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System Design Description-DDD

Temporary First Wall Design Description Document

This document describes the design prior to CDR of the Temporary First Wall , a level 2 PBS item within the blanket system.

Approval Process			
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Change Log			
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Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	29 Apr 2024	
v1.0	In Work	23 Oct 2024	Add the document
v1.1	Approved	23 Oct 2024	remove the comments in the last version
v1.2	Signed	04 Dec 2025	Changes based on the PDR design
v1.3	Approved	05 Dec 2025	Add the description of TFW 14 chamfer

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1 INTRODUCTION

1.1 Purpose

[I] This document describes the design of the Temporary First Wall (TFW), a PBS level 2 sub-system (16.TW) of the Blanket System (BS) (PBS 16). This document reports the design status prior to the conceptual design review, and acts as a reference document for final design description.

1.2 Scope

[I] The TFW configuration consists of 437 panels mount onto the blanket shield blocks (SB), as shown in Figure 1-2, both TFW and SB are inertially cooled.

[I] The configuration model of all TFW panels as given in Figure 1-1 **[RD 1]**.

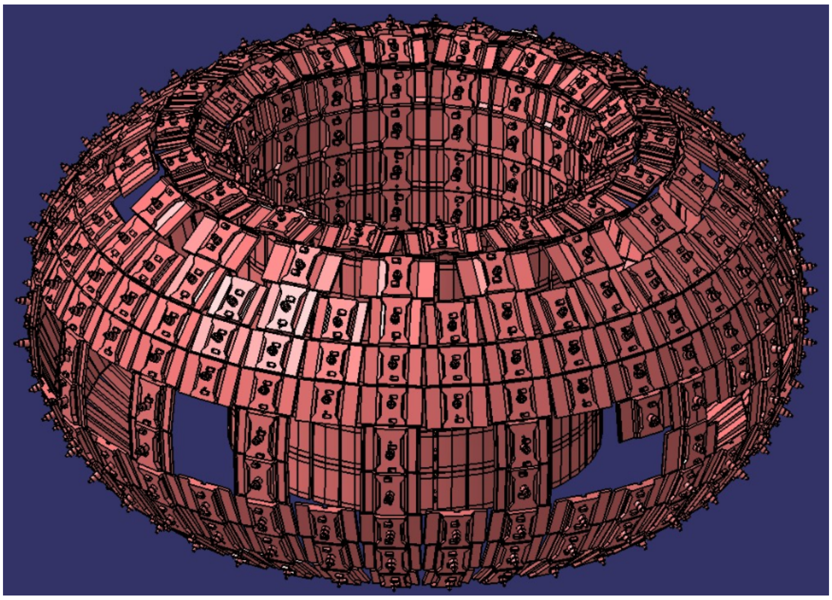


Figure 1-1 Configuration management models of all TFW panels

[I] The Plasma facing material (PFM) choice of the TFW panels is (with some exceptions) dictated by local thermal loads specified in [AD 11], as shown in Figure 1-2.

- In rows 1, 2 and 12-17 with lower convective plasma thermal loads and less risks impacted by disruptions and runaway electrons, and in rows 3-5 (plasma start up, limiter configuration), W heavy alloy WNiFe class 4 is chosen as armour material.
- In rows 6-11 and 18, TFW panels exposes to high stationary convective thermal loads or/and the high risk impacted by disruptions and REs during 15 MA/5.3T operation, bulk W is selected as the PFM.

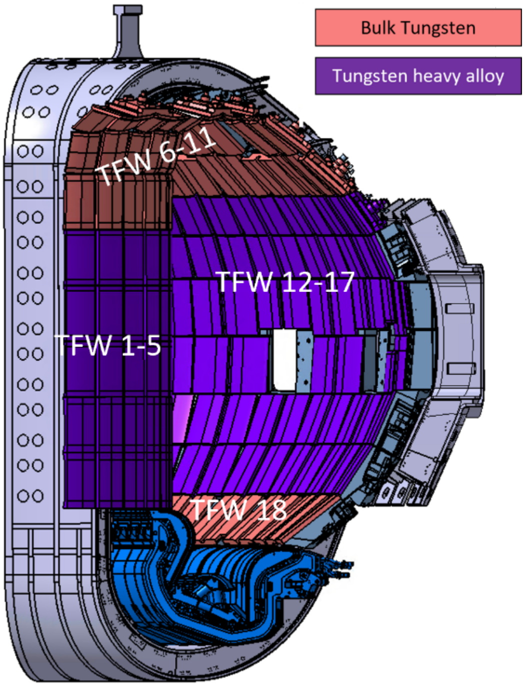


Figure 1-2. The PBS16 sub-system 'temporary first wall' configuration (left)

Table 1.2-1 Main design constraints depending on poloidal rows (see Applicability Map in **[AD 3]** *Plasma Heat Load Specification for the ITER Tungsten First Wall*)

Row	Main design constraints	SB	TFW configuration
01-02	Disruptions (lower probability), Moderate heat fluxes during normal operation	18	18
3-5	Start-up, Disruptions (in limiter configuration)	18	18
06	Disruptions, EC, IW limiter contact	18	18
07-10	Disruptions, High fluxes during diverted operation (secondary X-point region)	18	18
11	Disruptions, ports, EC	36	36
12-13	EC	36	36
14	EC, IC, ports Possible OW limiter contact (loss of control during Ramp-UP/Ramp-Down, 'cleaning' plasmas)	22	22
15		22	19
16-17	Possible OW limiter contact (loss of control during Ramp-UP/Ramp-Down, 'cleaning' plasmas)	36	36
18	Disruptions	36	36
Total number		440	437

1.3 Definitions

[I] implies informational statement, that doesn't necessarily pertain to the description of the design

BS Blanket System
W Tungsten
IW Inner Wall
SS Stainless Steel
TFW Temporary First Wall
SRO Start of Research Operation
SB Shield Block
VV Vacuum Vessel
VPS Vacuum plasma spray
OW Outer wall
PVD Physical Vapor Deposition
RE Runaway electrons
PFM Plasma facing material
Also see the complete list of all ITER Abbreviations.

1.4 References

1.4.1 Applicable Documents

Document No. and Title	IDM link	version
[AD 1] sSRD-16.TW (temporary first wall)	ITER_D_C59SXF	V2.1
[AD 2] Temporary First Wall Load Specification	ITER_D_92NARK	V1.2
[AD 3] Plasma Heat Load Specification for the ITER Tungsten First Wall	ITER_D_9PSPKZ	V3.2
[AD 4] IS-15.VV-16-007 VV Instrumentation and In-Service Inspection interface with Blanket System	TXQJEU	V1.9
[AD 5] IS-16-17-004 Interface between Blanket Modules/Manifolds & BOI	XX9MC5	V2.1
[AD 6] IS-16-17-005 Interface Sheet between Temporary First Wall Panels (PBS 16.TW) and Divertor Operational Instrumentation (PBS 17.OI)	CCDSL3	V1.2
[AD 7] IS-16-18.GI-001 Interface between Blanket System (PBS 16) and Gas Injection System (PBS 18.GI)	F7U8T3	V1.5
[AD 8] IS-16-18.PI-001 Interface between Blanket System (PBS 16) and Pellet Injection System (PBS 18. PI)	F7TX5Y	V1.10
[AD 9] IS-16-31-001 Vacuum Requirements for Blanket System	ITER_D_DVUUPV	V2.1
[AD 10] IS-16-47-001 Functional interface between Blanket System (PBS 16) and Plasma Control System (PBS 47)	TXRD66	V3.2
[AD 11] IS-16-51-001 Interface Sheet between PBS 16 Blanket System and PBS 51 IC H&CD System	EZD6ET	V2.1
[AD 12] IS-16-52-001 Upper Launcher interface with Blanket Modules	EN2R5B	V3.1
[AD 13] IS-16-52-002 Equatorial Launcher interface with Blanket Modules	ENFUNE	V3.0
[AD 14] IS-16-52-003 Electron Cyclotron stray power loading on Blanket System	ENGHC4	V3.1
[AD 15] IS-16-55-005 Interface Sheet between PBS 16 Blanket System and 55.F9 High Field Side Reflectometry	493F5L	V3.2

[AD 16] IS-16-55-006 Interface Sheet between PBS 16 Blanket System and PBS 55.D1 Bolometer System	6WMGVX	V3.6
[AD 17] IS-16-55-011 Interface Sheet between PBS 16 Blanket System and PBS 55.C1 and 55.C2 Core and Edge Thomson Scattering System	F96M2H	V2.1
[AD 18] IS-16-55-014 Interface Sheet between PBS 16 Blanket System and PBS 55.Q0 Equatorial Port Plug	4KU5D9	V3.1
[AD 19] IS-16-55-015 Interface Sheet between PBS 16 Blanket System and PBS 55.U0 Upper Port Plug	33A2C9	V4.0
[AD 20] IS-16-55-023 Interface Sheet between PBS 16. FW Blanket First Wall mounted Diagnostics and PBS 55 Diagnostics System	4GFHY6	V1.5
[AD 21] IS-16-55-027 Interface Sheet between PBS 16 Blanket First Wall and 55.E7 Radial X-Ray Camera	CCDV95	V1.6
[AD 22] IS-16-57-001 Interface Sheet between PBS 16 Blanket System and PBS 57 In-Vessel Viewing System	EUX4R7	V2.11
[AD 23] IS-16-66-001 Interface between Blanket System and RadWaste Treatment & Storage System	ITER_D_NC6FV8	V3.2
[AD 24] ITER Vacuum Handbook	ITER_D_2EZ9UM	V2.5

1.4.2 Reference Documents

Document # and Title	IDM link
[RD 1] 2025-11-24 - IRM + MAM PBS16 TFW pre-PDR	
[RD 2] 16.TFW Cursory check document Heavy design (row#04 type A) DM	ITER_D_AXVRYM
[RD 3] 16.TFW Cursory check document Heavy design (row#09) DM	ITER_D_B93BL7
[RD 4] CPD-Temporary First Wall installation	ITER_D_87T2B6
[RD 5] IC/STAC-30/5.1. Updated ITER Research Plan -Level 1	ITER_D_AXUP2U
[RD 6] IC/STAC-32/3.1. Level-2 and Level-3 ITER Research Plan	ITER_D_DUTXSZ v1.2
[RD 7] In vessel tolerances management table	ITER_D_UJ4JVC
[RD 8] ITER Materials Properties Handbook, Introduction, baseline 2009	ITER_D_2NRCSB
[RD 9] Structural Integrity Report for the Temporary FW Components	ITER_D_BZA7VA
[RD 10] DCM-16-TW Compliance Matrix SSRD downwards - SSRD-16-TW	ITER_D_C7ZPAV
[RD 11] Requirement for the CAD design of first wall plasma facing surface (Shape faceting)	ITER_D_BS3AK8

[RD 12] Blanket Module Alignment, Gap, and Step Requirements	ITER_D_87V3SE
[RD 13] 001630 Baseline 2024 - Scenario B - In-vessel changes (daughter of PCR-001600)	
[RD 14] 16.TW.Cursory_Check_meeting_CM_Temporary First Wall	ITER_D_AXVQD3
[RD 15] Normal Operations loads on TFW: Field Line Tracing study on the TFW PDR design (full wall coverage, faceted shape)	ITER_D_DEZZKJ
[RD 16] Justification of surface heat loads (FLT) penalties	ITER_D_EUEMY2
[RD 17] Heat Flux Compliance Summary and assumed FLT penalties	ITER_D_EV8WHS

2 BASIC SYSTEM FUNCTIONS AND CONFIGURATION

2.1 Functions

[I] In the 2024 baseline, the inertially cooled tungsten (W) Temporary First Wall (TFW) to be installed in Start of Research Operation (SRO) provides substantial minimization of the risks associated with physics uncertainties and plasma operational aspects for later operation in the DT-1 phase with deuterium-tritium plasmas. In particular, control and investment protection algorithms and systems (plasma control system, central interlock system, …) as well as the disruption mitigation system (DMS) will be commissioned with plasma during this phase both in L-mode to the nominal 15 MA/5.3 T levels as well as in H-mode to 7.5 MA/2.65T. The TFW panels are designed to sustain critical plasma scenarios defined in **[AD 3]** and for the loads defined in the **[AD 2]** *Temporary First Wall Load Specification*.

[I] The SRO phase is planned for 27 months of plasma operations including the demonstration of first plasma (FP), as given in the Figure 2-1.

