Commonwealth Edison Company
1400 Opus Place
Downers Grove, IL 60515

ComEd

October 3, 1995

Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Document Control Desk

Subject: Additional Information
Regarding the Increase in the
Interim Plugging Criteria for
Byron Unit 1 and Braidwood Unit 1
NRC Docket Numbers:50-454 and 50-456

References:
1. D. Saccomando letter to Nuclear Regulatory Commission dated September 1, 1995, transmitting the Technical Specification Amendment Request Supplement Pertaining to the 3 Volt Interim Plugging Criteria for the Steam Generators
2. D. Saccomando letter to Nuclear Regulatory Commission dated February 7, 1995, transmitting WCAP-14273

Reference 1 transmitted Commonwealth Edison Company (ComEd) supplemental amendment request which addressed Technical Specification changes necessary to increase the Interim Plugging Criteria (IPC) value to 3 volt for Byron and Braidwood Station Unit 1 Steam Generators. This supplement cites that the technical bases for the amendment request is contained in WCAP-14273, "Technical Support for Alternate Plugging Criteria with Tube Expansion at Tube Support Plate Intersections for Braidwood 1 and Byron 1 Model D-4 Steam Generators," which was transmitted via Reference 2. WCAP-14273 contains the hydrodynamic load model, TRANFLO which was used to calculated the amount of tube support plate movement during a main steam line break event.

Since the submittal of the WCAP-14273, ComEd has become aware that RELAP5 is the more universally accepted model for the evaluation of the hydrodynamic loads produced in a steam generator during a main steam line break event. ComEd has investigated the application of MOD2 and MOD3 and has concluded that RELAP5/MOD3 can be used to determine appropriate pressure loads in the bundle regions, if equilibrium temperature conditions are employed in these regions.

060039

A001

In the Attachment ComEd is providing the following information which justifies the appropriateness of RELAP5/MOD3:

I. Background
II. Application of RELAP5 Code for Prediction of the Steam Generator Blowdown History During a Main Steam Line Break
III. Instabilities in RELAP5/MOD3
IV. Conservatism
V. Conclusion

A margin of 1.5 has been added to the resultant loads to ensure additional conservatism. ComEd is proceeding to perform the structural analysis to determine which steam generator tubes need to be expanded to support the design bases as described in WCAP-14273.

In addition to this margin of 1.5, it is important to recognize that several other conservatism and/or margins have been applied to ensure the overall conservatism in the 3.0 volt IPC application at Byron Unit 1 and Braidwood Unit 1. A letter detailing these conservatism will be forwarded to the Staff promptly.

If you have any questions concerning this correspondence, please contact this office.

Sincerely,

Denise M. Saccomando
Nuclear Licensing Administrator

Attachment

cc: D. Lynch, Senior Project Manager-NRR
R. Assa, Braidwood Project Manager-NRR
G. Dick, Byron Project Manager-NRR
S. Ray, Acting Senior Resident Inspector-Braidwood
H. Peterson, Senior Resident Inspector-Byron
H. Miller, Regional Administrator-RIII
Office of Nuclear Safety-IDNS

Hydrodynamic Load Model Assessment

Background

Rapid depressurization following a main steam line break of a steam generator may result in large differential pressures, and therefore, significant loads on the tube support plates. The RELAP5/MOD3 computer code has been used by ComEd to evaluate the differential pressure across the steam generator tube support plates following a main steam line break. A model for the Westinghouse Model D4 steam generator at Byron1/Braidwood1 was developed and a series of predictions were performed to calculate the pressure history and the differential pressure at the support plates.

The purpose of this document is to demonstrate the applicability of RELAP5 for analysis of a steam line break blowdown scenario. In addition, the method of employing RELAP5/MOD3 will be discussed in light of metastable conditions in interfacial heat transfer discovered in the course of the performance of these calculations.

Applicability of RELAP5 Code for Prediction of the Steam Generator Blowdown History During a Main Steam Line Break

RELAP5 code has been developed as a best estimate tool for transient analysis of the pressurized water reactors. This code has been tested extensively by predicting the phenomenological problems, separate effects tests, as well as integral test problems. RELAP5/MOD3 has extended the capabilities of MOD2 by improving some of the existing models and adding new features which include: two energy equations for modeling non-equilibrium effects, reflood heat transfer model, revised constitutive equations for the interface drag and CCFL, and additional component and control system models.

The steam line break of a steam generator can be simulated by a calculational tool which contains governing equations and constitutive relations capable of predicting the depressurization history, void fractions and therefore level swell, and the losses across different components of the steam generator. Although all the best estimate codes are based on constitutive relations which are developed from steady state concepts, they contain empirical parameters which when combined within the codes have been able to predict the transient separate effects and integral tests, as well as plant transients.

Both RELAP5/MOD2 and MOD3 have been used to simulate liquid and steam blowdown tests. The most relevant separate effects tests are the GE one foot (test 1004-3) and four foot (test 5801-15) level swell tests, Ref. 1. Comparison of the data and predicted pressures by RELAP5/MOD2 and MOD3, Figures 1 and 2 (reproduced from Ref. 2), shows that both codes are equally capable of predicting the vessel pressure history. This means that the critical flow model and the overall vapor generation rates are representative of the actual conditions during blowdown. The comparison of the measured and predicted void fractions at different axial profiles at various times are shown in:

Figure 3	10 seconds	Test 1004-3
Figure 4	40 seconds	Test 1004-3
Figure 5	160 seconds	Test 1004-3
Figure 6	5 seconds	Test 5801-15
Figure 7	10 seconds	Test 5801-15
Figure 8	20 seconds	Test 5801-15

Again, both codes predict the void fraction profiles and, therefore, the level swell during the depressurization.

GE level swell tests were performed with an open bundle configuration and the predictive capability of RELAP with bundle geometric should also be demonstrated. Comparison of the predicted and measured void fractions for ORNL THTF rod bundle boil off tests has shown that RELAP5/MOD2 over predicts the void fraction and, therefore, under predicts the liquid level. The interfacial drag formulation in MOD3 was modified to incorporate the Chexal-Lellouche drift flux formulation. The predicted void fraction profiles by MOD2 and MOD3 for THTF test 3.09.101 are shown in Figure 9 and demonstrated (reproduced from Ref. 3) improved prediction of the void fraction by RELAP5/MOD3 for bundle geometries under co-current upward flow.

Instabilities in RELAP5/MOD3

A RELAP5 input model representing the Byron1/Braidwood1 Model D4 steam generator was developed and the blowdown history during a steam line break was predicted using RELAP5/MOD2 (Reference 4). The pressure drop across the P-TSP, Figure 10, shows a peak value of 1.97 psi at 0.6 seconds. This model was converted to MOD3 format and the prediction of the pressure drop across P TSP, Figure 11, shows a sharp peak of approximately 5.0 psi around 1.2 seconds. Since the MOD2 results did not indicate any secondary peaks, the spiking behavior was considered suspect and additional evaluations were performed. Cases were run that: 1) removed the interphase drag models, 2) changed the drag models from tube bundle to pipe, and 3) selected equilibrium temperature conditions in the bundle regions. The developers of the RELAP5/MOD3 computer code were contacted and extensive discussions and testing were performed. A review of the test results leads to the conclusion that the interfacial heat transfer behavior is a likely cause of the unphysical behavior observed in the model. This was additionally corroborated in discussions held with Dr. V. Ransom of Purdue University.

A review of the RELAP5/MOD3 assessment problems shows that Workshop problem 2 exhibits a strong oscillatory behavior with MOD3, particularly with respect to the bundle riser velocities, where the MOD 1 and 2 results are more quiescent. The D4 SG problem, with its detailed focus on the bundle velocity and dp behavior, along with flow reversal in the tube bundle, is likely to be very sensitive to this behavior.

To demonstrate the effects noted, plots from the test cases performed are provided. Figure 12 shows the base case (with instability) temperatures in a middle tube volume. Figure 13 shows the interfacial heat transfer parameters for the same volume (HIF and HIG expanded minor edit parameters). As can be seen, the amount of liquid phase superheat is significant (nearly 6 degrees F) and rapid resolution to near saturation occurs as a result of a rapid increase in HIF. The high levels of liquid superheat in a good mixing environment like the tube regions are not anticipated, and the values that exist following the instability are considered much more representative of the physical situation. Selecting a single momentum equation (by setting h=2 in the junction control words), effectively eliminates the interphase drag from consideration. Figures 14 (One momentum equation case), 15 (Fluid Temperature Response), and 16 (Interfacial Hear Transfer Coefficients) provide the predicted differential pressure across the P-TSP as well as the fluid temperatures and interphase heat transfer coefficients in the same middle tube volume. As can be seen, the instability assumes a similar oscillatory behavior as the base case following a rapid approach to saturation precipitated by interfacial heat transfer. This case demonstrates that the instability is not caused by the interphase drag models. The equilibrium case (setting e=1 in tube region volume control cards) shows that by causing the code to maintain the phasic temperatures nearly equal eliminates the pressure spiking behavior, (Figure 17), supports that the metastability is directly related to the determination of interfacial heat transfer.

