IDM DOCUMENT UID
27ZRW8

DOCUMENT VERSION / STATUS
5.3 / Approved

CHANGE NOTICE LAST INDEX
H

Top Level Project Technical Document

Project Requirements (PR)

Warning: Change Notices apply to this document's version.
Please refer to the Change Notice summary page (next page).

Change Notice summary page

#	Approval date	Justified by	Justification
A	20/08/2014 13:19:14	ETPBA9	ITER Site Signage and Graphics Standards
B	01/09/2014 12:36:57	N4QGT7	Definition of ITER Configuration at end of Phase 1 Assembly
C	13/11/2014 18:10:14	EZFN5L	Transfer of In-Vessel Viewing System (IVVS)
D	27/07/2015 20:41:29	R8XGLQ	Ex PCR-677 Supplement of the Project Requirement document (defining Types of Maintenance Equipment and Maintenance Classes)
E	06/02/2016 22:08:32	RY4SHM	ITER coil circuit polarity definitions
F	07/11/2016 15:09:47	S5M7NM	Chemical composition and impurity requirements for materials (update of Project Requirements)
G	23/08/2017 07:20:06	TWZA2X	Radiation maps update and becoming Annex to PR
H	24/10/2018 21:09:57	VBKUUN	Radiation maps ITER_D_V35THE becoming Annex to PR

The following changes apply to the following document 27ZRW8_v5_3

Change Notice A.WZ59MH. Approved on 20/08/2014 13:19:14
Change 1. Chapter / Section / Paragraph to be changed : N/A
From (old): *Action on IDM* --- **To (new):** Addition of ITER Site Signage & Graphics Standards (4ALJEU) in the references folder.
Change 2. Chapter / Section / Paragraph to be changed : 2.2
From (old): *new reference* --- **To (new):** [R33] ITER Site Signage & Graphics Standards (ITER_D_4ALJEU V2.4)
Change 3. Chapter / Section / Paragraph to be changed : 6.19

From (old):
new paragraphs
--- 	
To (new):
16.19 Site signage requirements
 	
In order to improve safety on the ITER site, all identification, labelling and signage shall be standardised to reduce the likelihood of error.[PRxxx]
Use of signage shall show information in both English and French to reflect the international project culture and its host country. [PRxxx]
 	
Labelling, colour coding, signage and display material at ITER is to serve the following primary functions:
 	
• Health & Safety
• Operational
    o Pipeline Identification
    o Plant Item Tagging
    o Electrical Component Labelling
    o Colours for Electrical Equipment Surfaces
    o Operator Aids
• Way finding
• Information

--- [PRxxx]
All labelling, colour coding and signage installed on the ITER site shall comply with the ITER Site Signage & Graphics Standards [R33]. [PRXXXX-R]

Change Notice B.WZ5KG6. Approved on 01/09/2014 12:36:57
Change 1. Chapter / Section / Paragraph to be changed : 3.3.2 Integrated commissioning
From (old): 3.3.2 Integrated commissioning --- **To (new):** 3.3.2 Integrated Commissioning and First Plasma
Change 2. Chapter / Section / Paragraph to be changed : 3.3.2 Integrated commissioning
From (old): At the end of the first construction period, an integrated commissioning of ITER systems shall be performed, to ensure correct functioning, and to assure readiness for plasma operations. [PR301-R] The production of the First Plasma will occur during this integrated commissioning. [PR1948-I] --- **To (new):** At the end of first construction period, an integrated commissioning of ITER systems shall be performed, to ensure correct functioning, and to assure readiness for plasma operations. [PR301-R] ~~The production of the First Plasma will occur during this integrated commissioning. [PR1948-I]~~ The integrated commissioning shall include a mechanical verification of position, loads, stresses, strains, magnet wedging, vibrations and temperatures under operational conditions. [*PR2382-R*] Demonstration of the successful integration of the tokamak core and principal plant systems shall be by establishing a first plasma of Bt ~ 2.65 T, Ip ~ 100 kA, tplasma ~ 100 ms, H2 and/or He, aided by at least 6 MW ECRH [*PR2383-R*] The following principles apply in the 1st assembly and integrated commissioning phases: [*PR2384-I*] Items should not be deferred that would lead to an unacceptably long 2nd assembly phase. [*PR2385*-P] 1. All installation operations requiring man access into the cryostat shall be executed during first installation phase [*PR2386-R*] Maximise parallel time to install and commission non-1st plasma systems [*PR2387-I*]

Change 3. Chapter / Section / Paragraph to be changed : Add 4.2.11
From (old): *Not present* --- **To (new):** 4.2.11 Requirements Specific to First Plasma Attempt

Change 4. Chapter / Section / Paragraph to be changed : 4.2.11 Requirements Specific to First Plasma Attempt
From (old): [none] --- **To (new):** Section 3.3.2 of the PR defined the aims of the Integrated Commissioning and First Plasma phase [*PR2389-I*]. This will be performed with a minimum hardware installation philosophy and therefore leads to a number of specific requirements [*PR2390-I*] For first plasma the full blanket installation will not be performed, but the Vessel shall be protected against 1MA plasma and runaway beams by sufficient scrape-off limiters. [*PR2391-R*] Temporary blanking shall be listed, planned, supplied and commissioned on all open penetrations to the vacuum boundaries [*PR2392-R*] Temporary isolation procedures (e.g. lock off of temporary openings, waveguides, unused bus-bars etc) shall be planned, agreed and safety assessed. [*PR2393-R*] Minimum cooling systems required for first plasma will be listed, planned and supplied, and other cryostat and vessel pipework shall be dry and isolated before introduction of Magnet cryogenics. [*PR2394-R*] The commissioning of the VVPSS shall be performed before first vessel bake [*PR2395-R*] Neutral Beam, ICRH, and equatorial ECRH will not be required for first plasma. [*PR2396-I*] For first plasma, sufficient diagnostics shall be installed to confirm plasma formation and to monitor machine behaviour. [*PR2397-R*]

Change Notice C.WZ5LYN. Approved on 13/11/2014 18:10:14
Change 1. Chapter / Section / Paragraph to be changed : 3.2.8 Remote handling system (PBS 23)
From (old): The Remote Handling System (RH) performs maintenance operations on the machine components that are classified for remote handling maintenance. [PR129-I] The RH system provides the following capabilities: • In-vessel viewing and metrology • Blanket module handling • Blanket manifold handling • In-vessel coil handling

- Divertor cassette handling
- Port plug handling
- In-vessel component and port plug transfer to/from Hot Cell
- In-vessel component and port plug maintenance and refurbishment in Hot Cell
- Neutral beam maintenance
- Neutral beam duct liner maintenance
- Dust and tritium inventory control
- In-service inspection
- In-vessel diagnostics maintenance
- Leak localization
- Support to the maintenance of type-B radwaste system in the Hot Cell.

--- [PR130-I]

To (new):
The Remote Handling System (RH) performs maintenance operations on the machine components that are classified for remote handling maintenance. [PR129-I]
The RH system provides the following capabilities:

- Blanket module handling
- Blanket manifold handling
- In-vessel coil handling
- Divertor cassette handling
- Port plug handling
- In-vessel component and port plug transfer to/from Hot Cell
- In-vessel component and port plug maintenance and refurbishment in Hot Cell
- Neutral beam maintenance
- Neutral beam duct liner maintenance
- Dust and tritium inventory control
- In-service inspection
- In-vessel diagnostics maintenance
- Leak localization
- Support to the maintenance of type-B radwaste system in the Hot Cell.

--- [PR130-I]

Change Notice D.WZ5RRB. Approved on 27/07/2015 20:41:29
Change 1. Chapter / Section / Paragraph to be changed : 6.15.6 Types of Maintenance Equipment
From (old): N/A --- **To (new):**

Three types of maintenance equipment are required from a viewpoint of the Control Scheme and Man Access into the work area. [PR3078-I]

6.15.5.1 Remote Handling Equipment (RHE)
This type of maintenance equipment is to operate where man access is not allowed, both during normal maintenance operations and rescue operations of the RH equipment. [PR3080-I]
Generally, the RHE is very complex, expensive equipment and its use requires special attention with regards to RH compatibility of the maintained components. Therefore, any request by the system designers for use of RHE for maintenance of a system's components shall be timely and deeply studied, well justified and highly optimized from a viewpoint of project integration, cost and schedule. [PR3081-R]
For information, the ITER RHE is the baseline equipment under the responsibility of PBS 23 "Remote Handling Equipment". [PR3082-I]
Table 6-4a: RHE type of maintenance equipment [PR3083-C]

Control Scheme	Man Access in the work area
Centralized remote control. Specially trained RHE Operator(s) control(s) the equipment remotely from the RH Control Room.	No man access in the work area during any RHE operations, both normal and rescue.

6.15.6.2 Human Assisted Equipment (HAE)
This type of maintenance equipment is to operate where man access is restricted and very limited in time. Therefore, man access is dedicated to completion of complex tasks for a limited amount of time, such as deployment of HAE or rescue operations. [PR3086-I]
One of the essential differences between HAE and RHE is that the HAE is dedicated equipment that is not integrated with any RHE. The HAE could be either off-the-shelf industrial equipment (for example, a robotic arm) or first-of-a-kind equipment developed for ITER. [PR3087-I]
Table 6-4b: HAE type of maintenance equipment [PR3088-C]

Control Scheme	Man Access in the work area
Local remote control. Specially trained HAE Operator(s) control(s) the equipment from a control station/board installed close to the target plant but protected from the direct hazards present in the work area.	Time limited man access during HAE operations. Nominally, the operations are performed without workers in the area. Exceptionally, the presence of workers in the work area could be required for some specific tasks that cannot be done remotely, such as HAE deployment or HAE rescue operations.

6.15.6.3 Hands-on Tool (HTL)
This is the name given to any other maintenance equipment that is not identified as RHE or HAE. [PR3091-I]
Table 6-4c: HTL type of maintenance equipment [PR3092-C]

Control Scheme	Man Access in the work area
Direct control. A well trained Operator controls the tool directly in the work area.	Full time man access during hand-on operations. The operations are performed with workers in the area, according to approved maintenance procedures and with appropriate personal protection.

Change 2. Chapter / Section / Paragraph to be changed : 6.15.7 Maintenance Classification

From (old):
N/A

To (new):
An ITER Maintenance Classification is applicable to any maintenance task that is defined by an ITER Designer or by the ITER Operator. [PR3095-I]
The Maintenance 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]). Therefore, this classification is maintenance environment oriented, and shall be assigned to any maintenance task that is defined by the ITER Designer or ITER Operator. [PR3096-R]
Maintenance tasks are identified from RAMI analysis and Safety Analysis in order to meet the Project's safety and availability requirements. They shall be specified and verified as part of the design process for ITER systems, under the responsibility of their TRO. [PR3097-R]
6.15.7.1 Maintenance Class 1
Maintenance Class 1 (MC1) includes any planned or unplanned maintenance activities that must be performed in environment of radiation exposure and/or radioactive contamination. Such a maintenance environment is expected in the Nuclear Buildings. 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. [PR3099-R]
Maintenance Class 1 shall be associated to any maintenance task which requires use of RHE or HAE. [PR3100-R]
In order to manage the ITER maintenance planning in a proper way, MC1 is divided into three sub-classes as follows:

- Maintenance Class 1-1 (MC1-1) shall be defined for any maintenance task which represents 1% or more of the ITER annual collective radiation dose exposure limit.
- Maintenance Class 1-2 (MC1-2) shall be defined for any maintenance task which is in the range from 0.1% to 1% of the ITER annual collective radiation dose exposure limit.
- Maintenance Class 1-3 (MC1-3) shall be defined for any maintenance task which represents less than 0.1% of the ITER annual collective radiation dose exposure limit.

--- [PR3101-I]
6.15.7.2 Maintenance Class 2
Maintenance Class 2 (MC2) includes any planned or unplanned maintenance activities that must be performed in environment of toxic and/or other hazardous but without risk of radiation exposure or radioactive contamination.
Maintenance Class 2 shall be associated to any maintenance task which is not classified as MC1 and which requires special PPE (Personal Protective Equipment) for workers, such as air suit or breathing mask. [PR3103-I]
In order to manage the ITER maintenance planning in a proper way, MC2 is divided into two sub-classes as follows:

- Maintenance Class 2-1 (MC2-1) shall be defined for any maintenance task which deals with Beryllium and require Beryllium waste management.
- Maintenance Class 2-2 (MC2-2) includes any other MC2 maintenance tasks that are not classified as MC2-1.

--- [PR3104-I] *6.15.7.3 Maintenance Class 3* Maintenance Class 3 (MC3) includes any planned or unplanned maintenance activities that are not classified as MC1 or MC2. [PR3106-I]

Change Notice E.WZ5S9U. Approved on 06/02/2016 22:08:32
Change 1. Chapter / Section / Paragraph to be changed : 4.3.2.2 Toroidal field and plasma current direction
From (old): The reference directionality of the toroidal current and field shall be as follows: plasma current in the clockwise direction looking from above with the same direction for the toroidal field, giving a downward (towards divertor X-point) ion grad-B drift direction (see Figure 4-4). [PR464-R] <hr>**To (new):** 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 4-4). [PR464-R]. This is in the opposite (i.e. negative) direction with respect to the toroidal direction as given by the ITER standard co-ordinate system.
Change 2. Chapter / Section / Paragraph to be changed : C2
From (old): 2.1 PR Annex documents, under configuration control <hr>**To (new):** Add reference to the new PR Annex on: ITER Toroidal Coordinate System and Coils Polarities. [A24] ITER Coordinate System and Coils Polarities (QRUDS6 v1.1)

Change Notice F.WZ5UT7. Approved on 07/11/2016 15:09:47
Change 1. Chapter / Section / Paragraph to be changed : 2.1 PR Annex documents, under configuration control
From (old): *Add new Annex document* <hr>**To (new):** [A24] Chemical composition and impurity requirements for materials (ITER_D_REYV5V v2.3)
Change 2. Chapter / Section / Paragraph to be changed : 8.2.5 Activation

From (old):
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. [PR1478-R]

To (new):
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 [A24].
[PR1478-R]

Change Notice G.X2957D. Approved on 23/08/2017 07:20:06

Change 1. Chapter / Section / Paragraph to be changed : 8.11/PR1549

From (old):
Qualification testing to verify the acceptability of a specific design will be conducted

in accordance with approved procedures that address, at a minimum:

- Use of adequate instrumentation
- Provisions for test monitoring
- Specification of suitable environmental conditions
- Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment
- Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions
- Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.

To (new):
Qualification testing to verify the acceptability of a specific design will be conducted

in accordance with approved procedures that address, at a minimum:

- Use of adequate instrumentation
- Provisions for test monitoring
- Specifications of suitable environmental conditions. For radiation conditions for

personnel, refer to the zoning mentioned in chapter 7.9.2. For radiation conditions for equipment not participating to shielding function, refer to the radiation maps [A26]. • Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment • Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions • Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.
Change 2. Chapter / Section / Paragraph to be changed : 2.1 PR Annex documents
From (old): --- **To (new):** *Add:* [A26] ITER Radiation Maps: - During DT plasma operations (Mode 0) : Radiation Maps During Plasma Operations (Mode-0) (ITER_D_RJLLFY v2.1) - During cask movements (Mode 2) : ITER Radiation Maps: Subtask 3 report (F8UEXR v1.0); ITER Radiation Maps: Subtask 4 report (67CN24 v1.1); ITER Radiation Maps: Subtask 5 report (HPX254 v1.0)

Change Notice H.X298RD. Approved on 24/10/2018 21:09:57
Change 1. Chapter / Section / Paragraph to be changed : 8.11/PR1549
From (old): Qualification testing to verify the acceptability of a specific design will be conducted in accordance with approved procedures that address, at a minimum: • Use of adequate instrumentation • Provisions for test monitoring • Specification of suitable environmental conditions. For the environmental conditions refer to the relevant zonings, and for radiation conditions for equipment refer to the radiation maps [A26] • Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment • Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions • Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.

To (new):
Qualification testing to verify the acceptability of a specific design will be conducted in accordance with approved procedures that address, at a minimum:

- Use of adequate instrumentation
- Provisions for test monitoring
- Specifications of suitable environmental conditions. For radiation conditions for personnel, refer to the zoning mentioned in chapter 7.9.2. For radiation conditions for equipment not participating to shielding function, refer to the radiation maps [A26].
- Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment
- Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions
- Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.

Change 2. Chapter / Section / Paragraph to be changed : 2.1 PR Annex documents

From (old):
[A26] ITER Radiation Maps:

- During DT plasma operations (Mode 0) : Radiation Maps During Plasma Operations (Mode-0) (ITER_D_RJLLFY v2.1)
- During Maintenance (Mode 1) : Mode 1 Radiation Maps (ITER_D_V35THE v2.3)
- During cask movements (Mode 2) : ITER Radiation Maps: Subtask 3 report (F8UEXR v1.0); ITER Radiation Maps: Subtask 4 report (67CN24 v1.1); ITER Radiation Maps: Subtask 5 report (HPX254 v1.0)

To (new):
[A26] ITER Radiation Maps:
- During DT plasma operations (Mode 0) : Radiation Maps During Plasma Operations (Mode-0) (ITER_D_RJLLFY v2.1)
- During Maintenance (Mode 1) : Dose rate contribution of activated components and structures during mode 1. (ITER_D_V35THE **v2.4**)
- During cask movements (Mode 2) : ITER Radiation Maps: Subtask 3 report (F8UEXR v1.0); ITER Radiation Maps: Subtask 4 report (67CN24 v1.1); ITER Radiation Maps: Subtask 5 report (HPX254 v1.0)

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02 Apr 2014 / 5.3 / Approved

EXTERNAL REFERENCE

Top Level Project Technical Document

Project Requirements (PR)

The Project Requirements (PR) document contains the ITER project-level technical requirements. The PR provides those requirements needed to establish the suitability of the ITER design for its mission. It is subsidiary to the Project Specification (PS), which gives mission requirements and constraints at the Council level (input to ITER Organization). The technical requirements in the PR are allocated and flow down to ITER systems for inclusion in System Requirements Documents (SRDs).

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Chiocchio S.**	**02 Apr 2014:signed**	**IO/DG/DIP/CCD**
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	Sands D.	**23 Apr 2014:recommended**	**IO/DG/SQS/QA**
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	Thomas P.	**15 Apr 2014:recommended**	**IO/DG/DIP/CHD**
	Watson T.	**22 Apr 2014:recommended**	**IO/DG/DIP/BSI**
Approver	**Motojima O.**	**24 Apr 2014:approved**	**IO/DG**
Document Security: level 1 (IO unclassified) *RO: Croset Jean-Philippe*			
Read Access	**LG: Blanket add right persons, LG: IO Cryogenic Section All, GG: In-kind Management Administration, LG: EED section leaders, LG: CEP-DDG, LG: MQP, LG: Integration Approach Panel Additional Read Access, LG: 2009 Integration Approach Review Panel Members, LG: 2009 Integration Approach Review WRITE acc...**		

Change Log				
Title (Uid)	***Version***	***Latest Status***	***Issue Date***	***Description of Change***
Project Requirements (PR) (27ZRW8_v5_3)	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
Project Requirements (PR) (27ZRW8_v5_2)	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.
Project Requirements (PR) (27ZRW8_v5_1)	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.
Project Requirements (PR) (27ZRW8_v5_0)	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
Project Requirements (PR) (27ZRW8_v4_6)	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)
Project Requirements (PR) (27ZRW8_v4_5)	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.
Project Requirements (PR) (27ZRW8_v4_4)	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)
Project Requirements (PR) (27ZRW8_v4_3)	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)
Project Requirements (PR) (27ZRW8_v4_2)	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)
Project Requirements (PR) (27ZRW8_v4_1)	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.
Project Requirements (PR) (27ZRW8_v4_0)	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.
Project Requirements (PR) (27ZRW8_v3_2)	v3.2	Signed	08 Jul 2009	Revised version ready for formal review (v45 on Wayne's PC)
Project Requirements (PR) (27ZRW8_v3_1)	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

Project Requirements (PR) (27ZRW8_v3_0)	v3.0	In Work	17 Apr 2009	
Project Requirements (PR) (27ZRW8_v2_11)	v2.11	Signed	27 Nov 2008	
Project Requirements (PR) (27ZRW8_v2_10)	v2.10	In Work	13 Oct 2008	Updated April-Sept 2008, expect signature Late 2008
Project Requirements (PR) (27ZRW8_v2_9)	v2.9	Signed	02 Sep 2008	Updated April-Sept 2008, expect signature Late 2008
Project Requirements (PR) (27ZRW8_v2_8)	v2.8	Signed	20 Aug 2008	Updated April-Sept 2008, expect signature Late 2008
Project Requirements (PR) (27ZRW8_v2_7)	v2.7	Signed	04 Aug 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_6)	v2.6	Signed	29 Jul 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_5)	v2.5	Signed	29 Jun 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_4)	v2.4	In Work	20 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_3)	v2.3	In Work	07 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_2)	v2.2	In Work	06 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_1)	v2.1	In Work	02 May 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v2_0)	v2.0	In Work	29 Apr 2008	2007 Baseline, Updated April 2008, expect signature June 2008
Project Requirements (PR) (27ZRW8_v1_1)	v1.1	In Work	24 Oct 2007	2007 Baseline
Project Requirements (PR) (27ZRW8_v1_0)	v1.0	In Work	23 Oct 2007	2007 Baseline

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1 Introduction

1.1 Purpose

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 in the Project Specification (PS) document [R01]. [PR4-I]

The PR establishes the technical baseline for the ITER project. [PR1885-I]

The PR provides a common basis for the development of the System Requirements Documents (SRDs) for the ITER systems. [PR2075-I]

The technical requirements that are in the PR are allocated and flow down to the ITER systems for inclusion in the System Requirements Documents (SRDs). [PR1893-I]

1.2 Scope

1.2.1 Control and revision

The PR shall be approved by the Director-General. [PR6-R]

Once approved, changes to the PR shall be controlled in accordance with the ITER Project Change Procedure [R10]. [PR1886-R]

1.2.2 Relationship to other project documents

1.2.2.1 Precedence

The PR shall meet the overall requirements that are specified in the ITER Project Specification [R01]. [PR30-R]

The performance requirements and the Design constraints in the PR shall be applied to all ITER systems. [PR31-R]

In addition to the PR, specific criteria and specifications shall be developed to satisfy the needs for a particular system, and these are provided in the System Requirement Documents. [PR2-R]

It is recognized that organizations that have responsibilities for systems planning, design, and construction may establish and apply more comprehensive criteria to satisfy their particular mission. [PR32-P]

There is no intent that the PR takes precedence over additional criteria, where those criteria meet or exceed the PR requirements. [PR2076-I]

If there exists a conflict between additional criteria and the PR, the PR should take precedence over those criteria. [PR33-P]

1.2.2.2 Project Specification document

The Project Specification document [R01] records verbatim, or points to the relevant texts, where the Parties to the Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project specify the scope of ITER, and lay down the constraints. The PS, therefore, represents the starting point for the development of the project and system requirements. [PR35-I]

1.2.2.3 Configuration Management Model and Site Master Plan

ITER Organization shall assure consistency among all project components. [PR38-R]

ITER Organization shall establish three-dimensional (3D) CAD models that make up the "Configuration Management Model" (CMM) [A03] which represents the geometry of the components in the facility. [PR1894-R]

The CMM is used to assure that interferences do not exist, and that the facility can be assembled and maintained as designed, taking into account tolerances, assembly operations, and operational movements. The CMM also defines envelopes for routing services to the tokamak for plant systems. [PR1895-I]

The CMM imposes design constraints for the design of the equipment that is within the facility. [PR1896-I]

The Site Master Plan [A13] defines the footprints of the civil structures within the site boundary. [PR39-I]

The Site Master Plan imposes design constraints for buildings and site infrastructures. [PR40-I]

1.2.2.4 Plant Description document

The Plant Description (PD) document [R02], summarises the design of the ITER site, systems, materials, and the nuclear safety approach. [PR43-I]

The PD outlines the physics and fusion analysis, and the expectation to satisfy the principal physics and technology missions of the ITER project. [PR42-I]

Annexes of the PD provide the results of assessments and verifications that are applicable to the plant as a whole. [PR1897-I]

The PD is updated during the life of the project on request of the ITER Director General. [PR1898-I]

However, the PD is not kept updated to be always consistent with all changes that are implemented in the baseline documentation, and it shall not be used as a reference document for any safety or quality related activity. [PR1899-R]

1.2.2.5 System Requirements Documents

The System Requirements Documents (SRDs) are the development specifications for the ITER systems. Each SRD provides those requirements that are needed to establish the suitability of the system (or sub-system) for its intended purpose. [PR45-I]

A listing of the PBS level-1 SRDs, sorted by PBS element, is provided in **Table 3-2**. [PR1900-I]

The PR, the CMM [A03], and the Site Master Plan [A13], provide the performance requirements and design constraints for developing all SRDs. [PR1901-I]

In all cases, PR requirements have precedence over the SRD requirements. [PR2077-I]

The SRDs are configuration-managed [R10]. [PR1902-I]

1.2.2.6 Safety Files

The RPrS [R08] (the Rapport Préliminaire de Sûreté) is the preliminary safety report that is used in the licensing process with the French regulatory authorities. The RPrS has been developed based on the design that was presented at the 2001 FDR, as modified by changes that have been approved in Technical Coordination Meetings between February 2002 and November 2007 and in approved Project Change Requests (PCRs) thereafter, and which have been incorporated in the 2010 ITER baseline. [PR47-I]

Safety requirements listed in the RPrS have been explicitly incorporated in the PR to ensure that they are propagated to all ITER systems, and that changes in the ITER design do not undermine the safety basis of the facility as documented in the RPrS. [PR1904-I]

Since the publication of the Decree for the ITER INB creation authorization (9 November 2012) [R31], this decree is the top level safety requirement document for ITER. [PR2372-I]

The ASN Decision 2013-DC-0379, dated 12 November 2013 [R32], establishes the prescription for the design and the construction of the licensed nuclear facility INB No. 174 called ITER. [PR2373-I]

1.3 Definitions

1.3.1 Structure of the document

The PR is structured in ten chapters. [PR8-I]

The first chapter is entitled *Introduction*, and includes: the use; control and revision; structure; terminology, conventions, and units; and relationship to other project documents. [PR1887-I]

The second chapter is entitled *Applicable documents*, and lists all documents that are referenced in the PR. [PR9-I]

The third chapter is entitled *Project description*, and provides a list of the ITER systems, and identifies their main functions. It also introduces the project functions. [PR10-I]

Plant requirements are contained in Chapter 4 through to Chapter 9:

- The fourth chapter (*Performance requirements*) identifies the project requirements, organized following the sequence of project functions that are defined in Chapter 3
- The fifth chapter (*Layout requirements*) provides the requirements and overall constraints that result from the selection of the ITER concept (as represented by the top-level drawings and models)

- The sixth chapter (*Operational requirements*) provides requirements that are related to the operation and maintenance of the plant
- *Environmental and safety requirements* are given in Chapter 7
- *Construction requirements* are provided in Chapter 8.

--- [PR11-I]

The ninth chapter contains additional requirements that are linked to project functions, such as requirements on the documentation, and access policy. [PR18-I]

The last chapter contains the appendices, such as the list of the abbreviations that are used in the text. [PR19-I]

1.3.2 Terminology, conventions, and units

Use of the words “system", "project", "facility” and "plant". In this PR, the top-level entity is referred to as the project or facility. The project or facility is comprised of systems that are comprised of sub-systems. [PR25-I]

The term Plants, or Plant Systems, is used in the PR with the same meaning as systems; in particular, for fluidic systems such as cryoplant, and tritium plant. [PR1888-I]

Use of the words “shall”, “should”, “may”, and “will”. The words “shall”, “should”, “may”, and “will” have the following specific meanings in the context of this document: "shall" is used wherever a provision is mandatory (it is a *Requirement*); "should" is used wherever it is necessary to express recommended provisions, and “may” is used to express allowed provisions (both are treated as *Potentialities*); "will" is used to express a declaration of purpose. It may also be necessary to use "will" in cases where the simple future tense is required. [PR21-I]

Use of the terms TBD and TBC. Within this document, the term “to be determined” (TBD) applied to a missing or incomplete requirement infers that additional effort (such as analysis, and trade studies) is required before the requirement can be completely specified. The term “to be confirmed” (TBC) implies that the requirement may be reviewed for appropriateness by the Project, and changed during the course of project development. [PR22-I]

Abbreviations and acronyms. Abbreviations and acronyms are used consistently throughout, without definition. A glossary of such abbreviations and acronyms can be found in Section 10.1. An on-line abbreviation dictionary is available on the ITER Technical Web site. [PR23-I]

The master of the PR is stored in the ITER requirements database. [PR1813-I]

Each element of the PR (paragraph, chapter heading, section heading, table heading, figure heading, table, figure, or footnote) has a unique and permanent identifier. [PR1889-I]

Each paragraph of the PR is then classified as being either a *Requirement*, a *Design constraint*, a *Potentiality* or *Information*. In the version that is uploaded to IDM, the paragraph identifier, and its classification (R, D, P or I), is indicated at the end, in square brackets. (For example, this paragraph has the identifier PR1890, and is for information). [PR1890-I]

Performance requirements state what functions the facility has to perform, and how well those functions have to be performed. [PR26-I]

Design constraints are a set of limiting or boundary requirements that must be adhered to while allocating requirements or designing the facility. They are drawn from externally imposed sources (for example, statutory regulations) as well as from internally imposed sources as a result of prior decisions that limit subsequent design alternatives [PR1891-I]

Units. SI (System International) units and derived units are used throughout the ITER project design and procurement. [PR24-I]

2 Applicable and reference documents

Section 2.1 lists the documents that are annexed to the PR, and that must be considered as an integral part of this PR, thus subject to the same change control procedure and approval level as the PR, in accordance with the ITER Project Change Procedure [R10]. [PR50-I]

Section 2.2 lists the documents that are referred to by the PR. With the exception of the first three, these documents are under version control. [PR51-I]

Section 10.2 summarises the changes that have been made to the documents that are listed in **Sections 2.1 and 2.2**. [PR2277-I]

In the current version of the document list, the following changes have been introduced since PCR-200:

- Table 2-1 has been split into Sections 2.1 and 2.2
- The version number of each document has been added.

--- [PR2276-I]

2.1 PR Annex documents, under configuration control

[A01] Y. Gribov et al, "CS and PF coils data and requirements to separatrix positioning for analysis of ITER plasma equilibria and poloidal field scenarios" (ITER_D_2ACJT3 V3.1)

[A02] ITER Plant Control Design Handbook (ITER_D_27LH2V V7.0)

[A03] Configuration Management Model (ITER_D_2EGQKE V1.7)

[A04] ITER Coordinate Systems (ITER_D_2A9PXZ V3.7)

[A05] ITER Vacuum Handbook (ITER_D_2EZ9UM V2.3)

[A06] Codes and Standards for ITER Mechanical Components (ITER_D_25EW4K V4.0)

[A07] Electrical Design Handbook, vol. 1 -5 (ITER_D_2F7HD2 V1.4, ITER_D_2E8QVA V1.4, ITER_D_2E8DLM V1.3, ITER_D_4B523E V3.0), ITER_D_4B7ZDG V3.0)

[A08] ITER Operations Handbook, vol. 2 (ITER_D_2LGF8N V1.3)

[A09] Magnet Structural Design Criteria, vol. 1 - 4 (ITER_D_2FMHHS V2.0, ITER_D_2ES43V V2.0, ITER_D_2FKTTG V2.0, ITER_D_2FDCA3 V2.0)

[A10] In-vessel Components, SDC-IC (Structural Design Criteria for ITER In-vessel Components) (ITER_D_222RHC V3.0)

[A11] ITER Structural Design Code for Buildings, Part I: Design Criteria (ITER_D_283B24 V2.10)

[A12] ITER Structural Design Code for Buildings, Part 2: Construction (ITER_D_2E2U9X V2.0)

[A13] ITER Site Master Plan (ITER_D_27X5FM V3.1)

[A14] ITER Load Specifications (ITER_D_222QGL V6.0)

[A15] Heat and Nuclear Load Specifications (ITER_D_2LULDH V2.3)

[A16] ITER Tritium Handbook (ITER_D_2LAJTW V1.4) under version control

[A17] ITER Remote Maintenance Management System (ITER_D_2FMAJY V1.6)

[A18] ITER Magnet Superconducting and Electrical Design Criteria (ITER_D_22GRQH V1.2)

[A19] Contents of PF scenario database (ITER_D_34263N V2.0)

[A20] ITER Site Meteorology (ITER_D_2UT36S V1.0)

[A21] ITER Materials Properties Handbook - Introduction (ITER_D_2NRCSB V1.3)

[A22] Safety Requirements for Buildings (ITER_D_2E4KSJ V3.6)

[A23] Safety Important Functions and Components Classification Criteria and Methodology (ITER_D_347SF3 V1.8) under version control

2.2 List of reference documents

[R01] ITER Project Specification (ITER_D_2DY7NG V2.0) under configuration control

[R02] ITER Plant Description (ITER_D_2X6K67 V1.1) under configuration control

[R03] ITER Plant Breakdown Structure (ITER_D_28WB2P V2.0) under configuration control

[R04] ITER WBS Dictionary (multiple files, ITER_D_2FTRRV)

[R05] ITER Assembly Plan (ITER_D_2263T6 V1.0)

[R06] Design Integration and Configuration Control Responsibilities for buildings/Areas on ITER Site (ITER_D_2F6ZKF V1.4)

[R07] ITER Research Plan (ITER_D_2FB8AC V2.0)

[R08] ITER INB Preliminary Safety Report (English version) (ITER_D_3ZR2NC V3.0)

[R09] ITER Plasma Performance Assessment (ITER_D_22HGQ7 V3.0)

[R10] ITER Project Change Procedure (ITER_D_22F4E5 V6.4)

[R11] ITER Quality Classification Determination (ITER_D_24VQES V4.1)

[R12] ITER Seismic Nuclear Safety Approach (ITER_D_2DRVPE V1.6)

[R13] ITER RAMI Analysis Program (ITER_D_28WBXD V4.3)

[R14] ITER Configuration Management Plan (ITER_D_27LHHE V1.11)

[R15] ITER Design Review Procedure (ITER_D_2832CF V3.1)

[R16] ITER Management and Quality Program (ITER_D_2NS3UH V1.2)

[R17] Requirement Allocation Document (ITER_D_2W3SFF V1.1)

[R18] Agreement on the Establishment of the ITER Organization (also called ITER Agreement) (ITER_D_2EW6RK v1.1)

[R19] ITER Remote Handling Code of Practice (ITER_D_2E7BC5 V1.2)

[R20] Static and Transient Magnetic Field Maps in Tokamak Building (ITER_D_3BQBVY V2.0)

Additional references added in PR 5.0:

[R21] Load Specification Annex - Internal Explosions: Hydrogen Deflagration in Tokamak Complex (ITER_D_BMQ9XM V2.0)

[R22] The ITER Human Factor Integration Plan (ITER_D_2WBVKU V2.0)

[R23] Site Support Agreement (ITER_D_2VU589 V1.0)

[R24] MQP Policy for ITER Investment Protection (ITER_D_3VUMVW V4.1)

[R25] Agreement between the Government of the French Republic and the ITER International Fusion Energy Organization (ITER_D_29P59M V1.0)

[R26] Y.R. Martin and T. Takizuka [J Phys: Conf Ser 123 (2008).

