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

May 5, 1994

Docket No. 52-003

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

Dear Mr. Liparulo:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION ON THE AP600

As a result of its review of Chapter 15 of the June 1992 standard safety analysis report for the AP600 design and the Code Qualification Document for WCOBRA/TRAC, the staff has determined that it needs additional information in order to complete its review. The additional information (Q440.145-Q440.156)* is needed to demonstrate the applicability of the Westinghouse WCOBRA/TRAC best estimate loss-of-coolant accident evaluation model to the AP600 design. Enclosed are the staff's questions. Please respond to this request by June 30, 1994 to support the staff's review of the AP600 design.

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 this request for additional information does 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's Public Document Room.

This request for additional information affects nine or fewer respondents, and therefore is not subject to review by the Office of Management and Budget under P.L. 96-511.

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*The numbers in parentheses designate the tracking numbers assigned to the questions.

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This request for additional information affects nine or fewer respondents, and therefore is not subject to review by the Office of Management and Budget under P.L. 96-511.

If you have any questions regarding this matter, you can contact me at (301) 504-1120.

Sincerely,

(Original signed by F. W. Hasselberg for)

Thomas J. Kenyon, Project Manager
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and License Renewal
Office of Nuclear Reactor Regulation

Enclosure:
As stated

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See next page

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REQUEST FOR ADDITIONAL INFORMATION
ON THE WESTINGHOUSE AP600 DESIGN

440.145 Section 28-2 of the Code Qualification Document (CQD) for WCOBRA/TRAC, "Compliance with Regulatory Guide 1.157, REGULATORY POSITION 1," states that application of WCOBRA/TRAC to the AP600 design is considered acceptable, based on information in the CQD and confirmatory tests and comparisons currently being performed on the unique features of the AP600 design, the results of which will be provided in other reports. Describe the specific features of the AP600 design that will be evaluated with these tests, and show how the results will be used to meet the requirements of the Regulatory Position. Are the results to be incorporated into a later edition of the CQD?

440.146 Justify the capability of WCOBRA/TRAC to adequately predict downcomer ECC bypass and CCFL phenomena for the UPTF tests. Section 14-4 of the CQD presents the comparison of code calculations to UPTF Tests 6 and 25, to evaluate the ability of the code to predict ECC bypass in the downcomer. Test 6 comprised five steady state runs with steam flows to establish points on a flooding curve for the downcomer.

a. Clarify the presentation and comparison of the code calculations to the test data. The interpretation of the comparisons would be facilitated if the data and code traces were plotted together. When different parameters are plotted together, i.e., test temperature and calculated enthalpy, a second (right side) y-axis would be appropriate. Also, the axis limits should represent the range of the data, where possible (e.g., Figures 14-4-26 and -27, -28 and -29, -30 and -31, etc.). For example, on Figure 14-4-37, if the data and the calculated results cannot be on the same plot, at least the vertical scale for the calculated result should be the same as for the data.

b. Test 6-131: As mentioned in Section 14-4-5 of the CQD, the code calculates the upper plenum/downcomer pressure rise to a higher pressure than shown by the data. Explain the reasons for the differences in responses. Also, it is stated that there is good agreement between calculated and test results after 70 seconds; however, the test pressure is about 1100 kPa at that time period and the code is still up at ~1350 kPa. Good agreement is delayed until ~100 seconds. Explain why the code overpredicts system pressure for the first 100 seconds. The timing of the calculated pressure decay following the end of steam injection is about 20 seconds slow. This timing delay is also present in the axial and azimuthal downcomer dp (Figures 14-4-30 and -31, -32 and -33, and -34 and -35). Is this delay related to prolonged lateral bypass flow in the calculated results? Was the steam flow boundary condition applied with the correct timing or was there a time shift? What is the mechanism responsible for the delay in the calculated lateral bypass flow? Does this indicate a deficiency in either the liquid entrainment or CCFL models? Explain the comparison in more detail. Note also that the code does not calculate the correct lower plenum and downcomer water levels, particularily at the end of this test (see Figures 14-4-36, -37, -38, and -39). Similar differences between the calculated and the measured water levels are also noted in Runs 132 and 135. Explain the reasons for the differences.

c. Tests 6-132 and 6-133: These tests are repeats of Run 6-131 with variations in injection flow rates and pressure; the comments identified for Run 131 apply to these comparisons as well. The CQD provides a nearly identical narrative for all of the runs of Test 6. Emphasize what the response differences were and how the code predictions serve to verify the adequacy of the CCFL model. The stated purpose of Test 6 was to establish points on a flooding curve for the downcomer. Provide analysis results detailing how well WCOBRA/TRAC predicted the points on the flooding curve.

d. Test 6-135: This run was with slightly higher containment backpressure - 360 vs. ~290 kPa. Explain why the code predicts more bypass high in the downcomer than for the low backpressure tests. Is this trend consistent with the test results? Justify the applicability of the CCFL models in the code and what it implies in terms of the ability of the code to successfully predict ECC bypass.

