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27ZRW8

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EXTERNAL REFERENCE / VERSION

Technical Requirements Specification

Project Requirements (PR)

This Project Requirements (PR) document contains the ITER project-level technical requirements that are needed to establish the suitability of the ITER design for its mission, as specified at the Council level in the Project Specification (PS) document.
The PR establishes the technical baseline for the ITER Project, and provides a common basis for the development of the System Requirements Documents (SRDs) for the ITER systems. The technical requirements that are in the PR are allocated and flown down to the ITER systems for inclusion in the SRDs.
The PR is complemented by its list of applicable documents - ITER_D_YQBMTQ - Applicable Document Matrix of the Project Requirements document (PR-ADMx).

Approval Process			
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Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: EUROfusion-DEMO, AD: IDM_Controller, AD: members-DA, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: Hot Cell...**		

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Change Log			
Project Requirements (PR) (27ZRW8)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	23 Oct 2007	2007 Baseline
v1.1	In Work	24 Oct 2007	2007 Baseline
v2.0	In Work	29 Apr 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.1	In Work	02 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.2	In Work	06 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.3	In Work	07 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.4	In Work	20 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.5	Signed	29 Jun 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.6	Signed	29 Jul 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.7	Signed	04 Aug 2008	2007 Baseline, Updated April 2008, expect signature June 2008
v2.8	Signed	20 Aug 2008	Updated April-Sept 2008, expect signature Late 2008
v2.9	Signed	02 Sep 2008	Updated April-Sept 2008, expect signature Late 2008
v2.10	In Work	13 Oct 2008	Updated April-Sept 2008, expect signature Late 2008
v2.11	Signed	27 Nov 2008	
v3.0	In Work	17 Apr 2009	
v3.1	Signed	11 Jun 2009	v3.0 on IDM was v33 on the author's PC v3.1 on IDM was v41 on the author's PC
v3.2	Signed	08 Jul 2009	Revised version ready for formal review (v45 on Wayne's PC)
v4.0	Signed	05 Aug 2009	1/ Internal IO review - 17 July 2009 - 5 August 2009 2/ new structure to the document, mainly by splitting the former "section 3. Project Requirements" following its sub-sections. 3/ the details of modifications between v3.2 and V4.0 are contained in the attached word file Draft version 48-1. 4/ The word file corresponding to the IDM 4.0 document is attached as Draft version 49-0.
v4.1	Signed	13 Sep 2009	Version 4.1 contains the Version 4.0 modified following comments and suggestions received from EU-DA, IN-DA, JA-DA and US-DA during August 2009. Additional modifications have been provided by IO. The main modification concerns the Plasma Scenarios Section and the Plasma Control Section that have been entirely reshaped.
v4.2	Signed	22 Sep 2009	Changes in response to reviewers' comments on previous version, including comments from the DAs As summarised in Table of modifications to the PR (2UXR4Y)
v4.3	Signed	25 Sep 2009	Changes in response to reviewers' comments on version v4.2,as summarised in Table of modifications to the PR (2UXR4Y)
v4.4	Approved	29 Sep 2009	Changes in response to reviewers' comments on version v4.3,as summarised in Table of modifications to the PR (2UXR4Y)
v4.5	Approved	07 Oct 2009	This version of the PR document has exactly the same content as version 4.4 It has been uploaded in IDM again to allow all reviewers to recommend it.
v4.6	Approved	07 May 2010	Changes in response to comments on version v4.5, made by IDM reviewers, STAC reviewers, and during the review of PCR-200, and are summarised in Table of modifications to the PR (2UXR4Y)
v5.0	Signed	02 Aug 2013	All changes to the PR are tracked, within the frame of PCR-300, and the table of "changes since v4.6" will be attached when v5.0 (or a subsequent version) is approved. Here is the list of changes to PR since version 4.6: • PCR-M026 (CN-000040) Deletion of PBS-67 • PCR-M215 (CN-000215 and 216) in Section 7.6 (was Section

			7.3 in PCR-200) • PCR-M250 in Section 7.1 • PCR-251 (CN-000190) Figure 5-1 and Table 4-8 (was Table 4-9 in PCR-200) • PCR-273 in PR453 and PR458 in Section 4.3.2.1, in Table 7-4 (was Table 7-2 in PCR-200) • PCR-300, harmonization of PR with RPrS • PCR-318, Table 5-2 • PCR-333 (CN-000173) full Section 6.13 • PCR-351 (CN-000213) Table 5-3 • PCR-385 (CN-000220) in Table 6-7 (was Table 6-6 in PCR-200), in PR1690 • PCR-387 (CN-000212) in Table 6-4 • PCR-393 in Section 7.3.4, 7.3.5 • PCR-398 (CN-000214) in Table 7-4 (was Table 7-2 in PCR-200) • PCR-402 Figure 5-1 • PCR-404, Table 5-3 • PCR-405, Table 5-1, Table 5-2 • PCR-408, Table 5-1, Table 5-2 • PCR-412, Table 7-4 (was Table 7-2 in PCR-200) • PCR-425 (CN-000218) in Section 6.10 • PCR-432 in Section 6.18, Section 7.3.4 • PCR-475, Figure 5-1 • PCR-495 (CN-000231) in Table 4-3, Section 4.3.5.1 • PCR-496 in Section 4.4.3
v5.1	Signed	10 Dec 2013	This version (v5.1) incorporates the accepted comments from the IDM reviewers of version v5.0. Also added, is the reference to the Order dated 7 February 2012 relating to the general technical regulations that are applicable to INB. The list of PCRs incorporated since the previous approved version is given in the description of version v5.0. (see change log on the second page of the the cover pages of this version). The table with track changes highlighting all changes to previous version and all comments to version v5.0 and, the responses of CIE/PEI, is given in the attached file.
v5.2	Signed	13 Jan 2014	This version (v5.2) incorporates the accepted comments from the IDM reviewers of version v5.1. Also added, is the decision of the ITER Council to have a full tungsten divertor since the begiinning of ITER. The list of PCRs incorporated since the previous approved version is given in the description of version v5.0. (see change log on the second page of the the cover pages of this version). The table with track changes highlighting all changes to previous version and all comments to version v5.0 and 5.1 and, the responses of CIE/PEI, is given in the attached file.
v5.3	Approved	02 Apr 2014	The version 5.3 of the PR includes changes due the PCR-300 and the following ones: PCR-M026, PCR-176, PCR-M125, PCR-M250, PCR-251, PCR-273, PCR-318, PCR-333, PCR-351, PCR-385, PCR-387, PCR-393, PCR-398, PCR-402, PCR-404, PCR-405, PCR-408, PCR-412, PCR-425, PCR-432 , PCR-475, PCR-495, PCR-496, PCR-582. Two companion documents are available to track changes between the version 4.6 (approved 14 May 2010) and version 5.3: - the change tracking text of the version 5.3: ITER_D_GGT4WD, that contains also the comprehensive list of the reviewer comments on V5.0, V5.1 and V5.2, with their answers. - the history of modifications to the PR since version 4.0: IDM_D_2UXR4Y
v6.0	Signed	25 Mar 2019	As part of establishing the 2016 ITER Technical Baseline (PCR-738 - Establishment of the 2016 ITER Baseline and its daughter PCRs ITER_D_UX2XW2 - PCR-738 Baseline 2016 daughters), the Project

			Requirements document (PR) has been revised to: • Reconcile it with the approved evolutions of the ITER Technical Baseline; • Ensure its consistent and integrated propagation across the ITER Buildings and Systems. The PR was consequently modified in order to: • Implement the new staged approach for ITER installation and operation and other approved project changes impacting the PR (PCR-M251, PCR-609, PCR-515, PCR-M354, PCR-710, PCR-722, PCR-755, PCR-M384); • Clarify, where necessary, the PR requirements to ensure that: o They reflect the current maturity in implementing the ITER Project needs; o They are suitably managed within the ITER Project. The approved evolutions to the PR between version 5.3 and version 6.0 are presented in • The PR change log document ITER_D_Y23R67 - Summary of PR revision for 2016 Baseline; • Its appendix ITER_D_Y244KY - Summary of PR revision for 2016 Baseline - Appendix A: Detailed modifications from PR v5.3 to Final PR v6.0.
v6.1	Signed	21 May 2019	Minor version to implement the reviewers comments as agreed. Record of implemented changes is provided in the comments. The PR Change Log Document and its annexes will be updated accordingly.
v6.2	Approved	28 May 2019	Minor version to implement the reviewers comments to version 6.1. Record of implemented changes is provided in the comments. The PR Change Log Document and its annexes will be updated accordingly.
v6.3	Approved	29 Apr 2020	Fast track revision for configuration management of this baseline document so that its last approved file available in IDM incorporates all the approved PR evolutions via: - the formal review & approval of PRv6.2 in IDM; - PR v6.2A addended with the PR Change Notice for PCR-001008 - Removal of the LHCD system from the upgrade scenarios [2FA42J]; - PR v6.2B addended with the PR Change Notice for PCR-738 - Additional minor corrections [2SXCVG]. This version of the PR (with its list of applicable documents [PR-ADMx, YQBMTQ) will be authorized in PLM for use within the whole ITER Project from May 2020. All the changes implemented in the PRv5.3 to produce this PR version 6.3 - as part of PCR-738 - Establishment of the 2016 Baseline - are outlined in the PR Change Log Document [Y23R67] and detailed in its appendix table [Y244KY]. There is also attached in the PR IDM metadata a Word file in track change between PRv5.3 and v6.3.
v7.0	Signed	26 Nov 2024	As part of establishing the 2024 ITER Technical Baseline (PCR-01600), the Project Requirements document (PR) has been revised to: • Reflect the Baseline 2024 / Scenario B (tungsten FW, boronization, new staged approach…). • Implement PR improvements (like PR simplifications and clean-up to remove “gold-plated” requirements, reflect project-level deviations/changes and improve the PR usability, as well as regularizing propagation of existing project-level requirements via the PR). All the changes implemented in the PRv6.3 to produce this PR version 7.0 - as part of PCR-001600 - Establishment of the 2024 ITER Technical Baseline - are outlined in the PR Change Log Document [CH6SC] and detailed in its

			appendix table [CH6TLA] (including a Word file in track change between PRv6.3 and PRv7.0 attached in the IDM metadata of [CH6TLA]).
v7.1	Approved	20 Jan 2025	Correction of the PR requirement PR6055 for the required environmental monitoring from SRO, to realign the PR with its applicable document [A41] ITER Safety strategy (9JWKBL v2.3), as part of PCR-1600. See Attached note detailing this change and rationale, as agreed with the stakeholder.

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1 INTRODUCTION

1.1 PURPOSE

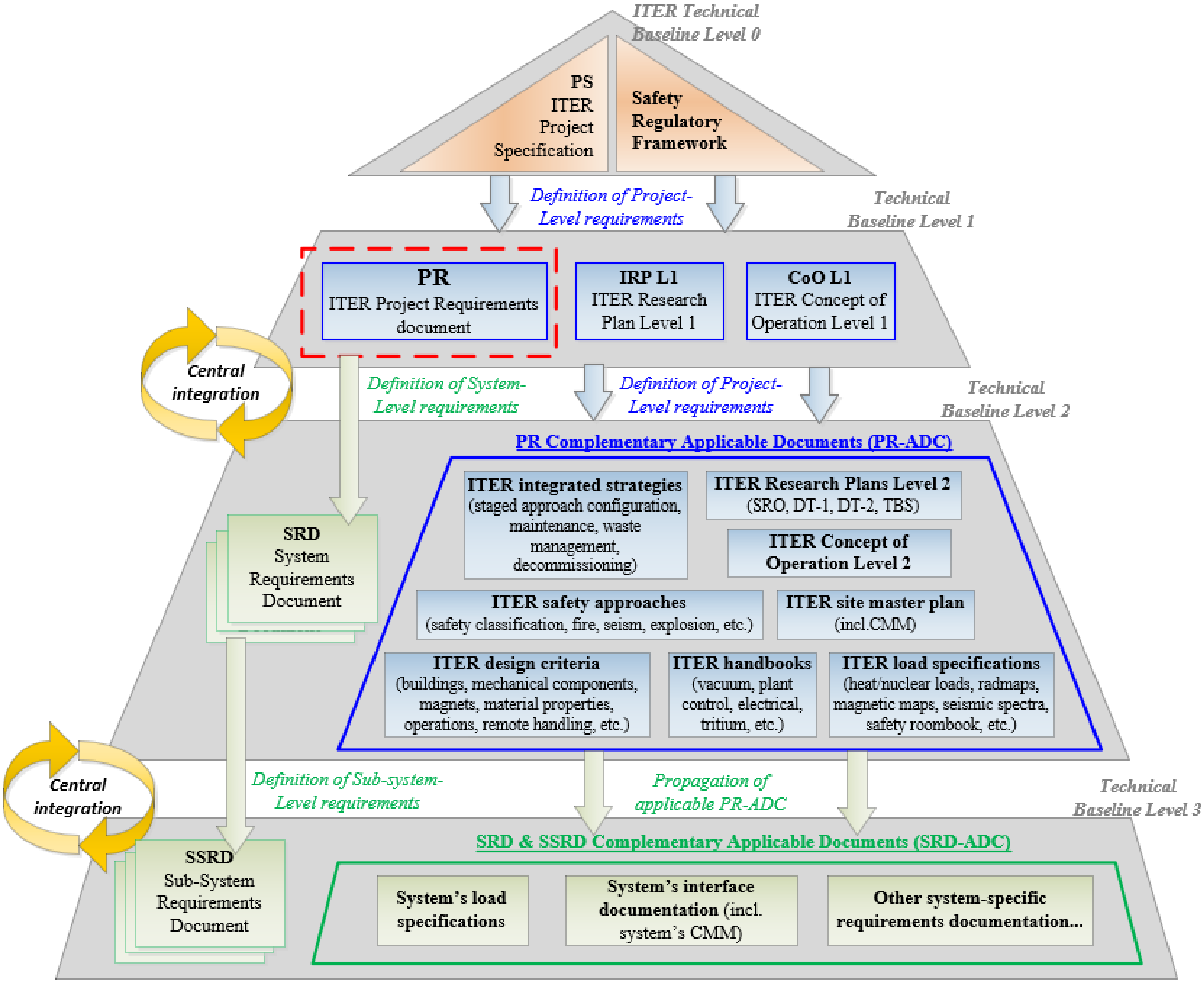
[PR4-I] This document is the ITER Project Requirements document (PR). The PR, including its Complementary Applicable Documents (PR-ADC), contains the ITER project-level technical requirements to be satisfied by the ITER Facility during its whole lifecycle (from design, construction, operation, till its decommissioning).

[PR2075-I] The PR (and its PR-ADC) provides a common technical basis to develop the design of the systems constituting the ITER Facility.

1.2 SCOPE

[PR1885-I] The PR (and its PR-ADC) contains the ITER project-level technical requirements that are needed to establish the suitability of the ITER design for its mission, as specified in the *Project Specification (PS) document [R01]*.

Figure 1-1: Architecture of ITER requirements specifications at system- & project-level



[PR6000-I] The PR (and its PR-ADC) is consistent with the following documents:

- The *Project Specification (PS) [R01]*, which specifies the overall objectives of the ITER Project and the ITER Facility.
- The Safety Regulatory Framework, which defines the regulatory requirements to be implemented in ITER licensing process with the French nuclear safety authorities (ASN) as requested in the PS. This includes the *Decree authorizing the creation of ITER Facility (9 November 2012) [R31]*, which is complemented by the *ASN Decision 2013-DC-0379 [R32] establishing the prescriptions for ITER design and construction, and subsequent exchanges with the ASN*.
- The *ITER Research Plan Level 1 (IRP L1 [R07])*, which describes, for each phase, the research and development activities foreseen to achieve the main PS operational and technical goals (including the plasma scenarios to be developed), as well as the overall timeline and the required ITER Facility configuration.
- The *ITER Concept of Operations Level 1 (CoO L1 [R41])*, which describes the operational objectives of the ITER Facility (including the cycles of operations, conduct of operations, operations organization and the main functions of ITER systems) to achieve the main PS operational goals.

[PR1893-I] The technical requirements that are in the PR are propagated to the ITER Systems, to define their system-level technical requirements for inclusion in their System Requirements Documents (SRDs and their Complementary Applicable Documents (SRD-ADC)).

[PR8-I] The PR includes the following chapters.

- *Chapter 2 - Applicable and Reference Documents*, listing all documents that are referenced in the PR.
- *Chapter 3 - Overall Description of ITER*, outlining the ITER Project, ITER Facility and its Systems.
- *Chapter 4 - Main ITER Activities and associated Performances*, regrouped by Plasma Generation, Maintenance, Waste Management and Plant Auxiliary Support.
- *Chapter 5 - Layout Requirements*, providing the physical integration constraints for ITER systems (as represented by the top-level drawings and models).
- *Chapter 6 - Operational Requirements*, providing requirements that are related to the operation of ITER facilities and systems.
- *Chapter 7 - Environmental, Safety, Health and Security Requirements*.
- *Chapter 8 - Construction Requirements*.
- *Chapter 9 - ITER Decommissioning requirements*.

1.3 ABBREVIATIONS AND CONVENTIONS

[PR23-I] Abbreviations and acronyms used in the PR are defined throughout the document and can be found in an on-line abbreviation dictionary available on the ITER Technical Web site.

[PR1889-I] Each statement of the PR has a unique and permanent identifier, which is composed as follows:

- Its unique numbering in the requirement management database (for example PR515),
- Its object type as one of the followings:
  - -R for requirement,
  - -I for information (including the PR references provided for information only),

  - Its classification as Defined Requirement, i.e. a requirement assigned to a Safety Important Component (SIC) so that it may perform the functions provided for in the safety demonstration required under the *INB Order [R30]*. The PR also includes Defined Requirements for Protection Important Activities (PIA).

[PR6001-I] The PR references several technical documents that are categorized as follows:

- The PR Input Applicable Document (PR-ADI), which are the parent documents of the PR. PR-ADI are the *Project Specification [R01]* and the Safety Regulatory Framework (including [R31] and [R32])). The PR is compliant with its PR-ADIs.
- The PR Complementary Applicable Document (PR-ADC), which are technical documents containing project-level requirements in complement to the PR and that are made applicable to ITER via the PR. ITER must comply with all PR-ADCs.
- Other documents only provided for information.

These documents are listed in the PR Chapter 2. Throughout the PR, the PR-ADC are tagged with identifiers starting with A (like [A10]), and the other documents with identifiers starting with R (like [R22]).

2 APPLICABLE AND REFERENCE DOCUMENTS

[PR50-I] This section lists the PR-ADC and other documents referenced in the PR, as explained in [PR6001- I].

[PR5411-R] ITER shall comply with the applicable version of each PR-ADC that are specified in the **last** authorized version of the PR Applicable Document Matrix (PR-ADMx) ITER_D_YQBMTQ - Applicable Document Matrix of the Project Requirements document (PR-ADMx).

Complementary Applicable Documents (PR-ADC)		
[A01]	CS and PF coils data and requirements to separatrix positioning for analysis of ITER plasma equilibria and poloidal field scenarios	2ACJT3
[A02]	Plant Control Design Handbook	27LH2V
[A03]	*Reference no longer required*	*N/A*
[A04]	ITER Coordinate Systems	2A9PXZ
[A05]	ITER Vacuum Handbook	2EZ9UM
[A06]	Codes and Standards for ITER Mechanical Components	25EW4K
[A07]	Electrical Design Handbook (EDH) Part 1: Introduction	2F7HD2
	EDH Part 2: Terminology & Acronyms	2E8QVA
	EDH Part 3: Codes & Standards	2E8DLM
	EDH Part 4: Electromagnetic Compatibility (EMC)	4B523E
	EDH Part 5: Earthing and Lightning Protection	4B7ZDG
[A08]	ITER Operational States	54L85L
[A09]	Magnet Structural Design Criteria Part 1: Main Structural Components and Welds	2FMHHS
	Magnet Structural Design Criteria Part 2: Magnet Windings (Radial Plates and Conductors) with High and Low Voltage Insulation and Epoxy Filler	2ES43V
	Magnet Structural Design Criteria Part 3: Bolts, Keys, Supports and Special Components	2FKTTG
	Magnet Structural Design Criteria Part 4: Cryogenic Piping	2FDCA3
[A10]	Structural Design Criteria for ITER In-vessel Components (SDC-IC)	222RHC
[A11]	ITER Structural Design Code for Buildings (I-SDCB) - Part1: Design Criteria	283B24
[A12]	ITER Structural Design Code for Buildings (I-SDCB) - Part 2: Construction	2E2U9X
[A13]	ITER Site Master Plan	27X5FM
[A14]	Load Specifications	222QGL
[A15]	Heat and Nuclear Load Specifications	2LULDH
[A16]	Tritium Handbook	2LAJTW
[A17]	RH Compatibility Procedure	2NRTWR
[A18]	Magnet Superconducting and Electrical Design Criteria	22GRQH
[A19]	Contents of PF scenario database	34263N
[A20]	ITER site meteorology	2UT36S
[A21]	ITER Materials Properties Handbook, Introduction, baseline 2009	2NRCSB
[A22]	Safety Requirements for ITER Facility Buildings	2E4KSJ
[A23]	Safety Important Functions and Components Classification Criteria and Methodology	347SF3
[A24]	ITER Coordinate System and Coils Polarities	QRUDS6
[A25]	Chemical composition and impurity requirements for materials	REYV5V
[A26]	Irradiation Scenarios	New
	Radiation Maps During Plasma Operations (Mode-0)	RJLLFY
	Dose Rate Contribution of Activated Components and Structures During Mode 1.	V35THE
	ITER Radiation Maps: Subtask 3 report	F8UEXR
	ITER Radiation Maps: Subtask 4 report	67CN24
	ITER Radiation Maps: Subtask 5 report	HPX254
[A27]	Safety requirement Roombook	KF63PB
[A28]	ITER Seismic Nuclear Safety Approach	2DRVPE

Complementary Applicable Documents (PR-ADC)		
[A29]	Static and Transient Magnetic Field Maps in Tokamak Building	3BQBVY
[A30]	Load Specification Annex – Internal Explosions: Hydrogen Deflagration in Tokamak Complex	BMQ9XM
[A31]	ITER Investment Protection Handbook	3VUMVW
[A32]	ITER Site Signage & Graphics Standards	4ALJEU
[A33]	ITER Research Plan Level 2 for SRO ITER Research Plan Level 2 for DT-1 ITER Research Plan Level 2 for DT-2 ITER Research Plan Level 2 for TBMS	New New New New
[A34]	ITER Fire Safety Approach	25SDBD
[A35]	Plant Control Design Handbook for Nuclear control systems	2YNEFU
[A36]	Load specification for buildings with safety requirements	2ERTXQ
[A37]	Radioprotection guide for ESPN application	2LTQ96
[A38]	ITER Integrated Maintenance Strategy	New
[A39]	ITER Integrated Waste Management Strategy	New
[A40]	ITER Decommissioning Strategy	New
[A41]	ITER Safety strategy	New
[A42]	Concept of Operation Level 2	New
[A43]	Methodology for ITER Hard Core Components	RMP3AC
[A44]	Nuclear Radiation Compatibility for Electrical, Electronic and Electromechanical Components	New
[A45]	As-Built Documentation Hydraulic Infrastructures - Technical Summary Report (Appendix 2)	359RUD

Reference Documents *(for information only)*		
[R01]	Project Specification	2DY7NG
[R02]	*Reference no longer required*	*N/A*
[R03]	ITER Plant Breakdown Structure	28WB2P
[R04]	*Reference no longer required*	*N/A*
[R05]	Assembly Plan	2263T6
[R06]	*Reference no longer required*	*N/A*
[R07]	ITER Research Plan Level 1	AXUP2U
[R08]	2012 Preliminary Safety Report (RPrS)	3ZR2NC
[R09]	*Reference no longer required*	*N/A*
[R10]	*Reference no longer required*	*N/A*
[R11]	Quality Classification Determination	24VQES
[R12]	*Reference no longer required*	*N/A*
[R13]	ITER RAMI Analysis Program	28WBXD
[R14]	ITER Configuration Management Implementation Plan	27LHHE
[R15]	*Reference no longer required*	*N/A*
[R16]	ITER Quality Assurance Programme	22K4QX
[R17]	*Reference no longer required*	*N/A*
[R18]	Agreement on the Establishment of the ITER Organization	2EW6RK
[R19]	ITER Remote Handling Code of Practice	2E7BC5
[R20]	*Reference no longer required*	*N/A*
[R21]	*Reference no longer required*	*N/A*
[R22]	ITER Human Factor Integration Plan	2WBVKU
[R23]	Site Support Agreement	2VU589
[R24]	*Reference no longer required*	*N/A*
[R25]	Headquarters Agreement in English	29P59M

Reference Documents *(for information only)*		
[R26]	*Reference no longer required*	*N/A*
[R27]	*Reference no longer required*	*N/A*
[R28]	*Reference no longer required*	*N/A*
[R29]	Initial analysis of the site and its environment (DAC_6_fr_ind3, French version) *English translation for guidance available ITER_D_7A7RDB*	6KH45V
[R30]	Order dated 7 February 2012 relating to the general technical regulations applicable to INB - FR *English translation for guidance available ITER_D_7M2YKF*	7GJHSE
[R31]	Decree No. 2012-1248 dated 9 November 2012 authorizing IO to create a basic nuclear facility called « ITER » - FR *English translation for guidance available ITER_D_CZK7M5*	C2JZNX
[R32]	ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the licensed nuclear facility INB No. 174 called ITER - FR *English translation for guidance available ITER_D_TYNPAZ*	LYH6QS
[R33]	*Reference no longer required*	*N/A*
[R34]	Staged Approach Configuration - Preliminary Functional Description	TVG7YK
[R35]	Staged Approach Configuration - PBS Level 3	SNE6G8
[R36]	*Reference no longer required*	*N/A*
[R37]	*Reference no longer required*	*N/A*
[R38]	Configuration Management Model process	V2ERKH
[R39]	Safe Access for Maintainability	RUGWUK
[R40]	Protective Equipment and Hostile Environment Layout	RBYZ42
[R41]	Concept of Operation L1	S7T73E
[R42]	Guidelines for ALARA Implementation	W6655F
[R43]	General Safety Principles	33AMDD
[R44]	ITER Beryllium Code of Practice	2XZMG6
[R45]	Réponse engagement 19.3 : double enveloppe autour des équipements contenant des isotopes d'hydrogène	GNQA2Z
[R46]	Alignment of defined requirements with RPRS and licensing document for PIC/SIC-1 cables	7UM6UR
[R47]	IO cabling rules	335VF9
[R48]	GIN 015 - Implementation of EU construction products regulation no.305/2011 (CPR regulation) to cables used for construction works within the ITER Project- Derogation	WQA2B6
[R49]	French Labor Code (FR)	Legifrance
[R50]	IC/STAC-25/4.1. Progress on the quantification of the possible degradation of the TF conductor with electromagnetic and thermal cycling and IO's risk mitigation plan	YG2GMA

3 OVERALL DESCRIPTION OF ITER

3.1 ITER FACILITY

[PR4956-I] As specified in the *ITER Project Specification [R01]*, the overall objectives of ITER Facility are to:

- Achieve extended burns (300-500 s) in inductively driven plasmas with the ratio of fusion power to auxiliary heating power (Q) of at least 10 for a range of operating scenarios, and with a duration sufficient to achieve stationary conditions on the timescales characteristic of plasma processes,
- Develop high reliability, long-pulse and fully non-inductive operation, aiming at $Q \geq 5$,
- Exploit the ITER's potential for technology testing of prototype components for future fusion power plants.

[PR6002-I] To achieve these objectives, the ITER Facility is constituted of a number of systems performing the following main activities:

- **Plasma generation**,
- **Maintenance** of ITER components,
- **Waste Management** for all ITER wastes,
- **Plant Auxiliary Support** for the above activities.

All these activities are developed and implemented in an integrated manner with a high level of **safety** as an essential requirement.

[PR56-I] The core of the ITER Facility is a Tokamak, in which the gaseous hydrogen fuel is heated to become a plasma where light elements can fuse and yield energy. The ITER systems are listed in *Section 3.2*.

[PR260-I] The ITER Site, which is located near CEA Cadarache near St. Paul-lez-Durance, France, is shown in the *ITER Site Master Plan [A13]*.

3.2 ITER SYSTEMS

[PR73-I] The list of ITER systems is defined in the ITER Plant Breakdown Structure (PBS) [R03] and is summarized in *Table 3-1*.

Table 3-1: ITER systems

PBS	System	Main functions for ITER plasma operation	Group *(see note 1)*
11	Magnet system	To produce the magnetic fields required to initiate, confine, shape and control the ITER plasma. This system includes the ITER superconducting coils: Toroidal Field (TF) coils, Central Solenoid (CS) coils, Poloidal Field (PF) coils, and Correction Coils (CC).	TK
15-VV	Vacuum Vessel (VV)	To house the fusion reactions and act as a first safety confinement barrier	TK
15-IV	In-Vessel Coil system (IVC)	To contribute to control the ITER plasma. IVC includes the Edge Localized Modes (ELM) coils and Vertical Stabilization (VS) coils.	TK
16	Blanket system	To constitute the primary interface to the ITER plasma in the vacuum vessel. The blanket modules constitute ITER first wall. To reduce heat and neutron loads in the vacuum vessel and ex-vessel components	TK
17	Divertor	To control the exhaust of waste gas and impurities from the vacuum vessel as well as the heat load from ITER plasma To reduce heat and neutron loads in the vacuum vessel and ex-vessel components	TK

PBS	System	Main functions for ITER plasma operation	Group *(see note 1)*
18	Fuelling and Wall Conditioning System (FWCS)	To provide the fuelling required to perform and control the ITER plasma, including for disruption mitigation and emergency fusion power shutdown. To contribute to conditioning the plasma-facing components (*Note 2*) and port plug front ends.	TKAS
22	Machine assembly and tooling system	To permit the assembly of the Tokamak Machine	*N/A*
23	Remote Handling Systems (RHS)	To perform the handling and maintenance of the Tokamak Machine components that are designed for remote handling maintenance	MWF
24-CR	Cryostat system	To ensure an ultra-cool, vacuum environment for the superconducting coils	TK
24-VP	Vacuum Vessel Pressure Suppression System (VVPSS)	To protect the first safety confinement barrier constituted of the vacuum vessel and its extensions against overpressure events	TK
26	Cooling Water System (CWS)	- Tokamak Cooling Waste System (TCWS): To remove the heat accumulated in VV, in-vessel components and Neutral Beam Injectors during ITER plasma; and to bake VV and in-vessel components to release trapped impurities. - Other CWS systems: To remove the heat accumulated in TCWS and other components, and to reject this collected heat into the Environment	TKAS PAS
27	Thermal Shield system (TS)	To limit the radiation heat load to the superconducting coils	TK
31	Vacuum System (VS)	To provide, at the required level, vacuum in VV and cryostat (TKAS) as well as to auxiliary systems (PAS)	TKAS PAS
32	Tritium Plant (TP)	To process the tritium and fuel gases from the whole ITER Facility, including providing the Detritiation Systems for detritiation of gases from the Tokamak Complex (TKAS) and from the Nuclear Maintenance and Radioactive Waste Management Facilities (MWF)	TKAS MWF
34	Cryogenic System (CS)	To provide low-temperature conditions for the magnet and vacuum pumping systems as well as some diagnostics	TKAS
41	Coil Power Supply and Distribution system (CPSD)	To provide electrical power required by the ITER coils and the Heat & Current Drive systems	PAS
43	Steady-State Electrical power supply Networks (SSEN)	To provide the electrical power required by all ITER systems (outside PBS41 scope)	PAS
44	Cable trays system	To provide cables, cable trays and pneumatic lines for all ITER systems, including their appropriate routing and protection	PAS
45	Control, Data Access and Communication system (CODAC)	To ensure continuous coordination of all ITER systems, including for diagnosis, configuration, function synchronization, as well as data retrieval, monitoring, and storage	PAS
46	Central Interlock System (CIS)	To provide investment protection for the ITER systems and components	PAS
47	Plasma Control System (PCS)	To control ITER plasma operation	TKAS
48	Central Safety System (CSS)	To provide protection for the personnel and the environment by executing safety Instrumentation and Control (I&C) functions	PAS
51	Ion Cyclotron Heating and Current Drive system (IC H&CD)	To provide ion cyclotron radio frequency power for plasma heating, control of sawteeth activity and wall conditioning.	TKAS
52	Electron Cyclotron Heating and Current Drive system (EC H&CD)	To provide electron cyclotron microwave frequency power for plasma heating and current drive, control of instabilities, and radiofrequency assisted breakdown for plasma initiation	TKAS

PBS	System	Main functions for ITER plasma operation	Group *(see note 1)*
53	Neutral Beam Heating and Current Drive system (NB H&CD)	To provide neutral beams for plasma heating and current drive, plasma rotation, fuelling, and plasma current and density profile control	TKAS
55	Diagnostics system	To provide the measurements necessary to control, evaluate and optimize plasma performance in ITER, as well as for machine protection and physics studies.	TKAS
56	Test Blanket Modules system (TBM)	To provide blanket for testing and validating design concepts of tritium breeding blankets	TKAS
57	In-Vessel Viewing System (IVVS)	To provide In-vessel inspection of plasma-facing components [(Note 2)] and port plug front ends	TKAS
58	Port Plug Test Facilities (PPTF)	To test and qualify the Port Plugs prior to their installation in the Tokamak Machine.	MWF
61	Site facilities	To provide fencing, water drainage networks, outdoor lighting, bridges, roads, footpaths, special foundations, and service trenches	PAS
62	Reinforced concrete buildings	To house and protect the ITER systems, including to provide the suitable environment for the housed components and personnel (like Heating, Ventilation and Air Conditioning (HVAC) systems, fire protection systems, lifts, lighting, internal drainage systems, etc.).	PAS
63	Steel frame buildings		PAS
64	Radiological and Environmental Monitoring System (REMS)	To perform radiological monitoring to assist in protection of personnel from ionizing radiation, including from tritium	PAS
65	Liquid and Gas Distribution system (LGD)	To provide non-cryogenic fluids require by ITER systems (including potable water, fire-fighting water, demineralized water, hot water for heating purposes, compressed air, breathing air, nitrogen, helium)	PAS
66	Radwaste Treatment and Storage system (RTS)	To manage the radioactive waste generated within ITER nuclear facilities	MWF
69	Access Control and Security System (ACSS)	To provide for the security and protection of the ITER plant from malevolent action and from access by unauthorized and unqualified personnel.	PAS
70	Site outside platform	To provide infrastructures and support facilities outside the ITER platform and interfaces with external	PAS
98	External services and interfaces system	To provide interfaces with services external to ITER Site, including the Magnet Cold Test Facility.	PAS

Note 1 *– In the PR, the systems are grouped as follows:*

- *Tokamak Machine (TKM)*
  - *TK: Tokamak systems/components (i.e. VV and its extensions (including VVPSS), magnets, TS, cryostat, blanket, divertor)*
  - *TKAS: Tokamak Auxiliary Systems (i.e. FWCS, VS, TP, PCS, H&CD, diagnostics, TCWS, TBM)*
- *MWF: Maintenance & Waste Management systems (i.e. RHS, RTS, PPTF)*
- *PAS: Plant Auxiliary Systems (i.e. CWS, VS, CPSD, SSEN, Cable Trays, CODAC, CIS, CSS, Buildings and Site Infrastructures, LGD, REMS, ACSS)*

Note that parts of the Cooling Water System and Vacuum System are TKAS (i.e. TCWS and Torus/Cryostat/NB pumping systems) and others are PAS.

Note 2: *At ITER, the plasma-facing components (PFC) are the in-vessel components that can directly interact with the plasma flux – this includes the following components:*

- *PBS16: only the blanket first wall panels (first wall)*
- *PBS17: only the divertor targets, dome, and reflectors*
- *PBS51: only the front end of ICH antenna*
- *PBS55: only FW material samples (as mounted on the first wall)*

Note that there are more in-vessel components that have surface areas exposed to neutrons, neutrals, and radiation emitted by the plasma, but do not interact directly with the plasma flux because they are protected by other components and/or recessed compared to the first wall (like PBS15-VV, other components of PBS16/17/51/55, and PBS52/53/56).

