Mail Envelope Properties (3FCF7577.481 : 18 : 20163)

Subject:	As discussed.
Creation Date:	12/04/2003 12:57PM
From:	Joelle Starefos
Created By:	JLS1@nrc.gov

Recipients	**Action**	**Date & Time**
westinghouse.com	Transferred	12/04/03 12:57PM
vijukrp (Vijukrp@westinghouse.com)		

Post Office	**Delivered**	**Route**
		westinghouse.com

Files	**Size**	**Date & Time**
30Qs.wpd	30196	12/04/03 12:56PM
MESSAGE	952	12/04/03 12:57PM

Options

Auto Delete:	No
Expiration Date:	None
Notify Recipients:	Yes
Priority:	Standard
Reply Requested:	No
Return Notification:	None
Concealed Subject:	No
Security:	Standard
To Be Delivered:	Immediate
Status Tracking:	All Information

From: Joelle Starefos
To: Vijukrp@westinghouse.com
Date: 12/04/2003 12:57PM
Subject: As discussed.

Ron,
Please let me know if any proprietary material was documented.
Thanks, Joelle

Joelle L. Starefos
Project Manager, AP1000
NRC/NRR/DRIP/RNRP
Mail Stop: OWFN 4D9A
(301) 415-8488
jls1@nrc.gov

DRAFT COMMENTS ON WESTINGHOUSE RESPONSE TO AP1000 DSER OPEN ITEMS (Westinghouse Letters DCP/NRC1608, DCP/NRC1611, and DCP/NRC1612, dated August 4, August 13, and August 15, 2003, respectively):

OPEN ITEM 15.2.7-1, Long-term Cooling (LTC):

1. Westinghouse used selected G1 and G2 full-scale boil-off tests at pressure and power levels, which are prototypic of AP1000 conditions, to validate the WCOBRA/TRAC core model. The validation also determined, via sensitivity studies, that it was necessary to apply a corrective multiplier of 0.8 to the interfacial drag model to accurately predict the average core void fraction. However, Westinghouse stated that in the AP1000 DEDVI event during LTC, the average core exit quality is always less than 50%. This flow regime is quite different than the boil-off scenarios of the G1 and G2 tests. In the boil-off mode the exit quality is approximately 1.0.

   Justify the applicability of the G1 and G2 tests to the AP1000 LTC conditions for use in validating the WCOBRA/TRAC results, and justify the validity of the corrective multiplier that was determined from benchmarks against the G1 and G2 tests for the AP1000 LTC model.

2. DSER OI 15.2.7-1P Page 8 states that Figure 8 shows that the "mixture level" is located in proximity of the hot leg centerline, whereas Figure 8 shows collapsed liquid level in the hot leg.

   Please clarify the discrepancy.

3. On DSER OI 15.2.7-1P Page 12, it is stated that "[the] expected flow regime at the top of the core is a churn or pulsating annular flow. The steam velocity is so low that entrainment of droplets is not expected to occur."

   Indicate why this condition does not contradict the argument that sufficient liquid is entrained to avoid boron precipitation.

4. In the revised DCD Section 15.6.5.4C.2 (DSER OI 15.2.7-1P Page 15), it is stated that there is a continuous flow of two-phase fluid into the hot legs, and mainly vapor flow toward the ADS Stage 4 valves occurs at the top of the pipe.

   What is basis to conclude (at the end of the section) that the recirculation core liquid throughput is more than adequate to preclude any boron buildup on the fuel?

5. Since the DEDVI break long-term cooling case described in the revised DCD Section 15.6.5.4C) is the same case for the revised WCOBRA/TRAC LTC calculation, explain why the void fraction at the hot assembly top cell presented in Figure 11 (DSER OI 15.2.7-1P Page 11) and figure 15.6.5.4C-3 (DSER OI 15.2.7-1P Page 20) are different (other than the 2500 second shift).

6. Tests at the AP1000 APEX facility indicate that the single failure of a stage 4-ADS valve produces lower core inventories if the failed valve is not in the pressurizer loop. The revised DCD Section 15.6.5.4C.2 (DSER OI 15.2.7-1P Page 14) states that the analysis of the

Attachment 2

DEDVI LTC case assumes failure of one of the two ADS-4 valves in the PRHR loop. Since the PRHR loop is the same loop that contains the pressurizer, justify that the small break analyses in Chapter 15 of the DCD are conservative in view of the test results from the APEX facility.

