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Your ref: Docket No. 52-006
Our ref: DCP/NRC1670

January 15, 2004

SUBJECT: Transmittal of Responses to AP1000 DSER Open Items

This letter transmits the Westinghouse responses to Open Items in the AP1000 Design Safety Evaluation Report (DSER). A list of the DSER Open Item responses transmitted with this letter is Attachment 1. The proprietary responses are transmitted as Attachment 2. The non-proprietary responses are provided as Attachment 3 to this letter.

The Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit are also enclosed with this submittal letter as Enclosure 1. Attachment 2 contains Westinghouse proprietary information consisting of trade secrets, commercial information or financial information which we consider privileged or confidential pursuant to 10 CFR 2.790. Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosures.

This material is for your internal use only and may be used for the purpose for which it is submitted. It should not be otherwise used, disclosed, duplicated, or disseminated, in whole or in part, to any other person or organization outside the Commission, the Office of Nuclear Reactor Regulation, the Office of Nuclear Regulatory Research and the necessary subcontractors that have signed a proprietary non-disclosure agreement with Westinghouse without the express written approval of Westinghouse.

D063

January 15, 2004

Correspondence with respect to the application for withholding should reference AW-04-1774, and should be addressed to James A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Please contact me at 412-374-4728 if you have any questions concerning this submittal.

Very truly yours,

R. P. Vijuk, Manager
Passive Plant Engineering
AP600 & AP1000 Projects

/Enclosure

1. Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit AW-04-1774.

/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1670
2. Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated January 15, 2004
3. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated January 15, 2004

Enclosure 1

Westinghouse Electric Company
Application for Withholding and Affidavit

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

January 15, 2004

AW-04-1774

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

ATTENTION: Mr. John Segala

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Transmittal of Westinghouse Proprietary Class 2 Documents Related to AP1000 Design Certification Review Draft Safety Evaluation Report (DSER) Open Item Response

Dear Mr. Segala:

The application for withholding is submitted by Westinghouse Electric Company, LLC ("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 documents. In conformance with 10 CFR Section 2.790, Affidavit AW-04-1774 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 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-04-1774 and should be addressed to the undersigned.

Very truly yours,

R. P. Vijuk, Manager
Passive Plant Engineering
AP600 & AP1000 Projects

/Enclosures

(1) I am Manager, Passive Plant Projects & Development, of the Westinghouse Electric Company LLC ("Westinghouse"), 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 Electric Company, LLC.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR 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 Electric Company, LLC 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 10 CFR 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) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Attachment 2 as Proprietary Class 2 in the Westinghouse Electric Co., LLC document: (1) "AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Response."

This information is being transmitted by Westinghouse's letter and Application for Withholding Proprietary Information from Public Disclosure, being transmitted by Westinghouse Electric Company letter AW-04-1774 to the Document Control Desk, Attention: John Segala, CIPM/NRLPO, MS O-4D9A.

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

(a) Provide documentation supporting determination of APP-GW-GL-700, "AP1000 Design Control Document," analysis on a plant specific basis

(b) Provide the applicable engineering evaluation which establishes the Tier 2 requirements as identified in APP-GW-GL-700.

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 Licensing Documentation.

(b) Westinghouse can sell support and defense of AP1000 Design Certification.

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 methodologies 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 performing and analyzing tests.

Further the deponent sayeth not.

AW-04-1774

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared James W. Winters, 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 Company, LLC ("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.

James W. Winters, Manager
Passive Plant Projects & Development
Nuclear Power Plants Business Unit

Sworn to and subscribed
before me this 15th day
of January, 2004

Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 2007
Member, Pennsylvania Association Of Notaries

DCP/NRC1670
Docket No. 52-006

January 15, 2004

DCP/NRC1670
Docket No. 52-006

January 15, 2004

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) 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 Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

January 15, 2004

Attachment 1

List of

Proprietary and Non-Proprietary Responses

Table 1 "List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1670"	
*Proprietary	*21.5-2P Addendum 1 Revision 1 21.5-2 Addendum 1 Revision 1

DCP/NRC1670
Docket No. 52-006

January 15, 2004

Attachment 3

AP1000 Design Certification Review
Draft Safety Evaluation Report Open Item Non-Proprietary Responses

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 21.5-2 (Response Addendum 1 Revision 1)

Original RAI Number(s): 440.169

Summary of Issue:

The applicant's submittals did not provide sufficient justification that the models and correlations in NOTRUMP or WCOBRA/TRAC have been adequately assessed to cover the ranges expected to occur in the upper plenum of the API 000. While correlations exist to model upper plenum entrainment phenomena, the issue that remains is adequacy of the database. Existing correlations are based on relatively small diameter vessels, low gas flow rates, and for some data, air-water as opposed to steam-water. Because of the small vessel size in these data, conditions were essentially one-dimensional. Flow in the upper plenum of the AP1000 is expected to be non-uniform and three-dimensional. Thus, a suitable database for assessing entrainment correlations in the upper plenum has not been established, Given the lack of well scaled experimental data on upper plenum entrainment phenomena and the importance of predicting this process in an advanced plant SBLOCA transient, it is recommended that new experimental data be obtained to support the use of the upper plenum entrainment models in the AP1000. This data was requested by the NRC staff in a letter dated March 18, 2008, from J, Lyons. Therefore, this is DSER Open Item 21.5-2.

NRC comments from 1/8/04 Conference Call:

Westinghouse needs to address the following regarding OI 21.5-2P Addendum in the August 13, 2003, submittal:

A. The third paragraph on Page 2 of DSER OI 21.5-2P Addendum 1 listed two OSU APEX tests, DBA-02 and DBA-03. The description of these two test conditions regarding the single failure of the ADS-4 is not correct. The DBA-02 test should have an ADS-4 failure on the non-pressurizer side, and the DBA-03 on the pressurizer side. Westinghouse needs to clarify the error.

B. In the last paragraph on page 3, there is a discussion on break modeling. Prediction of the break flow is important in analysis of a small break LOCA such as a DVI line break. The response states that the break flow is "slightly over-predicted." The scale on the figure is deceiving. The NOTRUMP vessel-side break flow rate over the first 100 seconds of the transient is roughly 30% greater than the data break flow.

C. On page 7, the NOTRUMP prediction of ADS-4 integrated mass flow is claimed to be "predicted reasonably" in Figure 21.5-2.25. However, the test data shown in that figure may not be correct. In Figure 21.5-2.25, the test data for DBA-02, given by the solid line, reaches 1000 lbm at 1200 seconds. In Figure 4 (On DSER OI 21.5-2P page 7), the DBA-02 results, shown by the dash line, are that the integrated mass is well below 1000 lbm including the time period to 1500 seconds. Westinghouse needs to clarify the discrepancy between Figure 4 and Figure 21.5-

2.25. If the Figure 4 data is correct, then the NOTRUMP results are not "predicted reasonably", but significantly over-predict the data.

D. Figures 21.5-2.19 and 21.5-2.23 should be re-submitted with the curves clearly identified. It appears that NOTRUMP over-predicts the levels, but the scale and the way the curves are plotted do not allow this to be viewed.

E. On page 5, the discussion on collapsed and two-phase levels, two-dimensional effects and subcooled core inlet temperatures are claimed to occur in the data. NOTRUMP, however, predicts the core inlet fluid to be at saturation between 400 and 100 seconds. Since a collapsed level will swell to a higher level if it is saturated, why does this not suggest a significant non-conservatism in NOTRUMP? Please explain.

F. The start of IRWST injection is significantly early in the NOTRUMP simulation of DBA-02. The claim on Page 7 that "NOTRUMP predicts IRWST flow reasonably well" is not justifiable. Early IRWST injection is non-conservative. Please explain why this discrepancy is considered acceptable in the NOTRUMP code's ability to predict the minimum vessel inventory.

Westinghouse Response: (Addendum 1 Revision 1)

Revision 1 addresses the NRC comments from the 1/8/04 conference call as follows:

A. Response

The test descriptions are corrected in this revision as indicated by the comment.

B. Response

The discussion on break flow comparison (for both DBA02 and DBA03) is modified as shown in the revision below.

C. Response

The figures provided in the stated references are accurate. The information provided in Figure 21.5-2.25 is the total ADS-4 discharge whereas the information provided in Figure 4 (DSER OI 21.5-2P) is the ADS-4 liquid discharge. The differences between these figures represent the vapor discharge out of the ADS-4 flow paths.

D. Response

The requested figures are provided below in color as Figures 1-4.

