Docket File

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

April 11, 1997

APPLICANT: Westinghouse Electric Corporation

FACILITY: AP600

SUBJECT: SUMMARY OF AP600 DESIGN REVIEW MEETING REGARDING THE PASSIVE CONTAINMENT COOLING SYSTEM (PCS) AND WGOTHIC COMPUTER CODE

On March 25, 1997, representatives of the U.S. Nuclear Regulatory Commission (NRC), Scientech, Inc. (NRC consultant), and Westinghouse Electric Corporation (Westinghouse) met in Rockville, Maryland, to discuss Sections 7 and 9 of WCAP-14407, "WGOTHIC Application of AP600." Attachment 1 is a list of meeting participants. Attachment 2 is a chronology of discussions and correspondence regarding Sections 7 and 9 prior to this meeting.

Westinghouse reviewed some of the changes that they intend to make on Section 9 with the staff. Included in the changes is the addition of three appendices to the section: (A) Core makeup tank (CMT) room flow diagrams, (B) Effects of stratification in the CMT room for heat sink utilization and assumptions, and (C) miscellaneous additional information, including international testing.

Attachment 3 is two sets of responses to the staff's discussion questions on draft Section 9. These responses were provided to the staff via facsimile on March 20 and 21, 1997. In the responses, Westinghouse identified the questions that they (1) wanted clarification of the staff's concern, (2) wanted to discuss the technical approach for their response, or (3) provided a draft response. Westinghouse and the staff focused their discussion on the questions that needed clarification or technical discussion. As noted in the facsimile cover page, Westinghouse responded to the questions using the documentation that is currently available and updated. At the conclusion of the discussions, Westinghouse stated they had a good understanding of the staff's concerns.

Due to time constraints, only a few items were discussed on Section 7. Attachment 4 is the Westinghouse draft responses to the staff's requests for additional information (RAIs). The responses were provided to the staff via facsimile on March 21, 1997. In the information, Westinghouse identified the questions that needed further clarification from the staff, provided responses, or identified the questions that they wanted to discuss their approach for the response. It was agreed that the questions would be discussed in a telephone conference call the following week.

Westinghouse informed the staff that they intend to respond to the discussion items and requests for additional information (RAIs) in the upcoming revision of WCAP-14407. The submittal is currently scheduled for mid-May 1997.

Future meetings and telephone conferences:

1) A telephone conference to discuss Westinghouse's approach to responding to staff questions on Section 7 of WCAP-14407 was tentatively scheduled for April 3, 1997.

2) A meeting to discuss Westinghouse's planned revisions to the WCAP-14812, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System," (PIRT report) and for staff feedback on WCAP-14845, "Scaling Analysis for AP600 Containment Pressure During Design Basis Accidents," (Scaling Report) was tentatively scheduled for April 17, 1997, in Monroeville.

If you have any questions, please contact me at (301) 415-8548.

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

Attachments: As stated

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WESTINGHOUSE/NRC MEETING

PASSIVE CONTAINMENT COOLING SYSTEM

MARCH 25, 1997

MEETING PARTICIPANTS

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| DIANE JACKSON | NRC/NRR/DRPM/PDST |
| JACK KUDRICK | NRC/NRR/DSSA/SCSB |
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Attachment 1

## Chronology

This chronology is provided as a history of the discussions and correspondence between the staff and Westinghouse leading to this meeting. It was not discussed as part of meeting.

### Section 9

| | |
|---|---|
| July 1, 1996 | Westinghouse submitted a draft version of Section 9 for staff review and comment. |
| August 1996 | The staff provided comments to Westinghouse on the draft version in telephone conference calls and facsimiles. |
| September 19, 1996 | Westinghouse submitted Section 9 as part of WCAP-14407, "WGOTHIC Application to AP600." It was noted in the cover letter that, due to time constraints, not all of the staff's comments were addressed. |
| January 29, 1997 | The staff issued requests for additional information (RAIs) on Section 9. Discussion items not addressed in the WCAP were included as RAIs. |
| March 20 - 21, 1997 | Westinghouse provided draft responses by facsimile. |

### Section 7

| | |
|---|---|
| May 21, 1996 | Westinghouse submitted a draft section of Section 7 for staff review and comment, "Method for Calculating the PCS Film Coverage Input for the AP600 Containment DBA Evaluation Model." |
| June 5 & 6, 1996 | Meeting to discuss water coverage. |
| September 19, 1996 | Westinghouse submitted Section 7 as part of WCAP-14407, "WGOTHIC Application to AP600." |
| January 29, 1997 | The staff issued requests for additional information on Section 7. |
| March 21, 1997 | Westinghouse provided draft responses by facsimile. |

Attachment 2

March 20, 1997

Subject: Informal Transmittal of Information on
- WCAP-14407 Ch 9 informal questions 67 - 132, and A1 - A11

To: Ed Throm Fax: 301-415-3577 (14 pages)

cc: Jim Gresham Dick Haessler
Brian McIntyre Tim Andreychek

Attached are proposed approaches to respond to the subject NRC review questions. The ones marked with a "T" are those which Westinghouse recommends to have technical discussions during the 3/25/97 PCS DBA meeting.

Unfortunately, the reviews of the proposed responses to Ch 9 informal questions 1-66, 72, and 91, and the Ch 7 RAIs were not completed by the end of today. We will forward those to you as soon as possible tomorrow.

It should be noted that WCAP-14407 Section 4, WCAP-14812, and WCAP-14845 have been issued subsequent to the issuance of NRC review comments on the preliminary draft Section 9. The attached responses assume the reviewers have access to all three WCAPs at this time.

Joel Woodcock

prelim.wp

Attachment 3

C= Clarification at meeting w/ NRC
S= Straight forward
T= Technical discussion @ meeting w/NRC

Responses to NRC Questions on Section 9 of the WCAP-14407

Several preliminary reports on AP600 mixing and stratification effects have been issued. The knowledge base was consolidated into NTD-NRC-96-4763 (Reference 1) which was reviewed by the NRC. Subsequent to the NRC review (Reference 2) of NTD-NRC-96-4763, the report was incorporated into WCAP-14407 (Reference 3) as Section 9. Throughout the responses, section number references (i.e., Section 9) refer to the section in WCAP-14407. In addition, Appendices A, B, and C refer to new appendices which will be added to Section 9 in WCAP-14407 in response to NRC requests for additional detail. Also note that the Figure numbers given in the responses are those from WCAP-14407.

Page 9 General Comment

In general, Section 9 will be revised in the following way to respond to NRC review comments:

Appendices A, B, and C will be added to Section 9 of WCAP-14407. Appendix A will provide a description of the CMT calculations performed.

Appendix B will provide a description of the effects of stratification on heat sink utilization within a volume.

Appendix C will provide a summary of test data available from which to judge acceptability of the circulation predicted by lumped parameter modeling.

Additional information will be added to figures for clarification.

Section 9 sensitivity cases will be rerun using the evaluation model in Section 4 Revision 1.

More references will be added to the text to support the observations and conclusions, as discussed below for specific questions.

S #67 The axial gradient in the bulk of the CMT room is not indicated on Figure 9-5. Appendix A will show the basis for the mixing time constant. Circulation rates and the resultant small mixing time constant support the statement that a small axial gradient is expected. Reference to Appendix A will be added to the text in Section 9.3.1.3. A jet cannot pass into the CMT room undissipated as discussed in the response to #68. A buoyant plume will rise from the CMT room drawing flow in from above and through the steam generator (SG) compartment. Therefore, Figure 9-5 is valid for all LOCA post-blowdown phases.

T #68 A jet cannot pass directly from the cold leg piping through the CMT room due to the physical layout. Assuming the source goes entirely into the CMT room is one of the extreme cases examined. To enter the CMT room, the source comes in from the steam generator (SG) into the vertical access tunnel (stairwell), then into the CMT room. Given the equipment/structures in the vertical access tunnel and the CMT room, and the location of the CMT room ceiling openings, there is no credible path for a jet to go from the cold leg piping through the CMT room undissipated. A

sketch will be provided to support this. Therefore, the source will be dissipated as it moves to the CMT room and will rise as a plume up to the CMT room ceiling. Therefore, the general pattern shown in Figure 9-5 is valid for all post-blowdown phases. This discussion will be included in Appendix A.

