Westinghouse Electric Corporation
Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-97-1154

August 19, 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: INFORMAL CORRESPONDENCE

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-97-1154 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-97-1154 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

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).

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AW-97-1154

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

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 20th day
of August, 1997

Janet A. Schwab

Notary Public

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

3140A WPF

(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-97-5282, August 19, 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 Power Plants that meet NRC requirements.

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

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

Further this information has substantial commercial value as follows:

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

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

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

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

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

Further the deponent sayeth not.

Attachment 1 to Westinghouse Letter DCP/NRC0996

DATE	ADDRESSEE	DESCRIPTION
5/19/97	Sebrosky	Advance draft of RAIs on WCOBRA/TRAC.
5/22/97	Sebrosky	Advance draft of NOTRUMP RAI - 440.339.
5/25/97	Sebrosky	Advance draft of WCOBRA/TRAC discussion items.
5/30/97	Huffman	Advance discussion item responses on WCOBRA TRAC CAD.

ENCLOSURE 2 TO WESTINGHOUSE LETTER DCP/NRC0996
(NON-PROPRIETARY VERSION OF ENCLOSURE 1)

Westinghouse
AP600 Project

Memo

To: Joe Sebrosky

From: Earl H. Novendstern

CC: B. McIntyre (NRC Informal Proprietary Correspondence File), B. Rarig, R. Kemper, D. Garner L. Hochreiter, F7.5.1.6

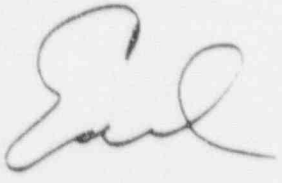
Date: Monday, May 19, 1997

Re: WC/T V&V LTC RAIs

Joe,

Attached are additional RAIs that will be issued in the next several days. I have marked them DRAFT only because they are not transmitted by a formal letter. No text will change when formally transmitted.

Please give to Lambrose and Bill. Many thanks.



DRAFT

Attachment A

Westinghouse Proprietary

Class 2

Tops of pages
to be

RAI 440.589

The trends in the WCOBRA/TRAC analyses of the OSU SB01 test show an overprediction of injection flow and an underprediction of exit flow. Extrapolation of these trends would lead to a conclusion that the calculated reactor vessel water level will not fit the test data well beyond the end of the window. Specifically, Figures 5.1-3 to 5.1-10 show that the injection flow rate is higher than the corresponding measured value. Figures 5.1-11 and 5.1-12 indicate that the injected water temperature is considerably lower. Figures 5.1-16 and 5.1-18 indicate that ADS 123 and ADS 4-1 flows are lower. If these trends continue, the calculated total injected water would be much greater than the test data shows and the calculated total boiloff and water exiting the RCS would be much less than the test data. This would result in an erroneously high value for the calculated reactor vessel water level sometime beyond the end of the window. Westinghouse should consider extending the window width (by 3 to 4 times the current length of 1000 seconds) to demonstrate that the eventual trend stabilizes and balances with the final vessel water level consistent with the test data.

Response:

As provided in Ref. 440.589-1 and discussed in the ACRS meeting on March 28, 1997, Westinghouse has performed several calculations of 3000 seconds in length which indicate no solution divergence. In each of the cases, comparisons with the OSU test data were as favorable at 3000 seconds as at the end of the original 1000 second window and for the Extended Time Sensitivity, the results at the end of 3000 seconds of calculation time were shown to be identical to calculations started 2000 seconds later and run for 1000 seconds. In addition, Figure 440.589-1 was presented at the ACRS meeting which demonstrates that total WC/T vessel inflow equals total vessel outflow for the OSU test comparison cases once the quasi-equilibrium solution has been reached.

It was noted at the ACRS meeting that the reactor vessel collapsed levels are systematically low (the conservative direction). Two factors contribute to this bias. First, as discussed in the WCOBRA/TRAC Code Qualification Document (WC/T CQD), WC/T tends to over predict liquid entrainment in the large break scenario. The equivalent effect in the Long Term Cooling (LTC) scenario is to carry out liquid from the upper plenum too easily and thus reduce the collapsed liquid level to a value below that observed in the tests. A second factor which contributes to the under predicted liquid level is the coarse noding in the top of the core and the bottom of the upper plenum, see Figure 2-2 in Ref. 440.589-2. To evaluate the impact of this noding, the Section 3 channels in the upper plenum, which were previously one cell high, were divided into three vertical cells. A set of calculations were performed for OSU Test SB01, during sump operation, in the time period from 18,000 seconds to 19,000 seconds. The comparison of the upper plenum levels and downcomer levels is attached in Figures 440.589-2 through 440.589-5. The upper plenum level is shown to be increased by 0.5 to 0.6 inches with the finer noding. Similiar results are observed in the hot leg levels. The increased number of vertical cells has a less significant effect on the downcomer level. While this does not show a major effect on the vessel levels, it does show the trend. It is noted that, the coarse noding was retained in the core (two vertical cells) and the radial noding in the upper plenum was not altered. Thus, additional improvements in level calculations are expected if a more detailed noding is used.

As was discussed at the ACRS meeting, the WC/T comparison with SB01 was the least accurate of the comparisons in Ref. 440.589-1 and Ref. 440.589-2. There are several factors which contribute to the differences in this comparison, if the uncertainities in the measured flow rates are not considered for the moment. First as shown in Table 440.589-1 line 4, the WC/T calculated total ADS flow rates are in good agreement with the total OSU measured ADS flow rates, even though the agreement between the respective ADS 4-1 and ADS 4-2 is less accurate. However, as previously reported, the total DVI flow rates, line 7, do not compare favorably with 1.09 lb/sec calculated by WC/T versus 0.86 lb/sec measured at OSU. The divergence between the calculated and measured DVI flows from the IRWST lines, Figures 5.1-3 and 5.1-4, is more pronounced as indicated in Table 440.589-1 lines 10 and 14. The major source of this discrepancy can be seen with a re-scaled plot of the break flows, see Figure 440.189-6 and 440.189-7, which indicate significant increases in the measured break flow at 14,500 seconds. If the measured break flows are accepted as correct, the total vessel inflows are in good agreement as shown on line 9 of Table 440.589-1. However, this implies that the WC/T calculated break flow rate is significantly under predicted, Table 440.589-1 line 8. Thus, the over prediction of the IRWST flows into the DVI lines is offset by an under prediction of break flow. This discrepancy is considered to be partially the result of measurement uncertainities on the DVI line flow rates. For example, the measured DVI flows from the IRWST are 0.17 lb/sec and 0.215 lb/sec with a 2σ uncertainity on each of $\pm$ 0.076 lb/sec. Thus, the flow rates measurements are have uncertainities of $\pm$ 45% and $\pm$ 35% respectively. Of more importance is the fact that the magnetic flowmeters, used for the liquid portion of the break flow, were not calibrated for reverse flow (into the vessel) and are only useful for showing trends. Thus, the data uncertainty clouds the conclusions which can be drawn from this specific test comparion and leads to the conclusion that the entire set of comparisons must be viewed together if valid conclusions are to be drawn.

In conclusion, the total vessel inflows and total vessel outflows, lines 4 and 9 in Table 440.589-1 balance quite well for both the WC/T calculation and the OSU test. Note, that all the individual values were checked when it was found that the measured break flow was mis-estimated due to poor scaling of the integrated breakflow plot, Figure 5.1.14. The component flows do not compare as well and this is considered to be primarily the result of the uncertainties in the measured flow rates. The argument that the calculations are not primarily at fault lies with the accuracy of the remaining comparisons. This is demonstrated in Figures 440.589-8 through 440.589-11 taken from the ACRS presentation.

References

440.589-1. NSD/NRC-97-5014, "WCOBRA/TRAC Long Term Cooling Letter Report", D.C Garner, March 10, 1997.

440.589-2. WCAP-14778, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1996.

Report Revision:
None

Table 440.589-1

SB-01 Quasi-Equilibrium Flow Rates During
Period from 14,500 to 15,000 Seconds

Line No.		WC/T Calculated Flow (lbm/sec)	OSU Measured Flow (lbm/sec)
	Vessel Outflows		
1.	ADS 1, 2, 3	0.005	
2.	ADS 4-1	0.463	
3.	ADS 4-2	0.729	
4.	Total Outflow (1 + 2 + 3)	1.197	
	Vessel Inflows		
5.	Total DVI-1	0.535	
6.	Total DVI 2	0.555	
7.	Total DVI (5 + 6)	1.090	
8.	2" Break Flow (into vessel)	0.070	
9.	Total Inflow (5 + 6 + 8)	1.160	1.125
	DVI Line Component Flows		
10.	IRWST/DVI-1	0.370	
11.	Sump/DVI-1	0.165	
12.	CMT-1/DVI-1	0.000	
13.	Total DVI-1 (10 + 11 + 12)	0.535	
14.	IRWST/DVI-2	0.290 **	
15.	Sump/DVI-2	0.165	
16.	CMT-2/DVI-2	0.100 **	
17.	Total DVI-2 (14 + 15 + 16)	0.555	

** Figure 5.1-4 includes 0.100 lbm/sec from CMT-2 with IRWST flow

WC/T Total Inflow / Total Outflow Comparison

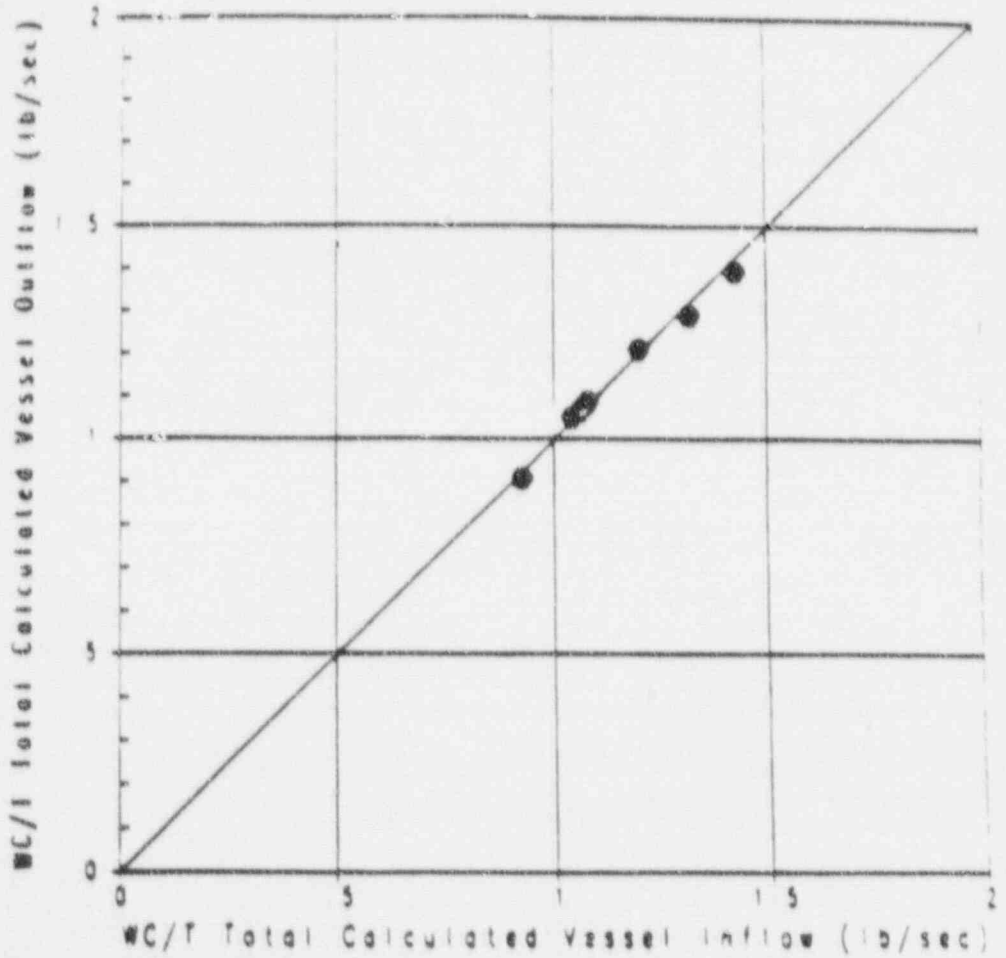
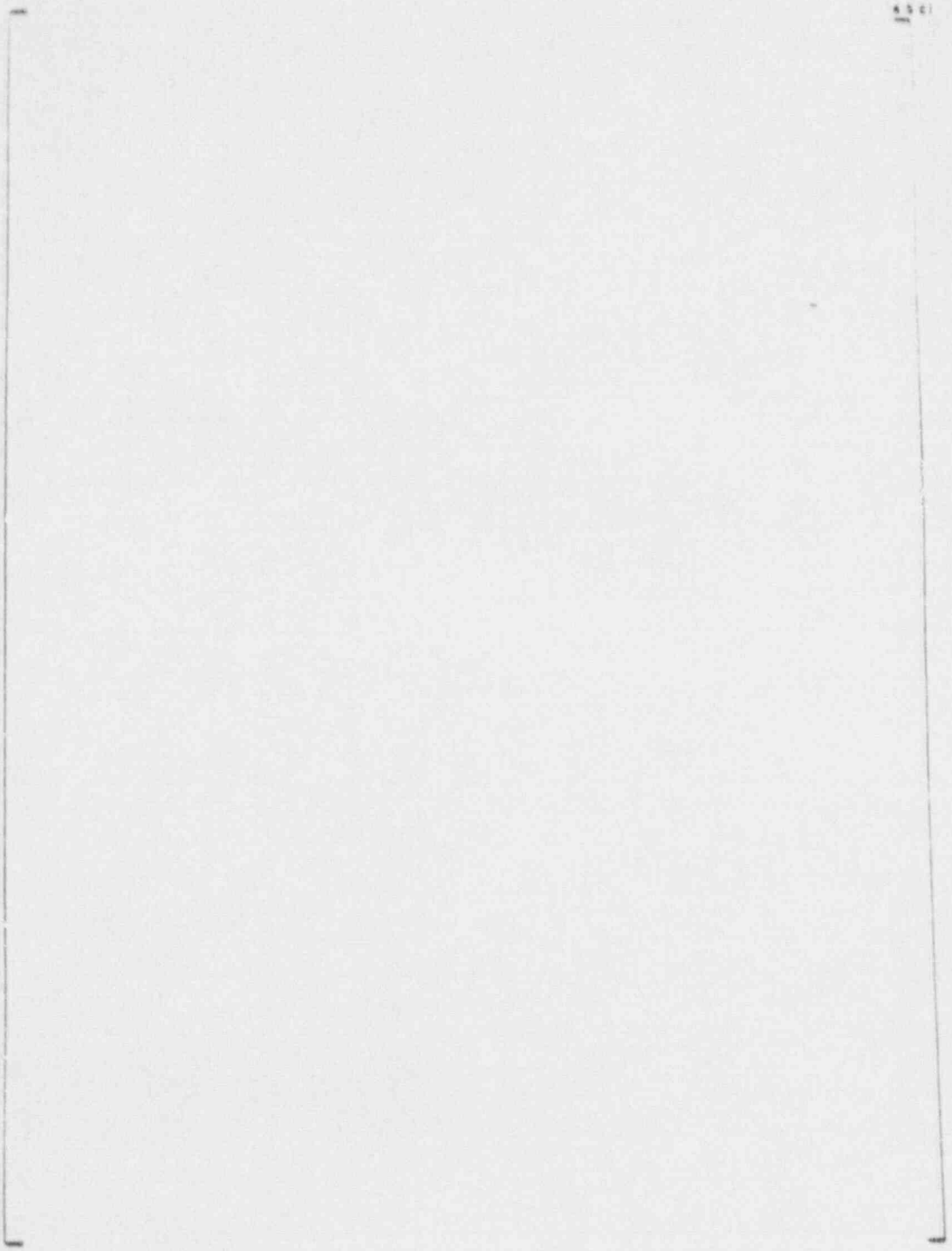


Figure 440.589-1



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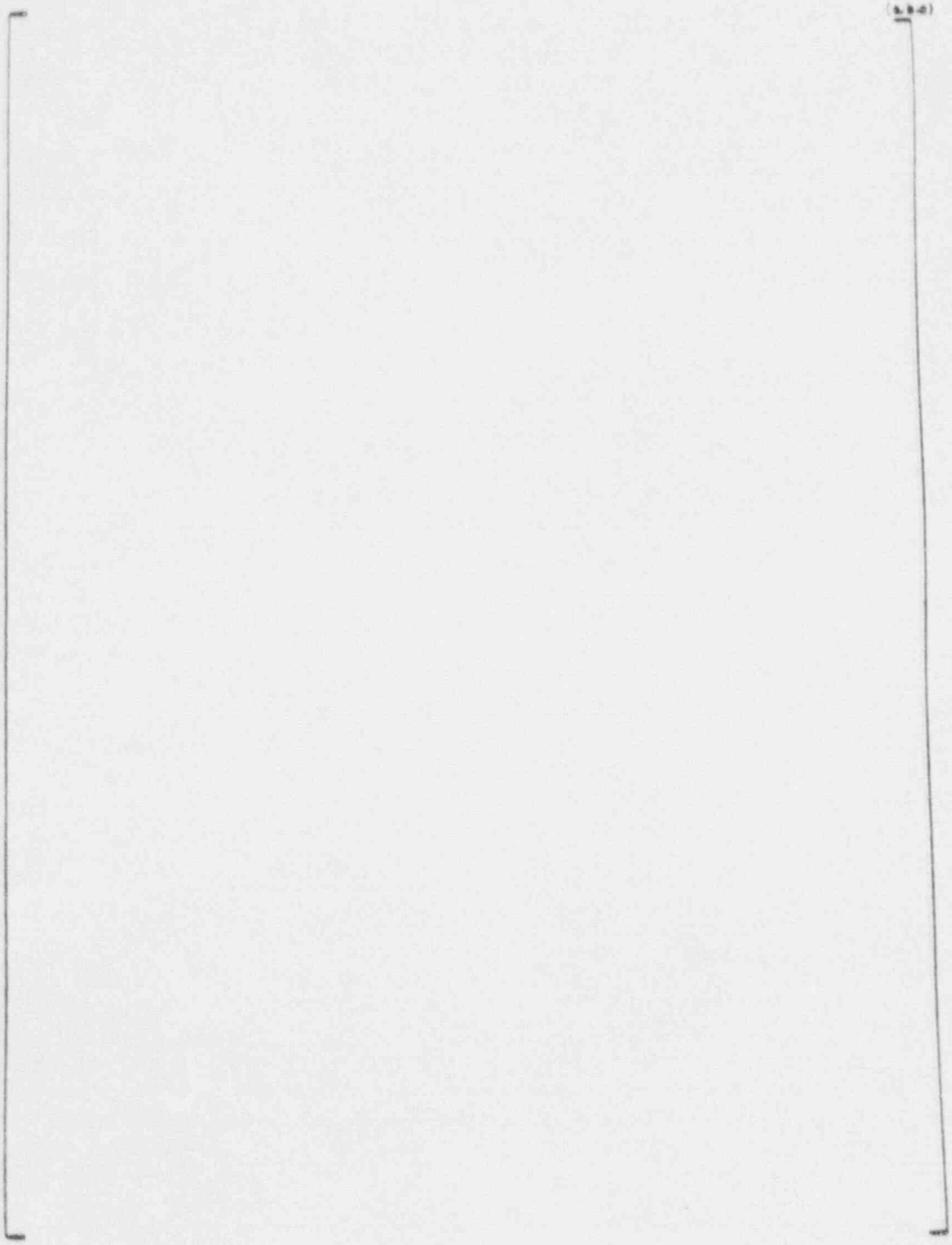

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[(a,b,c)

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Upper Plenum Liquid Level Comparison

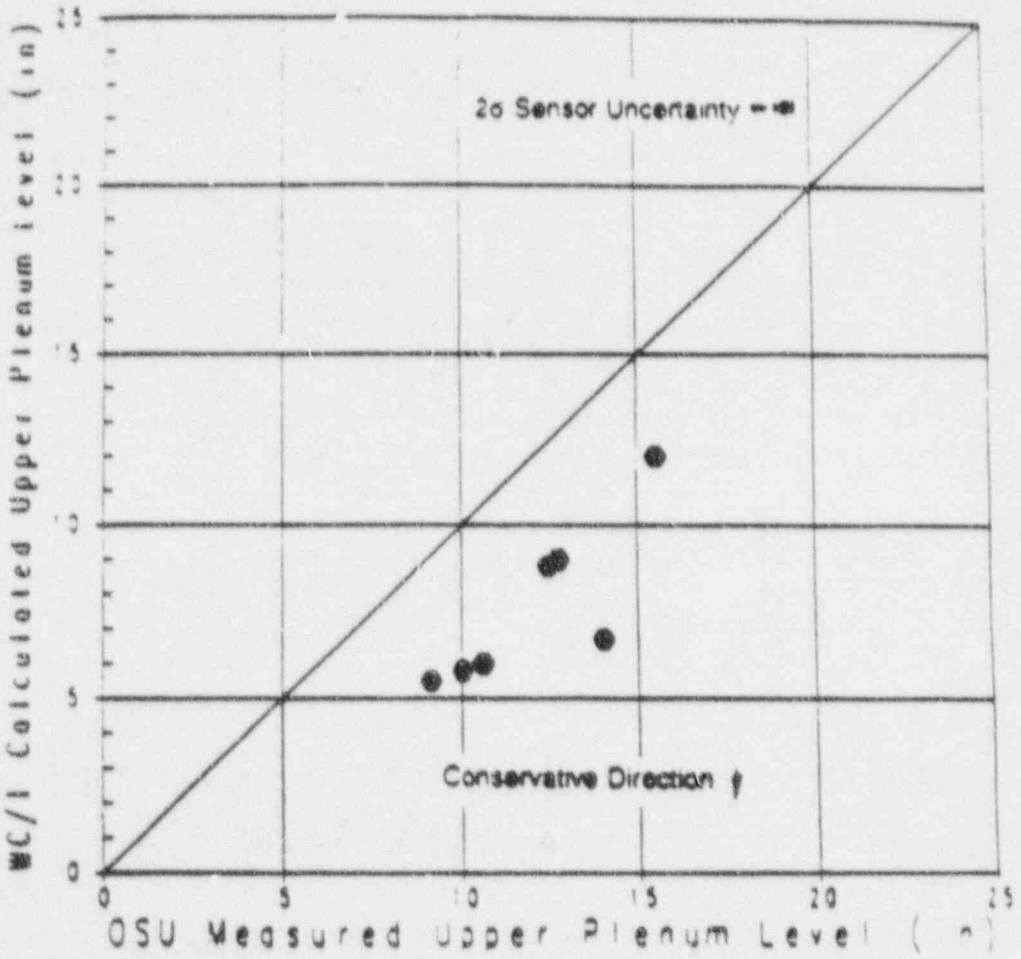


Figure 440.589-8

Downcomer Liquid Level Comparison

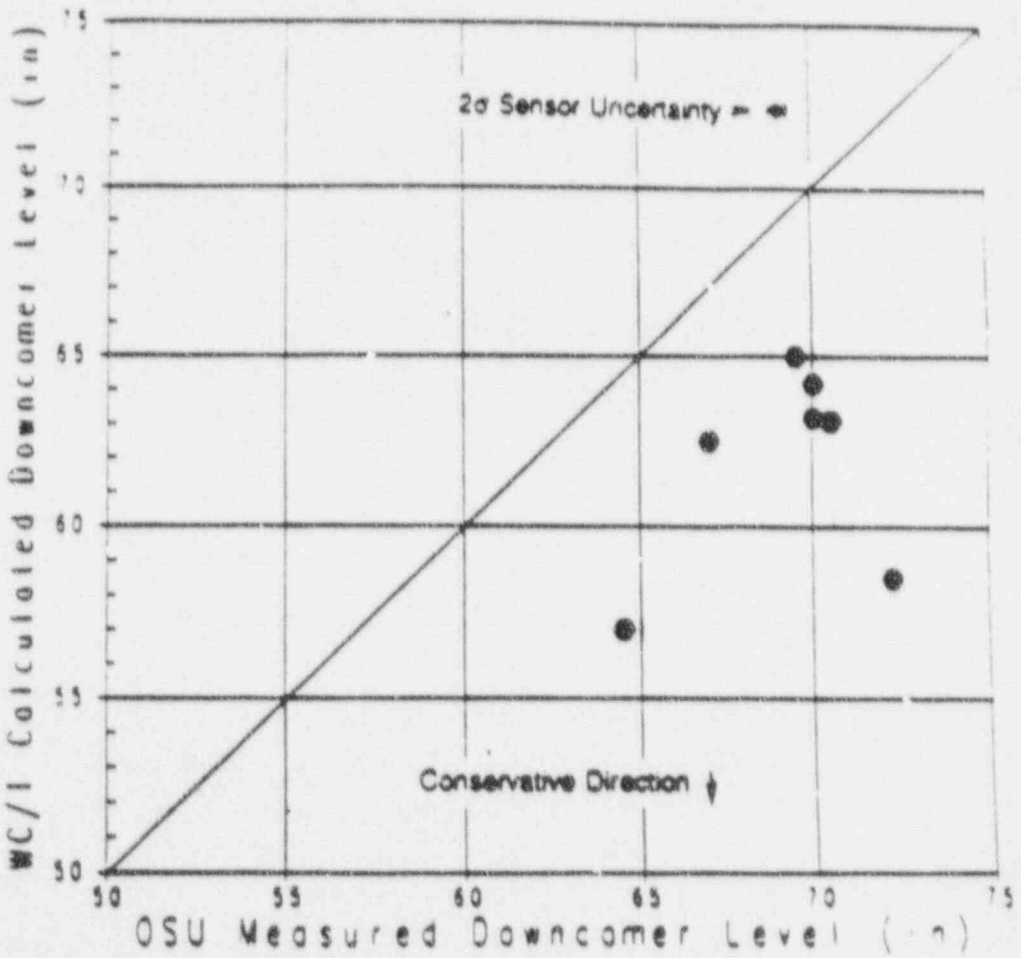


Figure 440.589-9

Reactor Vessel Total Inflow Comparison

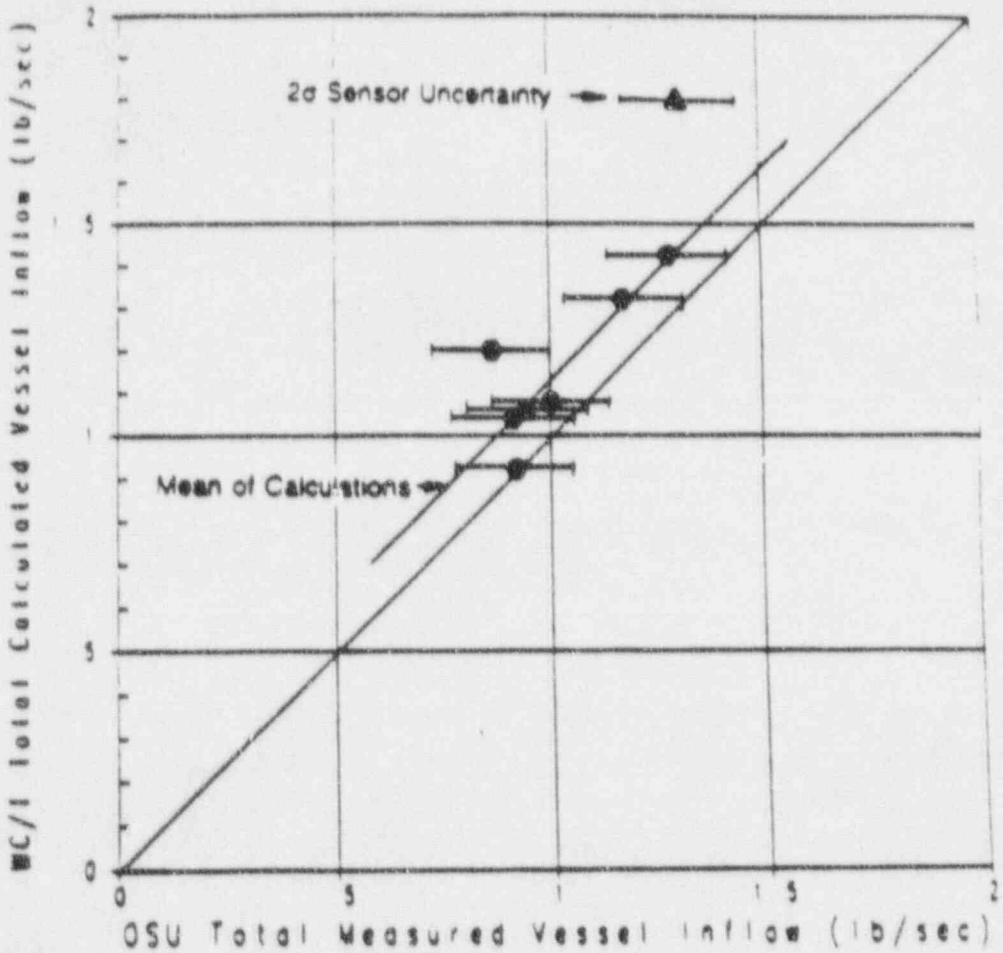


Figure 440.589-10

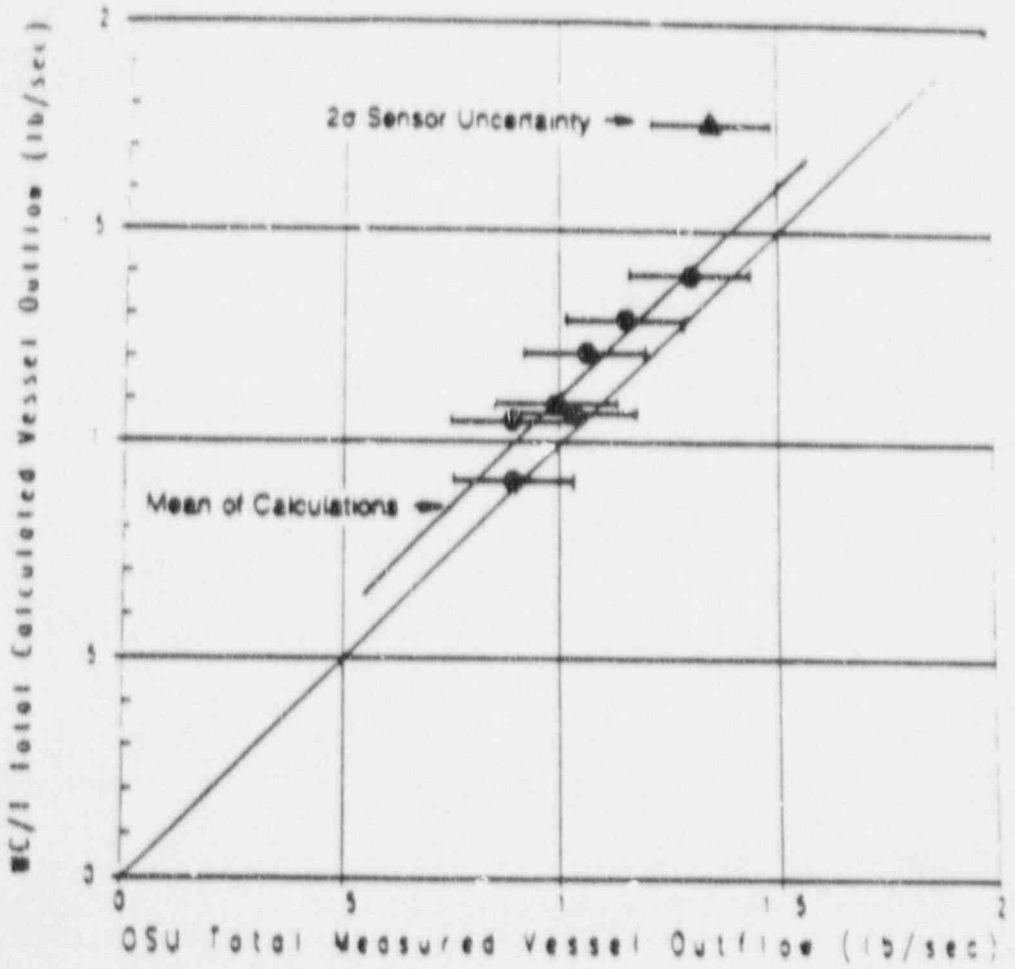


Figure 440.589-11

RAI 440.590

Page 5-34, 5th paragraph states that the discrepancy shown in the upper plenum calculated pressure (Fig. 5.2-2) is due to the uncertainty of the measured pressure values. However, uncertainty cannot account for a one sided difference unless some special instruments have been used. Please account for the above statement and the discrepancy of measured to calculated values.

Response:

As discussed in the revised response to RAI 440.563, "for Test SB10 the pressure measurement transducer was classified as unreliable, so the upper plenum pressure is based on a different pressure tranducer than is used for the other tests. For this reason, the WC/T prediction of pressure in Test SB10 relative to the data is not considered to be appropriate in assessing the capability of WC/T to model the OSU tests." As shown in the attached Figure 440.590-1 from the ACRS meeting of March 28, 1997, upper head (and upper plenum) pressures during the period of transition to sump injection and beyond are in the range of 15.6 to 16.0 psia independent of break size and location. Thus, the OSU data value of 17.7 psia reported for SB10 is considered to be unreliable and inappropriate for assessment of the WC/T pressure prediction capability.

Report Revision:

None

[redacted]

RAI 440.591

The calculational window for SB10 sump injection flow (Figures 5.2-5 and 5.2-6) stops at 14,500 seconds. This window does not envelop a significant change in the sump injection flow shown in the OSU test data which occurs when the sump injection valves open. Since the sump isolation valves opened at 14,800 seconds, the staff believes the window should continued to at least 16,000 seconds to give WCOBRA/TRAC the opportunity to calculate full sump injection flow.

Response:

Westinghouse has performed the suggested calculation and provided the results in Reference 440.591-1. The results can be found in Figures 2.5-1 through 2.5-28 of that report together with the following paragraph from that report.

The window selected was from test SB10 was initiated at 13,500 seconds, near the end of IRWST injection and extending to a time of 16,500 seconds at which time both sump check valves and sump isolation valves were fully open. This calculation is an extension of calculation 5.2 in Reference 440.591-2. The window included a period of upper plenum liquid level decrease following the switchover to sump flow and a subsequent period of increased core steaming rates due to lower DVI line flow rates and higher DVI line liquid temperatures. These conditions were calculated with reasonable accuracy as demonstrated in Figures 2.5-23 and Figure 2.3-21. The total DVI line flow rates into the vessel compared well with the test data during this extended time period as indicated in Figures 2.3-7 through 2.3-10. It is noted that the sump and IRWST flow rates and directions are also reasonable well predicted during this period except in portions of line 1 in the period following opening of the sump isolation valve, Figures 2.5-3 and 2.5-5. In this period, the calculated flow from the sump to the IRWST is higher than measured flow. Of particular significance, however, is the fact that the correct quasi-equilibrium solution is obtained near the end of the transient. This demonstrates, that after a significant perturbation to the boundary conditions (opening of the sump isolation valves), the solution will adjust the flow conditions and return to the correct values. It is further noted that, during this period, the reactor vessel levels were not significantly influenced.

References

440.591-1. NSD/NRC-97-5014, "WCOBRA/TRAC Long Term Cooling Letter Report", D.C.Garner, March 10, 1997.

440.591-2. WCAP-14778, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1998.

Report Revision:

None

RAI 440.592

Westinghouse assessment of the OSU SB-12 test states on page 5-66 that " the sump flow was inhibited in this calculation". Why was this done? How is the comparison of sump flow rates meaningful with this manipulation of the calculation? Could another test be substituted for this test without inhibiting sump flow? What is unique in this test for the WCOBRA/TRAC long term cooling validation?

Response:

Test SB-12 data records do not contain a significant period of sump injection. As a result, WC/T calculation comparisons in the sump injection period were considered to be for too short a period to be meaningful. Further, any deviations from the measurements could not be investigated through extension of the window period. Thus, the comparison with SB12 is intended to address only operation with flow from the IRWST and is included to show the LTC performance for a DEG Direct Vessel Injection Line Break.

Subsequently, a calculation comparison has been done with SB01 from 18.000 to 19.000 seconds when the the sump isolation valves have been opened and the levels in the IRWST and the sump have equilibrated. At the start of this comparison, the equilibrium sump/IRWST conditions have been established for over 2000 seconds so that the comparison addresses specifically sump injection. The comparisons provided in Figures 440.592-1 through 440.592-28 show good comparison with the OSU data with the following variations noted:

1. The reactor vessel level comparisons are low by 6 to 7 inches in the downcomer and 3 to 4 inches in the upper plenum, Figures 440.592-24 and 440.592-23, which is typical of other test comparsions and is in the conservative direction.

2. The core collapsed liquid level is low by about 2 inches, again a deviation in the conservative direction.

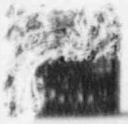
3. The Total DVI Flows, Figures 440.592-8 and 440.592-10 show deviation of +0.040 and +0.065 lb/sec which is within the 2 sigma uncertainlty of the flow measurements of $\pm$ 0.077 lb/sec.

4. The break flow measurements, Figure 440.592-14, show the same negative trend as the data, however since the magnetic flow meters were not calibrated for negative flows this comparison is not significant.

5. As has been indicated in a subsequent RAI , the low flow rates of the ADS 1-3 which are less than the measurement uncertainity render this comparison insignificant.

Based on the results of this comparison, it appears that WC/T provides a satisfactory quasi-equilibrium solution for LTC during sump operation well after the end of IRWST injection.

Report Revision: None



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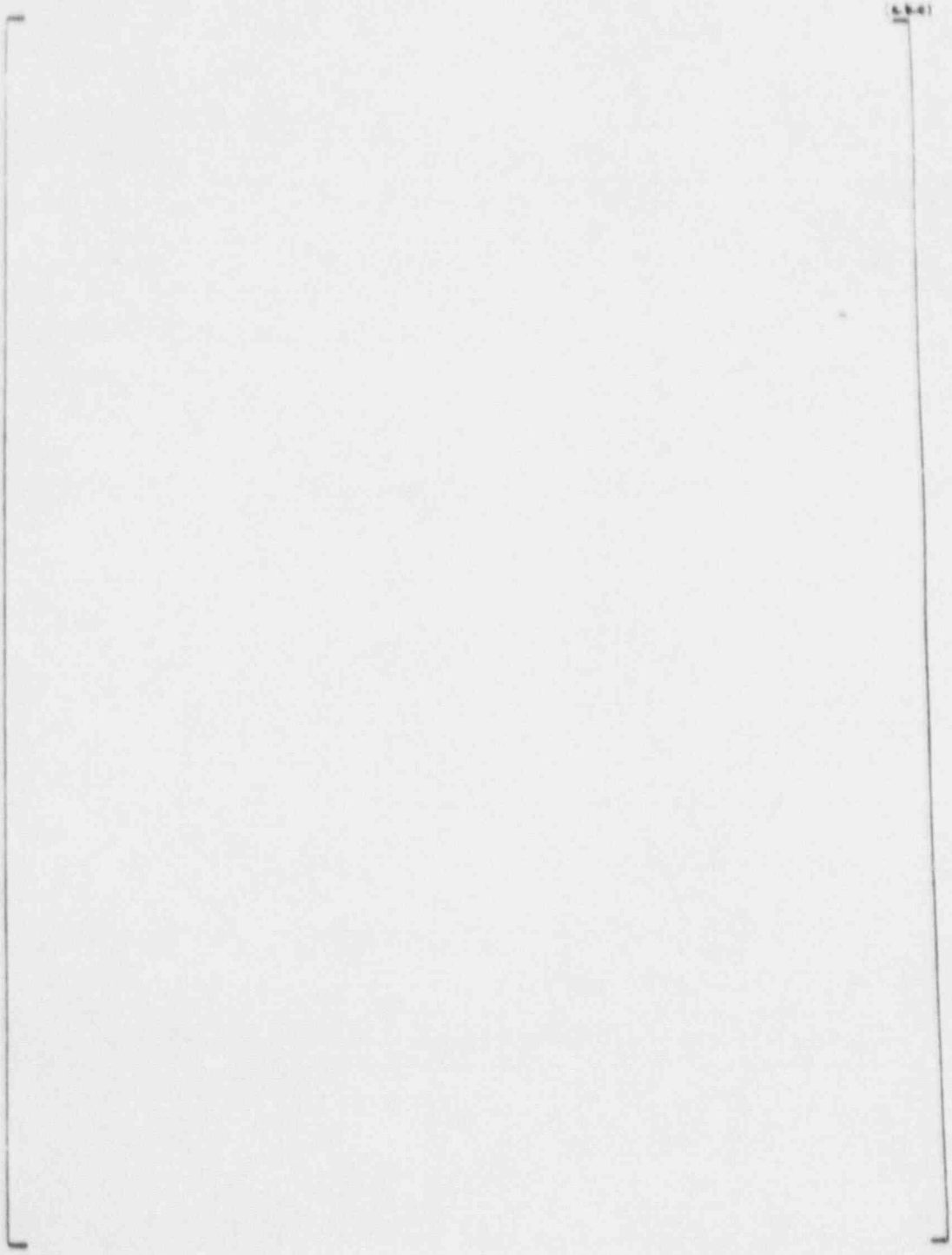
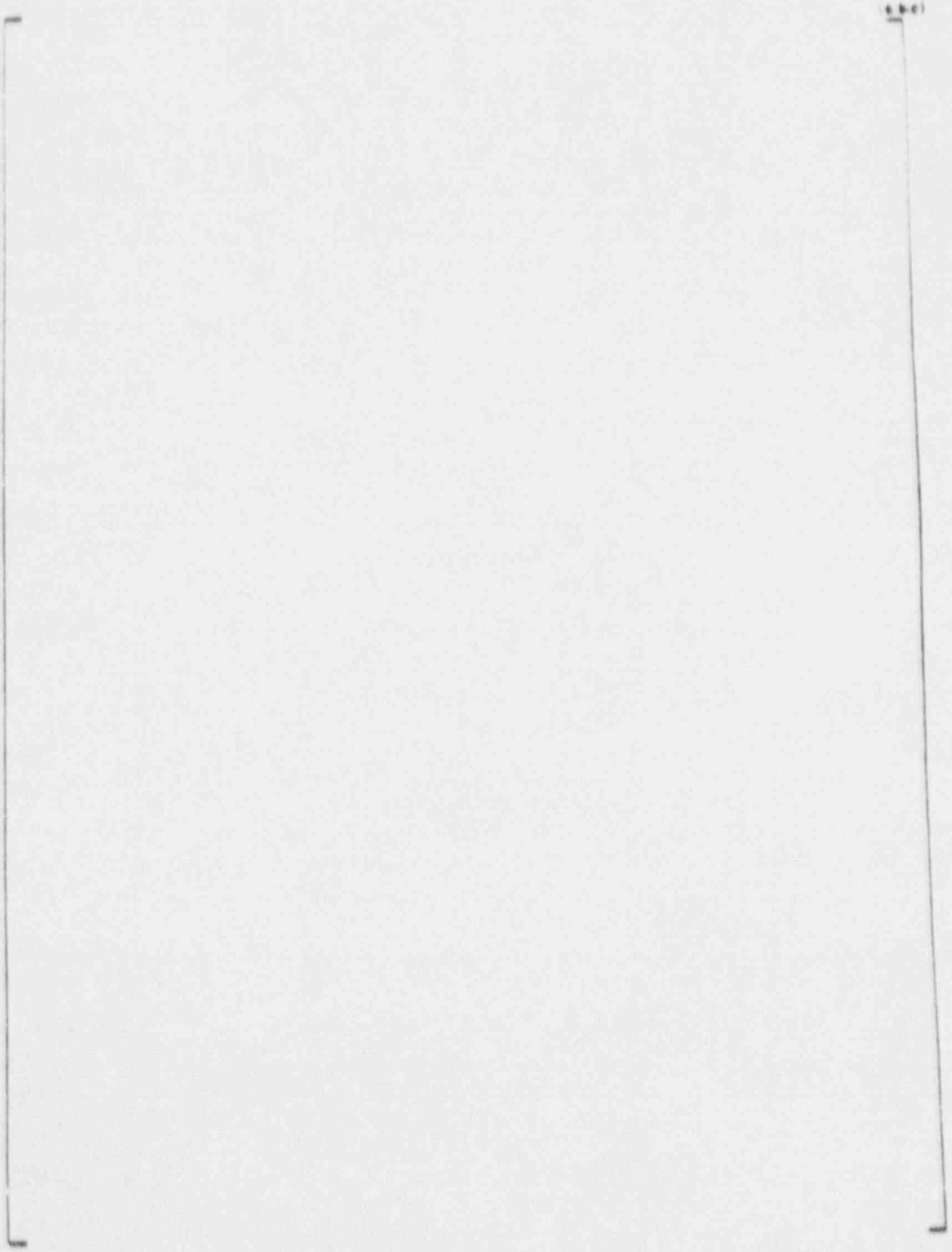
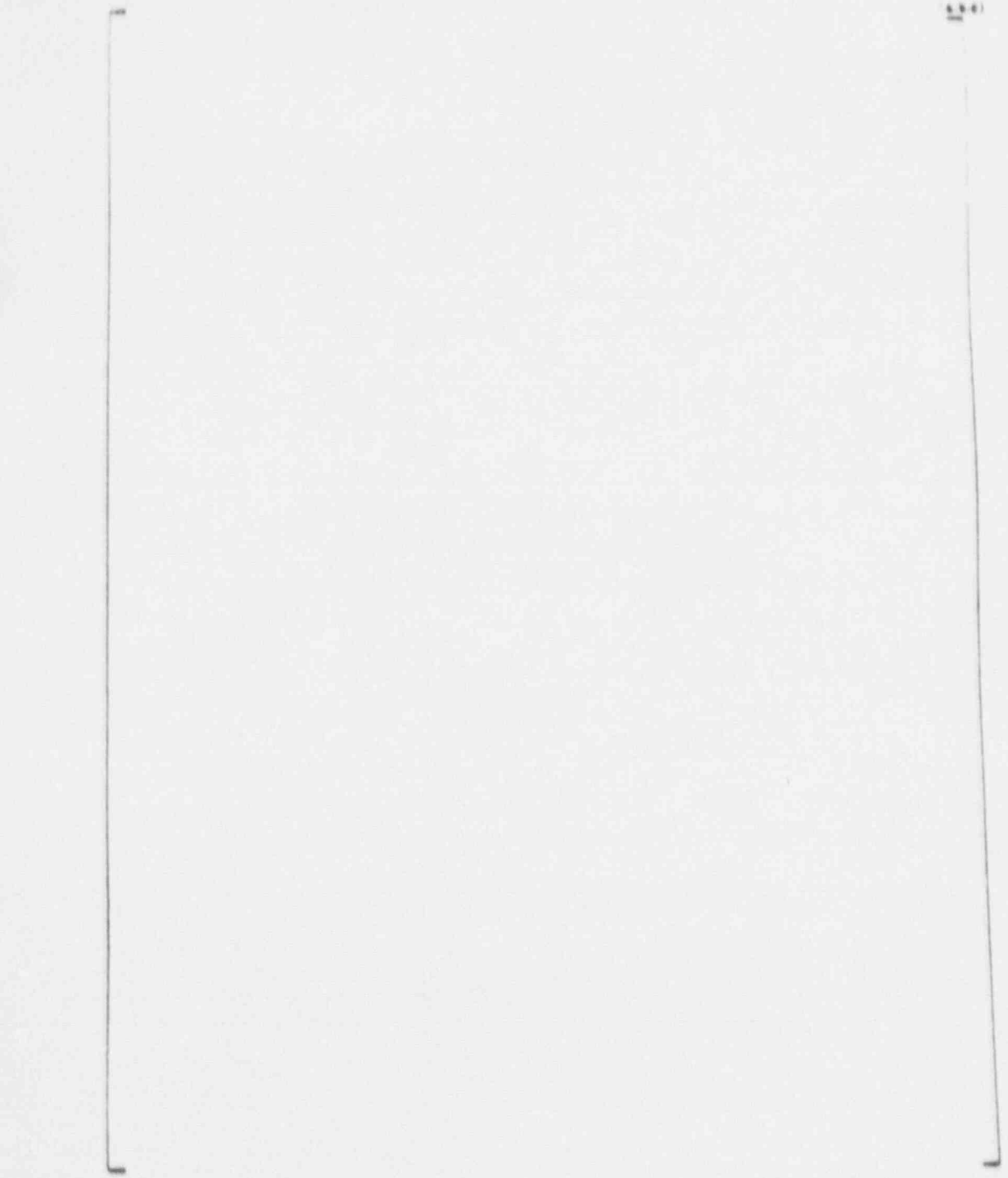
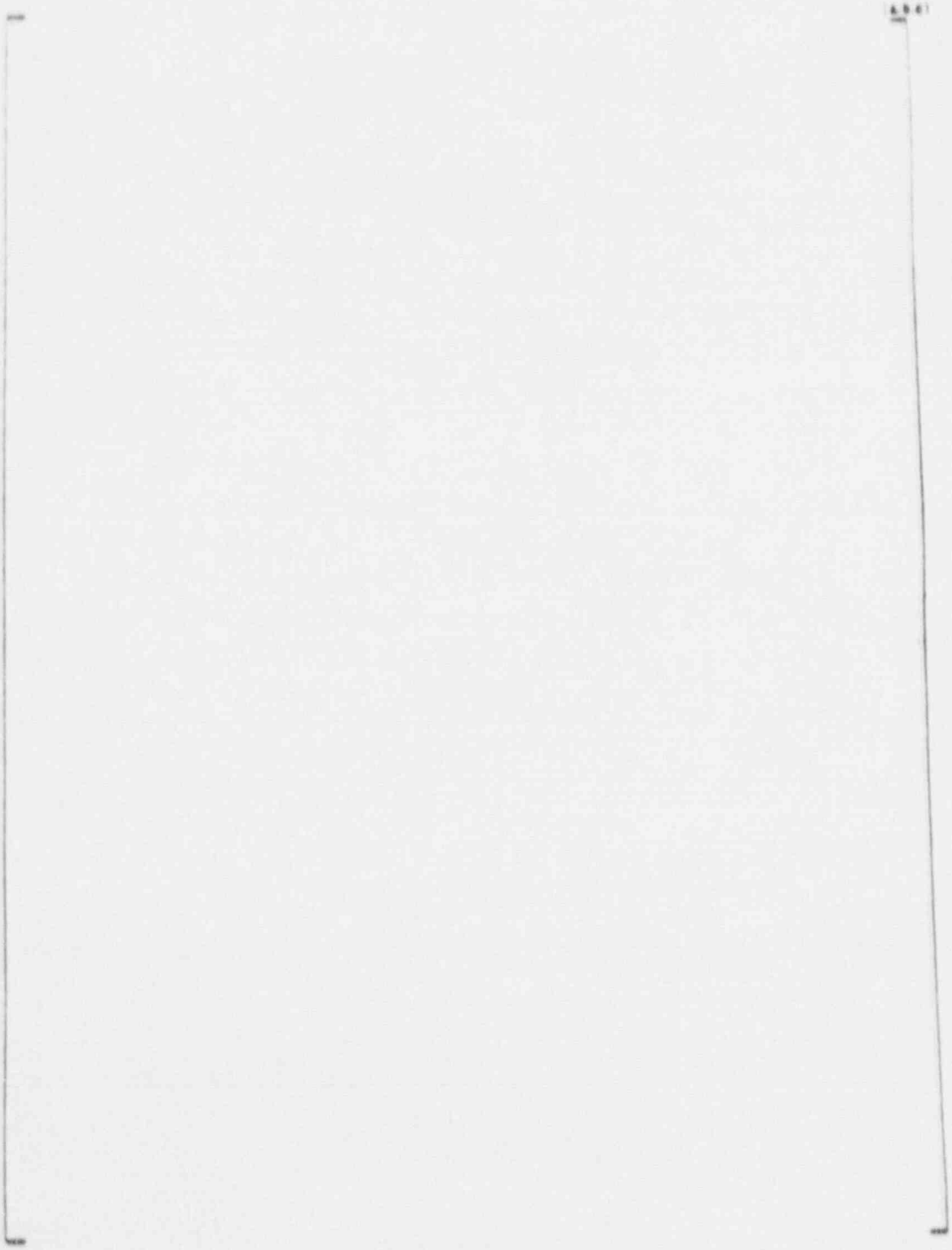
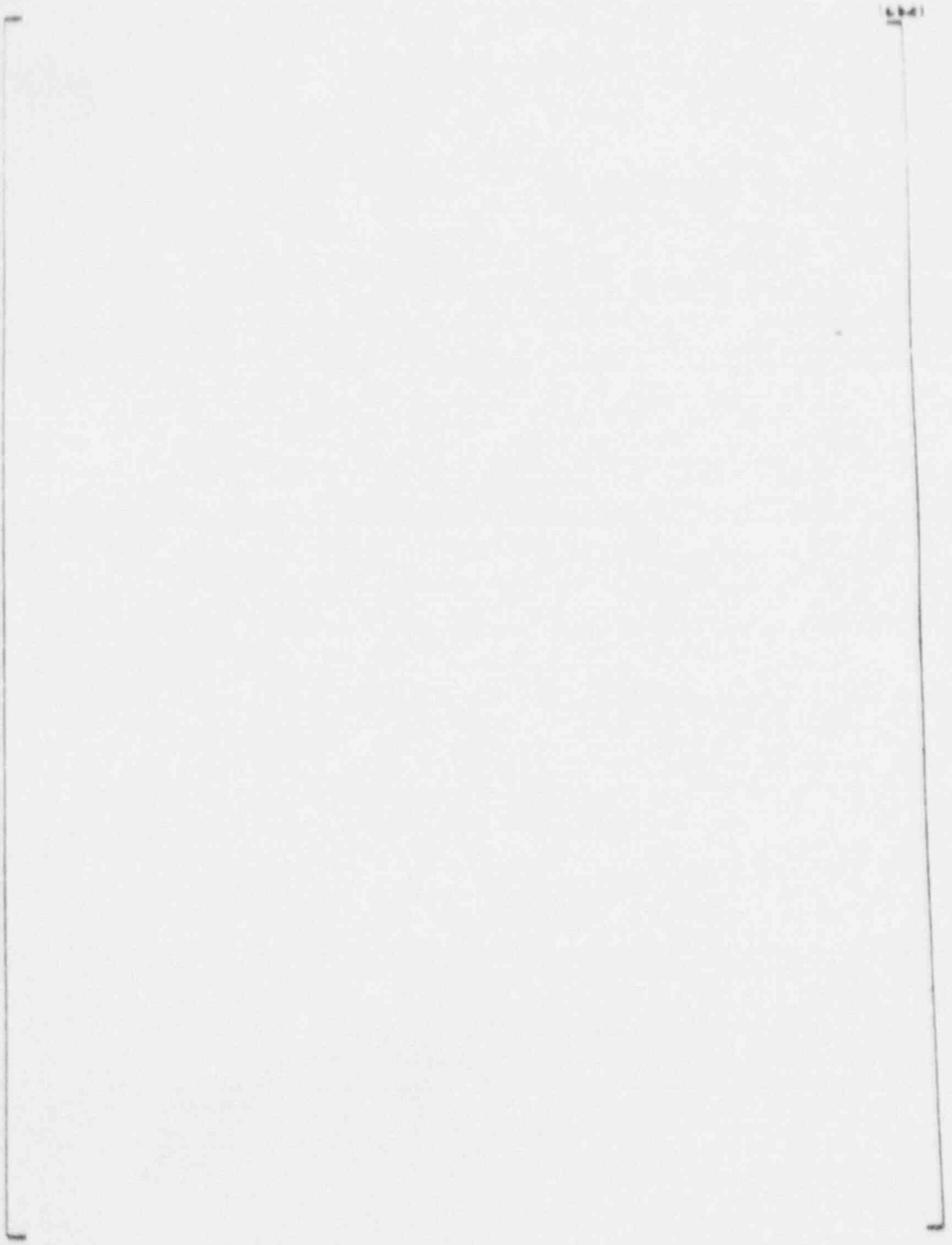
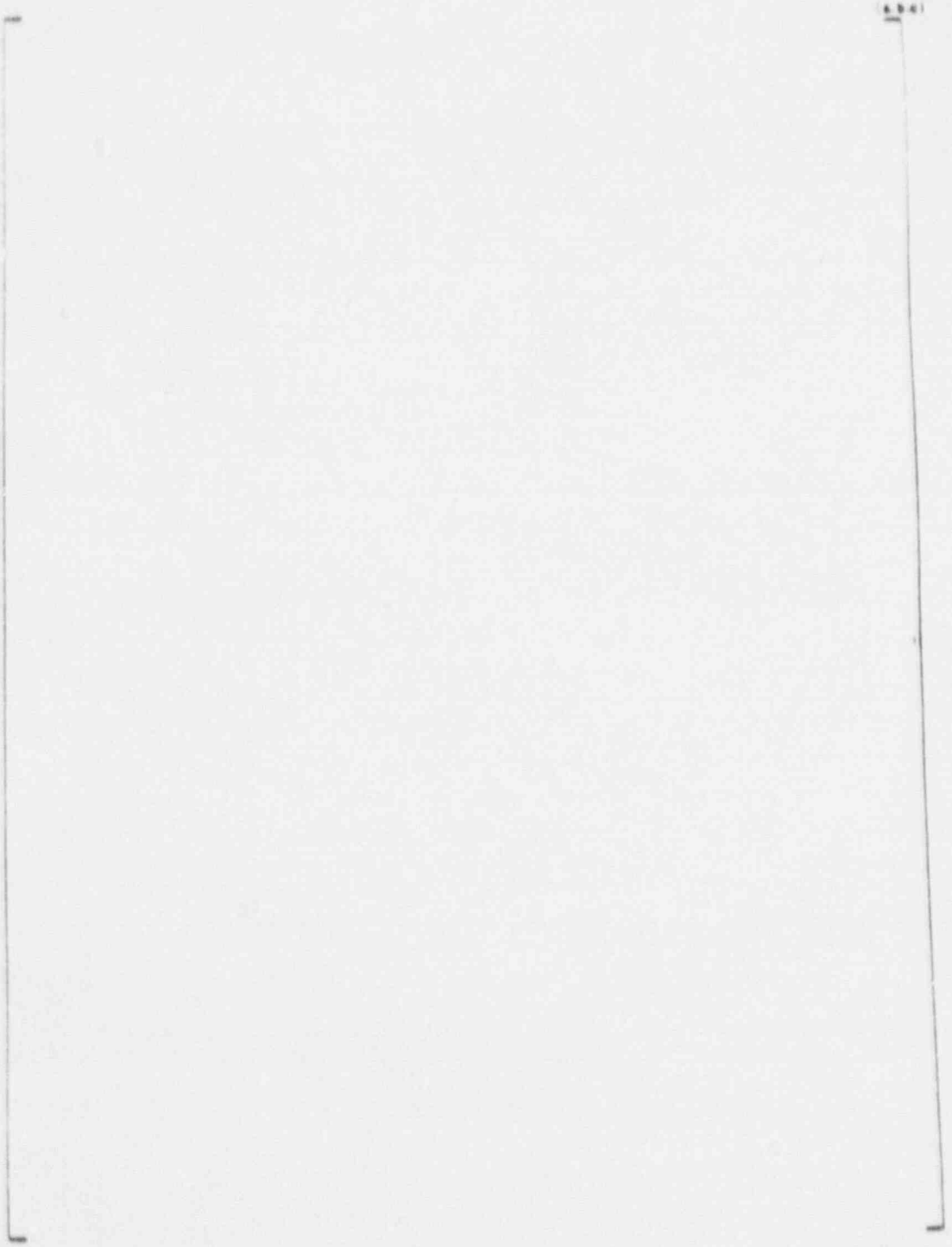


