Docket File
52-003

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

January 29, 1997

Mr. Nicholas J. Liparulo, Manager
Nuclear Safety and Regulatory Activities
Nuclear and Advanced Technology Division
Westinghouse Electric Corporation
P.O. Box 355
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SUBJECT: REQUESTS FOR ADDITIONAL INFORMATION (RAIs) ON WCAP-14407, "WGOTHIC APPLICATION TO AP600"

Dear Mr. Liparulo:

The Nuclear Regulatory Commission's (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. The enclosures are questions and concerns, identified as RAIs# 480.669 to 480.945 regarding Sections 4, 7, and 9 of WCAP-14407, "WGOTHIC Application to AP600" and the use of SATAN-VI for a loss-of-coolant-accident (LOCA) Blowdown. It is expected that WCAP-14407 will be updated to reflect the comments and concerns enclosed in this letter and provided in the December 31, 1996, letter.

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 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) 415-8548.

Sincerely,

original signed by:

Diane T. Jackson, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosures:
1. WCAP-14407, Section 4, "Description of WGOTHIC Evaluation Model"
2. WCAP-14407, Section 7, "Method for Calculating the PCS Film Coverage Input for the AP600 AP600 Containment DBA Evaluation Model"
3. WCAP-14407, Section 9, "Mixing Within Containment"
4. Request for Additional Information - Use of SATAN-VI for LOCA Blowdown Mass and Energy Releases.

cc w/enclosures:
See next page

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Docket No. 52-003
AP600

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AP600 - REQUEST FOR ADDITIONAL INFORMATION ON WCAP-14407, SECTION 4, "DESCRIPTION OF WGOTHIC EVALUATION MODEL"

This report, WCAP-14407 "WGOTHIC APPLICATION TO AP600," references WCAP-14382 ("WGOTHIC Code Description and Validation") as the WGOTHIC code package description and validation report. Yet the AP600 WGOTHIC model described in this report deviates substantially from what was described and validated in WCAP-14382. Westinghouse has changed its previous approach of simulating the AP600 above-operating deck region with a distributed-parameter model to a network of lumped-parameter nodes.

This change raises a number of concerns regarding consistencies of the new approach, including:

- The implementation specifics and computation results for the AP600 containment.
- The validation basis and comparisons of the clime/distributed-parameter approach versus clime/lumped-parameter approach.
- The validation basis and comparisons to experimental data.

480.669 Please justify the axial and radial spatial discretization for the above operating deck region. What is the relevant technical basis for the use of a multi-node network of lumped-parameter nodes in the above operating deck region? Lumped parameter networks have been observed to overpredict circulating flows. What calculations were performed to assure that this approach correctly models the flows in the above deck operating regions?

480.670 What nodalization studies have been performed to support the validity of the present network of lumped nodes? Please present comparisons between the lumped network approach and the results of the computational models contained in Section 13.

480.671 What comparisons were performed with the new model against the large-scale test (LST) and/or any other experimental data?

480.672 Have verification studies been performed with GOTHIC by other users? Specifically, has GOTHIC been applied using a network of lumped nodes and has it been compared to other models and/or experiments?

480.673 What sensitivity studies/nodalization studies have been performed to demonstrate the validity and the conservatism of the present AP600 Evaluation Model with respect to the second peak and 24 hour containment pressure criteria?

480.674 Describe the approach taken to ensure consistency in the overall methodology (climes, bounding, stratification) despite the change in containment analysis methodology.

All cross section schematics show a nodalization which implies subdivisions in accordance with the distributed parameter approach. However, page 4-1 clearly states that the model is a network of nodes. It would have been more conventional and descriptive if these figures presented the model as a "tube-and-tank" network of control volumes and flow paths.

480.675 Please modify the cross sectional nodalization diagrams for the evaluation model (figures such as Figure 4-31, Figure 4-32) to reflect the new modeling approach.

480.676 Provide unwrapped nodalization diagrams for the dome volume similar to that commonly provided for primary system nodalization schemes. The diagrams should show the complete network, including connections to the below operating deck compartments.

480.677 Indicate the break position (WGOTHIC node) for the LOCA and main steam line break (MSLB) on the graphical schematics.

480.678 Provide diagrams which show the participating thermal conductors for every compartment under consideration. These schematics are needed to accompany the text and make it easier to comprehend arguments concerning heat sink utilization, especially for conductors which are shared by compartments. Visualization of participating thermal conductors and conductor types is needed to evaluate consistency, completeness and overall methodology of heat sink utilization.

480.679 The review of the thermal conductor descriptions in Section 4 reveals that all of the conductors in the containment have been initialized at 120 °F, independent of position, type, orientation, etc. What is the technical justification for initializing all structures at the same 120 °F temperature regardless of whether they are located low or high up in the containment?

480.680 What is the technical basis for treating dead-ended compartments in the same manner with respect to mixing and stratification behavior, regardless of their flow paths, sizes, shapes, limited access of steam, enrichment of non-condensables at the bottom, pool formation, etc.? The compartments below the operating deck are all very different, and provide quite different scenarios for steam access. The arguments presented in Section 9 are based on generic considerations and do not necessarily apply for all of the below deck compartments in the AP600. (The Evaluation Model documented in Section 4 relies on generic arguments based upon mixing and stratification considerations which were presented in NSD-NRC-96-4763, *Assessment of Mixing and Stratification Effects on AP600 Containment*, July 1, 1996. However, the information contained in NSD-NRC-96-4763 has been superseded by the information presented in Section 9 of WCAP-14407. In addition, previous comments concerning Westinghouse's approach and assessment of

mixing and stratification issues have not yet been addressed. An update to Section 9 on "Mixing Within Containment" for inclusion into WCAP-14407 is expected to be provided in the near future.)

480.681 Are the quantities listed for control volumes and surfaces those of the original compartments or do they account for the special modeling assumptions? If the quantities listed do not account for the special modeling assumptions, then provide a separate table for each control volume which lists the quantities affected by the special model assumptions.

Below Operating Deck Regions

480.682 (Page 4-1) What is meant by the expression that the volumes "preserve elevations"? Is this referring to the fixed prescribed clime discretization or to some physical phenomenon?

480.683 (Page 4-2 and 4-3) Figures 4-1 and 4-2 show 3-D perspectives with cut lines providing and cross-sections in follow-up figures. This is a good approach and a substantial improvement over earlier presentation formats. However, please add one more figure to show the core makeup tank (CMT) room because of its size and overall importance for the below operating deck region.

480.684 (Page 4-4) Provide the following additional information:

a) the specification of the zero elevation location,
b) the definition of volume hydraulic diameter,
c) the definition of the inertia/inertial lengths, and
d) the definition of forward and reverse loss coefficients with the reference.

480.685 What is the technical basis and technical reference for specifying a single value of 1.5 for all flow path loss coefficients below the operating deck? What method and assumptions were used to derive this value?

480.686 Explain why a loss coefficient of 1.5 is valid for initially high mass flow rates as well as very low mass flow rates which occur towards the end of blowdown/refill?

480.687 What experimental evidence supports the value of 1.5 and why is the value the same for both directions and all flow paths with quite different shapes, sizes, positions etc.?

480.688 (Page 4-9) How is "bulk concrete" (conductor type 39) defined as compared to the other conductor types for the reactor cavity? What volume of concrete surrounding the cavity accounts for bulk concrete, given that the pool area is only 150 ft^2? The bulk concrete surface area of 2429 ft^2 seems very large.

480.689 Why is the reactor cavity a dead-ended compartment with two upper flow paths and one low-positioned flow path? Is flow path 253 always covered with sump water? If yes, why would it have the same loss coefficient as the other flow paths with steam flow?

480.690 What is the technical basis for condensation shutoff in the reactor cavity after the first 30 seconds? Please provide a specific reference or technical justification.

480.691 Since thermal conductor 1 is located at the top of the reactor cavity, one would expect steam to always occupy at least the upper part of the reactor cavity. Why is condensation at that conductor shut off?

480.692 Is the insulation material covering the other thermal conductors blowdown resistant?

480.693 Is the reactor pressure vessel completely, thermally isolated or insulated such that no enerqy is transferred into the cavity?

480.694 What is the transient liquid level history in the cavity during blowdown?

480.695 None of the conductor types 51, 48, 37 and 39, as specified in Subsection 4.3, list any special insulation material as a subregion. Why refer to these conductors as covered with insulation material?

