PPPL PRINCETON PLASMA PHYSICS LABORATORY

ENG-064 - ICD - INTERFACE CONTROL DOCUMENT

Bakeout Systems - Vacuum Vessel Structures Interface Control Document

NSTXU_1-1-2_ICD_102

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National Spherical Torus eXperiment Upgrade

National Spherical Torus Experiment Upgrade

Interface Control Document

BAKEOUT SYSTEM:
VACUUM VESSEL STRUCTURE

NSTX-U-ICD-BOS-VVS-0

Revision 0
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Change Record

Revision	Date	Description of Change
0	February 14, 2020	Initial Release

References

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

[2] SYSTEM REQUIREMENTS DOCUMENT, AUXILIARY SYSTEMS, NSTX-U-RQMT-SRD-005-01.

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

[4] Bakeout Bus Bar Loading Calculation, NSTXU_1-3-3-2-1_CALC_101

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

1. Purpose

This document describes the various interfaces between the following subsystems: Bakeout System and the Vacuum Vessel Structure. The interface locations and boundaries that connect the Bakeout System to the Vacuum Vessel Structure are identified based on different interface types.

2. Scope

The Bakeout System consists of the Helium Heating and Cooling System, Vacuum Vessel Water Heating and Cooling System and Bakeout Bus Bar. The Vacuum Vessel Structure consists of Vacuum Vessel, Umbrella Structure and Lids, Ports, and Coil supports. The scope of this document addresses any defined interfaces between these identified system elements.

3. Responsibilities

The interfaces are managed between the following organizations:

- Bakeout System
- Vacuum Vessel Structure
- Systems Engineering and Integration

4. Interfaces

Interface requirements in the following sections are identified with a requirement number, ICD followed by a number [ICD-BOS-VVS-X] where X is a sequential count beginning with 001, BOS represents Bakeout System and VVS represents Vacuum Vessel Structure. There is also a unique identifier for all interfaces in the format [#####-#####-X]. The identifier is a concatenation of two level 5 WBS values and the interface type. This is followed by an interface description and a list of references. References provide evidence pertaining to interfaces include but are not limited to drawings, calculations, or specifications. Reference also includes 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

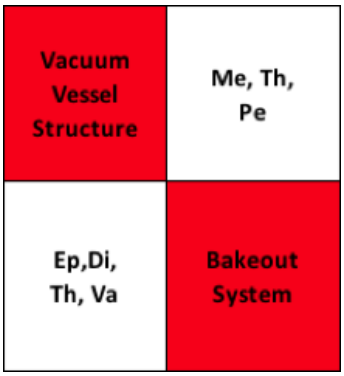
Heading	Abbreviation	Name
4.2	Me	Mechanical
4.3	Ep	Electrical Power
4.4	Si	Signal
4.5	Di	Diagnostics
4.6	Gf	Gas/Fluid
4.7	Va	Vacuum
4.8	Sw	Software
4.9	Th	Thermal
4.10	Pe	Plasma/Eddy/Halo Current

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 Structures	Me,Di, Pe			Th			Me,Th, Pe	Me		Me, Pe			Di		
		Vacuum Vessel Structure			Me,Va	Me, Va	Me	Me, Th, Pe	Me	Me,Va	Me,Di, Va		Si	Di, Me		
		Va	Centerstack Structures			Va, Th	Me, Gf	Me	Me					Di		
		Me	Me, Th, Ep	Magnets				Me			Di		SI	Di	Me	
Si		Me, Va			Heating Systems		Gf	Th		Me		Si	Si	Si	Si, Me, Di	
					Si, Va, Me, Sw, Gf	Vacuum Pumping System		Si	Si	Si	Si		Si,Va	Si	Si	
				Gf,Si			Coolant System	Gf				Gf,Sw	Si, Sw	Si	Si	
	Th, Gf	Ep,Di, Th, Va	Ep, Gf, Th, Pe		Si		Si	Bakeout System							Si, Me	
			Gf,Va			Me, Gf,Si			Gas Delivery System	Gf	Va		Si,Sw	Si	Si, Me	
		Gf				Si,Gf,Va			Me	Wall Conditioning System			Si,Sw		Me	
		Me,Va	Me,Va	Me	Me	Gf,Si	Gf			Va, Ep	Diagnostics		Si,Sw	Si	Si, Me	Si
				Ep	Ep	Ep	Ep	Ep	Ep	Ep	Ep	Power Systems	Ep,Si	Ep, Si	Si, Me, Di	Ep
					Si					Me, Si	Si		Centralized Instrumentation and Control	Si, Me		
												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



