Westinghouse Electric
Company, LLC

Nuclear Systems

Box 355
Pittsburgh, Pennsylvania 15230-0355

DCP/NRC1487
Project 711

October 8, 2001

Document Control Desk
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

ATTENTION: Mr. Alan Rae, NRC, MS 12E15

SUBJECT: Westinghouse Responses to NRC Requests for Additional Information

Dear Mr. Rae:

Attached please find the Westinghouse responses to the following Requests for Additional Information (RAIs) related to the pre-certification review of the AP1000:

P19	P59
P28	P61
P32	P64
P36	P66
P47	

The RAI enclosed as Attachment 1 is considered proprietary to Westinghouse. The RAIs enclosed in Attachment 2 are considered non-proprietary to Westinghouse.

Proprietary Submittal

The Westinghouse Electric Company proprietary information notice, application for withholding, and affidavit are also attached to this submittal letter as Attachment 3. RAI P036 is enclosed as Attachment 1 and contains Westinghouse proprietary information consisting of trade secrets, commercial information or financial information which we consider privileged or confidential pursuant to 10CFR2.790. Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosures

This material is for your internal use only and may be used for the purpose for which it is submitted. It should not be otherwise used, disclosed, duplicated, or disseminated, in whole or in part, to any other person or organization outside the Commission, the Office of Nuclear Reactor Regulation, the Office of Nuclear Regulatory Research and the necessary subcontractors that have signed a proprietary non-disclosure agreement with Westinghouse without the express written approval of Westinghouse.

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Correspondence with respect to the application for withholding should reference AW-01-1488, and should be addressed to Hank A. Sepp, Manager of Regulatory and Licensing Engineering, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Please contact me if you have questions on this issue at 412-374-5355.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development

/Attachments

1. "Westinghouse Response to NRC Request for Additional Information", P036, Westinghouse Proprietary, dated September 2001
2. "Westinghouse Response to NRC Requests for Additional Information", Westinghouse Non-Proprietary, dated September 2001
3. Westinghouse Electric Company Proprietary Information Notice, Application for Withholding, and Affidavit

cc: H. A. Sepp	Westinghouse, Monroeville, PA	1L	
C. B. Brinkman	Westinghouse, Rockville, MD	1L	1A

DCP/NRC1487
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Attachment 2

Westinghouse Non-Proprietary Responses to Requests for Additional Information Regarding the AP1000 Pre-Certification Review

REQUEST FOR ADDITIONAL INFORMATION

RAI: P019

Question:

Similarly it is stated that WGOTHIC will be used to estimate the containment pressure during long term cooling (LTC). If the estimated pressure is much higher than a realistic value, the core steaming rate will be underestimated. Is it possible that at the end of the LTC, the steaming will be inadequate to support slug flow in the Automatic Depressurization System (ADS) Stage 4 (ADS-4)? If the containment pressure estimated using WGOTHIC for LTC is low, the steaming rate at the initiation of the LTC will be overestimated. What confirmation is there that the code will function properly for ADS-4 performance?

Westinghouse Response:

The OSU APEX facility test simulations provided in WCAP-14776 demonstrate the capability of WCOBRA/TRAC to predict the phenomena associated with the AP600 long-term cooling transient, including ADS-4 performance. Inasmuch as the scaling bases of the OSU facility remain valid for the AP1000 design, this validation basis, which was approved for AP600, remains adequate for AP1000. The WGOTHIC code has been validated for predicting the long term portion of the LOCA transient, when decay heat is removed from containment through the shell to the environment, via its simulations of the large-scale tests (References 1, 2). The AP1000 DCD LTC analysis is a 10CFR50 Appendix K ECCS performance analysis. Because the AP1000 DCD LTC analysis is an Appendix K calculation, the WGOTHIC calculation uses input assumptions that produce a conservatively low containment pressure prediction, as identified in Reference 3.

The presence of a particular flow regime is not a requisite to ensuring the effectiveness of ADS Stage 4 in maintaining long-term core cooling in the AP1000. A review of Reference 4 reveals that, on a time-average basis, a highly voided flow condition ($\alpha > 0.98$) is present in the ADS-4 piping during the LTC phase of each test. During the LTC testing at the OSU facility intermittent slugs of low quality flow were observed to pass through the ADS-4 paths, followed by intervals of essentially pure vapor flow. The application of WCOBRA/TRAC to long-term cooling ECCS performance analysis has been validated by the simulation of these tests in Reference 5. The AP1000 continuous LTC preliminary calculation presented in Reference 6 likewise exhibits on a time-average basis a highly voided flow condition ($\alpha > 0.99$) in the ADS-4 piping throughout the time period analyzed. Intermittent slugs of low quality flow are expected to pass through the ADS-4 paths during the AP1000 LTC period as well. The fact that very similar high void flow conditions are present during LTC in the OSU facility tests and in the AP1000 analysis provides confidence that the WCOBRA/TRAC code will properly predict ADS-4 performance. Moreover, since there is little subcooling of the sump liquid during the containment recirculation phase of LTC, boiling continues in the AP1000 core for an extended interval of time in the LTC phase of postulated LOCA events.

REQUEST FOR ADDITIONAL INFORMATION

References:

1. WCAP-14382, "WGOTHIC Code Description and Validation," May 1995.
2. WCAP-14967, "Assessment of Effects of WGOTHIC Solver Upgrade from Version 1.2 to 4.1," September 1997.
3. Westinghouse response to AP1000 RAI P16, DCP/NRC1484.
4. WCAP-14292, Revision 1, "AP600 Low-Pressure Integral Systems Test at Oregon State University Test Analysis Report, September 1995.
5. WCAP-14776, Revision 4, "WCOBRA/TRAC OSU Long-Term Cooling Final Validation Report", March 1998.
6. WCAP-15612, "AP1000 Plant Description & Analysis Report," December 2000.

REQUEST FOR ADDITIONAL INFORMATION

RAI: P028

Question:

Flashing in the upper head is listed with medium or low safety significance in the PIRT. For (MSLB) analysis, especially with the larger steam generators of AP1000, flashing might occur in other portions of the reactor system including the intact steam generator U-tubes and the CMT pressure balance lines which might affect natural circulation. Justify that test data used in qualifying LOFTRAN for AP1000 analysis is adequate to evaluate reactor system flashing following a MSLB considering the relatively larger steam generators that will be part of the AP1000 design.

Westinghouse Response:

Aspects of this question were addressed in several responses to RAIs during AP600 Design Certification including RAI 440.284, 440.315 and SDSER Open Item 21.6.1.7-4. As discussed in these responses, LOFTRAN can detect if flashing would be predicted to occur, and such flashing is treated with appropriate conservatism, depending on the event being analyzed. If flashing is predicted to occur in the CMT, the effect of the potential steam accumulation at the top of the CMT pipe can be taken into account by a penalty on the cold leg to CMT balance line buoyancy calculation. This penalty reduces the overall driving head for the CMT and reduces the effective CMT flow rate. This penalty would be applied if its application was conservative for that particular event. It should be noted that for AP600 transient analyses, flashing was not predicted to occur in the CMT or the CMT balance line.

A loss of subcooling in the steam generator U-tubes would cause a stagnation in the predicted flow rate through that steam generator. This is generally not a safety concern for passive plants, because safety-related natural circulation heat transfer is provided by the PRHR heat exchanger.

For main steam line break, two types of analyses are performed. One type is to conservatively model core response. For this type of event, the assumptions are selected to maximize plant cooldown. As a result, the decay heat level is assumed to be zero, and reverse heat transfer (from the steam generator to the primary side) is set to zero. For this event, flow through the steam generator U-tubes may stagnate, however natural circulation continues through the PRHR and the core makeup tanks. Flashing in the top of the U-tubes is not a concern, and LOFTRAN is suitable for performing a bounding analysis of the core response.

The other type of main steam line break accident is that which maximizes the mass and energy released to containment. For this type of event, maximum heat transfer is assumed through the steam generators. If flashing or stagnation would be predicted to occur, the CMT penalty could be applied, provided this resulted in a conservative prediction of the mass and energy released to containment.