ComEd has been actively engaged in obtaining relevant test data with regard to this issue. To date we have recovered data for several Model Boiler (MB2) tests. (Reference 5) The data recovered concerns tests 2009, and 2013 which were full size steam breaks from hot zero power conditions, on a scale Model F steam generator. We have developed a RELAP5/MOD3 model of the test apparatus and are currently performing comparisons. Initial reviews indicate that RELAP 5 models macroscopic behavior, (depressurization rate, bulk flows, etc) very well, and our current focus is on the pressure drops in the bundle region. Test 2013 data at 0.1 second intervals and test 2009 data available at 1 second intervals support the conclusion that there is no major load causing phenomena beyond the initial fluid surge. This provides additional support for the use of equilibrium temperature modeling in the tube regions.

Based on the above results, ComEd has concluded that RELAP5/MOD3 can be used to determine appropriate pressure loads in the bundle regions, if equilibrium temperature conditions are employed in these regions. This approach captures the essential physics of the initial fluid motion in the tube region that represents the principal dynamic load on the TSPs, without experiencing non-physical behaviors due to artificial variations in interfacial heat transfer. This results in loads that are very comparable, and slightly conservative with respect to those predicted by other RELAP/MOD2, TRANFLO and Multiflex.

Conservatism

Hydrodynamic loads as defined by RELAP5 MOD3 have been increased by a factor of 1.5 to assure all unforeseen uncertainties have been included. In ComEd's original submittal, the definition of hydrodynamic loads was based upon the application of a margin of 2 to the loads predicted by TRANFLO. These loads were then backed up with additional evaluations using Multiflex. Subsequent to that submittal in February 1995, ComEd has performed additional analysis using RELAP5 MOD2 and MOD3, and has performed and docketed a hand calculation intended to quantify a bounding load. Based upon the convergence of all these analysis, ComEd's confidence in the bounding loads developed as part of RELAP 5 MOD3 justify the application of a 1.5 margin.

Conclusions

ComEd is currently completing an evaluation of the TSP response with differential pressure loads developed based on RELAP5/MOD3 version 1.1. This evaluation will include a series of sensitivity studies similar to those performed in WCAP-14273 for the bounding hot zero power case. This is believed to be the appropriate approach because:

1. RELAP5/MOD3 provides the most accurate characterization of flow regime and void fraction, thereby yielding the most representative load.

2. Initial comparisons with MB2 test data indicate that RELAP5/MOD3 captures the timing and magnitude of the differential pressures as well as the flow directions more accurately than other analytical tools.

3. RELAP5/MOD3 produces loads that are directly comparable both in timing and magnitude to previously generated hand calculations. (Reference 6)

4. RELAP5/MOD3 produces loads that are very comparable, and slightly conservative to those predicted by RELAP5/MOD2, TRANFLO and Multiflex.

5. Application of a 1.5 margin to the RELAP5/MOD3 hydrodynamic load is justified based on the convergence of analysis performed using other codes.

6. Several conservatism/margin exists which further ensures overall conservatism in the application of the 3 volt IPC.

References

1 . J.A. Findlay and O.L. Sazzi, "BWR Refill-Reflood Program-Model Qualification Task Plan," EPRI NP-1 527, NUREG/CR-1 899, GEAP-24898, Oct. 1981.

2. K.E. Catlson et. al., "RELAP51MOD3 Code Manual, Volume III: Developmental Assessment Problems," NUREG/CR-5535, EGG-2596, (Draft), Vol. 111, June 1990.

3. J.M. Putney, "Development of a new Bubbly-Slug Interfacial Friction Model for RELAP5, Final Report," ESTD/UOO75/R89, Oct. 1989.

4. K. B. Ramsden, "Calculation of Byron D4 SG Tube Support Plate Differential Pressures during MSLB with RELAP5M2," PSA-B-95-11.

5. Mendler et. al., "Prototypical Steam Generator (MB-2) Transient Testing Program Data Package for Steam Line Break Tests," EPRI Project RP1845-08, October 1985.

6. K. B. Ramsden, "An Independent Verification of Byron/Braidwood D4 SG Tube Support Plate Differential Pressures during MSLB," PSA-B-95-15.

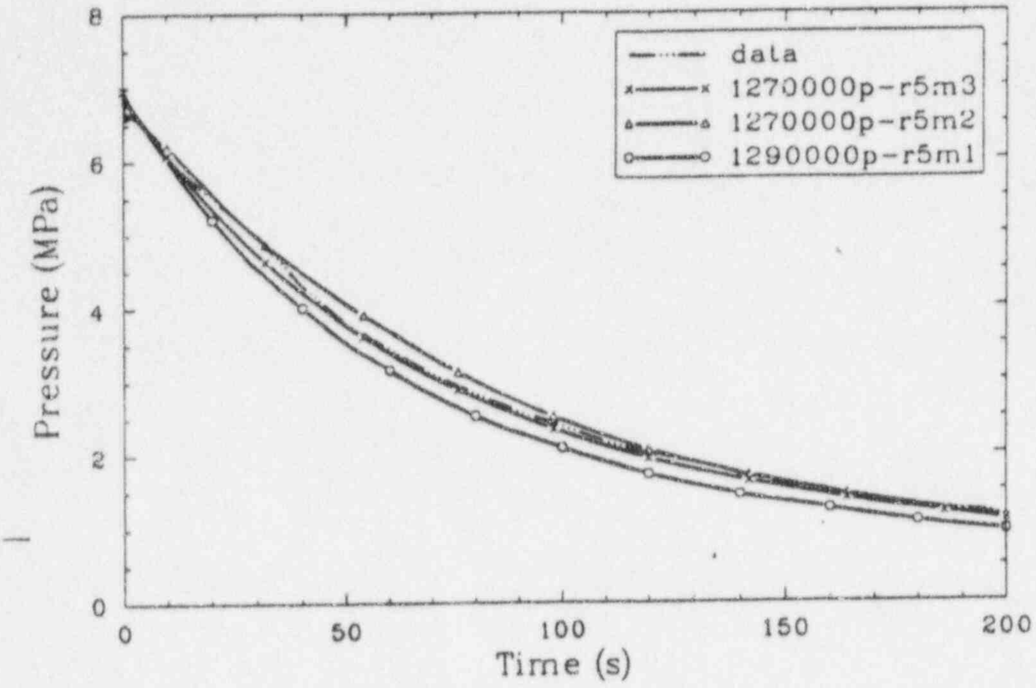


Figure 1 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) pressure in the top of the vessel for GE level swell Test 1004-3.

