National Spherical Torus eXperiment Upgrade

Recovery Project (RP) Magnet Field Scope

WBS 1.01.03.04

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

Antonio Falcon - Cognizant Engineer

Last edit: 3/10/20

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 1.04.01.03

WBS Title	RP Magnet Field Scope	WBS #	1.01.03.04
Project Cog.	Antonio Falcon	Assoc. Proj. Man.	Bill Gattoni
Design Scope	Make specific targeted modifications to existing NSTX-U magnets		
Technical Impact of Scope	Improved reliability of the tokamak core magnets		
Design Status	FDR completed in three phases: phase 1 (link), phase 2 (link), phase 3 (link) chits: link calculations: link drawings: link SoW/Tech Spec: N/A		
Fabrication Status	Work will commence following CDE-3B ESAAB approval		
Installation Status			

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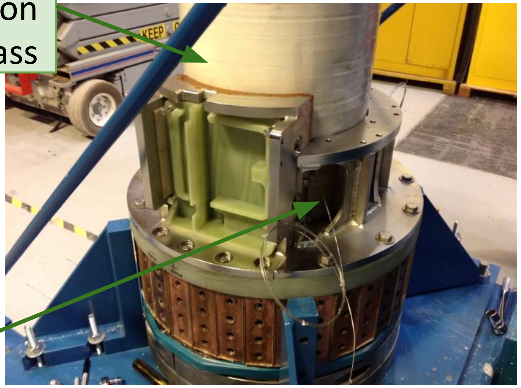
Magnet RP Scope

- Numerous chits at the Magnet Systems Design Verification and Validation Review (DVVR) addressed concerns with the existing magnets.
- Many were taken on as Project scope as Recovery was being defined.
- The outer-PF electrical testing scope was later moved to the PF-4/5 realignment WBS, in order to assure better work planning.
- Recovery Project Magnet Field Scope WBS moving forward contains
  - Improved grounding of aquapour wires
  - Remediation of OH ground plane paint
  - Periodic high-pots and inspection of the OH and TF bundle
  - Cooling Water System PLC Interlock
  - Remedial corrections to the G10 ring at the base of the OH coil

Stainless Steel Wires "Stuck" (I)

- Aquapour is a material like plaster of paris, removable with water
- A ~0.1" thick layer was applied to the outside of the TF coil, to be used as a winding surface for the OH coil.
  - Intent was to "wash" it out after the OH was cured
  - Four wires were embedded in the aquapour, to be used as "floss" to help remove the material
- During OH curing, the aquapour became saturated with CTD-425, forming a material that feels like pumice in your hand
- Wires and aquapour could not be removed.

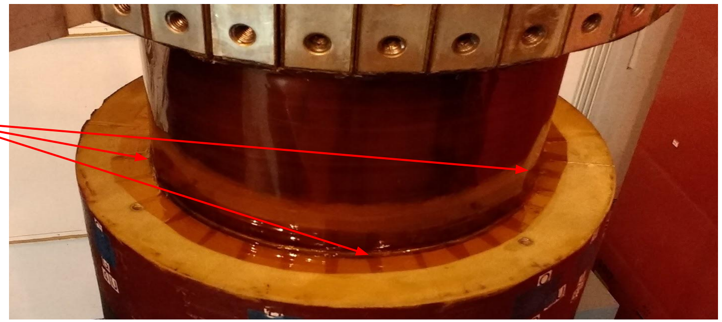
See DVVR presentation: link

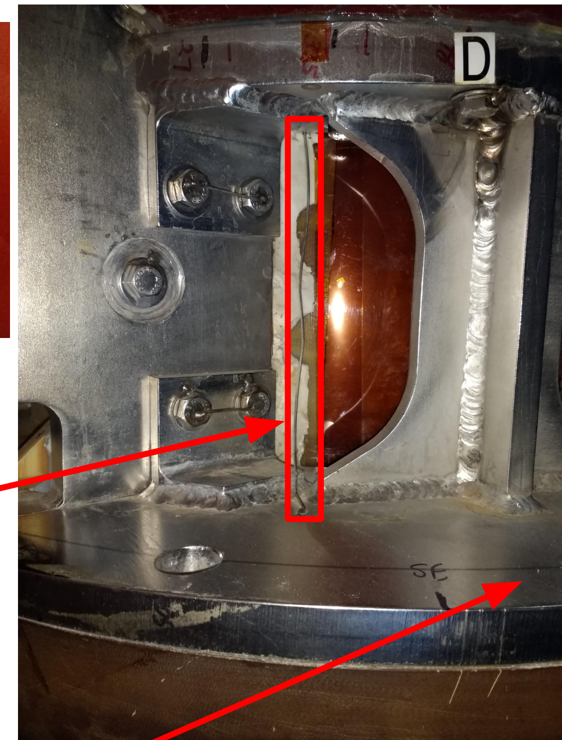


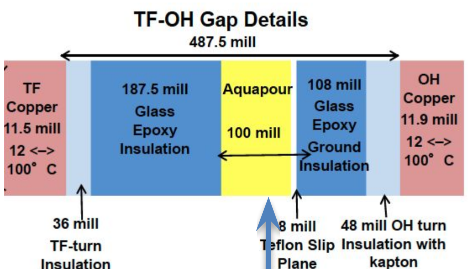
Stainless Steel Wires "Stuck" (II)

