71-980301-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: MINUTES OF HEATING/COOLING INTERFACE MEETING

References:

71-980224-CLN-01, "Heating and Cooling Interfaces"

In accordance with the reference memo a meeting was held on Friday 27 February to discuss various issues related to the heating and cooling of the vacuum vessel. The following were in attendance:

G Barnes	A Brooks*	J Chrzanowski	L Dudek	HM Fan
P Heitzenroeder*	R Kaita*	M Kalish	M Ono*	R Parsells
S Ramakrishnan	M Viola	M Williams		

* = part time

The following points were discussed and resolved as indicated.

1) What Dowtherm supply temperature is required to ensure 350C temperature at PFC surfaces?

Since there will be temperature drops as the Dowtherm progresses through the cooling circuits, and since there will be temperature gradients across the film thermal resistance, bulk material thermal resistances, interface thermal resistances, etc., it was decided to require that R Parsells should provide a Dowtherm temperature at the input to the vacuum vessel up to 375C, and that HM Fan should assume that the backplates of the PFCs are at 375C.

2) Where is the interface between the Heating/Cooling System and the PFCs?

It was agree that the PFC scope (WBS 11) would include the routing of the Dowtherm piping through the wall to the outside of the vacuum vessel, at which the Bakeout Heating/Cooling System (WBS 33) would make its connection. Interface connection shall be either a welded connection or a conflat flange.

3) Concerning the electrical breaks in the Dowtherm piping it was decided that within the vacuum vessel, including the penetration through the vacuum vessel wall, there is no need for electrical isolation. It was argued that the piping, being stainless steel, will have a relatively high resistivity (much higher resistivity than the passive plates, e.g.), such that induced currents should not be a problem. However it was noted that the level of induced currents can be minimized by routing the piping such that the area enclosed by the loops formed by the piping

which links poloidal flux is minimized. After the piping passes through the vacuum vessel wall however it will need to be electrically isolated from the piping to the source which will be grounded. Per the GRD...

1.1.5 General Electrical Isolation Requirements

b. All ancillary components which are in mechanical contact with the vacuum vessel shall be electrically isolated from the vacuum vessel. The isolation shall be rated to withstand a one minute AC hipot test at 2 kV AC rms.

It was decided that the responsibility for the electrical isolation is with R Parsells, WBS 33.

4) What is the plan for the bakeout ohmic heating power supply?

First, there was some discussion of the requirements (what is the resistance of the Center Stack casing, what heating power is required, and what is the temperature coefficient of resistance of the inconel material?). It was agreed that C Neumeyer will re-calculate the resistance of the CS casing and will try to identify an existing power supply which can supply the load. It was noted that the power supply can be thermostatically controlled (on/off bang-bang control) such that a perfect V/I match is not needed.

Following the meeting an estimate of the resistance was made, including the effect of temperature which will be minor. Results are given in the following table. This will be documented by the writer by separate memo. See following table for preliminary results.

Inconel resistivity (50C)	1.30E-06	Ω-m
	5.12E-05	Ω-in
Coefficient of resistance	0.00011	1/deg C
Radius Mid Section	6.660	in
Thickness Mid Section	0.157	in
Cross Section Mid Section	6.647	in^2
Length Mid Section	88.75	in
Resistance Mid Section (50C)	6.83E-04	Ω
Radius End Sections	9.875	in
Thickness End Sections	0.250	in
Cross Section End Section	15.708	in^2
L End Section	21.063	in
Resistance per End Section (50C)	6.86E-05	Ω
∑ Resistance Mid + 2 Ends (50C)	8.21E-04	Ω
Power	5000	watt
V for P @ 50C (note)	2.026	volt
I for P @ 50C (note)	2468.427	amp
V for P @ 600C (note)	2.084	volt
I for P @ 600C (note)	2399.528	amp
Note: Based on continuous V/I		

5) How are the connections for the bakeout ohmic heating power supply made?

The requirements are given in the GRD....

