Westinghouse Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-97-1123

June 17, 1997

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

ATTENTION: MR. T. R. QUAY

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION ON THE NOTRUPM FINAL VALIDATION REPORT

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-97-1123 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-97-1123 and should be addressed to the undersigned.

Very truly yours,

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

cc: Kevin Bohrer NRC OWFN - MS 12E20

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PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant specific review and approval.

In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) contained within parentheses located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Section (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR2.790(b)(1).

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Brian A. McIntyre, 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:

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

Sworn to and subscribed
before me this 17th day
of June, 1997

Notary Public

Notarial Seal
Janet A. Schwab, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires May 22, 2000
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety And Licensing, in the Advanced Technology Business Area, 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-97-5190, June 17, 1997 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 Fower 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.

ATTACHMENT 2

NON-PROPRIETARY RESPONSES TO
REQUESTS FOR ADDITIONAL INFORMATION ON
THE NOTRUMP FINAL VALIDATION REPORT

Question 440.599

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The report needs to document the specific judgments made by the Westinghouse analysts of the validity of each modified code model. Additionally, even though Westinghouse is making an Appendix K submittal, they have based much of their final V&V report on high ranked PIRT phenomena. Therefore, the report needs to document Westinghouse judgments of the ability of NOTRUMP to correctly represent all PIRT high ranked phenomena. These judgments should be summarized at the end of each applicable report section and a summary of all the assessments should appear in the conclusion of the report. These judgments should be made using the terms defined in Section 1.5. In cases where the judgment would be minimal or inadequate, analyses should be provided which show that the code results are conservative.

Response:

Section 1 of Reference 440.599-1 has been revised to include an overview of the model changes made in NOTRUMP, and the results of the code assessment. The intent is to provide the reader with a condensed version of the assessment process, starting from the PIRT and ending with the steps which will be taken in the AP600 Appendix K analysis to address several model deficiencies. This revised section contains the information requested in this RAI. In Section 1.6, a list of 7 key models required for prediction of AP600 phenomena are identified by reference to the PIRT. Each model is evaluated in Sections 1.7 to 1.12, and a judgment is made on the potential weaknesses or deficiencies of the model. Finally, in Sections 1.13 to 1.15, the results of the assessment studies performed in the FVR are discussed, and a final judgment is made regarding each model's ability to accurately simulate the phenomena. For those models whose performance was judged as minimal or inadequate, an additional evaluation was performed to determine the impact on the results, and whether the application of such a model in AP600 will be conservative. If such a judgment cannot be made, steps are described in Section 1.16 which will assure that the Appendix K application to AP600 will be conservative.

References:

440.599-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.600

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Section 3.2.2 discusses the validity of the Yeh correlation used in the drift flux model for core flooding. It indicates that the validity of the model is shown in reference 3-4. Reference 3-4 was written in 1985. The Yeh correlation used in NOTRUMP was modified recently as documented in section 2.3. Please provide a validation that is applicable to the modified Yeh correlation that is currently found in NOTRUMP.

Response:

The correct reference should have been Section 4 of Reference 440.600-1. In this section, level swell experiments in several test facilities are simulated with NOTRUMP, using the Yeh correlation in the drift flux model. This will be changed in Revision 2 of the NOTRUMP Final Validation Report.

References:

440.600-1 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

SSAR Revision: NONE

Question 440.601

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Section 3.2.5 states that "...CCFL is correctly predicted by NOTRUMP..." but then it continues to say that "... NOTRUMP will tend to predict more holdup of liquid... than indicated by data." Please make a specific judgement using the terms defined in Section 1.5.

Response:

To clarify the original text: what was meant was that the CCFL boundary is correctly recognized by NOTRUMP (i.e., countercurrent flow outside the permitted region is not calculated). In general, comparisons show that the CCFL boundary predicted by NOTRUMP lies below the data, which implies more liquid holdup. A specific judgment concerning the performance of the drift flux model is made in the response to RAI 440.599. In that response, it is concluded that the drift flux model performance is reasonable, although the predictions are not always within the range of the data. the conclusion that the model is reasonable is based on the fact that the model does not overestimate the degree of countercurrent flow possible, which is conservative.

SSAR Revision: NONE

Question 440.602

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Section 3.3.4 states that the flow reversal point predicted by NOTRUMP occurs at a lower vapor flow than indicated by the data. Does this considerable discrepancy indicate that the leveling drift flux model performance is reasonable or minimal? Is this behavior conservative?

Response:

It was indicated in Section 3.3.4 that the data curves described the maximum countercurrent flow allowed while maintaining the interface in a stable configuration. At higher flows, any disturbance on the interface would grow and result in a flow regime change. The countercurrent flow described by the levelizing drift flux model is the flow induced by differences in level from one component to the other. If the level difference is small, only a small amount of interfacial drag (i.e., a small vapor flow) is required to force the liquid to reverse. To check whether the levelizing model produced a reasonable initial level gradient for a given flow, it was compared with levels calculated using weir equations (for example, Figure 3.3-6 of Reference 440.602-1). Therefore, for most typical level gradients, the predicted j_g, j_f curve is expected to fall below the stability limit. For this reason, the levelizing drift flux model performance is judged as reasonable.

References:

440.602-1 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

SSAR Revision: NONE

Question 440.603

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

There are two apparently inconsistent references to Figure 3.4-11 in Section 3.4. The first reference is at the bottom of page 3.4-2 and it appears to refer to a figure that has been omitted. The second reference to Figure 3.4-11 is at the top of page 3.4-3. This second reference does match the Figure 3.4-11 that is included. Please provide the omitted figure and renumber the remaining figures.

Response:

In Section 3.4, the first reference to Figure 3.4-11 at the bottom of page 3.4-2 is incorrect. The correct figure reference is Figure 3.4-10. This typographical error will be corrected in Revision 2 of the NOTRUMP Final Validation Report for AP600. The second reference to Figure 3.4-11 in Section 3.4 at the top of page 3.4-3 is correct. There were no figures omitted from Section 3.4. The hand calculation referred to confirms the value plotted in Figure 3.4-10, but does not appear on the figure.

SSAR Revision: NONE

Question 440.604

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Please add conclusions to Section 3.4.

Response:

Section 3.4 documents the implicit treatment of gravitational head benchmark. The following text will be added to the end of Section 3.4 in Revision 2 of the NOTRUMP Final Validation Report for AP600:

In conclusion, the implicit treatment of fluid node gravitational head in the solution of the flowlink momentum conservation equations was verified with a simulation of an oscillating manometer, both with the explicit and implicit treatment of fluid node gravitational head. The pressure imbalances produced by the explicit treatment of fluid node gravitational head were quantified and checked with hand calculations. These pressure imbalances were shown to be virtually eliminated by the implicit treatment. In addition, perturbations in the interior fluid node pressures which were observed in the simulation were determined to be due to the incompressibility of the subcooled water in the manometer, and were unrelated to the fluid node gravitational head model. It is concluded that these perturbations are small and not a concern.

SSAR Revision: NONE

Question 440.605

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Figure 5.4-18 shows a step change in the PE5W data which appears erroneous. This was not discussed in the text. Including this step change distorts the scale of the plot. Please redraw the plot with the scale adjusted so the top of the step change is not included but the remainder of the plot is shown larger. Please explain the step change in the text.

Response:

The step change in the pressure, measured by PE5W for Test 240 shown on Figure 5.4-18 is incorrect. This is due to the failure of PE5W during Test 240 (see Table D-1 of Reference 440.605-1). Figure 5.4-18 will be revised to exclude the step change and the scales will be adjusted to expand the remainder of the plot. The text on page 5.4-2 for Test 240 will also be revised to indicate the failure of PE5W during the test. These revisions will be included in Revision 2 of Reference 440.605-2.

References:

440.605-1 WCAP-14324, Revision 1, "Final Data Report for ADS Phase B1 Tests", Westinghouse Electric Corp., 1997.

440.605-2 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.606

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The Westinghouse response to RAI 440.440 states that, "thermal stratification effects in the CMT are not identified as a specific thermal-hydraulic phenomena on the final small break LOCA PIRT chart." However, thermal stratification effects in the CMT are included as high-ranked phenomena on both the Westinghouse and the NRC PIRT charts. Please explain this difference. The RAI also requested that Westinghouse provide plots of the fluid driving heads calculated by NOTRUMP for each side of the CMT loop. Westinghouse responded that the requested plots would be provided in the final V&V report. The requested plots were not provided in the final V&V report.

Response:

The statement made in response to RAI 440.440 stating "The thermal stratification effects in the CMT are not identified as a specific thermal-hydraulic phenomena on the final small-break LOCA PIRT chart, given as Table 4 in the response to RAI 440.325" is in error. Thermal stratification is indeed identified as a highly ranked item in the final Westinghouse (Process Identification and Ranking Table) PIRT table, (Reference 440.606-1 Section 1.3) for the natural circulation and ADS blowdown phases of the Small Break Loss Of Coolant Accident (SBLOCA). It is not considered a highly ranked item during the initial transient blowdown phase however.

The original RAI was focused on the Core Makeup Tank Test simulations. The final Core Makeup Tank Test results, found in the NOTRUMP Final Validation Report (Reference 440.606-1) Section 6, state the following conclusions:

1) "NOTRUMP provides reasonably good agreement for the CMT drain flow for the 500-series tests where the CMT could circulate and heat up the volume of CMT water corresponding to 20-percent and 50-percent levels measured from the top of the CMT. As the CMT continues to heat completely, the NOTRUMP comparisons show less agreement with the data trends, particularly at the end of the test."

2) "The most important quantity is the time-averaged flow, which is delivered from the CMT to the steam/water reservoir... The average CMT circulating flow comparison agree well between the NOTRUMP calculations and the test data. In most cases, the calculated circulating flow is within the uncertainty of the flow measurement, indicating excellent agreement."

3) "The fluid temperature predicted by NOTRUMP indicates the presence of numerical diffusion so that a sharp thermal gradient is not predicted for the CMT 500-series tests. Since the circulating flow agree well between NOTRUMP and the test data, it is concluded that this level of accuracy is acceptable for the CMT fluid temperature distribution, and coarse noding such as that used in NOTRUMP is adequate to capture the thermal effects."

4) "The analysis of the 300-series tests indicates that the NOTRUMP code will model and capture thermal-hydraulic behavior for situations in which steam enters the top of the CMT. There is rapid condensation and mixing of the initially subcooled CMT liquid with the steam as it enters the CMT through the steam diffuser

AP600

at the top of the tank. The rapid condensation process continues until a liquid layer is formed at the top of the CMT, which is near the saturation temperature. At that time, the rapid condensation stops, and the CMT drains freely. NOTRUMP predicts the thermal-hydraulic effects observed in the test. the code prediction of when the rapid draining of the tank would begin shows scatter, but is conservative, i.e., longer, than the tests."

The results in Section 6 indicate that the recirculation and draining rates are both well predicted. Since the overall driving head must be correctly predicted to achieve this result (loss coefficients used are based on data and are not adjusted), it was concluded that the driving heads were well predicted and thus the specified plots were not considered necessary. In addition, the noding sensitivity study provided in Reference 440.606-2 indicated little impact on recirculation rates as a result of more detailed noding and support the judgment that these plots are unnecessary.

Of the facility specific transients simulated with the NOTRUMP code, the SPES 1 Inch Cold Leg Break (Test S00401) and OSU 0.5 Inch Cold Leg Break (Test SB23) exhibit extended recirculation times under which thermal stratification effects can be considered important. The SPES 2 Inch Cold Leg Break (Test S00303) also exhibits the symptoms associated with the lack of a thermal stratification model however, to a much lesser extent. These cases would benefit from the use of a more detailed model (20 equal nodes), as utilized in Reference 440.606-2. The results indicated improved thermal stratification performance although numerical diffusion was not completely eliminated. However, the revised noding results indicated negligible impact on predicted CMT recirculation rates. The base coarse NOTRUMP model results are considered conservative since they will result in lower core inlet sub-cooling and hence higher core steam generation and lower core mixture levels.

References

440.606-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

440.606-2 Westinghouse Response to NRC Request for Additional Information RAI 440.339, Letter NSD-NRC-97-5149, May 23, 1997.

SSAR Revision: NONE

Question 440.607

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

None of the NOTRUMP calculations (CMT test, SPES, nor OSU) predict the CMT temperature distribution observed in the test data. In the integral facility simulations this has caused delays in the start of ADS-1 as well as overly warm fluid being injected from the CMTs. It might be easier to develop a thermal stratification model for the CMTs rather than explain the discrepancies. In any case, this difficulty needs to be discussed in greater depth.

Response:

The NOTRUMP CMT model behavior is discussed in detail in the response to RAI 440.599. In that response, it is concluded that the lack of a CMT thermal stratification model in NOTRUMP and the coarse noding used (with the NOTRUMP 4-node CMT model) lead to significant differences in the CMT outlet temperature for small break transients, but that the continued use of the 4-node CMT model is acceptable because its effect on the transients is conservative (high core void fraction, delayed ADS). These conclusions are supported by the NOTRUMP CMT noding study which is documented in Reference 440.607-1.

References:

440.607-1. Westinghouse Response to NRC Request for Additional Information RAI 440.339, Letter NSD-NRC-97-5149, May 23, 1997.

SSAR Revision: NONE

Question 440.608

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

It appears that the NOTRUMP model of the SPES facility may underestimate the ambient losses and overestimate the heat transfer between the primary and the secondary. This should be discussed in more detail.

Response:

The modeling methodology utilized to simulate the ambient heat losses for the SPES-2 facility was to base the heat losses on information from the pre-operational test data for primary and secondary system components. These heat losses are lumped into heat loss circuits with primary systems being modeled as one circuit and each steam generator comprising a separate heat loss circuit. As such, three separate heat loss circuits are modeled by the NOTRUMP code for the SPES-2 facility.

Each heat loss circuit is comprised of external heat links which are connected to metal nodes modeled by NOTRUMP. Reference 440.608-1, Section 7.2 contains the information regarding the external heat loss links and affected components. The user provides each heat loss circuit modeled with a total desired heat loss. Transient heat losses are then calculated by the NOTRUMP model based on the changes in metal node conditions with a fixed external boundary heat transfer coefficient, heat transfer area, and heat sink temperature on a component by component basis. No attempt is made to model a transient external heat transfer coefficient due to insufficient available information. The ambient heat losses are subsequently determined as a result of calculated changes in the NOTRUMP metal node temperatures which are driven by the internal heat links and transient specific heat link heat transfer coefficients and primary conditions.

As stated in the response to RAI 440.613, the NOTRUMP steam generator heat transfer modeling is accurate for the range of conditions observed during the test simulations as well as the AP600 plant itself. As such, the primary to secondary (or secondary to primary) heat transfer is predicted accurately for the conditions observed.

References

440.608-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.609

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The Westinghouse response to RAI 440.489 indicates that nodalization studies would be performed to assess ways of improving PRHR heat transfer and the results would be presented in the final V&V report. The final V&V report did not document the results of any such nodalization studies and the PRHR heat transfer is found to be persistently underestimated by NOTRUMP when compared to the data from the SPES and OSU test facilities. Can these problems be fixed merely with a different nodalization or do they indicate an intrinsic deficiency in the NOTRUMP code? The Westinghouse response to RAI 440.513 indicated that the additional PRHR modeling issues raised in that RAI would be resolved in the final V&V report. These issues remain unresolved.

Response:

This RAI is addressed in the PRHR Noding Study section of the response to RAI 440.339. All RAI responses will be included in an Appendix in Revision 2 of Reference 440.609-1.

References:

440.609-1 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

SSAR Revision: NONE

Question 440.610

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The Westinghouse response to RAI 440.504 points out that using a check valve connected between ADS 1-3 line and atmospheric pressure to represent the vacuum breaker was ineffective. A more accurate representation of the elevation changes in the ADS 1-3 line would have made the vacuum breaker model effective. Perhaps a more accurate representation would be useful to resolve other problems as well. The OSU and SPES models of the pressurizer and ADS 1-3 do not predict as much pressurizer refill during ADS 1-3 flow as is observed in the tests and the model of the OSU pressurizer drains too quickly once ADS 4 begins to flow. These problems might be fixed by merely improving the NOTRUMP input.

Response:

The lack of a vacuum breaker model is not the reason for the difficulty NOTRUMP has in predicting the refill of the pressurizer. However, improved modeling in the pressurizer and surge line may help improve the prediction of the refill process. The analysis below of the 2"CL break examines the reason why the pressurizer level is underpredicted in nearly all the tests for both SPES and OSU. In addition to the figures in this response, reference is also made to figures from the NOTRUMP FVR (reference 440.610-1), and the Test Analysis Report (reference 440.610-2). The referenced figures are enclosed after the new figures, with the original figure numbers retained.

1. SPES 2"CL break

Evidence from test data (refer to Section 3.2 of reference 440.610-2).

Just prior to ADS 1-3 actuation at about [ ]^{a,b,c} seconds, the following conditions exist in the system:

a) The pressurizer pressure is [ ]^{a,b,c} psia (Figure 3.2-3), the pressurizer is empty (Figure 3.2-34), and the CMTs are draining (Figure 3.2-7).

b) The core exit void fraction is about [ ]^{a,b,c} percent (Figure 3.2-61). The upper plenum average void fraction is consistent with the core exit conditions (Figure 440.610-1).

c) The collapsed liquid level in the steam generator tubes (including the inlet plenum) is about 5 feet and is decreasing slowly (Figure 3.2-29). At the time that ADS is actuated, therefore, the tubes have not fully drained. Figure 3.2-64 shows the collapsed level (fractional) in the vertical portion of the hot leg (the levels in loop A are higher because the PRHR draws vapor from the hot leg). At this time, the mixture level is in the tubes. Therefore, the level in the hot leg actually reflects an average void fraction of about [ ]^{a,b,c} percent in the hot leg. In loop B the average void fraction is about [ ]^{a,b,c} percent, consistent with the upper plenum conditions. The total mass in the two hot legs including the steam generator inlet plenums is about [ ]^{a,b,c} lbm (Figure 3.2-63), and in the SG tubes is about [ ]^{a,b,c} lbm (Figure 3.2-30). In the SPES-2 test facility, about [ ]^{a,b,c} percent of the hot leg volume is above the surge line connection.

When ADS 1-3 opens, the following events occur in three distinct phases: Level swell phase ([ ]^{a,b,c} seconds), CCFL phase ([ ]^{a,b,c} seconds), and draining phase ([ ]^{a,b,c} seconds). These phases are described further below:

Level swell phase ([ ]^{a,b,c} seconds):

a) The pressurizer refills to about [ ]^{a,b,c} lbm (Figure 3.2-34). The core exit void fraction (Figure 3.2-61) and upper plenum average void fraction (Figure 440.610-1) fall to zero. This means that from about [ ]^{a,b,c} to about [ ]^{a,b,c} seconds, there is no steam generation in the core as a result of subcooled water being pulled into the core (Figure 3.2-2 shows that the core exit fluid is subcooled during this period).

b) The steam generator tubes drain (Figure 3.2-29), and the level in the hot leg falls to approximately the level of the pressurizer surge line connection to the hot leg (Figure 3.2-64).

c) During the period when the core is water solid, the flow into the pressurizer is nearly all water. This can be seen in Figure 440.610-2, which shows the average void fraction in the surge line, and the average void fraction in the bottom 57 inches of the pressurizer. Both regions are nearly full of water. Based on Figures 3.2-30 and 3.2-63, all the mass in the SG tubes ([ ]^{a,b,c} lbm), and about [ ]^{a,b,c} lbm in the hot legs flows into the pressurizer, resulting in a total of about [ ]^{a,b,c} lbm. The remaining mass of about [ ]^{a,b,c} lbm in the pressurizer comes from the upper plenum and core.

d) The void fraction near the top of the pressurizer falls to about [ ]^{a,b,c} percent (Figure 440.610-3). This is evidence that the mixture level reached the top of the pressurizer in the test. At about [ ]^{a,b,c} seconds, the void fraction increases, indicating that the mixture level has dropped below the top of the pressurizer. However, significant liquid flow is still measured out of ADS 1-3. There is a distinct distribution of void fraction in the mixture. This will happen if the vapor flow rate is increasing axially. Significant amounts of stored energy are being released from the initially hot pressurizer as the system cools from [ ]^{a,b,c}. About [ ]^{a,b,c} lbm of steam will be generated over 500 seconds, for an average flow of [ ]^{a,b,c} lbm/s. It is concluded that much of the vapor flowing into the ADS 1-3 line during this time is due to vapor generated in the pressurizer.

