Docket File

52-003

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

December 10, 1996

Mr. Nicholas J. Liparulo, Manager
Nuclear Safety and Regulatory Analysis
Nuclear and Advanced Technology Division
Westinghouse Electric Corporation
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SUBJECT: DISCUSSION ITEMS ON THE AP600 SCALING AND PIRT CLOSURE REPORT, WCAP-14727

Dear Mr. Liparulo:

As a result of its review of the June 1992 application for design certification of the AP600, the staff has determined that it needs additional information. Specifically, by letter dated September 18, 1996, Westinghouse submitted WCAP-14727 (AP600 Scaling and PIRT Closure Report). The enclosure to this letter contains discussion items concerning this report. We propose that the enclosed discussion items serve as agenda items for a currently unscheduled meeting concerning this report. During this meeting the staff will determine which of the enclosed discussion items need to be formally addressed by 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.

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If you have any questions regarding this matter, you may contact me at (301) 415-1132 or Bill Huffman at (301) 415-1141.

Sincerely,

original signed by:

Joseph M. Sebrosky, Project Manager
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Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosure: As stated

cc w/enclosure:
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AP600

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Comments on Scaling and PIRT Closure Report

Non-Scaling-Related Material

1. For OSU, "unanticipated phenomena" are handled appropriately, but there is no discussion of anomalous behavior related to hardware. Two specific instances are the break orifice flow in SB5 and the leaking check valve that affected the DVI line breaks. These are the subject of outstanding RAIs, and must be addressed by Westinghouse.

2. Changes in PIRT rankings <u>appear</u> to be based primarily on the results of code calculations, and not on insights from test results. If this is true, it is inconsistent with the intent of the staff in requesting preparation of the report. Since the objective of the test was to produce data to validate the code, changing phenomena rankings based on those calculations appears to be a circular process with no underlying physical basis. (This issue is raised again in the scaling-related section, in a similar context.)

3. In the discussion of applicability of PRHR results on p. 6-41, it is still not entirely clear that a full range of conditions has been considered for the PRHR heat exchanger. Is there a progression of events that could result in significant heating of the IRWST, such that its subcooling would be reduced while heat fluxes are still relatively high? Could this have an impact on heat transfer/CHF?

4. There is no discussion of fuel rod reactivity or core level phenomena in the LBLOCA PIRT (Section 2.2.2).

5. On p. 2-8, cold leg/accumulator flow asymmetries and accumulator discharge phenomena are not discussed. Also, why is DVI a separate item under "Downcomer," when the discussion indicates that it has been covered by other downcomer phenomena?

6. Section 2.2.3, p. 2-14: why is the hot leg nozzle bypass path not modeled?

7. In Table 2.4-8, why is loss of offsite power assumed to trip the pumps ("Core--Forced Convection)? Why is it not tied to receipt of an "S" signal or CMT actuation?

8. Table 2.4-11, p. 2-62: Justifications are missing.

9. Selection of initial/boundary conditions for LTC calculations h[illegible] been the subject of much discussion between the staff and Westinghouse. Westinghouse states on p. 2-67 that "the most limiting thermal-hydraulic conditions" are used. Westinghouse needs to be able to justify that the selected conditions are, in fact, "most limiting."

Enclosure

10. The argument is made once again on p. 64 that, since single tube experiments show an enhancement of boiling heat transfer when the tube is oriented horizontally (compared to a vertical orientation), using vertical data to model the upper horizontal section of the "C" tube should be "conservative." The staff does not believe that this has been conclusively demonstrated. On a qualitative basis, one can develop reasonable explanations for the enhancement of heat transfer on a single horizontal tube. However, the situation in a tube bundle is somewhat different; for instance, while there is nothing to interfere with bubble rise from a single tube, a horizontal bundle of tubes could act to trap vapor in the interior of the bundle more readily than might be expected in a vertically-oriented bundle, leading to earlier dryout than might be predicted from single-tube or vertical bundle results. The staff has previously suggested to Westinghouse that sensitivity analyses be performed, bounding the heat transfer performance of the heat exchanger to demonstrate that it can meet its performance requirements; that suggestion is renewed here.

11. On p. 9-4, Westinghouse should be careful about how the ADS test loop is characterized. The text says there is "no geometrical distortion relative to the plant." In one sense, this may be reasonably accurate (if the piping layout of the facility still represents the configuration in the plant). However, the detailed facility design is not exactly the same as the plant, with spool pieces and orifices/nozzles representing some valves in they system. Although Westinghouse attempted to match loss coefficients, flow areas, L/D, etc., there is still the potential for some distortion relative to the AP600 in this approach [Westinghouse could provide confirmatory data from the later (outside design certification) tests using 6 valves to demonstrate that the distortion was minimal]. Also, the staff notes that there are two ADS trains in the plant, and the piping configurations for the two are not identical (from the pressurizer to the sparger).

