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Technical Requirements Specification

Codes and Standards for ITER Mechanical Components

This document defines the selected reference Codes and Standards for the ITER mechanical components. Word version can be found in attachment.

Approval Process			
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Change Log			
Codes and Standards for ITER Mechanical Components (25EW4K)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	09 Mar 2007	This document defines the selected reference Codes and Standards for the ITER mechanical components
v1.1	Signed	05 Apr 2007	This document defines the selected reference Codes and Standards for the ITER mechanical components
v1.2	Approved	29 Aug 2008	This document defines the selected reference Codes and Standards for the ITER mechanical components
v2.0	Signed	31 May 2011	Modifications to the previous version have been introduced to: - be consistent with evolution of the design (modification of SRDs) and more accurate definition and justification of the selected C&S: - include Site Specific Requirements (ESP(PED), ESPN, French Quality Order 1984) - Include new industrial codes or new code versions (Europeran Norms were not referred in previous version - ASME Sec VIII Div 2, 2007) - Include further development of ITER specific Codes (Non-metallic windows (2011), SDC-IC)
v3.0	Signed	23 Feb 2012	General improvement of the document and completion of PCR 366 Details of changes can be found in the IDM attched word version which keep track of all changes with respect to the previous version 2.0
v4.0	Approved	21 Jun 2012	Version 1.2 => 2.0: Modifications to the previous version have been introduced to: - be consistent with evolution of the design (modification of SRDs) and more accurate definition and justification of the selected C&S: - include Site Specific Requirements (ESP(PED), ESPN, French Quality Order 1984) - Include new industrial codes or new code versions (Europeran Norms were not referred in previous version - ASME Sec VIII Div 2, 2007) - Include further development of ITER specific Codes (Non-metallic windows (2011), SDC-IC). Version 2.0 => 3.0 =>:4.0: General improvement of the document and completion of PCR 366. Details of changes can be found in the IDM attached word version file:" Answer on Comments on 25EW4K_v3 to 4.docx" which keeps track of all changes and explanations with respect to the previous versions 2.0 and 3.0. Comments of David Sands have been included in version 4.0 Document "Codes_and_Standards_for_ITER_Mechanical__25EW4K_v4_015 June2012_with Track changes.doc" is attached also
v5.0	Approved	28 Apr 2025	Version 4 => 5 Version 4 was prepare in 2012. There are many changes: Home regulation was changed: - New PED: Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 - Order dated 12th December 2005 concerning nuclear pressure equipment (ESPN) and ESPN Order of December 30th 2015 currently modified by French order 03/09/2018 - French Order of 7th of February 2012, concerning Basic Nuclear Installation - RCC-MRx code was include Table 1: List of Codes and Standards for the ITER mechanical components

			was significantly modified based on current status of PBS. Document “Codes_and_Standards_for_ITER_Mechanical__25EW4K_v.5 23 April 2025 TRACK CHANGES is included also.

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1 Purpose

The purpose of this document is to provide the list of Codes and Standards (C&S) applicable to the mechanical (structural) components of the ITER.

The Host Party Regulations related to structural systems and components (mainly related to pressure and nuclear pressure equipment) have been considered for the preparation of this document.

2 Scope

This document contains the general guide to the C&S selection that shall be used for design, manufacturing, inspection and testing of the different ITER components.

Due to unique feature of ITER, the multi-code approach is applied for the selection of the C&S for various ITER components. The main reasons for this approach are:

- the wide variety of the ITER components and loads (e.g. operational temperature from 4 K to ~ 1000K, neutron irradiation effect, etc.), which does not allow to use one existing industrial Code.
- presence of electromagnetic loads, which are not included in any codes
- the needs to use some advantages of specific existing Codes to cover the particular ITER operational requirements.
- the unique feature of some ITER components (magnet, in-vessels) for which there are no existing Codes, and special Codes shall be developed.
- the optimization of expertise and cost of equipment due to the procurement sharing with the ITER Members (industries from different countries have adequate expertise with different codes).

3 Abbreviations

The ITER Active Web Abbreviations Dictionary can be found at the following URL: https://portal.iter.org/Pages/abbreviations.aspx.
Additional or more frequently used abbreviations are here reported.

AISC	American Institute of Steel Construction
ANB	Agreed Notified Body, a Notified Body agreed/authorized by the French Nuclear Authority (Autorité de Surêté Nucléaire et de radioprotection) for the conformity assessment of the equipment which is under Order dated 12th December 2005 on Nuclear Pressure Equipment
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNR	French Nuclear Safety Authority (Autorité de Sûreté Nucléaire et de Radioprotection)
AWS	American Welding Society
C&S	Codes and Standards
CCWS	Component Cooling Water System
CHWS	Chilled Water System
ESP	French Environment Code mainly article L557 and R557
ESPN	Order dated 12th December 2005 concerning nuclear pressure equipment (ESPN) and ESPN Order of December 30th 2015 currently modified by French order 03/09/2018
ESR	Essential Safety Requirements as defined in PED and ESP
H&CD	Heating and Current Drive
HRS	Heat Rejection System
INB	Basic Nuclear Installation (from French "Installation Nucléaire de Base"
MSDC	Magnet Structural Design Criteria
NB	Notified Body, a company that has been nominated by a Member State and notified to the European Commission for the pressure equipment conformity assessment.
PBS	Plant Breakdown Structure
PED	Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 (PED) on the harmonization of the laws of the Member States relating to the making available on the market of pressure equipment
QA	Quality Assurance
RCC-MR	Design and Construction Rules for Mechanical Components of Nuclear Installations, RCC-MR Edition 2007.
RCC-MRx	Design and Construction Rules for Mechanical Components of Nuclear Installations: High Temperature, Research and Fusion Reactors, RCC-MRx
SDC-IC	Structural Design Criteria for In-vessel components
SEP	Sound Engineering Practice as defined in PED and ESP
TBM	Test Blanket Module
TCWS	Tokamak Cooling Water System – Primary Heat Transfer System (PHTS)

VST	Vapour Suppression Tank
VVPSS	Vacuum Vessel Pressure Suppression System

4 Basis for general approach

4.1 Basic principles

To ensure coherency between design, manufacturing, inspection and testing for the ITER mechanical systems, structures and components the C&S shall be identified and used. The selection of C&S for specific components is based on the comprehensive assessment of the C&S features, ITER operational conditions, ITER functional requirements and safety requirements. The ITER safety functions and the criteria presented for safety importance classification of structures, systems and components are defined in [Ref.1].
In some cases the coherency of C&S shall be insured at the so-called "equipment" level when the regulation requires such differentiation (for pressure equipment, see below).

4.2 Host Party regulations

A preliminary selection and development of C&S for the ITER components was done during the ITER design activity and reflected the ITER design features and generic safety requirements. After the selection of the ITER construction place, the Host Party requirements have been extensively studied and they shall be implemented.

In accordance with French regulation ITER will be a Basic Nuclear Installation in France (French acronym INB) because of the tritium inventory in the overall facility, not only in the vacuum vessel for fusion reactions, but in the Tritium Plant, and in the fuel cycle systems, the Hot Cell Facility and the Radioactive Waste buildings.

In France, the basic regulatory documents do not require specific design and manufacturing C&S, but require documents formulating general Essential Safety Requirements (ESR) and the ways how to fulfil these requirements from technical and legal point of view. The approach of the Regulation documents is to give the possibility of selecting design and manufacturing C&S to the Manufacturer of given equipment, but the conformity with the regulatory requirements shall be demonstrated.

Any assembly or set of assemblies including different pressure chambers and equipment is analysed and split in a series of equipment – linked together – to which the regulation is applied individually under the responsibility of the so-called manufacturer of the equipment.

There are several regulatory documents, which have to be taken into account, see below.

4.2.1 *Pressure Equipment Directive, 2014/68/EU*

The Pressure Equipment Directive (PED) was adopted by the European Parliament and the European Council in May 1997 (previous version was Pressure Equipment Directive 97/23/EC) and latest version 2014/68/EU is [Ref.2]. From 29 May 2002 the PED is obligatory throughout the European Union. The directive provides, together with the directives related to simple pressure vessels (87/404/EC), for an adequate legislative framework on European level for equipment subject to a pressure hazard.

The European Equipment Directive 2014/68/EU is in force in France, by French Environment Code mainly article L557 and R557, [Ref.3]. Acronym ESP is proposed to be used for above mentioned documents.

ESP is a main legal regulatory document in France for pressure equipment.

The ESP applies to the design, materials, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure greater than 0.5 bar over atmospheric pressure.

