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Contract

TechSpec Structural integrity of the ITER Vacuum Vessel Components – ANB Submission support & Design Deviation Review of the Manufacturing Design

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	<i>Name</i>	<i>Action</i>	<i>Affiliation</i>
<i>Signatory</i>	Seki F.	23 Apr 2014:signed	IO/DG/DIP/TKM/VV
<i>Co-signatories</i>	Martinez J.- M.	23 Apr 2014:signed	IO/DG/DIP/TKM/VV/VVTS
<i>Reviewers</i>	Choi C.- H.	23 Apr 2014:recommended	IO/DG/DIP/TKM/VV/VVTS
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1 Abstract

The purpose of this contract is to perform structural analysis of the interfaces components of the ITER Vacuum Vessel (VV) in order to complete/obtain the preliminary Agreed Notify Body (ANB) approval and to review the design deviations coming from the manufacturers and ITER PBS interfaces (Plant Breakdown Structure). The aim of these analyses is to assess structural integrity under several normal and abnormal events considering P-type & S-type damage according to the Vacuum Vessel Load Specifications (VV LS) [6] with regards to RCC-MR [1].

The ITER Vacuum Vessel components concerned by this task are mainly the following:

- In Vessel Coils
- In Wall Shielding
- VV Gravity Support
- VV Assembly&Transport main and partial attachments
- Remote Handling attachments
- Divertor Rails
- In Viewing Lower Penetrations & Divertor pipes

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.

2 Background

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 C&S (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).

All sectors have approximately the same design of the ports including gravity support. But three sectors have different equatorial segment parts. These sectors are called “irregular sectors” and their numbers are #02, #03 and #04. All the detail designs are explained in the ITER Vacuum Vessel & Ports Drawing Files defined for the conceptual baseline design in November 2010.

A preliminary ANB approval of this 2010 baseline VV design has been already obtained in 2013. In addition some design deviations have been already submitted (and will be submitted) in order to take into account the manufacturer and IO PBS interfaces requirements and will be also submitted to the ANB approval.

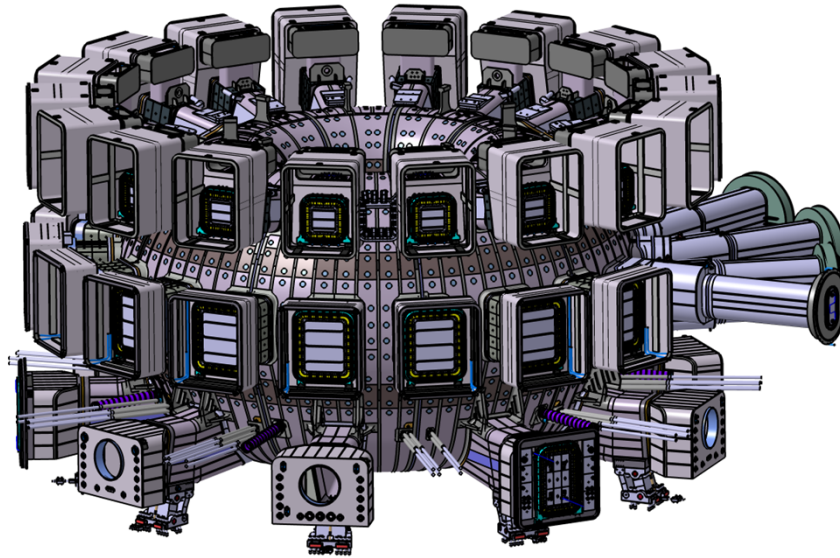


Figure 1 General view of the Vacuum Vessel & Ports, VV Gravity Supports and In Viewing Lower Penetration & Divertor Pipes

3 Scope of Work

The scope of work concerns the ITER Global Main Vessel (and also local VV components such as In Wall Shielding, In Vessel Coils, Gravity Support, Lifting Hook etc.). The objective of this work is to support the Vacuum Vessel Section in order to perform some analyses with regards to ITER Guideline for Structural Analyses [9] to reach the following objectives:

- to validate the design deviations of the VV components 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 preliminary ANB approval for the manufacturing design of the VV components concerned by the pressure boundaries.

4 Estimated Duration

The program of work is spread in 2 periods with a maximum of 24 months (including vacations).

1. First period: one Contractor's expert analyst is required during 200 working days (8 months).
2. Second period (optional): one Contractor's expert analyst is required during 200 working days (12 months). The decision will be given in writing based on IO decision the end of the first period.

5 Experience and profile requirements

The experience requirements are the following:

- Structural analysis of the pressure vessels considering pressure, seismic and electromagnetic loads.



- Thermo-mechanical analysis of the pressure vessels considering nuclear heating loads (steady-state and transient assumption).
- Experience in the Tokamak Systems or Fusion related systems or other Nuclear Systems.
- Experience in ANSYS software (Mechanical & Workbench). Experience in APDL is mandatory.
- RCC-MR and/or ASME Section VIII Div.2 codes (see [1] and [2])
- 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

6 Work Description

The purpose of analyses needed to the task described in chapter 3 is to demonstrate following the specific ANB requirements that a component (class 1 according to RCC-MR, like the Vacuum Vessel) does not undergo certain types of structural damage (P-type and S-type) when subjected to the loadings. The structural analysis consists of verifying compliance with criteria based on the analysis method considering the category (I, II, III & IV) and the type of damage. For this task, three methods of analysis could be used to determine stress, strain, and displacement of significant quantities and to compare these quantities with the maximum allowable values: Elastic analysis, Limit analysis & Elasto-plastic analysis.