3.3 ITER PROJECT

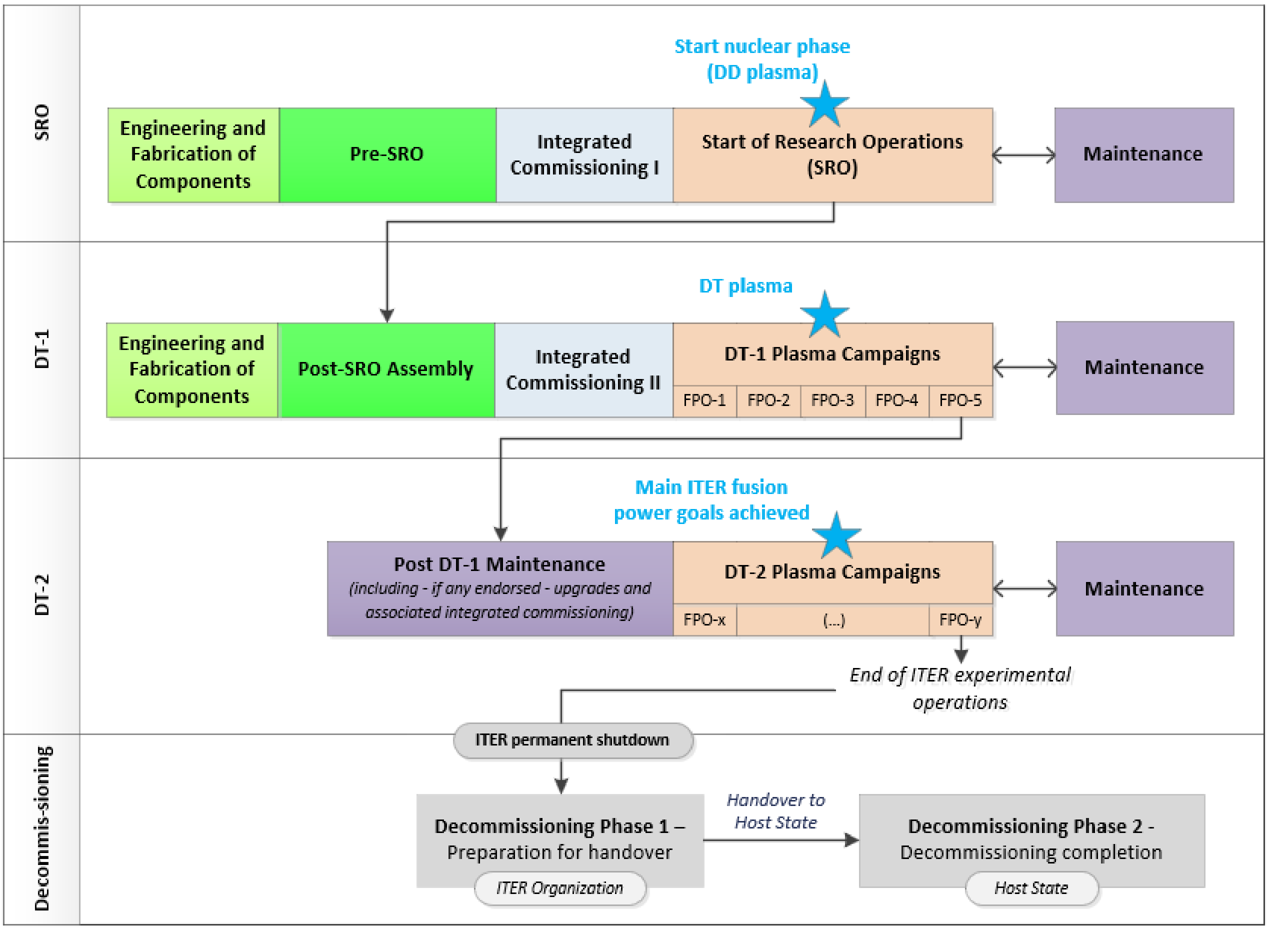
[PR289-I] The lifecycle phases for the ITER Project are:

- Construction (including design, manufacturing, installation, testing and commissioning),
- Operation (including plasma campaigns and related maintenance),
- Decommissioning which is split into 2 sub-phases (as per *ITER agreement [R18], Article 16*):
  - Phase 1 (*called Deactivation at ITER*) including all activities to be performed after ITER final phase of experimental operations to permit its handover to the Host State who will perform phase 2,
  - Phase 2 (*called Decommissioning at ITER*) including all activities to be performed after ITER handover to the Host State to permit the release of the ITER Site.

[PR299-I] As identified in *ITER Research Plan Level 1 [R07]*, the scientific exploitation of ITER up to the achievement of the Project Specification goals is divided into 3 main stages: Start of Research Operations (SRO), Deuterium-Tritium Phase 1 (DT-1) and Deuterium-Tritium Phase 2 (DT-2), each stage including a construction and operation phase. Following the final phase of experimental operations, ITER will undergo decommissioning.

[PR296-I] *Figure 3-1* shows the flow of these lifecycle phases throughout the planned operational campaigns.

Figure 3-1: ITER Project Phases



(Figure for illustrative purpose only, not indicative of any timescale or phase duration)

4 MAIN ITER ACTIVITIES AND ASSOCIATED PERFORMANCES

4.1 ITER PLASMA GENERATION AND ASSOCIATED PERFORMANCES

4.1.1 ITER Plasma Scenarios

4.1.1.1 DT reference plasma scenarios

[PR515-R] ITER shall be designed to meet the requirements of the three DT reference plasma scenarios that are specified in *Table 4-1,* and the additional key features given in the *Poloidal Field scenario database [A19]*.

- All ITER systems shall be designed to perform the Inductive reference scenario.
- The Hybrid and Non-inductive scenarios shall be achievable within the design requirements of the inductive scenario, excepting additional investments for auxiliary systems upgrades.

Table 4-1: DT reference plasma scenario parameters

Parameter	1. Inductive operation	2. Hybrid operation	3. Non-inductive operation
Plasma major radius (R) / Plasma minor radius (a) (m/m)	6.2 / 2.0	6.2 / 2.0	6.2 / 2.0
Toroidal field, BT (T)	5.3	5.3	5.3
Plasma current, IP (MA)	15.0	12.5	10.0
Elongation, κx/κ95	1.85 / 1.7	1.85 / 1.7	1.85 / 1.7
Triangularity, δx/δ95	0.48 / 0.33	0.48 / 0.33	0.48 / 0.33
Fusion power, Pfus (MW)	500	420	400
Auxiliary heating/current drive power (Padd) (MW)	50	70	80
Energy multiplication, Q	10	6	5
Burn time *Note 1* during Flat Top Phase (s)	450 *Note 2*	1000	3000
Total heating power, PTOT (MW)	151	154	160
Plasma thermal energy, Wth (MJ)	353	325	315
Normalized Confinement H_{98}	1.0	1.25	1.5
Maximum fuelling input (Pa-m^3/s)	200	160	120

Note 1: *For any ITER Tokamak plasmas, the* **Tokamak pulse** *is made of three main phases defined by the plasma current waveform:*

- ***Ramp-up****: Increase of plasma current from zero up to the nominal flat-top value. This phase in ITER typically lasts 10-100 s depending on flat-top plasma current value.*
- ***Flat-top****: Phase in which the plasma current is stationary. This can last from second to thousands of seconds in ITER.*
- ***Ramp-down****: Decrease of the plasma current from the nominal flat-top value to zero. Typically, in ITER, the ramp-down lasts 2-3 times the duration of the ramp-up.*

*DT plasmas include an additional phase, called "***extended burn***" or for simplicity "***burn***", during which stationary fusion power production is maintained during the flat-top of the Tokamak pulse. In that case, the flat-top can be divided into: entry to burn, extended burn and exit from burn. The duration of entry to burn and exit from burn depends on plasma scenarios but typically are in the range of 0-50 s. Note that entry to and exit from burn of 0s take place during ramp-up and ramp-down respectively. Thus, the burn phase is always equal or shorter than the flat-top.*

For non-DT plasmas (i.e. Tokamak pulses without burns), the "burn duration" specified in PR requirements should be considered to be the "pulse flat-top duration".

Note 2: *. The burn time for the DT reference inductive scenario (with 500 MW Q=10) is set to 450 s (PS target of 300 - 500 s) to remain consistent with the Tokamak pulse duty cycle of 25% or more, as specified in PR907.*

4.1.1.2 Flexibility DT scenarios

[PR2098-I] Following return of experience during DT plasma campaigns and for exploration of physics, ITER may be operated at the following enhanced parameters:

- DT plasma scenarios with up to 700 MW of fusion power for 100 s,
- DT plasma scenarios with plasma currents of up to 17 MA.

To permit this, the Tokamak (i.e. the vacuum vessel, in-vessel components, and the magnet systems) should be designed for the loads that are expected from such flexibility scenarios. Auxiliary systems could be upgraded if required.

It is currently shown [A14] that these flexibility requirements do not lead to additional technical requirements for the ITER systems and structures with respect to those derived from the three DT reference plasma scenarios in *Table 4-1*. However, prior to including these flexibility scenarios in ITER Technical Baseline, their expected loads on the Tokamak should be demonstrated as being enveloped by the inductive reference scenario given in *Table 4-1* (500 MW, 500 s, 15 MA).

[PR1770-R] ITER (with, if needed, additional investments for auxiliary systems upgrades) shall be able to perform the flexibility DT scenarios, with a plasma current of 17 MA and a fusion power of 700 MW for 100 s, if such flexibility scenarios are included in ITER Technical Baseline following the return of experience from the DT phases and the required technical and safety demonstration.

4.1.1.3 Staged Plasma Scenarios

[PR303-I] As specified in the *ITER Research Plan Level 1 [R07]*, the ITER operation campaigns are developed to achieve the main plasma objectives during SRO/DT-1/DT-2 that are outlined in *Table 4-2*.

Table 4-2: **Plasma objectives per plasma campaign stages**

Stage	Plasma objectives

SRO	**Overall objective is to demonstrate that ITER can reliably and safely operate at its maximum plasma current/field in L-mode and at reduced levels in H-mode in DD plasmas:**
	- To commission the Tokamak Machine and develop plasma scenarios up to:
	  o 15 MA/5.3 T in L-mode,
	  o 7.5 MA/2.65 T in H-mode with deuterium (DD) plasmas.
	- To validate modelling predications for ITER plasma scenarios in L- and H-mode.
	- To demonstrate and optimize divertor and first-wall protection and core impurity control methods (including in-vessel wall conditioning).
	- To assess the possibility to heat plasma with Ion Cyclotron Heating power (ICH), and to perform wall conditioning with EC Heat and Current Drive system (ECWC).
	- To demonstrate disruption mitigation up to 15 MA / 5.3 T.
	- To validate, with measurements obtained during deuterium operation, the radiation maps.
	- To assess the fuel (deuterium) retention and removal efficiency, production of dust and corrosion products, and in-vessel material analysis.
	- To consolidate the DT-1 plasma program.

DT-1	**Overall objective is to demonstrate routine Q = 10 operation with P_{fusion} = 500 MW and, at least 300 s burns:** - To commission control and protection systems with plasma up to Q = 10. - To demonstrate disruption mitigation up to Q = 10. - To develop robust plasma scenarios (disruption-free) in DT up to 15 MA/5.3 T in H-mode (or lower current levels if Q = 10 can be demonstrated at those levels). - To study the physics of burning plasmas and their integration with an all-W plasma-facing component configuration. - To address specific issues for the Test Blanket Modules system (TBM) research and development program, including high repetition operation with $P_{fusion} \geq 250$ MW. - To assess the possibility to increase Neutral Beam plasma heating (NBH) for DT-2. - To gather experimental data required to consolidate the DT-2 plasma program (as DT-1).

Stage	Plasma objectives
DT-2	**Overall objective is to achieve all the Project Specification goals:** - To commission control and protection systems required for the two Q = 5 ITER scenarios (long pulse and steady state) to sustain high Q operation over their nominal burn lengths (1000 and 3000 s, respectively). - To develop long, robust plasma scenarios (disruption-free) in DT to, at least, Q = 5 for their nominal burn lengths (1000 and 3000 s, respectively) and demonstrate the required current-drive capabilities. - To study the physics of high Q plasmas, including current-drive and enhanced H-mode confinement, and their integration with a configuration with all tungsten plasma-facing components over timescales of ~ 1000's. - To complete the TBM research and development program. - To explore the physics, integration and control aspects of Q > 10 plasmas up to 700 MW of fusion power. - To address technology and plasma scenario development, control and integration issues for future DEMO reactors, such as: a) the determination of the minimum set of diagnostics and actuators required for high Q operation, b) the determination of the required heating and current drive mix, c) demonstration of the increased core radiation as solution to the power exhaust problem in DT plasmas, etc.

[PR6003-R] The ITER operation campaigns shall be developed and executed in compliance with the *ITER Research Plans Level 2 for each phase SRO, DT-1 and DT-2, and for the Test Blanket Modules (TBM) Testing Program [A33]*.

4.1.2 Preparations for plasma operations

[PR6004-R] In order to execute the ITER Research Plan, the following Tokamak components shall be operational:

- From SRO, in their final configuration - except when specified otherwise:
  - Magnet system (all superconducting coils and their auxiliary sub-systems), energized and cooled by the Cryogenic System,
  - In-vessel coils system, energized and cooled by the Tokamak Cooling Water System (TCWS),
  - Vacuum vessel, cooled by TCWS and with all ports closed and evacuated (see *Section 5.3* for the installed Port Plugs),
  - Divertor, cooled by TCWS,
  - Blanket system, with temporary First Wall Panels,
  - Cryostat, closed and evacuated,
  - Thermal Shield System, cooled by the cryogenic system,
- From DT-1: same systems/components as for SRO, except for the blanket system, for which the temporary First Wall Panels are replaced by the final First Wall Panels, and for the installation of the remaining port plugs of the Test Blanket Modules (TBM) system.

For the required Tokamak Auxiliary Systems refer to the relevant sections below. For the required Plant Auxiliary Systems – see *Section 4.4*.

4.1.2.1 Cryostat evacuation

[PR384-R] The cryostat shall be designed for 100 vacuum pump-downs.

[PR385-R] The in-cryostat equipment shall be designed for 100 cool-down and warm-up cycles.

[PR387-R] Prior to cool-down, the cryostat shall be evacuated to a base pressure of 1E-04 Pa.

[PR388-R] The cryostat shall be evacuated from atmospheric pressure to 10 Pa within 24 hours.

[PR389-R] The cryostat shall be evacuated from 10 Pa to less than 1E-04 Pa within 160 hours.

[PR391-R] The maximum global in-leakage of helium into the cryostat, at cryogenic temperature, shall not exceed 1E-02 $Pa.m^3.s^{-1}$.

[PR392-R] The base pressure of the cryostat shall be maintained at less than 1E-04 Pa when the superconducting magnets are below room temperature.

[PR4959-R] The cryostat, and all components within or forming a boundary to vacuum, shall comply with the *ITER Vacuum Handbook [A05]*.

4.1.2.2 Vacuum vessel and neutral beam enclosure evacuation

[PR398-R] The vacuum vessel and neutral beam enclosures shall be designed for 500 vacuum pump-downs.

[PR394-R] The isolation valve between neutral beam and vacuum vessel enclosures shall be closed when one of these enclosures is vented.

[PR395-R] The vacuum vessel shall be capable of being pumped down from atmospheric pressure to 10 Pa within 24 hours.

[PR396-R] A base pressure of less than 1E-05 Pa (for hydrogen isotopes) shall be achieved in the vacuum vessel, after wall conditioning, prior to plasma operations.

[PR397-R] A base impurity pressure of less than 1E-07 Pa (the sum of partial pressures of impurity gases) shall be achieved in the vacuum vessel, after wall conditioning, prior to plasma operations.

[PR399-R] The vacuum vessel, and all components within or forming a boundary to vacuum, shall comply with the *ITER Vacuum Handbook [A05]*.

[PR400-R] The HNB/DNB enclosure, and all components within or forming a boundary to vacuum, shall comply with the *ITER Vacuum Handbook [A05]*.

[PR401-R] The neutral beam enclosure shall be capable of being pumped down from atmospheric pressure to 10 Pa within 24 hours.

[PR402-R] The global air-equivalent in-leakage into the neutral beam enclosure shall not exceed 1E-08 $Pa.m^3.s^{-1}$.

[PR143-R] The Vacuum Vessel Pressure Suppression System (VVPSS) shall limit pressurization of the vacuum vessel to a maximum of 0.15 MPa absolute.

4.1.2.3 Magnet cool-down and warm-up

[PR409-R] The superconducting coils shall be designed for 100* cool-down and warm-up cycles *(* Following the assessment of the final design of the TF coils [R50], the cool-down and warm-up cycles of the superconducting coils shall be reduced to maximize their service lifetime. [R50] recommends reducing the cool-down and warm-up cycles of the superconducting coils to around 25.)*

[PR407-R] Superconducting magnet systems shall be capable of being cooled down from room temperature to operating temperature within 30 days.

[PR1029-R] Superconducting magnet systems shall be capable of being warmed up from operating temperature to room temperature within 30 days.

[PR1030-R] The cryogenic system shall be capable of warming up or cooling down superconducting coils within 30 days.

[PR408-R] It shall be possible to cool down the TF coils to operating temperature within four days after a fast discharge.

4.1.2.4 Coil charging and discharging

[PR488-R] The TF, PF, CC and CS coils shall be designed to withstand the number of pulses that are specified over the life of ITER (*Section 6.2*) when operated for any of the reference scenarios (*Table 4-1*) or the equivalent for other scenarios when adjusted for fatigue life according to the procedures in the design criteria.

[PR492-R] A plasma disruption shall not trigger discharge of any of the superconducting coils.

[PR412-R] It shall be possible to charge the TF coils from zero current to full current (corresponding to 5.3 T at a major radius of 6.2 m) within 2 hours.

[PR413-R] Under normal conditions, it shall be possible to discharge the TF coils from full current (corresponding to 5.3 T at a major radius of 6.2 m) to zero current within 2 hours. This is referred to as a slow discharge.

[PR1767-R] Under abnormal conditions, it shall be possible to discharge the TF coils from full current (corresponding to 5.3 T at a major radius of 6.2 m) to zero current within 30 minutes. This is referred to as an accelerated discharge.

[PR414-R] The coils shall be protected against damage in case of a superconductor resistive transition. The magnets quench detection system and the Fast Discharge systems shall be operational for this purpose from SRO. This event is referred to as a fast discharge.

[PR1820-R] In the event of a TF fault, quench, or otherwise abnormal condition, all TF, CS, PF and CC coils shall be discharged to divert stored magnetic energy to an external energy sink.

[PR493-R] In the event that a fast discharge of the TF coils is required, a fast discharge of all the CS, PF and CC coils shall be invoked.

[PR489-R] In the event that a fast discharge of any PF or CS coil is required, a fast discharge of all of the PF and CS coils shall be invoked.

[PR491-R] A fast discharge of the PF and CS and CC coils shall not trigger the fast discharge of the TF coils.

[PR421-R] The time constant for TF fast discharge shall be greater than 11 s.

[PR418-R] The TF coils shall be designed to withstand 1000* charge-slow or accelerated discharge cycles over the life of ITER *(* Following assessment of the TF coils final design [R50], the slow/accelerated discharge cycles of the TF coils shall be reduced to maximize their service lifetime. [R50] recommends reducing the TF slow/accelerated-discharge cycles to around 100.)*

[PR419-R] The TF coils shall be designed to withstand 50* charge-fast discharge cycles over the life of ITER *(* Subsequently to the reduction of the slow/accelerated discharge cycles of the TF coils [PR418], the fast discharge cycles of the TF coils shall also be reduced to maximize their service lifetime).*

[PR420-R] The TF coils shall be designed to withstand 10 quenches over the life of ITER.

[PR490-R] The PF, CC and CS coils shall be designed to withstand 100 quenches over the life of ITER.

[PR416-R] The CS, PF and CC systems shall be designed for 500 fast discharges.

[PR415-R] The magnets and auxiliary systems shall be ready for plasma operation within 2 hours of a fast discharge of the CS, PF or CC.

4.1.2.5 Vacuum vessel and in-vessel component coolant parameters

[PR6005-R] The Tokamak Cooling Water System (TCWS) shall provide cooling and baking water/gas to the following Tokamak components during each stage, with the performances specified below:

- From SRO:
  - The vacuum vessel and its extensions,
  - The divertor, the in-vessel coils and the vacuum vessel ports clients.
- During DT-1 (in addition to the components identified for SRO): the blanket System and the installed Heating and Diagnostic Neutral Beam Injectors.
- During DT-2 (in addition to the components identified for DT-1): If implemented into ITER Technical Baseline - the cooling of the additional Heating Neutral Beam Injector.

[PR6006-R] The TCWS auxiliary systems for chemical & volume control, sampling, drying, and draining shall be available for the TCWS loops that are operational during SRO/DT-1/DT-2.

[PR452-R] The nominal inlet temperature of the TCWS coolant of the vacuum vessel and Neutral Beam ports (up to the torus isolation valve), for pre-pulse and during pulse, shall be 100°C, with a range ±10°C at nominal flow rate and pressure.

[PR5395-R] The nominal inlet pre-pulse and during pulse coolant temperature of all in-vessel components shall be 70°C, within a range of ±5°C, at nominal flow rate and pressure.

[PR1774-R] The maximum inlet water differential temperature between the Integrated Blanket ELM/VS coils and divertor (IBED) PHTS loop and the vacuum vessel cooling loop shall be controlled to be below 50°C during the entire duration of the Plasma Operation State (POS) and Testing and Conditioning State (TCS) and during the transients between these and Short-Term Maintenance (STM) and also between POS and Long term Maintenance (LTM) [A08].

4.1.2.6 Baking

[PR6007-R] The surfaces exposed to the primary vacuum shall be baked to remove the impurities that could affect the quality of the vacuum.

[PR2090-R] The blanket system, divertor , in-vessel coils, vacuum vessel ports and in-ports components shall be capable of being baked at 240°C.

[PR426-R] The main part of the vacuum vessel (torus) shall be capable of being baked at 200°C.

[PR427-R] All surfaces other than blankets, divertor, vacuum vessel and in-vessel components, that are exposed to the primary vacuum shall be baked at a temperature greater than 180°C, including the neutral beam port (up to the torus isolation valve) and the VVPSS piping (up to the rupture disk). Exceptions for lower-temperature baking of components that are at or beyond the vessel ports boundary shall be treated on a case-by-case basis.

[PR428-R] The capability for baking shall be provided while the superconducting coils are at any temperature between 5 K and 293 K.

[PR430-R] The vacuum vessel and in-vessel components shall be capable of being raised from operating temperature to the baking temperature within 2 days.

[PR431-R] Following baking, the vacuum vessel and in-vessel components shall be capable of being returned to their pre-pulse operating temperature within 24 hours.

[PR432-R] The rate of change of temperature of the vacuum vessel and in-vessel components shall not be faster than +5 K/h during warm-up, and -7 K/h during cool-down, considering thermal stresses.

[PR434-R] All ITER systems shall be designed to accommodate 500 baking cycles from the commissioning phase to the end of life of ITER.

4.1.2.7 Wall conditioning

4.1.2.7.1 Glow discharge cleaning (GDC)

[PR436-R] ITER shall provide the capability to perform, from SRO, GDC of plasma-facing surfaces with the vacuum vessel and all in-vessel components at their nominal pre-pulse operating temperatures, and at their nominal baking temperatures.

[PR438-R] ITER shall be capable of using any of the following gases for GDC: hydrogen, deuterium, and helium.

[PR6008-R] ITER shall provide the capability to perform GDC of the plasma-facing surfaces to support the boronization process.

[PR439-R] The TF, PF, CS, CC, ELM and VS coil currents shall be zero during GDC.

[PR440-R] Provisions shall be implemented to protect components that could be impacted by GDC.

4.1.2.7.2 Boron coating

[PR6009-R] ITER shall provide, from SRO, the capability to coat the plasma-facing surfaces with boron.

[PR6010-R] Provisions shall be implemented to protect components exposed to boronization if needed.

4.1.2.7.3 RF wall conditioning

Ion Cyclotron Heat and Current Drive (IC H&CD)

[PR803-R] The IC H&CD system shall provide up to 5 MW from SRO for wall conditioning (ICWC).

[PR6011-R] The IC H&CD system shall be capable of performing RF wall conditioning during at least 3600 s.

[PR6148-R] For IC H&CD system, the optimal ON/OFF modulation of the RF sources shall be determined considering the best compromise for cleaning efficiency while ensuring that the RF power/modulation are within the envelope conditions of systems design (including fatigue of their components).

[PR6149-I] Initially, for ICWC, it is proposed to consider a typical ON/OFF modulation with the RF sources being ON for 2 to 20 s, with the OFF time being the factor of 1 to 9 times larger than the ON time.

[PR804-I] The PBS55 Diagnostics provide some plasma parameter measurements which contributes to protect the IC antenna during IC wall conditioning (like impurities in plasma, see *Table 4-5*).

[PR6012-R] The IC H&CD shall include the diagnostics and protection systems required to protect the IC antenna from arcing during IC wall conditioning.

Electron Cyclotron Heat and Current Drive (EC H&CD)

[PR807-R] The capability to use the existing EC heating and current drive system for wall conditioning (Electron Cyclotron Wall Conditioning, ECWC) shall be assessed during SRO.

[PR6150-R] The EC H&CD system shall be capable of performing RF wall conditioning during at least 3600 s.

[PR6151-R] For EC H&CD system, the optimal ON/OFF modulation of the RF sources shall be determined considering the best compromise for cleaning efficiency while ensuring that the RF power/modulation are within the envelope conditions of systems design (including fatigue of their components).

[PR806-I] Initially, for ECWC, it is proposed to consider a typical ON/OFF modulation with the RF sources being ON for 0.5 to 2 s, with the OFF time being the factor of 2 to 100 times larger than the ON time.

[PR808-R] A poloidal magnetic field of about 0.1 T shall be provided for EC wall conditioning to improve uniformity.

4.1.2.8 NB H&CD source conditioning

[PR442-R] It shall be possible to isolate the neutral beam enclosures from the main vacuum vessel vacuum when conditioning the NB H&CD sources.

4.1.2.9 IC H&CD antenna conditioning

[PR444-R] The IC H&CD antennas shall be able to be conditioned, both in vacuum and in the presence of plasma.

4.1.2.10 EC H&CD launcher conditioning

[PR446-R] The EC H&CD launchers shall be conditioned in the presence of plasma.

4.1.3 Plasma initiation

[PR497-R] The vacuum vessel shall have a toroidal electrical resistance at operating temperature between 6 and 10 μΩ.

[PR498-R] The nominal toroidal resistance of equipment within the cryostat (excluding coil circuits) shall be greater than 4 μΩ.

[PR499-R] The combination of resistors for the switching network units (Central Solenoid modules, Poloidal Field coils PF1 and PF6) and waveforms in the AC/DC converters shall be chosen so as to produce an almost central plasma initiation. The plasma may contact predominantly either the inboard or the outboard wall.

[PR501-R] An EC H&CD power of at least 6.7 MW shall be delivered to the plasma for breakdown and burn-through assist (relevant for toroidal magnetic fields near to 50% and 100% of nominal field).

[PR502-R] After breakdown, the Poloidal Field system shall support a stable plasma equilibrium with an increasing current. This corresponds to the following conditions: (i) an average radial magnetic field component within the plasma of zero, where the magnetic field is produced both by coil currents and currents induced in conducting structures; (ii) a time-varying increase in the average vertical magnetic field component consistent with the increase of the corresponding “Shafranov field” required for plasma equilibrium at a given major radius; and (iii) to a nominal value of the decay index of the vertical magnetic field of 0.5.

4.1.4 Plasma control

[PR554-R] The evolution of the plasma shape, position, current, and profiles, during quasi-stationary conditions and plasma disturbances, shall be controlled to:

- optimize plasma performances and to minimize the frequency of plasma disruptions,
- avoid overheating plasma-facing components,
- protect plasma-facing surfaces from erosion and ablation.

[PR2103-R] Electromagnetic loads shall be kept within acceptable limits even in the event of potential failures in control, as specified in the *ITER Load Specification [A14]*.

[PR1809-R] The plasma shape, position, and divertor strike point locations shall be controlled to avoid overheating plasma-facing surfaces.

[PR1810-R] Edge Localized Modes (ELMs) shall be controlled to avoid excessive heat loads on plasma-facing surfaces.

[PR1812-R] Neoclassical Tearing Modes (NTMs) shall be controlled to optimize plasma performance and to minimize the frequency of disruptions.

[PR4962-R] The need to control Resistive Wall Modes (RWMs) to optimize performance in non-inductive scenarios shall be assessed.

[PR652-R] The thermonuclear burn shall be controlled during all plasma operations.

4.1.4.1 Nominal 15 MA target equilibrium

[PR557-R] ITER shall be designed based on the 15 MA target separatrix defined in [A01].

4.1.4.2 Slow timescale (quasi-static) control

[PR563-R] The plasma shape and position shall be controlled to avoid overheating shortening component lifetime through accelerated erosion and ablation of plasma-facing surfaces.

[PR564-R] Dynamic control of the separatrix using the Central Solenoid and Poloidal Field coil systems shall be consistent with the recovery time for restoration of the separatrix deviations from their desired quasi-static positions.

[PR1823-R] During the plasma current flat-top and in the absence of fast disturbances, the plasma current shall be controlled to less than ±2% or ±0.05 MA, whichever is less restrictive.

4.1.4.3 Fast timescale control of plasma-wall gap

[PR1824-R] The plasma control system shall minimize the frequency of events causing damage to the plasma-facing components, whether by localized melting, detachment of tiles, or breaching of water-cooling pipes.

[PR2113-R] To limit damage to the first wall components, the capability to limit transient contact of the separatrix with the first wall surface shall be provided during quasi-static operation and following all large-scale plasma disturbances: L- to H-mode transition, H- to L-mode transition, minor disruptions, locked modes, ELMs, as well as during switching-on and switching-off auxiliary heating.

4.1.4.4 Stabilization of plasma vertical displacements

[PR569-R] ITER shall include a system capable of stabilizing vertical motions of ITER plasmas and restoring the plasma to its preset position.

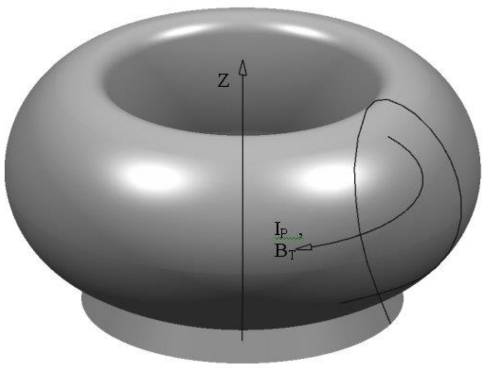
4.1.4.5 Toroidal field and plasma current direction

[PR464-R] The reference directionality of the toroidal plasma current and field shall be as follows: both the plasma current and toroidal field shall point in the clockwise direction looking from above, giving a downward (towards divertor X-point) ion grad-B drift direction (see *Figure 4-1*). This is in the opposite (that is, negative) direction with respect to the toroidal direction as given by the *ITER standard co-ordinate system [A24]*.

[PR466-R] The direction of the toroidal field and plasma current shall be reversible, in such a way that the field line maintains the same pitch angle orientation (that is, the directions of the toroidal field and the plasma current can only be changed together).

[PR467-R] The magnet systems shall be designed to operate for any combination of the directions of the plasma current and the toroidal field.

Figure 4-1: Toroidal field and plasma current direction



4.1.4.6 Toroidal field ripple

[PR469-R] Ferromagnetic inserts in the in-wall shielding near the outboard mid-plane shall be used to minimize the toroidal field ripple.

[PR2099-R] The toroidal field ripple due to the TF coils in the regular sectors of the vacuum vessel (with ferritic inserts but without Test Blanket Modules) shall be less than 0.5% at full toroidal field on the target separatrix, as defined in [A01].

[PR473-R] The toroidal field ripple in non-regular sectors (Neutral Beam sectors) shall be as small as reasonably achievable but in any case below 0.7% at full toroidal field on the target separatrix, as defined in [A01].

[PR474-I] The ripple requirement in the presence of TBMs remains the subject of continuing research and development.

4.1.4.7 Error fields requirements

[PR476-I] Error fields are non-axisymmetric magnetic fields due to design asymmetries, finite tolerances in fabrication and assembly, eddy currents, and magnetic materials and they may affect plasma performances by such effects as plasma braking and mode locking, loss of fast particles, degraded confinement of plasma, and localized heat fluxes.

[PR477-R] Error fields shall be managed in order to:

- Define an accepted method to calculate error field,
- Define allowable geometric tolerance for the fabrication and installation of the main Tokamak systems and metrology accuracy requirements,
- Control of other possible source of error fields (such as magnetic material masses and locations, design and location of current leads and joints),
- Define the current and voltage requirement for correction coils.

If these requirements are met, plasma performance will not be significantly impacted by error fields.

[PR482-R] The coils shall be designed, manufactured and installed to minimize their contribution to error fields that would be cause by the misalignment of the Central Solenoid, Toroidal Field, and Poloidal Field coil current centerlines.

[PR2102-R] Error fields ($B_{3\text{-mode}}$) from individual sources shall be less than 5E-06 B_0 unless formal project approval is granted.

[PR483-R] The correction coils shall be capable of reducing $B_{3\text{-mode}}/B_0$ to 5E-05.

4.1.4.8 Systems for plasma axisymmetric magnetic control

[PR6013-R] The plasma axisymmetric magnetic control shall be performed in compliance with the parameters specified in [A01].

[PR624-R] Representative time-dependent current traces for inductive scenarios have been generated [A19] and shall be used for design verification purposes.

[PR625-I] Variations in AC losses associated with deviations from the nominal plasma behavior for these representative cases may be accommodated by changes in the duration of the plasma current flat-top.

4.1.4.9 Control of Edge Localized Modes (ELMs)

[PR5397-R] ITER shall provide mean(s) to control ELMs.

[PR635-I] ITER will make use primarily of two ELM control techniques: application of Resonant Magnetic Perturbations (RMPs) fields and pellet injection.

[PR638-R] It shall be possible to rotate the RMP field distribution at rates up to five periods per second at full RMP amplitude (full coil current oscillations at 5 Hz, each coil current phase shifted according to the distribution of the rotating field with toroidal mode number n greater than 0).

4.1.4.10 Disruption handling

[PR655-I] A plasma disruption is characterized by a thermal quench phase and a current quench phase. Major disruptions (MDs) result in total loss of thermal energy and plasma current.

[PR656-R] ITER shall be designed to accommodate the plasma disruptions that are defined in the *Load Specifications [A14]*.

[PR659-R] All superconducting coils shall be designed not to quench in case of plasma disruption.

[PR660-R] A plasma disruption shall not trigger discharge of the TF superconducting coils.

[PR5398-R] The quench detection system of the magnets shall not trigger fast discharge of PF and CS coils in more than 90% of MD.

[PR661-R] The cryogenic system shall be designed to maintain the superconducting coils at operating temperature to avoid a quench in case of a major disruption.

4.1.4.11 Vertical displacement events

[PR663-I] A Vertical Displacement Event (VDE) is characterized by a drift phase of the plasma, followed by a thermal quench phase and a current quench phase.

[PR665-R] ITER shall be designed to accommodate VDEs as specified in the *Load Specifications [A14]*.

[PR666-R] A VDE shall not trigger discharge of the TF superconducting coils.

[PR5399-R] All superconducting coils shall be designed not to quench in case of VDE.

[PR5400-R] The quench detection system of the magnets shall not trigger fast discharge of PF and CS coils in more than 90% of VDE.

4.1.5 Plasma heating and current drive

[PR6014-I] ITER includes heating and current drive systems, which deliver to the plasma the heating powers specified in *Table 4-3*. Associated requirements for each H&CD systems are detailed in the sub-sections below (see also *Section 4.1.2.7* for specific H&CD requirements for wall conditioning and *Section 4.1.3* for plasma initiation).

Table 4-3: H&CD power to be delivered to plasma for SRO, DT-1 and DT-2 phases

Power delivered to plasma (MW)	SRO	DT-1 *(planned upgrades)*	DT-2 *(planned upgrades)*
EC	40	60 *(67)* Note 1	60 *(67)* Note 1
NB	0	33	33 *(50)* Note 2
IC	10	10 *(20)* Note2	10 *(20)* Note 2
Total	**50**	**103** *(up to 120 depending on triggered upgrades)*	**103** *(up to 137 depending on triggered upgrades)*

***Note 1**: The EC H&CD increase to add 20MW for DT-1 is part of the ITER Technical Baseline, the additional 7MW (up to 67MW) is a planned upgrade (see note 3).*
***Note 2**: The additional ICH/NBH power for DT-1 and DT-2 are planned upgrades (see note 3).*
***Note 3**: The planned upgrades for EC, NB and IC H&CD systems for DT-1 and DT-2 (Notes 1-2) are outside the ITER Technical Baseline, thus needing an ITER Council decision and dedicated Project Change Requests to trigger the works to complete their implementation.*

4.1.5.1 Ion Cyclotron Heating and Current Drive (IC H&CD)

[PR672-I] As specified in *[PR803-R]* , the IC H&CD provides wall conditioning from SRO.

[PR6015-R] During SRO, the usage of IC H&CD to provide 10 MW of IC power for plasma heating shall be tested.

[PR674-R] For SRO, the IC power shall be coupled to the plasma through one antenna in one equatorial port.

[PR673-I] Depending on the outcome of the ICH operation during SRO, the IC H&CD system may be upgraded to provide, from DT-1, 20 MW of IC power to the plasma, using the same antenna and equatorial port, and by adding the required additional radiofrequency (RF) power plant (i.e. the RF sources as well as the High Voltage Power Supply, combiners, cables, distribution boards, etc.).

[PR6016-R] Although the planned upgrade of IC H&CD system to 20 MW is outside of the current ITER Technical Baseline, ITER design shall permit its implementation before DT-1. This requires, in particular, the space reservation to install the additional RF power plant, and the guarantee that the existing IC H&CD sub-systems and associated auxiliary systems can cope or, at least, can be upgraded to operate with these additional RF power plant.

[PR675-R] The IC H&CD antennas shall be designed for two-quadrant operation; that is, the toroidal field shall be bi-directional, and the plasma current shall always be in the same direction as the toroidal field.

[PR676-R] The IC H&CD system shall be capable of operating at any frequency in the range of 40-55 MHz.

[PR1807-R] The IC H&CD system shall operate in quasi-Continuous Waves conditions for pulse lengths of up to 3600 s.

4.1.5.2 Electron Cyclotron Heating and Current Drive (EC H&CD)

[PR678-I] EC H&CD is required to provide heating and current drive, control Magneto-hydrodynamics (MHD) instabilities such as Neo-classical Tearing Modes (NTMs) and the sawtooth instability, assist in plasma initiation, and provide wall conditioning between pulses (pending further study). Requirements for plasma initiation are given in *Section 4.1.3*. Requirements for wall conditioning between pulses are given in *Section 4.1.2.7.3*.

[PR679-R] For each plasma campaign phases, the EC H&CD system shall provide EC power to the plasma at a frequency of 170 GHz and with the parameters specified in *Table 4-4*.

[PR680-R] The EC H&CD system shall be capable of providing ECH for Tokamak pulse lengths of up to 3600 s.

