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EXTERNAL REFERENCE / VERSION

Load Specification

Temporary First Wall Load Specification

This document describes all relevant loads acting on the Temporary First Wall. It was written following the "Guidelines for ITER System Load Specifications" and it is meant to be used in the frame of thepreliminary design of the Temporary First Wall.

Approval Process			
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Change Log			
Temporary First Wall Load Specification (92NARK)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	06 Jun 2024	
v1.0	In Work	19 Jun 2024	Add document
v1.1	Signed	19 Jun 2024	Implementation internal reviewer's comments
v1.2	Revision Required	10 Oct 2024	First official version of the Temporary First Wall, version prepared for CDR.
v1.3	Revision Required	25 Oct 2024	Replies to Isabel Nunes: Please see v1.2 comments of this load spec Changed [ADi 11] reference to report instead of presentation: IC/STAC-30/5.1. Updated ITER Research Plan - Level 1, ITER_D_AXUP2U v1.4 Changes implemented from Pedro Ruiz comments: R8, R25 and R101: Scope homogenized in Table 1, 18 and 11.2.1 to 16.TW including TFW panels and their attachments to SB R14: table 6 references moved to 4.4 interface references R17: TFW DDD [RD5] changed to v1.1 R40: Added Enovia tree of the relevant CAD models R68: Added room temperature for pretension loads R78: Added dynamic amplification information Changed reference for emissivity values (Material properties handbook) Removed SDC-IC level column in Table 21
v1.4	Revision Required	04 Nov 2024	Revision according to reviewer's comments
v1.5	Approved	08 Nov 2024	Minor change according to reviewer's comments
v1.6	Signed	03 Oct 2025	Changes according to the reviewer's comments on the previous version and the new version of the plasma heat load specification
v1.7	Approved	01 Dec 2025	Changes based on reviewer's comments in v1.6

Table of Contents

1 Purpose

[I] The purpose of this Load Specification is to define and prescribe the loads to be used for the integrity justification of the Temporary First Wall (TFW). Specifically, this document provides the following:

- A report of the TFW classification (Safety, Quality and Seismic).
- The preliminary description of all states of the TFW during their life (e.g. assembly, start-up, operation, maintenance, shut-down, et cetera).
- A report of the applicable codes and standards (e.g. SDC-IC v3.0) that will be used for the assessment of the design.
- The correlation between load categories and damage limits and the correlation between the damage limits and the structural design criteria (e.g. SDC-IC Service Loadings) in the applicable codes.
- The description of all events expected in each state (including normal, incident and accident conditions if needed).
- The specification of all load values to be considered to verify the structural integrity of the system and their categorization.
- The list of all load combinations to be considered to verify the structural integrity of the system and their categorization.
- The number of occurrences of each event during the life of the system and the number of load cycles.

[I] All loads defined in this document are in accordance with the *TFW Sub-System Requirement Document* [ADi 1].

[I] The structure of this document follows the recommendation from [RD 1**]** and uses the template provided in [RD 2**].**

[I] Since the TFW is installed only for SRO, the load specification will apply only for the plasma conditions expected in SRO phase according to the ITER Research Plan. This means essentially negligible neutron fluence and lower stationary thermal plasma loads than will be encountered by the final, actively cooled wall.

2 Scope

[R] The scope of this document is the PBS 16 Blanket Temporary First Wall system (PBS 16.TW) which includes the inertially cooled TFW panels and the TFW attachments to SB (central bolt, pads and electrical straps).

[R] The following PBS16 subsystems are not in the scope of this load specification:

- Blanket Module Connections (PBS 16.BC)
- Blanket First Wall Panels (PBS 16.FW)
- Blanket Shield Blocks (PBS 16.SB)
- Blanket Manifolds (PBS 16.MA)
- Blanket Neutral Beam Port Liners (PBS 16.NL)

[I] Some of these subsystems may be installed during the SRO phase without the hydraulic connections being functional. Their integrity can be justified using the loads described in this load specification and a justification report can be referenced in the Blanket Load Specification [RD 24].

[I] The scope does not include PICs as per [ADi 1] [16TWs54-R].

[R] This document version is prepared for the preliminary design review (PDR).

[R] The Blanket components have the following states: installation, commissioning, operation, removal, and decommissioning.

3 Scope of Reviewers

Please refer to the scope of reviewers detailed in the IDM page.

4 References

4.1 Input Applicable Documents

Document	IDM link
[ADi 1] Sub-System Requirement Document (s-SRD) 16.TW	ITER_D_C59SXF v1.2
[ADi 2] Design and Construction Rules for Mechanical Components of FBR. Nuclear Island, AFCEN, 2007	
[ADi 3] Load Specifications (LS)	ITER_D_222QGL v6.3
[ADi 4] IC/STAC-30/5.1. Updated ITER Research Plan - Level 1	ITER_D_AXUP2U v1.4
[ADi 5] Load Specification for the ITER Vacuum Vessel	ITER_D_2F52JY v3.4
[ADi 6] IC/STAC-32/3.1. Level-2 and Level-3 ITER Research Plan	ITER_D_DUTXSZ v1.2
[ADi 7] Disruption and Runaway Electron event distribution and severity during the SRO phase	ITER_D_CCK2DL v2.2

4.2 Complementary Applicable Documents

Document	IDM link
[ADc **1**] In-vessel Components, SDC-IC	ITER_D_222RHC v3.0
[ADc 2] Plasma Heat Load Specification for the ITER Tungsten First Wall	ITER_D_9PSPKZ v3.1
[ADc 3] IS-16-51-001 Interface Sheet between PBS 16 Blanket System and PBS 51 IC H&CD System	ITER_D_EZD6ET v2.1
[ADc 4] IS-16-52-003 Electron Cyclotron stray power loading on Blanket System	ITER_D_ENGHC4 v3.1
[ADc 5] Blanket modules dimension and weight	ITER_D_35ZJNQ v17.3
[ADc 6] DINA Disruption Folder	2PN3CN
[ADc 7] TFW bolt specification	ITER_D_CY9BQH
[ADc 8] Assessment of the ECH stray radiation loads in the vacuum vessel for the 2024 Baseline	ITER_D_8LVQFN v2.0
[ADc 9] ECH stray radiation load table for 2024 Baseline	ITER_D_CRYHWJ v1.2
[ADc 10] Justification of surface heat loads (FLT) penalties	ITER_D_EUEMY2 v1.0
[ADc 11] Normal Operations loads on TFW: Field Line Tracing study on the TFW PDR design (full wall coverage, faceted shape)	ITER_D_DEZZKJ

4.3 Reference Documents

Document	IDM link
[RD 1] Instructions for ITER System Load Specifications	ITER_D_33TTPJ v3.3
[RD 2] Template for ITER System Load Specifications	ITER_D_2PW74P v1.5
[RD 3] Procedure for Blanket Attachments Forces Evaluation	ITER_D_35KSPX v1.0
[RD 4] ITER Abbreviations	ITER_D_2MU6W5 v1.17
[RD 5] Temporary First Wall Design Description Document	ITER_D_B6HJUU v1.1
[RD 6] IC-CMAF 16.TFW Temporary Blanket First Wall Panels	ITER_BGL6X7_v1
[RD 7] ITER Vacuum Handbook	ITER_D_2EZ9UM v2.5
[RD 8] Study Overall Thermal Response BM Without Water Cooling during SRO	ITER_D_BGEY2S v1.0
[RD 9] Evaluation of the relevance of seismic events for Blanket Modules	ITER_D_C3FC5Y v1.0
[RD 10] Instructions for Seismic Analyses	ITER_D_VT29D6 v2.0
[RD 11] Global Tokamak Seismic Analysis Report	ITER_D_33W3P4 v2.1
[RD 12] Significant EM Load Cases for the ITER Blanket with DINA-2010 scenarios	ITER_D_33J5R4 v1.0
[RD 13] View factor calculation methodology for PBS16 components	ITER_D_5D27SP v1.0
[RD 14] Stray RF Power modelling in the Tokamak during EC operation	ITER_D_4D377D v3.1
[RD 15] Guidelines for FW-diagnostics interface analysis	ITER_D_47VZFM v3.0
[RD 16] DMS Heat Load Mitigation Targets	ITER_D_57VT5Y v1.3
[RD 17] Thermal behaviour of SS316L under DMS operation radiation flash	ITER_D_ ADCRCN v1.0
[RD 18] Material Properties Handbook IDM folder	29DDBF
[RD 19] Absorption measurements of IO samples at 170GHz	BGDWYP v2.0
[RD 20] SMITER FLT study - ICRH parasitic heat loads on FW#14-15 panels	7TYEY8 v1.0
[RD 21] RF-Sheath Heat Flux Estimates on Tore Supra and JET ICRF Antennae. Extrapolation to ITER, EFDA–JET–CP(09)05/01 report, L. Colas et al., June 2009.	
[RD 22] Bill of Materials for the TFW panels (16.TW)	ITER_D_CYAHU7 v1.0
[RD 23] R. Mitteau et al Journal of Nuclear Materials 463 (2015) 411–414	
[RD 24] Blanket load specification	ITER_D_ 3NSGK2v3.0
[RD 25] Significant EM Load Cases for the ITER Blanket with DINA-2010 scenarios	ITER_D_33J5R4 v1.0