7. The revised DCD Section 15.6.5.4C (DSER OI 15.2.7-1P Page 14) states that the LTC phase analysis uses the NOTRUMP DEDVI case at 25 psia containment pressure reported in Section 15.6.5.4B as initial conditions, and the WGOTHIC analysis of this event as boundary conditions.

   Please describe the model used to develop the containment backpressure and demonstrate that it represents a bounding and conservative estimate of containment pressure following a small break LOCA. Discuss any differences that may exist between this model and that used in the large break LOCA analyses. Please discuss how water spillage from a broken DVI line is mixed with the containment atmosphere and justify that the treatment is consistent with the Westinghouse ECCS evaluation model. Discuss the conservative treatment of non-safety related containment sprays and containment coolers in reducing containment pressure. Please also clarify if the 25 psia initial condition is consistent with the WGOTHIC analysis of the containment pressure as a function of time.

8. The revised DCD Section 15.6.5.4C.1 (DSER OI 15.2.7-1P Page 13) states that "Reference 24 [WCAP-15644, "AP1000 Code Applicability Report."] provides details of the AP1000 WCOBRA/TRAC modeling. The coarse reactor vessel modeling used for AP600 has been replaced with a detailed noding like that applied in the large-break LOCA analysis described in subsection 15.6.5.4A." Also, in the revised DCD Section 15.6.5.4C.3 (Westinghouse letter DCP/NRC1617, dated September 8, 2003), it is stated that in WCOBRA/TRAC analysis, the core is nodalized as described in Reference 24. However, neither WCAP-15644 nor DCD Subsection 15.6.5.4A provides detailed AP1000 WCOBRA/TRAC modeling.

   A. Please clarify where the core nodalization is described for the LTC analysis.

   B. Clarify whether the core nodalization is the same as that described in your "Summary" of the response to Open Item 15.2.7-1, which states that for the AP1000 LTC model, the core region was subdivided axially into 17 nodes.

9. DSER OI 15.2.7-1P Page 32 indicates WCAP-15644 will be revised to include the description and additional validation of the WCOBRA/TRAC LTC model discussed in this response. This is a confirmatory item.

10. The NRC staff is attempting to modify the RELAP5 AP1000 model to evaluate LTC. The current model does not model sump recirculation into the DVI lines. Please provide the following information to enable the staff to perform LTC confirmatory analyses with RELAP5 for a postulated double DVI line break.

A. Containment temperature, pressure, water level and boric acid concentration versus time for 30 days.

B. Recirculation line lengths, areas, elevations and resistances. All elevations including containment water levels should be given relative to the reactor vessel DVI nozzle elevation.

C. Recirculation valve actuation setpoints and the WCOBRA/TRAC calculated time for sump recirculation following a double ended DVI line break.

D. Sump screen resistance as a function of flow blockage.

<u>Post-LOCA Long Term Cooling BORON PRECIPITATION</u>

11. Unlike the conventional PWR plants which rely on simultaneous injection line-ups to flush the core to preclude boron precipitation, the AP1000 relies entirely upon the entrainment of high concentration boric acid in the core to be swept upward through ADS-4 flow paths, which are approximately 20 ft in vertical distance above the hot legs, to prevent boric acid precipitation. During the long term, it is not clear how high concentration boric acid is swept upward over these distances since it is expected that the steam produced in the core will collect in the upper head and upper plenum region above the top elevation of the hot leg. Steam will then collect and enter the hot leg from elevations above the top of the hot leg. As such, it is expected that much higher void fractions and even intermittent separated flow in the hot leg will show mostly steam flows in the top quarter to a third of the hot leg as it enters from the upper head and top of the upper plenum. During this horizontal run, it is not clear how the high concentrate boric acid in the upper plenum travels upward along the horizontal section of the hot leg to reach the entrance of the ADS-4 line on the top of the hot leg.

Moreover, two-dimensional effects would dictate that the high concentration boric acid entering the hot leg at the nozzle will tend to flow downward creating recirculation patterns returning most the concentration back toward the vessel. And, with the bulk of the steam flowing along the top of the hot leg, very little high boric acid content is expected to make it to the entrance of the ADS-4 line. Also, what little high boric acid content makes it to the initial vertical section of the ADS-4 line must now be pushed horizontally several feet where more concentrate will settle on the bottom of the horizontal section of the ADS-4 piping. The NRC expects that concentrations would build-up in the horizontal section as more steam separates from the liquid and flows along the top of the pipe. The high quality steam water mixture must then flow vertically several more feet in length with another 90 degree bend, which would be expected to de-entrain what little liquid has made it thus far. As such, it is not clear there is sufficient liquid exiting the torturous path through the ADS-4 lines to reduce the boric acid concentration in the manner suggested by Westinghouse. These issues are raised particularly since no dynamic calculations were performed which can be substantiated.

