Westinghouse
Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-96-930

February 16, 1996

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

ATTENTION: T. R. QUAY

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: WESTINGHOUSE RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON THE AP600

Dear Mr. Quay:

The application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10CFR Section 2.790, Affidavit AW-96-930 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-96-930 and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo for

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

cc: Kevin Bohrer NRC 12H5

2685A

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Nicholas J. Liparulo, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Nicholas J. Liparulo

Nicholas J. Liparulo, Manager
Regulatory And Engineering Networks

Sworn to and subscribed
before me this 16 day
of February, 1996

Rose Marie Payne

Notary Public

Notarial Seal
Rose Marie Payne, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Nov. 4, 1996
Member, Pennsylvania Association of Notaries

(1) I am Manager, Regulatory And Engineering Networks, Nuclear Services Division, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Energy Systems Business Unit in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) Enclosed is Letter NSD-NRC-96-4649, February 16, 1996 being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, Brian A. McIntyre (W), to Mr. T. R. Quay, Office of NRR. The proprietary information as submitted for use by Westinghouse Electric Corporation is in response to questions concerning the AP600 plant and the associated design certification application and is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of licensing advanced nuclear power plant designs.

This information is part of that which will enable Westinghouse to:

(a) Demonstrate the design and safety of the AP600 Passive Safety Systems.

(b) Establish applicable verification testing methods.

(c) Design Advanced Nuclear Power Plants that meet NRC requirements.

(d) Establish technical and licensing approaches for the AP600 that will ultimately result in a certified design.

(e) Assist customers in obtaining NRC approval for future plants.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for advanced plant licenses.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar advanced nuclear power designs and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

Appendix A

RAIs included in the February 16 transmittal

AP600 Testing

440.247
440.251
440.252
440.254
440.359
480.248
925.94
925.96
925.105

W/GOTHIC

480.276
480.308
480.331
480.332
480.333
480.381
480.382
480.383
480.384
480.385
480.386
480.387
480.393

Enclosure 2

Nonproprietary

Question 480.276

Re: Containment DBA calculation information
Provide the following information so that the NRC is able to update the AP600 containment models based on Revision 6 of the AP600 design:

a. WGOTHIC lump-parameter nodalization of the AP600 design, including internal containment volumes, primary containment cooling system volumes, elevations, and a sketch of the WGOTHIC nodalization.

b. WGOTHIC heat sink descriptions and a table listing areas, thicknesses, structure bottom and top elevations, etc.

c. WGOTHIC flow path tables (area, elevation)

d. IRWST drain down time (level vs. time) for a double-ended cold leg break.

e. Lower containment compartments flooding profile (volume vs elevation)

f. Updated mass and energy sources for double-ended cold leg break and main steam line break.

Response:

The requested containment DBA calculation information was provided informally to NRC reviewers on June 20, 1995, for geometry, and for LOCA boundary and initial conditions, followed with steamline break boundary conditions on July 11, 1995. The information that has been provided is documented in Reference 480.276-1.

References:

480.276-1 NSD-NRC-96-4642, "AP600 WGOTHIC Containment Model Information in Support of Response to RAI 480.276, February 15, 1996.

SSAR Revision: NONE

Question 480.308

Re: (WGOTHIC MODELS AND PHENOMENA)THE MSLB ACCIDENT SCENARIO
480.308 What analyses and sensitivity studies has WEC performed (or is planning to perform) for the main steam line break (MSLB) accident scenario?

Response:

Analyses and sensitivity studies for the main steamline break (MSLB) accident scenario have been performed, based on conclusions drawn from the LST Phase 3 tests with elevated, small diameter pipe at various orientations (Reference 480.308-1) and forced convection condensation separate effects tests (Reference 480.308-2). These studies were used to validate the use of WGOTHIC in lumped parameter mode with free convection for the MSLB evaluation model based on LST comparisons (Reference 480.308-3) and to identify the limiting MSLB mass and energy release scenario (Reference 480.308-4, Reference 480.308-5).

The LST showed that the high kinetic energy releases typical of MSLB scenarios drove mixing throughout the vessel and led to a significant forced convection component of heat and mass transfer on PCS surfaces. Meanwhile, the PIRT and energy partitioning for the AP600 show that the dominant heat removal mechanism on the inside of containment is condensation on the internal heat sink, (the accident is over before the PCS is assumed available). Thus, a conservative bias on heat and mass transfer correlations and the assumption of free convection on the inside PCS surface results in bounding condensation rates. With regard to the well mixed containment (per LST), placing the MSLB mass and energy boundary condition above the operating deck in the lumped parameter evaluation model leads to predicted stratification. This conseratively reduces the access of steam to internal heat sinks below deck. The combination of bounding condensation rates and predicted stratification for MSLB insures that the containment response evaluation model is bounding.

Mass and energy release scenarios have been examined. A failure of the main steam isolation valve (MSIV) is the limiting steamline break mass and energy release scenario. The failure of a main feedwater isolation valve (MFIV) does not result in any more mass discharge into containment than does the failure of an MSIV. An assumed MSIV failure in the mass and energy release analysis forces one steam generator to blow down regardless of break location, thus bounding several break location scenarios.

To confirm this, analyses of the mass and energy releases from 29 postulated steamline break cases, including various break sizes, initial power levels, and single failures, were performed, and the results of the two limiting cases have been presented (Reference 480.308-5). The spectrum of break sizes considers 1.388 ft^2 full double-ended ruptures, small double-ended ruptures ranging between 0.10 and 0.70 ft^2, and small split ruptures ranging between 0.37 and 0.442 ft^2. Power levels include low power cases (0% and 30% power) wherein more steam generator mass is available and high power cases (70% and 102% power) wherein more energy is available in the secondary fluid and the primary side. Single active system failures considered are the failure of the MSIV or the MFIV. Results from the analyses confirmed that the releases from a double-ended rupture of a main steam line with assumed MSIV failure is the limiting steamline break scenario. By performing sensitivities to break size, power level, and single failures, it is shown that other combinations of parameters and control systems interactions do not lead to more limiting cases. There are no significant differences in the AP600 control systems or plant layout, relative to the spectrum sensitivities, that could invalidate this conclusion, so the results remain applicable to the current AP600.

References:

480.308-1 WCAP-14135, Final Data Report for PCS Large-Scale Tests, Phase 2 and Phase 3, Page 1-11, July 1994.

480.308-2 WCAP-14326, Experimental Basis for the AP600 Containment Vessel Heat and Mass Transfer Correlations, Sections 3.8 and 3.9, March 1995.

480.308-3 WCAP-14382, WGOTHIC Code Description and Validation, May, 1995, page 8-10

480.308-4 NTD-NRC-95-4611, AP600 Containment Design Basis Analysis (Break Spectrum Analysis), December 15, 1995.

480.308-5 NTD-NRC-95-4504, Proposed Draft/Markups of SSAR Section 6.2 and 6.4, July 10, 1995, Section 6.2.1.1.1, 6.2.1.1.3

SSAR Revision: NONE

Question 480.331

Re: (WGOTHIC MODELS AND PHENOMENA)FINITE DIFFERENCE (FD) CALCULATIONS
480.331 To demonstrate the adequacy of the nodalization scheme for WGOTHIC in the finite difference mode, WEC needs to perform a grid resolution study to assess errors in the solution due to nodalization.

Response:

Noding studies have been completed to support the use of the distributed parameter (finite difference) evaluation model for calculation of the peak containment pressure. The results show that the noding in the distributed parameter evaluation model overpredicts the pressure and wall velocity converges only weakly. The forced convection enhancement to heat transfer is neglected in the SSAR analysis by assuming free convection inside containment to bound the effects of noding on velocity. Thus, the effects of noding are bounded in the evaluation model. Noding studies for the LST and AP600 distributed parameter model are summarized as follows.

Sensitivities of the WGOTHIC calculation to noding variations have been performed for the LST (Reference 480.331-2, Section 5.0) where the measured results provide a basis for determining the accuracy of calculational results. To confirm the applicability of the selected evaluation model noding for use on AP600 predictions, the LST noding studies have been supplemented with distributed parameter noding studies for the AP600.