(4) SS Wires located between OH and TF

At the top (3) of the wires are isolated and wrapped under kapton the 4th is broken below the OH face







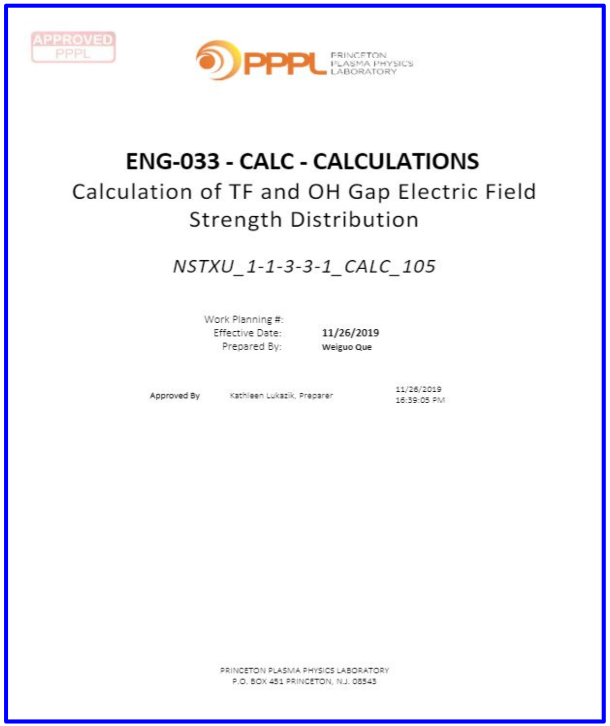
Wire

At the bottom the wires are bare and welded to the pedestal.

This area is covered by the OH skirt normally

Studies Performed

***NSTXU_1-1-3-3-1_CALC_105** concluded that the existence of the Aquapour and the wires did not affect NSTX-U performance if left floating.*


APPROVED PPPL

PPPL PRINCETON PLASMA PHYSICS LABORATORY

ENG-033 - CALC - CALCULATIONS

Calculation of TF and OH Gap Electric Field Strength Distribution

NSTXU_1-1-3-3-1_CALC_105

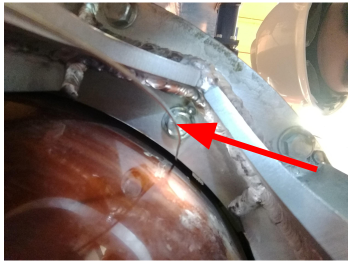
Work Planning #:
Effective Date: 11/26/2019
Prepared By: Weiguo Que

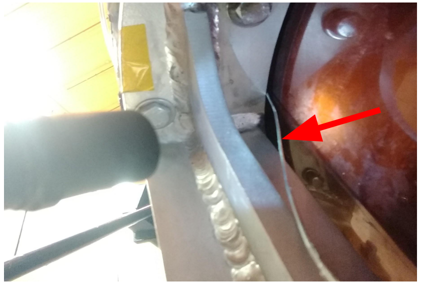
Approved By Kathleen Lukazik, Preparer 11/26/2019 16:39:05 PM

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

click calculation for link

<u>The analysis recommends that the wires remain floating. Design permits the option of grounding or floating the wires ex-situ.</u>



Aquapour Wire Mitigation

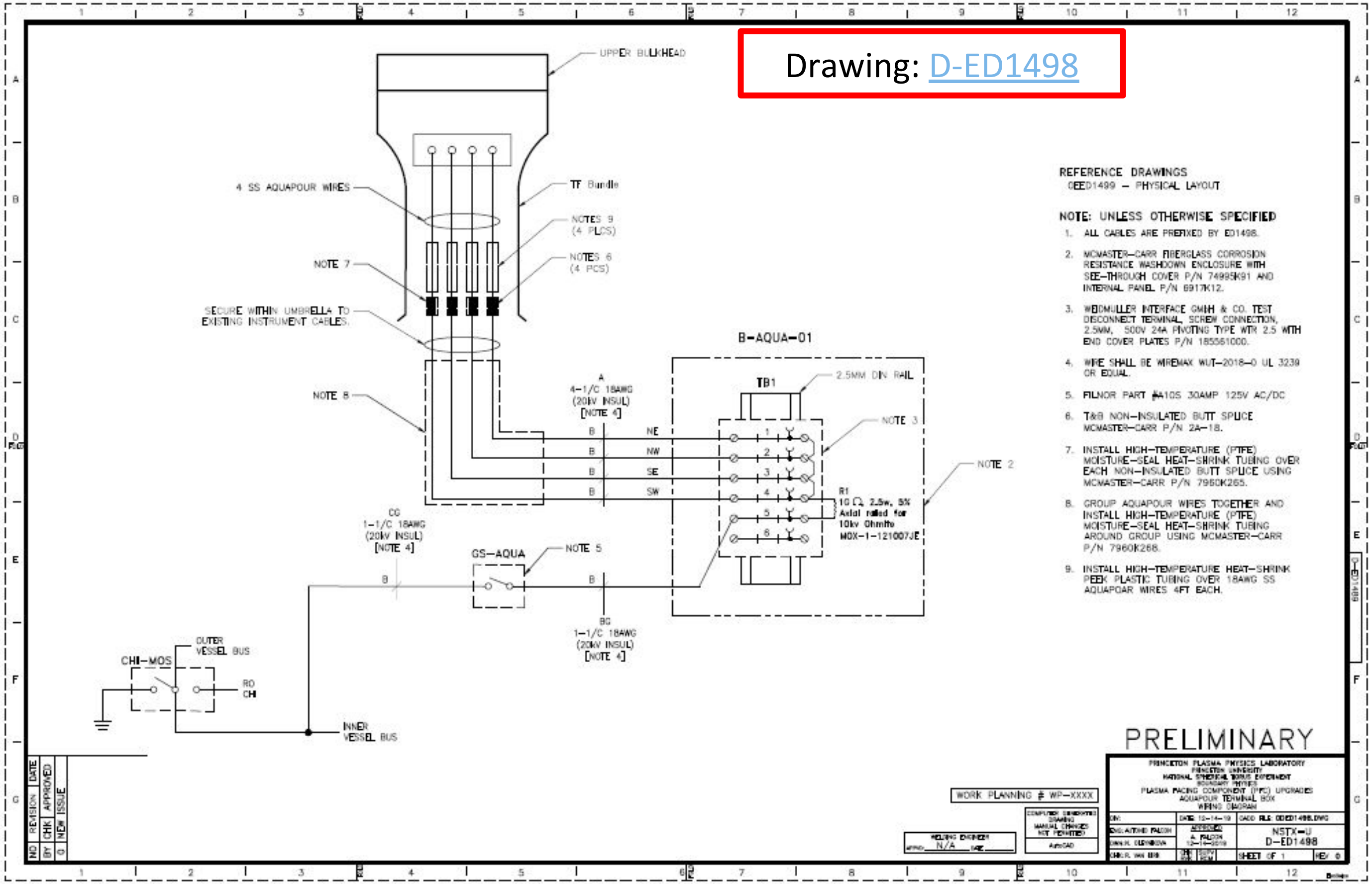
Top of wire lengths remain the same - encapsulated and wrapped in kapton

