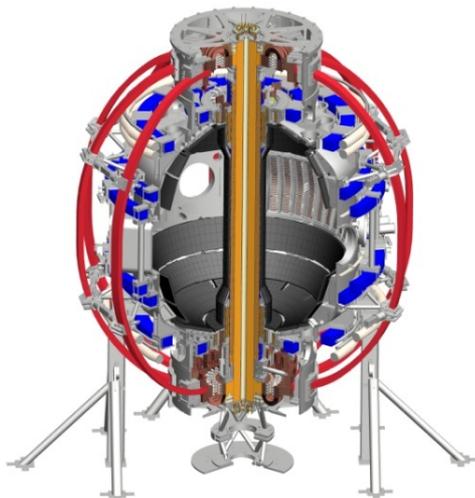


# *OH Coil Cooling Tube Arc Failure New Designs and Re-commissioning*

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**2015/05/28**

# Scope of this Presentation

- **Design upgrades relating to the OH Arc Fault**
  - *New designs address main and contributing technical flaws.*
- **Extent of Condition items**
  - *Description*
  - *Solutions*
- **Recommissioning system for CD4 and Operations**
  - *Pre CD4 items*
    - **Coil systems**
    - **Extent of Condition items**
  - *Post CD4 Items*
    - **Extent of Condition items**
    - **Other**

# Design Improvements - Arc Technical Faults

- 1. OH ground layer's grounding braid was not secured and formed a conductive loop.**

*Re-designed OH ground plane braid & clamp*

- 2. OH Compression System was electrically floating.**

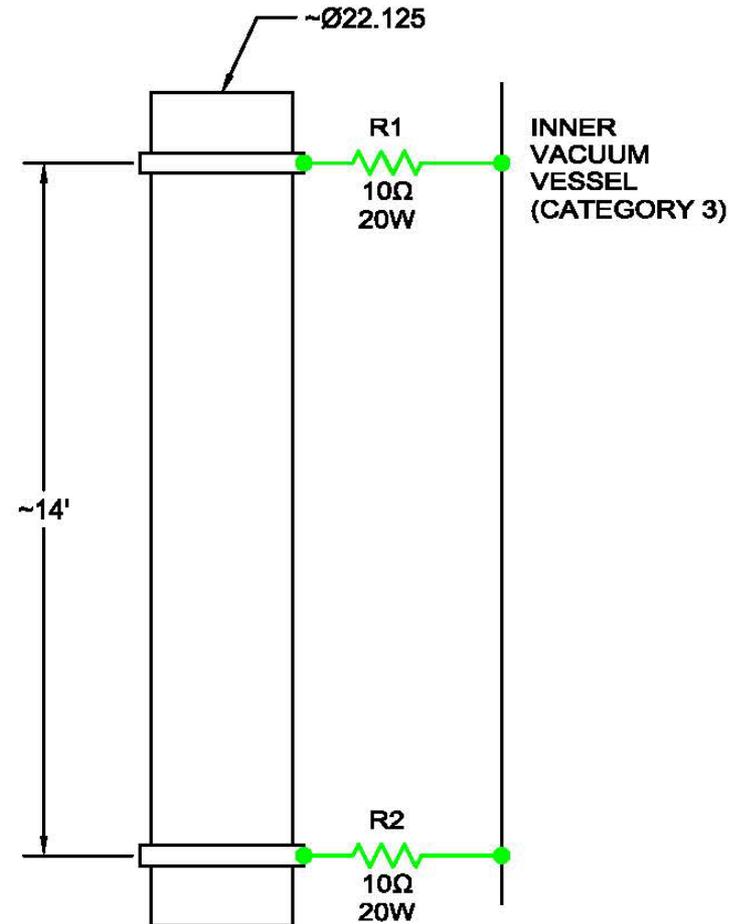
*Reference the OH Preload system to inner VV ground*

- 3. Improved OH cooling tube support brackets will be installed at both ends of the OH coil**

