

***INSPECTION
AND
CONFORMITY ASSESSMENT
OF THE
ITER REACTOR (VACUUM) VESSEL***

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Inspection of Nuclear Pressure Equipment

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VINCOTTE



- VINCOTTE PROVIDES MORE THAN 130 SERVICES
- BRANCHES IN 14 COUNTRIES
- MORE THAN 2500 EMPLOYEES WORLDWIDE
- VINCOTTE IS ACTIVE IN THREE DOMAINS :

SAFETY / QUALITY / ENVIRONMENT

- SERVICE TYPES :

CERTIFICATION / INSPECTION / ADVICE / TRAINING

- SELECTION FROM THE FIELDS OF EXPERTISE :

LIFTING / ELECTRICITY / PRESSURE / NDT/

CIVIL ENGINEERING / ENVIRONMENT / ...

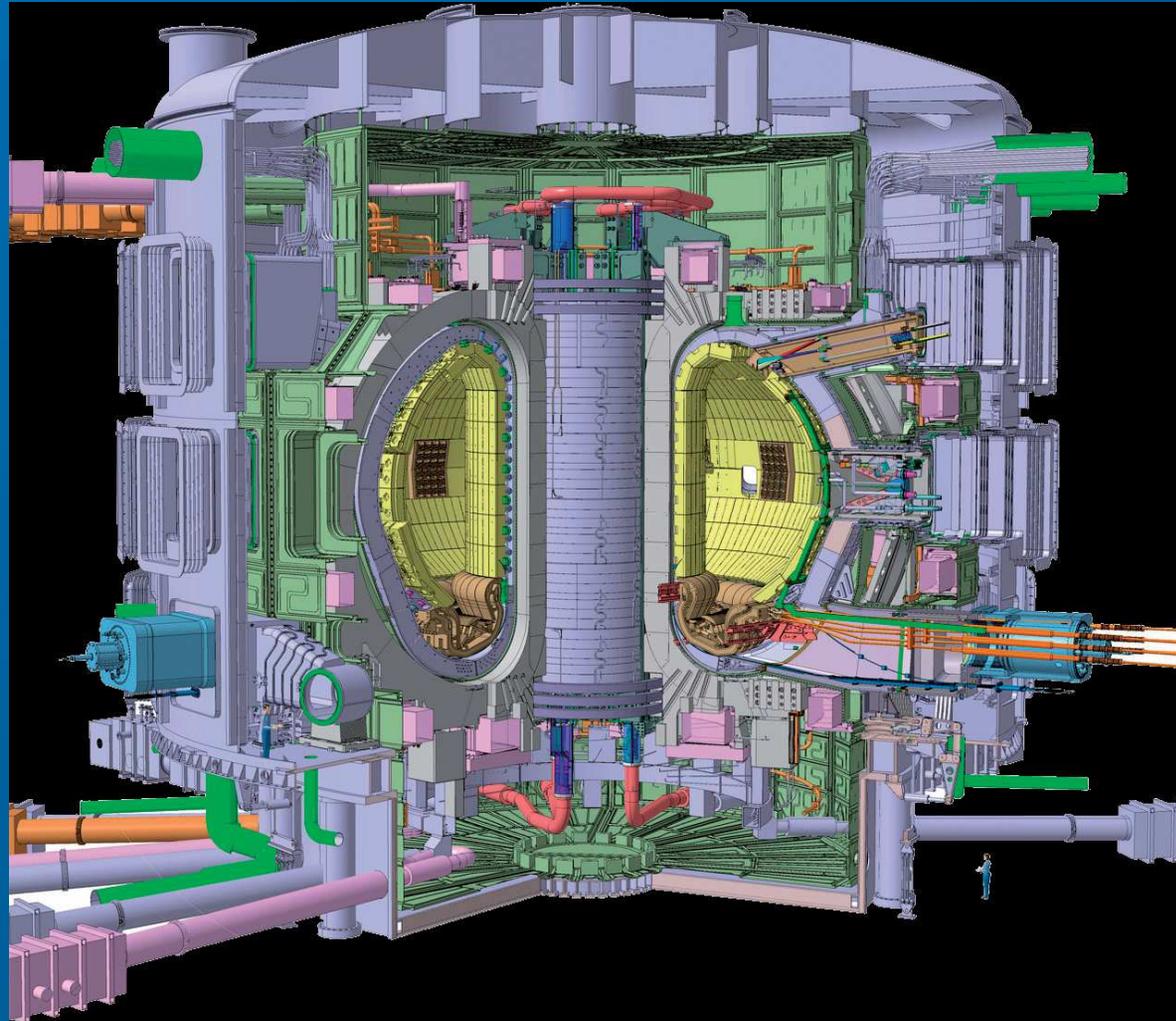
VINCOTTE



INSPECTION OF NUCLEAR PRESSURE EQUIPMENT

- **AUTHORIZED IN BELGIUM FOR INSPECTION OF NUCLEAR PRESSURE EQUIPMENT DURING :**
 - > NEW CONSTRUCTION (ASME III TRANSPOSED)
 - > REPAIR / REPLACEMENT (ASME XI TRANSPOSED)
 - > IN SERVICE INSPECTION (ASME XI TRANSPOSED)
 - NPP DOEL / TIHANGE / SCK-MOL
- **AUTHORIZED IN FRANCE FOR INSPECTION OF NUCLEAR PRESSURE EQUIPMENT ACCORDING ESPN ORDER OF THE 12th DECEMBER 2005.**
 - NPP ITER : Vacuum Vessel, Drain Tanks
 - NPP EPR-FLAMANVILLE : MFIV / MSIV