Bottom of wire:

- Encapsulate in high strength heat shrink into aquapour region
- Transition to 20kV 18 AWG insulated Cu wire (Wiremax UL 3239 150°C) through Terminal Crimp
- Secure insulated wire with kapton tape to OH base
- Route to a opening in the Outer Skirt and terminate in a terminal box.
- Copper wire can be terminated to ground, tested individually etc.

Grounding of Aquapour Terminal Box Wiring Diagram

Drawing: [D-ED1498]



OH Ground Plane

- A resistive paint was applied to the outer surfaces of the OH Coil to form an outer ground plane.
- It serves to shield the surrounding instrumentation (flux loops, thermocouples, etc.) from the transient voltages.

Ground plane paint

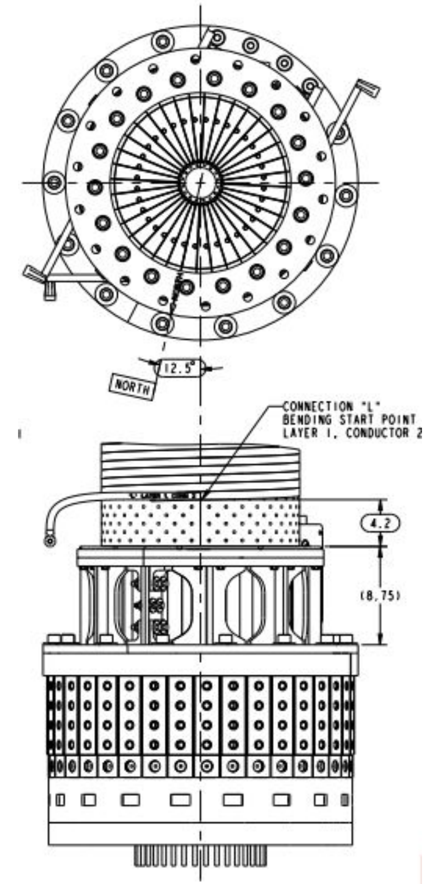
Fig. 1. OH coil with ground plane paint.

OH Ground Plane Paint will be Remediated

- The OH Ground Plane keeps the electrical field in the insulation to shield the surrounding instrumentation.
- Ground Plane has induced currents
- The voltage on the ground plane decays rapidly, from 600V to 50V in less than 30 milliseconds; therefore, the power dissipation is not a concern.
- Paint Resistivity should be between 400 ohms/square to 1000 ohms/square.
- The total resistance for the OH Ground Plane is 1000 ohms to 2500 ohms
- Apply Von Roll Corona Shield P8003 Paint and measure ground plane until within set resistivity range