S #69 Appendix B will provide the methods used for the hand calculation to assess stratification effects on integrated heat removal.

T #70 The subdivision of the CMT into three equal sections is a realistic approach based on the physical layout of the CMT room. The floor and the ceiling define two regions, and the grating and associated structural steel at the mid-plane of the room define the third region. This discussion will be included in Appendix B.

S #71 The outer surfaces of the floor and ceiling were mode... as an adiabatic boundary condition. The thermal boundary conditions used in the calculations were the lumped parameter CMT room steam concentrations (Figure 9-6) from a typical evaluation model calculation.

#72 later

S #73 a. The conclusions drawn from Figure 9-8 are not used to justify the volume being well mixed. The CMT room calculation shows that the mixing time constant is small so steam density gradients are not expected to be large. The steam stratification calculation shows that an extreme assumed gradient does not significantly affect the total integrated heat removal in the CMT room relative to the average steam concentration. Therefore, the lumped parameter model is reasonable to use. The figure also shows that stratification has a weak effect by the time of maximum containment pressure because the CMT heat sinks have reached thermal saturation. Although the results show that the benefit of enriched steam at the top is offset by the penalty of enriched non-condensibles at the bottom, a conservative approach is taken by neglecting upward facing surfaces. Thus, the evaluation model uses the lumped parameter model in a conservative way to bound potential penalties on floor heat transfer due to concentration of non-condensibles.

b. Table 9-1 will taken to the next level of detail to show the break scenarios evaluated.

S #74 During the blowdown, the high break mass flow pressurizes the SG compartment and flow exits based on the relative loss coefficients. Such pressure-driven flows are well represented by the lumped parameter node-network formulation. The first paragraph in Section 9.3.2 will be revised to more clearly describe the evaluation model with respect to the blowdown phase. During the blowdown phase, the high velocity jets exiting the openings of the SG compartment provide excellent circulation so it is reasonable to assume that the individual volumes are well mixed. A lumped parameter node is well suited for a well mixed volume.

S #75 Containment pressure can be well predicted by lumped parameter modeling for buoyancy dominated flows from breaks in lower containment regions, where

distributions within rooms are small. This is based on comparisons of lumped parameter predictions to HDR. The relevant conclusions from publicly available HDR code validation will be described in Appendix C.

T #76 An attempt was being made to distinguish between flows driven by high static pressure due to high mass flow rates, such as the SG compartment during blowdown, and flows within a room driven by local momentum effects, such as jet and wall entrainment. The paragraph will be clarified.

S #77 Based on the circulation rates present in AP600, gradients would be small within compartments and within the above-deck region during post-blowdown LOCAs. One may conclude that stratification is a second order effect which may be superimposed on a lumped parameter circulation calculation. Therefore, a reasonable solution can be based on an initial assumption of uniform properties within compartments, and the perturbation of stratification within a compartment can be studied separately.

S #78 All phases of the LOCA event are covered in Section 9.3.2 and its subsections. Section 9.3.2 will be revised to clarify which LOCA phase is being addressed throughout the discussion.

S #79 The distribution of volumes and heat sinks is provided in WCAP-14812 (Reference 4). It should be noted that only a small fraction of the volume exists below the break initially, and the lower compartments fill as primary water exits the break. Table 3-1 of WCAP-14812 will be added to Section 9. In addition, the relative elevation of the break source will be added to Figure 9-2, and the initial volume existing below the break elevation will be added to the text along with the volume fill height as a function of time.

S #80 The node-network solution is the WGOTHIC AP600 evaluation model described in Section 4. The sensitivity cases of Section 9 will be performed using the base model in Section 4, Revision 1, because of the potential for an effect of changing flow paths on predicted circulation.

S #81 The comparison shows that, for the LOCA blowdown phase, the details of the flow connections for the multi-node evaluation model are not important with respect to the pressure results. This is consistent with scaling results which show the volume compliance is the dominant pressure mitigator during blowdown. Clarification will be added to this paragraph in Section 9.3.2.1.

S #82 The evaluation model uses clime free convection correlations for the inner containment surface as described in Section 4.4.1 and 4.4.2 for wet stacks and dry stacks, respectively (note the first conductor inner surface forced convection heat transfer multiplier of $10^{-10}$). The evaluation model uses the Uchida correlation on internal heat sinks as described in Section 4.2.x.3 for each volume.

S #83 The heat sinks were eliminated entirely from the model.

Responses to NRC Questions on Section 9 of the WCAP-14407

S #84 a. "blowdown" will be revised to "blowdown pressure history".

b. The major conclusions of Section 9.3.2.1 are directed towards showing the relative insensitivity of the pressure results to the flow paths and heat sinks during blowdown. This section is redundant with Section 8, and the text will be revised to clarify conclusions which can be drawn from Section 8 relative to Section 9. Section 8 sensitivities will be run using the Section 4, Revision 1 evaluation model as a basis for consistency.

S #85 A new figure will be added to Section 9.3.1.1 which shows SG compartment and adjacent compartment pressures and containment pressure versus time.

S #86 a. The last sentence in Section 9.3.2.1 will be revised to "Thus, uncertainties in heat and mass transfer or stratification, and flow path effects, do not significantly impact the AP600 LOCA blowdown pressure history and the evaluation model adequately models the LOCA blowdown phase."

b. A sensitivity to the resistance at the SG exits will be provided to show the effects of different end-of-blowdown distributions on the pressure history during subsequent time phases. Since internal heat sinks saturate well before the maximum pressure, the effects of the post blowdown distributions are expected to be negligible. Figure 9-13 will be revised to be similar to WCAP-14845 Figure 10-4 to more clearly illustrate the effects.

T #87 For the effects of stratification on heat sink utilization, the most significant compartments (heat sinks) are the above-deck region (containment shell) and the CMT room (steel and jacketed concrete). A sentence to this effect will be added to the paragraph discussing stratification in Section 9.3.2.1. A summary of the compartment features is provided in Table 3-1 of WCAP-14812 (Reference 4) and will be added to Section 9. The relative locations of circulating compartments to a LOCA with the jet dissipated in the steam generator compartment will be shown in Figure 9-2.

T #88 Eliminating heat sinks from consideration produces a conservatively high pressure response since the heat sinks remove mass from the atmosphere by condensation. The maximum fill height inside containment is the 107' elevation. This corresponds to the bottom of the CMT room. The evaluation model includes the effects of containment filling in nodes which receive water and accounts for submerging walls.

S #89 See the response to #72 which addresses the first part of this question. The CMT room circulation calculations were performed at the time of maximum containment pressure as stated in Section 9.3.1.3. Similar circulation calculations will be included in Appendix A to address the different phases of the LOCA. Section 9.3.2.2 will be revised to summarize the CMT calculations presented in Appendix B.

S #90 As stated in Section 9.3.1.3, the CMT calculations were performed for a time near maximum containment pressure. Related to questions #68 and #89, the CMT

calculations will be included in Appendix A. The text in Section 9.3.1.3 will be revised to summarize and refer to Appendix A for CMT results for each of the post blowdown LOCA phases.

#91 later

S #92 Figure 9-14 shows the steam concentration distributions for the time covering the three phases of the transient. Figure 9-14 is being revised as noted in response to question #94 and #100.

C #93 Discuss at meeting with NRC.

S #94 Figures 9-9 and 9-14 will be updated with the Section 4 Revision 1 evaluation model results and clarified to address the question.

T #95 a. A single node model does not allow for the evaluation of the effects of circulation for a LOCA, or evaluation of the effects of different main steam line break elevations. Therefore, the evaluation model is based on a multi-node network.

b. A summary of experimental data used to determine that a buoyant plume will rise from the break compartment will be provided in Appendix C. It should be noted that the lumped parameter model is not being used to predict a particular realistic scenario on a best estimate basis. Rather, the lumped parameter model is used to perform sensitivities to various circulation patterns (and thus, time-wise development of steam concentrations) for the extreme cases of complete dissipation of momentum. The lumped parameter formulation is consistent with dissipated momentum.

S #96 The title for Figure 9-15 will be revised to indicate that the steam pressure ratios are at 24 hrs. Note that this figure will also be revised in response to question #100.

