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EXTERNAL REFERENCE

Technical Specifications (In-Cash Procurement)

Technical Specification - Mechanical Engineering Support for ITER Vacuum Vessel Port Structures and their Interfaces with others Plant Breakdown Systems

The purpose of this contract is to provide mechanical engineering services focused on ITER Vacuum Vessel Port Structures and their interfaces with the other ITER TKM PBS (Plant Breakdown Structures). The main activities will be to perform structural and thermal analyses in order to obtain/complete/keep the intermediate Agreed Notify Body (ANB) approval of the manufacturing design and to review the design deviations coming from the manufacturers and ITER PBS interfaces (Plant Breakdown ...

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1 Purpose

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The aim of these analyses is to assess structural integrity under several normal and abnormal events considering P-type & S-type damage with regards to RCC-MR [1] according to the Vacuum Vessel Load Specifications [2].

A close collaboration with RF and KO Domestic Agencies which are in charge of the Procurements Arrangement of these VV components will be required.

2 Scope

ITER is a large experimental Tokamak device being built to research fusion power. The ITER Vacuum Vessel (VV) is one of the most important & critical systems in the ITER project.

The main components that make up the VV are the main vessel, the port structures, the in vessel coils and the VV supporting system, see Figure 1. The VV is a torus-shaped double wall structure with shielding and cooling water between the shells. The basic vessel design is an all-welded structure. Only the outer shell serves as the first plasma confinement barrier. The VV components are designed and manufactured consistent with an accepted Codes & Standards (mainly the RCC-MR [1]). The VV is divided into nine toroidal sectors joined by field welding using splice plates at the central vertical plane of alternate ports (of the odd numbers). Most of the sectors (and associated ports and gravity supports) have approximately the same design. But three sectors have different equatorial segment parts. These sectors are called “irregular sectors” and their numbers are #02, #03 and #04. The associated irregular ports have the number #04, #05 & #06. More detailed description of the ITER VV is available in [3] and some detail designs for the conceptual baseline design in November 2010 are proposed in drawing files [4].

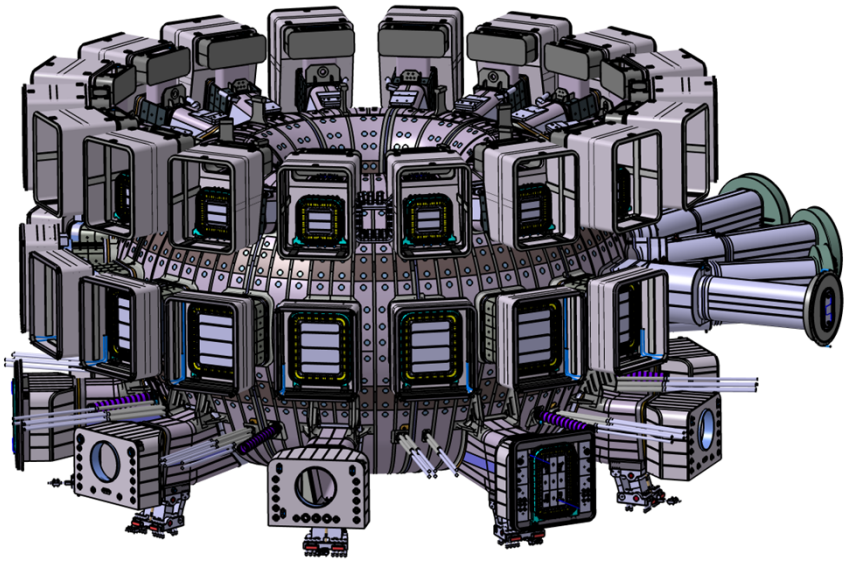

Figure 1 General view of the Vacuum Vessel & Ports, VV Gravity Supports and In Viewing Lower Penetration & Divertor Pipes

A preliminary ANB approval of this 2010 baseline VV design has been already obtained in 2013. Of course some additional design deviations have been already submitted (and will be submitted) to intermediate approvals in order to take into account the manufacturers and IO PBS interfaces requirements in waiting to obtain the final approval of the as-built design.