ESP introduces the categorisation (Category I – IV, Category IV is the highest) of the pressure equipment depending on the pressure hazard due to pressure, volume of vessel or diameter of pipe, type of fluid and temperature. There is an additional category which is called Sound Engineering Practice (SEP). Depending on certain conditions, there is the possibility of excluding pressure equipment from ESP. For each category the so-called modules for the conformity assessment in accordance with Essential Safety Requirement (ESR) are proposed. For equipment in category II – IV the conformity assessment has to be performed by Notified Body.

Manufacturer of equipment shall contract a Notify Body (when compulsory) and after completion of the conformity assessment shall declare conformity and issue CE mark.

If equipment does not fall under ESP, it shall be designed and manufactured in accordance with the standard engineering practice agreed between user and manufacturer.

For pressure equipment ESP allows to use e*xperimental design method*. The test programme must be clearly defined prior to testing and accepted by the notified body responsible for the design conformity assessment module, where it exists. This programme must define test conditions and criteria for acceptance or refusal. The actual values of the essential dimensions and characteristics of the materials which constitute the equipment tested shall be measured before the test. Where appropriate, during tests, it must be possible to observe the critical zones of the pressure equipment with adequate instrumentation capable of registering strains and stresses with sufficient precision.

Pressure equipment is subject to the provisions applicable to operation and re-qualification, as required in the French ESP Decree. The specific rules for the implementation of such requirements are established in France and they are described in the special order concerning the operation of the pressure equipment [Ref.4]. These rules shall be taken into account during design of the pressure equipment.

Derogations or exceptions to these rules for the ITER components must be justified.

The use of European Harmonised Standards for the design and manufacture of pressure equipment gives the presumption of conformity to those ESR listed in Annex ZA of the Harmonized Standard.

Many ITER systems and components include various types of equipment with maximum allowable pressure greater than 0.5 bar over atmospheric pressure. These include: magnets and magnet feeders and manifolds, thermal shield, equipment in cryoplant and cryodistribution system, the heat rejection system of cooling water systems, equipment for fuelling, Vacuum Vessel etc. The fluids (water, helium, nitrogen, etc.) in these systems are non-radioactive.

Order 18th August 2010 related to pressurized high voltage equipment [Ref.5] was issued in 2010:

- "enclosures for high-voltage electrical equipment": means pressure equipment used in high-voltage equipment rated for voltages above 1000 V ac (alternate current) and 1500 V dc (direct current) and where the maximum allowable pressure exceeds 0.5 bar for containing a fluid in Group 2;

- "equipment": a general term applicable to switching devices and their combination with the controlling, measuring, protecting and adjusting devices associated with them, as well as assemblies of such equipment with the connections, accessories, enclosures, and related structures;

- "pressure relief devices": devices intended to protect the enclosure against overpressure due to an internal defect; they are designed with a sufficient margin with regard to the maximum allowable pressure in accordance with standard IEC 62271-203 of November 2003.

This Order specifies design, manufacture and conformity assessment procedures with some additional supplementary requirements.

4.2.2 *French Order concerning nuclear pressure equipment (ESPN)*

This document [Ref.6] defines nuclear pressure equipment as equipment that meet the following conditions:

- pressure equipment as defined in accordance with ESP;
- equipment used in a basic nuclear facility;
- equipment directly containing radioactive substances;
- equipment whose failure lead to radioactive releases greater than 370 MBq.

ESPN has practically extended the application of the methodology foreseen by ESP (ESR, conformity modules, Notified Bodies etc.) to nuclear pressure equipment in France. ESPN has double classification of the equipment:

- pressure hazard based on ESP approach, Category I – IV, and Category 0 (equivalent to SEP);
- nuclear level, N1, N2 and N3.

In accordance with ESPN, Article 5, the operator of a basic nuclear facility must compile a list of nuclear pressure equipment used in the facility. The operator must determine and justify the nuclear level and category that are given to each equipment. This list and related justifications are to be made available to the Regulatory Body in France (ASNR, Autorité de Sûreté Nucléaire et de Radioprotection), and personnel in charge of monitoring pressure equipment.

There are some additional requirements to ESR of ESP/PED depending on the nuclear level of the equipment.

As far as C&S are concerned, the regulatory documents (ESP and ESPN) do not define specific requirements for the selection of the Codes, but only require that the conformity with ESR is demonstrated.

The ESPN defines also rules for maintenance and monitoring, periodic inspections, installation and operation and periodic re-qualifications of nuclear pressure equipment.

Derogations or exceptions to these rules for the ITER components must be justified and agreed with nuclear regulators (compensation measures might be required).

Manufacturer of nuclear equipment shall contract an Agreed Notify Body and after completion of the conformity assessment shall declare conformity.

Several ITER systems include nuclear pressure equipment as defined in ESPN: Vacuum Vessel and Ports, equipment in Primary Heat Transfer Systems (heat exchangers, pressurizers, etc.), equipment in the Tritium Plant, equipment in Test Blanket Modules systems, etc. This equipment is directly containing radioactive substances such as tritium, tritiated water, water with activated corrosion products and various radioactive isotopes, etc.

4.2.3 *Equipment out of scope of ESP and ESPN*

Various types of the ITER equipment operate at absolute pressure greater than 1.5 bar. However, in accordance with Article 2 of ESP at certain conditions the pressure equipment is considered as outside of the scope of ESP. Among those there is equipment which is primarily dimensioned for loads other than pressure, or, in other words, equipment for which pressure is not the significant design factor. This equipment is not under provisions of the ESP (see Article 2, Part II, point h). For many ITER pressurized equipment the main design driving loads are electromagnetic and thermal, which are significantly larger than fluid pressure. However, the conclusion of applicability of the ESP for specific equipment can only be reached after a case-by-case analysis.

If an equipment with absolute pressure greater than 1.5 bar is not under ESP regulation and within the exception of equipment referred to in points a) to r) in Article 2(II) of ESP, in accordance with ESPN, Article 2-I this equipment is not a nuclear pressure equipment.

4.2.4 *French Order of 7th of February 2012, concerning Basic Nuclear Installation*

This Order [Ref.7] defines the specific activities which shall be implemented by the Operator of a nuclear facility with regards to the safety demonstration. Quality Related Activities (QRA) which have an impact on the quality of Safety Important Components shall be identified by Operator and they are related to design, manufacturing, construction and operation of the nuclear facility. The Quality requirements of this order are implemented in the ITER Quality Assurance Program, which is applicable for the ITER system and components. Equivalent quality requirements must be implemented by the suppliers and/or contractors and following chain of subcontractors.

4.3 C&S selection for the ITER components

The selection of the C&S for the mechanical components is based on the comprehensive assessment of the available C&S and their features, ITER operational condition and safety requirements. Mechanical components include vessels, piping, tanks, pumps, valves, heat exchanges etc. and their supports. These components may fall under French regulations related to pressure and nuclear pressure equipment.

The principal safety requirement applicable to equipment fulfilling a confinement function is structural integrity and leak tightness. The design of the equipment must take into account the loading specified for each item of equipment. In accordance with ESP and ESPN the loads (pressure, electromagnetic forces, seismic, etc.) at foreseeable conditions shall be taken into account for equipment classification and design.

To ensure coherency between design, manufacturing, inspection and testing for each specific component one single Code shall be used. In some cases the coherency of Codes shall be ensured at the so-called "equipment" level when the regulation requires such differentiation.

Generally proposed C&S can be divided into two main categories:

1). ITER specific Design Criteria and Specifications:

- Magnet Structural Design Criteria, [Ref. 8]
- Structural Design Criteria for In-Vessel Components (SDC-IC), [Ref. 9]
- Technical Specifications for non-metallic windows and insulations, [Ref. 10]
- Specifications for design by experiment, [Ref. 11]

These Criteria and Specifications have been developed in cooperation with the ITER Parties because there are no available Industrial C&D which can cover specific features of the ITER design and operating conditions. The main specific features relate to the operation of magnet components at ~ 4 K under significant electromagnetic loads, while for the in-vessel components a change of material properties after neutron irradiation needs to be included in the design assessment

The detailed descriptions of these Criteria are presented in Chapter 5 of this document.

2). Existing industrial C&S:

- ASME codes, [Ref. 12, 13, 14, 15, 16]
- RCC-MR Edition 2007, [Ref. 17]
- RCC-MRx [Ref. 18]
- EU Harmonized Standards, [Ref. 19, 20, EN cryogenic standards, etc.]

Note: the edition year of the Codes is determined based on design and manufacturing requirements described in each PBS.

