# Interface Control Document PLASMA FACING COMPONENTS : CENTER STA

## Interface Document: NSTXU_1-1-1-1_IC_102

## REVISION 0

## October 31, 2019

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|---|---|---|
| **PREPARED BY:** | **Kathleen Lukazik** | 10/11/2019 12:44:15 PM |
| | Kathleen Lukazik, | |
| **REVIEWED BY:** | **Robert A. Ellis** | 10/11/2019 2:06:33 PM |
| | Robert A. Ellis, | |
| **REVIEWED BY:** | **George D. Loesser** | 10/11/2019 2:51:21 PM |
| | George D. Loesser, | |
| **REVIEWED BY:** | **Peter Dugan** | 10/17/2019 11:06:38 AM |
| | Peter Dugan, | |
| **REVIEWED BY:** | **Jonathan Klabacha** | 10/30/2019 2:30:33 PM |
| | Jonathan Klabacha, | |
| **APPROVED BY:** | **Yuhu Zhai** | 10/31/2019 12:40:39 PM |
| | Yuhu Zhai, | |

PRINCETON PLASMA PHYSICS LABORATORY
P.O. BOX 451
PRINCETON, N.J. 08543

National Spherical Torus Experiment Upgrade

# Interface Control Document

# PLASMA FACING COMPONENTS: CENTER STACK STRUCTURE

NSTX-U-ICD-002-PFC-CSS-00

**Revision 0**
**May 9, 2019**

_____
Prepared By: P. Dugan, Systems Engineering

_____
Reviewed By: J. Klabacha, PFC COG

_____
Reviewed: D. Loesser, Vacuum Vessel and Internal Hardware RE

_____
Reviewed: E.Ellis, Diagnostic RE

_____
Approved By: Y. Zhai, NSTX-U Project Engineer

**Change Record**

| Revision | Date | Description of Change |
|---|---|---|
| 0 | May 9, 2019 | Initial Release |
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# References

[1] GENERAL REQUIREMENTS DOCUMENT, NSTX-U-RQMT-GRD-001-01.

[2] SYSTEM REQUIREMENTS DOCUMENT, Plasma Facing Components, NSTX-U-RQMT-SRD-003-00.

[3] SYSTEM REQUIREMENTS DOCUMENT, VACUUM VESSEL AND INTERNAL HARDWARE, NSTX-U-RQMT-SRD-004-01.

[4] NSTXU Recovery Global Heat Balance Calculations, NSTXU-CALC-10-06-00.

[5] NSTX-U Center Stack Casing,Heating/Cooling Manufacturing and Installation Final Design.

[6] NSTX-U Disruption Analysis Requirements, NSTX-U-RQMT-RD-003-01.

[7] Field Errors and Heat Flux Enhancement, NSTXU-CALC-11-09-00, January 12, 2018.

[8] Stress Analysis of ATJ Center Stack Tiles and Fasteners, NSTX-U-Calc-11-03-01, February 17, 2014.

[9] Plasma Facing Components FDR CSFW Tiles, September 28, 2018.

[10] Plasma Facing Components FDR CSAS Tiles, 28 September, 2018.

[11] Plasma Facing Components FDR Inboard Divertor Vertical, 28 September 2018.

[12] Plasma Facing Components FDR Inboard Divertor Horizontal, 28 September 2018.

[11] Fields and Bdts for Further Analysis of PFC's NSTXU-CALC-11-08-00.

[12] Thermal Analysis Requirements, NSTX-U-RQMT-RD-013-00-00.

[13] EM Loads on Tiles, NSTXU-CALC-11-11-00.

[14] Combined Loads on Tiles, NSTXU-CALC-11-10-00.

[15] Thermal and structural loads on CSA tiles and variants (rows 5 and 6), NSTXU-CALC-11-21-00.

[16] Thermal and structural on IBDH tile and variants, NSTXU-CALC-11-18-00.

[17] Thermal and structural on IBDV HHF tile and variants, NSTXU-CALC-11-19-00.

[18] Thermal and structural on IBDV LHF tile and variants, NSTXU-CALC-11-20-00.

[19] Tolerancing Justification Report for Center Stack Casing, NSTXU-CALC-133-37-00.

[20] Calculate Halo and Eddy Current EM Loads on the CS Casing

# 1. Purpose

This document describes the various interfaces between the Plasma Facing Components and the Center Stack Structure. The interface locations and boundaries that connect the Plasma Facing Components to the Center Stack Structures are identified based on different types of interfaces.

# 2. Scope

The PFCs consist of tiles and mounting hardware for the Center Stack First Wall, Center Stack Angle Section, Inboard Divertor Vertical and Horizontal Targets, and Thermocouples. The Center Stack Structure components address Center Stack Casing, Horizontal Target Cooling System (Heat Transfer Plate), and Vertical Target Cooling System. (Heat Transfer Tube).

The scope of this document addresses any defined interfaces between these identified system elements.

# 3. Responsibilities Vacuum

The interfaces are managed between the following organizations:

- Plasma Facing Component (PFC)
- Vacuum Vessel and Internal Hardware (VVIH)
- Diagnostics (Thermocouples)
- Systems Engineering and Integration

# 4. Interfaces

Interface requirements in the following sections are identified with the requirement prefix, ICD, followed by a number [ICD-PFC-CSS-X]. “X” is a sequential count beginning with 1, “PFC” represents plasma facing components, and “IVS” represents In-Vessel Structures. There is also a unique identifier for all interfaces in the format [#####-#####-X]. The identifier is a concatenation of two level 5 SBS values and the interface type. This is followed by an interface description and a list of related artifacts. Artifacts in this case represent evidence of an

interface and include, but are not limited to, calculations, drawings, and technical specifications.