REQUEST FOR ADDITIONAL INFORMATION

RAI: P032

Question:

Provide analyses of main steam line break accidents for AP1000 using conservative assumptions for evaluation of the reactor core. Provide analyses for full power and hot standby. Assume that the most reactive control rod is stuck out and that the most severe single failure of safeguards systems occurs. Provide all assumptions so that the staff can perform audit calculations with RELAP5. Provide inputs used for reactor vessel mixing, reactivity feedback parameters and control rod reactivity insertion. Provide tables showing the timing of significant events. Provide plots of secondary and reactor system pressure, core power, reactor system temperatures and reactor system void formation.

Westinghouse Response:

The purpose of the current phase of the pre-certification review is to review the applicability of the codes approved for AP600 to the AP1000. Review of the results of the main steam line break for AP1000 will be performed during the review of the AP1000 Chapter 15 accident analysis. Westinghouse performed scoping analyses of selected accidents to provide the staff with an understanding of the phenomena associated with the AP1000. With regards to the main steam line break accident, scoping analyses were performed for the AP1000 for the purposes of determining the mass and energy releases associated with this event. With regards to analyzing this event for purposes of evaluating core response, different input assumptions are used. A methodology description documenting the inputs used for key assumptions will be provided with the LOFTRAN users manual, which will be provided under separate transmittal.

REQUEST FOR ADDITIONAL INFORMATION

RAI: P036

Question:

Westinghouse proposes to use an increased resistance model in NOTRUMP by which the ADS-4 subsonic flow resistance is increased by 42 percent. This model was benchmarked against OSU data for a 2 inch small break LOCA. Provide primary system pressure comparisons for the OSU test. We understand that the 42% increase in ADS-4 resistance are based on extrapolation of the OSU comparisons to the AP600 configuration. Please provide a similar evaluation of the effective ADS-4 resistance for AP1000. So that the effect of ADS-4 scale can be assessed, please provide evaluations of the effective ADS-4 resistance for the ROSA test comparisons requested under RAI P21.

Westinghouse Response:

The ADS-4 subsonic flow resistance increase quoted in RAI P36 is accurate for the runs performed for OSU only. The results of the detailed stand-alone momentum flux model for OSU indicated that a resistance increase of approximately 35% was necessary to account for the lack of a detailed momentum flux model in the NOTRUMP code. The simulations performed with NOTRUMP utilized a value of 42% which was an early calculation of the adjustment for momentum flux. The stand-alone momentum flux model and its application to AP600 was presented to the ACRS Thermal-Hydraulics subcommittee meetings held on May 11 & 12, 1998. In those meetings, comparison plots of the predicted pressurizer water level and IRWST injection flow rate for OSU were presented in comparison to actual test data. The attached figure provides a comparison of the NOTRUMP-predicted primary side pressure for OSU using the stand-alone momentum flux model and the resistance penalty developed for OSU.

A separate detailed stand-alone momentum flux model was created for the AP600 model such that extrapolation of the OSU values was not required. The stand-alone momentum flux model was used to determine a range of correction factors to account for the range of expected pressure-quality conditions in the ADS-4 vent path. Based on these calculations, a resistance increase value of 60% was selected based on the RCS conditions expected at the time of IRWST cut-in. In the AP600 SSAR analyses, the stand-alone momentum flux model was used to develop an IRWST level penalty, which was used to conservatively delay the point of IRWST injection in the AP600 small-break LOCA analysis. As discussed in Reference 2, the resistance penalty factor of 60% was also used in NOTRUMP small break LOCA analyses for AP600 and results were presented at the May 11&12 meetings to the ACRS. The resistance penalty has been shown to provide comparable results to the IRWST level penalty method from a global perspective of predicting minimum core inventory, pressurizer water level, and IRWST injection flow rate. However, the resistance penalty correction factor provides a more direct correction to the actual processes being modeled by NOTRUMP, and has been shown to provide good agreement with the OSU test data.

A separate detailed stand-alone momentum flux model was created for the AP1000 using the same methodology as AP600. Results indicate that the correction factor calculated for AP1000 is similar to AP600 and ranges from 60 to 70% (with an IRWST cut-in pressure of 30 psia) depending upon the ADS-4 vent path inlet quality. This is reasonable as the piping configuration for both plants is similar and the density effect on momentum flux is similar. For the AP1000 Chapter 15 small break LOCA analyses, Westinghouse will increase the resistance of the ADS-4 vent line by a factor of 60% consistent with the approach used for AP600. This approach conservatively bounds the lack of an explicit momentum flux model in the NOTRUMP code as approved for AP600. In addition, Westinghouse also plans to perform confirmatory calculations of this phase of the small break LOCA transients with WCOBRA-TRAC to demonstrate that NOTRUMP provides an appropriate bounding analysis of the IRWST injection phase of the small break LOCA.

No calculation has been made of the NOTRUMP momentum flux adjustment for ROSA since NOTRUMP was not used to model the ROSA facility.

References:

1. WCAP-15612, "AP1000 Plant Description and Analysis Report, dated December 2000.
2. WCAP-15644, "AP1000 Code Applicability Report," dated May 2001

a, c

Figure P036-1 Comparion of OSU Test SB18 Pressurizer Pressure vs. NOTRUMP Predicted Pressure using 42% Increase in ADS-4 Resistance

REQUEST FOR ADDITIONAL INFORMATION

RAI: P47

Question:

The volume of the AP1000 Core Makeup Tank (CMT) is increased to 2500 ft^3 from 2000 ft^3 in the AP600. Not specified however is the diameter for the AP1000 CMT, which is needed to consider the interfacial area for condensation. Please provide the CMT inner diameter, and resistance to flow leaving the CMT. In particular, verify that the ratio of the Richardson and Friction Π groups for the AP1000 CMT remain reasonably close to the ratio of those same groups in the Westinghouse CMT experiments.

In addition, provide evidence that the other CMT scaling groups that are affected by the new geometry and drain rate for the AP1000 CMT including Stanton number Π_{st}, liquid heat source ratio $\Pi_{q,l}$, and heat source ratio Π_q.

Westinghouse Response:

The CMT inside diameter is provided in section 11.2 of the AP1000 Plant Parameters, Revision 0 submitted in Westinghouse letter NRC/DCP1484 dated 9/12/01. The hydraulic resistance from the CMT discharge to the reactor vessel is also provided in that document.

Richardson and Friction numbers for AP600 and AP1000 relative to the CMT separate effects test are provided in Table 4.1-3 of WCAP-15613. Note that the ratio of Richardson number relative to Friction number (also provided in WCAP-15613) is considered important for scaling (see WCAP-13963, Scaling Logic for the Core Makeup Tank Test). The result of scaling of these dimensionless quantities supports the conclusion that AP600 and AP1000 are acceptably scaled to the CMT test facility.

The parameters in the Stanton number (Π_{st}) which differ between AP600 and AP1000 are the heat transfer area ($A_{S,0}$), reference liquid velocity in the pipe ($U_{l,0}$), and cross-sectional flow area of the CMT (a_c). Considering these three parameters indicates the ratio of the AP600 to AP1000 Stanton number will be about 0.7.

The parameters in the liquid heat source ratio ($\Pi_{q,l}$) which differ between AP600 and AP1000 are the heat loss through the CMT walls ($q_{s,0}$) (a function of the larger diameter CMT), the heated length of the CMT (l_0), the tank metal volume ($V_{s,0}$), and the heat transfer area ($A_{S,0}$). Considering these parameters, the ratio of AP600 to AP1000 liquid heat source ratio is about 1.2.

Finally, parameters in the heat source ratio (Π_q) which differ between AP600 and AP1000 are limited to the heat loss through the CMT walls ($q_{s,0}$) and the heat transfer area ($A_{S,0}$). Since temperature differentials and heat transfer conditions are approximately preserved for the two designs, the heat loss becomes dependent only on the heat transfer surface area; thus differences cancel and the AP600 to AP1000 heat source ratio is approximately preserved.

These comparisons provide further evidence that the CMT test scaling groups remain reasonably scaled for AP1000, and it can be concluded that the CMT tests remain valid for AP1000 for purposes of code validation.

REQUEST FOR ADDITIONAL INFORMATION

RAI: P59

Question:

For the one-inch cold leg break, provide figures showing predictions of water levels in the vessel upper head and upper plenum, the accumulators, the CMTs, and the pressurizer. Also, provide a figure showing the core exit flow quality, the steam flow at the core exit, the core inlet flow, the core inlet subcooling and the pressurizer pressure.