12. On p. 10-10, Westinghouse says "sufficient instrumentation has been provided" to acquire data on LTC phenomena. The operability of and uncertainties associated with those instruments are not addressed, however. (This is primarily an issue to be addressed in the code validation review.)

Scaling-Related Material

13. The organization of the report is not conducive to easy review. It would be more efficient to put a detailed descriptions and scaling bases for the facilities in an early chapter, rather than in 7 and 8.

14. In principle, the report follows Wulff's methodology in the top-down scaling analysis. However, the concept of inertia and impedance matrices has not been properly explored. These matrices are generated in a multi-loop system analysis, and particularly become very useful for analyzing complex and interacting flow path systems such as the AP600 SBLOCA scenarios. In view of the complexity of the problem, specifically in view of the time-consuming work associated with finding flow rates at each branch of a junction of a multi-loop system, the report uses one

dominant flow loop as a so-called "equivalent loop" and focuses on each phenomenologically distinct phase in order to obtain the most dominant π group(s) governing that specific phase. This is a more practical approach and ignores the details of scaling criteria for flow distribution and component interactions. Such a practical approach can be accepted as long as the flow distribution and component interactions are show not to be important relative to a more important phenomenon resulting from a single loop analysis, and as long as the results are properly analyzed, discussed, and finally the approach taken is justified in view of the multi-loop interactive flow paths. In most cases, at the beginning such assumptions are listed without a convincing technical discussion. Justifications are essential to show that the chosen single loop system captured dominant processes and phenomena and their associated scaling criteria for a given distinct phase of transients. Westinghouse is encouraged to implement convincing discussions as to why they are using such a single, non-interactive flow path and yet not losing essential information about flow distribution and component interactions.

15. Validation is necessary to demonstrate that the correct π's have been identified in the top-down scaling analysis, and to show that all the important phenomena have been taken into account. This can be done by balancing the mass conservation equation; if the important mass inflows and outflows are considered, then the equation will balance. Another validation process is to compare the experimental data coming from different test facilities using (dP^*/dt^*) vs. t^* or, preferably, P^* vs. t^*. The staff understands that this may not be easy, but it is the only way to confirm the validity of the methodology and the characteristic π groups, and it increases confidence in the scaling analysis. Note: the staff has explicitly recommended to Westinghouse numerous times in the past that validation of the PIRTs using results of the testing programs should be a key objective of this type of study. The foregoing comment, which is based on Professor Kojasoy's scaling review, essentially makes that same point once again in a slightly different context.

16. As part of the two-tier scaling approach, a component-level scaling analysis, which eventually led to the local-level (bottom-up) scaling, was carried out for the CMT and PRHR separate-effects tests. The π groups were properly derived from the relevant balance equations for each component. However, the π groups were not numerically evaluated and compared using experimental data and calculated plant values. It is thus difficult to assess whether the separate-effects tests were properly designed and whether the experimental data were the proper data for code validation.

17. Use of NOTRUMP and WCOBRA/TRAC to calculate the normalizing reference fluid and flow values for scaling and code assessment purposes appears to lead to a circular reasoning process. When validation of the code(s) is a primary objective of the scaling and experimental program, there is no technical justification for using the same computer code(s) to evaluate the reference values for scaling purposes. The reference normalization values should not be calculated using a code whose validity is in question.

18. There is a lack of uniformity and consistency in nomenclature in the

report. Although each chapter contains a nomenclature section, not all symbols in the text are defined. For instance, the subscript "f" in Chapter 8 was never described in the text and does not appear in the nomenclature.

Specific comments by chapter:

Chapter 3--Top-down scaling based on Wulff's method

19. The methodology is demonstrated for the Passive Cooling, ADS Blowdown, IRWST Injection, and Sump Injection phases. The high-pressure depressurization phase of an SBLOCA was not addressed at all; it was considered to be similar to the same phase in operating reactors. While the thermal-hydraulic behavior of the phase may be reasonably well-known, this phase sets up the initial conditions for the following (Passive Cooling) phase. Since the scaling groups are defined by initial and operating conditions that are selected and/or controlled for a test facility and prototype, it is essential to demonstrate the methodology for the initial phase, as well.

20. The Passive Cooling phase is analyzed in two periods: single-phase natural circulation and two-phase natural circulation. This appears to be an oversimplification of the complete process. The phase is initiated by an "S" signal, causing actuation of the CMTs and PRHR. These two processes are coupled and their comparative magnitudes are affected by break location and size, and the parameters associated with the PRHR and two CMT natural circulation loops, as well as the other four primary loops (two on each side) that were in operation before CMT and PRHR actuation. As noted previously, reducing the actual flow paths ignores the scaling criteria associated with flow distributions and component interactions. If these are not important, it should be convincingly demonstrated here rather than simply providing an assumption without justification. This would clarify (a) whether the replacement of an actual multi-loop system with a single-loop system and compensating CMT flow to the break flow have a technical basis; (b) whether all important processes have been covered; and (c) whether the resulting dimensionless groups are the most relevant groups characterizing this phase of the transient.

