Technical Specifications (In-Cash Procurement)

Technical Summary for In-Vessel Edge Local Mode Coils and Feeders (ELM-IVCF) Prototyping and Tooling Manufacturing

Technical summary of the Call for Nomination documentation related to the activities for In-Vessel Edge Local Mode Coils and Feeders (ELM Coils and Feeders) Prototyping and Manufacturing.
TECHNICAL SUMMARY

IN-VESSSEL EDGE LOCAL MODE COILS AND FEEDERS (ELM-IVDF) 
PROTOTYPING AND TOOLING MANUFACTURING

Call for Nomination
Reference IO/20/19022/ACS

1 Purpose

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

The Contracts subject of the present Call for Nominations covers the Phases I and II as detailed in Section 3:

• Phase I - Procedures Finalization for ELM Coils and Feeders production and Engineering design of tooling:

• Phase II - Manufacture of Tooling and Manufacture of First of Kinds.

The following Phase will be subject to a separate contract called “ELM IVCF Production Contract”:

• Phase III - Production of ELM coils and Feeders.

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.
The ELM Coils and Feeders, object of the present Call for Nomination, comprehend all ELM Coils with associated Feeders and the In Port VS Feeders, as shown in Figure 2.

2.1 ELM Coils and Feeders Winding

The ELM Coils System is composed by 3 ELM coils by sector (27 ELM Coils) and the ELM Feeders associated.

Each sector (9 in total) supports one Lower ELM Coil, one Equatorial ELM Coil and one Upper ELM.

All ELM Coils consist of six turns each of continuous SSMIC, provided by IO, joined together by Inconel Brackets and mounted to the VV behind the BSMs on IVC rails.

Each coil is joined to its feeder lines through Joints that assure the electrical continuity and the tightness of the cooling circuit.

The Upper Coil is joined only to the In Port Feeder. The Equatorial and Lower Coils have an In Vessel Feeder between the coil and In Port Feeder.

The four Upper VS Feeders and the four Lower VS Feeders have been integrated to this contract due to the similar design.
Figure 2. IVC ELM Coils and Feeders general overview.

One key feature of the ELM 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.
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 as shown in Figure 3.

The feeders run down along and are mounted to the VV inner shell. There is a separate feeder for each of the nine sectors with each feeder powering a single ELM coil/VS turn. The design of the feeders follows the general design of the coils and uses the same conductor (see above). The feeders are routed in pairs of conductor according to the VV Rail location, always having inlet and outlet of a coil/turn together.

The feeders can be classified in 2 groups: the In-Vessel feeders and the In-port feeders. The main different is the higher nuclear heat load as well as the rail attachments.
2.2 ELM Coils and Feeders Brackets Assembly

The ELM winding pack is made of brackets clamping the 6 turns together. The ELM brackets consists of 4 main sub-parts all welded together. The structure is completed by a central comb. The details are given in Figure 5.

The bracket manufacture foresees a rough machining to nominal dimensions and a final machining according to actual dimensions of manufactured coil and supports (rails) metrology. The preload of the conductors assures correct thermal transfer during operations, brackets must be in contact with the conductor jacket under all load conditions, which include electromagnetic loads and thermal loads that act in the direction to open the contact. To maintain the contact closed the brackets must be welded under external compression.

The bracket reference material is Inconel 625 due to excellent fatigue properties and mechanical strength at elevated temperatures.

![Figure 5: Standard ELM Bracket, made by an Upper and a Lower Clamp, an Upper and Lower Housing and Combs welded together.](image)

The coils are bolted to the VV through specific VV rails. The significant manufacturing tolerances of the VV in particular on the rail imposes to drill the hole of the bracket after metrology survey of rails according to the real position and orientation of the thread rails.

The Figure 6 shows the different parts of the ELM Bolting System for the theoretical position of the VV Rail and ELM Coil.

![Figure 6: ELM coil Bolting System](image)
The Feeder Bracket design relies on bolting of the subcomponents. The details are given in Figure 7.

![Figure 7: Example of Feeder Brackets (In port Feeder Bracket on the left, In Vessel Feeder Bracket on the right).](image)

There will be in total, including prototyping phase and final production, around 1200 Elm Coil brackets and 1300 Feeder brackets to be produced in Inconel 625 alloy.

3 Scope of the work

The activities related to the production of the ELM Feeders, VS Feeders and ELM Coils are grouped into three (3) identified main Phases. Phases I and II are subject to the present Contracts. Phase III will be subject to another contract. Here below the details of all activities to be carried out.

