52-003

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

November 8, 1996

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

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION (RAI) RELATED TO THE AP600 WGOTHIC REVIEW AREA

Dear Mr. Liparulo:

The Nuclear Regulatory Commission (NRC) Containment Systems and Severe Accident Branch staff has determined that it needs additional information in order to complete its review of the Westinghouse AP600 passive containment cooling system (PCS) and WGOTHIC computer code. Enclosure 1 is questions and concerns, identified as RAIs# 480.467 to 480.491, that are related to the GOTHIC documentation that supports the WGOTHIC 4.0 computer program and the AP600 Standard Safety Analysis Report design basis accident (DBA) evaluation model. As background, Westinghouse started with a description of WGOTHIC based on GOTHIC 3.4 in WCAP-13246. As discussed in EPRI RA-93-10, there were numerous documentation errors and some coding errors in version 3.4. In Westinghouse letters NTD-NRC-95-4577, October 12, 1995, and NTD-NRC-95-4595, November 13, 1995, the coding errors were addressed. WCAP-14382 and WCAP-14407 provided additional descriptive information on WGOTHIC 4.0. As new information is submitted to the staff and because your reliance on previously submitted information changed during this review, the staff has needed to re-review the information and has determined that these questions are required to complete the review. Enclosure 2 is RAIs related to WCAP-14407, "WGOTHIC Application to AP600," Section 13, "WGOTHIC Noding Studies in Support of the AP600 Evaluation Model." These RAIs are identified as RAI# 480.492 to 480.594. Although this report is not complete, the staff is attempting to be as thorough as possible with its review. As this report is updated, the staff will assess the need for additional questions on this section.

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 questions and comments 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 20 CFR 2.790, this letter will be placed in the NRC Public Document Room.

Y/1
DF03

If you have any questions regarding this matter, you may contact me at (301) 415-8548.

Sincerely,

original signed by:

Diane T. Jackson, Project Manager
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Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosures: As stated

cc w/enclosures:
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WGOTHIC Review Requests For Additional Information

References:

WCAP-14407, "WGOTHIC Application to AP600," A. Forgie, et al., September 1996.

WCAP-14382, "WGOTHIC Code Description and Validation," May 1995.

WCAP-13246, "Westinghouse-GOTHIC: A Computer Code for Analyses of Thermal Hydraulic Transients for Nuclear Plant Containment and Auxiliary Buildings," July 1992.

EPRI, "GOTHIC Design Review Final Report," EPRI, RA-93-10, September 30, 1993.

L. E. Wiles, et al., "GOTHIC Containment Analysis Package Qualification Report," NAI, NAI8907-09, Revision 2, Version 4.0, September 1993.

T. L. George, et al., "GOTHIC Containment Analysis Package Technical Manual," NAI, NAI8907-06, Revision 3, Version 4.0, September 1993.

T. L. George, et al., "GOTHIC Containment Analysis Package User Manual," NAI, NAI8907-02, Revision 4, Version 4.0, September 1993.

The following questions and concerns are related to the GOTHIC documentation that supports the WGOTHIC 4.0 computer program and the AP600 Standard Safety Analysis Report DBA evaluation model. Westinghouse started with a description of WGOTHIC based on GOTHIC 3.4 in WCAP-13246. As discussed in EPRI RA-93-10, there were numerous documentation errors and some coding errors in version 3.4. In Westinghouse letters NTD-NRC-95-4577, October 12, 1995 and NTD-NRC-95-4595, November 13, 1995, the coding errors were addressed. WCAP-14382 and WCAP-14407 provided additional descriptive information on WGOTHIC 4.0.

Question and Concerns: GOTHIC Technical Manual, NAI8907-06, Revision 3, Version 4.0, September 1993.

Ref: pg. 1-5:

There are models and correlations in GOTHIC that were not assessed during the qualification effort. These models are not used for the type of containment analysis for which GOTHIC has been developed and for which GOTHIC is the generally recommended analysis tool. These models could still be applied if necessary, however the user is responsible for demonstrating that the models are appropriate. One such model, readily identified in the manual text, is the critical flow model, Section 4.9.

480.462 Identify models used for the AP600 which have not been assessed as part of the GOTHIC qualification. This list needs to include models that are being applied outside their range of validity as tested in the qualification effort. For each model identified, how did Westinghouse demonstrate that the model is appropriate? This does not include models added to GOTHIC by Westinghouse specifically for the analysis of the AP600 PCS.

480.463 Ref: pg. 3-7: Is the quantity -GAMMA$_i$ the same as Γ_i? Is so, the documentation needs to be corrected. If not, what is -GAMMA$_i$? Since Γ_i appears to be used to identify an "interface" rate change, the nomenclature list of variables (pg. 0-4) should reflect this:

replace, if appropriate
"Γ - phase change due to heat transfer"

with
"Γ_i - interface rate change due to heat transfer"

At a minimum, this might help in understanding the relationship between Eq. 3.29 on pg. 3-7 and the subsequent discussions in Section 7.4 "Vaporization and Condensation," if in that section the subscript *I* is added to Γ to better relate the notation scheme in Table 7-2.

Ref: pg. 4-2

480.464 The Yeh correlation was developed for SBLOCA analyses. Now does it relate to containment pools, i.e., P,T, velocities, etc.? How are the bubble rise velocity and stable bubble size determined? Address these questions as they relate to the AP600 DBA evaluation model, and does the range of applicability of the Yeh correlation cover the range of AP600 accidents?

Ref: pg. 4-6

"In order to correctly calculate buoyancy induced flows in lumped parameter modeling, the variation in the static pressure within each volume is estimated to give the pressure loads at the junctions."

480.465 The AP600 models truncate the upper dome as a modeling convenience. How is the static head corrected in the AP600 DBA evaluation model to calculate buoyancy induced flows?