Results of the LST noding studies were compared against measurements of vessel pressure, velocity near the PCS surface, and axial steam density gradient (from noncondensible measurements and inferred from wall temperature measurements). The LST noding is developed in four stages:

LST Noding Study Summary		
Objectives	Test Modelled	Result
Using a simple geometry, identify where noding resolution is important	Baseline dry LST with no internals	See Reference 480.331-2 section 5.2.6. Results used to define the detailed distributed parameter model in Appendix A of Reference 480.331-2.
Show important phenomena observed in the LST have been modelled.	LST 212.1, 222.1	See Reference 480.331-2 section A.3. Primary parameters showed good agreement.
Simplify the noding without distorting the flow field	LST 212.1A	See Reference 480.331-2 section 5.2.9. Results (5.2.10) used to define the distributed parameter evaluation model noding (5.2.11).
Compare distributed parameter evaluation model noding to priority LST in detail to define impact of nodding on evaluation model pressure prediction. Confirm with non-priority LSTs that the results are consistent for a larger database.	Priority LSTs (Reference 480.331-2, Section 7.0) Nonpriority LSTs (Reference 480.331-2, Section 8.1.2)	See Reference 480.331-2 section 8.1.1. Results show that the selected nodding is well away from any cliffs in predicted pressure. The reasons for coarser noding predicting higher vessel pressure have been identified, and support that the effects of noding are bounded.

The LST purpose was to examine, on a large scale, the combined natural convection condensation on the interior of the containment with the exterior film evaporation behavior and air cooling heat removal for validation of heat and mass transfer correlations. The LST does not have the typical flow path into the steam generator compartment. Therefore, the effects of noding for the AP600, with the steam generator compartment flow path, have been confirmed with plant model noding studies (Reference 480.331-1). The results can be summarized as follows:

AP600 noding studies included "separate effects" models of the above deck region to examine noding convergence within that region and to compare results to traditional "noding convergence" studies and three noding representations of the AP600. The separate effects above-deck model showed that the code pressure results converged readily when the vertical to horizontal aspect ratio of nodes remained constant. Results also showed that pressure converged when aspect ratios varied. Velocity converges only slowly as noding is refined. However, the use of free convection

bounds the effects of noding on velocity as it affects mass transfer. Results of three noding representations of the AP600, each built by one of three different user organizations, show that in a wide range of noding strategies, the pressure is weakly sensitive and over-predicted by the strategies chosen. The first strategy was a distributed parameter model based on the Westinghouse lumped parameter model. The next model was a more finely noded distributed parameter model developed by Numerical Applications Inc. and was based on the distributed parameter evaluation model of the LST. The final model was a distributed parameter model developed by M.I.T. based on the results of their sensitivity studies. Both coarser and finer noding relative to the AP600 evaluation model was used, and the results showed that the pressure prediction is not sensitive to the strategies used. It was found that coarser noding drives more mixing and gi -s higher PCS wall velocities. The use of free convection allows the effects of noding to be bounding with respect to pressure predictions.

References:

480.331-1 NTD-NRC-96-4634, AP600 WGOTHIC Noding Convergence Studies, January 31, 1996.

480.331-2 WCAP-14382, WGOTHIC Code Description and Validation, May 1995.

SSAR Revision: NONE

Question 480.332

Re: (WGOTHIC MODELS AND PHENOMENA)FINITE DIFFERENCE (FD) CALCULATIONS
480.332 Is WEC aware that demonstrating convergence of first order upwind methods is considered to be very difficult, to the point, for example, that the ASME Journal of Fluids Engineering will not accept papers that utilize this numerical scheme? How will WEC demonstrate convergence for WGOTHIC analyses?

Response:

To model the complexities of multi-phase flow over a wide range of conditions a conservative, transportive, and stable scheme is used in WGOTHIC. The method used in WGOTHIC is termed "conservative" since the flux out of one computational cell is exactly the same as the flux into the adjacent cell, and it is "transportive" since quantities are never advected upstream. Most higher order schemes can not claim these two desirable, physically realistic properties. These properties, together with the fact the method used in WGOTHIC is based on local mass, energy, and momentum balances rather than an estimate of the derivatives of a set of partial differential equations, promotes convergence.

It is known that upwind differencing tends to flatten gradients more than some higher order methods. However, this effect decreases as the grid is made smaller. Therefore, solution accuracy can be established by demonstrating convergence on a series of grid sizes.

Reference 480.332-1 presents the results of several studies on noding and spatial convergence of the WGOTHIC code performed by Westinghouse and MIT.

In the first study, a simple parallelepiped model of a 1/32 slice of the AP600 containment above the operating deck is examined. Seven different models were constructed which varied the horizontal and vertical mesh, while keeping aspect ratios constant. These models all included the steam-only component for a large break LOCA, GOTHIC conductors for the shell assuming a constant outside wall temperature of 120°F, and Gido-Koestel as the mass transfer correlation. For this study, the predicted pressures, temperatures, wall velocities, recirculation flows, and steam partial pressures all converge for the simple model that was examined. This supports the conclusion that WGOTHIC does indeed converge (Reference 480.332-1, Figures 3-7).

The second study is a transitional step between the simple models of the first study and more detailed models that represent the entire AP600 in full detail. Results show how the models behave given that non-uniform node-size reductions were used, as opposed to the first, idealized, noding study. The second study models were based on only the above-deck region of the AP600 and no internal heat sinks or internal flow obstructions were modeled. In addition, the steam and liquid mass releases associated with a LOCA were used as the accident boundary condition, in contrast to the first study which only modeled the steam release portion of the LOCA transient. The results of the second study indicate the sensitivities to noding that were found for the simple model of the first study are also found for the more detailed model of the second study. The fact that the noding is non-uniform in the full above deck models and the liquid contribution of the LOCA is modeled tends to obscure the very clear convergence trends of the simpler models. However, velocities decrease as the number of cells is reduced, making coarser models conservative. In the AP600 evaluation model, the effects of velocity are conservatively ignored (free convection is assumed).

The third study examines complete AP600 models of the same problem built by different groups of people. The study addresses modeling differences that could be attributed to an analyst's interpretation of the problem being studies as well as sensitivities to break location and wall obstructions. The models included above deck PCS, climes, and below deck compartments and heat sinks. All of the models were found to predict essentially the same pressure transients. The wall velocities were found to be the most different between the models, which leads to differences in steam concentrations between the two models. These differences are minor in light of the fact that the pressures in all models agree very well through the time of the peak pressure. The fact that all four models predict essentially the same results shows that the code is not particularly sensitive to modeling differences that may be attributed to different modelers.

Additional noding studies (Reference 480.332-1 and 480.322-2, Section 6.0) were performed and compared to test results from the LSTs performed to support the AP600 design and analyses. These studies provide a basis for determining the accuracy of the code's calculational results and is used to confirm the applicability of the selected evaluation model noding for use in AP600 containment integrity calculations. Using a finely noded model, good agreement was shown with global and spatial parameters. The effect of simplified and more coarsely noded model was to increase predicted mixing and predicted vessel pressure.

References:

480.332-1 NTD-NRC-4634, AP600 WGOTHIC Noding Convergence Studies, January 31, 1996

480.332-2 WCAP-14382, WGOTHIC Code Description and Validation, May 1995.

SSAR Revision: NONE

Question 480.333

Re: (WGOTHIC MODELS AND PHENOMENA)FINITE DIFFERENCE (FD) CALCULATIONS
480.333 What is the role of finite difference calculations in the AP600 certification process?

Response:

Distributed parameter (finite difference) formulations will be used to calculate peak containment pressure for the loss-of-coolant accident in the AP600 design certification process. Long term loss-of-coolant accident and main steamline break results will be calculated using the lumped parameter methodology.

The distributed parameter formulation in WGOTHIC is used for two purposes. The first is to calculate the LST heat removal rates accurately and show that important phenomena are understood and can be bounded for the AP600. The detailed distributed parameter model shows good agreement to global and distributed data (Reference 480.333-1, Appendix A). The second is to perform evaluation model calculations through the time of peak pressure, when stratification can be postulated to adversely affect heat removal rates, and thus the pressure response. The peak pressure evaluation model uses noding based on the distributed parameter LST evaluation model with noding scaled up to AP600 (Reference 480.333-2, Section 6.4), and is supported by a noding convergence study. Please see the response to RAI 480.331, for the basis of the detailed parameter LST model and a discussion of supporting noding studies performed. Road maps have been provided which show how each important phenomenon in the PIRT is bounded in the evaluation model (reference 480.333-2).

References:

480.333-1 WCAP-14382, WGOTHIC Code Description and Validation, May 1995

480.333-2 NTD-NRC-95-4545, AP600 PCS Design Basis Accident Road Maps, August 31, 1995

SSAR Revision: NONE

Question 480.381

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
What is the impact of the pre-heating of the dome on the external surface film cooling? There appear to be inconsistencies between the models used and test observations. How is the film scaled to be sure that the correlations used are valid over the proper parameter ranges? What are the parameters?

