



National Spherical Torus eXperiment Upgrade

Interspace Vacuum Pumping System WBS 1.03.03.03

NSTX-U Recovery Project FDR – March 17-19, 2020

D. Cai - Cognizant Engineer

Last edit: 3/9/20

Outline

1. Overview

2. Scope

3. Requirements and Interfaces

4. Analysis/Prototyping

5. Chit Closure

6. Procurement, Fabrication, Installation, and Test

7. Risk - Project Risks and Design FMECA

8. Quality, Environmental, Safety, and Health

9. Summary

Overview - WBS 1.03.03.03

WBS Title	Interspace Vacuum Pumping System	WBS #	1.03.03.03
Project Cog.	D. Cai	Assoc. Proj. Man.	Gary Swider
Design Scope	Design, fabricate, and install a system to pump the interspaces of double O-ring seals		
Technical Impact of Scope	System ensures that large seals at the interface of the CS to the outer vessel to not degrade the vacuum quality		
Design Status	FDR completed on 2/20/2019, all chits resolved: review link chits: link calculations: link drawings: link		
Fabrication Status	Pumping manifold assembly in process		
Installation Status	Mechanical and electrical/control installation will be performed in NTC		

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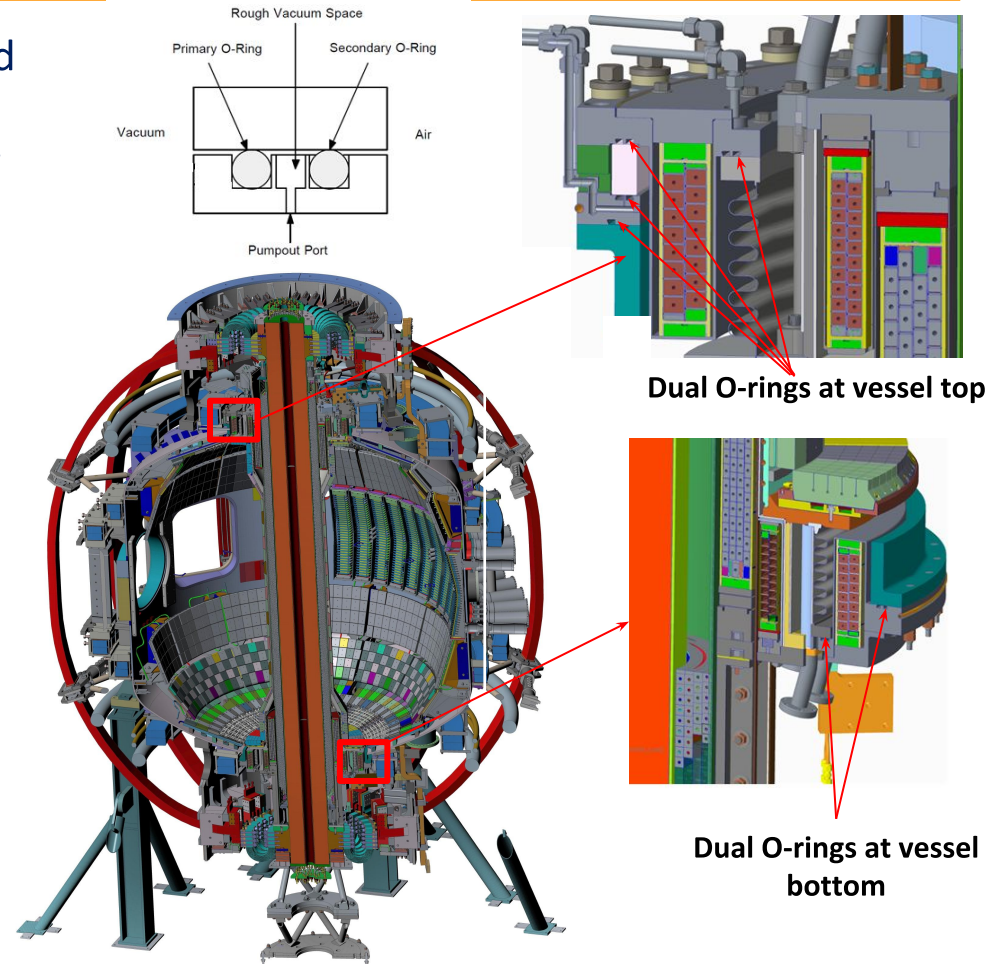
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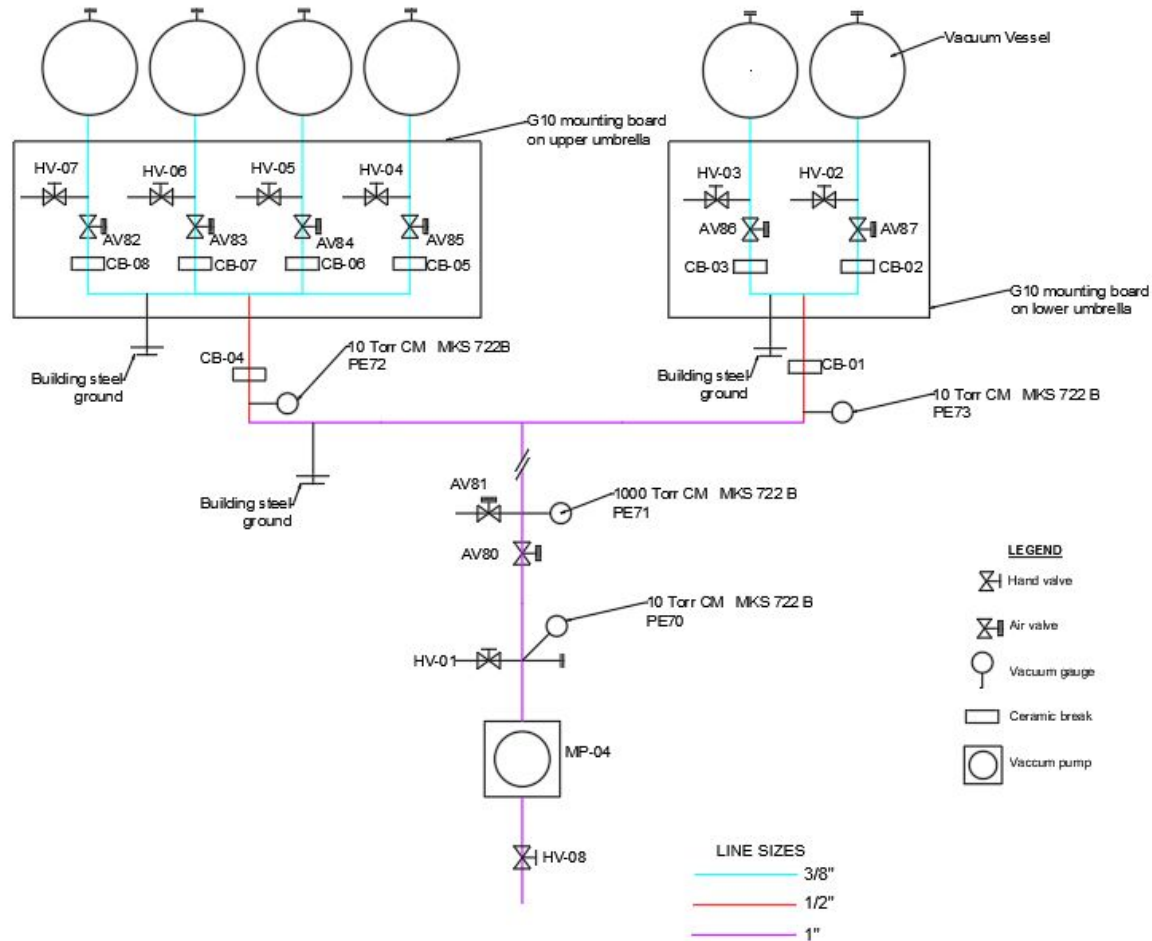
Interspace Vacuum Pumping System - Scope

