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Technical Specifications (In-Cash Procurement)

Summary of Technical Specification for VS Coils' Prototyping, Manufacturing and Installation

Call for Nomination documentation related to the activities for In-Vessel Coil Vertical Stability Coils (VS Coils) Prototyping, Manufacturing and Installation.

SUMMARY OF TECHNICAL SPECIFICATIONS

IN-VESSEL VERTICAL STABILITY COILS (IVC VS) PROTOTYPING, MANUFACTURING AND INSTALLATION

Call for Nomination
Reference IO/19/17228/PMT

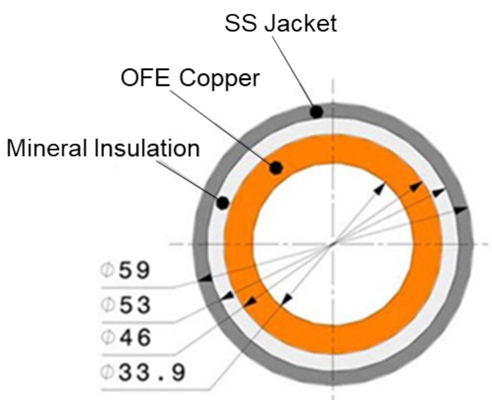
1 Purpose

This Call for Nomination is associated with the procurement of ITER In-Vessel Vertical Stability Coils (IVC VS), which includes all activities to be performed to manufacture and install in the ITER Tokamak the Upper VS Coil and the Lower VS Coils.

2 Introduction

ITER is a joint international research and development project aiming to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes. The seven members of the ITER Organization (IO) are: The European Union (represented by EURATOM), Japan, People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA. The ITER Organization is located in Saint Paul lez Durance – France. Further information is available on the ITER website: http://www.iter.org.

In-Vessel Coils (IVC) are normal-conducting coils located behind the Blanket Shield Modules inside the Vacuum Vessel. The system is composed by two set of coils, VS and ELM. Both coils systems are exposed to a considerable amount of dissipated power inside the Vacuum Vessel (VV), mainly coming from the gamma and neutron plasma irradiation and neutron heating during Deuterium-Tritium operations. This is combined with the VV normal operating temperature of 100°C and the in-vessel components bake-out temperature of 240°C. To withstand this environment while providing the required performance, the IVCs are made from water cooled, stainless steel jacketed, mineral-insulated conductors (SSMIC) – see Figure 1. The IVC Conductor manufacturing is object of a separate contract and will be supplied by IO in view of the Coil Turns manufacturing.



Materials description:
- Jacket: modified 316LN Stainless Steel
- Insulation: Magnesium Oxide compacted powder
- Conductor: OFE Copper (CW009A)

Materials thickness:
Jacket 3.0mm
Insulation 3.5mm
Conductor 6.05mm

Figure 1. IVC SSMIC Cross-section and layers definition (dimensions in mm).

The VS Coils, object of the present Call for Nomination, comprehend the Upper VS Coil (in the following UPR VS) and the Lower VS Coil (LWR VS), the first being located in the top portion of the VV, slightly above the Upper Ports, and the latter in the lower portion of the VV on the Triangular Support, as shown in Figure 2.

2.1 VS Coils Turns In-Situ Winding

Both UPR and LWR VS consist of four turns each of continuous SSMIC, provided by IO, joined together by Inconel Brackets and mounted to the VV behind the BSMs on IVC rails.