E. Response

The NOTRUMP core inlet conditions are not saturated but sub-cooled; however, the degree of sub-cooling is ~20 t0 30 °F less than that observed in the tests for the time period from 400 to approximately 1000 seconds. The reduced sub-cooling will result in higher predicted two-phase mixture level as the fluid is heated to saturation conditions. While this would represent a non-conservative behavior in terms of two-phase mixture level in a boiloff situation, the system response during this period of the transient is such that excess inventory exists in the upper plenum and hot leg regions and is swept out of the system via the ADS discharge paths. This also results in the removal of inventory from the vessel such that should a boiloff period be predicted to occur, the NOTRUMP simulation would subsequently conservatively predict this behavior. As long as excess injection flow exists the system stays in this "case B" mode of operation. If injection is reduced and ADS4 demands more flow than the injection can provide, then the level swell model is important in determining if/when the mixture level falls below the top of the core ("Case A" scenario). Note that the APEX-1000 NRC-05 test exhibited this transition from a Case B mode to a Case A mode.

The simulation of test NRC-05 performed with NOTRUMP exhibits the same core inlet sub-cooling mispredictions as observed in both tests DBA-02 and DBA-03; however, core uncovery is predicted quite reasonably by the NOTRUMP simulation. In fact, core uncovery is predicted to occur earlier than observed in the test. Since the Cunningham-Yeh correlation in NOTRUMP tends to underpredict the core void fraction and subsequently the two-phase mixture level under boil-off uncovery conditions, this is considered to be a conservative feature of the analysis model.

F. Response

Figure 21.5-2.28 shows the intact DVI injection flow test data and NOTRUMP prediction for test DBA-02. The NOTRUMP prediction shows CMT emptying in the 850 to 900 second time frame; the test data shows the CMT emptying at 900 to 925 seconds. The NOTRUMP prediction shows IRWST injection beginning at ~1100 to 1150 seconds; the test data shows IRWST injection at ~1200 to 1250 seconds. Thus the period of transition from CMT injection to IRWST injection is offset in time for NOTRUMP versus the test data, but has a similar duration (250 to 300 seconds) to that observed in the test. Figure 21.5-2.53 shows the intact DVI injection flow test data and NOTRUMP prediction for test DBA-03. In this case the test data shows no interruption in injection flow while the NOTRUMP prediction shows a brief interruption during the transition from CMT to IRWST injection. NOTRUMP provides acceptable prediction of the CMT to IRWST transition period.

The NOTRUMP simulations of the OSU tests are not intended to be performed in a conservative fashion. The analysis models for the AP1000 plant simulation are geared towards being conservative as described in the NOTRUMP Final Validation Report for AP600 (Reference 1). The major conservatisms are the use of the ANS 1971 +20% Decay Heat standard and the maximization of passive system component resistances to reduce cooling flows.

WESTINGHOUSE PROPRIETARY CLASS 2

Rev. 0

(a,b,c)

Figure 1:Test DBA-02, Core Collapsed Liquid Level

WESTINGHOUSE PROPRIETARY CLASS 2

Rev. 0

(a,b,c)

Figure 2: Test DBA-02, Downcomer Collapsed Liquid Level

WESTINGHOUSE PROPRIETARY CLASS 2

Rev. 0

(a,b,c)

Figure 3: Test DBA-03, Core Collapsed Liquid Level

WESTINGHOUSE PROPRIETARY CLASS 2

Rev. 0

(a,b,c)

Figure 4: Test DBA-03, Downcomer Collapsed Liquid Level

Westinghouse has provided a previous response to DSER Open Item 21.5-2. This response provides additional information to resolve this DSER Open Item and is labeled 21.5-2P Addendum 1.

In order to provide additional justification for the applicability of the NOTRUMP computer code to the AP1000 plant design, a sensitivity study was performed with the NOTRUMP model for AP1000 which increased upper plenum and hot leg entrainment as described in Reference 21.5-1.1. Additionally, a test plan was developed at the Oregon State University APEX Test facility as modified to reflect the AP1000 plant design. The detailed description of the APEX Test facility, as modified to reflect the AP1000 design, can be found in Reference 21.5-1.2. The APEX test facility has been scaled to the AP1000 plant design, as described in Reference 21.5-1.3, to assure appropriate facility response and support further computer code validation.

The results of the Reference 21.5-1.1 sensitivity study indicate that the AP1000 behavior is relatively insensitive to the amount of entrainment from the upper plenum and hot legs. The Reference 21.5-1.1 sensitivity study was performed assuming that the upper plenum, hot-leg, PRHR inlet and ADS-4 fluid nodes were homogenous, at the time of ADS-4 actuation, which increases potential liquid entrainment. The results indicate sufficient inventory remains in the vessel such that adequate core cooling is maintained. Reference 21.5-1.1 can be reviewed for additional details on the results of this study.

To further confirm the applicability of the NOTRUMP computer code to predict the AP1000 plant behavior for Small Break Loss Of Coolant Accidents (SBLOCAs), the revised OSU APEX test facility (References 21.5-1.2 and 21.5-1.3) was modeled with the Advanced Plant version of the NOTRUMP computer code. The noding diagram utilized for the Reference 21.5-1.3 OSU APEX simulations can be found in Figure 21.5-2.1. The model utilized for these simulations is similar to that utilized for the AP600 APEX simulations with the following exceptions:

- Revised noding in the Pressurizer
- Revised noding in the Core Makeup Tanks

The Pressurizer noding was altered from a single fluid node to multiple fluid nodes (See Figure 21.5-2.2) for several reasons. Firstly, the APEX facility was modified to accommodate the increase in Pressurizer volume required to represent the AP1000 plant design. The modification was such that a section was added to the upper pressurizer. This upper section is a larger diameter than the lower section. Therefore, to properly model the change in geometry requires an additional fluid node be added to the NOTRUMP model. In addition, to improve the predicted void distribution in the Pressurizer, additional fluid nodes were added to represent the Pressurizer surge line and split the common fluid node section, representing the Pressurizer tank, into [ ]a,c individual fluid nodes as can be seen in Figure 21.5-2.2.

The Core Makeup Tank (CMT) model was revised to add additional fluid nodes to enhance the fluid temperature distribution predicted by the NOTRUMP code. Since the NOTRUMP code does not have a thermal stratification model, when warm fluid is introduced to a fluid node, it is assumed to perfectly mix with the existing fluid node. As such, when only a few fluid nodes are modeled, the fluid temperature at the bottom of the CMT begins to artificially heat due to the numerical mixing effect. A sensitivity study was performed which altered the CMT noding from the standard [ ] a,c model to a [ ] a,c model in the AP600 APEX test series in RAI response 440.339 (Reference 21.5-1.5). The conclusions of this sensitivity study were as follows:

> *The conclusions of this study is that using more nodes in the CMTs represents a way to approximately simulate the CMT thermal stratification effects, to help account for the lack of a CMT thermal stratification model in NOTRUMP. This technique can be used to improve the CMT outlet temperature behavior in small break transients. This CMT noding study supports the conclusions of the independent assessments that are being conducted for the preparation of the summary section for Revision 2 of the NOTRUMP Final Validation Report for AP600. The summary section will indicate that the lack of a CMT thermal stratification model and the coarse noding used lead to significant differences in the CMT outlet temperature and resulting small break transient, but that the continued use of the [ ] a,c CMT model is acceptable because its effect on the transient is conservative (high core void fraction, delayed ADS).*

The CMT noding utilized for the studies presented herein are shown in Figure 21.5-2.3. One should note that for the transient results presented herein, the use of the increased CMT noding will not have a significant effect due to the time frame over which the CMTs are emptied for the DVI line break simulations. This was subsequently confirmed via the performance of a CMT noding sensitivity study for the APEX-1000 simulations where the original Reference 21.5-1.4 nodalization was utilized. As expected, revising the CMT noding had little effect on the DEDVI transient simulation results.

The APEX model simulations differ from that utilized in the AP1000 plant design as well. The same differences described above also apply to the modeling differences between the plant model and the OSU model. However, as described above, the CMT noding differences result in a conservative prediction of ADS actuation times and core average void fraction predictions.

Two OSU APEX test simulation results were performed with the Advanced Plant Version of the NOTRUMP computer code. These were:

- Test DBA-02, Double-Ended Direct Vessel Injection Line Break with an ADS-4 single failure on the non-Pressurizer side (ADS 4-1) side.
- Test DBA-03, Double-Ended Direct Vessel Injection Line Break with an ADS-4 single failure on the Pressurizer side (ADS 4-2) side.

The DEDVI line break represents the most severe accident for the AP1000 plant design in that it eliminates a full train of makeup capability. The modeling methodology utilized for the APEX simulations is the same as that utilized for the plant simulations with the following exceptions.

