Westinghouse
Electric Company

Box 355
Pittsburgh Pennsylvania 15230-C355

NSD-NRC-98-55-80
DCP/NRC1264
Docket No.: 52-003

February 27, 1998

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

Attention: Suzanne C. Black

Subject: Inspection Report No. 99900404/97-02: Reply to a Notice of Nonconformance

Reference: Letter, S. C. Black to N. J. Liparulo, "NRC Inspection Report No. 99900404/97-02", Dated January 28, 1998

This letter documents the Westinghouse response to an NRC inspection of the AF600 project conducted from November 17 through November 21, 1997. This inspection focused on design calculations and computer codes supporting the SSAR Chapter 15 transient analysis and the containment analysis portion of SSAR Chapter 6. Two nonconformances and an unresolved item were identified in the Reference.

Nonconformance 99900404/97-02-01 identified concerns with the design calculations conformance to the quality assurance requirements for design analysis and verification. A description of the corrective action, actions to prevent recurrence and a resolution schedule for each of these concerns is contained in Attachment 1. Five of the concerns were addressed as FSER Open Items where additional information was provided to supplement the design calculation. Two calculation notes were revised to provide justification for the engineering judgment exercised in the analysis. The impact of the revised calculations did not extend beyond the document involved. Two additions were made to the SSAR to include a discussion of the operator actions during a coolant inventory increase event and to modify the technical specifications to preclude potential boron dilution events. To prevent recurrence of the type of concerns cited in the nonconformance, WCAP-12601, the AP600 Program Operating Procedures, has been expanded to include requirements for design analysis documents to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Nonconformance 99900404/97-02-02 identified two failures to follow procedures in the use of WCOBRA/TRAC and GOTHIC. Corrective action requests (CARs) have been initiated and are discussed in detail in Attachment 1. Neither of these failures had an impact on the SSAR. Following the inspection, Westinghouse documentation was located that resolved the error reports from NAI on GOTHIC with 10CFR 21 implications. The error reports were dispositioned in accordance with our procedure WP 4.19.3, Error Reporting and Resolution. NAI errors not involving 10CFR 21 did require error resolution as part of the corrective action and this also has been completed. None of the errors reported had an impact on the AP600 containment analysis. In addition to the corrective action defined for AP600, Westinghouse Quality Systems is performing a self assessment on our disposition of error reports from other third party software suppliers. To prevent recurrence, the AP600 Project addressed this issue by providing additional training to the code responsible engineer. The training reinforced the requirements of Westinghouse procedure WP 4.19.3.

Unresolved Item 99900404/97-02-03 identified technical questions on six additional calculation r A detailed response to each of these concerns is also contained in Attachment 1. Additional infor in the design calculation could have assisted in the review and understanding of the calculation documentation. In response to several concerns on input to the containment analysis, corrections were made to the WGOTHIC material contained in calculation 1100-SOC- 001 and a reanalysis was performed. The revised containment peak pressure analysis (which will included in SSAR subsection 6.2.1) showed a slight reduction in the peak pressure.

The reference letter also requested that Westinghouse "assess the adequacy of the AP600 QA design review process and the integrity of the AP600 design." As documented in Attachment 1, a large majority of concerns identified by the NRC were related to the level of documentation provided in the calculation notes. These have been resolved by providing additional information. In addition, WCAP-12601, the AP600 Program Operating Procedures, has been expanded to include requirements for design analysis documentation to provide enhanced documentation of engineering judgment and verifiers comments resolution. The three SSAR modifications resulting from our corrective actions to the first nonconformance and the unresolved item are not expected to change the conclusions reached in the SSAR review.

To further confirm the integrity of the design review process, Westinghouse has initiated a Design Assessment Review (DAR) to evaluate an additional sample of calculations that support the Chapter 15 analysis and the containment analysis section of Chapter 6. The review plan shown in Attachment 2 was discussed with the NRC in a meeting on February 11, 1998. The DAR team will issue their final report by April 3, 1998.

The NRC also indicated their concern that a large number of discrepancies were noted by the inspection team "in such a small sample of the total population". To address this concern, a cause analysis was performed, under the leadership of the Westinghouse Quality Systems Department. Details and conclusions of the cause analysis are included as Attachment 3. The cause analysis assessment did not indicate a trend adverse to quality.

The focus of the root cause assessment was to establish the fundamental reasons for the lack of documentation by the Westinghouse authors and verifiers. Interviews were conducted with authors and verifiers of a sample of calculation notes that had been reviewed by the NRC during the inspection. The interviews were conducted within the framework of a root cause evaluation by using a combination of the "5 Whys" technique and engineering judgment. This assessment concluded that the root cause of the

lack of documentation supporting Westinghouse judgments is that the analyses were basically being prepared for internal review and verification by other qualified Westinghouse personnel. That the verifier had sufficient information to enable verification to be completed in accordance with the governing procedures, as evidenced by the verifiers signature, indicates that the author provided sufficient documentation detail. In response to the assessment, the AP600 project has supplemented the AP600 general procedures for design analysis to include requirements for enhanced documentation

Beyond efforts specifically related to AP600, an Error Free Engineering Initiative had been established by the Nuclear Service Division (NSD) as part of its ongoing quality improvement efforts. NSD is the division of Westinghouse responsible for safety analysis. This self identified initiative addresses six key areas; calculation note quality, design review and planning, software quality, corrective action, quality improvement, and engineering quality cost. Results of the AP600 interactions with the NRC were provided for consideration in the Error Free Engineering Initiative.

Responses to FSER Open Items noted in Attachment 1 and the corrective actions described in the contents of this transmittal provide the required support for closing the nonconformances and the unresolved issue from the NRC inspection. Results of the DAR will be available in early April and any necessary corrective actions will be implemented. Based on our evaluation of the results of the November 1997 NRC inspection observations, we believe that the quality of the design calculations conforms to the requirements of 10CFR50 Appendix B. We are expanding our procedure to provide an increased depth of documentation for the purpose of accommodating a third party review. Any AP600 analysis performed from this point forward will be documented in accordance with the revised procedure.

Please contact me or Bob Tupper on 412-374-5219 if you have any questions concerning this transmittal.

