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PG&E Letter DCL-00-030

U.S. Nuclear Regulatory Commission
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Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Response to NRC Reactor Systems Branch Questions Regarding WCAP-14707

Dear Commissioners and Staff:

On October 4, 1996, PG&E submitted WCAP-14707 (proprietary) and WCAP-14708 (nonproprietary), "Model 51 Steam Generator Limited Tube Support Plate Displacement Analysis for Dented or Packed Tube to Tube Support Plate Crevices," as part of DCL 96-206. Section 10 of the WCAP was provided in Revision 1, submitted to the NRC on May 30, 1997 in DCL-97-104. These WCAPs evaluate the impact of corrosion product accumulation in the tube to tube support plate (TSP) intersections in Diablo Canyon Power Plant (DCPP) Model 51 Steam Generators. This accumulation of corrosion products effectively locks the tubes to the TSPs. PG&E plans to apply the conclusions of WCAP-14707 to a future alternate repair criteria for primary water stress corrosion cracking at dented TSP intersections.

In a letter to PG&E dated December 13, 1999, the NRC requested additional information based on their review of WCAP-14707. PG&E's response to this request for additional information is provided in Enclosure 1.

Sincerely,

Lawrence F. Womack

cc: Edgar Bailey, DHS
Steven D. Bloom
Ellis W. Merschoff
David L. Proulx
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Enclosures

no prop. info
per. Steven Bloom

A001

Responses to NRC Reactor Systems Branch Questions Regarding WCAP-14707

General Information

Several of the following NRC requests for additional information question: 1) the relationship between the TRANFLO and RELAP5 computer programs; 2) the sensitivity studies performed to support the WCAP-14707 results; and, 3) the benchmarking performed to verify that the RELAP5 computer code is applicable to PG&E's Model 51 Steam Generators (SGs). PG&E has addressed these questions in the following general manner:

- As explained in the response to Request 1, the conclusions in WCAP-14707 are based only on the results of the RELAP5 computer code. Therefore, none of the PG&E responses address the TRANFLO computer code.
- Previous studies and submittals to the NRC have documented the sensitivity of the tube support plate (TSP) pressure drop results given by the RELAP5 code to changes in the model. The responses to Requests 4 and 5 relate these sensitivity studies to the TSP pressure drop results for the PG&E Model 51 SG presented in WCAP-14707.
- Reference 3 (previously submitted to the NRC) documents a comparison of model boiler test results to the RELAP5 computer code. The responses to Requests 5 and 8 explain why these benchmark results are also applicable to the Model 51 SG results submitted in WCAP-14707.

NRC Request 1:

Please provide the paper version of Reference 6: "TRANFLO: A computer Program for Transient Thermal Hydraulic Analysis with Drift Flux," MPR663, November 1980 and the computer code in electronic format.

PG&E Response:

The requested reference is not being provided, based on the discussion below.

The TSP displacement analyses of WCAP-14707 are based on application of hydraulic loads on the TSPs developed from the RELAP5 computer code. The TRANFLO results are provided in WCAP-14707 as an independent analysis supporting the magnitude of the loads obtained from the RELAP5 code. The report includes sensitivity results obtained using the TRANFLO code, and the conclusions from these results are essentially the same as found using RELAP5 for prior Model D4 SG analyses performed for Byron/Braidwood. The sensitivity trends of the hydraulic loads to input conditions are essentially independent of the SG model. Consequently, RELAP5 is the code of record for the conclusions of WCAP-14707. PG&E is not taking credit for any of the TRANFLO results and is basing all conclusions on the RELAP5 code results. Therefore, as discussed with the NRC on July 2, 1999, PG&E is only providing NRC requested information for the RELAP5 code.

NRC Request 2:

Please provide a description of all input assumptions used for the TRANFLO and RELAP5 analyses. If "input calculation notebooks" have been prepared for these analyses, provide copies of the notebooks.

