52-003

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 16, 1996

Mr. Nicholas J. Liparulo
Nuclear Safety and Regulatory Activities
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, Pennsylvania 15230

SUBJECT: DISCUSSION ITEMS FOR AP600 MEETING ON MISCELLANEOUS TESTING ISSUES

Dear Mr. Liparulo:

As a result of its review of the June 1992 applica.ion for design certification of the AP600, the staff has determined that it needs additional information in order to complete its review. The enclosed estions and comments have been developed by the staff as a result of the review of the following test program reports:

Passive Residual Heat Removal Heat Exchanger Final Test Report
Automatic Depressurization System Phase B1 Final Data Report
Automatic Depressurization System Phase B1 Test Analysis Report
OSU Program Final Data Report
OSU Program Test Analysis Report (Partial)

We propose that these question serve as an agenda item in an upcoming meeting concerning AP600 testing issues. During the meeting, the staff will determine which discussion items need to be formally addressed by Westinghouse.

In addition, an RAI(440.566) on the closure of scaling analysis of test data is included. This item was discussed at the December 18, 1995 meeting with Westinghouse.

You have requested that portions of the information submitted in the June 1992 application for design certification be exempt from mandatory public disclosure. While the staff has not completed its review of your request in accordance with the requirements of 10 CFR 2.790, that portion of the submitted information is being withheld from public disclosure pending the staff's final determination. The staff concludes that these followon questions do not contain those portions of the information for which exemption is sought. However, the staff will withhold this letter from public disclosure for 30 calendar days from the date of this letter to allow Westinghouse the opportunity to verify the staff's conclusions. If, after that time, you do not request that all or portions of the information in the enclosures be withheld from public disclosure in accordance with 10 CFR 2.790, this letter will be placed in the NRC Public Document Room.

These followon questions affect nine or fewer respondents, and therefore is not subject to review by the Office of Management and Budget under P.L. 96 511.

DF03

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If you have any questions regarding this matter, you may contact me at (301) 415-1141.

Sincerely,

original signed by:

William C. Huffman, Project Manager
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Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosure:
As stated

cc w/enclosure:
See next page

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Docket No. 52-003
AP600

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QUESTIONS, COMMENTS, AND DISCUSSION ITEMS

CONCERNING THE WESTINGHOUSE AP600 TEST REPORTS

PRHR Items

1. The staff has previously requested that Westinghouse provide a technical justification for the use of the database established from the straight-tube passive residual heat removal (PRHR) heat transfer tests to model the performance of the current "C-tube" PRHR heat exchanger (HX) design. The staff's concerns have related primarily to the modeling of dryout in tube bundles, especially in the upper horizontal portion of the HX, where heat fluxes are expected to be the greatest. In addition, recent evaluation of test data from the PRHR test program has raised questions about the reliability of all of the data from the test program, due to possible errors in conversion of instrument output to engineering units, and the apparent deviation of the test data from conventional correlations for calculating heat transfer coefficients. Accordingly, the staff requests that Westinghouse:

   a. Fulfill the earlier request for technical justification for modeling "C-tube" behavior using straight-tube data;

   b. Reexamine the data from the PRHR test program to determine if the conversion of instrument data was done properly;

   c. If the evaluation for (b) above shows that data conversions were not done properly, reconstitute the millivolt data, correct the conversions to engineering units, and demonstrate the overall reliability of all of the test data; and

   d. Provide a detailed explanation of the analytical models used to calculate heat exchanger performance, for the purposes of both unit design and accident and transient analyses; and show that these models (i) are validated over the range of thermal-hydraulic test data and expected AP600 performance, and (ii) can be shown within an acceptable error to calculate conditions representative of the design certification data for the PRHR system.

2. In view of the problems identified with the test data, the staff questions the adequacy of the PRHR Test Program Final Report. The report does not conform with the format of other AP600 test programs, nor does it provide all of the test data and associated analyses, on a test-by-test basis, for staff review. The report also lacks a detailed error/uncertainty analysis commensurate with those done for the other test programs.

3. In the FDR, in Chapter 4, the pressure drop data are used to indicate where "choking" is deemed to have occurred. What quantitative criteria were used to determine the locations where choking occurred? Are they the same as described in the TAR?

4. There appear to be significant inconsistencies in the parameters presented for Test 120 in the FDR. In Table 1.2-1, the nominal test pressure is shown as 1600 psig, and in the text in Chapter 4 (Section 4.1.2.2) the pressure is given as 1581 psig. However, in Table 4.1.1, the pressure is listed as 158 psia (inconsistent both as to value and to psia vs. psig), and the pressure plot on p. 4-12 shows the initial pressure as about 95 psig, which is inconsistent with everything else. Please explain and correct this information.

