# NSTX-U OH Fault
# Report on Extent of Condition

J. Hosea (chair), R. Ellis, N. Greenough, D. Mueller

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# Charge to the Committee

- Are there any other areas of NSTX-U, not yet identified, that might have been compromised by the fault, or be subject to similar defects? Are there any other similar weaknesses in the NSTX-U design or assembly that could lead to future difficulties?
- Committee members: Joel Hosea (chair), Robert Ellis, Nevell Greenough, Dennis Mueller

# Summary of activities

- Meeting with engineers to determine their concerns for extent of condition 5/19/2015
  - 9:00 Center Stack Project - Larry Dudek (discuss walk downs)
  - 9:30 Center stack configuration and hookup (Raftopoulos)
  - 10:00 Ground plane connections (Raki)
  - 10:30 TF connections (Raftopoulos)
  - 11:00 Water connections (Atnafu / Titus)
  - 11:30 Integrated testing/startup – C. Gentile / Al von Halle
  - 1:00 Test Cell Ground fault detector (Schneider)
  - 1:30 DCPS System – S. Gerhardt / Tim Stevenson
- Met the morning of 5/20/2015 to work on list of concerns.
- Walked down critical areas of NSTX-U afternoon of 5/20/15.
- Met 5/21/15 to work on report.
- Met 5/22/15 to work on report.

# General Areas of Concern

- Grounding
- Water Connections
- OH Coaxial Feed
- Electrical connections for TF flex connectors
- PF1A, 1B, 1C Considerations
- Bakeout Constraints
- Aquapour/epoxy between TF Inner Bundle and OH center stack
- Other areas of interest:
  - Ground fault/loop detector sensitivity lessened by capacitors installed across HHFW transmission line DC breaks
  - Adequacy of control room displays and associated computers.
  - Add cameras for real-time viewing of critical machine components.
  - Chain of command during operations

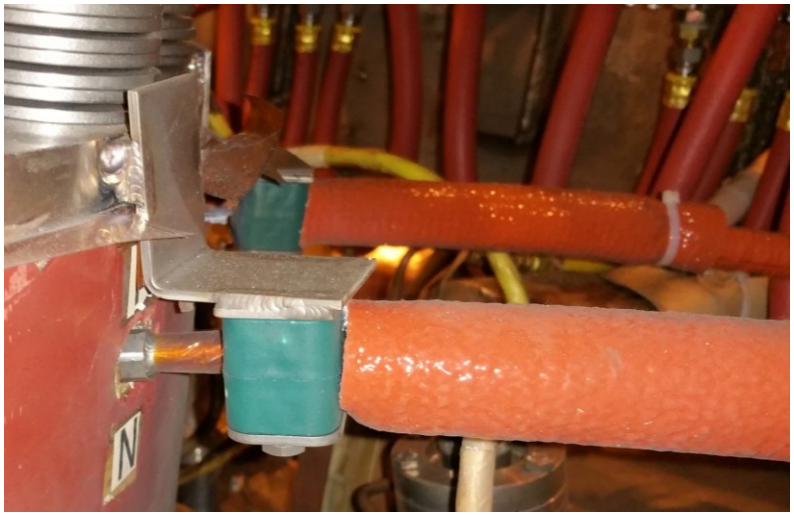
# Grounding

- OH ground plane and connection overall design
  - Do we need a lower ground plane connector?
    - Evaluation is required.
  - Design, fabrication, installation, connection and inspection of ground plane connector(s)
  - Ground through a 10 Ohm resistor
- OH Compression Stack Grounding
  - Through a 10 Ohm resistor.
- Grounding of buss supports at bottom of machine
- Grounding of metal spacers to TF water connector supports
- Who has an overall understanding of the machine grounding? Who is in charge of grounding, inspection thereof, and documentation on NSTX-U?
  - The latter individual should have the qualifications of the former.