## 4.1. Interface Types

The top-level interface types are defined in Table 1. Within each heading, there are sub-headings to address any special sub-elements that need consideration. For example, the Mechanical heading has four sub-elements that need to be addressed: Structural, Spatial, Location, and Wall/Floor Penetration. For those interface types with sub-interfaces, there are corresponding sub-sections.

Table 1. Interface Types.

| Heading | Abbreviation | Name |
|---|---|---|
| 4.2 | Me | Mechanical |
| 4.3 | Ep | Electrical Power |
| 4.4 | Si | Signal |
| 4.5 | Di | Diagnostics |
| 4.6 | Gf | Gas/Fluid |
| 4.7 | Va | Vacuum |
| 4.8 | Sw | Software |
| 4.9 | Th | Thermal |
| 4.10 | Pe | Plasma/Eddy/HaloCurrent |

Table 2 provides the N2 Diagram identifying all the interfaces for NSTX-U, while Table 3 provides the specific details of the interface.

Table 2. N2 Diagram Interface types.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plasma Facing Components | Me,Th, Pe | | Me,Th, Va,Pe | | | | | | Me | Me | Me, Pe | | Me | | | |
| | In-Vessel Structure | Me,Di, Pe | | | Th | | | Me,Th, Pe | Me | | Me, Di, Pe | | | Di | | |
| | | Vacuum Vessel Structure | | | Me,Va | Me, Va | Me | Me, Th, Pe | Me | Me,Va | Me,Di, Va | | Si | Di,Si | | |
| | | Va | Centerstack Structure | | | Va, Th | Me, Gf | Me | Me | Me | | | | Di | | |
| | | Me | Me, Th, Ep | Magnets | | | | Me | | | Di | | SI | Di | | |
| Si | | Me, Va | | | Heating Systems | | Gf | Th | | Me | | Gf, Si | Si | Si | Si | |
| | | | | | Si, Va, Me, Sw, Gf | Vacuum Pumping System | | Si | Si | Gf, Si | Si | | Si,Va | Si | Si | |
| | | | | Gf,Si | | | Coolant System | Gf | | | | Gf,Sw | Si, Sw | Si | | |
| | Th, Gf | Ep,Di, Th, Va | Ep, Gf, Th, Pe | | Si | | Si | Bakeout System | | | | | | Me | Si, Me | |
| | | | Gf,Va | Gf,Va | Ep | Gf,Si | | | Gas Delivery System | Me | Va | | Si,Sw | Si | Si | |
| | | Gf | Si | | | Si,Gf,Va | | | Gf | Wall Conditioning System | | | Si,Sw | Si | Si | |
| | | Me,Va | Me,Va | Me | Me | Gf,Si | Gf | | | Va, Ep | Diagnostics | | Si,Sw | Si | Si | Si |
| | | | | Ep | Ep | Ep | Ep | Ep | Ep | Ep | Ep | Power Systems | Si | Ep, Si | Ep, Si, Di, Gf | Ep |
| | | | | | Si | | | | | Me, Si | Si | | Centralized Instrumentation and Control | Si, Me | | |
| | | | | | | | | | | Sw | | Si | Si,Sw | Integrated Machine Operations | | |
| | | | | | | | | Ep | | | | | | | Operations & Safety Systems | |
| Me | | Me | Me | Me | Me | Me | | Me | Me | Me | Me | Me | Me | Me | Me, Ep | D-Site Locations (Test Cell |

Table 3. Callout.

| | |
|---|---|
| PFCs | Me,Th, Va, Pe |
| | Centerstack Structures |

The following sections address each of the interfaces. Section 5 addresses off-project interfaces such as the plasma. Off-project in this case represents an external interface.

## 4.2. Mechanical Interfaces

This paragraph addresses any type of mechanical interfaces to include a structural, spatial, location dependent interfaces or areas where penetrations into a wall or floor are required. These are identified independently as the interface parameters will likely be different.

### 4.2.1. Structural Interfaces

This identifies any interfaces between the system elements that require a structural interface. This could be based on various forces placed on the system and by the system.

| Identifier | Interface | Artifacts |
|---|---|---|
| 1.1.1.1.4-1.1.3.3.9-S | **Horizontal Target PFCs** tiles and their backing structures react to disruptions loads to the **Horizontal Target Cooling System** at the surface of the casing flange or cooling plate. | See Paragraph 4.2.1.1 Ref 16, Ref 19, Drawings ED1433, DC11124, DC11125, ED1391 |
| 1.1.1.1.3-1.1.3.3.6-S | **Vertical Target PFC** tiles, or structures designed to hold these tiles, are mounted to the surface of the **Center Stack Casing**, reacting loads on the PFCs. | See Paragraph 4.2.1.2 Ref 17, Ref 18, Drawings ED1435, ED1445, DC11204,ED1391 |
| 1.1.1.1.2-1.1.3.3.6-S | **CSAS PFC** tiles are mounted to the surface of the **Center Stack Casing**, reacting to loads PFCs during operations. | See Paragraph 4.2.1.3 Ref 10, Ref 15, Ref 19, Drawing ED-1419, DC11210,ED1391, ED1416, ED1417, ED1418, ED1419 |
| 1.1.1.1.1-1.1.3.3.6-S | **CSFW PFC** tiles are mounted to the surface of the **Center Stack Casing**, reacting loads on the PFCs. | See Paragraph 4.2.1.4 Ref 9, Ref 14, Ref 19, Drawings DC1458, DC11204, ED1391, 9D11554, ED1448 |