1.2.2 Vacuum Vessel & Support Structure

g. The lower dome of the outer section of the Vacuum Vessel shall be electrically grounded via eight toroidally symmetric connections to a single point connection to the facility ground, which is designed to permit opening for the purpose of testing of the integrity of electrical isolation between the Vacuum Vessel and other components and structures. Isolation shall be rated to withstand a one minute AC hipot test at 2kV. Grounding connections shall be sized to carry the current during CHI operations as well as the return of the current during bakeout heating of the center stack casing.

h. Four toroidally symmetric connection points shall be provided at the top and bottom of the center stack casing. Connections shall be sized to carry the current during CHI operations as well as the return of the current during bakeout heating of the center stack casing.

G. Barnes noted that he was planning on providing four 1" diameter rods connected to the bottom of the center stack casing, but that no plans had been made for the top.

M. Viola pointed out that although no plans had yet been made for the connections on the vacuum vessel, it should be easy due to the large number of spacious gussets on to which a connection can be made.

Concern was expressed with respect to the temperature gradients along the various electrical connections, and how hot the connecting conductors could become. C. Neumeyer was given the action to assess this.

It was agreed that, although the high ampacity CHI conductors would otherwise not be required until the CHI sustainment upgrade, the CHI conductors close to the machine should be made high ampacity as part of the baseline such that the bakeout ohmic heating power supply can be conveniently connected outside the tangle of equipment immediately surrounding the machine. WBS 5 (S. Ramakrishnan) was assigned this responsibility.

6) What should be the operating and bakeout temperatures of the vacuum vessel domes, cylinders, and ports?

The GRD says...

2.3.4 Pre-shot Temperature

a. In-vessel components shall be maintained at temperatures not less than 50°C between discharges.

2.3.2 Bakeout

a. The surfaces of the PFCs shall be heated during bakeout to 350°C.

b. The temperature of the inner Vacuum Vessel surfaces shall be heated to at least 150°C.

Even with the change to the use of new domes, the assumption that the vacuum vessel is allowed to float in temperature during bakeout, except for the port flanges which are cooled, is causing design problems (high temperature gradients and stresses) in the areas of the dome port welds and attachment points for the umbrella structure. It was decided, in conjunction with the decisions made at the prior day meeting (see attached note from J Chrzanowski) that, in order to bring the analysis of the vacuum vessel to closure in the context of the final design review chit resolution, that this analysis should proceed on the basis of a uniform 50C vacuum vessel temperature during operations and a uniform 150C vacuum vessel temperature during bakeout. In addition, in order to guide the design of the vacuum vessel heating/cooling, the amount of heating to be removed as a function of location on the vessel, achieve the 50C operations and 150C bakeout cases, needs to be known. The action item to provide this information was given to HM Fan.

However, subsequent to the meeting in a separate discussion (M Ono, C Neumeyer, M Viola) it was pointed out that the uniform temperature

assumption is not realistic with a practical arrangement of cooling lines. Still, it was recognized that we need to bring the baseline design effort to closure.

The following steps shall be taken:

a. HM Fan to compute the heat removal requirements as a function of location on the vessel, for the 50C and 150C cases. Although no practical cooling system will be able to achieve this, the information will be useful in terms of guiding the design of the cooling system.

b. M Viola to map out a practical arrangement of cooling loops on the vessel. The priority for the cooling lines for the ports, domes, and cylinder section should be to cool the port flanges, and to protect the port welds and other possible high thermal gradient/high stress areas. Henceforth the responsiblity for the design/procurement of the vaccum vessel cooling lines is assigned to M Viola, WBS 12.

c. R Parsells to proceed with the design of the Dowtherm system using the information generated in steps a. and b. above.

d. Either by estimate or ANSYS calculation, the pattern of temperature on the vacuum vessel with the practical cooling scheme as determined in steps b. and c. above shall be assessed. If significant gradients are predicted in critical areas then this temperature pattern shall be used as an input to the vacuum vessel stress analysis by HM Fan. Otherwise, the uniform temperature distribution (as planned on per the attachment) may be judged to be a reasonable working assumption.