PG&E Response:

The TRANFLO information is not being provided since only the RELAP5 analysis results will be used for any future license amendment requests as discussed in PG&E response to NRC request 1. All of the PG&E methodology, model development, and assumptions for performing the RELAP5 analysis of the TSP pressure drops during a Main Steam Line Break (MSLB) in the Model 51 SG are documented as Enclosure 2 to this letter in Calculation Notebook STA-042, dated October 2, 1996.

NRC Request 3:

Please provide the TRANFLO and RELAP5 input decks in electronic form.

PG&E Response:

The TRANFLO information is not being provided since only the RELAP5 analysis results will be used for any future license amendment requests as discussed in PG&E response to NRC request 1. The complete listing of the following five RELAP5 input decks which were developed, discussed, and documented in the Calculation Notebook STA-042 are being provided. These input decks generated the five RELAP5 cases presented in Table 7-1 of WCAP-14707 (Reference 6) and summarized below.

Input deck	**Case Description**
reidp1	Large Break Case 1 - No flow restrictor, Non-equilibrium
reidp2	Large Break Case 2 - No flow restrictor , Equilibrium
reidp3	Small Break Case 1 - Flow restrictor, Non-equilibrium
reidp4	Small Break Case 2 - Flow restrictor, equilibrium
reidp5	Large Break Case 2 - No flow restrictor, Non-equilibrium, water level sensitivity

Hard copy listings of these input decks are included in Enclosure 3. An electronic copy text version of each file is also enclosed on a 3 1/2" floppy disk.

NRC Request 4:

Please provide all nodalization sensitivity studies performed for both TRANFLO and RELAP5.

PG&E Response:

As previously discussed, PG&E is only crediting the RELAP5 code for determination of the pressure drop across the TSP during a MSLB. Therefore, only RELAP5 sensitivity studies are discussed here. PG&E performed RELAP5 sensitivity studies for the initial steam generator water level and the TSP loss coefficient for the Model 51 SG. These results are presented in Table 7-1 and 7-2 of WCAP-14707 (Reference 6) and demonstrate that the PG&E RELAP5 model generated conservatively large pressure drop values.

PG&E did not perform explicit nodalization studies for the Model 51 SG since significant similar RELAP5 analyses have been performed for the D4 and Model E steam generators. The characteristic RELAP5 hydraulic response generated for these sensitivity studies was determined to be directly applicable and considered as the basis for estbalishing an appropriately conservative Model 51 nodalization. These sensitivity results are presented in their entirety, in References 1 and 2, but a summary of the significant conclusions as applicable to the Model 51 analysis is presented below.

Model D4 Nodalization Sensitivity Studies

The RELAP5 evaluation of a Model D4 SG TSP pressure drops during a steam line break from hot standby is reported in Reference 1. The following reviews the results of the nodalization sensitivity cases evaluated in this reference.

The base case nodalization was designed to obtain the calculated junction pressure drops directly from the average pressure for the RELAP5 nodes on either side of the TSP. This nodalization was used to simplify the data reduction process, and obtain TSP pressure drop results directly from the code output without having to perform subsequent calculations. Since RELAP5 calculates the pressure value at the centroid of each individual node, the nodes adjacent to the junction representing the TSP must be small in order for the difference in the average values to physically represent only the pressure drop across the junction. As the selected node size increases, the centroid is farther from the TSP junction, and the calculated adjacent average pressures include additional elevation and velocity effects ocurring within the nodes, but which are actually upstream and downstream of the junction. This is important since the loads on the TSPs are established only by the change in pressure experienced directly across the TSP itself.

In order to ensure that using small nodes adjacent to the TSP did not introduce some bias into the calculated pressure drop results, an alternate model was analyzed with the additional thin nodes eliminated. The two models appear, respectively, in Figures 1 and 2 from Reference 1.