#### 4.2.1.1. Horizontal Target PFCs to Horizontal Target Cooling Systems

**Interface Notes:**

- Twelve 15° 5x5 IBDH tiles mounted in 180° sector grid by two rods per tile.
- Security pin is inserted to prevent accidental turn of the rod.
- IBDH tile is mounted to the tile frame using two OD rods. The two OD rods pass through ⅜" ID holes between the castellations using ball pin mounting. The rods are inserted, then rotated 110 degrees to lock the tiles into place.
- Frame, tiles, G rafoil liner and rods are mounted in vessel before IBDV-LHF, and OBD row 1.
- Drawing ED1391 provides the assembly and layout of the various tiles including the various diagnostic tiles

**ICD-PFC-CSS-001:** The IBDH mounting frame assembly is mounted directly to the Heat Transfer Plate. Figure 2 provides a view of the HTP shown in yellow on the left of the figure, while the right provides the frame. To mount the frame to the HTP requires four #10-24 X 7/8 LG HEX SOC HD CAP SCREW bolts for the inboard section and four- #10-24 X 3/8 LG HEX SOC HD CAP SCREW (not pictured) to the outboard section. The IBDH mounting frames are assembled in 180 degree sections as identified in Drawing ED1433. The Heat Transfer Plate weldments are defined in Drawings DC11124 and DC11125.

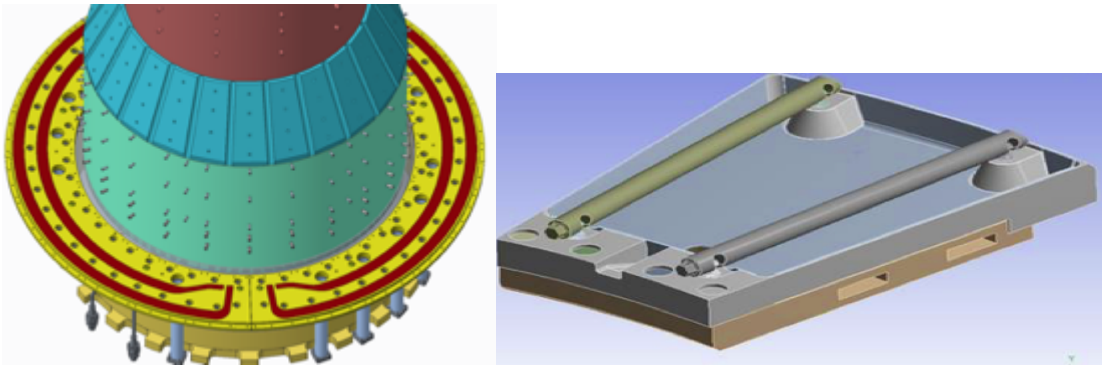

**Figure 2. IBDH tile mount.**

**ICD-PFC-CSS-002:** 0.030” Grafoil liner is placed between the tile, grid and the cooling plate.

**ICD-PFC-CSS-003:** The Bolt preload of 1,000N per tile applied between base and the Heat Transfer Plate.

**ICD-PFC-CSS-004:** The HTP that the PFC connects to will have a top and bottom flatness of 0.010” and parallelism of 0.010”.

### 4.2.1.2. Vertical Target PFCs to Vertical Target Cooling Systems

**Interface Notes:**

- Tiles are mounted in 60° sector grid x 6 for the upper region and 6 for the lower region.
- Tiles attached using pins connected to grid as shown in Figure 3. The backplate is bolted to the grid using studs on the center stack casing.

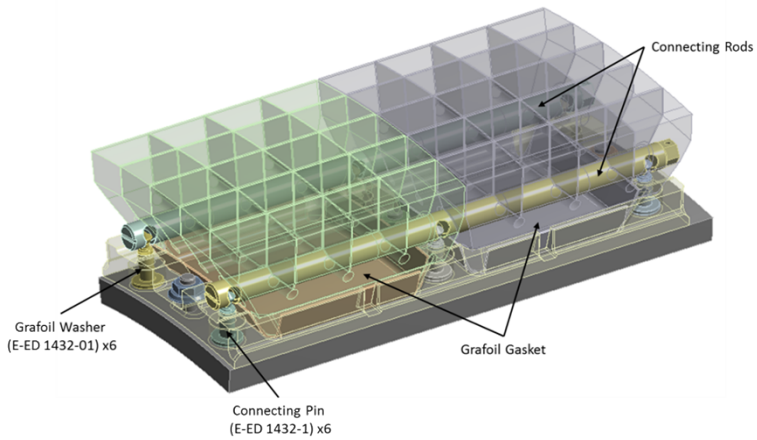


Figure 3. Tile base assembly.

- 3 rows of ¼-20 studs added to Center Stack.
- 750N pretension on each pin reacted within PFCs design.
- Drawing ED1391 provides the assembly and layout of the various tiles including the various diagnostic tiles
- Drawing ED1395 provide the thermocouple assembly.

**ICD-PFC-CSS-005:** Initial design calls for 5/16-18 UNC X .355 spiralock thread hex nut that bolts to the studs as shown in Figure 4, with a 0.030” Grafoil liner positioned between the tile and grid and center stack casing. The studs locations are identified in drawing DC11204.

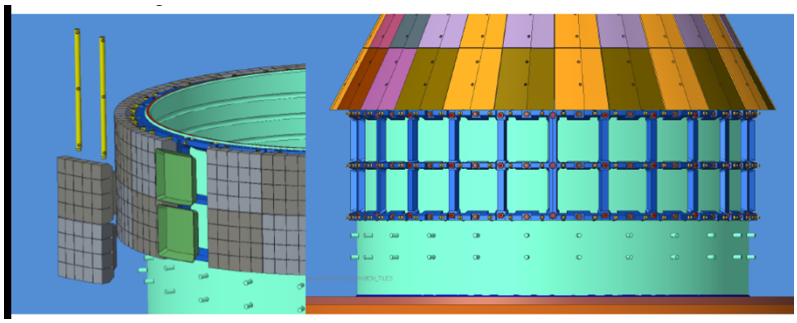

**Figure 4. HHF Tile attachment to grid on Center Stack.**

**ICD-PFC-CSS-006:** LHF tiles provide a T-bar with an alignment pin as shown in Figure 5, with a 5/16-18 UNC X .355 spiralock thread hex nut that bolts to the studs. The studs locations that the LHF tiles mount to is identified in drawing DC11204.