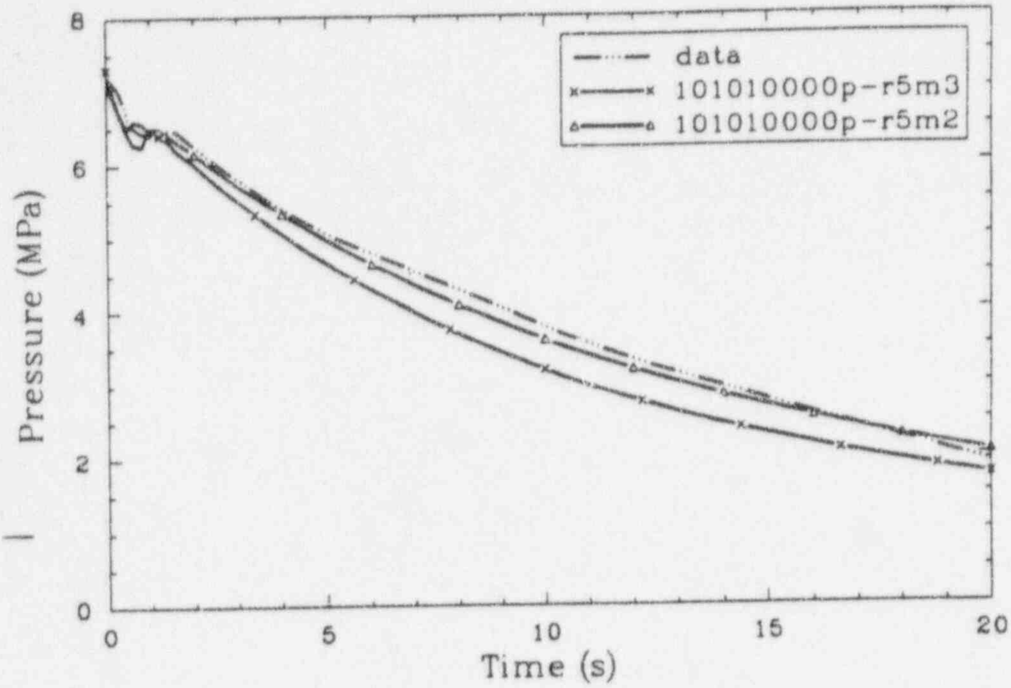
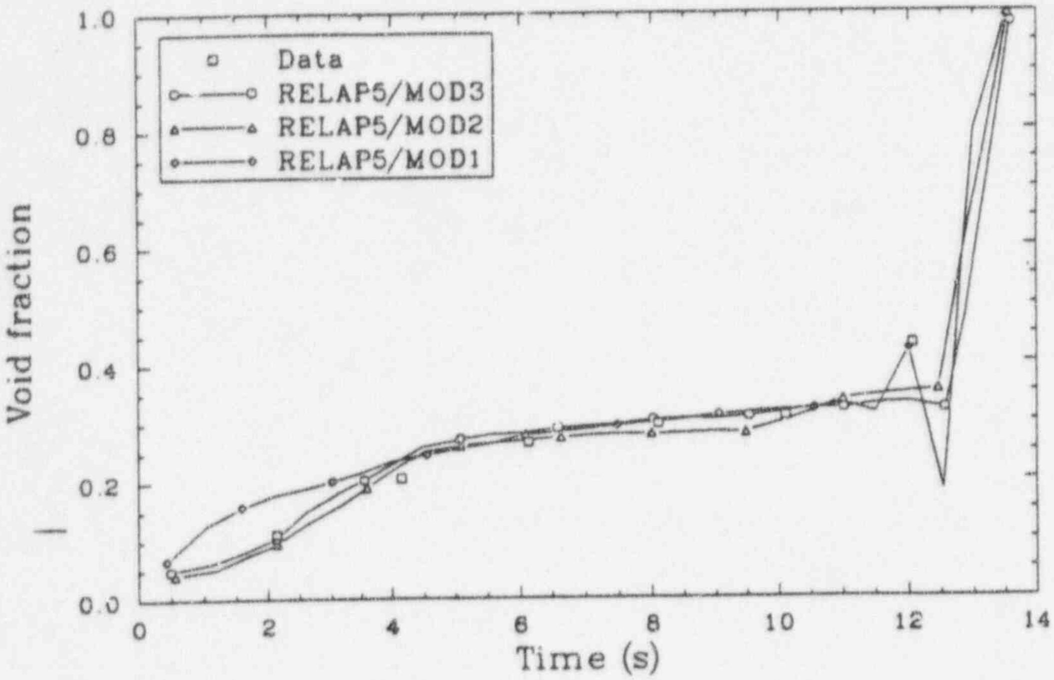


Figure 2 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) pressure in the top of the vessel for GE level swell Test 5801-15.



jen-r241

Figure 3 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 10 s for GE level swell Test 1004-3.

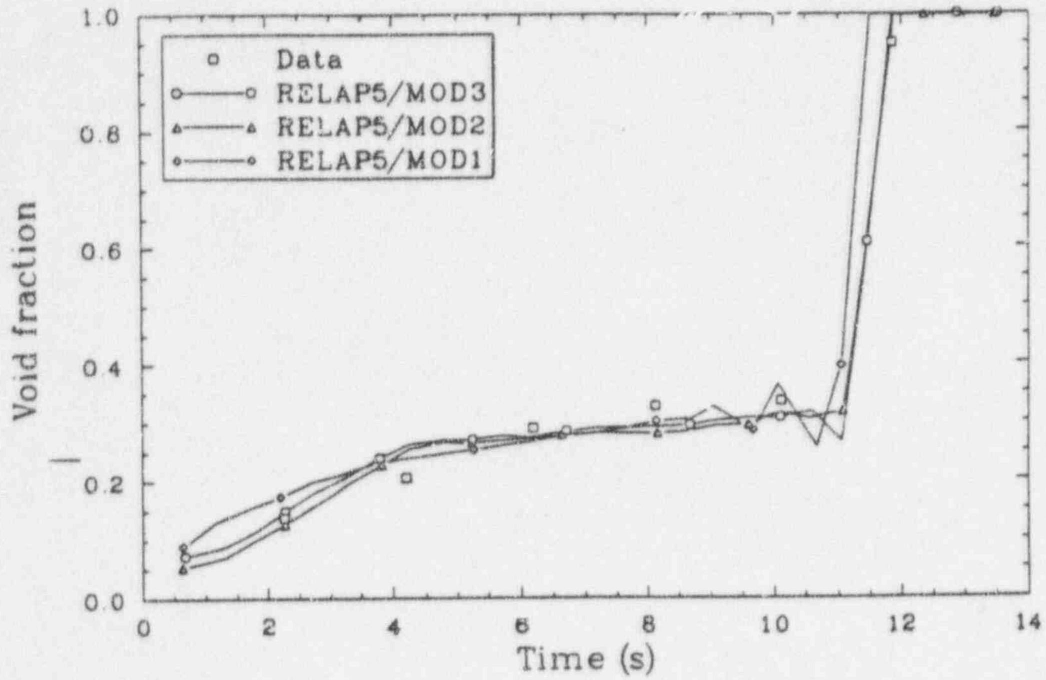


Figure 4 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 40 s for GE level swell Test 1004-3.