Ref: pg. 4-7:

"For lumped parameter analysis the junction momentum flux terms should not be used because momentum cannot be supplied to the junction from the volume." If used, the resulting pressure drop would be equivalent to the momentum flux and added to the friction and orifice drag pressure drops.

480.466 The text implies that the user can use momentum flux in lumped parameter junctions. Does the AP600 DBA evaluation model, the models presented in Sections 4, 5, 10, and 13 of WCAP-14407, or the models presented in the GOTHIC Qualification report, use momentum flux in these junctions? If so, what is the rationale? If not, what quality assurance procedure is in place to prevent use of the momentum flux in lumped parameter junctions?

There are four momentum flux options available, and they are user selected along with the user specified momentum control volumes in the vicinity of the junctions ends in the subdivided meshes. Further, "If the opening is relatively small, forcing the flow to be essentially one-dimensional through the junction, then option 1 [no momentum transport] or 2 [in-line momentum transport] should be selected."

480.467 Provide the methodology used to select the momentum flux option and the momentum control volumes in the AP600 evaluation model, the models presented in Sections 4, 5, 10 and 13 of WCAP-14407, and the models presented in the GOTHIC Qualification report. When in option 3 (transverse) and option 4 (both in-line and transverse) selected? How is "relatively small" evaluated and which option is selected (1 or 2), and why? What sensitivity studies have been performed to demonstrate that the guidance for the selection of the momentum flux options are appropriate for the AP600 DBA evaluation model?

Ref: pg. 4-8:

480.468 The text refers to a Figure 4-4 which is not in the document. It appears that the text is referring to the top portion of Figure 4-3. Either provide Figure 4-4 or correct the text to refers to the appropriate figure.

Ref: Section 4.6, "Critical Flow Model."

480.469 The critical flow models have not been fully verified. Are there locations in the AP600 where the plant geometry leads to the need to model critical flow? If so, how is the critical flow model validated for its use in the AP600 DBA evaluation model?

Ref: Section 5, "Engineering Safety Equioment."

480.470 In letter NTD-NRC-95-4577, "Updated GOTHIC Documentation," dated October 12, 1995, Westinghouse informed the staff that specific models were not used in the analysis of the AP600 containment and supporting analyses of tests using the WGOTHIC_S Version 1.2 computer program. The door component is the only engineering safety equipment component not on that list. A door is treated like a valve in GOTHIC. Are there "doors" in the AP600 DBA evaluation model which would require use of the valve component?

Ref: pg. 7-15:

It stated that "In general, when phase change occurs, it is assumed that the fluid leaves the source phase at the bulk temperature of that phase and enters the destination phase at the saturation temperature determined by the partial pressure."

480.471 What are the exceptions to this statement? Why are these exceptions appropriate for the AP600 DBA evaluation model?

Ref: pg. 7-19:

480.472 The thought attempted in the following needs to be completed:

> "The large values presented in the tables are based on the numerical The units of Btu/hr-ft2-F applies to all constant values of heat transfer coefficient given in the tables."

Ref: Tables 7-3 through 7-6. These tables describe the interfacial heat transfer coefficients. A comparison of the GOTHIC 4.0 description of the interfacial heat transfer coefficients (IHTC) as compared to the description provided in WCAP-13246 shows a number of differences. Westinghouse selected GOTHIC based on the information provided in WCAP-13246. The differences are:

Table	Coefficient	WCAP-13246 Correlation	GOTHIC 4.0 Correlation	Question Index
7-3: Small Bubble IHTC	H_{shvl}	Large	2.78	1,3
	H_{scvl}	Large	H_{shlv}	2, 2a, 4
7-4: Large Bubble IHTC	H_{scvl}	Large	278.	3
	H_{shlv}	Large	278.	3
7-5: Film/Drop IHTC	H_{scvl}	Large	H_{shvl}	2, 2b, 4
	H_{sclv} H_{scdv}	$f(H_{shlv})$ $f(H_{shdv})$	$f(H_{shlv})$ $f(H_{shdv})$	2, 5
	H_{scvd}	Large	H_{shvd}	2, 2c, 4
7-6: Pool/Drop IHTC	H_{scvl}	Large	$H_{shvl}/(1+B_e)$	2, 2d, 4
	H_{shlv} H_{scdv}	$f(H_{shvl})$ $f(H_{shdv})$	$f(H_{shvl})$ $f(H_{shdv})$	2, 5
	H_{scvd}	Large	2.78	1,3

480.473 (1) Why is the value 2.78 considered to be equal to "large" as original used in WCAP-13246? A reference and justification is needed. What value is used in the AP600 DBA evaluation model, the models presented in Sections 4, 5, 10 and 13 of WCAP-14407, and the models presented in the GOTHIC Qualification report?

(2) Should this be H_{shvl} to be consistent with the Tables 7-5 and 7-6? Are any of the H_i's under the column "correlation" correct? It is also unclear why the coefficients for subcooled interfacial heat transfer are related to superheated correlations. Or are they really references to the user supplied input (SCVL, SHVL, SCLL and SHLL) as described in Section 19.2, IC.2 of the GOTHIC User Manual? However, it is noted that the "LL" part of the subscript is not defined, see for example Table 7-2.

(2a) Should this actually be the reference to the user supplied value "SCVL" as described in Section 19.2, IC.2 of the GOTHIC User Manual?

(2b) Should this actually be the reference to the user supplied value "SHVL" as described in Section 19.2, IC.2 of the GOTHIC User Manual?

(2c) Should this actually be the reference to the user supplied value "SHLL" (*could this be "SHVD"*) as described in Section 19.2, IC.2 of the GOTHIC User Manual?

(2d) Should this actually be the reference to the user supplied value "SCVL" as described in Section 19.2, IC.2 of the GOTHIC User Manual?