Brian A. McIntyre

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

Attachment 1: Disposition of Nonconformances and Unresolved Item
Attachment 2: AP600 NRC Design Assurance Review Plan
Attachment 3: Cause Analysis of NRC Findings on Calculation Notes

cc: T. R. Quay, NRC/NRR/DRPM
R.L. Pettis, NRC/NRR/HQMB/DRCH
R. A. Gramm, NRC/NRR/HQMB/DRCH
J. D. Peralta, NRC/NRR/HQMB/DRCH
N. J. Liparulo, Westinghouse, NSD
M. Mutyala, Westinghouse, QPS
S. D. Rupprecht, NSD

Attachment 1: Disposition of Nonconformances and Unresolved Item from NRC Inspection 99900404/97-02

Several of the NRC concerns identified during the final inspection were identified as FSER Open Items and Westinghouse responses were provided prior to the release of the NRC Inspection Report. These have been identified in the Westinghouse response to the NRC observations noted below.

Nonconformance 99900404/97-02-01

NRC Observation 1:

SSAR-GSC-189, "AP600 SSAR Inadvertent ECCS Analysis," Revision 2, assumed the need of operator actions in the analyses of increased RCS inventory events, but failed to address:

· The availability of (1) unambiguous alarms or indications for increased RCS inventory events, and (2) clear procedural instructions to operators to take appropriate actions within the time-frame assumed in the analyses.

· 10 CFR 50.36, "Technical Specifications," §50.36(c)(2)(ii)(C).

· Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) to verify the capacity of the system including the RV head vent valves that would be used by operators to prevent pressurizer overfill from occurring as assumed in the analyses.

· Standard Safety Analysis Report (SSAR) text providing detail of the analyses that credited the requisite operator actions.

Steps taken to correct this item:

This observation was provided to Westinghouse as FSER Open Item 440.753F in a letter December 17, 1998 Westinghouse provided a response to FSER OI 440.753F in letter DCP/NRC1209 dated January 9, 1998. SSAR Section 15.5 has been revised to include a more complete discussion of the use of operator actions to mitigate the consequences of the increase in reactor coolant inventory events. In response to FSER OI 440.785F, a technical specification for the reactor vessel head vent valves has been incorporated. The PCS ITAAC has been modified to address the required capacity to accommodate overfill events.

Steps taken to prevent recurrence:

None required. This observation represents a difference in approach for Westinghouse and the NRC regarding what should be included in the SSAR. The requested information has been added to the SSAR, Technical Specifications and ITAAC.

Date corrective action and preventative measure will be completed:

Completed January 9, 1998.

NRC Observation 2:

SSAR-GSC-188, "AP600 Boron Dilution Analysis," Revision 0, relied on the boron mixing testing data documented in EGG-LOFT-5867 (Project No. P 394) to establish the required RCS circulation flow rate of 100 gpm in TS 3.4.9 and to support its complete boron mixing model assumed in the boron dilution analyses (SSAR 15.4.6). However, despite significant differences between the AP600 design and the test facility configuration and testing conditions discussed in EGG-LOFT-5867, SSAR-GCS-188 failed to reconcile the applicability of the boron mixing testing data to the AP600 design or to validate the complete boron mixing model assumed in the boron dilution analysis.

Nonconformance 99900404/97-02-01 (Continued)

Steps taken to correct this item:

This observation was provided to Westinghouse as FSER Open Item 440.754F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 440.754F in letter DCP/NRC1248 dated February 6, 1998. Technical Specification 3.4.9 has been modified to preclude potential boron dilution events when the reactor coolant pumps are not running by isolating the demineralized water isolation valves. SSAR subsection 15.4.6 is modified to reflect the change to the technical specification.

Steps taken to prevent recurrence:

None required, the requested information has been added to the SSAR and Technical Specifications.

Date corrective action and preventative measure will be completed:

Completed February 6, 1998.

NRC Observation 3:

SEC-APS-4838-CO, "Software Design Specifications of AP600 NOTRUMP User Externals Cycle 2," Revision 0, dated September 9, 1995, contained a statement that numerous errors in code parameters were reviewed as insignificant and would be corrected in a later code version however, no basis was given to support this conclusion.

Steps taken to correct this item:

Revision 0 of the calculation was issued to support a preliminary verification and validation (V&V) report as documentation of progress to date with the clear understanding it would be revised for the final V&V effort. The author and the verifier were familiar with the code progress and possessed the engineering competence needed to assess the impact of the documented errors as insignificant for the purpose of supporting preliminary NOTRUMP V&V. In accordance with the quality assurance procedures for code validation, the errors were listed in the code error report. All of the errors reported in Revision 0 were included as corrections in the modifications to the code reported in the subsequent revision of the code. No action is required to correct this item.

Steps taken to prevent recurrence:

None required. The items identified were previously corrected by the AP600 design process and represented only work in progress.

Date corrective action and preventative measure will be completed:

None required.

NRC Observation 4:

SEC-APS-4837-CO, "Software Change Specification of NOTRUMP Cycle 32," Revision 0, dated September 9, 1995, contained a statement that "...the author doesn't know enough about the subject (void propagation) to determine the impact of the reviewer's comments." No evidence existed to support resolution of the reviewer's comment.

Nonconformance 99900404/97-02-01 (Continued)

Steps taken to correct this item:

This calculation was revised to document the resolution of the reviewers comment during the NRC inspection. The impact did not extend beyond SEC-APS-4837-CO. The revised calculation was reviewed with the inspector and there are no open issues associated with this calculation.

Steps taken to prevent recurrence:

WCAP-12601 has been expanded to include requirements for calculation notes to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Date corrective action and preventative measure will be completed:

Completed February 27, 1997.