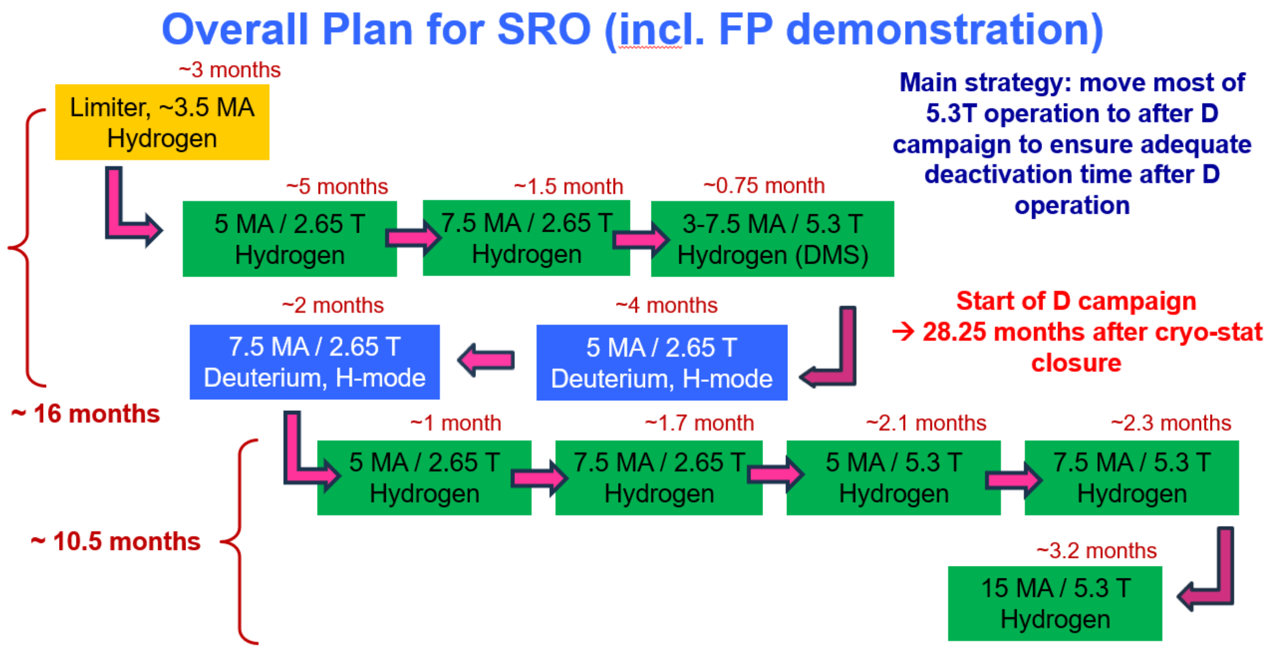


Figure 2-1 Overall operation plan for SRO phase

[I] The need for the TFW was recognized and included in the 2024 baseline through *PCR-1600 and its daughter PCRs* **[RD 13]**.

2.2 System Arrangement

[I] The TFW is a sub-system (16.TW) of the blanket system (PBS 16), and include 18 PBS level 3 items:

- 16.TW.01 – TFW row 1
- 16.TW.02 – TFW row 2
- 16.TW.03 – TFW row 3
- 16.TW.04 – TFW row 4
- 16.TW.05 – TFW row 5
- 16.TW.06 – TFW row 6
- 16.TW.07 – TFW row 7
- 16.TW.08 – TFW row 8
- 16.TW.09 – TFW row 9

- 16.TW.10 – TFW row 10
- 16.TW.11 – TFW row 11
- 16.TW.12 – TFW row 12
- 16.TW.13 – TFW row 13
- 16.TW.14 – TFW row 14
- 16.TW.15 – TFW row 15
- 16.TW.16 – TFW row 16
- 16.TW.17 – TFW row 17
- 16.TW.18 – TFW row 18

[I] All components of the TFW are in service during Start of Research Operation (SRO) phase. Before starting DT-1 phase, the TFW shall be removed.

2.3 Requirements

[I] The TFW requirements are defined in the *sSRD-16.TW (temporary first wall)*[**AD 1**] and its associated complementary applicable documents.

[I] In addition to the sSRD-16-TW, the TFW also follow the *Temporary Firs Wall load specification* [**AD 2**].

[I] Lastly, the design incorporates the requirements defined in several interface sheets, as described in §4.

2.4 Load Specifications

[I] This section briefly describes where to find further information regarding the types and magnitudes of load present on the TFW. These loads include EM loads, thermal loads, and seismic loads. Full details of these loads are available in the *Temporary First Wall load specification* [**AD 2**].

2.4.1 Seismic loads

[I] See §13.1.3 of the *TFW Load Specification* [**AD 2**].

2.4.2 EM loads

[I] See §13.1.4 of the *TFW load specification* [**AD 2**] for the electromagnetic (EM) input load cases. EM forces and moment loads are provided in resulting EM analysis reports.

2.4.3 Thermal loads

[I] See **[AD 3]** *Plasma Heat Load Specification for the ITER Tungsten First Wall* and §13.3 of the **[AD 2]** *Temporary First Wall Load Specification*. Thermal loads include 'normal operation' loads: plasma conductive and convective heat loads, photonic radiation and charge exchange, ion cyclotron parasitic heating and electron stray loads. A description of the expected off-normal events is also provided in both references.

2.5 System Performance Characteristics

[I] This section lists data and status of the TFW at all ITER life cycle states.

Table 2.5-1. Major operating states of the TFW through their lifecycle.

Operating State	Description of State
Installation	This encompasses fabrication, transportation, assembly, and installation.
Commissioning	The components are baked with the rest of the blanket system, following the processes outlined in their load specification.

	The components are subsequently cooled to warm-up conditions with the rest of the blanket system following the process outlined in their load specification.
Plasma Operation	Plasma Operation includes several sub-states at various temperatures and environments, as described in the TFW load specification **[AD 2]**.
Shutdown	The components are to be inertially cooled along with the rest of the blanket system, following their load specification.
Maintenance and Decommissioning	No maintenance is foreseen for TFW

3 Detailed Design Description

[I] To avoid the risk of a water leak on FW panels damaged by high energy REs, inertially cooled TFW panels are installed during the SRO phase, rather than the actively cooled final First Wall. This approach allows for operational learning for normal operation of 7.5 MA/2.65T H mode and 15 MA/5.3T and for disruption and REs mitigation up to 15MA/5.3T.

[I] For this purpose, the plasma poloidal and toroidal contours of each TFW panel shall be similar to that of the final FW panel counterpart but could deviate for purposes of design simplification, see **[16TWs82-R]** in **[AD 1]** *sSRD-16.TW (temporary first wall)*.

[I] The summary of these deviations and details on the rationale behind these proposed design simplifications is given in next Section 3.1 and Table 2.

[I] The validation of these design simplifications is part of the TFW design assessment, notably to verify the implication of surface peak loading or edge loading on simplified panels in terms of: W ingress to the plasma or cumulated damage (melting, recrystallization) possibly reducing the panel lifetime (notably in case of disruptions).

[I] The shaping of the TFW panels (toroidal shaping and poloidal set-backs) should allow protecting leading edges between panels for a maximum 'short-wave' radial misalignment **m_{rad} of 1 mm**, to be specified in **[RD 12]**, whereas the assumed maximum radial misalignment between neighbouring panel for the actively cooled FW is 5 mm.

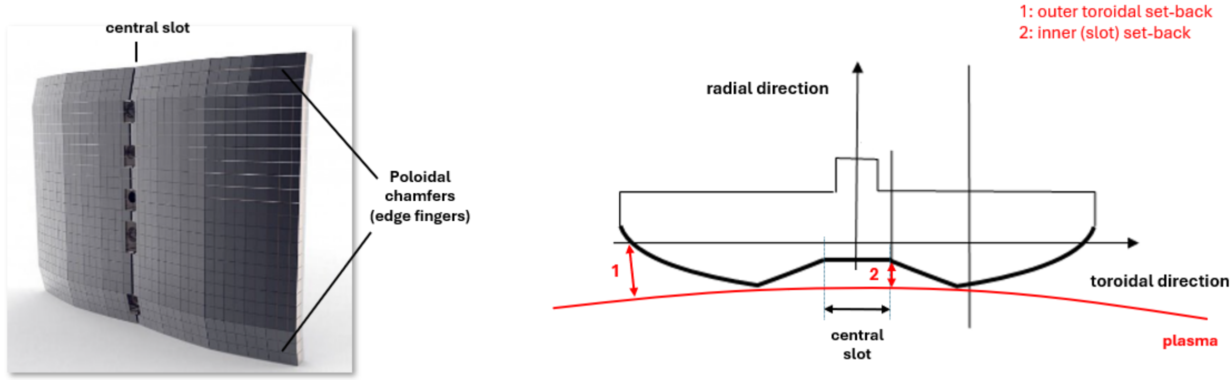


Figure 3-1: Definition of shaping parameters: (left) Illustration of a faceted inboard panel (actively-cooled FW) with poloidal chamfers - (right) Ideal toroidal shape for ITER FW panels (exaggerated scale in the radial direction)

Actively cooled FW (2024 Baseline)

	Panel row	Slot toroidal set-back	Outer toroidal set-back	Poloidal chamfer (edges fingers)	Comment
Inboard	1	35	30	30	
	2	35	30	30	
	3	35	30	30	Panels shaped for inboard limiter contact (plasma sart-up)
	4	35	30	30	
	5	35	30	30	
	6	35	30	30	Risky MD area
Top panels	7	60	60	36 - 40	
	8	60	60	40 - 30	
	9	60	60	30 - 30	
Outboard	10	60	60	55	
	11	20	30	0	
	12	20	30	0	
	13	20	30	0	
	14	10	70, *specific chamfer under investigation*	0	Initially shaped in 2009 for outboard limiter contact, large ports in rows #14-15
	15	10	70	0	
	16	15	30	0	
	17	20	30	0	
	18	20	30	0	Risky DW VDE area

Temporary FW

	Panel row	Slot toroidal set-back	Outer toroidal set-back	Poloidal chamfer (edges fingers)	Comment
Inboard	1	**15**	**15**	**0**	
	2	**15**	**15**	**0**	
	3	**15**	**15**	**0**	Panels shaped for inboard limiter contact (plasma sart-up)
	4	**15**	**15**	**0**	
	5	**15**	**15**	**0**	
	6	35	30	30	Risky MD area
Top panels	7	60	60	36 - 40	
	8	60	60	40 - 30	
	9	60	60	30 - 30	
Outboard	10	60	60	55	
	11	20	30	0	
	12	20	30	0	
	13	20	30	0	
	14	10	70, *straight chamfer implemented at the end of fingers*	0	Same shaping as the actively cooled FW has been kept
	15	10	70	0	
	16	15	30	0	
	17	20	30	0	
	18	20	30	0	Risky DW VDE area

Table 2: Summary and comparison of shaping features between the actively cooled FW (top) and the TFW (bottom) - specific panel variants are not included

3.1 Configuration Model

3.1.1 Toroidal shaping

[I] To comply with the TFW sSRD **[AD 1] [16TWs108-I]** *The toroidal profile of TFW panels is intended to protect edges as much as possible whilst ensuring an efficient spreading of heat loads on the surface, especially during transient (to mitigate intense local peak loading),* the surface shaping described in Table 2 is implemented on the TFW panels.

[I] The toroidal profile of the TFW panels aims at spreading heat loads on the plasma-facing surface to mitigate as much as possible local peak loading (also considering other design or manufacturing constraints). In addition, whilst avoiding all panel/ tile/finger leading edge is infeasible (especially during transients), the TFW toroidal and poloidal shape should intend to keep exposed edge loading within acceptable design limits during normal operation, and avoid damage yielding failure during transients.

[I] As shown in Figure 3-2, following TFW CDR panel's suggestion, the toroidal shaping of TFW panels have been improved : instead of 3 facets not conformal with the theoretical surface log shape, a new surface profile following the FW theoretical shaped surface has been used, but approximated with 5 large tiles.

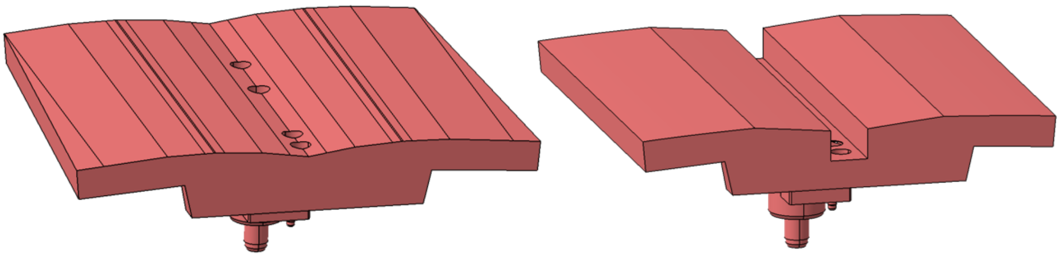


Figure 3-2 TFW toroidal shaping evolution: CDR (left), PDR (right)

[I] A faceting of the Final FWP logarithmic shapes have been applied, resulting in 5 large facets to ease TFW manufacturing and reduce cost (as shown in **Figure 3-3**). Faceting the theoretical curved shape of FWP surface is not ideal for plasma thermal load spreading, as yielding inevitably higher local peak heat load **[RD 11].** The resulting heat load 'penalty' on the proposed faceted shape is assessed by Field Line Tracing Analysis **[RD 15**]. Central roof tiles have been implemented to avoid having a gap at the panel apex, leading to the edge loading at high plasma parallel heat fluxes.

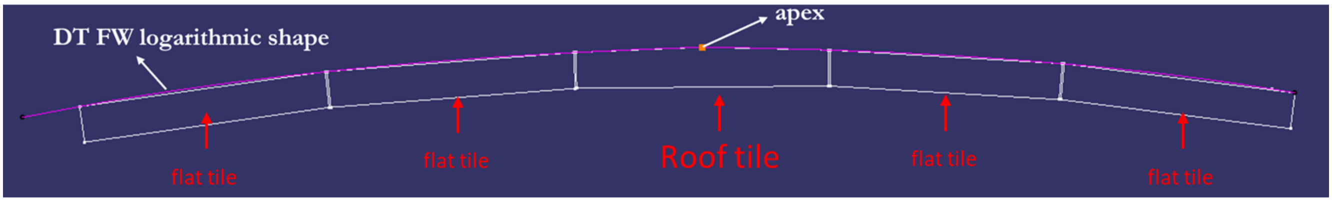


Figure 3-3: Illustration of the TFW PDR facet design (TFW row 4)

[I] To ease manufacturing and improve heat load distribution during start-up, the toroidal set-back for rows 1–5 has been reduced from 30 mm (as used in the DT first wall) to 15 mm. FLT analysis **[RD 15]** confirmed that the reduced set-back remains compatible with the plasma scenarios specified in **[AD 3].**

[I] A small step occurs at the transition between rows 5 and 6 as both TFW panels do not have the same toroidal set-backs (see Table 2 and **Figure 3-7**). The compatibility of such configuration with plasma operation and the risk of edge loading in this area remains to be analysed for the FDR, if the reduced set-back option (15mm) is confirmed.

