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NTD-NRC-96-4630
DCP/NRC0453
Docket No: STN-52-003

January 26, 1996

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

ATTENTION: T. R. QUAY

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

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse NRC requests for additional information on the AP600 Design Certification Test Program. Topics discussed in this transmittal include the NOTRUMP compute code, LOFTRAN computer code and the SPES-2 TAR. A listing of the NRC requests for additional information responded to in this letter is contained in Attachment A. These responses are also provided as electronic files in WordPerfect 5.1 format with Mr. Kenyon's copy.

Correspondence with respect to this transmittal should be addressed to Brian A. McIntyre, Manager of Advanced Plant Safety and Licensing, Westinghouse Electric Corporation, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

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Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Attachments
Enclosures

cc: T. Kenyon, NRC (w/o enclosures)
W. Huffman, NRC (1E)
R. C. Jones, NRC (w/o enclosures)
G. D. McPherson, NRC (w/o enclosures)
F. Eltawila, NRC (w/o enclosures)
R. Landry, NRC (1E)
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A. Levin, NRC (1E)
P. Boehnert, ACRS (4E)
N. J. Liparulo, Westinghouse (w/o enclosures)

NTD-NRC-96-4630

ATTACHMENT A

Attachment A

RAI's addressed in the January 26, 1996 submittal:

LOFTRAN	440.299
	440.322
	440.323
	440.449
NOTRUMP	440.331
	440.482
	440.485
	440.489
	440.504
	440.541
	440.543
	440.544
	440.545
	440.549
	440.551
	440.552
SPES-2 TAR	440.535
	440.536

Question 440.299

Re: LOFTRAN Code Applicability Document (CAD)

Section 3.2.1, page 3-5. How can the existence of any thermal stratification be modelled in the IRWST using the homogeneous, perfectly mixed approximation?

Response:

The LOFTRAN IRWST model described in the CAD can not model thermal stratification in the IRWST. Stratification in the IRWST was exhibited in both the PRHR heat exchanger tests (Reference 440.299-1) and the SPES-2 tests (Reference 440.299-2). Both of these tests show that the water heated by the energy transferred to the IRWST rises to the top of the tank forming a hot layer, while the lower regions of the tank stay relatively cool. As more energy is transferred to the IRWST, the hot layer at the top of the tank expands downward and eventually reaches the heat exchanger. In both tests, the increase in temperature at different levels in the IRWST was basically linear. It is expected that the overall heat transfer through the PRHR would increase if a stratified temperature profile were modeled instead of the perfectly mixed approximation, since for most of a transient the secondary temperature used in PRHR heat transfer calculations would be reduced.

Analyses of limiting non-LOCA events sensitive to a reduction in PRHR heat removal will be performed with stratification in the IRWST modeled with a temperature profile based on the data in References 440.299-1 and 440.299-2. The results will be compared to those obtained with the perfectly mixed approximation. These analyses will be performed using a special version of the code developed to investigate the impact of stratification on non-LOCA transients. The modifications allow the secondary side temperature used in the PRHR heat transfer calculations to be varied based on the height of the node in the IRWST, while remaining conservatively high. It is expected that these analyses will demonstrate that the perfectly mixed approximation provides conservatively low heat transfer. If modeling stratification in the IRWST produces more limiting transient results, the final SSAR will be updated to reflect this impact.

References:

440.299-1 WCAP-12980, Rev. 1, AP600 Passive Residual Heat Removal Heat Exchanger Test Final Report, 12/92.
440.299-2 WCAP-14309, Rev 1, AP600 Design Certification Program SPES-2 Tests Final Data Report, 7/95.

SSAR Revision: NONE

Question 440.322

Re: LOFTRAN Code Applicability Document (CAD)

How accurate is LOFTRAN in modeling the discontinuity of boron for CMT injection? Can square wave changes in boron concentration be adequately tracked? If the boron propagation is damped, why not model it as DVI?

Response:

The response to RAI 440.285 describes the boron transport model ("boron slug flow") used in CMT injection line. A wave is not modeled. Depending on the purge volume of the injection line and the flow rate out of the CMT this "boron slug flow" model could result in the initial injected boron reaching the core earlier than a wave model would predict. This would not have a significant impact on the transient core boron concentration and resulting core response for design basis transients. In addition, this slightly earlier core boron increase is offset by the conservative assumptions employed in the analyses, including: no boron in the injection line prior to CMT actuation, CMT injection into the cold leg rather than directly into the vessel (see response to RAI 440.282) and perfect mixing of boron in the CMT itself.

SSAR Revision: NONE

Question 440.323

Re: WCAP-14234 (LOFTRAN CAD)

What is the injection flow rate difference from the CMTs by the cold leg pressure or the DVI (in the vessel) pressure as a boundary condition for the CMT calculation? Please provide the details?

Response:

The LOFTRAN-AP and LOFTTR2-AP codes include terms to simulate the net pressure changes from the outlet of the reactor coolant pumps (RCPs) to the DVI nozzle locations. This allows for proper boundary conditions to be calculated for the CMT even though the code actually injects into the cold leg. As presented in the CMT flow calculations in the response to RAI 440.285, the driving pressure ($\Delta P_{Driving}$) used in calculating the CMT line flow rates is:

$$\Delta P_{Driving} = P_{CL} - BH_{BL} + BH_{TANK} + BH_{IL} - P_{Vessel}$$

Where:

P_{Vessel} = pressure at CMT injection point in reactor vessel downcomer
P_{CL} = pressure in cold leg where balance line connects
BH_{region} = buoyancy (elevation) head difference in the region

region = BL - balance line between cold leg and CMT
TANK - CMT
IL - injection line between CMT and vessel

The pressure at the vessel injection point (P_{Vessel}) is calculated from the RCP outlet pressure, the pressure loss along the cold leg and expansion as the flow enters the downcomer. Note that the differential pressure is a function of the square of the flow, so that once the RCPs trip the pressure drop is substantially reduced.

SSAR Revision: NONE

Question 440.331

Re: WCAP-14206 (NOTRUMP CAD)
440.331 On page 3-2, Section 3.3 describes code externals. The user defined subroutines appear to allow the user to alter the physics in the NOTRUMP code. As such, each of the user defined code externals should be described in detail for each NOTRUMP run as part of the input initial conditions. Please provide the specific inputs for the code externals used to perform the analyses in Ref. 12.

Response:

The user defined externals provide boundary conditions, controls, and properties to be provided to the NOTRUMP code. The user external functions are configuration controlled in the same manner as the NOTRUMP code configuration in that the user can not change the coding without the concurrence of the code responsible engineer. The inputs to the user external functions are determined; documented, and reviewed as inputs and they typically are not changed by the user unless the user is performing and documenting input sensitivity studies.

For the SSAR calculations, Reference 440.331-1, the AP600 NOTRUMP User External functions are described in Section 3.3 of WCAP-14206. Pertinent specific input used in the SSAR analysis follows:

CMT level setpoints for ADS actuation (both tanks):
Stage 1 - 67.5%, Stage 4 - 20%

The initial valve opening time for stages 2 and 3 are delayed 70 seconds and 120 seconds, respectively, after the previous stage begins to open via timers.

The minimum time delay between stages 1 and 4A equals 310 seconds.

Stage 4B valves begin to open 30 seconds after stage 4A valves begin to open.

A lag of 80 seconds is modeled between the CMT level of 67.5% being reached and the ADS valve 1 starting to open. A similar lag of 90 seconds exists for stage 4 after the 20% CMT level is reached.

ADS flow areas (per stage and without failures) and valve opening times equal:

ADS Stage	Full Open, Total Flow Area, ft^2	Valve Opening Time, sec
1	0.0639	30
2	0.2917	80
3	0.2917	80
4A	0.5278	30
4B	0.5278	30

Interfacial heat transfer to the DVI-injected water is computed using the DVI nozzle diameter.

Heat Transfer by condensation to the CMT wall is computed using the coefficient established based on the CMT tests.

Reactor trip signal occurs at a calculated pressure in the pressurizer of 1800 psia.

"S" signal occurs at a calculated pressure in the pressurizer of 1700 psia.

RCPs are modeled to trip automatically 16.2 seconds after "S" signal pressure value is reached.

Signal time delay after "S" signal pressure value is reached until the PRHR and CMT isolation valves begin to open is 21.2 seconds. The valve opening time is modeled as one second for each.

References

440.331-1 Letter NTD-NRC-95-4503, "Preliminary Marked Up Sections of SSAR Chapter 15, Revision 5"' July 10, 1995.

SSAR Revision: NONE

Question 440.449

Re: AP600 LOFTRAN-AP and LOFTTR2-AP Final Verification and Validation report

On page 3-3, it is stated that "Moderate void generation can occur for some transients when the RCS pressure drops very low, leading to a decrease in the water subcooling at the top of the CMT (e.g., steam line break, steam generator tube rupture). The LOFTRAN homogeneous - equilibrium slug flow model is capable of handling such situations."

Please define numerically what "Moderate void generation" is. What controls does LOFTRAN have to limit itself when not in the "moderate void" region? Does the code alert the user when it occurs? Normally, homogeneous-equilibrium means a code can handle subcooled liquid, two-phase mixture and superheated steam transitions in a control volume. Is this the case with LOFTRAN?