CCFL phase ([ ]^{a,b,c} seconds):

a) As the system continues to depressurize, subcooling is lost in the core at about [ ]^{a,b,c} seconds (Figure 3.2-2), and the core once again begins to generate steam (Figure 3.2-61). There is a second "level swell" as the energy previously absorbed by cold water now generates steam. The mass in the pressurizer increases for a second time (Figure 3.2-34). The core exit void fraction increases to about [ ]^{a,b,c} percent (Figure 3.2-61).

b) The level in the hot leg begins to fall below the level of the surge line (Figure 3.2-64), and vapor flows into the surge line, increasing its void fraction (Figure 440.610-2). There is evidence that CCFL conditions exist in the surge line. This can be seen in Figure 440.610-2, where the surge line void fraction is higher than the void fraction at the bottom of the pressurizer.

Drain phase (after [ ]a,b,c seconds):

a) The ADS 4 valve opens at about [ ]a,b,c seconds. About [ ]a,b,c seconds later, the pressurizer rapidly drains, while the surge line partly fills with water. Most of the steam generated in the core begins to flow out of ADS 4 (Figure 3.2-68), and CCFL conditions in the surge line can no longer be maintained. The IRWST flow also plays a role, increasing the core inlet subcooling and reducing steam generation.

NOTRUMP prediction (Refer to Section 7.3 of Reference 440.610-1):

Just prior to ADS 1-3 actuation at about 1200 seconds, the following conditions exist:

a) The pressure is about 700 psia (Figure 7.3.1-2), the pressurizer is empty (Figure 7.3.1-3), and the CMTs are draining (Figures 7.3.1-4,5).

b) The core average void fraction is about 20 percent (Figure 7.3.1-17) and in the upper plenum it is about 30 percent (Figure 440.610-1). Since the ADS valves open later, the void fractions are slightly lower than the data. The upper plenum void fraction is about 30 percent (Figure 440.610-1), and the mixture level is at the hot leg elevation (Figure 440.610-5).

c) The mixture level in the steam generator tubes is about 16 feet relative to the bottom of the tubes (Figure 440.610-5). The void fraction in the region of the hot leg connected to the surge line (fluid node 11 in Figure 7.2-2, Reference 440.610-1) is about 40 percent (Figure 440.610-6). There is therefore less mass above the surge line inlet in the prediction than in the test (about 60 lbm compared to [ ]a,b,c lbm).

Level swell phase (1200 - 1600 seconds):

a) The mixture level in the pressurizer increases to the top of the pressurizer (Figure 440.610-5). The core average void fraction (Figure 7.3.1-17) and upper plenum (Figure 440.610-4) both drop to zero, same as in the test. The pressurizer fills to about 50 lbm.

b) The mixture level in the steam generator tubes and hot leg falls to the surge line inlet elevation at about 1300 seconds (Figure 440.610-5).

c) During the short period when the mixture level is above the surge line (from 1220 to about 1300 seconds), the pressurizer mixture void fraction follows that of the mixture in the hot leg (Figure 440.610-6). When the hot leg mixture level falls below the surge line, the pressurizer void fraction increases because the steam flow into the surge line increases. Figures 440.610-7 and 8 plot the liquid and vapor flows into the pressurizer surge line (78) and at the top of the inclined hot leg (211). Figure 440.610-7 shows that the liquid flow from the regions above the surge line (SG tubes and inlet plenum) is zero (flow link 211) after about 1300 seconds, indicating that there is not much liquid stored above the surge line in the NOTRUMP prediction. Figure 440.610-8 shows that there is always vapor flow into the surge line in the NOTRUMP prediction. Unlike the test, therefore, the flow into the pressurizer is not all water during the level swell phase.

d) The void fraction in the mixture in the pressurizer is about 80 percent (Figure 440.610-6). Since there is only one fluid node, a void fraction distribution is not predicted. Figures 440.610-9 and 10 plot the inlet and outlet vapor and liquid flows in the pressurizer. NOTRUMP also predicts a higher vapor outflow due to the release of energy from the metal and flashing of the mixture. The liquid flows indicate that as much liquid is flowing out as is flowing in. The mass which can be stored in the pressurizer is therefore controlled by the void fraction predicted by the drift flux model for the given vapor flow which based on the previous discussion, is higher than in the test.

CCFL phase (1600-2300 seconds):

a) At about 1800 seconds, vapor is once again generated in the core, causing the upper plenum void fraction to increase (Figure 440.610-1).

b) The void fraction in the hot leg begins to increase (Figure 440.610-6), consistent with the increase in the upper plenum void fraction, which is similar to the collapsed level decrease in the test (Figure 3.2-64).

c) Liquid continues to flow into the surge line (Figure 440.610-7). Therefore, CCFL conditions are also predicted by NOTRUMP during this time.

Drain phase (after 2300 seconds):

a) When ADS 4 opens at 2375 seconds, the pressurizer is predicted to drain consistent with the test.

Assessment of NOTRUMP prediction of SPES test

The pressurizer refill is underpredicted by NOTRUMP primarily because the liquid mass in the upper regions of the system (hot legs, steam generator) is underpredicted at the time of ADS actuation. This underprediction is the result of the delay in CMT draining and ADS actuation in NOTRUMP, which allows additional draining of the steam generator and hot leg compared with the test. A review of the other SPES tests indicates that in all the tests, the mass stored above the surge line at the time of ADS 1-3 actuation is larger in the test than predicted by NOTRUMP. Because the initial refill is underpredicted, the time at which the pressurizer drains is also underpredicted. The implications of this on the AP600 analysis are discussed at the end of this response.

2. OSU 2" CL Break

Evidence from test data (refer to Section 5.2.2 of Reference 440.610-3):

Just prior to the time that ADS 1-3 opens at about [ ]^{a,b,c} seconds, the following conditions exist in the system:

a) The pressurizer is empty (Figure 5.2.2-35), and the CMTs are draining (Figures 5.2.2-8).

b) The core collapsed liquid level is about [ ]^{a,b,c} inches below the top of the rods (Figure 5.2.2-45). This implies an average void fraction in the core of about [ ]^{a,b,c} percent (Figure 8.3.1-17). In the upper plenum the collapsed liquid level is [ ]^{a,b,c} inches (Figure 5.2.2-49) which is about the level of the bottom of the hot leg ([ ]^{a,b,c} inches).

c) When ADS is actuated, the tubes have fully drained (Figure 5.2.2-32), the steam generator inlet plenum has partially drained with about [ ]^{a,b,c} lbm remaining in steam generator 2 (on the PRHR loop) and about [ ]^{a,b,c} lbm remaining in the other steam generator (Figure 5.2.2-31). The hot legs are full with about [ ]^{a,b,c} lbm of water each (Figure 5.2.2-58). In the OSU test facility, about [ ]^{a,b,c} percent of the volume of the hot leg is above the surge line connection.

When ADS 1-3 opens, the following events occur in three distinct phases: Level swell phase ([ ]^{a,b,c} seconds), CCFL phase ([ ]^{a,b,c} seconds), and draining phase ([ ]^{a,b,c} seconds). These phases are described further below:

Level swell phase ([ ]^{a,b,c} seconds):

a) The pressurizer and surge line refill to about [ ]^{a,b,c} lbm (Figure 5.2.2-34 and 35). Liquid fills the core region (Figure 5.2.2-45), and the core outlet fluid becomes subcooled (Figure 5.2.2-3), indicating that steam generation in the core has been suppressed. The pressurizer receives most of its water from the vessel, since there is little mass (only about [ ]^{a,b,c} lbm) stored above the surge line connection. In contrast to SPES, therefore, the downcomer level drops when ADS 1-3 actuates (Figure 5.2.2-42).

b) The steam generator plenum drains and the inclined portion of hot leg 2 (connected to the surge line) partially voids (Figure 440.610-11a), and the other hot leg voids significantly (Figure 440.610-11b). The high vapor flow into the surge line pulls water from the vessel upper plenum into hot leg 2, while the other hot leg drains into the upper plenum. Water is held up in the inclined portion of hot leg 2.

c) During the first 250 seconds after ADS, the surge line and pressurizer average void fractions are similar (Figure 440.610-12). This is indicative of two phase cocurrent flow through the surge line into the pressurizer. Since the core fluid is subcooled during most of this portion of the transient, most of the steam generation is due to evaporation of the top layer of saturated water, originally in the core and upper plenum, which has now moved into the pressurizer. Figure 440.610-13 shows the vapor and liquid flow out of the pressurizer during this period. The high liquid flow indicates that the mixture level is at the top of the pressurizer. Metal heat release is not expected to be a significant contributor to additional steam generation in this test, due to low initial temperatures and facility scale.

CCFL phase ([ ]^{a,b,c} seconds):

a) At about [ ]^{a,b,c} seconds, the system pressure has dropped such that the core fluid is no longer subcooled and vapor is once again generated in the core (Figures 5.2.2-3 and 5.2.2-45).

b) When vapor generation resumes in the core, the system depressurization rate is reduced, and in fact the pressure increases slightly (Figure 8.3.1-2). Although there is no vapor flow measured in any of the vent paths (Figure 440.610-14), it is likely that there is still some vapor flow which is not measured (the flow meters were designed to measure the high initial vapor flow during depressurization, not the lower flow generated by the simulated decay heat). At this time, the surge line void fraction increases (Figure 440.610-12), while the pressurizer void fraction remains low. This indicates that there is vapor flow into the pressurizer, and CCFL conditions exist in the surge line. This causes the liquid flow out of the ADS 1-3 valves to increase (Figure 440.610-13).

c) At [ ][a,b,c] seconds, the ADS 4 valves open. The vapor generated in the core now has three main escape paths, with smaller paths through the break and the upper head. The liquid flow out of ADS 1-3 is reduced to zero (Figure 440.610-15), indicating that the mixture level in the pressurizer is below the top of the pressurizer. The collapsed liquid level in the pressurizer also drops at this time (Figure 5.2.2-34). The void fraction in the surge line is reduced (Figure 440.610-16), indicating that the pressurizer is draining. However, at [ ][a,b,c] seconds the drain rate becomes much lower than what would be expected if the water were draining by gravity or by volume displacement of water by vapor, with CCFL in the surge line. It is concluded that the drain rate is controlled by vapor flow in the surge line, even though the measurements do not indicate vapor flow. Based on the ADS flow areas, it is estimated that [ ][a,b,c] percent of the generated steam will still flow through ADS 1-3 after ADS 4 has opened. As the core loses subcooling, the vapor flow becomes sufficient to produce CCFL conditions in the surge line. The estimated flow for OSU is higher than the value estimated for SPES [ ][a,b,c] and explains (along with the smaller facility height) the substantially longer time it takes for the OSU pressurizer to drain.

Drain phase ([ ][a,b,c] seconds):

a) Draining of the pressurizer is not completed until about [ ][a,b,c] seconds, when the steam generation rate in the core has again dropped to near zero. The surge line drains shortly after the pressurizer drains, then refills (Figure 440.610-16 shows both components approaching 100 percent void fraction at [ ][a,b,c] seconds).

In summary, the OSU test shows significant liquid accumulation in the pressurizer at ADS 1-3 actuation. Most of the liquid comes from the reactor vessel. The pressurizer drains slowly due to a prolonged CCFL period in the surge line.

<u>NOTRUMP predictions (refer to section 8 of Reference 440.610-1):</u>

Just prior to the time that ADS 1-3 opens at about 550 seconds, the following conditions exist in the system:

a) The pressurizer is empty (Figure 8.3.1-3, Reference 440.610-1), and the CMTs are draining.

b) The core collapsed liquid level is about 6 inches below the top of the rods (Figure 8.3.1-14). This implies an average void fraction in the core of about 15 percent (Figure 8.3.1-17), compared with [ ][a,b,c] percent for the test (this difference is due to lower subcooling in the lower plenum, as a result of lower PRHR heat transfer and higher temperature fluid from the CMT).

c) At the time that ADS is actuated, the tubes have fully drained (Figure 440.610-17), the steam generator inlet plenum has partially drained with about 14 lbm remaining in steam generator 2 (on the PRHR loop). The hot legs are full (Figure 440.610-17).

When ADS 1-3 opens, the following events occur in three distinct phases: Level swell phase (550 to 800 seconds), CCFL phase (800 to 1100 seconds), and draining phase (> 1100 seconds). These phases are described further below:

Level swell phase (550 - 800 seconds):

a) The pressurizer and surge line refill to about 290 lbm. The level in the inclined portion of the hot leg drops to the surge line elevation, and the mixture level reaches the top of the pressurizer (Figure 440.610-17). The collapsed liquid level fills the core region (Figure 8.3.1-14), but vapor generation in the core is not fully suppressed (Figure 440.610-21). Consequently, vapor is still available to flow into the pressurizer.

b) At about 650 seconds, the mixture level in the steam generator rises into the tubes, then begins to oscillate (Figure 440.610-17). This oscillation is driven by steam generation in the tubes, which are now hot due to primary depressurization (Figure 440.610-18). This steam generation pressurizes the system, pushing steam and water into the pressurizer. As the level drops out of the tubes, the steam generation is reduced, the system pressure drops, and both steam and liquid flow out of the pressurizer (Figures 440.610-19 and 20). This behavior persists until about 800 seconds, and contributes to additional vapor flowing into the pressurizer, and less liquid accumulation.

CCFL phase (800 - 1100 seconds):

From 800 seconds until ADS 4 opens at 1100 seconds, sufficient vapor generated in the core (Figure 440.610-21) flows into the pressurizer to prevent water from draining (no liquid downflow in Figure 440.610-20).

Drain phase (> 1100 seconds):

a) At 1114 seconds, the ADS 4 valves open. The vapor generated in the core now has three main escape paths, with smaller paths through the break and the upper head. The mixture level in the pressurizer begins to drop (Figure 440.610-22). The liquid flowrate at the surge line is intermittently downward (Figure 440.610-20), as less vapor flows into the surge line (Figure 440.610-20). The time at which the pressurizer and surge line both completely drain is 2000 seconds, [ ]^{a,b,c} than the test. Although the drain time for both the pressurizer and surge line is reasonably well predicted, the average predicted collapsed liquid level in the pressurizer is lower. In the test, the void fraction in the surge line is relatively high, about [ ]^{a,b,c} percent (Figure 440.610-16), indicating continued vapor flow through ADS 1-3 in the test (as supported by the fractional estimates given previously). In the NOTRUMP prediction, the pressurizer mixture void fraction approaches one (Figure 440.610-25), as does the vapor flow through ADS 1-3 (Figure 440.610-23).

The reason for the underprediction of vapor flow through ADS 1-3 in NOTRUMP is likely due to excess bypass of vapor through ADS 4-2, which is upstream of the surge line. Since NOTRUMP assumes stratified conditions in the hot legs at all times, the amount of vapor drawn through the branch line may be excessive when ADS 4 opens and vapor velocities become high.

b) At 1300 seconds, flow begins from the IRWST. NOTRUMP overpredicts the flow up to about 2000 seconds. This coincides with the time during which, in the test, the pressurizer continues to retain about [ ][a,b,c] feet of water (Figure 5.2.2-35) and the surge line retains about [ ][a,b,c] feet of water (Figure 5.2.2-38), for a total of [ ][a,b,c] feet. This translates to a pressure increase of about [ ][a,b,c] psi in the downcomer, relative to the case where the pressurizer is empty. Figure 440.610-26 shows that NOTRUMP underpredicts the pressure in the downcomer by about 1 psia as a result of the lower level in the pressurizer. This results in a higher IRWST flowrate as noted above.

Assessment of NOTRUMP prediction of OSU tests:

The NOTRUMP prediction reflects approximately what is observed in the test, except for the oscillations caused by steam generation in the steam generator tubes. The liquid refill of the pressurizer is underpredicted, due to the excess steam generated in both the core and the steam generator. The refill process is one primarily of volume replacement, where the vapor which flows out of the pressurizer is replaced by an equal volume of the mixture in the hot legs, upper plenum, and core. If that mixture is of a lower void fraction, the pressurizer mass will be higher.

This explanation is supported by several of the OSU tests simulated with NOTRUMP: the 0.5"cold leg break, the double ended DVI line break, and the inadvertent ADS. For these tests, the core average void fraction at ADS 1-3 actuation is predicted well by NOTRUMP (in the 0.5" cold leg case, Figure 8.3.2-17, the CMT fluid was forced to be lower to provide higher subcooling to the core, and in the DVI break and inadvertent ADS, Figures 8.3.6-17 and 8.3.7-17, there was no time for recirculation of the CMT fluid and subsequent heating to occur). Because the initial vapor content of the mixture is predicted well, so is the initial refill rate (Figures 8.3.2-3 and 8.3.7-3).

There is evidence in most of the tests that the water remaining in the pressurizer drains more rapidly in the NOTRUMP prediction than in the test as soon as ADS 4 is actuated. In all of the tests the reason is considered to be the same as that discussed for the 2"cold leg break: underprediction of the vapor flow out ADS 1-3 relative to ADS 4.

The underprediction of the collapsed liquid level in the pressurizer during the draining phase results in an overprediction of the IRWST flow rate for the period during which the pressurizer remains full in the test and empty in NOTRUMP. It is concluded that the low pressurizer liquid mass in NOTRUMP is a nonconservative feature of the NOTRUMP prediction, even though it is due partly to a conservatively high predicted vapor content in the core. This bias is addressed in the Revision 2 version of Section 1 of the NOTRUMP Final Validation Report.

References:

440.610-1 "NOTRUMP Final Validation Report for AP600", WCAP 14807, Revision 1, January 1997.

440.610-2 "AP600 SPES-2 Test Analysis Report", WCAP 14254, May 1995.

440.610-3 "AP600 Low Pressure Integral Systems Test at Oregon State University: Test Analysis Report", WCAP 14292, Revision 1, September 1995.

List of new figures for SPES:

List of new figures for OSU:

440.610-12. Average void fraction in surge line and pressurizer - data.

440.610-13. Liquid and vapor flow out of ADS 1-3 - data.

440.610-14. Flow meter vapor flow measurements

440.610-15. Liquid and vapor flow out of ADS 1-3 - data.

440.610-16. Average void fraction in surge line and pressurizer - data.

440.610-17. Mixture level in SG2 tube/plenum/vert. hot leg (13), horizontal hot leg (10), and pressurizer (9)- NOTRUMP.

440.610-18. SG2 primary and secondary pressures - NOTRUMP

440.610-19. Vapor flow in surge line - NOTRUMP

440.610-20. Liquid flow in surge line - NOTRUMP

440.610-21. Core outlet vapor flow - NOTRUMP and calculated from data

440.610-22. Mixture level in SG2 tube/plenum/vert. hot leg (13), horizontal hot leg (10), and pressurizer (9)- NOTRUMP.

440.610-23. Vapor flow through ADS 1-3 - NOTRUMP

440.610-24. Vapor flow through ADS 4 - NOTRUMP

440.610-25. Void fraction in pressurizer - NOTRUMP and data

440.610-26. Pressure at top of downcomer - NOTRUMP and data.

