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Subject: Steam Generator Internal Loading Following a Main Steam Line Break (MSLB) or Feedwater Line Break (FWLB)

Please find attached the Westinghouse response to a recent review and conclusions drawn by the Office of Nuclear Regulatory Research, US Nuclear Regulatory Commission (NRC) on steam generator internal loading following a main steam line break (MSLB) or feedwater line break (FWLB). Topics covered in this correspondence include:

1. Statement of the Issue
2. Evaluation of the Issue
3. Conclusion
4. References

Westinghouse concludes that the steam generator (SG) internal loading calculated by the NRC's TRACE computer code are comparable to conservative bounding calculations and to code results calculated by Westinghouse using the RELAP5 computer code as well as those from the use of TRANFLO. This is contrary to the Office of the Nuclear Regulatory Research's conclusion that the TRANFLO code led to non-conservative results.

If there are any questions in response to this correspondence, please contact Gary Whiteman at (724) 722-5584.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

cc: W. A. Macon
E. S. Peyton

Verification of Results from the TRANFLO Computer Program for Calculating Steam Generator Internal Loading Following Steam Line Break

1. Statement of the Issue

The issue is as follows: Material used at the recent presentation by the Office of Nuclear Regulatory Research to the Advisory Committee on Reactor Safeguards Joint Materials and Metallurgy and Thermal-Hydraulics Subcommittees on February 3, 2004 concluded that SG internal hydraulic loads calculated by the TRACE computer code during postulated steam line break (SLB) events are comparable to those obtained from conservative bounding calculations and to results calculated by Westinghouse using the RELAP5 computer code, but do not agree with Westinghouse TRANFLO calculations.

The above conclusion was drawn in the presentation by William J. Krotiuk, Office of Nuclear Regulatory Research (NRR), US Nuclear Regulatory Commission, and documented in "Steam Generator Internal Loading Following MSLB or FWLB," as a response to GSI-188, SG TAC No. 3.1a, 3.1b, 3.1c. The above document is a part of a progress report entitled "Progress on Steam Generator Action Plan Milestones – Overview" (Reference 1).

The Westinghouse response to the above issue concludes that the SG internal loadings calculated by TRACE are comparable to those from conservative bounding calculations and to code results calculated by Westinghouse using RELAP5 as well as TRANFLO. This is counter to the conclusion reached by the NRR representative with regard to the results from the TRANFLO computer code.

The above conclusion drawn by Westinghouse is supported by the following evaluation.

2. Evaluation of the Issue

Mr. Krotiuk presented results from the calculation of SG internal loads by TRACE and compared them with loads calculated by both the RELAP5 and TRANFLO codes, and included the comparison in a review package of 16 slides with a title "Steam Generator Internal Loading Following MSLB or FWLB," that became part of the package of Reference 1. Westinghouse has found that two slides, i.e., WJK-10, and WJK-15, involve incorrectly quoted numerical results from the TRANFLO code calculations, and one slide, i.e., WJK-16, that involves an incorrect conclusion regarding the TRANFLO calculations. The original three slides are reproduced herein as Tables 1, 2 and 3.

Apparently, the internal loading tabulated on both WJK-10 and WJK-15 were taken from a Westinghouse evaluation related to alternate repair criteria, a.k.a. ARC, for the Diablo Canyon Power Plant (DCPP) Steam Generators (SGs) that used the RELAP5/MOD3 code (WCAP-16170-P, Revision 0, Reference 2). The Diablo Canyon WCAP (Reference 2) documents a sensitivity study which was performed using TRANFLO. The results from the sensitivity study were used to develop a conservative multiplier for scaling (increasing) the internal loading results calculated by RELAP5/MOD3.

Section 4.6 in Reference 2 is entitled "Sensitivity Evaluation of SLB Hydraulic Loads and Uncertainty Factor." Table 4-7 in Reference 2 tabulates the TRANFLO analysis matrix. Table 4-8 in Reference 2 tabulates the peak pressure drops for seven tube support plates (TSPs). The Reference 2 sensitivity analysis matrix details are given in WCAP-14707, Reference 3. In Reference 3, Section 6.1, Analysis Plan, <u>Reference Analyses</u>, second paragraph, it is stated that:

"All TRANFLO cases were run under the assumption of an integral steam nozzle flow restrictor with a throat area of 1.4 ft^2."

As a result, one of the following conditions was used in all TRANFLO calculations reported on in Tables 4-7 and 4-8 in WCAP-16170-P (Reference 2):

- a 1.5 ft^2 pipe break occurred downstream of a 1.4 ft^2 flow restrictor, or
- a guillotine pipe break of 4.6 ft^2 occurred downstream of a 1.4 ft^2 flow restrictor.

Both WCAP-16170-P and WCAP-14707, References 2 and 3 respectively, did not include the internal loading calculated by TRANFLO for a break size of 4.6 ft^2 without a 1.4 ft^2 flow restrictor being present, because there were no calculations for such a situation.

