Interface Control Document MAGNETS : CENTER STACK STRUCTURE

Interface Document: NSTXU_1-1-3_IC_105

REVISION 0

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PREPARED BY:	**Kathleen Lukazik**	10/11/2019 12:40:15 PM
	Kathleen Lukazik,	
REVIEWED BY:	**Robert A. Ellis**	10/11/2019 2:04:51 PM
	Robert A. Ellis,	
REVIEWED BY:	**George D. Loesser**	10/11/2019 2:52:12 PM
	George D. Loesser,	
REVIEWED BY:	**Steve Raftopoulos**	10/11/2019 3:44:09 PM
	Steve Raftopoulos,	
REVIEWED BY:	**Peter Dugan**	10/17/2019 11:04:56 AM
	Peter Dugan,	
APPROVED BY:	**Yuhu Zhai**	10/21/2019 4:16:03 PM
	Yuhu Zhai,	

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

National Spherical Torus eXperiment Upgrade

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Interface Control Document

MAGNETS:
CENTER STACK STRUCTURE

NSTX-U-ICD-MAG-CSS-0

Revision 0
May 10, 2018

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Prepared By: P. Dugan, Systems Engineering

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

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Reviewed: S. Raftopoulos, Magnets RE

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Reviewed By: Y. Zhai, NSTX-U Project Engineer

Change Record

Revision	Date	Description of Change
0	May 10 2019	Initial Release

References

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

[2] SYSTEM REQUIREMENTS DOCUMENT, VACUUM VESSEL AND INTERNAL HARDWARE, NSTX-U-RQMT-SRD-004-01, March 14, 2018.

[3] SYSTEM REQUIREMENTS DOCUMENT, MAGNET SYSTEMS, NSTX-U-RQMT-SRD-002-02, March 8, 2018.

[4] Polar Region: PF1ABC Coil Supports Design Description, Preliminary Design Review 3/27/2018.

[5] NSTXU Recovery Global Heat Balance Calculations, NSTXU-CALC-10-6-00

[6] Overview of Analysis, Inner PF FDR, March 30, 2018.

1. Purpose

This document describes the various interfaces between the Magnets and the Center Stack Structures. The interface locations and boundaries that connect the Magnets and the Center Stack Structures are identified based on different interface types.

2. Scope

Both of these are focused around the center stack casing. The Magnets address the TF Inner Legs, OH Solenoid, PF-1a Coils, PF-1b Coils, and PF-1c Coils. The Center Stack Structures include the Center Stack Casing, Pedestal, PF-1a Support Structures, PF-1b Support Structures, PF-1c Support Structures and other supporting components such as the quilted, micro-porous insulation (e.g. Microtherm™.) The scope of this document addresses any defined interfaces between these identified system elements.

3. Responsibilities

The interfaces are managed between the following organizations:

- Magnets
- Vacuum Vessel Internal Hardware
- Systems Engineering and Integration

4. Interfaces

Interface requirements in the following sections are identified with a requirement number, ICD, followed by a number [ICD-MAG-CSS-X] where "X" is a sequential count beginning with 001, MAG represents Magnets, and CSS represents Center Stack 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 references. References provide evidence pertaining to interfaces and include but are not limited to drawings, calculations, or specifications. References also include a reference to a paragraph that identifies the set of interface definitions.

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 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/ Halo Current

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.

Centerstack Structures	
Me, Th	Magnets

The remainder of this document addresses each of the interfaces. Note the template includes a paragraph heading for each interface and a table for each interface type. In the event there is no interface, the table will remain blank with a blank row.

The following paragraphs in Section 4 address each of the interfaces, and Section 5 addresses any off-project interfaces. Off-project interfaces are those external interfaces that interact with the NSTX-U system.

4.2. Mechanical Interfaces

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

4.2.1. Structural Interfaces

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

Identifier	Interface	References
1.1.3.3.7-1.1.3.3.1-S	The CS Pedestal supports CS assembly and TF Inner Legs against gravity, as well as other loads at the interface between the lower torque plate and the upper surface of the pedestal.	See Paragraph 4.2.1.1, Drawing DC1890
1.1.3.3.6-1.1.3.3.1-S	The Center Stack Casing is supported by the TF Inner legs via a series of components including the OH skirt and casing support weldment at surface of G10 plate (Compression ring) bonded to the lower inner legs.	See Paragraph 4.2.1.2, Drawing DC1738
1.1.3.3.11-1.1.3.3.3-S	PF-1a Coil and leads are supported at surfaces of coil PF-1a Support Structures.	See Paragraph 4.2.1.3, Ref 4, Drawing DC1742
1.1.3.3.12-1.1.3.3.4-S	PF-1b Coil and leads are supported at surfaces of PF1b Support Structure.	See Paragraph 4.2.1.4, Ref 4, Drawing DC1743
1.1.3.3.8-1.1.3.3.5-S	PF-1c Coil and leads are supported at surfaces of PF-1c Support structures.	See Paragraph 4.2.1.5, Ref 4, Drawing DC1414
1.1.3.3.3-1.1.3.4-S	Inner PF1a coil terminal supports mount to the common flange	See Paragraph 4.2.1.6,

1.1.3.3.4-1.1.3.4-S	Inner PF1b coil terminal supports mount to the common flange	See Paragraph 4.2.1.7
1.1.3.3.5-1.1.3.4-S	Inner PF1c coil terminal supports mount to the capping flange	See Paragraph 4.2.1.8

Interface Notes:

- The drawing numbers provided are for existing drawings, which may be updated, or for new drawings which are created for the Machine Core Structures Final Design Review.