NRC Observation 5:

> *SEC-APS-4746-C0, "WCOBRA/TRAC Long-Term Cooling," provided no basis for concluding that "...variations in the initial conditions are expected to have relatively unimportant effects on the analysis results," and "the results of changing ICHP is noticeable but not large..."*

Steps taken to correct this item:

This observation was provided to Westinghouse as FSER Open Item 440.757F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 440.757F in letter DCP/NRC1212 dated January 13, 1998. Calculation SEC-APS-4746-C0 documents the analysis simulating the separate effect tests performed for the CMT. The comment cited deals with initializing the liquid temperature on the WCOBRA/TRAC cell modeling the short length of pipe immediately above the CMT to contain hot water. The cell has a volume which is only 1.5% of the uppermost cell in the CMT component to which it connects. The CMT component temperatures in the simulations are initiated at the test values, which are approximately room temperature. The impact of initiating the small pipe cell as hot water increases the net temperature value of the CMT entrance region (the entrance pipe cell and the CMT component top cell combined) at the start of the problem by only a small amount, 1.8 to 5.4 °F. No corrective action is required.

Steps taken to prevent recurrence:

WCAP-12601 has been expanded to include requirements for calculation notes to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Date corrective action and preventative measure will be completed:

No corrective action is required. Revision 23 of WCAP 12601 was issued February 27, 1998.

Nonconformance 99900404/97-02-01 (Continued)

NRC Observation 6:

LTCT-T2C-417, "WCOBRA/TRAC Geometrical Input Data for the OSU Testing," Revision 0, and LTCT-T2C-418, "OSU LTC Comparisons with WCOBRA/TRAC," Revision 1.

- *LTCT-T2C-417. Pages 180-181 (Figures 6 and 7) acknowledged the failure to fit DP vs (flow)^2, however, the basis provided was that "...despite the failure to match, overall agreement is reasonable." This unquantified anomaly was used as input to calculation LTCT-T2C-418.*

- *LTCT-T2C-418. On page 16, a bias of 0.2 psia was applied to the atmospheric pressure to compensate for the disparity in DP vs (flow)^2 in calculation LTCT-T2C-417. However, the calculation did not provide an explanation for the use of this bias.*

Steps taken to correct this item:

During the verification of LTCT-T2C-417, the verifier stated on page 179 of the calc note that "Despite the failure to fit, overall the WCOBRA/TRAC prediction of sump flow behavior seems reasonable." This is reasonable because Figures 6 and 7 consider a range in [flow]^2 of only 0-4 gpm^2, versus a test range of 9-67 gpm^2. Since a bias in pressure is to be applied to improve the WCOBRA/TRAC test prediction as noted in p. 175, the fact that sump [flow]^2 does monotonically decrease with Δ P decrease is adequate agreement for the 0-4 gpm^2 range in [flow]^2.

With regard to LTCT-T2C-418, Rev 2 of the calculation note was issued during the audit and the basis for the 0.2 psi offset was better documented. It was reviewed with the NRC Inspector during the audit.

Steps taken to prevent recurrence:

WCAP-12601 has been expanded to include requirements for calculation notes to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Date corrective action and preventative measure will be completed:

Completed February 27, 1998.

NRC Observation 7:

SSAR-GSC-356, "Two-Inch Break LOCA, LTC," Revision 0, presented a solution of DP vs. flow in which the author observed that a harmonic oscillation was built-in to the solution, and therefore, he proposed to take the average value. However, the inspection team could not determine if the average value was equal to the asymptotic solution had the oscillation not been present. The calculation also did not address the impact of oscillation in the asymptotic solution, the impact of the oscillation on the flow resistance, and the presence of the oscillation in the vessel flow, DP, and vessel collapsed liquid level solutions.

Steps taken to correct this item:

This observation was provided to Westinghouse as FSER Open Item 440.755F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 440.755F in letter DCP/NRC1227 dated January 23, 1998. The oscillation occurred in a run as a standalone problem specifically established to characterize the DVI piping resistance between the sump and reactor vessel junctions. The harmonic oscillation is believed to have been

introduced by the way in which one or more of the FILL and BREAK components employed was connected to the DVI network. The standalone problem was repeated and the oscillations disappeared. The asymptotic flow rate in the new calculation is equivalent to the average value of the solution obtained when the oscillations were present. The SSAR cases were reviewed and it was determined that harmonic oscillations comparable to those in SSAR-GSC-356 did not exist. Consequently, there is no impact on the SSAR and corrective action is not required.

Steps taken to prevent recurrence:

WCAP-12601 has been expanded to include requirements for calculation notes to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Date corrective action and preventative measure will be completed:

No corrective action is required. Revision 23 of WCAP 12601 was issued February 27, 1998.

NRC Observation 8:

SSAR-GSC-377, "SBLOCA Long-Term Cooling," identified discrepancies which included a calculation for negative (reverse) DVI flow with no corresponding physical explanation provided, a two sided open break which did not agree with a two-inch pipe break assumed in the calculation, and discrepancies related to initial conditions assumed for leakage through ADS 1-3.

Steps taken to correct this item:

This observation was provided to Westinghouse as FSER Open Item 440.756F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 440.756F in letter DCP/NRC1236 dated January 29, 1998. The ADS Stage 1-3 mass discharge referenced occurs during the sump injection phase of two two-inch cold leg break AP600 long-term cooling scenarios. WCOBRA/TRAC is initialized for these cases with the pressurizer empty, which is consistent with the long-term cooling test simulations. During the initial, pre-steady-state portion of the analyses, WCOBRA/TRAC predicts liquid to enter the pressurizer, which is consistent with the fact that "the WCOBRA/TRAC calculation is initially a transient until the mass redistributions occur." The code overrides whatever initial conditions are input to start a window mode calculation to define the solution for the boundary conditions specified.

The WCOBRA/TRAC mass balances for the scenarios referenced show that these cases are valid. Considering the two-inch cold leg break window of SSAR-GSC-377 reported in SSAR subsection 15.6.5.4C.3.5, the average total injection flow rate into the vessel through the DVI lines is 76 lbm/second. The average total flow through the ADS Stage 4 flow paths from the hot legs is equal to the injection flow. Therefore, the venting capability necessary for adequate core cooling is provided by ADS Stage 4 operation alone. The mass balance between the DVI and ADS flow rates is the same for the other SSAR-GSC-377 scenario referenced.