TF Conductor Insulation Deemed Satisfactory by Test

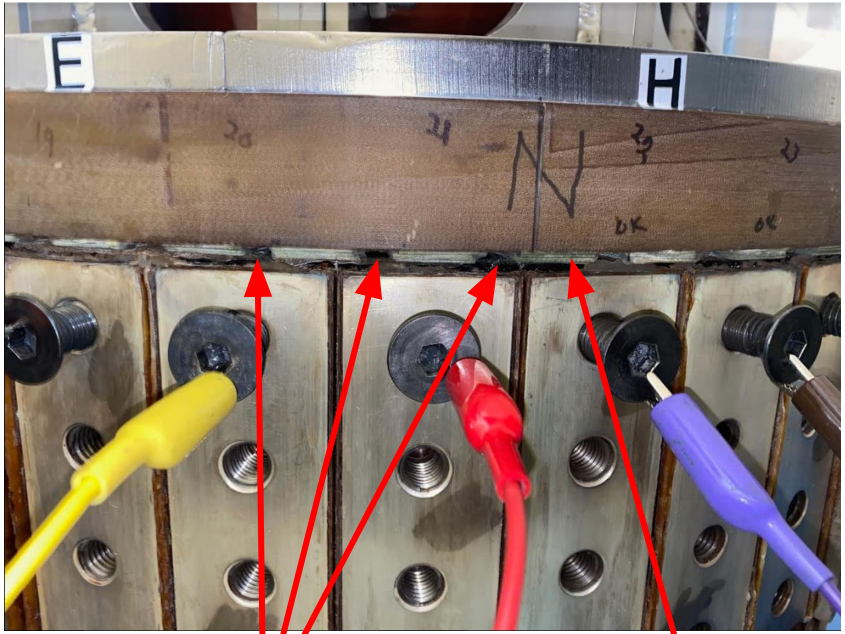
- Turn to turn testing was completed on December 2018 and October 2019
- At 41% Relative Humidity, readings were in the MOhm range; when the humidity was reduced (<35% RH) readings were in the GOhm range
- Meeting held with Facilities to discuss the desired environmental operating conditions as they pertain to the HVAC system within the NSTX-U Test Cell (NTC)
  - Facilities agreed to add additional dehumidification to the NTC as part of an ongoing project.
- We will now operate the TF Bundle in a controlled humidity of <35% all year around.



Cooling Water System Logic Change

- Current deployment of Cooling Water System disabled the permissive for the next shot when loss of flow in any circuit was detected;
- However, if cooling was lost on only one TF conductor at the end of a pulse, this would create an insulation thermal shear stress (calc)
  - Bars heat & expand during pulse, cooled bars would contract, uncooled bar would stay thermally expanded
- The updated logic will, upon loss of flow in any cooling water circuit
  - de-energize the high and low pressure pumps,
  - close the supply/return valves
  - disable the permissive for the next plasma shot
- By disabling the cooling water flow on all flow paths (PF, OH, TF) this eliminates the risk of excessive cool-down shear stress in the TF bundle, OH coil, etc

As Found G10 Shims/Gaps Will Be Potted In Place

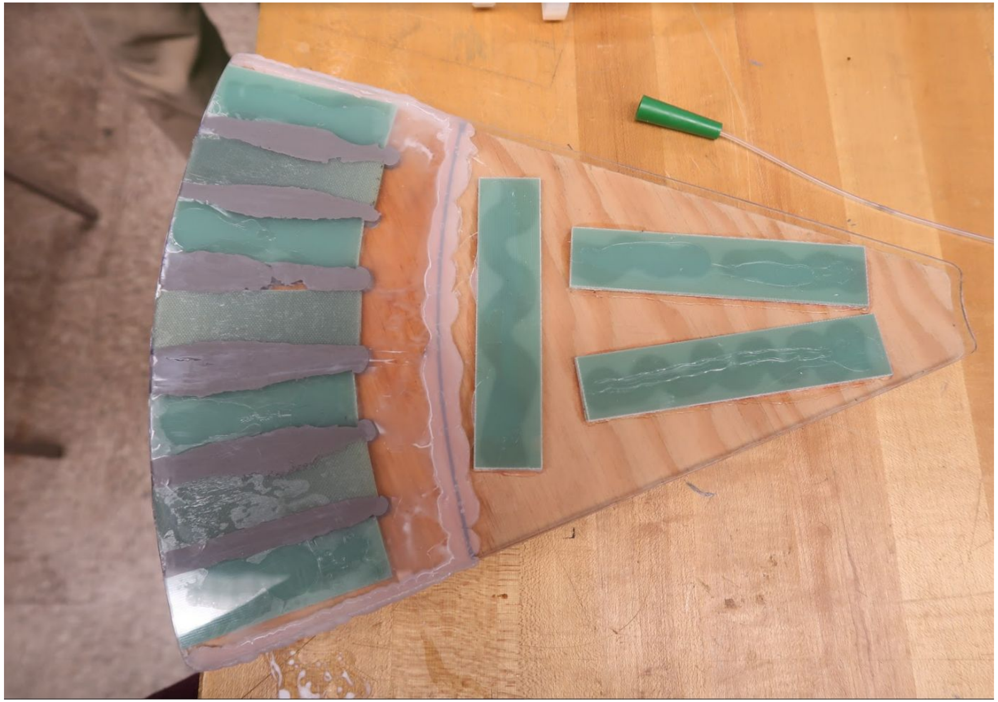


Spray all gaps with mold release, and inject grout. Wrap with fiberglass and epoxy

G10 Shims Installed with bead of RTV to hold in place

Issue	Consequence	Solution
Ability of the shims to work their way out under loads	Casing may become loose, compromising alignments and stressign coil leads	Installation of a band of wet layup around the shims, which prevents them from coming loose. (fiber glass painted with epoxy)
Non-uniform loading of the TF bars due to point contact on the localized shims	May apply vertical loads to the TF flags in a fashion inconsistent with assumptions of the inner-TF analysis from summer 2019	Install mold release between gaps, and install thixotropic grout to improve the uniformity of the preload

