

National Spherical Torus eXperiment Upgrade

NSTX-U Test Cell Shielding WBS 1.08.01.03

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

M. Cropper - Cognizant Engineer

Last edit: 3/09/2020

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 1.01.02.04

WBS Title	NTC Shielding	WBS #	1.08.01.03
Project Cog.	Mark Cropper	Assoc. Proj. Man.	Tom Jernigan
Design Scope	Provide additional shielding to penetrations. Installation of a labyrinth in the south high bay to shield the personnel door to the Gallery.		
Technical Impact of Scope	Allows unrestricted access to gallery and other areas near test cell under all operations scenarios		
Design Status	FDR completed on 1/14/2019: link chits: link calculations: link drawings: link SoW/Tech Spec: link		
Fabrication Status	Shield block fabrication complete, Labyrinth Wall fabrication complete		
Installation Status	Installation of the new personnel doors is complete. Movement of the card reader access control from the South High Bay interior door to the exterior door is complete. Additional shielding of wall penetrations is complete. DT generator testing is complete. Construction of the labyrinth proper complete; installation of the sprinklers will be completed by the end of the month.		

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DT Generator Testing Used to Determine Problematic Penetrations

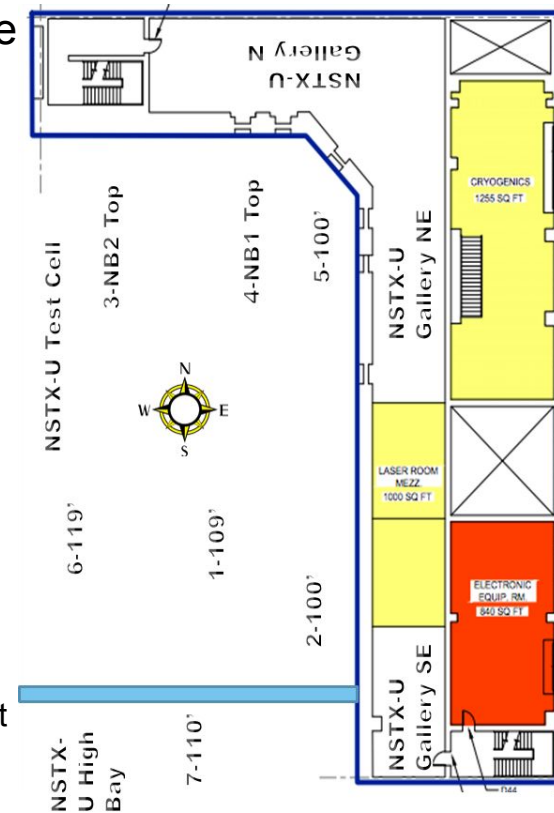
- Extrapolation of measurements made at locations around the NSTX-U Test Cell during the 2016 run campaign, demonstrated the need to improve the Test Cell shielding.

- In particular, some doors and penetrations lacked sufficient shielding to reduce the neutron flux from the test cell to acceptable levels during planned full performance shots.
- Dose rates outside the test cell for the 2016 run campaign were below the 10 CFR835 posting levels.

■ Area was posted and restricted while measurements were taken

- In response the NSTX-U Recovery Project Shielding Plan-[NSTX-U-PLAN-017-02](#) was developed.