Westinghouse Response:

Attached please find the requested plots. Note that these plots were generated with our preliminary NOTRUMP model used for the scoping analyses provided in WCAP-15612.

The purpose of the phase 2 pre-certification review is not to assess the safety analysis results for the AP1000, but rather is to determine whether the safety analysis codes and test data used for AP600 Design Certification are applicable to AP1000. Preliminary safety analysis results have been provided to permit the staff to understand the phenomena associated with the AP1000, in comparison to AP600. For that purpose, the SBLOCA results provided in WCAP-15612, including the 2-inch break, the DVI line break, and the inadvertent depressurization provide a range of AP1000 SBLOCA phenomena. Although the 1-inch break case was not included in that report, the results presented here can also be used to assess the AP1000 phenomena. We are currently developing the NOTRUMP model that we intend to use for the AP1000 safety analysis. We expect that it will provide results similar to the scoping analysis results.

Table P59-1: Sequence of Events for AP1000 1-in. Cold Leg Break	
Event	**Time (seconds)**
Break opens	0.0
Reactor Trip signal	245.7
Steam turbine stop valves close	246.7
"S" signal	254.5
Main feed isolation valves begin to close	259.5
Reactor coolant pumps start to coast down	254.5
ADS Stage 1	3813.6
ADS Stage 2	3883.6
Accumulator injection starts	3890
ADS Stage 3	4250
Accumulator Empties	4456
ADS Stage 4	4646.2
Core makeup tank empties	5720
IRWST injection starts	5918