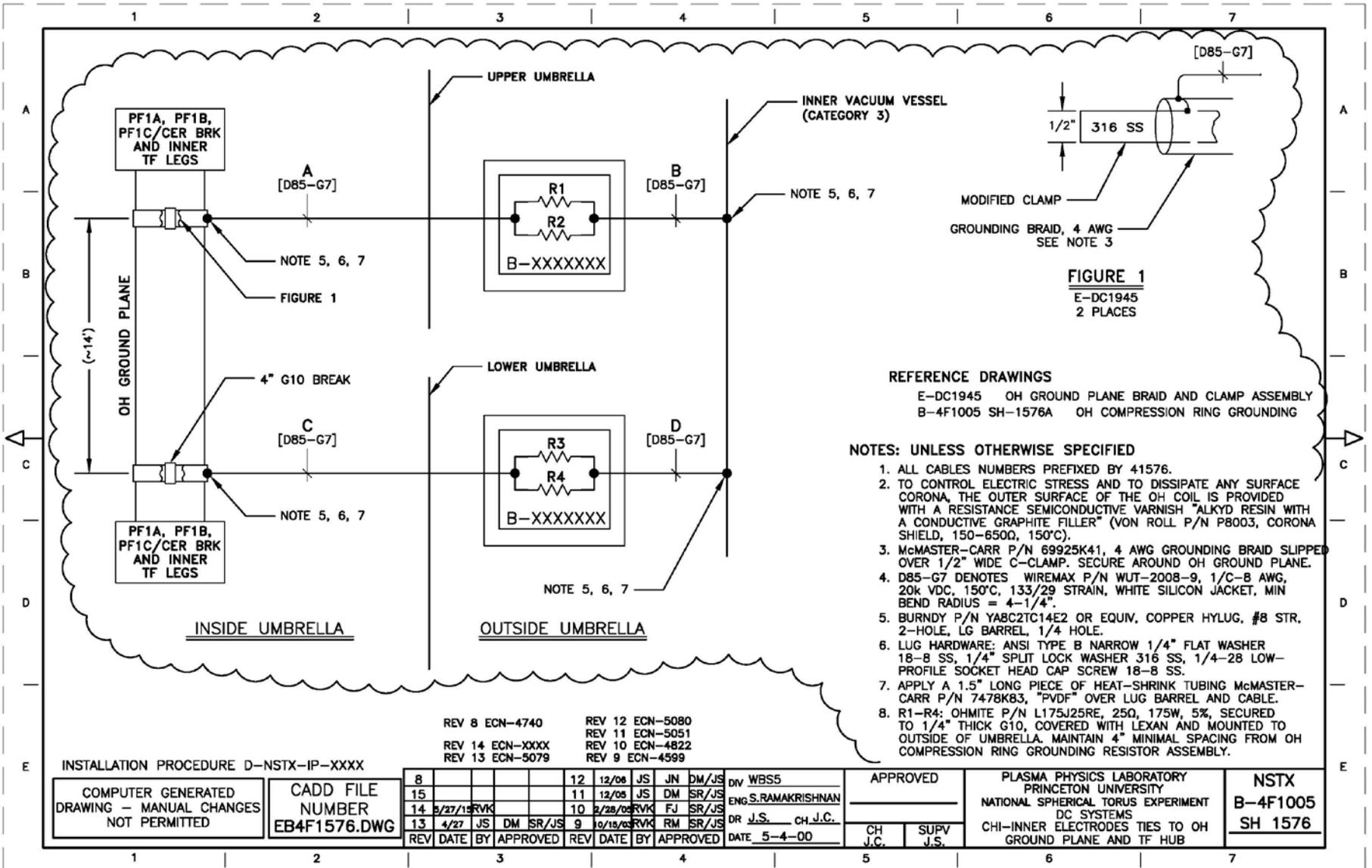
*Much improved high voltage hygiene*

# Item 1 - OH Ground Plane Grounding

- The OH ground plane grounding scheme has been re-envisioned with the following design criteria:
  - Provide grounding points at both ends of the ground plane.
  - **NO CONTINUOUS LOOPS**
  - At the top end, use a modified version of the design that worked for NSTX.
  - At the bottom end a new concept is being developed.
  - Both ends will be grounded to a single point (through resistors) to the inner vacuum vessel.



# Item 1 - OH Ground Plane Grounding - Schematic



# Item 1 - OH Ground Plane Top Clamp - Details

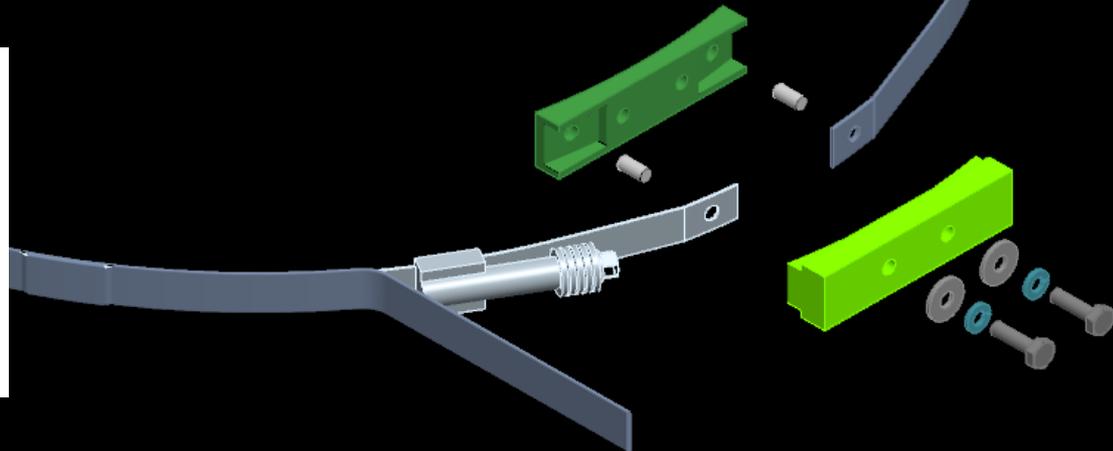
- The OH ground plane top clamp is being redesigned with the following design criteria:
  - Maintain tension during the OH temperature fluctuations.
  - Provide a 4” wide electrical break
  - Secure the ground braid (nickel plated copper, flattened tubular braid). The ground braid will slip over the hose clamp and will not be long enough to form a conducting loop. (will not span over the hose clamp’s electrical break)
  - Single point ground through resistor to the inner vacuum vessel.
- New drawings almost done – pending review/approval
- Materials needed are in-house.
- Peer Review planned for next week
- Procedure being developed

# Item 1 - OH Ground Plane Upper Clamp

*This is essentially the same clamp used for the original OH coil. Ground Braid, which is a flattened tube, can be slipped over the hose clamp and positively secured.*

*Modified "Breeze Constant-Torque, heavy duty clamp". The tightening mechanism is spring loaded. Needs to be lengthened via welded extension section.*