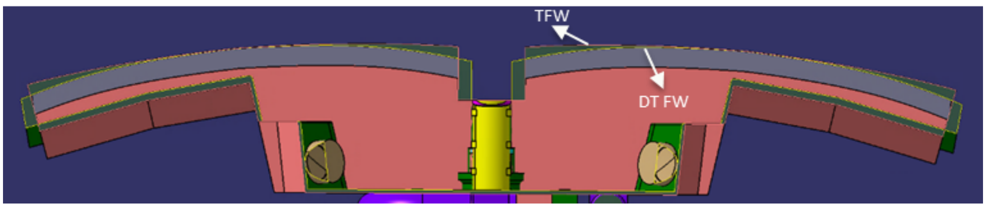


Figure 3-4: Illustration of DT FW and TFW toroidal set back (row 4)

[I] A simplification of the strong curvature of panels 14-15 (at the end of finger) is also proposed, keeping the same set-back, see Figure 3-5**.**

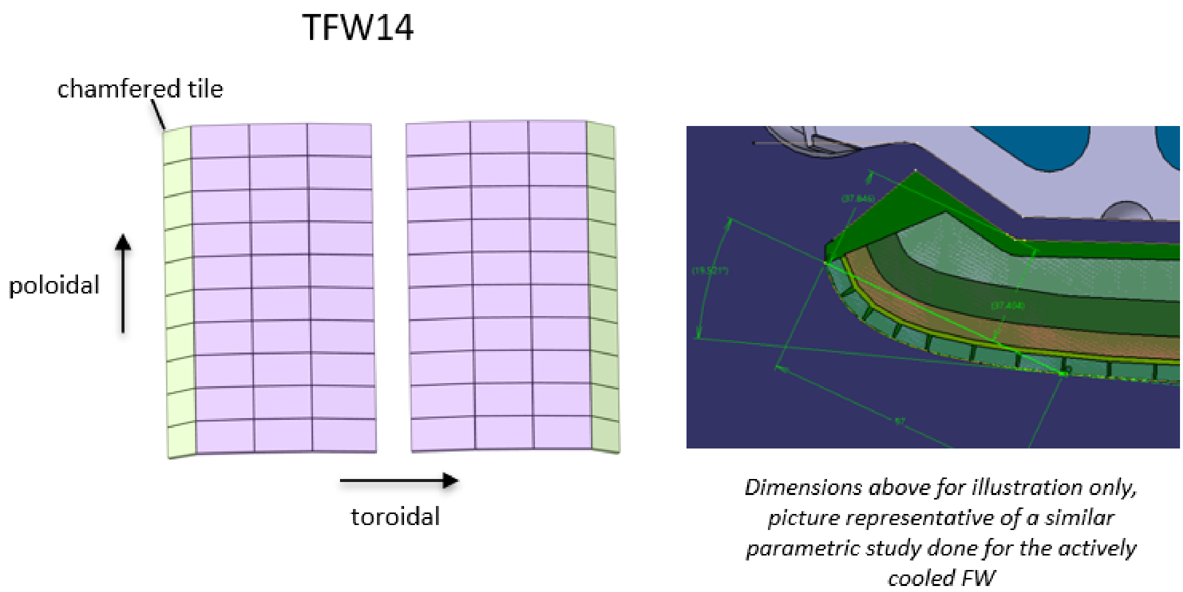


Figure 3-5 Simplified shaping implemented at the end of TFW 14 fingers, consisting in approximating the set-back curve by a simpler straight chamfer (single tile)

[I] The reduced toroidal setback on inboard rows leading to a clash with the blanket assembly tool (BAT) gripper, as shown in Figure 3-6. Further design improvement is needed to solve this clash in the FDR phase.

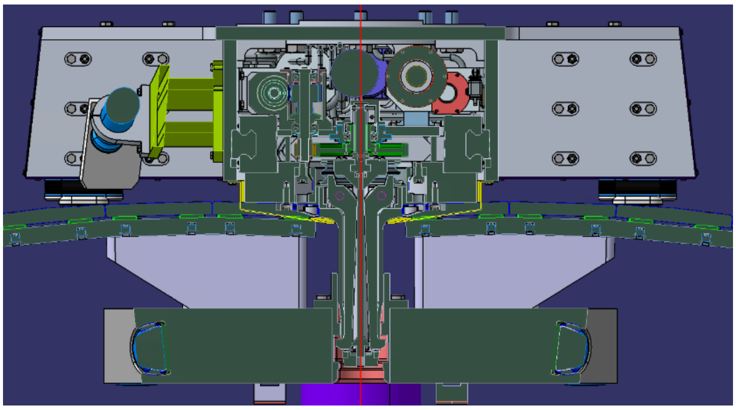


Figure 3-6 A clash between the TFW and the blanket assembly tool (BAT) gripper

3.1.2 Poloidal shaping

[I] Lessons learned from Be first-wall (FW) manufacturing show that edge fingers are complex both in design and in fabrication. In the 2024 baseline, the Be FW has been replaced with a W FW, increasing the melting threshold from approximately 1300 °C to about 3400 °C. This significantly enhances the thermal margin and better accommodates the high heat flux generated by poloidal leading edges. From these considerations, unlike to DT WFW, the poloidal chamfers in TFW rows 1-5 have been removed from the TFW PDR configuration. For TFW row 6, only the upper poloidal chamfer is kept to allow a smooth transition to the panel 7 above, since the disruptions and RE may impact this area and poloidal edges require better protection in this region.

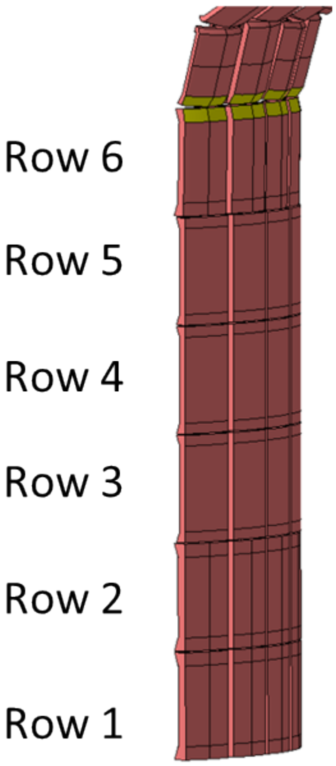


Figure 3-7: Illustration of TFW configuration model rows 1-6

[I] For the detailed model developed for row 9 for the TFW PDR, the latest poloidal chamfer dimensions agreed for the actively cooled FW (2024 Baseline model) have been taken as basis, and propagated to the TFW CM. This updated design (in pink in the **Figure 3-8** below) results in less steep poloidal chamfer slopes for top panels.

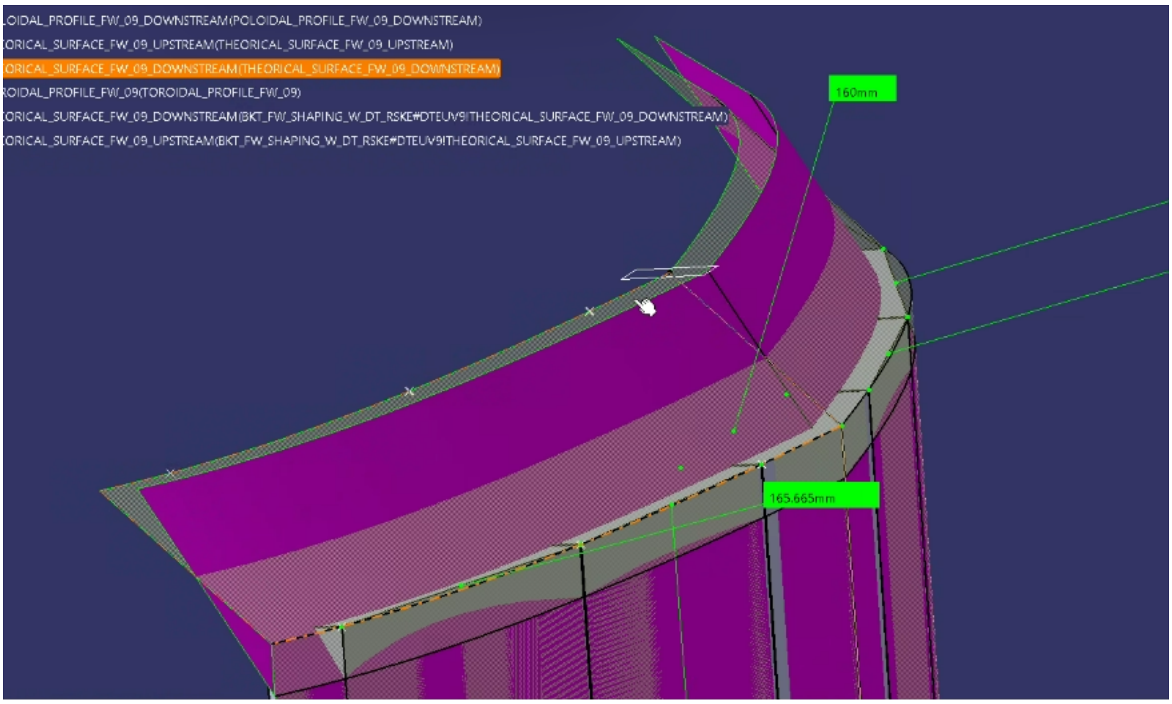


Figure 3-8: Illustration of TFW configuration model row 9.

3.1.3 Central slot width

[I] The central slot width for all TFW panels has been increased from 60 mm (in the DT FW) to 100 mm by "chopping" the tiles close to the central slot (as shown in **Figure 3-9**), without modifying the shaping (required set-backs).

[I] This design modification facilitates the implementation of the interface with both the diagnostics and remote handling systems. This leads an increase of view factor for diagnostics installed on the central slot, and this potential impact should be accessed.

[I] Regarding plasma convective/conducted loads, FLT analysis in **[RD 15]** has demonstrated that this enlarged central slot width does not yield edge loading for the specified plasma conditions in **[AD 3].**

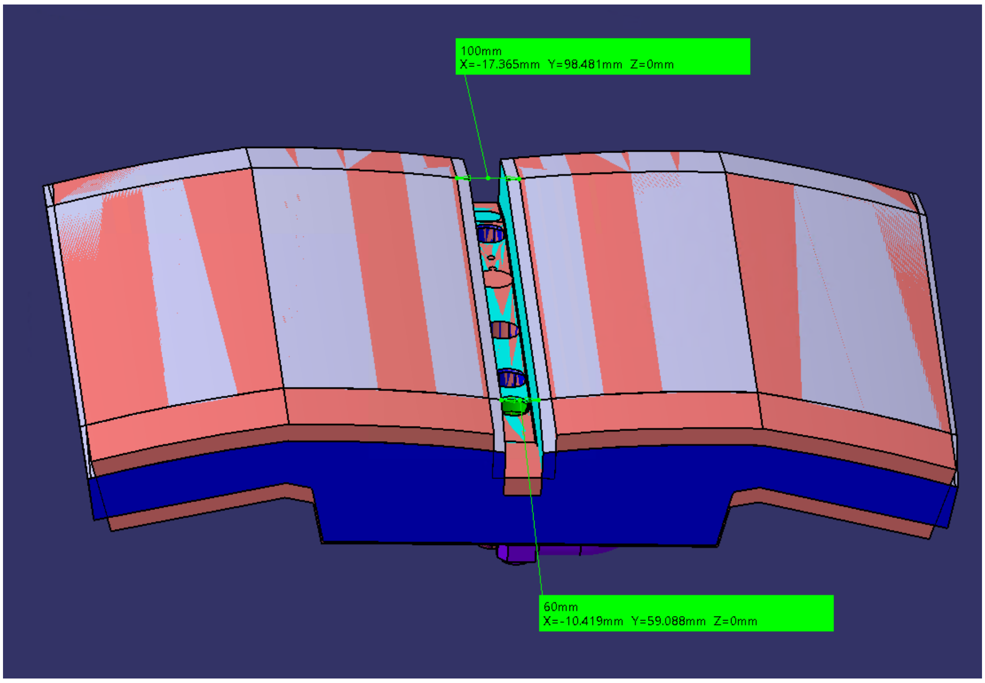


Figure 3-9: Illustration of the central slot width for both DT FW (gray) and TFW (red)

3.1.4 Removal of the trapezoidal (non-functional) areas for all TFW panels

[I] Many DT FW panels are trapezoidal, which results in each finger pair having a different length, complicating the panel manufacturing process. Removal of the *so-called* non-functional areas has been proposed for the DT FW in some outboard rows (RFDA scope) to simplify the manufacturing.

[I] Providing nuclear shielding and preventing tritium permeation on the shield blocks is less critical in the SRO phase. Therefore, the removal of non-functional areas from the TFW panels is subject to fewer constraints compared with the DT FW. For the PDR phase, the non-functional areas of all TFW panels have been removed. However, the impact of ECRH stray load exposure of uncovered shield blocks in some specific areas of the wall, resulting from this simplification, should be assessed. The same assessment should be done to assess the risk posed by the impact of large transients (especially in the top panel areas) during SRO.