Response:

With respect to the reduction of subcooling at the top of the CMT and LOFTRAN's ability to model the subsequent two-phase behavior, see the responses to RAI 440.284 and RAI 440.315 which describe the model implemented to account for possible losses of subcooling at the top of the CMT.

SSAR Revision: NONE

Question 440.482

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-001, JULY 1995
440.482 Please provide benchmark of the new critical flow model versus critical flow tests to justify and verify the coding changes. Also, please describe the model for unchoked conditions and explain how the model treats the transition from choked to unchoked conditions. Consider selected Marviken critical flow data for verifying the NOTRUMP code's ability to simulate subcooled, saturated two-phase, and single phase steam discharge.

Response:

The application of the Henry/Fauske and Homogeneous Equilibrium Model (HEM) for critical flow calculations is not new. This combination of these models was used in RELAP 4 as discussed in Section 4 of the NOTRUMP SPES preliminary validation report in Reference 440.482-1.

The validity of these two models was assessed in the response to RAI 952.95 which documented the ADS 4 valve area sensitivity study. RAI 952.95 examined the uncertainty in the critical flow from these two models to assess the margin in the ADS stage 4 valves. The uncertainty was typically found to be approximately 15% for the models over a range of pressures and inlet enthalpies for different tests. Comparisons were taken from the literature as well as the original papers. Figures 440.482-1 to 440.482-6 were taken from Reference 440.482-2 for the Henry/Fauske model for the subcooled and low quality portion of the flow. The references given in the figure titles refer to the references given in Reference 440.482-2. The figures show the agreement of the Henry/Fauske correlation for difference sets of data and different fluids. Superimposed on these figures are the model predictions multipled by 0.85 and/ or 0.7 to indicate a 15% to 30% uncertainty of the model relative to the data. As the figures indicate, the Henry/Fauske model agrees very well with the data, usually within 15%.

Similar plots for the HEM model are given in Figures 440.482-7 to 440.482-9 from references 440.482-2 and 440.482-3. As the figures indicate, the HEM model agrees within 15% for the data shown.

The data comparisons given in Figures 440.482-1 to 440.482-7 do not cover the full pressure range for the AP600 small-break LOCA, but rather cover the low pressure portion of the transient. The NOTRUMP SPES and OSU comparisons provided in the preliminary validation reports provide additional validation over the higher pressure range from 2250 psia down to 140 psia which overlaps with the data comparisons given in Figures 440.482-1 to 440.482-9. The method used for the SPES and OSU comparisons to the NOTRUMP predictions with the Henry/Fauske - HEM critical flow model was to use the integrated flow measurements from the beginning of the test, until the ADS stage 1 valve opened. The integrated flow (lbms) was divided by the time to reach ADS stage 1 to obtain an average mass flowrate out the break. The earlier of either the data or the prediction was used for the ADS stage 1 opening time for a given test. By using the integrated break flow data over this time period, the only flow path out of the system was through the break. Also, by selecting the time period before ADS stage 1, the additional complications of timing differences between the code and the data and a more complex mass distribution within the primary system are avoided. Figure 440.482-10 shows the comparison of the average break flow predicted by the NOTRUMP code and the measured average flow rate. Figure 440.482-11 shows the ratio of the measured flowrate to the predicted flowrate for the different tests. Both figures indicate that the combined Henry/Fauske - HEM model represents the critical flow with the similar uncertainties as the comparisons with the original data. The poorest comparison was the tests SB10, the double-ended cold line balance line break. If the measured-to predicted

(M/P) flow ratios are averaged, the average value of the M/P ratio is 0.95. Therefore, over the range of breaks, configurations and conditions expected for the small-break LOCA, the Henry/Fauske - HEM model predicts the break flow accurately. A discharge coefficient of unity was used in both cases since the break orifice has a rounded inlet.

The RAI requested that consideration be given to comparing the Henry/Fauske - HEM model to the Marvikin critical flow data. The Marvikin tests are for large break LOCA's and simulate the critical flow through a large pipe and valve, rather than a small break in the wall of a pipe. It is believed that the use of the SPES and OSU test data is more typical for the small-break application of these models in NOTRUMP.

The Henry/Fauske - HEM critical flow model was programmed in NOTRUMP along with the orifice flow equation. The coding logic performed both the orifice flow calculation and the Henry/Fauske - HEM critical flow calculation and selected the minimum of the two flows. This is different from how the code treated the transition from choked to unchoked conditions for all of the original critical flow correlations (including the Moody correlation). The original logic compared the recipient pressure to the throat pressure. If the recipient pressure was less than the throat pressure, the flow was considered to be choked. If the recipient pressure was greater than the throat pressure, the flow was considered to be unchoked. There was also smoothing logic such that there would not be step changes in flow at the point where the receiver pressure equals the throat pressure. The original logic is described in Appendix M of WCAP-10079-P-A.

In the interest of consistency, it is planned to use the same logic for the transition from choked to unchoked conditions for all critical flow models. The smoothing logic may be refined to give better blending between choked and unchoked flow. The final form of the smoothing logic will be described in the Final Validation Report.

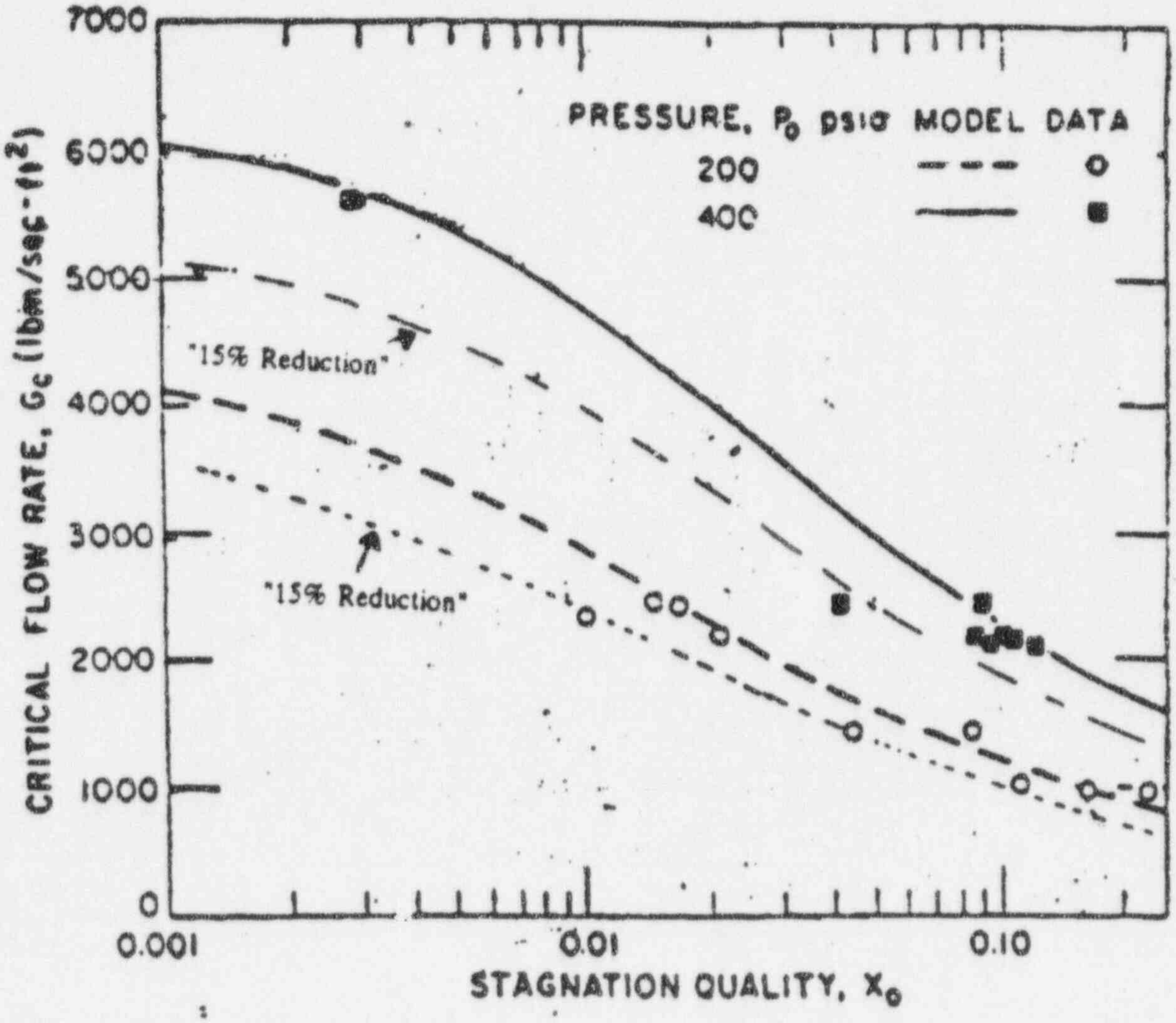
References

440.482-1 Meyer, P.E., Graziosi, G., Gonzalez, J., Kester, D.A., Saunders, S.E., and L.E. Hochreiter, "NOTRUMP Preliminary Validation Report for SPES-2 Tests", PXS-GSR-002, (July 1995).