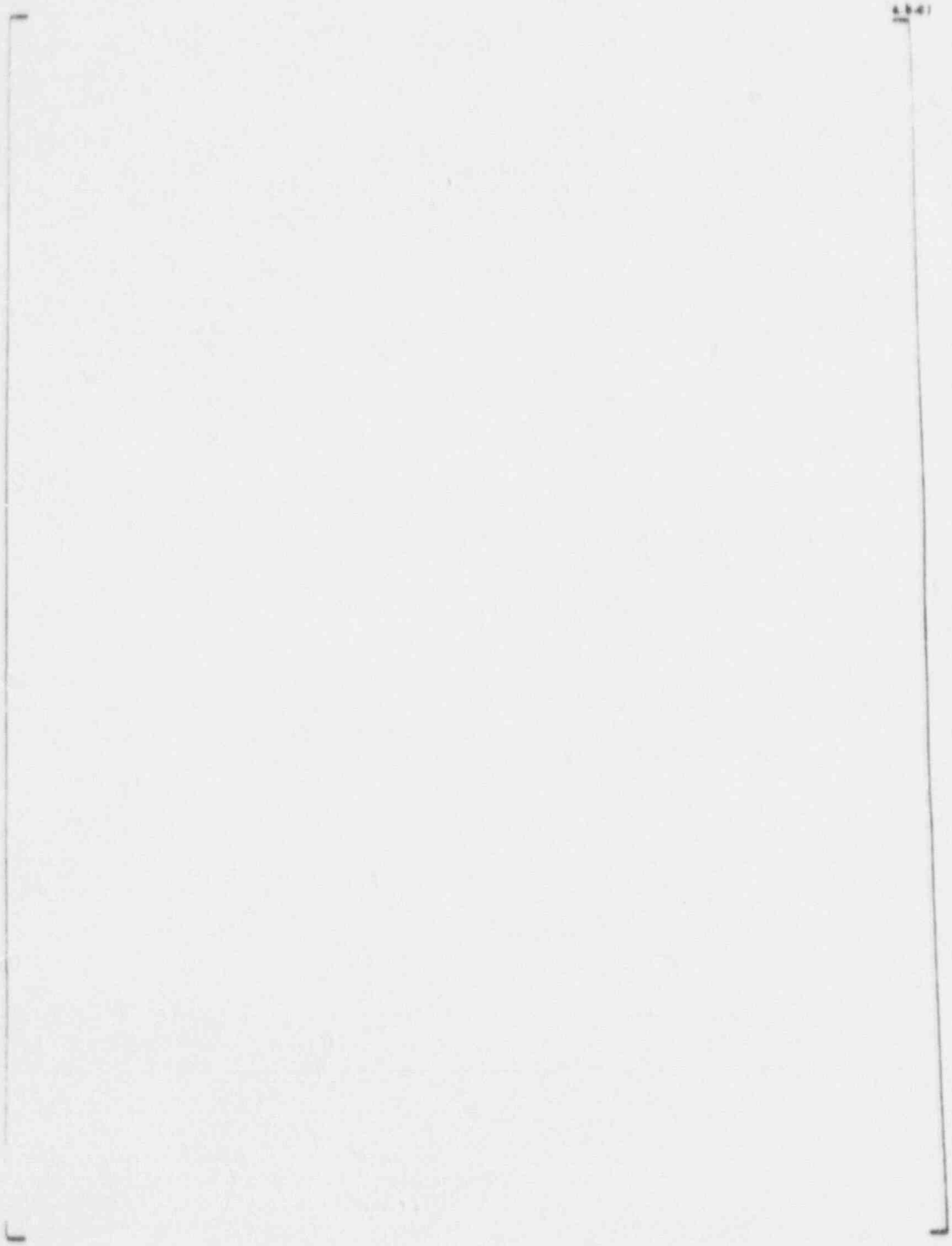


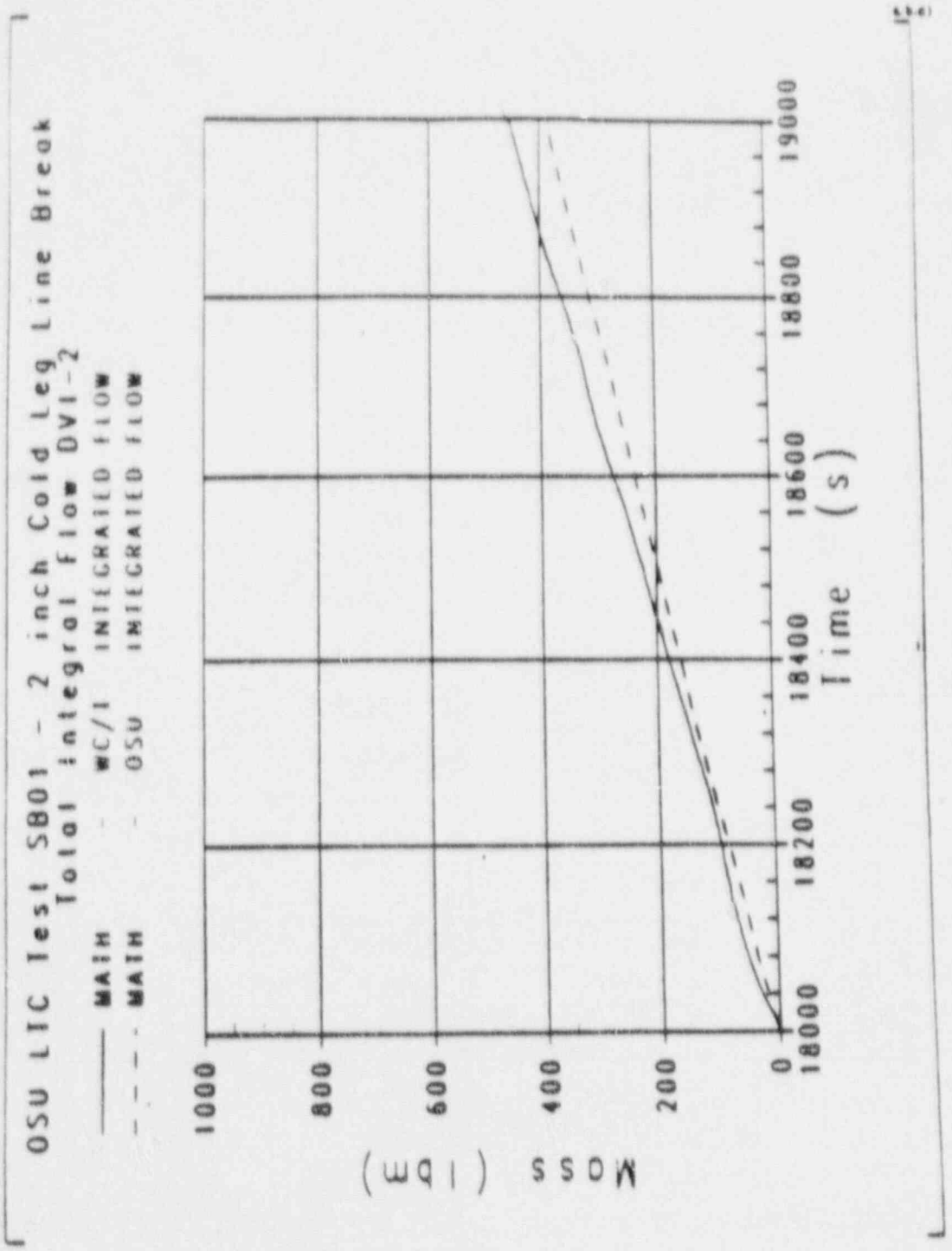


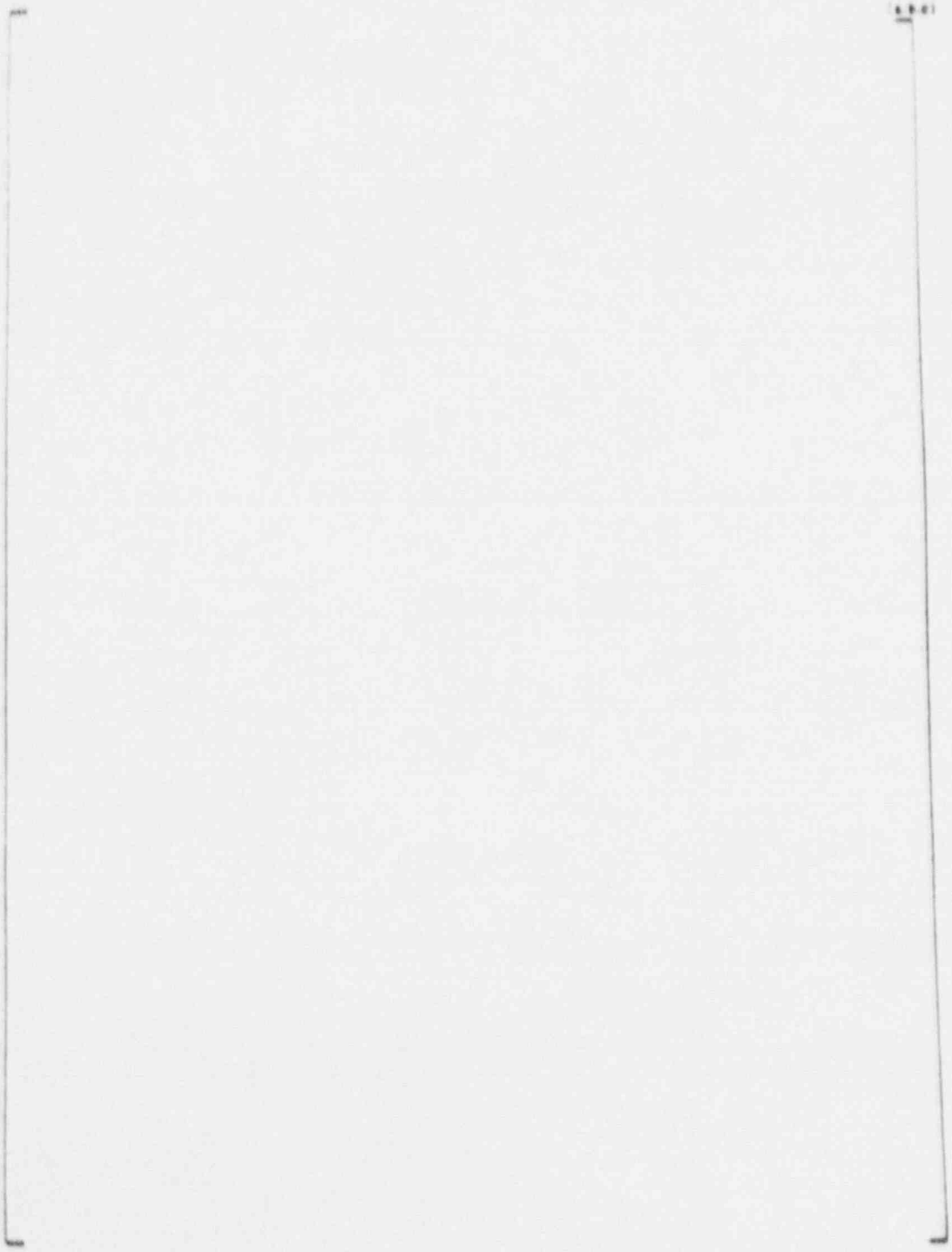


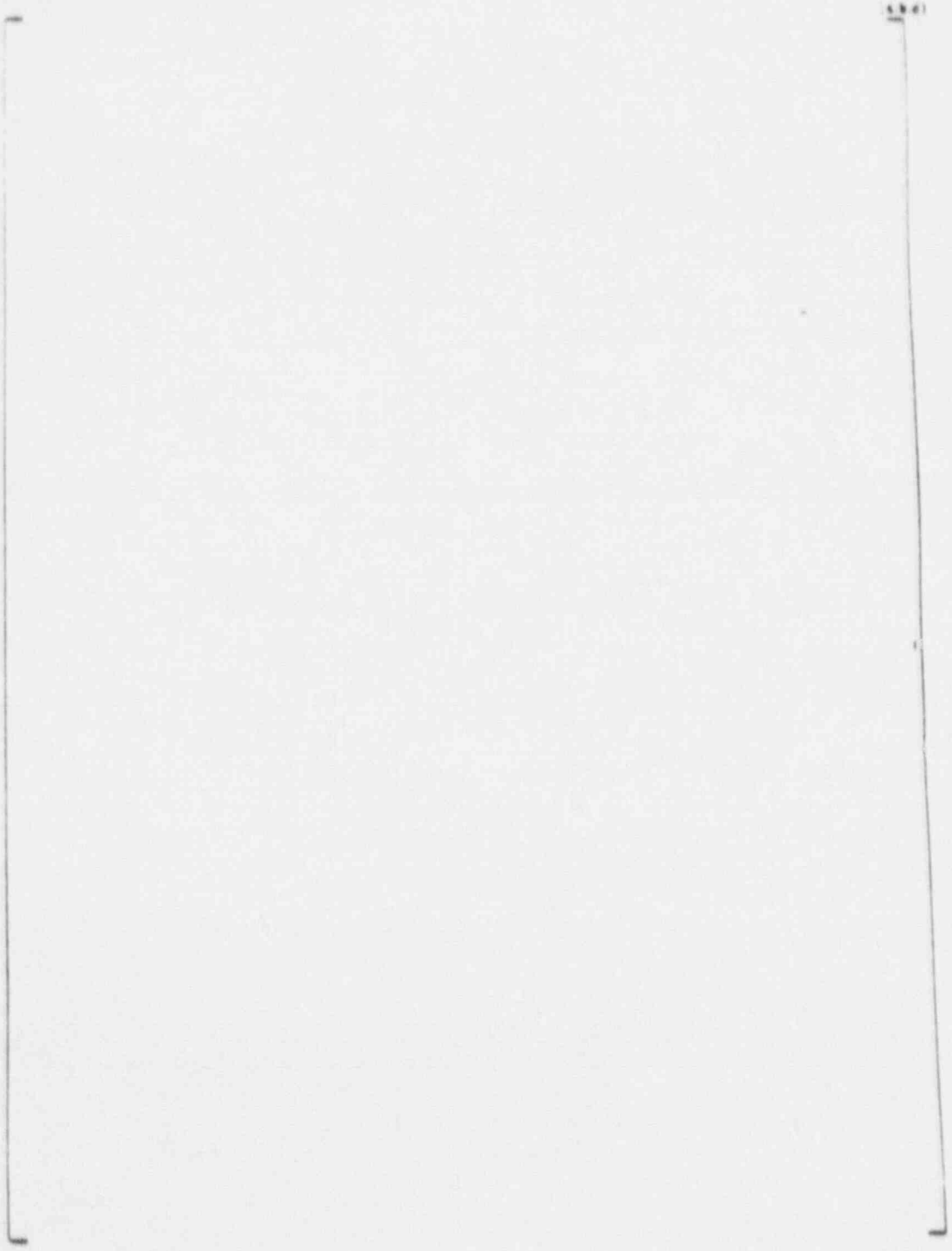


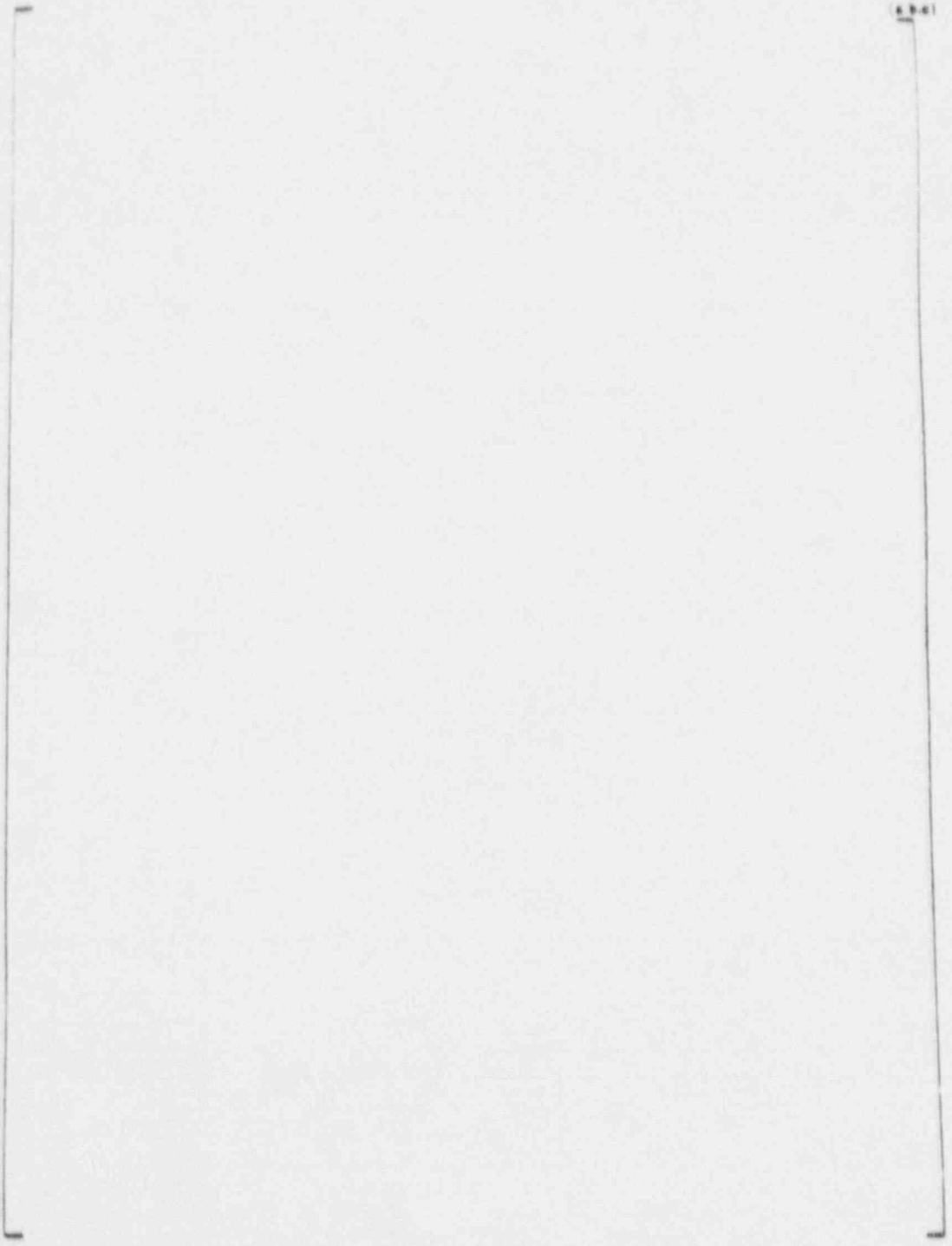


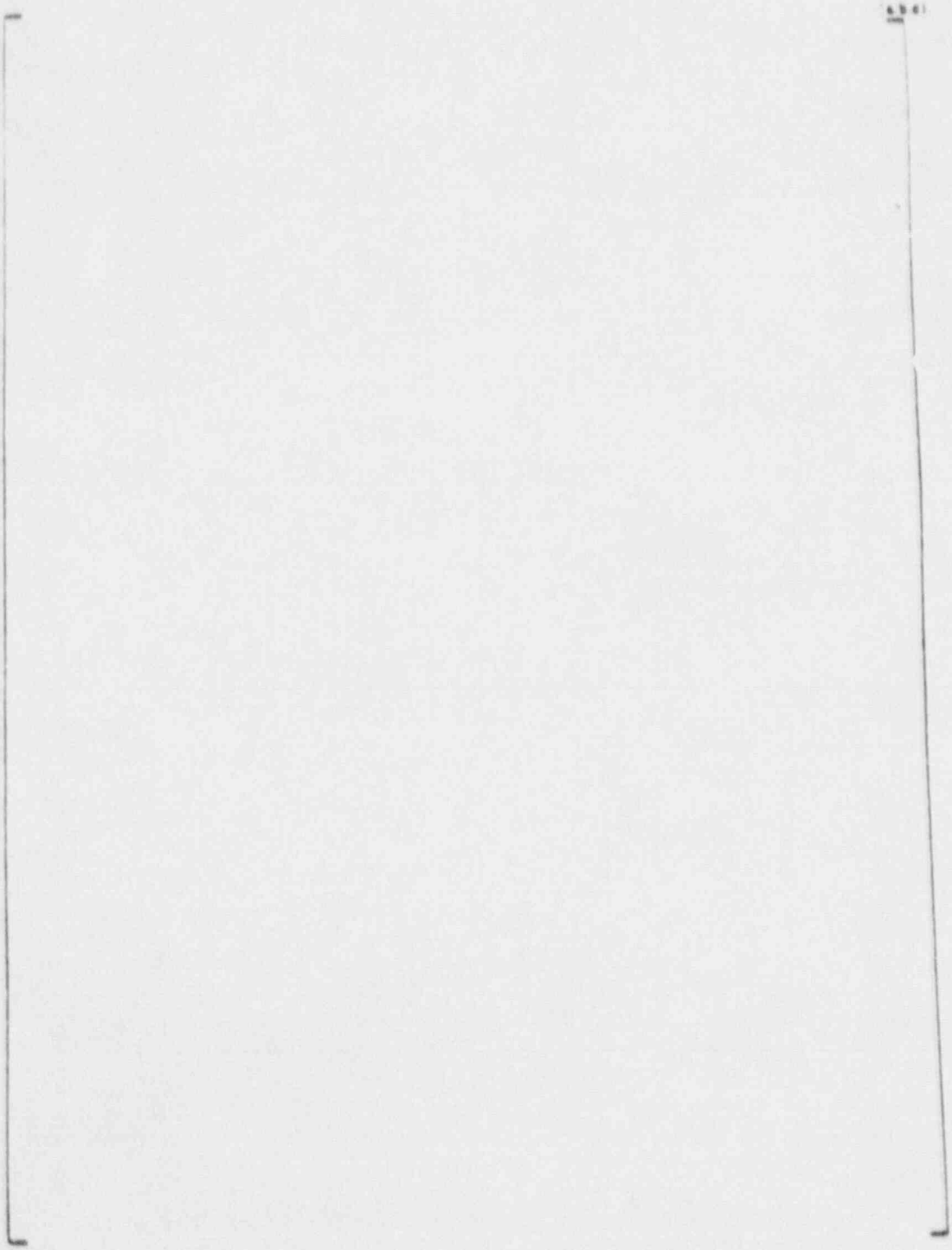


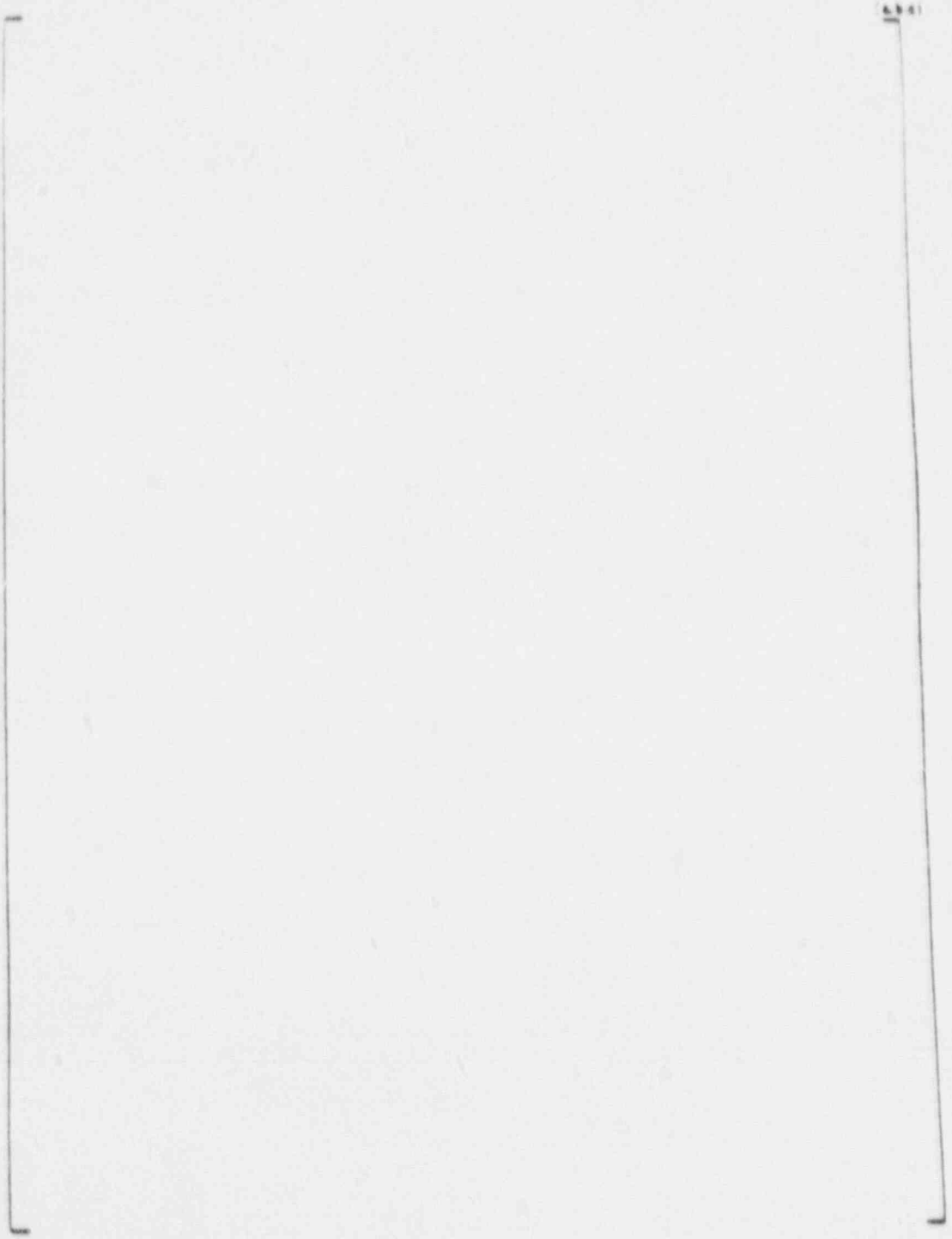

OSU LIC Test SB01 - 2 inch Cold Leg Line Break
Total Integral Flow DVI-2
MAIN WC/I INTEGRATED FLOW
MAIN OSU INTEGRATED FLOW
Mass (lbm)
1000
800
600
400
200
0
18000
18200
18400
18600
18800
19000
Time (s)

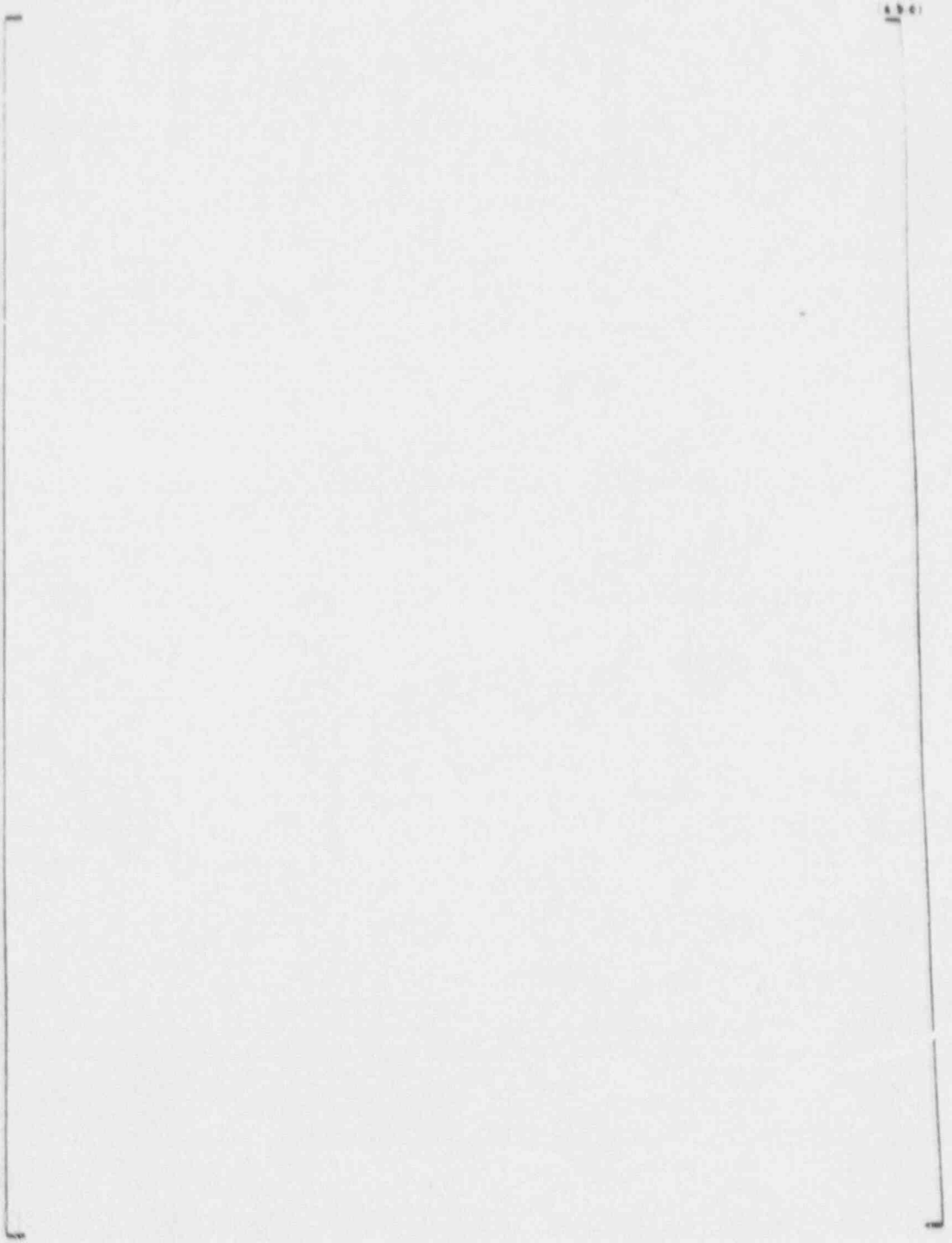


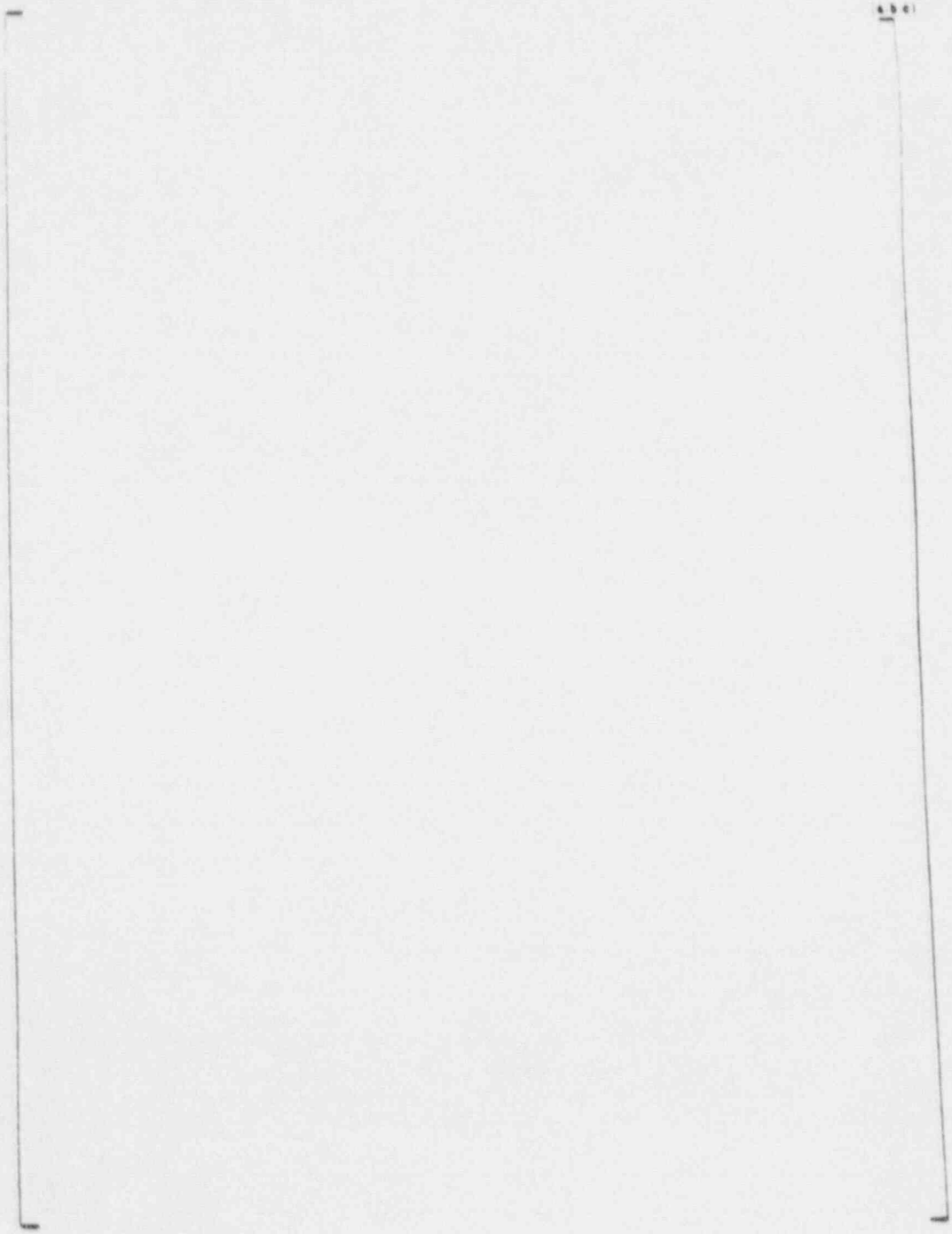












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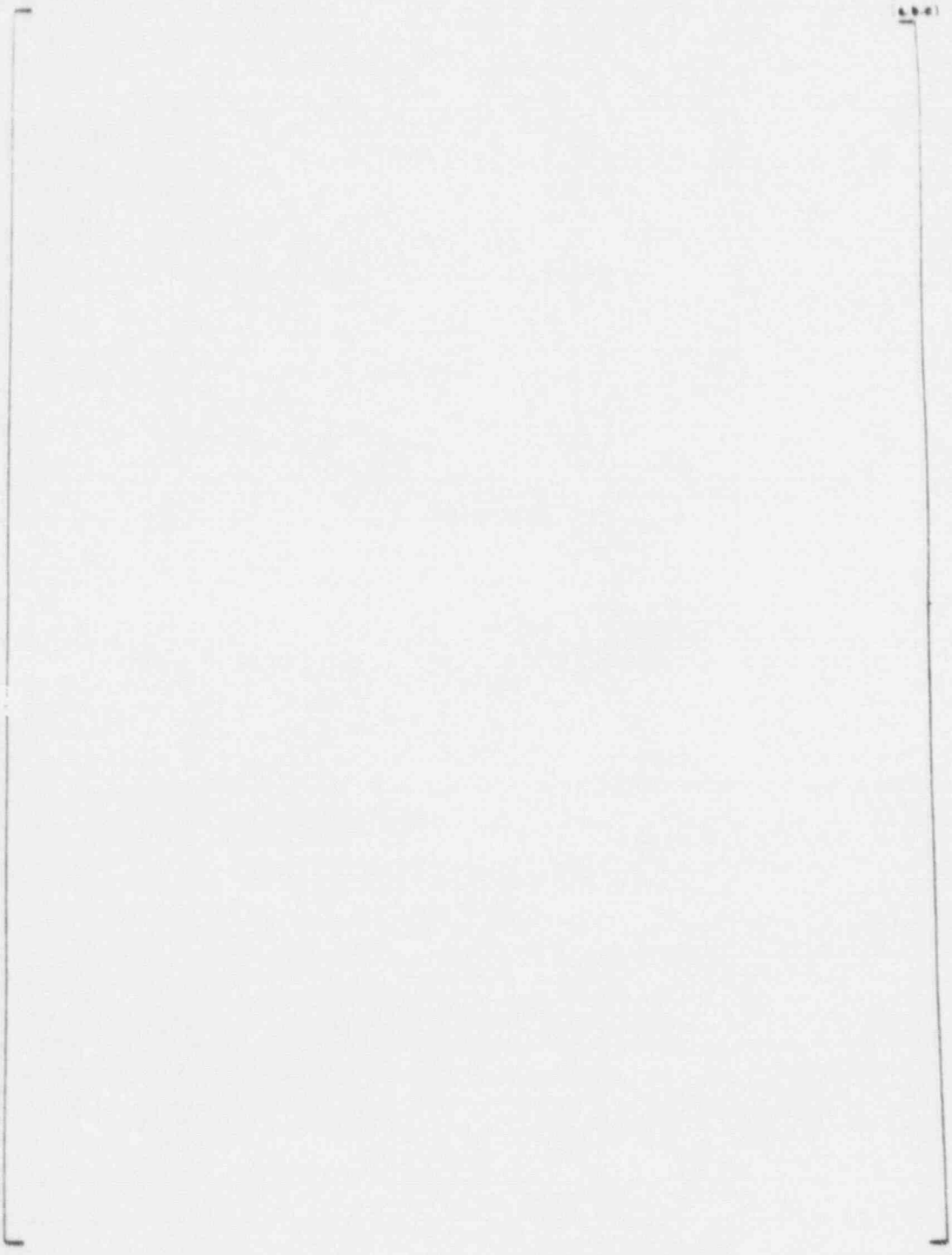
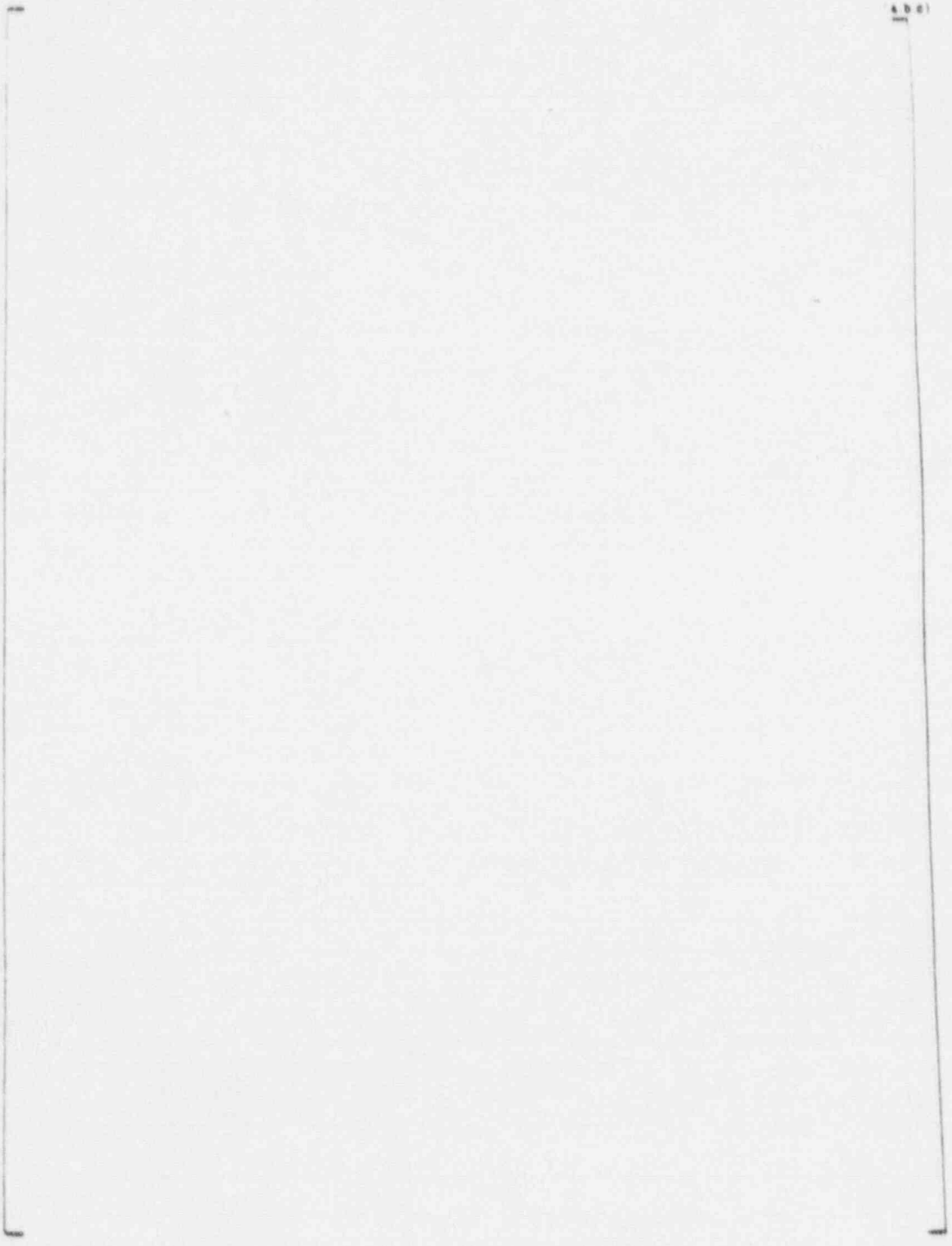
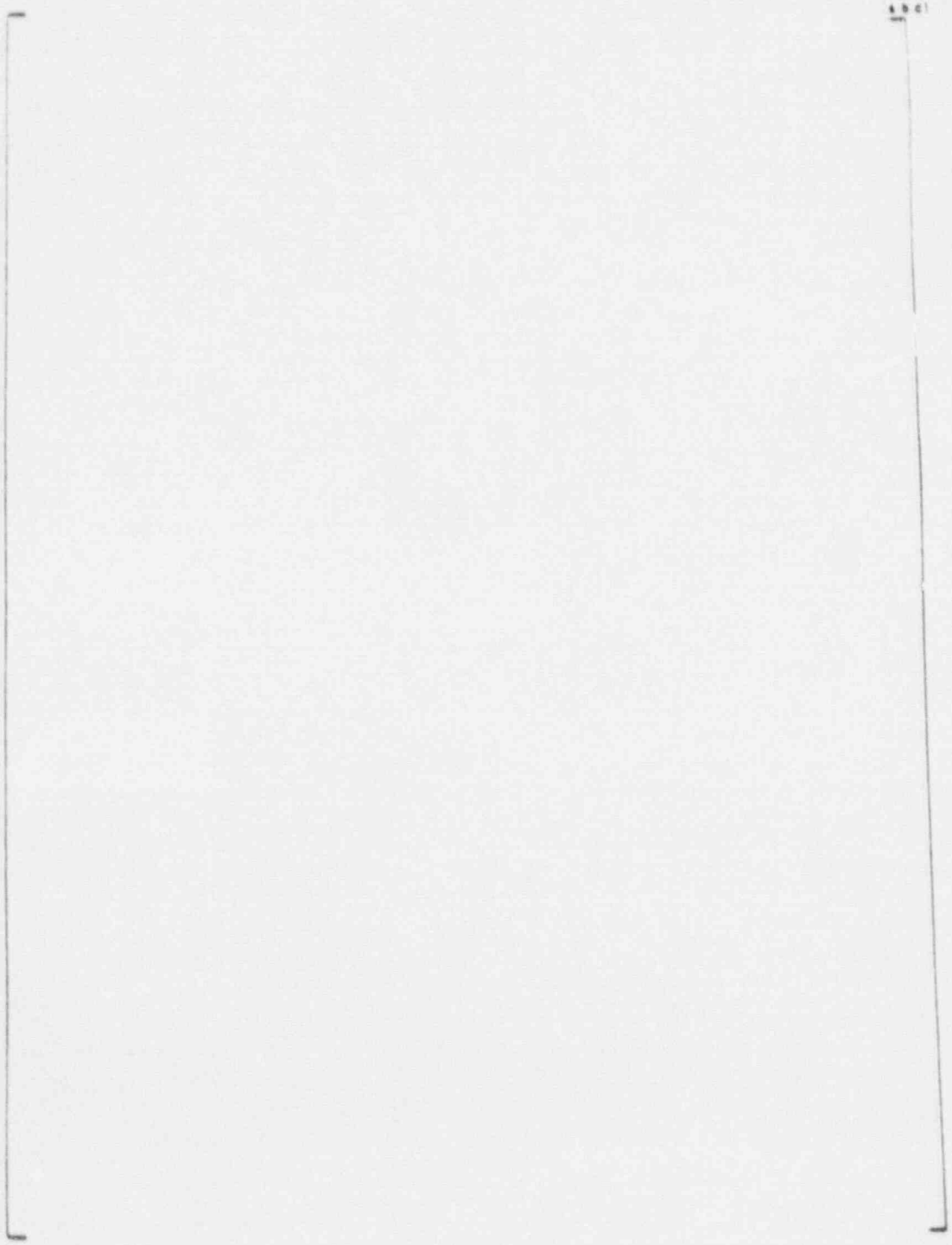






RAI 440.593

In Figure 6-8, the measured and calculated ratios of the inflow and outflow are a function of time. How would these ratios change if the calculations were performed for longer time intervals.

Response:

As indicated in the report, the values presented are the quasi-equilibrium values for the four WC/T vs. OSU comparisons. As such, they are average values over periods of 600 to 700 seconds. While all of these cases have not been extended to 3000 seconds, Test SB10 has been. The time wise variations are contained in Table 440.593-1. For the WC/T results, the maximum variation between total flow in and total flow out occurs between 15,000 and 15,500 seconds. This coincides with a slight reduction in vessel liquid inventory in the upper plenum during this period as indicated by Figure 440.593-1. Similiarly, the OSU test data indicates a period of time from 14,000 seconds to 15,000 seconds during which the outflow exceeds the inflow by approximately 6%. This also corresponds to a reduction in upper plenum inventory, Figure 440.593-1, although there appears to be a time shift of approximately 500 seconds. Considering the uncertainity in the flow rate measurements, this agreement is considered good. In any case, the variation in the outflow to inflow parameters with time is small considering variations in DVI line flows in this period of transition from IRWST injection to sump injection.

Table 440.593-1

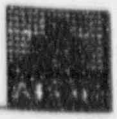
Total Vessel Outflow / Total Vessel Inflow for SB10

Time Period (seconds)	WC/T Total Outflow / Total Inflow	OSU Total Outflow / Total Inflow
14,000 to 14,500	0.994	[a, b, c]
14,500 to 15,000	1.005	
15,000 to 15,500	1.063	
15,500 to 16,000	1.026	
16,000 to 16,500	1.044	

Report Revision:

None

[ ]



RAI 440.594

How were the boundary conditions of pressure, temperature, and void fraction at the break applied? Page 5-1 WCAP-14776 states that the break separator level, temperature, and pressure were used to determine the boundary conditions. However, page 5-4 states that reverse flow from the break separator into the cold leg could not be predicted while page 5-5 states that reverse flow was predicted. Simliar statements appear on page 5-93. When reverse flow is predicted, is the inflow into the reactor coolant system at the appropriate conditions based on the measurements in the break separator? If so, isn't the separator implicitly modeled through the applied boundary conditions?

Response:

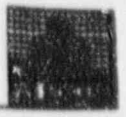
The statement "The simulation did not model that break separator, so reverse flow into the cold leg because of the break seperator filling cannot be predicted" which appears on page 5-4 and also on page 5-93 is an editorial error. The draft for the report was based on the Preliminary Validation Report, LTCT-GSR-003, which contains this statement. In Reference 440.594-1, the break seperator was modeled as a sink/source component with the appropriate pressure, temperature and liquid level. This sentence will be removed in the Revision 1 to Reference 440.591-1.

References:

440.594-1. WCAP-14776, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1996.

Report Revision:

None



RAI 440.595

In WCAP-14776, the predicted downcomer level was 15 in. below the measured value for Test SB23. The predicted level was below the elevation of the DVI line while the measured level was at the bottom of the cold leg. The discrepancy is much larger than the error for the other tests (about 5 in.). Is this discrepancy for Test SB23 significant? Why was predicted downcomer level worse for this test?

Response:

The predicted vessel levels in Test SB23 can be understood most clearly when compared to SB01 since the primary difference is the cold leg break flow area. Test SB23 approximates a no break calculation since the hydraulic resistance of a 1/2 inch break flow path is large with respect to the hydraulic resistance of the DVI lines, a factor of approximately 40 greater than the IRWST to vessel line and a factor of 6 to 8 greater than the sump to vessel line. Conversely, for the 2 inch break SB01 test, the hydraulic resistance of the break is 16 times larger and the break is the roughly equivalent of having a third DVI line; assuming that the break separator liquid level is equal to the IRWST level. The separator level is lower but only slightly so during the periods of the window mode calculations. While the reverse break flow magnitudes are suspect due to lack of calibration, it is noted that the indicated break flow rate for the SB01 test is -0.260 lb/sec versus -0.022 lb/sec for the SB23 test. Thus, test SB01 has a significantly different balance of the inlet to outlet hydraulic resistances than SB23 and an increase in the calculated liquid levels of about 4.5 inches in the downcomer and correspondingly in the core plus the upper plenum. With a significantly reduced inlet flow resistance and an increased vessel through flow of only 5% to 10%, it is reasonable to expect the vessel liquid levels to be greater for the SB01 test. Thus, it is concluded that the calculated lower level for SB23 should be expected and does not represent an anomaly in the data comparisons.

Report Revision:

None

RAI 440.596

WCAP-14776 states (page 6-2) that the pressure drop across the ADS 4 lines is relatively small compared to the resistance of the DVI lines. What are the calculated frictional pressure drops across the ADS 4 lines and DVI lines during sump injection for one of the tests? What is the predicted void fraction at the ADS 4 flow nozzles for the corresponding period?

Response:

During the early period of IRWST injection when steam formation in the core is minimal, the pressure losses across the ADS 4 valves are small with respect to the DVI line losses. With the initiation of significant boiling in the core, the two phase pressure losses in the ADS 4 valves shift the balance of pressure losses. The calculated frictional pressure drops across the ADS 4 lines and DVI lines during sump injection for a 50 second period of SB-01 sump injection are provided in Figures 440.596-1 and 440.596-2. These results are taken from the 1000 second window calculation provided in response to RAI 440.592. The short window is being provided with a print frequency of 0.1 seconds to accurately show the pressure drop and void fraction fluctuations. This window is considered to be representative of the larger window and to the general condition of sump injection. The void fractions in the ADS 4-1 and ADS 4-2 valves are provided in Figure 440.596-3.

Based on the results shown for the sump injection phase, it is concluded that the DVI line pressure drop and and ADS 4 pressure drop are of similiar magnitude during this period. The statement on page (6-2) will be revised as follows:

"The ranking of this parameter has been reduced from high to medium. The basis for the reduction is sensitivity studies, varying the ADS Stage 4 valve losses, which indicated no significant effects on the levels in the core and core coolability during LTC. Therefore, the uncertainity in parameters such as the flow regime and separation at the ADS tee are of reduced importance, and comparisons of the ADS Stage 4 flow rates with WCOBRA/TRAC are sufficient for the validation of the code pressure drop calculation."

The sensitivity studies which support this conclusion are discussed in the response to RAI 440.597.

Report Revision:

WCAP-14776, **Page 6-2**, paragraph 2.

DVI-2 Line Pressure Losses from
IRWST to Reactor Vessel

Figure 440.596-1

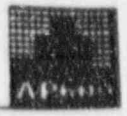
ADS 4 Valve Pressure Losses

Figure 440.596-2

ADS 4 Valve Void Fractions

——— ADS 4-1
- - - - ADS 4-2

Figure 440.596-3



RAI 440.597

WCAP-14776 states on page 6-2 that sensitivity calculations showed that the calculated levels were not significantly affected by ADS-4 losses. Where are these sensitivity calculations documented? How sensitive was the total flow through the primary system to the ADS-4 losses during sump injection?

Response:

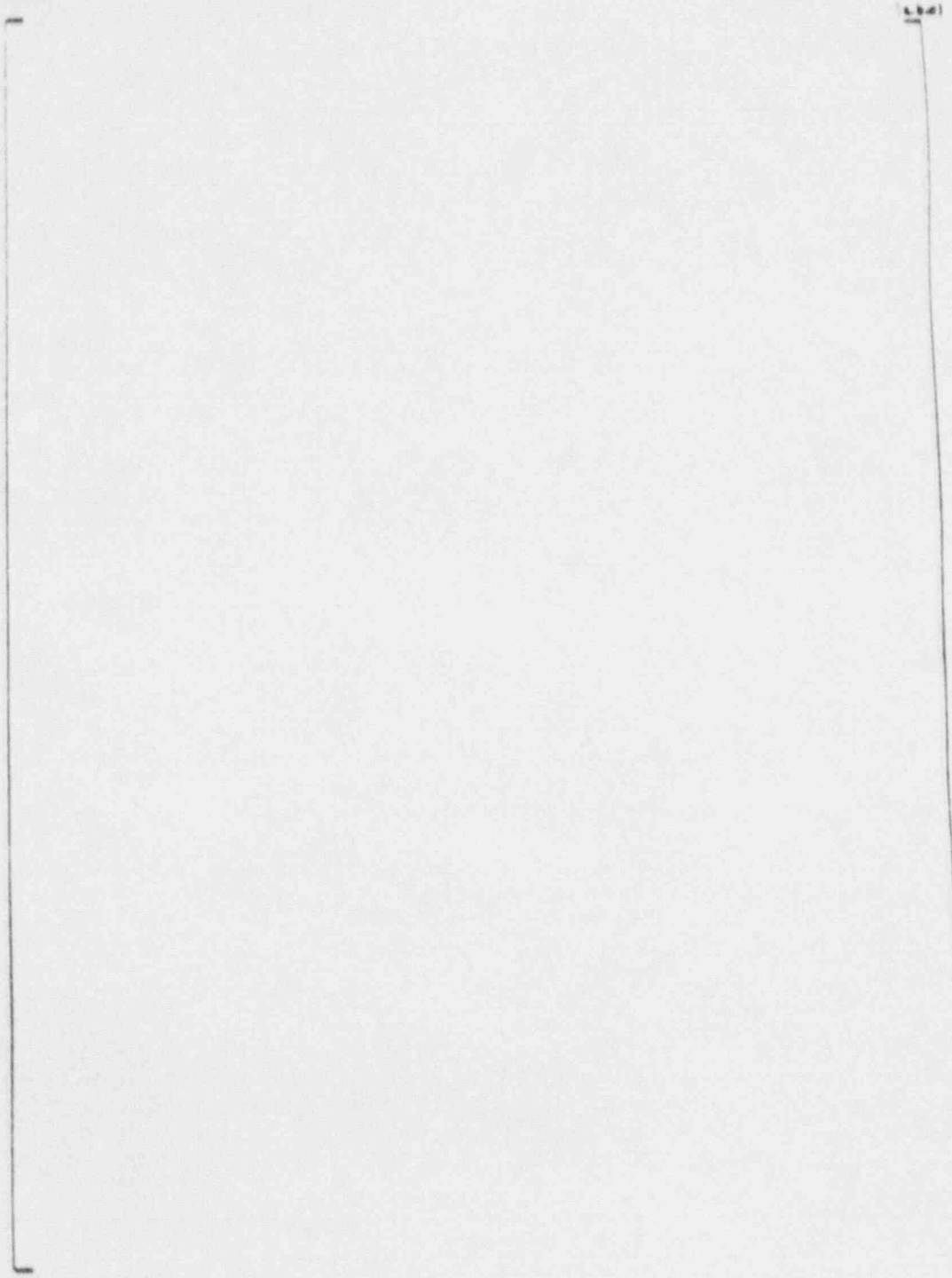
The sensitivity to ADS-4 pressure losses has been calculated for the SB-01 window period of 18,000 second to 19,000 second during which the flow to the DVI lines comes entirely from the sump. In this calculation the loss coefficient of the ADS 4 valves was increased by 50% in both loop 1 and loop 2. As shown in Table 440.597-1 below, the total flow through the primary system decreased by approximately 19%. Correspondingly, the collapsed liquid level in the vessel decreased by 0.40 inches. The change in vessel levels is shown in the attached Figures 440.597-1 through 440.597-4. The rate of steam generation in the core increases from approximately 0.85 lbm/sec. to 0.95 lbm/sec to compensate for the reduced injection flow rate.

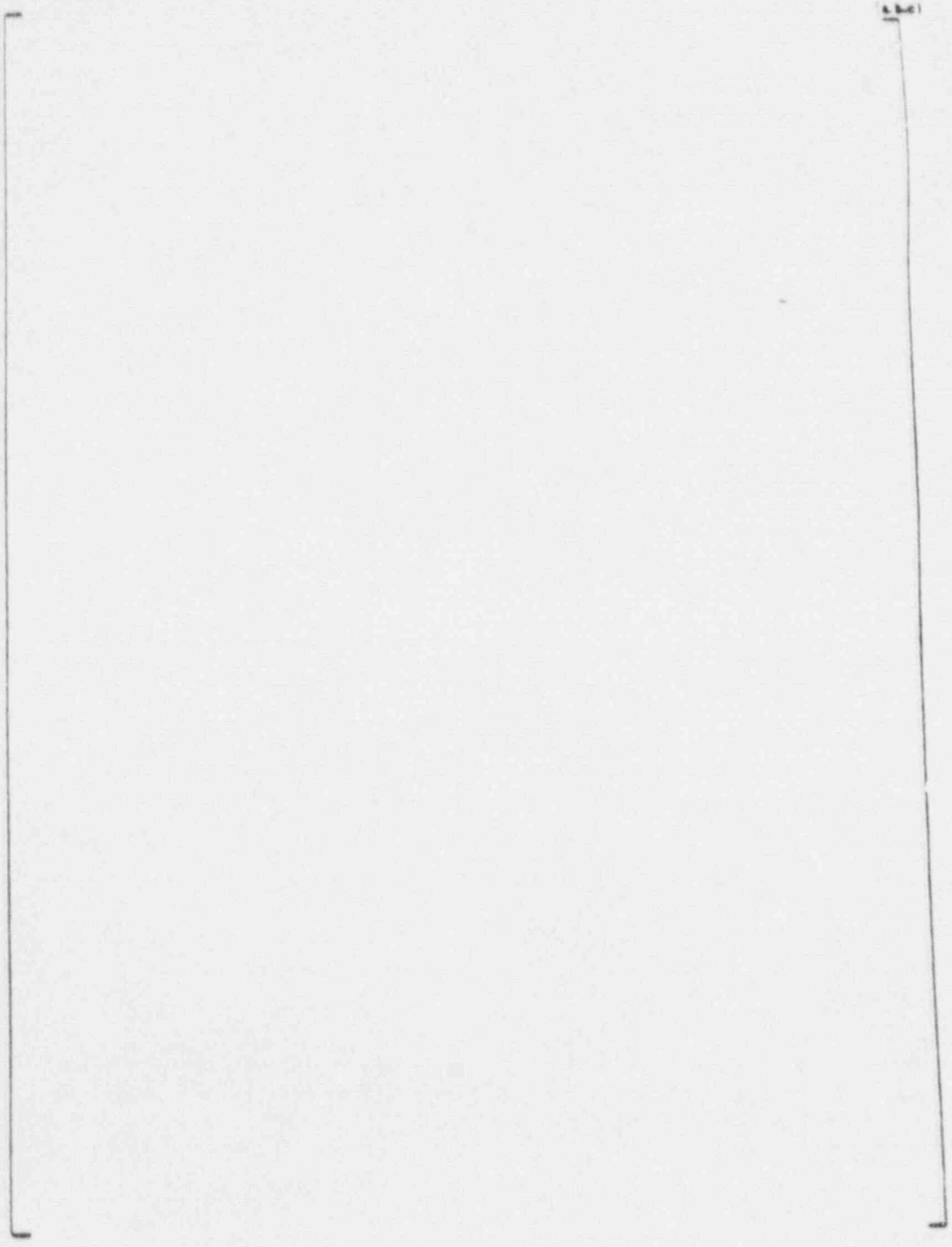
Table 440.597-1
Sensitivity of Vessel Conditions to 50% Increase in
ADS 4 Pressure Loss Coefficient (Test SB-01)

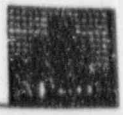
Total Vessel Inflow	Reference Calculation	+50% ADS-4 K_f Calculation	Variation
DVI-1 (lbm/sec)	0.426	0.368	
DVI-2 (lbm/sec)	0.460	0.392	
2" Break (lbm/sec)	0.068	0.016	
Totals	0.954	0.776	-19.6%
Total Vessel Outflow			
ADS 1, 2, 3 (lbm/sec)	0.021	0.021	
ADS 4-1 (lbm/sec)	0.303	0.220	
ADS 4-2 (lbm/sec)	0.635	0.531	
Totals	0.959	0.772	-18.6%
Upper Plenum Level (in)	6.1	5.7	-0.4 in
Downcomer Level (in)	57.5	57.1	-0.4 in
Steam Generation in Core (lbm/sec)	0.850	0.950	

Report Revision: None

[ ] a,b,c







RAI 440.598

The calculated upper plenum liquid levels shown in WCAP-14776 are not consistent with the presentation Westinghouse made to the staff on March 12, 1991. For example, Figure 5.1-23 of the report shows that the calculated level is about 14 in. for Test SB-01 while page 45 of the presentation material shows that the calculated level is about 9 in. Why are the calculated results different between the report and the presentation?

Response:

The upper plenum collapsed liquid levels reported in WCAP-14776 were based upon an inappropriate selection of upper plenum channel for calculating the level in the WC/T plotting package. As shown in Figure 2-2 of the WCAP, there two channels in Section 3 of the upper plenum, channel 15 and channel 50. Channel 15 is an annular global channel located adjacent to the core barrel and does not see core outlet flow intering at the bottom. Channel 50 is the core outlet channel and all flow from the core enters this channel. Due to the desire to minimize the number of nodes, these channels have only one vertical node for the 11.9 inch height. As a consequence, the global channel tends to have a high liquid fraction over the entire height while the core outlet channel more correctly reflects the core outlet void fraction. Using the void fraction in the global channel 15 produces an unrealistiqly high indication of upper plenum collapsed liquid level which significantly exceeds the collapsed liquid level in the downcomer. Conversely, use of the channel 50 void fraction in the collapsed liquid level calculation produces level which compares favorably with the downcomer collapsed liquid level and reflects the manometric relationship between the two flow channels. Thus, subsequent to the WCAP, all reported upper plenum collapsed liquid levels reflect the void fraction in channel 50. The WCAP will be updated to also reflect this basis for the upper plenum levels.

Report Revision:

WCAP-14776, Pages 3-6, 3-22, 3-38, 3-54, 5-28, 5-59, 5-86, and 5-118.

General Comment 1.

Westinghouse should consider including the measured and calculated loss factors for the ADS 123 and ADS 4 flow paths in Table 3-7.

Response:

Pressure loss coefficients for the OSU ADS 123 and ADS 4 lines and valves were calculated from single phase handbook data and based on the physical dimensions obtained from the piping drawings. These values were input to WC/T which calculated two phase multipliers based upon the local fluid conditions. Satisfactory pre-operational test data was not available for comparison. As reported in WCAP-14252, the ADS 123 line resistance was measured, however, the orifice plate, designed to simulate the valves, was not installed. No tests were performed in this test series to determine the pressure loss coefficients of the ADS 4 lines and valves.

Report Revision: None

General Comment 2.

The report correctly states that the mass flow through the ADS 123 valves was negligible during the long-term phase. The comparisons between the calculated and measured values are then characterized as excellent for Test SB10, fair for Test SB12, and good for Test SB23. The variation in characterizations is inappropriate considering the uncertainty in the data. According to Appendix D of WCAP-14252, the uncertainty in the ADS 123 liquid flow measurement (FMM-601) is 1.342 gpm or about 0.18 lbm/sec, which is much greater than the measured values. Furthermore, since the level is near the bottom of the pressurizer during the long-term phase, no liquid flow would be expected through ADS 123. Steam flow through ADS123 would be expected, but no reliable measurements of the steam flow are available because the instruments were not ranged properly for the long-term phase. In fact, the reported steam flow rate (FVM-601) was less than zero, which is clearly impossible, during the window period for three of the four tests. Thus, the staff has conclude that the ADS 123 flow measurements are very uncertain and that the apparent differences in the "goodness" of the comparisons for the tests are not meaningful.

Response:

In retrospect, we agree. The discussion on the ADS 123 flows in WCAP-14776 will be modified to reflect the significance of the uncertainty in the vapor flow measurements.

Report Revision:

WCAP-14776, Page 5-35 para. 4, Page 5-66 para. 4, and Page 5-93 para. 5.

General Comment 3.

The calculated DVI 1 flow rate reported in the text on page 5-65 for Test SB12 (0.87 lbm/s) is inconsistent with Figures 5.5-3, 5.3-4, and 6-1 (about 1.2 lbm/s). Similarly, page 5-66 states that the total calculated ADS 4 flow is 1.12 lbm/s while Figures 5.3-14, 5.3-18, and 6-6 indicate that it is about 1.35 lbm/s. These apparent discrepancies between the text and figures affect the global mass balance discussion on page 5-67 as well as the summary of results presented in Section 6 (including Figure 6-3).

Response:

The calculated DVI 1 flow rate reported in the text on page 5-65 for Test SB12 should have been 1.14 lbm/sec and the total calculated ADS 4 flow on page 5-66 should have been 1.35 lbm/sec. The values on pages 5-65 and 5-66 were taken from a tabulation which included a earlier WC/T calculation for Test SB12 and had not been updated to reflect the plots in the WCAP. Pages 5-65 and 5-66 will be updated appropriately. Section 6 was developed from an updated table and contains none of the early calculational results.

Report Revision:

WCAP-14776, Pages 5-65 and 5-66.

General Comment 4.

The mass ratio comparisons shown in Figure 6-8 appear to be contradictory. The figure shows that the ratio of flow out to flow in is greater than unity for the tests (indicating that vessel levels should be decreasing) and less than unity for the calculations (indicating that vessel levels should be increasing). Thus, the trends of the calculation appear to be wrong. The text should justify why these results are adequate.

Response:

The text will be updated to reflect a re-evaluation of the predicted ratios which were presented at the ACRS meeting and which showed that WC/T inflow and outflow are equal, Figure 440.GC4-1. The deviations in the measured ratios results primarily from the uncertainty in the vessel inflow and outflow test measurements. This is significant when the negative break flow rates become large, such as in Test SB01, since the flow meters were not calibrated for reverse flow at OSU. This effect is discussed in detail in RAI 440.589

Report Revision:

WCAP-14776, Page 6-3

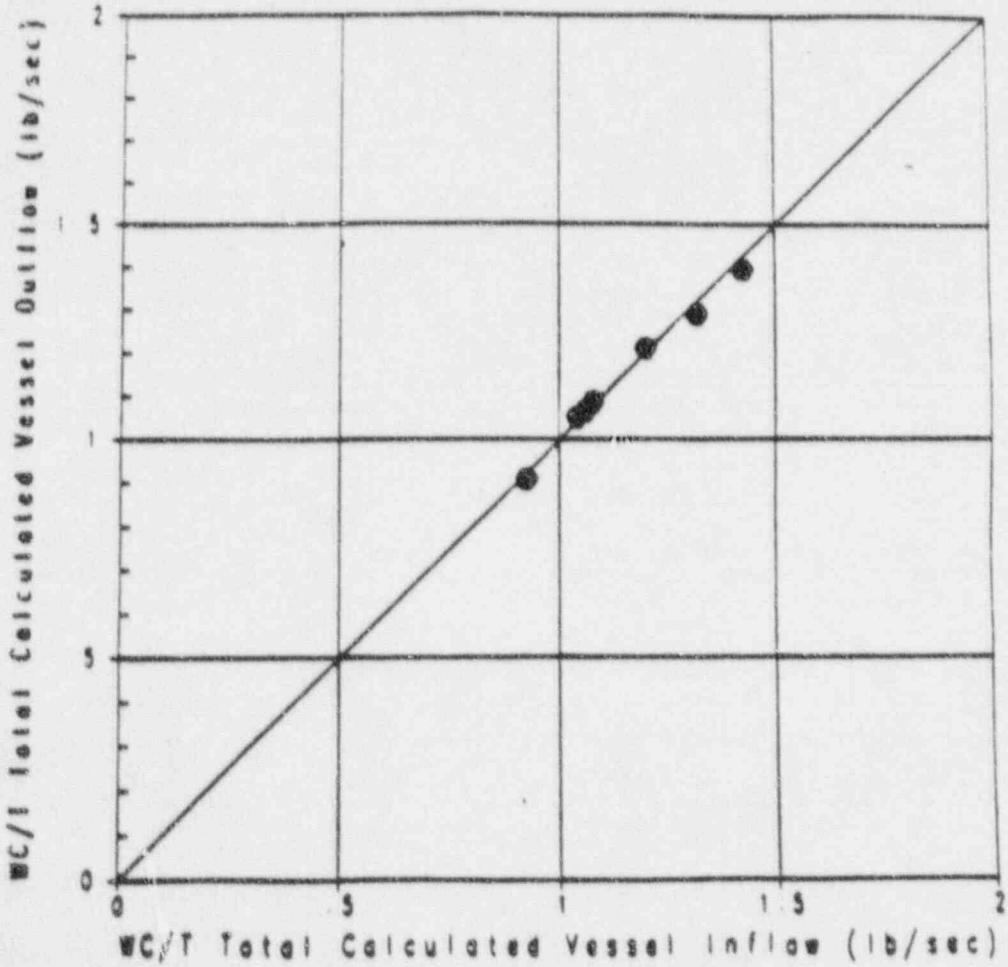


Figure 440.GC4-1

DRAFT

Attachment 13 -

~~(1)~~ Non Proprietary

RAI 440.589

The trends in the WCOBRA/TRAC analyses of the OSU S801 test show an overprediction of injection flow and an underprediction of exit flow. Extrapolation of these trends would lead to a conclusion that the calculated reactor vessel water level will not fit the test data well beyond the end of the window. Specifically, Figures 5.1-3 to 5.1-10 show that the injection flow rate is higher than the corresponding measured value. Figures 5.1-11 and 5.1-12 indicate that the injected water temperature is considerably lower. Figures 5.1-16 and 5.1-18 indicate that ADS 123 and ADS 4-1 flows are lower. If these trends continue, the calculated total injected water would be much greater than the test data shows and the calculated total boiloff and water exiting the RCS would be much less than the test data. This would result in an erroneously high value for the calculated reactor vessel water level sometime beyond the end of the window. Westinghouse should consider extending the window width (by 3 to 4 times the current length of 1000 seconds) to demonstrate that the eventual trend stabilizes and balances with the final vessel water level consistent with the test data.

Response:

As provided in Ref. 440.589-1 and discussed in the ACRS meeting on March 28, 1997, Westinghouse has performed several calculations of 3000 seconds in length which indicate no solution divergence. In each of the cases, comparisons with the OSU test data were as favorable at 3000 seconds as at the end of the original 1000 second window and for the Extended Time Sensitivity, the results at the end of 3000 seconds of calculation time were shown to be identical to calculations started 2000 seconds later and run for 1000 seconds. In addition, Figure 440.589-1 was presented at the ACRS meeting which demonstrates that total WC/T vessel inflow equals total vessel outflow for the OSU test comparison cases once the quasi-equilibrium solution has been reached.

It was noted at the ACRS meeting that the reactor vessel collapsed levels are systematically low (the conservative direction). Two factors contribute to this bias. First, as discussed in the WCOBRA/TRAC Code Qualification Document (WC/T CQD), WC/T tends to over predict liquid entrainment in the large break scenario. The equivalent effect in the Long Term Cooling (LTC) scenario is to carry out liquid from the upper plenum too easily and thus reduce the collapsed liquid level to a value below that observed in the tests. A second factor which contributes to the under predicted liquid level is the coarse noding in the top of the core and the bottom of the upper plenum, see Figure 2-2 in Ref. 440.589-2. To evaluate the impact of this noding, the Section 3 channels in the upper plenum, which were previously one cell high, were divided into three vertical cells. A set of calculations were performed for OSU Test S801, during sump operation, in the time period from 18,000 seconds to 19,000 seconds. The comparison of the upper plenum levels and downcomer levels is attached in Figures 440.589-2 through 440.589-5. The upper plenum level is shown to be increased by 0.5 to 0.6 inches with the finer noding. Similar results are observed in the hot leg levels. The increased number of vertical cells has a less significant effect on the downcomer level. While this does not show a major effect on the vessel levels, it does show the trend. It is noted that, the coarse noding was retained in the core (two vertical cells) and the radial noding in the upper plenum was not altered. Thus, additional improvements in level calculations are expected if a more detailed noding is used.

As was discussed at the ACRS meeting, the WC/T comparison with SB01 was the least accurate of the comparisons in Ref. 440.589-1 and Ref. 440.589-2. There are several factors which contribute to the differences in this comparison, if the uncertainities in the measured flow rates are not considered for the moment. First as shown in Table 440.589-1 line 4, the WC/T calculated total ADS flow rates are in good agreement with the total OSU measured ADS flow rates, even though the agreement between the respective ADS 4-1 and ADS 4-2 is less accurate. However, as previously reported, the total DVI flow rates, line 7, do not compare favorably with 1.09 lb/sec calculated by WC/T versus 0.88 lb/sec measured at OSU. The divergence between the calculated and measured DVI flows from the IRWST lines, Figures 5.1-3 and 5.1-4, is more pronounced as indicated in Table 440.589-1 lines 10 and 14. The major source of this discrepancy can be seen with a re-scaled plot of the break flows, see Figure 440.189-6 and 440.189-7, which indicate significant increases in the measured break flow at 14,500 seconds. If the measured break flows are accepted as correct, the total vessel inflows are in good agreement as shown on line 9 of Table 440.589-1. However, this implies that the WC/T calculated break flow rate is significantly under predicted, Table 440.589-1 line 8. Thus, the over prediction of the IRWST flows into the DVI lines is offset by an under prediction of break flow. This discrepancy is considered to be partially the result of measurement uncertainities on the DVI line flow rates. For example, the measured DVI flows from the IRWST are 0.17 lb/sec and 0.215 lb/sec with a 2σ uncertainity on each of $\pm$ 0.076 lb/sec. Thus, the flow rates measurements are have uncertainities of $\pm$ 45% and $\pm$ 35% respectively. Of more importance is the fact that the magnetic flowmeters, used for the liquid portion of the break flow, were not calibrated for reverse flow (into the vessel) and are only useful for showing trends. Thus, the data uncertainty clouds the conclusions which can be drawn from this specific test comparion and leads to the conclusion that the entire set of comparisons must be viewed together if valid conclusions are to be drawn.

In conclusion, the total vessel inflows and total vessel outflows, lines 4 and 9 in Table 440.589-1 balance quite well for both the WC/T calculation and the OSU test. Note, that all the individual values were checked when it was found that the measured break flow was mis-estimated due to poor scaling of the integrated breakflow plot, Figure 5.1.14. The component flows do not compare as well and this is considered to be primarily the result of the uncertainties in the measured flow rates. The argument that the calculations are not primarily at fault lies with the accuracy of the remaining comparisons. This is demonstrated in Figures 440.589-8 through 440.589-11 taken from the ACRS presentation.

References

440.589-1. NSD/NRC-97-5014, "WCOBRA/TRAC Long Term Cooling Letter Report", D.C.Garner, March 10, 1997.

440.589-2. WCAP-14776, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1996.

Report Revision:
None

Table 440.589-1

SB-01 Quasi-Equilibrium Flow Rates During
Period from 14,500 to 15,000 Seconds

Line No		WC/T Calculated Flow (lbm/sec)	OSU Measured Flow (lbm/sec) (a,b,c)
	Vessel Outflows		
1.	ADS 1, 2, 3	0.006	
2.	ADS 4-1	0.463	
3.	ADS 4-2	0.729	
4.	Total Outflow (1+2+3)	1.197	
	Vessel Inflows		
5.	Total DVI-1	0.535	
6.	Total DVI-2	0.555	
7.	Total DVI (5 + 6)	1.090	
8.	2" Break Flow (into vessel)	0.070	
9.	Total Inflow (5+6+8)	1.160	
	DVI Line Component Flows		
10.	IRWST/DVI-1	0.370	
11.	Sump/DVI-1	0.165	
12.	CMT-1/DVI-1	0.000	
13.	Total DVI-1 (10+11+12)	0.535	
14	IRWST/DVI-2	0.290 **	
15	Sump/DVI-2	0.165	
16	CMT-2/DVI-2	0.100 **	
17	Total DVI-2 (14+15+16)	0.555	

** Figure 5.1-4 includes 0.100 lbm/sec from CMT-2 with IRWST flow

WC/T Total Inflow / Total Outflow Comparison

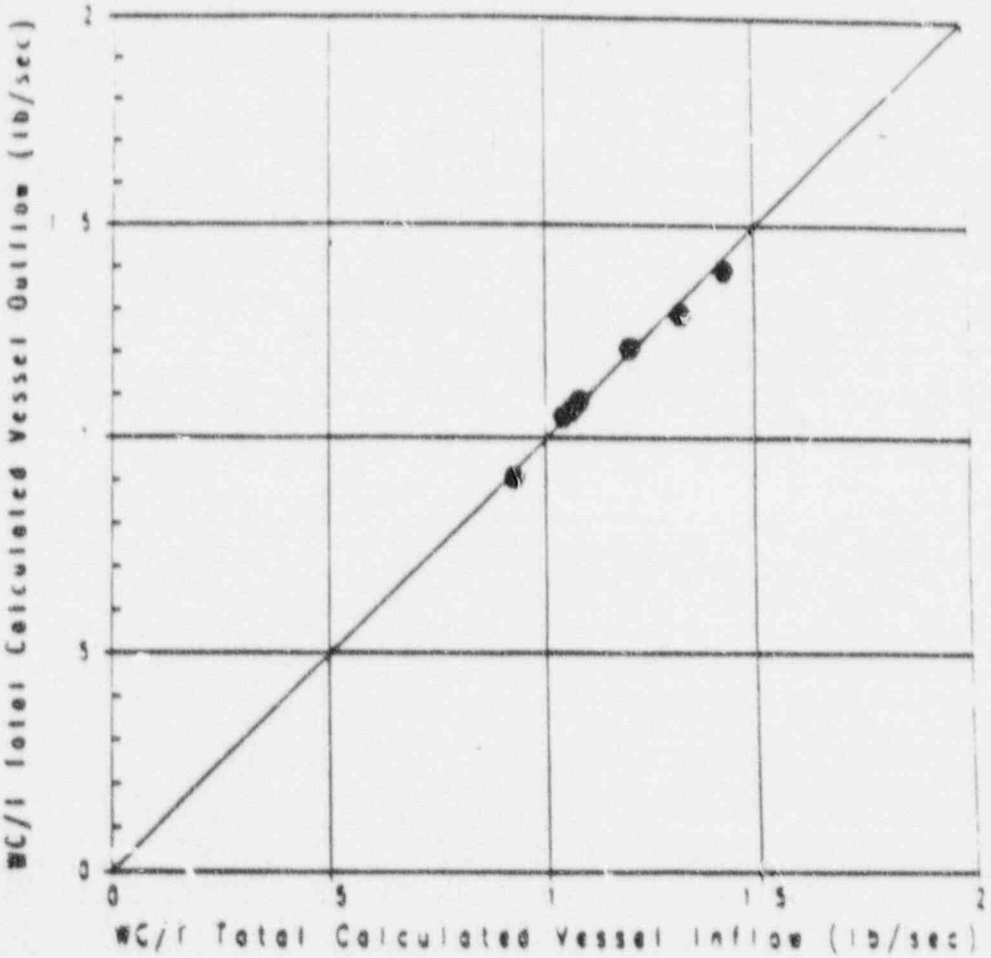


Figure 440.589-1

Upper Plenum Liquid Level Comparison

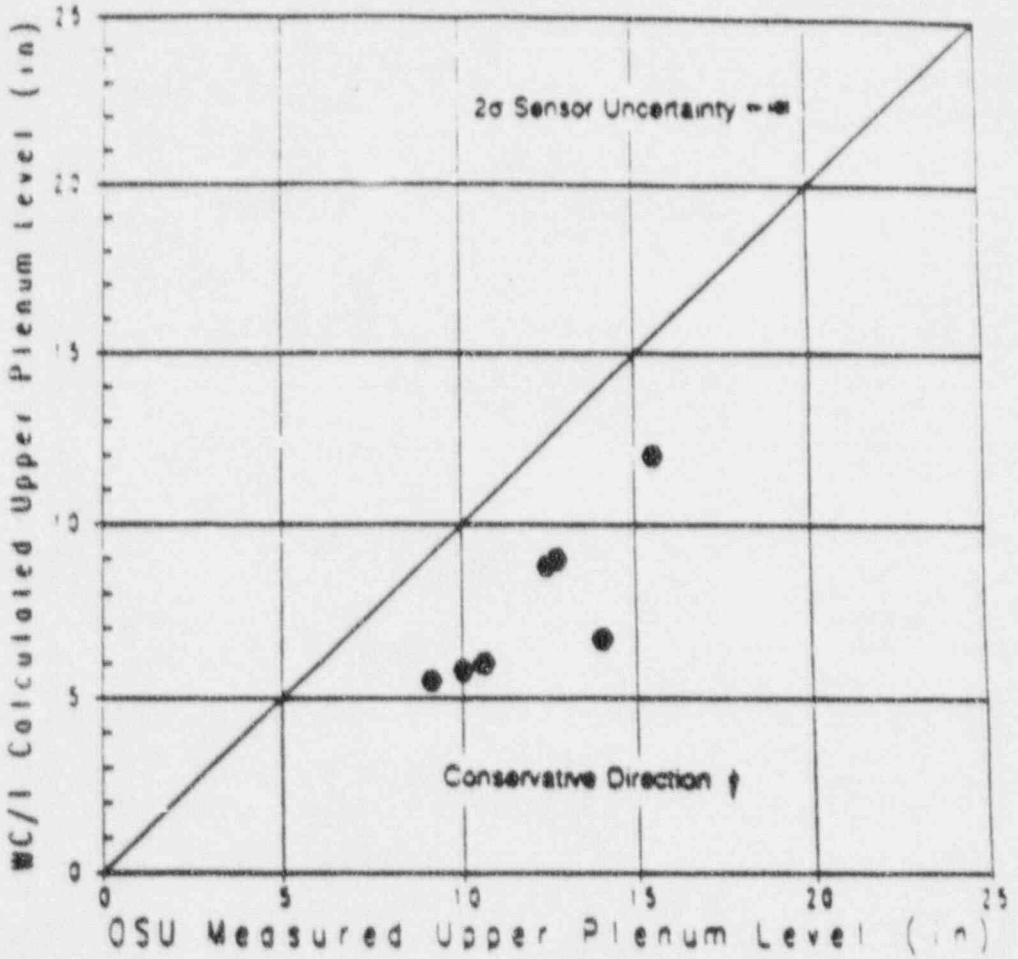


Figure 440.589-8

AP600

Downcomer Liquid Level Comparison

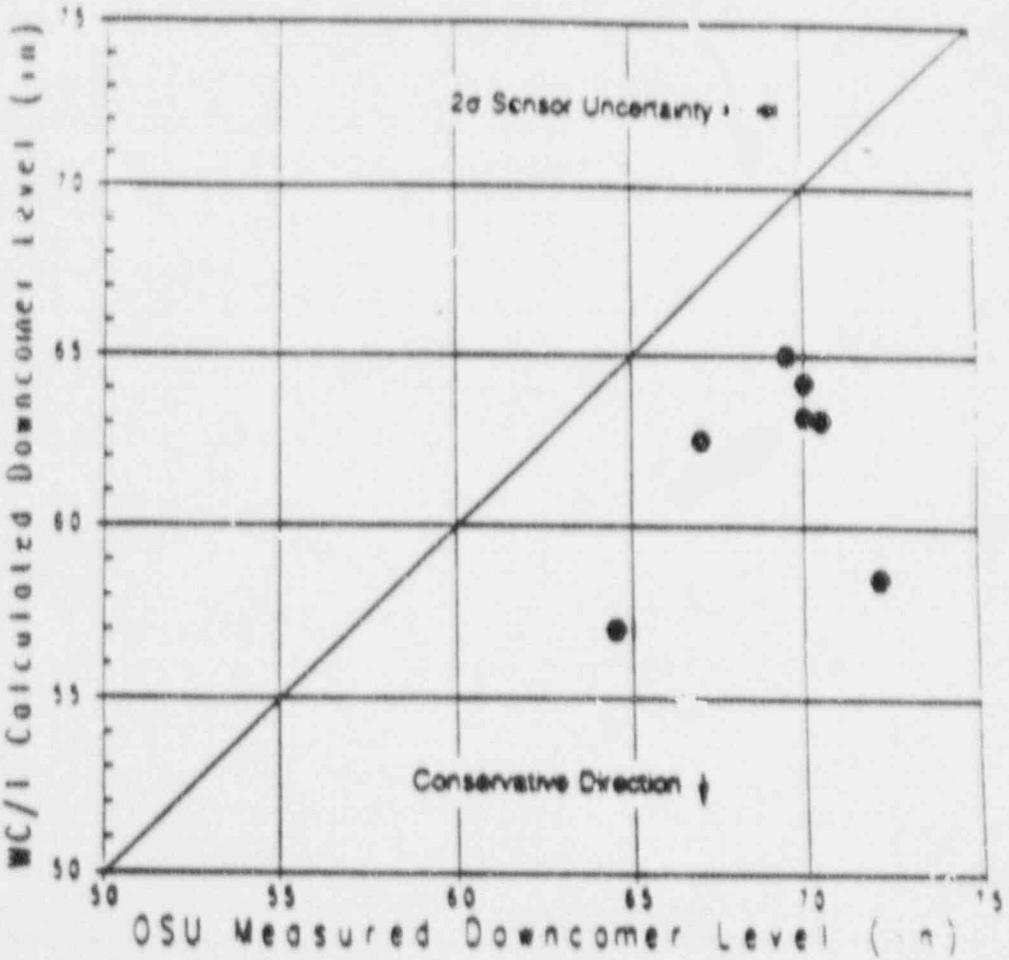


Figure 440.589-9

Westinghouse

Reactor Vessel Total Inflow Comparison

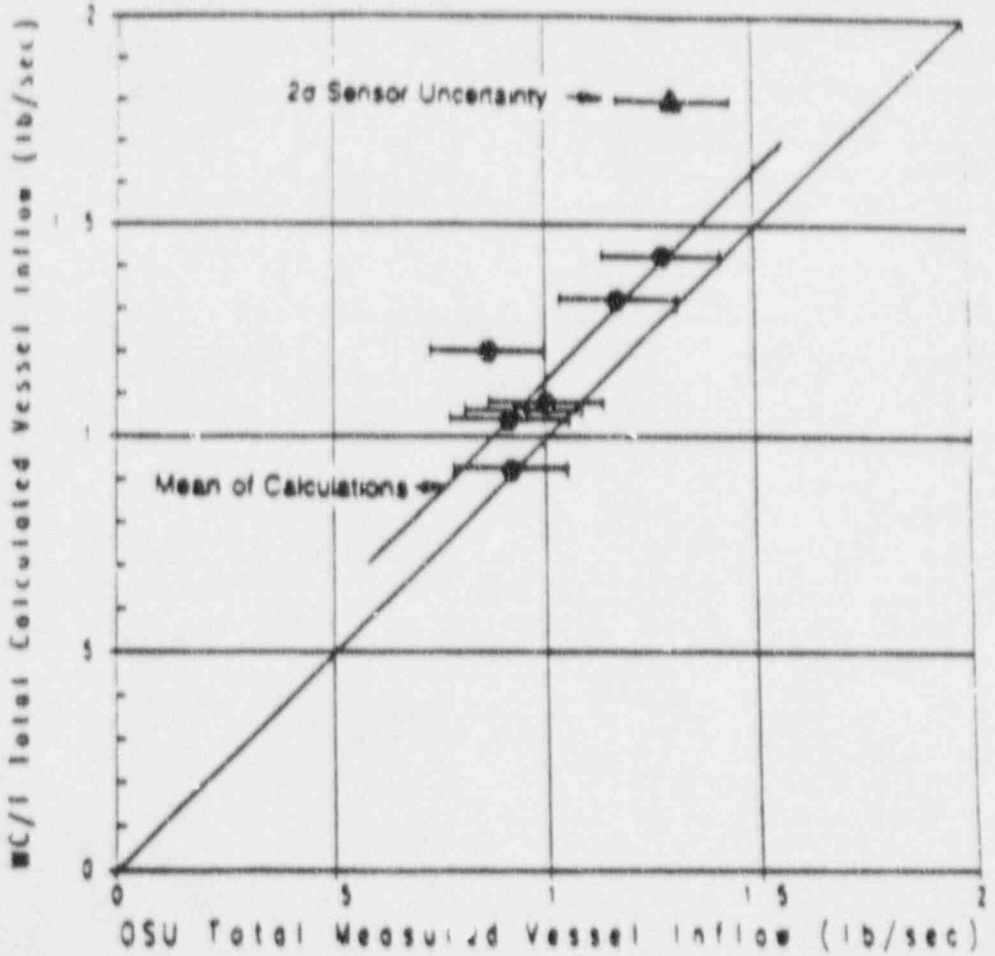


Figure 440.589-10

Reactor Vessel Total Outflow Comparison

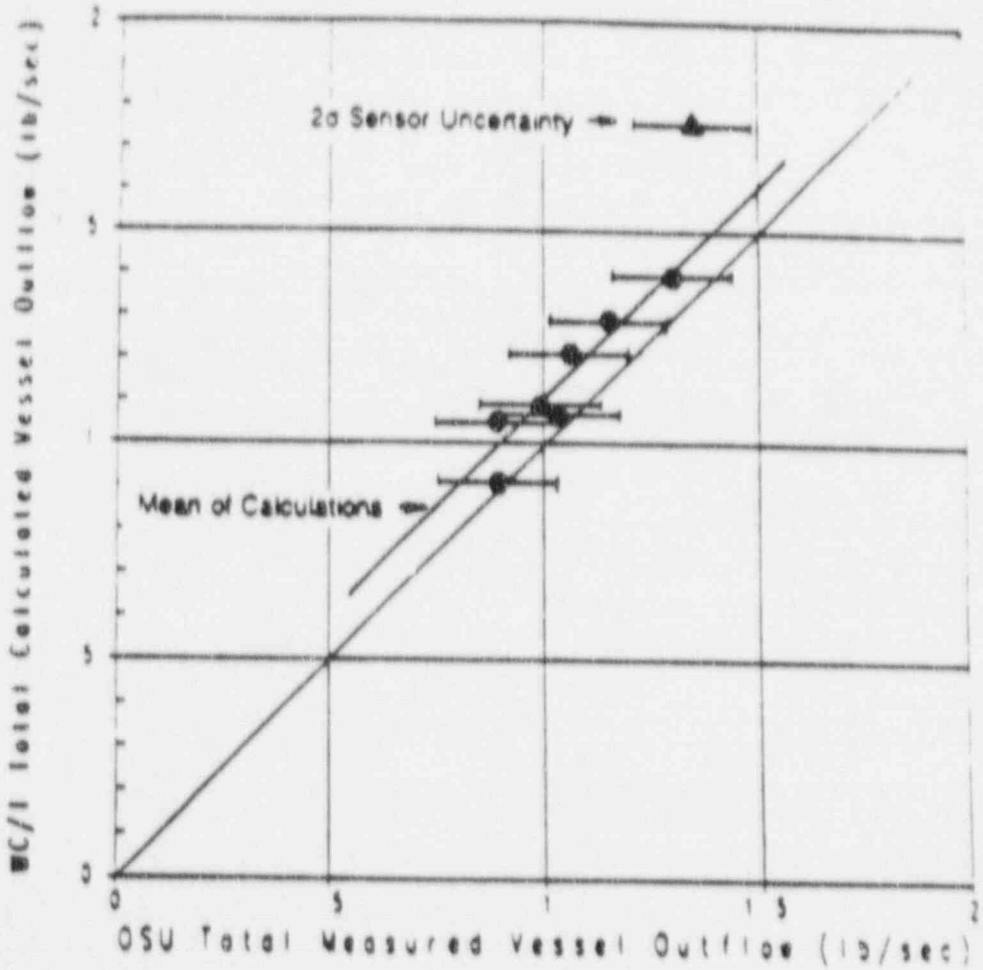


Figure 440.589-11

[redacted]

RAI 440.590

Page 5-34, 5th paragraph states that the discrepancy shown in the upper plenum calculated pressure (Fig 5.2-2) is due to the uncertainty of the measured pressure values. However, uncertainty cannot account for a one sided difference unless some special instruments have been used. Please account for the above statement and the discrepancy of measured to calculated values.