SSAR Revision: NONE

(a.b.c)

Figure 440.610-1

(a.b.c)

Figure 440.610-2

(a.b.c)

Figure 440.610-3

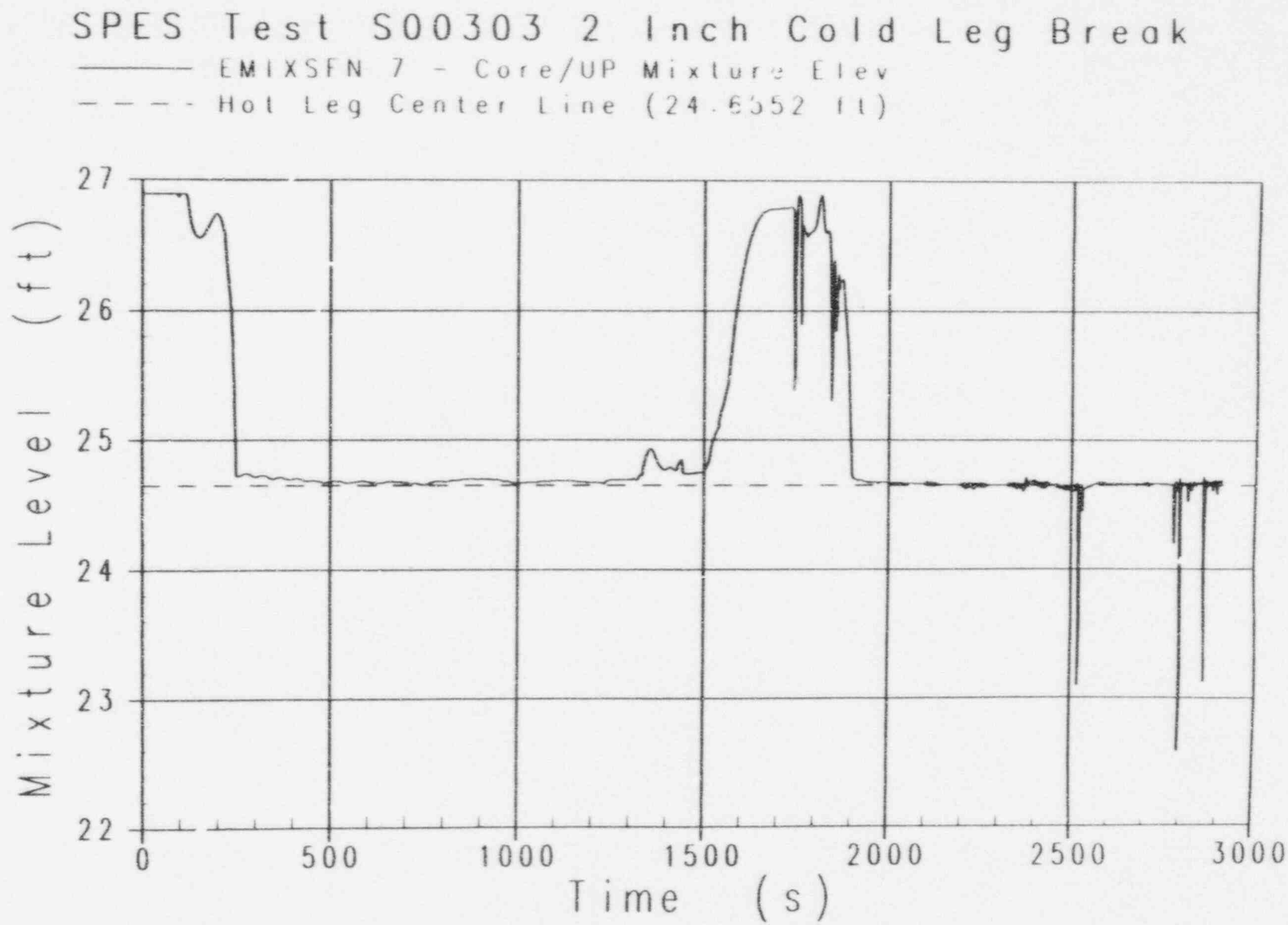

Figure 440.610-4

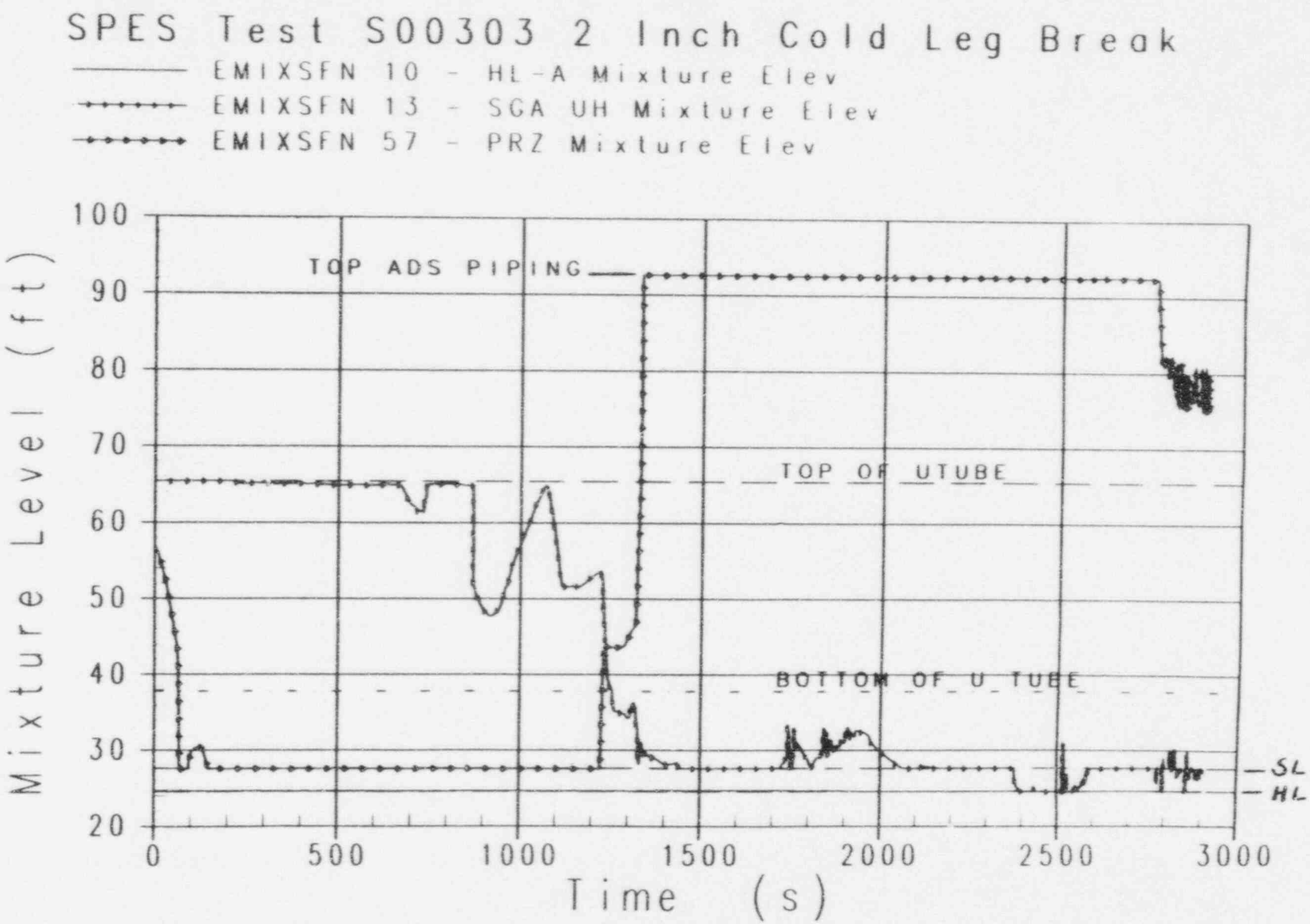

Figure 440.610-5

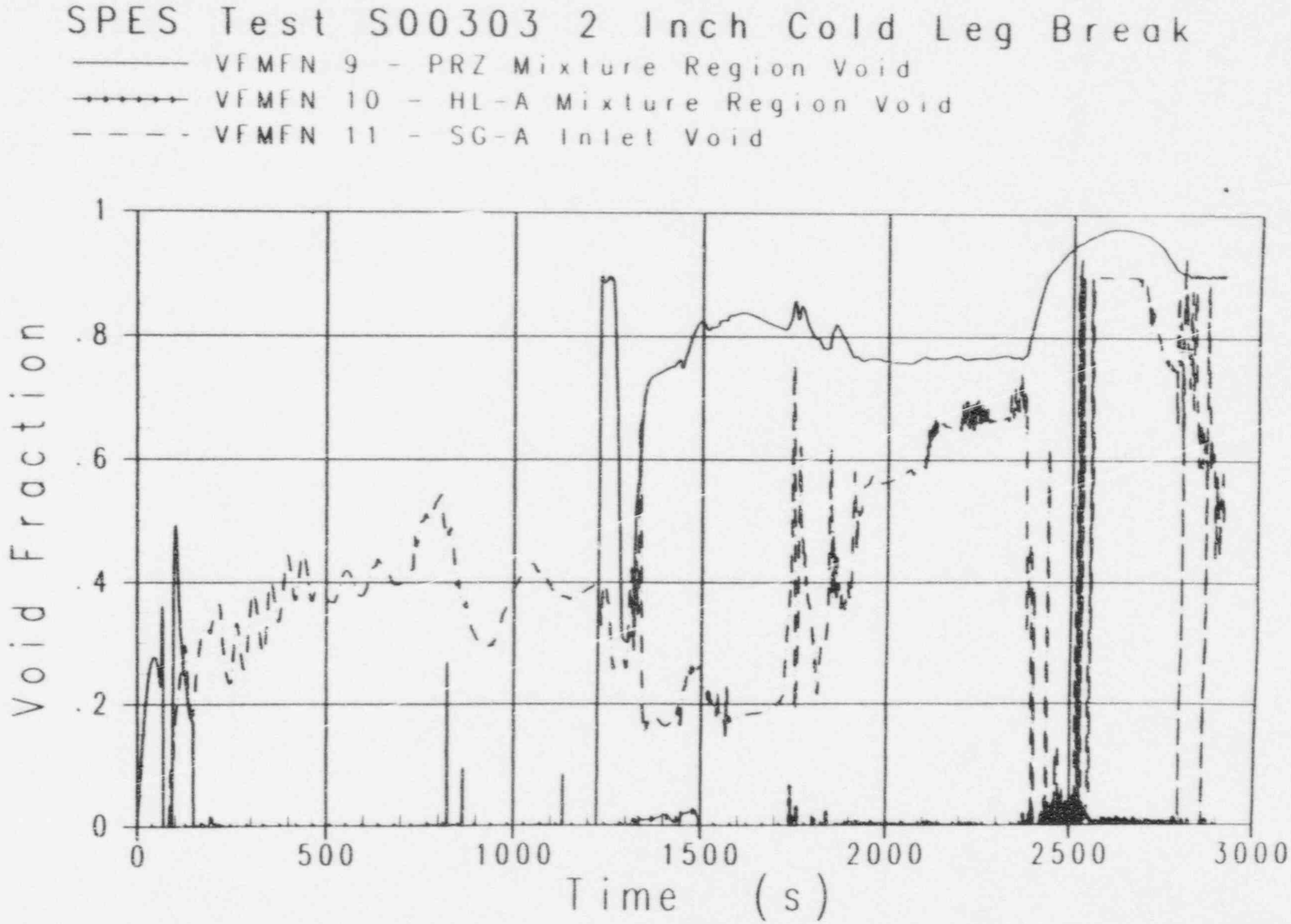

Figure 440.610-6

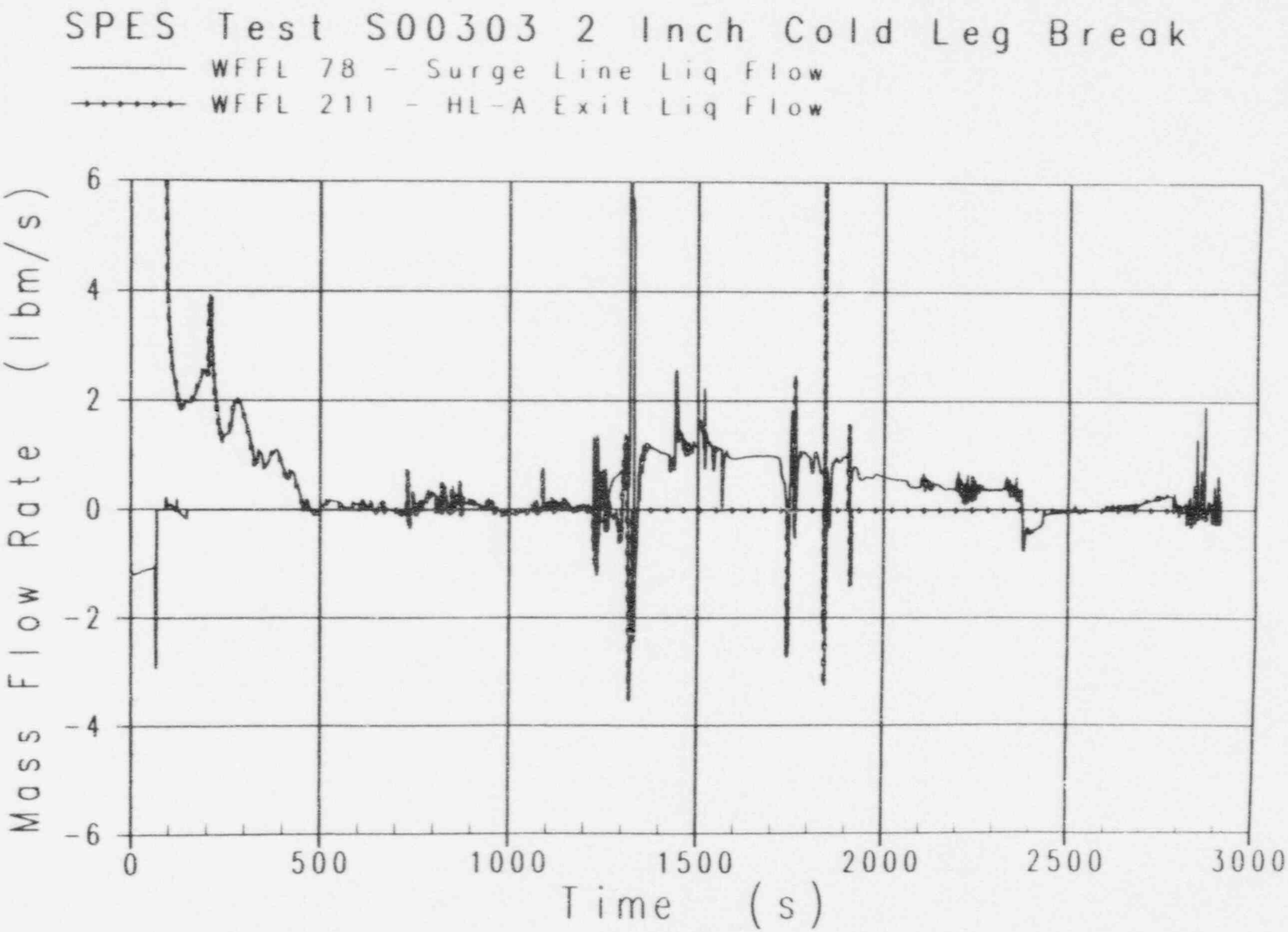

Figure 440.610-7

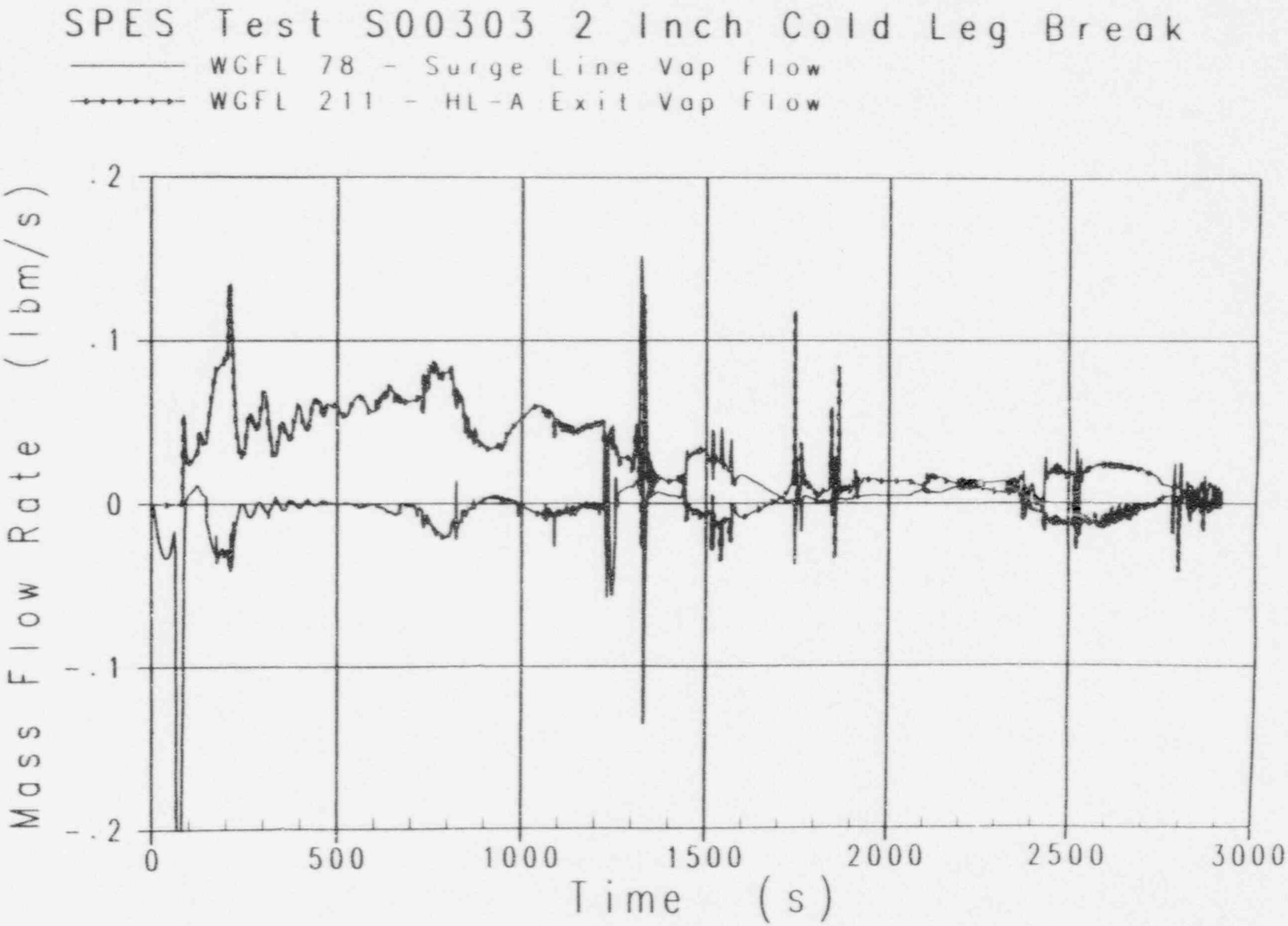

Figure 440.610-8

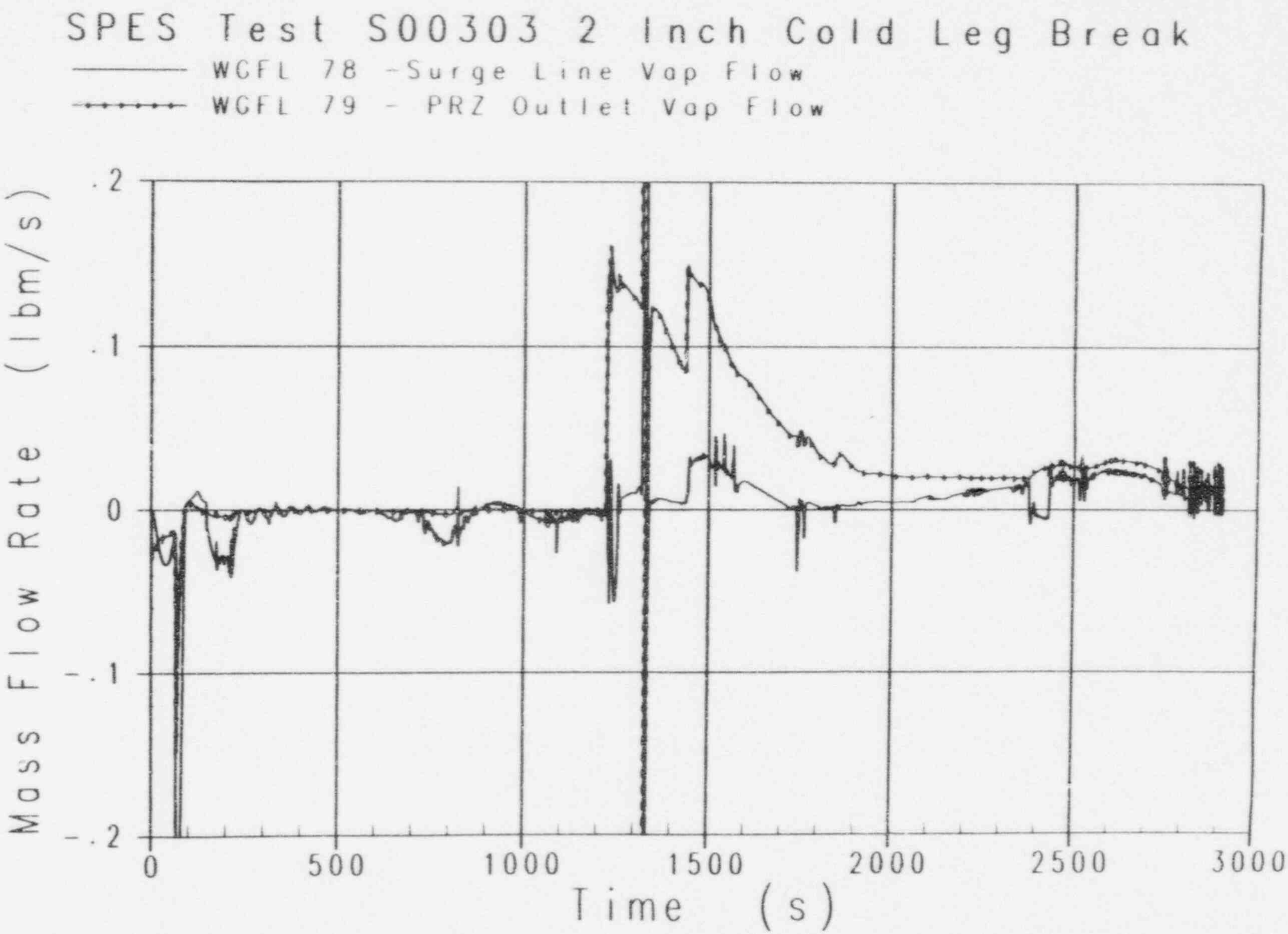

Figure 440.610-9

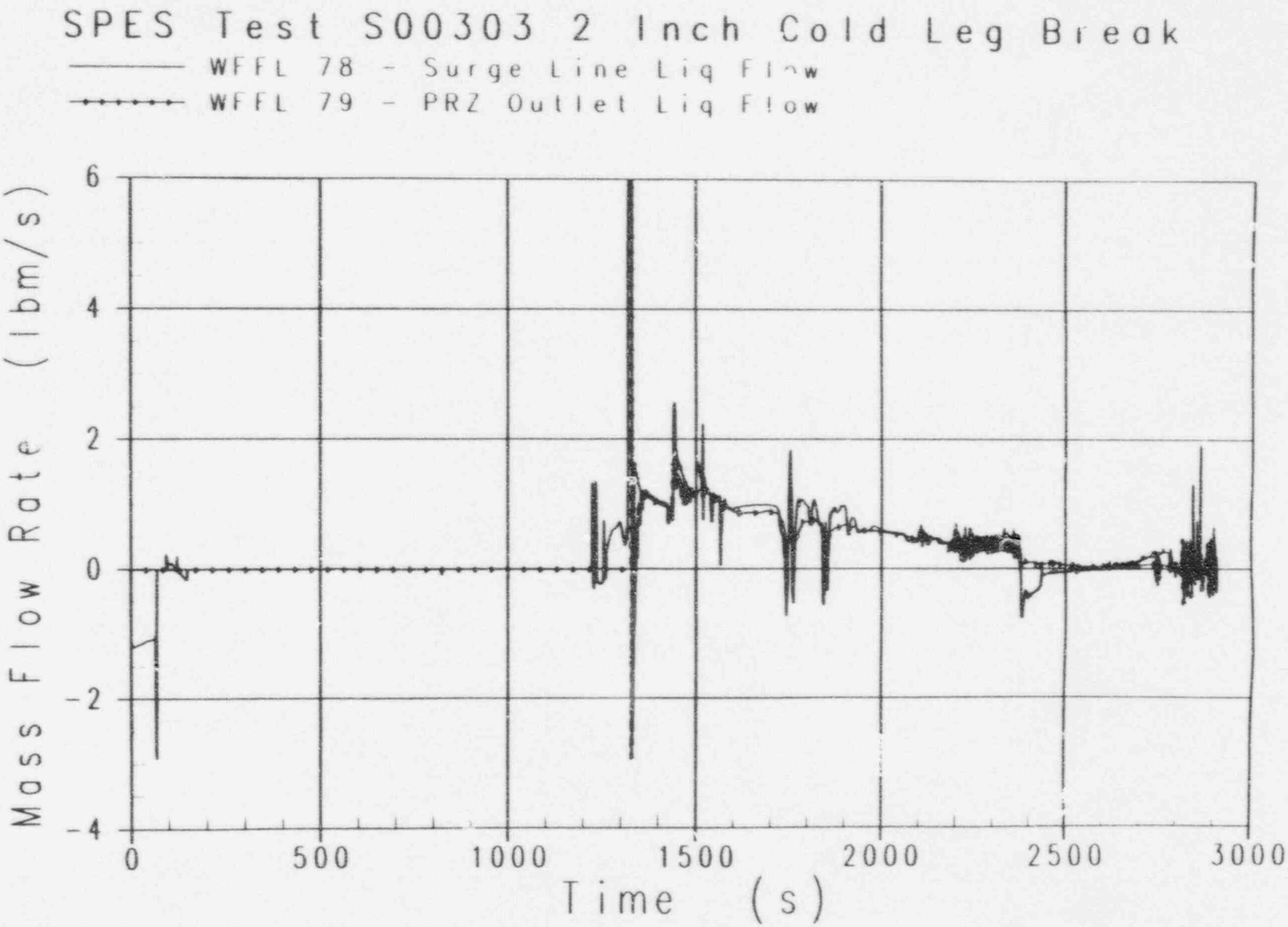

Figure 440.610-10

FIGURES FROM REFERENCE 1, SECTION 7

(a,b,c)

Figure 7.3.1- 2

(a,b,c)

Figure 7.3.1– 3

(a.b.c)

Figure 7.3.1- 4

(a,b,c)

Figure 7.3.1- 5

(a,b,c)

Figure 7.3.1-17

FIGURES FROM REFERENCE 2, SECTION 3.2