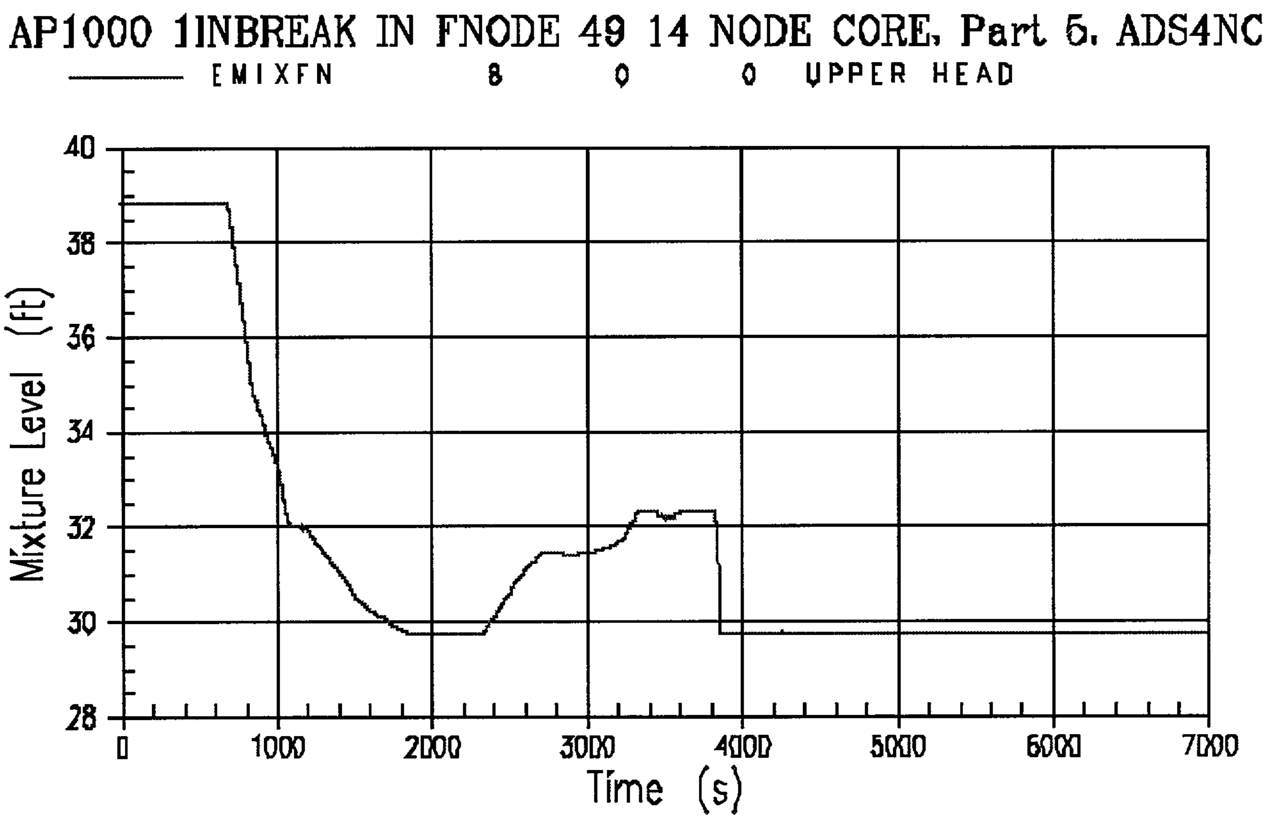

Figure P59-1: Upper Head Level – 1-inch Cold Leg Break

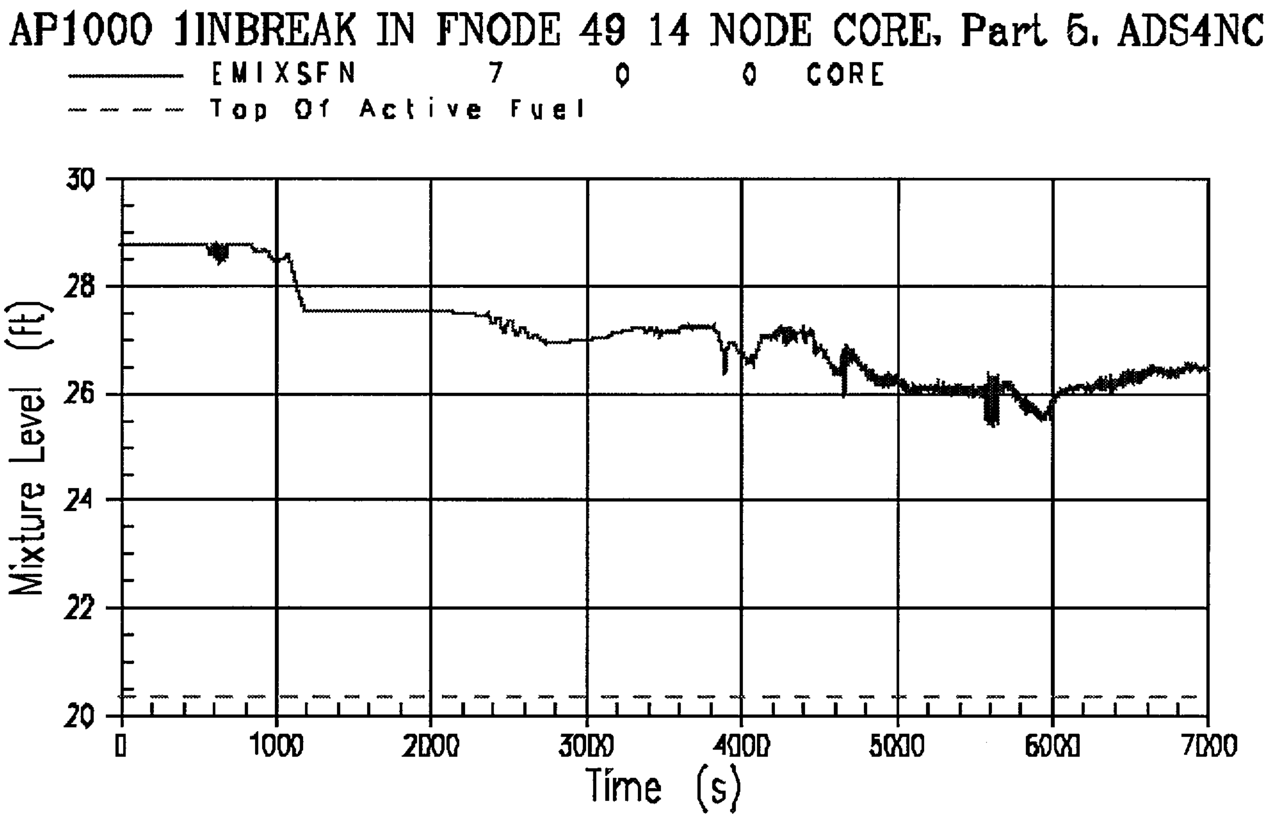

Figure P59-2: Upper Plenum Level – 1-inch Cold Leg Break

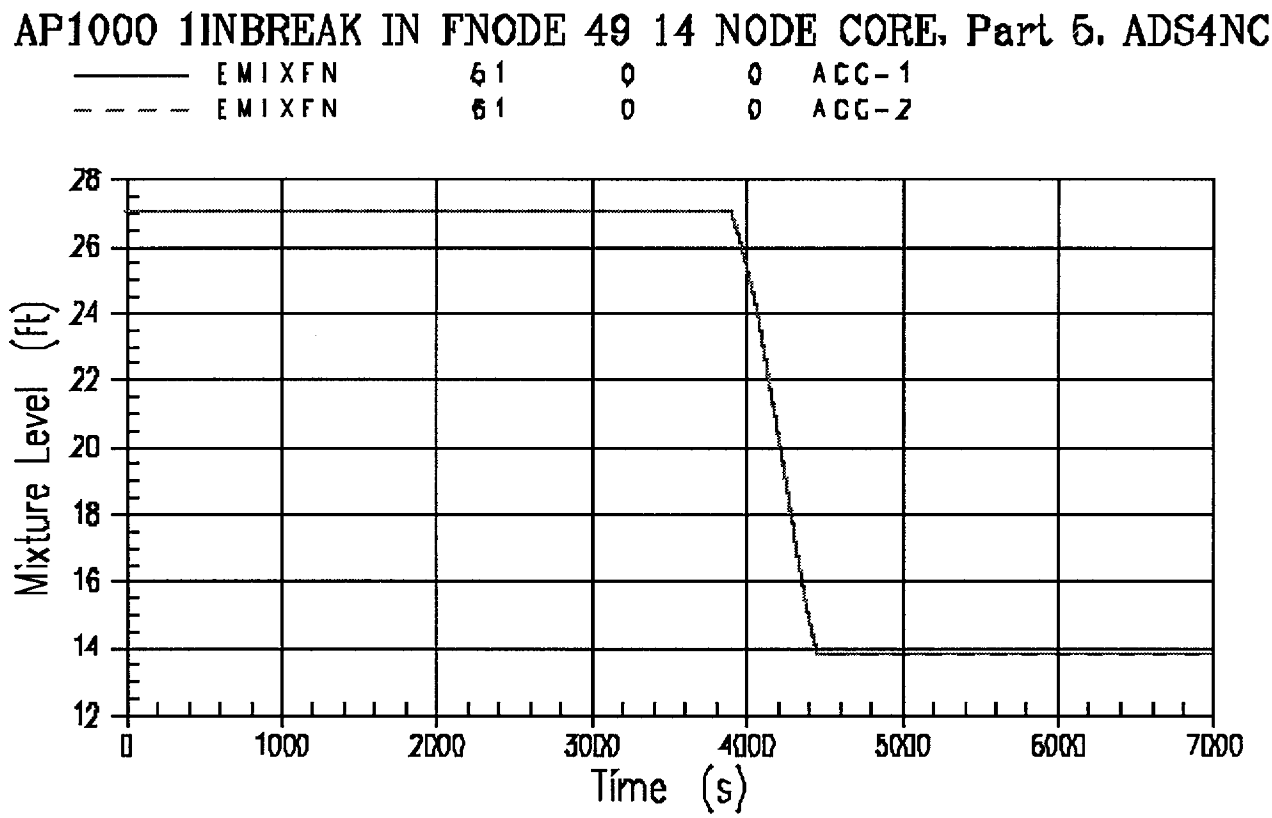

Figure P59-3: Accumulator Level – 1-inch Cold Leg Break

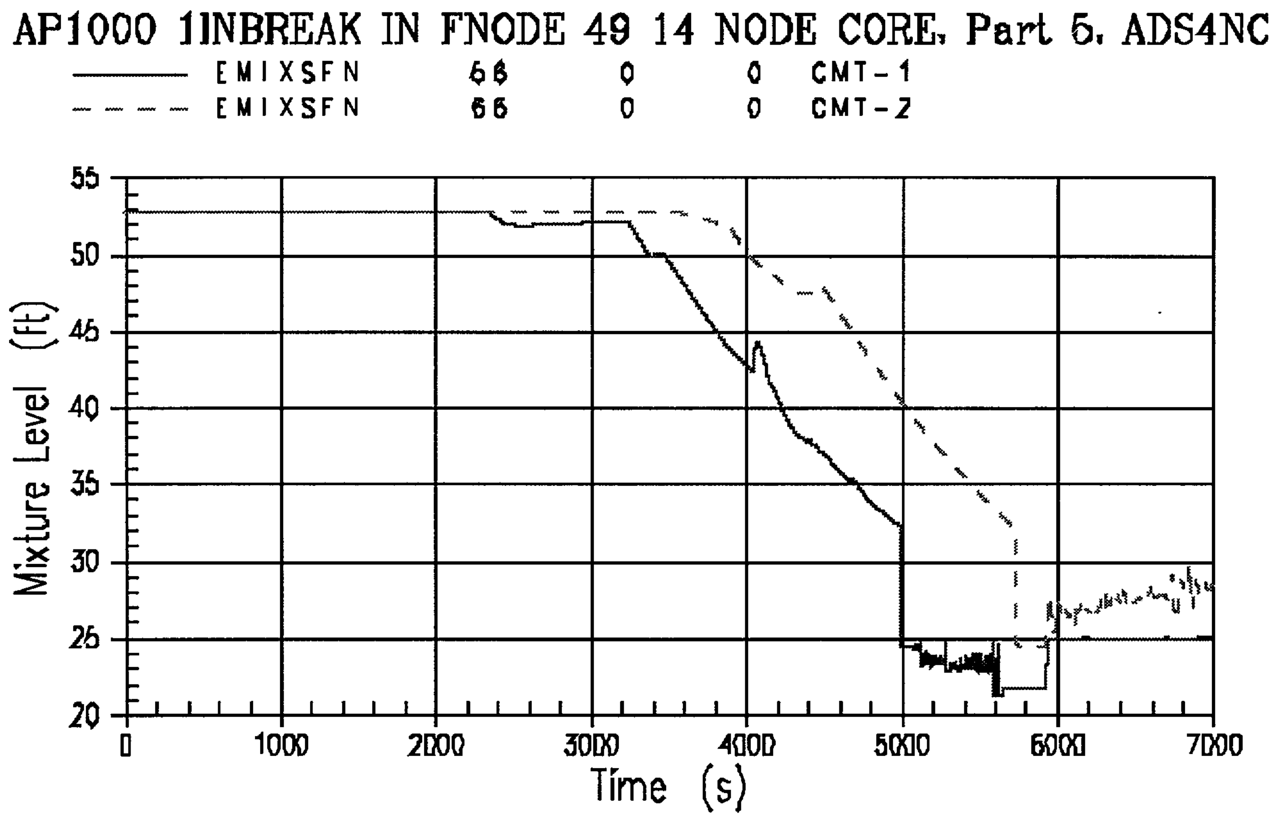

Figure P59-4: CMT Level – 1-inch Cold Leg Break

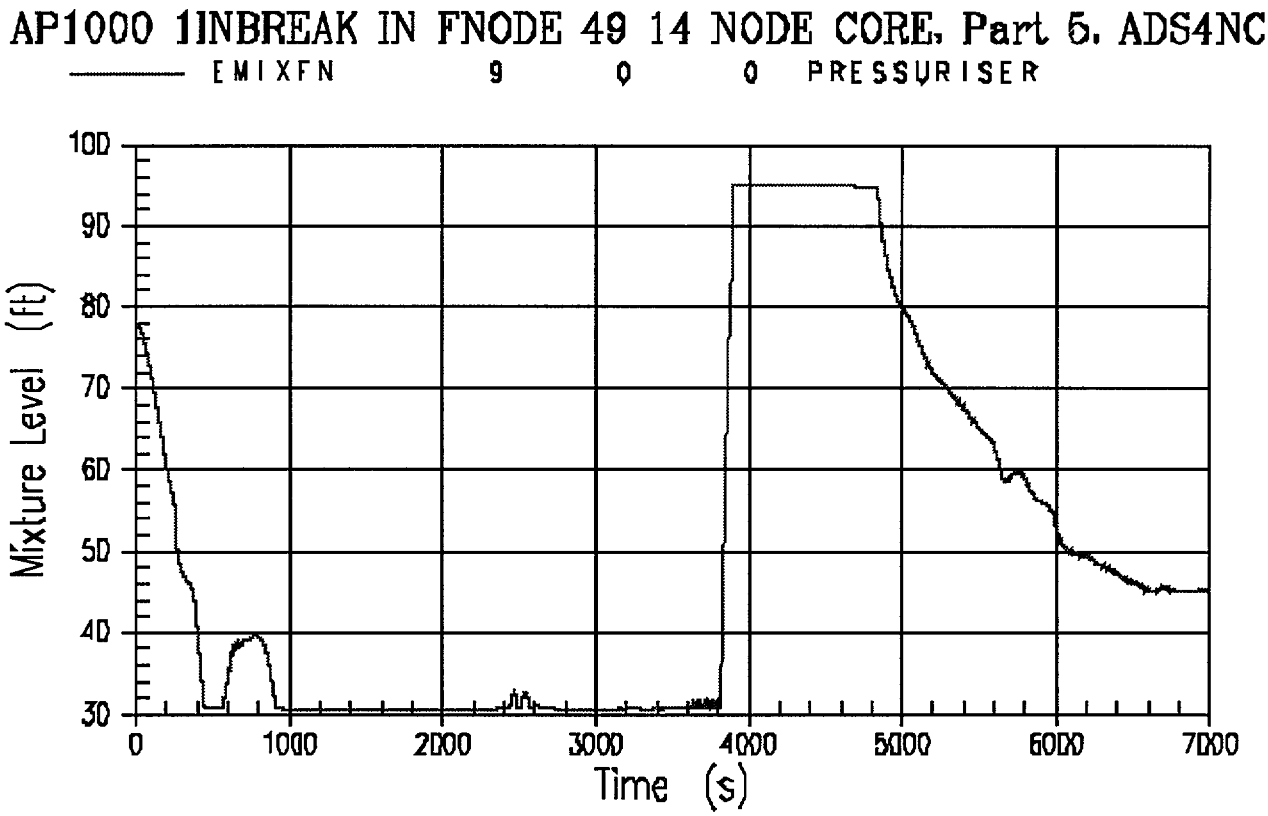

Figure P59-5: Pressurizer Level – 1-inch Cold Leg Break