*Electrical Break. G-10 with SS pins to restrain hose clamp*



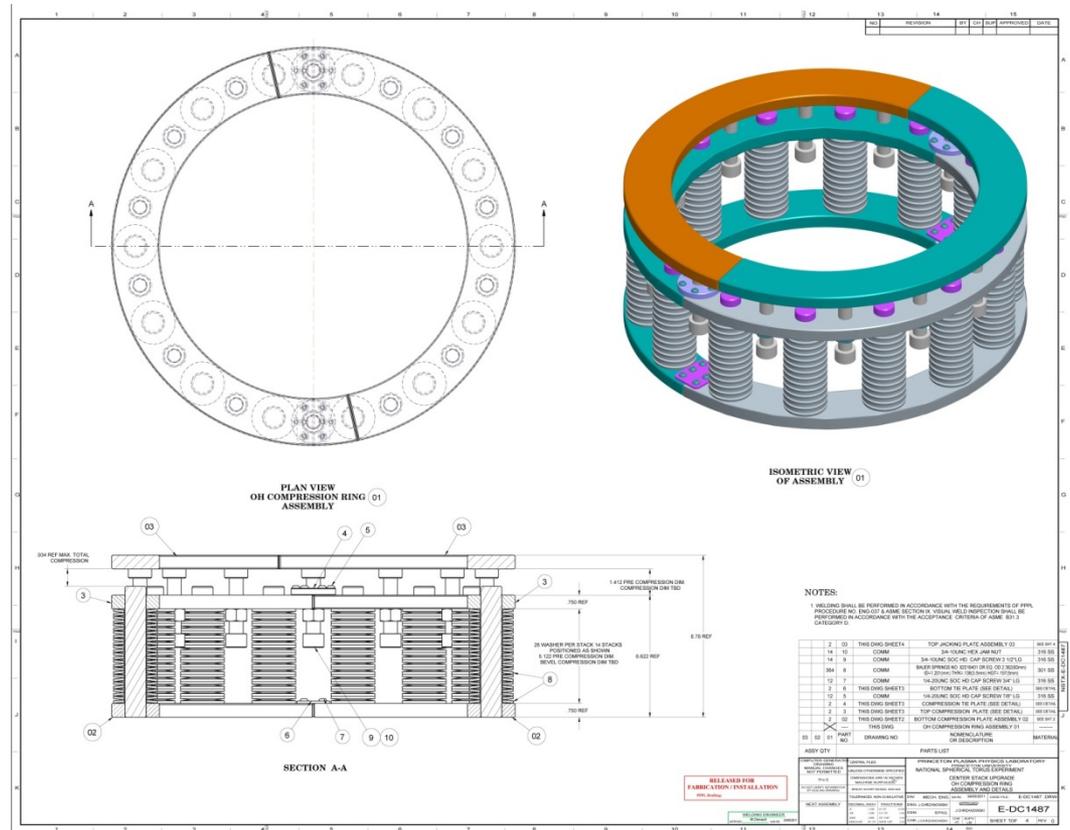
# Item 1 - OH Ground Plane Bottom Clamp

- The new OH ground plane bottom grounding system is being designed with the following design criteria:
  - Maintain contact during the OH temperature fluctuations.
  - Single point ground through resistor to the inner vacuum vessel.
- Drawings not started – field conditions must be factored into the design effort.
- Peer Review planned for ASAP – not before design details have matured.
- Procedure will be developed.



# Item 2 - OH Compression Ring Assembly

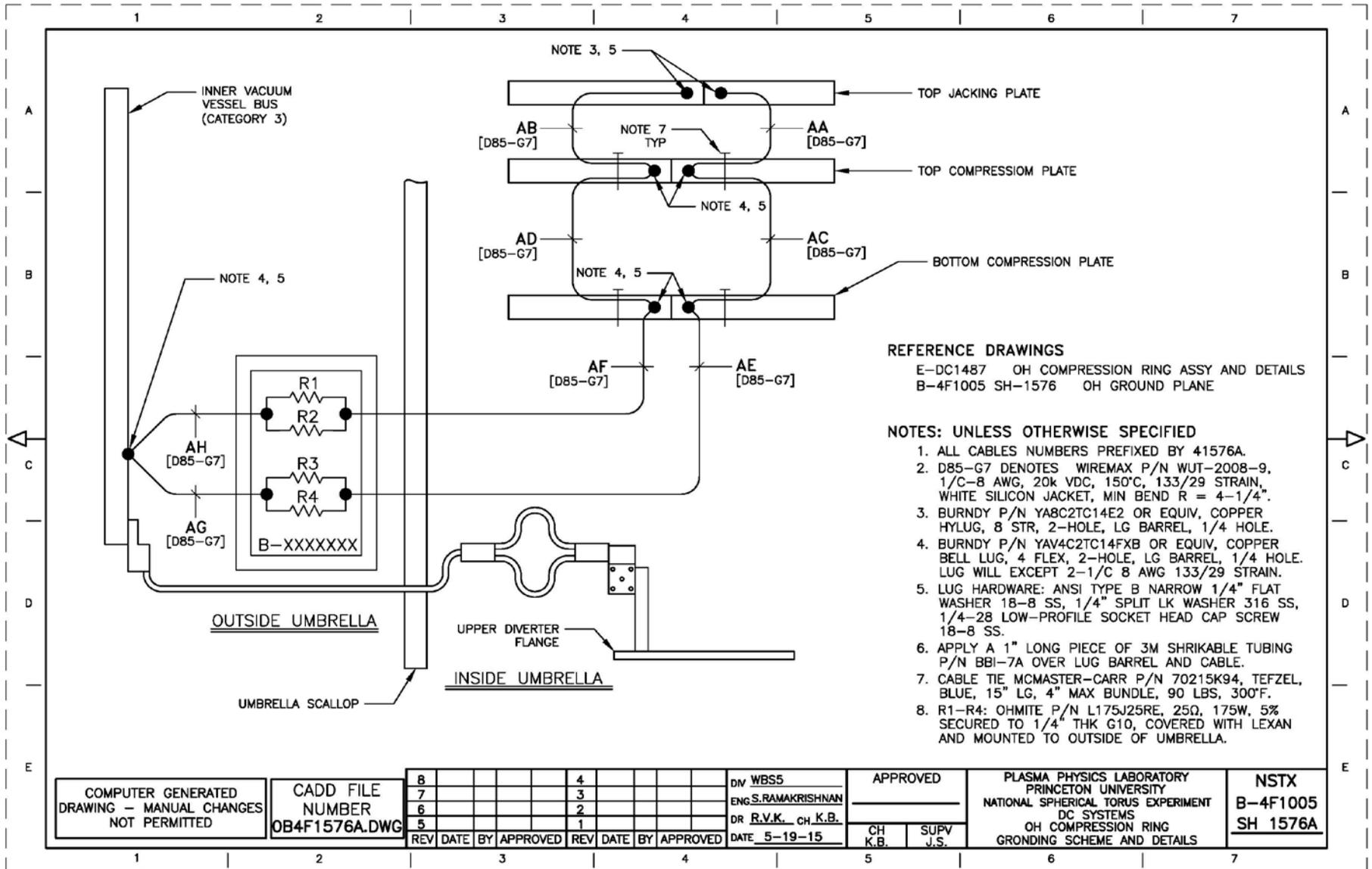
- OH compression ring is an assembly of split rings with welded posts that hold belleville spring washers.
  - We will install jumper cables to ensure that all the ring segments are grounded.
- A single point grounding cable will be bonded (through resistors) to the inner vacuum vessel.
- Grounding scheme must be coordinated with installation of OH cooling tube isolating supports. **All these items must be carefully field fit.**
- Drawings ready for review/approval
- Peer review planned for next week
- Procedure being developed.