5. The analysis for Test 120 in the FDR states that the major pressure drops occur across VAD-1 and VAD-2. However, the data in Fig. 4.1-6 appear to show that the latter pressure drop occurs not across the valve alone, but rather across the entire stage 2 section (valve and orifice). Please explain these differences.

6. Similar to the previous question, data from Tests 130 and 140 appear to indicate that large pressure drops occur across the stage 3 (Test 130) and stage 2 and 3 (Test 140) orifices rather than the valves themselves. For Test 250, choking appears to occur across the stage 2 orifice rather than the valve. Explain these apparent discrepancies or, alternatively, demonstrate that the data support your analyses.

7. Figure 4.2-1 in the FDR and Fig. 4-170 in the TAR purport to show the same tests (210, 211, and 212). However, the actual flow and quality shown for the tests are substantially different in the two figures.

   a. Please explain the apparent discrepancy between the two figures.

   b. The actual test conditions shown for these tests appear to fall substantially outside of the range shown as "intended." Explain why these tests are considered to be "acceptable," and how the necessary thermal-hydraulic range for AP600 is covered if the tests differ so much from the conditions specified in the matrix.

   c. How are code models to be validated over the range of operating qualities above around 20-30 percent? There appear to be no data, either intended or actual, in the upper portion of the range.

8. The previous question is relevant to other tests shown in the FDR and the TAR, with regard to discrepancies in flow/quality between the plots in the two reports, test acceptability where test conditions appear to be substantially outside of the specified ranges, and the coverage of the entire range of operating conditions. Examples include:

   a. Test 250: a single test is not representative of the entire range of operating conditions.

b. Tests 330, 331 (multiple runs), 320, 321, 322, 350, 351: discrepancies between FDR and TAR; acceptability of tests not meeting "intended" conditions; tests lying outside of envelope of operating conditions.

Please provide a discussion of the relationship of ADS test data to projected AP600 operating conditions, and explain the (i) acceptability of tests nominally outside the range of projected operating conditions and (ii) adequacy of the test program to provide data to model AP600 ADS operation.

9. In FDR Sections 4.2.3 and 4.3.3, it is stated that quench tank volume increased by 85 percent and 85-90 percent of the change in supply tank mass, respectively (emphasis added).

   a. What is meant by these statements?

   b. Assuming that the intent of these statements is to compare quench tank mass change to supply tank mass change, what are the implications of apparent mass balance errors of 10-15 percent? Since flows are inferred by supply tank mass changes, are these errors/uncertainties acceptable for the test data?

10. The discussion in Section 4.2.2.10 states that the flow in Test 242 "is no greater than the flow in Test 241...." This is not borne out by the plots in Figs. 4.2.37 and 4.2.41, which show Test 242 mass flow (peak and plateau) is substantially more than Test 241. Please reconcile the discussion and the data.

11. The criteria for determining test acceptability are not clear, especially for tests where no quasi-steady (or "plateau") region was seen in the mass flow. For instance, Test A046340 is considered "acceptable," but its flow vs. time does not exhibit any real plateau, and looks substantially different from A006340, which is a similar test. Please elaborate on how test acceptability was determined, and how the tests with no "plateau" region were evaluated.

12. In several "hot quench tank" tests, water was apparently ejected from the quench tank. While the staff recognizes that the VAPORE quench tank is in no way scaled to the AP600 IRWST, this does raise a question about IRWST response if it has been heated for a long period prior to ADS actuation. How is the AP600 IRWST expected to respond if the ADS is actuated when the IRWST is at substantially elevated temperatures?

13. In FDR Section 5.0, there seem to be two conflicting statements about the coverage of the ADS Phase B1 tests. The first paragraph states that the tests "closely match the limits of the AP600 operating envelope when the peak flow rates are considered." Two paragraphs later, though, the first bullet refers to "data...over a wide range of quasi-steady-state flow rates."

   a. Are the tests evaluated in terms of the peak flow, the quasi-steady (plateau) flow (where it exists), or both? If peak flow is a significant aspect of the test, why is the test mass flow rate (e.g., Table 4.4-1) evaluated at 20 seconds, which is well past the peak in most cases?

b. How does the relative brevity of the tests affect the usefulness of the data?

c. While the plots such as Fig. 4.3-3 indicate that the AP600 operating range includes qualities between 26 percent and 99 percent, no tests covered that range, at least at the inlet. How will the operating envelope in the range of intermediate qualities be covered by test data? If that range will not be covered in tests, explain why the database is sufficient.