T #97 The predicted steam concentrations for various representative compartments are shown in Figures 9-9 and 9-14. The focus of 9.3.2.3 is on determining the steam concentrations at 24 hours. The trend towards increased mixing over time in the lumped parameter model leads to a very small density gradient between above-deck and the CMT room at 24 hours. This will be clarified in the text in Section 9.3.2.3.

S #98 The well mixed result is a steam concentration calculation where the same steam/air content from the evaluation model is used to calculate the steam concentration if it were well mixed. The CMT room and above-deck steam concentrations are from the evaluation model which has the penalties on upward facing floors and dead ended compartments. The text will be clarified.

S #99 Refer to the responses to questions #79 and #87.

T #100 a. The evaluation model has a multi-node model of the above-deck region to better

Responses to NRC Questions on Section 9 of the WCAP-14407

allow the code to (steam concentrations in) predict reasonable circulation patterns. There is a predicted deviation between nodes at the operating deck level and dome apex. Figures 9-9 and 9-14 will be revised to more clearly indicate the nodes plotted. The long term results are clearly conservative for the extreme case of well mixed due to the dominance of the PCS surfaces. The evaluation model noding is presented in Section 4. As shown in Section 4, there are 7 horizontal planes between the operating deck and the dome apex. Appendix B will provide the assessment of stratification effects currently contained in Section 9.3.1.3, extended to more clearly address potential stratification in the above-deck region, using similar methods.

T #101 Figures 9-16, 9-18, and 9-20 will be extended to 24 hours. Long term results are conservatively biased with increased mixing. Evaluation of the effects of increased mixing at 24 hours, relative to the evaluation model, is given in Section 9.3.2.3.

S #102 A single node model for the long term phase is not being used. Figures 9-16, 9-18, and 9-20 are from the results of the evaluation model described in Section 4 and the plots will be expanded to 24 hours as discussed in the response to #101.

T Figures 17, 19, and 21

Figures 9-17, 9-19, and 9-21 are snapshots at the time near maximum containment pressure. Figure 9-17 showed flow patterns and steam concentrations for a LOCA with the break momentum dissipated in the broken loop steam generator cavity. This sensitivity case resulted in the highest containment pressure, so additional figures will be added to show how the flow patterns and steam concentrations evolve for three representative times during the event.

Figures 9-17, 9-19, and 9-21 will be revised to show:

a. The location of the break
b. The time of the snapshot
c. A description of the time of the snapshot in the figure title.

The above-deck regions in the figures are simplified representations of the multi-node above-deck model. The evaluation model with the noding described in Section 4 was used. The sketched region representing the above deck region will be revised to more clearly show this.

S #103 Evolution of the flow patterns at various times during the LOCA will be added as discussed in the response to "Figures 17, 19, and 21."

S #104 See the response to question #103.

S #105 The time on Figures 17, 19, and 21 corresponds to the time near maximum containment pressure. Evolution of the flow patterns at various times during the LOCA will be added as discussed in the response to question #103.

T #106 Section 9.3.1.2 showed that the extreme case of an undissipated jet is not limiting.

The lumped parameter model is used to study the hypothetical extreme cases of all momentum dissipated, for which the lumped parameter model is a reasonable tool. Because of plume and wall entrainment rates, which will be discussed in Appendix A for the CMT room and Appendix C for the above-deck region, the axial steam density gradients within the above-deck region and CMT compartment are shallow. After incorporating stratification penalties discussed in Section 9.3.2.4, it is reasonable to use the lumped parameter model to perform sensitivities. Such reasonableness is judged based on comparing expected circulation patterns to those predicted by the model shown in Figures 9-17, 9-19, and 9-21 (see also the response to #107). The results discussed in Section 9 show that a wide range of possible circulation patterns and resulting evolution of steam distributions with time were examined to select the limiting scenario. This discussion will be added to the beginning of section 9.3.2.4 to clarify its purpose.

T #107 The lumped parameter evaluation model over-mixed between adjacent open volume nodes where entrainment dominates, due to numerical diffusion. As discussed in RAI 480.390, which relates to specific test data, the multi-node lumped parameter model over-predicts the amount of mixing between the LST below deck and above-deck regions. This is seen by comparing the slow, long-duration pressure rise predicted by the multi-node lumped parameter model to the observed longer term pressure rise in the test. In other words, the LST shows a continual gradual pressure increase due to longer term non-condensible mixing, and the lumped parameter shows the longer term increase but at a higher rate. It is believed that the lumped parameter rate of pressure increase is due to numerical diffusion, based on the better agreement when the distributed parameter model is used with its higher noding resolution. The time frame for the pressure increase is on the order of hours (both observed and predicted). The segregation between above-deck and below deck concentrations is much less for AP600 due to the presence of flow paths for circulation into the steam generator compartment, so the effect of over-mixing on non-condensible distributions should be less for AP600. (The effect of over-mixing on predicted velocities is eliminated by the use of free convection correlations internal to containment.) Thus, it is concluded that the multi-node lumped parameter model is a reasonable tool to examine circulation and concentration sensitivity to assumed circulation patterns for low momentum (low Fr number) scenarios through the time of maximum pressure at about 20 minutes.

The longer term (through 24 hours and beyond) prediction of the multi-node lumped parameter model tends toward a homogeneous condition as evaluated and discussed in Section 9.3.2.3.

S #108 The case in which the buoyant plume is placed in the CMT room is one extreme case of the sensitivity cases examined with the node network (lumped parameter evaluation) model. As described in Sections 9.3.1.3 and 9.3.2.4, another sensitivity case examined jet dissipation in the vertical access tunnel and the plume is predicted to split between the CMT room and the unaffected SG compartment according to the relative losses in the evaluation model. Note that the node network connections are the same for all of the sensitivities performed. Due to the potential concern raised for flow connections to affect the circulation results in previous

questions, the sensitivities in Section 9 will be rerun using the Section 4 Revision 1 evaluation model.

T #109 The small sensitivity is physically based, and can be expected because the sensitivities show that circulation affects the rate at which the internal heat sinks saturate, but they saturate well before the time of maximum pressure (WCAP-14845, Figure 10-4, Reference 8). Therefore, it is shown that even a rather wide range of transient steam concentrations in the CMT room (Figures 9-17, 9-19, and 9-21) do not have a significant impact on the calculated maximum pressure. Thus, the results are not sensitive to circulation pattern, and the most limiting case has been selected.

S #110 As stated in the response to #108, the flow resistance coefficients were the same for all vents for all three scenarios, and the values are specified in Section 4.

S #111 In the context of Section 9.2.2, a low Fr number is defined as one in which buoyancy dominates and a high Fr is defined as one in which the kinetic energy of the source dominates. The AP600 containment is buoyancy dominated during post-blowdown LOCA, and kinetic energy dominated during LOCA blowdown and MSLB. As discussed in Section 9.2.2, the LST configuration is represented in both buoyancy and kinetic energy dominated situations. The AP600 does not have a significant time frame during which intermediate Fr occurs (WCAP-14845, Section 6.5.2); therefore, the transition from buoyancy to kinetic energy dominated flows has not been specifically studied.

S #112 Mixing as a function of Fr is used to qualitatively assess stratification gradients and to ascertain the relation of LST internal mass transfer data to AP600. No functional relationship between mixing and Fr is required for this approach.

T #113 Experimental data has been discussed in Section 9.2.2. The large scale test (LST) results discussed in Section 9.2.2 and Section 6.5.2 of WCAP-14845 show the density gradient for the above-deck region and between the above-deck and below-deck regions. The LST results indicate some degree of kinetic energy driven circulation below the operating deck grating would occur in the AP600 design for the high Froude number of a main steam line break. This circulation would be difficult to quantify, so no credit is taken for it. A bounding lumped parameter model was used which dissipates kinetic energy in the above-deck nodes and minimizes the predicted ingress of steam into the below deck region as discussed in Section 9.4.2 and shown in Figure 9-25 for the MSLB evaluation model..

S #114 Based on the LST results in Section 9.2.2, kinetic energy is sufficient to drive circulation in the regions below the break and even below the operating deck for a break at the top of the steam generator. See also the response to #103.