440.147 Demonstrate the applicability of WCOBRA/TRAC to the calculation of the ECC bypass phase for the AP600 design. The AP600 downcomer is not typical of a current generation PWR. It has a significantly larger annular gap width, and there is no thermal shield in the annular region. Discuss the applicability of the test results to this design. The design includes a reflector: a large metal mass occupying most of the barrel-baffle region (between the fuel bundle and the inside of the core barrel). The AP600 design also employs direct injection of the accumulator liquid into the downcomer. The lower plenum is significantly more open than for a current generation PWR; there are no instrument penetrations, there is a single lower core support which also accomplishes any bundle inlet flow distribution.

a. Explain how these differences will affect the penetration of ECC liquid. What test comparisons demonstrate the capability of WCOBRA/TRAC to correctly calculate ECC penetration and bypass in the AP600 downcomer?

b. Address the influence of thermal contact between the reflector and the core barrel on hot wall ECC delay.

c. Address the influence of the reduced resistance of the lower plenum structures during blowdown. How will it affect the expected duration of reverse steam flow and how will this impact the duration of the ECC bypass period?

440.148 a. The upper plenum crossflow de-entrainment model is based on the results from Dallman and Kirchner[b] which uses an air-water mixture as a simulant for steam-water. The range of validity is based on conditions existing during reflood and is stated as a maximum of 4 bars pressure else Re_G and We_G become atypically high. It is not shown to be applicable during the automatic depressurization sequence, which begins at a much higher pressure (~1100 psi, or about 75 bars). Justify the models intended for use in the prediction of interphasic drag and liquid entrainment/deentrainment.

b. It is also important to calculate the correct liquid deentrainment or phasic separation at the surge line nozzle. Explain how you will represent this phenomena in the Best Estimate LOCA Methodology.

440.149 Clarify the presentation and comparison of the code calculations to the test data for the LOFT tests that simulate reflood-related phenomena in the analysis of the LBLOCA for the AP600 design. See Q440.146(a).

440.150 LOFT L2-5 data (Figures 14-1-26, -36, and -37) show a significantly higher intact hot leg liquid flow during core reflood (~40 to 60 seconds) than that calculated by <u>W</u>COBRA/TRAC. Is this response related to entrainment during quench front advancement or to ECC nozzle condensation in the intact cold leg? Explain why <u>W</u>COBRA/TRAC does not capture this response feature.

440.151 The conclusion drawn in Section 14-2-6-5 of the CQD attributes poor predictions of core heat transfer in CCTF Run 75 to underprediction of system pressure. Provide further justification for this conclusion.

a. The code appears to be overpredicting core steam temperature, and therefore, underestimating post-dryout heat transfer from the heater rods. Specifically, the data showed more droplet entrainment (lower quality mixture) and, therefore, less superheat than that calculated by the code. The trend of the data for CCTF Run 62 (Figures 14-2-31 through 14-2-41) low in the core (below 10.0 ft) showed that the channel steam temperature drops to saturation coincident with increased fuel cladding surface cooling, thereby resulting in the turnover of cladding heatup. Provide additional justification for the interfacial heat transfer and droplet entrainment models. This may be because of underprediction of liquid droplet entrainment in the steam during core reflood, a conclusion that would be consistent with the

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[b] J. C. Dallman and W. L. Kirchner, *De-Entrainment Phenomena on Vertical Tubes in Droplet Cross Flow*, NUREG/CR-1421, LA-8316-MS, April 1980.

underprediction of the LOFT L2-5 intact hot leg mass flow noted above. The explanation offered in the Section (14-2) of the CQD implies that the data are not realistic because of quenching of the steam temperature sensor probes. Justify this explanation.

b. In Volume I, page 5-8, it is stated that bubbles of superheated steam are unlikely to occur extensively in a LOCA transient because the large interfacial area will quickly drive the system to saturation. This statement seems justified according to the CCTF data but appears to contradict the calculated results. Explain the high superheat response predicted by the code.

c. In the description of the interfacial heat and mass transfer models (in Chapter 5), there is a preponderance of the number "278" for superheated vapor, subcooled vapor, and superheated liquid:

- $h_{i,SHV}$ = 2.78 (a constant is assumed)
- $h_{i,SCV}$ = 2780.0 (a large constant value is assumed, presumably to drive the mixture toward equilibrium)
- $h_{i,SHL}$ = 278.0 (a large value is assumed in order to drive the liquid towards saturation).