4.2.1.1. Pedestal - TF Inner Legs/CS Assembly

Interface Notes:

- The pedestal provides alignment mechanisms to align the Center Stack Assembly to the vessel centerline.

ICD-MAG-CSS-001: The assembly is of the pedestal to the Center Stack is shown in Figure 1. The interface is described in Detail G of drawing DC1890 to connect the pedestal to the Center Stack hardware using .5/8-11 UNC-2A x 3" LG HEX HEAD BOLT - MIN YIELD 95 KSI.

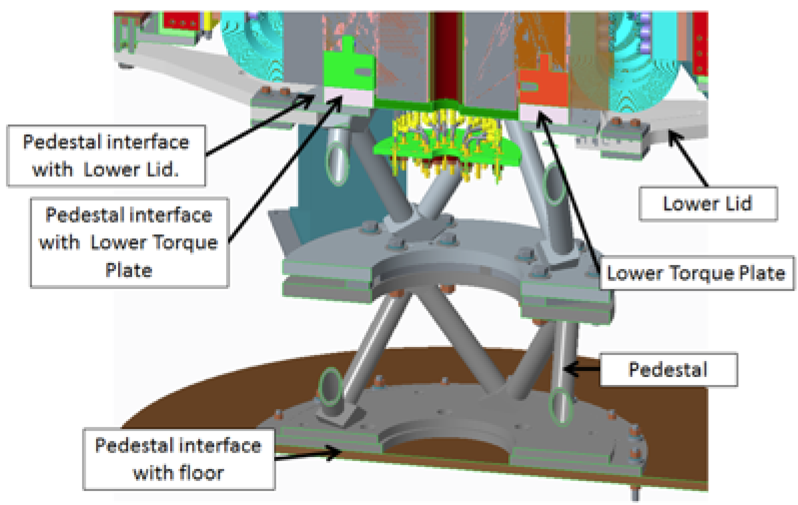

Figure 1. Pedestal to Center Stack

4.2.1.2. CS Casing and TF Inner Legs/OH Skirt

Interface Notes:

- Existing drawing numbers used in this ICD and are likely to change as a result of the MCSs FDR.
- Adjustment mechanisms are available to adjust the Center Stack assembly.
- Several sets of shims will be used to laterally, and axially, adjust the lower part of the Center stack assembly. The TF/OH coarse position adjustment shims are located between the lower and upper pedestal assemblies. Details on these shims may be found in drawing DC1563. They are the fit-up shims associated with Note 8. Center Stack Casing height and tilt adjustment shims may be found at the Outer Skirt interface. Lateral supports are mounted at the top of the CS assembly to control lateral movement of the upper structure.

ICD-MAG-CSS-002: The interface is described in drawing DC1738 TF-Inner Core and Center Stack Case Assembly DC1435 Center Stack Case Weldment Assembly, and uses 3/8-16UNC-2B HEX NUT. Figure 2 identifies the component hardware. An anti-rotating method (safety wire, tack-weld nuts, etc) are used to prevent the nuts from backing-out.

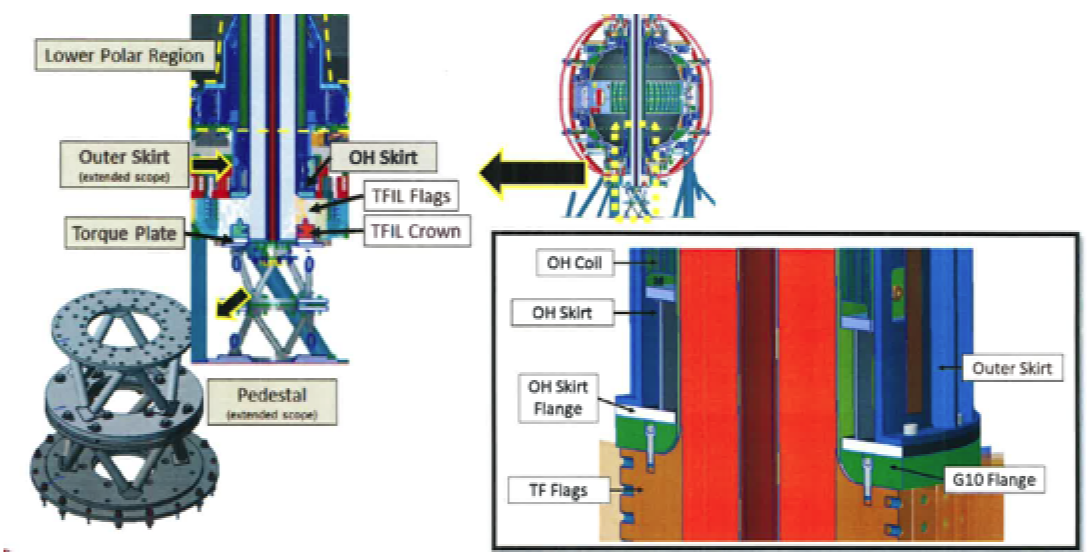

Figure 2. Lower structural assembly

4.2.1.3. PF-1a Coil & Leads to Support Structure

ICD-MAG-CSS-003: The G10 Shims and a hanger flange are first placed on the coil. The slings are then wrapped around the coils at particular toroidal locations. To secure the slings, the ends of the slings are then inserted into slots in the capture flange. This locks the slings in place. The belleville washers, stack and transfer pins, and set screw must also be installed. See Figure 3 below for details. The set screws are then tightened to the preload torque setting. This tightening will have the visual effect of taking the slack out of the slings. The final overall preload forces and torques may be found in the polar region installation instructions. The red is the coil pack and the other colors represent the structure.

