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Energy Systems

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DCP/NRC1003
NSD-NRC-97-5289
Docket No.: 52-003

August 22, 1997

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: T. R. QUAY

SUBJECT: AP600 RESPONSE TO REQUESTS FOR ADDITIONAL INFORMATION

Reference: 1. Westinghouse Letter DCP/NRC0973, "AP600 Response to Requests for Additional Information," dated August 5, 1997

Dear Mr. Quay:

Enclosed are the Westinghouse responses to NRC requests for additional information related to WCAP-14407, "WGOTHIC Application to AP600." Responses are provided for the items listed in the attached table. These RAI responses are the second group of RAIs related to information contained in WCAP-14407, Rev. 1, and include the RAI responses related to 2-D conduction which were scheduled to be completed on 8/31/97. The first group of RAI responses related to WCAP-14407, Revision 1 was sent to you via Reference 1.

These responses close, from the Westinghouse perspective, these items. The NRC should review these responses and inform Westinghouse of the status to be designated in the "NRC Status" column of the OITS.

Please contact Bruce Rarig on (412) 374-4358 if you have any questions concerning this submittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

E004/,

jml

Enclosure

cc: D. C. Scaletti, NRC (w/ Enclosure)
N. J. Liparulo, Westinghouse (w/o Enclosure)

Attachment to DCP/NRC1003

OITS Number	RAI Number	OITS Number	RAI Number	OITS Number	RAI Number	OITS Number	RAI Number	OITS Number	RAI Number
2881	480.388	4776	480.743	4868	480.826	4900	480.858	5479	480.1041
2882	480.389	4782	480.749	4869	480.827	4901	480.859	5551	480.1051
3415	480.408	4791	480.758	4870	480.828	4902	480.860	5552	480.1052
3416	480.409	4797	480.764	4871	480.829	4903	480.861	5553	480.1053
3417	480.410	4803	480.770	4872	480.830	4904	480.862	5554	480.1054
3418	480.411	4810	480.777	4873	480.831	4905	480.863	5555	480.1055
3420	480.413	4811	480.778	4874	480.832	4906	480.864	5556	480.1056
3421	480.414	4812	480.779	4875	480.833	4907	480.865	5557	480.1057
4008	480.494	4819	480.786	4876	480.834	4908	480.866	5558	480.1058
4528	480.596	4821	480.788	4877	480.835	4909	480.867	5559	480.1059
4529	480.597	4825	480.792	4878	480.836	4910	480.868	5560	480.1060
4530	480.598	4827	480.794	4879	480.837	4911	480.869	5561	480.1061
4531	480.599	4834	480.801	4880	480.838	4912	480.870	5562	480.1062
4532	480.600	4836	480.803	4881	480.839	4944	480.902	5563	480.1063
4534	480.601	4841	480.808	4882	480.840	5460	480.1022	5564	480.1064
4535	480.602	4842	480.809	4883	480.841	5462	480.1024	5565	480.1065
4536	480.603	4843	480.810	4884	480.842	5463	480.1025	5566	480.1066
4552	480.618	4844	480.811	4885	480.843	5464	480.1026	5567	480.1067
4567	480.633	4845	480.812	4886	480.844	5465	480.1027	5568	480.1068
4569	480.635	4846	480.813	4887	480.845	5466	480.1028	5569	480.1069
4570	480.636	4847	480.814	4888	480.846	5467	480.1029	5570	480.1070
4571	480.637	4848	480.815	4889	480.847	5468	480.1030	5571	480.1071
4572	480.638	4849	480.816	4890	480.848	5469	480.1031	5572	480.1072
4573	480.639	4850	480.817	4891	480.849	5470	480.1032	5573	480.1073
4589	480.655	4851	480.818	4892	480.850	5471	480.1033	5574	480.1074
4715	480.682	4854	480.819	4893	480.851	5472	480.1034	5575	480.1075
4718	480.685	4855	480.820	4894	480.852	5473	480.1035	5576	480.1076
4719	480.686	4856	480.821	4895	480.853	5474	480.1036	5577	480.1077
4720	480.687	4857	480.822	4896	480.854	5475	480.1037		
4737	480.704	4861	480.823	4897	480.855	5476	480.1038		
4752	480.719	4862	480.824	4898	480.856	5477	480.1039		
4758	480.725	4863	480.825	4899	480.857	5478	480.1040		

OITS: 2881
RAI: 480.388

In Ref. 480.388-1, it is indicated that the weathered surface exhibited marginally better wetting characteristics than the unweathered surface. If during the life of the plant, the shell exterior is returned to a pre-weathered condition, what is the impact of larger values of (30 to 58 degrees)? Quantify "marginally." Should the DBA evaluation model Rref include consideration of an unweathered surface to assure bounding analyses?

Response:

Reference 480.388-1 has been substantially revised and the basis for determining the stable film coverage area and evaporation rate is based entirely on the PCS test results presented in Reference 480.388-2. The model in question that used "Rref" and wetting angles, is no longer used.

References:

480.388-1 NTD-NRC-94-4286, "Supplemental Information on AP600 Film Flow Coverage Methodology," August 31, 1994.

480.388-2 WCAP-14407, Revision 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 2882
RAI: 480.389

Reference 480.389-1 provides the results of calculations with WGOTHIC to 13 LST tests (212.1A, -B, -C, 214.1A, -B, 216.1A, -B, 219.1A, -B, -C, 222.1, 222.4A , and -B) and the blind test, Test 220.1. For each test, provide a table similar to that requested above which includes the parameters used to determine the water coverage (q", T, , Rref, PCS flow rate, PCS water temperature, etc.). Data needs to be provided for each wetted area. At what time in the transient are these data selected and how is the data used to obtain the water coverage used for each test prediction. Were the water coverage data calculated before the tests were run based on the planned (expected) striping specified in the test matrix?

Response:

The water coverage that was input to the WGOTHIC model of the LST for the calculations presented in Reference 480.389-1, Section 8, used the measured water coverage for each test. The PCS film coverage model was not used. The only parameter used to determine the water coverage was the test identifier (212.1A, 212.1B, etc.). The measured coverage is the value reported in Reference 480.389-2, Section 4, that represents the fraction of the total circumference covered by water just above the gutter.

References

480.389-1 WCAP-14382, "WGOTHIC Code Description and Validation," May 1995.

480.389-2 F. E. Peters, WCAP-14135, Rev. 1, "Final Data Report for PCS Large-Scale Tests, Phase 2 and Phase 3," April 1997.

SSAR Revision: NONE

OITS: 3415
RAI: 480.408

Reference 3 in the attachment to NTD-NRC-95-4561, "Scaling Role in AP600 PCS DBA Analysis," dated September 19, 1995, indicates that R.W. Borchardt was the recipient of letter NTD-NRC-95-4545 from N.J. Liparulo. In actuality that letter was sent to T.R. Quay by B.A. McIntyre. Since the NRC document control system (DCS) can use recipient or author as a search parameter, this error should be corrected to facilitate location of letter NTD-NRC-95-4545 in the DCS.

Response:

The reference has been corrected, as documented in Westinghouse Letter DCP/NRC0408, Revision 1, dated 8/12/97.

SSAR Revision: NONE

OITS: 3416
RAI: 480.409

In the first paragraph of Section 1.0 in WCAP-14382, the description of the PCS implies a single annular region. At the end of Section 1.1, the baffle, riser and downcomer are mentioned. The Introduction needs to be written to better describe the PCS air-annulus region (downcomer, baffle and riser).

Response:

A general description of the annulus region is given in the first paragraph of the Introduction to WCAP-14382, and Section 1.1 provides a brief summary of the PIRT. WCAP-14382 is a report on the WGOTHIC code validation and does not provide details of the AP600 design. A more complete description of the annulus downcomer and riser is given in References 480.409-1 and 480.409-2.

References:

480.409-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.409-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 3417
RAI: 480.410

On page 2-2 of WCAP-14382, it is stated that changes were made to the pre-processor program to assist in model development, and that these changes were verified by hand. Provide a description of these changes. Are these changes only related to the new features added by Westinghouse to model, for example, the "climes" regions? Were changes made to simplify the setting up of the distributed parameter nodal models when the model is not representing a true rectangular, orthogonal geometry? Discuss the hand verification performed. How complex are the changes?

Response:

The changes made to the GOTHIC pre-processor program were related to the generation of the clime model input. No changes were made to the pre-processor to simplify the setting up of distributed parameter nodal models not representing a rectangular, orthogonal geometry.

The changes to the GOTHIC pre-processor program are a significant addition in that they simplify the input of parameters related to the clime model. The pre-processor program creates the input data file for the solver program. Prior to using WGOTHIC pre-processor version 2.0, the formatted clime model input was prepared by hand and then merged with the GOTHIC solver input file to create the WGOTHIC solver input file. In WGOTHIC pre-processor version 2.0, an additional menu item was added to the main menu. Selecting this item transfers the user to the menus related to the creation of the clime model input. This version of the WGOTHIC pre-processor allows for a more convenient tabular input format which streamlines and simplifies the user input. The user input entered through the clime pre-processor menus is saved in the pre-processor data file.

The GOTHIC solver input data file consists of several "groups" of data. The output from the clime pre-processor input menus is written to a separate group in the WGOTHIC solver input data file, group 24. The group 24 input calculations were performed by hand and compared with those calculated by the pre-processor to verify the coding in the clime pre-processor input menus.

SSAR Revision: NONE

OITS: 3418
RAI: 480.411

On page 2-2 of WCAP-14382, the inclusion of the wall-to-wall radiant heat transfer is identified as the core modification to GOTHIC. This new conductor is referred to as the "clime." What other changes have been made to GOTHIC (excluding corrections of known coding errors)?

Response:

The Westinghouse clime model is composed of a set of subroutines. These subroutines are used to: calculate the convective heat and mass transfer to/from the various clime conductor surfaces (including wall-to-wall radiant heat transfer), track the liquid films that form or are applied to the various clime conductor surfaces, and solve the one-dimensional wall conduction equation for the various clime conductors.

The Westinghouse clime model subroutines were added to the GOTHIC solver program to create the WGOTHIC solver program. In addition to including the arrays required for the clime model input/output variables, three changes were made to the GOTHIC solver code to incorporate the clime model subroutines:

- A call to the subroutine that reads the clime input was added
- A call to the main subroutine for the clime model, was added
- A call to the subroutine that generates the clime output was added

The clime model subroutines interface with the GOTHIC solver subroutines through the heat and mass source terms for the volumes that are connected to the clime conductors.

The modifications made to GOTHIC to create WGOTHIC are described in Section 3 of Reference 480.411-1.

Reference:

480.411-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 3420
RAI: 480.413

In the attachment to letter NTD-NRC-95-4596, dated November 13, 1995, a sensitivity analysis is provided for the deck flow area. Which DBA was used, what was the size and location of the break? In the figure, the run is identified as both GOTHIC Version W-gothic 2.1.1.1 and as W-GOTHIC 1.2.1.1. Are these the same code? Identify the changes that are included in the version used for this analysis as compared with the 1.2 version of W-GOTHIC. This figure is marked preliminary. Why?

Response:

The referenced letter has been superseded. Circulation and stratification within the containment during various events is addressed in Section 9 of reference 480.413-1.

A distributed parameter model of the AP600 containment was used with a typical DECLG LOCA boundary condition for the deck flow area sensitivity analysis presented in NTD-NRC-95-4596. The break was located in the lower east SG compartment. The distributed parameter model is no longer used for AP600 containment DBA analyses.

The deck flow area sensitivity analysis was performed using WGOTHIC solver program version 1.2.1.1. This version of the solver was created by increasing the size of certain array dimensions in the configured WGOTHIC version 1.2 solver program to allow it to load and run the distributed parameter model. The WGOTHIC pre-processor program version that was used to generate the plot was numbered 2.1.1.1. It was also created by increasing the size of certain array dimensions in the configured WGOTHIC version 2.0 pre-processor program to allow it to load and run the distributed parameter model. These versions have been superseded with the configured WGOTHIC (pre-processor, post-processor and solver programs) version 4.1.

The figure was marked preliminary because review of the input calculations had not been completed at the time the letter was issued.

References:

480.413-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 3421
RAI: 480.414

In the attachment to letter NTD-NRC-95-4595, dated November 13, 1995, a comparison analysis is provided of W-gothic_s Ver 1.2 to W-gothic_s Ver 1.2.2.1 for a cold leg break. How does this version compare with the deck area version identifies as both GOTHIC Version W-gothic 2.1.1.1 and as W-GOTHIC 1.2.1.1. Are these the same code? Identify the changes that are included in the version used for this analysis as compared with the 1.2 and 1.2.1.1 versions of W-GOTHIC.

Response:

The configured WGOTHIC code (pre-processor, post-processor and solver programs) version 4.1. supersedes all previous versions of WGOTHIC.

WGOTHIC solver versions 1.2.1.1 and 1.2.2.1 are not identical. WGOTHIC solver version 1.2.1.1 was created by increasing the size of certain array dimensions in the configured WGOTHIC version 1.2 solver program to allow it to load and run the distributed parameter model for the deck flow area sensitivity case presented in NTD-NRC-95-4596. WGOTHIC solver version 1.2.2.1 was created by updating the configured WGOTHIC version 1.2 solver program to remove the differences, as documented in NTD-NRC-95-4577 and NTD-NRC-95-4595 (excluding the clime model), that were identified between the GOTHIC version 4.0 solver program and the WGOTHIC version 1.2 solver program.

SSAR Revision: NONE

OITS: 4008
RAI: 480.494

Summarize the physical quantities measured in Large-Scale Test (LST) facility and the results of comparisons with WGOTHIC computational results provided in Reference 480.494-1 that leads Westinghouse to conclude that no compensating errors occurred. Address both the distributed-parameter results as well as the lumped-parameter results to support use of the lumped-parameter approach for the AP600 DBA evaluation model. Address differences between WGOTHIC 4.0 and the version of WGOTHIC used for the Reference 480.494-1 studies.

Response:

Westinghouse has changed its approach to use a bounding lumped parameter evaluation model, which limits the applicability of the above question. The issue of Large Scale Test (LST) facility verification runs for WGOTHIC is addressed here only in the context of the bounding lumped parameter approach. In addition, the AP600 Evaluation Model methodology has been documented based on WGOTHIC 4.1 (Reference 480.494-2).

Westinghouse does not claim that no compensating errors exist in the lumped parameter formulation. WCAP-14382, Section 8.2 discusses the existence of lumped parameter compensating errors, and provides a basis for bounding their effects by using only free convection inside containment.

While both distributed and lumped parameter models were used in the process of evaluating the ability of WGOTHIC to capture physical aspects of AP600 containment transients, the DBA evaluation model was constructed using the lumped parameter formulation to yield a bounding estimate. The LST distributed parameter results are supporting information used during the LST analysis stage to develop insight to be able to bound the effects of compensating errors when using the simplified momentum formulation in lumped parameter. The distributed parameter model of WCAP-14382, Appendix A, was shown to represent well each pressure-limiting mechanism during the LST transients. Comparisons of experimental data and code predictions that led to this conclusion are documented in WCAP-14382 Appendix A: vessel pressure, condensate flow rate, excess condensate flow rate, air partial-pressure-ratio, and average wall temperature changes at representative elevations. Since good agreement was seen for the local parameters that determine calculated mass transfer rates, and good agreement also occurred with global pressure, it is concluded that the distributed parameter pressure predictions are good for the right reasons. This adds confidence that the effects of compensating errors in lumped parameter have been correctly identified.

Lumped parameter models lack the detail and flexibility that make it possible for distributed parameter models to reasonably capture the more significant processes during a transient like the AP600 design basis transients. The LST was instrumental in the development of the bounding DBA evaluation model because it was used to understand how lumped parameter biases apply to AP600 and make the necessary input adjustments to provide bounding predictions. The lumped parameter model developed for the LST showed that while most phenomena were captured adequately, compensating errors did occur; comparisons of experimental data and code predictions (vessel pressure and air partial-pressure ratio) are presented in Section 8 of WCAP-14382.

The two quantities that caused compensating errors are:

- near-wall velocity—over-predicted, and
- steam concentration—under-predicted.

Estimated magnitudes of the effect of the compensating errors on predicted shell heat flux are included in the response to RAI 480.?82. The resolution was to eliminate the forced convection component in the calculation of the shell heat-transfer coefficient. Effectively, this removes the source of under-predicting heat rejection through the shell. Nothing was done to adjust steam concentration under-predictions, since these contribute to the conservatism of the lumped parameter DBA evaluation model. Steam distribution effects are bounded as discussed in Reference 480.494-2, Section 9.

Regarding the second part of this question, code validation studies of Reference 480.494-1 were performed using WGOTHIC version 1.2, and the DBA evaluation model studies performed in Reference 480.494-2, were performed with WGOTHIC version 4.1. Section 3 of Reference 480.494-2 contains an overview of the WGOTHIC development and differences between the two code versions and summarizes the development of WGOTHIC. As described in the attachment to letter ND-NRC-95-4577, the differences in AP600 DBA LOCA DECLG response between GOTHIC 3.4c and GOTHIC 4.0 are relatively minor. WGOTHIC version 4.0 resulted from integrating the WGOTHIC climes into GOTHIC 4.0. WGOTHIC version 4.1 was created to fix an error in the clime routines when dryout was predicted. The effect of the upgrade in code version on the conclusions in WCAP-14382 are addressed in the response to RAI 480.1023.

Reference:

480.494-1 WCAP-14382, "WGOTHIC Code Description and Validation," May 1995

480.494-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4528
RAI: 480.596

In WCAP-14407, Section 1 (p. 1-3), the last sentence of the paragraph states, ".... it is seen that there is over 10 psi of margin to the peak predicted pressure when most, but not all, conservatism is taken out of the input."

Please identify the remaining conservatisms introduced by specified input data and provide an estimate of their contribution. Are there other conservatism not included in the study which are ranked medium or high that could add to the conservatism?

Response:

Section 1 of WCAP-14407, Rev. 1, has been amended and no longer contains the statement identified in RAI 480.596. Sensitivities to various modeling assumptions are quantified and documented within applicable sections of the revised report. For example, Section 7 documents the sensitivity of calculated pressure history to variations in water coverage assumptions and Section 10 quantifies the conservatism represented by some of the significant assumptions made for the model in terms of change in calculated containment pressure history.

SSAR Revision: NONE

OITS: 4529
RAI: 480.597

In regards to WCAP-14407, Section 1, aside from the conservatism introduced by the input data selection, the AP600 design basis accident (DBA) evaluation model setup introduces another level of conservatism by applying a network of lumped-parameter nodes.

Please quantify the conservatism induced by the model choice in comparison to those introduced by input data.

Response:

The conservatism induced by the choice of the lumped parameter approach to model the AP600 containment for the transients considered, relative to both a distributed parameter model and scale model test data, is demonstrated in Reference 480.597-1, which demonstrates the conservatism of the containment Evaluation Model developed for the AP600 design.

References

480.597-1 WCAP-14382, "WGOTHIC Code Description and Validation," May, 1995

SSAR Revision: NONE

OITS: 4530
RAI: 480.598

In WCAP-14407, Section 1, Westinghouse states, "The justifications for the input and modeling assumptions that have been made in creating the bounding DBA model of the AP600 containment are provided, and sensitivities on the WGOTHIC evaluation model to important input parameters are included."

However, careful examination of the text in Section 1 or in the following sections indicates that Westinghouse never states that the bounding DBA model described in Section 4 was indeed exercised and applied for all of the sensitivity studied listed and documented in WCAP-14407.

Please state whether the WGOTHIC DBA evaluation model described in section 4 was used to obtain the results of the various sensitivity studies documented in the later sections 5, 6, 7, 8, 9, 10, 11 and 13.

Response:

The sensitivity studies documented in Sections 5, 6, 7, 8, 9, 10, and 11 of Reference 480.598-1 are based on the base case Evaluation Model described in Section 4 of Reference 480.598-1. For the sensitivities described in Section 12, a preliminary version of the Evaluation Model input deck was used, as stated in Section 12.2.2 of Reference 480.598-1. Section 13 has been withdrawn, and is not included in Reference 480.598-1.

References:

480.598-1 WCAP-14407, Rev. 1,"WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4531
RAI: 480.599

It is a general practice to validate modeling assumptions by direct comparisons with experimental data which covers the spectrum of applicable phenomena and conditions. These comparisons are not provided in WCAP-14407 for the AP600 DBA evaluation model.

Provide a summary of the comparisons between experimental data and the specific model described in Section 4 which justify the claims cited above from WCAP-14407.

Response:

The validation of modeling assumptions used in the AP600 containment Evaluation Model is demonstrated in WCAP-14382, Reference 480.599-1. This document provides the comparison of specific modeling approaches and assumptions to scale model experimental data collected for the AP600 design.

References

480.599-1 WCAP-14382, "WGOTHIC Code Description and Validation," May, 1995

SSAR Revision: NONE

OITS: 4532
RAI: 480.60^

In regards to WCAP-14407, for each item in Table 2-1 and 2-2 identified as requiring scaled test resolution, describe which scaled tests are applicable and provide a discussion of how the item was resolved.

Response:

Section 4.4 of Reference 480.600-1 describes the use of scaled test results to support the basis for the PIRT ranking and to justify the Evaluation Model treatment of applicable phenomena.

The two tables have been amended and combined in a single table, Table 2-1, "Phenomena Identification and Ranking Table - Summary of High and Medium Ranked Phenomena," in the revised WGOTHIC Application Report (Reference 480.600-2). Table 2-1 in Reference 480.600-2 cross-references each phenomenon to the appropriate subsection of Section 4.4 of Reference 480.600-1.

References:

480.600-1 WCAP-14812, Rev. 1, "Accidents Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.600-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4534
RAI: 480.601

PIRT Tables 2-1 and 2-2 have a format which is much simpler than the tables presented in earlier documentation, e.g. NSD-NRC-96-4643. The earlier tables which ranked phenomena by event, event phase, component and the phenomena were more detailed (e.g. break source mass and energy, direction, momentum and density, previously listed separately, are now combined). This simplification has eliminated some items previously ranked as medium for various events or phases, e.g. break pool mixing/stratification and segregation, mass transfer and internal resistance. Also, some phenomena which are now combined may be quite different for the different phases of an event.

Section 2 references NSD-NRC-96-4643 which has PIRT tables that are very different in structure and content than those presented in Section 2. Please reconcile the differences in the information presented in these documents, and provide explanations for any high or medium ranked items which have been eliminated.

Response:

Section 2.3 of WCAP-14407, Rev. 1 (Reference 480.601-1), has been amended to be consistent with WCAP-14812, Rev. 1 (Reference 480.601-2). In general, Section 2 of WCAP-14407, Rev. 1, has been simplified to present only an overview for the PIRT to facilitate understanding the phenomena effects and how the applicable phenomena are addressed in the AP600 containment Evaluation Model. The detailed tabular presentation regarding the AP600 containment Evaluation Model approach to capturing phenomena has been eliminated from Section 2 of Reference 480.601-1.

References:

480.601-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

480.601-2 WCAP-14812, Rev. 1, "Accidents Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4535
RAI: 480.602

PIRT Tables 2-1 and 2-2 have a format which is much simpler than the tables presented in earlier documentation, e.g. NSD-NRC-96-4643. The earlier tables which ranked phenomena by event, event phase, component and the phenomena were more detailed (e.g. break source mass and energy, direction, momentum and density, previously listed separately, are now combined). This simplification has eliminated some items previously ranked as medium for various events or phases, e.g. break pool mixing/stratification and segregation, mass transfer and internal resistance. Also, some phenomena which are now combined may be quite different for the different phases of an event.

Please explain how the rankings given in the PIRT were confirmed. What use was made of the scaled test data for this confirmation?

Response:

Section 4.4 of Reference 480.602-1 describes the use of scaled test results, (as well as scaling analysis, sensitivity studies, and expert review) to support the basis for the PIRT ranking and to justify the Evaluation Model treatment of applicable phenomena.

Tables 2-1 and 2-2 were deleted from the revised WGOTHIC Application Report (Reference 480.602-2). A new Table 2-1 is provided in Reference 480.602-2 which cross-references each phenomenon to the appropriate subsection of Section 4.4 of Reference 480.602-1.

References:

480.602-1 WCAP-14812, Rev. 1, "Accidents Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.602-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4536
RAI: 480.603

PIRT Tables 2-1 and 2-2 have a format which is much simpler than the tables presented in earlier documentation, e.g. NSD-NRC-96-4643. The earlier tables which ranked phenomena by event, event phase, component and the phenomena were more detailed (e.g. break source mass and energy, direction, momentum and density, previously listed separately, are now combined). This simplification has eliminated some items previously ranked as medium for various events or phases, e.g. break pool mixing/stratification and segregation, mass transfer and internal resistance. Also, some phenomena which are now combined may be quite different for the different phases of an event.

Tables 2-3 and 2-4 give information on the PIRT application which is organized by module. The PIRT phenomena listed are organized and ranked differently from Tables 2-1 and 2-2. Please explain the relationship between the phenomena and rankings in the PIRT and PIRT application tables.

Response:

Section 4.4 of Reference 480.603-1 describes the basis for the PIRT ranking, how the phenomenon is implemented in the Evaluation Model, the justification of the Evaluation Model treatment of the phenomenon, and the Evaluation Model treatment of uncertainty. Table 2-1 of Reference 480.603-2 cross-references each phenomenon to the appropriate subsection of Section 4.4 of Reference 480.603-1.

Section 2.3 of Reference 480.603-2 has been amended to be consistent with Reference 480.603-1. In general, Section 2 of Reference 480.603-2 has been simplified to present only an overview for the PIRT to facilitate understanding the phenomena effects and how the applicable phenomena are addressed in the AP600 containment Evaluation Model. The detailed tabular presentation regarding the AP600 containment Evaluation Model approach to capturing phenomena has been eliminated from Section 2 of Reference 480.601-1.

References:

480.603-1 WCAP-14812, Rev. 1, "Accidents Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.603-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4552
RAI: 480.618

Subsections 5.2 - 5.9 give results for parameter changes without describing the study approach. Subsection 5.3 describes the impact of the selected input value for the relative humidity (inside containment) and Figure 5-1 reveals that the reference case generates a higher containment pressure response than the sensitivity limit value of 100% relative humidity. Westinghouse explains this by the maximum amount of non-condensible gas present for the reference limit value of 0% relative humidity.

In WCAP-14407, Section 5, what correlation controls the impact of non-condensibles on heat transfer? Is it the Uchida-correlation for the heat sinks below the operating deck or is it controlled by PCS energy and mass transfer?

Response:

The DBA peak pressure occurs at about 1200 seconds. Reference 480.618-1, Figure 9-43 shows that internal heat sinks absorb most of their energy capacity during blowdown (30 seconds), with an energy removal rate decreasing to about 10% of the rate of energy removed by the steel shell by 1000 seconds.

Since the internal heat sinks reach maximum thermal effectiveness well before the time of peak pressure, penalizing the rate of energy removal on internal heat sinks has only a small effect on peak pressure. Therefore, the penalty to mass transfer on the steel shell, via the PCS mass transfer correlations (Reference 480.618-1), dominates the effect of the initial noncondensible content on peak pressure.

References:

480.618-1 WCAP-14326, Rev. 1, Experimental Basis for the AP600 Containment Vessel Heat and Mass Transfer Correlations," May 1997.

480.618-2 WCAP-14407, Rev. 1, "Application of WGOTHIC to AP600," July 1997.

SSAR Revision: NONE

OITS: 4567
RAI: 480.633

Section 5 of WCAP-14407 presents a sensitivity study on initial conditions. Subsection 5.8 presents the impact of a change in the downcomer-riser annulus loss coefficient versus the reference case with Figure 5-6 revealing no effect. Reference is made to test data obtained from a 14-degree 1/6 scale model.

In WCAP-14407, Subsection 5.8 (p. 5-11), what does this loss coefficient encompass?

Response:

The sensitivity calculation referenced in the RAI has been superseded by a similar calculation presented as Case 5 in Section 10 of Reference 480.633-1. The hydraulic loss coefficient input values for the various flow paths in the annulus downcomer and riser of the AP600 containment Evaluation Model include both the form and skin friction components of resistance to air flow. The hydraulic loss coefficient for the downcomer-riser annulus used in the AP600 containment Evaluation Model is a bounding value that is based on the 14-degree 1/6 scale model, Reference 480.633-2, plus 30 percent, plus an additional velocity head.

As shown in Figure 10-1 of Reference 480.633-1, using experimentally derived hydraulic loss coefficients obtained from the 1/6 scale model test data, plus 10 percent, yields only a small decrease in calculated containment pressure. This demonstrates that the AP600 containment Evaluation Model is insensitive to the value of hydraulic loss coefficients used over the range considered.

References:

480.633-1 WCAP-14407, Rev. 1, "WGOTHIC Applications to AP600", July 1997

480.633-2 WCAP-13328, "Tests of Air Flow Path for Cooling the AP600 Reactor Containment," 1992

SSAR Revision: NONE

OITS: 4569
RAI: 480.635

WCAP-14407, Subsection 5.9 (p. 5-11) presents the effect of changes in the steel jacket-to-concrete air gap thickness, results of which are displayed in Figures 5-7 and 5-8. The following questions arise from the information presented.

Inspection of Table 5-1 reveals that all steel jacket-to-concrete air gap thicknesses have been set to zero (perfect thermal contact) for the reference design basis computation. Please explain why a zero gap thickness was expected to result in a conservative maximum containment pressure response, as required by Westinghouse's parameter selection principles?

Response:

Westinghouse has submitted Reference 480.635-1 which supersedes Reference 480.635-2 on which the original questions were based. The WGOTHIC Evaluation Model assumes a gap of .005 inches. As discussed in the response to RAI 480.636-1, this is larger than the actual gap expected for AP600 and is a conservative value.

References

480.635-1 "WGOTHIC Application to AP600," WCAP-14407, Rev. 1, July 1997, Section 5

480.635-2 "WGOTHIC Application to AP600," WCAP-14407, Rev. 0, September 1996, Section 5

SSAR Revision: NONE

OITS: 4570
RAI: 480.636

Section 5 of WCAP-14407 presents a sensitivity study on initial conditions. WCAP-14407, Subsection 5.9 (p. 5-11) presents the effect of changes in the steel jacket-to-concrete air gap thickness, results of which are displayed in Figures 5-7 and 5-8. The following questions arise from the information presented.

In WCAP-14407, Subsection 5.9, the staff considers the Westinghouse 5 mil estimate of the steel jacket-to-concrete air gap (based on an assumed shrinkage length) to be questionable. Five mils is the approximate thickness of a human hair. As Westinghouse has noted, local variation in aggregates and curing conditions may cause variations in the void content and ultimate shrinkage the structural concrete. Westinghouse should provide data on observed air gap values for structural concrete which span the range of composition and curing practices expected for AP600. Why was 20 mils selected as a conservative upper bound for the gap thickness value? The staff requests Westinghouse provide additional justification for this value as well.

Response:

Westinghouse considers the 5 mil steel jacket-to-concrete air gap to be an appropriate conservative assumption in the WGOTHIC Evaluation Model. The steel surface plates on these walls are one-half inch thick and are connected to each other by vertical trusses at 30 inch centers. The steel surface plates are connected to the concrete by embedding these trusses and also by six inch long welded studs. The surface plates are stainless steel for the IRWST and refueling canal boundaries and are carbon steel elsewhere. The shear studs on the stainless steel plates are spaced at 10" horizontally and 8" vertically. The shear studs on the carbon steel plates are spaced at 10" horizontally and 9.6" vertically. The welded studs plus trusses result in a direct steel conduction path across the interface between the surface plate and the concrete. The contribution of this steel with much higher thermal conductivity has been neglected in the WGOTHIC evaluation model. Additionally, radiation across the gap is neglected in the WGOTHIC model. The typical configuration for these structures is illustrated in Figure 3.8.3 in the SSAR.

Concrete is placed into the structural modules and will initially bond to the surface plates. The wet concrete weight will load the steel plates and result in permanent outward deformation of the plates spanning between the trusses. Mechanical and thermal loading and shrinkage may break this bond when the plate slides over the concrete. However, the welded studs will keep the surface plates in contact with the concrete at the stud locations and gaps between the studs would be very small. Generally, as the concrete shrinks the steel surface plates will move with the surface of the concrete. The evaluation model conservatively assumes a five mil gap for the steel jacketed concrete heat sinks. A one mil gap was assumed for the sensitivity study of nominal conditions presented in Reference 480.636-1.

A sensitivity to various gap assumptions has been performed; assumed gap widths of 10, 20, and 125 mils were used in the three sensitivity analyses. The AP600 containment evaluation model described in Reference 480.636-1 was used as the basis for the sensitivity analyses. The LOCA transient was selected for the sensitivity study because the transient is longer than the MSLB, allowing more time for the effects of differences in the gap thickness to become evident.

The peak pressure response comparison with the reference model is shown in Figure 480.636-1; the peak pressure for each case is given in the table below.

Case	Peak Pressure (psig)
Evaluation Model - 5 mil	43.9
Case 1 - 10 mil	44.1
Case 2 - 20 mil	44.4
Case 3 - 125 mil	45.3

Figures 480.636-2 through 480.636-5 present the temperature profile through steel jacketed concrete conductor 202 at 1000 and 10,000 seconds with air gaps of 5, 10, 20, and 125 mils, respectively. This conductor connects the upper east SG compartment (volume 4) with the south CMT room (volume 104).

An additional sensitivity was performed for the MSLB transient as summarized below.

Case	Peak Pressure (psig)
Evaluation Model - 5 mil	44.8
Case 1 - 125 mil	45.2

Reference:

480.636-1 "WGOTHIC Application to AP600," WCAP-14407, Rev. 1, July 1997, Section 10.