(a.b.c)

Figure 3.2- 2

Figure 3.2- 3

(a.b.c)

(a.b.c)

Figure 3.2- 7

(a,b,c)

Figure 3.2-28

Figure 3.2-29

(a.b.c)

(a.b.c)

Figure 3.2-30

(a,b,c)

Figure 3.2-34

(a,b,c)

Figure 3.2-61

(a,b,c)

Figure 3.2-63

(a.b.c)

Figure 3.2-64

Figure 3.2-68

(a.b.c)

(a.b.c)

Figure 440.610-11A

(a,b,c)

Figure 440.610-11B

(a,b,c)

Figure 440.610-12

(a,b,c)

Figure 440.610-13

(a,b,c)

Figure 440.610-14

(a,b,c)

Figure 440.610-15

(a,b,c)

Figure 440.610-16

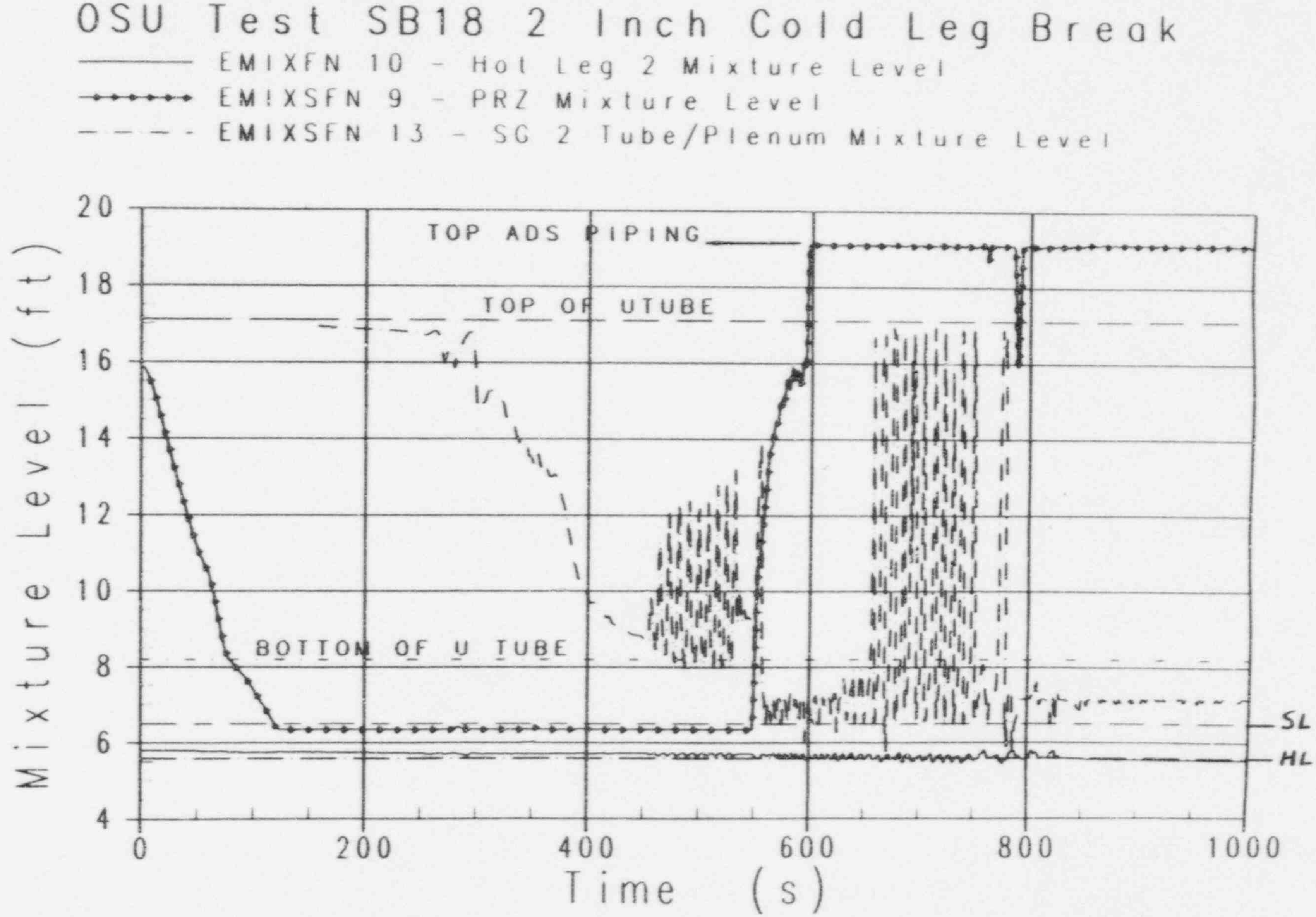

Figure 440.610-17

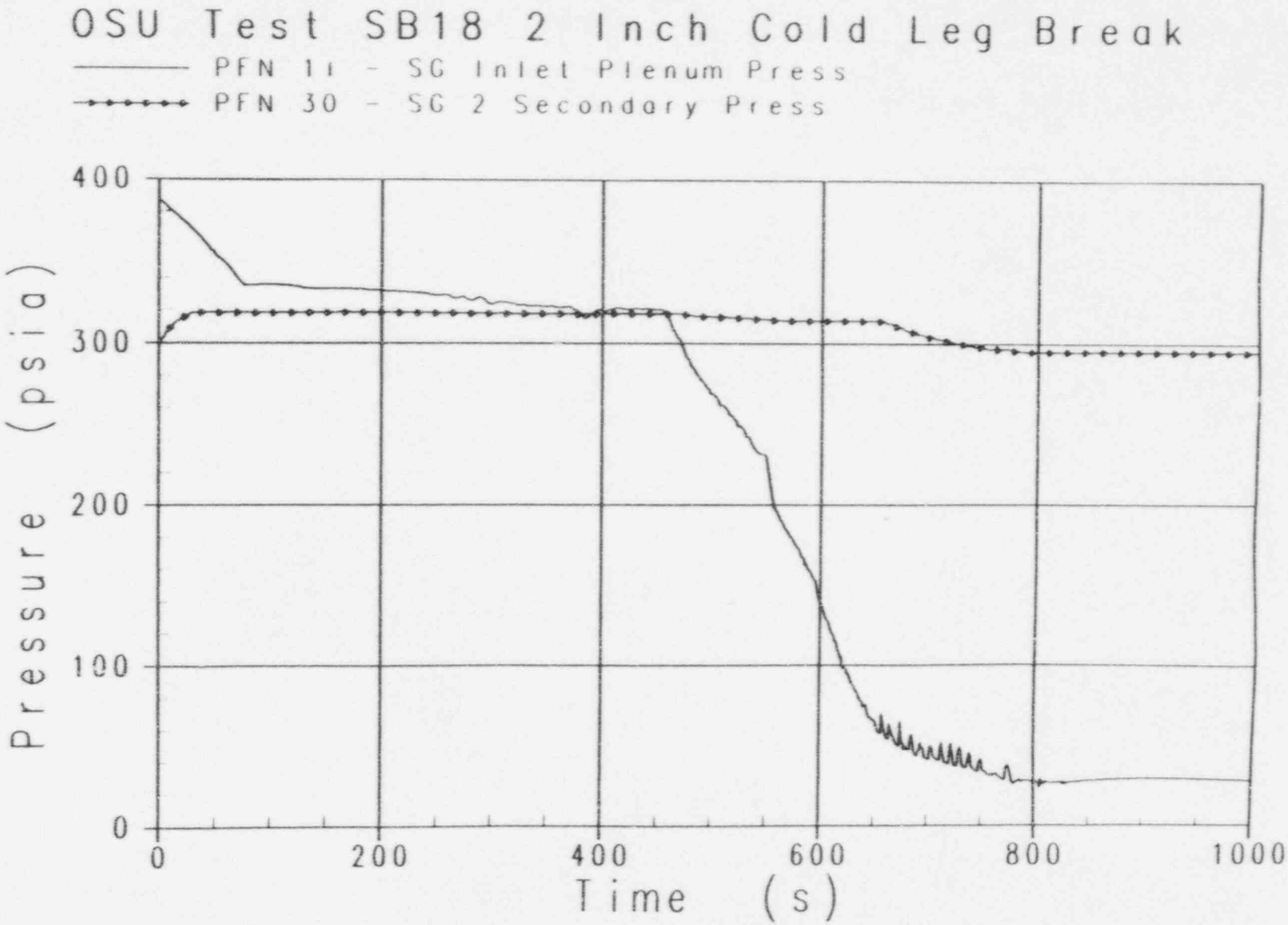

Figure 440.610-18

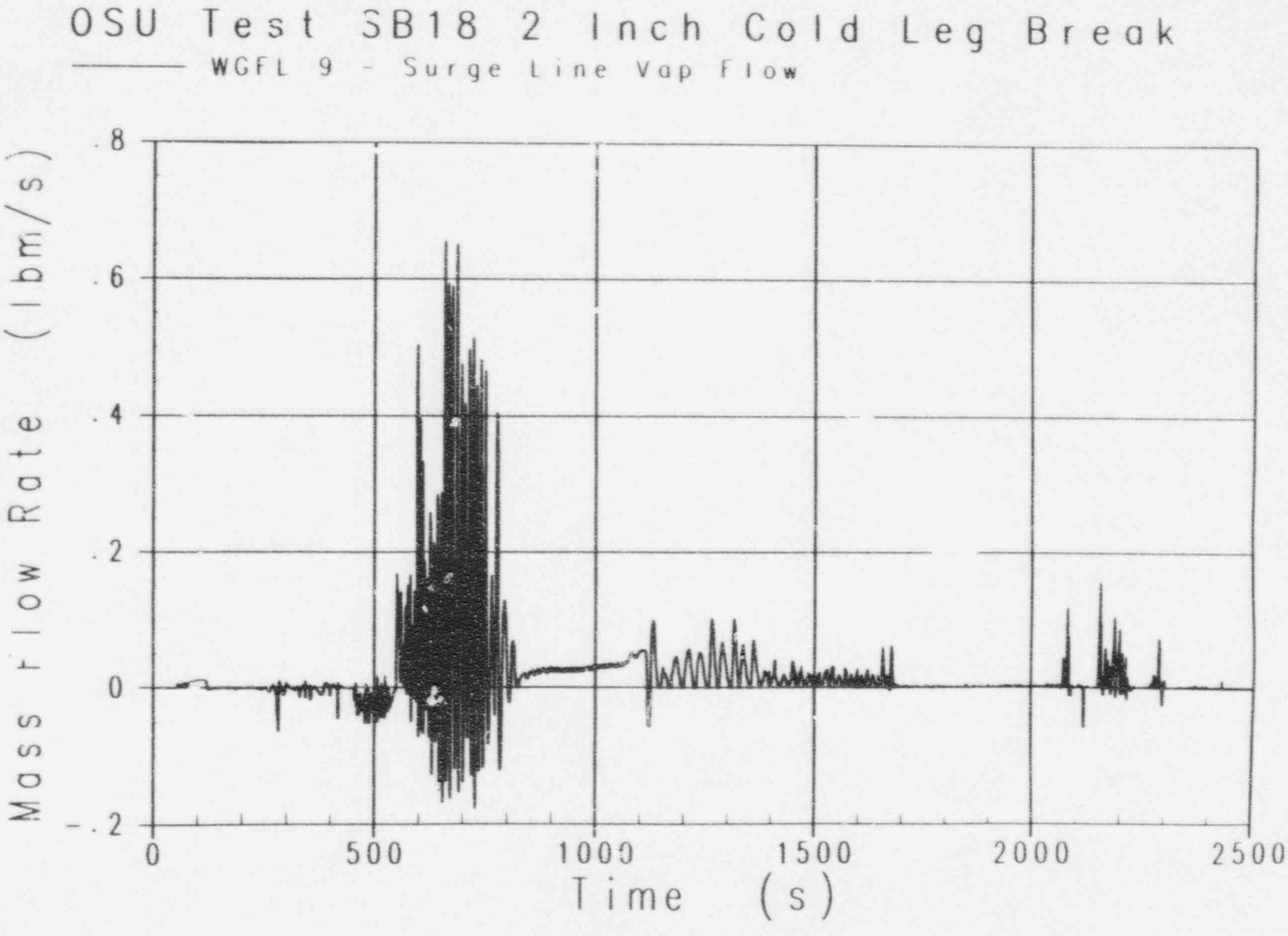

Figure 440.610-19

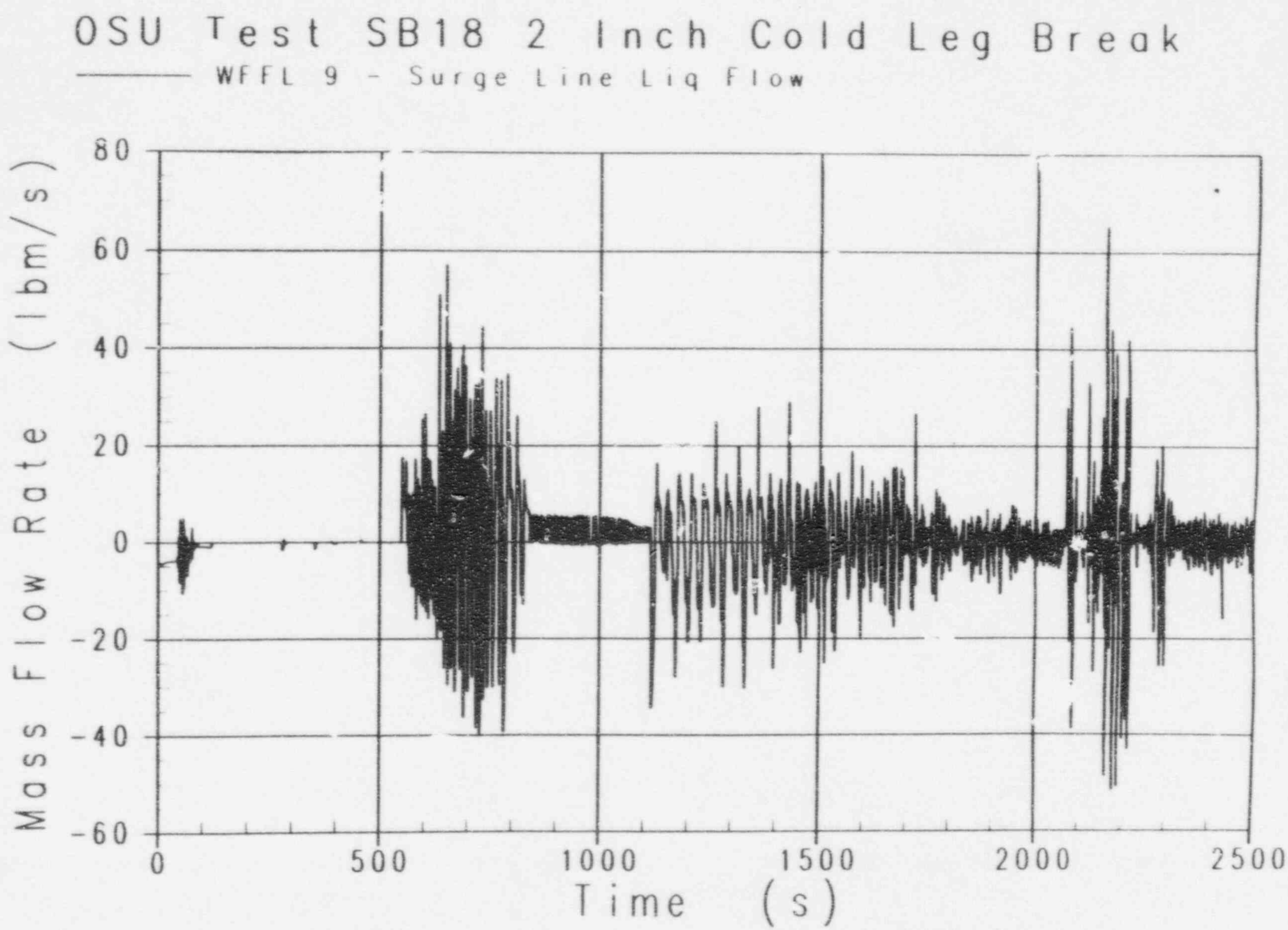

Figure 440.610-20

(a.b.c)