It appears that these heat transfer coefficients are arbitrary and have little or no physical basis. Substantiate the interfacial heat transfer models used by the code.

d. It appears that WCOBRA/TRAC does not include the major influences of structures on the flow regime transition. At the highest levels, calculated quench times for rods 2 (low power) at 10.0 ft and 3 (average power) at 11.68 ft were sooner than the data. Is this an early calculated top-down quench that is not supported by the data? Or is this because of the calculated T_{min} of 700 to 900 °F discussed in Section 14-2 of the CQD? It is stated on page 14-2-17 that the mass in the upper core was underpredicted by the code. It is further noted on page 14-2-19 that the prediction (measurement?) of substantial mass retention in the upper core region in the CCTF tests was attributed to a flow regime transition, possible resulting from the rewetting of structural members, the effects of which are not simulated. Should the structure rewetting effect be included in the flow regime transition model? It appears to significantly affect the outcome of the calculation, primarily the predicted core inventory distribution and heater rod cooling. Explain whether and why this model produces an adequate representation of the phenomena present in the core during reflood.

e. Section 14-2-6-5 of the CQD (CCTF Run 75) states that the code predicts significantly lower pressure during this lower plenum injection test, and that this is responsible for the underprediction of reflood cooling. It is implied that this result is an anomaly because the scaled (FLECHT SET) results did not exhibit a similar pressure drop. However, the reference cited, Akimoto et. al.,[c] apparently does not support this conclusion. Instead, the response difference between full size and scaled results is attributed to flow area scaling. Provide further explanation for the overprediction of vessel-to-broken cold leg delta-p and broken cold leg steam flowrate.

f. In Section 14-2-7 of the CQD, "Overall Comparisons and Conclusions," Test 75 is singled out as poorly predicting the fuel temperature results, but some cladding surface temperature responses for the other CCTF tests (62, 63, and 67) appear to show the same trend. It is further noted in Reference 1 of the CQD that the maximum broken cold leg dp was ~50 kPa in the base case (62) and ~60 kPa in the FLECHT coupling test (75). Because the difference is small (only about ~1.5 psi), similar responses for the two tests should be expected, as shown. Therefore, provide further clarification on the conclusion that the Test 75 prediction is significantly poorer than the others.

440.152 Provide additional justification to explain the comparison to SCF Test 604 results (Section 14-3-6-1 of the CQD).

a. This case resulted in underpredicted cladding temperatures in the region above the core midplane (Figure 14-3-11), and an earlier downward temperature slope of cladding temperature, that indicate overprediction of quench front advancement. Calculated steam temperatures are again overestimating the time superheat is present. As with the CCTF comparisons, provide additional explanation to justify whether and why the code is predicting the correct thermal-hydraulic responses.

b. As described on page 14-3-16, pressure oscillations in the calculated result indicated the prediction of gravity reflood oscillations. This phenomenon does not appear in the data. Are these oscillations responsible for the overprediction of the heat transfer at the quench front? The overprediction of quench front advancement may be related to the observation that fuel rewet onset temperature value (discussed in Section 6-2-6) is too high. Provide a more detailed explanation of this phenomenon, showing cause-effect relationships.

c. Provide additional justification for the statement that the instrumentation may not be adequate to capture the phenomena. Include evaluations of instrument sensitivity and time response characteristics. If the oscillations are present but damp out, state why. If the gravity reflood oscillations are not present in the test, clarify why WCOBRA/TRAC predicts them.

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[c] H. Akimoto, T. Iguchi, Y. Murao, *Pressure Drop through Broken Cold Leg during Reflood Phase of Loss-of-Coolant Accident of Pressurized Water Reactor*, Journal of Nuclear Science and Technology, 21(6), pp. 450-465 (June 1984).

d. Inventory is underpredicted in the upper half of the core. The code apparently predicts an early quench low in the core but a late quench high in the core. Clarify the reasons for the differences between the calculated results and the data.

440.153 Accumulator injection will be followed by injection of the N_2 pressurizing gas. The staff has raised an issue regarding the successful gravity draining of the CMT/IRWST in the presence of the pressurization effect of the cover gas. Identify applicable assessment data and demonstrate the acceptability of the LOCA Methodology to be used for evaluation of long term cooling response for the AP600 design.

440.154 If extended core boiloff occurs, boric acid will accumulate and precipitate, thus interfering with the ability to maintain core cooling. There is, therefore, a need to demonstrate subcooled liquid throughput during the long term portion of the transient that will maintain boric acid concentration within acceptable limits. Describe the methodology that will be used, and how it will be used, to evaluate this issue, including applicable data assessments.

440.155 An integral part of the AP600 design is the passive containment cooling system (PCCS). Westinghouse does not appear to be using a containment model in WCOBRA/TRAC. Identify and justify the methodology to be used to predict the performance of the PCCS and its role in the long term coolability of the core, including comparisons to applicable assessment data, and how the methodology is to be incorporated into the AP600 evaluation.

440.156 Long term cooling is an issue for gravity-drained systems with low driving heads with competing forces present. This is not addressed in the CQD. Describe the methodology to be used for verifying the adequacy of the ability of the AP600 to emplcy long term cooling, including the assessment data and a demonstration of its applicability.