SSAR Revision: NONE

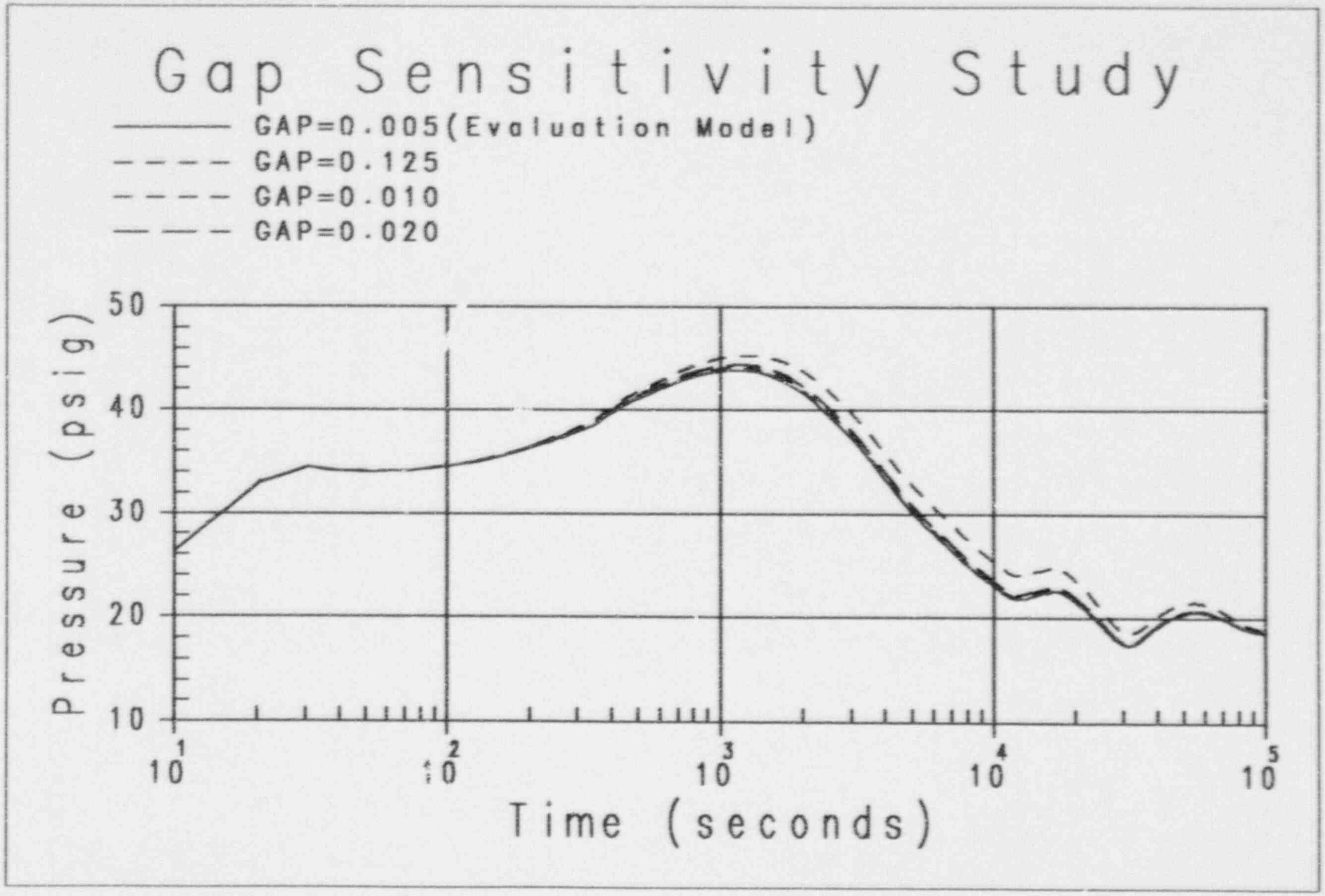


Figure 480.636-1 - Pressure Comparison

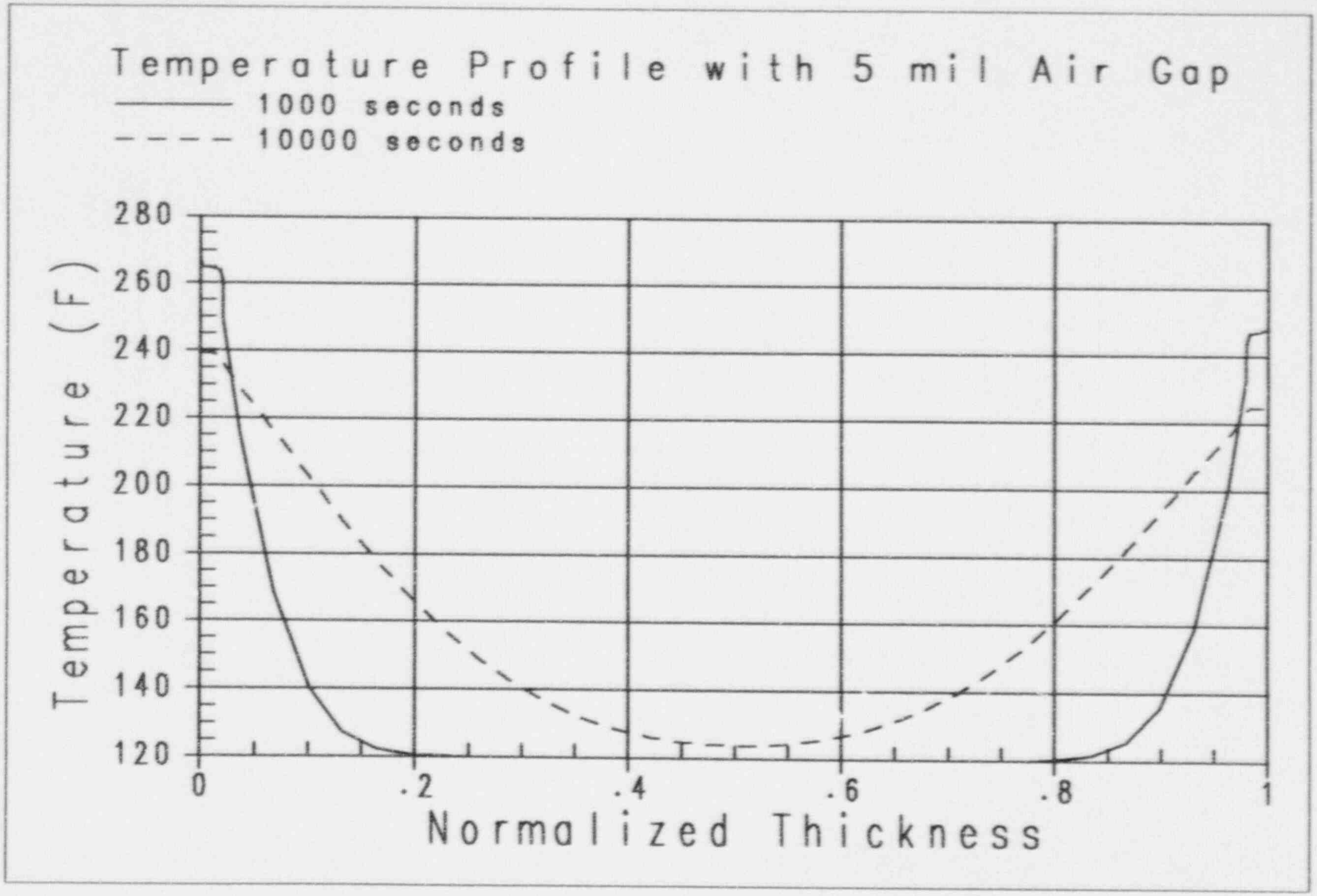


Figure 480.636-2 - Conductor 202 Temperature Profile with a 5 mil Air Gap

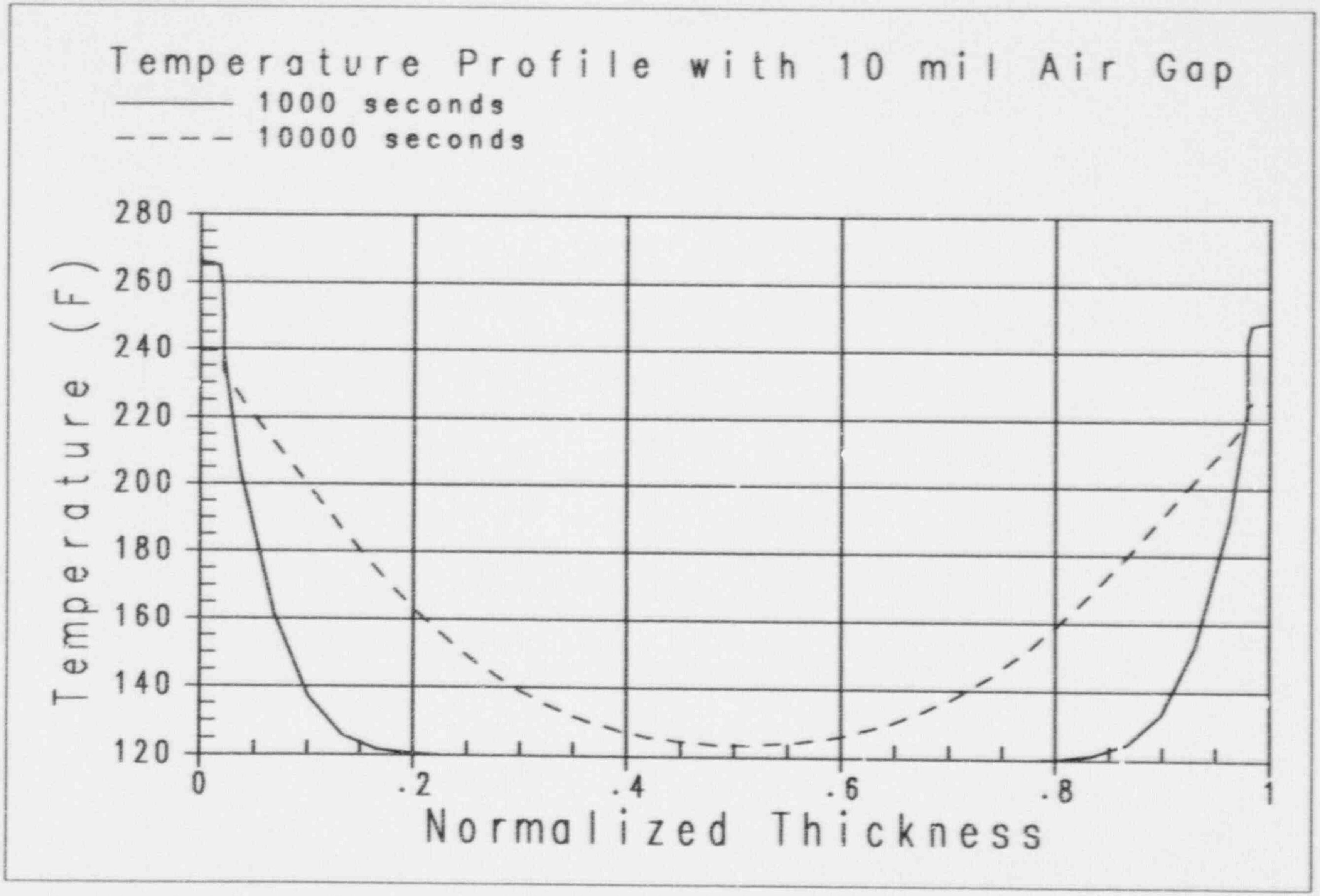


Figure 480.636-3 - Conductor 202 Temperature Profile with 10 mil Air Gap

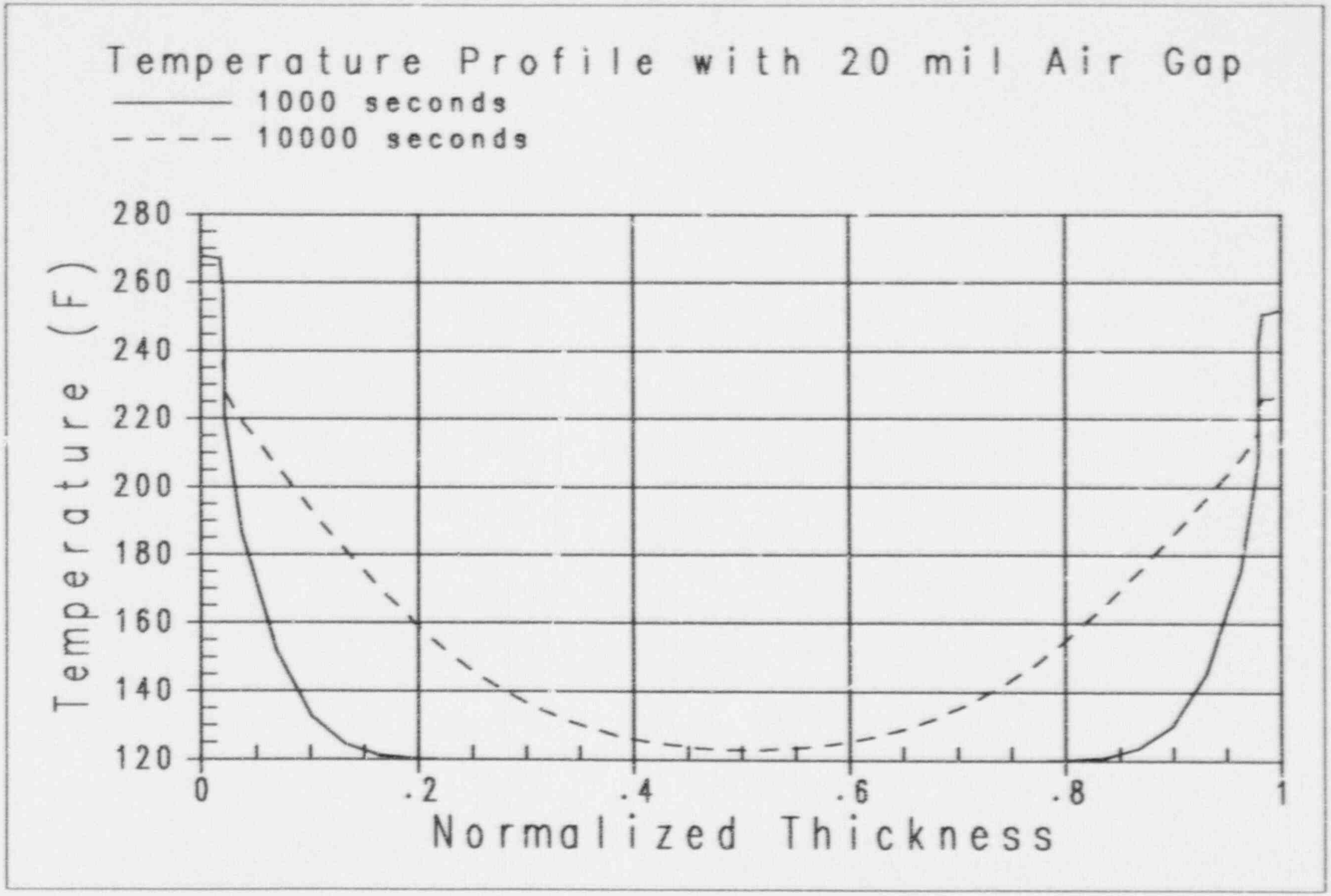


Figure 480.636-4 - Conductor 202 Temperature Profile with 20 mil Air Gap

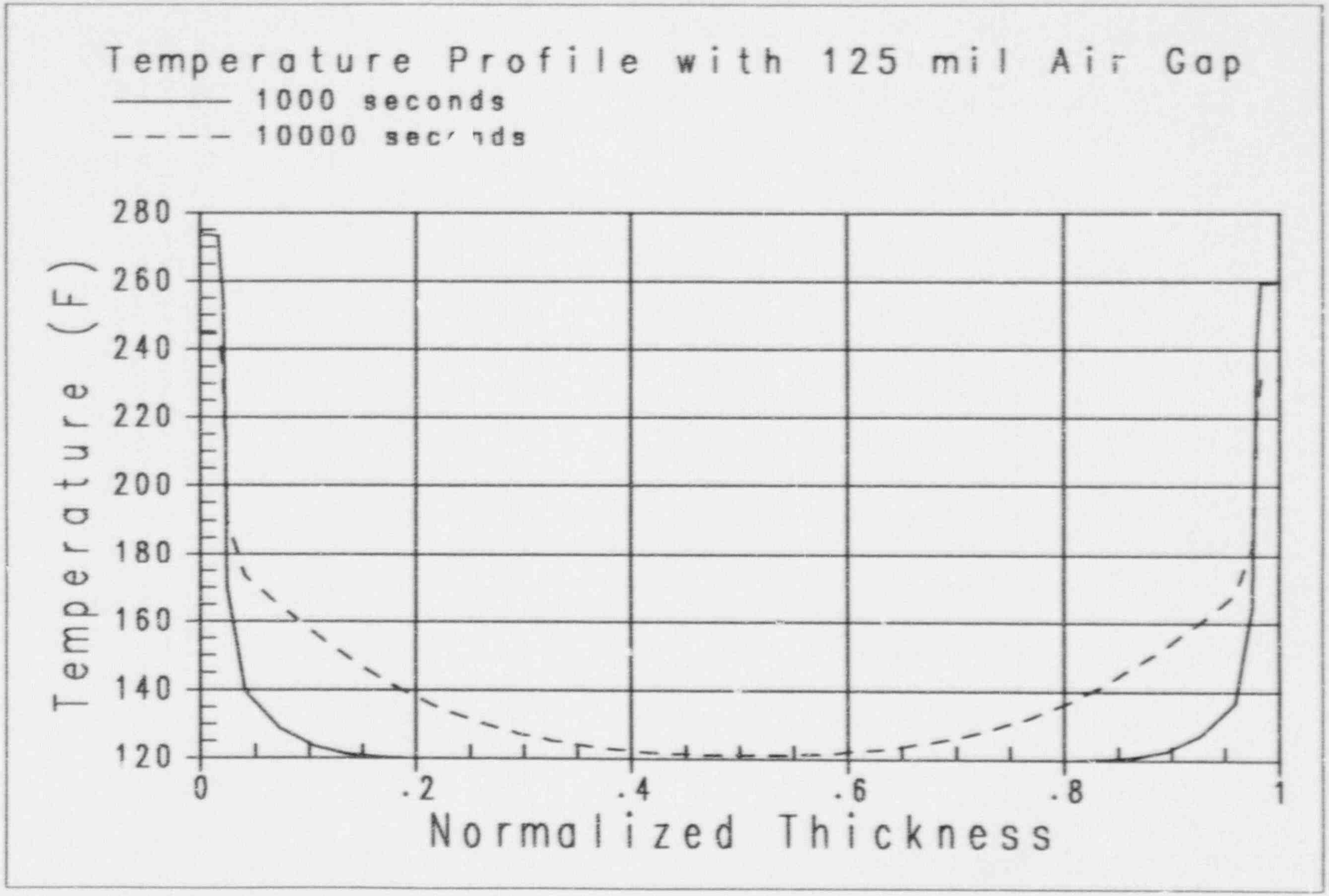


Figure 480.636-5 - Conductor 202 Temperature Profile with 125 mil Air Gap

OITS: 4571
RAI: 480.637

Section 5 of WCAP-14407 presents a sensitivity study on initial conditions. WCAP-14407, Subsection 5.9 (p. 5-11) presents the effect of changes in the steel jacket-to-concrete air gap thickness, results of which are displayed in Figures 5-7 and 5-8. The following questions arise from the information presented.

In WCAP-14407, Subsection 5.9, how large is the fraction of affected surfaces compared to the total heat sink surface area? How much of heat sink volume is associated with these surfaces?

Response:

Westinghouse has submitted Reference 480.637-1 which supersedes Reference 480.637-2 on which the original questions were based; this response is written relative to reference 480.637-1.

The total steel jacketed concrete surface area accounted for in the evaluation model is 54,600 ft^2, which constitutes 57% of all concrete heat sink surfaces. The steel jacketed concrete volume is 75,000 ft^3, which is 51% of the total concrete heat sink volume considered in the evaluation model. These figures are for inside containment regions, only, and do not consider the shield building concrete.

References:

480.637-1 "WGOTHIC Application to AP600," WCAP-14407, Rev. 1, July 1997, Section 5

480.637-2 A. Forgie, et al., "WGOTHIC Application to AP600," WCAP-14407, Rev. 0, September 1996, Section 5

SSAR Revision: NONE

OITS: 4572
RAI: 480.638

Section 5 of WCAP-14407 presents a sensitivity study on initial conditions. WCAP-14407, Subsection 5.9 (p. 5-11) presents the effect of changes in the steel jacket-to-concrete air gap thickness, results of which are displayed in Figures 5-7 and 5-8. The following questions arise from the information presented.

In WCAP-14407, Subsection 5.9, why is the effect of air gap resistance on containment pressure only noticeable between 400 and 5000 seconds and not at later times?

Response:

The steel jacketed concrete behaves much like a heat sink with no gap in the initial stages of the transient until the steel jacket is thermally saturated. Thus the impact of the gap on the blowdown peak pressure is small since the heat capacity of the concrete has little impact on energy removal during this time. The gap does affect the containment pressure during the time when the post-blowdown peak pressure occurs because the additional resistance of the gap inhibits heat absorption by the concrete. During the long term time phase the impact of the gap is small since the heat sinks are nearly thermally saturated and the pressure is dictated by the balance between releases to the containment and heat removal via the PCS. A sensitivity to gap size is included in Reference 480.638-1 and in the response to RAI 480.636-1.

Reference:

480.638-1 "WGOTHIC Application to AP600," WCAP-14407, Rev. 1, July 1997, Section 10.

SSAR Revision: NONE

OITS: 4573
RAI: 480.639

Section 5 of WCAP-14407 presents a sensitivity study on initial conditions. WCAP-14407, Subsection 5.9 (p. 5-11) presents the effect of changes in the steel jacket-to-concrete air gap thickness, results of which are displayed in Figures 5-7 and 5-8. The following questions arise from the information presented.

In WCAP-14407, Subsection 5.9, the temperature profiles displayed in Figure 5-8 cannot be identified with the respective air gap thickness because of the graphical display chosen. Please replot this figure so that the information presented can be understood.

Response:

Please refer to the response to RAI 480.636.

SSAR Revision: NONE

OITS: 4589
RAI: 480.655

In WCAP-14407, Section 10, Case 6 removed the assumption of no heat sink access of steam in dead-ended compartments. By removing this limitation, how much additional heat sink surface and volume is made accessible to the steam as compared to the previous cases?

Response:

The AP600 containment Evaluation Model treats several compartments in the lower containment as being dead ended; i.e., not having a flow path to upper containment. The Evaluation Model conservatively assumes that, following the initial blowdown period, there is no vapor flow into these compartments and therefore takes no credit for condensation on the surface of heat sinks in these volumes. The compartments in lower containment treated as dead-ended volumes and the total surface areas of the affected thermal conductors is summarized in Table 480.655-1. A listing of the individual thermal conductors and their corresponding surface areas is given in Reference 480.655-1, Section 4.

Reference:

480.655-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997

SSAR Revision: NONE

Table 480.655-1 **AP600 Containment Evaluation Model Summary of Dead-Ended Volumes and Associated Thermal Conductor Surface Areas**

Volume Number	Description	Volume (ft^3)	Affected Surface Area (ft^2)
1	Reactor Vessel Cavity	986.71	986.71
2	S.E. Accumulator Room	10,205.84	4,786.75
3	N.E. Accumulator Room	13,286.10	6,328.01
7	Upper Refueling Room	39,404.50	6080.40
109	Lower Refueling Room	5,218.80	2,433.83
8	IRWST	83,210.90	11,051.49
103	Chem. & Vol. Control Cavity	15,729.90	6994.25
Totals		168,042.75	38,661.44

OITS: 4715
RAI: 480.682

What is meant by the expression that the volumes "preserve elevations"? Is this referring to the fixed prescribed clime discretization or to some physical phenomenon?

Response:

The phrase appearing on Page 4-1 of WCAP-14407, Rev. 0 which states "...preserve elevations..." refers to the manner in which the free volume inside containment above the operating deck is modeled in the AP600 containment Evaluation Model. Adjacent stacks of nodes modeling the inside free volume of the containment are defined to have identical cell elevations to prevent artificial "numeric" mixing.

Reference 480.682-1, Section 4.2 has been revised to more clearly state the benefits of this modeling approach.

Reference:

480.682-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997.

SSAR Revision: NONE

AP600

OITS: 4718
RAI: 480.685

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

Response:

The technical basis and references for the loss coefficients are as follows:

1. Below-deck flow paths through doorways, tunnels, or other inter-compartment connections are assigned forward and reverse loss coefficients of 3.0, which is characteristic of natural circulation gas flow through doorways (1991 ASHRAE Handbook - Heating, Ventilating, and air-conditioning Applications, Page 47.5). Flow path 261 is the refuel cavity drain line to the west steam generator cavity and has been assigned a forward/reverse loss coefficient of 1.68 based on liquid flow through commercial grade pipes.

2. For flow paths of uniform area, such as across node boundaries that do not have a physical partition, there is no form loss, so a value of 0.0 is assigned.

Table 4-111 in WCAP-14407, Rev. 1 summarizes all flow paths in the AP600 Evaluation Model, including forward/reverse loss coefficients.

SSAR Revision: NONE

OITS: 4719
RAI: 480.686

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

Response:

The loss coefficient of 3.0 is used which is representative of natural circulation gas flow through doorways (1991 ASHRAE Handbook - Heating, Ventilating, and Air-Conditioning Applications, Page 47.5).

The maximum value of the hydraulic coefficient for a sudden contraction is K = 0.5, which simulates an infinite source feeding the contraction. Similarly, the maximum value for the hydraulic coefficient for a sudden expansion is K = 1.0, which simulates a small source feeding an infinite sink. Thus, the maximum value for the total hydraulic loss coefficient for a high velocity flow passage through a contraction is calculated as 1.5. The use of a value of 3.0 is conservative as it limits flow into the rooms, minimizing the amount of steam available to condense on heat sinks, thereby maximizing the predicted pressure response to the postulated event. This conservatism is evaluated as having a small effect on the calculated pressure response because the duration of high velocity mass flow is relatively short, (~30 seconds).

Finally, sensitivity studies on the loss coefficient are presented in WCAP-14407, Rev. 1, Section 9.3.2.1, to address uncertainty in the natural circulation loss coefficient as implemented in the lumped parameter model. These studies indicate a weak dependence of peak containment pressure to selected value of the below-deck loss coefficient.

SSAR Revision: NONE

OITS: 4720
RAI: 480.687

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

Response:

The loss coefficient of 3.0 is used which is representative of natural circulation gas flow through doorways (1991 ASHRAE Handbook - Heating, Ventilating, and Air-Conditioning Applications, Page 47.5). Also, sensitivity studies on the loss coefficient are presented in WCAP-14407, Rev. 1, Section 9.3.2.1, to address uncertainty in the natural circulation loss coefficient as implemented in the lumped parameter model. These studies indicate a weak dependence of peak containment pressure to selected value of the below-deck loss coefficient.

SSAR Revision: NONE

OITS: 4737
RAI: 480.704

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

Response:

The Uchida correlation is used to calculate free convection condensation heat transfer on internal structural heat sinks. As discussed in Reference 480.704-1, the Uchida correlation can significantly over-predict the total heat transfer coefficient for gas mixtures with non-condensible partial pressures less than 1 atmosphere. For non-condensible gas partial pressures greater than or equal to 1 atmosphere, the Uchida correlation is shown to conservatively under-predict the total heat transfer coefficient.

During the blowdown phase of DBA LOCA (i.e., during, approximately, the first 30 seconds), the non-condensible gas partial pressure in the below deck compartments of the AP600 Evaluation Model (EM) may decrease below 1 atmosphere. Thus, during the blowdown phase of the DBA analysis, the free convection portion of the total heat transfer may be over-predicted by use of the Uchida correlation. However, during the blowdown phase, forced convection is the dominant mode of heat and mass transfer, and this is conservatively neglected in the AP600 EM calculations. The net result is a conservative bias in the calculation of heat and mass transfer during the blowdown phase of the DBA analysis.

The conservative bias for heat and mass transfer that results from use of the Uchida correlation in situations where forced convection is important is evident in validation studies against the CVTR tests. For instance, Reference 480.704-2 shows that the Uchida correlation significantly under predicts data from the CVTR tests where significant internal velocities may be inferred.

References:

480.704-1 P. F. Petterson, "Theoretical Basis for the Uchida Correlation for Condensation in Reactor Containments", Nuclear Engineering and Design, 162, 301-306 (1996).

480.704-2 R. C. Schmidt, G. E. Bingham, J. A. Norberg, "Simulated Design Basis Accident Tests of the Carolinas Virginia Tube Reactor Containment - Final Report", IN-1403 (December, 1970)

SSAR Revision: NONE

OITS: 4752
RAI: 480.719

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

Response:

Steam condensation on containment heat sinks is ranked in Reference 480.719-1 as medium importance for the LOCA blowdown phase. During the blowdown phase, the liquid inventory escapes from the reactor coolant system with high kinetic energy as a steam-water mixture, and the steam component of the RCS inventory pressurizes the containment structure. To do this, steam must enter each compartment, dead-ended or otherwise, in the containment.

Steam enters the dead-ended compartments with some velocity component during the postulated LOCA. The calculation of steam velocity into the dead-ended compartments is internally calculated in the WGOTHIC code. The Evaluation Model reduces the calculation of condensation by modelling the process with the Uchida correlation, which is applicable to natural convection driven condensation. Thus, the AP600 containment Evaluation Model calculates less condensation in dead-ended compartments during the blowdown phase which results in a conservative calculation of the containment pressure response to the blowdown phase of the postulated LOCA.

A description of how the phenomenon is implemented and the justification for the treatment of the phenomenon is given in Section 4.4.3F of Reference 480.719-1.

Reference:

480.719-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4758
RAI: 480.725

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

Response:

The circumferential vent layout from the IRWST to the outer annuli is shown in Figure 480.725-1. These vents are modeled as WGOTHIC model flow paths 17, 18, and 19. The combined flow area of these paths is modeled as 95.03 ft^2.

SSAR Revision: NONE

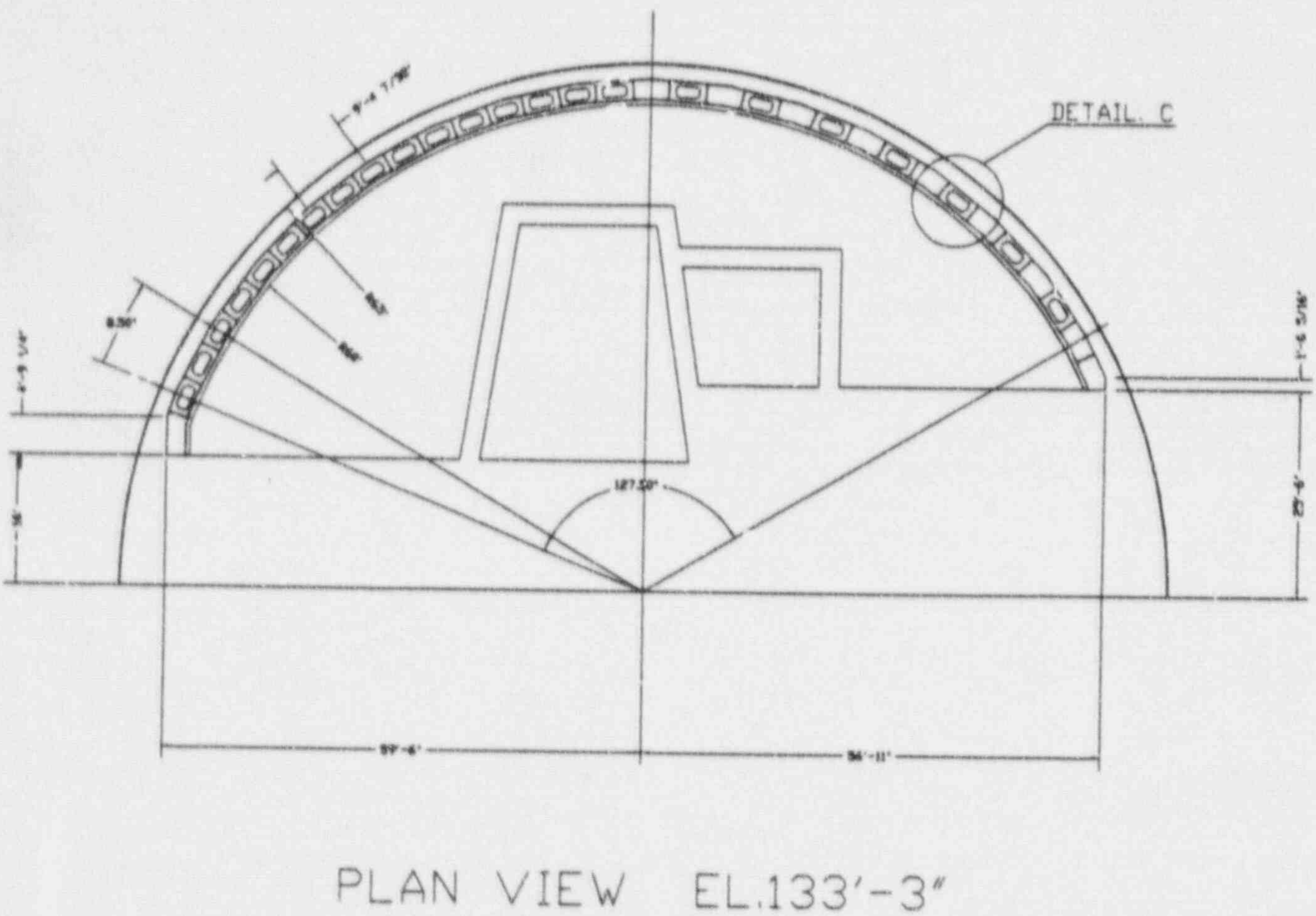


Figure 480.725-1 IRWST Vents

OITS: 4776
RAI: 480.743

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

Response:

A typographical error was made in the preparation of Figure 4-35, "Above-Deck East Steam Generator Room Cross-Section -- AA," for WCAP-14407, Rev. 1. The figure incorrectly identifies Volume 70 being connected to Volume 61 by flow path 16; the correct flow path specification is Volume 70 connected to Volume 16 by flow path 16 of Table 4-4 (16-to 16). A marked up copy of Figure 4-35 correcting this error is attached as part of the response to this RAI. A corrected Figure 4-35 will be provided as errata to Revision 1 of WCAP-14407.

Figure 4-35 of WCAP-14407, Rev. 1, has been amended to clarify the flow paths joining nodes. Arrowheads have been added to both ends of the lines depicting flow junctions between pairs of nodes to indicate the possibility of flow in either direction between a pair of coupled nodes.

Figure 4-35 of WCAP-14407, Rev. 1, is an accurate depiction of cutline AA shown in Figure 4-33, "Upper East Steam Generator Room." The flow paths shown in Figure 4-35 are annotated to indicate the flow path number from Column 1 of Table 4-4 and the connecting volume. For example, the flow path from Volume 24 is annotated as "14-to 16" and indicates that Volume 24 is connected to Volume 16 with flow path number 14 from Table 4-4. Three of the pairs of volumes for which flow paths are defined, 24 and 16, 23 and 15, and 22 and 14, are at the same elevation. The remaining pair of volumes, 70 and 16, volume 16 is actually adjacent to but below volume 70. The lines depicting the flow paths between the pairs shown in Figure 4-35 were drawn so as to minimize crossing of numbered nodes in the figure and do not represent the actual elevation of the flow junction and thereby keeping Figure 4-35 easy to read.

SSAR Revision: NONE

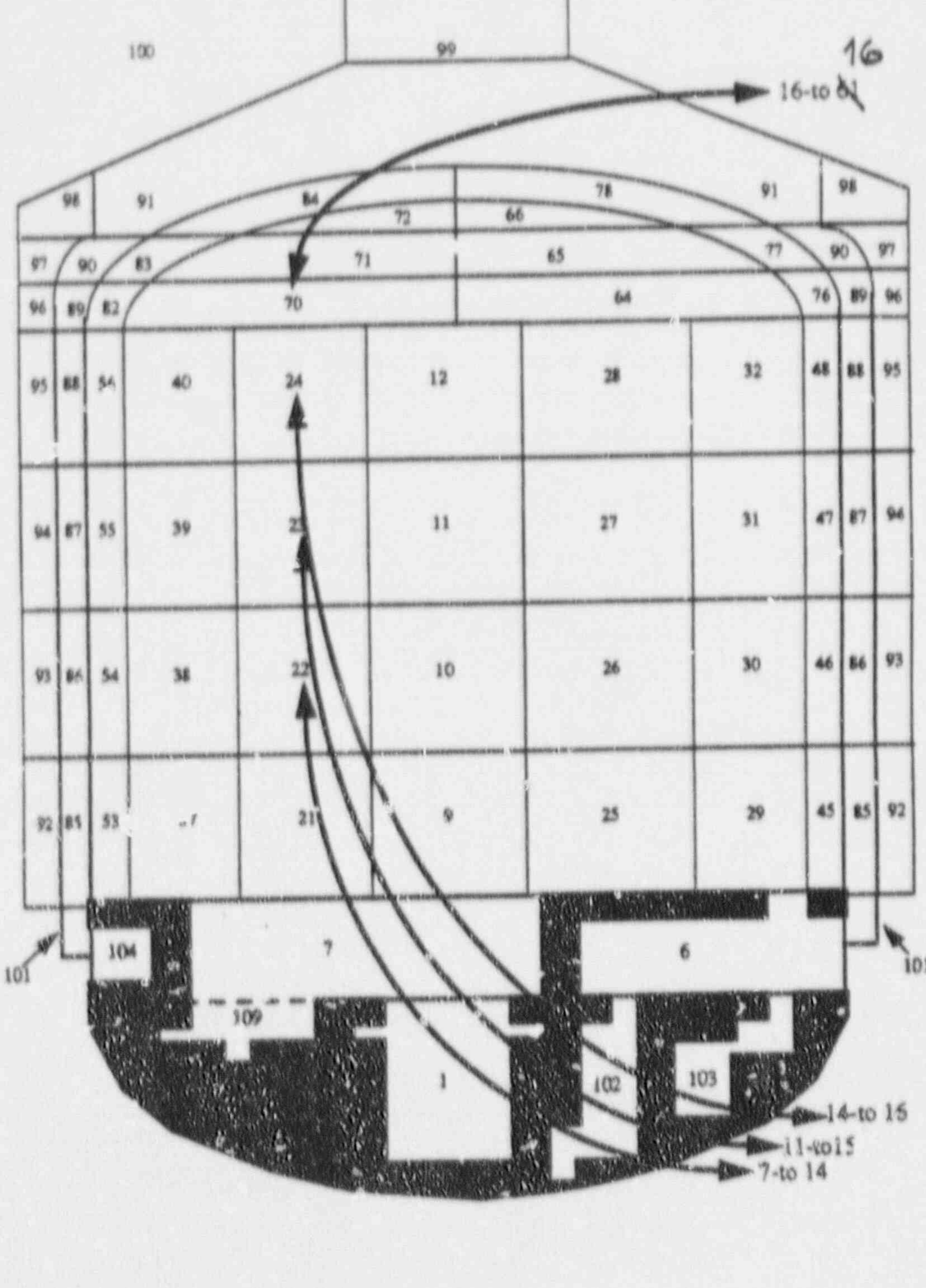


Figure 4-35 Above-Deck East Steam Generator Room Cross-Section - AA

OITS: 4782
RAI: 480.749

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

Response:

As described in Reference 480.749-1, Section 4.2.13.3, there are five thermal conductors modeled in Volume 13. These conductors represent the four walls of the east steam generator cubicle between the 135' -3" and 148' -0" elevations. Therefore, they all use the same conductor type (Type 27). As shown in the following table, metallic structures located within the steam generator cubicle (other than the steam generator shell itself) all reside above the 148' -0" elevation; therefore, there are no metallic heat sinks included in Volume 13. The metallic heat sink details included in the AP600 Evaluation Model (EM) are consistent with the AP600 General Arrangement Drawings, Revision 8. Heat transfer from the steam generator shell and main steam line is included as part of the mass and energy release calculation and used as input to the AP600 EM

Upper East Steam Generator Room Metallic Heat Sink Summary

Metallic Equipment Description	Lowest Equipment Elevation	AP600 Evaluation Model Node Containing Metallic Equipment	AP600 Evaluation Model Thermal Conductor
Upper portion of steam generator No. 2	135' -3"	13, 14, 15	N/A
Jib Crane	148' -0"	14, 15	101, 104
Feedwater nozzle platform	149' -7"	14	102
Upper manway platform	162' -1"	14	103
Main steam line	174' - 6 3/4"	15	N/A

Reference:

480.749-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4791
RAI: 480.758

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

Response:

The jib crane lies between the 148' -0" and 178' -6" elevations, thus, it spans Volumes 18 and 19 in the Upper West Steam Generator Room. The jib crane is, therefore, modeled as two separate thermal conductors -- one for Volume 18 and another for Volume 19. As indicated in Section 4.2.14.3 of WCAP-14407, Rev. 1, the jib crane is modeled with the sixth and ninth thermal conductors (i.e., thermal conductor numbers 104 and 107 in the AP600 Evaluation Model). The vertical mast of the jib crane located between the 148' -0" and 170' -0" elevations is assigned to thermal conductor 104 and located in Volume 18. The remainder of the vertical mast above the 170' -0" elevation, plus the horizontal jib, are assigned to thermal conductor 107, which is located in Volume 19.

SSAR Revision: NONE

OITS: 4797
RAI: 480.764

Re: WCAP-14407, "WGOTHIC Application to AP600," A. Forgie, et al., September 1996, SECTION 4, "DESCRIPTION OF WGOTHIC EVALUATION MODEL"

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

Response:

The figure referenced in the RAI shows the flow paths connecting the fluid nodes or cells in the North Inner-half annulus. It has been superseded by Reference 480.764-1, Figure 4-43. The objective of the figure is to illustrate the flow path connections between pairs of nodes in the north inner-half annulus as viewed from the B-B cross section. The revised figure indicates pairs of nodes connected by a flow path by a line drawn between the two connected nodes and with arrows on both ends of the line.

Listed adjacent to the line, and in larger font than the cell or node number, is the flow path number. This flow path number corresponds to the flow path number listed in Reference 480.764-1, Table 4-10, "Flow Paths for the North Inner-Half Annulus Volumes". Table 4-10 also lists start and end nodes for the flow paths, as well as the hydraulic characteristics of the flow path.

References

480.764-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997

SSAR Revision: NONE

OITS: 4803
RAI: 480.770

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

Response:

The current AP600 WGOTHIC node and junction model provides a consistent representation of the primary containment and PCS. Consistency of the current model is assured through testing of the AP600 WGOTHIC lumped parameter model, as documented in Reference 480.779-1.

Reference:

480-770-1 WCAP-14382, "WGOTHIC Code Description and Validation," May 1995.

SSAR Revision: NONE

OITS: 4010
RAI: 480.777

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

Response:

The radial dimensions of the internal stiffener are 2'-6" for the webbing and 1.754" for the flange, for a total radial width of 31.754". Please refer to the accompanying Figure 480.777-1 for additional stiffener details. The portion of the internal stiffener that is contained in node 30 (i.e., stiffener structure out to a radius of 63 ft.) is also indicated on the figure. Finally, the heat sink calculation assumes that the entire stiffener is located below the 170'-0" elevation such that the entire height of the 1'-2" flange is contained within node 30.

SSAR Revision: NONE

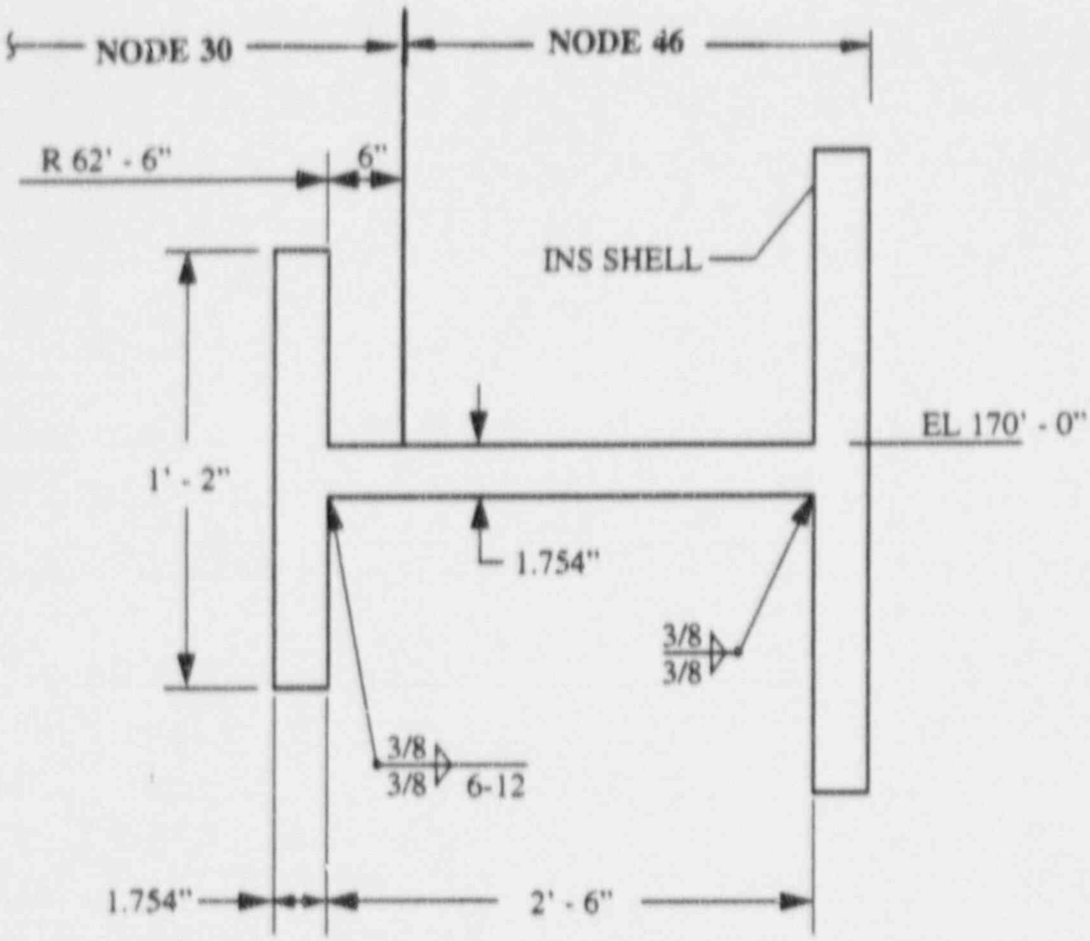


Figure 480.777-1 Internal Stiffener

OITS: 4811
RAI: 480.778

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

Response:

The requested diagram, indicating crane girder details and node location, is attached as Figure 480.778-1.

SCAR Revision: NONE

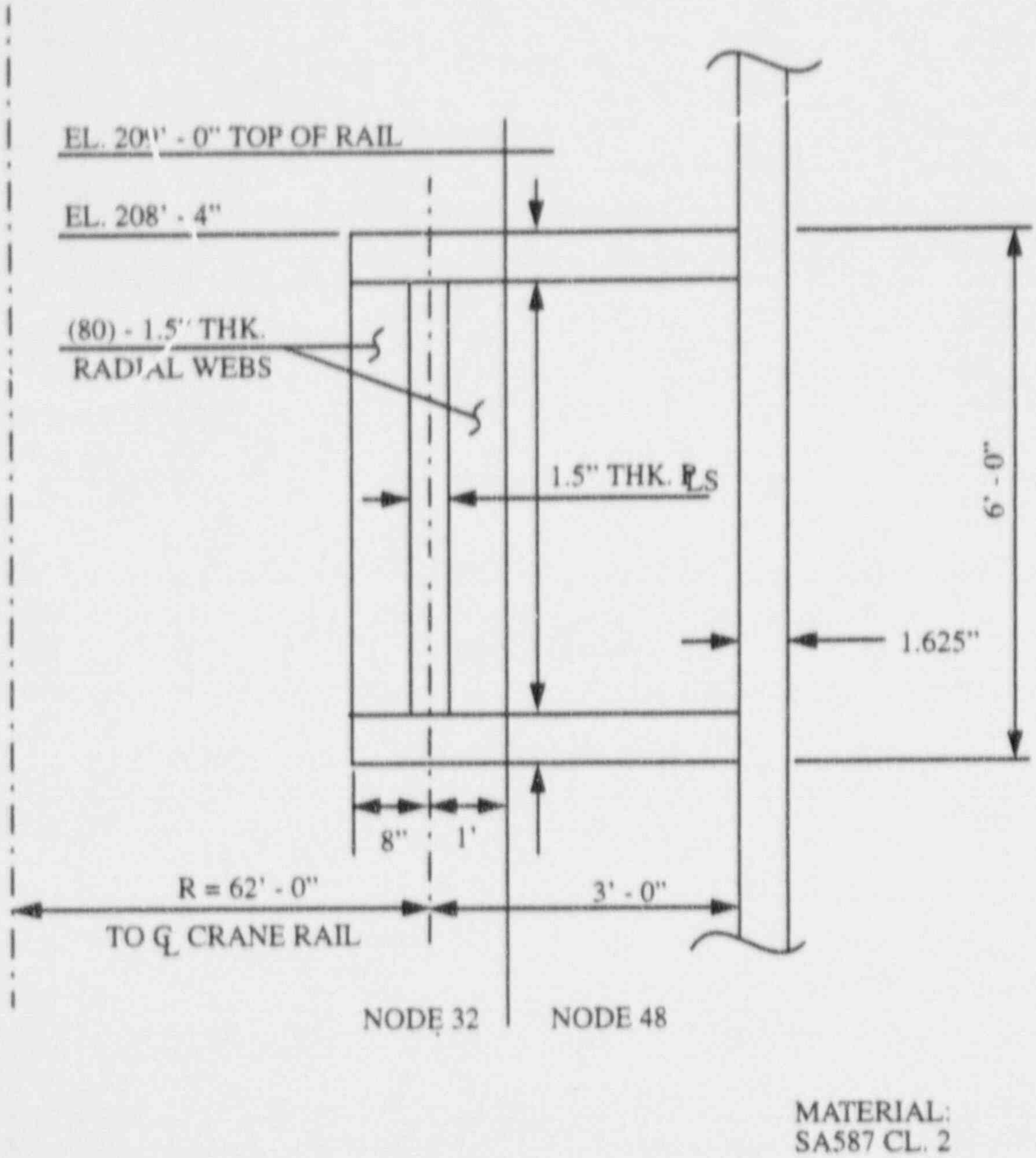


Figure 480.778-1 Crane Girder

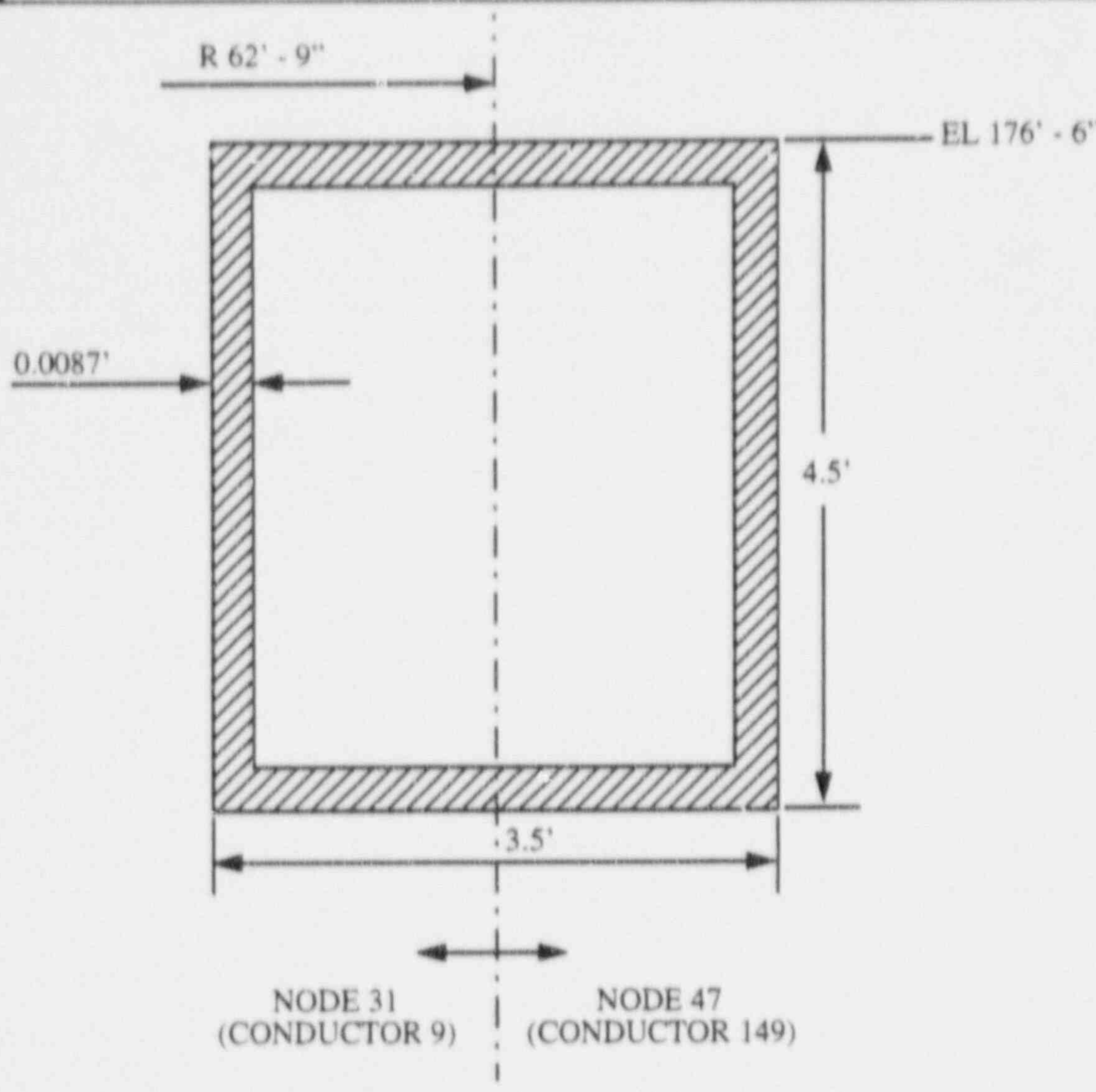
OITS: 4812
RAI: 480.779

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

Response:

The calculation of HVAC ring duct geometric properties for modeling as conductor 122 assumes that half of the ring duct (vertical center-line) is contained in node 31 (as conductor 122) and half is contained in node 47 (as conductor 148). Please refer to the accompanying Figure 480.779-1 for additional ring duct details.