# OH Water Connections

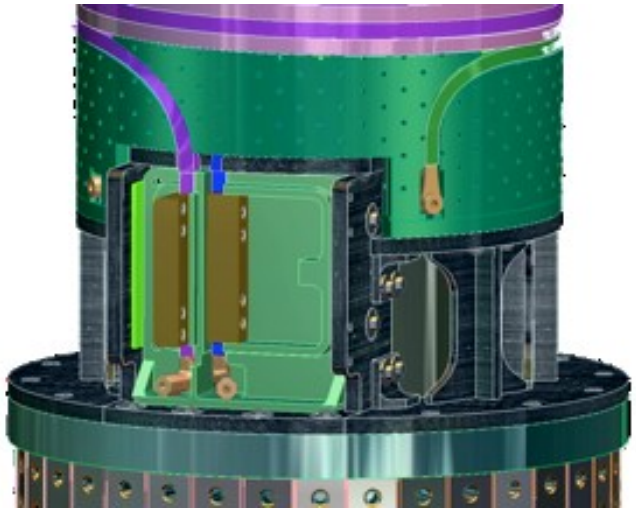
- Need an approved design with proper insulation - underway .
  - Original parts were field fit.
  - New design must have electrical engineering input to insure proper high voltage insulating techniques - underway.

Original implementation of OH water connections

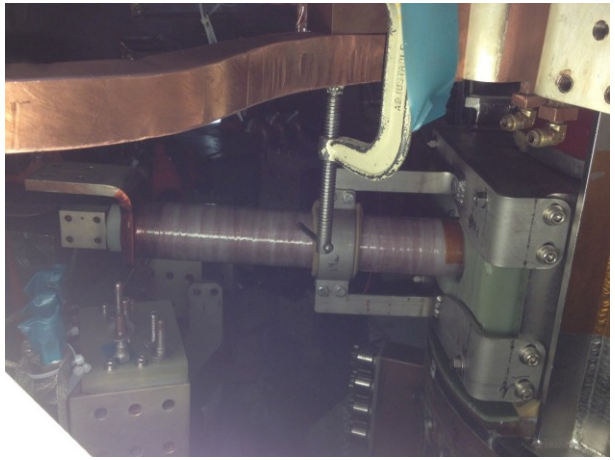


# OH Coaxial feed

- Must insure integrity of joints – measure voltage drops for test current.
  - Use temperature stickers.
  - Check periodically
    - How can they be viewed?
  - Inner joints from coax connector to coil are insulated on side – measurement via water feed should be possible.
  - View accessible stickers periodically with borescope.
- Evaluate design assumptions – particularly with regard to the need for support of the inner conductor – and determine whether the feed must be potted, or if a system of shims around the inner conductor, is feasible.
  - The coax feed should be potted unless there is justification for altering the present design and requirements.
  - Be sure the design, construction, installation and analysis of the connector box are also consistent.
- Review the “high voltage hygiene” in the connector box.
- Consider a means of detecting series joint arcs in connector box.



OH lead blocks



OH coax feed installed

# TF Outer – Inner Electrical Connections

- Critical connection with several elements in series.
  - Fit-up is critical.
- Accurate joint resistance measurements are required.
  - NSTX-U has relied on purely mechanical measurements of joint characteristics. [torque, feeler gauges]
  - Investigate if techniques exist for proper measurement of joint resistance. Voltage across the TF inner leg connection can be measured via the water connection with current running through the connector assembly and the leg