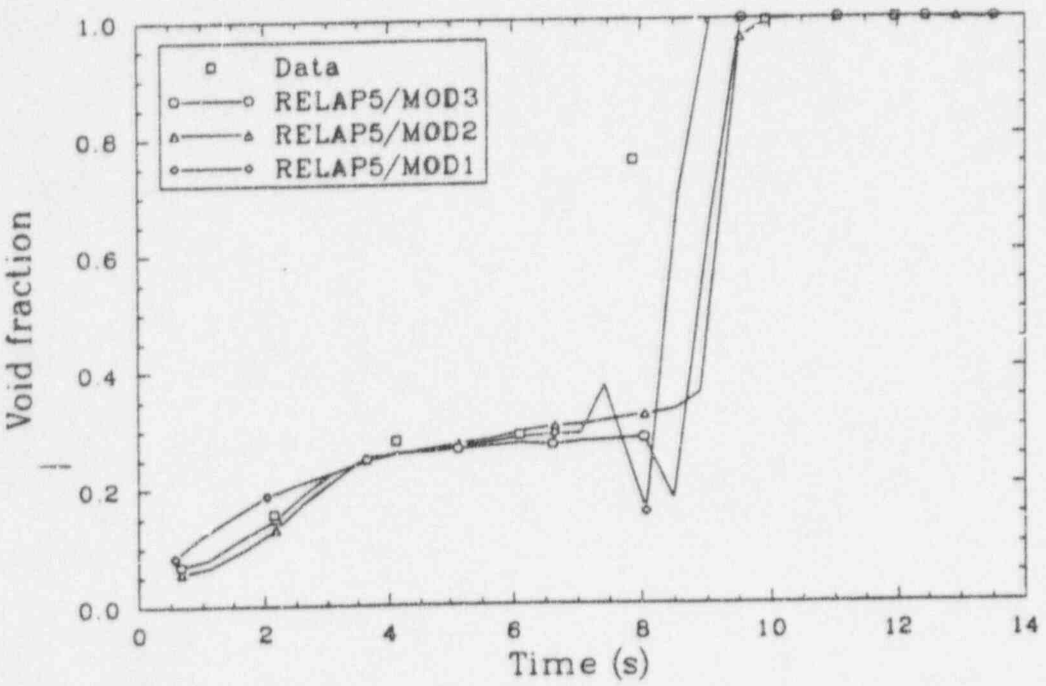
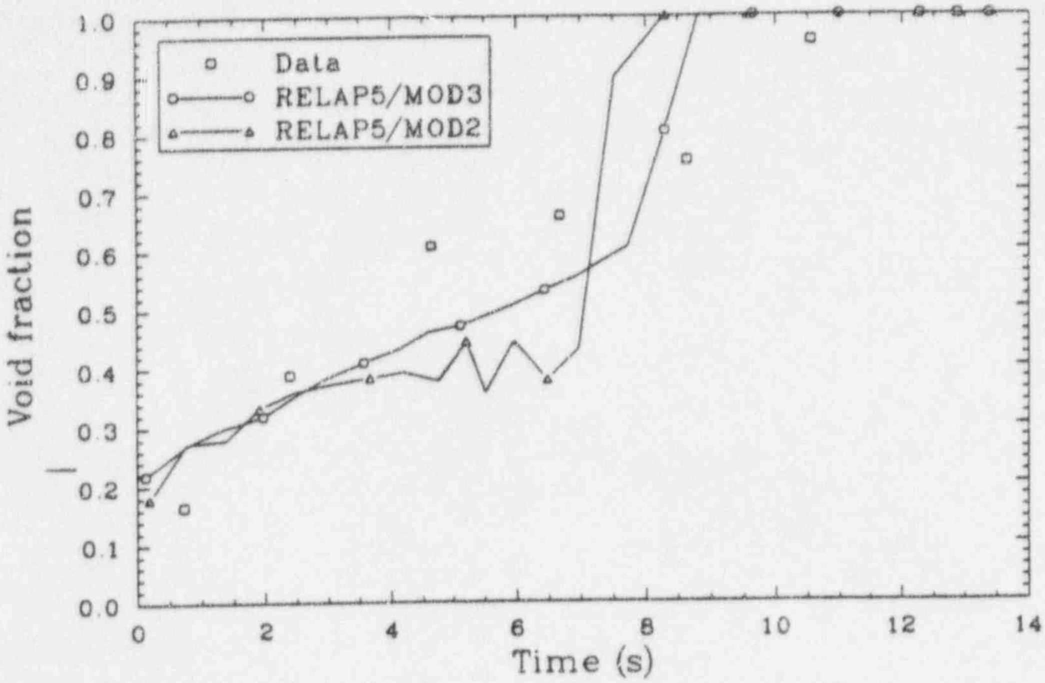
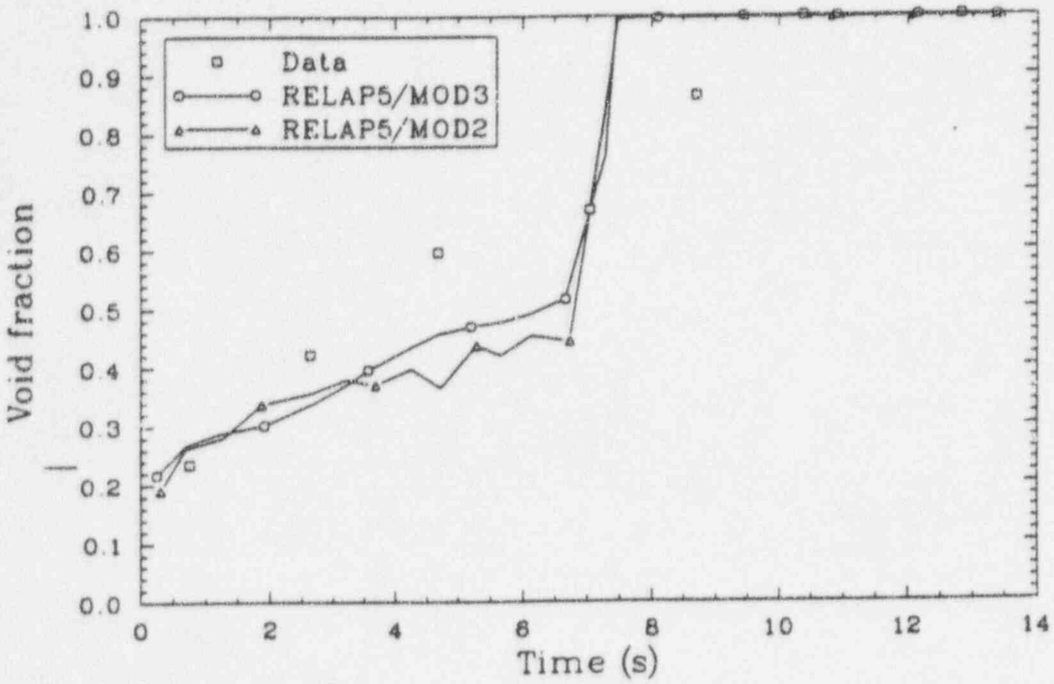


Figure 5 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 160 s for GE level swell Test 1004-3.



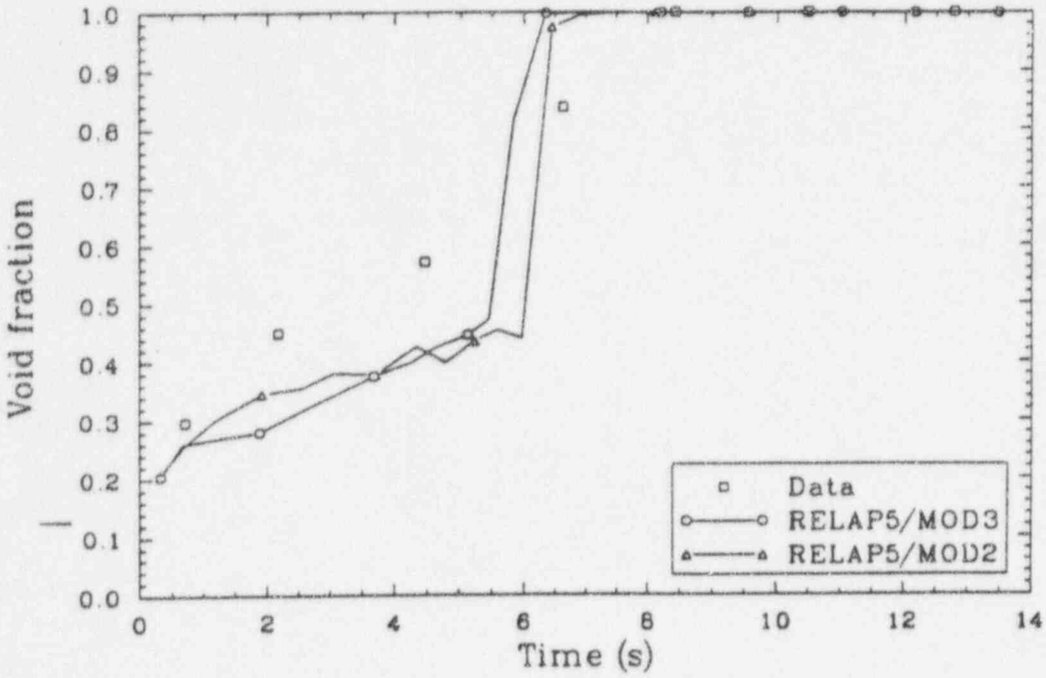
jen-1291

Figure 6 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 5 s for GE level swell Test 5801-15.



jenn-r301

Figure 7 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 10 s for GE level swell Test 5801-15.



jen-r311

Figure 8 Measured and calculated (RELAP5/MOD1, MOD2, MOD3) void fraction profile in the vessel at 20 s for GE level swell Test 5801-15.