The scope of work of this contract concerns the VV port structures and also all interfaces linked with the ports such as port plug sealing flanges, in-vessel remote handling attachments upper port extension lifting attachment for sectors assembly and transport, etc. The objective of this work is to support the Vacuum Vessel & Thermal Shield Section in order to perform some structural and thermal, static and transient, linear and non-linear, analyses with regards to ITER Guideline for Structural Analyses [5] to reach the following objectives:

- to validate the design deviations of the VV ports structures coming from the manufacturer and ITER PBS interfaces by verification of the structural integrity with regards to RCC-MR and additional ANB requirements,
- and to obtain intermediate ANB approval for the manufacturing design of the VV ports structures concerned by the pressure boundaries.

The following tasks shall be treated:

- Completion of a global FE shell model of the whole VV including ports, plugs & bellows. Introduction of the manufacturing design modifications.
- ANB intermediate approval of the VV Port Structures Manufacturing Design using FE solid model.
- Completion of VV Port Plug Sealing Flanges structural analysis by comparison with mock-up test results.
- VV Assembly & Transport main and partial attachments.
- In-Vessel Remote Handling attachments in regular equatorial and lower ports.
- In Vessel Components supports in the VV&Ports (Excepted Blanket Modules)

Of course this list is not exhaustive and could be modified in case of critical urgent additional analysis activities to be performed during the working period.

3 Definitions

Here are the main terminology and acronyms used in this document:

APDL	ANSYS Program Development Language
AQ	Assurance Quality
FDR	Final Design Review
IO	ITER Organization
LS	Load Specification
VV	Vacuum Vessel
RFDA	Russian Federal Domestic Agency
KODA	Korean Domestic Agency
TRO	Technical Responsible Officer
DET	Design Exchange Transfer
PBS	Plant Breakdown System
TKM	Tokamak Machine

For a complete list of ITER abbreviations see: ITER Abbreviations (ITER_D_2MU6W5).

4 References

[1] RCC-MR, "Design and Construction Rules for Mechanical Components of FBR. Nuclear Island", AFCEN, Edition 2007

[2] Load Specification for the ITER Vacuum Vessel; ITER_D_2F52JY

[3] ITER Vacuum Vessel and Ports, General description in view of VV ANB control; ITER_D_2FFSQ4

[4] ITER Vacuum Vessel and Ports Drawing files (2010 Design submitted to ANB); ITER_D_2FQ8F9

[5] ITER Guideline for Structural Analyses; ITER_D_33QJSK

[6] ANSYS, Inc. Release v15.0

[7] Summary of Vacuum Vessel Materials Data for Structural Analysis; ITER_D_229D7N

[8] AQ Sheet of Finite Element Analysis – Template ITER_D_2UU4HT

5 Estimated Duration

The program of work is estimated for a maximum period of 26 months in ITER Organization site by two analysis experts.

6 Experience and profile requirements

The experience and profile requirements are set out as follows:

Ideally

- General experience of engineering calculations, mechanics and strength of materials.
- Experience in structural Finite Element analysis (static, steady-state and transient thermal, modal, dynamic and seismic) using shell and solid element types considering non-linear contact interfaces.
- Experience in ANSYS software (Mechanical & Workbench) [6]. Experience in APDL.
- Experience in thermo-mechanical analysis of pressure vessels.
- Experience in the Tokamak Systems or Fusion related systems or other Nuclear Systems.
- Experience in the analysis of fusion devices components or nuclear components of the kind used in ITER or in similar fusion devices.
- Experience in RCC-MR [1].
- Experience in preparation and/or submission of analysis report to the Agreed Notified Body (ANB) which is required by a regulator (ASN/Autorité de Sureté Nucléaire or other) as a third party inspector.
- Fluency in English both written & oral

7 Work Description

The purpose of work is to demonstrate that the VV port structures do not undergo certain types of structural damage (defined in a dedicated pressure equipment Code & Standards: RCC-MR [1]) when subjected to the postulated loading conditions defined in a dedicated Load Specifications [2]. The prevention of these damage will be done by structural analysis which consists of verifying compliance with criteria based on the analysis method considering the

event category (I, II, III & IV) and the type of allowed damage as outlined in the Design Basis following the ITER guideline [5].