Response:

There is no adverse impact of pre-heating of the dome on the ability of the PCS film to wet the surface at the initiation of the transient (Reference 480.381-1) due to:

1. The long time constant for heat up of the outer shell surface relative to the actual initial application of water from the PCS bucket which results in maximum calculated surface temperatures of less than 70°F;

2. The maximum calculated surface temperature with the evaluation model 660 second delay of application of PCS water being less than 230°F; and

3. The demonstrated ability of the advancing film front to wet prototypical surfaces at surface temperatures up to 240°F.

The Zuber-Staub film stability model does assume certain aspects of film behavior which are inconsistent with observed film behavior. The assessment of external PCS water coverage uses the Zuber-Staub model and relevant parameters selected to conservatively bound the observed evaporating film behavior (Reference 480.381-2).

Scaling of the liquid film models is related to the water coverage model used to assess coverage for evaporative heat transfer for input to the WGOTHIC evaluation model (please see responses to RAI's 480.382, 480.383, 480.384, 480.385, and 480.387) for discussion of test data versus AP600 ranges and reference 2 for scale-ability of the Zuber-Staub model). Scaling of the liquid film models is also related to the validation of the application of Chun and Seban wavy laminar heat transfer for calculation of the liquid film equivalent thermal conductivity (Reference 480.381-3). Both of the above film models are scalable and are based on appropriate ranges of test data so that the correlations are valid for application to AP600 PCS DBA. The parameters for both models are identified in the above references.

References:

480.381-1 NSD-NRC-96-4646 " Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

480.381-2 NTD-NRC-96-4635, "AP600 Containment DBA Evaluation Model, Water Coverage Model", January 31,1996.

480.381-3 NTD-NRC-94-4100, AP600 Passive Containment Cooling System Letter Reports, Enclosure 2, April 18, 1994.

AP600

SSAR Revision: NONE

Question 480.382

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
480.382 Provide a comparison of the expected surface temperature range for the AP600 (both LOCA and MSLB) and compare this range to the test range (110 F to 180 F). Provide this comparison for the time period around the peak pressure as well as for the long term, about 24 hours. Do the tests cover the expected AP600 conditions and support the use of 20 degrees for "Theta"? What would be the impact of using 28 degrees for "Theta"?

Reference:

1. "A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

The expected external containment shell surface temperature range for the AP600 has been provided (Reference 480.382-1, Section on Expected Film Coverage Parameter Ranges for AP600). The range of the test data bound the expected AP600 range around the time of initial water application, time of peak pressure, and long term (24 hours).

Low flow test data (Reference 480.382-1, Figures 11 and 12) show that stable film flows exist using the predicted Zuber-Staub minimum film stability criteria with wetting angles less than 20 degrees. The assumed contact wetting angle in the Zuber-Staub model, as applied to AP600, conservatively bounds data for stable flowing films and eliminates any significant sensitivity of the results to the assumed heat flux (References 480.382-1 and 480.382-2). The sensitivity of the Zuber-Staub film stability model to wetting angle is provided in Reference 480.382-1, section on Sensitivity to Assumed Wetting Angle.

References:

480.382-1 NSD-NRC-96-4646, "Conservation in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

480.382-2 NTD-NRC-96-4635, "AP600 Containment DBA Evaluation Model, Water Coverage Model", January 31,1996.

SSAR Revision: NONE

Question 480.382

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
480.382 Provide a comparison of the expected surface temperature range for the AP600 (both LOCA and MSLB) and compare this range to the test range (110 F to 180 F). Provide this comparison for the time period around the peak pressure as well as for the long term, about 24 hours. Do the tests cover the expected AP600 conditions and support the use of 20 degrees for "Theta"? What would be the impact of using 28 degrees for "Theta"?

Reference:

1. "A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

The expected external containment shell surface temperature range for the AP600 has been provided (Reference 480.382-1, Section on Expected Film Coverage Parameter Ranges for AP600). The range of the test data bound the expected AP600 range around the time of initial water application, time of peak pressure, and long term (24 hours).

Low flow test data (Reference 480.382-1, Figures 11 and 12) show that stable film flows exist using the predicted Zuber-Staub minimum film stability criteria with wetting angles less than 20 degrees. The assumed contact wetting angle in the Zuber-Staub model, as applied to AP600, conservatively bounds data for stable flowing films and eliminates any significant sensitivity of the results to the assumed heat flux (References 480.382-1 and 480.382-2). The sensitivity of the Zuber-Staub film stability model to wetting angle is provided in Reference 480.382-1, section on Sensitivity to Assumed Wetting Angle.

References:

480.382-1 NSD-NRC-96-4646, "Conservation in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

480.382-2 NTD-NRC-96-4635, "AP600 Containment DBA Evaluation Model, Water Coverage Model", January 31,1996.

SSAR Revision: NONE

Question 480.383

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
480.383 Provide a comparison of the water temperature (assumed for design basis accident (DBA) evaluations) for the AP600 PCS to the water temperature in the wetting tests. Provide justification that the temperature, and therefore the thermodynamic properties used in the Zuber-Staub model, is appropriately covered by the wetting tests to validate use of the model.

Reference:

1. "A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

A comparison of the water temperature assumed for DBA evaluations for the AP600 PCS to the water temperature in the wetting tests, and a discussion of the appropriateness of the database relative to thermodynamic properties used in the application of the Zuber-Staub model have been provided (Reference 480.383-1). The database covers the appropriate range of liquid film properties for application to AP600.

References:

480.383-1 NSD-NRC-96-4646, "Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

SSAR Revision: NONE

Question 480.384

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
Provide a table similar to Table 3 in Ref. 1 that includes the following data for each test: (1) the PCS water temperature, (2) the PCS water flow rate, (3) the surface heat flux (q") and (4) the temperature (T) used to evaluate the liquid film properties. These data are required to calculated the predicted coverage. If is not always considered to be 20 degrees, include the value used for each case in the table and justify it's selection. Since the PCS water flow rate may not be constant, how is the value obtained for the comparisons? How are q" and T determined for the comparisons? What is the range of q" (from the heat flux thermocouple pairs) in each test? What is the range of the surface temperatures in the each test?

Reference:

1." A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

The database used to establish the method to apply Zuber-Staub to the AP600 covers the range of AP600 parameters. A table similar to Table 3 in the cited reference has been provided (Reference 480.384-1), including for each test and for AP600 the:

- PCS water temperature
- PCS water flow rate
- average wet surface heat flux
- inlet and exit Γ value
- maximum wet surface temperature
- minimum wet surface temperature

A discussion of the temperature used to evaluate film properties and the value and basis for the wetting angle is provided in Reference 480.384-1, (sections on Determination of Bounding Stability Margin Value and Sensitivity to the Assumed Wetting Angle). The value for the PCS water flow rate in the comparisons is the time averaged flow rate as reported in the final data report (References 480.384-2 and 480.384-3). A discussion of how the heat flux and surface temperature is obtained for tests used to validate the application of the Zuber-Staub model to AP600 has been provided (Reference 480.384-1, section on Determination of Bounding Stability Margin Value).

The ranges of heat flux and surface temperatures in the test database relative to values estimated for AP600 have been provided (Reference 480.384-1, Table 6).

References:

480.384-1 NSD-NRC-96-4646, "Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

480.384-2 WCAP-13566, AP600 One Eighth Large Scale Passive Containment Cooling System Heat Transfer Test Baseline Data Reports, October 1992

480.384-3 WCAP-14135, Final Data Report for PCS Large Scale Tests, Phase 2 and Phase 3, July 1994

SSAR Revision: NONE

Question 480.385

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
480.385 Compare the q" and T values from the above response to the q" and T values expected in the AP600 (for both LOCA and MSLB) to demonstrate that the test data encompasses the AP600. While the test matrix indicates only a single comparison, in an AP600 analysis there are multiple axial and radial regions modeled, each with it's own set of properties. Provide this data for each region for the time period around the peak pressure as well as for the long term, about 24 hours.

Reference:

1. "A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

Please see Table 6 of Reference 480.385-1 for the ranges of heat fluxes and temperatures relative to AP600, used in validating the method of applying the Zuber-Staub model to AP600 LOCA. The test data encompasses the AP600. The AP600 MSLB transient is over prior to the conservatively delayed initiation of PCS water flow, so no external water flow is credited for that event.

