NSTX

71-000111-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: CENTER STACK UPGRADE

A concept has been developed for the center stack upgrade. Upgraded parameters are:

$$B_t = 0.75\text{T}$$

$$\phi_{oh} = 2 \times 0.75 \text{ weber}$$

These values are 2.5 times the baseline NSTX values, suggesting that we could approach $I_p \approx 2.5$MA, if flux consumption, PF equilibria, and disruption considerations allow. With a single swing of OH we should be able to get at least 1MA, allowing inductive start up followed by CHI and/or RF sustainment.

The following are the main features of the proposed design point:

R_0	0.9	m
a	0.616	m
R_0/a	1.47	
R_0+a	1.518	m
B_{tf} @ R_0	0.75	T
I_{tf} per turn (36 turns)	94	kA
V_{tf} (no-load)	1	kV
ESW_{tf}	5.4	sec
ϕ_{oh}	2 x 0.75	weber
I_{oh} per turn (1114 turns)	24	kA
V_{oh} (no-load)	8	kV
ESW_{oh}	1.1	sec
R_{oh} (center)	0.2077	m
ΔR_{oh} (over copper)	0.0692	m
ΔZ_{oh} (over copper)	+/- 2.1	m
$R_{center\ stack}$ (over PFC tiles)	0.2864	m

In arriving at this design, the following constraints were applied:

- Assumed R_0 + a shall match existing design so as to conform to existing HHFW antenna;
- TF inner leg bundle matched in turns and +/- Z to fit up with existing outer legs;
- TF conductor sized for $T_{max} \approx 90^{o}C$ with 5.4 second equivalent square wave (ESW) which is sufficient for 5 second flat top with 1kV, 4 parallel power supply;
- Allowed for additional ground insulation on TF bundle to face CHI voltage on OH tension tube;
- OH coil height +/- Z same as existing;
- OH conductor sized for $T_{max} \approx 90^{o}C$ with 1.1 second ESW, which is sufficient for 1 second I_p flat top based on I_p ramp rates and flux states extrapolated from original NSTX baseline design;
- OH scenario per above requires 6kV power supply; assumed 8kV power supply (to provide control voltage margin) and allowed for additional insulation;
- Increased OH-to-center stack casing gap to allow slightly more room for diagnostics and Microtherm insulation, compared to baseline;
- Adopted standard wall thickness for tension tube and center stack casing to avoid custom requirement (this drove up costs on the baseline);
- Assumed 0.75″ thickness center stack tiles, compared to 0.5″ in present design (increased space for tile diagnostics, along with possible gas injection on inboard midplane).

Concerning the engineering allowables, it is noted that:

- peak temperatures, even in case of L/R decay after $\int i^2(t)dt$ corresponding to rated ESW, are $< 100\,^{o}C$;
- Central $B_{oh} \approx 8T$ is approximately same as existing design, and hoop stress in first layer of OH coil is projected to be ≈ 70% of existing design;
- TF inner leg insulation shear stress is projected to be ≈ 80% of existing design, based on the fact that, while Boh*Itf has increased, the area reacting the force has increased to a greater degree.

The only major departure from the design and fabrication of the baseline machine concerns the OH conductors. On the baseline, using 4 layers wound 2-in-hand, we were able to obtain sufficient conductor length to avoid a splice. In the new design, assuming 4 layers wound 2-in-hand, the required extrusion billet size is greater than that available (we were already at the limit on the baseline). Therefore we need to make a conductor joint, or wind more conductors in hand, or divide the OH coil into separate upper and lower halves.

