor for audits, reviews, surveillance and inspection activities including those involving a sub-contractor.

The contractor shall provide to IO the access to documentation, personnel and to his subcontractor's premises during all stages of the contract for purposes of audit, review, surveillance and inspection.

There could have the ASN/ITER scheduled or non-scheduled inspection/surveillance and the right of access to the contractor property have to be granted.

11.3 CAD design requirements

The reference scheme is for the Contractor to work in an asynchronous manner on the ITER CAD platform as described in [12]. The use of CATIA V5 is not required. No work in ENOVIA is requested.

Drawings and 3D native files shall be stored in SMDD by the contractor in a dedicated folder given by IO at the KOM.