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Technical Specifications (In-Cash Procurement)

TechSpec Mechanical Engineering Services for Vacuum Vessel and Pressure Suppression System

The purpose of this contract is to perform analyses on two main components of the ITER Tokamak Vessel:• firstly, the Vacuum Vessel Pressure Suppression System (VVPSS) Relief Piping in order to satisfy the structural analyses requirement of the final design review and for procurement finalization;• and secondly, the Vacuum Vessel (VV) itself 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) by structural, thermal and thermal-hydraulic analyses.

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TechSpec Mechanical Engineering Services for Vacuum Vessel and Pressure Suppression System (P7D2LV_v1_1)	v1.1	Approved	09 Jul 2014	Modification of the estimated duration.
TechSpec Mechanical Engineering Services for Vacuum Vessel and Pressure Suppression System (P7D2LV_v1_0)	v1.0	Approved	14 May 2014	

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1 Abstract

The purpose of this contract is to perform analyses on two main components of the ITER Tokamak Vessel:

- firstly, the Vacuum Vessel Pressure Suppression System (VVPSS) Relief Piping in order to satisfy the structural analyses requirement of the final design review and for procurement finalization;
- and secondly, the Vacuum Vessel (VV) itself 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) by structural, thermal and thermal-hydraulic analyses.

2 Background and Objectives

ITER is a large experimental Tokomak device being built to research fusion power. The ITER Vacuum Vessel (VV) is one of the most important & critical systems in the ITER project due to its Nuclear Pressure Equipment nature. The device is normally operated under vacuum conditions, but due to the presence of high temperature and water cooled components, there is a possibility for pressurization. The ITER Vacuum Vessel Pressure Suppression System (VVPSS) is designed to protect the VV from over pressurization caused by in-vessel coolant leakage.

The objectives of this contract are to provide the ITER Organization with mechanical engineering services regarding structural, thermal and thermal-hydraulic analysis.

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 focused mainly on neutral beam injection system.

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.