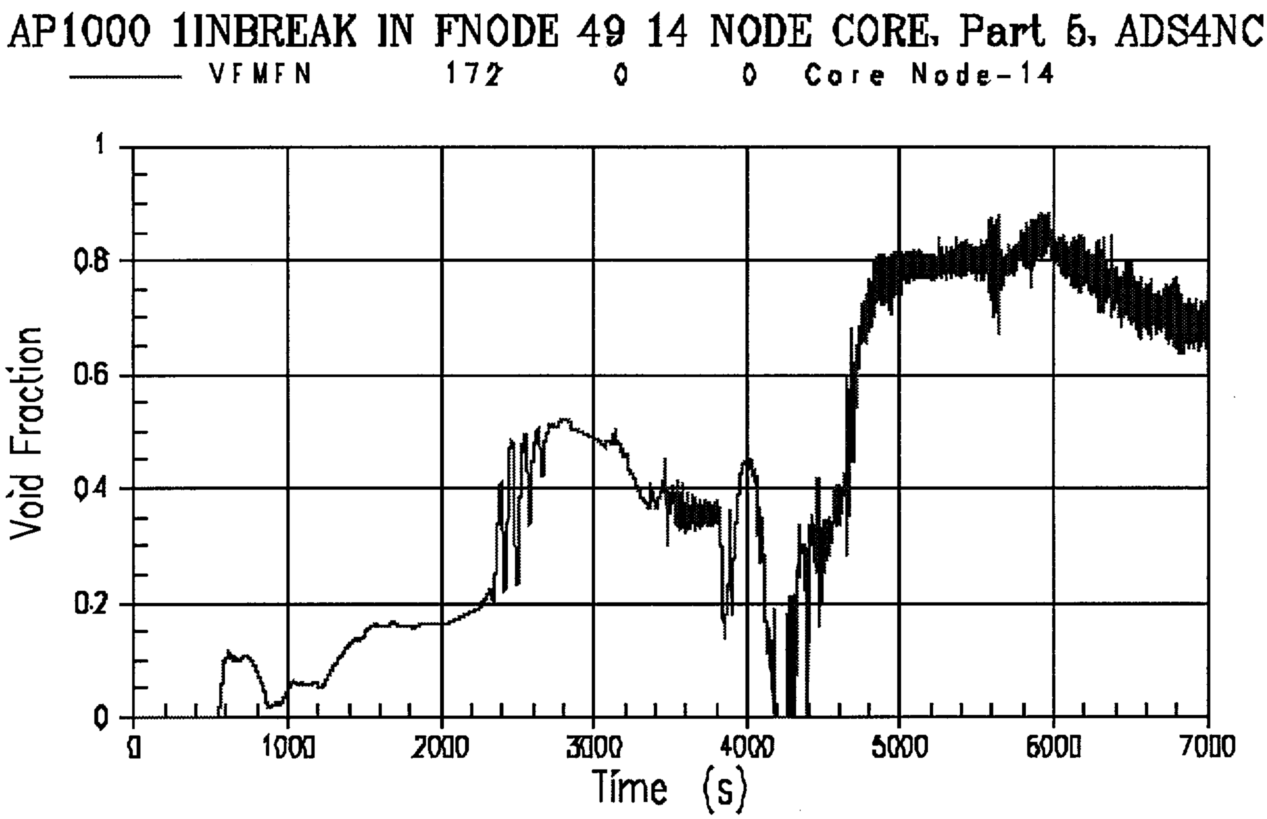

Figure P59-6: Core Exit Void Fraction – 1-inch Cold Leg Break

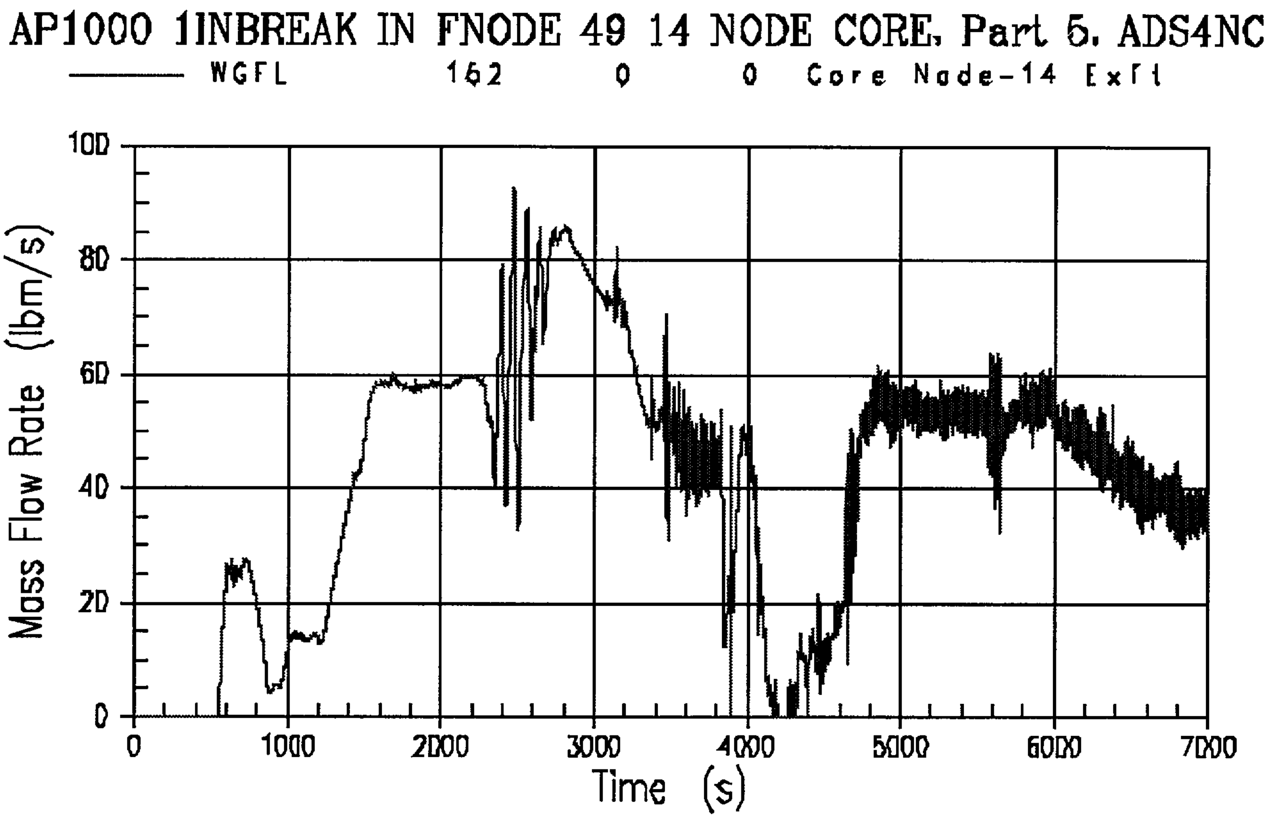

Figure P59-7: Core Exit Steam Flow – 1-inch Cold Leg Break

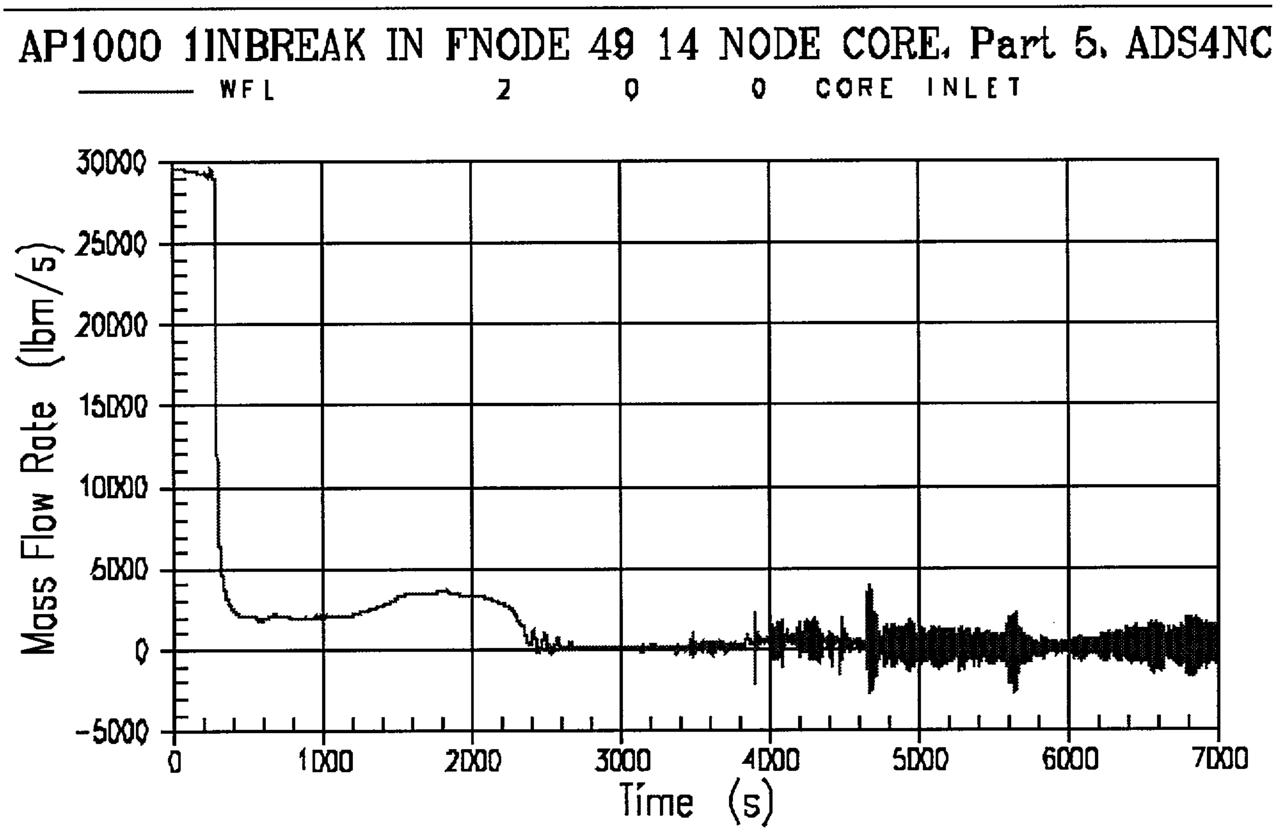

Figure P59-8: Core Inlet Flow – 1-inch Cold Leg Break

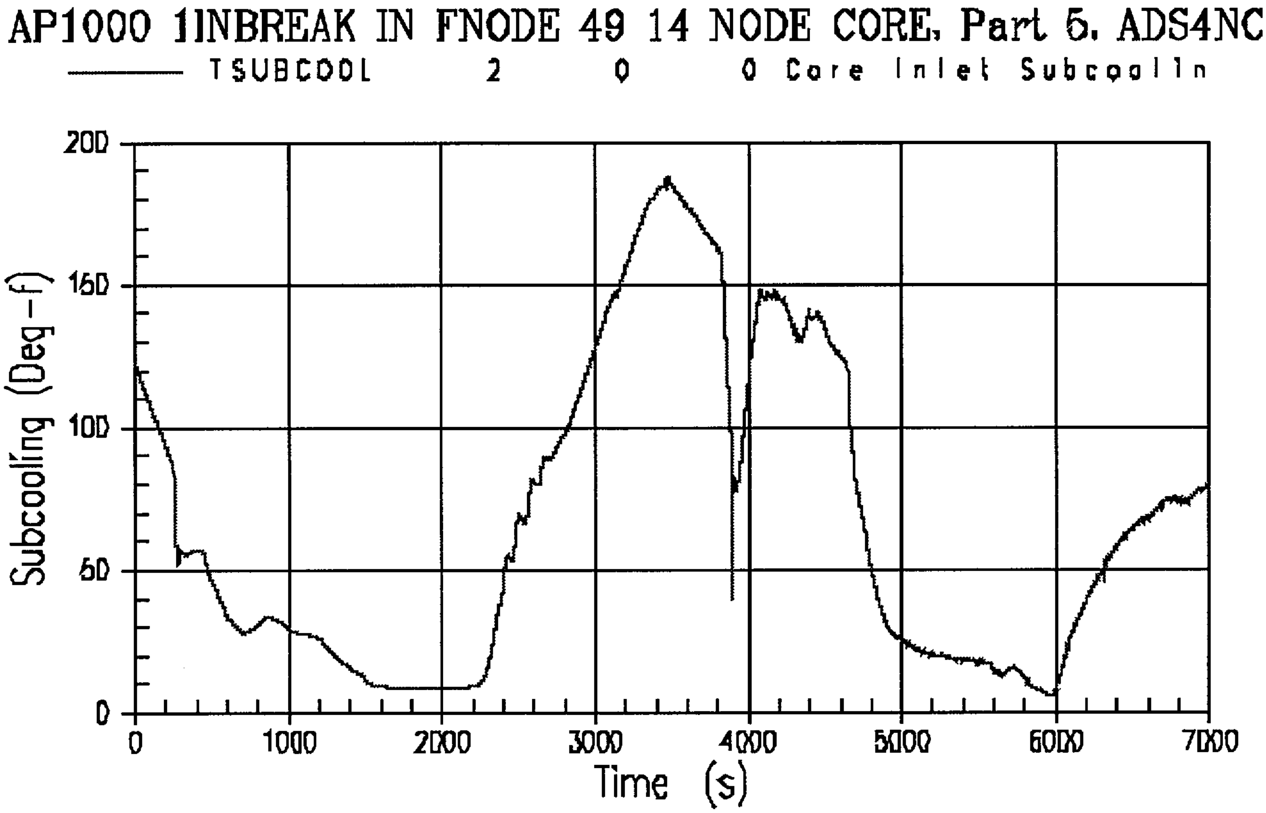

Figure P59-9: Core Inlet Subcooling – 1-inch Cold Leg Break

RAI: P61

Question:

Section 4 of WCAP-15613 states that "processes, phenomena, components, and interactions found to be less important for AP600 as a result of testing, scaling, and analysis are not scaled for AP1000 so as to focus attention on those phenomena found to be dominant." However, certain phenomena, which were not identified as high importance in the AP600 but are ranked high importance in the AP1000, are evaluated for scaling. Discuss the criteria used to determine which high importance phenomena in the AP1000 but not in the AP600 are scaled for the AP1000, or otherwise.