Table 4-4: EC H&CD parameters for SRO, DT-1 and DT-2 phases

	SRO	DT-1 *(planned upgrade)*	DT-2 *(planned upgrade)*
Power delivered to plasma (MW)	40	60 *(67)* ***Note 1***	60 *(67)* *Note 1*
Maximum burn duration (s) (steady state or modulation)	Flat top only - up to 100 s depending on first wall loads	300-500	3000
Number of operational equatorial port launchers	1	2 ***Note 1***	2
Number of operational upper port launchers	3	3 *(4)* ***Note 1***	3 *(4)* ***Note 1***
***Note 1**: The ECH power increase from 40 to 60MW for DT-1 is part of ITER Technical Baseline, and requires the installation of the 2nd equatorial port launcher (and its auxiliary systems) during Post-SRO Assembly.* *If endorsed for DT-1 or DT-2 (following an ITER Council decision and dedicated Project Change Requests to trigger its implementation in ITER Technical Baseline), the ECH planned upgrade from 60 to 67MW will be achieved using the 4th upper port launcher which will be already installed for SRO but not operational (its commissioning and the installation of its required auxiliary systems are part of this planned upgrade).*			

4.1.5.3 Neutral Beam Heating and Current Drive (NB H&CD)

[PR688-I] The NB H&CD system provides neutral beams for plasma heating and current drive, plasma rotation, plasma fuelling, and plasma current and density profile control. The Diagnostic Neutral Beam System provides a dedicated neutral beam for He ash measurements using Charge Exchange Recombination Spectroscopy (CXRS). The Diagnostic Neutral Beam System also allows localized measurements of various plasma parameters.

[PR6017-I] The NB H&CD system (both heating and diagnostic) is not required to be operational for SRO, however the majority of the system is installed to permit its commissioning during SRO.

4.1.5.3.1 Heating Neutral Beam (HNB)

[PR690-R] For DT-1 and DT-2, the HNB system shall deliver 33 MW to the plasma through two HNB injectors (HNB01 & 02), each injector delivering 16.5 MW through a dedicated equatorial port.

[PR832-I] Depending on the REX built-up during DT-1, the NB H&CD system may be upgraded to provide, from DT-2, 50 MW of NB power to the plasma, by adding a third HNB injector (HNB03) through a third equatorial port.

[PR4995-R] Although the HNB03 upgrade is outside of the current ITER Technical Baseline, ITER shall permit its implementation before DT-2. This requires, in particular, the anticipated installation of the captive components for HNB03, and the guarantee that the existing NB H&CD sub-systems and associated auxiliary systems can cope or, at least, can be upgraded to operate this third HNB injector.

[PR693-R] The HNB system shall be capable of providing NBH for Tokamak pulse lengths up to 3600 s.

[PR694-R] The HNB shine-through on the blanket first wall during operation at low plasma density shall not exceed power levels defined in the *Heat and Nuclear Load Specifications [A15]*, taking other heating sources into consideration.

[PR695-R] Based on the monitoring of the first-wall surface temperature (performed by Diagnostic Systems), the HNB power shall be regulated to avoid overheating the first wall and shield blocks due to NB shine-through during operation at low plasma density.

[PR696-R] The HNB power shall be variable for plasma heating and current drive control.

4.1.5.3.2 Diagnostic Neutral Beam (DNB)

[PR698-R] For DT-1 and DT-2, the DNB system shall deliver 1.4 MW to the plasma through a single beamline with a 100 keV H0 beam with line-averaged plasma densities (n_e) greater than 0.30 E+20 / m^3.

4.1.6 Power handling

[PR711-I] Heat loads on the vacuum vessel and in-vessel components are specified in the *Heat and Nuclear Load Specifications [A15]*.

4.1.6.1 Plasma heat and nuclear loads

[PR714-R] In case of unmitigated transients like Vertical Displacement Events (VDE), runaway electrons and disruptions, some local damage of the armor material is acceptable. As far as possible, taking into account the other surface heat loads, the armor thickness shall be chosen to maximize the protection of the water cooling channels during the heat deposition due to runaway electrons, so as to minimize the risk of gross damage that could cause a water leak.

[PR6018-R] The blanket system, divertor and vacuum vessel shall shield the ex-vessel components from plasma nuclear loads, so that the subsequent heat and neutron exposure of the ex-vessel components remains within the envelope defined in the *Heat and Nuclear Load Specifications [A15]*.

4.1.6.2 Plasma-facing surface material

[PR717-R] The divertor and blanket shall have tungsten for all their plasma-facing surfaces. For blanket, this shall apply also to the temporary protection components installed during SRO and which are replaced with the final First Wall Panels for DT-1.

[PR719-R] The plasma-facing surfaces of ITER components other than blanket and divertor shall be constructed of materials that are compatible with the plasma environment and required plasma quality (to be approved by IO's Science).

[PR1800-R] The first wall shall be designed to provide limiting surfaces that define the plasma boundary during start-up and ramp-down.

4.1.6.3 Disruption mitigation

[PR723-R] To mitigate the effects from disruptions and VDEs on the ITER Tokamak Machine (for Investment Protection), a Disruption Mitigation System (DMS) shall be operational from SRO to terminate the plasma.

[PR726-R] The DMS shall mitigate the most severe effects from electromagnetic and thermal loads as well as from runaway electrons during disruptions and VDEs to minimize the need for intervention and to support routine and reliable operation of the device.

[PR732-R] ITER operation shall be recovered on a timescale of no more than three hours after the DMS use to mitigate a disruption.

[PR733-R] The DMS shall be distributed at several locations in the torus and shall include redundancy.

[PR734-R] The Plasma Control System (PCS) shall permit, from SRO, to execute, control and monitor all plasma operations so to avoid, predict and mitigate the occurrence of plasma loss-of-control events.

[PR5422-R] To trigger the DMS for mitigating a forthcoming plasma disruption or VDE, ITER shall be able to predict and detect, from SRO, disruptions and VDEs with a reliability that ensures the required lifetime of in-vessel components.

4.1.6.4 Fusion power shutdown

[PR791-R;Defined Requirement] A fusion power shutdown system (FFPSS) shall be provided, from DT-1, with the capability to inject impurity gases to abruptly terminate a pulse, with appropriate safety redundant provisions. The FFPSS shall be fully operational for testing during SRO.

4.1.7 Plasma fuelling, pumping and exhaust management

[PR6019-R] During SRO, ITER shall perform the following fuel cycle activities, with the performances specified in the following sections:

- To store the non-tritium gases required for the following fuel cycle activities.
- To inject into the vacuum vessel:
  - He-4, H2, D2 and impurity gases and pellets for plasma fuelling and control,
  - Impurity gases and pellets for studies of impurity transport and radiative cooling enhancement,
  - Gas mixtures to perform wall conditioning (GDC, Boronization and ICWC).
- To collect the exhaust gases from the vacuum vessel and other process components containing the above gases and potentially traces of tritium generated during DD plasmas (including the fuelling system, vacuum system, Tokamak cooling water system, and diagnostics).
- To process the collected exhaust gases, including their recycling for storage and/or their discharge to the Environment following appropriate treatment and control, in particular for the Diborane gas during and after boronization.
- To provide leak detection and localization on the above gas transfer routes and processes.

[PR6020-R] During DT-1 and DT-2, ITER shall perform the same fuel cycle activities as during SRO (see *PR6019-R*), except for:

- The impurity pellets injection, which is no longer required during DT-1 and DT-2,
- The following additional activities:
  - To store tritium gas, and inject it into vacuum vessel for plasma fuelling,
  - To provide H_2 and D_2 gases to the heating and diagnostics Neutral Beam injectors,
  - To extend the transfer of exhaust gases from NB injectors,
  - To track and perform accountancy of tritium inventory on the ITER site,
  - When required, to detritiate liquid or gaseous effluents produced within ITER Nuclear Facilities, in order to comply with the ALARA Principles application and/or with ITER Site discharge limits (see *Section 4.3.2*),
  - When relevant to recover tritium from liquid or gaseous effluents for storage and recycling.

[PR6021-R] From the first receipt of tritium on ITER Site, ITER shall have the capacity for managing this tritium.

4.1.7.1 Bounding fuelling rates and tritium supply limits

[PR743-R] During the helium plasma operation (up to 100 s flat-top), the bounding fuelling rate (gas puffing) shall not exceed 60 $Pa.m^3.s^{-1}$ average including 120 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz) when operating with helium-4.

[PR738-R] During SRO operation (up to 100 s flat-top), the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 200 $Pa.m^3.s^{-1}$ average including 400 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz) when operating with H_2 and D_2.

[PR740-R] During DT-1/DT-2 operation, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 200 $Pa.m^3.s^{-1}$ average including 400 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz) for burn times up to 450 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above).

[PR741-R] During DT-1/DT-2 operation, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 160 $Pa.m^3.s^{-1}$average including 320 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz) for burn times between 450 and 1000 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above).

[PR742-R] During DT-1/DT-2 operation, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 120 $Pa.m^3.s^{-1}$ average including 240 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz) for burn times between 1000 and 3000 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above).

[PR739-R] During DT-1/DT-2 operation, the T_2 supply (90% T, 10% D) shall be limited to 111 $Pa.m^3.s^{-1}$ average including 222 $Pa.m^3.s^{-1}$ peak (for durations up to 10 s at an average frequency of 0.01 Hz), which is equivalent to 100 $Pa.m^3.s^{-1}$ average including 200 $Pa.m^3.s^{-1}$ peak of pure T_2.

4.1.7.2 Torus pumping

[PR745-R] In plasmas, the neutral particle pressure under the divertor dome shall be in the range of 1 to 10 Pa.

[PR746-R] In helium plasmas (including mixtures with H), the neutral particle pressure under the divertor dome shall be in the range of 0.25 to 10 Pa.

[PR757-R] The torus pumping system shall exhaust low concentrations (less than 1%) of extrinsic impurities used to promote divertor radiation. It shall also be capable of pumping, over longer periods, larger quantities of extrinsic impurities used during burn termination or disruption mitigation.

[PR758-R] The pumping speed for the helium produced as a result of a plasma burn shall be close to the pumping speed for fuelling species.

4.1.7.3 Pellet injection

4.1.7.3.1 Hydrogenic pellet injection

[PR642-R] The nominal pellet injection frequency shall be adjustable from 4 Hz up to 60 Hz.

[PR5405-I] The frequencies specified in *PR642-R* can be achieved by the combination of several injectors.

[PR643-R] The nominal pellet speed at the injector shall be 300 $m.s^{-1}$ with a maximum of 500 $m.s^{-1}$.

[PR5406-I] The integrity of pellet is not required for injection velocities above 300 m/s.

[PR644-R] The pellet injector shall be capable to operate with a DT mixture containing between 0% T_2 and at least 90% T_2.

[PR645-R] The capability shall be provided to adjust within the full range the volume of the core fuelling pellet and of the ELM pacing pellet within 3 s during a pulse.

[PR646-R] The capability to select between the core fuelling and ELM pacing functions shall be provided for each injector within one hour between pulses.

[PR647-R] The capability shall be provided to change the pellet injection frequency by a factor of two within 0.25 s during a pulse.

[PR5407-R] The capability shall be provided for each injector to adjust the operating value of pellet throughput by ±20% of the maximum throughput of configuration in use within 0.2 s during a pulse.

[PR761-R] A throughput per injector of up to 120 $Pa.m^3.s^{-1}$ shall be provided for H_2 and D_2 pellets, and of up to 111 $Pa.m^3.s^{-1}$ for T_2 pellets (90% T, 10% D) which equals 100 $Pa.m^3.s^{-1}$ of pure T_2.

ELM pacing by hydrogenic pellet injection

[PR641-R] The capability to trigger ELMs through Low Field Side (LFS) as well as through High Field Side (HFS) DT pellet injection (pellet pacing) shall be provided.

[PR650-R] The time averaged injection rate for ELM pacing shall have an accuracy of +/- 5%.

[PR762-I] Pellet injection requirements for ELM suppression (pellet pacing) are provided in *Section 4.1.4.9*.

Core fuelling by hydrogenic pellet injection

[PR760-R] High Field Side (HFS) pellet injection shall be provided for core fuelling.

[PR5408-R] The time averaged injection rate for core fuelling shall have an accuracy of +/- 5%.

4.1.7.3.2 Impurity pellet injection

[PR764-R] During SRO only, an injection capability of up to five pellets per plasma pulse shall be provided for argon and neon impurity pellets.

4.1.7.4 Gas fuel injection

[PR766-R] Gas fuelling rate shall be within bounding fuelling rates and tritium supply limits given in *Section 4.1.7.1*.

[PR767-R] The response time of gas fuelling injection from zero to 63% at 20 Pa.m^3.s^{-1} shall be within 1 second.

4.1.7.5 Gas impurity injection

[PR769-R] The capability of injection of impurity gas species such as nitrogen, argon, helium-3, xenon and neon shall be provided from SRO.

[PR770-R] For the flat-top duration of ITER plasma scenarios, the capability for impurity gas injection up to two species at a total average rate of 20 Pa.m^3.s^{-1} shall be provided.

[PR772-R] The response time of gas impurity injection from zero to 63% at 5 Pa.m^3.s^{-1} shall be within 1 second.

4.1.7.6 Neutral Beam Fuelling

[PR774-R] The capability to fuel protium gas at the rate of 49 Pa.m^3.s^{-1} to each of the heating neutral beam injectors shall be provided during plasma operation and 51 Pa.m^3.s^{-1} to each of the heating neutral beam injectors shall be provided during conditioning/commissioning operations.

[PR775-R] The capability to fuel deuterium gas at the rate of 23 Pa.m^3.s^{-1} to each of the heating neutral beam injectors shall be provided during plasma operation and 25 Pa.m^3.s^{-1} to each of the heating neutral beam injectors shall be provided during conditioning/commissioning operations.

[PR776-R] The capability to fuel hydrogen gas at the rate of 9 Pa.m^3.s^{-1} to the neutralizer of the diagnostic neutral beam injector shall be provided during commissioning, plasma operation, and conditioning.

[PR777-R] The capability to fuel deuterium gas at the rate of 6 Pa.m^3.s^{-1} to the neutralizer of the diagnostic neutral beam injector shall be provided during commissioning, plasma operation and conditioning.

[PR778-R] The capability to fuel hydrogen gas at the rate of 8 Pa.m^3.s^{-1} to the high voltage deck of the diagnostic neutral beam injector shall be provided during commissioning, plasma operation and conditioning.

4.1.7.7 Fuel recycling

[PR6022-R] For any plasma scenario, ITER shall have a minimum, continuous full isotopic separation rate of 32 Pa.m^3.s^{-1} for unburned DT fuel for recycling (time averaged over pulses).

[PR6023-R] For any plasma scenario, ITER shall be able to perform recycling of the unburned DT fuel up to 100 Pa.m^3.s^{-1} including the full isotopic separation and the internal direct recycling streams (time-averaged over pulses).

4.1.8 Plasma diagnostics

[PR780-I] The ITER plasma diagnostics systems are required to provide accurate measurements of plasma behavior and performance.

[PR781-I] Measurements for ITER plasma diagnostics have five possible roles:

- Machine protection (1.a1),
- Basic machine control (1.a2),
- Advanced plasma control (1.b),
- Evaluation and physics studies (2),
- Maintenance and inspection outside plasma operation (3).

[PR782-R. The Tokamak Machine shall only perform a plasma operation if the diagnostic systems that are required to ensure the necessary machine protection and plasma control are operational (roles 1.a1 and 1.a2).

[PR783-R] The Tokamak Machine shall only perform advanced plasma operation if the necessary advanced diagnostic systems are operational (role 1.b).

[PR784-I] ITER Tokamak Machine may operate even when a measurement for evaluation and physics studies (2. role), and maintenance and inspection outside plasma operation (3. role) is not provided.

[PR786-R] The measurements of plasma behavior and performances that are listed in *Table 4-5* shall be provided for each plasma campaign phase. Their roles and contributions in achieving the ITER Research Plans are detailed in the *ITER Research Plans Level 2 [A33]*.

Table 4-5: Required Diagnostics measurements

Measurement Family *Note **	Measurement Parameters *Note **			Required during *Note **		
	ID	Parameter	Role	SRO	DT-1	DT-2
1. Plasma Current	MP 001a	Ip	Machine protection 1a.1	X	X	X
	MP 001b	Itor	Machine protection 1a.1	X	X	X
	MP 100	Plasma Current for Central Safety System	Machine protection 1a.1	X Note 4	X	X
2. Plasma Position and Shape	MP 004	Main plasma gaps, Dsep	Basic machine control 1a.2	X	X	X
	MP 002	Divertor channel location (r dir.)	Basic machine control 1a.2	X	X	X
	MP 003	dZ/dt of current centroid	Machine protection 1a.1	X	X	X
3. Loop Voltage	MP 005	Vloop	Basic machine control 1a.2	X	X	X
4. Plasma Energy	MP 006	Beta P	Machine protection 1a.1	X	X	X
5. Radiated Power (Prad)	MP 008a	Prad total, main plasma (Stationary)	Basic machine control 1a.2	X Note 1	X	X
	MP 008b	Prad, top region, upper X-point (Stationary)	Advanced plasma control 1b	X Note 1	X	X
	MP 008c	Prad total, main plasma + upper X-point (transient)	Physics studies 2	X Note 1	X	X
	MP 007a	Prad total, divertor (Stationary)	Basic machine control 1a.2	X Note 1	X	X
	MP 007b	Prad total, divertor (transient)	Physics studies 2	X Note 1	X	X
	MP 009a	Prad total (Stationary)	Machine protection 1a.1	X Note 1	X	X
	MP 009b	Prad total (Transient)	Physics studies 2	X Note 1	X	X
6. Line-Averaged Electron Density (ne)	MP 011	∫ne dl / ∫ dl	Basic machine control 1a.2	X	X	X

Measurement Family *Note **	Measurement Parameters *Note **			Required during *Note **		
	ID	Parameter	Role	SRO	DT-1	DT-2
7. Neutron Flux and Emissivity	MP 015	Total neutron flux	Machine protection 1a.1	X *Note 2*	X	X
	MP 014	Neutron / alpha source profile	Advanced plasma control 1b	-	X	X
	MP 012	Fusion power	Basic machine control 1a.2	-	X	X
	MP 013	Fusion power density	Basic machine control 1a.2	-	X	X
	MP 102	Total fusion power	Machine protection 1a.1	-	X	X
8. Error Field, Locked Mode and RWM	MP 016a	Br/<Bp> RWM	Machine protection 1a.1	X	X	X
	MP 016b	Br/<Bp> Error Field	Machine protection 1a.1	X	X	X
	MP 016c	Br/<Bp> Locked Mode	Machine protection 1a.1	X	X	X
9. Low (m,n) MHD Modes, Sawteeth, Disruption Precursors	MP 017	Btheta (complex, at wall) /<Bp>	Machine protection 1a.1	X	X	X
10. Plasma Rotation	MP 019	VTOR	Advanced plasma control 1b	X *Note 1*	X	X
	MP 018	VPOL	Advanced plasma control 1b	-	X	X
11. Fuel Ratio in Plasma Core	MP 020	nT/nD Core	Basic machine control 1a.2	-	X	X
12. Impurity Species Monitoring *B: Boron* *C: Carbon* *O: Oxygen* *W: Tungsten* *Cu: Cupper* *Ne: Neon* *Ar: Argon* *Xe: Xenon* *(see also family 32 + 35)*	MP 022	B, C, O Relative Concentration *(O for condition monitoring)*	Basic machine control 1a.2	X	X	X
	MP 021a	C, O influx *(O for condition monitoring)*	Basic machine control 1a.2	X	X	X
	MP 021b	B influx	Basic machine control 1a.2	X	X	X
	MP 021c	W, B influx distribution	Physics studies 2	X	X	X
	MP 024	Cu Relative Concentration	Basic machine control 1a.2	X	X	X
	MP 023	Cu influx	Machine protection 1a.1	X	X	X
	MP 028	W Relative Concentration	Basic machine control 1a.2	X	X	X
	MP 027	W influx	Machine protection 1a.1	X	X	X
	MP 026	Extrinsic (Ne, Ar, Xe, N_2) Relative Concentration	Basic machine control 1a.2	X	X	X
	MP 025	Extrinsic (Ne, Ar, Xe, N_2) influx	Basic machine control 1a.2	X	X	X
13. Zeff (Line-averaged)	MP 029	Zeff (Line-averaged)	Basic machine control 1a.2	X	X	X
14. H-mode: ELMs and 2 L-H Transition Indicator	MP 030	ELM visible radiation bursts	Machine protection 1a.1	X	X	X
	MP 031	ELM density transient	Physics studies 2	X	X	X
	MP 032	ELM temperature transient	Physics studies 2	X	X	X
	MP 033	L-H D-alpha step	Basic machine control 1a.2	X	X	X
15. Runaway Electrons	MP 034	E max	Physics studies 2	X	X	X
	MP 035	I runaway	Advanced plasma control 1b	X	X	X

Measurement Family *Note **	Measurement Parameters *Note **			Required during *Note **		
	ID	Parameter	Role	SRO	DT-1	DT-2
16. Operational Parameters	MP 039	Max. surface temperature for divertor	Machine protection 1a.1	X *Note 1*	X	X
	MP 040a	Fine surface metrology for divertor	Physics studies 2	X *Note 2*	X	X
	MP 040b	Fine net erosion and redeposition for First Wall	Physics studies 2	X *Note 2* *Note 5*	X	X
	MP 038	Divertor gas pressure (Pdiv)	Basic machine control 1a.2	X	X	X
	MP 037	Gas composition in divertor (Fuel, He, impurities)	Basic machine control 1a.2	X *Note 1*	X	X
	MP 041	Position of the ionization front for divertor	Basic machine control 1a.2	X *Note 1*	X	X
17.Visible Image & Wall Temperature of First Wall and Divertor dome/baffle	MP 042	Surface luminance for FW and divertor dome/baffle	Machine protection 1a.1	X *Note 1*	X	X
	MP 043	Surface temperature for FW and divertor dome/baffle	Basic machine control 1a.2	X *Note 1*	X	X
	MP 044	surface temperature during ELMs for FW and divertor dome/baffle	Physics studies 2	X *Note 1*	X	X
18. Gas Pressure and Composition in Main Chamber	MP 046	Main chamber gas pressure (Pmain)	Basic machine control 1a.2	X *Note 1*	X	X
	MP 045	Gas composition in main chamber (Fuel, He, impurities)	Basic machine control 1a.2	X	X	X
19. Gas Pressure and Gas Composition in Ducts	MP 048	Duct gas pressure (Pduct)	Basic machine control 1a.2	X	X	X
	MP 047	Gas composition in ducts (Fuel, He, impurities)	Basic machine control 1a.2	X *Note 1*	X	X
20. In-Vessel Inspection	MP 049	Wall image	Maintenance and inspection 3	X *Note 1*	X	X
21. Halo Currents	MP 050a	Poloidal current in one sector	Machine protection 1a.1	X	X	X
	MP 050b	Current distribution in divertor cassette	Machine protection 1a.1	X	X	X
22. Toroidal Magnetic Field	MP 051	BT	Basic machine control 1a.2	X	X	X
23. Electron Temperature (Te) Profile	MP 052	Core Te	Advanced plasma control 1b	X	X	X
	MP 053	Edge Te	Physics studies 2	X	X	X
24. Electron Density (ne) Profile	MP 054	Core ne	Advanced plasma control 1b	X	X	X
	MP 055	Edge ne	Advanced plasma control 1b	X	X	X
25. Current Profile	MP 056	q(r)	Physics studies 2	- *Note 3*	X	X
	MP 057	Normalized Position of q=1.5,2 surfaces [r(q=1.5,2)/a]	Advanced plasma control 1b	- *Note 3*	X	X
	MP 058	Normalized Position of qmin [r(qmin)/a]	Advanced plasma control 1b	- *Note 3*	X	X
26. Zeff Profile	MP 059	Zeff profile	Physics studies 2	-	X	X

Measurement Family *Note **	**Measurement Parameters** *Note **			**Required during** *Note **		
	ID	**Parameter**	**Role**	**SRO**	**DT-1**	**DT-2**
27. High Frequency Instabilities (MHD, NTMs, AEs, turbulence)	MP 060	Fishbone Btheta(mode) / <Bp>	Physics studies 2	X *Note 1*	X	X
	MP 062	TAE Btheta(complex) / <Bp>	Physics studies 2	X *Note 1*	X	X
	MP 063	TAE $\delta ne/ne$, $\delta Te/Te$	Physics studies 2	X *Note 1*	X	X
	MP 061	NTM $\delta Te/Te$ (complex) 100ms integration time	Advanced plasma control 1b	X	X	X
28. Ion Temperature (Ti) Profile	MP 064	Core Ti	Advanced plasma control 1b	X *Note 1*	X	X
	MP 065	Edge Ti	Physics studies 2	-	X	X
29. Core He Density	MP 066	nHe/ne	Advanced plasma control 1b	-	X	X
	MP 067	Profile of He-3 concentration	Advanced plasma control 1b	-	X	X
30. Confined Alphas and Fast Ions	MP 069	Alpha Energy spectrum	Physics studies 2	-	X	X
	MP 068	Alpha Density Profile	Physics studies 2	-	X	X
	MP 070	p,D,T,He-3 energy spectrum	Physics studies 2	-	X	X
31. Escaping Alphas and Fast Ions	MP 071	Fast particle loss distribution	Physics studies 2	-	X	X
	MP 072	Fast particle loss flux	Physics studies 2	-	X	X
32. Impurity Density Profile	MP 074	Fractional content, Z<=10	Advanced plasma control 1b	X *Note 1*	X	X
	MP 073	Fractional content, Z>10	Advanced plasma control 1b	X *Note 1*	X	X
33. Fuel Ratio in the Edge	MP 076	nT/nD Edge	Basic machine control 1a.2	-	X	X
	MP 075	nH/nD Edge	Physics studies 2	-	X	X
34. Neutron Fluence	MP 077	First wall neutron fluence	Basic machine control 1a.2	-	X	X
	MP 101	Neutron fluence for lifetime fluence determination	Machine protection 1a.1	X *Note 2* *Note 1*	X	X
35. Impurity and D,T Influx (Γ) in Divertor	MP 078a	Γ_W, Γ_B	Machine protection 1a.1	X *Note 1*	X	X
	MP 078b	Γ_c	Physics studies 2	X	X	X
	MP 079	Γ_H, Γ_D, Γ_T	Basic machine control 1a.2	X *Note 1* *(for D and H)*	X	X
36. Plasma Parameters at the Divertor Targets	MP 080a	ne Divertor Target	Physics studies 2	X	X	X
	MP 080b	Divertor Target Parallel Ion Flux	Advanced plasma control 1b	X	X	X
	MP 081	Te Divertor Target	Physics studies 2	X	X	X
37. Radiation Profile (Prad)	MP 083a	Prad profile, main plasma + upper X-point (Stationary)	Basic machine control 1a.2	X *Note 1*	X	X
	MP 083b	Prad profile, main plasma + upper X-point (transient)	Physics studies 2	X *Note 1*	X	X
	MP 083c	Prad vertical line integrals main plasma + upper X-point (transient)	Physics studies 2	X *Note 1*	X	X
	MP 082a	Divertor Prad Profile (Stationary)	Advanced plasma control 1b	X *Note 1*	X	X
	MP 082b	Divertor Prad Profile (transient)	Physics studies 2	X *Note 1*	X	X
38. Heat Loading Profile in Divertor	MP 086	Divertor surface temperature	Advanced plasma control 1b	X *Note 1*	X	X

Measurement Family *Note **	Measurement Parameters *Note **			Required during *Note **		
	ID	Parameter	Role	SRO	DT-1	DT-2
	MP 085	Divertor power load	Advanced plasma control 1b	X *Note 1*	X	X
39. Divertor Helium Density	MP 087	nHe Divertor	Basic machine control 1a.2	-	X	X
40. Fuel Ratio in the Divertor	MP 089	nT/nD Divertor	Physics studies 2	-	X	X
	MP 088	nH/nD Divertor	Physics studies 2	X *Note 2*	X	X
41. Divertor Electron Parameters	MP 090	ne Divertor	Physics studies 2	-	X	X
	MP 091	Te Divertor	Physics studies 2	-	X	X
42. Ion Temperature (Ti) in Divertor	MP 092	Ti Divertor	Physics studies 2	-	X	X
43. Divertor Plasma Flow	MP 093	Vp	Physics studies 2	*No longer required*		
44. Fuel Ratio in Plasma Core	MP 094	nH/nD Core	Physics studies 2	-	X	X
45. Neutral Density between Plasma and First Wall	MP 095	D+T influx in main chamber	Basic machine control 1a.2	X *Note 1*	X	X
46. Dust Monitoring	MP 097a	Surface Concentration of mobilizable dust (divertor cassette body under the dome and VV floor)	Physics studies 2	X *Note 2*	X	X
	MP 097b	Dust size distribution	Physics studies 2	X *Note 2*	X	X
	MP 097c	Viewing of dust area on and under the divertor	Physics studies 2	X *Note 2*	X	X
47. Hydrogen Isotopes Monitoring	MP 099a	Divertor Surface H, D, T Concentration	Physics studies 2	X *Note 2*	X	X
	MP 099b	First Wall Surface H, D, T Concentration	Physics studies 2	X *Note 2* *Note 5*	X	X
48. In-vessel ECH stray radiation	MP 103	In-vessel ECH stray radiation intensity	Basic machine control 1a.2	X	X	X

Note: The purpose of this table is only to identify the measurement parameters (MP) that must be available to meet the ITER scientific and/or safety objectives for each plasma campaign phase, including – as relevant –plasma control, plasma parameters monitoring, systems testing and/or to support the ITER knowledge acquisition program (see IRP L2 [A33]).*

All MPs listed in this table are required during DT-1 and DT-2 (tagged with "X").

For SRO, not all MPs are required; and for such MPs (tagged "-"), the table does not address any eventual anticipated installation of the associated diagnostic systems to reflect, for example, captive components (in line with [R34] and [R35]), or the early-availability of diagnostic systems (as authorized in ITER Technical Baseline).

Note 1: The MP available at SRO does not need to meet the final requirements in terms of spatial/time resolution to support the experimental program.

Note 2: The MP is not strictly needed for the SRO scientific objectives, but it is required for ITER knowledge acquisition program during SRO to support the first validation step of safety-related assumptions, getting experience for the quantification and control of plasma events (runaway electrons, disruptions, plasma vertical displacements events), radiation maps, dust production and in-vessel fuel retention.

Note 3: The MP is desirable for SRO but not included in ITER Technical Baseline. If the availability of this parameter is deemed necessary during SRO, its implementation in the baseline will require a dedicated Project Change Request.

Note 4: MP100 is not strictly needed for SRO scientific objectives, but it is required to perform the safety function to monitor the plasma current to ensure it does not exceed 15 MA [R31, R32].

Note 5: The First Wall samples are installed in the vacuum vessel prior to starting SRO. It is planned to remove them for analysis at the end of SRO and to replace them for DT-1. During DT-1 and DT-2 Long-Term Maintenance periods, the samples are removed and replaced remotely as required.

4.1.9 Post-discharge operations

4.1.9.1 Data archiving

[PR2175-R] All configuration data and a history of operational data shall be stored, and shall be available in the Main Control Room (see *Section 6.8.2*) as needed for the operation of the ITER Facility.

[PR794-R] All scientific and replica of operational data shall be kept in archives outside the nuclear island of ITER in a standard data storage facility.

[PR795-R] A remote backup of all ITER configuration-, scientific- and operations- data shall be provided at a location that is at a distance of at least 50 km from the primary storage location.

[PR1769-R] Some computational resources shall be provided to all ITER Members to enable efficient pre-processing of the data and reduce the need of data transfer to all Members.

4.1.9.2 Vacuum base pressure

[PR797-R] A base pressure of less than 5E-04 Pa (for hydrogenic species) shall be achieved by the end of the dwell periods between pulses when operated at maximum duty cycle.

[PR798-R] A base impurity pressure of less than 1E-07 Pa (the sum of partial pressures of impurity gases) shall be achieved by the end of the dwell periods between pulses when operated at maximum duty cycle.

4.1.10 Tritium breeding

[PR6024-I] No Test Blanket Module (TBM) systems are installed for operation at SRO.

[PR254-R] During DT-1, four TBMs shall be tested simultaneously, with their auxiliary sub-systems, in order to demonstrate and validate:

- The process for tritium breeding, on-line tritium extraction and control, and tritium accountancy.
- The process for TBM high-grade heat power extraction.
- The methods and models to extrapolate built-up Return of Experience (REX) to the DEMO breeding blankets.

[PR6025-R] The infrastructures serving the TBMs shall be designed and built to enable the sequential tests of different TBM versions and types.

[PR6026-I] In the development of the DD and DT operation in DT-2, the TBM systems configuration will evolve as per their specific research program.

4.1.11 ITER planned upgrades for plasma generation

4.1.11.1 Resistive wall modes control upgrades

[PR815-I] Resistive Wall Modes (RWM) may become unstable in cases of very high β_N (about 3.0) at low rotation speeds. Following assessment (see *[PR4962-R]* and the required technical and safety demonstration), RWM control may be required.

[PR817-R] The Coil Power Supply and Distribution System (CPSD) shall be designed to control voltage/current for RWMs in Edge Localized Modes (ELMs) coils. Other ITER systems may require upgrades to perform RWM control.

4.1.11.2 Auxiliary system upgrades for hybrid and non-inductive scenarios

[PR834-R] ITER auxiliary systems shall be upgradable (with additional investment) to meet the requirements of the Hybrid and Non-inductive scenarios that are defined in *Section 4.1.1*. Parameters for the Hybrid and Non-inductive scenarios are shown in *Table 4-1*.

[PR6027-I] As specified in *[PR1770-R]*, ITER auxiliary systems are also upgradable (with additional investment) to perform the flexible DT plasma scenarios.

4.1.11.3 Flexibility for high-duty cycle

[PR6028-I] To fulfil the objective of the Test Blanket Modules (TBM) Testing Program in terms of breeding, tritium extraction and power extraction at high performance during DT-2, it is expected to operate back-to-back pulses during several days (> 6 days) on three shifts. For the case of the inductive operation, this means that ~ 500 GJ are generated with 2 pulses per hour, with an average of ~ 133 MW on a daily basis - see the *IRP Level 2 for TBMs Testing Program [A33]*. However, prior to including such high-duty operation in ITER Technical Baseline, its loads on the Tokamak Machine and auxiliary systems should be demonstrated as being enveloped by the SRO/DT-1/DT-2 plasma campaigns).

[PR842-R] The ITER Tokamak and facility (with, if needed, additional investments for the upgrade of auxiliary systems) shall be able to accommodate plasma operation, during DT-2, with a time-averaged fusion power of 133 MW for each of the design scenarios that are specified in *Section 4.1.1.1* (as detailed in the *IRP Level 2 for TBMs Testing Program [A33])*.

4.2 ITER MAINTENANCE AND ASSOCIATED PERFORMANCES

[PR6029-R] The ITER Maintenance Facilities shall be designed, constructed and operated in compliance with the overall architecture and construction planning specified in the *ITER Integrated Maintenance Strategy [A38]*.

4.2.1 Non-nuclear Maintenance

[PR6030-R] ITER shall provide facilities to store all ITER SSCs following their delivery by suppliers, until their installation within ITER Facility (including all SSCs to be installed during assembly phases and spare SSCs for maintenance activities).

[PR6031-R] During the whole ITER lifetime until its handover to the Host State, ITER shall ensure that its non-radioactive SSCs, which are designed for maintenance, can be maintained in-situ and/or by using ITER facilities and/or 3rd party facilities (including as required the provision for transfer, storage, and testing of these SSCs, and any specific tools to perform these activities).

[PR6032-R] From Pre-SRO Assembly and the following phases, ITER shall provide a facility to perform the environmental and functional testing of non-radioactive diagnostics, heating and TBM port plugs prior to their installation into the vacuum vessel (i.e. Port Plug Test Facility (PPTF) installed in non-nuclear facility).

4.2.2 Nuclear Maintenance

[PR1055-R] ITER shall provide facilities to maintain the radioactive SSCs, which are designed for maintenance during each stage SRO/DT-1/DT-2 (including their assembly phase) and the first decommissioning phase until ITER handover to the Host State.

[PR6033-R] ITER shall provide the remote handling equipment (RHE) that is required to perform the foreseen maintenance of radioactive SSCs (including tools for the installation/removal of these SSCs in radioactive environment).

[PR1058-R] ITER shall provide transfer casks (and any other devises and logistics) to transport radioactive SSCs between ITER nuclear facilities.

[PR1059-R] ITER shall provide facilities to:

- Store and maintain specific tools that are required for the maintenance of all radioactive SSCs and that are radioactively contaminated during these maintenance activities,
- Store radioactive SSCs yet to be maintained,
- Store radioactive SSCs that have been maintained until their transfer for installation back into the ITER Facility.

[PR6034-R] ITER shall provide test facilities to confirm, when required, that the radioactive SSCs have been maintained to the required level of quality.

[PR6035-R] ITER shall permit the Post Irradiation Examination of specific in-vessel components, either in ITER facilities or via 3rd party facilities.

4.2.2.1 Specific nuclear maintenance performances

4.2.2.1.1 Nuclear Maintenance of the Tokamak

During SRO Plasma Operations

[PR6036-R] No nuclear maintenance shall be planned during SRO on in-vessel components.

[PR6037-R] If the failure or damage of in-vessel components occurs during SRO, one of the following maintenance options shall be implemented:

- If the failure or damage occurs before DD shots (i.e. before activation of the vacuum vessel and of the in-vessel components):

  - If the Tokamak Machine remains safely and efficiently operational, the SRO phase could be completed as planned in the *ITER Research Plan for SRO [A33]*.
  - If deemed necessary and provided there is no local activation due to runway electrons events, corrective maintenance could be performed either in-situ, or by using existing Pre-SRO Assembly tools and ITER non-nuclear facilities for their replacement/repair.
- If the failure or damage occurs after DD shots (i.e. after activation):
  - If the Tokamak Machine remains safely and efficiently operational, the SRO phase could be completed as planned in the *ITER Research Plan for SRO [A33]*.
  - If the Tokamak Machine can no longer be operated safely and efficiently, the SRO phase is stopped to execute the Post-SRO Assembly (with appropriate corrective actions) prior to starting DT-1.

[PR6038-R] During SRO, maintenance of ex-vessel components of the Tokamak shall be performed hands-on.

<u>During Post-SRO Assembly</u>

[PR6039-R] If required, maintenance on in-vessel components during Post-SRO Assembly shall only start after a decay period permitting hands-on intervention using the Pre-SRO Assembly tools and existing non-nuclear facilities.