Pages 4-10 to 4-15:

480.696 The reactor drain tank (RDT) volume has ten thermal conductors which are cited by Westinghouse. Does the RDT cavity initially contain any liquid which occupies part of the compartment?

480.697 Thermal conductor 1 constitutes the wall at the cavity base (see Figure 4-7) and thus should be "bulk concrete." Although the volume pool area is 424 ft^2, the surface area of the conductor is only 109.75 ft^2. In the reactor cavity, it was the opposite. Are these values correct? How are the surface areas of cavity bases determined and how are those related to pool areas?

480.698 W'y are the values for frictional length and loss coefficients the same despite the enormous differences in flow paths as well as the fact that Flow path 253 is carrying liquid instead of air/steam/liquid mixture?

480.699 What criteria were applied to group such widely differing components, as a sump pump, RDT and RDT-heat exchanger into one single thermal conductor, type 17? How are the equivalent surface area and conductor thickness values calculated?

480.700 A single lumped node is used to represent the RDT cavity. This compartment is a complex shaped flow path between the steam generator compartments. As such, it constitutes a fairly large sized, important link between the break location and other below operating deck compartments. Please explain and justify this model approach.

480.701 (Page 4-16) The correct unit dimension of the volume pool area should be ft^2, rather than ft. Please correct the text.

480.702 (Page 4-19) The correct figure number in the text should read Figure 4-9, rather than 4-7. Please correct the text.

480.703 The accumulator cavity together with the adjacent valve and piping room has a very complex shape (See Figure 4-8), which is represented as a single node. Why were such widely different compartments grouped into a single node?

Page 4-21:

480.704 Provide experimental evidence for the validity of the Uchida-correlation for condensation during the first 30 seconds.

480.705 Provide information about the anticipated pool layer height as a function of time in sufficient detail to allow the assessment of the degree of conservatism inherent in the reduction of the floor surface area.

480.706 Provide information about the amount of non-condensable gas (hydrogen and nitrogen) entrapped in dead-ended compartments below-operating deck. Why are these gases not part of any later time phase mixing process?

480.707 (Page 4-24) The northeast accumulator cavity connection junction is shown in Figure 4-11, not Figure 4-9. Please correct the documentation.

Special Modeling Assumption Subsections for the Below Deck Operating Nodes

a) Nodalization

480.708 Please justify the use of a single-node, single-layer representation (except CMT) for the very complex shaped and often multiply connected compartments below the operating deck. The standard practice is to apply several lumped-parameter nodes connected with stacked flow paths.

480.709 Most of the compartments are 20 or more feet high. Provide experimental evidence which demonstrates that a single-node representation suffices to simulate all of the important transient phases (blowdown, transition, long-term).

480.710 Provide information about the anticipated water liquid levels in each of the below-operating deck compartments in order to evaluate the remaining surface areas available for condensation heat transfer.

b) Flow Paths

480.711 Many flow paths extend over a total height of 10 or more feet. Standard practice is to model those flow paths by stacks of multiple vents. Provide the rationale for not using this modeling feature (except CMT) for all flow paths of this size for below-operating deck.

480.712 List all of the flow paths which are completely or partly covered by the anticipated water liquid levels during and after a DBA.

480.713 The friction length and loss coefficient values appear to have been selected primarily to best model the initial (few seconds) blowdown phase. Provide information (or specific references to published or docketed documents) which show the validity of the chosen values for the post-blowdown parts of the DBA-transient.

480.714 Provide information which shows how the selected values handle full and part-coverage with liquid filling up the compartments over time.

480.715 List the validation studies performed which support the basis for recirculating flows and which indicate that the selected input values also appropriately cover the long-term transient phase.

c) Thermal Conductors

480.716 The treatment of conductors varies from compartment to compartment. In some compartments even handrails are accounted for, while other compartments do not specify nearly as much detail. List the criterion used to classify and categorize the internal conductors in each compartment into specific types as documented in WCAP-14407. Is the volume fraction for thermal conductors subtracted from the control volume for all compartments? List the rationale for conductor selection and lumping.

480.717 No information is provided which show the discretization of heat sinks into one or two-sided conductors and "bulk concrete." Although the conductor type "bulk concrete" is numerically specified, no relationship is provided on how to transfer compartment-specific "bulk concrete" into this specific conductor. Please provide this information.

480.718 The thermal conductor types documented list the accessible surface area for steam condensation and heat transfer. However, numerous compartments are flooded by water after the DBA-event, thereby reducing the surface area according to the liquid levels reached.

Provide information about the compartment-specific fractions of surface areas which would be affected by pool formation and liquid level increase in addition to the pool floor surface areas documented.

480.719 One result of the mixing and stratification assessment documented in Section 9 and entered into Table 2-3 (Section 2 of WCAP-14407), which largely affects the modeling approach, is the concept of limited steam access to dead-ended compartment surface areas. Yet, the steam has full access to the heat sinks for the first 30 seconds. Provide arguments, data and references which support this approach and list why it is necessary to provide this heat sink capability for the first 30 seconds into the blowdown.

480.720 (Page 4-58) The south CMT flowpath junctions are shown in Figures 4-21, 4-22 and 4-23; please correct the text.

480.721 (Page 4-73) The refueling room junctions are shown in Figure 4-27. Please correct the text.

Page 4-77:

480.722 Provide information about the anticipated pool level height as a function of time for the refueling canal volume after DBA-initiation. Provide information about the fraction of surface areas available to steam access as a function of pool level height.

480.723 Has the reduction of surface area been accounted for in the specification of the conductor surface areas provided in Section 4.2.10.3?

480.724 (Page 4-80) These junctions are shown in Figure 4-29, instead of 4-22. Please correct the text.

480.725 Provide a figure which shows the circumferential vent layout connections from the in-containment refueling water storage tank (IRWST) to the outer quarter annuli.

Page 4-84:

480.726 Provide information about the water in the IRWST with regard to:

- volume
- liquid level as a function of time
- initial temperature and temperature distribution
- anticipated temperature distribution as a function of time and elevation

480.727 Please provide additional information about the segmentation of the IRWST into five horizontal slices. Does this mean that Volume 7 is subdivided into 5 one-dimensional slices?

Above Operating Deck Region

In the AP600 Evaluation Model documented in Section 4, all of the computational features of the subdivided, distributed-parameter approach have been eliminated. Lumped-node networks have an inherent limitations of averaging local momentum information and predicting zero velocities in the lumped nodes. The computed velocities in the artificial flow vents/tube-tank network are not representative of the velocity distribution in the continuum. In addition, the AP600 Evaluation Model has a coarse nodalization for the above-operating deck region, providing only averaged values for large subspaces. In this way, information about jet/plume mixing and stratification is lost. This information was previously thought to be important as an outcome of the PIRT (phenomena identification and ranking table) process.

Subsections 4.2.12 (page 4-86) through 4.2.32 (page 4-212) describe the above-operating deck internal containment region and its subregions as specified by control volumes and flowpaths which constitute the network of lumped-parameter nodes. In the above deck region, "rooms" and "compartments" have a different character as most of the defined "rooms" and "compartments" have virtual interfaces in the open free-volume region above-operating deck. Only the two steam generator compartments may comply with the traditional "room" or "compartment" definition.

The chosen segmentation certainly simplifies the model description but care should be exercised to interpret results in the context of these "virtual" rooms.

Page 4-86:

480.728 Figure 4-30 does not show the cylindrical central room, but the south inner-half annulus compartment instead. Figure 4-31 depicts the cylindrical central room but has the incorrect figure captions. Figure 4-32 highlights the cylindrical central room but refers to the south inner-half annulus in the figure caption. Please correct or replace these figures.

480.729 Why does the number of clime elevations limit the number of vertical segments in the lumped-parameter network? What physical and/or computed quantity necessitates equal numbers of vertical clime and lumped node network segmentation?

480.730 Provide information about connecting junctions' elevations for the cylindrical central room which are required to eliminate potential elevational differences.

480.731 Justify the selection of one node in the radial direction for the cylindrical central room.

480.732 Provide information on how artificial flow patterns are suppressed in the single radial node model for the cylindrical central room, especially considering the fact that the DBA-LOCA is asymmetrically positioned in one of the SG-compartments.

480.733 In Table 4-1, Volume 9 is listed as having a pool area of 706.5 ft^2. However the subsequent volumes, Volumes 10, 11 and 12, do not have horizontal conductor surfaces or pool surfaces for condensation. Why are pool surface areas listed for these volumes?