When liquid is present in the pressurizer, the discharge of same through ADS Stages 1-3 is to be expected. Mass is discharged through ADS Stages 1-3 at an average rate of about 4 lbm/second between 3300 and 4000 seconds of the subsection 15.6.5.4C.3.5 case. The pressurizer behavior is effectively independent of the reactor vessel during this time interval because the pressurizer receives no inlet flow through the surge line; the flow through ADS Stages 1-3 depletes the pressurizer mass inventory.

Nonconformance 99900404/97-0201 (Continued)

The magnitude of flow between the IRWST and/or the sump and the reactor vessel through the DVI lines during long-term cooling is determined by the pressure balance that exists. As described in SSAR subsections 15.6.5.4C.3.4 and 5, the upper plenum pressure rises when the liquid level is high in the upper plenum and the hot legs. More liquid (and less steam) is vented through the ADS Stage 4 flow paths. When the pressure in the reactor vessel upper plenum temporarily increases, injection flow from the IRWST/sump will diminish until the vessel pressure has been reduced by the venting of higher quality fluid through the ADS Stage 4 flow paths. Check valves adjacent to the IRWST isolation valves do not permit the flow to reverse direction; flow back into the IRWST and/or the sump is possible only if one (or more) of these check valves is assumed to remain open under a negative pressure gradient. For conservatism, the IRWST line check valves are assumed to remain open in the SSAR long-term cooling analyses so that the potential reduction in core collapsed liquid level due to negative flow in the DVI lines is considered. The AP600 design provides adequate venting capacity in the ADS Stage 4 flow paths to assure that the necessary flow from IRWST and/or sump occurs during long-term cooling under conservative Appendix K assumptions. The AP600 SSAR long-term cooling analysis subsection demonstrates that the performance of the AP600 complies with the 10CFR50.46 requirements for long-term core cooling. No corrective action is required.

Steps taken to prevent recurrence:

WCAP-12601 has been expanded to include requirements for calculation notes to provide enhanced documentation of engineering judgment as well as adequate information to indicate how verifiers comments are resolved.

Date corrective action and preventative measure will be completed:

No corrective action is required. Revision 23 of WCAP 12601 was issued February 27, 1998.

Nonconformance 99900404/97-02-02

NRC Observation 1:

WCOBRA/TRAC code error report for MOD 7A, Revision 1, listed an error affecting timestep control which was not evaluated for the specific case of the AP600 design. In addition, code failures identified in AP600 calculations were not reported and tracked in Westinghouse's error tracking system.

Steps taken to correct this item:

Westinghouse issued CAR 98-1014 to document the corrective action associated with this finding. As part of the 10CFR50.46 annual report review for 1997, the "error affecting time step control" was evaluated generically for WCOBRA/TRAC best estimate LOCA applications. The peak clad temperature impact of using analysis restarts was generically identified to be zero °F for best estimate LOCA applications.

The "code failures" mentioned above refer to aborted runs. Only those code failures that are identified as code errors are tracked in the W error tracking system. The code aborts noted in the NRC inspection report are not considered errors.

Steps taken to prevent recurrence:

The error affecting time step has been evaluated for WCOBRA/TRAC restarts. No further action is required.

Date corrective action and preventative measure will be completed:

Evaluation of the restarts is documented in internal letter SAE-LIS-98-054 dated February 12, 1998.

NRC Observation 2:

Over 100 code errors associated with GOTHIC (after Version 4.0) were identified to Westinghouse by the developer, Numerical Applications, Inc. (NAI). NAI stated to Westinghouse that some of the errors could affect safety determinations and may be reportable under 10 CFR Part 21. Westinghouse could not provide documentation to support the review and disposition of these code errors.

Steps taken to correct this item:

Westinghouse issued CAR 97-1332 to document the corrective action associated with this finding. The error report disposition for the NAI notices, that may be reportable under 10 CFR 21, were completed and documented in Westinghouse internal letter NTD-NSA-CRA-94-304, dated December 7, 1994. This could not be located at the time of the inspection because of engineers working off-site during that week. There were additional error reports, without 10 CFR 21 implications, that had not been dispositioned at the time of the inspection. All of the error reports were evaluated, dispositioned and documented in internal letter SAE-CRA-97-345 dated December 23, 1997 which was issued to the Westinghouse GOTHIC users.

Users of the code were requested to:

1. Review the errors in GOTHIC version 4.0 as reported by NAI and confirm the disposition of those errors.

2. On a return receipt acknowledgment form attached to the letter to either
   A. Document their concurrence with the error disposition, or
   B. Identify their reason(s) for not concurring with the disposition.

All authorized users have completed their review and returned their acknowledgment forms. All authorized users concur with the evaluation and disposition of errors in GOTHIC version 4.0 that indicated the errors did not impact the containment analysis being performed at Westinghouse.

Steps taken to prevent recurrence:

The AP600 Project addressed this issue by providing additional training to the code responsible engineer. The training reinforced the requirements of Westinghouse procedure WP 4.19.3 "Software Error Reporting and Resolution", and WP 4.19.4 "External Computer Codes".

In addition, the Westinghouse Quality Systems department has initiated a self assessment to determine how the error reports from other third party suppliers are dispositioned.

Date corrective action and preventative measure will be completed:

The AP600 corrective action has been completed. The Quality System self assessment will be completed by March 16, 1998.

Unresolved Item 99900404/97-02-03

NRC Observation 1:

The main change made to GOTHIC by Westinghouse to make WGOTHIC is the film heat transfer package used in modeling the AP600 containment shell which Westinghouse refers to as the clime model which is a large and complicated model change. The inspector reviewed CN CRA-93-219-R0 which is the design specification of the clime model. The beginning of the document describes what is called a complete and correct mathematical and physical model of the film energy transport but the equations are not mathematically and physically complete and correct. A complete and correct description would start out with mass, momentum and energy balances on the film and then show what terms can be neglected to obtain the final mathematical model. Several terms are obviously missing from the equations including condensation and evaporation terms which appear about 60 pages after the original "complete" model equations are discussed. There are also terms missing that depend on the time rate of change of the film thickness that result from the application of Leibniz's rule to the integral balance equations for a moving boundary problem. These missing terms may be negligible if the film thickness is changing slowly, but the assumptions incorporated into the complete equations should be clearly stated in the documentation.