For the LOCA time periods around the peak pressure and at 24 hours, a discussion of the axial and azimuthal variations in heat fluxes and properties has been provided (Reference 480.385-1).

References:

480.385-1 NSD-NRC-96-4646, "Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison with the Range of Film Parameters in the PCS Test Data with Ap600", February 15, 1996

SSAR Revision: NONE

Question 480.386

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.
480.386 Since the Zuber-Staub model requires as input the expected q" and T (the liquid film temperature at which the properties are evaluated), and since q" and T are both transient parameters, how is the water coverage that is used in the AP600 DBA calculated? It seems that the model requires knowledge of the results before the calculation is performed.

Reference:

1. "A Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System," PCS-GSR-003, July 1994.

Response:

The water coverage used in the AP600 DBA is discussed in Reference 480.386-2, (section on Determination of Film Input for the AP600 Evaluation Model). The method of application of the Zuber-Staub liquid film stability model to AP600 is based on an assumed wetting angle that conservatively bounds stable film data and results in a lack of sensitivity to heat flux. In this way, parameters can be chosen that simplify the application of Zuber-Staub to AP600. Conditions during the DBA transient are conservatively bounded and the need for iteration between the water coverage calculation and the WGOTHIC evaluation model are minimized (Reference 480.386-1). The calculation is verified to insure bounding values have been used.

References:

480.386-1 NSD-NRC-96-4646, "Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

480.386-2 NTD-NRC-96-4635, "AP600 Containment DBA Evaluation Model, Water Coverage Model", January 31, 1996.

SSAR Revision: NONE

Question 480.387

Re: The following question is based on the WEC March 29-30, 1995 ACRS Presentation on Scaling.

In Ref. 2, it is indicated that the stability parameter, referred to as Rref, when set to a specific value, conservatively predicts results from the 1/8th scale Large Scale Tests (LST) and full scale Water Distribution Tests (WDT). With the exception of one test, this is true. Will a new value of Rref be determined to bound all the test data as part of the revised DBA approach to develop a bounding evaluation model? If the test ranges do not adequately cover the AP600 (in terms of q" and T), can a value of Rref be determined for use in a bounding evaluation model?

Reference:

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

Response:

A simplified method of conservatively applying the Zuber-Staub liquid film stability model to AP600 has been developed (Reference 480.387-1) which uses Rref on the dome and the Zuber-Staub model with a conservative wetting angle on the side wall. The application of Zuber-Staub to AP600 conservatively represents test observations. The method is summarized as follows.

A new value of Rref has been determined for prediction of film splitting on the AP600 dome to bound data from the full scale water distribution test and the LST dome. Geometry associated with maximum ASME weld butt-up tolerances governs coverage on the dome. Rref accounts for those manufacturing tolerances, and provides a conservative boundary condition for input to the sidewall coverage calculation.

Evaporation of the AP600 liquid film is expected to lead to thinning of the film with constant wet stripe width, based on observations of the SST, LST, and wet flat plate tests. A wetting angle which conservatively bounds stable liquid film data is used to calculate sidewall coverage using the Zuber-Staub model which conservatively predicts that film stripes will narrow rather than thin.

Test ranges cover the AP600, so that appropriate data are used to validate the method of applying the Zuber-Staub model to AP600 (Reference 480.387-2).

References:

480.387-1 NTD-NRC-96-4635, "AP600 Containment DBA Evaluation Model, Water Coverage Model", January 31, 1996.

480.387-2 NSD-NRC-96-4646, "Conservatism in Modeling of the PCS Film in the DBA Evaluation Model and Comparison of the Range of Film Parameters in the PCS Test Data with AP600", February 15, 1996.

SSAR Revision: NONE

Question 480.393

Re: 480.393 The modeling of the LST, particular the dome region, has changed from that presented in a meeting on November 15, 1994 and referred to as the "Subdivided WGOTHIC Model" to the distributed parameter model presented in Ref. 3 (Figure 5-34). If appears that no changes have been made in the lumped parameter model, this should be verified. Justify the model presented in Ref. 3 and what impact, if any, the modeling of the dome region has on the WGOTHIC results as compared to the old model. How are user inputs determined to account for the actual geometry? The model description should be expanded to include a pictorial representation of the "climes" and discuss how the "climes" are modeled: wet and dry stripes, number of "climes" in a stack, recommended user input parameters, etc. Also discuss how volume, mass, area and momentum are properly accounted for in the model. The discussion should also address modelling of the AP600 and any additional requirements on user input.

Reference:

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

Response:

The WGOTHIC applications report (Reference 480.393-1) will contain a chapter on "WGOTHIC Model Description" The following addresses the specific questions asked in this RAI.

The distributed parameter and lumped parameter evaluation models are described in Reference 480.393-2, (Section 6.0). The presentation of November 15, 1994, provided a status of preliminary results as requested by NRC. The dome modelling was changed to the simpler right circular cylinder approach of Reference 480.393-2, Figure 6-2, to eliminate numerical effects associated with the stepped representation of the dome in the November 15, 1994 model, which occurred only at the highest delivered steam flow rates. The stepped representation yielded an unrealistic velocity downward along the vessel wall as compared to test data for high steam flow tests, which was improved with the right circular cylinder model.

The distributed parameter model is justified based on comparisons to test data in Reference 480.393-2 Appendix A for the detailed distributed parameter model (similar in noding detail to the November 1[illegible], 1994 model) and in Reference 480.393-2 Section 8.0 for the LST distributed parameter evaluation model. The AP600 distributed parameter and lumped parameter evaluation models are scaled up from the LST as discussed in Reference 480.393-2 section 6.4. The validation of this method is based on comparisons to LST data, and the evaluation model nodding does not deviate from this approach.

User inputs for the right circular cylinder representation of the dome are selected to simultaneously conserve total dome surface area and volume and is discussed in Reference 480.393-2, section 6.2.1. This approach accounts for the heat transfer, continuity, and momentum effects in the dome region. This method has been validated using LST test data (Reference 480.393-2, Section 6.2.1) and is applied to the AP600 evaluation model in a similar manner (Reference 480.393-2, Section 6.4.1).

AP600

Expanded model descriptions and sketches for the "climes" are provided in Figures 480.393-1, 480.393-2 and 480.393-3. Included in the AP600 WGOTHIC model description chapter of the applications report (Reference 480.393-1) will be a pictorial representation of the climes, how the clime wet and dry stripes are modelled, the number of climes in a stack and azimuthally, and typical recommended user input parameters for material properties and geometry.

Volume, mass, area, and momentum are properly accounted for in the model, and validated with LST data, as discussed above.

References:

480.393-1 WCAP-14407, Application of WGOTHIC to AP600 for PCS DBA Evaluation Model, June 1996 (to be issued).

480.393-2 WCAP-14382, WGOTHIC Code Description and Validation, May 1995.