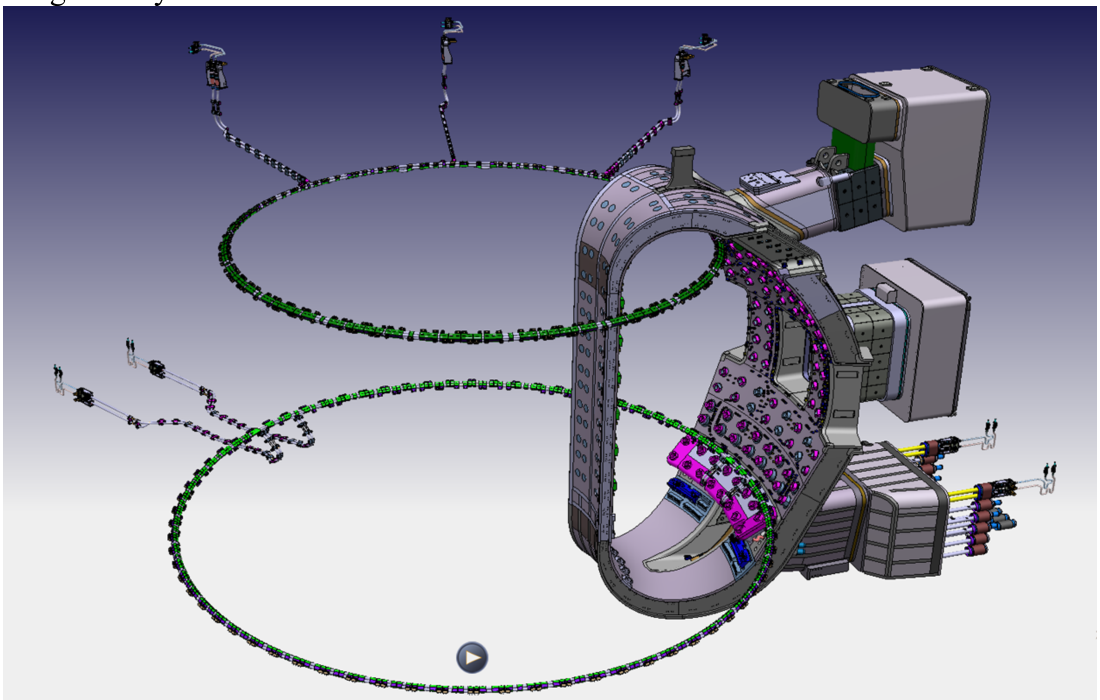


Figure 2. IVC VS Coils general overview.
The UPR VS has an overall diameter of ~12 m for a total weight of ~3 tons, the LWR VS has an overall diameter of 15m for a total weight of ~4 tons (considering only conductor and brackets).

One key feature of the VS Coils is that each coil turn consists of a continuous conductor line formed to the final shape without intermediate joints, as shown in Figure 3: this configuration implies that the coil turns must be wound and assembled inside the VV in ITER premises (In-Situ Winding), leading to the need to develop ad-hoc procedures and tooling to perform the operation in the delicate and space limited VV environment. This operation has been deeply investigated and the outcomes of the study is reported in the Appendix A of the Technical Specification, that eviscerates the main technological issues and proposes a suitable procedure and set of equipment to perform the operations.

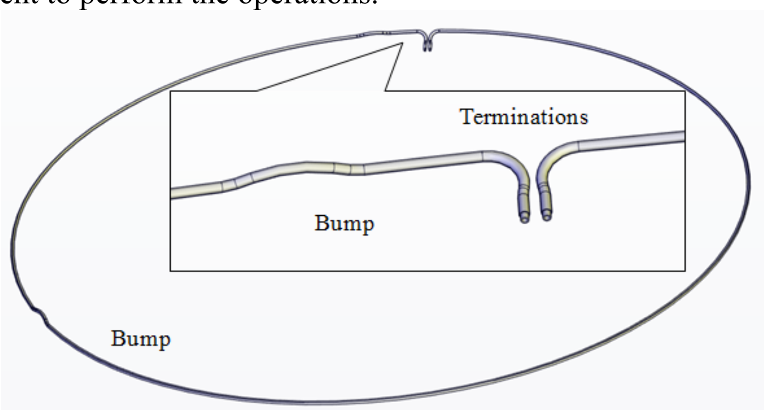


Figure 3: Example of one UPR VS turn formed by one continuous conductor length, showing the bumps and the terminations. The UPR VS coil turn is ~38 m long, while a LWR VS Coil turn is ~47 m long.

Each wound turn ends with two terminations to connect the inlet and outlet feeder lines that prosecute inside the ports to provide water and electricity supply to the coil. On top, to allow for the exiting of the terminations for each turn, the adjacent turns must have bumps as shown in Figure 3.
Terminations and bumps will require ad-hoc bending machines to be installed inside the VV in conjunction with the main winding machine.
In total, 8 turns must be wound in-situ to manufacture both UPR and LWR VS.