ITER TOKAMAK

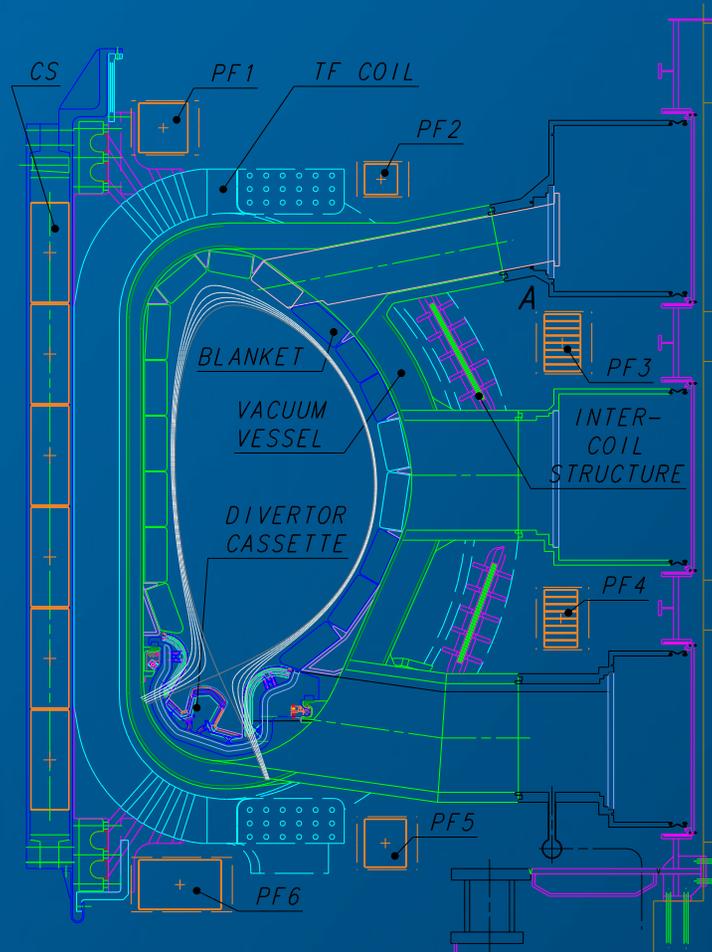


ITER TOKAMAK



Major components

- Toroidal Field Coils
- Poloidal Field Coils
- Central Solenoid
- Vacuum Vessel
- Ports
- Support Structure
- Blankets
- Divertors
- Cryostat
- Thermal shield