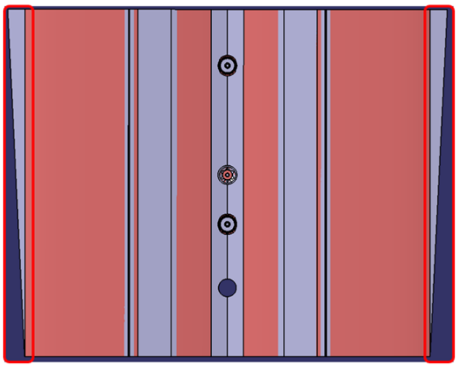


Figure 3-10: Illustration of the removal of the trapezoidal (non-functional) areas in TFW row 13

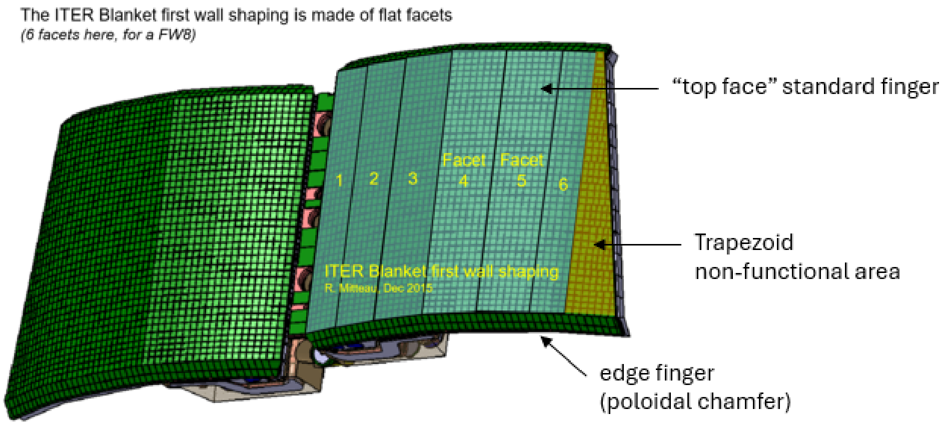


Figure 3-11: Illustration of trapezoidal (non-functional) areas for the final FW#8

3.2 TFW detailed design description

3.2.1 Detailed design overview

As shown in the figures below, the TFW panel preliminary design consists of 10 fingers per panel, each of them attached to a stainless steel beam via bolted connections. Each finger consists of 10 tiles, each of them attached to a stainless steel support via bolted connections. The beam is equipped with interfaces for the SB, TFW installation tools and diagnostics. The interfaces are detailed in §4.

Three detailed models have been drafted for the PDR thermal-structural and EM analyses: one model in row 4 designed to address the high convective plasma thermal load during plasma start up **[RD 2]**, one model in row 9 designed to address the high convective plasma thermal load during flat top (second x-point) and high thermal and EM loads during 15 MA disruptions **[RD 3]** and one model in row 14 designed to address an accumulation of heat loads from plasma and from heating systems (ECRH and ICRH).

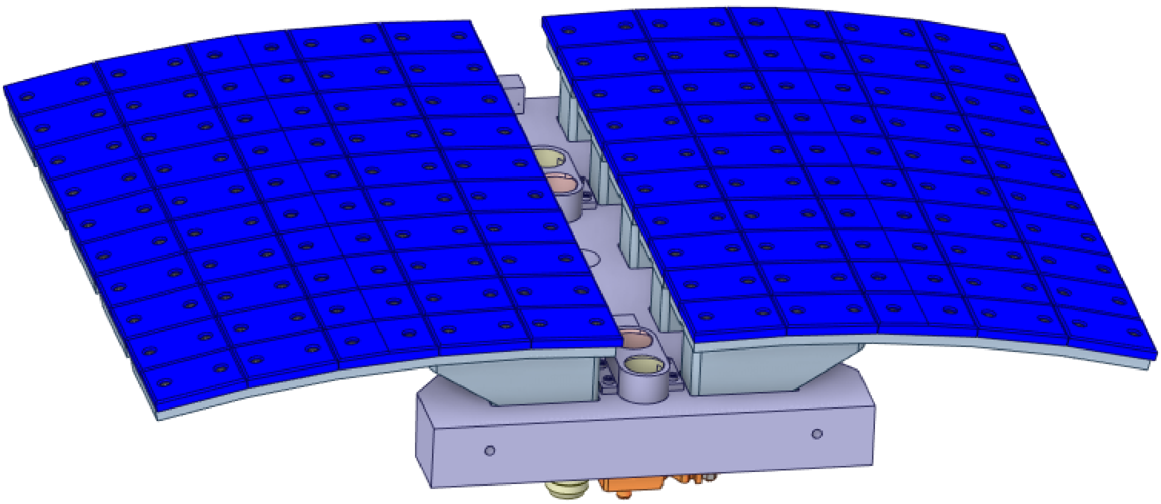


Figure **3-12**: TFW design in row 4 (front view)

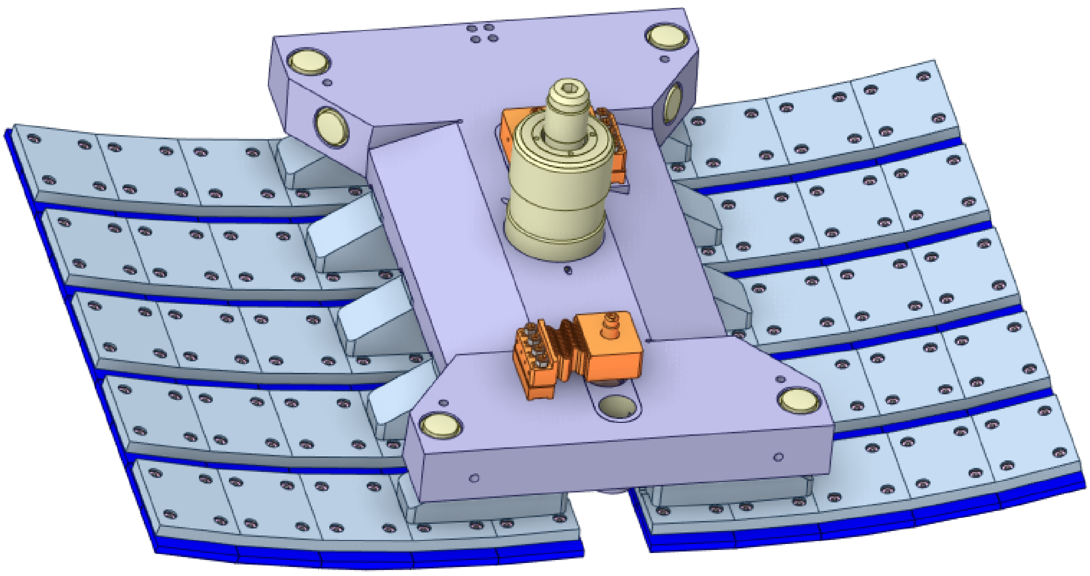


Figure **3-13** TFW design in row 4 (back view)

The tiles are either made of pure Tungsten or Tungsten Heavy Alloy (WHA), see the figure below. Tungsten-coated tiles are currently outside of the PDR baseline and kept as back-up in case the qualification and R&D tests are successful. Each of the plasma facing material (W, WHA, W-coating) can be mounted as a tile on the fingers. They can even be changed later on or mixed within the same panel if needed. Currently, this is not the case and the tiles are made of the same material within the same panel.

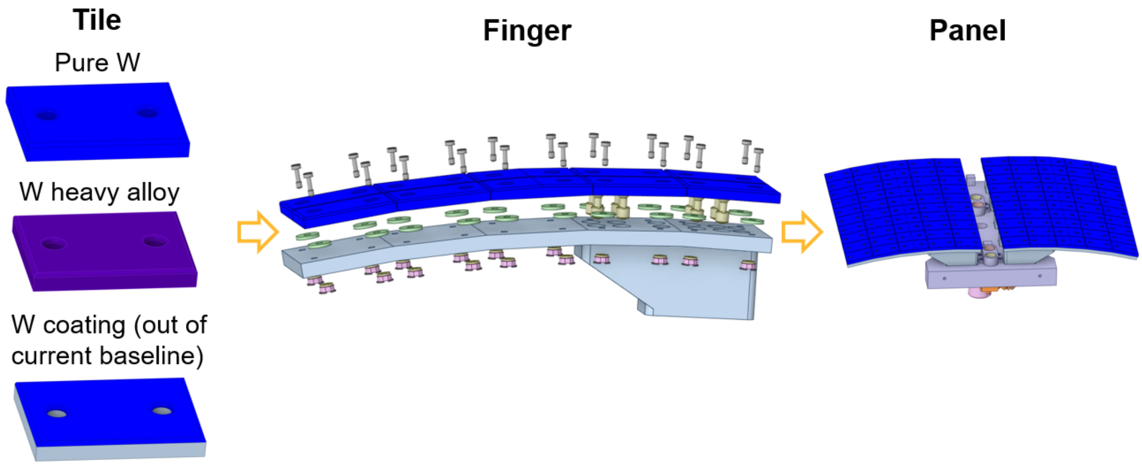


Figure **3-14** TFW design strategy with different armour materials

3.2.2 *Tile design*

The tiles are mechanically connected to the stainless steel structure thanks by two bolted connections consisting of M8 bolt, spring washer, a nut and a washer playing the role of a spacer between the tile and the structure. The detail of this connection is shown in the figure below.

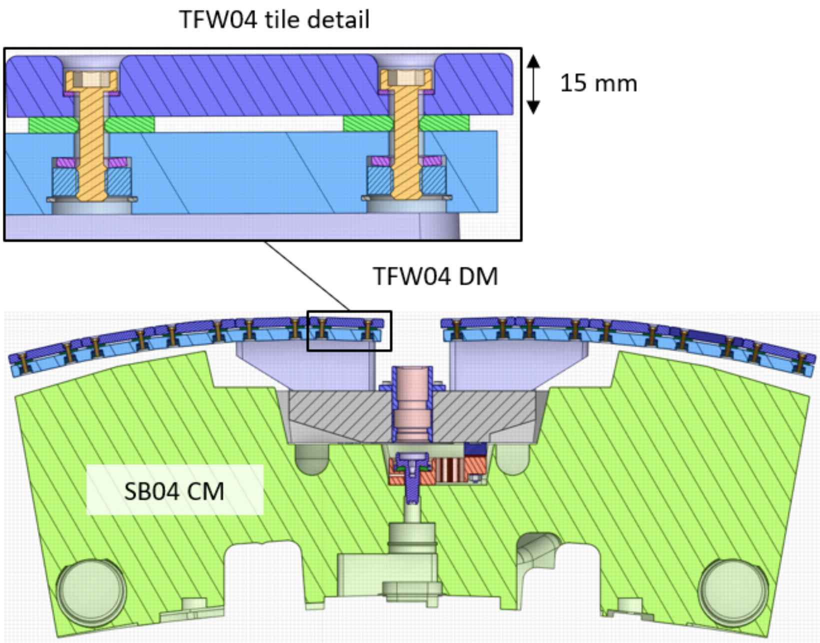


Figure **3-15** Overview of the tile location and the bolted connections

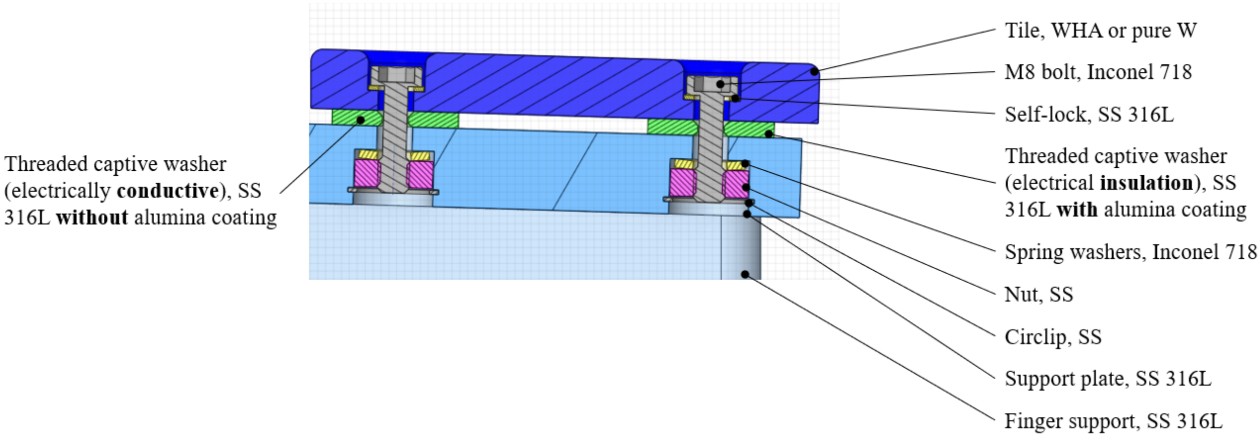


Figure **3-16** Detail of the tile connection to the SS support

Each part of the bolted connection is designed to be captive, therefore no fasteners will fall into the vacuum vessel during assembly or in case of maintenance. The nut is trapped by a circlip and is designed to slide within its compartment in such a way that the spring washer function is respected, see below.

