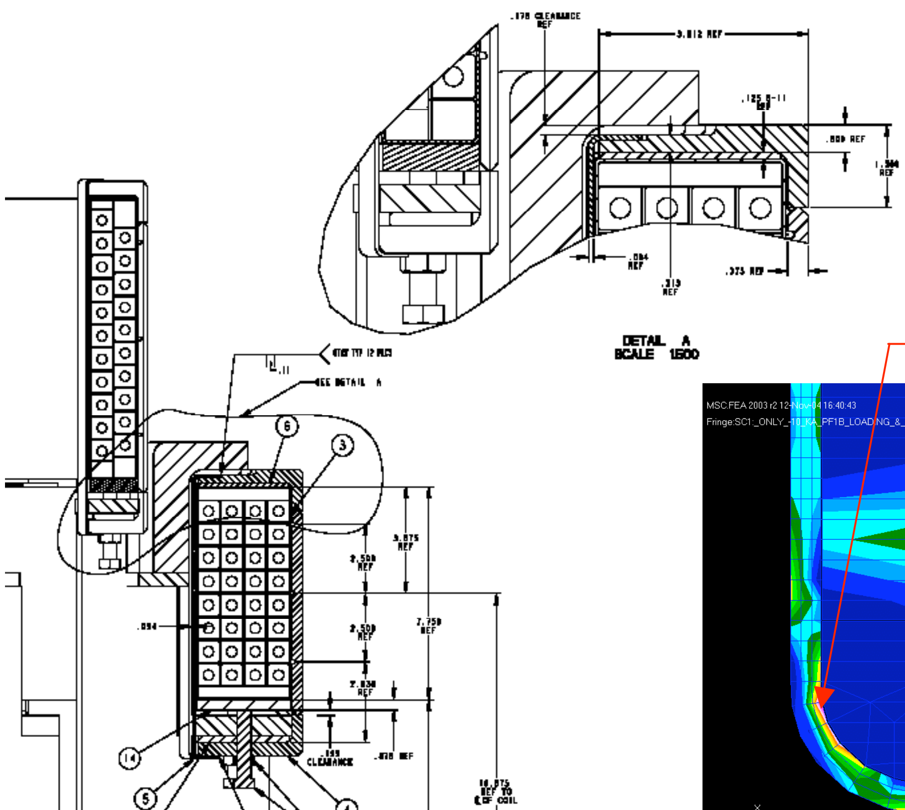
PRINCETON UNIVERSITY: PPPL Mechanical Engineering Division MED-111204-FD

TO: C Neumeyer DATE: 12 Nov 2004

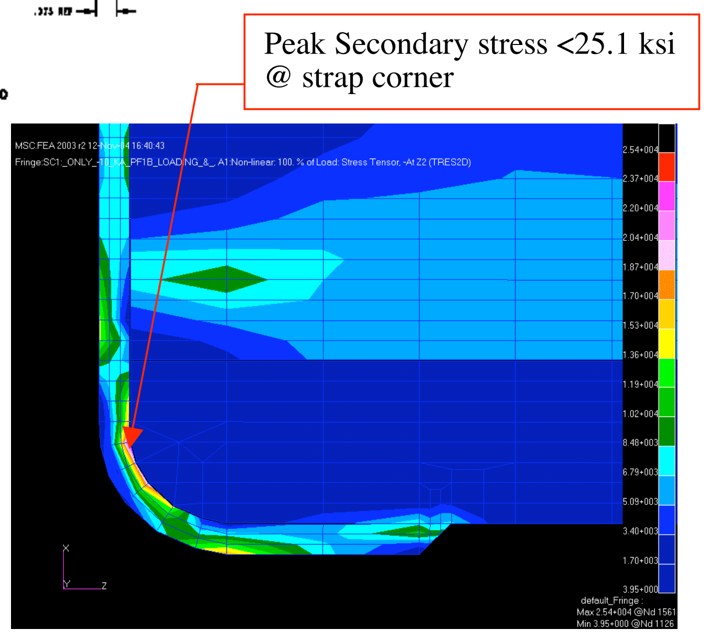
FROM: F. Dahlgren SUBJECT: NSTX-PF1a&b Coil Support Analysis

A structural and thermal analysis was performed for the new NSTX PF1a&b coil supports. Various current levels in the coil and adjacent PF & OH coils were examined to determine the maximum safe current operating limits for the coils in question (OH solenoid, PF1a, and PF1b).