<u>During DT-1 Plasma Operations</u>

[PR6040-I] During DT-1, the following maintenance activities on the Tokamak are to be performed remotely when there are unacceptable radiological risks from the components to be maintained, and/or from the environment for their in-situ maintenance.

[PR6041-R] Each in-vessel Tokamak component, for which nuclear maintenance is foreseen during DT-1, shall be designed and maintained in compliance with the *"<u>new-spare</u>"* strategy, which requires that:

- The component to be maintained is replaced by an entire new spare (i.e. no planned in-situ maintenance and/or no planned removal/installation of specific parts of the component). New spares are of the same design than the replaced item or, if needed, with a configuration modified to account for the return of experience and still compatible with the existing nuclear maintenance facilities (including authorized design evolutions of TBM system).
- No repair/refurbishment on the component (part/whole) is planned within the Nuclear Maintenance Facilities.
- For the Test Blanket Modules System, *[PR1081-R]* applies.
- Exception to these rules:
  - *<u>To be authorized on a case by case</u>*: small repairs for other Tokamak components could be performed within the Nuclear Maintenance Facilities (during DT phases) provided that <u>both</u>:
    - For the types and extents of the component damages and the repair activities that are considered, the feasibility of the effective repairs by RH technology is confirmed.
    - The repair activities have no impact on the design of the maintenance facilities and associated systems, the related investment cost and the ITER integrated construction, operation and maintenance programs.

[PR1081-R] For DT-1, the ITER Nuclear Maintenance Facilities (including the associated Remote Handling Systems) shall ensure the execution of the nuclear maintenance tasks that are listed in *Table 4-6*.

[PR6042-I] Full blanket first wall and/or divertor upgrade is not foreseen after Post-SRO Assembly.

[PR2200-I] The TF and PF coils replacement after the activation phase is not considered for DT-1.

Table 4-6: Tasks to be completed by ITER Nuclear Maintenance Facilities during DT-1

		PLANNED TASKS DURING DT-1			**OTHER FORESEEN TASKS DURING DT-1**		
		Planned tasks for each Long-Term Maintenance (LTM) ***Note 1***		**Planned total nb of items handled over DT-1** ***Note 2***	**Corrective maintenance to be performed during a Long-Term Maintenance (LTM)** ***Note 5***		**Total nb of items that could be handled over DT-1**
Clients	**Components** ***Note 3***	**Type of tasks**	**Nb of items**		**Type of tasks**	**Duration of tasks**	
PBS15-VV	Vacuum Vessel	VV in-service inspection	*TBD*	*TBD*	*None foreseen*	*N/A*	*N/A*
PBS16	Shield Blocks (SB)	*None planned*	*N/A*	*N/A*	Replaced by new spares when failed	*TBD* ***Note 5***	2 SB
	First Wall Panels (FWP)	*None planned*	*N/A*	*N/A*	Replaced by new spares when failed	Target duration is within one LTM for: ***Note 5*** 1 cassette **or** 3 panels ***(Note 8)***	12 FWP
PBS17	Divertor cassette	*None planned*	*N/A*	*N/A*	Replaced by new spares when failed		3 cassettes
PBS23	Remote Handling Systems (RHS)	*None planned*	*N/A*	*N/A*	Repaired when failed ***Note 6***	*TBD* ***Note 5***	TBD
PBS24-VP	VVPSS rupture disk cartridges	Replaced by new spares	Up to 2 cartridges	Up to 8 cartridges	*None foreseen*	*N/A*	*N/A*
	VVPSS Rupture Disk Assembly (RDA)	*None planned*	*N/A*	*N/A*	Replaced by new spare when ruptured or failed	*TBD* ***Note 5***	1 RDA **or** 1 BLVA
	VVPSS Bleed Line Valve Assembly (BLVA)	*None planned*	*N/A*	*N/A*	Replaced by new spare when failed	*TBD* ***Note 5***	
PBS31	Torus Cryopumps seals	Replaced by new spares	Up to 2 seals	Up to 8 seals	*None foreseen*	*N/A*	*N/A*
	Full Torus Cryopumps (TCP)	*None planned*	*N/A*	*N/A*	Replaced by new spare when failed	*TBD* ***Note 5***	1 TCP
	Valve Head Assembly (VHA)	*None planned*	*N/A*	*N/A*	Replaced by new spare when failed	*TBD* ***Note 5***	1 VHA
PBS53	NB Cesium ovens	Replaced by new spares	6 HNB ovens 1 DNB oven	28 ovens	*If needed, to be considered as corrective maintenance on a Large NB component, as detailed below*		
	Large NB components	*None planned*	*N/A*	*N/A*	Replaced by new spare when failed	*TBD* ***Note 5***	1 component
PBS51/ 52/55	Port Plugs (incl. diagnostics racks)	*None planned*	*N/A*	*N/A*	Replaced by new spares or small repair, when failed ***Note 6***	*TBD* ***Note 5***	6 PP

		PLANNED TASKS DURING DT-1			OTHER FORESEEN TASKS DURING DT-1		
		Planned tasks for each Long-Term Maintenance (LTM) ***Note 1***		Planned total nb of items handled over DT-1 ***Note 2***	Corrective maintenance to be performed during a Long-Term Maintenance (LTM) ***Note 5***		Total nb of items that could be handled over DT-1
Clients	**Components *Note 3***	**Type of tasks**	**Nb of items**		**Type of tasks**	**Duration of tasks**	
PBS56 ***Note 4***	TBM Port Plugs	Replaced by new spare	Up to 2 PP *(i.e. 2 frames + 4 TBM + 4 shields)*	Up to 8 TBMs *(exported to owners along DT-1)*	*None foreseen*	*N/A*	*N/A*
				Up to 4 TBM-frames + 8 TBM-shields	*None foreseen*	*N/A*	*N/A*
	TBM Pipe Forest (PF)	Replaced by new spare or maintained ***Note 4***	Up to 2 PF	Up to 4 PF	*None foreseen*	*N/A*	*N/A*
	TBM Ancillary Equipment Units (AEUs)	Maintained	Up to 2 AEU	Up to 4 AEU	*None foreseen*	*N/A*	*N/A*
PBS57	IVVS probes	Replaced by new spare	Up to 6 probes over 2 LTMs	Up to 12 probes	*None foreseen*	*N/A*	*N/A*
Various PBS ***Note 9***	Primary closure plates and Ex-Vessel Equipment (EVE)	Temporary storage to clear ports for access	*As required to perform the planned tasks*		Temporary storage to clear ports for access	*As required to perform the foreseen tasks*	
	Ex-Vessel Equipment (EVE)	*None planned*	*N/A*	*N/A*	Repaired when failed ***Notes 6&7***	*TBD* ***Note 5***	*TBD*

Note 1: *The duration of the planned tasks cumulated over one LTM period (i.e. maximum 6 months) concerns only the activities performed to complete the full components replacement and VV inspections (including RHS deployment). The preparation of the new spare components, the activities to be performed on the removed components (like inspection, testing, repair, storage and/or waste management), and the planned maintenance of the Nuclear Maintenance Facilities and the Remote Handling Systems (PBS23) are performed outside the LTM periods; and they are not detailed in this table.*

Note 2: *The total number of items planned to be handled over DT-1 is derived by multiplying the number of items to be handled during each LTM by the number of LTMs planned during DT-1 (i.e. 4 LTMs over DT-1), except for TBM/IVVS which the overall values for DT-1 have been given by PBS-56 and PBS-57. This excludes tasks planned before and after DT-1.*

Note 3*: The preparation of the new spare components is performed outside the Nuclear Maintenance Facilities.*

Note 4*: In case of TBM PF repair, it should have no impact on the Nuclear Maintenance Facilities volume, layout, capability, investment cost and the planned maintenance activities. Note that a third change of TBM PPs is planned post-DT1 (not included in this table).*

Note 5: *If required, the corrective maintenance of a failed component required for operation would be performed during the next LTM for which the planned occurrence, duration and/or tasks could be adapted as required. There is no prescribed duration for these corrective maintenance tasks; the target time for their execution will be driven by design, engineering and cost considerations. As for the planned tasks (see Note 1), the new spares preparation and activities to be performed on removed components are not detailed in this table.*

Note 6: *The possibility for repair should be confirmed considering the damage that can be expected and the possibility of making effective repairs for each type of component by RH technology. Small repairs should have no impact on the Nuclear Maintenance Facilities volume, layout, capability, investment cost and the planned maintenance activities.*

Note 7: *For repairs of Ex-Vessel Equipment (EVE) that cannot be performed in-situ in the Tokamak Complex.*

		PLANNED TASKS DURING DT-1			OTHER FORESEEN TASKS DURING DT-1		
		Planned tasks for each Long-Term Maintenance (LTM) *Note 1*		Planned total nb of items handled over DT-1 *Note 2*	Corrective maintenance to be performed during a Long-Term Maintenance (LTM) *Note 5*		Total nb of items that could be handled over DT-1
Clients	Components *Note 3*	Type of tasks	Nb of items		Type of tasks	Duration of tasks	

Note 8: *The Blanket First-Wall Panels to be replaced are assumed to be in proximity within the Tokamak, requiring a single deployment of the in-vessel remote handling systems. If this is not the case, the duration of the maintenance tasks can be increased accordingly.*

Note 9: *Temporary storage and corrective maintenance of Ex-Vessel Equipment (EVE) can concern PBS 15-VV-II, PBS 18, PBS 24-VP, PBS 26-PH, PBS 31, PBS 51/52/53, PBS 55, PBS 56 and PBS 57. The Nuclear Maintenance Facilities will provide the required space and integration for the clients' needs for their foreseen EVE corrective maintenance, knowing that some maintenance operations could be outsourced.*

During DT-2 Plasma Operations

[PR6043-R] The nuclear maintenance activities to be performed for the Tokamak Machine during DT-2 in the ITER Nuclear Maintenance Facilities (including the associated Remote Handling Systems) shall be defined using the SRO and DT-1 return of experience.

4.2.2.1.2 Nuclear Maintenance of Auxiliary Systems

During SRO Plasma Operations and Post-SRO Assembly

[PR6044-R] During SRO plasma operations and Post-SRO Assembly, the maintenance of all Tokamak-Auxiliary and Plant-Auxiliary Systems shall be performed hands-on.

During DT-1 and DT-2

[PR6045-R] The components of the Tokamak-Auxiliary and Plant-Auxiliary Systems that are radioactively contaminated during DT-1 and DT-2 plasma operation (like part of TCWS, VVPSS, fuelling & pumping systems, and Tritium Plant) shall be maintained in-situ or within on-site Nuclear Maintenance Facilities or using 3rd party facilities (i.e. outsourcing of maintenance).

4.2.2.2 Specific remote handling performances

[PR6046-R] ITER shall provide systems and tools to perform the following handling activities:

- During Pre-SRO Assembly: to install the in-vessel components and some NB cell components, within a mixed assembly systems / hands-on operating regime.
- During SRO Plasma Operations:
  - Some assembly systems used during Pre-SRO Assembly are available during SRO, if necessary to perform hands-on operation.
- During Post-SRO Assembly:
  - To replace the temporary First Wall Panels (FWP) with definitive FWPs within a mixed assembly systems / hands-on operating regime.
  - To install the remaining port plugs not installed in pre-SRO (e.g. TBMs, ECH Equatorial Port Plug #15, Diagnostics Upper Ports #3 and #10) within a mixed assembly systems / hands-on operating regime.
  - To Install the remaining Diagnostic Racks not installed in pre-SRO within a mixed assembly systems / hands-on operating regime.
  - To install the Neutral Beam remaining front end components and internal components of Neutral Beam vessels within a mixed assembly systems / hands-on operating regime.
- During DT-1: to perform nuclear maintenance and radwaste management within a RH operating regime.
- Before DT-2: (if endorsed) to install the third HNB injector, and to perform the planned nuclear maintenance of ITER components within a RH operating regime.
- During DT-2: Specific remote handling performances shall be defined using the SRO and DT-1 return of experience.

4.3 ITER WASTE MANAGEMENT AND ASSOCIATED PERFORMANCES

[PR6047-R] The ITER Waste Management Facilities shall be designed, constructed, and operated in compliance with the overall architecture and construction planning specified in the *ITER Integrated Waste Management Strategy [A39]*.

4.3.1 Non-radioactive Waste & Effluent Management

[PR6048-R] ITER shall collect all the industrial, sanitary and precipitation liquid effluents it produces during its whole lifetime, and provide appropriate retention capacity, monitoring and (if required) processing prior to discharge.

[PR6049-R] ITER shall process its collected sanitary effluents so that they can be discharged (following authorization) to the Host State network in compliance with the authorized discharge limits ([A45] Appendix 2).

[PR6050-R;Defined Requirement] ITER shall process its collected industrial effluents so that they can be discharged (following authorization) to the industrial effluents treatment station of the Host State, in compliance with the authorized discharge limits ([A45] Appendix 2) and with a maximum discharge flow rate of 60 m^3/day [R29].

[PR6051-R] ITER shall collect all the solid non-radioactive waste it produces during its whole lifetime, and condition them, as required, to permit its transfer to appropriate 3rd party facilities.

4.3.2 Radioactive Waste & Effluent Management

[PR1065-R;Defined Requirement] No radioactive material processing shall lead to a high-level radioactive waste stream as defined by the French 3rd party facility responsible for managing the disposal of such waste in France.

[PR2209-R;Defined Requirement] Suitable management routes shall be implemented for all radioactive waste generated throughout ITER lifetime.

4.3.2.1 Gaseous radioactive effluents management

[PR6052-R;Defined Requirement] ITER shall collect all gaseous radioactive effluents generated within ITER Nuclear Facilities during their whole lifetime, and process them if required so that they can be released ALARA into the Environment, in compliance with the estimated gaseous discharges from ITER normal operation (*2012 RPrS [R08], Volume I, Chapter 10, Section 3.4.3*).

4.3.2.2 Liquid radioactive effluents management

[PR1064-R;Defined Requirement] ITER shall provide the Waste Management Facilities required to manage all ITER liquid radioactive effluents generated within ITER Nuclear Facilities during their whole lifetime (and in compliance with *ITER Integrated Waste Management Strategy [A39]* and ITER *Decommissioning Strategy [A40]*), including:

- Their appropriate collection and buffer storage prior to processing,
- Their processing to transform in solid waste and/or their discharge through ITER industrial wastewater discharge network or transfer to 3rd party facilities for final treatment.

4.3.2.2.1 Specific requirements for safety drain tanks

[PR1067-R] In case of an incidental in-vessel water leak, ITER shall be able to:

- clean the vessel and the safety drain tank(s), so to restart its plasma campaign within one year,
- collect and treat the resulting contaminated water as specified in *ITER Integrated Waste Management Strategy [A39]*.

4.3.2.3 Solid radioactive waste management

[PR6053-I] Radioactive solid waste to be generated at ITER includes (as defined by the French 3rd party facility responsible for managing the disposal of such waste in France):

- TFA waste: very low-level solid radioactive waste, for French "*Déchets TFA, Très Faible Activité*",
- Purely tritiated (PT) waste: solid radioactive waste exclusively contaminated with tritium (i.e. waste not irradiated by neutrons, and without contamination of other radionuclides),
- Type A waste: short-lived low-level solid radioactive waste, for French "*Déchets Type A or FAVC, Faible et Moyenne Activité à durée de Vie Courte*". The Type A waste with high dose rate requiring remote handling management is sub-categorized as "Type A+ waste". The Type A waste with lower dose rate is generally managed hands-on.
- Type B waste: Long-lived intermediate-level solid radioactive waste, for French "*Déchets Type B or MAVL, Moyenne Activité et durée de Vie Longue*".

[PR1061-R;Defined Requirement] ITER shall provide the waste management facilities required to process all ITER solid radwaste generated within ITER Nuclear Facilities during their whole lifetime (and in compliance with *ITER Integrated Waste Management Strategy [A39]* and *ITER Decommissioning Strategy [A40]*), including:

- Its buffer storage prior to treatment, if required,
- Treatment, if required,
- Pre-packaging/packaging and characterization,
- Storage of subsequent waste packages until their transport to 3rd party facilities for (as relevant) storage, treatment and/or disposal.

[PR1062-R;Defined Requirement] For all its TFA and Type A waste, ITER shall

- Treat (if needed) and package the waste in compliance with the Waste Acceptance Criteria (WAC) of the 3rd party facility for, as relevant, their treatment, interim storage and/or disposal,
- Be able to store the subsequent waste packages for periods up to 9 months before transfer to that 3rd party facility.

[PR1063-R;Defined Requirement] For its Purely Tritiated waste, Type A waste with high dose rate (Type A+) and Type B waste, ITER shall:

- Treat and package as agreed with the Host State, as specified in the *ITER Integrated Waste Management Strategy [A39]*,
- Store the subsequent waste packages until handover of the ITER Facility to the Host State as agreed in *ITER Decommissioning Strategy [A40]*.

[PR2207-R;Defined Requirement] Solid radioactive waste shall be transported (if required) from its source location to the relevant waste management facility (ITER or 3rd party facilities) using containers and transport systems providing the required level of control and safety protection.

[PR2208-R;Defined Requirement] Solid radioactive waste packages shall be controlled prior to transport within ITER Site and/or to a 3rd party facility for storage, treatment and/or disposal.

4.4 ITER PLANT AUXILIARY SUPPORT AND ASSOCIATED PERFORMANCES

[PR6054-I] ITER Plant Auxiliary Support for Plasma Generation, Maintenance and Waste Management includes the following activities:

- Site requirements from Host Member,
- Centralized control,
- Radioprotection and environmental monitoring,
- Service supply (electrical power, water/cryogenic cooling, fluid/gas),
- ITER Site Infrastructures and Buildings.

4.4.1 Site Requirements for Host Member

[PR312-R] The Host Member, EU, shall make available, or cause to be made available, to ITER Organization land, facilities, buildings, goods and services in support of the site, as summarized in the annexes to the *Site Support Agreement [R23]*.

[PR313-I] The details of such support, as well as the procedures for cooperation between ITER Organization and the Host Member, are covered by the *Site Support Agreement [R23]*.

4.4.1.1 Land

[PR1962-I] The Host Member has made available to ITER Organization a land area of approximately 181 ha for the duration of the ITER project (construction, operation and deactivation): a period of at least 35 years [R18], [R23].

[PR316-I] The main part of this land area, around 115 ha, as indicated in the *Site Master Plan [A13]*, is managed by ITER Organization, while the remaining area continues to be managed by the Host Member. The land has been provided ready to use, cleared of forest and with platforms created. The external fencing was constructed by the Host Member [R23].

[PR1963-R] The foundation soil of the ITER site shall have the capability to bear building loads of at least 25 t/m^2 at locations where buildings are to be constructed.

[PR1964-I] It is expected that it will be possible to provide, at the specific location of the Tokamak Building, means to support the average load of 65 t/m^2 at a depth of 25 m.

[PR1965-R] The soil (to a depth of 25 m) shall not have unstable surrounding ground features.

[PR317-R] The building sites shall not be susceptible to significant subsidence and differential settlement.

4.4.1.2 Headquarters construction

[PR319-R] Certain infrastructure facilities, buildings and services shall be provided by the Host Member in support of the design, procurement, construction, installation, commissioning and operation activities for the ITER project, as agreed in various agreements and amendments thereto.

4.4.1.3 Roads

[PR1966-R] The roads and paths, both internal and external to the ITER nuclear site boundary (see the *Site Master Plan [A13]*) shall be of a standard to permit access to the ITER buildings for all ITER goods, including all the components that are provided in-kind, and for personnel.

[PR321-R] The lighting and drainage of the roads and paths, both internal and external to the ITER nuclear site boundary, shall be up to the Host Member's legislation and standards [R23].

4.4.1.4 Transport of components

[PR323-R] The Host Member shall provide transport services from the "*Port Autonome de Marseille"* or, in case of air transport from Marignane airport, to the ITER site for all components that are contributed by the Members or purchased by ITER and that are delivered using the Logistics Service Provider that is selected by ITER Organization in collaboration with the Domestic Agencies.

[PR1967-I] The maximum size and weight of the transported components (including packaging and frames) are given in *Section 8.7.1*.

4.4.1.5 Electrical power

[PR325-R] The Host Member shall provide installation and maintenance of a 400 kV AC power source that is able to provide up to 500 MW for the pulsed loads, as well as 120 MW for the continuous loads, with a total reactive power up to 200 Mvar demand from the pulsed loads, and 48 Mvar from the continuous loads.

4.4.1.6 Water supply and sewage

[PR328-R] The Host Member shall provide a continuous supply of potable water that meets the average (0.2 m^3/mn) and peak (3 m^3/mn) consumption rates of the ITER facility (the average daily consumption is estimated to be about 400 m^3) [R23].

[PR1970-R] The peak consumption rates for potable water shall cover leaks and fire protection.

[PR1971-R] The potable water supply shall require no treatment or processing for normal industrial purposes (such as for drinking water or for makeup of the demineralized water system).

[PR1972-R] The potable water connections shall be at the site boundary.

[PR1969-I] The detailed functional and physical interface requirements for potable water are defined in the relevant interface control documents.

[PR1973-R] The Host Member shall supply raw water for use in cooling towers to dissipate on average 450 MW (thermal) energy to the environment [R23].

[PR1974-I] The total raw water consumption of about 16 m^3/mn is determined for the average heat load of a complete plasma pulse cycle (450 MW) [R23].

[PR1975-I] During periods of no pulsing, the raw water consumption would drop to about 5 m^3/mn [R23].

[PR1976-R] The raw water connections shall be inside the ITER site boundary, near the Cooling Tower Basin. (See the *Site Master Plan [A13]*).

[PR330-I] The detailed functional and physical interface requirements for the raw water supply are defined in the relevant interface control documents.

[PR1977-R] The Host Member shall provide a sanitary water drainage system with a capacity for a peak ITER site population of 1000, up to 4000 during construction, on two shifts, including IO staff, DA staff and contractors [R23].

[PR1978-R] The sanitary water drainage system shall be adequate for a construction workforce of up to 3000 people, and will be provided by the Host Member [R23].

[PR1979-R] The sanitary waste connections shall be at the ITER site boundary.

[PR1980-R] The Host Member shall provide an industrial drainage network with a capacity for an average of 200 m^3/day [R23].

[PR1981-R] The industrial water drainage connections shall be at the ITER site boundary.

[PR336-R] The peak water flow rate from the Cooling Tower Basin shall be 4000 m^3/day based on two-shift operations, and 6000 m^3/day based on three-shift operations, with a monthly average of less than 3000 m^3/day.

[PR1982-R] The maximum annual flow rate from the Cooling Tower Basin shall be 1 020 000 m^3/year.

[PR337-R] The Cooling Water System discharge connections shall be inside the ITER site boundary, near the Cooling Tower Basin.

[PR338-I] The detailed functional and physical interface requirements (including administrative limits on tritium and other radioactive materials) for the Cooling Water System discharge from the Basin are in the relevant interface control documents.

[PR340-R] The Host Member shall provide a precipitation water drainage system.

4.4.1.7 Waste disposal

[PR342-R] ITER shall agree with Host Member the routes for the disposal of industrial, radioactive, and toxic waste and effluents that is generated during the course of the ITER construction, operation and decommissioning. The detailed functional and physical interface requirements (including administrative limits and packaging requirements) are defined in the *Site Support Agreement [R23]* between ITER Organization and the Host Member.

4.4.1.8 Communications

[PR346-R] The Host Member shall provide a high-speed network connection with high availability to support data transfer and other communication requirements during the ITER construction and operation, as specified in the *Site Support Agreement [R23]*.

[PR1986-I] The high-speed network provider will provide this service in compliance with standards for comparable large scientific projects.

[PR1985-I] The other standard communications infrastructure such as (mobile) telephone connections will be provided with the support of the Host Member.

[PR347-I] All the ITER participating countries are expected to provide compatible network infrastructure and assist in the establishment of efficient routing protocols as needed.

4.4.2 ITER Plant Auxiliary Supports

4.4.2.1 Radiological and Environmental Monitoring

[PR6055-R;Defined Requirement] ITER shall include the following radiological and environmental monitoring to support occupational safety and limitation of exposure of the Public and Environment to potentially harmful substances during each stage (via individual portable and/or fixed devices, including as necessary local alarms and display):

- From SRO:
  - Individual monitoring for the presence of hazardous gases (CO, NOx, Diborane) and oxygen deficiency.
  - For the Tokamak complex, work areas and/or individual monitoring for radiation dose,
  - Liquid and gaseous effluents monitoring for radioactive (including tritium and beta-gamma emitters) substances, toxic substances and chemicals,
  - Monitoring of outdoor environment and groundwater for toxic substances and chemicals, including an onsite meteorological station,
- During Post-SRO Assembly: To extend the above monitoring to Beryllium prior to the receipt of the Test Blanket Modules containing this material and to tritium once it is received on site for Tritium Plant commissioning.
- For DT-1 and DT-2 (in addition to SRO functions),
  - For all nuclear maintenance and radwaste management facilities, work areas and/or individual monitoring for radiation dose and chemicals,
  - Monitoring for airborne radioactivity (including tritium) and surface contamination for all radiological and ventilation zones, confinement systems, liquid and gaseous effluents, outdoor environment and groundwater,

  - External radioactive contamination of movement of radioactive sources/materials exiting/entering the INB via personnel or vehicles.

4.4.2.2 Centralized control

[PR6056-I] The ITER Centralized Systems includes:

- The Control, Data Access and Communication System (CODAC) for mainly operational, engineering and scientific data handling, exchanges and archiving,
- The Central Interlock System (CIS) for the Investment Protection (IP) of the ITER systems by execution investment protection Instrumentation & Control (I&C) functions,
- The Central Safety System (CSS) for the protection of the personnel and the environment by executing safety Instrumentation and Control (I&C) functions.

Note: See *Section 4.1.4 – Plasma control* for the required functions and performances of the Plasma Control System.

[PR6057-R] CODAC and CIS shall implement the centralized control of data management and IP functions for the buildings and systems that are operational for each stage SRO/DT-1/DT-2, as specified in interface documentation.

[PR6058-R;Defined Requirement] CSS shall implement the centralized control of safety functions for the buildings and systems that are operational for each stage SRO/DT-1/DT-2, as specified in interface documentation.

4.4.2.3 Vacuum supply

[PR6059-R] ITER shall provide to the following vacuum functions, as specified in interface documentation:

- From SRO:
  - Provide vacuum to vacuum vessel and cryostat,
  - Provide guard vacuum to all cryogenic systems (except for the non-connected parts of the Neutral Beam (NB) injectors),
  - Detect vacuum-leakage.
- From DT-1, as SRO, plus the additional connections for the fully installed NB injectors.
- From DT-2, as DT-1, plus the additional connections if the third NB injectors is installed.

4.4.2.4 Electrical power supply

[PR901-R] The ITER Steady State Electric Power Supply Network (SSEN) and the Coil Power Supply Distribution system (CPSD) shall

- Provide electrical power required by their client components, as specified in interface documentation.
- Compensate the reactive power that is consumed by their client components.

[PR6060-R] The SSEN and CPSD shall receive power from the French high-voltage grid (“*Réseau de Transport d'Electricité”* (RTE)) and limit the net reactive power flow and voltage fluctuations of the RTE grid that are induced by ITER operations, to levels agreed with RTE.

[PR6061-I] The main ITER/RTE interfaces are given in *Table 4-7*.

[PR6062-R] The CPSD shall protect all ITER superconducting coils by fast discharge of their stored energy in case of quench.

[PR6063-I] The safety requirements for the SSEN and CPSD are given in *Section 7.3.1*. Also refer to *Section 4.1.11.1* for CPSD requirements for RWM.

Table 4-7: Site electrical power constraints

Voltage	400 kV +/- 5%
Frequency	50 Hz +/- 1%
Minimum short circuit power at 400kV Under normal operating conditions	10 GVA
Maximum voltage deviation	+/- 3%
Maximum active power of SSEN	120 MW
Maximum reactive power of SSEN	48 MVAR
Maximum active power of CPSD	500 MW
Maximum reactive power of CPSD	200 MVAR
Maximum active power derivative of CPSD	280 MW/s
Maximum active power step of CPSD	60 MW

[PR6064-R] The SSEN shall be operational from SRO to supply all electrical loads required by its client components, as specified in interface documentation.

[PR6065-R] The CPSD shall be operational from SRO to power:

- All ITER superconducting coils with their full nominal current,
- The EC and IC H&CD systems to be operational from SRO (i.e. 40 MW of ECH and 10 MW of ICH),
- The NB H&CD for commissioning during SRO (i.e. 33 MW of NBH to be operational only from DT-1).

[PR6066-R] The CPSD shall be upgraded to power the additional H&CD power:

- For DT-1 (in addition to the SRO electric loads): the additional ECH of 20 MW (plus if endorsed an additional 7 MW), and if endorsed the planned ICH increase by 10 MW.
- For DT-2 (in addition to the DT-1 electric loads): if endorsed the planned increase of NBH by 17 MW.

[PR6067-R] All cables shall be installed in steel cable trays and conduits, which shall provide adequate physical protection and ensure reliable support to the cables during and after installation.

4.4.2.5 Cooling water supply

[PR6068-R] The Cooling Water System (CWS) shall provide cooling water required by its client components, as specified in interface documentation.

[PR6069-I] See *Section 4.1.2.5 - Vacuum vessel and in-vessel component coolant parameters* for the required functions and performances of the Tokamak Cooling Water System (TCWS).

[PR6070-R] The CWS shall provide the following heat transfer functions:

- From SRO:
  - The cooling of components, which are operational from SRO (other than those deserved by TCWS) like HVAC (Heating, Ventilation and Air Conditioning systems), LAC (Local Air Coolers), EC H&CD and Diagnostic components, etc.,
  - Heat transfer from all the operational CWS loops for reject into the Environment.
- For DT-1 (in addition to the SRO functions):
  - The cooling of the additional EC H&CD gyrotrons and additional Diagnostic systems,
  - The cooling of components installed during Post-SRO Assembly, other than those deserved by TCWS,

  - If implemented into ITER Technical Baseline - the cooling required by the additional IC H&CD system.
- For DT-2 (in addition to the DT-1 functions): If implemented into ITER Technical Baseline - the cooling required by the additional HNB Injector.

[PR6071-R] The CWS auxiliary systems for, as required, chemical & volume control, sampling, draining, shall be available for the loops that are operational during SRO/DT-1/DT-2.

4.4.2.6 Cryogenic supply

[PR6072-R] The Cryogenic System (CS) shall provide, from SRO, the liquid helium required by its client components for cooling down and warming up, as specified in interface documentation. The only exception is the NBI injectors which will only be connected to CS for DT-1.

4.4.2.7 Fluid/gas supply

[PR6073-R] ITER shall provide the fluid and gas required by all ITER buildings and systems that are operational for SRO, DT-1 and DT-2, as specified in this document and in relevant interface documentation.

4.4.2.8 ITER Buildings

[PR6074-R] All ITER Buildings shall be operational for SRO except for:

- The Nuclear Buildings to house the nuclear maintenance and radwaste management processes that are planned to be operational for DT-1 and for DT-2,
- Buildings and areas for the Emergency Power Supply Diesel Generators and their auxiliary sub-systems to be operational from DT-1, and in any case before the reception of tritium on site,
- Any additional building and/or services that may be required if any H&CD upgrade is implemented into the baseline for DT-1/DT-2.

[PR6075-R] Each operational Building shall include the required sub-systems and components:

- If applicable, shielding, fire and confinement barriers (including - within their scope - penetrations providing the same properties than the crossed barriers),
- Fire protection, including detection, alarm and suppression systems, and dry risers,
- Bund alarms and leak detection,
- Protection against other postulated accidental events and aggressions like overpressure, airplane crash, etc.,
- HVAC, including LAC, ductworks and dampers,
- Personnel lifts, stairs and evacuation routes,
- Components/materials lifting and handling appliances,
- Doors,
- Drainage systems, including active drainage, industrial drainage, sanitary drainage and rainwater drainage,
- Lighting and emergency lighting,
- Site communication and IT network (excluding scope of PBS 69 - Access Control and Security Systems),
- Small power installation,
- Lightning protection and earthing,
- In-building environment monitoring, control and alarm systems for e.g. temperature, humidity, etc. (excluding scope of PBS 64 – Radiological and Environmental Monitoring System),

- Required I&C for the above building systems.

[PR6076-R;Defined Requirement] The Nuclear Buildings shall also include, from SRO, seismic monitoring and hydrogen detection.

4.4.2.9 Site infrastructures

[PR6077-R] All Site Infrastructures shall be available from SRO, except for the K2 plant bridge which will be installed during Post-SRO Assembly.

4.4.2.10 Security systems

[PR6078-R;Defined Requirement] The ITER Access Control and Security System (ACSS) shall provide for the security and protection of the ITER Facility from malevolent actions and from access by unauthorized and unqualified personnel, as required during the whole ITER lifecycle.

5 LAYOUT REQUIREMENTS

5.1 CONFIGURATION MANAGEMENT MODEL

[PR857-R] Each ITER Structure, System and Component shall be constructed and operated in compliance with ITER Configuration Management Model (CMM) in order to assure physical integration and consistency between all the components housed within ITER buildings and on their external civil structures, while implementing requirements from:

- Collision analysis,
- Interface constraint definition and checking between systems,
- Space allocations for systems to be designed considering supports and penetrations,
- Tolerance studies,
- Assembly and RH maintenance simulations.

[PR866-R] ITER system elements within buildings and their external civil structures on ITER Site shall comply with the space reservation constraints and physical interface characteristics specified in *ITER Configuration Management Model (CMM) [R38]*.

5.2 SITE MASTER PLAN

[PR868-R] The layout of ITER Buildings and Site Infrastructures that are located within ITER Site boundary shall comply with the *ITER Site Master Plan [A13]*.

5.3 PORT ALLOCATIONS

[PR870-R] The port numbering scheme shall comply with *ITER Coordinate Systems [A04]*.

[PR1665-R] Any components belonging to systems in remote handling port plugs (see equatorial and lower ports identified in *Tables 5-1 and 5-3*) shall be removable to allow access for remote handling operation.

5.3.1 Equatorial port allocations

[PR874-R] The allocation of equatorial ports during each stage shall be in accordance with *Table 5-1*.

Table 5-1: Equatorial port allocations

Equatorial Port	Allocated to *Note 2*		
	SRO	DT-1	DT-2
1	*Closed*	Diagnostics GDC Electrode	*As DT-1*
2	Diagnostics DMS	*As SRO*	*As DT-1*
3 (RH port) *Note 1*	*Closed*	Diagnostics / GDC Electrode	*As DT-1*
4 (small rad.)	*Closed*	DNB	*As DT-1*
4 (tangential)	*Closed*	HNB01	*As DT-1*
5 (tangential)	*Closed*	HNB02	*As DT-1*
6 (tangential)	Torus Leak Detection	*As SRO*	HNB03 *(Note 3)*
7	*Closed*	*Closed*	*Closed*
8 (RH port) *Note 1*	Diagnostics GDC Electrode DMS	*As SRO*	*As DT-1*

Equatorial Port	Allocated to *Note 2*		
	SRO	DT-1	DT-2
9	Diagnostics	*As SRO*	*As DT-1*
10	Diagnostics GDC Electrode	*As SRO*	*As DT-1*
11	Diagnostics	*As SRO*	*As DT-1*
12 (RH port) *Note 1*	Diagnostics GDC Electrode	*As SRO*	*As DT-1*
13	IC	*As SRO*	*As DT-1*
14	EC	*As SRO*	*As DT-1*
15	*Closed*	EC	*As DT-1*
16	*Closed*	Test Blanket	*As DT-1*
17 (RH port) *Note 1*	Diagnostics GDC Electrode DMS	*As SRO*	*As DT-1*
18	Closed	Test Blanket	*As DT-1*
Note 1*: see PR1665-R above* ***Note 2****: Unused ports are closed with temporary closure plates or dummy plugs to maintain the vacuum leak tightness.* ***Note 3****: if HNB upgrade endorsed*			

5.3.2 Upper port allocations

[PR878-R] The allocation of upper ports for each stage shall be in accordance with *Table 5-2*.

Table 5-2: Upper port allocations

Upper Port	Port Plug allocation for *Note 2*		In Port allocation for
	SRO	DT-1 & DT-2	SRO/DT-1 & DT-2
All UP	-	-	In-Vessel Diagnostics Blanket manifolds
1	*Closed*	Diagnostics	Mid and Lower ELM coil feeders Blanket Instrumentation
2	Diagnostics DMS GDC Electrode	*As SRO*	Upper ELM coil feeder
3	*Closed*	Diagnostics	Mid and Lower ELM coil feeders Gas Injection line (including FPSS)
4 *Note 1*	Diagnostics Roughing filters	*As SRO*	Upper ELM coil feeder
5 *Note 1*	Diagnostics Roughing filters	*As SRO*	Mid and Lower ELM coil feeders
6 *Note 1*	Diagnostics Roughing filters	*As SRO*	Upper ELM coil feeder Blanket Instrumentation
7 *Note 1*	Diagnostics Roughing filters	*As SRO*	Mid and Lower ELM coil feeders Blanket Instrumentation
8	Diagnostics DMS GDC Electrode	*As SRO*	Upper ELM coil feeder Gas Injection
9	*Closed*	Diagnostics	Mid and Lower ELM coil feeders

Upper Port	Port Plug allocation for Note 2		In Port allocation for
	SRO	DT-1 & DT-2	SRO/DT-1 & DT-2
10	*Closed*	Diagnostics	Upper ELM coil feeder Gas Injection (including FPSS)
11	Diagnostics GDC Electrode	*As SRO*	Mid and Lower ELM coil feeders
12 *Note 3*	EC	*As SRO*	Upper ELM coil feeder Upper VS coil feeder Blanket Instrumentation
13 *Note 3*	EC	*As SRO*	Mid and Lower ELM coil feeders Blanket Instrumentation
14	Diagnostics GDC Electrode DMS	*As SRO*	Upper ELM coil feeder Upper VS coil feeder Gas injection
15	EC	*As SRO*	Mid and Lower ELM coil feeders
16	EC	*As SRO*	Upper ELM coil feeder Upper VS coil feeder
17	*Closed*	Diagnostics GDC Electrode	Mid and Lower ELM coil feeders
18	Diagnostics	*As SRO*	Upper ELM coil feeder Upper VS coil feeder Blanket Instrumentation
***Note 1**: No port cell. Access is through the NB cell, with higher radiation levels (Zone C) and less hands-on access.* ***Note 2**: Unused ports are closed with temporary closure plates or dummy plugs to maintain the vacuum leak tightness.* ***Note 3**: The 2 EC launchers are installed in UP#12 during Pre-SRO Assembly but only one is operational from SRO. The second launcher will be made operational for DT-1 or DT-2 if the planned upgrade to increase ECH from 60 to 67 MW is endorsed. The 2 EC launchers installed in UP#13 are operational from SRO.*			

5.3.3 Lower port allocations

[PR882-R] The allocation of ITER systems to lower ports (with some fixed penetrations for in-vessel viewing, ELM-VS coil feeders, and divertor manifolds) shall be, for each stage, in accordance with *Table 5-3*.