440.482-2 Henry, R.E. and H.K. Fauske, "The Two-Phase Critical Flow of One-component Mixtures in Nozzles, Orifices, and Short Tubes", Trans ASME J. Heat Transfer, Vol 93, pg 179-187, (May 1971).

440.482-3 Hutcherson, M.N., "Contribution to the Theory of the Two-Phase Blowdown Phenomena", ANL-75-82, (1975).

SSAR Revision: NONE



Comparison between proposed model and experimental data of references [26, 27]

Figure 440.482-1

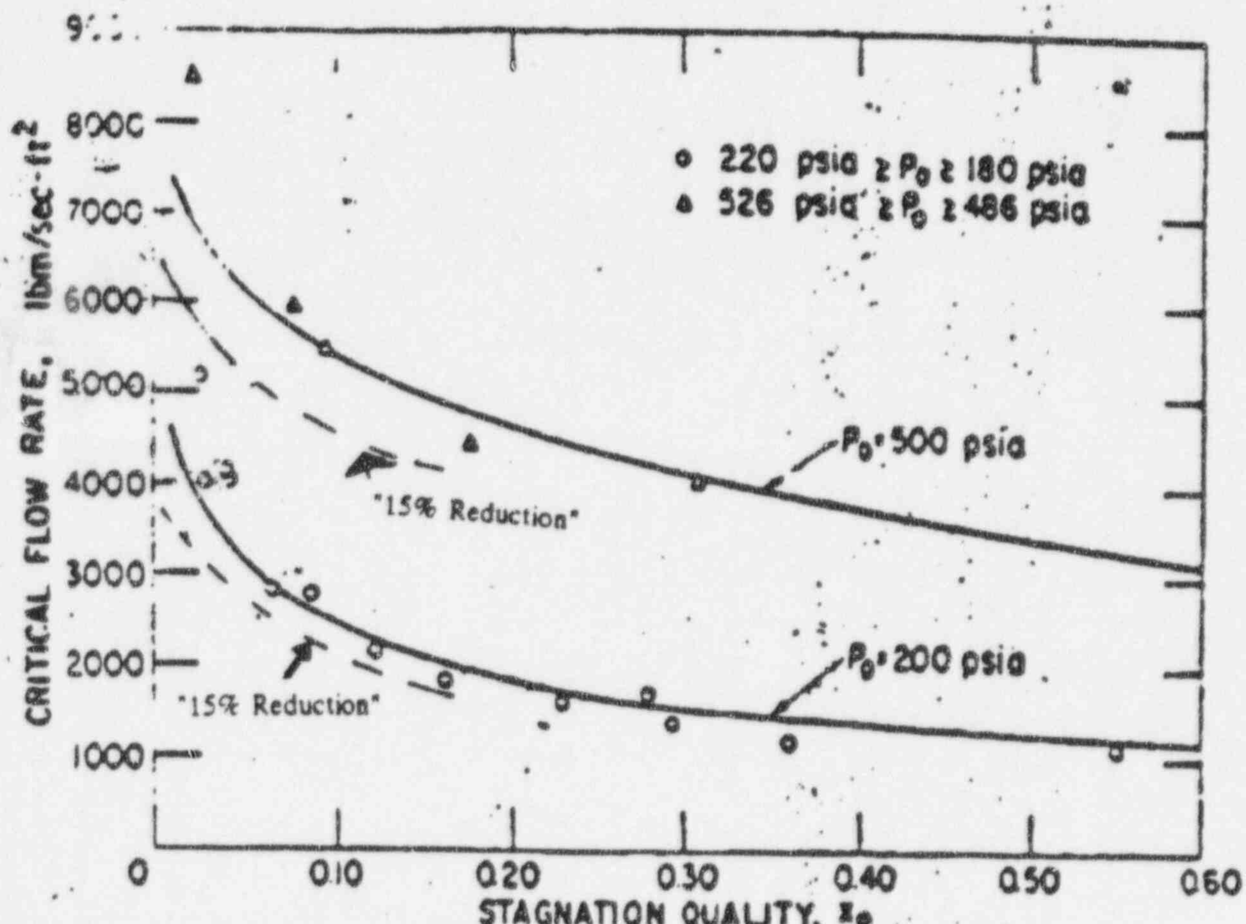
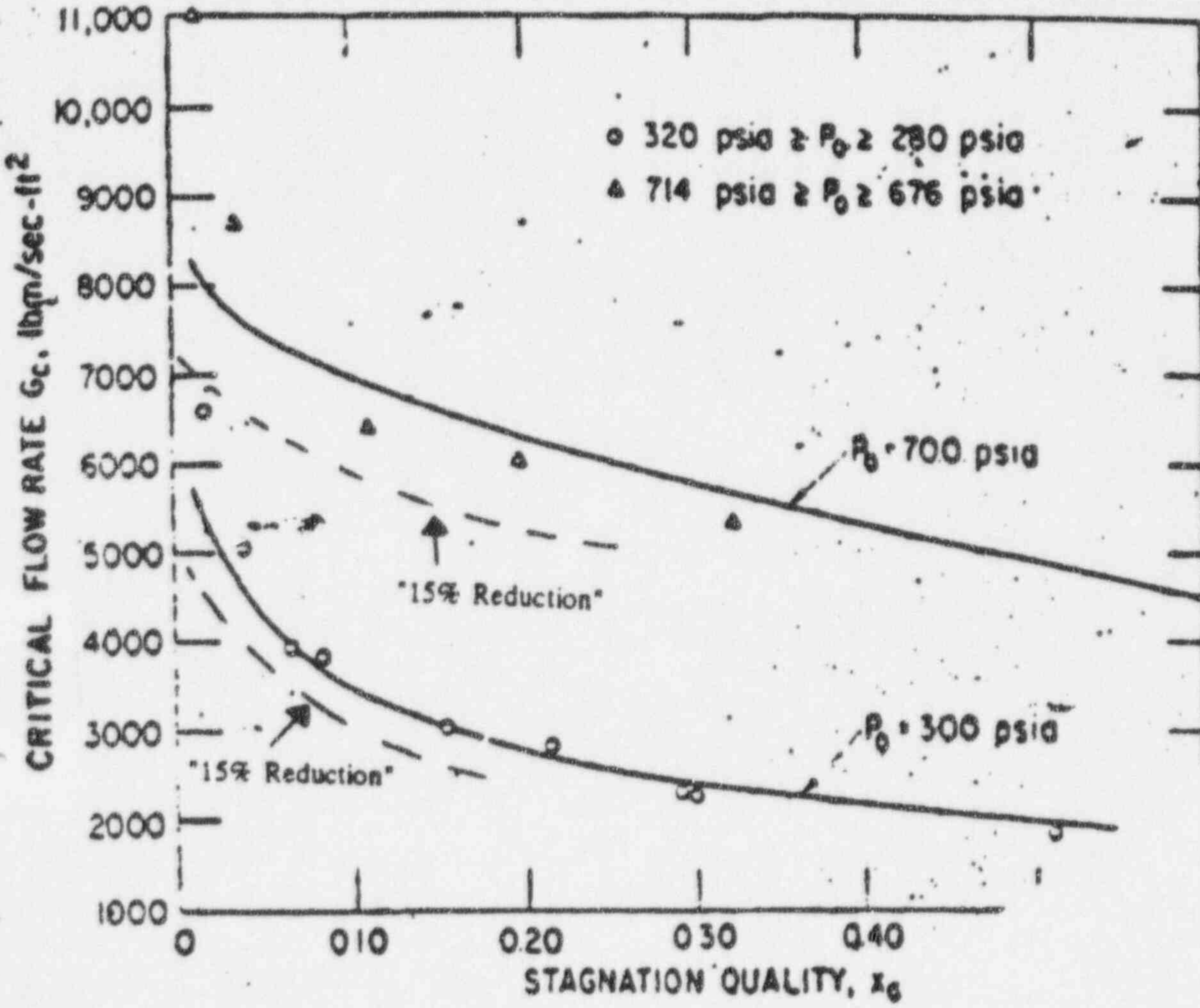