Historically for the ITER project US C&S have been selected as the main C&S because the US standards are familiar to most participants and because they are the origin of and consistent with many other national standards. In particular, the ASME Boiler and Pressure Vessel code and related codes for piping, valves, and pumps were adopted as the standards for the project. ASME Section VIII Division 2 is selected as the main code for various vessels. However, the rules could be changed to Section VIII Division 1 for certain pressure vessels if analysis shows that Division 1 can be applied.

NOTE for application of ASME codes for ITER pressure and non-pressure equipment:

- In case of use of ASME codes it is not a mandatory requirement that the manufacturing company is ASME stamp holder (U, N, etc.), however it is generally strongly recommended as additional ITER Quality requirements will be imposed if non code stamped companies are used.
- In case of exceptions to the ASME requirements, these exceptions should be clearly identified and justified.

RCC-MR Edition 2007 is proposed as the design and construction code for the ITER Vacuum Vessel and Port Components, Neutral Beam Vessel, Diagnostic and Heating Port Plugs, and some other ITER systems and components

Various European harmonized standards were recently developed (e.g. EN 13445 – Unfired Pressure Vessels). These standards are considered to be in conformity with Essential Safety Requirements of ESP and ESPN regulations. The use of these standards is proposed for some pressure equipment with goal to facilitate conformity demonstration with regards to ESR of ESP.

4.4 Design considerations, service conditions and criteria levels

ITER identifies four categories of event (or conditions):

- I - Operational,
- II - Likely,
- III - Unlikely,
- IV -Extremely unlikely.

The different damage limits are specified depending on the category of the events and the relevancy of the component to the safety class.

The designers shall specify the loading conditions depending on the event categories and damage limits for each of the component. General rules for the loading specification are given in Load Specification document [Ref.21].

Criteria levels are aimed at preventing a specific degree of damage to the component in question. Four distinct criteria levels are given: A, B, C, and D, with the general objectives defined below:

Criteria Level	**General objective**
A	Negligible damage. All structures, systems, and components are functional.
B	Negligible damage. All structures, systems, and components are functional. Anticipated maintenance and minor adjustment might be required. Same service level as for Criteria Level A but with lower margin.
C	May be significant local distortion. May need to inspect, call for repair or replacement of faulty components.
D	May be large general distortion and investment loss. Repair may not be considered economic. Minimum safety functions shall be maintained.

Service conditions or criteria levels are used in accordance with the codes identified in this document for each component.
The analysis and terminology of different codes are not necessarily identical. It is recommended to use terminology and analysis as prescribed in the code used for each component.

ITER documents (detail load specification documents of each single component) defines in a case by case basis the association of the of load category with the criteria level. As a general strategy for loads associated to events in category I and II the criteria level A is applied. For loads associated to events in category III and IV the criteria levels C and D are applied respectively. This basic strategy can be modified for reasons related to special safety requirements or for ITER capital investment protections.

The document [Ref.22] provides guideline to define the allowable limits for structural service criteria level C and D in case the selected design code does not provide any indication. Rules are provided for ultimate limit state. Ultimate limit state is a structural condition (of the component or vessel) associated with burst or collapse, or with other forms of structural failure. These include failure by gross plastic deformation and plastic collapse (due to monotonic or cyclic loads), rupture caused by fatigue, collapse caused by instability, and leakage which affects safety, and any other state prior to collapse which, for simplicity, is considered in the place of the collapse itself.

4.5 Materials and design allowable

The material properties used in the analysis shall be defined by the code used for each component. If material grades or properties differ from those given in the code, justification documents shall be provided.

Requirements for materials for pressure and nuclear pressure equipment are described in the ESP and ESPN. Product material specifications shall be based on requirements of applicable regulations and C&S.

5 Brief description of ITER specific design criteria

5.1 Magnet Structural Design Criteria

For the design of the ITER Magnet Structures the specific Magnet Structural Design Criteria have been developed [Ref.8]. These Design Criteria result from extensive assessment of the features of various existing C&S (ASME, Section III, Section VIII, ASME B31.3, API 579, etc.). Existing C&S generally exclude the low temperature range (there are very recently developed European Harmonised Standards for cryogenic application, but the experience on their application is limited), however the methodologies in these Codes are in many cases applicable.

5.1.1 *Scope of the Magnet Structural Design Criteria*

The Magnet Structural Design Criteria includes the following parts.

Part 1: Main Structural Components and Welds, which is applicable for

- Toroidal Field (TF) coil cases
- Outer Intercoil Structures (OIS)(not bolts and keys)
- Feeder Ducts

Part II: Magnet Windings (Radial Plates and Conductors) with High and Low Voltage Insulation and Epoxy Filler

- TF winding pack and case-winding filler
- Poloidal Field (PF) winding packs
- Central Solenoid (CS) coil winding packs
- Correction Coils (CC) coil winding packs

Part III: Bolts, Keys, Supports and Special Components

- CS pre-compression system (top and bottom flanges and vertical tie plates)
- CS coil interface plates (between coils)
- Inner Poloidal Keys
- OIS bolts and keys
- OIS finger joints
- Pre-compression rings (PCR)
- TF coil gravity supports
- Feeders internal piping
- PF coil covers
- Supports between PF and TF coils and between CS and TF coils
- Supports for Correction Coils

Part IV: Cryogenic Piping - based on general rules of ASME B31.3

There are also 6 Appendixes providing detailed recommendations and analytical solutions:

- Stress Intensity Factor Analysis
- LEFM Crack Growth Assessment
- Magneto-Mechanical Stability of the CS and PF Coils
- Stress concentration and mean stress effect corrections for fatigue analysis of the ITER magnet bolts
- Mean Stress Effect on Fatigue Analysis
- Residual Stresses in Conductor Conduit Caused by Winding

5.1.2 *Basis Criteria for Magnet Structural Design Criteria*

The main purpose of the ITER magnet structural criteria is to establish a design rules and component assessment methodology relevant to components operating in the range 4-77K and extended to room temperature under abnormal operating conditions. Existing codes generally exclude this low temperature range (there are very recently developed EU harmonised standards for cryogenic application, but the experience on its application is limited), but the methodologies in these codes are in many cases applicable.

The document refers to are magnets and their support structures. These will have a different stress system compared to plants consisting of pressure vessels, pipes and their supports, and use different types of materials. However various design methods reviewed for the so-called 'defect free' codes [ASME, RCC-MR] as well as those dealing explicitly with defects in structures [R6, BS7910, API579] have been found in most cases to be compatible for use in the cryogenic temperature range when the relevant material properties are used. There are certain conditions with regards to the magnet components that this document will address. Operating largely without in-service inspection, the questions of safety factors, the operating loads, residual stresses, non-destructive examination sensitivity and reliability, and accuracy of material data relevant to the fracture and fatigue prediction procedures, become more significant at the design stage for the magnets than for conventional high temperature components.

5.2 Structural Design Criteria for In-vessel components

The ITER Structural Design Criteria for In-vessel Components (SDC-IC) [Ref.9] contains rules for structural design of various in-vessel components. The scope of SDC-IC is limited to metallic components.

5.2.1 *Scope of the SDC-IC*

The SDC-IC is applicable to the following WBS elements:

PBS	Title
15-IVC	In-Vessel Coils
16	Blanket
17	Divertor

In addition, the SDC-IC is applicable to in-vessel portions of other PBS components, see following table:

PBS	Title
18	Fuelling and Wall Conditioning
23	Remote Handling Equipment (divertor supports)
51	Ion Cyclotron H&CD
52	Electron Cyclotron H&CD
53	Neutral Beam H&CD and Diagnostic Neutral Beam
54	Lower Hybrid H&CD
55	Diagnostics (metallic components)
56	Test Blanket Modules*

* Selection of Code is addressed to TBM Working Group.

5.2.2 *Basis of the SDC-IC*

SDC-IC development was undertaken as collaboration among four Participating Teams (Europe, Japan, the Russian Federation, and the United States) starting from the early design phase of the ITER machine. The SDC-IC was based on the RCC-MR code, Edition 1985 as a convenient starting point, and extensive modifications have been provided to include unique

structure of ITER components, useful features of other codes (in particular ASME), and national requirements to address the unique features of these components.

The SDC-IC is composed by several parts which address the issues related to each system (blanket, divertor, heating, diagnostic, etc.):

SDC-IC consists of the main Design Criteria document and annexed appendixes.
The main document includes definitions and classifications of different damage and failure modes, type of stresses, joints, thermal creep phenomena, buckling, etc. The other parts of document include design rules for general single layer homogeneous structures at low and elevated temperatures, rules for welded joints and rules for bolts. Design rules for multilayer heterogeneous structures are included also, but they are limited to only low temperature application.