(3) Why is the value 278. considered to be equal to "large" as original used in WCAP-13246? A reference and justification is needed. What value is used in the AP600 DBA evaluation model, the models presented in Sections 4, 5, 10 and 13 of WCAP-14407, and the models presented in the GOTHIC Qualification report?

(4) Since the recommended values in section 19.2, IC.2 of the GOTHIC User Manual are either 1.0 (SCVL, SHVL, and SHLL [SHVL?] or 0.1 (SCLL [SCVL?], and these values are then multiplied by 278 to set an upper limit, how does this change from "large" as was original Westinghouse's intent in selecting GOTHIC? What values are used in the AP600 DBA evaluation model?

(5) The coefficient for H_{sclv} and H_{shlv} relate to correlations based on H_{shlv}, and the coefficient H_{scdv} relate to correlations based on H_{shdv}. This seems to be inconsistent. Explain why both a subcooled and a superheated interface can relate to a superheated correlation.

The documentation needs to be corrected, as necessary. Also, clarification of the significance of the user supplied values SCVL, SHVL, SCLL and SHLL need to be related to the interfacial heat transfer coefficients. What are the values used for the AP600 DBA evaluation model?

The GOTHIC design review noted that "The correlations for H_{shvl} and H_{shlv} in Table 7-3 are interchanged."

480.474 In comparing WCAP-13246 to GOTHIC 4.0, it is noted that H_{shvl} only changed from "Large" in the WCAP to 2.78 in GOTHIC 4.0. Further in going from the WCAP to GOTHIC 4.0, for H_{shlv} the correlation reference (Rowe, et al.) remains the same but the second part of the correlation was dropped. Explain the significance of the design review comment that the two correlations were interchanged but no change made in GOTHIC 4.0. Also explain why, and what is the significance of, the second part of the referenced correlation being dropped. What correlation is used for the AP600 DBA evaluation model?

480.475 In Table 7-5, the correlation for coefficient H_{shlv} was modified from the WCAP-13246 version to restrict the value $2k_i/\delta$ to a minimum value of 278. Why was this necessary? What is used in the WGOTHIC computer program?

480.476 Equation 12.17 on page 12-5 appears to have an error. Should J_i be J_{18}? The documentation should be corrected, as appropriate.

Question and Concerns: GOTHIC Qualification Report, NAI8907-09, Revision 2, Version 4.0, September 1993.

Westinghouse is relying on the EPRI GOTHIC Qualification Report to support use of the GOTHIC computer program, as modified to be WGOTHIC, for the AP600 PCS DBA evaluation. This includes use of the lumped parameter model as well as the distributed parameter models in Sections 4, 5, 10, and 13 of WCAP-14407 and also models in WCAP-14382, and the ability of the computer program to calculate containment pressure and temperature responses.

The following experiments were analyzed using the distributed parameter (DP) model, as described in WCAP-14382:

WCAP-14382 Descriptions of GOTHIC Qualification Tests

Test	Description
Battelle-Frankfurt Test 6	1 DP volume, 55 cells
Battelle-Frankfurt Tests 12 and 20	5 lumped parameter volumes 1 DP volume, 2 cells
Hanford Engineering Development Laboratory Tests HM-5 and HM-6	1 DP volume, 300 cells
Light Water Reactor Aerosol Containment (LACE) Experiments Tests LA-5 and LA-6	1 lumped parameter volume 1 DP volume, 2 cells
Carolina's Virginia Tube Reactor (CVTR) Tests 3, 4 and 5	2 lumped parameter volumes 2 DP volumes, 20 cells

In reviewing the GOTHIC Qualification Report, only the LACE and CVTR results provide direct comparisons of the GOTHIC calculations to the test data for pressures and temperatures. For the CVTR experiments a comparison of the predicted pressure using the DP model shows a higher calculated peak than a model based on the lumped parameter approach.

480.477 How does Westinghouse use these simple DP models to justify the lumped parameter model for the AP600 DBA evaluation model, as discussed in Sections 4, 5, 10, and 13 of WCAP-14407? What key modeling consideration went into the development of the GOTHIC qualification models, such as number of volumes, number of cells, interconnections (areas, loss coefficients, momentum options) between lumped and subdivides volumes and between cells in DP volumes, and how is this guidance used in the development of the models in WCAP-14407?

480.478 Direct comparisons to test pressures and temperatures need to be provided for the Battelle and Hanford experiments. (Temperature comparisons for the Hanford tests are presented in the GOTHIC Qualification Report.)

480.479 Only the Hanford model for test HM-6 uses the "unwrapping" technique to model a cylindrical geometry in the required rectangular grid format to properly treat momentum effects. Test HM-5 is modeled using a "true" rectangular grid approach. How does Westinghouse use these modeling approaches to justify the AP600 distributed parameter models in Section 13 of WCAP-14407?

Question and Concerns: GOTHIC User Manual, NAI8907-02, Revision 4, Version 4.0, September 1993.

Ref: pg. 7-4:

The preprocessor will let the user edit volume parameters for a 3D subdivided volume, however these values will not be used in the GOTHIC_S input deck.

480.480 How does GOTHIC let the user know that these changes made by the preprocessor editor do not change the actual model, or how else is the user informed that such illegal operations cannot be performed? How does Westinghouse verify that the data deck (model) is correct and that this illegal edit has not occurred?

Ref: pg. 7-6: Section 7.1.3 "Turbulence Parameters"

480.481 What criteria are used for the AP600 DBA evaluation model, the models presented in Sections 4, 5, 10, and 13 of WCAP-14407, and the models presented in the GOTHIC Qualification report, to model turbulence? Which shear forces are used in which volumes? How are the mixing lengths determines, and how are the Prandtl numbers determined?

480.482 The definition of the Prandtl number appears to conflict with its definition on pg. 9-4 of the GOTHIC Technical Manual (Eq. 9.20). The heat capacity appears in Eq. 9.20 but is not accounted for in the input description.