[R27] Experimental studies of ITER demonstration discharges, A C C Sips et al, Nucl. Fusion 49 085015 (2009)

[R28] Development of ITER 15MA ELMy H-mode Inductive Scenario, C. E. Kessel et al, Nucl. Fusion 49 085034 (2009)

[R29] Etude d'impact - Partie 1: Analyse de l'état initial du site et de son environnement (ITER_D_7A7RDB V1.0)

[R30] Order dated 7 February 2012 relating to the general technical regulations applicable to INB (ITER_D_7M2YKF V1.6)

[R31] Decree No. 2012-1248 dated 9 November 2012 authorising IO to create a basic nuclear facility called «ITER». (ITER_D_CZK7M5 V1.1)

[R32] ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the design and construction of the licensed nuclear facility INB No. 174 called ITER. (ITER_D_MU6PP3 v1.0)

3 Project description

3.1 General description of the ITER tokamak

As specified in the PS [R01], ITER is a long-pulse tokamak with elongated plasma and single null poloidal divertor. [PR1905-I]

During nominal inductive operation, ITER shall produce a D-T fusion power of 500 MW, for a burn length of 450 s, with the injection of 50 MW of auxiliary power. [PR54-R]

Reference tokamak parameters are provided in **Table 3-1**. [PR1906-I]

Table 3-1: Reference plasma parameters

Total fusion power	500 MW
Total fusion power (short pulse)	700 MW
Q - fusion power/additional heating power	>= 10
Average 14MeV neutron wall loading	> 0.5 MW/m^2
Plasma inductive burn time	450 s
Plasma major radius (R)	6.2 m
Plasma minor radius (a)	2.0 m
Plasma current (I_p)	15 MA
Vertical elongation @ 95% flux surface Vertical elongation @ separatrix (κ_{95})	1.70 1.85
Triangularity @95% flux surface Triangularity @separatrix (δ_{95})	0.33 0.49
Safety factor @95% flux surface (q_{95})	3
Toroidal field in vacuum @6.2 m radius (B_t)	5.3 T
Plasma volume	816 m^3
Plasma surface area	680 m^2
auxiliary heating/current drive power	73 MW
Peak power to remove from ITER Site	1200 MW

A cut-away view of the ITER tokamak is provided in **Figure 3-1**. The magnet system provides a magnetic confinement shaping and control of the plasma inside the torus shaped vacuum vessel. [PR56-I]

Inside the vacuum vessel, the internal components (and their water content), including blanket modules, divertor cassettes, glow discharge cleaning electrodes, in-vessel coils, and port-mounted components (such as heating antennas, test blanket modules, and diagnostics modules) absorb radiated heat and neutrons from the plasma, and protect the vessel and magnet coils from excessive neutron radiation. [PR57-I]

The heat that is deposited in the internal components, and in the vacuum vessel, is rejected to the environment by means of the Cooling Water System (CWS). The CWS is also employed to bake, and consequently clean, in conjunction with the vacuum pumping system, the plasma-facing surfaces that are inside the vacuum vessel, by releasing trapped impurities. [PR58-I]

The entire tokamak is enclosed in a cryostat, with thermal shields between the hot components and the cryogenically-cooled magnets. [PR1907-I]

The main assumptions for the ITER design consider that:

- The centering force that acts on the D-shaped TF coils is reacted by these coils by wedging in the vault that is formed by their straight sections. The TF coil windings are enclosed in strong cases that are used, also, to support the external PF coils.
- The out-of-plane forces on the TF coils are taken up by the wedging and the inter coil structures.
- The vacuum vessel is a double-walled structure that is directly supported via the lower ports by the cryostat pedestal ring.
- The magnet system is supported by gravity supports, one beneath each TF coil.

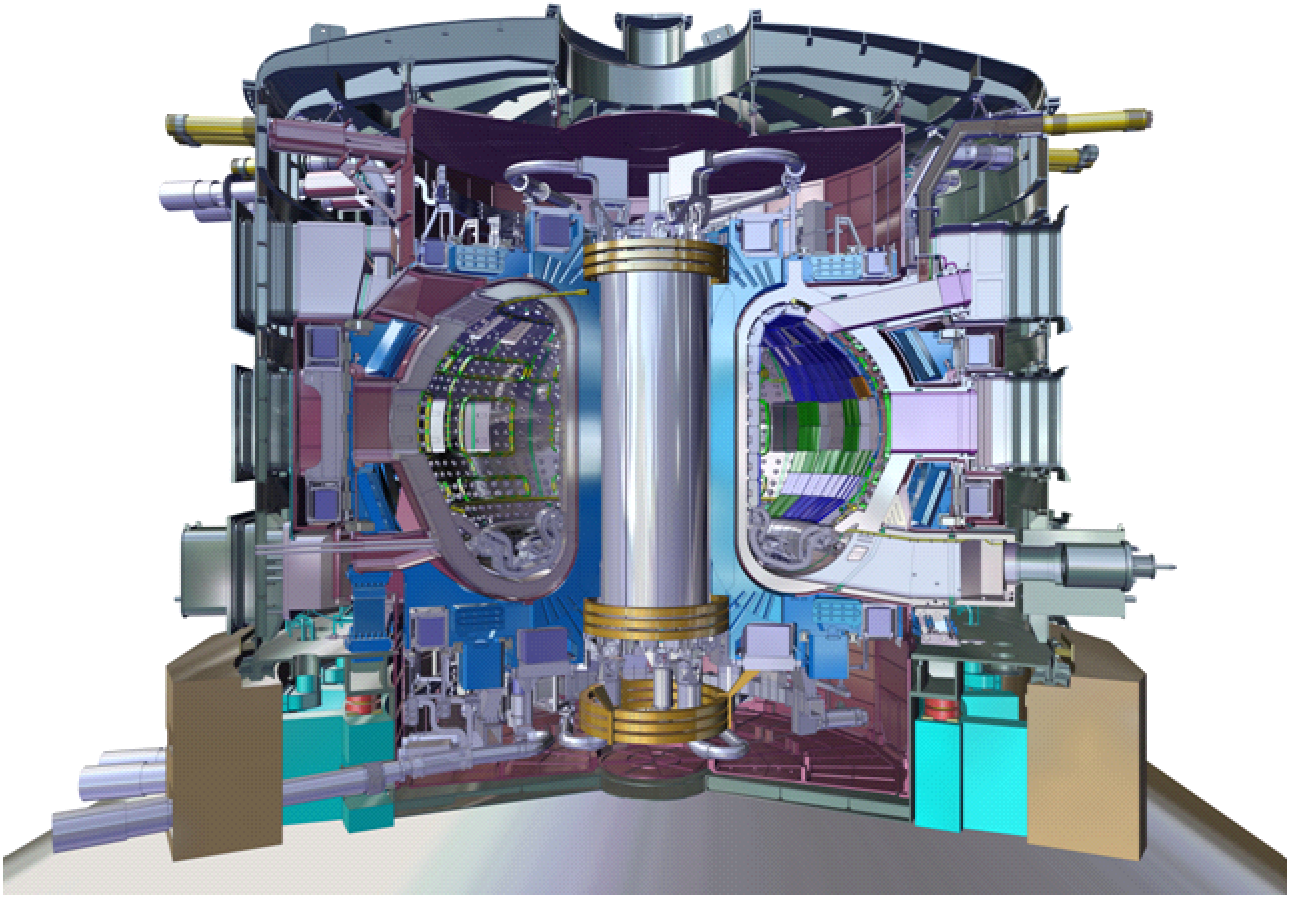
--- [PR1909-I]

The inductively-driven pulse has a nominal burn duration of 450 s, with a pulse repetition period as short as 1800 s. [PR1912-I]

With non-inductive current drive from the Heating and Current Drive systems, the burn duration will be extended to 3000 s. [PR1913-I]

The integrated plasma control is based on feedback from diagnostic sensors, and will act on the PF system, the pumping, fuelling (H, D, T, He and impurities such as N_2, Ne and Ar), and heating systems. [PR1914-I]

Figure 3-1: Cut-away view of the tokamak



ITER will be constructed at a new facility near CEA Cadarache near St. Paul lez Durance, France. Major buildings to be constructed include:

- Tokamak Complex comprising the Tokamak Building (B11), the Tritium Plant Building (B14) and the Diagnostic Building (74)
- Hot Cell Building (B21)
- Radwaste Building (B23)
- Personnel Access Control Building (B24)
- Laydown, Assembly Building (B13) and RF Heating Building (B15)
- Control Building (B71), equipped with centralized control systems for the entire ITER basic nuclear installation
- Utility-related buildings (such as electric utilities, and fluid utilities).

--- [PR61-I]

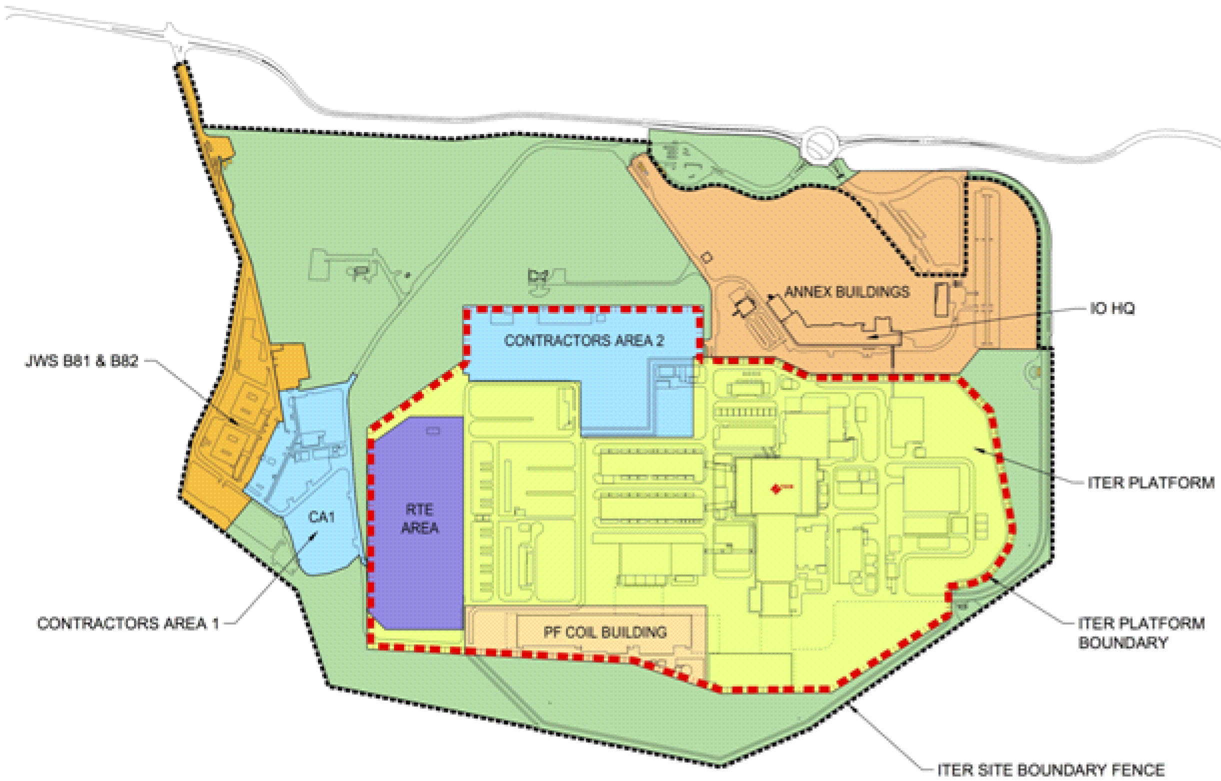
The ITER Site comprises:

- INB Area: defined as the area comprised within the perimeter of the Nuclear Installation (Installation Nucléaire de Base)
- ITER Platform: defined as the levelled area that is within the ITER Site, comprising the INB Area, the PF Coil Fabrication Building (B55), the R.T.E. Switchyard Area (B48), the ITER electrical switchyard and Contractors Area Number 2

- Site Outside Platform.

Figure 3-2 shows the various part of the ITER site. [PR260-I]

Figure 3-2: ITER site



3.2 Description of the ITER project

The list of ITER systems is defined in the ITER Plant Breakdown Structure (PBS) [R03] and is summarised in **Table 3-2**. The scope of each system is defined in the ITER Work Breakdown Structure (WBS) Dictionary [R04]. [PR73-I]

The performance requirements in this document (Chapter 4) are allocated to the systems, and are documented in the System Requirements Documents (SRDs). [PR71-I]

Detailed functional and physical interface requirements between ITER systems are defined in the relevant Interface Control Documents (ICDs). [PR72-I]

A short description of each of the ITER systems, and their functions, is provided in the following sections. [PR75-I]

Table 3-2: ITER systems

PBS	System
11	Magnet system
15-VV	Vacuum vessel
15-IV	In-vessel coil system
16	Blanket system
17	Divertor system
18	Fueling and wall conditioning system
22	Machine assembly and tooling system
23	Remote handling system
24-CR	Cryostat system
24-VP	Vacuum vessel pressure suppression system
26	Cooling water system
27	Thermal shields system
31	Vacuum system
32	Tritium plant
34	Cryogenic system
41	Coil power supply and distribution system
43	Steady-state electrical power supply networks
44	Cable trays system
45	Control, data access and communication system
46	Central interlock system
47	Plasma control system
48	Central safety system
51	Ion cyclotron heating and current drive system
52	Electron cyclotron heating and current drive system
53	Neutral beam heating and current drive system
54	Lower hybrid heating and current drive system
55	Diagnostics system
56	Test blanket modules system
58	Port plug test facilities
61	Site facilities
62	Reinforced concrete buildings
63	Steel frame buildings
64	Radiological and environmental monitoring system
65	Liquid and gas distribution system
66	Radioactive waste treatment and storage system
69	Access control and security system
70	Site outside platform
98	External services and interfaces system

3.2.1 Magnet system (PBS 11)

The Magnet System consists of four coil systems — Toroidal Field (TF) coils, Central Solenoid (CS) coils, Poloidal Field (PF) coils, and Correction Coils (CC) — plus the feeders that bring helium cooling and electrical power to the coils. [PR78-I]

The TF coils provide the toroidal magnetic field for confining the plasma. [PR79-I]

The PF coils and the CS coils provide the change in poloidal magnetic flux that is needed to initiate the plasma, to generate the plasma current, and to maintain this current during the burn time. [PR83-I]

The PF coils provide the poloidal magnetic field for the plasma shaping and position control, and contribute to the inductive plasma current drive. [PR81-I]

The CS contributes towards the fields that are needed to shape and control the plasma. [PR84-I]

The CCs compensate for low mode number error fields that are due to asymmetries in the design of the tokamak, geometric tolerances during assembly, and the influence of magnetic materials. [PR82-I]

The TF coils are arranged in a toroidal array of 18 NbSn superconducting coils. [PR1915-I]

The CS is an assembly of six NbSn superconducting coils that are positioned along the vertical axis of the tokamak. [PR80-I]

The PF coils are arranged in an array of six NbTi superconducting ring coils that are positioned along the vertical axis of the tokamak, with three above the horizontal equatorial plane and three below. [PR1916-I]

The CCs are arranged in an array of 18 NbTi superconducting coils. [PR1917-I]

3.2.2 Vacuum vessel (PBS 15-VV)

The Vacuum Vessel System provides:

- The vacuum boundary for the plasma vacuum
- Shielding, to reduce the nuclear heating in the superconducting coils, and the activation of components that are outside the vacuum vessel
- A primary confinement of tritium and activated materials, inside the vacuum vessel and in the vacuum vessel cooling water
- Passive stabilization of the plasma, by providing a conductive shell that is tight fitting to the plasma, while allowing control of the plasma current by providing adequate toroidal resistance
- Toroidal field ripple reduction, through the use of ferromagnetic inserts
- Removal of decay heat in the in-vessel components, in the event of a loss of cooling or loss of flow to those components
- Structural support for the in-vessel components, including blanket modules and in-vessel coils
- Access for in-vessel component services and port-mounted equipment.

--- [PR86-I]

The vacuum vessel is a double-walled structure, and has a set of upper ports, equatorial ports, and lower (divertor) ports, to allow access for plasma heating, fuelling, diagnostics, and in-vessel component services. [PR96-I]

The interspace between the vacuum vessel walls contains the in-wall shielding blocks to absorb neutrons and to reduce toroidal field ripple, and is filled with cooling water. [PR1918-I]

The vacuum vessel is composed of nine toroidal sectors of 40° each. [PR2078-I]

3.2.3 In-vessel coils system (PBS 15-IV)

Edge Localized Modes (ELMs) can produce large impulsive heat loads to the divertor. To mitigate this effect, resonant magnetic perturbations are introduced by a poloidal and toroidal array of in-vessel ELM coils that are mounted outboard of the plasma, on the vacuum vessel, behind the blanket modules. The ELM coils may also be used to control resistive wall modes as future upgrade. Fast vertical instabilities can exceed the stabilisation capacity of the external Poloidal Field (PF) coils. [PR99-P]

Included in the in-vessel coil array are two toroidally continuous Vertical Stabilisation (VS) coils, above and below the equatorial ports, that provide fast vertical position stabilisation of the plasma. [PR100-I]

3.2.4 Blanket system (PBS 16)

The Blanket System provides the following functions:

- Contributing to absorbing radiation and particle heat fluxes from the plasma
- Contributing to providing shielding to reduce heat and neutron loads in the vacuum vessel and ex-vessel components
- Providing a plasma-facing surface that is designed for a low influx of impurities to the plasma
- Providing limiting surfaces that define the plasma boundary during startup and shutdown
- Providing passage for the plasma diagnostics, for the viewing systems, for the microwave antennas or launchers, and for other minor ancillaries.

--- [PR102-I]

The Blanket System comprises an array of blanket modules (BMs). [PR109-I]

Each BM is mounted to the vacuum vessel through a mechanical attachment system of flexible supports and keys. [PR1919-I]

Each BM has electrical straps that provide electrical connection to the vacuum vessel. [PR1920-I]

Cooling water to the BM is supplied by manifolds that are supported by the vacuum vessel behind or at the side of the BM. [PR1921-I]

3.2.5 Divertor system (PBS 17)

The Divertor System contributes to the removing of the radiative and convective heat fluxes from the plasma. [PR111-I]

The Divertor System allows the control and the removal to the vacuum system of the ashes that are produced by the fusion process. [PR2079-I]

The Divertor System contributes to the nuclear shielding of the vacuum vessel and the superconducting magnets. [PR1922-I]

The Divertor System facilitates the monitoring and the recovery of the tritium and of the activated dust. [PR2080-I]

The Divertor System consists of 54 cassettes that are located at the bottom of the plasma chamber. [PR1923-I]

3.2.6 Fueling and wall conditioning system (PBS 18)

The Fuelling and Wall Conditioning System provides several functions including:

- Providing gases (H, D, T and He) and pellets (H, D and T) to fuel the plasma
- Providing pellets (D and T) to control ELMs
- Providing gases (H and D) to the neutral beam injectors
- Injecting minority species (gases H, D, He and ^{3}He; pellets H and D) into the plasma to enable the respective IC H&CD minority heating scenarios
- Injecting impurity gases into the divertor plasma for radiative cooling, plasma detachment control and discharge termination
- Injecting impurity pellets into the plasma for studies of impurity transport and radiative cooling enhancement
- Injecting of gases and pellets for disruption mitigation and suppression of runaway electrons
- Providing an emergency Fusion Power Shutdown System (FPSS)
- Providing wall conditioning systems that reduce and control impurity and hydrogenic fuel outgassing from plasma-facing components.

--- [PR113-I]

The tokamak fuelling system is designed to inject gas or solid pellets of hydrogen, deuterium, and tritium, as well as impurities in gaseous or solid form. [PR1908-I]

During plasma start-up, fuel will be introduced into the vacuum vessel chamber by the gas injection system. The plasma will progress from electron-cyclotron-heating-assisted initiation, in a circular, limiter configuration, to an elongated divertor configuration as the plasma current is ramped up. [PR59-I]

In inductive scenarios, reducing the fuelling rate terminates the burn by slowly ramping down the fusion power. This phase is followed by plasma current ramp-down, and finally by plasma termination. [PR1911-I]

3.2.7 Machine assembly and tooling system (PBS 22)

The Machine Assembly and Tooling System enables the cleaning, handling, manipulation, alignment, and stabilization of the tokamak components from the outside assembly area to the tokamak pit, via the Cleaning Facility and the Assembly Hall (see the Site Master Plan [A13]). [PR125-I]

Assembly tooling is used during machine assembly. The tooling may also be used for maintenance, but in this case it may be necessary to modify the tooling to accommodate changes in the machine configuration. It enables the operations that are required for machine assembly, including the on-site handling, preparation, sub-assembly and assembly of the tokamak components. [PR124-P]

The Machine Assembly and Tooling System includes all of the equipment that is required to control the tokamak assembly quality, with the exception of the vacuum testing (which is to be performed by PBS 31) and radiography equipment. [PR126-I]

3.2.8 Remote handling system (PBS 23)

The Remote Handling System (RH) performs maintenance operations on the machine components that are classified for remote handling maintenance. [PR129-I]

The RH system provides the following capabilities:

- In-vessel viewing and metrology
- Blanket module handling
- Blanket manifold handling
- In-vessel coil handling
- Divertor cassette handling
- Port plug handling
- In-vessel component and port plug transfer to/from Hot Cell
- In-vessel component and port plug maintenance and refurbishment in Hot Cell
- Neutral beam maintenance
- Neutral beam duct liner maintenance
- Dust and tritium inventory control
- In-service inspection
- In-vessel diagnostics maintenance
- Leak localization
- Support to the maintenance of type-B radwaste system in the Hot Cell.

--- [PR130-I]

The RH will support the machine assembly operations. [PR139-I]

3.2.9 Cryostat System (PBS 24-CR)

The Cryostat System provides a vacuum environment for the superconducting coils and other in-cryostat components that operate at cryogenic temperatures. [PR141-I]

The cryostat provides penetrations for services to in-cryostat components and vacuum vessel ports. [PR1924-I]

The cryostat transfers all the loads that derive from the tokamak basic machine and the cryostat itself, during the normal and off-normal operational regimes, and at specified accidental conditions, to the floor of the tokamak pit through its support structures. [PR1925-I]

3.2.10 Vacuum vessel pressure suppression system (PBS 24-VP)

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

The VVPSS consists of a large steam suppression tank, connected to the vacuum vessel through a large duct that is closed by a rupture disk, and bypass lines that are closed by isolation valves. [PR1926-I]

The VVPSS should contain enough water at room temperature to condense the steam that results from the most adverse in-vessel coolant leaks. [PR2081-P]

3.2.11 Cooling water system (PBS 26)

The Cooling Water System (CWS) removes heat from the ITER components and rejects it to the environment. [PR1927-I]

In addition, the CWS performs the following functions:

- Removing heat from client systems
- Controlling water chemistry, to minimize corrosion in client systems
- Providing the capability to drain and dry the cooling loops, to facilitate maintenance of the components in the CWS and client systems
- Facilitating leak detection and leak localization, for CWS and client systems
- Monitoring heat removed from the in-vessel components and vacuum vessel.

--- [PR157-I]

The CWS consists of four systems: the Tokamak Cooling Water System (TCWS), the Component Cooling Water System (CCWS), the Chilled Water System (CHWS), and the Heat Rejection System (HRS). [PR145-I]

The TCWS removes heat from the divertor, blanket modules, vacuum vessel, in-vessel components, in-port components, and Neutral Beam (NB) system components that are within the NB enclosure, and controls the pre-pulse temperature of those components. [PR146-I]

The TCWS provides baking for the vacuum vessel and in-vessel components, and decay heat removal in conjunction with other mechanisms of decay heat removal. [PR1928-I]

The TCWS clients all have the potential to be contaminated with tritium and activated corrosion products. TCWS components that are in contact with the cooling water provide primary confinement of these radioactive inventories. [PR1929-I]

The CCWS is divided in two loops:

- CCWS-1 tranfers heat from TCWS to HRS, and could be radioactively contaminated.
- CCWS-2 transfers heat from ancillary equipment to HRS, and is not susceptible to radioactive contamination.

--- [PR149-I]

The CHWS is divided in two loops:

- CHWS-H1 is safety-related and rejects heat directly to the environment through two separate and redundant air-cooled chillers (CHWS-H1A and CHWS-H1B).
- CHWS-H2 is non-safety-related and transfers heat to CCWS-2.

--- [PR153-I]

The HRS rejects the heat from CCWS to the environment. [PR148-I]

Heat from all the cooling water loops, except CHWS-H1, is ultimately transferred to HRS, then rejected to the atmosphere through the induced draft cooling towers. [PR2082-I]

3.2.12 Thermal shield system (PBS 27)

The thermal shields limit the radiation heat load to the superconducting coils, from warm internal or external sources, to levels that can be tolerated by the coils, and removed by the helium cryogenic system. [PR164-I]

In particular, the shields intercept thermal radiation from the warm surfaces of the vacuum vessel and port outer walls, the VV supports, the cooling pipes, other warm ducting and the cryostat inner wall, as well as restricting heat loads that are transferred by conductance through the magnet gravity supports by means of thermal anchors. [PR1930-I]

The temperature of the thermal shields is 80 K. [PR1931-I]

3.2.13 Vacuum system (PBS 31)

The Vacuum System provides vacuum in the torus, cryostat, and auxiliary systems, at the level that is necessary for the operation of ITER. [PR1932-I]

The Vacuum System performs the following functions:

- Evacuating and pumping of client systems (torus, neutral beams, cryostat, cryogenic distribution systems, diagnostics, EC/IC transmission lines)
- Exhausting of pumped/released gases to the Tokamak Exhaust Processing, or to the Vent Detritiation System, or to the Non Active Exhaust System
- Providing controlled venting of the torus, cryostat and all other vacuum systems
- Providing the leak testing of the vacuum integrity of all systems that may be exposed to a primary, service or cryostat vacuum, both during construction and during operation
- Measuring the total in-leakage into the vacuum vessel, cryostat and service vacuum clients (in particular for external air leaks into the vacuum vessel and cryostat) both during construction and operation
- Measuring the in-situ leak rates of individual elements, both during construction and operation
- Providing the capability to locate, at the component and element level, any unacceptable leak rate, both during construction and operation

- Providing the capability for leak testing, in the operational configuration, the various systems of the torus, cryostat and pellet injectors, during the final construction and commissioning of the machine, and after upgrade, repair or maintenance
- Periodic confirmation of the integrity of the radiological confinement boundaries and pressure boundaries to comply with regulatory and codes and standards requirements
- Pumping of the interspaces between feedthroughs, seals, and bellows that are deemed sufficiently fragile to need a second vacuum barrier to enable differential pumping, to allow leak mitigation and continued plasma operation if the reliability of a single feedthrough would otherwise not be adequate to meet the overall availability requirements of the tokamak, or would result in excessive individual and collective maintenance worker dose during leak localization and repair
- Filling and pressure monitoring of interspaces with inert tracer gas, to perform leak detection and localization.

--- [PR166-P]

3.2.14 Tritium plant (PBS 32)

The Tritium Plant processes the tritium and fuel gases from the whole ITER facility. [PR1933-I]

The Tritium Plant provides Detritiation Systems for detritiation of gases from the Tokamak Complex and from the Hot Cell. [PR2083-I]

The Tritium Plant handles tritium shipments; storage of tritium and other fuel gases; tritium inventory measurements; delivery of gases to fuelling systems; delivery of divertor impurity seeding gases to fuelling systems; processing of tokamak and neutral beam exhaust to remove hydrogen isotopes for fuel recovery by isotope separation; removal and recovery of tritium from the Test Blanket Module extraction systems (if required); analysis of process gases; radiological control of vent atmospheres for normal operation including maintenance; mitigation of tritium release resulting from accidents; detritiation of tritium-contaminated water; and sub-atmospheric room pressure control (air depression) for establishing a release path in the case of incidents or accidents. [PR180-I]

Processes at ITER are engineered to minimize the production of highly-tritiated water. A Highly Tritiated Water Treatment technology (HTW) is available at ITER to deal with the transfer, storage, processing and recovery of tritium with a capability to process up to 2 Pa m^3/s from these process streams. [PR181-I]

3.2.15 Cryogenic system (PBS 34)

The Cryogenic system performs the following functions:

- Cooling down and warming up of the cryostat and torus cryopumps

- Cooling down, filling and warming up of the Magnet System, and of the 80 K Thermal Shield System
- Cooling down and warming up of the Neutral Beam cryopumps, pellet injection system, diagnostics, and other small users
- Maintaining magnets, current leads, and cryopumps at nominal operating temperatures, over a wide range of operating modes, with pulsed heat loads due to nuclear heating and magnetic field variations
- Accommodating periodic regeneration of cryopumps
- Accommodating resistive transitions and fast discharges of the magnets, and recovery.

--- [PR183-I]

3.2.16 Coil power supply and distribution system (PBS 41)

The coil power supply and distribution system provides the pulsed power for energizing the TF, PF, CS, CCs, and In-Vessel Coils to generate, confine, and control the plasma. [PR192-I]

The coil power supply and distribution system provides protection for the coils: in the event of quenches; in the event of over-currents or over-voltages due to abnormal or fault conditions in the power supplies; and in the event of high voltages due to earth faults. [PR1934-I]

3.2.17 Steady-state electrical power supply networks (PBS 43)

The steady-state electrical power supply networks provide different voltage class power supplies as described in [A07]:

- Steady-state power, in class IV, to all the electrical loads of the ITER plant auxiliary and utility systems, during normal operation, from the power grid
- Steady-state power, in class I, II and III, to the safety-related and investment protection loads of the ITER plant auxiliary systems, in case of unavailability of the class IV network, from diesel motor generators
- Class II AC power to plant loads, from class III or IV power through AC/DC/AC inverters that are connected to batteries
- Class I DC power to plant loads, from class III or IV power through AC/DC rectifiers that are connected to batteries.

--- [PR195-I]

3.2.18 Cable trays system (PBS 44)

Cable trays system manages a centralized control of cables, cable trays and pneumatic lines for all ITER systems. [PR1760-I]

The cable trays system provides the infrastructure and the tools for the management and the routing of all cables, cable trays and pneumatic lines. [PR1935-I]

3.2.19 Control, Data Access and Communication System (PBS 45)

The Control, Data Access and Communication System (CODAC) performs the following functions:

- Networking, to communicate information between all ITER systems and CODAC
- Monitoring the ITER plant, and displaying the status to operator stations
- Acquiring, archiving and providing controlled access to all engineering and scientific data concerning the operation of ITER, for the duration of the project and beyond
- Specifying and verifying the parameters that are used during ITER operation, including during plasma pulses both on-site and remotely
- Providing, distributing and monitoring a project-wide time reference
- Providing, distributing and recording audio and video information inside the plant
- Operating ITER in terms of Global Operating States that are linked to the Operation Limits and Conditions (OLC)
- Managing Instrumentation and Control (I&C) for all ITER systems.

--- [PR201-I]

The Control, Data Access and Communication System (CODAC) includes the following:

- The infrastructure for controlling plasmas and other pulse-related activities
- The infrastructure for providing all calculations that are needed for ITER operation, including verification before and during plasma pulses, and diagnostic data evaluation during plasma pulses
- Features allowing ITER to be efficiently exploited from remote sites
- Equipment allowing the ITER systems to be operated independently, for commissioning, testing and maintenance
- Features allowing the collaborative research activity to be efficiently executed, given the distributed nature of the research teams
- Operator consoles, allowing the operation of the ITER facility at the engineering level of each plant, and at the operation level of the integrated plant.

--- [PR2084-I]

3.2.20 Central interlock system (PBS 46)

The Central Interlock System provides investment protection for the ITER systems by:

- Inhibiting combinations of actions among all ITER systems that might endanger the integrity of any ITER component

- Applying automatic interlocks that are generated on the basis of the ITER status
- Applying automatic interlocks that are generated on the basis of the interlocking levels that are defined in the Operation Limits and Conditions (OLC)
- Applying manual interlocks.

--- [PR218-I]

The Central Interlock System signals the internal and external status of the ITER systems to CODAC, for monitoring, displaying and archiving, and provides warning threshold information to ITER operators. [PR224-I]

3.2.21 Plasma control system (PBS 47)

The Plasma Control System controls nearly all aspects of plasma operation including:

- Certain types of wall conditioning and tritium removal that are performed during plasma operation with toroidal field
- Plasma initiation
- Control of plasma current shape and position during all phases of the pulse: ramp-up, flat-top, and ramp-down
- Control of power and particle flux to the first wall and divertor
- Control of plasma fuelling, isotopic mixture, non-inductive current profile, plasma pressure and fusion burn
- Disruption prediction, avoidance, and, when necessary, mitigation via the Central Interlock System
- Control of non-axisymmetric plasma stability, including sawteeth, ELMs, Neoclassical Tearing Modes (NTMs), error field and Resistive Wall Modes (RWMs), and Alfvén eigenmodes
- Exception handling, which is the first level of machine protection, including controlled plasma termination, for plasma and plant events that lie inside the Central Interlock System interlock limits.

--- [PR226-I]

The Plasma Control System will not control the toroidal field, the vessel and in-vessel baking and the steady glow discharge cleaning. [PR237-I]

The Plasma Control System uses input data from scenarios and sequence algorithms, together with real-time data from plasma diagnostics and machine instrumentation, to produce outputs to actuators that are used to set up the necessary conditions for plasma operation, to produce plasma, to control all aspects of the plasma evolution and all plasma parameters that are necessary to operate ITER throughout all phases of the plasma discharge. [PR238-I]

3.2.22 Central safety system (PBS 48)

The ITER safety control systems provide protection for the personnel and the environment by executing safety I&C (Instrumentation and Control) functions. [PR1936-I]

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. They include all I&C devices from sensor signals to actuator commands, including operator desk controls and processing equipment that is responsible for generating the signals that are required to fulfill the safety functions. They also include the processing of data that are necessary for operator control in accident or post-accident conditions. [PR1937-R]

The Central Safety System coordinates the distributed safety systems, presents central and local safety systems data to the Safety Operator's Desk, and executes manual commands from the Safety Operator's Desk. [PR1938-I]

The Central Safety System transfers its data and signal status information to CODAC for archiving, and additional monitoring and displaying. [PR241-I]

3.2.23 Ion cyclotron heating and current drive system (PBS 51)

The Ion Cyclotron Heating and Current Drive (IC H&CD) System provides ion cyclotron radio frequency power for plasma heating, current drive, control of sawteeth activity, and wall cleaning. [PR243-I]

3.2.24 Electron cyclotron heating and current drive system (PBS 52)

The Electron Cyclotron Heating and Current Drive (EC H&CD) System provides electron cyclotron microwave frequency power for plasma heating and current drive, control of instabilities via localized current drive, wall conditioning (TBC), and RF-assisted breakdown for plasma initiation. [PR245-I]

3.2.25 Neutral beam heating and current drive system (PBS 53)

The Neutral Beam Heating and Current Drive (NB H&CD) System provides neutral beams for plasma heating and current drive, plasma rotation, fuelling, and plasma current and density profile control. [PR1939-I]

The Diagnostic Neutral Beam System provides a dedicated neutral beam, for helium ash measurements, using Charge Exchange Recombination Spectroscopy (CXRS). It also allows localized measurement of various plasma parameters, such as ion temperature and impurity density. [PR1940-I]

The heating beams are also used to measure the magnetic fields in the plasma, by Beam Emission Spectroscopy. [PR247-I]

3.2.26 Lower hybrid heating and current drive system (PBS 54)

The Lower Hybrid Heating and Current Drive (LH H&CD) System provides off-axis current drive capability. [PR1941-I]

Although LH H&CD equipment is not part of the ITER construction project, ITER must be able to accommodate future LH H&CD upgrades. [PR249-I]

3.2.27 Diagnostics system (PBS 55)

The Diagnostics System provides measurements of plasma behavior and performance, including those that are needed for machine protection and basic machine control, those that are required for advanced plasma control and those that are required for evaluation and physics studies. [PR251-I]

3.2.28 Test blanket modules system (PBS 56)

The Test Blanket Modules system provides blankets for testing and validating design concepts of tritium breeding blankets that are relevant to a power-producing reactor. [PR253-I]

The test of six Test Blanket Modules (TBM) and associated systems shall be accommodated. For each TBM, the testing includes the initial installation during the H-phase and up to three replacements during the first ten years of ITER operation. [PR254-R]

3.2.29 In-Vessel Viewing System (PBS 57)

TBD. [PR1762-I]

3.2.30 Port plug test facilities (PBS 58)

The port plug test facilities allow testing and qualification of port plugs prior to installation on the tokamak, or after refurbishment in the Hot Cell Facility. [PR258-I]

3.2.31 Site facilities (PBS 61)

The Site facilities include the fencing, water drainage, outdoor lighting, bridges, roads, footpaths, special foundations, and service trenches, as identified on the Site Master Plan [A13]. [PR1942-I]

3.2.32 Reinforced concrete buildings (PBS 62)

The Reinforced Concrete Buildings comprise all concrete buildings on the ITER site, including the Tokamak Complex buildings, the Laydown and Assembly-Hall Building, the Cleaning Facility Building, the Hot Cell Building, the Radwaste Building, the Personnel Access Control Building, and the Control Building. [PR262-I]

3.2.33 Steel frame buildings (PBS 63)

The Steel Frame Buildings include all steel frame buildings on the ITER site that are not part of the PBS 62. [PR264-I]

3.2.34 Radiological and environmental monitoring system (PBS 64)

The Radiological and Environmental Monitoring System (REMS) performs radiological monitoring to assist in protection of personnel from ionizing radiation, including from tritium. [PR1945-I]

The REMS performs airborn beryllium monitoring. [PR2354-I]

The REMS performs routine data collecting on the radiological state of the ITER plant throughout the whole lifetime of the ITER project. [PR2085-I]

The Environment Monitoring System (EMS) provides information on the environmental impact of ITER operations, as necessary to ensure compliance with environmental regulations. [PR1946-I]

In certain buildings, the HVAC (Heating, Ventilation and Air Conditioning) system must change configuration automatically in the event of increased tritium-in-air levels, for the protection of the environment and the public. This function is performed by specific tritium-in-air monitors that are included in the Radiological and Environmental Monitoring System. [PR266-I]

3.2.35 Liquid and gas distribution system (PBS 65)

Liquid and Gas Distribution system distributes non-cryogenic fluids to buildings within the ITER site: potable water; fire-fighting water; demineralized water; hot water for heating purposes; compressed air; breathing air; nitrogen, helium. [PR268-I]

3.2.36 Radioactive waste treatment and storage system (PBS 66)

The Radioactive Waste Treatment and Storage system performs the following functions during the ITER operation phase, and until the deactivation phase:

- Treating and storing intermediate-level and long-lived (Type B or MAVL, "Moyenne Activité et durée de Vie Longue") radioactive waste in the Hot Cell Building
- Storing purely tritiated waste in the Hot Cell Building, or in an adequate area
- Treating and storing low- and intermediate-level and short-lived (Type A or FAVC, "Faible et Moyenne Activité à durée de vie courte") solid radioactive waste and liquid effluent in the Radwaste Building
- Treating and storing very low-level radioactive waste (TFA, Très Faible Activité).