21. There still appear to be problems with Figs. 3.3.2 and 3.3.3.--even the corrected version of Fig. 3.3.3 seems not to have the loop right.

22. Selection of reference parameters is the most critical selection for a scaling procedure. The pressure should be scaled as

$$P^* \equiv \frac{P - P_{min}}{P_{max} - P_{min}} = \frac{P - P_{min}}{\Delta P}$$

where P_{min} is the minimum pressure and P_{max} is the maximum pressure. In a given phenomenologically distinct phase (or period) of a transient, P_{max} would be the initial pressure and P_{min} would be the final pressure for the specific phase. As a result, for each distinct phase or period, the pressure scale should be adjusted to make pressure variation limited by

$$0 \leq P^* \leq 1.0 \quad \text{and} \quad 0 \leq (dP^*/dt^*) \leq 1.0$$

The comments on p. 3-21 with regard to Wulff's recommendation are not correct. Each phase should be scaled with a different ΔP.

23. In treating two-phase flows, the balance equations are properly weighted by single- and two-phase volumes. However, each is assumed to be constant. Is that true? Is such an assumption necessary? For a given transient, these volumes are changing.

24. The vapor or liquid (preferably vapor) mass balance equation should be included in a drift-flux (or mixture) model formulation of the two-phase flow field. This balance equation has not been considered in the top-down scaling presented in this chapter. This is the balance equation that will give indications about phase distributions.

25. Equation (3-63) is correct. However, the discussion following the equation depends where the equation is applied. The staff understands that there is no general model or correlation for critical flow which is valid for a wide range of pipe lengths, pipe diameters, and upstream conditions, including subcooled liquid. However, use of a simple critical flow model instead of the discussion following Eq. (3-63) would be more convincing.

26. Neglecting inertia effects in Eq. (3-72) appears to be reasonable, but why? One of the objectives of a scaling analysis is to reveal and differentiate important terms from unimportant terms. If a term is not important, the scaling analysis should show that it is negligibly small when compared to other terms.

27. π groups emanating from the dimensionless balance equations at each phase of the transient are properly documented and the significance of each π group is adequately described. Figures comparing π groups between AP600, OSU, and SPES-2 are informative and helpful. However, there is significant scatter and variations between NOTRUMP calculations, hand calculations, and experimental data, and it is unclear why the hand calculations, in general, seem to be best in terms of agreement. Also, some values of π groups are significantly higher than unity. It would be helpful if discussion addressing these discrepancies was provided.

28. Although the scaling bases for the two facilities described in Chapters 7 and 8 are conceptually different from one another, the analysis of π groups and ratios of π groups, as well as the comparisons among the scaled-up test results and AP600 behavior indicate that the facility tests and AP600 plant calculations compare reasonably well. In spite of deficiencies in the top-down scaling procedure discussed above, the tests and plant calculations appear to capture the highly rated key phenomena identified in the PIRT process.

Chapter 4--CMT testing

29. From the physical point of view, each mode of operation is satisfactorily described and the component-level balance equations are carefully non-dimensionalized to derive the proper π groups. Up to this point, everything is well-documented. However, several problems were encountered in reviewing design criteria for experiments and analyzing experimental results:

    a. Numerical values of the π groups were not evaluated in the report, making it difficult to assess the nature of scale distortions.

    b. From information given in the report, it is concluded that the recirculation phase scaling requires that

    $$\frac{A_m}{A_p} = \frac{V_m}{V_p}$$

    Is this correct? If so, then geometric and kinematic scaling require that the CMT cross-sectional area scaling ratio is the same as the inlet and outlet piping cross-sectional area ratios. This type of information was not documented, making it difficult to judge the nature of geometric similarity between the test facility and the prototypic CMT. For example, it is impossible to assess if the Ri similarity requirement is satisfied for the CMT recirculation mode.

    c. Figures 4.3.1 - 4.3.4 are not clearly documented and do not support the text explanations and conclusions reached at the bottom of p. 4-17.

    d. Equation (4-20) should define the free convection heat transfer coefficient, not the relevant Nu.

    e. The CMT drain-down mode balance equations and π groups were developed with great care from a mechanistic point of view. However, as in the case of the recirculation mode, a numerical evaluation of the π groups in this report would facilitate a comparative similarity analysis. (They could possibly be brought over from the CMT scaling report.)

    f. Figures 4.3.7 - 4.3.11 do not represent narrative explanations of the figures given at the top of p. 4-28. Component-level similarity requirements and scaling distortions are not documented numerically, making it difficult to judge if scaling distortions are reflected in π group ratios, and if the important phenomena are adequately simulated in the CMT tests.

    g. Test overlaps between the separate-effects tests and the SPES-2 and OSU integral facilities are properly documented with regard to pressure, mass flow, and fluid temperature.