FIG. 10

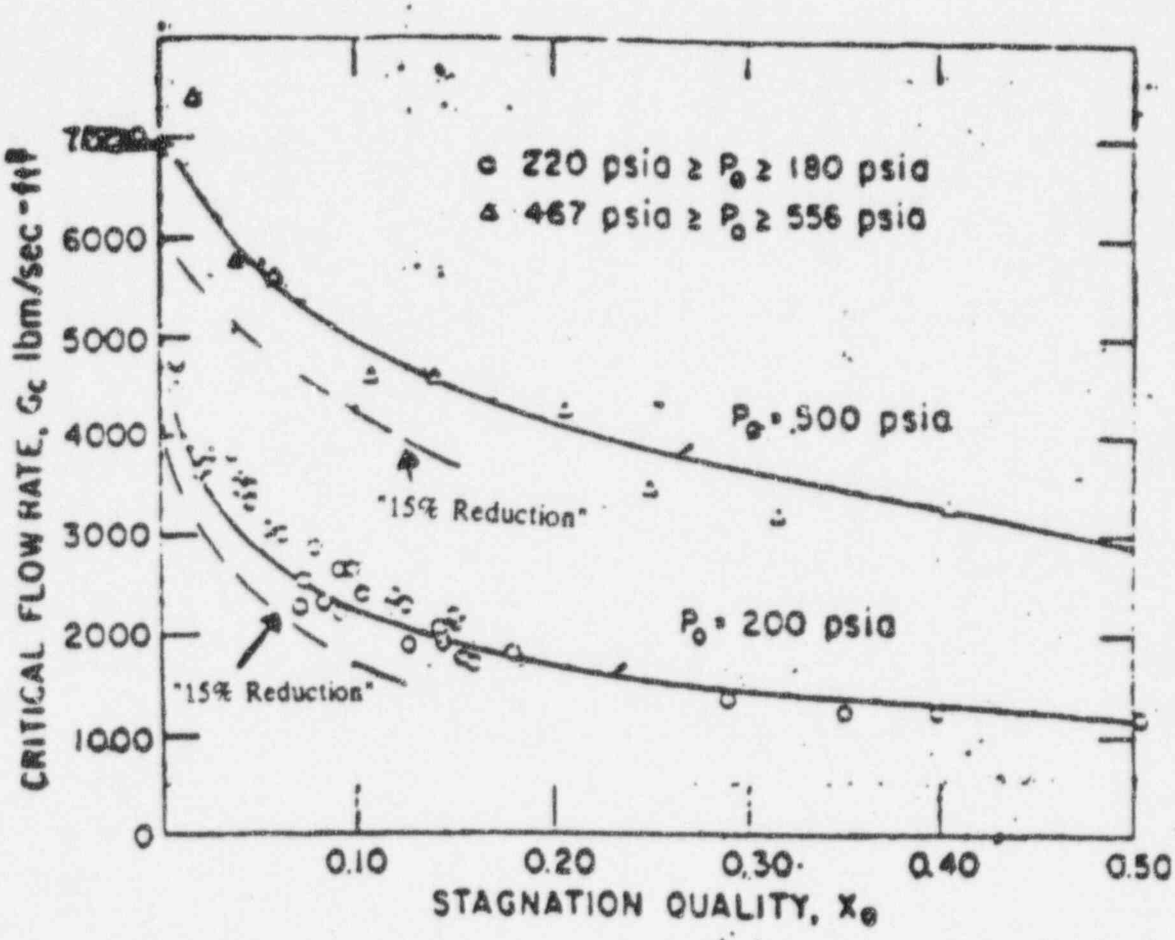
Comparison between proposed model and carbon dioxide data of reference [17]

Figure 440.482-2



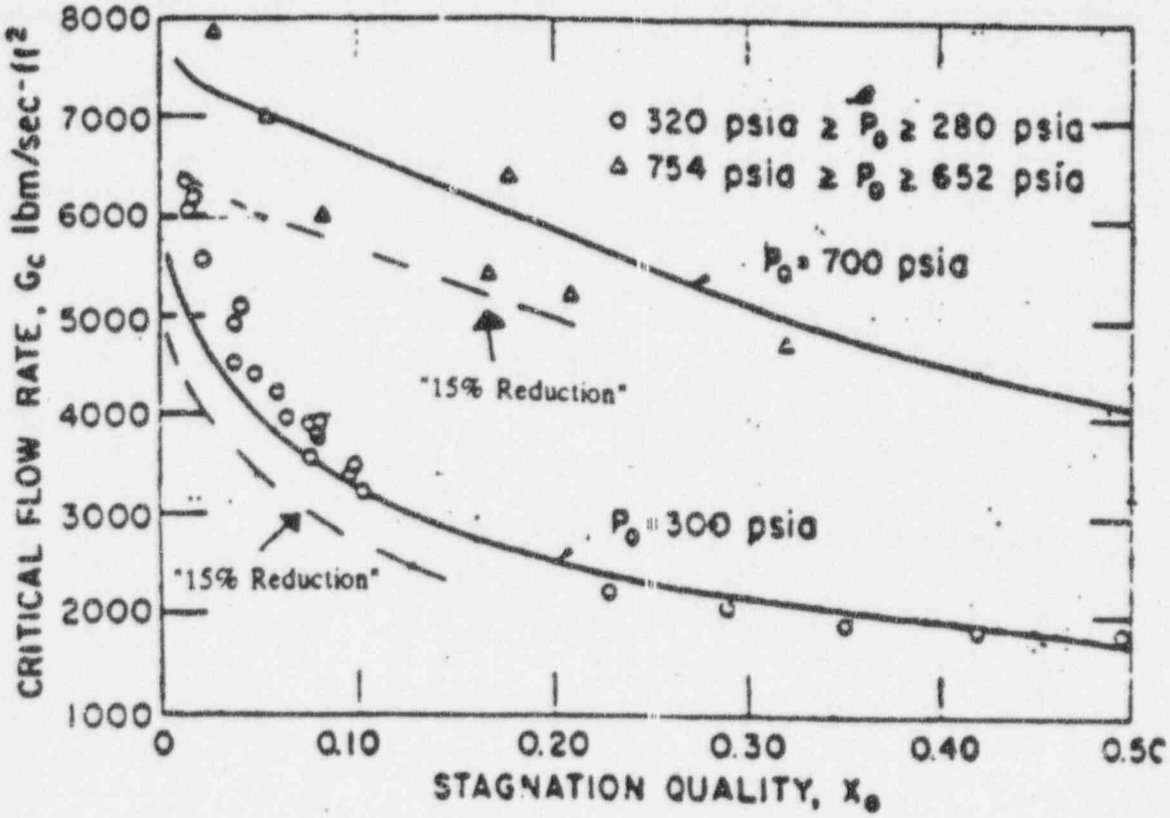
Comparison between proposed model and ca. of reference [17]

Figure 440.482-3



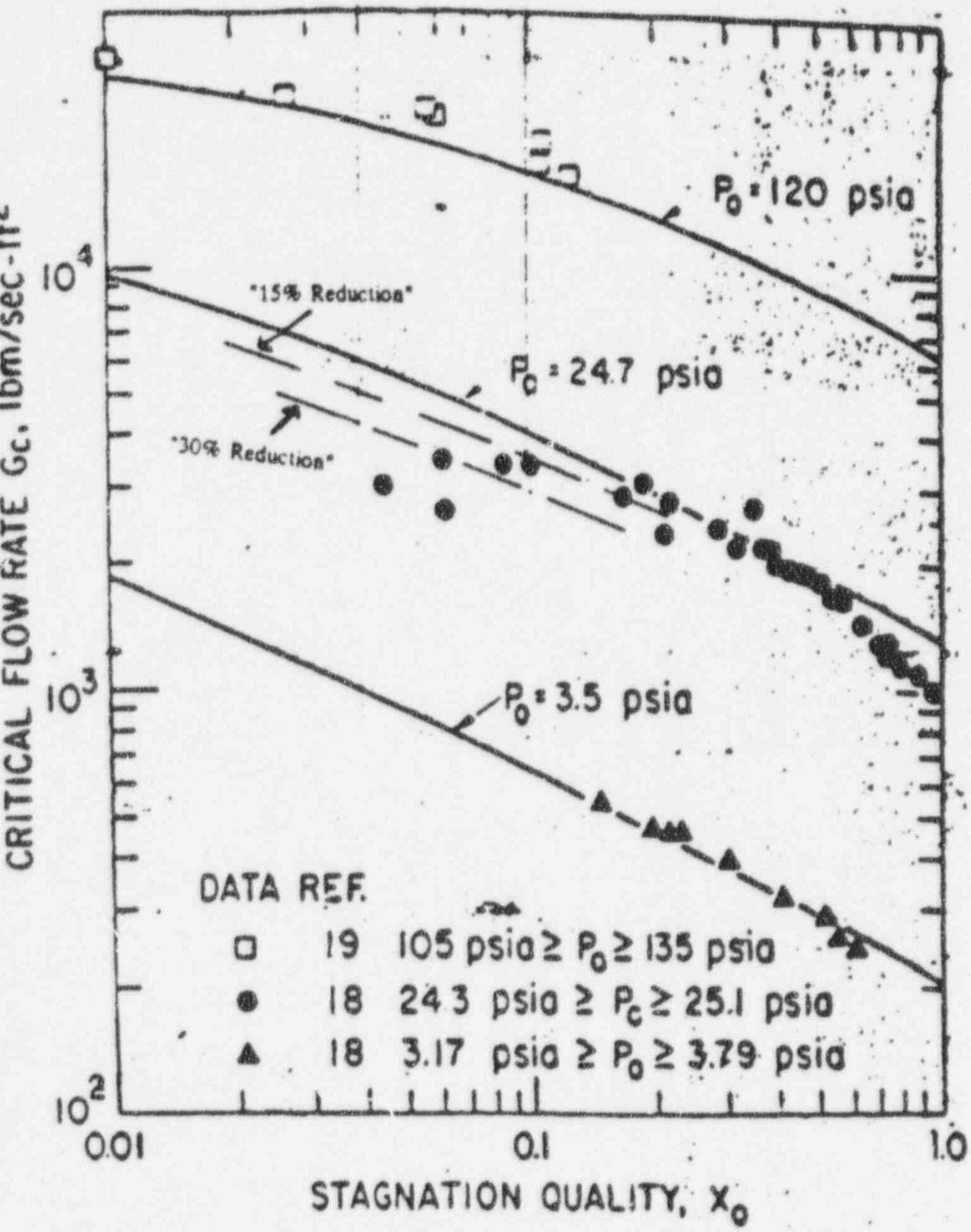
Comparison between proposed model and two-phase orifice data of reference [17]