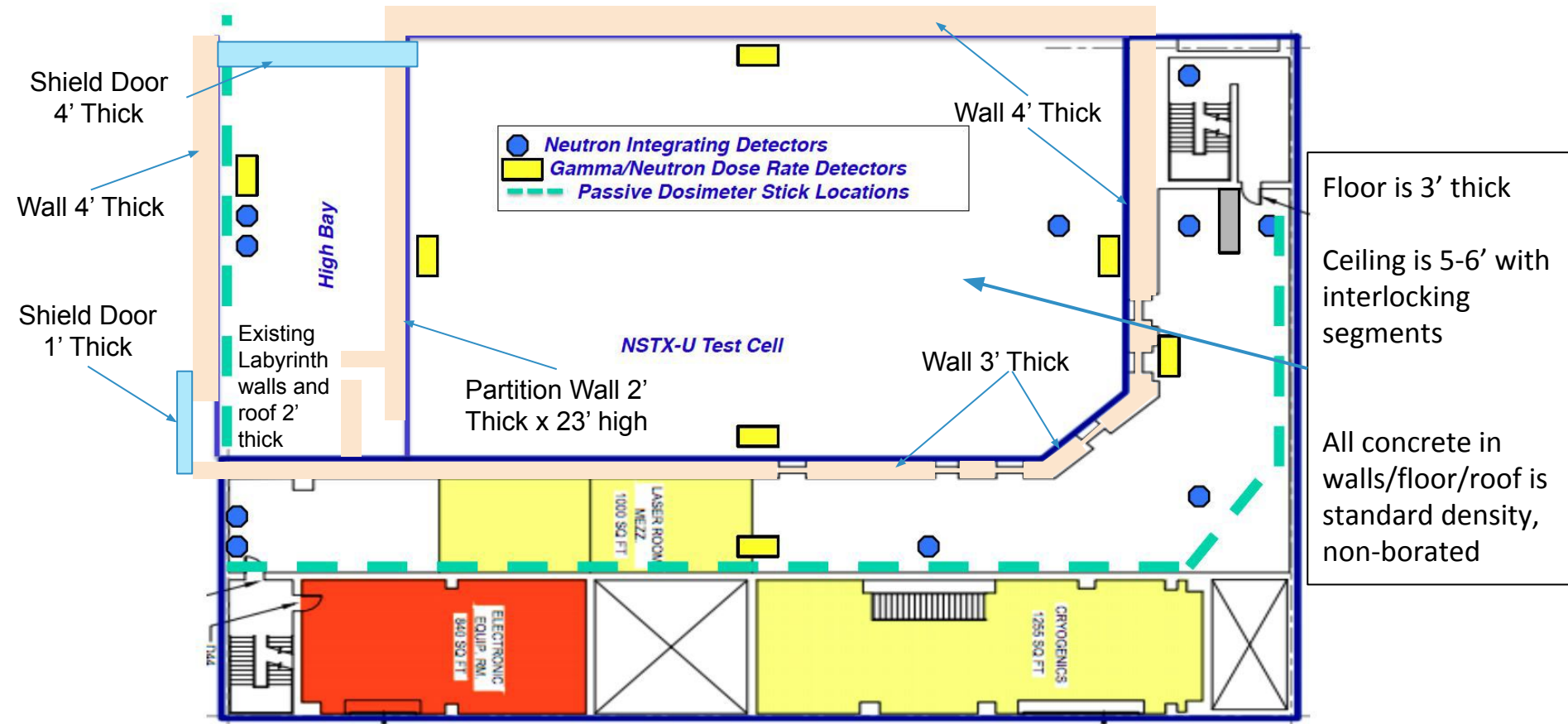
- Phase 1 has been completed.
 - 20 suspect areas had measurable neutron dose rates
 - Of the 20 suspect areas showing dose rates we determined that 11 of those areas were considered the primary contributors to the dose rate outside the test cell walls.
 - However, given that not all penetrations were easily challenged (due to various obstructions), additional penetrations, similar to the problematic ones, were shielded.



Overview/Evolution of Plan

	Step	Deliverable
✓	1 Monitor radiation during run at site boundary and occupied regions in the vicinity of the test cell (<i>backup slides</i>)	Assessment of needs to improve shielding
✓	2 Challenge shielding with D-T generator (<i>backup slides</i>)	Identification of problematic penetrations
✓	3 MCNP calculations of potential shielding configurations	Shielding schemes that have good neutronics performance
✓	4 Shielding design	Practical designs for shielding
✓	5 Construction	Shielding implementation
✓	6 Challenge shielding with D-T generator	Assessment of efficacy of new shielding
N/R	7 Optional – Repeat 3-6 as “Phase II” shielding as necessary	Further shielding improvements if necessary
	8 Monitor radiation during run at site boundary and regions in the vicinity of the test cell.	Final assessment of shielding efficacy in service