S #115 Circulation figures for two additional times during the MSLB transient, which include steam concentrations, will be added.

S #116 It is reasonable to expect that, for the MSLB where internal heat sinks dominate

pressure mitigation, a break in the CMT room which contains the majority of internal heat sinks (WCAP-14812, Table 3-1) would be less limiting than a MSLB in the above-deck region. This was confirmed by calculation as described in Section 9.4.1.2.

S #117 The LST WGOTHIC model was used to gain insight on the noding structure's effects on steam mixing. The evaluation of steam concentration biases in Section 9.4.2 is based on an examination of what the model predicted, recognizing that the lumped parameter model inherently cannot predict kinetic energy effects. Therefore, the objective is to compare MSLB lumped parameter results to each other for cases with various assumed break elevations. The resulting conservative predicted stratification between above- and below-deck is shown in Figure 9-25. Due to the lack of a simulated steam generator flow path in the LST model, Westinghouse will replace the LST model studies in Section 9.4.2 with equivalent studies using the more appropriate AP600 evaluation model.

S #118 The lumped parameter model dissipates momentum in a node. Therefore, buoyancy is the only driving force, and buoyancy promotes upward flow of the steam. The dissipation of momentum in a node, therefore, does not promote over-mixing in a downward direction.

S #119 As discussed in the response to question #117, the study in Section 9.4.2 will be replaced with an equivalent study using the AP600 evaluation model.

S Figure 23
Figure 9-23 is not clear. However, as discussed in response to #117, an equivalent study based on the evaluation model will be performed and the text and figures will be clarified.

S #120 The evaluation model, described in Section 4, will be used to rerun the sensitivity study in Section 9.4.2 (see response to question # 117). The locations for the steam concentrations plotted will be provided.

S #121 The text will be clarified relative to the assumed break location.

T #122 Mixing is not a phenomena itself, but is a qualitative term. Westinghouse is revising Section 9 to more clearly focus on circulation and stratification as they affect steam concentrations and resulting mass transfer. Appendix C will be provided giving a summary of test data available from which to judge acceptability of the circulation predicted by lumped parameter modeling.

T #123 The multi-node lumped parameter evaluation model introduces biases in two regions: the multiple-node above-deck region and the one-node-per-compartment below deck region. The biases due to use of lumped parameter can be summarized as follows:

<u>Above-deck region lumped parameter biases</u>

Responses to NRC Questions on Section 9 of the WCAP-14407

Jet/plume entrainment is over-predicted, leading to under-prediction of the axial steam gradient and over-prediction of velocities.

Because of the short-time constant for circulation and large volumetric entrainment rates in the above-deck region, the bias on concentration gradient is not large. However, an extreme gradient, well beyond what would be expected based on LST results has been studied and has shown a weak sensitivity of total heat removal to the assumed gradient.

The lumped parameter velocity bias is eliminated by the use of free convection heat and mass transfer on all internal surfaces.

Below deck compartment region

Each compartment below deck is modeled with a single homogeneous fluid node. This represents a bias relative to axial concentration gradients which may exist in a compartment. When the plume is assumed to enter the CMT room, which has the largest group of heat sinks in the below deck region, the CMT room has been shown to have a short time constant for circulation due to high volumetric flows entrained into the plume so that the CMT room stratification gradients are shallow. Thus, the gradients within the CMT room deviate from well mixed by a small amount. An extreme case of stratification was studied for the effects on heat sink utilization, as discussed in Section 9.3.1.3, and the CMT room heat sink utilization was relatively insensitive to the two stratification scenarios.

Upward-facing floors

Although not related to the use of lumped parameter, a bias in the evaluation model exists relative to the liquid film thickness on upward facing floors that do not accumulate deep pools (surfaces that are designed to drain to lower elevations). As discussed in Section 9.3.2 and WCAP-14812, Section 4.4.3C, horizontal surfaces facing up may build up films thick enough to degrade heat transfer into the solid surface. Therefore, a bias has been introduced into the evaluation model by modeling upward facing surfaces as insulated to conservatively bound this effect.

Other DBA model biases

The DBA lumped parameter model contains additional biases due to input values specifically targeted to bound the significant uncertainties. These input biases are described or examined in WCAP-14407, Tables 4-102, 4-103, 4-104, 4-105, 4-106, 4-107, 4-108, 5-1, 10-1, 14-1, 14-2, 14-3, 14-4, and 14-5, and Section 7.4.2.

5 #124 By demonstrating that the model predicts less steam circulation below the break location than would be expected, the model is conservatively limiting the access of steam to internal heat sinks located below the operating deck. This results in a conservative containment pressure for the transient which bounds the effects of

stratification. As discussed in the response to question #117, the LST studies will be replaced by more appropriate studies using the evaluation model.

#125 The conclusion is based on the steam concentrations in the above-deck nodes, as predicted by the model, being nearly uniform as compared to LST data (Figure 9-1) which shows mixing below the operating deck. This will be addressed more clearly in the revision described in the response to question #117.

#126 The elevation of the evaluation model assumed break node will be added to the text and the node will be identified relative to the model described in Section 4. The results of the evaluation model study will show that predicted mixing occurs throughout the AP600 above-deck region based on Froude number comparisons, but limits access of steam below-deck.

#127 The LST results show that the above-deck region and regions below-deck are well mixed for a MSLB. Placing the break at the node above the operating deck in the evaluation model bounds the physics of the AP600 design. This break location provides conservative results as compared to the LST data which shows mixing below the deck. Locating the break at a higher elevation in the model would increase the maximum predicted containment pressure, however, the data shows that the operating deck location sufficiently bounds the circulation and stratification expected for a high kinetic energy break.

#128 Refer to the responses to questions #117 and #118. The phrase "conservatively limits steam access" will be revised to state that the noding structure conservatively reduces steam access to the below deck heat sinks by dissipating momentum which reduces the circulation to nodes below the break.

#129 All upward facing surfaces, including the operating deck are neglected. When applicable for a given node, this is discussed in the "Special Modeling Assumptions" subsections in Section 4 for each compartment. See also the response to #91.

#130 For Figure 9-25, the figure title will be corrected and the 4 curves will be identified.

#131 The MSLB evaluation model differs from the LOCA model, described in Section 4, only in the mass and energy boundary conditions and the assumed break location node.

#132 a. Refer to the response to question #126.

b. Refer to the response for question #127 for a discussion on the selection of the assumed break location in the evaluation model.

#A1 We concur that the LST does not cover the blowdown phase of a LOCA. Section 9.2.19 will be revised to clarify which LOCA phases are relevant to the LST.

#A2 The last sentence in Section 9.2.2 will be revised to "The high degree of mixing for test 222.4 compared to test 222.2 is due to the high kinetic energy of the injected

fluid because that is the only significant difference between the two tests."

S #A3 Appendix C will be added to Section 9 to summarize applicable conclusions from the HDR studies.

S #A4 Section 9.2.1 will be revised to refer to Section 6.5.3 of WCAP-14845, and the specific LOCA tests will be listed in Section 9.2.1.

S #A5 The text in Section 9.3.1.2 has already been corrected from 4% to 8%. The text will be clarified as follows: "From the point of view of pressure mitigation, Section 8.5 of WCAP-14845 shows that volume compliance is the most significant factor during blowdown. Figure 9-11 shows that, during blowdown, the internal heat sinks absorb only 8% of the total integrated break energy released during the first 3000 seconds of the transient."

S #A6 Three references will be added to the text in Section 9.3.1.3. They are References 5, 6, and 7 at the end of these responses.

S #A7 Refer to the response to question #70.

S #A8 Refer to the response to question #83.

S #A9 Yes, the evaluation model uses the Uchida correlation which has been shown to be conservative by approximately a factor of 2 or more. The last sentence in Section 9.3.2.1 will be revised as follows: "Thus, uncertainties in heat and mass transfer or stratification and flow path effects do not significantly impact the AP600 LOCA blowdown pressure history."

S #A10 Refer to the response to question #121.

S #A11 The sentence referred to in Section 9.4.2 will be reworded as suggested for clarification.

<u>References</u>

1. NSD-NRC-96-4763, Docket No.: STN-52-003, July 1, 1996,"Assessment of Mixing and Stratification Effects on AP600 Containment."