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 a structural, spatial, location dependent interfaces or areas where penetrations into a wall or floor are required. These are identified independently as interface parameters will likely be different.

4.2.1. Structural Interfaces

Identifier	Interface	References
1.1.2.1.1-1.3.3.2.1-S	Disruption JxB forces reacted at joint between the **vessel** and the **Bakeout Bus** Work	See Paragraph 4.2.1.1

4.2.1.1. Vessel - Bakeout Bus Work

Interface Notes:

- The Upper Bus Bar requires minimal redesign while the lower is a significant redesign due to the CHI bus redesign.

ICD-BOS-VVS-001: At the upper section, Is connected in three locations at Bays C, E, and J . The upper Bakeout Bus Bar connections are shown in orange in Figure 1 attached to the umbrella structure.

Figure 1. Upper Bakeout Bus Bar

ICD-BOS-VVS-002: At the lower section, Is connected to the vessel at three locations. The lower Bakeout Bus Bar connections shown in Figure 2 shows the Bus Bar connected to the umbrella. Figure 3 provides a view of “T” (red) welded to the vessel. The Bakeout Bus Bar design has included the JxB forces in [Ref 4].

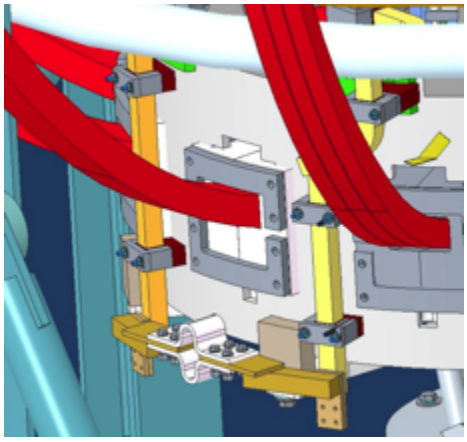


Figure 2. Lower Bus Bar on Umbrella

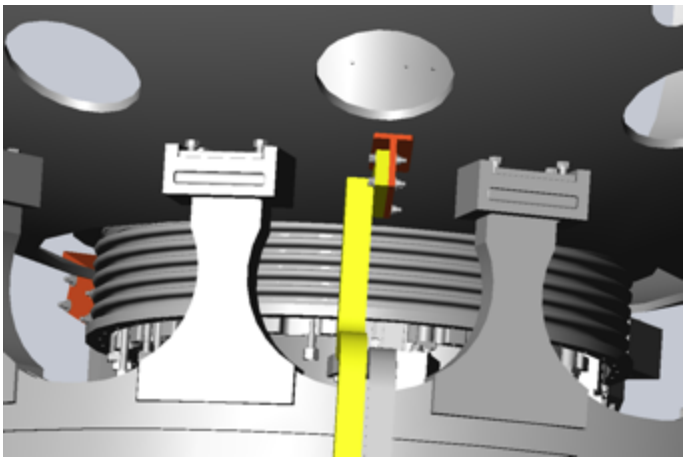


Figure 3. Bus Bar welded to Vessel

4.2.2. Spatial Interface

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

Identifier	Interface	References
N/A		

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 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
1.3.3.2.1-1.1.2.1.1-P	The three bakeout electrical connections are mounted to the vessel surface	See Paragraph 4.3.1, Drawing DC1861, DC1684
1.3.3.2.1-1.1.2.1.1-P	The vacuum vessel is grounded via the Bakeout Bus Work	See Paragraph 4.3.2, Drawing 4F1005, DC1498

4.3.1. Vacuum - Vessel Electrical Connections

Interface Notes:

- The Bakeout Bus Bar was previously referred to as the CHI bus.
- The upper Bakeout Bus Bar is not changing significantly; however, the CHI Bus Bar is completely changing and will be addressed in either new drawings or updates to the Lower CHI bus in Drawing DC1498 as part of the Bus Bar Design Review.
- Bakeout connections will be replaced with G-10 in the upper portion during operations.