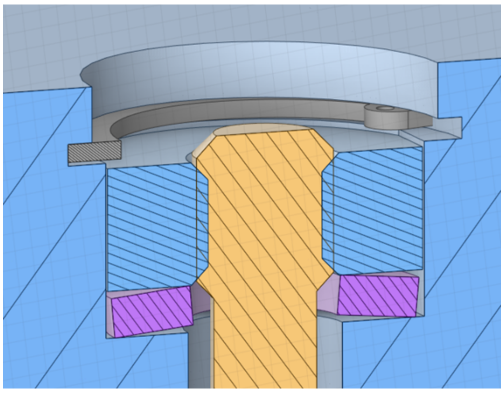
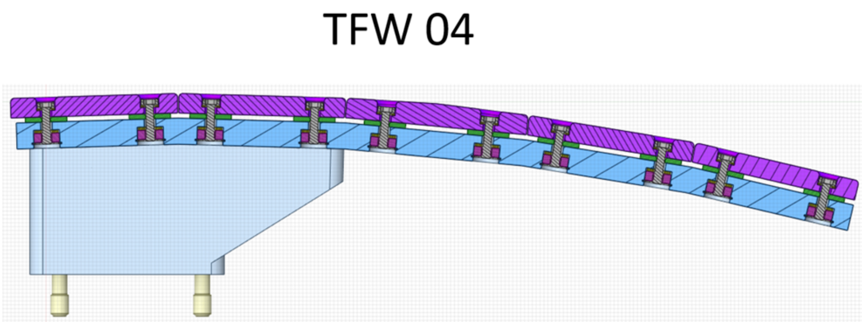


Figure **3-17** Detail of the spring washer and nut

In the current baseline, as shown in Figure 1-2, the tile are:

- 15mm thick with WHA from row 01 to 05, with an exception for the central tile with roof shape
- 20mm thick with pure W from row 06 to 11 and row 18 , with an exception for the central tile with roof shape
- 15mm thick with WHA from row 12 to 17, with one exception for the tiles at the extremities of the panels close to ports with 20mm

A cross section of the representative panels in these 3 regions is shown below.



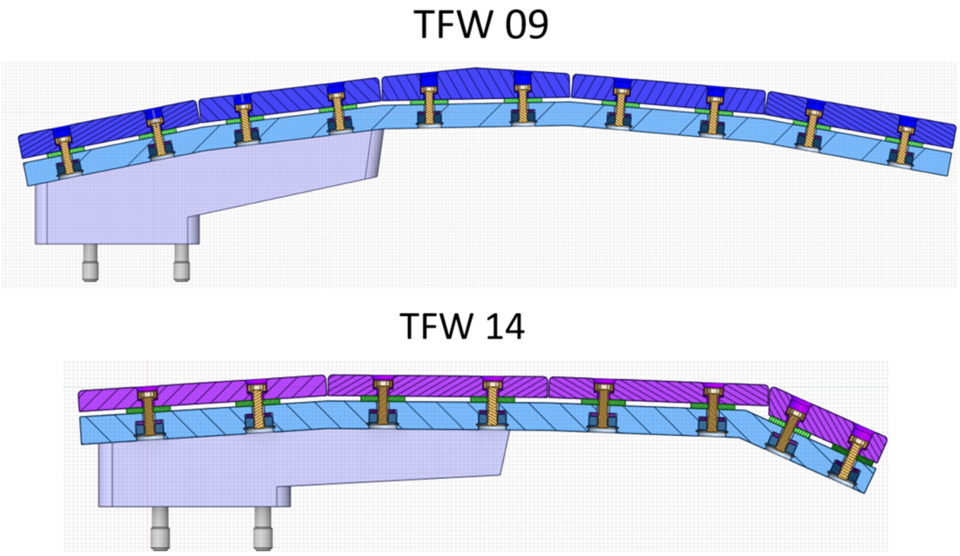


Figure **3-18** Detail of the tile material, faceting and thickness for specific regions (row 04, 09 and 14)

The tile thickness depends on the need for heat capacity and the material depends on the risk for thermal loads during disruptions and runaway electrons. The toroidal length of the tile and the poloidal height are a compromise between the number of tile (related to cost) and the risk of fracture during EM events. The toroidal length of the tile varies from 92mm for the smallest one and 181mm for the longest one, both extremes being part of TFW14. The span between the 2 bolts of a tile is standard and applies for all tiles except one tile, it is 80 mm.

Radii of 3mm have been added to the edges of the tiles and around the bolt holes in order to avoid sharp edges and dissipate the edge loads. Bolts are recessed in order avoid any plasma convective heat flux, to shadow them from plasma radiation and to allow for heat diffusion within the tile before reaching the bolt. Layers thicknesses for 15mm and 20mm thick tiles is provided in the figure below. 5mm are kept below the bolt head to reduce the stresses.

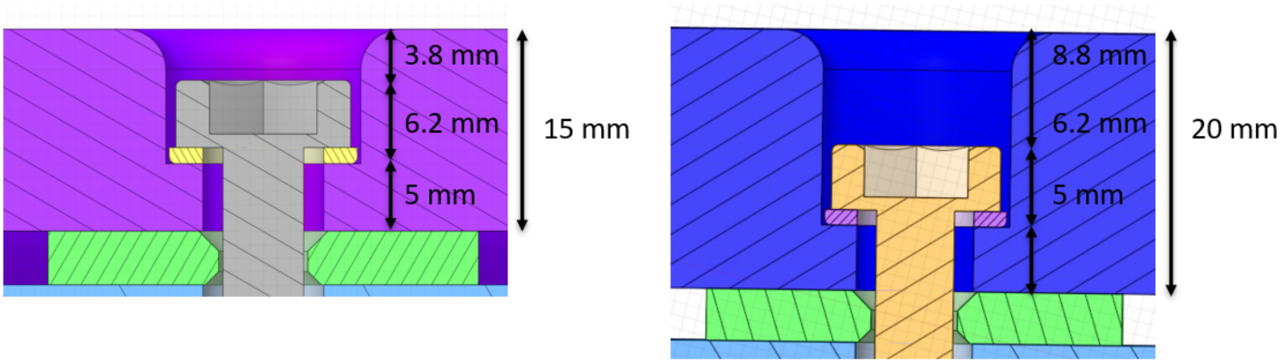


Figure **3-19** Layers thicknesses for 15 and 20mm thick tiles

3.2.3 Finger design

Most of the panels have standard fingers while some other panels, typically in disruption regions, have so called edge fingers with tiles representing the poloidal chamfer. See an example for row 04 and 09 below.

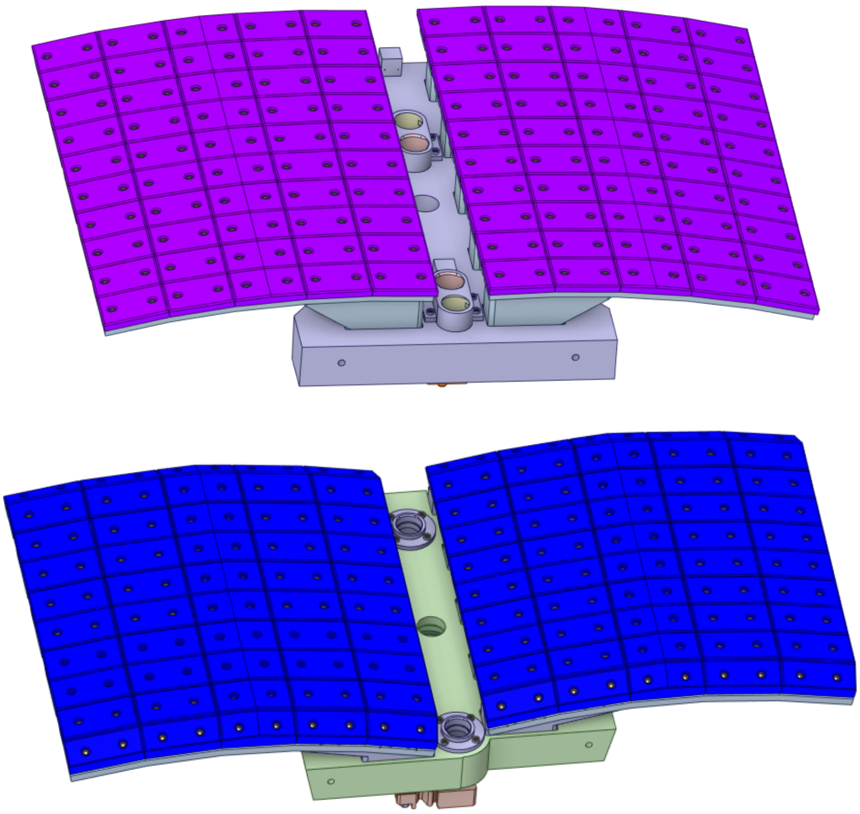


Figure **3-20** TFW04 with 10 standard fingers only (top) and TFW09 with 6 standard fingers and 4 edge fingers (bottom)

The design for edge fingers is similar to the design for standard fingers but the complexity for design and manufacturing is very different. See below an example of standard and edge fingers in TFW09.

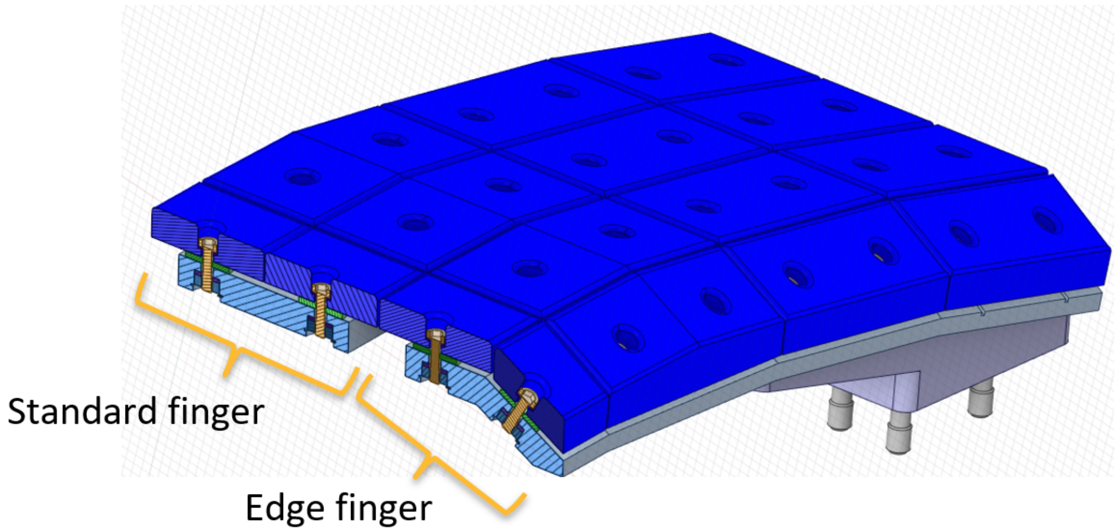


Figure **3-21** Standard and edge fingers in TFW09

Each finger is composed of a faceted plate following the tiles facets and of a support connecting this plate to the beam, detailed in the next chapter. Both the plate and the support are connected with bolts, whose number and size are designed to withstand the worst-case EM load. A rib between these two components helps transferring the some of the forces to the structure, avoiding shear with the bolts, see the cross sections in the figures below.

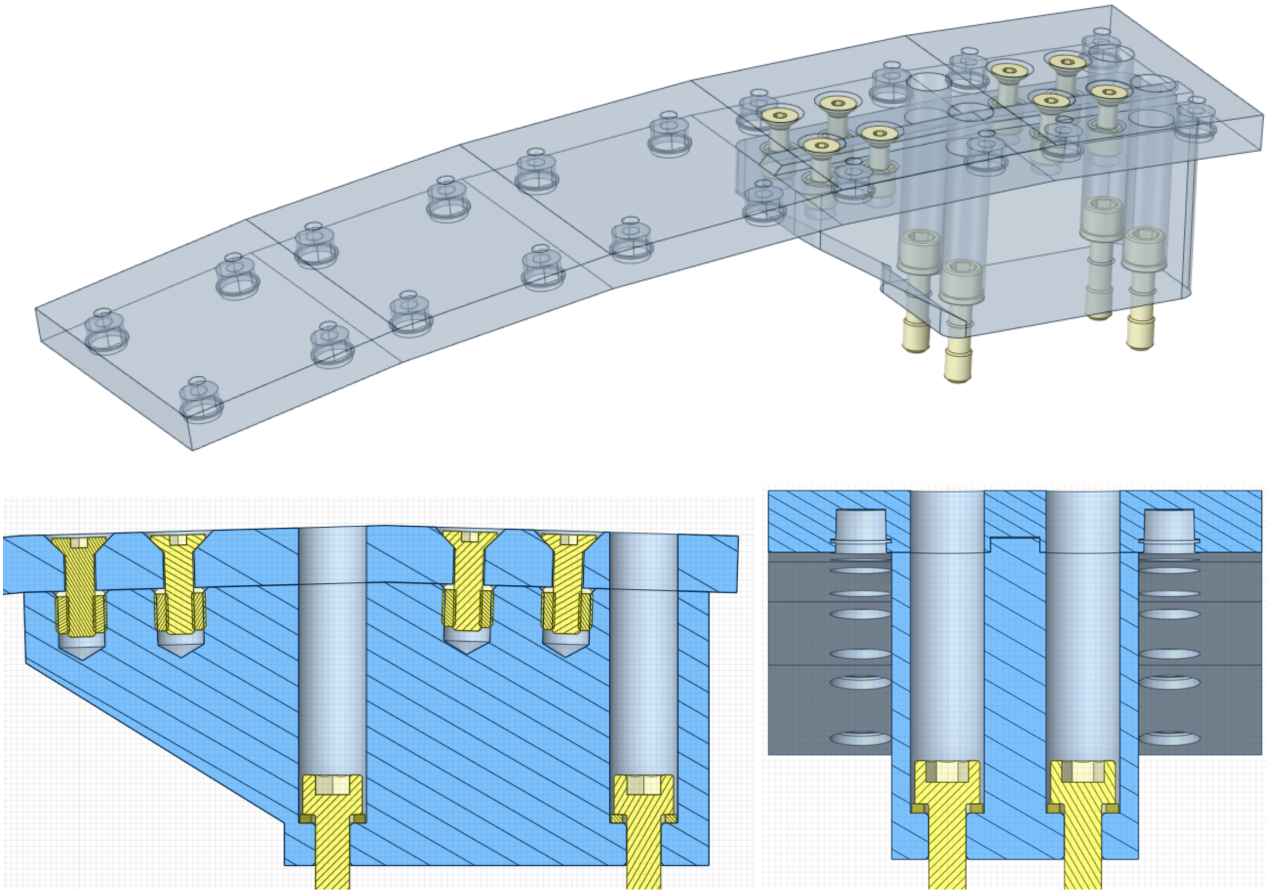


Figure **3-22** Finger detail and connection between plate and support

3.2.4 *Beam design*

The beam connects the fingers to the SB and integrates the fingers thanks to four M14 bolts. Its design has changed a lot between CDR and PDR mostly because the CDR version of the beam was deforming too much under EM loads. The thickness of the beam has then been changed from 30mm to 90mm. In reality, the beam doesn't need to be that thick for a deformation point of view but it gives margins for the interfaces with diagnostics and remote handling, it allows to thread the barrel into the beam and to use the same design than the DT FW for all TFW-SB connections (Electrical straps, pads, central bolt). The beam is slitted in 4 locations in order to reduce the poloidal moment generated by the beam under Eddy current, see the figure below. In addition, the fingers are embedded within the beam to avoid the shear in the bolts by transferring the poloidal forces created by the radial Halo current.