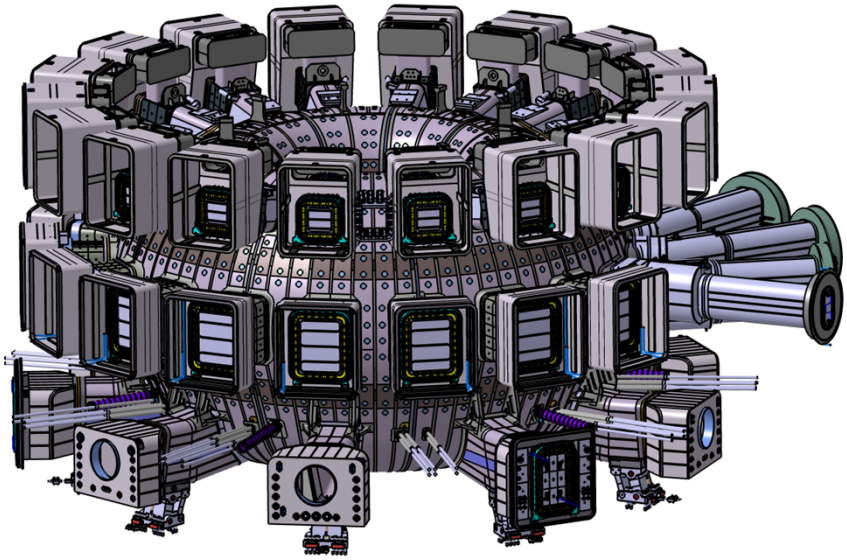
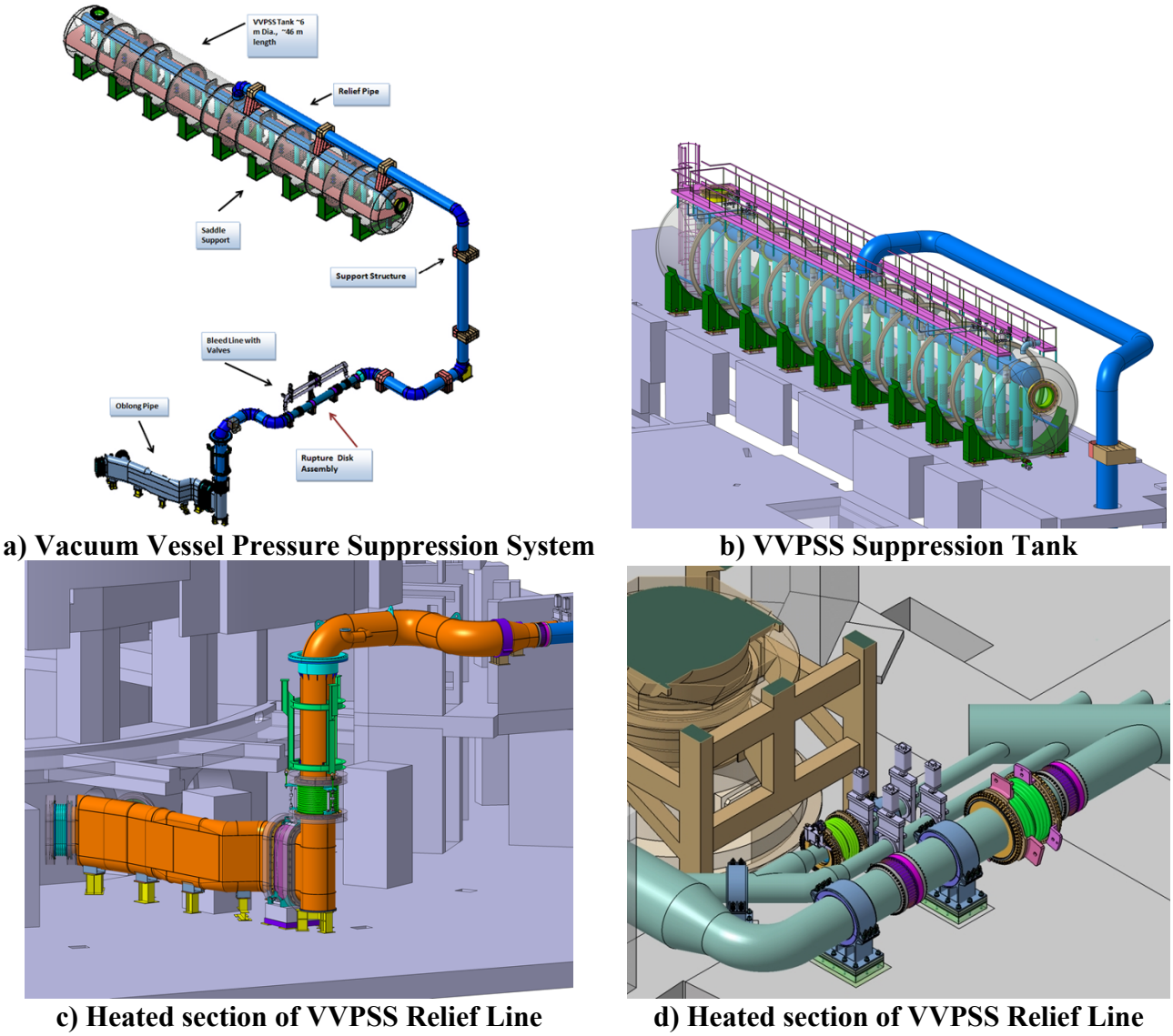


Figure 1 General view of the Vacuum Vessel

The Vacuum Vessel Pressure Suppression System (VVPSS) as shown in Figure 2 a limits the VV internal pressure, in the case of loss of coolant from the in-vessel components, to 0.15 MPa. This is a safety function as a large internal pressure could lead to a breach of the primary confinement barrier.

- The VVPSS includes a large linear tank of ~46 m length and 6.0 m diameter, containing water (~ 675 t at $<30^0$ C) to condense the steam resulting from the most adverse in-vessel coolant leak.
- The tank (see Figure 2b) is connected to the Vacuum Vessel through the Relief Line. Due to project requirements, the Relief Line is relatively long ~100m and has several turns and transitions. This relief line incorporates double rupture disc assemblies which constitute the vacuum boundary between the Vacuum Vessel and the suppression tank during normal operation.
- The relief line (see Figure 2c) also includes a bypass system for the rupture discs, consisting of bypass pipes containing isolation valves, which are designed to open during incidents when the Vacuum Vessel pressure is less than the opening pressure of the rupture discs. As this relief line is connected to the primary vacuum, it is required to be baked to 200°C for a section. The resulting thermal expansion and support requirements shall be considered in this analysis.
- The connection of this system to the ITER Vacuum Vessel is through a high aspect ratio section of pipe which is required due to interface and space requirements (see Figure 2d). The unique shape and heating requirements of this pipe shall be considered. It can be seen that this section of piping is not well aligned with conventional ASME code calculations. Nevertheless; the piping and bellows shall be covered by this structural integrity report and code assessment.