SSAR Revision: NONE

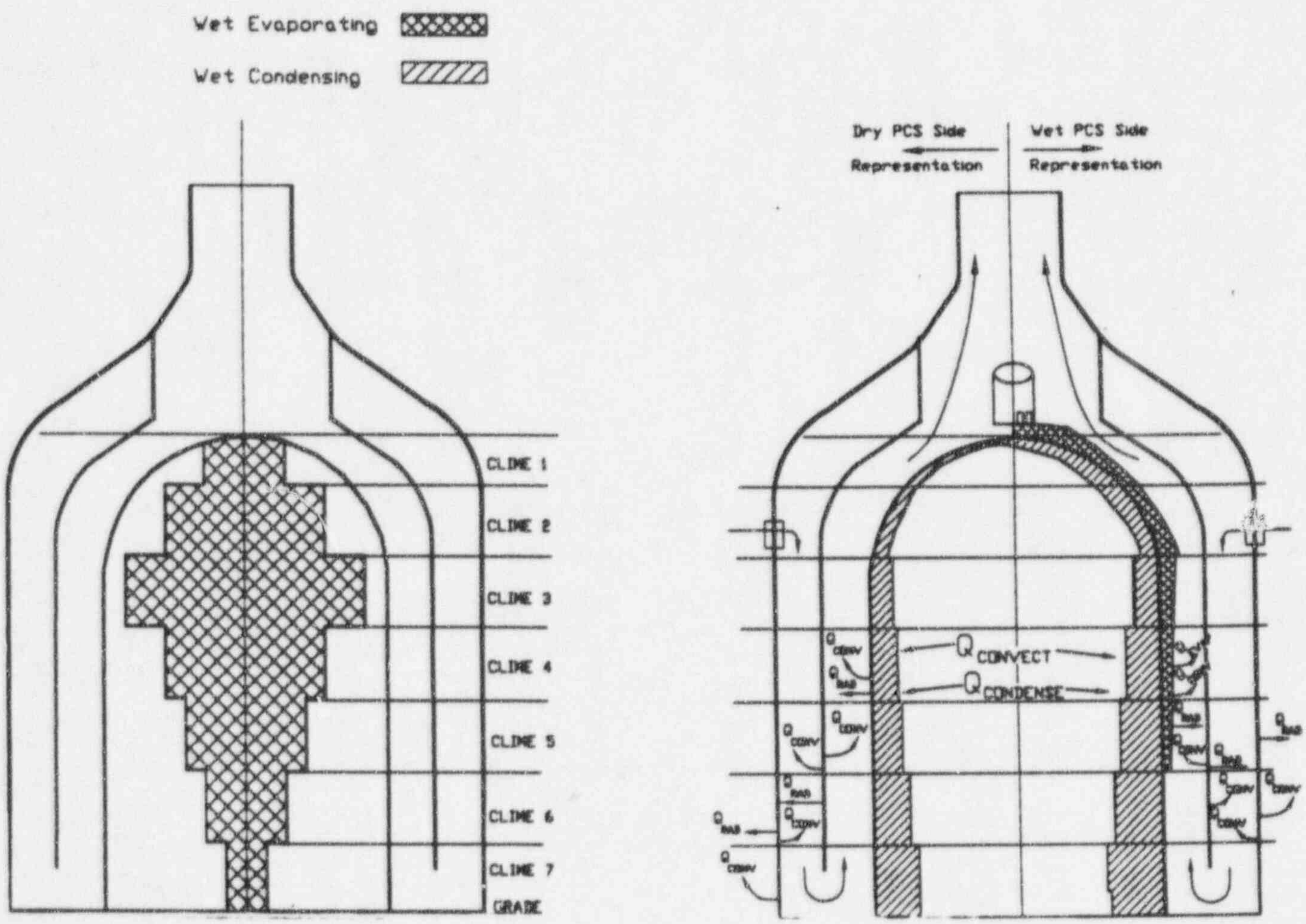


Figure 480.393-1

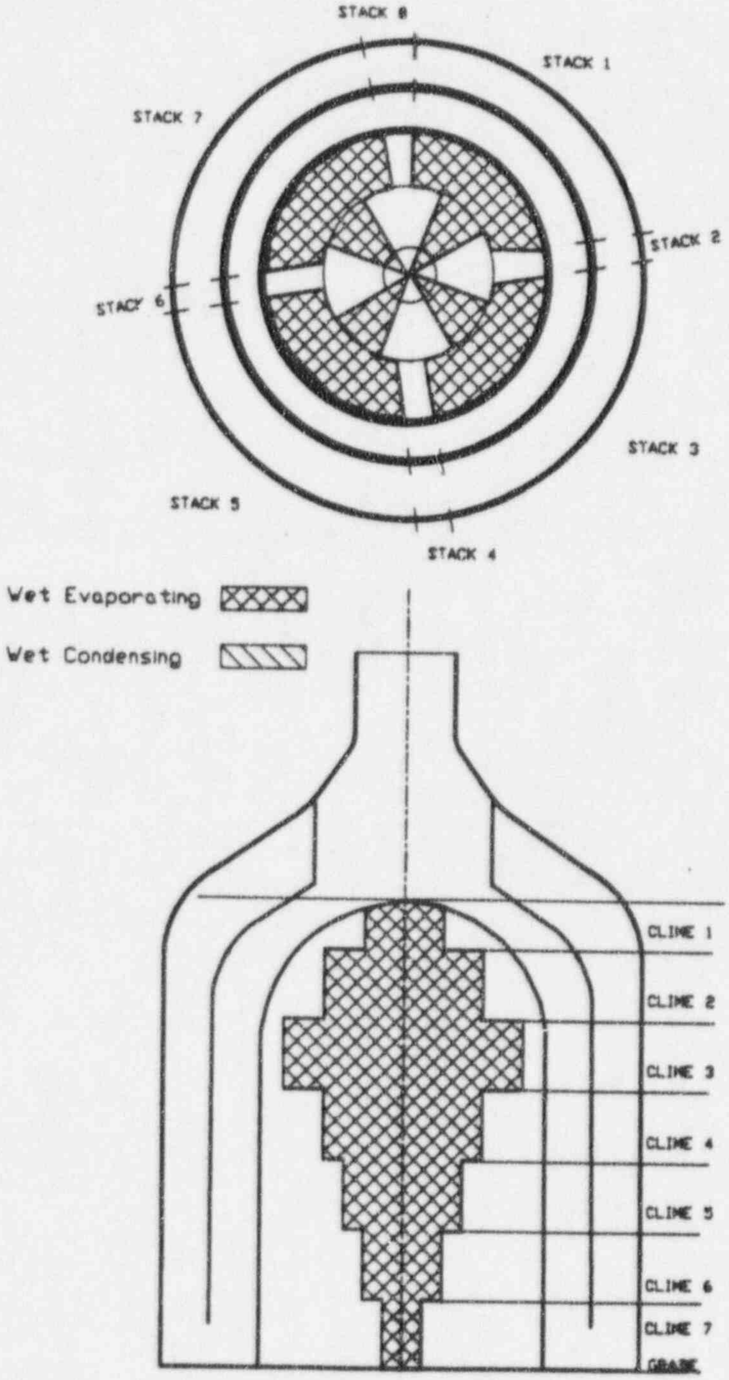
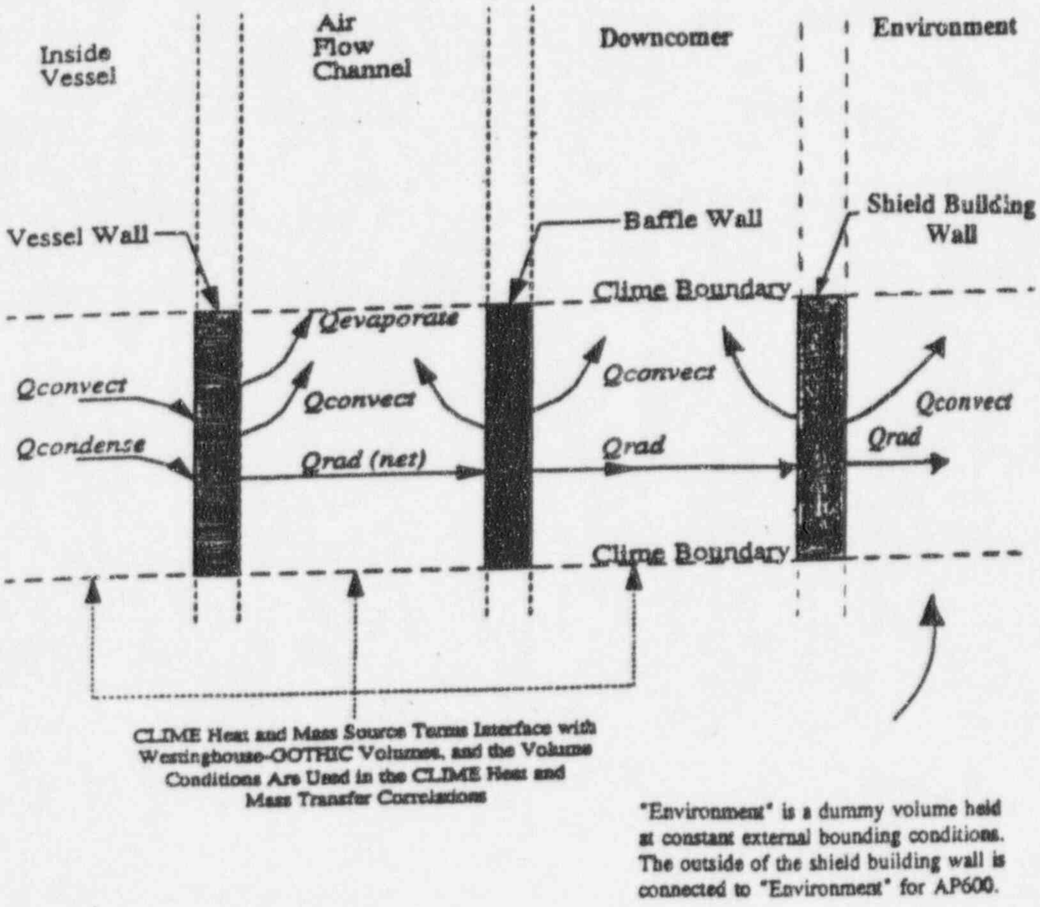


Figure 480.393-2

The climes are the 3 shaded heat sinks, and the correlations for heat/mass transfer serving as heat/mass source terms for WGOTHIC fluid node solutions, and liquid film heat/mass balance and path tracking.