[PR2177-R] No removable lower port plugs shall be provided at the odd numbered port positions.

[PR884-R] Divertor diagnostics, and diagnostics electrical services, shall be accommodated at even numbered port positions.

[PR885-R] There shall be no vacuum vessel penetrations crossing the field joints between sectors.

[PR1678-R] Diagnostics systems shall not affect the pumping conductance.

Table 5-3: Lower port allocations

Lower Port	Lower Port allocation for SRO/DT-1/DT-2	
	Port Type	Content
All	-	Divertor manifold
1	Cryostat access flange	Large cryostat access flange
2	Divertor Remote Handling port	Vacuum Vessel In-Service Inspection Divertor rails and Divertor remote Handling System (DRHS)

Lower Port	Lower Port allocation for SRO/DT-1/DT-2	
	Port Type	**Content**
		Diagnostics rack
3	In-vessel viewing port	IVVS
4	Divertor pumping port	Blanket manifold Fuelling pellet injection system Gas injection Torus cryopump
5	In-vessel viewing port	IVVS Cryostat access flange
6	Divertor pumping port	Vacuum Vessel In-Service Inspection Blanket manifold and instrumentation Gas injection Torus cryopump Dust filtering system
7	Cryostat pumping flange	Cryostat cryopump
8	Divertor Remote Handling port	Vacuum Vessel In-Service Inspection Divertor Rails and RHS *For DT-1/2 only*: Diagnostics Rack
9	In-vessel viewing port	IVVS Cryostat access flange
10	Divertor pumping port	Blanket manifold Pellet injection system: impurity for SRO, fuelling for DT-1/2 Gas injection Torus cryopump
11	In-vessel viewing port	IVVS
12	Divertor pumping port	VS coil feeders Vacuum Vessel In-Service Inspection Blanket instrumentation Gas injection Torus cryopump Dust filtering system
13	Cryostat pumping flange	Cryostat cryopump
14	Divertor Remote Handling port	Vacuum Vessel In-Service Inspection Divertor rails and RHS *For DT-1/2 only*: Diagnostics Rack
15	In-vessel viewing port	IVVS Cryostat access flange
16	Divertor pumping port	Blanket manifold Fuelling pellet injection system Gas injection Torus cryopump
17	In-vessel viewing port	IVVS
18	Divertor pumping port	VS coil feeders Vacuum Vessel In-Service Inspection Blanket instrumentation Gas injection Torus cryopump

6 OPERATIONAL REQUIREMENTS

6.1 DESIGN LIFE

[PR895-R] ITER shall be designed for an operating lifetime no less than 20 years.

[PR1827-R] The design life of systems (including buildings) that are required to be operational during construction, commissioning and/or until handover of ITER Facility to the Host State shall be specified accordingly.

[PR896-R] The nuclear buildings shall be designed for a 70-year life.

6.2 NUMBER OF PULSES

[PR904-R] ITER shall be capable of operating for at least 30,000 pulses.

6.3 PROGRESSIVE START-UP AND COMMISSIONING

[PR899-R] Operating parameters shall be progressively increased during different plasma operations in order to verify the integrated systems perform safely and in accordance with operational design intent as defined in *ITER Research Plans Level 2 [A33]*.

[PR533-R] ITER shall allow operation over a range of plasma parameters in hydrogen (H), helium (He) and deuterium (D) to allow the necessary commissioning with plasma and preparatory experiments for deuterium-tritium operation to be completed.

[PR534-R;Defined Requirement] Plasma scenarios for H, He and D operation shall necessarily encompass a wide range of plasma parameters up to the maximum technical capability of the Tokamak in order to address:

- Development of the discharge scenario required for full DT phase reference operation, including features such as plasma current initiation, current ramp-up, formation of a divertor configuration and current ramp-down.
- Commissioning of core Tokamak systems, such as Poloidal Field system, Correction Coils system, in-vessel coil systems up to the maximum value of plasma current and toroidal field (15 MA / 5.3 T).
- Progressive commissioning of the Plasma Control System, together with interlock and protection circuits and safety-important systems, as required by the technical performance of the Tokamak and the level of plasma performance achieved.
- Development of the "Progressive Start-up" strategy for determination of maximum loads on vessel and in-vessel structures due to disruptions and vertical displacement events.
- Provision of experimental data to validate the ITER licensing assumptions.
- Commissioning with plasma of all Tokamak auxiliary systems: H&CD, diagnostics, fuelling, pumping for which DT plasmas are not required.
- Characterization of hydrogenic retention and dust production, and demonstration of techniques for their control.
- Commissioning of appropriate mitigation techniques against the consequences of plasma transients and loss of control.
- Demonstration of power handling capabilities of plasma-facing components within the heat load limitations of H, He, and D plasmas including semi-detached divertor operation and low impurity level.
- Achievement of type-I ELMy H-modes for sufficient durations to allow an adequate physics basis for the implementation of full DT plasma operation including aspects such as H-mode power threshold scaling and energy and particle transport at the ITER scale.
- Finalization of nuclear commissioning with a minimum amount of tritium, within the authorized limits of ITER Licensing.

[PR547-R] Plasma scenarios for H, He and D operation will be established within the facility design basis for DT operation, excepting that the neutral beam injection system shall be capable of high power, long pulse operation in hydrogen at 870 keV.

6.4 PLASMA PULSE DURATION AND REPETITION

[PR5352-R] ITER shall be capable of executing Tokamak pulses with duration of up to 3600 s.

[PR907-R] During any plasma operation phase, ITER shall perform a minimum of 2 Tokamak pulses per hour (i.e. the Tokamak pulse repetition time* shall be 1800 s or less), with the following exceptions:

- For burns longer than 450 s, the Tokamak pulse repetition time* shall be a maximum period of 4 times the duration of the previous pulse, i.e. the Tokamak pulse duty cycle shall be 25% or more.
- For DT-1:
  - For Q = 10 / 300 s burns, ITER shall be able to perform a minimum of 1 Tokamak pulse per hour.
  - For lower Q values (for any burn duration), several pulses per hour may be possible, in line with the fuel recycling capacity as specified in *Section 4.1.7.7*.
- For any plasma scenario during DT-2, the Tokamak pulse duty cycle ≥ 25% for burns > 450 s will be achieved by operating with the fuel recycling capacity specified in *Section 4.1.7.7*.
- Note that:
  - * The repetition time between Tokamak pulses is defined as the time between the start of a Tokamak pulse and the start of the next Tokamak pulse.
  - For non-DT plasmas (i.e. no burns), the “burn durations” quoted in this requirement must be considered as “pulse flat-top durations” (see *Table 4.1*).

6.5 DESIGN OPERATING SCHEDULE

[PR910-R] ITER shall be designed for a DT phase lasting at least 14 years.

[PR912-R] ITER shall be designed to be capable of operating for periods of 11 consecutive days while accommodating three-shift daily plasma operation, followed by 3 days of routine maintenance.

[PR911-R] ITER shall be designed so that plasma operation can be conducted for periods of up to 16-months continuously in three 8-hours work-shift daily operating mode to perform the following actions: plasma operations, test, conditioning, routine maintenance.

6.6 NEUTRON PRODUCTION

[PR916-R] Over its whole planned lifetime (SRO/DT-1 and DT-2), ITER shall be designed to provide an average neutron fluence of 0.30 MW.y.m^{-2}, which corresponds to the cumulated production of 3E+27 neutrons at end of ITER plasma operation.

[PR917-R] Over its whole planned lifetime (SRO/DT-1 and DT-2), ITER shall accommodate a maximum instantaneous average neutron flux of at least 0.5 MW.m^{-2}.

[PR6079-R] To comply with *ITER Staged Approach Strategy [R34]*, the ITER plasma operation campaigns shall be defined and executed to comply with the maximum-activation level requirements allocated to SRO and DT-1 phases, as specified in *Table 6-1*.

Table 6-1: Maximum activation-related requirements during SRO and DT-1

Stage	Maximum activation-related requirement [Note 3]	Target maximum neutron production at the end of each phase [Note 3] *(cumulated with previous stage)*
SRO	At the end of the SRO plasma campaign, man-access into VV is possible, to perform Post-SRO Assembly within a mixed assembly/hands-on regime	1.5E+20 n [Note 1]
DT-1	No production of Type B waste during DT-1	3.5E+25 n [Note 2]

***Note 1**: Plasma generating neutron fluxes of 1E+15 - 1E+17 n/s with low neutron energy (~2.5 MeV, dominant)*

***Note 2**: Plasma generating neutron fluxes of 2E+20 n/s with high neutron energy (~14MeV, dominant)*

***Note 3**: For each phase SRO and DT-1, the maximum activation-related requirement is achieved by:*

- *Limiting the overall neutron fluence to be generated during the entire phase,*
- *Interlaying, throughout the phase, experiments with high/low neutron production to allow for sufficient decay of radiation levels by the end of the phase,*
- *If needed, implementing a decay period at the end of the phase.*

[PR6080-R;Defined Requirement] ITER shall be designed and operated to collect the experimental data required to consolidate, during each stage and for the next stage, the models for the neutrons radiation maps that are used to define radiation zonings, equipment qualification, as well as needs for nuclear maintenance and radioactive waste/effluents management.

6.7 Containment of Water in the Cryostat

[PR1828-R] The length and number of TCWS pipes inside the cryostat shall be minimized.

[PR919-R] Cooling pipes within the cryostat vacuum boundary shall be double-contained with guard pipes to ease leak detection and reduce risk of water leaks from the TCWS piping into the cryogenic environment.

[PR1830-R] The number of cryostat vacuum penetrations for TCWS needs shall be minimized.

6.8 Plant Operation

[PR922-R] ITER shall be operated in accordance with the operational program and the operating states of the Tokamak Machine that are specified in the *ITER Operational States [A08]*, and for the whole ITER Facility in the *Concept of Operation Level 2 documentation [A42]*.

6.8.1 Plant Operation Zone

[PR925-R] No ITER system shall be controlled or configured by personnel outside of the Nuclear Installation (INB) perimeter. For this purpose, a Plant Operation Zone (POZ) is defined, which geographically almost equals the perimeter of the INB.

[PR5303-I] The Plant Operation Zone is a collection of computers or hardwired networks, and of plant system equipment connected to those networks, required for integrated plant operation.

[PR935-R] There shall be no automatic transfer of data of any type onto the Plant Operation Zone (POZ) from any other computer networks.

[PR2190-R] There shall be a physical separation between the Plant Operation Zone network and any other networks to ensure that there can be no unauthorized transfer of data.

[PR2191-R] All data transfers between the Plant Operation Zone network and any other networks shall be executed through dedicated secure mechanisms.

[PR936-R] Transfers onto the Plant Operation Zone (POZ) network shall be initiated manually, and all parameters, pulse schedules and other data that are so loaded onto the POZ network shall be verified by, and under the responsibility of, an authorized individual located in the control room as if they had themselves created this data.

6.8.2 Operation control rooms

[PR926-R] ITER plasma operations shall be controlled from a single Main Control Room (MCR).

[PR927-R] Control or configuration of ITER systems shall be made from ITER Main Control Room except where control or configuration of individual systems from local control panels is authorized.

[PR928-R] ITER shall include appropriate Control Systems to permit the centralized control of nuclear maintenance and radwaste management activities that are performed remotely, under the overall coordination of the MCR. When authorized, appropriate local control can be provided.

[PR929-R] The Tritium Plant shall be managed from a dedicated Tritium Plant Control Systems within ITER Main Control Room (MCR).

[PR930-R] The Sites Services Building shall have an appropriate local control area to facilitate the management and maintenance of non-pulse related systems.

6.9 REMOTE PARTICIPATION

[PR938-R] Experimental data and information on plant system status shall be copied from the plant network in order to make it available on the ITER general network for analysis and remote collaboration.

[PR939-R] There shall be technological means, including video conferencing and remote data access, to enable collaboration between Main Control Room personnel and remote participants regarding the execution of the experimental program.

6.10 INSTRUMENTATION AND CONTROL OF ITER SYSTEMS

[PR942-R] ITER systems shall contain adequate instrumentation & control to ensure the following functions:

- To ensure human safety/security,
- To enable control of the ITER system,
- To ensure equipment integrity and interlock,
- To monitor the system state,
- To record all system control actions,
- To control system operations,
- To prepare plasma pulses,
- To ensure plasma discharge quality,
- To control maintenance and waste management activities,
- To monitor and record system performance.

[PR953-R] ITER systems shall contain instrumentation to measure all parameters that may affect their required functions, quality, availability or which may predict failures or indicate the need of maintenance.

[PR954-R] Instrumentation and Control (I&C) of ITER systems shall be designed in accordance with the *Plant Control Design Handbook [A02]*.

6.11 RELIABILITY, AVAILABILITY, MAINTAINABILITY AND INSPECTABILITY

[PR6081-R;Defined Requirement] The ITER Facility shall undergo maintenance in order to:

- Eliminate failures of components that are critical to guarantee the safe and reliable operation of the ITER Facility,
- Maintain acceptable levels of reliability for components that are non-critical for safety, ITER operation cycles and research objectives.

[PR6082-R] ITER components shall be constructed and operated so they can be maintained safely and efficiently in order to achieve and sustain the availability and reliability targets of their systems/sub-systems and ultimately of the ITER Facility, for their entire lifecycle.

[PR2216-I] This PR section gives the overall project-level objectives to be met by ITER Facility and its systems in terms of RAMI - Reliability (probability of a failure-free operation), Availability (ratio of operating time to the sum of operating time and downtime), Maintainability (ability to undergo repairs and modifications) and Inspectability (capacity to be monitored, accessed and diagnosed). To guarantee these RAMI objectives are met, ITER implements the *RAMI Analysis Program [R13]* for the design, manufacturing, test, commissioning, operation, and maintenance of its Structures, Systems and Components (SSC), which permits to identify the possible failure modes of SSCs, to reduce their effects by implementing corrective or preventive actions and to evaluate the SSC performance with a regard to the RAMI objectives within the SSC lifecycle.

6.11.1 Availability

6.11.1.1 Main functions inherent availability objective

[PR981-R] To allow ITER to reach the Tokamak Machine operational availability target (60% in H-phase), the systems and/or main functions required to achieve plasma operation shall be designed to reach the Inherent Availability objectives given in *Table 6-2*.

Table 6-2: Inherent availability objectives for main functions for the Tokamak Machine operation

System	PBS	A_H (%)	A_{D-T} (%)	Main Function *(see note in PR2234)*	A_H (%)	A_{D-T} (%)
Magnet system	11	96.1	92.2	To provide magnetic confinement	99.0	98.0
				To induce current plasma and provide stabilization control	99.0	98.0
				To provide field for plasma equilibrium	99.0	98.0
				To provide corrective field	99.0	98.0
Vacuum vessel	15	99.7	98.7	To provide vacuum and first confinement barrier	99.7	98.7
Blanket system	16	91.8	90.0	To exhaust power & provide thermal & nuclear shielding	91.8	90.0
Divertor	17	92.8	91.0	To exhaust power & to control particles	92.8	91.0
Fuelling & Wall Conditioning	18	99.5	97.2	To inject gas	99.9	99.4
				To inject pellets for disruption mitigation	99	99
VVPSS	24	99.9	99.9	To prevent overpressure in the VV	99.9	99.9
Cryostat		99.4	99.4	To protect the magnets from thermal loads	99.4	99.4
Cooling Water System	26	94.0	94.0	To reject the heat loads	98.9	98.9
				To cool & bake components	98.7	98.7
				To produce chilled water	98.5	98.5
				To cool & bake Tokamak components	97.8	97.8

System	PBS	A_H (%)	A_{D-T} (%)	Main Function *(see note in PR2234)*	A_H (%)	A_{D-T} (%)
Thermal Shields	27	99.9	99.9	To provide thermal shielding	99.9	99.9
Vacuum system	31	99.3	97.6	To provide fluids for cryopump operations	99.9	99.9
				To provide vacuum	99.4	97.7
Tritium Plant	32	N/A	80	To recycle tritium and provide tritium fuel	N/A	80.0
				To detritiate liquid/gaseous effluents	N/A	98.7
Cryoplant & cryodistribution	34	91.2	91.2	To provide cooling power	96.0	96.0
				To distribute cooling power	96.0	96.0
				To transport cryogenic fluids	99.0	99.0
CPSD	41	85.4	92.8	To supply and distribute power to the pulsed loads	92.0	92.0
				To supply and distribute power to the coils	93.0	93.0
				To ensure proper grounding of the coils	99.9	99.9
				To ensure fast discharge of stored energy	99.9	99.9
SSEN	43	99.2	99.2	To provide Class I, II power supply	99.9	99.9
				To provide Class III power supply	99.9	99.9
				To provide Class IV power supply	99.4	99.4
CODAC	45	98.8	98.8	To perform Control, Data Acquisition & Communication	98.8	98.8
Central Interlock System	46	99.9	99.9	To protect the investment	99.9	99.9
Plasma Control System	47	98.8	98.8	To control the plasma	98.8	98.8
Central Safety System	48	99.9	99.9	To protect people & environment with SIC components	99.9	99.9
EC H&CD	52	88.2	84.5	To assist plasma start-up with EC	98.0	96.0
Diagnostics	55	79.1	77.3	To measure parameters for IP functions	98.5	98.5
				To measure parameters for basic control	98.0	98.0
Reinforced Concrete Buildings	62	99.3	99.3	To shelter activities within nuclear buildings	99.3	99.3
Steel Frame Buildings	63	99.9	99.9	To shelter activities within non-nuclear buildings	99.9	99.9
Radiological & Environmental Monitoring	64	99.9	99.9	To monitor radiology & environment	99.9	99.9
Liquid & Gas Distribution	65	97.8	97.8	To provide fire protection water	99.9	99.9
				To provide breathing air	99.8	99.8
				To provide demineralized water	99.9	99.9
				To provide potable and hot water	99.8	99.8
				To provide compressed air	99.0	99.0
				To provide He and N2 gas	99.4	99.4
Access Control & Security Systems	69	99.8	99.8	To provide real-time security functions	99.9	99.9
				To provide Security-Relevant Communications Between Staff, Security Officers & Guards. (COM)	99.9	99.9

[PR2228-R] To allow ITER to reach the ITER research program operational availability target, the main functions of ITER systems, required to perform the physics program shall be designed to reach the Inherent Availability objectives given in *Table 6-3*.

Table 6-3: Inherent availability objectives for additional main functions for the physics program

System	PBS	A_H (%)	A_{D-T} (%)	Main Function *(see note in PR2234)*	A_H (%)	A_{D-T} (%)
In-Vessel Coils	15	98.7	96.7	To control VDEs	99.5	98.5
				To control ELMs	99.2	98.2
Fuelling & Wall Conditioning	18	-	-	To inject pellets	99.8	97.8
IC H&CD	51	87.3	83.6	To perform IC heating or current drive	90.0	88.0
EC H&CD	52	-	-	To perform EC heating, current drive or control MHD instabilities	90.0	88.0
NB H&CD	53	90.0	85.0	To perform NB heating or current drive	90.0	85.0
Diagnostics	55	-	-	To measure parameters for advanced control	91.0	90.0
				To measure parameters for performance and physics	90.0	89.0
Test Blanket System	56	80.0	75.0	To demonstrate the feasibility of tritium breeding and electricity production	80.0	75.0

[PR2231-R] To allow ITER to reach its operational availability targets, the systems and/or main functions used for maintenance and waste management shall be designed to reach the Inherent Availability objectives given in *Table 6-4*. Those targets are set in *Table 6-4* to address first the preventive maintenance and planned upgrades expected to be performed during the 6-month Long-Term Maintenance shutdowns and then the corrective maintenance operations that might happen during the experimental campaign in Plasma Operation States, Test and Conditioning States or Short-Term Maintenance.

Table 6-4: Inherent availability objectives for main functions for maintenance and waste management

System	PBS	A_H (%)	A_{D-T} (%)	Main Function *(see note in PR2234)*	A_H (%)	A_{D-T} (%)
Fuelling & Wall Conditioning	18	-	-	To perform Glow Discharge Cleaning and boronization	99.8	97.8
Remote handling	23	79.8	71.8	To ensure cask transfers	97.0	95.0
				To perform planned remote maintenance of ITER equipment	96.0	94.0
				To remotely handle blanket modules	95.0	93.0
				To remotely handle divertor cassettes	95.0	93.0
				To remotely handle NBH&CD system	95.0	93.0
IC H&CD	51	-	-	To perform IC wall conditioning	97.0	95.0
Port Plug Test Facility	58	99.0	97.0	To test the port plugs	99.0	97.0
Radwaste Treatment & Storage	66	N/A	90.2	To treat and store Type A & TFA waste	N/A	94.0
				To treat and store Type B and to store Purely Tritiated Waste	N/A	96.0

[PR2234-I] In addition to the availability targets, a margin is given, equal to ±0.1% for an availability target of 99% or more, ±0.2% for an availability target between 95% and 99% and ±0.5% for an availability target lower than 95%.

6.11.1.2 Overall machine operational availability objective

[PR974-R] Taking into account 365 working days per year and 24 working hours per day, ITER shall be designed for an operational machine availability of at least 32% on average over ITER H-phase (up to 40% over one month of operation) in a three-shift operating mode with a Mean Scheduled Down Time (MDTS) not greater than 11.3 months over every two-year experimental campaign. When taking into account the scheduled downtime for planned inspection, maintenance and upgrades of ITER systems, the machine shall meet an inherent machine availability of 60% for "basic" plasma operation.

6.11.1.3 Specific availability requirements

[PR989-R] In order to optimize their availability, ITER systems shall be designed in such a way that the time to repair is reduced as much as possible.

[PR2238-R] Recommendations for spare parts provisioning shall be provided following the RAMI requirements analysis of the systems, both for scheduled and unscheduled maintenance and taking into account the operating conditions, the benefits of using as many standard parts as possible and the risk of components obsolescence over the lifetime of ITER.

[PR2241-R] All specific tools and test equipment needed for packaging, handling, storage, transportation, installation, test and maintenance of the systems equipment on site shall be provided. When assembly tools are planned to be used for maintenance during an ITER operation phase, their design, construction and maintenance (including any planned upgrades) shall comply with their expected lifetime, and loads and environmental conditions for this usage.

[PR996-R] For every credible major technical risk that would compromise the required operational capability of ITER, mitigation actions and/or provisions for recovery shall be decided in terms of design changes, tests, operation procedures and/or maintenance/spares plan with the objective to mitigate the risk or reduce its criticality level below the limit defined for the major risks.

[PR2247-R] In cases where the risk occurrence cannot be sufficiently reduced, specific provisions shall be defined for recovery including failure detection, localization repair and verification, in addition to an inspection plan to be able to prevent the failures.

6.11.2 Reliability requirements

[PR960-R] ITER systems and components shall be suitably qualified to demonstrate that they comply with the reliability requirements allocated during the RAMI analysis. In case of deviations from such requirements, compensating/correcting actions shall be identified and implemented as required.

6.11.3 Maintainability and Inspectability

[PR1000-R] All ITER Structures, Systems and Components shall be constructed and operated to ensure they can be accessed for their maintainability and inspectability.

[PR1002-R] ITER Structures, Systems and Components shall be designed and operated in such a way as to reduce the time to detect, identify, locate and repair any failure/malfunction, or sign of impending failure.

[PR2254-R] Components and subsystems shall be as much as possible integrated in such a way that those requiring the most frequent maintenance shall be the more readily accessible.

6.12 INSPECTION

6.12.1 In-vessel viewing

[PR1005-R] An In-Vessel Viewing System (IVVS) shall be provided, from SRO, to view and inspect the blanket and divertor plasma-facing surfaces and to provide their dimensional measurements.

[PR1006-R] The IVVS shall be designed to operate with the vacuum vessel under vacuum and when the vacuum vessel is vented.

[PR1007-R] The IVVS shall be designed to operate with the in-vessel components at temperatures in the range of 20°C to 100°C.

[PR6083-R] The IVVS shall be compatible with the requirements to permit the Tokamak baking (i.e. compatibility with vacuum environment and temperature of interfacing components).

[PR1008-R] The IVVS shall be designed to operate in a radiation environment during DT-1 and DT-2.

[PR1009-R] The IVVS shall be capable of being deployed in 4 hours and stowed in 4 hours.

6.12.2 Vacuum leak localization

[PR1011-R] The capability to localize all vacuum leaks that affect or have the potential to affect operations shall be provided.

[PR1012-R] The precision of vacuum leak localization shall be such as to minimize component repair/replacement operations and for each leak shall give certainty of position to a single replaceable or repairable section of a component.

[PR2193-R] When multiple vacuum leaks occur on different components or in different locations these shall also be individually localizable down to individually replaceable components or repairable sections.

[PR1013-R] The methods applied for vacuum leak localization shall minimize the time required to locate leaks. A good level of confidence of the position of leaks shall be obtained within one week of leaks being detected and effecting operations.

[PR2194-R] Should mitigation of the vacuum leak require major intervention (such as coil warm-up, or blanket module replacement) then techniques giving further precision and certainty of the leak position shall be applied as part of this intervention but shall not add more than one week to this intervention.

[PR1014-R] The design of components and systems which form a vacuum boundary or feed fluid or gas to such a component or system shall give due consideration to integrate the methodologies of vacuum leak localization which are to be applied.

[PR2195-R] The techniques of localization shall be appropriate to the potentially leaking vacuum boundary, the leak size, the leak type, the leak accessibility, and risk of the leak.

[PR2196-R] The methods of vacuum leak localization shall be designed and performed following the ALARA principle with respect to worker dose.

[PR2197-I] A vacuum leak localization strategy is formed following research and development into techniques.

6.13 MAINTENANCE CONDITIONS

[PR6084-I] Specific requirements for remote handling during maintenance are given in *Section 6.14* and for workers protection in *Section 7.5*.

[PR1953-R;Defined Requirement] Once tritium has been produced in plasma and/or injected into the vacuum vessel, the vessel and in-vessel components shall be baked, before venting the vacuum vessel, in order to remove tritium until the tritium venting rate is deemed acceptable (operational decision).

[PR1954-R;Defined Requirement] Once the vacuum vessel has been activated and before performing in-vessel maintenance/assembly, radioactive dust shall be collected and removed (to acceptable level) to mitigate the spread of radioactive contamination throughout facilities.

[PR1018-R] The preparatory works, including the time to reach the required environmental conditions that enable hands-on maintenance activities inside the vacuum vessel and inside the cryostat, shall not exceed 2 weeks, and 4 weeks, respectively, after reaching the acceptable dose rate for personnel defined in *PR1130-R*.

[PR1022-R;Defined Requirement] The vacuum vessel shall be vented with dry nitrogen prior to introducing personnel or remote handling equipment as appropriate.

[PR6085-R] The vacuum vessel or cryostat shall be vented with humidity-controlled air to provide a suitable environment for remote handling equipment.

[PR1032-R] The capability shall be provided to vent the cryostat with dry air or nitrogen from vacuum to atmospheric pressure within 48 hours.

[PR1023-R] ITER coils shall be de-energized prior to providing access for personnel or remote handling equipment in the vacuum vessel or cryostat.

[PR2205-R] The residual magnetic field in the volume within the vacuum vessel that can be accessed by remote handling equipment during remote handling operation shall not exceed 1 mT.

[PR1025-R] The temperature of the vacuum vessel shall be maintained in the range of 20°C to 50°C when remote handling equipment is present.

6.14 HANDLING REQUIREMENTS

6.14.1 Handling equipment requirements

[PR2201-R] Handling equipment (including transfer and lifting systems) shall be designed and operated so to prevent any injury to the personnel and any damage to the handled equipment or surrounding components (especially SIC components and systems containing effluents). This includes the optimization of the required number of handling activities, the transfer trajectory and lifting height as well as protection measures to be put in place in the event of the failure (direct or indirect) of the handling system or an operation error.

[PR2202-R] Appropriate measures of quality control shall be implemented for the manufacturing, installation and operation of handling equipment (including transfer and lifting systems) **-** including periodic qualification tests for lifting equipment.

[PR2203-R;Defined Requirement] In the event of the failure of a handling system, appropriate recovery systems and procedures shall be available (as necessary).

6.14.2 Remote Handling (RH) requirements

[PR1073-R;Defined Requirement] As a general principle at ITER, provisions for remote operation shall be made for all environments where the dose-rate to workers exceeds the target of 100 µSv/h. Subsequently, the As Low As Reasonably Achievable (ALARA) principles shall be applied (in line with design and Remote Handling (RH) studies) to minimize occupational doses to workers (including both individual and collective doses).

[PR6086-I] The application of the ALARA principle on top of this dose-rate target can drive (provided appropriate authorization) a deviation from the initial target and/or the implementation of fully/partially remote operations, additional radioprotection measures, design and/or operation evolutions. See [R42] for guidelines to apply the ALARA principles.

[PR1078-R] All Structures, Systems and Components (SSC) located in radiologically controlled areas (including in the vacuum vessel and its extensions, port cells, neutral beam cell, nuclear maintenance and radwaste management facilities) shall be analyzed for their RH classification as described in the *ITER RH Compatibility Procedure [A17]*.

[PR1079-R] All Structures, Systems and Components (SSC) with an RH classification shall be designed for RH compatibility as described in the *ITER RH Compatibility Procedure [A17]*. Guidelines for designing for RH compatibility are provided in the *RH Code of Practice [R19]*.

[PR1071-R] All remote handling systems/equipment shall be designed in accordance with the guidelines provided in the *RH Code of Practice [R19]* and *RH Compatibility Procedure [A17]*.

[PR1024-R] Remote handling systems/equipment shall be designed to operate in the environment conditions of the locations where the tasks for which they have been designed are to be carried out. Environment conditions for their own maintenance and storage shall also be implemented in their design.

6.15 HUMAN FACTOR ENGINEERING

[PR1093-R;Defined Requirement] In order to remove risks associated with human performance and error (or to mitigate their consequences) on ITER safety, operability, and availability, ITER design and operation shall implement in an integrated manner the Human and Organizational Factor (HOF) requirements specified in the *ITER Human Factors Integration Plan (HFIP)* [R22].

[PR2211-R;Defined Requirement] All ITER Systems shall be designed and operated in accordance with the *ITER Human Factor Integration Plan (HFIP)* [R22] and recommendations from the suppliers.

6.16 INVESTMENT PROTECTION REQUIREMENTS

[PR2213-I] Investment Protection (IP) is a function referring to any form of prevention or guarantee that an unacceptable loss of investment or operational time will not occur due to any fault or failure in Structures, Systems or Components (SSC) that could occur during ITER normal operation (including commissioning, inspection, testing, maintenance) and/or postulated incidental situations. Note that fire, malevolent acts, or safety related incidents/accidents are excluded from IP scope.

To achieve IP within ITER, the IP risk assessment process is implemented in the design phase in order to:

- Identify hazards for investment whose control will impact on ITER systems design and/or operation,
- Assess the level of risk related to these hazards in order to mitigate them.

[PR2214-R] ITER shall ensure that risks to investment are mitigated to the appropriate level and in an integrated manner across the entire ITER Facility, as defined in the *Investment Protection Handbook [A31]*.

[PR2356-R] In order to remove or mitigate risks to investment, the design and operation of ITER systems shall implement adequate measures as identified by the IP risk assessment and defined by the *Investment Protection Handbook* [R24].

[PR1310-R] In compliance with the requirements for Investment Protection, the ITER Facility shall be designed to be reasonably expected to restart and operate in normal situation after an SL-1 event without special maintenance or tests in particular for Nuclear Pressure Equipment.

6.17 SITE SIGNAGE REQUIREMENTS

[PR3214-R] All identification, labelling and signage shall be standardized to reduce the likelihood of error.

[PR3215-R] Use of signage shall show information in both English and French to reflect the international project culture and its host country.

[PR3216-I] Labelling, color coding, signage and display material at ITER is to serve the following primary functions:

- Health and Safety,
- Operational,
    - Pipeline identification,
    - Plant item tagging,

    - Electrical component labelling,
    - Colors for electrical equipment surfaces,
    - Operator aids,
- Way finding,
- Information.

[PR3217-R] All labelling, color coding and signage installed on the ITER site shall comply with *the ITER Site Signage and Graphics Standards [A32]*.

6.18 INTEGRATED COMMISSIONING

[PR301-R] At the end of each assembly period (Post SRO and Post DT-1 assembly), an integrated commissioning of ITER systems shall be performed as specified in *ITER Research Plans Level 2 [A33]*, to ensure correct functioning, and to assure readiness for plasma operations.

6.19 OTHER OPERATION REQUIREMENTS

6.19.1 Operation Task classification

[PR3095-I] An ITER Operation Task Classification is applicable to any operation task that is defined by an ITER Designer or by the ITER Operator.

[PR3096-R;Defined Requirement] The Operation Task Classification is intended to support the performance of relevant engineering analyses, and an adequate implementation of the ITER limit for annual collective radiation dose exposure, as established in *[PR1129-R]* and for exposure to other toxic materials. Therefore, this classification is operation environment oriented, and shall be assigned to any operation task that is defined by the ITER Designer or ITER Operator.

[PR3097-R;Defined Requirement] Operation tasks shall be specified and verified as part of the design process for ITER systems, under the responsibility of their TRO, and implement decisions from relevant analysis such as waste management, RAMI and safety analysis.

6.19.1.1 Operation Task class 1

[PR4965-I] Operation Task Class 1 (OTC1) includes any operation activities that must be performed in environment of radiation exposure and/or radioactive contamination. Such an operation environment is expected in the Nuclear Buildings. This concerns mainly nuclear maintenance (planned and unplanned) and radioactive waste management.

[PR3099-R;Defined Requirement] The natural background radiation at the ITER site shall not be considered as a contributor to the annual collective radiation dose exposure until otherwise decided by the ITER Operator.

[PR3100-R;Defined Requirement] Operation Task Class 1 (OTC1) shall be associated to any operation task which requires use of Remote Handling Equipment or Human Assisted Equipment.

[PR3101-R;Defined Requirement] In order to manage the ITER operation planning in a proper way, the Operation Task Class 1 (OTC1) is divided into three sub-classes as follows:

- Operation Task Class 1-1 (OTC1-1) shall be defined for any operation task which represents 1% or more of the ITER annual collective radiation dose exposure limit,
- Operation Task Class 1-2 (OTC1-2) shall be defined for any operation task which is in the range from 0.1% to 1% of the ITER annual collective radiation dose exposure limit,
- Operation Task Class 1-3 (OTC1-3) shall be defined for any operation task which represents less than 0.1% of the ITER annual collective radiation dose exposure limit.

6.19.1.2 Operation Task class 2

[PR3103-I] Operation Task Class 2 (OTC2) includes any operation task that must be performed in environment of toxic and/or other hazardous but without risk of radiation exposure or radioactive contamination. This concerns mainly non-nuclear maintenance (planned and unplanned) and non-radioactive waste management.

[PR3104-R;Defined Requirement] Operation Task Class 2 (OTC2) shall be associated to any operation task which is not classified as OTC1 and which requires special PPE (Personal Protective Equipment) for workers, such as air suit or breathing mask. In order to manage the ITER operation tasks planning in a proper way, OTC2 is divided into two sub-classes as follows:

- Operation Task Class 2-1 (OTC2-1) shall be defined for any operation task which deals with Beryllium and require Beryllium waste management (associated with TBM components and related activities),
- Operation Task Class 2-2 (OTC2-2) includes any other OTC2 operation tasks that are not classified as OTC2-1.

6.19.1.3 Operation Task class 3

[PR3106-I;Defined Requirement] Operation Task Class 3 (OTC3) includes any operation task that is not classified as OTC1 or OTC2.

6.19.2 Procedures and documentation

[PR1588-R] The construction, operation and decommissioning of the ITER Facility and each of its systems/components shall be documented in accordance with the requirements of *ITER Quality Assurance Programme (QAP) [R16]* and of *ITER Configuration Management Plan [R14]*.

7 ENVIRONMENTAL, SAFETY, HEALTH AND SECURITY REQUIREMENTS

7.1 GENERAL SAFETY APPROACH

[PR1110-R;Defined Requirement] ITER shall be designed, constructed, and operated in accordance with the applicable French safety regulations.

7.1.1 ITER safety functions

[PR6087-I] ITER has the following two fundamental safety functions:

- **Management of confinement** of hazardous substances: to control the risks of spreading hazardous substances within the ITER Facility and/or to the Environment in normal, incidental and accidental situations. This function covers:
  - *Radioactive confinement* for all radioactive substances, in all forms (solid, liquid, dust, gas, aerosols), like tritium, activated and/or radioactively contaminated components/items and wastes/effluents.
  - *Toxic confinement* for all non-radioactive, toxic substances in all forms (solid, liquid, dust, gas, aerosols), like SF_6, diborane, solvents, beryllium, etc.
  - Note that inventories of hazardous substances, which could jeopardize ITER radioactive and/or toxic confinement due to their reactive chemical properties (like flammable, explosive, corrosive, etc.), are managed as specified for the supporting safety functions: “Protection of fundamental safety functions”.
- **Radioprotection** to control the risk of exposure to ionizing radiations.