14. The ADS Phase B1 TAR does a reasonably good job in explaining the kinds of analyses that were performed on the data, e.g., two-phase multipliers, critical flow, etc. What is not clear is how this information is going to be used. Are specific models for two-phase subsonic and critical flow in piping networks and valves going to be validated for use in the AP600 accident analysis codes? Or is the analysis simply an aid to better understanding of the behavior of the system during these tests?

15. On p. 4-22 in the TAR, it is stated that "it is not essential to make a determination of whether choking occurred in the ADS test components. The pertinent issue is whether the computer models used to analyze the AP600 plant ADS can correctly predict the two-phase pressure drops and flow measured in the tests." The data from these tests establish a basis for validation of analytical models. However, the implication of the statement seems to be that if the calculations of overall pressure drops and flows through the piping/valve network are acceptably accurate, details of the various component pressure drops and flows do not matter. This would seem to provide little confidence that the code models would be able to predict accurately any conditions that fell outside the relatively narrow range represented by the ADS tests that were analyzed (including those of the second train of ADS in the plant, since the piping network is somewhat different from the first ADS train). This is especially true considering that flow splits in the ADS tests were inferred, not measured, and there appears to be no way to confirm the inferred flow distribution. Since flow splits depend on pressure loss characteristics of the various network components and the condition of the flow passing through those components (choked or unchoked). Westinghouse should explain how the models can adequately differentiate between choked and unchoked flow.

The staff takes note of the discussion in Section 4.4.3, e.g., the tendency of orifices not to "choke" in the classical sense. However, no quantitative evidence is presented to support the conclusion that the ADS gate valves would tend to behave as orifices in critical flow; in addition, while there are models that predict the limiting flow condition in orifices, no comparison to such models is presented in the TAR. Westinghouse should (a) present a quantitative analysis of the data to substantiate its conclusions (possibly including comparison to data from the Phase B2 series of tests), and (b) explain how the models used to calculate ADS 1/2/3 performance represent the thermal-hydraulic conditions in the piping/valve network.

16. The implications in Sections 1 and 5 of the TAR are that the gate valves for stages 2 and 3 were of substantially different design and configuration. How do the differences between these two valves contribute to the variations in the data (and derived quantities).

OSU Final Data and Test Analysis Reports

A set of questions based on the preliminary versions of the FDR and the TAR were provided to Westinghouse previously. The following questions reflect more detailed reviews of the final versions of the reports.

FDR Related Questions

17. Recent staff evaluation of OSU data indicates that a check valve failure in the normal RHR line opened a flow path between the two DVI lines. The largest potential impact of this occurrence appears to be in DVI-line break tests, in which flow from the intact DVI line could be diverted to the broken line. Explain how this condition affects reliability of test data from OSU for these events, and how the flow path is accounted for in analyzing the data. The tests' ability to meet Westinghouse's established acceptance criteria should also be discussed.

18. The "sequence of events" specifies event timing with much higher precision than the facility's normal data acquisition rate would appear to support. How were the times determined?

19. All of the test descriptions include sections on "Inoperable Instruments." For several of the tests, the cold leg flow meters were damaged and inoperable (see, for example, Section 5.4.1.2). It is stated that differential pressures were used to infer cold leg flows. However, the relevant instruments are not plotted for these tests.

    a. Why are the instrument readings not included in the FDR?

    b. These types of readings can only be correlated with flow in single-phase conditions. How was the flow measured (or, was the flow measured) in two-phase conditions? Are the data considered to be reliable for single- and/or two-phase flows?

    c. Explain how the necessary information on cold leg flows can be derived from the available data.

20. Over a range of several thousand seconds in many tests, the PRHR HX wide range level appears to drift upwards considerably. Explain what is occurring: is this an actual change in level, or is an instrumentation problem?

21. Figure 5.4.2-72 presents calculated break flow from the reactor vessel for Test SB13, presumably because the total break flow includes contributions from other components. Are other such plots available for

tests where such a differentiation is relevant? Also, in Section 6, there are comparison plots (with varying time scales) of total break flow for 4 tests. Since the tests have breaks in various locations, and the total break flow can include contributions from more than just the reactor vessel, depending on break location, please elaborate on the significance of these plots.

22. Please explain fully what calibration procedures were followed for the BAMS. How is uncertainty in the break flow rate determined? Is there any attempt to compare integral break/ADS flow with the total flow collected in the BAMS and the sump(s)?

23. How were actual operating conditions factored into the measurement uncertainty analysis; in other words, were there conditions during the tests that could affect instrument accuracy (e.g., voiding in sense lines) that were not represented in the as-calibrated uncertainties, and if so, how were these conditions included in the uncertainty analyses? Were historical data--based on instrument responses from earlier tests--used to help estimate uncertainties?

The following questions are related to the detailed presentation of data for Test SB01 in Section 5.1.1 of the FDR.