2.2 VS Coils Brackets Assembly

The coil turns are joined together with brackets, shown on the Left in Figure 4, which consist of three main parts in Inconel 625 alloy, the Upper and Lower Clamps and the Central Housing, welded under pressure in order to assure the thermal contact between the Bracket and the conductor under thermal and electromagnetic load. A central Inconel 625 Comb, which is part of the Central Housing, is also welded to the Upper and Lower Housings in order to provide mechanical continuity in the middle of the bracket. The details of the proposed welding procedure can be found in the Appendix B of the Technical Specification.

The brackets can be divided in standard and irregular brackets, one example of standard bracket can be seen in Figure 4 while one example of irregular bracket is shown in Figure 5, where the bracket geometry is changed to accommodate terminations and bumps. Standard brackets dimensions are approximately 140x140 mm (without the flanges) for 120 mm of length, while irregular brackets are usually bigger, around 300 mm long and up to 200 mm height with similar width to standard brackets.

There will be in total, including prototyping phase and final production, around 400 regular brackets and 200 irregular brackets to be produced in Inconel 625 alloy.

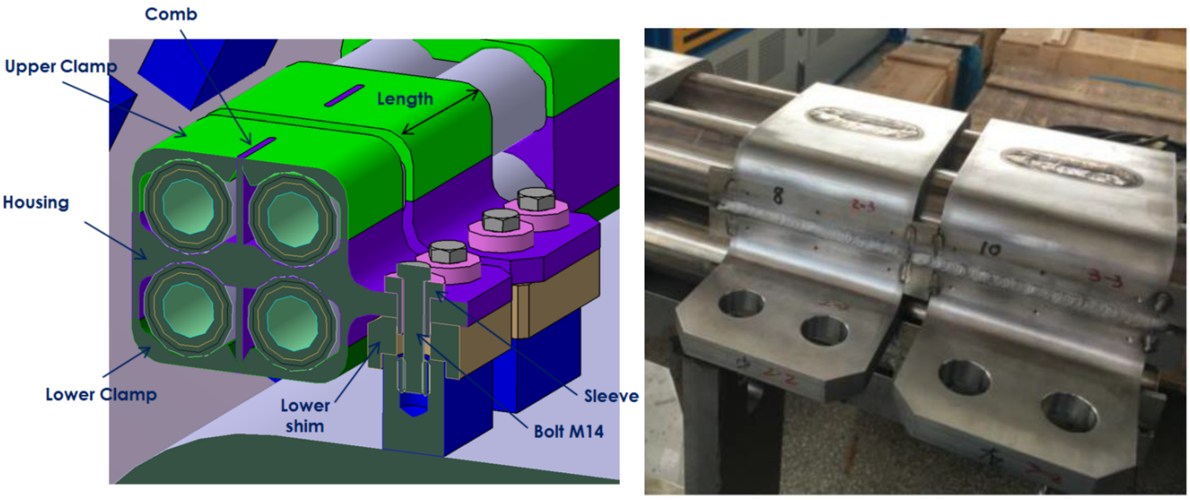


Figure 4: Left: Cross-section of a standard VS Bracket, made by an Upper and a Lower Clamp, a central Housing and Combs welded together. The Bracket is then bolted to the VV rails using a Sleeve/Shims combination to overcome alignment tolerances.
Right: Bracket prototype after assembly, showing the TIG welds on the sides and on the Comb.

To perform the assembly, the formed coil turns must be conveniently stored in the VV, the Lower Clamps must be placed on welding supports and the first two turns must be lowered on the Clamps. The assembly prosecutes with the Central Housing, the Combs, the latter two coil turns and finally the Upper Clamp. The pack must then be compressed while performing the TIG welds on the bracket sides and on the Combs in order to provide the needed pre-compression to the final assembly, which can be seen on the right in Figure 4.

On top of the regular brackets shown in Figure 4, there are special brackets in the areas close to terminations and bumps which require a different design as shown in Figure 5.

2.3 VS Coils Installation

The assembled coil must then be installed in position and bolted on the VV rails by a tailored Shims/Sleeve combination, cross-section shown on the left in Figure 4, in order to accommodate the variations in the rails positions due to manufacturing tolerances of VV and Coils: the shims must therefore be customized to adapt to the final VV and assembled coil geometries, basing on metrology data obtained from the VV once it will be completed.