ICD-BOS-VVS-003: The upper Bakeout Bar connections are provided in Drawing DC1861. Drawing DC 1684 Sheet 4 provides the brazement for the Vacuum Vessel Base Bracket. Drawing DC 1684 Sheet 9 provides the umbrella support brackets and vacuum vessel base. Drawing DC 1684 Sheet 10 provides the vacuum vessel connector brazement. Figure 1 provides a model of the vessel with the bus bars (orange) that are connected to the umbrella.

ICD-BOS-VVS-004: The lower Bakeout Bar as shown in Figure 3 provides mounts that are welded to the vessel. The yellow represents the jumpers that connect the Inner legs to the outer legs of the bakeout. The goal of the design is to provide similar resistance across all of the jumper connections.

4.3.2. Vacuum Vessel - Grounding

Interface Notes:

- The grounding system has changed as a result of removing the CHI bus and moved from two grounds to a single ground through the connection to the Bakeout Bus Bar.
- The Lower Ground bar may get a new number and the old drawing voided based on the significance of changes to the design

ICD-BOS-VVS-005: There will be a single ground that connects the ground bus to the nearest Bakeout Bus Bar. Figure 4 provides a graphic of the approach for connecting one copper bar (Copper Rectangle) to connect to the Ground Bus (Line Drawing). Drawing 4F1005 Sheet 1579 provides an overall grounding drawing.

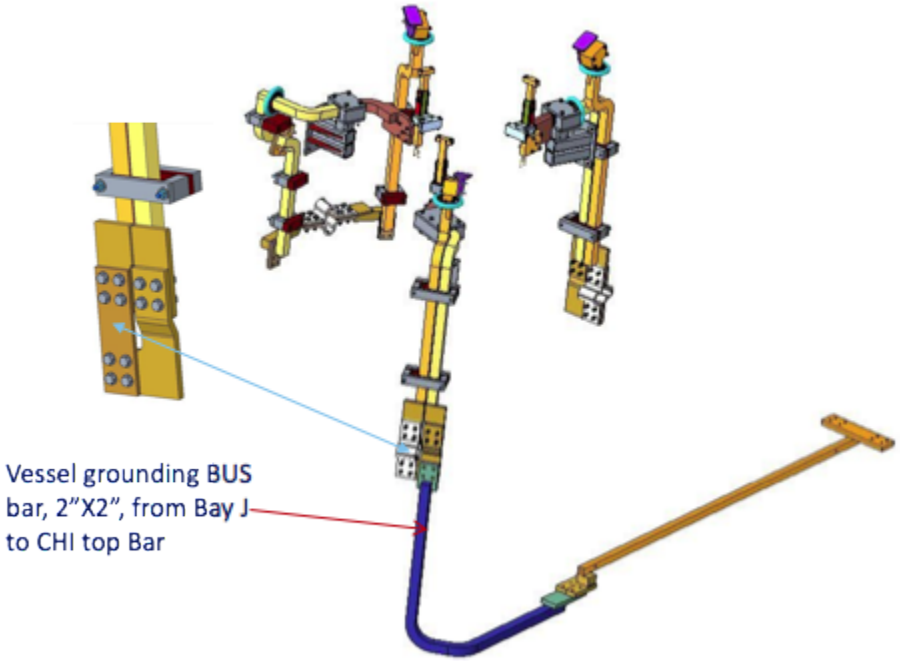


Figure 4. Connection of a Bakeout Bus Bar to the Ground Bus

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
1.3.3.1.3-1.1.2.2-D	Thermocouples measure temperature of select helium tubing components.	See Paragraph 4.5.1

4.5.1. Helium Tubing - Thermocouples

ICD-BOS-VVS-006: The helium lines are installed on the tubes next to the helium access ports inside the vessel. Electrically isolated thermocouples are mounted on the 1" loop pipes at each supply/return connection to the helium manifolds as shown on the blue dots on Figure 5.