2. NRC informal review questions - Part 1 from D. Jackson (NRC) to J. Butler (Westinghouse), 8-22-96; Part 2 from D. Jackson (NRC) to J. Butler (Westinghouse), 11-8-96.

3. WCAP-14407, "WGOTHIC Application to AP600," September 1996.

4. WCAP-14812, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System," December 1996.

5. Jaluria, Y. "Buoyancy Driven Wall Flows in Enclosure Fires," Twenty-first Symposium (International) on Combustion, The Combustion Institute, 151-157 (1986).

6. Goldman, D., Jaluria, Y., "Effect of Opposing buoyancy on the Flow in Free and Wall Jets," Journal of Fluid Mechanics, 166, 41-56 (1986).

7. Jaluria, Y., Cooper, L.Y., "Negatively Buoyant Wall Flows Generated in Enclosure Fires," Progress in Energy and Combustion Science, 15, 159-182 (1989).

8. WCAP-14845, "Scaling Analysis for AP600 Containment Pressure During Design Basis Accidents," February 1997.

March 21, 1997

Subject: Informal Transmittal of Information on
- WCAP-14407 Ch 9 questions 1 - 66, 72, and 91

To: Ed Throm Fax: 301-415-3577 (9 pages)

cc: Jim Gresham Dick Haessler
Brian McIntyre Tim Andreychek

Attached are proposed approaches to respond to the subject NRC review questions. The ones marked with a "T" are those which Westinghouse recommends to have technical discussions during the 3/25/97 PCS DBA meeting.

It should be noted that WCAP-14407 Section 4, WCAP-14812, and WCAP-14845 have been issued subsequent to the issuance of NRC review comments on the preliminary draft Section 9. The attached responses assume the reviewers have access to all three WCAPs at this time.

Joel Woodcock

prelim.wp

C = Clarification at meeting w/NRC
S = Straight forward response
T = Technical discussion @ meeting w/NRC

# Responses to NRC Questions on Section 9 of WCAP-14407

Several preliminary reports on AP600 mixing and stratification effects have been issued. The knowledge base was consolidated into NTD-NRC-96-4763 (Reference 1) which was reviewed by the NRC. Subsequent to the NRC review (Reference 2) of NTD-NRC-96-4763, the report was incorporated into WCAP-14407 (Reference 3) as Section 9. Throughout the responses, section number references (i.e., Section 9) refer to the section in WCAP-14407. In addition, Appendices A, B, and C refer to new appendices which will be added to Section 9 in WCAP-14407 in response to NRC requests for additional detail. Also note that the Figure numbers given in the responses are those from WCAP-14407.

In general, Section 9 will be revised in the following way to respond to NRC review comments:

- Appendices A, B, and C will be added to Section 9 of WCAP-14407. Appendix A will provide a description of the CMT calculations performed.
- Appendix B will provide a description of the effects of stratification on heat sink utilization within a volume.
- Appendix C will provide a summary of test data available from which to judge acceptability of the circulation predicted by lumped parameter modeling.
- Additional information will be added to figures for clarification.
- Section 9 sensitivity cases will be rerun using the evaluation model in Section 4 Revision 1.
- More references will be added to the text to support the observations and conclusions, as discussed below for specific questions.
- Time phases will be made consistent with the final PIRT and Scaling time phases.

C #1, #2, #3

Discuss at meeting with NRC.

T #4

The mixing and stratification effects that must be bounded are mentioned in Section 9.1, paragraph 3 and will be summarized in Table 9-1. In summary, the pressure transient is potentially affected by parameters which influence the dominant heat removal mechanism, mass transfer. Mass transfer has as its primary parameters steam concentration, and, in the case of forced convection conditions, velocity. Large-scale circulation and entrainment into jets or plumes can drive mixing and can affect local values of steam concentration and velocity near heat transfer surfaces. Jet and plume entrainment and wall boundary layer entrainment within compartments or the above-deck region can also result in stratification, or the existence of a vertical steam concentration gradient. Therefore, an assessment of the effects of mixing and stratification should focus on how the steam concentration and velocity fields are affected by circulation and stratification. Since the evaluation model assumes only free convection inside the containment, the potential benefit of forced convection, when it exists, is neglected. Therefore, the assessment can be further focused on the potential effects of circulation and stratification on steam concentration distributions.

# Responses to NRC Questions on Section 9 of WCAP-14407

C #5, #6

Discuss at meeting with NRC.

S #7 (W) will update Table 9-1 to clarify the time phases.

S #8 Table 9-1 was intended to state that for open-ended compartments (e.g. compartments with multiple flow paths which have a circulation pattern) heat sink utilization is not sensitive to stratification. This is discussed in Section 9.3.1.3. Clarification will be provided to Table 9-1.

S #9 Sensitivity cases presented in Section 9.3.1.3 (last paragraph on page 16) and shown in Figures 9-6, 9-7, and 9-8 provide the justification for the utilization of heat sinks. The 3-region CMT stratification calculation considered the bottom one third to be exposed to the air rich concentration. Appendix B will contain information about this calculation.

S #10 "Well-mixed" is a conservative assumption when the PCS is the dominant heat removal mechanism. This is discussed in Section 9.3.2.3.

S #11 The applicability of WGOTHIC for long term containment modeling is discussed in Section 9.3.2 and in References 5 and 6 from Section 9.6.

S #12 Refer to the response to #4 for the definition of important physical quantities. The gradient referred to in Table 9-1 is the steam concentration gradient above- and below-deck for the WGOTHIC analysis. The effect of a bounding gradient or integrated heat sink energy removal is discussed in Section 9.3.2.3 and concluded to be insignificant. Also refer to the response to #106 for Section 9 clarification.

S #13 Qualitative discussions for the DECLG LOCA indicate that the high kinetic energy jet case is non-limiting. A qualitative discussion of the three LOCA break scenarios is provided in Section 9.3.1. A relatively low energy break would result in higher peak containment pressures since the induced circulation patterns would result in reduced utilization in the internal heat sinks.

S #14 Table 9-1 will include break positions and locations considered in the subsequent sections.

S Pg. 2: Section 1.1 Definitions

Additional text will be added to the mixing definition noting that diffusion also contributes to mixing under stratified conditions. Also, the text in the third paragraph in Section 9.1 will be updated to clarify the intent of the statement.

S Pg. 2: Last Paragraph

The comment concerning stagnation in dead-ended compartments is noted. This is discussed in Section 9.3.2.2. The objective here is to define 'segregation' and give a simplified example of how segregation occurs.

C #15, #16, #17

Responses to NRC Questions on Section 9 of WCAP-14407

Discuss at meeting with NRC.

S Pg. 3: Section 2.1 LOCA Configuration

(W) will provide reference to the Scaling Analysis report for the Froude numbers and will provide discussion noting that the LST does not cover the blowdown phase of the LOCA.

S #18 (W) will provide a brief discussion of the Froude number and provide a reference to the appropriate section of the Scaling Analysis report.

S #19 Section 10.0 of the Scaling Analysis Report provides Fr number data for the blowdown, transition, and post-blowdown phases for the LOCA transient. Reference to this section will be included.

C #20 Discuss at meeting with NRC.

S #21 The Fr-number range quoted covers the post-blowdown LOCA time phases. See the response to #18 above.

S #22 (W) will provide discussions of the LST methods with respect to LOCA modeling. Use of a diffuser is not intended to provide a "LOCA" model, but rather a known uniform velocity profile. This known quantity can then be used to draw test conclusions through the data reduction.

S #23 The post-blowdown portion of the transient is being addressed with Figure 9-1. See the response to #18 above.

S #24 Since there is no simulated flow path between the open and steam generator compartments in the LST, data for mixing down to the heel of the LST vessel cannot be used to draw conclusions directly for AP600. LST stratification data within the above-deck region has been used to estimate axial density gradients that may occur in the AP600 above-deck region. Based on scaling, the vertical steam density gradient in AP600 would be shallower than that in the LST for the same Froude number. The actual flow path into the AP600 steam generator compartment would allow large scale circulation which would reduce stratification gradients. However, because of the atypicality of the LST for assessing the influence of large scale mixing on stratification gradients, the evaluation model assessment conservatively considered a degree of stratification greater than that observed in the LST. The text in Section 9.2.1 will be revised to include the above discussion.