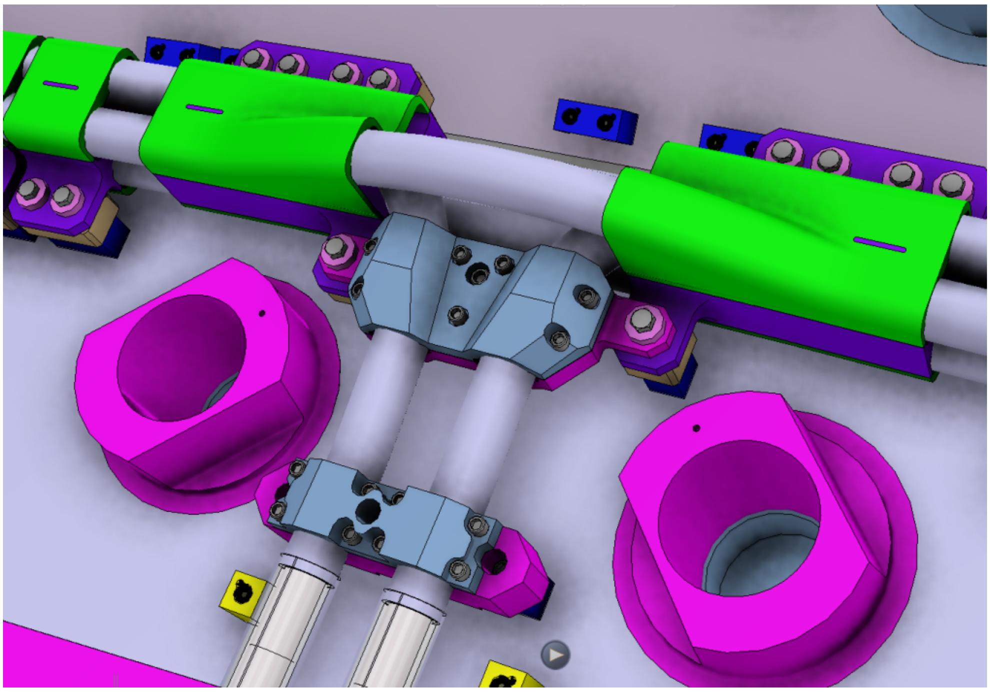


Figure 5. Detail of LWR VS Termination and Bump, showing the special brackets around the Bump and the location of the joint to connect to Feeder lines.

3 Scope of the work

As introduced in the previous Chapter, there are several activities related to the production and installation of the IVC VS Coils to be addressed in four (4) identified main Phases. Here below a short summary of all activities to be carried out inside the different Phases:

<u>Phase I</u> – *Engineering design of tooling and Procedures Finalization for VS Coils In-Situ Winding*:

- Finalization of winding procedure;
- Engineering design of all ancillary equipment like winding tooling, in-situ equipment and coils installation fixtures;
- Finalisation of bracket assembly and welding/NDT procedures for coils assembly;
- Development of metrology procedure for brackets final machining;
- Development of brackets welding reparation procedure;
- Development of coils installation procedure inside the VV.

Phase II – *Tooling procurement and VS coil full-size Prototype*:

- Production of a full size prototype of the LWR VS Coil at the manufacturer's premises using developed tooling and procedures, which includes the following activities:
    - Procurement of all designed tooling and ancillary equipment in view of the coils manufacturing;
    - Preparation of assembly space in a suitable premise to simulate the VV constraints and installation of all equipment as per final In-Situ winding layout;
    - Production of required number of brackets for the LWR VS prototype;
    - Winding of all 4 turns, welding of brackets and NDT;
    - Installation of LWR VS Coil on a Jig representative to the VV rails;
    - Metrology.

Phase III – *In-Situ Installation Verification*

- Production of a short mock-up of UPR VS Coil ("3 sectors turns") and its installation in the TTTF (Trials and Test Training Facility, a specially developed facility that simulates 3 entire VV sectors to make assembly tests. The tests, to be performed in TTTF inside ITER premises, are to simulate the installation of the UPR VS Coil within analogous environment as the final installation, which includes:
    - Installation of all equipment as per final In-Situ winding layout in TTTF;
    - Production of required number of brackets for the UPR VS TTTF mock-up;
    - Winding of all 4 "3 sectors turns" and moving of formed coils turns sectors inside the TTTF;
    - Lifting of coils turns sectors as per final procedure;
    - Assembly with welding of brackets;
    - Lifting and installation of UPR VS TTTF Mock-up on the VV rails;

Phase IV – *VS Coils In-Situ Winding, Assembly and Installation*

- Production and acceptance of the required number of brackets for final manufacturing of entire LWR VS and UPR VS;
- In-situ winding of VS Coils, to be performed inside the VV in ITER premises, including:
    - Preparation of area and installation of equipment;
    - Winding and assembly of UPR VS Coil and LWR VS Coil.