Test Cell Shielding - Basic Parameters - Scope

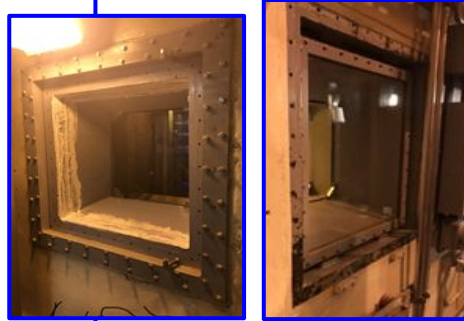
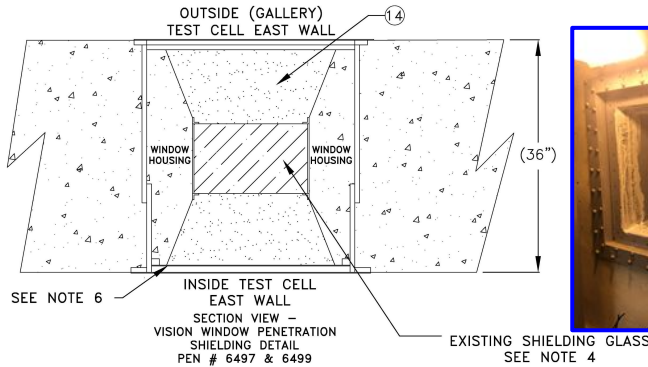


Penetration Shielding - Scope

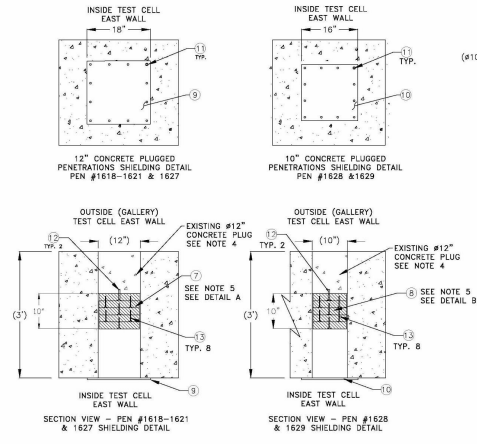
- All penetrations have been identified and documented on a drawing.
 - [E-FA1030](#), *NSTX-U Test Cell Penetration Arrangement*.
- Details of each penetration have identified and documented on drawings.
 - [E-FA1064](#), *Test Cell East Wall Penetrations Shielding Diagram Plans & Details*.
 - [E-FA1065](#), *Test Cell Northeast Wall Penetrations Shielding Diagram Plans & Details*.
 - [E-FA1066](#), *Test Cell North Wall Penetrations Shielding Diagram Plans & Details*.
- Shielding details for each of the penetration has also been identified and documented on drawings 1064-1066.

Scope - Methods Developed for Filling “Standard” Penetration

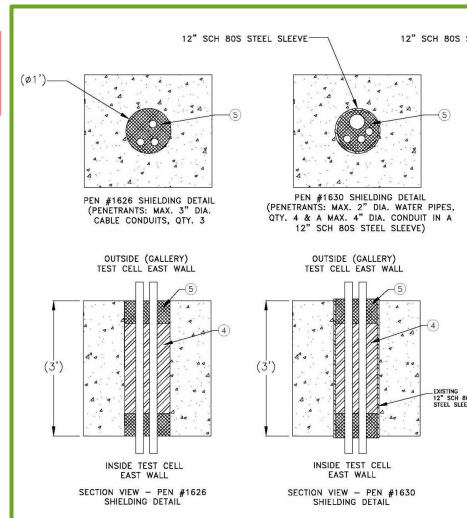
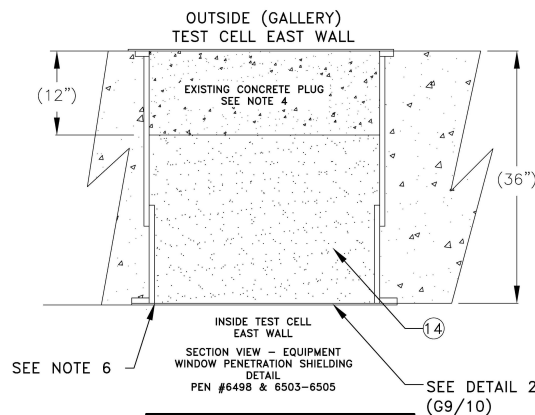
Typical “Vision Window” - Grout both Sides