Phase I – Procedures Finalization for ELM Coils and Feeders production and Engineering design of tooling:

- **Part 1: Procedures Finalisation for ELM Coils and Feeders production**
  - Develop ELM Coils and Feeders winding procedure;
  - Develop drilling procedure according to VV survey;
  - Develop customization procedure;
  - Develop Terminations Sealing procedure;
  - Develop Equatorial ELM Coils Terminations bending in the VV;
  - Finalise Brackets Assembly Procedures;
  - Finalise Brackets welding procedures;
  - Finalise ELM and VS Feeders Assembly Procedure;
  - Finalise ELM coils Assembly Procedure;
  - Prepare Brackets welds repair procedure;
  - Production of Feeder and Coil Brackets to validate assembly, welding, sealing and repair procedure (number of tests to be defined by supplier as part of planning);
  - Finalise Feeders and ELM coils design.

- **Part 2: Tooling Engineering design and mockup**
  - Engineering design of all ancillary equipment to winding, to assembly, to drill and to customize all the type of ELM coil and Feeder;
  - Perform preliminary trials to finalise the equipment design;
  - Final Design Review of Tooling.
Phase II – Manufacture of Tooling and Manufacture of First of Kinds:

- Part 1: MRR and Procurement of Tooling
  - MRR of all Tooling;
  - Procurement of all Tooling.

- Part 2: Manufacture of First of Kind
  - Manufacture of VS Feeder First of Kind;
  - Qualification of VS Feeder First of Kind;
  - Manufacture of One Upper ELM Coil First of Kind;
  - Qualification of Upper ELM Coil First of Kind.

- Part 3: ELM Coils and Feeders MRR
  - Feeders MRR;
  - ELM Coils MRR;

Phase III – Production of ELM coils and Feeders

- Part 1: Feeders production
  - Produce Feeders
  - Produce manufacturing documentation for Feeders
  - FAT of Feeders
  - Delivery of Feeders

- Part 2: ELM Coils production
  - Produce ELM Coils
  - Produce manufacturing documentation for ELM Coils
  - FAT of ELM Coils
  - Delivery of ELM Coils

List of equipment to provide for each phase:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Size (mm)</th>
<th>Weight (kg)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>ELM Coil Mock-up</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>02</td>
<td>In Port Feeder Mock-up</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>03</td>
<td>Terminations Sealing Mock-up</td>
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<td>TBD</td>
<td>TBD</td>
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</table>

Table 1: Quantities for the different types of equipment and materials for Phase I

<table>
<thead>
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<th>Weight</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
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<td>Tools to wind and drill the ELM coils and Feeders</td>
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<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>05</td>
<td>Tools to Bend Equatorial ELM Coil in the VV</td>
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<td>TBD</td>
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<tr>
<td>06</td>
<td>Adjustable Jig to simulate VV rails position for Upper ELM Coil</td>
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<tr>
<td>07</td>
<td>Adjustable Jig to simulate VV rails position for VS In Port Feeder</td>
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<tr>
<td>08</td>
<td>Extremity Sealing Mock-up</td>
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<td>09</td>
<td>Upper ELM Coil First of Kind</td>
<td>500x1200x4300</td>
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<td>10</td>
<td>VS In Port Feeder First of Kind</td>
<td>600x5900x1200</td>
<td>430</td>
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</table>

Table 2: Quantities for the different types of equipment and materials for Phase II
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
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<th>Weight</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Upper ELM coils</td>
<td>500x1200x4300</td>
<td>1200</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>Equatorial ELM coils</td>
<td>600x2600x3300</td>
<td>1425</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>Lower ELM coils</td>
<td>500x1200x4400</td>
<td>1325</td>
<td>10</td>
</tr>
<tr>
<td>19</td>
<td>Adjustable Jigs for ELM Coils and Feeders</td>
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<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
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<td>ELM In Port Feeder</td>
<td>1500x3800x300</td>
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<td>24</td>
<td>Equatorial ELM In Vessel Feeder</td>
<td>700x2500x300</td>
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<td>10</td>
</tr>
<tr>
<td>26</td>
<td>Lower ELM In Vessel Feeder</td>
<td>1300x5200x800</td>
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</tr>
<tr>
<td>30</td>
<td>Upper VS Feeder</td>
<td>600x5900x1500</td>
<td>340</td>
<td>5</td>
</tr>
<tr>
<td>32</td>
<td>Lower VS Feeder</td>
<td>600x5900x1200</td>
<td>430</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3: Quantities for the different types of equipment and materials for Phase III

The overall work is foreseen to be completed in a timeframe of around 5 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 and half year to manufacture the First of Kind and qualify manufacturing procedures;
- Around two year and half to perform manufacture ELM Coils and Feeders.

4 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 use ad-hoc winding machines developed from third party specialized companies;
- Previous experience in manufacturing and welding of parts in austenitic steels and/or Nickel super alloys;
- Previous experience in machining customization according to a survey;
- Previous experience in performing manufacturing/reparation activities, with special regard to Ultra-High Vacuum environment (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…);
- Capability to perform metrology of important component with high precision;
- 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.

5 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.