C #25, #26, #27, #28, #29, #30
Discuss at meeting with NRC.

S Pg. 3 and 4: MSLB Configuration

The test data is provided in Figure 9-1. All conclusions discussed in this section are derived from this figure. However, it is noted that Figure 9-1 is not specifically called out in this section. (W) will add a reference in the text to Figure 9-1 to clarify the discussion.

Responses to NRC Questions on Section 9 of WCAP-14407

S #31 Figure 3.3 of WCAP-14190 shows the steam volumetric flow rate as a function of time for the DECLG break, from which circulation times can be determined for any time of interest. This will be shown for the above-deck region in Appendix C.

S #32 The information in Appendix C will address the entrainment in the above-deck region.

C #33 Discuss at meeting with NRC.

S Pg. 5/6: Mixing and Stratification Assessment for LOCA

The text in this section was updated for the WGOTHIC Applications Report. Table 9-1 will also be edited for further clarification. These changes will provide a better picture of the three LOCA time phases and the actual times (from transient initiation) for each phase.

S #34 Time phases will be made consistent with the final PIRT and Scaling time phases.

S #35 a. Refer to the response to #79.

b. Reference to Section 4 will be provided which details the evaluation model volumes, flow paths, and heat sinks.

S Pg. 6 The CMT room plays an important part in the transient pressure mitigation for several reasons, all of which are discussed later in this report. The CMT room contains a much larger percentage of below deck heat sinks than the accumulator compartments for instance. Even though 40% of the steel and 60% of the concrete heat sinks are not in the CMT room, no other single below-deck compartment contains as many heat sinks. Also, the CMT room is the largest (volume) of the below deck compartments and contains many flow paths. These flow paths mean that the CMT room is of significant importance with respect to both above and below deck circulation patterns. Additional text will be added to this section to clarify the thought.

S #36 For the sensitivity studies in Section 9, modeling of the steel and concrete in the below deck compartments is based on Revision 8 of the General Arrangement Drawings. Text will be revised to clarify that the basis for the sensitivity studies is the evaluation model described in Section 4 Revision 1.

S #37 The CMT room heat sinks are primarily important during the transition phase of the LOCA transient, as are all of the below deck compartments. The time constant for the steel heat sinks is relatively short ( < 1200 seconds), while the concrete has a much longer time constant. Figure 9-13 presents heat sink utilization as a function of time, and shows the times which the steel and concrete heat sinks are most utilized.

S Pg. 6: LOCA Break Scenarios

(W) will update Table 9-1 to include information relevant to the three break location scenarios.

S #38 (W) will update Table 9-1 to include clarification of the time phases discussed, the relative importance of each phase, and the important parameters, phenomenon, and conclusions.

Responses to NRC Questions on Section 9 of WCAP-14407

S #39 (W) will provide more information in the section which supports the three jet scenarios discussed in Sections 9.3.1.1 through 9.3.1.3. Also refer to the response to #55.

S #40 The discussion related to whether the jet points upward through the SG compartment vs. outward through the stairwell is qualitative and considers bounding extremes. However, the calculated Froude number (Fr) from the LST data are useful in assessing the influence of high kinetic energy and break elevation, such as delineating between a high energy jet which rises out of the SG compartment relatively undissipated vs. a low energy jet which dissipates in the SG compartment. Section 10 of the Scaling Analysis report discusses the use of the Fr number for characterizing jet plumes in the LST and AP600 DBA models.

S #41 LST data relating to the three jet scenarios are discussed in Section 10.0 of the Scaling Analysis report.

S Fig. 4 displays . . .

The axes on Figure 9-4 will be corrected.

S #42 The code used for the mass flow rate is listed in Section 4, Table 4-107. The final LOCA mass and energy release model will be described in SAR Section 6.2.1.3.2.

S #43 Figure 9-4 is a conservative upper bound and will be revised to be consistent with Section 4 Revision 1.

S #44 Containment back pressure was accounted for by assuming the containment pressure was 45 psig (the design value). This assumption will be discussed in SAR Section 6.2.1.3.2.3.

S The scenario developed . . .

(W) will add more detail to the discussion of the locally dissipated jet and will refer to the WGOTHIC Evaluation Model description in Section 4 for specific room geometry. The estimated SG pressurization can be confirmed for the forced-flow blowdown by a simple nodal network solution.

S #45 Section 4 Figures 4-94, 4-95, 4-96, and 4-97 will be updated to more clearly show the liquid and steam portions of the transient. Post blowdown steam released from the break for this dissipated jet case is assumed to rise up through the SG compartment while the liquid falls.

S #46 The LST does not simulate an AP600 transient as discussed in WCAP-14845, Section 11. Rather, in the context of Section 9, the data is used to assess stratification within the above and below deck regions based on the appropriate scaling of the LST Fr numbers to the AP600. The applicability of specific test to LOCA post blowdown and MSLB are discussed more fully in Section 6.5 of WCAP-14845. References will be added to Section 9.2.

S #47 The CMT room flow calculation will be presented in Appendix A. In addition, WGOTHIC break sensitivities discussed in Section 9.3.2.4 and presented in Figures 9-17, -19, -21 show the calculated circulation rates associated with the CMT room. Reference will be

made to these evaluations.

C #48 Discuss at meeting with NRC.

S #49 The answer to this question is contained in Section 10 of the Scaling Analysis report. As a measure of stability, or lack thereof, the volumetric Fr number can be used to assess vertical density gradients. Fr numbers orders of magnitude greater than unity imply Reynolds number (or kinetic energy) dominated phenomena, while Fr numbers much less than unity imply the Reynolds number is not important for mixing in containment. WCAP-14845, Figure 6-2, shows that LOCA blowdown is sufficiently strong to break up any pre-existing stratification.

S #50 (W) will provide a clearer connection between the jet scenarios discussed in this report and the data in the Scaling Analysis Report. A high-energy jet would vigorously mix the above deck region (as well as the below deck region) because the jet is assumed to be undissipated at the exit of the SG compartment, thus it will entrain a large volume of the above deck atmosphere as it rises from the SG compartment exit. Additional information provided in response to comment #39 will further help to resolve this comment.

S #51 Section 10 of the Scaling Analysis Report forms the basis for considering the effects of mixing and stratification. Reference to this report will be added.

S #52 Section 10 of the Scaling Analysis Report provides the basis for this scenario, which is based on the volumetric Fr number. Reference to this report will be added.

S #53 Refer to the response to #39.

S #54 Refer to the response to #50.

S #55 The qualitative discussion concerning containment circulation patterns for various break scenarios are confirmed via break location sensitivity studies documented in Section 9.3.2.4. (W) will provide a summary of a simplistic jet-pump calculation representing the broken-loop SG compartment. This calculation will provide quantitative supporting evidence for below deck circulation associated with the jet-up scenario.

S #56 Section 9.3.2.4 and Figures 9-17, -19, -21 discuss and present the calculated circulation patterns for a spectrum of break scenarios at the time of peak containment pressure. Reference will be provided to this section of the report.

S #57 Section 9.3.2.4 will be updated to include circulation pattern data at significant transient times (i.e. end of blowdown, beginning of the long term cooling phase, for the base case transient).

T #58 Due to the extensive structure in the SG compartment which provides support for not only the Steam Generator, but also the hot and cold leg piping, the ADS piping, and maintenance manways it is highly doubtful that a double-ended guillotine break of one of the RCS cold leg pipes would result in the pipe deflecting in such a manner that break fluid would have an unobstructed pathway into the stairwell. However, the DBA is not a mechanistic model. Rather the DBA considers extreme circumstances in order to bound

the range of accident possibilities. Therefore, the jet into the stairwell scenario has been postulated as one of the extreme cases and is evaluated in this analysis.

S #59 Descriptions of the AP600 compartments and vent paths as modeled in the WGOTHIC evaluation model are provided in Section 4. Reference will be added.

S #60 Post-blowdown circulation patterns are given for all three break scenarios in Figures 9-17, -19, and -21. These figures not only identify the circulation flows, but also the steam concentrations in the major below deck volumes.

S #61 Refer to the response to #58.