a) Vacuum Vessel Pressure Suppression System **b) VVPSS Suppression Tank**

c) Heated section of VVPSS Relief Line **d) Heated section of VVPSS Relief Line**

Figure 2: 3D View of Vacuum Vessel Pressure Suppression System

3 Scope of Work

The tasks are to provide the ITER Organization with engineering services in order to complete the analyses of:

- Firstly, the VVPSS Relief Piping to satisfy the requirement of the final design review and for procurement finalization by structural analysis with regards to ASME B31.3 using CAESAR software (The analysis if the Oblong “non-standard” piping and the Suppression Tank are definitely not included in this scope of work. Only the interfacing loads to these components need to be considered.)
- and secondly, the Vacuum Vessel (VV) itself 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) by structural, thermal, thermal-hydraulic analyses with regards to RCC-MR using ANSYS Mechanical & CFX software.

The scope of this task includes also some various contributions of specialised services in different mechanical engineering fields which could be depend to the professional experience of the Contractor's expert analyst.

4 Estimated Duration

The program of work is spread with a maximum of 12 months (including vacations) for one Contractor's expert analyst required during 200 working days in IO site.

5 Experience and profile requirements

The experience requirements are the following:

- **Experience in Structural Finite Element Analysis (linear and nonlinear, thermal, seismic etc.). Knowledge of engineering calculations, mechanics, strength of materials, analysis of mechanical components, piping support structures, bellows and pressure vessels codes has to be demonstrated during the professional experience.**
- **Experience in ANSYS software (Mechanical/Workbench/CFX) is mandatory.**
- **Experience in CAESAR II software is mandatory.**
- **Experience to apply the design rules defined in RCC-MR, ASME Section VIII Div.2 and ASME B31.3 Category M codes (see [1], [2] & [3])**
- Experience in Thermal Hydraulic Analysis will be considered as an advantage.
- 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 would be an advantage.
- Experience in the analysis of fusion devices components or nuclear components, knowledge of the ITER project and major systems of ITER will be considered as an advantage.
- Sufficient experience with CATIA v5 to interact with the design office.
- Sufficient experience to deliver the scope of work with independent autonomy.
- Fluency in English

6 Work Description

The purpose of work is to demonstrate that a component does not undergo certain types of structural damage when subjected to the postulated loading conditions and keep its coolant performance:

- The structural analysis 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 [9].
- The thermal hydraulic analysis consists to confirm an adequate coolant behavior during normal operation and baking

The analyses should be done with the following software:

- Preliminary by CAESAR II for piping system. The additional analysis shall be done with the FEM software ANSYS. As sections of the VVPSS are supported by sliding

supports, special attention shall be given to applying boundary conditions correctly in these areas.

- by ANSYS Mechanical/Workbench for all the other structural assessments.
- by ANSYS CFX for the thermal-hydraulic analysis.

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). 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. **Damages prevention by structural analyses:**
   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. **Coolant performance assessment by thermal-hydraulic analyses:** The evaluation of the hydraulic performance of the water cooled parts will be evaluated by observation of temperatures and water flow parameters (e.g., the flow velocities, pressure drops, heat transfer coefficient etc.).

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
   - Testing
   - Electro-magnetic loads from Plasma disruption and Vertical Displacement events transferred mechanically to the VV by pressure or forces.
   - Seismic loads
   - Thermal (steady-state or/and transient) effect (by conduction, convection and radiation)
   - Thermal hydraulic loads from incident and accident events
   - Installation/Assembly
   - 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 [5], [6], [7] and additional Memo's.)
- Material data shall be provided by ITER Organization. (Refer to the Summary of Vacuum Vessel Materials Data for Structural Analysis [4].)

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 to perform the work:

- 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, 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 preliminary design can be envisaged and an improvement of the design proposed if needed.

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

For each main topics, the list of deliverables is the following:
Deliverable #01: The contractor's analysts also shall submit draft reports summarizing the analysis activities described above. The reports should contain all the methodology, models and results properly according to IO's standard. This deliverable will include:

- Analysis models (All files: Modified or Improved.)
- Macros to apply loads on the models.
- Draft reports to explain all the methodology & results. .