480.734 Why have the hydraulic diameters for volumes 11 and 12 values of 1000.00 while Volume 10 has a value of only 74.51?

480.735 Why does the cylindrical central room not extent up to the AP600 steel shell in the axial direction?

480.736 Why have all the forward (and reverse) loss coefficients been set to zero in the last column of Table 4-2? This is certainly incorrect for Flowpath 1 (WGOTHIC Flowpath Number 13) which, on page 4-73, has values of 1.5 for the forward and reverse loss coefficients. Furthermore, the table entries for the bottom elevation for this flowpath differ by 0.2 ft between page 4-73 and Table 4-2 (page 4-87). Please explain and correct any necessary text.

480.737 Explain what flowpaths 2-lower and 2-upper, 5-lower and 5-upper and 10-lower and 10-upper mean.

480.738 Why have Flowpaths 19 and 21 no lower and upper entries? Why are there no further entries in Table 4-2 for the "upper" flow paths?

480.739 Explain why the "free" Volumes 10, 11, and 12 are modeled as compartments with "virtual" flows, thereby necessitating the need for the modeling approach for vertical junction connections as described in the GOTHIC version 4.0 user manual (Page 16-6).

480.740 The GOTHIC 4.0 user manual recommends two parallel junctions in order to properly account for buoyancy driven flows. The GOTHIC 4.0 user manual also states: "When it is clear that buoyancy forces will not influence the flow, then wall openings can be modeled with a single junction." Justify the use of only one horizontal flow path to connect the cylindrical central room with its neighboring control volumes at each elevation. Please consider all phases of the transient.

480.741 Are there any conductors at the left and right side boundaries (steam generator compartments) of Volumes 9, 10 and 11? As shown in Figure 4-31, Volume 9 should be bounded by conductors at lower elevations.

Page 4-91:

480.742 What is meant by "as radial movement extends outward from the center..." (Same phrase occurs in all other descriptions)? What is moving?

480.743 Please clarify the flow paths shown in Figure 4-35. Are the directions of the arrows for cutline AA correct? Explain the notation in Figure 4-35. What does 16-to 16 and 14-to 16, etc., mean?

480.744 Provide information on why Flowpath 1 (WGOTHIC Flowpath number 7) is listed with zero forward/reverse loss coefficients in Table 4-4, while page 4-30 lists values of 1.5 for the same flow path?

480.745 Why are the flow areas of Flowpaths 4, 8, and 12 so much smaller as compared to the flow areas of Flowpaths 2, 6, 10 and 14, although the flow path heights are about the same (differences are less than 1 ft) for all of the aforementioned flow paths?

480.746 Do separating compartment walls exist between Volumes 10 and 14, 11 and 15, 12 and 16? If no separating compartment walls exist, provide information why horizontal flow paths between SG-room and cylindrical control room have been artificially curtailed in the evaluation model, while on the other hand horizontal paths towards the steel shell are extremely large.

Page 4-96 :

480.747 Please explain why there is neither a separating concrete wall between Volume 13 and Volume 9, which should be accounted for as a thermal conductor, nor a flow path between Volumes 13 and 9 (see Figure 4-34)?

480.748 Do any other platforms exist besides of the upper manway platform at 162.08 ft?

480.749 Explain why there are no other conductor types in Volume 13 other than Type 27 (steel jacketed concrete).

480.750 Explain how pipes, staircases, gratings, superstructures have been accounted for in the thermal conductors defined for Volumes 14 and 15.

Page 4-98:

480.751 Provide justification for 1) the selection of a stack of 4 single-node lumped-parameter volumes for modeling the steam generator rooms and 2) connecting the below- with the above-operating deck regions only with single flow paths. How can this SG-room model account for the different flow situations anticipated during the different accident phases?

480.752 Were the axial elevations for Volumes 13 and 14 chosen to coincide with separating platforms?

480.753 (Page 4-98) The second line of the control volume description paragraph should read: "... as shown in Figure 4-36." Please correct the text.

480.754 Explain the differences in the construction details between Upper East and West Steam Generator Rooms as displayed in Figures 4-33 and 4-36 by the highlighted lines. Are there different elevations involved? This is not apparent from Tables 4-3 and 4-5 which have identical entries.

480.755 Second line in the flow path description paragraph should read: "... the cell boundaries in the upper west steam ..." Please correct the text.

Page 4-100 and 4-101:

480.756 According to Figure 4-36, no separating wall exist between Volumes 17 and 9. Explain why no flow path is specified between Volumes 17 and 9 (compare Figure 4-37)?

Page 4-103:

480.757 Explain why no thermal conductor is specified between Volumes 17 and 9?

480.758 Describe how the jib crane was apportioned for specifying the ninth thermal conductor.

Page 4-105:

As shown in Figure 4-39 for the South and in Figure 4-42 for the North Inner-Half Annulus Compartments, respectively, these two compartments comprise a large and very complex shape containment region above the operating deck. The entries in the Control Volume Tables 4-7 and 4-9 reveal that each of the control volumes constituting the stack of nodes has a free volume which is a factor of 3-to-4 times larger than any of its neighboring nodes. As displayed in Figures 4-39 and 4-42, respectively, the inner half annulus compartments, modeled each as a single node, interface with the east and west steam generator compartments and the cylindrical control room. This modeling approach may completely homogenize whatever radial differences may exist in physical containment quantities across the transverse between the SG-compartments.

480.759 Provide quantitative comparisons with experiments which support the adopted modeling concept for the south and north inner-half annulus compartments.

480.760 Provide results of distributed-parameter WGOTHIC-analyses which support this large lumped-parameter node approach.

480.761 Provide justification for the validity of this nodalization approach for all phases of the accident.

480.762 Provide additional top views for the different axial elevations to display flow path information. Provide additional text describing details of the flow path selection which is otherwise difficult to display.

480.763 Explain the graphical presentation shown in Figure 4-40 with respect to the cutline BB depicted in Figure 4-39.

480.764 Explain the graphical presentation shown in Figure 4-43 with respect to the cutline BB and associate arrows (view direction) in Figure 4-42.

Page 4-110:

480.765 Provide information, whether any cutoff criterion has been applied for the specification of the thermal conductors, as the number of conductors (11) seems low for such a large portion of the containment. Have any staircases, pipes etc. been discarded?

480.766 Please, correct the description of the ninth thermal conductor on page 4-111. The sentence should read: "... conductor represents the wall between the upper east ..."

480.767 Provide information on how the refueling machine is apportioned to the 7th and 11th thermal conductors, respectively, in the south inner-half annulus compartment. What support systems of the refueling machine have been accounted for the specification of the thermal conductor?

480.768 What structures have been accounted for in specifying the 6th thermal conductor representing the integrated head stand?

Pages 4-122 to 4-145:

480.769 Explain why in Figures 4-48 and 4-54 the inside radius of the west and east mid-quarter annulus compartments, respectively, does not properly circumscribe the respective west and east steam generator compartments.

480.770 Changing from a compartment-oriented approach to the polar coordinate system leads to incompatibilities at common control volume interfaces in the radial and azimuthal directions. Please clarify the reasons for changing the modeling approach from the inner-half annulus to the mid-quarter annulus compartments. What checks and validation studies were performed to insure that incompatibilities did not arise as a result of this change?

480.771 Explain the approach taken for specifying the flow paths between North Inner-Half Annulus Compartment (South Inner-Half Annulus) and the adjoining North Mid-Quarter Annulus (South Mid-Quarter Annulus), as the inside surfaces of the latter only coincide over part of the outside surfaces of the former.

480.772 Explain how the flow paths are specified for connecting the West (East) Mid-Quarter Annulus Compartments with the West (East) Steam Generator Compartment and parts of the surfaces of both North and South Inner-Half Annulus Compartments. How are these part surfaces apportioned to flow paths? Identify those flow paths in the respective tables and provide comments in the respective subsections.

480.773 Explain why the radius of the outer surface of the Mid-Quarter Annulus Compartments have been set to 63 feet and not simply extended up to 65 feet, the inside containment surface?

480.774 List any special considerations which lead to the introduction of the Mid-Quarter Annulus Compartment Layer. What is the purpose of these four control volumes?

480.775 (Page 4-122) Last sentence should read: " ...are shown in Figures 4-46 and 4-47." Please correct the text.

Page 4-127:

480.776 Provide a list of the internal structures that have not been accounted for as thermal conductors for the mid-quarter annulus compartments.

480.777 What is the radial width of the internal stiffener? Provide a diagram showing the dimensions of the internal stiffener, which represents Conductor 5 in Control Volume 30, and show what fraction of the stiffener penetrates into Control Volume 30.