The structural analysis software ANSYS Mechanical/Workbench [6] shall be used.

Some hand calculation can be envisaged, but the demonstration must be robust and its use will depend to acceptance of IO TRO.

The analysis method should follow the steps below:

1. **Preparation of analysis model:** The analysis model should be made from the CAD model delivered by DET (Design Exchange Transfer). New model creation and or revision will be required. For example if 3-D solid model is too heavy to handle, 2-D shell model or partial 2-D shell model with 3-D solid model could be used after discussion with IO TRO.
2. **Damages prevention by structural analyses (using RCC-MR [1]):**

   By elastic analyses, Primary damage should be examined and verified against proposed loads. The load should be single and combined loads. If necessary, limit analysis should be performed, especially when the highest peak stress goes up more than allowable stress. In elastic analyses, bolt preload should be applied correctly and the contact surface quality should be checked.

   If necessary, secondary type damage including ratcheting and fatigue should be verified for only category I & II events by elastic or elasto-plastic analysis considering the cyclic loads.
3. **Single & Combined loads**: Load specification will be supplied by IO. Before getting new results of loads, the analysis expert can prepare analysis model first and perform test analyses with previous loads. The previous loads will also be supplied by IO. Main loads will be as follows:
   - Gravity
   - Pressure (internal & external)
   - Testing
   - Electro-magnetic loads from Plasma disruption and Vertical Displacement events transferred mechanically to the VV by pressure, forces or displacements.
   - Seismic loads
   - Thermal (steady-state or/and transient) effect (by conduction, convection and radiation)
   - Loads from incident and accident events
   - Installation/Assembly/Transport
   - Combined loads by above loads.

Input data:

- Geometry: CAD part and/or other models (If required a Data Exchange Transfer of the updated CATIA model will be made).
- Loads shall be provided by ITER Organization. (Load specifications [2] and additional Memo's).
- Material data shall be provided by ITER Organization (Summary of Vacuum Vessel Materials Data for Structural Analysis [7]).

Output data:

The main output data (the results) shall be compiled into a comprehensive report, including the tables and figures illustrating the mechanical reactions and the distribution of stresses, strains, displacements in the analyzed part at all applied loads and load combinations.

8 Responsibilities

ITER Organization, IO:

IO will provide the needed information and access to the appropriate ITER files for executing this work when needed.

In particular, IO will make available any technical information, for example 3D models, layouts and drawings, input data for the loads, references, etc. needed for Contractor to perform the work:

- Definition of the task and the input data needed for the analysis.
- Check each model/results performed by the analysis expert with a QA sheet (see [8]).

The documents containing this information must be returned to IO on completion of the contract.

Contractor:

The Contractor appoints a responsible person who shall represent the Contractor for all matters related to the implementation of this contract. One of the analysis experts could be the responsible person.

The analysis experts will perform analyses and provide results according to the scope of the work outlined above.

The analysis experts will work in ITER Organization site during all the estimated duration, see §5.

9 List of deliverables and due dates

1st step **Submission of draft deliverable**: The analysis experts shall submit draft reports for each sub-tasks and main tasks. The reports should contain all the methodology, models and results properly according to IO's standard. This deliverable will be already submit to an internal review procedure of the contractor and shall include:

- Analysis models (DB files: Modified or Improved)
- Macros to apply boundary and loading conditions on the models (Developed in APDL).
- Draft reports to explain all the methodology & results following ITER IO's frame.
- Final reporst to take into account IO's comments.
- Two page summaries to put in the IO's VV stress report (Structural Integrity report of the VV& Ports).

2nd step **Submission of final deliverable**: Final deliverable including all the IO comments done on the draft deliverable for final approval by the IO Technical responsible Officer.

