1X-980929-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: PEER REVIEW OF CENTER STACK CASING/OUTER VV ELECTRICAL CONNECTIONS

References:

[1] 1X-980923-CLN-01, "Center Stack Casing /Outer VV Electrical Connections"

A peer review was conducted of the design for the center stack casing/outer vacuum vessel electrical connections. The design basis was given in the reference memo.

The following persons were in attendance:

J Chrzanowski
S Kaye
H Kugel
L Morris

There were no formal chits written, although the following list of issues is noted:

1) Due to the congestion of the TF flex lead area, the connection to the vertical riser bus bars cannot be made at this radial location; instead, it seems most desirable to make the connection outside of the umbrella radius.

2) Due to the virtual inaccessibility of the regions inside of the radius of the umbrella structure, jumpers are not practical at those locations. In addition, even if the full scheme for connections is not implemented in the 1st plasma timeframe, because of these accessibility issues, the center stack casing terminals need to be installed and routed outside of the umbrella radius for 1st plasma jumpering and beyond.

3) There is no compelling reason to install the vertical riser bus bars prior to CHI operations, assuming that the center stack casing terminal is routed outside of the umbrella radius, so that they can be installed at a later date.

4) Spare NSTX PF1a conductor can be used in lieu of the 1" x 1" x 0.25" dia hole conductor suggested in the reference memo. The attached spreadsheet reflects a revision from what was given in the reference memo, based on using 0.787" x 0.787" x 0.3543" dia hole.

5) There was some discussion of the issues related to the use of copper vs. stainless steel rods for the connections to the center stack casing flange.

Copper rods, with much lower resistance than stainless steel, would most closely replicate a continuous vacuum vessel, which the connections are aimed at emulating when all jumpers are in place. At the meeting there was no strong consensus on this issue; neither the physics or engineering side expressed a strong preference. However, in discussions following the meeting, the concern that, due to different coefficients of thermal expansion, the copper rod/inconel flange joint would become loose after time and would not serve well as a high current joint, was raised. Due to this concern, and the lack of a compelling physics argument on the issue, it has been decided to use stainless steel rods, tack welded at the joint with the flange in order to prevent loosening. This approach is the most attractive from the engineering perspective, and will be adopted lacking any clear rationale to the contrary.

6) Stray fields from the connections could potentially effect physics. Although the writer claimed at the meeting that there should be no effect during breakdown since there will be no currents, this, in retrospect is not true since, in the fully jumpered state, there could be currents induced by the TF. A complete assessment of stray fields due to the coil and subject leads still needs to be made.

7) For 1^{st} plasma, if the only objective is to jumper across one ceramic insulator gap, then it can be argued that a fairly simple (e.g. cable) jumpering can be used. Since I_p will be low (target is 50kA) and background fields due to TF and PF will be low, this is probably true. The main driver for 1^{st} plasma installations is the fact that accessibility later on will be very limited.

8) Detailed layout, including supports, needs to be developed. Analysis of supports needs to be performed.

Cond resistivity @ 20C	1.73E-06	Ω-cm
Cond res temp coeff	0.00393	1/degC
Cond heat capacity	0.386	J/gm-degC
Cond density	8.89	gm/cc
Ambient Temperature	35	deg C
Max Current	5000.0	amp
Max ∫i^2dt	6.45E+02	A^2-s
Min ESW	5.000	sec
Min Repetition Period	300.0	sec
Max RMS Current	645.5	amp
Bus length per pole	6	feet
Inlet temperature	35	deg C
Max temperature	80	deg C
Conductor width	0.787	in
Conductor height	0.787	in
Cooling hole dia	0.3543	in
Corner radius	0.039	in
# Conductors	1	

Cond CSA	0.5	sq in
	3.4	sq cm
Res @ 20C per pole	9.43E-05	Ω
Res @ 25C per inch	1.34E-06	Ω/inch
Water flow/conductor	2	GPM
Water flow velocity	6.5	feet/sec
	198.4	cm/sec
#Series Water Paths	2	
ΔP	2.9	psi
Heat Capacity	4.21E+03	J/degC
Heat Capacity per inch	5.84E+01	J/degC/in
Thermal Res of Coolant	1.89E-03	deg C/watt
Film Res Cond to Coolant	8.22E-04	deg C/watt
Total Res Cond to Coolant	2.71E-03	deg C/watt
Thermal tau	11.4	sec
Res @ Tmax per pole	1.05E-04	Ω
Voltage Drop @ Imax (both poles)	1.1	volt
Conductor I^2R Loss per pole	43.9	watt
Total Conductor Loss	87.8	watt
Additional Heat Input	500.0	watt
Total Heat Input	587.8	watt
Tmax @ Irms	36.6	deg C
Tmax @ Irms + ΔT @ Imax @ ESW min	41.7	deg C
Separation	1	in
CL-CL Bus Spacing s	1.787	in
width a	0.787	in
height b	0.787	in
a/b ratio	1	
(s-a)/(a+b)	0.635324	
k factor	0.986846	
Operating Current	5000.0	amp
Operating Force	7.45519	#/foot
Short Circuit Current	120000	amp
Short Circuit Force	4294.189	#/foot
	357.8491	#/in
Support Spacing	6	in
Support Force	2147.095	#
#Bolts	2	
Bolt Load	1073.547	#
Moment of Inertia	0.031968	in^4
Section Modulus	0.081241	in^3
Elasticity	1.60E+07	
Force/length	357.8491	#/in
Bending Moment	1610.321	in-lb
Stress	19821.64	psi
Deflection	0.011806	in

cc:

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P Heitzenroeder
S Kaye
H Kugel
L Morris
M Ono
S Ramakrishnan
M Williams

NSTX File