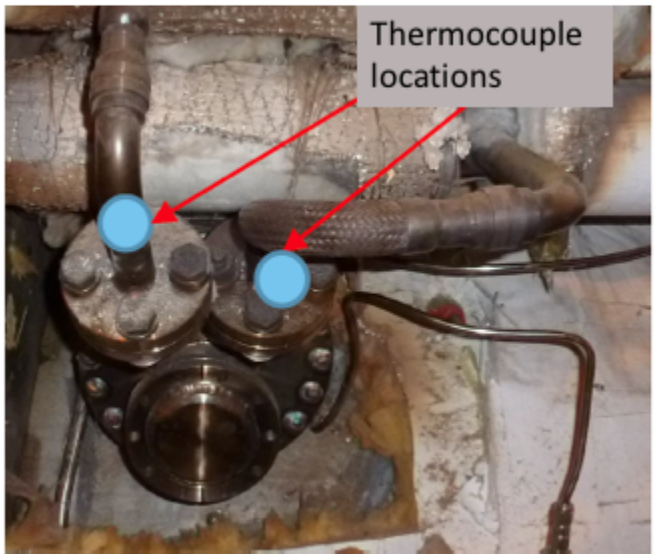


Figure 5. Thermocouple locations on helium supply and return lines

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
1.3.3.1.4-1.1.2.1.1-V	The weld connecting the helium feedthrough to the vessel port extension	See Paragraph 4.7.1, Drawing DB1076

4.7.1. Helium Feedthrough - Vessel Port

ICD-BOS-VVS-007: There are 6 ports that are welded around the vessel. Drawing DB1076 provides the details of the ports. A diagram of the port is provided in Figure 6.

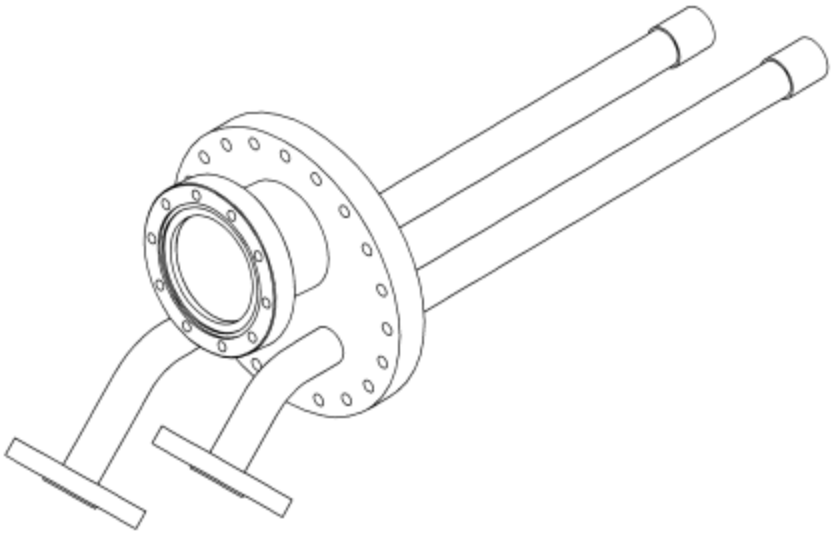


Figure 6. Helium Heating/Cooling Port

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
1.3.3.3.2-1.1.2.1.1-T	MTWS tubing is attached to the vessel surface	See Paragraph 4.9.1, Drawing EB1002
1.1.2.1.1-1.3.3.2.1-T	The Bakeout Bus Work joint must tolerate a range of thermal scenarios,	See Paragraph 4.9.2

	from **room temperature** to the full outer vessel **bakeout** temperature.	

4.9.1. MTWS - Vessel Surface

Interface Notes:

- The MTWS tubes are already in place and not part of recovery scope but are included for completeness.

ICD-BOS-VVS-008: Figure 7 shows a representation of the tubes that are connected to the exterior of the vessel. The Red and Green lines represent ½" tubing, The Blue lines represent ¼" tubes. The aqua lines represent removable flex tubing.