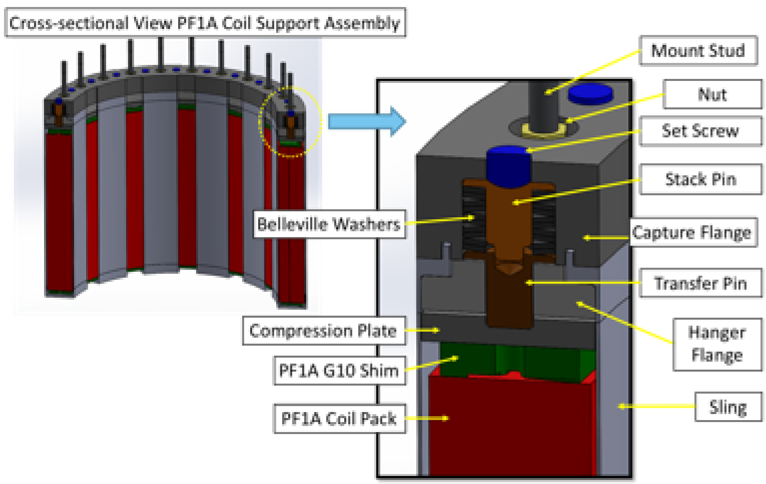

Figure 3. PF1A Coil Support.

ICD-MAG-CSS-004: The total coil preload is 113.2 klb. This translates to a torque on each belleville washer stack. This specification will be defined as part of the MCS FDR.

ICD-MAG-CSS-005: On the flange side on the coil support assembly, keys are used at interfacing parts (i.e., coil-to-compression plate) as shown in Figure 4 to transfer lateral loads and maintain coil position.

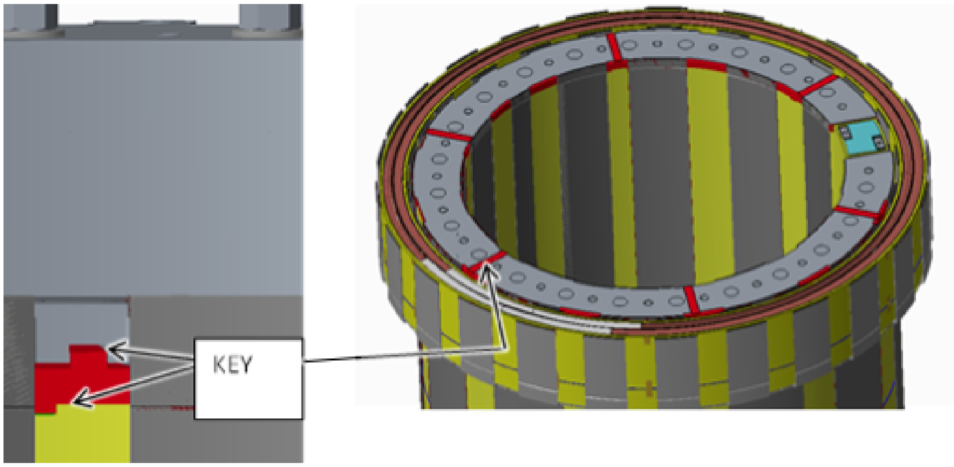

Figure 4. PF-1a Assembly Key

ICD-MAG-CSS-006: The PF-1a leads (orange) are contained in a bracket assembly in Figure 5.

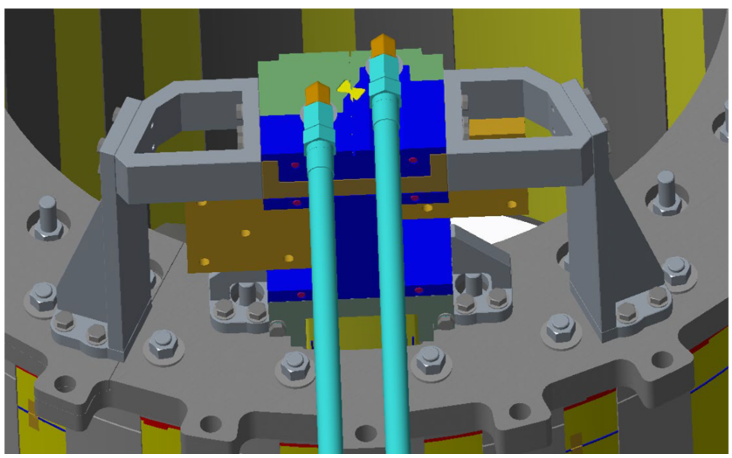
Figure 5. PF-1a Upper Coil Terminal

4.2.1.4.   PF-1b Coil & Leads to Support Structure

ICD-MAG-CSS-007: The PF1B Coil is mounted to the Common A/B Flange as shown in Figure 6. The slings are installed around the coils, and multiple flanges bolted together “capture” the slings, locking them into position.