--- [PR278-I]

3.2.37 Access control and security system (PBS 69)

The Access Control and Security System provides for the safety of personnel by ensuring that access to hazardous or potentially hazardous areas is possible only if certain protective conditions are satisfied, and by limiting such access to suitably qualified personnel. [PR1947-I]

The Access Control and Security System provides for the security and protection of the ITER plant from sabotage and from access by unqualified personnel. [PR287-I]

3.2.38 Site outside platform (PBS 70)

The Site Outside Platform includes all infrastructure and support facilities that are part of the ITER scope, and that are located outside of the ITER platform, as shown in **Figure 3-2**. [PR1764-I]

3.2.39 External services and interfaces system (PBS 98)

The External Services and Interfaces system groups all functions that are required by ITER Organization and that are provided by external services, such as nuclear services, off-site electricity supply, water supply, other fluids supply (such as cryogenics), drains, telecommunications and networks. [PR1766-I]

3.3 ITER project functions

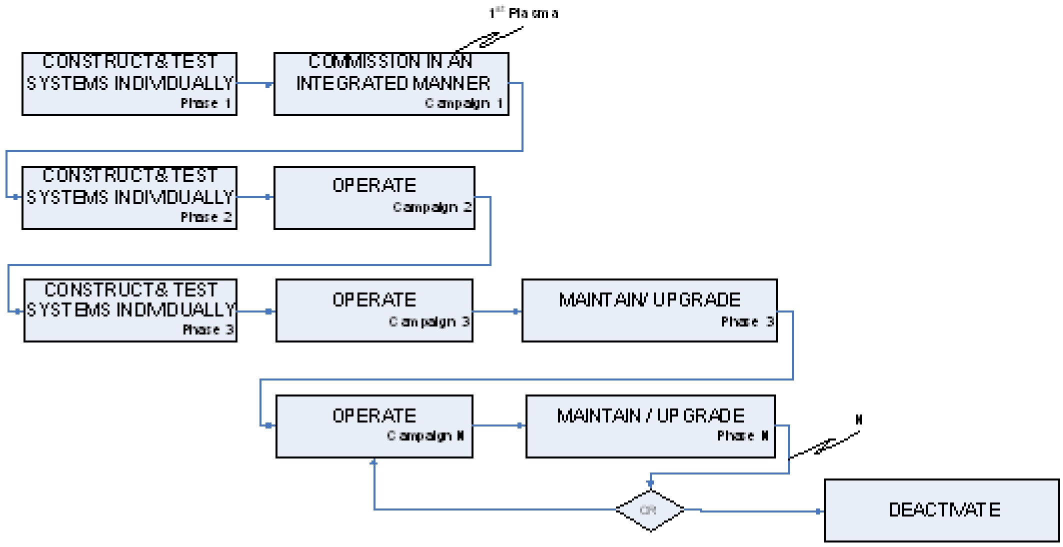
The top-level functions for the ITER project are:

- Construction of ITER
- Integrated Commissioning
- ITER operations
- Maintenance and upgrades
- Deactivation of ITER.

--- [PR289-I]

Figure 3-3 shows the flow between these top-level functions over the lifecycle of ITER, and provides the foundation for the functional requirements within this specification. [PR296-I]

Figure 3-3: ITER Master Functional Flow Block Diagram (FFBD)



3.3.1 Construction of ITER

The construction of ITER involves the preparation of the site, civil construction works, machine assembly, plant system installation and individual system testing. This shall be phased in three construction periods, as shown in **Figure 3-3**. [PR299-R]

3.3.2 Integrated commissioning

At the end of the first construction period, an integrated commissioning of ITER systems shall be performed, to ensure correct functioning, and to assure readiness for plasma operations. [PR301-R]

The production of the First Plasma will occur during this integrated commissioning. [PR1948-I]

3.3.3 ITER Operations

The ITER operations function includes preparation for and execution of plasma operation, and ultimately the implementation of the ITER Research Plan [R07]. [PR303-I]

An operational campaign consists of typically 16 months of operations (see Section 6.6). [PR304-I]

Each operation day will have three 8-hour work shifts, as defined in Section 6.6. [PR305-I]

3.3.4 Maintenance and upgrades

In the maintenance and upgrades function, major interventions are possible on the machine, to repair or upgrade ITER systems. [PR307-I]

The first steps in performing maintenance and reconfiguration involve diagnosing and isolating faults, and making restricted areas safe for personnel access. [PR1949-I]

Waiting periods, of up to 24 hours for contact dose rates to subside, may be required in the TCWS vault and other areas that surround the tokamak, after D-T operations commence. [PR1950-P]

Access to the inside of the cryostat will require extended periods of time for warming up the superconducting coils and thermal shields to room temperature. [PR1951-I]

Personnel access to the inside of the vacuum vessel shall be prohibited once the vacuum vessel becomes activated, and consequently all in-vessel maintenance activities shall be done remotely. [PR1952-R]

Before venting the vacuum vessel, the vessel and in-vessel components shall be baked to remove as much tritium as possible. [PR1953-R]

In-vessel dust will be collected and removed, to the maximum extent possible, to mitigate the spread of contamination throughout the facility. [PR1954-I]

The Neutral Beam enclosure vessels will become activated during D-T operations, and consequently shall require remote maintenance. [PR1955-R]

The TF coils shall be discharged prior to deploying personnel or in-vessel remote handling equipment in the vacuum vessel (In-vessel viewing equipment is designed to be deployed when the vacuum vessel is under vacuum and the TF coils are energized. Remote handling equipment is designed to be deployed when the TF coils are de-energized and the vacuum is vented). [PR1956-R]

Major reconfigurations and upgrades shall be completed prior to machine activation. [PR1957-R]

The Hot Cell Facility shall be used for the refurbishment of worn and failed activated components. [PR1958-R]

The discarded and activated materials shall be treated and stored in the Hot Cell Building or in the Radwaste Building, depending on the radioactive waste classification. [PR1959-R]

Once maintenance and reconfiguration activities are complete, preparation for plasma operations can begin. [PR308-I]

3.3.5 Deactivation of ITER

The Deactivation of ITER involves deactivating the facility, and removing tritium, beryllium and readily mobilizable sources of radioactivity. [PR1960-I]

Following deactivation of the facility, the Host Member (see Section 3.4) shall be responsible for dismantling the facility and disposing of the waste. [PR310-R]

3.3.6 Plant operational state

The ITER Plant shall always be in one of the following four well defined Global Operational States:

- **Long Term Maintenance (LTM) state:** This is used for long term maintenance or upgrade. A sufficient nuclear decay period is required before starting the LTM. Some systems may be in operation during LTM.
- **Short Term Maintenance (STM) state:** This may be scheduled or unscheduled following a failure. The vessel is evacuated, all magnets are at zero current but are cooled.
- **Test and Conditioning State (TCS):** Most systems are ready for test-pulsing (with no plasma); cooling systems are in low-flow; magnets can be operating; access is very restricted and tightly controlled.
- **Plasma Operation State (POS)**: This is the state waiting for, during the countdown, execution and end of a plasma pulse, including IC wall conditioning.

--- [PR1819-R]

Transitions from one state to another are well controlled, and require a number of conditions to be satisfied. [PR1961-I]

3.4 Site requirements

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]. [PR312-R]

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]. [PR313-I]

3.4.1 Land

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]. [PR1962-I]

The main part of this land area, around 115 ha, as indicated in the Site Master Plan [A13], will be managed by ITER Organization, while the remaining area will continue to be managed by the Host Member. The land shall be provided ready to use, cleared of forest and with platforms created. The external fencing shall be constructed by the Host Member [R23]. [PR316-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. [PR1963-R]

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. [PR1964-I]

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

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

3.4.2 Headquarters construction

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. [PR319-R]

3.4.3 Roads

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. [PR1966-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]. [PR321-R]

3.4.4 Transport of components

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. [PR323-R]

The maximum size and weight of the transported components (including packaging and frames) are given in **Section 8.8.1**. [PR1967-I]

3.4.5 Electrical power

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. [PR325-R]

Detailed functional and physical interface requirements are defined in the contract between the Host Member and the Operator of the French electric power transmission grid (RTE). [PR1968-I]

3.4.6 Water supply and sewage

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]. [PR328-R]

The peak consumption rates for potable water shall cover leaks and fire protection. [PR1970-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). [PR1971-R]

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

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

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

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]. [PR1974-I]

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

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

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

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]. [PR1977-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]. [PR1978-R]

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

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

The industrial water drainage connections shall be at the ITER site boundary. [PR1981-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. [PR336-R]

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

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

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. [PR338-I]

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

3.4.7 Waste disposal

The Host Member shall accept for disposal industrial, radioactive, and toxic waste that is generated during the course of the ITER construction, operation and deactivation. [PR342-R]

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. [PR1984-I]

3.4.8 Communications

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. [PR346-R]

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

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

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

4 Performance requirements

4.1 Construction and facility start-up

4.1.1 Assembly sequence

The assembly sequence is described in the ITER Assembly Plan [R05]. [PR351-I]

4.1.2 Fabrication and assembly tolerances

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. [PR353-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 ripple and field error requirements in **Sections 4.3.2.3** and **4.3.2.4** can be met.

--- [PR357-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 4.3.10** can be met.

--- [PR361-R]

4.1.3 Vacuum acceptance leak rates

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. [PR367-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. [PR368-R]

The air-equivalent leak rate for the total torus vacuum system (including all in-vessel components and attachments) shall be less than 2×10^{-7} $Pa.m^3.s^{-1}$. [PR369-R]

The leak rate for an individual vacuum vessel sector (that is, 40° of the total torus) shall be less than 1×10^{-8} $Pa.m^3.s^{-1}$. [PR370-R]

The leak rate for the completed cryostat (including all in-cryostat components and attachments) shall be less than 1×10^{-4} $Pa.m^3.s^{-1}$. [PR371-R]

Testing methods and principles, and the acceptance leak-rate, for all vacuum components shall be in accordance with the *ITER Vacuum Handbook* [A05]. [PR372-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. [PR2086-R]

During maintenance operations, appropriate measures shall be taken to protect vacuum envelopes. [PR2087-R]

The failure of a vacuum envelope shall be monitored (by measuring pressure within the envelope), with appropriate alarm systems provided. [PR2088-R]

4.1.4 Integrated systems testing

A comprehensive integrated system test program shall be provided to verify, prior to plasma operations, that applicable ITER systems operate safely and as expected. [PR374-R]

Distributed systems shall be tested according to an approved test plan prior to their operation. [PR375-R]

4.2 Preparations for plasma operations

4.2.1 Cryostat evacuation

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

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

Prior to cool-down, the cryostat shall be evacuated to a base pressure of 10^{-4} Pa. [PR387-R]

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

The cryostat shall be evacuated from 10 Pa to less than 10^{-4} Pa within 160 hours. [PR389-R]

The maximum global in-leakage of helium into the cryostat, at cryogenic temperature, shall not exceed 10^{-2} $Pa.m^3.s^{-1}$. [PR391-R]

The base pressure of the cryostat shall be maintained at less than 10^{-4} Pa when the superconducting magnets are below room temperature. [PR392-R]

4.2.2 Vacuum vessel and neutral beam enclosure evacuation

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

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

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

A base pressure of less than 10^{-5} Pa (for hydrogen isotopes) shall be achieved in the vacuum vessel, after wall conditioning, prior to plasma operations. [PR396-R]

A base impurity pressure of less than 10^{-7} Pa (the sum of partial pressures of impurity gases) shall be achieved in the vacuum vessel, after wall conditioning, prior to plasma operations. [PR397-R]

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

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

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

The global air-equivalent in-leakage into the neutral beam enclosure shall not exceed $1x10^{-8}$ $Pa.m^{3}.s^{-1}$. [PR402-R]

4.2.3 Magnet cool-down and warm-up

The superconducting coils shall be designed for 100 cool-down and warm-up cycles. [PR409-R]

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

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

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

The TF coils shall be capable of being cooled down to operating temperature within four days of a fast discharge. [PR408-R]

4.2.4 Coil charging and discharging

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** and **Section 4.3.1**) or the equivalent for other scenarios when adjusted for fatigue life according to the procedures in the design criteria. [PR488-R]

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

The TF coils shall be capable of being charged from zero current to full current (corresponding to 5.3 T at a major radius of 6.2 m) within 2 hours. [PR412-R]

The TF coils shall be capable of being discharged from full current (corresponding to 5.3 T at a major radius of 6.2 m) to zero current within 2 hours under normal conditions. This is referred to as a slow discharge. [PR413-R]

The TF coils shall be capable of being discharged from full current (corresponding to 5.3 T at a major radius of 6.2 m) to zero current within 30 minutes under abnormal conditions. This is referred to as an accelerated discharge. [PR1767-R]

The magnet quench detection system shall be designed to discharge coils to prevent overheating (hot spot) of the jacket conductors above 150 K. This is referred to as a fast discharge. [PR414-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. [PR1820-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. [PR493-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. [PR489-R]

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

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

The TF coils shall be designed to withstand 1000 charge-slow or accelerated discharge cycles over the life of ITER. [PR418-R]

The TF coils shall be designed to withstand 50 charge-fast discharge cycles over the life of ITER. [PR419-R]

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

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

The CS, PF and CC systems shall be designed for 500 fast discharges. [PR416-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. [PR415-R]

4.2.5 Baking

The blanket shall be capable of being baked at 240°C ±10°C. [PR424-R]

The divertor shall be capable of being baked up to 350°C. [PR425-R]

The in-vessel components of the IC H&CD System shall be capable of being baked at 240°C ±10°C. [PR2090-R]

The vacuum vessel and the other in-vessel components shall be baked at 200°C +0/-10°C. [PR426-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. [PR427-R]

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

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

Following baking, the vacuum vessel and in-vessel components shall be capable of being returned to their pre-pulse operating temperature (see Section 4.3.2.1) within 24 hours. [PR431-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. [PR432-R]

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

During D-T pulse operation, the estimated baking cycles are 40. [PR2092-I]

4.2.6 Glow discharge cleaning (GDC)

The facility shall provide the capability to perform GDC indefinitely with the vacuum vessel and all in-vessel components at their nominal pre-pulse operating temperatures. [PR436-R]

The facility shall provide the capability to perform GDC indefinitely with the vacuum vessel and all in-vessel components at their nominal baking temperatures. [PR437-R]

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

PF, CC, VS coil currents shall be zero during GDC. [PR439-R]

Provisions shall be made to isolate the neutral beam enclosures during GDC. [PR440-R]

4.2.7 NB H&CD source conditioning

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

4.2.8 IC H&CD launcher conditioning

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

4.2.9 EC H&CD launcher conditioning

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

4.2.10 Pre-operational commissioning and testing

Prior to the initiation of plasma operations, the operation state of ITER systems shall be determined. [PR448-R]

4.3 Plasma operations

4.3.1 Plasma scenarios

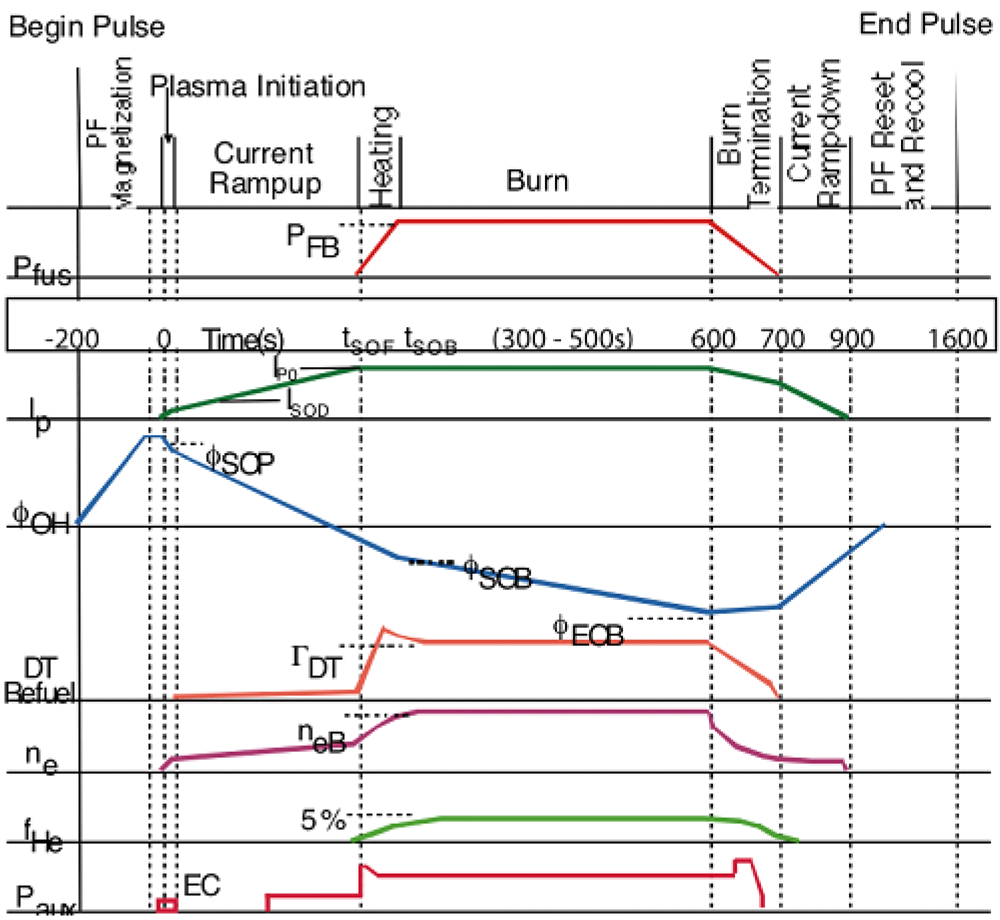
Five types of plasma scenarios have been defined to organize the plasma operations and the ITER experimental program, based on different parameters used during the plasma discharge:

- three D-T reference plasma scenarios (see Section 4.3.1.1)
- the commissioning plasma scenarios (see Section 4.3.1.2) that will be used before the D-T phase
- the flexibility scenarios (see Section 4.3.1.3) that will be prepared to operate ITER at enhanced parameters

--- [PR2097-I]

An ITER D-T discharge should have the schematic form illustrated in **Figure 4-1**, which defines the conceptual structure of the plasma scenario. According to the scenario heating and current drive will also be exploited during the current ramp-up phase to optimize the use of inductive flux and to control the plasma current profile. [PR504-P]

Figure 4-1: Schematic of ITER D-T plasma discharge scenario



The timing shown is illustrative and referred to the 15 MA Q=10 Inductive scenario. The Hybrid and Non-inductive scenarios will have similar generic waveforms, but the details, in particular, for the timing of fuelling, H&CD operation and critical pulse transitions will differ. [PR506-I]

4.3.1.1 D-T reference plasma scenarios

The following three plasma scenarios, defined as "reference" scenarios have been developed as illustrations of scenarios demonstrating the key ITER mission goals:

- Inductive operation: 500 MW, Q = 10, 15 MA operation with heating during current ramp-up
- Hybrid operation
- Non-inductive operation: weak negative shear operation

--- [PR510-I]

ITER shall be designed to meet the requirements of the three reference scenarios. (Upgrade requirements for auxiliary (non-tokamak) systems for the Hybrid Operation and Non-Inductive Operation scenarios are provided in Section 4.4.4). [PR515-R]

Nominal plasma parameters, for the reference scenarios, derived from calculations with the PRETOR predictive simulation code, are shown in **Table 4-1**. [PR516-I]

All ITER systems, including plasma-facing components, shall be designed to meet the three reference plasma scenarios. The procedure for calculating the heat loads, together with the maximum expected heat loads, is defined in the ITER Heat and Nuclear Load Specifications [A15]. [PR507-R]

ITER is designed to conduct experiments in a wide range of experimental parameters in D-T operation. The limiting values of coil currents, fusion power, heating powers and other plasma-related requirements have been determined after complex studies of the expected regimes to obtain a broad operational window consistent with the requirements of satisfying the ITER mission as defined in the Project Specification [R01]. [PR509-I]

The Poloidal Field scenario database obtained through self-consistent simulations of ITER plasma scenarios **[**A19**]** describes key features of the scenarios and gives IDM links to the corresponding folders with scenario data. [PR1822-I]

Table 4-1: D-T reference plasma scenario parameters [R09]

Parameter	1. Inductive operation	2. Hybrid operation	3. Non-inductive operation
R/a (m/m)	6.2 / 2.0	6.2 / 2.0	6.35 / 1.85
Toroidal field, BT (T)	5.3	5.3	5.18
Plasma current, IP (MA)	15.0	13.8	9.0
Elongation, κx/κ95	1.85 / 1.7	1.85 / 1.7	2.0 / 1.85
Triangularity, δx/δ95	0.48 / 0.33	0.48 / 0.33	0.6 / 0.4
Fusion power, Pfus (MW)	500	400	356
Padd (MW)	50	73	59
Energy multiplication, Q	10	5.4	6
Burn time (s)	450	1000	3000
Minimum repetition time (s)	1800	4000	12000
Total heating power, PTOT (MW)	151	154	130
L-H transition power, PL-H (MW) (note 1)	76	66	48
Plasma thermal energy, Wth (MJ)	353	310	287
Maximum fuelling input (Pa-m3/s)	200	160	120

Note 1: As defined in equation 2 of [R26]. [PR1634-C]

The methodology and physics basis for the definition of the three reference scenarios are provided in the Plasma Performance Assessment [R09]. [PR518-I]

Although experimental uncertainties remain, the maturity of the physics basis for the type I ELMy H-mode scenario leads to its selection as the ITER baseline scenario for the Q greater than or equal to 10 mission. The physics bases for the Hybrid and Non-inductive scenarios continue to evolve rapidly and the parameters listed in **Table 4-1** are nominal values which allow testing of design assumptions for ITER systems. [PR519-I]

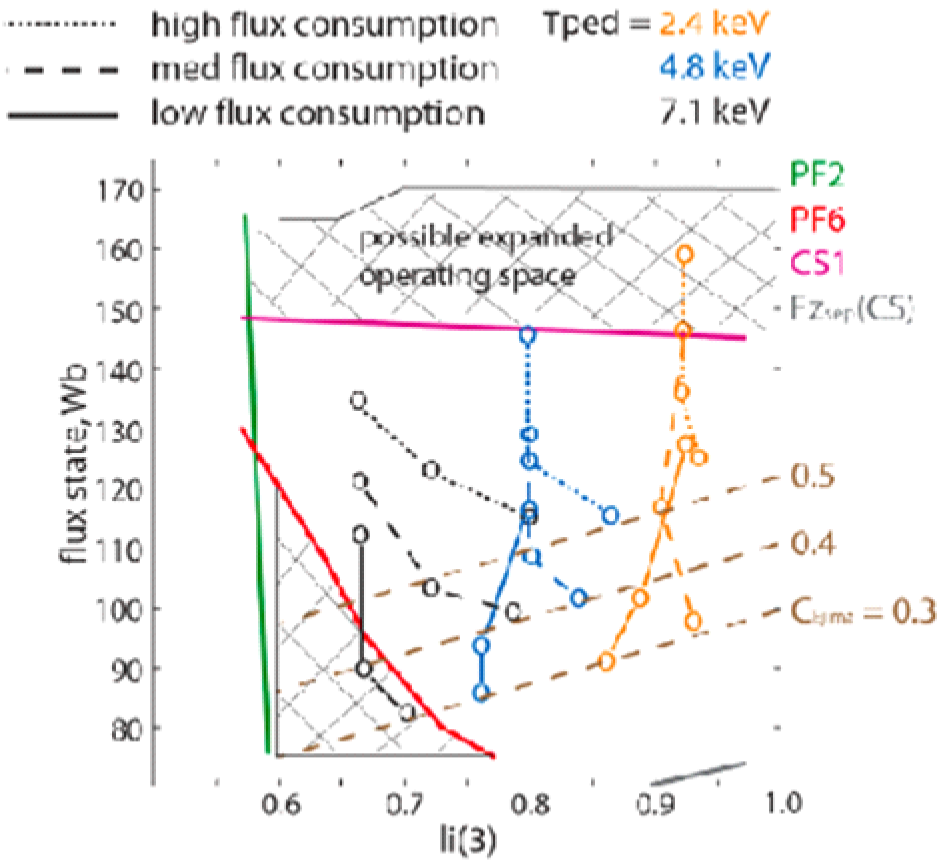
Within the current physics basis, the illustrative parallel heat loads specified for the 15 MA reference scenario are expected to provide an upper limit for the Hybrid and Non-inductive reference scenarios. [PR520-I]

The 15 MA Q = 10 Inductive scenario provides the design basis for key tokamak systems, in particular the Central Solenoid, Poloidal Field and in-vessel coil systems. The Hybrid and Non-inductive scenarios should be achievable within these design requirements, excepting additional investments for auxiliary systems. [PR521-P]

The basis for the specification of the Central Solenoid, Poloidal Field and power supply requirements for plasma control detailed in Section 4.3.4 is provided by results of extensive analyses that have been performed for the 15 MA, Q = 10 Inductive scenario using free boundary equilibrium/scenario numerical codes over ranges in critical plasma parameters (li, βp …) validated in tokamak experiments (see [R27]). The results of these analyses, expressed in terms of the plasma flux state at the Start Of Burn are shown in **Figure 4-2** and **Figure 4-3**, below. (The formal definition of parameters utilized in the flux state analysis is given in [R28]). [PR522-I]

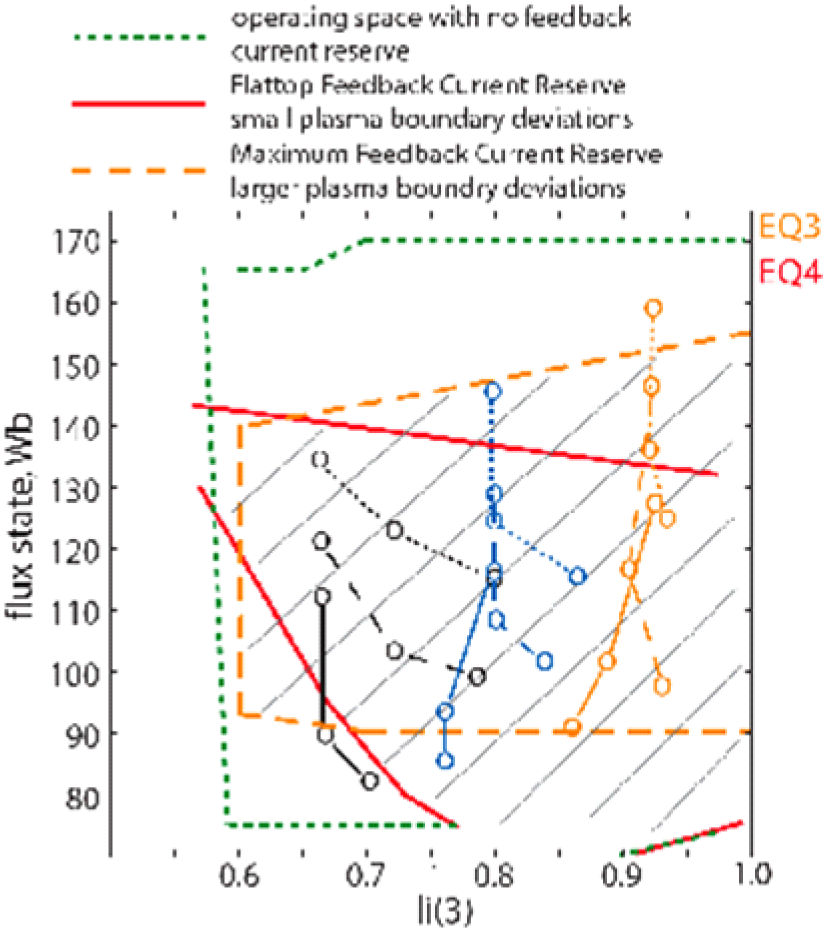
The variation in the flux state diagrams among figures reflects the uncertainties associated with assumptions on parameters such as the current profile and with different optimization algorithms for plasma control currents. The target equilibrium used for these analyses is shown in **Figure 4-5** in Section 4.3.4.1. [PR523-I]

Figure 4-2: Flux state diagram for the start of burn to end of burn phase for 15 MA Q = 10 Operation (I)



(I) The flux state diagram shown in **Figure 4-2** has been calculated by the TSC, Corsica, TOSCA and CREATE-NL codes which use free-boundary equilibrium codes to establish existence boundaries for the reference separatrix of **Figure 4-5** consistent with the ITER Central Solenoid and Poloidal Field systems. For a given value of internal inductance (li3), the flux difference between the boundaries at low values of flux at the boundaries at high value defines the maximum flux available for the current flat-top, including burn. Also shown are the minimum values of flux consumption associated with several values of the Ejima coefficient, CEjima, which accounts for resistive flux consumption during the current ramp-up. These lines are indicative of the additional constraint on flux available for the current flat-top associated with the evolution of the plasma from the CS premagnetization state to the point tSOF in **Figure 4-1**. The variation in available flat-top flux among the codes results from variations in the assumptions made relating to plasma equilibrium profiles and to the assumed permissible deviation from the reference separatrix of **Figure 4-5**. The formal definition of parameters utilized in the flux state analysis is given in [R28]. [PR525-C]

Figure 4-3: Flux state diagram for the start of burn to end of burn phase for 15 MA Q = 10 Operation (II)



(II) The flux state diagram shown in **Figure 4-3** has been calculated by the Corsica code and provides additional information relating to **Figure 4-2**. In particular, a series of time-evolved plasma scenarios encompassing ohmic, L-mode and H-mode operation in D-T plasmas has been calculated and superimposed on the operating space, demonstrating the capability for long duration current flat-top or plasma burn under varying assumptions [A19] . Trajectories of D-T H-mode plasmas are shown for a range of values of H-mode pedestal electron temperature, illustrating the capability of the Central Solenoid and Poloidal Field systems to support D-T H-mode operation over a substantial range in this key parameter. [PR527-C]

4.3.1.2 Plasma scenarios for H, D and He operation, commissioning plasma scenarios

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. [PR533-R]

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 D-T 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 as per the RPrS [R08] for determination of maximum loads on vessel and in-vessel structures due to disruptions and vertical displacement events (Section 4.3.7)
- 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 D-T 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 D-T 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.

--- [PR534-R]

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

4.3.1.3 Flexibility scenarios parameters

The possibility to operate ITER at enhanced parameters shall be assessed. Flexibility requirements include:

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

--- [PR2098-R]

These flexibility requirements should not lead to additional technical requirements for the ITER systems and structures with respect to those derived from the three D-T reference plasma scenarios in **Table 4-1**. [PR549-P]

Magnet systems shall be designed to operate with a plasma current of 17 MA. All other systems shall be designed for 15 MA operation. [PR1770-R]

ITER auxiliary (non-tokamak) systems shall be upgradable (with additional investment) to operate with a fusion power of 700 MW for 100 s. [PR836-R]

4.3.2 Readiness for plasma operation

4.3.2.1 Vacuum vessel and in-vessel component coolant parameters

The inlet pre-pulse and during pulse coolant temperature of the Vacuum Vessel, Neutral Beam port (up to the torus isolation valve) and in-vessel components (unless otherwise specified below) shall be 100°C, rangeability ±10°C, accuracy ±2% at nominal flow rate and pressure that are defined in the relevant SRDs. [PR452-R]

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

The requested measurement accuracy for the pressure, temperature and flow rate of TCWS is ±2% of the nominal value. [PR2371-R]

The pre-pulse and during pulse coolant parameters at the divertor inlet (that is, at cassette pipe stubs) shall be:

- Inlet operating temperature: 70°C with rangeability (-5 / +5 °C)
- Inlet pressure: 4.0 MPa with rangeability (-0.2 / +0.6 °C)
- Flow rate for all 54 divertor cassettes: minimum 870 kg/s.

--- [PR453-R]

The pre-pulse and during pulse-coolant parameters at the blanket inlet (that is, at chimney bulk head) shall be:

- Inlet operating temperature: 70°C with rangeability (-5 / +5 °C)
- Inlet pressure: 4.0 MPa with rangeability (-0.2 / +0.6 °C)
- Flow rate for all 440 wall mounted Blanket modules: minimum 3140 kg/s.