The overall work is foreseen to be completed in a timeframe of around 4 and half years, here a rough indication of each phase expected duration:

- Around one year to conclude the engineering activities and to finalize the procedures foreseen in Phase I;
- Around one year to manufacture the full size LWR VS prototype and qualify manufacturing procedures;
- Around one year to perform installation verification of UPR VS TTTF Mockup and qualify installation procedures, work to be carried out in TTTF, inside the ITER premises;
- Around one and a half year to perform the final In-Situ Winding, Assembly and Installation of the VS Coils in the ITER Tokamak, work to be carried out in ITER premises.

4 Tentative Timetable

A tentative timetable as it follows:

Call For Nomination	May 2019
Pre-Qualification	June - July 2019
Call for Tender	August-September 2019
Tenders Submission	October-November 2019
Contract awarding	December 2019 – January 2020

5 Candidature

Participation is open to all legal persons participating either individually or in a grouping (consortium) which is established in an ITER Member State.

The UK is not a party to the ITER Agreement but part of EURATOM. In the most likely scenario of a BREXIT without a withdrawal agreement between the EU and the UK or a delay of the BREXIT date (no deal BREXIT), then until 30 March 2019, the UK remains a full member of the EU and until that date UK entities retain the right to participate in IO procurement procedures. However, as from 30 March 2019, should any UK bidding as a prime contractor or consortium partner, will be rejected from the procurement procedure as UK entities will no longer have the right to participate in IO procurement procedures.

A legal person cannot participate individually or as a consortium partner in more than one application or tender. A consortium may be a permanent, legally-established grouping or a grouping, which has been constituted informally for a specific tender procedure. All members of a consortium (i.e. the leader and all other members) are jointly and severally liable to the ITER Organization. The consortium cannot be modified later without the approval of the ITER Organization.

Legal entities belonging to the same legal grouping are allowed to participate separately if they are able to demonstrate independent technical and financial capacities. Bidders' (individual or consortium) must comply with the selection criteria. IO reserves the right to disregard duplicated references and may exclude such legal entities from the tender procedure.

6 Experience and key competencies

The Candidates will need to demonstrate that they have the capabilities to successfully perform the entire scope of work mentioned above and in particular:

- Previous experience in manufacturing large magnet coils and/or complex piping systems and related auxiliary equipment;
- Previous experience in developing complex tooling for coils winding and assembly;
- Previous experience in manufacturing and welding of parts in austenitic steels and/or Nickel super alloys;

- Previous experience in performing in-situ manufacturing/reparation activities, with special regard to Ultra-High Vacuum environment (space constraints, cleanliness),
- Knowledge of ASME and ISO standards the qualification of welding procedures, joint preparation, inspection and testing;
- Experience in development of high-quality welding procedures and design of joints;
- Experience in development of Non-Destructive Testing procedures for welding;
- Capability to perform qualification tests at its premises (i.e. Visual and Volumetric examinations, Pneumatic and Hydrostatic pressure tests…);
- Experience in handling, bending and cutting metallic pipes and conductors similar to the presented SSMIC;
- Experience in manufacturing components for Ultra-High Vacuum and Nuclear applications;
- Comprehension of Technical Specifications and experience in writing Manufacturing Inspection Plans and Qualification Plans;
- Understanding of all technical challenges related to the work and capability to provide alternative technical solutions if asked/required.

7 Quality Assurance (QA) requirements

The organization conducting these activities should have an ITER approved QA Program or an ISO 9001 accredited quality system.

Prior to the commencement of the task, a Quality Plan must be submitted for IO approval giving evidence of the accredited quality system and describing the organization of this task, the skill of workers involved in the study, any anticipated sub-contractors and giving details of who will be the independent checker of the activities.

Prior to commencement of any manufacturing, a Manufacturing Inspection Plan (MIP) must be approved by ITER who will mark up any planned interventions.