- No passive residual heat exchanger heat transfer [ ] a,c was applied.
- The ADS-4 flow paths were modeled with the [ ] a,c during the transition to non-critical conditions and subsequently the orifice equation for post-critical flow.

The methodology utilized to model the ADS-4 flow paths in the OSU simulations differed from that utilized for the AP1000 plant analysis. In the AP1000 plant simulations, the ADS-4 flow paths are altered from [ ]^{a,c} flow paths to [ ]^{a,c} flow links once non-critical conditions have been reached in both ADS-4 paths. At that time, the FLOAD4 resistance adjustment factor (Reference 21.5-1.5) of [ ]^{a,c} is placed on both ADS-4 flow paths and the transient simulation is continued. Note that the plant and OSU test facility differ in the ADS-4 flow path in that for the plant, the ADS-4 squib valve is the last component in the path and discharges directly to containment. For APEX, the squib valve is represented by a flow venturi with subsequent piping to the ADS-4 separator. This level of detail is not represented in the NOTRUMP model for the APEX test facility. For the APEX simulations performed herein, the ADS-4 flow links in the NOTRUMP model utilized the [ ]^{a,c}. This model was selected based on the results of comparisons of predicted with measured ADS-4 flow. In order to assess the effect of the change in modeling methodology on the AP1000 plant results, the DEDVI line break, assuming atmospheric containment conditions, was re-performed with the same modeling assumption as utilized for the APEX test facility [ ]^{a,c}. The results obtained indicate only a minor change in the predicted ADS-4 behavior and subsequently IRWST injection behavior. To further supplement this conclusion, the APEX-600 test series Double-Ended DVI line break (Test SB12) was also re-performed utilizing the revised ADS-4 methodology. Again, only minor differences in ADS-4 flow and subsequently IRWST injection times were observed.

The NOTRUMP simulation result comparisons of tests DBA-02 and DBA-03 are presented below.

Comparison of NOTRUMP Simulation to Test Data For Test DBA-02

Figure 21.5-2.4 and Figure 21.5-2.5 compare the pressure at the top of the pressurizer and downcomer regions for the test and the NOTRUMP simulation. The pressure decreases initially due to the blowdown through the break. The depressurization rate slows (and stops for NOTRUMP) when the primary system becomes saturated. Following actuation of ADS-1 at [ ]^{a,b} seconds in the test (81.3 seconds for NOTRUMP), the depressurization rate increases significantly. The downcomer pressure is provided since this pressure ultimately controls the onset of intact IRWST (IRWST-2) injection. The trends observed in the downcomer pressure closely follow that observed in the pressurizer. The agreement between the test data and the prediction are reasonable since the trends observed are similar.

Figure 21.5-2.6 shows the collapsed liquid level in the pressurizer for the test and the NOTRUMP simulation. The break flow causes a rapid decrease in pressurizer level and empties the pressurizer at approximately [ ]^{a,b} seconds for the test and 70 seconds for the NOTRUMP simulation. The pressurizer level increases following ADS actuation for both the test and the simulation with NOTRUMP initially refilling faster than the test until ADS-2 actuation. The NOTRUMP simulation collapsed mixture level recovers to slightly lower level following ADS actuation compared to that observed in the test facility. Following ADS-4 actuation, both the test and NOTRUMP simulations indicate a period of continued pressurizer refill until the ADS-4 flow paths become dominant. The collapsed level predicted by NOTRUMP decreases in a similar manner to that observed in the test following ADS-4 actuation. Therefore, the NOTRUMP results are considered to be in reasonable agreement with the test data.

Figure 21.5-2.7 and Figure 21.5-2.8 shows the collapsed liquid levels in CMT-1 and CMT-2 for the test and the NOTRUMP simulation respectively. In the test, CMT-1, which is attached to the broken DVI line begins draining out the break at [ ]^{a,b} seconds in the test compared to 20 seconds for the NOTRUMP simulation. This can also be seen in the CMT injection flow plots (Figure 21.5-2.9 and Figure 21.5-2.10). As such, the NOTRUMP simulation transitions from re-circulation to draindown mode earlier than observed in the test and subsequently predicts higher injection flows. CMT-2 transitions from recirculation to draindown mode at about [ ]^{a,b} seconds (150 seconds for NOTRUMP). The comparisons indicate that the NOTRUMP intact CMT drains slightly earlier than observed in the test. This is due to the earlier predicted emptying of the intact Accumulator (Figure 21.5-2.16 and Figure 21.5-2.28). The conclusions that can be reached are that the NOTRUMP CMT predictions are considered to be in reasonable agreement with the test data. The under-prediction of the transition to CMT-1 draindown mode negligibly impacts the predicted ADS-1 actuation time compared to the test results and is considered reasonable.

Figure 21.5-2.11 through Figure 21.5-2.14 present the collapsed steam generator level comparisons between the test and NOTRUMP simulations. As can be seen, the NOTRUMP results are in good agreement with the test data.

Figure 21.5-2.15 and Figure 21.5-2.16 presents the collapsed liquid levels in accumulator 1 and accumulator 2 for the test and the NOTRUMP simulation. The comparison between the test and the NOTRUMP simulation is considered good for both accumulators with the interruption of accumulator 1 discharge appropriately presented by the NOTRUMP simulation following the transition of CMT-1 from recirculation to draindown mode.

The next series of plots relate to the collapsed and two-phase levels at different locations in the vessel. The trends of the simulation plots are in reasonable agreement with the test up to approximately ADS-2 actuation. Following ADS-2 actuation, the test and NOTRUMP simulations diverge as a result of the test-observed, two-dimensional downcomer behavior which cannot be modeled with the NOTRUMP [ ]^{a,c} downcomer (See Reference 21.5-1.5 for additional details). A review of the core inlet temperature (Figure 21.5-2.29) indicates that the NOTRUMP simulation is predicting sub-cooled conditions whereas the test indicates saturated core entry exist. This can be partly attributed to the lack of two-dimensional downcomer modeling and partly due to heating of the intact DVI injection flow as it impinges on the core barrel. The NOTRUMP model has appropriate heat transfer models from fluid to metal structures in the downcomer fluid node but does not account for the heating of the injected fluid as it impinges onto the core barrel. As such, the injected fluid will retain higher sub-cooling than would be observed in the test facility. To assess the impact of downcomer sub-cooling on the transient simulations, a sensitivity was performed with NOTRUMP in which the intact DVI fluid streams (CMT and Accumulator) were heated to [ ]^{a,c}. The results indicate the divergence observed between the test and NOTRUMP simulation was significantly reduced although not totally eliminated (Figure 21.5-2.17 and Figure 21.5-2.18). This indicates that core inlet sub-cooling, or lack thereof, is partly responsible for the divergence between the NOTRUMP simulation and the test response.

The core collapsed level (Figure 21.5-2.19) plot is in reasonable agreement with the test up to approximately ADS-2 actuation. However, they diverge between [ ]^{a,b} and [ ]^{a,c} seconds due to lack of two-dimensional downcomer modeling and heating of DVI injection flow as discussed above. The core behavior between the test observed and NOTRUMP predictions re-converge at approximately [ ]^{a,c} seconds. In both cases, the core level initially decreases as inventory is lost from the system. The levels increase following accumulator injection. Once the accumulators empty, the levels continue to increase as a result of CMT-2 injection. Following CMT-2 empty, an injection gap period is encountered. During this period, the core collapsed level slowly decreases until IRWST-2 injection occurs. Since the NOTRUMP simulation predicts a slightly early IRWST-2 injection compared to the test results, it exhibits an earlier recovery than observed in the test. However, the level response is similar between the simulation and test data. A comparison of the core average void fraction is provided as Figure 21.5-2.20. This figure shows lower predicted void fractions during the same divergence period as described above; however, once the conditions re-converge at near [ ]^{a,c} seconds, the NOTRUMP simulation and test data are in reasonable agreement for the remainder of the transient.

The collapsed upper plenum level (Figure 21.5-2.21) indicates that both NOTRUMP and the test simulation have a significant amount of fluid in this region. The upper plenum collapsed level response in the NOTRUMP simulation indicates more sensitivity to the injection gap period than observed in the test (i.e. NOTRUMP predicting a higher inventory loss compared to the test over the injection gap period). The upper plenum two-phase level (Figure 21.5-2.22) follows the same trends as observed in the core and downcomer, that being that the trends are followed reasonably well until ADS-2 through about [ ]^{a,c} seconds. The two-phase level information indicates that both the test and NOTRUMP simulations behave similarly during the injection gap period with both the test and simulation indicating a decrease in mixture level until IRWST-2 injection commences. The NOTRUMP simulation and test data are considered to be in reasonable agreement.