Appendix A, Materials Design Limit Data, currently includes the material properties data.

Appendix B, Guideline for Analysis, provides analysis methods and guidelines of the design rules of SDC-IC.

Appendix C, Rationale or Justification of the Rules, includes the background information including references to literature that provided the foundation for the rules proposed in the SDC-IC.

For the manufacturing of the in-vessel components generally there are two types of technical procedures:

1) Manufacturing procedures for parts or components which are addressed by conventional Codes and directive requirements. These procedures are typically related to conventional welding, brazing joining, and NDT. The related specifications shall be prescribed in accordance with Code or Directive or Order requirements. To be compatible with ESP and ESPN requirements, the recommended manufacturing Code is EN 13445.

2) Manufacturing procedures for parts or components which are not addressed by conventional Code requirements (e.g. tungsten/Cu joints for first wall, non-metallic material joining, etc.). For this type of manufacturing procedures ITER specific Technical Specification Documents shall be prepared or they will be defined in the Procurement technical specification Documents. The justifications shall be supported by R&D.

An activity to update SDC-IC has been on-going in 2011 with the support and involvement of all DAs. New approved version was issued in 2012.

Additional Appendixes are being included:

- Design by Experiment.

- Consistency of design rules and manufacturing rules defined in EN 13445; comparison of manufacturing rules in EN 13445 and RCC-MR Edition 2007.
- Relationship with ESP/ESPN requirements.
- Rules for In-Vessel Coils.

5.3 Window assemblies with non-metallic parts and insulations

For the window assemblies which include non-metallic parts and insulations a document that defines the technical specifications for the design, manufacturing, testing and inspection is going to be prepared.

5.3.1 *Scope*

Scope of this technical specification includes:

- the assemblies (i.e. flange mounted windows) that include parts made of non-metallic materials (i.e. fused silica, quartz, sapphire, etc.) and that, being part of the first confinement boundary[Ref.10].
- windows for view and transmission of energy (under preparation).
- insulations for bushing application in neutral beam system (under preparation).

5.3.2 *Basic features of the technical specifications*

Non-metallic materials are generally not allowed in pressure vessel codes and there is no existing industrial standard that specifies the criteria for the design, manufacturing, and testing of these parts and components that can be directly applied for ITER.

It is therefore necessary to develop technical rules with prescriptions regarding the design, fabrication, and testing of components primarily built of non-metallic parts and belonging to first confinement. Justifications of the selected criteria and the soundness of the selected rules shall be presented in the technical specifications.

5.4 Design by experiment rules

Many ITER components (e.g. divertor, blanket) operate at very specific conditions under intensive particle and heat flux, neutron irradiation, etc. Due to design requirements these components include joints of dissimilar materials such as Beryllium/Copper alloy, Tungsten/Copper alloys, Carbon Fibre Components/Copper Alloys, Copper/Stainless steel, etc. Taking into account that there is no existing Code addressing these types of components, these joints are being designed based on Design-By-Experiment rules. These general requirements for these rules are a part of the SDC-IC document.[Ref.9]

5.4.1 *Scope of the Design by experiment*

These rules are based on practices which are used in various fusion facilities and supported by extensive ITER R&D program [Ref.11]. Basically these rules include:

- Development and selection of suitable joining technologies by manufacture and extensive testing of small scale mock-ups (Be/Cu, W/Cu, C/Cu, etc.);
- Qualification of most promising technologies by testing of design representative mock-ups including non-destructive examination, determination of allowable defects, and maximum allowable heat fluxes;
- Final manufacture of the components and application of an extensive qualification program before installation in the ITER.

For these systems Technical Specification documents for each specific component are part of the Procurement Arrangement documentation.

6 Brief description of main selected codes and standards

6.1 RCC-MR

RCC-MR code, Edition 2007 [Ref.17], is selected as code for the ITER vacuum vessel.
Information on RCC-MR codes and other AFCEN norms can be found in
http://www.afcen.com/index.php.

6.1.1 *Scope of the RCC-MR*

Adoption of RCC-MR code is prescribed for components or parts that form plasma chamber first confinement barrier (see also chapter 8) and for some system related components. The RCC-MR code is applicable to the following components:

- the main vacuum vessel;
- the ports;
- connecting ducts;
- vacuum vessel supports;
- permanent attachments to vacuum vessel and ports
- port plugs
- closure plates
- neutral beam vessels
- cryopump housings
- some part of port plugs providing first confinement

6.1.2 *Basic features of the RCC-MR*

Major reason for the selection of RCC-MR is to simplify the licensing process. The code presents also the following advantages:

- the basic structural material for the ITER vacuum vessel (316 L(N)-IG) is included in the list of material specified by the code;
- there is a special section dedicated to box-type structure (this applies to the double shell with poloidal ribs).
- the European harmonized standards are introduced in the code instead of French AFNOR standards, where applicable.

Appendix A18 of RCC-MR introduces the requirements of the ESP and ESPN which are applicable for the ITER vacuum vessel.

Appendix A19 gives complementary requirements specific for the design of the ITER vacuum vessel. The vacuum vessel is classified as a Class 2 welded box structure which allows to reflect the double shell assembly and to categorize the type of authorized welded joints. Section RC3800 covers components with double shell and internal ribs connecting the two shells with or without a leak tightness function. Special requirements are also defined for permanent attachments which are non-pressure retaining (e.g. copper coating), which are not covered by code. Technical specifications shall be prepared and shall include justification of adopted solutions.

6.2 RCC-MRx

RCC-MRx Code is the result of the merger of the RCC-MX 2008 developed in the context of the research reactor Jules Horowitz Reactor project, in the RCC-MR 2007 which set up rules applicable to the design of components operating at high temperature and to the Vacuum Vessel of ITER. The first edition of RCC-MRx was in 2012, the latest edition in 2022.

Edition 2022 has a lot of modifications including:

- Aligning to EN harmonized norms addressing compliance to EN-13445, 13480, Eurocode 3, and to regulation such as PE and NPE. RCC-MRx is part of the Code Europeanization initiative CEN WS 64.
- Guideline to implement Chinese norms is provided.
- RCC-MRx technical rules applicable to fusion Vacuum Vessels are close to those of RCC-MR 2007. RCC-MRx provides separate box structure provisions & tables for fusion-Vacuum Vessels and research reactors.
- RCC-MRx also addresses design rules for irradiation. Steel data for 316L/304L are significantly supplemented.
- Probationary Phase Rule (PPR) code case Section includes specifications and data for reduced activation steel Eurofer and CuCrZr Alloy (PPR23) use of the Chinese HJB norms for fusion.
- Next edition is 2025. To note of opened discussion opportunity with RCC-MRx Subcommittee for a further development of fusion specific provisions in the code.

6.3 ASME codes

Information on ASME codes can be found in http://www.asme.org/kb/standards.

6.3.1 *Scope of ASME codes*

ASME codes are internationally recognized codes for various type of pressure equipment. The codes cover all aspects of design, materials, fabrication, examination, inspection, testing, and certification of pressure vessels and their associated pressure relief devices

The ASME codes apply generally to the ITER mechanical components that are classified as pressure equipment (PE), but these codes may apply for some non-pressure equipment (e.g. vacuum chambers and pipes).

6.3.2 *Basic features of the ASME codes*

The ASME Boiler and Pressure Vessel codes and related C&S to piping, valves, and pumps were adopted as the standards for some systems and components in ITER.

Vessel
ASME Section VIII Division 2 [Ref.12] is selected as the main code for various vessels. Section VIII Division I may be used for certain pressure vessels if analysis shows that Division I can be applied.

Piping:
The selected piping code, ASME B31.3 [Ref.13], is a section of the ASME Code for Pressure Piping, B31.

The organization and provisions of this code are similar to ASME Section VIII, to which it is a companion.
Requirements defined for Fluid Service Category M[1] are selected for piping with radioactive fluids, e.g., tritiated water, etc. and for piping that are part of the first confinement barrier. This selection is made as a compensation measure for non-using a nuclear code.
B31.3 allows operation at cryogenic temperature.

Piping components: valves, fittings, flanges, and bolting
ASME B31.3 contains a Chapter IV, Standards for Piping Components, in which Table 326.1 lists standards for various components, including valves, fittings, flanges, and bolting. For the components listed in that table, the dimensional standards apply, and the pressure and temperature ratings of the components are accepted for pressure design in accordance with B31.3 paragraph 304.7.1. Unlisted components may also be used provided that they satisfy conditions in B31.3 paragraph 304.7.2 paragraph A304.7.2.