Westinghouse Response:

For the AP600, high ranked phenomena for SBLOCAs, Non-LOCAs, and containment pressure transients were scaled where passive safety systems or components were involved and influence the behavior of the transient. For high ranked phenomena for which safety analysis code validation already exists or for situations in which passive safety systems or components do not operate or do not have a significant influence on the behavior of the transient, scaling was not performed. Examples of such situations include Large Break LOCAs and the blowdown phase of a SBLOCA.

Large Break LOCAs for AP600 and AP1000 behave similar to and involve the same phenomena as conventional plants for which safety analysis code validation already exists. The blowdown phase of a SBLOCA is of short duration and passive safety systems and components have virtually no influence on the transient until after the end of blowdown. Based upon PIRT reviews and analysis, AP1000 is expected to behave similar to AP600 in this regard and therefore, like AP600, scaling was not performed for the AP1000 large break LOCA or for the SBLOCA blowdown phase.

WCAP-15613 provides scaling studies of important, high ranked phenomenon for AP1000. The report provides comparisons of important scaling groups covering the range of important phenomenon that were typically scaled for AP600. The methodology followed in WCAP-15613 is derived from the hierarchical two-tiered approach methodology of Zuber as discussed in section 4.1.2. This approach included top-down scaling which captured multiple processes such that they could be scaled relative to one another. Some phenomena that are ranked high in the PIRTs for AP600 were found not to be of high importance when scaled with respect to other high ranked phenomena. Examples of this include break and accumulator flow in the ADS blowdown phase of a SBLOCA. AP600 scaling analysis showed that ADS flow dominates the depressurization of the RCS during this phase. As the AP1000 ADS-1/2/3 design is same as AP600, the AP1000 scaling focused on ADS critical flow discharge during the ADS blowdown phase and did not scale the break or accumulator flow. In effect, although the PIRT reviewers qualitatively judged some phenomenon to be of high importance, the numerical assessment of these phenomena showed that they were not as important compared with other highly ranked phenomena.

Two phenomena were increased in ranking to high for AP1000. These were hot leg entrainment and upper head entrainment. These phenomenon are similar, and hot leg entrainment is considered more important because of its direct affect on the ADS-4 venting process. Therefore scaling evaluations of hot leg entrainment were provided for both AP600 and AP1000. Meaningful scaling for upper head entrainment is difficult to achieve, and not as important as hot leg entrainment, and therefore explicit scaling of this phenomenon was not performed for either AP600 or AP1000. However, the design of the AP600 and AP1000 upper head configurations are the same for both plants, and scaling of hot leg entrainment was judged to be sufficient to evaluate the importance of entrainment.

The report also provides bottom-up scaling of selected phenomenon, where more detailed assessment is needed for a specific component or process. This method is useful in assessing separate effects, and where top-down scaling is not useful or practical. This two-tiered approach for AP1000 demonstrates that the tests performed for AP600 are sufficiently scaled for AP1000, and that a sufficient data base of test information is available for the purposes of safety analysis code validation. Essentially, the safety analysis code validation performed for AP600 remains valid for AP1000.

REQUEST FOR ADDITIONAL INFORMATION

RAI: P64

Question:

Section 4.1.2.3.1of WCAP-15613 states that AP600 scaling analyses by Wulff and Reyes found that mass and energy injection into the RCS during the ADS phase from the CMTs and accumulators is small relative to the ADS discharge flow and energy, and therefore, that the boundary of the RCS volume is rigid, and the rate of pressure change is governed by the core steam generated by the decay heat, and the ADS vented steam.

(i) Provide a comparison of the relative magnitudes of ADS steam flow rate, core steam generation rate, CMT drain rate, and accumulator injection rate during the ADS phase (see Figure 4.1-2).

(ii) Is the conclusion valid for all sizes of SBLOCA including DVI line break?

(iii) In the ADS phase, the rate of pressure change equation (Eq. 4-35) does not include the effect of nitrogen gas in the accumulators. Provide justification of neglecting the nitrogen in the pressure change rate.

Westinghouse Response:

i and ii) The flow rates into and out of the reactor vessel during the time when ADS Stages 1, 2, and 3 are operating have been converted into volumetric flows and are listed for comparison in Table P64-1 below. The flow rates used to obtain these volumetric flows were obtained from the 1-inch CL break, 2-inch CL break, and double-ended DVI break AP1000 NOTRUMP analysis cases. The volumes listed include both the water and steam portions of the flows as applicable and, of course, consider the transient temperature and pressure vs. time.

For the 1-inch break, the ADS 1/2/3 volumetric flow is shown to be ~16 times greater than the volume of water delivered to the reactor vessel from the CMTs and accumulators. Likewise, the core steam generation, which is considered in the pressure scaling method, is several times greater than the water delivered to the reactor vessel.

Similarly, the volumes of the ADS 1/2/3 flows and steam generated by the core are even larger in comparison to the CMT and accumulator flows following a 2-inch break. The comparison of volumes in this case show the CMT and accumulator flow to be a factor of ~28 times smaller than the ADS flow volume and ~10 times smaller than the core steam volume.

The results also show that the large difference in flow volume between the ADS and core steam volumes does apply to breaks including the DEDVI break. However, the scaling study for evaluating the adequacy of the test facility ADS simulation only used the small break cases where RCS depressurization is more important.

iii) The rate of pressure change equation did not include the effect of nitrogen gas that is discharged from the accumulators when they empty because this effect could not be included in the computer models used to calculate the plant response. The effect of the gas however was examined carefully in the response of the scaled test facilities and found to have little impact. For example, the SPES2 test S00303 (2-inch cold leg break) shows that the effect of the nitrogen injection on reactor pressure is small. Plot 2 of Reference 1 provides a plot of reactor pressure that shows a small temporary increase in reactor pressure at ~1500 seconds when the accumulators empty. This pressure rise is ~20 psi but more importantly the pressure rise quickly dissipates and has little impact on the pressure decay trend to the time when the ADS 4th stage is actuated.

Table P64-1, AP1000 Fluid Volume In/Out of RCS During ADS 1/2/3

	1-inch CL Break	2-inch CL Break	DEDVI Break
ADS 1/2/3 Fluid Discharged (ft^3)	103400	215500	71100
Core Steam Generation During ADS 1/2/3	19800	76500	83800
CMT Injection	3005	4400	400
Accumulator Injection	3400	3400	1060

References

1. WCAP-14309, Revision 1; "SPES2 Tests Final Data Report" dated July 1995

AP1000 PRE-CERTIFICATION REVIEW

REQUEST FOR ADDITIONAL INFORMATION

RAI: P66

Question:

Explain how Eq. 4-118 is derived from Eq. 4-117 of WCAP-15613.

Westinghouse Response:

Attached please find our derivation of Equation 4-118 from Equation 4-117. WCAP-15613 will be updated to include this derivation at the next revision.

REQUEST FOR ADDITIONAL INFORMATION

EQN 4-118 can be obtained from Eqn. 4-117 as follows:

Starting with Eqn. 4-117 of WCAP-15613:

$$[X_e]_R = \left[\left(\frac{\Delta h_{sub}}{h_{fg}}\right)^2 \frac{\left[\left(Z_{IRWST} - Z_{\substack{core\\inlet}}\right) - \left(Z_{\substack{core\\outlet}} - Z_{\substack{core\\inlet}}\right)\right]}{\left(Z_{IRWST} - Z_{\substack{core\\inlet}}\right)} - \frac{1}{2}\left(\frac{q_{core}}{\rho_f \bullet h_{fg}}\right)^2 \frac{\left[\left(\Sigma \frac{R}{A^2}\right)_{DVI} + \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{ADS}\right]}{g\left(Z_{IRWST} - Z_{\substack{core\\inlet}}\right)} \right]_R^{\frac{1}{2}}$$