Typical Plugged Circular Penetration



Typical “Equipment Window” - Grout Added to Augment Existing Concrete Plugs



Note: All designs verified by MCNP calculations - upcoming slides

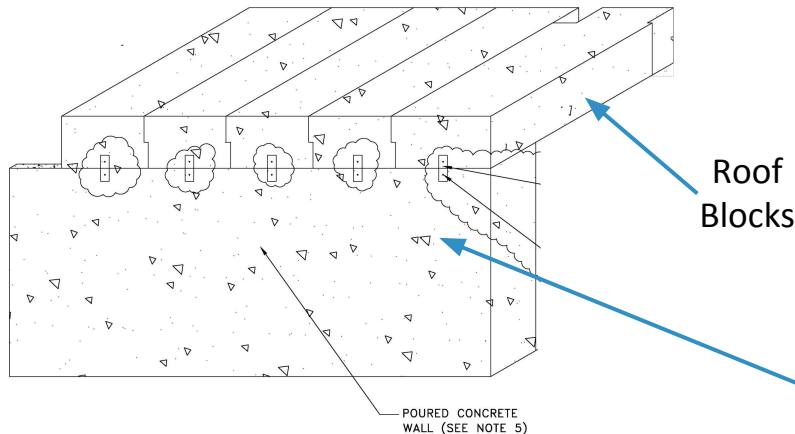
Typical Cable or Pipe Feedthrough Fire Stop and Neutron Putty

See:
[E-FA1064](#)
[E-FA1065](#)
[E-FA1066](#)

Charge question: 1A

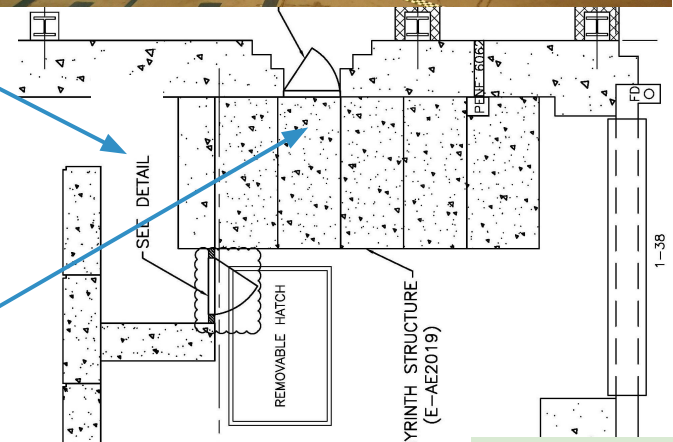
Scope - New Labyrinth Construction

- The labyrinth walls will be poured in the field (per DWG# [D-PE213002](#)).
- The labyrinth roof blocks will be constructed per drawing [#E-AE2019](#).
- The roof concrete blocks have interlocking features at joints.
- The seams between existing wall and labyrinth roof will be sealed with concrete patching material.



Existing
Labyrinth

New
Labyrinth



We are Improving the shielding in more than 95% of the Existing Penetration Area

	Total Penetration Area (in ²)	Fraction with Shielding being Improved
East	11300	96%
North	8100	96%
Northeast	3600	100%

In some cases, this involves augmenting the previous 1' thick shielding

All Occupied Areas Outside NTC Wall Projected to Show Acceptable Doses

	Conversion Factor w/o Shielding mrem/10 ¹⁵ N	Before Recovery Project Shielding Improvements - See Shielding Plan		Assume 4x10 ¹⁷ N/day and 3x10 ¹⁹ N/yr		Following Recovery Project Shielding Improvements	
		Max Daily Dose mrem	Max Annual Dose mrem	Additional Shielding Attenuation Factor	Specific Shielding Improvement	Max Daily Dose mrem	Max Annual Dose mrem
Target Based on Acceptable Risk	---	100	5000	---	---	100	5000
North Stairwell	0.10	41	3007	1.00E-04	Close North Wall Concrete Door	0.0	0.3
Outside North Shield Wall	0.10	41	3007	1.00E-04		0.0	0.3
Inside North Cage	10.02	4060	300743	1.00E-04		0.4	30.1
Gallery North Wall	0.15	61	4512	1.00E-04		0.0	0.5
Gallery North East Corner DATS	0.10	41	3007	1.00E-03	Shield HHFW Penetrations	0.0	3.0
Gallery East DATS	0.05	20	1503	1.00E-03	Fill Vision Windows, Shield HHFW Penetrations, Labyrinth	0.0	1.5
Gallery East Wall	0.15	59	4360	1.00E-03		0.1	4.4
Gallery South East Corner	1.05	426	31577	1.00E-04	New Labyrinth	0.0	3.2
Neutral Beam Shop	0.01	4	300	1.00E-04	New Labyrinth	0.0	0.0
MER Mezzanine	0.32	130	9624	1	None	130	9624