SSAR Revision: NONE



Duct length in node

$$L = \frac{1}{4}2\pi R = \frac{\pi R}{2} = \frac{\pi \times 62.75}{2} = 98.6 \text{ ft}$$

Figure 480.779-1 HVAC Ring Duct

OITS: 4819
RAI: 480.786

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

Response:

The flow paths connecting volumes of the east mid-quarter annulus with volumes of the north and south inner-half annuli are:

South Inner-Half Annulus Volume Number	WGOTHIC Flow Path Number	East Mid-Quarter Annulus Volume Number	WGOTHIC Flow Path Number	North Inner-Half Annulus Volume Number
40	111	44	76	28
39	107	43	70	27
22	63	42	64	26
21	57	41	58	25

This information is taken from Reference 480.786-1, Table 4-18.

Reference:

480.786-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997.

SSAR Revision: NONE

OITS: 4821
RAI: 480.788

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

Response:

The lumped parameter modeling approach used in the AP600 Evaluation Model (EM) is based on the lumped parameter noding scheme used to model the AP600 Large Scale Test (LST) for validation of the WGOTHIC code as documented in the following sections of Reference 480.788-1;

Section 6.3	Lumped Parameter LST Input Model
Section 6.4.2	Noding of the AP600 Lumped Parameter Evaluation Model
Section 8.2	Lumped Parameter Comparison Results

As recommended on page 6-8 of Reference 480.788-1, the radial thickness of the Outer-Quarter Annulus Rooms of the AP600 containment Evaluation Model has been made proportional to that of the LST model, using the ratio of the radii of the containment vessel for AP600 to that of the test vessel as the proportionality factor. Also, no benefit would be expected with increased noding due to numerical mixing inherent in lumped parameter models. Thus, the four nodes along the containment circumference are a balance between modeling based on scale model data and the limitations inherent in the modeling approach.

References

480.788-1 WCAP-14382, "WGOTHIC Code Description and Validation," May, 1995

SSAR Revision: NONE

OITS: 4825
RAI: 480.792

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

Response:

The flow path arrow 10 between Volumes 50 and 51 in Figure 4-61 of WCAP-14407, Rev. 1 is located incorrectly. Flow path arrow 10 (which represents AP600 Evaluation Model (EM) flow path 135) actually connects Volumes 51 and 52. Due to the presence of the internal stiffener at the 170' -0" elevation, the flow area between Volumes 50 and 51 is completely blocked, and so no vertical flow path exists in the Outer-Quarter Annulus Rooms across the volume boundary at the 170' -0" elevation.

A markup of Figure 4-61 is attached, and shows the correct location of flow path arrow 10. A corrected Figure 4-61 will be issued as an errata to WCAP-14407, Rev. 1.

Please see response to RAI 480.791 for additional details of the flow blockage at the 170' -0" elevation.

SSAR Revision: NONE

For Table 4-22 Flow Path 10 connects nodes 52 and 51, not 50 and 51

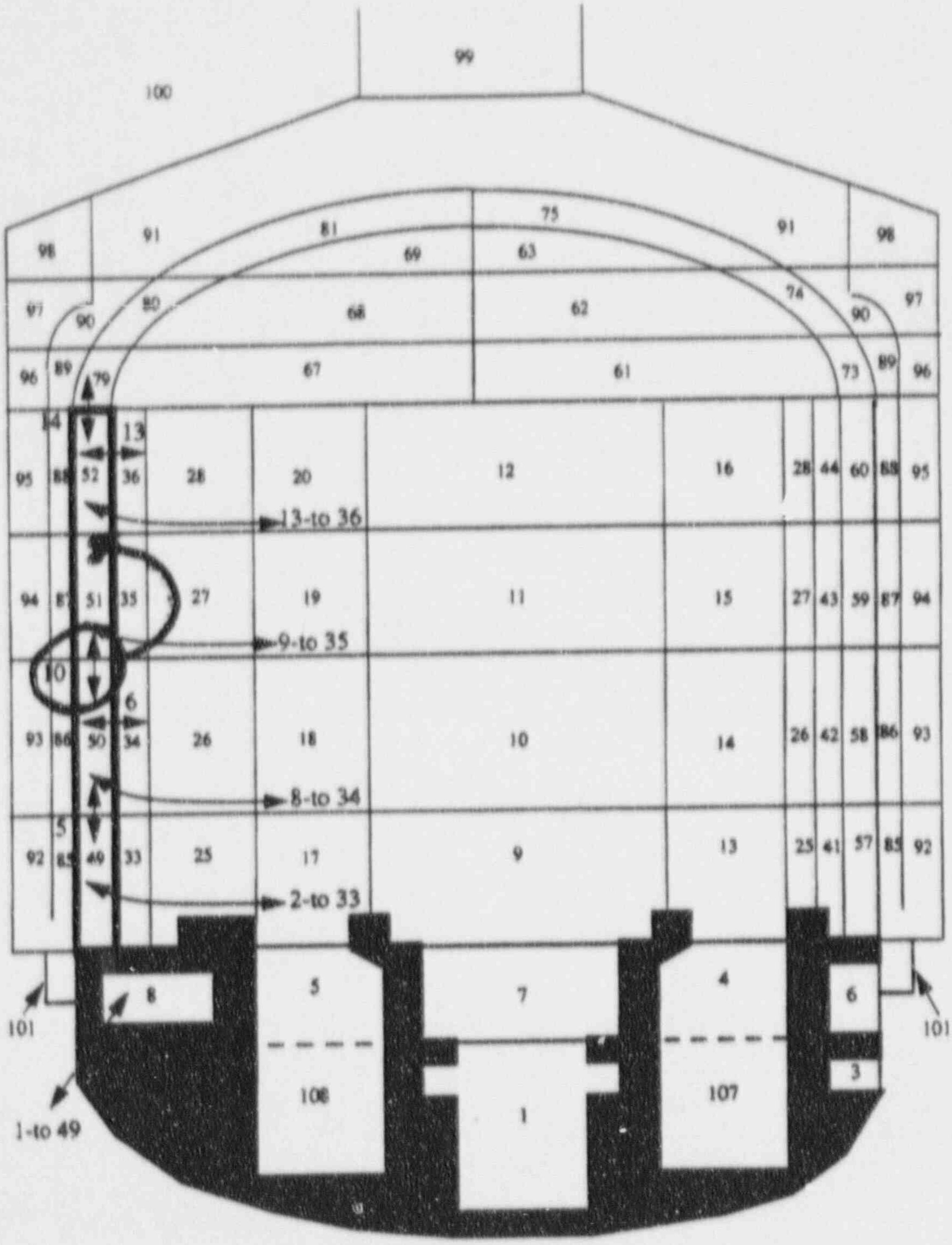


Figure 4-61 West Outer Quarter Annulus Cross-Section – BB

OITS: 4827
RAI: 480.794

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

Response:

Table 4-22 of WCAP-14407, Rev. 1 has been expanded to include the two nodes connected by Flow Path 1, as shown in Figure 4-61. Figure 4-61 has also been amended to identify the node from which Flow Path 1 emanates.

SSAR Revision: NONE

OITS: 4834
RAI: 480.801

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

Response:

The polar crane bridge and motor trolley are located between El. 209' -0" and El. 224' -9", and they are assumed to be positioned as shown in Figure 480.801-1. Thus, one-quarter of the metallic structure is located in each of nodes 61, 64, 67, and 70.

SSAR Revision: NONE

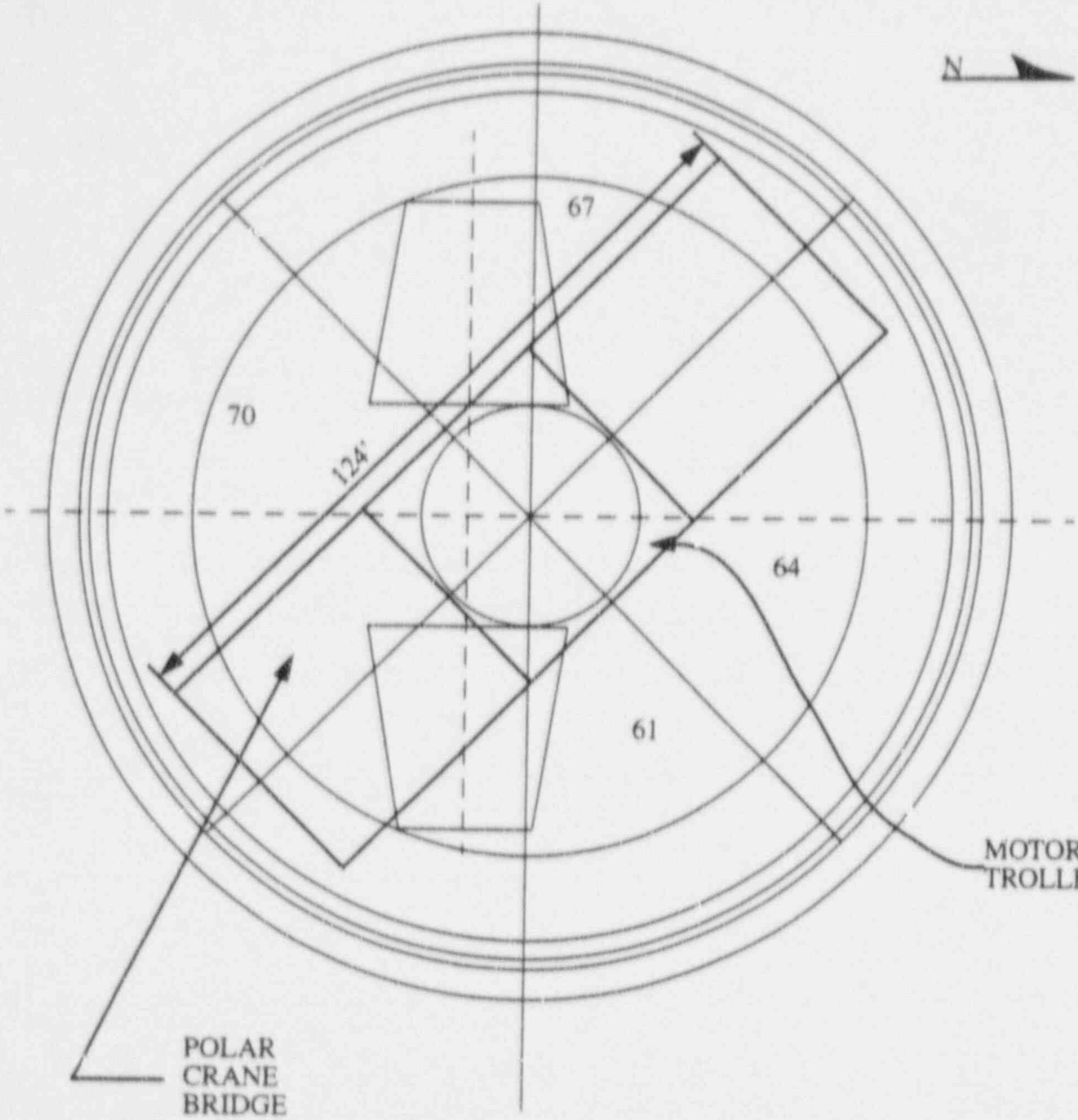


Figure 480.801-1 Polar Crane Bridge and Motor Trolley

OITS: 4836
RAI: 480.803

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

Response:

The affected columns of Reference 480.803-1, Tables 4-27, 4-35, 4-37, and 4-47 are not correctly labeled. Marked up pages of Reference 480.803-1 showing the corrected tables are attached. These corrections will be issued as errata to Reference 480.803-1.

Reference:

480.803-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

- The fifth thermal conductor represents the portion of the crane girder in the east outer quarter annulus. This is WGOTHIC model thermal Conductor 165 and is fully contained in Volume 60.

  - Conductor Type = 19 (see Section 4.3)
  - Surface Area = 550.55 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The sixth conductor is #194, as discussed previously in Section 4.2.7.3.

4.2.24.4 Special Modeling Assumptions

Conductor 162 represents the internal stiffener. This is essentially a large I-beam that is attached to the containment shell so that the web runs horizontally. This arrangement can lead to condensate collecting on top of the web. Once a pool forms, there would be no condensation on the web and condensation could occur only on the pool surface. It is conservative, with respect to peak pressure, to neglect this surface area starting at the initiation of the event since any condensation that could occur early in the event is neglected.

Conductor 164 is the internal ring duct. Since this a duct with limited access to the inner surface, the inside surface has been modeled as insulated so that condensation can only occur on the outside of the duct.

4.2.25 East Quarter Inner Dome Compartment

This control volume represents one quarter of the inner dome region located between the 209-foot and 254-foot elevations (see Table 4-27). The region extends radially outward from the center of containment to 63 feet. This region is beneath the 2-foot deep set of volumes adjacent to the inner containment shell surface. This region is highlighted in Figure 4-69.

Table 4-27 East Quarter Inner Dome Compartment Parameters

Volume Description	Free Volume (ft^3)	Lower Elevation (ft)	~~Volume Height~~ Upper Elevation (ft)	Pool Area (ft^2)	Hydraulic Diameter (ft)
Volume 61	48300.15	209.0	224.75	3115.67	98.34
Volume 62	37591.68	224.75	240.50	2953.64	1000.0
Volume 63	18100.54	240.5	254.33	1859.48	1000.0

4.2.29 East Quarter Outer Dome Compartment

This control volume represents one quarter of the outer dome region located between the 209-foot and 256.3-foot elevations. The region extends inward 2 feet from the inner surface of containment. This region is highlighted in Figure 4-77.

4.2.29.1 Control Volume Description

The east quarter outer dome volumes extend inward from the containment shell and encompass the region between the containment shell to a depth of 2 feet into containment as shown in Figure 4-77. This section is broken up into three vertical segments (see Table 4-35). Moving radially outward from the center of the model, adjacent cells are assigned uniform elevations to ensure that artificial flow patterns are not created due to elevational differences between connecting junctions.

Table 4-35 East Quarter Outer Dome Compartment Parameters

Volume Description	Free Volume (Ft³)	Lower Elevation (Ft)	~~Volume Height~~ Upper Elevation (Ft)	Pool Area (Ft²)	Hydraulic Diameter (Ft)
Volume 73	3234.87	209.0	224.75	200.96	7.83
Volume 74	3925.13	224.75	240.50	228.65	8.09
Volume 75	3975.24	240.5	256.33	263.16	7.51

4.2.29.2 Flowpath Description

The east quarter outer dome compartments are connected to adjacent volumes by 12 junctions (see Table 4-36). These junctions represent the flow path through the cell boundaries in the east quarter outer dome compartments. These junctions are shown in Figures 4-77 and 4-78.

4.2.29.3 Thermal Conductor Description

There are no conductors modeled inside these volumes.

4.2.29.4 Special Modeling Assumptions

There are no special modeling assumptions for these volumes.

4.2.30 North Quarter Outer Dome Compartment

This control volume represents one quarter of the outer dome region located between the 209-foot and 256.33-foot elevations. The region extends inward 2 feet from the inner surface of containment. This region is highlighted in Figure 4-80.

4.2.30.1 Control Volume Description

The north quarter outer dome volumes extend inward from the containment shell and encompass the region between the containment shell to a depth of 2 feet into containment as shown in Figure 4-80. This section is broken up into three vertical segments (see Table 4-37). Moving radially outward from the center of the model, adjacent cells are assigned uniform elevations to ensure that artificial flow patterns are not created due to elevational differences between connecting junctions.

Table 4-37 North Quarter Outer Dome Compartment Parameters

Volume Description	Free Volume (Ft^3)	Lower Elevation (Ft)	Upper Elevation ~~Volume Height~~ (Ft)	Pool Area (Ft^2)	Hydraulic Diameter (Ft)
Volume 76	3234.87	209.0	224.75	200.96	7.82
Volume 77	3925.13	224.75	240.50	228.65	8.09
Volume 78	3975.24	240.5	256.33	263.16	7.51

4.2.30.2 Flowpath Description

The north quarter outer dome compartments are connected to adjacent volumes by 12 junctions (see Table 4-38). These junctions represent the flow path through the cell boundaries in the north quarter outer dome compartments. These junctions are shown in Figures 4-79 and 4-80.

4.2.30.3 Thermal Conductor Description

There are no conductors modeled inside these volumes.

4.2.30.4 Special Modeling Assumptions

There are no special modeling assumptions for these volumes.

4.2.35 PCS Chimney Volume

This control volume represents the PCS chimney. The region extends from the top of the containment shell to the top of the shield building. This region is highlighted in Figure 4-87.

4.2.35.1 Control Volume Description

The PCS chimney volume extends upward from the shield building roof at 286.0 feet, to the top of the containment shield building at 307.25 feet, as shown in Figure 4-87. This section is represented by a single segment, as shown in Table 4-47 below.

Table 4-47 PCS Chimney Volume Parameters

Volume Description	Free Volume (ft^3)	Lower Elevation (ft)	~~Volume Height~~ Upper Elevation (ft)	Pool Area (ft^2)	Hydraulic Diameter (ft)
Volume 99	17290.78	286.0	~~21.5~~ 307.25	804.25	32.0

4.2.35.2 Flowpath Description

The PCS chimney volume is connected to adjacent volumes and boundaries by two junctions. These junctions represent the flow path through the cell boundaries in the PCS chimney volume (see Table 4-48). These junctions are shown in Figure 4-87.

Table 4-48 Flow Paths for the PCS Chimney

Flow Path	WGOTHIC Flow Path Number	Nodes Connected		Bottom Elevation ft	Path Height ft	Flow Area ft^2	Hydraulic Diameter ft	Inertia Length ft	Friction Length ft	Forward/ Reverse Loss Coefficient
		Start	End							
1	242	99	1P	307.4	0.01	803.84	32	100	0	1.294/1.294
2	232	91	99	285.9	0.01	803.84	32	147	0	2.046/2.046

OITS: 4841
RAI: 480.808

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

Response:

As noted in the RAI, the containment steel shell is accounted for in the climes. The incorporation of the steel shell into the climes is discussed in Section 4 of WCAP-14407, Rev. 1.

1) How the steel shell is accounted for in the containment Evaluation Model is outlined in Section 4.1, "Introduction," to WCAP-14407, Rev. 1. The fourth paragraph of Section 4.1 identifies that volumes, heat sinks, and flow paths for each model volume are provided in Section 4.2, while the material properties and heat sink geometry are described in Section 4.3. The fifth paragraph of Section 4.1 notes that the AP600 passive containment cooling system (PCS) is modeled using a special structure called a clime and that the input for the AP600 containment Evaluation Model is described in Section 4.4.

2) Section 4.4,1, "Wet Stacks," and 4.4.2, "Dry Stacks," of WCAP-14407, Rev. 1 identify in detail the association of conductors to WGOTHIC volumes inside containment, inside the riser, inside the downcomer and to the environment.

Thus, Section 4.1 describes, in general terms, the treatment of the steel containment shell in the AP600 containment Evaluation Model, and the detailed treatment of the steel containment shell is described in Section 4.4.

SSAR Revision: NONE

OITS: 4842
RAI: 480.809

The inside containment nodalization is divided into quadrants. Outside of the containment, the quarter-region modeling has been replaced by a single node representation of the downcomer and annulus for each axial elevation. Please justify this approach. Does not the azimuthal lumping of the downcomer and annulus artificially (and non-conservatively) smooth out any asymmetries computed inside the containment using the four quadrant model?

Response:

The use of a single node to represent the outside containment annulus and downcomer for each axial elevation implies that a one-dimensional hydraulic model is used for the external flow paths. As described in Reference 480.809-1, Section 4.4.9A, "PCS Natural Circulation" for the Riser Annulus and Chimney Volume and Section 4.4.13A, "PCS Natural Circulation", validation of the external annulus modeling methods against the LST has been performed and is documented in WCAP-14382, Sections 5, 6, 7 and 8. Furthermore, Section 4.4.9A identifies that LST tests without the fan operating are applicable for validation of prediction methods for natural convective flows through the annulus with the one-dimensional annulus flow model. Calculations from the lumped one-dimensional downcomer and annulus flow model have been compared to data from the LST natural circulation and determined to be conservative. Thus, the one-dimensional model defined in the AP600 EM is justified.

Another important effect is the heat transfer from the containment steel shell which is modeled through the use of eight stacks of seven climes each around the periphery of the containment shell. Any asymmetries computed inside containment using the four quadrant approach is accounted for as a boundary condition to the climes model.

Reference:

480.809-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4843
RAI: 480.810

WCAP-14407, Rev. 0 states that the clime locations were selected to ensure that artificial flow patterns were not created. Explain how artificial flow patterns would be created in the one-dimensional stack of outside-containment nodes.

Response:

The statement in question refers to artificial flows for flowpaths inside containment, not the one-dimensional stack of nodes representing the riser and downcomer, respectively, outside of the containment shell.

SSAR Revision: NONE

OITS: 4844
RAI: 480.811

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

Response:

The entries in the fourth column of Tables 4-43, and 4-45, of WCAP-14407, Rev. 1 have been corrected to be the upper elevations of the volumes. In Table 4-47, the column heading was changed to "Volume Height" to be consistent with the table entry.

The term "pool area" is carried over from its use in describing the modeling below the operating deck. Its use does not imply that Westinghouse expects these regions to flood.

SSAR Revision: NONE

OITS: 4845
RAI: 480.812

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

Response:

The lumped parameter modeling approach currently used in the AP600 Evaluation Model (EM) for the outside containment regions is based on the lumped parameter noding scheme used to model the AP600 Large Scale Test (LST) for validation of the WGOTHIC code. As mentioned in Reference 480.812-1, Section 4.4.9A, validation of the external annulus modeling methods against the LST has been performed and is documented in WCAP-14382, Sections 5, 6, 7 and 8. Furthermore, Section 4.4.9A also states that a one-dimensional flow path in the external annulus of the LST WGOTHIC model shows the ability of the one-dimensional model to predict the riser phenomena. The results of a clime noding sensitivity study are reported in Section 12.3.2, "AP600 Containment Model," of Reference 480.812-2. For this study, Volume 91 and the top clime were divided at the first weir. As shown in Figures 12-28 through 12-46, increasing the number of climes and volumes was not observed to change the calculational results. Thus, the one-dimensional model defined in the AP600 EM is justified.

Reference:

480.812-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.812-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4846
RAI: 480.813

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

Response:

Friction and form losses are accounted for by providing conservative loss coefficients for all outside containment annulus flow paths. This is consistent with the recommendation of Reference 480.813-1, Section 4.4.9A and 4.4.13A. Since friction losses are modeled through the loss coefficients, the AP600 Evaluation Model has been revised to reflect friction lengths of 0.0 ft for all outside containment annulus flow paths.

By convention, all vertical flow paths are assigned heights of 0.1 ft. Flow path 1 shown in Table 4-44 and Table 4-46 of WCAP-14407, Rev. 1 is a horizontal flow path; therefore, the actual height of this interface is provided.

A master table containing all flow paths used in the AP600 Evaluation Model has been provided as Table 4-111 of WCAP-14407, Rev. 1. This table includes the friction lengths and loss coefficients assigned to the flow paths.

Reference:

480.813-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4847
RAI: 480.814

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

Response:

A master table describing all flow paths used in the AP600 Evaluation Model (EM) has been provided as Table 4-111 of WCAP-14407, Rev. 1. This table includes a reference to the 1/6th-scale Air Flow Path Test (WCAP-13328), which forms the basis for the PCS annulus loss coefficients used in the AP600 EM.

SSAR Revision: NONE

OITS: 4848
RAI: 480.815

Outside Containment Upflow Annulus Volumes, Page 4-216:
Twice on this page, conductor types are referenced to Section 2.2. Should these references be to Section 4.3? This also occurs on Pages 4-220, 4-223, 4-224, and 4-247 through 4-267.

Response:

The typographical errors identified by this RAI were not corrected in Reference 480.815-1. Marked up pages of Reference 480.815-1 with the corrections are attached. These will be issued as errata to Reference 480.815-1.

Reference:

480.815-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997.

SSAR Revision: NONE

- The fifth thermal conductor represents platform at 261.0 feet in the PCS chimney. This is WGOTHIC model thermal Conductor 177 and is located entirely within Volume 91.

  - Conductor Type = 4 (see Section 4.3)
  - Surface Area = 71.05 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The sixth thermal conductor represents the concrete floor at 266.0 feet in the PCS chimney. This is WGOTHIC model thermal Conductor 181 and is located entirely within Volume 91.

  - Conductor Type = 36 (see Section 4.3)
  - Surface Area = 1101.33 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The seventh thermal conductor represents valve room walls in the PCS chimney. This is WGOTHIC model thermal Conductor 182 and is located entirely within Volume 91.

  - Conductor Type = 36 (see Section ~~2.2~~ 4.3)
  - Surface Area = 636.0 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The eighth thermal conductor represents concrete support platforms in the PCS chimney. This is WGOTHIC model thermal Conductor 198 and is located entirely within Volume 91.

  - Conductor Type = 30 (see Section ~~2.2~~ 4.3)
  - Surface Area = 6678.6 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The ninth thermal conductor represents the top of the shield building in the PCS chimney. This is WGOTHIC model thermal Conductor 199 and is located between Volume 91 and the environment.

  - Conductor Type = 30 (see Section ~~2.2~~ 4.3)
  - Surface Area = 11772.9 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

4.2.35.3 Thermal Conductor Description

There are two conductors modeled inside this volume.

- The first thermal conductor represents the platform at 298.5 feet in the PCS chimney. This is WGOTHIC model thermal Conductor 178 and is located entirely within Volume 99.

  - Conductor Type = 4 (see Section ~~2.2~~ 4.3)
  - Surface Area = 39.46 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

- The second thermal conductor represents cylindrical portion of the PCS chimney. This is WGOTHIC model thermal Conductor 200 and is located between Volume 99 and the environment.

  - Conductor Type = 30 (see Section ~~2.2~~ 4.3)
  - Surface Area = 2161.4 ft^2
  - Heat Transfer Coefficient = Uchida-split phase/Uchida-split phase
  - Initial Temperature = 120°F

4.2.35.4 Special Modeling Assumptions

There are no special modeling assumptions for these volumes.

4.3 CONDUCTOR TYPE DESCRIPTIONS

The heat sinks in the WGOTHIC model of the AP600 are constructed of components referred to as thermal conductor types. A thermal conductor type can be described as the cross-sectional composition of a given wall. The benefit is that these cross-sections can be used repeatedly whenever a wall of that type is modeled. The WGOTHIC model of the AP600 utilizes 52 different types of wall or conductor types. These walls vary in thickness and composition.

The walls are all constructed from a set of materials for which the properties can vary with temperature but have been input as constants. Table 4-49 provides the materials and their properies. A separate entry is provided for the material properties of the paint on the inside surface of the containment. This was done in order to conservatively eliminate radiation heat transfer from the inside of containment to the shell.

A wall can consist of a number of regions which are typically used to represent the different materials (e.g., epoxy paint, carbon steel) used to make the conductor type. A region may also

4.4.1.2 First Clime, Stacks 1 through 4

The first clime extends downward from the 256.33-foot elevation to the 240.5-foot elevation on the containment shell, and extends outward to the shield building. There is no baffle in this region of the annulus (between the top of the dome and the shield building), so a "dummy" conductor is modeled as a thin wall with a low specific heat input value and a high thermal conductivity input value to minimize the thermal resistance. Both sides of the dummy conductor are connected to the same volume.

The PCS cooling flow is applied to outside of the first conductor in this clime. The input values for this clime are the same for stacks 1 through 4.

FIRST CONDUCTOR – CONTAINMENT SHELL

- Inner Radiation Boundary Temperature = 120°F
- Inner WGOTHIC Volume = 81, 84, 75, 78 (Stacks 1, 2, 3, 4 respectively)
- Outer WGOTHIC Volume = 91
- Conductor Type = 20 (see Section 4.5) 4.3
- Inner Surface Heat Transfer Model = Mixed Convection
- Inner Surface Free Convection Heat Transfer Multiplier = 0.73
- Inner Surface Forced Convection Heat Transfer Multiplier = 1e-10
- Outer Surface Heat Transfer Model = Mixed Convection
- Outer Surface Free Convection Heat Transfer Multiplier = 0.84
- Outer Surface Forced Convection Heat Transfer Multiplier = 0.84
- Gravity Vector = 9.378 ft/s^2
- Perimeter = 22.92 ft
- Surface Area = 1300 ft^2
- Initial Temperature = 120°F

SECOND CONDUCTOR – BAFFLE

- Inner WGOTHIC Volume = 91
- Outer WGOTHIC Volume = 91
- Conductor Type = 52 (see Section 4.3)
- Inner Surface Heat Transfer Model = Mixed Convection
- Inner Surface Free Convection Heat Transfer Multiplier = 1.0
- Inner Surface Forced Convection Heat Transfer Multiplier = 1.0

OITS: 4849
RAI: 480.816

Outside Containment Upflow Annulus Volumes, Page 4-216 of WCAP-14407:
Explain why the Uchida correlation is used for determining the heat transfer coefficient in a non-condensing situation. Provide information or references which justify the use of Uchida for the flow conditions inside the upflow annulus.

Response:

The thermal conductors for Section 4.2.33, "Outside Containment Upflow Annulus Volumes," are described on pages 4-218 and 4-219 of Reference 480.816-1. As identified in the text accompanying each thermal conductor description on these two pages, these conductors represent structures in the upflow annulus or PCS chimney that are exposed to the air flow in the upflow annulus. Initially, these structures are at the ambient environment temperature. As the postulated transient progresses, PCS water is heated and evaporated from the containment shell. At the elevations these structures are included in the model, evaporated PCS flow may condense on the surface of these initially cooler structures represented by these thermal conductors. Thus, the use of the Uchida correlation is appropriate for the thermal conductors in these volumes.

Reference:

480.816-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4850
RAI: 480.817

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

Response:

Thermal conductors in the annulus (stairs, platforms, etc.) are handled in the GOTHIC solver and are not included in the Westinghouse clime calculations. These thermal conductors do not conduct heat to the baffle. They are treated as a heat sink or source, and only exchange thermal energy with the working fluid. Condensation on the surface of these conductors is calculated using the Uchida correlation. Condensate is modeled as running off the conductor and collecting on the "floor" or bottom of the fluid volume to which the conductor is attached. Flow paths between stacked vertical volumes allow condensate to flow downward and collect in the drain at the bottom of the downcomer/riser.

SSAR Revision: NONE

OITS: 4851
RAI: 480.818

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

Response:

Reference 480-818-1, Section 4.4.13A states that there is a low sensitivity of containment pressure to changes in the loss coefficients. Nonetheless, unrecoverable losses in the downcomer annulus, riser annulus, and chimney, which are taken from the 1/6 scale air flow tests, as described in Reference 480-818-1, Section 2.2.4, are conservatively applied at 130 percent of the experimentally derived value. Thus, conservative loss coefficients are used in the Evaluation Model, and the use of a 0/0 loss coefficient on Evaluation Model flow path 230 is consistent with this modeling approach.

Reference:

480.818-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4854
RAI: 480.819

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

Response:

Figure 4-86 of WCAP-14407, Rev. 1 has been revised to accurately and clearly indicate the flow paths and the upstream and downstream volumes.

SSAR Revision: NONE

OITS: 4855
RAI: 480.820

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

Response:

Figure 4-86, "Outside Containment Downflow Annulus Cross-Section -- BB," of Reference 480.820-1, shows a flow path between fluid nodes 91 (top of riser) and 98 (top of downcomer). The specifics of this flow path are given in Table 4-46, "Flow Paths for the Outside Containment Downflow Annulus," of Reference 480.820-1. This flow path allows for evaporated PCS fluid to be drawn into and mixed with the downflow air from the environment. This evaporated flow is available to condense on cooler surfaces modeled by thermal conductors in the downflow annulus volumes. The thermal conductors associated with the volumes shown in Figure 4-86 are described on page 4-223 of Reference 480.820-1 and are exposed to the mixture of ambient air and air/evaporated water from the top of the riser. These conductors are initially cooler than the vapor mixture from the riser and may support condensation of evaporated liquid. Thus, the use of the Uchida correlation is appropriate for the thermal conductors in the volumes modeling the containment downcomer.

Reference:

480.820-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4856
RAI: 480.821

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

Response:

Thermal conductors in the annulus (stairs, platforms, etc.) are handled in the GOTHIC solver and are not included in the Westinghouse clime calculations. These thermal conductors do not conduct heat to the baffle. They are treated as a heat sink or source, and only exchange thermal energy with the working fluid. Condensation on the surface of these conductors is calculated using the Uchida correlation. Condensate is modeled as running off the conductor and collecting on the "floor" or bottom of the fluid volume to which the conductor is attached. Flow paths between stacked vertical volumes allow condensate to flow downward and collect in the drain at the bottom of the downcomer/riser.

SSAR Revision: NONE

OITS: 4857
RAI: 480.822

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

Response:

Flowpath 242 connects node 99 to boundary condition 1P to model flow from the PCS chimney to the environment. Flowpath 233 connects boundary condition 2P to node 98 to model flow from the environment to the PCS downcomer. Specific flowpath parameters can be found in WCAP-14407, Rev. 1, Table 4-48 for flowpath 242 and Table 4-46 for flowpath 233.

SSAR Revision: NONE

OITS: 4861
RAI: 480.823

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

Response:

Please see response to RAI 480.816. Evaporated PCS fluid being vented to the ambient may condense on the initially cooler structures modeled in the PCS chimney volume. Thus, use of the Uchida correlation is appropriate for the thermal conductors in this volume.

SSAR Revision: NONE

OITS: 4862
RAI: 480.824

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

Response:

Thermal conductors in the annulus (stairs, platforms, etc.) are handled in the GOTHIC solver and are not included in the Westinghouse clime calculations. These thermal conductors do not conduct heat to the baffle. They are treated as a heat sink or source, and only exchange thermal energy with the working fluid. Condensation on the surface of these conductors is calculated using the Uchida correlation. Condensate is modeled as running off the conductor and collecting on the "floor" or bottom of the fluid volume to which the conductor is attached. Flow paths between stacked vertical volumes allow condensate to flow downward and collect in the drain at the bottom of the downcomer/riser.

SSAR Revision: NONE

OITS: 4863
RAI: 480.825

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

Response:

Evaporated PCS fluid being vented to the ambient may condense on the initially cooler inside surface of the top of the shield building and the PCS chimney. Thus, use of the Uchida correlation is appropriate for the inside surface of the thermal conductors representing the concrete bounding volume 91 (top of shield building) and 99 (PCS chimney).

The second "Uchida" does refer to heat transfer at the outside surfaces of both the top of the shield building and the PCS chimney. In the AP600 containment Evaluation Model, the thermal conductors were set to initial temperatures of 120°F and the ambient is set to 115°F. Therefore, no condensation is expected to occur at the outside surfaces of either the top of the shield building top or the PCS chimney.

However, assigning the Uchida correlation to the outside surface of these two conductors will allow limited heat transfer from the comparatively warm thermal conductors modeling 36-inch thick concrete walls to the cooler ambient environment boundary condition. Given the thermal properties of concrete, the thickness of the concrete being modeled, and the small heat transfer coefficient obtained from the Uchida correlation under "no condensation" conditions, the effect of modeling heat transfer at the outside surface of these two conductors is evaluated as being insignificant. This is demonstrated in Figure 480.825-1 which shows the through-thickness temperature profiles thermal conductor 199 (top of shield building) at 2,000 and 90,000 seconds of transient time. Note that the relative distances of "0" and "1" represent the inside and outside surfaces, respectively, of the top of the shield building.

SSAR Revision: NONE

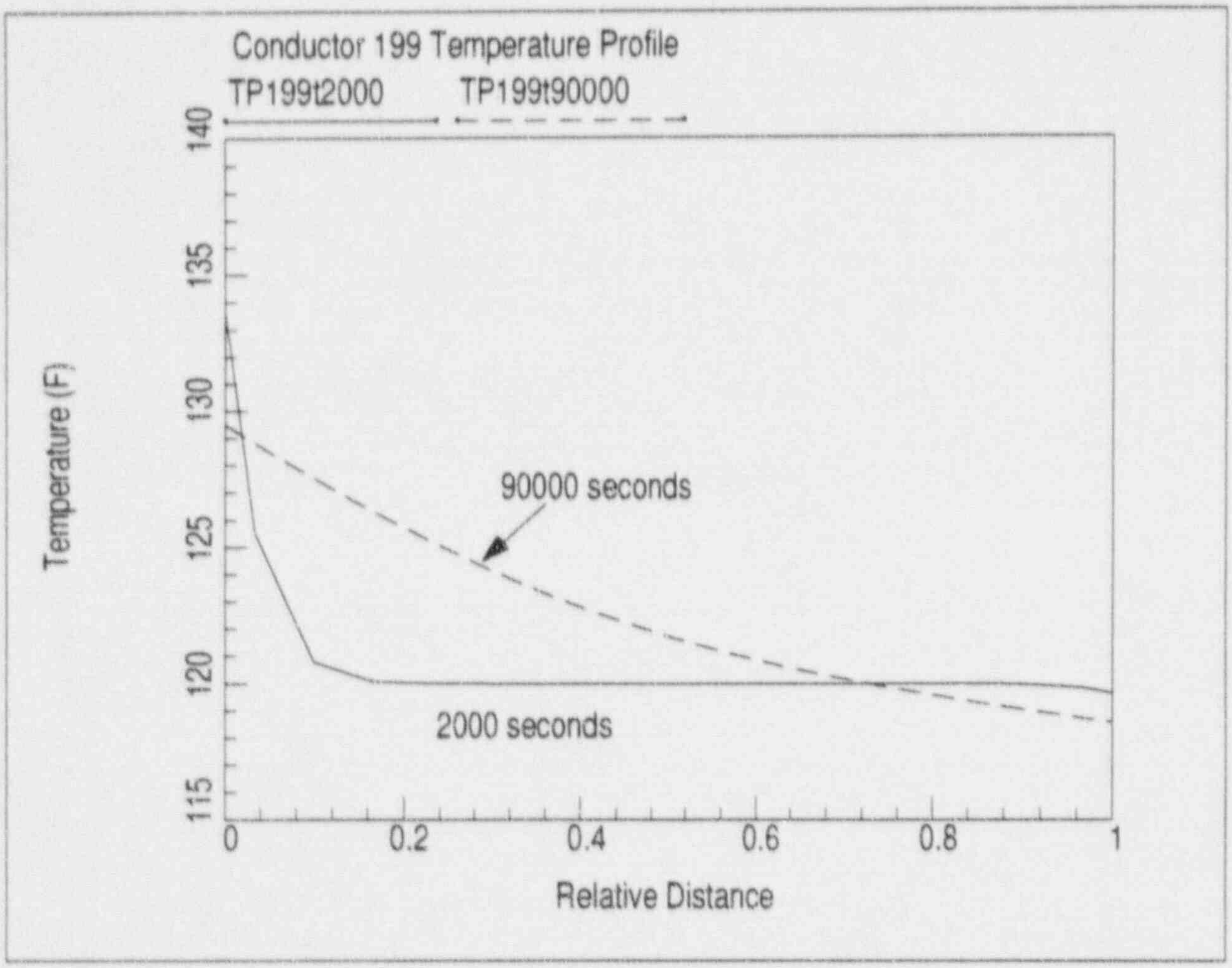


Figure 480.825-1 Conductor 199 Temperature Profile

OITS: 4868
RAI: 480.826

What are the technical references which support the tabulated values?

Response:

The technical references for the thermal conductor material properties shown in Table 4-49, "Conductor Material Properties," of Revision 1 of WCAP-14407, Reference 480.826-1 are as follows:

Concrete

1) ASHRAE Handbook 1989 Fundamentals, Pages 22.8 and 22.9,

2) Properties of Concrete in Reactor Vessels, R. D. Browne, March, 1967

3) Final Report on Thermal Properties of Concrete at Elevated Temperatures, Figure A.4, Hirth, Polivka, Pirtz, Clinch Breeder Reactor Plant project, ORNL-BRP-81/1/R1, August 1984

All Other Materials

1) Chemical Engineers' Handbook, Perry and Chilton, McGraw Hill Book Company (1973)

2) Mark's Standard Handbook for Mechanical Engineers, Avallone and Baumeister, McGraw Hill Book Company (1978)

3) Heat Transfer, J. P. Holman, McGraw Hill Book Company (1976)

4) Principles of Heat Transfer, F. Kreith, Second Edition, International Textbook Company, (1965)

5) Heat Transmission, McAdams, Third Edition, McGraw-Hill Book Company, (1954)

Emissivities

1) Heat Transmission, McAdams, Third Edition, McGraw-Hill Book Company, (1954)

2) Principles of Heat Transfer, F. Kreith, Second Edition, International Textbook Company, (1965)

3) Radiation Heat Transfer, Sparrow and Cess, Hemisphere Publishing Corporation, (1978)

4) Thermophysical Properties of Matter, Volume 8 Thermal Radiative Properties - Nonmetallic Solids, Y. S. Touloukian and D. P. Dewitt, Plenum Publishing Company.

5) "Reactor Passive Containment Cooling System Small Scale Containment Cooling Tests", R. F. Wright, D. R. Spencer, F. Delose, presented at ANS/ASME Nuclear Energy Conference, San Diego, August 23-26, 1992.

Reference:

480.826-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 4869
RAI: 480.827

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

Response:

Reference 480.827-1, Section 4.4.3H ranks radiation from the containment volume to containment heat sinks as low for the MSLB, low for LOCA phases blowdown, peak pressure, and long term, but medium for the LOCA refill phase. Also, Reference 480.827-1, Sections 4.4.3D and 4.4.3E rank internal heat sink conduction and heat capacity as medium or high for all LOCA phases and the MSLB. Thus, conservatively bounded material properties, including the material dry and wet emissivities, are used for AP600 internal conductors to maximize containment pressure.

The material properties are based on data available in the open literature, rather than on in-house tests, with the exception of the emissivity for inorganic zinc paint. The inorganic zinc paint emissivity is based on PCS Small-Scale Tests, as documented in Reference 480.827-2.

Reference:

480.827-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

480.827-2 WCAP-14134, "AP600 Passive Containment Cooling System Integral Small-Scale Tests", August 1994

SSAR Revision: NONE

OITS: 4870
RAI: 480.828

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

Response:

Material properties for the AP600 containment Evaluation Model are defined in the input to WGOTHIC as constants. The values for material properties are selected to minimize the energy transfer to the thermal conductors in the temperature range of interest for the AP600 containment Evaluation Model. The temperature range of interest is from 212°F to about 500°F. Thus, the reference temperature used to evaluate the thermal properties is dependent upon how the property varies with temperature. For example, over the temperature range of interest, the thermal conductivity of Type 304 stainless steel increases with increasing temperature. Thus, a value for thermal conductivity of Type 304 stainless steel at 212°F was used to define the thermal conductivity for stainless steel input to the WGOTHIC code for the AP600 containment Evaluation Model. This is conservative as minimizing heat transfer to thermal conductors maximizes the calculated containment pressure.