In addition, related to Equation 8, an artificial thermal capacitance equal to half the thermal capacitance of the film is added to the thermal capacitance of the wall node adjacent to the film for numerical stability reasons. Adding this artificial term introduces an error in energy conservation. The term should either be removed from the equations or justification provided that the error introduced is negligible.

Westinghouse Response:

This observation was provided to Westinghouse as FSER Open Item 480.1114F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 480.1114F in letter DCP/NRC1221 dated January 20, 1998. A complete description of the governing equation derivation in a single location with assumptions stated has been provided in WCAP 14407, Revision 1. The calculation note CN-CRA-93-219-R0 is written for a target audience that has access to the documentation for previous versions of WGOTHIC's, versions 1.0 and 1.1. Thus, the calculation note provides only the modifications necessary to previously derived governing equations. The following provides additional information regarding several statements in the observation, and a clarification of the numerical method implemented for the liquid film.

The film equation in the calculation note is the energy equation, derived to include terms for convective energy transport and energy storage in the film – the two terms being added to the film equation for the upgrade to WGOTHIC version 1.2. Condensation and evaporation terms are in the equation, represented as "Q(Tsurf)", which represents the sum of condensation/evaporation, radiation, and convection, which are functions of the surface temperature of the film, Tsurf.

The liquid film is assumed to be a constant thickness during a time step, since its thickness varies slowly with time. External to containment, the film flow rate is applied as a user input and is known to vary relatively slowly with time, relative to the time step size. Internal to containment, the film flow rate results from condensation on the cooler shell surface. For the small time steps used in the code, film thickness can again be assumed to be constant during a time step. Therefore, there is no need to treat the liquid film as a moving boundary.

The numerical method chosen is justifiable and introduces no errors, as follows. A numerical method is used for solution of the temperature at the discontinuity (where the film and solid surface meet) to provide numerical stability. The technique employed replaces the finite difference form of the boundary condition between two different materials (the heat flux into the boundary is equal to the heat flux out of the boundary). Instead, a control volume spanning ½ layer into the film and ½ layer into the solid is defined, and a control volume equation is derived. The control volume equation is correct as derived, and results in an explicit representation of the energy storage in the

water and solid in the control volume, which models the damping of the boundary temperature during rapid transients, giving increased numerical stability. The value of the boundary temperature is solved by using the control volume equation, which includes the energy storage in the adjacent ½ layers. Temperatures for nodes away from boundaries are solved by using the finite difference governing equation, which accounts for energy storage in the ½ layers adjacent to each node.

The term "artificial" in the calculation note is used to identify the difference between the traditional finite difference boundary condition used between dissimilar materials (Equation 2, repeated below) and the finite volume equation (Equation 8, repeated below) which replaces the governing equation and boundary condition for the boundary node.

$$k_{wall}\frac{T^1_{wall}-T^2_{wall}}{\Delta x_{wall}} = 2k_{film}\frac{T_{avg}-T^1_{wall}}{\delta x_{film}} \qquad 2$$

$$\left[\rho_{wall}\cdot C_{p,wall}\frac{\Delta x}{2}+\rho_{film}\cdot C_{p,film}\frac{\delta x_{film}}{4}\right]\frac{dT^1_{wall}}{dt} = k_{wall}\frac{T^2_{wall}-T^1_{wall}}{\Delta x} - 2k_{film}\frac{T^1_{wall}-T_{avg}}{\delta x_{film}} \qquad 8$$

An approach based on the boundary condition specified in equation 2 would use the governing finite difference equation where the energy storage term for ½ layers adjacent to the boundary appear. An approach based on equation 8 replaces the governing equation and its boundary condition at the interface with equation 8 where the energy storage term is explicitly included. Either approach is mathematically and physically correct, and the one implemented in WGOTHIC provides for numerical stability. Thus, the approach does not represent an error.

NRC Observation 2:

CN-CRA-95-089, "Validation and Verification of INOUT Small Internal-Use Computer Program" Rev. 0 and 1.

The document disclosed that the author's response to the reviewer comment concerning an incorrect value for an area as used in the calculation was not considered to be of sufficient consequence to warrant a code revision. No specific evaluation to support the conclusion was provided and the inspector could not assess the impact without recourse to the originator. It was also noted by the author that if other changes were found to be necessary then this error should be corrected.

Westinghouse Response:

This concern was originally identified at a Westinghouse inspection readiness review. The document was revised prior to the November inspection to provide the additional documentation requested by the inspector. The revised calculation showed that there was no error in the original document. Westinghouse believes there are no more open or unresolved issues associated with this calculation.

Unresolved Item 99900404/97-02-03 (Continued)

NRC Observation 3:

CN-CRA-94-147, "Phase 2/3 Large Scale Test Lumped Parameter WGOTHIC Base Case Deck," Revisions 0 and 1.

The review of this document disclosed that the reviewer's comments and the author's responses were imbedded in the document. In general, the author's responses were found to include sufficient details to assess the responses. The inspection team noted that errors in the model were found after the computer analyses had been performed. In one case, the author's response indicated that a k-loss factor was likely acceptable if other specific conditions were met. There was no statement as to the expectation of the condition being met or verified.

Westinghouse Response:

Westinghouse reviewed both revisions of the calculation CN-CRA-94-147 and established that the verifiers comments expanded the applicability of the K factor over a greater range of Reynolds numbers and no further evaluation was required. Westinghouse believes there are no more open issues associated with this calculation.

NRC Observation 4:

CN-TA-96-153 AP600, "Steamline Break Mass and Energy," Revision 0.

The review disclosed that errors existed in the analyses that were identified after the computer runs had been completed. The inspection team determined that some errors would be conservative and that some would be non-conservative. The author's assessment was that there was no impact associated with the errors. It was also noted that the specific errors did not occur in the limited analyses that support design certification. The inspection also disclosed that the computer program used to calculate the SSAR mass and energy releases for the steamline breaks is LOFT4AP Version 1.8 and that the values presented in the SSAP are consistent with this supporting calculation.