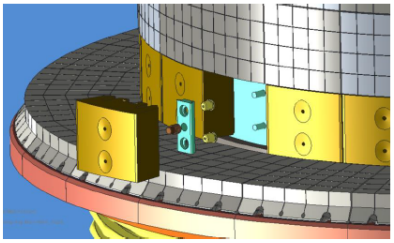

**Figure 5. LHF Tile Attachment.**

### 4.2.1.3. CSAS to Center Stack Casing

**Interface Notes:**

- 24 col x 2 rows x 2 section= 96 tiles.
- Variations on the CSA Tile
  - Rows 5 Style 1 Base Tile D
  - CSA Row 5 - Style 1 - Thermocouple
  - CSA Row 5 - Style 2 - Base tile & Thermocouple
  - CSA Row 6 - Style 1 - Base tile & Thermocouple
  - CSA Row 6 - Style 2 - Base tile, Thermocouple, Gas Injection, & Gas injection shoulder

- Tiles use Fish-scaling  Ref  10.
- Tile to tile gap between IBDV and CSA tiles is .040”.
- Drawing ED1391 provides the assembly and layout  of the various tiles including the various diagnostic tiles

**ICD-PFC-CSS-007**: 2 IN718 cap screws hold the tile via t-bar to the casing.  Bolt torque is 1,607 N.

**ICD-PFC-CSS-008**: The T-bar uses ¼-28 UNF x ⅝ HEX SOC Screw to connect to the  tapped holes on the Center Stack Angled Section as shown in Figure 6.  The screws are shown protruding from the T-bars (gold) on the left and orange on the right. The mounting holes are located on drawing DC11210 Sheet 25 Section AM-AM.

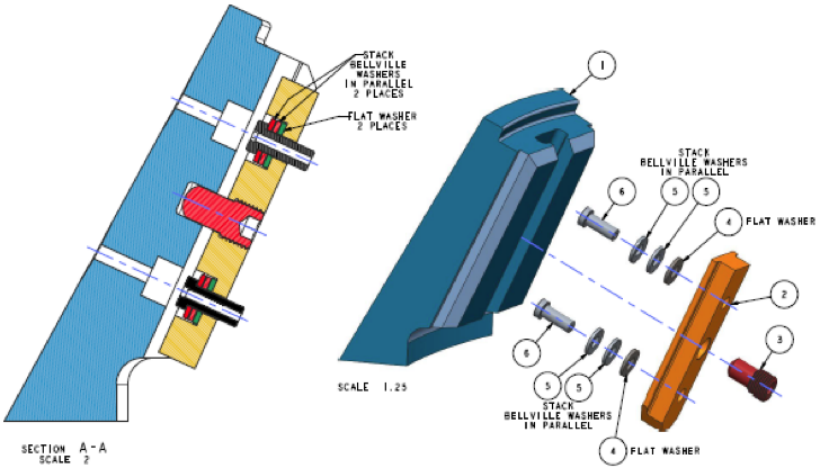


**Figure 6. CSAS Model.**

**ICD-PFC-CSS-009**: Pre-install shim made from  0.03”-.06” grafoil.

### 4.2.1.4. CSFW to Center Stack Casing

**Interface Notes:**

- 24 col x 15 rows = 360 tiles: 180 Bolted, 180 Floating.
- Multiple variations in CSFW tiles.

- Grafoil bushing integrated into rod.

- Drawing ED1391 provides the assembly and layout of the various tiles including the various diagnostic tiles
- 9D11554 provides the Centerstack Thermocouple assembly
- ED1391 Centerstack Assembly is shown in drawing ED1391.

**ICD-PFC-CSS-010**: The studs location that the CSFW tiles mount to is identified in drawing DC-11204 Sheet 2.

**ICD-PFC-CSS-011**: The PFCs are mounted via a Rail and Pin system that is mounted to the studs using 5/16-18 UNC x .355 threaded Hex Allen nuts as shown in yellow in Figure 7. Section DD of drawing ED1458 Section D-D shows the interconnection between the stud and the tile mount. ED1448 shows the T20 Drive Nut for tiles Row 7-21. Tiles are bolted to the studs using the rail represented by CSFW (B). The pins then connect the floating tiles represented by CSFW(F). A thin grafoil sheet, approximately 0.030" thick, is placed between the floating tile and the Center Stack Casing.

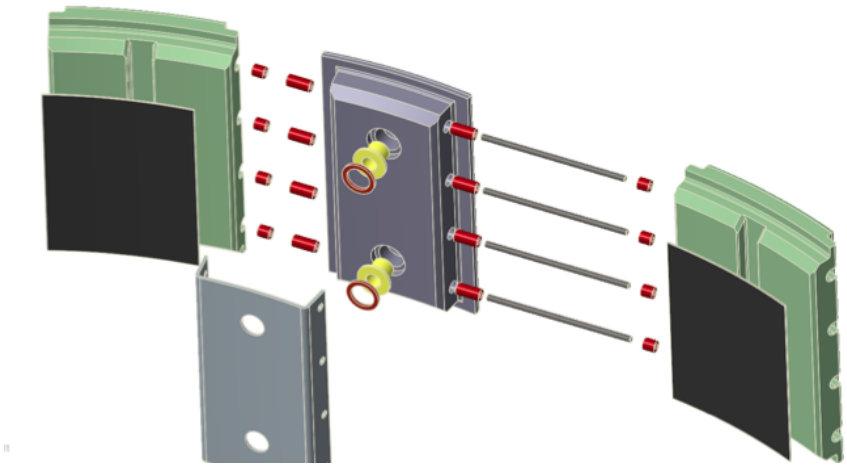

**Figure 7. CSFW Pin & Rail System.**

**ICD-PFC-CSS-012**: Ref 14 specifies a preload torque of 6.5 ft-lb on the nut.

### 4.2.2. Spatial Interface

This identifies any interfaces between the system elements pertaining to spatial restrictions for constraints. In some cases, one or more drawings may be used to capture the interfaces but may have been included to make the interface stand alone.