4.4 Interface References

PBS	Interface Control Document	Reference
PBS15	Vacuum Vessel	ITER_D_2NR7LR v3.1
PBS16	Blanket System	ITER_D_AGBMZL v3.1
PBS17	Divertor System	ITER_D_2KTFAD v2.5
PBS18	Fueling and Wall Conditioning System	ITER_D_2MGX75 v2.7
PBS22	Machine Assembly and Tooling	ITER_D_2FNR6R v2.7
PBS31	Vacuum System	ITER_D_495KFU v3.0
PBS47	Plasma Control System	ITER_D_6N5BTR v2.1
PBS51	Ion Cyclotron Heating and CD System	ITER_D_2LAEWB v4.1
PBS52	Electron Cyclotron Heating and CD System	ITER_D_33ZNNM v4.0
PBS55	Diagnostics	ITER_D_33MYP2 v6.8
PBS57	In-Vessel Viewing System	ITER_D_NC8CVR v1.5
PBS66	Radwaste Treatment and Storage Systems	ITER_D_49CLTF v2.2

5 System Classifications

[I] The system classification of the components in the scope of this load specification is defined in [ADi 1] and is summarized in Table 5-1.

Table 5-1 System components classification

Component	Safety Class	Quality Class	Seismic Class	ESP/ESPN	Vacuum Class
PBS 16.TW	non-PIC [16TWs54-R]	QC2 [16TWs53-R]	SC-2 [16TWs55-R]	Excluded	VQC 1B [16TWs56-R]

[I] The TFW has no tritium, electrical power, environmental or fire behaviour classifications. [ADi 1] [16TWs58-I].

[I] The TFW is not remote handling classified.

6 Codes and Standards

[R] To assess the acceptability of TFW components under the loads defined in this document, designers shall follow the *SCD-IC* [ADc 1] [16TWs178-R] to assess the acceptability of each component's behaviour.

7 Definitions

7.1 Units

[I] All loads are provided using the International System (SI) base and derived units. The only exception to this rule is that degrees Celsius may be used instead of Kelvin. The complete list of units used in this document is provided in the table below.

Table 7-1 List of Units used in this Load Specification

Quantity	Unit name	Unit symbol	In SI base units
Length	Meter	m	
Mass	Kilogram	kg	
Time	Second	s	
Temperature	Kelvin	K	
	Celsius	°C	
Acceleration			m/s²
Angular acceleration			rad/s²
Angular velocity			rad/s
Density			kg/m³
Energy, Work	Joule	J	N·m
Entropy			N·m/K
Force	Newton	N	kg·m/s²
Frequency	Hertz	Hz	1/s
Moment			N·m
Second moment of area			m⁴
Power	Watt	W	N·m/s
Pressure	Pascal	Pa	N/m²
Stress	Pascal	Pa	N/m²
Young´s Modulus	Pascal	Pa	N/m²
Thermal flux density			W/m²
Velocity			m/s

7.2 Coordinate systems

[I] The loads summarized in this document are either given in the cylindrical coordinate system of the ITER tokamak machine or in the local Cartesian coordinate system of a specific blanket module.

[I] The axes/directions of this coordinate system are named: radial, vertical, and toroidal. The identifier of the toroidal angle is φ. Also, the directions “poloidal” and “toroidal” are often used for load directions, which are defined in the plasma coordinate system, see Figure 7-1:

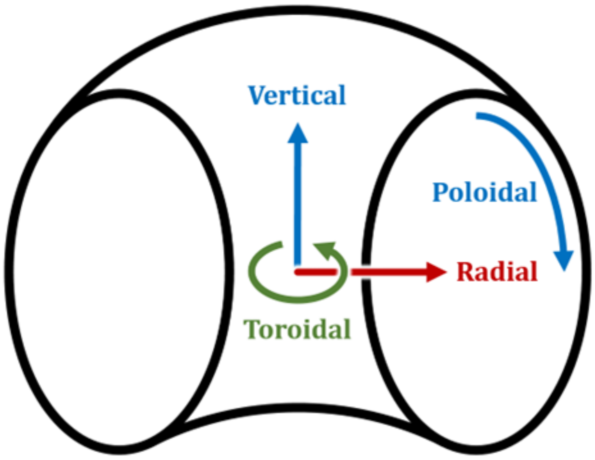

Figure 7-1 Definitions of tokamak directions and cylindrical coordinate system

[I] A detailed explanation on the definition of the origin of each local coordinate system is given in [RD 3]. Some examples, for different BMs are given in **7-2**. Hereafter, the main definitions are summarized:

- "X" – Radial; positive direction – towards plasma
- "Y" – Toroidal; positive direction – opposite to toroidal plasma current and toroidal field
- "Z" – Poloidal; positive direction – upwards inboard and downwards outboard.

7-2

7.3 Abbreviations

[I] For a complete list, see *ITER Abbreviations* [RD 4].

Table 7-2– Abbreviations

BC	Blanket Connections
BKT	Blanket System/Component
BM	Blanket Module
CMM	Configuration Management Model
CS	Central Solenoid
cqt	Current quench time
DAF	Dynamic Amplification Factor
DM	Detailed Model
ECRH	Electron Cyclotron Resonance Heating
ELM	Edge-Localized Mode
EM	Electromagnetic
ES	Electrical Strap
FDR	Final Design Review
FEM	Finite Element Model
FT	Flat-Top plasma phase
FW	First Wall
FLT	Field Line tracing
ICD	Interface Control Document
ICRH	Ion Cyclotron Resonance Heating
IMK	Inter Modular Key
MD	Major Disruption
MFD	Magnet Fast Discharge
NO	Normal Operation
PA	Procurement Arrangement
PDR	Preliminary Design Review
PF	Poloidal Field
RD	Ramp-down plasma phase
RU	Ramp-up plasma phase
SB	Shield Block
SDC-IC	Structural Design Criteria for in Vessel components
SLS	System Load Specification
SRO	Start of Research Operation
SS	Stainless Steel
SU	Start-Up plasma phase
TCK	Toroidal Centering Key
TCWS	Tokamak Cooling Water System
TF	Toroidal Field
TFW	Temporary First Wall
TPF	Toroidal Peaking Factor
VDE	Vertical Displacement Event
VS	Vertical Stability
VV	Vacuum vessel

8 Types of Loads

[I] The following type of loads are covered in this Load Specification:

- Inertial loads: these are caused by accelerations of masses induced by gravity, seismic events and displacements of supporting structures imposed by plasma disruptions.
- Electromagnetic (EM) loads: volumetric forces and moments generated by the interaction between electric currents flowing through conductive materials and magnetic fields.
- Pressure loads: external pressure conditions caused by accidental events.
- Thermal loads, due to interaction with the plasma and plasma heating systems.
- Thermal loads due to temperatures imposed by interfacing systems or accidental events.
- Assembly or installation loads due to pretension.