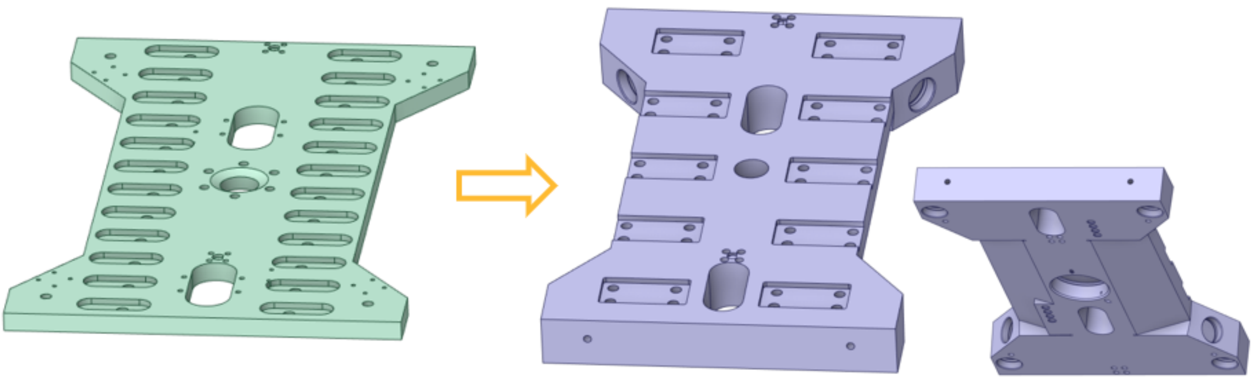


Figure **3-23** CDR (left) vs PDR (right) beam designs

The strategy to connect the beam to the SB is similar to the DT FW design, with an initial gap between the barrel and the SB that gets closed during the central bolt preload (between 200 and 300kN for this TFW04 with 1.5mm gap). The rest of the preload is then applied but is not inducing stresses in the barrel anymore. The DT FW strategy with spherical washers and a Spiralock central bolt is reproduced to allow angular misalignment between the SB and the TFW. The detail of this connection is shown in the figure below.

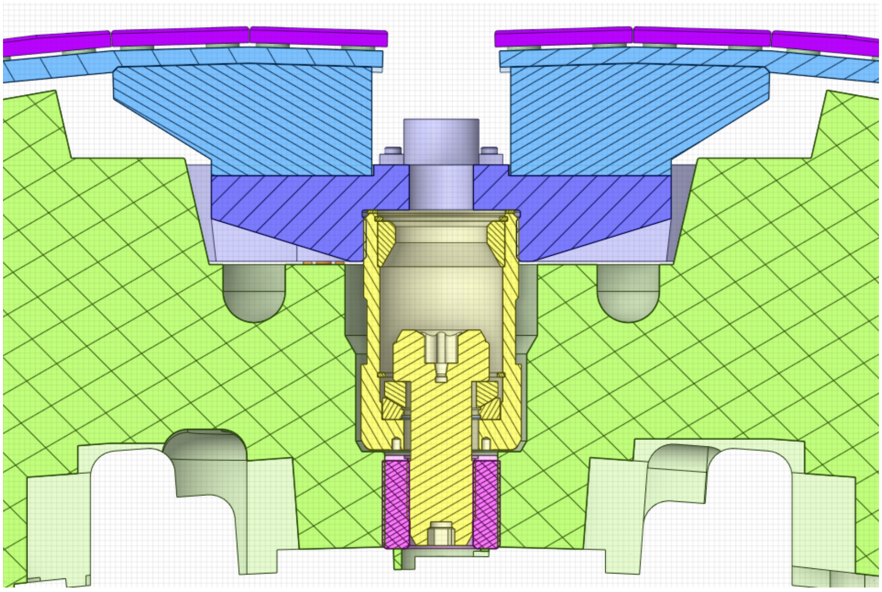


Figure **3-24** Detail of beam design, barrel and central bolt

3.2.5 Gaps and steps between tiles and fingers

[I] To protect edges between fingers and tiles against potential plasma field line penetration and misalignments, toroidal gaps between tiles is set to 1 mm, and poloidal gaps between fingers is set to 2mm for the PDR design, for both W and WHA panels.

[I] Given than the gap sizes are close to the EC wave ~ 0.8mm, the implementation of rounded edges in risky areas (e.g. the ones with cables nearby) will be investigated.

[I] The bolt hole diameters span is 14.5 mm. Radius of 3mm is implemented at the sharp edges of these bolt holes to better spread loads and mitigate melting damage or local overheating in case of edge loading.

[I] The tolerance band foreseen for gaps and steps between tiles and fingers are: m_tor +/-0.5mm, m_rad +/-0.3mm.

3.3 Description of TFW-SB connections

The TFW-SB connections, such as the electrical straps, the radial and X-pads, and the central bolt are duplicated from the DT FW design. The main reasons for that decision are:

- Homogenization of assembly and disassembly sequences
- Identical interfaces between DT FW and TFW
- Very similar EM loads because of the full magnetic configuration at the end of SRO (15 MA/5.3T)
- Time saving for re-designing and qualifying new components

3.4 Mechanical Design

[I] The mechanical attachment of W plates on SS support is detailed in §0.

[I] The TFW panels are mechanically connected to the SB via bolted connections which is detailed in the blanket interface section (§4.2)

3.5 Seismic Design

[I] The seismic load has been considered in TFW load combination.

3.6 Instrumentation and Controls Design

[I] The feasibility to install operational instrumentation on TFW is under development. Preliminary results will be shown during the CDR meeting.

3.7 Vacuum Design

[I] The TFW do not form part of the primary vacuum boundary, but are inside the primary vacuum; they therefore shall be designed as Vacuum Class VQC 1B components. **[16TWs56-R][AD 1].**

[I] The design, assembly, construction, and operation of the TFW shall comply with the ITER Vacuum Handbook **[16TWs100-R] [AD 1].**

3.8 Electromagnetic Design

The finger concept with several W tiles in toroidal direction assembled on SS support is designed to reduce the forces and moments induced from eddy currents during a disruption.

Full electrical contact is made to the SB via electrical straps as shown in Figure 4-2.

Electrical path is presented in the figure below.

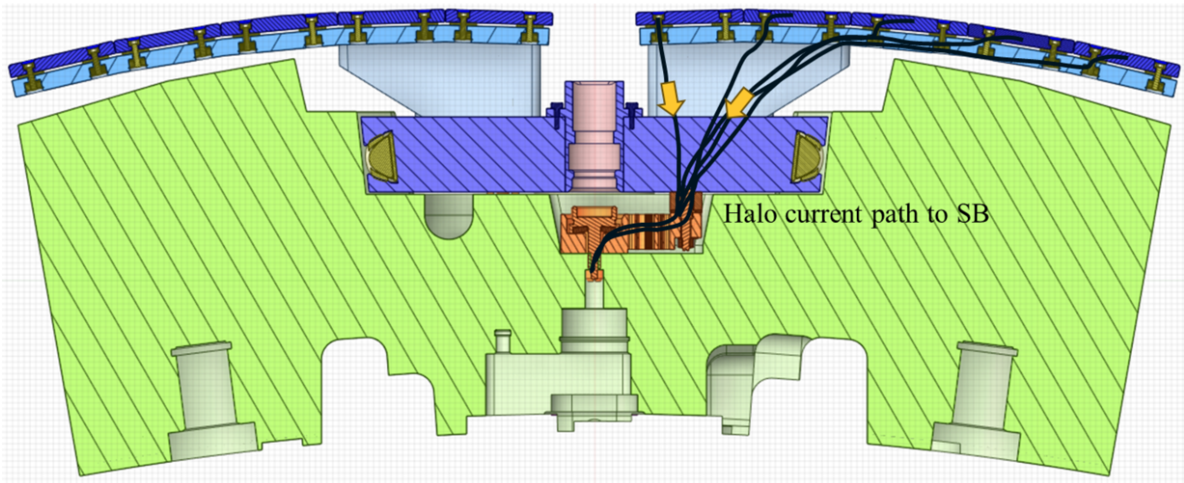


Figure **3-25** Electrical path for Halo current

3.9 Nuclear Shielding Design

[I] SB contributes the nuclear shielding for VV. There are no nuclear shielding requirements for the TFW design **[AD 1]**.

3.10 Material selection

[I] The structural parts of the TFW are fabricated from non-magnetic austenitic stainless-steel type 316L-IG.
[I] The plasma facing parts for the heavy design concept are fabricated from W-IG. For the light design concept, the plasma facing material is W coating on austenitic stainless steel (316L-IG).

3.11 Manufacturing Design

[I] The manufacture of the heavy design is designed based on simple manufacturing process. The bulk W is machined or cut to the designed shaping and dimensions, and then bolted to the structural support to form a finger.

[I] The manufacture of the light design is designed based on W coating 316L-IG structural material.

3.12 Installation and Assembly Design

The installation of the TFW onto the SB is described in the *CPD-Temporary First Wall installation* **[RD 4]**.

[I] For further detail will be described in the interface sheet between TFW and blanket assembly tools.

3.13 Testing and Inspection Plan

This section will be expanded in the following revision of the document.

3.14 Decommissioning Plan

This section will be expanded in the following revision of the document.

4 INTERFACE DESIGN

[I] The TFW interfaces are controlled within the interface control documents (ICD) created for PBS 16. Each ICD contains instructions on how the two systems interface, and where to find the relevant interfacing information. They each list the location and basic contents of each interface sheet of relevance.

Table 3.14-1. Each interfacing PBS is associated to the referenced interface control document.

Interfacing PBS No.	Interfacing PBS	Interface Control Document
PBS 15.VV	Vacuum Vessel	ITER_D_2NR7LR
PBS 16	Blanket	ITER_D_AGBMZL
PBS 17	Divertor	ITER_D_2KTFAD
PBS 18	Fuelling and Wall Conditioning System	ITER_D_2MGX75
PBS 22	Machine Assembly Tooling	ITER_D_2FNR6R
PBS 31	Vacuum	ITER_D_495KFU
PBS 47	Plasma control System	ITER_D_6N5BTR
PBS 51	Ion Cyclotron Heating and CD System	ITER_D_2LAEWB
PBS 52	Electron Cyclotron Heating and CD System	ITER_D_33ZNNM
PBS 55	Diagnostics	ITER_D_33MYP2
PBS 57	In-Vessel Viewing System	ITER_D_NC8CVR
PBS 66	Radwaste Treatment and Storage	ITER_D_49CLTF

[I] The interface requirements of the TFW are documented through interface sheets. This section describes the design implementation of each interface.

Table 3.14-2. TFW relevant IS. Blue rows are 16.TW specific; Others are general to the Blanket System.

PBS No.	Interfacing PBS	Applicable Interface Sheet	Reference
PBS 15.VV	Vacuum Vessel	IS-15.VV-16-007	**[AD 4]**
PBS 17	Divertor	IS 16-17-004	**[AD 5]**
		IS-16-17-005	**[AD 6]**
PBS 18	Fuelling and Wall Conditioning System	IS-16-18.GI-001	**[AD 7]**
		IS-16-18.PI-001	**[AD 8]**
PBS 22	Machine Assembly Tooling	To be created	
PBS 31	Vacuum	IS-16-31-001	**[AD 9]**
PBS 47	Plasma control System	IS-16-47-001	**[AD 10]**
PBS 51	Ion Cyclotron Heating and CD System	IS-16-51-001	**[AD 11]**
PBS 52	Electron Cyclotron Heating and CD System	IS-16-52-001	**[AD 12]**
		IS-16-52-002	**[AD 13]**
		IS-16-52-003	**[AD 14]**
PBS 55	Diagnostics	IS-16-55-005	**[AD 15]**
		IS-16-55-006	**[AD 16]**
		IS-16-55-011	**[AD 17]**
		IS-16-55-014	**[AD 18]**
		IS-16-55-015	**[AD 19]**
		IS-16-55-023	**[AD 20]**
		IS-16-55-027	**[AD 21]**
PBS 57	In-Vessel Viewing System	IS-16-57-001	**[AD 22]**
PBS 66	Radwaste Treatment and Storage	IS-16-66-001	**[AD 23]**

4.1 Vacuum Vessel Interface (PBS 15.VV)

[I] The TFW interfaces with the vacuum vessel solely in respecting the nominal clearances in the radial, toroidal, and poloidal directions between the TFW and VV temperature monitoring sensors in accordance with the In-Vessel tolerance management table **[RD 7]**.
[V] The model approval for the CMAF v1 **[RD 1]** is more than 10 mm in all directions from VV temperature monitoring sensors.