<100 mrem/yr dosimetry requirement MER Mezzanine - area off limits via PSS-SIS

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Requirements Defined and Met

SOURCE	REQUIREMENT	Met
NSTX-U-RQMT-GRD-01	Penetrations in the test cell walls and floor shall have appropriate neutronics shielding or labyrinths.	✓
NSTX-U-RQMT-SRD-010	New structures shall be qualified for seismic events	✓
NSTX-U-RQMT-SRD-010	Access to areas adjacent to the Test Cell shall have unrestricted access	✓
NSTX-U-RQMT-SRD-010	Shielding shall support a total site boundary limit of 10 mRem/year, as documented in the NSTX-U SAD	✓
NSTX-U-RQMT-RD-007	All radiation shielding shall be designed so as to accommodate any required fire stops, as applicable.	✓
NSTX-U-RQMT-RD-007	The functionality of piping, cabling, and other services using penetrations shall not be impeded by the installation of shielding.	✓
NSTX-U-RQMT-RD-007	Shielding designs for doors, labyrinths, and windows shall be verified by neutronics analysis.	✓
NSTX-U-RQMT-RD-007	Labyrinths shall have widths, heights, lighting, and fire protection consistent with applicable life safety and architectural codes.	✓

Complete RVTM maintained by Project Systems Engineering

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Analysis/Prototyping

- South High Bay Labyrinth Structural Design Calculation:
[NSTXU-CALC-81-01-01](#)
- NSTX-U Test Cell Shielding Analysis by MCNP:
[NSTXU-CALC-81-02-02](#)
- MPTS Penetration Shielding Analysis using MCNP:
[NSTXU 1-8-1-1-5 CALC 100](#)
- All Materials are COTS, no prototyping required

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All Chits have been Closed

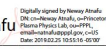
Chit Resolution
Report: [link](#)


 National Spherical Torus eXperiment Upgrade

Chit Resolution Report for *NSTX-U Test Cell Shielding*

NSTX-U-REC-097-02

February 28, 2019

Prepared By: 
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Approved By: 
Timothy N. Stevenson
Responsible Engineer

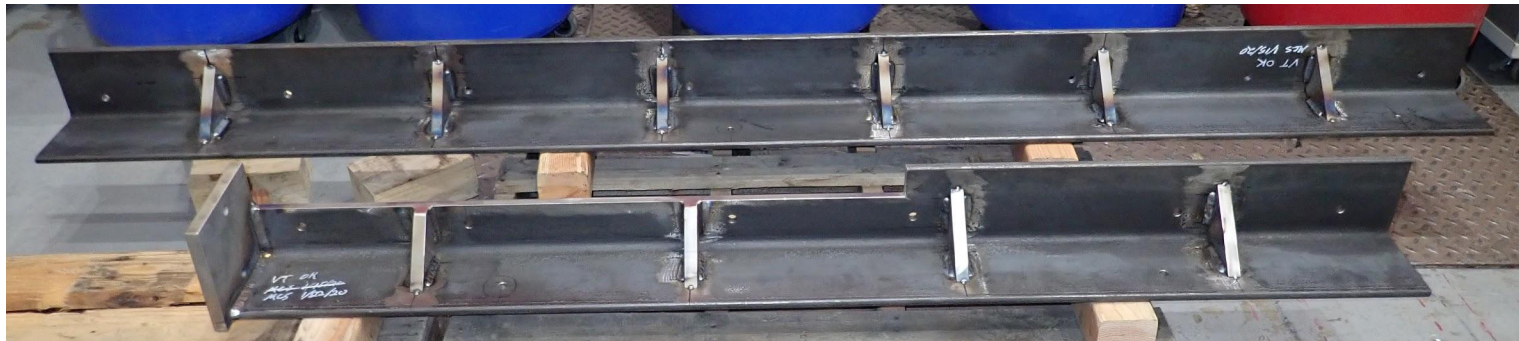
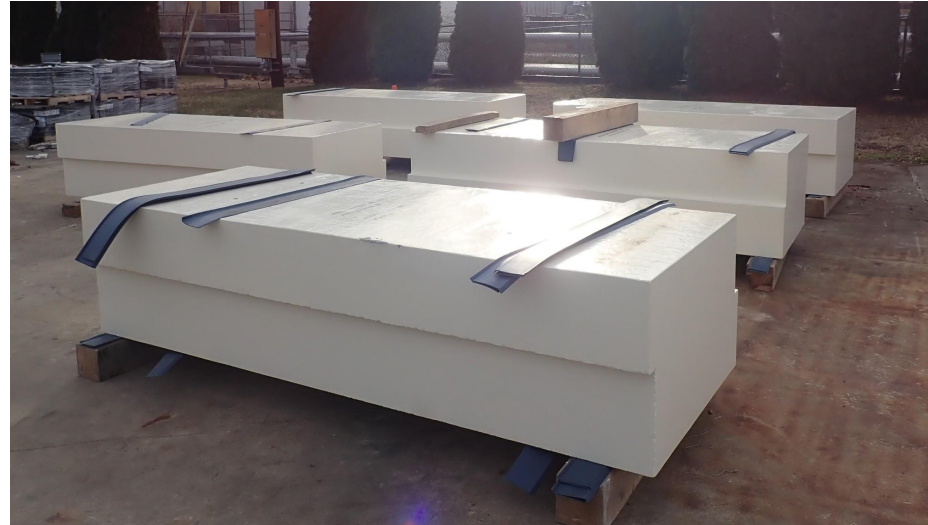
Approved By: 
Yuhu Zhai
Project Engineer