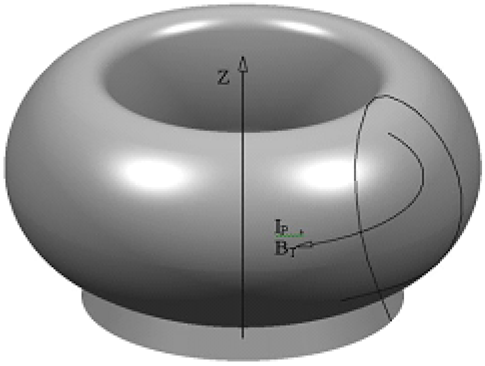
--- [PR458-R]

The VVPSS piping (up to the rupture disk) during the pre-pulse and pulse shall be controlled at 100°C, rangeability ±10°C, accuracy ±2%. [PR1773-R]

4.3.2.2 Toroidal field and plasma current direction

The reference directionality of the toroidal current and field shall be as follows: plasma current in the clockwise direction looking from above with the same direction for the toroidal field, giving a downward (towards divertor X-point) ion grad-B drift direction (see Figure 4-4). [PR464-R]

Figure 4-4: Toroidal field and plasma current direction



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). [PR466-R]

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

4.3.2.3 Toroidal field ripple

The toroidal field ripple is defined as $\delta(R, Z) = (B_{max}-B_{min})/(B_{max}+B_{min})$, where B_{max} and Bmin are maximum and minimum values of the toroidal magnetic field on the circle with coordinates (R, Z). [PR472-I]

The ripple requirements are determined by loss of fast particles and by potential changes in H-mode characteristics. A maximum toroidal field ripple at the plasma separatrix of <1% is enough to avoid excessive fast particle losses in all reference scenarios defined in **Table 4-1**. The quantitative influence of toroidal field ripple on plasma performance in the H-mode remains the subject of continuing R&D and at this time the prudent approach is to make ripple as small as reasonably achievable. [PR470-I]

Ferromagnetic inserts in the in-wall shielding near the outboard mid-plane shall be used to minimize the toroidal field ripple. [PR469-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]. [PR2099-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]. [PR473-R]

The ripple requirement in the presence of TBMs remains the subject of continuing R&D. [PR474-I]

4.3.2.4 Error fields requirements

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. [PR476-P]

The goal of introducing error fields requirements is 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. [PR477-I]

The calculation and assessment of acceptability of the design shall be based on the "3-mode" locked mode threshold (LMT) criterion: $B_{3\text{-mode}}/B_0 = \sqrt{(B_{2,1}/B_0)^2 + 0.8\,(B_{3,1}/B_0)^2 + 0.2\,(B_{1,1}/B_0)^2} < 5.0 \times 10^{-5}$ where $B_{1,1}$, $B_{2,1}$, and $B_{3,1}$ are the amplitudes of the normal component of the helical magnetic field on the q = 2 magnetic surface and 5.3T is the nominal value of toroidal magnetic field (B_0) at a major radius of 6.2 m. This is explained in Section 5.1.2.1. of [R02]. [PR479-R]

The misalignment of the Central Solenoid, Toroidal Field, and Poloidal Field coil current centrelines, arising during the coil manufacture, installation and assembly, is the main contributor to the error field. [PR2100-I]

Installation and fabrication tolerances for the coils shall be designed taking this requirement into account. [PR482-R]

Other sources of error are magnetic field compensation coils for the neutral beam and passive magnetic shielding located around the machine, magnetic masses in the test blanket modules, currents in reinforcement in concrete structures, tilt or rotation in Central Solenoid. [PR2101-I]

Error fields ($B_{3\text{-mode}}$) from individual sources shall be less than $5 \times 10^{-6}\,B_0$ unless formal project approval is granted. [PR2102-R]

The Correction Coils are required to be capable of reducing $B_{3\text{-mode}}/B_0$ to 5×10^{-5}. [PR483-I]

4.3.3 Plasma initiation

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

The nominal toroidal resistance of equipment within the cryostat (excluding coil circuits) shall be greater than 4 μΩ. [PR498-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 (11 independent circuits) shall be chosen so as to produce an almost central plasma initiation. The plasma may contact predominantly either the inboard or the outboard wall. [PR499-R]

Breakdown occurs when the toroidal electric field in the centre of the breakdown region reaches approximately 0.3 V/m. [PR500-I]

An ECRH power of at least 6 MW shall be provided for breakdown and burn-through assist (relevant for toroidal magnetic fields near to 50% and 100% of nominal field). [PR501-R]

The plasma initiation occurs in a central location and the startup gyrotron frequency is 170 GHz, the same as H&CD frequency. [PR495-I]

At plasma initiation, the Poloidal Field system should be capable of reducing the axisymmetric component of stray magnetic field over an acceptable volume of the breakdown region to less than 3 mT. [PR1821-P]

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. [PR502-R]

The ICH&CD shall contribute to achieving plasma breakdown, burn-through and assisted current rise by delivering a fraction of the nominal power. These functions are assumed not to drive the IC system design. [PR496-R]

4.3.4 Plasma control

The evolution of the plasma shape, current, and profiles shall be controlled to meet experimental objectives. [PR554-R]

The Plasma Control functions operate over a range of timescales, from quasi-stationary conditions to rapid (about 1 ms) plasma disturbances. [PR1808-I]

Electromagnetic loads shall be kept within acceptable limits even in the event of potential failures in control. [PR2103-R]

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

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

Neoclassical Tearing Modes (NTMs) shall be controlled to optimize plasma performance and to minimize the frequency of disruptions, while control of Resistive Wall Modes (RWMs) may be necessary to optimize performance in non-inductive scenarios. [PR1812-R]

The thermonuclear burn shall be controlled for periods ranging from several hundred seconds (Inductive operation) to several thousand seconds (Non-inductive operation), either in terms of the fusion power output or of the fusion power amplification factor, Q. [PR652-R]

4.3.4.1 Nominal 15 MA target equilibrium

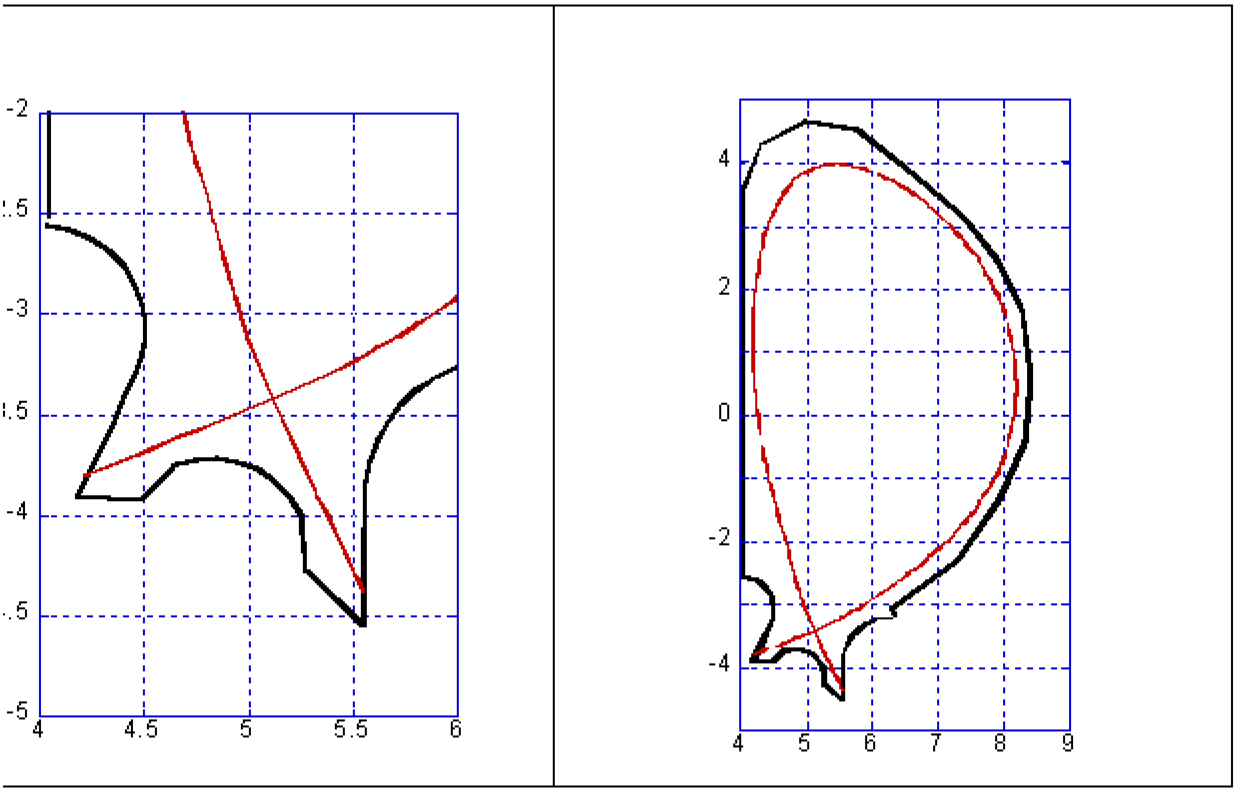
ITER shall be designed based on the 15 MA target separatrix defined in [A01]. [PR557-R]

This target separatrix is designed to satisfy plasma-wall separation, to limit quasi-stationary heat loads on the first wall, and to maintain the location of the divertor strike points, to assure controlled operation of the divertor plasma state as well as avoidance of excessive heat loads beyond the specified high heat flux region of the vertical divertor target. [PR558-I]

Plasma equilibria for Hybrid and Non-inductive scenarios remain the subject of ongoing research. [PR559-I]

Since the reference scenarios defined in **Table 4-1** require operation at currents of less than 15 MA, the specification of requirements for plasma equilibrium control associated with the 15 MA scenario, in particular, at high values of li (about 1.2) provides margin for plasma equilibrium control in the Hybrid and Non-inductive scenarios (see Figure 4-5). [PR560-I]

Figure 4-5: Nominal 15 MA target separatrix for analysis of Q = 10 D-T plasma scenarios and equilibrium control (TOSCA code)



4.3.4.2 Slow timescale (quasi-static) control

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

Quasi-static shape control parameters are specified in **Table 4-2** for all reference scenarios and flexibility scenarios. [PR2111-I]

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. The special case of plasma-wall contact imposes additional constraints and the requirements are specified in Section 4.3.4.3. [PR564-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 ±0.05MA, whichever is less restrictive. [PR1823-R]

Table 4-2: Quasi-static shape control parameters (timescale greater than 10 s)

Parameters	Unit	Value
Maximum downward displacement of the separatrix inner leg relative to the leg of target separatrix	mm	50
Maximum upward displacement of the separatrix inner leg relative to the leg of target separatrix	mm	150
Maximum inward displacement of the separatrix outer leg relative to the leg of target separatrix	mm	50
Maximum outward displacement of the separatrix outer leg relative to the leg of target separatrix	mm	150
Minimum clearance between the separatrix and the inner part of the first wall	mm	~100 mm at low βp (e.g. at start of heating) ~150 mm at high βp (e.g. at burn)
Minimum clearance between the 40 mm flux surface (note 1) and the first wall (unless otherwise specified)	mm	80
Minimum distance between the inner and outer separatrices at the outboard equatorial plane (for reliable operation in a single-null divertor configuration.)	mm	40

Note 1: The 40 mm flux surface is defined as the flux surface that passes through a point 40 mm outside the separatrix at the outboard equator. [PR1638-C]

4.3.4.3 Fast timescale control of plasma-wall gap

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

The precise duration of plasma-wall contact leading to such occurrences will depend on the detailed design of the first wall, but can be anticipated to be much less than 1 s. This duration will be determined precisely once the final design of the first wall is specified. [PR2112-I]

To limit this damage 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. [PR2113-R]

In cases where the plasma control system is unable to satisfy this requirement, the Disruption Mitigation System specified in Section 4.3.10.3 will be triggered to avoid excessive heat loading of the first wall. [PR567-I]

4.3.4.4 Stabilization of plasma vertical displacements

Elongated plasmas in ITER are vertically unstable and, in the absence of an active control system, drift vertically with a characteristic time determined by the decay time of currents in the vacuum vessel (about 0.1 s). The vertical position of the plasma shall be stabilized by a feedback system typically measuring vertical drift velocity and controlling the horizontal magnetic field created by poloidal field coils. [PR569-R]

A system capable of stabilizing vertical motions of ITER plasmas and restoring the plasma to its preset position will consist of both:

- ex-vessel Poloidal Field coils (PF2, PF3, PF4, PF5) maintaining the required equilibrium radial field over longer timescales within the current limit specified by IVS1 in Section 4.3.5.3 (designated VS1)
- in-vessel coils, for fast (less than 0.1 s) response (designated VS3),

--- [PR570-I]

The performance of the overall system controlling vertical plasma displacements (VS1+ VS3) shall satisfy:

- The system stabilizing plasma vertical displacements shall be capable of restoring the plasma to its specified vertical position after a maximum uncontrolled vertical drift with target value of 16 cm for a nominal full aperture plasma with li < 1.2 . The frequency and number of occurrences per pulse of such large amplitude events shall be limited by scenario design to be ≤0.1 Hz and 3, respectively. The total number of these events should be no more than 30000 over the lifetime of ITER.
- Uniformly distributed noise in the dz/dt measurement with an RMS value of 0.6 $m.s^{-1}$ and a bandwidth of 1 kHz shall be assumed for vertical stability control assessments. In cases where only VS1 is used, the noise amplitude used in performance assessments should be assumed to be 0.2 $m.s^{-1}$.
- In the absence of specific plasma equilibrium disturbances and over timescales that are long compared with the radial field penetration time for the vacuum vessel, the vertical stabilization system will maintain the plasma vertical position within limits corresponding to the amplitude and bandwidth of noise specified above.

--- [PR575-R]

In the case that the in-vessel coils fail (VS3), the vertical stabilization system based on external coils shall be upgradeable in the following way:

- The necessary busbar connections allowing the possible use of the Central Solenoid coils CS2U and CS2L as a component of the external vertical stabilization circuit (designated VS2) shall be made available
- The VS1 shall be capable of 9 kV operation
- The VS2 loop shall be capable of 6 kV operation
- The VS1 and VS2 circuits alone shall be capable of restoring the plasma to its specified vertical position and avoid separatrix contact with the first wall/divertor dome after a maximum uncontrolled vertical drift with a target value that depends on the plasma li(3) as in the formula:

--- [PR574-R]

$$Z_0(cm) = 160\, e^{-3.7 l_i(3)} + 1.8$$

Where the definitions of l_i and β_p are below:

$$l_i = l_i(3) = \frac{2V\langle B_{pol}^2 \rangle}{(\mu_0 I_p)^2 R}, \qquad \beta_p = \beta_p(1) = \frac{2\mu_0 \langle p \rangle_V}{\langle B_{pol} \rangle_L^2}$$

where the notation $\langle\ \rangle_V$ implies a plasma volume average and the notation $\langle\ \rangle_L$ implies a plasma boundary average:

$$\langle A \rangle_V = \int_V A\,dV \Big/ \int_V dV, \quad \langle A \rangle_L = \oint A\,dl_{pol} \Big/ \oint dl_{pol}.$$

In these definitions, B_{pol} is the total poloidal magnetic field, dl_{pol} is the poloidal element of the plasma boundary, R is the plasma major radius, V is the plasma volume, p is the plasma kinetic pressure and μ_0 is the permeability of free space.

The frequency and number of occurrences per pulse of such large amplitude events shall be limited by scenario design to be less than or equal to 0.1 Hz and 3, respectively. The total number of these events should be no more than 30,000 over the lifetime of ITER. [PR1802-R]

4.3.5 Systems for plasma axisymmetric magnetic control

Plasma axisymmetric magnetic control is provided by the "poloidal field system" that comprises the Central Solenoid, the Poloidal Field coils, the in-vessel, normal conductor, "Vertical Stabilization" (VS) coils and the coil power supplies. [PR581-I]

Plasma axisymmetric magnetic control relies on measurements of plasma current, position and shape derived from the magnetic diagnostics and possibly other diagnostic systems. [PR2114-I]

Plasma axisymmetric magnetic control acts on currents flowing in the Central Solenoid and Poloidal Field coils to achieve plasma initiation and subsequent control of the plasma current, position and shape according to target waveforms of the controlled parameters. [PR2115-I]

Fast control of the plasma vertical position shall be provided by the in-vessel VS coils, while currents flowing in several of the superconducting coils contribute to the stabilization of plasma vertical displacements. [PR582-R]

Analyses of 15 MA Q = 10 Inductive plasma operation scenario defined in Section 4.3.1.1, including the capability for control of the plasma equilibrium following specified disturbances, leads to the following requirements on the performance of the CS and PF coils and their power supplies. [PR583-I]

4.3.5.1 Location and dimensions of the Central Solenoid and Poloidal Field coils

The Central Solenoid and Poloidal Field coils position (R, Z co-ordinates of the conductor cross section centre), the size of coil conductor cross sections (ΔR, ΔZ) and the number of turns (N) shall conform to the values in **Table 4-3**. These data are referenced to the tokamak operating temperature in the system of co-ordinate with Z = 0 in the Tokamak Global Coordinate System (TGCS). The TF mid-plane, at operating temperature, is estimated to be at Z=-10mm (TGCS). [PR585-R]

Table 4-3: Location and sizes of the Central Solenoid and Poloidal Field coils [A01]

Coil	R, m	Z, m	ΔR, m	ΔZ, m	N
CS3U	1.687	5.464	0.740	2.093	554
CS2U	1.687	3.278	0.740	2.093	554
CS1U	1.687	1.092	0.740	2.093	554
CS1L	1.687	-1.072	0.740	2.093	554
CS2L	1.687	-3.258	0.740	2.093	554
CS3L	1.687	-5.444	0.740	2.093	554
PF1	3.943	7.574	0.959	0.984	248.6
PF2	8.284	6.540	0.580	0.715	115.2
PF3	11.992	3.275	0.696	0.954	185.9
PF4	11.992	-2.234	0.638	0.954	169.9
PF5	8.391	-6.727	0.812	0.954	216.8
PF6	4.334	-7.466	1.559	1.107	459.8

Note: R, Z co-ordinates of the centre of the coil cross-sections [PR587-C]

Size (ΔR, ΔZ) and number of turns of each coil (4K, without ground insulation) [PR588-C]

4.3.5.2 Maximum Central Solenoid and Poloidal Field coil currents and fields

When individually energized, the CS and PF coils shall be capable of operating anywhere within the range of currents and fields defined by the following points in (I,B) space - ($-I_{max}$, 0), ($-I_{max}$,$-(B@I_{max})$), ($-(I@B_{max})$, $-B_{max}$), (0, $-B_{max}$), (0, B_{max}), ($I@B_{max}$, B_{max}), (I_{max}, $B@I_{max}$), and (I_{max}, 0) - where the values for I_{max}, $I@B_{max}$, B_{max}, and $B@I_{max}$ are defined in **Table 4-4**. [PR590-R]

Table 4-4: Maximum Central Solenoid and Polodial Field coil currents and fields

Coil	Imax (kA)	B (T) @ Imax	I (kA) @ Bmax	Bmax (T)
CS3U	45	12.6	40	13.0
CS2U	45	12.6	40	13.0
CS1U	45	12.6	40	13.0
CS1L	45	12.6	40	13.0
CS2L	45	12.6	40	13.0
CS3L	45	12.6	40	13.0
PF1	48	6.4	41	6.5
PF2	55	4.8	50	5.0
PF3	55	4.8	50	5.0
PF4	55	4.8	50	5.0
PF5	52	5.7	33	6.0
PF6	48	6.4	41	6.5
PF6 (0.4 K subcooling)	52	6.8	41	7.0

4.3.5.3 Required Central Solenoid and Poloidal Field coil current combinations

Magnet systems shall be capable of operating with combinations of Central Solenoid and Poloidal Field coil currents that are required to support the operating spaces defined by **Figure 4-2** and **Figure 4-3** as exemplified by scenario waveforms defined in the document [A19], with full toroidal field (5.3 T at 6.2 m) subject to the following constraints: [PR593-R]

The maximum current in the VS1 stabilizing circuit, I_{VS1}, does not exceed 22 kA where I_{VS1} is defined as $I_{VS1} = I_{PF2} + I_{PF3} - I_{PF4} - I_{PF5}$. [PR594-I]

The net vertical electromagnetic load on the Central Solenoid coils does not exceed 60 MN. [PR596-I]

The vertical separating force figure of merit (as described next) on the Central Solenoid assembly, F_{VSF}, does not exceed 120 MN. (The resultant stresses in the CS shall be confirmed by a detailed analysis before proposed scenarios are implemented in operation.) [PR597-R]

F_{VSF} is referred to as a figure of merit because it does not represent the true vertical separating force due to EM loads where the Central Solenoid assembly is supported from the bottom. However, it was used as a constraint in assessing the accessible operating space so it is included here. [PR598-I]

It is defined by:

$$F_{VSF} = \frac{|F_z(Upward)| + |F_z(Downward)|}{2}$$

Here F_z(*Upward*) is defined as <u>maximum</u> value among the following six values:

- F_z(CS3U),
- F_z(CS3U) + F_z(CS2U),
- F_z(CS3U) + F_z(CS2U) + F_z(CS1U),

- F_z(CS3U) + F_z(CS2U) + F_z(CS1U) + F_z(CS1L),
- F_z(CS3U) + F_z(CS2U) + F_z(CS1U) + F_z(CS1L) + F_z(CS2L),
- F_z(CS3U) + F_z(CS2U) + F_z(CS1U) + F_z(CS1L) + F_z(CS2L) + F_z(CS3L),

--- [PR601-I]

and F_z(*Downward*) is defined as minimum value among the following six values:

- F_z(CS3L),
- F_z(CS3L) + F_z(CS2L),
- F_z(CS3L) + F_z(CS2L) + F_z(CS1L),
- F_z(CS3L) + F_z(CS2L) + F_z(CS1L) + F_z(CS1U),
- F_z(CS3L) + F_z(CS2L) + F_z(CS1L) + F_z(CS1U) + F_z(CS2U),
- F_z(CS3L) + F_z(CS2L) + F_z(CS1L) + F_z(CS1U) + F_z(CS2U) + F_z(CS3U).

--- [PR609-I]

Note that Fz(Downward) has a negative sign. [PR617-I]

The Central Solenoid coils CS1U and CS1L have identical currents. [PR618-I]

The Central Solenoid and Poloidal Field coil currents and fields lie within the operating space defined in Section 4.3.5.2. [PR619-I]

Resultant vertical loads on the Poloidal Field coils lie within the limits specified in **Table 4-5**. [PR620-I]

Table 4-5: Maximum vertical loads on Poloidal Field coils

Coil	Maximum +ve load (MN)	Maximum -ve load (MN)
PF1	110	-150
PF2	15	-75
PF3	40	-90
PF4	90	-40
PF5	160	-10
PF6	170	-190
PF3+PF4	10	-60

Note: +ve is upwards vertical in global coordinate system. [PR622-C]

4.3.5.4 Target Waveforms

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

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

4.3.5.5 Power supply voltage requirements

The Central Solenoid coils CS1U and CS1L shall be connected in series, having identical currents. [PR627-R]

Power supplies for the Central Solenoid coils CS1U and CS1L circuit shall be interleaved such that the maximum voltage to earth and terminal voltages do not exceed the values in other CS circuits. [PR628-R]

All other Central Solenoid coils and Poloidal Field coils shall have independent power supplies. [PR629-R]

The VS1 circuit includes up to 6 converters attached to Poloidal Field coils PF2, PF3, PF4, and PF5 for vertical stability control. [PR2134-I]

Voltages required for plasma initiation in the Central Solenoid coils, Poloidal Field coils PF1 and PF6 are produced by Switching Network Units and AC/DC converters connected in series. [PR2135-I]

The maximum value of on-load voltage produced by the Switching Network Units is 8.5 kV (except for that in the Central Solenoid coils CS1U and CS1L modules, producing 6 kV in each coil) and the maximum number of steps in the value of resistors of the Switching Network Units is 2. [PR630-I]

The Poloidal Field coils PF2, PF3, PF4 and PF5 use only AC/DC converters. [PR2136-I]

The available number of AC/DC converters connected in series in each circuit is shown in **Table 4-6**. [PR2137-I]

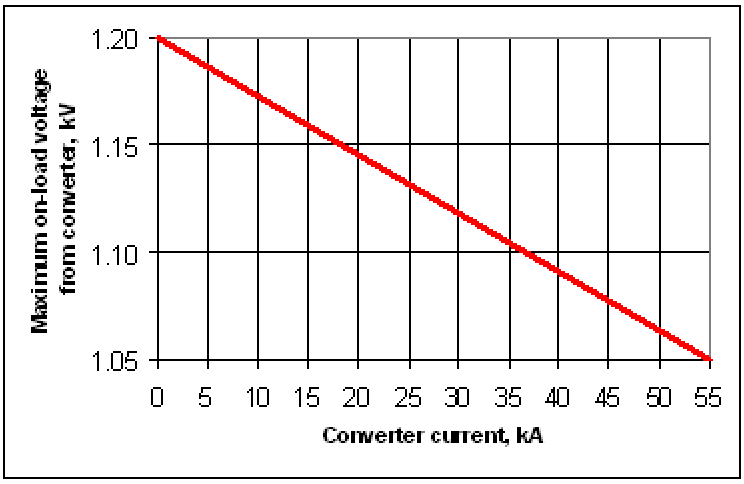
Table 4-6: Number of converters

Coil	Configuration for first plasma	Basic configuration
CS3U	1	1 or 2
CS2U	1	1 or 2
CS1U	1	1 or 2
CS1L	1	1 or 2
CS2L	1	1 or 2
CS3L	1	1 or 2
PF1	1	1 or 2
PF2	3	3
PF3	3	3
PF4	3	3
PF5	3	3
PF6	1	1 or 2
VS1 circuit	2	6

All converters are identical. [PR2138-I]

The maximum value of the on-load voltage produced by the converter varies with the current flowing in the converter as shown in **Figure 4-6**. [PR1826-I]

Figure 4-6: Maximum value of the on-load voltage produced by and AC/DC converter against the current flowing in the converter



4.3.6 Control of Edge Localized Modes (ELMs)

ELMs have the potential of seriously overheating the plasma-facing surfaces of the divertor and other plasma-facing components leading to enhanced rates of Plasma-Facing Component (PFC) erosion and shortening the PFC lifetime. ITER will therefore require an adequate capability for the mitigation of ELM heat loads. [PR633-I]

Resonant Magnetic Perturbations (RMPs) have the potential to eliminate ELMs. Pellet injection has been shown to trigger low energy ELMs frequently enough to be manageable. Other techniques, such as producing regular small vertical plasma displacements, have also been shown to control ELM behaviour. R&D is continuing to investigate all of these techniques with the aim of improving the capability for the quantitative specification of requirements for such techniques to be effective in ITER. [PR634-I]

ITER will make use primarily of two ELM control techniques: application of RMP fields and pellet injection. [PR635-I]

RMPs shall be provided that are calculated to result in overlapping n=3 or 4 islands (Chirikov parameter greater than or equal to 1.1, and is defined as the ratio of the average island size to the island separation) in the edge layer for ELM suppression. The region of the plasma edge over which this condition must be satisfied at ITER is Y (r) > g, where Y is the normalized poloidal flux and g is in the range g = 0.8-0.9. The precise value of g for each of the reference scenarios remains the subject of R&D. [PR637-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). [PR638-R]

The capability to trigger ELMs through Low Field Side (LFS) D-T pellet injection (pellet pacing) shall be provided. Pellets for pellet pacing shall be provided in two nominal sizes: 33 mm^3 and 17 mm^3. [PR641-R]

The nominal pellet injection frequency shall be 4 Hz with a maximum frequency of 40 Hz. [PR642-R]

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

The fuelling mixture shall be adjustable between 100% D_2 and 90% T_2. [PR644-R]

The capability to change the pellet size ±20% from nominal within 0.2 s during a pulse shall be provided. [PR645-R]

The capability to change the nominal pellet size within one hour between pulses shall be provided. [PR646-R]

The capability to change the pellet injection frequency by a factor of two within 3 s during a pulse shall be provided. [PR647-R]

A maximum pellet fuelling rate of 120 $Pa.m^3.s^{-1}$ shall be provided for H_2 and D_2. [PR648-R]

A maximum pellet fuelling rate of 111 $Pa.m^3.s^{-1}$ shall be provided for T_2 (90% T_2, 10% D_2). [PR649-R]

The fuelling rate from pellet pacing shall be controllable within ±5 %. [PR650-R]

4.3.7 Disruption handling

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. [PR655-I]

The disruption definition in the Load Specifications [A14] cites an initial plasma current of 15 MA. Disruptions are assumed to occur at the mid-burn in reference Inductive Operation Scenario defined in Section 4.3.1.1. [PR656-I]

Four types of major disruptions are considered. Type I has a slower current quench but a higher likelihood of occurrence. Type II has a faster current quench but a lower likelihood of occurrence. Type III has same current quench as the Type II disruption but a shorter thermal quench time. Type IV has faster current quench time than Type II or III. Another Type IV major disruption is initially slow and finally fast (same quench rate as Type II or III) current quench. [PR657-I]

The runaway electron population reduces the speed of the plasma current quench. The runaway electrons could be generated for all of the major disruptions events. [PR658-I]

ITER shall be designed to accommodate major disruptions as specified in the Load Specifications [A14]. Accommodating disruptions means that only Type III or IV major disruption will not induce a failure or a coil quench. However, cumulative effects such as erosion and ablation can be managed within the scheduled maintenance allocations with disruption mitigation system. [PR659-R]

Superconducting coils shall be designed to not quench or trigger a fast discharge in the presence of type I or II disruptions as defined in the Load Specifications [A14]. [PR660-R]

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

Requirements on the Disruption Mitigation System are specified in Section 4.3.10.3. [PR669-I]

4.3.8 Vertical displacement events

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

VDEs start with the plasma drifting up or down without significant loss of plasma current and stored kinetic energy. The thermal quench may start between when the plasma first contacts the wall and when the edge safety factor (q_{edge}) drops to 1.5. For conservatism, the current quench is assumed to start when q_{edge} drops to 1.5 for the specification of mechanical load. During the current quench, the plasma is still drifting. Halo currents which flow between the plasma and plasma-facing structures may appear. No runaway electrons are anticipated for VDEs. [PR664-P]

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

Three types of VDEs are considered. With disruption mitigation system, likelihood of occurrence for Type III and IV shall be sufficiently low. Toroidal Field coils shall be designed not to quench, and not to trigger a fast discharge, in the presence of type II VDEs as defined in the Load Specifications [A14]. [PR666-R]

4.3.9 Plasma heating and current drive

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

IC H&CD is required to provide heating and centrally-peaked current drive. The system will also be used for wall conditioning between pulses as specified in Section 4.3.14.3. [PR672-I]

The system shall be configured to provide 20 MW of IC power to the plasma. [PR673-R]

The IC power shall be coupled to the plasma through two launchers in two equatorial ports. [PR674-R]

Launchers 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. [PR675-R]

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

The IC system shall operate in quasi-CW conditions: pulse lengths of up to 3600 s and a duty cycle of 25%. [PR1807-R]

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

EC H&CD is required to provide heating and current drive, control 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 4.3.3. Requirements for wall conditioning between pulses are given in Section 4.3.14.3. [PR678-I]

The EC H&CD system shall provide 20MW of EC power to the plasma at a frequency of 170 GHz for periods up to 3600 s. [PR679-R]

The EC H&CD Power shall be delivered through one equatorial port launcher and four upper port launchers. [PR680-R]

The equatorial port EC H&CD launcher shall be capable of delivering 20MW to the plasma and shall have a toroidal steering with access of $0 < \rho_T \leq 0.4$. [PR681-R]

The upper port EC H&CD launchers shall be capable of delivering 6.7 MW each to the plasma. [PR682-R]

Upper steering mirrors used in EC H&CD launchers shall provide a poloidal steering with approximately a 20° (specific angle determined for optimum control of MHD activity) toroidal inclination between the beam and poloidal cross-section with access of $0.3 < \rho_T \leq 0.8$. (The exact value of the steering angles depends on the specific launching geometry.) [PR683-R]

Lower steering mirrors used in EC H&CD Upper Launchers shall provide a poloidal steering with approximately a 20° (specific angle determined for optimum control of MHD activity) toroidal inclination between the beam and poloidal cross-section with access of $0.6 < \rho_T \leq 0.86$. [PR684-R]

An in-line, automatic, and remotely-controlled switching system to share the RF power between the upper and equatorial EC H&CD launchers shall be provided. [PR685-R]

The EC H&CD system power shall be adjustable with a modulation of 5 kHz. [PR686-R]

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

The NB H&CD system provides neutral beams for plasma heating and current drive, plasma rotation, 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. [PR688-I]

4.3.9.3.1 Heating Neutral Beam (HNB)

The HNB system shall deliver 33 MW to the plasma through two beamlines during D-T operation. Each beamline shall be capable of delivering 16.7 MW with a 1 MeV D0 beam with line-averaged plasma densities (n_e) greater than 0.35×10^{20} /m^3. [PR690-R]

The HNB system shall deliver 33 MW to the plasma through two beamlines during hydrogen (H) operation. Each beamline shall be capable of delivering 16.7 MW with a 0.87 MeV H0 beam with line-averaged plasma densities (n_e) greater than 0.45×10^{20} /m^3. [PR691-R]

Beamlines of the HNB system shall be aimed with a tangency radius of 5.276 m and be adjustable for aiming at any elevation between -0.154 m and -0.420 m at the tangency radius. [PR692-R]

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

The HNB shinethrough on the blanket first wall during operation at low density plasma shall not exceed power levels defined in the Heat and Nuclear Load Specifications [A15]. [PR694-R]

The first-wall surface temperature shall be monitored and the HNB power regulated to avoid overheating the first wall due to NB shinethrough during operation at low plasma density. [PR695-R]

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

4.3.9.3.2 Diagnostic Neutral Beam (DNB)

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 x 10^{20} /m^3. [PR698-R]

The DNB shall be aimed 6º from perpendicular to the plasma at the equatorial plane. The vertical aiming angle is 0.89° pointing downwards. [PR699-R]

The DNB will be modulated at 5 Hz with:

- 1/6 duty factor (3 s ON, 20 s OFF) total on time 3600 s
- modulation depth of 100%

--- [PR700-I]

4.3.10 Power handling

Heat loads on the vacuum vessel and in-vessel components are specified in the Heat and Nuclear Load Specifications [A15]. These loads include power fluxes during the steady and transient phases. Transient phenomena include ELMs, MARFES, major disruptions, VDEs, L-H and H-L transitions, massive gas injection, and loss of control. Some of the specifications for more localized heat loads, such as those resulting from ripple-trapped particles, runaway electrons, NB shinethrough, or the operation of RMP coils, are undergoing refinement with more advanced calculations, taking into account the final tokamak design parameters (such as ripple map, RMP coil distribution, first wall panel shape). [PR711-I]

4.3.10.1 Plasma heat loads

The vacuum vessel and in-vessel components shall be designed to accommodate the heat loads specified in the ITER Heat and Nuclear Load Specifications [A15]. [PR713-R]

In case of unmitigated transients like VDE, runaway electrons and disruptions, some local damage of the armour material is acceptable. As far as possible, taking into account the other surface heat loads, the armour 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. [PR714-R]

4.3.10.2 Plasma-facing surface material

The initial divertor (to be installed during construction phase 2, see **Figure 3-3**) shall have tungsten for all its plasma-facing surfaces. [PR717-R]

The blanket first wall shall have beryllium on plasma-facing surface and other materials, such as steel, copper alloy, tungsten may be used in limited areas. [PR719-R]

The first wall shall be designed to provide limiting surfaces that define the plasma boundary during startup and shutdown. [PR1800-R]

4.3.10.3 Heat load mitigation

Plasma loss-of-control events can result in direct plasma contact to the wall or in a major disruption. These can lead to excessive heat flux on the plasma-facing components. [PR722-I]

To prevent physical damage to the vessel and in-vessel components, the Disruption Mitigation System (DMS) shall be developed to terminate the plasma. [PR723-R]

Potential candidate approaches for the mitigation exist, but additional R&D is needed before final selection, especially concerning the mitigation of runaway electrons. [PR724-I]

The DMS is for investment protection . [PR725-I]

The DMS aims at mitigating the most severe effects of disruption and VDEs to minimize the need for intervention and to support routine and reliable operation of the device. Target values for the mitigation system are:

- Energy load on divertor target: 1/5 to 1/10
- Energy load on first wall: less than 1/10 (VDEs)
- EM load due to halo currents: 1/2 to 1/3
- Runaway electrons: less than 1/10.