9 Main Loads

[I] The main loads on the TFW components are the thermal loads during normal operation as defined in [ADc 2], and the electromagnetic loads during disruption events.

[I] The thermal loads come from a combination of:

- The plasma heat load (by charged particles, photonic radiation, charge exchange),
- Plasma heating systems (ECH and ICH).

[I] The electromagnetic loads are the strongest primary loads on the TFW system and are the design drivers for the structural attachment design.

[I] In addition to the above loads, pretension, inertial and seismic loads must be considered both as single and combined load cases.

[I] The thermal loads during disruptions may occur simultaneously with the EM loads, which will cause local cracking, recrystallization, and melting within a short period. At this PDR stage, thermal loads during disruptions can be treated as independent from EM loads.

[I] The neutronic heat loads are considered negligible since the SRO neutron fluence is several orders of magnitude lower than the DT neutron fluence [ADi 4].

10 Path of the Main Loads

[I] The main mechanical loads incurred on the TFW follow the path defined by:

- TFW panels towards the Shield Block through the TFW central bolt and pads
- Shield Blocks towards the Vacuum Vessel through the Blanket Module Connections (flexible cartridges and poloidal and centering key pads)

[I] The full load path of main loads follows the Figure below, in which 'in-VV components' includes the shield blocks, TFW panels and blanket module connections.

[I] The path for the Halo and induced eddy currents are from TFW to the SB through the first set of electrical straps and from the SB to the VV through the second set of electrical straps.

[I] The path of the main loads is shown in Figure 10-1.

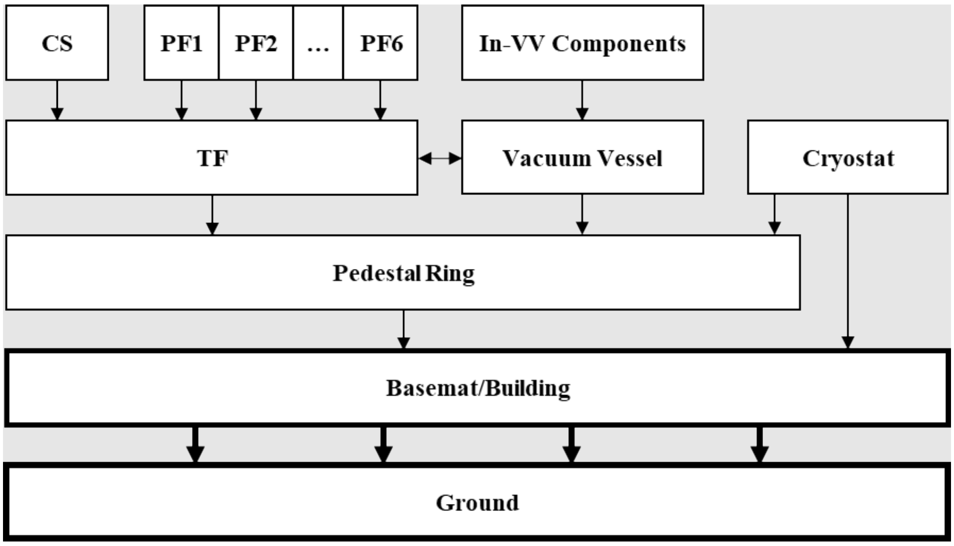

Figure 10-1 Path of the main loads

11 System Description

11.1 Design Status and Geometry

[I] The TFW is in preliminary design phase.

[I] The detailed models in row 4 and 9 have been drafted and synchronized in TOKAMAK_COMPLEX as shown in Figure 11-1.

Figure 11-1 Enovia tree of TFW CAD models

11.2 System Design Description

[I] See [RD 5] for the Temporary First Wall Design Description Document.

11.2.1 System, Components, Parts

[I] The Blanket components that are under the scope of this SLS includes:

- TFW Panels
- TFW attachments to SB (central bolt, pads and electrical straps)

[I] The main function of the TFW is to provide thermal shielding of the vacuum vessel, the shield blocks, and other in-vessel systems from plasma and particle loads during plasma operations and to stop direct plasma interaction on those systems.

[I] The TFW can also function as a limiter, primarily during plasma current ramp-up phases.

[I] The Blanket system consists of wall-mounted modules covering ~600 m^2. The BMs are segmented into 18 poloidal locations: rows 1 to 6 are the inboard region, rows 7 to 10 are the upper region and rows 11 to 18 are the outboard region (see Figure 11-2). The inboard and upper modules (except BM10) are segmented toroidally into 18 equal modules, while the outboard modules (except BM14 and 15) are segmented into 36 modules. In the upper and equatorial port region (BM10, 14 and 15), the modules are located between ports and therefore segmented into 18 modules. The configuration model of all TFW panels is shown in [RD 6].

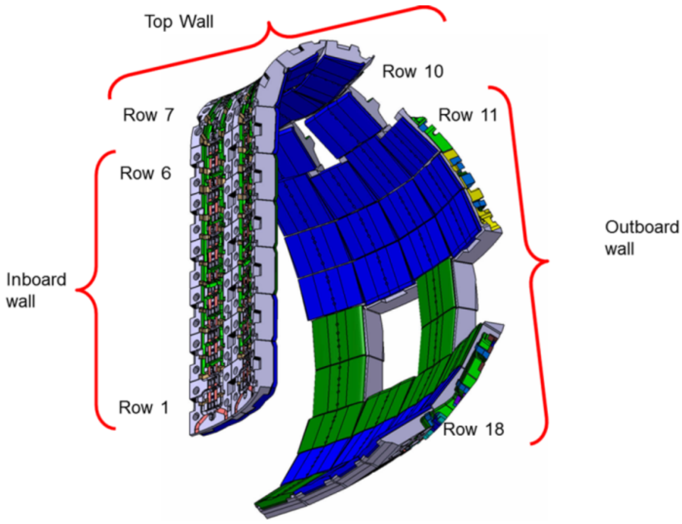

Figure 11-2 Inboard, upper and outboard BMs

[I] The Plasma facing material (PFM) choice of the TFW panels is (with some exceptions) dictated by local thermal loads specified in [ADc 2] (See detailed PFM distribution in [RD 22]).

[I] The PDR configuration assumes full wall coverage. See the number of TFW panels per row in the table below.

Table 11-1 the number of TFW panels per row

Row	SB	TFW
#01-02	18	18
#03-05	18	18
#06	18	18
#07-10	18	18
#11	36	36
#12-13	36	36
#14	22	21
#15	22	18
#16-17	36	36
#18	36	36
Total number of units	440	437

[I] The wall mounted BMs during the SRO phase comprise two major components: the Temporary First Wall (TFW) panel which faces the plasma and the Shield Block (SB) without active cooling. These components are tied together through a central bolt.

11.2.2 Materials

[I] All TFW components are made from approved materials (except W heavy alloy) as specified in the ITER Vacuum Handbook [RD 7] and are all non-magnetic.

Table 11-2 TFW materials

Component	Material/grade
TFW plasma facing armor material	Pure Tungsten tiles / W coating on SS tiles/ W heavy alloy tiles
TFW supports	Stainless steel 316 L / Inconel 718 / AlBr / 660 / Cu

11.2.3 Fabrication and Assembly

[I] The details of the Temporary First Wall panel fabrication and assembly will be given in the *TFW Design Description Document* [RD 5].

11.2.4 Functions

The TFW functions are detailed in [ADi 1] and presented below:

[I] The design of the TFW should mimic to the best extent possible the full Tungsten First Wall used in later operation and shall define the plasma boundary during limiter operation [16TWs44-I,46-R].

[I] The TFW shall contribute to absorbing radiation and particle heat fluxes from the plasma [16TWs47-R].