Westinghouse Response:

Westinghouse issued CAR 98-1019 to document the corrective action associated with this finding. Included in CN-TA-96-153 are the following verifier comments:

Comment 1 Two data are wrong in the hot zero power deck without impact on the final result (table in paragraph 2.5.2.1.1.) Primary average temperature : 551.3 is implemented in the deck and not 551.5 °F Initial enthalpy of the CMT balance line : 543.56 is used in the runs and not 548.40 BTU/lbm.

Comment 2 The manual actuation of the PRHR for the case 30% power and a break size of 0.1 ft^2 is wrong (see table in paragraph 2.5.2.1.2). The PRHR should be actuated at 77.5 seconds. During the transient the PRHR is injecting 7 seconds sooner at 70.5 seconds. This does not have an impact on the final result.

Comment 3 Some errors were found in the feedwater flow calculation table for the full DER. These errors were corrected in the tables but not in the input data.

Comment 4 The energy flow rate for the 30% power level is wrong. It should be : 1193.2 * 9636.85 = 11498689 BTU/sec. The value used in this analysis is higher (11504664 BTU/sec) so that it is conservative for the energy result. No rerun is necessary.

Each of the verifier's comments is discussed below. It should also be noted that the limiting cases of CN-TA-96-153 have been reanalyzed (for other purposes) and are documented in CN-CRA-97-13.

Comment 1

Two issues are identified:

a) It was desired that a value of 551.5 °F and not 551.3 °F be used as the average RCS temperature for hot zero power analyses. The analyses inadvertently used a value 0.2 °F lower than was desired.

It should be noted that the AP600 design no load average RCS temperature is 545 °F. Current steamline break methodology as applied to licensed operating plants, performs the HZP analyses at the design no load temperature. Uncertainties are not applied to the initial RCS temperature at HZP conditions as they are for at power cases.

In the course of performing the AP600 analyses several times, the no load operating temperature has been modified. Therefore, to minimize possible reanalysis if the design no load temperature was changed from 545 °F, the at power temperature uncertainties (-7.0 to +6.5 °F) were also applied to the HZP average RCS temperature. Using this band around the design no load temperature is expected to prevent or minimize reanalysis if the no load temperature is changed.

The analyses used an uncertainty of +6.3 °F instead of the +6.5 °F as was desired.

b) Initial enthalpy of the CMT balance line : 543.56 BTY/lbm is used in the runs and not 548.40 BTU/lbm. The steamline break analyses is performed at several power levels (102%, 70% 30% and 0%). When setting the initial conditions for each power level, the analyst must also manually set the fluid temperatures in the unisolated portions of the CMT connection lines which may be affected by the change in the initial reactor coolant temperature. This is done iteratively by making a short LOFTRAN run and observing the calculated initial cold leg temperature and enthalpy. In the final run the enthalpy (temperature) of the unisolated portions of the CMT connections lines should be set based on the reactor coolant temperature. The analyses used the slightly colder 30% power value for enthalpy instead of the 0% power value.

This input affects the initial starting CMT recirculation flow. However, once the CMTs begin injecting, the lines are quickly swept clear of the original fluid within a few seconds and is replaced by fluid from the RCS and the CMT and has no further impact on the results. The volume of the unisolatable nodes in question are only a few tenths of a percent of the CMT loop overall volume.

This was caused by a typographical error and an oversight of the analyst. The analyst derived the appropriate temperature but did not update the input to the code. For the reasons stated above the impact on the results is inconsequential.

Comment 2

The PRHR is actuated 7 seconds earlier than it should have been during the 0.1 ft^2 steam line break from 30% power case.

As documented on page 143 of CN-TA-96-153, during the 0.1 ft^2 steam line break from 30% power case, the steam generators dry out, and the releases are terminated after 9194 seconds. During the event the integrated releases are 229800. lbm and 273700000. BTU. The PRHR has no impact on the mass and energy releases if the reactor returns to power and only a small benefit if the reactor does not return critical. If the reactor is critical the core power

increases to supply the heat load of the PRHR and the energy transfer to the faulted steam generator is not significantly impacted. If the reactor is not critical the PRHR will remove a small portion of the energy from the RCS which would otherwise be transferred to the steam generator and released from the break. Since the PRHR heat transfer area is ~ 4300 ft^2 and the steam generator is 75000 ft^2, the steam generator dominates the event.

This integrated energy of the PRHR over 7 seconds is very small when compared to the energy released through the break during the event and has an insignificant impact on the results. Based on this evaluation, the impact on the results is inconsequential.

Comment 3

For the purposes of steam line break mass and energy release calculations, it is conservative to use high values of feedwater flow to the faulted steam generator. Every pound of water entering the steam generator eventually becomes a pound of steam in the containment. During a steam line break, the steam flow from the steam generators increase and the steam generators depressurize. The feedwater control system uses a two element controller which tries to match feedwater flow to steam flow and to maintain programmed steam generator level. To conservatively approximate the performance of the feedwater control system it is assumed that the control system fully opens the feedwater control valve on the faulted steam generator in an attempt to match the steam flow from the SG. With the feedwater control valve fully open the feedwater flow is controlled by the head-flow characteristics of the feedwater pumps. The feedwater pumps are not explicitly modeled in LOFTRAN and feedwater flow must be calculated manually and entered as a table into the code.

Tables of feedwater flow as a function of steam generator back pressure are supplied by balance of plant designers. As input LOFTRAN accepts table of feedwater flow as a function of time. An iterative process is used to define the feedwater flow. A test LOFTRAN run is made with estimate feedwater flow rates to calculate the time dependent steam generator pressures. Using the steam generator pressures calculated by LOFTRAN, new feedwater flow rates are [illegible] and input to LOFTRAN again. During the course of the review, three arithmetic errors were noted in the hand calculations for feedwater flow. One of the errors resulted in feedwater flow being 1% conservatively higher. The other two arithmetic errors affected the hand calculated feedwater flow after the time at which main feedwater is isolated.

The comment resulted from an arithmetical error in the conservative direction and had no impact on the results.