The references from which values of the AP600 containment Evaluation Model material thermal properties were selected are listed in the response to RAI 480.826. Also contained in these references is information, in either tabular or graphical form, about the temperature dependencies of the material properties. The values for material thermal properties selected for input to WGOTHIC for the AP600 containment Evaluation Model are listed in Table 4-49, "Conductor Material Properties" of Reference 480.828-1.

Reference:

480.828-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July, 1997.

SSAR Revision: NONE

OITS: 4871
RAI: 480.829

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

Response:

Figure 4-88 from WCAP-14407, Rev. 1 presents a generic depiction of a WGOTHIC conductor. A specific conductor type may or may not have four regions. Also, the region thickness, number of subregions, and material types for each region varies among specific conductor types. Thus, it is not possible to annotate Figure 4-88 to provide detailed information regarding region description, material type, etc. However, Section 4.3 of WCAP-14407, Rev. 1 does provide an explanation of Figure 4-88, and Tables 4-49 through 4-101 provide the conductor-specific information requested in this RAI.

SSAR Revision: NONE

OITS: 4872
RAI: 480.830

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

Response:

Structures and equipment of similar thickness and material composition are lumped together to form thermal conductors while conserving the total surface area of the structures. The thickness is specified such that total volume is preserved. Given the lumped parameter approach used in the AP600 Evaluation Model (EM) to represent containment volumes, all heat sinks in a given volume will be exposed to identical containment atmosphere conditions, so no benefit would be gained from a more precise modeling of thermal conductors. Equipment contained entirely within a volume and bulk concrete surfaces are modeled as one-sided thermal conductors, while structures forming walls or partitions between volumes are modeled as two-sided thermal conductors with each side connected to the appropriate volume.

SSAR Revision: NONE

OITS: 4873
RAI: 480.831

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

Response:

Biot numbers are not required input to GOTHIC to define conductor types. The Biot numbers were calculated for the material types shown in Section 4.3 of WCAP-14407, Rev. 0 to indicate appropriate selection of the subregion node thicknesses. The Biot numbers have been removed from the tables in WCAP-14407, Rev. 1, Section 4.3.

SSAR Revision: NONE

OITS: 4874
RAI: 480.832

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

Response:

Biot numbers are not a required input to WGOTHIC. Biot numbers were calculated to aid in the definition of subregion thicknesses. Details of the calculations are in calculation notes that are available for NRC audit. Also, please see response to RAI 480.831.

SSAR Revision: NONE

OITS: 4875
RAI: 480.833

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

Response:

Please see response to RAI 480.831 and 480.832.

SSAR Revision: NONE

OITS: 4370
RAI: 480.834

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

Response:

Please see response to RAI 480.831 and 480.832.

SSAR Revision: NONE

OITS: 4877
RAI: 480.835

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

Response:

Please refer to response to RAI 480.636.

SSAR Revision: NONE

OITS: 4878
RAI: 480.836

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

Response:

Please refer to response to RAI 480.636 for a description of the construction of these structures and the expected gaps. Concrete is placed in the steel plate modules in accordance with ACI 349, as described in SSAR subsection 3.8.3.6.3. There will be no air gap at the time of concrete placement. The 0.005 inch air gap is a conservative assumption used in the containment analyses.

SSAR Revision: NONE

OITS: 4879
RAI: 480.837

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

Response:

Material properties for the AP600 containment Evaluation Model are defined in the input to WGOTHIC as constants. Values for material properties are selected to minimize the energy transfer to the thermal conductors in the temperature range of interest for the AP600 containment Evaluation Model. The temperature range of interest is from 212°F to about 500°F. For example, over the temperature range of interest, the thermal conductivity of Type 304 stainless steel increases with increasing temperature. Thus, a value for thermal conductivity of Type 304 stainless steel at 212°F was used to define the thermal conductivity for stainless steel input to the WGOTHIC code for the AP600 containment Evaluation Model. This is conservative as minimizing heat transfer to thermal conductors maximizes the calculated containment pressure.

The references from which values of the AP600 containment Evaluation Model material thermal properties were selected are listed in the response to RAI 480.826. The values for material thermal properties selected for input to WGOTHIC for the AP600 containment Evaluation Model are listed in Table 4-49, "Conductor Material Properties" of Reference 480.837-1.

Reference:

480.837-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997.

SSAR Revision: NONE

OITS: 4880
RAI: 480.838

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

Response:

The roof of the shield building between the 249' -2" and 286' -" elevations is modeled through a combination of thermal conductors in Volume 98 and in clime 1. The 249' -2" elevation marks the transition from the cylindrical portion of the shield building to the conical roof portion of the shield building so the heat sinks in question cover the conical portion of the shield building above 249' -2" only.

Section 4.2.34.3 of WCAP-14407, Rev. 1 describes WGOTHIC thermal conductor number 197, which models the shield building roof between the 249' -2" elevation and the 256' -4" elevation. The remaining portion of the roof from the 256' -4" elevation up to the 286' -6" elevation is modeled with the third thermal conductor of the first clime. Note that this conductor appears once in each of the eight stacks.

In summary, the conical roof of the AP600 reactor building is properly accounted for through a combination of thermal conductors in Volume 98 and clime 1.

SSAR Revision: NONE

OITS: 4881
RAI: 480.839

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

Response:

The climes for the AP600 Evaluation Model are selected based on the clime selection from the WGOTHIC LST model. Guidance on application of the LST vessel noding scheme to the full scale AP600 Evaluation Model is provided in WCAP-14382, Section 6.4.

SSAR Revision: NONE

OITS: 4882
RAI: 480.840

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

Response:

The use of a single node is used to represent the outside containment annulus and downcomer for each axial elevation implies that a one-dimensional hydraulic model is used for the external flow paths. Validation of the external annulus modeling methods against the LST has been performed and is documented in WCAP-14382, Sections 5, 6, 7 and 8.

Another important effect is the heat transfer through the containment steel shell which is modeled through the use of eight stacks of eight climes each around the periphery of the containment shell. Any asymmetries computed inside containment stemming from the use of four inside containment quadrants are accounted for by the use of eight stacks in the climes model.

SSAR Revision: NONE

OITS: 4883
RAI: 480.841

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

Response:

The text on Page 4-244 of WCAP-14407, Rev. 1 has been corrected.

SSAR Revision: NONE

OITS: 4884
RAI: 480.842

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

Response:

Condensate which is assumed to be stripped from the inside surface of the AP600 containment shell due to contact with the crane rail and internal stiffener is immediately placed in the containment water pool. There is no time delay for transport of the stripped condensate.

SSAR Revision: NONE

OITS: 4885
RAI: 480.843

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

Response:

The WGOTHIC climes model of thermal radiation to a conductor surface assumes a constant, user-supplied surface temperature. For the AP600 Evaluation Model (EM), the "inner radiation boundary temperature" for the first conductor (containment shell) of the wet and dry stacks, as listed in Sections 4.4.1 and 4.4.2 of WCAP-14407, is the assumed constant temperature for the thermal radiation calculations. However, the containment shell is assigned conductor type 20 which uses 6 mils of oxidized carbo zinc paint as the inside surface material type (see Table 4-69 of WCAP-14407, Rev. 1), and the oxidized carbo zinc paint is assigned dry and wet emissivities of 1.E-10 (see Table 4-49 of WCAP-14407, Rev. 1). Therefore, thermal radiation is essentially shut off on the inside surface of the containment shell. This provides a conservative bias to the inside containment heat transfer model and is consistent with recommendations of Reference 480.843-1, Section 4.4.7B.

Reference:

480.843-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4886
RAI: 480.844

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

Response:

Although the mixed convection option is selected for the AP600 Evaluation Model (EM) containment shell inside surface, a multiplier of 1E-10 is applied to the forced convection component of the model (see Sections 4.4.1 and 4.4.2 of WCAP-14407). Therefore, only free convection is effectively used to model mass transfer on the shell inside surface. This approach is taken to access the mass transfer analogy to the McAdams correlation for turbulent-free convection heat transfer which was added as part of the WGOTHIC climes model (see Section 3 of WCAP-14407). This approach is consistent with guidance presented in Reference 480.844-1, Sections 4.4.7A and 4.4.7C.

Reference:

480.844-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4887
RAI: 480.845

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

Response:

The use of forced and free convection heat and mass transfer multipliers for the containment shell outside surface provides a conservative bias to the heat and mass transfer models and is consistent with guidance presented in Reference 480.845-1,Sections 4.4.7H and 4.4.7N.

Reference:

480.845-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4888
RAI: 480.846

Please describe how the gravity vector is calculated and explain how this term is used in the PCS film flow and WGOTHIC models. Are these gravity vectors used to help calculate the view factors used for radiation heat transfer? If not, please explain how the view factors are calculated for the surfaces at different angles.

Response:

The gravity vectors for the conductors of the climes model, summarized in WCAP-14407, Rev. 1, Sections 4.4.1 and 4.4.2, are used in the condensate film flow velocity calculation and do not play a role in the radiation heat transfer model. Since the climes consist of a series of concentric cylinders the view factor to characterize radiation between the cylinder surfaces is assumed to be 1.0. Only the dome region does not strictly consist of a concentric cylinder geometry, however, the surfaces in the dome region are also assumed to have view factors of 1.0.

The gravity vector represents the acceleration due to gravity that would occur along the surface of a clime. For a clime that represents a straight vertical section of the containment, the gravity vector magnitude would be equal to the gravitational acceleration constant, 32.2 ft/sec ^{2}. For a horizontal surface, the gravity vector would be 0.0 ft/sec ^{2}. For sloped, curved surfaces in between vertical and horizontal, the gravity vector is based on the straight line slope over the height of the clime. For instance, the thermal conductor representing the containment shell between the 240' -6" and 256' -4" elevations in the first clime (see Sections 4.4.1.2 and 4.4.2.1 in WCAP-14407, Rev. 1) has a total height of 15.83 ft and a radial dimension of 52.0 ft. The linear slope in this region is, therefore, arctan (15.83/52) = 16.932 degrees above horizontal. The gravity vector acting along the slope of this surface is then sin (16.9)+32.2 = 9.378 ft/sec ^{2}.

SSAR Revision: NONE

OITS: 4889
RAI: 480.847

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

Response:

As discussed in Reference 480.847-1, Sections 4.4.10A, 10B, 14A, and 14C, in the AP600, the shield building and baffle surfaces are essentially in forced convection by the time the external shell temperature rises significantly. Therefore, the mixed convection correlations can be used. Furthermore, the convective heat transfer mechanism on the shield building and baffle is given a low ranking. Thus, nominal heat transfer multipliers are used in the Evaluation Model.

Reference:

480.847-1 WCAP-14812, Rev. 1, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System", June 1997

SSAR Revision: NONE

OITS: 4890
RAI: 480.848

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

Response:

The heat and mass transfer is considered independently for each stack at each clime elevation outside containment. Thus, each stack provides an individual heat source or sink term to the adjacent inside containment volume. The individual clime heat source and sink terms are then summed or input to the standard GOTHIC model of the inside containment volumes.

SSAR Revision: NONE

OITS: 4891
RAI: 480.849

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

Response:

The heat and mass transfer is considered independently for each stack at each clime elevation outside containment. Thus, each stack provides an individual heat source or sink term to the upflow annulus gas volume at each clime elevation. The individual clime heat source and sink terms are then summed to arrive at a net rate of energy exchange with upflow annulus.

SSAR Revision: NONE

OITS: 4892
RAI: 480.850

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

Response:

The text in question on Page 4-272 of WCAP-14407, Rev. 1 has been modified to reflect that only Figure 4-93 is depicting the film flow rate. As mentioned in response to RAI 480.851, Figure 4-93, has been revised to reflect the evaporation limited film flow rate that is actually used for input to the AP600 Evaluation Model.

SSAR Revision: NONE

OITS: 4893
RAI: 480.851

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

Response:

The quantity input to the AP600 Evaluation Model is the evaporated flow rate presented in Table 4-102 and Figure 4-93 of WCAP-14407, Rev. 1. Section 7.5 of WCAP-14407, Rev. 1 presents a detailed description of the film mass flow rate calculations. The text in Section 4.4.3 has been modified to more clearly explain the basis for the film mass flow rates, to clearly indicate that the contents of Table 4-102 and Figure 4-93 reflect the actual AP600 EM input, and to reference Section 7 of WCAP-14407, Rev. 1.

SSAR Revision: NONE

OITS: 4894
RAI: 480.852

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

Response:

The first paragraph of Section 4.4.4 on Page 4-274 of WCAP-14407, Rev. 1 has been modified to more clearly describe the treatment of PCS film flow runoff.

The film mass flow rate input to WGOTHIC is the evaporated flow rate determined by the PCS film coverage model. WGOTHIC is expected to evaporate all of the applied flow, but the code is not constrained to do so. Any film runoff collects in "dummy" control volumes adjacent to the climes at the bottom of the PCS stacks. Specifically, dummy control Volumes 105 and 106 collect any runoff from the eighth clime on the wetted stacks. Therefore, water does not pool around the bottom of the containment shell, nor is it allowed to submerge a portion of the shell or reduce the air inlet area at the PCS downcomer-to-riser interface. Any runoff is collected in the dummy control volumes and removed from further consideration in the WGOTHIC calculations. This modeling approach is consistent with the AP600 design which incorporates storm drains at the base of the PCS riser.

SSAR Revision: NONE

OITS: 4895
RAI: 480.853

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

Response:

The reference values and the basis for their selection for outside containment initial conditions are given in Table 4-103 of WCAP-14407, Rev. 1. Similarly, the reference values and the basis for their selection for inside containment initial conditions is given in Table 4-104 of WCAP-14407, Rev. 1. WCAP-14407, Rev. 1, Section 4.5 has been modified to state the basis for the selection of initial condition values.

The basis for selecting the range of parameters considered for initial containment relative humidity is given in WCAP-14407, Rev. 1 Section 5.3, initial containment pressure in Section 5.4, initial containment temperature in Section 5.5, initial ambient humidity in Section 5.6 and initial ambient temperature in Section 5.7. The range of initial conditions input to the sensitivity calculations are summarized in Table 5-2. Results of the sensitivity calculations are summarized in Table 5-3 for the postulated LOCA, and in Table 5-4 for the postulated MSLB. The tabulated information presented in Tables 5-3 and 5-4 show that the variation in peak pressure calculated by the Evaluation Model for the range of sensitivities considered is small, and the reference values listed in Tables 4-103 and 4-104 provide for the calculation of a conservative (maximum) peak pressure at times of interest during the transient.

SSAR Revision: NONE

OITS: 4896
RAI: 480.854

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

Response:

References for the technical specification conditions for the IRWST are listed in Table 4-104 of WCAP-14407, Rev. 1. For the sensitivity studies detailed in Section 5, the minimum IRWST liquid volume fraction defined by the technical specifications was used and the IRWST inventory temperature was set equal to the ambient containment temperature. For example, for Case 3 of Section 5, the initial temperature of the ambient containment atmosphere and containment heat sinks was set to 50°F; the initial IRWST fluid inventory was also set to 50°F. The mass and energy releases assumed an IRWST temperature of 120°F, however, and were not modified for the sensitivity studies.

SSAR Revision: NONE

OITS: 4897
RAI: 480.855

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

Response:

Sections 4.5.2.1 and 4.5.2.2 of WCAP-14407, Rev. 1 have been expanded to include discussions of the contents of Figures 4-94 through 4-106. Relevant references are also included.

SSAR Revision: NONE

OITS: 4898
RAI: 480.856

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

Response:

Revised figures for LOCA and MSLB boundary conditions have been added to Section 4.5.2 of WCAP-14407, Rev. 1. Figure 4-105 and 4-106 show the time history of the same variable; the steam flow rate out the break. Figure 4-105 shows the first 50 seconds of the transient, whereas Figure 4-106 extends the history plot to 5000 seconds. Figure 4-105 was included to more clearly show the early steam release to containment resulting from the steam line break.

SSAR Revision: NONE

OITS: 4899
RAI: 480.857

Explain the significance of Figure 4-99 in WCAP-14407, Rev. 0.

Response:

Figure 4-99 of WCAP-14407, Rev. 0 became Figure 4-94 in WCAP-14407, Rev. 1, and is a plot of the IRWST injection flow for a postulated LOCA.

The IRWST drain rate is derived from the anticipated passive core cooling system (PXS) requirements as modeled in the AP600 mass and energy release calculation. The IRWST drain rate as a function of time then becomes an input quantity for the AP600 Evaluation Model (EM). The purpose of Figure 4-94 is, therefore, to document the time dependent AP600 EM input quantity. Section 4.5.2.1 of WCAP-14407, Rev. 1 has been expanded to include discussion of the contents of Figure 4-94.

SSAR Revision: NONE

OITS: 4900
RAI: 480.858

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

Response:

Figures defining the MSLB time-dependent boundary conditions have been added to Section 4.5.2 of WCAP-14407, Rev. 1 (Figures 4-104 through 4-106).

SSAR Revision: NONE

OITS: 4901
RAI: 480.859

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

Response:

Plots of water level vs time for all below-operating deck compartments have been added to Section 4.7.1 of WCAP-14407, Rev. 1. Also, please see response to RAI 480.712 which identifies the below-operating deck flow paths which will be completely or partially covered by the anticipated water level from a DECL-LOCA.

SSAR Revision: NONE

OITS: 4902
RAI: 480.860

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

Response:

The reference to containment volume expansion of 1.5% has been removed from WCAP-14407, Rev. 1, Section 4.5.1. A revised basis for containment internal free volume is provided in Table 4-107.

SSAR Revision: NONE

OITS: 4903
RAI: 480.861

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

Response:

Assumptions used in the metallic heat sink calculation are:

1. Non-heat sinks:
   - reactor vessel
   - steam generators
   - pressurizer
   - reactor coolant pumps
   - regenerative heat exchangers
   - cold legs
   - hot legs
   - main steam line
   - feedwater line

2. Most piping and valves, cable trays, HVAC ducts, cabinets, and electrical junction boxes are not included in the calculation. It is conservative to underestimate the quantities of metallic structures, and thereby underestimate heat sinks inside containment.

3. All structural materials are assumed to be carbon steel. Liner plates and material coatings of the plates are included as part of the concrete heat sink calculations. The IRWST is stainless steel.

4. Two types of paint are considered: epoxy and carbo zinc.

SSAR Revision: NONE

OITS: 4904
RAI: 480.862

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

Response:

Assumptions used in selecting flow paths are:

1. A flow path is any physical opening or area between two volumes where a fluid could pass. In addition, flow paths can occur at imaginary boundaries between two volumes where no physical barrier exists.
2. Physical openings between volumes in which grating exists should be considered as flow paths.
3. Hatches, cable trays, pipe trays, and HVAC ducts are considered to be closed to the inside environment of the containment building and are not considered as flow paths.
4. Pipe penetrations having pipes with a diameter of 12 inches or less are not considered as flow paths. Piping greater than 12 inches is assumed to have 4 inches of insulation completely around the outside perimeter.

SSAR Revision: NONE

OITS: 4905
RAI: 480.863

Please revise Table 4-104 to add the steel jacket-to-concrete air gap thickness, the internal flow paths loss coefficients, and the special dead-ended room modeling approach.

Response:

Dimension specifications for modeling the steel jacket-to-concrete air gap thickness in conductors is provided in Section 4.3 of WCAP-14407, Revision 1, for conductor types 27, 28, 29, 31, 32, 33, 34, 35, 37, 38, 39, 40, 41, 43, 44, 46, 47, 48, 49 and 50.

The information on loss coefficients for the internal flow paths is provided in WCAP-14407, Rev. 1, Table 4-111 in 24 separate flow path summary tables (please see the Table of Contents for specific table numbers) and is summarized in Section 4.2.xx.1 where xx is the subsection numbers 1 through 35.

The information on special modeling assumption for the dead-ended compartments is provided in WCAP-14407, Rev. 1 in Sections 4.2.1.4, 4.2.3.4, 4.2.4.4, 4.2.9.4, and 4.2.11.4, which are entitled Special Modeling Assumptions.

The requested information is too voluminous to be presented in a single summary table. Please refer to the specific section and table numbers summarized above to obtain the requested information.

SSAR Revision: NONE

OITS: 4906
RAI: 480.864

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

Response:

Appropriate references to the standard safety analysis report and technical specification values have been added to Section 4.5 of WCAP-14407, Rev. 1.

SSAR Revision: NONE

OITS: 4907
RAI: 480.865

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

Response:

The use of a maximum initial internal temperature is a conservative assumption that minimizes the effect of internal heat sinks on reducing the calculated containment pressure.

SSAR Revision: NONE

OITS: 4908
RAI: 480.866

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

Response:

A reference for RCS volume expansion due to uncertainty and thermal expansion has been added to WCAP-14407, Rev. 1, Table 4-108.

SSAR Revision: NONE

OITS: 4909
RAI: 480.867

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

Response:

A reference for the conservative increase in core-stored energy has been added to WCAP-14407, Rev. 1, Table 4-108.

SSAR Revision: NONE

OITS: 4910
RAI: 480.868

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

Response:

A reference for increasing initial steam generator mass inventory by 10% has been added to Table 4-108 of WCAP-14407, Rev. 1.

SSAR Revision: NONE

OITS: 4911
RAI: 480.869

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

Response:

The flow paths used in the AP600 Evaluation Model to simulate LOCA and MSLB break locations as well as the location, timing and discharge of 4th-stage ADS are discussed in Section 4.5.2 of WCAP-14407, Rev. 1. Also, a master table describing all flow paths used in the AP600 Evaluation Model (EM) has been provided in Table 4-111 of WCAP-14407, Rev. 1. This table includes details of the flow paths used to model the break and 4th-stage ADS discharge locations.

SSAR Revision: NONE

OITS: 4912
RAI: 480.870

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

Response:

Hydrogen mass is not considered in the AP600 containment DBA analysis. This is consisten. with current Westinghouse DBA analysis methodology.

SSAR Revision: NONE

OITS: 4944
RAI: 480.902

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

Response:

The sensitivity calculation is attached.

SSAR Revision: NONE

AP600

AP600 PCS Evaporation Rate Sensitivity to Gamma Min

1.0 Approach

Calculations were performed with the PCS water coverage model to determine the sensitivity of the PCS cooling water evaporation rate to Γ_{min} for the range $0 < \Gamma_{min} < 200$ lbm/hr-ft. The reference value used in the Evaluation Model is $\Gamma_{min} = 120$ lbm/hr-ft. In addition to the independent variable in this study, Γ_{min}, the evaporation heat flux and the PCS delivered water flow rate vary with time. An examination of how each of these variables change with time suggests an approach for organizing the calculation:

- Figure 480.902-1 shows the PCS delivered flow rate is nearly constant except where step reductions in the PCS delivered flow rate occur at 10,800 and 108,000 seconds (3 and 30 hours). The time intervals and delivered flow rates assumed for this analysis are presented in Table 480.902-1. The flow rates are the minimum that occur over each time interval. One set of calculations is performed for each of the three time intervals.

- Figure 480.902-1 also shows the WGOTHIC calculation of the time variation in the external film surface heat flux due to evaporation for a design basis LOCA. The surface heat flux peaks at less than 3800 BTU/hr-ft^2 at approximately 1000 sec. Note that after 10,800 sec the heat flux remains within a relatively small range of 1000 to 2000 BTU/hr-ft^2. The approximate heat flux range during each time interval is listed in Table 480.902-1. Heat flux is treated as a parameter in each set of calculations.

- The PCS film coverage model was run with Γ_{min} as the independent variable, using values of 0, 50, 100, 150, and 200 lbm/hr-ft for the calculations. The nominal, or reference value is 120 lbm/hr-ft.

Since water evaporation is the dominant energy removal process, the containment pressure history only changes if the water evaporation rate history changes. Thus the effect of Γ_{min} on the evaporation rate will first be considered, then the sensitivity of pressure to the water evaporation rate history will be considered.

Table 480.902-1
Parameters for Γ_{min} Sensitivity Study

Time Interval, hr sec	0.94 to 3 337 to 10,800	3 to 30 10,800 to 108,000	>30 >108,000
Minimum Delivered Flow Rate, gpm lbm/sec	426 58.7	110 15.2	63 8.67
Approximate Heat Flux, BTU/hr-ft^2	1500 to 4000	1000 to 2000	1000 to 2000

2.0 Calculations

The rate at which water evaporates from the containment shell was calculated for the specified range of Γ_{min} with heat flux as a parameter for each flow step. Figures 480.902-2, -3, and -4, show results for the three sets of calculations corresponding to applied water flow rates of 58.7, 15.2, and 8.67 lbm/sec, respectively. Each figure shows that at low heat fluxes, the evaporation rate is unaffected by Γ_{min}. However, if the heat flux is high enough, the evaporation rate decreases with increasing Γ_{min}. The figures also permit a simple calculation of the runoff flow rate by taking the difference between the delivered and evaporated flow rates. At sufficiently high heat fluxes, the runoff flow rate increases with increasing Γ_{min}, but always decreases with increasing heat flux.

Figure 480.902-2 shows Γ_{min} has no effect on the evaporation rate during the 0 to 3 hour time interval, since the peak heat flux is less than 4000 BTU/hr-ft^2. It can be concluded that the evaporation rate does not change over the range of Γ_{min} examined for time less than 3 hr. Since the evaporation rate does not change, the containment pressure response is not sensitive to Γ_{min} during the time containment pressure peaks and begins to reduce. The initial PCS water flow rate is sufficiently high compared to the amount of water evaporated that Γ remains above Γ_{min}, and the wetted surface area does not decrease.

Figure 480.902-3 shows the maximum evaporation rate at Γ_{min} = 200 lbm/hr-ft and 2000 BTU/hr-ft^2 is only 10% less than at the reference value of Γ_{min} = 120 lbm/hr-ft. The consequence of an increase in Γ_{min} during this time interval is a modest increase in the pressure during the time out to 24 hours. At lower heat fluxes the sensitivity is less.

Figure 480.902-4 shows that at the delivered flow rate of 8.67 lbm/sec the evaporation rate is weakly sensitive to Γ_{min}. The effect on pressure is small relative to the reference case.

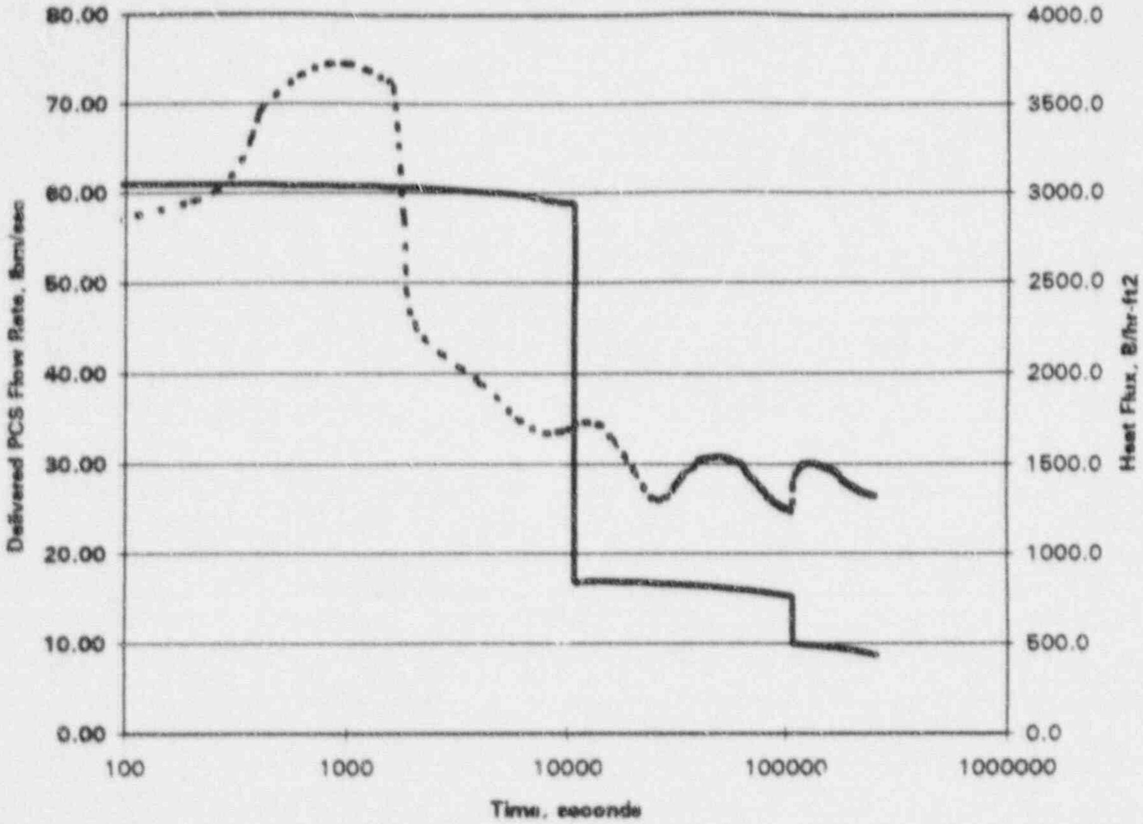


Figure 480.902-1 PCS Water Flow Rate and Evaporation Heat flux on the Outer Surface of the AP600 Containment Shell

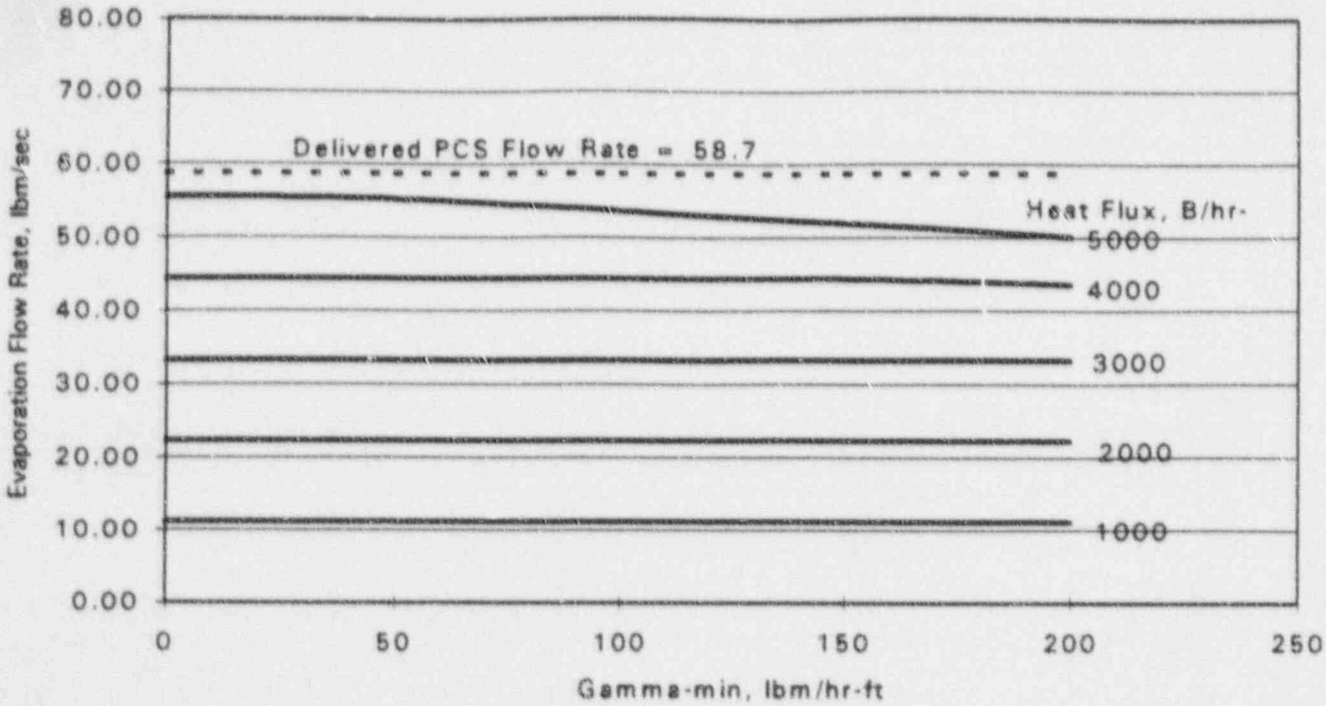


Figure 480.902-2 **Evaporation Rate Sensitivity to Gamma-min at a PCS Flow Rate of 58.7 lbm/sec**

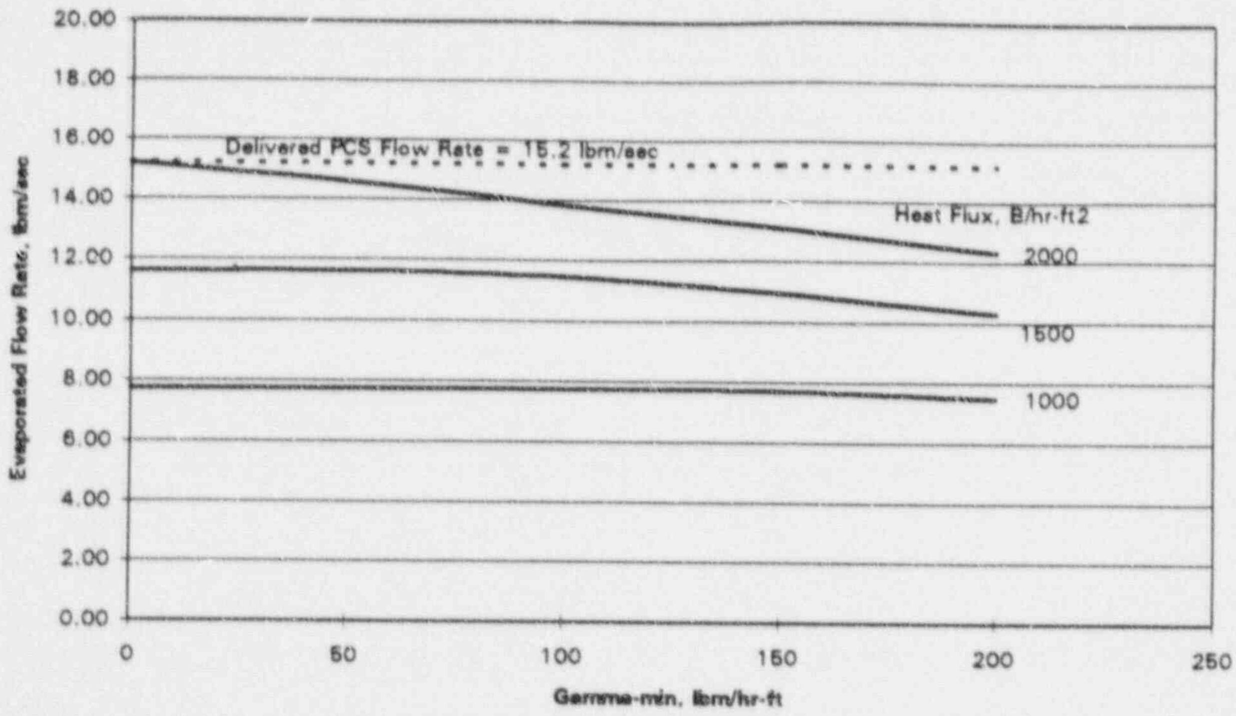


Figure 480.902-3 Evaporation Rate Sensitivity to Gamma-min at a PCS Flow Rate of 15.2 lbm/sec

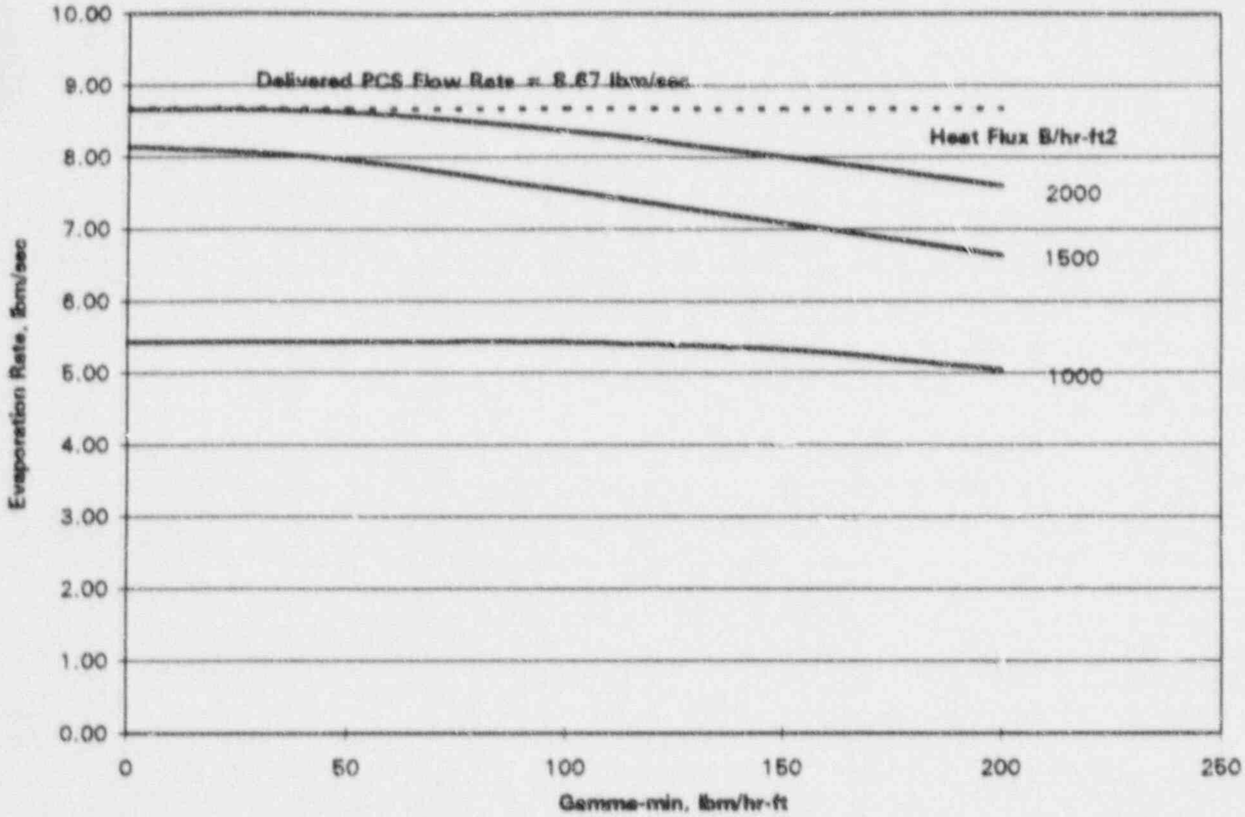


Figure 480.902-4 Evaporation Rate Sensitivity to Gamma-min at a PCS Flow Rate of 8.67 lbm/sec

OITS: 5460
RAI: 480.1022

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The applicant needs to expand the one sentence discussion of the technical differences between WGOTHIC Versions 4.0 and 4.1 presented in the cover letter and incorporate this discussion in the body of WCAP-14407, specifically the over-prediction of heat removal from a clime which experiences dryout. Describe the changes to the "ccvel" subroutine and its impact on the annulus inertia lengths.

Response:

Version 4.1 of WGOTHIC was used to perform all calculations reported in WCAP-14407, Rev. 1, "WGOTHIC Applications to AP600". The code is described in Section 3, "Overview of WGOTHIC," of WCAP-14407, Rev. 1.

WGOTHIC solver version 4.1 was created to correct an error in the clime model. This error resulted in the over-prediction of heat removal by a partially wet clime conductor surface. To correct this error, the computational capabilities of the Westinghouse clime model source code were extended to vary the area of the dry portion of a partially wet clime conductor surface and to track the shell inside and outside temperatures of both the wet and dry portions of a partially wet clime.

The annulus region of the AP600 containment model is divided into two sets of stacked lumped-parameter volumes, one representing the downcomer and the other representing the riser. In reviewing the output from a previous AP600 containment model, it was discovered that the cell centered velocities were about twice the junction velocities in this region. This resulted in an over-prediction of the resulting heat removal by the PCS since the cell centered velocity is used as an input to the Westinghouse clime model heat and mass transfer calculations.

The cell centered velocity is calculated by GOTHIC subroutine ccvel. The junction inertia length input values are used as weighting factors in the cell centered velocity calculation for the lumped parameter volume. Using junction inertia length input values based on the cell height results in a cell centered velocity that is about twice the corresponding junction velocity for the lumped parameter volumes in the annulus region of the AP600 containment model. Consequently, the junction inertia length input values for this region were adjusted to yield a more accurate cell centered velocity for the Westinghouse clime model heat and mass transfer calculations.

Use of the updated subroutine ccvel in WGOTHIC solver version 4.1, with junction inertial lengths calculated consistent with the formulation of ccvel, result in the accurate calculation of velocities in the fluid cells or nodes.

SSAR Revision: NONE

OITS: 5462
RAI: 480.1024

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

a) Why was an arbitrary selection process used to define the downcomer-to-riser volume ratio?
b) Why is the sensitivity model much shorter than the AP600?
c) The applicant needs to compare (in tabular form) the Reynolds, Prandtl, and Grashof numbers for the coolant flow through the downcomer and annulus in the Section 12.1 sensitivity study model to the Section 12.2 AP600 containment model.

Response:

The introduction to Section 12.2, "Model Descriptions," of WCAP-14407 Rev. 1, states that the simplified model used for these sensitivity calculations provides for the study of phenomenological changes caused by changing the clime noding detail. No attempt was made to model the AP600 design with the simple annulus clime model described in Section 12.2.1 of WCAP-14407, Rev. 1. Rather, the phenomenological response to changes in the clime noding predicted by the simple model, relative to the success criteria identified in Section 12.1.5, "Success Criteria," of WCAP 14407, Rev. 1 is applicable to the AP600.

On this basis, a direct comparison between calculations obtained from the sensitivity model and the AP600 plant model is not provided.

SSAR Revision: NONE

OITS: 5463
RAI: 480.1025

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

a) The applicant needs to justify the use of the selected film flow rate for two of the three sensitivity studies. This value is 20 times greater than the value selected which results in dryout in the simulated riser section.
b) The applicant needs to compare the Gamma,(Γ - lbm/ft-sec), and the Reynolds number for the film flows used in the Section 12.1 sensitivity study model to the Section 12.2 AP600 containment model.

Response:

It is noted in the introduction to Section 12.2, "Model Descriptions," of WCAP-14407, Rev. 1 that the simplified model used for these sensitivity calculations provides for the study of phenomenological changes caused by changing the clime noding detail and that a detailed comparison of the results calculated with this model to those calculated by the AP600 model is not meaningful. No attempt was made to model the AP600 design with the simple annulus clime model described in Section 12.2.1 of WCAP-14407, Rev. 1. Rather, the phenomenological response to changes in the clime noding predicted by the simple model, relative to the success criteria identified in Section 12.1.5, "Success Criteria," of WCAP 14407, Rev. 1 is applicable to the AP600.

a) As stated in Section 12.2.1 of WCAP-14407, Rev. 1, "...the film boundary conditions are selected to cover a range of temperatures and flow rates considered typical for the AP600 plant." For example, the temperature of the water film applied to the simplified annulus model, 100°F and 200°F, bounds the applied film temperature of the AP600 containment Evaluation Model. The purpose of the sensitivity study was to observe predictions of phenomenological changes and trends associated with clime noding detail, not simulate the AP600 plant.

b) As noted above, a direct comparison between calculations obtained from the sensitivity model and the AP600 plant model is not meaningful.