[I] The TFW shall protect the shield block, Vacuum Vessel, and other in-vessel components against transient thermal responses that are higher than acceptable to those components. [16TWs48-R].

[I] The TFW shall provide passage for the in-vessel viewing systems, microwave antennas or launchers, the gas and pellet fueling systems, and other minor ancillaries [16TWs49-R].

11.2.5 Interfaces

[I] The most important interfaces in which loads are exchanged with and within the Blanket components are the Blanket System (PBS16), the Ion Cyclotron Heating System (PBS 51), the Electron Cyclotron Heating System (PBS 52). These are explained in more detail in the ensuing sub-sections. The full list of interfacing PBSs and references to existing interface sheets is available section 4.4 [ADi 1].

11.2.5.1 Blanket Systems (PBS 16) internal physical interfaces: PBS 16.TW and PBS 16.SB

[I] The physical interfaces between the TFW and SBs assure mechanical and electrical functions.

11.2.5.2 Ion Cyclotron Heating System and CD (PBS 51) interfaces

[I] As per the 2024 baseline, only one ICRH antenna remains installed in the port #13 [ADc 3]. The TFW surrounding the ITER ICRF antenna can interact with the high-power RF field during the following operation modes of the IC H&CD system:

- Plasma heating and current drive mode: the IC H&CD system provides full power during plasma operation. Parasitic sheath RF power can load neighboring TFW panels during IC operation. The sheath heating load on TFW is given in section 13.3.3
- For tritium removal and wall conditioning (Ion Cyclotron Wall Conditioning, ICWC), where the optimal modulation ON/OFF has to be determined. Initially, typical ON/OFF modulation being 10 to 50% at ON durations of 2 to 20 seconds are proposed, with the ICWC procedures likely to last several tens of minutes, with a capability for at least 1 hour. The maximum ICRF power couple to the plasma during ICWC mode is 2.5MW.

11.2.5.3 Electron Cyclotron Heating System and CD (PBS 52) interfaces

[I] The PBS 52 EC H&CD consists of Upper and Equatorial Launchers, including the Front Shields. The system is designed to deliver a nominal power of 40 MW to the plasma during SRO [ADc 4].

[I] For the Plasma start-up phase, up to 20 MW of EC power will be injected from the Equatorial port 14 in the “empty” ITER chamber at the beginning of a discharge to assist gas ionization (breakdown) and plasma formation (burn through). In this phase there may be very little EC power absorption by the plasma, so that significant quantities of the launched power will be deposited and multiply reflected. The second reflection will occur on the outboard wall [RD 14].

[I] For the subsequent phases of the plasma discharge, three possible stray radiation loading have been identified: shine through, diffuse stray loading and X1 Cross-polarization. A more detailed description can be found in [ADc 4].

[I] The ECRH heat load on TFW is given in section 13.3.4.

12 States of System and Components

[I] The TFW will pass through several different stages during its lifetime. There are described in the following sub-sections.

12.1 Fabrication, transportation, assembly, and testing

[I] The TFW will be temporarily stored on-site prior to installation. Stresses and strains accumulated during fabrication are negligible compared to those found during operation.

12.2 Commissioning

[I] The TFW components will undergo several commissioning phases (ECRH, ICRH, Disruption mitigation system, etc.). Accumulated energy, stresses and strains during commissioning are assumed to be negligible compared to those found during operation.

12.3 Operation

[I] Operation includes many sub-states at various temperatures and environments, which are each described in detail below.

12.3.1 Initial conditions of a plasma pulse

[I] The vacuum vessel (VV) is at a uniform temperature of 100 °C and is the closest component to the TFW to be actively cooled. Between the VV and the TFW, several components (as described in §11.2) conduct and radiate the heat to the VV. The initial temperature of each BM depends on its location and on the accumulated energy from the previous plasma pulses.

[R] The initial temperature of the TFW and its surroundings shall be considered at a temperature of 200°C as an envelope assumption for preliminary design development derived from preliminary thermal assessments which accounts for heat accumulation after several days of full power operation. This value will be revised in the FDR phase if needed.

12.3.2 Baking

[I] In the SRO phase, the baking loads are considered negligible since the baking temperature will be much lower than the normal operation temperatures. In addition, the baking is not planned through any pressurized system within the TFW.

12.3.3 Normal Plasma Operation

[R] The 5 MA plasma current H mode operation at half-strength magnetic field (2.65 T at 6.2 m) and 15 MA plasma current L mode operation at full-strength magnetic field (5.3 T at 6.2 m) are two key plasma scenarios envelopes for designing TFW, in addition to possible inner wall and outer wall limiter contacts, as defined in [ADc 2]

[I] In designing an inertially cooled plasma-facing component, it is crucial to quantify the heat power deposition over time. For this purpose, the following plasma pulse phases are distinguished for heat load discretization (see detailed definitions in [ADc 2]):

- Start-up (SU)

- Ramp-up (RU)
- Flat-top (FT)
- Ramp-down (RD)

[R] For the design of the inertially cooled TFW, 30 seconds of flat top duration is considered. The pause phase between two plasma pulses shall be at least 1800 seconds (30 minutes) [ADi 6].

[R] TFW panels shall be designed for a total of 8500 plasma cycles of different power as an approximate value based on 27 months of SRO campaign, 24 operating days per month, 13 'good' shots average per day[ADi 6].

12.3.4 Plasma instabilities

[R] Both Major Disruptions (MD) and Vertical Displacement Events (VDE) shall be considered as electromagnetic load cases for the TFW components. See section 13.1.4 for more detail.

[I] Both Major Disruptions (MD) and Vertical Displacement Events (VDE) thermal loads on the TFW are out of design basis (i.e. are not a design driver), as the large uncertainties present on these loads would render an impractical design if they were to be considered as mandatory design loads. See section 13.3.5 and the [ADc 2] for more detail.

12.3.5 Shut-down for maintenance and upgrade

[I] During the shut-down periods of ITER, the TFW temperature will decrease within several days down to room temperature (20°C), hence no transient effects are assumed to be relevant.

12.4 Decommissioning

[I] The TFW will be dis-assembled and will be temporarily stored on-site prior to disposal. Stresses and strains accumulated during decommissioning are assumed to be negligible compared to those found during operation.

13 Single Load Cases

[I] This section describes all single load cases imparted on the TFW components during various stages of life (see Table 13-1). These include mechanical loads, accident loads, thermal loads, specific loads, and interface loads. §13.5 reports the load cases that are excluded as they are considered to be insignificant.

Table 13-1 Summary of single loads acting on TFW panels (EM categories are defined in [ADi 3])

Loads	Description
EM Cat I	• Worst case EM event Cat I
EM Cat II	• Worst case EM event Cat II
EM Cat III	• Worst case EM event Cat III
Thermal loads during normal operation	• Plasma, ICH and ECH heat loads
Thermal loads during disruptions (for design performance study)	• Worst case disruption 15 MA unmitigated

13.1 Mechanical Loads

13.1.1 Dead Weight

[R] The approximated masses of each TFW with their center of gravity using the Tokamak Global Coordinate System (TGCS) are listed in [ADc 5].

13.1.2 Assembly and Pretension Loads

[R] The bolts pre-tension shall be accounted and derived from the main EM loads between the TFW and the SB and between the TFW parts based on the rules defined in the SDC-IC.

[I] Pretention loads are applied at room temperature.

[I] It is recommended to track the evolution of the bolt preload in the different load cases for the bolt assessments and to update the thermal contact conductance if needed. At this time during preliminary design maturity, the bolt preload values are still being defined. These will be populated in [ADc 7] to ensure consistency with assumed values in analysis.

13.1.3 Seismic Loads

[I] For the case of the TFW, the kinetic energies and reaction forces associated to the highest seismic event are at least one order of magnitude smaller than those associated with an electromagnetic Cat II disruption [RD 9]. Although not strictly extrapolated to the TFW and similarly attached components, this analysis is also likely applicable to all Blanket components, demonstrating that:

1. Seismic single load cases are enveloped by EM load cases.
2. The simplified seismic approach of zero period acceleration (ZPA) at the blanket-to-vessel connection points is allowed for load combination analyses.
3. Cat IV load combination events including seismic loads are beyond design basis.