Figure 21.5-2.23 shows the collapsed liquid level in the downcomer for the test and the NOTRUMP simulation. Again there is reasonable agreement between the test and the simulation up to ADS-2 actuation. Following ADS-2 actuation, the test-observed and NOTRUMP-predicted behavior, while similar in trend, diverge. This is once again attributed to the lack of two-dimensional capability in the NOTRUMP [ ]a,c downcomer (see Reference 21.5-1.5 for additional details) and downcomer sub-cooling as described previously. As such, the downcomer levels are predicted reasonably well by NOTRUMP up to ADS-2 actuation and with the noted discrepancy between ADS-2 and [ ]a,c seconds. The comparisons are considered to be reasonable beyond [ ]a,c seconds.

These comparisons demonstrate that the highly ranked PIRT items related to the levels in the core, upper plenum, and downcomer are predicted reasonably well by NOTRUMP up to ADS-2 actuation and with the noted discrepancy between ADS-2 and [ ]a,c seconds. The comparisons are once again considered reasonable beyond [ ]a,c seconds. The discrepancy period is not considered to be a serious deficiency as the vessel inventory at the critical time of intact IRWST injection is reasonably predicted by NOTRUMP and is consistent with past observations for the DVI line break (Reference 21.5-1.5).

Figure 21.5-2.24 presents a comparison of the vessel mixture inventory between the test and NOTRUMP simulation. As can be seen, the NOTRUMP simulation generally under-predicts the test data with the exception of the period of divergence between ADS-2 and [ ]a,c seconds. This indicates that during the time region of importance, (i.e. Post ADS-4 to IRWST injection) that the NOTRUMP code conservatively predicts the vessel conditions. The slightly early IRWST-2 injection, predicted by NOTRUMP, is clearly seen in this figure as the point at which the minimum inventory is predicted. This indicates that the NOTRUMP code is performing reasonably.

Figure 21.5-2.25 shows the integrated mass flow through ADS stage-4 for the test and the NOTRUMP simulation. These curves show that the ADS stage-4 flow is slightly over-predicted by NOTRUMP after about 450 seconds. The flows match reasonably well as indicated by the parallel behavior of the integrated flow curves and the observed trends. This agreement in the slope of the curves demonstrates that the PIRT highly ranked items related to ADS stage-4 (critical flow, two-phase pressure drop, and valve loss coefficients) are predicted reasonably by NOTRUMP.

Figure 21.5-2.26 shows the integrated mass flow out of the break for the test and the NOTRUMP simulation. For this simulation, the NOTRUMP model applied a discharge coefficient of [ ]a,b to more accurately represent the results observed in the test. Differences in modeling of the break and break measurement system in the test and NOTRUMP simulations also affects the results. This is described

In more detail in the response to RAI.440.721(d) (Reference 21.5-1.8). The integrated break flow predicted by NOTRUMPshows the general trends of the test break flow. The NOTRUMP break flow model used for the DCD AP1000 analysis predicts higher break flow for equivalent conditions than the break flow model used for the NOTRUMP test simulations This demonstrates that the PIRT highly ranked item of break critical flow can be conservatively predicted by NOTRUMP.

Figure 21.5-2.27 and Figure 21.5-2.28 show the total DVI line flow rates between the NOTRUMP simulation and the test for DVI line 1 and DVI line 2 respectively. The simulation data, provided for DVI line 1, represents the break flow from the DVI side piping of the DEDVI break. As can be seen, although the trends are predicted, the behavior of the ruptured DVI line (DVI-1) over-predicts the initial CMT draindown rate as described earlier. This causes an early prediction of ADS actuation for the NOTRUMP simulation compared to the test prediction. However, this is assessed to have a minimal impact on the results. As such, the results are considered reasonable. Figure 21.5-2.28 presents the intact side DVI line flow (DVI-2) for both the test and NOTRUMP simulation. The results indicate that the intact side DVI flow is predicted well by NOTRUMP. Since this path represents the makeup source, it represents an important characteristic that is well predicted by the NOTRUMP simulation.

Figure 21.5-2.29 and Figure 21.5-2.30 present the core inlet and core outlet temperatures between the test and NOTRUMP simulation respectively. The core inlet temperature is approximately the same as the simulation until approximately 150 seconds of the transient, while the outlet temperature is predicted well. After 300 seconds, the core inlet fluid temperature is over-predicted and is likely due to the removal of the PRHR model from the NOTRUMP simulation to conservatively account for the potential accumulation of non-condensable gases in the PRHR tubes, which cannot be directly modeled with NOTRUMP. As such, the NOTRUMP comparisons are considered reasonable.

Comparison of NOTRUMP Simulation to Test Data For Test DBA-03

Figure 21.5-2.31 and Figure 21.5-2.32 compare the pressure at the top of the pressurizer and downcomer regions for the test and the NOTRUMP simulation. The pressure decreases initially due to the blowdown through the break. The depressurization rate slows (and stops for NOTRUMP) when the primary system becomes saturated. Following actuation of ADS-1 at [ ][a,b] seconds in the test (84.4 seconds for NOTRUMP), the depressurization rate increases significantly. NOTRUMP predicts a higher pressure than observed in the test for most of the time. The trends observed in the pressurizer are also observed in the downcomer pressure response as well. As such, the agreement between the test data and the prediction is considered to be reasonable for the primary pressure response with the trends of the data being similar to that observed in the test.

Figure 21.5-2.33 shows the collapsed liquid level in the pressurizer for the test and the NOTRUMP simulation. The break flow causes a rapid decrease in pressurizer level and empties the pressurizer at approximately [ ]^{a,b} seconds for the test and 70 seconds for the NOTRUMP simulation. The pressurizer level increases following ADS actuation for both the test and the simulation with NOTRUMP initially refilling faster than the test until ADS-2 actuation. The NOTRUMP simulation collapsed mixture level recovers to approximately the same level following ADS actuation. Following ADS-4 actuation, both the test and NOTRUMP simulations indicate a period of continued pressurizer refill until the ADS-4 flow paths become the dominant depressurization paths. The pressurizer collapsed level decreases in a similar manner following ADS-4 actuation for both the simulation and the test data. Therefore, the NOTRUMP results are considered to be in reasonable agreement with the test data.

Figure 21.5-2.34 and Figure 21.5-2.35 shows the collapsed liquid levels in CMT-1 and CMT-2 for the test and the NOTRUMP simulation respectively. In the test, CMT-1, which is attached to the broken DVI line begins draining out the break at [ ]^{a,b} seconds in the test compared to 20 seconds for the NOTRUMP simulation. This can also be seen in the CMT injection flow plots (Figure 21.5-2.36 and Figure 21.5-2.37). As such, the NOTRUMP simulation transitions from re-circulation to draindown mode earlier than observed in the test and subsequently predicts higher injection flows. The comparisons indicate that the NOTRUMP intact CMT drains earlier than observed in the test. This is due to both the earlier predicted emptying of the intact Accumulator by the NOTRUMP simulation (Figure 21.5-2.43 and Figure 21.5-2.53) and the earlier IRWST injection observed in the test. The conclusions that can be reached are that the NOTRUMP results for the CMT behavior is considered to be in reasonable agreement with the test data. The under-prediction of the transition to CMT-1 draindown mode negligibly impacts the predicted ADS-1 actuation time compared to the test results and is considered reasonable.

Figure 21.5-2.38 through Figure 21.5-2.41 present the collapsed steam generator level comparisons between the test and NOTRUMP simulations. As can be seen, the NOTRUMP results are in good agreement with the test data.

Figure 21.5-2.42 and Figure 21.5-2.43 shows the collapsed liquid levels in accumulator 1 and accumulator 2 for the test and the NOTRUMP simulation. As can be seen, the intact accumulator injection characteristics differ significantly between the NOTRUMP simulation and the test. When one reviews the injection characteristics compared to test DBA-02, the intact accumulator differs in an unexpected fashion. Since the differences between test DBA-02 and test DBA-03 are limited to the ADS-4 failure location, the changes expected, between test DBA-02 and DBA-03, should occur following ADS-4 actuation. However, as can be seen the transients diverge prior to this time. The comparison between the test and the NOTRUMP simulation is considered good for accumulator 1; however, the comparison for accumulator 2 is considered minimal. The minimal prediction is considered to have a negligible impact on the results as the composite effect of CMT and accumulator injection is reasonably/conservatively predicted by NOTRUMP. This is particularly evident in the time period prior to IRWST injection during which the NOTRUMP vessel mass is conservatively predicted relative to the test (Figure 21.5-2.49).