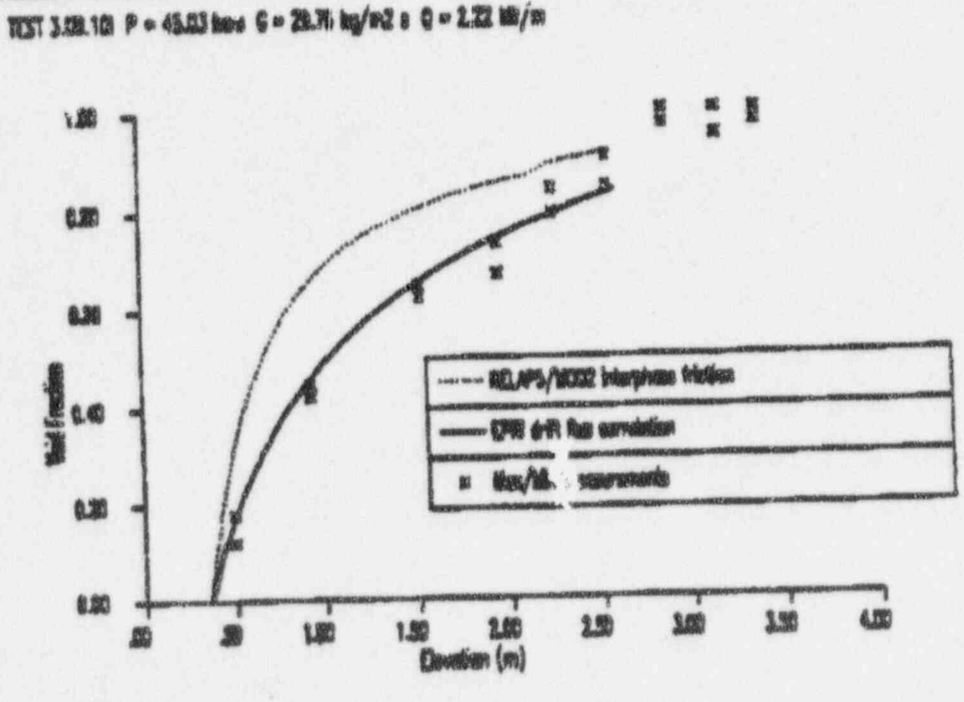


Fig. 9 Comparison of Void Fraction Models for ORNL Test 3.09.10I

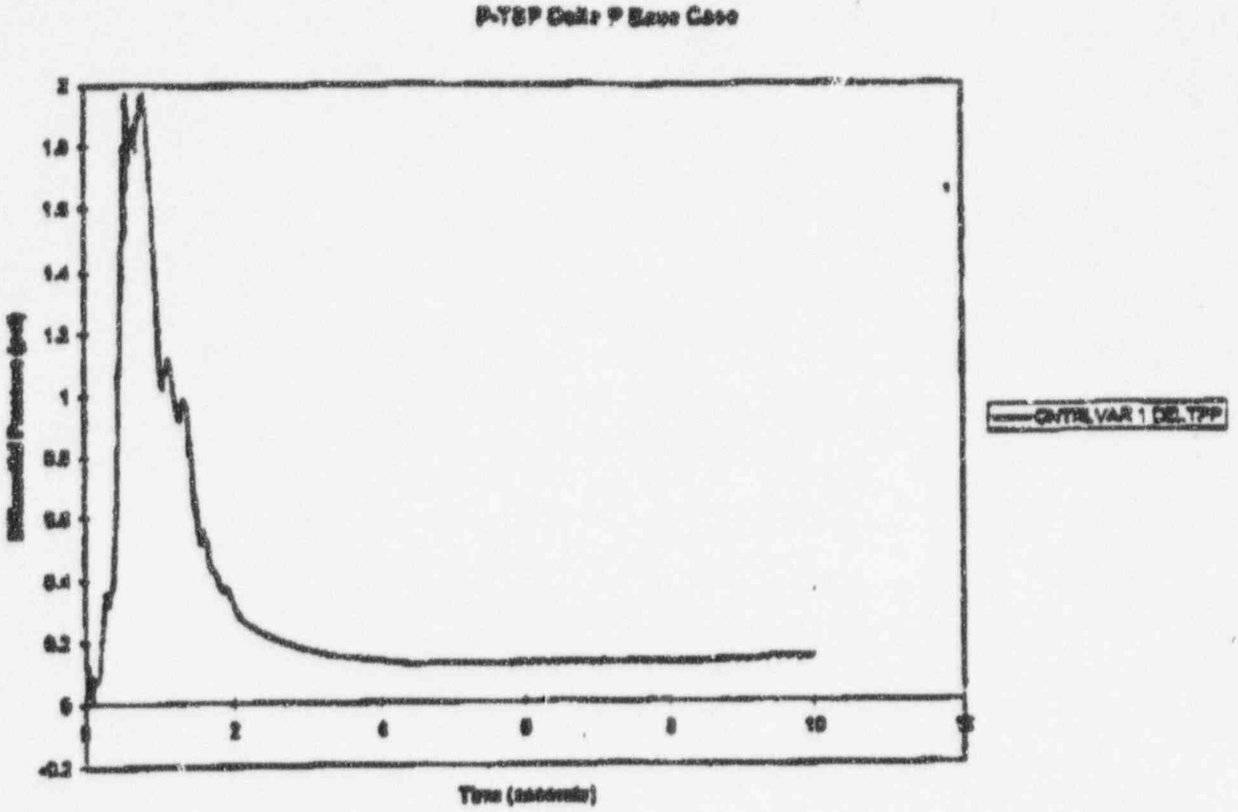


Figure 10-**P-TSP Differential Pressure Base Case** RELAP5 M2

Figure 11

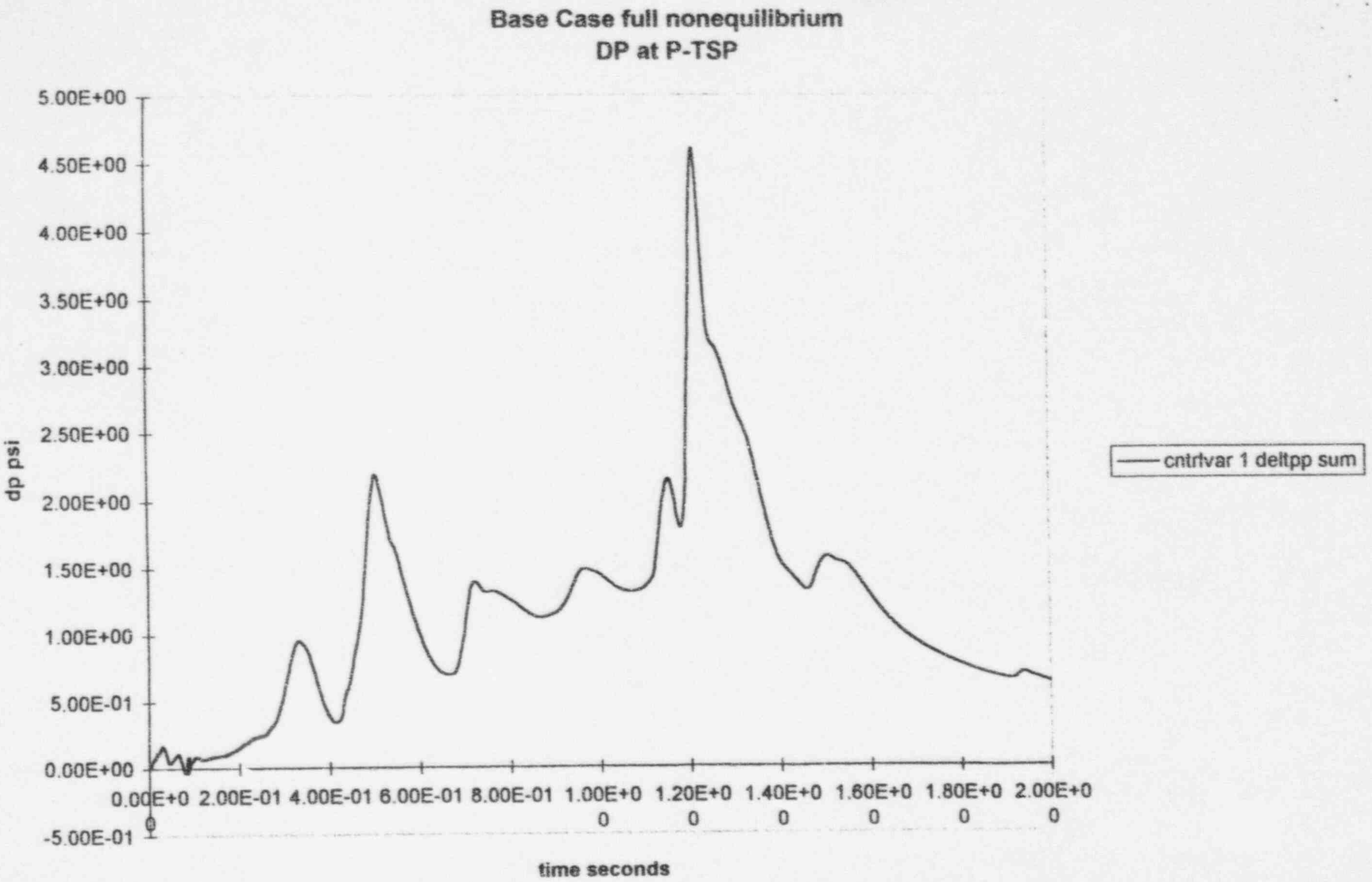

Base Case full nonequilibrium
DP at P-TSP
5.00E+00
4.50E+00
4.00E+00
3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
-5.00E-01
dp psi
0.00E+00
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+00
1.20E+00
1.40E+00
1.60E+00
1.80E+00
2.00E+00
time seconds
cntrlvar 1 deltpp sum