Westinghouse-GOTHIC Clime Wall Source Term Models

Figure 480.393-3

Question 440.247

Re: Input needed for RELAP5 model

Identify which pipes have been changed to Schedule 140.

Response:

The only pipe in the AP600 reactor coolant system which is Sch. 140, is the 20-inch normal RHR pump suction line directly off the bottom of the loop 2 hot leg. This line is identified as 20 BTA L139 on P&ID, RCS M6 001.

SSAR Revision: NONE

Question 440.251

Provide CVCS makeup/letdown system information (piping diagrams and pump curves), including information on the design and performance of the auxiliary pressurizer spray function.

Response:

The chemical and volume control system makeup system distribution and pump performance curve were provided in Westinghouse letter NTD-NRC-95-4457, dated May 8, 1995. This letter provided calculated flow path resistances throughout the chemical and volume control system rather than piping diagrams. The orifices will be analytically sized to obtain the desired overall system resistance, and thus flow performance.

The resistances for the chemical and volume control system flow path which provides the auxiliary pressurizer spray function is included in the reference letter. The chemical and volume control system provides approximately 100 gpm of spray flow during reactor coolant system operations when the reactor coolant pumps are not operating. Auxiliary spray flow is typically required during cooldowns of the reactor coolant system after the last operating reactor coolant pump is tripped. It is used at the end of cooldown to collapse the steam bubble in the pressurizer. It is also used to add chemicals to the pressurizer during heatups and cooldowns.

SSAR Revision: NONE

Question 440.252

Re: Input needed for RELAP5 model

Describe the leads, lags, and gains for the feedwater level control system and the post-trip Tave trending control.

Response:

The leads, lags, and gains in the AP600 steam generator feedwater level control and the post-trip Tavg trending control are not required for Chapter 15 safety analyses. This information will be available to support the detailed design when AP600 specific control system setpoint studies have been completed. The AP600 safety analyses have been performed using bounding assumptions for the steam generator main and startup feedwater control as applicable for the event being analyzed. Specific examples of assumed conditions for key events are provided below.

The steam line break analysis performed to establish mass and energy releases to containment (Ref. SSAR Chapter 6, Section 6.2) maximizes the feedwater flow to the faulted generator to maximize the impact on containment. The feedwater flow is calculated assuming that the feedwater control valve for the faulted generator opens fully and that the feedwater control valve for the intact generator remains unchanged from its initial position prior to the event. This assumption maximizes feedwater flow to the faulted generator. The attached Tables 440.252 1a and 1b to 4a and 4b, provide the feedwater flow vs. pressure for the faulted and intact steam generators; at four different initial reactor powers. Startup feedwater flow is also assumed to be at a maximum fixed flow of 1350 gpm. The main feedwater to the steam generators is isolated by the S-signal and startup feedwater is isolated on low Tcold, afterwhich all heat removal from the primary system occurs via the PRHR heat exchanger.

Following initiating events that result in a decrease in heat removal by the secondary system (SSAR Chapter 15, Section 15.2), feedwater addition is minimized; and in the limiting case, heat removal is solely provided by the PRHR heat exchanger. For events in which the secondary system does not impact the the analysis results, steam generator level is maintained constant by matching feedwater flow with steam flow.

SSAR Revision: NONE

Table 440.252-1a Faulted Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 100% Power

Faulted Steam Generator Pressure [psia]	Faulted Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	14784	11726				
815	20306	17248	14850			
615	25872	22110	19712	16192		
415	30492	26598	24310	20944	19008	
215	33000	30976	27676	25344	23408	22000
15	35200	35200	32076	29260	27280	24640

Table 440.252-1b Intact Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 100% Power

Faulted Steam Generator Pressure [psia]	Intact Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	11616	16874				
815	8294	13552	18150			
615	4928	10890	15488	19008		
415	308	7502	13090	16456	20592	
215	0	4224	9724	14256	18392	22000
15	0	0	7524	12540	16720	19360

Table 440.252-2a Faulted Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 70% Power						
Faulted Steam Generator Pressure [psia]	Faulted Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	14762	12408				
815	21164	17446	15708			
615	25168	22176	20130	18656		
415	30184	26730	24288	22814	20196	
215	33000	30690	28424	25432	24156	22990
15	35200	34848	31416	29304	28006	26840

Table 440.252-2b Intact Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 70% Power						
Faulted Steam Generator Pressure [psia]	Intact Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	9438	13992				
815	7436	11154	15092			
615	3432	8624	12870	17204		
415	616	6270	10912	14586	17204	
215	0	2310	8976	11968	15444	18810
15	0	352	5984	10296	13794	17160

Faulted Steam Generator Pressure [psia]	Faulted Steam Generator Feedwater Flow [gpm] Intact Steam Generator Pressure 1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	10868	8437				
815	15400	12540	11264			
615	17600	17578	14212	13068		
415	19800	19800	18601	16720	14960	
215	22000	22000	22000	19866	18392	16698
15	23100	24200	24200	24200	21252	20064

Table 440.252-3a Faulted Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 30% Power

Faulted Steam Generator Pressure [psia]	Intact Steam Generator Feedwater Flow [gpm] Intact Steam Generator Pressure 1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	3432	5863				
815	0	3960	6336			
615	0	1122	4488	6732		
415	0	0	2299	5280	7040	
215	0	0	0	3234	5808	7502
15	0	0	0	0	4048	6336

Table 440.252-3b Intact Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 30% Power

Table 440.252-4a Faulted Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 0% Power						
Faulted Steam Generator Pressure [psia]	Faulted Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	12408	13013				
815	15400	15510	15180			
615	17600	17424	17578	17204		
415	19800	19800	19206	19646	19437	
215	22000	22000	22000	21340	20680	20460
15	24200	24200	24200	24200	23232	22748

Table 440.252-4b Intact Steam Generator Feedwater Flow as a Function of Steam Generator Back Pressure at 0% Power						
Faulted Steam Generator Pressure [psia]	Intact Steam Generator Feedwater Flow [gpm]					
	Intact Steam Generator Pressure					
	1015 psia	815 psia	615 psia	415 psia	215 psia	15 psia
1015	0	1287				
815	0	990	1320			
615	0	176	1122	1496		
415	0	0	594	1254	1463	
215	0	0	0	660	1320	1540
15	0	0	0	0	968	1452

Question 440.254

Provide detailed information on the criteria for the CMT, accumulator, and IRWST orifice sizing.

Response:

The injection lines for each of these tanks contains an orifice that is used to control the flow resistance of the lines. The resistance is controlled to prevent the injection flow from being too small or too large. The AP600 safety analysis performed for the SSAR is based on line resistances which include these orifices. During plant startup testing, orifices will be setup to control the line resistance of the injection lines. As shown below, consideration in the safety analysis is given for variation of the core makeup tank, accumulator and IRWST injection line resistances.

CMT Orifice: The CMT line orifice will be adjusted to provide flow resistance between the following minimum / maximum values:

	Min.	Max.
CL to CMT	[ ]a,c	[ ]a,c ft/gpm²
CMT outlet to RV	[ ]a,c	[ ]a,c ft/gpm²

During plant startup each CMT orifice will be adjusted to provide the CMT to reactor vessel line resistances shown above. Note that this line resistance includes the reactor vessel nozzle and deflector resistances. With these resistances one CMT provides an injection flow of 787 to 945 gpm with the following assumptions:

- RCS at atmospheric pressure and drained
- CMT full of water at 70°F (28 ft total driving head from CMT water level to reactor vessel nozzle)

Accumulator Orifice: The accumulator injection line orifice will be adjusted to provide flow resistance between the following minimum / maximum values:

	Min.	Max.
Accum to RV	[ ]a,c	[ ]a,c ft/gpm²

During plant startup the orifice in each accumulator injection line will be adjusted to provide the line resistances shown above. Note that this line resistance includes the reactor vessel nozzle and deflector resistances. With these resistances one accumulator provides an injection flow of 9240 to 10,330 gpm with the following assumptions:

- RCS at atmospheric pressure and drained
- Accumulator water temperature at 70°F, volume at 1700 ft³ and gas pressure at 700 psig