Response:

As discussed in the revised response to RAI 440.563, "for Test SB10 the pressure measurement transducer was classified as unreliable, so the upper plenum pressure is based on a different pressure tranducer than is used for the other tests. For this reason, the WC/T prediction of pressure in Test SB10 relative to the data is not considered to be appropriate in assessing the capability of WC/T to model the OSU tests." As shown in the attached Figure 440.590-1 from the ACRS meeting of March 28, 1997, upper head (and upper plenum) pressures during the period of transition to sump injection and beyond are in the range of 15.6 to 16.0 psia independent of break size and location. Thus, the OSU data value of 17.7 psia reported for SB10 is considered to be unreliable and inappropriate for assessment of the WC/T pressure prediction capability.

Report Revision:

None

RAI 440.591

The calculational window for SB10 sump injection flow (Figures 5.2-5 and 5.2-6) stops at 14,500 seconds. This window does not envelop a significant change in the sump injection flow shown in the OSU test data which occurs when the sump injection valves open. Since the sump isolation valves opened at 14,800 seconds, the staff believes the window should continued to at least 16,000 seconds to give WCOBRA/TRAC the opportunity to calculate full sump injection flow.

Response:

Westinghouse has performed the suggested calculation and provided the results in Reference 440.591-1. The results can be found in Figures 2.5-1 through 2.5-28 of that report together with the following paragraph from that report.

The window selected was from test SB10 was initiated at 13,500 seconds, near the end of IRWST injection and extending to a time of 16,500 seconds at which time both sump check valves and sump isolation valves were fully open. This calculation is an extension of calculation 5.2 in Reference 440.591-2. The window included a period of upper plenum liquid level decrease following the switchover to sump flow and a subsequent period of increased core steaming rates due to lower DVI line flow rates and higher DVI line liquid temperatures. These conditions were calculated with reasonable accuracy as demonstrated in Figures 2.5-23 and Figure 2.3-21. The total DVI line flow rates into the vessel compared well with the test data during this extended time period as indicated in Figures 2.3-7 through 2.3-10. It is noted that the sump and IRWST flow rates and directions are also reasonable well predicted during this period except in portions of line 1 in the period following opening of the sump isolation valve, Figures 2.5-3 and 2.5-5. In this period, the calculated flow from the sump to the IRWST is higher than measured flow. Of particular significance, however, is the fact that the correct quasi-equilibrium solution is obtained near the end of the transient. This demonstrates, that after a significant perturbation to the boundary conditions (opening of the sump isolation valves), the solution will adjust the flow conditions and return to the correct values. It is further noted that, during this period, the reactor vessel levels were not significantly influenced.

References

440.591-1. NSD/NRC-97-5014, "WCOBRA/TRAC Long Term Cooling Letter Report", D.C.Garner, March 10, 1997.

440.591-2. WCAP-14778, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1996.

Report Revision:

None

RAI 440.592

Westinghouse assessment of the OSU SB-12 test states on page 5-66 that " the sump flow was inhibited in this calculation". Why was this done? How is the comparison of sump flow rates meaningful with this manipulation of the calculation? Could another test be substituted for this test without inhibiting sump flow? What is unique in this test for the WCOBRA/TRAC long term cooling validation?

Response:

Test SB-12 data records do not contain a significant period of sump injection. As a result, WC/T calculation comparisons in the sump injection period were considered to be for too short a period to be meaningful. Further, any deviations from the measurements could not be investigated through extension of the window period. Thus, the comparison with SB12 is intended to address only operation with flow from the IRWST and is included to show the LTC performance for a DEG Direct Vessel Injection Line Break.

Subsequently, a calculation comparison has been done with SB01 from 18,000 to 19,000 seconds when the the sump isolation valves have been opened and the levels in the IRWST and the sump have equilibrated. At the start of this comparison, the equilibrium sump/IRWST conditions have been established for over 2000 seconds so that the comparison addresses specifically sump injection. The comparisons provided in Figures 440.592-1 through 440.592-28 show good comparison with the OSU data with the following variations noted:

1. The reactor vessel level comparisons are low by 6 to 7 inches in the downcomer and 3 to 4 inches in the upper plenum, Figures 440.592-24 and 440.592-23, which is typical of other test comparsions and is in the conservative direction.

2. The core collapsed liquid level is low by about 2 inches, again a deviation in the conservative direction.

3. The Total DVI Flows, Figures 440.592-8 and 440.592-10 show deviation of +0.040 and +0.065 lb/sec which is within the 2 sigma uncertainity of the flow measurements of $\pm$ 0.077 lb/sec.

4. The break flow measurements, Figure 440.592-14, show the same negative trend as the data, however since the magnetic flow meters were not calibrated for negative flows this comparison is not significant.

5. As has been inficated in a subsequent RAI , the low flow rates of the ADS 1-3 which are less than the measurement uncertainity render this comparison insignificant.

Based on the results of this comparison, it appears that WC/T provides a satisfactory quasi-equilibrium solution for LTC during sump operation well after the end of IRWST injection.

Report Revision: None

RAI 440.592

Westinghouse assessment of the OSU SB-12 test states on page 5-66 that " the sump flow was inhibited in this calculation". Why was this done? How is the comparison of sump flow rates meaningful with this manipulation of the calculation? Could another test be substituted for this test without inhibiting sump flow? What is unique in [redacted] test for the WCOBRA/TRAC long term cooling validation?

Response:

Test SB-12 data records do not contain a significant period of sump injection. As a result, WC/T calculation comparisons in the sump injection period were considered to be for too short a period to be meaningful. Further, any deviations from the measurements could not be investigated through extension of the window period. Thus, the comparison with SB12 is intended to address only operation with flow from the IRWST and is included to show the LTC performance for a DEG Direct Vessel Injection Line Break.

Subsequently, a calculation comparison has been done with SB01 from 18,000 to 19,000 seconds when the the sump isolation valves have been opened and the levels in the IRWST and the sump have equilibrated. At the start of this comparison, the equilibrium sump/IRWST conditions have been established for over 2000 seconds so that the comparison addresses specifically sump injection. The comparisons provided in Figures 440.592-1 through 440.592-28 show good comparison with the OSU data with the following variations noted:

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5. As has been indicated in a subsequent RAI , the low flow rates of the ADS 1-3 which are less than the measurement uncertainity render this comparison insignificant.

Based on the results of this comparison, it appears that WC/T provides a satisfactory quasi-equilibrium solution for LTC during sump operation well after the end of IRWST injection.

Report Revision: None

RAI 440.593

In Figure 6-8, the measured and calculated ratios of the inflow and outflow are a function of time. How would these ratios change if the calculations were performed for longer time intervals.

Response:

As indicated in the report, the values presented are the quasi-equilibrium values for the four WC/T vs. OSU comparisons. As such, they are average values over periods of 600 to 700 seconds. While all of these cases have not been extended to 3000 seconds, Test SB10 has been. The time wise variations are contained in Table 440.593-1. For the WC/T results, the maximum variation between total flow in and total flow out occurs between 15,000 and 15,500 seconds. This coincides with a slight reduction in vessel liquid inventory in the upper plenum during this period as indicated by Figure 440.593-1. Similiarly, the OSU test data indicates a period of time from 14,000 seconds to 15,000 seconds during which the outflow exceeds the inflow by approximately 6%. This also corresponds to a reduction in upper plenum inventory, Figure 440.593-1, although there appears to be a time shift of approximately 500 seconds. Considering the uncertainity in the flow rate measurements, this agreement is considered good. In any case, the variation in the outflow to inflow parameters with time is small considering variations in DVI line flows in this period of transition from IRWST injection to sump injection.

Table 440.593-1

Total Vessel Outflow / Total Vessel Inflow for SB10

Time Period (seconds)	WC/T Total Outflow / Total Inflow	OSU Total Outflow / Total Inflow
14,000 to 14,500	0.994	[ ]a, b, c
14,500 to 15,000	1.005	
15,000 to 15,500	1.083	
15,500 to 16,000	1.026	
16,000 to 16,500	1.044	

Report Revision:

None

[redacted]

RAI 440.594

How were the boundary conditions of pressure, temperature, and void fraction at the break applied? Page 5-1 WCAP-14776 states that the break separator level, temperature, and pressure were used to determine the boundary conditions. However, page 5-4 states that reverse flow from the break separator into the cold leg could not be predicted while page 5-5 states that reverse flow was predicted. Similar statements appear on page 5-93. When reverse flow is predicted, is the inflow into the reactor coolant system at the appropriate conditions based on the measurements in the break separator? If so, isn't the separator implicitly modeled through the applied boundary conditions?

Response:

The statement "The simulation did not model that break separator, so reverse flow into the cold leg because of the break seperator filling cannot be predicted" which appears on page 5-4 and also on page 5-93 is an editorial error. The draft for the report was based on the Preliminary Validation Report, LTCT-GSR-003, which contains this statement. In Reference 440.594-1, the break seperator was modeled as a sink/source component with the appropriate pressure, temperature and liquid level. This sentence will be removed in the Revision 1 to Reference 440.591-1.

References:

440.594-1 WCAP-14776, "WCOBRA/TRAC OSU Long-Term Cooling Final Verification Report", D.C. Garner, et. al., November 1996.

Report Revision:

None

RAI 440.595

In WCAP-14776, the predicted downcomer level was 15 in. below the measured value for Test SB23. The predicted level was below the elevation of the DVI line while the measured level was at the bottom of the cold leg. The discrepancy is much larger than the error for the other tests (about 5 in.). Is this discrepancy for Test SB23 significant? Why was predicted downcomer level worse for this test?

Response:

The predicted vessel levels in Test SB23 can be understood most clearly when compared to SB01 since the primary difference is the cold leg break flow area. Test SB23 approximates a no break calculation since the hydraulic resistance of a 1/2 inch break flow path is large with respect to the hydraulic resistance of the DVI lines, a factor of approximately 40 greater than the IRWST to vessel line and a factor of 6 to 8 greater than the sump to vessel line. Conversely, for the 2 inch break SB01 test, the hydraulic resistance of the break is 16 times larger and the break is the roughly equivalent of having a third DVI line; assuming that the break separator liquid level is equal to the IRWST level. The separator level is lower but only slightly so during the periods of the window mode calculations. While the reverse break flow magnitudes are suspect due to lack of calibration, it is noted that the indicated break flow rate for the SB01 test is -0.260 lb/sec versus -0.022 lb/sec for the SB23 test. Thus, test SB01 has a significantly different balance of the inlet to outlet hydraulic resistances than SB23 and an increase in the calculated liquid levels of about 4.5 inches in the downcomer and correspondingly in the core plus the upper plenum. With a significantly reduced inlet flow resistance and an increased vessel through flow of only 5% to 10%, it is reasonable to expect the vessel liquid levels to be greater for the SB01 test. Thus, it is concluded that the calculated lower level for SB23 should be expected and does not represent an anomaly in the data comparisons.

Report Revision:

None

[redacted]

RAI 440.596

WCAP-14776 states (page 6-2) that the pressure drop across the ADS 4 lines is relatively small compared to the resistance of the DVI lines. What are the calculated frictional pressure drops across the ADS 4 lines and DVI lines during sump injection for one of the tests? What is the predicted void fraction at the ADS 4 flow nozzles for the corresponding period?

Response:

During the early period of IRWST injection when steam formation in the core is minimal, the pressure losses across the ADS 4 valves are small with respect to the DVI line losses. With the initiation of significant boiling in the core, the two phase pressure losses in the ADS 4 valves shift the balance of pressure losses. The calculated frictional pressure drops across the ADS 4 lines and DVI lines during sump injection for a 50 second period of SB-01 sump injection are provided in Figures 440.596-1 and 440.596-2. These results are taken from the 1000 second window calculation provided in response to RAI 440.592. The short window is being provided with a print frequency of 0.1 seconds to accurately show the pressure drop and void fraction fluctuations. This window is considered to be representative of the larger window and to the general condition of sump injection. The void fractions in the ADS 4-1 and ADS 4-2 valves are provided in Figure 440.596-3.

Based on the results shown for the sump injection phase, it is concluded that the DVI line pressure drop and and ADS 4 pressure drop are of similiar magnitude during this period. The statement on page (6-2) will be revised as follows:

"The ranking of this parameter has been reduced from high to medium. The basis for the reduction is sensitivity studies, varying the ADS Stage 4 valve losses, which indicated no significant effects on the levels in the core and core coolability during LTC. Therefore, the uncertainty in parameters such as the flow regime and separation at the ADS tee are of reduced importance, and comparisons of the ADS Stage 4 flow rates with WCOBRA/TRAC are sufficient for the validation of the code pressure drop calculation."

The sensitivity studies which support this conclusion are discussed in the response to RAI 440.597.

Report Revision:

WCAP-14776, **Page 6-2**, paragraph 2.

RAI 440.597

WCAP-14776 states on page 6-2 that sensitivity calculations showed that the calculated levels were not significantly affected by ADS-4 losses. Where are these sensitivity calculations documented? How sensitive was the total flow through the primary system to the ADS-4 losses during sump injection?

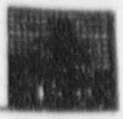
Response:

The sensitivity to ADS-4 pressure losses has been calculated for the SB-01 window period of 18.000 second to 19.000 second during which the flow to the DVI lines comes entirely from the sump. In this calculation the loss coefficient of the ADS 4 valves was increased by 50% in both loop 1 and loop 2. As shown in Table 440.597-1 below, the total flow through the primary system decreased by approximately 19%. Correspondingly, the collapsed liquid level in the vessel decreased by 0.40 inches. The change in vessel levels is shown in the attached Figures 440.597-1 through 440.597-4. The rate of steam generation in the core increases from approximately 0.85 lbm/sec. to 0.95 lbm/sec to compensate for the reduced injection flow rate.

Table 440.597-1
Sensitivity of Vessel Conditions to 50% Increase in
ADS 4 Pressure Loss Coefficient (Test SB-01)

	Reference Calculation	+50% ADS-4 K Calculation	Variation
Total Vessel Inflow			
DVI-1 (lbm/sec)	0.426	0.368	
DVI-2 (lbm/sec)	0.460	0.392	
2" Break (lbm/sec)	0.068	0.016	
Totals	0.954	0.776	-19.6%
Total Vessel Outflow			
ADS 1, 2, 3 (lbm/sec)	0.021	0.021	
ADS 4-1 (lbm/sec)	0.303	0.220	
ADS 4-2 (lbm/sec)	0.635	0.531	
Totals	0.959	0.772	-18.6%
Upper Plenum Level (in)	6.1	5.7	-0.4 in
Downcomer Level (in)	57.5	57.1	-0.4 in
Steam Generation in Core (lbm/sec)	0.850	0.950	

Report Revision: None



RAI 440.598

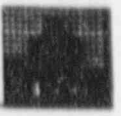
The calculated upper plenum liquid levels shown in WCAP-14776 are not consistent with the presentation Westinghouse made to the staff on March 12, 199[illegible]. For example, Figure 5.1-23 of the report shows that the calculated level is about 14 in. for Test SB-01 while page 45 of the presentation material shows that the calculated level is about 9 in. Why are the calculated results different between the report and the presentation?

Response:

The upper plenum collapsed liquid levels reported in WCAP-14776 were based upon an inappropriate selection of upper plenum channel for calculating the level in the WC/T plotting package. As shown in Figure 2-2 of the WCAP, there two channels in Section 3 of the upper plenum, channel 15 and channel 50. Channel 15 is an annular global channel located adjacent to the core barrel and does not see core outlet flow intering at the bottom. Channel 50 is the core outlet channel and all flow from the core enters this channel. Due to the desire to minimize the number of nodes, these channels have only one vertical node for the 11.9 inch height. As a consequence, the global channel tends to have a high liquid fraction over the entire height while the core outlet channel more correctly reflects the core outlet void fraction. Using the void fraction in the global channel 15 produces an unrealistichy high indication of upper plenum collapsed liquid level which significantly exceeds the collapsed liquid level in the downcomer. Conversely, use of the channel 50 void fraction in the collapsed liquid level calculation produces level which compares favorably with the downcomer collapsed liquid level and reflects the manometric relationship between the two flow channels. Thus, subsequent to the WCAP, all reported upper plenum collapsed liquid levels reflect the void fraction in channel 50. The WCAP will be updated to also reflect this basis for the upper plenum levels.

Report Revision:

WCAP-14776. Pages 3-6, 3-22, 3-38, 3-54, 5-28, 5-59, 5-86, and 5-118.



General Comment 1.

Westinghouse should consider including the measured and calculated loss factors for the ADS 123 and ADS 4 flow paths in Table 3-7.

Response:

Pressure loss coefficients for the OSU ADS 123 and ADS 4 lines and valves were calculated from single phase handbook data and based on the physical dimensions obtained from the piping drawings. These values were input to WC/T which calculated two phase multipliers based upon the local fluid conditions. Satisfactory pre-operational test data was not available for comparison. As reported in WCAP-14252, the ADS 123 line resistance was measured, however, the orifice plate, designed to simulate the valves, was not installed. No tests were performed in this test series to determine the pressure loss coefficients of the ADS 4 lines and valves.

Report Revision: None

General Comment 2.

The report correctly states that the mass flow through the ADS 123 valves was negligible during the long-term phase. The comparisons between the calculated and measured values are then characterized as excellent for Test SB10, fair for Test SB12, and good for Test SB23. The variation in characterizations is inappropriate considering the uncertainty in the data. According to Appendix D of WCAP-14252, the uncertainty in the ADS 123 liquid flow measurement (FMM-601) is 1.342 gpm or about 0.18 lbm/sec, which is much greater than the measured values. Furthermore, since the level is near the bottom of the pressurizer during the long-term phase, no liquid flow would be expected through ADS 123. Steam flow through ADS123 would be expected, but no reliable measurements of the steam flow are available because the instruments were not ranged properly for the long-term phase. In fact, the reported steam flow rate (FVM-601) was less than zero, which is clearly impossible, during the window period for three of the four tests. Thus, the staff has conclude that the ADS 123 flow measurements are very uncertain and that the apparent differences in the "goodness" of the comparisons for the tests are not meaningful.

Response:

In retrospect, we agree. The discussion on the ADS 123 flows in WCAP-14776 will be modified to reflect the significance of the uncertainty in the vapor flow measurements.

Report Revision:

WCAP-14776, Page 5-35 para. 4, Page 5-66 para. 4 and Page 5-93 para. 5.

General Comment 3.

The calculated DVI 1 flow rate reported in the text on page 5-65 for Test SB12 (0.87 lbm/s) is inconsistent with Figures 5.5-3, 5.3-4, and 6-1 (about 1.2 lbm/s). Similarly, page 5-66 states that the total calculated ADS 4 flow is 1.12 lbm/s while Figures 5.3-14, 5.3-16, and 6-6 indicate that it is about 1.35 lbm/s. These apparent discrepancies between the text and figures affect the global mass balance discussion on page 5-67 as well as the summary of results presented in Section 6 (including Figure 6-3).

Response:

The calculated DVI 1 flow rate reported in the text on page 5-65 for Test SB12 should have been 1.14 lbm/sec and the total calculated ADS 4 flow on page 5-66 should have been 1.35 lbm/sec. The values on pages 5-65 and 5-66 were taken from a tabulation which included a earlier WC/T calculation for Test SB12 and had not been updated to reflect the plots in the WCAP. Pages 5-65 and 5-66 will be updated appropriately. Section 6 was developed from an updated table and contains none of the early calculational results.

Report Revision:

WCAP-14776, Pages 5-65 and 5-66.

General Comment 4.

The mass ratio comparisons shown in Figure 6-8 appear to be contradictory. The figure shows that the ratio of flow out to flow in is greater than unity for the tests (indicating that vessel levels should be decreasing) and less than unity for the calculations (indicating that vessel levels should be increasing). Thus, the trends of the calculation appear to be wrong. The text should justify why these results are adequate.

Response:

The text will be updated to reflect a re-evaluation of the predicted ratios which were presented at the ACRS meeting and which showed that WC/T inflow and outflow are equal, Figure 440.GC4-1. The deviations in the measured ratios results primarily from the uncertainty in the vessel inflow and outflow test measurements. This is significant when the negative break flow rates become large, such as in Test SB01, since the flow meters were not calibrated for reverse flow at OSU. This effect is discussed in detail in RAI 440.589

Report Revision:

WCAP-14776, Page 6-3

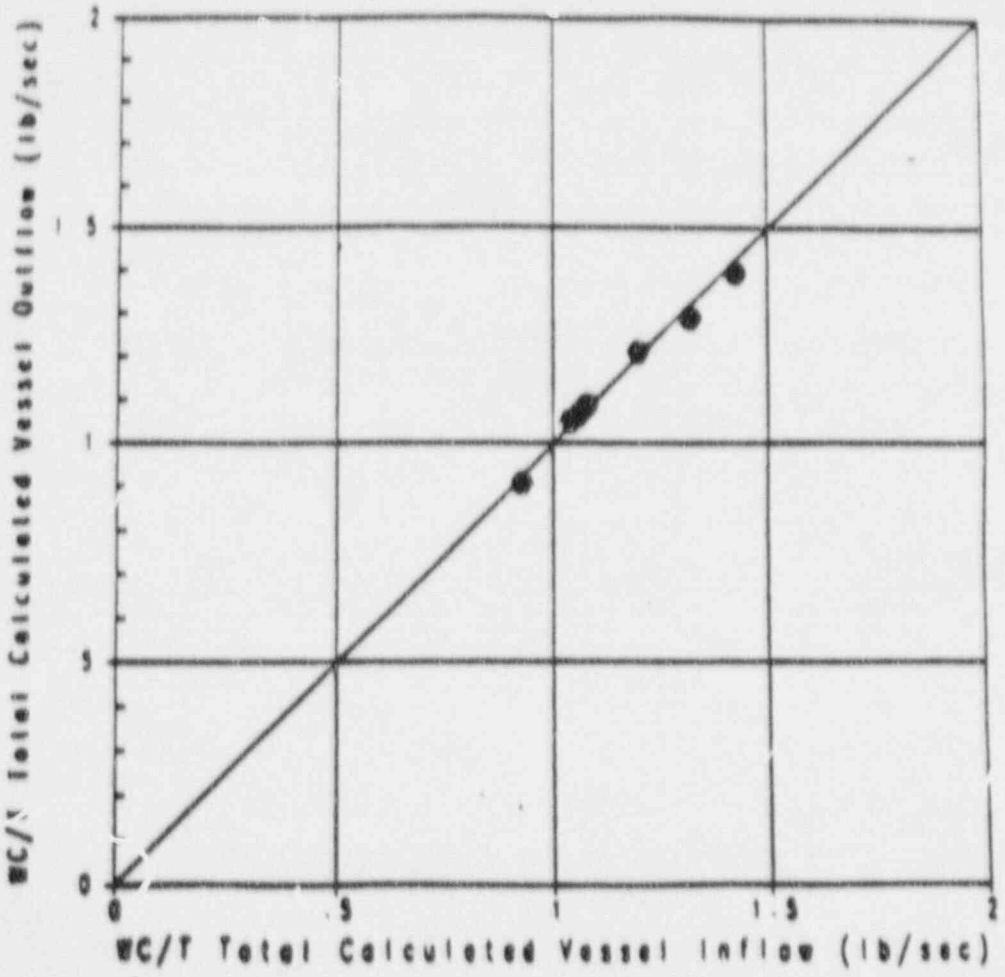


Figure 440.GC4-1

Westinghouse
AP600 Project

Memo

To: Joe Sebrosky ECE 3-09

From: Earl H. Novendstern

CC: B. McIntyre (NRC Informal Proprietary Correspondence File), B. Rang, Bob Osterneder, L. Hochreiter, F7.5.1.3

Date: Thursday, May 22, 1997

Re: NOTRUMP RAI - 440.339

Joe,

Attached is our response to the above RAI on NOTRUMP sensitivity studies. I have marked them DRAFT only because they are not transmitted by a formal letter. No text will change when formally transmitted.

Please give to Ralph and Bill. Many thanks.

Earl

Question 440.339

Re: WCAP-14206 (NOTRUMP CAD)
On Page 4-16, Item 2, it is stated that since no change to the numerical scheme has been made to NOTRUMP that no noding nor time step studies are needed. The INEL disagrees with this statement. Since the successful performance of the passive safety systems depend on the accurate modeling of the small pressure differences that characterize AP600 phenomenological behavior, node and time step size can affect the magnitude of these small pressure differences driving the flow in the system. Please provide time step and nodalization studies to justify the AP600 nodalization.

Response:

In addition to the nodalization studies performed and included in the level swell portion of the NOTRUMP Final Validation Report, Reference 440.339-1 (sections 4.2.5 and 4.3.4), other studies were performed. Summaries of three of these studies are attached: 1) PRHR noding, 2) CMT noding, and 3) AP600 time step sensitivity study.

PRHR NODING STUDY

The results of the calculations presented in the NOTRUMP Preliminary Validation Reports (References 440.339-1 & 2) for various break sizes for both the SPES and OSU test facilities showed underprediction of the PRHR heat transfer and a corresponding overprediction of the PRHR outlet temperature. To understand this difference between the test and NOTRUMP results, a PRHR nodalization study was conducted with a more detailed PRHR model for both the primary and secondary side of the PRHR. The nodalization study was performed using the SPES PRHR Model. This study was performed in two parts.

Part 1, described below as the "Stand-Alone PRHR Model", is developed based on the SPES-2 PRHR geometry. This part, as the name indicates, models only the PRHR of the SPES-2 test facility and is connected to boundary nodes at the inlet and outlet of the PRHR.

Part 2, involves renodalization of both the primary and secondary side of the SPES-2 PRHR test facility and simulation of the 1 inch and 2 inch cold leg break transients.

Part 1 - (Stand-Alone PRHR Model Based on the SPES-2 PRHR Geometry)

The purpose of this portion of the study is to determine the effect of alternate noding of the primary side of the PRHR. The IRWST is modeled as two nodes as in the Preliminary Validation Report. Three different noding schemes are studied as shown in Figures 440.339-1 through 440.339-3. The first scheme is a three node PRHR model (Figure 440.339-1). This model provides a basis for the rest of the study. The second model (Figure 440.339-2) is a four node PRHR model, with two horizontal nodes to model the top horizontal section of the PRHR piping. The third model (Figure 440.339-3) is a five node PRHR model, with three horizontal nodes to model the top horizontal section of the PRHR piping. Two boundary nodes, one at the entrance and the other at the exit of the PRHR were modeled at subcooled fluid conditions, with the inlet flow varying between 1.0 and 0.175 lbm/sec (with a flow velocity varying between 8.4 ft/sec and 1.7 ft/sec). Based on Reference 440.339-3, which indicates that a large fraction of the total PRHR heat transfer occurs in the initial horizontal section of the PRHR tubes, it was believed that renodalization of the top horizontal section of the PRHR tube would result in closer agreement with the test data. However, the results of this study (discussed later) show that the horizontal nodalization has negligible effect on the calculated PRHR outlet temperatures. This led to the renodalization of the vertical section of the PRHR tubes, which is discussed in Part 2 below.

Part 2 - (Model of the SPES-2 Test Facility)

In this part of the study, both the primary (vertical section) PRHR tubes and the IRWST were renodalized to study the effect on the PRHR heat transfer. The SPES-2 model was chosen since it is believed to be more critical; its transients involve the same temperature gradients between the primary system and the IRWST as the AP600 plant. Two different noding schemes were chosen for the vertical section of the

PRHR tube. The first model (Figure 440.339-4) is a four node model and the second model (Figure 440.339-5) is a 16 node model. The secondary side of the PRHR is renodalized (using 11 nodes) which includes an influence zone described below.

Influence Zone

The influence zone model is shown in Figures 440.339-4 and 440.339-5. Smaller size fluid nodes (see below for additional details) are modeled in the region surrounding the vertical section of the PRHR tube to form a hydraulic channel around the tube. The remaining portion of the IRWST is modeled with large size nodes. This method is chosen because the PRHR will be heating a relatively small portion of the overall IRWST water volume in the region near the PRHR tubes and will cause a recirculation flow due to bouyancy effects within the IRWST. This allows for more accurate prediction of the PRHR heat transfer and a better match to the test data. The original SPES-2 model used in the preliminary validation calculations (Reference 440.339-1) consisted of a two-node IRWST, and only one node had heat links connected to the PRHR tube, so no circulation was simulated.

3D/3D Influence Zone Model

The boundary of the influence zone is first calculated as 3 times the PRHR tube outer diameter, based on the experimental data (Reference 440.339-5) showing that the water temperature drops to bulk temperature of the tank moving outward radially from the tube wall. The IRWST is divided cross-sectionally into two parts: the influence zone (nodes 166 through 170) and the rest of the tank (nodes 171 through 176). The 3D/3D corresponds to the effective flow area of the heat links calculated based on three times the PRHR tube diameter and the hydraulic channel fluid node volume and flow link flow area also calculated based on three times the PRHR tube diameter.

3D/5D Influence Zone Model

To increase the amount of secondary side water that the PRHR tube interacts with, the influence zone fluid node volume and flow link flow area are increased to be based on five times the tube outer diameter, while the effective flow area of the heat links are maintained at three times the tube diameter. The large influence zone model allows more liquid to be heated and mixed around the PRHR tubes, thus affecting the PRHR heat transfer characteristics.

AP600

RESULTS OF PRHR NODING STUDY

Stand-Alone PRHR Model Simulations

The results of the stand-alone PRHR model are shown in Figures 440.339-6 through 440.339-11. These results indicate that renodalization of the horizontal section of the PRHR has very little effect on the predicted PRHR outlet temperature (see Figure 440.339-11). Figures 440.339-6 through 440.339-9 show that the PRHR inlet temperature, is higher at the entrance (first PRHR node 111) as the number of horizontal nodes increase. This is expected with smaller node size, which has less heat transferred to the metal. However, the temperature at the top of the vertical section of the PRHR (or the end of the horizontal section), varies very little as the number of horizontal nodes are increased. This indicates that the overall heat transfer in the horizontal portion of the PRHR tubes has not changed very much due to increased number of primary side nodes. This being the case, the fluid temperature predicted in the rest of the PRHR show very little difference between the three cases analyzed. This led to the study of the effect of increased nodes in the vertical portion of the PRHR tubes which was performed as part of the SPES-2 PRHR sensitivity study.

Increased Vertical PRHR Nodes and Increased IRWST Nodes with Influence Zone

The results of the SPES-2 tests simulation using the three diffferent nodalizations are shown in Figures 440.339-12 through 440.339-41. Figures 440.339-12 through 440.339-28 show the results of the 2-inch cold leg break simulation. The PRHR inlet and outlet temperatures are compared for the various cases analyzed with the SPES-2 test data (Figures 440.339-12 and 440.339-13). The inlet temperature plots show that there is negligible difference between the various cases presented, which is to be expected. The PRHR outlet temperature is shown in Figure 440.339-13 for the various cases analyzed. Comparing this figure to Figure 7.3.1-31 given in the Final Validation Report (Reference 440.339-4), it is seen that the more detailed noding affects the PRHR outlet temperature to a great extent in the first 200 seconds of the transient, which results in lower temperatures as compared to the data. To get a better understanding of this temperature difference between the original model (presented in Reference 440.339-4) and the more detailed model of the PRHR, the primary secondary heat transfer within the PRHR was more closely studied between the two simulations and discussed below.

The case with the 16 vertical PRHR nodes with the larger influence zone was chosen for this comparison, since Figure 440.339-13 shows that the effect of the larger influence zone (with the larger hydraulic channel surrounding the vertical portion of the PRHR tubes) is more pronounced than the effect of increasing the number of nodes in the vertical portion of the PRHR. Figures 440.339-14 and 440.339-15 are snapshots of the NOTRUMP results at 200 seconds and 700 seconds for the two cases. The primary to secondary heat transfer rates at various representative sections (to show the trend) of the PRHR along with the fluid velocity in the IRWST are given for the two cases. These figures show that the more detailed secondary noding induces a recirculation flow within the IRWST (which is not present in the

original case) resulting in a higher heat transfer rate at the vertical section of the PRHR and therefore lower PRHR temperatures. The flow induced in the secondary side due to more detailed noding, places it in the subcooled forced convection regime, which results in a higher heat transfer rate. The higher heat transfer rate is more due to the fact that the forced convection model uses the bulk fluid temperature rather than the saturation temperature (T_{sat}) as the heat sink. This indicates that the modeling of the PRHR secondary side (IRWST) has a greater influence on the PRHR heat transfer than increasing the number of nodes on the PRHR primary side. The overall PRHR heat transfer and the primary to secondary heat transfer for the various sections of the PRHR are plotted in Figures 440.339-17 through 440.339-20. These figures show that the model with the larger influence zone does result in a higher heat transfer rate thus lowering the PRHR fluid temperature. Note that Figure 440.339-13 shows that the outlet fluid temperature is underpredicted during the first 200 seconds of the transient. However, Figure 440.339-17 shows that the overall PRHR heat transfer is also underpredicted for the first 200 seconds. This implies that the PRHR heat transfer underprediction is due to a PRHR flow (Figure 440.339-16) which is too low early in the transient. Figures 440.339-21 through 440.339-29 show the primary and secondary pressures and the flows from the accumulators, CMTs, IRWSTs and the ADS Stages 1-3. These plots indicate that changing the PRHR noding has negligible effect on the overall transient and the timings of the various events during the transient. These sensitivity studies were terminated at 1700 secs, after which time the PRHR heat transfer is not significant.

Figures 440.339-30 through 440.339-43 show the results of the 1-inch cold leg break simulation. These sensitivity studies were terminated at 4000 seconds for the 4 node model, after which time the PRHR heat transfer is not significant. However, the simulation with the 16 node model was terminated earlier at 2500 seconds, since sufficient information about the trends of the results are obtained by this time. Plots presented are similar to those presented for the 2-inch cold leg break. The PRHR inlet and outlet temperatures are compared for the various cases analyzed with the SPES-2 test data. Only the cases with the large influence zone are analyzed based on the results of the 2-inch cold leg break simulations. Summarizing these results, it can be seen that the PRHR outlet temperatures are lower than those shown in Figure 7.3.2-31 of Reference 440.339-4 for the same transient during the first 2000 seconds of the transient, for the same reasons as in the 2-inch cold leg break case. The figures also show that the case with the 16 vertical nodes results in slightly lower temperatures as compared to the case with the 4 vertical nodes. The plots of the PRHR heat transfer rates are given in Figures 440.339-33 through 440.339-36. Figures 440.339-37 through 440.339-43 showing the primary and secondary pressures and the flows from the accumulators, CMTs, IRWSTs and the ADS Stages 1-3 indicate that the more detailed noding of the secondary side has negligible affect on the overall transient and the timings, as in the 2-inch cold leg break simulations.

CONCLUSIONS OF PRHR NODING STUDY

Based on the results of the PRHR noding study discussed above, it is concluded that more detailed noding of the PRHR primary and secondary side results in underprediction of the PRHR primary outlet temperature early in the transient (i.e., overprediction of PRHR heat transfer). The prediction is better later in the transient. However, the overall prediction is not significantly improved using detailed noding. As indicated above, the main reason for the underprediction of PRHR heat transfer in the base case is underprediction of PRHR primary flow. The more detailed noding of the PRHR secondary is not needed and the original noding scheme with two secondary nodes is adequate for code validation, particularly since underprediction of the PRHR heat flow rate will lead to conservative results.

CORE MAKEUP TANK (CMT) NODING STUDY

This section summarizes a noding study related to the Core Makeup Tanks (CMT). The Oregon State University (OSU) integral effects test SB23 (0.5-inch cold leg break) is chosen for the CMT noding study, due to the sensitivity of this simulation to the performance of the CMTs regarding thermal stratification/mixing effects.

The reference NOTRUMP simulation for OSU test SB23 which is used as a base for comparison in this CMT noding study is documented in Section 8.3.2 of Reference 440.339-4. Specifically, it is the OSU SB23 simulation identified as "adjusted", which uses cold initial CMT temperatures and 125% PRHR heat transfer area. This case employs a 4-node CMT model (as do all of the OSU, SPES-2, and AP600 plant NOTRUMP simulations), in which the size of the CMT nodes varies from the smallest node at the top to the largest node at the bottom (the total tank volume division is 10% in the top node, 15% in the next two nodes down, and 60% in the bottom node). As explained in Reference 440.339-4, the adjustments in the NOTRUMP simulation of OSU test SB23 were performed in an attempt to obtain a more reasonable representation of the ADS Stages 1 through 3 actuation times. The concern with the original, "unadjusted" 4-node CMT NOTRUMP simulation of OSU test SB23, as reported in Reference 440.339-4, was a significant (approximately 2000 seconds) delay in the prediction of ADS actuation compared to the test data. This was attributed to a high core inlet temperature NOTRUMP prediction, which caused system repressurization and resulted in delayed CMT draining (and thus delayed ADS actuation). The high core inlet temperature was caused in part by excessive thermal mixing in the CMTs, so that the water leaving the CMTs was too hot compared to the test data, and underpredicted PRHR heat removal, so that the water leaving the PRHR was too hot compared to the test data. To confirm that CMT and PRHR model deficiencies caused the poor prediction, the NOTRUMP model was "adjusted" with cold initial CMT temperatures and 125% PRHR heat transfer area. The adjustments lowered the core inlet temperature, which ultimately resulted in ADS actuation close to that of the test data, as reported in Reference 440.339-4. The "adjusted" case with cold initial CMT temperatures and 125% PRHR heat transfer area represents the best NOTRUMP simulation of OSU test SB23 with the 4-node CMT model.

The NOTRUMP CMT noding sensitivity study for OSU test SB23 uses 20 equal nodes in each CMT. Three NOTRUMP transients with the 20-node CMT model are performed, and comparisons are made to the "adjusted" OSU test SB23 simulation with the 4-node CMT model of Reference 440.339-4 (which hereafter is referred to as the "NOTRUMP OSU SB23 4-node CMT reference case"). The first transient with the 20-node CMT model employs the cold initial CMT temperatures and 125% PRHR heat transfer area, in order to provide a one-to-one comparison with the NOTRUMP OSU SB23 4-node CMT reference case. The other two transients are variation cases with the 20-node CMT model, one with nominal initial CMT temperatures and 125% PRHR heat transfer area, and the other with nominal initial CMT temperatures and nominal PRHR heat transfer area. The pertinent portion of the transient for this study is 0 to 2500 seconds ("transient part 1" of the NOTRUMP OSU SB23 4-node CMT reference case), which extends through ADS Stages 1 through 3.

The noding diagrams for the NOTRUMP OSU 4-node CMT model are contained in Figure 8.2-2 of Reference 440.339-4 for the fluid nodes and flow links, and in Figure 8.2-3 of Reference 440.339-4 for the

metal nodes and heat links. The noding diagrams for the NOTRUMP OSU 20-node CMT model are contained in Figures 440.339-44 through 440.339-47. Figure 440.339-44 contains CMT-1 fluid nodes and flow links, Figure 440.339-45 contains CMT-2 fluid nodes and flow links, Figure 440.339-46 contains CMT-1 metal nodes and heat links, and Figure 440.339-47 contains CMT-2 metal nodes and heat links.

RESULTS OF CMT NODING STUDY

In the following discussions, the NOTRUMP OSU SB23 simulations are referred to as Cases 1 through 4.

Case 1 is the NOTRUMP OSU SB23 4-node CMT model with cold CMT temperatures and 125% PRHR heat transfer area (i.e., the NOTRUMP OSU SB23 4-node CMT reference case of Reference 440.339-4);

Case 2 is the NOTRUMP OSU SB23 20-node CMT model with cold CMT temperatures and 125% PRHR heat transfer area;

Case 3 is the NOTRUMP OSU SB23 20-node CMT model with nominal CMT temperatures and 125% PRHR heat transfer area;

Case 4 is the NOTRUMP OSU SB23 20-node CMT model with nominal CMT temperatures and nominal PRHR heat transfer area.

Table 440.339-1 contains a comparison of key event times for these four cases. Table 440.339-2 lists the figures which contain the plotted results for these cases. Figures 440.339-48 through 440.339-63 contain plots of quantities which are directly applicable to this CMT noding study. These include CMT temperature profile plots for Cases 1 through 4 in Figures 440.339-48 through 440.339-55, and comparison plots of all cases and the test data for CMT bottom temperatures, CMT levels, PRHR outlet temperature, core inlet temperature, and DVI temperatures in Figures 440.339-56 through 440.339-63. The remaining Figures 440.339-64 through 440.339-70 contain plots of other key system quantities. Note that the time scale is 0 to 4000 seconds in all of the Figures 440.339-48 through 440.339-70, to match that used in the plots in Section 8.3.2 of Reference 440.339-4, for ease of comparison.

For the one-to-one comparison of the transient results of Case 1 and Case 2 (i.e., the straight comparison of the 4-node CMT model to the 20-node CMT model with no other differences), the CMT bottom node temperature plots (Figure 440.339-56 for CMT-1; Figure 440.339-57 for CMT-2) show a decrease in the thermal mixing in the CMTs with the 20-node CMT model. The bottom node of each CMT starts to heat up early in Case 1, at approximately 200 seconds, while in Case 2, the heat up begins later, at approximately 800 seconds. The CMT temperature profile plots of Figures 440.339-48, 440.339-49, 440.339-52, and 440.339-53 show that the finer noding in Case 2 produces a more gradual decrease in the temperatures from the top node to the bottom node of each CMT with a flatter profile near the bottom, which also indicates that thermal mixing is reduced in the CMTs with the 20-node model. The lower outlet temperature of the CMTs in Case 2 directly leads to a lower temperature in the DVI nodes in Case 2, as indicated in Figure 440.339-62 for DVI-1 and Figure 440.339-63 for DVI-2. The DVI nodes are also affected by the injection of the accumulators, which are discussed briefly below. Correspondingly,

Case 2 has a lower core inlet temperature than Case 1 does, as indicated in Figure 440.339-61. During the CMT draining period and before ADS actuation, the core inlet temperature in Case 2 is lower than it is in Case 1 by as much as approximately 15 to 20°F. The other contributor to the core inlet temperature, the PRHR outlet temperature, is essentially the same in Cases 1 and 2 (as indicated in Figure 440.339-60) as expected, since both cases employ the 125% PRHR heat transfer area.

Regarding the CMT levels in the Case 1 to Case 2 comparison, the CMTs start draining slightly earlier in Case 2 compared to Case 1 (CMT-1 approximately 40 seconds earlier and CMT-2 approximately 60 seconds earlier, referring to Table 440.339-1). The CMTs then drain slightly faster in Case 2 than in Case 1, as indicated in the CMT level plots (Figure 440.339-58 for CMT-1; Figure 440.339-59 for CMT-2). This behavior in the CMT levels leads to ADS actuation approximately 400 seconds earlier in Case 2 than in Case 1 (recall from Table 8.3.2-1 of Reference 440.339-4 that ADS stage 1 actuation occurs when the CMT level relative to the bottom tap decreases to 41 in. (3.4 ft.), plus 15 seconds). Relative to the test data, the CMT drain prediction in Case 2 is poorer than it is in Case 1. The more rapid CMT drain rate in Case 2 compared to Case 1 is related to the water in the smaller top node in the 20-node CMT model reaching saturation more quickly than the water in the larger top node in the 4-node CMT model. The results and trends of the other key system parameters (Figures 440.339-64 through 440.339-70) are similar in Cases 1 and 2. However, it is observed that the pressurizer pressure (Figure 440.339-64), during the CMT draining period and before ADS actuation, decreases more in Case 1 than it does in Case 2, by as much as approximately 40 psia. Consistent with this, the accumulators drain faster in Case 1 than they do in Case 2 during this period, as seen in the accumulator level plots (Figure 440.339-65 for ACC-1; Figure 440.339-66 for ACC-2).

Next, including the more realistic cases of nominal initial CMT temperatures with the 20-node CMT model, Cases 3 and 4, in the comparison discussion, it is observed that the temperature of the bottom node of each CMT (Figures 440.339-56 and 440.339-57) is almost the same in Cases 3 and 4 (as is the case with the temperature of each DVI node, per Figures 440.339-62 and 440.339-63). In both Cases 3 and 4, the heat up of the bottom node of each CMT starts at approximately 800 seconds, which is analogous to the behavior in Case 2 (it is only shifted on the temperature scale due to the initial CMT temperature difference). Also, the heat up rate of the bottom node of each CMT before ADS actuation is less in Cases 3 and 4 than it is in Case 2. However, the test data indicates essentially no heat up in the bottom of the CMT until after 2000 seconds, and only a slight heat up thereafter in the time period just before ADS actuation. After ADS actuation and before the CMTs drain completely, the rapid heat up of the bottom node of each CMT in all three 20-node CMT cases (Cases 2 through 4) is similar to that of the test data (it is only shifted in time due to the ADS actuation time differences). Cases 2 through 4 all have ADS actuation earlier than in Case 1 (Case 2 approximately 400 seconds earlier, as stated above; Case 3 approximately 370 seconds earlier; Case 4 approximately 330 seconds earlier). The differences in ADS actuation times in Cases 3 and 4 as compared to Case 2 are consistent with the times at which the CMTs begun draining. The PRHR outlet temperature is approximately the same in the cases with 125% PRHR heat transfer area (Cases 1 through 3), and this value is correspondingly lower than the PRHR outlet temperature in Case 4 with nominal PRHR heat transfer area (see Figure 440.339-60). Although the artificial increase of the PRHR heat transfer area to 125% of nominal in Cases 1 through 3 yields a lower PRHR outlet temperature which is closer to the test data than that of Case 4, it is still considerably higher

than the test data value (suggesting that an artificial increase of the PRHR heat transfer area to value higher than 125% of nominal may improve it even more). In Cases 3 and 4 before ADS actuation, given that the CMT outlet temperatures are the same and the PRHR outlet temperature is lower in Case 3, the core inlet temperature is correspondingly lower in Case 3 than in Case 4 (see Figure 440.339-61). In general, the results and trends of the other key system parameters (Figures 440.339-64 through 440.339-70) are close to each other in the three 20-node CMT cases (Cases 2 through 4).

CONCLUSIONS OF CMT NODING STUDY

The NOTRUMP OSU SB23 CMT noding study shows that the 20-node CMT model results in a more realistic CMT thermal stratification/mixing representation, enough to cause a delay in the increase of the CMT injection temperature to enable more reasonable ADS actuation times, compared to the 4-node CMT model without adjustments. From the one-to-one comparison of the 4-node CMT model to the 20-node CMT model with no other differences (both having the artificial cold initial CMT temperatures and 125% PRHR heat transfer area), there is a marked improvement with the 20-node CMT model, in that it shows a decrease in thermal mixing in the CMTs. The onset of heat up of the bottom node of each CMT is delayed significantly in the 20-node case, to approximately 800 seconds as opposed to only about 200 seconds in the 4-node case. This is still earlier than the test data, which shows no heat up in the bottom of the CMT until approximately 2000 seconds. Although the actuation of ADS is predicted to occur approximately 400 seconds earlier in the 20-node case than in either the 4-node case or the test (due to a slightly faster draining of the CMTs in the 20-node case), this is still much more reasonable than the delayed (approximately 2000 seconds) ADS actuation in the original "unadjusted" 4-node case.

The return to nominal initial CMT temperatures with the 20-node CMT model (while retaining the 125% PRHR heat transfer area) yields results which are not very different than those of the 20-node CMT model with cold initial CMT temperatures (and 125% PRHR heat transfer area). This shows that the CMT noding is sufficient to decrease the thermal mixing in the CMTs, such that it is not necessary to artificially decrease the initial CMT temperatures with the 20-node CMT model. It is also noted that the onset of heat up of the bottom node of each CMT in the 20-node model is independent of the initial CMT temperatures; the heat up of the bottom node of each CMT in the 20-node model begins at approximately 800 seconds with either the cold or the nominal initial CMT temperatures. The return to nominal PRHR heat transfer area with the 20-node CMT model (while retaining the nominal initial CMT temperatures) yields results which are not very different than those of the 20-node CMT model with 125% PRHR heat transfer area (and nominal initial CMT temperatures). This shows that the PRHR performance is not as important as the behavior of the CMTs (both the CMT outlet temperature and CMT level draining) in this simulation. However, it is true that artificially increasing the PRHR heat transfer area to 125% of nominal allows the NOTRUMP prediction of the PRHR outlet temperature to more closely match the test data, suggesting that further increasing of the PRHR heat transfer area could improve it even more.

The conclusion 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 transients, but that the continued use of the 4-node CMT model is acceptable because its effect on the transient is conservative (high core void fraction, delayed ADS).

Table 440.339-1
OSU SB23 0.5-inch Cold Leg Break Events

Event	Test (seconds)	NOTRUMP Case 1 (seconds)	NOTRUMP Case 2 (seconds)	NOTRUMP Case 3 (seconds)	NOTRUMP Case 4 (seconds)
CMT-1 Starts Draining	[redacted]	1145	1105	1135	1160
CMT-2 Starts Draining		1165	1105	1135	1155
ADS Stage 1 Open		2276	1871	1909	1947
ADS Stage 2 Open		2323	1910	1956	1994
ADS Stage 3 Open		2383	1978	2016	2054
ADS Stage 4 Open		*2891	2198	2230	2261
Accumulator-1 Empty		*2579	2183	2236	2278
Accumulator-2 Empty		*2582	2188	2239	2281

Explanation of NOTRUMP "Cases" in Table 440.339-1

Case 1: 4-node CMT, cold initial CMT temperatures, 125% PRHR heat transfer area;
(the NOTRUMP OSU SB23 4-node CMT reference case from Reference 440.339-4);

* Note: these events in Case 1 occurred in part 2 of the transient (which was started at 2500 seconds), in which the PRHR was removed from the model.

Case 2: 20-node CMT, cold initial CMT temperatures, 125% PRHR heat transfer area;
(case for one-to-one comparison with Case 1; only difference is 20 CMT nodes instead of 4).

Case 3: 20-node CMT, nominal initial CMT temperatures, 125% PRHR heat transfer area;
(variation case: return to nominal initial CMT temperatures).

Case 4: 20-node CMT, nominal initial CMT temperatures, nominal PRHR heat transfer area;
(variation case; return to nominal initial CMT temperatures and PRHR heat transfer area).

Table 440.339-2
Plot Figures for OSU SB23 0.5-inch Cold Leg Break Results

Figure No.	Title
440.339-48	NOTRUMP CMT-1 Temp Profile - 4nd Cold CMT Temps, 125% PRHR HT
440.339-49	NOTRUMP CMT-1 Temp Profile - 20nd Cold CMT Temps, 125% PRHR HT
440.339-50	NOTRUMP CMT-1 Temp Profile - 20nd Nom CMT Temps, 125% PRHR HT
440.339-51	NOTRUMP CMT-1 Temp Profile - 20nd Nom CMT Temps, Nom PRHR HT
440.339-52	NOTRUMP CMT-2 Temp Profile - 4nd Cold CMT Temps, 125% PRHR HT
440.339-53	NOTRUMP CMT-2 Temp Profile - 20nd Cold CMT Temps, 125% PRHR HT
440.339-54	NOTRUMP CMT-2 Temp Profile - 20nd Nom CMT Temps, 125% PRHR HT
440.339-55	NOTRUMP CMT-2 Temp Profile - 20nd Nom CMT Temps, Nom PRHR HT
440.339-56	CMT-1 Bottom Temperature Comparison
440.339-57	CMT-2 Bottom Temperature Comparison
440.339-58	CMT-1 Level (Relative to Bottom Tap) Comparison
440.339-59	CMT-2 Level (Relative to Bottom Tap) Comparison
440.339-60	PRHR Outlet Temperature Comparison
440.339-61	Core Inlet Temperature Comparison
440.339-62	DVI-1 Temperature Comparison
440.339-63	DVI-2 Temperature Comparison
440.339-64	Pressurizer Pressure Comparison
440.339-65	ACC-1 Level (Relative to Bottom Tap) Comparison
440.339-66	ACC-2 Level (Relative to Bottom Tap) Comparison
440.339-67	ADS 1-3 Integrated Total Mass Flow Comparison
440.339-68	Integrated Total Break Mass Flow Comparison
440.339-69	SG-1 Pressure Comparison
440.339-70	SG-2 Pressure Comparison

AP600 TIME STEP SENSITIVITY STUDY

In order to investigate the sensitivity of the AP600 plant results to changes in the time step size used, a study was performed. The 2-inch cold leg break in fluid node 19 was chosen for the study as a representative case for the plant. The base case for this study is the plant SAR case reported in Reference 440-339-6. The NOTRUMP code calculates a variable time step size as described in Section 10 of Reference 440.339-7. The time step size is limited between maximum and minimum values input by the user. The maximum and minimum values used for all AP600 calculations are 0.01 sec and 0.0001 sec respectively. To determine a reasonable time step size to be set for the sensitivity study, the time step size for the base case was plotted and a significantly smaller time step size was chosen such that the base calculation time step size is bounded most of the time. The value chosen for the study was 0.001 sec. This time step was set constant by setting both the maximum and minimum values to 0.001 sec. The results of this sensitivity are shown in Figures 440.339-72 through 440.339-85 which compare the base results to the sensitivity case for the key variables. As can be seen, although there are minor differences in results, the trends are nearly identical with little change in core mixture level and DVI injection flow rates. This confirms the code predictions are well converged and not sensitive to reductions in the time step size.

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AP600

OVERALL CONCLUSIONS

The results of the sensitivity studies included in the response to this RAI show that NOTRUMP for AP600 is converged with respect to time step size. In addition, variations in PRHR noding had little effect on the results. Increasing the number of CMT nodes results in a more correct simulation of stratification, but retaining the 4 node CMT model is conservative.

References:

440.339-1 Meyer P.E. et. al, "PXS-GSR-002: NOTRUMP Preliminary Validation Report for SPES-2 Tests", Westinghouse Electric Corporation, July 1995.

440.339-2 Willis, M.G. et. al, "LTCT-GSR-001: NOTRUMP Preliminary Validation Report for OSU Tests", Westinghouse Electric Corporation, July 1995.

440.339-3 WCAP-14292, Revision 1, "AP600 Low-Pressure Integral Systems Test at Oregon State University Test Analysis Report", Section 6.1.2 [LTCT-T2R-600].

440.339-4 WCAP-14807, Revision 1, "NOTRUMP Final Validation Report for AP600", by Fittante, R. L. et. al, January 1997.

440.339-5 WCAP-12980, "AP600 Passive Residual Heat Removal Heat Exchanger Test Final Report", Rev. 2, by Hochreiter, L. E., et. al, September 1996.

440.339-6 Letter NSD-NRC-97-5136, dated 5/15/97.

440.339-7 WCAP-10079-P-A, "NOTRUMP - A Nodal Transient Small Break and General Network Code", by Meyer, P. E., August 1985.

SSAR Revision: NONE

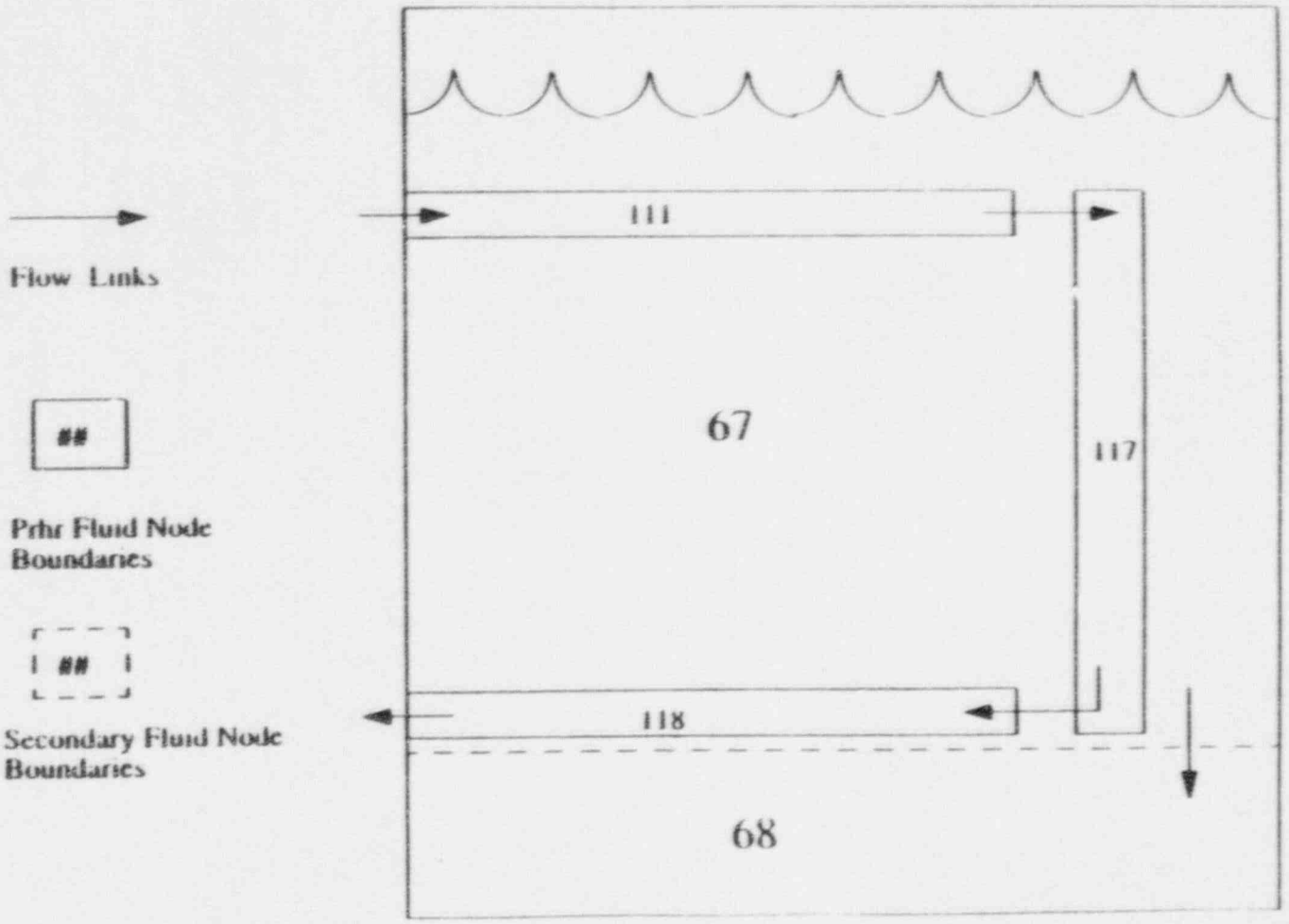

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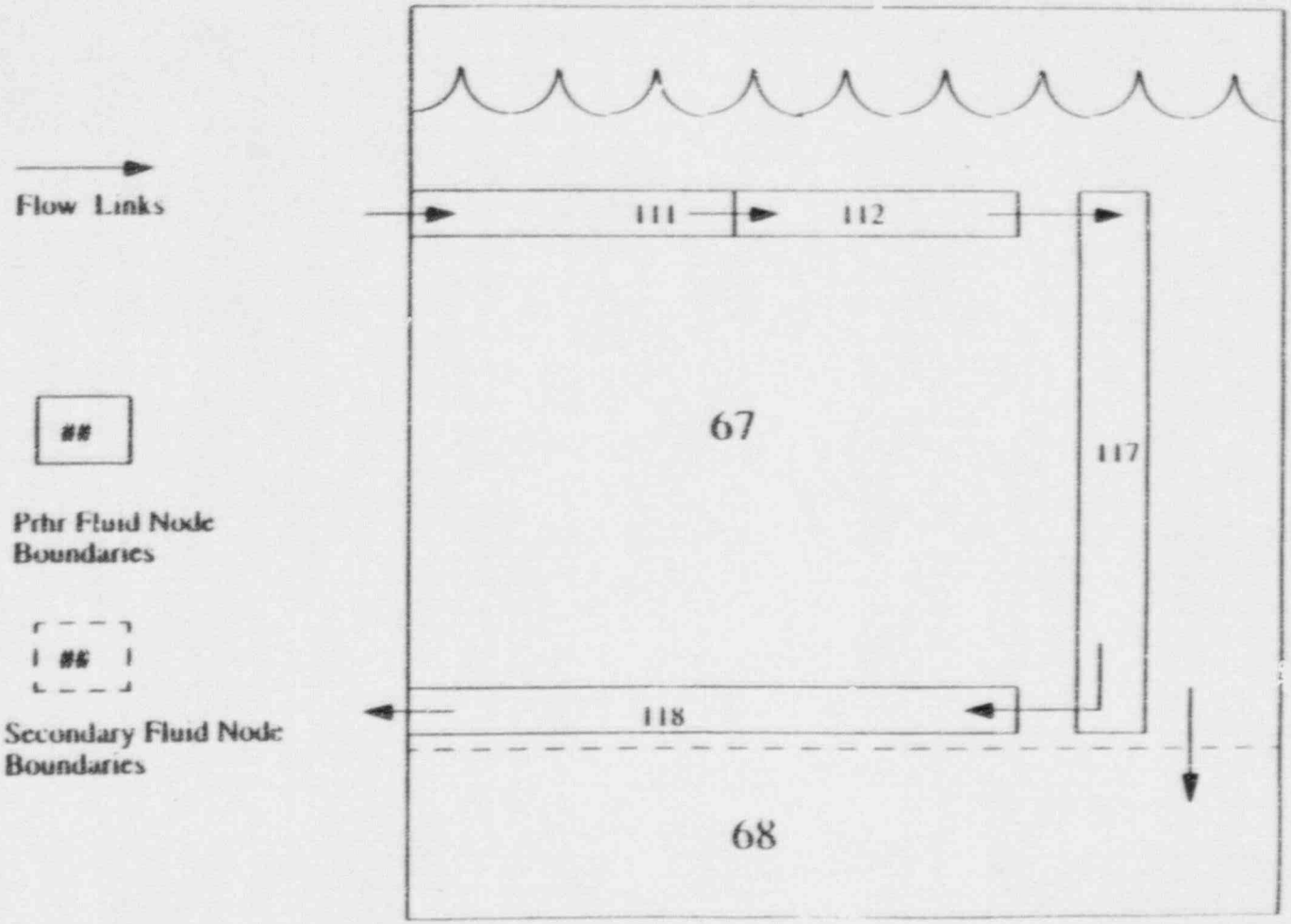
Figure 4b.339-1 - Stand Alone PRHR Model 3 Node PRHR Models


Flow Links
##
Prhr Fluid Node Boundaries
##
Secondary Fluid Node Boundaries
111
112
67
117
118
68

END

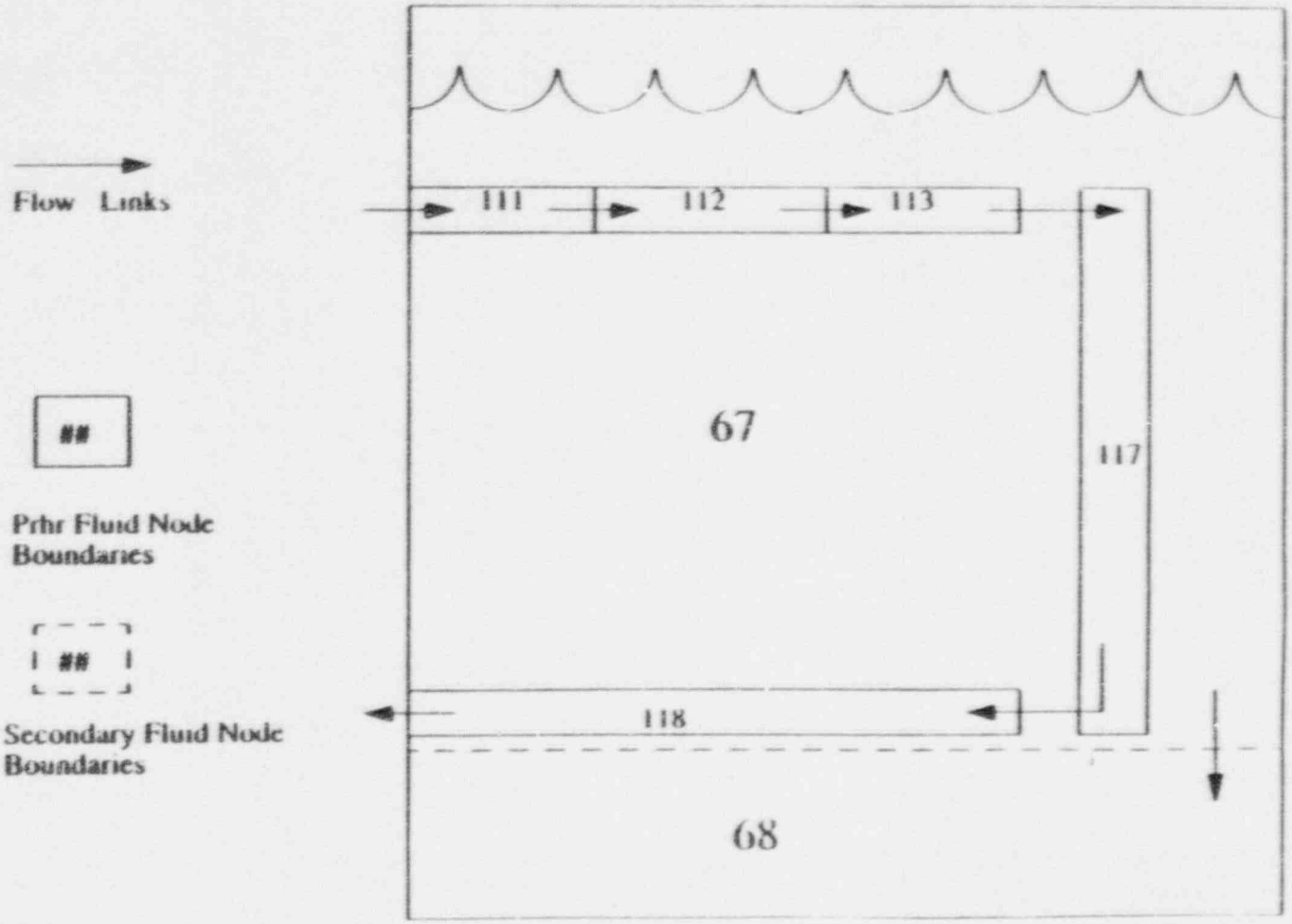


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Figure 10.339-3 - Stand Alone PRHR Model (5 Node PRHR Model)