Figure 12

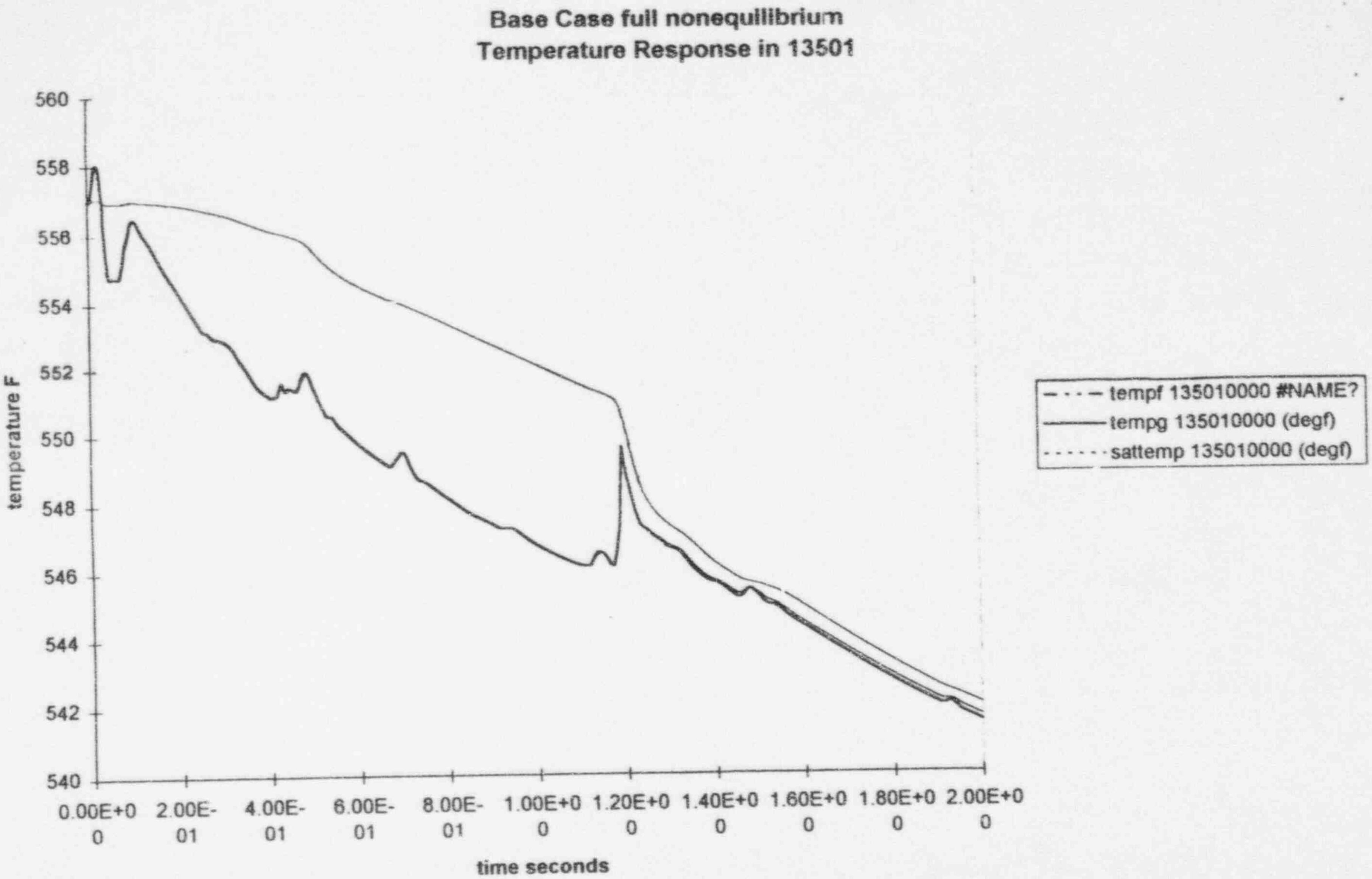

Base Case full nonequilibrium
Temperature Response in 13501
560
558
556
554
552
550
548
546
544
542
540
temperature F
0.00E+0 0
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+0 0
1.20E+0 0
1.40E+0 0
1.60E+0 0
1.80E+0 0
2.00E+0 0
time seconds
tempf 135010000 #NAME?
tempg 135010000 (degf)
sattemp 135010000 (degf)

Figure 13

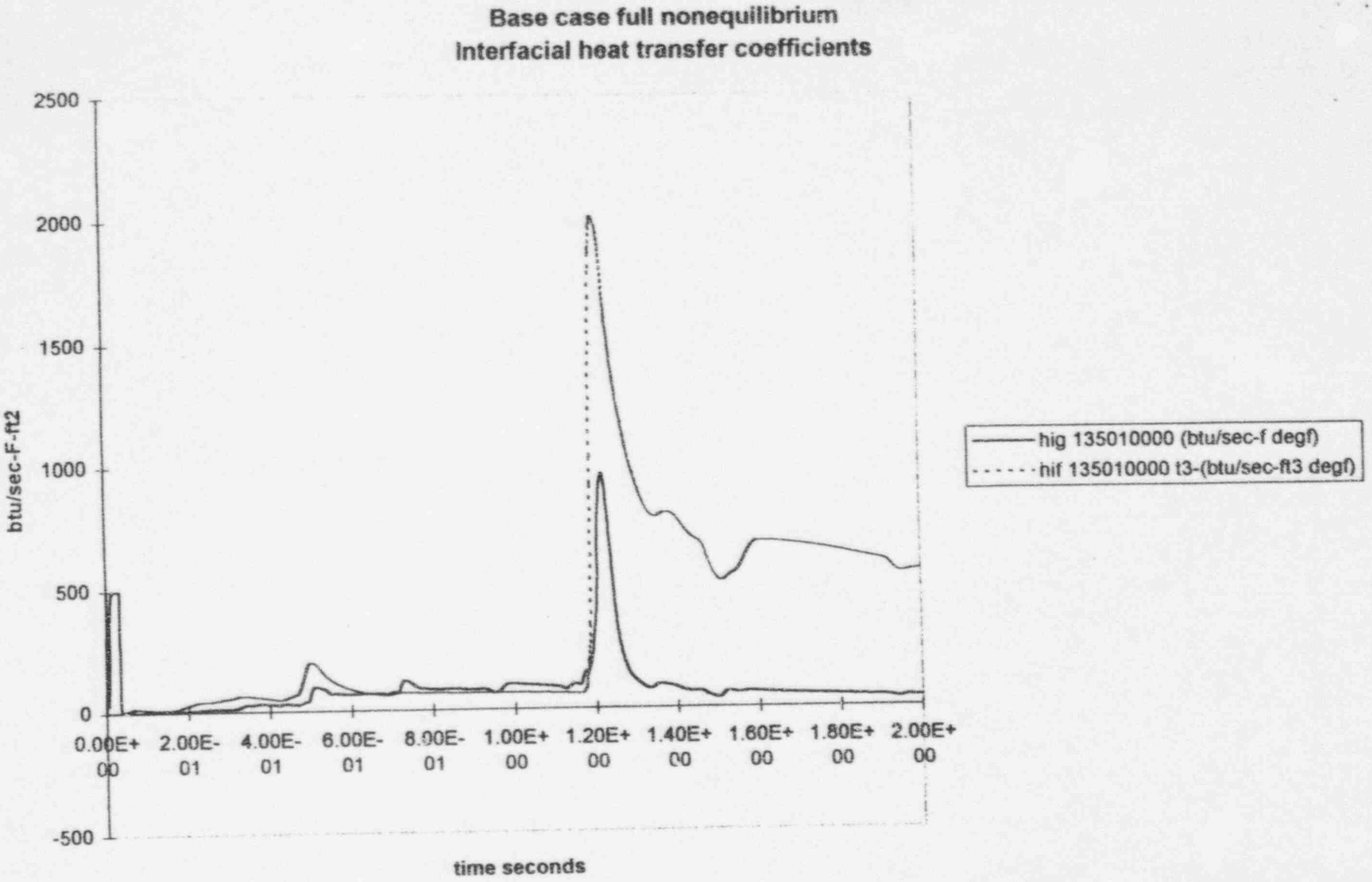

Base case full nonequilibrium
Interfacial heat transfer coefficients
2500
2000
1500
1000
500
0
-500
btu/sec-F-ft2
0.00E+00
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+00
1.20E+00
1.40E+00
1.60E+00
1.80E+00
2.00E+00
time seconds
hig 135010000 (btu/sec-f degf)
hif 135010000 t3-(btu/sec-ft3 degf)