--- [PR726-I]

The disruption mitigation system shall allow recovery of ITER operation on a timescale of no more than three hours. [PR732-R]

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

In case of transients like H-L transition and plasma re-attachments, the plasma control system shall be equipped with the means to prevent physical damage to the in-vessel components and, ultimately, to trigger the disruption mitigation system. [PR734-R]

4.3.11 Plasma fuelling and pumping

4.3.11.1 Bounding fuelling rates and tritium supply limits

During the hydrogen and deuterium phases, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 200 $Pa.m^3.s^{-1}$ average and 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. [PR738-R]

During the D-T phase, the T_2 supply (90% T, 10% D) shall be limited to 111 $Pa.m^3.s^{-1}$ average and 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 and 200 $Pa.m^3.s^{-1}$ peak of pure T_2. [PR739-R]

During the D-T phase, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 200 $Pa.m^3.s^{-1}$ average and 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 400 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above). [PR740-R]

During the D-T phase, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 160 $Pa.m^3.s^{-1}$average and 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 400 s and 1000 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above). [PR741-R]

During the D-T phase, the bounding fuelling rate (gas puffing plus pellet injection) shall not exceed 120 $Pa.m^3.s^{-1}$ average and 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 s and 3000 s when operating with H_2, D_2, and T_2 (subject to T_2 supply limits above). [PR742-R]

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

4.3.11.2 Divertor pumping

The divertor neutral particle pressure during D-T plasma operations (and during hydrogenic plasma operation in general) is expected to be in range of 1 to 10 Pa when operating with a diverted plasma configuration. [PR745-I]

In He plasmas (including mixtures with H), the neutral particle pressure in the divertor is expected to be in the range 0.25 to 10 Pa when operating with a diverted plasma configuration. [PR746-I]

The divertor pumping system shall provide adequate and controllable pumping speed to maintain a specified pressure under the dome for steady conditions with a variable fuelling rate:

- For He plasma operation (including the simultaneous use of hydrogenic pellet injection):
    - for an under-dome pressure in the range 4 to 10 Pa: throughput up to 120 $Pa.m^3.s^{-1}$

- for an under-dome pressure less than 4 Pa: throughput less than 120 $Pa.m^3.s^{-1}$ and a minimum pumping speed of 30 $m^3.s^{-1}$

For D-T plasma operation:

- for an under-dome pressure in the range 3 to 10 Pa: throughput up to 200 $Pa.m^3.s^{-1}$
- for an under-dome pressure less than 3 Pa: throughput less than 200 $Pa.m^3.s^{-1}$ and a minimum pumping speed of 50 $m^3.s^{-1}$

--- [PR747-R]

The net pumping speed from the divertor shall be adjustable between 0% and 100% within 10 s. [PR755-R]

During D-T plasma operation, the torus pumping system shall be capable of sustaining flat-top pulse lengths of up to 400 s at the maximum fuel throughput of 200 $Pa.m^3.s^{-1}$ [PR756-R]

The pumping system shall exhaust low concentrations (less than 1%) of extrinsic impurities used to promote divertor radiation, together with gaseous hydrocarbons resulting from chemical sputtering of CFC PFCs. It shall also be capable of pumping, over longer periods, larger quantities of extrinsic impurities used in the course of burn termination or disruption mitigation. [PR757-R]

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

4.3.11.3 Core fuelling

High Field Side (HFS) pellet injection shall be provided for core fuelling. Pellets for core fuelling shall be provided in two nominal sizes - 90 mm^3 and 50 mm^3. [PR760-R]

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

Pellet injection requirements for ELM suppression (pellet pacing) are provided in Section 4.3.6. [PR762-I]

4.3.11.4 Pellet impurity injection

A maximum impurity injection rate of 10 $Pa.m^3.s^{-1}$ shall be provided for Ar, Ne, and N_2. [PR764-R]

4.3.11.5 Gas fuel injection

Gas fuelling rate shall be within bounding fuelling rates and tritium supply limits given in Section 4.3.11.1. [PR766-R]

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

4.3.11.6 Gas impurity injection

The capability of injection of impurity gas species such as N_2, Ar and Ne shall be provided. [PR769-R]

The capability for impurity gas injection up to two species at an average rate of 10 $Pa.m^3.s^{-1}$ for each gas species shall be provided. [PR770-R]

The capability for impurity gas injection up to two species at a peak rate of 100 $Pa.m^3.s^{-1}$ for each gas species shall be provided. [PR771-R]

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

4.3.11.7 Neutral Beam Fuelling

The capability to fuel hydrogen gas at the rate of 49 $Pa.m^3.s^{-1}$ to each of the heating neutral beam injectors shall be provided during hydrogen plasma operation. [PR774-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 deuterium and D-T plasma operation. [PR775-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 hydrogen plasma operation. [PR776-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 deuterium and D-T plasma operation. [PR777-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 hydrogen, deuterium and D-T plasma operation. [PR778-R]

4.3.12 Plasma diagnostics

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

Measurements for ITER plasma diagnostics have four possible roles:

- Machine protection (1.a1)
- Basic machine control(1.a2)
- Advanced plasma control (1.b)
- Evaluation and physics studies (2.)

--- [PR781-I]

ITER shall not operate without a working diagnostic providing every measurement for machine protection (1.a1 role) and basic control (1.a2 role). [PR782-R]

ITER shall not operate advanced operation without a working diagnostic providing every measurement for advanced plasma control (1.b role). [PR783-R]

ITER may operate even when a measurement for evaluation and physics studies (2. role) is not provided. [PR784-P]

There may be a future “safety function” for dust measurements; this is currently under investigation. [PR785-P]

The diagnostics listed in **Table 4-8** shall be provided for the measurements listed in **Table 4-7**. [PR786-R]

According to their technologies, ITER plasma diagnostics systems may have different contributions to different measurements. The following contributions shall be considered:

- Primary: diagnostic is well suited to the measurement
- Back-up: diagnostic provides similar data to primary, but has some limitations
- Supplementary: diagnostic validates or calibrates the measurement but is not complete in itself.

--- [PR2359-R]

Table 4-7: Required measurements classified by role

Measurement	Parameter	Role	Range to cover
1. Plasma Current	I_p	Machine protection 1a 1	0 — 25 MA
2. Plasma Position and Shape	Main plasma gaps, D_{sep}	Basic machine control 1a.2	-
	Divertor channel location (r dir.)	Basic machine control 1a.2	-
	dZ/dt of current centroid	Machine protection 1a 1	0 — 5 m/s
3. Loop Voltage	V_{loop}	Machine protection 1a 1	0 — 500 V
4. Plasma Energy	$Beta_p$	Machine protection 1a 1	0.01 — 5
5. Radiated Power	Main Plasma P_{rad}	Basic machine control 1a.2	0.1 MW — 1 GW
	X-point / MARFE region P_{rad}	1b	30 kW — 0.3 GW
	Divertor P_{rad}	Basic machine control 1a.2	30 kW — 0.3 GW
	Total P_{rad}	Machine protection 1a 1	30 MW — 300 GW
6. Line-Averaged Electron Density	?n_e dl / ? dl	Basic machine control 1a.2	10^{18} — $2x10^{22}$ m^{-3}
7. Neutron Flux and Emissivity	Total neutron flux	Machine protection 1a 1	10^{14} — $7.5x10^{20}$ $n.s^{-1}$
	Neutron / a source	Advanced plasma control 1b	10^{14} — $6x10^{18}$ $n.m^{-1}.s^{-1}$
	Fusion power	Basic machine control 1a.2	100 kW — 1.5 GW
	Fusion power density	Basic machine control 1a.2	1 $kW.m^{-3}$ — 1.5 $MW.m^{-3}$
8. Error Field, Locked Mode and RWM	Br/<Bp>	Machine protection 1a 1	10^{-4} — 10^{-2}
9. Low (m,n) MHD Modes, Sawteeth, Disruption Precursors	Btheta(complex, at wall)/<Bp>	Machine protection 1a 1	10^{-4} — 10^{-2}
10. Plasma Rotation	VTOR	Advanced plasma control 1b	1 — 200 $km.s^{-1}$
	VPOL	Advanced plasma control 1b	1 — 50 $km.s^{-1}$

Measurement	Parameter	Role	Range to cover
11. Fuel Ratio in Plasma Core	nT/nD	Basic machine control 1a.2	0.01 — 10
12. Impurity Species Monitoring	Be, C, O rel. conc.	Basic machine control 1a.2	10^{-4} — $5x10^{-2}$
	Be, C, O influx	Machine protection 1a.1	10^{16} — $5x10^{19}$ $m^{-2}.s^{-1}$
	Cu rel. Conc.	Basic machine control 1a.2	10^{-5} — $5x10^{-3}$
	Cu influx	Machine protection 1a.1	10^{15} — $5x10^{18}$ $m^{-2}.s^{-1}$
	W rel. conc.	Basic machine control 1a.2	10^{-6} — $5x10^{-4}$
	W influx	Machine protection 1a.1	10^{14} — $5x10^{17}$ $m^{-2}.s^{-1}$
	Extrinsic(Ne,Ar, Kr) rel. Conc.	Basic machine control 1a.2	10^{-4} — $2x10^{-2}$
	Extrinsic (Ne, Ar, Kr) influx	Basic machine control 1a.2	10^{16} — $2x10^{19}$ $m^{-2}.s^{-1}$
13. Zeff(Line-averaged)	Zeff	Basic machine control 1a.2	1 — 5
14. H-mode: ELMs and2 L-H Transition Indicator	ELM Da bursts	Machine protection 1a.1	-
	ELM density transient	physics studies 2	$5x10^{18}$ — $3x10^{20}$ m^{-3}
	ELM temperature transient	physics studies 2	0.05 — 10 keV
	L-H Da step	Basic machine control 1a.2	-
15. Runaway Electrons	Emax	physics studies 2	1 — 100 MeV
	Irunaway	physics studies 2	0 — 10 MA

Measurement	Parameter	Role	Range to cover
16. Divertor Operational Parameters	Max. surface temperature	Machine protection 1a1	200 — 3600 °C
	Erosion rate		0.1 — 1 mm.s^{-1}
	Net erosion		0 — 3 mm
	Gas pressure (Pdiv)	Basic machine control 1a.2	10^{-4} — 20 Pa
	Gas composition Fuel, He, impurities	Basic machine control 1a.2	10^{-8} — 20 Pa
	Position of the ionisation front	Basic machine control 1a.2	0 — 1 m
17. First Wall (FW) Visible Image & Wall Temperature	FW Surface luminance –	Machine protection 1a1	40 — 10^{5} cd.m^{-2}
	FW Surface temperature	Basic machine control 1a.2	200 — 3600 °C
	FW surface temperature during ELMs	physics studies 2	400 — 3600 °C
18. Gas Pressure and Composition in Main Chamber	Gas pressure (Pmain)	Basic machine control 1a.2	10^{-4} — 1 Pa
	Gas composition Fuel, He, impurities	Basic machine control 1a.2	10^{-8} — 1 Pa
19. Gas Pressure and Gas Composition in Ducts	Gas pressure (Pduct)	Basic machine control 1a.2	10^{-4} — 20 Pa
	Gas composition Fuel, He, impurities	Basic machine control 1a.2	10^{-8} — 20 Pa
20. In-Vessel Inspection	Wall image	3	100 % coverage of FW and divertor
21. Halo Currents	Poloidal current	Machine protection 1a1	0 — 3 MA
22. Toroidal Magnetic Field	BT	Basic machine control 1a.2	-5.5 — 5.5 T
23. Electron Temperature Profile	Core Te	Advanced plasma control 1b	0.5 — 40 keV
	Edge Te	physics studies 2	0.05 — 10 keV
24. Electron Density Profile	Core Ne	Advanced plasma control 1b	$3x10^{19}$ — $3x10^{20}$ m^{-3}
	Edge Ne	Advanced plasma control 1b	$5x10^{18}$ — $3x10^{20}$ m^{-3}

Measurement	Parameter	Role	Range to cover
25. Current Profile	q(r)	physics studies 2	0.5 — 5
	r(q=1.5,2)/a	Advanced plasma control 1b	0.3 — 0.9
	r(qmin)/a	Advanced plasma control 1b	0.3 — 0.7
26. Zeff Profile	Zeff	physics studies 2	1 — 5
27. High Frequency Instabilities (MHD, NTMs, Aes, turbulence	Fishbone Btheta(mode) / < Bp>	physics studies 2	10^{-4} — 10^{-2}
	TAE Btheta(complex) / <Bp>	physics studies 2	10^{-4} — 10^{-2}
	TAE δN / n, δT/T	physics studies 2	$5x10^{-6}$ — $5x10^{-4}$
	NTM δT / Te (complex. 100ms integration time	Advanced plasma control 1b	$0.1x10^{-2}$ — $5x10^{-2}$
28. Ion Temperature Profile	Core Ti	Advanced plasma control 1b	0.5 — 40 keV
	Edge Ti	physics studies 2	0.05 — 10 keV
29. Core He Density	nHe/ne	Advanced plasma control 1b	1 — 20%
	Profile of 3He concentration	Advanced plasma control 1b	1 — 10%
30. Confined Alphas and Fast Ions	Alpha Energy spectrum	physics studies 2	0.1 — 3.5 MeV
	Alpha Density Profile	physics studies 2	10^{17} — $2x10^{18}$ m^{-3}
	p,D,T,He3	physics studies 2	0.1 — 1 MeV
31. Escaping Alphas and Fast Ions	First wall flux. Alphas	physics studies 2	0.01 — 20 $MW.m^{-3}$
	First wall flux. Non- Alphas	Advanced plasma control 1b	0.001 — 2 MWm^{-3}
32. Impurity Density Profile	Fractional content, Z<=10	Advanced plasma control 1b	0.5 — 20 %
	Fractional content, Z>10	Advanced plasma control 1b	0.01 — 0.3 %
33. Fuel Ratio in the Edge	nT/nD	physics studies 2	0.01 — 10
	nH/nD	physics studies 2	0.01 — 0.1
34. Neutron Fluence	First wall fluence	Basic machine control 1a.2	0.1 — 1 $MW.m^{-2}.y$
35. Impurity and D,T Influx in Divertor	GBe, GC, GW	Machine protection 1a 1	10^{17} — 10^{22} $atom.s^{-1}$
	GD, GT	Basic machine control 1a.2	10^{19} — 10^{25} $atom.s^{-1}$

Measurement	Parameter	Role	Range to cover
36.Plasma Parameters at the Divertor Targets	ne	Advanced plasma control 1b	10^{18} — 10^{22} m^{-3}
	Te	Advanced plasma control 1b	1 — 150 eV
37. Radiation Profile	Main plasma Prad	physics studies 2	100 $W.m^{-3}$ — 1 $MW.m^{-3}$
	X-point/MARFE region Prad	Advanced plasma control 1b	30 $kW.m^{-3}$ — 300 $MW.m^{-3}$
	Divertor Prad	Advanced plasma control 1b	10 $kW.m^{-3}$ — 100 $MW.m^{-3}$
38. Heat Loading Profile in Divertor	Surface temperature	Advanced plasma control 1b	200 — 3600 °C
	Power load	Advanced plasma control 1b	0.1 — 5 $GW.m^{-2}$
39. Divertor Helium Density	nHe	Basic machine control 1a.2	10^{17} — 10^{21} m^{-3}
40. Fuel Ratio in the Divertor	nT/nD	physics studies 2	0.01 — 10
	nH/nD	physics studies 2	0.01 — 0.1
41. Divertor Electron Parameters	ne	physics studies 2	10^{19} — 10^{22} m^{-3}
	Te	physics studies 2	0.3 — 200 eV
42. Ion Temperature in Divertor	Ti	physics studies 2	0.3 — 200 eV
43. Divertor Plasma Flow	Vp	physics studies 2	10^{3} — 10^{5} $m.s^{-1}$
44. nH/nD Ratio in Plasma Core	nH/nD	physics studies 2	0.01 — 0.1
45. Neutral Density between Plasma and First Wall	D/T influx in main chamber	Basic machine control 1a.2	10^{18} — 10^{20} $atom.m^{-2}.s^{-1}$
46. Dust Monitoring	Dust accumulation rate	Basic machine control 1a.2	10^{-4} - 10^{-2} $kg.m^{-2}$/pulse
	Dust concentration	Machine protection 1a.1	10^{-2} — 10 $kg.m^{-2}$
47. Tritium Monitoring	H, D, T accumulation rate	Basic machine control 1a.2	$2x10^{19}$ — $2x10^{21}$ m^{-2} / pulse
	Tritium concentration	Machine protection 1a.1	10^{20} — $2x10^{24}$ m^{-2}

Table 4-8: List of diagnostic systems and their locations

Technique Family	PBS 55	Diagnostic	Innermost Component Location
Magnetics	A.01	Outer Vessel Sensors	Vacuum Vessel (VV) Outer Surface
	A.02	Inner Vessel Sensors	VV Inner Surface
	A.03	Divertor Magnetics	Divertor Cassette (DC) D02,D04,D08,D10,D14,D16
	A.04	External Rogowski	Within TF coil case
	A.05	Diamagnetic Loop	VV Outer surface; VV Inner surface; around TF case
	A.06	Halo Current Sensors	VV Inner Surface; DC
Neutron	B.01	Radial Neutron Camera	E01
	B.02	Vertical Neutron Camera	Cryostat D02(CENTER)
	B.03	Microfission Chambers	VV Inner Surface
	B.04	Neutron Flux Monitors (Ex-vessel)	E07(DD PHASE), E08, E17(DT PHASE),
	B.07	Gamma Ray Spectrometers (interfaces)	E01
	B.08	Activation System	VV Inner Surface UP11, UP18, E07, E17 D06, D12, D18
	B.11	High Resolution Neutron Spectrometer (interfaces)	E01
	B.12	Divertor Neutron Flux Monitors	Divertor Cassette (DC) D02, D08, D14
	B.13	Vertical Gamma Spectroscopy	D02 (CENTER)
Optical	C.01	Thomson Scattering (Core) (Main plasma)	E10
	C.02	Thomson Scattering (Edge)	E10
	C.04	Thomson Scattering (Divertor, Outer)	D10(GAP)
	C.05	Toroidal Interferometer/Polarimeter	VV inner surface; Other port BSM E09
	C.06	Polarimeter	Blanket slots UP10, E10
	C.07	Collective Scattering (LFS front end)	VV Inner surface
Bolometric	D.01	Bolometers (All)	VV Inner surface UP01, E01, D08, D10, D16(CASSETTE)

Technique Family	PBS 55	Diagnostic	Innermost Component Location
Spectroscopic and NPA	E.01	CXRS Based On DNB (Core)	UP03, UP 17
	E.02	H-Alpha Spectroscopy	UP02 (Divertor Outer), UP02(outer Edge), UP07 (inner edge), UP07(outer edge), E11 (Divertor inner), E12(upper edge)
	E.03	VUV Grazing Image (Main Plasma, x2)	E11, UP18
	E.04	Divertor Impurity Monitor	UP02, E01, D02(GAP,CENTER,GAP)
	E.05	X-Ray Crystal Spectrometer (CORE)	E09
	E.07	Radial X-Ray Camera	E12
	E.08	Neutral Particle Analyser	E11
	E.10	Laser Induced Fluorescence	D10
	E.11	MSE Based On Heating Beam (Core, HB4), (Edge HB5)	E01, E03
	E.12	CXRS Based On DNB (Edge)	E03
	E.13	X-Ray Spectrometry (edge) (Survey)	UP09, E11
	E.14	Hard X-ray Monitor (H-PHASE)	E12
	E.15	BES Based On DNB (CORE) (EDGE)	UP03, E03
	E.16	Divertor Spectroscopy (VUV)	E11
Microwave	F.01	ECE(Main Plasma)	E09
	F.02		
	F.03	Reflectometer (Plasma Position)	VV Inner surface UP01 (GAPS 4&5) UP14 (GAP 6), E10 (GAP 3)
	F.09	Reflectometer (Main Plasma, HFS) Reflectometer (Main Plasma, LFS)	VV Inner surface UP08 UP09 E11, UP17
	F.10	Interferometer (Divertor)	D08 (GAP, GAP)
	F.12	ECE transmission receiver (Main Plasma)	E09

Technique Family	PBS 55	Diagnostic	Innermost Component Location
Plasma Facing and Operational	G.01	IR Cameras, Vis/IR TV (Midplane) (4 OF 4)	E01, E03, E09, E12
	G.02	Thermocouples	D10, D16 (CASSETTE)
	G.03	Pressure Gauges	E10 D04,D08,D10,D16(CASSETTE), D04,DO6,D12,D18 (PUMPING DUCT)
	G.04	Residual Gas Analyzers	E11, D04, D12,D18(PUMPING DUCT)
	G.06	IR Thermography (Divertor)	D16(CENTER)
	G.07	Langmuir Probes	D02, D08, D14(CASSETTE)
	G.08	Erosion Monitor (gcg)	D14 (CS40)
	G.09	Dust Monitor	D04 (CS11), D14 (CS39&41)
	G.10	IR Cameras, Vis/IR TV (Upper) (6 OF 6)	UP02 UP05 UP08 UP10 UP14 UP17
	G.11	Thermocouples	D02(CASSETTE)
Diagnostic Engineering	N.01	In-Vessel Services	VV Inner surface; DC
	N.03	Port Plugs And First Closures	In port BSM hole
	N.04	Interspace Blocks And Second Closures	On VV flange (air side)
	N.05	Divertor Components	DC
	N.06	Ex-Bioshield Electrical Equipment	Port Cell
	N.07	Window Assemblies	VV flange

4.3.13 Fusion power shutdown system

A fusion power shutdown system shall be provided with the capability to inject impurity gases to abruptly terminate a pulse. [PR791-R]

4.3.14 Post-discharge operations

4.3.14.1 Data archiving

All configuration data and a history of operational data shall be stored, and shall be available in the Main Control Room (see Section 6.10) as needed for the operation of the ITER plant. [PR2175-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. [PR794-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. [PR795-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. [PR1769-R]

4.3.14.2 Vacuum base pressure

A base pressure of less than 5 x 10^{-4} Pa (for hydrogenic species) shall be achieved by the end of the dwell periods between pulses when operated at maximum duty cycle. [PR797-R]

A base impurity pressure of less than 10^{-7} 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. [PR798-R]

4.3.14.3 RF wall conditioning

The purpose of RF wall conditioning is to limit the release of hydrogen isotopes and non-hydrogenic gas impurities during plasma operation and to limit tritium inventory in plasma facing components. [PR800-I]

The capability to use the existing IC heating and current drive system for wall conditioning between pulses with up to 20% of nominal power shall be provided. [PR803-R]

Diagnostics for IC antenna protection shall be provided for IC wall conditioning. [PR804-R]

There are indications that the EC H&CD system can be used for wall conditioning, typical duty cycles being about 1 second ON / about 10 seconds OFF mode. [PR806-I]

The capability to use the existing EC heating and current drive system for wall conditioning between pulses with about 0.1 MW (up to 0.4 MW) of coupled power shall be assessed. [PR807-R]

A poloidal magnetic field of about 0.1 T (possibly rotating in about 5 seconds) shall be provided for EC wall conditioning to improve uniformity. [PR808-R]

4.4 Upgrade requirements

4.4.1 Divertor upgrades

The divertor design shall accommodate replacement of the divertor cassettes during operations. [PR812-R]

4.4.2 Resistive wall mode control upgrades

Resistive wall modes (RWM) may become unstable in cases of very high β_N (about 3.0) at low rotation speeds. [PR815-P]

If regular RWM instabilities interfere with ITER operations, the ITER design must be upgradeable to provide a system that is capable of stabilizing RWMs. This stabilization may be achieved with a feedback system that is capable of monitoring the poloidal field amplitude of the resonant RWM with n=1, and of producing helical magnetic field of the same structure and appropriate phase shift with external coil(s). [PR817-P]

The characteristic frequency response that is required for RWM feedback stabilization is about 10 Hz, and the amplitude of the helical field produced by the stabilizing coils depends on the amplitude of low frequency plasma noise on the magnetic sensors used. It will be measured before the upgrade is implemented. [PR818-I]

4.4.3 Heating and current drive upgrades

Four heating and current drive upgrade scenarios were developed to ensure the necessary flexibility for advanced operating regimes. [PR821-I]

The design of ITER shall not preclude the possibility of accommodating the combinations of heating and current drive upgrades specified in **Table 4-9**. [PR822-R]

Table 4-9: Heating and current drive upgrade scenarios

	Initial Configuration		H&CD Upgrade Scenario 1		H&CD Upgrade Scenario 2		H&CD Upgrade Scenario 3		H&CD Upgrade Scenario 4	
	Power (MW)	Equa-torial ports	Power (MW)	Equa-torial ports	Power (MW)	Equa-torial ports	Power (MW)	Equa-torial ports	Power (MW)	Equa-torial ports
NB	33	2	33	2	50	3	50	3	50	3
IC	20	2	40	2 (*)	20	1 (*)	40	2	20	1 (*)
EC	20	1	40	1	40	1	40	1	20	0
LH	0	0	20	1	20	1	0	0	40	2
TOTAL	73	5	133	6	130	6	130	6	130	6

Note *: One IC antenna will allow to couple 10 MW in a broad range of plasma scenarios, with provision for the large uncertainties existing in the plasma edge density profiles. The number of antennas effectively required to deliver 20 or 40 MW in the upgrade scenarios will depend on the plasma-loading range effectively achieved, to be assessed after acquisition of sufficient experimental information. [PR1783-C]

The IC H&CD system shall be upgradable (with additional investment) to 40 MW of ICRF power to the plasma through two launchers in two equatorial ports. [PR825-R]

The EC H&CD system shall be upgradable (with additional investment) to 40 MW of ECRF power to the plasma through the existing launchers (one equatorial and four upper port launchers). [PR827-R]

ITER shall be upgradable (with additional investment) to provide 20 MW, or up to 40 MW, of LHRF power to the plasma at a single frequency between 3.7 and 5.0 GHz through one or two equatorial ports with a plasma density between the launcher and separatrix in the range of $4x10^{17}$ to $10x10^{17}$ m^{-3}. [PR830-R]

The NB H&CD system (HNB) shall be upgradable (with additional investment) even after D-T operation to deliver 50 MW through three ports. [PR832-R]

In all scenarios, the reserved location for the IC H&CD and LH H&CD upgrades shall be located in the Assembly Building with an equivalent volume, as for the initial configuration. [PR2094-R]

In all scenarios, except scenario 4, the reserved location for the EC H&CD upgrade shall be in an area that is located between the Assembly Building, the RF Heating

Building and the Cleaning Facility Building, with an equivalent volume, as for the initial configuration. [PR2095-R]

4.4.4 Auxiliary system upgrades for hybrid and non-inductive scenarios

ITER auxiliary (non-tokamak) systems shall be upgradable (with additional investment) to meet the requirements of the Hybrid and Non-inductive scenarios that are defined in Section 4.3.1. Parameters for the Hybrid and Non-inductive scenarios are shown in **Table 4-1**. [PR834-R]

4.4.5 Tritium breeding blanket modules

The capability to install tritium breeding blankets on the outboard side of the Vacuum Vessel, as a future upgrade, shall not be precluded. [PR839-R]

4.4.6 High duty cycle

The ITER tokamak and facility shall be capable of being upgraded to accommodate operation with a time-averaged fusion power of 133 MW for each of the design scenarios that are specified in Section 4.3.1.3. [PR842-R]

4.4.7 Fuelling upgrades

The pellet injection system shall be upgradable (with additional investment) to a six-injector configuration. [PR845-R]

4.5 Deactivation

ITER Organization shall provide the site Host Member with all records, "as-built prints", information and equipment pertinent to dismantling after deactivation. [PR847-R]

ITER Organization shall develop a plan to put the plant in a safe, stable condition while it awaits dismantling. [PR848-R]

Residual tritium that is present at the end of ITER operations shall be recovered to secure storage and/or shipping containers. [PR849-R]

Residual mobile activation products and hazardous materials that are present at the end of ITER operations shall be recovered to secure storage and/or shipping containers so that they can be shipped to a repository as soon as practical. [PR850-R]

ITER deactivation shall include the removal of in-vessel components and their packaging for long-term storage. [PR851-R]

Removal of in-vessel components from the vacuum vessel, during ITER de-activation, shall be performed by remote handling tools and personnel who have been trained for maintenance during the previous ITER normal operation. [PR2096-R]

Liquids that are used in ITER systems may contain activation products, which shall be removed before the liquids can be released into the environment or solidified as waste. All liquids shall be rendered to a safe, stable form during the deactivation phase, further cooling shall be unnecessary. [PR852-R]

During the deactvivation and decommissioning phase, the components of ITER shall be protected against corrosion, to prevent spreading of contamination or unacceptable hazards to the public or workers. [PR853-R]

5 Layout requirements

5.1 Configuration Management Model

The CMM shall be used to assure consistency between all components and with the buildings of the Tokamak Complex:

- 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

--- [PR857-R]

For information, equipment of other buildings that are outside the scope of the CMM is managed according to the Design Integration and Configuration Control responsibilities for buildings and areas on the ITER site [R06]. [PR864-I]

The minimum gap between in-cryostat different PBS components shall be 50 mm, unless other value is specified in the relevant SRDs or Interface Sheets. [PR865-R]

ITER system elements within the Tokamak Complex (Tokamak Building, Diagnostics Building, and Tritium Plant Building) shall conform to the space envelope constraints and interface characteristics specified in the CAD assemblies, parts, and drawings in the CMM [A03]. [PR866-R]

5.2 Site Master Plan

The layout of buildings on the ITER site is defined in the ITER Site Master Plan [A13]. [PR868-I]

5.3 Port allocations

The port numbering scheme is defined in the ITER Coordinate Systems [A04] document. [PR870-I]

5.3.1 Equatorial port allocations

The initial allocation of equatorial ports shall be in accordance with the column labeled “Initial configuration” in **Table 5-1**. [PR874-R]

ITER shall be capable of accommodating the heating and current drive upgrade scenarios specified in Section 4.4.3 with the equatorial port allocations specified in **Table 5-1**. [PR875-R]

Table 5-1: Equatorial port allocations

Port	Initial configuration	Scenario 1[1]	Scenario 2	Scenario 3	Scenario 4
1	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics
2	Test Blanket	Test Blanket	Test Blanket	Test Blanket	Test Blanket
3 (RH port)[2]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]
4 (small rad.)	DNB	DNB	DNB	DNB	DNB
4 (tangential)	HNB	HNB	HNB	HNB	HNB
5 (tangential)	HNB	HNB	HNB	HNB	HNB
6 (tangential)		Diagnostics	HNB	HNB	HNB
7	Closed	Closed	Closed	Closed	Closed
8 (RH port)[2]	Diagnostics / GDC Electrode[5]/ DMS	Diagnostics / GDC Electrode[5]/ DMS	Diagnostics / GDC Electrode[5]/ DMS	Diagnostics / GDC Electrode[5]/ DMS	Diagnostics / GDC Electrode[5]/ DMS
9	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics
10	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics
11	Diagnostics[3]	LH	Diagnostics[4]	Diagnostics	Diagnostics[4]
12 (RH port)[2]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]
13	IC	IC	LH5	IC	LH5
14	EC	EC	EC	EC	LH
15	IC	IC	IC	IC	IC
16	Test Blanket	Test Blanket	Test Blanket	Test Blanket	Test Blanket
17 (RH port)[2]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]	Diagnostics / GDC Electrode[5]
18	Test Blanket	Test Blanket	Test Blanket	Test Blanket	Test Blanket

Note 1: Scenario 1 allows 40 MW of IC and 20 MW of LH. An option of 20 MW of IC and 40 MW of LH is also being considered using the same three ports. [PR1662-C]

Note 2: Diagnostics in the four remote handling ports (3, 8, 12 and 17) need to be removable to allow access for remote handling operation. [PR1665-C]

Note 3: Diagnostics in port EP11 shall be removed for upgrade scenario 1. In case diagnostics necessary for the machine protection and the basic plasma operation are located in that port, they will be relocated in another port - or their functions will be fulfilled by another diagnostic system. [PR1666-C]

Note 4: Scenario 2 and scenario 4 foresee 20 MW of IC power (see Section 4.4.3). If the diagnostics in port 11 are moved to port 8, port 11 will be used for the LH and port 13 remains for the second IC antenna. See also footnote to **Table 4-9**. [PR1663-C]

Note 5: Temporary GDC electrodes will be installed at the vicinity of port plugs for the first plasma. [PR2176-C]

5.3.2 Upper port allocations

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

Table 5-2: Upper port allocations

Port	Port plug	In Port	
1	Diagnostics	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
2	Diagnostics	In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold Disruption Mitigation System
3	Diagnostics / GDC Electrode	In-Vessel Diagnostics Mid and Lower ELM coil feeders GDC[2]	Blanket water manifold
4[1]		In-Vessel Diagnostics Gas Injection (including FPSS) Upper ELM coil feeder	Blanket water manifold
5[1]	Diagnostics	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
6[1]		In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold
7[1]	Diagnostics	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
8	Diagnostics	In-Vessel Diagnostics Upper ELM coil feeder Disruption Mitigation System	Blanket water manifold GDC[2]
9	Diagnostics	In-Vessel Diagnostics Gas Injection	Blanket water manifold Mid and Lower ELM coil feeders
10	Diagnostics	In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold
11	Diagnostics	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
12	EC	In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold
13	EC	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
14	Diagnostics	In-Vessel Diagnostics Gas injection Upper ELM coil feeder	Blanket water manifold GDC[2] DMS
15	EC	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
16	EC	In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold
17	Diagnostics	In-Vessel Diagnostics Mid and Lower ELM coil feeders	Blanket water manifold
18	Diagnostics5	In-Vessel Diagnostics Upper ELM coil feeder	Blanket water manifold

Note 1: No port cell. Access is through the NB cell, with higher radiation levels (Zone C) and less hands-on access. [PR1669-C]

Note 2: Temporary GDC electrodes will be installed at the vicinity of port plugs for the first plasma. [PR1670-C]

5.3.3 Lower port allocations

The allocation of lower ports shall be in accordance with **Table 5-3**. [PR882-R]

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

Some fixed penetrations (for in-vessel viewing, ELM-VS feeders, and divertor cooling manifolds) shall be accommodated as shown in **Table 5-3**. [PR883-R]

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

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

Table 5-3: Lower port allocations

Port	Type	Content
1	Cryostat access flange	Large cryostat access flange
2	Divertor Remote Handling port	RH / Diagnostics Rack
3	In-vessel viewing port	IVV
4	Divertor pumping port	Housing (PIS type) Torus cryopump Pellet Injection System
5	In-vessel viewing port	IVV, Cryostat access flange
6	Divertor pumping port	Housing (Diagnostic type) Torus Cryopump
7	Cryostat pumping flange	Cryostat Cryopump
8	Divertor Remote Handling port	RH / Diagnostics Rack
9	In-vessel viewing port	IVV Cryostat access flange
10	Divertor pumping port	Housing (PIS type) Torus cryopump Pellet Injection System
11	In-vessel viewing port	IVV
12	Divertor pumping port	Housing (Diagnostic type) Torus Cryopump
13	Cryostat pumping flange	Cryostat Cryopump
14	Divertor Remote Handling port	RH / Diagnostics Rack
15	In-vessel viewing port	IVV Cryostat access flange
16	Divertor pumping port	Housing (PIS type) Torus cryopump Pellet Injection System
17	In-vessel viewing port	IVV
18	Divertor pumping port	Housing (Diagnostic type) Torus Cryopump

Divertor cooling manifolds are located in every lower port. [PR1676-I]

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

5.4 Location of diagnostics

Diagnostics shall be located in accordance with **Table 4-8** Measurement requirements. [PR888-R]

Diagnostics mounted in ports shall be located in accordance with **Figure 5-1** whereas the location of the diagnostics plugs is defined in **Table 5-1**. [PR889-R]

Diagnostics located in the vacuum vessel shall be located in accordance with **Table 5-4**. [PR890-R]