The IO Technical Responsible Officer shall review each deliverables and reply, within 15 days, with a commented version of the deliverable(s). The contractor analysts shall perform all the necessary modifications or iterations to the deliverables and submit a revised version. The contract will be considered completed after IO has accepted the last deliverable covered by the budget.

The following table gives an overview of the tasks linked with the deliverables and some proposal of due dates:

Who	Main Tasks	Sub-Tasks	Deliverable Type		Due Date (Priority order can be changed)
All	Kick-off Meeting				T0
Analysis Expert 1	A: Completion of a global FE shell model of the whole VV including ports, plugs & bellows (with irregular parts). - Based on 2010 baseline design -	Global structural assessment – Draft deliverable	#01	Step 1	T0+5.5 months
		Global structural assessment – Final deliverable	#01	Step 2	T0+6 months
	B: ANB intermediate approval of the VV irregular equatorial port structures using FE solid model. - Based on manufacturing design -	Irregular equatorial port #04 – Draft deliverable	#02	Step 1	T0+11.5 months
		Irregular equatorial port #04 – Final deliverable	#02	Step 2	T0+12 months
		Irregular equatorial port #05 & #06 – Draft deliverable	#03	Step 1	T0+17.5 months
		Irregular equatorial port #05 & #06 – Final deliverable	#03	Step 2	T0+18 months
	C: global FE shell model of the whole VV including ports, plugs & bellows (with irregular parts). - Based on main manufacturing design modifications -	Global structural assessment – Draft deliverable	#04	Step 1	T0+23.5 months
		Global structural assessment – Final deliverable	#04	Step 2	T0+24 months
Analysis Expert 2	D: VV Assembly & Transport and Remote Handling attachments (main and partial). - Based on Manufacturing design modifications and revised lifting loads	In Vessel Components remote handling – Draft deliverable	#05	Step 1	T0+1.5 months
		In Vessel Components remote handling – Final deliverable	#05	Step 2	T0+2 months
		VV Upper port lifting lugs during Assembly & Transport – Draft deliverable	#06	Step 1	T0+3.5 months
		VV Upper port lifting lugs during Assembly & Transport – Final deliverable	#06	Step 2	T0+4 months
		VV Hook during Assembly & Transport – Draft deliverable	#07	Step 1	T0+5.5 months
		VV Hook during Assembly & Transport – Final deliverable	#07	Step 2	T0+6 months
	E: Completion of VV Port Plug Sealing Flanges structural analysis by comparison with mock-up test results.	Structural Analysis of Sealing Flange Lip Seal by comparison with mock-up – Draft deliverable	#08	Step 1	T0+9.5 months
		Structural Analysis of Sealing Flange Lip Seal by comparison with mock-up – Final deliverable	#08	Step 2	T0+10 months
	F: In-Vessel Components supports based on manufacturing designs of VV&Ports (excepted Blanket Modules)	ELM&VS coils supports – Draft deliverable	#09	Step 1	T0+11.5 months
		ELM&VS coils supports – Final deliverable	#09	Step 2	T0+12 months
		ELM&VS feeders supports – Draft deliverable	#10	Step 1	T0+13.5 months
		ELM&VS feeders supports – Final deliverable	#10	Step 2	T0+14 months

Who	Main Tasks	Sub-Tasks	Deliverable Type		Due Date (Priority order can be changed)
		Blanket manifold supports – Draft deliverable	#11	Step 1	T0+15.5 months
		Blanket manifold supports – Final deliverable	#11	Step 2	T0+16 months
		Divertor rails supports – Draft deliverable	#12	Step 1	T0+17.5 months
		Divertor rails supports – Final deliverable	#12	Step 2	T0+18 months
	G: ANB intermediate approval of the lower port structures manufacturing design using FE solid model. (Mainly port extension)	Lower port remote handling – Draft deliverable	#13	Step 1	T0+20.5 months
		Lower port remote handling – Final deliverable	#13	Step 2	T0+21 months
		Lower port cryopump – Draft deliverable	#14	Step 1	T0+23.5 months
		Lower port cryopump – Final deliverable	#14	Step 2	T0+24 months
All	Close-Out Meeting				T0+24 months

10 Acceptance Criteria

All the methodology and assessments have to be fully consistent with Codes & Standard defined in the scope of work. All the related articles must be referred clearly. The reports, memorandums and QA check lists should be well enough organized to be submitted to IO. Models and macros should be well saved in IDM as electronic data.