IRWST Orifice: The IRWST injection line orifice will be adjusted to provide flow resistance between the following minimum / maximum values:

	Min.	Max.
IRWST to RV	[ ]^{a,c}	[ ]^{a,c} ft/gpm^2

During plant startup the orifice in each IRWST injection line will be adjusted to provide the line resistances shown above. Note that this line resistance includes the reactor vessel nozzle and deflector resistances. With these resistances one IRWST line provides an injection flow of 1262 to 1785 gpm with the following assumptions:

- RCS at atmospheric pressure and drained
- IRWST water temperature at 70°F and level at 27 ft above the tank floor (30.4 ft total driving head from IRWST to reactor vessel nozzle)

SSAR Revision: NONE

Question 440.359

Re: CMT Final Data Report and Final Test Analysis Report

Test 050319 is shown in Table 3.7-6 of the Final Data Report (FDR) as having met all acceptance criteria and being acceptable. However, the CMT level plot for this test (p. F-182) shows very odd behavior that is far different from other similar tests. Specifically, the CMT level undergoes a step decrease at the start of the test, levels out for about 3 minutes, and then undergoes a second step decrease of about a foot of water, after which it begins to refill. No discussion of this behavior is included in the FDR, and the test is not one of those chosen for detailed analysis in the Test Analysis Report (TAR). Provide an explanation of the behavior of the CMT for this test, focusing on any specific test conditions that could account for the apparently anomalous level signals.

Response:

The CMT level plot for Test C050319 on page F-182 of the CMT Final Data Report is incorrect and will be re-issued as an errata sheet for this report. The wrong data channel was used to create this plot for inclusion in the Final Data Report. This production error did not affect the electronic data used for subsequent analysis of the test and code validation. A review of the CMT level plot for all other tests in the report as well as the other plots shown for Test C050319 did not reveal any other errors of this nature in Appendix F of the report.

A review of the electronic test data , shown in Figure 440.359-1, as transmitted in the Day-of-Test Report for Test C054319, gives the measured response of the differential pressure transducer, PDT6. Since the transducer is referenced to the top of the CMT, the transducer response increases as level decreases. This data confirms that the CMT level in Test C050319 behaves in a manner similar to that of the other 300 Series tests given in the CMT Final Data Report. Test acceptability is not affected.

SSAR Revision: NONE

a, b

Figure 440.359-1 PDT6, Overall CMT Level 1-6

Question 480.248

Re: OSU Test HS-02

The noise in the upper head noted in run U-2004 corresponds to a sharp spike in LDP-140, and appears consistent with a water hammer event. Westinghouse should provide a discussion of the possible causes for the water hammer during this test, including an assessment as to the possibility of such an event occurring during an actual small-break loss-of-coolant accident (SBLOCA).

Response:

Westinghouse has performed an evaluation of events that occurred during the OSU matrix testing that resulted in a similar noise and corresponding pressure spike in LDP-140 as in Test Run U-2004. This evaluation documents observations and video recordings that were taken during the matrix tests and investigates corresponding instrumentation responses. This study of possible steam condensation events and the resultant depressurization concluded that the effects of the rapid depressurization were not significant and that they had no adverse impact on the test facility.

This evaluation, entitled "Report of Steam Condensation Events at the OSU AP600 Test Facility" will be issued to the NRC by February 28, 1996. Possible causes of the observed events are discussed in the report and empirical scoping calculations are provided in order to better understand the mechanisms involved.

SSAR Revision: NONE

Question 952.94

Re: PRHR HX Analysis

Provide a commitment to submit a literature search and calculations quantifying critical heat flux in the passive RHR heat exchanger. Perform additional investigation of the open literature to add to the database of information on critical heat flux (CHF) limits for tube bundles and arrays. Also perform additional calculations related to fluid conditions in the PRHR heat exchanger and submit these calculations to the staff for review. These calculations should provide a quantification of the CHF margin that exists during heat exchanger operation.

Response:

Westinghouse will perform a literature review to investigate if data and or correlations exist in the open literature which would help determine the critical heat flux (CHF) limit on the horizontal section of the PRHR heat exchanger. A list of references investigated will be provided. Westinghouse will also perform calculations to estimate the fluid conditions in the PRHR to investigate the margins to CHF for those limiting transients in which the PRHR heat removal capacity is important.

The literature review will be completed and sent to the NRC by February 29, 1996. The PRHR fluid calculations and margin to CHF study will also be submitted to the NRC by February 29, 1996.

SSAR Revision: NONE

Question 952.96

Re: Valve Testing Roadmap

Provide a commitment to submit a narrative of an ADS valve testing "roadmap". The road map is to include additional information on the testing to be performed outside of design certification was requested by the staff to assess the adequacy of the test plans.

Response:

An ADS valve testing "road map" will be submitted to NRC by February 29, 1996 and will provide additional information on testing of the ADS valves to be performed outside of design certification.

SSAR Revision: NONE

Question 925.105

Re: OSU/APEX Test Facility Scaling

The OSU/APEX scaling report has recently been reviewed in detail by the Office of Research, and a question has been raised regarding the scaling approach used for the frictional pressure drop for this facility. The specific issue concerns the assumptions made in deriving the friction number, especially with regard to the relative magnitude of the frictional and form losses in facility components. The approach used in the APEX scaling report has the potential for distorting the time-scaling relationships for the facility, thus affecting the phenomenology of transients performed in the facility as compared to those that would occur in the AP600 plant. The data from the cold and hot shakedown tests, plus the data from the matrix tests that have been performed, should provide an adequate basis for determining whether these distortions exist. Accordingly, Westinghouse should:

a. Provide an order-of-magnitude comparison between the two terms of the loss coefficient (the frictional loss of the type (fl/D) and the form loss K), based on the experimental data available for the principal natural circulation loops (e.g., primary system, PRHR, ADS/IRWST/RV, etc.). The extent of the documentation should be consistent with the uncertainty of the measurements and with the complexity of the flow modes exhibited by the system.

b. In order to identify the range of operating conditions of the APEX facility and to assess the scaling distortions associated with the momentum equation, provide the following experimental data or estimates:

1. liquid single-phase velocity in the various active loops
2. temperature distribution and phase distribution in each of the active natural circulation loops
3. estimates of the density difference and of the differences in elevation between the thermal centers in each of the active loops
4. density of the liquid single phase where the velocity measurements are obtained or can be estimated
5. estimates of the overall loss coefficient
6. form losses estimated from inspection of the geometrical characteristics of each flow loop
7. two-phase flow multiplier (e.g., Martinelli-Nelson) from measurements or estimates of the quality
8. estimates of the frictional losses
9. comparison of the frictional and form losses in the active loops

Response:

According to the OSU/APEX scaling analysis report, the total loop friction number should be 1. This includes both the skin friction factor and the form loss coefficient. This ideal ratio can be achieved if all other ideally scaled parameters are used. However, ideal line sizes are not feasible to use in most lines and the next size (larger) standard tubings or pipings are used instead. With the properly scaled line lengths, the volume ratio will be distorted slightly. To minimize other distortions, the pressure drop along a line is properly scaled and cold drawn tubing is used whenever possible. To further control the pressure drop ratio, an orifice plate is used in the line. Moreover, the geometry of each line in the test facility duplicates that of the AP600. Therefore, the distribution of skin friction loss and form loss is reasonably preserved in the test.

Table 1 provides a comparison of friction loss vs. form loss using either matrix test data or shakedown test data.

(a) Comparison between the friction loss and form loss is shown in Table 1. Please note that data on ADS lines are not available in the shakedown test; and direct measurement of two phase flow in these lines are not feasible in the matrix test. Also note that single phase liquid was measured in these lines.

It is shown in the table that the dominating loss is from form loss, with the exception of the PRHR Hx lines. The frictional losses in the PRHR Hx inlet and outlet lines are relatively high. However, this is also the case in AP600.

It should be pointed out that the table was constructed using matrix test data as much as possible, and with maximum flow rates. Shakedown test data were also used whenever matrix test data was not available.

(b) 1. Single phase liquid velocity for various lines is included in Table 1.

2. Temperature distribution and phase distribution varies from test to test and can be found in the data plots iven for each test in Reference 925.105-1. In general each line has temperature measurements to track temperature variation in time.

3. Estimates of the density differences and the thermal centers can be made from the temperature distribution by way of the test from the quick look reports.