Figure 5-1: Distribution of diagnostics mounted in the ports

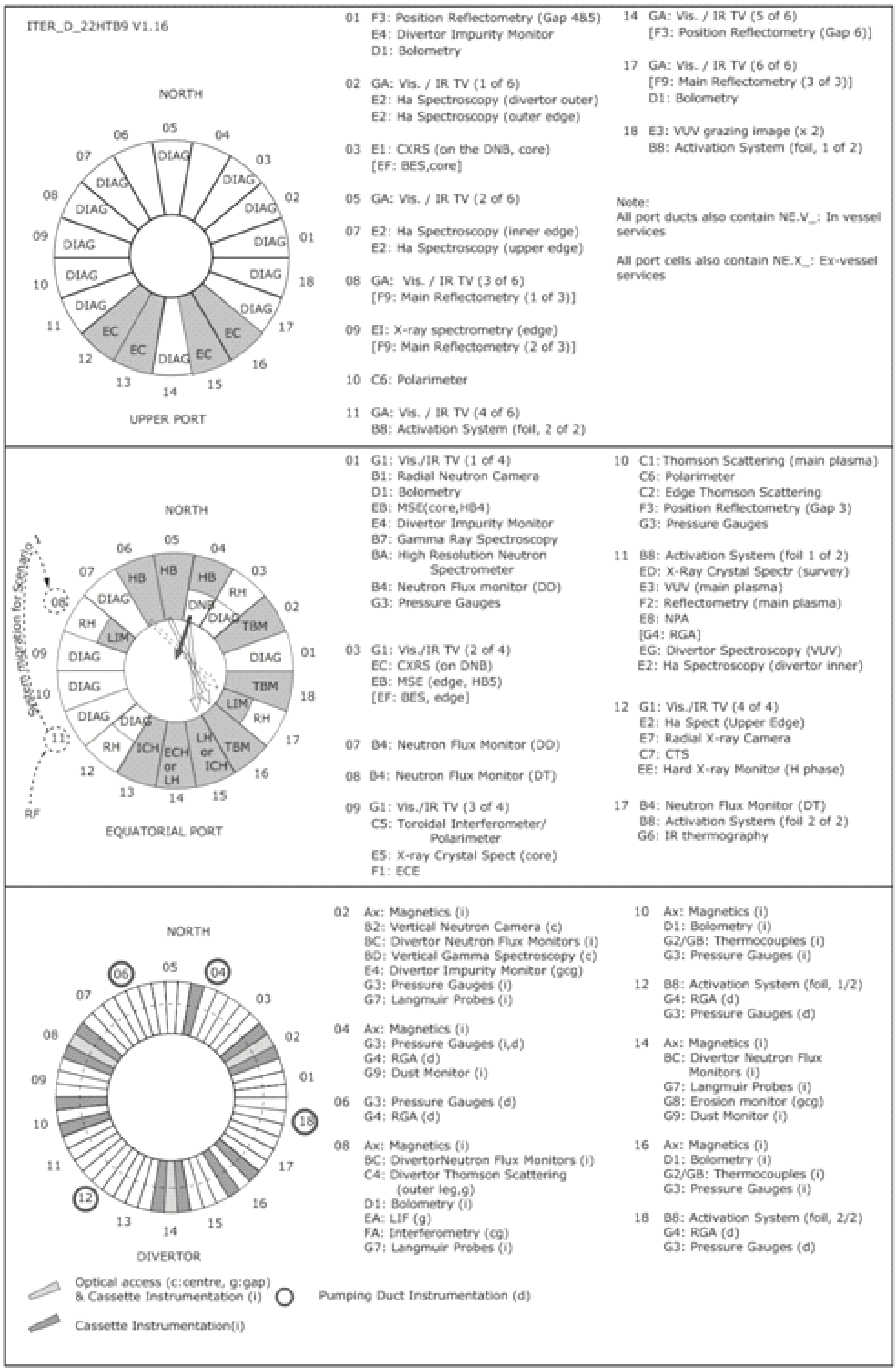


Table 5-4: Distribution of diagnostics mounted in the vacuum vessel

ID	DIAGNOSTIC	Unit	VV SECTOR	|	1	|	2	|	3	|	4	|	5	|	6	|	7	|	8	|	9
			PORT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Diagnostic Neutral Beam	Beam Duct					1														
A.01	Outer Flux Loops	Loop Feed Point					2						2						2		
A.01	Outer Vessel Sensors	2-axis Coil Pair							60						60						60
A.01	Outer Vessel Sensors (steady state)	2-axis Hall Probe					20						20						20		
A.02	Continuous Flux Loop	Loop Feed Point					2						2						2		
A.02	HF Coil Poloidal Array	Coil				18			18			18			18			18			18
A.02	MHD - Dedicated Saddle Loop	Loop		8		8		8		8		8		8		8		8		8	
A.02	Partial (& Complete) Flux Loops	Loop				20			20			20			20			20			20
A.02	Resistive Wall Mode sensors	Coil			2			2			2			2			2			2	
A.02	Tangential coils, Hardwired	Coil			24						24						24				
A.02	Normal coils, Hardwired	Coil			8						8						8				
A.02	Tangential coils, replaceable	Coil					24						24						24		
A.02	Normal coils, replaceable	Coil					8						8						8		
A.05	Diamagnetic Loop	Loop				1						1						1			
A.05	Diamagnetic Loop inner compensation	Coil				2						2						2			
A.05	Diamagnetic Loop inner compensation	Loop				2						2						2			
A.05	Diamagnetic loop outer compensation	Coil			2						2						2				
A.06	Halo Rogowski Poloidal Array	Coil		18			18			18			18			18			18		
A.06	Halo Rogowski Toroidal Array	Coil			6	6		6	6		6	6		6	6		6	6		6	6
B.03	Microfission Chambers	Detector			6										6						
B.08	Neutron Activation (Foil Capsule)	Exposure Cell								1				3	2					1	5
D.01	Bolometer Array	Miniature Camera		7	1						3								3	7	1
F.03	Position Reflectometry	Waveguide & Antenna		4													2				
F.09	Main Reflectometry (High Field Side)	Waveguide & Antenna									4	2								2	
C.06	CTS	Waveguide													10						
G.02	Thermocouples, inboard	Thermocouple Element		4	4	4		4			4	4		4			4			4	
G.02	Thermocouples, outboard	Thermocouple Element		3			6						6						6		
N.01	Cryostat Cabling	256-core loom			1		1		1		1		1		1		1		1		1
N.01	Divertor Port Cabling	80-Way Feedthrough			8		3		1		8		4		1		6		7		1
N.01	Upper Port Cabling	48-Way Feedthrough		4	3	5	3	3	5	5	3	3	5	4	2	5	3	4	6	2	4
N.01	VV Wall Poloidal Cable Conduits	36-Core Loom		3	2	4	2	2	4	3	2	2	3	2	2	3	2	2	4	2	2

6 Operational requirements

6.1 Design life

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

The design life of systems (including buildings) that are required to be operational during commissioning and/or deactivation periods shall be specified accordingly. [PR1827-R]

The Tokamak Complex and Hot Cell Building shall be designed for a 70 year life. [PR896-R]

6.2 Number of pulses

ITER shall be capable of operating for at least 30,000 pulses in order to satisfy the overall requirement specified in the Project Specification document [R01]. [PR904-R]

6.3 Progressive start-up

Progressive start-up is assumed in the RPrS [R08]. [PR898-I]

Operating parameters shall be progressively increased during initial H operation, D operation, and D-T operation in order to verify the integrated systems perform safely and in accordance with operational design intent. [PR899-R]

6.4 Site electrical power constraints

High-level design assumptions and constraints, applicable at the ITER/RTE interface (also known as Prionnet) unless otherwise noted are given in **Table 6-1**. [PR901-I]

Table 6-1: Site electrical power constraints

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

The limit on active power derivative is currently under discussion between ITER Organization and RTE. [PR1775-C]

6.5 Duty factor and pulse repetition time

The duty factor is defined as the ratio of plasma burn duration to pulse repetition. [PR906-I]

ITER shall be designed to operate with a duty factor of at least 25% for burn duration greater than 450 s. [PR907-R]

ITER shall be designed to operate with a pulse period time not exceeding 1800 s for burn duration less than 450 s. [PR908-R]

6.6 Design operating schedule

ITER shall be designed for an active (D-T) phase lasting at least 14 years. [PR910-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. [PR912-R]

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

6.7 Neutron production

Annual neutron fluence limit was derived from operation at 400 MW (Design Scenario 3 with 1000 s pulse length) for one year at an availability close to unity (very limited unscheduled downtime). [PR914-I]

The maximum instantaneous neutron flux corresponds to a peak fusion power of 525 MW (500 MW +5% for controllability). [PR915-I]

ITER shall be designed to provide an average neutron fluence of 0.30 $MW.y.m^{-2}$ in the active phase in order to satisfy the overall requirement specified in the Project Specification document [R01]. [PR916-R]

ITER shall accommodate a maximum instantaneous average neutron flux of at least 0.5 $MW.m^{-2}$ in order to satisfy the overall requirement specified in the Project Specification document [R01]. [PR917-R]

6.8 Containment of water in the cryostat

The length and number of pipes inside the cryostat shall be minimised. [PR1828-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. [PR919-R]

All TCWS pipes in the cryostat shall be contained within restrained guard pipes. This is to reduce the risk of pipe-whip in the case of a break that could damage a neighbouring pipe or anything else in the cryostat systems. [PR1829-R]

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

6.9 Procedures of operation

Global operating states and sub-states and transitions between them are described in the Operations Handbook [A08]. [PR921-I]

ITER shall be operated in accordance with the Operations Handbook [A08]. [PR922-R]

Procedures shall be developed for all ITER operations (including maintenance and decommissioning). These procedures shall describe the appropriate organization to guarantee their application, the authorization required as well as actions to be taken in event of an emergency such as in case of a fire, an equipment failure or ITER On-Site Emergency. [PR2189-R]

6.10 Plant operation

ITER Organization, as Operator of the ITER machine, shall be responsible for all actions inside the perimeter of the Nuclear Installation (INB). [PR924-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. [PR925-R]

There shall be no automatic transfer of data of any type onto the Plant Operation Zone (POZ) from any other computer networks. [PR935-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. [PR2190-R]

All data transfers between the Plant Operation Zone network and any other networks shall be executed through dedicated secure mechanisms. [PR2191-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. [PR936-R]

There shall be a single Main Control Room and supporting facilities within the Control Building (71), and a Backup Control Room located within the Personnel Access Control Building (24). [PR926-R]

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

Remote handling and Hot Cell Facility activities shall be controlled by the RH Control Suite located close to these installations. [PR928-R]

The tritium plant shall be managed from a Tritium Plant Control Room within the protected area inside the Main Control Room (MCR, in Building 62-71). The Tritium Plant shall be capable of limited operations from the ITER Backup Control Room (BCR, in Building 62-24). [PR929-R]

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

Health physics personnel shall be located within the Personnel Access and Control Building to ensure appropriate controls of persons entering and leaving controlled areas. [PR931-R]

There may be industrial areas, with limited facilities and air conditioning, for task-related activities such as maintenance facilities within the Diagnostic Building (74). [PR932-P]

Other than the above cases, there shall be no other permanent occupation by personnel of plant areas, that is, offices or control rooms, within the INB perimeter. [PR933-R]

In all cases working within the INB perimeter shall be subject to a Permit to Work system. [PR934-R]

6.11 Remote participation

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. [PR938-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. [PR939-R]

6.12 Instrumentation and control of ITER systems

Required measurements shall be developed through the interface control process. [PR941-R]

Plant systems shall contain adequate instrumentation to ensure the following functions:

- To ensure human safety/security
- To enable control of the plant system
- To ensure equipment integrity and interlock
- To monitor the system state
- To record all system control actions
- To control tokamak system operations
- To prepare plasma pulses
- To ensure plasma discharge quality
- To monitor and record system performance.

--- [PR942-R]

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

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

6.13 Reliability, Availability, Maintainability and Inspectability

The Reliability, Availability, Maintainability and Inspectability (RAMI) requirements shall be an input in the specifications, design, testing, operation and maintenance of the ITER systems. [PR956-R]

They integrate availability and reliability objectives to match the machine operation requirements and the ITER RAMI Analysis Program [R13] by using the rules defined in terms of the failure criticality level. [PR2216-I]

The main drivers to define the ITER facility Reliability and Availability targets are the pulse number defined in Section 6.2 and the neutron fluence defined in Section 6.7 requirements, along with the Mean Scheduled maintenance/upgrade Down-Time necessary to be able to conduct the ITER research program with the expected availability. [PR2215-I]

6.13.1 ITER functional breakdown

Reliability and availability are characteristics that are assigned to the functions of the system. [PR2219-I]

Knowledge of its hardware architecture is usually not enough. Functional analysis methods are used to determine the reliability. [PR959-I]

The main functions identified for RAMI requirements, derived from the RAMI analyses performed on the ITER systems, are regrouped in different functional groups:

- **Machine Operation** regroups the Safety & Investment Protection functions, the functions related to structures, the utilities functions necessary to sustain the activity of the plant as well as main functions (components) of the tokamak.
- **Physics Programme** gathers the functions required for physics experiments which are not specifically required for machine operation.
- **Maintenance** relates to the functions that are not necessary for performing a plasma pulse but are nevertheless essential to keep ITER in working order: wall conditioning, remote handling, the hot cell facility, the port plug test facility and the radwaste treatment and storage.

--- [PR2217-I]

To be able to allocate separately RAMI objectives to each function, the systems (PBS) have been broken down as a hierarchy of functions on multiple levels, from the main operational functions fulfilled by the system to the basic functions performed by the components. [PR2220-I]

6.13.2 Availability

One of the main objectives for ITER is its availability in order to deliver sufficient plasma time for the research programme. [PR2221-I]

Availability is defined as the ratio of operating time to the sum of operating time and downtime during experimental campaigns, assuming that the required external resources needed are provided. [PR970-I]

Availability can be further defined as either inherent availability or operation availability. [PR2222-I]

The inherent availability is defined as the ratio of the operating time (or Mean Up Time: MUT) to the sum of operating time (or MUT) and not-scheduled downtime due to corrective maintenance (or Mean Down Time not-scheduled: MDTns). It does not take into account the loss of operating time due to the planned preventive maintenance or upgrade periods, but only the loss of operating time due to failures of the system. [PR2223-I]

The operational availability is defined as the ratio of the operating time (MUT) to the sum of operating time (MUT), downtime due to corrective maintenance (MDTns) and downtime due to preventive maintenance, tests and upgrades (or Mean Down Time scheduled: MDTs). Operational availability is thus lower than inherent availability as it is also reduced by time lost without any failure of the system. [PR2224-I]

When allocating availability and reliability objectives to the systems or their main functions, it is better to use inherent availability, which is only related to the design and is not impacted by the preventive maintenance rhythm that does not result from failures. [PR971-I]

To assess the overall availability of the machine for plasma operation and for the execution of the scientific programme, it is better to use operational availability, as it takes into account management decisions such as the operation rhythm and the planned maintenance programme. [PR2225-I]

6.13.2.1 Main functions inherent availability objective

While using the definition previously given, the inherent availability is defined as:

- $A_i = MUT / (MUT + MDT_{NS})$

--- [PR982-I]

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

The availability AI of a group of Systems/Functions can be approximated with a series system/function logic:

- $A_i = 1 / (1 + \Sigma I=1 \text{ to } n\ \lambda(I)\ MDT_{NS}(I))$

where n is the number of systems/functions, λ(I) is the failure rate of the System/Function, I, which causes a Mean Down Time of MDTNS(I). [PR983-I]

Table 6-2: Inherent availability objectives for the main functions necessary for Machine Operation

System	PBS	A_H (%)	A_{D-T} (%)	Main Function	A_H (%)	A_{D-T} (%)
Magnet	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 Modules	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
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
Thermal Shields	27	99.9	99.9	To provide thermal shielding	99.9	99.9
Vacuum Pumping	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
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

System	PBS	A_H (%)	A_{D-T} (%)	Main Function	A_H (%)	A_{D-T} (%)
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
ECH&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 GHe and N2	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

Note *: The Detritiation System shall have an availability of 98.72%. [PR2376-C]

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

Table 6-3: Inherent availability objectives for the additional main functions necessary for the Physics Programme

System	PBS	A_H (%)	A_{D-T} (%)	Main Function	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
ICH&CD	51	87.3	83.6	To perform IC heating or current drive	90.0	88.0
ECH&CD	52	-	-	To perform EC heating, current drive or control MHD instabilities	90.0	88.0
NBH&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

To allow the machine to reach its operational availability targets, the systems and/or main functions used for maintenance 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. [PR2231-R]

Table 6-4: Inherent availability objectives for the main functions necessary for Maintenance

System	PBS	A_H (%)	A_{D-T} (%)	Main Function	A_H (%)	A_{D-T} (%)
Fuelling & Wall Conditioning	18	-	-	To perform Glow Discharge Cleaning	99.8	97.8
Remote handling	23	79.8	71.8	To ensure cask transfers	97.0	95.0
				To remotely handle and refurbish port plugs	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
ICH&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
Rad-waste 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 PTW	N/A	96.0

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%. [PR2234-I]

6.13.2.2 Overall machine operational availability objective

While using the definition previously given, the operational availability is defined :

- $A_o = MUT / (MUT + MDT_S + MDT_{NS})$

--- [PR2235-I]

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. [PR974-R]

An eight month scheduled down time, including two months for preparatory activities for opening the vacuum vessel and getting the machine back on line, will be allocated on average every two years as major shutdown (long-term maintenance state, LTM) for maintenance and/or upgrades of all the systems. [PR2237-I]

In-vessel activities involving remote handling shall not exceed six months every two years. [PR2236-R]

For out-vessel maintenance/upgrade activities, there shall be no planned outages additional downtime outside these defined periods unless it can be performed during normal plasma operation (hidden maintenance). [PR978-R]

The scheduled periods for machine inspections and maintenance tasks are defined in detail in the ITER Operations Plan (to be issued). [PR979-I]

To reach that overall machine operational availability objective while taking into account this scheduled downtime for planned inspection, maintenance and upgrades, the machine must meet an inherent machine availability of 60% for "basic" plasma operation. This translates into a list of inherent availability targets for the main functions performed by the ITER systems. [PR980-I]

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. [PR989-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. [PR2238-R]

Standardization shall be privileged when selecting multiple numbers of similar components that can be used by several systems throughout ITER in order to reduce the number of required spare parts, tools, skills, procedures, storage spaces and associated costs. [PR2239-R]

Procedures and training documents shall be provided to ITER Organization for operation, test and maintenance of the systems equipment on site, both as paper and electronic media, and shall be complete, updated and easily available. [PR2240-R]

All tools and test equipment needed for packaging, handling, storage, transportation, test and maintenance of the systems equipment on site must be provided to IO. Assembly tools shall be designed in such a way as they may be modified later to be used for maintenance during the operation phase of ITER, and shall thus be resilient and multi-purpose. [PR2241-R]

The supplier shall identify any facility requirements for the equipment that needs to be tested and maintained outside the Hot Cell Facility (control cubicles for instance). [PR2242-R]

A Major Risk Register shall be prepared using the Functional Analysis, Reliability Block Diagrams and Failure Mode, Effects, and Criticality Analysis described in the ITER RAMI Analysis Programme [R13]. [PR2243-R]

The severity scaling of the failure modes shall be oriented towards machine availability with an objective to reach the overall machine availability targets. [PR2244-R]

The Criticality (severity x occurrence) value leading to a major technical risk for the ITER machine will be defined by the Project. [PR2245-I]

For each major risk, a detailed analysis shall be made of causes via their occurrence and effects via their severity. [PR2246-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. [PR996-R]

In cases where the risk level 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. [PR2247-R]

The supplier shall demonstrate that the availability of the function performed by its design can meet the allocated availability requirement given in **Table 6-4**. [PR2248-R]

6.13.3 Reliability requirements

The reliability is the ability that an item will perform its intended function without failure in a specified time interval under given conditions and without including a maintenance period. It is thus one of the levers with which ITER can reach its availability objective, the other being the maintainability. [PR2249-I]

Reliability characteristics consistent with the calculations performed during the RAMI analysis shall be demonstrated by the supplier as part of the qualification process. [PR960-R]

The warranty period shall be used as a validation period for the reliability characteristics of the system equipment. [PR2250-R]

Deviations from requirements shall be identified and compensating/correcting actions identified and implemented. [PR2251-R]

6.13.4 Maintainability and Inspectability

The objective of Maintainability is to develop equipment and systems which can be maintained in the least time, at the least cost, with a minimum expenditure of support resources, without adversely affecting the item's performance or/and its safety characteristics. [PR998-I]

Inspectability is defined as that characteristic of design and integration that allows in-situ monitoring of equipment performance with regard to the amount of usable lifetime remaining. [PR2252-I]

Inspectability includes the accessibility to equipment to evaluate the material degradation and diagnostics to determine incipient failure. It is one of the characteristics of maintainability with a preventive objective. [PR999-I]

Accessibility to the physical interface points shall be taken into account as a way to improve the maintainability and inspectability of the concerned components, and thus ultimately the availability of the systems. [PR1000-R]

The maintainability shall ensure the minimum time to recognize, isolate and correct a malfunction, to understand and apply technical procedures, to gain access to faulty items, to repair or replace faulty items and to test and verify accuracy and adequacy of the maintenance actions. [PR1001-R]

The maintainability shall require the lowest amount possible of required facilities, tools, tests, support requirements and maintenance staff training to enable the fulfillment of maintenance requests. [PR2253-R]

As a general rule, the systems and their components shall be designed in such a way as to reduce the time to detect, identify, locate and repair any failure, or sign of impending failure. [PR1002-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. [PR2254-R]

Test engineering as a provision and access of test points, shall be involved at an early stage to define test requirements and design test approach. [PR2255-R]

As this consideration is mostly specific to the components themselves, inspectability requirements shall be addressed in detail in the SRDs specific to each system. [PR2256-R]

6.14 Inspection

Periodic inspections shall be performed during installation and maintenance periods to detect metallic equipment potentially left or loose in a magnetic zone. [PR2192-R]

6.14.1 In-vessel viewing

An In-Vessel Viewing System (IVVS) shall be provided which is capable of viewing and inspecting the first wall and providing dimensional measurements of first wall components. [PR1005-R]

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

The IVVS shall be designed to operate with the in-vessel components at temperatures in the range of 20°C to 120°C. [PR1007-R]

The IVVS shall be designed to operate in a radiation environment up to 1500 Gy/hr. [PR1008-R]

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

6.14.2 Leak localization

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

The precision of 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. [PR1012-R]

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

The methods applied for 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. [PR1013-R]

Should mitigation of the 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. [PR2194-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 leak localization which are to be applied. [PR1014-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. [PR2195-R]

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

A leak localization strategy shall be formed following R&D into techniques. [PR2197-R]

6.15 Maintenance conditions

Maintenance plans shall be developed for all maintenance scenarios with a probability of occurrence greater than 10^{-6}, over the 20-year life of ITER. [PR1016-R]

Maintenance procedures and tools shall be provided for maintenance scenarios with a probability exceeding 10^{-1} over the 20-year life of ITER. [PR2198-R]

For maintenance scenarios with a probability of occurrence lower than 10^{-1}, but for which serious feasibility concerns exist, such as machine sector replacement in the case of a TF coil failure, maintenance plans shall be developed and the required tooling conceptualized. [PR2199-R]

TF coil replacement after the activation phase is not considered. Only PF coil 1 and 2 replacement shall be considered after the activation phase. [PR2200-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. [PR2201-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. [PR2202-R]

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

Following achievement of the dose rate, hands-on maintenance shall be possible within two weeks for in-vessel operations, and within four weeks for in-cryostat operations. [PR1018-R]

Before the first deuterium-tritium starts, the ITER device and facility shall be capable of being upgraded to provide personnel access to the interior of the vacuum vessel in the presence of Be dust for hands-on maintenance. [PR1019-R]

Requirements for remote handling are provided in Section 6.16 [PR1021-I]

The vacuum vessel or cryostat shall be vented with dry nitrogen or humidity-controlled air prior to introducing personnel or remote handling equipment as appropriate. [PR1022-R]

Remote handling equipment is required to operate in dry air. [PR2204-I]

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

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

The residual magnetic field inside the vacuum vessel or cryostat shall not exceed 1 mT for enabling access for personnel or remote handling equipment. [PR2205-R]

Remote handling 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. [PR1024-R]

The temperature of the vacuum vessel or cryostat shall be maintained in the range of 20°C to 50°C when remote handling equipment is present, and 20°C to 25°C for personnel access. [PR1025-R]

6.15.1 In-vessel tritium inventory control

The requirements for the tritium inventory are detailed in section 7.4.1. [PR2370-I]

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

Taking into account measurements uncertainties on in-vessel tritium inventory, tritium shall be removed before the inventory approaches the safety limits. [PR1035-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. [PR1036-R]

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

The tritium removal shall rely on:

- The capability to bake all VV and in-vessel components as described in Section 4.2.6.1
- Wall-cleaning techniques.

--- [PR1038-R]
Baking shall be carried out:

- Before any planned or unplanned 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.

--- [PR1042-R]
The duration of baking shall be commensurate with the tritium desorption rate; see Section 4.2.5. [PR1046-R]

6.15.2 In-vacuum vessel dust inventory control

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

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

Methods to assess the global erosion in the vacuum vessel shall be provided (IVVS). [PR1050-R]

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

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. [PR1052-R]

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

6.15.3 Refurbishment and disposal of in-vessel components

Facilities shall be provided in the Hot Cell Building for refurbishment of failed or worn in-vessel components which are designed for refurbishment (including remote handling equipment). Test facilities to confirm refurbishment shall be provided. [PR1055-R]

Personnel access shall be provided to Hot Cell Building when dose rates permit. [PR1056-R]

Personnel access to the Hot Cell Building requires beryllium protection and measures to limit the spread of beryllium. [PR1057-I]

Transfer casks shall be provided for transport of activated or contaminated in-vessel components between the Tokamak Complex and the Hot Cell Building. [PR1058-R]

Facilities shall be provided for storage of replacement parts of in-vessel components (including activated or contaminated components that have been refurbished) and for storage of associated equipment, such as RH tools and transfer casks. [PR1059-R]

Appropriate measures (for example, confinement, monitoring, decontamination, exposure limitation, access control) shall be implemented in order to minimize worker exposure to beryllium and beryllium compounds throughout ITER lifetime (including ITER construction and its non-nuclear phase). [PR2206-R]

6.15.4 Processing of radioactive waste

Facilities and equipment to process activated and contaminated components (including appropriate process, pre-packaging, packaging, and temporary storage) shall be provided. [PR1061-R]

Facilities to process low-level and very-low-level radioactive waste for periods up to six months before disposal shall be provided. [PR1062-R]

Facilities to store intermediate-level radioactive waste for periods up to 20 years prior to disposal by the Host country shall be provided. [PR1063-R]

Facilities and equipment to treat radioactive liquid waste shall be provided. [PR1064-R]

No radioactive material processing shall lead to a high-level radioactive waste stream. [PR1065-R]

Solid radioactive waste shall be transported (if required) from its source location to the treatment facility using appropriate containers and transport systems that ensure the maintenance of the required level of confinement and radiation shielding. [PR2207-R]

Solid waste packages shall be controlled prior to transport and disposal. [PR2208-R]

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

6.15.5 Safety drain tank

It shall be possible to process the contaminated water discharged to safety drain tank(s) following an in-vessel water leak. [PR1067-R]

It shall be possible to process the water and to clean the safety drain tank(s) to allow the restart of the ITER plant within one year. [PR1068-R]

It shall be possible to process the contaminated water from the VVPSS to allow the restart of the ITER plant within one year. [PR1776-R]

6.16 Remote maintenance requirements

The ITER Organization policy regarding maintenance provision is to balance risk and cost by assigning a remote handling (RH) classification for maintenance tasks according to the likelihood of them having to be carried out, and to define the level of provision to be made for each classification. [PR1075-I]

The ITER remote handling system (PBS-23) shall be designed in accordance with the guidelines provided in the ITER Remote Maintenance Management System document [A17]. [PR1071-R]

Provisions for remote maintenance shall be made for all environments where hands-on maintenance would result in ITER administrative limits (less than 100 µSv/h) being exceeded. [PR1073-R]

Table 6-5: Remote Handling (RH) Classification

Classification	Task	RH Provision
RH Class 1	Scheduled maintenance tasks (upgrades, predictable refurbishment)	Plant designed to be RH-compatible for maintenance. Maintenance equipment procured and operation sequences planned in detail prior to machine operations. Maintenance tasks verified on physical mock-ups before design is finalized.
RH Class 2	Task probability > 3.10^{-1} but not scheduled tasks (in 20-year period)	Plant designed to be RH-compatible for maintenance. Maintenance equipment procured and operation sequences planning in detail prior to machine operations. Novel aspects of maintenance tasks verified on physical mock-ups before design is finalized.
RH Class 3	Task probability > $3.\ 10^{-2}$ but < 3.10^{-1} (in 20-year period)	Plant designed to be RH-compatible for maintenance. Maintenance equipment and operation sequences designed prior to machine operations.
Unclassified	Task probability < $3.\ 10^{-2}$ or no credible need for remote maintenance (in 20-year period) (For Example) TF coil, Lower PF coil	No provision

All equipment in the in-vessel, Neutral Beam cell, and Hot Cell controlled areas shall be analyzed for their RH classification defined in **Table 6-5**, as described in the ITER Maintenance Management System document [A17]. [PR1078-R]

All ITER systems with an RH classification shall be designed for RH compatibility. Guidelines for designing for RH compatibility are provided in the RH Code of Practice [R19]. [PR1079-R]

The remote maintenance tasks shown in **Table 6-6** shall comply with the scheduled shutdowns defined in the ITER Operations Plan (to be issued). [PR1081-R]

The ITER maintenance facilities shall ensure execution of the scheduled remote maintenance tasks (RH Class 1) within the scheduled maintenance time (**Table 6-6**). [PR1082-R]

Table 6-6: Scheduled remote handling maintenance tasks

Task	Maintenance Time (note 1)
Divertor Cassette Exchange (54 units)	6 months
Blanket Replacement of all First Wall Panels	24 months
Test Blanket Modules (3 units)	2 months
NB caesium oven	1 month

Note 1: This time excludes ITER stop/start time. [PR1690-C]

Unscheduled remote maintenance tasks (failures that did not require an unscheduled shutdown or system upgrades) shall be performed during the remaining available time of a scheduled shutdown. The number of unscheduled tasks performed will depend on the time required to perform each task, their priority, and the possibility to carry out parallel remote handling operations (see **Table 6-7**). [PR1084-R]

The remote maintenance systems (PBS-23) shall be capable of processing, in parallel, tasks from the different columns (pools) shown in **Table 6-7**. [PR1087-R]

Table 6-7: ITER maintenance task pools

Pool A Tasks (est. 3 months each)	Pool B Tasks (est. 3 months each)	Pool C Tasks (est. 2 months each)	Pool D Tasks (est. 2 months each)	Pool E Tasks (est. 2 months each)
1× Equatorial Diagnostic Plug maintenance	1 × Upper Diagnostic Plug maintenance	3 × Test Blanket exchange	18 × Divertor cassette exchange	1 × NB caesium oven change
1× Equatorial ECH antenna upgrade	1× Upper port EC antenna upgrade	2 × Diagnostic rack exchange	37 × Blanket module replacements (based on a complete blanket replacement 2-year campaign)	1 × NB Fast Shutter maintenance (unplanned maintenance)
1× Equatorial ICH antenna upgrade		1 × IVVS exchange		1 × NB ion source caesium cleaning
1× Equatorial port limiter upgrade	1 × Torus cryopump maintenance			

For pools A and B, the maintenance systems shall be capable of processing, in series, two tasks in a six-month maintenance period. [PR1089-R]

For pools C, D, and E, the maintenance systems shall be capable of processing, in series, three tasks in a six-month maintenance period. [PR1090-R]

6.17 Human factor engineering

Human performance and human error can have a major impact on the safety of a nuclear installation, as well as in operability, availability, and maintainability and inspectability aspects. Human and Organizational Factors shall be considered within the ITER Project. [PR2210-R]

ITER Organization will retain responsibility for Human and Organizational Factors at the overall system level and will assure and integrate the HF inputs from suppliers. The ITER Human Factors Integration Plan (HFIP) [R22] was established in order to:

- Ensure that human and organizational factors risks across and within the ITER project are competently identified and managed all along the entire design and supply chain
- Ensure that all systems and design shall satisfy the requirements set out in this document and meet regulatory requirements
- Derive, manage and assure ITER Human Factors requirements to the entire system design and supply chain
- Develop and provide detailed Human Factors guidance for suppliers (such as checklists, methods, and guidance on standards)
- Provide ITER with Human Factors acceptance criteria and assurance of supplier Human Factors activities
- Oversee the integration of Human Factors output across the overall ITER Project
- Oversee and guide ITER design, development and implementation teams on Human Factors issues with systems interfaces (support for systems integration)
- Oversee and guide human and organizational factors within ITER Organization to ensure proper integration and delivery of human factors within and across the entire system design and supply chain.

--- [PR1093-R]

The HFIP defines a systematic application of Human and Organizational Factors throughout the ITER project, from concept to decommissioning with reference to all systems and activities (particularly in view of operation and maintenance optimization) where Human Factors plays an important role from a safety and availability point of view. [PR1092-I]

All systems shall be designed in accordance to the *ITER Human Factor Integration Plan (HFIP)* [R22]. [PR2211-R]

6.18 Investment protection requirements

Investment Protection 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). Such failure may be direct, through the action of other SSC or due to events related to the operation of the plant or the plasma, or through external influence such as earthquake. The policy on investment protection is defined in MQP Policy for ITER Investment Protection [R24]. [PR2213-P]

Risks to investment categorised as Severe or above shall be mitigated as defined in the Investment Protection Strategy. [PR2214-R]

Each system design shall take into account possible impact on other SSC, for example due to collapse, debris, leaks and deflagration. [PR2356-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 ESPN components. [PR1310-R]

7 Environmental, safety, and health requirements

7.1 Natural environment

The design of all ITER systems, and subsystems, and the planning of the shipping, storage, construction and machine operation, shall take into account the meteorological conditions, and the risks of abnormal conditions. The meteorological conditions, and some Cadarache-specific criteria that are imposed by French and European norms, are reported in [A20]. [PR1105-R]

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

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

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

A secure 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. [PR1108-R]

The ITER rainwater management system (taking account of rainwater run-off) shall be designed to protect the ITER installations against a 100-year return period rainfall plus 20% margin. [PR1988-R]

The ITER installations shall be designed to withstand a 100-year return flood. [PR1989-R]

All nuclear buildings shall be designed to prevent ingress of rainwater and groundwater, in combination with the Precipitation Water Drainage System. [PR1990-R]

ITER buildings shall be designed to withstand wind gusts of 166.6 km/h at 50 m above ground level [R29]. [PR1991-R]

The ITER installations shall be designed to withstand extreme permanent winds up to 29 m/s at 10 m above ground level [R29]. [PR1992-R]

The ITER installations shall be designed to withstand extreme cold conditions; that is, air temperatures down to -25ºC and temperatures of -15ºC for concrete structures and isolated structures [R29]. [PR1993-R]

The ITER installations shall be designed to withstand extreme heat conditions; that is, air temperatures up to +45ºC and temperatures of +40ºC for buildings [R29]. [PR1994-R]

The ITER installations shall be designed to withstand extreme snow conditions; that is, a normal loading up to 80 daN/m^2, an exceptional loading up to 150 daN/m^2 [R29]. [PR1995-R]

7.2 General safety objectives

ITER shall be designed, constructed, and operated in accordance with the French safety regulations as provided for in Article 14 of the ITER Agreement [R18]. [PR1110-R]

The potential for the public and workers to be exposed to radiological and other hazards shall be limited by design, construction, operation, and preparation for decommissioning. (Decommissioning is the responsibility of the Host country, France, not of ITER Organization, so requirements during that phase are not covered by ITER project documents.) The policy shall be to ensure that exposures are As Low As Reasonably Achievable (ALARA) and to provide defence-in-depth for potential incidents and accidents. [PR1111-R]

For radiological hazards, the dose objectives that are presented in **Table 7-1** shall be respected during normal operation and off-normal events (incidents and accidents) with the following definitions and guidelines:

- **Normal Operation situations** (including operation, testing, and maintenance): events and plant conditions that are planned and required for ITER normal operation, including some faults, events or conditions that can occur as a result 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 due to failures one or more times during the life of the plant
- **Accidental situations:** postulated event sequences or conditions that are not likely to occur during the life of the plant
- **Hypothetical events:** beyond the design basis. These 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.

--- [PR1112-R]

The ITER design shall be failure-tolerant, and no single failure of components shall result in significant consequences to the personnel, public and/or environment. [PR1996-R]

No cliff-edge effect: this shall be demonstrated by showing that the magnitude of the consequences of a postulated event is bounded, and that there is no large increase as the safety functions are progressively degraded. [PR1118-R]

Counter measures limited in time and space should 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.

--- [PR1119-P]

Table 7-1: Radiological safety objectives

General safety objectives		
	For personnel	For the public and environment
Situations in design basis		
Normal situations	As low as reasonably achievable, and in any case less than: Maximum individual dose <= 10 mSv/yr Average individual dose for workers classified for radiation exposure <= 2.5 mSv/yr	Releases less than the limits authorised for the installation Impact as low as reasonably achievable and in case less than: <= 0.1 mSv/yr
Incidental situations	As low as reasonably achievable and in any case less than: 10 mSv per incident	Release per incident less than the annual limits authorized for the installation. = 0.1 mSv
Accidental situations	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
Situations beyond design basis		
Hypothetical events	No cliff-edge effect; possible counter-measures limited in time and space	

7.3 Safety-important systems, structures, and components

7.3.1 General criteria

ITER Systems, Structures and Components (SSC) that play an important role in the protection of ITER and its environment, shall be classified as Protection Important Components, as considered in the INB order of the 7th February 2012 [R30]. [PR2377-R]

PIC that play an important safety role, and that contribute in respecting ITER Generic Safety Objectives during an abnormal event, shall be classified as Safety Importance Class (SIC) 1 or 2 or Safety Relevant (SR), following the criteria and methodology that is described in ref [A23], based on the consequences of their failure. The top-level criteria for the identification are:

- Criterion A: their failure can directly initiate an incident or accident leading to significant risks of exposure or contamination
- Criterion B: their operation is required to limit the consequences of an incident or accident that leads to significant risks of exposure or contamination

- Criterion C: their operation is required to ensure the functioning of the other SIC components.