Please address the following limitations in the Westinghouse simplified model regarding the boron concentration analysis (provided in Attachment 1 to Westinghouse letter DCP/NRC1612 dated August 15, 2003):

A. The simplified model is one-dimensional and therefore does not account for the two-dimensional radial void distribution in the hot leg, nor in the horizontal sections of the ADS-4 piping. Separated flow is not modeled in the hot leg nor the ADS-4 piping. Also, the vertical flow regime map does not apply to the horizontal section of the hot leg nor the horizontal sections of the ADS-4 piping. As such, it does not appear that the void distribution and attendant flow regimes in the horizontal sections were properly determined. The resulting ADS-4 exit qualities are also questionable.

B. The simplified model assumes homogeneous fluid behavior which dictates that liquid will always exit the ADS-4 piping. The model cannot simulate the collection of steam in the top portion of the hot leg piping which could become separated and chug intermittently causing step increases in boric acid content during the long term. It is not clear that intermittent chugging will flush the boric acid content from the vessel. This limitation applies to the horizontal sections of the ADS-4 piping as well.

C. The boric acid profile in the hot leg is expected to be non-uniform with a gradient that would promote the return of high concentrate boric acid toward the bottom of the hot leg which will flow back into the vessel. The one-dimensional model cannot simulate these effects.

D. The quality out the ADS-4 line is assumed to be the same as that at the core exit (with an adjustment to account for pressure difference). This assumption is not considered valid and, with the above-mentioned limitations of one-dimensional modeling approach, cannot be verified. Since steam will collect in the top portion of the hot leg and there is a large horizontal section in the ADS-4 piping, the quality of the fluid exiting ADS-4 is not expected to be the same as that exiting the entire core region.

E. To provide a theoretical steady-state prediction of the fluid quality exiting the ADS-4 piping given its complex geometry and the fact that correlations do not exist to predict such behavior is conjecture and cannot be used as a basis for computing the liquid flow from the RCS during the long term. Furthermore, if dynamic multi-dimensional computations were performed, there would be no data to verify the calculation, particularly since no test data exists for the ADS-4 geometry and fluid conditions during the very long term.

F. Cooler containment water will condense steam and cool the water in the horizontal section of the ADS-4 lines causing crystalization of boric acid in this region. This could increase the resistance in the ADS-4 lines, limit the venting capability of this system, and cause boric acid to accumulate faster in the RCS.

12. Please provide the following information regarding the boron concentration analysis given in DCP/NRC1612 entitled "Transmittal of Westinghouse Response to Boron Precipitation during LTC Phase," dated August 15, 2003:

A. ADS-4 quality and liquid mass flow rate versus time used to generate Fig. 5.
B. RCS injection mass flow rate versus time for the analysis in Fig. 5 (CMTs, accumulators, IRWST, and Sump).
C. Core inlet mass flow rate and fluid temperature versus time for Fig. 5
D. A plot of the core exit steaming mass flow rate versus time from Fig. 5.
E. Hot leg void fraction versus time

F. Core exit void fraction versus time

13. Please provide justification for the mixing volume assumed in the boric acid precipitation analysis.

14. Does the head of water in the core and upper plenum consider the additional mass due to the boric acid that concentrates in this region? If not, please explain the omission, especially when sensitivity studies show high concentrations in the core. How does the 35,000 ppm concentration in the core, lower plenum, and upper plenum and other portions of the hot side of the RCS affect the flow rate entering the inner vessel? Please explain.

15. It is stated that the analysis of the boron concentration in the core (Attachment 1: AP1000 Long Term Boron Concentration Evaluation, Section 3) assumed the core to only mix with the water in the upper plenum having a minimum mass of 27,490 lb, which is based on WCOBRA-TRAC analysis.

    What is the basis of the minimum mass of 27,490 lb in the precipitation analysis? Please explain.

<u>OPEN ITEM 21.5-1, CONFIRMATORY SENSITIVITY ANALYSIS</u>:

16. For the comparison of the integrated liquid discharge through ADS-4 between the base DCD case and the revised noding model, Figure 21.5-1.12 on DSER OI 21.5-1P Page 11 has an inconsistency in that the heading states "ADS-4 Liquid Discharge Comparison," whereas the actual figure is for ADS-4 integrated vapor discharge.