The next series of plots relate to the collapsed and two-phase levels at different locations in the vessel. The trends of the simulation plots are in reasonable agreement with the test up to approximately ADS-2 actuation. Following ADS-2 actuation, the test and NOTRUMP simulations diverge as a result of the test-observed, two-dimensional downcomer behavior which cannot be modeled with the NOTRUMP [ ]^{a,c} downcomer (See Reference 21.5-1.5 for additional details) and the downcomer sub-cooling as described in the previous discussion of test DBA-02.

The core collapsed level (Figure 21.5-2.44) plot is in reasonable agreement with the test up to approximately ADS-2 actuation. However, they diverge time between [ ]^{a,b} and [ ]^{a,c} seconds as discussed above. The core behavior between the test observed and NOTRUMP predictions re-converge at approximately [ ]^{a,c}. In both cases, the core level initially decreases as inventory is lost from the system. The levels increase following accumulator injection. Once the accumulators empty, the levels continue to increase as a result of CMT-2 injection. For this case, the test indicates that continuous injection will occur while the NOTRUMP simulation indicates an injection gap period will occur. During this predicted injection gap, the NOTRUMP core mixture level decreases slightly until IRWST-2 injection occurs at which time a core level recovery occurs. A comparison of the core average void fraction is provided as Figure 21.5-2.45. This figure shows lower predicted void fractions during the same divergence period as described above; however, once the conditions re-converge at near [ ]^{a,c} seconds, the NOTRUMP simulation and test data are in reasonable agreement for the remainder of the transient.

The collapsed upper plenum level (Figure 21.5-2.46) indicates that both NOTRUMP and the test simulation have a significant amount of fluid in this region as was observed in test DBA-02. The upper plenum collapsed level response in the NOTRUMP simulation indicates the same behavior as observed in the test. The upper plenum two-phase level (Figure 21.5-2.47) follows the same trends as observed in the core and downcomer, that being that the trends are followed reasonably well until ADS-2 through about [ ]^{a,c} seconds. The comparisons also indicate that that the NOTRUMP simulation does not recover the two-phase level as quickly as a result of the predicted injection gap as compared to the test observed conditions.. Following IRWST injection, the test indicates a more rapid increase in the two-phase mixture level as compared to the NOTRUMP simulation, which increases more slowly. As such, the two-phase mixture level is conservatively predicted by NOTRUMP following intact IRWST injection and is considered reasonable.

Figure 21.5-2.48 shows the collapsed liquid level in the downcomer for the test and the NOTRUMP simulation. Again there is reasonable agreement between the test and the simulation up to ADS-2 actuation. Following ADS-2 actuation, the test-observed and NOTRUMP-predicted behavior diverges. This is attributed to the lack of two-dimensional capability in the NOTRUMP [ ]^{a,c} downcomer (see Reference 21.5-1.5 for additional details) and downcomer sub-cooling as described previously. As such, the downcomer levels are predicted reasonably well by NOTRUMP up to ADS-2 actuation and with the noted discrepancy between ADS-2 and [ ]^{a,c} seconds. The comparisons are considered to be reasonable beyond [ ]^{a,c} seconds.

These comparisons demonstrate that the highly ranked PIRT items related to the levels in the core, upper plenum, and downcomer are predicted reasonably well by NOTRUMP up to ADS-2 actuation and with the noted discrepancy between ADS-2 and [ ]^{a,c} seconds. The comparisons are once again considered reasonable beyond [ ]^{a,c} seconds.

Figure 21.5-2.49 presents a comparison of the vessel mixture inventory between the test and NOTRUMP simulation. As can be seen, the NOTRUMP simulation generally under-predicts the test data with the exception of the period of divergence between ADS-2 and [ ]^{a,c} seconds. This indicates that during the time region of importance, (i.e. Post ADS-4 to IRWST injection) that the NOTRUMP code conservatively predicts the vessel conditions. The delay in the predicted IRWST-2 injection is clearly seen in this figure as the point at which the minimum inventory is predicted. This indicates that the NOTRUMP code is performing reasonably.

Figure 21.5-2.50 shows the integrated mass flow through ADS stage-4 for the test and the NOTRUMP simulation. These curves show that the ADS stage-4 flow is slightly over-predicted by NOTRUMP. This comparison demonstrates that the PIRT highly ranked items related to ADS stage-4 (critical flow, two-phase pressure drop, and valve loss coefficients) are predicted reasonably by NOTRUMP.

Figure 21.5-2.51 shows the integrated mass flow out of the break for the test and the NOTRUMP simulation. For this simulation, the NOTRUMP model applied a discharge coefficient of [ ][a,b] to more accurately represent the results observed in the test. The integrated break flow predicted by NOTRUMP shows the general trends of the test break flow. The NOTRUMP break flow model used for the DCD AP1000 analysis predicts higher break flow for equivalent conditions than the break flow model used for the NOTRUMP test simulations. Differences in modeling of the break and break measurement system in the test and NOTRUMP simulations also affects the results. This is described in more detail in the response to RAI.440.721(d) (Reference 21.5-1.8). The test observed conditions indicate additional liquid discharge occurring at approximately [ ][a,c] seconds as a result of the higher observed downcomer mixture level compared to the NOTRUMP predicted results. In addition, since the test indicates earlier IRWST injection, compared to the NOTRUMP simulation, the break flows follow this trend as well. The general trends of the test break flow are similar to the NOTRUMP prediction. This demonstrates that the PIRT highly ranked item of break critical flow can be conservatively predicted by NOTRUMP.

Figure 21.5-2.52 and Figure 21.5-2.53 show the total DVI line flow rates between the NOTRUMP simulation and the test for DVI line 1 and DVI line 2 respectively. The simulation data, provided for DVI line 1, represents the break flow from the DVI side piping of the DEDVI break. As can be seen, although the trends are predicted, the behavior of the ruptured DVI line (DVI-1) over-predicts the initial CMT draindown rate. This results in an early prediction of ADS actuation for the NOTRUMP simulation compared to the test prediction. However, this is assessed to have a minimal impact on the results. As such, the results are considered reasonable. Figure 21.5-2.53 presents the intact side DVI line flow (DVI-2) for both the test and NOTRUMP simulation. The results indicate that the intact side DVI flow is predicted reasonably by NOTRUMP.

Figure 21.5-2.54 and Figure 21.5-2.55 present the core inlet and core outlet temperatures between the test and NOTRUMP simulation respectively. The core inlet temperature is approximately the same as the simulation until approximately 150 seconds of the transient, while the outlet temperature is predicted well. After 300 seconds, the core inlet fluid temperature is over-predicted and is likely due to the removal of the PRHR model from the NOTRUMP simulation to conservatively account for the potential accumulation of non-condensable gases in the PRHR tubes, which cannot be directly modeled with NOTRUMP. As such, the NOTRUMP comparisons to considered reasonable for the modeling capability available.

Overall Conclusions

The following conclusions can be reached by reviewing the NOTRUMP predicted response compared to the test observed conditions:

- NOTRUMP predicts the effect of the ADS-4 single failure location as observed in the test.
- NOTRUMP conservatively predicts vessel inventory during the ADS-4 to IRWST injection period.
- NOTRUMP predicts the pressurizer mixture level performance reasonably well.
- NOTRUMP predicts IRWST injection flow reasonably well.
- The divergence of vessel inventory between ADS-2 actuation to approximately [ ][a,c] seconds is a multi-dimensional effect and sub-cooling effect which can not be properly modeled by NOTRUMP; however, the duration of this period is small and the ADS-4 to IRWST injection period is considered to be reasonable.
- The results indicate that the NOTRUMP code performs reasonably compared to tests designed specifically for comparisons to the AP1000 plant design. As such, it continues to be applicable for analyses of SBLOCA events for the AP1000 plant design.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

WCAP Revision:

The information from this RAI response will be incorporated into WCAP-15644, AP1000 Code Applicability Report.

References:

21.5-1.1 DSER Open Item 21.5-1 Response.

21.5-1.2 OSU-APEX-03002, Revision 0, OSU Facility Description Report for AP1000 Simulation Series, K. C. Abel, et al., Oregon State University, Department of Nuclear Engineering, May 12, 2003.

21.5-1.3 OSU-APEX-03001, Revision 0, Scaling Assessment for the Design of the OSU APEX-1000 Test Facility, J. Reyes, et al., Oregon State University, Department of Nuclear Engineering, May 12, 2003.

21.5-1.4 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 2, Section 8.0, August 1998.