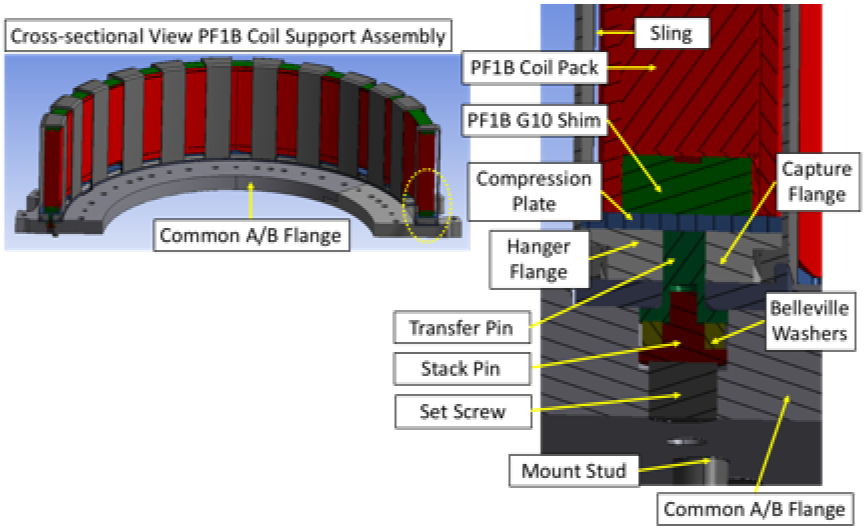

Figure 6. PF1B Coil Support using Common A/B Flange.

ICD-MAG-CSS-008: The total Coil preload is 60 klb. This translates to a torque on each belleville washer stack. THis specification will be defined as part of the MCS FDR.

ICD-MAG-CSS-009: On the flange side on the coil support assembly, keys are used at interfacing parts (i.e., coil-to-compression) as shown in Figure 7 to transfer lateral loads and maintain coil position.

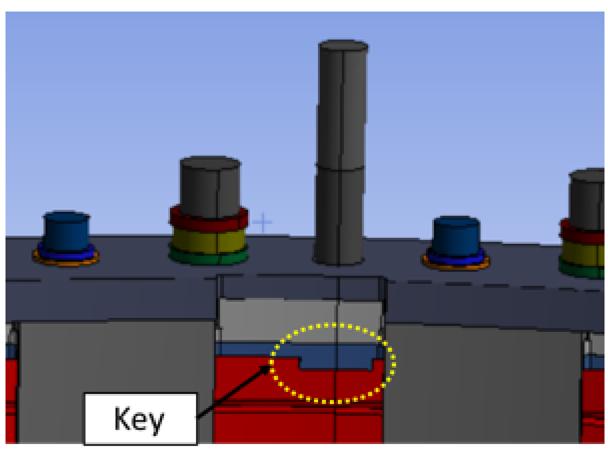

Figure 7. PF1b Coil Assembly Key.

ICD-MAG-CSS-010: The PF-1b leads (orange square below) are contained in a bracket assembly in Figure 8.

Figure 8. PF-1b Upper Coil Terminal

4.2.1.5. PF-1c Coil & Leads to Support Structure

ICD-MAG-CSS-011: The lower PF1C support is machined from a single forging as shown in Figure 9. No Preload is required.

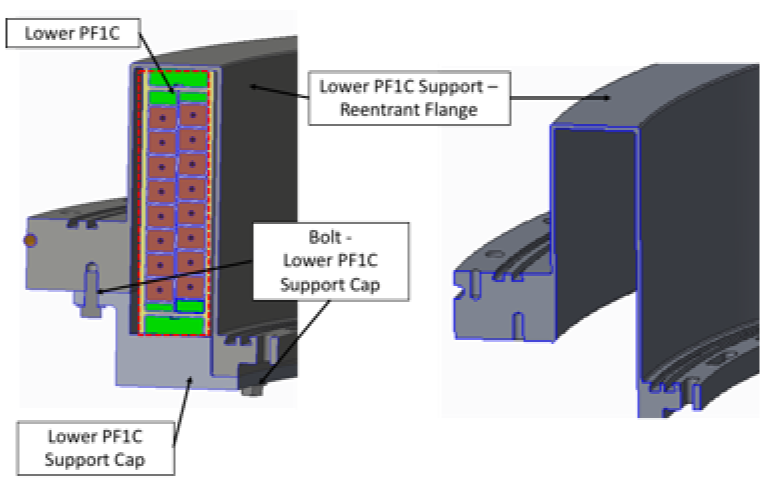

Figure 9. Lower PF-1C and Support Flange.

ICD-MAG-CSS-012: PF1c coil support uses keys between the structures and one of the coil contact surfaces as shown in Figure 10 to position the coils and restrain coil motion.

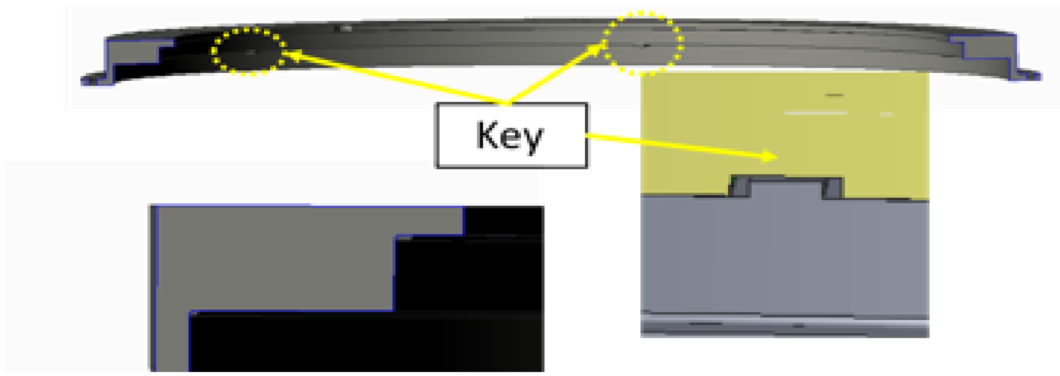

Figure 10. PF-1c Support Cap Key.