These ITER fundamental safety functions are complemented by the following supporting safety functions:

- **Safety auxiliary support**, which provide the auxiliaries (like power, fluid and gas, I&C) that are necessary to perform, monitor, and control each fundamental safety function when it is required .
- **Protection of fundamental safety functions**, which protect each fundamental safety function against hazards that could prevent its achievement when it is required.

[PR6088-I] ITER also implements the provisions necessary to:

- **Inconveniencies management**, where inconveniencies are the nuisances and impacts of ITER Facility on the Public Health and Sanitation and on the Environment due to ITER normal operation, like for example noise, visual impacts, water intake, normal gaseous/liquid effluent discharges, etc.
- **Waste management**, for all the solid waste generated by ITER during its whole lifetime.
- **Emergency situation management** by (as appropriate) placing and maintaining ITER in a safe state, and by performing the surveillance of the safety parameters of ITER Facility and of the toxic and radioactive substances released in the Environment, and the coordination with authorities and the Public.

[PR6089-I] In addition, ITER implements measures for **Occupational Health and Safety (OHS)** in order to prevent or mitigate all risks of injury or long-term illnesses to workers from workplace exposures other than radiological risks.

7.1.2 ITER safety objectives

[PR6090-R;Defined Requirement] When a hazardous substance presents combined type of risks (radioactive, toxic and/or chemically reactive), the safety measures implemented to control its inventory shall cover the overall risk, in compliance with the most envelope PR requirements.

7.1.2.1 Radiological safety objectives

[PR6091-I] The creation and operation of ITER is mainly governed by the *Order dated 7 February 2012 relating to the general technical regulations applicable to basic nuclear installations (INB)* (INB Order, [R30]). The INB Order establishes the general rules relating to the design, construction, operation, final shutdown, dismantling, maintenance, and surveillance of INB in order to protect the safety, health and sanitation of the Public, and the Environment, by ensuring that the level of risks and inconveniencies from INB is as low as possible under economically acceptable conditions. This leads to the identification and management of nuclear safety functions, Protection Important Components and Activities (PIC/PIA) and their Defined Requirements.

[PR1111-I] The potential for the Public and workers to be exposed to radiological hazards generated by ITER is prevented, and otherwise, limited by design and operation, during normal operation, incidents and accidents (with the following definitions and guidelines):

- **Normal Operation situations** (during operation, testing and maintenance, as well as post-SRO integrated commissioning & assembly): events and plant conditions that are planned and required for ITER normal operation, including some faults, events or conditions that can occur because of ITER's experimental nature (for example, disruption type I).
- **Incidental situations:** Deviations from normal operation, event sequences or plant conditions that are not planned but that are likely to occur at least once during the life of ITER Facility, and which, in view of appropriate design provisions, do not cause any significant damage to items important to safety and do not lead to accident conditions.
- **Accidental situations – Design Basis Accidents (DBA):** Postulated accidents that are considered to be unlikely during ITER lifetime, and that lead to accident conditions for which the facility is designed in accordance with established design criteria and conservative methodology, and for which radioactive releases are kept within acceptable limits.
- **Design Extension Conditions (DEC):** Postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process for the facility in accordance with best estimate methodology, and for which radioactive releases are kept within acceptable limits. DEC are studied to assure that the design has an adequate ultimate safety margin, and are based on the analysis of postulated event sequences that are considered to be implausible, or of extremely low frequency.

To implement this, ITER follows the principles of justification, optimization, and limitation of radiological risks, by applying:

- The **As Low As Reasonably Achievable (ALARA) principles**, a process to determine the appropriate level of protection and safety needed to maintain exposures to ionizing radiations as low as reasonably achievable, and in all cases below the authorized limits, taking into account the state of technology, and economical and social factors. Guidelines for the ALARA principles application are available in [R42].
- The **Defense-in-Depth principle**, which consists in implementing a set of successive lines of defense that are adequately independent to prevent the occurrence of incidents/accidents, and failing this, to detect their incidence and mitigate their impacts. Guidelines to implement this approach are given *ITER General Safety Principles [R43]*.
- Note that, as a good practice, both principles (whole or part) can also be used to manage risks from non-radioactive, toxic substances present in the INB perimeter.

[PR1112-R;Defined Requirement] For radiological hazards, ITER shall be designed and operated (including maintenance) to ensure that the dose objectives of *Table 7-1* are respected during normal operation, incidental and accidental events.

Table 7-1: General Radiological Safety Objectives

(Note 1)	**For personnel**	**For the public and environment**
Situations in design basis		
Normal situations	As low as reasonably achievable, and in any case: - Maximum individual dose < 10 mSv/yr - Average individual dose for workers classified for radiation exposure < 2.5 mSv/yr	Releases less than the limits authorized for the installation Impact as low as reasonably achievable and in any case < 0.1 mSv/yr
Incidental situations	As low as reasonably achievable and in any case < 10 mSv per incident	Release per incident : the annual limits authorized for the installation < 0.1 mSv
Accidental situations *(Note 2)*	Take into account the constraints related to the management of the accident and post-accident situation	No immediate or deferred counter measures (confinement, evacuation) < 10 mSv No restriction of consumption of animal or vegetable products
Design extension basis		
Design Extension Conditions *(Note 2)*	Possible counter measures limited in time and space (see PR1119 below)	
Note 1*: See ITER load specifications for the normal, incidental, accidental and design extension conditions that are postulated for ITER Facility and its SSCs.* ***Note 2****: See PR1118 for overall cliff edge effects analysis*		

[PR1996-R;Defined Requirement] The design of ITER safety Structures, Systems and Components (SSC) shall be sufficiently failure-tolerant, and no failure of SSCs shall result in unacceptable consequences to the workers, the Public and/or the Environment.

[PR1118-R;Defined Requirement] When assessing postulated accidental situations (i.e. Design Basis Accidents (DBA) including (when needed) Design Extension Conditions (DEC)), ITER design and operation shall be verified to ensure that there are no cliff-edge effects. A cliff-edge effect is an instance of severely abnormal facility behavior caused by an abrupt transition from one facility status to another following a small deviation in a facility parameter, and thus a sudden large variation in facility conditions in response to a small variation in an input [IAEA].

[PR1119-R;Defined Requirement] Counter measures limited in time and space shall be addressed by considering consequences in relation to guidelines such as:

- The avoidance of the need for public evacuation, for which a guideline is 50 mSv of avertable dose in a period of no more than one week, according to IAEA recommendations and French regulations,
- The limitation of the need for short-term sheltering, for which a guideline in French regulations is 10 mSv,
- The limitation of the need to ban the consumption of food products, by studying the likely contamination levels and predicting the extent (in space and time) of such banning, if any.

7.1.2.2 Hazardous non-radiological safety objectives

[PR6092-I] The ITER facilities and Structures, Systems and Components (SSCs), which contribute in managing hazardous, non-radiological risks to the safety, health and sanitation of the Public, and the Environment (like toxicity, fire or explosion without radiological consequences), are classified as Installation Classified for the Protection of the Environment (ICPE). These ITER ICPE facilities and SSCs are regulated as follows:

- Those that are within ITER INB and are essential to ITER operation (i.e. part of the INB) are subject to the same provisions as the INB itself, as per the *INB Order [R30]*.
- Those that are within ITER INB and are not essential to ITER operation, or are outside the INB perimeter, (i.e. not part of the INB), are subject to the ICPE provisions as per the applicable French ICPE regulations.
- Those that are within ITER INB are under the authority of the French Nuclear Safety Authority (ASN).

[PR6093-R;Defined Requirement] Hazardous non-radiological inventories shall be managed following applicable regulations, industrial standards and best practices, to prevent or limit their risks to the workers' health, to the safety, health and sanitation of the Public, and to the Environment.

[PR2032-R;Defined Requirement] The annual limit for the release of SF_6 gas into the environment shall be maintained at below 0.5% of the overall SF_6 volume that is present on site.

[PR6094-R;Defined Requirement] The risk from beryllium releases to the Environment and exposure to workers and the Public shall remain within the authorized limits that are specified in the *ITER Beryllium Code of Practice* [R44], which also provides guidelines for the safe management of beryllium.

7.1.3 Safety-important systems, structures, and components (SIC)

7.1.3.1 Safety classification

[PR2377-I;Defined Requirement] ITER Systems, Structures and Components (SSCs) that play an important role in protecting the Public and the Environment, are classified as Protection Important Components (PIC), as considered in the INB order [R30].

The PIC SSCs that contribute to manage radiological risks during normal operation and to respect ITER Radiological Safety Objectives during an incident and/or accident, are further classified as **Safety Important Class (SIC)**, following the criteria and methodology that is described in *Safety Important Functions and Components Classification Criteria and Methodology* [A23] and based on the consequences of their failure on ITER safety.

- The ITER systems that are classified as SIC and their main safety functions are listed in [A23].
- The Defined Requirements, identified at project-level, that the SIC SSCs must satisfy, during their whole lifetime, to perform their safety functions when required during normal, incidental and accidental situations are specified in the PR and relevant PR-ADC.
- Note that the PR also contains Defined Requirements, identified at project-level, for Protection Important Activities (PIA) for example: the non-aggression of PIC and the protection of the Public and Environment.

[PR1256-R;Defined Requirement] PIC that contribute to manage radiological risks during normal operation and to respect ITER Radiological Safety Objectives during an incident and/or accident shall be classified as Safety Importance Class (SIC) 1 or 2, in compliance with *Safety Important Functions and Components Classification Criteria and Methodology* [A23].

[PR2046-R;Defined Requirement] SIC that are pressure equipment containing radioactive substances with a specific level of risk of radioactive release in case of failure, shall be classified as nuclear pressure equipment (NPE), in compliance with *Codes and Standards for ITER Mechanical Components* [A06].

[PR6095-I] SIC components are also allocated classes for their credited safety function during earthquakes and hardened safety core situations as detailed in *Section 7.4.3*. Other ITER classifications may also apply as detailed in *Section 8.1*.

7.1.3.2 Guidelines related to safety importance class (SIC) components

[PR1302-R;Defined Requirement] SIC Structures, Systems and Components shall be designed (including qualification), fabricated, installed, commissioned, inspected and maintained in accordance with the applicable codes, standards, and authorized ITER specifications. Related rules and standards shall be selected for each SIC using the guidelines that are given in *Safety Important Functions and Components Classification Criteria and Methodology* [A23].

[PR6096-R;Defined Requirement] The SIC components that are classified as Nuclear Pressure Equipment (NPE) shall be designed, manufactured, installed, operated, maintained and tested in compliance with *Radioprotection guide for NPE application [A37]*.

[PR1301-R;Defined Requirement] The design of SIC Systems, Structures, and Components (SSC) shall include all loading events (see *PR1486-R* and *PR6137-R*) for which the components may be required to perform a safety function. This shall include, as necessary, the ageing effect of the environmental conditions and loads to which a SIC is exposed during its expected service life, followed by the incidental/accidental conditions and loads during/after which the SIC must perform its required safety function.

[PR2047-R;Defined Requirement] ITER shall be designed to provide redundant and, where appropriate, diverse SIC systems, as necessary to achieve the required reliability for their credited safety functions. The safety analysis shall be performed by assuming the application of the single failure of any SIC.

[PR1214-R;Defined Requirement] The reliability of all ITER systems shall be commensurate with the potential impact on the confinement barrier, using passive means as a back-up, where possible.

[PR1248-R;Defined Requirement] Safety Important Components (SIC) shall be subject to monitoring, as needed to ensure that safety functions are being performed, as assumed in the safety analysis. The monitoring program may require parameters to be displayed in the Main and Emergency Control Rooms to ensure the assumed operability and reliability.

[PR1204-R;Defined Requirement] Systems shall provide the capability for testing and for monitoring parameters, as necessary, to ensure availability and function, as credited in the safety analysis.

7.2 MANAGEMENT OF CONFINEMENT

[PR2018-I] Each inventory of radioactive and/or toxic substances is confined by a coherent set of physical barriers that are associated, as necessary, with dynamic ventilation systems. ITER strategy to confine each radioactive/toxic inventory with significant risks is to implement two confinement systems, based on static and dynamic barriers, as detailed below:

- The **first confinement system** focuses on the protection of the staff directly working around the confined inventory, such as the vacuum vessel and its extension, process equipment and piping, hot cells, waste packages, etc. This system prevents the dispersion of the mobilizable inventory within the nuclear building during normal operation and is credited as the first confinement system against the release of the confined radioactive and/or toxic substances during/after an incident/accident that could impact it.
- The **second confinement system** focuses on the protection of the Public and the Environment, such as rooms with appropriate depressurization, filtration, and detritiation. This system limits environmental releases during/after an incident/accident during which the first confinement system fails to completely contain the confined inventory. This system is distinct from the first confinement system.
- A confinement system is constituted of one or several **physical barriers** (e.g. the walls/slabs constituting the last confinement barrier of a nuclear building, a process pipe within a double envelope or inside a glove box), and can be depressurized by a **dynamic confinement system**. Penetrations through a static barrier (up to and including the isolation and/or filtration devices) are part of the confinement system.

7.2.1 Radioactive and toxic confinement

[PR6097-R;Defined Requirement] The confinement systems provided to manage each radioactive and/or toxic inventory (in terms of the number of barriers, the need for dynamic confinement and their required performance and robustness during normal, incidental and accidental situations) shall be commensurate to the level of risks associated with that inventory and the hazards to be considered, in compliance with the application of both the Defense-in-Depth and ALARA principles.

- The project-level requirements for the confinement of the most significant radioactive and/or toxic inventories during DT plasma operations are specified in the PR.
- A graded approach to reflect the progressive safety provisions to be implemented during the ITER project phases pre-DT plasma operation is specified in the *Safety Strategy [A41]*.

7.2.1.1 Number of confinement systems

[PR1157-R;Defined Requirement] Two confinement systems shall be provided for each principal inventory of radioactive or toxic material, unless formal project approval for a single confinement system is given.

[PR2017-R;Defined Requirement] Formal project approval for a single confinement system may be given by ITER Organization if justified by analyses that shall show that the failure of this single confinement system results in small consequences.

[PR1158-I] In some foreseen normal, incidental and accidental situations, a confinement system may be temporarily removed from service, or become inoperable. These include in-vessel maintenance, confinement testing, confinement maintenance, and single system failure.

[PR1164-R;Defined Requirement] When a confinement system is removed, compensatory measures shall be taken to limit the risk in the unlikely event of a challenge to the remaining confinement system. These compensatory measures shall include, as necessary:

- Limiting the mobilizable source term:
    - Baking of the vacuum vessel and the in-vessel components to reduce the in-vessel tritium inventory shall be performed,
    - In-vessel dust removal shall be performed, for example vacuuming of dust,
    - The volumes (potentially) containing tritium-atmosphere shall be detritiated prior to opening, to obtain a low tritium concentration in the volume (in particular for the vacuum vessel),
    - Inventories shall be segregated or stabilized to a safe state.
- Limiting the energy that is available to mobilize inventories:
    - Processes shall be shut down,
    - Cooling water systems servicing in-vessel components shall be depressurized.
- Confinement measures:
    - In-vessel maintenance and transfer of in-vessel components shall be carried out, at pressures that are below adjacent room pressures,
    - Filtration and/or detritiation shall be maintained,
    - Leak-tight, fire-resistant transfer casks shall be used to transfer activated components, and components that are contaminated with toxic or radioactive contaminants, between the Tokamak Machine and the Nuclear Maintenance and Radioactive Waste Management Facilities,
- Alternate, temporary systems and/or barriers (like tents) shall be provided.

[PR6098-R;Defined Requirement] For tritium confinement in process circuits/systems (e.g. tritium fuelling, tritiated gas exhaust from the vacuum vessel during DT plasma, or other tritium plant processes), a second enclosure (inerted or under vacuum) shall be implemented to the process equipment containing 0.1 g or more of mobilizable tritium-HTO which could diffuse into the building during normal operation or be released in incidental/accidental situations [R45]. Exception can be authorized provided appropriate provisions are implemented to prevent, detect and/or limit the associated risk due to workers exposure to tritium.

7.2.1.2 Need for dynamic confinement

[PR6099-I] When necessary, a static confinement is complemented by a dynamic confinement to prevent or limit - during normal, incidental and/or accidental situations - the risk of workers exposure to atmospheric/surface contamination of radioactive/toxic substances, and the risk of spreading this contamination outside its first confinement system.

[PR6100-I] At ITER, the rooms containing or that may become contaminated by mobilizable radioactive/toxic inventories (and in some cases, also adjacent rooms) are deserved by ventilation systems, which are adapted to the level of radioactive/toxic contamination present in the rooms in normal, incidental, and accidental situations, and the associated needs for filtration, pressure cascade, and air renewal rates. These systems include the Heating, Ventilation, and Air Conditioning systems (HVAC) of the nuclear buildings and, for rooms where there is a risk for tritium release, the Detritiation Systems (DS) provided by the Tritium Plant. This is implemented by establishing the appropriate ventilation zoning in each nuclear building (in association with fire sectorization (see *Section 7.4.2.4*)).

[PR1336-R;Defined Requirement] Ventilation zones shall be established in compliance with the ventilation zoning criteria given in *Table 7-2*, ensuring that each ventilation zone is enveloped by appropriate physical barriers and equipped with a ventilation system providing the required level of filtration, pressure cascade, and air renewal rate.

Table 7-2: Ventilation zoning criteria

Permanent contamination (DAC) (1)	Accidental contamination (DAC) (1)	Confinement class (1)	Application for ITER ventilation zoning
0	0	C1	Normal HVAC
<= 1	<= 80	C2 **(3)**	Nuclear HVAC with filtered exhaust and able to be detritiated/filtered
<= 1	<= 4000 **(2)**	C3 **(3)**	Filtered exhaust and detritiated depending upon contamination expected **(2)**
<= 80 <= 4000 **(2)** > 4000	<= 4000 **(2)** >= 4000 >= 4000	C4* **(3)** C4** **(3)** C4*** **(3)**	Recirculated **(4)** filtered and detritiated with, as required, filtered and/or detritiated exhaust stream **(2)**.

Note 1*: The derived air concentration (DAC) is used as defined in PR1242 for considering internal exposure hazard and ventilation zoning definition. DAC takes into account all the surface and atmospheric radioactive contamination present in the considered ventilation zone (radioactive aerosols/gas and tritium together).*

Note 2*: As stated in PR1244, in case of accidental tritium contamination above 1E+08 Bq/m^3 in a ventilation zone (around 300 DAC of HTO), the HVAC of that ventilation zone is isolated, and its depressurization and exhaust management performed by a detritiation system (DS).*

Note 3*: The ventilation zone is a second confinement system for a radioactive inventory.*

Note 4*: Recirculation is included for enhanced tritium recovery, and does not significantly impact confinement.*

7.2.1.3 Specific requirements for confinement systems

[PR1181-R;Defined Requirement] The allowable leak-rates for confinement barriers shall be as specified in *Table 7-3*.

[PR1183-R;Defined Requirement] The confinement systems shall be capable of returning the confined volume to below atmospheric pressure within a specified period, following an accident.

[PR1184-R;Defined Requirement] The confinement systems shall be provided with a detritiated, filtered, controlled and monitored pathway, to control any release that follows an incident or accident, until releases without their operation are acceptable.

[PR1185-R;Defined Requirement] Exhaust from ventilation zones shall be routed to filtration/detritiation systems (as required by ventilation zoning) in order to limit releases to the outside, and to prevent back draught phenomena occurring from one area to another.

[PR1186-R;Defined Requirement] Pressures within buildings that may receive radioactive leakages shall be kept lower than atmospheric pressure for any weather conditions that are considered in the design.

[PR1187-R;Defined Requirement] Air flow within the buildings shall be directed from lower to higher zones of contamination.

[PR1188-R;Defined Requirement] Ventilation exhaust shall go through controlled and monitored release points.

[PR1189-R;Defined Requirement] Valves that are part of a confinement boundary shall operate within required periods after detection of the onset of an incident or accident.

[PR1190-R;Defined Requirement] The confinement isolation valves shall assume their safe position on loss of auxiliary supply (like power or compressed air).

[PR1244-R;Defined Requirement] If the atmospheric concentration of tritium exceeds 1E+08 Bq/m^3, the ventilation of the affected zone shall be automatically isolated, and its depressurization and exhaust management shall be performed by the Detritiation System until the radiological levels are acceptable again, and the HVAC is running.

[PR1192-R;Defined Requirement] The confinement systems shall be designed to ensure their function in all conditions and events for which their function is credited in the safety analysis.

[PR1193-R;Defined Requirement] The confinement systems shall be designed against all loads and conditions that result from accident sequences during/after which their function is credited in the safety analysis.

[PR1194-R;Defined Requirement] Designated areas within the buildings shall resist the effects of accidents such as pressurization failure, explosion, loss of secondary confinement for radioactive inventory, pipe whip, and fire, if failure threatens safety equipment or workers.

[PR1197-R;Defined Requirement] Penetrations through a confinement system shall be justified with respect to their impact on the effectiveness of the confinement system.

[PR1198-R;Defined Requirement] The penetrations through a confinement system shall neither increase the likelihood or consequences of failure of the confinement system, nor introduce new failure modes beyond those that are addressed in the safety analysis: a penetration crossing a confinement barrier shall reconstitute the barrier properties. Provision of adequate reliability may require the use of such items as double barriers, double bellows, double windows, double isolation valves, and robust sealing.

[PR1200-R;Defined Requirement] Structural integrity of buildings shall be ensured in case of under pressure, for example due to failure of vacuum boundaries (even in worst-case scenarios).

[PR1201-R;Defined Requirement] Systems/components to ensure the confinement function shall be independent, and physically separated, to avoid common mode of failure that could lead to loss of both systems.

[PR1206-R;Defined Requirement] Confinement systems shall be designed and constructed to allow testing, inspection, monitoring, and maintenance, as needed, to assure the initial and continuing performance that is assumed in the safety analysis.

7.2.1.4 Assessment values for confinement systems

[PR1210-R;Defined Requirement] ITER shall comply with safety design constraints given in *Table 7-3*.

Table 7-3: Safety Assessment values for confinement systems

Component	Parameter	Safety Assessment Value
Components of the vacuum vessel and its extensions providing the 1st barrier of 1st confinement system	Range of design pressure	0 to 0.2 MPa absolute
	Leak rate	<= 1 volume %/day at 0.1 MPa pressure differential
TCWS	Max. Pressure Leak rate	5 MPa (FW/BLK) 5.1 MPa (DIV) 2.6 MPa (VV) 3 MPa (NBI) Normal operation leakage: ≤ 1 kg/hr (total for all loops) – *under revision*
VVPSS (activated in case of vacuum vessel overpressure)	Max. Pressure Leak rate	0.17 MPa ≤ 1 volume %/ day at 0.1 MPa pressure differential
Safety drain tank(s) (in case of in-vessel pipe break)	Max. Pressure Leak rate	0.2 MPa <= 1 volume %/ day at 0.1 MPa pressure differential
Vault area (including TCWS vault, CVCSs area and TCWS vault annex, pipe shafts, upper and lower pipe chases, guard pipes	Max. Pressure Leak rate	0.2 MPa < 100 volume %/day at 0.1 MPa pressure differential < 5.5 volume %/day at 300 Pa pressure differential
Gallery rooms (all galleries at all levels, volumes containing piping for fuelling and vacuum pumping between port cells and Tritium Plant Building, rooms containing vacuum vessel pressure suppression system, cryostat space room)	Max. Pressure Leak rate	0.12 MPa < 100 volume %/day at 300 Pa overpressure < 820 volume %/day at 0.02 MPa pressure differential
Drain tanks room	Max. Pressure Leak rate	0.2 MPa < 100 volume %/day at 0.1 MPa pressure differential < 5.5 volume %/day at 300 Pa pressure differential
Fuel processing systems	Leak rate	No leakage outside guard pipes
Isotope Separation System (ISS) process piping	Leak rate	No leakage assumed outside first confinement
Areas C4***, C4** and C3 in the nuclear maintenance and radioactive waste management facilities	Max. Pressure Leak rate	0.105 MPa ≤ 1 volume %/hour at normal operating negative pressure (from -0.2 kPa to -0.1 kPa relative to atmosphere) ≤ 5.8 volume %/hour at 5kPa pressure differential
Areas (C2 areas) in the nuclear maintenance and radioactive waste management facilities	Max. Pressure Leak rate	0.105 MPa <100 volume %/day for C2-2 areas at normal operating negative pressure (-0.05 kPa relative to atmosphere) <=240 volume %/day for C2-1 areas at normal operating negative pressure (-0.05 kPa relative to atmosphere)

Component	Parameter	Safety Assessment Value
NBI cell	Max. Pressure Leak rate	0.2 MPa absolute <= 100 volume %/day at 0.1 MPa pressure differential <= 5.5 volume %/day at 300 Pa pressure differential
Port cell	Max. Pressure Leak rate	0.16 MPa absolute <=100 volume %/day at 300 Pa pressure differential <= 1420 volume %/day at 0.06 MPa pressure differential
Detritiation systems	Detritiation efficiency	> 99 % (normal) > 90 % (during a fire)
	HVAC isolation and switching time	< 30 s (between detection at trigger point and isolation)
	HVAC isolation set point	1E+08 $Bq.m^{-3}$
High Efficiency Particulate Air (HEPA) filters	Filter efficiency	> 99.9 % (normal and during a fire)
Tritium Plant (fire sectors)	Max. Pressure Leak rate	0.105 to 0.31 MPa absolute *(Note 1)* < 100 volume % /day at 300 Pa pressure differential < 410 volume % /day at 5 kPa pressure differential
Tritium Plant (outer wall)	Max. Pressure Leak rate	0.105 to 0.19 MPa absolute *(Notes 1&2)* < 24 volume % /day at 300 Pa pressure differential < 100 volume % /day at 5 kPa pressure differential
Note 1: Depends on location (see [A30]). *Note 2: Leakage rate limitation at pressure higher than 5 kPa shall consider the following extrapolation law:* - *Leak rate (volume%/day) = 1.413 x $(Pint-Pext)^{1/2}$* - *with internal and external pressures Pint and Pext in Pa.*		

7.2.2 Control of confined inventories

[PR1142-R;Defined Requirement] ITER shall be designed and operated so that radioactive and/or toxic inventories are maintained as low as reasonably achievable and within the limits that are authorized for ITER Site, buildings, zones, systems and components. Both the quantity and level of toxicity of such inventories shall be controlled and monitored in each confinement system (e.g. a nuclear building and each of its ventilation zones, the vacuum vessel and its extensions, a hot cell, a waste package, etc.) to maintain them within the associated safety limits, in compliance with the safety demonstration.

[PR6101-I] The inventory limits (defined at project-level) for the entire ITER Facility and those specific to the Tokamak Complex systems are given in this document.

[PR6102-R;Defined Requirement] The inventory limits specific to the buildings and systems for ITER Nuclear Maintenance and Radwaste Management Facilities shall be defined as part of their design development.

[PR1401-R;Defined Requirement] The radioactive and/or toxic inventories present in ITER Buildings shall be controlled by physical means, administrative means, or both, in order to limit the inventories that are potentially vulnerable to a single incident/accident.

[PR6103-R;Defined Requirement] All radioactive and/or toxic inventories shall be controlled taking into account the associated uncertainties for their measurement and derivation, the margins used in the safety demonstration, and the progressive acquisition of associated knowledge during ITER operation.

7.2.2.1 Control of tritium inventory

[PR1149-R;Defined Requirement] The total site tritium inventory shall not exceed 4 kg.

[PR2009-R;Defined Requirement] Tritium accountancy shall be undertaken on ITER Site in accordance with the international obligations related to non-proliferation and export control.

7.2.2.1.1 Control of in-vessel tritium inventory

[PR1145-R;Defined Requirement] The mobilizable tritium inventory within the vacuum vessel and extensions (including the Neutral Beam enclosures, Neutral Beam cryopumps, torus cryopumps) shall not exceed 1000 g (limit for DT-2).

[PR1034-R;Defined Requirement] In-vessel tritium inventory shall be monitored through periodic measurement.

[PR1036-R] In-vessel tritium inventory estimates shall rely on physical inventory taking and a validated procedure to determine the difference between the amount of tritium injected or bred and the amount of tritium extracted or burned.

[PR1037-R] Local tritium monitoring and sampling during in-vessel intervention shall provide another support for the estimate of in-vessel tritium inventory measurements.

[PR1035-R;Defined Requirement] Taking into account measurements uncertainties on in-vessel tritium inventory, tritium shall be removed before the inventory approaches the safety limits.

[PR1038-I] The tritium removal relies on:

- The capability to bake all vacuum vessel and in-vessel components as described in *Section 4.1.2.6*,
- Wall-conditioning techniques as described in *Section 4.1.2.7*.

[PR1042-R;Defined Requirement] Baking shall be carried out:

- Once tritium has been introduced into the vacuum vessel: before any planned venting of the machine to limit the spread of tritium,
- In any other circumstance where the tritium inventory build-up in the vacuum vessel will approach the safety limits considering the uncertainties.

7.2.2.1.2 Control of other tritium inventories

[PR1146-R;Defined Requirement] The mobilizable tritium inventory in a fire sector (see *Section 7.4.2.4*) shall be limited to 70 g, with some exceptions that are individually authorized.

[PR1147-R;Defined Requirement] The maximum tritium concentration in the cooling water of the Primary Heat Transfer System (PHTS) for the vacuum vessel shall not exceed 0.21 $mg.m^{-3}$ (76 MBq/kg).

[PR1148-R;Defined Requirement] The maximum tritium concentration in the PHTS cooling water of in-vessel components shall not exceed 0.32 $mg.m^{-3}$ (114 MBq/kg).

[PR6104-R;Defined Requirement] Provisions shall be implemented to minimize tritium permeation.

7.2.2.2 Control of activation products inventory

7.2.2.2.1 Control of in-vessel activated-dust inventory

[PR1153-R;Defined Requirement] The total inventory of in-vessel, activated dust shall not exceed 1000 kg (limit for DT-2).

[PR1048-R] The in-vessel dust inventory shall be monitored through periodic measurements.

[PR1049-R;Defined Requirement] The in-vessel dust shall be removed before the inventory approaches the safety limits having considered the measurement uncertainties.

[PR1050-R;Defined Requirement] Methods to assess the global erosion in the vacuum vessel shall be provided.

[PR1051-R;Defined Requirement] Methods to perform local monitoring and sampling to assess local dust erosion and deposition in the vacuum vessel shall be provided.

[PR1052-R;Defined Requirement] Removal of dust from accumulation areas in the vacuum vessel shall be provided at any divertor replacement and on every other occasion where in-vessel maintenance operations are carried out.

[PR1053-R;Defined Requirement] The possibility of dust removal via vacuum cleaning of the plasma-facing component surfaces shall be provided using the in-vessel remote handling systems.

7.2.2.2.2 Control of other activated products inventories

[PR1154-R;Defined Requirement] The level of Activated Corrosion Products (ACP) in cooling systems shall be minimized to limit their contribution to workers dose, and to ensure that the cooling water can be (as appropriate) discharged to ITER industrial drainage or processed in ITER radwaste management facilities and/or 3rd party facilities.

[PR2031-R;Defined Requirement] Cryogenic needs at locations where there may be a neutron flux shall be met by helium, not liquid nitrogen, in order to prevent and reduce the risk of generating C14 through activation.

7.3 AUXILIARY SAFETY SUPPORT

[PR1262-R;Defined Requirement] Auxiliary support services that are required for SIC to perform their safety functions (including power, fluid/gas, I&C, cooling water) shall be designed and operated (including maintenance) such that the intended safety functions can be fulfilled when required during normal operation as well as incidental and accidental events.

[PR1196-R;Defined Requirement] SIC auxiliary support services shall be provided to dynamic SIC systems/components so as to maintain mitigation functions even when postulating the loss of off-site power.

7.3.1 Safety power supply systems

[PR1264-R;Defined Requirement] The Class I, II and III safety power supply systems shall have sufficient generating or stored energy capacity to power SIC loads, when necessary, even if one of the safety emergency generators fails to start, or starts and fails to accept loads [A07].

[PR1265-R;Defined Requirement] The maximum power interruption times shall be:

- Class I: no time delay
- Class II: full load transfer within one-half cycle of the degraded power-sensing signal
- Class III: full load transfer within a specified time of the degraded power-sensing signal (30 s or more, depending on the start-up sequence of the electrical consumers that are supplied by the emergency diesel generators).

[PR1270-R;Defined Requirement] The electrical power for all safety control systems shall be non-interruptible.

[PR1271-R;Defined Requirement] Steady-state power supplies shall provide remote-controlled breakers and switchgear, such that all major non-safety loads may be disconnected by the plant electrical control center.

[PR1272-R;Defined Requirement] The Class I and II safety power supply systems shall provide power for at least one hour to safety loads.

[PR1273-R;Defined Requirement] The Class I and II safety power supply systems shall have a reliability that exceeds 0.999 per hour.

[PR1274-R;Defined Requirement] The Class III safety power supply systems shall have a reliability that exceeds 0.99 per loss of power event.

[PR1275-R;Defined Requirement] The Class III safety power supply systems shall have sufficient on-site fuel to maintain full safety loads for 3 days.

[PR1276-R;Defined Requirement] Provisions shall be made to auto/manual-synchronize each emergency/backup power source to its bus, for periodic testing.

7.3.2 Safety ancillary fluids

[PR1278-R;Defined Requirement] The supply of SIC compressed air, SIC demineralized water, and SIC nitrogen that are required to perform the safety functions required in normal/incidental/accidental situations, shall be separated from other non-SIC supply systems.

7.3.3 Safety monitoring and control

[PR6105-I] Refer to *Section 7.3.3.1* and *Section 7.8* for the specific control rooms for crisis and security management.

[PR1937-R;Defined Requirement] The ITER safety control systems, both central and local ones, shall enable the control of the ITER safety I&C functions by managing the safety thresholds.

[PR785-R;Defined Requirement] The means to monitor the plasma current, neutron fluence, fusion power, tritium and dust shall be provided.

[PR1205-R;Defined Requirement] Signals that are associated with safety parameters, such as pressure or radiation level, shall be provided to actuate safety actions, such as isolation of confinement.

[PR1207-R;Defined Requirement] In all situations, all SIC components shall be monitored and controlled from ITER Main/Emergency Control Rooms so that ITER Facility can be put and maintained in a safe state.

[PR6106-R;Defined Requirement] The ITER safety control systems, both central and local ones, shall be designed in accordance with the *Plant Control Design Handbook [A02]* and the *Plant Control Design Handbook for Nuclear control systems [A35]*.

7.3.3.1 Safety control rooms strategy

[PR6107-R;Defined Requirement] The ITER Main Control Room (MCR) shall permit to monitor and control ITER safety functions and their associated SIC Structures, Systems and Components during ITER normal operation. In case of incidental and accidental situations that do not impact the operability and habitability of the MCR, the MCR shall permit to bring and maintain the whole ITER Facility in a safe state during/after these events.

[PR6108-R;Defined Requirement] ITER shall have an Emergency Control Room (ECR) that permits, when the MCR is not available and/or not operational, to bring and maintain the ITER Facility in a safe state. The ECR shall remain available and operational at all times:

- During normal operation (including its maintenance),
- During/after incidental and accidental situations, providing the environment and auxiliaries required for human habitability and the functioning of the housed SIC components, with a minimum autonomy of 72 hours (without maintenance).

7.3.3.2 ITER weather monitoring

[PR1987-R;Defined Requirement] The weather conditions shall be monitored continuously.

[PR1106-R;Defined Requirement] Records of the meteorological conditions shall be kept for the whole duration of the project.

[PR1107-R;Defined Requirement] Records of the meteorological conditions shall be used for the preparation and implementation of the ITER site emergency plan.

[PR1108-R;Defined Requirement] A weather-warning system shall be set up to warn against abnormal weather conditions that can impact the construction of ITER, or limit the operation of ITER systems and/or create risks for the personnel on site, or for the investment.

7.4 PROTECTION OF FUNDAMENTAL SAFETY FUNCTIONS

7.4.1 Generic safety protection approach

7.4.1.1 Hazardous inventory control

[PR6109-R;Defined Requirement] For hazardous substances which introduce a risk of damaging a SIC with the loss of a required safety function (like fuels, explosive substances (hydrogen, ozone, dust), fire loads, chemical energy, magnets energy, etc.), ITER shall be designed and operated to maintain their inventories as low as reasonably achievable and within the limits that are authorized for ITER Site, buildings, zones, systems and components. The quantity of such inventories shall be minimized, controlled, and monitored.

7.4.1.2 Non-aggression of SIC

[PR6110-I] See also *Section 8.9* for SIC preservation during shipping, storage, construction, commissioning, operation and maintenance.

[PR1311-R;Defined Requirement] Operation, inadvertent actuation or damages to components shall not prevent SIC systems, structures, or components from accomplishing their safety functions when required.

7.4.2 Internal hazards

7.4.2.1 Heat removal

[PR2048-R;Defined Requirement] ITER shall include appropriate systems to enable the removal of accumulated heat (from electrical equipment) under any design basis situations, in order to protect the personnel and SIC components.

[PR2020-R;Defined Requirement] ITER cooling systems shall ensure the heat removal that is required by some SIC clients to perform their safety functions when required.

[PR1215-R;Defined Requirement] ITER shall be designed to permit the removal of the heat that could be generated by accidental sequences and that could challenge (directly and indirectly) a confinement barrier.

7.4.2.2 Pressure loads

[PR1217-R;Defined Requirement] All ITER Systems, Structures and Components (SSC) shall provide means to accommodate the pressure loads that are due to unplanned release of coolants, in particular those that are used for in-vessel components, vacuum vessel and superconducting magnets.

[PR2022-R;Defined Requirement] A pressure suppression system shall be incorporated reliably to maintain the pressure rise below the design pressure of the vacuum vessel in the case of an incidental/accidental event such as the ingress of coolant from a failed in-vessel component (i.e. Vacuum Vessel Pressure Suppression system (VVPSS)).

[PR2023-R;Defined Requirement] Passive devices (such as rupture disks) shall be used in the flow path between the vacuum vessel and the Vacuum Vessel Pressure Suppression System (VVPSS) tank.