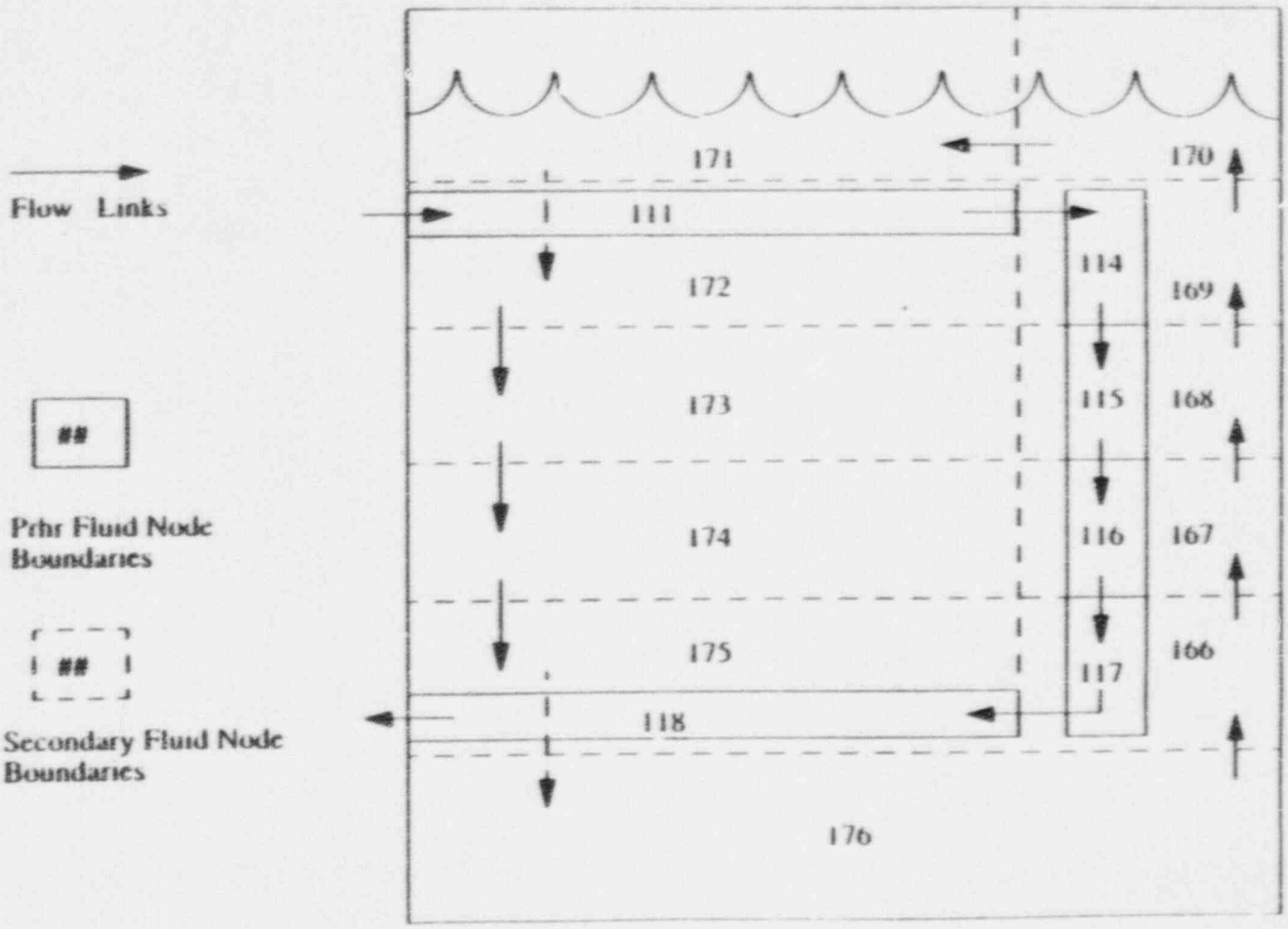

Figure 440.339-4 - SPES-2 PRHR Model (6 Node PRHR With Influence Zone)

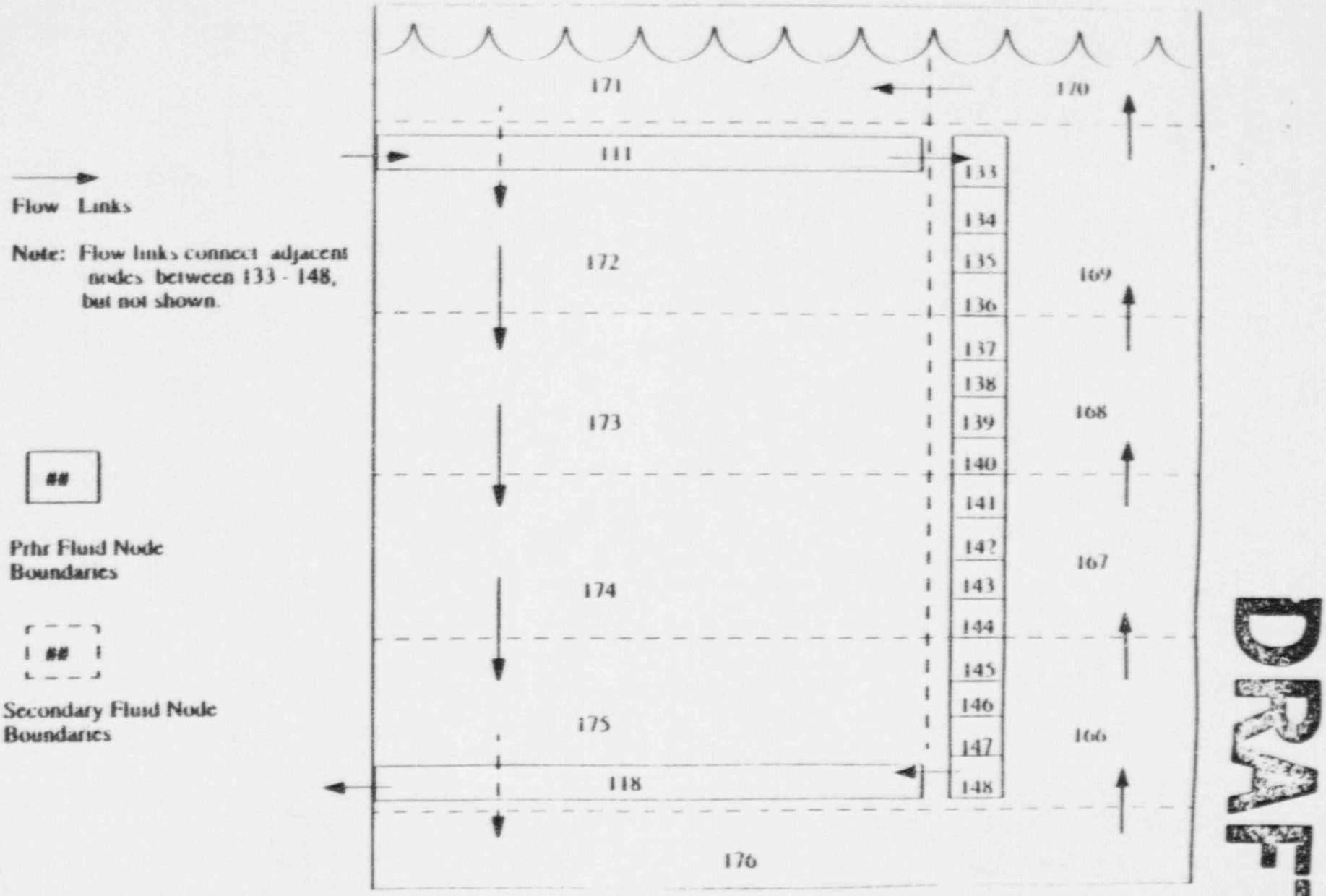

Figure 440.339-5 - SPES-2 PRHR Model (18 Node PRHR With Influence Zone)

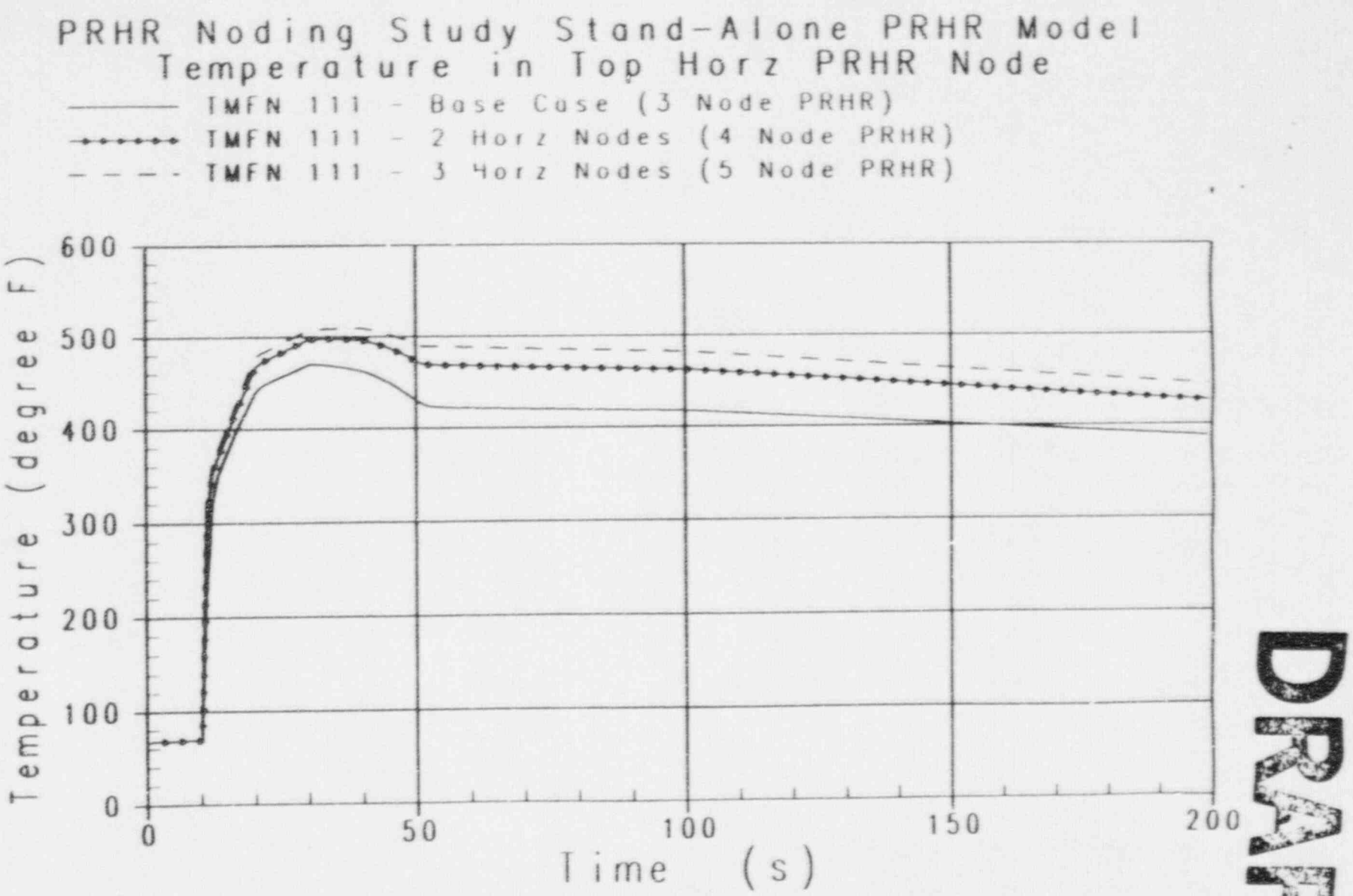

Figure 440.339- 6

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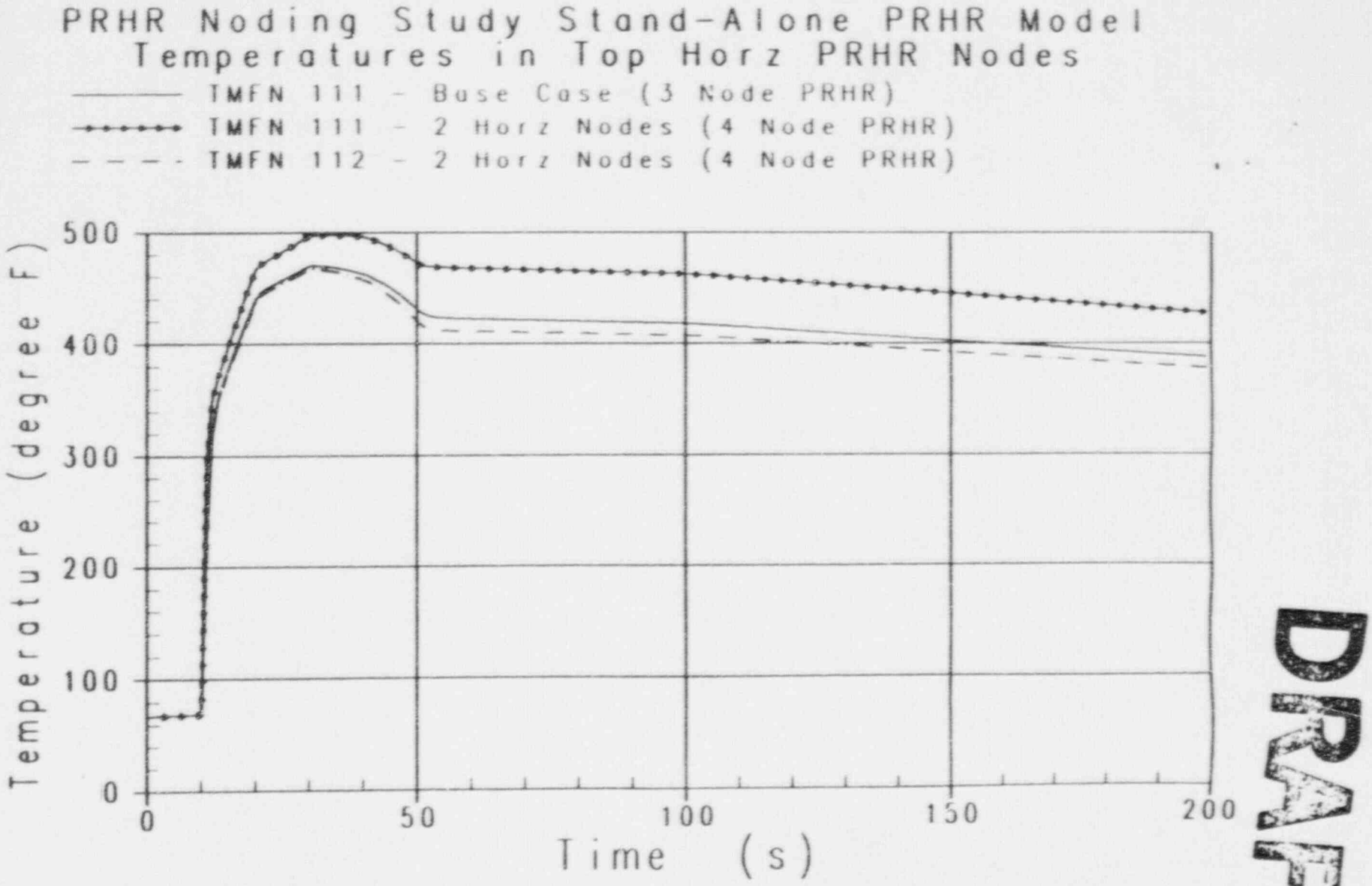

Figure 440.339- 7

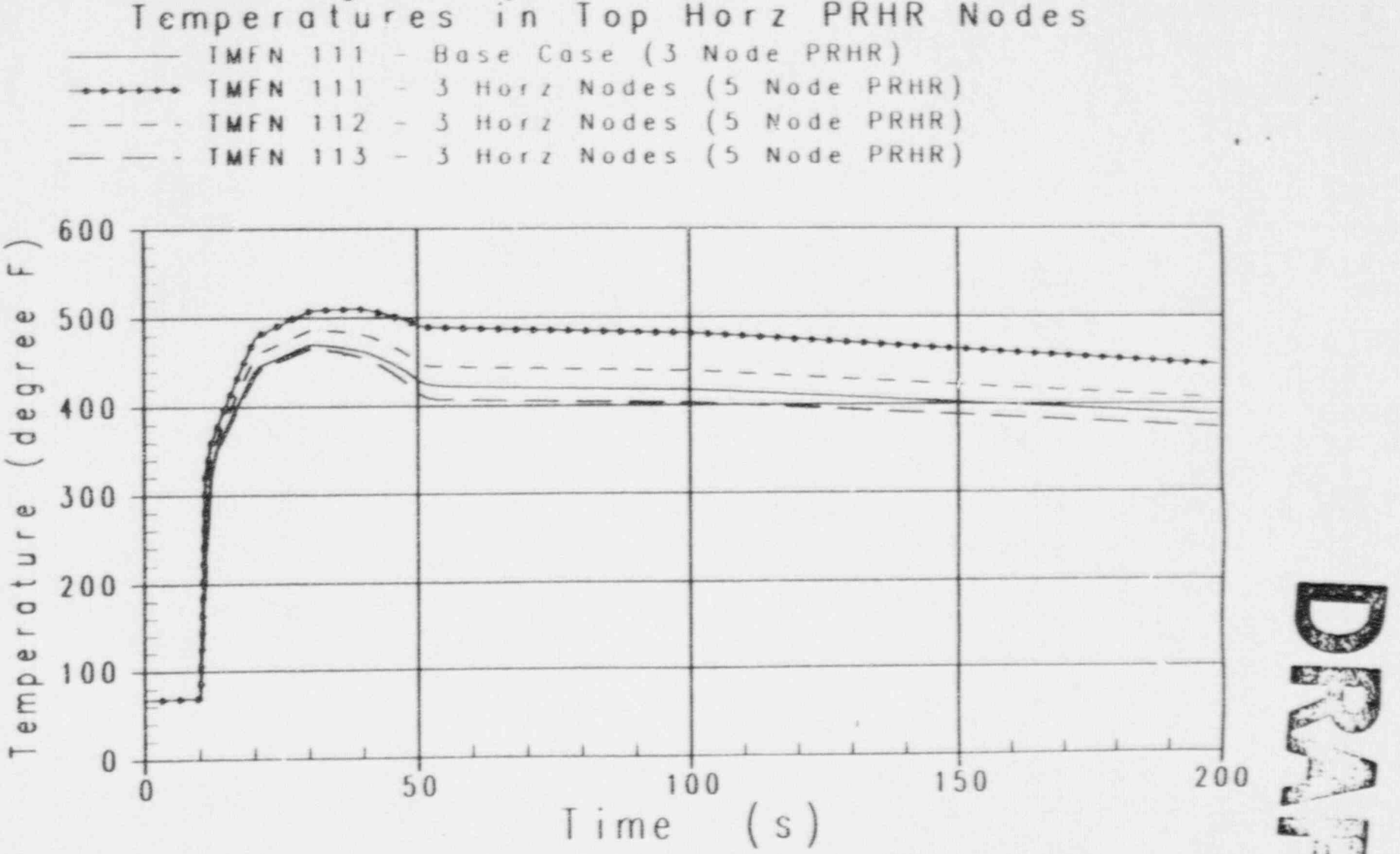

Figure 440.339- 8

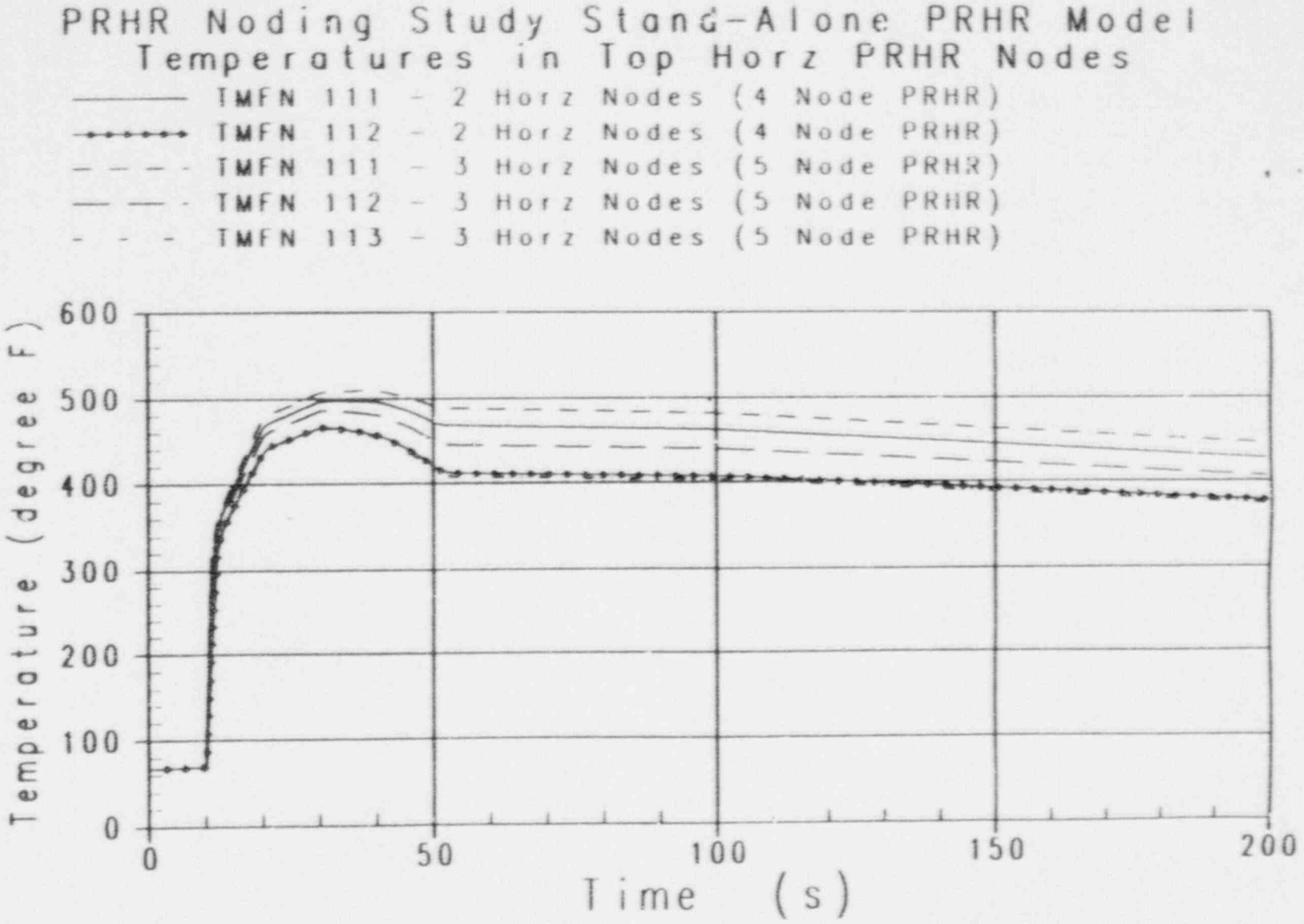

Figure 440.339- 9

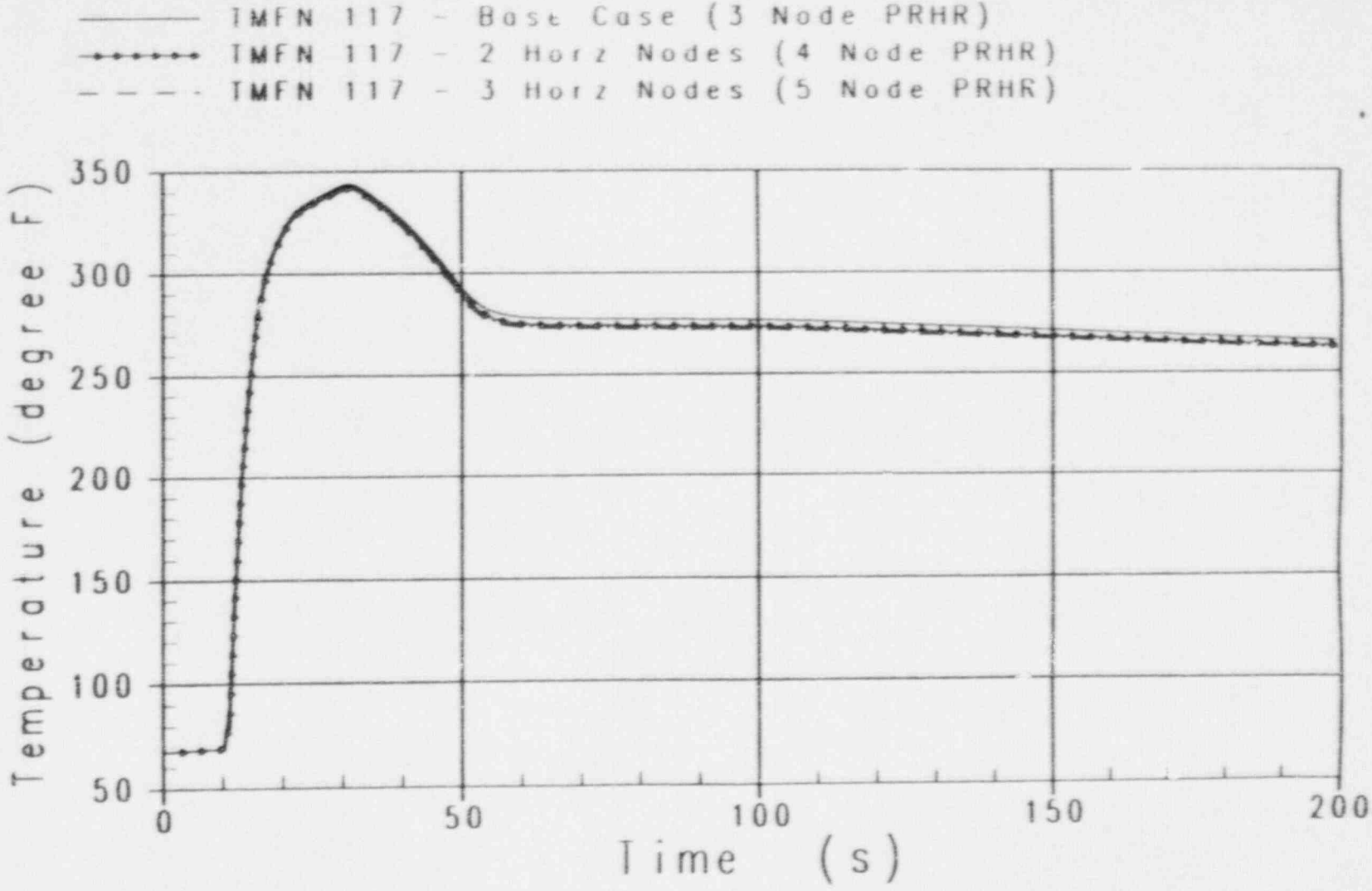

Figure 440.339-10

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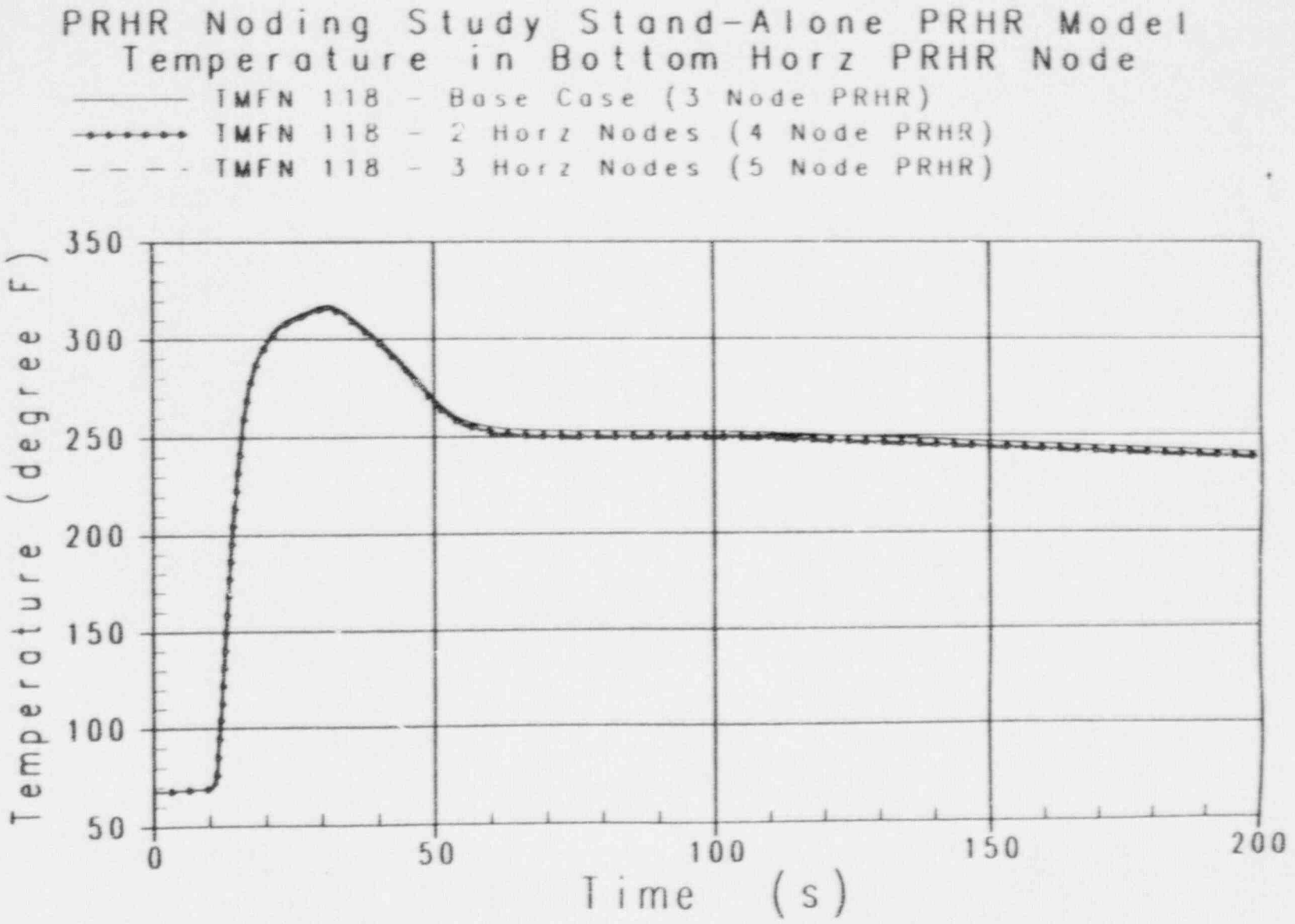

Figure 440.339-11

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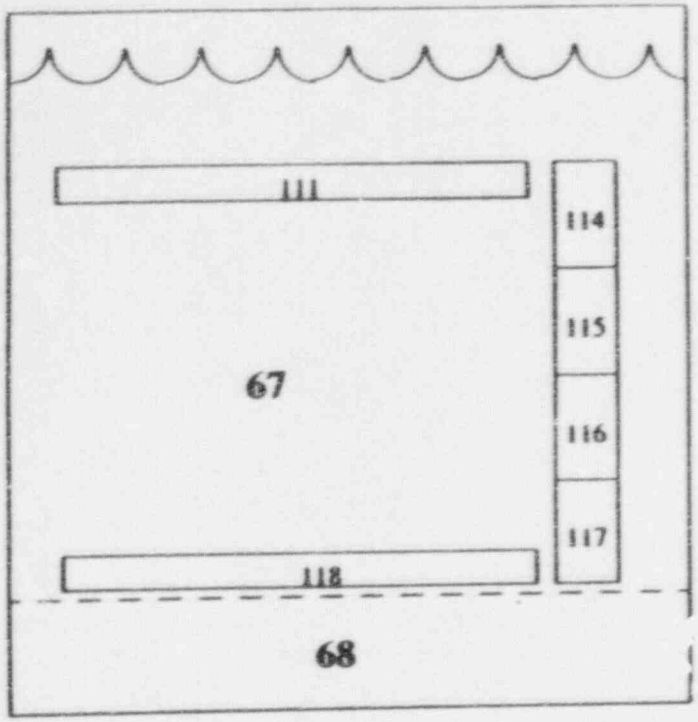
(a,b,c)

[redacted]

(a,b,c)

[ ]



PARAMETER	TIME = 200 secs	TIME = 700 secs
QMHL 111 to 67	25.4 Btu/sec	53.81 Btu/sec
QMHL 114 to 67	13.44 Btu/sec	36.86 Btu/sec
QMHL 117 to 67	3.75 Btu/sec	11.05 Btu/sec
QMHL 118 to 67	3.18 Btu/sec	7.42 Btu/sec

Heat transfer mode = Nucleate Boiling (NB)

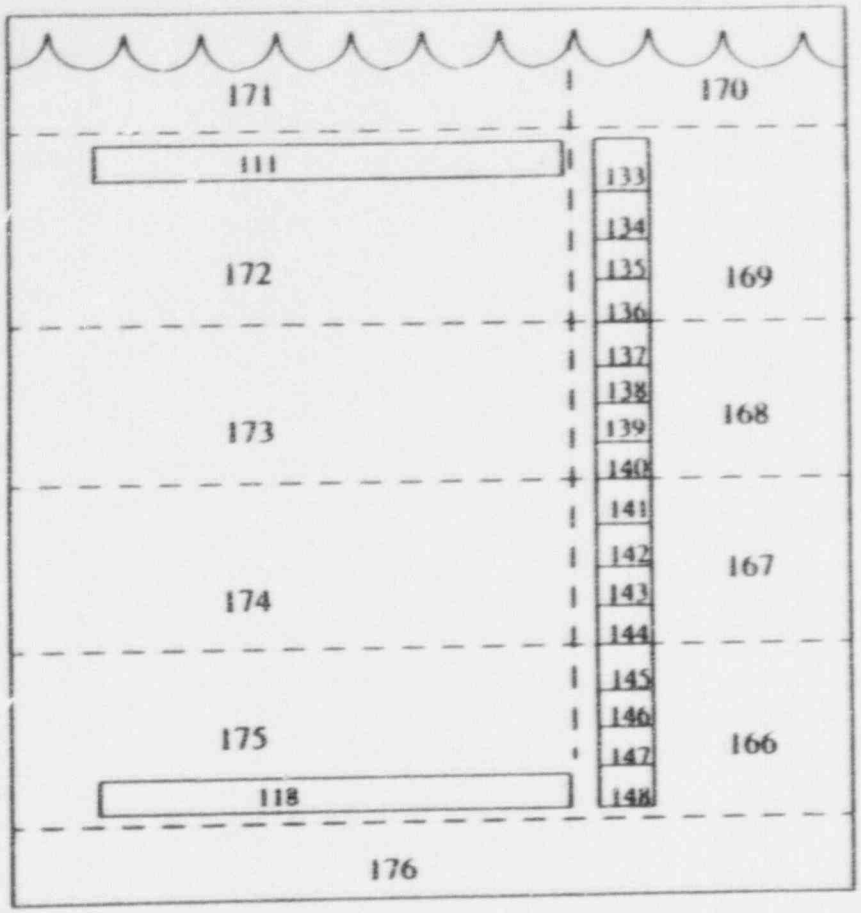
QMHL - Heat transfered from metal to fluid

Note: In this original noding scheme no influence zone is modeled.

Therefore, the flow velocity within the IRWST is 0.0.

The NOTRUMP heat transfer package always choses NB as the heat transfer mode at zero velocity.

Figure 440.339-14 - Snapshot of PRHR Heat Transfer for the Original Model (From Reference 3)



PARAMETER	TIME = 200 secs	TIME = 700 secs
QMHL 111 to 172	26.4 Btu/sec (NB*)	53.27 Btu/sec (NB*)
QMHL (133-136) to 169	19.03 Btu/sec (SCFC*)	40.97 Btu/sec (NB*)
QMHL (145-148) to 166	4.91 Btu/sec (SCFC*)	15.19 Btu/sec (SCFC*)
QMHL 118 to 175	1.22 Btu/sec (SCNC*)	4.76 Btu/sec (SCNC*)
Fluid Velocity Within the IRWST	1.5 ft/sec	1.3 ft/sec

QMHL - Heat transfered from metal to fluid

Note: * - Defines the Heat Transfer Regime

NB - Nucleate boiling
SCFC - Subcooled forced convection
SCNC - Subcooled natural convection

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Figure 440.339-15 - Snapshot of PRHR Heat Transfer for the 16 Vert Node PRHR Model

(a,b,c)

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(a.b.c)

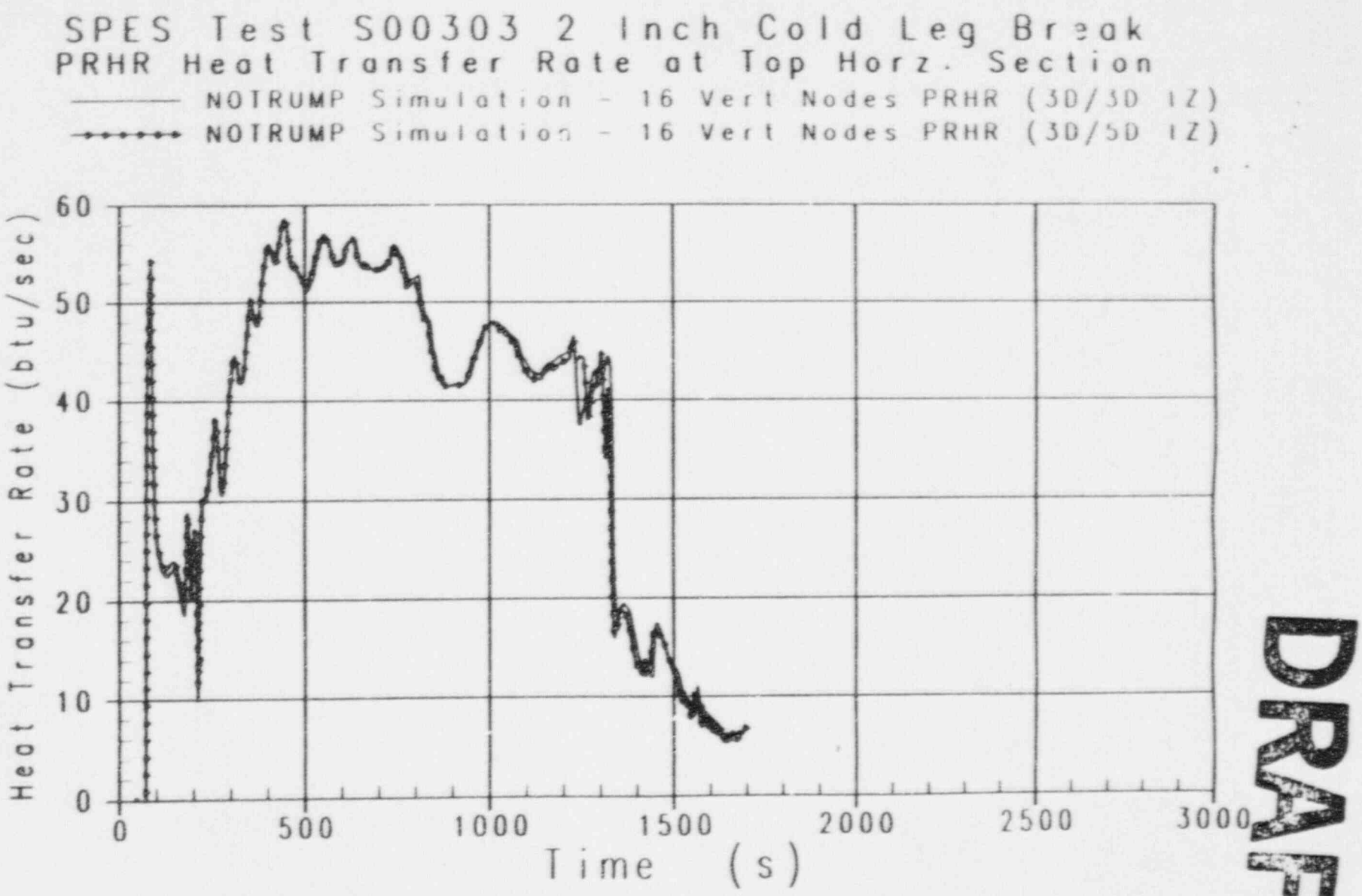


Figure 440.339-18

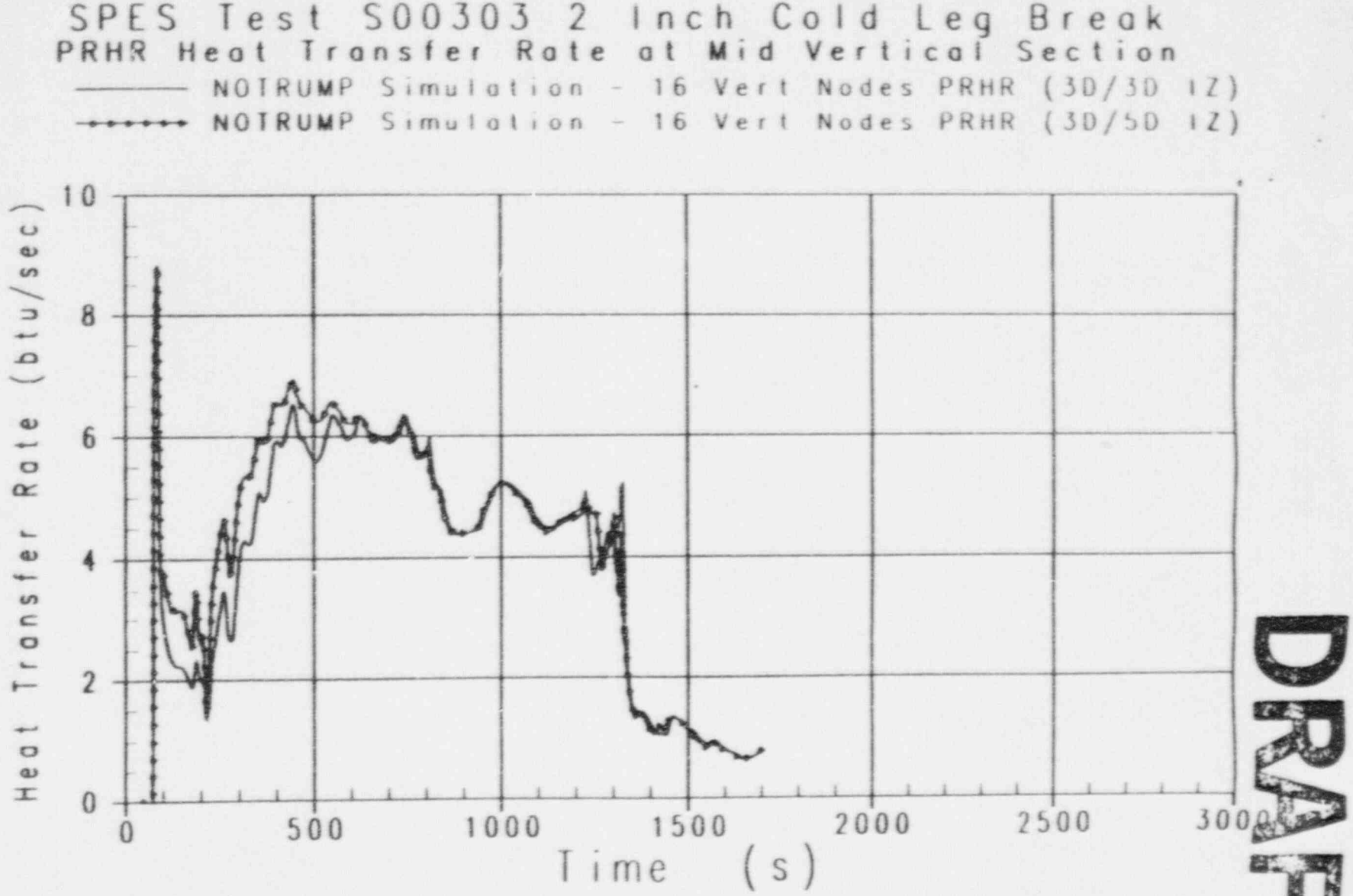
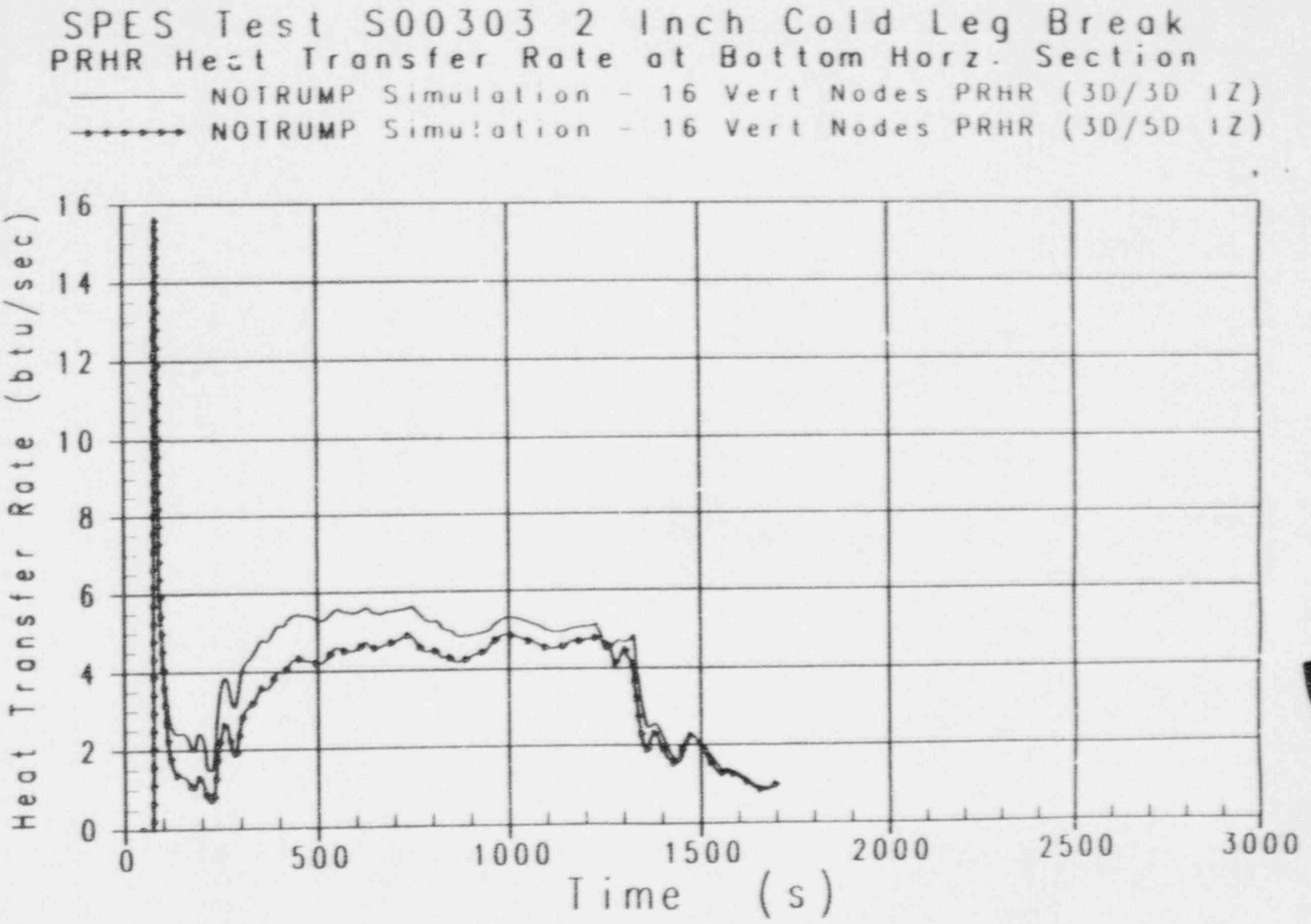


Figure 440.339-19



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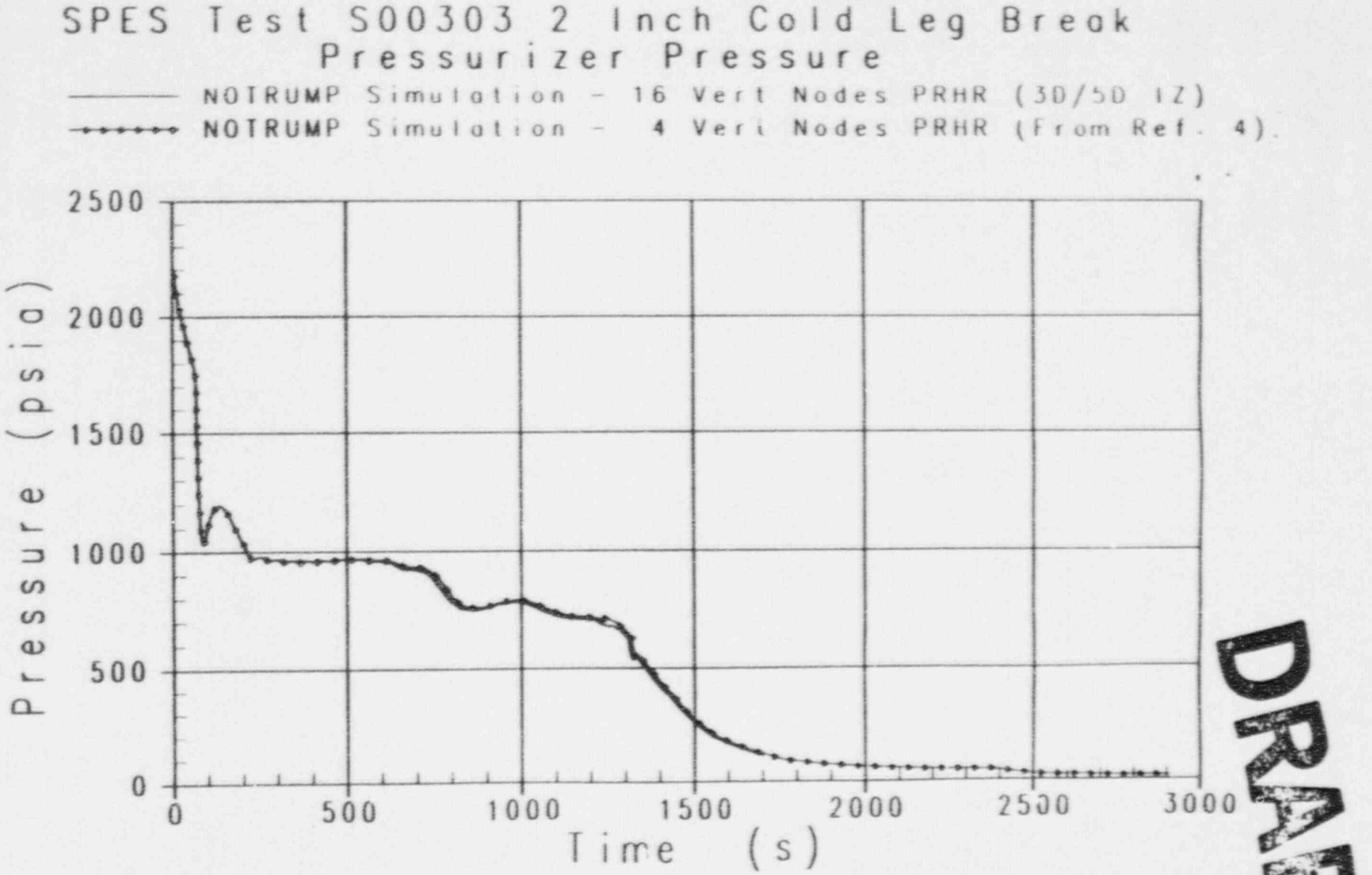

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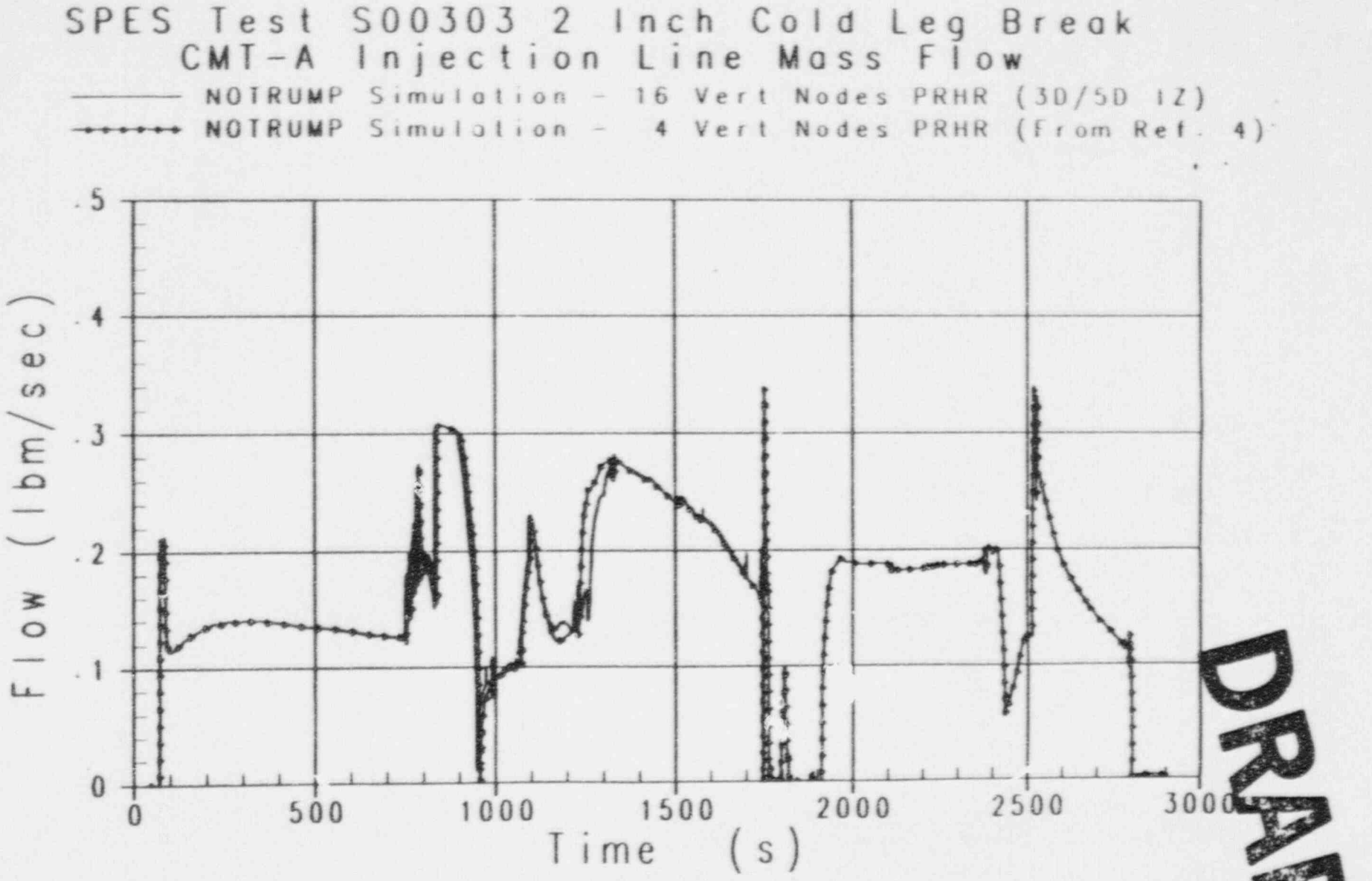

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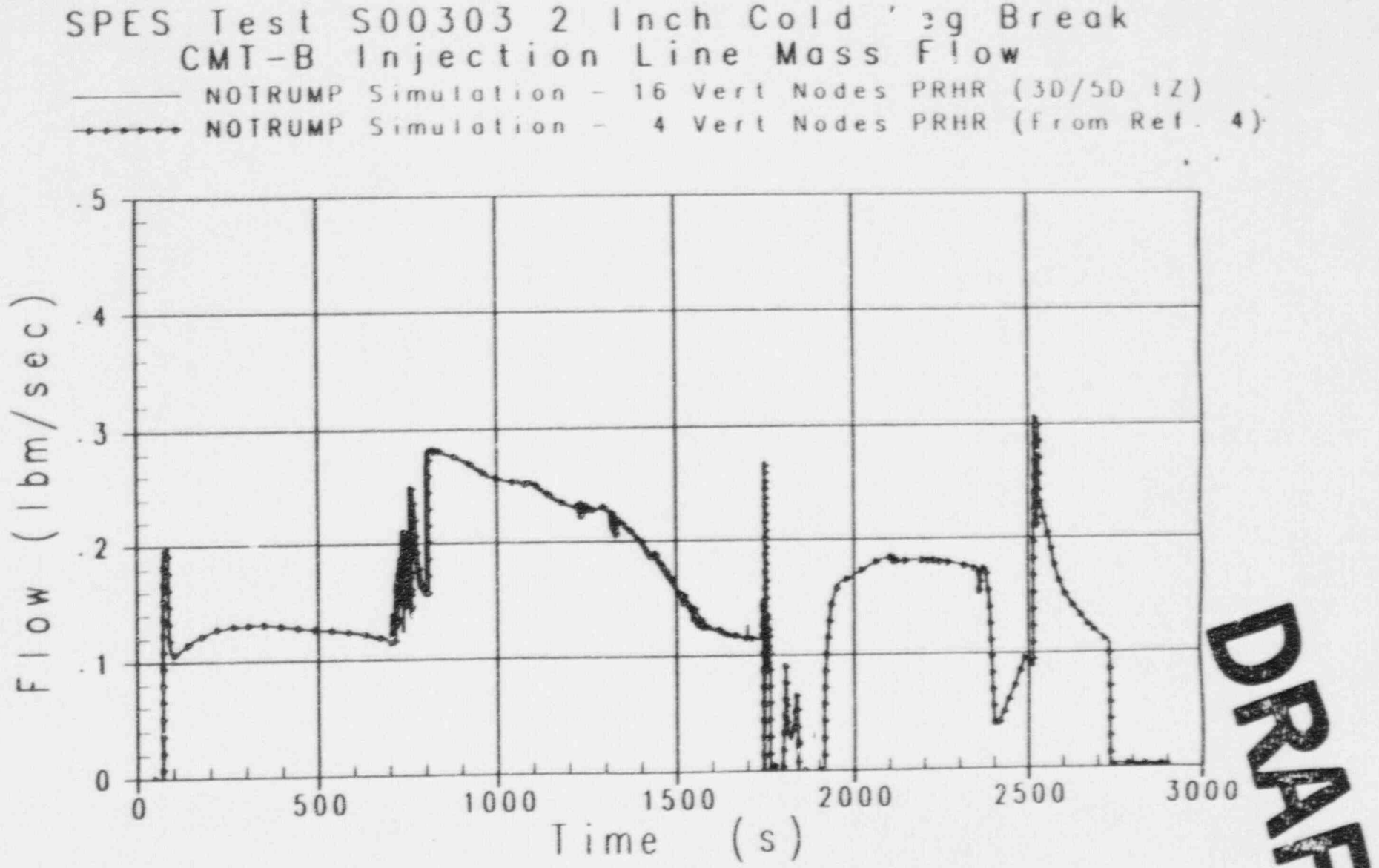

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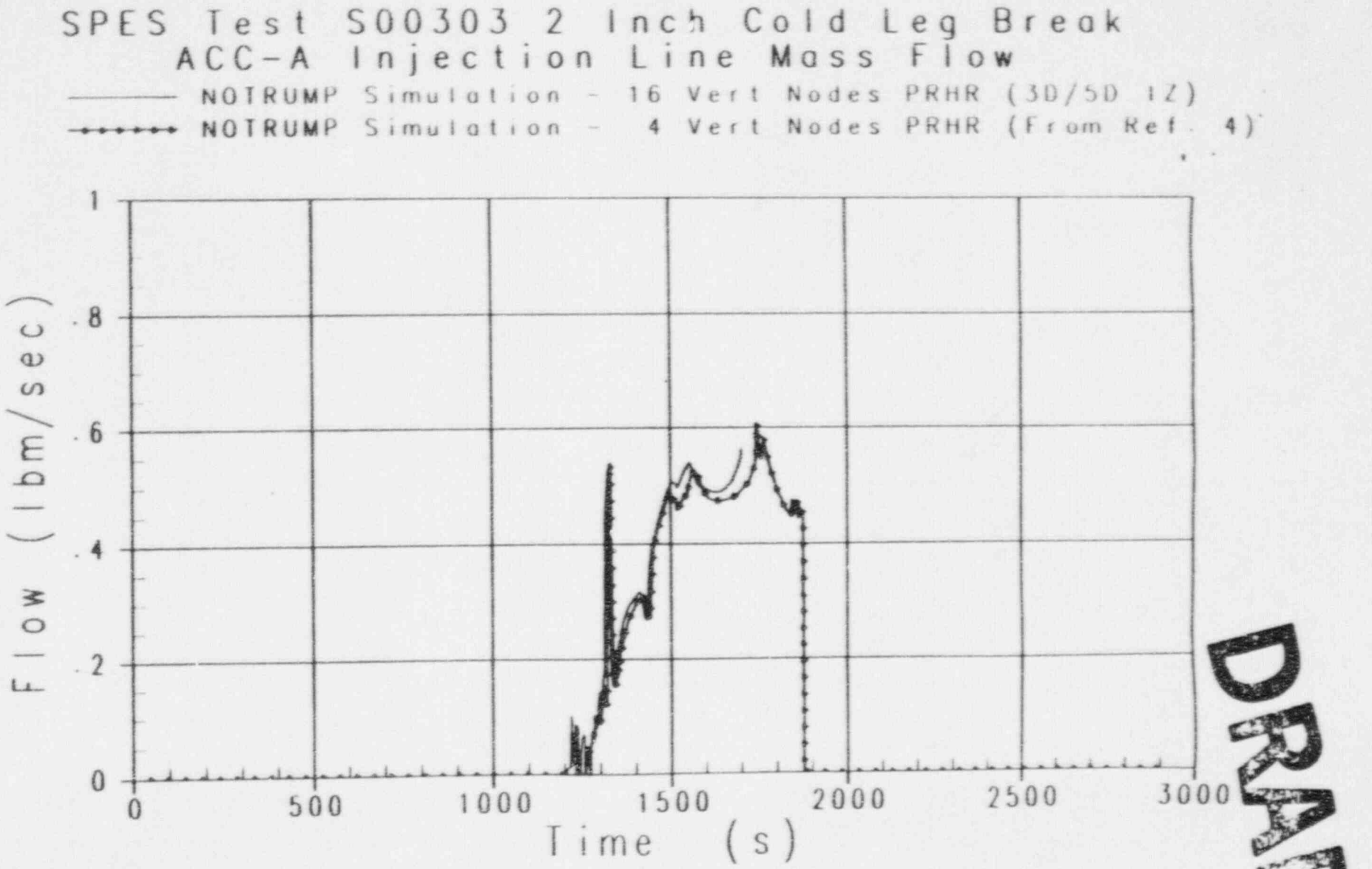

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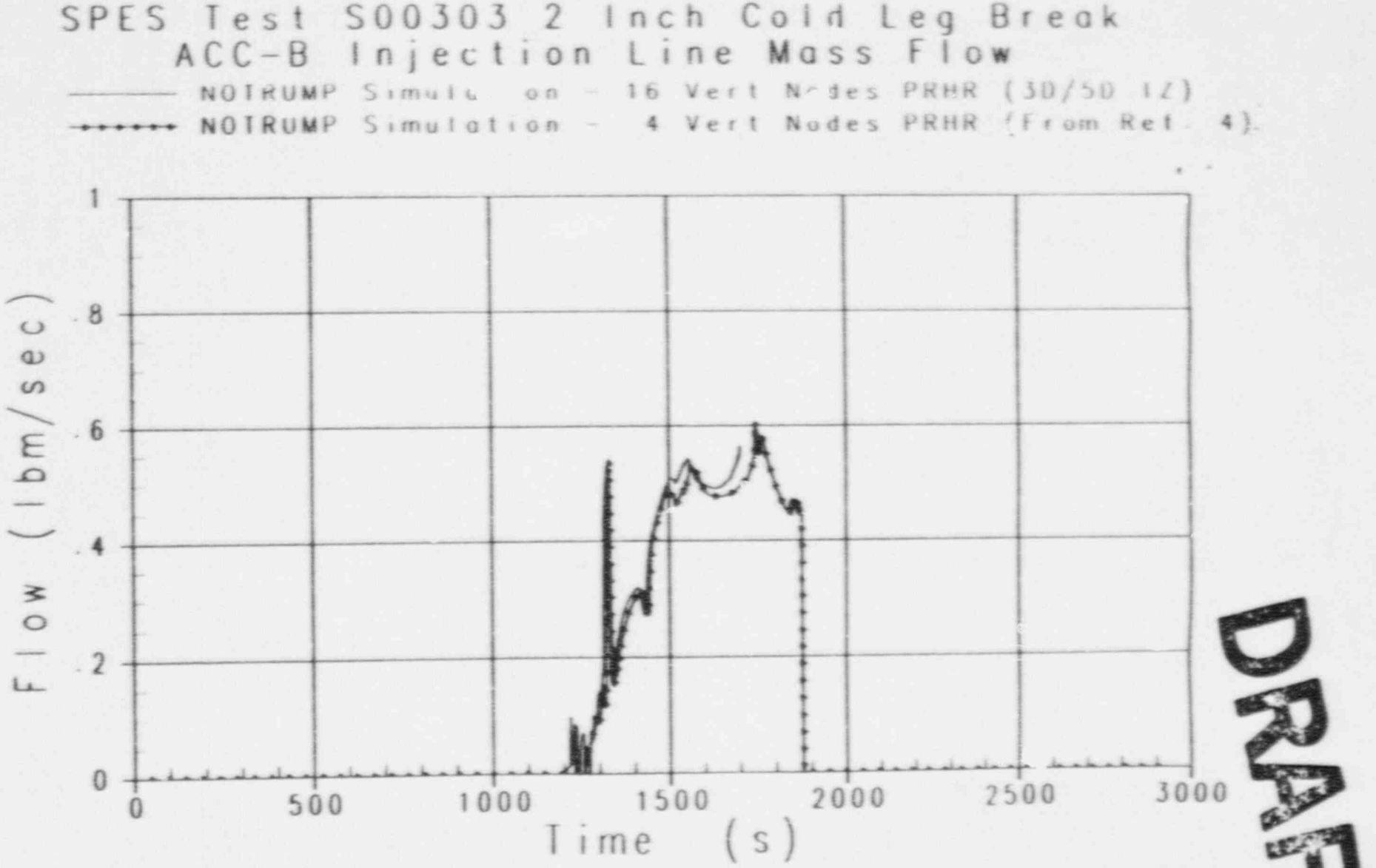


Figure 440.339-25

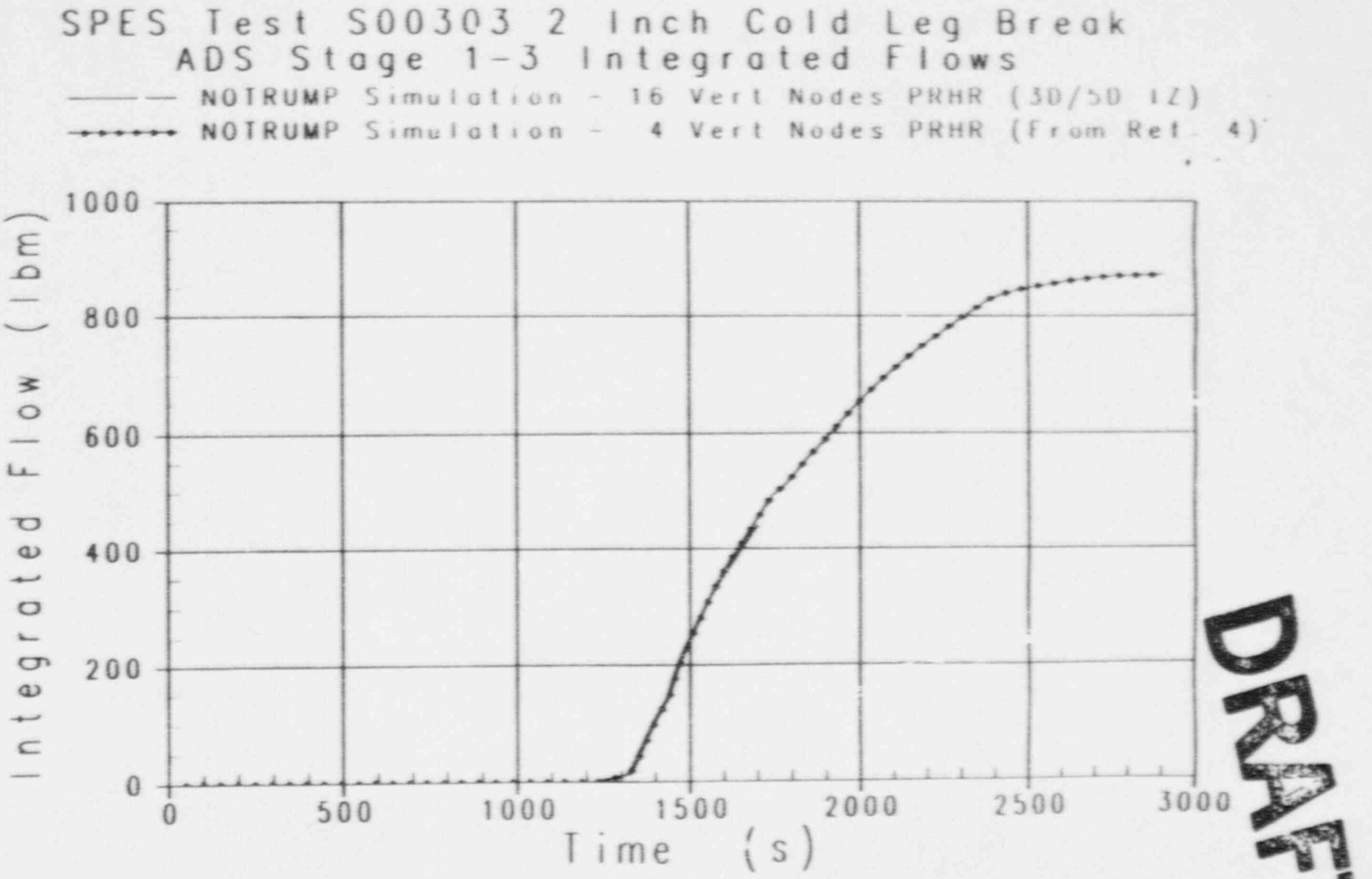
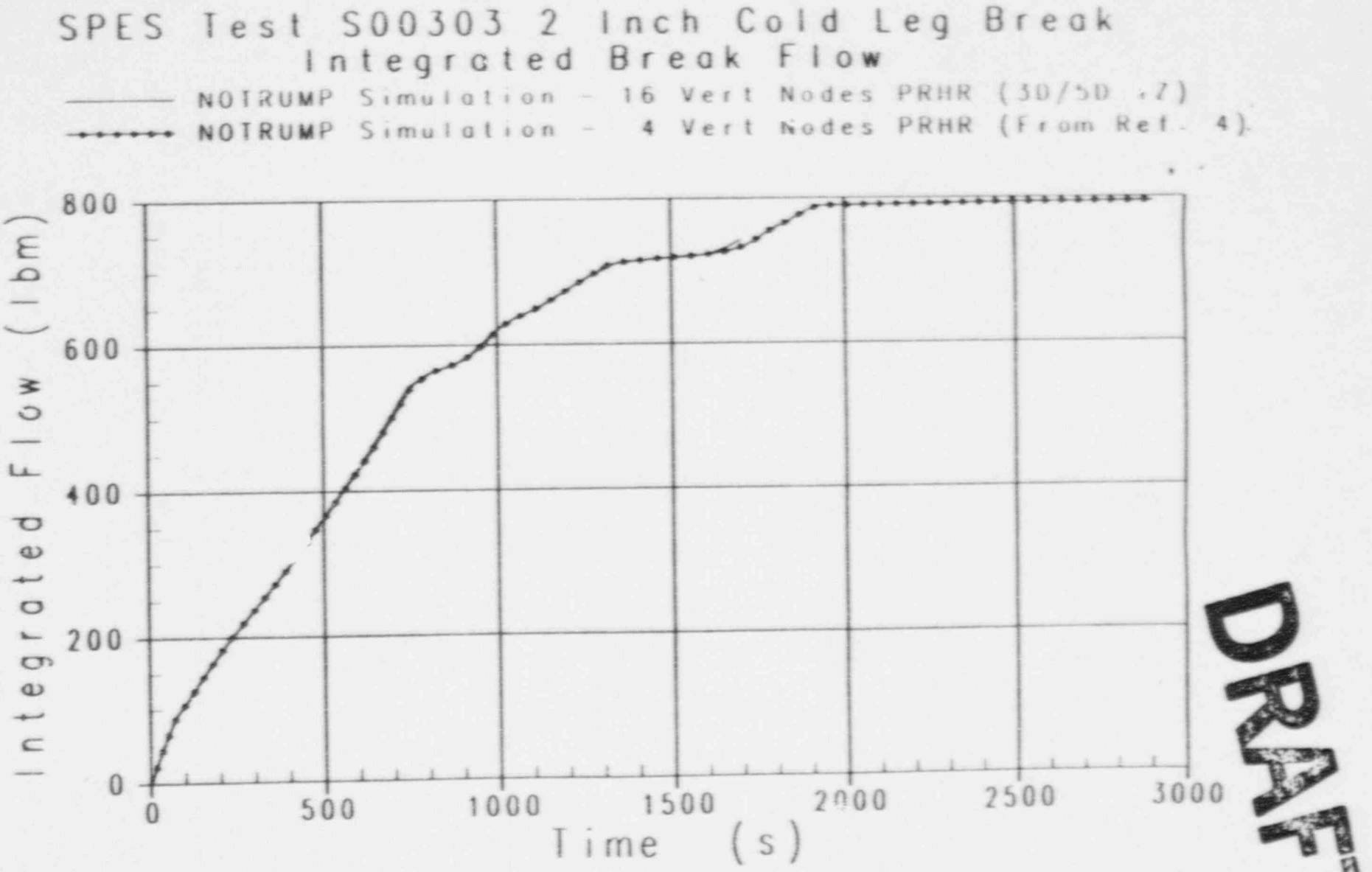