Figure 440.482-4



Comparison between proposed model and two-phase orifice data of reference [17]

Figure 440.482-5



Comparison between proposed model and two-phase nitrogen orifice data of references [18, 19]

Figure 440.482-6

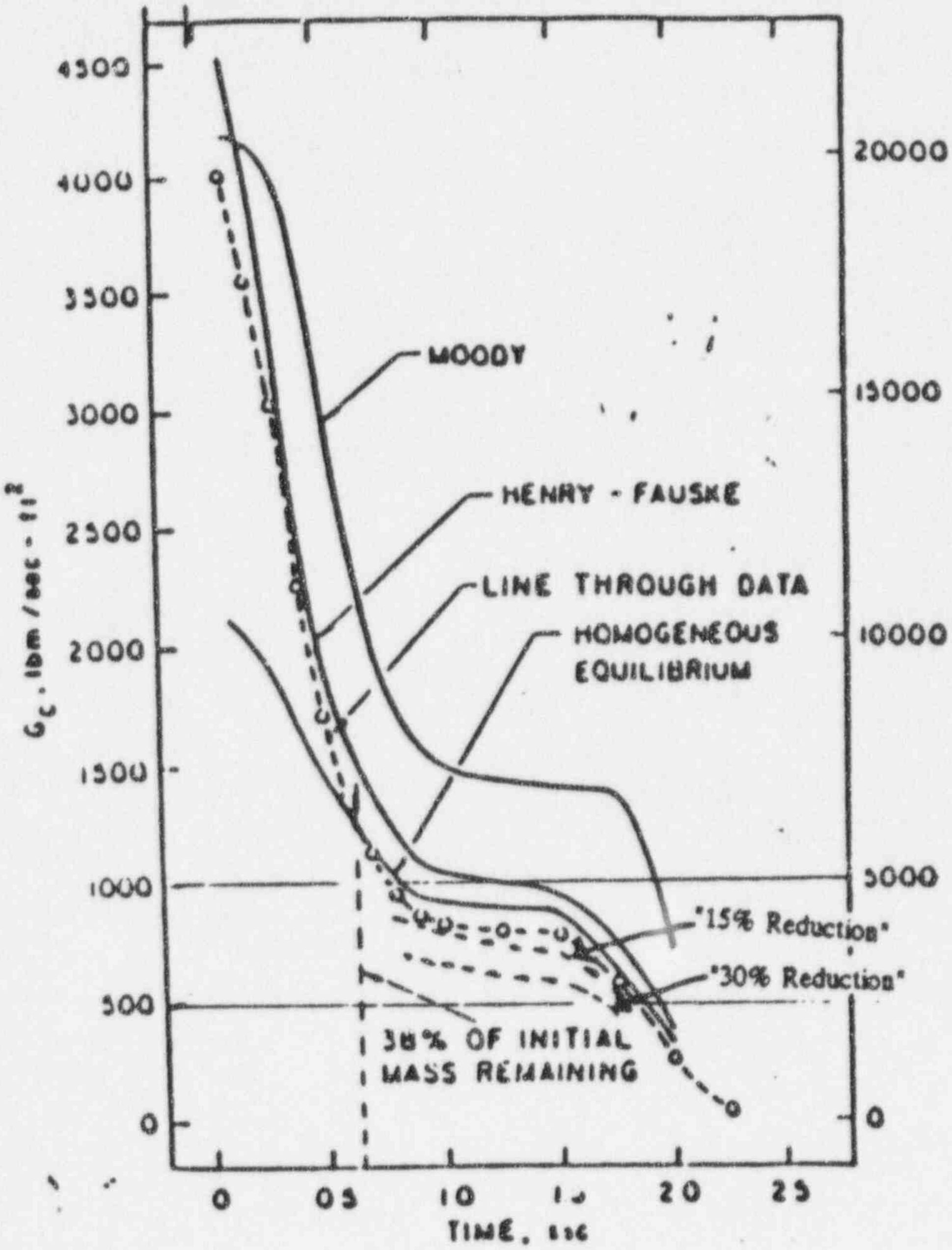