Ref: pg. 16-10:

"The momentum transport option should be activated when using several junction connections to model an opening between two volumes that is larger than the cell mesh in either of the two volumes. Ideally, the subvolumes should match up across the opening and one junction used for each pair of cells. If a close match is not possible, it is better not to transport the transverse momentum. If the transport option is not activated, the outflow from a subdivided removes the associated momentum and discards it."

480.483 In the last sentence should the word "volume" be added after subdivided?

480.484 What is meant by 'it is better to discard' the momentum? Does this situation occur in the AP600 DBA evaluation model the models presented in Sections 4, 5 , 10, and 13 of WCAP-14407, or the models presented in the GOTHIC Qualification report, and if so, how is it treated?

480.485 How does this recommendation to discard momentum relate to the statement on pg. 16-23 that the momentum transport option should always be used for any subdivided volume.

Ref: pg. 16-12:

"Based on experimental evidence for blowdown analysis, it is recommended that the liquid be injected in droplet form with a diameter on the order of 20 microns. Injecting the liquid as a film will result in superheated liquid and less steam in the atmosphere and lower peak pressures."

480.486 What is the assumption used for the AP600 DBA evaluation models, both for LOCA and for MSLB analyses? When the blowdown phase is over, are the assumptions changes? Why or why not?

Ref: pg. 16-27 and 16-28:

"Therefore, it is recommended that the mixing length be set to as small a value as possible while still producing the turbulence effect. This will require some experimentation to determine the optimum parameters for a given problem."

480.487 How are the mixing lengths set and what is the target turbulence effect for the AP600 DBA evaluation model which uses the subdivided volume model? What sensitivity analyses were, or will be, performed to validate the mixing lengths used?

Questions and Concerns: WCAP-14407, "WGOTHIC Application to AP600," September 1996.

On page 3-4, the last paragraph in Section 3.2 alludes to the lineage of WGOTHIC 4.0 as it relates to the GOTHIC computer program. As written, it appears to imply that WGOTHIC is based on GOTHIC 4.0 computer coding not version 3.4 coding (with known errors corrected). In order to determine which future EPRI GOTHIC error notifications may have an impact on AP600 analyses it is necessary to know the exact version of GOTHIC, combined with Westinghouse corrections and changes, that forms the base for WGOTHIC.

480.488 A comparison of this description to the description provided in WCAP-14382, which refers to version 3.4 of the GOTHIC family, when combined with responses to NRC concerns with known code errors as discussed in EPRI RA-93-10 (see Westinghouse letters NTD-NRC-95-4577, October 12, 1995 and NTD-NRC-95-4595, November 13, 1995) leaves at question the exact parentage of WGOTHIC 4.0. Is WGOTHIC based on version 3.4 with known code errors corrected or is it based on version 4.0? Figures 3-1 and 13-1 should be revised as appropriate, for example:

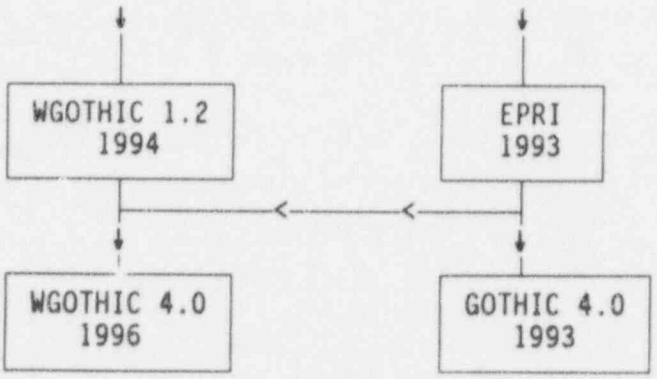

Table 4-107 in WCAP-14407 describes the mass and energy inputs used for the AP600 evaluation.

480.489 For LOCA, the table identifies SATAN 78, WCAP-10325-P-A. Should this be SATAN VI, and should the references be:

Shepard, R. M., et al., "Westinghouse Mass and Energy Release Data for Containment Design," WCAP-8264-P-A, June 1975 (Proprietary), and WCAP-8312-A, Revision 2, August 1975 (Non-Proprietary).

"Westinghouse LOCA Mass and Energy Release Model for Containment Design - March 1979," WCAP-10325, May 1983 (Proprietary).

480.490 For MSLB, should the references be:

Land, R. E., "Mass and Energy Releases Following a Steam Line Break," WCAP-8822 (Proprietary), and WCAP-8860 (Non-Proprietary), September 1976.

Burnett, T. W. T., "LOFTRAN Code Description," WCAP-7907-P-A (Proprietary) and WCAP-7907-A (Non-Proprietary), June 1984.

480.491 Why is the non-AP600 version of LOFTRAN acceptable for the AP600 analyses? Does Westinghouse plan to use the LOFTRAN-AP version for the final SSAR analyses? (WCAP-14234, "LOFTRAN and LOFTTR2 AP600 Code Applicability Document," E. L. Calin, November 1994, and WCAP-14307, "AP600 LOFTRAN-AP and LOFTTR2-AP Final Verification and Validation Report," W. Scherder, et al., June 1995)

AP600 - REQUEST FOR ADDITIONAL INFORMATION ON WCAP-14407,
SECTION 13, "WGOTHIC NODING STUDIES IN SUPPORT OF THE
AP600 EVALUATION MODEL"

Section 13.1

The introduction provides an overview of GOTHIC/WGOTHIC features, their different possible modes of applications and an overview of the approach to demonstrate spatial convergence as documented in the remaining sections.

This introduction raises a number of issues and concerns, primarily because none of these efforts mentioned appear to relate to the WGOTHIC AP600 DBA evaluation model presented in Section 4.