Figure 440.339-26



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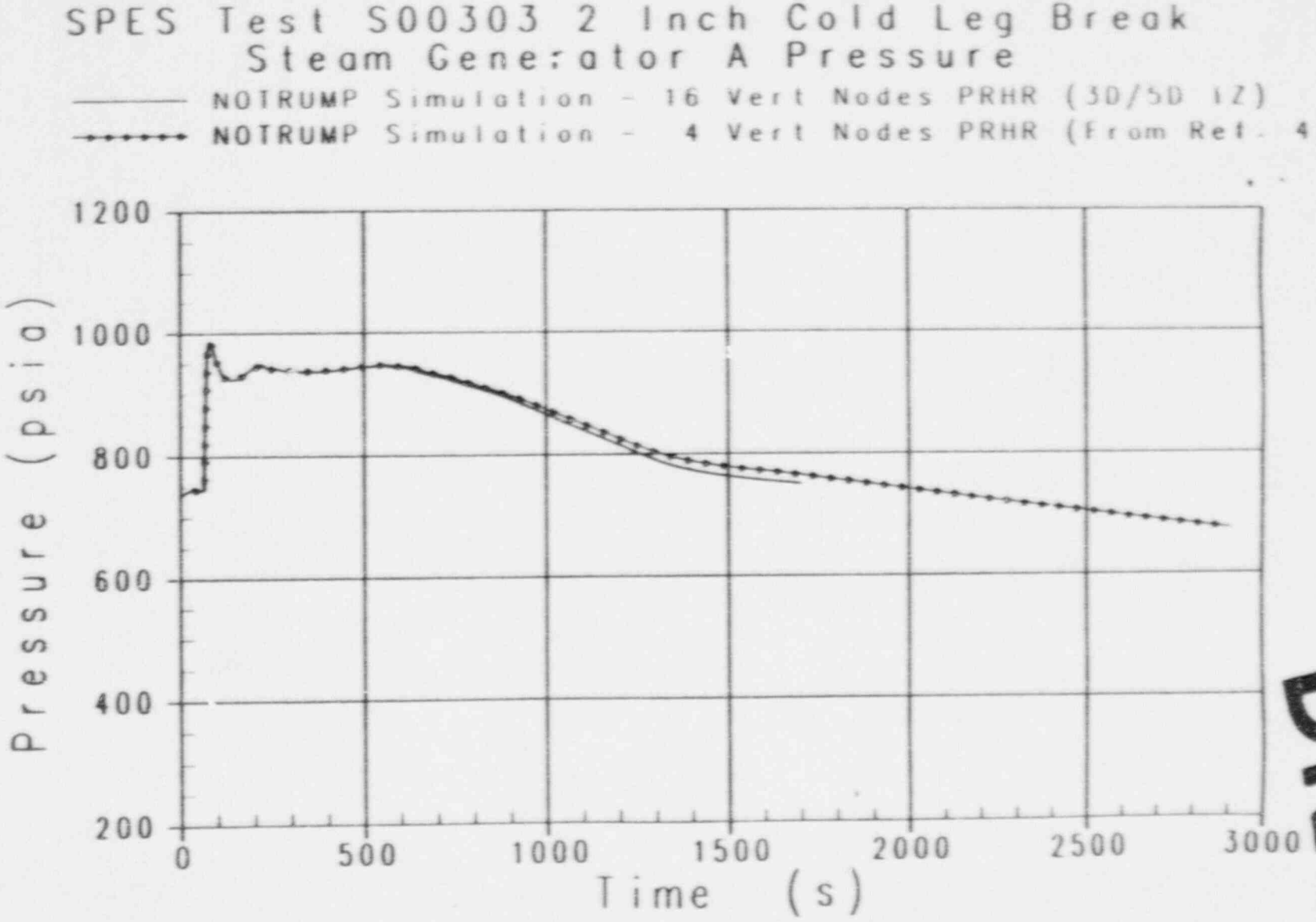

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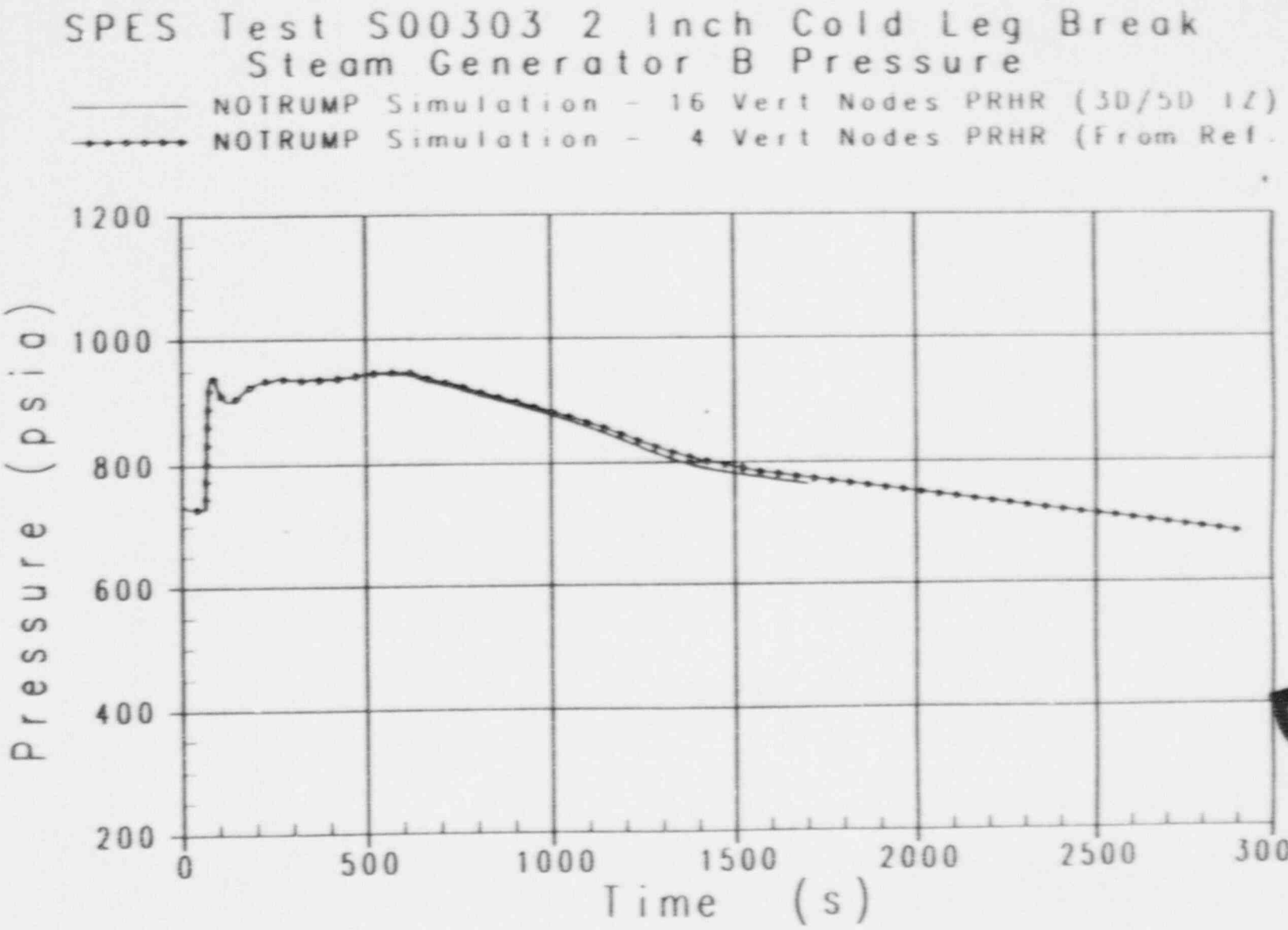

Figure 440.339-29

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(a,b,c)

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(a,b,c)

[redacted]

(a,b,c)

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(a,b,c)

[redacted]

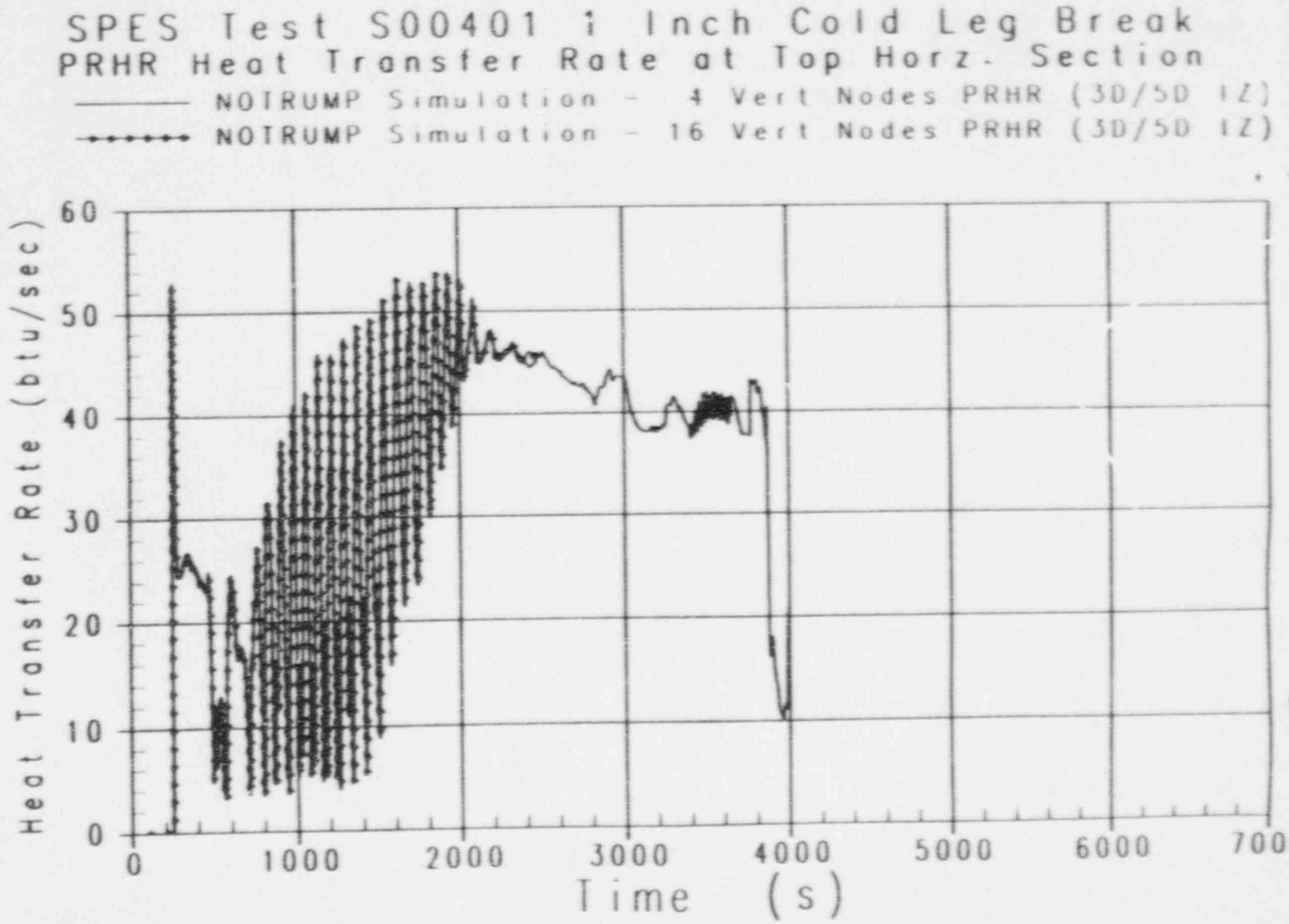
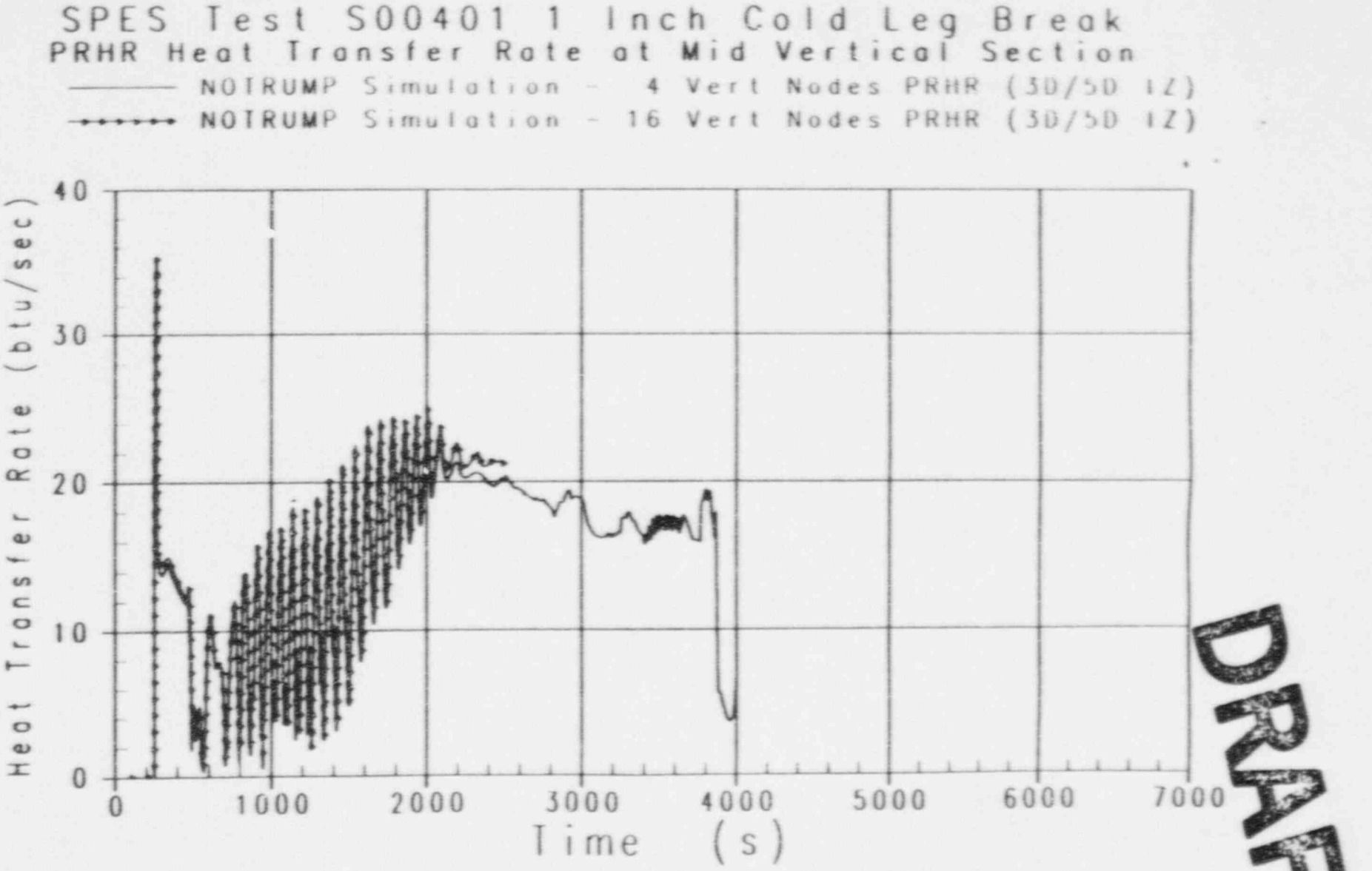


Figure 440.339-34



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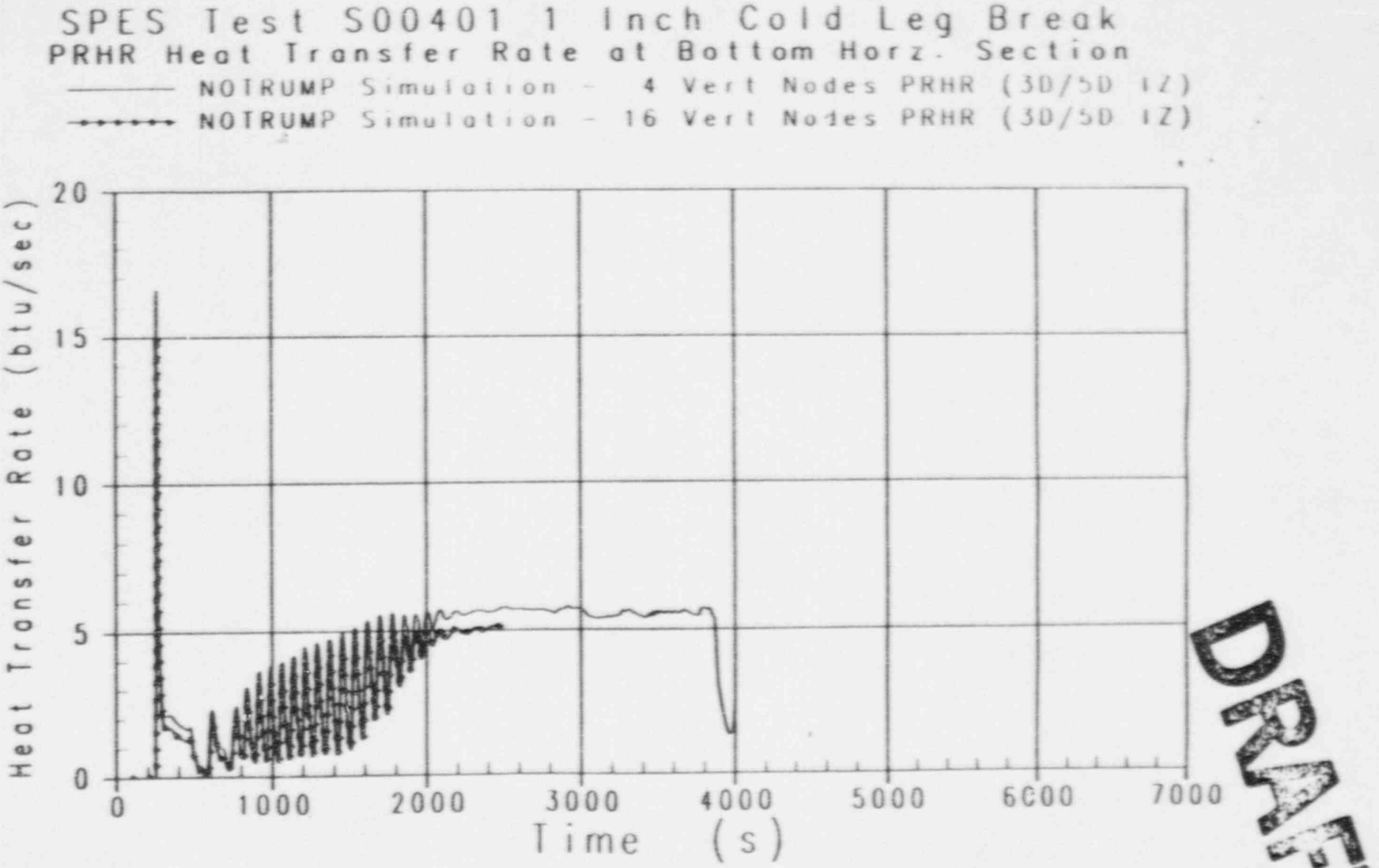

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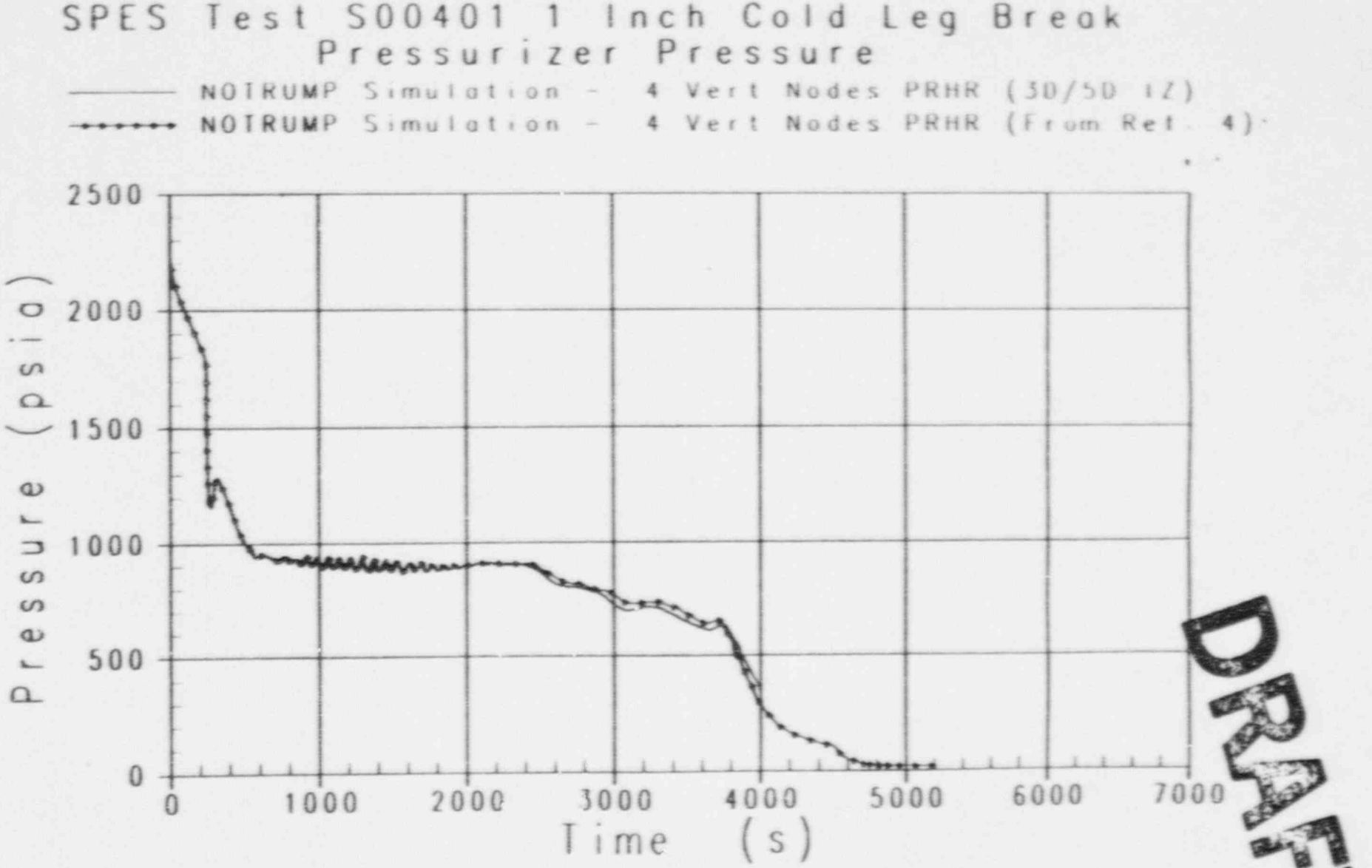

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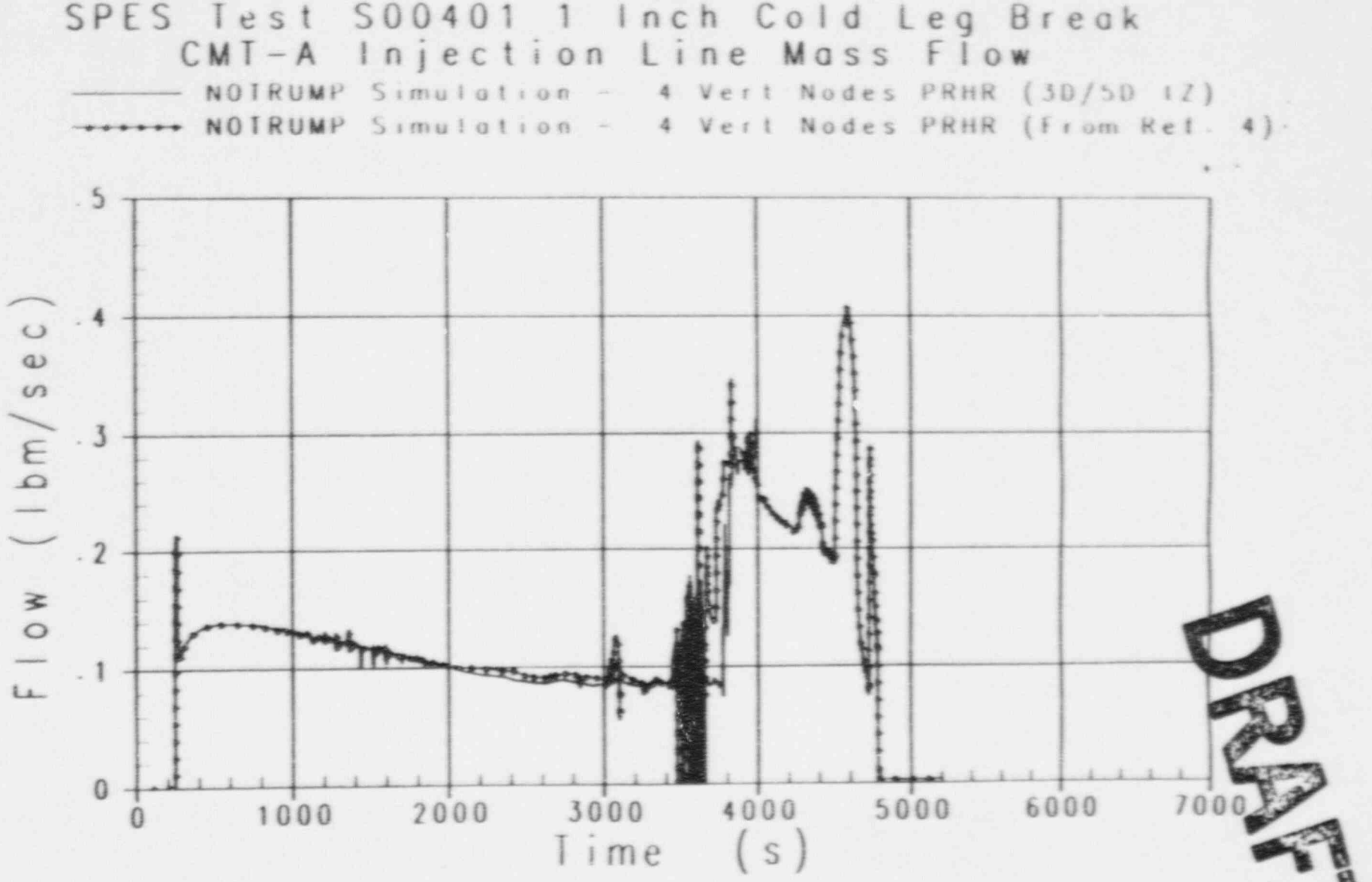

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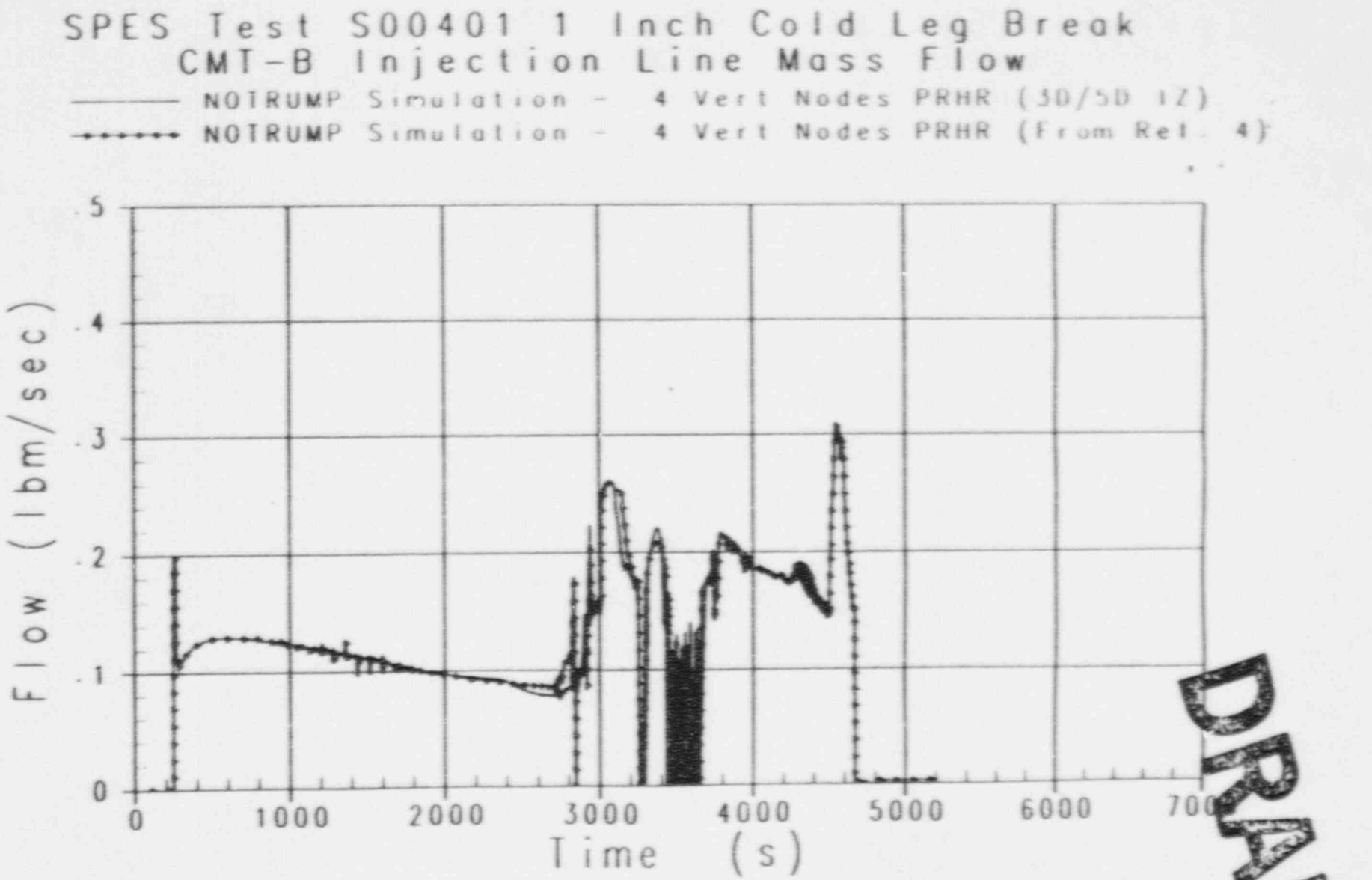

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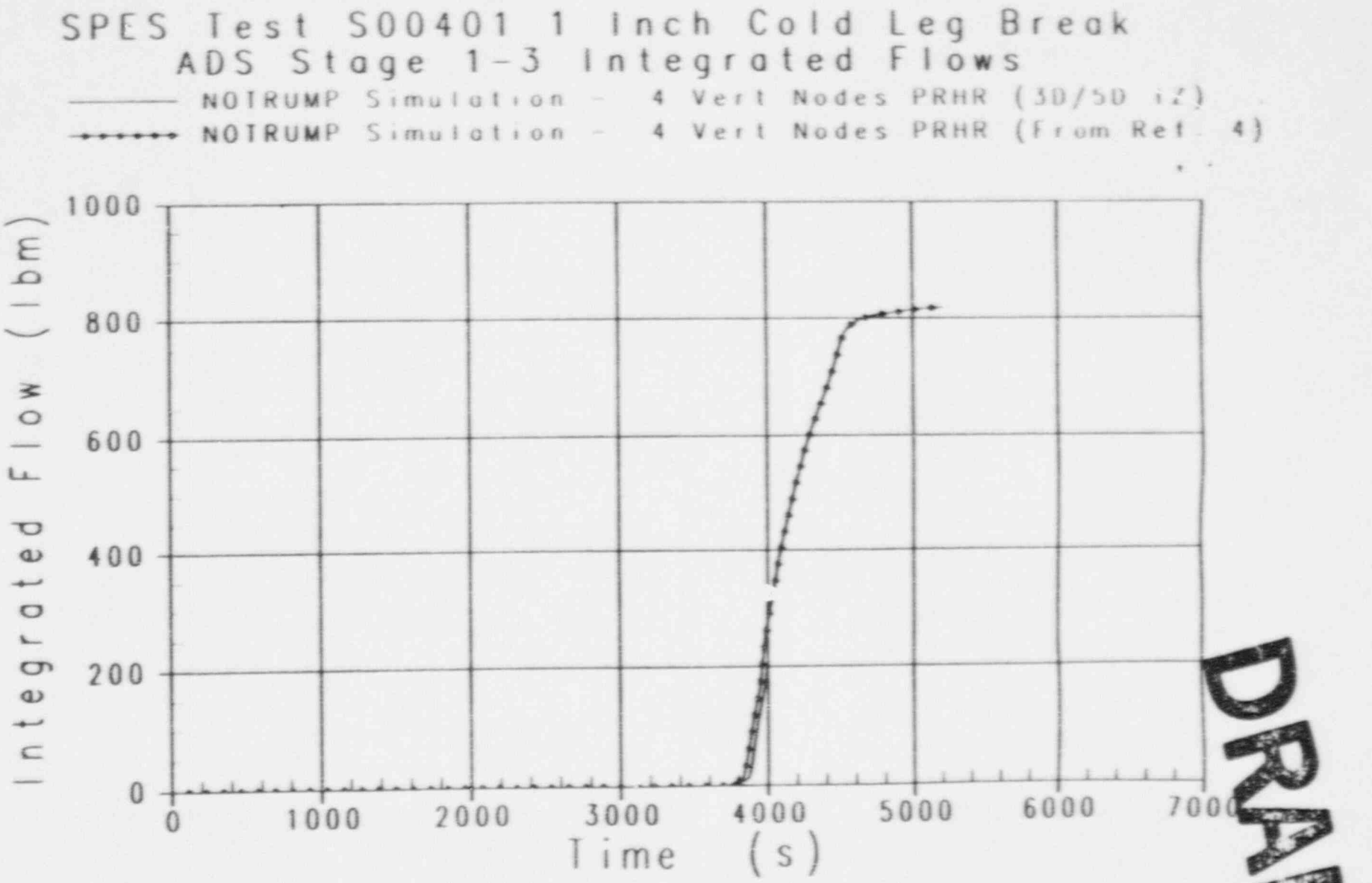

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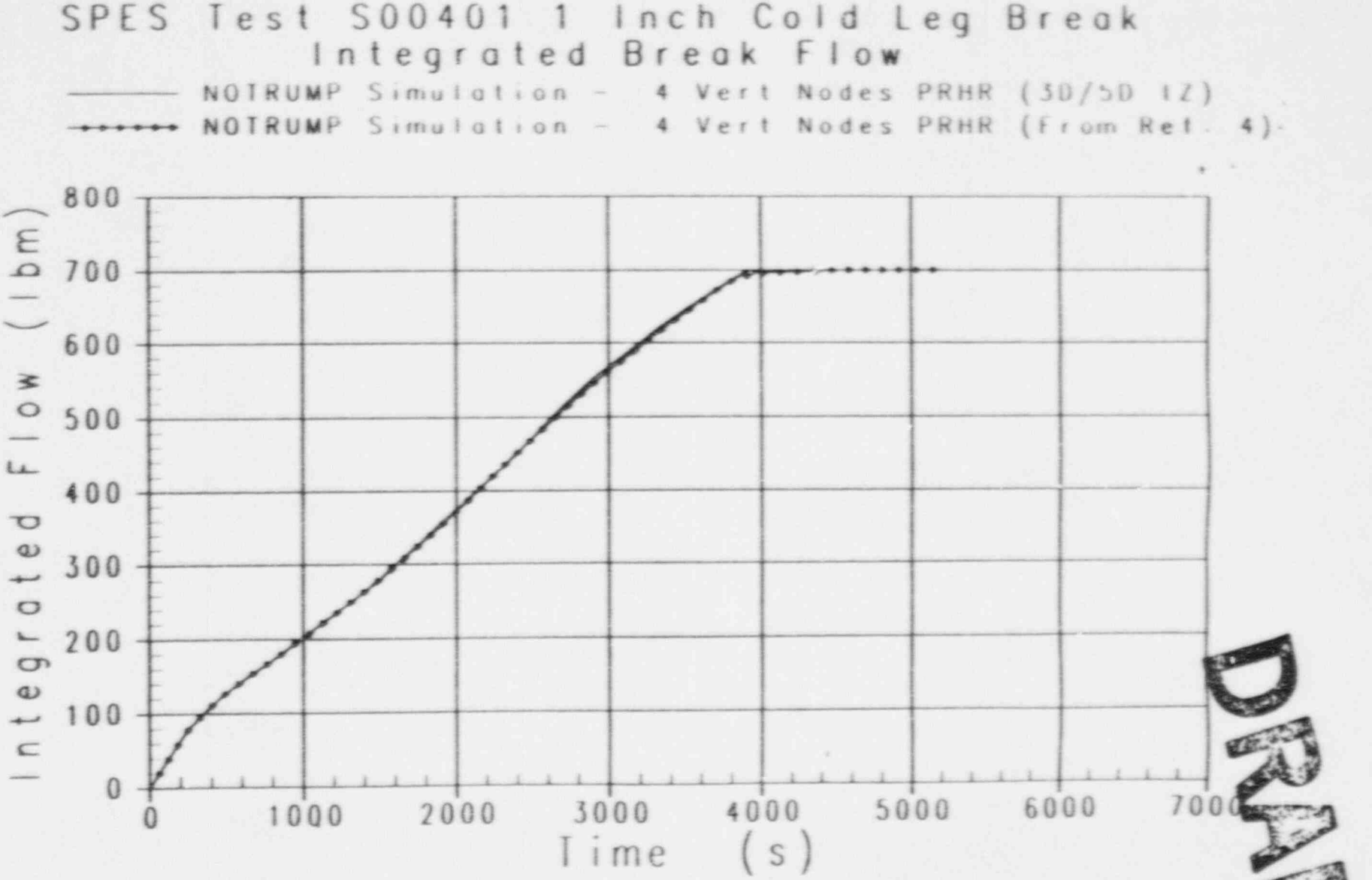

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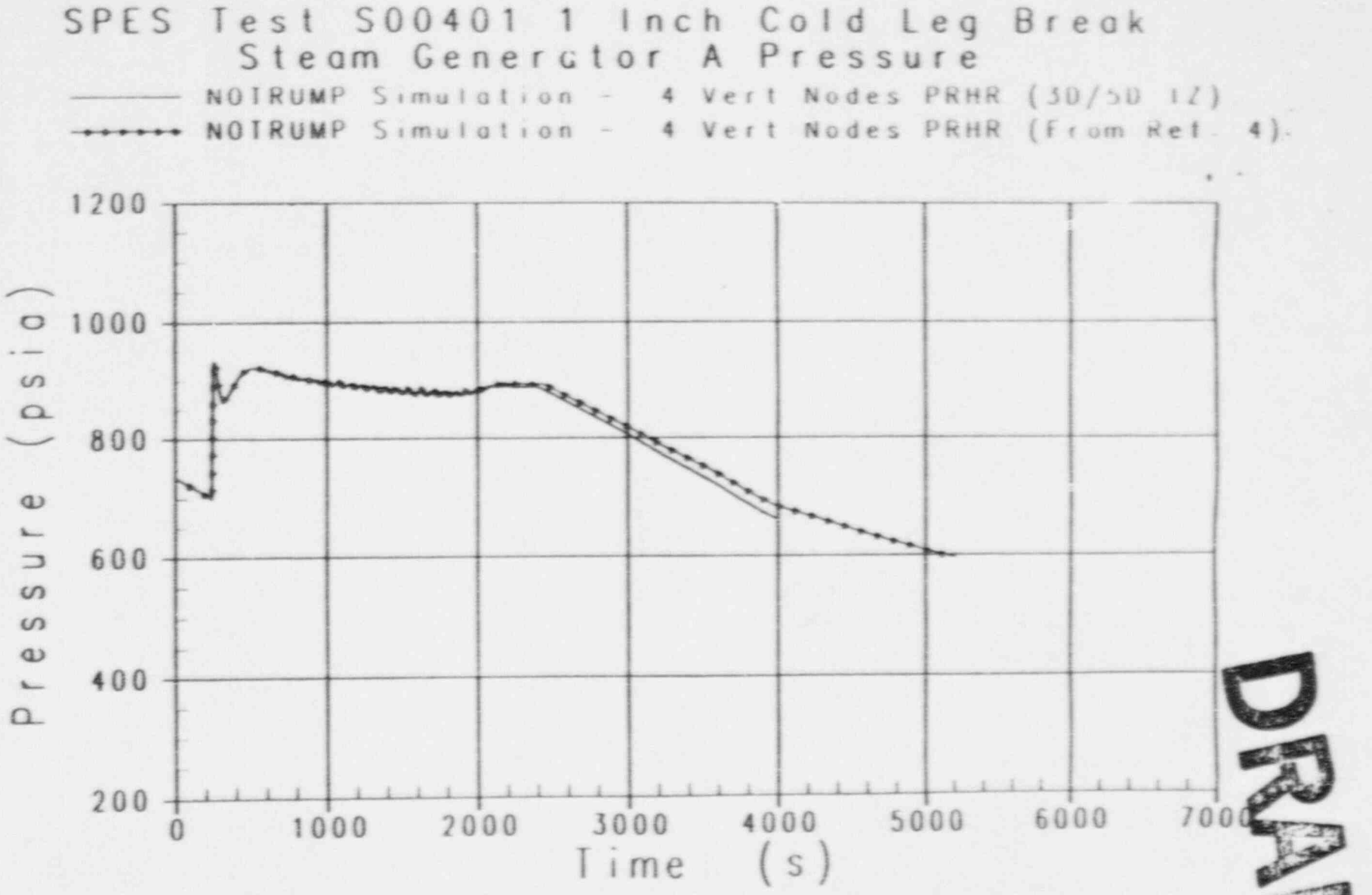

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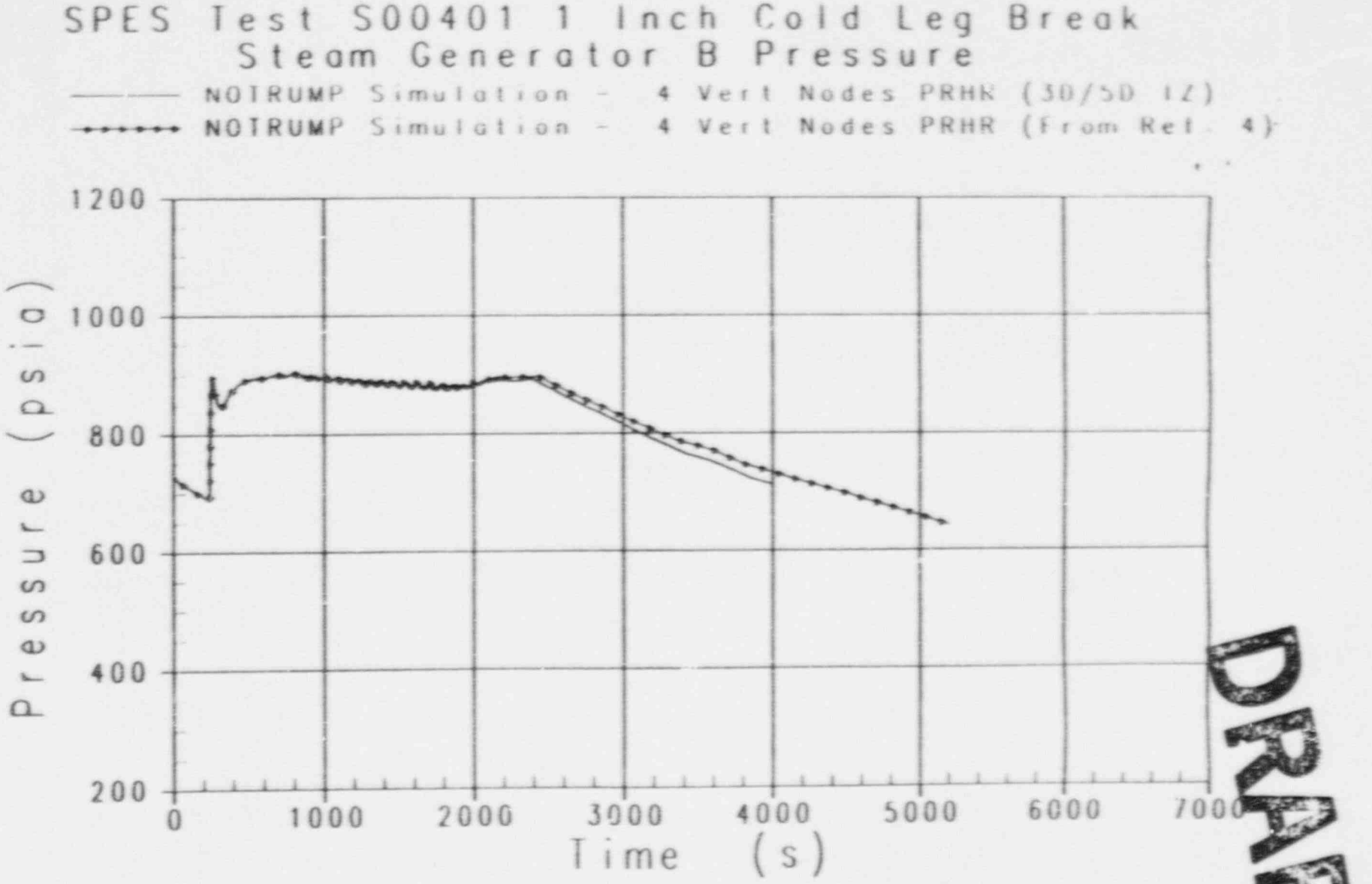


Figure 440.339-43

Figure 440.339-44
NOTRUMP OSU CMT-1 Fluid Node / Flow Link Noding Diagram for 20-Node CMT Model

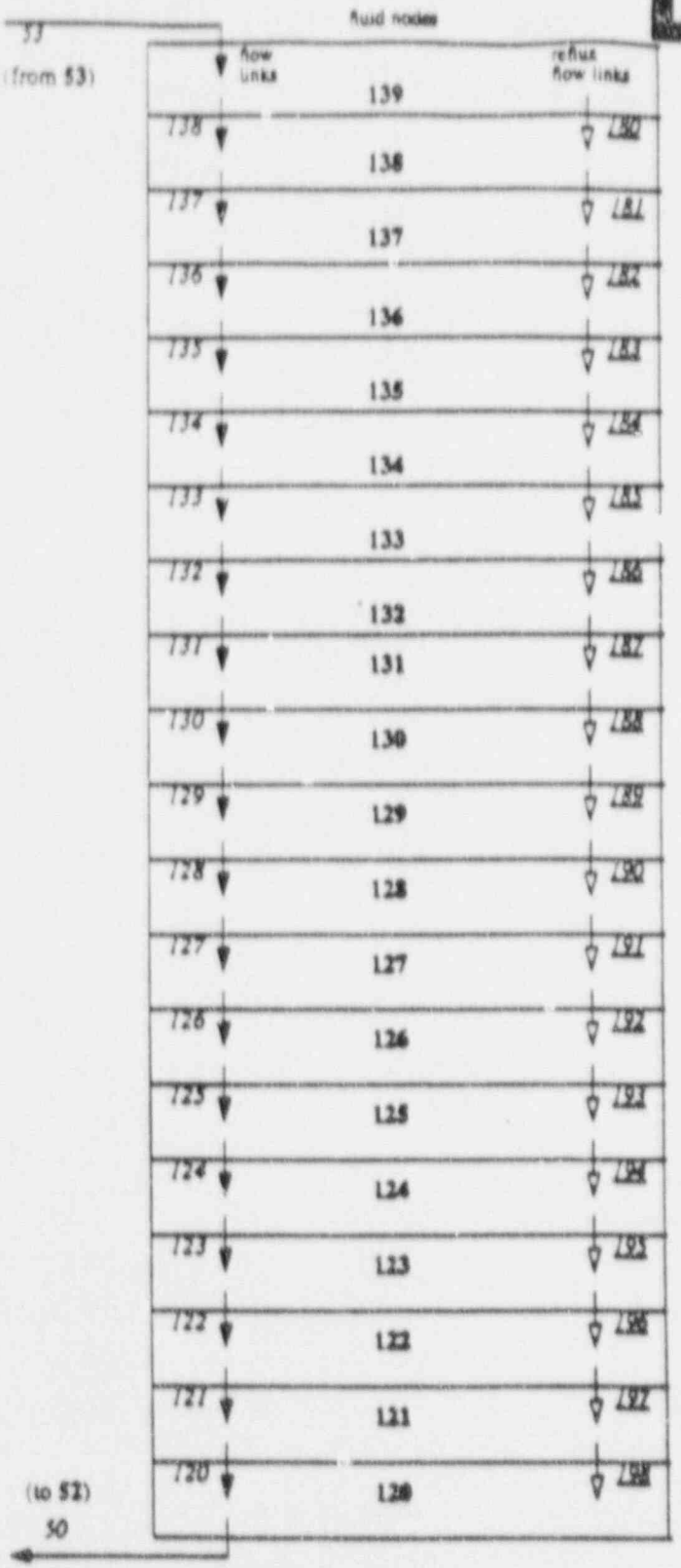


Figure 440.339-45
NOTRUMP OSU CMT-2 Fluid Node / Flow Link Noding Diagram for 20-Node CMT Model

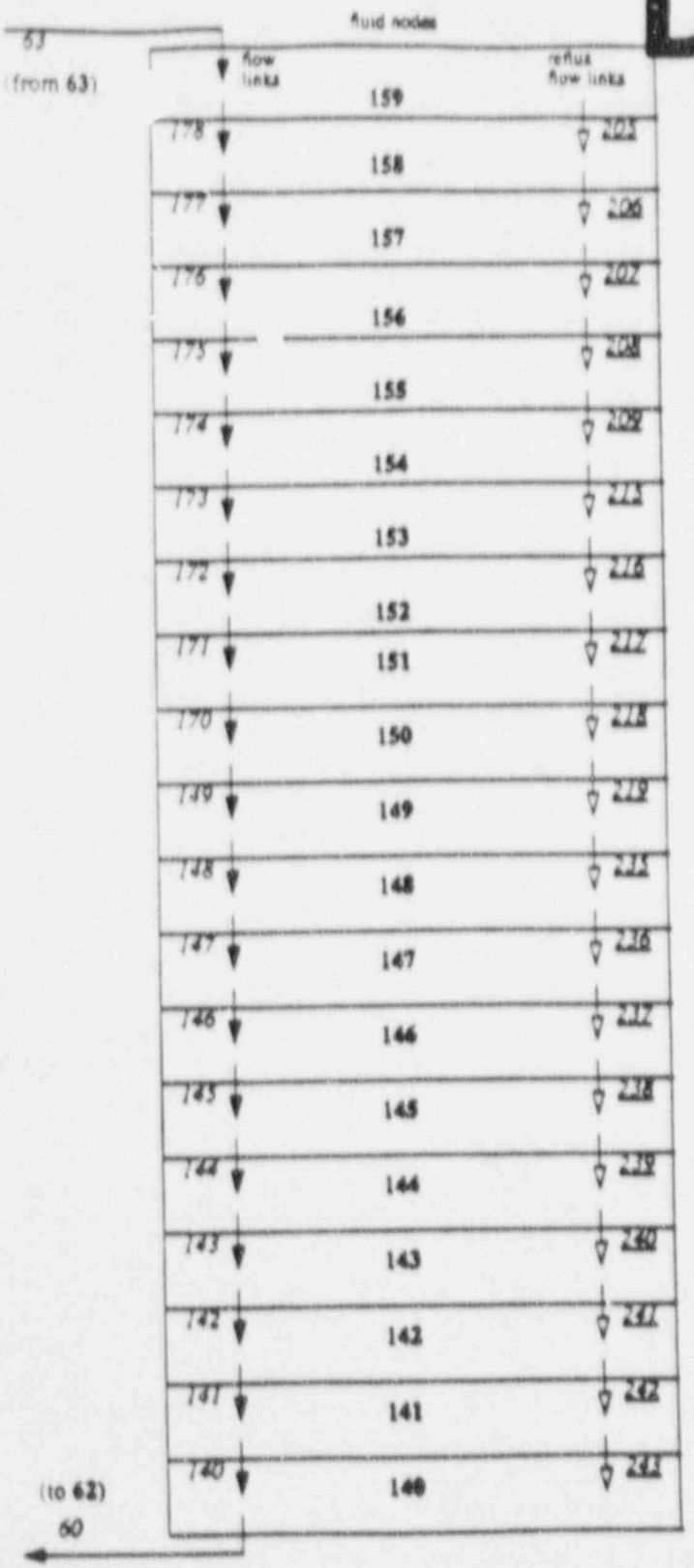


Figure 440.339-46
NOTRUMP OSU CMT-1 Metal Node / Heat Link Noding Diagram for 20-Node CMT Model

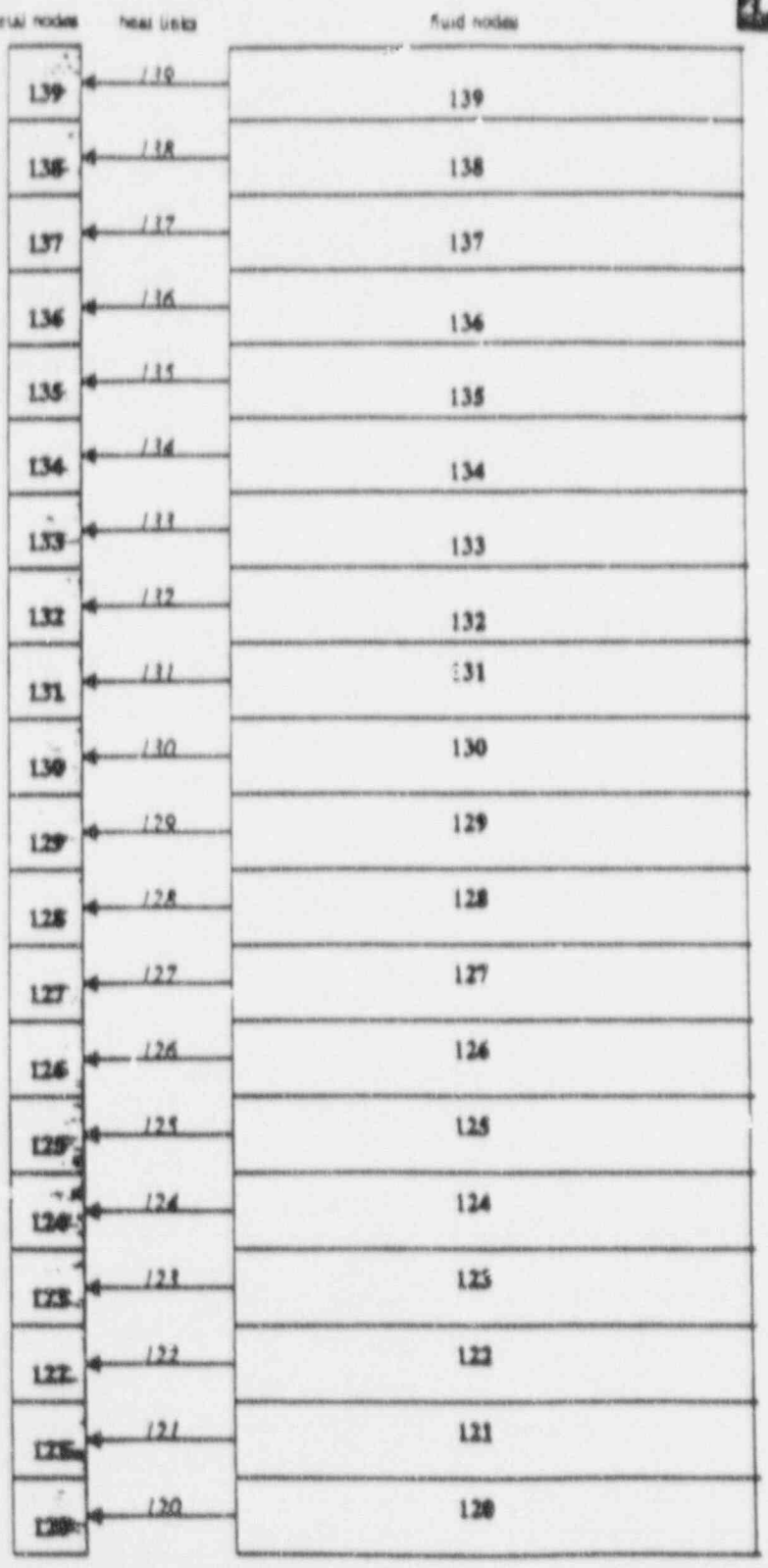
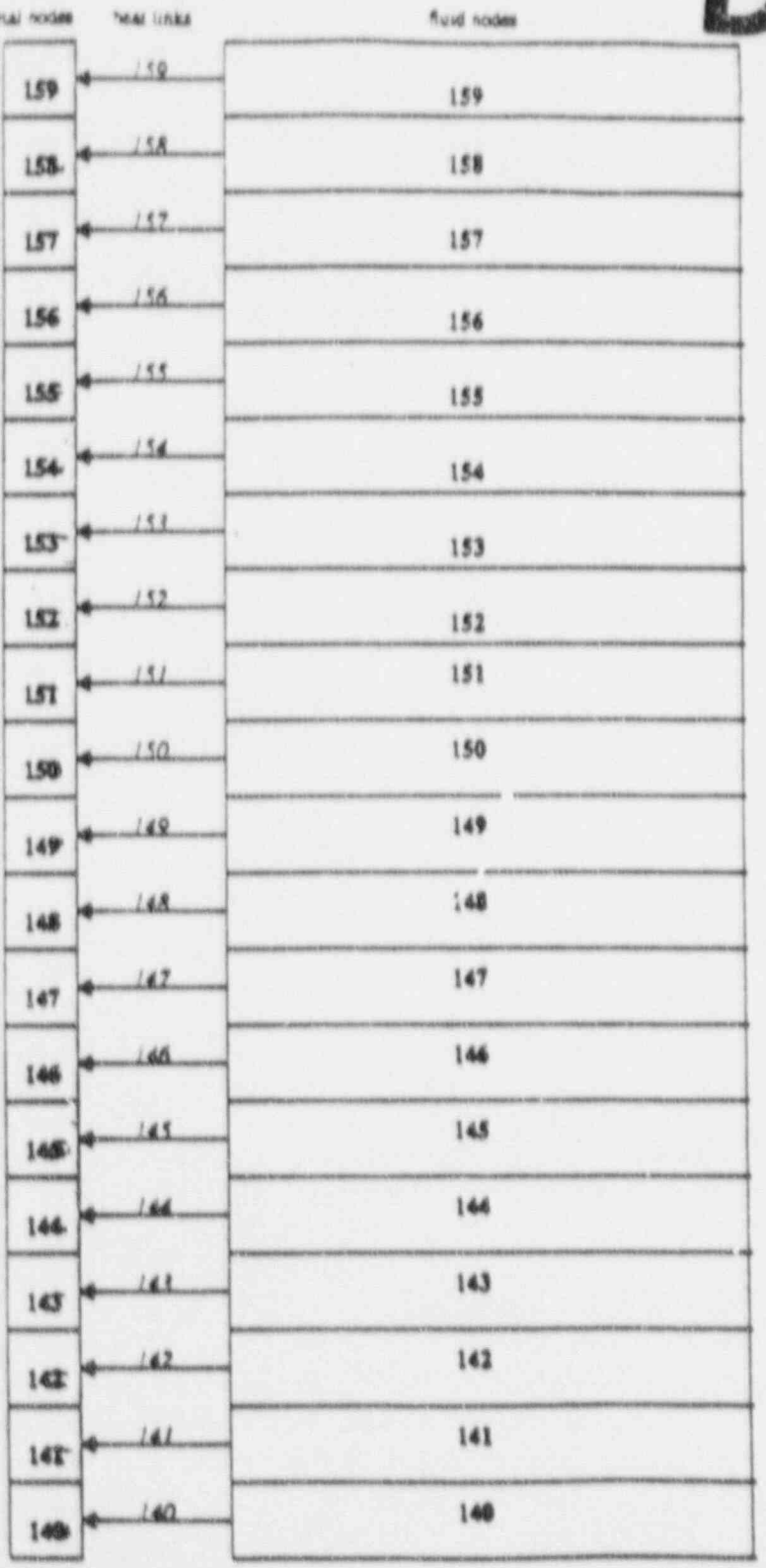


Figure 440.339-47
NOTRUMP OSU CMT-2 Metal Node / Heat Link Noding Diagram for 20-Node CMT Model