Figure 440.482-7

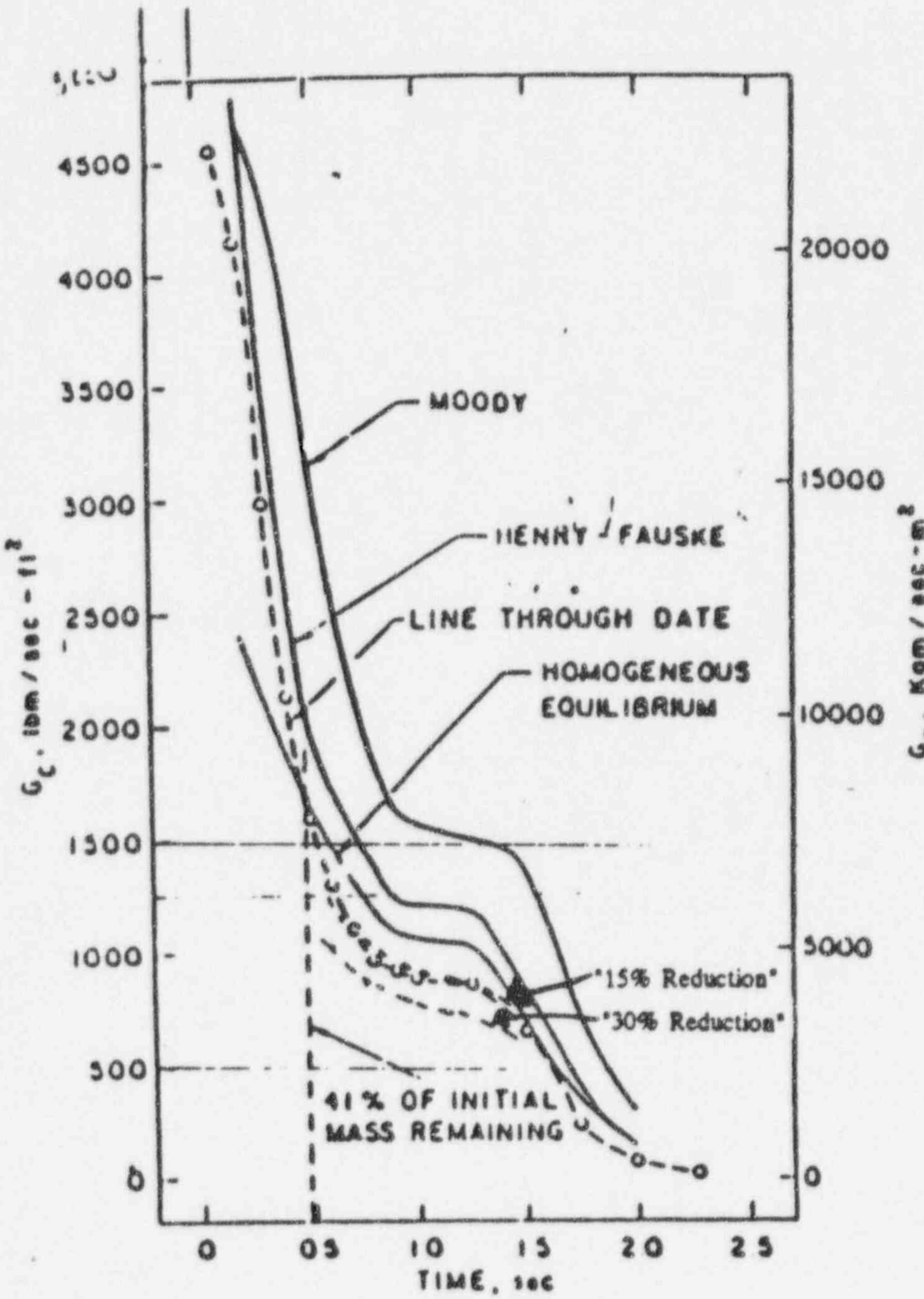
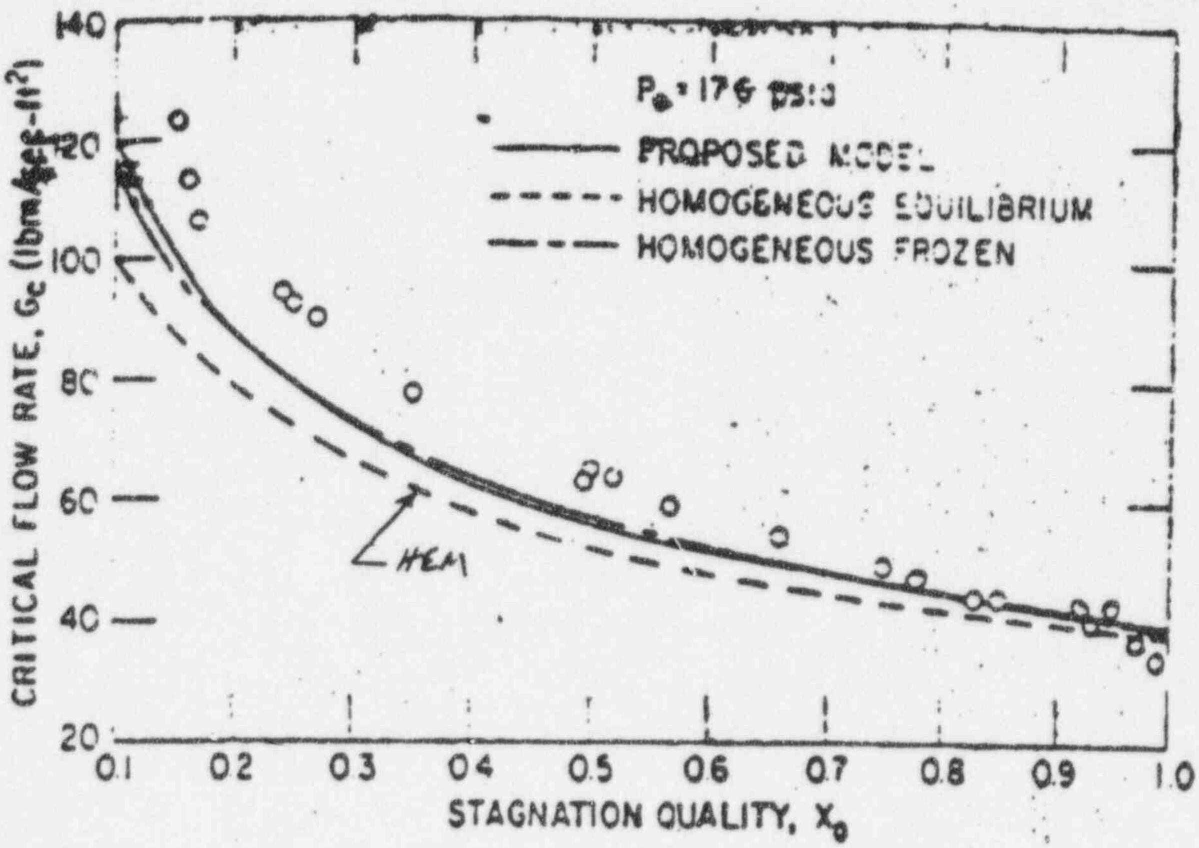
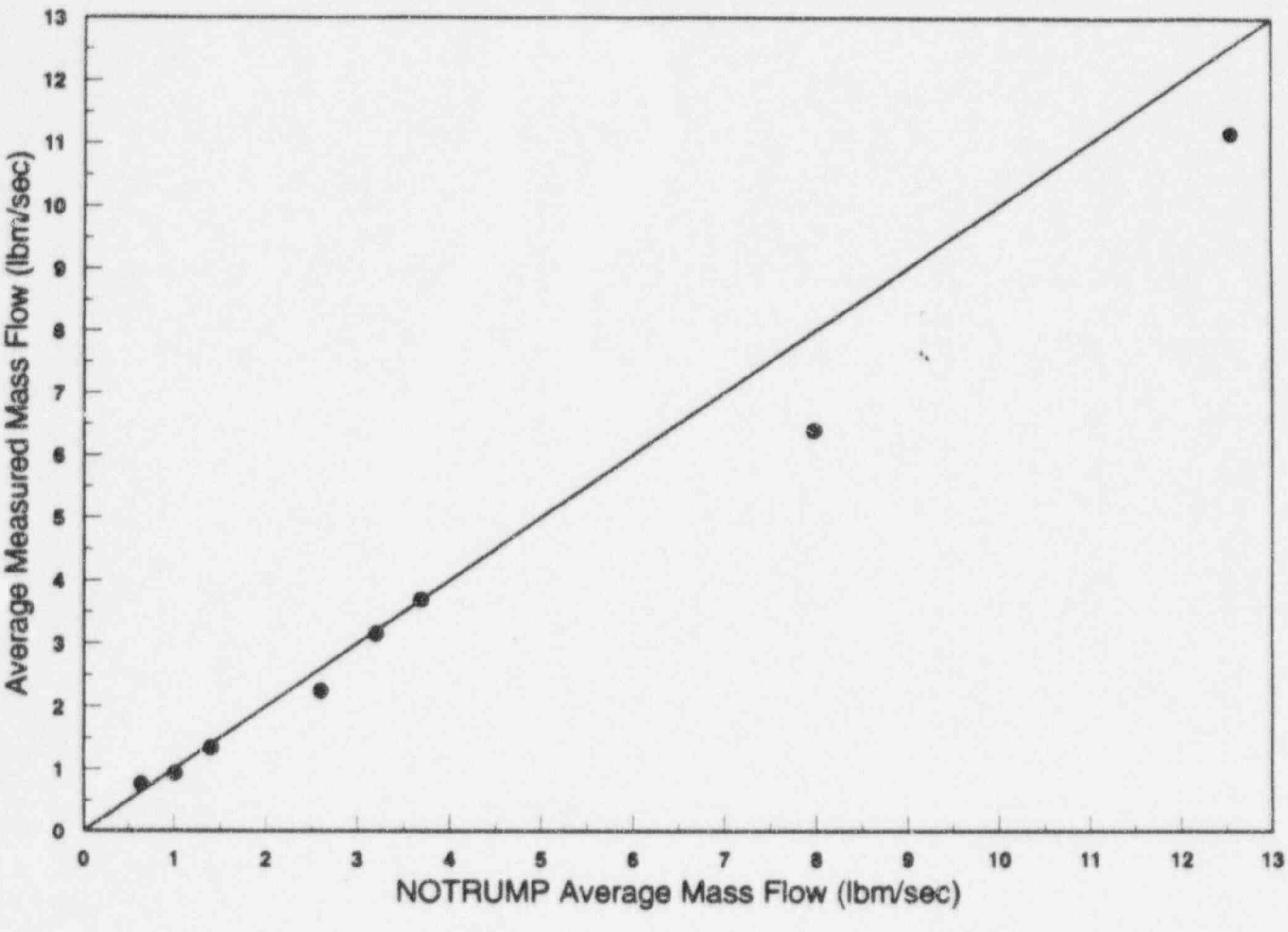


Figure 440.482-8



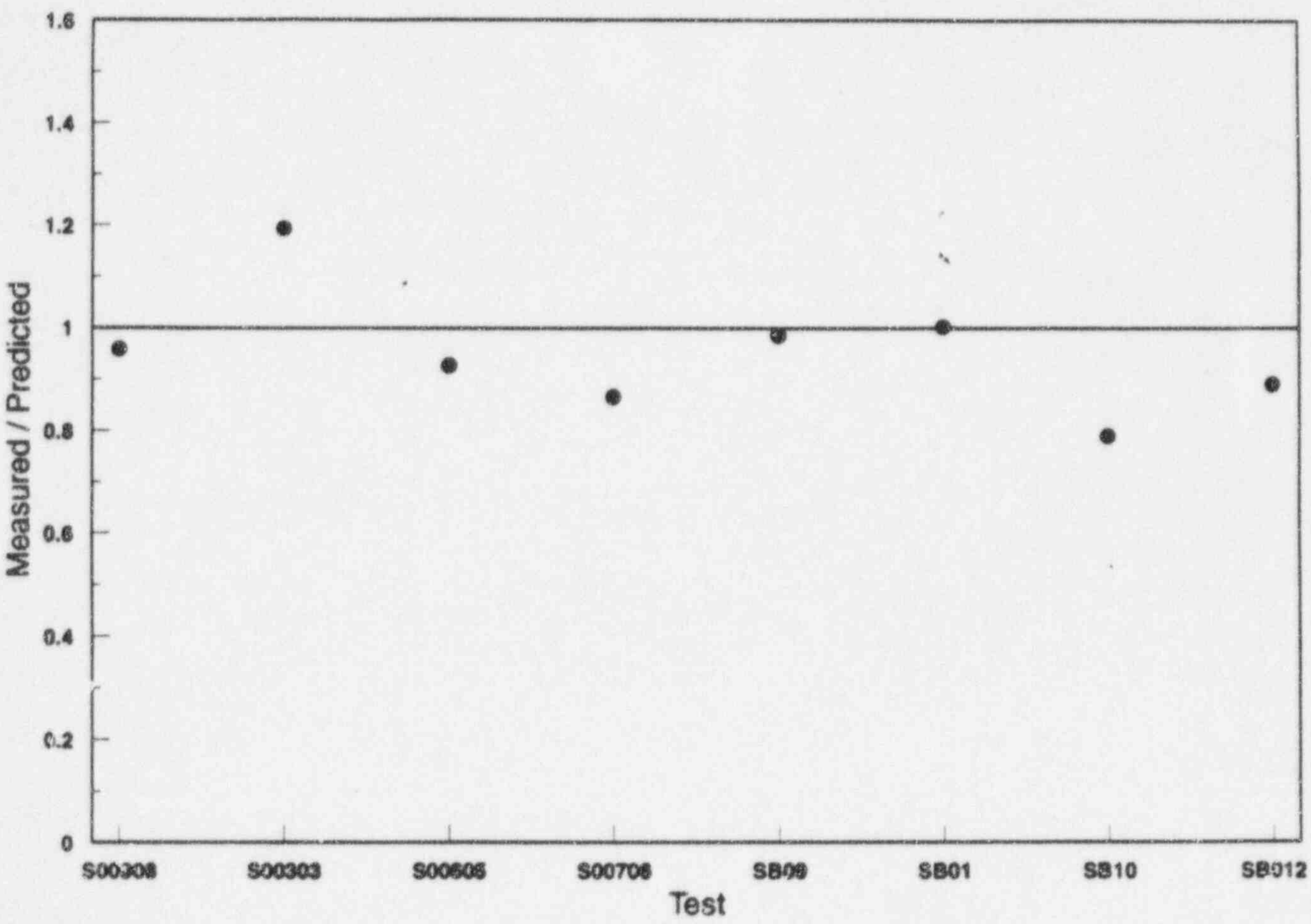
Comparison of critical flow predictions and experimental data of reference [30]