Solution with Structural Filler Chosen to Enforce Uniformity of Loads Uniform and Trap Shims



- Extensive Prototyping Program
  - Technician who performed work, installed the G10 shims currently deployed
  - Multiple types of epoxy were tested in the Materials Test Lab
  - Multiple wooden prototypes were tested to see how the epoxy would flow, fill, and expand in the injected area
  - Epoxy injection was done “blindly” to mimic the as built configuration, ensuring the technician can fill the gaps without seeing the epoxy flow
  - Mold released samples of CTD 425 and G10 tested to ensure epoxy will not adhere to the surface
- Spray gaps with PTFE Mold Release
- Inject Loctite 9394C to fill the gaps between the shims

Brand	ID	Mix Ratio (Volume)	Mix Ratio (Weight)	Mixed Density (g/cm^3)	Modulus (GPa)	Viscosity (PaS)	Pot Life (min)	Curing time at 25° C (hrs)
Loctite	EA 9394C	-	5:1	1.38	4.2	160	420	48

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Key Requirements Defined and Met

Source	Requirements	Comment	met
NSTX-U-RQMT-GRD-001	Waveform Specifications, Duty Cycle	Provides highest level requirements for 2 MA, 1 T, 10 MW, 5 second operation	✓
NSTX-CRIT-0001	Design Criteria	Provides the project definition of margin for loads vs. allowables	✓
NSTX-RQMT-SRD-02	hi-pot requirement	Table of numerical hi-pot values	✓
NSTX-RQMT-SRD-02	OH ground plane	Requirements for ground plane itself, configurable leads	✓
Design Point Spreadsheet	Vertical loads	Describes equilibrium vertical loads on the casing	✓
NSTX-U-RQMT-RD-011	Displacements leading to equilibrium side loads	Describes coil tilts and shifts which put equilibrium side loads on the casing	✓
NSTX-U-RQMT-RD-003	Halo and eddy loads	Describes disruption scenarios that put transient vertical (eddy) and halo (side) loads on the casing	✓
NSTX-RQMT-SRD-04	Cooling Water Interlock	Provides loss-of-cooling conditions which require the cooling water to be terminated	✓

Complete RVTM maintained by Project Systems Engineering

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Calculations Verify Design Meets Requirements

Physical Quantity	Calculation #	Content
TF stresses	NSTXU_1-1-1_CALC-101	Provides the limit on the temperature between the TF bars in order to stay within the allowable stresses for magnet insulation.
OH Ground Plane Paint	NSTXU_1-1-3-3-2_CALC_100	Detailed analysis of the ground plane paint, including recommendation for the final value
Bolt Reaction forces on G10 ring	NSTXU_1-1-3-3_CALC_104	Shows that the bolt reaction forces on the G10 ring are acceptable once the dynamic behavior of the CS assembly under transient load is known
Electric fields in TF-OH gap	NSTXU_1-1-3-3-1_CALC_105	Shows electric field in TF-OH gap as a function of the the grounding of the aquapour wires

Repository for Magnet Field Scope calculations here:
https://drive.google.com/open?id=1NZ2BqzIN_WOlo7IiDw7n3zgXzbBGDZPj

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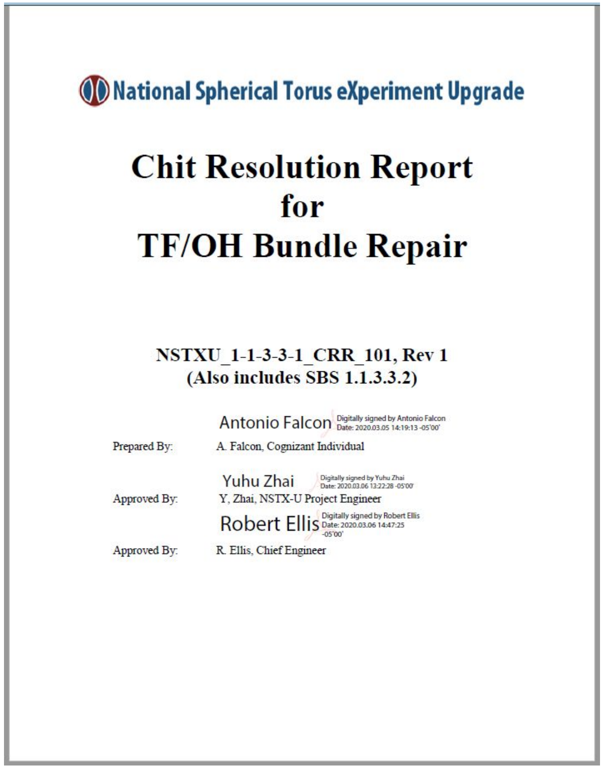
All Chits have been Closed

Chits closed at FDR

Chits generated at FDR also closed


National Spherical Torus eXperiment Upgrade

Chit Resolution Report
for
TF/OH Bundle Repair

NSTXU_1-1-3-3-1_CRR_101, Rev 1
(Also includes SBS 1.1.3.3.2)

Antonio Falcon Digitally signed by Antonio Falcon Date: 2020.03.05 14:19:13 -05'00'
Prepared By: A. Falcon, Cognizant Individual

Yuhu Zhai Digitally signed by Yuhu Zhai Date: 2020.03.06 13:22:28 -05'00'
Approved By: Y. Zhai, NSTX-U Project Engineer

Robert Ellis Digitally signed by Robert Ellis Date: 2020.03.06 14:47:25 -05'00'
Approved By: R. Ellis, Chief Engineer

Chit Resolution Report: link

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Manufacturing/Procurement

<u>OH Ground Plane</u>

New/additional paint will be purchased (Commercial Off the Shelf).