480.778 Provide a diagram showing the crane girder, which presents Conductor 10 in Control Volume 32, and show what fraction of the girder is part of Control Volume 32.

480.779 Explain whether the ring duct, Conductor 9, is fully embedded in Control Volume 3 or only a fraction of it. Is there any support structure for the ring duct? Has this been lumped into the conductor type? Provide a diagram.

Page 4-133 to 4-148:

480.780 Explain why the flow path arrow indicators in the axial direction have been omitted in Figures 4-49 and Figure 4-55.

480.781 Explain what the double arrows for 3, 9, and 15 actually mean and what control volumes they really connect to in Figures 4-49 and Figure 4-55.

Page 4-135:

480.782 Explain how the hydrogen recombiner unit has been lumped into an equivalent conductor of Type 14. Explain how the complete containment recirculation unit has been lumped into an equivalent conductor of Type 3.

480.783 Explain why the heat transfer coefficient of the fourth conductor, e.g. one half of the integrated head package concrete wall, is specified as Uchida/Uchida.

Page 4-141:

480.784 Explain why the flow path arrows have been omitted in Figure 4-52.

Page 4-142:

480.785 Explain why there are no radial flow path arrows displayed in Figure 4-53 for connecting the south mid-quarter annulus control volumes with the respective control volumes of the South Outer Quarter Annulus control volumes.

Page 4-146:

480.786 Explain what flow paths connect the control volumes of the East Mid-Quarter Annulus Compartment to respective ones of the north and south inner-half annulus compartments.

Page 4-153:

480.787 Provide the rationale behind the specification of the small-sized outer-quarter annulus compartments. How was their radial width selected?

480.788 Explain why only four nodes along the containment circumference suffice for proper simulation of asymmetric positioned breaks.

Page 4-154:

480.789 In all previous tables summarizing the flow path characteristics, all entries in the column "frictional length" were set equal to one for all flow paths in the network. However, in Table 4-20 this quantity takes on values of 17.38, 19.5 and 102.1 for a number of flow paths listed. Explain why certain flow paths for the north-outer quarter annulus (and similarly for the other outer quarter annulus compartments) have been assigned frictional lengths with values being much larger than one, while others remain at one, the standard value used for all flow paths connecting the control volumes of the inner containment region. What features of the flow paths for the outer-quarter annulus compartments determine the large changes?

Page 4-157:

480.790 Explain why there is no axial flow path displayed between Volumes 46 and 47 in Figure 4-59?

480.791 Provide information about the platforms at 162 and 172 feet and clarify whether these platforms can act as flow blockages in the axial direction?

Page 4-163:

480.792 Explain why no axial flow path exist between Volumes 51 and 52. Does any flow blockage in the axial direction exist at this elevation? Why is this elevation different from the one in North Outer-Quarter Annulus Compartment?

480.793 Provide information about Flow Path 1 shown in Figure 4-61. Does this flow path return the containment shell condensate flow to the IRWST? How wide is this condensate return gap?

Page 4-179:

480.794 Please correct the entries in the fourth column of Table 4-27 labeled "Upper Elevation." The columns presents the axial height, not the upper elevations.

480.795 Explain why the values for hydraulic diameter varies between 1000 and 33 for control volumes which are otherwise identical (for example, compare Tables 4-27 and 4-33).

480.796 Each inner dome compartment occupies a quarter of the total dome region, except for the 2 feet wide region at the steel shell. Provide the rationale for this modeling approach for the upper dome region.

480.797 What experimental evidence and validation studies support the use of a quarter inner dome region that radially extends from the axis of the cylindrical central room up to the outside surface of the mid-quarter annulus compartment?

480.798 What bias is anticipated for mixing in this region as a result of this modeling approach?

Page 4-180:

480.799 Explain how the flow path characteristics for Flow Paths 1 through 4 are specified to represent the common interface between Control Volumes 61 and 12, 16, 28, and 44? Are those simply apportioned according to their common surface area?

Page 4-181:

480.800 Why have all values for the frictional length for all flow paths set equal to one in Table 4-28?

480.801 Explain how the polar crane is apportioned among the four quarter inner dome compartments.

Pages 4-197 through 4-212:

480.802 Please correct the titles of Subsections 4.2.29 and 4.2.30 which should read "East Quarter Outer Dome Compartment" and "North Quarter Outer Dome Compartment," respectively.

Page 4-197:

480.803 Please correct the entries in the fourth column of Table 4-35 labeled "Upper Elevation." These entries are the axial heights, not the upper elevations.

Page 4-198:

480.804 Explain why the values of the frictional length for the various flow paths in Table 4-36 vary between 1 and 101, whereas they were set equal to one for all flow paths between the inner control volumes.

480.805 What are the specific characteristics of the flow paths with frictional lengths much larger than one?

Page 4-201:

480.806 Provide information about how the flow path characteristics are determined for Flow Paths 2, 6, and 10 which simulate flows across curved interfaces.

480.807 Explain why a fraction of the polar crane bridge is not apportioned to those volumes.

480.808 Explain why no reference is made to the containment steel shell, which is accounted for by the climes and described in Section 3 of WCAP-14407.

Outside Containment Upflow Annulus Volumes

Page 4-213:

480.809 The inside containment nodalization is divided into quadrants. Outside of the containment, the quarter-region modeling has been replaced by a single node representation of the downcomer and annulus for each axial elevation. Please justify this approach.

Does not the azimuthal lumping of the downcomer and annulus artificially (and non-conservatively) smooth out any asymmetries computed inside the containment using the four quadrant model?

480.810 WCAP-14407 states that the clime locations were selected to ensure that artificial flow patterns were not created. Explain how artificial flow patterns would be created in the one-dimensional stack of outside-containment nodes.

480.811 Please correct the fourth column of Tables 4-43, 4-45, and 4-47 labeled "Upper Elevation." These columns are axial heights, not upper elevations. Why are the fifth columns of these tables labeled "Pool Area" instead of "Flow Area"? Does this imply that Westinghouse expects these regions to flood?

480.812 The top of dome node, Control Volume 91, is much greater in size than all of the other outside-containment nodes. Its volume is more than 150% of the total volume of all of the upflow nodes. Please justify this unusual noding division. Show that the large size of this node does not artificially influence the PCS sensitivity results, particularly to changes in the PCS flow evaporation location.

Page 4-214:

480.813 Explain why all values for the frictional lengths shown in Tables 4-44, 4-46, and 4-48 have been set equal to one, although these control volumes are bounded by two surfaces. Why are "Path Heights" show as 0.1 ft for all but the bottom nodes in Tables 4-44 and 4-46?

480.814 Please add a footnote to Tables 4-44, 4-46, and 4-48 which references the reports or documents which derived or experimentally determined the flow loss coefficients.

Page 4-216:

480.815 Twice on this page, conductor types are referenced to Section 2.2. Should these references be to Section 4.3? This also occurs on Pages 4-220, 4-223, 4-224, and 4-247 through 4-267.

480.816 Explain why the Uchida correlation is used for determining the heat transfer coefficient in a non-condensing situation. Provide information or references which justify the use of Uchida for the flow conditions inside the upflow annulus.

480.817 How are these thermal conductors included in the clime equations. Do they conduct heat to the baffle? How is condensation on these structures treated? If the condensate is allowed to runoff, where does it runoff to? If not, is the condensate assumed to continually build up on these thermal conductors?

Page 4-217:

480.818 Why has Flow Path 6 in Table 4-46 been assigned a value of 0/0 for the forward/reverse flow loss coefficients?

Page 4-219:

480.819 Why does the arrow point opposite the normal direction of flow for Flow Path 7 (between Nodes 97 and 98) in Figure 4-86?

Page 4-220:

480.820 Explain why the Uchida-correlation is used for determining the heat transfer . ...icient at the inside surface of the shield building in a non-condensing situation? Provide information or references which justify the use of Uchida for the flow conditions at the shield building wall.

480.821 How are these thermal conductors included in the clime equations. Do they conduct heat to the shield building wall? How is condensation on these structures treated? If the condensate is allowed to runoff, where does it runoff to? If not, is the condensate assumed to continually build up on these thermal conductors?

Page 4-221:

480.822 Please provide the flow path parameters for the connections from the annular chimney section to the environment and from the environment into the downcomer.