Figure 440.482-9



Comparisons of NOTRUMP Critical Flow Model with SPES and OSU Break Flow

Figure 440.482-10



Measured / Predicted Critical Flow Ratios for the SPES and OSU Tests

Figure 440.482-11

Question 440.485

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-001, JULY 1995
440.485 Please describe the Section 4.0 coding and modeling changes that were included in the NOTRUMP simulations for (1) AP600 NOTRUMP Automatic Depressurization System Preliminary Validation Report of RCS-GSR-003, and (2) AP600 NOTRUMP Core Makeup Tank Preliminary Validation Report for 500-Series Natural Circulation Tests of MT01-GSR-011.

Response:

For the runs contained in the NOTRUMP Automatic Depressurization System Preliminary Validation Report (RCS-GSR-003), three of the coding and modeling changes were utilized: 1) Section 4.3, Modifications to Drift Flux Correlations, 2) Section 4.4, the Net Volumetric Flow-Based Momentum Equation, and 3) Section 4.17, the Henry-Fauske/HEM Critical Flow Correlation. The coding and modeling changes not used are expected to have no significant effect on the results of these runs. These runs will be redone with the applicable models activated and the results reported in the NOTRUMP Final V&V Report.

For the runs contained in the AP600 NOTRUMP Core Makeup Tank Preliminary Validation Report for 500-Series Natural Circulation Tests (MT01-GSR-011), none of the coding and modeling changes of Section 4.0 were utilized. The coding and modeling changes are expected to have no significant effect on the results of these runs. These runs will be redone with the applicable models activated and the results reported in the NOTRUMP Final V&V Report.

SSAR Revision: NONE

Question 440.489

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-001, JULY 1995

440.489 Fig. 5.1-29 shows that the NOTRUMP code overpredicts the PRHR outlet temperature. Please explain why the NOTRUMP code underpredicts the PRHR heat transfer. Justify how this model deficiency results in conservative AP600 small break LOCA ECCS performance predictions.

Response:

The overprediction of the PRHR outlet temperatures indicates that the PRHR heat transfer is being underpredicted by NOTRUMP. This is caused by the simplified modelling of the PRHR on the tube-side, IRWST-side, or both. The important primary and secondary side heat transfer effects are noted below. As indicated in the Westinghouse response to RAI 440.513, alternate nodalizations in the area of the PRHR / IRWST will be investigated for the final validation report.

Primary Side Effects: The primary side heat transfer will be dependent on the rate and quality of the flow through the PRHR. Any differences will have an impact on the performance of the PRHR.

Secondary Side Effects: As seen from Figure 2-1 of Reference 440.489-1, the NOTRUMP model of the OSU facility represents the IRWST water volume as a single, homogeneous node. In reality the PRHR will be heating a relatively small proportion of the overall IRWST water volume in the region of the PRHR heat exchanger, and will not be uniformly heating the entire tank of water. The heating of the water near the PRHR heat exchanger will cause a recirculation flow to arise within the IRWST, and a single IRWST fluid node is not capable of representing any such circulation. This simplified modelling will lead to an underprediction of the PRHR heat transfer, which is why the above investigation will be carried out.

Please refer to the Westinghouse response to RAI 440.546 for a discussion of the impact of the overprediction of PRHR outlet temperatures on ECCS performance during a small break LOCA.

Reference

440.489-1 LTCT-GSR-001, "NOTRUMP Preliminary Validation Report for OSU Tests", Proprietary, July1995.

SSAR Revision: NONE

Question 440.504

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-001, JULY 1995

440.504 Please explain the NOTRUMP calculated large negative ADS 1-3 flows shown in Fig. 5.4-17 after 440 seconds.

Response:

The negative flow through the ADS 1-3 lines, as shown in Figure 5.4-17 of Reference 440.504-1, indicates that the pressure in the IRWST is higher than that in the ADS 1-3 piping.

As noted in Reference 440.504-2, for OSU matrix test SB01, the measured pressures in the ADS 1-3 sparger, ADS 1-3 separator and the pressurizer all went negative during the test, and remained lower than the IRWST pressure until the IRWST drained to below the sparger. In subsequent tests, a vacuum breaker was fitted to the ADS 1-3 discharge and such behavior was no longer observed.

The NOTRUMP model for OSU includes a check valve from the ADS 1-3 piping fluid node to a containment boundary volume, in order to represent the vacuum breaker. The IRWST tank is also pressurized through a flow link to a second containment boundary volume. However, the representation of the vacuum breaker maintains a piping pressure which will be considerably lower than the pressure at the outlet of the sparger in the IRWST. The NOTRUMP modelling is therefore unable to prevent reverse flow while there is a large head of water in the IRWST. In the NOTRUMP model of the AP600 plant, reverse flow through the ADS 1-3 piping is prevented by inclusion of a check valve in the line. This prevents any reverse flow and is thus a better approximation to the vacuum breaker in the plant design. Such a representation will be investigated for the NOTRUMP OSU model used for the final validation report.

References

440.504-1 LTCT-GSR-001, "NOTRUMP Preliminary Validation Report for OSU Tests", Proprietary, July1995.

440.504-2 WCAP-14252, "AP600 Low-Pressure Integral Systems Test at Oregon State University Final Data Report", Proprietary [LTCT-T2R-100], May 1995.

SSAR Revision: NONE

Question 440.535

Re: SPES-2 Test Analysis Report

As noted in previous discussions with Westinghouse, the emphasis in the SPES-2 TAR on mass/energy balances, with some discussion of relevant phenomenology later in the report, omits the important step of extending the insights gained from the test program to modeling both SPES-2 behavior and --ultimately-- AP600 response, using Westinghouse's accident analysis computer codes. To the extent that this information is contained in the code validation and verification reports, the staff's review of this information is incomplete until those documents can be evaluated.

Response:

The SPES-2 Final Data Report (Reference 440.535-1) and the SPES-2 Test Analysis Report (Reference 440.535-2) together form a complete record of the test data and its subsequent analysis. These reports, and references therein, demonstrate the adequacy of the tests for simulating the key thermal hydraulic phenomena which occur in the AP600 plant. The NOTRUMP Preliminary V&V Report (Reference 440.535-3) and LOFTRAN Final V&V Report (Reference 440.535-4) provide comparisons between the Westinghouse accident analysis computer codes and the test results. These comparisons provide confidence that the computer codes are adequate for modeling transient conditions in the AP600 plant. Additional code-to-test comparisons of NOTRUMP will be completed with the issuance of the NOTRUMP Final Validation Report and will further demonstrate the applicability of the Westinghouse accident analysis codes to the AP600 design.

References

440.535-1 WCAP-14309, Revision 1, "AP600 Design Certification Program SPES-2 Tests Final Data Report," Proprietary, July, 1995

440.535-2 WCAP-14254, Revision 1, "AP600 SPES-2 Test Analysis Report," Proprietary, November 1995

440.535-3 PXS-GSR-002, "NOTRUMP Preliminary Validation Report for SPES-2 Tests," July 1995

440.535-4 Final, "AP600 LOFTRAN-AP and LOFTTR2-AP Final Verification and Validation Report" Proprietary [PXS-GSR-100], June 1995.

SSAR Revision: NONE

Question 440.536

Re: SPES TAR

In view of the emphasis placed upon mass and energy balances, the statement in the last paragraph on p. 3.1-1 is somewhat troubling. Westinghouse refers to the necessity of making "some reasonable assumptions" concerning mass outflows through the automatic depressurization system valves. There does not seem to be any attempt in the TAR to quantify the effects that uncertainties arising from those assumptions might have on the evaluation of the test data. Although an error analysis for the data themselves is included in the FDR, this is not sufficient to account for uncertainties due to, for example, assumption of a particular two-phase flow regime in calculations of mass/energy balances. This issue must be addressed in more detail by Westinghouse.

