NSTX CALCULATION FORM

NOTE: All signatures on this form require a printed name, signature, and date.

WBS 13 ________ Calculation #13-13 ______Revision #0__________

Title Center Stack Stress Analysis

Originator's signature John Spitzer

Purpose: The purpose of these analyses was to determine the deflection/stress levels on the center stack casing resulting from halo current loads as well as the deflections and stresses in the casing and support as a result of bakeout and operational heat loads.

References: NSTX Memos:
1) 13-961010-JMB-01, Estimate of Halo Loads for Inner Leg of the Vacuum Vessel
2) 13-970217-AWB-02, Loads on CS from Plasma Disruption
3) 13-970214-AWB-02, Thermal Analysis of VV/CS during Normal Operation
4) 13-970214-AWB-01, Bakeout of Vacuum Vessel and Internals
5) 13-970214-JMS-01, Centerstack Halo Current Stress Analysis
6) 13-970214-JMS-02, Stress Analysis of the Centerstack Case and Support Structure from Bakeout and Operational aThermal Loads

Assumptions: -The loads on the center stack as a result of halo currents are calculated in Reference 1. Thermal loads for normal operation and bakeout are given in References 3 and 4.

-The center stack dimensions used in the analysis were those that were accurate at the time the halo loads were calculated. The casing is modeled as 4 mm thick Inconel.

- For the halo analysis the casing is assumed to be fixed at the base and guided at the top of the casing. No support structure is explicitly modeled.

-For the thermal analysis plates representing the support structure from the upper plate of the lower hub assembly are included in the model. The base of these plates is assumed to be fixed and the top of the casing is guided. Since there are thermal gradients throughout the structure, the material properties used in these models are chosen at an average temperature.

Calculation: All analyses were performed using ANSYS 5.2 Model input files reside on /work1/jspitzer on ead01.pppl.gov.

Model input files for halo analyses:
cshlwgcns.tf1 - centered non-symm. halo current interaction with tf
cshlwgcns.pf1 - centered non-symm. halo current interaction with pf

cshlwgcns.pftf1 - centered non-symm. halo current interaction w/ tf&pf
cshlwgdis.pftf1 - displaced non-symm. halo current interaction w/ tf&pf

Model input files for thermal analyses:
cswgbo - temperature distribution during bakeout
cswgbo1np - structural response to bakeout temperature distribution
cswgop - temperature distribution during operation
cswgop1np - structural response to operating temperature distribution

Conclusion

The results of the various analyses are documented in References 5 and 6. These analyses indicate that the stresses in all instances are well below the allowable stress level of 2/3 of the yield stress of Inconel at temperature. The predicted deflections in all analyses are considered insignificant. No formal analysis of the loads resulting from plasma disruption were performed since these loads were considered benign. While some slight dimensional changes have taken place since that time these are not expected to have any significant impact on the result.

I have reviewed this calculation and to my professional satisfaction it is properly performed and correct.

Checker's signature John C. Citrolo April 11, 1997

NSTX

13-970214-JMS-02

TO: ***Distribution***
FROM: ***J. Spitzer***
SUBJECT: Stress Analysis of the Centerstack Case and Support Structure from Bakeout and Operational Thermal Loads

References:

1) NSTX Memo: 13-970214-AWB-01 "Bakeout of Vacuum Vessel and Internals"

2) NSTX Memo: 13-970214-AWB-01 "Thermal Analysis VV/CS during Normal Operation"

NSTX Drawings

13.E.0101.0 - Centerstack Top @ 0° and 90° Layout.
13.E.0102.0 - Centerstack Bottom @ 0° and 90° Layout.

The Inconel centerstack casing is supported at its base by a support structure which reacts the loads through the TF hub assembly to the hot cell floor. This support structure is comprised of a series of annular rings separated by eight 0.5 in. thick vertical plates spaced 45° apart The support structure is bolted to the casing at the top and connected to the TF hub assembly at its base (13.E.0102.0). At the top, the casing is "guided" by the hub assembly to prevent translational movement but is free to grow vertically (13.E.0101.0)

Reference 1 describes the thermal analysis of the vacuum vessel and PFCs during bakeout. From this analysis the centerstack casing temperature is predicted reach a maximum temperature of 390°C. To examine the effect of this thermal load on the centerstack and support structure, the centerstack model created to analyze the halo current loads was modified. The new model of the centerstack and support structure, Figure 1. In the analysis for the support structure only the vertical plates were explicitly modeled. These plates were assumed fixed at their connection to the TF hub assembly. At the top the centerstack restrained in the translational directions but free to move vertically.