--- [PR1256-R]

ITER nuclear pressure equipment (ESPN) shall comply with the safety requirements that are associated with its ESPN class for design, manufacture, qualification, installation and operation, testing and inspection [A06]. [PR2046-R]

7.3.2 Auxiliary safety systems

Support services for systems that provide safety functions shall be designed and operated such that the intended safety function can be fulfilled when required. [PR1262-R]

7.3.2.1 Safety-relevant power supply systems

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

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 startup sequence of the electrical consumers that are supplied by the emergency diesel generators).

--- [PR1265-R]

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

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 centre. [PR1271-R]

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

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

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

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

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

7.3.2.2 Ancillary fluids

The compressed air supply or demineralised water supply or SIC nitrogen supply, for instruments that are needed to maintain confinement barriers in accidental situations, shall be separated from other non-SIC supply systems. [PR1278-R]

7.3.3 Guidelines related to safety importance class (SIC) components

The design of SIC systems, structures, and components shall include all loading events for which the components may be required to perform a safety function. [PR1301-R]

Design rules and standards shall be selected for each system or component, in consideration of SIC, using the guidelines in **Table 7-2**. [PR1302-R]

ITER shall be designed to provide redundant and, where appropriate, diverse systems, as necessary to achieve the required reliability. [PR2047-R]

Operation, inadvertent actuation or damage to components that are not SIC, shall not prevent SIC systems, structures, or components from accomplishing their safety functions when required. [PR1311-R]

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. [PR2048-R]

Table 7-2: Guidelines related to Safety Importance Class (SIC) components

Issue	Guideline for Safety Important Class components
1. Design (use of codes and standards, degree of conservatism, margins, etc.)	a. Code and regulatory requirements for design, fabrication, testing etc. shall be followed. Deviations from code requirements shall be documented. b. Where an appropriate design code does not exist, an agreed surrogate developed specifically for ITER may be used. c. Testing, proven and documented manufacturing process, control of materials, etc. shall be provided for prototype/non-code items. d. Standard commercial components shall be acceptable if appropriate to conditions of use.
2. Materials (restrictions on which materials can be used, extent of testing, sources of data, margins in data, etc.)	a. Materials to be specified and compliance ensured. b. Materials in standard commercial component may be acceptable if appropriate to conditions of use.
3. Fabrication and Installation (manufacturing process qualification, weld types, welding procedures and welder qualification, etc.)	a. Manufacturing, assembly and installation process/procedures to be specified and compliance ensured. b. Compliance with design code and regulatory requirements (if applicable). c. Standard, proven, commercial component fabrication may be acceptable.
4. Examination (extent of inspection, third party or owner, non-destructive examination, etc prior to operation.)	a. Examination and acceptance tests during fabrication/construction as needed to ensure safety function to be specified and compliance ensured. b. Compliance with design code and regulatory requirements (if applicable).
5. Testing (pressure testing, performance testing, etc prior to operation)	a. Testing required to demonstrate safety function to be specified and compliance ensured. b. Compliance with design code requirements (if applicable).

Issue	Guideline for Safety Important Class components
6. In-Service or Periodic Inspection (inaugural, frequency and extent of in-service tests)	a. In-service inspections, monitoring and/or tests or compensatory measures taken to ensure that the equipment can continue to provide its safety functions with the required level of reliability. b. Test records, calibration records, personnel training requirements, etc. to be specified as part of the normal maintenance procedures. c. Compliance with the regulatory requirements
7. Equipment qualification	a. Justification to be provided that component can withstand the normal and abnormal environmental conditions that may arise from an accident at the end of their service life for which their operation is needed. For equipment which is required in the event of an earthquake, this includes seismic qualification.
8. Reliability	a. System to perform its credited safety function even with single active fault/failure (or alternative system available to provide the safety function). b. Use of proven, good industrial quality components may suffice as a justification.
9. Independence, physical separation	a. Safety function shall not be undermined by underlying common cause or cascading failures. b. Protective I&C for a system should be separate and functionally isolated from process instrumentation for that system (separate signal channels appropriately de-coupled and shielded), and with physical separation between redundant channels.
10. Equipment status indication	a. Status under normal conditions and functioning of system under emergency use as appropriate available to operators, possibly at remote location.

7.3.4 System seismic requirements

SL-1 (Seismic Level-1) response spectra are defined as one-third of the envelope of the SMS and the PALEO-earthquake response spectra. SL-1 corresponds to an event with a probability of the order of 10^{-2} per year, and represents an investment protection earthquake level (following the Nuclear Pressure Equipment regulation, it corresponds to a foreseeable event). [PR1305-I]

SL-2 response spectra (also called SSE, Safe Shutdown Earthquake) are defined by the envelope of two spectra: SMS and PALEO-earthquake response spectra. SMS and PALEO-earthquake are calculated in accordance with the ITER Seismic Nuclear Safety Approach [R12]. [PR1306-I]

SMHV (Séismes Maximaux Historiquement Vraisemblables, or Maximum Historically Likely Earthquakes) are the most penalising earthquakes that are liable to occur over a period of about 1000 years. [PR2178-I]

Peak ground accelerations and design response spectra for seismic events are defined in the Load Specifications [A14]. [PR1307-I]

Those SIC components that are required to perform safety functions during, or after, a SL-2 earthquake, shall be designed such that their capabilities are maintained. [PR2049-R]

The collapse, falling, dislodgement or any other spatial response of a component, as a result of an earthquake, shall not jeopardize the functioning of other components that provide a safety function during or after the earthquake. [PR1308-R]

The combination of loads from earthquakes with other loading events shall be considered. [PR1309-R]

The ITER installation shall be equipped with a seismic detection system to provide a warning notification of a seismic event. [PR2050-R]

Table 7-3: System seismic requirements

PBS	System	Safety Requirements during and following SL-2 earthquake
11	Magnet Systems	No damage to vacuum vessel or cryostat confinement barriers.
15	Vacuum Vessel	Leakage from vacuum vessel no greater than that assumed in safety analysis
16 17	Blanket Divertor	No damage to vacuum vessel
18	Fuelling and Wall Conditioning	No significant leakage of activity 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 activity from system to rooms
24	Cryostat	No damage to vacuum vessel Vacuum vessel pressure suppression system functional
26	Cooling Water System	No significant leakage from system Chilled water to 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 activity 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.
34	Cryogenics System	No impact on SIC and SR components
41	Coil Power Supply & Distribution	Ability to switch off PF coil power supplies remains functional during and after earthquake;
43	Steady State Power Supplies	Ability to provide power to systems providing safety function retained; interruption during earthquake acceptable; must be able to be restarted.
46	Central Interlock System	Safety interlocks remain operational
48	Central Safety System	Safety system remains operational
51 52 53 54 55	Ion Cyclotron H&CD Electron Cyclotron H&CD Neutral Beam H&CD Lower Hybrid H&CD Diagnostics	No significant leakage of activity from system into rooms
56	Test Blankets	No significant leakage of activity (or lithium, if applicable) from system into rooms
62	Tokamak Complex Hot Cell	Integrity of the main structure is to be maintained Vent and clean-up systems are functional Detritiation systems Fire detection capability remains operational for fire sensitive rooms
64	Radiological Protection	Ability to monitor (estimate) releases from site retained Radiation protection monitoring (possibly portable) available
65	Liquid Distribution	Fire protection available following earthquake

7.3.5 Fire protection for SIC electrical, instrumentation and control components

The components of two redundant SIC-1 systems shall be located in independent and separate fire sectors (fire sectors are defined in Section 7.9.7). [PR2052-R]

Each train (A and B) of the electrical supply and the I&C cabling of the SIC-1 cubicles shall be routed through independent and separate fire sectors. [PR2367-R]

The SIC-1 cubicles shall be located in dedicated rooms that do not contain SIC-2 or SR or non-SIC cubicles. [PR2053-R]

The SIC-1 cubicles shall be equipped with automatic fire detection and suppression systems. [PR2179-R]

The components of SIC-2 systems for which there is a redundancy requirement shall be located in two independent and separate fire sectors. [PR2054-R]

The redundancy SIC-2 cubicles can be implemented with the SR, and non-SIC cubicles at dedicated and separate places in the same room. The minimum distance between SIC-2 and non-SIC cubicles shall be 2 m. This room (and not the cubicles themselves) shall be equipped with automatic fire detection and suppression systems. [PR2055-R]

Each train (A and B) of the electrical supply and of the I&C cabling of the SIC-2 cubicles, shall be routed through different fire sectors. [PR2056-R]

Concerning the SIC-2 cubicles for which there is no redundancy requirement, their implementation in the same room as SR and non-SIC cubicles is possible if all the cubicles (SIC-2, SR and non-SIC) are equipped with automatic fire detection and suppression systems. [PR2057-I]

In any given room, all the SIC-1 cubicles shall be on the same Train (A or B) for power supply and I&C cabling. [PR2058-R]

In any given room, all the SIC-2 cubicles shall be on the same Train (A or B) for power supply and I&C cabling. [PR2059-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. In addition, in all nuclear buildings, all cable trays shall have a metallic cover to minimize the risk of fire propagation. [PR2379-R]

7.4 Inventory control guidelines

All ITER systems shall be designed and operated so that radioactive and hazardous inventories are maintained as low as reasonably achievable and within the limits that are authorized for the site, plants, zones, systems and components. [PR1142-R]

This shall include inventories of all hazardous substances and fuel that is stored on site, as well as radioactive and hazardous waste and effluents that are generated during ITER operation and decommissioning. [PR2007-R]

Both the quantity and level of toxicity of such inventories shall be minimized, controlled and monitored. [PR2008-R]

7.4.1 Tritium inventory

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

The tritium inventory shall be tracked, with measurement uncertainties estimated to assure that inventory limits are respected. [PR1144-R]

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

The mobilizable tritium inventory within the vacuum vessel and extensions, that is, the vacuum boundary (including the Neutral Beam enclosures, Neutral Beam cryopumps, torus crypopumps, and measurement uncertainties) shall not exceed 1000 g. [PR1145-R]

The tritium inventory in a fire sector (see Section 7.9) shall be limited to 70 g, with some exceptions that are individually authorized. [PR1146-R]

The maximum tritium concentration in the vacuum vessel PHTS cooling water shall not exceed 0.21 $mg.m^{-3}$ (76 MBq/kg), including measurement uncertainties. [PR1147-R]

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

7.4.2 Activation products

The total inventory of in-vessel, activated dust (such as beryllium dust and tungsten dust) shall not exceed 1000 kg, including measurement uncertainties. [PR1153-R]

The inventory of beryllium dust and tungsten dust, on surfaces that become sufficiently hot to be reactive with steam or air during incidents, shall not exceed 11 kg for beryllium dust or 76 kg for tungsten dust, or a linear combination of the two species, taking into account that 11 kg beryllium or 76 kg tungsten is the quantity which, if fully reacted with steam, leads to 4 kg hydrogen in the vessel. Deflagration of more than this quantity exceeds 0.2 MPa peak dynamic pressure, the limit for the first confinement barrier (see **Table 7-4**). [PR1152-R]

There shall be provisions for measuring or estimating the inventory of activation products to assure that inventory limits are not exceeded. [PR1151-R]

The level of activated corrosion products in cooling systems shall be minimized, for example through the selection of materials in systems. [PR1154-R]

7.5 Confinement of radioactive and hazardous materials

7.5.1 Number of radioactive and hazardous materials confinement systems

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

Each confinement system shall include one or more static barriers, or dynamic components, to confine the inventory at risk. Static barriers require no moving parts to fulfill their confinement function (such as vacuum vessel, process piping) whilst dynamic components require moving parts (such as isolation devices or detritiation systems). [PR2018-R]

Formal project approval for a single confinement system may be given by ITER Organization if justified by analyses that shows that the failure of this single confinement system results in small consequences. [PR2017-P]

In some foreseen normal operations or off-normal events, 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. [PR1158-P]

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:
    - 350°C baking of the divertor, to reduce the tritium inventory in co-deposited layers, shall be performed
    - Baking of the Vacuum Vessel and the in-vessel components to reduce the tritium inventory in co-deposited layers, shall be performed
    - In-vessel dust removal shall be performed, for example vacuuming of dust
    - The vessel atmosphere shall be detritiated prior to port opening, to obtain a low tritium concentration in 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 and the Hot Cell Building
    - Alternate, temporary systems and/or barriers (like tents) shall be provided.

--- [PR1164-R]

7.5.2 Requirements to ensure the radioactive and hazardous materials confinement function

Rooms that may become contaminated with beryllium aerosol shall be equipped with a confinement system to ensure a minimum beryllium removal efficiency of 99.9% prior to release into the environment. [PR2016-R]

The allowable leak-rates for confinement barriers are specified in **Table 7-4**. [PR1181-I]

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

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. [PR1184-R]

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

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. [PR1186-R]

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

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

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

The confinement isolation valves shall assume their safe position on loss of power. [PR1190-R]

Designated areas within the buildings shall have passive and active features that prevent, detect, retard or extinguish fire that threaten or degrade safety-related components or worker safety. [PR1191-R]

If the atmospheric concentration of tritium exceeds 10^8 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. [PR1244-R]

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. [PR1192-R]

The confinement systems shall be capable of withstanding all loads and conditions that result from accident sequences. [PR1193-R]

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. [PR1194-R]

Fire loading shall be minimized, and shall be such as to prevent the spread of fire between fire sectors. [PR1195-R]

Emergency power and SIC compressed air shall be provided to dynamic systems/components so as to maintain mitigation function even postulating the loss of off-site power. [PR1196-R]

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

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 fire or a confinement barrier shall reconstitue 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. [PR1198-R]

Analyses shall be performed to identify credible failure modes, and to provide assurance of reliable performance of credited safety functions. [PR1199-R]

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

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

The routing/piping of confinement barriers shall be such as to avoid potential damage to confinement systems by movement of equipment during maintenance. [PR1202-R]

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

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

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. [PR1206-R]

In all situations, the Main Control Room (see Section 6.10), or the Backup Control Room, that both have the capability to monitor and to control SIC components and to put the plant in a safe state, shall remain habitable. [PR1207-R]

7.5.3 Assessment values for confinement of radioactive and hazardous materials

The values in **Table 7-4** were used in the safety analyses. These values are imposed as design constraints to ensure that the design stays within the basis of safety analyses. [PR1210-I]

Table 7-4: 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 piping	Max. Pressure Leak rate	5 MPa (FW/BLK) 5.1 MPa (DIV) 2.6 MPa (VV) 3 MPa (NBI) = 1 kg/hr (total for all loops)
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 @ 300 Pa overpressure < 820 volume %/day at 0.02 MPa pressure differential

Component	Parameter	Safety Assessment Value
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
Hot Cell Building C4***, C4** and C3 areas	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
Hot Cell buildings (C2 areas)	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)
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 setpoint	10^8 Bq.m-3
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 [R21]). [PR2279-C]

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. [PR2368-C]

7.5.4 Protection of radioactive and hazardous materials confinement systems

7.5.4.1 Heat removal

The design of all ITER systems shall provide reliable means to remove the heat that is generated during normal operation, as well as the decay heat of activation products after shutdown, and the heat from potential chemical reactions, if this heat could lead to a challenge to a confinement barrier including indirectly (for example, by elevated temperatures causing a higher rate of a hydrogen-producing chemical reaction). [PR2020-R]

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. [PR1214-R]

Reliable, long-term, post-accident cooling shall be available to remove the maximum power that is transferred to the vacuum vessel under such conditions. [PR1215-R]

7.5.4.2 Control of confinement pressure

ITER shall be equipped with appropriate devices to prevent plasma transients from challenging confinement barriers. [PR2021-R]

All ITER systems, structures and components 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. [PR1217-R]

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 off-normal event such as the ingress of coolant from a failed in-vessel component. [PR2022-R]

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. [PR2023-R]

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

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

The VVPSS shall be provided with a means (Suppression Tank Vent System, ST-VS) to remove non-condensable gases, if present in off-normal events. [PR1218-R]

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. [PR1219-R]

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

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). [PR2026-R]

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 systems or confinement, shall be designed to prevent the generation of a missile or to limit the consequences associated with this hazard. This shall include periodic control, testing and inspection in order to detect precursor signs of associated missile risks. [PR2027-R]

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 control, testing and inspection, to detect precursor signs of associated pipe whip risks. [PR2028-R]

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). [PR2029-R]

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). [PR2030-R]

7.5.4.3 Control of chemical energy

The design of all ITER systems shall be such that chemical energy inventories are controlled to avoid energy and pressurization challenges to confinement. [PR1225-R]

ITER shall be designed to minimize hydrogen production, to avoid explosive mixtures of hydrogen with air/oxygen with the potential to challenge a confinement barrier, and to minimize the release of chemical energy as heat. [PR1223-R]

The total quantity of hydrogen inside the vacuum vessel and connected volumes (HNBI, DNBI, cryopumps) including the hydrogen contained in the circuits or the cryopanels and the one that is produced by chemical reactions (such as between beryllium and coolant water or steam that leaks from a failed in-vessel component) shall be limited to below 4 kg H_2 (that is, the quantity at which deflagration would lead to a maximum pressure exceeding the vacuum vessel safety assessment pressure value, 0.2 MPa). This limitation implies the need to avoid elevated temperatures that would accelerate the beryllium/steam reaction, including the termination of plasma power in the event of loss of cooling of plasma-facing components, and the limitation of dust accumulation on hot surfaces. [PR1224-R]

The quantity of air that could enter the vessel (such as through a failed penetration line, or a cooling pipe that has fully drained) shall be limited to below 50 kg of air (that is, the quantity at which a hydrogen or dust detonation could result in a maximum pressure exceeding the vacuum vessel safety assessment pressure value, 0.2 MPa). This limitation may be satisfied by limiting the size of penetrations, and/or by the provision of isolation valves. [PR1226-R]

Reliable separation, typically provided by two barriers, shall be provided between volumes that may contain air and hydrogen, including during off-normal conditions. [PR1227-R]

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. [PR1228-R]

Cryogenic needs at locations where there may be a neutron flux or other ionizing radiation should be met by helium, not liquid nitrogen. [PR2031-P]

The use of nitrogen in any region that is subject to radiation shall be justified by an analysis of the possible generation of C14 through activation and of ozone through radiochemical conversion of trace levels of oxygen. [PR1229-R]

7.5.4.4 Control of halogenated materials

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. [PR1231-I]

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.) [PR1232-R]

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. [PR2032-R]

7.5.4.5 Control of magnetic energy

The superconducting coils shall be designed to avoid quench during plasma operation, including plasma disruptions. [PR2033-R]

The magnet system shall be equipped with devices to detect any loss of superconductivity. [PR2034-R]

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. [PR1234-R]

A means shall be provided to detect short circuits in the poloidal and central solenoid coils, and to close the EPMS (Explosive-actuated Protective Make Switch) at the output of the converters that will avoid further delivery of electrical energy. [PR1235-R]

7.5.4.6 Design provision for internal and external aggressions

The design of all ITER systems shall include provisions to minimize the potential for other hazards that could challenge confinement systems. These include internal aggressions, such as fire or flooding, and external aggressions, such as earthquakes or extreme weather conditions. [PR1237-R]

The ITER installation shall be designed, and appropriate measures taken, to minimize the risk of external fire around the installation and, if such an event were to occur, to prevent its propagation inside the nuclear buildings. [PR2035-R]

In the event of an aircraft crash, the design and layout of the radiologically controlled buildings, and of the buildings that contain Protection Important Components (PIC), shall protect all PIC that they contain. [PR2036-R]

In the event of an aircraft crash, Protection Important Components (PIC) 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). [PR2037-R]

The ITER facility 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. [PR2003-R]

The ITER buildings that contain Protection Important Components (PIC) 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. [PR2004-R]

7.6 Radiation protection

The As Low As Reasonably Achievable (ALARA) principle shall be applied to minimize occupational doses. [PR1997-R]

The ALARA procedure shall be applied before work in a radioactive zone is authorized. [PR1126-R]

An assessment shall be made of the work that is to be performed during operation, maintenance, and repair so that the design may ensure that worker exposures to radiological and other hazards are ALARA and in all cases within the General Safety Objectives, Section 7.2 and the guidelines for exposure to such hazards. [PR1127-R]

Habitable space shall provide safe ingress and egress paths. [PR1128-R]

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. [PR1998-R]

The collective annual worker dose, averaged over the operational life time of ITER, shall be ALARA and in any case shall not exceed an annual target of 0.5 person.Sv. [PR1129-R]

Where hands-on maintenance activities in port cells and in other locations in the ITER facility requiring human access are performed, dose rate shall be as low as reasonably achievable and shall not exceed 100 µSv/h in yellow zones and 10 µSv/h in green zones, at 10^6 s (about 12 days) after shutdown without formal project approval. The dose will be estimated 30 cm from the nearest accessible surface and must take into account the surface contamination, airborne tritium as well as activated materials. [PR1130-R]

To minimize radiation exposure to the workers in port cells (with the exception of the Neutral Beam injectors cell), with the bioshield plug in place, the dose rate shall be as low as reasonably achievable, and shall not exceed 10 micro-Sv/hr at 24 hours after shutdown, without formal project approval. The dose will be estimated 30 cm from the nearest accessible surface. [PR1782-R]

The dose rate and the level of atmospheric and surface 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. [PR1131-R]

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. [PR1132-R]

First confinement system 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. [PR1133-R]

Food, drinks, tobacco, personal cosmetics, handkerchiefs shall not be allowed when a contamination risk may exist. [PR1134-R]

The changing rooms shall be separated in two parts, one for civil clothes, the other for work clothes. Showers and sinks shall be available. [PR1135-R]

If there is a risk of contamination, the surfaces of habitable room equipment shall be made of materials that are easy to decontaminate. [PR1136-R]

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 contamination or a dose rate that is higher than the green-zone limit (see Radiological Zoning, Section 7.9.2) and to take account of temporary changes in the classification of rooms, in accordance with the operating mode. [PR1137-R]

For radiological zones, other than orange and red (see Section 7.9.2), the individual sources of radiation shall be clearly indicated, and shall be communicated to workers prior to entry. [PR1138-R]

Human access shall be forbidden in radiological red and orange zones (see Section 7.9.2), without special authorization from the ITER Director-General. [PR1139-R]

Human access to radiological yellow zones (see Section 7.9.2) shall be subject to specific authorization procedures. [PR1140-R]

Shielding against ionizing radiation shall be maintained during all design basis situations (including maintenance). [PR1999-R]

Radiation protection (fixed or mobile shielding in conjunction with access control for the radiological zone) shall be provided between sources of ionizing radiation and the personnel, in order to limit dose rates to levels that are As Low As Reasonably Achievable (ALARA). [PR2000-R]

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 (such as beryllium) 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. [PR2001-R]

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. [PR2002-R]

7.7 Monitoring

7.7.1 Radiological protection of workers

ITER Organization shall develop and implement a suitable Radiation Protection Program (RPP) that will include worker classification and access control as well as a system of authorization and associated procedures. [PR1241-R]

The ITER RPP shall be reviewed periodically to check its efficiency, and to optimize it where possible. [PR2357-R]

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. This includes but is not limited to monitoring of tritium, neutron, gamma, radon gas, particles, and ^{14}C. [PR2005-R]

The evacuation alarm activation level shall be 1 DAC in areas with human habitation of a potentially-contaminated sector. An alert will be set at 0.1 DAC to inform the workers to place everything in a safe state before evacuating. (Derived Atmospheric Concentration 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 3×10^5 Bq/m^3.) [PR1242-R]

Personnel access at levels higher than 1 DAC may be permitted with specific authorization, provided that proper individual protection is used. [PR1243-P]

7.7.2 Radiological and environmental monitoring

The design of all ITER systems shall provide means for monitoring and controlling radioactive or hazardous material releases (gaseous or 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. [PR1246-R]

The design of all ITER systems shall provide systems using best available techniques for assuring reliable information on all operational events and accidents, and for monitoring the performance of the confinement and its protection during accidents. [PR1247-R]

Protection Important Components (PIC) 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 Backup Control Rooms (Section 6.10) to ensure the assumed operability and reliability. [PR1248-R]

The environmental monitoring system shall be capable of monitoring levels, to ensure respect of the authorized release limits. [PR1250-R]

The Radiological and Environmental Monitoring system shall provide monitoring and warnings for chemical and radiological hazards, and for ionizing radiation fields. [PR1251-R]

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. [PR1252-R]

The Fixed Area Monitors (tritium-in-air, gamma, neutron, radioactive gas, ^{14}C) shall be state-of-the-art and shall have a minimum detectable level that is consistent with the radiological zoning for the area. [PR1253-R]

ITER shall have an environmental monitoring system that is able to operate in cooperation with the CEA site at Cadarache [R23]. [PR2044-R]

Oxygen levels in zones that are accessible to personnel, where there is a potential risk of anoxia, shall be monitored, with appropriate alarm systems. [PR2045-R]

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). [PR1249-R]

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. [PR2039-R]

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. [PR2040-R]

Prior to opening the double confinement of a hydrogen-bearing system, measures shall be taken to avoid the presence of potentially explosive conditions. [PR2041-R]

Appropriate measures shall be taken to minimize and control the in-cryostat ozone inventory, to prevent or minimize the risk of ozone explosion. [PR2042-R]

The strength of magnetic fields shall be monitored with fixed and/or portable detectors, as required, with appropriate alarm systems provided. [PR2043-R]

7.8 Safety requirements for the Test Blanket Modules System

All ex-vessel parts of the cooling system, and other auxiliary systems of the Test Blanket Modules System, shall be considered part of the first confinement system. [PR1315-R]

Decay heat removal shall be achieved by thermal radiation and conduction from the Test Blanket Modules System to the Tokamak. [PR1316-R]

Chemical reactions between coolant, air and breeder/multiplier material shall be limited, so that the confinement function of the Test Blanket Modules System is not challenged. [PR1317-R]

Self-sustaining chemical reactions shall be precluded by design of the Test Blanket Modules System. [PR1318-R]

Hydrogen production by each Test Blanket System (TBS) shall be limited to 2.5 kg hydrogen, to limit the explosion hazard. [PR1323-R]

Special consideration for lithium fires shall be made for the Test Blanket Systems that contain a liquid lithium loop. [PR1319-R]

Intermediate cooling loops shall be provided for Test Blanket Systems that contain a liquid lithium loop. [PR1320-R]

Gaseous leaks of helium from each Test Blanket System to the vacuum vessel shall be limited to 45 kg helium, to assure reliable functioning of the VVPSS. [PR1321-R]

Specific provisions shall be implemented to control additional radioactive source terms due to the activation of the Test Blanket Modules. [PR1322-R]

7.9 Zoning

Zoning shall be established in the nuclear buildings, to protect people, equipment, and the environment from the effects of perceived hazards during all phases of the facility life cycle. For the ITER facility, zoning applies to: Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Radiofrequency, Fire, Waste. [PR1325-R]

7.9.1 Ventilation zoning

Ventilation zones shall be established, based on the estimated atmospheric contamination, consistent with **Table 7-5**. [PR1336-R]

Table 7-5: Ventilation zoning standards

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

Note 1: Recirculation is included for enhanced tritium recovery, and does not significantly impact confinement. [PR1708-C]

Note 2: To take into account only internal exposure hazard, the derived atmospheric concentration (DAC) is used as defined in PR1242. [PR1338-C]

7.9.2 Radiological zoning

Radiation zones shall be established in accordance with the risks of internal exposure (through inhalation of airborne contamination and skin transfer) and of direct external exposure. Each zone corresponds to a dose rate range, and has associated time and access conditions. [PR1340-R]

The radiological zoning shall be based on total dose, as listed in **Table 7-6**, or on equivalent doses to hands and feet, as also listed in **Table 7-6**, when the external exposure to hands and feet exceeds the total exposure. [PR1342-R]

The radiological zoning shall be defined for each plant operation state, following the criteria of **Table 7-6**. [PR1343-R]

The marking (signing) of the radation zones from greyish blue to red shall follow the norm (ref. MF M 60-101) and shall be clearly posted on all access routes to the zones. The marking of the radiation zones shall be modified according to every change to the zoning. [PR2060-R]

Access conditions for the personnel to the radiological zones shall be as given in **Table 7-7**. [PR1344-R]

The tunnel for cask transfers between the Tokamak Building and the Hot Cell Buiding shall be designed and constructed to avoid needing an exclusion zone outside the nuclear buildings during the cask transfers [R32]. [PR2378-R]

Table 7-6: Radiological zoning

Zone	Control type	Radiological Zone Identification	Total dose - external and internal exposure (1)	External exposure to hands, forearms, ankles and feet (2)
Unregulated zone		White zone	Effective dose < 80 µSv/month	
Supervised zone		Blue zone	Effective dose per hour < 7.5 µSv (3)	< 0.2 mSv/h
Controlled zone	-	Green zone	Effective dose per hour < 25 µSv (3)	< 0.65 mSv/h
Controlled zone	Specially regulated	Yellow zone	Effective dose per hour < 2 mSv and Dose equivalent rate < 2 mSv/h	< 50 mSv/h
Controlled zone	Specially regulated (4)	Orange zone	Effective dose per hour < 100 mSv and Dose equivalent rate < 100 mSv/h	< 2.5 Sv/h
Controlled zone	Forbidden (4)	Red zone	Effective dose per hour > 100 mSv and Dose equivalent rate > 100 mSv/h	> 2.5 Sv/h

Note 1: 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). [PR1347-C]

Note 2: In case of exposure of the eye lens (crystalline), these values should be multiplied by 0.3 (150/500). [PR1348-C]

Note 3: If the source is always present, these values can be interpreted as a dose-equivalent rate. [PR1349-C]

Note 4: Human access is forbidden without special authorization. [PR1350-C]

Table 7-7: Access conditions for personnel

Radiological Zone identification	Access conditions for personnel	
Blue zone	Trefoil sign indicating risk of external exposure (blue)	Limited for Unexposed Unlimited for Class A and B
Green zone	Trefoil sign indicating risk of internal or external exposure (green) (1)	Limited for Unexposed and Classification B Unlimited for Class A
Yellow zone	Trefoil sign indicating risk of internal or external exposure (yellow) (1)	Limited for all personnel
Orange zone	Trefoils indicating: • risk of external exposure (orange) • risk of internal exposure (orange)	
Red zone	Trefoils indicating: • risk of external exposure (red) • risk of internal exposure (red) • access prohibited	Prohibited except with consultation and authorization

Note 1: Under normal situations, with no detectable atmospheric contamination permitted in green or yellow zones, the trefoils only indicate the risk of external exposure [PR1354-C]

Note 2: French regulations classify workers as Type A and Type B. 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 exposed to ionizing radiation and not classified Type A. [PR1355-C]

7.9.3 Anti-deflagration zoning

Anti-deflagration zoning provides a means of locating explosion risks in the buildings, in order to implement suitable risk prevention measures, both in terms of building design and of the use of their systems and equipment. [PR1357-I]

In accordance with the European Directive 94/9/EC(ATEX), hazardous locations shall be classified, and anti-deflagration zones established, according to the frequency with which an explosive atmosphere may form, and the length of time for which this atmosphere lasts:

- Zone 0: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is present permanently, frequently or during long periods
- Zone 1: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is liable to be present occasionally under normal operation
- Zone 2: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is not likely to be present under normal operations or, if present, only for short periods

- Zone 20: location where explosive atmosphere in the form of combustible dust cloud is present in the air permanently, frequently or during long periods
- Zone 21: location where explosive atmosphere in the form of combustible dust cloud is liable to be present occasionally under normal operation
- Zone 22: location where explosive atmosphere in the form of combustible dust cloud is not likely to be present under normal operation or, if present, only for a short period.

--- [PR1358-R]

Ventilation shall provide sufficient air renewal to avoid hydrogen concentration in rooms where there is an explosion risk. [PR1366-R]

The concentration of hydrogen in air (tritium, deuterium, protium and/or mixtures of these isotopes) shall not exceed 1% in explosive areas to stay below 1/4 of the inferior inflammability limit. [PR2061-R]

If there is no potential for an explosive mixture, the area shall be defined as having ”no zoning”. [PR1367-R]

"Normal operation" means situations where facilities and equipment are used in accordance with their design parameters. [PR1369-I]

7.9.4 Beryllium zoning

Beryllium zones shall be established in accordance with the zoning criteria that are listed in **Table 7-8**. [PR1373-R]

Access to beryllium zones shall be restricted in accordance with **Table 7-8**. [PR1374-R]

Proper signage shall be placed in areas, to be consistent with **Table 7-8** beryllium zoning requirements. [PR1375-R]

Table 7-8: Beryllium zoning criteria and access control

Beryllium zone	Beryllium zoning criteria		Access and control conditions for personnel
	Beryllium atmospheric concentration (μg/m^3)	Beryllium surface contamination (μg/m^2)	
Beryllium non-controlled zone	< 0.01	< 0.1	No plausible risk of presence of beryllium, no access limitation.
Beryllium controlled zone	0.01 < [Be] < 0.2	0.1 < [Be] < 10	No risk of dispersal of beryllium aerosols, vapour, and dusts. Possible presence of beryllium, in concentrations below the detection limits of monitoring equipment. Access limited to 'beryllium' qualified personnel. Stay times and possible safeguards adapted to the risk of exposure, depending on the operations to be performed.
Beryllium breathing protection zone	> 0.2	> 10	Presence of contamination and/or potential overshooting of controlled beryllium zone limit values. Access limited to 'beryllium' qualified personnel, Confined and ventilated zone requiring use of respiratory protection gear.

7.9.5 Magnetic zoning

Thresholds and conditions of exposure of personnel to magnetic fields shall be established as per **Table 7-9**. [PR1378-R]

Proper signage shall be placed in areas where the magnetic thresholds that are identified in **Table 7-10** might be exceeded. [PR1379-R]

Magnetic field zones and access and control conditions shall be established as per **Table 7-11**. [PR1380-R]

Table 7-9: Magnetic field thresholds and conditions of exposure

	Regulatory or recommended thresholds for magnetic field	Conditions of exposure for personnel
Workers	200 mT (2000 Gauss)	8 hours non-stop/ day Entire body
	2 T (20000 Gauss) (dB/dt) < 3 T/s for t > 10 ms (dB/dt)2.t < 0.09 T2/s for t < 10 ms	Temporary Entire body Comply with the conditions opposite, including temporal variations of the magnetic field (such as during power interruption or device switch-on)
	5 T (50000 Gauss)	Duration < 5 min/h Body extremities
	> 10 mT (100 Gauss)	The medical care office is to be informed in the case of regular exposure
General public	40 mT (400 Gauss)	Non-stop
	> 40 mT	Occasionally access authorized under regulated conditions and without exceeding the threshold values for worker exposure

Table 7-10: Thresholds for other areas that should be properly signed

Public announcement regarding possible exposure to magnetic field	0.5 mT (5 Gauss)
Risk for persons wearing a cardiac stimulator (e.g. pacemakers)	0.5 mT (5 Gauss)
Risk associated with airborne metal objects attracted by magnetization (missile effect)	3 mT (30 Gauss)
Risk of deterioration of magnetic media (analogue watches, credit cards, magnetic tape, floppy disks, etc.)	From 1 to 10 mT (10 to 100 Gauss) depending on media

Table 7-11: Magnetic field zones and access conditions

Zone Name	B [mT]	Access and Control Condition for Personnel
Non-controlled magnetic zone	< 10	No access limitation, warning signs for persons wearing a cardiac stimulator
Controlled magnetic zone	> 10,< 200	Access limited to 8 hours per day
Prohibited magnetic zone	> 200	Access prohibited, except under exceptional circumstances or in case of duly certified temporary access

7.9.6 Radiofrequency zoning

The radiofrequency exposure for personnel who are working in areas that are adjacent to sources of hazard shall comply with the following limits that are recommended by the International Commission on Non-Ionizing Radiation (ICNIR). [PR1385-R]

The power density for ECRH and LHCD waves shall not exceed 5 $mW.cm^{-2}$. [PR1386-R]

The exposure limit for workers expressed as Equivalent Power density for ICRH plane waves is less than 1.0 $mW.cm^{-2}$. [PR1387-I]

7.9.7 Fire zoning

Fire zoning shall be set up to limit the spread of fire and fumes, and to confine the fire within predefined volumes, to allow enough time to extinguish the fire. Fire zoning shall be based on fire sectors and confinement sectors in accordance with regulations. [PR1396-R]

Note that the two defined areas (Fire Sectors and Confinement Sectors) can be congruent. [PR1394-I]

7.9.7.1 General requirements

A fire sector is a volume that is composed of a room or group of rooms that are delimited by walls that 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. [PR1390-I]

A confinement sector is a volume that is composed of a room or group of rooms with characteristics that are designed to limit the dispersal of toxic or radioactive materials outside this volume in the event of fire. [PR1392-I]

Confinement sectors are associated with fire sectors when there is an identified risk of radioactive substances being released and leading to a dose of 10 mSv to the site boundary. These sectors shall be designed to prevent and limit the release of such substances to the environment. [PR2260-R]

To prevent or limit the propagation of fire within the ITER installation, each room that has, or may have, a potential fire risk shall be classified into fire sectors, according to the level of this risk. [PR2062-R]

7.9.7.2 Fire sector boundaries and characteristics

Fire sector boundaries shall ensure there is no spread of radioactive or hazardous substances to a room or zone in which these substances cannot be confined and kept from spreading to the environment. [PR1398-R]

Fire sector boundaries shall ensure there is no loss of safety function through failure of SIC components. [PR1400-R]

The radioactive inventory shall be controlled in the fire sectors of the buildings by physical means, administrative means, or both, in order to limit the radioactive inventory that is potentially vulnerable to a single fire. [PR1401-R]

Fire loading and fire resistance shall be controlled in the fire sectors of the buildings, to avoid damage, such that at least one confinement barrier remains intact. [PR1403-R]

Fire sectors shall be surrounded by physical, fire-resistant barriers, with a fire resistance rating of at least two hours. [PR1404-R]

Doors and penetrations through fire barriers shall offer the same degree of fire resistance as the rest of the fire barrier. In the event of an internal fire, doors shall maintain their integrity, insulation and leak tightness with a pressure difference equal to +/-0.05 bar between the affected fire sector and the adjacent areas. [PR1405-R]

Openings through fire barriers shall be filled-in using a material that guarantees the same degree of fire resistance as the rest of the fire barrier, using a process that is verified by an approved organization. [PR1406-R]

Electric cables and other materials that run through a fire sector shall not contribute to the spread of fire (C1 cables, or cables that are protected by a flame-retardant material for a radiologically-controlled building). [PR1407-R]

Electric cables, and other materials that run through a fire sector, and that are required to operate in the event of fire, shall be fire-resistant (CR1 cables, or cables that are protected by a fire-resistant material for radiologically-controlled buildings). [PR1408-R]

Ventilation ducts and pipes that run through a fire sector shall be protected by a fire-resistant material. [PR1409-R]

Ventilation ducts that open into a fire sector shall be equipped with fire valves or dampers. These valves or dampers shall be installed as near as possible to the fire sector walls. The piping between the valve or damper and the fire sector boundary shall be protected by a fire-resistant material. [PR1410-R]

HEPA filters shall be fire-resistant (minimum efficiency of 99.9% during a fire). [PR1412-R]

7.9.8 Waste zoning

Waste zones shall be established within the nuclear facilities, and shall include:

- "Radioactive waste zones" (Zones de Déchets Nucleaires, 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.

