Codes and Standards for ITER Vacuum Vessel

VACUUM VESSEL

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AREVA NP
Introduction

ITER VV Safety function and regulation requirements

Code Addendum covering ITER VV

Status of ITER Addendum and RCC-MR 2007

Supporting R&D programme
Introduction: Why shall we use C&S?

- Use of an existing Code for design and construction of a safety classified component provides several advantages which are important for the acceptance by any Safety Authority.

- A main advantage is the rationale of the organization of rules covering material procurement, design and analysis rules, fabrication, welding & examination.

- For instance, the goal of the rules is to obtain and work materials to produce parts and components which have properties equal or better than the data used is the design and prevent from defects that may further significantly affect their strength.

- At each step are provided general rules and specific rules based on feedback from relevant industrial experience or which can be anticipated.

- This provides an overall consistency to guarantee the structural integrity of a component.

- Continuous feedback from experience (Update of the Code)

- Makes easier relationships between Sub-contractors, Manufacturers and S/A
The primary functions of the Vacuum Vessel (VV) are to provide a high quality vacuum for the plasma, as well as the first confinement barrier of radioactive materials. The decay heat of all the in-vessel components can be removed by the natural circulation of water in the VV cooling loops.

The VV is hence a safety classified component.

The VV is a double-chamber equipment belonging to a Nuclear Basic Facility that contains radioactive inventory (inside water chamber and inside plasma chamber) larger than 370 MBq.

The water chamber is a Cat IV pressure equipment.

The VV is hence a Nuclear Pressure Equipment according to ESPN Order dated 12th December 2005.
Code Addendum covering ITER VV – Why?

**ITER VV main peculiarities:**
- Complex geometry
- Double wall welded structure
- Large extent of One sided welds – some with no back-side access (e.g. Splice at field joint, ribs at outer shell, ..)
- Extensive application of U.T for Stainless Steel welds in lieu of Radiographic Examination with access limitations involving need to implement new methods
- Possible use of Photo Thermal Camera instead of LPT for compatibility with high vacuum requirements
- Large number of permanent attachments
- Possible laser welding application
- Suitable rules for bolts (pressure retaining is not main purpose)

**Inherent access restrictions will make strict application of ESP/ESPN requirements for pressure test and ISI impossible (not directly within the Code)**
Europe has been involved in the preparation of a Code Addendum covering the peculiarities of ITER VV

The first step was a peer review of C&S proposal made by ITER

It was found that a mix of Nuclear and Non Nuclear sections of Codes was not suitable for this SIC component

The selection of RCC-MR implied less technical difficulties and amendments in particular:

- ITER Grade material is derived from Superphenix Grade 316 L(N) and covered by specification within RCC-MR. Associated design stress Sm of 130 Mpa at 200°C is suitable for the VV design. Conversely, this material is not covered by ASME.
- Design rules for welds found in RB 3800 for Class 1 box type structures can be derived for the double wall structure of the Vacuum Vessels. RB3800 section covers components with double shell and internal ribs connecting the two shells with or without leak tightness function is relevant to the ITER VV case.
- Even if no existing Nuclear Code is covering past experience on fusion devices Vacuum Vessels, many of the problems of application of design and construction rules are common to several technologies and relevant to ITER VV case.
Status of ITER Addendum and RCC-MR 2007

Introduction of European (Harmonized) Standards

Requirements of ESP/ESPN

ITER VV needs including comments to Draft Addendum

RCC-MR 2007
Status of ITER Addendum and RCC-MR 2007

- **Introduction of European Harmonized Standards**
- **RCC-MR 2007**

- **Detailed Review of 2002 Edition to check the adequacy of new Standards**
  - **Every section of the code involved:**
    - Section 2 (Materials)
    - Section 3 (NDE)
    - Section 4 (Welding)
    - Section 5 (fabrication)
    - Section 1 partly impacted: tensile characteristics (A3)
Facilitate the compliance to the regulation

Addition of a specific appendix A18 for equipments submitted to the Pressure regulation
- Non mandatory appendix