Comment 4

Depending upon the break size and location, the LOFTRAN model does not simulate the blowdown of the main steam piping. To account for the piping blowdown, hand calculations are performed. The LOFTRAN calculated steam flows from the exits of the steam generators are adjusted by the results of the hand calculations to properly account for the piping blowdown.

In calculating the reverse flow from the piping, an arithmetical error resulted in an energy flow of 11504664 BTU/sec being used instead of 11498689 BTU/sec. This value is +0.05% high in the conservative direction (i.e. it increases the energy release to containment).

Unresolved Item 99900404/97-02-03 (Continued)

NRC Observation 5:

1100-SOC-001, "Containment Volumes and Heat Sinks," Revisions 0 through 4.

The review of Revisions 2 through 4 disclosed that the development of the containment volumes and heat sinks were developed and updated based on the nuclear island general arrangement drawings starting with Revision 6 and ending with Revision 8. Rev. 0 was a preliminary scoping document that was completely revised in Rev. 2. No specific review comments were identified however each page contained a sign off block with the author and verifier (reviewer's) signatures. Minor deviations were identified such as use of "estimated" and "assumed" dimensions for non-critical components and diagrams without units or dimensions clearly identified.

With respect to SSAR 6.2.1.3 and 6.2.1.4, Westinghouse needs to:

a. Evaluate the significance of the insulation on the free volume used to determine the peak containment pressure. Provide adequate justification, as appropriate, that the free volume is conservative.

b. Evaluate the significance of the insulation on the flow path characterizations used to determine the peak containment pressure, including flow areas and form losses, for both paths connecting below operating deck compartments as well as flow paths connecting below operating deck regions to above operating deck regions. Assess the effects for each of the 4 LOCA phases as well as the MSLB.

With respect to SSAR 6.2.1.2, Westinghouse needs to:
c. Evaluate the significance of the insulation on the flow path characterizations used to determine the differential pressures across subcompartment walls, including flow areas and form losses, for both paths connecting below operating deck compartments as well as flow paths connecting below operating deck regions to above operating deck regions.

d. With respect to the flooding issues, Westinghouse needs to:
Evaluate the significance of the insulation on compartment flooding, address both timing and levels, as well as which compartments would be affected.

Westinghouse Response:

This observation was provided to Westinghouse as FSER Open Item 448.1112F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 480.1112F in letter DCP/NRC1236 dated 1/29/98. Calculation Note 1100-SOC-001 Rev. 6, "Containment Volumes and Heat Sinks," issued January 8, 1998, documents the basis for neglecting the insulation on piping and equipment when calculating free volume for containment pressure calculations, and shows that the free volume calculation is acceptable. Westinghouse has also confirmed that insulation was considered in calculations of flow path characteristics for containment pressure and subcompartment differential pressure input.

Response to (a)

The presence of metallic reflective insulation can be neglected for the calculation of free volume. In addition, the free volumes used in peak pressure calculations have been confirmed to be acceptable (Calculation Note 1100-SOC-001), consequently no change to the evaluation model volume input is required.

Response to (b)

The presence of insulation was considered for flow path calculations in the prior versions (Revs 0-5) of Calculation Note 1100-SOC-001, no related flow path changes in the evaluation model inputs are necessary.

Response to (c)

The geometry used in the calculations to determine the differential pressures across subcompartment walls accounts for the presence of insulation.

Response to (d)

The presence of metallic reflective insulation can be neglected for calculation of free volumes used in the evaluation of flooding levels within compartments and in the identification of which compartments may be subjected to flooding since the effective value is small relative to the flooded value.

NRC Observation 6:

CN-CDBT-92-233, "AP600 WGOTHIC Input Deck Development," Revisions 2 and 3.

The review disclosed that errors existed in the analyses that were identified after the computer runs had been completed. The specific errors identified by the reviewer in Revision 3, dated May 22, 1997, concerning errors in areas and k-loss factors, were determined to have negligible impact on the analyses and therefore reanalyses were not performed. No discussion on how this conclusion was reached was provided. As a result, Westinghouse needs to:

a. *Provide justification that the impact of these errors and incorrect loss coefficients are conservative, or that the cumulative impact of known errors would not result in a change in the pressure calculation greater than 0.2 psig. The loss factors selected were considered to be applicable to "natural circulation" but, for the flow paths in question, the loss factors should not have been applied. Assess the effects for each of the 4 LOCA phases as well as the MSLB.*

b. *Provide justification for allowing known errors to remain in the licensing analyses that support design certification. Include the supporting knowledge base employed by Westinghouse that is used to assess errors to determine that, in consideration of the 0.2 psig (½ of 1%) margin in the calculated allowance to the design pressure, known errors have a negligible impact (for example only conservative errors remain, or that the cumulative impact of known errors would not result in a change in the pressure calculation greater than 0.2 psig). Consideration should be given to both accumulation of errors as well as the impact of errors in consideration of the different phenomena and characterizations for each of the four LOCA phases and the MSLB.*

Westinghouse Response:

This observation was provided to Westinghouse as FSER Open Item 480.1113F in a letter December 17, 1998. Westinghouse provided a response to FSER OI 480.1113F in letter DCP/NRC1236 dated 1/29/98.

For the containment pressure Design Basis Analyses using WGOTHIC, Westinghouse has corrected the flow area and loss coefficient values. Known errors have been corrected in the WGOTHIC evaluation model used to calculate the peak containment pressure. The revised results, to be incorporated into SSAR subsection 6.2.1, Rev. 21, show a lower peak pressure than previously calculated.

Attachment 2: AP600 NRC Design Assurance Review Plan

DCP/DCP0343

From : New Plant Projects Division
WIN : 284-5390
Date : February 10, 1998
Subject : **AP600 NRC Design Assurance Review Plan**

To :	D. N. Alsing	- EC W5-12	E. H. Novendstern	- EC E4-26
	J. A. Gresham	- EC E4-26	R. S. Orr	- EC E3-05
	M. Mahlab	- EC E3-07A	R. B. Tupper	- EC E3-08
	P. R. Mandava	- EC E3-05	R. P. Vijuk	- EC E3-06
	B. A. McIntyre	- EC E3-09	J. W. Winters	- EC E3-08
cc :	W. E. Cummins	- ECE3-07		
	M. Mutyala	- EC W5-10		
	S. D. Rupprecht	- EC E4-16		

The NRC AP600 Final Inspection identified concerns about the effectiveness of Westinghouse's review of the design calculations. To respond to NRC concerns, it is necessary to take additional steps to establish that the Westinghouse design documentation meets the 10CFR50 Appendix B, design verification and quality assurance requirements. A Design Assurance Review is being initiated to assess a sample of AP600 documentation that support SSAR Chapter 6 containment analysis and Chapter 15, Accident Analysis.