# Item 2 - OH Compression Ring Grounding Cabling



# Item 2 - OH Compression Ring Grounding Schematic



COMPUTER GENERATED  
DRAWING - MANUAL CHANGES  
NOT PERMITTED

CADD FILE  
NUMBER  
OB4F1576A.DWG

8				4			
7				3			
6				2			
5				1			
REV	DATE	BY	APPROVED	REV	DATE	BY	APPROVED

DIV WBS5  
 ENG.S.RAMAKRISHNAN  
 DR R.V.K. CH.K.B.  
 DATE 5-19-15

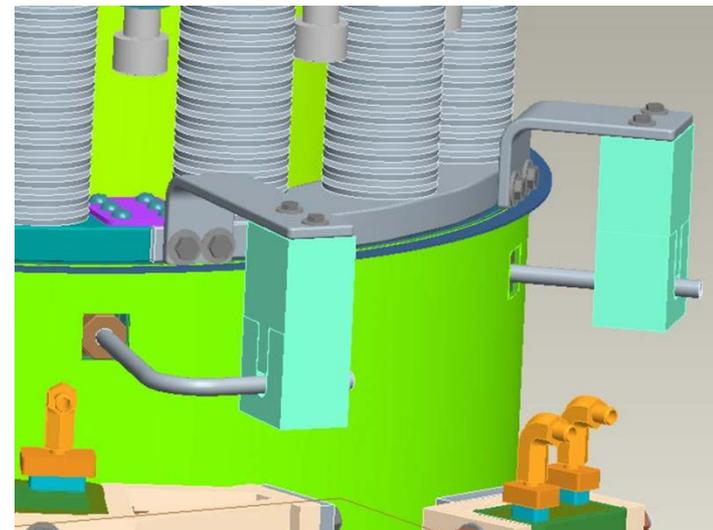
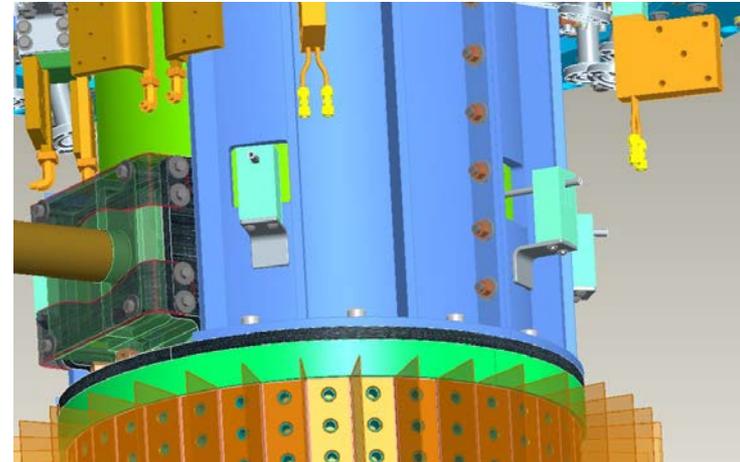
APPROVED  
 CH K.B.  
 SUPV J.S.

PLASMA PHYSICS LABORATORY  
 PRINCETON UNIVERSITY  
 NATIONAL SPHERICAL TORUS EXPERIMENT  
 DC SYSTEMS  
 OH COMPRESSION RING  
 GRONDING SCHEME AND DETAILS

NSTX  
 B-4F1005  
 SH 1576A

# Item 3 - Redesigned OH Cooling tube support clamps

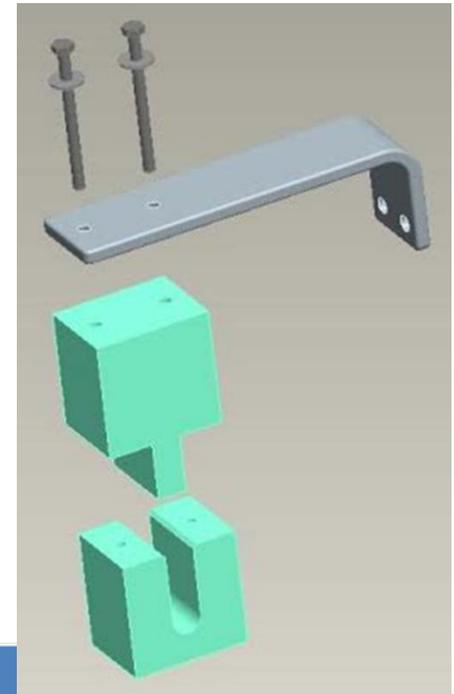
- Support clamps reconfigured so that there is larger clearance between energized and grounded components
- Support clamps have been analyzed via electrostatic FEA and have adequate safety factor.
- Prototype has passed hi-pot to 26kV
- New G-10 disk (the blue ring) Installed between the OH coil and the OH compression stack will overhang further than any metallic component improve electrical standoff for both line-of-sight and tracking path length.
- Kapton tape will be applied on all the grounded metallic surfaces that face the cooling tubes. Tefzel tube over the SS cooling tube.
- All metal edges shall be rounded.
- Production parts will be bench tested to 13kV and in-situ (installed on coil) tested to 9kV.
- Drawings generated
- Peer review held 5/22 - successful
- Shop is fabricating parts
- Procedure being developed



# Item 3 - Redesigned OH Cooling tube support clamp details

Cooling tube no closer that 1.25” from grounded components

- The New clamp drawing - E-DC1943
- Installation/assembly dwg - E-DC1944
- Sample clamps were fabricated and passed 26 KV hi-pot test