480.492 Westinghouse chose the distributed-parameter model for the above-deck region to better represent plume and jet entrainment (see middle of page 13-1) for the studies presented in this section. How does Westinghouse represent these phenomena in the lumped-parameter network for the AP600 DBA evaluation model? Explain how Section 9 addresses the plume and jet entrainment to support the use of the lumped-parameter for the AP600 DBA evaluation model.

480.493 If these phenomena are now judged to be unimportant (or can be addressed in a conservative manner for a lumped-parameter model), why would a noding study of the distributed-parameter model be of value for the current WGOTHIC AP600 DBA evaluation model? While it may be possible to observe the effects of plume and jet entrainment on these distributed-parameter models, this does not address modeling concerns for nodal studies with a lumped-parameter approach.

480.494 Summarize the physical quantities measured in Large-Scale Test (LST) facility and the results of comparisons with WGOTHIC computational results provided in Reference 4 that leads Westinghouse to conclude that no compensating errors occurred. Address both the distributed-parameter results as well as the lumped-parameter results to support use of the lumped-parameter approach for the AP600 DBA evaluation model. Address differences between WGOTHIC 4.0 and the version of WGOTHIC used for the Reference 4 studies.

480.495 Explain how the LST studies served as the basis for both the distributed-parameter model and the lumped-parameter AP600 DBA evaluation model developments.

480.496 As mentioned at the bottom of page 13-1, regions of high gradients in the LST needed more detailed noding in the distributed-parameter model to agree well with the experiment. How did this insight enter and affect the lumped-parameter AP600 DBA evaluation model?

Enclosure 2

In Section 13.2, the results from studies performed by MIT for bare shell noding studies on two-dimensional, parallelepiped models are provided in support of the WGOTHIC computer program and the noding selected for modeling the AP600.

480.497 Which version of WGOTHIC was used to perform these studies? If the version differs from WGOTHIC 4.0, discuss the differences and their impact on the results provided.

480.498 How have the rather unequal radial slice volumes which exist in the AP600 been converted into the WGOTHIC Cartesian modeling approach? Refer to the guidance in Section 16 of the GOTHIC User Manual and Section 12.2.2 in the GOTHIC Qualification Report.

480.499 Provide a discussion on the merit of this study to demonstrate that the assumption and nodal scheme used in the AP600 DBA evaluation model are appropriate. This studies uses the velocity dependent Gido-Koestel correlation (not reviewed by the staff at Westinghouse's request) while the AP600 used free convection only. There are no structures or internals modeled for these studies. The AP600 exterior boundary is not a constant temperature. What would be the effect of using free convection in these studies?

480.500 MIT should re-graph the results so that the comparisons from curve to curve can been made based on the curve identifiers being unique for each case, or provide sufficient detailed listing of each output to verify that the notations for each plot are correct as provided.

480.501 Provide a detailed description of the input for each model: node size, volume, momentum assumption between cells, initial conditions (pressure, temperature, etc). How and what heat sinks were modeled in the bare shell models? What turbulent model was used in WGOTHIC?

480.502 What does "near the centerline" means for the release position? Does this imply that the model is based on the principle of symmetry to actually study a larger system that is represented? How, and why, does this position change with changing the node size? How representative is a convergence study, which assumes perfect symmetry and a centered release, to the AP600 plant?

480.503 How were the steam and enthalpy releases, shown in Figures 13-3 and 13-4, derived? Are they scaled, nominal values? Why is the mixture component neglected for the study but included in the other studies? It appears that the vapor flow in this study is about equal to the vapor flow in the full above-deck case while this case represents only 1/32 of the region.

480.504 Why are results only shown for 2000 seconds, while the release functions are shown for 10^5 seconds?

480.505 Provide the location used for each model to present the pressures shown in Figure 13-5. At the deck level is not sufficient, the specific node should be identified for each model. Is it near the break location, at the far wall, or somewhere in between? Is it the maximum pressure? Why has the pressure at the deck level been chosen for comparison?

480.506 What does "the code converges from the top down" mean?

480.507 Figure 13-6 is titled differential temperatures but the y-axis indicated Pressure (psia) as does the data. Correct the figure and provide the location used for each model to present the data shown in Figure 13-6. Add an additional plot for, or include, the equal sized models (4x4, 8x8 and 16x16). Provide the location used for each model to present the additional data. Top and bottom are not sufficient, the specific node should be identified for each model. Are they taken near the break location, at the far wall, or somewhere in between? Do they show maximum differences?

480.508 Based on the text it is expected that Figure 13-6 will be replaced with a differential temperature curve, similar to that in the study original provided. In the original study the 2x4z model indicated a temperature inversion. Why does this occur? Figure 13-9 also indicates the inversion.

480.509 Why is the temperature difference between top and bottom cells a measure for code convergence?

480.510 What does 2000 seconds of execution mean? What does "not until they each converged to a final invariant state" means? Are the time scales in the figures time into the accident or computation time to reach steady-state? Do they represent computer CPU time or time into the transient?

480.511 Provide the location used for each model to present the flow velocities shown in Figure 13-7. Near wall, mid-height are not sufficient, the specific node should be identified for each model. Are they taken near the break or at the far wall, or somewhere in between?

480.512 What makes Westinghouse believe that the predicted velocities shown in Figure 13-7 are correct? Both, Figure 13-7 and associated text on page 13-6 are unclear because it seems that the velocities should be highest for coarse noding.

480.513 What causes the vapor velocities (Figure 13-7) for the most detailed nodal schemes to continue to increase after about 800 seconds?

480.514 Provide the location used for each model to present the flow rates shown in Figure 13-8. Mid-height is not sufficient, the specific node should be identified for each model. Are they taken near the break or at the far wall, or somewhere in between?

480.515 How does Westinghouse conclude that Figure 13-8 shows convergence? In all cases the slope of the curves is negative from 1,000 seconds on.