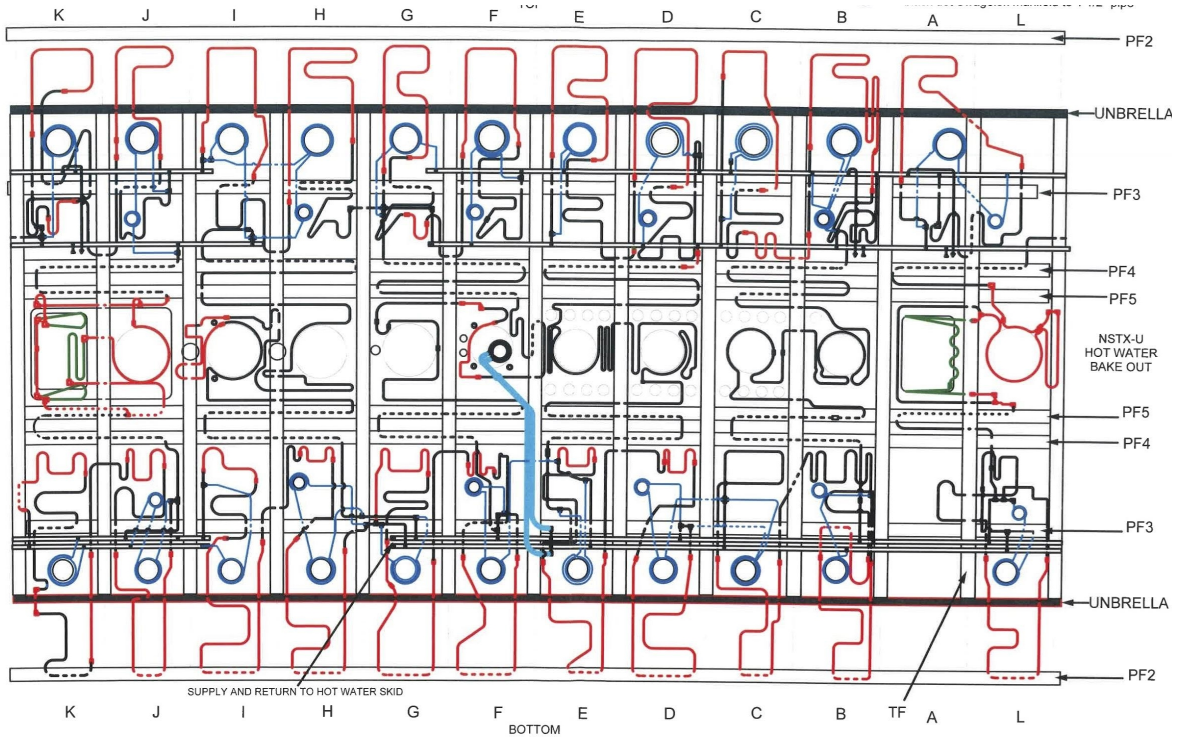


Figure 7. MTWS Tubing Diagram

ICD-BOS-VVS-009: The interface where the water lines are connected is between Bays G & H consists of Swagelock fittings as indicated in Drawing EB1002.

4.9.2. Bakeout Bus - Thermal Scenarios

ICD-BOS-VVS-010: The temperature ranges from 20 deg C room temperature to 180 deg C. This includes water cooled sections, e.g., flags, as well as non-water-cooled, e.g., legs. Calculation Ref 4 with input data from ref 5 provided justification to the design.

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 Eddie/Halo Currents.

Identifier	Interface	References
1.1.2.1.1-1.3.3.2.1-E	Halo current will flow through connections bridging inner and outer **vessel**, applying load to the **bus work**.	See Paragraph 4.10.2.1

4.10.2.1. Outer Vessel - Bus Work

Interface Notes:

- Calculation will be completed for the FDR

ICD-BOS-VVS-011: There is a HALO current that will cross the Bus work of 120 KA is shared by three legs. There will be a maximum of 70 KA across one leg as addressed in Ref 4.

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.

There are no external interfaces.