ICD-MAG-CSS-013: The PF-1c Upper uses a G10 Lead and support block as shown in Figure 11.

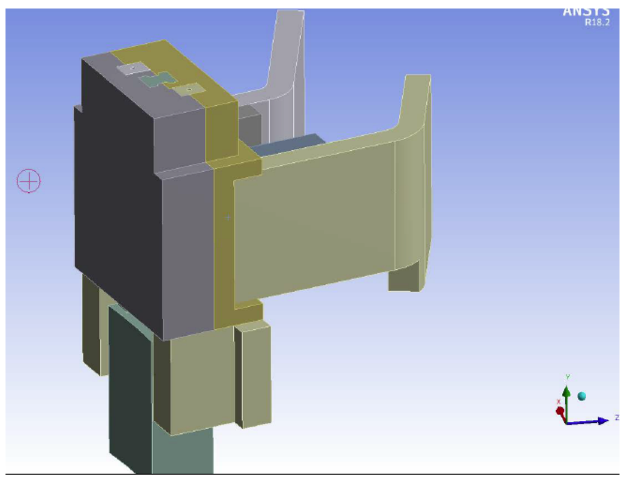

Figure 11. PF1c Lead Support.

4.2.1.6. PF-1a- Common Flange

ICD-MAG-CSS-014: The PF-1A has coil terminal supports as shown in Figure 11 that are mounted to the common flange. Figure 5 is a close-up of the support.

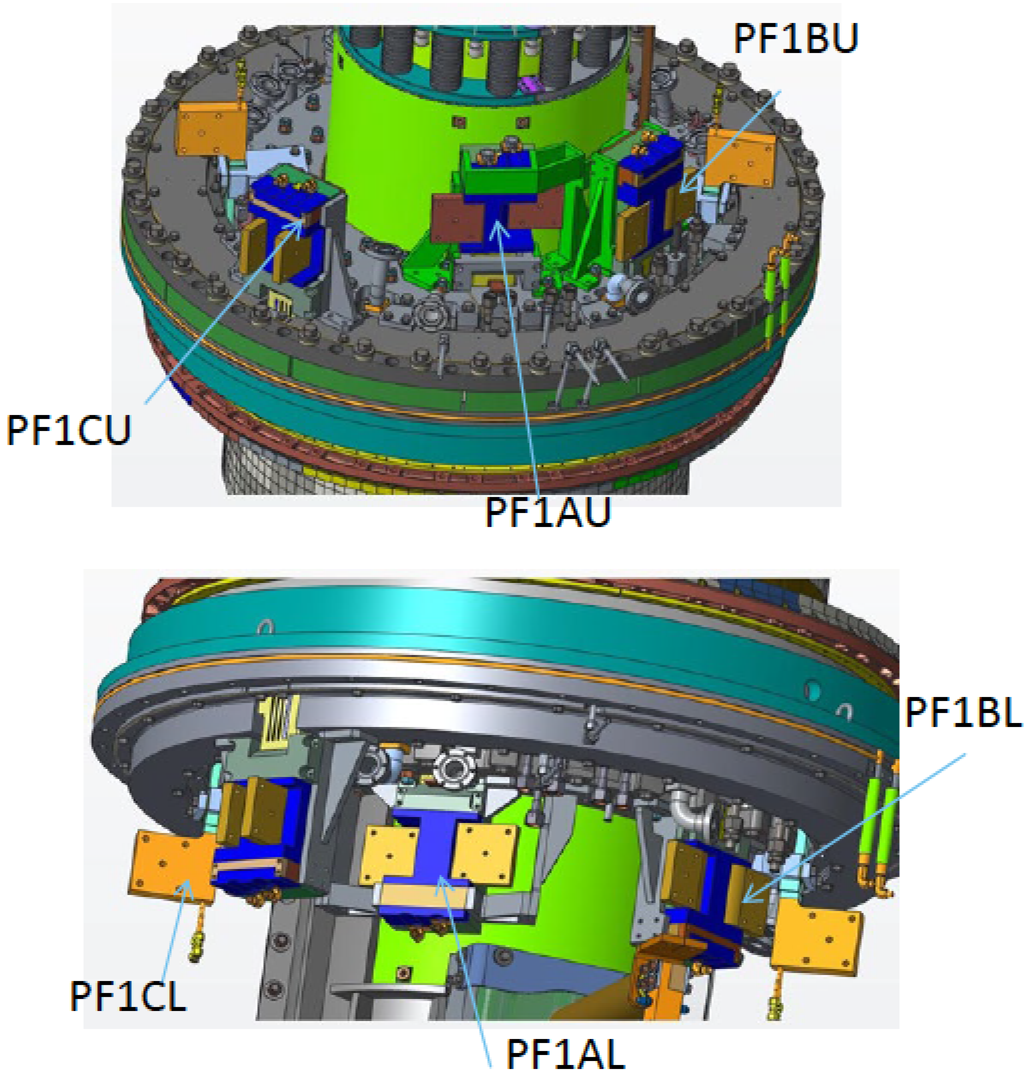

Figure 11. Terminal Support Structures

4.2.1.7. PF-1b - Common Flange

ICD-MAG-CSS-015: The PF-1b has coil terminal supports as shown in Figure 11 that is mounted to the common flange. Figure 8 is a close-up of the support

4.2.1.8. PF-1c - Common Flange

ICD-MAG-CSS-016: The PF-1c has coil terminal supports as shown in Figure 11 that is mounted to the capping flange. Figure 12 is a close-up of the support.