11 Specific requirements and conditions

To improve the quality of each analysis, a first step of AQ analysis review (model, method, results…) should be done by the analysis expert himself and by the second analysis expert linked with this contract. IO AQ sheet could be used (see [8]) but a Contractor AQ document could be proposed but it should be approved by IO Technical Responsible Officer.

A second step of AQ review of the models and a review of the results must be made by IO Technical Responsible Officer. In this case IO AQ sheet must be used. These reviews must be performed before any insertion of results in reports.

The final report should be submitted in paper version and electronic format (MS WORD). Additionally, all the analysis models and APDL macros should be submitted in electronic format and should be ready to use by IO.

12 Work Monitoring / Meeting Schedule

The work will be managed by means of Analysis Progress Meetings. The Progress Meetings will be called by the ITER Organization, once per week in informal free discussion style, to review the progress of the work, the technical problems, the interfaces and the planning. The main purpose of the Analysis Progress Meetings is to allow IO TRO and the analysis experts to:

i) Allow early detection and correction of issues that may cause delays.
ii) Review the completed and planned activities and asses the progress made.
iii) Permit fast and consensual resolution of unexpected problems.
iv) Clarify doubts and prevent misinterpretations of the specifications.

In addition to the Progress Meetings, if necessary, the IO TRO and/or the Contractor may request additional formal Progress Meetings to address specific issues to be resolved.
All the documents or data prepared for Progress Meetings should be saved in the IDM, as evidence and/or back data to understand the works done by the analysis experts. For the report or presentation for the Analysis Progress Meeting, there is no special form, but they should contain clear results, conditions or problems to be solved.

Some experts from the Domestic Agencies may be invited by IO to participate in the meetings.

The following progress meetings will be foreseen:

Scope of meeting	Point of Check/deliverable	Occurrence	Place of meeting
Kick-off contract	Work program	1 meeting	IO site
Analysis Progress meetings (occur each week and can be canceled by IO)	Checking progress	Weekly	IO site
Final deliverable review meeting (summarizing all the sub-task activities to conclude a main task activities)	Checking the content of the main task	1 meeting	IO site

13 Delivery time breakdown

The payment will be done by sub-task intermediate deliverables invoicing justified by delivery of report in which all the sub-task activities have been summarized.

14 Quality Assurance (QA) requirements

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

The general requirements are detailed in ITER Procurement Quality Requirements (ITER_D_22MFG4).

Prior to commencement of the task, a Quality Plan must be submitted for IO approval giving evidence of the above and describing the organisation for 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 (see Procurement Requirements for Producing a Quality Plan (ITER_D_22MFMW)).

Documentation developed as the result of this task shall be retained by the performer of the task or the DA organization for a minimum of 5 years and then may be discarded at the direction of the IO. The use of computer software to perform a safety basis task activity such as analysis and/or modelling, etc. shall be reviewed and approved by the IO prior to its use, in accordance with Quality Assurance for ITER Safety Codes (ITER_D_258LKL).

15 Safety requirements

ITER is a Nuclear Facility identified in France by the number-INB-174 (“Installation Nucléaire de Base”).

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

In such case the Suppliers and Subcontractors must be informed that:

- The Order 7th February 2012 applies to all the components important for the protection (PIC) and the activities important for the protection (PIA).
- The compliance with the INB-order must be demonstrated in the chain of external contractors.
- In application of article II.2.5.4 of the Order 7th February 2012, contracted activities for supervision purposes are also subject to a supervision done by the Nuclear Operator.

For the Protection Important Components, structures and systems of the nuclear facility, and Protection Important Activities the contractor shall ensure that a specific management system is implemented for his own activities and for the activities done by any Supplier and Subcontractor following the requirements of the Order 7th February 2012 (available by a request).