13.1.4 EM Loads due to Plasma Scenarios

[I] This chapter describes the approach used to calculate the EM loads on TFW panels in a similar way as the Blanket Load Specification [RD 24].

[I] The ITER Load Specification [ADi 3] is not yet updated for the SRO phase, therefore first numbers are derived from [ADi 7].

[I] In a physical sense, transient electromagnetic loads on the TFW are limited to **induced currents:**

- **Eddy currents**, induced by the mechanism of conservation of the magnetic fluxes (from all sources) crossing conductive parts. They are closed in loops which are fit in either a single conductive part or in a set of several interconnected conductive parts.
- **Halo current,** induced by the mechanism of conservation of the toroidal magnetic flux in the plasma core region. This current is closed via a conductive loop formed partly by conductive structures and partly by periphery plasma layer (a layer with "open" magnetic lines which intercepts TFW panels).

[I] Eddy currents do exist in principle (with different intensities) at any time moment of any transient EM event including normal operation, but halo current is considered only in the current quench phases of VDEs and MDs, when the last closed flux surface touches the plasma facing conductive wall.

[I] Maximal EM loads on the TFW are caused by two kinds of abnormal terminations of plasma pulse: **Major Disruptions** (MDs) and **Vertical Displacement** Events (VDEs):

- A **MD** consists in an abnormal termination of plasma pulse typically initiated by a loss of thermal energy confinement, followed quickly by a thermal quench and then by plasma current decay, with the corresponding vertical drift and compression of the plasma core.
- A **VDE** consists in an abnormal termination of plasma operation initiated by a loss of vertical plasma position, followed by an irreversible vertical drift of still confined plasma until contact with the plasma-facing surfaces occurs in limiter configuration. A thermal quench occurs soon after followed by accelerated plasma current decay, with the corresponding vertical drift and further compression of the plasma core.

[I] Both in VDEs and MDs, the halo current reaches a significant value after the time moment when plasma touches the wall. Both events result in plasma drift to either the upper or lower part of the vessel.

[I] The ITER project has for the most part used the DINA code for simulations of plasma evolution. The code delivers waveforms (time dependent functions) of many plasma parameters, time dependent profiles of toroidal and poloidal plasma current densities and time dependent poloidal distributions of halo current intercepting the FW.

[I] DINA simulates axially symmetric (2-D) plasma evolution. In disruption current quench phases, rotating magnetohydrodynamic instabilities can often lead to a loss of axial symmetry which will distort the DINA predicted symmetric halo current distribution, adding cyclic component to halo related EM loads in BMs.

[R] The electromagnetic loads on the TFW components shall be based on electromagnetic analysis calculations to reflect the latest designs.

[I] The results obtained during the Benchmarking activity [models 2007-DINA simulations 2007] and the ones on models 2007 – DINA simulations 2010, (see [RD 12]), helped to identify the most demanding EM cases of Category I, II and III plasma events for each TFW position.

[R] In the following tables, the plasma events to be analyzed for each TFW are listed. The naming corresponds to those used in [ADc 6] for each event. The grey cells are to be addressed with detailed EM and preferably dynamic analysis, white cells are not applicable.

[I] With a structure subjected to dynamic EM loads, either a full transient structural analysis is performed, or suitable dynamic amplification factor is included in a static structural calculation as per [RD 1] [SLS197-R].

[R] MD III disruptions shall be derived from the corresponding MD II event by scaling the MD II thermal quench phase from 1.0 to 0.5 ms.

[I] EM Category IV events are considered beyond design basis for the TFW System. Hence, they are not considered design loads for the TFW, which is a non-SIC system.

Table 13-2 Category I plasma events [ADi 3]. Grey boxes indicate the scenario to be studied that is assumed to envelop other load cases.

Cat. I events	**MD-I**			
Scenario	MD_DW_lin_50ms_Cat.I	MD_DW_exp_22ms_Cat.I	MD_UP_lin_50ms_Cat.I	MD_UP_exp_22ms_Cat.I
TFW1	■			
TFW2	■			
TFW4				■
TFW6			■	
TFW7			■	
TFW8			■	
TFW9			■	
TFW10			■	

TFW11				■
TFW12				■
TFW14				■
TFW15		■		
TFW16	■			
TFW18	■			

Table 13-3 Category II plasma events [ADi 3]. Grey boxes indicate the scenario to be studied that is assumed to envelop other load cases.

Category II events	**VDEslow**		**VDEfast**		**VDEslow/ fast**		**MD-II [thermal quench = 1.0 ms]**			
Scenario	VDE_DW_slow_Cat.II	VDE_UP_slow_Cat.II	VDE_DW_fast_Cat.II	VDE_UP_fast_Cat.II	VDE_DW_slow_fast_Cat.II	VDE_UP_slow_fast_Cat.II	MD_DW_lin_36ms	MD_DW_exp_16ms	MD_UP_lin_36ms	MD_UP_exp_16ms
TFW1			■				■			
TFW2			■				■	■		
TFW4								■		■
TFW6				■						
TFW7				■						
TFW8		■		■						
TFW9		■		■						
TFW10		■		■						
TFW11										■
TFW12								■		
TFW14								■		
TFW15								■		
TFW16			■							
TFW18			■							

Table 13-4. Category III plasma events [ADi 3]. Grey boxes indicate the scenario to be studied that is assumed to envelop other load cases[1,2].

Category III events	VDEslow		VDEfast				MD-III* [thermal quench = 0.5 ms]			
Scenario	VDE_DW_slow	VDE_UP_slow	VDE_DW_lin_36ms	VDE_DW_lexp_16ms	VDE_UP_lin_36ms	VDE_UP_lexp_16ms	MD_DW_lin_36ms	MD_DW_exp_16ms	MD_UP_lin_36ms	MD_UP_exp_16ms
TFW1	■		■	■						
TFW2	■		■	■				■		■
TFW4								■		■
TFW6						■		■	■	
TFW7					■				■	■
TFW8		■			■				■	
TFW9		■			■				■	
TFW10		■			■	■			■	
TFW11					■					
TFW12								■		
TFW14								■		
TFW15				■						
TFW16								■		
TFW18			■	■				■		

[R] During SRO, it is assumed that 17.4% of the total number of full current and magnetic field pulses will end with a plasma disruption in addition to the deliberate disruptions which gives a total number of 325 full power disruptions [ADi 7] .

[I] The disruptivity varies within the SRO campaign, detailed numbers are given in §14.2.2 and in [ADi 7] for a less conservative fatigue calculation.

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[1] The missing rows in this table are enveloped by the analysis performed for other neighboring rows with similar design. As an example, rows 3 & 5 are enveloped by the analysis performed in row 4.

[2] The presumably most demanding EM cases of Category I, II and III plasma events for each TFW row are identified in [RD 25].

[R] The figure below reports the frequency of current quench time assumed for the design of ITER components [ADi 3]. Following this distribution, the more severe condition for a MD I event (50 ms and 22 ms for linear and exponential decays respectively) envelopes 87% of all disruptions (700). The most severe condition for disruption II envelopes the rest 13% (100). A summary is reported in Table 13-5.