ASME B16.34 [Ref. 14] is the generic standard for flanged and welded valves. It is accepted by its inclusion in B31.3 Table 326.1. If piping components not covered by B16.34 are needed, additional standards can be selected, from Table 326.1.

Pumps
Two ANSI standards applicable to ITER and which are consistent with B31.3 are ASME B73.1 [Ref. 15] and ASME B73.2 [Ref. 16]. In addition, two American Petroleum Institute (API) standards are applicable to ITER:

- API 610, Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry [Ref.23];
- API 685, Sealless Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services [Ref.24].

These standards are selected as the preferred path because of lower cost and consistency with other industry-standard codes. However, if special pumps are needed for which there are no ANSI standards, the rules of ASME Section III-NC could be used. Other standards may be selected and justified on a case-by-case basis.

Component supports
The standard for the supports of a specific component shall be selected in order to be consistent with the code selected for the component itself. Codes selected for the component supports normally include requirements for the supporting elements and associated parts. In case of lack

[1] ASME B31.3 definition of *Category M Fluid Service:* a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken.

of specifications, especially considering ITER specific requirements, additional technical specifications shall be prepared and approved by IO.

Expansion joints (bellows)
ASME B31.3 shall be used for the design, manufacturing and testing of bellows. In particular, Appendix X of this standard contains the allowable stress and safety factors. The EJMA Standard can be used for the details of the design.
The manufacturer or fabricator of bellows has to provide the guarantee that the parameters that define the bellows properties used for the design of the bellows are appropriate. Any non-standard bellows design (i.e. multiply rectangular bellows) shall be qualified as required by B31.3, mainly paragraph 304.7.2, unless otherwise specified by the owner (ITER). Stiffness, strength and fatigue tests have to be performed following the B31.3 requirements and/or ITER specifications in Procurement Arrangement documents.

6.3.3 *Additional specifications to cover specific features*

For the components with special features that are not covered by ASME codes rules special addenda/technical specifications are being prepared. These addenda/specifications, whenever necessary, will also include:

- modifications required to comply with site specific regulations (ESP/ESPN and safety requirements see Chapter 4 and 7);
- special requirements for Category III and IV events (whenever required – See [Ref.22]);
- ITER specific requirements (including those form ITER QA classification, seismic classification, vacuum classification, and capital investment protection).

The quality classification process applied in ITER and, in particular, the procedures to be followed for determining the ITER QA Program requirements for safety/non safety items and/or services are defined in [Ref.25].

Components that are SIC qualified have to comply with specific safety requirements related to design (including loads) and manufacturing. These requirements are covered by the selected basic code plus ITER specific requirements. The ITER specific requirements are defined in the Project Requirements [Ref.26] and ITER Project Management & Quality Program (MQP) documents and all their annexes. More specifically:

- Requirements related to Loads and events to be considered for the design in [Ref.21]
- Requirements related to Design verifications in [Ref.27]
- Requirements related to Analysis QA in [Ref.28]
- Requirements related to Design limits [Ref.21, Ref 22]
- Requirement for manufacturing in [Ref.25]

Requirements for components that are vacuum classified are in [Ref.29].
Requirements for components that are tritium classified are in [Ref.30].

Seismic classifications and requirements are defined in [Ref.31].

6.4 European harmonized standards

Harmonized standards are European standards produced (in consultation with member states) by European standards organizations CEN/CENELEC. There are several harmonized standards which support ESR of EU Pressure Equipment Directive 2014/68/EU:

EN 13445 - Unfired Pressure Vessels
EN 13480 - Metallic Industrial Piping
EN 13458 - Cryogenic vessels - Static vacuum insulated vessels.
EN 14197 - Cryogenic vessels - Static non-vacuum insulated vessels
EN 12434 - Cryogenic vessels - Cryogenic flexible hoses
EN 13648 - Cryogenic vessels - Safety devices for protection against excessive pressure

Note: the edition year of the standards is determined based on design and manufacturing requirements described in each PBS.

Information on European Norms can be found in
http://ec.europa.eu/enterprise/policies/european-standards/index_en.htm.

6.4.1 *Scope of the harmonized standards*

EN 13445 specifies the requirements for the design, construction, inspection and testing of unfired pressure vessels.

EN 13480 specifies the requirements for industrial piping systems and supports, including safety systems, made of metallic materials (but initially restricted to steel) with a view to ensure safe operation.

EN 13458 specifies requirements for the design, fabrication, inspection and testing of static vacuum insulated cryogenic vessels designed for a maximum allowable pressure of more than 0.5 bar.

EN 14197 specifies requirements for the design, fabrication, inspection and testing of static non-vacuum insulated cryogenic vessels designed for a maximum allowable pressure of more than 0,5 bar.

EN 12434 gives design, construction, type and production testing, and marking requirements for non-insulated cryogenic flexible hose used for the transfer of cryogenic fluids.

EN 13648 specifies the requirements for the design, manufacture and testing of safety valves for cryogenic service,

6.4.2 *Basic features of the harmonized standards*

Use of harmonized standards within the limits of the scope of these standards gives a presumption of conformity with the corresponding Essential Safety Requirements of applicable Directive and associated regulations.

6.4.3 *Additional specifications to cover specific features*

For the components with special features that are not covered by EN codes rules special addenda/technical specifications are being prepared. These addenda/specifications, whenever necessary, will also include:

- modifications required to comply with site specific regulations (safety requirements see Chapter 4);

- special requirements for Category III and IV events (whenever required – See [Ref.22]);
- ITER specific requirements (including those form ITER QA classification, seismic classification, vacuum classification, and capital investment protection).

The quality classification process applied in ITER and, in particular, the procedures to be followed for determining the ITER QA Program requirements for safety/non safety items and/or services are defined in [Ref.25].
Components that are SIC qualified have to comply with specific safety requirements related to design (including loads) and manufacturing. These requirements are covered by the selected basic code plus ITER specific requirements. The ITER specific requirements are defined in the Project Requirements [Ref.26] and ITER Project Management & Quality Program (MQP) documents and all their annexes. More specifically:

- Requirements related to Loads and events to be considered for the design in [Ref.21]
- Requirements related to Design verifications in [Ref.27]
- Requirements related to Analysis QA in [Ref.28]
- Requirements related to Design limits [Ref.21,Ref. 22]
- Requirement for manufacturing in [Ref.25]

Requirements for components that are vacuum classified are in [Ref.29].
Requirements for components that are tritium classified are in [Ref.35].

Seismic classifications and requirements are defined in [Ref.31].

7 Compliance of ASME codes with ESP and ESPN

ASME has published documents that provide guides to demonstrate conformity to requirements defined in PED [Ref. 32, 33, 34]. These documents describe how to meet PED requirements designing and manufacturing of pressure equipment in accordance with Section VIII Division 1 and Section I of ASME Boiler and Pressure Vessel Code.

For the ITER pressure and nuclear pressure equipment the use of the following ASME codes and standards is under consideration:

- ASME BPV Code Section VIII Division 2, Edition 2007 or Edition 2010 for vessels
- ASME B31.3 Code, Edition 2006 or 2008 for piping
- ASME B31.3 Code, Edition 2006 or 2008, Appendix X, Bellows according to EJMA Standard, 8th Edition
- ASME B16.34 Standard Edition 2004 for valves
- ASME B73.1 Edition 2001 (Reaffirmed 2007) and B73.2 Edition 2003, Standards for pumps
- Compliance of ASME B31.3 Ed 2010 and Essential Safety Requirements of PED/ESPN

For each selected C&S, its compliance with French ESP and ESPN regulations has been analysed. The results of this activity are presented in the series of reports, see Ref. 35.

For all applicable Essential Safety Requirements that are not or are only partially covered by each selected C&S, complementary specifications have been provided.

These final reports can be considered as reference model for ESR reconciliation templates, to be used by the Manufacturer of the pressure and nuclear pressure equipment to comply with the ESP and ESPN regulations.

8 Code for the first confinement barrier of the plasma chamber

A primary vacuum and first confinement of tritium and activated materials inside the plasma chamber will be provided by different systems, structures and components.
These systems are:

- Vacuum Vessel and Ports
- Closure plates
- Neutral Beam Vessels
- Diagnostic and Heating Port plugs – closure plate of these equipment
- Vacuum system
- Fuelling and pellet injection
- Port plugs for Test Blanket Modules Systems
- Cryopump housing
- Non-metallic components providing vacuum and confinement barriers:
    - Diagnostic windows
    - Windows for heating systems
    - High voltage bushing

Some of these systems are nuclear pressure equipment falling under ESPN regulation, some of them are not under the regulation (not subjected to pressure loads or coolant pressure) and outside of the scope of ESP and ESPN.
Some components are non-standard equipment (non-metallic materials) and for ITER ad-hoc technical specifications shall be prepared as described above.