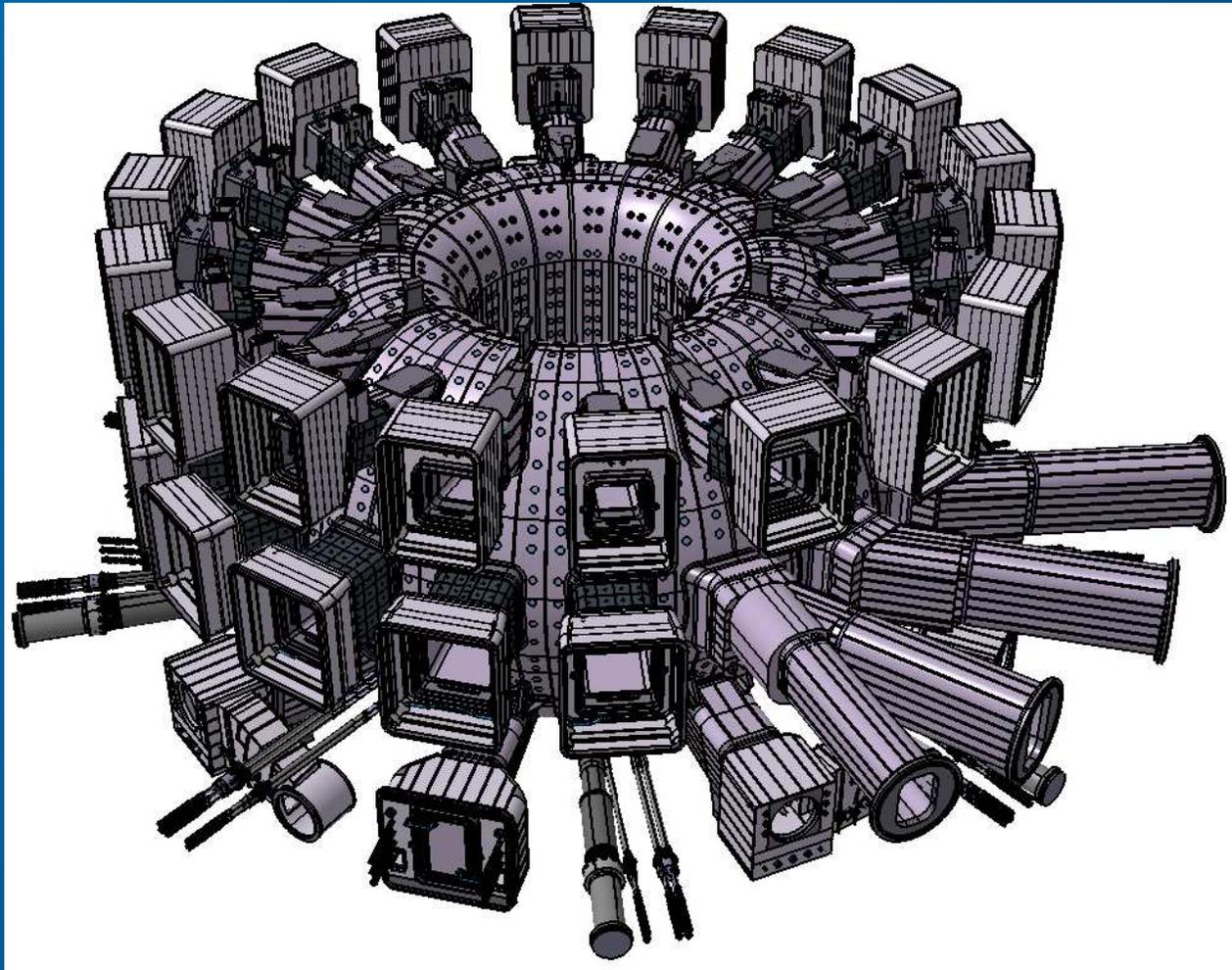


ITER VACUUM VESSEL

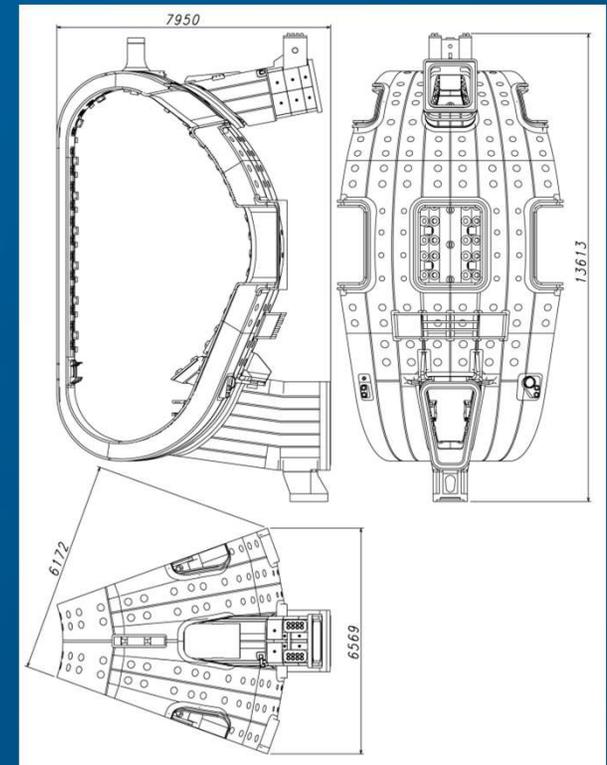
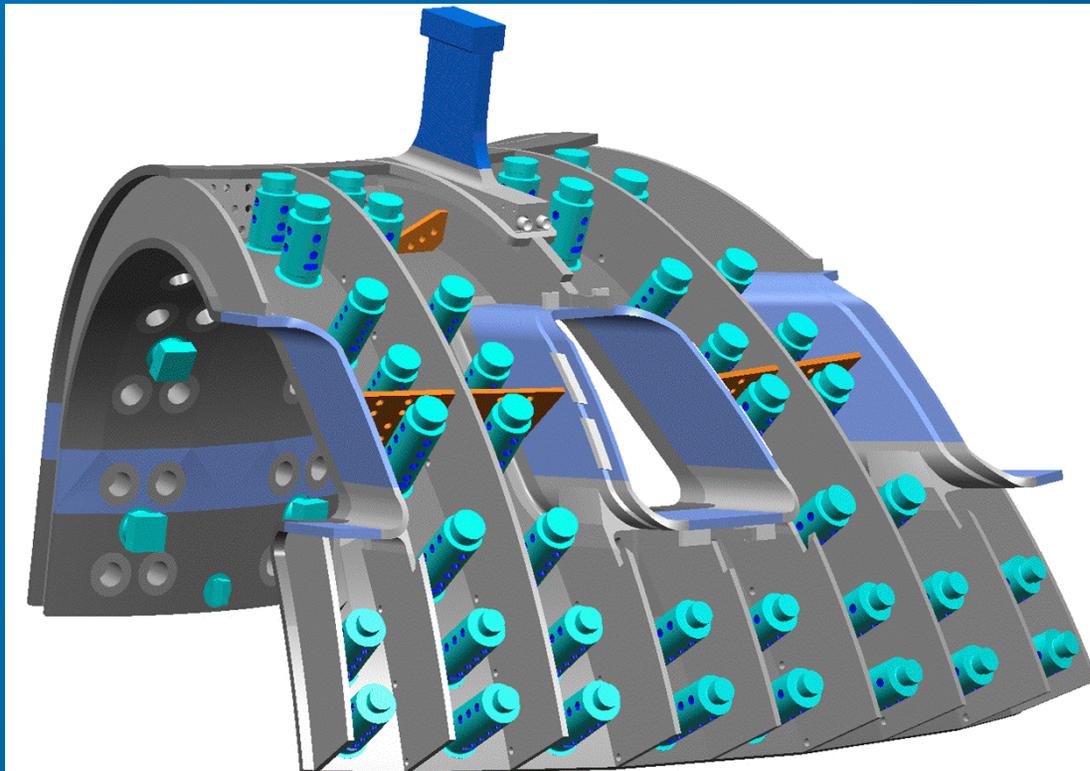


Major parts :

- 9 x 40°-sectors
- 18 upper ports
- 17 equatorial ports
- 9 lower ports
- 9 VV gravity supports
- penetrations



ITER VACUUM VESSEL



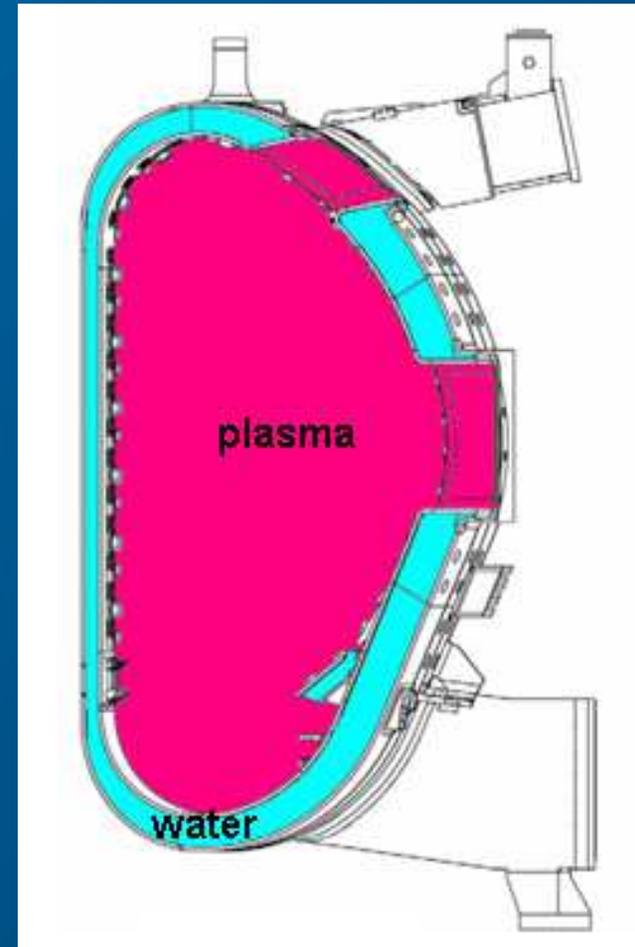
Double wall structure with rib stiffeners and blanket module support housings