480.516 Provide the location used for each model to present the partial-pressure differences shown in Figure 13-9. Top-to-bottom is not sufficient, the specific node should be identified for each model. Are they taken near the break or at the far wall, or somewhere in between?

480.517 Why would the vapor velocity profile be steep along the cylindrical wall, when it is already condensed at the ceiling and upper part of the side wall?

480.518 Why would the velocity profile be flat towards the center when there exists an ascending steam jet at the center?

480.519 Westinghouse states, in reference to Figure 13-7, that the more detailed models may not have reached convergence to a final invariant state within 2000 seconds of execution. That would also affect the results of the previous figures. What then is the value and outcome of this study?

480.520 Why does Westinghouse think that the section nearest the outer wall is smaller, when effectively a slice model was chosen whose interfaces are largest at the outer boundary?

480.521 Why would the recirculation flow provide insight into t' amount of mixing in the model, when according to the text all im .tant phenomena are dominated by boundary layer behavior an :ts modeling and the velocity is flat towards the center? How an here would mixing occur?

480.522 Why are the flow rates for the individual noding schemes constant over time when the injected mass flow rate shown in Figure 13-3 is quartered over that time span?

480.523 Why would the top nodes have highest steam fractions when this is the position where condensation occurs and steam depletes?

480.524 For what other results does WGOTHIC not show noticeable effects?

480.525 What comparison presented in the available figure indicates the advantage of maintaining the aspect ratio? What criterion was used to establish the aspect ratio in the first place?

480.526 How does the conclusion reached that "if the aspect ratios of the cells is maintained, then convergence is easier to identify," justify studies on the AP600 that do not maintain this aspect ratio?

In Section 13.3, the results from studies performed by MIT for bare shell noding studies on full above-deck models are provided in support of the WGOTHIC computer program and the noding selected for modeling the AP600.

480.527 Which version of WGOTHIC was used to perform these studies? If the version differs from WGOTHIC 4.0, discuss the differences and their impact on the results provided.

480.528 Provide a discussion on the merit of this study to demonstrate that the assumption and nodal scheme used in the AP600 DBA evaluation model are appropriate. This studies uses the velocity dependent Gido-Koestel correlation (not reviewed by the staff at Westinghouse's request) while the AP600 used free convection only. There are no structures or internals modeled for these studies. The AP600 exterior boundary is not a constant temperature. What would be the effect of using free convection in these studies?

480.529 Provide a detailed description of the input for each model: node size, volume, momentum assumption between cells, initial conditions (pressure, temperature, etc). Provide a nodalization diagram for each model. What turbulent model was used in the three distributed parameter models summarized in Table 13-2?

480.530 When no heat sinks were modeled, what does the statement "GOTHIC conductors were modeled ...." means?

480.531 Why haven't the predictions performed been taken out to 10^5 seconds (for any of the studies in Section 13) to be able to evaluate WGOTHIC's capability and modeling assumptions on the 24 hour pressure criteria?

480.532 Provide the location used for each model to present the pressures shown in Figure 13-12, the temperatures and temperature differences shown in Figure 13-13, the velocities shown in Figure 13-14, and the partial-pressures shown in Figure 13-15. Specifically, identify the nodes where the data are obtained.

480.533 Explain why the addition of 4 azimuthal nodes reducing the peak pressure as shown in Fig. 13-12? (From "1a-112" to "2a-224.)

480.534 Figure 13-13, which has two parts, in not consistent with the accompanying text. Revises the text accordingly.

480.535 The y-axis label on Figure 13-13(b) needs to reflect differential temperature.

480.536 Explain the erratic behavior of model "3a-392" temperature as seen in Figure 13-13 and partial pressures as seen in Figure 13-15.

480.537 What explanations can Westinghouse provide for the temperature difference results depicted in the lower part of Figure 13-13 for the various models?

480.538 What conclusions does Westinghouse draw from the comparisons for the lumped-parameter network results in view of its AP600 DBA evaluation model documented in Section 4?

480.539 Explain the diverging result in the velocity for the "1a-112" model after 1,400 seconds as compared to the other three cases as seen in Figure 13-14. What conclusions does Westinghouse draw from the results by the lumped-parameter model (1a-112), with the opposite velocity direction for times after 1400 seconds?

480.540 Is the sign convection used in Figure 13-14 the same as in Figure 13-7 for the simpler models?

480.541 What explanations and conclusions can Westinghouse provide for the highly fluctuating results for most of the models examined?

480.542 Why are the velocities shown in Figure 13-14 in the opposite direction as compared to Figure 13-7? The text states that this study confirms the results of the previous study with the simpler models. Based on the comparison between Figures 13-14 and 13-7 the contrary is true.

480.543 Since Section 13.2 does not contain any temperature graphs for the simple bare shell models, the staff cannot evaluate Westinghouse's conclusion that there is agreement with the simple models, as stated on page 13-17. However, in looking at the original report, it appears that the trend is opposite: the simple model shows temperature inversions for few nodes while the full above-deck models shows the opposite. Is this attributed to the differences in the mass and energy input assumptions? Which parameters are critical to predicting the heat and mass transfer in the AP600? It appears that the more detailed models result in higher peak containment temperatures.

480.544 What explanations can Westinghouse provide for the rather irregular steam concentration behavior with time for the different models, especially in view of the temperature difference behavior shown in Figure 13-13?

480.545 What leads Westinghouse to believe that the above operating deck region is a well-mixed environment, when Figure 12-13 clearly indicates an inverse temperature gradient of 20 °F?

480.546 What are the features of the full above-deck models as compared to the previous simple models? Is it the full dome representation versus slice approach?

480.547 What evidence can Westinghouse really pinpoint from the figures which clearly shows the conservatism inherent in coarsely nodalized models with respect to heat and mass transfer?