[PR2024-R;Defined Requirement] A drain line shall be provided to drain water from the vacuum vessel to drain tanks, to limit long-term steam formation.

[PR2025-R;Defined Requirement] The VVPSS and drain tanks shall be de-pressurized, and the gas vented through the Vent Detritiation System.

[PR1218-R;Defined Requirement] The VVPSS shall be provided with a mean (Suppression Tank Vent System, ST-VS) to remove non-condensable gases, if present in incidental/accidental events.

[PR1219-R;Defined Requirement] The Tokamak Cooling Water System (TCWS) vault shall be designed to maintain its confinement function in case of a hypothetical double-ended guillotine break of the largest coolant pipe during pulsed operation and baking, with some means to relieve pressure if necessary.

[PR1220-R;Defined Requirement] Overpressure relief to a closed vessel or process shall be provided for liquefied or solidified tritiated gases in the Tritium Plant.

[PR2026-R;Defined Requirement] The system that supplies liquid helium to ITER systems shall limit the potential release of helium within the vacuum vessel to 50 kg (protection measure to guarantee the confinement function of the VVPSS).

7.4.2.3 Halogenated materials

[PR1231-I] Halogenated materials include all solids liquids and gases that contain fluorine, chlorine, bromine or iodine. In industrial applications, halogenated materials are often present in such items as process gases, electrical cable insulation, floor and wall coatings, paints and cleaning solvents.

[PR1232-R;Defined Requirement] The use of halogenated materials is forbidden in areas or volumes that are served by the Detritiation System (DS) or by the Tokamak Exhaust Processing System (TEPS). Exceptions shall require a formal project approval. (The procedure for formal project approval shall include approval of the Nuclear Safety and Tritium Plant Responsible Officers.)

7.4.2.4 Internal fire

7.4.2.4.1 Fire protection approach

[PR1280-I] The objectives of Fire Protection are to:

- Prevent fire and fire damage that could lead to the loss or jeopardize of nuclear safety functions, mainly:
  - the inability to bring and maintain ITER Facility in a safe state (including intervention of emergency response teams),
  - the release of radioactive and/or toxic substances within the facility and/or to the Environment,
  - workers exposure to ionizing radiations.
- Ensure human safety.
- Limit damage to ITER Structures, Systems and Components for investment protection.

To implement this, ITER applies the following “Defense-in-Depth” approach:

- Fire prevention,
- Fire detection, and suppression,
- Fire mitigation, to prevent spread and to limit the consequences of a fire,
- Fire incident response.

The specific provisions to be implemented to meet these objectives are outlined below. They are based on the establishment of fire sectors (see *Section 7.4.2.4.4*).

[PR1191-R;Defined Requirement] ITER shall implement the provisions permitting to prevent, detect, retard and/or extinguish fire that could threaten or degrade workers safety, Safety Important Components (SIC) and other ITER Structures, Systems and Components (SSCs) important for ITER Investment Protection, as specified in *ITER Fire Safety Approach document [A34]*.

7.4.2.4.2 Fire prevention

[PR1195-R;Defined Requirement] Fire loading in each fire sector shall be minimized (with appropriate control and monitoring measures), and shall be such as to comply with the required fire resistance of that sector in order to prevent the collapse of structures and the spread of fire.

[PR6111-R;Defined Requirement] The overall fire loading in a building shall be minimized (with appropriate control and monitoring measures), and shall be such as to comply with the required fire resistance of that building in order to prevent its collapse.

[PR2268-R;Defined Requirement] Because of the high risk of fire and/or explosion, maintenance activities in rooms housing systems/components containing explosive substances (for example, tritium, hydrogen, diborane, etc.) shall be limited to periods when the processes using such substances are shut-down and these substances are appropriately isolated or removed.

[PR2271-R;Defined Requirement] Potential ignition sources shall be prevented or limited, and where an ignition source is present in a room, area or component, the appropriate protection measures shall be taken.

7.4.2.4.3 Fire detection

[PR2272-R;Defined Requirement] Each room of nuclear buildings and/or buildings containing Safety Important Components (SIC) shall be equipped with a fire-detection and alarm system appropriate to that risk and to the environmental conditions of the room.

[PR6112-R;Defined Requirement] In nuclear buildings and/or buildings containing Safety Important Components (SIC), the fire detection systems shall remain operational during and following SL-2 earthquake.

7.4.2.4.4 Fire suppression

[PR2273-R;Defined Requirement] Each room of nuclear buildings and/or buildings containing Safety Important Components (SIC) shall have fire suppression systems/equipment (fixed and/or mobile) appropriate to the fire risk, the response time of the fire detection system, the potential presence of contamination sources and the need to protect workers (including fire fighters) and SIC against the fire and associated secondary hazards (including those resulting from the type of fire suppression system used).

[PR6113-R;Defined Requirement] In nuclear buildings and/or buildings containing Safety Important Components (SIC), the fire suppression systems shall remain operational during and following SL-2 earthquake.

7.4.2.4.5 Fire effect mitigation

[PR1390-I] The effects of fires that could occur within a building are mitigated by establishing a fire sectorization of the whole building volume, in line with the following guidelines.

- A fire sector is a volume that is composed of a room or group of rooms that are delimited by walls/slabs (including their penetrations) and are designed to keep an internal fire (within the volume) from spreading outside (or to keep an external fire from spreading inside) for a duration that is sufficient to extinguish the fire.
- A building has at least one fire sector covering its entire volume. The subsequent division of this overall fire sector into several fire sectors and their layout depends on the identified fire risks, design choices and fire hazard analysis. This includes (but is not limited to):
    - The need to prevent common mode of failure that could jeopardize the required safety functions, and/or to protect workers and investments.
    - The available options for segregating fire loads and/or inventories/equipment at risk, for extinguishing the fire within the required response time, etc.
    - For fire sectors containing mobilizable radioactive/toxic substances, the need to mitigate the risks that a fire occurring in such sectors could lead to radioactive/toxic releases with unacceptable consequences to workers, the Public and/or the Environment.
- Fire sectorization is defined with ventilation zoning (see *Section 7.2.1.2*) to ensure:
    - When applicable, the confinement of radioactive/toxic inventories during normal, incidental and accidental situations, with the required leak-tightness, filtration, pressure cascade and air renewal.
    - The non-propagation, via the ventilation systems, of fire, fumes and potential radioactive/toxic contamination into fire sectors and into the building in case of an external fire (see *Section 7.4.3.3*).

[PR1396-R;Defined Requirement] Fire sectorization shall be set up in ITER Buildings to limit the spread of fire and fumes, and to confine the fire within predefined volumes, to allow enough time to extinguish the fire.

[PR6114-R;Defined Requirement] When fire sectorization cannot be provided to manage an identified fire risk, other compensatory measures shall be implemented to prevent the occurrence of that risk or to mitigate its consequences to an acceptable level.

[PR2062-R;Defined Requirement] To prevent or limit the propagation of fire/fumes within nuclear buildings and/or buildings containing SIC, each room that has, or may have, a potential fire risk for the objectives of ITER Fire Protection shall be classified as a fire sector or included in a suitable fire sector, according to the level of this risk and as specified in *ITER Fire Safety Approach document [A34]*. Fire sectors are identified in *ITER Safety Roombook [A27]*.

[PR2260-R;Defined Requirement] When a fire in a given fire sector can lead to a radioactive/toxic release with an unacceptable consequence to the Public and/or the Environment (e.g. reaching the authorized limits like a dose of 10 mSv at the site boundary, see *Section 7.1.2*), one or a suitable combination of the following measures shall be implemented:

- Additional fire protection measures to remove or reduce the risk of downgrading the first confinement system of the inventory at risk and/or the fire barriers of the fire sector (e.g. segregation or isolation of the fire loads, distance, wrapping with fire-resistant materials, etc.).
- The fire sector is identified as a second confinement system enveloping the inventory at risk (in addition to the last confinement barrier of the nuclear building), with physical barriers and an associated ventilation system both designed to prevent and limit the release of the mobilized radioactive/toxic substances to the Environment.
- The boundaries of the fire sector are distinct from those of the last confinement barrier of the nuclear building. To implement this, these boundaries are separated by at least one ventilation zone that permits to collect the mobilized radioactive/toxic substances released from the fire sector and to prevent and limit release into the Environment.

[PR1288-R;Defined Requirement] For each radioactive/toxic inventory, at least one confinement system shall remain intact during and following a fire.

<u>Requirements on SSCs located in Fire Sectors</u>

[PR6115-R;Defined Requirement] When a SIC component is required to perform a safety function during/after a fire occurring within its fire sector, provisions shall be implemented (as needed) to ensure that the SIC component can perform its credited safety function.

[PR2052-R;Defined Requirement] For SIC systems that have redundant SIC trains, the redundant SIC components shall be located in independent and separate fire sectors. However, this independence/separation may not be possible in some cases, and when it is required to locate both redundant SIC components in the same fire sector, at least one of these components shall be protected against fire in order to maintain its required functionality.

[PR2367-R;Defined Requirement] For the SIC auxiliary systems that have redundant SIC trains (including power supply, I&C, fluid & gas), the redundant SIC trains providing the same safety function shall be routed through independent and separate fire sectors. However, this independence/separation may not be possible in some cases, and when redundant trains are required to go through the same route, the intrusive train [R46] shall be protected against fire to maintain its required functionality.

[PR2058-R;Defined Requirement] In any given room containing SIC components of a SIC train, all the SIC components shall be connected to the same SIC train for their required services (like power supply, I&C, gas & fluid) – for example Train A SIC cubicles only connected to Train A SIC services.

[PR2053-R;Defined Requirement] The main SIC electrical enclosures for centralized control/power supply of SIC components shall be located in dedicated SIC rooms, which shall not include any non-SIC electrical enclosures (with the definitions of the concerned electrical enclosures for centralized control/power given in *EDH [A07]* and SIC rooms identified *Safety Roombook [A27]*).

[PR2179-R;Defined Requirement] Each SIC-1 electrical enclosure that are located in SIC rooms shall be equipped with automatic fire detection and suppression system within its enclosure. When located in the same room than a SIC-1 electrical enclosure, each SIC-2 electrical enclosure shall also be equipped with an automatic fire detection and suppression system within its enclosure enclosures (with the definitions of the concerned electrical enclosures given in *EDH [A07]* and SIC rooms identified *Safety Roombook [A27]*).

[PR1407-R;Defined Requirement] Electric cables that run through a fire sector boundary shall not contribute to the spread of fire by design and/or protection with a flame-retardant material, in order to comply with one of the equivalent standards listed below ([R47] and [R48]):

- IEC 60332-3 and IEC 60332-1,
- NF C320-70 C1,
- For cables in nuclear buildings: Euroclass with minimum class Cca-1sb-d1a1 according to EN50757,
- For cables in non-nuclear buildings: Euroclass with minimum class Cca-1sb-d2-a2 according to EN50757.

[PR1408-R;Defined Requirement] Electric cables, that run through a fire sector, and that are required to operate in the event of fire, shall be fire-resistant, by design and/or protection with a fire resistant material, in order to comply with the NF C 32-070 (that is, CR1 Class) or IEC 60331 ([R47]).

[PR2379-R;Defined Requirement] In all buildings containing SIC and/or radioactive substances, all cable trays shall have a metallic cover to minimize the risk of fire propagation. In addition, a 2-hour fire protection envelope may be implemented on cable trays depending on the level of risk, in case of fire.

<u>Requirements on boundaries of Fire Sectors</u>

[PR1404-R;Defined Requirement] Fire sectors shall be surrounded by physical, fire-resistant barriers, with a fire resistance rating of at least two hours (fire sector boundaries).

[PR1405-R;Defined Requirement] Penetrations through a fire sector boundary (like doors, pipes/ducts, cables/busbars, etc., including if any infilling/sealing) shall offer the same degree of fire resistance as the rest of that boundary (alone and/or with a fire-resistant material protection).

[PR1410-R;Defined Requirement] Ventilation ducts/pipe that open into a fire sector shall be equipped with fire valves or dampers to isolate that sector in case of fire. These valves/dampers shall be installed as near as possible to the fire sector boundary. The valves/dampers and the pipe/ducts connecting them to the fire sector boundary shall provide the same degree of fire resistance as that boundary (alone and/or with a fire-resistant material protection).

[PR1412-R;Defined Requirement] High Efficiency Particulate Air (HEPA) filters at fire sector boundaries shall be fire-resistant (minimum efficiency of 99.9% during a fire).

<u>Requirements on volume of Fire Sectors</u>

[PR1403-R;Defined Requirement] Fire loading and fire resistance within a nuclear building containing radioactive materials shall be implemented and controlled in the building fire sectors, to ensure - in case of fire - that at least one confinement barrier remains intact for any radioactive inventory.

[PR2274-R;Defined Requirement] In the event of a fire in a ventilation zone, the air supply of the ventilation system towards this zone shall be isolated.

7.4.2.5 Internal explosion

7.4.2.5.1 In-vessel explosion hazards

[PR1224-R;Defined Requirement] ITER shall reduce the risk of a dust and hydrogen explosion to occur in the vacuum vessel, and in all cases ensure that the integrity of the vacuum vessel and its extensions (including their penetrations and the VVPSS) is maintained, i.e. the resulting pressure in the vacuum vessel and its extensions shall not exceed their safety assessment pressure value of 0.2 MPa (*Table 7-3*). To achieve this objective, ITER shall minimize and control:

- The accumulation of hydrogen, its isotopes and dust in the vacuum vessel and its extensions,
- Temperature of plasma-facing surfaces (as elevated temperatures accelerate the accidental chemical reaction with dust),
- Water/steam/air ingress in case of in-vessel components failure,
- Hydrogen production from accidental scenarios of the Test Blanket Modules system.

[PR1227-R;Defined Requirement] Reliable separation, typically with two barriers, shall be provided between volumes that may contain air and hydrogen, including during incidental/accidental conditions.

[PR1228-R;Defined Requirement] Isolation shall be provided to prevent air ingress into the vacuum pumping system, fuelling system or Tritium Plant in the event of air ingress into the vacuum vessel.

[PR1229-R;Defined Requirement] The use of liquid nitrogen in any region that is subject to radiation shall be justified by an analysis of ozone through radiochemical conversion of trace levels of oxygen.

7.4.2.5.2 Other internal explosion hazards

[PR1358-R;Defined Requirement] In compliance with the European Directive 94/9/EC (ATEX), ITER shall establish anti-deflagration zones, according to the frequency with which an explosive atmosphere may form, and the length of time for which this atmosphere lasts. Following identification of rooms/areas with explosion risks, ITER shall implement suitable risk prevention measures, both in terms of building design and of the use of their systems and equipment.

[PR6116-R;Defined Requirement] A second enclosure (inerted or under vacuum) shall be implemented to process equipment containing 6.2 g or more of mobilizable hydrogen and/or deuterium which could diffuse into the building during normal operation or be released in incidental/accidental situations [R45]. Exception can be authorized provided appropriate provisions are implemented for the prevention, detection and/or limitation of the associated explosion risk.

[PR2061-R;Defined Requirement] The concentration of hydrogen in air (tritium, deuterium, protium and/or mixtures of these isotopes) shall not exceed 1% (i.e. <25% of the hydrogen Lower Explosive Limit (LEL) of 4% ([R49], *Circulaire 9 Mai 1985*)). To ensure this, in rooms where there is such a flammability risk:

- Systems that contain/produce hydrogen shall prevent or minimize their hydrogen release into these rooms.
- The layout of these rooms shall prevent the risk of hydrogen accumulation in specific volumes/areas/zones.
- Ventilation shall provide sufficient air renewal within these whole rooms to avoid hydrogen accumulation.

[PR2039-R;Defined Requirement] The hydrogen atmospheric concentration, in areas with a potential risk of accumulation of tritium, deuterium, protium and/or mixtures of these isotopes, shall be monitored, with appropriate alarm systems provided.

[PR6117-R;Defined Requirement] System/process equipment that contains (or may contain) explosive substances (such as hydrogen, dust, or ozone) shall be designed and/or operated to prevent the risk of an internal explosion that could damage a radioactive/toxic confinement barrier (by for example venting, inerting, or ventilating to remain below the Lower Explosive Limit (LEL), preventing air ingress, etc.).

[PR2040-R;Defined Requirement] Rooms, areas or systems that contain or that may contain an explosive atmosphere (such as hydrogen, dust, or ozone) shall be equipped with an appropriate monitoring system to detect the potential explosive atmosphere.

[PR2041-R;Defined Requirement] Prior to opening the double confinement of a hydrogen-bearing system, measures shall be taken to avoid the presence of potentially explosive conditions.

7.4.2.6 Internal flooding

[PR2261-R;Defined Requirement] Means shall be provided to detect a leakage of coolant from a primary heat transfer system loop into the TCWS vault, so that the vault can be isolated to minimize releases.

[PR2069-R;Defined Requirement] Systems that contain water or liquid effluents shall be designed to minimize leakage.

[PR2071-R;Defined Requirement] Systems that contain water or liquid effluents shall be suitably monitored (including periodic inspection) in order to detect, as soon as possible, a leakage, and shall be equipped with an appropriate alarm system.

[PR2070-R;Defined Requirement] In the event of a water or liquid effluent leak, it shall be possible to isolate the leaking system, purge it and/or collect the leakage.

[PR6118-R;Defined Requirement] SIC components that could be prevented from performing their safety function required during a flooding event shall be protected.

[PR6119-R] Means shall be provided to localize a leakage from components containing liquids.

7.4.2.7 Mechanical impacts

[PR2027-R;Defined Requirement] Systems (such as systems of high energy fluid piping/containers, and systems with risks of explosion or with potential failure of moving parts) that could impact SIC Structures, Systems and Components, shall be designed to prevent the generation of a missile or to limit the consequences associated with this hazard. This shall include periodic testing and inspection in order to detect precursor signs of associated missile risks.

[PR2028-R;Defined Requirement] Systems that transport high energy fluids (with a pressure greater than 20 bar absolute, or a temperature greater than 100ºC) shall be designed to prevent pipe whipping, or to limit the consequences that are associated with this hazard. This shall include periodic testing and inspection, to detect precursor signs of associated pipe whip risks.

[PR2029-R;Defined Requirement] SIC components shall be protected against the risk that is associated with potential missiles from high energy fluid circuits (pressures greater than 20 bar absolute, or temperatures greater than 100ºC) or other potential sources for missiles (such as internal explosion, failure of a machine with moving parts).

[PR2030-R;Defined Requirement] SIC components shall be protected against the risks that are associated with potential pipe whipping from high energy fluid circuits (pressures greater than 20 bar absolute, or temperatures greater than 100ºC).

[PR1202-R;Defined Requirement] Appropriate measures shall be implemented to ensure that collision with moving equipment, and/or drop loads, during construction, operation and maintenance cannot prevent SIC components to perform their required safety functions.

7.4.2.8 Magnetic and electromagnetic hazards

[PR6120-R;Defined Requirement] ITER shall implement all the necessary measures to prevent the failure of SIC components due to magnetic and electromagnetic hazards.

[PR6121-I] See also requirements for magnetic zoning in *Section 7.5.4* and electromagnetic compatibility in *Section 8.6*.

[PR2033-R;Defined Requirement] The superconducting coils shall be designed to avoid quench during plasma operation, including plasma disruptions.

[PR2034-R;Defined Requirement] The magnet system shall be equipped with devices to detect any loss of superconductivity.

[PR1234-R;Defined Requirement] To ensure that failures in magnets do not damage systems that provide safety functions, a means shall be provided to detect a quench in a toroidal field coil, and rapidly to discharge its energy.

[PR1235-R;Defined Requirement] A means shall be provided to detect short circuits in the poloidal and central solenoid coils, and to close the Explosive-actuated Protective Make Switch (EPMS) at the output of the converters that will avoid further delivery of electrical energy.

7.4.2.9 Erroneous operator action

[PR6122-I] See *Section 6.15* regarding Human Factor requirements.

7.4.2.10 Specific hazards associated with Test Blanket Module Systems

[PR1322-R;Defined Requirement] The Test Blanket Module (TBM) system shall be designed and operated (including their maintenance and the TBM replacement) to comply with ITER Licensing requirements.

[PR1316-R;Defined Requirement] Decay heat removal shall be achieved by thermal radiation and conduction from the Test Blanket Module system to the Tokamak.

[PR1317-R;Defined Requirement] The Test Blanket Module (TBM) system shall prevent or limit chemical reactions between its coolant, air and breeder/multiplier material that could jeopardize the TBMs confinement function. Appropriate measures shall be implemented to mitigate the consequences from such TBMs abnormal scenario.

[PR1318-R;Defined Requirement] Self-sustaining chemical reactions shall be precluded or their risk and consequences minimized by design of the Test Blanket Modules System.

[PR1323-R;Defined Requirement] Hydrogen production by each Test Blanket Modules system shall be limited to 2.5 kg hydrogen, to limit the explosion hazard.

[PR1319-R;Defined Requirement] Special consideration for lithium fires shall be made for the Test Blanket Module system that contain a liquid metal loop.

[PR1321-R;Defined Requirement] Gaseous leaks of helium from each Test Blanket Module System to the vacuum vessel shall be limited to 50 kg helium, to assure reliable functioning of the VVPSS.

7.4.3 External Hazards

7.4.3.1 External electricity supply interruption/variation

[PR6123-R;Defined Requirement] In case of a Loss Of Off-site electrical Power (LOOP) or power station blackout (SBO), the ITER SIC systems and components, which require electrical power to perform the necessary safety functions (including to place and maintain ITER in a safe state), shall remain operational.

7.4.3.2 Earthquake

[PR1459-R;Defined Requirement] Each ITER Structure, System and Component (SSC) that must perform a safety function, and/or ensure the non-aggression of SIC, during and/or after a SL-2 earthquake shall be allocated the corresponding seismic classification (SC1 or SC2 (S or SF)), in accordance with *the ITER Seismic Nuclear Safety Approach [A28*] and *Table 7-4*.

[PR2049-R;Defined Requirement] Each ITER Structure, System and Component (SSC) that is allocated a seismic class shall be designed, constructed and operated (including its maintenance) such that their capabilities are maintained as credited during/after the SL-2 seism, in accordance with *ITER Seismic Nuclear Safety Approach [A28]*.

[PR2050-R;Defined Requirement] The ITER Facility shall be equipped with a seismic detection system to provide a warning notification of a seismic event.

[PR1307-I;Defined Requirement] Peak ground accelerations and design response spectra for seismic events are defined in the *Load Specifications [A14]*.

[PR1309-R;Defined Requirement] The combination of loads from earthquakes with other loading events shall be considered.

[PR1308-R;Defined Requirement] The collapse, falling, dislodgement or any other spatial response of a component, as a result of any earthquake, shall not jeopardize the functioning of other components that provide a safety function during or after the earthquake.

Table 7-4: Main system seismic requirements

PBS	System	Main Safety Requirements during and following SL-2 earthquake (from DD plasma)
All	All systems	Non-aggression of SC1 components Seismic behavior and potential damages to the systems' components do not result in damages to any SC1 components that could jeopardize their required safety function. Taking into account the potential displacement, collapse, missile generations, leakage, etc., of the system components.
11	Magnet Systems	No damage to the vacuum vessel and its extensions that could jeopardize their confinement function
15	Vacuum Vessel	Leakage from vacuum vessel and its extensions no greater than that assumed in safety analysis
16 17	Blanket Divertor	No damage to vacuum vessel and its extensions that could jeopardize its confinement function
18	Fuelling and Wall Conditioning	No significant leakage of radioactivity from system to rooms Vent detritiation systems (Normal and Standby systems) continue to function; interruption during earthquake acceptable; must be able to be restarted. Able to reach safe storage state for tritium. Maintain confinement (DS) function.
23	Remote Handling Equipment	No significant leakage of radioactivity from casks to rooms No damage to confinement barriers (vacuum vessel and its extensions, casks, hot cells, etc.) that could jeopardize their confinement function
24	Cryostat & VVPSS	No damage to vacuum vessel and its extensions that could jeopardize its confinement function Vacuum vessel pressure suppression system functional
26	Cooling Water System	No significant leakage from system Chilled water for long-term cooling of VV PHTS and DS continues; interruption during earthquake acceptable; must be able to be restarted.
31 32	Vacuum Pumping and Leak Detection Tritium Plant	No significant leakage of radioactivity from system to rooms Vent detritiation systems (Normal and Standby systems) continue to function; interruption during earthquake acceptable; must be able to be restarted. Able to reach safe storage state for tritium. Maintain confinement (DS) function.
41	Coil Power Supply & Distribution	Maintain the ability for TF fast discharge and to switch off PF coil power supplies remains functional during and after earthquake
43	Steady State Power Supply	Maintain the ability to provide safety power to systems providing safety function retained; interruption during earthquake acceptable; must be able to be restarted.
48	Central Safety System	Safety systems remain operational

PBS	System	Main Safety Requirements during and following SL-2 earthquake (from DD plasma)
51 52 53 55	Ion Cyclotron H&CD Electron Cyclotron H&CD Neutral Beam H&CD Diagnostics	No significant leakage of radioactivity from system into rooms
56	Test Blankets	No significant leakage of radioactivity (or lithium, if applicable) from system into rooms
62/63	Buildings ad their systems	SIC/SC1 buildings: Maintain integrity of the main structures to protect the housed SC1 components. Fire detection & suppression capability remains operational SIC LAC: Maintains local temperature required for SC1 components B7S: As SIC/SC1 buildings above + HVAC maintained for personnel habitability and SC1 components protection Vent and clean-up systems are functional
66	Nuclear maintenance and radwaste management systems	No significant leakage of radioactivity from systems to rooms
64	Radiological & Environmental Monitoring	Retain the ability to monitor (estimate) releases from site Radiation protection monitoring (possibly portable) available
65	Liquid Distribution	Maintain the required SIC Nitrogen/Compressed Air/Distilled water
Other PBS	Other ITER systems	*No specific requirements other than for non-aggression of SC1 stated in the first row*

7.4.3.3 External Fire

[PR2035-R;Defined Requirement] The ITER Facility shall be designed, and appropriate measures taken, to minimize the risk of external fire around buildings and ITER Site, and if such an event were to occur, to prevent its propagation inside the nuclear buildings.

7.4.3.4 External explosion

[PR2003-R;Defined Requirement] The ITER facilities shall be sited at an appropriate distance from the site boundary, to mitigate the impact of the overpressure wave and projectiles that are induced by a potential explosion involving an installation that is located close to the ITER site boundary fence.

[PR2004-R;Defined Requirement] The ITER buildings that contain Safety Important Components (SIC) shall be able to withstand an overpressure wave of 50 mbar from whatever direction it comes, for example, due to an explosion on the road close to ITER site boundary fence.

7.4.3.5 Extreme climatic conditions & External flooding

[PR1988-R;Defined Requirement] The civil structures of ITER buildings and site infrastructures shall be designed and built to maintain their structural integrity and weather-tightness under extreme climatic conditions (including wind, snow, rain, temperature, hygrometry, sun, external and groundwater flooding), as specified in *Safety Requirements for ITER Facility Buildings* [A22], *Load specification for buildings with safety requirements* [A36] and *ITER Structural Design Code for Buildings (I-SDCB) - Part1: Design Criteria* [A11].

[PR6124-R;Defined Requirement] Any SIC component exposed to the outdoor environment shall be designed and built to perform its safety functions required during extreme weather, with the same loads and conditions specified for buildings (including as required wind, snow, rain, temperature, hygrometry, sun, external and groundwater flooding - see *PR1988*).

7.4.3.6 Aircraft crash

[PR2036-R;Defined Requirement] In the event of an aircraft crash, the design and layout of the radiologically controlled buildings, and of the buildings that contain Safety Important Components (SIC), shall protect all SIC that they contain.

[PR2037-R;Defined Requirement] In the event of an aircraft crash, Safety Important Components (SIC) that are located outside the radiologically controlled buildings shall be provided with sufficient redundancy, and shall be separated in such a way that, if one should be destroyed, the other would remain available and allow the safe state of the facility to be maintained (such as emergency diesel generators).

7.4.3.7 Hazardous atmospheric releases

[PR6125-R;Defined Requirement] In case of atmospheric releases of hazardous substances, the Emergency Control Building shall prevent air ingress into the building to protect the accommodated personnel.

7.4.3.8 Extreme natural external hazards

[PR6126-R;Defined Requirement] ITER shall demonstrate the following safety objectives for the extreme natural external hazards, which are described in *Load Specifications [A14]* (like SL-3 seism or extreme weather conditions):

- Doses on the reference population groups < 10 mSv,
- No groundwater pollution,
- No level of ionizing radiation exposure that prevents human interventions.

[PR6127-I] ITER components that have to perform safety functions during/after an extreme external hazard are identified as Hardened Safety Core Components (HSCC).

[PR6128-R;Defined Requirement] The function of a HSCC shall not be jeopardized by the failure of a non-HSCC.

[PR6129-R;Defined Requirement] The HSCCs shall be designed and qualified in compliance with the methodology and requirements defined in the *Methodology for ITER Hard Core Components* [A43].

7.5 WORKERS PROTECTION

7.5.1 Radioprotection

7.5.1.1 Radioprotection approach

[PR1997-I] The As Low As Reasonably Achievable (ALARA) principles is applied at ITER to minimize occupational doses by employing all “reasonable means”.

[PR1127-R;Defined Requirement] For each ITER system and its components that are located and/or are planned to be maintained and/or inspected in nuclear environment, their design and operation shall minimize worker exposure to radiological hazards by applying the ALARA principles, and in all cases by ensuring that occupational doses are within:

- The General Safety Objectives given for personnel in *PR1112*.
- Their contributions to the annual target for ITER collective annual worker dose (see *PR1129*) is ALARA.

[PR1129-R;Defined Requirement] The collective annual worker dose, averaged over the operational lifetime of ITER, shall be ALARA and in any case shall not exceed an annual target of 0.5 person.Sv.

[PR1126-R;Defined Requirement] The ALARA principles shall be applied before work in a radioactive zone is authorized.

[PR6130-I] Guidelines for the ALARA principles are provided in *Guidelines for ALARA Implementation [R42]*.

[PR1130-R;Defined Requirement] When hands-on activities are performed in a radiological zone (including port cells, the Neutral Beam cell, hot cells, nuclear maintenance and storage areas), the dose rate in that zone shall be ALARA. To implement this,

- As a general principle:
  - The dose rate shall not exceed the target of 100 µSv/h in yellow radiological zones and 10 µSv/h in green radiological zones. For radiological zones close to the Tokamak: this dose rate is to be estimated up to 1E+06 s (about 12 days) after shutdown of the Tokamak Machine.
  - The dose rate in port cells (with the exception of the Neutral Beam injectors cell), with the bioshield plug in place, shall not exceed the target of 10 µSv/hr at 24 hours after shutdown of the Tokamak Machine.
  - In both cases, the dose rates are to be estimated at 30 cm from the nearest accessible surface, taking into account (as relevant) the surface contamination, airborne tritium and activated materials.
- Subsequently, the ALARA principles shall be applied to minimize occupational doses to workers (including both individual and collective doses).

[PR6131-I] The application of the ALARA principle on top of these dose-rate targets can drive (provided appropriate authorization) a deviation from the initial target and/or the implementation of fully/partially remote operations, additional radioprotection measures, other design and/or operation evolutions. See [R42] for guidelines to apply the ALARA principles.

[PR2378-R;Defined Requirement] The design and construction of the tunnels used by the remote transfer casks between the Tokamak Building and the Nuclear Maintenance and Radwaste management Facilities shall be built to ensure there is no risk of ionizing radiation outside the buildings during these transfers.

[PR1241-R;Defined Requirement] ITER Organization shall develop and implement a suitable Radiation Protection Program (RPP) that will include workers classification and access control as well as a system of authorization and associated procedures.

[PR2357-R;Defined Requirement] The ITER Radiation Protection Program (RPP) shall be reviewed periodically to check its efficiency, and to optimize it where possible.

[PR931-R] ITER shall provide Health Physics services and equipment permitting to ensure appropriate controls of persons entering and leaving controlled areas of Nuclear Buildings.

7.5.1.2 Radiological zoning

[PR1343-R;Defined Requirement] Workers exposure to radiological hazards shall be minimized by establishing, in ITER Nuclear Buildings (i.e. housing radioactive substances), a radiological zoning for each plant operation state, in line with the dose criteria given in *Table 7-5* and by applying the associated access controls as prescribed in *Table 7-6* (including mandatory monitoring (airborne and surface contamination), signage, Personnel Protection Equipment, procedures).

[PR6132-R;Defined Requirement] No nuclear operations shall be allowed in non-controlled radiological zones. In case of suspected/known radioactive contamination outside a radiological zone, appropriate measures shall be implemented to protect workers from radiological exposure until the contamination can be cleaned to less than the contamination limit or until a permanent radiological zone is established.

[PR1138-R;Defined Requirement] For radiological zones other than orange and red (see *Table 7-5*), the individual sources of radiation shall be clearly indicated, and shall be communicated to workers prior to entry.

Table 7-5: Radiological zoning

Zone *(Note 1)*	**Control type** *(Note 3)*	**Radiological Zone Identification** *(Note 4)*	**Total effective dose for the entire body - external and internal exposure** *(Note 2)*	**Maximum total equivalent dose on extremities or skin**	**Maximum effective dose from radon**
Unregulated zone		White zone	< 80 μSv/month	< 4 mSv per month	< 6 mSv per year
Supervised zone	Specially regulated	Blue zone	1.25 mSv integrated on a month	Extremities/skin zone: > 4 mSv per month	Radon zone: > 6 mSv per year
Controlled zone	Specially regulated	Green zone	4 mSv integrated on a month		
Controlled zone	Specially regulated	Yellow zone	2 mSv integrated on one hour		
Controlled zone	Forbidden	Orange zone	< 100 mSv integrated on one hour AND < 100 mSv averaged over a second		
Controlled zone	Forbidden	Red zone	≥ 100 mSv integrated on one hour OR ≥ 100 mSv averaged over a second		

Note 1: *Radiation zones are established in accordance with the risks of internal exposure (through inhalation of airborne contamination and skin transfer)* ***and*** *of direct external exposure, considering that the workplaces are continuously occupied (according to the planned maximum occupancy rate for each workplace). Each zone corresponds to a dose rate range, and has associated time and access conditions. The radiological zoning is based on the most constraining dose criteria: the total effective dose for the whole body* ***or*** *the equivalent doses to the skin or extremities (hands, forearms, ankles and feet)* ***or*** *radon dose.*

Note 2: *Total dose rate is the sum of external dose rate and internal dose rate. Internal dose rate can be calculated, using airborne concentration, as a ratio of "Derived Air Concentration" (DAC) (see definition of DAC in PR1242).*

Note 3: *See Table 7-6.*

Note 4*: See the Safety Roombook [A27] for the radiological zoning allocated to the rooms.*

Table 7-6: Access conditions for personnel

Radiological Zone identification *(Note 4)*	**Required signage** *(Note 3)*	**Access for classified workers** *(Note 2)*	**Access for non-classified workers**
Blue zone or radon / extremities / skin zones	Trefoil sign indicating risk of external exposure (blue)	Permitted to type A and B workers	Specific authorization required from the employer
Green zone or radon / extremities / skin zones	Trefoil sign indicating risk of internal or external exposure (green) *(Note 1)*	Permitted to type A and B workers	Specific authorization required from the employer
Yellow zone or radon / extremities / skin zones	Trefoil sign indicating risk of internal or external exposure (yellow) *(Note 1)*	Limited to only type A and B workers who need to operate in these zones	Specific authorization required from the employer, with additional provisions and information
Orange zone or radon / extremities / skin zones	Trefoils indicating: - risk of external exposure (orange) - risk of internal exposure (orange)	Prohibited except with consultation and special authorization	Prohibited
Red zone or radon / extremities / skin zones	Trefoils indicating: - risk of external exposure (red) - risk of internal exposure (red)	Prohibited except with consultation and special authorization based on a nominative register at every entrance in such zone	Prohibited

Note 1: *Under normal situations, as no detectable atmospheric contamination is permitted in green or yellow zones, the trefoils only indicate the risk of external exposure.*

Note 2: *French regulations classify workers as Type A and Type B and defines specific provisions for non-classified workers, pregnant women, less than 18 years old workers or for exceptional emergency situations. Type A workers include those whose exposure to ionizing radiation may lead to a dose greater than 6 mSv during 12 consecutive months, and Type B workers include those that are not type A and whose exposure to ionizing radiation may lead to a dose greater than 1 mSv during 12 consecutive months. Other constraints on skin, extremities or crystalline apply for workers likely to be exposed.*

Note 3: *The marking (signing) of the radiological zones from blue to red (and for radon/extremities zones) follows the applicable norms (ISO361) and is clearly posted on all access routes to the zones. The marking of the radiological zones is modified according to every change to the zoning.*

Note 4*: See the Safety Roombook [A27] for the radiological zoning allocated to the rooms.*

7.5.1.3 Radiation monitoring

[PR1131-R;Defined Requirement] The dose rate and the level of atmospheric and surface radioactive contamination, in the rooms that are accessible to personnel, shall be monitored using fixed and/or mobile equipment, depending on the potential or proven hazards.

[PR2005-R;Defined Requirement] Personnel exposure to ionizing radiation shall be monitored via a network of detectors that are located in rooms together with, as appropriate, active and passive dosimeters that are worn by the personnel and individual medical surveillance.

[PR1242-I] The personnel access in rooms with airborne radioactive contamination is controlled depending on the level and nature of the potential contamination that would result in workers dose, taking into consideration the effectiveness of personnel protection equipment and any other protection measures put in place. Airborne contamination level in a room is expressed in Derived Air Concentration (DAC). DAC is defined as the airborne concentration that leads to the maximum allowed dose for workers (20 mSv), if breathed during the maximum annual work duration (2000 hours), without any external dose. For tritium only exposure, 1 DAC is equal to 3.4E+05 Bq/m^3.

[PR1243-R;Defined Requirement] Where personnel access is authorized in rooms with airborne radioactive contamination, the airborne contamination level shall be monitored with alarms to:

- Alert the personnel when the room contamination level has reached a specified fraction of the defined DAC limit for that room (usually 10%),
- Evacuate personnel when the room DAC limit is reached.