Req. has been submitted to Procurement.

<u>Aquapour Wires</u>

All components are Commercial Off the Shelf and minimal M&S.

<u>G10 Ring</u>

Loctite 9394C (2 quarts on hand)

<u>G10 Ring Commercial Off the Shelf items</u>

Catheters, syringes,1” fiberglass wrap(exact type used on PF coils)

Henkel Hysol RE-2039 Epoxy Resin for wrap

Hysol HD-3404 Epoxy Hardener

Installation/Testing

OH Ground Plane

Work will follow the current installation procedure (Apply paint and measure resistivity)

Aquapour Wires

Installation will follow the to be developed procedure for the extension of the wires and termination at the terminal box(end to end testing of wires to check ground / float)

Cooling Water System Interlock

Software only changes; testing will follow to be developed test procedure to monitor PLC logic with in field instrumentation (opening and closing of valves)

G10 Ring

Create an installation procedure to cover TF faces, flash-shield slots, and anywhere the epoxy has the potential to contaminate

- Perform Insulation Resistance Test after cleaning in between the shims
- Apply mold release to one turn or gap of the G10 Ring, and let dry
- Megger Test mold released area
- Inject Epoxy into mold released area, and let cure
- Megger Test Epoxy area and compare results
- Continue or pause mold release/epoxy application as decided by High Voltage SME

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Project Risks are Actively Being Managed

Risk	Score (1-81)	Open/Retired	Risk Retirement Event
If the interface with the lower TFIL crown fails the structural design criteria	35	RETIRED	duplicate
If during design effort, analyses find the existing G10 ring or crown structures incapable of sustaining loads	28	RETIRED	TF Bundle Investigation/Magnet RP FDR3
If assessment of PF 2,3,4,5 thermal expansion shows insufficient design margin.	25	RETIRED	FDR
If TF bundle lower G10 ring is found to be inadequate	25	RETIRED	FDR for TF Bundle
M9-3, if there is a rupture of an Inner TF leg cooling tube.	15	OPEN	Completion of bakeout

Project Risks are Actively Being Managed

Risk	Score (1-81)	Open/Retired	Risk Retirement Event
If analysis of VDE effects on OH bundle shows launch loads > the Belleville preload	12	OPEN	FDR
If analysis of the TF Bundle shows unacceptable delamination stress	3	RETIRED	Completion of testing
If updated calculations show that desired bakeout temperatures cannot be reached with current He flow rates	1	RETIRED	

FMECA - Inner TF (I)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
TF Inner Legs, Flags, and Connecting Bus Work	Turn-to-turn arc at inner-TF bus work	Water leak or item falling across leads; transient over-voltage condition	Damage to bus work; may be sufficiently severe to require replacement	12	Shorted Turn Protection System	None	None	4
TF Inner Legs, Flags, and Connecting Bus Work	Water leak at inlet on TF inner leg	Fitting or hose failure	Potential loss of cooling; coil grounded; damage to nearby components	9	CWS Flow and Temperature Instrumentation	FCPC Ground Fault Detection	Vessel and Diagnostic Grounds	4
TF Inner Legs, Flags, and Connecting Bus Work	Cracks develop on the TF lead extensions	fatigue from EM loads	ultimately, failure of the lead extension leading to electrical fault	9	FCPC Ground Fault Detection	DCPS Software	None	4
TF Inner Legs, Flags, and Connecting Bus Work	Cooling water path blockage on single conductor path	debris	larger thermal gradient causes severe delamination of the hot turn	8	CWS Flow and Temperature Instrumentation	None	None	2
TF Inner Legs, Flags, and Connecting Bus Work	Flash shields fall out before or during an operations phase	insufficient glue, aging of glue	arc between TF conductors	8	Shorted Turn Protection System	None	None	4

FMECA - Inner TF (II)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
TF Inner Legs, Flags, and Connecting Bus Work	Arc to ground on TF bus work inside umbrella	Water leak or item falling across leads; transient over-voltage condition	Damage to coil faces of bus work; may be severe up to a requiring replacement	8	FCPC Ground Fault Detection	None	None	3
TF Inner Legs, Flags, and Connecting Bus Work	Turn-to-turn arc around flash shields on inner-TF bundle	Water leak or item falling across leads; transient over-voltage condition	Damage to coil; may be sufficiently severe to require replacement	8	Shorted Turn Protection System	None	None	4
TF Inner Legs, Flags, and Connecting Bus Work	TF turns become delaminated	Excessive torsional shear applied to inner-TF coil	excessive twist of the bundle, transfers load to outer structures, flex strap damage	8	DCPS Software	Fiber Optic Strain, Temp., Disp. Meas.	TF Twist Measurement	4
TF Inner Legs, Flags, and Connecting Bus Work	Ground Wall insulation failure on inner-TF	Mechanical damage during maintenance or operations; inadvertent over-voltage condition during operations or testing	Excessive current to ground, or arcing, during operations; may degrade over time; may mandate replacement	8	FCPC Ground Fault Detection	None	None	4
TF Inner Legs, Flags, and Connecting Bus Work	Water hose disconnection on single inlet on inner leg	debris	larger thermal gradient causes severe delamination of the hot turn	8	CWS Flow and Temperature Instrumentation	None	None	4