For metallic parts which form the first confinement barrier of plasma vacuum chamber it is proposed to use one code. This code shall be used for nuclear pressure equipment (e.g. Vacuum Vessel) and for other components, which are non-pressure equipment. The proposed Code is RCC-MR Edition 2007 which already includes ITER Vacuum Vessel (Appendix A19 – ITER Vacuum Vessel Specialities).

Using one code has some benefits for licensing of the ITER plasma chamber which provide first confinement. These advantages are:

- Reduction of risk with delay of licensing ITER facility
- Unification of technical procedures for connections of various components
- Simplification of interface requirements
- It may be beneficial from schedule point of view

For systems which, due to various reasons, do not apply RCC-MR Code, other C&S can be used. It shall be demonstrated that the proposed C&S are in compliance with safety requirements established for these systems and components.

9 Generic rules for interfaces between components with different C&S

Due to application of various C&S, significant attention shall be paid to the definition of C&S for the interfaces between different components. Interface Management Procedure (28VNJG) defines interface control documents which include interface requirements. Interface requirements shall include applicable C&S for execution of interface joints, required examination and testing.

Where an interface between components (or a portion thereof) having different classification (such as safety class, quality class, ESPN/ESP level/category, etc.), the interface shall be classified to the more stringent class. As a consequence where there is an interface of components designed and manufactured by different C&Ss, for the interface a C&S that complies with the highest classes shall be applied. A designer is not restricted from proposing or using ad-hoc criteria for the interface to ensure adequate safety and quality.

10 List of Codes and Standards for the ITER components

Table 1 contains a summary list of Codes and Standards for each ITER component. In the selection of the reference code the equipment classification into the safety, QA, and seismic class or category has to be taken into account. The general guidelines for the safety classification are defined in [Ref.1].

The requirements for detailed classification for each component are defined in the System Requirement Documents. Documents describing detailed classification of pressure and nuclear pressure shall be prepared.

Note:

The selection of the edition date of Codes and Standards for the ITER equipment shall be done for each system before the final design review. Generally, the use of latest edition of Codes is recommended. Edition date of Code shall be included in equipment specifications or procurement.

NOTE for application of ASME codes for ITER pressure and non-pressure equipment:

- In case of use of ASME codes it is not a mandatory requirement that the manufacturing company is ASME stamp holder (U, N, etc.), however it is generally strongly recommended as additional ITER Quality requirements will be imposed if non code stamped companies are used.
- In case of exceptions to the ASME requirements, these exceptions should be clearly identified and justified.

Table 1: List of Codes and Standards for the ITER mechanical components.

PBS No.	Title	ESP/PED Category or ESPN Category & Level (see note*)	Selected Codes	Comments
11	Magnets	Magnet structures are not under ESP/PED Manifolds and piping under ESP/PED (SEP and Category I)	Design: Magnet Structural Design Criteria EN 13480-3 for feeders piping Manufacturing**: Technical specifications based on ASME and EN standards for feeders piping: EN13480-4 for piping manufacture EN13458-2 for safety device strategy ISO 4126 for burst disc and quench valve sizing.	In accordance with ESP/PED, the magnet structures are outside of scope of ESP/PED because "pressure is not significant design factor", see IDM_D_2M4AL6. Manifolds and piping are under ESP/PED, and are classified in Category Sound Engineering Practice (SEP) and Category I. Notified Body is not involved.
15-VV	Vacuum Vessel	ESPN: Category IV for pressure and Nuclear Level N2	Design and manufacturing: RCC-MR Edition 2007 Items not covered by RCC-MR – Technical specifications	Conformity with ESR of ESPN shall be provided. Agreed Notified Body shall check design, manufacturing and conformity with regulation.
15-IVC	In-vessel Coil Systems	Out of the scope of ESP and ESPN [Ref. 38, 39]	Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts – ASME or EN standards - Non-conventional parts – Technical specifications	In accordance with ESP/PED, the in-vessel coil systems are outside of scope of ESP/PED because "pressure is not significant design factor" [Ref. 38, 39]. Final selection of code will be done during finalization of design.

16-MA	Blanket manifolds	Blanket manifolds are excluded from ESP and ESPN [Ref. 39, 40]	Design: RCC-MR Edition 2007 Manufacturing: EN 13480 [Ref. 63] Items not covered by RCC-MR/EN – Technical specifications	In accordance with ESP/PED, Blanket manifolds are excluded from ESP/PED, because “pressure is not significant design factor” [Ref. 39, 40].
16	Blanket System (including Operational Instrumentation)	Outside of the scope of ESP and ESPN [Ref. 38]	Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts - EN standards EN 13445, - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement	In accordance with ESP/PED Blanket is excluded of scope of ESP/PED because “pressure is not significant design factor” [Ref. 38]. Technical specifications are related to non-Code techniques i.e. joints W/Cu, SS/Cu, non-metallic parts and insulation.
17	Divertor (including Operational Instrumentation)	Divertor is excluded from ESP/PED and ESPN [Ref. 38].	Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts –EN standards EN 13445 - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement	In accordance with ESP/PED Divertor is outside of scope of ESP/PED because “pressure is not significant design factor” [Ref. 38]. Technical specifications are related to non-Code technique i.e. joints W/Cu, SS/Cu, non-metallic parts and insulation.

18	Fuelling and wall conditioning	PED/ESPN applicable for some equipment. Some equipment is not under the scope of ESP and ESPN [Ref. 38]	Design and manufacturing: [According to SRDs] vessels: EN standards or ASME Section VIII Div. 2 piping: EN standards or ASME B31.3 (Category M for pipe with radioactive fluid and acting as first confinement barrier) bellows: EN standards or ASME B31.3, Appendix X/EJMA valves: EN standards or ASME B16.34 Pumps: EN standards or ASME B73.1M/B73.2M EN standards related to cryogenic equipment Additional specifications to cover specific ITER requirements (see par.6.2.3 and 6.3.3) <u>Irradiated items</u>: Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts – EN standards EN 13445, - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement	In accordance with ESP/PED, some equipment in this system can be excluded from ESP/PED because "pressure is not significant design factor" [Ref. 38]. Conformity with ESR of ESP and ESPN shall be provided. For piping with radioactive fluid or acting as first confinement barrier (B31.3) Service Category M is selected. Deviation from this selection needs to be approved by IO.
22	Machine Assembly	Some of equipment which will be assembled on site are under ESP (e.g. cryogenic equipment) and ESPN (e.g. Vacuum Vessel) regulations	Shall follow C&S selected for assembled equipment	Shall follow requirements of regulations for assembled equipment.

23	Remote Handling Equipment	Out of scope of ESP/PED	According to SRDs [Ref. 41], Design for Blanket remote handling system: - EN 13001-1, EN 13001-2, EN 13001-3-1 Design for Divertor remote handling system: - Eurocode 0, Eurocode 3, Eurocode 9 - EN 13001-1, EN 13001-2, EN 13001-3-1 Design for Casks and Plug handling system: - For parts providing confinement function - RCC-MR Edition 2007 - ISO 17874, ASTM C 1533-02, ASTM C 1615-05, ASTM C 1554-03, ASTM C 1661-07 - Eurocode 0, Eurocode 3, Eurocode 9 - EN 13001-1, EN 13001-2, EN 13001-3-1 Design for Neutral beam remote handling system: - ASME NUM-1 :2016 - EN 13001-1, EN 13001-2, EN 13001-3-1 Design for Hot cell remote handling system: - ISO 17874, ASTM C 1533-02, ASTM C 1615-05, ASTM C 1554-03, ASTM C 1661-07 - Gloveboxes : AGS-G001, AGS-G002, AGS-G003, AGS-G004, AGS-G006, AGS-G010 - RCC-MRx 2015	[Ref. 41] PBS 23 - Remote Handling System (SRDs)

24- CR	Cryostat	Not under ESP/PED Torus Cryopump housing Cryostat supports and horizontal lugs Pedestal ring and horizontal plate Bearing structure	Design and manufacturing: vessel: ASME Section VIII Div. 2 supports: ASME Section VIII Div.2 bellows: ASME B31.3, Appendix X/EJMA large size rectangular bellows: ASME Section VIII Div.1 [Ref. 42] Items not covered by ASME codes: technical specifications (see par.6.2.3) ASME Section VIII Div.2 (Changed from RCC-MR 2007 by PCR-404) [Ref. 42] ASME III Subsection NF (or equivalent) ASME III Subsection NC (or equivalent) EN 1337: Structural bearings, [Ref. 36]	Components and parts providing support to the tokamak machine are designed and manufactured following nuclear code to improve machine safety.
24- VP	Vacuum Vessel Pressure Suppression System Vapour Suppression Tank	ESPN VVPSS: ESPN Level N2 Category IV [Ref. 43] VST: Category IV for pressure and Nuclear Level N2 [Ref. 44, 45]	Design and manufacturing: vessel: ASME Section VIII Div. 2 piping: ASME B 31.3, Category M, additional ASME Section VIII Div.2, ESPN FR SFMMMB support structure: EPE ITER SMPX 1020 000 Rev 0 piping supports: ASME Section III NF Items not covered by ASME codes: technical specifications (see par.6.2.3)	Conformity with ESP/PED/ESPN is needed (see Chapter 7).