The above work should be completed ASAP. The goal of completing the vacuum vessel design close-out by conducting a final chit resolution review by end of March requires that all of this work be completed prior to that time!

It is noted that after the meeting P Heitzenroeder suggested that it may be possible to enhance the effectiveness of cooling using means other than simple welding of tubes on to the vessel. He mentioned the use of an underlying layer of copper fabric/mesh/wool material. This should be considered by M Viola and R Parsells.

7) What temperature can be expected on the port covers where diagnostics will be mounted, given that the port flanges will be cooled but that the port covers will be exposed to significant radiation? How should the port covers be cooled?

It was decided that the design of the Dowtherm cooling loops associated with the cooling of the port flanges should include features (free runs of pipe and/or fittings) which will accommodate a tap for the extension of the loop on to the port cover in case the diagnostic(s) on that port cover cannot withstand the anticipated temperatures.

cc:

G Barnes
A Brooks
J Chrzanowski
L Dudek
HM Fan
P Heitzenroeder
D Johnson
R Kaita
M Kalish
B Nelson
M Ono
R Parsells
S Ramakrishnan
M Viola
M Williams

NSTX File

Attachment

To: Distribution **Date:** February 26, 1998

From: James H. Chrzanowski **Subject:** Vacuum Vessel/ Structure Analysis

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A meeting was held on Thursday morning February 26, 1998 to discuss the remaining analysis work to be completed on the vacuum vessel, umbrella structure and V.V. support structure. There was much discussion and uncertainty what the vacuum vessel temperatures would be during normal operations. The cost impact for maintaining the vessel at 50 °C could be significant. This will be discussed further at tomorrow's V.V. Heating/Cooling meeting at 2:00 PM in the NSTX Conference Room.

It was recommended that the following three design cases be analyzed to confirm the final design of the Tokamak Structure (V.V., Umbrella structure & V.V. Support). These cases will also be discussed at tomorrow's meeting.

The present plan is for HM to complete a new model of the vessel including the new domes, V.V. straight section, new outer divertor support structure and vacuum vessel supports. Using this model the following three cases would be analyzed.

CASE 1..... Bakeout Case

Temp. Of Torque Structure ..... Assumes 11 legs/slides at room temperature
(T_{vv}) Temp. Of vessel..... 150°C
Divertor Loads/ load reactions ..... 370°C
Passive Plates..... 370°C
Vacuum Pressure Loads
Gravity loads

CASE 2 ..... Normal Operations Case

Temp. Of Torque Structure ..... Room temperature
(T_{vv}) Temp. Of Vacuum Vessel..... 50°C
(T_{pp}) Temp. Of Passive Plates.....50°C (350°C ?)
(T_{Div}) Temp. Of Divertors ..... 50°C (350°C ?)
Vacuum Pressure Loads
Gravity loads
Electromechanical (EM) loads from PF and TF coils
Seismic loads

Design of Rib structure and Vacuum Vessel Legs can be obtained from this design case.

CASE 3 ..... Disruptive Load Case

Temp. Of Torque Structure ..... Room temperature
(T_{vv}) Temp. Of Vacuum Vessel..... 50°C
(T_{pp}) Temp. Of Passive Plates..... 50°C (350°C ?)
(T_{Div}) Temp. Of Divertors ..... 50°C (350°C ?)
Vacuum Pressure Loads

Gravity Loads
Electromechanical (EM) loads from PF and TF coils
Disruptive Load Reaction at Domes &
Passive Plate Disruptive Loads to Vessel

Please review the assumptions used in these cases prior to tomorrow's meeting.

Cc	P. Heitzenroeder	C. Neumeyer	L. Dudek
	M. Viola	H.M. Fan	R. Parsells
	M. Ono	M. Williams	