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Labyrinth Roof Blocks & Supports

- The labyrinth roof blocks were constructed per drawing #[E-AE2019](#) by an external vendor.
- The roof concrete blocks have interlocking features at joints to eliminate shine through.
- Completed Roof Blocks delivered to PPPL from vendor.
- Roof Block support brackets have been fabricated and Installed.



New Labyrinth Construction

- The labyrinth walls were poured in the field (per DWG# [D-PE213002](#)).
 - Concrete was vibrated during pour to eliminate voids
- The seams between existing wall and labyrinth roof will be sealed with concrete patching material
- Gaps in existing labyrinth will be filled with neutron putty or grout

View from above



South High Bay prior to
labyrinth wall pours

View looking from the Neutral
Beam Building

Installation of Labyrinth Roof Block



Installation of Block #3



All Five Blocks Installed

Scaffolding

- Scaffolding contractor brought in to erect scaffolding to reach upper penetrations
- Scaffolding eliminated the need to work off large extension ladders with fall protection PPE



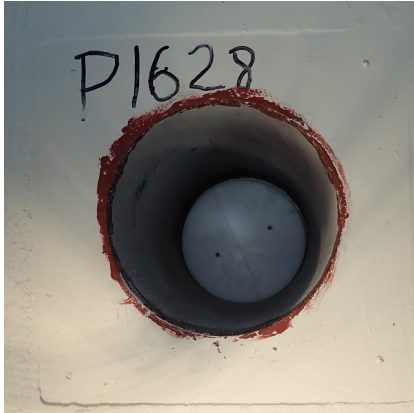
Gallery Scaffolding

North Wall Scaffolding

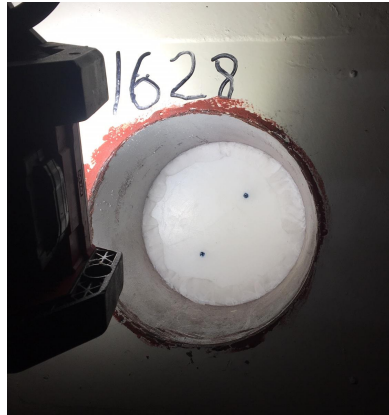


East Wall Scaffolding

Circular Penetration Shielding



Installation of first Polly Disk



Installation of last Polly Disk



Hilti FireStop



Installation of Neutron Putty

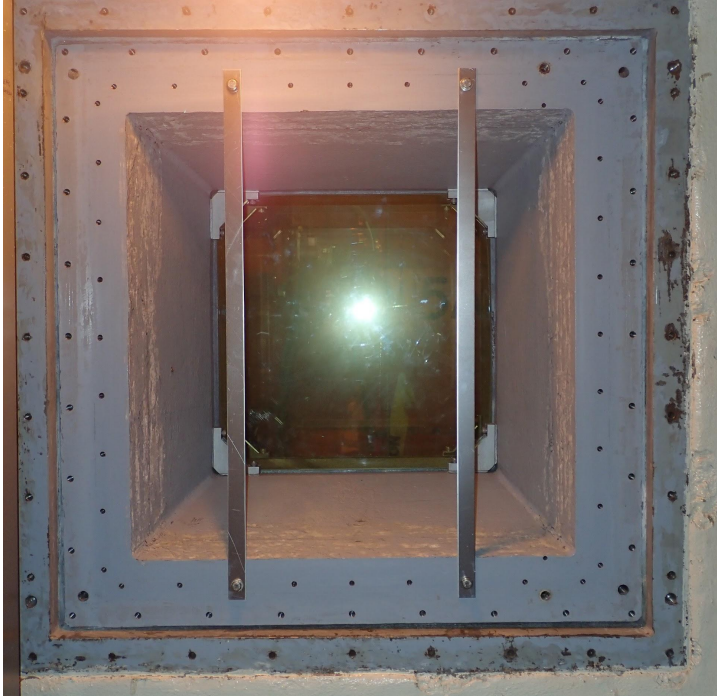


Installation of Rockwool