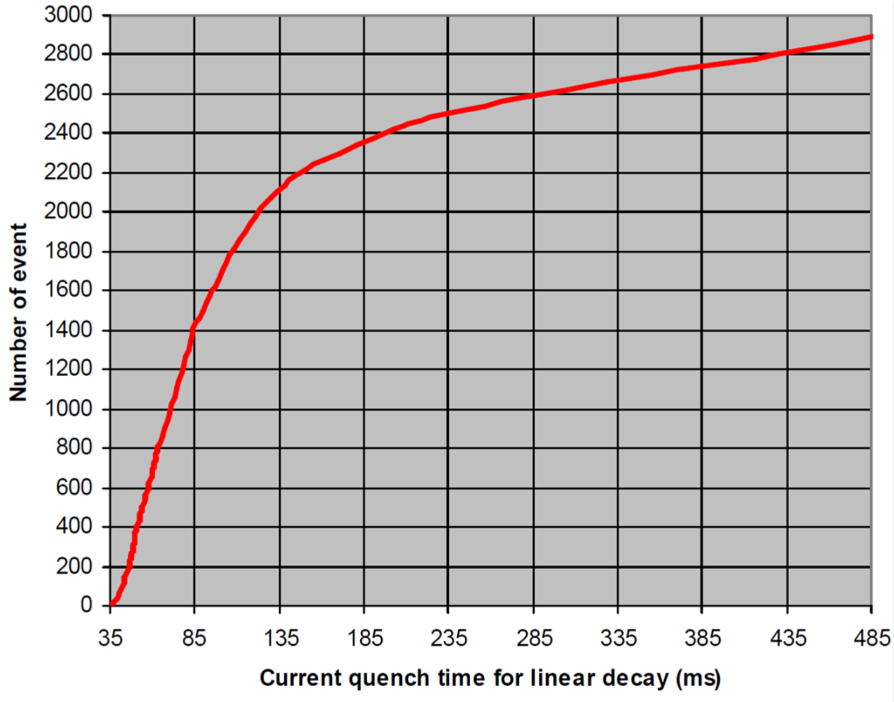

Figure 13-1 Frequency of plasma current quench time assumed for the design of ITER components (linear current quench)

[R] The number of MD events to be considered for the design has an impact on the fatigue damage and the aging effects. For the majority of the cases the loads and maximum strains in the structures surrounding the plasma can be assumed, as first approximation, proportional to $1/t_{cq}$ (t_{cq}=current quench time). In these cases, to simplify the analyses, the total cumulative damage of the full disruption population can be calculated assuming an equivalent number of disruptions with the most extreme condition for disruption II (36 ms linear or 16 ms time constant for exponential) or for disruption I (50 ms linear or 22 ms time constant for exponential) [ADi 3].

Table 13-5 Scaling factors account for MD events that are not explicitly calculated [ADi 7]

Events	Load Category	Linear decay t_{cq} [ms]	Exponential decay t_{cq} [ms]	Scaling factor	Number of events	Number of cycles/event[3]	Number of full current and field events

[3] Number to be revised if a dynamic analysis is performed

Major Disruption I	Cat I	≥50	≥22	0.72	3070	5	250
Major Disruption II	Cat II	≥36 <50	≥16 <22	1	470	5	40
Major Disruption III	Cat III	≥26 <36	≥11.3 <16	1	1	5	1

[R] The number of VDE events to be considered for the fatigue design is presented below alongside the characteristics of the typical VDEs [ADi 7].

Table 13-6 Main VDE events

Events	Load Category	Drift direction	Number of events	Number of cycles/event[4]	Number of full current and field events
VDE II Slow/Fast	Cat II	Up/Down	350	5	30
VDE III Slow/Fast	Cat III	Up/Down	1	5	1

[I] The design value of the halo current for in-vessel components depends on its poloidal location inside the VV. The estimate of the intercepted halo currents shall include the interception of the poloidal and toroidal components.

[R] Table 13-7 defines the design value of the intercepted poloidal halo current that may occur in each toroidal row in a slow VDE III [ADi 3]. Data reported in the table does not represent a single simulation event but represents the envelope of many possible VDE cases.

[R] For slow VDE II the halo current magnitudes must be scaled by a factor of 0.56 with respect to the slow category III event.

[R] For fast VDEs Category III the halo current magnitudes must be scaled by a factor of 0.6 with respect to the corresponding slow category III event.

[R] Additional halo current due to misalignment of the in-vessel components shall be considered. Recommended value for peak factor due to misalignment is equal to 1.15.

[R] If ever the configuration is changed such that some TFW panels are not installed and the SB is left facing plasma while being sufficiently recessed to receive negligible halo current, the

[4] Number to be revised if a dynamic analysis is performed

values in the table need to be corrected assuming that the current will be intercepted by the adjacent modules in the same row.

Table 13-7 Maximum intercepted poloidal Halo current in each module in slow VDE III for the PDR configuration.

Blanket row	VDE drift direction	Total intercepted Halo current for an entire row [kA]	Number of TFW modules in a toroidal row	Maximum intercepted Halo current for a single module [kA]
1	Down	3546	18	197
2	Down	2448	18	135
3	Down	2448	18	136
4	Up	1944	18	108
5	Up	3240	18	180
6	Up	3240	18	180
7	Up	3240	18	180
8	Up	3240	18	180
9	Up	3240	18	180
10	Up	3240	18	180
11	Up	3240	36	90
12	Up	1296	36	36
13	Up	1296	36	36
14	Up	550	22	25
15	Down	703	19	37
16	Down	1620	36	45
17	Down	1620	36	45
18	Down	6480	36	180
			437	

13.1.5 Inertial VDE Loads

[I] Inertial VDE loads in the ITER tokamak are currently under finalization. Further details can be found in the Blanket LS [RD 24] where the stress levels in the Blanket components induced by the inertial VDE are estimated to be low, and they are enveloped by the other design loads. They are therefore considered negligible for the TFW.

13.1.6 EM loads due to other EM transients

[I] Other EM transients are associated with ELMs, MARFEs, toroidal and poloidal field coil fast discharges (MFDs), operation of poloidal field system and in vessel coils. They all lead to relatively small EM loads at the TFW, see stated in §5.1 of [RD 24]

[I] From results of recent experiments it can be inferred that, under specific conditions during VDEs, induced current can flow toroidally and poloidally between adjacent First Wall fingers and panels resulting in net radial forces on the FW fingers. Numerical extrapolation of these currents from the experiment to the ITER case are difficult because the conduction mechanism is not yet very clear. Nevertheless, some margins should be applied to the allowable radial loads on the fingers to consider these likely loads.

13.1.7 Structural Loads due to Component Operation

[I] No structural loads are expected due to component operation.

13.2 Loads in Incident and Accident Events

[I] The TFW components are not of a protection important class (PIC), therefore incident and accident load cases are not to be considered for design purposes.

13.3 Thermal Loads

[R] The categorization of heat loads (HL-Cat.) is defined in [ADc 2]. The thermal loads considered as TFW design basis or for design performance/mitigation only is summarized in **Table 13-8**.

Table 13-8 Summary of the thermal loads considered as TFW design basis or for design performance/mitigation only

	Design basis	**Out of design basis** for design performance analysis and mitigation by design when practical
HL Cat.I	Stationary thermal loads during diverted operation, including rad+CX and time-averaged ELMs (mitigated for DT, unmitigated or mitigated ELMs for SRO) Stationary thermal loads during plasma limiter contact on the wall[5] H&CD 'normal operation' loading	Mitigated MD/VDE TQ and CQ MARFE instability causing transient peak radiation loads on the wall (<0.1s) Radiation flashing during mitigated MD/VDE TQ and CQ with moderate energy/radiation asymmetry
HL Cat.II	N/A	Unmitigated/Mitigated MDs in limiter mode during start-up on the inner wall Unmitigated MDs/VDEs

[5] The FWP design is fixed by consideration of the ensemble of specified limiter configurations in [ADc 2]. These configurations may impose in turn restrictions on what can be permitted during actual ITER operation if posing too much constraints on the design. These restrictions will be imposed by operating instruction

		Unmitigated ELMs Radiation flash loading caused during mitigated MD/VDE at very high plasma energy/producing very large radiation asymmetry
HL-Cat.III	N/A	Unmitigated MDs/VDEs Runaway electrons

[R] Thermal loads during normal plasma operations (in limiter or diverted mode) shall be considered as design basis for TFW.