SSAR Revision: NONE

OITS: 5464
RAI: 480.1026

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1. In Figure 12-3, the applicant needs to identify the climes and resistances which represent the thick steel plate. Also, identify the climes and resistances which represent the acrylic plate.

Response:

In WCAP-14407, Rev. 1, Figure 12-3, the conductors "1ax" represent the 0.5-inch metal plate, where x varies from 1 to the maximum number of climes in the model. Similarly, the conductors "1bx" represent the acrylic cover where "x" again varies from 1 to the maximum number of climes in the model.

SSAR Revision: NONE

OITS: 5465
RAI: 480.1027

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

a) What does the thick steel plate represent in the AP600? If it is the AP6C0 containment shell, why is it much thinner and why not include the inorganic zinc paint? If it is the baffle, why was the baffle modeled much thicker than the actual baffle dimension for the AP600?
b) What does the acrylic plate represent in the AP600? If it is the baffle, does the acrylic plate provide a satisfactory representation of the heat transfer to the downcomer?
c) What is the impact of the acrylic baffle on the sensitivity results?
d) Compare the Biot number for the thick steel plate and the acrylic cover to either the AP600 containment shell or baffle plate, which ever is correct.

Response:

It is noted in the introduction to Section 12.2, "Model Descriptions," of WCAP-14407 "WGOTHIC Applications to AP600 -- Revision 1," that the simplified model used for these sensitivity calculations provides for the study of phenomenological changes caused by changing the clime noding detail and that a detailed comparison of the results calculated with this model to those calculated by the AP600 model is not meaningful. No attempt was made to model the AP600 design with the simple annulus clime model described in Section 12.2.1 of WCAP-14407 (Revision 1). Rather, the phenomenological response to changes in the clime noding predicted by the simple model, relative to the success criteria identified in Section 12.1.5, "Success Criteria," of WCAP 14407 (Revision 1) is applicable to the AP600.

a) The 0.5-inch steel plate is the heat source for the simple annulus clime model; it represents a source of thermal energy. The simple clime model was developed to study changes due to clime noding detail and does not model the AP600.

b) The acrylic plate separates the annulus into a downcomer and a riser. The simple clime model was developed to study changes due to clime noding detail and does not model the AP600.

c) Heat transfer through the acrylic plate has a negligible effect on the natural draft flow rate of air through the annulus.

d) The simple clime model was developed to study changes due to clime noding detail and does not model the AP600. A detailed comparison of the results calculated for this model to those calculated of the AP600 is not meaningful.

SSAR Revision: NONE

OITS: 5466
RAI: 480.1028

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

The applicant needs to justify the selection of a sub-atmospheric pressure boundary condition. Also, identify the node noted on Page 12-6 as the fixed pressure boundary: Figure 12-3 shows an exit and an entrance node, Nodes 1P and 2P, which are unconnected.

Response:

The simple annulus model does not simulate the AP600 design. The purpose of the sensitivity calculations performed with the simple annulus model is to study and evaluate changes in phenomenological response calculated when the clime noding is changed. The pressure of 14.2 psia is representative of the atmospheric pressure at 1200 ft. above sea level.

In WCAP-14407, Rev. 1, Figure 12-3, Nodes 1P and 2P are the fixed-pressure boundary conditions. Node 1P is connected to Volume 10 (the downcomer entrance) by flow path 10. Node 2P is connected to Volume 1, (the riser exit), by flow path 9.

SSAR Revision: NONE

OITS: 5467
RAI: 480.1029

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

On Page 12-5 of WCAP-14407, the applicant states that the riser and downcomer stacks were divided into nodes of equal size. What values were given for the volumes, flow areas, frictional lengths and boundary conditions for the exit and entrance nodes (Nodes 1P and 2P of Figure 12-3)?

Response:

In WCAP-14407, Rev. 1, Figure 12-3, Nodes 1P and 2P represent fixed pressure boundary conditions (14.2 psia) and do not have volumes associated with them. The flow area for the junctions connecting the boundary conditions to the riser and downcomer stacks are the same as the values used for the other junctions in the riser and downcomer. The values for frictional length sum to the height of the stack.

SSAR Revision: NONE

OITS: 5468
RAI: 480.1030

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

Why does the drain require the addition of a dummy clime? Could not a simple volume (Volume 18) be added to facilitate draining of the annulus runoff, instead of a dummy clime which has dummy heat transfer connections to the containment and from the downcomer? As the AP600 Evaluation Model uses an "evaporation limited flow," why was it necessary to add this dummy clime to the AP600 Evaluation Model?

Response:

Placing the film runoff flow into the annulus could perturb the air flow, particularly at the higher film flow rates used in the simple annulus model. The purpose of the dummy clime is to allow any liquid film remaining on the surface of the clime conductors to flow directly into a drain volume that is located outside of the annulus air flow path. The simple annulus model drain volume (Volume 18) is also used to collect liquid from the annulus air flow path that might form as a result of falling droplets.

In the AP600 containment Evaluation Model, the dummy clime does not connect to either the containment or downcomer volumes. Therefore, there is no heat transfer between the containment and annulus through the dummy clime. Similar to the simple annulus model, a drain volume (Volume 101), is connected to the dummy clime in the Evaluation Model, and is also used to collect liquid from the annulus air flow path that might form as a result of falling droplets.

The dummy clime was required to be added to the Evaluation Model to perform the water coverage sensitivity studies presented in Section 7 of Reference 480.1030-1. The full delivered PCS flow rate was used for these sensitivity studies, so there was a substantial amount of film runoff during the first 3.5 hours of the transient.

References:

480.1030-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997

SSAR Revision: NONE

OITS: 5469
RAI: 480.1031

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

The applicant needs to justify the use of a constant temperature heat source for the Clime Sensitivity Model. In the WGOTHIC evaluation model, the temperature of a dry clime would be much hotter than a wet clime. This model forces the surface temperature to remain the same, artificially minimizing the impact of temperature dependent differences on evaporation and radiation heat transfer rates.

Response:

The simple annulus model does not simulate the AP600 design. The purpose of the sensitivity calculations performed with the simple annulus model is to study and evaluate changes in phenomenological response calculated when the clime noding is changed.

The fixed inside surface boundary conditions result in the calculation of different outside surface temperatures, depending upon whether the outside surface is wet or dry. Sensitivity calculations were performed for wet (both hot and cold films were applied), partially wet, and dry outside surface conditions to cover the range of phenomena that the AP600 containment Evaluation Model is expected to address.

SSAR Revision: NONE

OITS: 5470
RAI: 480.1032

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

The applicant needs to confirm the accuracy of the information presented in Figures 12-18 and 12-19. Have these two figures been erroneously exchanged during the document preparation process?

Response:

Figures 12-18 and 12-19 had been erroneously exchanged during document preparation. The error has been corrected in WCAP-14407, Rev. 1.

SSAR Revision: NONE

OITS: 5471
RAI: 480.1033

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

The applicant needs to provide plots showing the annulus and downcomer pressure, density, and flow velocity profiles for the three clime models at 2000 seconds.

Response:

This RAI requests additional plotted information from calculations obtained using the simplified annulus model. The simple annulus model does not simulate the AP600 design. The purpose of the sensitivity calculations performed with the simple annulus model is to study and evaluate changes in phenomenological response calculated when the clime noding is changed. Results of calculations performed with the simplified annulus model should not be inferred to represent typical values that would be obtained from calculations performed with the AP600 containment Evaluation Model.

The requested plots are attached. The titles to the plots, listed below, incorporate a case number that is related to the case numbers given in Reference 480.1033-1, Table 12-1, "Input Parameters for Annulus Clime Model Sensitivity Study,".

Figure 480.1033-1	Case 1, All Dry Case, Downcomer Pressure
Figure 480.1033-2	Case 1, All Dry Case, Downcomer Density
Figure 480.1033-3	Case 1, All Dry Case, Downcomer Velocity
Figure 480.1033-4	Case 1, All Dry Case, Riser Pressure
Figure 480.1033-5	Case 1, All Dry Case, Riser Density
Figure 480.1033-6	Case 1, All Dry Case, Riser Velocity
Figure 480.1033-7	Case 2, All Wet, High Subcooling Case, Downcomer Pressure
Figure 480.1033-8	Case 2, All Wet, High Subcooling Case, Downcomer Density
Figure 480.1033-9	Case 2, All Wet, High Subcooling Case, Downcomer Velocity
Figure 480.1033-10	Case 2, All Wet , High Subcooling Case, Riser Pressure
Figure 480.1033-11	Case 2, All Wet, High Subcooling Case, Riser Density
Figure 480.1033-12	Case 2, All Wet, High Subcooling Case, Riser Velocity
Figure 480.1033-13	Case 3, All Wet, Low Subcooling Case, Downcomer Pressure
Figure 480.1033-14	Case 3, All Wet, Low Subcooling Case, Downcomer Density

Figure 480.1033-15	Case 3, All Wet, Low Subcooling Case, Downcomer Velocity
Figure 480.1033-16	Case 3, All Wet, Low Subcooling Case, Riser Pressure
Figure 480.1033-17	Case 3, All Wet, Low Subcooling Case, Riser Density
Figure 480.1033-18	Case 3, All Wet, Low Subcooling Case, Riser Velocity
Figure 480.1033-19	Case 4, Partially Wet, High Subcooling Case, Downcomer Pressure
Figure 480.1033-20	Case 4, Partially Wet, High Subcooling Case, Downcomer Density
Figure 480.1033-21	Case 4, Partially Wet, High Subcooling Case, Downcomer Velocity
Figure 480.1033-22	Case 4, Partially Wet, High Subcooling Case, Riser Pressure
Figure 480.1033-23	Case 4, Partially Wet, High Subcooling Case, Riser Density
Figure 480.1033-24	Case 4, Partially Wet, High Subcooling Case, Riser Velocity

In reading the figures listed above, note that the calculated results for the 4, 8, and 16 clime models have been plotted on the same axes for comparison. As was done for the plots of Figure 12-12 through Figure 12-23 of Reference 480.1033-1, the data from the 8 and 4 clime models is represented as 2 and 4 points, respectively, on the plots to match the 16 points of the 16 clime model. Also, Node 16 is always taken to be at the bottom of both the downcomer and the riser. Finally, the velocity of the bottom of the downcomer is calculated as the average of the node above it (in the downcomer) and the bottom node in the riser portion of the model.

References:

480.1033-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997

SSAR Revision: NONE

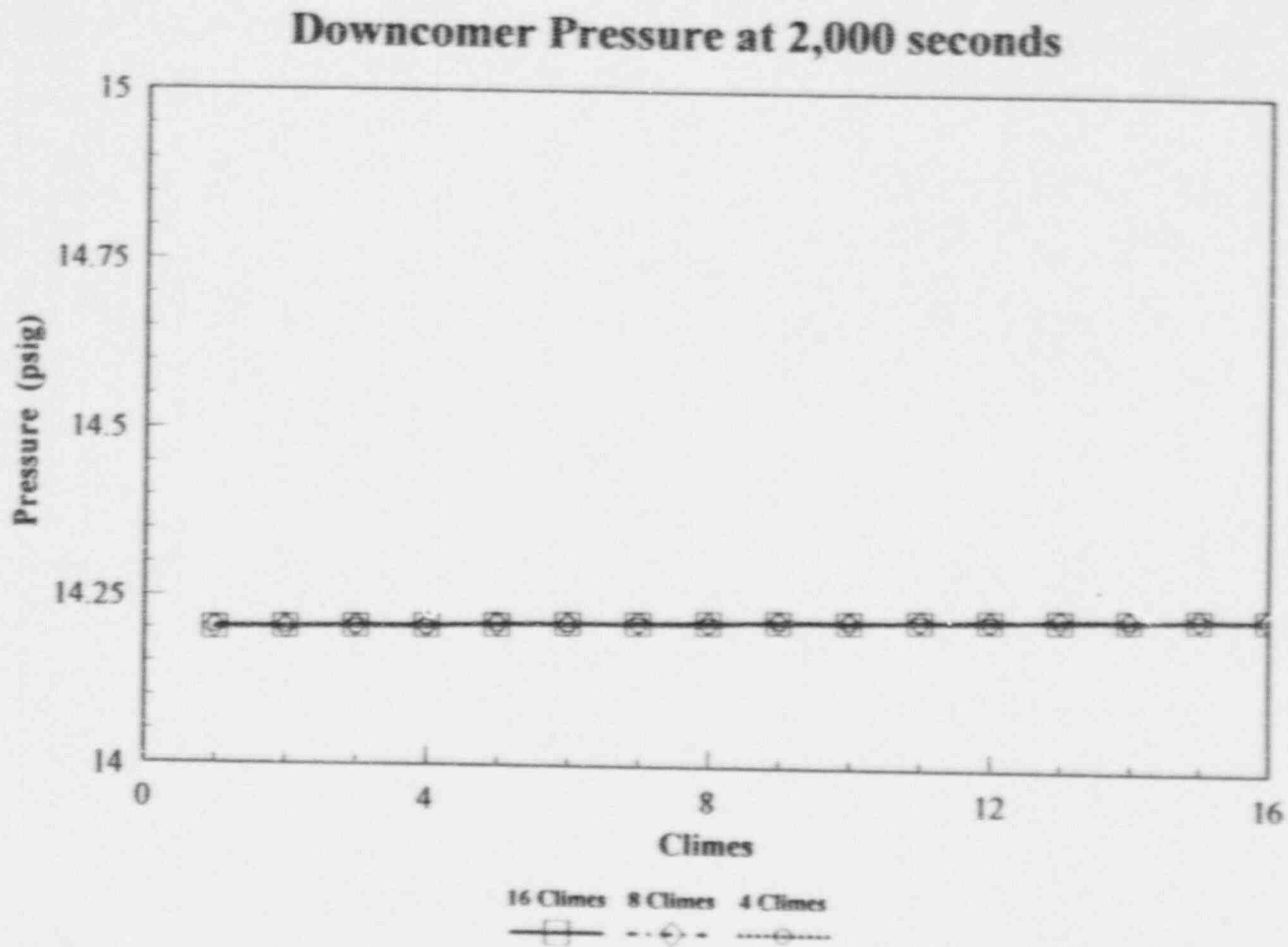


Figure 480.1033-1 Case 1, All Dry Case, Downcomer Pressure

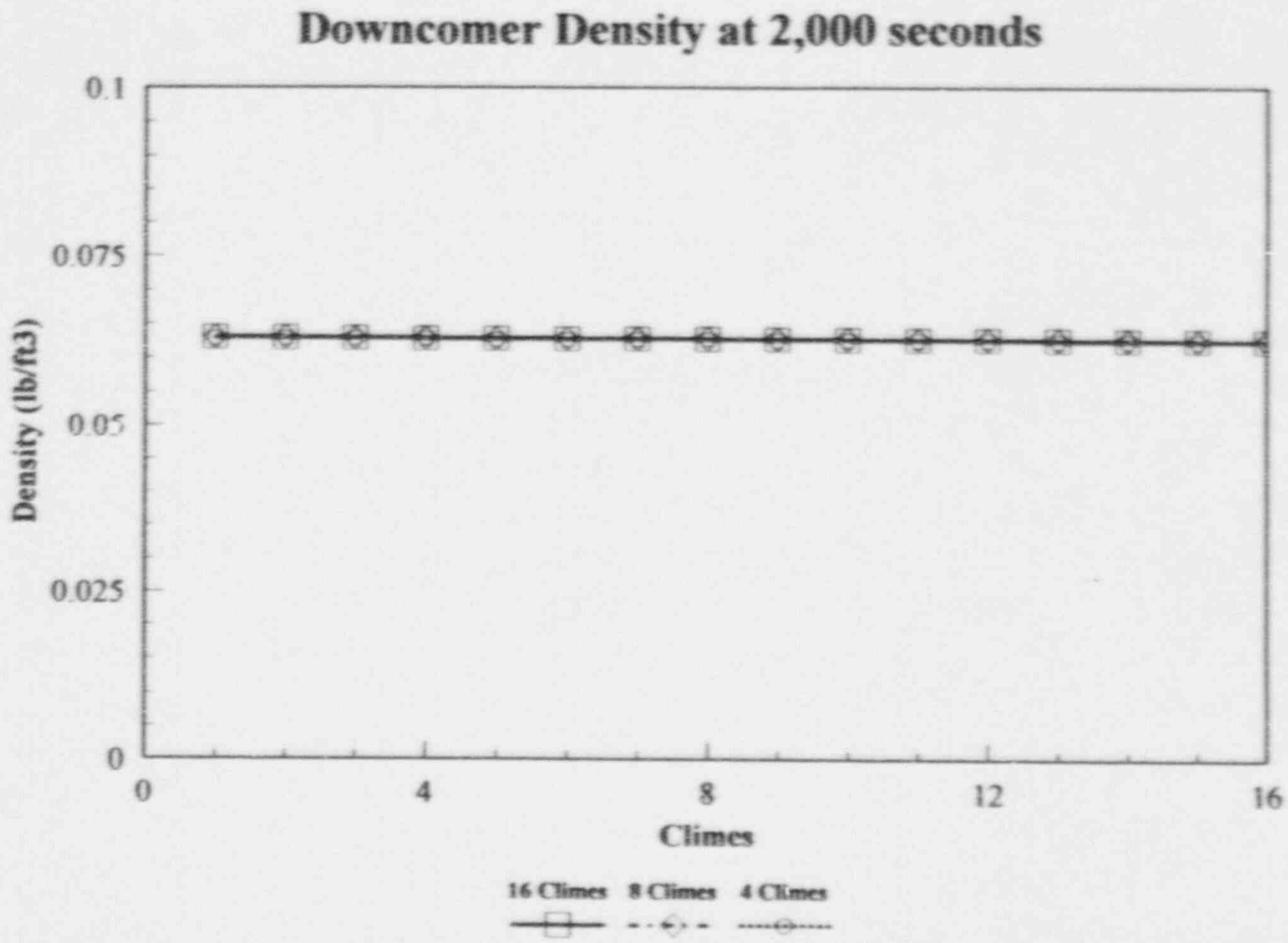


Figure 480.1033-2 Case 1, All Dry Case, Downcomer Density

AP600

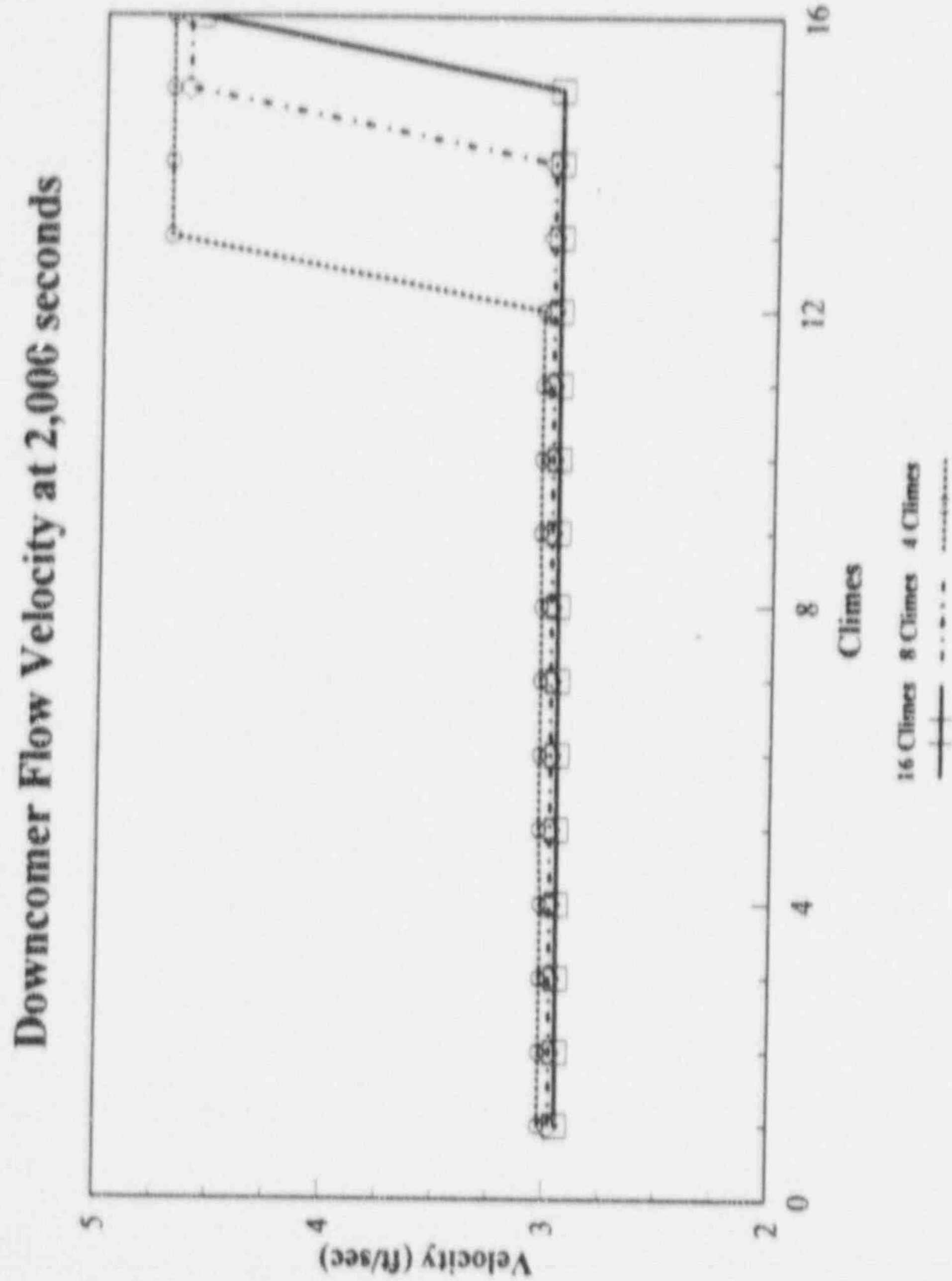


Figure 480.1033-3 Case 1, All Dry Case, Downcomer Velocity

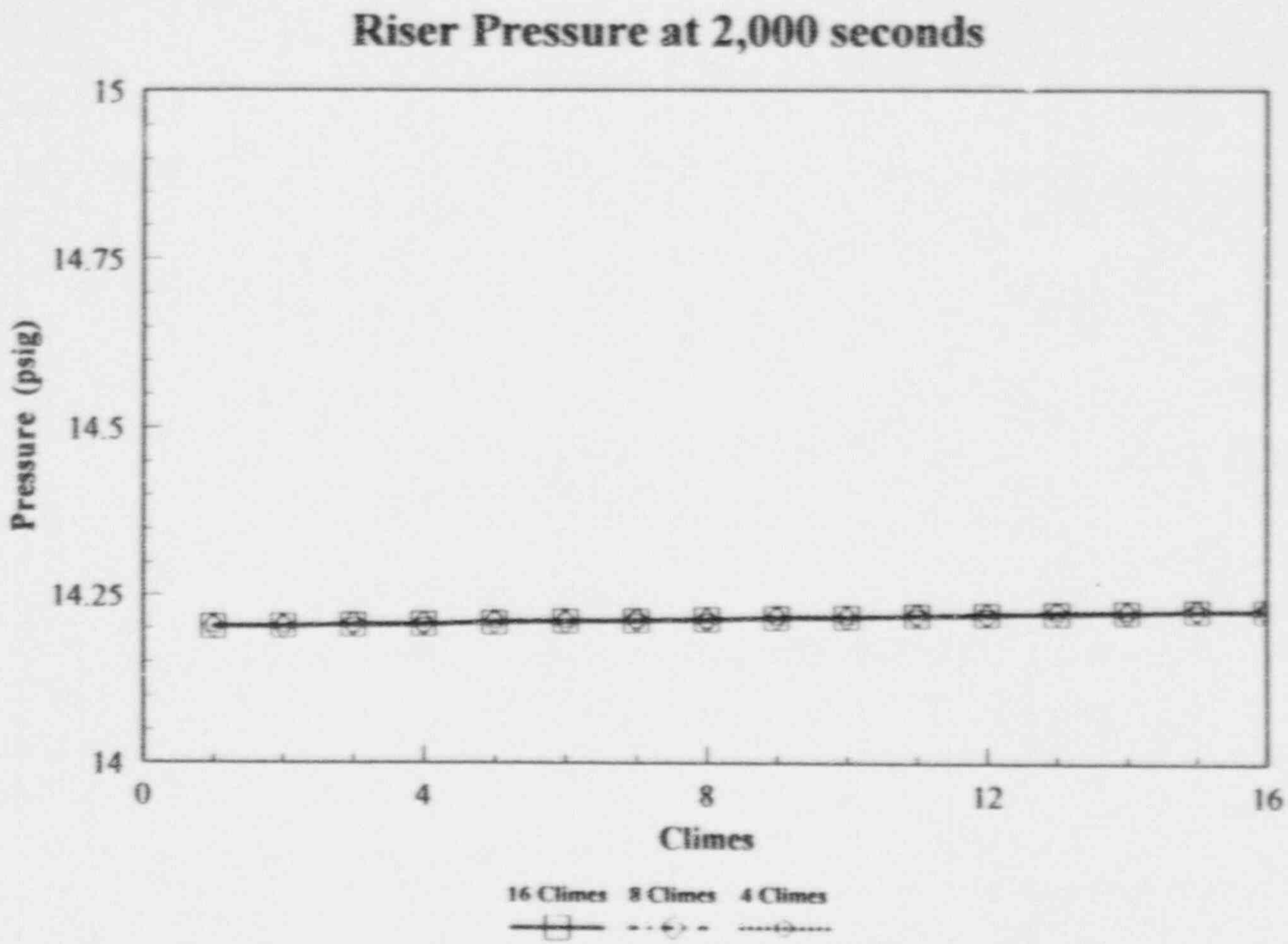


Figure 480.1033-4 Case 1, All Dry Case, Riser Pressure

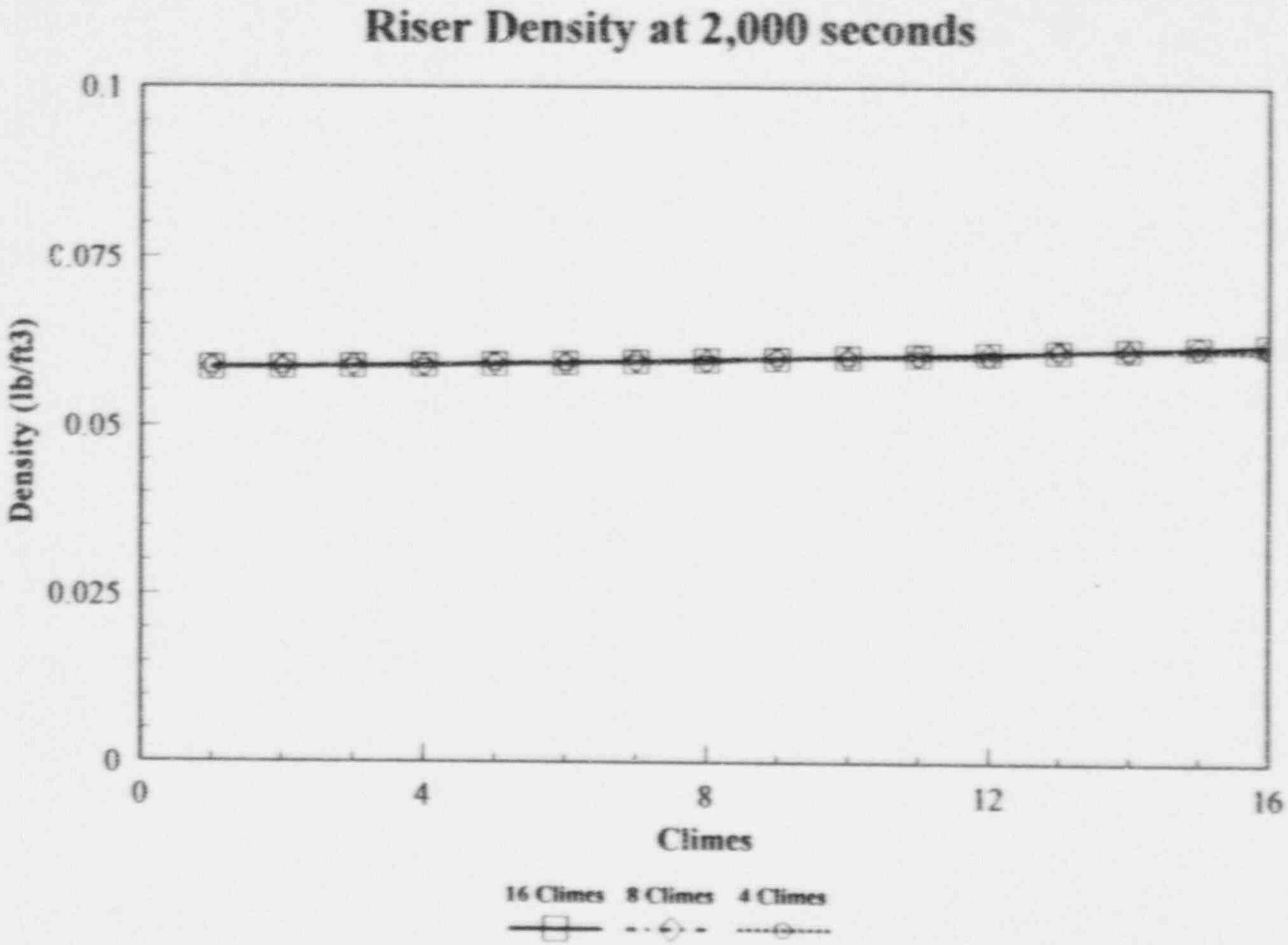


Figure 480.1033-5 Case 1, All Dry Case, Riser Density

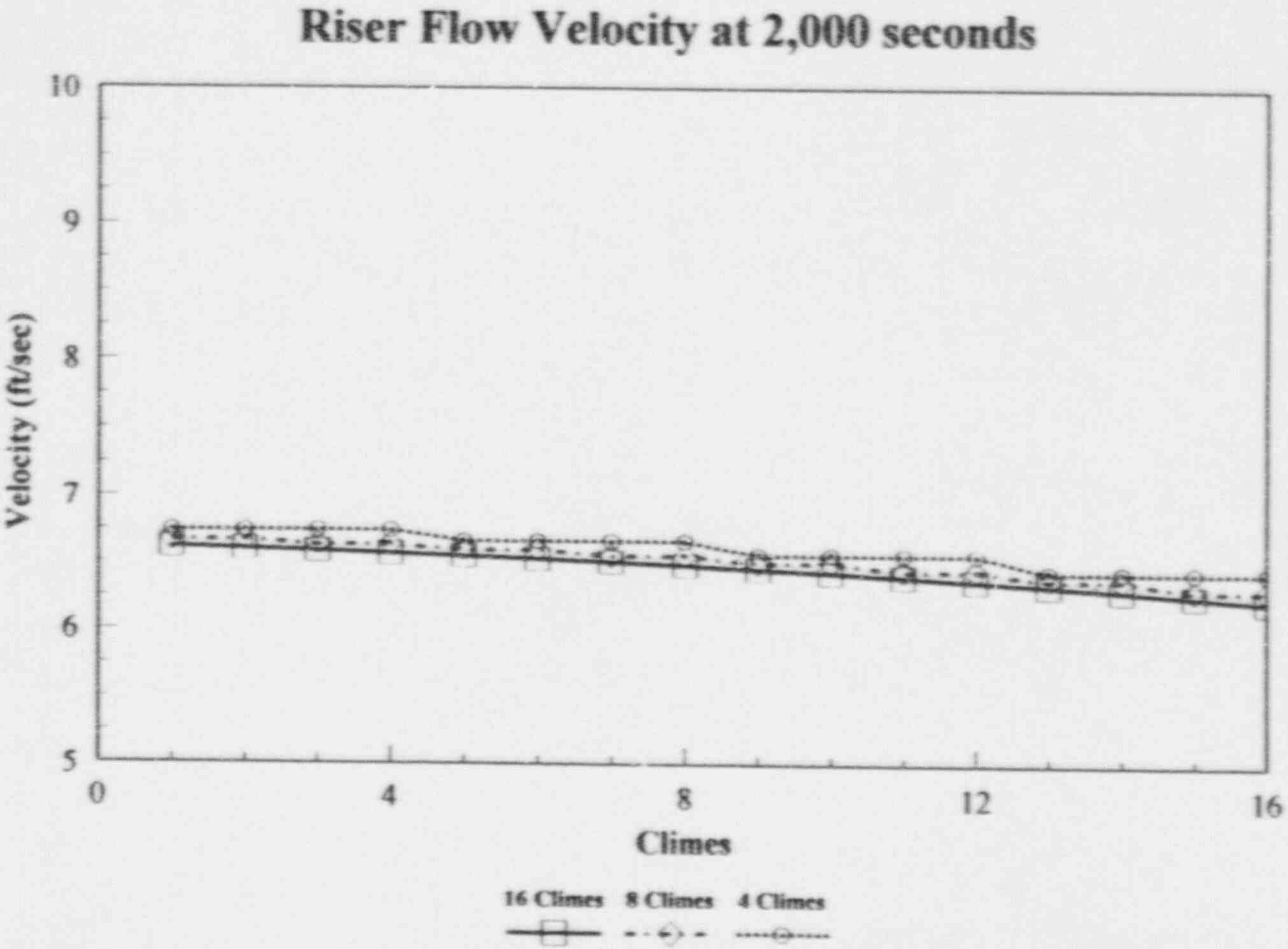


Figure 480.1033-6 Case 1, All Dry Case, Riser Velocity

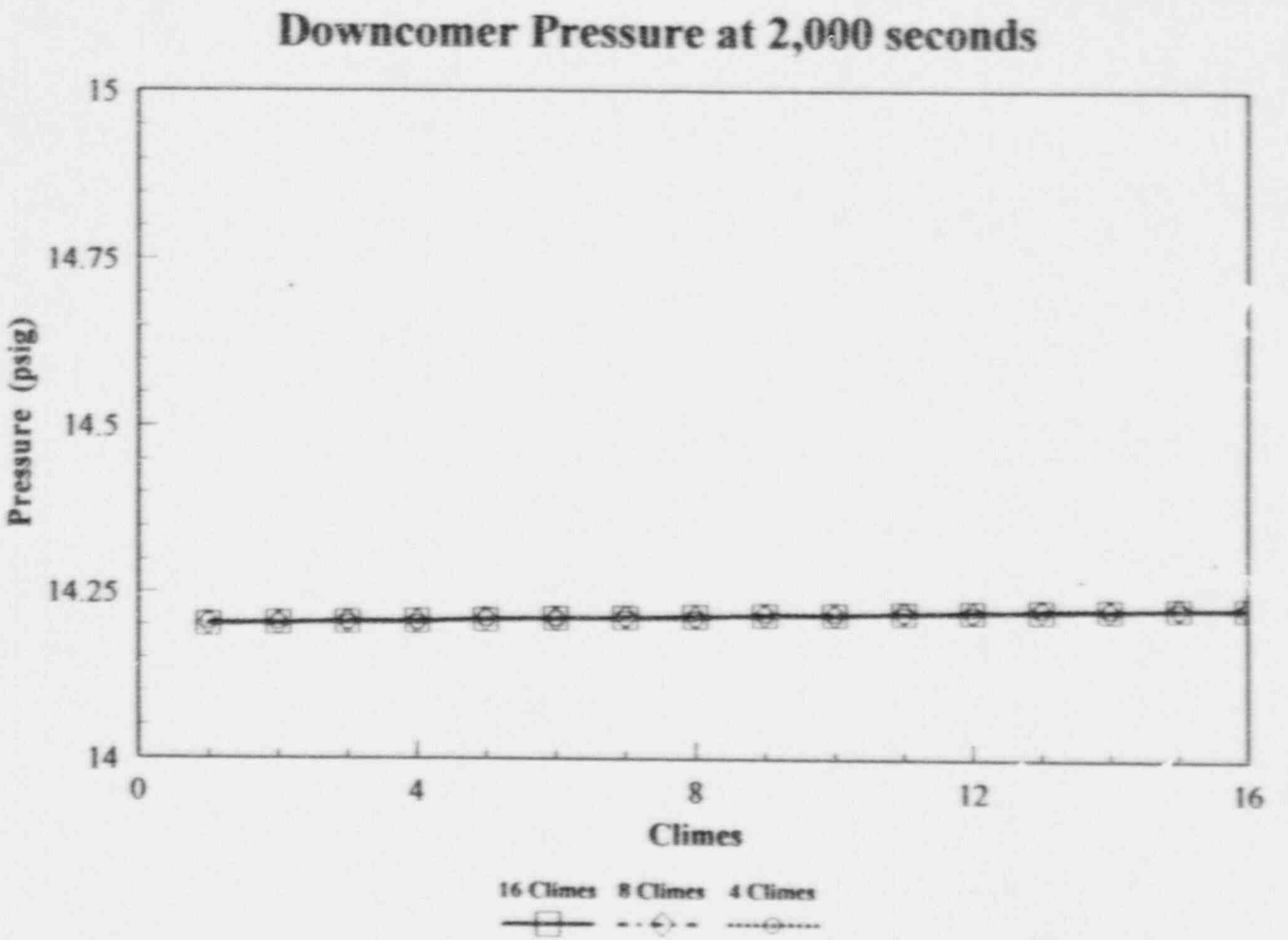


Figure 480.1033-7 Case 2, All Wet, High Subcooling Case, Downcomer Pressure

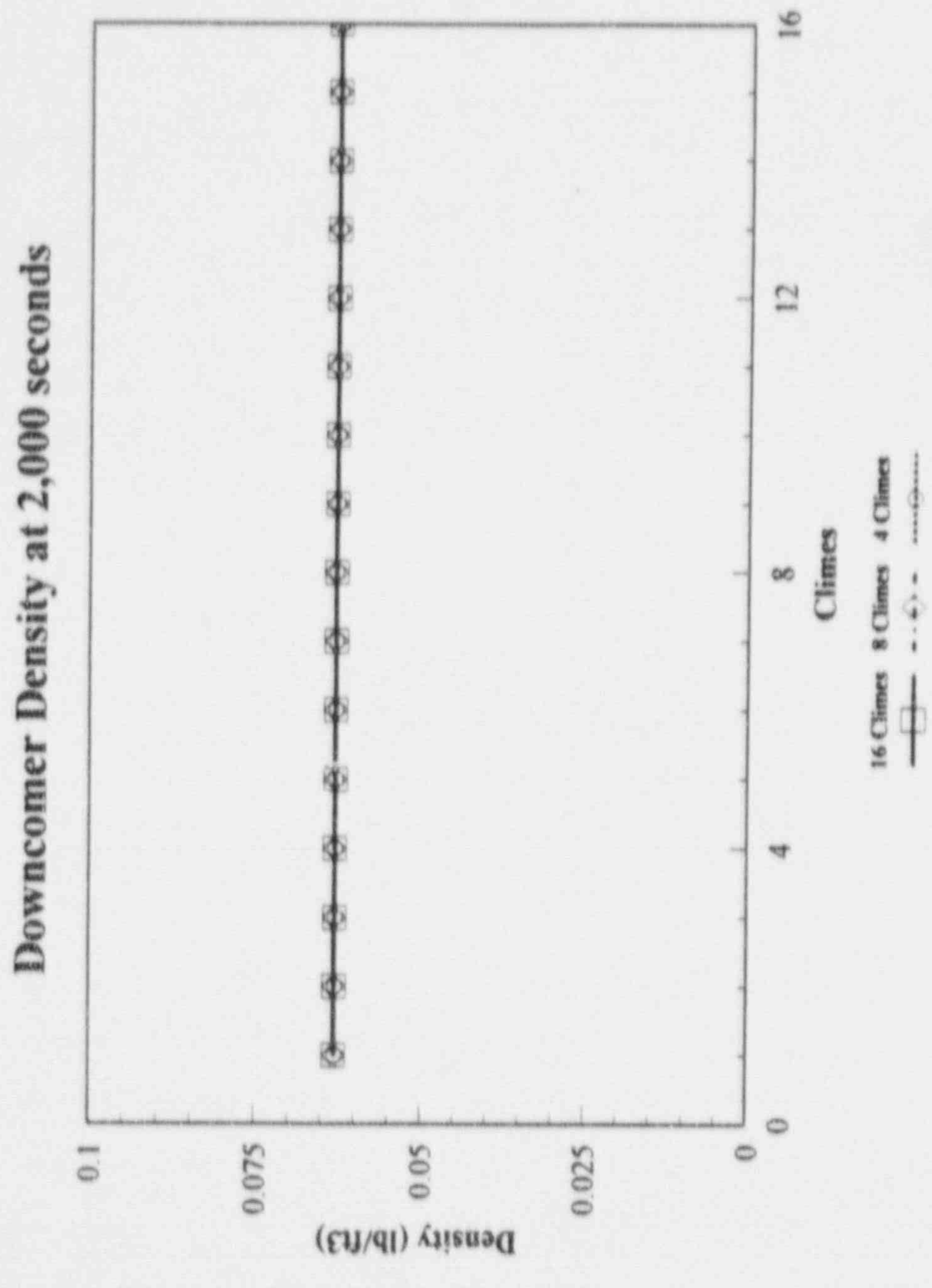


Figure 480.1033-8 Case 2, All Wet, High Subcooling Case, Downcomer Density

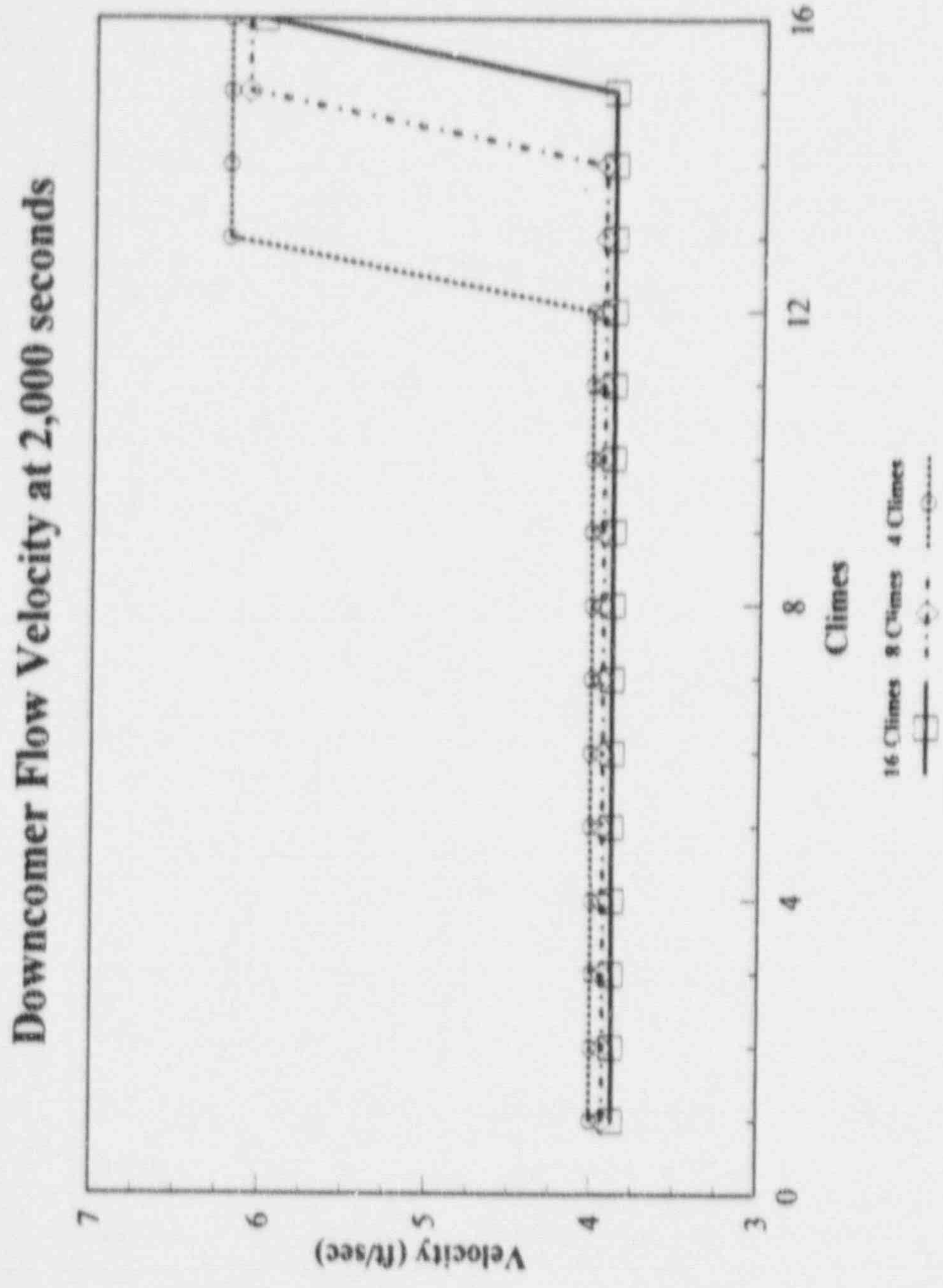


Figure 480.1033-9 Case 2, All Wet, High Subcooling Case, Downcomer Velocity

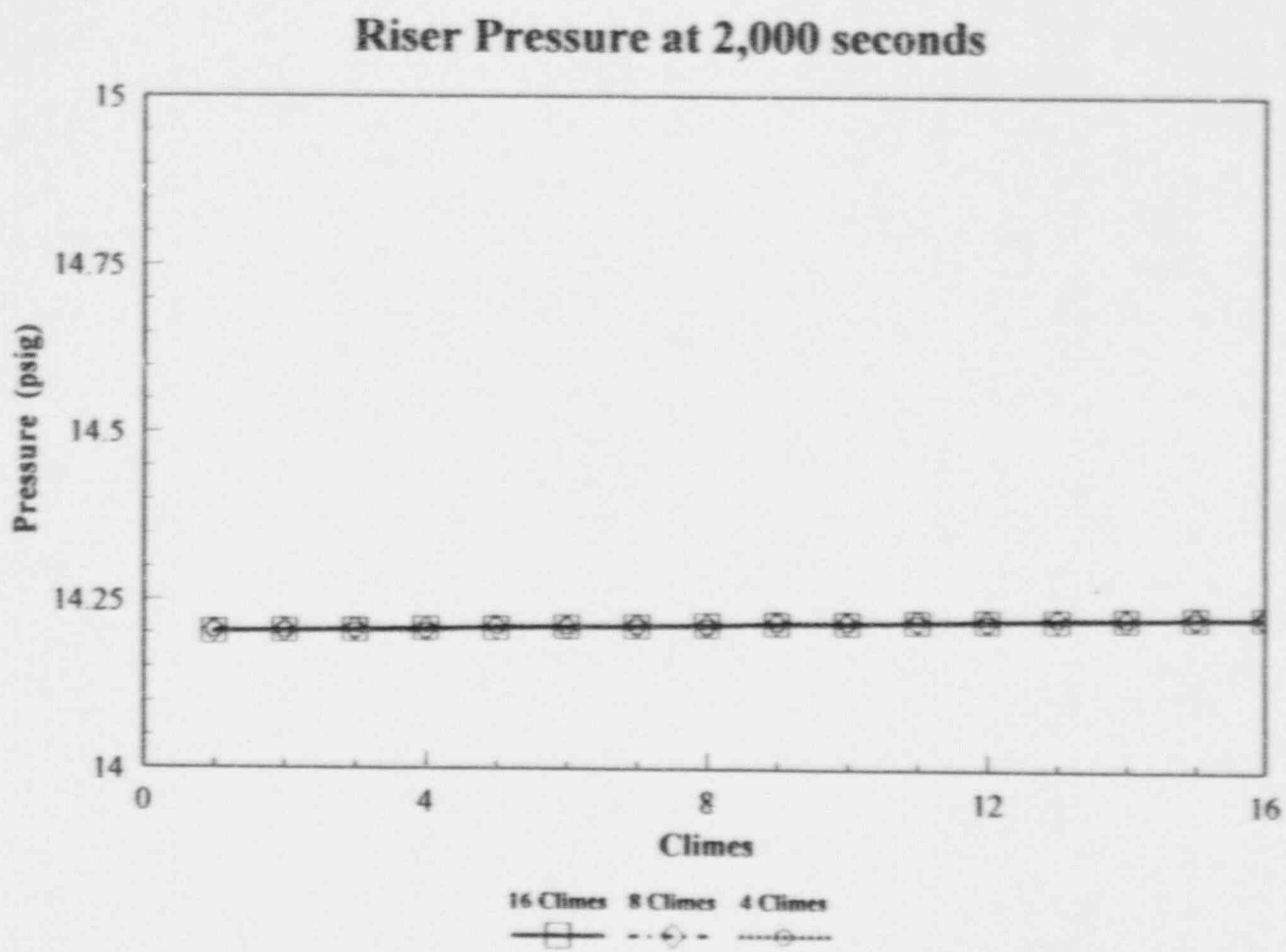


Figure 480.1033-10 Case 2, All Wet , High Subcooling Case, Riser Pressure

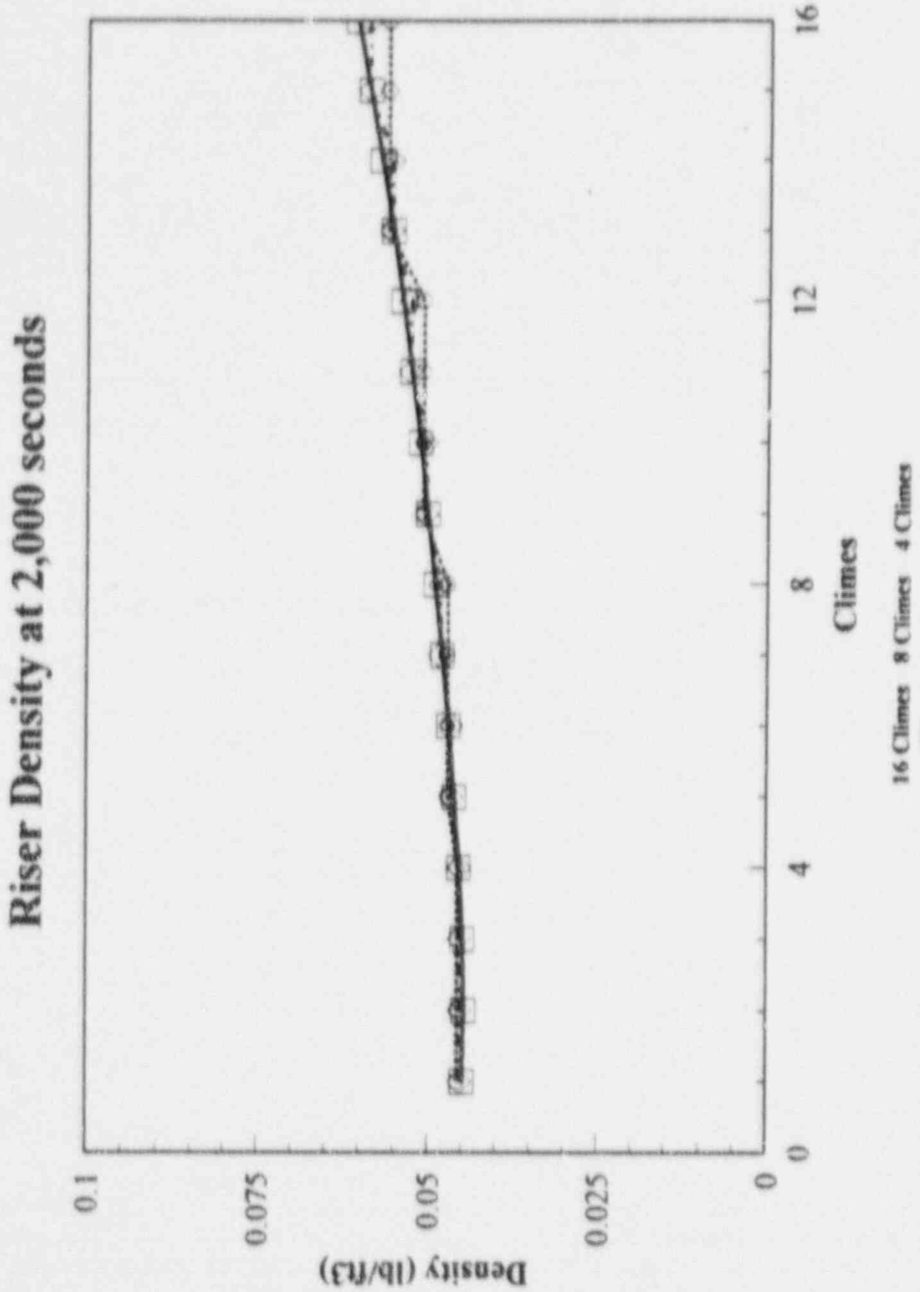


Figure 480.1033-11 Case 2, All Wet, High Subcooling Case, Riser Density

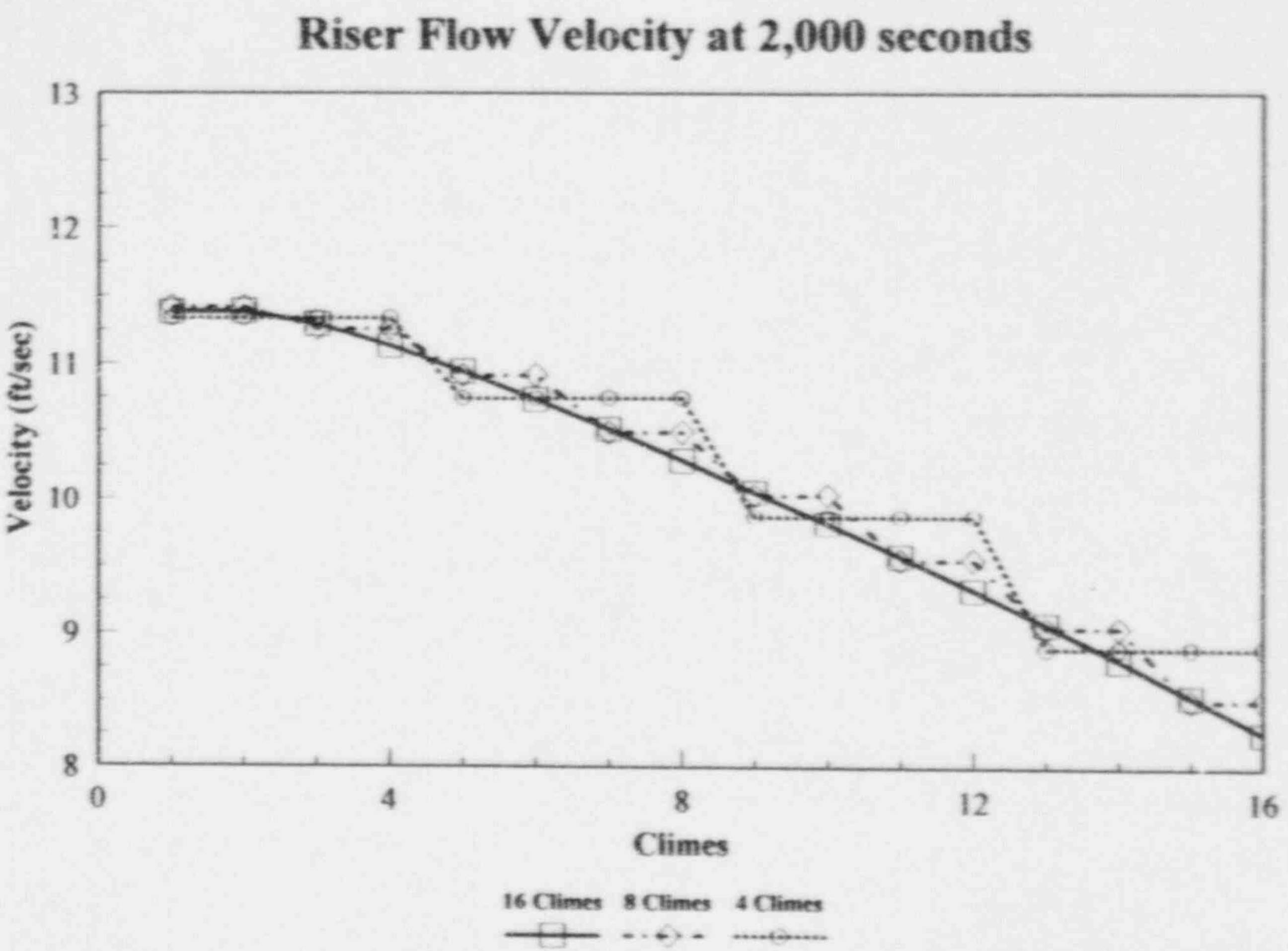


Figure 480.1033-12 Case 2, All Wet, High Subcooling Case, Riser Velocity

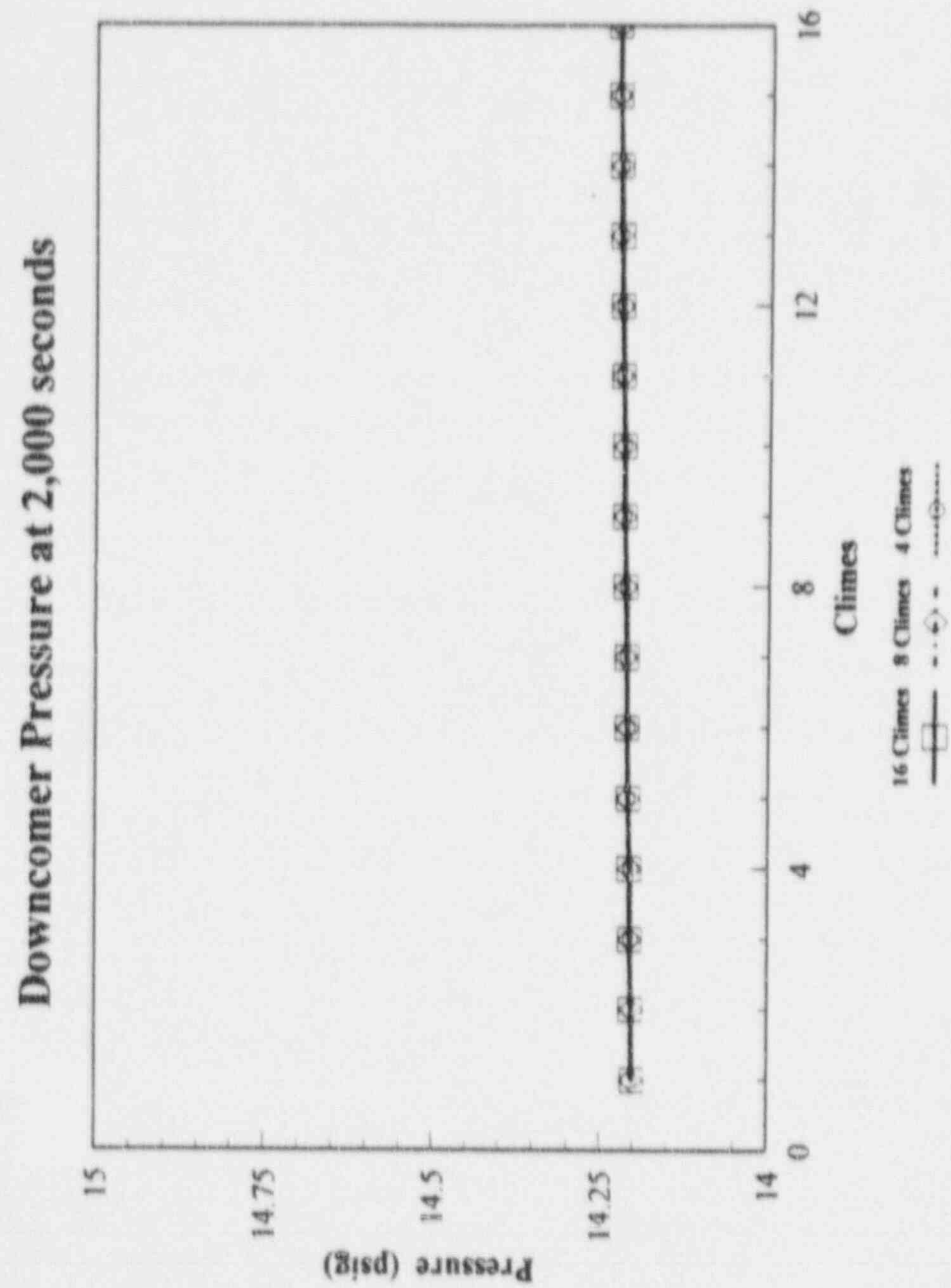


Figure 480.1033-13 Case 3, All Wet, Low Subcooling Case, Downcomer Pressure

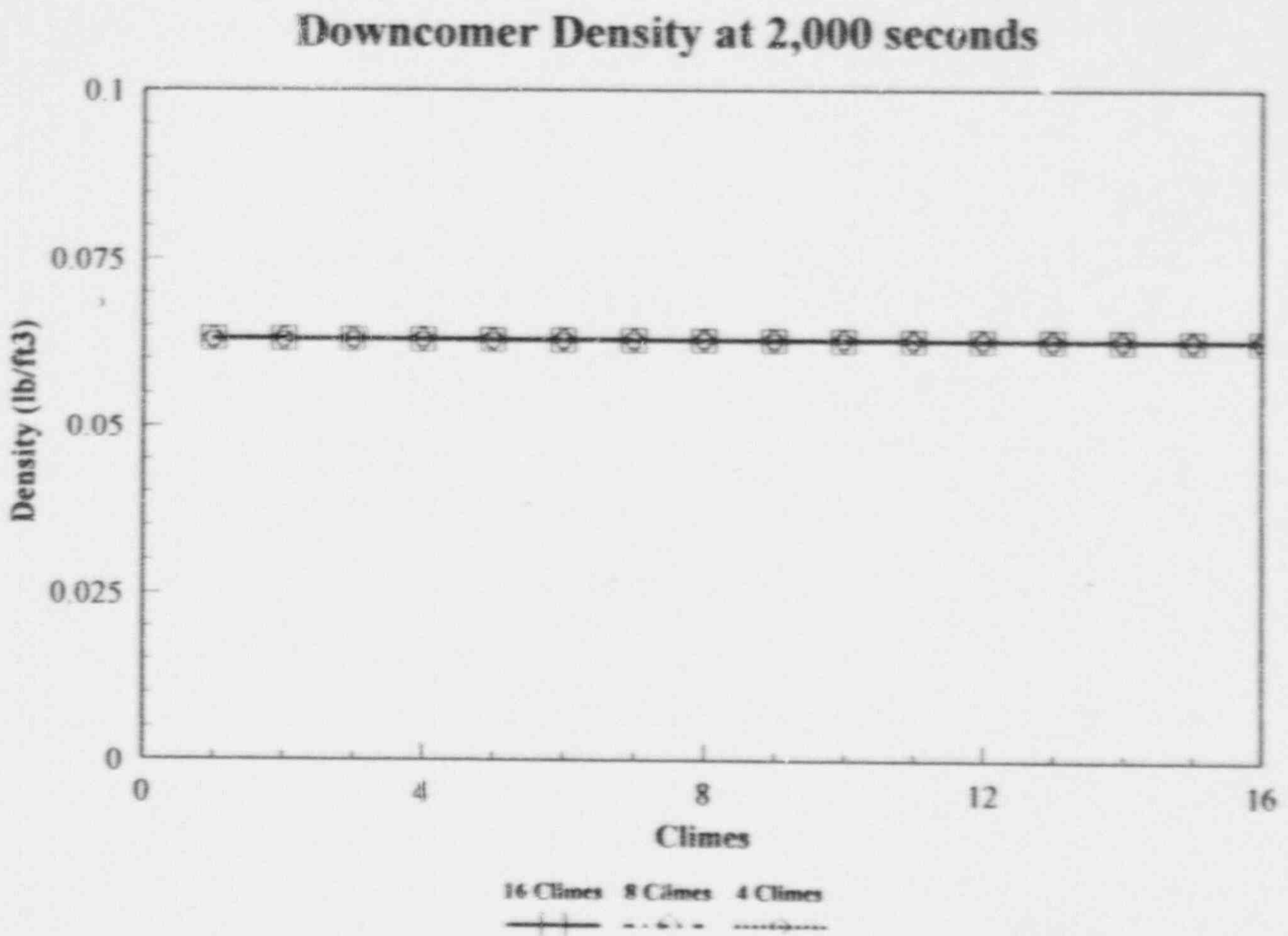


Figure 480.1033-14 Case 3, All Wet, Low Subcooling Case, Downcomer Density

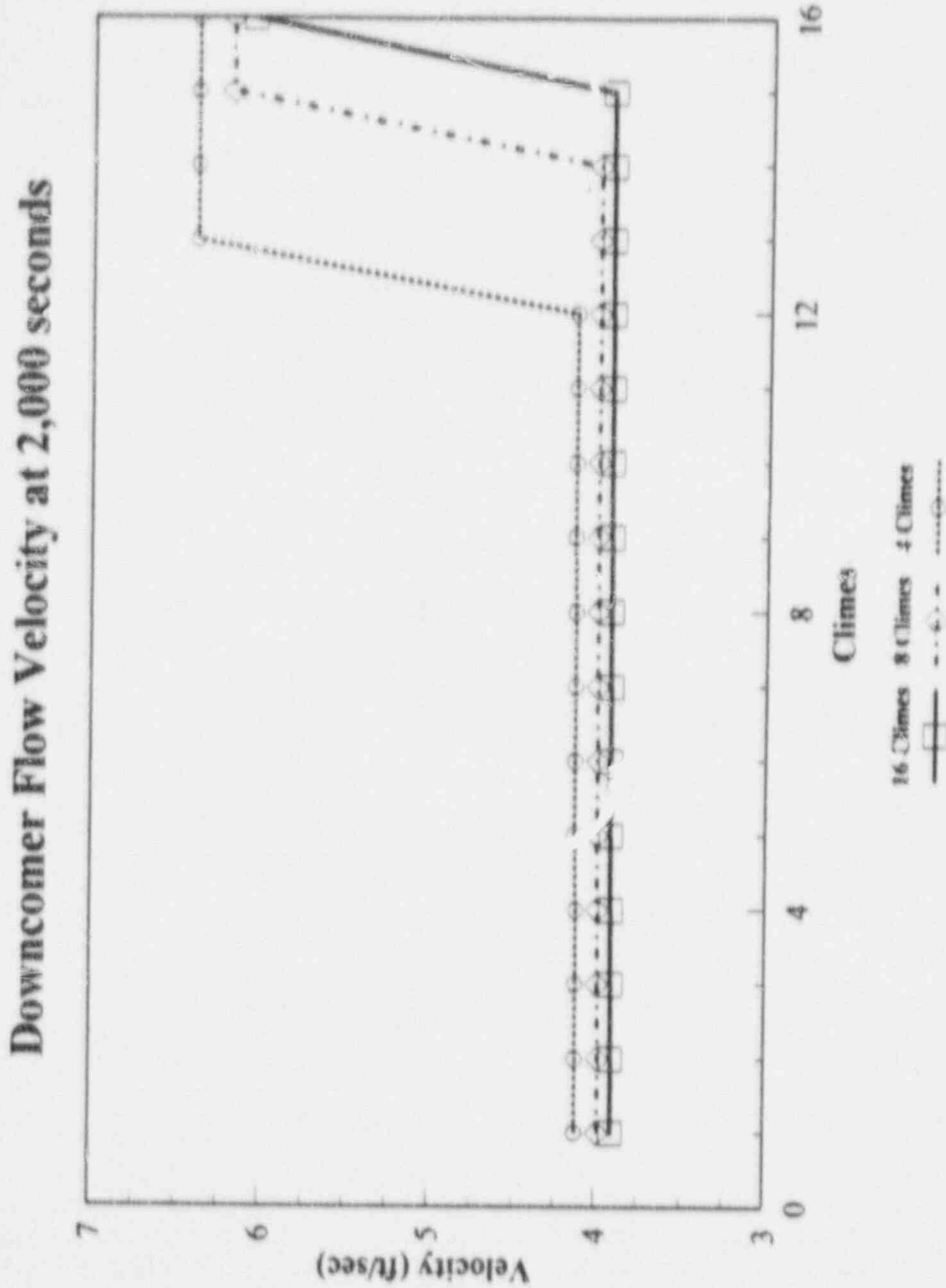


Figure 480.1033-15 Case 3, All Wet, Low Subcooling Case, Downcomer Velocity

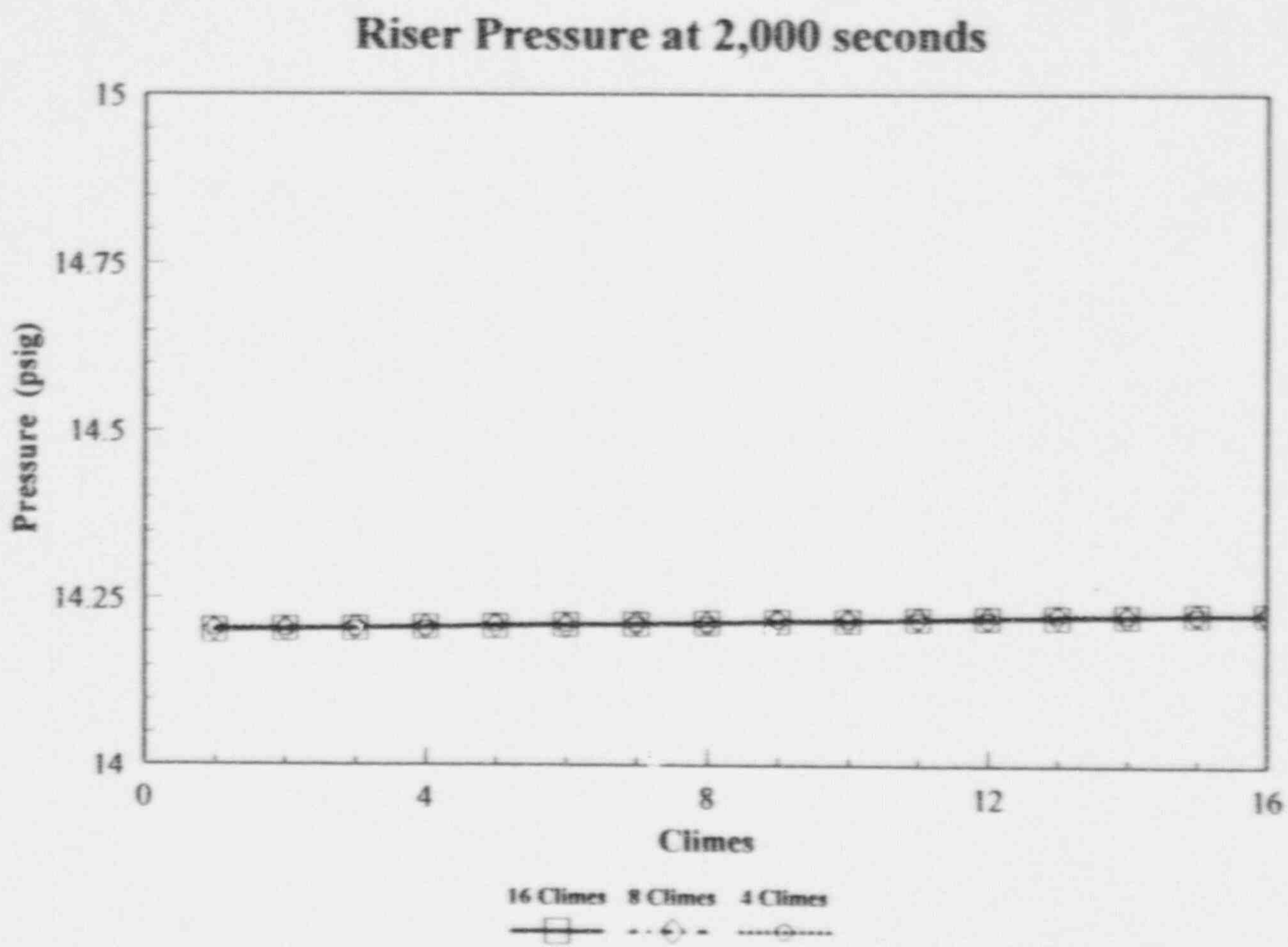


Figure 480.1033-16 Case 3, A / Wet, Low Subcooling Case, Riser Pressure

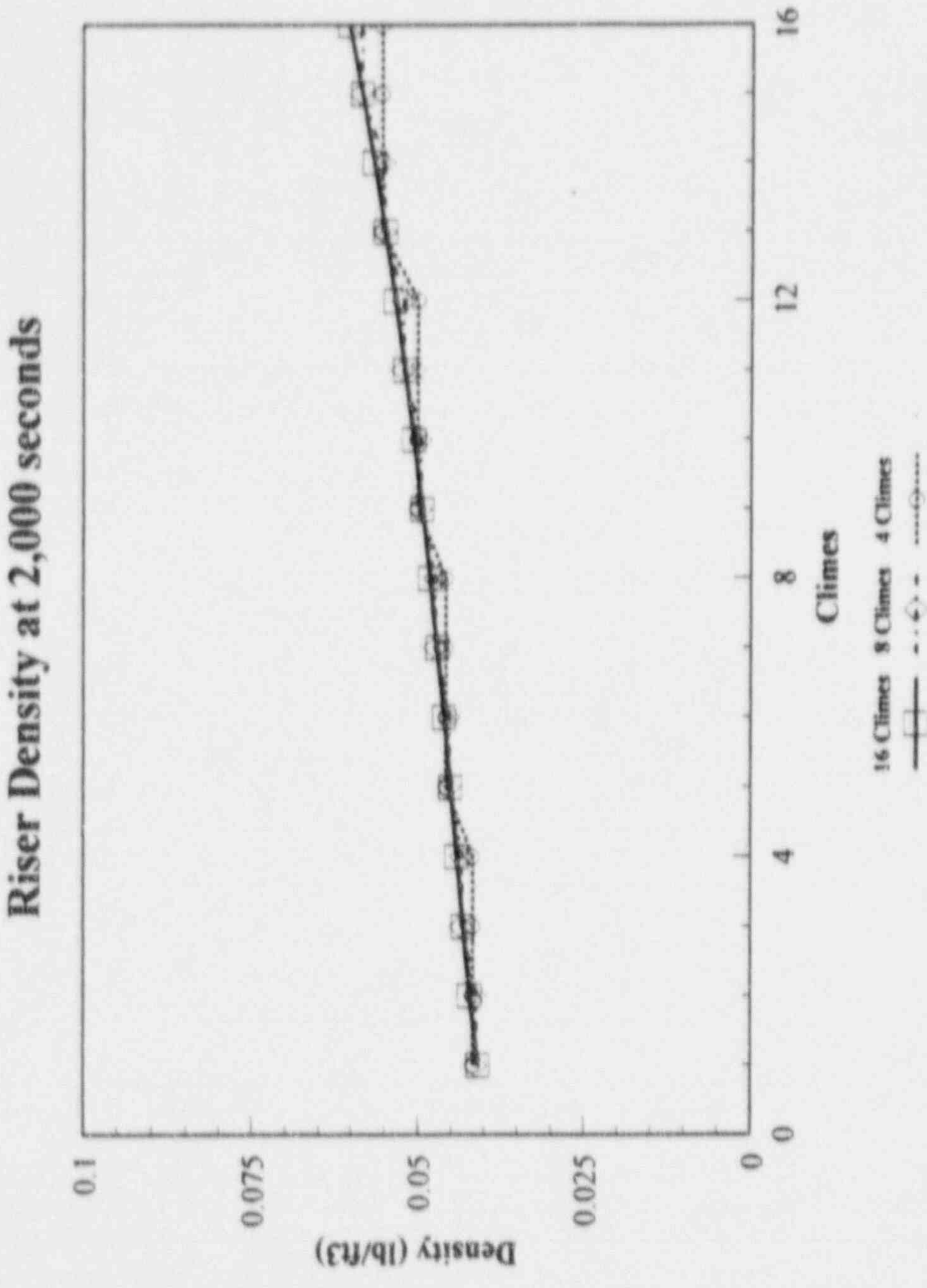


Figure 480.1033-17 Case 3, All Wet, Low Subcooling Case, Riser Density

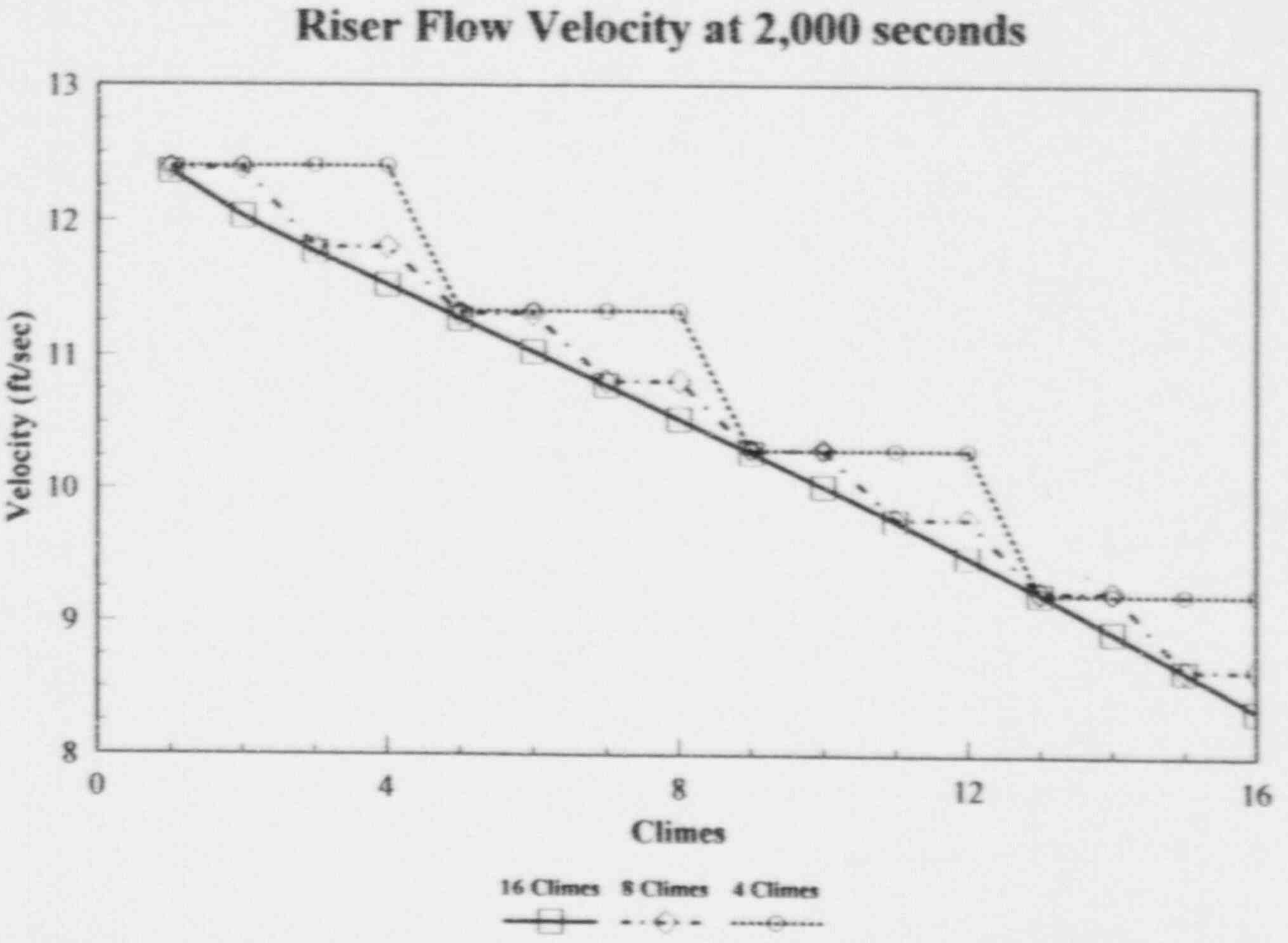


Figure 480.1033-18 Case 3, All Wet, Low Subcooling Case, Riser Velocity

Westinghouse

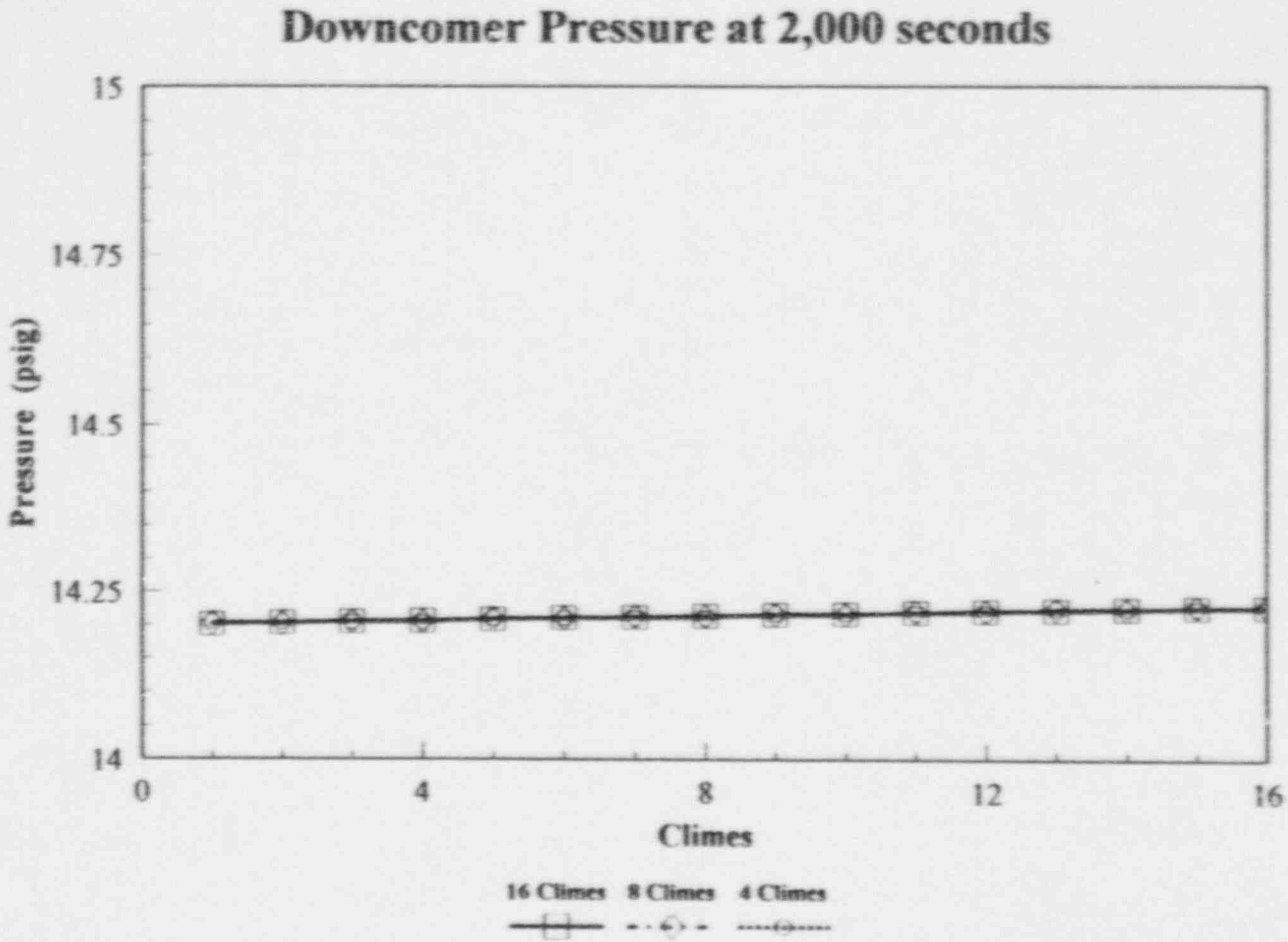


Figure 480.1033-19 Case 4, Partially Wet, High Subcooling Case, Downcomer Pressure

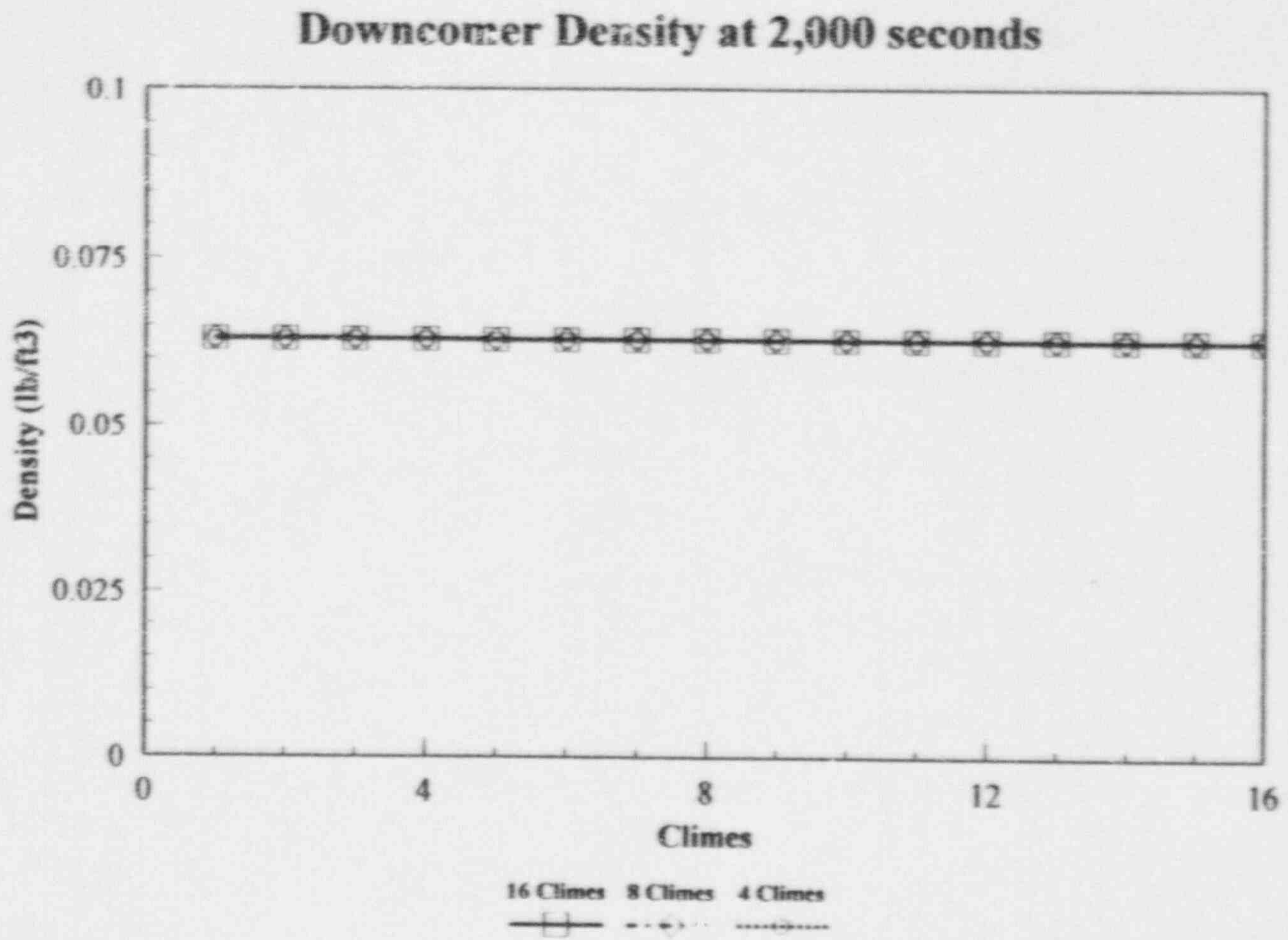


Figure 480.1033-20 Case 4, Partially Wet, High Subcooling Case, Downcomer Density