S #62 (W) will provide an additional level of detail concerning these calculations in Appendix A.

S #63 The information necessary to calculate the mixing time constant is provided in Section 9.3.1.3, and is simply the CMT room volume divided by the entrainment flow rate in minutes. This number represent the time it takes to cycle the CMT room volume. Appendix A will contain information on the CMT room calculation.

S #64 A description of the AP600 compartments and vent paths as modeled in the WGOTHIC evaluation model is provided in Section 4. Reference will be added. In addition, Appendix A will contain information on the CMT room calculation.

S #65 Refer to the response to #62.

S #66 Refer to the response to #63

S #G1 through #G11
See the responses for general questions #A1 through #A11

T #72 WCAP-14236, Section 3.9, shows that the nominal PCS correlations provide a reasonable prediction of mass transfer for free convection, or low Froude (Fr), conditions over the whole range of steam concentrations, and Section 4.3 notes that the correlation is slightly conservative with a 0.983 mean. It is desirable to assess the AP600 physics using the best available correlation. It is not believed to be useful to perform this calculation using a correlation which may have a bias which varies over the steam concentration range when evaluating AP600 physics.

S #91 a. The evaluation model described in Section 4 was used for the results in Figure 9-13.

b. Yes, upward facing surfaces in all compartments have been insulated and condensation for dead-end compartment heat sinks during the post-blowdown phases is not included in the evaluation model. When applicable for a given node, this is discussed in the "Special Modeling Assumptions" subsections in Section 4 for each compartment. In the model, the condensation heat transfer is multiplied by zero, however, convective and radiant heat transfer is still calculated by the code. Figure 10-4 of WCAP-14845 shows that this is a negligible contributor to the overall heat transfer. A similar figure will replace Figure 9-13 based on the evaluation model of Section 4 Revision 1.

Responses to NRC Questions on Section 9 of WCAP-14407

References


1. NSD-NRC-96-4763, Docket No.: STN-52-003, July 1, 1996,"Assessment of Mixing and Stratification Effects on AP600 Containment."

2. NRC informal review questions - Part 1 from D. Jackson (NRC) to J. Butler (Westinghouse), 8-22-96; Part 2 from D. Jackson (NRC) to J. Butler (Westinghouse), 11-8-96.

3. WCAP-14407, "WGOTHIC Application to AP600," September 1996.

March 21, 1997

Subject: Informal Transmittal of Information on
- WCAP-14407 Ch 7 RAIs 480.871 - 480.909

To: Ed Throm Fax: 301-415-3577 (41 pages)

cc: Jim Gresham Dick Haessler
Brian McIntyre Tim Andreychek

Attached are proposed approaches to respond to the subject NRC review questions. The ones marked with a "T" are those which Westinghouse recommends to have technical discussions during the 3/25/97 PCS DBA meeting.

It should be noted that WCAP-14407 Section 4, WCAP-14812, and WCAP-14845 have been issued subsequent to the issuance of NRC review comments on the preliminary draft Section 9. The attached responses assume the reviewers have access to all three WCAPs at this time.

Joel Woodcock

prelim.wp

Attachment 4

# RAI Binning Code

C ⇒ Question not understood; clarification by NRC is requested

S ⇒ Straightforward response offered

T ⇒ Technical discussion with NRC requested

# 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 determined coverage. The range of the test data was compared with the estimated AP600 range during DBA. The test data was found to be acceptable for application to the development 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 of large measurement errors are also essential to judge the acceptability of test results.

S 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.

**RESPONSE:**

Two actions are taken in response to this item;

1) The identified text in the Executive Summary will be amended to more clearly state the basis for including data in the evaluation of water coverage.

2) The "goodness" of the test data for each test summarized in Subsection 7.2 is considered a test acceptance question and will be addressed in a separate letter to NRC. Response to this item will not be incorporated into a revision of Section 7.

# 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"

WCAP-14407 states: "A film stability model, based on 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 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 operation conditions.

T 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 operating 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 decontamination
- Surface roughness and plate misalignment
- Contact angle uncertainty (include aging)

**RESPONSE:**

Westinghouse has bounded test data which accounts for 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
- Plate misalignment

Coating degradation will be controlled under the AP600 inspection and maintenance program. Preliminary examination suggest wetting characteristics of the surface improve with aging. Westinghouse requests further clarification and discussion on this item.

# 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"

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.

**RESPONSE:**

S Westinghouse will include calculations in the amended Section 7.

# 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"

480.87 Please provide the mathematical definition of "evaporation-limited" PCS flow ate.

**RESPONS.:**

S

The mathematical definition of "evaporation-limited" PCS flow is;

$$\dot{m}_{APPLIED} = \dot{m}_{PCS\ ACTUA.} - \dot{m}_{PREDICTED\ RUNOFF}$$

This definition limits the applied PCS flow rate in the evaporation-limited model to be that which is predicted to be evaporated. Westinghouse will amend the text of Section 7 to include this definition statement

# 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"

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."

**RESPONSE:**

S

The last sentence in the last paragraph is incorrect. Westinghouse will correct the sentence in the amended Section 7.

# 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"

pg 7-1

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

**RESPONSE:**

S

The actual per cent of the energy removal is through evaporation varies over time with changes in the PCS flow rate and the decay heat generation rate. The 80% value is based on steady state large scale test observations. Westinghouse will clarify the text of the amended Section 7 to indicate the basis for the partioning of heat removed by the various modes of heat transport.

will include test number

# 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"

WCAP-14407 states in the second paragraph: "The rapid heating of the cold water as it spread 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.

T

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?

**RESPONSE:**

The water coverage fractions used in WCAP-14407 are based on a PCS flow of 220 gpm. The design calls for a PCS flow of 440 gpm. The larger AP600 PCS flow provides for larger water coverage fractions than reported in WCAP-14407. Westinghouse will add explanatory text to the amended Section 7 to note the increase in PCS flow, and therefore the water coverage fractions used in the analyses are bounded by those of the AP600 plant.

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"

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

**RESPONSE:**

1.) Westinghouse will rephrase and clarify the text in the amended Section 7.

2.) Breaking down the film is not a benefit.

# 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"

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

T 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.

**RESPONSE:**

Film thickness is not a measured quantity. Film coverage is measured. Knowing the applied flow and the film coverage, a film thickness is inferred.

No change to the text of Section 7 will be implemented in response to this RAI.

# 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"

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

**RESPONSE:**

T

From testing, it was observed that the film width decrease is approximately linear. The assumption of constant film flow rate, $\Gamma_{MIN}$, results in an exponential decrease in film width as the film evaporates. The assumption of constant $\Gamma_{MIN}$ does not match the test observations and, because it predicts less coverage than observed, is conservative. Westinghouse will incorporate a statement of explanation regarding the use of the exponentially decreasing film width to the amended Section 7.

# 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"

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.

**RESPONSE:**

T

The fabrication and erection of the AP600 containment shell will be accomplished to ASME code requirements. Inspections will be performed during the fabrication and erection process to assure code requirements are satisfied. The fabrication, erection and inspection of the containment shell to ASME code requirements will assure surface irregularities are within prescribed limits at the time of construction. Inspection and maintenance of coatings on the outside surface of the containment shell is addressed in the AP600 inspection and maintenance plan.

No change to the text of Section 7 will be implemented in response to this RAI.

# 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"

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?

**RESPONSE:**

T

Westinghouse will amend the text of Section 7 to include a response to the point of this RAI.

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"

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 were aged. For each test sample with an aged surface, estimate the simulated age of the surface in terms of service years.

**RESPONSE:**

T

This question is determined to be a test description/acceptance question. Westinghouse will respond to this question by separate letter. No revision to Section 7.0 is planned as a result of responding to this question.

# 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"

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 underpredict the amount of runoff. Please explain.

**RESPONSE:**

S

The film is uniform, wary laminar below the point of application. Westinghouse will clarify the description of the observed behavior of the water coverage near the point of application in the amended Section 7.

# 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"

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

**RESPONSE:**

S

Westinghouse will add the requested equations to the text for Table 7-1 in the amended Section 7.0.

# 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"

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?

**RESPONSE:**

S

Westinghouse will amend Table 7-1 to clarify the definition of "bottom" in the amended Section 7.