Figure 440.610-21

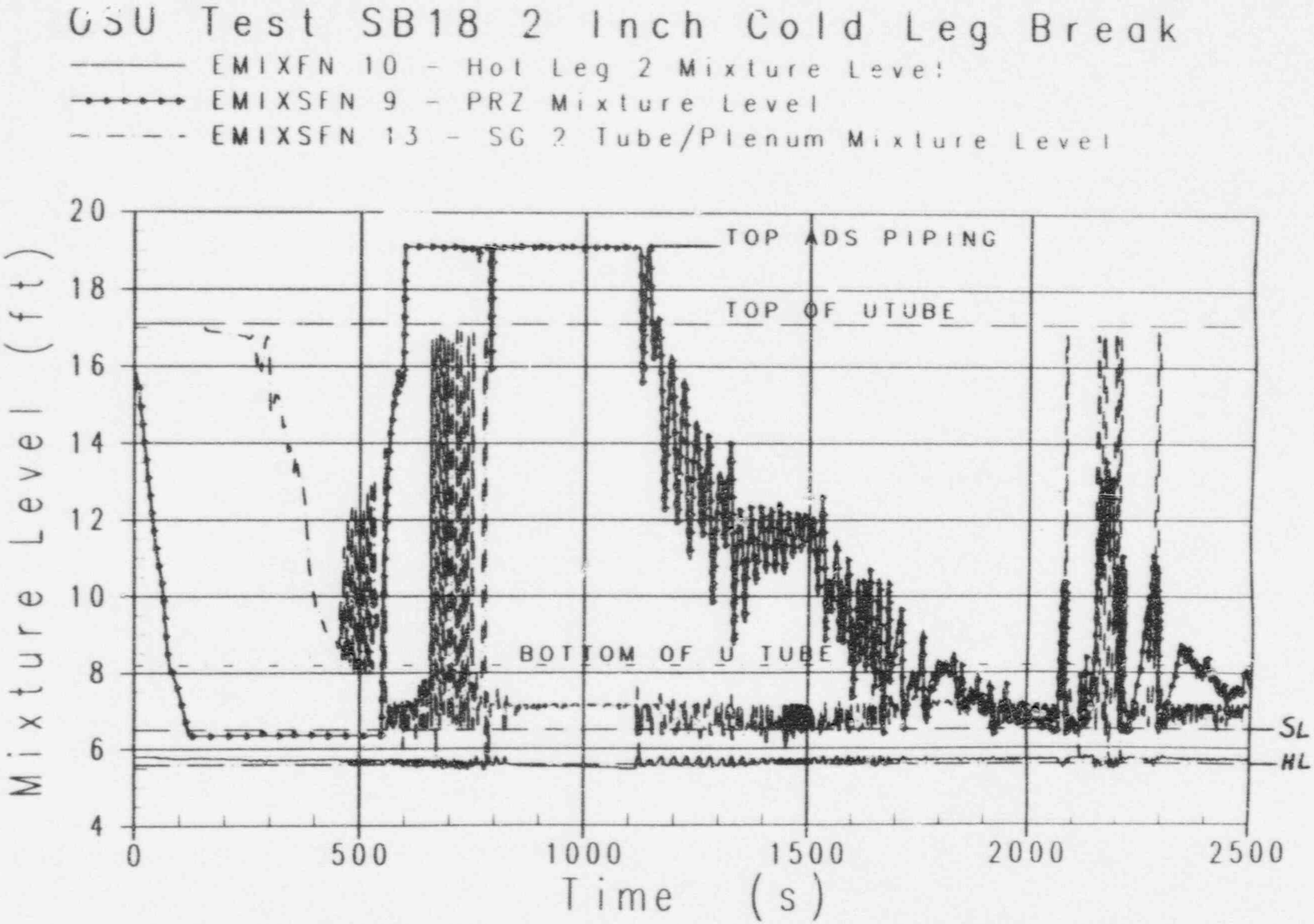

Figure 440.610-22

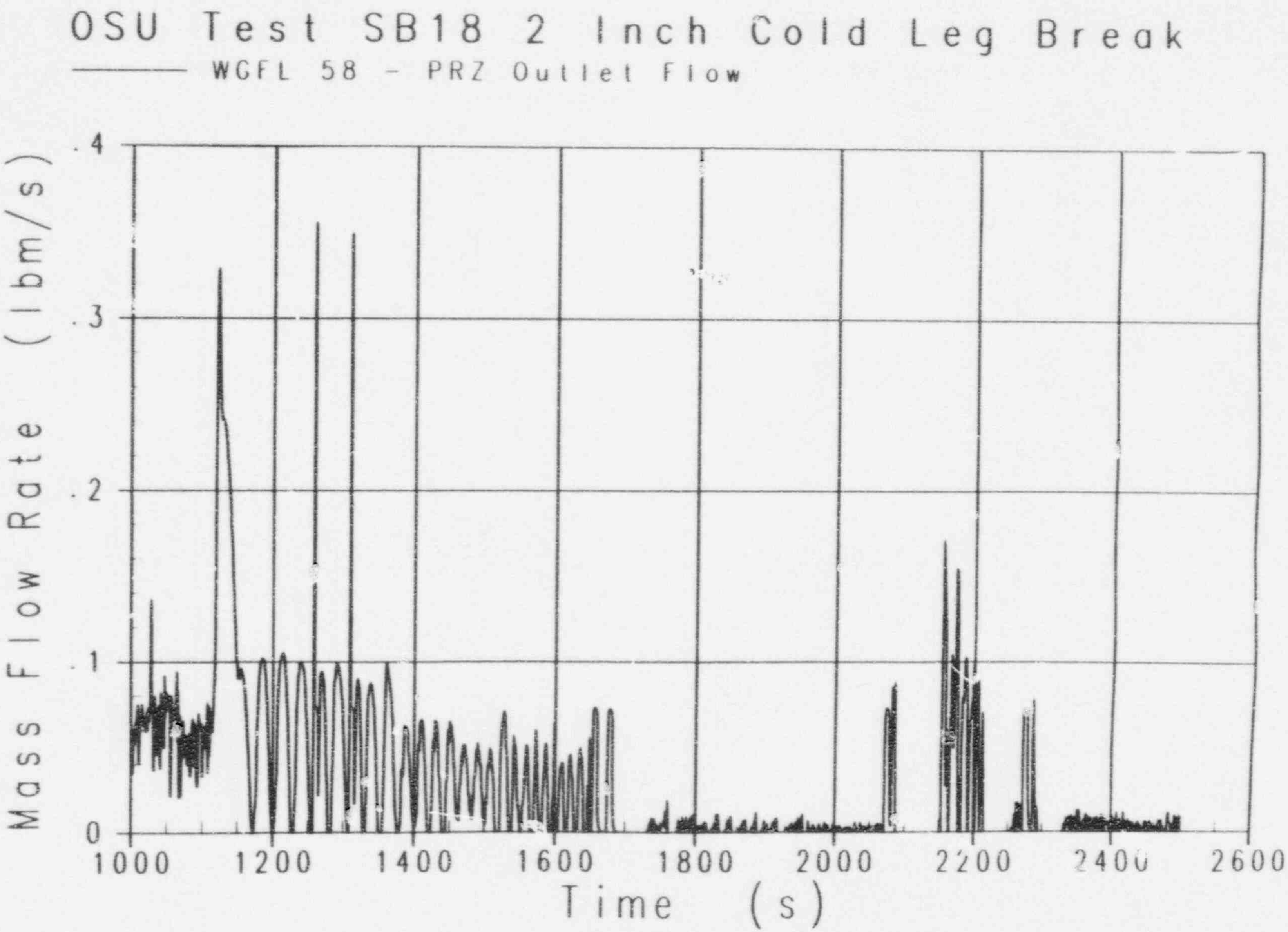

Figure 440.610-23

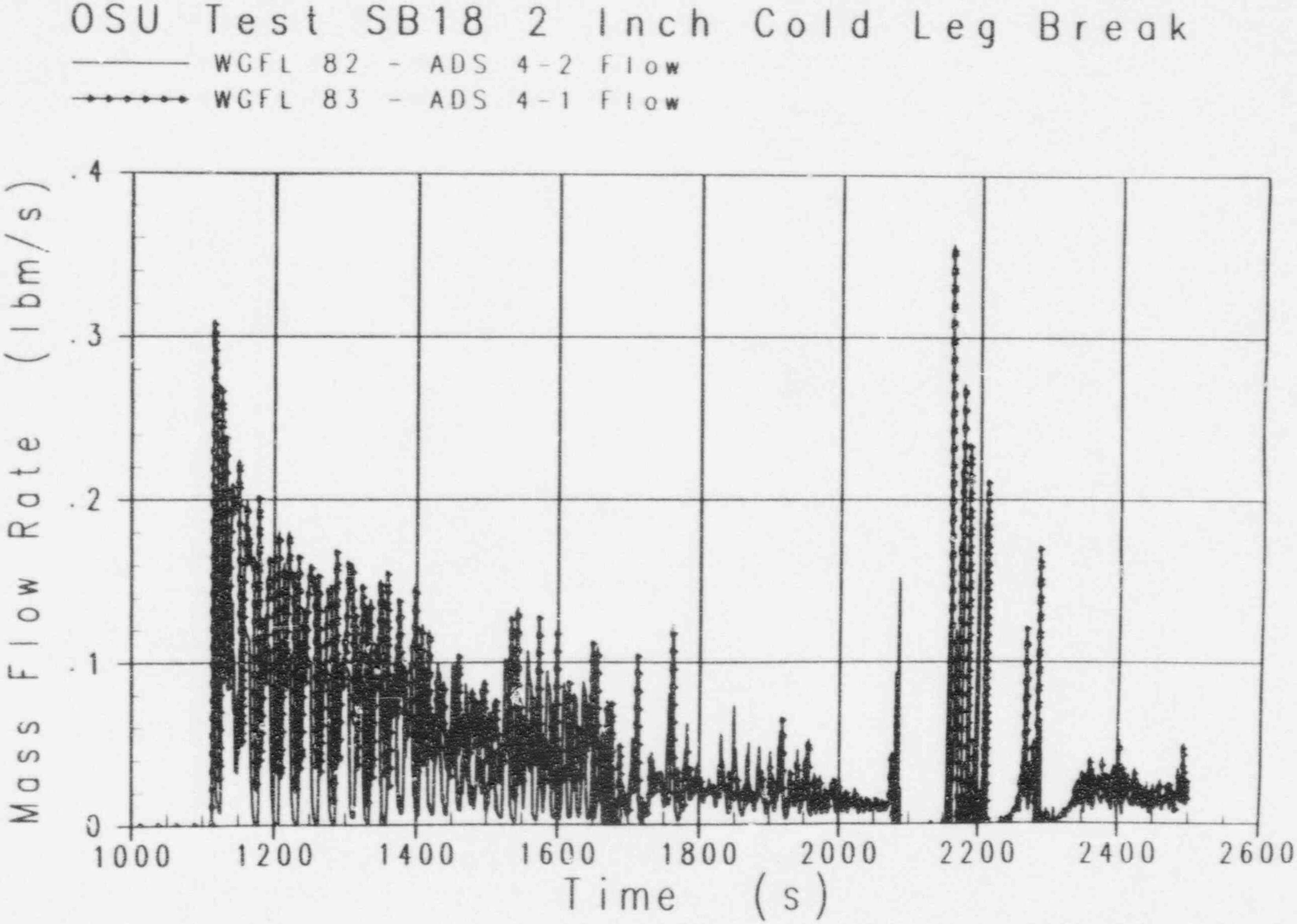

Figure 440.610-24

(a,b,c)

Figure 440.610-25

(a,b,c)

Figure 440.610-26

FIGURES FROM REFERENCE 1, SECTION 8

(a,b,c)

Figure 8.3.1- 2

(a,b,c)

Figure 8.3.1- 3

(a,b,c)

Figure 8.3.1-14

(a,b,c)

Figure 8.3.1-16

(a.b.c)

Figure 8.3.1–17

(a,b,c)

Figure 8.3.1-18

(a,b,c)

Figure 8.3.2- 3

(a.b.c)

Figure 8.3.2-17

(a,b,c)

Figure 8.3.6-3

(a,b,c)

Figure 8.3.6–17

(a,b,c)

Figure 8.3.7- 3

(a.b.c)

Figure 8.3.7–17

FIGURES FROM REFERENCE 3, SECTION 5.2

(a,b,c)

Figure 5.2.2- 3

(a,b,c)

Figure 5.2.2- 8

(a,b,c)

Figure 5.2.2-17

(a.b.c)

Figure 5.2.2-31

(a,b,c)

Figure 5.2.2-32

(a,b,c)

Figure 5.2.2-34

(a,b,c)

Figure 5.2.2-35

(a.b.c)

Figure 5.2.2-37

(a.b.c)

Figure 5.2.2-38

(a,b,c)

Figure 5.2.2-42

(a.b.c)

Figure 5.2.2-45

(a,b,c)

Figure 5.2.2-49

(a,b,c)

Figure 5.2.2-55

(a.b.c)

Figure 5.2.2-58

(a,b,c)

Figure 5.2.2-65

(a,b,c)

Figure 5.2.2-66

(a,b,c)

Figure 5.2.2-67

(a,b,c)

Figure 5.2.2-68

Question 440.611

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

RAI 440.510 asks for an explanation for why the NOTRUMP code over-predicts the IRWST injection flow rates during the early part of IRWST injection. The Westinghouse response indicates that this is caused by over prediction of ADS 4 flow. The final V&V report indicates that it is caused by a low pressure in the DVI line in the calculation. This behavior (over-prediction of the initial IRWST injection) was observed in nearly all of the calculations of SPES and OSU even though the ADS-4 flow is not always over-predicted. Please provide a more complete explanation.

Response:

Predictions of IRWST injection flow rates are controlled by the back-pressure influencing the IRWST injection flow paths. Variations in predicted ADS performance, both ADS 1-3 and ADS 4, are key factors since they contribute significantly to the system and Downcomer/DVI depressurization.

A review of the SPES IRWST injection plots from the NOTRUMP Final Validation Report (Reference 440.611-1) does not indicate a problem related to over-prediction of IRWST injection flow. In fact, the NOTRUMP code, in most instances takes slightly longer to achieve similar IRWST injection rates than observed in the test data and reaches a slightly lower maximum flow rate than the test.

A review of the OSU test predictions in Reference 440.611-1 indicates there are several potential factors which result in NOTRUMP predicting higher IRWST injection flows than observed in the test. All these identified elements affect the DVI line/Downcomer pressures and thus the NOTRUMP predicted IRWST injection flow rates. The identified elements are as follows:

Downcomer Pressure Related

1) The NOTRUMP OSU model under-predicts the pressurizer mixture level following ADS-4 actuation which results in lower resistance through, and subsequently higher vapor flow out of, the ADS stage 1 through 3 flow paths. A review of the IRWST flow rates and pressurizer mixture level plots indicate that a portion of the divergence in flow occurs approximately when the NOTRUMP collapsed pressurizer level drops off span. Up to this time, the predicted NOTRUMP downcomer pressure (Figure 440.611-1) is either higher than or equivalent to the test data resulting in similar IRWST flows.

2) Differences in downcomer mixture levels between the NOTRUMP simulations and the tests affect the downcomer pressure at the DVI line and ultimately IRWST injection flows.

3) Variations in the predicted NOTRUMP ADS-4 flows, compared to the tests, result in differences in downcomer pressure and subsequently IRWST injection flow rates.

DVI Line Pressure Related

1) The differences in CMT drain times also affect the IRWST injection flow rates predicted by the NOTRUMP code. When the CMT drain time calculated by NOTRUMP is late relative to the test data, the CMTs flows and IRWST flows, if applicable, interact thereby affecting IRWST injection performance in addition to the downcomer pressure differences. Following CMT empty time, downcomer pressure differences alone control the IRWST injection performance.

The primary element which affects a majority of the OSU simulations is the under-prediction of the Pressurizer collapsed levels and the subsequent affect on steam venting through the ADS stage 1 through 3 flow paths. This is discussed in further detail in the response to RAI 440.610.

References:

440.611-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Figure 440.611-1

Question 440.612

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The OSU model does not include ambient losses from the steam generator secondary. An explanation should be provided to justify why this is acceptable.

Response:

No specific secondary system ambient heat losses were modeled by the NOTRUMP code for the OSU facility simulations since the losses were not considered important. The OSU test facility was not designed to directly measure total steam generator ambient heat losses; therefore, modeling of these losses would have to be inferred from the available instrumentation. The available instrumentation from the OSU test facility includes steam generator secondary ambient heat loss information from the downcomer region. This information indicates that the total steam generator heat losses, following primary steam generator tube draining, are less that 5 btu/sec. This is significantly less that observed in the SPES test facility. A review of the transient simulation results indicate that while the NOTRUMP secondary conditions (pressures and temperatures) generally remain higher than observed in the test, they are not expected to have a significant effect on the results for the reasons stated below.

During the NOTRUMP transient simulations, the primary steam generator tubes drain at approximately the same rate as observed in the test facility. The steam generators initially serve as the primary heat removal source until the Passive Residual Heat Removal (PRHR) system is actuated. Once PRHR heat removal becomes sufficient, the primary system depressurizes below that of the steam generators subsequently making them an RCS heat source. This coincides approximately with the end of the steam generator tube drain period. Since the steam generators do not remain the primary heat removal mechanism following the actuation of the PRHR system, the absence of modeling the secondary ambient heat losses are considered acceptable because these heat losses become significant only after the steam generators have drained and are no longer affecting the primary system. The differences in the post drain secondary conditions will only affect RCS performance should refill of the steam generator tubes occur. This will result in larger secondary to primary heat addition and a larger corresponding RCS pressure increase.

Additionally, sensitivities were performed on the 0.5 inch cold leg break (Test SB23) which indicated modeling of ambient heat losses on the steam generator secondary side had a negligible effect on primary system performance. As such, the lack of a secondary ambient heat loss model in the NOTRUMP simulations of OSU is not considered an impediment to performing accurate simulations.

SSAR Revision: NONE

Question 440.613

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.1-3, Westinghouse states that the NOTRUMP calculation relies excessively on steam generator heat transfer because of low PRHR heat transfer. On page 7.3.1-7 in the discussion of Figures 7.3.1-37 through 7.3.1-39, Westinghouse states that the initial secondary pressure was set higher than in the test in order to match the primary conditions. This implies that when the NOTRUMP secondary pressure was set at the experimental value, the primary temperature was too low. In order to raise the primary temperature the secondary pressure was raised. This is an indication that the heat transfer from the primary to the secondary is too high. Thus, the excess reliance on the steam generators in the NOTRUMP calculation may be due largely to the excessive primary to secondary heat transfer and only partially to the low PRHR heat transfer. Please explain the root cause for the over-prediction of the heat transfer through the steam generators. Is it due to an inadequacy in the NOTRUMP code itself or only in the SPES input? How does this impact the AP600? (Note: this problem is persistent for all of the SPES test analyses.)