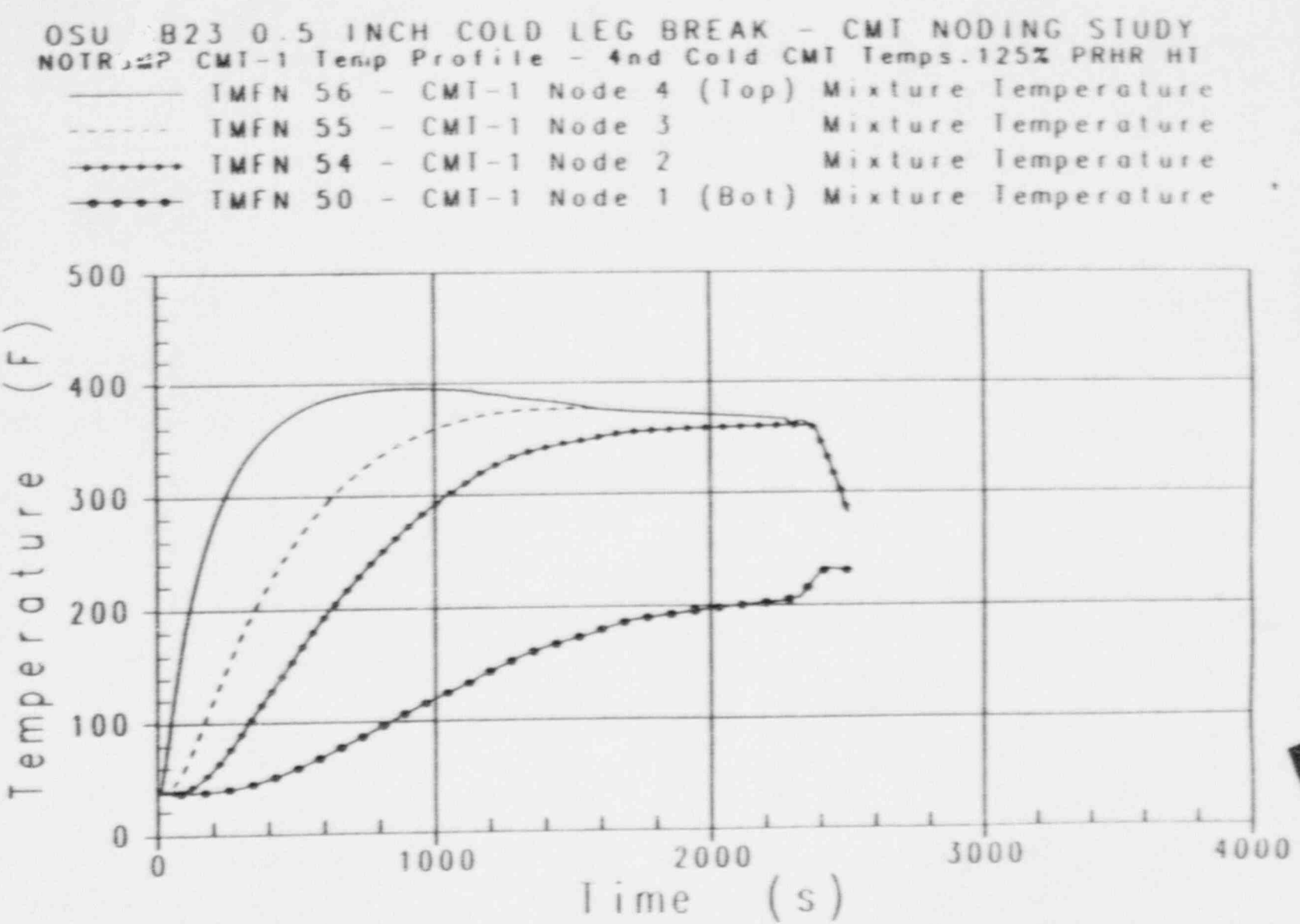


Figure 440.339-48

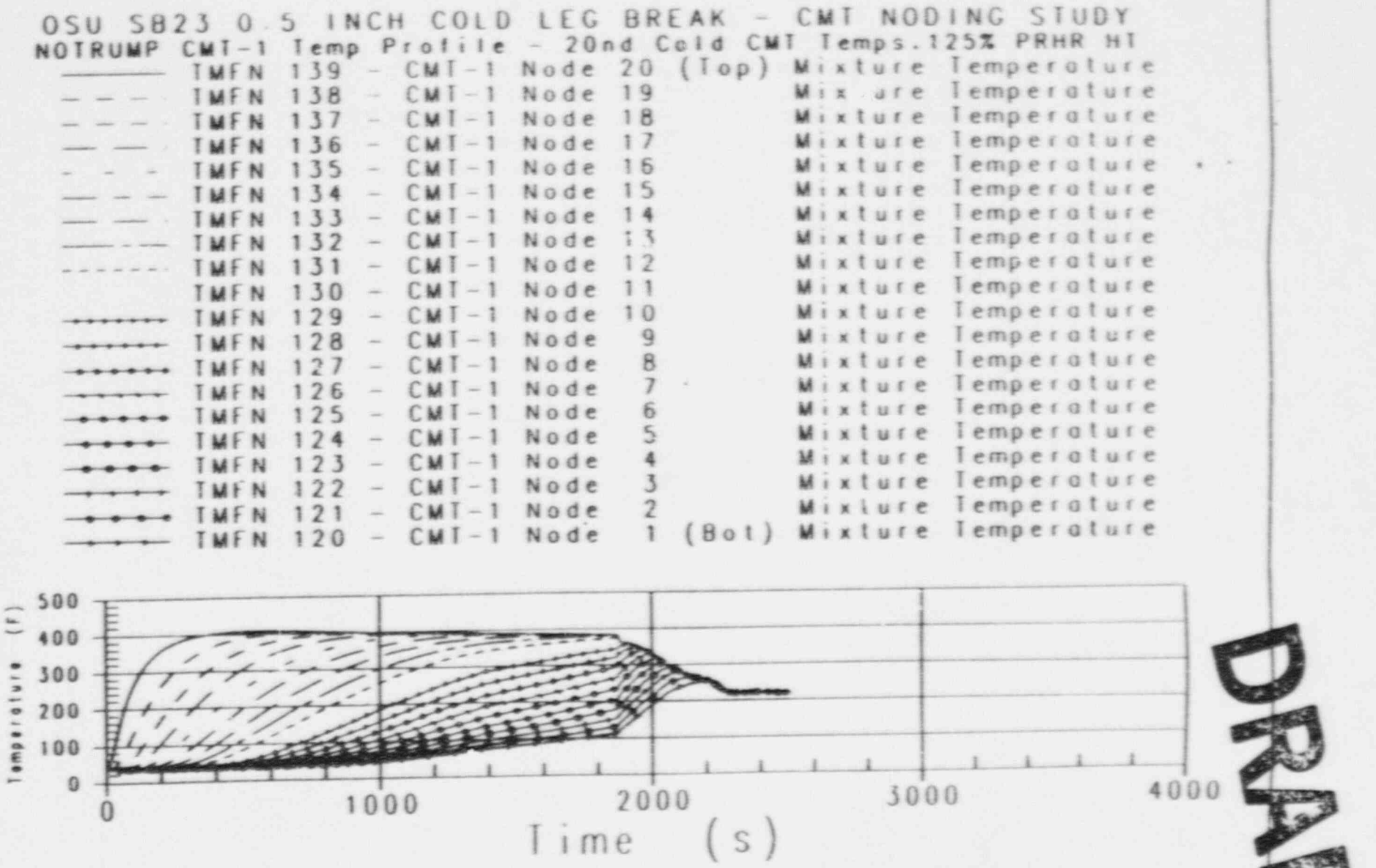


Figure 440.339-49

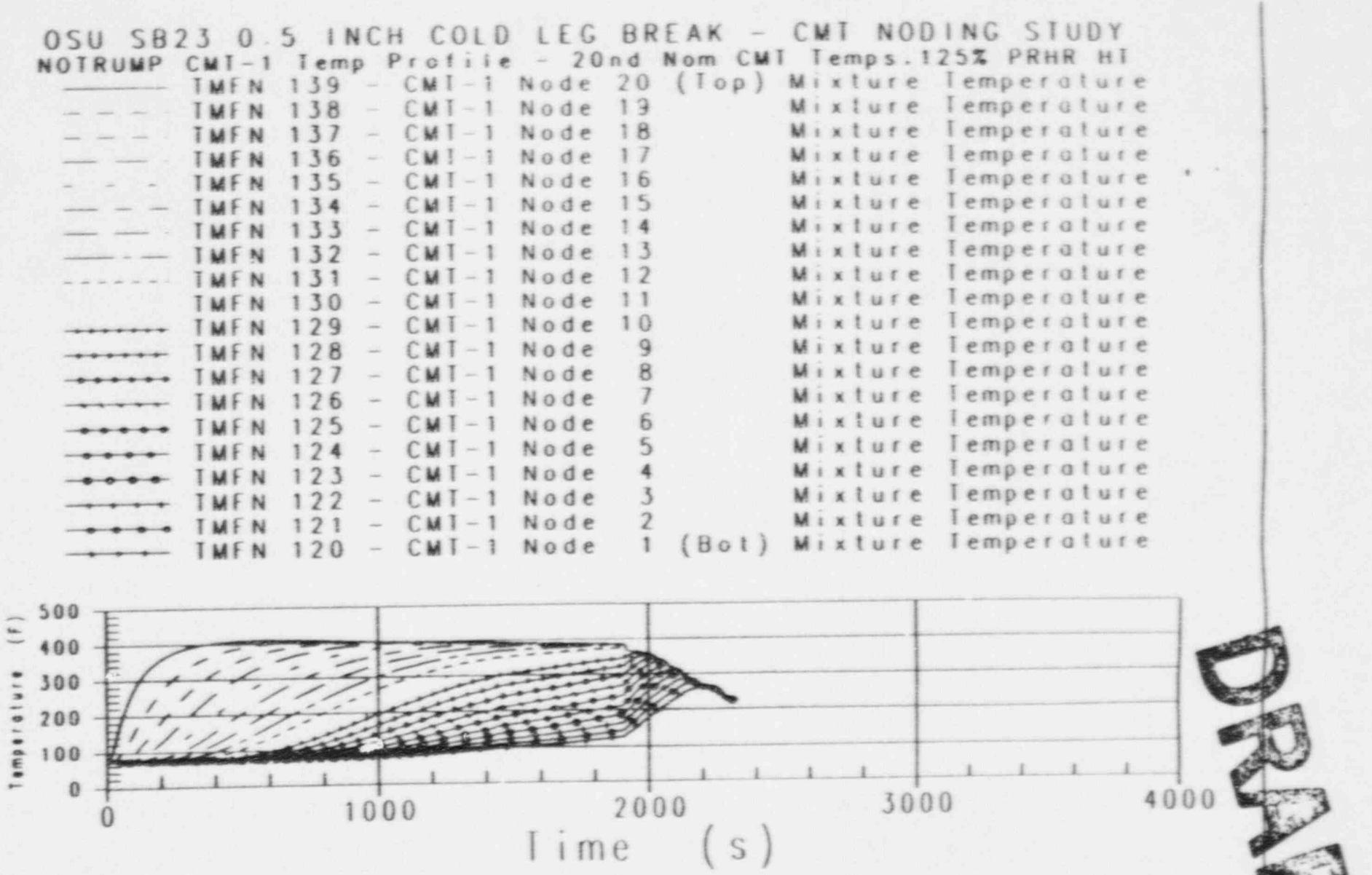


Figure 440.339-50

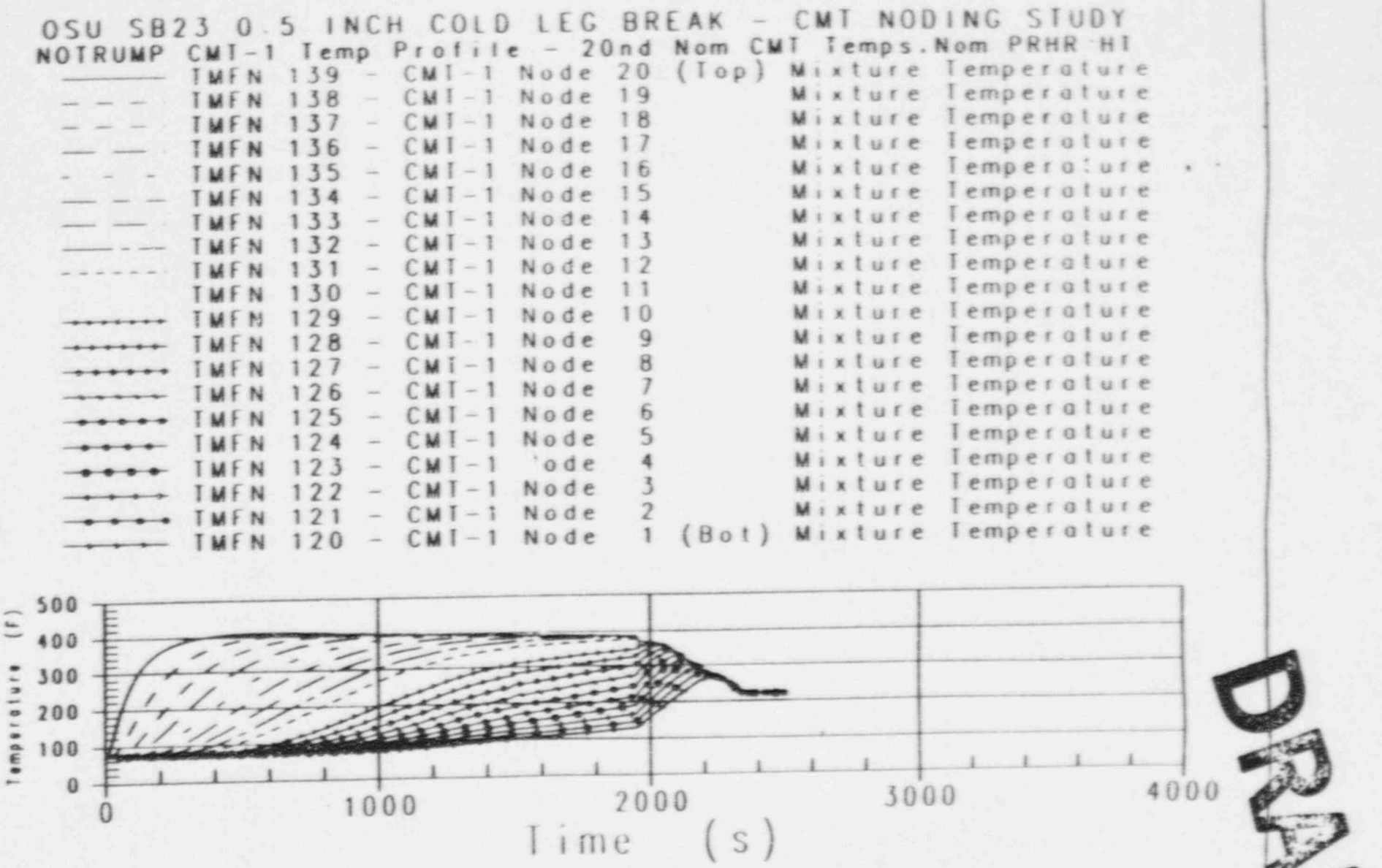


Figure 440.339-51

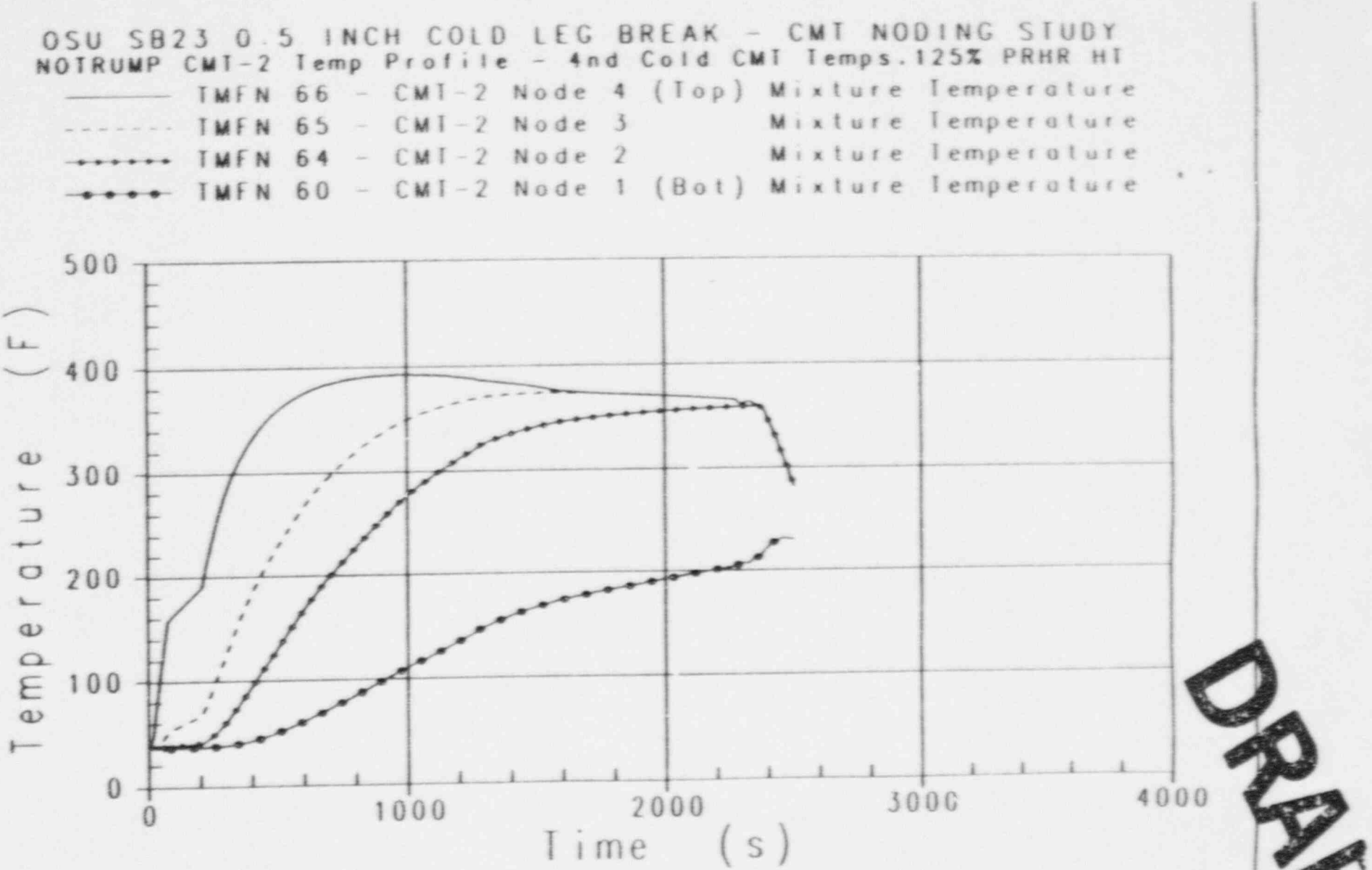


Figure 440.339-52

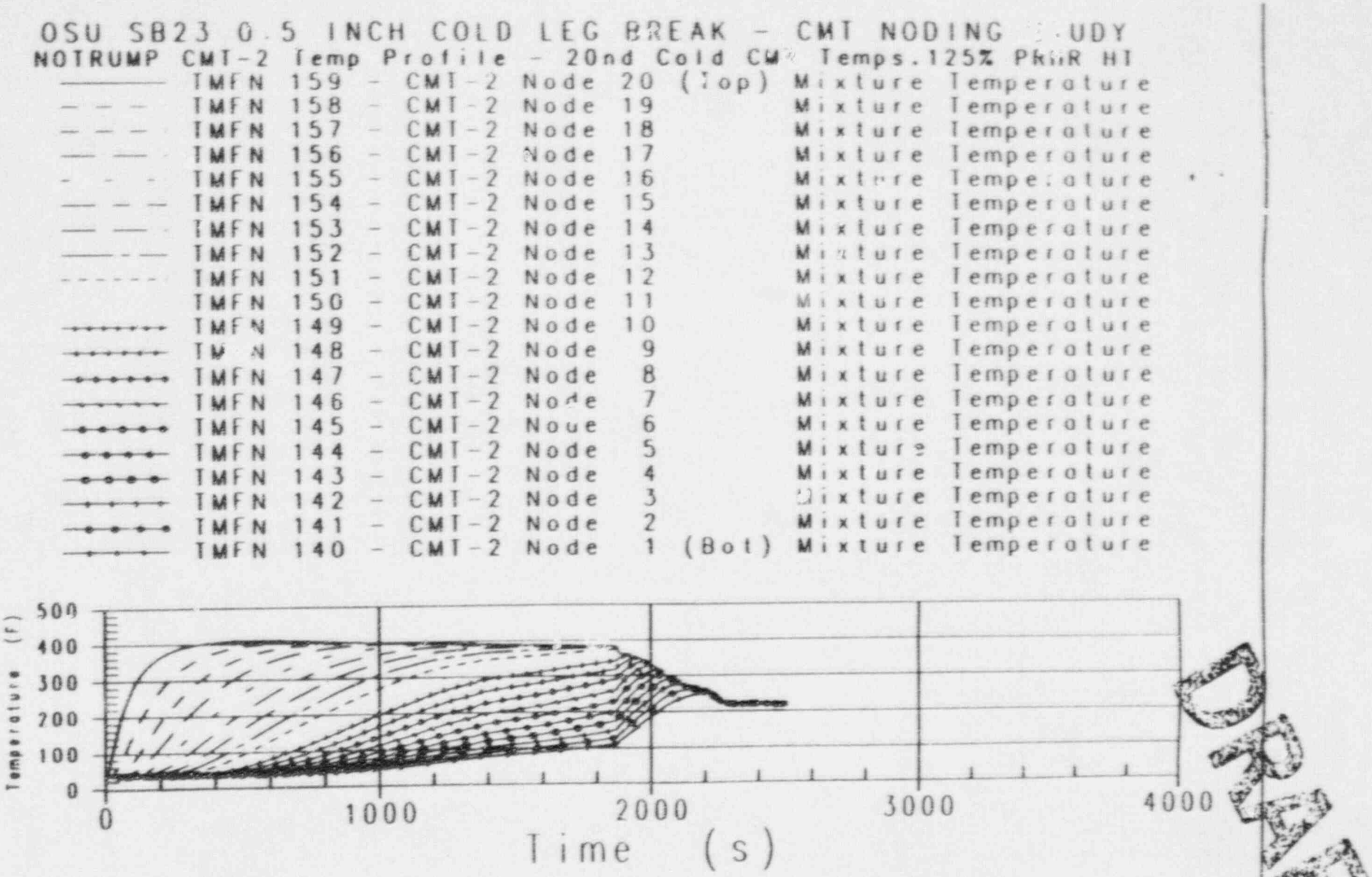


Figure 440.339-53

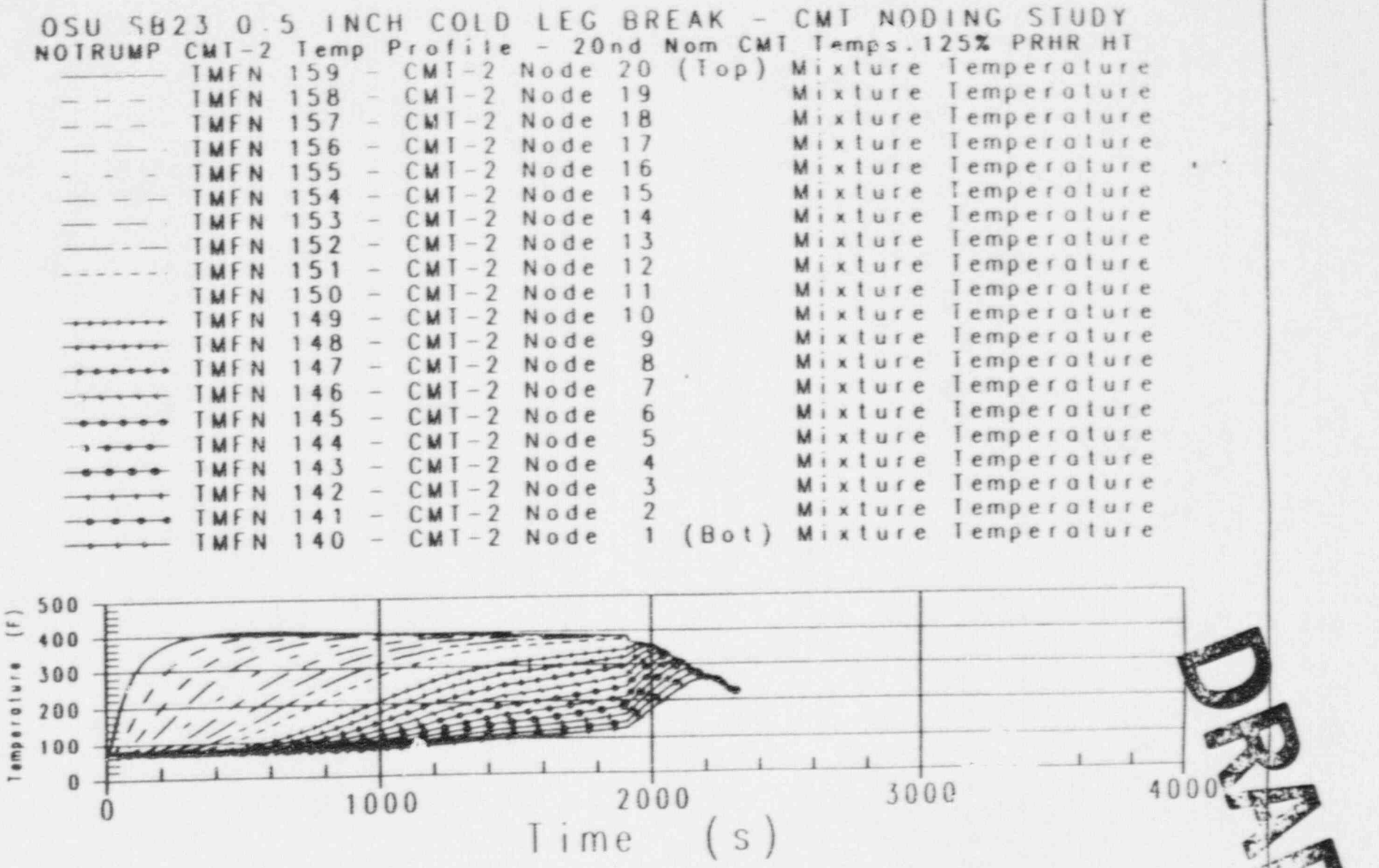


Figure 440.339-54

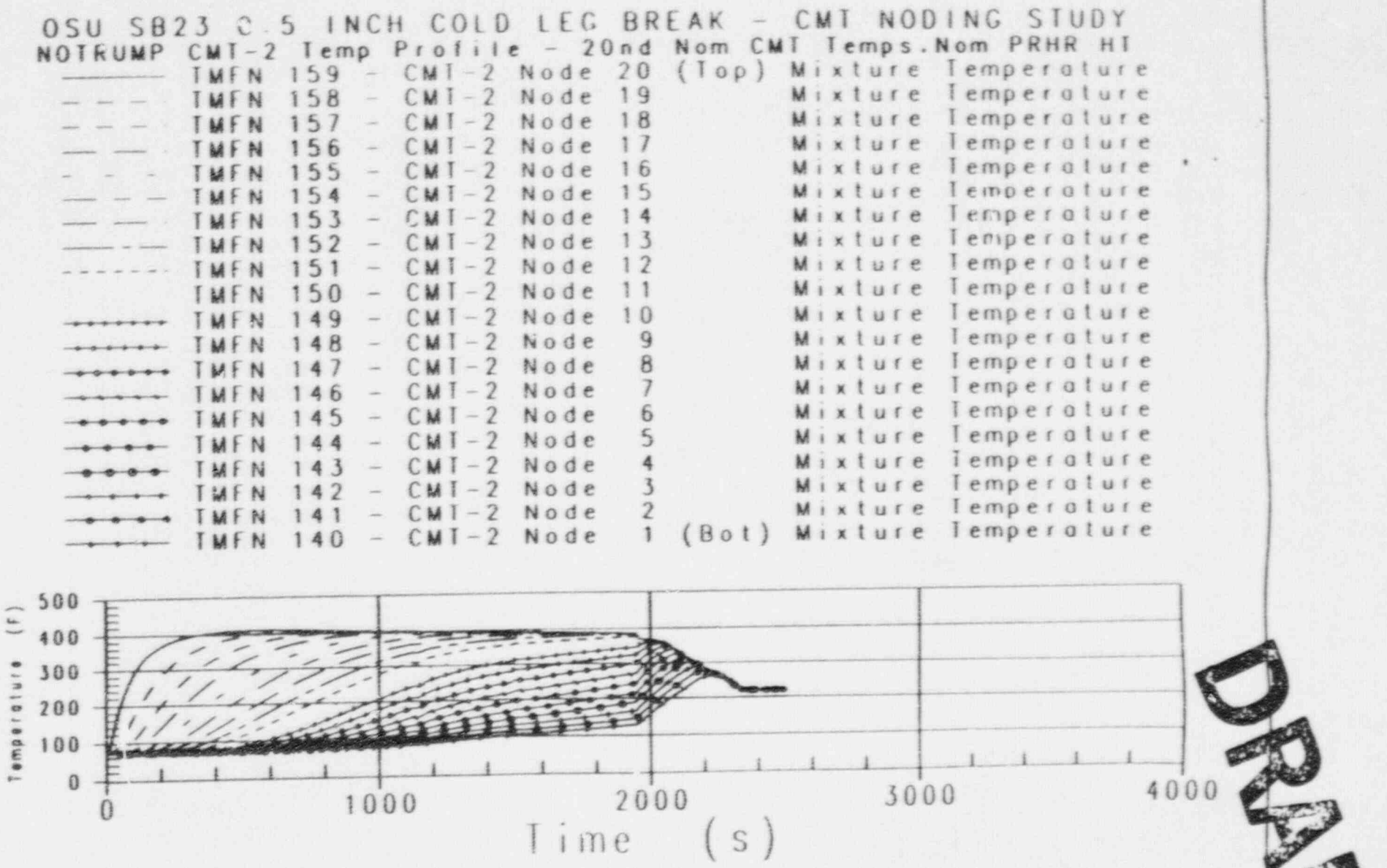


Figure 440.339-55

DRAFT

(a,b,c)

[redacted]

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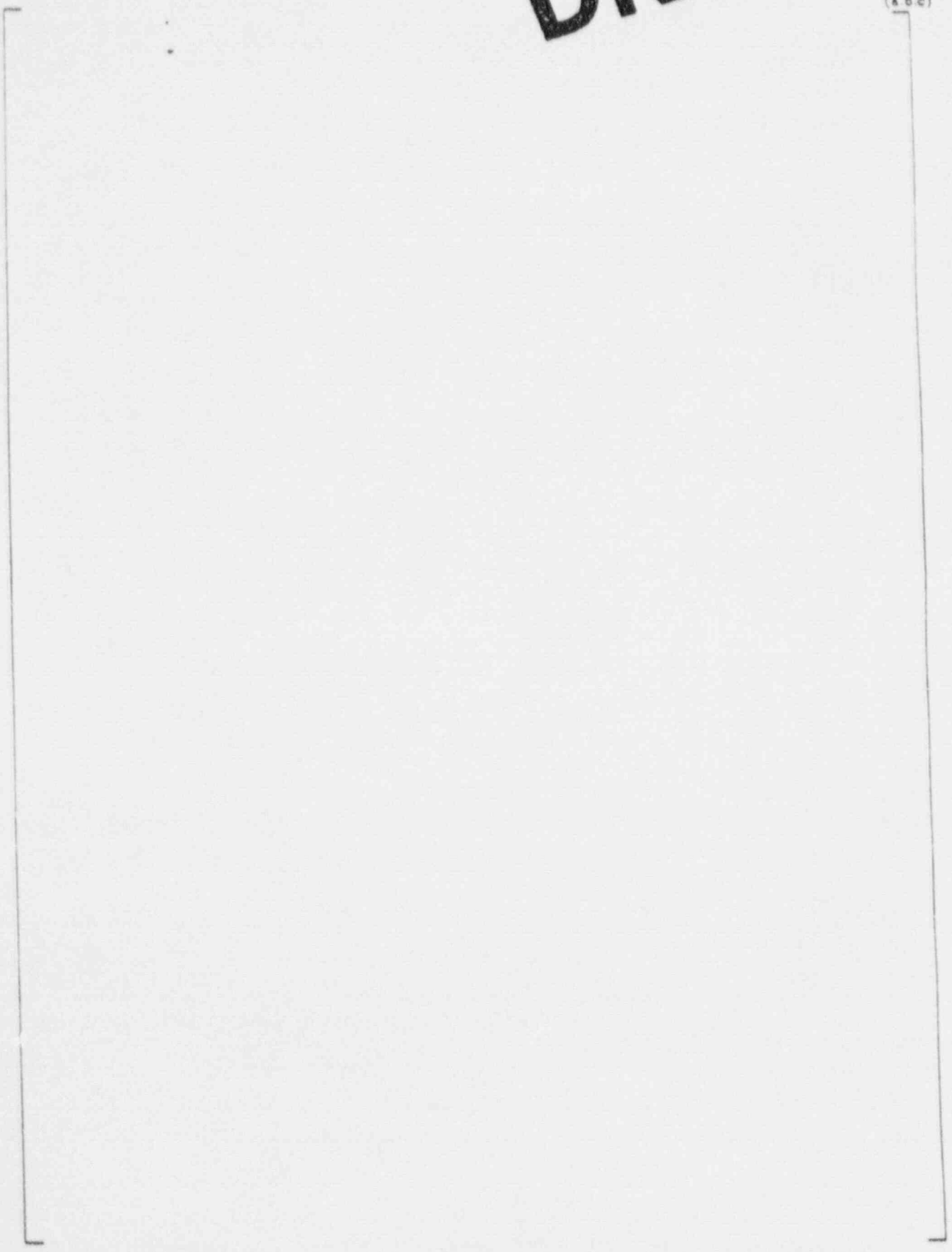
(a,b,c)



DRAFT

(a,b,c)

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(a,b,c)

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(a,b,c)

[redacted]

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DRAFT

(a,b,c)

DRAFT

(a,b,c)

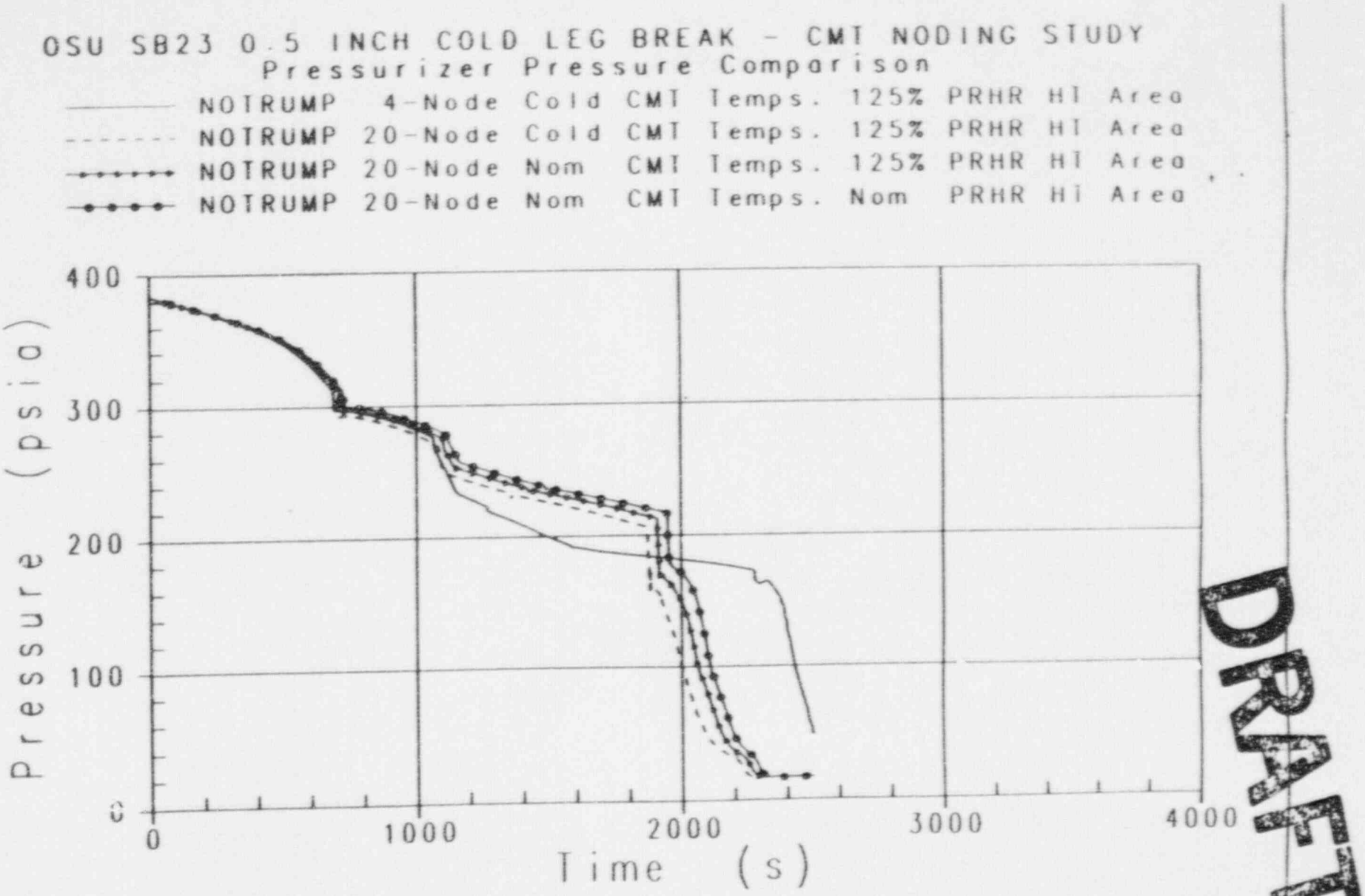

Figure 440.339-64

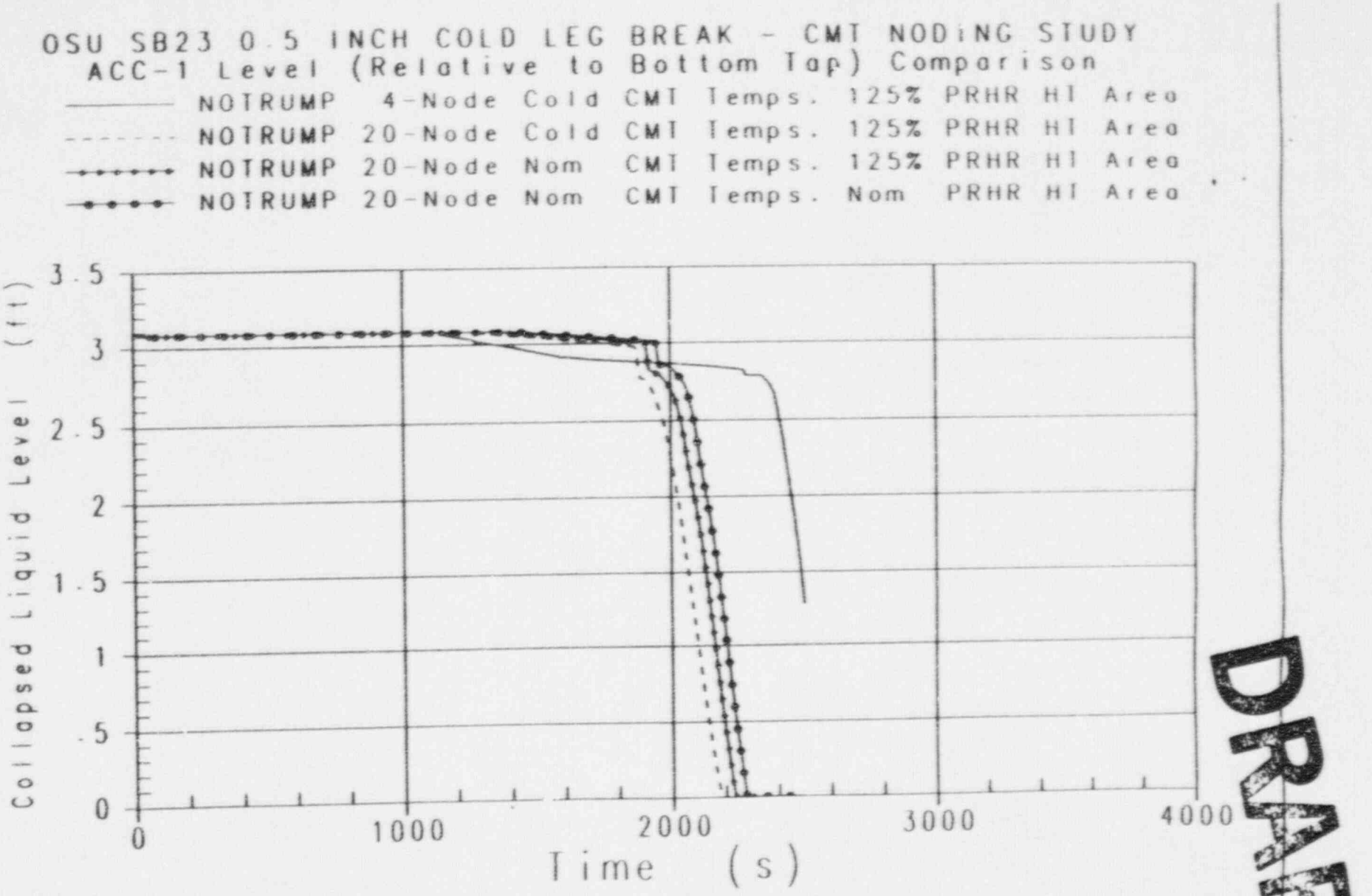

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Figure 440.339-65

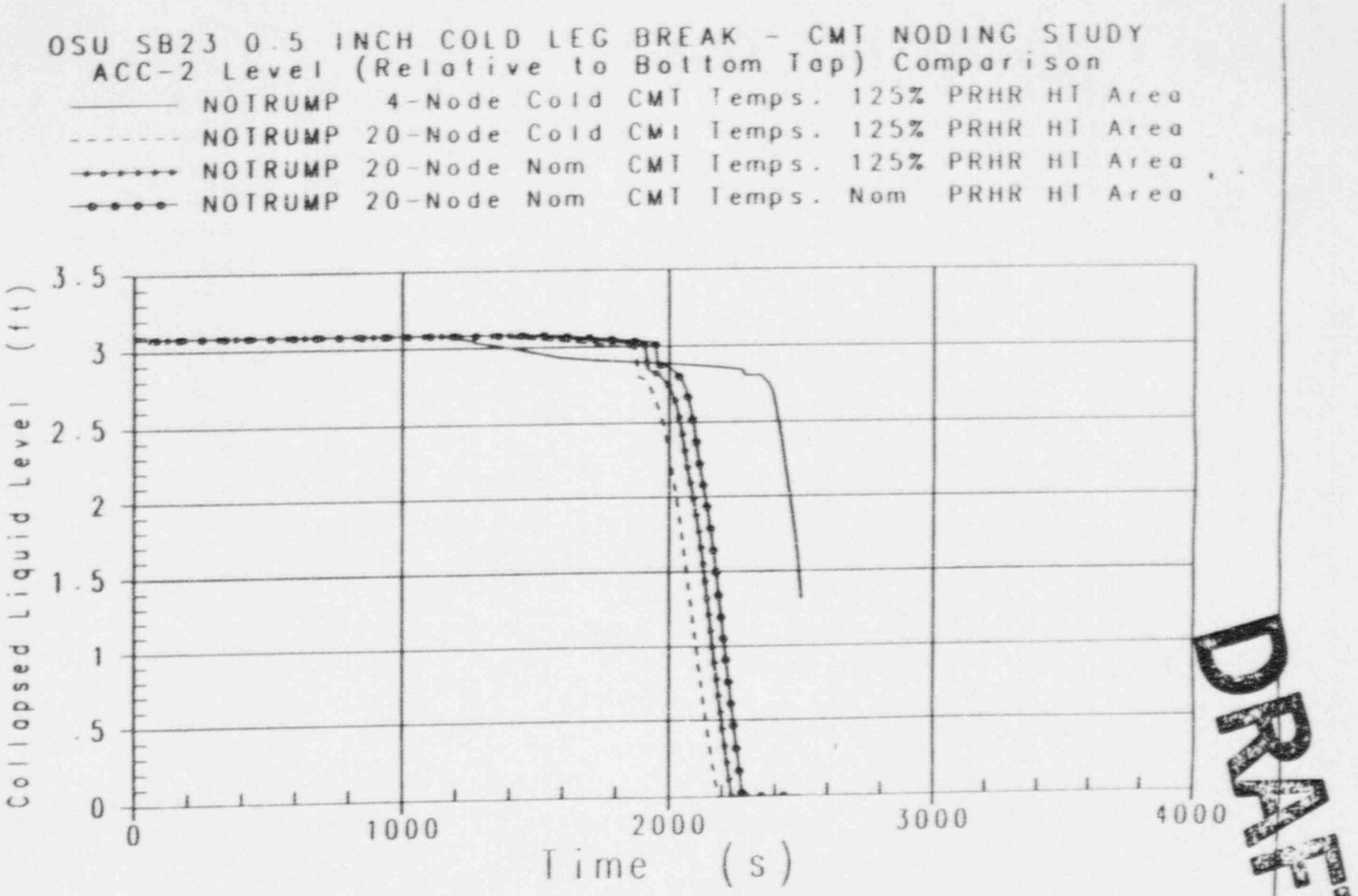


Figure 440.339-66

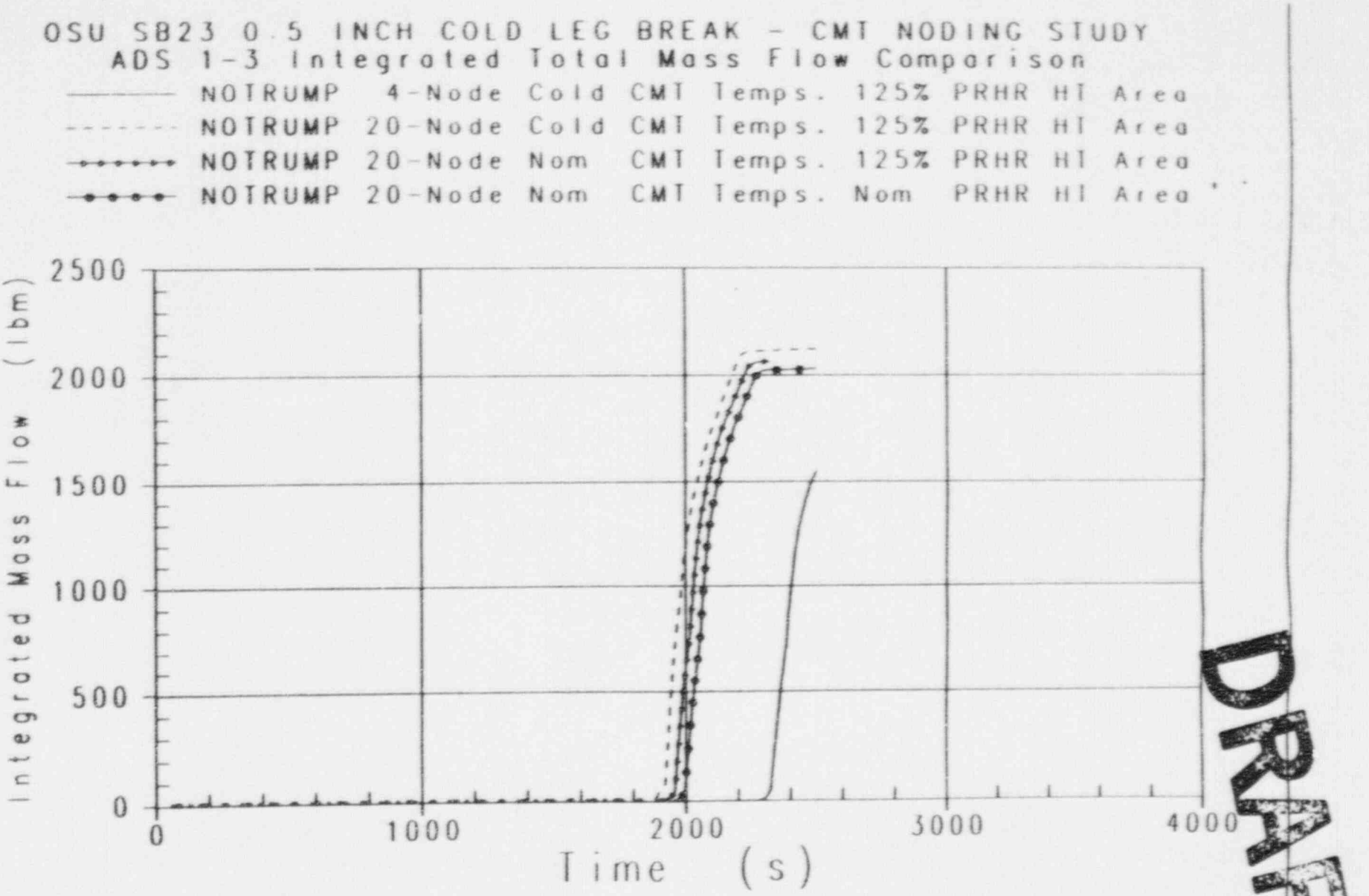


Figure 440.339-67

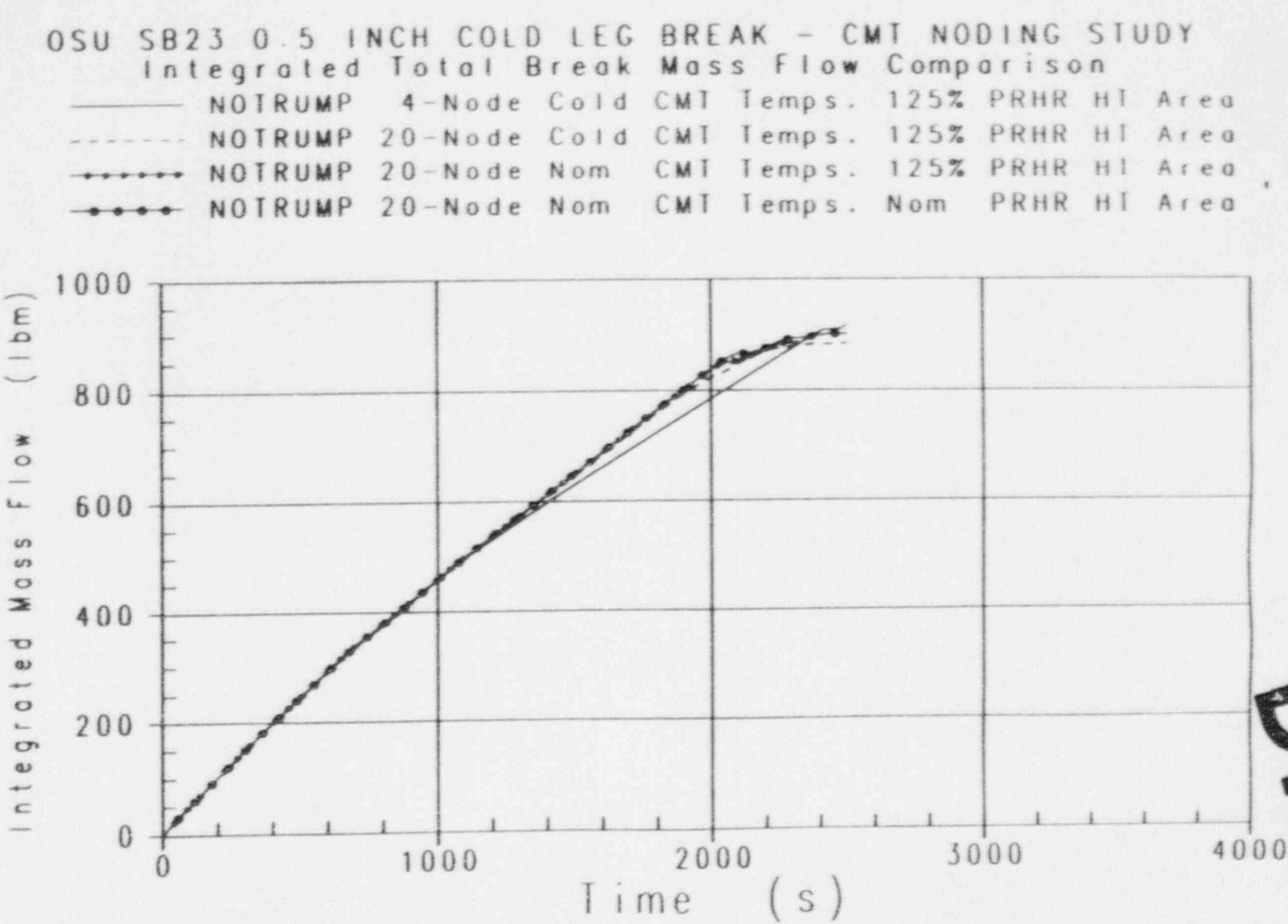


Figure 440.339-68

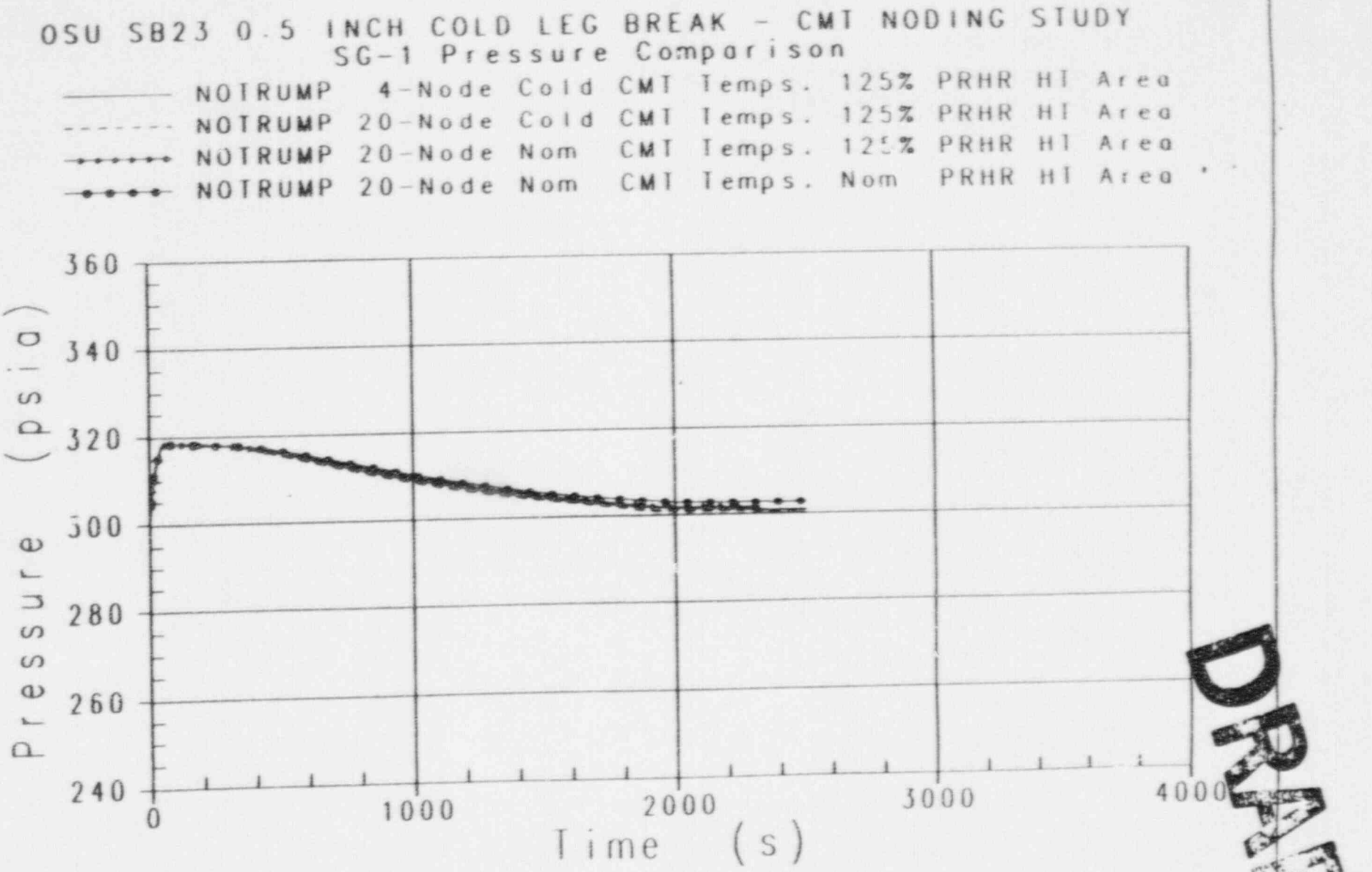


Figure 440.339-69

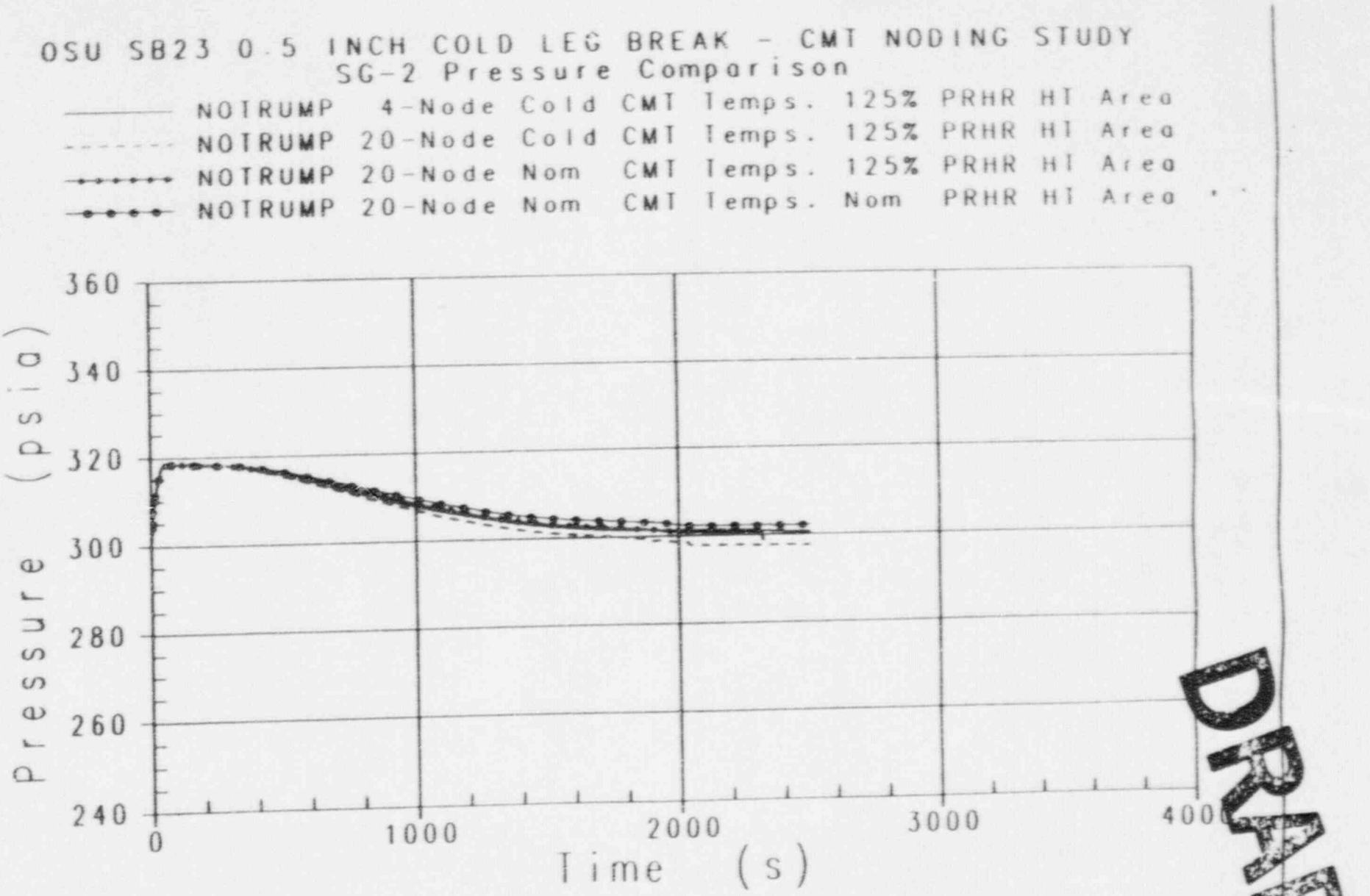


Figure 440.339-70

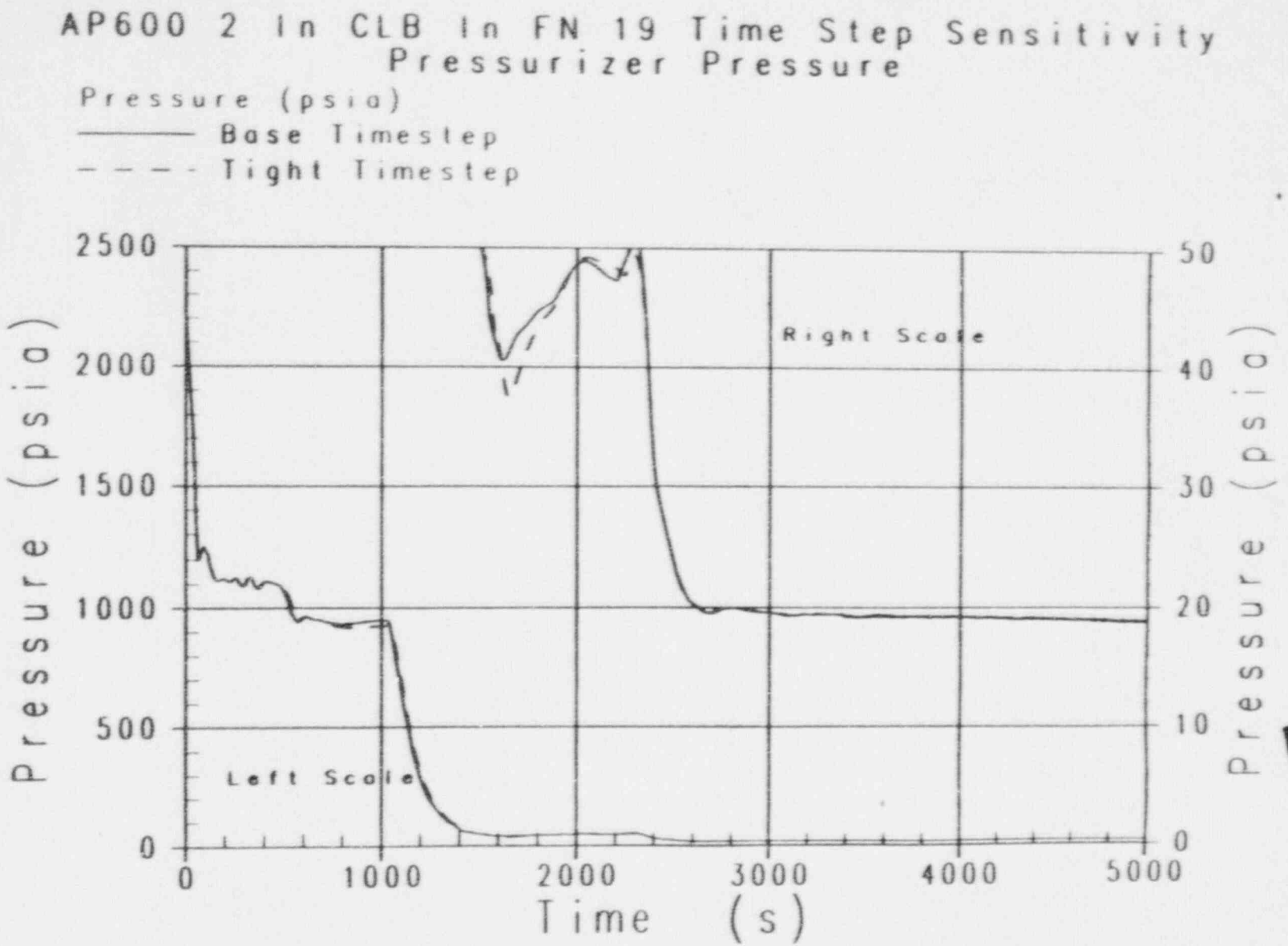
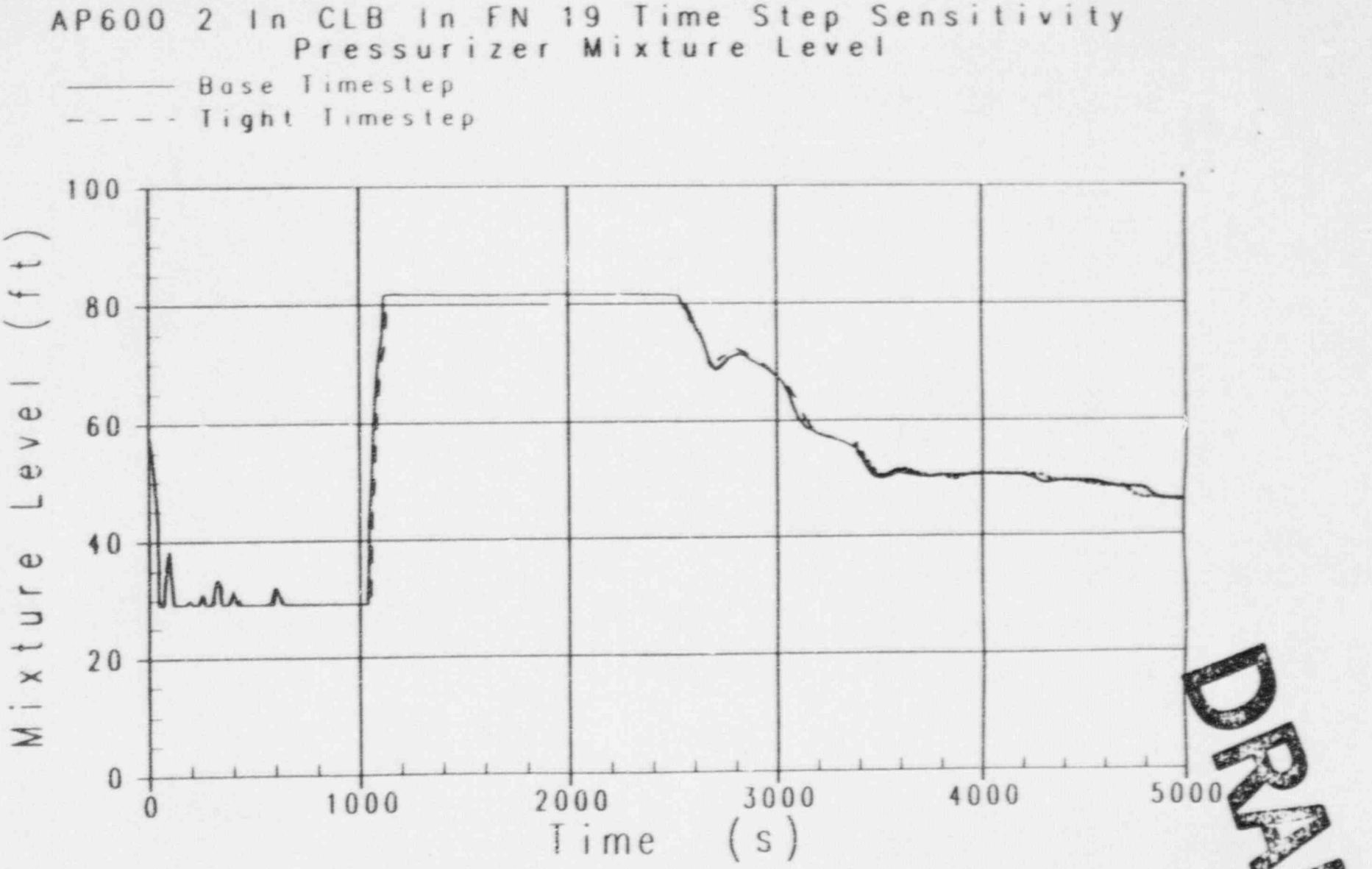


Figure 440.339-72



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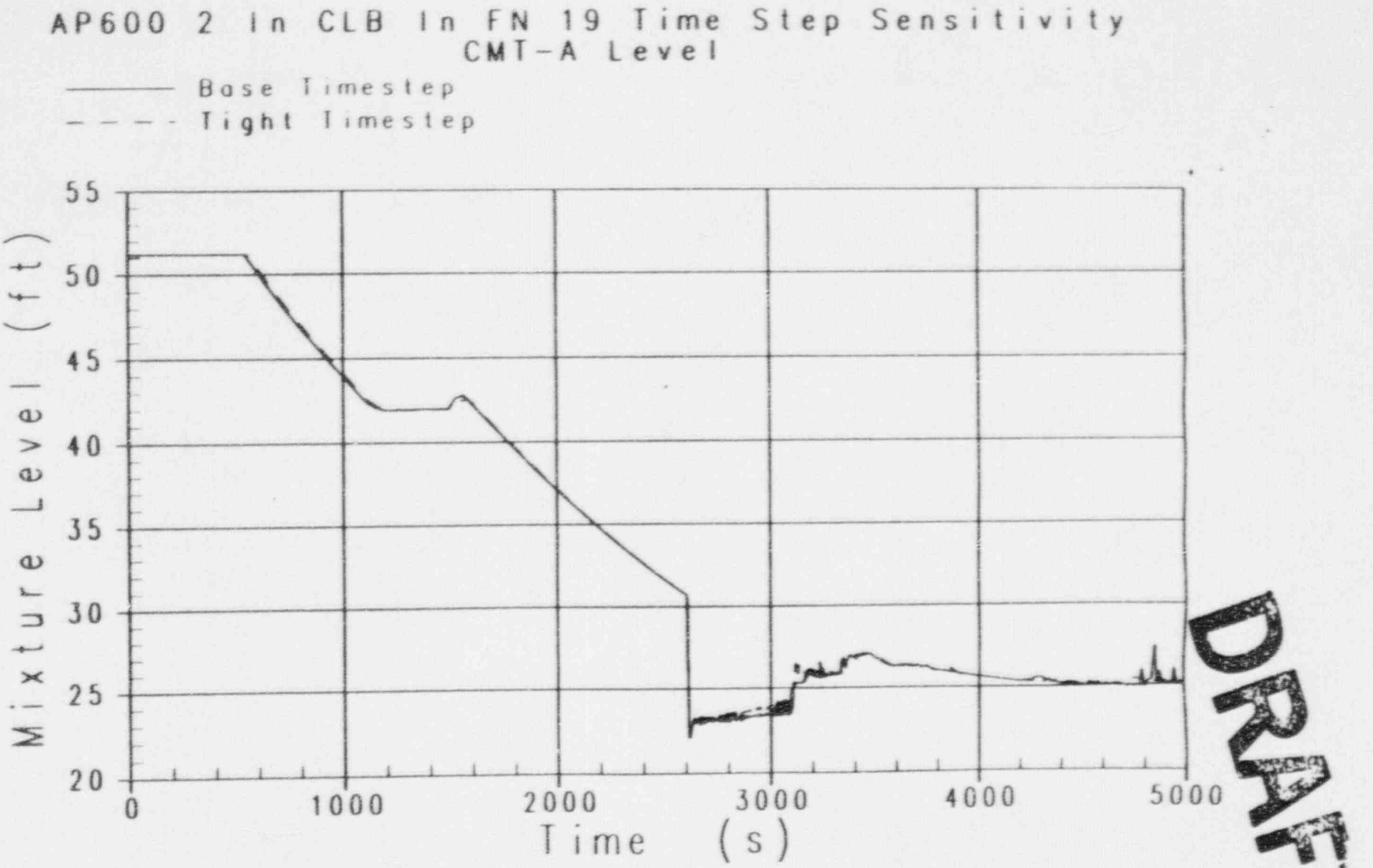