Table 4 tabulates results of the loads as calculated by TRANFLO Case 1, and reported on in both WCAP-16170-P and WCAP-14707. TRANFLO Case 1 was noted to be directly comparable to RELAP5 Case SB2 in the detailed case discussion in Reference 3. The SB2 loading values were given in Table 4-3 in Reference 2. As noted in Table 4, there are no calculations for a break size of 4.6 ft^2 without the 1.4 ft^2 flow restrictor.

Based on this discussion, Tables 1, 2 and 3 are revised herein to appear as Tables 5, 6 and 7, respectively. As shown in Table 5, the loadings to various TSPs calculated by TRANFLO (Case 1) are comparable to those by TRACE and RELAP5 (Case SB2), even without applying the 1.5 uncertainty multiplier.

Table 7 provides a corrected viewgraph to supersede that of Table 3 in order to appropriately conclude that the SG internal loads calculated by TRACE are comparable to conservative bounding calculations and to code results calculated by Westinghouse using RELAP5 and TRANFLO.

3. Conclusion

According to the above discussion, it is concluded that the SG internal loads calculated by TRACE are comparable to conservative bounding calculations and to code results calculated by Westinghouse using RELAP5 and TRANFLO.

4. References

1. Muscara, J., "Progress on Steam Generator Action Plan Milestones – Overview," ACRS Joint Materials and Metallurgy and Thermal-Hydraulics Subcommittees, US NRC Office of Nuclear Regulatory Research, Division of Engineering Technology, February 3 and 4, 2004.
2. "Diablo Canyon SG Alternate Repair Criteria Based on Limited Tube Support Plate Displacement," Westinghouse WCAP-16170-P, Revision 0, November 2003.
3. "Model 51 Steam Generator Limited Tube Support Plate Displacement Analysis for Dented or Packed Tube to Tube Support Plate Crevices," Westinghouse WCAP-14707, Revision 0, August 1996.

Table 1

TSP Loadings at Hot Standby

	4.6 ft^2 MSLB TRANFLO	4.6 ft^2 MSLB RELAP5	4.6 ft^2 MSLB TRACE
TSP 7 (Top)	2.46 psi (3.69* psi)	9.6 psi	8.57 psi
TSP 6	1.82 psi (2.73* psi)	8.1 psi	5.06 psi
TSP 5	1.25 psi (1.88* psi)	6.1 psi	3.84 psi
TSP 4	0.91 psi (1.37* psi)	4.5 psi	2.63 psi
TSP 3	0.58 psi (0.87* psi)	3.2 psi	1.16 psi
TSP 2	0.31 psi (0.47* psi)	2.0 psi	0.15 psi
TSP 1 (Bottom)	-0.12 psi (-0.18* psi)	1.9 psi	-0.33 psi

	1.5 ft^2 MSLB TRANFLO	1.4 ft^2 MSLB RELAP5	1.4 ft^2 MSLB TRACE
TSP 7 (Top)	1.67 psi (2.51* psi)	2.26 psi	2.68 psi
TSP 6	1.22 psi (1.83* psi)	2.14 psi	1.70 psi
TSP 5	0.83 psi (1.25* psi)	1.56 psi	1.23 psi
TSP 4	0.53 psi (0.80* psi)	1.35 psi	0.87 psi
TSP 3	-0.28 psi (-0.42* psi)	1.23 psi	0.43 psi
TSP 2	-0.23 psi (-0.35* psi)	1.25 psi	0.08 psi
TSP 1 (Bottom)	-0.26 psi (-0.39* psi)	1.12 psi	-0.06 psi

Note, an upward directed pressure differential is defined as positive
*TRANFLO values with Westinghouse recommended 1.5 uncertainty multiplier.

Table 2

SG Conservative Bounding Calculations

TSP Peak Pressure differential Comparisons for 4.6 ft^2 MSLB
With System Initially at Hot Standby

	TRANFLO	RELAP5	TRACE	Moody/Acoustic Calc. &
TSP 7 (Top)	2.46 psi	9.6 psi	8.57 psi	9.0 psi
TSP 6	1.82 psi	8.1 psi	5.06 psi	7.6 psi
TSP 5	1.25 psi	6.1 psi	3.84 psi	6.4 psi
TSP 4	0.91 psi	4.5 psi	2.63 psi	5.4 psi
TSP 3	0.58 psi	3.2 psi	1.16 psi	4.6 psi
TSP 2	0.31 psi	2.0 psi	0.15 psi	3.8 psi
TSP 1 (Bottom)	-0.12 psi	1.9 psi	-0.33 psi	3.3 psi (1.6# psi)

Note, an upward directed pressure differential is defined as positive.
& Differential pressure conservatively calculated ignoring depressurization wave travel through annular feedwater region.
# TSP 1 pressure differential adjusted for depressurization wave travel through annular feedwater area.