Assuming a maximum +24kA OH and 20kA in the other PF coils, the maximum reversed polarity combination for PF1a/b is roughly +15kA for PF1a and -10kA for PF1b. This produces a vertical load of –11,100 lbs on PF1a and 25,600 lbs on PF1b. These vertical loads, along with the pre-load and thermal expansion of the coil, subject the new 0.093" thick coil support straps to a peak (local secondary) stress intensity of 25.1 ksi. This is the maximum allowable secondary stress permitted by most structural codes for 304L stainless. While it would be preferable to use an alloy having higher stress allowables, scheduler constraints and material availability favors using 304L which is readily available on site. The minimum yield stress for 304L is 25.1 ksi, and the primary stress allowable based on a 2/3rd yield criteria is 16.7 ksi at room temperature. Some additional available current combinations are summarized in the attachment.



NSTX PF1a & PF1b Coils and Supports



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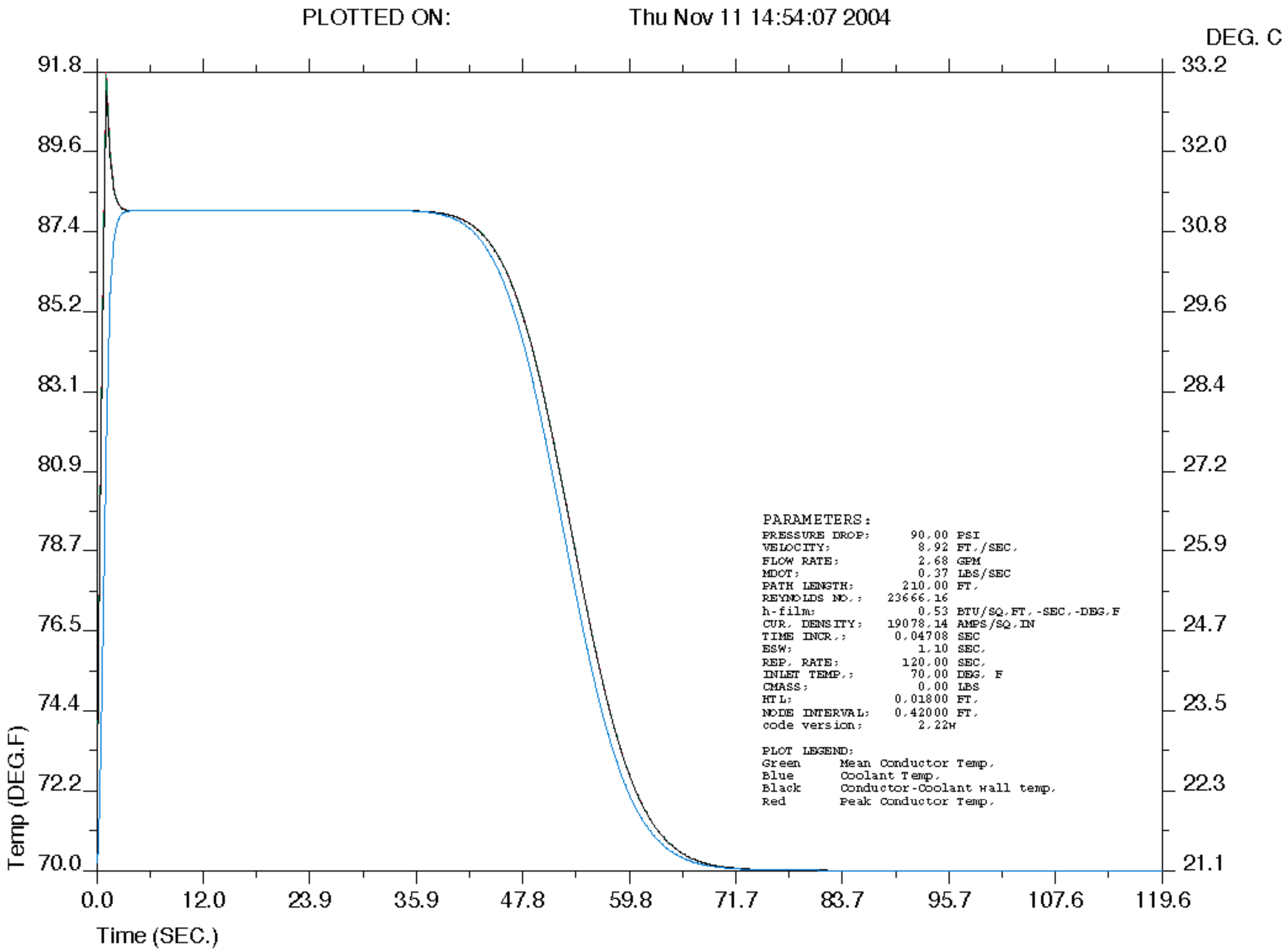
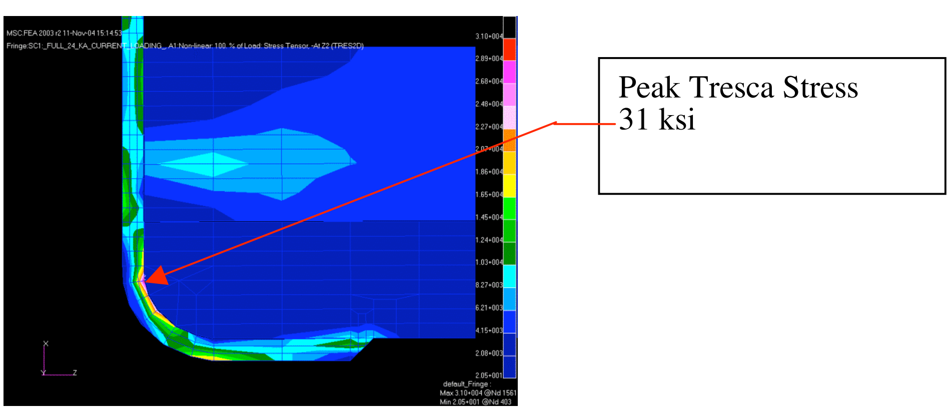
A thermal analysis of the PF1b coil indicates a temperature rise of ~22 deg.F with a thermal recovery time of roughly 80 seconds. This is for a 10kA current with a 1 sec ESW and 70 deg.F inlet water temperature. The plot below is the thermal response at the coil cooling circuit exit (which will be the slowest to recover).



NSTX PF1b Cooling Analysis (32 turns)

NSTX-PF1B-COIL RUN - 11/11/04

Using this coil temperature and the EM load based on a 25kA OH, 20kA PF1a, a -10kA current in PF1b, and 20kA in the remaining coils, the peak (local) stress in the coil support strap (with EM load + thermal + pre-load) will be 31 ksi which still exceeds the 304L allowable (1.5x16.7 = 25.1 ksi) by 20%.