Figure 440.339-74

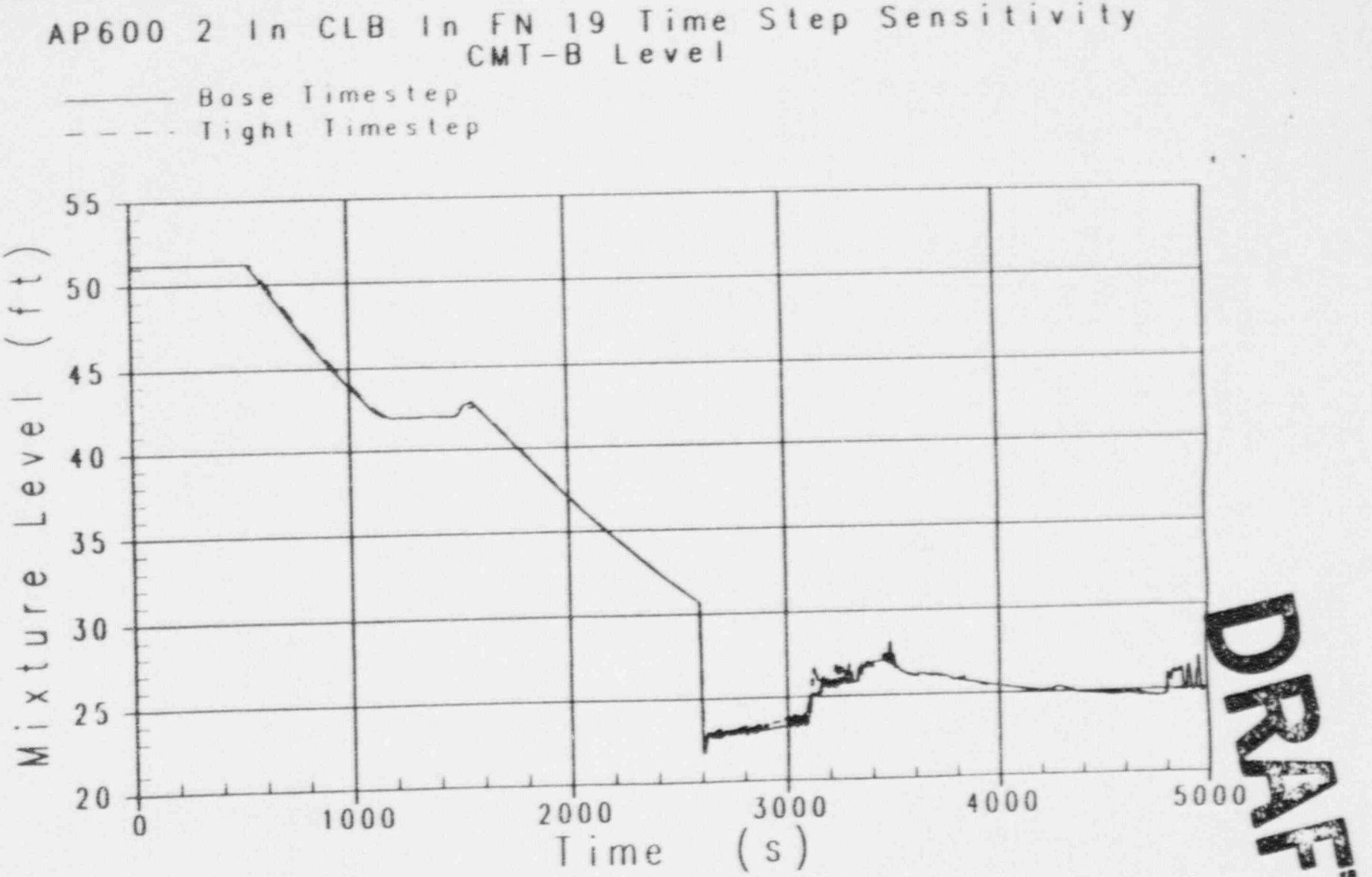


Figure 440.339-75

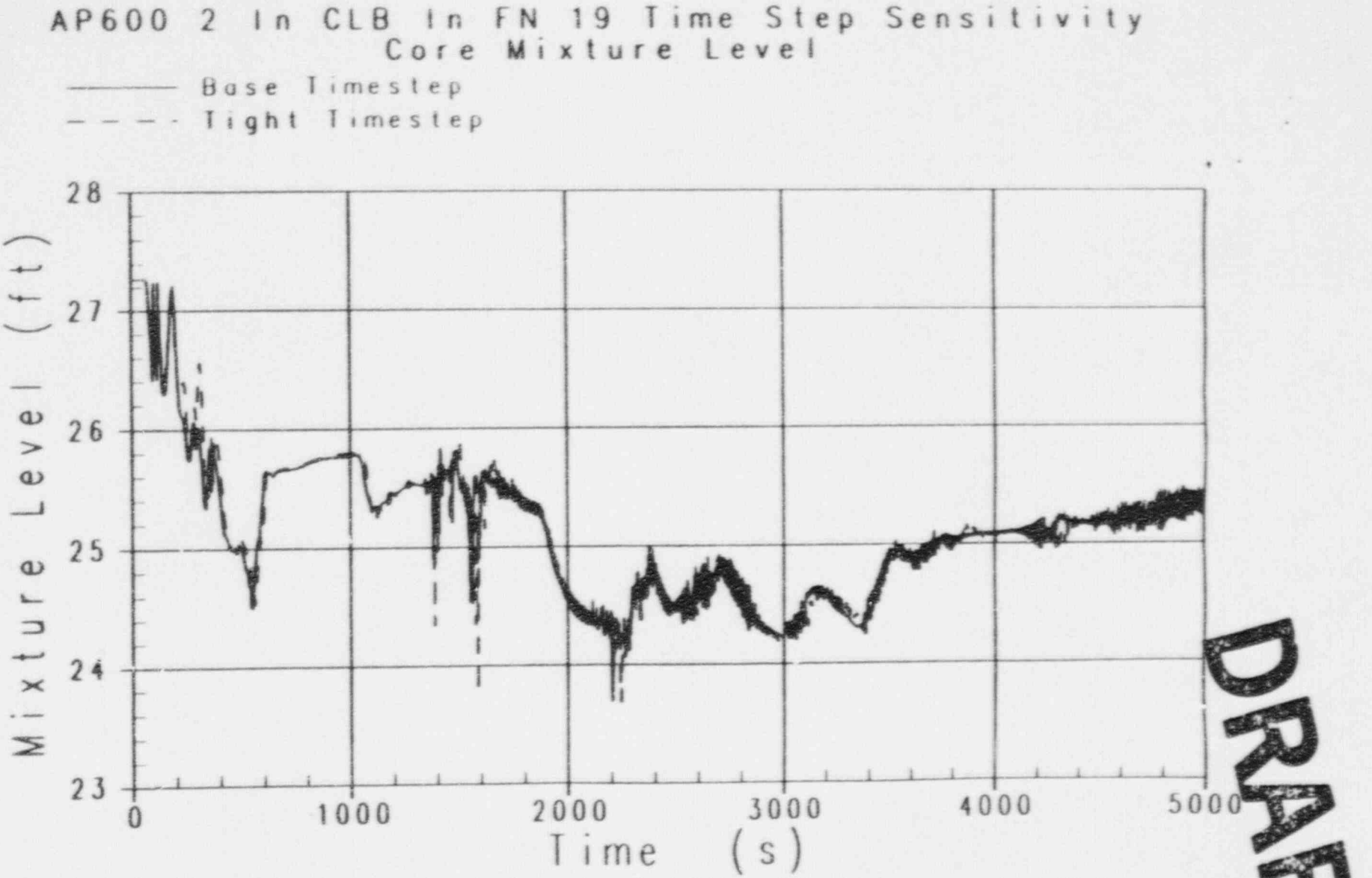


Figure 440.339-76

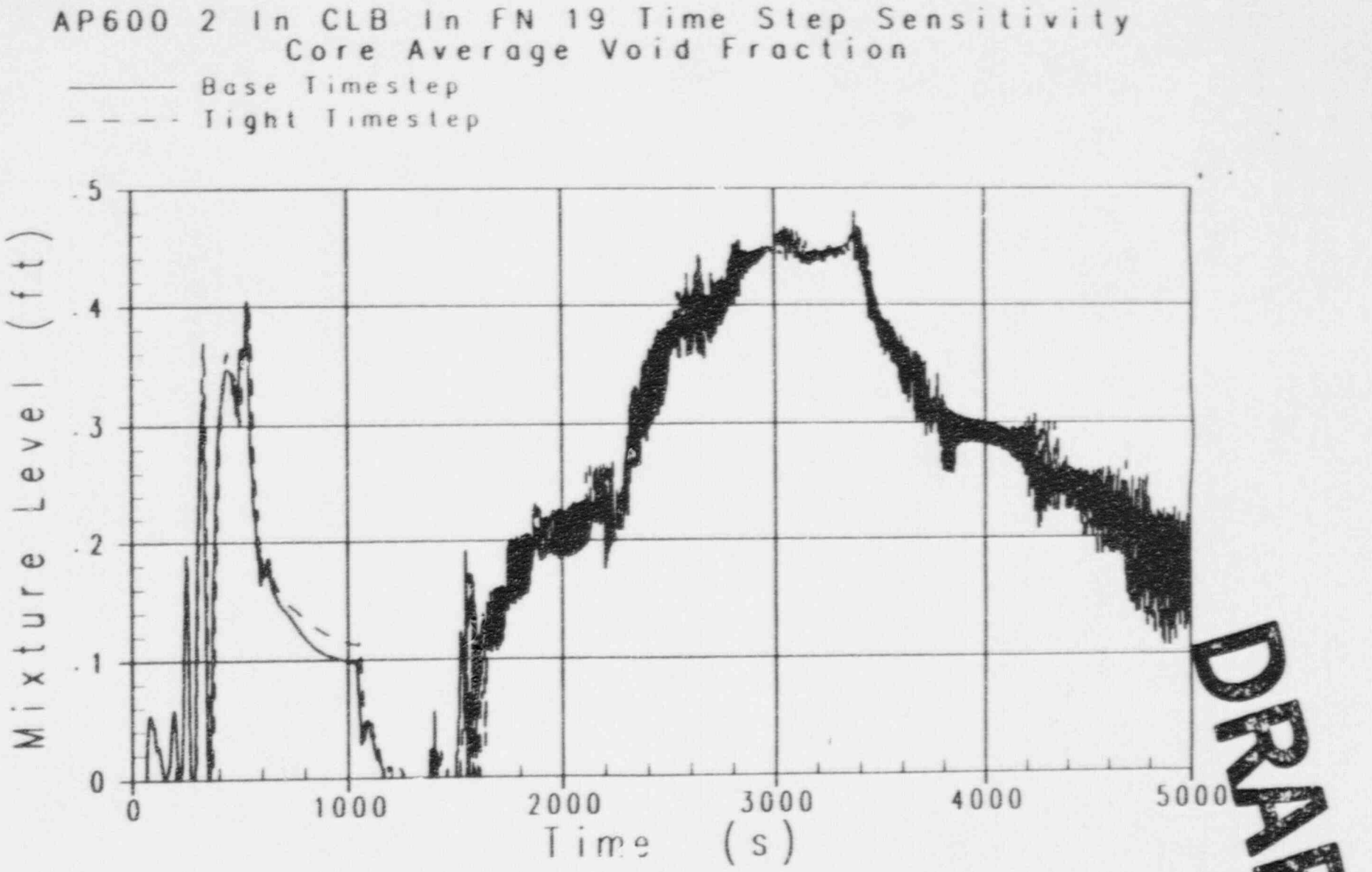


Figure 440.339-77

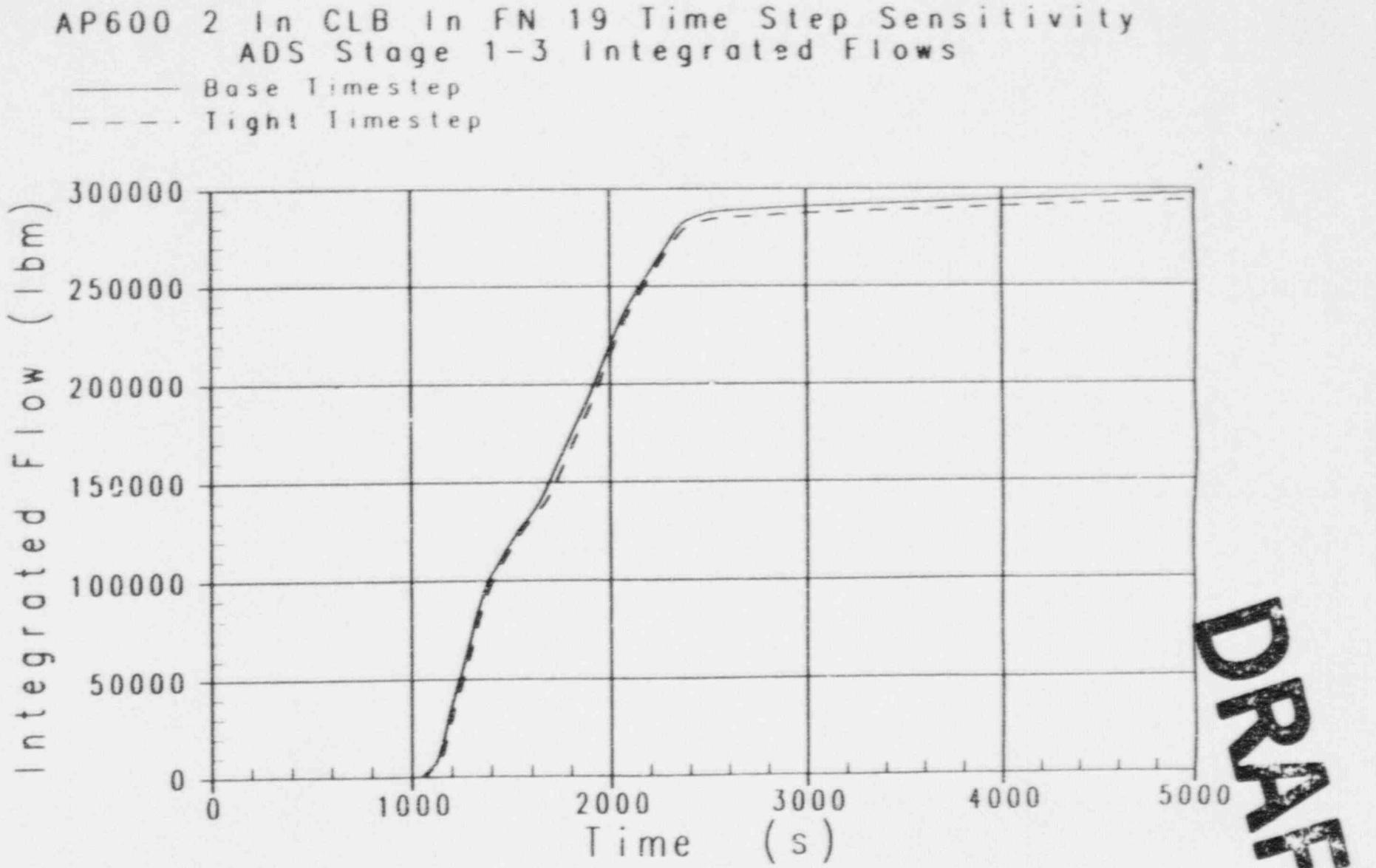


Figure 440.339-78

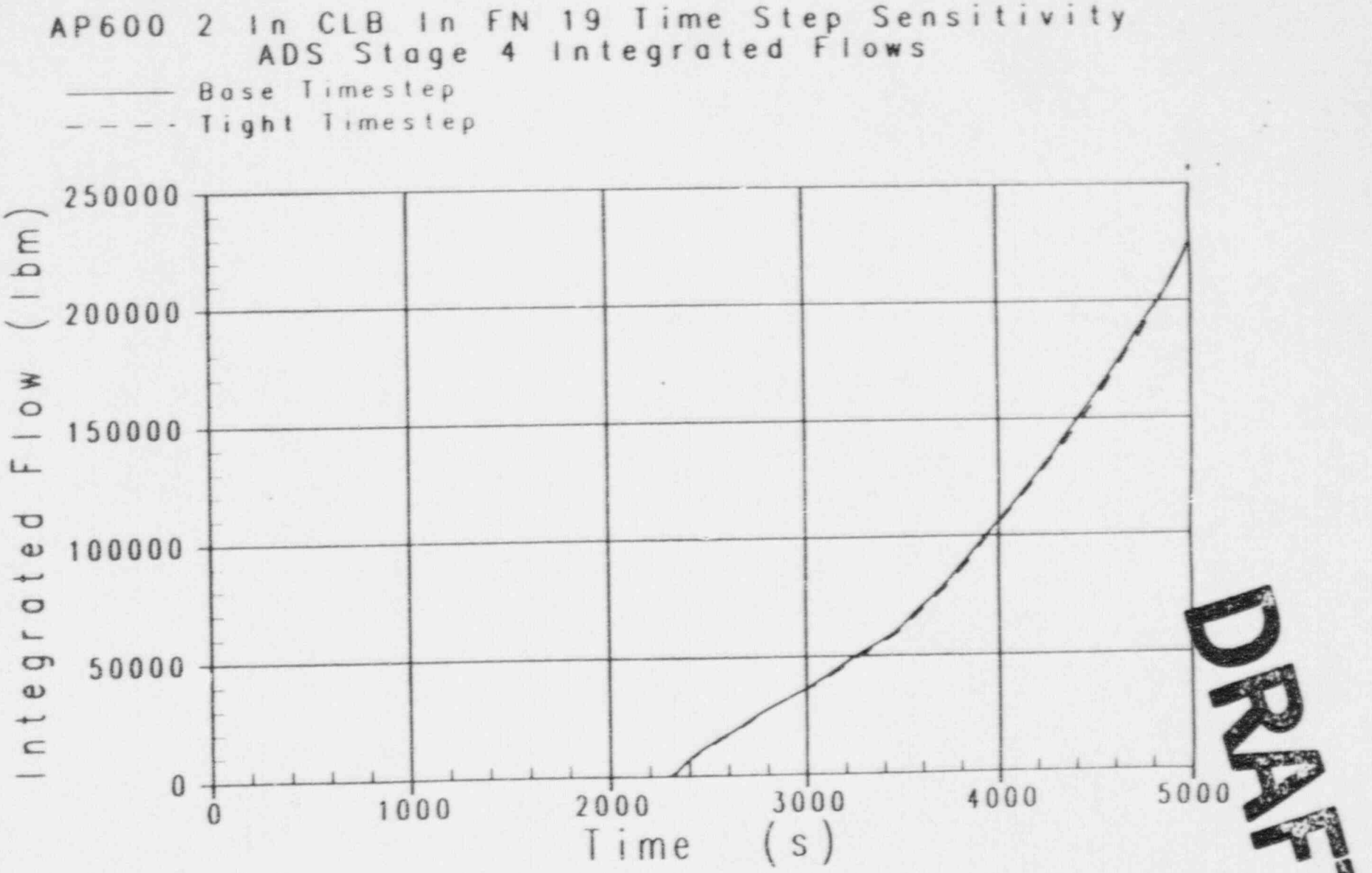


Figure 440.339-79

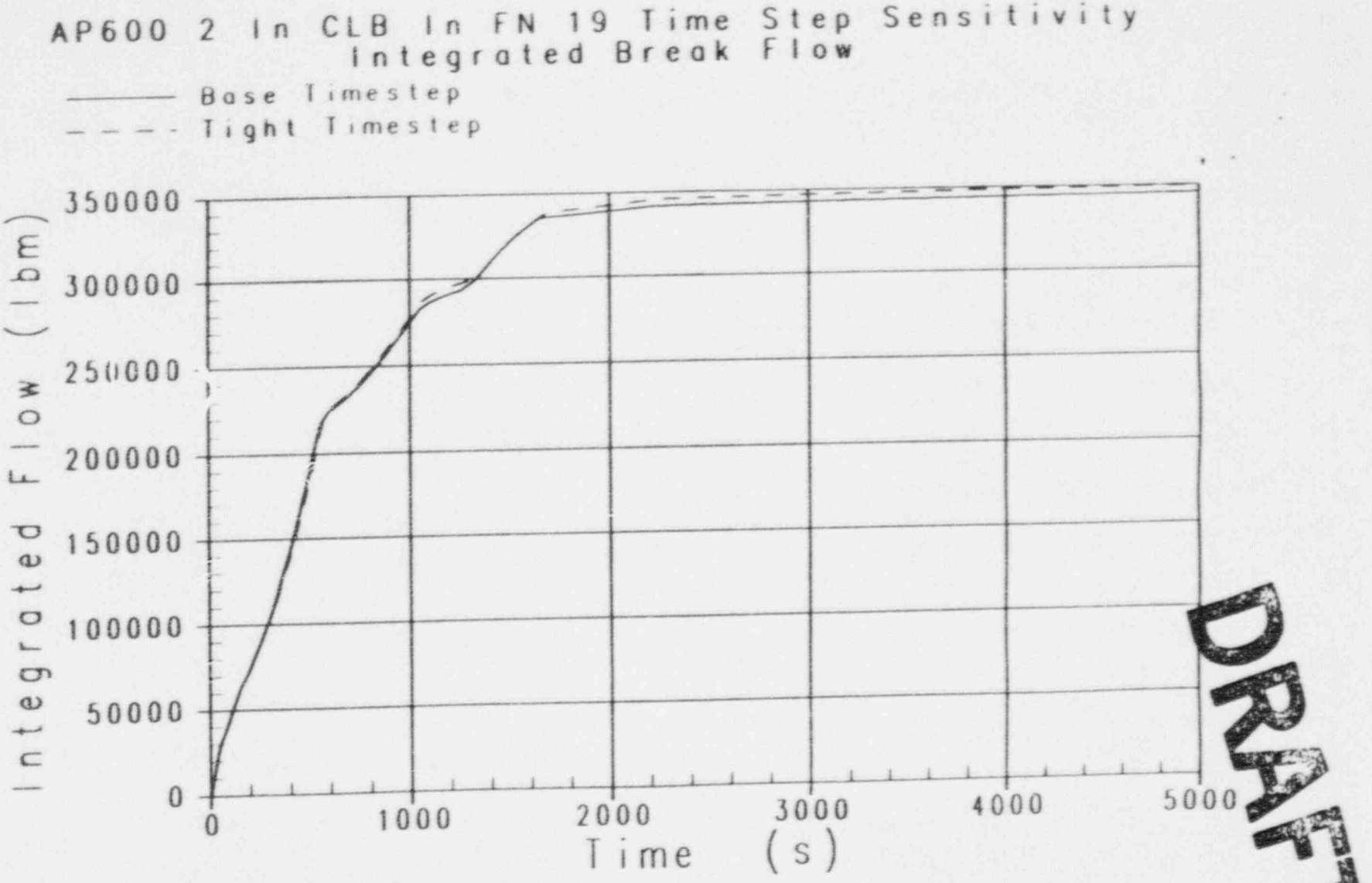
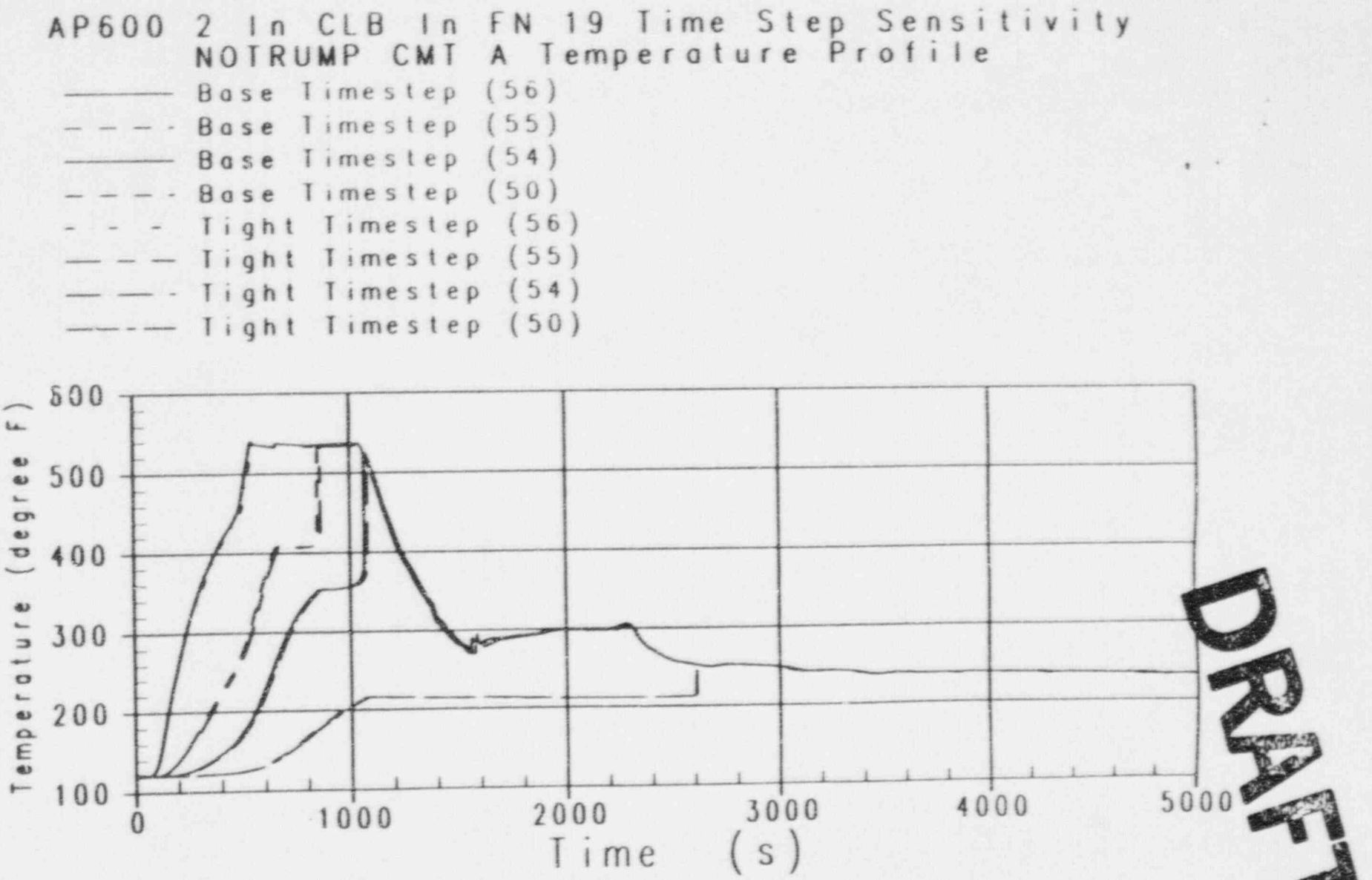


Figure 440.339-80



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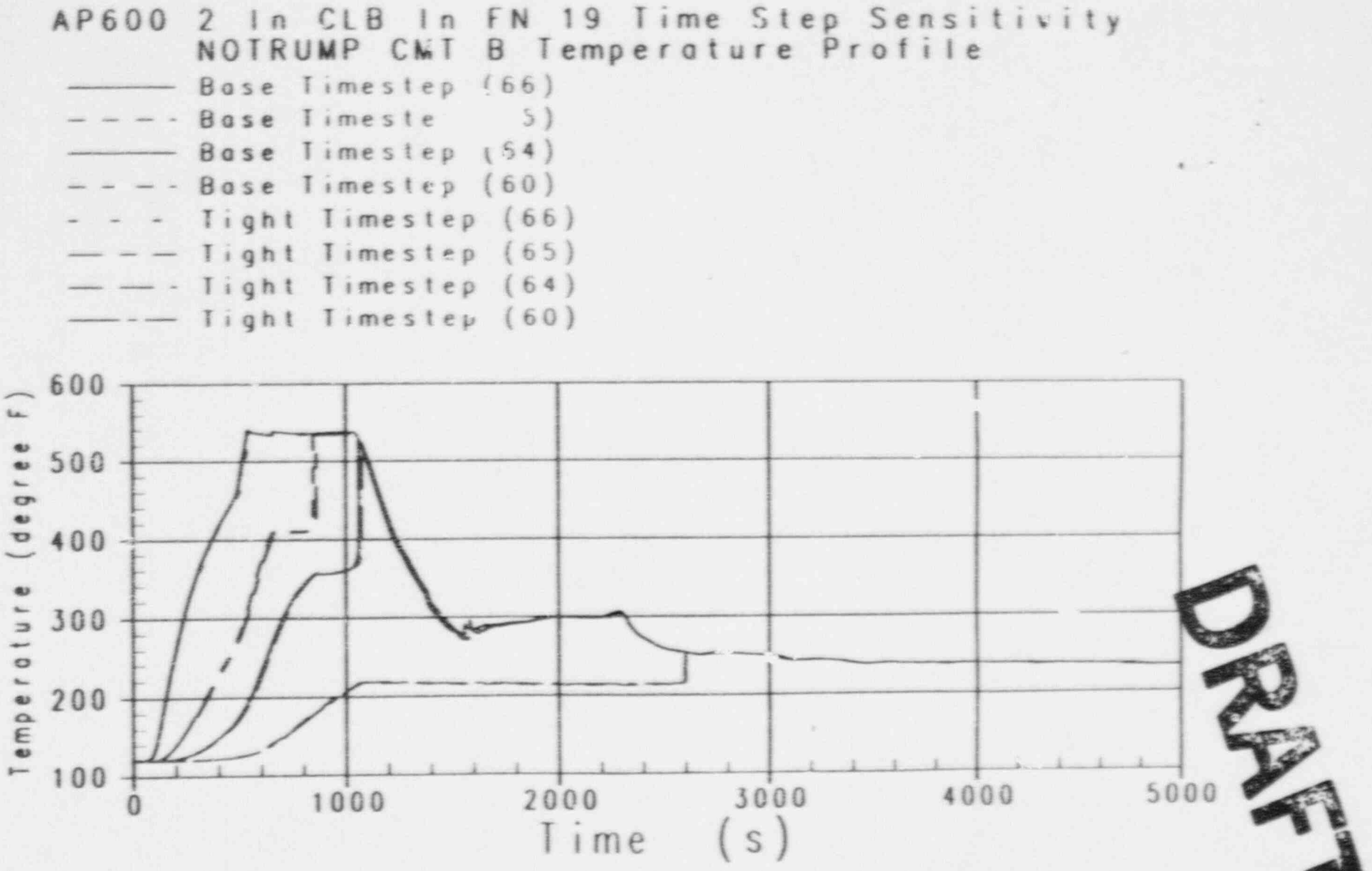


Figure 440.339-82

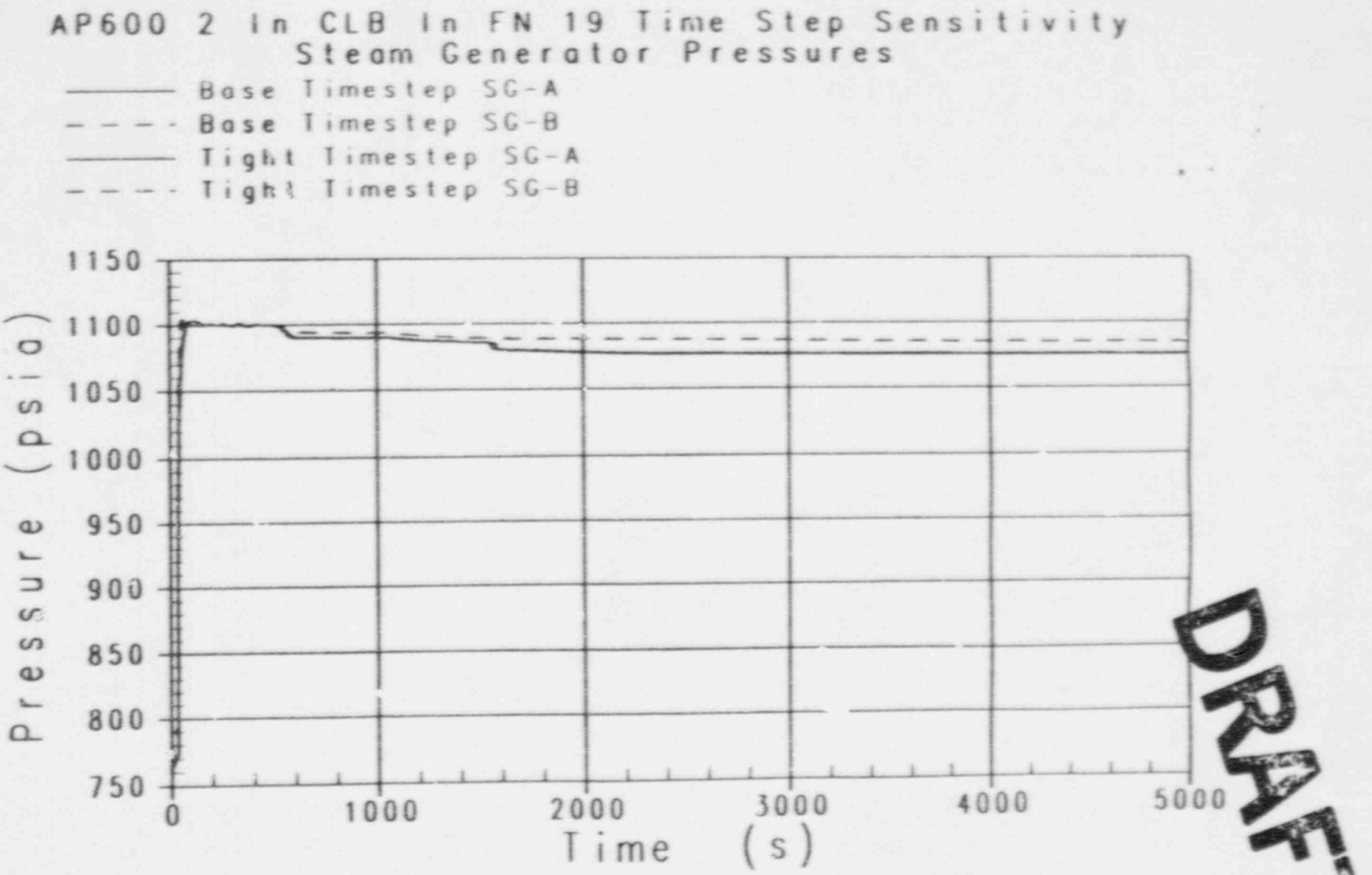


Figure 440.339-83

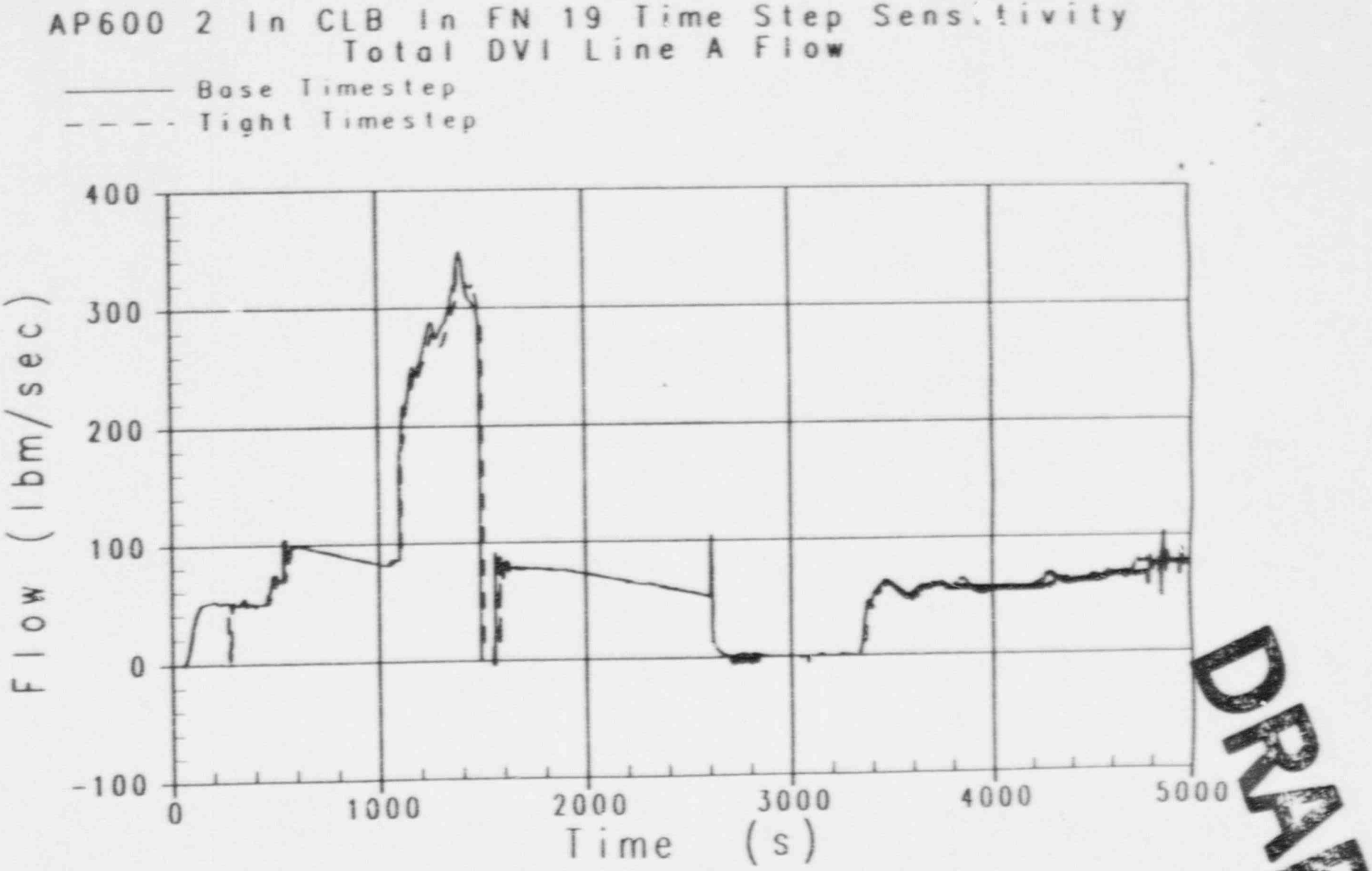


Figure 440.339-84

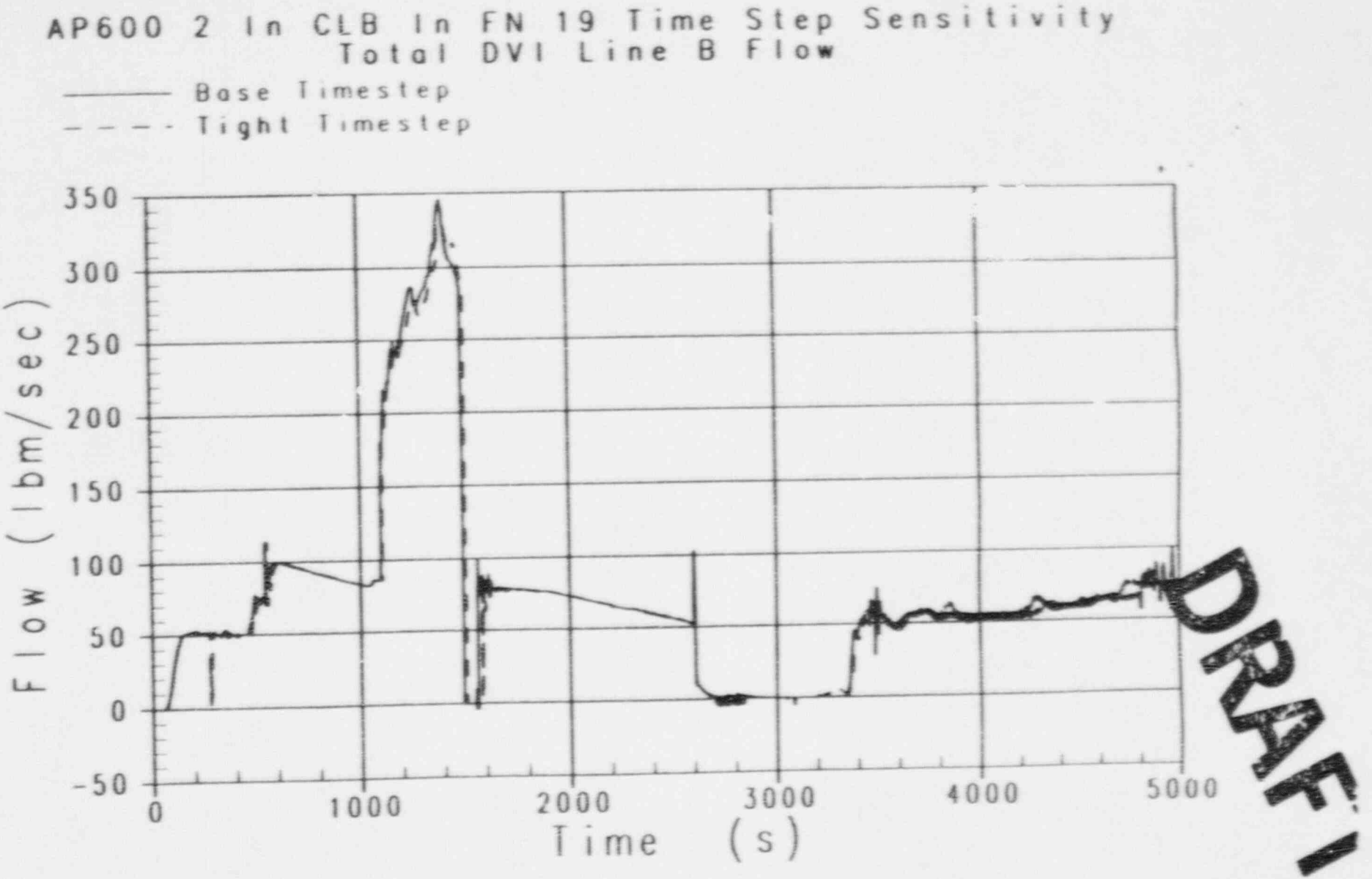


Figure 440.339-85

Westinghouse
AP600 Project

Fax

EICE 3-09

To: Joe Sebrosky

From: Earl H. Novendstern

CC: B. McIntyre (NRC Informal Proprietary Correspondence File), B. Rang, S. Fanto, R. Kemper, L. Hochreiter, F7.5.1.2

Pages: 1+ 28

Date: Sunday, May 25, 1997

Re: WC/T V&V CAD RAIs/Discussion Items

Joe,

Attached are additional RAIs/discussion items that will be issued in the next several days. I have marked them DRAFT only because they are not transmitted by a formal letter. No text will change when formally transmitted.

Please give to Lambrose and Bill. Many thanks.

Earl

DRAFT

3. For the AP600 WCOBRA/TRAC model, clarify if AP600 has flow mixers in the upper plenum. If yes, include the flow mixers in Westinghouse's response to the following question. Channel 25 is used to combine two types of structures (see top of page 2-25). Justify the flow paths of the two types of structures in the upper plenum are sufficiently similar to allow this combination without biasing the combined calculated flow relative to what each type of structure would receive if modeled separately.

Response: AP600 has no flow mixers as such. The WCOBRA/TRAC modeling which combines into one channel fuel assemblies located beneath support column and open hole locations is no different from the approved 3/4 loop plant approach. The AP600 upper core plate geometry is such that the hole diameters at these two locations are[

] to cause pooling or holdup of liquid.

AP600 SSAR subsection 15.6.5.4A.3.2 presents a sensitivity case in which hot assembly channel 27 was relocated from below an open hole to beneath a support column. Comparing SSAR Figures 15.6.5A-1 through 3 with Figures 15.6.5.A-4 through 6, this change in location results in almost no difference in the value of or the elevation at which the PCT is computed, or in the flow behavior in the assembly. This result shows that the two locations are sufficiently similar hydraulically to permit their combination into a single average core channel in the AP600 WCOBRA/TRAC model.

OITS 4650

DRAFT

10. The following questions relate to Section 4.2.

a. Westinghouse revised the database for the blowdown cooling heat transfer uncertainty evaluation to better match the AP600 conditions, but in the end concluded the original uncertainty distribution was better and more conservative because the new distribution had less scatter than the original distribution. Justify this conclusion because the original distribution allows for larger multipliers and a larger average multiplier than the one developed in Section 4.2.

OITS 4672

b. Clarify what Westinghouse means in Section 4.2 by the original distribution because distributions from the RMR, Reference 2, and the final 3-/4-loop plant distribution from Reference 6 are referenced.

4673

d. Because Reference 6 contains the final blowdown cooling heat transfer distribution for 3-/4-loop plants, justify why that distribution was not used in Figure 4.2-1.

4677

f. Followup to Discussion Item 5a, May 17, 1996, letter. Based on Table 4.2-1, Westinghouse stated the Oak Ridge National Laboratory data better represented the AP600 during blowdown cooling than the original data base in the RMR/Reference 6. However, Westinghouse decided to use the uncertainty range based on the original database. Therefore, Westinghouse still needs to provide a response to Item 5a to show the mass fluxes for the tests in the database for the original uncertainty range are representative of AP600 or are conservative.

4676

Responses:

10.a. The AP600 blowdown cooling heat transfer multipliers distribution has been established via the direct comparison of WCOBRA/TRAC results with the [

] a,c The cumulative distribution for AP600 analysis is presented as Figure 4.2-2 in WCAP-14171, Revision 1.

10.b,d. The distribution labelled as 'RMR' on Figure 4.2-2 is exactly that, the blowdown cooling heat transfer distribution presented in Reference 10-1. It is shown for illustrative purposes only. The final, approved blowdown cooling heat transfer distribution for 3/4 loop plants is based on Figure 36 of Reference 10-2; it is depicted as a cumulative frequency distribution in the attachment.

10.f. As described in part (a) of this question, [

] a,c

References:

10-1. NTD-NRC-95-4575, Letter from N. J. Liparulo (W) to R. C. Jones, Jr. (USNRC), 'Revisions to Westinghouse Best-Estimate Uncertainty Report,' October 13, 1995.

10-2. NTD-NRC-96-4672, Letter from N. J. Liparulo (W) to R. C. Jones, Jr. (USNRC), 'Resolution of Issues Related to Review of WCAP- 12945-P,' March 25, 1996.

DRAFT

11. The following question relates to Section 4.3.

a. While the reflood heat transfer results for the low temperature tests for AP600 are within the bounds of the 3-/4-loop plant results, the 3-/4-loop plant results have a wider range than the low temperature data for the AP600. Because Westinghouse concluded it was acceptable to use the 3-/4-loop plant uncertainty distribution for the AP600, this implies that a larger multiplier than that supported by the low temperature data is applied in the AP600 uncertainty evaluation. It also implies that a smaller multiplier than that supported by the low temperature data is applied in the AP600 uncertainty evaluation. Therefore, more information is needed to justify the proposed Westinghouse approach for the reflood heat uncertainty distribution.

CITS 4678

Response: The cold temperature reflood tests were simulated to assess the reflood heat transfer model applicability to AP600. Results obtained fell well within the bounds of the 3/4 loop plant bare results and exhibited [

]a,c

Reference 11-1: Letter, N. J. Liparulo (Westinghouse) to R. C. Jones, Jr. (USNRC), "Open Issues and Confirmatory Items Related to Review of WCAP-12945-P", NSD-NRC-96-4631, January 26, 1996.

FIGURE 11-1

Cold Reflood HTC Multiplier Distribution

Distribution from Forced Reflood Tests Simulations with WCT-MOD7A/

○——○	YVALUE	1	0	0	Base Data
△ - - △	YVALUE	1	0	0	Cold Data

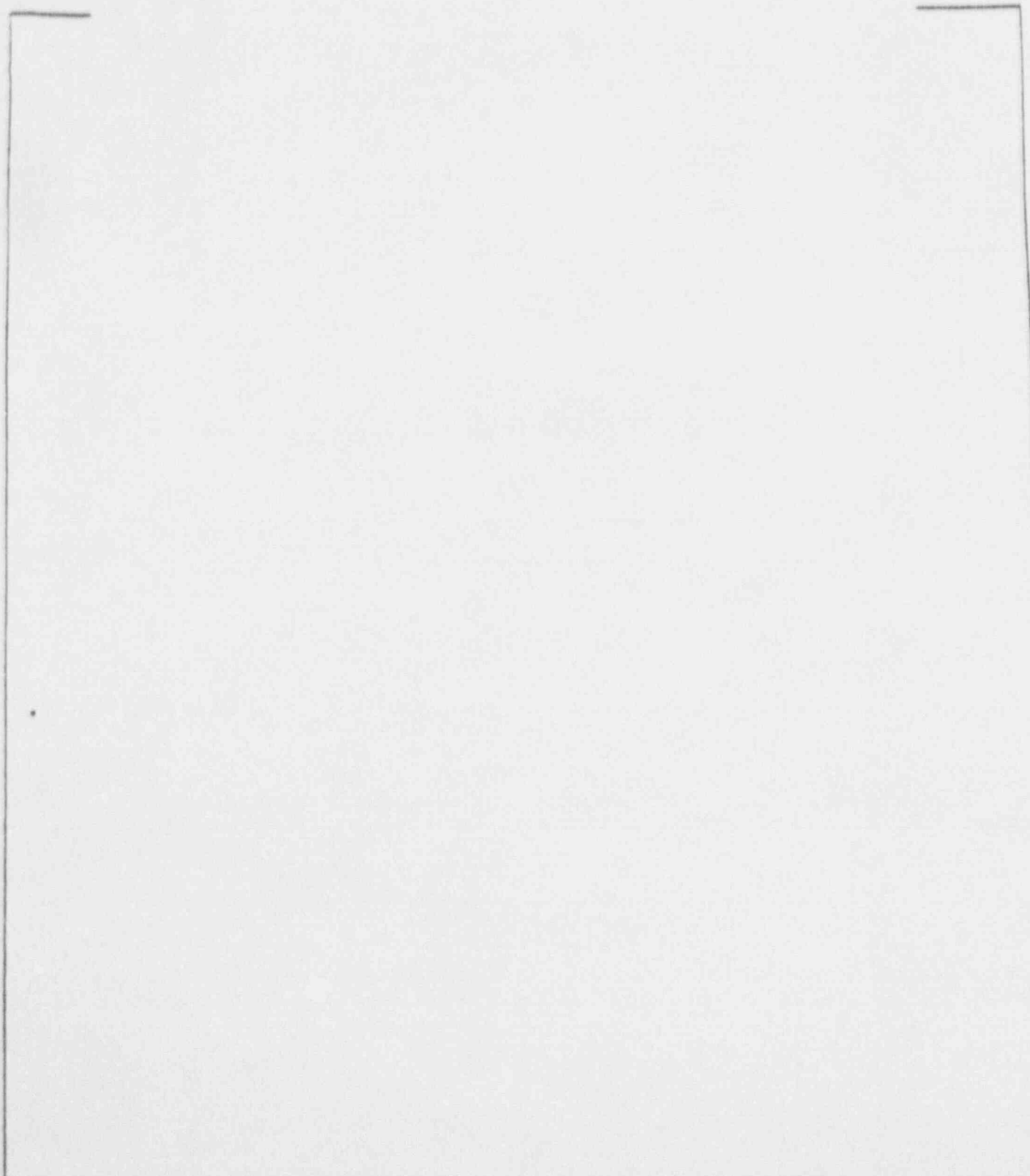
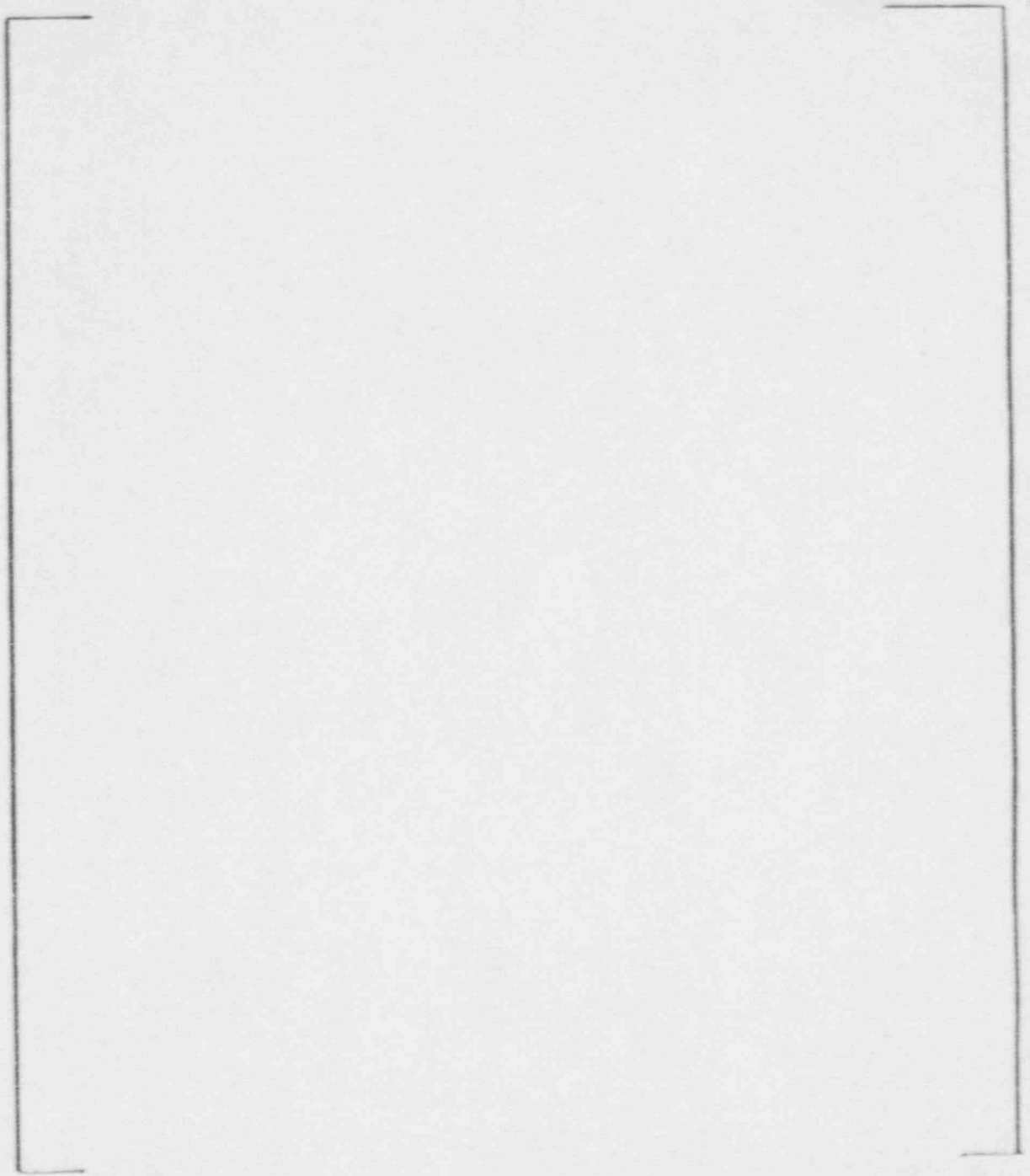


FIGURE 11-2

Cold Reflood HTC Multiplier Distribution

Distribution from Forced Reflood Tests Simulations with RCT-WOOTA

a,c

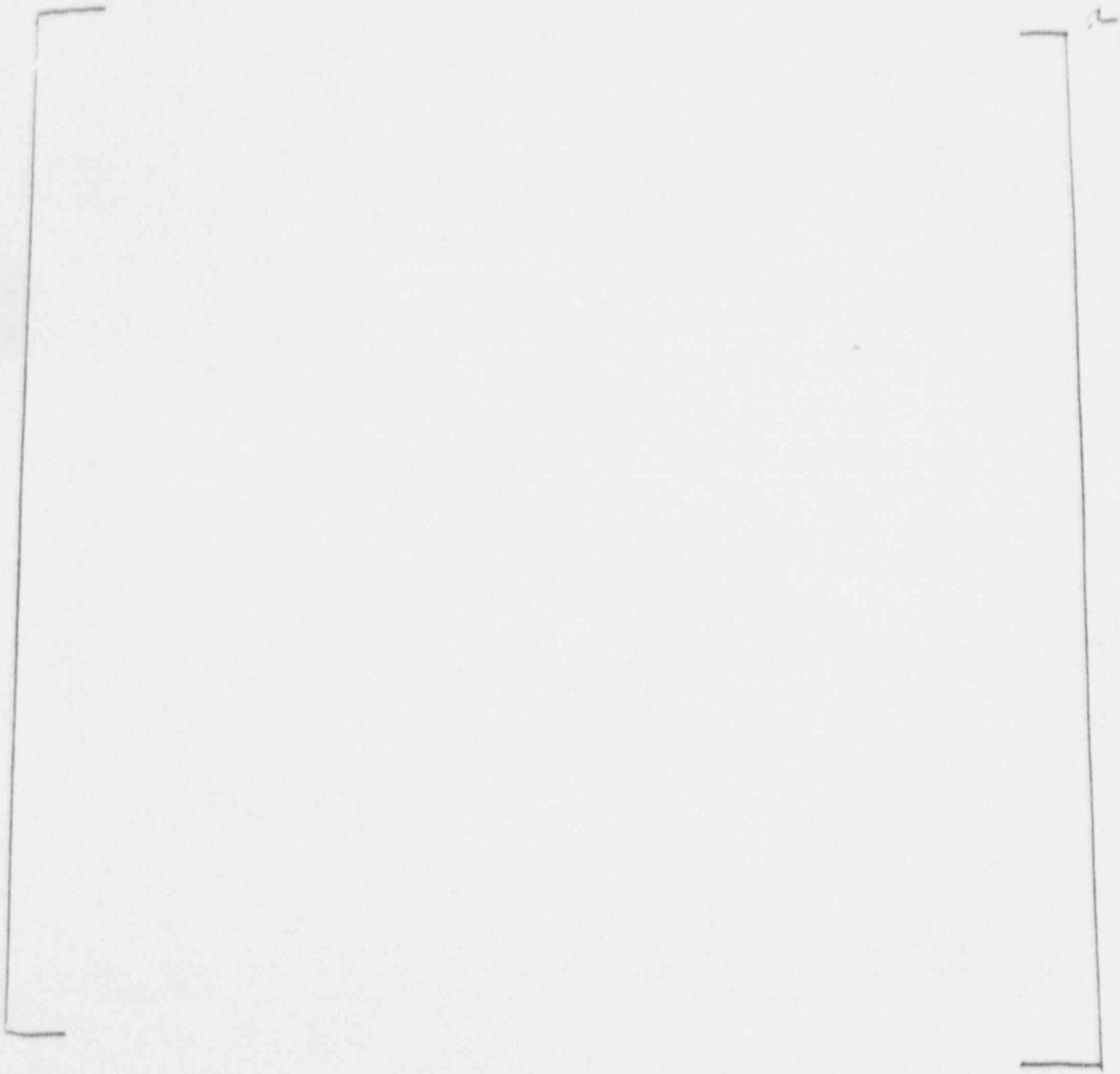


DRAFT

FIGURE 11-3

Reflood HTC Multiplier Distribution

Distribution Normalized with Flooding Rate/



12.e. Clarify how the upper head temperature is calculated. The wording on page 4-14 is not clear.

Response: The AP600 reactor vessel upper head fluid temperature has been computed by the reactor vessel design group using a suitable CFD computer code. In the AP600 WCOBRA/TRAC analysis, an upper head temperature consistent with the presumed vessel Taverage value is employed. Best estimate upper head fluid temperature is calculated based on the design values of spray nozzle flow and guide tube loss coefficients, together with the expected core outlet/upper plenum pressure distribution.

To obtain a bounding high value of the upper head temperature, the maximum mean value from the CFD code is applied in WCOBRA/TRAC. This value is obtained by modeling upper head hydraulic parameters considering possible flow pattern variations which would maximize the computed upper head temperature for a given Taverage. For AP600, the maximum mean temperature [

] a,c

on the calculated upper head temperature.

Hotter upper head temperatures are generically more limiting in large break LOCA analyses because the earlier flashing which occurs drains the upper head earlier in the transient. This then limits the amount of upper head liquid available to cool the core via downflow, since more of this liquid is directed out of the upper plenum into the hot legs. When the upper head fluid temperature is lower, when it approaches the Tcold fluid temperature, more liquid is available in the upper plenum to provide effective downflow core cooling during blowdown.

OITS 4683

DRAFT

4. a. Does Westinghouse use the approved version of WCOBRA/TRAC, WCOBRA/TRAC MOD7A.Rev.1, in its AP600 analyses?

OITS 5021

b. Are all AP600 design changes (relative to three- and four-loop plants) that are important to LBLOCA addressed through code input (for example, direct vessel injection and the accumulators)? That is, clarify that Westinghouse did not need to modify WCOBRA/TRAC, MOD7A.Rev.1, to analyze AP600.

5022

Response: The approved version of WCOBRA/TRAC, WCOBRA/TRAC MOD7A Revision 1, is modified slightly for the AP600 SSAR large break LOCA analyses solely to facilitate AP600-specific passive safety system modeling. All of the WCOBRA/TRAC updates introduced to model AP600 features are described in WCAP-14776; those which are employed in the large break LOCA best-estimate analyses are described below for convenience.

a, c

DRAFT

a,c

When the above AP600-related features are not selected, results obtained from the AP600 version of WCOBRA/TRAC MOD7A, Revision 1 are identical to those from the approved WCOBRA/TRAC version.

9. The following questions relate to Section 4.1.

a. Westinghouse discussed removing some tests from the previous database used to develop the minimum film boiling temperature (T_{min}) uncertainty distribution. Clarify this statement as some of the tests listed were not part of the original T_{min} database.

The reviewer is correct in that there were G-1 and G-2 tests which were not listed in Table B-7 of the WCOBRA/TRAC RMR which were used to determine the value of T_{min} to be used for the AP600 calculations.

The G-1 and G-2 tests listed in Table B-7 from the WCOBRA/TRAC RMR were reviewed to determine which were most applicable for the AP600 blowdown conditions. Of the tests listed in Table B-7, tests G-1, 146 and 153 were found to be applicable. Also G-2 test 669 was also found to be applicable. The remaining G-1 and G-2 tests from the total data base were examined and test G-1, 154 and G-2 test 672 were added to the data base for the minimum film boiling temperature for the AP600. The individual thermocouples for these tests were reviewed to insure that they met the criterion given on page 4-2 of the WCOBRA/TRAC CAD (WCAP-14171). As the report indicates, there were a total of [ ] to give the T_{min} distribution which was then used for the AP600 plant calculations.

The resulting value of T_{min} determined from those tests for the AP600 was slightly more conservative (lower) with the average value of [ ] such that the AP600 fuel rods would have to be calculated to cool down further during film boiling until quench is predicted.

OITS 4668

DRAFT

17. While reviewing Westinghouse's responses to NRC RAIs 440.585, 440.586, and 440.587, the INEL noted that the reflood temperature response for the peak cladding temperature (PCT) calculated by WCOBRA/TRAC (see Figure 2.2-26) is different from the one calculated in the NRC calculations performed by Los Alamos National Laboratory (LANL) (see Figure 13). Provide information to answer the following questions to help clarify the reasons for this difference.

(a) In the LANL report, LANL stated their model represented the AP600 design as of November 15, 1994. Are there design changes made to AP600 after that date that would account for the differences in calculated responses? If design differences are affecting the results, clarify the design changes and the impact they have on the PCT differences noted between the two calculations.

(b) If part (a) did not explain the differences, are they due to code modeling differences? If code modeling differences are affecting the results, Westinghouse should provide information where possible that may explain the reason for the differences between the code results.

(c) Are the reflood differences affected by the blowdown cooling differences discussed in RAIs 440.585 and 440.586? If yes, does the calculated reflood PCT difference impact Westinghouse's response to those RAIs or indicate the need to consider other models or phenomena to include the AP600 uncertainty evaluation.

(d) Even accounting for the blowdown cooling differences, there is still approximately 180°F difference in reflood PCT. Can Westinghouse offer any information that may explain the reasons for this difference? Are models and phenomena that affect this reflood PCT difference accounted for in Westinghouse's AP600 uncertainty methodology? If yes, clarify how. If not, justify why not.

(e) If Westinghouse argues that the parameter variation in the global run matrix covers the models/phenomena that cause the PCT differences, clarify if Westinghouse has completed any of those analyses. If yes, provide the results for review. If no, will Westinghouse commit to performing some of the runs to show the size of the PCT variation in AP600 as a result of the parameter ranges analyzed in the run matrix?

Response: In comparing the different calculated PCT values from the WCOBRA/TRAC CAD (WCAP-14171-Revision 1) and the Los Alamos report on the AP600 large-break calculation using the TRAC code (LA-UR-95-4431), one can not use Figure 13 in the LANL report, because this is a composite plot of the maximum temperature calculated anywhere in the core at that given time for all the fuel rods, whereas the WCOBRA/TRAC calculation is for a single hot rod. (Refer to the footnote on page 15 of the LANL report and note that there is an error in the footnote; the figure that they should refer to is Figure 13, not Figure 5). In response to the specific questions in this RAI:

(a) As the attached figures indicate, there has been some adjustment in the accumulator and/or DVI line input parameters which is reflected in the Westinghouse WCOBRA/TRAC calculations and not in the LANL calculations. As a result, higher accumulator flow is calculated in the Westinghouse

OITS 4697

calculation early in time as the lower plenum and downcomer are refilling such that there is a higher liquid level in the core earlier in time. This behavior is shown in Figures 17-1 to 17-3. The more rapid refilling results in a lower calculated reflood WCOBRA/TRAC PCT as compared to the TRAC calculation, as shown in Figure 17-4 for the individual hot rods calculated by TRAC.

4698

(b) There are also modeling differences between the two calculations. WCOBRA/TRAC explicitly models the heat transfer effects of spacer grids in the fuel assembly. The AP600 fuel assembly is the Vantage 5H design which incorporates intermediate flow mixing vane grids in the upper elevations of the fuel assembly. The modeling of the spacer grids will promote improved heat transfer both during the downflow blowdown period in which a significant downflow exists, as well as during the reflood period. The heat transfer improvement of spacer grids was shown in the WCOBRA/TRAC CQD when WCOBRA/TRAC was compared to the ORNL film boiling experiments which showed the effects of the spacer grids. The FEBA reflood tests also showed the effects of the spacer grids. In both the blowdown and the reflood periods, the rod heat transfer will be enhanced by the spacer grids. To our knowledge, the TRAC code does not include modeling of the fuel assembly spacer grids; therefore, the heat transfer calculated in TRAC will be lower than that calculated in WCOBRA/TRAC.

4699

(c) The reflood differences are given in parts (a) and (b) above. They are due to the difference in the accumulator behavior as well as the effects of spacer grids to improve the predicted heat transfer.

4700

(d) The explanation for the differences is given above. The effects of the grid modeling are included in the ranging of blowdown and reflood heat transfer, which is based on tests which cover the calculated AP600 conditions and also includes rod bundle data which includes reactor-type spacer grid (G-1 and G-2) blowdown tests, as well as the ORNL film boiling tests and the G-2, FLECHT-SEASET, and FEBA reflood tests. The uncertainty of these models is included in the calculated code uncertainty as well as in the AP600 ranging calculations. Furthermore, the AP600 SSAR large break LOCA analysis uses bounding accumulator input parameters to minimize the delivery of water and extend the predicted reactor vessel refill time.

4701

(e) The ranging effects of the hot rod heat transfer were performed in the 'hot spot' calculations using the distributions which were developed for the AP600, as documented in the SSAR Revision 12 submittal, and the 95th percentile PCT was calculated. The effects of the spacer grids on the blowdown and the reflood heat transfer are included in the WCOBRA/TRAC code uncertainty, which is a lower bound to the uncertainty value applied to determine the 95th percentile PCT value.

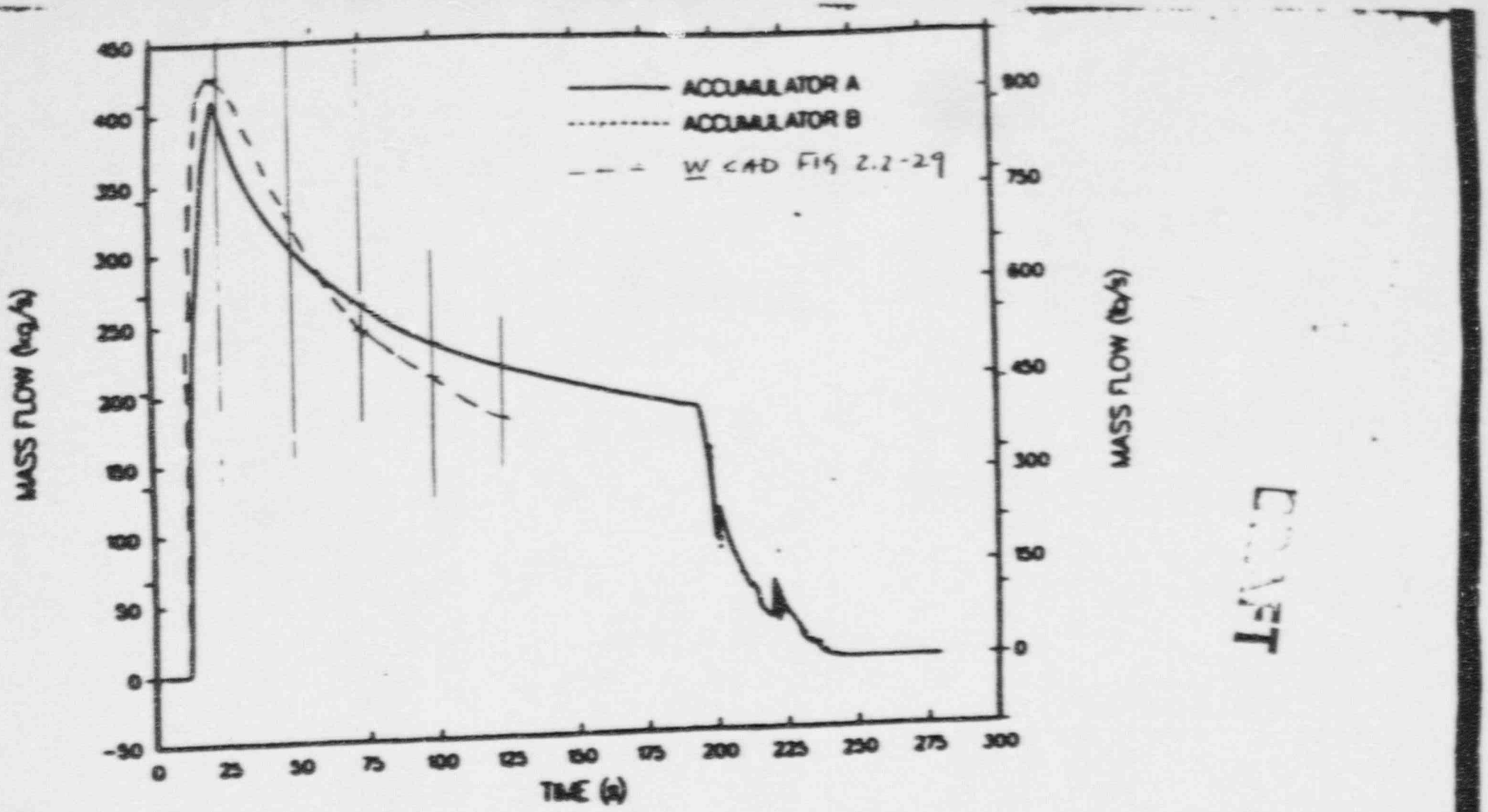
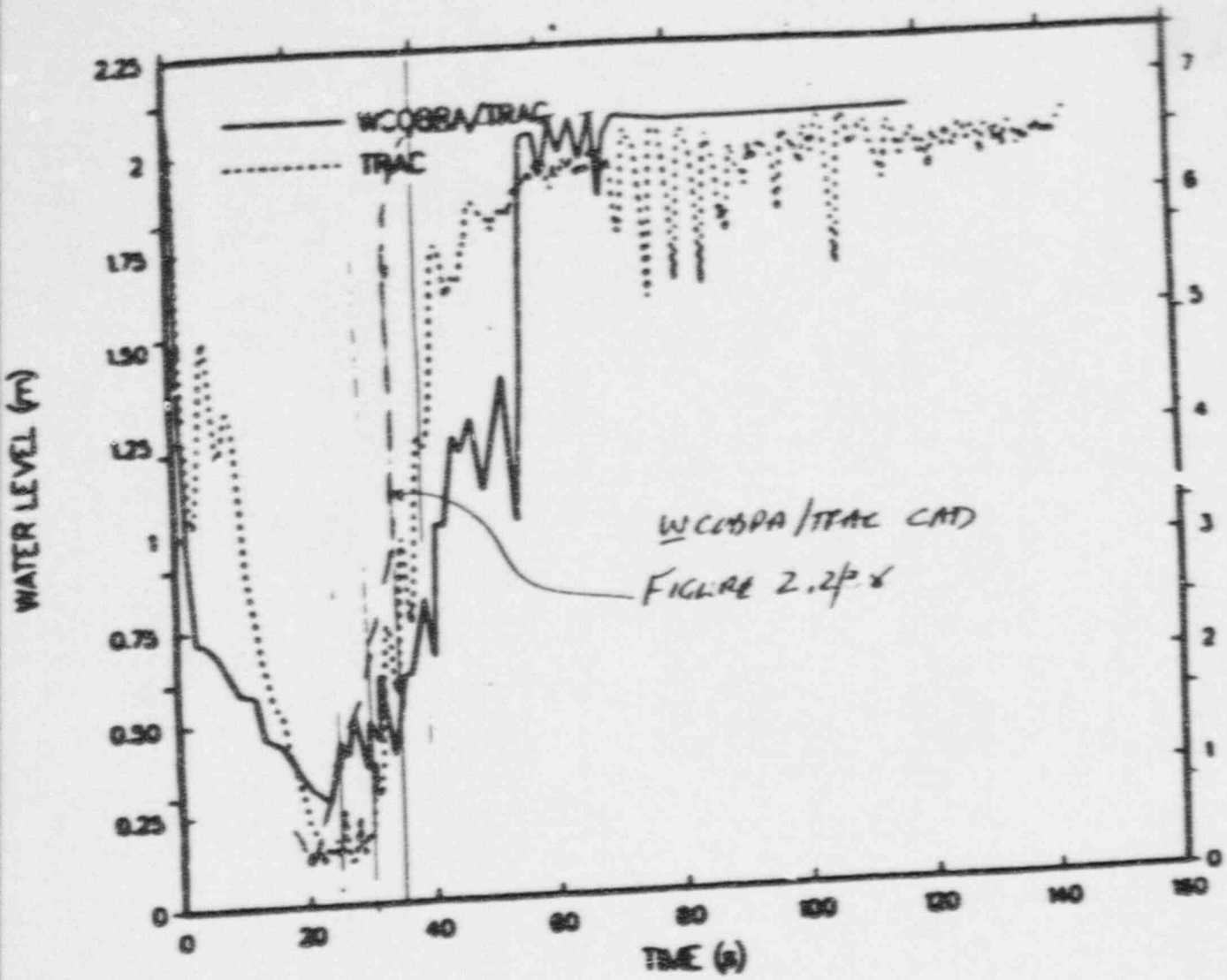


Fig. 15. Accumulator mass flows.

FIGURE 12-1



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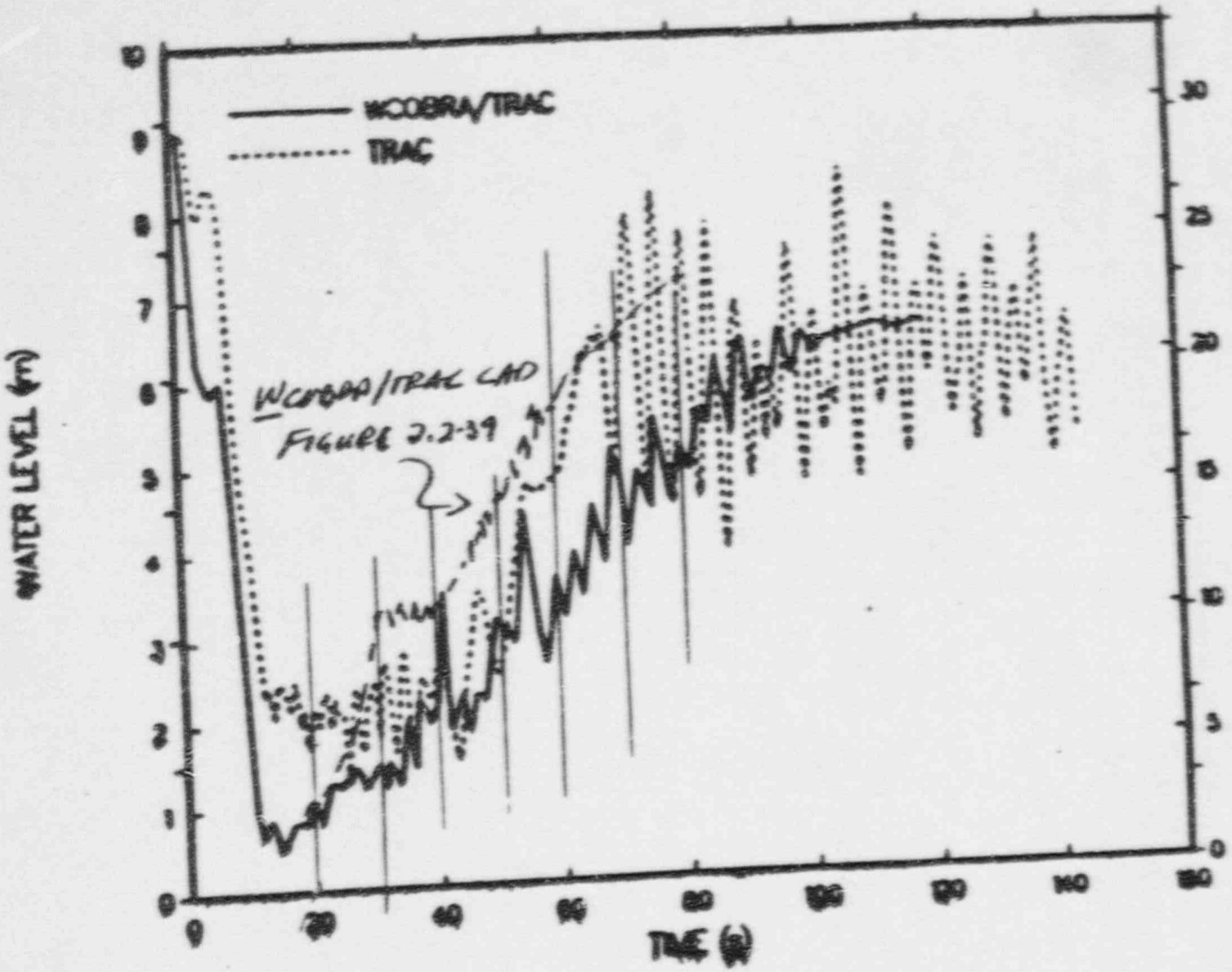
3. Comparsion of WCOBRA/TRAC and TRAC lower-plenum liquid level

Figure 17-2



ig. 64. Comparsion of WCOBRA/TRAC and TRAC downcomer liquid level.

FIGURE 17-3

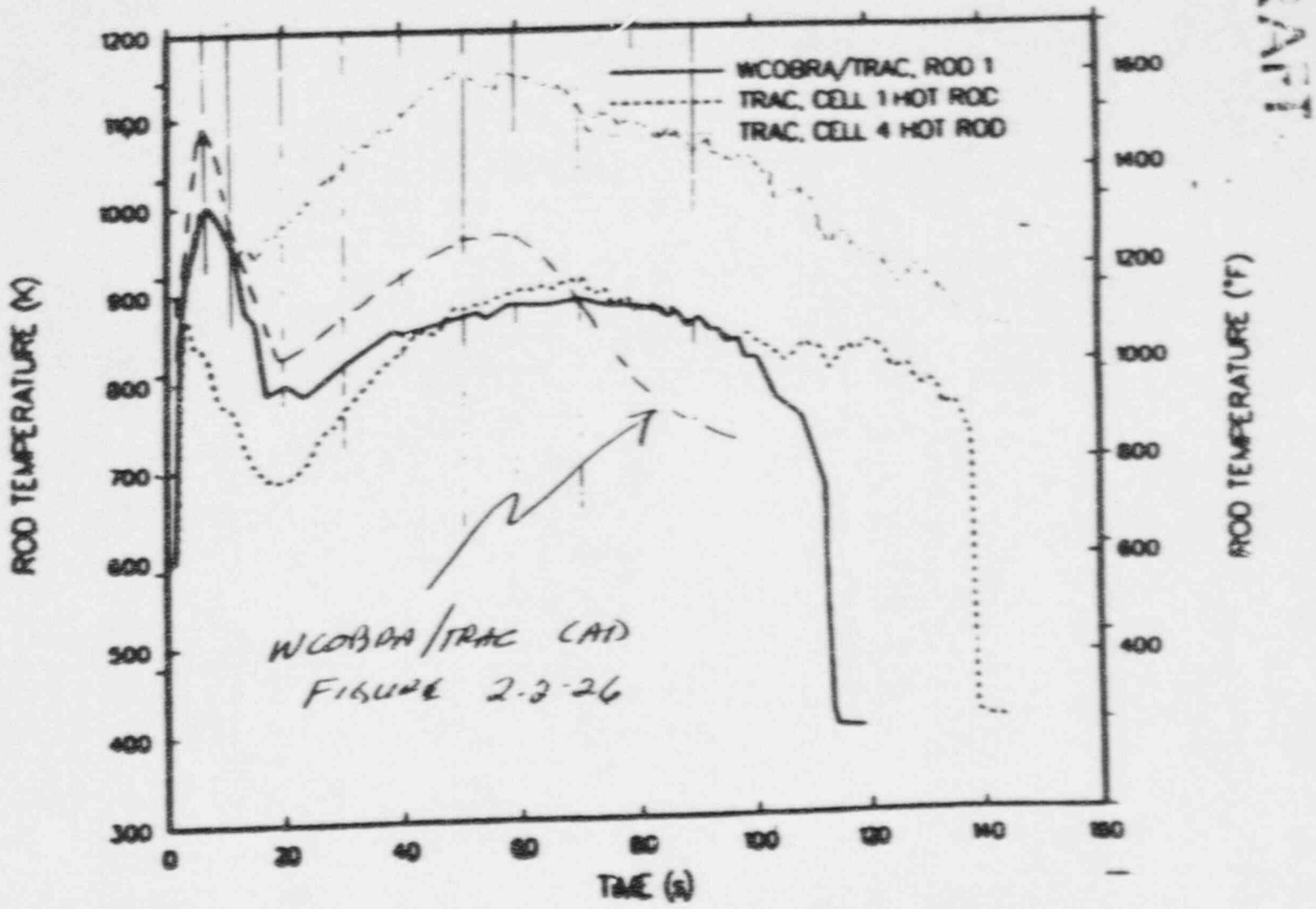


Fig. 66. Comparsion of WCOBRA/TRAC and TRAC hot-rod cladding temperatur
6-ft rod elevation.

FIGURE 17-4

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9. c. Table 4.1-1 lists the tests used to determine the $T_{w/s}$ uncertainty for AP600. Section 4.1 also listed the tests not used from the 3-/4-loop review. However, comparison of the tests shown in Section 4.1 to those listed in Table B-7 of the RMR found Westinghouse did not discuss its inclusion or exclusion of all the tests used to develop the $T_{w/s}$ uncertainty for 3-/4-loop plants. For those tests not discussed in Section 4.1, clarify the reasons for Westinghouse's handling of those tests.

This question is very similar to question 9a. Most tests given in Table B-7 were found to not to have the flow and subcooling conditions typical of the AP600 blowdown. Therefore, other G-1 and G-2 tests were used along with the remaining tests from Table B-7, which did have conditions applicable to the AP600 transient.

CITS 4670

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2.e. Westinghouse did not discuss the following highly ranked PIRT items in Table 2.1-2: core 3D flow and void generation/distribution, core flow reversal/stagnation, upper head blowdown flow and flow area, downcomer condensation, and direct vessel injection (DVI).

Response: Discussion of the individual items cited in the question follow below:

Core 3-D Flow/Void Generation and Distribution: To account for uncertainty in the 3-D flow/void generation and distribution, the limiting hot assembly location is identified and then used in the bounding plant calculations (Reference SSAR subsection 15.6.5.4A). Multi-dimensional effects are also captured by the four separate assembly groupings modeled in the core nodalization scheme. The response to question 11(3) provides additional commentary on 3-D effects during reflood.

Core flow reversal/stagnation: The core voids very quickly during a large break LOCA, and DNB occurs quickly for DECLG breaks. The impact of differing blowdown core flow patterns is investigated in the break flow parameter variations in the global model series of runs specified in Table 4.5-1.

Upper head blowdown flow/flow area: The discharge of fluid from the upper head into the upper plenum during blowdown due to flashing is an important factor in core cooling. For AP600, minimal uncertainty exists in the upper fluid head volume and in the area of the flow paths from the upper head. As discussed in the response to question 12.e, the upper head fluid temperature is bounded in the SSAR analyses by applying the "maximum mean" upper head fluid temperature associated with the Tavg value assumed. Together with the design values for upper head geometry, the use of this temperature enables WCOBRA/TRAC to provide a suitable calculation of upper head flow behavior during the blowdown phase of a large LOCA.

Downcomer condensation: The impact of downcomer condensation is investigated in the global model series of runs specified in Table 4.5-1.

Direct Vessel Injection: The ability of WCOBRA/TRAC to predict DVI-related phenomena is confirmed by the CCTF and UPTF DVI test simulations presented in Chapter 3.

OITS 4647

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2.g. For hot wall effects in the downcomer and lower plenum, Westinghouse provided information different from that supplied for 3- 4-loop plants in Reference 5. Clarify the reasons for the differences.

Response: Hot wall effects are ranked the same for 3/4-loop plants and the AP600. Nevertheless, some differences in phenomena exist. In the 3/4-loop plants, heating of water in the downcomer during reflood can eventually cause boiling, which results in level swell and the spilling of water through the broken cold leg. AP600 is equipped with large accumulators that provide injection of highly subcooled water until after quench of the fuel rods is calculated. No downcomer boiling is predicted. Further, because no boiling occurs and because the AP600 accumulators inject through the DVI nozzles, little liquid is lost through the break after the end of ECC bypass in AP600.

OITS 4649

8. The following questions relate to the UPTF analysis in Section 3.2.

a. On page 3-72, Westinghouse noted the test results showed increased flow to the lower plenum when liquid was discharged from the cold leg to the downcomer. WCOBRA/TRAC does not calculate liquid slug discharge for UPTF Test 21 because it underpredicted cold leg filling. As noted on page 3-75, this is one reason for the conservative WCOBRA/TRAC calculation. However, cold leg filling is not expected in AP600 because of steam flow in the cold leg that was not represented in the UPTF test. How does Westinghouse factor this test to AP600 difference into the interpretation of the code/data comparisons for this test?