Figure 14

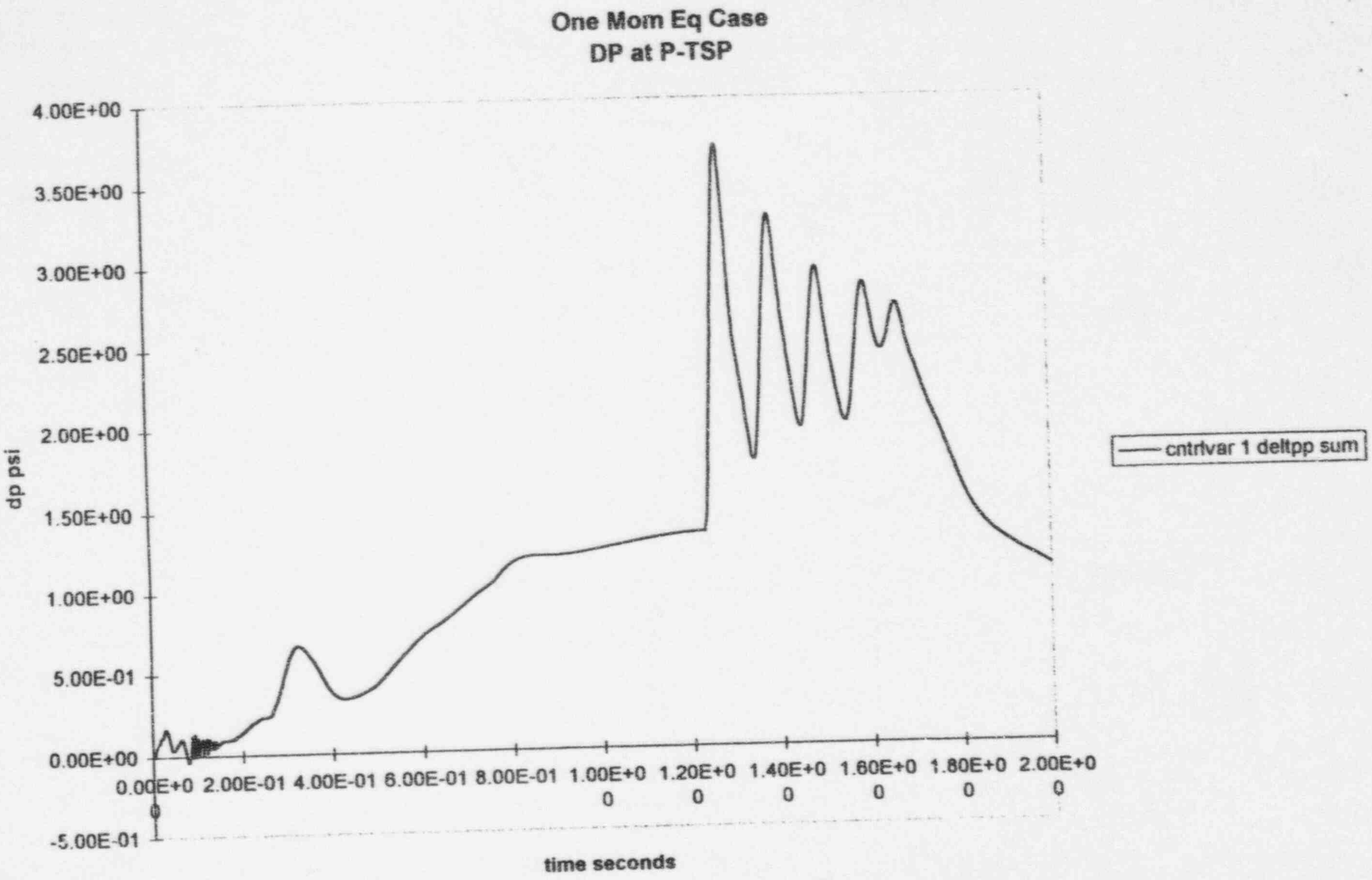

One Mom Eq Case
DP at P-TSP
4.00E+00
3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
1.00E+00
5.00E-01
0.00E+00
-5.00E-01
dp psi
0.00E+00
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+00
1.20E+00
1.40E+00
1.60E+00
1.80E+00
2.00E+00
time seconds
cntrlvar 1 deltpp sum

Figure 15

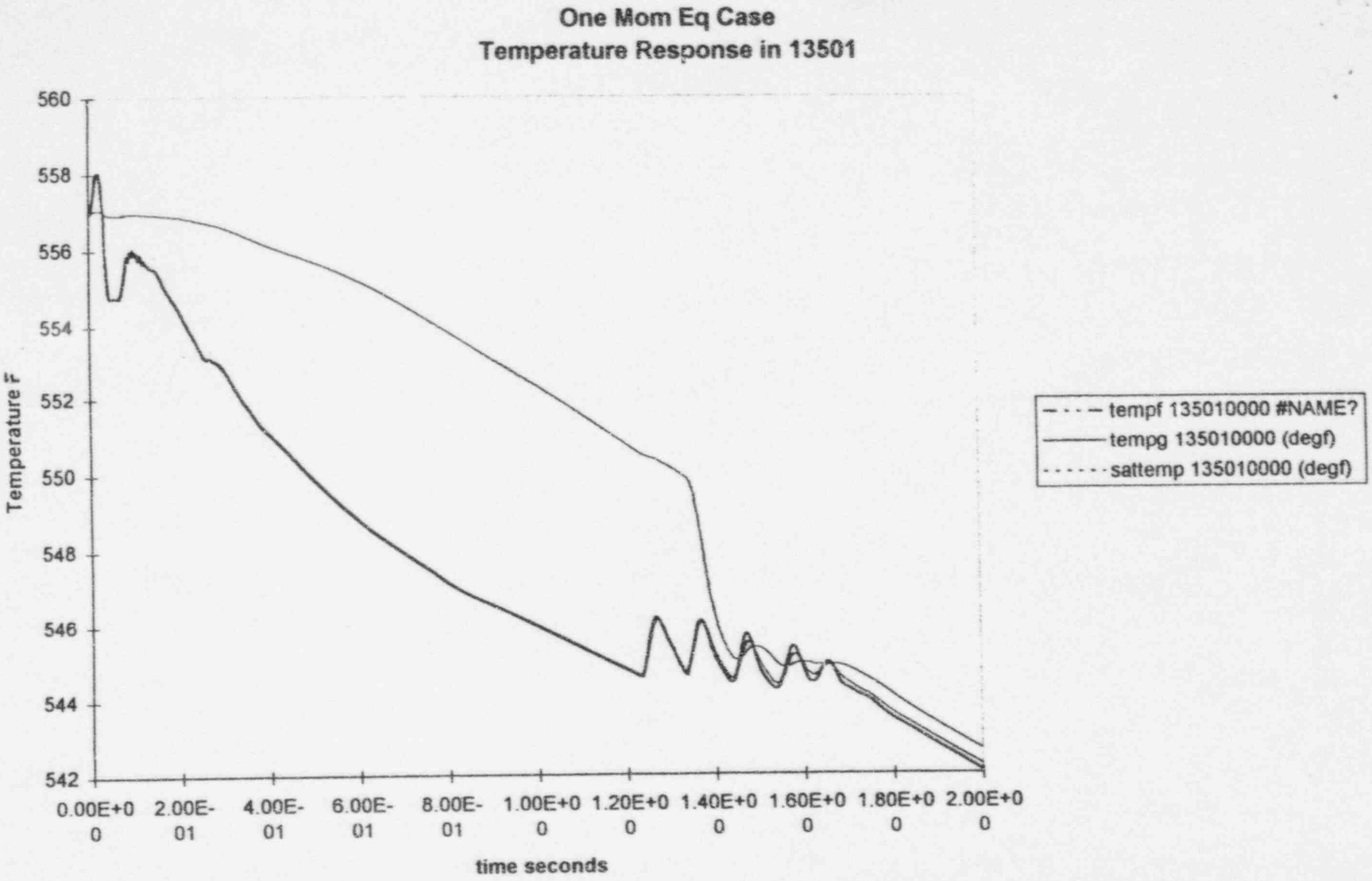

One Mom Eq Case
Temperature Response in 13501
560
558
556
554
552
550
548
546
544
542
Temperature F
0.00E+0 0
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+0 0
1.20E+0 0
1.40E+0 0
1.60E+0 0
1.80E+0 0
2.00E+0 0
time seconds
tempf 135010000 #NAME?
tempg 135010000 (degf)
sattemp 135010000 (degf)