Below is a table summarizing various currents and loads:

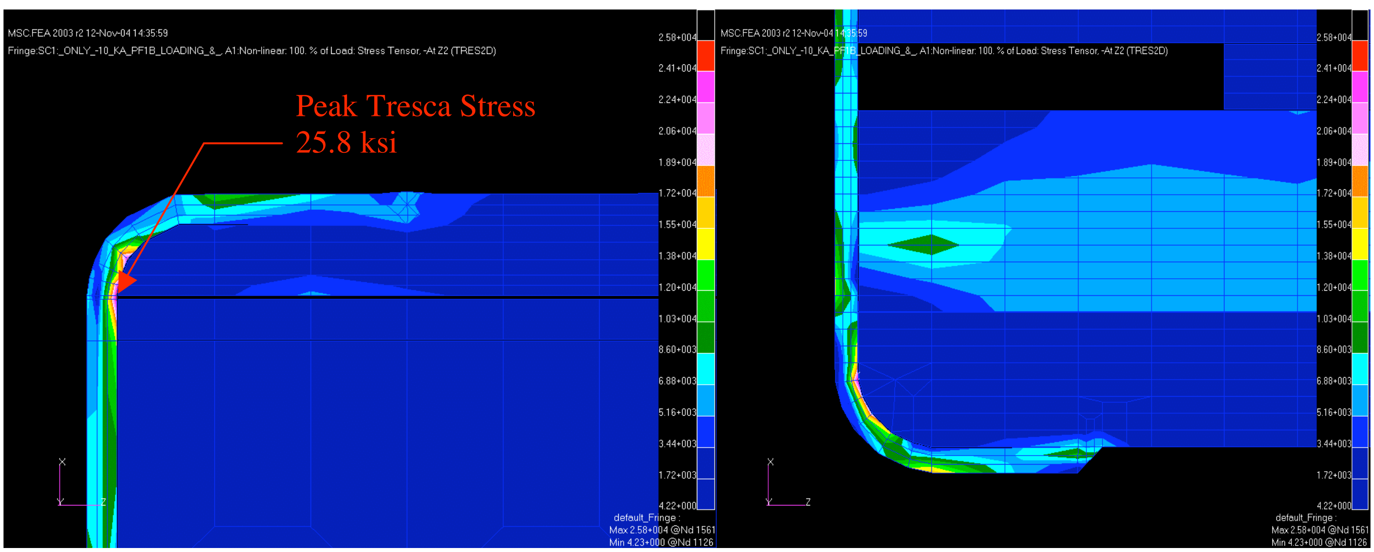
LOAD CASE	OH (kA)	PF1a (kA)	PF1b (kA)	PF2 –PF5 (kA)	PF1a Load (KIP)	PF1b Load (KIP)
1	24	20	-10	20	-16.7	**33.3**
2	20	20	-10	20	-14.2	26.9
3	22	18	-10	20	-13.0	26.6
4	24	15	-10	20	-11.1	25.6
5	24	16	-10	20	-11.8	26.3
6	-24	15	-10	20	-6.2	-1.7
7	-24	20	-10	20	-8.3	-1.3
8	24	24	-10	20	-17.7	**32.0**
9	24	-24	-10	20	17.7	-2.3
10	24	24	20	20	**32.9**	**-64.0**

The loads in red produce primary stresses (and/or weld stresses) that exceed the strap allowables for 304L

Comparing the 1st and 2nd loadcase gives an indication of the OH current influence on PF1b loads. Comparing the 1st with the 4th & 5th loadcases gives an indication of PF1a's influence on the PF1b loading.

The highlighted 5th loadcase appears to be the maximum combination of currents (using positive OH & PF1a and negative 10kA PF1b currents).

The figures below are Tresca stress contours at the strap corners of the PF1b support for loadcase 5:



The peak local stress at the strap corner is 25.8 ksi which just marginally exceeds the $1.5xS_m$ that is the maximum value typically specified for secondary stresses in ductile materials such as 304L in most structural codes. A small area of the fillet weld also exceeds the ASME PBV Code allowable when a weld efficiency of .45 is used. AISC code weld allowable is generally the lesser of .55Sy or .3Su, which would be 13.7ksi. The peak weld stress is <12ksi.