| Identifier | Interface | Artifacts |
|---|---|---|
| 1.1.1.1.3-1.1.3.3.6-Sp | **Vertical Target PFC** allowance for wire bundles from CSFW, CSAS, and IBDV diagnostic wires to run to the organ pipes on the **Horizontal Target Cooling System casing** flange; allowance for gas delivery tubing. | See Paragraph 4.2.2.1 Drawing 9D11556 |
| 1.1.1.1.4-1.1.3.3.9-Sp | **Horizontal Target PFCs** allowance for wire bundles from CSFW, CSAS, and IBDV diagnostic wires to run to the organ pipes on the **Center Stack Casing** flange; allowance for gas delivery tubing. | See Paragraph 4.2.2.2 Drawing 9D11556 |
| 1.1.1.1.2-1.1.3.3.6-Sp | **CSAS PFC** allowance for wire bundles from the **CSFW and CSAS diagnostics**; allowance for gas delivery tubing. | See Paragraph 4.2.2.3 Drawing 9D11556 |
| 1.1.1.1.1-1.1.3.3.6-Sp | **CSFW PFC** provides sufficient gaps, allowing for wire bundles from the CSFW diagnostics on the **Center Stack Casing**; allowance for and gas delivery tubing. | See Paragraph 4.2.2.4 Drawing 9D11556 |
| 1.1.1.1.3-1.1.3.3.6-Sp | **Vertical Target PFC** alignment of mounting hardware with **Vertical Target Cooling System**. | See Paragraph 4.2.2.5, Ref 11, Ref 19, Drawings ED1435, ED1445, DC11204 |
| 1.1.1.1.4-1.1.3.3.9-Sp | **Horizontal Target PFCs** alignment of mounting hardware with **Heat Transfer Plate**. | See Paragraph 4.2.2.6, Ref 19, Ref 12 Drawings 9D11556, ED1433, DC11124, DC11125 |

| | | |
|---|---|---|
| 1.1.1.1.2-1.1.3.3.6-Sp | **CSAS PFC** alignment of mounting hardware on the **Center Stack Casing**. | See Paragraph 4.2.2.7. Drawings EDC11210, ED1445, Ref 10, Ref 19 |
| 1.1.1.1.1-1.1.3.3.6-Sp | **CSFW PFC** alignment of mounting hardware on the **Center Stack Casing**. | See Paragraph 4.2.2.8. Drawings ED1445, DC11204, Ref 19 |

**Interface Notes:**

- Drawing 9D11556, as shown in Figure 8, provides cabling runs for the sensors. Many of these interfaces use the cabling runs to ensure access to the cables.