# 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"

T 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 between the springline with any accuracy.

**RESPONSE:**

T The water coverage fractions reported Section 7.4.2 were developed from videotape records of the 220 gpm equivalent flow Water Distribution Tests as follows;

| Location | Coverage | Method of Determining |
|---|---|---|
| ▸ Between the dome top and 1st weir | 25 % | Visual Inspection |
| ▸ 1st weir to 2nd weir | 65 % | Visual inspection and calculated using an averaged elliptical surface area |
| ▸ 2nd weir and below | 90 % | Measured |

Westinghouse will include an explanation of how the water coverage fractions are determined in the amended Section 7.

# 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"

T

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.

**RESPONSE:**

As noted in the response to RAI 480.877, the water coverage fractions used in WCAP-14407 are based on a PCS flow of 220 gpm. The design calls for a PCS flow of 440 gpm. The larger AP600 PCS flow provides for larger water coverage fractions than reported in WCAP-14407. It is believed that the increase in flow overwhelms the measurement error. Westinghouse will add explanatory text to the amended Section 7 to note the increase in PCS flow, and therefore the water coverage fractions used for the analyses are bounded by those that would exist for the AP600 plant.

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"

S

480.889 Table 7-4 lists the film inlet temperature for case 107A5U as 800° F. Should this be 80° F.

**RESPONSE**:

The film inlet temperature for case 107A5U listed in Table 7-4 is incorrectly listed as 800° F. The correct value of the inlet is 80° F. Table 7-4 will be amended to list the correct value in the amended Section 7.

## 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"

S

480.890 In discussing 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 had been performed to determine that the flow oscillations did not fundamentally alter the film stability and water coverage measurements?

**RESPONSE:**

An analysis of the maximum and minimum flow rates resulting from the oscillations is presented in Appendix A of Section 7. Observations and the analysis performed support the following conclusions;

- Water coverage was observed to have small changes at the bottom of the test article, and,
- Film stability was not affected.

These conclusions are stated in Appendix A of Section 7.

No change to the text of Section 7 will be implemented in response to this RAI.

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"

C

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.

**RESPONSE:**

The WGOTHIC code does not calculated water coverage area; rather, it calculates a point of dryout on a fixed area that is an input (clime node) to the code. The calculation uses heat flux as a function of elevation. Westinghouse will modify the text in the amended Section 7.0 to clarify how heat fluxes vary and are used in the calculations.

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"

S 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 Figures.

**RESPONSE:**

Data from the forced coverage tests were not used. Other forced coverage cases not included are 207.1, 207.3 and 208.1. This is stated on page 7-14.

No change to the text of Section 7 will be implemented in response to this RAI.

# 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"

S 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.

**RESPONSE:**

The current AP600 technical specifications identify a minimum PCS temperature of 40° F.

No change to the text of Section 7 will be implemented in response to this RAI.

# 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"

S 480.894 Please add the values for "Runoff Film Temperature," "Bottom Sidewall Film Flow Rate" and "Marangoni Number" to Table 7-6 for AP600.

**RESPONSE:**

Westinghouse will add estimates of the requested parameters to Table 7-6 in the amended Section 7.

## 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"

S

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 reason for the change.

**RESPONSE:**

No change in time to fill and reach steady-state flow conditions was intended by the usage of "about 10 minutes" instead of 11 minutes; they were taken to be similar times inferred from a video record of the test. Westinghouse will modify the text of the amended Section 7 to be consistent with terminology previously used.

# 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"

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

**RESPONSE:**

The purpose of the calculation was to estimate the time required to heat the exterior surface of the dry shell to the boiling point. Several approximations were made in performing the calculation, one was an average containment atmosphere temperature of 250° F over the time period of interest. Without integrating the area under the curve of Figure 7-4, the use of 250° F is judged to be a reasonable first approximation to the average containment temperature over the time period of interest.

Based on current mass and energy results, the calculation results shown in Figure 7-4 will be reviewed and recalculated, as appropriate, for inclusion in the amended Section 7.

# 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"

S 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.

**RESPONSE:**

The value of 75 Btu/hr-ft$^2$-°F for the post-LOCA internal atmosphere to PCS shell energy transfer coefficient is based on inspection of previous WGOTHIC calculations. Westinghouse will modify the text associated with identifying this value to note the origin of this approximation in the amended Section 7.

# 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"

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

S

480.898 In the formula for wetted perimeter, $r_{WETTED}$, on pg. 7-27 (or WDL on 7.A-12), the predicted circumference, $r_{SPLIT}$, 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 wetter perimeter.

**RESPONSE:**

The formula for wetter perimeter as given on pages 7-27 and 7.A-12 is incorrect. Westinghouse will correct the error in the amended Section 7. Westinghouse will also review and correct the calculations with regard to bounding the test data that may have been affected by this error.

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"

S

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.

**RESPONSE:**

This comment will be addressed in the amending of Section 7.0. The model and version of WGOTHIC used will be described; differences, if any, between the those used for Section 4.0 and Section 7.0 will be identified and the impact of those differences on calculated results evaluated.

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"

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.

**RESPONSE:**

Westinghouse will modify the text of the amended Section 7 to identify the mass and energy forcing functions used in the calculation reported in this section.

# 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"

S 480.901 The sensitivity calculation for water overage location varied the coverage are 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.

**RESPONSE:**

Westinghouse will perform the requested calculations and provide a summary of the results in the amended Section 7.

# 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"

T

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

**RESPONSE:**

The value of the minimum stable film flow rate, $\Gamma_{MIN}$, used in the calculation is a bounding value that minimizes the water coverage area. The use of larger values of $\Gamma_{MIN}$ only further bound (adds additional conservatism to an already conservative or bounding assumption. The use of small values of $\Gamma_{MIN}$ would increase the water coverage area and provide for increased heat removal and lower containment pressures.

Westinghouse will add text explaining the use of a bounding $\Gamma_{MIN}$ value that provides for a conservatively small water coverage area to the amendment of Section 7.

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"

pg 7-46:

S 480.903 Subsection 7.5.4 states that the base case assumed delay time is 600 seconds for a 220 gpm 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 of the PCS design flow, and correct the text accordingly.

**RESPONSE:**

The use of a delay of 600 seconds is conservative for the 440 gpm design flow rate. Westinghouse will clarify the text to state that this is conservative in the amendment to Section 7.

# 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"

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 one 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."

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

**RESPONSE:**

The Zuber-Staub model is used to bound the data collected for the AP600 surface.

No change to the text of Section 7 will be implemented in response to this RAI.

# 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"

pg 7.A-5:

T

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?

**RESPONSE:**

The Zuber-Staub model is used to bound the data for the AP600 surface.

No change to the text of Section 7 will be implemented in response to this RAI.

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"

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

**RESPONSE:**

The reference to Section A.6 on page 7.A-7, fourth paragraph, is incorrect. The correct reference should be to Section 7.A-6. Westinghouse will correct this typographical error in amending Section 7.

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"

pg. 7.A-8

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

**RESPONSE:**

In amending Section 7.0, Westinghouse will add to the discussion of Figure 7.A-1 a table identifying test number and conditions associated with the data plotted in Figure 7.A-1.

# 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"

pg. 7.A-9

T

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 the AP600. Please comment on how this figure supports the Westinghouse position.

**RESPONSE:**

In the amended Section 7, Westinghouse will do the following;

- Add a table listing the bounding values plotted in Figures 7.A-2 and 7.A-3
- Provide text describing how the data were obtained, and,
- Provide text describing how the figure supports the Westinghouse position.

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"

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?

**RESPONSE:**

1.) The equation used to define circumferential average heat flux is;

$$\bar{h}_{CIRCUMFERENCE} = \frac{\sum h_{WETTED,\, i}}{n}$$

where

$h_{WETTED,\, i}$ is the wetted surface heat flux at an elevation

$n$ is the number of wetted surfaces (stripes) at an elevation

Westinghouse will add this definition in the amended Section 7.

2.) Westinghouse has evaluated the uncertainty associated with this number and will provide a discussion in the amended Section 7.

3.) Westinghouse has not evaluated if there is a correlation between the local (instantaneous) exit Reynolds number and the local heat flux.