Page 4-223:

480.823 Explain why the Uchida-correlation is used for determining the heat transfer coefficient in a non-condensing situation? Provide information or references which justify the use of Uchida for the flow conditions in the PCS chimney.

480.824 How are these thermal conductors included in the clime equations. Do they conduct heat to the shield building? How is condensation on these structures treated? If the condensate is allowed to runoff, where does it runoff to? If not, is the condensate assumed to continually build up on these thermal conductors?

480.825 Explain why "Uchida/Uchida" is used for the shield building top and the cylindrical portion? Does the "second Uchida" refer to heat transfer from the outside of the PCS chimney (a 36-inch concrete structure) to the ambient? If so, provide information or references which justify the use of Uchida for the flow conditions outside the PCS chimney.

Subsection 4.3 Conductor Description

Page 4-226 to 4-242: The material properties for the thermal conductor types are listed in Table 4-49. Thermal conductor parameters are documented in tables for each of 51 conductor types.

Page 4-226:

480.826 What are the technical references which support the tabulated values?

480.827 Have in-house tests to obtain any of the properties, e.g., dry and wet emissivities been performed?

480.828 What are the reference temperatures for the material properties listed in Table 4-49? Provide plots which show the temperature dependencies of the material properties over the temperature range of interest.

Page 4-227:

480.829 Please add a description of the region, material type, material region, etc. into the WGOTHIC Conductor Noding Diagram, Figure 4-88.

480.830 Provide information, possibly in the form of a generic figure, which shows how large, complex shaped concrete masses are transformed into an equivalent thermal conductor with one- or two-sided heat transfer.

Pages 4-228 to 4-242:

480.831 How is the Biot-number defined for each conductor type?

480.832 With the thickness and thermal conductivity given for the surface region, what is the value chosen for the heat transfer coefficient in the Biot-number?

480.833 Is the heat transfer coefficient in the Biot-number computed using the Uchida-correlation?

480.834 What atmospheric conditions were assumed? For what instant in time has the heat transfer coefficient been selected? Were all assumed conditions the same throughout the containment for all conductor types, leading to one and the same heat transfer coefficient applicable to all conductor types?

Out of the total of 51 conductor types, Types 27, 28, 29, 31, 32, 33, 34, 35, 37, 38, 39, 40, 41, 43, 44, 46, 47, 48, 49, and 50 have a steel jacket and therefore a finite-sized air gap between steel and concrete. For all of the conductor types cited above, a single air gap size of 0.005 inches has been selected throughout.

480.835 What is the technical basis for selecting the air gap thickness of 0.005 in. for all of the relevant conductors?

480.836 How does Westinghouse plan to verify the air gap thickness of 0.005 in. for the as-built massive concrete structures below-operating deck?

480.837 As a bounding approach is used for the 1-D transient heat conduction analysis with WGOTHIC (see Section 2), the properties of materials are claimed to have been conservatively chosen. Provide information about the conservatisms inherent in the selected material properties as compared to their nominal values.

Subsection 4.4 Clime Noding Description

Page 4-242:

480.838 Why is the top portion of the shield building shell, between Volume 98 and the environment, apparently accounted for twice? This component is the fourth thermal conductor for the outside containment downflow annulus. It is also included as the third conductor of the first clime on Page 4-247.

480.839 Explain (or provide references for) the basis for the selection of seven climes.

480.840 Explain (or provide references for) the basis why eight stacks of climes were chosen, with two stacks applied per quadrant, when there is only one coolant node in the outside upflow annulus?

480.841 (Page 4-244) First sentence should read "... are shown in Figure 4-89."

480.842 Is the condensate from the crane rail and internal stiffener which is transported to the IRWST assumed to have a transport time delay?

480.843 Explain what is meant by inner radiation boundary temperature? Is this the initial temperature?

480.844 Explain why mixed convection is listed as the inner surface heat transfer model, when Section 2 and all other information clearly specify that only the free convection mode is considered?

480.845 Why are the multipliers for outer steel shell free and forced convection the same?

Page 4-247:

480.846 Please describe how the gravity vector is calculated and explain how this term is used in the PCS film flow and WGOTHIC models. Are these gravity vectors used to help calculate the view factors

used for radiation heat transfer? If not, please explain how the view factors are calculated for the surfaces at different angles.

480.847 Why is the inner/outer surface free and forced convection heat transfer multiplier 1.0 for the baffle and shield buildings?

480.848 Describe the procedure used to couple computed quantities from two different stack types to one single inside containment node at each clime elevation.

480.849 Describe the procedure used to couple computed quantities from 8 stacks around the circumference of the steel shell with one single outside containment node for the whole upflow annulus at each clime elevation.

Page 4-268:

480.850 The text refers to Figures 4-92 and 93 as showing the film mass flow rates. However, only Figure 4-93 is actually depicting the total film mass flow rate. Please correct the text.

480.851 Please clarify the film mass flow values tabulated in Table 4-101 and shown in Figure 4-93. Are these "evaporation limited" film flow rate values? Please provide a detailed description of the computations from which these values were obtained.

Page 4-271:

480.852 Please clarify the last sentence of the first paragraph: "The condensate flow off the last clime and any excess PCS cooling film is directed into the control volume adjacent to the clime surface." Please describe what happens to the liquid film run off from the shell which accumulates at the bottom of Clime 7 of Wet Stacks 1 through 4 and Control Volume 53 of the annulus.

Subsection 4.5 Initial and Boundary Conditions

480.853 WCAP-14407 states that the outside containment initial conditions are based on the worst possible conditions for the site. Contrary to this, for example, the initial steam pressure ratio and relative humidity have not been set at the worst possible conditions, and the 115 °F external temperature assumed for LOCA conditions does not include an allowance for reflux from the PCS chimney. Please provide a justification for the selection each of the quantities listed in Table 4-102. If sensitivity studies were used to justify these parameters, provide a reference to the specific study and explain how these results constitute a base for the evaluation model.

480.854 Please provide reference(s) for the technical specification IRWST conditions, including minimum IRWST liquid volume fraction and temperature listed in Table 4-103. What values of IRWST liquid volume fraction and temperature were used for the sensitivity studies documented in Section 5?

Page 4-272:

480.855 Please expand this first paragraph to include descriptions of the contents of Figures 4-94 through 4-99. Provide information how these curves for mass flows, enthalpies, reactor coolant system (RCS) pressure and IRWST draindown rate histories were obtained. List references where applicable.

480.856 Explain why the respective time histories of the quantities stop at different instants in time in many of the figures.

480.857 Explain the significance of Figure 4-99.

480.858 Figure 4-94 through 4-99 are for the DECL-LOCA (double-ended cold leg) break. Please provide similar figures for the MSLB.

480.859 Identify the compartments and associated flowpaths which are flooded by time-dependent liquid fills resulting from DECL-LOCA break flow, emergency core cooling system (ECCS) refill and condensate. Provide the time-dependent fill rates for these compartments and flowpaths.

480.860 Provide the value of the containment temperature for which the containment volume increases by 1.5-percent. Provide a calculation or identify a reference.

480.861 What does "small" mean with regards to eliminate trays, pipes etc. from modeling? What is the basic underlying criterion for the specification of thermal conductors?

480.862 What does "small" mean with regards to flow path size? What is the basic underlying criterion for eliminating a flow path?

480.863 [illegible] revise Table 4-104 to add the steel jacket-to-concrete air [illegible] ckness, the internal flow paths loss coefficients, and the [illegible] dead-ended room modeling approach.

page 4-279:

480.864 Provide a reference for the standard safety analysis report (SSAR) and technical specification values.

480.865 Provide the reference(s) which documents that homogeneous, maximum initial internal temperature distribution always lead to conservative containment pressure histories

480.866 Provide the reference(s) for the percentage values listed for volume increases due to thermal expansion and uncertainty.

480.867 Provide information and the reference(s) about the selection of the value for the core stored energy increase. What is the rationale behind this value?

480.868 What is the rationale for the selected value for initial steam generator mass increase? Please provide the reference(s).

Page 4-280:

480.869 Please add the LOCA and MSLB break locations to this table.

480.870 Is the resultant hydrogen added to the mass of non-condensable, treated separately or neglected?

AP600 - REQUEST FOR ADDITIONAL INFORMATION ON WCAP-14407, SECTION 7, "METHOD FOR CALCULATING THE PCS FILM COVERAGE INPUT FOR THE AP600 CONTAINMENT DBA EVALUATION MODEL"

page vii:

WCAP-14407 states: "The PCS test data was examined with respect to the parameters that determine the coverage. The range of the test data was compared with the estimated AP600 range during a DBA. The test data was found to be acceptable for application to the development and validation of a film stability model."