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Table 3

SG Loading Following MSLB or FWLB

- **Generic Safety Issue 188 and SG Action Plan Items 3.1a, 3.1b, 3.1c**
  - Perform thermal-hydraulic calculations using TRACE to assess loads on a Steam Generator tube support plate and tubes following MSLB or FWLB

- **Conclusions:**
  - TRACE is capable of calculating the thermal-hydraulic conditions inside a PWR SG following a MSLB or FWLB
  - TRACE successfully predicts the transient thermal-hydraulic conditions for acoustically and flow dominated blowdown tests
  - The SG internal loading calculated by TRACE are comparative to conservative bounding calculations and to code results calculated by Westinghouse using RELAP5, but do not agree [this is incorrect] with Westinghouse TRANFLO calculations.
  - The largest SG internal forces are developed by the acoustic transients occurring in the first seconds following a break.

Table 4

TSP Loadings at Hot Standby by TRANFLO (Case 1, Reference 2)

Location	Loading for 4.6 ft^2 MSLB, psi	Loading for 1.4 ft^2 MSLB, psi
TSP 7 (Top)	NC	2.46
TSP 6	NC	1.82
TSP 5	NC	1.25
TSP 4	NC	0.91
TSP 3	NC	0.58
TSP 2	NC	0.31
TSP 1 (Bottom)	NC	-0.12

Note: NC = No Calculation

Table 5

TSP Loadings at Hot Standby

	4.6 ft^2 MSLB TRANFLO	4.6 ft^2 MSLB RELAP5	4.6 ft^2 MSLB TRACE
TSP 7 (Top)	NC	9.6 psi	8.57 psi
TSP 6	NC	8.1 psi	5.06 psi
TSP 5	NC	6.1 psi	3.84 psi
TSP 4	NC	4.5 psi	2.63 psi
TSP 3	NC	3.2 psi	1.16 psi
TSP 2	NC	2.0 psi	0.15 psi
TSP 1 (Bottom)	NC	1.9 psi	-0.33 psi

Note: NC = No Calculation

	1.4 ft^2 MSLB TRANFLO	1.4 ft^2 MSLB RELAP5	1.4 ft^2 MSLB TRACE
TSP 7 (Top)	2.46 psi (3.69* psi)	2.26 psi	2.68 psi
TSP 6	1.82 psi (2.73* psi)	2.14 psi	1.70 psi
TSP 5	1.25 psi (1.88* psi)	1.56 psi	1.23 psi
TSP 4	0.91 psi (1.37* psi)	1.35 psi	0.87 psi
TSP 3	0.58 psi (0.87* psi)	1.23 psi	0.43 psi
TSP 2	0.31 psi (0.47* psi)	1.25 psi	0.08 psi
TSP 1 (Bottom)	-0.12 psi (-0.18* psi)	1.12 psi	-0.06 psi

Note, an upward directed pressure differential is defined as positive
*TRANFLO values with the Westinghouse recommended 1.5 uncertainty multiplier.

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Table 6

SG Conservative Bounding Calculations

TSP Peak Pressure differential Comparisons for 4.6 ft^2 MSLB
With System Initially at Hot Standby

	TRANFLO	RELAP5	TRACE	Moody/Acoustic Calc. &
TSP 7 (Top)	NC	9.6 psi	8.57 psi	9.0 psi
TSP 6	NC	8.1 psi	5.06 psi	7.6 psi
TSP 5	NC	6.1 psi	3.84 psi	6.4 psi
TSP 4	NC	4.5 psi	2.63 psi	5.4 psi
TSP 3	NC	3.2 psi	1.16 psi	4.6 psi
TSP 2	NC	2.0 psi	0.15 psi	3.8 psi
TSP 1 (Bottom)	NC	1.9 psi	-0.33 psi	3.3 psi (1.6# psi)

Note: NC = No Calculation

Note, an upward directed pressure differential is defined as positive.
& Differential pressure conservatively calculated ignoring depressurization wave travel through annular feedwater region.
# TSP 1 pressure differential adjusted for depressurization wave travel through annular feedwater area.

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Table 7

SG Loading Following MSLB or FWLB

- **Generic Safety Issue 188 and SG Action Plan Items 3.1a, 3.1b, 3.1c**
  - Perform thermal-hydraulic calculations using TRACE to assess loads on a Steam Generator tube support plate and tubes following MSLB or FWLB

- **Conclusions:**
  - TRACE is capable of calculating the thermal-hydraulic conditions inside a PWR SG following a MSLB or FWLB
  - TRACE successfully predicts the transient thermal-hydraulic conditions for acoustically and flow dominated blowdown tests
  - The SG internal loading calculated by TRACE are comparable to conservative bounding calculations and to code results calculated by Westinghouse using RELAP5 and TRANFLO.
  - The largest SG internal forces are developed by the acoustic transients occurring in the first seconds following a break.

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