    Please clarify.

17. The text on DSER OI 21.5-1P Page 3 states that Figure 21.5-1.14 presents a comparison of the upper downcomer pressure between the base case and the sensitivity case, but the actual figure is for pressurizer pressure (except for the heading). The text also states that the pressurizer mixture level response (Figure 21.5-1.25) reflects the change in pressure response (Figure 21.5-1.14) observed in the model.

    Clarify the discrepancy regarding Figure 21.5-1.14.

<u>OPEN ITEM 21.5-2, UPPER PLENUM LIQUID ENTRAINMENT TESTING</u>:

18. In the response to DSER Open Item 21.5-2P (Westinghouse letter DCP/NRC1611, August 13, 2003), the core collapsed liquid level for AP1000 APEX tests 02 and 03 are given in Figures 7, 11, 21.5-2.17, 21.5-2.19, and 21.5-2.44. Report OSU-APEX-03002 "OSU APEX-1000 Test Facility Description Report" indicates that uncompensated core level is provided by instrument LDP-118. The core collapsed liquid level figures for the tests performed are provided in the CDs attached to the Test Acceptance Reports OSU-AP1000-02 through OSU-AP1000-05.

    A. Why do the test acceptance reports not present the core collapsed liquid level figures for various tests? Please incorporate these figures in the test acceptance reports.

B. Provide and justify the modifications that are made to the uncompensated core level to produce the results presented in the response to DSER OI 21.5-2.

19. As mentioned in the ACRS Meeting in Monroeville in July, 2003, the APEX test facility contains an oversized downcomer. The oversized downcomer will produce high liquid inventories for extended periods of time which will maximize the liquid and two-phase levels in the core and upper plenum. This suggests the APEX facility cannot be used to simulate the minimum liquid and two-phase levels in the inner vessel that could occur following small breaks in the AP1000 plant. With a larger downcomer, more liquid mass will be retained in the vessel for small breaks. The statements in the Westinghouse August 13, 2003 letter (DCP/NRC1611) that the APEX-1000 facility is well scaled to AP1000 and the two-phase level remains in the upper plenum while the core remains covered for all phases of the simulated accident may not be appropriate and is misleading.

Please discuss the impact of the larger downcomer on the relevant APEX tests and explain why the facility test results can be used to demonstrate that significant amounts of inventory in this facility apply to the anticipated AP1000 response. Please also explain the statement that the APEX tests show the insensitivity of the AP1000 system behavior to entrainment is unaffected in lieu of the excessive amounts of liquid in the inner vessel during the tests referred to in the August 13, 2003 letter.

20. In APEX-1000 Test DBA-02, Figure 21.5-2.26 (in Westinghouse letter DCP/NRC1611, August 13, 2001) shows the comparison of integrated vessel side break flow between the test data and NOTRUMP simulation.

Please explain why the integrated break flow test data decreases after about 1050 seconds.

21. In the time period between approximately 350 and 1000 seconds for the DBA-02 test simulation, Figure 21.5-2.29 shows the core inlet temperature calculated by NOTRUMP to be about 25°F higher than data; whereas Figures 21.5-2.30 and 21.5-2.20 respectively show almost the same core outlet temperature and the core average void fractions between the test data and the NOTRUMP simulation.

Explain the apparent inconsistency between the test data and the NOTRUMP simulation in terms of energy balance.

22. For the NOTRUMP simulation of both DBA-02 and DBA-03 tests, Figures 21.5-2.19 and 21.5-2.44, respectively, show NOTRUMP overpredicts the core collapsed liquid level for the time period between about 100 to 400 seconds. Figures 21.5-2.20 and 21.5-2.45, respectively, indicate NOTRUMP underpredicts core average void fraction between the same time period. Westinghouse attributes the non-conservative NOTRUMP calculations to its lack of two-dimensional downcomer modeling and heating of DVI injection flow. The sensitivity study performed with higher injection temperature still show non-conservative, though reduced, NOTRUMP predictions (Figures 21.5-2.17 and 18).
Please explain why, with the same downcomer modeling deficiency, the NOTRUMP

calculations of the core liquid level and void fraction are comparable with the tests after 400 seconds.