[I] Thermal loads during off-normal events mitigated/unmitigated disruption, runaway electrons event and unmitigated ELMs events are considered for TFW design performance/mitigation studies only, which should not drive the design of the TFW.

[R] As the TFW is inertially cooled, the thermal loads described in this section shall be applied as time-dependent (transient approach).

[I] All the other normal operational states (besides L-mode 15 MA and H-mode 7.5 MA plasma operations) as defined in [ADc 2] are not relevant from the design perspective since the thermal loads are expected to be lower.

[I] The normal operation thermal loads affecting the mechanical behaviour of the TFW system are:

- Plasma photonic radiation and charge-exchange.
- The plasma heat load (heat carried by charged particles).
- Plasma heating system loads (ICH and ECH).

[R] Under operating conditions, the combination of the full set of heat loads is possible. However, if the plasma radiates some of its power, this power must of course be deducted from the charged particles heat loads and vice versa. The strategy is developed in the load combination Section 14.2.1 based on two envelope plasma scenarios.

[R] The TFW panels shall be designed for 1,000 full power plasma cycles as part of a total of 8,500 plasma cycles [ADi 6] [ADi 7] that can be decomposed and classified by different plasma power levels to scale down the loads and reduce the conservatism for fatigue calculation. The corresponding heat loads are defined in [ADc 2].

13.3.1 Plasma conductive and convective heat loads (due to charged particles)

[I] The TFW is exposed to significant heat fluxes carried by the charged particles from the plasma, impacting the plasma-facing surface along the magnetic field lines. The incident heat flux due to convection and conduction varies differently for each TFW row during plasma phases, depending on the plasma operation mode: whether in limiter mode, where the plasma contacts the wall, or in diverted mode (X-point configuration).

[I] Time-dependent charged particle loads are calculated using the Field Line Tracing (FLT) code SMITER. These loads are output from SMITER as text files, discretized over time, and contain heat flux values for x,y, and z coordinates in the TGCS.

[R] The most critical loads from the worst-case scenario shall be applied. To determine the most critical scenario, the total energy per TFW (or part of TFW such as finger or tile) and the energy per unit of area can be identified in the FLT calculation reports. Ideally, a master document should summarize this data for each panel row, specifying the identified worst-case scenario.

[R] For the PDR, heat load maps from the FLT calculation report [ADc 11] are used.

[R] For the design, penalty factors shall be applied to the base heat fluxes [ADc 10], they will be calculated for the TFW based on several parameters such as shaping, faceting, alignment capabilities, and tokamak precision. At PDR, a recommended penalty factor of 1.5 shall be applied for all TFW panels. A more detailed penalty breakdown may be developed in the future.

[R] As the plasma conductive and convective heat loads are design dependent, they shall be based on the latest wall configuration, or shall be derived from a similar wall configuration by referencing the CMM version used in the FLT analyses.

13.3.2 Photonic radiation and charge exchange surface loads

[R] The radiation and charge-exchange energy density for the 15 MA L mode radiation[6] dominant scenario specified in [ADc 2] is 4 MJ/m^2.

Table 13-9 Radiation and charge exchange during the SRO phase

	Start-up (inner TFW#3-4-5 only)	**Ramp-up**	**Flat-top**	**Ramp-down**	**Total**
Duration [s]	Max. 10	70	Max. 30	70	180
Average Rad + CX heat flux [kW/m^2]	~30	~20	~50	~20	-
Rad + CX energy [MJ/m^2]	0.15	1.3	1.6	1.3	~ 4

[6] The combination of radiation+ CX loads defined in Table 13-9 with the plasma convective/conducted loads is specified in Section 14.2.1 for both the radiation dominant and convection dominant cases.

(* The combination of radiation+ CX loads defined in Table 13-9 with the plasma convective/conducted loads is specified in Section 14.2.1 for both the radiation dominant and convection dominant cases)

[R] For recessed surfaces shadowed from plasma charged particles but still exposed to radiation and charge-exchange, photonic loads shall be applied based on 3D view factor analysis, following the methodology outlined for the calculation of 3D plasma view factors [RD 13].

13.3.3 Ion Cyclotron Heating and CD RF parasitic heat loading

[I] As per [ADc 3] *IS-16-51-001 Interface Sheet between PBS 16 Blanket System and PBS 51 IC H&CD System*, the ICH is used only during the diverted flat-top phase, for both the SRO and DT phases. No IC RF parasitic heat loads to TFW panels are considered during the plasma ramp-up and ramp-down phases.

[I] During plasma operations, the parasitic *direct RF power dissipation* (ohmic skin losses to the wall) is very small and can be safely neglected.

[I] Thermal loading to the wall during *Ion Cyclotron Wall Conditioning* ICWC is also considered negligible and enveloped by larger ICRH parasitic loading expected during stationary diverted plasmas.

[I] During IC H&CD operation, *RF parasitic heat loads* can impact the wall locally, effectively adding to the maximum parallel heat flux $q_{||}$ that would otherwise be incident on the TFW panels. This parasitic loading can reach the panels surrounding the ICRH antenna on:

- row14 and 15 on either side of equatorial port 13,
- on the lower half of row 13 (located top-right) in the same region,
- on the upper half of row 16 (located bottom-left) in the same region.

[R] The Temporary First Wall shall be assessed under an assumed uniform parallel heat flux $q_{||-RF}$ contribution from ICRH up to 1.0 MW/m^2 for the duration of the flat top, mapped to the FW panel surface. The uniform mapping is a conservative simplification of the assumed peak heat flux distribution of IC parasitic loading, as described in [ADc 3] *IS-16-51-001 Interface Sheet between PBS 16 Blanket System and PBS 51 IC H&CD System*.

[R] The above RF heat load should be projected to derive the local incident RF loads ($Q_{inc,IC\ RF\ parasitic} = Q_{//,IC\ RF\ parasitic}$ * sin (α) where α is the magnetic field line impact angle on the shaped surface of the neighbouring panel). The incident loads are therefore design dependent.

13.3.4 Electron Cyclotron Heating and CD RF parasitic heat loading

[R] According to measurements having been conducted in [RD 19]., 1% of ECH beam absorption shall be conservatively considered for Tungsten and 2% for stainless steel.

[R] The ECH loads shall be considered as time, spatially, and scenario dependent with loads evolving as a function of the plasma phases, as detailed in [ADc 8] and [ADc 9].

13.3.5 Thermal Loads due to off-normal events

[R] Thermal loads during off-normal events as detailed in **Table 13-8** are out of design basis. The list of off-normal plasma scenarios to be considered for TFW design performance study only is given in Table 3 [ADc 2].

13.3.6 Thermal radiation losses of the TFW

[I] Thermal radiation occurs between the TFW parts and with the surrounding TFW. Emissivities are given in the *Material Properties Handbook* depending [RD 18] on the wall temperature.

[I] Based on experience it is conservatively recommended not to apply thermal radiation losses to surfaces exposed to charged particles heat fluxes due to the high uncertainty regarding surface conditions during operation.

13.4 Electrical straps loads

[R] The loading conditions of electrical straps depend on the factors listed below:

- Initial deformations caused by assembly misalignments
- Imposed displacements due to relative thermal displacement between TFW and SB
- Displacement between TFW and SB due to the dynamic behaviour of the two components under EM loads for FW/SB electrical straps
- Eddy current passing through all straps in the thermal quench and current quench phases
- Halo current passing through straps of some BMs in the current quench phase
- Joule heating (mostly at elastic elements and demountable contacts)

[R] The Electrical Strap loads shall be calculated based on the component's misalignments, thermal, structural and EM analyses of the most critical BM module (TFW and SB).

[R] Considering that the E-straps are functional and not structural components and that they consist of several lamellas to transport current, the SDC-IC criteria will be applied assuming the Criteria Level C also for category I/II loads. The aim of level C criteria is to protect the component against the same damage as level A but the safety margins are set so that local permanent deformation and small levels of overall deformation could occur, while the component is limited with reasonable confidence, against the damage of immediate fracture.