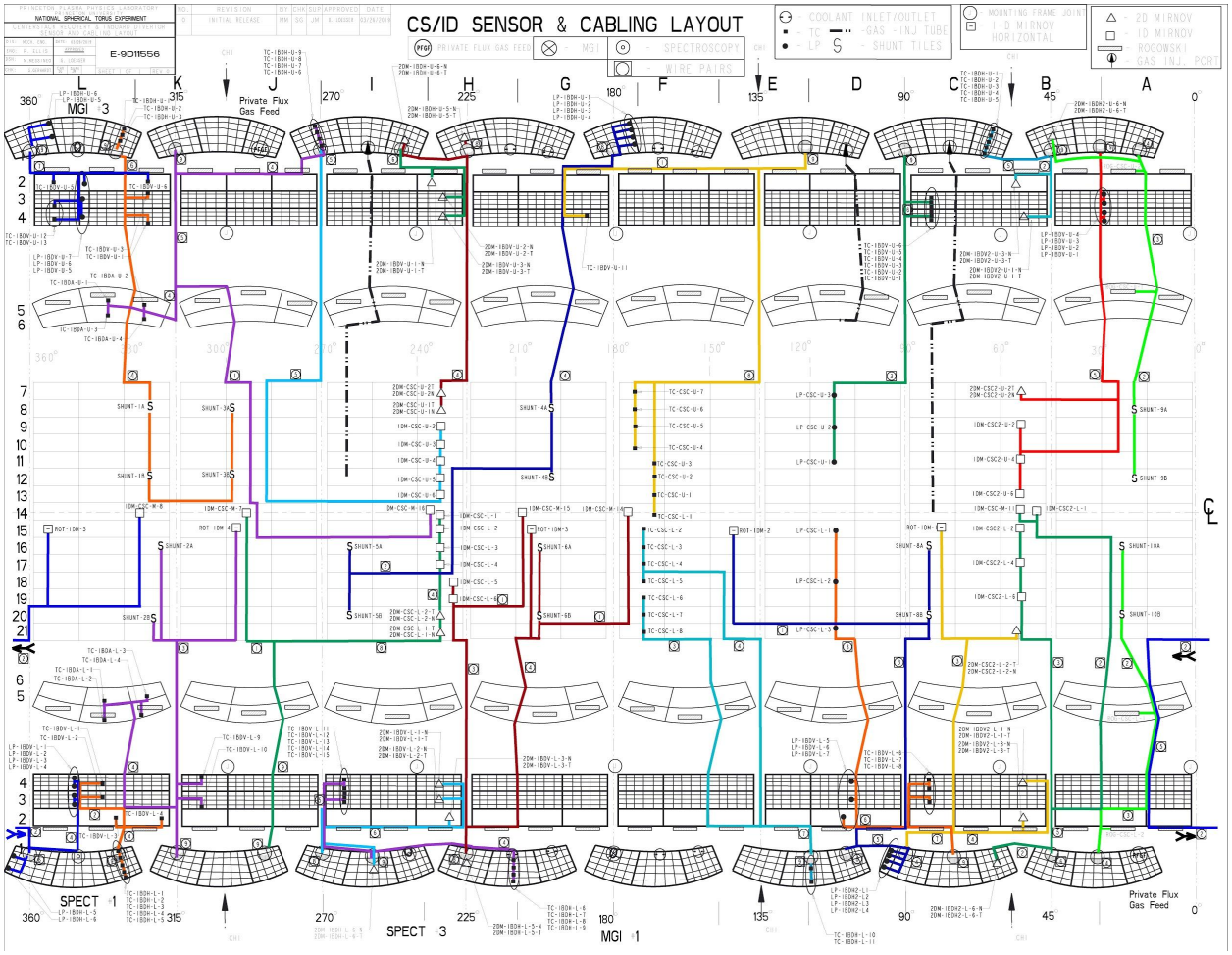

Figure 8. Sensor and Cabling Layout.

- The Heat Transfer Plate (HTP) is mounted to the horizontal flange is within the Center Stack scope.
- Per Ref 5, HTP alignment goal will have an offset less than 0.02" and a perpendicularity less than 0.5 mRad with respect to the axis of the Centerline and IBDV Casing. The HTP represented in Drawings DC11124, DC11125 gets mounted to the Horizontal Divertor Flange.

#### 4.2.2.1. Vertical Target PFCs to Horizontal Target Wire Runs

**ICD-PFC-CSS-013**: The cable runs are identified by the colored lines in the Drawing 9D11556. Along the left side of Figure 8, the number under 360 identifies the various tile rows. The vertical tiles are represented on both top and bottom by the row reference 2, 3, and 4. Note how cable runs for rows greater than 4( i.e. 5-21) are routed through the vertical tiles. There is a practical limit to the number of pairs of cables, i.e., eight pairs, that can be run through the tiles. All PFC sensor connections to the organ pipes are via the Horizontal Target.

#### 4.2.2.2. Horizontal Target PFCs to Center Stack Wire Runs

**ICD-PFC-CSS-014:** The sensor location and cabling in drawing 9D11556. The cable runs are identified by the colored lines in the drawings. Along the left side of Figure 8, the number under 360 identifies the various tile row references. The horizontal tiles are represented on both top and bottom by tile reference 1. All cable runs are routed through the horizontal tiles to the organ pipes.

**ICD-PFC-CSS-015**: Each organ pipe sensor connection interface is connected to a feedthrough flange and is captured in Drawing 9D1095.

#### 4.2.2.3. CSAS PFC to Vertical Target Wire Runs

**ICD-PFC-CSS-016**: The sensor location and cabling runs are identified in Drawing 9D11556. The cable runs are identified by the colored lines in the drawings. Along the left side of the drawing, the number under 360 identifies the various tile row references. The CSAS tiles are represented on both top and bottom by the references 5 and 6. Note how cable runs for rows greater than six (i.e., 7-21) are routed through the CSAS tiles to the vertical target. All PFC sensor connections to the organ pipes are via the Horizontal Target.

#### 4.2.2.4. CSFW to CSAS Wire Runs

**ICD-PFC-CSS-017:** The sensor location and cabling runs are identified in Drawing 9D11556. The cable runs are identified by the colored lines in the drawings. Along the left side of the drawing, the number under 360 identifies the various tile row references. The CSFW tiles are represented by the tile row references 7 through 21. The CSFW cable runs are routed through the CSAS tiles and continue until they reach the organ pipes on the Horizontal Target. All PFC sensor connections to the organ pipes are addressed in Paragraph 4.2.2.2.

#### 4.2.2.5. Vertical Target PFC – CS Casing Alignment

**ICD-PFC-CSS-018:** The stud tolerances are addressed in Section 8 of Ref 19. Tolerance of position is Ø.020" for all studs as identified in drawing ED1435. Drawing ED-1145 provides an assembly of the tiles to the casing.

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#### 4.2.2.6. Horizontal Target PFC - HTP Alignment

**Interface Notes:**

- The Horizontal Target PFC tiles will interface with the mounting to Heat Transfer plate structure that supports the PFCs and grid.
- The Tile Gap between tiles is 0.04" with a tile gap tolerance of 0.01".

**ICD-PFC-CSS-019:** The HTP Assemblies are identified in drawings DC11124 HTP (Top) & DC11125 (Bottom). The tolerances are included on the drawing to include parallelism and flatness. Section 5 of Ref 19 provide the tolerances for the IBD-H. Drawing ED1145 provides an assembly of the tiles to the casing.

#### 4.2.2.7. CSAS to CSC Alignment

**ICD-PFC-CSS-020:** In order for the CSAS PFCs to effectively function, they have to be aligned in accordance with drawing DC1439. The tapped hole alignment is provided in sections 3, 8 of Ref 19 and drawing DC11210, Sheet 23. Drawing ED-1445 provides an assembly of the tiles to the casing.