24. In Test SB01, the low accumulator pressure is attributed to cooling in the accumulator by the nitrogen. Could changes in gas solubility also affect the pressure?

25. In the brief table in Section 5.1.1.1, is the "dimension" for each CMT thermocouple its axial distance from the top of the CMT? If not, what does "dimension" mean?

26. Section 5.1.1.2 presents a very good discussion on compensation for inoperable instruments. The one exception is for PT-201, which is identified as being unreliable; the statement is made that "a sufficient amount of other pressure data are available," but the sources of those data are not identified. Please specify the data that were used to compensate for this instrument.

27. Please explain the sequence of events for the test on p. 5.1.1-5. Table 5.1.1-3 shows that accumulator injection actually began shortly before ADS-1 actuation, while the description implies the ADS actuated first, followed by accumulator injection.

28. While the problems with the steam generator U-tube instrumentation are described well, it is not clear precisely why an indicated level of +20" corresponds to empty tubes at about 300 seconds (p. 5.1.1-7). Are there alternative instruments that can be used to verify this timing?

29. The "trends" that are cited for some inoperable level instrumentation in the steam generators (e.g., LDP-207, -208) are somewhat difficult to spot, for instance, discerning the draining of the hot legs. HL-2 is asserted to begin to drain around 288 seconds; the associated curve

(Fig. 5.1.1-11) barely seems to wiggle at that time. Please explain what corroborating instrument readings or qualitative insights from the facility response were used in verifying the described events.

30. Please clarify the discussion of timing in the two sections on "Initial Depressurization Phase" and "ADS Phase" (on p. 5.1.1-8). The last paragraph of the first section states that ADS-1 was opened at about 461 seconds. However, the second paragraph of the second section seems to imply that the ADS was already open at 450 seconds, when accumulator injection began.

    Some additional apparent inconsistencies were also noted in the description of the ADS phase:

    a. 2nd paragraph, p. 5.1.1-9: DP-114 is stated to sharply <u>increase</u> to -10" at 602 seconds. It actually appears to decrease to that reading. A similar statement is made at the bottom of p. 5.1.1-15.

    b. 2nd paragraph, p. 5.1.1-10: Fig. 5.1.1-24 is cited as evidence of the pressurizer temperature increasing above saturation conditions after 26,500 seconds. This figure shows no such increase.

31. In the description of the IRWST injection phase (p. 5.1.1-10), reflood of the surge line and pressurizer is supposedly confirmed by the HL, surge line, and pressurizer temperature indications. The hot leg temperatures in Fig. 5.1.1-14 appear to subcool when they are stated to do so, but the pressurizer and surge line temperatures in Fig. 5.1.1-27 do not indicate subcooling. Please explain.

32. The description of events near the end of IRWST injection, referenced to Fig. 5.1.1-34, is somewhat confusing. What is the significance of the so-called "negative pressure remaining in the CMTs" on the indicated level? Are the CMTs actually empty at that time, or are they simply indicating zero level due to a slight relative vacuum in the tanks?

33. What is the significance of the large spike at the inception of sump injection flow (FMM-901, Fig. 5.1.1-37)? (Note: this same behavior was observed in many SBLOCA tests.)

34. Is there additional information beyond that in Fig. 5.1.1-39 that supports the description of events at 15,786 seconds and beyond (i.e., sump injection valves opening, DVI flows decreasing, and equalization of sump and IRWST levels)?

35. Some of the (derived) values of steam percentage shown in Figs. 5.1.1-3 and -4 fall either below zero or above 100 percent. Explain why this occurred and what, if any, significance these values have.

36. The pressurizer heater power spikes sharply around 600 seconds (Fig. 5.1.1-24). This appears to correlate to a sharp down-spike in pressurizer level on Fig. 5.1.1-58. Is this just "noise," or is there a correlation between these two events.

37. Explain why the flow indication for the IRWST overflow (FMM-703, Fig. 5.1.1-25) goes negative between about 250 and 750 seconds.

38. It appears that the break separator loop seal flow peaked around 50 seconds, not at 24 as indicated(p. 5.1.1-29). The description of the flow variation with time in the text would lead one to expect a monotonically decreasing flow until about 978 seconds, which is not the case; for instance, the loop seal flow appears to increase significantly just prior to ADS-1 initiation, and again before ADS-4. Also, what is the significance, if any, of the "bump" just prior to 1000 seconds, lasting for about 150 seconds? The flow does indeed fall momentarily to zero, as described on p. 5.1.1-29, but it recovers immediately to about 2 gpm. Please discuss the significance of these deviations.

The following questions are related to the detailed presentation of data for Test SB18 in Section 5.1.2 of the FDR.