This statement implies that Westinghouse's criteria for acceptability was limited to tests that spanned the expected ranges of the key parameters. However, the "goodness" of a test should be assessed as well as its range. Criteria such as consistency and repeatability of the measurement technique, standard error and variance of data obtained, and an assessment of whether the test procedure had inherent biases or large measurement errors, are also essential to judge the acceptability of test results.

480.871 Please expand the discussion presented to include the criteria Westinghouse used to judge the "goodness" of the test data for each of the tests whose results are summarized in Subsection 7.2.

WCAP-14407 states: "A film stability model, based or a modified form of the Zuber-Staub model for determining dry spot stability, was developed to determine a maximum value for the minimum stable film flow rate. The film stability model was compared with PCS test data for both evaporating and subcooled films. This model bounds the test data."

The Zuber-Staub model (Ref. Zuber and Staub, Int. J. Heat Mass Transfer, 9 pp. 897, 1966) is theoretical. While the use of the Zuber-Staub model may have value as a means to identify the important forces and parameters that determine film flow stability, its simplifying assumptions (e.g., that the liquid film is always saturated, the flow is always laminar, and the surface is free of imperfections) do not represent the physical conditions expected for the AP600 PCS film. Westinghouse has not presented separate effects test data to support the use of the modified Zuber-Staub model. Therefore the staff questions the use of the Zuber-Staub model as a quantitative predictor. It is not enough to bound the limited integral test data. Westinghouse must show that the minimum stable film thickness obtained with the modified Zuber-Staub model is conservatively predicted under the worst expected AP600 operational conditions.

480.872 Please provide a discussion and summary plots which clearly show the expected conservatism in the Westinghouse water coverage model, as applied to the worst combination of operational conditions for AP600. Include the following parameters:

- Location (dome, sidewall)
- Heat flux

- PCS liquid subcooling
- Flow rate/regime (laminar, wavy laminar, turbulent)
- Outside air and shell/baffle/shield building temperature
- Coating degradation and surface contamination
- Surface roughness and plate misalignment
- Contact angle uncertainty (include aging)

480.873 Please provide details of the calculations Westinghouse performed to assure that the evaporation-limited PCS flow is equivalent to using the actual PCS film flow with a time and elevation dependent coverage fraction. None of sensitivity studies provided in Section 7.5 show the equivalence of the "evaporation-limited flow" to the transient and position dependent PCS flow rate and coverage fraction.

480.874 Please provide the mathematical definition of "evaporation-limited" PCS flow rate.

The last sentence of the last paragraph states: "As expected, when the actual PCS flow rate was used (not the evaporation limited flow rate), the calculated peak pressure increased as the coverage area was decreased."

480.875 Provide details of the WGOTHIC calculations and results which support this statement. Please clarify the apparent contradiction between this statement and the previous statement that the "evaporation-limited PCS flow is equivalent to using the actual PCS film flow with a time and elevation dependent coverage fraction."

pg 7-1:

480.876 Please provide the basis for the estimate that 80 percent of the energy removal is through evaporation. Identify the events and phases for which this condition is estimated to occur.

WCAP-14407 states in the second paragraph: "The rapid heating of the cold water as it spreads out onto the surface of the dome causes the film to become unstable and break down into multiple streams. In addition, surface irregularities caused by plate misalignment during welding also help to break down the film at the top of the dome." This discussion highlights the importance of the heat flux on subcooled film stability.

480.877 How does Westinghouse justify the values, based on data taken from the unheated Water Distribution Tests, for the water coverage fractions for the top two AP600 model "climes" that represent the dome region, when the AP600 dome will be heated?

480.878 What is meant by "help to break down the film?" Is this a benefit?

The third paragraph states: "After some minimum value of film thickness is reached, further evaporation causes the film width to decrease." Westinghouse assumes that evaporation will cause the film width (wetted perimeter) to

decrease smoothly in an exponential fashion. Zuber and Staub (Ref. Zuber and Staub, Int. J. Heat Mass Transfer, 9 pp. 897, 1966.) assumed that once the minimum film stability criterion is exceeded, the film would split into fingers around dry spots.

480.879 How does the data show that a minimum film thickness has been reached? The above statements indicate that the flow could remain as thick rivulets.

480.880 Please provide justification for the assumption that evaporation will cause the film width (wetted perimeter) to decrease smoothly in an exponential fashion.

480.881 In addition to plate misalignment during welding, other surface irregularities can affect the stability of the liquid film. Please discuss Westinghouse requirements for maximum allowable surface irregularities and how conformance to these requirements will be demonstrated during the plant lifetime.

480.882 At what point in the calculation is the runoff flow subtracted? Is this flow properly considered in the PCS tank level and pressure head calculation? How is the sensible heat from the subtracted runoff flow treated? Does the runoff flow subtraction procedure preserve the distance at which the remaining PCS coolant flow reaches saturation?

pg. 7-3:

480.883 How did Westinghouse determine that the zinc coated surface was indeed prototypical? For each of the tests identified in Section 7.2, please describe the quantification performed for surface coating thickness, surface roughness, irregularity size, etc. Identify whether each test was performed with a freshly coated or an aged surface. Describe how the surfaces was aged. For each test sample with an aged surface, estimate the simulated age of the surface in terms of service years.

The second paragraph of Water Film Formation Test Section (Section 7.2.1) states: "The film thickness was not uniform near the point of application; it was thinnest just below the application point and thicker on both sides. The film stripe continued to spread (more slowly as the surface became more vertical) and a very thin, wet region was created at the edges as the film traveled downwards."

480.884 This observed behavior appears to contradict the Westinghouse assumption that the film has a constant cross-sectional thickness as the water travels down the PCS shell. If the liquid film has a non-uniform cross sectional area, the equations on pages 7-27 through 7-30 may under predict the amount of runoff. Please explain.

pg. 7-4:

480.885 Please add an equation defining the Reynolds and Marangoni numbers as used in Table 7-1.

480.886 In Table 7-1 the "LST Test Data Ranges" box refers to "Peak Heat Flux at Bottom". To what "Bottom" does this refer?

pg. 7-5:

480.887 Please explain how the water coverage fractions above the first weir, between the weirs and from the second weir down (refer to Section 7.4.2, page 7-33) were obtained from the "measured" Water Distribution Tests, phase 3 data. As shown in Table 7-2, wetted perimeter measurements were taken just above the second weir and after the springline. From this data, it is difficult to infer the average data above the first weir, between the two weirs and below the springline with any accuracy.

480.888 Based on the techniques used to determine the water coverage fractions, estimate the uncertainty in the values and the impact of including these uncertainties when evaluating the PCS performance. The data provided in Table 7-2 suggests that the measurement accuracy is ±1% in the coverage fraction.

pg. 7-10:

480.889 Table 7-4 lists the film inlet temperature for case 107A-5U as 800 °F. Should this be 80 °F?

pg. 7-12:

480.890 In discussing the flow oscillations, WCAP-14407 states that the flow oscillations had a small effect on the coverage. In the absence of test data without flow oscillations, how was this statement justified? What analysis has been performed to determine that the flow oscillations did not fundamentally alter the film stability and water coverage measurements?

pg. 7-14:

480.891 The second bulleted paragraph states that a relatively uniform wall temperature and heat flux was maintained over the evaporating surface. However, a higher than proportional heat transfer rate is experienced on the dome, as discussed in the prior paragraph. Presumably, this is caused by sensible heating of the PCS film flow. How is the non-uniform heat flux distribution factored into the water coverage area calculation?

pg. 7-16 and 7-A14, 7-A15:

480.892 Why was the data for tests 216.1A and 216.1B omitted from Table 7-5, and Figures 7.A-5 and 7.A-6? Please add these data points to the Table and the Figures.

pg. 7-18 and 7-19:

480.893 In the last paragraph of page 7-18 and in Table 7-6, the minimum applied film temperature is given as 40 °F. AP600 technical specifications specify 50 °F. Please clarify.

480.894 Please add values for "Runoff Film Temperature", "Bottom Sidewall Film Flow Rate" and "Marangoni Number" to Table ;-6 for AP600.

pg. 7-20:

480.895 The third paragraph states that "about 10 minutes" is required to fill the water distribution system and reach steady-state for a 220 gpm flow. Previous documents used 11 minutes. Both estimates are based on video tape data from the Water Distribution Tests. Please clarify the reasons for the change.

pg. 7-21:

480.896 Please explain why 250 °F was selected for the asymptotic internal containment temperature, T_∞, when 260-265 °F is more appropriate based on the containment atmosphere curve shown in Figure 7-4 on page 7-23.