A Review Team, composed of technical experts independent of the calculations being reviewed, has been established to perform the review. Dr. William LaPay will serve as the team leader. The technical experts will perform an independent review of a sample of AP600 calculation notes for accuracy and documented verification. This will include a review of documented calculations and interviews with the author and/or verifier as needed. Enclosed herewith is an outline of the Design Assurance Review Plan.

The Team will issue a final report at the end of their review. Jim Winters is responsible to manage the interface with the Team and the completion of corrective actions resulting from the Team's review. Please provide the Review Team your full cooperation and support.

Original Signed By

R. M. Vijuk, Manager
AP600 Projects

/Attachment

2162alf.doc

Westinghouse Review and Verification of Design Documentation
AP600 PROJECT

Design Assurance Review Plan

OBJECTIVE:

Assess the adequacy of the AP600 the safety analysis documents supporting the SSAR Chapter 15 and the portion of Chapter 6 on containment analysis to satisfy the design certification provisions of Appendix B in10 CFR Part 50.

FOCUS OF REVIEW:

Safety related calculations that form the basis for Chapter 15 and the portions of Chapters 6 related to containment analysis of the SSAR.

AREAS TO BE REVIEWED:

A representative sample of AP600 calculations will be selected. Three distinct areas will be evaluated which include the plant configuration input to the analysis, the analysis itself, and V&V.

REVIEWERS:

Leader:	William LaPay
LOCA (Large and Small Break)	Mitch Nissley, Tim Andreycheck,
Non-LOCA Analysis	Steve Love
Containment Systems	Bob Jakub, Nick Trikouros (EPRI/GPU)
Long Term Cooling	John Spaargaren, Dan Golden
Radiological	Bob Lutz, Stan Anderson
Team Support	Ted Batt (V&V), Jeff Himler (Mechanical), QA
	Bob Tupper (AP600 Interface)

REVIEW PROCESS:

1. Develop a sample selection based on the matrix shown on Figure 1.
2. Establish the review criteria
3. Perform Calculation Reviews
4. Characterize and document review results

PLAN/SCHEDULE:

Selection of team/sample	February 9, 1998
Review Start	February 10, 1998
Review Complete	March 20, 1998
Project Comment on Review	March 27, 1998
Issue Assessment Report	April 3, 1998

CORRECTIVE ACTIONS:

Complete by April 30, 1998

Figure 1 Calculation Sample Areas

Analysis Area	Input	Analysis	Code V&V
Large Break LOCA		X	
Small Break LOCA	X	X	X
Non LOCA		X	
Containment	X	X	X
Radiological		X	
Long Term Cooling		X	X

Attachment 3: Summary of Assessment to Determine Root Cause
<u>of NRC Concern on Documentation Detail</u>

An AP600 self assessment was performed to determine the root cause for the NRC concern with the level of documentation supporting engineering judgments in calculations reviewed during the NRC Inspection documented in Report No. 99900404/97-02 dated January 26, 1998.

The NRC Inspection Report cites examples of design calculations which were considered by the inspection team to contain discrepancies or errors without documentation of an adequate evaluation by Westinghouse. The focus of this assessment was to establish the root cause for the lack of documentation by the Westinghouse authors and/or verifiers. Interviews were conducted with eleven authors and/or verifiers of approximately 14 calculation notes that had been reviewed by the NRC during the inspection. The interviews were conducted within the framework of a root cause evaluation using a combination of the "5 Whys" technique and engineering judgment.

Observations from the interviews with the authors and/or verifiers included:

- The authors and/or verifiers were familiar with the requirements for design analyses documentation detail as required by ASME NQA-1 and the QMS:

  > *"They (design analyses) shall be sufficiently detailed as to purpose, method, assumptions, design input, references, and units such that a person technically qualified in the subject can review and understand the analyses and verify the adequacy of the results without recourse to the originator". (ASME NQA-1)*
  >
  > *"Design analysis documents are legible, reproducible, and describe the purpose method, assumptions, design input, and references such that the analysis can be reviewed and verified by a person technically qualified in the subject without recourse to the preparer". (QMS)*

- The authors prepare their analyses with the understanding that the *"person technically qualified in the subject"* is another member in their functional area experienced with the Westinghouse design and methodology. Both authors and verifiers considered that most of the judgments reflected in the calc notes were intuitively obvious to those familiar with the work product.

- Many authors and/or verifiers agreed that in retrospect, given that this was a development project and subject to third party reviews, more documentation detail could have been provided in some cases.

- Some authors and/or verifiers reported that because of the developmental nature of the program, the continuing flow of changes, and the knowledge that analyses were going to be revised to accommodate future changes, the correction of "insignificant" errors was documented for future revisions of the document, while significant errors, if any, were corrected.

This assessment concluded that the root cause of the lack of documentation supporting Westinghouse judgments is that the analyses were basically being prepared for internal review and verification by other qualified Westinghouse personnel. That the verifier had sufficient information to enable verification to be completed in accordance with the governing procedures as evidenced by the verifiers signature, indicates that the author provided sufficient documentation detail. Some of the authors and verifiers were also influenced by the knowledge that as a development project, future revisions would afford an opportunity to clean-up "insignificant" errors.

Recommendation for management consideration as a result of this assessment:

In order to further assure that documentation detail provided in Westinghouse analyses is sufficient for the purpose intended, it is recommended that assignment of future work include guidance in terms of the audience for which the work is being prepared, if other than the internal Westinghouse verifier. This should be accomplished in the design planning phase. WCAP 12601 would be an appropriate documentation of the guidance for the AP600 Project.