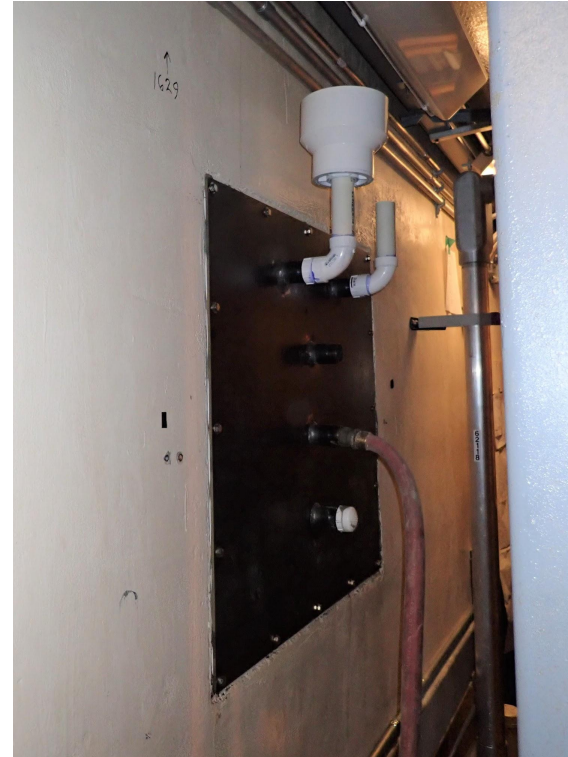


Hilti FireStop

Windows Grouting



Window prior to Installation of Grout Plate



Grout being pumped into Window

Test Cell North Door



Shield Door (Battleship) Open



Shield Door (Battleship) Closed

DT Generator Test Results

Location	Highest Reading Pre Shielding Upgrade (μRem/hr)	Highest Reading Post Shielding Upgrade (μRem/hr)
NSTX Test Cell North Door and Vestibule (see note 1)	2,500	0
North Wall Center, Height 16 Feet, Lateral Distance 10 Feet From Upper Windows 6500 and 6501)	100	0
RF Feed Thru #6111 – 6116 / Window 6502, Penetration 1616 and 1617 (height 19')(see Note 2)	500	100
Penetration 1636 Northeast Wall (height 10')	100	0
Penetration 1594 North Wall (height 10')	100	0
Penetration 1591 North Wall (height 10')	100	0
Large Window Behind Panel B-GIS-2A North Wall #6495 (height 4')	300	0
Inside gas cylinder cage north wall	200	0
North east wall to 8' between large window 6497 and cable tray penetrations 1622 and 1623	700	0
Window 6497 center on contact (height 4')	400	0
Cable tray penetration 1623 (height 10')	400	0
Large Window 6503 lateral distance 10 feet, height 12 feet	300	0
General area 12-foot-high penetrations 1622, 1623, 1624, 1625	200	0
Penetration 6360 east wall (height 5')	100	0
Penetration 6310 east wall (height 5')	400	0
Door 44-110A south east high bay door (I-31)	25,000	0
Laser water chiller storage tank and pump (height 4')	1,000	0
NB power conversion bldg. door D44-116 floor reading	200	0
Penetration 6136 laser mezzanine (12' height)	600	0