26	Cooling Water System	TCWS - ESPN: Category from 0 to IV for vessels Category I-III for piping Level N2 and N3 Other systems CCWS, HRS, CHWS - non-nuclear, but ESP/PED All water pumps are not under the scope of ESP/PED [Ref. 38]	Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B 31.3 (TCWS: ASME B31.3, Category M) Piping supports: Additional technical specifications (approved by IO) providing more prescriptive requirements than those in B31.3 shall be prepared pumps: ASME B73.1 / B73.2 API 610, API 685 valves: ASME B16.34 bellows ASME B31.3, Appendix X/EJMA supports: AISC Steel Construction Manual; ANSI/AISC N690; AWS D1.1/D1.1M; and AWS D1.6 EN 13445 for Pressure Vessels for Drying System Heater and Vacuum Vessel Primary Heat Transfer System (PHTS) Baking Heater Items not covered by ASME codes: technical specifications (see par.6.2.3)	Conformity with ESP/PED/ESPN is needed (see Chapter 7). Agreed Notified Body shall check design, manufacturing and conformity depending on ESPN Category of equipment. For piping with radioactive fluid (B31.3) Service Category M is selected as compensation measure in alternative to nuclear code. Deviation from this selection needs to be approved by IO. In accordance with ESP/PED, pumps are outside of the scope of ESP/PED because “pressure is not significant design factor” [Ref. 38].

27	Thermal Shields	ESP/PED Thermal shield panels could be excluded - pressure is not significant design factor. Agreed with ANB APAVE Piping and manifolds – SEP and Category I.	Design and manufacturing: - ASME B 31.3, Category M, for piping - ASME Sec VIII Div. 2 for panels and supports - EN 13458: Cryogenic vessels – Static vacuum insulated vessels - EN 12434: Cryogenic vessels - Cryogenic flexible houses - EN 13468: Cryogenic vessels - Safety devices for protection against excessive pressure - EN 13480: Metallic Industrial Piping Note: Code case for use low temperature materials properties for TS panels is under preparation Items not covered by ASME or EN codes: technical specifications (see par.6.2.3 and 6.3.3)	Conformity with ESP/PED is needed, where ESP/PED applicable for Category I equipment (see Chapter 6). In case of equipment is in pressure Category I, Notified Body is not involved. For piping (B31.3) Service Category M is selected as compensation measure in alternative to nuclear code. Deviation from this selection needs to be approved by IO.

31	Vacuum	Cryopumps and supplied piping are under ESP/PED Category – 0-IV	Design and manufacturing: EN 13445 for cryopump (closure plate provide first confinement) Vacuum Vessel rough pumping system, cryopump regeneration (some of them are first confinement barrier): Vessel: ASME Section VIII Div. 2 piping: ASME B31.3, (Category M for first confinement barrier) bellows: ASME B31.3, Appendix X/EJMA Items not covered by codes: technical specifications (see par.6.2.3) Main EN standards for cryogenic application. EN 13445-Unfired Pressure Vessels EN 13480-Metallic Industrial Piping EN 13458-Cryogenic vessels - Static vacuum insulated vessels. EN 14197-Cryogenic vessels - Static non-vacuum insulated vessels EN 12434-Cryogenic vessels - Cryogenic flexible hoses EN 13648-Cryogenic vessels - Safety Items not covered by EN codes: technical specifications (see par.6.3.3)	Conformity with ESP/PED is needed, where ESP/PED applicable for Category more than SEP, (see Chapter 7). In case of equipment is in pressure Category more than I Notified Body is involved. For piping with first confinement function (B31.3) Service Category M is selected as compensation measure in alternative to nuclear code. Deviation from this selection needs to be approved by IO.

32	Tritium Plant & Detritiation	ESPN and ESP/PED Category 0-IV Level N2, N3 or non-nuclear for various parts of the system	Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B 31.3 (Category M for pipe with radioactive fluid) valves: ASME B 31.3, B16.34 bellows: ASME B 31.3, Appendix X, EJMA Items not covered by codes: technical specifications (see par.6.2.3) *Note: Some clauses of ASME BPVC Section III Division 1 may also be applied.*	Conformity with ESP/PED/ESPN is needed (see Chapter 7). Agreed Notified Body shall check design, manufacturing and conformity depending on ESPN Category of equipment. For piping with radioactive fluid (B31.3) Service Category M is selected as compensation measure in alternative to nuclear code. Deviation from this selection needs to be approved by IO.
34	Cryogenic System	ESP/PED, Cat 0 - IV for various parts of the system	Design and manufacturing: EN 13445-Unfired Pressure Vessels EN 13480-Metallic Industrial Piping EN 13458-Cryogenic vessels - Static vacuum insulated vessels. EN 14197-Cryogenic vessels - Static non-vacuum insulated vessels EN 12434-Cryogenic vessels - Cryogenic flexible hoses EN 13648-Cryogenic vessels - Safety ASME codes are back-up, providing conformity with ESR of ESP/PED Items not covered by EN codes: technical specifications (see par.6.2.3 and 6.3.3)	Conformity with ESP/PED is needed if ASME codes are used. Notified Body shall check design, manufacturing and conformity for equipment with Category more than I.
41	Coil Power Supply and Distribution	Cooling system for this PBS may fall under ESP/PED requirements	Electrical Design Handbook, part 3 [Ref.37].	Note: Some equipment may fall under requirements of French Order 18th August 2010, [Ref. 5].

43	Steady State Electrical Network	n/a	Electrical Design Handbook, part 3 [Ref. 36].	Note: Some equipment may fall under requirements of French Order 18th August 2010, [Ref.5]
44	Cable Tray Infrastructure	n/a	Specifications are provided in related SRD	-
51	Ion Cyclotron Heating & Current Drive (ICH & CD) System	Excluded from ESP/ESPN [Ref. 38, 46]	RCC-MR Edition 2007 - components providing first confinement barrier of the plasma chamber For other parts (non-SIC): Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B31.3 or RCC-MR 2007 or related EN standards In case of application of ASME B31.3 additional technical specifications for piping supports shall be specified as required Items not covered by codes: technical specifications (see par.6.2.3) <u>Irradiated items:</u> Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing, inspection: - Conventional Parts – ASME or EN standards EN 13445 (depending on Party) - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement <u>Non-metallic windows</u> Technical specifications are under development [Ref.10]	In accordance with ESP/ESPN, ICH&CD are excluded from ESP/ESPN, because “pressure is not significant design factor” [Ref. 38, 46] and because exclusion of transmission line.

52	Electron Cyclotron Heating & Current Drive (ECH & CD) System	Most equipment are excluded from ESP/ESPN [Ref. 38, 47, 48] Some equipment (cooling jumpers outside of the port plug) is under discussion to fall out of the scope of ESP and ESPN [Ref. 47, 48]	RCC-MR Edition 2007 or ASME Sec III – components providing first confinement barrier of the plasma chamber For other parts (non-SIC): Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B31.3 or RCC-MR 2007 or related EN standards In case of application of ASME B31.3 additional technical specifications for piping supports shall be specified as required. Items not covered by codes: technical specifications (see par.6.2.3) <u>Irradiated items</u>: Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts – ASME or EN standards EN 13445 (depending on Party) - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement <u>Non-metallic windows</u> Technical specifications are under development [Ref.10]	In accordance with ESP/PED, most equipment of this system can be excluded from ESP/PED because “pressure is not significant design factor” [Ref. 38, 47, 48] and because exclusion of transmission line.