Response:

The exact statement is "This causes an increased reliance on the SGs for heat removal ***early*** in the transient which in turn causes their pressures to be higher than the test." Once the Passive Residual Heat Removal (PRHR) system becomes dominant, the steam generators no longer serve as a heat sink but rather become a heat source. Once the steam generator tubes drain, the steam generators serve only to heat the steam space which occupies the steam generator tubes. A review of the steam generator pressure and temperature plots provided in the Final Validation Report support this observation and demonstrate that NOTRUMP follows the observed trends of the data albeit somewhat delayed due to PRHR performance differences.

Adjusting the steam generator secondary side pressures to achieve appropriate primary conditions is a standard NOTRUMP modeling procedure. This is required since the NOTRUMP steam generator model is a simple one node lumped model and not an explicit multi-node recirculating steam generator. This modeling approach is identical to that utilized for conventional Pressurizer Water Reactors as well as the test simulations and AP600 modeling. To obtain the appropriate primary conditions with a single node steam generator model, while achieving appropriate steam flow rates, secondary pressures are adjusted. The subsequent overpredictions of the steam generator pressures by NOTRUMP is primarily due to underpredictions of PRHR heat removal and the conservative lack of steam generator ambient heat loss modeling. Due to the nature of the small break LOCA transient, and the specific features of the AP600 plant design, particularly the PRHR system, the steam generators do not play a significant role in the small break LOCA transient response.

In conclusion, the NOTRUMP steam generator heat transfer modeling is acceptable for the range of conditions observed during the test simulations as well as the AP600 plant.

SSAR Revision: NONE

Question 440.614

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

At the bottom of page 7.3.1-5 and for each of the SPES test analyses, Westinghouse says that the upper head does not drain properly in the NOTRUMP model because of differences in the initial upper head temperature, flow rates, and ambient losses. All of these things could have and should have been corrected in the SPES NOTRUMP input. Why weren't these errors corrected?

Response:

The text of each of the sections will be revised in Revision 2 of Reference 440.614-1 to remove the reference to differences to initial upper head temperature. These simulation temperatures are close to the data values and further investigation has shown that they are not the cause of the difference in time when the upper head reaches saturation and begins to drain.

The flow rates between the upper head and upper plenum and between the upper head and downcomer as well as the ambient heat losses from the upper head were modeled based on the facility data for steady state such that the simulation reached the appropriate upper head temperature and flow rates during steady state. Once the tests are initiated, there is little valid data regarding the ambient heat losses and the downcomer to upper head flow rate since the flow meter used to measure this flow path is out of range when the flow goes negative. This occurs early in the tests (i.e., at 64 seconds for the 2 inch cold leg break). Therefore, any changes to the ambient heat loss or flow path characteristics would not be based on data. Because of this, the model was not changed after the differences in the upper head draining characteristics were observed.

Also, the figure showing the upper head collapsed liquid level has been revised for all cases as a result of corrections identified during the final review of the plotting routines. An example plot is shown in Figure 440.614-1 for test S00303. The new figures show the upper head level starting to decrease in the simulation earlier than the test (which was the same as the previous figures) because the upper head reaches saturation temperature earlier in the simulation than the test. The difference in the new figures for most of the cases is that the upper head level in the simulation stops decreasing for a period of time when the level reaches the elevation of the pipe connecting the upper head to the downcomer. In the simulations, steam flowing from the upper plenum to the upper head and into the downcomer prevents significant liquid flow from the upper head to the upper plenum for a period of time after the upper head level reaches the elevation of the pipe connecting the upper head to the downcomer. This prevents further drain of the head until the steam flow decreases enough to allow substantial liquid flow from the upper head to the upper plenum. While there is no test data for the flow between the head and upper plenum, the liquid holdup must be less than the simulation since the test upper head level drains at a faster rate than the simulation once this level is reached. The discussion of the upper head collapsed liquid level plots will be revised to include the above information in Revision 2 of Reference 440.614-1.

References:

440.614-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

(a,b,c)

Figure 440.614-1

Question 440.615

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

All of the SPES and OSU NOTRUMP calculations have a problem that whenever any water enters the cold legs it passes up the balance lines. This is not physically accurate. Is this due to deficiencies in the horizontal stratification model or a horizontal stratification entrainment model?

Response:

The problem is not when water enters the cold legs but rather when sufficient water enters the cold legs such that the mixture level enters into the contact region of the cold leg balance lines. A review of the transient simulation results indicates this is consistent with the NOTRUMP predictions of the collapsed downcomer levels which show that during the periods in which the NOTRUMP level is higher than the test results, and in or above the cold leg and subsequently the cold leg balance line contact regions, NOTRUMP predicts refill of the cold leg balance lines.

SSAR Revision: NONE

Question 440.616

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Figures 7.3.3-27 and 28 show that NOTRUMP considerably underpredicts the ADS flow but on page 7.3.3-6 the text says that the agreement is reasonable. Please reevaluate this judgement.

Response:

For this simulation, the ADS flows are significantly underpredicted by NOTRUMP. The agreement between the test data and the simulation should be classified as minimal instead of reasonable. The result of the underprediction of ADS flows is that less mass leaves the system which, by itself, would result in more mass in the system in the simulation versus the test. However, for this simulation, more mass exits the system through the break than in the test as shown in Figure 7.3.3-29, and less mass enters the system from the IRWST as shown in Figures 7.3.3-25 and 7.3.3-26. The overall system inventory (power channel plus loop masses) is lower for the simulation compared to the test as shown in Figure 440.616-1. The writeup in Section 7.3.3 will be changed in Revision 2 of Reference 440.616-1 to say that the agreement is minimal and to include the above information, and the system inventory plots will be included in Section 7.4 for all cases.

References:

440.616-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

(a,b,c)

Figure 440.616-1

Question 440.617

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.3-7 the discussion of Figure 7.3.3-39 says that the secondary level for steam generator B in the test is not available. However, the steam generator B level does appear on the plot. Please revise the text and explain the steam generator B level.

Response:

The statement that the level for SG-B is not available is incorrect and will be removed from Revision 2 of the report. The discussion immediately prior to this statement applies to the secondary side level in both steam generators.

SSAR Revision: NONE

Question 440.618

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.4-2 Westinghouse merely says that the cold leg temperature is underpredicted. There is no discussion of why. Please provide the reason why.

Response:

The statement on page 7.3.4-2 that "CMT draining is delayed in NOTRUMP relative to the test because cold leg temperature is underpredicted in NOTRUMP." will be revised in Revision 2 of Reference 440.618-1. The reason for the delay in CMT draining is that in the NOTRUMP simulation the top CMT node must reach saturation temperature before draining begins while the test shows that the CMT can begin draining with subcooled liquid in the top of the tank if sufficient vapor enters the tank. This is discussed in Section 1.0 of Revision 2 of Reference 440.618-1. However, as indicted on page 7.3.4-3 of Reference 440.618-1, the draindown of CMT-B, which causes ADS actuation, is matched reasonably well even though the start of draindown is delayed.

References:

440.618-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.619

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.4-4 Westinghouse states that the performance of accumulator B is unimportant. However, it appears that an overprediction of the accumulator B flow causes CMT B flow to be unduly reduced. This delays the predicted draining of CMT B and delays ADS. That makes the performance of accumulator B important. The flow resistance should be modeled correctly. Please revise this section to acknowledge the importance of the accumulator B flow or provide enough information to justify the Westinghouse position.

Response:

It is stated on page 7.3.4-4 that the "Accumulator B performance in test S00706 is unimportant to core cooling because accumulator B drains directly into the collection tank." It is believed that this statement is correct. There is no clear indication from the data that the accumulator B flow is overpredicted by NOTRUMP for this test (see response to RAI 440.622) or that CMT B flow is unduly reduced. The flow resistance is modeled correctly. The prediction of ADS actuation in the simulation is reasonable as it is within 11 seconds of the test value. While injection from accumulator B does have some effect on the draining of CMT B, the draining is so rapid for this large break that the effect is not significant.

SSAR Revision: NONE

Question 440.620

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.4-4 Westinghouse states that the downcomer level is overpredicted without explanation. Then it is stated that the predictions are adequate. The agreement to data appears to be minimal. NOTRUMP predicts a higher core level at the time of the minimum core level in the test. Additionally, the core level prediction is not well matched to the data at the start of IRWST injection. Please reevaluate the discussion of these issues.

Response:

The collapsed downcomer level is overpredicted beginning at approximately 300 seconds in the simulation for two reasons. First, there is essentially no voiding in the downcomer in the simulation while there appears to be voiding in the test lower downcomer which causes the level in the annular downcomer above the tubular downcomer to remain above the DVI line elevation (the break elevation). As a result of the higher two phase level in the annular downcomer, there is more mass exiting the downcomer via the break in the test compared to the simulation as seen in Figure 7.3.4-29. The fact that there is greater flow out the break in the test compared to the simulation is related to the amount of subcooling in the core and downcomer, and the annular downcomer modeling. In the test, the fluid in the core region quickly reaches saturation and remains saturated for the entire transient. In the simulation, the core region also reaches saturation relatively quickly, however, the lower core nodes become subcooled at approximately 300 seconds, following ADS actuation and accumulator injection. The downcomer regions in the test show some subcooling until ADS 2 is opened, and then much of the tubular downcomer reaches saturation. There is a clear temperature profile from the bottom of the tubular downcomer to the top and into the annular downcomer with the saturated fluid being at the bottom of the tubular downcomer and subcooled fluid being at the top near the break. In the simulation, the mixture in the three downcomer nodes remains subcooled throughout the transient. Because of the increased subcooling in the core and downcomer in the simulation relative to the test, there is less steam generation in the simulation. In the test, the lower downcomer continues to flash maintaining a steam flow upward toward the break. This maintains a void fraction in the annular downcomer for the test and carries liquid with it out the break. The DVI flow that enters the annular downcomer through DVI line A must flow around the annular downcomer to reach the tubular downcomer pipe which is located directly below DVI line B. Steam flowing out the vessel side of the break is more likely to entrain liquid in the test than in the simulation which models one node for the lower annular downcomer. The result is that in the simulation the DVI flow enters the annular downcomer and flows down to the tubular downcomer while in the test, more of it is entrained out the break resulting in a lower downcomer level and less driving head for the core level.

The second reason for the higher collapsed downcomer level is that the total DVI-A injection flow rate is higher in the simulation than in the test from approximately 270 to 600 seconds. During the early part of this period, the collapsed downcomer and core levels become higher in the simulation than in the test.

The agreement between the simulation and test for the downcomer and core collapsed levels will be recategorized as minimal in Revision 2 of Reference 440.620-1, and the above discussion will be included in the text.

References:

440.620-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.621

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.4-5, in the discussion of Figure 7.3.4-21, Westinghouse points out some considerable problems with the agreement of the NOTRUMP prediction and the test data but does not discuss the cause of the discrepancies. Please provide an explanation of the discrepancies.

Response:

The first discrepancy related to Figure 7.3.4-21 noted on page 7.3.4-5 is that the predicted CMT-A injection flow rate is lower than the test when CMT-A has begun draining in the test but not in the simulation (100 to 250 seconds). The reason for the lower simulation flow is the fact the test has started the draindown phase while the simulation is still in the circulation phase. Once the draindown phase starts for the simulation, the CMT-A injection flow rate increases to a value similar to the test draindown rate. Shortly after draindown begins in the simulation, the system pressure decreases enough to allow the accumulators to inject. For the test, the accumulators inject slightly earlier than the simulation. The CMT-A injection rate is affected by the accumulator injection. For both the simulation and the test, the CMT flow rate decreases. The decrease is greater in the test than in the simulation. This is due in part to the fact that the accumulator injection flow rate is higher in the test than in the simulation as seen in Figure 7.3.4-23 because of the higher system pressure in NOTRUMP. The total DVI flow rate (Figure 7.3.4-40), which is comprised of CMT plus accumulator injection, is similar for the simulation and test during the period when the CMT and accumulator are injecting.

SSAR Revision: NONE

Question 440.622

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In Figure 7.3.4-24, the agreement between the NOTRUMP prediction and the test data appears to be minimal. Please provide an explanation and/or a new calculation.

Response:

The comparison appears to be minimal for the following reasons:

1) The instrumentation used to measure the accumulator flow has a maximum measurement value of approximately 1.05 lbm/sec. Therefore, anytime the indicated value is at 1.05 lbm/sec, the actual flow could be higher.

2) The test data appears to be erroneous during the period of time from approximately 20 to 60 seconds. During this period, the data for accumulator B level (Figure 7.3.4-13) shows a continual decrease even though the injection flow rate shows zero flow.

3) The initial accumulator mass in the NOTRUMP simulation is lower than the actual mass due to incorrect input that was recently discovered. The measured accumulator level was used to set the initial level (and mass) in NOTRUMP, but additional volume (and mass) below the bottom tap was not accounted for. This difference does not significantly affect the key results; however, the effect is noticeable as discussed below.

Assuming that during times when the flow meter is indicating its maximum value, the flows are similar between the test and the simulation, then the agreement between the test data accumulator flow and the NOTRUMP simulation is reasonable. The assumption is based on the fact that the test and simulation flows for accumulator A are reasonably matched and the fact that the injection flows stop at approximately the same time for both the test and the simulation (approximately 175 seconds) at approximately the same accumulator pressure. For the test, accumulator B injects for a second period of time beginning at approximately 350 seconds (Figure 7.3.4-24). There is no similar second period of injection in the simulation because the accumulator has emptied in the first injection period due to the low initial accumulator mass noted above.

SSAR Revision: NONE

Question 440.623

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

At the top of page 7.3.4-6, Westinghouse says that NOTRUMP underpredicts the downcomer voiding. This is only true for the tubular part of the downcomer. Voiding in the annular part of the downcomer is overpredicted by NOTRUMP. Please provide an explanation.

Response:

In the NOTRUMP simulation, the level in the downcomer stack of nodes drops below the bottom of the annular portion at approximately 200 seconds (Figures 7.3.4-18 and 7.3.4-19). Up to that time, the collapsed level agrees reasonably well with the test data. The void fraction in the annular region is overpredicted in NOTRUMP only in the sense that the level has dropped out of the node which then has a void fraction of 1.0. As indicated on page 7.3.4-6, NOTRUMP underpredicts the downcomer void fraction in the tubular region which then allows the level in the downcomer stack of nodes to drop below the annular portion.

SSAR Revision: NONE

Question 440.624

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 7.3.4-6, Westinghouse says that Figure 7.3.4-32 compares the PRHR heat transfer but provides no discussion. Please discuss the results shown in this figure.

Response:

Figure 7.3.4-32, a comparison plot of the PRHR heat transfer rate for the test data and the NOTRUMP simulation, shows that once the PRHR return line mass flow rates (Figure 7.3.4-30) and PRHR inlet temperatures (Figure 7.3.4-31) stabilize and are simular between the test and the simulation, the NOTRUMP model underpredicts the PRHR heat transfer. This is seen from about 100 to 300 seconds on the figures. This underprediction of PRHR heat transfer is also observed in other tests. For break sizes as large as the double ended DVI line break, shown in Section 7.3.4, the PRHR heat transfer does not have a significant affect on the key events in the transient since the break and ADS are the primary energy removal paths.

SSAR Revision: NONE

Question 440.625

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The results shown in Figure 7.3.5-11 are quite different from other tests. Please provide an explanation of these results.

Response:

Following the transmittal of Reference 440.625-1, the final internal Westinghouse reviews of the supporting documentation identified a number of changes that were needed to the plotting package used to generate the comparison plots and to the simulation of SPES test S01007. As a result, this test simulation was redone and the plots regenerated. The revised information for this and all tests will be contained in Revision 2 of Reference 440.625-1. Assuming that the difference noted in the above RAI refers to the initial level (which is the key difference between this test plot and that for other tests), this difference no longer exists. To show this, the reissued Figures 7.3.5-11 and 7.3.2-11 for tests S01007 and S00401 respectively are included here as Figures 440.625-1 and 440.625-2.

References:

440.625-1 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

SSAR Revision: NONE

(a.b.c)

Figure 440.625-1

(a,b,c)

Figure 440.625-2

Question 440.626

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In all of the NOTRUMP calculations for OSU the distribution of fluid in the vessel is skewed when compared to the test data. The calculated core level is consistently low and the downcomer le el is consistently high. Is it possible that NOTRUMP is failing to represent an important phenomenon?

Response:

The response to RAI 440.610 contains a detailed analysis of the NOTRUMP prediction of the SPES and OSU tests, focusing on the pressurizer refill prediction. It is concluded that NOTRUMP under predicts pressurizer refill when ADS 1-3 actuate, because of the higher vapor content in the core and upper plenum mixture. Because more vapor is vented out of ADS 1-3 than liquid, less mass is drawn from the downcomer region in most of the tests. The reason for the downcomer level overprediction in the DVI line breaks includes additional phenomena which are discussed in the response to RAI 440.620.

SSAR Revision: NONE

Question 440.627

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In Figure 8.3.1-22, NOTRUMP underpredicts the CMT 2 recirculating flow rate. This could be an effect of the leaky check valve in the NRHR system. Please comment.

Response:

The underprediction of the CMT-2 recirculation flow rate by NOTRUMP for the OSU test SB18 (2-in. cold leg break) is not due to check valve leakage in the NRHR system. Closer examination of the flows into and out of DVI Line 2 for the test indicates that the total DVI Line 2 flow measured by flow meter FMM-206 matches the sum of the flows measured by flow meters FMM-504 (CMT-2 injection flow), FMM-402 (accumulator-2 injection flow) and FMM-702 (IRWST-2 injection flow). The reason for the discrepancy in the CMT-2 recirculation flow rate is due to the delay (about 60 seconds) in the transition from the recirculation mode to the drain down mode predicted by NOTRUMP, as seen in Figure 8.3.1-5 of Reference 440.627-1. The test flow rate increases sooner than the simulation, since the CMT drains earlier in the test. While it appears that the simulation underpredicts the flow rate, the prediction and the data are actually in reasonable agreement when the shift in timing is accounted for.

Leakage in Test SB12 (Double-Ended Guillotine DVI Line Break)

Test SB12 was also studied to determine if there is any leakage in the NRHR system. The total flows measured in DVI lines 1 and 2 by flow meters FMM-205 (upstream of the break) and FMM-206 respectively were compared to the sum of the CMT, accumulator and IRWST injection flows into each line, and the following observations are made:

a. For the first 360 seconds of the transient (until IRWST-2 injection), the total flow from DVI line 2 into the downcomer is less than the sum of the CMT and accumulator injection flows into that line. This indicates that part of the injection flow into DVI line 2 is leaking through the check valve into the NRHR system for this test.

b. The total flow out of DVI line 1 through the break is greater than the sum of the CMT, accumulator, and IRWST injection flows in that line. While examining the injection flows into DVI line 1, it is found that the indicated CMT-1 injection flows reach the maximum indicated flow for flow meter FMM-501. Therefore, the CMT flow could be higher than the indicated flow. Therefore, the test data is not shown on Figures 8.3.4-21 and 8.3.4-22 as indicated on page 8.3.4-5 of Reference 440.627-1.

To understand the effect of the leaky check valve on the transient, a NOTRUMP run was made to simulate test SB12, with the leakage modeled as a break at the bottom of the CMT-2 tank. The break flow area was calculated based on the maximum leakage, which was estimated based on the flow difference between the flows in and out of DVI line 2. This approach was used for ease of modeling and to also obtain a bounding case. The results indicate that the leakage has no significant effect on the overall transient. The only effect of the leakage on the transient is the earlier draining of CMT-2, which however, does not affect the timings of any major events such as ADS actuation. Therefore, the results presented in Section 8.3.4 of Reference 440.627-1 remain valid for test SB12.

References:

440.627-1 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

SSAR Revision: NONE

Question 440.628

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In the discussion of Figure 8.1.3-27, Westinghouse says that no conclusions can be drawn. ADS 1-3 flow is a highly ranked PIRT item for which the ability of NOTRUMP must be assessed. Westinghouse points out that the fluid conditions were different. Please explain why the fluid conditions were different. Discuss the implications to AP600 calculations, possible causes, and possible solutions to the problem.

Response:

The response to RAI 440.610 provides information on the likely cause of the inaccurate prediction of ADS 1-3 flow in many of the OSU tests. In nearly all of the SPES and OSU simulations, the refill of the pressurizer was underpredicted when ADS 1-3 was actuated. The reason for this underprediction was attributed to the higher vapor content of the mixture at the time of ADS. This caused the conditions in the pressurizer to also be of higher vapor content. Consequently, the mass flow through the ADS was underpredicted.