21.5-1.5 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 3, Appendix-A, RAI-440.796F, Part a, August 1998.

21.5-1.6 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 1, Section 6, August 1998.

21.5-1.7 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 3, RAI 440-339, August 1998.

21.5-1.8 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 3, RAI 440-721(d), August 1998.

21.5-1.9 WCAP-14807, Revision 5, NOTRUMP Final Validation Report for AP600, Volume 3, RAI 440-721(f), August 1998.

a, c

Figure 21.5-2.1 APEX NOTRUMP Original Noding Diagram a, c

Figure 21.5-2.2 APEX Pressurizer Model Modifications

CMT-1 CMT-2

a,c

Figure 21.5-2.3 APEX Core Makeup Tank Model Modifications

21.5-1.1 DBA-02: Double-Ended Injection Line Break w/ Single Failure in ADS 4-1 Path Sequence of Events

Event	Test Data Time (seconds) a,c	NOTRUMP Time (seconds)
Break opens		0.0
Reactor trip signal		0.0
Steam turbine stop valves close		0.0
CMT Isolation Valves Open		8.2
Main feed isolation valves begin to close		3.1
Reactor coolant pumps start to coast down		8.2
		8.2
		8.2
		8.2
ADS Stage 1		81.33
Intact accumulator injection starts		122
ADS Stage 2		128.33
ADS Stage 3		188.33
ADS Stage 4-1		246.33
ADS Stage 4-2		276.33
Intact accumulator empties		349.05
Intact loop core makeup tank empties		908
Intact loop IRWST injection starts*		1122
		1150*

Note:
*Continuous injection period

21.5-1.2 DBA-03: Double-Ended Injection Line Break w/ Single Failure in ADS 4-2 Path Sequence of Events

Event	Test Data Time (seconds) a,c	NOTRUMP Time (seconds)
Break opens		0.0
Reactor trip signal		0.0
Steam turbine stop valves close		0.0
CMT Isolation Valves Open		8.2
Main feed isolation valves begin to close		3.1
Reactor coolant pumps start to coast down		8.2
		8.2
		8.2
		8.2
ADS Stage 1		84.22
Intact accumulator injection starts		123
ADS Stage 2		131.22
ADS Stage 3		191.22
ADS Stage 4-2		249.23
ADS Stage 4-1		279.23
Intact accumulator empties		346.44
Intact loop core makeup tank empties		922
Intact loop IRWST injection starts*		930
		975*

Note:
*Continuous injection period

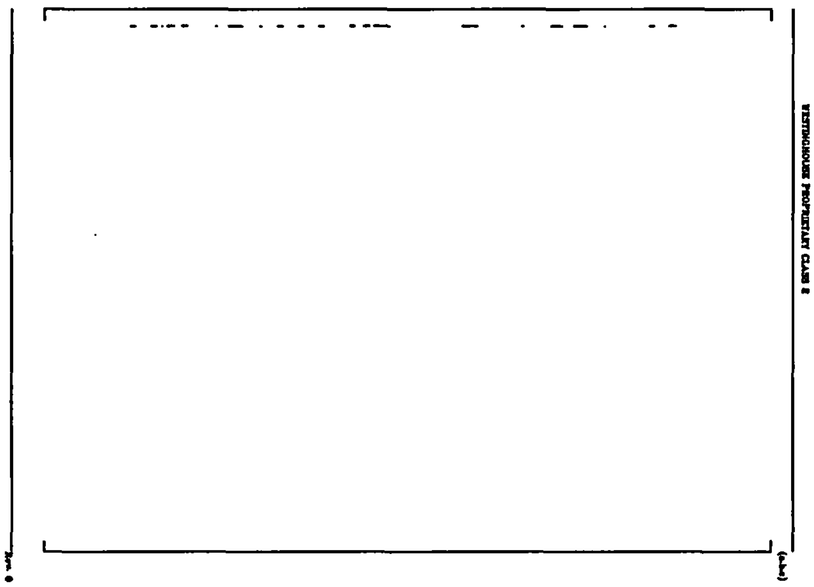

Figure 21.5-2.4 Test DBA-02, Pressurizer Pressure Comparison

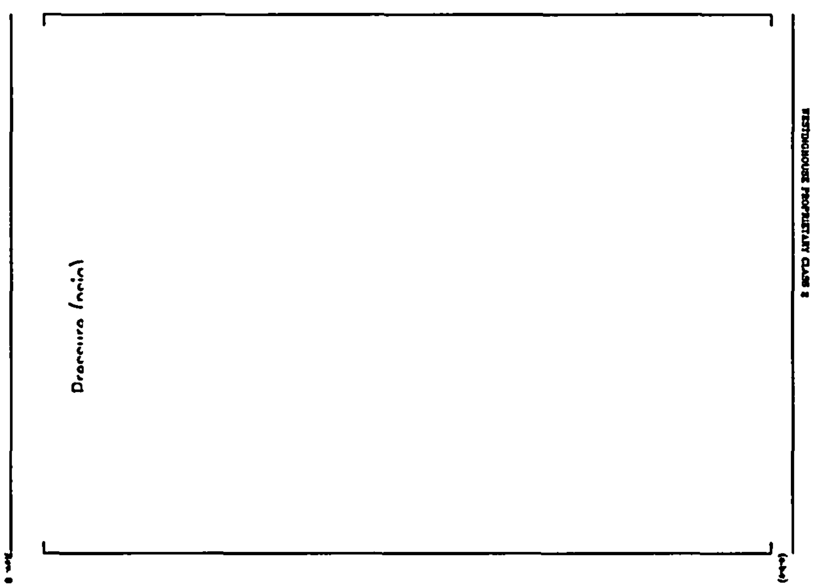

Figure 21.5-2.5 Test DBA-02, Downcomer Pressure Comparison

Figure 21.5-2.6 Test DBA-02, Pressurizer Collapsed Level

Figure 21.5-2.7 Test DBA-02, CMT-1 Collapsed Liquid Level

Figure 21.5-2.8 Test DBA-02, CMT-2 Collapsed Liquid Level

Figure 21.5-2.9 Test DBA-02, CMT-1 Injection Flow

Figure 21.5-2.10 Test DBA-02, CMT-2 Injection Flow

Figure 21.5-2.11 Test DBA-02, SG-2 Hot Side Collapsed Liquid Level

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Figure 21.5-2.12 Test DBA-02, SG-2 Cold Side Collapsed Liquid Level

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Figure 21.5-2.13 Test DBA-02, SG-1 Hot Side Collapsed Liquid Level

Figure 21.5-2.14 Test DBA-02, SG-1 Cold Side Collapsed Liquid Level

Figure 21.5-2.15 Test DBA-02, ACC-1 Collapsed Liquid Level

Figure 21.5-2.16 Test DBA-02, ACC-2 Collapsed Liquid Level

Figure 21.5-2.17 Test DBA-02, DC Sub-cooling Sensitivity, Core Collapsed Liquid Level

Figure 21.5-2.18 Test DBA-02, DC Sub-cooling Sensitivity Downcomer Collapsed Liquid Level

Figure 21.5-2.19 Test DBA-02, Core Collapsed Liquid Level

Figure 21.5-2.20 Test DBA-02, Core Average Void Fraction

Figure 21.5-2.21 Test DBA-02, Upper Plenum Collapsed Liquid Level

Figure 21.5-2.22 Test DBA-02, Upper Plenum Two-Phase Mixture Level

Figure 21.5-2.23 Test DBA-02, Downcomer Collapsed Liquid Level

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Figure 21.5-2.24 Test DBA-02, RPV Mixture Mass

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Rev. 0 (a,b,c)