As discussed earlier, when using large nodes, the RELAP5 calculated average fluid properties at the centroid no longer accurately represent the conditions directly at the TSP. Therefore, it is not appropriate to directly compare the large node average pressure values with those obtained using the smaller nodes. The RELAP5 calculated pressure drop across a junction is of the form $\Delta P = K \times \rho \times v^2$. Since the loss coefficient K is a constant, and the fluid density ρ does not change significantly, the dominant term in the equation is the fluid velocity squared. Therefore, comparing the calculated fluid velocity at the TSP junctions for the two models is indicative of any relative difference in the pressure drop. Figures 9, 10 and 11 of Reference 1 compare the fluid velocities across the F, M & P support plates for the two models. These are the second, fourth and seventh (top) tube support plates in the Model D4. The character and magnitude of the velocity transients are seen to be minimally changed. Table 1 lists peak velocities for the three plates and each model. Using the fact that pressure drops are proportional to the velocity squared, Table 1 also estimates the effect on pressure drops which results from the alternate nodalization. The results establish that the RELAP5 calculated pressure drop is not sensitive to the size of the nodes used. This is expected since the tube bundle geometry for Westinghouse Steam Generators is essentially axially uniform except for the TSPs themselves. Therefore, the modeling of the TSP geometry and in particular the junction loss coefficient are the key factors in determining the dynamic pressure drop, as presented for the Model 51 SG in WCAP-14707.

Table 1 Effect of Nodalization on Fluid Velocities and Pressure Drops

Nodalization Case	Support Plate Peak Velocities and Pressure Drop Effect		
	F TSP	L TSP	P TSP
Base	0.62	1.24	1.80
Alternate	0.61	1.22	1.79
Pressure Drop Effect %	3.0	3.3	1.1

Model E Nodalization Sensitivity Studies

The RELAP5 evaluation of a Model E steam generator, for TSP pressure drops during a steam line break from hot standby, is reported in Reference 2. The following reviews the results of the nodalization sensitivity cases evaluated in this reference.

The base case nodalization for the determination of the Model E tube support pressure drops is schematically pictured in Figure 4-1 and pictured as a network in Figure 4-3 in Reference 2. Two nodalization alternatives were examined in the Model E evaluation. Since the base case for the Model E used large node sizes, a sensitivity study was performed using thin nodes similar to the Model D4 RELAP5 model. Second, a radial discretization in the upper bundle was performed to evaluate the validity of the one dimensional flow assumptions there.

Thin Support Plate Nodes

The loads on the tube support plates are a result of the pressure difference across the tube support plate. For a transient analysis, the pressure difference between two nodes calculated by RELAP5 includes terms in the momentum equation which are not directly applied to the support plates. Therefore, the direct use of the pressure difference between the adjacent nodes may result in a significant over-estimate of the load on the tube support plate. The Model E analysis used the density and the velocity of the fluid mixture passing through a support plate to determine the load on the support plate given the loss coefficient. The Model D4 analysis used thin nodes adjacent to the support plates so the pressure difference could be calculated directly from the average node pressure. This alternate Model E case uses the Model D4 thin node approach to calculate the loads on the support plates for comparison to the Model E base case results. Figure 5.24 in Reference 2 shows that the calculated pressure drops for the R & Q plates which experience the largest pressure drops, (see Figure 4-1 in Reference 2) do not vary significantly between the two cases. This demonstrates again that the RELAP5 code is not sensitive to the node size used to model the tube bundle volumes for Westinghouse steam generators.

Model Radial Discretization

The base case Model E analysis assumed one dimensional flow in the tube bundle by specifying a single flow path in the upper tube bundle (see Figure 4-1 of Reference 2, nodes 39-34). To determine the effect of radial variation of fluid conditions in the tube bundle, three nodes near the top of the tube bundle were subdivided radially for this analysis case. The added nodes to the upper bundle are pictured in Figure 4-6 of Reference 2. This analysis case permits examination of radial pressure variation on TSP pressure differences.

The addition of two radial nodes to three nodes in the upper part of the bundle had no material effect on the steam line break (SLB) transient and the radial variation of pressure difference across the plate was not significant. Figure 5.27 of Reference 2 shows no discernible difference in the blowdown characteristics from the baseline. Figure 5.28 of Reference 2 shows that the pressure difference transients for the Q & R plates are also unchanged. In addition, Figures 5-29 and 30 of Reference 2 show that the radial variation of pressure difference across these Q & P plates is not significant. This evaluation confirms that the one dimensional treatment of blowdown in the tube bundle is appropriate for calculating TSP loads.