[R] Regarding the M-type damage, at levels C, the same set of rules apply as for level A, but with different safety factors and load factors (see SDC-IC table IC-3220).

[R] Regarding the C-type damage, fatigue damage will be assessed following the same set of rules as for level A.

[I] Not all the loads listed above are applied at the same time and they are different for each BM. However, the e-straps are the same for all BMs. Hence, the analysis shall be performed for the likely worst combination of the listed loads.

13.5 Not Significant Load Cases

[I] This subsection lists the states in which no design-driving loads occur (see Table below).

Table 13-10 Insignificant load cases

Insignificant load cases	Justification
Transient effects during heating and cool down before and after baking	The heating/cooling transitory effects induce small thermal gradients, therefore negligible thermal stresses. A verification has been performed for one BKT component in [RD 15].
Baking	As explained in Section 12.3.2.
Seismic events	As explained in Section 13.1.3.
Other EM events	As explained in Section 13.1.6.
Loads during transport and assembly of the components	These loads should be very small in comparison to operational loads. During transportation and assembly, the expected accelerations are at the same level with the gravity, therefore the induced stresses are low compared with EM and seismic events induced stresses.
Transient radiation flash during operation of the disruption mitigation system	The studies presented in [RD 16] and [RD 18] have shown that SS316L melting under these conditions would only lead to surface roughening and not to any large-scale erosion.
Magnet Fast Discharge	MFD cause relatively small EM loads in the blanket, which are considered to be within the load envelope of the most demanding EM events.
EM Category IV events	EM Cat IV events are considered beyond design basis for the Blanket components (non-SIC).
Inertial VDE loads	The stresses in the Blanket components are expected to be low (see [RD 24])
Internal VV explosion	An internal explosion affecting tokamak and first confinement barrier components is defined as beyond design. In case of air ingress inside the VV, deflagration or detonation of the hydrogen/air mixture is not studied, as it is proposed that the ITER design will contain provision for prevention of such an explosion, for example by injection of an inert gas into the vessel, see [ADi 3] Load Specifications (LS)].

14 Load Combinations

14.1 Categorization of Load Combinations

[I] The design basis conditions and events (design load combination) specified in [ADi 3] and [ADc 2] are propagated via the load combinations specified below.

[I] The ITER loading conditions are categorized, into four classes based on the expectation of occurrence:

- Category I: Operational Loading Conditions
- Category II: Likely Loading Conditions
- Category III: Unlikely Loading Conditions
- Category IV: Extremely Unlikely Loading Conditions

[R] Table 14-1 is based on the template provided in Table 4-2 of [ADi 3] and provides the damage limits that apply to each part in the scope of this load specification.

Table 14-1 Damage limits applicable to the scope of the load specification

Component of 16.TW	Safety Class	Cat. I	Cat. II	Cat. III	Cat. IV	Test
TFW panel and attachments to SB	Non-SIC	Normal	Normal	Emergency	NA	Test
TFW electrical straps	Non-SIC	Emergency	Emergency	Emergency	NA	Test

[R] Table 14-2 shows the correlation between damage limits and the service levels defined by the codes prescribed in §6.

Table 14-2 Correlation between damage limits and SDC-IC Service Levels

Damage Limit	SDC-IC Service Level
Normal	A
Upset	A
Emergency	C
Faulted	D
Test	Test

14.2 List of Load Combinations

14.2.1 Combination of thermal loads

[R] Two thermal load combinations have been identified as potential worst-case scenarios for the thermal loads on the SRO wall during 15MA L-mode plasma [ADc 2] and shall be considered:

1. **Radiation dominant scenario** with the highest radiation and charge-exchange loads and consequently (due to the peaking factor on radiation loads) corresponding to the maximum energy to the entire wall.
2. **Convective/conductive dominant** with the highest convected and conducted plasma loads to the wall, leading to local peaks of temperature.

[I] This realistic approach, based on the conservation of energy, consists for the radiative dominant load combination of removing the radiative load from the input power to calculate the convective and conductive load and vice versa for the convective/conductive load combination.

[I] Table 14-3 summarizes these two thermal load combinations for 15 MA L mode operations detailed in [ADc 2], applicable to the Ramp-up, Flat-Top and Ramp-down phase..

[I] Table 14-4 shows the thermal load combination for 7.5 MA H mode operations.

Table 14-3 Thermal load combinations for 15 MA/5.3T L mode operations

Load combination		**Radiative dominant**[7]	**Conductive/Convective dominant**[8]	**Unit**
Plasma radiation + CX	Power	~2900	~1500	MJ
	Power density	4	1	MJ/m^2
Plasma conductive + convective	Power	30% scaling of FLT totals [ADc **11**]	100% scaling of FLT totals [ADc **11**]	MJ
	Power density	maps from FLT design-dependent analysis [ADc **11**]	maps from FLT design-dependent analysis [ADc **11**]	MJ/m^2
Total energy to TFW	Power	~3000	~1000	MJ

[7] (Built from public/iter/105073)

[8] (Built from public/iter/ 105069)

Load combination	Radiative dominant[9]	Conductive/Convective dominant[10]
Plasma radiation + CX	100% scaling of the radiation load defined in section 13.3.2	25% scaling of the radiation load defined in section 13.3.2
Plasma conductive + convective	30% scaling of FLT totals [ADc **11**]	100% scaling of FLT totals [ADc **11**]

Table 14-4 Thermal load combinations for 7.5 MA/2.65T H mode operation

Load combination:	7.5 MA/2.65T H mode[11] (scale down from DINA scenario 105069)	**Unit**
Plasma radiation and charge exchange load	0.4	MJ/m^2
Plasma conductive + convective	maps from FLT design-dependent analysis [ADc 11]	MJ/m^2

9 (Built from public/iter/105073)

10 (Built from public/iter/ 105069)

11 H mode scenario only corresponds to conductive/convective dominant cases

14.2.2 Load combinations

[I] Table 14-5 and Table 14-6 summarize all load combinations for the various stages of life of the system.

Table 14-5 Load combination considered for TFW design basis

# Load	Mechanical	EM	Thermal	Category	No. of events	No. of full current/magnetic field events
	§13.1.2	§13.1.4	§13.3	§14.1	[ADi 7]	[ADi 7]
I-01	pre-tension	-	Normal operation thermal loads	Cat. I	8500	1000
I-02	pre-tension	MD/VDE cat. I	Normal operation thermal loads	Cat. I	3070	250
II-01a	pre-tension	MD cat. II	Normal operation thermal loads	Cat. II	470	40
II-01b	pre-tension	VDE cat. II	Normal operation thermal loads	Cat. II	350	30
III-01a	pre-tension	MD cat. III	Normal operation thermal loads	Cat. III	-	-
III-01b	pre-tension	VDE cat. III	Normal operation thermal loads	Cat. III	-	-

Table 14-6 Load combination considered for TFW performance analysis only

# Load	Mechanical	EM	Thermal	Category	No. of events (including failed)	No. of full current/magnetic field (including failed)
	§13.1.2	§13.1.4	§13.3	§14.1	[ADi 7]	[ADi 7]
II-02	-	-	Normal + Off Normal operation thermal loads	Cat. II		
III-03	-	-	Normal + Off Normal operation thermal loads	Cat. III		

[R] For disruptions and VDEs, the number of equivalent cycles per event has to be determined based on the dynamic response of each single component. If a dynamic analysis is not performed, a conservative number of cycles per event to be considered is 5 as per [ADi 5].

[R] For cycling loads, the two states being cycled between depend on the load case. The analyst shall check all possible combinations and the enveloping cases will be presented in the analysis report.

[R] Category III load combinations shall be specified to occur once in the SRO lifetime.

Appendix A – Inputs to be consolidated for FDR

To be consolidated	Comments
ITER_D_222QGL v6.3 - Load Specifications (LS)	• Not updated with W wall and SRO phase • 13.1.4 EM Loads due to Plasma Scenarios