[PR1132-R;Defined Requirement] Fixed radiation monitoring equipment shall display readings at a central control location, and at points of access to the monitored rooms, so that personnel can assess the radiological status of the rooms before entering.

[PR1253-R;Defined Requirement] The Fixed Area Monitors (tritium-in-air, gamma, neutron, radioactive gas, ^{14}C) shall have a minimum detectable level that is consistent with the radiological zoning for the area.

7.5.2 Workers protection against radioactive and toxic contamination

[PR1504-R;Defined Requirement] Specific design provisions shall be undertaken to avoid that solid, liquid and gaseous toxic products affect workers during normal operations and to avoid spread of these materials into rooms accessible to workers.

[PR1137-R;Defined Requirement] Physical measures (such as interlocks, and wearing of protective clothing) and/or administrative measures (such as warning signs, and sound messages) shall be set up to restrict access to rooms that have atmospheric/surface contamination (in particular radioactive and/or diborane), and/or a dose rate that is higher than the green-zone limit and to take account of temporary changes in the room zoning, in accordance with the operating mode.

[PR1135-R;Defined Requirement] The changing rooms shall be separated in two parts, one for civil clothes, the other for work clothes. Showers and sinks shall be available.

[PR1133-R;Defined Requirement] First confinement systems shall be such that there is no need to wear individual protection equipment in routine operations. The necessity (if any) to wear individual protection equipment in a regulated zone shall be clearly indicated.

[PR2001-R;Defined Requirement] Temporary access areas or changing rooms for workers to put on and remove any protective equipment that is required to protect against internal/external exposure to ionizing radiation or hazardous substances shall be provided, as needed, especially for maintenance operations on ventilation and filtration components. They shall be implemented as close to the working area as possible, and shall include waste collection areas.

[PR2002-R;Defined Requirement] If personnel must enter a zone that is contaminated by radioactive or hazardous substances, they shall wear appropriate personal protective equipment, as required for their protection and to limit the spread of contamination.

[PR1136-R;Defined Requirement] If there is a risk of contamination, the surfaces of habitable room equipment shall be made of materials that are easy to decontaminate.

7.5.3 Workers access to working areas

[PR1252-R;Defined Requirement] Monitoring shall be provided in rooms/areas that are under access control, and shall confirm or override the logic of the Access Control and Security System to allow or deny access, based on actual measured conditions.

[PR1128-R;Defined Requirement] Habitable space shall provide safe ingress and egress paths.

[PR1998-R;Defined Requirement] In event of an emergency, appropriate evacuation routes, and associated auxiliary systems, shall enable the safe evacuation of the personnel. This includes but is not limited to evacuation paths and exits, emergency lighting, and communication and warning systems.

[PR5404-R] For personnel access to the vacuum vessel or cryostat, the temperature shall be maintained in the range authorized by IO Health and Safety.

[PR5416-I] In compliance with the French Labor Code, the size of the corridor for human access is defined according to the type of environment.

[PR5417-R] For non-hostile environment, the passage width shall be at least 800 mm (*Article R4323-12 of the French Labor Code [R49]*).

[PR5418-I] For hostile environment, the *Article R4323-7 of French Labor Code [R49]* applies and the analysis of the references [R39] and [R40] provides the minimum passage width.

[PR5419-R] For hostile environment, the passage width shall be at least 900 mm.

7.5.4 Occupational Health and Safety

[PR2263-I] Occupational Health and Safety (OHS) is related to the prevention or mitigation of all risks of injury or long-term illnesses from workplace exposure to workers (including any visitors on ITER Site), in accordance with the *French Labor Code [R49]*. This includes the worker radioprotection that is specified in Section 7.3, as well as other “non-nuclear” hazards that may affect workers, such as:

- Cryogenic hazards, including oxygen deficiency hazards,
- Explosion risk (hydrogen or other),
- Toxic hazards,
- Fire risk,
- Electrical hazards,
- Laser risk,
- Circulation of and interaction with heavy plant (truck, cranes).

For this, the Hazard Identification and Risk Assessment (HIRA) process is implemented in design phase in order to:

- Identify workplace OHS hazards whose control will impact on ITER systems design and/or operation,
- Assess the level of risk related to these hazards in order to control them.

[PR1444-R] ITER design and operation shall implement:

- Appropriate protection measures to reduce the frequency or the probability of an OHS risks to occur,
- The rules to follow for the design, manufacturing, installation and utilization of equipment in order to protect people and equipment from OHS risks.

[PR1448-R] Information shall be provided on panels at relevant places to inform people about the risks, the individual protection systems needed, the state of the equipment, alarms and other information relevant to OHS.

[PR1438-I] The ITER facility utilizes large quantities of cryogens in the cryoplant and Tokamak areas during operation. Risks include:

- Asphyxiation by displacement of oxygen in the event of large spills,
- Material-behavior changes by contact with cryogens,
- Burns from contact with cryogens,
- Pressurization from rapid expansion of cryogenic gases.

[PR1447-R] Appropriate training shall be mandatory before access to a zone that has cryogenics-related safety risks.

[PR1449-R] The wearing of appropriate individual protection equipment shall be mandatory before accessing an area where there may be non-nuclear safety risks to workers.

[PR2045-R] Oxygen levels in zones/areas that are accessible to personnel, where there is a potential risk of anoxia (like cryogenic installations), shall be monitored, with appropriate alarm systems.

[PR5421-I] Regarding workers protection during maintenance activities, the requirements *PR5417* and *PR5419* applies.

7.5.4.1 *Magnetic zoning*

[PR2043-R] The strength of magnetic fields shall be monitored with fixed and/or portable detectors, as required, with appropriate alarm systems provided (including any electric, magnetic, radiofrequency and electromagnetic fields, static and with varying frequencies).

[PR1378-R] Thresholds and conditions of exposure of workers and the Public to magnetic fields shall be established as per *Tables 7-7 and 7-8*.

[PR1380-R] Magnetic field zones and access and control conditions shall be established as per *Table 7-9*, for each plant operation state.

Table 7-7: Limits for workers exposure to magnetic fields

Frequency (*f*) range *([R49], Art. R4453-3)*	**Limits for workers exposure to magnetic fields *(Note 1)***				
	Sensory effects		**Health effects**		
	Localized head exposure	**Localized limbs exposure**	**Entire body**	**Localized head exposure**	**Localized limbs exposure**
Static field (0 Hz)	2 T	8 T	8 T	-	-
> 0 - ≤ 1 Hz	2 T	8 T	8 T	-	-
1 - < 10 Hz	0.7/f V/m	-	1.1 V/m	-	-
10 - < 25 Hz	0.07 V/m	-	1.1 V/m	-	-
25 - ≤ 400 Hz	0.0028 V/m	-	1.1 V/m	-	-
400 Hz - < 3 kHz	-	-	1.1 V/m	-	-
3 kHz - < 100 kHz	-	-	3.8 10^{-4} f V/m	-	-
100 kHz - < 10 MHz	-	-	3.8 10^{-4} f V/m	10 W/kg	20 W/kg
10 MHz - < 0.3 GHz	-	-	0.4 W/kg	10 W/kg	20 W/kg
0.3 GHz - < 6 GHz	10 mJ/kg	-	0.4 W/kg	10 W/kg	20 W/kg
6 GHz - ≤ 300 GHz	-	-	50 W/m^2	-	-

Notes:

1. *Magnetic fields include any electric, magnetic, radiofrequency and electromagnetic fields, static and with varying frequencies.*
2. *Limits and effects on the body to be considered depending on magnetic field frequency (f):*
   a. *0 - 1 Hz: limits on magnetic flux density for static fields (0 Hz) and on electric field strength for time-varying fields up to 1 Hz to prevent effects on the cardiovascular and central nervous system.*
   b. *1 Hz - 10 MHz: limits on electric field strength to prevent effects on nervous system functions.*
   c. *100 kHz – 6 GHz: limits on SAR to prevent whole-body heat stress and excessive localized heating of tissues (including limit on SA between 0.3 GHz and 6 GHz).*
   d. *10 GHz and 300 GHz: limits on power density to prevent heating in tissue at or near the body surface.*
3. *Magnetic flux density (Tesla): The force that acts on moving charges*
4. *Electric field strength (V/m): The force exerted on a charged particle regardless of its motion in space.*
5. *SAR (W/kg): Specific energy absorption rate averaged over the whole body or over parts of the body.*
6. *SA (J/kg): Specific energy absorption per unit mass of biological tissue.*
7. *Power density (W/m^2): Radiant power incident perpendicular to a surface, divided by the area of the surface.*

Table 7-8: Limits for Public exposure to magnetic fields (0 Hz to 300 GHz)

Frequency (f) range *(1999/519/CE)*	**Magnetic Flux density (mT)**	**Current density (mA/m²) (rms)**	**Whole body average SAR (W/kg)**	**Localized SAR (head and trunk) (W/kg)**	**Localized SAR (limbs) (W/kg)**	**Power density, S (W/m²)**
Static field (0 Hz)	40	-	-	-	-	-
>0 - ≤ 1 Hz	-	8	-	-	-	-
1 - ≤ 4 Hz	-	$8/f$	-	-	-	-
4 – ≤ 1000 Hz	-	2	-	-	-	-
1000 Hz - ≤ 100 kHz	-	$f/500$	-	-	-	-
100 kHz - ≤ 10MHz	-	$f/500$	0.08	2	4	-
10 MHz – ≤ 10 GHz	-	-	0.08	2	4	-
10 - ≤ 300 GHz	-	-	-	-	-	10

Notes:

1. *Same notes as Table 7-7, but replacing electric field strength by current density (A/m²) being the current flowing through a unit cross section perpendicular to its direction in a volume conductor such as the human body or part of it.*
2. *The limit on current density is intended to protect against acute exposure effects on central nervous system tissues in the head and trunk of the body and includes a safety factor. Since it refers to adverse effects on the central nervous system, it may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.*
3. *Refer to 1999/519/CE for guidelines to derive current densities and SAR to be considered in the risk assessments.*

Table 7-9: Magnetic field zones and access conditions

Rules to set-up magnetic zoning for buildings, rooms and areas comprising magnetic fields ***(Note 1)***			
Magnetic Zone Name	**Risks to be managed**	**Threshold**	**Access and control condition for personnel**
Any zone	*See below*	*See below*	Posting safety signs at the entrances to the concerned buildings, fenced premises, rooms/areas (as appropriate).
Interference magnetic zone	Interference with active implanted devices, e.g. cardiac pacemakers	Static magnetic fields ≥ 0.5 mT	Access prohibited for any persons wearing active implanted devices.
Projectile magnetic zone	Attraction and projectile risk in the fringe field of high field strength sources	Static magnetic fields ≥ 3 mT (with source >100 mT)	Measures (temporary/fixed) to be implemented as determined, on a case by case, by the risk assessment.
Controlled magnetic zone	Adverse effects on health of the workers and Public	Magnetic fields < the applicable limit given in Table 7-8 depending on the type of field/effects to be considered	Access prohibited for all Public Access to workers authorized provided: - Workers are suitably trained. - Boundaries are physically delimited (fixed or mobile depending on the situations). - Fixed devices for status warning are implemented.
Prohibited magnetic zone	Adverse effects on health of workers, including adverse sensory effects	Magnetic fields ≥ the applicable limit given in Table 7-7 depending on the type of field/effects to be considered	Access prohibited for all Public and workers
Note 1 - Magnetic fields include any electric, magnetic, radiofrequency and electromagnetic fields, static and with varying frequencies between 0 and 300 GHz.			

7.6 INCONVENIENCIES MANAGEMENT

7.6.1 Environmental monitoring

[PR1246-R;Defined Requirement] The ITER Facility shall include means for monitoring and controlling radioactive and/or hazardous substance releases (gaseous and liquid), as well as dose rates to the Public around the site and in areas that are accessible to site staff as well as the impact of the ITER Facility on the Environment. The necessary provisions will be defined to ensure that ITER meets the related regulatory requirements.

[PR2044-R;Defined Requirement] ITER shall have an environmental monitoring system that is able to operate in cooperation with the CEA site at Cadarache [R23].

[PR1250-R;Defined Requirement] The environmental monitoring system shall monitor levels, to ensure respect of the authorized release limits.

[PR1251-R;Defined Requirement] The Radiological and Environmental Monitoring system shall provide monitoring and warnings for chemical and radiological hazards, and for ionizing radiation fields.

[PR1249-R;Defined Requirement] The release monitoring system shall provide measurement of all the release types (including tritium, beryllium, radiological particulate emissions and effluents, ^{14}C, ^{41}Ar, NO_X, CO, CO_2, SO_2).

7.6.2 Effluents

[PR1427-R;Defined Requirement] All effluents (airborne and waterborne, radioactive and other hazardous substances) shall be identified, and their quantity and characteristics shall be estimated during ITER construction, operation and maintenance.

[PR1428-R;Defined Requirement] Releases of radioactive and other hazardous effluents (airborne and waterborne) shall be kept As Low As Reasonably Achievable (ALARA) and in all cases within design and operational guidelines.

[PR1429-R;Defined Requirement] The Detritiation System shall collect and detritiate Radioactive tritiated gaseous effluents (if needed) so that they can be released ALARA into the Environment, in compliance with the estimated gaseous discharges from ITER normal operation (*2012 RPrS [R08], Volume I, Chapter 10, Section 3.4.3*).

[PR2262-R;Defined Requirement] Fluid effluents shall be monitored, characterized, controlled and discharged per approved procedures.

[PR2072-R;Defined Requirement] Potential liquid effluents that are generated by the fire suppression substances, or a leak of an effluent-bearing system, shall be collected, to prevent dispersion of radioactive or toxic substances.

7.7 WASTE MANAGEMENT

7.7.1 Radioactive and hazardous waste

[PR1436-R;Defined Requirement] Solid radioactive and other hazardous wastes that arise throughout the ITER lifetime (from construction through to decommissioning and dismantlement) shall be identified and their quantity and level of radioactivity and/or toxicity, shall be minimized by design and operation.

7.7.2 Waste zoning

[PR1420-R;Defined Requirement] Waste zones shall be established within the nuclear facilities, and shall include:

- "Radioactive waste zones" (*Zones de Déchets Nucléaires*, ZDN, in French) within which the waste that is produced is liable to be contaminated or activated. This waste consists of very low-level (TFA, in French), low-level (FAVC, in French), intermediate-level (MAVL, in French) as the ITER facility does not generate high-level (HA, in French) waste.
- "Non-radioactive waste zones" (*Zones de Déchets Contrôlés*, ZDC, in French) within which the waste that is produced is not liable to be contaminated or activated.

[PR1424-R;Defined Requirement] Waste from a radioactive waste zone shall be processed in a radioactive management facility.

[PR1425-R;Defined Requirement] Waste from a non-radioactive waste zone shall be processed in a non-radioactive treatment facility.

7.8 Emergency Situation Management

[PR1286-R;Defined Requirement] ITER shall be designed and operated so that it can be brought and maintained in a safe state in case of any incidents/accidents (including postulated combination of situations).

[PR6133-I] Refer to *Sections 6.8.3 and 7.3.3* for ITER Control Room arrangement to manage safety during normal operation and incidents/accidents.

[PR6134-R;Defined Requirement] ITER shall have appropriate facilities to host the crisis management teams, and to provide the systems and services they require to perform their mission in line with the ITER Site Emergency Plans (including communications with ITER control rooms, command posts and, external authorities and organizations).

[PR6135-R;Defined Requirement] The organization of the crisis management facilities shall ensure that the crisis management teams can perform their mission at all times:

- During normal operation of the ITER Facility (including their own maintenance),
- During/after any incidental/accidental events identified for ITER with an autonomy of 72 hours for operationality and habitability without the need for any maintenance (for example fire, earthquake, aircraft crash, loss of off-site power supply, accidental releases of hazardous substances from ITER or outside ITER, malicious acts, etc.).

[PR5428-R] ITER shall comprise an emergency response building, within ITER Restricted Protection Zone (delimited by the ITER High Security Fence and including the INB perimeter), to permit rapid interventions (7d/7d, 24h/24h) in case of unexpected conventional safety and/or security events occurring within this zone.

7.9 Security

[PR1573-R;Defined Requirement] ITER Organization shall guarantee the security of its "Installation Nucléaire de Base (INB)" as defined in French laws and regulations, including the equipment and facilities required for the operation of this installation and its related installations and equipment, during their construction, operation, deactivation, and in providing for decommissioning, in accordance with the *Headquarters Agreement signed between the French Government and ITER Organization [R25]*.

[PR1574-R] Security functions shall be provided to ensure the following security objectives for the ITER plant:

- The safety of persons by ensuring that access to hazardous or potentially hazardous areas is possible only if certain protective conditions are satisfied, and limiting such access to suitably qualified persons,
- The security and protection of the plant from sabotage and access by unqualified personnel,

- The confidentiality of data, designs, other information and materials covered by export control and non-proliferation treaties.

[PR1579-R] The ITER security system shall achieve the security objectives by at least:

- Ensuring that access to controlled zones and equipment is only permitted when local environmental conditions are appropriate,
- Only permitting authorized persons to enter controlled zones,
- Determining who is, or has been at a particular moment, present within controlled zones,
- Ensuring that access to information and documents is controlled and authorized.

[PR1584-R] The security functions shall be supported both by technical systems and by management procedures.

[PR1585-R] Safeguards shall be implemented to guard against the theft of tritium.

[PR1586-R] Information pertaining to areas where tritium is stored, such as the Tritium Plant Building, shall be treated as secure information.

[PR6136-R] ITER shall provide:

- A Security Command Post (SCP) to supervise the security of ITER Site and its facilities, during normal operation and security events during/after which the SCP remains available and operational.
- A Backup Security Command Post (bSCP) to be used in the event of the unavailability of ITER Security Command Post.

8 CONSTRUCTION REQUIREMENTS

8.1 CLASSIFICATION OF SYSTEMS, STRUCTURES, AND COMPONENTS

[PR1456-R] ITER Systems, Structures, and Components (SSC) shall be designed and operated (including qualification, manufacturing, installation, maintenance, preservation, commissioning and testing) in accordance with the requirements imposed by the following classifications :

- For all SSCs:
  - Quality Class (QC), in accordance with *the ITER Quality Classification Determination [R11]*.
  - Investment Protection Class (IPC), in accordance with *ITER Investment Protection Handbook [A31]*.
- For pressure equipment: Equipment Sous Pression class (PED), in accordance with *Codes and Standards for ITER Mechanical Components [A06]*.
- For SSCs that (may) contain tritium and/or are (may come) into contact with tritium: Tritium Class (TC) in accordance with *ITER Tritium Handbook [A16]*.
- For SSCs that are exposed to the Tokamak/cryostat vacuum environment, and/or are part of vacuum systems: Vacuum Class (VQC), in accordance with *ITER Vacuum Handbook [A05]*.
- For SSCs that are designed for maintenance in nuclear environment, and/or that perform nuclear maintenance/radwaste management activities: Remote Handling (RH) class, as defined in *Section 6.14.2*.

[PR1457-I] For safety-related classifications see: *Section 7.1.3* for Safety Important Component (SIC) and Nuclear Pressure Equipment (NPE), *Section 7.4.3* for seismic (SC1/SC2) and Hardened Safety Core (HSCC) classifications, *Section 6.19.1* for Operation Task Class (OTC).

8.2 MATERIALS, PROCESSES, AND PARTS

[PR1463-R] The materials for the ITER Structures, Systems and Components (SSC) shall be selected in accordance with the properties specified in the *Materials Properties Handbook [A21], ITER Vacuum Handbook [A05], ITER Tritium Handbook [A16], Nuclear Radiation Compatibility for Electrical, Electronic and Electromechanical Components [A44]* and *Chemical Impurities document [A25*].

8.2.1 Magnetic materials

[PR1465-R] Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval.

[PR1466-R] The materials and fabrication processes of the in-vessel components shall be selected considering whenever possible the minimization of the error fields.

[PR1467-I] Outside the cryostat, the use of magnetic materials is allowed for the building structural elements.

[PR1468-I] In the Tokamak Building, magnetic materials with high permeability can be used to provide magnetic shielding to Neutral Beam Injection components, electronic components and cooling water components (for example, pump motors) provided error field requirements are met (see *Section 4.1.4.7*).

[PR1470-R] The blanket module materials and manufacturing process shall not modify the average local field in a blanket module by more than 0.1%.

8.2.2 Corrosion prevention and control

[PR2180-R] Materials and their joints which are in contact with fluid shall be selected taking into account their corrosion resistance during ITER lifetime.

[PR1476-R] To prevent corrosion damage of materials in cooling circuits, the appropriate water chemistry shall be established and controlled within specified limits for all modes of operation including commissioning, plasma operation, baking, and hot and cold standby states.

[PR2181-R] The methods for controlling the corrosion behavior during operation shall be established for all systems.

8.2.3 Activation

[PR2182-R;Defined Requirement] Materials which are subject to neutron irradiation shall be selected taking into account their possible activation during ITER operation.

[PR1478-R;Defined Requirement] Depending on operational conditions (such as maximum expected neutron flux and fluence) and allowable dose rate, the requirements for specific impurities in chemical composition of materials which give significant contribution to activation of materials shall be established. These limits on impurities' concentration shall be technically feasible and reasonably achievable. The requirements for limit of impurities are defined in [A25].

[PR2183-R;Defined Requirement] Low activation materials shall be selected when it enables to reduce the contact dose, decay heat and the activation level of radioactive waste, according to reference [A25].

8.3 SPECIFICATIONS, CODES AND STANDARDS

[PR1481-R] ITER mechanical components shall be designed in accordance with the codes and standards identified in the *Codes and Standards for ITER Mechanical Components [A06]* (which includes the *Structural Design Criteria for Magnet [A09] and for In-Vessel Components [A10]*).

[PR1482-R] ITER electrical components shall be designed in accordance with the codes and standards identified in the *Electrical Design Handbook Part 3: Codes and Standards [A07]*.

[PR1483-R] The civil structures of ITER buildings and of site infrastructures shall be designed in accordance with the *ITER Structural Design Code for buildings, Part I: Design Criteria [A11]* and *Part II: Technical Specifications [A12]*.

[PR1484-R] ITER magnets shall be designed in accordance with *ITER Magnet Superconducting and Electrical Design Criteria [A18]*.

[PR1486-R] All ITER Structures, Systems and Components (SSCs) shall be designed, constructed, and operated so that they can perform the functions, and maintain the characteristics/qualities, which are required during normal operation and as needed for Investment Protection. This shall be based on the SSC locations, their functional analysis, and the applicable loads and environmental conditions from the ITER load specifications * :

- *ITER Site Meteorology [A20],*
- *Load Specifications [A14],*
- *Heat and Nuclear Load Specification [A15],*
- *Safety Requirements for ITER Facility Buildings [A22],*
- *Load specification for buildings with safety requirements [A36],*
- *Radiation maps [A26],*
- *Safety Requirement Roombook [A27],*
- *Static and Transient Magnetic Field Maps in Tokamak building [A29],*
- *Load Specification Annex - Internal Explosions: Hydrogen Deflagration in Tokamak Complex [A30],*
- Specific loads from interfacing Structures, Systems and Components, as defined in the applicable interface documentation.

Note *: These specifications shall be complemented at a later stage to cover the ITER Nuclear Maintenance and Radwaste management Facilities.

[PR6137-R] ITER Systems and components shall be constructed and operated (including their maintenance and inspection) in compliance with the zoning requirements of the rooms/areas where they are located, in terms of (as applicable) Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Fire, Waste, and as specified in the zoning documentation for the relevant nuclear facility.

- For the Tokamak Complex:
    - For equipment qualification: *Radiation maps [A26], Magnetic maps [A29]*,
    - For all other zoning: *Safety Roombook [A27]*.
- For Nuclear Maintenance and Radwaste management Facilities: *Yet to be defined*.

8.4 MECHANICAL DESIGN

8.4.1 Assembly sequence

[PR351-I] The assembly sequence is described in the *ITER Assembly Plan [R05]*.

8.4.2 Fabrication and assembly tolerances

[PR353-R] Fabrication and assembly tolerances for ITER components shall be established during ITER design and verified during the fabrication and assembly of ITER components to ensure that ITER can be constructed and operated.

[PR357-R] Position and alignment requirements for ITER coil systems shall be established during ITER design and verified during assembly and commissioning to ensure that:

- ITER can be constructed and operated,
- The error field requirements in *Section 4.1.4.7* can be met.

[PR361-R] Position and alignment requirements for the ITER vacuum vessel and plasma-facing components shall be established during ITER design and verified during assembly and commissioning to ensure that:

- ITER can be constructed and operated,
- The power handling requirements in *Section 4.1.6* can be met.

[PR865-R] The minimum gap between in-cryostat different PBS components shall be 50 mm, unless other value is specified in the relevant System Requirement Documents (SRDs) or Interface Sheets.

8.4.3 Vacuum acceptance leak rates

[PR367-R] All components and system forming a vacuum boundary shall be designed to facilitate leak testing using tracer gas leak detection methods during the construction of ITER.

[PR368-R] Vacuum components shall be acceptance leak-tested prior to delivery to the ITER site, prior to installation, and as part of an installation where it reduces the risk of installing leaking components.

[PR369-R] The air-equivalent leak rate for the total torus vacuum system (including all in-vessel components and attachments) shall be less than 2E-07 $Pa.m^3.s^{-1}$.

[PR370-R] The leak rate for an individual vacuum vessel sector (that is, 40° of the total torus) shall be less than 1E-08 $Pa.m^3.s^{-1}$.

[PR371-R] The leak rate for the completed cryostat (including all in-cryostat components and attachments) shall be less than 1E-04 $Pa.m^3.s^{-1}$.

[PR372-R] Testing methods and principles, and the acceptance leak-rate, for all vacuum components shall be in accordance with the *ITER Vacuum Handbook [A05]*.

[PR2086-R] Vacuum envelopes (that is, any components that form part of the vacuum boundary, including their penetrations) shall be designed and manufactured using appropriate standards and processes to guarantee that sufficient margins exist in all loading conditions.

[PR2087-R] During maintenance operations, appropriate measures shall be taken to protect vacuum envelopes.

[PR2088-R] The failure of a vacuum envelope shall be monitored (by measuring pressure within the envelope), with appropriate alarm systems provided.

8.5 ELECTRICAL DESIGN

[PR1489-R] The design of the earthing and lightning protection systems shall provide a safe environment for personnel and avoid electrical hazards.

[PR1490-R] All surfaces, including bus and cooling lines, which are exposed to the cryostat vacuum shall be connected at the earth point of the Tokamak.

[PR1491-R] All in-vessel components except for active parts and special sensors shall be electrically connected to the vacuum vessel.

[PR1492-R] The vacuum vessel shall be electrically connected to the cryostat via the connecting ducts and cryostat bellows (along with the tube-type penetrations at the lower level of the machine).

[PR1493-R] Magnet structures shall be connected to or insulated from each other in such a way to avoid flowing of large induced currents during plasma operation.

[PR1494-R] The vacuum vessel shall be electrically insulated from the magnet system.

[PR1495-R] For Electromagnetic Compatibility (EMC) considerations, electrical conducting objects within the Tokamak Complex shall be earthed as described in the chapter 8 of the *EDH-Part 4 [A07]*.

[PR1496-R] Coil power supplies shall be capable of being isolated from the earth grid, in order to test for leakage current.

[PR1498-R] To limit the amplitude of the fault current, the earthing system of the coil power supplies (CPSD, PBS41) shall be based on soft/floating earthing with a system for the real-time detection of the first earth fault.

[PR1499-R] Buildings, outdoor structures and power supply components shall be protected by a lightning protection system to avoid transient overvoltage and ensure the proper plant operation.

8.6 ELECTROMAGNETIC COMPATIBILITY

[PR1501-R] As a general requirement for electromagnetic compatibility and shielding, all ITER electrical components shall be designed to comply with IEC 61000.

[PR5304-I] For a few systems, it is not feasible to shield the component and limit its electromagnetic emission within the constraints specified in IEC 61000 therefore deviation from this standard is allowed. Concerned systems are the magnets (with their DC busbars) and Radiofrequency (RF) sources of H&CD systems.

[PR5305-I] For H&CD systems, personal safety limits for radiofrequency (RF) radiations are provided in *Section 7.5*.

[PR1772-R] The components installed near the Tokamak shall withstand the magnetic field generated by the magnets and their DC busbars [A29].

[PR5306-R] Radiofrequency (RF) leakage through vacuum vessel opening and diagnostics windows shall be avoided. In particular any conductive circuit that can pick up radiofrequency power from inside the vacuum vessel shall be properly filtered to avoid RF radiation outside the vacuum vessel.

[PR5307-I] A typical example is the glow discharge system circuits which feature an electrical circuit in the vicinity of the plasma and have insulated feedthroughs and external power circuits that risk radiating high radiofrequency power levels outside the vacuum vessel and disturb cryogenic measurements and diagnostics.

8.7 TRANSPORTABILITY

8.7.1 Maximum component size and weight

[PR1509-R] The limitations in size and weight of the components (including packages and frames) shall be as follows:

- Maximum length: 19 m with an exception for crane beams: 47 m on a single line,
- Maximum width: 9 m,
- Maximum height: 9.1 m,
- Maximum weight: 600 t.

8.7.2 Tritium shipments

[PR1516-R;Defined Requirement] Tritium Shipments shall be in B(U) containers capable of storing not more than 70 g of tritium (B(U) is an IAEA classification for containers qualified for transportation of radioactive material.)

8.8 STANDARDIZATION

[PR1522-R] A standardization policy shall be implemented as much as reasonably acceptable throughout all ITER systems in order to ensure as much interchangeability of similar components as possible, the objective being to reduce the cost of operating and maintaining the ITER machine with a high availability by reducing:

- Complexity of the design,
- Number of required spare parts and associated storage space,
- Number of tools required to repair/adjust/calibrate the components,
- Diversity of skills and training required to operate and maintain the systems,
- Number of procedures required to operate and maintain the systems,
- Complexity of decommissioning, dismantling and recycling operations at the end of the lifecycle of the machine,
- Costs and delays associated with all of the above.

[PR1531-R] Each system shall take into account as a crucial design principle the importance of using interchangeable components inside its own boundaries.

[PR1532-R] Major components being used in sufficient numbers in several systems and/or procured by several ITER Members shall be considered for standardization:

- At least through the definition of standard specifications that are issued in design handbooks in order to assure interchangeability,
- Or, ONLY in specific cases and AFTER prior agreement of the concerned Members, through the suggestion of specific model(s) and supplier(s) in the Procurements Arrangements.

8.9 PRESERVATION

[PR6138-R] From their manufacturing until entering in operation within ITER Facility, all ITER Structures, Systems and Components (SSCs) shall be preserved for Investment Protection. This shall ensure that SSCs retain their required characteristics and performances, including prevention of deterioration over time and protection from external damages, during their shipping, storage, installation, testing, commissioning and maintenance prior to operation.

8.10 QUALIFICATION AND SYSTEMS FUNCTIONAL TESTING

[PR6139-R] All ITER Structures, Systems and Components (SSC) shall be qualified to demonstrate they can perform their allocated functions with the required level of quality and performances. The extent and type of qualification shall be compliant with applicable specifications, codes and standards, and commensurate with the level of risks associated with the SSC role, technological novelty and complexity, etc.

[PR374-R;Defined Requirement] At the end of its construction, each system/sub-system involving active SIC components shall undergo a comprehensive functional testing to verify it operates safely and as expected.

[PR6152-R] In order to mitigate Investment Protection risks, testing and commissioning of the magnet systems shall be performed as far as possible prior to their installation.

8.11 STAGED CONSTRUCTION REQUIREMENTS

[PR6140-R] The ITER Facility and its systems that are built and operational at the end of each assembly phase shall permit to perform the subsequent plasma campaigns, as specified in the relevant *ITER Research Pans Level 2 [A33]*, and the *Staged Approach Configuration - PBS Level 3 [R35]*.

[PR1019-R;Defined Requirement] The ITER Facility and its systems that are built for SRO, and their operation during SRO, shall permit the execution of the maintenance and upgrades foreseen during Post-SRO Assembly (including testing and system's commissioning). In particular, the dose rate within the vacuum vessel shall permit personnel access to perform hands-on in-vessel activities.

[PR6141-R;Defined Requirement] The ITER Facility and its systems that are built for DT-1, and their operation (including maintenance) during DT-1, shall not preclude the foreseen maintenance and (if any endorsed) upgrades required for DT-2. To achieve this,

- All ITER components, which are installed to perform DT-1 and are permanent or cannot be replaced or upgraded shall be constructed and maintained to be able to perform their functions during DT-2.
- Any foreseen maintenance and upgrades of the ITER Facility that must be executed during the Post-DT1 Maintenance phase shall be demonstrated as feasible.

[PR4978-R] There shall be no planned cryostat re-opening after its closure at the end of the pre-SRO Assembly: all in-cryostat components are installed before cryostat closure including permanent maintenance fixtures.

[PR2392-R] Vacuum vessel blank flanges shall be installed for temporary closure where the systems will not be installed; this includes the blank flanges for vacuum vessel ports, Neutral Beams and all the additional ones for the feedthroughs not installed.

[PR2393-R;Defined Requirement] Temporary isolation procedures for SIC components (for example, lock off of temporary openings, waveguides, unused busbars) shall be planned, agreed and safety assessed.

9 DECOMMISSIONING REQUIREMENTS

9.1 ITER DECOMMISSIONING PHASES

[PR1960-R;Defined requirement] At the end of ITER plasma operation, ITER shall be permanently shut down and decommissioned in order to bring the ITER Facility (the entire ITER site/buildings) into the safe state permitting its release, as agreed in *ITER Decommissioning Strategy [A40]*.

[PR6142-I] The ITER decommissioning activities will include:

- Potential upgrades of the existing maintenance and radioactive waste management facilities (or new facilities to be implemented on site) to perform the planned decommissioning efficiently and safely,
- The removal of all residual radioactivity present in all ITER Nuclear Buildings,
- The treatment and packaging of all waste generated by the decommissioning activities to permit (as required) their on-site storage and/or their transfer to 3rd party facilities for interim storage, final treatment and/or disposal,
- Any additional final conditioning of the packaged radioactive waste that are produced during ITER operation & maintenance and stored on-site pending their transfer to 3rd party facilities for interim storage, final treatment and/or disposal,
- Demolition of conventional buildings and site restoration.

[PR6143-I] This decommissioning work will be performed into 2 phases (to be defined in the ITER Decommissioning Strategy [A40]):

- **Phase 1 (called Deactivation at ITER)**: To bring the ITER Facility and Site to the reference state agreed (and updated as needed) with the Host State allowing change of Nuclear Operator (this may include removal of part/all in-vessel components and the decontamination of identified systems, with management of the associated waste).
- **Phase 2**: all remaining decommissioning activities.

[PR310-R;Defined requirement] ITER Organization shall be responsible for completing ITER Decommissioning Phase 1, and the Host State for performing ITER Decommissioning Phase 2. ITER Organization shall work with the Host State to develop the *ITER Decommissioning Strategy [A40]* and Plan.

[PR6144-I] The *ITER Agreement on the Establishment of the ITER Organization [R18]* and the *Headquarter agreement between ITER Organization and Host State [R25]* defines the high commitments for ITER Decommissioning.

9.2 SPECIFIC DECOMMISSIONING REQUIREMENTS

9.2.1 Decommissioning requirements to be implemented in design, construction & operation

[PR6145-I] Decommissioning must be considered as early as possible in ITER Project by implementing the following requirements.

[PR6146-R;Defined Requirement] ITER shall be designed, licensed, constructed, operated and maintained in order to permit its safe and efficient decommissioning, as detailed in the ITER Decommissioning Strategy [A40].

[PR848-R;Defined Requirement] ITER Organization shall develop a plan to put the ITER Facility in a safe, stable condition while it awaits dismantling.

9.2.2 Objectives of ITER Decommissioning Phase 1 (Deactivation)

[PR851-R;Defined Requirement] ITER Decommissioning Phase 1 shall include the reduction of the source term, in order to reach the agreed state of the facility, and the preparation of the handover of ITER Facility to the Host State , as agreed in *ITER Decommissioning Strategy [A40].*

[PR2096-R;Defined Requirement] Removal of activated/radioactively contaminated components from the vacuum vessel and its ports, the NB cell and port cells, if done during ITER Decommissioning Phase 1, shall be performed by remote handling tools used during ITER operational maintenance and Suitably Qualified and Experienced Personnel (SQEP).

[PR849-R;Defined Requirement] During Decommissioning Phase 1, tritium fuel that is present at the end of ITER operations (including any residual tritium that can be recovered) shall be transferred to secure containers, which will be shipped to a 3rd party facility as soon as practical.

[PR850-R;Defined Requirement] During Decommissioning Phase 1, residual radioactive dust - that is present at the end of ITER operations - in the vacuum vessel & its extensions and other radioactively contaminated zones in ITER nuclear facilities (as identified in the agreed ITER Decommissioning Strategy [A40]) shall be recovered with remote handling tools used during ITER assembly and maintenance and by Suitably Qualified and Experienced Personnel (SQEP).

[PR6147-R;Defined Requirement] ITER shall manage (as agreed ITER Decommissioning Strategy [A40]) all radioactive waste and effluents generated during Decommissioning Phase 1 so that it can be safely stored on ITER site until its hand-over to the Host State , and/or transferred to a 3rd party facility for its storage/disposal.

[PR852-R;Defined Requirement] During the ITER Decommissioning Phase 1,

- Systems containing liquids contaminated with activation products and/or tritium shall be drained.
- The drained liquids shall be rendered to a safe, stable form so that they can be released into the environment or solidified as radioactive waste compliant with disposal in French disposal or treatment in 3rd party facility.

[PR853-R;Defined Requirement] During all ITER decommissioning phases, ITER components shall be protected against ageing (including corrosion), to prevent spreading of contamination or unacceptable hazards to the public or workers and to maintain availability in case their use is further required, as agreed in *ITER Decommissioning Strategy [A40].*

[PR847-R;Defined Requirement] ITER Organization shall provide the Host State with all records, "as-built prints", information and equipment pertinent to continue decommissioning after handover of ITER Facility to the Host State.

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