Shielding and cooling water between shells

ITER VACUUM VESSEL



Size: - Torus outside diameter - Torus inner diameter - Torus height - Shell thickness	19.4 m 6.5 m 11.3 m 60 mm
Water inlet temperature - Normal operation - Baking	100° C 200° C for VV
Water inlet nominal pressure main vessel - Normal operation - Baking	1.1 MPa abs 2.4 MPa abs
Pressure inside plasma chamber during operation	0 MPa abs (vacuum)
Volume of coolant in main vessel	200 m ³ (9 sectors)
Coolant	Water
Total mass of assembled vessel Total mass in operating conditions	± 5000 ton ± 9000 ton
Material	316L(N)-IG



FRENCH ESPN ORDER



NUCLEAR PRESSURE EQUIPMENT

- French Order related to Nuclear Pressure Equipment (NPE/ESPN)
December 12th, 2005
- Definition of Nuclear Pressure Equipment :
 - is pressure equipment as defined in the PED ;
 - is used in a Basic Nuclear Installation ;
 - directly ensures containment of radioactive substances ;
 - in case of failure leads to release of activity above 370 MBq.

FRENCH ESPN ORDER



NUCLEAR PRESSURE EQUIPMENT

- ESPN has practically extended the application of the PED :
 - > Risk Category
 - > Essential Safety Requirements
 - > Conformity Assessment Modules
- However :
 - > Other selection criteria for Conformity Assessment Modules
 - > Additional Essential Safety Requirements depending on the nuclear level
 - > Radioprotection Requirements
 - > In Service Inspection Requirements

FRENCH ESPN ORDER



APPLIED TO THE ITER VACUUM VESSEL

- MULTICHAMBER NUCLEAR PRESSURE EQUIPMENT
 - nuclear level N2
 - risk category IV
- MANUFACTURER : **ITER ORGANIZATION**
- AGREED NOTIFIED BODY: **AIB-VINCOTTE**
- CONFORMITY ASSESSMENT MODULE G