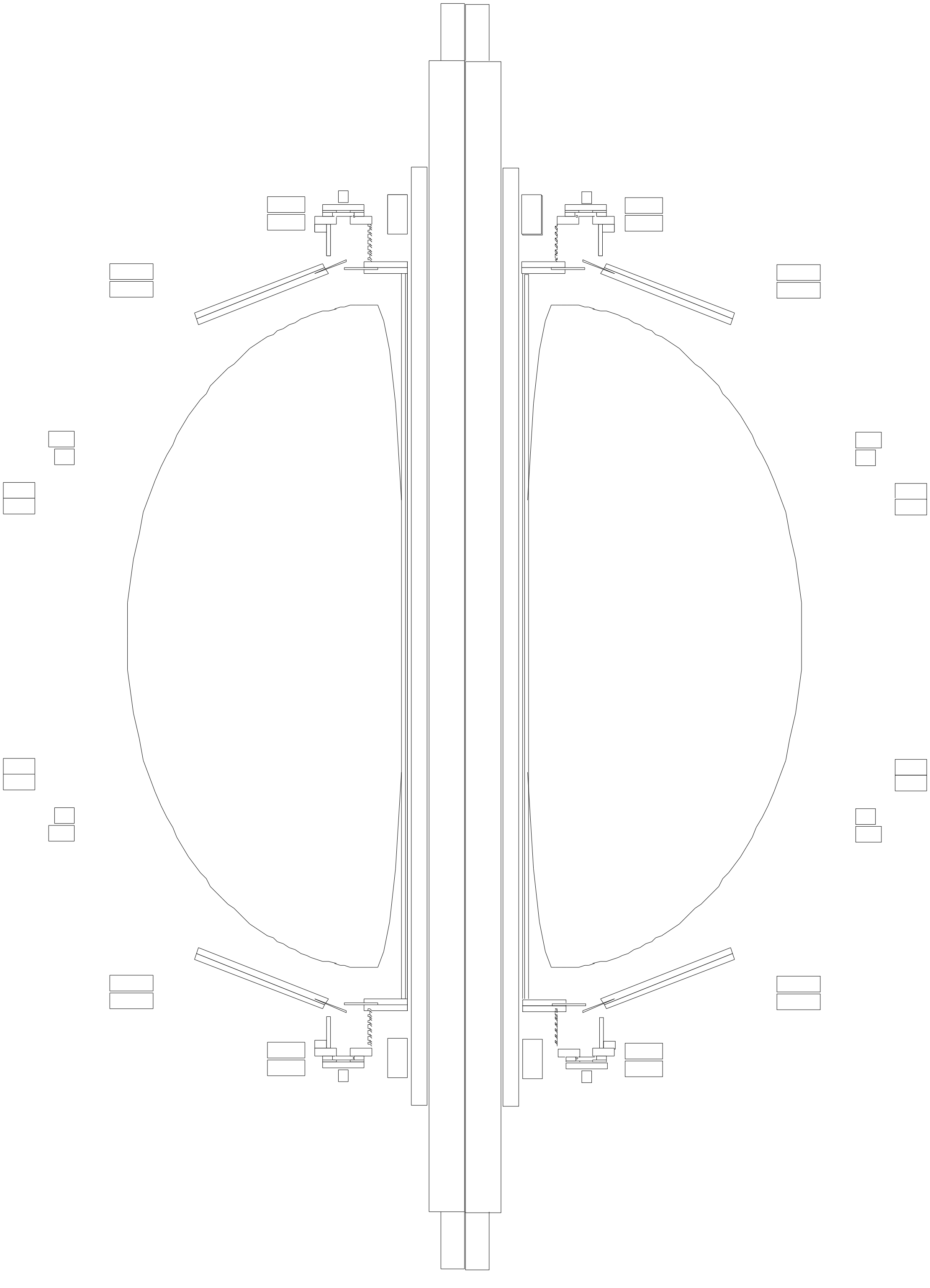
The attached figure shows a cross section with a plasma shape $\kappa = 2.4$ and $\delta = 0.4$. This demonstrates that the new design moves as desired in the direction of the ARIES-ST in terms of higher elongation, triangularity, and aspect ratio compared to the baseline. Existing components shown for reference are VV nozzle mounting flange, outboard divertor tiles, and outer (2,3,4,5) PF coils.

Other features to be noted are:

- It is proposed to eliminate the PF1 "a" "b" coil concept, in favor of one midplane symmetric PF1 coil set. The PF1b coil shown has the same R, ΔR and ΔZ as the existing PF1b lower coil, but at a slightly greater distance from the midplane. Equilibria cases need to be run to determine if this scheme is viable.

- It is proposed to consider a CHI insulator configuration which consists of an annular ceramic disc (like a washer), oriented horizontally. Further, this insulator would be aligned (at the same elevation Z) with the current centers of PF1 and PF2 (existing PF2 coil locations shown). In this case the vertical field contributions from PF1 and PF2, by far the most significant due to proximity, will always be normal to the electric field between the electrodes on either side of the insulator, thereby providing a magnetic insulation effect. Stray radial fields at the insulator would be feedback compensated by a small coil mounted just above the insulator as shown.

- Insulating shields would be affixed to the outboard divertor plates and center stack casing as shown to eliminate line of sight from the plasma to the ceramic insulator region.



Cost estimates need to be developed for:

- New OH and TF coils, including TF flex joints;
- New center stack magnetic diagnostics;
- New center stack casing;
- New center stack PFCs;
- Assembly of above in RESA building;
- New ceramic insulator assemblies and associated shields;
- New PF1 coils;
- New coils and power supplies to null out field at ceramic;
- Power systems modifications.

cc:

J Chrzanowski
T Egebo
P Heitzenroeder
S Kaye
M Ono
F Paoletti
M Peng
S Ramakrishnan
R Raman
A Von Halle
M Williams

NSTX File