- System provides sufficient pumping speed for O-ring interspace
- Continuously monitoring the condition of all seals
- In case of leak, system will be capable of identifying which O-ring is causing issue
- Double ceramic break design to prevent effect of arcing on pressure transducer
- Automatic system backfill
- Expansion to additional interspaces can be accommodated
- Vacuum pressures of 5×10^{-2} Torr at the inlet ports to the Interspaces in a dead-ended configuration



Interspace Vacuum Pumping System - Scope

P&ID of the interspace vacuum pumping system



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Requirements and Interfaces

Source	Requirements	Comment	met
NSTX-U-RQMT-GRD-001	General requirements	vacuum pumping, electrical isolation	✓
NSTX-CRIT-0001	Design criteria	Provides the project definition of margin for loads vs. allowables	✓
NSTX-U-RQMT-SRD-004	Detailed system requirements for IVPS	Requirements including pumping speed and pressure, as well as future expansion	✓
NSTX-U-RQMT-RD-010	Magnetic permeability requirement	Base material, machining and welding	✓
NSTX-U-RQMT-RD-003	Disruptions	Provides guidance on disruption currents and loads	✓

Details of Interfaces Defined in Interface Control Documents

System 1	System 2	ICD Link	Exposition
Vacuum Pumping System	Center Stack Structures	link	Defines interface between the IVPS and the double O-rings
Operations & Systems Safety	Vacuum Vessel	link	Defines interface between IVPS and the Umbrella
Operations & Systems Safety	External (Exhaust)	link	Defines interface between the IVPS and external system exhaust in the test cell

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Analysis and Prototyping

Physical Quantity	Calculation #	Comment
Interspace Vacuum Pumping System (IVPS), Pumping Speed	NSTXU-CALC-33-04-00	Calculated the pumping speed delivered to the dual o-ring space. Pump line conductance is much larger than the conductance between the two o-rings


No prototyping required for the system; uses commercial off the shelf (COTS) components in a configuration similar to other vacuum systems on NSTX-U

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All Chits have been Closed

All Chits closed including FDR chits

 **National Spherical Torus eXperiment Upgrade**

**Chit Resolution Report
for
Interspace Vacuum
Pumping System**

NSTX-U-REC-107-01

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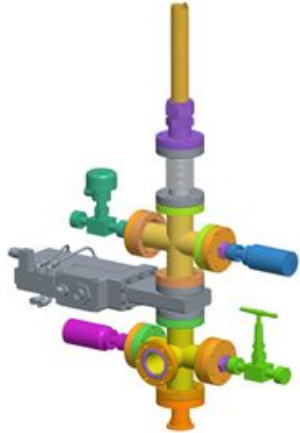
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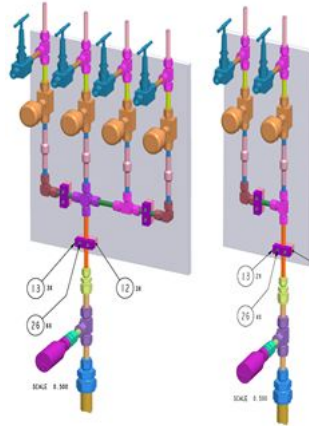
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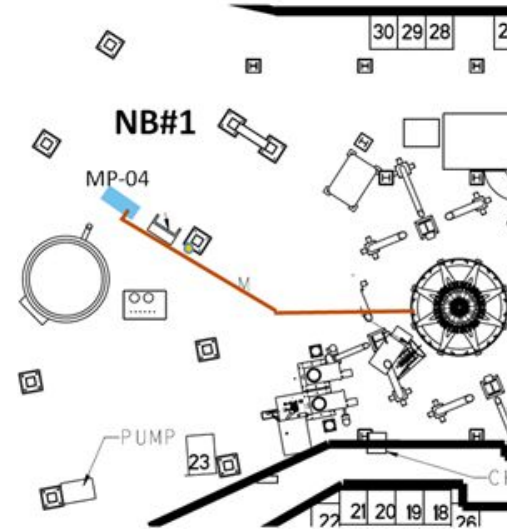
Procurement, Fabrication, Installation, and Test