Response: Consideration of the draining of cold legs filled during the UPTF tests does not alter the conclusion that WCOBRA/TRAC provides a conservative calculation of ECC bypass. The lower plenum mass inventory comparison of UPTF Test 21 vs. the WCOBRA/TRAC simulation and the comparison of cold leg inventories between the two are reviewed for each case at the end of the WCOBRA/TRAC simulation.

For UPTF Test 21 Phase A, WCOBRA/TRAC predicts only 6000 lbm to be in the lower plenum at 98 seconds, whereas in the test 43000 lbm were measured (Figure 3.2-16). Comparing the cold leg mass inventories of Figure 3.2-23, the sum of the cold leg masses in the test equals 22000 lbm, whereas WCOBRA/TRAC predicts only 8000 lbm to be present. Thus, the WCOBRA/TRAC result could be skewed low relative to the Test 21 , Phase A result by 14000 lbm. Even if this is presumed to be the case, the WCOBRA/TRAC underprediction of lower plenum inventory remains greater than 20000 lbm.

For UPTF Test 21 Phase BI, WCOBRA/TRAC predicts only 8000 lbm to be in the lower plenum at 120 seconds, whereas in the test 27000 lbm were measured (Figure 3.2-24). Comparing the cold leg mass inventories of Figure 3.2-31, the sum of the cold leg masses in the test equals 9500 lbm, whereas WCOBRA/TRAC predicts only 6500 lbm to be present. Thus, the WCOBRA/TRAC result could be skewed low relative to the Test 21 , Phase BI result by 3000 lbm. Even if this is presumed to be the case, the WCOBRA/TRAC underprediction of lower plenum inventory remains greater than 15000 lbm.

For UPTF Test 21 Phase BII & BIII, WCOBRA/TRAC predicts only 36000 lbm to be in the lower plenum at 395 seconds, whereas in the test 53000 lbm were measured (Figure 3.2-32). Comparing the cold leg mass inventories of Figure 3.2-39, the sum of the cold leg masses in the test equals 14500 lbm, whereas WCOBRA/TRAC predicts only 9500 lbm to be present. Thus, the WCOBRA/TRAC result could be skewed low relative to the Test 21 , Phase BII & BIII result by 5000 lbm. Even if this is presumed to be the case, the WCOBRA/TRAC underprediction of lower plenum inventory remains greater than 10000 lbm.

OITS 4660

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8.b. Does the discussion in part a of this question impact the information provided and conclusions drawn by Westinghouse on page 3-80 as it relates to the DVI location difference between UPTF and AP600 and the effect of the DVI location difference on application of the UPTF Test 21 results to AP600?

Response: The conclusion of page 3-80 in WCAP-14171, Revision 1, that the UPTF Test 21 configuration favors continued ECC bypass relative to the AP600 downcomer geometry still holds. ECC bypass predicted by WCOBRA/TRAC for the AP600 geometry is conservative and bounding.

OITS 4661

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8.f. On page 3-82 Westinghouse stated that WCOBRA/TRAC predicts the different flow behavior that results from cold leg or downcomer injection. In Test 21, ECC water breakup on the downcomer wall resulted in greater bypass relative to UPTF Test 6 (see page 3-82). This implies that the WCOBRA/TRAC calculated bypass for Test 21 should be greater than the WCOBRA/TRAC bypass calculated for UPTF Test 6. Provide the calculated ECC bypass results for Tests 6 an 21 that support this argument. This also implies that the conservatism of the WCOBRA/TRAC ECC bypass results for UPTF Test 21 should be greater than the conservatism of the WCOBRA/TRAC ECC bypass results for Test 6. Clarify if this is true.

Response: Individual runs from UPTF Test 6 are compared with runs of UPTF Test 21 that were conducted with similar steam mass flowrate and liquid subcooling conditions. Test 6, Run 132 [steam flow 293 kg/s, ECC subcooling 54C] conditions correspond well with those of Test 21, Run 274Bi [steam flow 298 kg/s, ECC subcooling 101C]. Also, Test 6, Run 136 [steam flow 104 kg/s, ECC subcooling 28C] conditions correspond well to those of Test 21, Run 274iii [steam flow 102 kg/s, ECC subcooling 47C].

The attached figures (from Reference 8f-1) show the measured and WCOBRA/TRAC-predicted vessel mass inventories for the two UPTF Test 6 runs. In each figure, the dashed line superimposed is the refilling determined (method 2) from the vessel refill rate, and the solid line superimposed is the refilling identified from a mass balance (method 1). WCOBRA/TRAC predicts a delayed refilling for Run 132 by about 20 seconds, and it predicts the refilling of Run 136 well.

In contrast, consider Figures 3.2-24 and 3.2-32 of WCAP-14171, Revision 1. In both of these simulations, WCOBRA/TRAC predicts ECC bypass to continue throughout the transient such that the vessel is never predicted to refill to the extent observed in the Test 21 run. The WCOBRA/TRAC prediction of ECC bypass is more conservative for UPTF Test 21 than for Test 6.

Reference 8f-1:Westinghouse letter to USNRC NTD-NRC-95-4511, Attachment 00.

OITS 4665

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Figure 8f1 Predicted vessel mass for UPTF test 136

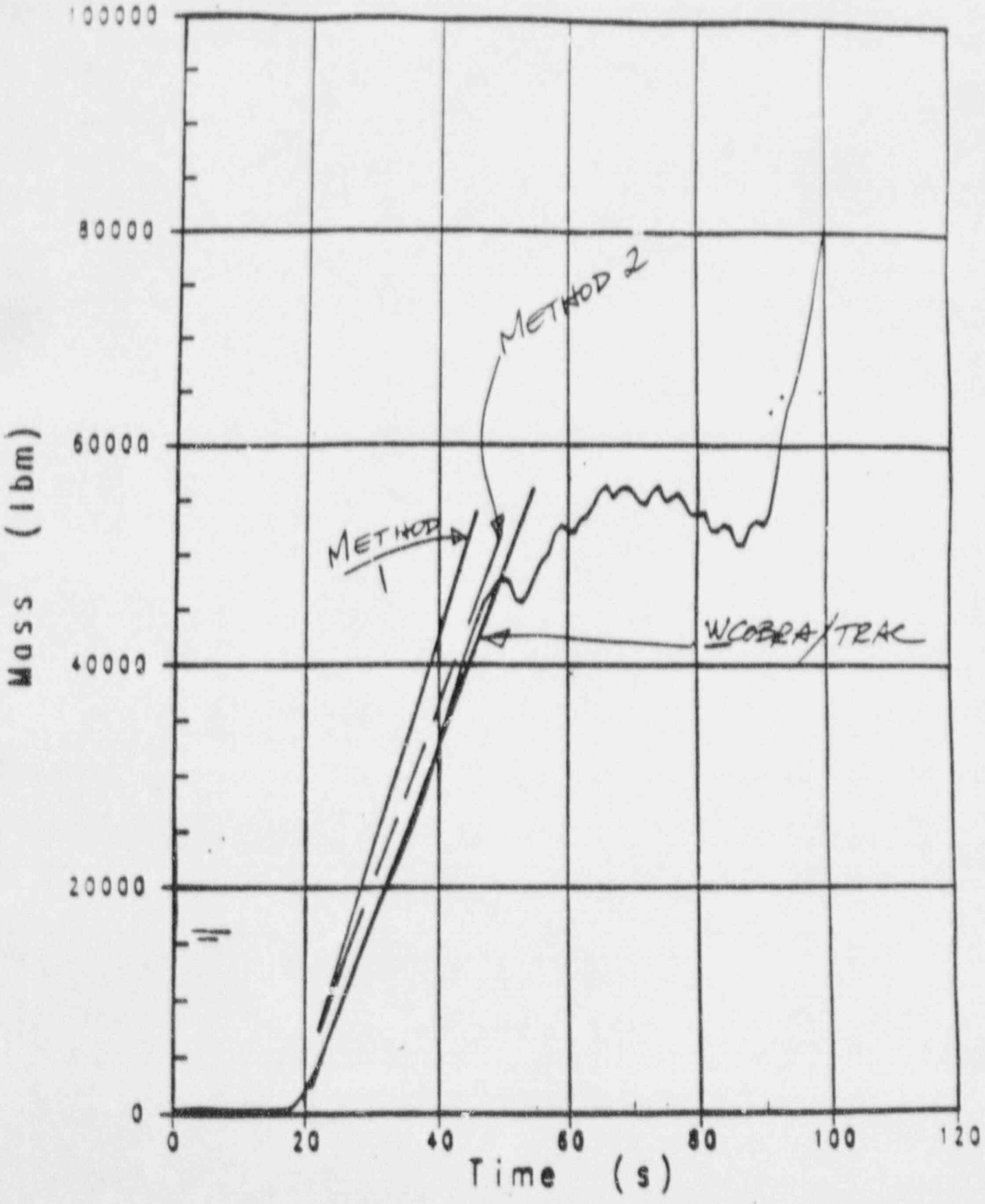
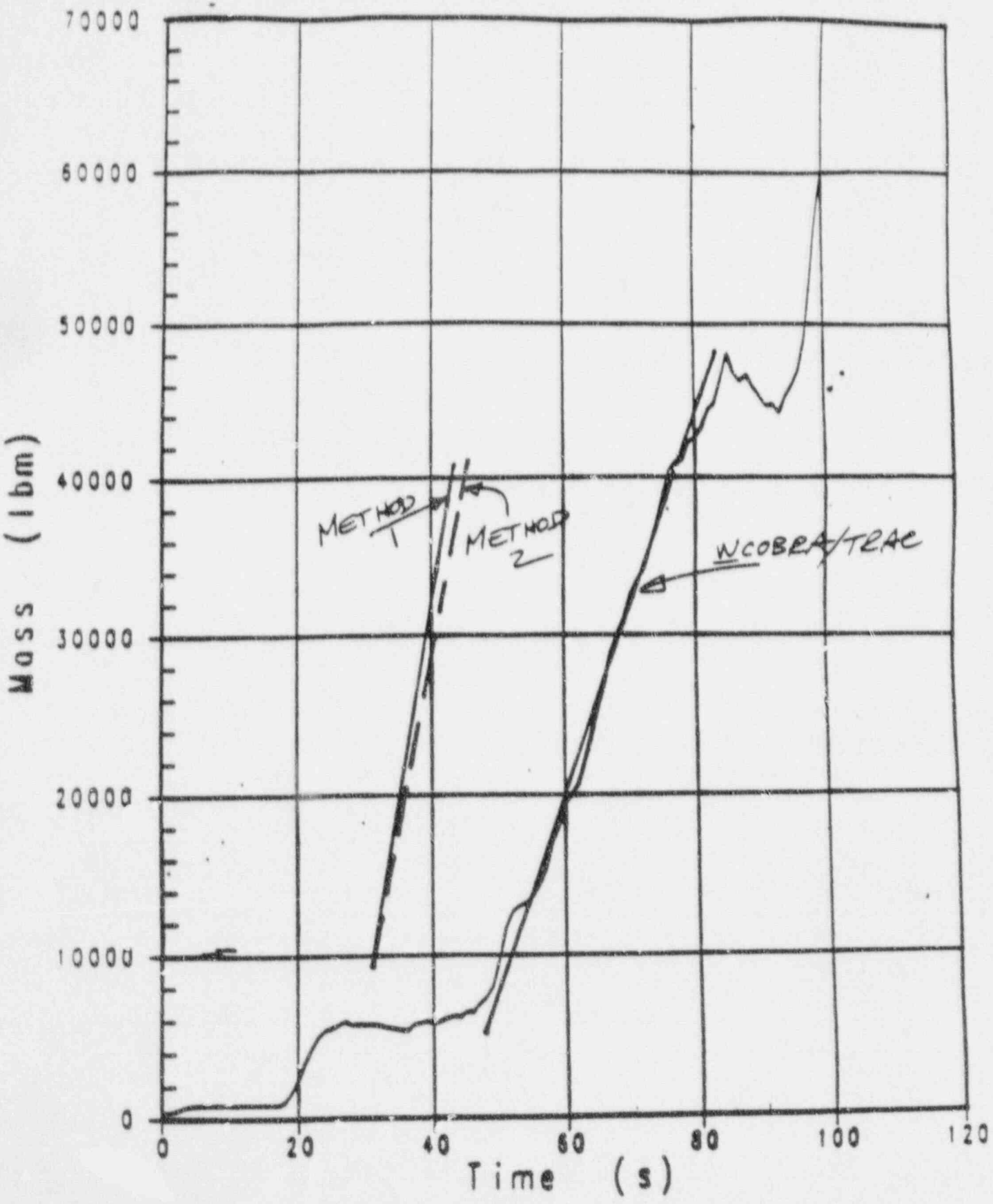


Figure 8f2 Predicted vessel mass for UPTF test 132



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8.g. As a followup to Discussion Item 6b in the May 17, 1996, letter, clarify if the following interpretation by the INEL of the information in Section 3.2.7 is correct. Westinghouse argues:

(1) In the UPTF Test 21 configuration, it is easier to bypass ECC than in AP600.

(2) WCOBRA/TRAC provides a conservative calculation of ECC bypass in Test 21.

(3) The AP600 plant calculation ends bypass at a lower steam flow than end-of-bypass in UPTF.

Based on 1, 2, and 3, Westinghouse concluded that WCOBRA/TRAC provides a conservative ECC bypass calculation for AP600.

Is this argument also the basis for the response to discussion Item 6d?

Response: The WCAP-14171, Revision 1 WCOBRA/TRAC simulations of UPTF Test 21 predicted more flow into the lower plenum for Phase BII than for any other phase. While it is true that the conditions of the Phase BII test more closely resemble those of the AP600 than do those of any other UPTF test, the Phase BII test has much lower injection liquid subcooling than the AP600 calculation. Therefore, an end of ECC bypass as predicted for AP600 is not in conflict with the UPTF Test 21 Phase BII result; as stated on page 3-80 of WCAP-14171, Revision 1, high subcooling helps to facilitate the end of ECC bypass. The INEL interpretation is correct: Westinghouse has determined that WCOBRA/TRAC provides a conservative ECC bypass calculation for AP600.

OITS 4666

DRAFT

8.1. On page 3-80, Westinghouse stated termination of ECC bypass is more easily achieved in AP600 than in UPTF Test 21 configuration. However, based on the information provided by Westinghouse regarding steam flow at end-of-bypass, this is not the case. What are the implications of this difference on determining the applicability of WCOBRA/TRAC to the AP600?

8.1. In terms of downcomer steam mass flux, in the AP600 large break LOCA analysis presented in WCAP-14171, Revision 1, Chapter 2, WCOBRA/TRAC does not predict the termination of ECCS bypass and the beginning of the lower plenum refill until the steam flux equals 3.4 lbm/sec-sq.ft. This steam mass flux is well below the lowest value among the UPTF bypass tests at which liquid delivery into the lower plenum begins (5.8 lbm/sec-sq.ft., in Run 274/BIII). The AP600 value predicted by WCOBRA/TRAC is therefore conservative.

OITS 4667

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12.m. For the single-failure discussed on page 4-17, justify that it is the most limiting that can be assumed for the AP600.

Response: For AP600 design basis large break LOCA events, a single active failure in the passive safety systems is assumed. The single failure of an accumulator check valve is not credible; the large differential pressure which initiates the operation of the accumulator check valve makes its failure a beyond design basis assumption, as it is for current generation plant LOCA analyses. Among the other AP600 passive safety systems, the core makeup tanks and the PRHR are the only ones which operate during the LOCA before the quenching of the core is calculated. Because the piping layout of each features parallel valves, the operation of neither CMT nor the PRHR can be eliminated by a single failure. To minimize any possible beneficial effects of the injection of CMT water prior to accumulator injection, the single failure modeled in WCOBRA/TRAC is the failure of one of the CMT isolation valves to open on receipt of an S signal.

OITS 4691

Westinghouse

FAX COVER SHEET

RECIPIENT INFORMATION		SENDER INFORMATION	
DATE:	Friday, May 30, 1997	NAME:	Earl H Novendstern
TO:	Bill Huffman	LOCATION:	Westinghouse
PHONE:	x1141	PHONE:	(412) 374 4790
COMPANY:	NRC	FAX:	(412) 374-4011

Cover + Pages = 1 + 30

Comments:

Bill - Attached are advance RAI/discussion item responses on WCT CAD. They are marked draft, only because they haven't gone out under a Westinghouse Cover Letter. No text should change when finally submitted.

Please give copy to Lambrose. Thanks.

Earl

ECE 3

cc: B. McIntyre (NRC Informal Proprietary Correspondence File), S. Fanto, R. Kemper, L. Hochreiter, File 7.5.1.2

Westinghouse Proprietary Information

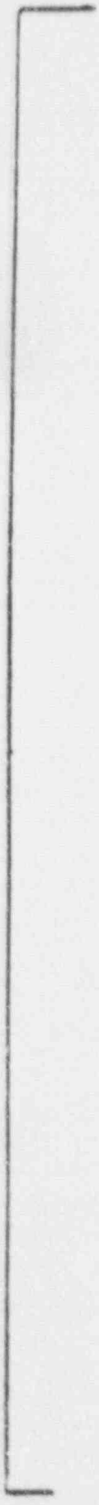
1.i. As a followup to Discussion Item 8d, May 17, 1996, letter.

(1) Westinghouse gave the same ranking to pump performance in the AP600 as for the 3-/4-loop plants. For 3-/4-loop plants the ranking was justified in Section 3.1.2 of the RMR. Because of the different type of pumps in AP600, Westinghouse needs to supply the same kind of information provided in the RMR for the AP600 pumps.

Response: The AP600 RCP performance very closely mirrors that of the RCPs of Westinghouse 3 and 4-loop plants. As shown in Figure 1.i.1-1, the pump head curves shown in RMR Figures 3.1.2-1 and 2 for the 3-loop plant are virtually identical for the AP600 RCP. Therefore, the RCP performance [and the discussion of same] in the RMR also applies to the AP600 such that the conclusions of RMR Section 3.1.2 also apply to AP600. The loop side break flow plot (Figure 1.i.1-2) for AP600 is also very similar to the three loop plant WCOBRA/TRAC equivalent prediction (Figure 1.i.1-3, taken from the RMR), further indicating that the same PIRT ranking is appropriate. The magnitude of the AP600 maximum flow rate is lower because the AP600 cold leg is smaller in diameter than the 3-loop plant cold legs, and because a CD=0.8 discharge coefficient is being modeled.

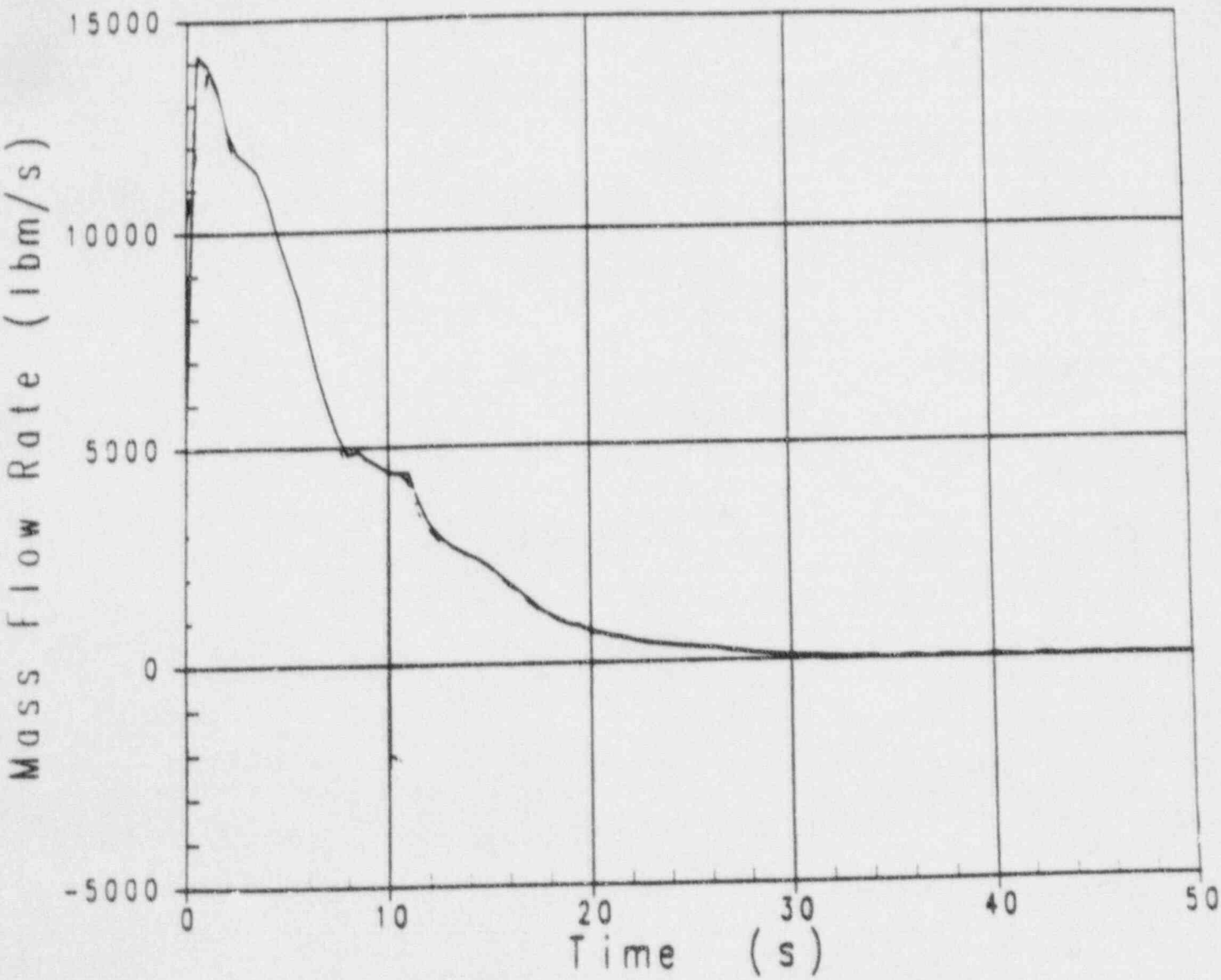
OITS 4642

FIGURE 1.2.1-1 HOMOLOGOUS CURVES FOR THREE LOOP PLANT: COMPARED TO AP600 a,c



AP600 LBLOCA WC/T CAD CASE 0: DECLG, CD=0.8, Tmin=800F, WITH PXS
Figure 1.2.1-2: Loop Side Break Flow Splitting-Blowdown

———	MTH00046	60	1	0 MASS FLOWRATE
- - - -	MTH00040	12	1	0 MASS FLOWRATE
- - - -	MTH00034	13	1	0 MASS FLOWRATE
— — —	MTH00044	9	1	0 MASS FLOWRATE



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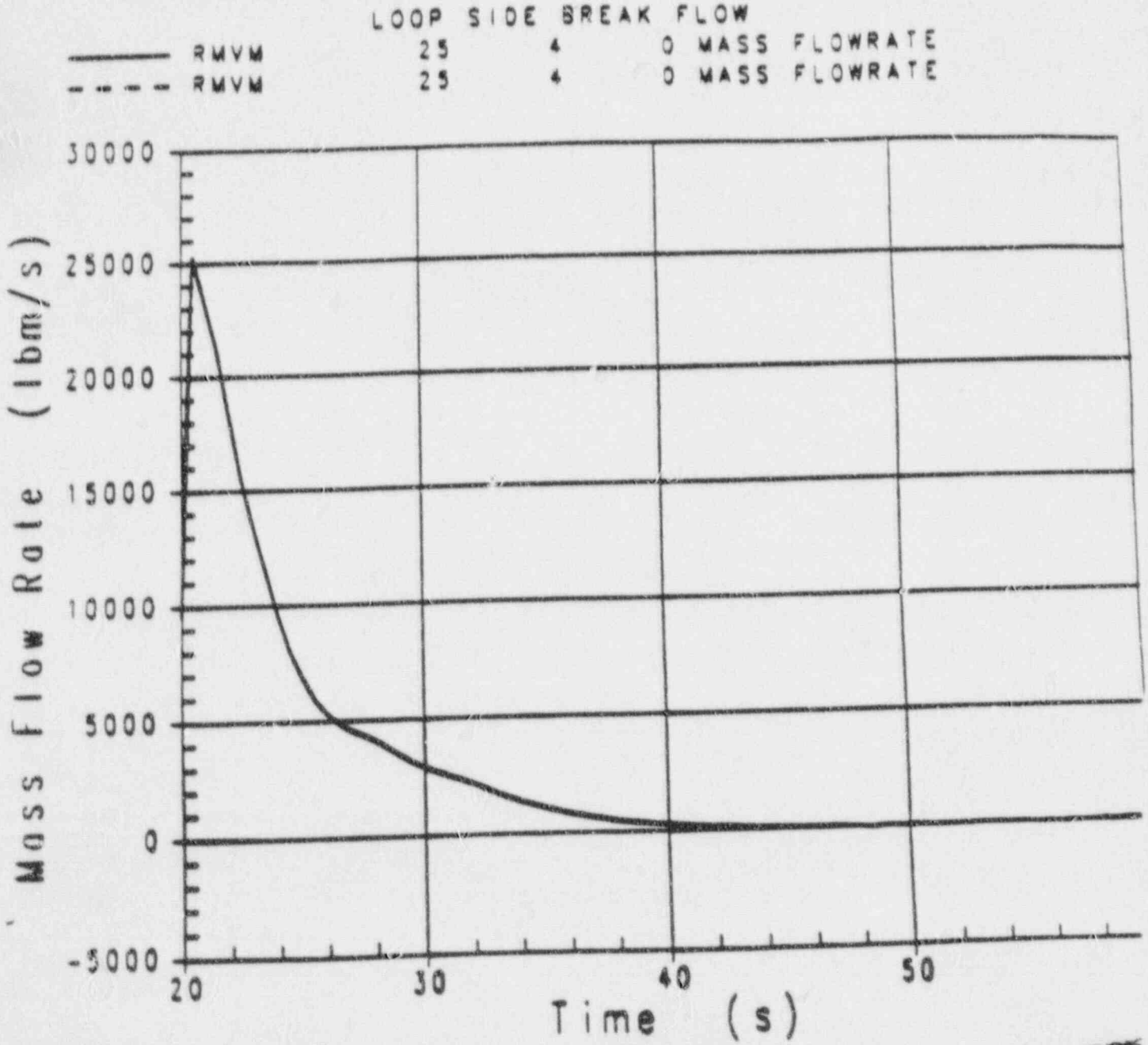


Figure 1.2.1-3

2. a. The approved methodology presented sensitivity studies for time steps and burnup. Do any of these studies need to be redone for AP600 because of design differences or calculational differences that affect the results for AP600 relative to three- and four-loop plants? Please provide some justification with your answer.

UITS 5018

Response: The AP600 fuel design is equivalent to that of many three and four-loop Westinghouse plants: 17X17 rod array, IFM and mixing vane grids, extended length fuel cycles. Generic fuel performance data of rod internal pressure and pellet temperature are the basis of the input for the fuel rods modeled in the AP600 SSAR analysis. The burnup of the hot rod and the hot assembly rod [a,c] Overall, the decay heat difference at the two burnups is modest, so any effect on the hot rod PCT is minimal. Because AP600 fuel performance parameters correspond closely to those of the fuel modeled in the burnup study performed and because the AP600 exhibits its 95th percentile PCT during blowdown, no additional sensitivity study is warranted for the AP600 application of WCOBRA/TRAC.

The AP600 analyses are performed using the time step strategy established for the three- and four-loop plants (Response to CQD RAI4-50, in the Reference below). The primary plant investigated in the time step study is a three-loop plant with vessel dimensions very similar to AP600. As noted in the response in the Reference, [a,c] As for the plant studied, the blowdown cooling is provided predominantly by liquid downflow from the upper plenum; therefore, the same time step size is indicated. The refill periods of the two plants are similar in duration; because AP600 has similar dimensions to the three-loop plant analyzed, and because the accumulator injection rate is also comparable, the end of bypass and refill phenomena are properly captured for AP600 when the same time step is used. The downcomer/core flow interaction and the effect of boiling in the downcomer on collapsed levels are the significant phenomena during the late reflood period. The AP600 does not exhibit downcomer boiling at any time during the cladding temperature transient prior to total fuel rod quenching, so the existing study has investigated a more sensitive situation than the AP600 encounters. Overall, because time step sizes in the AP600 SSAR and WCAP-14171, Revision 1 analyses do not exceed the established time step criteria from the three-loop plant time step study, the AP600 large break LOCA WCOBRA/TRAC SSAR calculations are performed using appropriate time step size selections.

Reference: Letter NTD-NRC-95-4473, N. J. Liparulo (Westinghouse) to Document Control Desk (USNRC), "Preliminary Responses to Requests for Additional Information Regarding WCAP-12945-P", NTD-NRC-4473, Attachment HH, May 31,1995.

OITS 5018

DRAFT

Question 8. In WCAP-14171-P, Revision 1, the WCOBRA/TRAC analysis of Cylindrical Core Tes: Facility Run 58 did not calculate the oscillations observed in the test results. Clarify if this was due to the WCOBRA/TRAC analysis calculating that the downcomer level did not recover to the DVI nozzle elevation. If this was the case, clarify the reasons for the difference relative to the test data which did show the downcomer level recovering to the DVI nozzle elevation. If not, clarify the reasons for the WCOBRA/TRAC and test differences.

Response:

In the Run 58 simulation, the downcomer level did not recover to the DVI nozzle elevation. This can be seen from the void fraction distribution in the downcomer. The noding diagram for CCTF is shown in Figure 3.1-6 of WCAP-14171-P, Revision 1. Note that the DVI is entered into Channels 53 and 54, which are at the same level as the hot and cold leg attachments. Consider the stack of downcomer cells represented by Channel 53 and the Channels immediately below it. These Channels are also shown in Figure 8-1. The DVI is [ ]a,c

Figure 8-2 shows the predicted void fraction Channels 53, 42, and 31. Channels 53 and 42 remain at relatively high void fraction throughout the simulation. The void fraction in Channel 53 is fairly constant at α=0.9, because of the constant injection rate of coolant from the DVI into that cell. The void fraction in Channel 31 is seen to oscillate, with $\alpha < 0.6$ except for a few brief periods.

Figure 8-3 shows the void fraction in Channel 31 again, as well as the void fraction in Channel 20 and the top continuity cell in Channel 10. The cells below Channel 31 remain liquid solid once they are filled early in the transient. From Figures 8-2 and 8-3, it can be concluded that the collapsed liquid level in the downcomer does not recover to the DVI nozzle level. The level remain at least one cell [ ]a,c below the DVI nozzle. Because this (predicted) level did not recover to the DVI nozzle, the level oscillations as described by the CCTF researchers did not occur in the simulation.

The downcomer level did not recover to the DVI nozzle elevation, because of the small over-prediction of entrainment from the core and upper plenum to the hot legs. This results in a smaller vessel inventory in the simulation than in the experiment.

OITS 5026

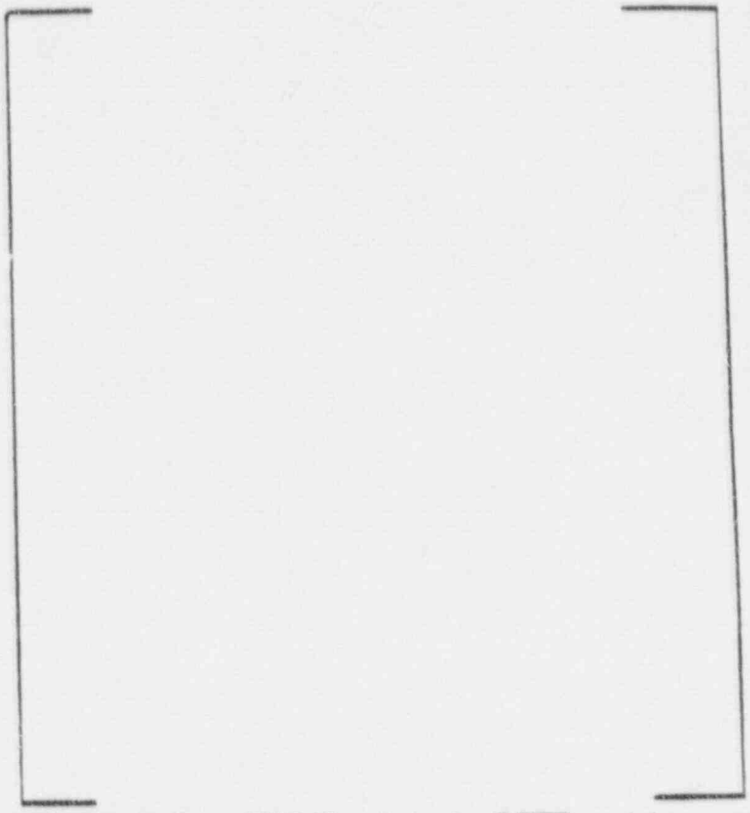


Figure 8-1. Downcomer Channels Below a DVI Nozzle in the CCTF model.

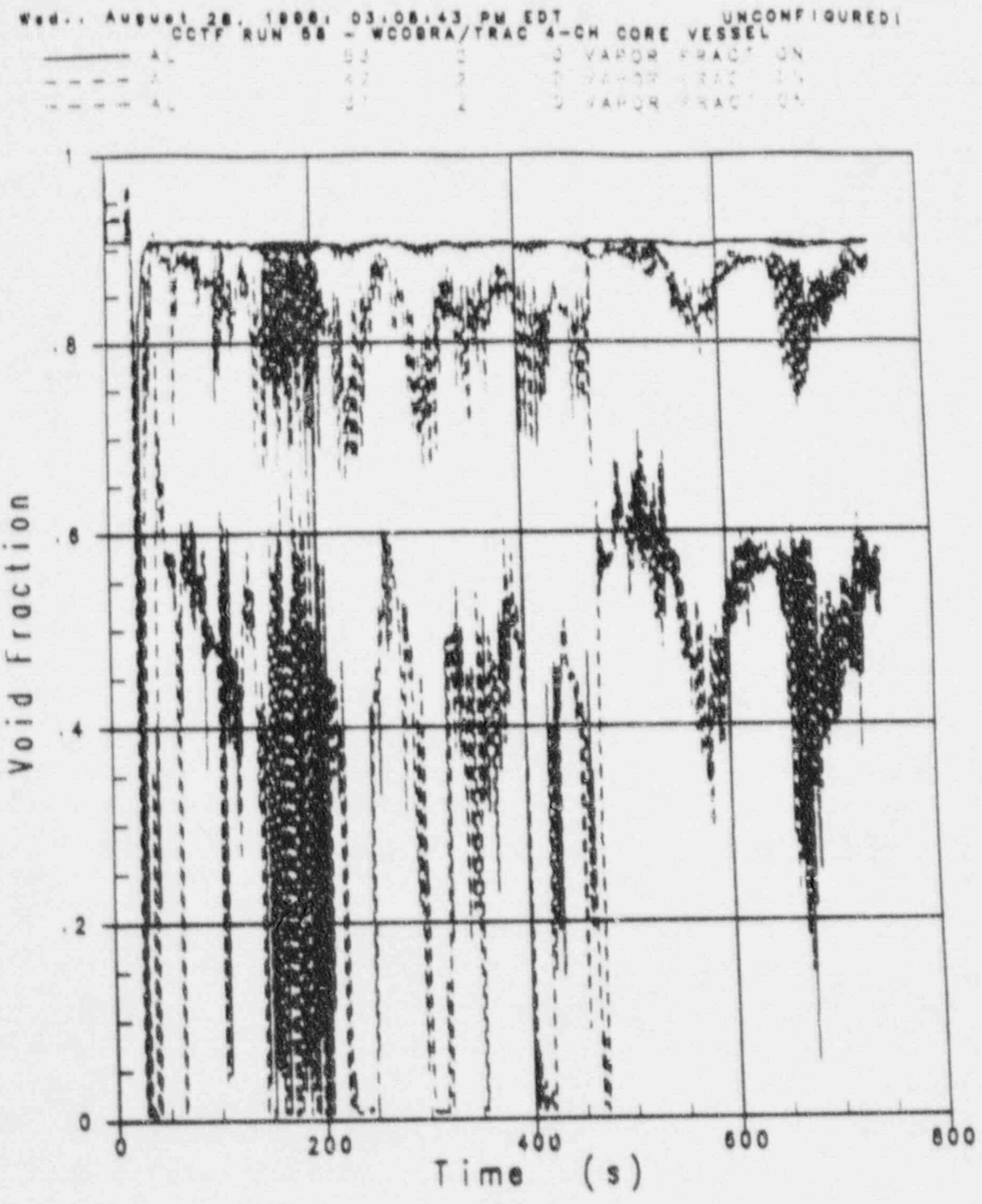


Figure 8-2. Downcomer Void Fraction; Channels 53, 42, and 31

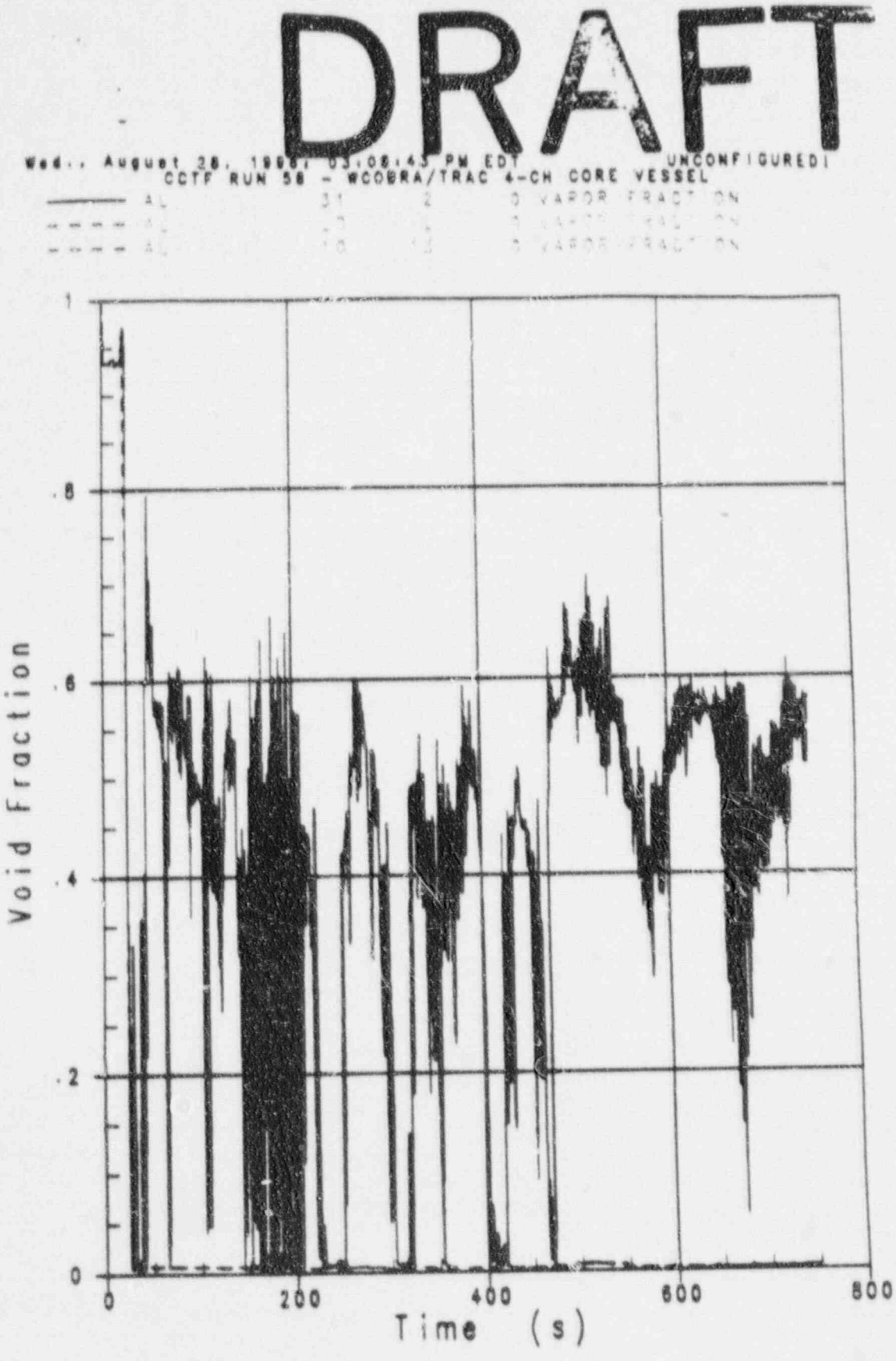
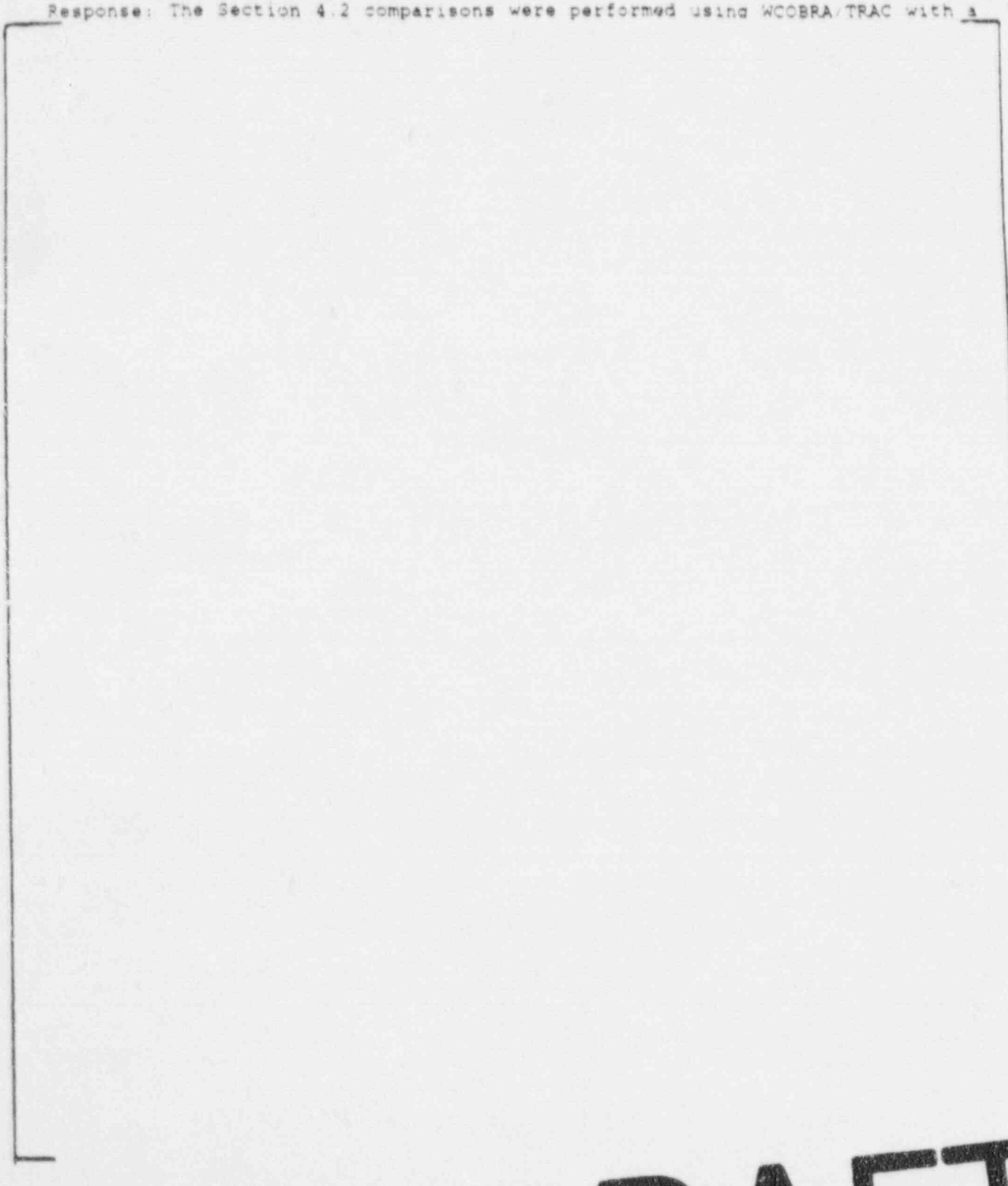


Figure 8-3. Downcomer Void Fraction, Channels 31, 20, and top of 10.

OITS 4674

10.c. For the comparisons provided in Section 4.2, Westinghouse found WCOBRA/TRAC overpredicted the ORNL heat transfer data used as the database. In Reference 6, however, Westinghouse found that WCOBRA/TRAC underpredicted the same data. Clarify whether the overprediction or the underprediction of the ORNL data is correct, and clarify the reason(s) for the different results in Section 4.2 versus Reference 6.

Response: The Section 4.2 comparisons were performed using WCOBRA/TRAC with a [redacted] a,c



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[redacted] 2,c

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12.h. On page 4-16, Westinghouse discussed the basis for how loop resistances are handled in the AP600 uncertainty analysis. INEL would like to request Westinghouse provide WCOBRA/TRAC analyses to directly support the conclusions for AP600 (see RMR Section 5.1.5). This is because of the different pumps in AP600. Also the following needs to be addressed. Does the AP600 2 x 4 configuration change the estimates of the other loop resistances relative to the major resistances (see RMR Section 3.1.2 and CQD Section 26-4)? Is the flow split to the break via the vessel or via the hot leg due to the 2 x 4 configuration different enough from that in 3- 4-loop plants that it would affect this analysis and need to be considered?

Response: The parameter of interest in RMR Section 5.1.5 is the [ ] a,

The flow split associated with the AP600 2X4 configuration does not significantly alter behavior in the broken loop between the pump and vessel sides of the break. Figure 12.h-1 shows the flow out of the loop side of the break (dashed line), through the steam generator tubes (solid line), and through the intact cold leg of the broken loop (dash/dot curve). During the first eight seconds of the transient, flow in the intact cold leg decreases from its initial 2300 kg/sec value but remains in the original (positive) direction or near zero. It is not an important factor in this period, during which the PCT occurs at approximately six seconds; the flow to the break is from the hot leg. By eight seconds the PCT has decreased almost 100F from the peak value.

During the period 8-18 seconds, flow reverses in the intact cold leg of the broken loop to feed the break, after which time this flow is small in magnitude. Before this time interval the core cooling via downflow from the upper plenum into the core average power fuel assemblies (Figures 2.2-34 and 35) has already been established, so the quenching of the core average assemblies which enables the fast reflooding of the core that leads to a low reflood PCT is not a consequence of loop side break flow phenomena. The magnitude of the reverse flow through the intact cold leg in the broken loop is never large enough to dominate the break flow. In summary, the flow supplied the loop side of the break by the intact cold does not make enough difference to indicate a need to revisit the basis already established to model loop resistance variations in the AP600 SSAR large break LOCA analysis.

OITS 4686

AP600 BELOCA CAD CASE 0: DECLG.CD=0.8.Tmin=800F.WITH PXS (u21)

———	MT-00040	11	5	0 MASS FLOWRATE (SG-B outlet)
- - - -	RMVM	12	1	0 MASS FLOWRATE (Break)
- - - -	RMVM	13	1	0 MASS FLOWRATE (Intact Cold Le

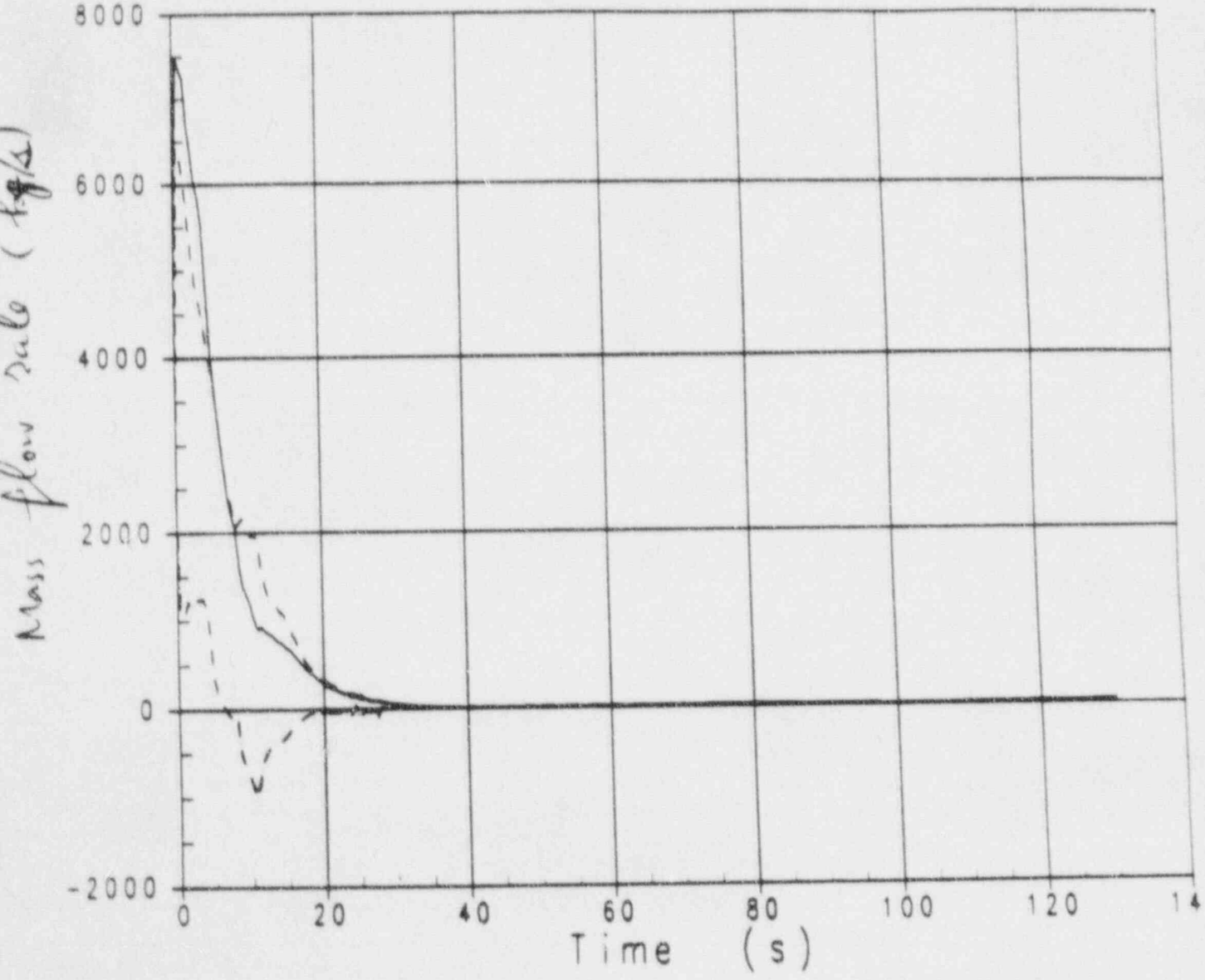

FIGURE 12h-1

12.1. For the broken loop cold leg nozzle loss coefficient and the condensation multiplier, are there any AP600 differences (such as the 2 x 4 configuration, DVI, or any others) that would affect the nominal values or ranging for these parameters relative to the 3-/4-loop plants? For the BLCL nozzle loss coefficient this is a followup to Discussion Item 4, May 17, 1996, letter.

Response: The WCOBRA/TRAC condensation multiplier range in the AP600 SSAR large break LOCA analysis is [ ]a,c

In the AP600 design, condensation during a large break LOCA event is primarily due to the injection of the accumulator water through the DVI nozzles. The condensation occurring in the reactor vessel is likely to be greater in AP600 than in cold leg injection plants because the AP600 vessel receives colder water in the downcomer due to the direct injection. This effect is calculated by WCOBRA/TRAC. The use of the same (XC=1.0) condensation multiplier as the reference value for AP600 WCOBRA/TRAC cases and the application of the multiplier range used for the cold leg injection plants is in order for the AP600.

The nozzle which connects the cold leg with the reactor vessel downcomer is designed with a comparable radius of curvature as the existing 3-loop plants. Therefore, the nozzle K-factor is similar, and the same nominal value and range of values are used for KN.

OITS 4687

12.j. Justify why the uncertainty ranges from RMR Table 3.1.3-1 apply to the AP600.

Response: The fuel specified for the AP600 is a standard Westinghouse 17X17 product. Because the fuel design is equivalent, the fuel rod uncertainties listed below from RMR Table 3.1.3-1 can be ranged in the same way within HOTSPOT as is done for 3/4-loop plant analyses: fuel conductivity, fuel packing fraction, fuel gap heat transfer coefficient, rod internal pressure, fuel stored energy, cladding burst temperature, cladding burst strain, and Zirconium-water reaction. The fuel stored energy/limiting time in life is bounded in the SSAR analysis. The same fuel rod uncertainties apply even though, as previously noted in the [a, c

]

Furthermore, the other parameters identified in Table 3.1.3-1 are bounded in the AP600 SSAR analysis and are not part of the fuel rod uncertainty evaluations. The bounding axial power distribution is identified and used in the analysis. [a, c

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OITS 4688

DRAFT

12.1. Clarify the condensation multiplier range to be used in the run matrix. Page 4-16 and Table 4.5-1 show one thing and page 4-17 another. Based on the approved methodology, the page 4-17 values seem to be correct.

Response: The Table 4.5-1 values indicate the condensation multipliers which are modeled in the WCOBRA/TRAC global model matrix to be run. The wider range of values cited on p.4-17 is applied in the uncertainty methodology determination of the 95th percentile PCT. The AP600 SSAR global model WCOBRA/TRAC spectrum shows little sensitivity to condensation. The PCT results shown below illustrate this; the case references are those from Table 4.5-1 in WCAP-14171, Revision 1.

[a,

OITS 4690

DRAFT

14. Section 4.6 discussed the 95th percentile calculation. Clarify the following questions:

a. What is the base PCT used for the Monte Carlo analysis? Justify the PCT chosen.

Response:

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OITS 4693

16. In the November 25, 1996 call, Westinghouse stated than Discussion Item 12 in the May 17, 1996, letter was addressed in Section 4. Review of Section 4 did not find all the information needed to address this item. Westinghouse needs to provide a comparison that shows for AP600 conditions how all the highly ranked PIRT items or items identified in Regulatory Guide 1.157 are covered by the assessments. See Table 3.1.2-1 in the RMR as an example of the what the INEL is looking for on the AP600. Additional illustrations of the needed information are found in References 9 and 10.

Response: The assessment ranges for items identified in Regulatory Guide 1.157 and/or highly ranked in the Westinghouse 3&4 Loop plant PIRT have been discussed in existing best-estimate LOCA methodology references, such as those provided in the question. The AP600 ranges for these parameters are the same as the 3/4 loop plant values, except for blowdown and reflood cooling.

Subsections 4.2 and 4.3 of WCAP-14171, Revision 1 provide the additional assessments performed to cover the range of conditions for AP600 for blowdown cooling and reflood heat transfer. Table 4.2-1 illustrates the comparison of the ORNL Tests modeled with AP600 conditions during blowdown cooling. For the subsection 4.3 reflood heat transfer WCOBRA/TRAC test simulations, the initial mid-core cladding temperatures are approximately 500F and 1000F. These compare favorably with the 6.0 Ft. values shown on Figure 2.2-41 for the AP600 transient. At the 40-second bottom of core recovery time, Rods 3 and 4 are both within 20F of 500F, while Rod 2 temperature is about 1030F. Thus, the tests modeled are relevant to the AP600 range, even though [

]a,c

The remaining category of items to be addressed are the parameters which showed HIGH on the AP600 PIRT, but were not HIGH in the 3&4 Loop plant PIRT. These items are:

Rewet - the assessment performed is described in WCAP-14171, Revision 1, subsection 4.1. A conservative value of Tmin is established for WCOBRA/TRAC AP600 analysis.

Upper head phenomena - the 'maximum mean' temperature is used in AP600 analyses to bound the upper head temperature, which is discussed in the response to item 12.e. The blowdown and flow area processes for the upper head have been covered for AP600 conditions by the full-pressure, full-temperature LOFT test simulations performed in the CQD.

Accumulator discharge during reflood - this is ranked HIGH for AP600 and not for the 3&4 Loop plants because the accumulators in AP600 are larger in size and discharge for a much longer time interval during the AP600 large break LOCA transient. Existing assessments of accumulator discharge are adequate for AP600 as well.

Direct Vessel Injection - Chapter 3 of WCAP-14171, Revision 1 is devoted to the CCTF and UPTF direct vessel injection test WCOBRA/TRAC simulations. These simulations assess the code against the available direct vessel injection test data for reflood and refill behaviors.

OITS 4696

Westinghouse non-Proprietary Information

3. How will Westinghouse determine the ranges for the sensitivity studies on the AP600 bounded parameters (for example, the temperature ranges for accumulator water or plant average temperature)?

OITS 5020

Response: The ranges of parameters investigated in the studies to determine bounding values for the AP600 large break LOCA analysis are based on plant design and/or operational values. The results of the sensitivity study cases may be found in Section 15.6.5.4A of the AP600 SSAR. The bounding initial condition values of parameters are applied in calculating the 95th percentile PCT.

The individual parameters and the origins of their ranges follow:

Accumulator gas pressure/water volume - bounding high and low values of pressure are from the relevant Technical Specification. To extend the time period required to fill the vessel lower plenum, the water volume is bounded high per Technical Specification.

Accumulator water temperature - the upper bound value is Technical Specification maximum allowable containment temperature value of 120F; the 80F minimum value is a lower bound estimate consistent with normal full-power operation

Peripheral assembly power - maximum and minimum values are taken from the AP600 core design loading patterns

RCS fluid temperature (Thot)- the upper bound value equals the design maximum Thot value of 600F, plus the identified measurement uncertainty of 6.5F. Based on this, the RCS thermal design flow of 97100 gpm per loop, and 102% core power, Tcold is established. The sensitivity behavior is determined by executing cases with Thot equal to 606.5, 600, and [600 - 6.5] equals 593.5F.

Pressurizer pressure - the range equals the nominal operating value of 2250 psia plus/minus the identified measurement uncertainty of 50 psi; runs are performed at 2200 and 2300 psia initial pressure

Radial reflector metal temperature - the reflector is heated by gamma-ray energy deposition. In WCOBRA/TRAC sensitivity cases, the upper bound design value of 662F is applied in one case, while in the other the core fluid temperature is specified as a lower bound radial reflector metal temperature.

Steam Generator Tube Plugging - Initially, the AP600 will exhibit little or no SGTP. For the sensitivity case, 10% SGTP is chosen as representative of the anticipated maximum plugging level.

RCP trip time - A sensitivity case is performed assuming the loss of offsite AC power at the inception of the LOCA event. The base assumption is that the RCPs operate until tripped by an "S" signal.

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Core axial power distributions - The standard Westinghouse core design axial distributions apply to AP600. Therefore, the same set of power shapes as in the RMR (Reference 1) are applied to AP600.

Reference: Letter, N. J. Liparulo (W) to R. C. Jones, Jr. (USNRC), "Revisions to Westinghouse Best-Estimate Methodology," NTD-NRC-95-4575, October 13, 1996.

OITS 5020

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7.e. Is the basis for the better comparison of the BLHL liquid flow in the Rev. 1 CCTF analysis the improved BL modeling in the revised calculation? This will clarify the response to Discussion Item 1b. in the May 17, 1996, NRC letter.

Response: Improved modeling of the broken loop in the simulation of CCTF Test 58 presented in WCAP-14171, Revision 1 produces the better comparison of WCOBRA/TRAC to data.

OITS 4658

7.f. WCOBRA/TRAC analysis no oscillations vs test data with oscillations. Westinghouse did not clarify the reasons for differences between the code results and the data for the core and downcomer differential pressure differences or the steam flows in the cold legs or the liquid flows in the hot and cold legs. (Discussion Item 6c, May 17, 1996, letter).

Response: For further discussion of WCOBRA/TRAC not predicting the oscillations in CCTF Test 58, refer to the response to 2/26 set Question 8. The core and downcomer differential pressure differences in Test 58 are predicted well by the code, as shown in WCAP-14171, Revision 1 Figures 3.1-35B and 3.1-36B. The steam flows in the cold legs and the liquid flows in the hot and cold legs are also predicted well in the respective WCAP-14171, Revision 1 figures, during the 500 second time period of interest until fuel rod quench occurs; the sole exception to this is the Loop 1 cold leg steam mass flow, which is overpredicted by the code.

OITS 4659

12.g. On page 4-16, Westinghouse discussed the basis for concluding that the uncertainty for reactor coolant pumps in 3- / 4-loop plants could be applied to AP600. However, Westinghouse needs to provide a comparison for the AP600 pumps as in CQD, Volume 5, Appendix C. It is the information provided there that determines the pump uncertainty.

Response: As noted in the response to item 1(i)1, the homologous curves of the AP600 RCP are similar to those of other Westinghouse RCPs. Therefore, the sources used to obtain the uncertainty values for single-phase RCP performance data in 3-loop and 4-loop plants are equally applicable to the AP600 analysis.

As in CQD Volume 5, Appendix C, and RMR Section 3.1.2, the large uncertainty associated with two-phase RCP data in the dissipative mode is not important. The Appendix C discussion that demonstrates this is based on the IP2 WCOBRA/TRAC analysis. CQD Figures 22-2-4 and 22-2-5 show the IP2 intact and broken loop RCP inlet void fractions. For purposes of comparison, the intact and broken loop RCP inlet void fractions from an AP600 DECLG break case are presented as Figures 12.g-1 and 2; these void fraction profiles at the RCP entrance are similar to the identified CQD figures. Because the void fraction inlet condition and the pump homologous curves of the AP600 both agree well with the 3/4-loop plant cases, and the blowdown progression in the intact and broken loops from positive head into the dissipative mode does as well, the pump model uncertainty approach developed for 3-loop and 4-loop plants applies to the AP600 SSAR analysis.

OITS 4685

FIGURE 12.g-1

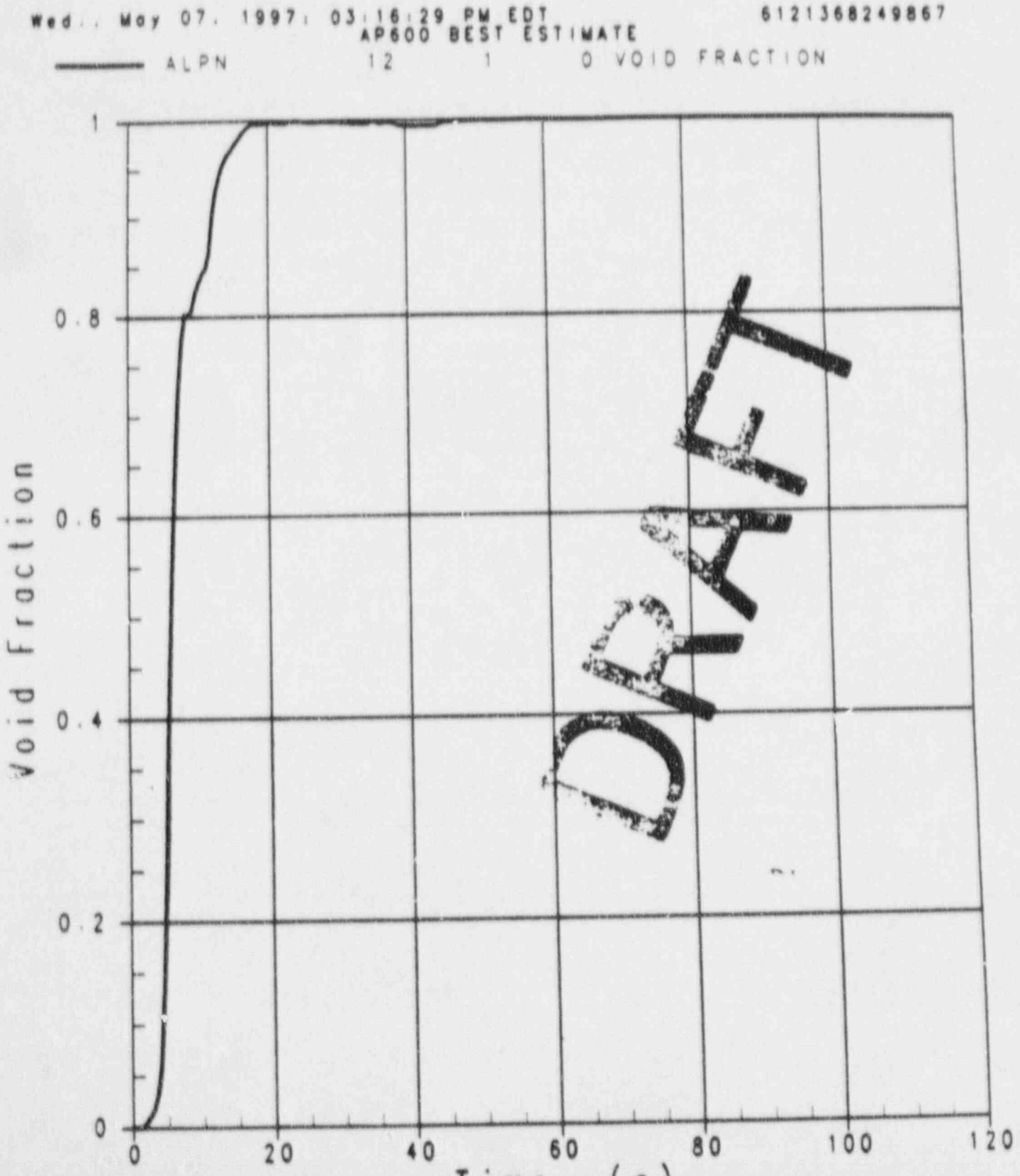
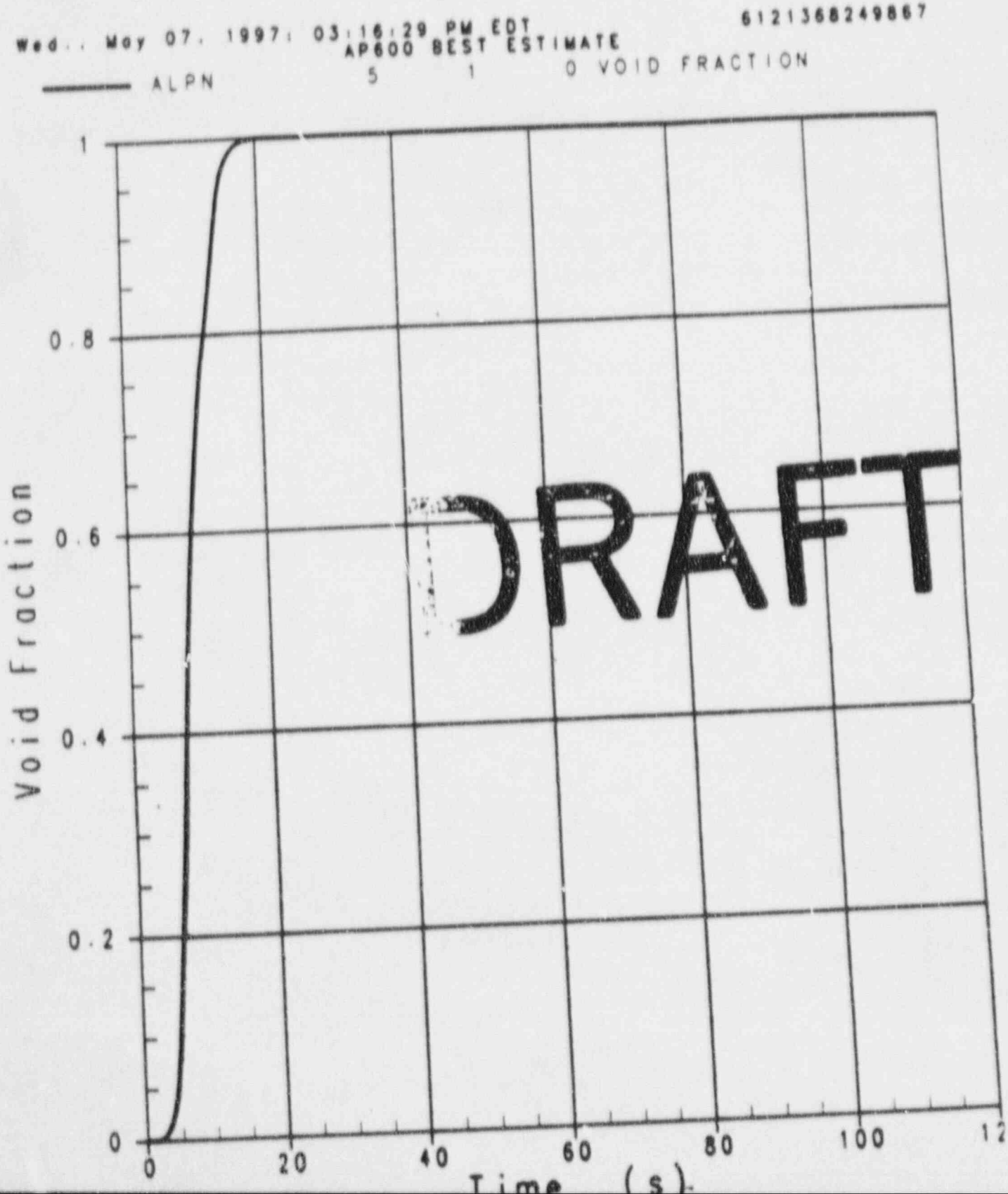

Wed., May 07, 1997: 03:16:29 PM EDT
6121368249867
AP600 BEST ESTIMATE
ALPN 12 1 0 VOID FRACTION
Void Fraction
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
DRAFT

FIGURE 12.9-2


Wed., May 07, 1997: 03:16:29 PM EDT
AP600 BEST ESTIMATE
6121368249867
ALPN 5 1 0 VOID FRACTION
Void Fraction
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
12
Time (s)
DRAFT

13. On page 4-24, Westinghouse stated the thermal-hydraulic run matrix was developed to include the effects of the limiting split break. Clarify this statement as Table 4.5-1 does not show split breaks. On page 4-25, Westinghouse stated split breaks would be investigated further if it proves more limiting than the double-ended guillotine break. Provide additional information to clarify what Westinghouse meant by this statement.

Response: Table 15.6.5-8 in the AP600 SSAR presents the results of the spectrum of cold leg split breaks performed with the bounding plant initial conditions and power distribution to identify the limiting discharge coefficient. The calculated PCT of the limiting split break (CD= 2.0) is lower than that for the reference DECLG break case. The first reflood peak of the CD= 1.0 split break is slightly higher than the corresponding temperature of the reference DECLG case. Consistent with the general approach outlined in the Reference, the 95th percentile reflood PCT for the limiting split break transient was compared to the 95th percentile PCT result from the initial Monte Carlo simulation for the DECLG break (i.e., the Monte Carlo simulation prior to applying the superposition/ validation correction). Table 15.6.5-9 in the SSAR shows the limiting split break is less limiting in PCT performance than the 95th percentile value for the DECLG break, so no further analysis is necessary.

Per Regulatory Guide 1.157, subsection 4.4, the evaluation of peak cladding temperature at the 95% probability level need only be performed for the worst-case break identified by the break spectrum analysis in order to demonstrate conformance with 10CFR50.46 paragraph (b). The nominal PCT values calculated by WCOBRA/TRAC for the non-limiting split breaks, shown in SSAR Table 15.6.5-8, together with the 95th percentile PCT for the limiting CD=1.0 split presented in Table 15.6.5-9, comprise the AP600 large break LOCA best estimate methodology split break results.

OITS 4692

Reference:

Letter, N. J. Liparulo (W) to F. R. Orr (USNRC), "Docketing of Supplemental Information Related to WCAP-12945-P," NSD-NRC-96-4744, June 12, 1996.

15. Reference 1 only discussed the PCT calculation. 10 CFR 50.46, part b, includes other criteria to be met. Clarify how the AP600 methodology accounts for the other criteria.

Response: The WCOBRA/TRAC-predicted cladding oxidation associated with the transients analyzed is zero because the calculated cladding temperatures are so low. In the HOTSPOT runs to investigate the local model variable impact on calculated PCT, the 95th percentile oxidation at the peak location is 0.2%. In light of these results, and because the 95th percentile PCT is below 1700F (SSAR Table 15.6.5-9), the local metal-water reaction is minimal for the AP600 large break LOCA event, as is the core average metal-water reaction value. The conclusion drawn from these results is the 10CFR50.46 criteria of 17% maximum local fuel rod oxidation and 1% maximum core-wide fuel oxidation are met with margin, and no further runs are necessary to show compliance (Ref. AP600 SSAR Subsection 15.6.5.4A.3.5).

At the calculated temperatures in Table 15.6.5-9, fuel rod rupture is not predicted to occur. Therefore, the core geometry remains unaffected and remains coolable throughout the transient. Separate calculations are performed in SSAR Section 15.6.5.4C to show that in the long term the AP600 exhibits adequate ECCS performance for the large break (and other) LOCA events.

OITS 4695