Organization of A18:
- Definitions, Principle of classification, role of parties, technical documents to provide
- Prescriptions for ESP, ESP N1, N2, N3....for design, fabrication, NDE, materials
- Hydrostatic Pressure Test

Requirements considered in the code are recalled in a table

The requirements not considered in the code shall be dealt with in the Equipement Specification
# Status of ITER Addendum and RCC-MR 2007

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Vacuum Vessel – Benoît GIRAUD

ITER proposed classification

VV is a double chamber pressure vessel component (P_{plasma} < 0.2 \text{ Mpa}, P_{water} \text{ up to } 3\text{MPa})

Radioactivity inventory/release:
1. Water loops: Depending on assumed coefficient of 1/1000 for ^{16}\text{N} and ^{17}\text{N} isotopes, the nuclear level of vacuum vessel is either N2 (> 370 \text{ GBq}) or N3.
2. Plasma chamber: relevant from N2 but low pressure

Proposed classification: to be further confirmed

ESPN N2 cat IV was assumed

Associated RCC-MR classification: Level 2, box type structure RC 3800 consistent with VV design approach
Status of ITER Addendum and RCC-MR 2007

RAEVA

ITER VV Needs

• Rules for bolts (RB 3280 +A6)
• Materials
• Electron Beam and Laser welding
• Pressure test
• Rules for box structures + NDE (RC 3800+RC4000)

What remains very specific to ITER VV: A19
• Detailed categorization of welded joints
• Special rules for Permanent attachments, sealing welds, Cu coating,
• Use of alternative NDE methods (U.T and PTC),
• Low Co materials
ITER classified as a class 2 welded box-type structure which allows to reflect the double shell assembly and to categorize the type of authorized welded joints

**Inner shell: Cat1**
- Full penetration (no permanent strip)

**Outer shell: Cat 2**
- = Cat 1 + one sided angle weld

**Internals main ribs: Cat3**
- = Cat 2 + permanent backing strip

**Others (brackets): Cat4**
- = Cat 3 + partial penetration welds
Ex. Associated NDE requirements

**Inner shell/Outer shell:**
- Cat1 & Cat 2
  - 100% RX or U.T alternative

**Internals main ribs:** Cat3
- 10% volumetric

**Others (brackets):** Cat4
- No volumetric examination

### Table 7720

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<th>Type of welded joint</th>
<th>Examinations</th>
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<th>Non destructive examination</th>
<th>Criteria</th>
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<tr>
<td>1.1 Butt welded joint (outer face accessible)</td>
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Volumetric examination: radiography or ultrasound
Surface examination: radiography, magnetic particle, ultrasonic, ultrasonic, magnetic particle
Main deviations to Code practices are on **NDE** and especially on U.T examination of one-sided austenitic steel welds involving alternative methods to standard reflection (creeping wave, tandem, ? Phased-array,...)

The **R&D programme on U.T and PTC** examination must be continued and actual qualification steps activated up to a level sufficient to gain confidence on the applicable methods and associated performances.

In addition, limited access possibilities for inspection during pressure test and for In-Service Inspection call for the development of a set of compensatory measures mainly based on load following and monitoring and global tests which sensitivity is to be assessed.
**PART 1 : History of RCC-MR**

1\textsuperscript{st} edition of RCC-MR \quad June 85  
1\textsuperscript{st} addendum \quad November 87  
2\textsuperscript{nd} addendum \quad May 93  
2\textsuperscript{nd} edition of RCC-MR \quad June 93  
3\textsuperscript{rd} edition of RCC-MR \quad 2002 (FR/EN)  
4\textsuperscript{th} edition of RCC-MR \quad 2007 (FR/EN)

The RCC-MR has been presented to French Safety Authorities  
And used for:  
- the construction of one spare IHX for SPX1,  
- the design and construction of the new Fuel Storage Tank of SPX1,  
- The design of European Fast Reactor,  
- The studies for the lifetime extension of PHENIX and procurement of several spare components (Heat Exchangers, Pumps, Tanks, pipes,...)  
- The Indian PFBR  
- Several Advanced Fission Reactor projects