Response:

The SPES facility did not have, as an objective of that test, any means of determining the proportions of steam and liquid leaving via the ADS system. For ADS stage 4, saturated liquid is assumed throughout the discharge. This is a reasonable assumption except in the early stages of ADS-4 discharge, when a small error will result. For ADS stages 1 to 3, it was assumed that the discharge was saturated water when the void fraction at the top of the pressurizer was less than 0.9, and saturated steam otherwise.

To quantify the uncertainty associated with the assumption regarding the quality of the ADS stage 1 to 3 discharge, two additional analyses of the 2-in reference case (S00303) have been undertaken. In the first case the discharge has been assumed to be saturated liquid throughout, and in the second, saturated steam is assumed throughout. These cases quantify the maximum uncertainty that can arise. The ADS stage 1 to 3 fluid energy resulting from these two analyses, along with that reported in Reference 440.536-1, are shown in Figure 440.536-1. This figure shows the maximum uncertainty range at each point in time. Figure 440.536-2 shows the impact of the three assumptions on the overall energy balance error. It can be seen that the assumptions used in Reference 440.536-1 provides the best overall energy balance error.

It should be noted that in the SPES-2 facility ADS stages 1 to 3 discharge to a common condenser and catch tank system so that all the discharge fluid is weighed. The different assumptions regarding the quality of the discharge therefore have no impact on the mass balance results.

Reference

480.242-1 WCAP-14254, Revision 1, "AP600 SPES-2 Tests Analysis Report," Proprietary [PXS-TZR-110], November 1995.

SSAR Revision: NONE

Question 440.541

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-004, SEPTEMBER 1995
440.541 Explain the reason for the NOTRUMP calculated higher pressurizer pressure from 500 to 800 seconds in Figure 5.2-1.

Response:

The hold up of the NOTRUMP pressurizer pressure from 500-800 seconds is related to the slower drain of CMT-2 for the NOTRUMP simulation compared to the test data (CMT-1 is on the loop with the broken balance line and drains later). Because of the delayed draining of the CMT, ADS actuation is delayed by approximately 300 seconds. The mixture temperatures of the top two nodes in the CMT-2 remain 40-60°F below saturation temperature at 400 seconds. This lower temperature causes the slower drain of the CMT-2 as steam continues to condense at the top of the CMT longer than cases with higher temperatures in the CMT.

The lower temperature is caused by the brief amount of accumulator injection beginning shortly after 300 seconds which makes it way from the downcomer to CMT-2. Since the system pressure does not fall after accumulator injection starts, the injection stops by 500 seconds. Near the beginning of the simulation, the pressure falls about 80 seconds earlier than in the test. Furthermore, the accumulator pressure in the simulation was set 30 psi higher than in the test so accumulator injection was predicted early relative to the test. At this earlier time, the large inventory of water in the downcomer contributes to the ease with which cold water reaches the CMT-2. By correcting the initial accumulator gas pressure, which will be done for the runs contained in the NOTRUMP Final V&V Report, accumulator flow initiation and the test transient phenomena, including pressurizer pressure, should be better predicted.

SSAR Revision: NONE

Question 440.543

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-004, SEPTEMBER 1995
440.543 Explain the reason for the delayed accumulator injection in Figures 5.2-13 and 5.2-14.

Response:

This response is related to that for RAI 440.541. Initially, NOTRUMP predicts accumulator injection earlier than the test data. This is attributed to a higher accumulator gas pressure modeled in NOTRUMP compared to the test. As indicated in the response to RAI 440.541, this early accumulator injection results in delayed draining of the CMT-2 and delayed ADS actuation compared to the test data. After the initial accumulator injection stops, sustained accumulator injection is delayed in the NOTRUMP run until ADS actuation is predicted. It is expected that use of the same accumulator gas pressure in NOTRUMP as in the test will produce more consistent results between NOTRUMP and the test data. This change will be made for the runs in the NOTRUMP Final V&V report.

SSAR Revision: NONE

Question 440.544

Re: NOTRUMP PVR FOR OSU TESTS, LTCT-GSR-004, SEPTEMBER 1995
Figure 5.2-19 shows the ADS 4-2 flow which was overpredicted from 1300 to the end of the calculated transient at 1600 seconds. Explain the reason for the ADS overpredicted flow rate and the impact on the codes' ability to predict and/or bound the long term two-phase level in the core and upper plenum during IRWST and sump injection.

Response:

Following the initiation of ADS stage 4, the flow through ADS stages 1-2-3 is close to zero in the test. At this time DVI flow, which is basically IRWST injection, is about the same as the flow through the ADS stage 4 valves. Since, NOTRUMP initially predicts higher IRWST injection flow rates compared to the test data, the consequent NOTRUMP ADS stage 4 flow rates are also higher compared to the test data.

WCOBRA/TRAC is the code used for long term cooling simulations, ie. for long term IRWST and sump injection. NOTRUMP simulations are continued only until sustained IRWST injection is predicted.

SSAR Revision: NONE

Question 440.545

Re: NOTRUMP Preliminary Validation Report for OSU Tests, LTCT-GSR-004, September 1995

Explain the reasons for the overprediction of the PRHR outlet temperatures in Figure 5.2-29 from about 850 seconds to the end of the plot at 1600 seconds. Address the impact of the PRHR temperature overpredictions on natural circulation flow and the minimum core/upper plenum mixture level in the vessel during both the short and long term.

Response:

Please refer to Westinghouse response to RAI 440.489 for a discussion of the overprediction of PRHR outlet temperature and Westinghouse response to RAI 440.546 for a discussion of the impact of higher primary system fluid temperatures on ECCS performance during a small break LOCA.

SSAR Revision: NONE

Question 440.549

Re: NOTRUMP Preliminary Validation Report for OSU Tests

These tests were run well beyond the 1600 second end times for these comparisons. Explain why the code was not run beyond these end times as the IRWST flow was still increasing when the run was terminated. Show the NOTRUMP predictions with the data out to the time the IRWST flow stabilizes. Also, show the downcomer and upper plenum fluid levels out to this time.

Response:

For the analysis of small break LOCA's, NOTRUMP will be used for the short term phase of the transient, and WCOBRA/TRAC for the long-term cooling part of the transient. The transition from the short-term, to long-term cooling phases is defined by the start of sustained IRWST injection. The OSU tests, and to a certain extent the SPES-2 tests, have been continued for a significant period of time, beyond the initiation of IRWST injection, into the long-term cooling phase.

All of the NOTRUMP analyses reported in References 440.549-1 through 440.549-4 have been continued until sustained IRWST flow has been achieved in both the test, and the simulation. This allows the accuracy of NOTRUMP predictions of the time for IRWST injection to be assessed. Furthermore, as noted in the Westinghouse response to RAI 440.510, it is clear from results reported in References 440.549-1 and 440.549-5, that the magnitude of the IRWST flow predicted by NOTRUMP is consistent with the final steady state flow seen in the tests. The details of the transient beyond the time of IRWST injection are analyzed using WCOBRA/TRAC, and thus there is no requirement for the NOTRUMP analyses to be continued after sustained IRWST flow is achieved.

References

440.549-1 LTCT-GSR-001, "NOTRUMP Preliminary Validation Report for OSU Tests", Proprietary, July 1995.

440.549-2 LTCT-GSR-004, "Addendum to NOTRUMP Preliminary Validation Report for OSU Tests", Proprietary, July 1995.

440.549-3 PXS-GSR-002, "NOTRUMP Preliminary Validation Report for SPES-2 Tests," Proprietary, July 1995.

440.549-4 PXS-GSR-004, "Addendum to NOTRUMP Preliminary Validation Report for SPES-2 Tests," Proprietary, September 1995.

440.549-5 WCAP-14292, Revision 1, "AP600 Low-Pressure Integral Systems Test at Oregon State University Test Analysis Report," Proprietary [LTCT-T2R-600], September 1995.

SSAR Revision: NONE

Question 440.551

Re: Addendum to the NOTRUMP Preliminary Validation Report for SPES-2 Tests, PXS-GSR-004, September 1995

Figure 5.4-23 shows the NOTRUMP overprediction of the liquid inventory above the core for the entire event. Explain the reasons for the overprediction and explain the impact of this non-conservative result on the code's ability to predict or bound the minimum inventory in the vessel for AP600 small break LOCA analysis predictions.

Response:

Please refer to Westinghouse response to RAI 440.520 which includes results for test S00908.

SSAR Revision: NONE

Question 440.552

Re: NOTRUMP Preliminary Validation Report for SPES-2 Tests (PXS-GSR-004, September 1995)

Show the NOTRUMP comparisons farther in time or when the IRWST flow reaches a more stable flow rate. Also, show the downcomer and upper plenum fluid levels out to his time.

Response:

Please refer to the response to RAI 440.549.

SSAR Revision: NONE

Question 440.551

Re: Addendum to the NOTRUMP Preliminary Validation Report for SPES-2 Tests, PXS-GSR-004, September 1995

Figure 5.4-23 shows the NOTRUMP overprediction of the liquid inventory above the core for the entire event. Explain the reasons for the overprediction and explain the impact of this non-conservative result on the code's ability to predict or bound the minimum inventory in the vessel for AP600 small break LOCA analysis predictions.

Response:

Please refer to Westinghouse response to RAI 440.520 which includes results for test S00908.

SSAR Revision: NONE