For the bakeout scenario, the model was analyzed using ANSYS with temperatures on the entire centerstack set to 400°C while the base of the support was set to room temperature, 20°C. Figure 2 illustrates the temperature distribution within the support for this condition. Using this temperature distribution as body forces the stresses and displacments in the model were calculated. During baking the casing grows nearly 0.75 in. vertically and ~.080 in. radially at the supports. Since the centerstack is free to grow vertically it is this radial growth that creates a bending stress in the support, Figure 3. The resulting von Mises stresses in the supports are given in Figure 4 and has a maximum value of ~20 ksi.

A similar analysis was conducted for the temperature distribution during operations. Reference 2 predicts a maximum temperature in the casing of ~ 560°C at the midplane. During operations the inboard divertor will be cooled so temperatures at the lower and upper centerstack flanges are set at 50°C. The base of the support structure is again set at 20°C in this analysis although some heating of this structure is likely to occur during operation. Figure 5 illustrates this temperature distribution. The Sz and Svm stress distribution is given in Figures 6 and 7. Since the inboard divertor and thus the base of the casing is cooled during operation the radial growth, and thus the stresses at the support are minimal.

Distribution:

J. Bialek J. Citrolo P. Heitzenroeder C. Neumeyer NSTX File

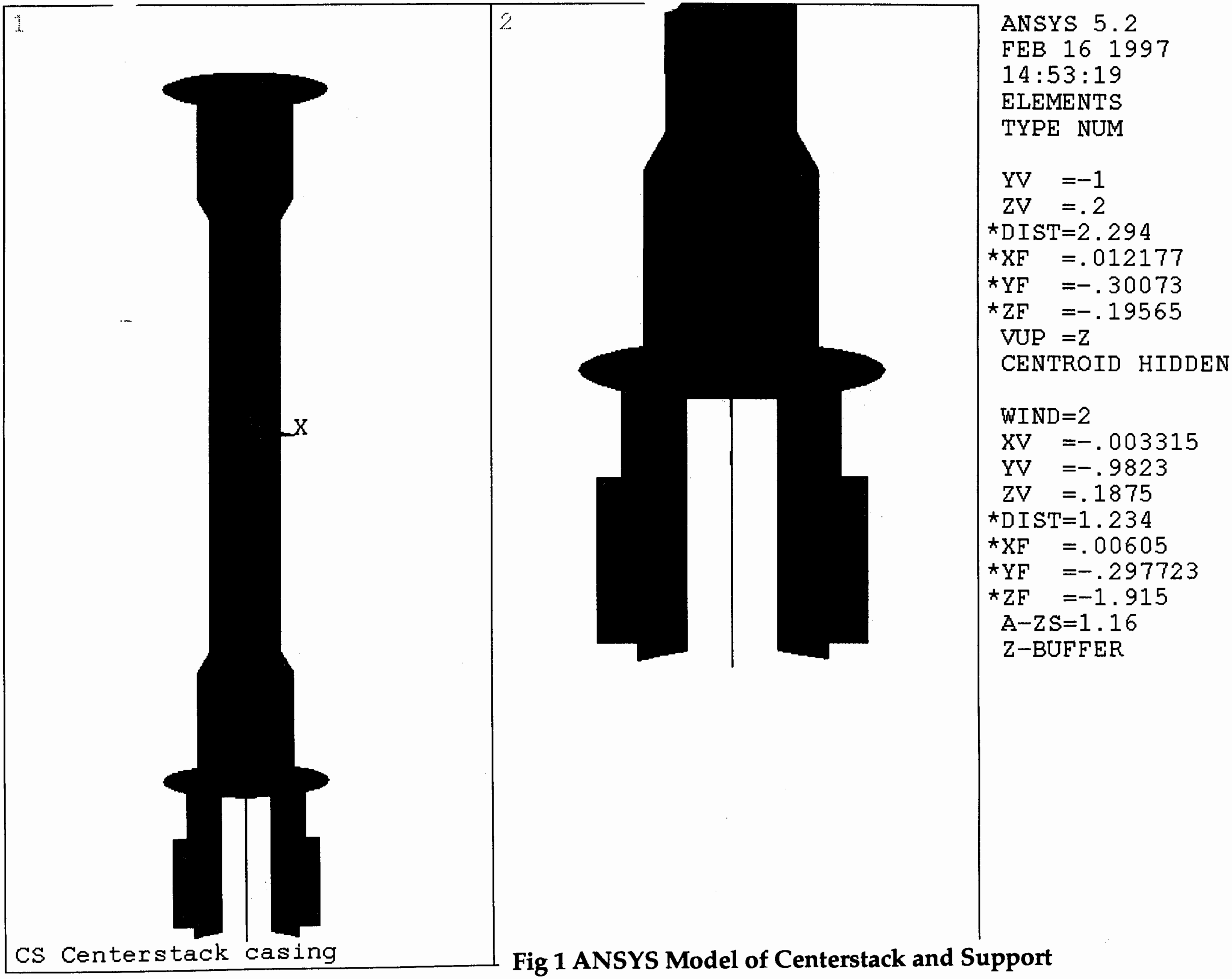

Fig 1 ANSYS Model of Centerstack and Support

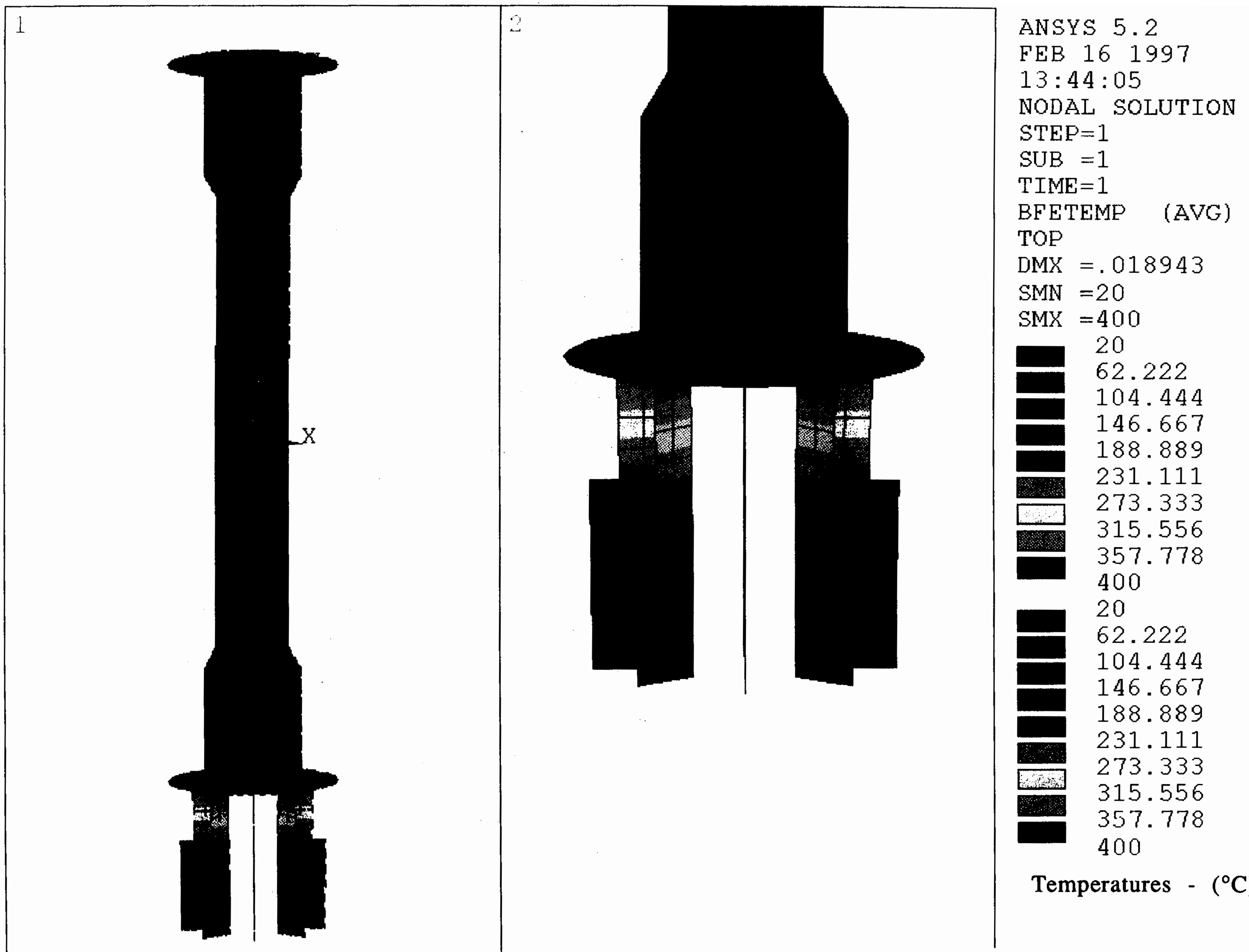

Fig 2 T ˆperature Distribution during Bakeout