FRENCH ESPN ORDER



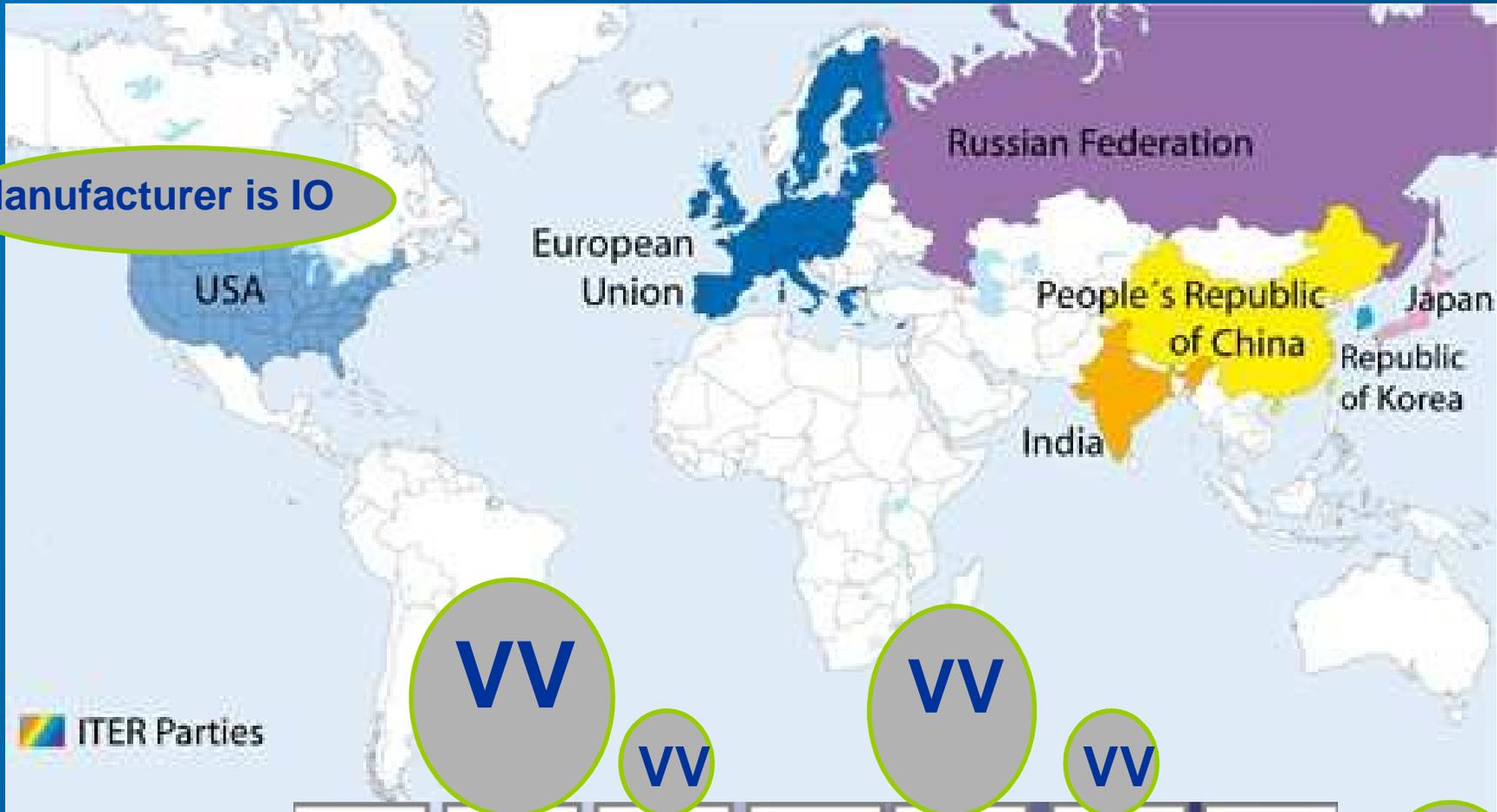
APPLIED TO THE ITER VACUUM VESSEL

- CONFORMITY ASSESSMENT MODULE G
 - > Design Review
 - > Inspection during Manufacturing in the Shops
 - > Inspection during Assembly in Cadarache
 - > Inspection of the Pressure Testing & Final Assessment
- LACK OF ACCESSIBILITY DURING MANUFACTURING
LACK OF ACCESSIBILITY IN OPERATION
→ **COMPENSATORY MEASURES**

ITER VACUUM VESSEL SUBCONTRACTORS



Manufacturer is IO



 Chinese Participant Team	 European Participant Team	 Indian Participant Team	 Japanese Participant Team	 Korean Participant Team	 Russian Participant Team	 USA Participant Team
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+IO

ITER VACUUM VESSEL

SUBCONTRACTORS



- **KODA – HYUNDAI HEAVY INDUSTRIES**
 - > 2 SECTORS
 - > 9 LOWER PORTS
 - > 17 EQUATORIAL PORTS
- **EUDA – ANSALDO / MANGIAROTTI / WALTER TOSTO**
 - > 7 SECTORS
- **RFDA – MANNESMAN DIESEL TURBO**
 - > 18 UPPER PORTS
- **INDA – AVASARALA : IN WALL SHIELDING STRUCTURE**
- **IO – ENZA : ASSEMBLY**

ITER VACUUM VESSEL



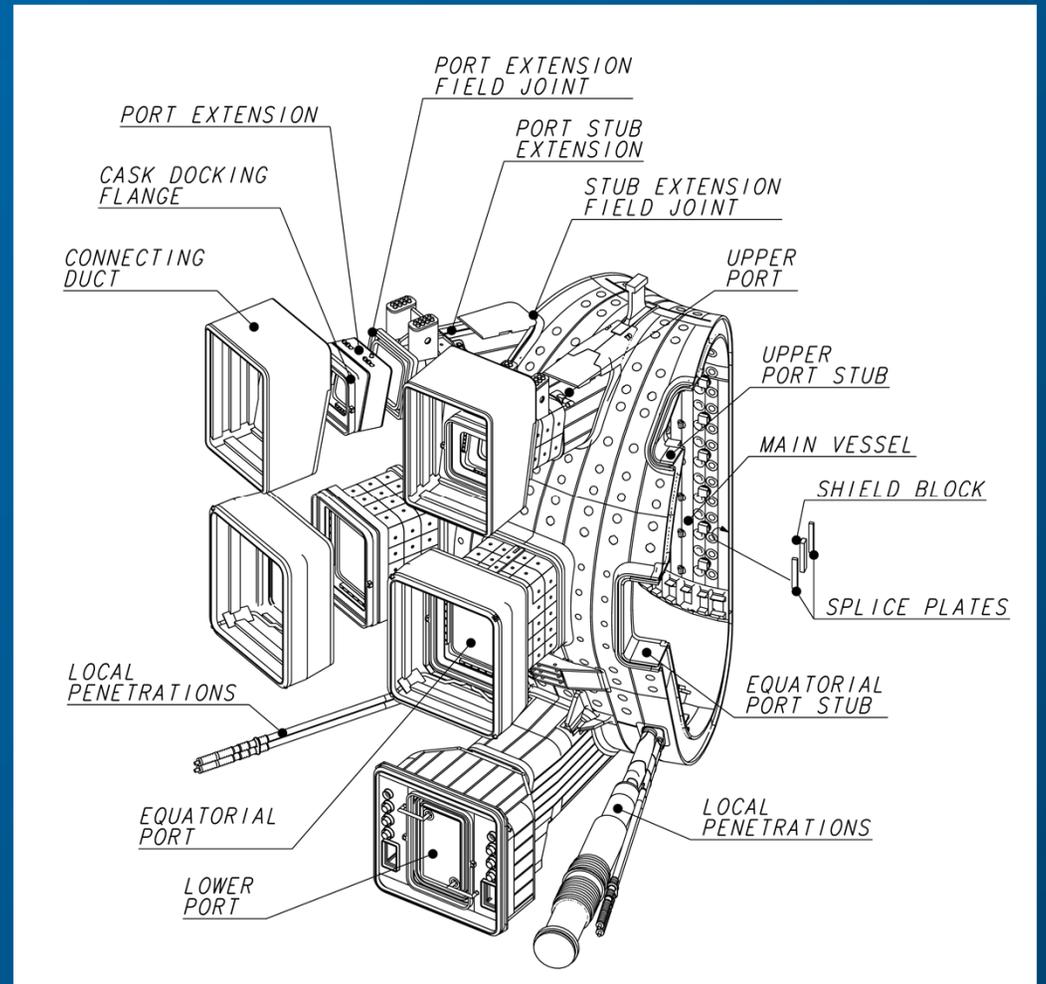
DESIGN REVIEW - Classification VV Parts

PARTS CLASSIFICATION :

