11-980129-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: PEER REVIEW ON NSTX PLASMA FACING COMPONENTS

Approved: ____________
M Ono

A successful peer review covering the NSTX Plasma Facing Components (PFCs) was held on 29 January. Presentation materials and chits are attached.

Attendees were as follows:

G Barnes[A]	J Chrzanowski	D Gates	P Goranson	P Heitzenroeder[A]
R Kaita[A]	S Kaye*,[A]	J Levine*	F Malinowski*	B McCormack*,[A]
B Nelson[A]	C Neumeyer[A]	M Ono*,[A]		

* = part time
A = action item assigned (see chit table)

This review covered the evolution of the design since the Final Design Review (FDR) held on 31 July 1997 (1X-970807-PB-01). The continued evolution of the design after the FDR was necessitated by the many chits generated at the FDR as well as the need to identify a new source of PFC raw materials, after discovery that the inventory at PPPL was inadequate.

The subject review was intended as a pre-requisite for:

1) Placing orders for PFC raw materials (carbon fiber composite (CFC) and graphite)

2) Finalizing the documentation of the design (drawings, calculations, etc.) which will be completed at the time of the Final Chit Resolution Review (FCRR), to be held end of March.

Based on this review approval is hereby granted to proceed with the above steps.

Major remaining issues are as follows.

<u>Halo Current Loads on Center Stack Tiles</u>

Calculations for the halo current loads on the center stack tiles did not allow for a toroidal peaking factor and were based on B_t @ R_0 of 3kG, not 6kG. Therefore on this basis they are low by a factor of 4, as indicated in the following table.

	Present Assumption	Worst Case Assumption	

Ip	1000000	1000000	amp
Fraction	0.4	0.4	
Peaking	1	2	
R	18.97	18.97	cm
#Tile Segments	24	24	
Itile	16666.7	33333.3	amp
Ro	85.4	85.4	cm
B(Ro)	0.3	0.6	T
B(R)	1.4	2.7	T
ΔZtile	15.24	15.24	cm
Ftile	3430.7	13722.9	N
	771.2	3084.9	lbs
Atile	75.7	75.7	cm^2
	11.7	11.7	in^2
Pressure	65.7	263.0	lbs/in^2

The above calculation assumes a vertical (z direction) current flow at a radius (r) at the middle of the tile thickness. In practice it is thought that the current flow will be mainly in the inconel center stack casing since its conductivity greatly exceeds that of the tiles, and the full current will only be present in the tile as it exits the center stack. However the direction of the current flow will be such that the vertical component is reduced (it must be reduced in order for there to be a radial component (current exiting) in the first place). This factor needs to be accounted for if the design requirement is to be reduced.

Another unresolved issue remains as to whether or not it is possible for the direction of the halo current to be opposite to that of the TF inner leg current, in which case there is a pull out force on the tile. Standard arguments for current and field directions would indicated that it is not possible to generate a tile pullout force; instead there would be a force attracting the tiles to the center stack. If this is indeed true then the halo current issue becomes much less significant.

In any case the pull out strength of the present tile and mounting design, is the best that can be achieved given the allowable radial build and the available materials (in fact the test results indicate that the Allied Signal material is twice as good in this respect as the previously envisaged FMI material).

So, as a practical matter the position taken by the project is to proceed with the present design, given the uncertainties and conservatism inherent in the halo current assumptions. Ultimately only the operational experience with disruptions and halo currents in NSTX will lead to a better understanding of the situation and, if necessary, restrictions on operations (e.g. B_t). In the meantime Physics will endeavor to provide better guidance.

Thermal Capability of PFCs

Heat loads on the outboard divertor are very high in the case of the double null plasma configuration. Depending on the model used for heat deposition (one or two sided distribution, one or three e-foldings, etc.) from the scrape off layer the peak flux estimates range from ≈ 800 to 1700 watts/cm^2. The latter (higher) number is given in the GRD. Heat loads from other configurations are much less (peak 430 watts/cm^2 for natural divertor, 1080 watts/cm^2 for single null divertor, per the GRD). Analysis of the heating of the ATJ graphite tiles planned for the outboard divertor indicates that in the double null case the peak temperature will exceed the allowable (sublimation) temperature of 1200C after some time less than 5 seconds if the worst case peak flux assumptions are taken. If the best case assumptions are taken then the temperatures remain below allowables at 5 seconds. Sweeping of the strike point can be used to alleviate this situation, possibly allowing the full 5 seconds but analysis of this is incomplete at present.

In any case, besides sweeping, the only known solution to this problem would be to use a higher thermal conductivity material on the outboard divertor. Data presently in hand indicates that the Allied Signal material has thermal conductivity roughly twice that of the other materials considered (FMI, ATJ, POCO), albeit estimated (not measured) at high temperature. However, based on the volume of the Allied Signal (AS) material required to install it on the outboard divertor it would be very costly. The relative volumes of material are estimated in the following table. The utilization factor of 0.5 for the center stack (CS) is based on the use of the AS material on "every other stripe". The utilization factor of 2 for the outboard divertor (OBD) reflects the presence of both the upper and lower units. Since the cost of the AS material for the CS is on the order of $50K, the factor of 10 in volume would imply a cost of ≈ $500K to install this material on the OBD.

