Westinghouse

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

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

Direct tel: 412-374-4728
Direct fax: 412-374-5005
e-mail: vijukrp@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP/NRC1678

February 2, 2004

SUBJECT: Transmittal of Responses to AP1000 DSER Open Items

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

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

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

D063

February 2, 2004

Correspondence with respect to the application for withholding should reference AW-04-1788, and should be addressed to James A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

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

Very truly yours,

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

/Enclosure

1. Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit AW-04-1788.

/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1678
2. Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated February 2, 2004
3. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated February 2, 2004

Enclosure 1

Westinghouse Electric Company
Application for Withholding and Affidavit

Westinghouse

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

February 2, 2004

AW-04-1788

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

ATTENTION: Mr. John Segala

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

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

Dear Mr. Segala:

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

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject documents. In conformance with 10 CFR Section 2.790, Affidavit AW-04-1788 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

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

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-04-1788 and should be addressed to the undersigned.

Very truly yours,

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

/Enclosures

AW-04-1788

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

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

James A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company, LLC

Sworn to and subscribed
before me this 2nd day
of February, 2004

Notary Public

Notarial Seal
Sharon L. Fiori, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires January 29, 2007
Member, Pennsylvania Association Of Notaries

(1) I am Manager, Regulatory Compliance and Plant Licensing, of the Westinghouse Electric Company LLC ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Electric Company, LLC.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Attachment 2 as Proprietary Class 2 in the Westinghouse Electric Co., LLC document: (1) "AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Response."

This information is being transmitted by Westinghouse's letter and Application for Withholding Proprietary Information from Public Disclosure, being transmitted by Westinghouse Electric Company letter AW-04-1788 to the Document Control Desk, Attention: John Segala, CIPM/NRLPO, MS O-4D9A.

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

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

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

Further this information has substantial commercial value as follows:

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

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

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

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

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for performing and analyzing tests.

Further the deponent sayeth not.

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Copyright Notice

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Docket No. 52-006

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PROPRIETARY INFORMATION NOTICE

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

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

February 2, 2004

Attachment 1

List of

Proprietary and Non-Proprietary Responses

Table 1

"List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1678"

Appendices for OI 21.5-2P**	Appendices for OI 21.5-2P**
Appendix 1P: Email dated 1/27/04*	Appendix 1: Email dated 1/27/04
Appendix 2P: Email dated 1/28/04*	Appendix 2: Email dated 1/28/04
Appendix 3P: Email dated 1/29/04*	Appendix 3: Email dated 1/29/04
Appendix 16P: Email dated 1/30/04*	Appendix 4: Email dated 1/27/04
Appendix 17P: Email dated 2/2/04*	Appendix 5: Email dated 1/28/04
Appendix 18P: Email dated 2/2/04*	Appendix 6: Email dated 1/29/04
	Appendix 7: Email dated 1/29/04
	Appendix 8: Email dated 1/29/04
	Appendix 9: Email dated 1/29/04
	Appendix 10: Email dated 1/29/04
	Appendix 11: Email dated 1/29/04
	Appendix 12: Email dated 1/29/04
	Appendix 13: Email dated 1/29/04
	Appendix 14: Email dated 1/29/04
	Appendix 15: Email dated 1/30/04
	Appendix 16: Email dated 1/30/04
	Appendix 17: Email dated 2/2/04
	Appendix 18: Email dated 2/2/04
	Appendix 19: Email dated 1/28/04**
* Proprietary	

**Some Appendices are also applicable to OI 15.2.7-1

***See email message in each attachment for transmittal time.

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Attachment 3

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

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Appendix 1

Email dated 1/27/04

"APEX ADS-4 Line Resistance"

Appendix 1
DCP/NRC1678
Docket No. 52-006

February 2, 2004

Conway, Elizabeth M. (Alfieri)

From: Gongaware, Jacqueline J.
Sent: Tuesday, February 03, 2004 8:42 AM
To: Conway, Elizabeth M. (Alfieri)
Subject: FW: FW: APEX ADS-4 Line Resistance

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:33 AM
To: Gongaware, Jacqueline J.
Subject: FW: FW: APEX ADS-4 Line Resistance

From: Vijuk, Ronald P.
Sent: Tuesday, January 27, 2004 11:30 AM
To: 'Bajorek, Steve'
Cc: John Segala; Joseph Colaccino; Wright, Richard F.
Subject: RE: FW: APEX ADS-4 Line Resistance

21.5-2P Item APEX Scaling 012704.doc

Steve,

Above file shows which APEX resistances are measured and which are calculated.