This deliverable is expected to be submitted approximately 5 months after the Kick-Off meeting.

Deliverable #02: Final deliverable including all the IO comments concerning the Deliverable #01 for final approval by the IO Technical responsible Officer. This deliverable is expected to be submitted approximately 1 month after the submittal of Deliverable #01.

The IO Technical Responsible Officer shall review the deliverables and reply, within 10 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.

9 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, 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 Cryostat or Vacuum Vessel 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.

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.

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 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 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.

The following progress meetings will be foreseen:

Scope of meeting	Deliverable type (see §8)	Point of Check/deliverable	Occurrence	Place of meeting	Due Dates (T0:Kick-off meeting)
Kick-off contract	Minutes	Work program	1 meeting	IO site	T0
Analysis Progress meetings (occur each week and can be canceled by IO)	-	Checking progress	Weekly	IO site	
Draft Relief Piping Structural Integrity Report	#1	Document review	1 meeting	IO site	TO+5months
Relief Piping Structural Integrity Report Final deliverable	#2	Revision review	1 meeting	IO site	TO+6months
VV Component Analysis Report	#1	Document review	1 meeting	IO site	TO+11months
VV Component Analysis Report Final Deliverable	#2	Revision review	1 meeting	IO site	TO+12months

12 Payment schedule / Cost and 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) and the number of working days.

13 Task Management

13.1 Resources

The Contractor will provide dedicated resources for this contract. This analyst(s) will be dedicated fully to this contract to fulfil the sub tasks.

13.2 Work Plan and Progress Reports

The work plan will be suggested by ITER IO at each time along the schedule. The plan could be changed with very short notice or without any previous notice according to the analysis work situation. Nevertheless, the requested work plan will be limited within subtask activities described in the Annex 1.

The work will be managed by means of weekly progress Meetings and/or formal exchange of documents transmitted by emails which provide detailed progress. Progress Meetings will be called by the ITER Organization, to review the progress of the work, the technical problems, the interfaces and the planning.

The main purpose of the Progress Meetings is to allow the ITER Organization/VVPSS Technical Responsible Officer and the Contractor Technical Responsible Officers to:

a) Allow early detection and correction of issues that may cause delays;
b) Review the completed and planned activities and asses the progress made;
c) Permit fast and consensual resolution of unexpected problems;
d) Clarify doubts and prevent misinterpretations of the specifications.

In addition to the Progress Meetings, if necessary, the ITER Organization and/or the Contractor may request additional meetings to address specific issues to be resolved. Experts from the Domestic Agencies may be invited by ITER Organization to participate in the meetings.

For all Progress Meetings, a document describing tasks done, results obtained, blocking points must be written by the engineer. All the documents or data prepared for Progress Meetings should be saved in the ITER Document Management System, as evidence and/or back data to understand the works done by the contracted 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. This is a requirement of the French Quality Order 2012 and is required for ITER Safety relevant components.

13.3 Contract Changes

The change of Contract, requested by ITER Organization or the Contractor, may be possible during the execution of the work, provided that the total cost of the contract does not change. However, for any change, explicit agreement shall be signed between ITER Organization and the Contractor in accordance with the administrative rules stated in the Section 8 (Administration) of this agreement. This rule also applies to changes on the project plan, starting date of activities and subtasks, if any, and on the delivery date of the deliverables. Changes to the contract schedule shall be requested and processed within the original duration of the contract.

13.4 Information and Documentation Management

The official correspondence and documentation related to the execution of the contract, and all intermediate and final reports shall be stored and managed using IDM.

14 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).

15 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] ASME B31.3, "Code for Pressure Piping, Section on Power Piping", Ed 2007
[4] Summary of Vacuum Vessel Materials Data for Structural Analysis; ITER_D_229D7N
[5] Load Specification for the ITER VVPSS; ITER_D_34Q3WT
[6] Load Specifications (ITER_D_222QGLv6.0)
[7] Load Specification for the ITER Vacuum Vessel; ITER_D_2F52JY
[8] AQ Sheet of Finite Element Analysis – Template ITER_D_2UU4HT
[9] ITER Guideline for Structural Analyses; ITER_D_33QJSK

APDL	ANSYS Program Development Language
AQ	Assurance Quality
FDR	Final Design Review
IO	ITER Organization
LS	Load Specification
NB	Neutral Beam
SIR	Structural Integrity Report
VV	Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System