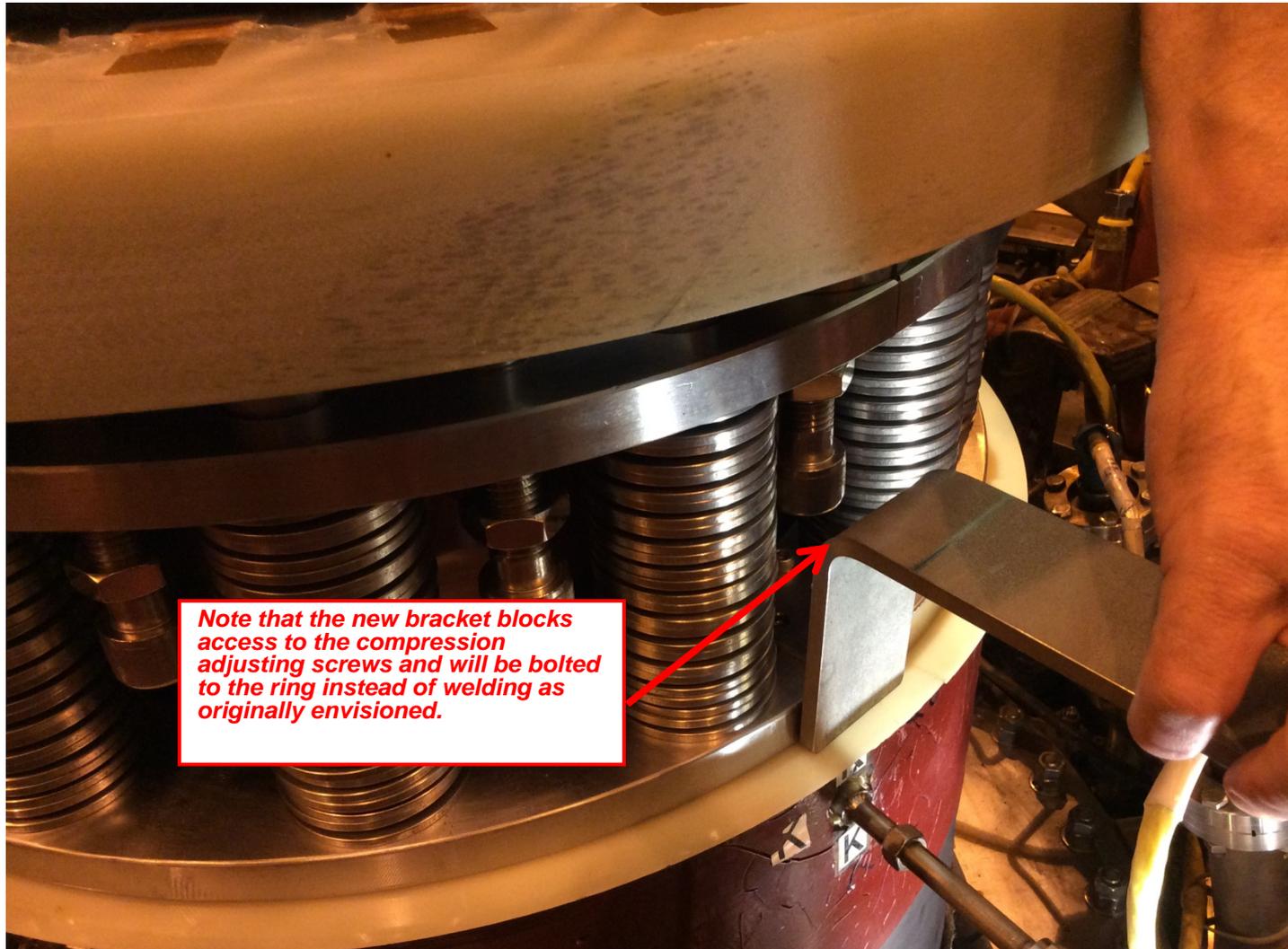


**New OH Clamps Hi-Pot Test Result**

Hi-Pot Voltage (KV)	0	5	9	17	26
Duration (Min.)	1	1	3	5	5
Measured Current ( $\mu$ A)	0	0	0	0	14
Calculated Resistance (G $\Omega$ )	$\infty$	$\infty$	$\infty$	$\infty$	1.86

The acceptable resistance is  $\geq 1$  G $\Omega$

## *Field Fitting to the OH Compression Ring Assembly is a necessary an Iterative Process*

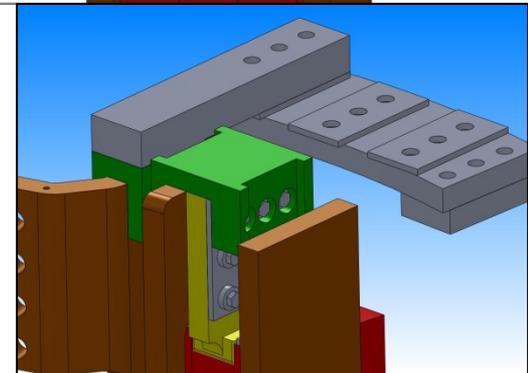
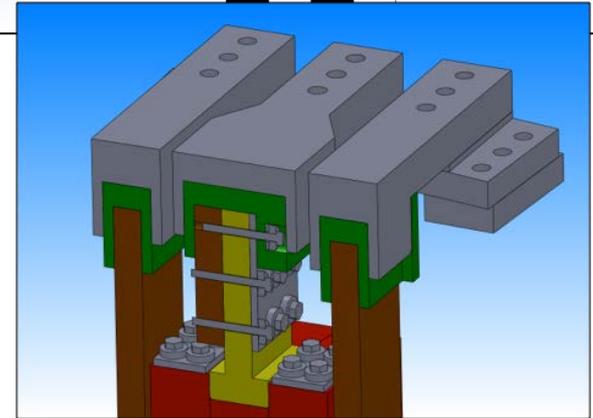
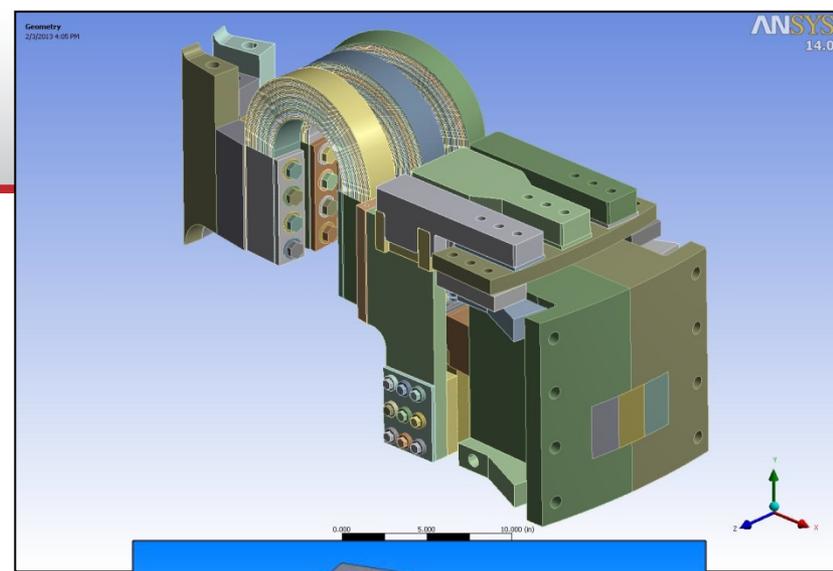