480.897 Please justify the value of 75 Btu/hr-ft^2-°F for the post-LOCA internal atmosphere to PCS shell energy transfer coefficient.

pg. 7-27 and 7.A-12:

480.898 In the formula for wetted perimeter, r_{wetted}, on pg. 7-27 (or WDL on 7.A-12), the predicted circumference, r_{splt}, on pg. 7-27 (or CI on 7.A-12) is averaged with the circumference at the springline. Please explain the reason for this extra step in the calculation procedure, which always increases the predicted wetted perimeter.

pg. 7-36:

480.899 Describe the model used for the Section 7 study: number of nodes, flow paths, climes, WGOTHIC computer code version used, etc. If the computer program version differs from WGOTHIC 4.0 version to be used for the final SSAR analyses, discuss the differences and their impact on the results provided. With respect to the model described in Section 4, discuss modeling differences and their impact on the results provided.

480.900 What driving forcing functions (break mass flow rate, energy addition) were used to obtain the computational results? What blowdown computer program was used to predict break flow and associated energy? Provide a plot of the mass and energy profiles used, or a reference location.

480.901 The sensitivity calculation for water coverage location varied the coverage area as well as the location. Please reperform the sensitivity case for water coverage location (dome and sidewall coverage cases only) preserving the coverage area (e.g., 36% coverage for both cases). Please extend the calculations to show results (Figure 7-8) to 24 hours.

pg. 7-42:

480.902 Section 7.5 includes four sensitivity studies. However, none of these calculations show the sensitivity of the peak pressure to Gamma min (Γ_{min}) - the minimum film thickness. Please add this sensitivity calculation.

pg. 7-46:

480.903 Subsection 7.5.4 states that the base case assumed delay time is 660 seconds for a 220 gpm water flow rate. This is inconsistent with the 440 gpm flow rate quoted in Sections 7.2 and 7.3 (see pages 7-14 and 7-20). Please clarify Westinghouse's position on PCS design flow, and correct the text accordingly.

pg 7.A-2

Ponter, et. al., (Ponter, Davies, Beaton and Ross, Int. J. Heat Mass Transfer, 10 pp. 1633, 1967) stated, when discussing the poor agreement of experimental data to the Zuber-Staub model, that: "This is not surprising when ones compares the actual dynamics of the system with the assumptions made in the model. This was developed for laminar flow conditions, assuming a parabolic velocity profile. Above a Reynolds number (Re) of 20, surface waves are apparent which between the Re range of 300 to 1120, cause liquid circulation sufficient to induce mixing. In this range the simple models will not simulate actual flow conditions."

480.904 The expected range of Reynolds numbers for AP600 side wall films is 0 to 2900. Please comment.

pg. 7.A-5:

480.905 The advancing contact angle value was selected for the evaluation model, "because it is the upper bound of the measured, steady-state values for a heated, weathered surface." This may be the maximum value for wetted surfaces, which are not expected to exceed 180 °F. However, the dry strips, which form parallel to the wet strips, are predicted to reach temperatures of 260 °F. How can the Zuber-Staub model with this contact angle be used to predict rewet?

480.906 On page 7.A-7, fourth paragraph, should the reference be to Section 7.A.6, not Section A.6?

pg. 7.A-8:

480.907 Please uniquely identify each data point in Figure 7.A-1 so the test and test conditions can be determined.

pg. 7.A-9:

480.908 Please uniquely identify the error ranges given in Figure 7.A-2 so the test and test conditions can be identified in Table 7-5 (pg. 7-15). Please explain how the "cold" (80 °F) and "hot" (180 °F) estimated film breakdown data were obtained. Please provide a single figure which combines the data shown in Figures 7.A-2 and 7.A-3 in units of lbm/hr-ft instead of Reynolds number. This figure should reflect the expected breakdown temperatures and Reynolds numbers for AP600. Please comment on how this figure supports the Westinghouse position.

480.909 Describe how the circumferential average heat flux value is determined, and what is the uncertainty in this value? Is there a correlation between the local (instantaneous) exit Reynolds number and the local heat flux?

AP600 - REQUEST FOR ADDITIONAL INFORMATION ON WCAP-14407,
SECTION 9, "MIXING WITHIN CONTAINMENT"

The staff has provided comments to Westinghouse on a preliminary version of Section 9 as furnish in Westinghouse letter NSD-NRC-96-4763, dated July 1, 1996, "Assessment of Mixing and Stratification Effects on AP600 Containment." Westinghouse, in its letter NSD-NRC-96-4816, dated September 10, 1996, submitting WCAP-14407, has indicated that Section 9 is being revised to incorporate these comments. The staff has identified additional information needed for the AP600 review based on Section 9 of WCAP-14407.

Page 9-1 :

Reference is made to the Standard Review Plan (SRP) with the following introductory sentence: "DBA evaluations of AP600 containment pressurization transients follow an approach which bounds uncertainties in parameters important for containment response, similar to that recommended in the Standard Review Plan."

480.910 Provide a list of the similarities between the AP600 DBA evaluation and the SRP recommendations which clarifies the degree of similarity between the two approaches on a one-to-one basis. Identify those elements that are treated in a bounding manner. Describe how the DBA evaluation bounding approach directly complies with the SRP recommendations.

480.911 Describe how momentum considerations, as a result of the worst case set selection process, are accounted for in the lumped-parameter DBA-evaluation model described in Section 4, which does not deal with momentum in the node volumes or between the nodes.

480.912 What is the meaning of the last part of the last sentence of the first paragraph: "... and to bound the potential for reduced heat sink efficiency where the lumped-parameter model oversimplifies"?

480.913 Once a worst case scenario has been selected, describe the means which assure that the oversimplifications introduced by using the lumped-parameter approach and the network of lumped-nodes above the operating deck do not counteractively render the bounding approach ineffective.

As stated in the second paragraph, Westinghouse's assessment focuses on the potential effects of steam concentration distributions driving the heat removal mechanisms at the inside vessel surface.

480.914 Describe how this important driving potential is properly computed with the lumped-parameter networks with no appropriate momentum treatment, oversimplification of buoyancy-driven phenomena, numerical "overmixing", and huge volume-averaged nodes.

480.915 List the inherent biases in the lumped-parameter evaluation model. Provide the bases for their quantification, or list reasons why these mixing and stratification related phenomena do not lend themselves to the quantification of bias. How does Westinghouse insure that the simple DBA approach bounds these inherent bias?

Last paragraph: Westinghouse states that during blowdown (0 to ~30 seconds) there is very little heat sink utilization.

480.916 Explain why heat transfer to internal structures is utilized in the DBA-evaluation model for the first 30 seconds during blowdown and turned off thereafter.

480.917 Explain the results of LST experiments which show that metallic structures absorb most of the energy within the first 30 seconds.

480.918 What are the driving forces for overmixing of heavier-than-steam noncondensables from below-operating to above-operating deck regions? Quantify the penalty and provide a comparison with the appropriate SRP-recommendation. Is the penalty constant over time or is it a time-dependant function?

Page 9-2:

Westinghouse states that "the evaluation includes a logical sorting and organization of plausible break scenarios that are quantified by various analytical models and selected experimental results. The analytical models include hand calculations and the use of WGOTHIC for sensitivities to the range of predetermined large-scale circulation patterns."

480.919 Describe the model that was used for the WGOTHIC sensitivity studies.

480.920 As no reference is made to the application of the DBA-evaluation model described in Section 4, explain why this model was not used for this purpose.

480.921 What does "predetermined large-scale circulation patterns" mean? How were these patterns determined? What role did the LST and the scaling study play is this determination?

480.922 Explain how the logical sorting and organization of plausible break scenarios relate to the PIRT-process and its outcome as documented in Section 2 of WCAP-14407.

480.923 List the selected experimental tests and respective test data results which fully comply with the plausible break scenarios selected.

480.924 What are the driving forcing functions for the large-scale, density-driven circulations between compartments?

480.925 Describe how the WGOTHIC model used for the sensitivity study on large-scale circulation patterns was qualified and validated.

480.926 What considerations were given to the momentum driven phenomena and their eliminations in the context of the lumped-parameter approach?