39. Please discuss why the times of certain events and values of some parameters differed substantially from SB01. For instance, why did CMT-1 drain faster in SB18, resulting in ADS actuation some 71 seconds earlier? Note that this timing also affected accumulator injection, so that, even though the accumulators started at lower pressure in SB18 than in SB01, they began to inject earlier in the transient.

40. The explanation for the holdup of CMT-2 injection is that the accumulator injection closed the CMT outlet check valve, thus preventing CMT-2 from draining. However, Fig. 5.1.2-6 shows CMT-2 level hanging up between around 125 and 350 seconds, while Fig. 5.1.2-16 does not show significant accumulator injection until about 400 seconds, by which time CMT-2 is draining at roughly the same rate as CMT-1. Is there another possible explanation for this behavior, such as condensation at the top of CMT-2?

41. At the top of p. 5.1.2-6, it is stated that minimum core barrel level occurred at 1000 seconds later than in SB01. Is this correct? If so, why is there such a discrepancy in the two tests when other parameters seem to be in fairly close agreement?

42. Is there a correlation in the actual readings of the level instruments (shown as steam percent) in Fig. 5.1.2-3 and the pressure differential sensors in Fig. 5.1.2-19? That is, can one really discern the direction of flow into or out of the upper head, or are the spikes merely indicative of the condensation event without regard to real magnitude or direction of level and flow changes? The behavior of these sensors appears to be reasonably consistent over many tests in which similar events occurred (e.g., SB01, SB19).

The following questions refer to specific tests as presented in Section 5 of the FDR.

43. In comparing Test SB19 to Test SB01:

    a. Why is the transition from recirculation to draining in the CMTs later in SB19 than in SB01?

b. Is there a systematic explanation for differences in core levels and timing of events during the initial depressurization phase?

c. Why are break flows higher in SB19 for the first 400 seconds?

44. For Test SB09:

a. In Fig. 5.3.2-72, is the PRHR HX flow really negative, or there just a zero offset in the curve?

b. Why does accumulator #1 show negative flow at about 12,000 and 21,000 seconds?

45. For Test SB12:

a. Explain why ADS1-3 flow becomes negative (Fig. 5.4.1-18).

b. Following ADS-4 actuation at about 250 seconds, one would tend to expect pressurizer level to decrease. However, Fig. 5.4.1-31 shows pressurizer steam percent decreasing, implying that level increases. Please explain this apparent inconsistency. This same behavior is noted for Test SB13.

46. For Test SB13, Fig. 5.4.2-72:

a. What is the difference between the "old" and "updated" figures?

b. Why does the break flow drop below zero in the first 40 seconds of the transient?

47. Please explain the data for Test SB28, in Fig. 5.4.3-1. Is this the result of a large zero offset for FMM-501?

48. Figure 6.1.21 presents a comparison of measured break flow for several tests. Are any calculated break flow results available that account for the effects of mass storage in the separator tank?

The following comments and questions concern the OSU TAR, including a review of the "general" sections and of two specific tests, SB01 and SB18. Additional questions on other tests will be provided to Westinghouse at a future date.

49. The discussion of the PIRT (Section 1.3) in the TAR is rather abbreviated, and the rationale for the selection of phenomena and their rankings is never really addressed. The PIRT appears geared largely to the NOTRUMP code, since it does not appear to include phenomena that the code is unable to represent (e.g., cold leg stratification). Other phenomena are simply not called out, irrespective of NOTRUMP's capabilities; for instance, flashing in the CMT as a means of causing the transition from recirculation to draining is not addressed. In addition, some of the rankings chosen do not appear to be well-supported by the data. For example, CMT recirculation is ranked "medium" for SBLOCAs. However, data from the test program appear to the staff to demonstrate that the recirculation phase of the transient--and transition to

draining--is one of the determining factors in the timing of ADS initiation and subsequent system depressurization. The reasons for assigning it a "medium" ranking rather than "high" are not clear.

50. There is a slight inconsistency in the description of the scaling methodology on pp. 1.4-1 and 1.4-2. The "hierarchy" of evaluation at the top of p. 1.4-2 implies that a module is a part of a subsystem (this is also shown in Table 1.4-1). On p. 1.4-1 (third paragraph), the wording seems to indicate that a subsystem and a module are equivalent. Please clarify.

51. How are source and sink terms accounted for in the scaling equations (e.g., Eq. 1.4-1)?

52. In Section 1.5, the OSU data and AP600 NOTRUMP calculations are compared. In Fig. 1.5-6, what causes the oscillations observed in the test data? Can the physical mechanism be represented by the computer model? If not, what impact does this have on ability to model system behavior?