# Extent of Condition Findings

- **These items were discovered during the disassembly and/or after retrospective review and discussions amongst staff.**
  - Inconel TF flag support brackets (found cracked G-10 isolator)
  - OH coaxial bus (retrospective review)
  - Ungrounded metallic structures (retrospective review)
  - Tarnished silver plating (visual inspection at disassembly)
  - Electrical Joint resistance measurements (procedure review)
  - Diverter bake-out options (review of data from mini-bake-out)

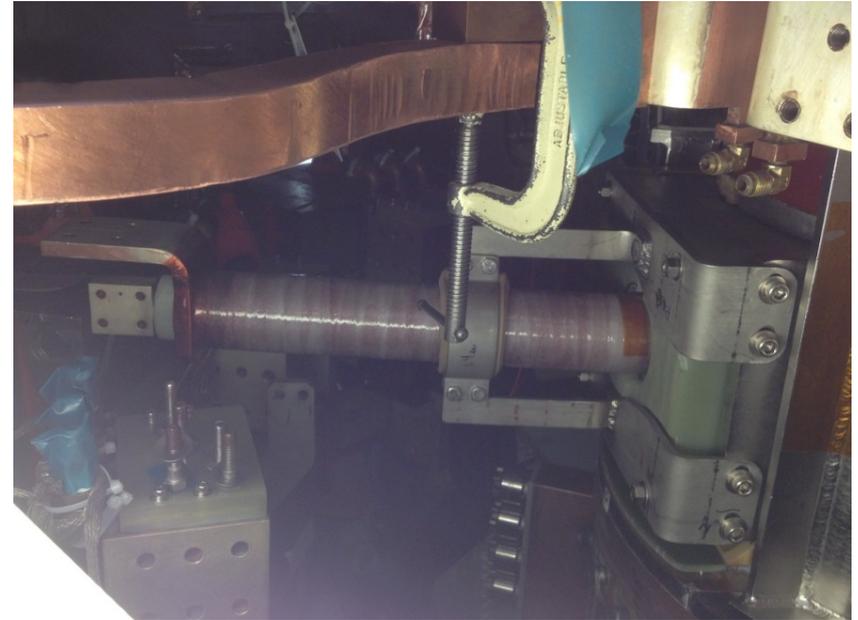
# Inconel TF flag supports

- TF flag supports are required to prevent electromagnetic loads from transferring to the outer TF leg flag braze joints.
- Design intent required elimination of gaps - structural gap filler was specified.
- Specified structural filler was unavailable – Hysol/glass bead slurry was substituted, but abandoned for hard shimming when the fit between parts was deemed acceptable during field inspections.
- At disassembly four (of 72) G-10 isolators were found to be cracked. It is difficult to ascertain whether stack-up of tolerances, installation technique or gaps between parts were the cause of the cracks.
- Specified structural filler has recently become available, has been ordered and received.
- Bench trials have shown that the filler applies easily (does not run or drip) and can be disassembled readily (mold release applied).