Outer to inner TF connection

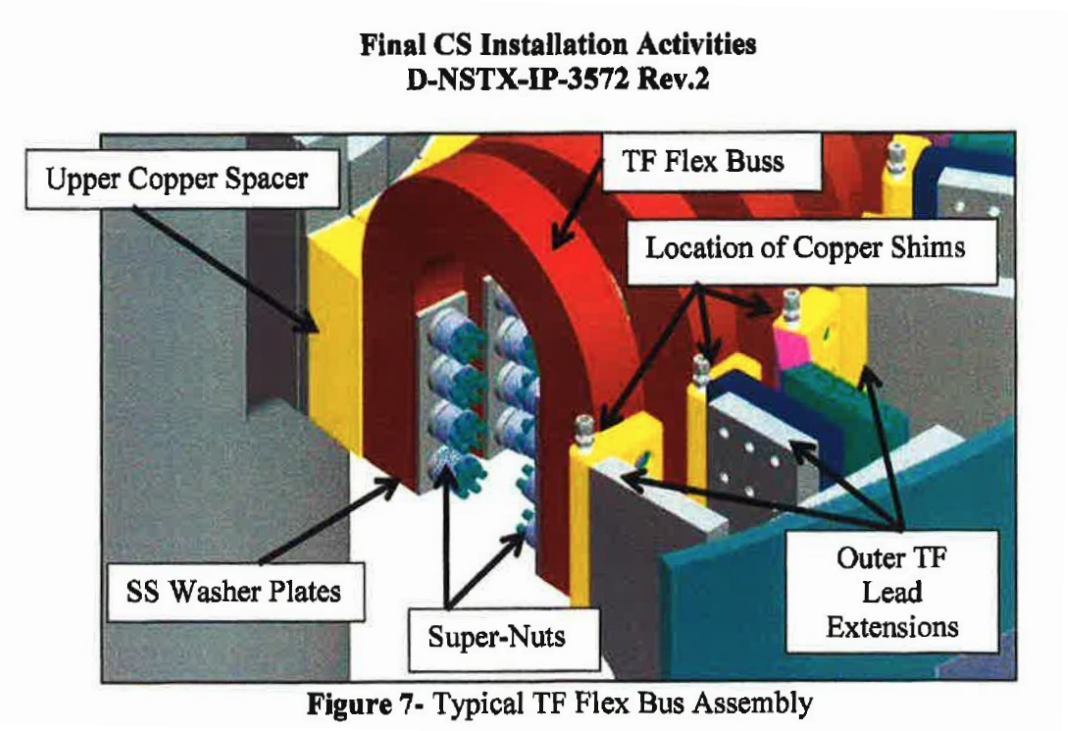
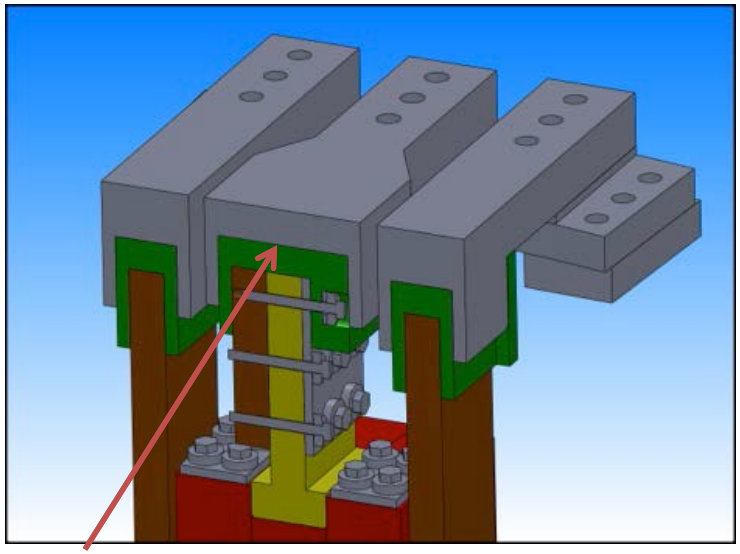


Figure 7- Typical TF Flex Bus Assembly

# TF Outer – Inner Electrical Connections (cont.)

- Improve quality and uniformity of silver plating of contact surfaces.
  - Tarnishing of silver plated areas has been observed.
  - Variable thickness, observable by eye, of silver plating?
- Cracking of G-10 spacers on TF connector restraints
  - Structural adhesive will now be used to fill joints
  - Any analysis on its performance?
- Use temperature stickers, monitor with a borescope or camera/fiber optic bundle.