Both the cases described above demonstrate the insensitivity of the tube support plate pressure drops to RELAP5 model nodalization changes.

<u>NRC Request 5:</u>

Please provide all assessment analyses performed for both TRANFLO and RELAP5, including descriptions of the test facilities, code input models, and code results/data comparisons.

<u>PG&E Response:</u>

RELAP5 has been benchmarked for a blowdown transient using the Model Boiler 2 (MB2) test facility. This test computer model comparison is documented in detail in Reference 3. The report includes a description of the RELAP5 modeling of the test configuration, the code results obtained, and comparison with the test data. What follows is a summary of the report comparison results. This summary is only meant to provide an overview of the results contained in the reference which should be consulted for more details on all aspects of the comparison. Material presented is drawn directly from the reference.

The MB2 test article represents a 1% scale model of the Model F, feedring steam generator. The model contains a tube bundle, tube support plates, and upper internals simulating the Model F SG. The model F, in turn, is quite similar to the Model 51 SG which contains these same elements. A diagram of the test article bundle region, showing the tube support plates and pressure taps, is found in Figure 3-7 from Reference 4 and included in Appendix C of Reference 3.

A SLB test of MB2 was conducted, collecting pressure differences across the tube support plates. A RELAP5 model (Figure 1 in Reference 3) was developed to simulate this test article. A SLB transient, from the same initial conditions, was run using the RELAP5 model.

Several figures from Reference 3, show the base case results, comparing RELAP5 output with the test data. Figure 2 in Reference 3 presents the dome pressure blowdown rate for the transient showing comparable decay rates for the test and RELAP5 results. Figures 4 through 9 in Reference 3 present the MB2 test data for pressure drops and RELAP5 results for TSP pressure drops. Each pressure difference compared has a different zero time value as a result of static pressure differences. However, considering the pressure drop change from the initial value to the peak value, the results show that RELAP5 predicts larger pressure differences than shown in the test. Reference 3 discusses these results in more detail and also presents the results from a non-equilibrium case.

Reference 3 concludes that RELAP5 can be used to develop conservative pressure loads on the tube support plates during steam line break conditions - a principal purpose of the calculation. The above summary presents only a fraction of the results in Reference 3 which can be reviewed for additional details.

NRC Request 6:

Please provide the results of Model 51 steam generator analyses performed using the RELAP5 code, including pressure drops, void fractions, and mass flow rates (all phases) for all nodes within the steam generator.

PG&E Response:

RELAP5 output data has been provided for the Large Break Case 2 since these were the pressure drop results used to calculate the tube support plate forces in WCAP-14707 (Reference 6). The output values include the pressures for each of the sixteen volumes, and the mass flow rates and void fractions for each of the seventeen inter-volume flow junctions located on the secondary side of the RELAP5 Model 51 SG model. This data was obtained using a standard RELAP5 strip file so that the data frequency is consistent with the minor edit frequency of the original restart output file. This data has been uploaded into the following EXCEL files which are contained on the enclosed 3 1/2" floppy disks:

Junction vapor void fractions file - stripvjfg.xls , sheet stripvjfg1!

Junction mass flow rates file -	stripjun.xls ;	sheet stripjun_lb! ,	(lb/sec)
		sheet stripjun_kg! ,	(kg/sec)
Volume pressure file -	strippre.xls ;	sheet strippre1_psi!,	(psi))
		sheet strippre1_pa!,	(Pascal)

Using simple mathematical manipulations, this data can be used to generate the pressure drops and the liquid void fractions for the secondary side.

It should be noted that since the exact input decks are being provided as part of this response, each of the five RELAP5 case output results can be reproduced, and any additional desired data can be obtained using a standard RELAP5 strip file.

NRC Request 7:

Please provide all user guidance documents in the possession of Westinghouse or Pacific Gas and Electric that describe or otherwise relate to the use of the TRANFLO code.