The response to RAI 440.610, and the Revision 2 version of Section 1 of the NOTRUMP Final Validation Report* discuss the implications of these results to AP600 calculations. The cause of the low predicted ADS mass flow is a low predicted pressrizer refill at ADS actuation. The cause of the low pressurizer refill is the result of low predicted system mass and high vapor content, which is a conservative bias in the early stages of the transient. Late in the transient, the underpredicted pressurizer mass could lead to a nonconservative bias. This non-conservatism will be evaluated for AP600 plant calculations as described in the Revision 2 version of Section 1 of the NOTRUMP Final Validation Report.

SSAR Revision: NONE

Question 440.629

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In Figure 8.3.1-29, the predicted break flow is quite inaccurate. Westinghouse explains that this is because accumulator water reaches the break. Please make a judgement of the NOTRUMP ability to properly model the break flow. Why does the accumulator water reach the break in the calculation and not in the test? How can this be fixed? How will this affect AP600 calculations? Is this conservative?

Response:

The inaccurate prediction of break flow is a direct result of the low predicted pressurizer refill at ADS 1-3 actuation. As discussed in the response to RAI 440.610, when ADS 1-3 opens the volume of mixture lost through the ADS is replaced by an equal volume of mixture from the loops and vessel. If the mixture is mostly subcooled as it is in the test, vapor generation is suppressed and the volume is replaced primarily by liquid pulled from the core and downcomer. If the mixture is mostly saturated, as it is in the NOTRUMP prediction, vapor is generated and the volume is replaced by this generated vapor, and the liquid in the downcomer is not pulled through, and therefore remains in the downcomer. As seen in Figure 8.3.1-18, the test downcomer level drops at ADS actuation (390 seconds), while the predicted downcomer level does not change (550 seconds). As a result, liquid injected through the DVI line fills the downcomer and flows back into the cold leg.

Correcting the problem would involve correctly predicting the vapor content or subcooling of the mixture in the vessel prior to ADS actuation. The primary reason the subcooling is underpredicted in NOTRUMP is because the CMT delivers too much energy during the recirculation phase, and the PRHR heat removal rate is underpredicted. As discussed below, the excess steam generation which results from these model deficiencies is a conservative feature which is appropriate for an Appendix K evaluation model.

There is a fundamental limit to the amount of water which can be retained in the system. This limit is controlled by the degree of subcooling in the mixture, which determines the vapor generation rate, and the void fraction which results from the vapor generation. If the amount of liquid predicted to flow from the ADS is low, and the predicted void fraction is high, then the calculation will compensate by ejecting the excess liquid through the break. This is the reason the system mass is underpredicted in most of the tests, even though the flow out the ADS is underpredicted. NOTRUMP is considered to be conservative because the vapor content which must be vented is overpredicted.

SSAR Revision: NONE

Question 440.630

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Please explain the sudden drops in the calculated secondary temperatures in Figure 8.3.1-38.

Response:

The mixture level in steam generator 2 (SG-2) rises into the tubes on the hot leg side at about 650 seconds as discussed in the response to RAI 440.610 (see Figure 440.610-17). This causes reverse heat transfer in the secondary side and a corresponding drop in the secondary side temperature, seen in Figure 8.3.1-38. The later drop in the temperatures for both SGs (between 2150 and 2200 seconds) occurs following IRWST injection, when there is a second rise in the mixture level in the SG tubes. This is shown on Figure 440.610-22 for SG-2. A similar level rise is also predicted in SG-1 at the same time.

SSAR Revision: NONE

Question 440.631

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Please draw some conclusions from Figures 8.3.1-42 and 43. Why is the calculated temperature high? Could this cause the low core level?

Response:

The high core inlet temperatures are a result of several factors. First, the under-prediction of the Passive Residual Heat Removal (PRHR) system performance results in higher cold leg temperatures and subsequently core inlet temperatures in the NOTRUMP simulation when compared to the test information. Secondly, the differences in progression from the recirculation phase to drain-down phase of Core Makeup Tanks (CMTs) injection results in additional deviations in core inlet temperatures and finally, the lack of a detailed thermal stratification model in the CMTs results in warmer fluid being injected into the reactor vessel downcomer region over the longer term when compared to the test. As a result of the warmer core inlet fluid conditions, the collapsed core mixture predicted by NOTRUMP is lower than observed in the test. The higher core inlet conditions result in higher core vapor generation rates which results in slower de-pressurization rates and requires higher energy removal rates via the Automatic De-pressurization System (ADS) and the break.

SSAR Revision: NONE

Question 440.632

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

For OSU test SB23 the break area was not the area of the installed orifice. How did this happen? What was the break area? Is this related to the problem with the break area in the performance of test SB05?

Response:

The actual break flow rate in OSU test SB23 is approximately twice as large as would be expected with the installed orifice. Because of this difference, the simulated break area in OSU test SB23 is approximately twice the flow area of the installed orifice. It is not definitely known how the difference in break flow rate occurred. However, the most likely cause is an alternate leak path from the cold leg into the break separator. This is the same reason believed to have caused the discrepancy between expected and actual break flow rates in OSU test SB05 as discussed in detail in Reference 440.632-1. OSU test SB05 also has the actual break flow approximately twice as large as would be expected with the installed orifice.

References:

440.632-1. Westinghouse Response to NRC Request for Additional Information RAI 440.584, Letter NSD-NRC-97-5163, June 1997.

SSAR Revision: NONE

Question 440.633

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In the discussion of OSU test SB23 on page 8.3.2-3, Westinghouse mentions that the test data appears to have found a source of vapor that drains the tubes in steam generator 1. Is this real? Could this be an instrument problem? Please explain where the vapor came from and why it only exhibited its presence in the draining of the steam generator 1 tubes.

Response:

A review of the data from the available instrumentation from the test facility supports draining of the steam generator 1 tube region prior to steam generator 2. The OSU Final Data Report (Reference 440.633-1) section 5.15 indicates bulk flashing occurs in the steam generator 1 tubes whereas steam generator 2 exhibits only limited tube boiling. The differences in steam generator tube flashing can be attributed to the break's proximity to steam generator 1 (Cold Leg 3) which affects local saturation conditions as well as differences in steam generator secondary fluid conditions. Another possible contributor is that the Passive Residual Heat Removal (PRHR) system is connected to RCS loop 2. The PRHR system reduces the flow rates through SG-2 thereby increasing the fluid residence and subsequently reduces boiling in the tube region.

References:

440.633-1 WCAP-14252, "AP600 Low_Pressure Integral Systems Test as Oregon State University, Final Data Report," C. L. Dumsday, et. al., May 1995.

SSAR Revision: NONE

Question 440.634

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

There is some confusion either in the text or in the figure labels for Figures 8.3.2-6 through 9. Steam generator 1 and steam generator 2 may be switched.

Response:

In Section 8.3.2.2 which documents the NOTRUMP simulation of OSU test SB23, the text at the top of page 8.3.2-6 incorrectly has steam generator 1 and steam generator 2 switched regarding figure references. The correct figure references should have been that Figures 8.3.2-6 and 8.3.2-7 refer to steam generator 2 (not steam generator 1), and Figures 8.3.2-8 and 8.3.2-9 refer to steam generator 1 (not steam generator 2). These typographical discrepancies will be corrected in Revision 2 of the NOTRUMP Final Validation Report for AP600. The steam generator figure labels in this section are correct.

SSAR Revision: NONE

Question 440.635

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

There are many problems with OSU test SB23 (both the test itself and the calculation). Credibility of the final V&V is diminished by the Westinghouse claim that there is reasonable agreement between NOTRUMP and the test data considering all the test uncertainties and the calculation adjustments. Westinghouse should reassess this conclusion.

Response:

Your observations regarding the uncertainties with both the test data and NOTRUMP calculations are accurate. The response to RAI 440.629 discusses the possible cause for the disparity in the initial break flow prediction between the NOTRUMP code and the actual observed data. This response will be factored into the Revision 2 section 8.3.2.1 write-up. Additionally, CMT noding sensitivity studies, documented in the response to RAI 440.339, indicate improved simulation capability relative to the test although discrepancies still exist. Westinghouse will revise the results section for test SB23 to state that the agreement of the comparisons is considered minimal since modifications were required to the base NOTRUMP model to achieve a representative level of comparison. Note however, that the base un-modified model is clearly a conservative representation of the 0.5 inch cold leg break as a result of significantly delayed ADS actuation. Due to the extended period of break flow prior to activation of ADS, the predicted minimum inventory is lower than would be predicted with a more accurate simulation thereby resulting in decreased margin to core uncovery. No core uncovery was predicted to occur for this case however.

SSAR Revision: NONE

Question 440.636

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

Please provide an explanation of the poor agreement in Figure 8.3.3-40.

Response:

Figure 8.3.3-40 is a comparison plot of the test data and the NOTRUMP simulation for the DVI-1 line flow for OSU test SB13 (2-in. DVI-1 line break). The DVI-1 line flow test data value in Figure 8.3.3-40 is that measured by flow meter FMM-205, contained in the portion of the DVI-1 line which is upstream of the break. The poor agreement in Figure 8.3.3-40 occurred because the incorrect flow was plotted for the NOTRUMP simulation value. The NOTRUMP simulation value in Figure 8.3.3-40 is the flow in the portion of the DVI-1 line which is downstream of the break, between the break and the reactor vessel.

Regarding the available DVI-1 line flow test data, the flow measured by flow meter FMM-205 in the portion of the DVI-1 line which is upstream of the break is equal to the total of the DVI-1 line flow contributions from the CMT-1 injection flow (measured by flow meter FMM-501), the ACC-1 injection flow (measured by flow meter FMM-401), and the IRWST-1 injection flow (measured by flow meter FMM-701). Regarding the NOTRUMP simulation, the DVI-1 volume, which is modeled as fluid node 52 as shown in the NOTRUMP OSU noding diagram in Figure 8.2.2 of Reference 440.636-1, has three flow paths entering, which are the CMT-1 injection line (modeled as flow link 50), the ACC-1 injection line (modeled as flow link 51), and the IRWST-1 injection line (modeled as flow link 56), and has two flow paths exiting, which are the DVI-1 line portion downstream of the break, between the break and the reactor vessel (modeled as flow link 52), and the break flow path (modeled as flow link 80).

The NOTRUMP simulation comparisons to the test data were correctly plotted for the individual contributions to the DVI-1 line flow (CMT-1 injection line flow in Figure 8.3.3-21, ACC-1 injection line flow in Figure 8.3.3-23, and IRWST-1 injection line flow in Figure 8.3.3-25). However, in Figure 8.3.3-40 the NOTRUMP simulation flow in the portion of the DVI-1 line between the break and the reactor vessel was incorrectly compared to the test data DVI-1 line flow upstream of the break measured by flow meter FMM-205, causing the poor agreement in Figure 8.3.3-40. What should have been plotted in Figure 8.3.3-40 for the NOTRUMP simulation, to have a one-to-one comparison to the test data flow measured by flow meter FMM-205, is the sum of the flows in the CMT-1 injection line, the ACC-1 injection line, and the IRWST-1 injection line.

The plot with the corrected NOTRUMP simulation value for the DVI-1 line flow is contained in Figure 440.636-1. It will be used to replace the plot of Figure 8.3.3-40 in Revision 2 of Reference 440.636-1.

References:

440.636-1. Fittante, R. L., et. al., "NOTRUMP Final Validation Report for AP600," Westinghouse Electric Corporation, WCAP-14807, Revision 1, January 1997.

SSAR Revision: NONE

(a,b,c)

Figure 440.636-1

Question 440.637

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In Figure 8.3.4-5 the flow from accumulator 2 affects the flow from CMT-2 far more in the NOTRUMP calculation than in the test. Please explain.

Response:

As noted in RAI 440.627, a leaky Normal Residual Heat Removal (NRHR) check valve exists in the OSU test facility. This leaky valve only becomes important in transient simulations in which a large pressure difference exists between the Direct Vessel Injection (DVI) lines such as the Double Ended Direct Vessel Injection (DEDVI) line break (Case SB12). As a result, although it appears as though accumulator 2 is having an impact on the CMT-2 mixture level response, the actual cause is attributable to the leaking NRHR system valve. Since no safety system signals are keyed off of the CMT-2 tank for the SB12 simulation, the effect is considered negligible on transient results.

Sensitivities performed on the SB12 simulation indicate that while the CMT-2 level is affected by modeling the leak, the overall transient response is not significantly changed.

SSAR Revision: NONE

Question 440.638

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 8.3.4-6 at the end of paragraph 1 and the beginning of paragraph 2, no conclusions were drawn regarding ADS 1-3 flow. Please document what causes the discrepancies in ADS 1-3 flow, break flow, and pressurizer level.

Response:

The inaccurate prediction of ADS 1-3 flow in this test is a direct result of the low predicted pressurizer refill at ADS 1-3 actuation. As discussed in the response to RAI 440.610, when ADS 1-3 opens the volume of mixture lost through the ADS is replaced by an equal volume of mixture from the loops and vessel. If the mixture is mostly subcooled as it is in the test, vapor generation is suppressed and the volume is replaced primarily by liquid pulled from the core and downcomer. If the mixture is mostly saturated, as it is in the NOTRUMP prediction, vapor is generated and the volume is replaced by this generated vapor, and the liquid in the downcomer is not pulled through, and therefore remains in the downcomer. As seen in Figure 8.3.4-18, the test downcomer level drops at ADS 2 actuation (139 seconds), while the predicted downcomer level does not change (136 seconds).

SSAR Revision: NONE

Question 440.639

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

There is a persistent problem in both SPES and OSU NOTRUMP calculations caused by water entering the cold legs when there is no water there in the tests. Why does this happen? Can you present comparison figures showing the cold leg levels in the test and the calculation? Many of the NOTRUMP inaccuracies are blamed on what the cold leg levels are. Please evaluate how these level problems can be eliminated.

Response:

As indicated in the response to RAI 440.629, water enters the cold leg in the predictions as a direct result of the low predicted refill of the pressurizer and low liquid flow out ADS 1-3. When the water fills the cold legs, the balance line and CMT sometimes refill. Figure 440.639-1 compares the predicted collapsed liquid level in CL-1 with the measured value for OSU test SB18. Comparing this with the timing of the pressurizer refill in Figure 8.3.1-3, it can be seen that the cold leg filling coincides with the time at which the pressurizer has almost completely refilled in the test, while it has only partially refilled in the NOTRUMP calculation. It is primarily the lack of liquid pull-through when ADS opens that causes the cold legs to retain water.

SSAR Revision: NONE

(a,b,c)

Figure 440.639-1

Question 440.640

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 8.3.5-4 Westinghouse discusses Figures 8.3.5-10 and 11 and points out that the calculated behavior of the balance line level is wrong beyond 1500 s. Yet Westinghouse states that NOTRUMP predicts well the PIRT items related to the balance line. This is confusing and requires more explanation. Please reassess this judgement and revise the section to clearly explain that the refill is caused by nonphysical refill of the cold legs.

Response:

The discussion of the cold leg balance lines will be re-written as follows:

> The balance line collapsed levels are shown in Figure 8.3.5-10 and 8.3.5-11. An initial level forms in the cold leg balance lines as flashing of the balance line fluid occurs. However, the levels remain near the top of the balance lines until the SG tubes drain allowing additional vapor to reach the cold legs and subsequently the cold leg balance lines. The trends related to initiation of cold leg balance line draining are reasonably well represented by the NOTRUMP code; however, the overall prediction must be considered minimal due to the subsequent refill periods observed in the simulation which were not observed in the tests.

It is postulated that the balance line level refills are a result of the under-prediction of the pressurizer refill period by the NOTRUMP code following ADS 1-3 actuation and subsequent accumulator injection. Since the collapsed pressurizer level is under-predicted, the downcomer and cold leg levels are over-predicted resulting in balance line refill being predicted. Additional details regarding the pressurizer refill under-prediction are provided in the response to RAI-440.610.

SSAR Revision: NONE

Question 440.641

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

On page 8.3.6-2 in the second paragraph, the calculated behavior of CMT1 is very different from the test data. Why? What does this say about NOTRUMP?

Response:

For test SB10 (double-ended guillotine cold leg balance line break), the simulation does not predict CMT-1 draining late in the transient as seen in the test (Figure 8.3.6-4 of Reference 440.641-1) for the following reason:

After ADS-3 actuation, the fluid nodes and flow links comprising CMT-1 and the corresponding upper cold leg balance line are removed from the model. This is done to increase the speed of the calculations, given that the performance of CMT-1 is not important for this event.

The same approach is also used in the simulation of SPES test S00908 (double-ended guillotine cold leg balance line break) by removing CMT-B and the associated upper cold leg balance line nodes at 1000 seconds, which is after ADS-3 actuation.

Sections 8.3.6 and 7.3.6 of Reference 440.641-1 will be modified in Revision 2 to indicate that the CMT and the associated upper cold leg balance line nodes were removed from the simulation as discussed above.

References:

440.641-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.642

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

In the last paragraph on page 8.3.6-3, 55 seconds is wrong. Perhaps it should be 5.5 seconds.

Response:

In Section 8.3.6.2, which documents the NOTRUMP simulation of OSU test SB10, the text in the last paragraph on page 8.3.6-3 incorrectly indicates that the pressurizer in the NOTRUMP simulation empties at 55 seconds. The correct time that the pressurizer empties in the NOTRUMP simulation of OSU test SB10 is 10 seconds. This typographical error will be corrected in Revision 2 of the NOTRUMP Final Validation Report.

SSAR Revision: NONE

Question 440.643

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

The comments contained in RAIs 440.613 through 440.642 are examples of areas in the final V&V where discussions do not appear to be adequate. Please re-examine the analyses presented in the final V&V report for areas which need additional discussion or explanation.

Response:

The NOTRUMP prediction of SPES and OSU exhibit certain common features, in particular:

Low inlet subcooling and excess vapor generation.

Low prediction of the pressurizer refill during ADS, and resulting low prediction of liquid flow out the ADS.

Generally late prediction of CMT drain.

Prediction of high IRWST flow for the OSU tests.

Rather than repeat the same observations for all the tests, the tests were examined as a group and related to the findings from the single effects studies. The areas which were not well predicted and which have implications for the AP600 analysis such as those above are examined and summarized in a revised Section 1 which is included in Revision 2 of Reference 440.643-1. This section contains a summary which discusses the most important results of the assessment studies. To prepare this summary, a review of all the test predictions was performed. While there are some details in the comparisons which may not have been discussed on a specific test basis in the Final Validation Report or the responses to the RAIs, it is concluded that those aspects which have the greatest impact on the AP600 analysis have been addressed.

Reference:

440.643-1 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

SSAR Revision: NONE

Question 440.644

Re: WCAP-14807, Revision 1 (NOTRUMP Final Validation Report)

For each case where the quench model was used, a mixture level plot should be included that shows the calculation results with and without the quench model. Please specify the guidelines that should be followed in order to decide whether the quench model needs to be used. Clearly state that, because of these guidelines, no AP600 analysis would ever use the quench model.

Response:

The core quench model (described on page 5-9 of Reference 440.644-1) was utilized for the NOTRUMP simulations of four of the G2 level swell tests and for the four-node model in the noding sensitivity study for the Achilles test. The G2 level swell tests are described in Sections 4.4 of Reference 440.644-2 and the Achilles model noding sensitivity study is described in Section 4.3.4 of Reference 440.644-2. The following revisions will be made to Reference 440.644-2 to indicate the use of the core quench model:

A. For the G2 level tests (Tests 723, 729, 732 and 733) that utilized the core quench model, the mixture level plots (Figures 4.4-29 through 4.4-32 of Reference 440.644-2) will be revised to include results of the NOTRUMP simulations with and without the quench model. The text on pages 4.4-13 (last paragraph of Section 4.4.8.1) and 4.4-16 (first four paragraphs) of Reference 440.644-2 will also be revised to indicate the use of the core quench model for these tests. A sample set of plots are given in Figures 440.644-1, 440.644-1A, 440.644-1B, and 440.644-1C.

B. For the Achilles model noding sensitivity study, the mixture level plot (Figure 4.3-13 of Reference 440.644-2) will be revised to include the results of the four-node model with and without the quench model. The mixture level plot is shown in Figure 440.644-2. The text on page 4.3-6 (last paragraph) of Reference 440.644-2 will also be revised to indicate the use of the core quench model for the four-node Achilles model.