Figure 16

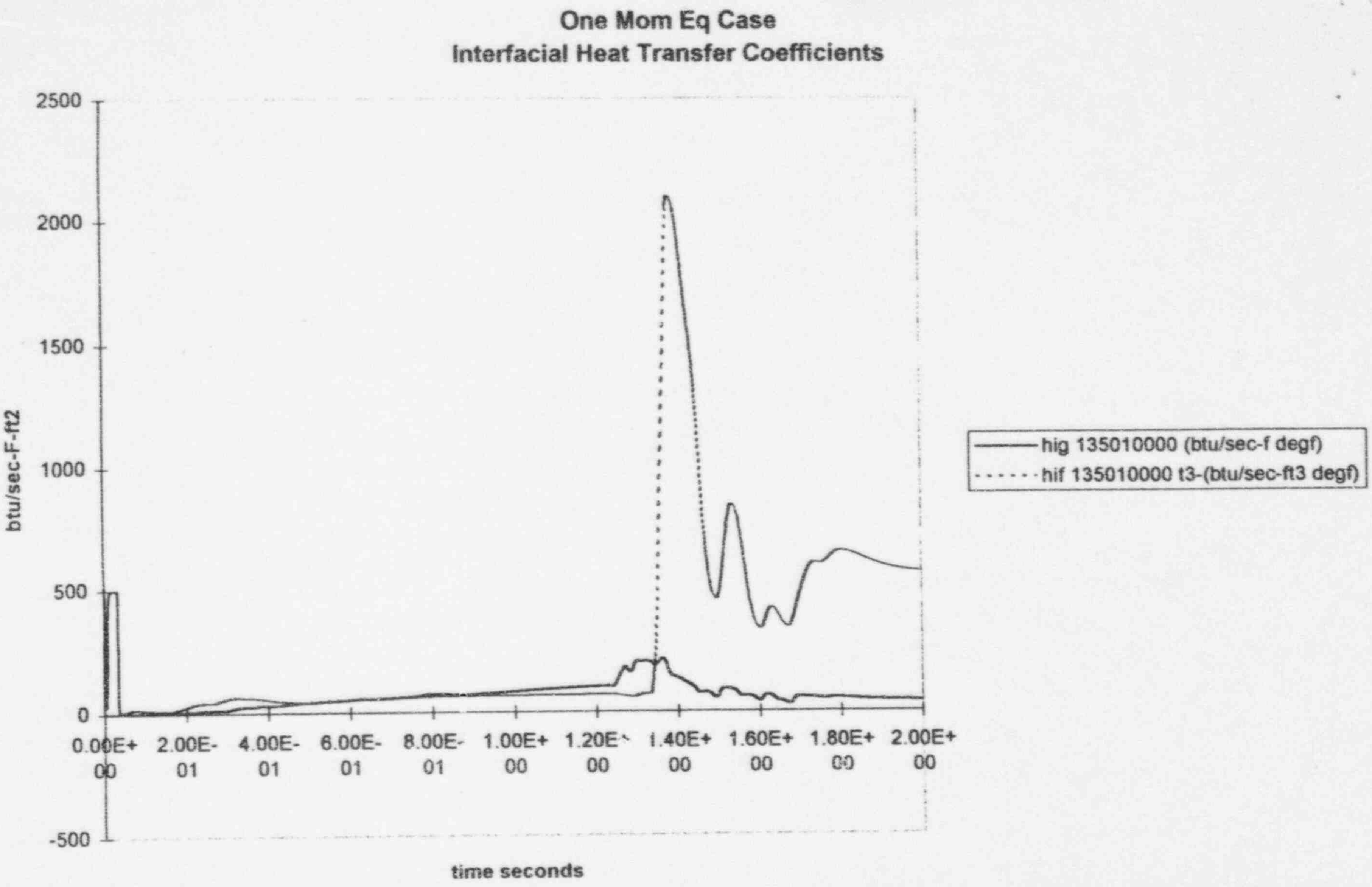
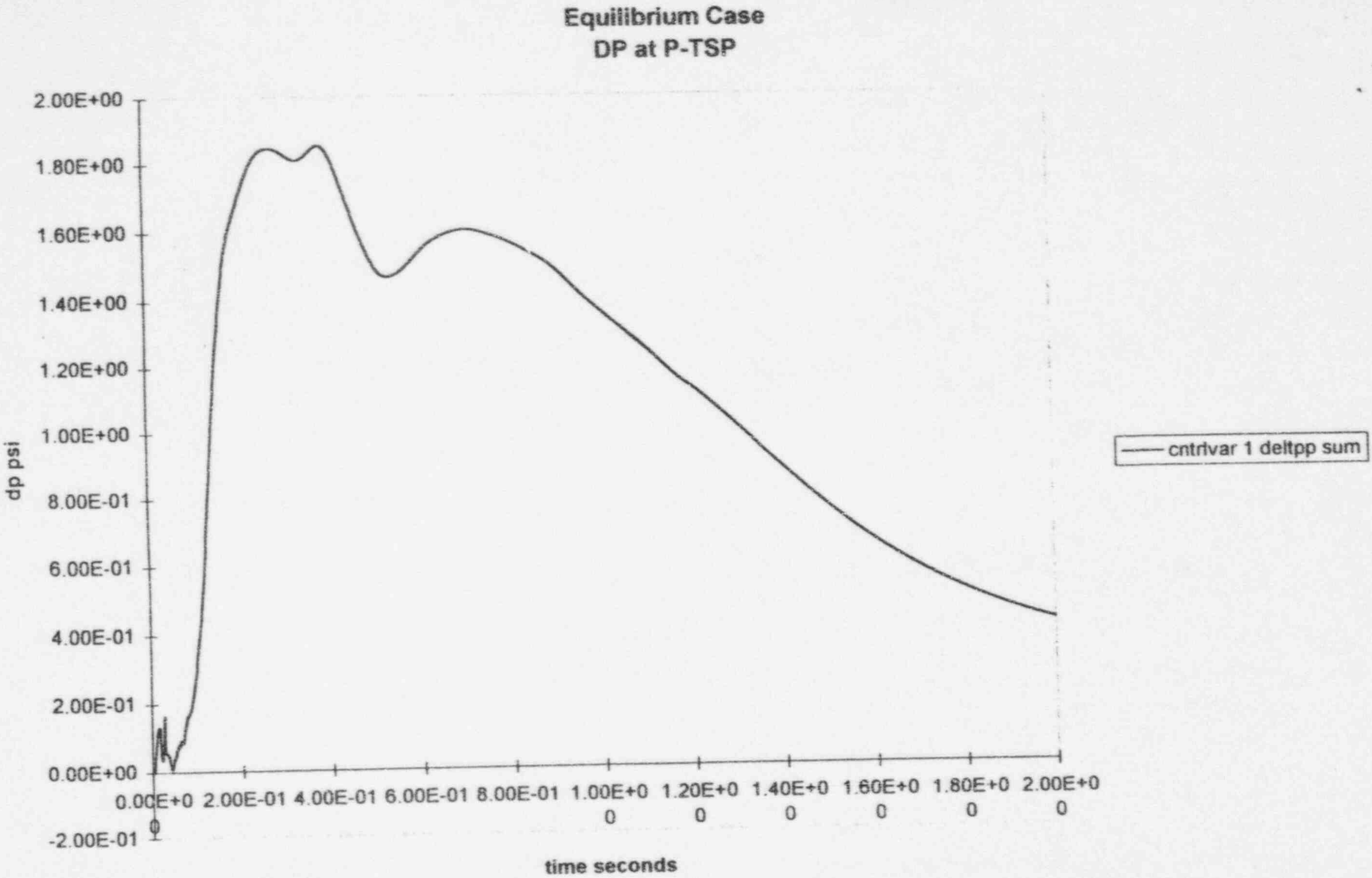

One Mom Eq Case
Interfacial Heat Transfer Coefficients
btu/sec-F-ft2
2500
2000
1500
1000
500
0
-500
0.00E+00
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+00
1.20E+00
1.40E+00
1.60E+00
1.80E+00
2.00E+00
time seconds
hig 135010000 (btu/sec-f degf)
hif 135010000 t3-(btu/sec-ft3 degf)

Figure 17


Equilibrium Case
DP at P-TSP
2.00E+00
1.80E+00
1.60E+00
1.40E+00
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
-2.00E-01
dp psi
0.00E+00
2.00E-01
4.00E-01
6.00E-01
8.00E-01
1.00E+00
1.20E+00
1.40E+00
1.60E+00
1.80E+00
2.00E+00
time seconds
cntrlvar 1 deltpp sum