- main pressure parts
- pressure parts
- parts contributing to pressure resistance
- other parts

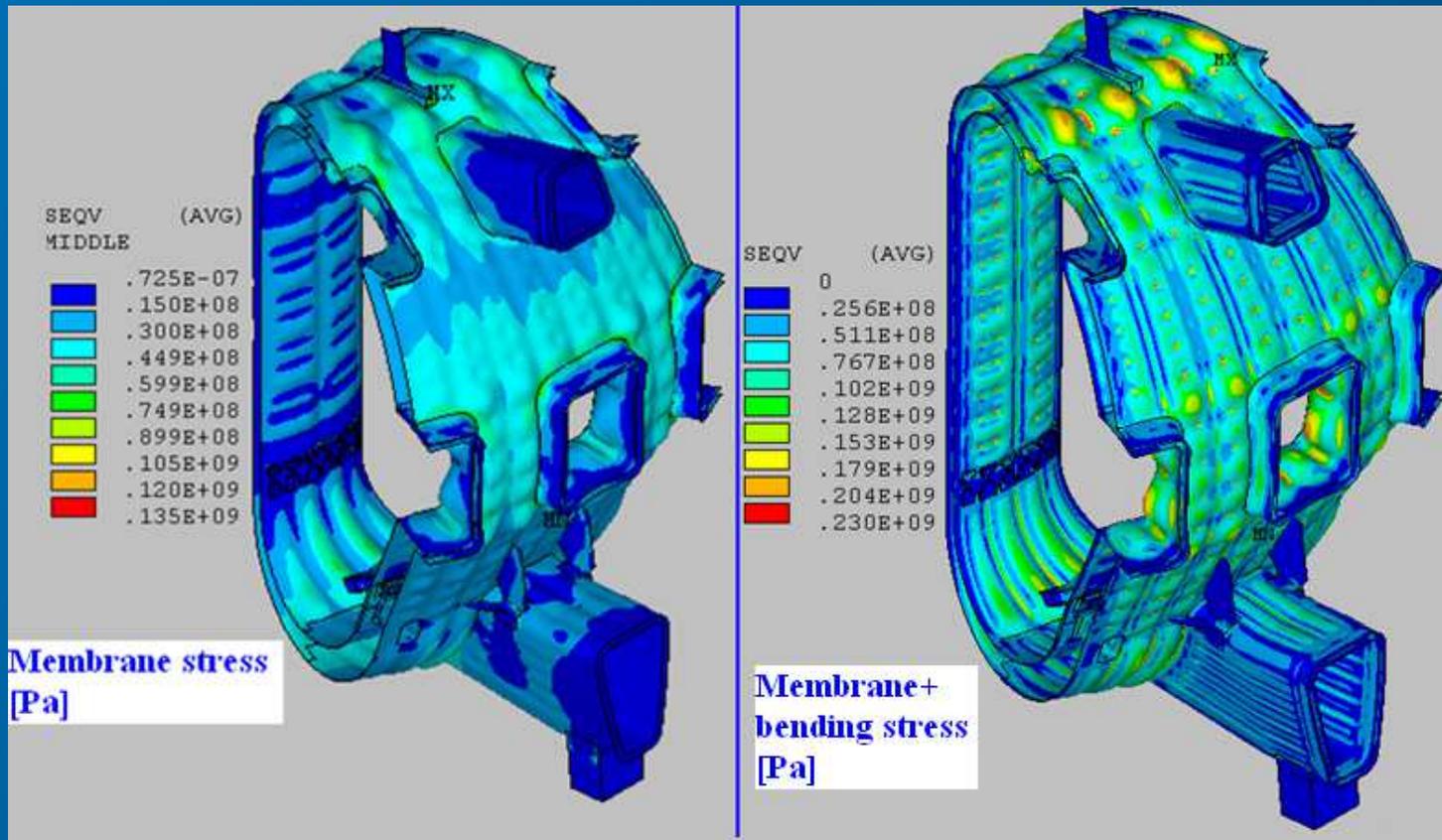
→ DIFFERENT REQUIREMENTS FOR

- material properties
- material certificates
- stress categorization
- non destructive examination
- etc.