These revisions will be included in Revision 2 of Reference 440.644-2.

Guidelines for the Use of the Core Quench Model

The core quench model will be utilized for a small break NOTRUMP transient simulation *only* if the following two conditions exist simultaneously:

A. When the two-phase mixture level in the heated region (core) is decreasing and below the top of the heated region,

and

B. when a sudden mixture level spike exists in the heated region without a corresponding increase in the mass inventory entering the heated region.

For the AP600 SSAR analyses, the two-phase mixture level does not decrease below the top of the active fuel for any of the NOTRUMP simulated small break transients (Reference 440.644-3). Therefore, the core quench model is not utilized in the AP600 small break SSAR analyses.

References:

440.644-1 WCAP-14869, "MAAP4/NOTRUMP Benchmarking to Support the use of MAAP4 for AP600 PRA Success Criteria Analyses", Westinghouse Electric Corp., April 1997.

440.644-2 Fittante, R. L., et. al, WCAP 14807, Revision 1, "NOTRUMP Final Validation Report For AP600", Westinghouse Electric Corp., January 1997.

440.644-3 AP600 SSAR Revision 13, Subsection 15.6.5.4B.

SSAR Revision: NONE

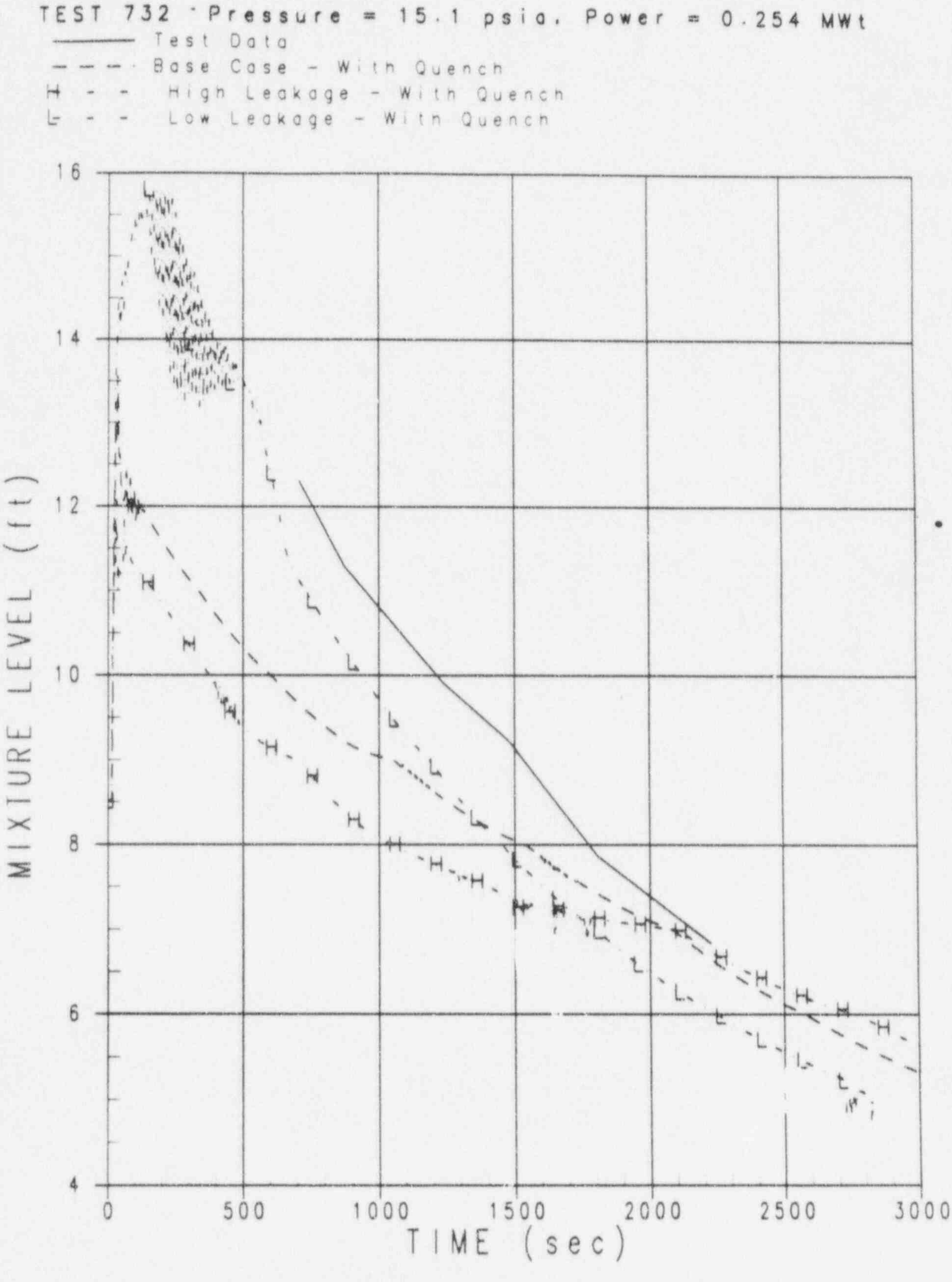

Figure 440.644-1

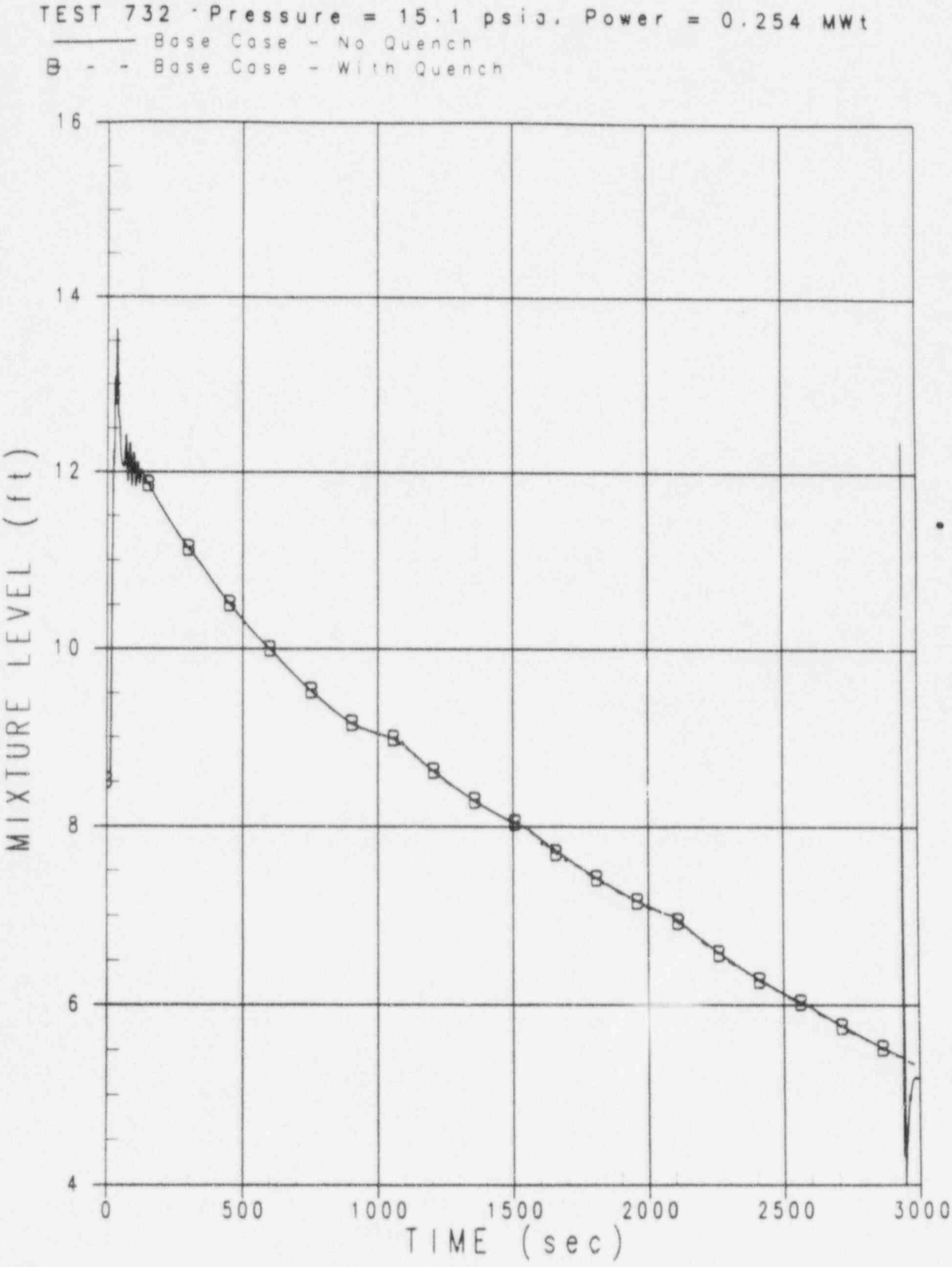

Figure 440.644-1A

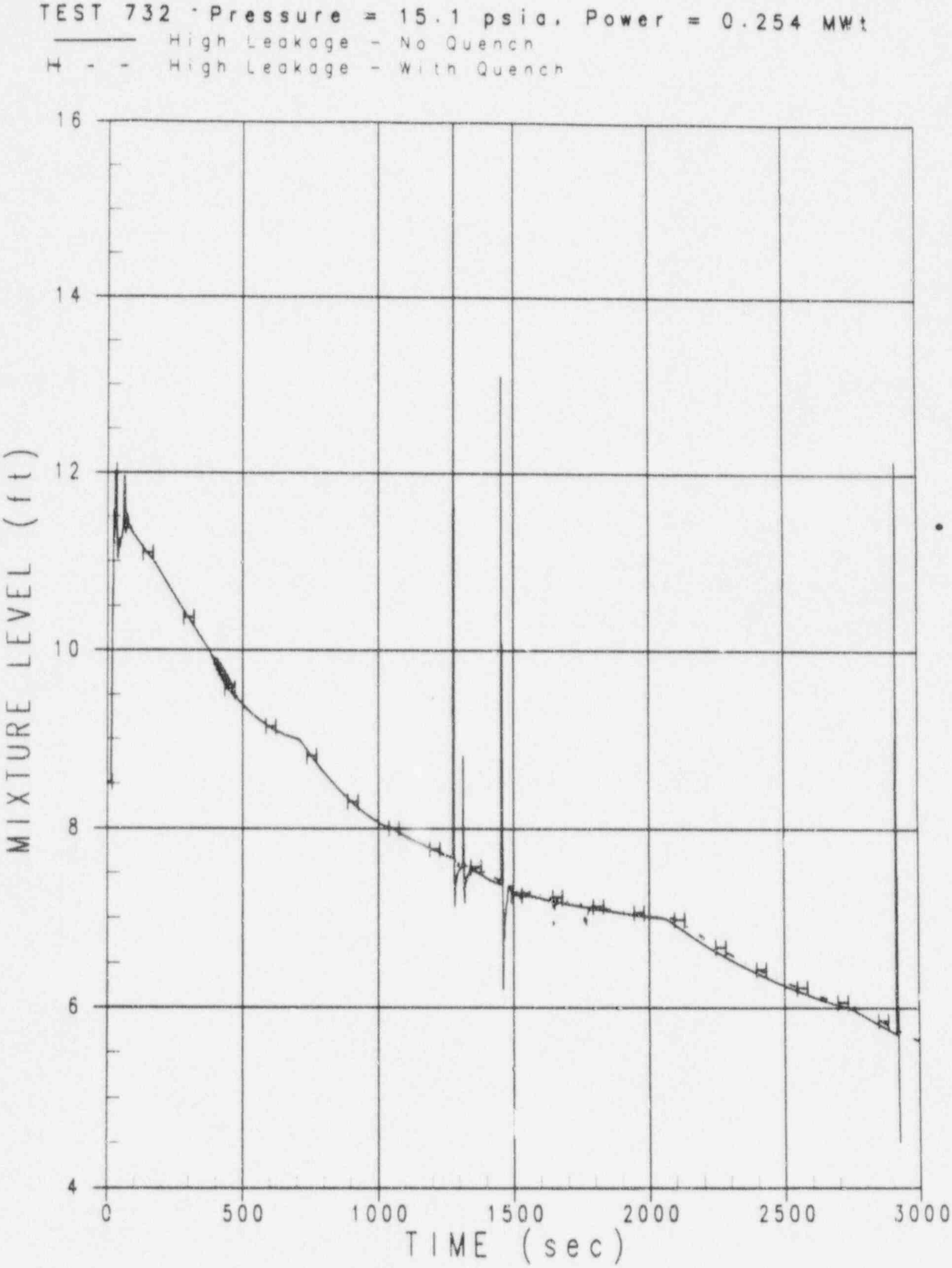

Figure 440.644-1B

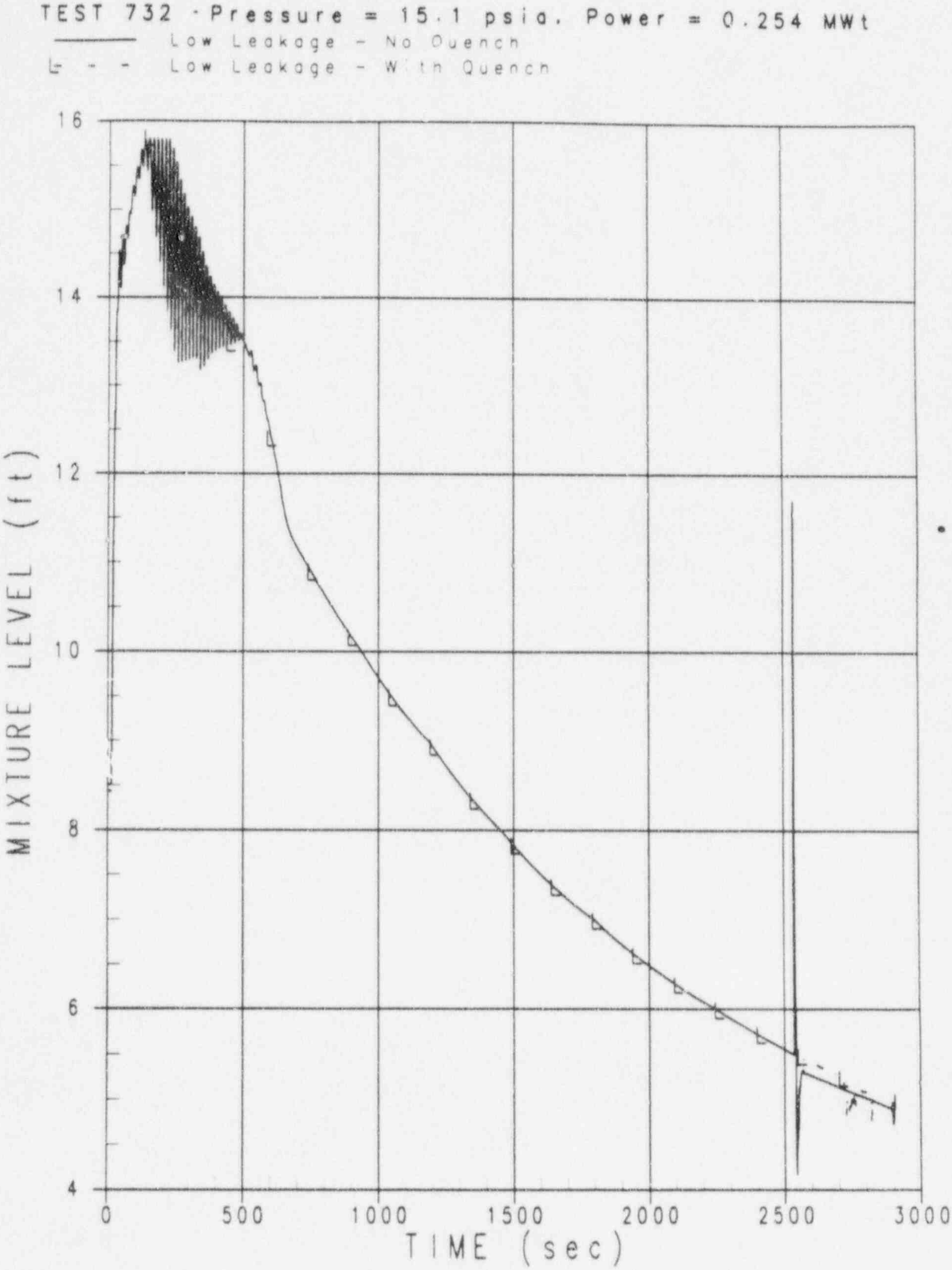

Figure 440.644-1C

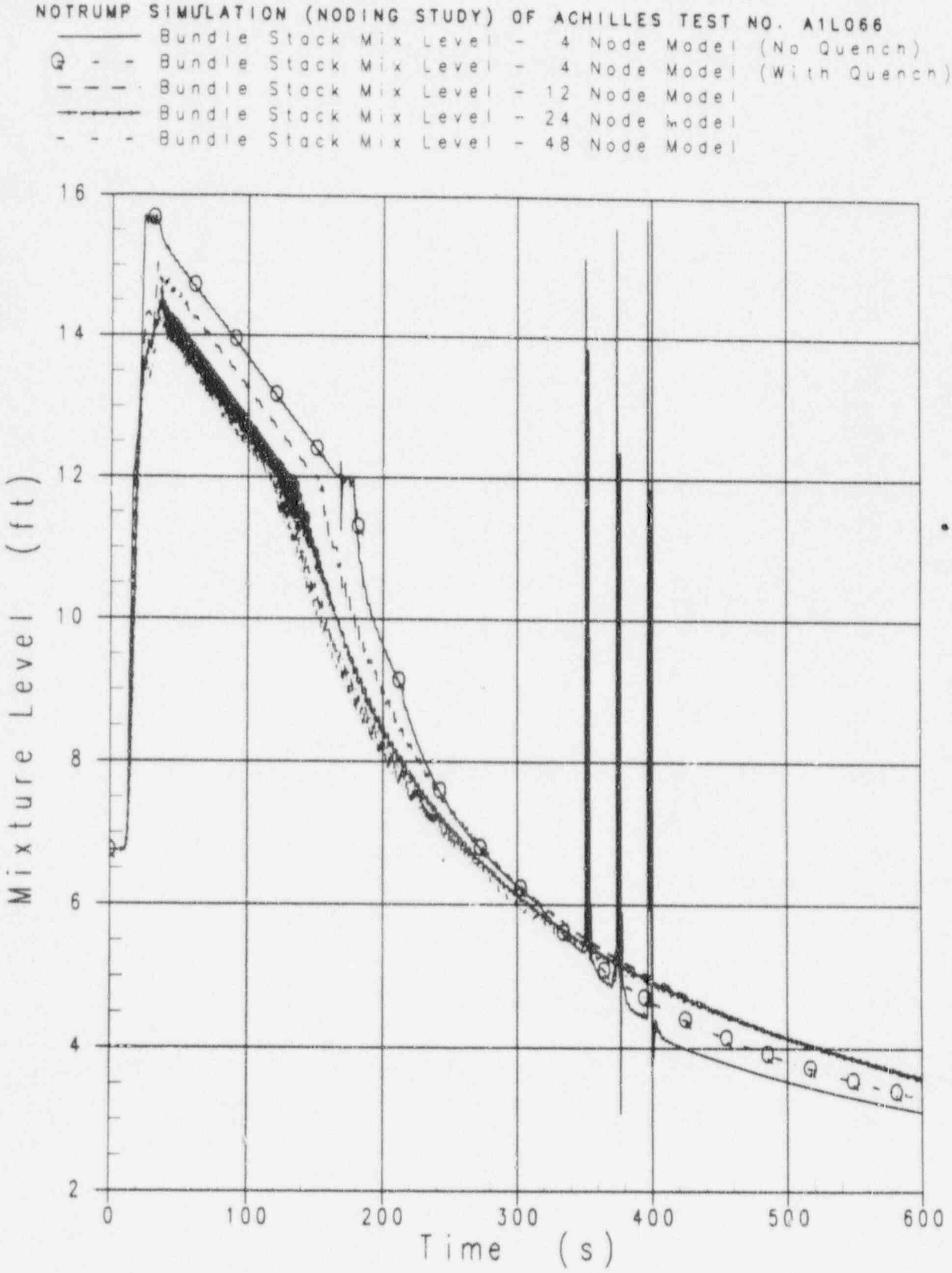

Figure 440.644-2