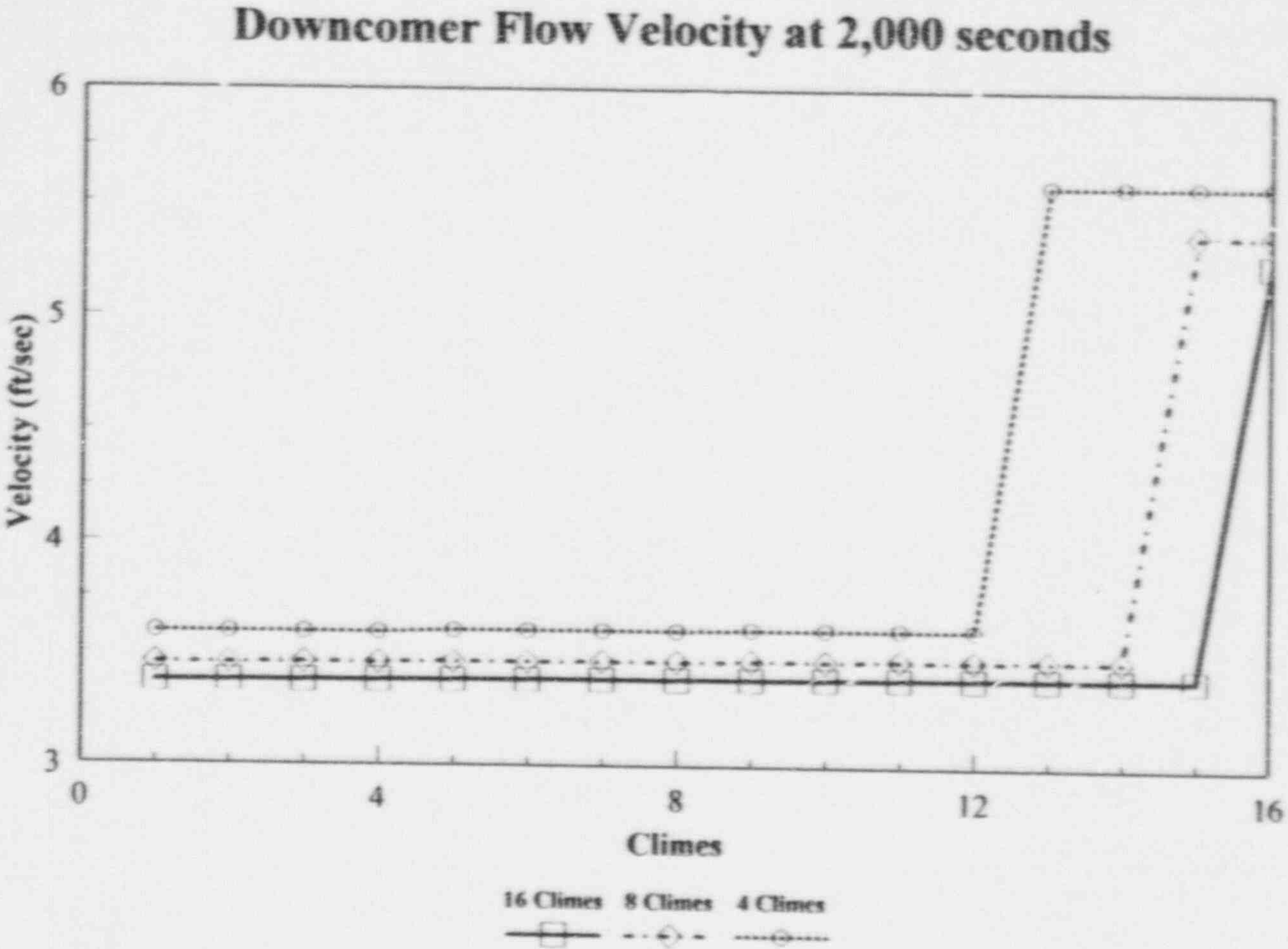


Figure 480.1033-21 Case 4, Partially Wet, High Subcooling Case, Downcomer Velocity

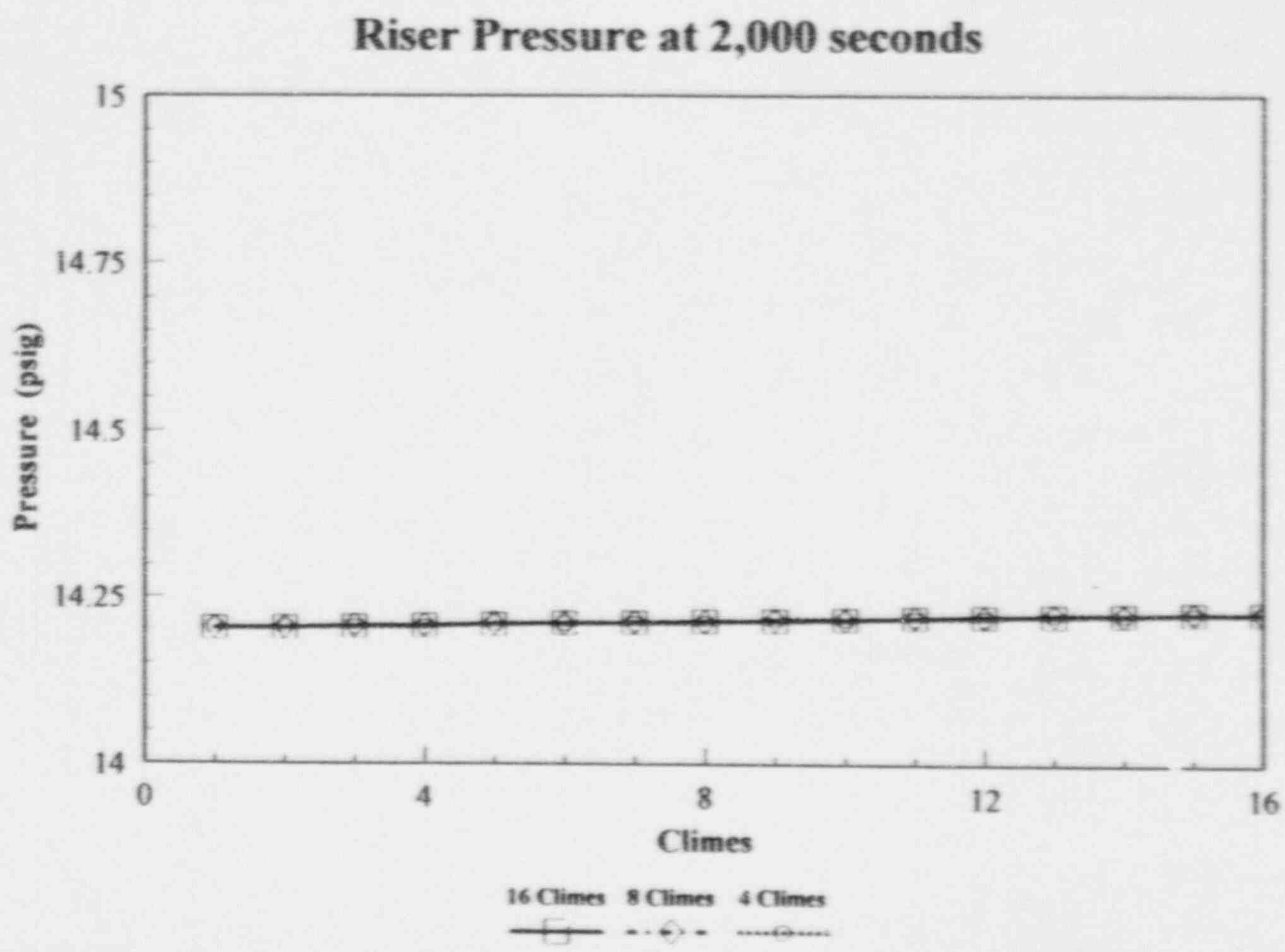


Figure 480.1033-22 Case 4, Partially Wet, High Subcooling Case, Riser Pressure

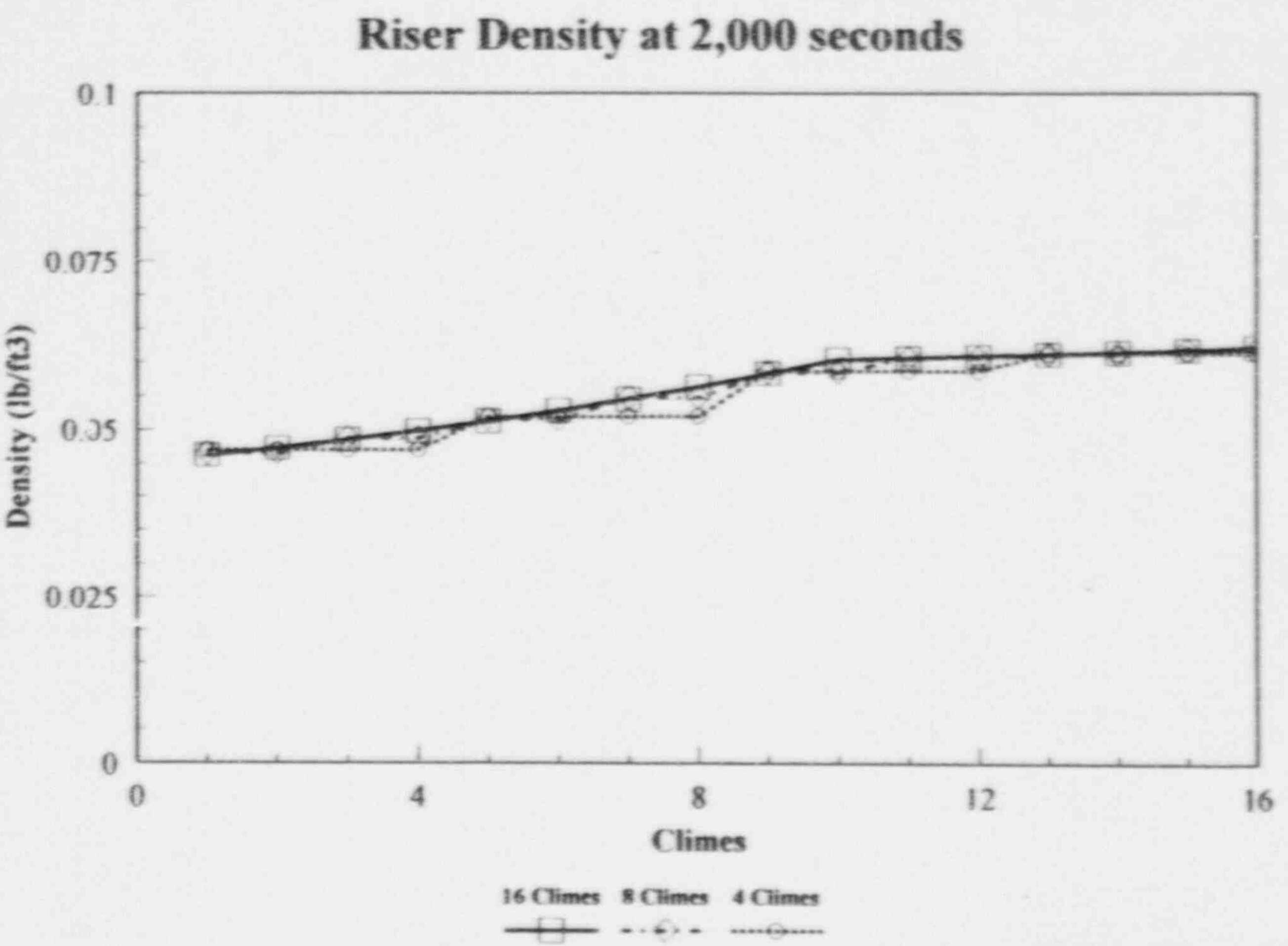


Figure 480.1033-23 Case 4, Partially Wet, High Subcooling Case, Riser Density

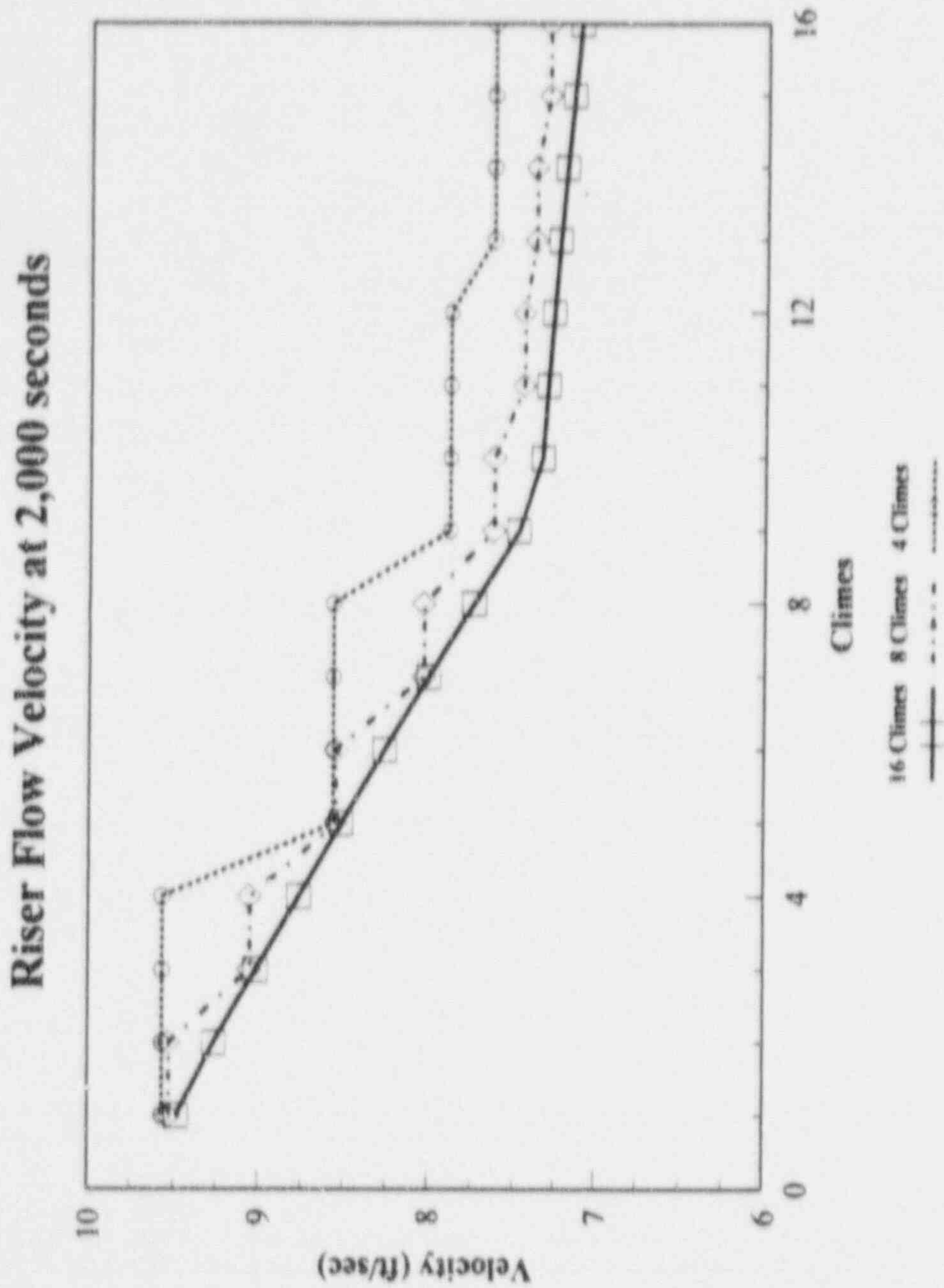


Figure 480.1033-24 Case 4, Partially Wet, High Subcooling Case, Riser Velocity

OITS: 5472
RAI: 480.1034

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the Clime Noding Sensitivity Study discussed in Section 12.2.1 and the results presented in Section 12.3.1.

On Page 12-8, the applicant states that figures provided show that the WGOTHIC results were close to steady-state at the end of the 2000-second transient period. Since 2000 seconds are required for the annulus air flow calculations to approach steady-state, an initialization procedure must be used by Westinghouse to set the WGOTHIC downcomer and annulus air flow velocities to their steady-state values in lieu of preceding the start of the blowdown calculations with a 2000 second "null-transient." The applicant needs to describe this procedure and provide a technical justification for its use.

Response:

The 2000 second transient reported in Section 12.3.1, "Simple Annulus Clime Model," of WCAP 14407, Rev. 1 is not a "null-transient" as the text of the RAI suggests. Rather, the 2000 second transient was run to allow comparison of both transient and steady state calculations among the various clime noding sensitivity cases considered.

The AP600 Evaluation Model assumes no air movement through the downcomer and riser prior to the postulated event. This assumption is conservative as it precludes establishing a) temperature gradients in the containment shell prior to initiation of the event, and b) air flow past the exterior surface of the containment shell prior to initiation of the event. Thus, no "null-transient" calculations are performed for the AP600 Evaluation Model.

SSAR Revision: NONE

OITS: 5473
RAI: 480.1035

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

The applicant needs to incorporate the changes to the WGOTHIC Evaluation Model, as described on Pages 12-6 and 12-7, into the Evaluation Model description provided in Section 4 of WCAP-14407.

Response:

The changes identified on page 12-6 and 12-7 have been incorporated into the WGOTHIC AP600 containment Evaluation Model that is described in Section 4, "Description of WGOTHIC Evaluation Model," of Reference 480-1035-1.

References

480.1035-1 WCAP-14407, Rev. 1, "WGOTHIC Applications to AP600", July 1997.

SSAR Revision: NONE

OITS: 5474
RAI: 480.1036

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

The applicant needs to provide an evaluation of the differences between WGOTHIC Versions 4.0 and 4.1 on the previous calculations presented in the current "WGOTHIC Application to AP600" report, WCAP-14407. This evaluation should present a technical justification why these existing calculations remain valid. Those calculations deemed most likely to be impacted by the change from version 4.0 to 4.1 (including the modeling changes related to below operating deck region loss factors, heat structures, renodalization, and modified mass and energy releases) should be rerun and comparison plots of pressure, PCS air and film temperature, heat flux, and heat removal rate should be presented.

Response:

WGOTHIC Version 4.0 has been superseded. Version 4.1 of WGOTHIC was used to perform all calculations reported in Reference 480.1036-1. The AP600 containment Evaluation Model described in Reference 480.1036-1 was used for all calculations except for those reported in Section 12. The major differences between the Evaluation Model and the AP600 containment model used for the sensitivity studies presented in Section 12 are described in Section 12.2.2 of Reference 480.1036-1

Reference:

480.1036-1 WCAP-14407, "WGOTHIC Applications to AP600", Rev. 1, July 1997.

SSAR Revision: NONE

OITS: 5475
RAI: 480.1037

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

a) The applicant needs to provide a more detailed discussion of the AP600 models used for the case with an increase in the number of climes in a stack (the axial sensitivity study) and the case with an increase in the number of stacks (the azimuthal sensitivity study).

b) As in all WGOTHIC analyses previously submitted for staff review, do these cases also include a "one-to-one" correspondence of a GOTHIC PCS annulus fluid node to clime pair (the wet and dry regions) to containment dome (above operating deck region) fluid node? If not, and considering the withdrawal of Section 13 from WCAP-14407 on noding studies in support of the evaluation model, how does Westinghouse conclude that the dome (above operating deck region) nodalization is appropriate, provides a converged solution, and does not contains numerical instabilities?

c) Particularly for the azimuthal study provided, with fixed fluid boundary nodes it does not appear to the staff that there would be any differences (temperatures, heat fluxes, etc.) between the set of wet or set of dry climes associated with the same set of boundary nodes. Please provide an explanation.

Response:

a) All model input, except for the number of climes or stacks, is identical for the AP600 containment model sensitivity cases presented in WCAP-14407, Rev. 1, Section 12. For the sensitivity of axial climes on calculational results, the number of volumes in the downcomer and riser were doubled with the total volume and area preserved. For the stack sensitivity case, the number of stacks was doubled with the total volume and area preserved. Additional descriptive text has been added to Section 12.2.2, "AP600 Containment Model," of WCAP-14407, Rev. 1.

b) The AP600 containment Evaluation Model does not have a one-to-one correspondence of PCS annulus fluid nodes to clime node conductor pairs. There are four clime conductor pairs connected to each PCS annulus riser and downcomer fluid volume. The stack sensitivity case doubled this to eight clime conductor pairs for each PCS annulus riser and downcomer fluid volume. The clime noding sensitivity studies presented in WCAP-14407, Rev. 1, Section 12 demonstrate that the model is not sensitive to the annulus and/or clime noding.

c) The approach taken in performing the noding sensitivity study was to make noding the only variable in the calculation, thereby making it easy to evaluate its impact on the calculations. This is a commonly accepted approach to parametric study. Fixing the fluid boundary conditions (pressure and temperature at the downcorner inlet, pressure at the riser outlet) for the calculations does not necessarily fix the values of the calculated parameters, such as temperature or velocity, in the annulus if the model is sensitive to the noding. The calculations reported in Section 12.3.2, "AP600 Containment Model," of WCAP-14407, Rev. 1 demonstrate that the calculation scheme is not sensitive to smaller azimuthal stacks.

SSAR Revision: NONE

OITS: 5476
RAI: 480.1038

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

Figures 12-28 through 12-36 all terminate at about 43,200 seconds (12 hours). Please extend these figures to span 24 hours. Do any of the wet stack climes experience dryout in this time period? If so, please indicate the time of dryout on the figures. Is this the dryout behavior expected for the AP600 loss-of-coolant-accident (LOCA)?

Response:

The calculations in question were performed with valid input for only 43,500 seconds (~12 hours) of solution time and adequately demonstrates that the noding sensitivities have negligible impact on the calculation of the phenomenological processes considered during the transient. There is no difference in the calculated phenomenological behavior(s) before and after 43,500 seconds. Therefore, there is no technological benefit to extending the transients to 24 hours.

As observed from the plots of wet heat flux, Figures 12-29 and 12-30, and film temperatures, Figures 12-33 and 12-34, of WCAP-14407, Rev. 1 (Reference 480.1038-1), dryout of the wet stacks is predicted to occur. At 43,500 seconds, for those climes experiencing dryout, the heat flux drops sharply (compared to the other climes) and the shell temperature increases sharply (compared to that for the other climes).

As described in Section 7 of Reference 480.1038-1, the PCS flow rate input for the Evaluation Model is adjusted to bound the amount of evaporation. The dryout behavior predicted by the AP600 containment Evaluation Model is not the same as would be expected for the AP600 during a postulated LOCA event. The AP600 containment Evaluation Model has four stacks. Within each stack, the applied PCS water is treated as covering a constant azimuthal traverse. Thus, dryout behavior predicted by WGOTHIC the Evaluation Model will be axially, from the bottom up. The AP600 PCS weir design provides for the formation of multiple stripes of PCS liquid flowing across the exterior of the containment shell. Therefore the dryout behavior of the AP600 plant is expected to be both in the azimuthal (narrowing of the stripes) and axial directions (from the bottom to the top of containment) as the PCS flow rate changes over time.

Reference:

480 1038-1 WCAP-14407, "WGOTHIC Applications to AP600", Rev. 1, July 1997.

SSAR Revision: NONE

OITS: 5477
RAI: 480.1039

SECTION 12, "CLIME NODING STUDY," OF WCAP 14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

Are the changes (both to WGOTHIC 4.1 and to the AP600 model) expected to impact the main steam line break (MSLB) cases?

Response:

Calculations for both the LOCA and MSLB events have been rerun with Version 4.1 of the WGOTHIC code and the AP600 Evaluation Model as described in Section 4, "Description of WGOTHIC Evaluation Model," of WCAP-14407, Rev. 1. The results of the calculations are summarized in Section 4.7 of WCAP-14407, Rev. 1.

SSAR Revision: NONE

OITS: 5478
RAI: 480.1040

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

The applicant needs to provide comparative plots of heat flux and film temperatures versus clime location for a representative wet stack and the heat flux and shell surface temperature versus clime location for a representative dry stack for the "base case clime" and "increased number of climes case" AP600 models prior to blowdown, at 30 seconds, at 1500 seconds, and at 24 hours.

Response:

The requested information is provided in the following figures of WCAP-14407, Rev. 1, Section 12:

Figure 12-29	Wet Heat Flux vs. Clime; AP600 Containment Model, Base Case
Figure 12-30	Wet Heat Flux vs. Clime; AP600 Containment Model, Double Clime
Figure 12-31	Dry Heat Flux vs. Clime; AP600 Containment Model, Base Case
Figure 12-32	Dry Heat Flux vs. Clime; AP600 Containment Model, Double Clime
Figure 12-33	Film Temperature vs. Clime; AP600 Containment Model. Base Case
Figure 12-34	Film Temperature vs. Clime; AP600 Containment Model, Double Clime
Figure 12-35	Dry Film Temperature vs. Clime; AP600 Containment Model, Base Case
Figure 12-36	Dry Film Temperature vs. Clime; AP600 Containment Model, Double Clime

As explained in the response to RAI 480.1038, valid calculations have been performed for transient time up to 43,500 seconds. Thus, the requested information is provided in the plots identified above for 0, 30, 1,500, and 43,500 seconds. Also, as noted in the response to RAI 480.1038, there is no difference in the calculated phenomenological behavior(s) before and after 43,500 seconds. Therefore, there is no technological benefit to extending the transients to 24 hours.

SSAR Revision: NONE

OITS: 5479
RAI: 480.1041

SECTION 12, "CLIME NODING STUDY," OF WCAP-14407, "WGOTHIC APPLICATION REPORT"

The following questions refer to the AP600 Containment Clime Noding Sensitivity Study discussed in Section 12.2.2 and the results presented in Section 12.3.2.

The applicant needs to provide the annulus and downcomer pressure, air temperature, density, and flow velocity profiles for the "base case clime" and "increased number of climes case" AP600 models prior to blowdown, at 30 seconds, at 1500 seconds and at 24 hours. How does Westinghouse confirm that these profiles represent stable and converged flow solutions?

Response:

The requested information is provided in the following figures of Section 12;

Figure 12-37	Annulus Pressure vs. Clime; AP600 Containment Model, Base Case
Figure 12-38	Annulus Pressure vs. Clime; AP600 Containment Model, Double Clime
Figure 12-39	Air Temperature vs. Clime; AP600 Containment Model, Base Case
Figure 12-40	Air Temperature vs. Clime; AP600 Containment Model, Double Clime
Figure 12-41	Air Density vs. Clime; AP600 Containment Model, Base Case
Figure 12-42	Air Density vs. Clime; AP600 Containment Model, Double Clime
Figure 12-35	Air Velocity vs. Clime; AP600 Containment Model, Base Case
Figure 12-36	Air Velocity vs. Clime; AP600 Containment Model, Double Clime

As explained in the response to RAI 480.1038, valid calculations have been performed for transient time up to 43,500 seconds. Thus, the requested information is provided in the plots identified above for 0, 30, 1,500, and 43,500 seconds. Also, as noted in the response to RAI 480.1038, there is no difference in the calculated phenomenological behavior(s) before and after 43,500 seconds. Therefore, there is no technological benefit to extending the transients to 24 hours.

The purpose of the noding sensitivity study is to demonstrate the solutions obtained are insensitive to changes in the clime noding pattern. From comparing the plots of Figures 12-35 through and Figures 12-42, changes in noding patterns do not result in changes in calculated density, temperature, velocity or pressure of air in the annulus. It is therefore concluded that the calculated density, temperature, pressure and velocity profiles in the annulus are stable and converged flow solutions for the conditions considered.

SSAR Revision: NONE

OITS: 5551
RAI: 480.1051

In Reference 480.1051-1, Section 1: Introduction, the Water Distribution Test (WDT) and the Large Scale Test (LST) are referenced to support the conclusion that an alternating pattern of wet and dry vertical stripes will form, with known coverage values for different applied flow rates and heat fluxes. The WDT, which had a prototypical water distribution system, was performed only at cold conditions. The heated LST had a non-prototypical water distribution system (J-tubes) instead of notched weirs, and had only one data point with a wetted coverage area in the range of interest for this evaluation. The vertical sections of both of these test facilities were much shorter than the AP600. Given these deficiencies, justify the statements made in the second paragraph:

> "As evidenced by test data, the flow distribution weirs develop alternating wetted and dry, vertical stripes of containment surface areas. These stripes become clearly segregated as the applied water flow rate is reduced. Heat removal from the wetted area is greater than...".

Response:

The Phase 3 Water Distribution Test results show that as the PCS flow is reduced, the water streams applied by the individual V-notches in the second (lower) set of distribution troughs do not spread sufficiently to join. Since the streams follow the fall line of the containment dome surface, and since this surface is highly sloped at this location (35 degrees and increasing), and since the dome surface is increasing in perimeter as the streams flow outward; the streams become segregated at an overall fixed spacing. This is clearly evident in video recordings of this test.

Both the large and small scale heat transfer tests showed that streams, once formed on the vertical sidewalls of the test vessels, remained distinct and flowed downward in uniform width stripes that did not meander or wander. The only horizontal movement observed was small and is best described as the formation of a dry patch which caused a stream to split. These dry patches were in a vertical orientation, since the existence of a dry patch causes the film flow rate adjacent to the dry patch to increase in thickness and the film stripe resumes its downward vertical path. Note that dry patches only occurred where the film flow rate was very low due to the fact that most of the water had been evaporated, or that there initially had been little water flow.

References:

480.1051-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5552
RAI: 480.1052

Regarding Reference 480.1052-1, Section 2: Effect of Circumferential (2-D) Conduction, describe, or provide a reference to the description of the relevant AP600 water distribution tests. Provide a table which summarizes the observed striping characteristics as a function of applied flow rate and axial height for the cold WDT tests. This table must provide the range of parameters tested for each "striping test", e.g., test ID, flow rate, film temperature, observed coverage fraction, number of wet and dry stripes, widths of the stripes at the springline, and stripe widths at the bottom of test section.

Response:

WCAP-13960, Rev. 0 pages 46, 50 and 51, and 55 are tables listing the requested information for test run 10 (100 gpm equivalent flow), test run 12 (55 gpm equivalent flow), and test run 14 (55 gpm equivalent flow, with the worst tilt of the weir); respectively. This stream information was obtained at the dome springline elevation, and the streams were observed to not change over the remaining 4 feet of vertical sidewall of the test article.

References:

480.1052-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5553
RAI: 480.1053

Provide "striping" information for the heated LST tests. This table must provide the range of parameters tested for each "striping test", e.g., test ID, flow rate, heat flux, film temperature, observed coverage fraction, number of wet and dry stripes, widths of the stripes at the springline (for any tests where this observation may have been made), and stripe widths at the bottom of test section.

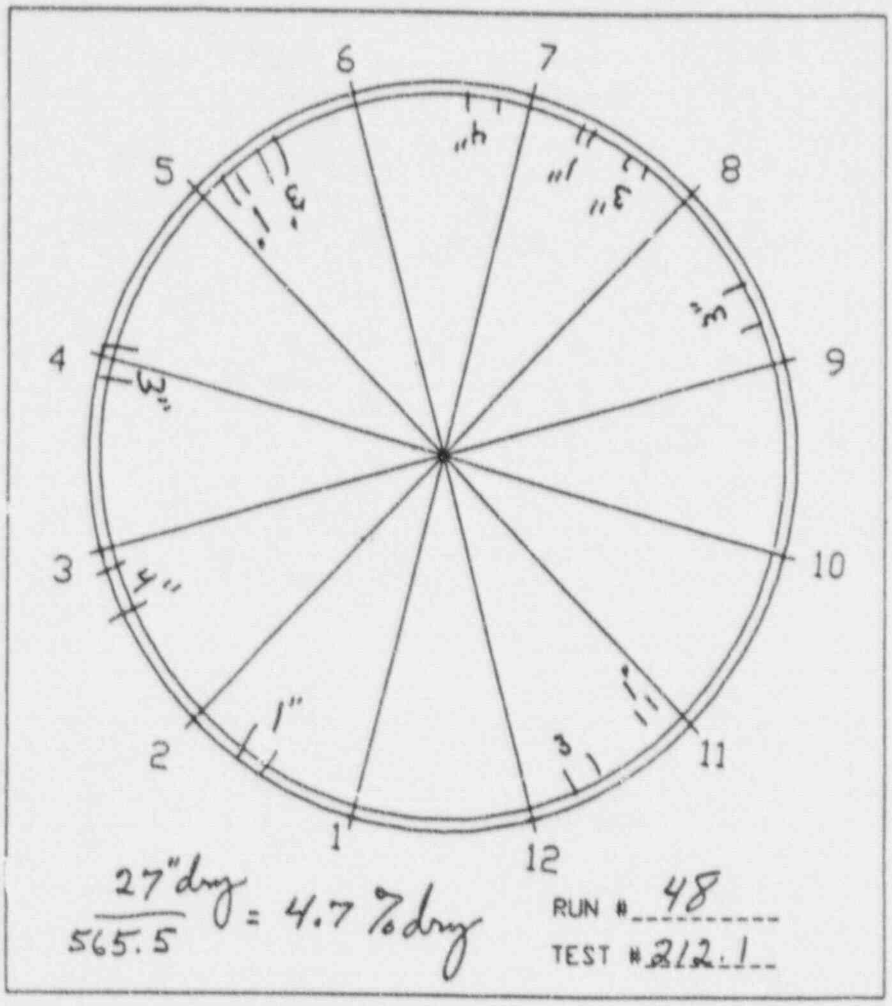
Response:

The number of stripes, the stripe widths, and the locations of these stripes at the bottom of the LST test vessel were measured and documented in the completed test procedure for each individual test run. Copies of these measurements for matrix tests 212.1, Run RC048C and 213.1, Run RC050C are provided as Figures 480.1053-1 and -2, respectively. This information was used to determine the wet area coverage percentages reported in WCAP-14135, Rev. 1; the "Final Data Report for PCS Large Scale Tests, Phase 2 and Phase 3." The information on the water flow rate onto and off the vessel and other pertinent test parameters are contained in WCAP-14135, Rev. 1, Table 4.3-3 for run RC048C, and Tables 4.4-3 and 4.4-8 for run RC050C.

SSAR Revision: NONE

AP600

TEST DATA SHEET
WATER COVERAGE DATA

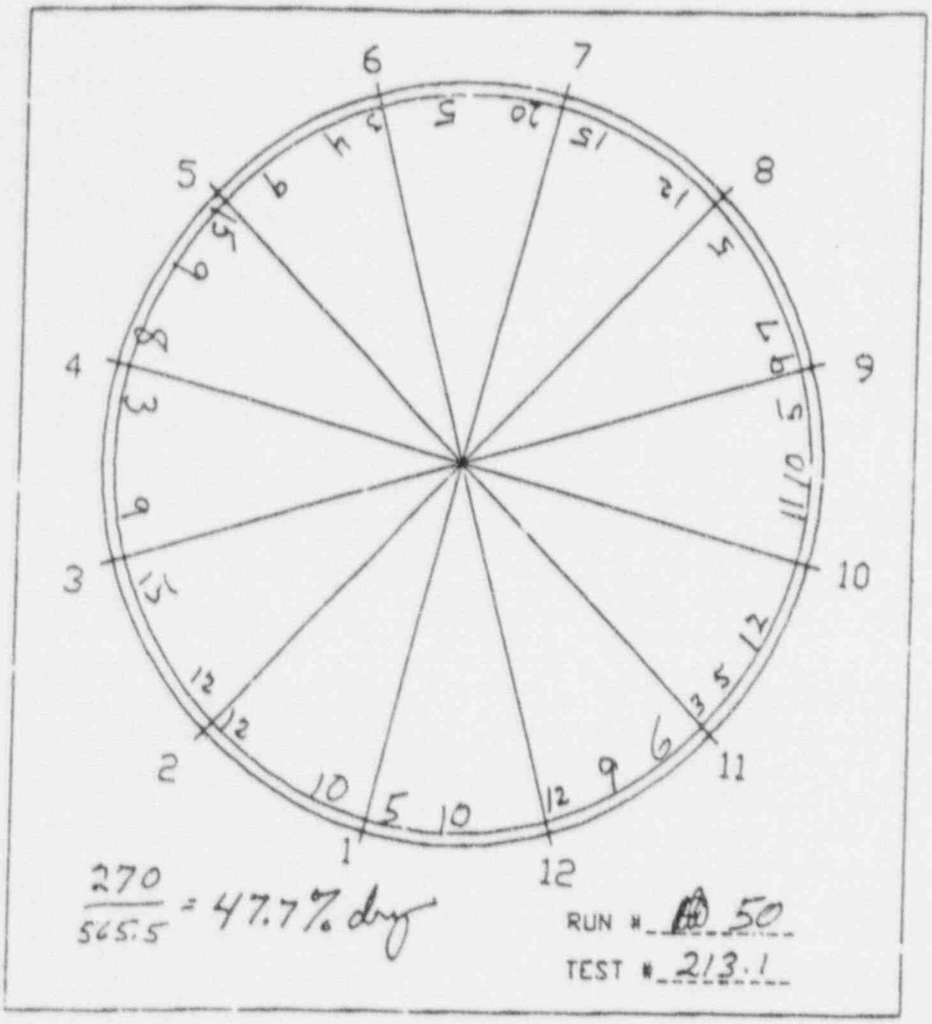


Signature: ______ Date: 8/12/93 Time: 13:45

Figure 480.1053-1 Measurements for matrix test 212.1, Run RC048C

Westinghouse

TEST DATA SHEET
WATER COVERAGE DATA



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10

Figure 480.1053-2 Measurements for matrix test 213.1, Run RC050C

OITS: 5554
RAI: 480.1054

Regarding Reference 480.1054-1, Section 2.1: Geometry of the Wet and Dry Vertical Stripes, justify the assumption that stripes are always centered under a weir notch. What is the impact of plate misalignments and welding imperfections? What is the impact of the baffle plate standoffs, if any? The second weir is at the 50 foot radius, and the springline is at 65 foot radius. Water leaving the second weir must travel about 45 feet to reach the springline. Does the WDT data records indicate whether stripes were always centered under each weir notch in all tests?

Response:

The water distribution testing shows that the water flowing from the V-notches creates streams below each notch. Welding imperfections and plate misalignments on the dome can only have a local, limited impact on the streams applied by the second ring of weirs since the weld/plate seams are in the radial direction; the same direction the streams are flowing. The streams do not have to cross a weld/plate seam until they reach the dome spring line, where the weld/plate seam is horizontal and the containment surface is vertical. On the vertical side wall surface, the air baffle stand-offs have little impact on the streams since the stand-offs are open U-channels through which water can flow down and air can flow up. These open channels are constructed from 1/4 inch thick steel plate and present a very small frontal area to water or air flow. This frontal area is small compared to the stream width even at the lowest PCS water flow rate. It is noted that the air baffle standoffs used in the large scale test were 3/4-inches in width and did not disturb the film flow, i.e. water remained attached all around the standoffs.

References:

480.1054-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5555
RAI: 480.1055

Regarding Reference 480.1055-1, justify the assumption that the stripe width is uniform over the entire PCS shell. What effects would a non-uniform heat flux through the shell (due to off-center break location, or jet impingement) have on the placement of PCS wet/dry stripes. Show that the assumption of uniform stripe width is valid even when evaporation causes the flow to drop below the minimum stable flow. How are the dome regions above the second weir handled?

Response:

The assumption that the stripe width is uniform, and that the width is established by Γ_{dist} is consistent with the simple but overall conservative basis used for determining the wetted surface of the containment in the Evaluation Model. In reality, the width of an individual stripe can be wider or narrower than the assumed uniform width; or may even change in width as it proceeds down the containment shell. These changes in width can be caused by local variations in the shell shape that affect the fall line of the stream, or that act to confine or spread an individual stream. Since the constructed containment shell may have many such local variations, the actual average stream width is expected to be the uniform width assumed in the analysis.

A non-uniform heat flux due to an off-center break location or jet impingement on the shell that resulted in heating a portion of the shell to higher temperatures than would occur with a completely mixed air/steam mixture, would of course result in higher evaporation from the hotter portion of the shell. This would result in the streams in this portion of the shell being narrower or fully dried, resulting in more water evaporation and heat removal at any given containment pressure. Thus, the assumed uniformly mixed air/steam with uniform shell temperature and corresponding uniform wet or dry heat fluxes, and uniform water stream narrowing used in the water coverage calculation is conservative.

No credit is taken for evaporation of water from the dome region above the second ring of weirs in the water coverage calculation portion of the Evaluation Model. As discussed in Reference 480.1055-2, Section 7, the dome region above the second ring of weirs is assumed to only heat the "cool" delivered water to its evaporation temperature.

References:

480.1055-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1055-2. WCAP-14407, Rev. 1 "WGOTHIC Application to AP600," July 1997.

SSAR Revision: NONE

OITS: 5556
RAI: 480.1056

Regarding Reference 480.1056-1, Section 2.2: Inside and Outside Heat Transfer Boundary Conditions, describe the differences between the model used for the 1-dimensional steady-state calculations of the PCS and the WGOTHIC Evaluation Model. Why was the WGOTHIC Evaluation Model (described in Chapter 4 of Ref. 480.1056-2) not used? Are the mass and heat transfer correlations biased as in the evaluation model or are the nominal values used?

Response:

The boundary conditions for the ANSYS calculation were calculated using an in-house computer code called INOUT. This code has been verified against the large scale PCS test results and uses the same computational method as WGOTHIC for both the inside and outside heat transfer processes. However, INOUT is only a single point calculation and therefore a well-mixed containment air/steam mixture temperature corresponding to the containment global pressure, and an estimated average cooling air temperature and velocity for each pressure analyzed, is used. WGOTHIC was not used for the 1-D calculations in order that the normalization of the 2-D heat transfer rates would be performed on a consistent basis. The mass and heat transfer results from INOUT were used to determine effective overall heat transfer coefficients to and from the steel containment shell. These coefficients were biased to account for the conservative multipliers applied to WGOTHIC. Also see the response for RAI 480.1057 for additional comparisons between the 2-D calculation and WGOTHIC.

References:

480.1056-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1056-2. WCAP-14407, "WGOTHIC Application to AP600," A. Forgie, et. al., September 1996.

SSAR Revision: NONE

OITS: 5557
RAI: 480.1057

Regarding Reference 480.1057-1, Section 2.2: Inside and Outside Heat Transfer Boundary Conditions, list the assumptions used to derive the inside and outside boundary conditions for the 1-D and 2-D heat conduction models. Provide details of the polynomial fits and values for the heat transfer coefficients and boundary conditions used at the design containment pressure and at half of the design containment pressure.

Response:

The assumptions used to derive the inside and outside boundary conditions used in the 2-D heat conduction calculations, and the 0 and 100 percent wetted (1-D) calculations used to normalize the 2-D heat transfer are listed below:

- The initial air pressure inside containment was assumed to be 15.7 psig.
- The initial inside containment air and structure temperature was assumed to be 120°F.
- The cooling air inlet temperature was assumed to be 115°F, in that the average air temperature along the cooling flow path was estimated to be ≥ 130°F.
- The thickness of the water film on the inside and outside surfaces of the containment shell was assumed to be 0.005 inches (fixed value in INOUT).
- The thickness of the shell coating was assumed to be 0.004 inches (fixed value in INOUT).
- The conductivity of the steel shell was assumed to be 28.5 Btu-ft/hr-ft^2-°F (fixed value in INOUT) for the heat transfer boundary condition calculation. Note that the ANSYS calculation uses a conservative steel conductivity of 24 Btu-ft/hr-ft^2-°F.