4. Density of the single phase liquid for applicable lines is included in Table 1.

5. Overall loss coefficient can be obtained in Table 1.

6. Form losses can be obtained with information in Table 1.

7. The OSU/APEX facility was designed using the two phase flow multiplier for those lines with two phase flow. The multiplier used in the design is based on a homogenous model. Equation 6.240 in Reference 925.105-2 shows the details of this multiplier.

8&9. Table 1 shows the frictional loss, the total loss and the comparison of the two losses.

SSAR Revision: NONE

References: 925.105-1 WCAP-14252; Low-Pressure Integral Systems Test at Oregon State Univeristy Final Data Report, May 1995

925.105-2 WCAP-14270; Low-Pressure Integral Systems Test at Oregon State Univeristy Facility Scaling Report, January 1995

Table 1 OSU/APEX Test Principle Line Pressure Drop Summary

Notes:

1. Adjusted total DP = measured DP + any adjustments not included in the DP measurement, eg. cntrance loss not included in the line from bottom of ACC1 to DVI#1 downcomer.
2. Direct measurement of line DP was not made in matrix tests. However, shakedown tests verifying line resistance were made. These data will be used along with measured flow rate in matrix tests.
3. Total pressure drop was calculated using Crane 410 manual. The low side root valve for DP801 was found clugged after shakedown test. The same calculated method was used to calculate pressure drop at the PRHR Hx outlet line. The calculated result was found to be within 10% of the measured value. Therefore, this method can be used for the PRHR Hx inlet line.

	(SB1) Bottom of CMT01 to DVI#1 Downcomer	(SB1) Bottom of CMT02 to DVI#2 Downcomer	(SB1) Bottom of ACC01 to DVI#1 Downcomer	(SB18) ACC02 Bottom to DVI#2 Downcome	(SB18) Bottom of IRWST to DVI#1 Downcomer: Bottom of IRWST to Node T4	Node T4 to DVI#1 Downcome	(SB18) Bottom of IRWST to DVI#2 Downcome: Bottom IRWST to Node SN1	Node SN1 to DVI#2 Downcome	(SB18) Note 2 CMT02 TO CL#1 BALANCE LINE
Q, Measured Flow Rate, gpm	7.4	7.4	21	21	9.7	9.7	10.1	10.1	8
Time Measured, seconds (Approx.)	300	300	650	560	2200	2200	2150	2150	255
d, Line ID, in	1.12	1.12	1.12	1.12	2.25	1.12	1.5	1.12	1.12
L, Line Length, ft	31.2183	22.03	28.44	24.031	31.158	17.492	28.25	14.27	19.1
Temperature, F	65.00	65	65.8	66.6	65	65	65	65	426
Pressure, psia	302.70	302.7	42.7	43.7	14.7	14.7	16.2	16.2	324.7
Phase (Liquid, Steam or Both)	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
RHO, density, lb/ft^3	62.38	62.38	62.32	62.32	62.32	62.32	62.32	62.32	52.63
V, Calculated Velocity, ft/sec	2.410	2.410	6.838	6.838	0.783	3.159	1.834	3.289	2.605
Re, Reynold's Number	2.1E+04	2.1E+04	5.9E+04	5.9E+04	1.4E+04	2.7E+04	2.1E+04	2.8E+04	1.5E+05
DP_f, Frictional Loss, in H2O	9.25	6.51	53.10	44.87	0.51	8.36	3.68	7.40	4.40
DP_ts, (Shakedown)Total DP, in H2O	63.22	58.33	272.31	295.726	NA	NA	NA	NA	13.69
DP_tm, Measured Total DP, in H2O	63	61	275	282	73	SameLine	73	SameLine	NA
DP_tm_adjusted, in H2O (note 1)	63.00	61.00	279.36	286.36	73.06		73.31		
(Measured & adjusted total DP)									
DP_ts_adjusted, in H2O	NA	NA	NA	NA	NA		NA		23.18
DP_f / DP_tm_adjusted, %	14.68%	10.68%	19.01%	15.67%	12.15%	BothLine	15.11%	BothLine	18.98%
or DP_f / DP_ts_adjusted, %									

Table 1 OSU/APEX Test Principle Line Pressure Drop Summary (Continued)

		(Note 2.)		(Note 2.)		Cold Legs Using Shakedown Test Data At Ambient Temperature			
	(SB5) CMT#1 to CL#3 Balance Line	(SB18) Primary Sump Tank (MOVline) to Branch Tee.	(SB18) Branch Tee to DVI#1 Downcomer	(SB18) Primary Sump Tank (MOVline) to Branch Tee.	(SB18) Branch Tee to DVI#2 Downcomer	Cold Leg No. 1	Cold Leg No. 2	Cold Leg No. 3	Cold Leg No. 4
Q, Measured Flow Rate, gpm	3	1.12	1.12	1.12	1.12	330.37	346.8	338.3	328.1
Time Measured, seconds (Approx.)	220	14244.4	14244.4	14244.4	14244.4	NA	NA	NA	NA
d, Line ID, in	1.12	2.25	1.12	1	0.87	3.548	3.548	3.548	3.548
L, Line Length, ft	21.668	6.67	21.8	24.115	20.41	5.88021	5.85	5.8698	5.921
Temperature, F	420.00	139.5	139.5	168	168	68	68	68	68
Pressure, psia	322.70	14.97	14.97	14.97	14.97	14.7	14.7	14.7	14.7
Phase (Liquid, Steam or Both)	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
RHO, density, lb/ft^3	52.82	61.39	61.39	60.84	60.84	62.3	62.3	62.3	62.3
V, Calculated Velocity, ft/sec	0.977	0.090	0.365	0.457	0.604	10.720	11.253	10.977	10.646
Re, Reynold's Number	5.5E+04	3.7E+03	7.4E+03	8.6E+03	9.9E+03	3.1E+05	3.2E+05	3.2E+05	3.1E+05
DP_f, Frictional Loss, in H2O	0.58	0.002	0.19	0.36	0.59	7.84	8.59	8.20	7.78
DP_ts,(Shakedown) total DP, inH2O	3.95	4.120236	included	5.68222	included	265.983	248.18	247.66	248.12
DP_tm, Measured Total DP, in H2O	NA	NA	at left	NA	at left	NA	NA	NA	NA
DP_tm_adjusted, in H2O (note 1)	5.28	NA	NA	NA	NA	NA	NA	NA	NA
(Measured & adjusted total DP)									
DP_ts_adjusted, in H2O	NA	4.12	included	5.68	included	265.98	248.18	247.66	248.12
DP_f / DP_tm_adjusted, %	10.95%	4.69%	included	16.81%	included	2.95%	3.46%	3.31%	3.14%
OR DP_f / DP_ts_adjusted, %									

Table 1 OSU/APEX Test Principle Line Pressure Drop Summary (Continued)

	PRHR Hx Inlet Line (Shakedown Test)		PRHR Hx Outlet Line	Hot Legs Using Shakedown Data	
	(Ambient)	(Ambient)	(Ambient)	(Ambient)	(Ambient)
	HL Flge to ADS4 Tee	ADS4 tee to PRHR Hx Inlet		H.L. #1	H.L. #2
Q, Measured Flow Rate, gpm	15.01	15.01	15.01	668.67	674.78
Time Meas.red, seconds (Approx.)	NA	NA	NA	NA	NA
d, Line ID, in	1.61	1.26	1.26	5.05	5.05
L, Line Length, ft	6.8	24.15	29.55	4.677	4.6
Temperature, F	68.00	68.00	68.00	68.00	68.00
Pressure, psia	14.70	14.70	14.70	14.70	14.70
Phase (Liquid, Steam or Both)	Liquid	Liquid	Liquid	Liquid	Liquid
RHO, density, lb/ft^3	62.3	62.3	62.3	62.3	62.3
V, Calculated Velocity, ft/sec	2.365	3.862	3.862	10.723	10.821
Re, Reynold's Number	3.1E+04	4.0E+04	4.0E+04	4.4E+05	4.4E+05
DP_f, Frictional Loss, in H2O	1.37	14.06	17.21	4.05	4.06
DP_ts,(Shakedown)total DP, in H2O	29.00	included	29.38	60.72	71.61
DP_tm, Measured Total DP, in H2O	(Note 3)	NA	NA	NA	NA
DP_tm_adjusted, in H2O (note 1)	NA	NA	NA	NA	NA
(Measured & adjusted total DP)					
DP_ts_adjusted, in H2O	29.00		30.77	60.72	71.61
DP_f / DP_tm_adjusted, %	53.23%		55.92%	6.67%	5.66%
OR DP_f / DP_ts_adjusted, %					