FMECA - Inner TF (III)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
TF Inner Legs, Flags, and Connecting Bus Work	Excessive resistive heating of joints in the bus work	Loss of preload of bolted connections	Damage to electrical faces of outer leg flag	8	None	None	None	4
TF Inner Legs, Flags, and Connecting Bus Work	Excessive resistive heating of joint at the interface to the inner leg	Loss of preload of bolted connections	Damage to electrical faces of inner leg flag	8	None	None	None	4
TF Inner Legs, Flags, and Connecting Bus Work	Internal coil turn-to-turn failure	Insulation failure due to manufacturing error; transient over-voltage condition	Coil is inoperative, must be replaced	8	None	None	None	8
TF Inner Legs, Flags, and Connecting Bus Work	Delamination of TF inner leg turn to turn insulation	Thermal and EM stresses exceeding the allowable stress at the conductor/insulator interface	Larger twist of the coil under EM load	6	Fiber Optic Strain, Temp., Disp. Meas.	DCPS Software	None	6
TF Inner Legs, Flags, and Connecting Bus Work	Water leak at outlet on TF inner leg	Fitting or hose failure	coil grounded; damage to nearby components	6	CWS Flow and Temperature Instrumentation	FCPC Ground Fault Detection	Vessel and Diagnostic Grounds	4

FMECA - OH (I)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Ohmic Heating Solenoid	Arc within OH lead block, from + to - polarity	water entering; slight movement of conductors; debris in the lead block	Coil is inoperative, must be replaced	12	Shorted Turn Protection System	None	None	4
Ohmic Heating Solenoid	Damage to lower turns of the OH coil	TF pulls the OH coil due to aquapour interaction	electrical and mechanical integrity of the coil no longer maintained	12	DCPS Software	None	None	4
Ohmic Heating Solenoid	Damage to lower turns of the OH coil	excessive vertical load on the OH coil overcomes belleville washer downward load	electrical and mechanical integrity of the coil no longer maintained	12	DCPS Software	None	None	4
Ohmic Heating Solenoid	Water leak on OH conductors/hoses at lead block	fitting failure	insulators compromised; potential arc across leads and coil damage	12	FCPC Ground Fault Detection	Shorted Turn Protection System	CWS Flow and Temperature Instrumentation	9
Ohmic Heating Solenoid	Insulation or Cu failure	Excessive hoop tension	Electrical fault	12	DCPS Software	None	None	4

FMECA - OH (II)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Ohmic Heating Solenoid	Water leak at fittings on upper end of OH coil	fitting failure	microtherm insulation compromised; dust washed onto insulators; potential water getting into lead block and compromising electrical integrity there	9	FCPC Ground Fault Detection	Shorted Turn Protection System	CWS Flow and Temperature Instrumentation	9
Ohmic Heating Solenoid	Fracture of insulation between layers of the OH coil	non-uniform cooling wave propagation between the layers, that due to incorrect radial gradient of flow speed	vertical loads no longer uniformly carried; extra stress at layer interface causes electrical failure	8	CWS Flow and Temperature Instrumentation	None	None	4
Ohmic Heating Solenoid	Fracture of insulation between layers of the OH coil	radial temperature gradient during bakeout	vertical loads no longer uniformly carried; extra stress at layer interface causes electrical failure	8	CWS Flow and Temperature Instrumentation	None	None	4
Ohmic Heating Solenoid	Damage to lower turns of the OH coil	slow OH coil compression ("creep") under preload leads to effective loss of preload	electrical and mechanical integrity of the coil no longer maintained	8	Fiber Optic Strain, Temp., Disp. Meas.	None	None	4

FMECA - OH (III)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Ohmic Heating Solenoid	OH coil ground wall insulation failure	Mechanical damage during maintenance or operations; inadvertent over-voltage condition during operations or testing; arcing to aquapour-trapped wires	Excessive current to ground, or arcing, during operations; may degrade over time; may mandate replacement	8	FCPC Ground Fault Detection	None	None	4
Ohmic Heating Solenoid	OH cooling water blockage on single channel	debris in line	severe thermal gradient may drive insulation damage	8	CWS Flow and Temperature Instrumentation	None	None	2
Ohmic Heating Solenoid	Single water feed becomes fully detached at bottom	fitting failure	severe thermal gradient may drive insulation damage	8	CWS Flow and Temperature Instrumentation	None	None	2
Ohmic Heating Solenoid	Damage to OH upper water feed	Arc to ground on OH conductors at upper water feeds	cannot cool coil; water deluge on insulators	8	FCPC Ground Fault Detection	None	None	3
Ohmic Heating Solenoid	Damage to OH lower water feed	Arc to ground on OH conductors at lower water feeds	cannot cool coil; water deluge on insulators	8	FCPC Ground Fault Detection	None	None	3
Ohmic Heating Solenoid	Internal OH coil turn-to-turn failure	thermal stresses; manufacturing issue	coil is not usable, must be replaced	8	None	None	None	8