Figure 21.5-2.25 Test DBA-02, Integrated ADS-4 Discharge

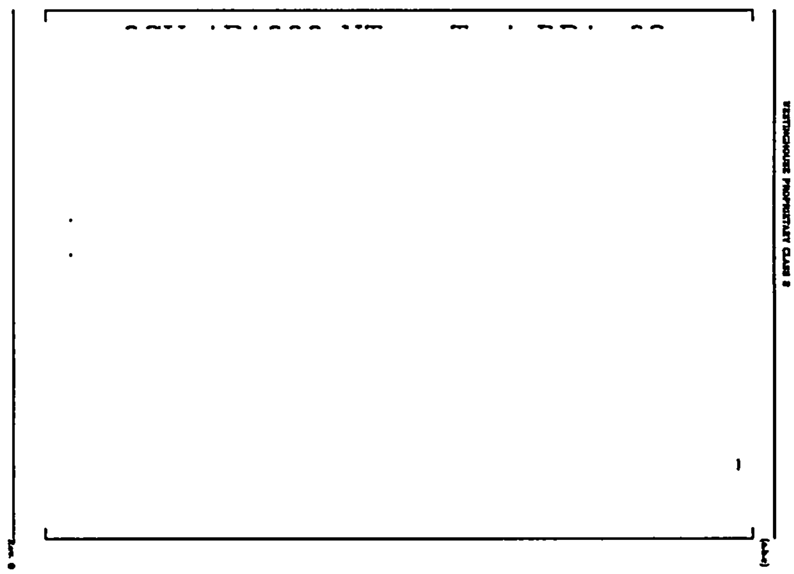

Figure 21.5-2.26 Test DBA-02, Integrated Vessel Side Break Flow

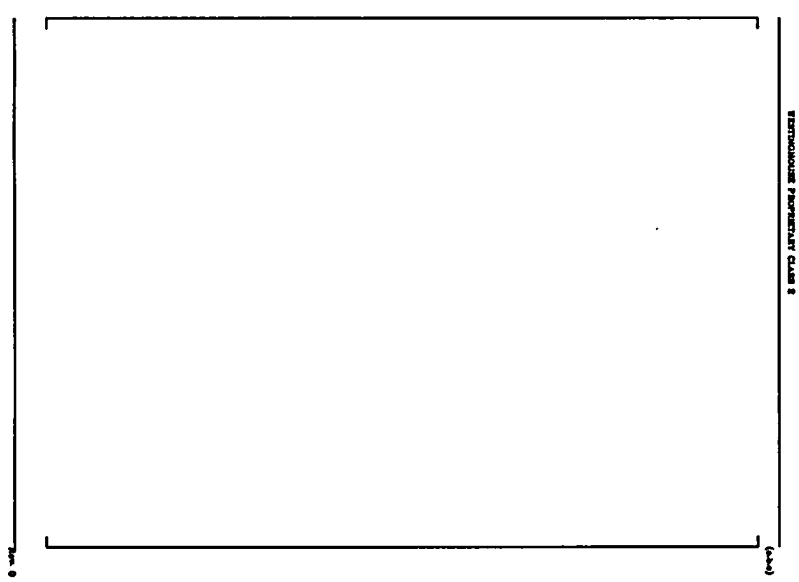

Figure 21.5-2.27 Test DBA-02, DVI-1 Injection Flow (Loop Side Break)

Figure 21.5-2.28 Test DBA-02, DVI-2 Injection Flow

Figure 21.5-2.29 Test DBA-02, Core Inlet Temperature

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(a,b,c)

Figure 21.5-2.30 Test DBA-02, Core Outlet Temperature

WESTINGHOUSE PROPRIETARY CLASS 2

(a,b,c)

Figure 21.5-2.31 Test DBA-03, Pressurizer Pressure

Figure 21.5-2.32 Test DBA-03, Downcomer Pressure

Figure 21.5-2.33 Test DBA-03, Pressurizer Collapsed Liquid Level

(a,b,c)

Figure 21.5-2.34 Test DBA-03, CMT-1 Collapsed Liquid Level

(a,b,c)

Figure 21.5-2.35 Test DBA-03, CMT-2 Collapsed Liquid Level

Figure 21.5-2.36 Test DBA-03, CMT-1 Injection Flow

Figure 21.5-2.37 Test DBA-03, CMT-2 Injection Flow

Figure 21.5-2.38 Test DBA-03, SG-2 Hot Side Collapsed Liquid Level

Figure 21.5-2.39 Test DBA-03, SG-2 Cold Side Collapsed Liquid Level

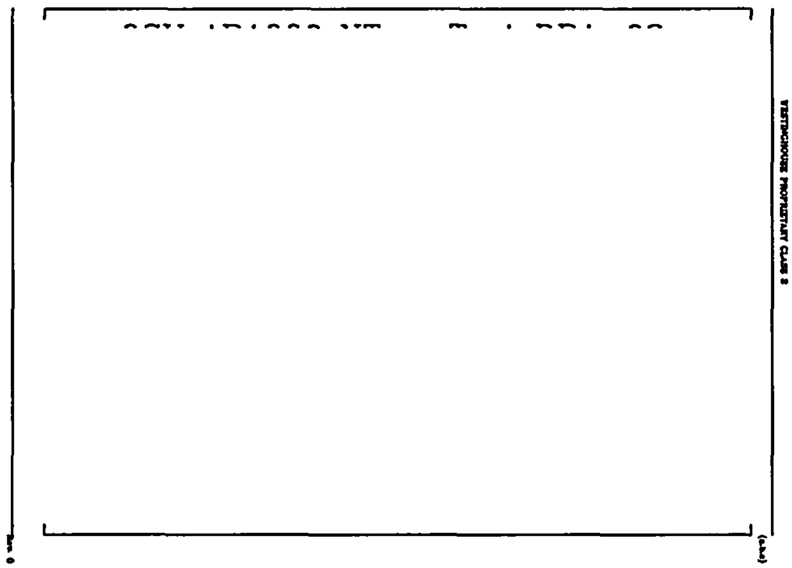

Figure 21.5-2.40 Test DBA-03, SG-1 Hot Side Collapsed Liquid Level

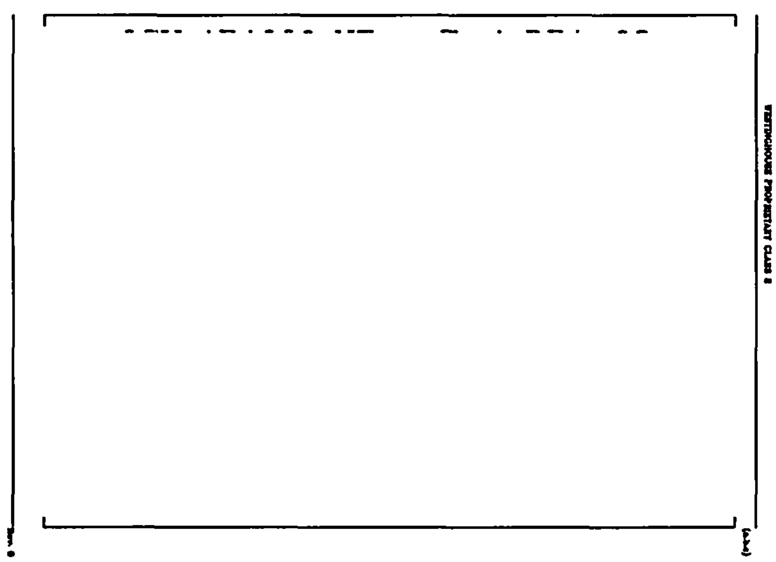

Figure 21.5-2.41 Test DBA-03, SG-1 Cold Side Collapsed Liquid Level

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(a,b,c)

Figure 21.5-2.42 Test DBA-03, ACC-1 Collapsed Liquid Level

WESTINGHOUSE PROPRIETARY CLASS 2

(a,b,c)