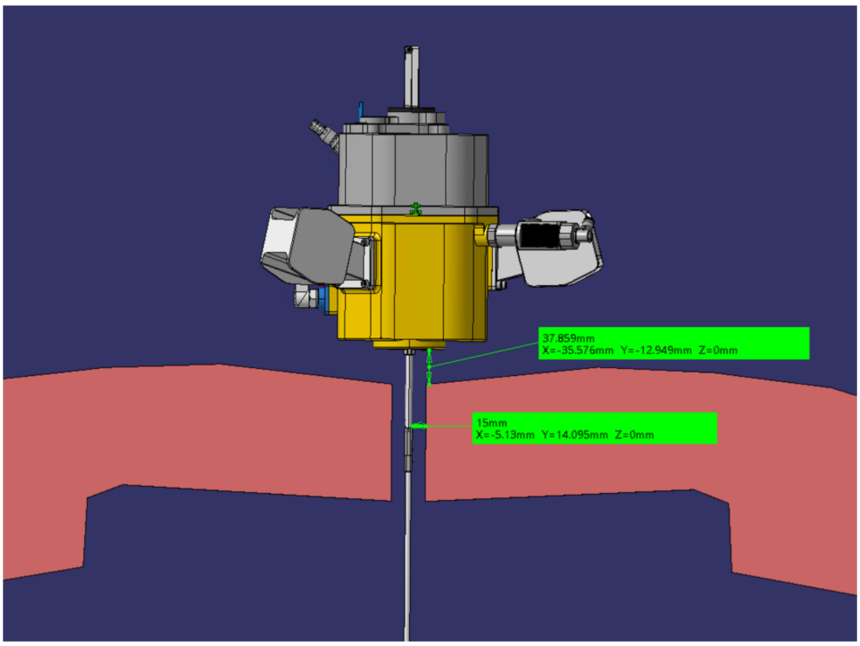


Figure 4-1 TFW clearance to VV inspection tools

4.2 Blanket Interface (PBS 16) and machine assembly tooling interface (PBS 22)

[I] This section describes the implementation of the interface points between the TFW and the blanket sub-system shield block and machine assembly tooling.

[I] All TFW interfaces with the Shield Blocks replicate as much as reasonably achievable those of the final First Wall.

[I] As shown in Figure 4-2, the principal attachment between FW and SB is the central bolt. The central bolt will be in parking position during the TFW insertion and prior bolting.

[I] The TFW electrical straps, fixed on TFW central plate, provide electrical connection between TFW and SB. They are pressed against SB by bolt tightening ensuring correct conductance.

[I] The interfaces for handling are the gripping holes on which gripping fingers will be fixed that will apply a force on the TFW surfaces in order to counteract the torque during handling.

[I] The TFW panel is positioned onto the SB by means of insulated pads fixed on the TFW central plate (see Figure 4-2and Figure 4-3)

- TFW radial position is provided by contact of the 4 TFW radial pads to SB ensured by central bolt pretension
- TFW orientation is made by 4 TFW X pads.

[I] The installation of the TFW onto the SB is detailed in the *CPD-Temporary First Wall installation* **[RD 4]**.

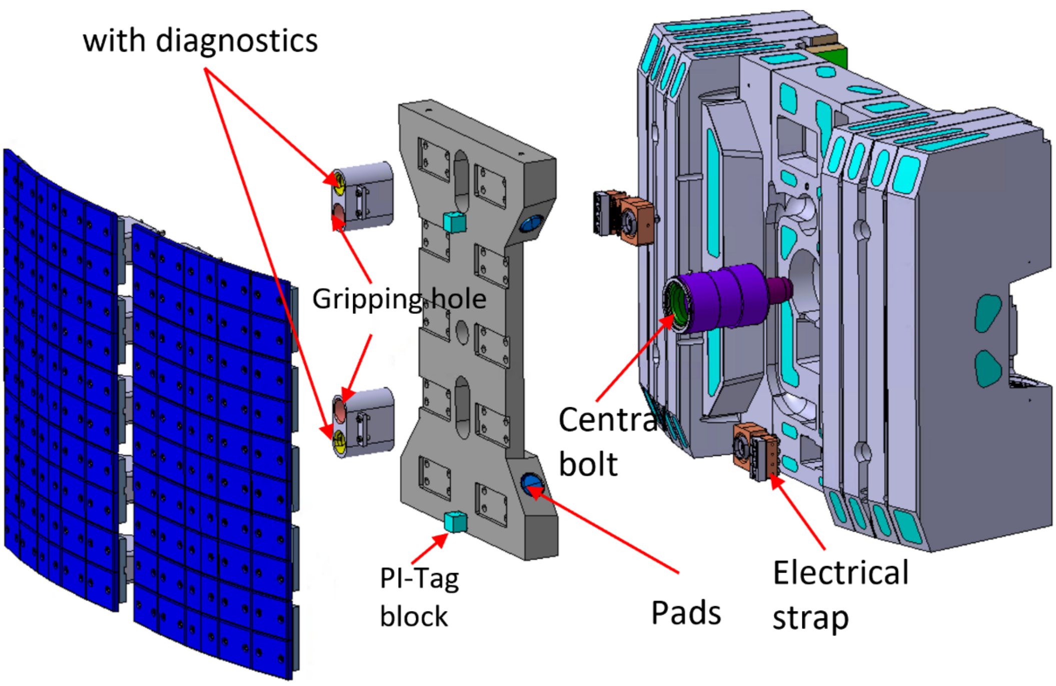


Figure 4-2 exposed view of shield block and TFW

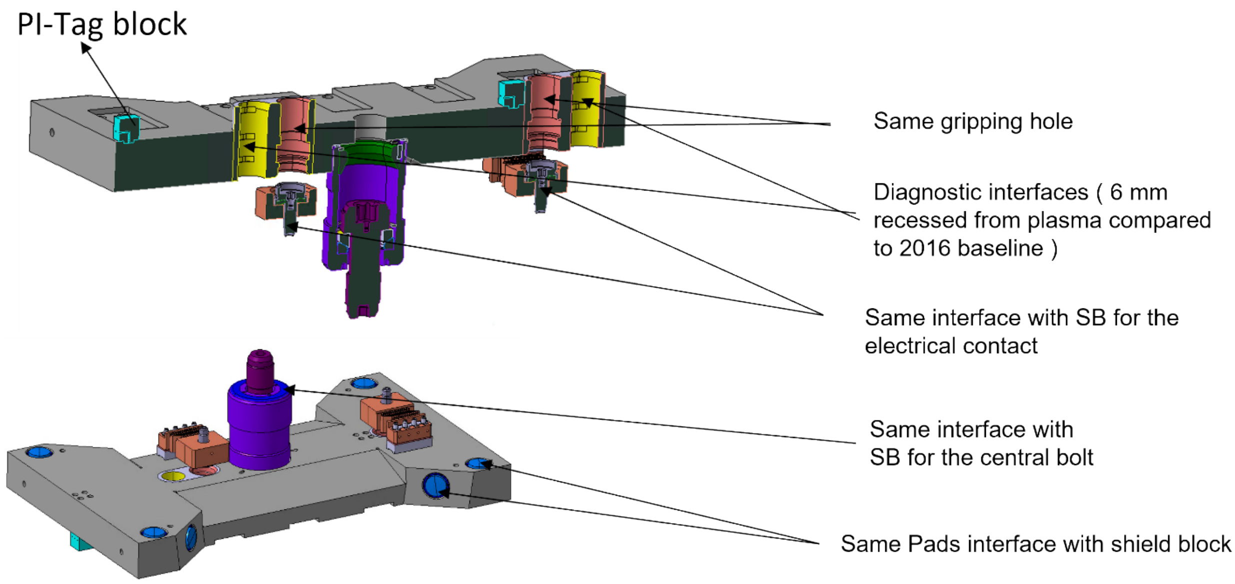


Figure 4-3 Cross section of the TFW interface with blanket assembly tools and SB

4.3 Divertor interface (PBS 17)

[I] This section describes the implementation of the interface requirements between the TFW and the divertor operational instrumentation 17.OI. The TFW scope has been added in the *IS-16-17-004* **[AD 5**]. A new interface sheet *IS-16-17-005* **[AD 6**] between TFW and 17.OI.TI has been created.

[I] A selected number of Temporary First Wall (TFW) panels will be equipped with Operational Instrumentation for monitoring of main thermal fields in these components during ITER Start of Research Operation (SRO) phase. The Optical Fiber Temperature Sensors (OFTS) will be installed on TFW panels. An initial proposal of instrumented TFW panels for further investigation is shown in Figure 4-4.

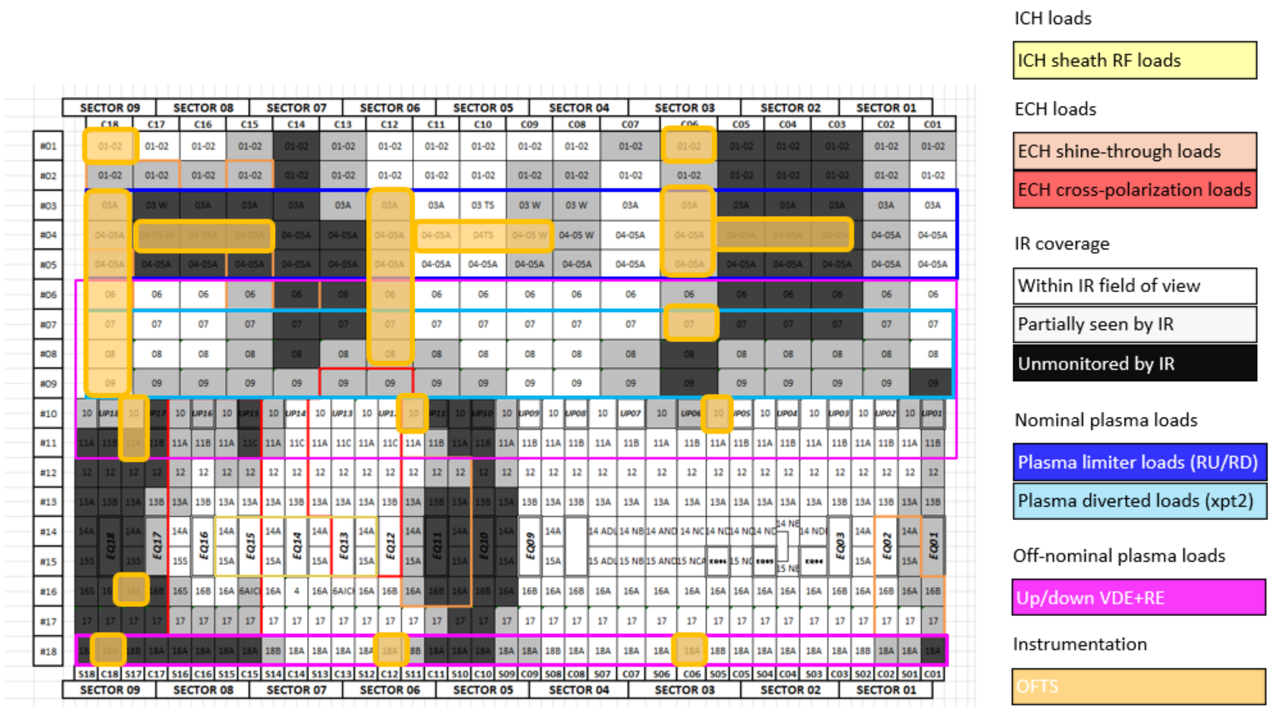


Figure 4-4 An initial proposal of instrumented TFW panels

4.4 Fuelling and Wall Conditioning System interface (PBS 18)

[I] This section describes the implementation of the interface requirements between the TFW and the Fuelling and Wall Conditioning System. The interface sheets *IS-16-18.GI-001*[**AD 7**] and *IS-16-18.PI-001*[**AD 8**] will be updated to add the TFW scope.

[V] The interface review and model approval meeting **[RD 1**] verified a gap of 38 mm between two neighbouring TFW panels for FPIS Dispersion Cone.

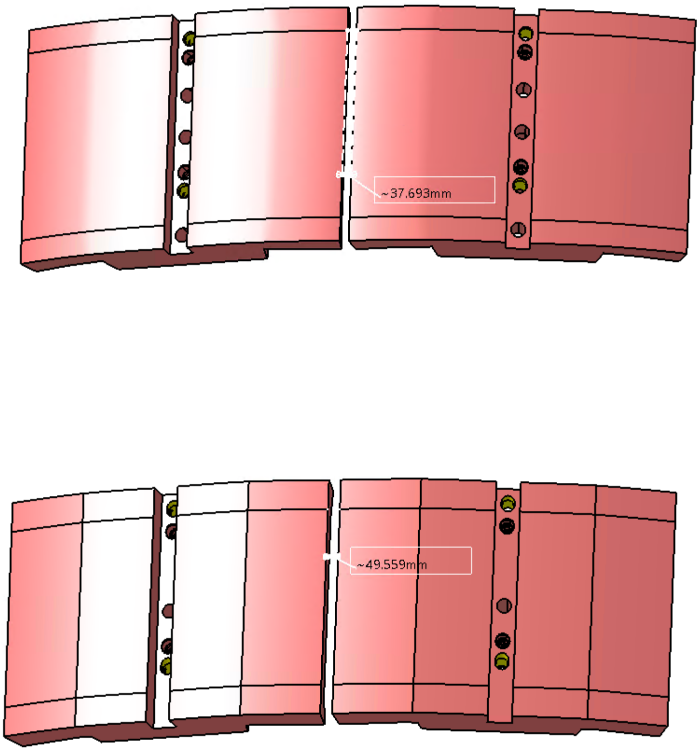


Figure 4-5. The toroidal gap of 38 mm between two neighbouring TFW panels for FPIS Dispersion Cone.