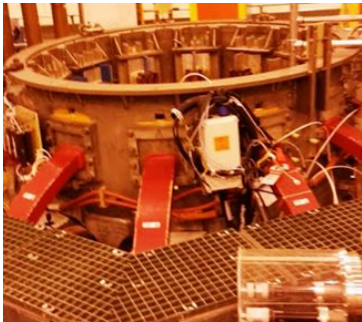
Vacuum pumping
intake/exhaust assemblies



Pumping manifolds



Floor layout



NSTX-U vessel-upper



Vacuum pump

- Standard off-the-shelf gas components, fittings and hardwares have been purchased and mostly received
- In-house made machining components for manifolds completed
- Pumping manifolds and intake/exhaust assembling started
- Preparing installation package and testing procedures

NCRs and ECNs During IVPS Fabrication/Installation To Date

No NCR or ECN required so far for fabrication and installation

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Risk - Project Risks and Design FMECA

Risk	Score (1-81)	Open/Retired	Risk Retirement Event
No WBS-specific risks for this project element			

Risks regarding procurement delays, fitup, etc held at the Project level

FMECA - Operations Risks (I)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Interspace Vacuum Pumping System	Vacuum leak develops in IVPS pumping lines	vibration; are disturbed during nearby operations	Pressure rise in pumping line resulting in inadequate interplace pump-out and impact on plasma operations	4	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	IVPS vacuum pump fails during operations	age, manufacturing problem	Pressure rise in pumping line; system may not be operational impacting plasma operations	4	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	IVPS pressure sensor fail - high reading	electronics failure	automatic mode is compromised, will not ever show pressure low enough to open AVs	3	Interspace Vacuum Pumping System	None	None	3
Interspace Vacuum Pumping System	IVPS pressure sensor fail - low reading	electronics failure	automatic mode is compromised, will open AVs prematurely, resulting in the pressure in the interspace going transiently too high	3	Interspace Vacuum Pumping System	None	None	3

FMECA - Operations Risks (II)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Interspace Vacuum Pumping System	IVPS pressure gauge fails during operations	age, manufacturing problem	inability to diagnose system pressure; system may not be operational	2	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	IVPS ceramic break mechanical failure	some bracket failure; impact by a tool	IVPS cannot function; interspaces go to atmospheric pressure	2	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	IVPS ceramic break electrical failure	dirt or other contamination	inability to high-pot the vessel	2	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	Any IVPS air valve (AV82-AV87) fail in open position	valve mechanical failure	interspace will go to atmospheric pressure during pulse, may slightly compromise machine vacuum	2	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	Any IVPS air valve (AV82-AV87) fail in closed position	valve mechanical failure, loss of air	inability to pump out interspace	2	Interspace Vacuum Pumping System	None	None	2

FMECA - Operations Risks (III)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Interspace Vacuum Pumping System	IVPS vent valve AV81 fails in closed position	valve mechanical failure, loss of air	automatic cycling compromised, and ceramic breaks are at vacuum during pulse, potentially leading to arc breakdown	2	Interspace Vacuum Pumping System	None	None	2
Interspace Vacuum Pumping System	IVPS vent valve AV81 fails in open position	valve mechanical failure	automatic cycling compromised, atmospheric pressure in interspaces all time, leading to potential machine vacuum compromise	2	Interspace Vacuum Pumping System	None	None	2

11 FMs, all of acceptable risk:

- No risk to people or the environment
- Failures can be readily repaired

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Quality, Environmental, Safety, & Health

- Travelers required for all machining components
- Approved installation procedures required for all mechanical and electrical work
- PTP shall be performed to validate the IVPS functionality

Assemblies	Vendor	QA LEAD	QA BACK-UP	QC
All mechanical and electrical assemblies	PPPL fabrication Shops	Ramos	Malinowski	Ramos

- Potential ES&H concerns:
 - Design: none
 - Fabrication: mitigated by standard PPPL ES&H program
 - Installation: mitigated by standard PPPL ES&H program
 - Operation: mitigated by standard PPPL ES&H program

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Summary

- Requirements have been met via a combination of analysis and test.
- Interfaces are considered in the design and documented in the ICDs
- All chits related to the IVPS job are closed
- No Category 1 and 2 risks
- No potential hazard of item/activity to people/environment