Figure 21.5-2.43 Test DBA-03, ACC-2 Collapsed Liquid Level

Figure 21.5-2.44 Test DBA-03, Core Collapsed Liquid Level

Figure 21.5-2.45 Test DBA-03, Core Average Void Fraction

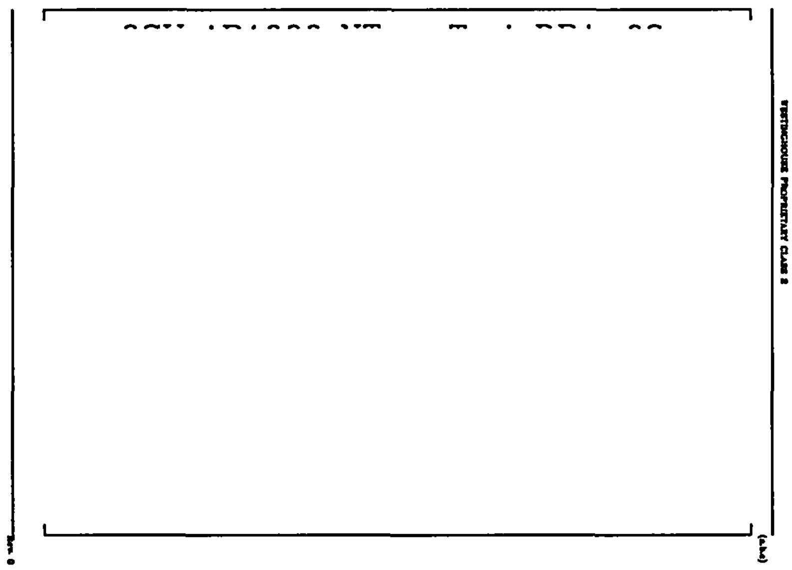

Figure 21.5-2.46 Test DBA-03, Upper Plenum Collapsed Liquid Level

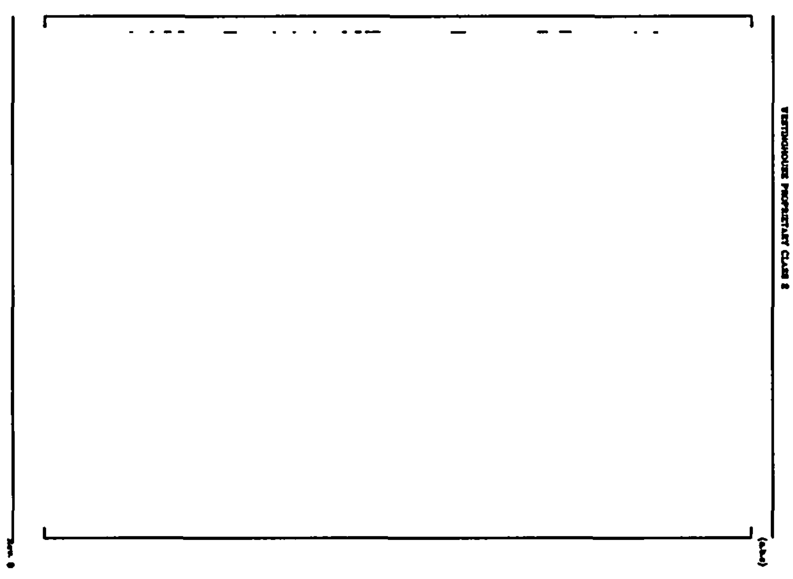

Figure 21.5-2.47 Test DBA-03, Upper Plenum Two-Phase Mixture Level

Figure 21.5-2.48 Test DBA-03, Downcomer Collapsed Liquid Level

Figure 21.5-2.49 Test DBA-03, RPV Mixture Mass

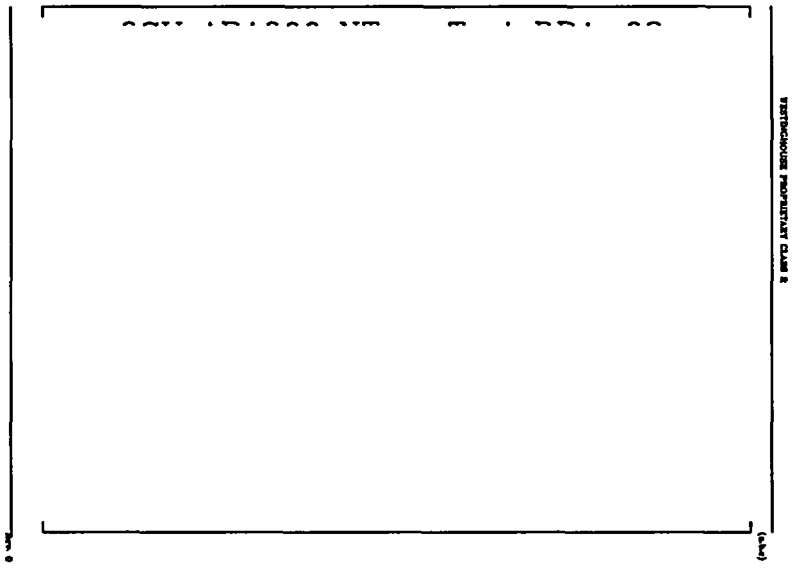

Figure 21.5-2.50 Test DBA-03, Integrated ADS 4 Discharge

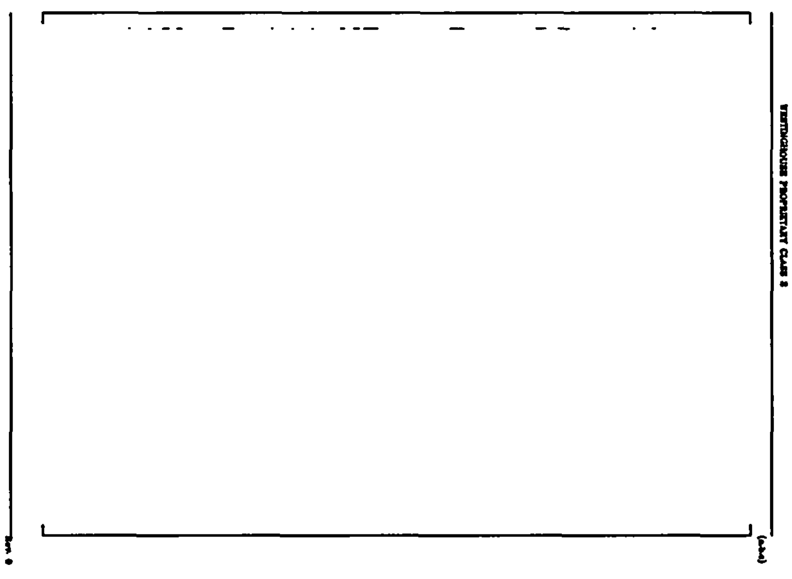

Figure 21.5-2.51 Test DBA-03, Integrated Break Discharge

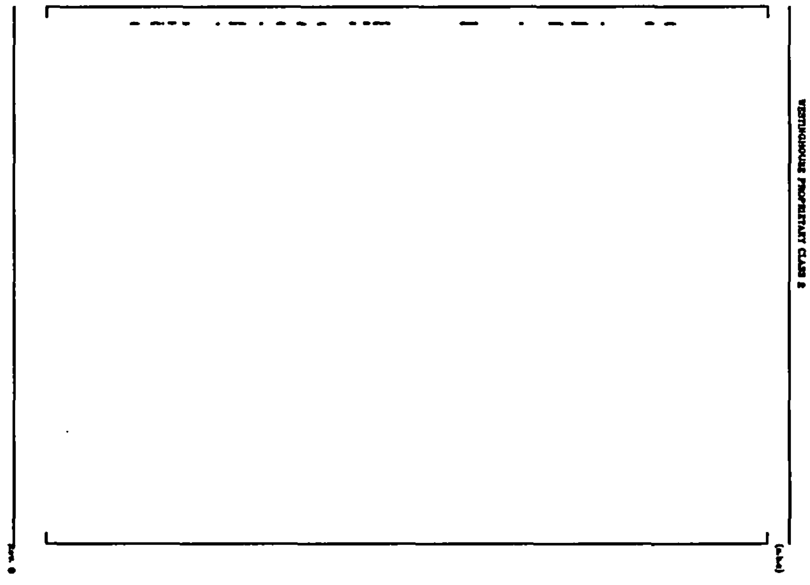

Figure 21.5-2.52 Test DBA-03, DVI-1 Injection Flow (Loop Side Break)

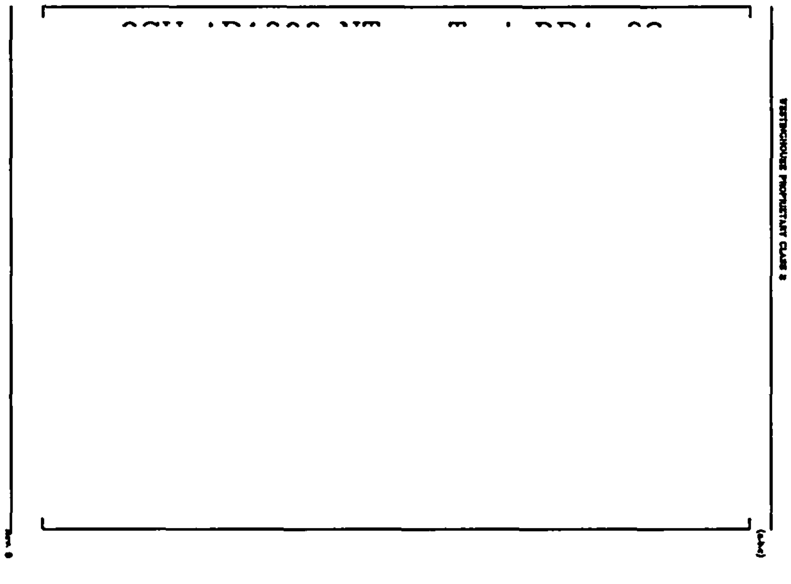

Figure 21.5-2.53 Test DBA-03, DVI-2 Injection Flow

Figure 21.5-2.54 Test DBA-03, Core Inlet Temperature

Figure 21.5-2.55 Test DBA-03, Core Outlet Temperature