Section 13.4 provides the results of AP600 noding studies performed by three different groups: Westinghouse, MIT and NAI.

480.548 What conclusions does Westinghouse draw from the fact that both lumped-parameter and distributed-parameter models overpredicted the pressure? (The comparisons provided in Reference 4 are only for the "steady-state" pressure comparison and subject to interpretation as unspecified time-averaged values were used to summarize the results. There is no identified trend for transient cases.)

Subsection 13.4.2 describes the computational efforts involving the complete containment modeling of the AP600. All models examined used a lumped-parameter network for the below-operating-deck region. Also, this is the first study incorporating Westinghouse's clime model. The two earlier studies involved only the GOTHIC-code using correlations and models not to be used for the AP600 DBA SSAR analyses and without the clime features and PCS-modeling.

480.549 Which version (or versions) of WGOTHIC was (were) used to perform these studies? If the version differs from WGOTHIC 4.0, discuss the differences and their impact on the results provided.

480.550 Provide a detailed description of the input for each model: node size, volume, momentum assumption between cells, initial conditions (pressure, temperature, etc). Provide a nodalization diagram for each model.

- What is the relevant technical reference describing the AP600 lumped-parameter model developed by Westinghouse for above operating deck region?
- What is the relevant technical reference for the Westinghouse distributed-parameter model which was noted based on the above?
- What is the relevant technical reference for the NAI distributed-parameter model?
- What is the relevant technical reference for the MIT distributed-parameter model?
- Are the models identical for the below-operating deck region for all 4 models listed in Table 13-3?
- Did any of the models use a turbulence model?

480.551 Which LOCA was used for the mass and energy input data (break location and size)? Figures 13-10 and -11, provide the data, and it is noted that they appear in a different order than characterized by

the text. How do the data used for this study compare to the AP600 DBA evaluation model? For example, as compared to the guidance used in Standard Review Plan Section 6.2.1.3, "Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents," to develop the mass and energy input data. How would the results of these analyses change based on using the prescribed DBA mass and energy releases?

- Did all models use the identical boundary and initial conditions and forcing functions?
- What release position was chosen? Was it identical for all four models?

On page 13-23 of WCAP-14407 it is stated that: "The third model was a more finely noded distributed parameter model developed by Numerical Applications, Inc. (NAI, the developers of the GOTHIC code) and is used in the Standard Safety Analysis Report (SA) analyses of the AP600."

480.552 If this NAI model is used for the SSAR analyses in support of the AP600 design certification, provided a detailed description of the model, similar to Section 4 of WCAP-14407. How are the sensitivity studies presented in Sections 5 and 10 of WCAP-14407 impacted if this model is used as the reference?

On page 13-23 of WCAP-14407 is noted that the NAI model "was found to have inadequate noding through the internal heat sinks."

480.553 Attributing the pressure difference solely to internal heat sink modeling would mean that only those control the second peak and turnaround characteristics. Was there also an error in the clime heat structures as well? Is the statement incorrect? If so, revise it.

480.554 What are the contributions from the PCS and internal heat sinks, respectively, to limit the peak pressure and turnaround characteristics which in turn will control the pressure level at 24 hours?

480.555 What is meant by internal heat sinks in the NAI model? Are they only those below the operating deck or above the deck as well, or both?

480.556 What were the refinements in the noding of the internal heat sinks of the NAI model?

480.557 Although those noding refinements resulted in peak pressure agreement, why is the depressurization gradient thereafter much steeper?

480.558 Is Westinghouse proposing use of the NAI model with the error or the corrected NAI model? If the error was corrected to produce Figure 13-16, then why has Westinghouse not corrected the remaining figures to provide a valid base for comparison of the results?

480.559 Annotate Table 13-3 with the plot identified for each case. The discussions between the NAI, the MIT version of the NAI, etc. are difficult to follow. There are apparently five (or perhaps six) models in this section as compared to the four listed.

Insights for modeling large-scale circulation encompassing regions below the operating deck solely rest upon the performance of AP600 distributed-parameter model computations because the LST did not provide the appropriate flow paths.

480.560 Describe the lumped parameter model referenced in Figure 13-17 (top). Compare it to the model described in Section 4 of WCAP-14407. Which version of WGOTHIC was used to calculate the response? Discuss the differences (both in the model, and if necessary in the computer program version). This case does not appear to be either the reference case used in Section 5 of WCAP-14407 or the case used in Section 10 of WCAP-14407.

480.561 What is the relevant technical reference providing information about the appropriateness of the lumped-parameter noding as compared to results of the AP600 distributed-parameter model?

480.562 What criteria did Westinghouse use to conclude that the AP600 modeling would need less noding detail than the LST?

480.563 In Figure 13-17 (bottom) is the curve marked NAI the MIT ("6c-MIT") results? Or is it the "8c-NAI" results? Or is this a sixth case, not previously identified? Please explain. In any case the curve marked "NAI" does not agree with the results provided in Figure 13-16. Please explain. Identify the location (node) in each model used to develop the pressure plots. Correct the figure appropriately.

480.564 In comparing the results, it appears that the lumped parameter case (top curve Figure 13-17) is non-conservative as compared to the "7c-NAI" and the "NAI" models (bottom curve Figure 13-17). Explain the note on the top graph. How important is the modeling of the dome to the results? Does the statement mean that the model is not appropriate to the study?

480.565 Figure 13-18 shows in the upper part the top temperature and should show the top-to-bottom temperature difference, in the lower part, but the ordinate is termed "Partial Pressure Ratio." Identify the location (nodes) in each model used to develop the pressure plots and correct the bottom y-axis title.

The differences between the different curves for both temperatures and temperature differences are judged as quite substantial.