53	Neutral Beam Heating & Current Drive (NBH & CD) System	Out of scope of ESP and ESPN: NB Duct Liners, Transmission Lines, DCGs (Direct Current Generators), DCFs (Direct Current Filters), TPS (Testing Power Source) tanks [Ref. 38, 49, 50, 51, 52] Cooling pipes Line with SF6 is under PED and ESPN Piping valves for SF6 system are under Category IV level N3 [Ref. 64]. Some items (DNB, HNB1 and HNB2) are Category II - III, level N3 [Ref. 53, 54]. Some items are non-ESPN, but SEP of ESP/PED [Ref. 53, 54].	RCC-MR Edition 2007- components providing first confinement barrier of the plasma chamber EN 13445 for cryopumps and EN codes for cryosupply For other parts (non-SIC): Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B31.3 or RCC-MR 2007 or related EN standards Items not covered by codes: technical specifications <u>Irradiated items</u>: Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts –EN 13445 or ASME (depending on Party) - Non-conventional parts – Technical specifications Pressure testing: ESP/PED requirement Insulating bushing: (first confinement barrier) Technical specifications are under development [Ref. 53] Piping: ASME B31.3 Pipe flanges: ASME Section III NC-3658.3 Flanged fittings: ASME Section III NC-3658.3 Support: AISC N690 Valve: ASME Section III NC-3521	In accordance with ESP/PED, some equipment in this system can be excluded from ESP/PED because “pressure is not significant design factor” [Ref. 38, 49, 50, 51, 52]. For items which are under ESPN Conformity with ESR of ESP and ESPN shall be provided. Note: Some equipment may fall under requirements of French Order 18th August 2010, [Ref. 5].

55	Diagnostics	Excluded from ESP and ESPN [Ref. 38, 39, 55, 56, 57, 58]	RCC-MR Edition 2007 - components providing first confinement barrier of the plasma chamber <u>For other parts (non-SIC equipment):</u> Design and manufacturing: vessels: ASME Section VIII Div. 2 piping: ASME B31.3 or corresponding EN standards or RCC-MR In case of application of ASME B31.3 additional technical specifications for piping supports shall be specified as required. Items not covered by codes: technical specifications (see par.6.2.3) <u>Irradiated items</u>: Design: Structural Design Criteria for In-Vessel Components (SDC-IC) Manufacturing: - Conventional Parts – EN standard EN 13445 or ASME (depending on Party) - Non-conventional parts – Technical specifications - Pressure testing: ESP/PED requirement where applicable <u>Non-metallic windows</u> Technical specifications are under development [Ref.10]	In accordance with ESP/PED, some equipment in this system can be excluded from ESP/PED because “pressure is not significant design factor” [Ref. 38, 39, 55, 56, 57, 58]. In case of ESP/PED or ESPN application, conformity with ESP/PED/ESPN is needed (see Chapter 6). Depending on Category Notified Body (or ANB) shall check design, manufacturing and conformity.

56	Test Blankets System	Some equipment (Dummy TBM, TBM Frame) excluded from ESP/PED and ESPN [Ref. 38] Water decay tanks – PED Category IV, Nuclear level N2 [Ref. 59]	RCC-MR Edition 2007 - components providing first confinement barrier of the plasma chamber EN 13480 EN 13445 Selection of C&S is responsibility of DAs, developing the TBS.	In accordance with ESP/PED, some equipment in this system can be excluded from ESP/PED because "pressure is not significant design factor" [Ref. 38]. Selection of Code is addressed to TBM Working Group. In case of ESP/PED or ESPN application, conformity with ESP/PED/ESPN needs to be demonstrated.
57	In-Vessel Viewing Systems [Ref. 60]	Out of scope of ESP and ESPN [Ref. 60]	[Ref. 60] IVVS Design and manufacturing: RCC-MRx 2012 For parts providing confinement function – RCC-MR Edition 2007 shall be used for design and manufacturing Non-metallic windows – IO technical guidelines for design and manufacturing Mechanical elements of IVVS – SDC-IC for design	The current design of the IVVS does not include any components categorized as ESPN. If the IVVS design evolve to include ESPN components, they will have to comply with the requirements associated with its ESPN class [Ref. 60]

58	Port Plug Test Facility	For Nuclear Test Stands - ESP/PED and ESPN [Ref. 61]: Vessels of Equatorial Test Tank and Upper Test Tank – PED Category IV, Nuclear level N2 [Ref. 59, 61] ESP/PED [Ref. 61]: Most equipment of Heating Systems of Equatorial Test Stand and Upper Test Stand are non-ESPN, but PED categories from I to IV. The chambers of Equatorial Test Tank and Upper Test Tank are non-ESPN, but PED Category IV. For non-Nuclear Test Stands - ESP/PED [Ref. 62]: Heating system – PED Categories form I to IV, Test tank (water loop) – PED Category IV	Design and manufacturing: vessels: ASME Section VIII Div1 or .2 piping: ASME B31.3 valves ASME B16.34 pumps for fluid ASME B73.1 / B73.2 or corresponding EN standards In case of application of ASME B31.3 additional technical specifications for piping supports shall be specified as required. Items not covered by codes: technical specifications (see par.6.2.3)	Conformity with ESP/PED and ESPN is needed where applicable.
64	Radiological and Environmental Monitoring	N/A	Design and manufacturing: piping: ASME B31.3 or corresponding EN standards (e.g. EN 13480)	-

65	Liquid & Gas Distribution	Under ESP/PED Vessels – Category IV Piping Category 0 - III	Design and manufacturing: Vessel EN 13445 piping: EN 13480 Items not covered by codes: technical specifications (see par.6.2.3)	Conformity with ESP/PED is needed where applicable. Depending on Category Notified Body shall check design, manufacturing and conformity.

Notes:

* Detailed list of each individual nuclear pressure equipment and pressure equipment shall be prepared for each PBS

** Manufacturing includes materials procurement, forming, machining, assembling, welding, brazing, heat treating, examination, testing, and inspection where applicable.

*** tbd = to be determined.

**** N/A – not applicable

11 References

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6 French Order of December 30th 2015 currently modified by French order 03/09/2018 (ESPN)

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8 Magnet Structural Design Criteria
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Part III: Bolts, Keys, Supports and Special Components, ITER_D_2FKTTG.
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9 Structural Design Criteria for ITER In-vessel Components (SDC-IC), ITER_D_222RHC.

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11 SDC-IC – Design by Experimental Methods, Annex1, ITER_D_49BQM7

12 ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Alternative Rules for Construction of Pressure Vessels, The American Society of Mechanical Engineers, New York

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16 Specifications for Vertical In-Line Centrifugal Pumps for Chemical Processes (ASME B73.2), The American Society of Mechanical Engineers, New York

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18 Design and Construction Rules for Mechanical Components of Nuclear Installations: High Temperature, Research and Fusion Reactors, RCC-MRx Edition 2022

19 EN 13445: - Unfired Pressure Vessels

20 EN 13480: - Metallic Industrial Piping

21 Load Specifications, ITER_D_222QGL

22 Allowable values and limits in service level C and D for ITER mechanical components, ITER_D_3G3SYJ

23 API 610, Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry

24 API 685, Sealless Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services
25 Quality Classification Determination, ITER_D_24VQES.
26 Project Requirements Document (PR), ITER_D_27ZRW8
27 Design Review Procedure, ITER_D_2832CF
28 Analyses and calculations, ITER_D_22MAL7
29 ITER Vacuum Handbook, ITER_D_2EZ9UM
30 Tritium Handbook (2LAJTW)
31 ITER Seismic Nuclear Safety Approach, ITER_D_2DRVPE
32 Guide for ASME Stamp Holders, Use of ASME Sec. VIII, Div. 1 to Meet the EC Pressure Equipment Directive (97/23/EC), ASME, July 2, 2001
33 ASME Section I PED Guide, Supplement to Guide for ASME Holders Use of ASME Sec. I to Meet the Pressure Equipment Directive (97/23/EC), STP/PT-002, ASME, May 27, 2005
34 Guide to the use of ISO 15649 and ANSI/ASME B31.3 for piping in Europe in compliance with the Pressure Equipment Directive, FD CEN/TR 14549, July 2005
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4 - Compliance ASME B31.3 bellows and ESP/ESPN, ITER_D_35JYWW
5 - Compliance ASME B16.34 and ESP/ESPN, ITER_D_33YHTZ
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42 SRD-24-CR (Cryostat) (ITER_D_28B2TP)
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57 Première Paroi Supérieure des Diagnostics, Justification de la demande de classification des Premières Parois Supérieures des Diagnostics comme n'étant pas soumis aux dispositions des Titres II et III du Décret 99-1046 et non soumis à l'Arrêté ESPN (ITER_D_ MU33EE)
58 55.QC. Justification of the exclusion of the modular DSM from pressure equipment regulations (ITER_D_4ETUEL)
59 List of NPE-vessel in IO (ITER_D_ YSMF7S))
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