#### 4.2.2.8. CSFW to CSC Alignment

**ICD-PFC-CSS-021:** CSFW PFCs are identified in drawing ED1445 and need to align stud locations identified in drawing DC11204. The stud tolerances are addressed in Section 8 of Ref 19. Tolerance of position is Ø.020" for all studs. Drawing ED-1445 provides an assembly of the tiles to the casing.

#### 4.2.2.9. Location Interfaces

This identifies any interfaces between the system elements that have any particular dependencies on element location or location constraints.

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

### 4.2.3. Wall/Floor Penetration Interfaces

This identifies any interfaces between the system elements and any penetrations or modifications to the wall or floor of the D-Site building.

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

## 4.3. Electrical Power Interfaces

This identifies any interfaces between the system elements requiring AC, DC, rectification or power conditioning.

| Identifier | Interface | Artifacts |
|---|---|---|

| | | |
|---|---|---|
| N/A | | |

## 4.4. Signal Interfaces

This identifies any interfaces between the system elements and signals that are used to either send or receive control information or data. It explicitly includes the type of physical interfaces such as Ethernet, Fiber Optic, or any specific protocols.

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

## 4.5. Diagnostic Interfaces

This identifies any interfaces between the system elements with any instrumentation or diagnostic equipment to collect performance data.

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

## 4.6. Gas/Fluid Interfaces

This paragraph has two different types of interfaces: Gas and Fluid.

### 4.6.1. Gas Interfaces

This identifies any interfaces between the system elements that use any type of gas (e.g., He).

| Identifier | Interface | Artifacts |
|---|---|---|

| | | |
|---|---|---|
| N/A | | |

### 4.6.2. Fluid Interfaces

This identifies any interfaces between the system elements that use any type of gas (e.g., ionized water).

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

## 4.7. Vacuum Interfaces

This identifies any interfaces between the system elements that pertain to the Vacuum. This interface is between Diagnostics and the Center Stack.

| Identifier | Interface | Artifacts |
|---|---|---|
| 1.1.1.1.8-1.1.3.3.6-V | **PFC Thermocouples** sensor leads leave the vacuum at the flange on end of organ pipe on the **Center Stack Casing** flanges. | Drawings 9D1095 |

### 4.7.1. Thermocouple sensors to Organ Pipe

**ICD-PFC-CSS-022:** The organ pipe port and sensors are documented and identified in drawing 9D1095. There are over 100 sheets to this drawing. For example, each flange is identified as Feedthru Letter location A-L followed by numeral to determine the port (e.g., “FEEDTHRU K-L-2”). Each pair of wires mapped to sensors are called out in the drawing.

**ICD-PFC-CSS-023:** The Feedthrough connector is a 19 pin Ceramaseal Flange.

## 4.8. Software Interfaces

This identifies any interfaces between the system elements that use software that may exchange interfaces with other software components. This includes application programming interfaces (APIs) or any other exchange of information between different software applications.

| Identifier | Interface | Artifacts |
|---|---|---|
| N/A | | |

## 4.9. Thermal Interfaces

This identifies any interfaces between the system elements that pertain to Thermal characteristics. In the analyses the same plot for thermal analysis is used to describe each of the interfaces per Ref [7]. Small changes to either the normal tile surface, flux angle, or both can have a significant impact on heating. (At 1 deg a .5 deg change increases surface normal heat fluxes by 50%.)

| Identifier | Interface | Drawing |
|---|---|---|
| 1.1.1.1.4-1.1.3.3.9-T | **Horizontal Target PFCs** tiles and their backing structures transfer heat during bakeout and operates at the surface of the **Horizontal Target Cooling System** casing flange or cooling plate. | See Paragraph 4.9.1 Ref 4, ref 16. |
| 1.1.1.1.3-1.1.3.3.6-T | **Vertical Target PFC** tiles, or structures designed to hold these tiles, are mounted at the surface of the **Center Stack** | See Paragraph 4.9.2 Ref 4, Ref 17, Ref 18. |

| | | |
|---|---|---|
| | **Casing**, transferring heat to PFCs during bakeout and from PFCs during operations. | |
| 1.1.1.1.2-1.1.3.3.6-T | **CSAS PFC** tiles are mounted to the surface of the **Center Stack Casing**, transferring heat to PFCs during bakeout and from PFCs during operations. | See Paragraph 4.9.3 Ref 4, Ref 15 |
| 1.1.1.1.1-1.1.3.3.6-T | **CSFW PFC** tiles are mounted to the surface of the **Center Stack Casing**, transferring heat to PFCs during bakeout and from PFCs during operations. | See Paragraph 4.9.4, Ref 4, Ref 9. |

**Interface Notes**:

- The five thermal scenarios are identified in Ref 12.
- Thermal scenarios based on 'end of pulse' and 'end of day' scenarios consider thermal ratcheting throughout the day. These scenarios focus on interfaces between PFCs and the support structures, but not the tile surface.

### 4.9.1. Horizontal Target

**ICD-PFC-CSS-024:** The temperature at the end of the day peaks at 86°C in Scenario 2.

**ICD-PFC-CSS-025:** The temperature peaks at 194°C in Scenario 2.

**ICD-PFC-CSS-026:** The bakeout temperature reaches 351°C.

**ICD-PFC-CSS-027:**The thermal expansion is estimated to be ~.120".

### 4.9.2. Vertical Target

**ICD-PFC-CSS-028:** The temperature at the end of the day peaks at 99°C in Scenario 3.

**ICD-PFC-CSS-029:** The temperature during a pulse ranges peaks at 149°C in Scenario 3.

**ICD-PFC-CSS-030:** The bakeout temperature reaches 306° C.

### 4.9.3. CSAS Target

**ICD-PFC-CSS-031:** The temperature at the end of the day on the CSAS peaks at 165°C in Scenario 3.

**ICD-PFC-CSS-032:** The temperature during a pulse peaks at 208°C in Scenario 4.

**ICD-PFC-CSS-033:** The bakeout temperature reaches 316°C.

### 4.9.4. CSFW Target

**ICD-PFC-CSS-034**: The temperature at the end of the day on the CSFW reaches a peak of 236°C.

**ICD-PFC-CSS-035:** The temperature after a pulse is 241°C with the high being along the tiles in Scenario 4.

**ICD-PFC-CSS-035**: The bakeout temperature reaches 346°C at 8KA on the tiles. Per ref 4, the First Wall structure has a peak temperature of 465°C at 8KA.