FMECA - OH (IV)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Ohmic Heating Solenoid	OH coil ground wall insulation failure	Overheating from microtherm failure	Electrical isolation is compromised. Excessive Ground Current	8	Center Stack Coil Thermocouples	None	None	4
Ohmic Heating Solenoid	Water leak at fittings at lower end of OH coil	fitting failure	degradation of insulators	6	CWS Flow and Temperature Instrumentation	None	None	6
Ohmic Heating Solenoid	Upper ground plane connections becomes loose	vibration; inadequate installation	potential corona in vicinity of ground insulation and noise on flux loops; loose connection hardware within the umbrella may cause electrical problems with bus work	4	None	None	None	4
Ohmic Heating Solenoid	Lower ground plane connections becomes loose	vibration; inadequate installation	potential corona in vicinity of ground insulation and noise on flux loops; loose connection hardware within the umbrella may cause electrical problems with bus work	4	None	None	None	4

FMECA - OH (V)

System	Failure Mode	Failure Cause	Failure Effect	R	Detection/ Mitigation System (1)	Detection/ Mitigation System (2)	Detection/ Mitigation System (3)	R_R
Ohmic Heating Solenoid	Failure of in-line braze joint	bad joint during manufacture; over-pressure condition	internal water leak compromises turn-to-turn insulation; high resistance leads to excessive joint heating.	4	None	None	None	4
Ohmic Heating Solenoid	Delamination of turn to turn insulation	thermal stresses in coils	none	0	None	None	None	0

Many failure modes identified for TF and OH coils

<u>Primary Active Mitigations:</u>
DCPS - limits currents, pulsed I^2t, moments/torques/stresses
Cooling Water Systems - flow and outlet water temperature interlocks
Ground Fault Detectors - Coil ground faults
Shorted Turn Protection - Arcs at terminals, on water feeds, etc

Belleville washers used to maintain joint preload

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

Environmental, Safety, & Health

- Work hazards during installation are standard industrial hazards:
  - Hand tools, LOTO, etc.
- Hazards mitigated through PPPL ISM and ES&H internal procedures:
  - Job Hazard Analysis completed prior to the start of planned work.
    - (Cutting, using power tools, eye protection, etc.)
  - Work scheduled via the rollover and work control center to avoid work area conflicts.
  - All Lockout/Tagout preformed per PPPL procedure ESH-016

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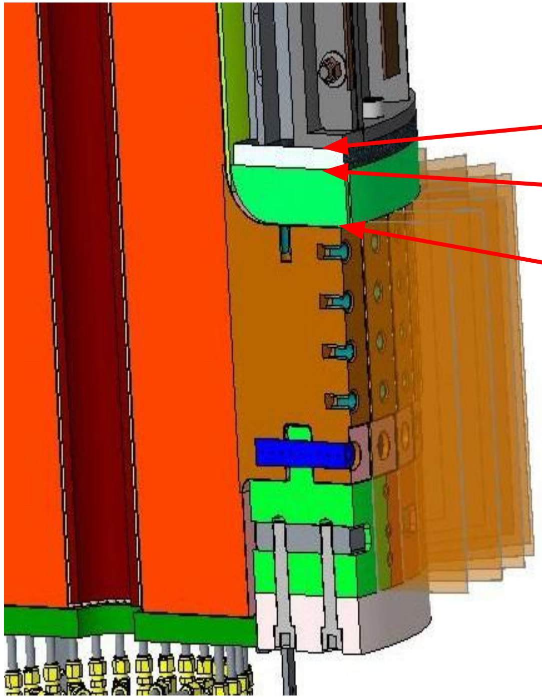
Summary

- Requirements defined in the GRD and the various SRDs (Magnet Systems, Vacuum Vessel, etc.) have been met by the design as supported by analysis, calculations, testing, and the new/updated drawings.
- Interfaces are considered in the design and detailed in the Magnet Systems Document
- All DVVR, PDR, and FDR chits regarding the TF/OH bundle have been summarized and closed within the TF/OH Bundle Repair CHIT Report.
- All Design Risks have been reviewed and identified; the project plans set in place will retire all risks.
- Environmental, Safety, & Health considerations are standard practices for the laboratory; all work will follow Pre-Job Briefs, Installation Procedures, and Test Procedures,

Backup

PPPL Revisited Loading of G10 Ring at Base of OH Coil



Interface #	Component #1	Component #2	Loads
1	Outer Skirt	Inner Skirt	Vertical loads, sliding
2	Inner Skirt	G10 Ring	Vertical loads, sliding
3	G10 Ring	TF Bundle	Vertical loads, sliding

Issue	Consequence	Solution
The G10 ring had been baked beyond its rated service temperature during the curing, potentially weakening it.	The tensile capability of the keensert compromised, resulting in them failing and the casing coming loose.	Calculation shows loads of 600-1000 lbf; these are less than the allowables (link, link)
New vertical loads identified during Recovery may overstress the keenserts and G10	The tensile capability of the keensert exceeded, resulting in them failing and the casing coming loose.	Calculation shows loads of 600-1000 lbf; these are less than the allowables (link, link)
Lack of positive restraint at the three interfaces listed in Table 1.2-2.	Casing may slide “sideways”, compromising alignments and stressing coil leads	-Grout Type 1 Bolts to register the skirt interfaces to provide positive restraints at skirt interfaces -Rely on the aquapour & friction to provide restraint at the G10/TF interface

Memo with key background info: link