ITER VACUUM VESSEL

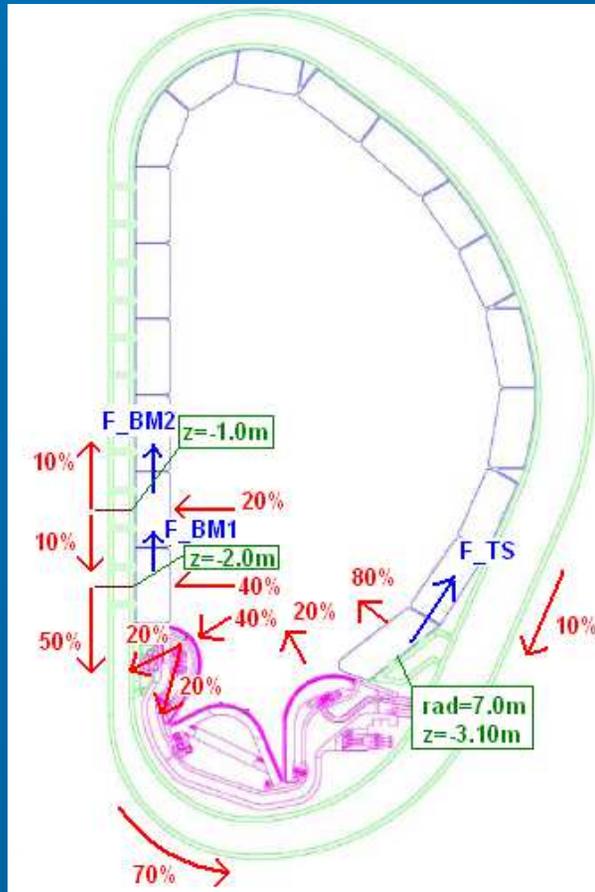
DESIGN REVIEW – Stress Analysis



Stress distributions under hydrostatic test pressure

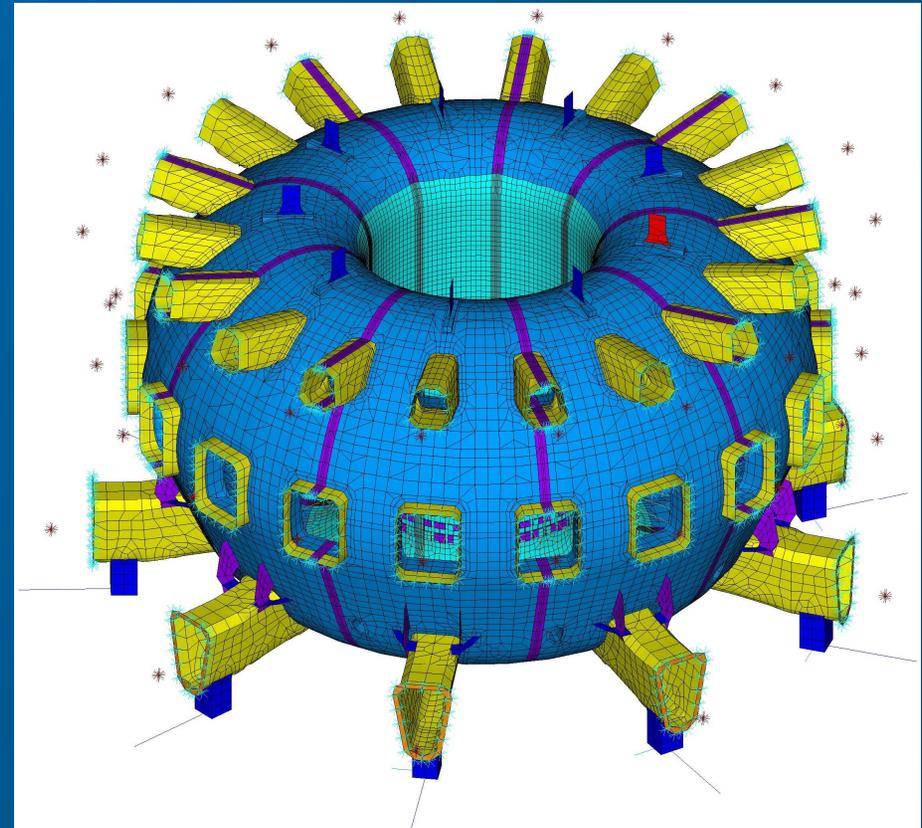
ITER VACUUM VESSEL

DESIGN REVIEW – Stress Analysis



Halo current distribution

VDE Downward



Full model

ITER VACUUM VESSEL



DESIGN REVIEW - In-Service Inspection

- **ISI is complex because :**
 - particular VV geometry
 - structures around VV (inside & outside)
 - activation of materials

-> Development of special techniques
- **Monitoring during operation :**
 - (1) Vacuum gauge, Residual Gas Analyzer
 - (2) Instrumentation on the VV :
 - > thermocouples
 - > strain gauges
 - > acceleration measurement
 - > displacement measurement
 - (3) Ex-Vessel measurement of the water chemistry
- **Periodic inspection without replacement of IVC :**
 - (1) Pressure test of cooling double shell
 - (2) Leak test
 - (3) Visual inspection on accessible locations
- **Inspection after removal of IVC :**
 - (1) Visual inspection
 - (2) Surface defect inspection
 - (3) Volumetric examination