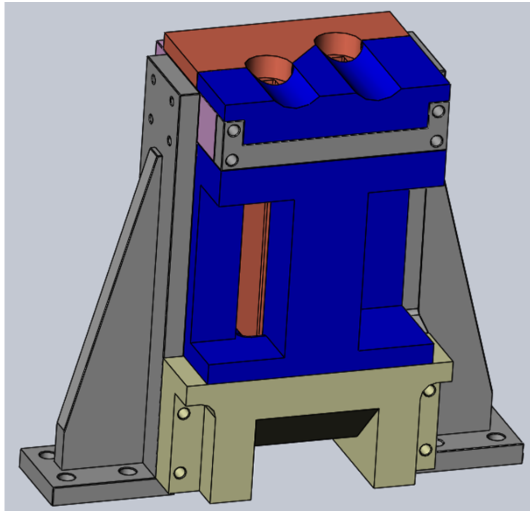

Figure 12. Terminal Support

4.2.2. Spatial Interface

This identifies any interfaces between the system elements pertaining to spatial restrictions or constraints.

Identifier	Interface	References
1.1.3.3.5-1.1.3.3.8-Sp	**Vertical Cooling** heat transfer tubes need to allow the **PF-1a coil** to fit through with sufficient clearance for alignment.	See Paragraph 4.2.2.1
1.1.3.3.4-1.1.3.3.12-Sp	PF1c support accommodate coil expansion	See Paragraph 4.2.2.2
1.1.3.3.3-1.1.3.3.11-Sp	PF1b slings accommodate coil expansion	See Paragraph 4.2.2.3
1.1.3.3.3-1.1.3.3.11-Sp	PF1a slings accommodate coil expansion	See Paragraph 4.2.2.4
1.1.3.3.3-1.1.3.3.11-Sp	Space needs to be allocated for microtherm between Center Stack casing and the OH coil	See Paragraph 4.2.2.5
1.1.3.3.3-1.1.3.3.11-Sp	Space needs to be allocated for microtherm between centerstack casing and the PF-1a coil	See Paragraph 4.2.2.6

1.1.3.3.5-1.1.3.3.8-Sp	Space needs to be allocated for microtherm between the collar and the PF-1B coil	See Paragraph 4.2.2.7

Interface Notes:

- In addition to the spatial interfaces identified below, there is space required as part of the installation to access the components
- Much of the spatial interfaces require deliberate placement of components in the gaps between slings

4.2.2.1. PF-1A Coil - HTT

ICD-MAG-CSS-017: The radial clearance is 0.20” between the microtherm(white) around the HTT clamp (green bar around orange tubes) magnet sling as shown in Figure 13. Figure 14 shows the plan view for the where the slings (grey), HTT clamps (green), Microtherm (white), and Rogowski Coil (brown)

Figure 13. Vertical Cooling Model.

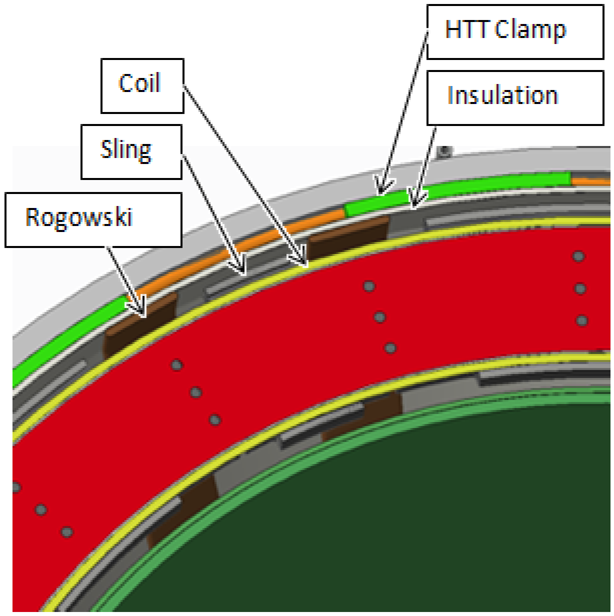

Figure 14. Coil and Slings Plan View.

4.2.2.2. PF-1C Coil - PF-1C Support

ICD-MAG-CSS-018: Figure 9 shows that the cap sandwidges the PF1c coil into the support. Keys fix the PF1c's torsional and lateral movement. Friction will be the only restraining force on radial expansion. After a quick initial assembly, the bottom of the cap might be shaved slightly to lower the friction force exerted on the PF1c coils.

4.2.2.3. PF-1B Coil - PF-1B Slings

ICD-MAG-CSS-019: During operations the coils will expand. The slings need to account for coil expansion. The expansion values will be provided in time for the FDR.

4.2.2.4. PF-1A Coil - PF-1A Slings

ICD-MAG-CSS-020: During operations the coils will expand. The slings need to account for coil expansion. The expansion values will be provided in time for the FDR.

4.2.2.5. Microtherm - OH Coils

ICD-MAG-CSS-021: A gap needs to be maintained between the OH coil and the Center Stack casing. This gap allows for TF/OH radial expansion, insulation, Rogowski coils, and other various electronic components/wiring that must run along the TF/OH coil, see Figure 15.