Squaring both sides, then multiplying and dividing the right hand size of Eqn. 4-117 by the second term inside the brackets on the right hand side yields:

$$[X_e]_R^2 = \left\{ \left(\frac{1}{2}\right)\left(\frac{q_{core}}{\rho_f \bullet h_{fg}}\right)^2 \frac{\left[\left(\Sigma \frac{R}{A^2}\right)_{DVI} + \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{ADS}\right]}{g\left(Z_{IRWST} - Z_{\substack{core\\inlet}}\right)} \right\}_R \bullet \left[\frac{(\Delta h_{sub})^2\ 2 \bullet g \left[\left(Z_{IRWST} - Z_{\substack{core\\inlet}}\right) - \left(Z_{\substack{core\\outlet}} - Z_{\substack{core\\inlet}}\right)\right]}{\left(\frac{q_{core}}{\rho_f}\right)^2 \left[\left(\Sigma \frac{R}{A^2}\right)_{DVI} + \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{ADS}\right]} - 1 \right]_R$$

Using the homogeneous equilibrium model for the two-phase multiplier; the resistance term in the numerator of the coefficient on the right hand side of the above equation can be expressed as:

$$\left[\left(\Sigma\frac{R}{A^2}\right)_{DVI}+\Phi_{fo}^2\left(\Sigma\frac{R}{A^2}\right)_{ADS}\right]=\left(\Sigma\frac{R}{A^2}\right)_{\substack{1\Phi\\ \text{Region}}}+\Phi_{fo}^2\left(\Sigma\frac{R}{A^2}\right)_{\substack{2\Phi\\ \text{Region}}}=\left(\Sigma\frac{R}{A^2}\right)_{\substack{1\Phi\\ \text{Region}}}+\left[1+X_e\left(\frac{\Delta\rho}{\rho_g}\right)\right]\left(\Sigma\frac{R}{A^2}\right)_{\substack{2\Phi\\ \text{Region}}}$$

The single phase contribution and two phase contributions can be grouped together as follows:

$$\left[\left(\Sigma\frac{R}{A^2}\right)_{\substack{1\Phi\\ \text{Region}}}+\left(\Sigma\frac{R}{A^2}\right)_{\substack{2\Phi\\ \text{Region}}}\right]+X_e\left(\frac{\Delta\rho}{\rho_g}\right)\left(\Sigma\frac{R}{A^2}\right)_{\substack{2\Phi\\ \text{Region}}}=\left(\Sigma\frac{R}{A^2}\right)_{\substack{1\Phi+2\Phi\\ \text{Region}}}+X_e\left(\frac{\Delta\rho}{\rho_g}\right)\left(\Sigma\frac{R}{A^2}\right)_{\substack{2\Phi\\ \text{Region}}}$$

Where the first term on the right hand side represents the single phase contribution of the entire single-phase and two-phase regions. The second term represents the two-phase contribution.

Now, the quality scaling ratio can be re-expressed as follows:

$$[X_e]_R^2=\left\{\frac{1}{2}\left(\frac{q_{core}}{\rho_f\bullet h_{fg}}\right)^2\frac{\left[\left(\Sigma\frac{R}{A^2}\right)_{1\Phi+2\Phi}+X_e\left(\frac{\Delta\rho}{\rho_g}\right)\left(\Sigma\frac{R}{A^2}\right)_{2\Phi}\right]}{g\left(Z_{IRWST}-Z_{\substack{core\\ inlet}}\right)}\right\}_R\bullet\left[\frac{(\Delta h_{sub})^2\bullet 2g\left[\left(Z_{IRWST}-Z_{\substack{core\\ inlet}}\right)-\left(Z_{\substack{core\\ outlet}}-Z_{\substack{core\\ inlet}}\right)\right]}{\left(\frac{q_{core}}{\rho_f}\right)^2\left[\left(\Sigma\frac{R}{A^2}\right)_{1\Phi}+\Phi_{fo}^2\left(\Sigma\frac{R}{A^2}\right)_{2\Phi}\right]}-1\right]_R$$

For situations where the two phase contribution dominates; that is

$\left(\Sigma \frac{R}{A^2}\right)_{1\Phi+2\Phi} << X_e \left(\frac{\Delta\rho}{\rho_g}\right)\left(\Sigma \frac{R}{A^2}\right)_{2\Phi}$ and therefore $\left(\Sigma \frac{R}{A^2}\right)_{1\Phi} << \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{2\Phi}$ follows, the quality scaling ratio can be simplified to:

$$[X_e]_R^2 = \left\{ \frac{1}{2}\left(\frac{q_{core}}{\rho_f \bullet h_{fg}}\right)^2 \frac{X_e \left(\frac{\Delta\rho}{\rho_g}\right)\left(\Sigma \frac{R}{A^2}\right)_{2\Phi}}{g\left(Z_{IRWST} - Z_{\substack{core \\ inlet}}\right)} \right\}_R \left[\frac{(\Delta h_{sub})^2 \bullet 2g\left[\left(Z_{IRWST} - Z_{\substack{core \\ inlet}}\right) - \left(Z_{\substack{core \\ outlet}} - Z_{\substack{core \\ inlet}}\right)\right]}{\left(\frac{q_{core}}{\rho_f}\right)^2 \bullet \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{2\Phi}} - 1 \right]_R$$

The above can be further simplified by noting $\left(\frac{1}{2g}\right)_R = 1.0$ and Eqn. 4-118 is finally obtained:

$$[X_e]_R = \left(\frac{q_{core}}{\rho_f \bullet h_g}\right)_R^2 \left(\frac{\Delta\rho}{\rho_g}\right)_R \left[\frac{\left(\Sigma \frac{R}{A^2}\right)_{2\Phi}}{\left(Z_{IRWST} - Z_{\substack{core \\ inlet}}\right)} \right]_R \left[\frac{(\Delta h_{sub})^2 \bullet 2g\left[\left(Z_{IRWST} - Z_{\substack{core \\ inlet}}\right) - \left(Z_{\substack{core \\ outlet}} - Z_{\substack{core \\ inlet}}\right)\right]}{\left(\frac{q_{core}}{\rho_f}\right)^2 \Phi_{fo}^2 \left(\Sigma \frac{R}{A^2}\right)_{2\Phi}} - 1 \right]_R$$

The above form is useful in that it is similar to that derived for the saturated fluid case with an additional term to account for subcooled fluid conditions. It is reasonable to expect this result for situations where low pressure and modest quality exists such as during IRWST injection in AP600 and AP1000. When near atmospheric pressure, the density ratio $\left(\frac{\Delta\rho}{\rho_g}\right)$ is on the order 10^3 and the two-phase contribution dominates the pressure drop.

DCP/NRC1487
Project 711

October 8, 2001

Attachment 3

Westinghouse Electric Company

Proprietary Information Notice, Application for Withholding, and Affidavit

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) contained within parentheses located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

Westinghouse Electric Company, LLC

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-01-1488

October 8, 2001

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. Samuel J. Collins

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Transmittal of Westinghouse Proprietary Class 2 Document, "NRC Request for Additional Information," October 2001

Dear Mr. Collins:

The application for withholding is submitted by Westinghouse Electric Company, LLC ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10CFR Section 2.790, Affidavit AW-01-1488 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-01-1488 and should be addressed to the undersigned.

Very truly yours,

J. W. Winters, Manager
Passive Plant Projects & Development

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COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared James W. Winters, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company, LLC ("Westinghouse"), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

James W. Winters, Manager
Passive Plant Projects & Development

Sworn to and subscribed
before me this 9th day
of October, 2001

Notary Public

Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 2003
Member, Pennsylvania Association of Notaries

(1) I am Manager, Passive Plant Projects & Development, in the Nuclear Systems Division, of the Westinghouse Electric Company LLC ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Electric Company, LLC.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Electric Company, LLC in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

The proprietary information sought to be withheld in this submittal is that which is appropriately marked in the Westinghouse report, "AP1000 Pre-Certification Review Request for Additional Information, RAI: P036" (Proprietary Class 2), for submittal to the Commission. This information is being transmitted by Westinghouse's letter and Application for Withholding Proprietary Information from Public Disclosure, being transmitted by Westinghouse Electric Company (Westinghouse letter AW-01-1488) and to the Document Control Desk, Attention: Alan C. Rae, MS 12E15.

This information is part of that which will enable Westinghouse to:

(a) Use Analytical Models for Small Break LOCA

(b) Use computer codes to analyze postulated accident conditions.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for Licensing Documentation.

(b) Westinghouse can sell support and defense of AP1000 Design Certification.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar methodologies and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for performing and analyzing tests.

Further the deponent sayeth not.