## 4.10. Plasma Interfaces

This paragraph has two different types of interfaces: Plasma and Eddie/Halo Current.

### 4.10.1. Plasma Interfaces

This identifies any interfaces between the system elements with the Plasma.

| Identifier | Interface | Artifacts |
|---|---|---|
| | Defined in off project interfaces | |

### 4.10.2. Eddy/Halo Current Interfaces

This identifies any interfaces between the system elements with the Eddy/Halo Currents.

| Identifier | Interface | Artifact |
|---|---|---|
| 1.1.1.1.3-1.1.3.3.6-P | Vertical justification? Halo currents and potentially eddy currents transferred from the **Vertical Target PFCs** tiles and their mounting structures to the **Center Stack Casing** at the casing surface. | See Paragraph 4.10.2.1 Ref 6, Ref 11, Ref 17, Ref 18, Ref 20 |
| 1.1.1.1.2-1.1.3.3.6-P | Halo currents and potentially eddy currents transferred from the **CSAS PFC**s tiles and their mounting structures to the **Center Stack Casing** at the casing surface. | See Paragraph 4.10.2.2, Ref 6, Ref 11, Ref 15 |
| 1.1.1.1.1-1.1.3.3.6-P | Halo currents and potentially eddy currents transferred from the **CSFW PFC** tiles and their mounting structures to the **Center Stack Casing** at the casing surface. | See Paragraph 4.10.2.3 Ref 6, Ref 11, Ref 14 |
| 1.1.1.1.4-1.1.3.3.9-P | Halo currents and potentially eddy currents transferred from the **Horizontal Target PFCs** tiles and their mounting structures at the surface of the **Horizontal Target Cooling System.** | See Paragraph 4.10.2.4 Ref 6, Ref 11, Ref 16. |

### 4.10.2.1. Vertical Target – Center Stack Casing

**ICD-PFC-CSS-036**: The Halo load are included in the calculations in Ref 17. Its Impact on the casing including a Halo, Eddy, and PFC combined loads are defined in Ref 20.

**ICD-PFC-CSS-037**: The eddy moments are included in Ref 17. The calculations include a combined Halo and Eddy current section. Impact of eddy currents on the casing are defined in Ref 20.

#### 4.10.2.2. CSAS – Center Stack Casing

**ICD-PFC-CSS-038**: The Poloidal width are identified in Table 1 of Ref 13. Figure 12 provides the calculation for the Halo Strike Current HALO Loads in Ref 13. Loads are identified in Table 2 of Ref 13. Impact on the casing, including combined Halo, Eddy, and PFC loads are defined in Ref 20.

**ICD-PFC-CSS-039**: The dB/dt are identified in Table 1 of Ref 13, while eddy moments are identified in Table 2 of Ref 13. Impact of eddy currents on the casing are defined in Ref 20.

#### 4.10.2.3. CSFW – Center Stack Casing

**ICD-PFC-CSS-040**: The poloidal width are identified in Table 1 of Ref 14. Figure 12 provides the calculation for the Halo Strike Current HALO Loads in Ref 14 and loads are identified in Table 2 of Ref 14. Impact on the casing including a combined Halo, Eddy, and PFC load are defined in Ref 20.

**ICD-PFC-CSS-041**: The dB/dt are identified in Table 1 of Ref 14 while eddy moments are identified in Table 2 of Ref 14. Impact of eddy currents on the casing are defined in Ref 20.

#### 4.10.2.4. Horizontal Target PFCs Horizontal Target Cooling Systems

**ICD-PFC-CSS-042**: The Halo load are included in the calculations in Ref 16. Impact on the casing including a Halo, Eddy, and PFC combined loads are defined in Ref 20.

**ICD-PFC-CSS-043**: The eddy moments are included in Ref 16. The calculations include a combined Halo and Eddy current section. Impact of eddy currents on the casing are defined in Ref 20.

# 5. Off-Project Interfaces

The off-project interfaces are components that are not specifically part of the NSTX-U system. They may include external systems and interfaces where the program has little control over part of the interface. They are provided for completeness.

**ICD-PFC-CSS-044**: The Plasma interacts with CSFW tile, and imposes thermal and Electromagnetic loads per Ref 14.

**ICD-PFC-CSS-045**: The Plasma interacts with the CSFW tiles and causes sputtering and tile erosion.

**ICD-PFC-CSS-046**: The Plasma interacts with the CSAS tiles and imposes thermal and Electromagnetic loads per Ref 15.

**ICD-PFC-CSS-047**: The Plasma interacts with the CSAS tiles and causes sputtering and tile erosion.

**ICD-PFC-CSS-048**: The Plasma interacts with IBD-H tile and imposes and imposes thermal and Electromagnetic loads per Ref 16.

**ICD-PFC-CSS-049**: The Plasma interacts with IBD-H tile and causes sputtering and tile erosion.

**ICD-PFC-CSS-050**: The Plasma interacts with IBD-V tile and and imposes thermal and Electromagnetic loads per Ref 17 for high heat flux and Ref 18 for low heat flux.

**ICD-PFC-CSS-051**: The Plasma interacts with IBD-V tile and causes sputtering and tile erosion.