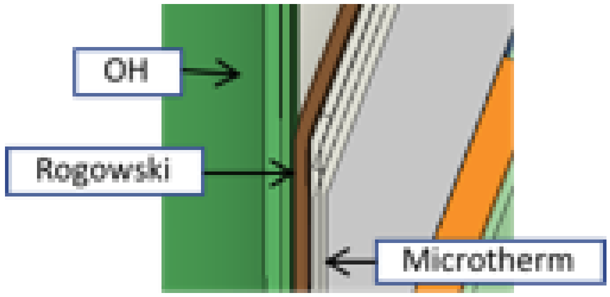

Figure 15. Microtherm between OH coil and Center Stack Casing

4.2.2.6. Microtherm - PF-1A Coils

Interface Notes:

- The microtherm will likely have other components such as diagnostics (Ip Rogowskis, Flux Loops, Thermocouples) that are contained in the CSS-Diagnostic ICD.

ICD-MAG-CSS-022: A gap needs to be established between the PF-1A coil and the Center Stack casing Inboard Divertor Vertical (IBDV) and HTT clamp or air gap for the tubes as Shown in Figure 16. The inlet/outlet heat transfer tube (orange) can run vertically as shown in the right side of Figure 16.

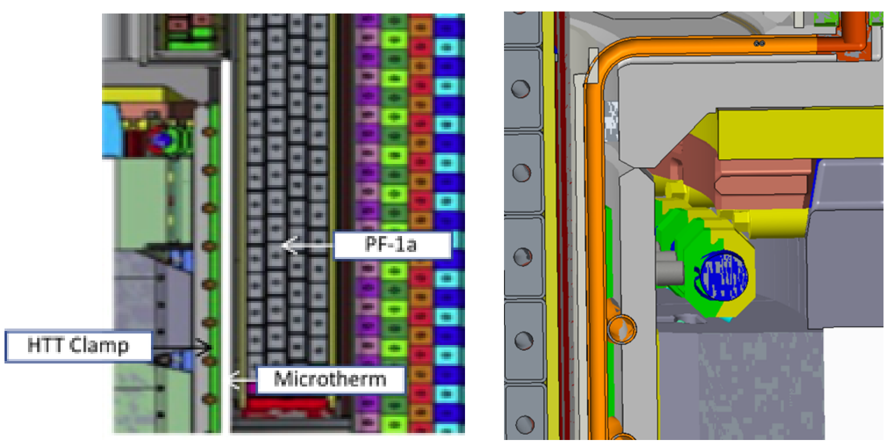

Figure 16. Microtherm between PF-1A coil and Center Stack Casing

4.2.2.7. Microtherm - PF1B Coils

User Interface

- The Microtherm will have other components such as diagnostics (Ip Rogowskis, Flux Loops, Thermocouples) that are discussed in the CSS-Diagnostic ICD.

ICD-MAG-CSS-023: A gap needs to be established between the PF-1B coil and the bellows. Figure 17 shows the microtherm (in rightmost white line) between the coil and the bellows.The bellows will also have a layer of microtherm. as shown by the leftmost white line in Figure 17.

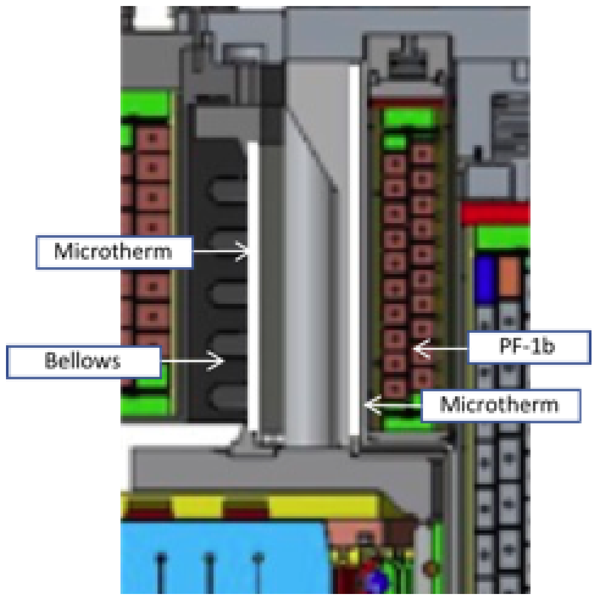

Figure 17. Microtherm between PF-1B and Bellows

4.2.3. Location Interfaces

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

Identifier	Interface	References
N/A		

4.2.4. 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	References
N/A		

4.3. Electrical Power Interfaces

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

Identifier	Interface	References
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 interface such as Ethernet or Fiber Optic or any specific protocols.

Identifier	Interface	References
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	References
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	References
N/A		

4.6.2. Fluid Interfaces

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

Identifier	Interface	References
N/A		

4.7. Vacuum Interfaces

This identifies any interfaces between the system elements that pertain to the Vacuum.

Identifier	Interface	References
N/A		

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	References
N/A		

4.9. Thermal Interfaces

This identifies any interfaces between the system elements that pertain to Thermal characteristics.

Identifier	Interface	References
1.1.3.3.6-1.1.3.3.2-T	Microtherm on **Ohmic Heating Solenoid** to provide thermal isolation of the **Center Stack Casing.**	See Paragraph 4.8.1 Reference 5
1.1.3.3.6-1.1.3.3.3-T	Microtherm blanket provides thermal isolation between **PF-1a Coils** and **Center Stack Casing.**	See Paragraph 4.8.2 Reference 5
1.1.3.3.6-1.1.3.3.4-T	Microtherm blanket provides thermal isolation between **PF-1b Coils** and **Center Stack Casing.**	See Paragraph 4.8.3 Reference 5

Interface Notes:

- Microtherm is used to protect the coils from the peak temperatures in ref 5, while fitting in the spacing between the Center Stack casing and the coils.
- The interface focuses on the structural areas as shown in Figure 18. Using the global thermal analysis [ref 5], Thermal temperatures near the magnets are considered. The cooling water is used to capture the heat from the plasma, before the heat can get to, and negatively affect, the magnets.