53. Section 4.2, on level compensation refers to a "straight numeric average" of temperature is used to compensate some differential pressure level sensors (LDPs - see the second paragraph on p. 4.2-1). However, a general methodology for compensation is presented in Section 4.1. How do these procedures differ?

54. In Section 4.3, please explain how Eqs. 4.3-11 and 4.3-12 were developed.

55. As noted in Section 4.4, that flowmeter readings for mass flow calculations are unreliable when two-phase flow is being measured. Mention is made of inferring mass flow from the CMT and CLBL mass conservation equations, but the specific methodology is not shown. Please provide detail on that methodology.

56. Section 4.4.6 describes the use of fluid thermocouples to obtain "pseudo-metal" temperatures. It is not clear from the material in the TAR how this is accomplished. Please clarify:

    a. How the fluid thermocouple(s) representing the "pseudo-metal" temperature(s) is/are chosen; and

    b. If the temperature of that fluid thermocouple is "adjusted" in any way to account for a metal-to-fluid temperature difference.

    c. Also, how, if at all, are uncertainties in metal temperature as a result of this process estimated and propagated?

    d. Please confirm that what is actually being done in this process is to indirectly calculate the first term on the right hand side of Eq. 4.4-68

57. Are the effects of fluid accumulation between the ADS "valves" (at the pressurizer) and the separator considered? Also, is this part of the measurement system "pre-filled" with water?

58. Is the differential term in Eq. 4.6-2 meant to apply to the liquid only or to both the liquid and the vapor?

59. On page 4.6-8, it is stated that the energy loss to ambient is zero because of the heat tracing on the system piping. Was it verified experimentally that energy loss and energy gain (from heat tracing to the fluid in the piping) was negligible? A similar question applies to Sections 4.7.5.4 and 4.7.5.5.

60. In the first lines of Eq. 4.7.21 (first term to the right of the equal sign) and Eq. 4.7.22 (term on the left-hand-side of the expression), the subscript "f" on c_p and T should be removed. In addition, the way in which these equations (and previous similar equations) are expressed implies that the liquid and the vapor are at the same temperature. Is this assumption confirmed by the data? If the liquid and vapor are found to differ significantly in temperature, the form of these equations needs to be changed to account for that fact.

61. In the first paragraph of Section 4.8.1, what is meant by "an orifice was in place within the span of the level transducer." The staff has not been able to find any documentation related to this orifice or its function. Please clarify the purpose of this orifice and the correction procedure.

62. Two "issues" are identified concerning the core fluid thermocouples in Section 4.11, but no subsequent analysis or explanation of the issues is provided. Specifically,

    a. How did the fluid temperature histories at the center and perimeter differ?

    b. The "best average core temperature" is asserted to be represented by the center-rod temperatures, without quantitative justification. Why is this procedure preferable to a weighted average of the core and perimeter rods?

    c. The noise in the core fluid temperatures is asserted to be "unrelated to core thermal-hydraulic phenomena." How was this determined? To what was the noise related?

63. Please clarify the factor of 1/2 in Eq. 4.11-1. The implication in the opening paragraph of Section 4.11.2 is that two of the four KW-XXX instruments (Table 4.11.3) would sum to the total core power. Which instruments are redundant (e.g., do KW-101 and KW-102 indicate the same [nominal] power)?

64. Do the "TFM" instruments in Table 4.15-3 appear in the P&ID? If not, please clarify their locations and measurements.

65. On p. 5.1.1-1, Fig. 5.1.1-3 is described as showing "the calculated quantity of steam generated in the core" during the test. How was this calculated? What is plotted is a rate of steam production, expressed as a mass flow rate. Is this the net rate of steam flow leaving the reactor vessel?

66. The refilling of the CMTs during the IRWST injection phase is covered in both the FDR and the TAR (Section 5.1.1 of each report); the discussions are essentially identical. The reason given for the failure of the CMTs to drain immediately after refill is that the check valves were held shut by the head of the IRWST. Is it possible that the CMTs remained at a partial vacuum after the refill? How would this affect evaluate of the data and the FDR/TAR explanations for the overall system behavior in these events.

67. The CMT refill process is also discussed in Section 6.1.1 of the TAR. In that section, it is postulated that the CMT refill ends due to reduction of level in the cold legs. Staff analysis, however, indicates that the limiting factor may be the ability of the CMTs to maintain an adequate vacuum relative to the reactor vessel; i.e., refilling stops due to reduction of differential pressure, rather than the "breaking" of the siphon. How would this affect evaluation and explanation of the behavior provided by the TAR.