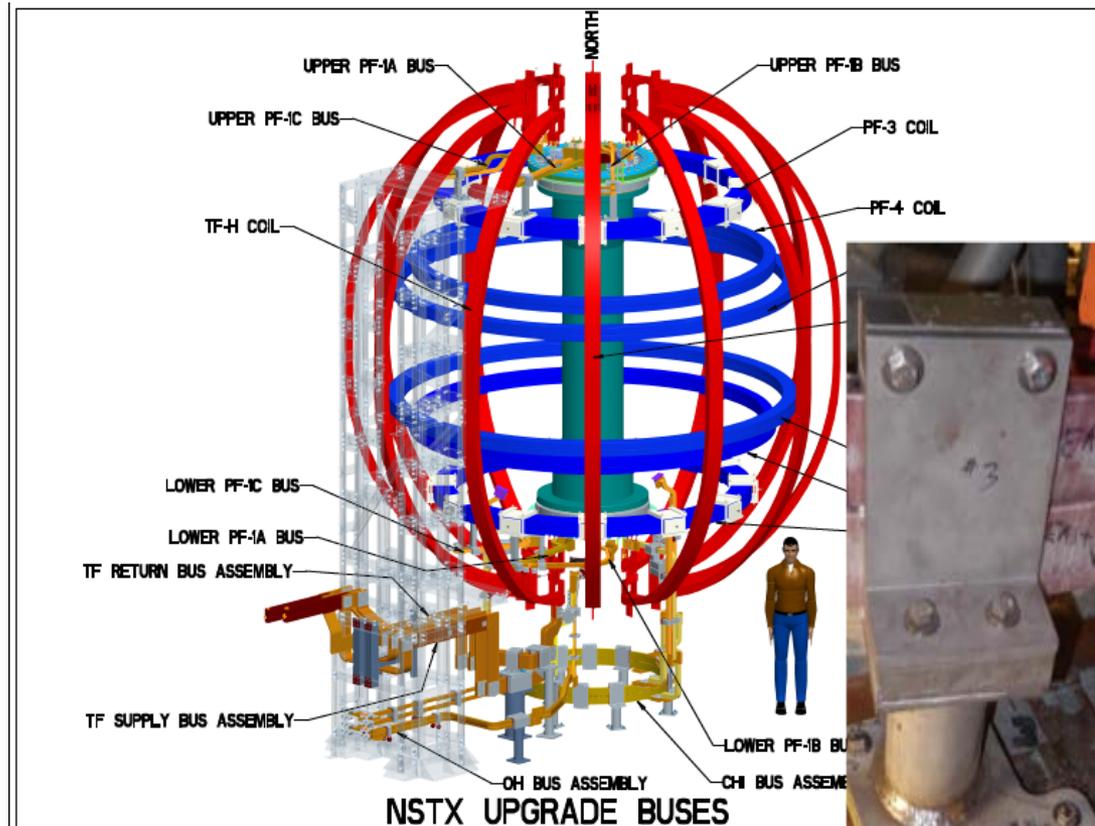
# OH Coaxial Feedthrough

- Clearance between the OH coax inner/outer conductors is required for the initial installation! The current design provides .010" radial clearance between the G-10 and the inner/outer conductors.
- The G-10 insulator between the OH coax inner/outer conductors shall be modified so that it conforms tightly to the inner conductor. Clearance between the G-10 and the outer conductor shall be adequate to ensure proper mating of electrical joints.
- While on the bench and disassembled, epoxy fill holes shall be made in the outer conductor shell.
- After installation, epoxy shall be injected into the void between the G-10 and the outer conductor.
- Trial fitting indicate that the in-situ potted coax will be removable.
- Bench testing of epoxy backfill process is underway.
- Modified drawings and Peer Review to follow successful trial.



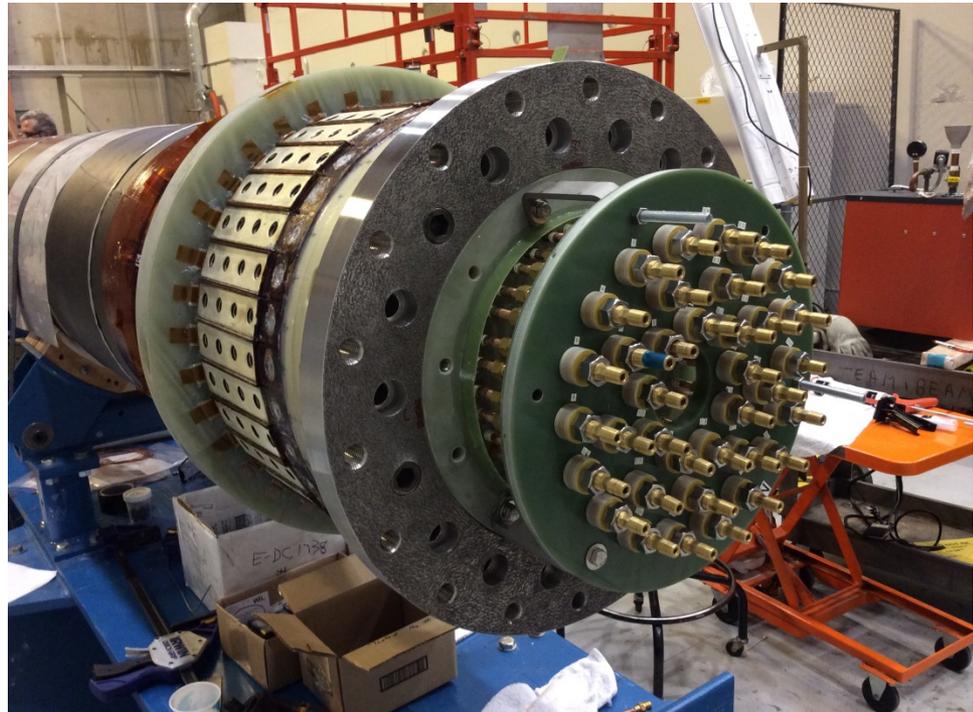
# Grounding the Bus Support Brackets

- The bus supports to the ground were not grounded appropriately.
- Details will be coordinated with electrical engineering group.
- Drawings being generated for the installation of grounding cables which will connect these supports to the proper category ground.



# Grounding the TF cooling tube bulkhead brackets

- These brackets support a G-10 plate that supports the 36 TF inner leg cooling tubes and were not grounded.
- Top side brackets will be referenced to outer vessel ground.
- Bottom side brackets will be referenced to building steel ground.
- Details will be coordinated with electrical engineering group and documented on new drawing.



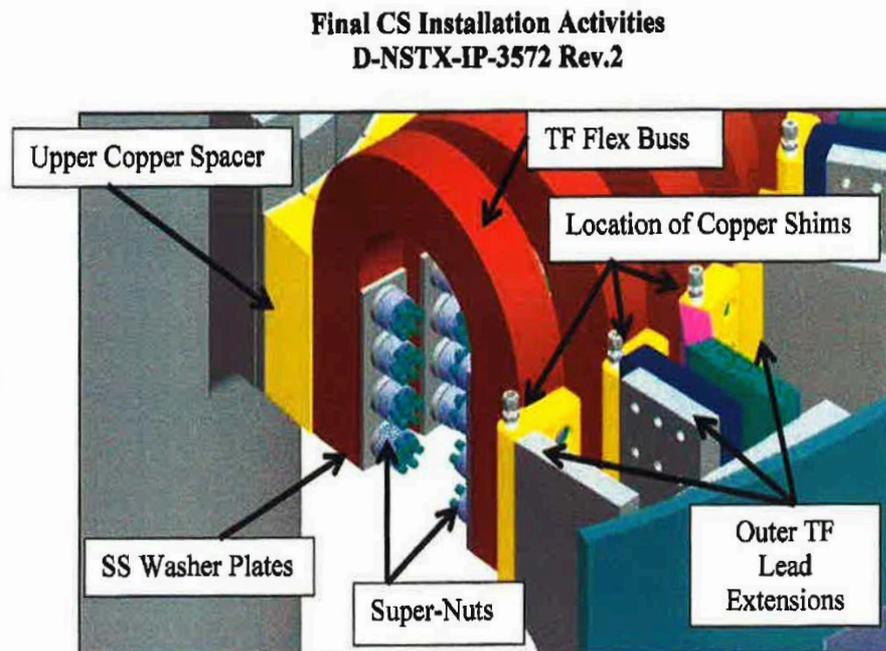
# Tarnished Silver Plating on Electrical Contact Surfaces

- Stains found on silver-plated TF joints
- Stains appear to be silver tarnish.
- Present on significant number of joints.
- We have experienced two events with water spraying onto these areas. Likely caused by water entering joints through capillary action or by exposure to air.
- Surfaces have good flatness – most have measured flat to within 0.001”
- Have price quote from local tester to perform analysis to confirm that it is tarnish.