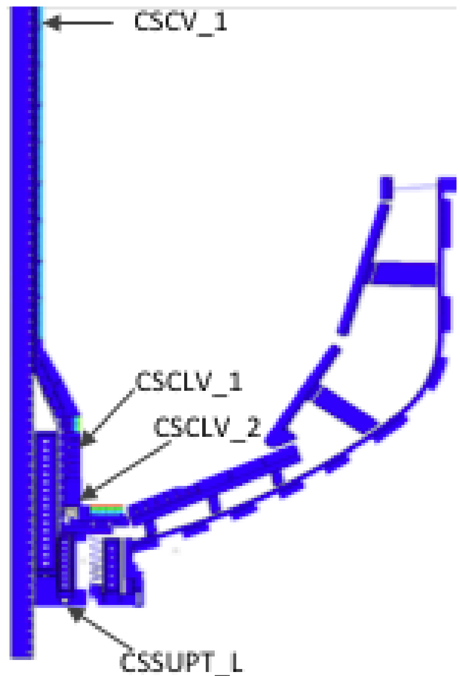

Figure 18. Thermal Structure model

4.9.1. OH to Center Stack Casing Thermal Analysis

ICD-MAG-CSS-024: The Center Stack First Wall (CSCV1) ranges from ~ 105 to 235 degrees C . The outlet temperature of the water ranges from ~ 20 to 100 degrees C.

ICD-MAG-CSS-025: The Center Stack First Wall (CSCV1) Bakeout has a maximum of ~465 to degrees C. The outlet temperature of the water is ~41 degrees C.

4.9.2. PF-1a - Center Stack Casing

ICD-MAG-CSS-026: The Vertical Section (CSCLV1 or 2) ranges from ~15 to 150 degrees C. The outlet temperature of the water ranges from ~12.5 to 60 degrees C. Figure 19 provides the thermal scenarios of the cooling tubes has a maximum temperature of ~147 degrees C (green).

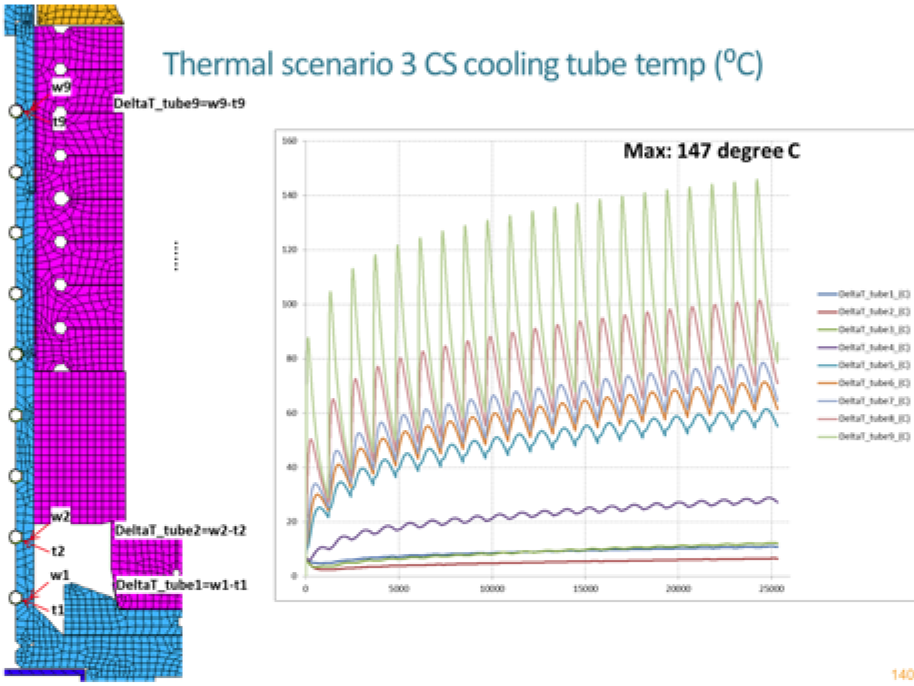

Figure 19. Thermal Scenario with Cooling tubes

ICD-MAG-CSS-027: The Vertical Section (CSCLV1 or 2) Bakeout temperatures ranges from ~ to degrees C. The outlet temperature of the water is ~ 15 degrees C.

4.9.3. PF-1b to Center Stack Casing

ICD-MAG-CSS-028: The Vertical Section (CSSUPT) Normal Operating temperature ranges from ~32 to 43 degrees C. The outlet temperature of the water ranges from ~13 to 100 degrees C. Figure 19 provides the thermal scenarios of the cooling tubes has a maximum temperature of ~100 degrees C (red).

ICD-MAG-CSS-029: The Vertical Section (CSSUPT) Bakeout temperature has a maximum of ~135 to degrees C. The outlet temperature of the water is ~ 21 degrees C.

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	References
N/A		

4.10.2. Eddy/Halo Current Interfaces

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

Identifier	Interface	References
N/A		

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 on part of the interface. They are provided for completeness.

The plasma will have an effect on the electromagnetic loads associated with both the magnets and the supporting structures. These loads as identified in Ref 1 are considered in the design of the various components.