	CS	OBD	
R	18.97	90	cm
L	225.425	66	cm
Utilization	0.5	2	
t	1.27	2.54	cm
Vol	17060.1695	189596.373	cm^3

Therefore as a practical matter the position taken by the project is to limit the use of the AS material to the CS.

Thermal Shock & Testing

Thermal shock issues remain to be addressed. In needs to be confirmed that the materials will not suffer mechanical failure when subjected to the pulsed high heat flux. It is anticipated that data is available in the literature for the ATJ graphite material. One of the chits calls for research into this. However, there is no published data for the AS material. Considering that the AS material has never been used in a fusion application (it is a disk brake material) there is a risk that some unanticipated problem may occur at high heat flux. Up to now tests on the mechanical pullout properties, and bakeout properties, have been performed, but no experience exists with high heat flux. In addition the thermal conductivity at high temperature is estimated by the vendor, and has not been measured. So the project would like to perform high heat flux tests (at Sandia) but does not have budget allocated for this (est. ≈ $50K required). Also, in order to meet the project schedule we need to order the AS materials (6-7 month lead time) ASAP. So, any test results can only come after the fact. Thus there is a risk that the AS material is untested. If we were to perform the tests the results would come too late to influence the design but could be useful as a guide to operations. Therefore the project position is that the tests will not be performed using funds from the construction project. If another source of funds (e.g. NSTX operations, or other technology development) is available then the project would be strongly in favor of performing the tests.

So, considering the above issues and arguments, the most prudent course of action is to act now to order the PFC raw materials, and to proceed with the final design documentation based on the design presented at the review.

The following is a summary of the chits.

Chit	Disposition	Action
1) In procurement spec, include a diagram which shows the x-y-z axes, and the required dimensions of the blocks of CFC raw material. Allow no possibility for misinterpretation.	Agree. It is crucial that the fibers are aligned in the correct direction.	G Barnes to include in spec.
2) Due to the confusion on the x-y-z directions place on each tile drawing a (picture of a) cube identifying fiber direction so that there is no mistake during manufacturing.	Agree. It is crucial that the fibers are aligned in the correct direction.	B Nelson to include on center stack tile drawings.
3) Halo current calculation on CS tiles needs to be checked. Should assume 40% of 1MA w/toroidal peaking factor of 2, and Bt=6kG @ 85.4 cm. Can halo forces be in both directions?	Agree; need to clarify requirement.	S Kaye to issue memo elaborating on requirements, and adjust PRD accordingly (if necessary). Then B Nelson to update calculations.
4) Evaluate thermal shock issues, both on Allied Signal and ATJ material.	Agree. However, data on Allied Signal material can only be obtained by test.	P Heitzenroeder to look for sources of ATJ data. M Ono to seek sources of funding for High Heat Flux Test at Sandia.
5) Change outboard divertor material to stainless steel from copper, in order to reduce conductivity.	Agree, this will reduce impact on start up and will reduce disruption currents/forces.	B Nelson
6) Decide on silver (or other) plating on passive plate electrical connections. Also, estimate net toroidal electrical resistance including plates, jumpers, contact resistances, and toroidal gap path through supports.	Agree.	B Nelson to address plating issue and provide dimensions and geometry of flexible connectors and supports. C Neumeyer to calculate resistance.
7) Confirm that space available for Mirnovs is adequate.	Agree.	See following chit.
8) Inner wall tiles covering pickup coils need to be counter bored to accommodate 2.5 x 2.5 x 0.254 cm sensors (with clearance). Possibility is to widen channel from 0.49" to 1.0: (nominally rectangular cross section)* on all inner wall tiles, except those holding Langmuir probes (which need "shelf"). * Update drawings - not all show same cross section.	Agree.	See following chit.

9) Inform WBS4 of tile thicknesses on inner divertor, outer divertor, secondary passive plates, and primary passive plates, and provide maximum dimensions of counter bored holes permitted for pickup coils. Optimal size is much larger than inner wall coils, which were limited by space. Also remember slots for wires in all tiles.	Agree	See following chit.
10) Devise inner wall tile design which permits installation/locking of Mirnovs.	Agree.	B McCormack and G Barnes to come to closure on size of Mirnovs at various locations, tile cutouts to accommodate Mirnovs and wiring, and features required to permit installation and replacement of failed coils.
11) Consider alternate material (instead of A286) for inner wall tile attachment nuts. Silver plating A286 seems undesirable.	Agree.	G Barnes/B Nelson
12) Vent mount holes for divertor plates (vented bolts).	Agree, required to eliminated trapped volumes.	G Barnes/B Nelson
13) Compute halo current loads on outboard divertor plate tiles and check against pullout strength.	Agree, pending guidance per chit 2.	C Neumeyer to calculate loads, B Nelson to confirm strength.
14) Get specific information on req'ts (wire size) for passing flux loop wires under passive plate supports.	Agree.	B McCormack
15) Confirm requirement for allowable tile-tile gap between passive plate tiles on neighboring plates.	Agree. Direction given at meeting (1" gap, based on 1" dimension to back plate) needs to be confirmed.	S Kaye

w/o attachments:

G Barnes
P Bonanos
J Chrzanowski
T Egebo
D Gates
P Goranson
P Heitzenroeder
R Kaita
S Kaye
H Kugel
J Levine
F Malinowski
B McCormack
B Nelson
C Neumeyer
M Ono
M Peng
J Schmidt
M Williams

NSTX File (w/attachments)