23. For DBA-03 test, Table 21.5-1.2 (DSER OI 21.5-2P Addendum 1 Page 18 in Westinghouse letter DCP/NRC1611, August 13, 2001) indicates that the intact accumulator injection starts at 110 seconds and empties at 510 seconds for the test data, and starts at 123 seconds and empties at 346.44 seconds for the NOTRUMP simulation. Page 9 states that the comparison for accumulator 2 [Intact] is considered minimal, and that the minimal prediction is considered to have a negligible impact on the results as the composite effect of CMT and accumulator injection is reasonably/conservatively predicted by NOTRUMP.

    Please explain the cause of the large difference between the NOTRUMP simulation and test data with regard to the accumulator injection starting and empty times.

24. It is noted that several different NOTRUMP model approaches are used in the NOTRUMP simulation of the APEX-1000 tests compared to the AP1000 small break LOCA DBA analysis. These include revised noding in the pressurizer, revised noding in the core makeup tank, no PRHR heat transfer area adjustment is applied, use of different ADS critical and noncritical flow models, and use of a break flow multiplier to more accurately represent the results observed in the test.

    Please provide a complete list of all differences of the NOTRUMP model between the APEX-1000 simulation and AP1000 plant analyses, and justify why the test simulation conclusions can be applied to the NOTRUMP models used for the AP1000 analysis.

25. For the test DBA-04, 2-inch cold leg break simulation (Test Acceptance Report OSU-AP1000-04), Table 4-1 indicates that the assumed single failure is failure of 1 of 2 lines in one ADS-4 train on the pressurizer side, whereas Section 5.0, "Test Procedure," states that the 100-percent flow nozzle was installed in the ADS 4-2 (on hot leg 2) and the 50-percent flow nozzle was installed in ADS 4-1 (on hot leg 1). Since the pressurizer is on hot leg 2, the use of 50-percent flow nozzle on hot leg 1 appears to simulate a single failure of ADS-4 on the non-pressurizer side, contradictory to Table 4-1.

    A. Please clarify this inconsistency.

    B. The results of the DBA-02 and DBA-03 tests simulating DVI line break indicate that the single failure of ADS-4 valve on the non-pressurizer side is limiting. Please explain why a single failure of ADS-4 valve on the pressurizer side was simulated for the DBA-4 2-inch cold leg break test.

26. Please describe the significance of OSU test TR-02 in comparison with test DBA-04 in particular discuss the actions of ADS 1 through 4. Table 4-1 of report OSU0AP1000-5 indicates that no ADS 1 through 3 were operable. The text of that report on page 5-1 states that after ADS 1 had opened ADS4-1 was opened manually and ADS4-2 was opened manually 30 seconds later. Table 6-2 of that report indicates that ADS 1,2,3,and 4 all opened automatically with ADS4-2 opening 25 seconds later than ADS4-1. Please discuss these inconsistences and provide the location of the ADS4 valve that was assumed to have failed for the test in relationship to the pressurizer for the test.

27. In its August 13, 2003, letter (DCP/NRC-1611), Westinghouse provided in Response Addendum 1 the NOTRUMP simulation of APEX-AP1000 tests DBA-02 and DBA-03.

Please provide the NOTRUMP simulation of other APEX-AP1000 tests.

28. The APEX test matrix contained a subset of tests expected to produce the lowest vessel collapsed liquid levels. The selection of these tests was in part based on results of NOTRUMP simulations. Westinghouse indicated that similar liquid levels were predicted for inadvertent ADS 1-3, 2 inch hot leg break and the DEDVI break. The DEDVI break is considered to be limiting small break LOCA and assessment has focused on this case. Please demonstrate the adequacy of the NOTRUMP simulation of inadvertent ADS 1-3 to ensure that the limiting break has been identified.

OPEN ITEM 21.5-3, CORE LEVEL SWELL:

29. The Cunningham-Yeh correlation as described on OI 21.5-3 Page 3 has an error in the critical bubble radius term R_{bcr}.

Please confirm that it is only a typographic error and the correct Cunningham-Yeh correlation is used in the study.

30. Westinghouse has relied on comparison to data to validate NOTRUMP's modeling of level swell and upper plenum entrainment phenomena during the ADS-4/IRWST injection transition phase. These phenomena are high ranked during this phase because heat transfer from the rods to the coolant depends strongly on the proximity of the two-phase level and the amount of droplets in the dispersed flow heat transfer regime. As a result, the staff is thoroughly reviewing this information. If the NOTRUMP code were shown to conservatively predict rod heat up for appropriately scaled test cases run at APEX-1000 that demonstrated heat up, such as NRC-AP1000-05, then the uncertainty in the staff's review of the effect of level swell could be reduced.