4.5 Vacuum Interface (PBS 31)

[I] This section describes the implementation of the interface requirements between the TFW and the Vacuum system. The interface sheet *IS-16-31-001* [**AD 9**] will be updated to add the TFW scope.

Further details specific to the PBS 31 interface will be provided in fabrication specification documentation.

4.6 Ion Cyclotron Heating and CD System Interface (PBS 51)

[I] This section describes the implementation of the interface requirements between the TFW and the ICH system. The TFW scope has been added in the interface sheet *IS-16-51-001*[**AD 11**].

[V] The interface review and model approval meeting **[RD 1**] verified the clearances between the TFW and the ICRH system.

4.7 Electron Cyclotron Heating and CD System (PBS 52)

[I] This section describes the implementation of the interface requirements between the TFW and the ECH system. The interface sheets IS-16-52-001[**AD 12**], IS-16-52-002 [**AD 13**], IS-16-52-003 [**AD 14**] have been updated to add the TFW scope.

[V] The interface review and model approval meeting **[RD 1**] verified the clearances between the TFW and the ECRH system.

[I] The EC stray power load on TFW during SRO phase is simulated via the collaboration between PBS 16, PBS 52 and science division. Preliminary results will be shown during the PDR meeting.

4.8 Diagnostic Interface (PBS 55)

[I] This section describes the implementation of the interface requirements between the TFW and diagnostic systems. The interface sheets IS-16-55-005 **[AD 15]**, IS-16-55-006 **[AD 16]**, **[AD 21** IS-16-55-011 **[AD 17]**, IS-16-55-014 **[AD 18]**, IS-16-55-015 **[AD 19]**, IS-16-55-023 **[AD 20]** have been updated to add the TFW scope. A new interface sheet IS-16-55-027 **[AD 21]** between PBS 16 Blanket First Wall and 55.E7 Radial X-Ray Camera has been created, and the TFW scope has been included.

[I] As shown in Figure 4-2 and Figure 4-3, the TFW panels are providing a similar interface for 55.GD and 55.C5 as the final first wall.

[V] The interface review and model approval meeting **[RD 1]** verified the physical interface between the TFW and all interfacing diagnostic systems, as shown in Figure 4-6and Figure 4-7.

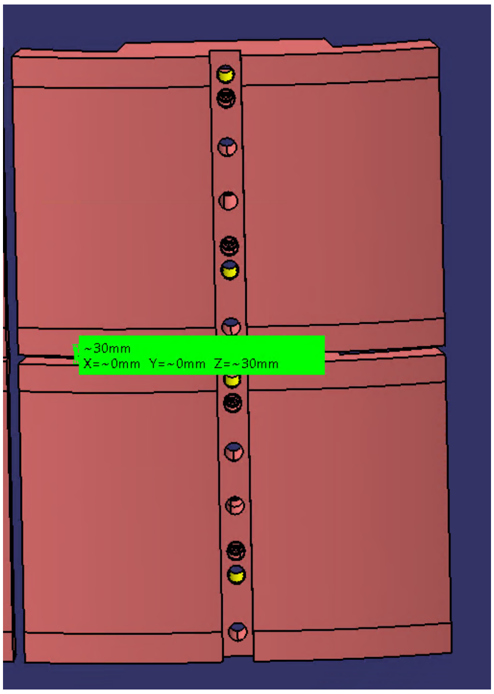


Figure 4-6 The poloidal gap of 30 mm between two TFW panels for installing 55.F9 antenna.

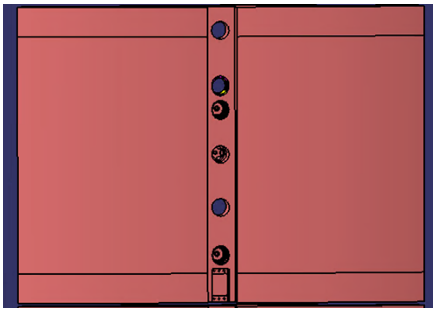


Figure 4-7 The cut-out on central plate of TFW panels in row 3 & 4 for installing 55.C1 & C2.

4.9 In-Vessel Viewing System Interface (PBS 57)

[I] This section describes the implementation of the interface requirements between the TFW and In-Vessel Viewing System. The interface sheet IS-16-57-001 **[AD 22]** will be updated to add the TFW scope.

[I] As shown in Figure 4-2and Figure 4-3, the TFW panels are providing a similar interface for IVVS fiducials and adapters as the final first wall.

[V] The interface review and model approval meeting **[RD 1]** verified the physical interface between the TFW and in-vessel viewing system, as shown in Figure 4-8.

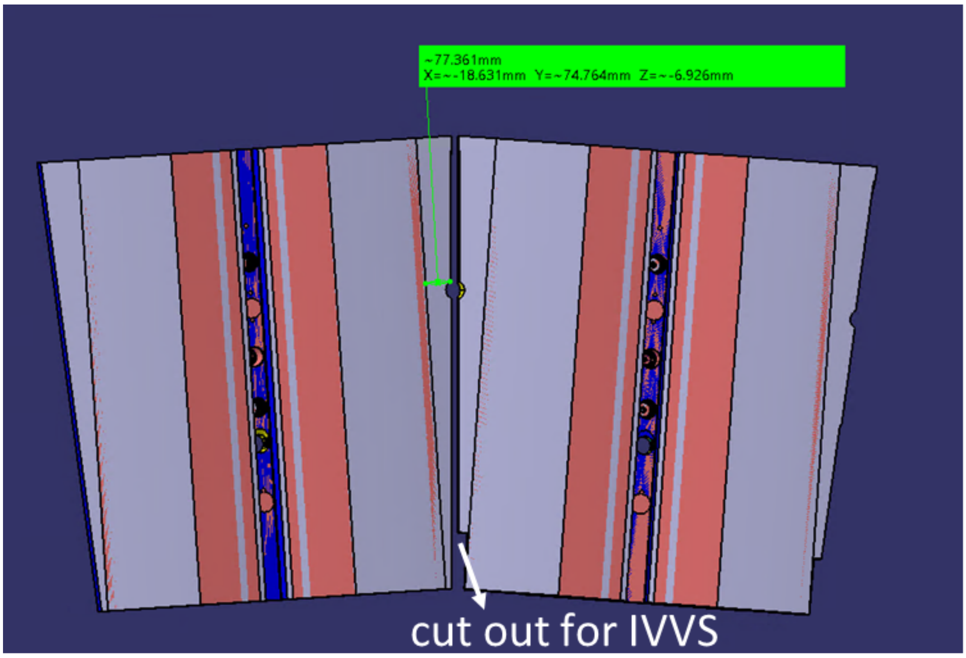


Figure 4-8 The cut-out on TFW panels in row 18 for In-Vessel Viewing System

4.10 Radwaste Interface (PBS 66)

[I] This section describes the implementation of the interface requirements between the TFW and the Radwaste system. The interface sheet *IS-16-66-001* **[AD 23]** has been updated to add the TFW scope.

No design details have been implemented that are specific to the PBS 66 interface.

5 SAFETY DESIGN

5.1 Monitoring Design

This section will be expanded in the following revision of the document.

5.2 Occupational Safety

This section will be expanded in the following revision of the document.

6 OPERATION AND MAINTENANCE

6.1 Operation Modes and Load Cases

[I] This section outlines all activities associated with the TFW throughout the lifetime of the components. This starts from receipt of the components at Cadarache until the components leave the site for disposal.

The TFW panels are designed to function in SRO phase by nature of being designed for the different thermal and EM loads. The relevant states are accounted for in the *Temporary First Wall load specification* [**AD 2**].

6.2 Remote Handling

The TFW is not Remote Handling (RH) Classified. **[AD 1**] [**16TWs59-I]**

6.3 Failure Modes and Effects Analysis (RAMI)

[I] No RAMI analysis has been performed specific to the TFW.

7 VERIFICATION AND VALIDATION SUMMARY

[I] The verification of the TFW is accomplished through the tracking of individual requirements inside the sub-System Requirements Document as well as the interface requirements. During each phase of the sub-system's development, each requirement is evaluated to check two things.

[I] First, the propagation of requirement is confirmed. In some cases, propagation is deferred, as the correct location could be a procurement arrangement or a manufacturing specification, and is not relevant to the current design maturity. In all other cases, the status is assessed as various stages of 'implementation'.

[I] Second, the design is assessed to determine if it complies with the requirement. Again, verification of many of the requirements is not possible during the initial design phases; in these cases, the verification is deferred. In all other cases, the requirement is assessed at various level of 'verification'.

[I] The propagation and verification of each requirement in the *sub-System Requirements Document (s-SRD-16-TW)* [**AD 1**] is tracked through DOORS, and will be exported to excel as a status report of the design prior to PDR in the *DCM-16-TW* [**RD 10**]. The design implementation of many of the requirements in the sSRD-16-TWform the basis of this document; many of the requirements link directly to text in this DDD. Many of the interface requirements are linked directly to the design implementation descriptions in the *Interface Design Chapter* (§4) of this document.

[I] TFW panels require demonstration of structural and thermal acceptability both as self-consistent parts and within the safety context of the ITER vacuum vessel. This acceptability is based structural analysis, which takes input from electromagnetic and thermal analyses results. The structural analysis then uses these inputs for assessing acceptability with regards to the SDC-IC rules for the components themselves as well as with regards to RCC-MR rules for interfaces with the vacuum vessel. The summary of this work is provided through the *Structural Integrity Report* [**RD 9**].

8 MODELS, PROCUREMENT, AND POST-DESIGN CONSIDERATIONS

8.1 List of 2D and related 3D CATIA models

The designs described in this document correspond to the drafted revisions following CATIA models in the **[RD 14]**. The corresponding CM versions are shown in the Figure below for illustration only.

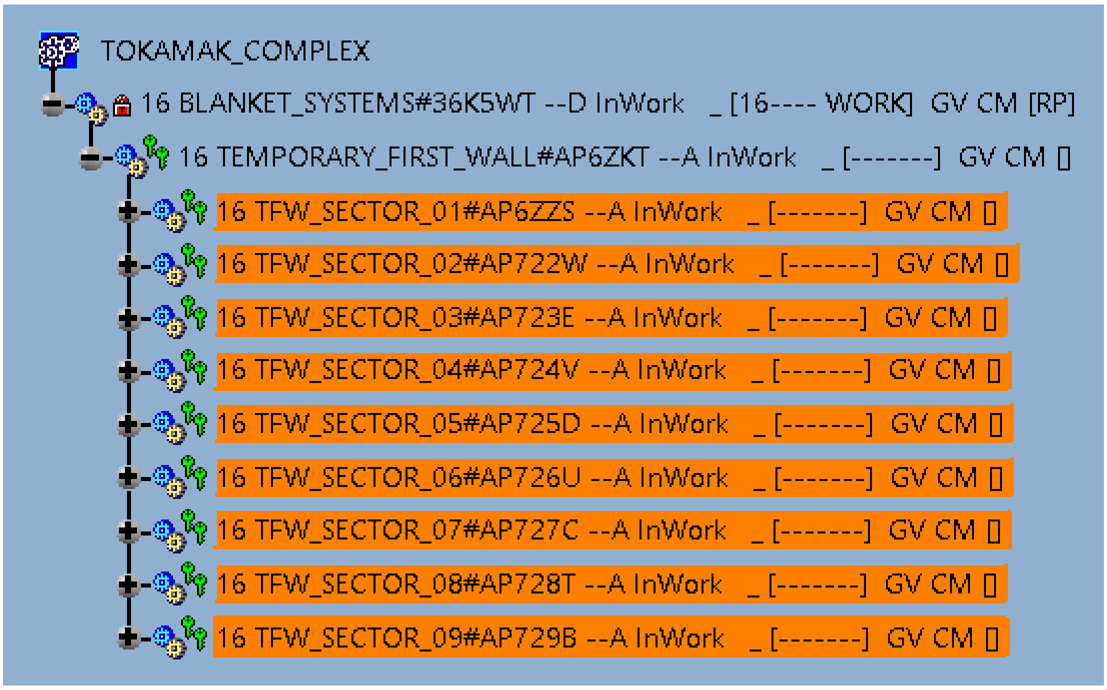


Figure 8-1. Location of the drafted TFW 3D CATIA configuration management models.

The position of the TFW panels is verified via the design integration checking of the CMAF to assure that there is no clash with interfacing systems.

2D drawings will be included along with the subsequent revision of this document in the next version.

8.2 Procurement

[I] The TFW panels are built-to-print and will be procured through the IO. All components are under the responsibility of PBS 16 to procure.

Table 8.2-1. Procurement arrangement for the temporary first wall panels.

PBS	Name	ID
PBS 16.TW	Temporary First Wall	

- End of the Document -