Tarnish on silver plated connectors



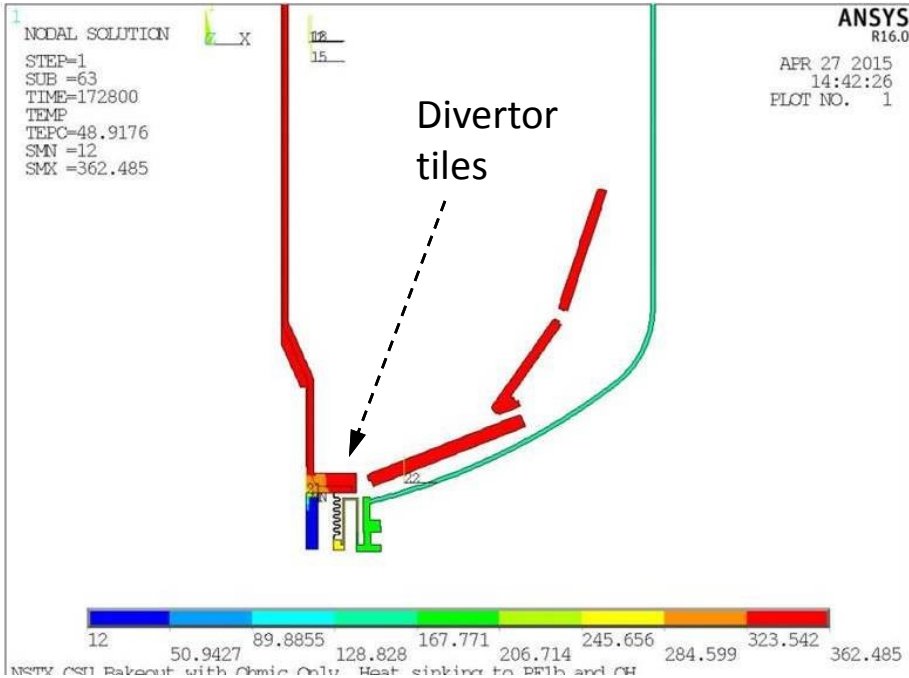
G-10 caps that cracked → improve contact with structural adhesive??

# PF1A, 1B, 1C Considerations

- Shorting between PF-1A ground wrap and OH ground plane.
  - It cannot be repaired without removing center stack.
  - What are the ramifications? Minor.
- PF-1C can be heated by the plasma
  - Only a minor issue when PF-1B is not energized, but the strike point can still hit the PF-1C can.
  - Energizing PF-1C so as to push the strike point towards the plasma will avoid this.
  - Operations can administratively avoid the problem.
  - A clear set of operating constraints needs to be developed.
- Bakeout issue with PF-1B (Art Brooks analysis)
  - Divertor tiles will not reach adequate temperature unless heated by the He system.
  - If heated by He, the G10 spacer and ground wrap of PF-1B will exceed allowable limits.
  - There is also the issue of stress in the welds securing PF-1B upper and PF-1A upper.
  - Management must decide whether to bake to over 300C and accept risks to PF-1B
  - Connections to divertor plates must be able to accommodate the He heating system.

# Bakeout Constraints on Machine Operations

- Failure to reach desired 350C bakeout for divertor tiles is predicted.
  - Refer to PF-1A, B, and C considerations
- High temperature is needed for bakeout of divertor plates to provide for good plasma performance.
- Preparations need to be made to add hot He gas heating to the divertor plates to reach desired temperature of 350C.
- Discoloration of CHI leads after Center Stack bake.
  - Need to understand the cause




- Heating of graphite tiles is adequate with He heating of divertor plates
- But PF1B G-10 spacer and wrap get too hot
- Also the welds taking up launching loads may be over stressed

# Aquapour/Epoxy between TF inner bundle and OH Center Stack

- Operation of OH and TF combined with PLC controlled water heater to program the water temperature profile.
  - Controlled through DCPS using $I^2t$.
  - Constrains the pulse repetition rate.

# Other Areas of Interest

- Ground fault/loop detector sensitivity lessened by capacitors installed across HHFW transmission line DC breaks.
  - Used in the past with the same capacitors.
  - Loop faults are present in the diagnostic ground system.
- Adequacy of control room computers and associated displays for the COE.
- Add cameras for real-time viewing of critical machine components.
- Chain of command during operations.
  - Clear line of command to and from the COE during off-normal events