PG&E Response:

No action required per the discussion in response to NRC Request 1.

NRC Request 8:

Please provide a description of the dominant physical processes, the needed model capabilities, how the chosen tool meets these needs, and the inherent uncertainties in the chosen model.

PG&E Response:

For the present program, the key results required from the MSLB analysis of the Model 51 SGs are the time dependent loads on the tube support plates during the event. The postulated MSLB from a steam generator at hot standby involves depressurization initiated fluid motions. The loads on the plates are proportional to the pressure drop created due to the fluid moving across the plates. Therefore, given an appropriate loss coefficient to represent the TSP junction geomtery, the code must adequately calculate the pressure drop across the plate for the two phase flow conditions which would occur as a result of a MSLB depressurization event.

The RELAP5 Code was explicitly designed to model and predict such dynamic two phase condtions. The code calculates and solves the momentum, energy and continuity equations separately for both the liquid and vapor phases. This allows RELAP5 to calculate non-equilibrium conditions between the liquid and vapor phases which is critical for predicting behavior during a MSLB. The present code and its predecessors have been and continue in wide use throughout the industry. The code has been benchmarked against a number of blowdown tests including the MB2 test described in the response to NRC Request 5. Additionally, the code has been extensively tested in LOCA applications and has been used for licensing applications by vendors and utilities.

The most useful application of RELAP5 is the modeling of the MB2 steam generator described in NRC Request 5. The MB2 test article has all the same steam generator elements as the Model 51 SG, including a tube bundle with tube support plates, the steam drum upper internals and a downcomer. Therefore, the MB2 model accurately predicts a Model 51 SG response. RELAP5 conservatively calculated tube support plate pressure drops during a simulated steam line break. The code also reproduced other aspects of the blowdown such as the rate of depressurization and the indicated flow split in the bundle which are characteristic of the Model 51 response during a MSLB event.

The previous discussions have already demonstrated that the key MSLB physical phenomenon are consistent between the Model 51 and the D4 SG models which have similar tube bundle geometries for evaluating pressure drop effects. The PG&E analysis also used the same version of the RELAP5 computer code as was used in the Commonwealth Edison (ComEd) Reference 5 report, which supported a similar license amendment request for the D4 SG. However, there were some minor modeling option differences between the PG&E analsysis and the ComEd analysis. Therefore, the original WCAP-14707 results were evaluated and found not to be significantly impacted when using the same RELAP5 modeling options as documented in the Reference 5 ComEd report.

Only the limiting Large Break Case 2 (LB2) from WCAP-14707 was evaluated since all five of the previously analyzed cases generated similar overall thermal hydraulic characteristic responses. The main difference was in the rate of depressurization and the subsequent peak pressure drop magnitude which was due more to the break size and initial steam generator conditions than the model options selected. Table 2 lists the RELAP5 modeling options for each junction and volume within the model and compares the original PG&E option selections to the ComEd D4 model options.

Figure 1 of this enclosure compares the original Model 51 pressure drop across the number seven tube support plate, with the results obtained with the revised model which implements the ComEd model options which were used for the D4 SG analysis. The results indicate that the characteristic response is not significantly changed, but the peak pressure is actually reduced for the D4 options case. In order to identify the source for the reduced peak pressure results, two additional sensitivity studies were performed. Since the ComEd analysis used longer time step intervals as summarized in Table 3 of this enclosure, the PG&E Model 51 SG was rerun using these time step values. The results plotted on Figure 1 show that this revision had an insignificant effect on the results. This is expected since the ComEd time step sensitivities in Reference 6 demonstrated that the time step size was appropriately small for the D4 analysis.

A second additional sensitivity case was performed using all of the D4 modeling options except for the restoration of the abrupt area change option, which was used in the original PG&E model as summarized in Table 2 of this enclosure. The abrupt area change is a RELAP5 option to model junctions with a significnat change in cross section geometry such as valves and flow orifices. If not enabled, then RELAP5 calculates the pressure drop across the junction based on smooth geometry transition correlations. These results are also plotted on Figure 1 of this enclosure, and demonstrate that the D4 case with the abrupt area change option generated essentially the same peak pressure response as the original PG&E Model 51 SG analysis.