ITER VACUUM VESSEL

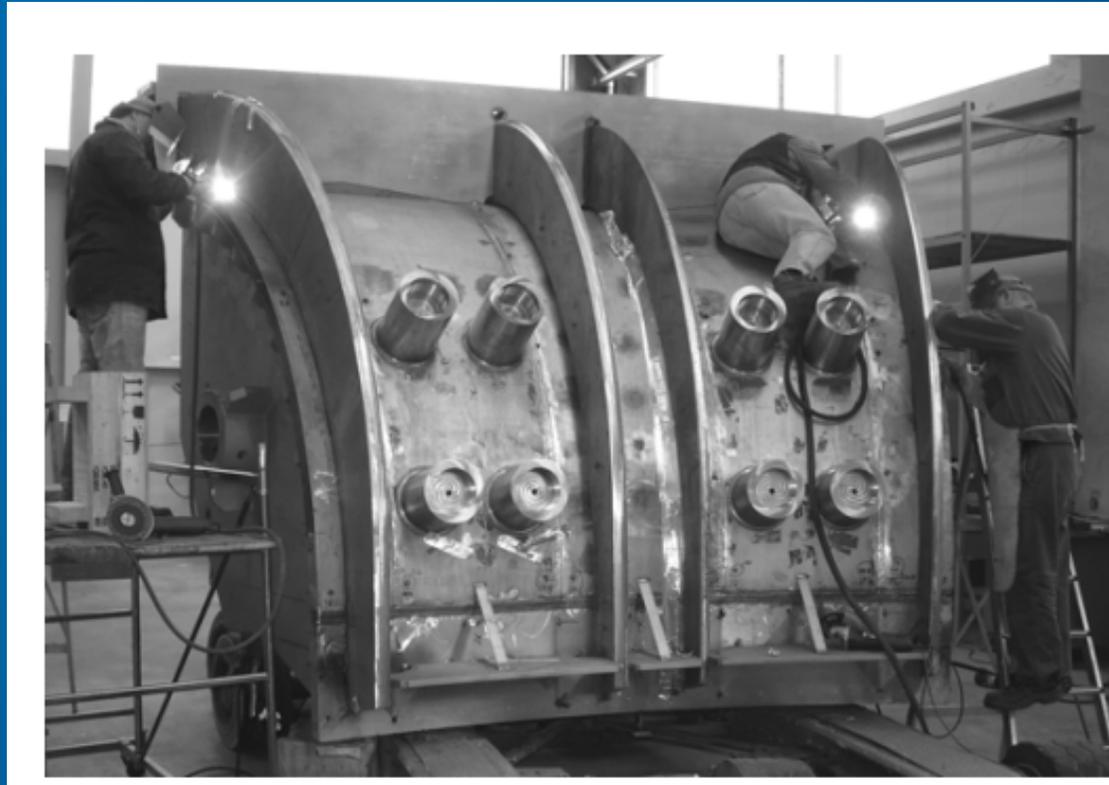


INSPECTION OF MANUFACTURING

- FURTHER DESIGN REVIEW PLUS
 - REVIEW CONCEPTUAL MANUFACTURING DESIGN
 - REVIEW DETAILED MANUFACTURING DESIGN
- MATERIAL SUPPLY
- TENTHS OF THOUSANDS OF PIECES
- TENTHS OF THOUSANDS OF WELDS
- ABOUT 100 WELDING PROCEDURE SPECIFICATIONS
- ADVANCED NON DESTRUCTIVE EXAMINATION
- INDIRECT VISUAL EXAMINATION
- VERY SEVERE DIMENSIONAL TOLERANCES

ITER VACUUM VESSEL

INSPECTION OF MANUFACTURING



PARTIAL MOCK-UP

ITER VACUUM VESSEL



INSPECTION OF MANUFACTURING

AT THE CURRENT STAGE (MARCH 2015) :

- FINISHING MANUFACTURING DESIGN
- MATERIAL SUPPLY
- QUALIFICATION OF MANUFACTURING PROCEDURES
 - > FORMING
 - > HEAT TREATMENT
 - > WELDING PROCEDURES
 - > NON DESTRUCTIVE EXAMINATION PROCEDURES
- QUALIFICATION OF PERSONNEL
 - > WELDERS
 - > NON DESTRUCTIVE EXAMINATION PERSONNEL

ITER VACUUM VESSEL



INSPECTION OF MANUFACTURING

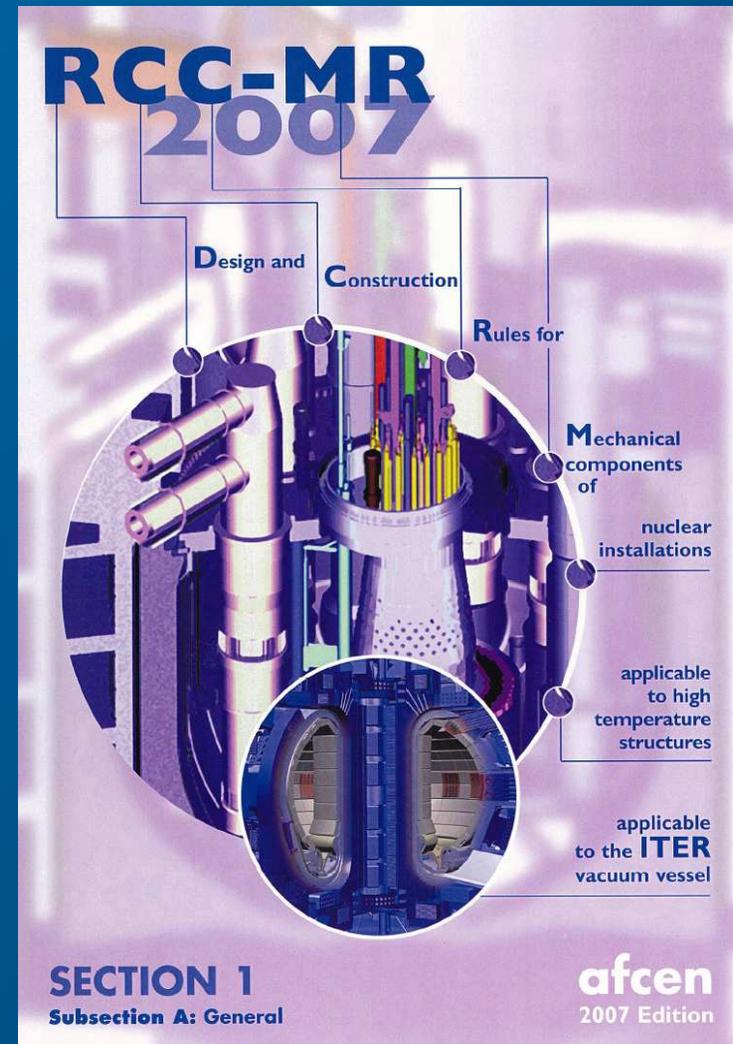
- KODA STARTED WELDING IN 2014 FOR THEIR SCOPE :
 - > 2 SECTORS
 - > LOWER PORTS
 - > EQUATORIAL PORTS
- EUDA AND RFDA WILL START WELDING IN 2015
- VV ASSEMBLY IN CADRARACHE : START IN 2017 ?

ITER VACUUM VESSEL

RCC-MR CODE



- High temperature structures
 - Quality Assurance
 - Materials
 - Design
 - Fabrication
 - Welding
 - Nondestructive Examination
 - RC 3800 : box structures class 2
 - Appendix A19 : ITER VV
 - Non Harmonized Standard
 - ESR of PED/ESPN satisfied ?
 - RPR of ESPN satisfied ?
- Assessment of the RCC-MR for the VV
(Appendix 18 is helpful)



ITER VACUUM VESSEL



CONCLUSION

- COMPLEX PROJECT
 - > TECHNICAL
 - > MANAGEMENT
- INTERNATIONAL ENVIRONMENT
 - INCREASE OF NUMBER OF CONTACTS AND KNOWLEDGE
- STATE OF THE ART TECHNOLOGY
- MEETING BETWEEN SCIENTIFIC WORLD / INDUSTRY