The analyses should be done with the FEM software ANSYS, see [3]. 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). The solid model is recommended for the analysis. Additional new model creation will be welcomed. 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. P type damage verification: By elastic analyses, P type 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.
3. S type damage verification: If necessary, S type damage including progressive deformation and fatigue should be verified for only category I & II events by elastic or elasto-plastic analysis considering the cyclic loads.
4. Single & Combined loads: Load specification will be supplied by IO. Before getting new results of loads, the Contractor's analyst 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
- Electro-magnetic loads from Plasma disruption and Vertical Displacement events transferred mechanically to the VV by pressure or forces.
- Seismic loads
- Thermal effect (by conduction, convection and radiation)
- 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. (Refer to the Load specifications [6] and additional Memo's.)
- Material data shall be provided by ITER Organization. (Refer to the Summary of Vacuum Vessel Materials Data for Structural Analysis [5].)

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. Because of this report would be susceptible to be submitted directly at the ANB, some updates should be envisaged taken into account the ANB comments.

7 Responsibilities (including customs and other logistics)

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's analyst to perform the work:

- Location, desk and computer with ANSYS software.
- Definition of the task and the input data needed for the analysis.
- Check each model/results performed by the Contractor's analyst 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, the Contractor's responsible analyst, who shall represent the Contractor for all matters related to the implementation of this contract.

The Contractor's analysts will perform analyses and provide results according to the scope of the work outlined above; an assessment of the conceptual design can be envisaged and an improvement of the design proposed if needed.

The Contractor's analysts shall work in ITER Organization on site with IO Technical Responsible Officer to facilitate a close communication.

8 List of deliverables and due dates (proposed or required by ITER)

The contractor's analysts shall submit draft and final reports. The report should contain all the methodology, models and results properly according to IO's standard.

The IO Technical Responsible Officer shall review the deliverables and reply, within 10 days, with a commented version of the deliverable(s). The Contractor's 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.

Deliverables as follows:

- Analysis models (DB files: Modified or Improved)
- Macros to apply loads on the models.
- Draft report to explain all the methodology & results following ITER IO's frame.
- Final report to take into account IO's comments.
- Two page summaries to put in the IO's stress report.

9 Acceptance Criteria (including rules and criteria)

All the methodology and assessments have to be fully consistent with RCC-MR, see [1]. All the related articles in [1] must be referred clearly. The reports, summary sheets and QA check list should be well enough organized to be submitted directly to the ANB. Models and macros should be well saved in IDM as electronic data.

10 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 Contractor's analyst himself and by another analyst coming from the VV Analysts Team. 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.

11 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 Contractor's analyst to:

- i) Allow early detection and correction of issues that may cause delays.
- ii) Review the completed and planned activities and assess 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 Contractor's analysts. 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.

For each Contract, the following meetings should 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 draft deliverable review meeting	Checking the content	1 meeting	IO site

12 Payment schedule / Cost and delivery time breakdown

The payment will be done by monthly invoicing justified by delivery of monthly report in which the list of deliverables will be inserted (if any).

13 Quality Assurance (QA) requirement

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 document [ITER Procurement Quality Requirements \(22MFG4\)](#). Prior to commencement of the task, a Quality Plan [Quality Plan \(22MFMW\)](#) 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.

[The VV is a SIC Quality Class 1 component.](#)

Prior to commencement of any manufacturing, a Manufacturing & Inspection Plan [Manufacturing and Inspection Plan \(22MDZD\)](#) must be approved by ITER along with who will mark up any planned interventions.

Deviations and Non-conformities will follow the procedure detailed in IO document [MQP Deviations and Non Conformities \(22F53X\)](#)



Prior to delivery of any manufactured items to the IO Site, a Release Note must be signed [MQP Contractors Release Note \(22F52F\)](#).

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, it should fulfil IO document on Quality Assurance for ITER Safety Codes [Quality Assurance for ITER Safety Codes \(258LKL\)](#).



14 References / Terminology and Acronyms

- [1] RCC-MR, “Design and Construction Rules for Mechanical Components of FBR. Nuclear Island”, AFCEN, Edition 2007
- [2] ASME SECTION VIII Div.2 ‘ ‘ Rules for Construction of Pressure Vessels – Alternative rules’ ’ Ed 2010
- [3] ANSYS, Inc. Release 11.0 or 12.0 - Documentation for ANSYS.
- [4] Design Description Document 1.5 Vacuum Vessel; [ITER_D_22FPWQ](#)
- [5] Summary of Vacuum Vessel Materials Data for Structural Analysis; [ITER_D_229D7N](#)
- [6] Load Specification for the ITER Vacuum Vessel; [ITER_D_2F52JY](#)
- [7] ITER Vacuum Vessel and Ports, General description in view of VV ANB control; [ITER_D_2FFSQ4](#)
- [8] AQ Sheet of Finite Element Analysis – Template [ITER_D_2UU4HT](#)
- [9] ITER Guideline for Structural Analyses; [ITER_D_33QJSK](#)

IO	ITER Organization
VV	Vacuum Vessel
DDD	Design Description Document
LS	Load Specification
APDL	ANSYS Program Development Language
AQ	Assurance Quality
DCR	Design Change Request
ANB	Agreed Notify Body
TRO	Technical Responsible Officer