Figure 480.1057-1 provides a graphic comparision of the inside heat transfer coefficients for the wetted surface vs. the containment pressure calculated for the 2-D ANSYS boundary conditions, and similar inside heat transfer coefficients obtained directly from the WGOTHIC SSAR case. The polynomial fit for these curves is also delineated. It can be seen that the WGOTHIC inside heat transfer coefficients are greater than or equal to the calculated ANSYS heat transfer boundary conditions at all containment pressures.

Figure 480.1057-2 provides a graphic comparision of the outside heat transfer coefficients for the wetted surface vs. the outside containment steel shell surface temperature calculated for the 2-D ANSYS boundary conditions, and similar outside coefficients obtained directly from the WGOTHIC SSAR case. The polynomial fit for these curves is also delineated. It can be seen that the calculated ANSYS outside heat transfer coefficients are greater than WGOTHIC.

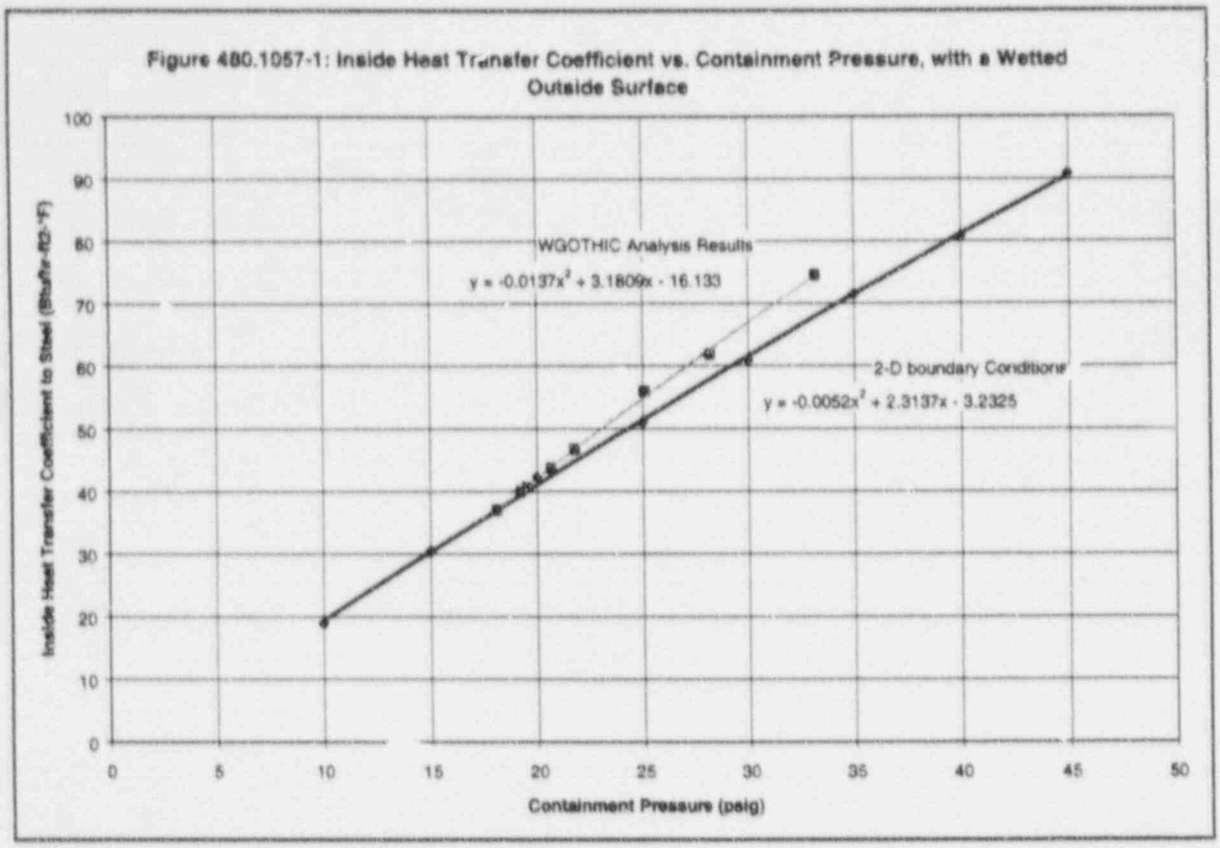
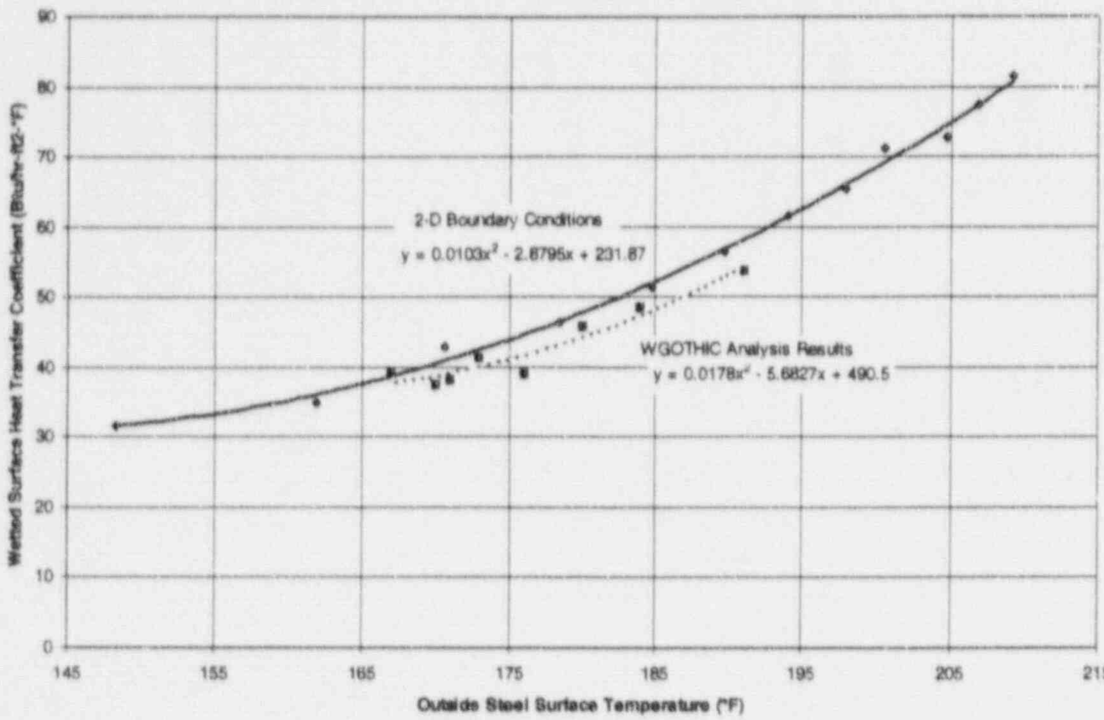


Figure 480.1057-1: Inside Heat Transfer Coefficient vs. Containment Pressure, with a Wetted Outside Surface
WGOTHIC Analysis Results
y = -0.0137x² + 3.1809x - 16.133
2-D boundary Conditions
y = -0.0052x² + 2.3137x - 3.2325
Inside Heat Transfer Coefficient to Steel (Btu/hr-ft2-°F)
Containment Pressure (psig)
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
50

Figure 480.1057-2: Outside Wetted Heat Transfer Coefficient vs. Outside Steel Surface Temperature



These comparison curves show that in the ANSYS calculation, heat transfer to the steel shell is underpredicted and heat transfer from outside wetted surfaces is overpredicted compared to WGOTHIC, which results in a conservative prediction of the importance of circumferential heat conduction through the steel shell for the 2-D heat transfer enhancement at all pressures used in the Evaluation Model. It is also noted that the heat transfer coefficient used to calculate the heat transfer from the dry outside surface in the ANSYS calculation is conservatively high compared to WGOTHIC.

References:

480.1057-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

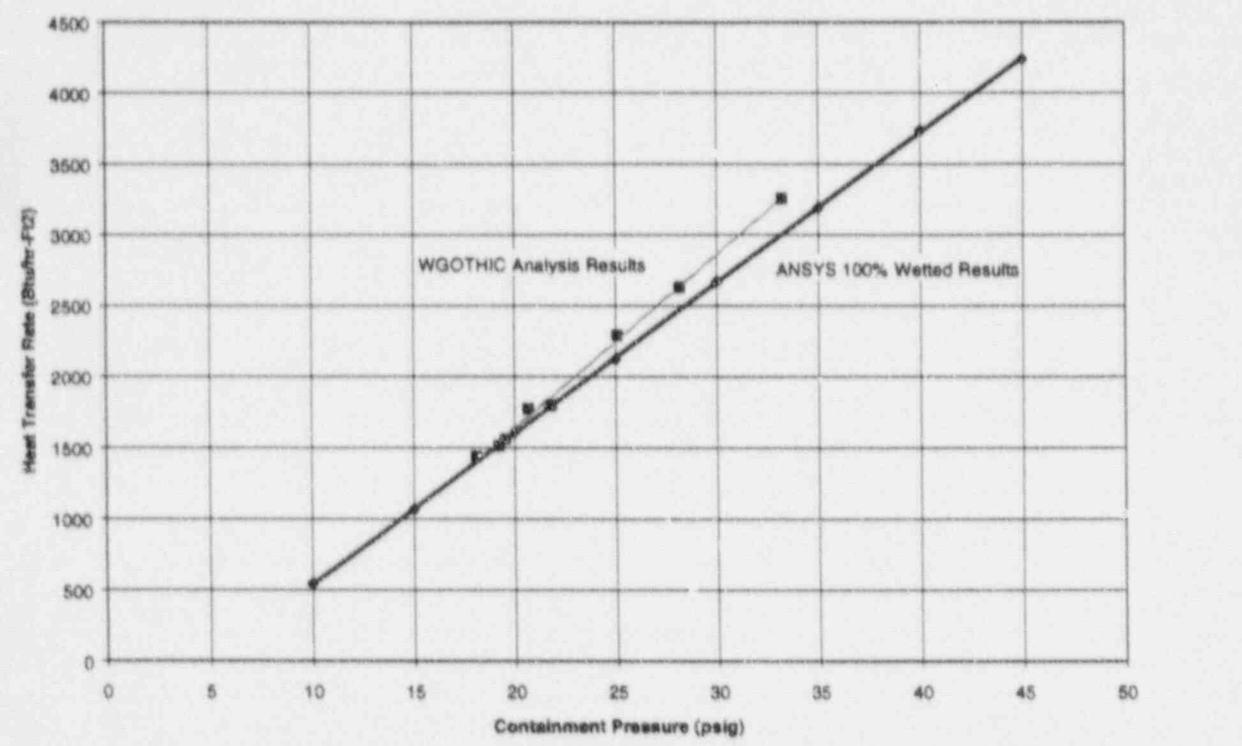
OITS: 5558
RAI: 480.1058

Regarding Reference 480.1058-1, Section 2.2: Inside and Outside Heat Transfer Boundary Conditions, explain why the 1-dimensional steady state heat transfer rates calculated at all containment pressure/temperature conditions are higher than the corresponding heat transfer rates calculated by WGOTHIC, when both calculations use the same heat and mass transfer methodology?

Response:

The statement in Reference 480.1058-1, Section 2.2 that the one-dimensional steady-state heat transfer rates calculated with the boundary conditions used in the 2-D conduction model are higher than the corresponding heat transfer rates calculated by WGOTHIC needs clarification. This statement refers to a comparison to the heat transfer rates that were used in the film coverage model, and which are less than the actual WGOTHIC heat transfer rates for conservatism. A comparison of the actual area-weighted WGOTHIC heat transfer rates from the wetted climes shows that the 1-dimensional steady-state heat transfer rates calculated from a wetted surface by the ANSYS calculation are lower than or equal to the heat transfer rates obtained from the WGOTHIC SSAR case at corresponding containment pressures. This is illustrated in Figure 480.1058-1.

Figure 480.1058-1: Heat Transfer vs. Containment Pressure, with a Wetted Outside Surface



References:

480.1058-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5559
RAI: 480.1059

Regarding Reference 480.1059-1, Section 2.2: Inside and Outside Heat Transfer Boundary Conditions, provide a schematic drawing of the 1-dimensional model with all boundary and symmetry conditions specified. Show the mesh spacing selected. State whether the baffle was included in the model. List the values used for all input parameters in the 1-dimensional steady-state conduction study. Identify any differences in these parameters from the WGOTHIC Evaluation Model (Chapter 4 of Reference 480.1059-2).

Response:

Refer to the RAI response for 480.1061 for details concerning the ANSYS conduction half-cell model and mesh spacing. Refer to the RAI response for 480.1057 for a listing of the input parameters used in the conduction study and comparisons to the WGOTHIC Evaluation Model.

References:

480.1059-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1059-2 WCAP-14407, "WGOTHIC Application to AP600," A. Forgie, et. al., September 1996.

SSAR Revision: NONE

OITS: 5560
RAI: 480.1060

Regarding Reference 480.1060-1, Section 2.2: Inside and Outside Heat Transfer Boundary Conditions, provide figures which show the results of the 1-dimensional calculations for the shell surface temperatures (inside and outside) and for the heat fluxes calculated over the range of containment pressures.

Response:

The shell surface temperatures and heat fluxes calculated with the ANSYS 2-D model for fully wet or dry surfaces (only 1-D, radial heat conduction occurring) are listed below. These heat fluxes were used to normalize the heat fluxes obtained with 2-dimensional heat conduction through the steel containment shell at the same corresponding containment pressures.

Contain. Pressure (psig)	Inside Air/Stm. Temp. (°F)	Wet Outside Surface			Dry Outside Surface		
		Inside Steel (°F)	Outside Steel (°F)	Ht. Flux (Btu/hr-ft²)	Inside Steel (°F)	Outside Steel (°F)	Ht.Flux (Btu/hr-ft²)
10	179	150.38	147.33	541	171.47	170.67	142
15	201	166.22	160.25	1057	193.47	192.23	219
20	217.5	179.3	170.2	1614	210.93	209.36	278
25	230.6	189.08	177.12	2120	224.26	222.44	324

References:

480.1060-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5561
RAI: 480.1061

Regarding Reference 480.1061-1, Conduction (ANSYS) Model Description, provide a schematic drawing of the 2-dimensional model with all boundary and symmetry conditions specified. Show the mesh spacing selected. State whether the baffle was included in the model. List the values used for input parameters in the 2-dimensional conduction study, including the containment and annulus boundary conditions actually used for the 2-D ANSYS-simulation and the steady-state 1-dimensional, radial temperature profile used as the initial condition for the 2-dimensional study. Identify any differences in these parameters from the WGOTHIC Evaluation Model (Chapter 4 of Reference 480.1061-2).

Response:

ANSYS Half-Cell Noding

A schematic drawing of the 2-dimensional half-cell model for the ANSYS calculation for 20 psig containment pressure with an overall sidewall wetted percentage of 25% is shown in Figure 480.1061-1. The elements and nodes shown for this half-cell model are typical of the other cases that were run. However, the half-cell models for each coverage fraction were customized to increase the number of nodes (and decrease the node spacing) at the boundary between the wetted outside surface (water stripe) and the dry outside surface. The table below shows the number of elements and nodes that were used for each of the wetted fraction meshes:

Overall Containment Coverage (%)	Number of Elements	Number of Nodes
5	1216	739
10	1220	741
15	1406	834
20	1364	813
25	1412	837
30	1424	843
35	1388	825
40	1464	863
50	1430	846
60	1416	839
70	1390	826
80	1376	819
90	1226	744
95	1434	848

ANSYS Half-Cell Boundary Conditions

The boundary conditions applied to the half-cell model consisted of an inside heat transfer coefficient from the air/steam mixture to the inside surface of the steel containment shell for each containment pressure, a polynomial equation which defines the heat transfer coefficient from the wetted outside surface as a function of the outside surface temperature of the steel containment shell, a constant heat transfer coefficient of 3.5 Btu/hr-ft^2-°F from the dry outside steel containment shell surface, and a constant outside cooling air temperature of 130°F. In addition, adiabatic boundary conditions were used for the right and left side of the half-cell model to represent the symmetry and periodicity of the half-cell. The response to RAI 480.1057 provides the inside and outside effective heat transfer coefficients that are the important boundary conditions for the ANSYS calculation, compared to the corresponding coefficients obtained directly from the WGOTHIC portion of the Evaluation Model.

Note that the ANSYS calculation does not require a radial temperature profile for an initial condition. ANSYS establishes the temperature profile through the steel shell by determining a heat balance between the heat into and out of the steel shell, consistent with the boundary conditions.

The air baffle was not included in the ANSYS model. However, the effect of the baffle on heat transfer was included in establishing the outside heat transfer coefficient boundary conditions.

References:

480.1061-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1061-2 WCAP-14407, "WGOTHIC Application to AP600," A. Forgie, et. al., September 1996.

SSAR Revision: NONE

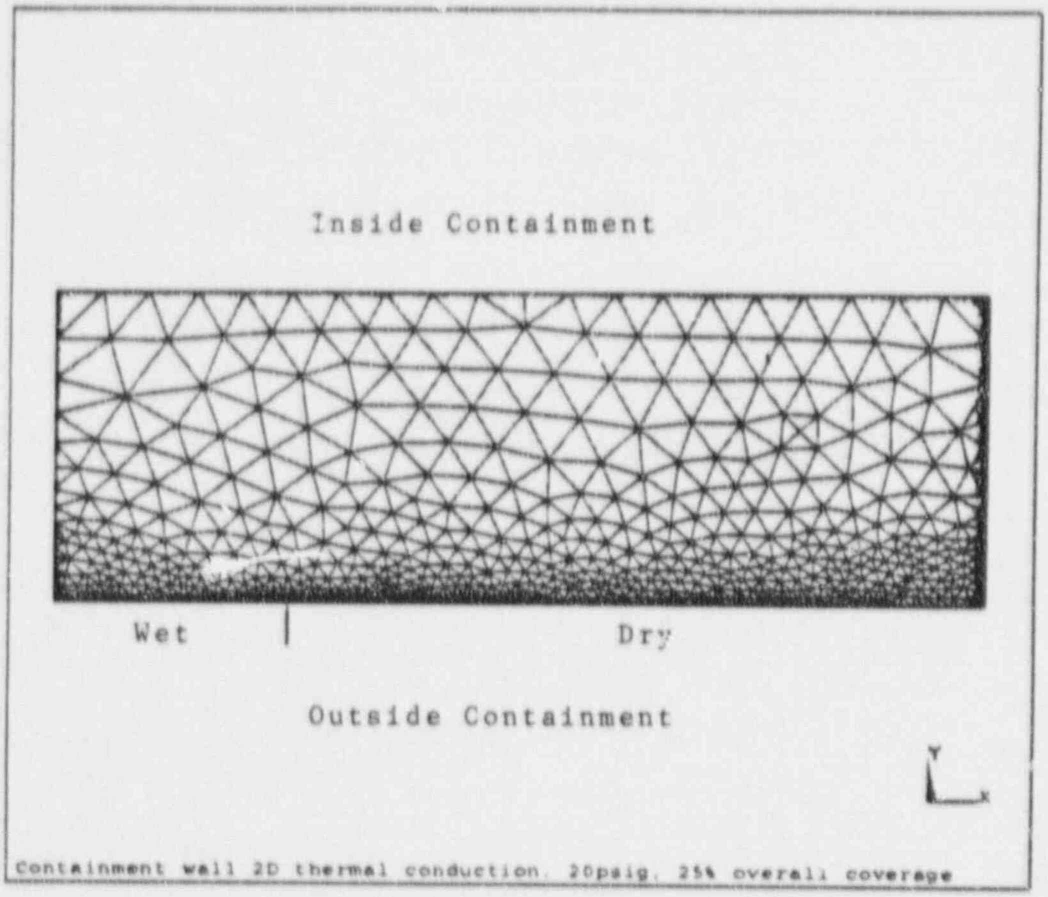


Figure 480.1061-1 ANSYS Half-Cell Mesh Model

OITS: 5562
RAI: 480.1062

Regarding Reference 480.1062-1, Conduction (ANSYS) Model Description, the ANSYS conduction model description make no mention of the special coating which is applied inside and outside PCS shell. The coating has a relatively low thermal conductivity and its omission may cause the 2-D analyses to be non-conservative. Confirm that coatings were omitted in the 2-D conduction analyses. Compare the Figure 2 results to a calculation which includes these coatings.

Response:

The effect of the low conductivity water film and steel coating, both on the inside and outside steel surfaces as applicable, was considered in establishing the heat transfer boundary conditions to and from the steel shell that were used in the ANSYS calculation. Therefore the ANSYS calculation results already includes their small impact.

References:

480.1062-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5563
RAI: 480.1063

Regarding Reference 480.1063-1, Section 2.4: Conduction (ANSYS) Model Results, explain the assumptions used to determine the evaporation rate from the 2-dimensional film as compared to the 1-dimensional prediction.

Response:

There are no differences between the assumptions and the heat transfer boundary conditions used to determine the heat removal rates in the 2-dimensional calculations, and the 1-dimensional calculations (the completely wetted or dry cases) used for normalization.

References:

480.1063-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5564
RAI: 480.1064

Regarding Reference 480.1064-1, Section 2.4: Conduction (ANSYS) Model Results, Figures 3 and 4 indicate the y-direction as being perpendicular to the shell surface. Consequently, the figure captions of Figures 5 and 6 quote the wrong directions. They should read x-direction instead of y-direction. Therefore, on Figures 5 and 6:

- Correct the direction in figure captions
- Add the thermal flux results from 1-D computations
- Indicate clearly boundaries between wet and dry surfaces
- Label the axes correctly
- Explain the meaning (convention) of the minus values

Response:

Figures 5 and 6 are correctly labeled. The convention used in all figures is that the (-y) direction is perpendicular to, and out from, the outside surface of the shell. Thus, the heat fluxes shown are negative. However, the label on Figure 4 of Attachment 2 to letter NSD-NRC-97-5152, dated may 23,1997 is incorrect and should be "Thermal Flux Gradients (Btu/hr-ft^2) in Y-Direction." The labeling for this figure has been corrected and is shown as Figure 7-8 in Section 7.4 of WCAP-14407, Rev. 1.

References:

480.1064-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5565
RAI: 480.1065

Regarding Reference 480.1065-1, Section 2.5: Insights from the PCS Large Scale Testing, provide the experimentally measured evidence (i.e., thermocouples values and pressure sensors) which support the conclusion that an equal amount of heat was removed in test cases 212.1C and 213.1C. Present a sample calculation which uses this sensor data.

Response:

Tables 4.3-3 and Table 4.4-3 of WCAP-14135, Rev.1, "Final Data Report for PCS Large-Scale Tests Phase 2 and 3," provide experimental evidence which supports the conclusion that an equal amount of heat was removed in test cases 212.1C and 213.1C, respectively. These tables which summarize the boundary conditions and test instrumentation measurement results for each of these tests, show that the source steam mass flow rate and enthalpy, collected condensate temperature and flow rate, and the amount of water evaporated were nearly identical in both tests. Therefore, the data provide clear evidence that the energy input to the test vessel, and energy removed from the test vessel are also nearly identical.

References:

480.1065-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5566
RAI: 480.1066

Regarding Reference 480.1066-1, Section 2.5: Insights from the PCS Large Scale Testing, provide experimentally measured evidence (i.e., thermocouples values) which support the conclusion that elevated wet surface temperatures and enhanced water evaporation occurs at wetted locations adjacent to dry stripes.

Response:

Experimental evidence which supports the conclusion that elevated wet surface temperatures and enhanced evaporation occurs at wetted locations adjacent to dry stripes has been included in Section 7.4 of WCAP-14407, Rev. 1. Tables 7-4 and 7-5 present the test vessel inside and outside shell temperatures at elevations D and E where stripes were observed to occur in test 213.1C. In these tables the wall temperature data have been used to calculate the wall delta-temperatures and local heat fluxes. The calculated heat fluxes in test 213.1C at areas that are wetted (as indicated by high wall delta-temperatures), are significantly higher than the wet areas in test 212.1C.

References:

480.1066-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5567
RAI: 480.1067

Regarding Reference 480.1067-1, Section 3.0: Application to AP600 Containment Evaluation Model, provide a numerical example of the calculation of the evaporation limited flow rate and the correction factors for 2-dimensional conduction. As section 2.5 qualitatively describes the observed differences between test run RC048C of test matrix 212.1 and test run RC050C of test matrix 213.1, use these LST tests as the basis for this numerical example. After applying the film coverage methodology, compare the calculated results to the experimental data available. Are the equivalent wetted surface areas in the WGOTHIC model larger than those that could be supported by the WDT data?

Response:

The wetted surface areas calculated using the water coverage methodology in the Evaluation Model are less than the water coverage observed in the large scale PCS matrix tests 212.1, Run RC048C and 213.1, Run RC050C. This underprediction of the test vessel wetted surface area results in an under prediction of the vessel heat removal due to water evaporation. A numerical example of the Evaluation Model calculated water coverage and amount of water evaporated for each of these tests is provided below and compared to the actual observed values. Test data and results used below were obtained from WCAP-14135, Rev. 1, "Final Data Report for PCS Large-Scale Tests, Phase 2 and Phase 3."

Matrix Test 212.1, Run RC048C

The pertinent test boundary conditions and test results that are used in the Evaluation Model calculation are:

- Applied water flow rate — 8712 lbs./hr.
- Average evaporative heat flux — 3763 Btu/hr-ft^2 (based on overall heat balance using test data)
- Estimated Z_{MAX} — 13 feet (based on overall heat balance using test data)

The water coverage portion of the Evaluation Model would predict that the fraction of the containment shell wetted by the applied water at Z = 0 is;

Wetted fraction = (8712 lbs./hr.)/((Γ_{DIST})(Sidewall circumference)) = 0.63

where: Γ_{DIST} = 293 lbs./hr.-ft.
Sidewall circumference = π(15 ft.) = 47.12 feet

The water coverage portion of the Evaluation Model would predict that the amount of water evaporated from the test vessel is;

Water evaporated = (Wetted Area)(Water evaporation rate per hr-ft^2)(M) = 1617 lbs.

where: Wetted area = (Wetted fraction)(Sidewall circumference)(Z_{MAX})
= (0.63)(47.12 ft.)(13 ft.) = 385.9 ft^2

Water evaporation rate = (Evaporative heat flux) / (h_{fg})
= 3.763 lbs./hr.-ft^2

M = 2-D conduction multiplier for 0.63 wet fraction
= 1.1138
(where the increase in evaporation due to 2-D heat conduction has been assumed to be 1/2 of AP600 because the test vessel steel shell is ~1/2 as thick as the AP600 containment vessel.)

Note that the above calculation results in a water film flow rate at the bottom of the test vessel of 7095 lbs./hr. per 29.7 feet of wetted circumference, or 239 lbs./hr.-ft.; which is greater than Γ_{MIN} (120 lbs./hr.-ft.). Therefore, the water coverage portion of the evaluation model would predict that the water coverage (water stripe widths) will not change as a function of Z.

The above calculated water coverage fraction (0.63) and water evaporation rate (1617 lbs./hr.) are conservative compared to the actual test, where the coverage fraction observed at the bottom of the shell was 0.95 and the observed water evaporation rate was 2268 lbs./hr.

For completeness, test data and results from matrix test 212.1, Run RC048C used to establish the input for the above calculations are listed below for information.

• Applied water flow rate / temperature	8712 lbs./hr. / 75.7°F
• Water runoff flow rate / temperature	6444 lbs./hr. / 148.4°F
• Total water evaporation rate	2268 lbs./hr.
• Heat removal by evaporation	2.30E6 Btu/hr.
• Heat removed by heating applied water	0.63E6 Btu/hr.
• Heat removed by convection and radiation	0.21E6 Btu/hr.
• Total heat removed based on steam/cond.	3.14E6 Btu/hr.
• Average wetted area heat flux from TC pairs	4106 Btu/hr-ft^2

<u>Matrix Test 213.1, Run RC050C</u>

The pertinent test boundary conditions and test results that are used in the Evaluation Model calculation are:

- Applied water flow rate / temperature — 2988 lbs./hr. / 78.1°F
- Average evaporative heat flux — 4830 Btu/hr-ft^2
  (based on overall heat balance, assuming that the overall wetted fraction is 0.75, and 2-D conduction effect ignored)
- Estimated Z_{MAX} — 15 feet

The water coverage portion of the Evaluation Model would predict that the fraction of the containment shell wetted by the applied water at Z = 0 is;

Wetted fraction = (2988 lbs./hr.)/((Γ_{DIST})(Sidewall circumference)) = 0.22

where: Γ_{DIST} = 293 lbs./hr.-ft.
Sidewall circumference = π(15 ft.) = 47.12 feet

The water coverage portion of the Evaluation Model would predict that the amount of water evaporated from the test vessel is;

Water evaporated = (Wetted Area)(Water evaporation rate per hr-ft^2)(M) = 1048.5 lbs.

where:

Wetted area = (Wetted fraction)(Sidewall circumference)(Z_{MAX})
= (0.22)(47.12 ft.)(15 ft.) = 155.5 ft^2

Water evaporation rate = (Evaporative heat flux) / (h_{fg})
= 4.83 lbs./hr.-ft^2

M = 2-D conduction multiplier for 0.22 wet fraction = 1.396
(where the increase in evaporation due to 2-D heat conduction has been assumed to be 1/2 of AP600 because the test vessel steel shell is ~1/2 as thick as the AP600 containment vessel.)

Note that the above calculation results in a water film flow rate at the bottom of the test vessel of 1939.5 lbs./hr. per 10.2 feet of wetted circumference, or 190 lbs./hr.-ft.; which is greater than Γ_{MIN} (120 lbs./hr.-ft.). Therefore, the water coverage portion of the evaluation model would predict the water coverage (water stripe widths) will not change as a function of Z.

The above calculated water coverage fraction (0.22) and water evaporation rate (1033 lbs./hr.) are conservative compared to the actual test, where the coverage fraction observed at the bottom of the shell was 0.52 and the observed water evaporation rate was 2520 lbs./hr.

For completeness, test data and results from matrix test 213.1, Run RC050C used to establish the input for the above calculations are listed below for information.

- Applied water flow rate / temperature — 2988 lbs./hr. / 78.1°F
- Water runoff flow rate / temperature — 468 lbs./hr. / 142.1°F
- Total water evaporation rate — 2520 lbs./hr.
- Heat removal by evaporation — 2.56E6 Btu/hr.
- Heat removed by heating applied water — 0.19E6 Btu/hr.
- Heat removed by convection and radiation — 0.33E6 Btu/hr.
- Total heat removed based on steam/cond. — 3.08E6 Btu/hr.
- Average wetted area heat flux from TC pairs — 5163 Btu/hr-ft^2

Summary of Results

The table below summarizes the above comparisons between the water coverage calculation method used in the Evaluation Model versus the coverage and water evaporation rate observed in the tests. These comparisons clearly show that the water coverage calculation method results, for input to the WGOTHIC portion of the Evaluation Model, are conservative.

	Test 212.1, Run RC048C		Test 213.1, Run RC050C	
	Coverage Fraction	Water Evaporated	Coverage Fraction	Water Evaporated
Water Coverage Model	0.63	1617 lb_m/hr	0.22	1048.5 lb_m/hr
Observed in Test	≥ 0.95	2268 lb_m/hr	≥ 0.52	2520 lb_m/hr

Reference:

480.1067-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE

OITS: 5568
RAI: 480.1068

Regarding Reference 480.1068-1, Section 3.1: Calculating Fraction of PCS Water That Does Not Evaporate, explain why assumption (1) is appropriate for the derivation presented. The liquid flow is applied to an initially hot surface. Quantities derived from cold tests must be confirmed for hot surface film flow behavior.

Response:

The basis for using Γ^*_{dist} derived from the cold Water Distribution Test is presented in Reference 480.1068-1, Section 7.3.1.

Reference:

480.1068-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5569
RAI: 480.1069

Regarding Reference 480.1069-1, Section 3.1: Calculating Fraction of PCS Water That Does Not Evaporate, justify the inherent assumption of equation (3) that the evaporation rate is proportional to the flow rate. Should not the evaporation rate be a function of the wetted surface area?

Response:

Equation 3, $d\dot{m}/dZ = -\phi_m W$, is a simple statement of conservation of mass. Over an elemental area of height dZ, constant width W, and width averaged evaporation flux ϕ_m, the difference between the mass flow rates in and out is $d\dot{m} = -\phi_m W\, dZ$. That is, the mass flow rate is equal to the mass flux times the area.

Reference 480.1069-1 presents the subject equation correctly (with the minus sign) in Equation 7-4.

References:

480.1069-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5570
RAI: 480.1070

Regarding Reference 480.1070-1, Section 3.1: Calculating Fraction of PCS Water That Does Not Evaporate, provide an explanation of the calculation procedure for the evaporation rate, ϕ_m, and for the flow rate per unit width, Γ_{min}.

Response:

The evaporation mass flux, ϕ_m is the average sidewall mass flux calculated by the WGOTHIC code, and is discussed in Reference 480.1070-1, Section 7.5.2.2. The basis for the minimum stable film flow rate, Γ_{min} is defined in Section 7.3.2.

References:

480.1070-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5571
RAI: 480.1071

Regarding Reference 480.1071-1, Section 3.2: Evaporation Limited Flow Calculation, what is the calculational procedure for the dome region above the second weir?

Response:

The PCS water coverage model described in Reference 480.1071-1, Section 7, does not consider evaporation above the second weir. The PCS water coverage model conservatively limits evaporation to the side wall.

References:

480.1071-1 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5572
RAI: 480.1072

Regarding Reference 480.1072-1, how is the evaporation heat flux determined? Which and how many time values are "selected times." Explain.

Response:

The evaporation heat flux (actually the mass flux) is determined by dividing the total mass evaporation rate on the climes below the second weir by the total evaporation area. The result is the average evaporation mass flux calculated consistent with the temperatures and partial pressures inside and outside the shell.

The selected time values are listed in Reference 480.1072-2, Table 4-102. At each time value, the evaporation rate predicted by the PCS film coverage model is higher than the flow rate input to WGOTHIC. Time values are selected such that the time integral of the flow history input to WGOTHIC is not significantly underpredicted, which would result in an unnecessarily high pressure history. The trade-off is that more time steps require more engineering time and effort.

References:

480.1072-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1072-2. WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5573
RAI: 480.1073

Regarding Reference 480.1073-1, Page 9, "...; thereby assuring that WGOTHIC predicts limited evaporation of PCS water." Clarify what is meant by this sentence.

Response:

The WGOTHIC model and the PCS water coverage model, and their relationship, are more clearly described in Reference 480.1073-2, Section 7.5.

The water evaporation rate at any point in time is calculated consistent with stability and coverage area by the PCS film coverage model using the average evaporation mass flux calculated by WGOTHIC. The resulting evaporation rate, not the total PCS flow rate delivered to the dome, is input to WGOTHIC. That way, WGOTHIC cannot evaporate more water than is consistent with both the WGOTHIC and PCS film coverage models.

References:

480.1073-1. "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1073-2. WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

OITS: 5574
RAI: 480.1074

Regarding Reference 480.1074-1, page 9, explain the convergence procedure used for the evaporation mass flux iteration. Specify the convergence criterion used for this procedure. What is meant by "consistent and slightly higher than the values assumed for input under Step 1 (Step 1 values come from WGOTHIC)? Specify how many interactions are commonly needed for convergence.

Response:

The convergence procedure was more clearly defined in Reference 480.1074-2, Section 7.5.2.2. The PCS film coverage model predicts the evaporation rate $\dot{m}_{evap}$ is an increasing function of the evaporation heat flux, ϕ_{n}, with parameters that include the PCS water flow rate, Γ_{dist} which determines the wetted circumference at the top of the sidewall, and the minimum stable film flow rate, Γ_{min}. WGOTHIC predicts that the evaporation heat flux decreases as the mass evaporation rate increases, since increased mass evaporation decreases pressure. The simultaneous solution to these two functions is the point at which they intersect when plotted on a ϕ_{n}, $\dot{m}_{evap}$ map, as shown in Figure 480.1074-1. Since the iteration process used here makes it difficult to achieve an exact solution, a conservative solution is accepted. A conservative solution relative to containment pressure results when the evaporation rate used in the WGOTHIC model is less than the evaporation rate from the exact solution. In Figure 480.1074-1, a conservative solution lies on the WGOTHIC curve on the lower right side of the simultaneous solution. The lower WGOTHIC evaporation rate and conservative solution results for either:

- At the same heat flux the PCS film coverage model evaporation rate is greater than the WGOTHIC evaporation rate, or
- At the same evaporation rate the WGOTHIC heat flux is greater than the heat flux used in the PCS film coverage model.

Both of these are shown on Figure 480.1074-1. The latter criterion was used for the containment pressures presented in Reference 480.1074-2.

The WGOTHIC heat flux ranged from 0.1 to 7.0 % greater than the PCS film coverage model input heat flux at the same mass evaporation rate.

References:

480.1074-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1074-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600", July 1997, Westinghouse Electric Corporation.

SSAR Revision: NONE

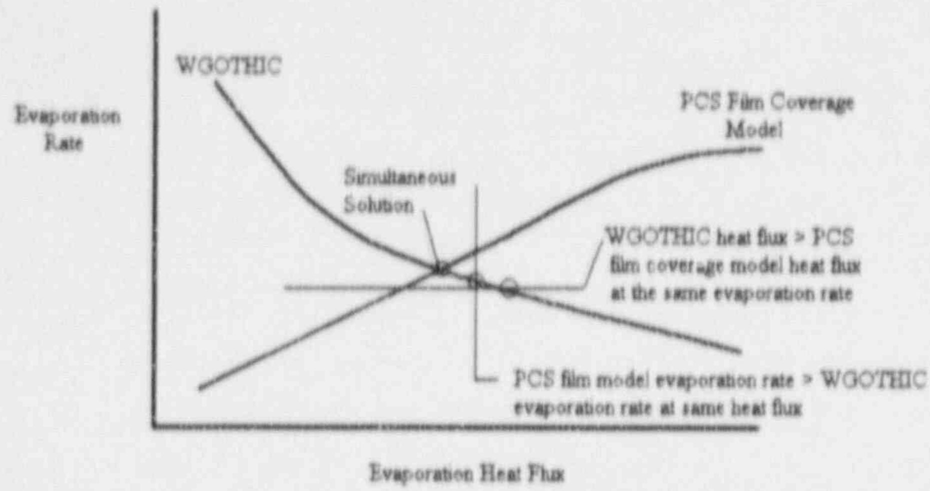


Figure 480.1074-1 Simultaneous Solution of WGOTHIC and PCS Film Coverage Model

OITS: 5575
RAI: 480.1075

Regarding Reference 480.1075-1, Section 3.2: Inclusion of 2-Dimensional Conduction Effects, Westinghouse states that the film evaporation rate is also a function of the stripe width. Furthermore, it was stated before that the wetted stripe width resulted from experimental observations. Therefore, the sentence : "Thus, the calculation of the width of the film stripe is accomplished by iteration", needs further explanation.

Response:

The statement that the water stripe width is iteratively calculated, refers to the fact that the water coverage calculation portion of the Evaluation Model decreases the stripe width as water is evaporated, consistent with maintaining the film flow rate (flow rate per foot of wetted width) at Γ_{min} (120 lb_m/hr-ft). When the stripe width decreases, the wetted coverage fraction decreases, and the heat flux increases as specified in Reference 480.1075-2, Equation 7-1. The water coverage calculation is performed by calculating the stripe width and resulting coverage fraction and heat flux in a step-wise fashion, in small length steps of Z from where $\Gamma = \Gamma_{min}$, down the containment sidewall to Z_{max} (the bottom of the sidewall).

References:

480.1075-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997

480.1075-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997.

SSAR Revision: NONE

OITS: 5576
RAI: 480.1076

Regarding Reference 480.1076-1, Section 3.2: Inclusion of 2-Dimensional Conduction Effects, the sentence above Equation (16) is difficult to comprehend and should be rephrased such that both W an W_0 are uniquely defined. Define these terms clearly using words. Is Equation (16) displayed in Figure 2 or derived from this figure by curve-fitting? How many calculated values were available for performing the curve fit? Is there a sensitivity to shell surface temperature, annulus air temperature or film subcooling which is not included as parameters in the Equation (16) fit?

Response:

480.1076-1, Equation 16 has been more clearly defined in Section 7.4 of Reference 480.1076-2 (see Equation 7-1). The term W/W_0 is the wetted fraction of the containment shell perimeter at a given elevation where W is the wetted perimeter or the total width of all the water stripes, and W_0 is the circumference of the containment sidewall. For example: if the applied water flow rate is 36000 lb_m/hr (72gpm), the initial wetted perimeter (W) at the top of the sidewall is simply $W = 36000/\Gamma_{dist}$ = 122.87 feet (where Γ_{dist} = 293 lb_m/hr-ft); W_0 (the total sidewall perimeter) is 408.5 feet; resulting in a W/W_0 of 0.30. Since the wet stripes are regularly spaced, each ANSYS half-cell also has a wetted fraction of 0.30 (with a small correction factor of 1.0214 for the wider dry stripe under each weir assembly distribution box).

Equation 16 (see Equation 7-1 in Section 7.4 of Reference 480.1076-2) lower bounds the curves shown in Figure 2 for the range of pressures and water coverage fractions at which it is used in the Evaluation Model. The curves in 480.1076-1, Figure 2, the normalized heat flux enhancement caused by 2-dimensional heat conduction, are determined by the ANSYS calculation whose outside boundary condition is the heat flux vs.the shell surface temperature. This outside boundary condition was established with consideration of the cooling air temperature. Sensible heating of a subcooled water film is not relevent in the water coverage calculation portion of the Evaluation Model where this equation is utilized.

References:

480.1076-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

480.1076-2 WCAP-14407, Rev. 1, "WGOTHIC Application to AP600," July 1997.

SSAR Revision: NONE

OITS: 5577
RAI: 480.1077

Regarding Reference 480.1077-1, Section 3.2: Inclusion of 2-Dimensional Conduction Effects, the Westinghouse procedure adds wetted area to adjust for 2-D conduction effects. This additional wetted surface area removes more heat by evaporation. However, an equivalent dry area is removed, reducing radiation heat loss and convection from the dry surface. As evaporation is a significantly more dominant effect than radiation/dry surface conduction, the heat loss reduction from dry area reduction will not be consistent with the heat loss gain from wet area enlargement. Although the heat transfer rate may be maintained, the mechanisms driving the heat transfer are changed.

Faulty results may be obtained from non-physical adjustment procedures. For example, Figure 2 suggests that decreasing wetted stripe widths (coverage area) will cause the normalized evaporation rates to go to infinity. Therefore this curve could be used to "optimize" the heat transfer by adjusting the coverage area. WGOTHIC analysis may show that this is the preferential cooling mode for the PCS. Please explain how Westinghouse will prevent this from occurring. Indicate any technically meaningful limit line for this figure.

Response:

The heat flux enhancement factor, M, does not go to infinity as the water coverage fraction approaches zero; but in the limit is 2.6694 as the wetted fraction, W/W_0, approaches zero. In fact, the heat removal by evaporation (the product of the WGOTHIC 1-D heat flux, the wetted area, and the corresponding M) always decreases with decreasing wetted area. Therefore, the heat flux enhancement factor cannot be used to artificially "optimize" the heat transfer by adjusting the heat transfer area.

References:

480.1077-1 "Description of Method to Account for Circumferential (2-Dimensional) Conduction Through the Steel Containment Shell for Containment Pressure Analyses", Attachment 2 of NSD-NRC-97-5152, May 23, 1997.

SSAR Revision: NONE