68. Section 6.1.3 of the TAR discusses the late-phase flow oscillations in the OSU facility. The staff still believes that the explanation of the oscillatory behavior may be incomplete. While only one oscillatory mode is implied, lasting several thousand seconds, staff evaluation (including the results of confirmatory tests at OSU) has indicated that there are at least three separate types of oscillations. Aside from the mechanisms described by Westinghouse, there appears to be a connection between a second set of oscillations and the second draining (after refill) of the CMTs; a third oscillation very late in the transient (e.g., 14,000-15,000 seconds in SB01) appears to be related to an interaction between the test loop and the BAMS (and is thus non-prototypic with respect to the AP600). The staff requests that Westinghouse reexamine the data in regards to the mechanisms for oscillatory behavior in the OSU facility.

69. There is no discussion in either the FDR or the TAR of the oscillatory behavior that occurs at the initiation of IRWST injection in most tests. This type of behavior has been seen, as well, in the NRC's confirmatory tests in both ROSA and OSU, and is believed to involve complex interactions between the IRWST, ADS-4 valves, and the pressurizer. The oscillatory behavior can be observed by examining, for instance, Figs. 5.1.2-5 and 5.1.2-48 in the FDR (Test SB18); note that the oscillations begin at the inception of IRWST flow and do not cease until the pressurizer level drops to zero (at which time the flow peaks). The staff requests that Westinghouse examine the data and explain the mechanism driving these oscillations, and discuss the potential for this mechanism to exist in the AP600 plant.

70. There is very little coverage overall in the TAR of the effect of uncertainties. Although the subject of data error analysis is discussed in detail in the FDR, the TAR should provide for considerations beyond instrumentation errors. Manipulation of the data is done in the TAR using the output of several instruments simultaneously or sequentially, such as adjusting level readings using density corrections derived from temperature data at discrete locations. Some energy balance calculations used fluid thermocouple data in place of wall temperatures. Assumptions were made in various calculations, which may or may not have been

verified experimentally. With regard to heat transfer to the environment, for instance, heat traced components were assumed to be adiabatic, and heat losses for other components were calculated using simplified assumptions for convective and radiation heat transfer. Data were "filtered" (e.g., oscillations were smoothed), and, for core fluid temperatures, peripheral temperatures were disregarded as being "less representative" of core conditions. Furthermore, the staff's post-test evaluation of Westinghouse's data has, for example, noted component failures and systems interactions that may affect uncertainties in key parameters (e.g., failure of an RHR check valve to the DVI line and interaction between BAMS and the rest of the loop causing oscillatory behavior).

Although the overall mass and energy balances for each test provide a gross estimate of uncertainty for the system during these tests, it is not clear that the overall calculations are sufficient; the data will be compared with analyses performed with Westinghouse's design basis accident analysis codes on more than simply the basis of overall mass and energy conservation for the system. The overall uncertainties may bound the uncertainties associated with key parameters, e.g., core collapsed liquid level and mixture level; however, there is also the possibility that compensating errors could reduce the overall uncertainties compared to those related to individual parameters. The staff considers this to be an important issue, and requests that Westinghouse provide a discussion of estimation of uncertainties in view of (but not limited to) the points discussed above, with quantitative supporting information.

Editorial Comments Related to the Testing Reports

ADS Phase B1 Final Data Report (FDR) and Test Analysis Report (TAR)

1. Section 4.2.5, states that Test A043331, "as expected, achieved a higher mass flow and steam quality than A003331." However, what was expected (as explained in the previous paragraph) was a lower steam quality in A043331, and that was, in fact, the case, as shown by Figs. 4.3-20 and 4.3-24. It would appear that the word "lower" should be inserted before "steam quality."

2. Figure 4.5.1 is useful as a summary of the test program. However, it would be useful to include the AP600 operating range, as is shown on (for example) Fig. 4.3-3, to assist in ascertaining whether the database is sufficient (not just "acceptable") for code validation.

OSU Final Data Report

3. It would be valuable, in the FDR, if a table were included showing setpoints for the actuation of various control events. A table showing system configuration for each test would also be useful, especially where changes in equipment, component availability, and loop characteristics (e.g., different orifices in various lines) were changed.

4. To assist the staff's analyses of OSU tests, several initial conditions should be provided for each test. These include:

   Steam Generator Level (LDP-601)
   PRHR Level
   PRHR Inlet Temperature (TF-803)
   CMT Pressures (PT-501, PT-502)

5. Additional information is would be helpful on pressure tap elevations and elevation differences other than those already included for the reactor vessel. In fact, a table showing all instrument elevations would be especially valuable, rather than having to extract that information from the P&IDs.

6. Some of the plots presented in the FDR are of failed or unreliable instruments. Although these instruments may be unreliable, the data could still be useful from a qualitative standpoint. These plots should be labeled such that it is clear the instrument is failed.