# Electrical Contact Surface Resistance

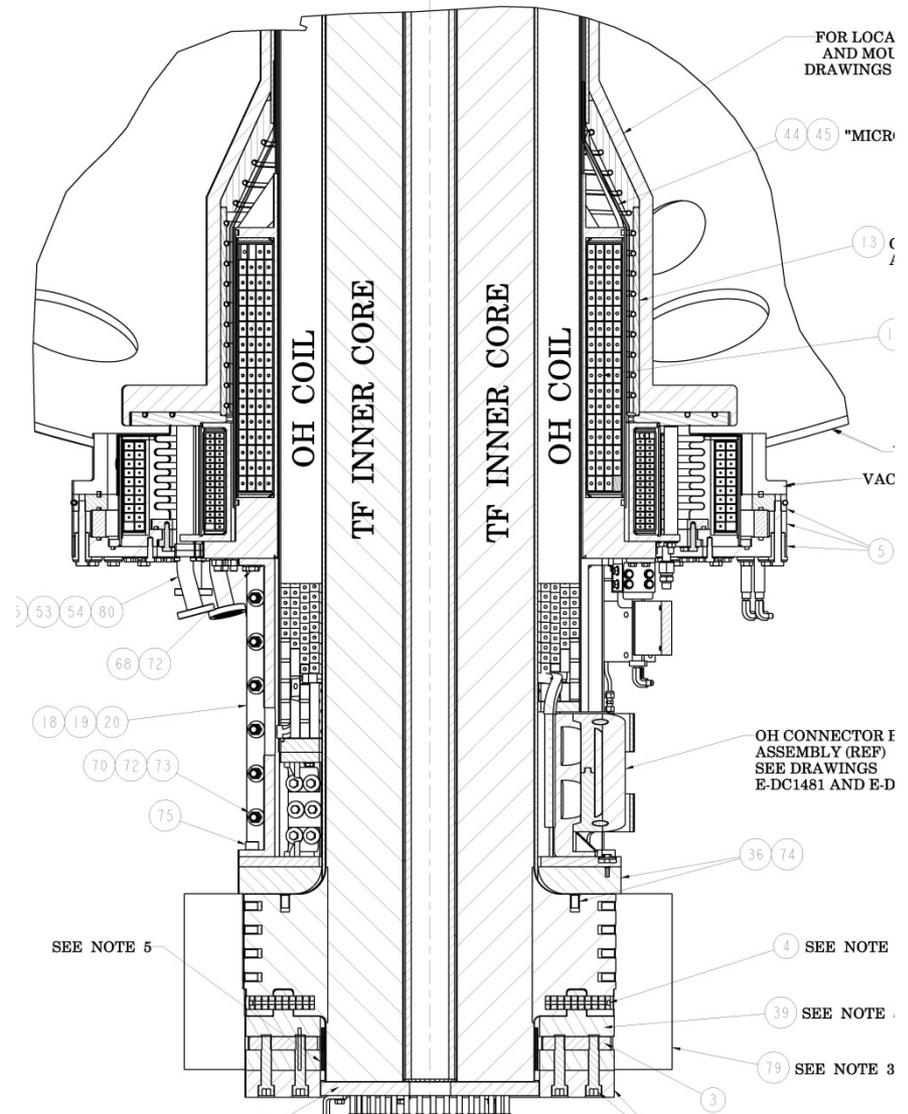
- Resistance measurements of electrical joints were made with Biddle instrument.
- Many joints could not be directly measured due to access restrictions – measurements across multiple joints were taken instead.
- We are evaluating the recommendations from electrical engineering to provide better resistance measurements for all bolted-up electrical joints.
- Techniques from electrical engineering shall be incorporated into the re-installation procedure(s).
- Plan to expand the use of temperature stickers to better monitor electrical joint temperatures. We'll need an plan for inspecting the hard-to-see stickers.



**Figure 7- Typical TF Flex Bus Assembly**

# Divertor Bake-out Options

- During the mini bake-out, it was realized that the tiles in the divertor region were not achieving desired temperature.
- There are copper cooling lines embedded in the centerstack case that are there for cooling Inner PF coils 1A and 1B.
- We are extending the cooling tubes to the outer edge of the umbrella, where they will be available for “alternate” plumbing configurations in the future.



# Design Review Schedule

- Cooling Tube Bracket
  - May 22, 2015. Deemed Successful
- Upper OH Ground Plane Grounding System & OH Compression Ring Grounding
  - Week of 6/1
- OH Coaxial Bus
  - Week of 6/1
- Lower OH Ground Plane Grounding System
  - TBD

# Re-commissioning the NSTX-U for CD4

- ✓ Disassembly complete
- ✓ Cleanup of OH complete.
- ✓ Successful flow and hydrostatic checks of OH cooling passages (complete)
- ✓ Successful Megger of the coils in the upper umbrella - OH, TF, PF-1A and PF2 (complete)
- ✓ Disassembly of lower TF flexes to facilitate access to replace lower cooling tube support clamps.
- Manufacture replacements for damaged components (in fabrication).
- Cleanup of the ceramic break – currently not passing inner-to-outer vessel hi-pot.
  - Install re-designed cooling tube support clamps, OH compression ring grounding cable(s) and re-designed OH ground braid/strap (upper & lower\*\*).
  - Install OH Coax feed-through & inject with filler\*\*.
  - Water system reconnection (within the umbrella), hydrostat OH cooling fittings.
  - Electrical tests of OH (before it's buried by TF connections).
  - Clean and silver plate (as required) the TF electrical connections\*\*.
  - Re-install TF flexes and Inconel support brackets with structural filler\*\*.
  - Water system reconnection, flow rebalancing
  - Repeat sections of the coil PTPs as appropriate.
  - Extend diverter cooling tubes to outer edge of umbrella\*\*.
  - Ground all ungrounded metallic structures\*\*.

\*\* Addresses an “Extent of Condition” concern

# Post CD4 tasks

- OH Preheater
  - Prevents cold water to be fed into a *hot* coil.
  - Designed to mitigate stress induced by a cooling wave in the OH coil
  - Has been extensively reviewed. Installation planned for next outage.
- Diverter cooling tube transition to He bake-out system
  - Need analysis & review prior to transitioning from cooling to heating to ensure that ramifications to PF-1A and PF-1B are understood.

# Questions?

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Thank you!