These results demonstrate that the SGTSP loads calculated by the original PG&E Model 51 SG RELAP5 model are not significantly affected by the slight differences in modeling options that were used in the Reference 6 analysis. In addition, the PG&E model predicts conservatively larger pressure drops with respect to the same conditons evaluated by the NRC approved ComEd model for the D4 SG.

Table 2: RELAP5 Model Option Comparison

Model Option Description	**PG&E Original Model 51 Option**	**Revised PG&E Model 51 Option (ComEd D4 Model Option)**
Volume Control Flags - tlpvbfe		
t - Thermal Front Tracking Model	off	off
l - Mixture Level Tracking Model	off	off
p - Water Packing Scheme	on	on
v - Vertical Stratification Model	on	on (except separator volume)
b - Interphase Friction Model	rod bundle correlation in tube bundle volumes, pipe correlation elsewhere	rod bundle correlation in tube bundle volumes, pipe correlation elsewhere
f - Wall Friction Calculation Model	on (except separator)	on (except separator and dome volumes)
e - Equilibrium Calculation Model	off (except tube bundle volumes)	off (except tube bundle volumes, downcomer, preheater)
Junction Control Flags - efvcahs		
e - Modified PV Term in Energy Equation	off	off
f - Counter Current Flow Limit (CCFL) Option	off	off
v - Horizontal Stratification Model	off	off (except tube bundle riser, steam dryer, upper dome, and SG exit nozzle junctions)
c -Choking Option Model	on	on (except for primary side junctions)
a - Abrupt Area Change Option	off (except feedring, separator, and pipe break junctions)	off (except for SG exit nozzle and break junctions)
h - Non/homogenous Momentum	on	on

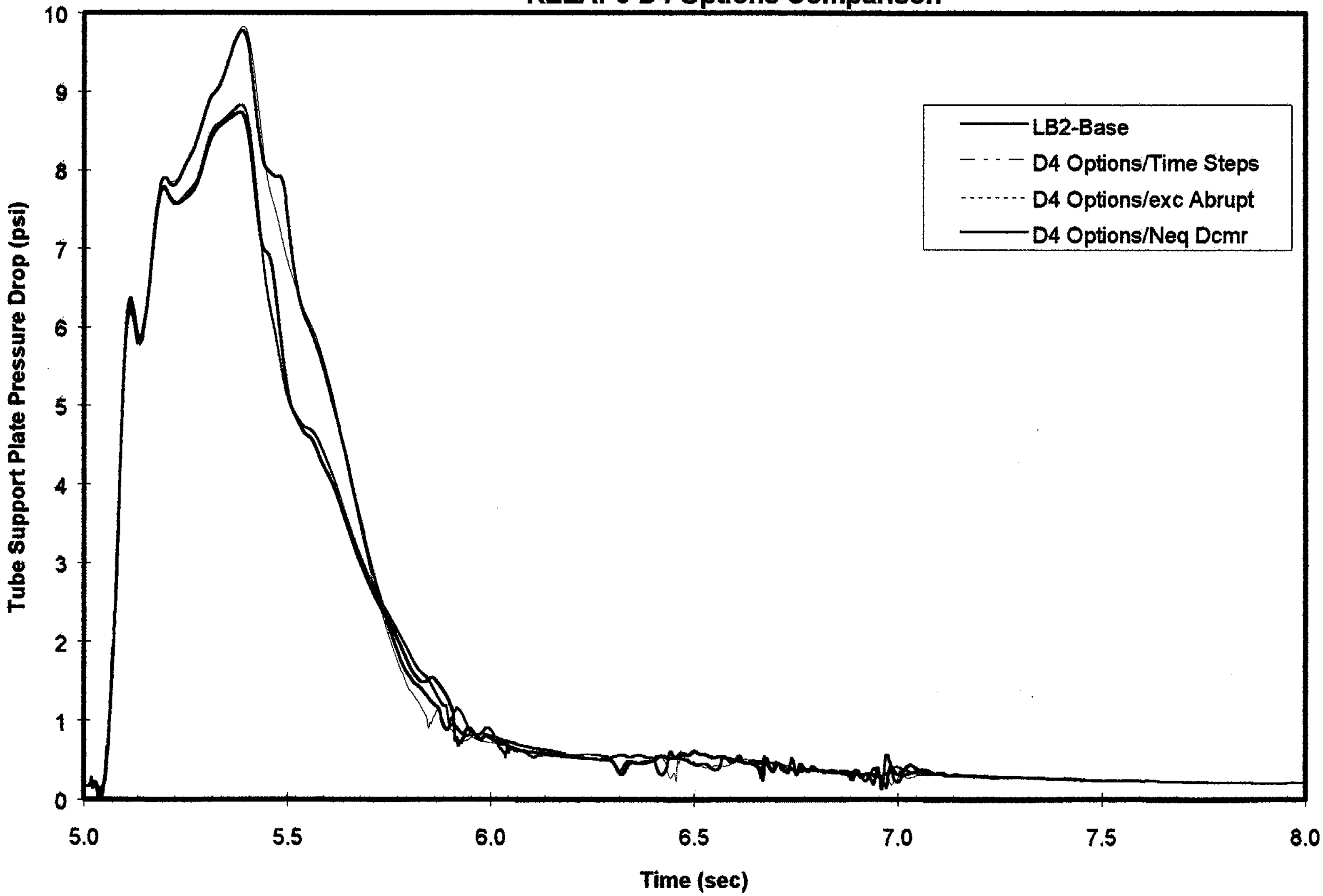
Model Option Description	**PG&E Original Model 51 Option**	**Revised PG&E Model 51 Option (ComEd D4 Model Option)**
Equation Option		
s - Momentum Flux Option	on	on
Separator Junction Option	default	default