7. In the plots for SB28, collapsed level data for selected components (specifically, the pressurizer and surge line) are not included, although steam percent (based on indicated level) is plotted. This is inconsistent with the data sets for other tests, where the levels are included. Steam percent without a collapsed level is of minimal use. It would be useful to have collapsed liquid level and steam percent plots for all the tests.

8. On p. 5.1.1-5, the reduction in pressurizer pressure relative to the IRWST is referred to as "negative pressure." If this is a differential (or gage) pressure, it should be appropriately noted. What is described in this specific case is a siphon effect, with the pressurizer pressure at a small vacuum relative to the IRWST, and, in the absence of the vacuum breaker (added to the ADS discharge line after this test), backflow of liquid through the sparger to the pressurizer. While the staff believes that Westinghouse understands well the events occurring in this phase of the test, the description could be stated more clearly. The phrase "negative pressure" is used elsewhere in the FDR, as well (e.g., pp. 5.1.1-11, 5.1.1-12). The same general comments apply to these instances.

9. In Figure 5.1.1-34, the CMT and IRWST levels, as plotted, really are not referenced to the same absolute elevation, but rather to the "zero" level in each component. Reading the text, one would expect that the CMTs would start draining when the IRWST level curve drops below the CMT level curves, which is not the case due to the offset in "zero" elevation between the CMTs and the IRWST. Putting the CMT and IRWST levels on different ordinates showing the offset would make interpretation of this plot much easier. The same general comment is relevant to Fig. 5.1.1-35.

<u>OSU Test Analysis Report</u>

10. In Eq. 1.4-10 and immediately following, should "Yo" be "Y_o"?

11. The use of orifice plates to adjust pressure drops in the test facility to correspond to the desired, scaled AP600 values, while a standard practice, does introduce some distortion in the facility, since the variation of an orifice's pressure drop with flow is not necessarily the same as that of the pipe or fitting represented. A full description of the orifice plates used, including size and location, would be useful.

12. With regard to the ADS 1-3 flow measurement system, it would help the reader understand the measurements if the TAR indicated that the loop seal in the liquid drain line is filled prior to a test. This is true for ADS-4, as well.

13. It should be noted that the use of temperature readings in Fahrenheit (p. 4.6-2) could lead to errors where actual temperatures, and not temperature differences, are needed (e.g., Eq. 4.6-2, where the derivative expands into two terms, one of which involves temperature only). In fact, following the convention established, for instance, in Eq. 4.4-59, it would be preferable to show this term as ($T-T_{ref}$). See Section 4.7.5.1 as well.

14. In Step 5 on p. 4.6-3, the reference to "break separator tank" should be to the ADS 1-3 separator.

15. It appears that the subscripts on the mass differential terms on the right hand side of Eqs. 4.6-10 and 4.6-11 should be "ADS 1-3 SEP."

16. In Eq. 4.7-3, the specific heat should have an additional subscript "f." Also, it would be useful to provide a statement that the vapor term is neglected.

17. Why, in Section 4.8, does nomenclature (subscripts) for vapor and liquid change from "f" and "g," used previously, to "LIQ" and "STM?"

18. In Section 4.8.1, first paragraph, it is stated that this is a procedure for calculating liquid mass in the "sump tanks." Should this be "separator tank?"

19. There appears to be an inconsistency in instrument identification between the OSU P&ID and the list in the reports. PT-905 (see Eq. 4.8-4) is not on the P&ID, though DP-905 is; PT-903 is on the P&ID, but not in the instrument list. The same comment applies to Eq. 4.8-24. Please clarify and/or correct.

20. For consistency, an additional subscript "f" should appear on c_p between the equal signs in Eq. 4.8-15.

Scaling RAI

440.566 As discussed at the meeting between Westinghouse and the NRC staff on December 18, 1995, the issue of scaling requires "closure" based on evaluation of the data from the design certification test program. While the specific procedure for accomplishing this closure is to be determined by the applicant, some of the technical areas that need to be addressed include:

a. "Validation" of the AP600 PIRTs; i.e., an examination of the PIRTs for the various events and phases thereof to determine if the test data support the phenomena and their associated importance (ranking).

b. Demonstration that the important phenomena are reflected in the scaling analyses for the test facilities, and that significant distortions suggested by the facility scaling analyses and/or observed during testing can be explained and accounted for. This is equivalent to "validating" the assumptions made in performing the scaling analyses.

c. Along with (b), demonstration that the appropriate dimensionless parameters, especially those representing phenomena determined to be of "high" importance, are within a thermal-hydraulic range in the test programs consistent with that expected in the AP600 plant. In addition, code models that address these phenomena must be shown to be validated over the appropriate thermal-hydraulic parametric range.