Westinghouse states that "the assumption of dissipation of the break momentum within the SG compartment at the primary system pipe elevation is limiting because other plausible scenarios were shown to have improved heat sink utilization." This contradicts the previous statement of "little heat sink utilization" as well as LST test data.

480.927 Describe the test data which confirm the statement of limiting scenario.

480.928 Why is the undissipated forced jet with more mixing not limiting? This contradicts the statement previously cited that overmixing results in a penalty for heat sink utilization of PCS.

480.929 Describe why the objectives were changed from scenario to scenario.

480.930 How can a DECLG (double-ended cold leg guillotine) break be rationalized as a buoyant plume and what experimented information exists that support this?

480.931 What lumped-parameter WGOTHIC-model was used for selecting the potentially limiting buoyant source release positions?

480.932 Describe what circulation pattern can be expected (predetermined) in each case and what experimental information exist for confirming the expectation?

480.933 What does confirmation by WGOTHIC computation really mean, when the lumped-parameter model is set up according to the expected (predetermined) circulation pattern?

480.934 Describe how the WGOTHIC lumped-parameter model handles a buoyant source, especially when using only single calculational node for each below deck compartment.

Westinghouse states that "an assumption of a buoyant release within the broken SG-compartment minimized heat sink effectiveness and led to the highest calculated peak pressure." This contradicts the statement on overmixing effect on the previous page and all other statements regarding PCS.

480.935 Identify appropriate LST-tests which indicate that the heat sink effectiveness is minimized.

480.936 Does the statement refer to only the below operating deck heat sinks?

480.937 What pressure peak is referred to, the first or the second one?

The last paragraph of page 9-2 contains statements about the DBA-AP600 evaluation model as with regards to mixing and stratification phenomena evaluated in the follow-up chapters.

480.938 List the momentum-driven and buoyancy affected phenomena which are accounted for in the stacked network of lumped nodes for the above-operating deck region.

480.939 List the momentum-driven and buoyancy affected phenomena which are accounted for in the single layer of chained single nodes representing each major below operating deck compartment.

480.940 Why is it necessary to assess the effect of larger than computed density gradients when overmixing is the model of choice for minimizing heat sink utilization in the above operating deck region?

480.941 As stratification (layers of cold heavy noncondensable air) in the below-operating deck lumped-parameter nodes has been indirectly accounted for by reducing horizontal heat sink utilization, how can overmixing transport air-enriched atmosphere to the upper dome shell where it provides another margin (penalty) by reducing condensation in the presence of noncondensables?

Page 9-3: last paragraph

480.942 Why is Section 7 mentioned? Is this a typographical error?

Page 9-4, 2nd paragraph:

480.943 Reference is made to Section 2 for the evaluation model. This is seemingly a typographical error and should possibly read as Section 4.

A summary of missing, or useful, information in the figures and the figure captions in Section 9 of WCAP-14407 is provided below. This information will facilitate the staff's review and understanding of the model described in Section 4 of WCAP-14407. Hand mark-ups of the figures containing this information, in advance of the formal revision to WCAP-14407, are requested.

480.944 Provide revised figures with the following information:

Fig. 9-1:

a) Radial and azimuthal positions of measurement locations F and E; provide top view for indications; are those the same for LOCA and MSLB?
b) Instants in time for which these steam concentrations were measured; should be different for LOCA and MSLB
c) Steam concentrations for any elevation higher than E

Fig. 9-2:
a) Break locations for LOCA and MSLB

Fig. 9-3:
a) Break locations for LOCA (SG-compartment) and MSLB in case of CMT-break

Fig. 9-4:
a) Name of primary system LOCA-code with reference

Fig. 9-5:
a) Reference to Fig. 9-3 with appropriate names of floor and ceiling vent flow openings
b) Specification of transient phase for which this phenomenological flow pattern is supposed to apply
c) Hint that ceiling inflow extends around the circumference whereas ceiling outflows are a few discrete vents (steamline penetrations, elevator shaft, stairwell to operating deck)
d) Potential for countercurrent flow through circumferential gap

Fig. 9-6:
a) Break scenario: LOCA or MSLB?
b) Source or reference for applied steam concentration

Fig. 9-7:
a) Break scenario: LOCA or MSLB?
b) Source or reference for applied steam concentration
c) No input data for times longer than 1 hour

Fig. 9-8:
a) Break scenario: LOCA or MSLB?
b) No results for times longer than 1 hour

Fig. 9-9:
a) Jet scenario not referenced, what case?
b) Break position not referenced, presumably SG-West
c) No radial positions for the dome quantities provided, along vertical axis above SG-West?

Fig. 9-10:
a) Typo in figure caption
b) What jet case is compared?
c) Break position

Fig. 9-11:
a) Break scenario: LOCA or MSLB?
b) Internal means total or below operating deck?
c) No results beyond 3,000 sec, why?
d) List source, reference, WGOTHIC-network or a one-node, hand-computation?

Fig. 9-12:
a) What jet scenario?
b) Reference to Section 4 with regards to the evaluation model
c) Internal heat sinks means total or below operating deck?

Fig. 9-13:
a) Break scenario: LOCA or MSLB?
b) Source, reference for the values shown, WGOTHIC-network or one node?
c) Curves for concrete and PCS cannot be clearly differentiated
d) Jacketed steel with or without air gap allowance

Fig. 9-14:
a) Break scenario: LOCA or MSLB?
b) Jet scenario?
c) Reference to Section 4 regarding notation of 9R81, 9R38 etc.
d) What does upper compartment mean? Steam concentration averaged over total region above operating deck?
e) WGOTHIC network node model?

Fig. 9-15:
a) Break scenario: LOCA or MSLB?
b) Jet scenario?
c) Time axis missing
d) Instant in time missing, what is long-term 80,000 seconds?
e) WGOTHIC-network computed or one node for above operating deck?
f) Upper compartment volume-averaged over total region above operating deck?

Fig. 9-16:
a) WGOTHIC model used? Reference to Section 4?

Fig. 9-17:
a) Break position missing (SG-East?)
b) What WGOTHIC model? Single node above deck?
c) List number of nodes in WGOTHIC-model (total of 6?)

Fig. 9-18:
a) WGOTHIC model used? Full network above operating deck or one node?

Fig. 9-19:
a) Break location
b) Instant in time is missing for which results are shown
c) WGOTHIC model applied?

Fig. 9-20: refer to items for Figs. 9-16 and 18.

Fig. 9-21: refer to items for Figs. 9-17 and 19

Fig. 9-22:
a) What MSLB scenario
b) Froude number definition refer to text
c) What coordinates above deck?
   - Axial?
   - Radial?
   - Azimuthal?
d) LST: reference needed, test numbers

Fig. 9-23:
a) Break scenario: LOCA or MSLB?
b) Jet scenario?
c) What room?
d) What WGOTHIC model used?
e) Elevation measured from where to what height?
f) What instant in time? What transient phase?

Fig. 9-24: refer to items for Fig. 9-23

Fig. 9-25:
a) What WGOTHIC-model was used?
b) What do the curves mean in terms of compartments?

Fig. 9-26:
a) What WGOTHIC-model was used?

Fig. 9-27:
a) What WGOTHIC-model was used?

AP600 - REQUEST FOR ADDITIONAL INFORMATION
USE OF SATAN-VI FOR LOCA BLOWDOWN MASS AND ENERGY RELEASES

480.945 Westinghouse has proposed using the SATAN-VI computer code for calculation of mass and energy releases to the containment during large break LOCAs for the AP600. SATAN-VI is not part of the large break LOCA code package submitted by Westinghouse for AP600 large break LOCA analyses, and has therefore not been reviewed by the staff for this application. Therefore, if Westinghouse uses SATAN-VI to calculate mass and energy releases to the containment during an AP600 large break LOCA, we require that Westinghouse provide adequate justification to demonstrate that SATAN-VI gives conservative results. This could be accomplished by (1) submitting the code for formal review and approval by the staff, or (2) providing SATAN-VI analyses that are benchmarked against WCOBRA/TRAC, Westinghouse's large break LOCA SSAR code, over a spectrum of large break LOCA cases.

If Westinghouse chooses the second option, the following information must be included in the material provided to the NRC:

1. Demonstration that SATAN-VI is capable of modeling AP600 components (e.g., spherical accumulators, CMTs, 2 x 4 loop layout) and AP600 plant response.

2. Plots showing comparison of results from SATAN-VI and WCOBRA/TRAC for a spectrum of large break LOCAs, including worst-case predictions for each code. The plots must include time-dependent and integral predictions for mass and energy.