Table 3: RELAP5 Model Time Step Comparison

	PG&E Original Model 51 Option		Revised PG&E Model 51 Option (ComEd D4 Model Option)	
RELAP5 Time Interval Definition	dtmin	dtmax	dtmin	dtmax
Prior to MSLB occurrence	1.E-7	0.005	1.E-7	0.0001
MSLB Break and up to 0.3 sec. after	1.E-7	0.00001	1.E-7	0.0001
Up to 1.0 seconds after MSLB	1.E-7	0.00001	1.E-7	0.0001
Up to 1.5 seconds after MLSB	1.E-7	0.000025	1.E-7	0.0001
Up to 2 seconds after MSLB	1.E-7	0.000025	1.E-7	0.0005
To end of analysis	1.E-7	0.00005	1.E-7	0.001

Figure 1

Tube Support Plate 7 Pressure Drop
Case LB2, No Restrictor, Equilibrium
RELAP5 D4 Options Comparison



References

1. Kevin B. Ramsden, Calculation of Byron 1/ Braidwood 1 D4 Steam Generator Tube Support Plate Loads with RELAP5M3, ComEd Report PSA-B-95-17, October, 1995.

2. WCAP-15163, Rev. 1, Technical Support for Implementing High Voltage ARC at Hot Leg Limited Displacement TSP Intersections for S. Texas Unit 2 Steam Generators, March, 1999.

3. Kevin B. Ramsden, A RELAP5M3 Comparison of Model Boiler 2 Main Steam Line Break from Hot Zero Power Test, ComEd Report PSA-B-95-18, October, 1995.

4. NUREG/CR-4751, Loss of Feed Flow, Stram Generator Tube Rupture and Steam Line Break Thermohydraulic Experiments, MB-2 S/G Transient Response Program, October 1986.

5. Commonwealth Edison Calculation PSA-B-95-17 Rev. 0, :Calculation of Byron / Braidwood 1 D4 Steam Generator Tube Support Plate Loads with RELAP5M3," 10/11/95.

6. WCAP-14707, "Model 51 Steam Generator Limited Tube Support Plate Displacement Analysis for Dented or Packed Tube to Tube Support Plate Crevices," August 1996.