1. The first test was performed with the shield door (battleship door) open, the second test with the shield door closed.
2. This data matches the predicted dose rate from the HHFW wave guides in the calculation. The calculation shows neutron leakage from inside the hollow pipe.
3. Minimal detectable level (MDL) of the detector is 10 μRem/hr

Fabrication -Summary

- Penetration Shielding work completed on schedule
- Personnel Door replacement and card reader installation completed ahead of schedule
- Labyrinth wall construction completed on schedule
- Labyrinth Roof Block Installation completed a couple of weeks behind schedule
- DT Generator testing completed on schedule
- Entire job on track to complete on schedule

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Project Risks are Actively Being Managed

Risk	Score (1-81)	Open/Retired	Risk Retirement Event
If the neutron generator testing shows neutrons passing through unshielded penetrations	20	RETIRED	Prior to commissioning
If there are issues with Subcontractors and Vendors (e.g. not meeting quality assurance or delay in product delivery)	16	RETIRED	receipt of purchased components

FMECA - All risks Mitigated to Acceptable Level

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
NTC Walls	Shield door to TFTR TC left open during operations	conduct of operations error	Individuals who may be in the TTC exposed to neutrons that are generated by NSTX-U operations	9	Personnel Safety System (SIS)	Trapped Key System	None	3
NTC Walls	Shield door to NBPC left open during operations	conduct of operations error	Individuals who may be in the NBPC exposed to neutrons that are generated by NSTX-U operations	9	Personnel Safety System (SIS)	Trapped Key System	None	3
NTC Walls	North "battleship" door left open during operations.	conduct of operations error	Individuals who may be in the north part of the gallery exposed to neutrons that are generated by NSTX-U operations	9	Personnel Safety System (SIS)	None	None	3
NTC Walls	Lead-lined door at southeast NTC entrance left open	conduct of operations error	Individuals in the gallery exposed to photon dose	9	Personnel Safety System (SIS)	None	None	3
NTC Walls	Labyrinth structural failure	design or construction error	individual passing through labyrinth injured by collapse	4	None	None	None	4
NTC Walls	Grout or polyethylene sheets fall out of sealed penetrations	mechanical failure	individual in gallery exposed to neutrons generated by NSTX-U operations	2	None	None	None	2

Primary failure modes are shielding doors misconfigured; PSS-SIS and TKS mitigate those risks

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Quality, Environmental, Safety, & Health

- Concrete pouring was optimized to ensure uniform fill
 - pouring optimization, vibration of the concrete
- Safety has been at the forefront of work planning
 - Scaffolds were used instead of ladders; designed and assembled by professional scaffolding installers
 - Fall protections was utilized were required
 - Silica hazard - appropriately addressed
 - Air monitoring was not needed
 - respiratory protection was used as needed
 - dust minimization controls - (vacuum, water)
 - Standard power and hand tools were used, with appropriate PPE
 - PPPL hoisting and rigging program was followed
 - Work was planned to manage flow of traffic in the work areas

Managed by the
PPPL worker safety
program (ESH-5008)

SAD & ASO Considerations

- DVVR chits were review and screened for USI's
 - As a result two USID's were generated
 - 18-006: Update SAD to reflect changes to shielding
 - 18-007: Update Drawings to reflect change to shielding
- The PDR & FDR's were screened for USi's
 - One USID was issued
 - 18-039: Include shield safety analysis in the SAD
- The draft SAD is being updated for Shielding improvements

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Summary

- NTC shielding remediation job has completed its design cycle
- Phase 1 of penetration shielding complete
- Construction of the labyrinth proper complete
 - Sprinkler installation to be complete by the end of March
- DT generator testing of the efficacy of the new shielding completed
 - Newly installed shielding performed as predicted by the calculations
 - Phase 2 of the penetration shielding not required
- Environmental, Safety & Health issues were understood and addressed on a daily basis
 - Strong Safety presence during all phases of construction
 - No issues to date
- The NSTX-U SAD is being update for shielding improvements
- On track to complete on schedule well ahead of reassembly work