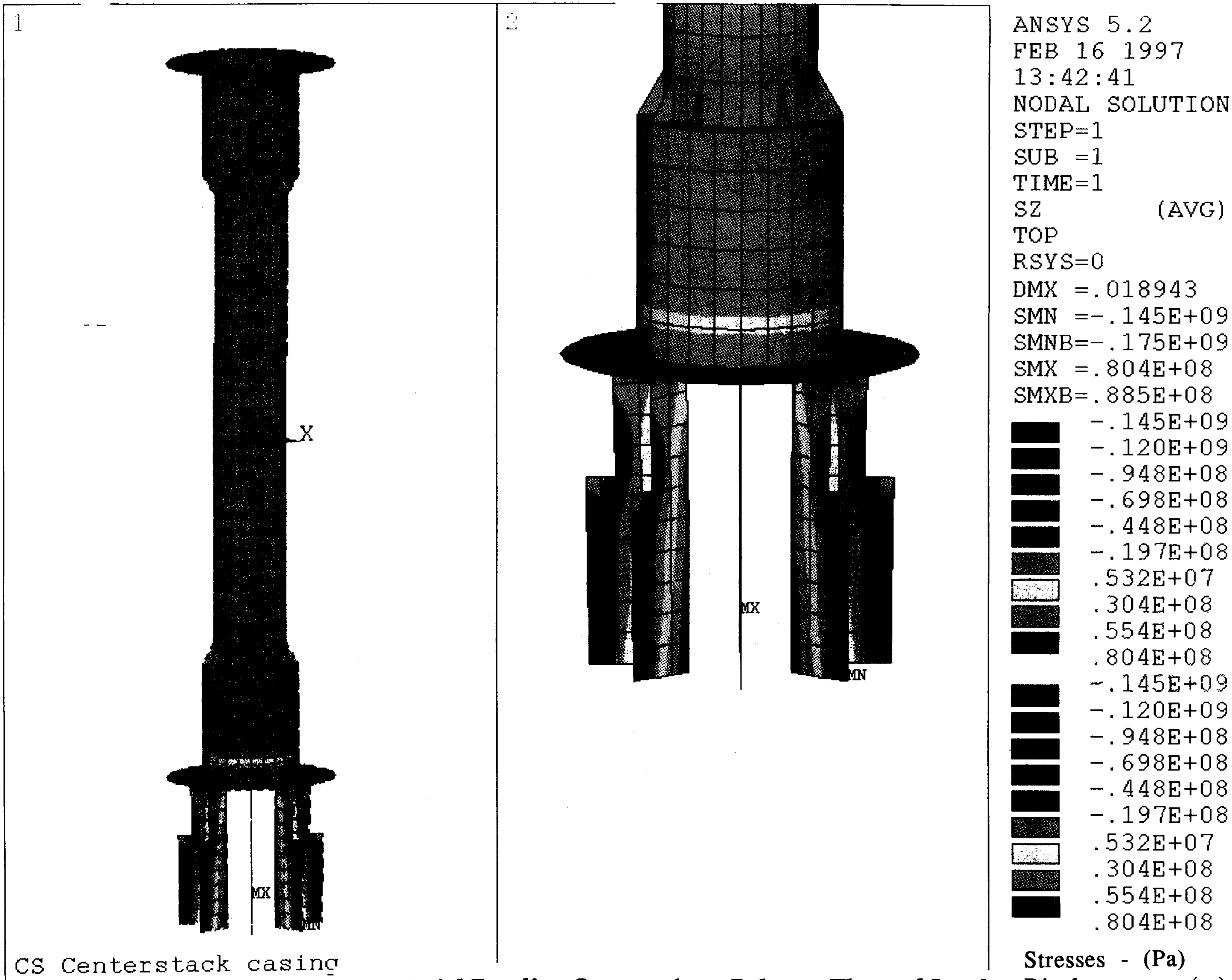

Fig 3 Axial Bending Stresses from Bakeout Thermal Loads

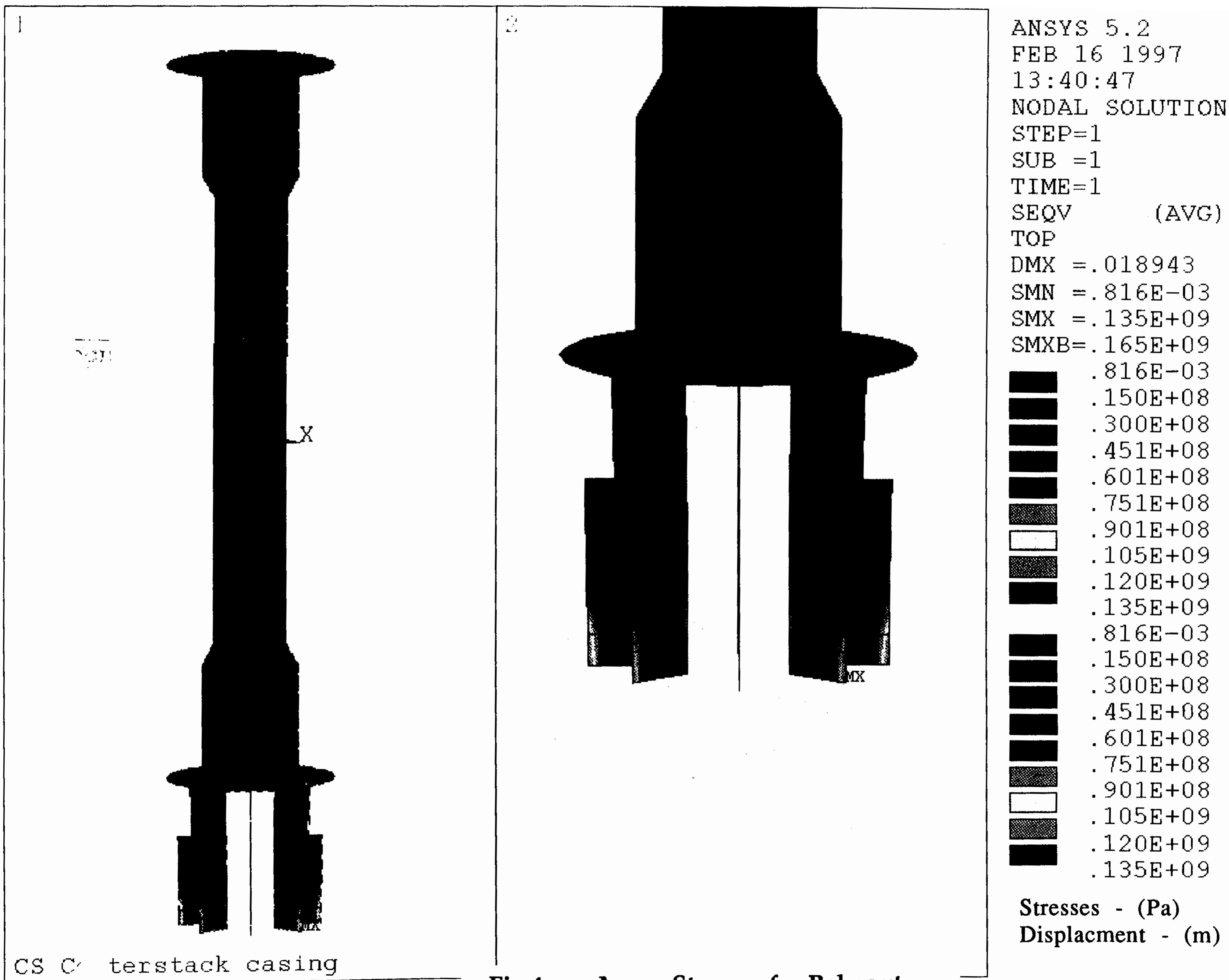

Fig 4 von M s Stresses for Bakeout

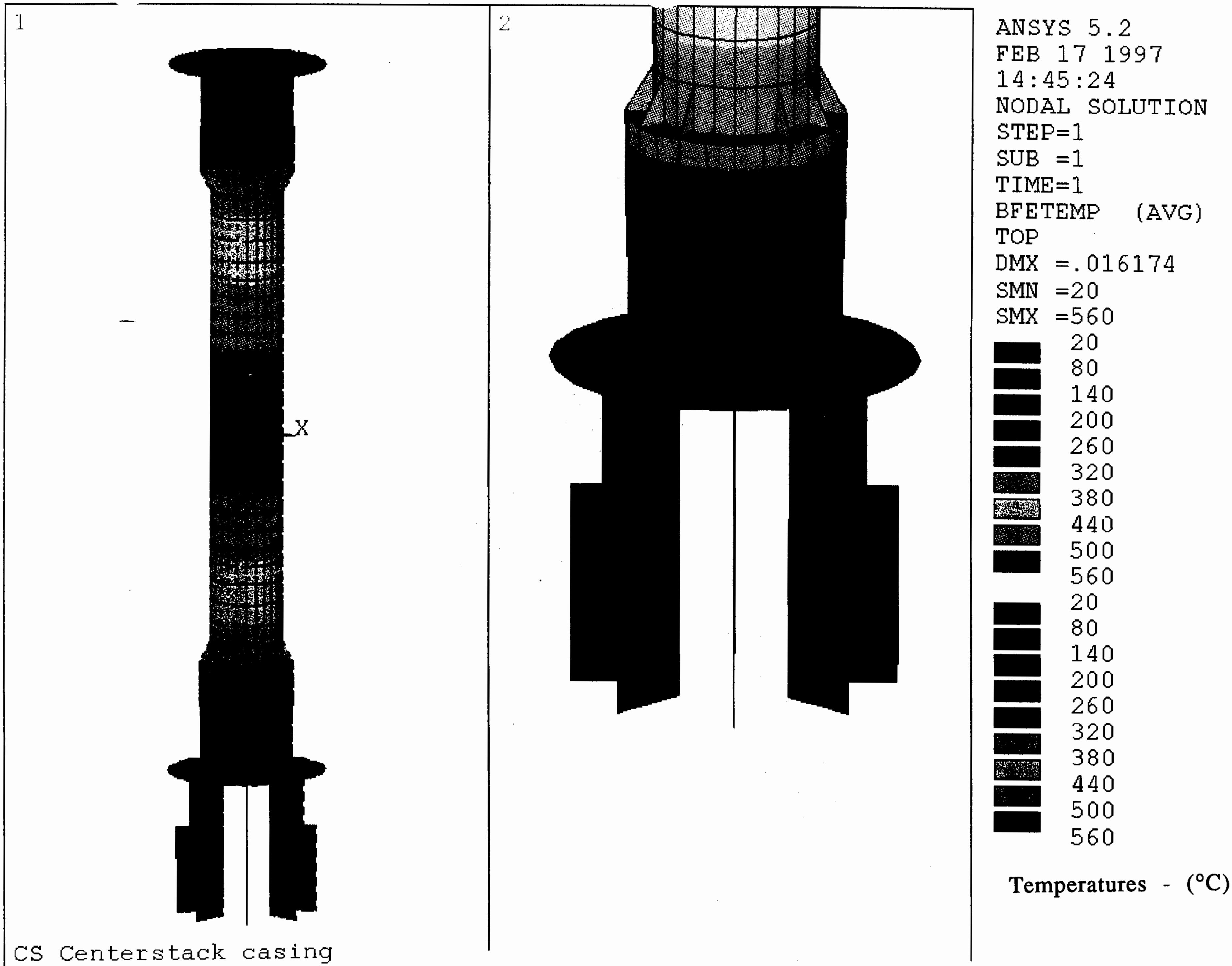

Fig 5 Temperature Distribution during Bakeout

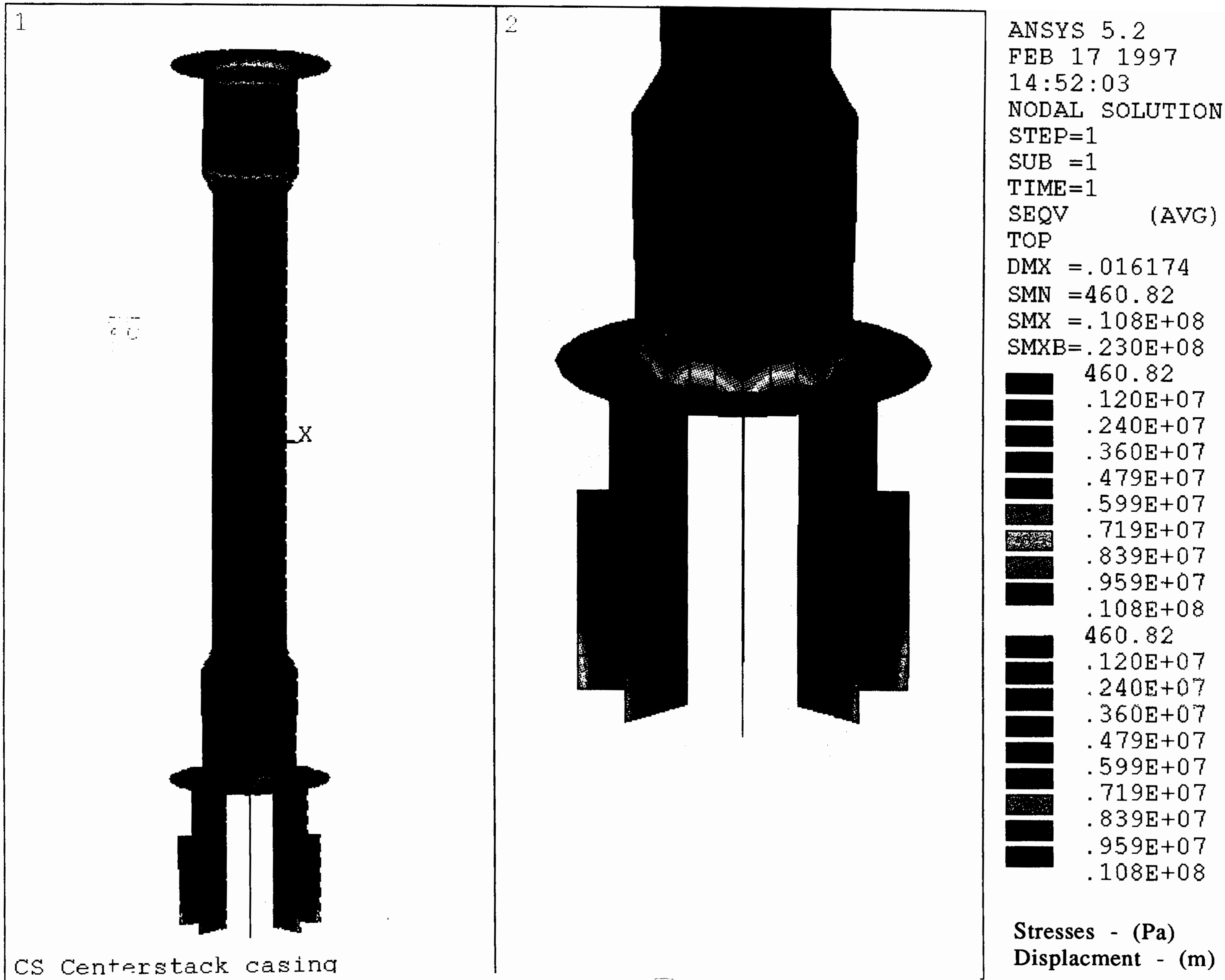

Fig 7 von Mises Stresses for ‾ rating Thermal Loads