--- [PR1420-R]

Waste from a radioactive waste zone shall be processed in a radioactive treatment facility. [PR1424-R]

Waste from a non-radioactive waste zone shall be processed in a non-radioactive treatment facility. [PR1425-R]

7.10 Effluents

All effluents (airborne and waterborne) shall be identified, and their quantity and characteristics shall be estimated for normal operation and maintenance. This shall include, as a minimum, radioactive materials, hazardous materials, direct radiation, magnetic fields, and thermal emissions. [PR1427-R]

Releases of radioactive materials shall be kept As Low As Reasonably Achievable (ALARA) and in all cases within design and operational guidelines. [PR1428-R]

Radioactive tritiated gaseous effluents shall be released through the Detritiation System to control releases. [PR1429-R]

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. [PR2261-R]

Fluid effluents shall be monitored, characterized, controlled and discharged per approved procedures. [PR2262-R]

Systems that contain water or liquid effluents shall be designed to minimize leakage. [PR2069-R]

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. [PR2071-R]

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. [PR2070-R]

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. [PR2072-R]

7.11 Radioactive and hazardous waste

Radioactive and other hazardous liquid and gaseous effluents that arise from operation shall be limited to the maximum extent possible in the design, and their impact shall be maintained As Low As Reasonable Achievable (ALARA) during operation. [PR1435-R]

For solid radioactive and other hazardous wastes that arise throughout the plant life (from construction through to decommissioning and dismantlement) the quantity and the level of radioactivity, or toxicity, shall be minimized by design and operation. [PR1436-R]

7.12 Occupational health and safety

Occupational Health and Safety (OHS) is related to the prevention or mitigation of all risks of injury or long term illnesses from workplace exposure other than nuclear risks. [PR2263-I]

IO staff and contractors might be exposed to a wide range of "non-nuclear" hazards, such as:

- Beryllium
- Cryogenic hazards, including oxygen deficiency hazards
- Explosion risk (hydrogen or other)
- Fire risk
- Electrical hazards

- Laser risk
- Circulation of and interaction with heavy plant (truck, cranes).

--- [PR2264-I]
Hazard identification and risk assessment (HIRA) process shall be implemented in design phase in order to:

- identify workplace OHS hazards whose control shall have impact on ITER systems design
- assess the level of risk related to them in order to control them.

--- [PR2265-R]
Preventive measures shall be considered in the design phase to reduce the frequency or the probability of an event and that should establish the rules to follow for the construction, installation and utilization of equipment in order to protect people and equipment from OHS risks. [PR1444-R]

Preventive measures to reduce the severity of an event include notable automated systems reducing the reliance on human intervention and thereby increasing reliability should be considered. [PR1446-P]

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 occupational health and safety. [PR1448-R]

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-behaviour changes by contact with cryogens
- Burns from contact with cryogens
- Pressurization from rapid expansion of cryogenic gases.

--- [PR1438-I]
Appropriate training shall be mandatory before access to a zone that has cryogenics-related safety risks. [PR1447-R]

Individual cryogenic protection equipment may include clothing, safety glasses, and safety gloves. [PR1449-P]

The cryogenic installations are exposed to the risk of anoxia and they shall comply to the general requirement on monitoring of oxygen levels in zones accessible to personnel. [PR1450-R]

7.13 Fire protection

Fire protection for the ITER site shall be provided to meet the following objectives:

- Prevent fire and fire damage that could lead to the release of radioactive or hazardous material to the environment

- Limit releases in the case of postulated fires to within acceptable limits
- Ensure personnel safety
- Limit damage to the machine and property (investment protection).

--- [PR1280-R]

It shall be possible to maintain ITER in a safe condition during and following a fire. [PR1286-R]

Fire protection systems in zones containing radioactive material shall help to minimize the potential for fire to challenge confinement systems or to disable safety functions. [PR1287-R]

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

To provide an adequate degree of fire protection for ITER, a "defence-in-depth" fire protection program shall be established that includes:

- Fire prevention
- Fire detection, and suppression where appropriate
- Fire mitigation, to prevent spread and to limit the consequences of a fire, and to extinguish it as soon as possible
- Fire incident response.

--- [PR1291-R]

Fire loads in rooms containing tritium shall be kept to a minimum and shall include only those materials related to the process. [PR2267-R]

Because they may introduce or generate fire loads, maintenance activities in rooms containing tritium shall be limited to periods when the tritium process is shut down and the hydrogen is removed from the process. [PR2268-R]

Any fire loads introduced or generated in a room containing tritium during tritium process shutdown shall be removed before tritium processing starts up. [PR2269-R]

The quantity of combustible materials and loads in each room or area shall be limited to the minimum process requirements, with appropriate control and monitoring measures. [PR2270-R]

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

Each room of the nuclear buildings and of the building containing Protection Important Components (PIC) shall be equipped with a fire-detection and alarm system appropriate to that risk and to the environmental conditions of the room. [PR2272-R]

Each room of the nuclear buildings and of the building containing Protection Important Components (PIC) shall have fire suppression systems (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 personnel (including fire fighters) and PIC against the fire and associated secondary hazards (including those resulting from the type of fire suppression system used). [PR2273-R]

In the event of a fire in a ventilation zone, the air supply of the ventilation system towards this zone shall be isolated. [PR2274-R]

Appropriate auxiliary systems for fire protection shall be provided within buildings such as permanent emergency lighting, communication system. [PR2275-R]

8 Construction requirements

8.1 Classification of systems, structures, and components

ITER Systems, Structures, and Components (SSC) shall be classified for safety class, quality class, seismic class, vacuum class, and remote handling class. [PR1456-R]

Criteria and guidelines for Safety Important Class (SIC) are provided in Section 7.7. [PR1457-I]

Quality classification shall be determined in accordance with the ITER Quality Classification Determination [R11]. [PR1458-R]

Seismic classification shall be determined in accordance with the ITER Seismic Nuclear Safety Approach [R12]. [PR1459-R]

Vacuum classification shall be determined in accordance with the ITER Vacuum Handbook [A05]. [PR1460-R]

Remote handling classification shall be determined in accordance with the ITER Remote Maintenance Management System [A17]. [PR1461-R]

8.2 Materials, processes, and parts

The materials for the ITER systems shall be selected in accordance with the properties specified in the Materials Properties Handbook [A21]. [PR1463-R]

8.2.1 Magnetic materials

Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval. [PR1465-R]

The materials and fabrication processes of the in-vessel components shall be selected considering whenever possible the minimization of the error fields. [PR1466-R]

Outside the cryostat, the use of magnetic materials is allowed for the building structural elements. [PR1467-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 4.3.2.4). [PR1468-I]

More stringent requirements for magnetic permeability shall be established for the blanket modules. [PR1470-R]

8.2.2 Vacuum materials, processes, and parts

ITER shall be designed, constructed, and operated in accordance with the requirements specified in the ITER Vacuum Handbook [A05]. [PR1472-R]

8.2.3 *Tritium processing and inventory management*

ITER shall be designed, constructed, and operated in accordance with the requirements in the ITER Tritium Handbook [A16]. [PR1474-R]

8.2.4 *Corrosion prevention and control*

Materials and their joints which are in contact with fluid shall be selected taking into account their corrosion resistance during ITER lifetime. [PR2180-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. [PR1476-R]

The methods for controlling the corrosion behaviour during operation shall be established for all systems. [PR2181-R]

8.2.5 *Activation*

Materials which are subject to neutron irradiation shall be selected taking into account their possible activation during ITER operation. [PR2182-R]

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. [PR1478-R]

Where the use of lower-activated materials will allow a reduction in contact dose and decay heat and to a decreased activation of waste, they should be selected. [PR2183-P]

8.3 Codes and standards

The Codes and Standards for ITER Mechanical Components [A06] is a comprehensive document that defines the codes and standards to be used in the design of ITER mechanical components. It invokes the Structural Design Criteria for ITER Magnet Components [A09] and Structural Design Criteria of In-vessel Components [A10] so they are not separately invoked in this PR. [PR1480-I]

ITER mechanical components shall be designed in accordance with the codes and standards identified in the Codes and Standards for ITER Mechanical Components [A06]. [PR1481-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]. [PR1482-R]

ITER buildings shall be designed in accordance with the ITER Structural Design Code for buildings, Part I: Design Criteria [A11] and Part II: Technical Specifications [A12]. [PR1483-R]

ITER magnets shall be designed in accordance with ITER Magnet Superconducting and Electrical Design Criteria [A18]. [PR1484-R]

8.4 Mechanical design

ITER Load Specifications [A14] shall be used as the basis for the preparation of fully comprehensive detail load specification on single systems or components. [PR1486-R]

8.5 Electrical design

The design of the earthing and lightning protection systems shall provide a safe environment for personnel and avoid electrical hazards. [PR1489-R]

All surfaces, including bus and cooling lines, that are exposed to the cryostat vacuum shall be connected at the earth point of the tokamak. [PR1490-R]

All in-vessel components except for active parts and special sensors shall be electrically connected to the vacuum vessel. [PR1491-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). [PR1492-R]

The magnet structures shall be earthed with sufficient resistance to limit eddy currents during plasma operation. [PR1493-R]

The vacuum vessel shall be electrically insulated from the magnet system. [PR1494-R]

The use of double or multiple earthing points shall be avoided, since this can create loops for eddy currents and produce electromagnetic noise. [PR1495-R]

Components, particularly portions of coil power supplies and piping system, shall be capable of being isolated from the earth grid, in order to test for leakage current. [PR1496-R]

The earthing shall be equipped with real-time monitoring systems to detect the presence of loops. [PR1497-R]

To limit the amplitude of the fault current, the earthing system of the coil power supplies (PBS41) shall be based on soft/floating earthing with a system for the real-time detection of the first earth fault. [PR1498-R]

Buildings, outdoor structures and power supply components shall be protected by a lightning protection system to avoid transient overvoltages and ensure the proper plant operation. [PR1499-R]

8.6 Electromagnetic shielding

IEC standards define the limits of perturbation for electronics devices and the limits of susceptibility. All these standards are included in IEC 61000. [PR1771-I]

As a general requirement for electromagnetic compatibility and shielding, all ITER electrical components shall be designed to comply with IEC 61000. [PR1501-R]

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. These specific cases are:

- The magnetic stray field produced by superconducting magnets and large DC busbars. In these cases magnetic shielding is not foreseen and the components installed near the tokamak shall withstand the corresponding magnetic fields [R20]
- Radio frequency generators for heating and current drive systems. High power radio frequency systems are required for plasma heating and current drive. Radio frequency generators and transmission lines shall comply for personal safety with Section 7.9.6
- Tokamak vacuum vessel openings and diagnostics windows shall avoid radio frequency leakage. Any conductive circuit that can pick up RF power from inside the vacuum vessel (VV) should be properly filtered to avoid RF radiation outside the VV. 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 RF power levels outside the VV and disturb cryogenic measurements and diagnostics.

--- [PR1772-R]

8.7 Toxic products

All solid, liquid and gaseous toxic products needed for ITER construction and operation shall be identified and their quantity and characteristics estimated for normal operation, including maintenance operations. [PR1503-R]

The inventory for all solid, liquid and gaseous toxic products shall be limited to the maximum extent possible in the design, and their impact maintained As Low As Reasonable Achievable (ALARA) during operation. [PR2184-R]

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. [PR1504-R]

These provisions shall consider potential corrosive, inflammable and explosible issues associated with these toxic products. [PR2185-R]

Provisions shall allow monitoring and characterization of gaseous or liquid releases of the toxic products towards the environment. [PR1505-R]

8.8 Transportability

8.8.1 Maximum component size and weight

The limitations in size and weight of the components (including packages and frames) are 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.

--- [PR1509-I]

8.8.2 Tritium shipments

20 to 25 kg of tritium will be required for D-T operation of ITER. [PR2186-I]

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.) [PR1516-R]

8.9 Identification and control of items

ITER Organization shall implement a method for identifying items at their receipt and during all stages of manufacturing, delivery and installation. [PR1518-R]

Where traceability is required, as for all SIC systems, structures or components, or for parts whose lifecycle has to be monitored during the life of the project, unique identification of individual items or batches shall be implemented. [PR1519-R]

ITER Organization shall develop and maintain a database that allows to secure and access all records related to any traceable item. [PR1520-R]

8.10 Standardization

A standardization policy shall be implemented as much as reasonably acceptable throughout all ITER plant 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
- 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.

--- [PR1522-R]

Each plant system shall take into account as a crucial design principle the importance of using interchangeable components inside its own boundaries. [PR1531-R]

Major components being used in sufficient numbers in several plant systems and/or procured by several 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.

--- [PR1532-R]

Analysis of the current design documents shall lead to the definition of a list of high-priority components suitable, relative to their number and cost, to be considered for standardization. [PR2187-R]

Dedicated Experts Working Groups shall be designated to assess the requirements and operating conditions of those components in the different systems where they will be used, and to take into account technical and commercial factors to produce a limited number of specifications and standards “packages” that could be used as widely as possible in the systems and required from the suppliers in order to ensure that their products are compatible and can share common spare parts. [PR1536-R]

8.11 Design verification

The design verification is the activity confirming the overall design integrity of systems and/or structures through the design reviews / alternative calculations / qualification tests, to ensure that safety-related systems or structures are adequately designed and that design requirements are adequately incorporated in the design. [PR1538-I]

The scope of design verification shall be applied to all safety-related systems, structures, and components. However, certain important non-safety-related systems and structures are included in the design verification at the discretion of ITER Organization management. [PR1539-R]

Design verification should be conducted at the earliest possible time after the related design documents have been sufficiently developed to permit a meaningful design verification, prior to release for fabrication, installation, or release to another organization for use in design and/or manufacturing activities. [PR1540-P]

Design verification by qualification testing shall be performed as early as possible and prior to the point when related system, structures, and/or components are installed. [PR1541-R]

In all cases, design verification shall be completed prior to the design being relied upon to perform its function. [PR1542-R]

If an alternate calculation method or a qualification test method for design verification of a system, structure or component has not been developed or there is difficulty in its application, then the design review shall be used as the design verification method of the system, structure or component. The design review shall be performed either as specific review by one or more independent reviewers competent in a single discipline or by multi-disciplinary review performed by a multi-disciplinary review team. [PR1545-R]

If it is possible to verify the design integrity of a system, structure or component by design verification using only design calculation, and an alternate calculation method has been developed, then the alternate calculation shall be used as the design verification method of the system, structure or component. [PR1547-R]

If performance of a related component has not been verified due to application of a new design concept, then the qualification test by model test under conditions that simulate the most adverse design conditions shall be used as the design verification method for the component. [PR2188-R]

Qualification testing to verify the acceptability of a specific design will be conducted in accordance with approved procedures that address, at a minimum:

- Use of adequate instrumentation
- Provisions for test monitoring
- Specification of suitable environmental conditions
- Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment
- Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions
- Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks.

--- [PR1549-I]

The design verification shall be made in accordance with ITER Management and Quality Program [R16] and the Design Review Procedure [R15]. [PR1558-R]

DA/supplier-level design verification shall be implemented in accordance with relevant procedure that ITER Organization accepts during the review of DA/suppliers documents or data related to purchased equipment and material, manufactured and supplied by suppliers. [PR1559-R]

The Performance Requirements in Section 4 are verified by determining the Quality Class in accordance with the “Quality Classification Determination” document [R11]. The appropriate actions are then applied in accordance with the ITER Management and Quality Program (MQP) [R16] [PR1561-I]

9 Additional Requirements

9.1 Integrated Logistics Support

ITER shall define and implement a project-wide strategy for Integrated Logistics Support (ILS). In particular this shall cover:

- Test facilities and testing management
- Spares inventory management
- Technical documentation
- Facilities management
- Packaging, handling, storage, and transportation
- Technical and operational human resources management for sustainable maintenance and operations.

--- [PR1564-R]

9.2 Security

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]. [PR1573-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.

--- [PR1574-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.

--- [PR1579-R]

The security functions shall be supported both by technical systems and by management procedures. [PR1584-R]

Safeguards shall be implemented to guard against the theft of tritium. [PR1585-R]

Information pertaining to areas where tritium is stored, such as the Tritium Plant Building, shall be treated as secure information. [PR1586-R]

9.3 Documentation

The ITER documentation such as all specifications, drawings, technical manuals, test plans, procedures, and installation instruction data shall be documented in accordance with the requirements of ITER Management and Quality Program (MQP) [R16] and of ITER Configuration Management Plan [R14]. [PR1588-R]

The technical documentation shall include repair manuals, maintenance manuals, user manuals, and other documents that are used to operate or support the system and data to support these, such as:

- Technical manuals
- Technical and supply bulletins
- Transportability guidance technical manuals
- Calibration procedures
- Repair parts and tools lists
- Corrective maintenance instructions
- Preventive maintenance and predictive maintenance instructions
- Drawings/specifications/bills of materials/ “as built” technical data packages
- Software documentation
- Component lists
- Safety Important Component list
- Lifting and tie-down instructions
- Hazardous Material documentation.

--- [PR1589-R]

The technical documentation shall be provided to ITER for all plant systems, their components and parts. [PR2257-R]

The technical documentation shall be supplied in a standardized electronic format in the English language. [PR1604-R]

9.4 Personnel and training

In order to ensure the availability of suitably qualified staff to operate and maintain ITER over its lifecycle, it is necessary to ensure the availability in sufficient numbers of personnel having not only the required formal qualifications, but equally training, knowledge and experience of operating and maintenance of the ITER machine. [PR1606-I]

ITER Organization shall implement a training plan and manage human resources to ensure the transmission of knowledge and experience throughout the ITER lifecycle. [PR1607-R]

Staff shall be suitably trained and qualified to undertake ITER operations (including maintenance activities). [PR2258-R]

9.5 Requirements of subordinate elements

Proper flowdown of requirements shall be verified:

- The mapping of requirements in Section 4 to the ITER project elements in Section 3.2 is provided in the Requirements Allocation Document [R17]
- All other requirements and design constraints in Sections 5 to 9 (outside those in this Section 9.5) also apply to the ITER project elements in Section 3.2.

--- [PR1609-R]

10 Appendices

10.1 Abbreviations

316L	A type of Stainless Steel
AACT	Automated Air Cushion Transporter
AAR	Accident Analysis Report
AC	Alternating Current
ACB	Auxiliary Cold Box
ACP	Activated Corrosion Products
ADS	Atmosphere Detritiation Systems
AEU	Ancillary Equipment Unit
AH	Additional Heating
AHU	Air Handling Unit
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
AP	Assembly Plan
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BAS	Breathing Air System
Be	Beryllium
BeCA	Beryllium Controlled Area
BES	Beam Emission Spectroscopy
BM	Blanket Module
BOS	Baking Operation State
BSM	Blanket Shield Module
C	Celsius
C	Carbon
CAD	Computer Aided Design
CAS	Compressed Air System
CB	Cassette Body
CC	Correction Coil
CCB	Cryostat Cold Box
CCWS	Component Cooling Water System
CD	Current Drive
CEA	Commissariat à l'Energie Atomique
CFC	Carbon-Fibre Composite
CHWS	Chilled Water System
CMM	Cassette Multifunctional Mover
CMM	Configuration Management Model
CODAC	Control, Data Access and Communication

C&S	Codes & Standards
CS	Central Solenoid
CSD	Control System Design and Assessment (document)
CSH	Control System Design Handbook
CCS	Civil Construction and Site Support
CSVS	Cryogenic Service Vacuum System
CTB	Cold Termination Box
CTCB	Cryoplant Termination Cold Box
CTM	Cassette Toroidal Mover
CTS	Cryostat Thermal Shield
Cu	Copper
CV	Cold Valve
CVB	Cold Valve Box
CVCS	Chemical & Volume Control Systems
CW	Continuous Wave
CWS	Cooling Water System
CXRS	Charge Exchange Recombination Spectroscopy
D	Deuterium
DAC	Derived Atmospheric Concentration
DATR	Directement Affectés à des Travaux sous Rayonnements
DBD	Design Background Document
DC	Direct Current
DC	Divertor Cassette
DCR	Design Change Request (form)
DDD	Design Description Document
DDG	Deputy Director-General
DG	Director-General
DIV/LIM	Divertor/Limiter
DMS	Disruption Mitigation System
DNB	Diagnostic Neutral Beam
DP	Decommissioning Procedure
DR	Draining and Refilling System
DRG	Design Requirements & Guidelines
DOORS	Dynamic Object Orientated Requirements System
DS	Detritiation System
DW	Demineralized Water
DY	Drying System

EC	Electron Cyclotron
ECCD	Electron Cyclotron Current Drive
ECE	Electron Cyclotron Emission
ECH	Electron Cyclotron Heating
ECRH	Electron Cyclotron Resonance Heating
EDH	Electrical Design Handbook
ELM	Edge Localized Mode
EMS	Environment Monitoring System
EPMS	Explosive-actuated Protective Make Switch
EOB	End Of Burn
EOC	End Of Cooling
ES&H	Environment, Safety and Health
ESPN	Nuclear Pressure Equipment
ETS	Equatorial Thermal Shield (central cryostat)
EU	European Union
FAVC	Faiblement Activé à Vie Courte
FDR	Final Design Report
F/M	Ferritic/Martensitic (steel)
FMEA	Failure Modes & Effects Analysis
FPSS	Fusion Power Shutdown System
FPWS	Fire Protection Water System
FSTS	Front Support Thermal Shield
FW	First Wall
FWCD	Fast Wave Current Drive
GDC	Glow Discharge Cleaning
GIS	Gas Introduction System
GSSR	Generic Site Safety Report
GVS	Guard Vacuum System
H	Hydrogen
H&CD	Heating & Current Drives
HC	Hot Cell
HCB	Hot Cell Building
HCF	Hot Cell Facility
He	Helium
HEPA	High Efficiency Particulate Air filters
HF	High Frequency
HFIP	Human Factors Integration Plan
HFS	High Field Side
H-mode	High Confinement mode
H/L	H-Mode/L-Mode indicator

HNB	Heating Neutral Beam
HNL	Heat and Nuclear Load
HP	Health Physics
HRS	Heat Rejection System
HTS	Heat Transfer System
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
HVDC	High Voltage Direct Current
HWS	Hot Water System
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
IC	Ion cyclotron
ICD	Interface Control Document
ICE	Ingress of Coolant Event
ICH	Ion Cyclotron Heating
ICRF	Ion Cyclotron Resonant Frequency
ICRH	Ion Cyclotron Resonance Heating
IC-x	ITER Council Meeting x
IDM	ITER Document Management
IEC	International Electrotechnical Commission
ILS	Integrated Logistics Support
IMMS	ITER Maintenance Management Plan
INIRC	International Non-Ionizing Radiation Committee
IO	ITER Organization
IOIS	Intermediate Outer Intercoil Structure
Ip	Plasma Current
IPS	Integrated Project Schedule
IR	Infra-red
ISO	International Organization for Standardization
ISS	Isotope Separation System
IVT	In-Vessel Transporter
IVV	In-Vessel Viewing
IVVS	In-Vessel Viewing System
JET	Joint European Torus
LFS	Low Field Side
LHH	Lower Hybrid Heating
LHCD	Lower Hybrid Current Drive
LHe	Liquid Helium
Li	Lithium
LIM	Limiter
L-L	Low Level
LLPS	Low-Level waste Processing System
LN2	Liquid Nitrogen
L-mode	Low confinement Mode

LS	Load Specifications [22]
LSM	Lower Steering Mirror
LTM	Long Term Maintenance
MAC	Management Advisory Committee
MAMuG	Multi Aperture Multi Grid
MAR	Materials Assessment Report
MARFE	Multifaceted Asymmetric Radiation from the Edge
MAVL	Moyenne Activité et durée de Vie Longue
MFRS	Manufacturers
MGS	Magnet Gravity Support
MHD	MagnetoHydroDynamic
MIC	Mineral Insulated Cable
MMA	Manual Metal Arc-welding
MOU	Matching Optics Unit
MPC	Magnet Power Conversion
MPSSN	Magnet Power Supply Switching Network
MQP	Management Quality Program
MSE	Motional Stark Effect
MSEC	Magnet Superconducting and Electrical Design Criteria
MSLD	Mass Spectroscopy Leak Detection
N2	Nitrogen
NAG	Neutron Analysis Group
NAR	Nuclear Analysis Report
NB	Neutral Beam
NBI	Neutral Beam Injection
NBPS	Neutral Beam Power Supply
Nb3Sn	Niobium-Tin
NbTi	Niobium-Titanium
NG-TIG	Narrow Gap (row gap) Tungsten Inert Gas (for arc welding)
NPA	Neutral Particle Analyzer
NTM	Neo-classical tearing mode
OLC	Operating Limits and Conditions
OIS	Outer Intercoil Structures
PA	Procurement Arrangement
PAD	Plant Assessment Documents
PBS	Plant Breakdown Structure
PbLi	Lead-lithium
PCR	Project Change Request
PD	Plant Description (document)
PDDG	Principal Deputy Director-General
PDS	Plant Design Specifications
PED	European Pressure Directive

PF	Poloidal Field
PFC	Plasma-Facing Component
PG	Plasma Grid
PHTS	Primary Heat Transfer Systems
PID	Project Integration Document
PID	Proportional, Differential and Integral Control
POS	Plasma Operation State
POZ	Plant Operation Zone
PPA	Plasma Performance Assessment
PPEN	Pulsed Power Electrical Network
PP&RE	Project Plan and Resource Estimate
PR	Project Requirements
PRM & PS	Personal Radiation Monitoring & Protection System
PRS	Pump Regeneration Sequence
PS	Power Supply
PS	Project Specification
PT	Participating Team
PWS	Potable Water System
QA	Quality Assurance
R&D	Research & Development
RAD	Radiation Hardness Manual
RAMI	Reliability, Availability, Maintainability, Inspectability
RCC-MR	Design and Construction Rules for Mechanical Components of FBR Nuclear Islands (AFCEN)
RF	Radio Frequency
RGA	Residual Gas Analyzer
RH	Remote Handling
RHM	Remote Handling Manual
RHP	Remote Handling Procedures
RID	Residual Ion Dump
RMP	Resonant Magnetic Perturbations
RMS	Root Mean Square
RoD	Record of Decisions
RPC	Reactive Power Compensation
RPP	Radiation Protection Program
RPrS	Report Préliminaire de Sûreté
RT	Room Temperature
RTE	Réseau de transport d'Electricité (Operator of the French electric power transmission grid)
RWM	Resistive Wall Mode

SCADA	Supervisory Control And Data Acquisition
SCHe or SHe	Supercritical Helium
SCS	Supervisory Control System
SDC	Structural Design Criteria
SDS	Storage and Delivery System
SF6	Sulphur hexa-fluoride
SGVS	Service Guard Vacuum System
SIC	Safety-Important Component
SID	System Interface Document
SL	Seismic Level
SLDS	Service Leak Detection System
SOB	Start of Burn
SO-ECH	Start Of ECH
SOF	Start of Flat top
SOF/B	Start of Flat top/Burn
SOH	Start of Heating
SOL	Scrape-Off Layer
SRS	Service Roughing System
SS	Stainless Steel
SS	Steady State
SSEN	Steady State Electrical Network
SSTS	Side Support Thermal Shield
STAC	Science and Technical Advisory Committee
STM	Short Term Maintenance
STS	Short Term Standby
STS	Support Thermal Shield
ST-VS	Suppression Tank Vent System
SVS	Service Vacuum System
T	Tritium, Tesla
TAE	Toroidal Alfven Eigenmode
TBA	To Be Assessed
TBC	To Be Confirmed
TBD	To Be Determined
TBM	Test Blanket Module
TC (T-C)	Tokamak Complex
TCM	Technical Coordination Meeting
TCS	Test & Conditioning State
TCWS	Tokomak Cooling Water System
TF	Toroidal Field
TFA	Très Faible Activité
TFC	Toroidal Field Coil
TGCS	Tokamak Global Coordinate System
Th	Thermal
TIG	Tungsten Inert Gas (for arc welding)

TLD	Thermoluminecent Dosimeter (radiation badge)
TM	Tritium Manual
TP	Tritium Plant
TS	Thermal Shield
TS	Thomson scattering
TSA	Tokamak Structural Assessment
TTS	Transition Thermal Shield
TVS	Tokamak Vent System
UHV	Ultra High Vacuum
UNS	Type of Stainless Steel
UP	Upper Port
UPS	Uninterruptible Power Supply
USM	Upper Steering Mirror
UV	Ultra Violet
VDE	Vertical Displacement Event
VDO	Derived Operational Value
VDS	Vent Detritiation System
Vis/IR	Visible / Infra-red
VP	Vessel Pressure or Protection??
VQC	Vacuum Quality Classification
VSWR	Voltage Standing Wave Ratio
VTL	Vacuum Transmission Line
VUV	Vacuum Ultra Violet
VV	Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System
VVTS	Vacuum Vessel Thermal Shield
W	Tungsten
WBS	Work Breakdown Structure
WDS	Water Detritiation System

10.2 Change log since PCR 200

Note that PCR-200 officially started the list of Technical Baseline documents that are under configuration control: after this date. All documents under configuration control require at least a PCR to be modified. [PR1622-I]

So as to leave an historical trace, the list of documents that are no more referenced in the PR names the PR version at which the document was removed from the reference list, and the reason why. [PR2358-I]

Changes recorded in PR since PCR-200:

- PCR-M026 (CN-000040) Deletion of PBS-67
- PCR-176 in Section 3.2.6
- PCR-M125 (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
- PCR-582 in Section 4.3.10.2, 4.4.1

--- [PR1730-I]
Changes on PR annexes that are under configuration control:

- PCR-M066: [A07] Electrical Design Handbook: Codes and Standards - Parts 1, 2, 3, 4, 5
- PCR-M053: [A08] ITER Operations Handbook, vol 2, V1.3
- PCR-M207: [A09] Struct. Design Criteria for ITER Magnet Components vol 1- 4, V2.0
- PCR-M266: [A02] ITER Plant Control Design Handbook V6.1
- PCR-214: [A22] Safety Requirements for Buildings V3.6
- PCR-366: [A06] Codes and Standards for ITER Mechanical Components V4.0
- PCR-397: [A11] ITER Structural Design Code for Buildings, part I, V2.10; and [A14] ITER Load Specifications
- PCR-483: [A10] Structural Design Criteria for ITER in-vessel Components V3.0
- PCR-412: [A22] Safety Requirements for Buildings V3.6
- multiple PCRs: [A13] ITER Site Master Plan V3.1: PCR-M097, PCR-M157, PCR-M168, PCR-055, PCR-060, PCR-156, PCR-158, PCR-172, PCR-187, PCR-186, PCR-190, PCR-198, PCR-200, PCR-205, PCR-218, PCR-276, PCR-285, PCR-294, PCR-298, PCR-305, PCR-313, PCR-321, PCR-322,

PCR-329, PCR-330, PCR-333, PCR-335, PCR-336, PCR-352, PCR-353, PCR-359, PCR-361, PCR-401, PCR-414, PCR-415, PCR-427, PCR-429, PCR-435, PCR-438, PCR-454, PCR-459, PCR-465, PCR-471, PCR-485, PCR-486, PCR-496

--- [PR1731-I]
PR Annexes have been put under configuration control after PCR-200:

- [R01] ITER Project Specification (June 2008) V2.0 since 15 Nov 2010 (ITER_D_2DY7NG)
- [R02] ITER Plant Description V1.1 since 15 Oct 2009 (ITER_D_2X6K67)
- [R03] ITER Plant Breakdown Structure V2.0 since 19 Apr 2011 (ITER_D_28WB2P)

--- [PR1732-I]
PR annexes with no change since PCR-200:

- [A01] Y. Gribov et al, "CS and PF coils data and requirements to separatrix positioning for analysis of ITER plasma equilibria and poloidal field scenarios" V3.1 (ITER_D_2ACJT3)
- [A03] Configuration Management Model V1.7 (ITER_D_2EGQKE)
- [A04] ITER Coordinate Systems V3.7 (ITER_D_2A9PXZ)
- [A05] ITER Vacuum Handbook V2.3 (ITER_D_2EZ9UM)
- [A12] ITER Structural Design Code for Buildings, Part II: Technical Specifications V1.1 (ITER_D_2E2U9X)
- [A15] Heat and Nuclear Load Specifications V2.3 (ITER_D_2LULDH)
- [A17] ITER Remote Maintenance Management System V1.6 (ITER_D_2FMAJY)
- [A18] ITER Magnet Superconducting and Electrical Design Criteria V1.2 (ITER_D_22GRQH)
- [A19] Contents of PF scenario database V2.0 (ITER_D_34263N)
- [A20] ITER Site Meteorology V1.0 (ITER_D_2UT36S)
- [A21] ITER Materials Properties Handbook - Introduction V1.3 (ITER_D_2NRCSB)

--- [PR1733-I]
De-referenced documents:

- Coil Forces for Plasma Scenarios (ITER_D_2NNQU5 v1.1) not approved, so de-referenced in PR v5.0
- Magnetic Field Drawings (multiple files: ITER_D_2NPKGN, ITER_D_2NM229, ITER_D_2NNTH4, ITER_D_2NPMNB, ITER_D_2NSPG2, ITER_D_2NT8UL, ITER_D_2NUJXS, ITER_D_2MS9EV, ITER_D_2NSJL9, ITER_D_2MWKYR) not approved, so de-referenced in PR v5.0

- ITER Operations Plan (ITER_D_2NS4FE v1.0) obsolete, so de-referenced in PR v5.0

--- [PR1734-I]