Centerstack Plasma-Facing Components for NSTX Upgrades

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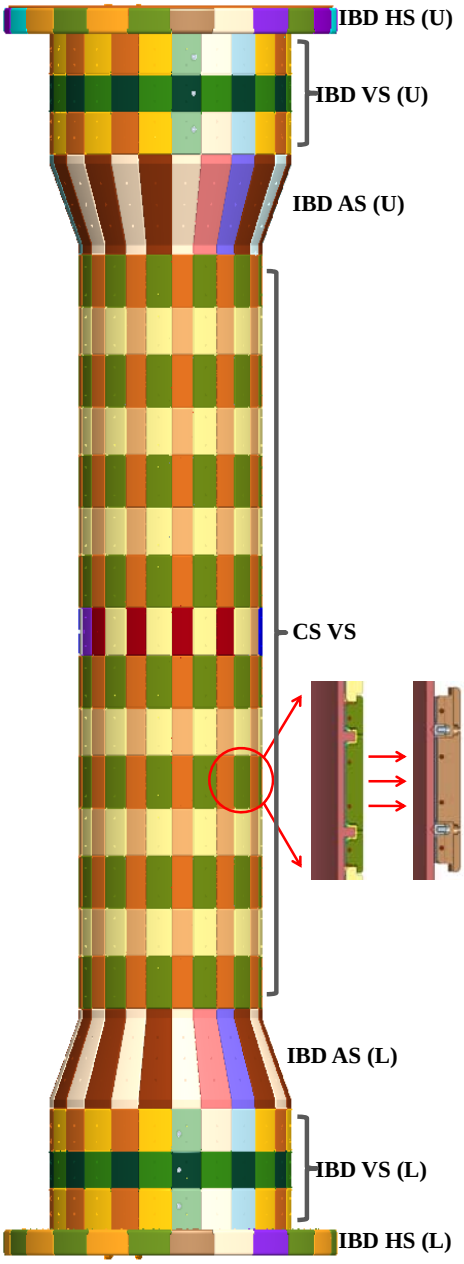
Abstract

The National Spherical Torus Experiment (NSTX) is a low aspect ratio, spherical torus (ST) device which is located at Princeton Plasma Physics Laboratory (PPPL). This device is presently being updated to enhance its physics by doubling the TF field to 1 Tesla and increasing the plasma current to 2 Mega-amperes. amperes. The heart of the upgrade involves a new Centerstack Assembly (CSA). The CSA consists of the inner legs of the Toroidal Field (TF) windings, the Ohmic Heating (OH) solenoid, three pair of inner Poloidal Field (PF) coils, thermal insulation, diagnostics diagnostics and an Inconel casing which forms the inner inner wall of the vacuum vessel boundary. The outside outside surface of the Inconel casing is protected from from the heat loads by a layer of carbon fiber tiles The tiles The upgrade of the CSA will increase the casing diameter, requiring the replacement of all the carbon-based Plasma-Facing Components (PFCs). Additionally, Additionally, due to other upgrades to the operating capacity of the device, the PFCs need to be improved to to withstand higher heat fluxes and larger disruption forces. A combination of 2D and 3D carbon fiber composites have been proposed to provide adequate thermal shielding as well as offer sufficient mechanical mechanical properties to tolerate higher, thermally-induced stresses within the tiles. The attachment scheme scheme for this upgrade presents several possible changes to the original design: replacing the weld stud with a weld nut, changing the soft joints to a hard design design in order to facilitate the implementation of the Spiralock thread technology, and finally, the removal of of Grafoil from the system in order to thermally isolate isolate the PFCs from the Centerstack Casing.

PFC Specifications

- Carbon based only to minimize impurity influx to plasma, E-Mag interactions, and lithium compounding.
- Designed in accordance with upgrade heat flux loading for a Double Null (DN) type plasma.
- Tiles need to include slots and wire passages for diagnostics.
- All tiles will need to be designed to accommodate a 350 350 °C bakeout temperature.

NSTX-U Centerstack



Proposed Changes

MATERIAL: Improve thermal and mechanical capabilities capabilities of the tiles by using a combination of 3D and and 2D carbon fiber composite (CFC).

- 3D CFC on the Inboard Divertor (IBD) where heat loading is largest.
  - This material has exceptional thermal and and mechanical properties, allowing the tiles to withstand high thermal stresses.
- 2D CFC on Centerstack vertical section (CS VS) VS) for "fastener" tiles.
  - These tiles are the thinnest and need mechanical properties better than that of ATJ.
- Preliminary analysis of the CSA cooling system showed that there was substantial tile thermal ratcheting.
  - Possible threat to equipment inside the CS CS casing.
  - Grafoil is removed from tiles in order to thermally isolate the tiles and prevent over-over-heating.

FASTENING SCHEME: Attempt to improve current fastening methods which are problematic.

- Replace all threaded fasteners with Spiralock thread tech which is self-locking (all tiles), and replace nut caps with weld nuts and bolts (IBD VS and CS VS).
  - Spiralock requires a hard joint and a 75% 75% S_p preload.
- Implement improved coatings on all threaded fasteners to avoid galling or cold welding.
- Improve tolerances between tiles, ensuring proper gaps for thermal expansion and better installation results.

TILE SIZE AND LAYOUT: Attempt to simplify number of of tiles and improve diagnostic coverage.

- Tile count: from ~900 => 600
  - Tiles increased in size but still within acceptable limits
- Increased diagnostic count and coverage.
  - Mirnov, Rogowski, Langmuir, Thermocouple
- Layout accommodates new gas injection scheme scheme on mid-plane and upper shoulder.

NSTX-U PFC Thermal Loading Increase

	NSTX		NSTX-U		
	SN	DN	SN	DN	
CS VS					
qavg	0	0	0	0	MW/m^2
IBD AS, VS					
qavg	2.99	1.19	3.82	1.53	MW/m^2
qpeak	4.73	1.89	6.05	2.42	MW/m^2
IBD HS					
qavg	6.8	3.63	9.65	5.15	MW/m^2
qpeak	10.76	5.74	15.27	8.15	MW/m^2

Ongoing Work and Recent Changes

- Due to administrative decision, all tiles on the NSTX-U CSA will be made of high-performance isotropic graphite such as ATJ.
  - Cost savings and preferable for in-vessel Lithium use.
- Additional analysis showed that Grafoil will be required to keep tile stresses in the allowable range for ATJ.
  - Grafoil will now included in tile-to-casing interfaces.
  - Cooling system effectiveness will be increased to prevent thermal ratcheting. ratcheting.
- Weld nut concept must be abandoned due to tile thickness constraints and nut cap concept will be resumed (IBD VS and CS VS).
- Final analysis (*under final review*) shall determine tile loading.
  - E-Mag loading is assumed to be inward, pushing tiles into the CS.
  - Thermal loads will dictate final fastener design.