480.566 What are the reasons for the deviations between the results of the distributed-parameter models?

480.567 What are the reasons for the obvious discontinuities in the predicted temperatures?

480.568 Explain why model "5c-West" is apparently sensitive to the increase in the mixture component of the input flow (see Figure 13-11 around 1,200 seconds as seen in Figure 13-18, -19, -20, and -21, while other models show no such sensitivity. If the change in mixture flow does not explain this, what does, and why is this not seen in the other models?

Comparing Figures 13-18 and 13-13 of the previous study indicate that none of the conclusions from the latter hold up for the "real" containment simulation. This is specifically true for the top-to-bottom temperature difference, which has the opposite tendency in the previous study as compared to the results shown in Figure 13-18 for a total containment simulation.

480.569 What conclusions does Westinghouse draw by comparing the results between Figure 13-18 and Figure 13-13?

480.570 Why are the predicted times to peak temperature so much different between the various models? Are the PCS models so different? Are the boundary conditions so different?

480.571 How can the staff evaluate Westinghouse's contention, on page 13-25 that the revised NAI model temperature agrees with the other cases when the data are not provided?

480.572 How can the staff evaluate the overall "consistency" in the three cases if the revised NAI results are not shown? Provided revised figures for all cases with the "7c-NAI" model used for comparison to show the results of the corrected model, the "8c-NAI" model. This includes the results in Section 13.5, "Additional Sensitivities."

480.573 What is the "containment integrity analysis" referred to on page 13-34, Section 13.6. Is this the three distributed parameter cases studied in Section 13.4, one of which has a known error?

480.574 What is the "AP600 distributed parameter evaluation model" referred to on page 13-34, Section 13.6? Is this the NAI model stated to be used in the SSAR analyses on page 13-23?

Figure 13-19 depicts the predicted near-wall velocities.

480.575 Explain why the MIT-model predicts a high upward velocity for the first 400 seconds (data not within the plot scales).

480.576 Explain why at later times, downward velocities in the MIT-model differ by a factor of two.

480.577 Explain the pronounced discontinuities noticeable in the plots. Again, the comparison with the velocities obtained for the bare shell models shows the opposite velocity direction.

480.578 What criteria does Westinghouse use to conclude that the velocities shown in Figure 13-19 are "very" similar?

480.579 What level of accuracy would be needed for the computed near-wall velocities to call them the result of a converged solution?

480.580 The upper part of Figure 13-20 does not show the global recirculation, it only shows the total downflow and the lower part depicts the condensation rate. The figure caption is incomplete and should be expanded to cover both parts as well as to provide more detail at what axial position the total downflow was evaluated.

480.581 What is meant by the upper half of the containment in the figure caption? Is this the region above the operating deck? Or half of the containment region being modeled?

480.582 Why has the onset of PCS at 660 seconds shown no noticeable effect on any of the computed quantities, not even upon the condensation rate?

480.583 What criteria is Westinghouse using to term a region well-mixed?

480.584 What are the radial temperature differences at different axial heights?

Peak pressures are computed to occur at around 1100 seconds. PCS is turned on at 660 seconds.

480.585 Why is PCS becoming a dominant heat removal mechanism after 1100 seconds? Why does this not show up in the condensation rate?

480.586 What heat sink or combination of heat sinks provides the turnaround of the pressure at 1100 seconds?

480.587 Explain how the bare shell model provides the basis for extending the conclusions from the simple models to the complete AP600 model. The bare shell models conclusions are based on uniform aspect ratio while neither the simple models nor the AP600 models use uniform aspect ratios.

On page 13-29, Westinghouse refers to the large computed differences in steam partial pressures and makes a statement that the predicted pressures are still close and offers as the explanation that the clime heat and mass transfer are relatively insensitive. This clearly indicates that containment pressure alone is not an unique criterion to judge the accuracy of predictions.

None of these noding studies seem to directly relates to the development and performance of the lumped-parameter model described in Section 4 of WCAP-14407. Peak pressure as a sole evaluation criterion does not seem to justify any model since large variations in steam concentration, internal flows rates and patterns, and temperatures do not seem to impact pressure. There must be additional criteria to judge the overall acceptability of an analytical model.

480.588 How does Westinghouse consider the total combination of temperature, steam and velocity distributions together with the temporal energy partitioning to evaluate an acceptable level of predictive code accuracy or predictive capability? This insight seems to have be used in evaluating resulted from the LST.

480.589 How does Westinghouse explain the large predicted difference in top steam and top-to-bottom steam concentration differences? Are the boundary and initial conditions so different? Have different input parameters been used? How much of these differences are attributable to "user effects?"

The Westinghouse-model ("5c-West") predicts that the whole axial extend of the containment center plane is occupied by the same steam concentration as that predicted at the top of the containment.

480.590 How would this nearly homogeneous steam concentration evolve, given that the mass and energy injections occur offset from the center?

While Westinghouse refers to the lumped-parameter model, none of the figures compared this case with any of the distributed-parameter model results.

480.591 What is the comparison basis for Westinghouse to claim that all models (including the lumped-parameter one) predict "essentially" the same pressure histories?

480.592 What is the impact of the newly identified steel jacket-to-concrete air gap thickness (Section 5 of WCAP-14407) for the heat sinks on these studies?

Subsection 13.5: Additional Sensitivities

No details are given on what was actually quantitatively changed in the models.

480.593 How large were the obstructions considered in the MIT-model to make a change in the computed pressure?

480.594 Why would the pressure increase when the obstructions provide additional heat sinks?

Subsection 13.6: Conclusions

480.595 In WCAP-14382, Section 6 provided explicit guidance for the development of an AP600 model based on Westinghouse's experience with studies for the Large-Scale Test facility. Since this guidance exists, please describe how the different groups acted independent from one another to come up with the models. What information was provided? Was this guidance provided? What lead each group to develop a different model for the same problem? What factors were considered to be most important to the model development?