Ron

From: Stephen Bajorek(SMTP:SMB4@nrc.gov)
Sent: Tuesday, January 20, 2004 8:00 PM
To: vijukrp@westinghouse.com
Cc: John Segala; Joseph Colaccino; wrightrf@westinghouse.com
Subject: Re: FW: APEX ADS-4 Line Resistance

Thanks. Please be sure to characterize the DVI and CMT resistances you sent in the Jan 9 response as either measured or estimated.

Steve

>>> "Vijuk, Ronald P." <vijukrp@westinghouse.com> 01/20/04 04:15PM >>>
Steve,

Here are the measured APEX ADS4 resistances. We missed getting the measured values for these in the item 10 table of our response.

Ron

> ----------
> From: Wright, Richard F.
> Sent: Tuesday, January 20, 2004 4:02 PM
> To: Vijuk, Ronald P.
> Subject: APEX ADS-4 Line Resistance
>
> Ron,
>
> Please forward to Steve.
>
> ADS4-1 (single valve failure) 2.262e-03 ft/gpm2
> ADS4-1 (no failure) 3.292e-04 ft/gpm2
>
> ADS4-2 (single valve failure) 2.432e-03 ft/gpm2
> ADS4-2 (no failure) 3.217e-04 ft/gpm2
>
>
> Reference: OSU-F-09, AP1000 ADS 4 Discharge Line Flow Test, Rev. 1, May
> 2003
>
>
>

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

10. *Provide or verify the final design values for the AP1000 and APEX as configured for AP1000 testing. Figure 2-2 of Reference 2 shows the pressurizer attached to Loop 2. So, let loops "1" or "A" designate the non-pressurizer loop while loops "2" or "B" represent the pressurizer side. Line resistances should represent $R = K/A^2$ such that the single phase pressure drop across the line is given by $\Delta P = R * 0.5 * \rho V^2$.*

Requested parameters are provided in the following table.

a.c

Parameter	AP1000	APEX
R_{cmt1} ; CMT-1 resistance from CMT to vessel	3.547e-05 ft/gpm^2	
R_{cmt2} ; CMT-2 resistance from CMT to vessel	3.439e-05 ft/gpm^2	
$(L/A)_{cmt1}$; Inertial length from CMT-1 to DVI nozzle	257.9 ft-1	
$(L/A)_{cmt2}$; Inertial length from CMT-2 to DVI nozzle	258.6 ft-1	
$\Delta Z_{cmt\text{-}dvi}$; Elevation change from bottom of CMT to DVI centerline	2.309 m	
$\Delta Z_{cmt\text{-}boc}$; Elevation change from bottom of CMT to bottom of active core	25.62 ft	
V_{RPV} ; RPV volume	3559.75 ft3	
V_{UP} ; Upper plenum volume	691.91 ft3	
V_{LP} ; RPV volume below active core	440.31 ft3	
$\Delta Z_{prz\text{-}hl}$; Elevation change from bottom of pressurizer to HL centerline	19.23 ft	
$\Delta Z_{hl\text{-}dvi}$; Elevation difference between hot leg centerline and DVI line centerline	1.67 ft	
$\Delta Z_{dvi\text{-}boc}$; Elevation difference between DVI line centerline and bottom of active core	26.36 ft	
R_{SL} ; Pressurizer surge line resistance	1.796e-7 ft/gpm^2	
L_{SL} ; Surge line total length	88.87 ft	
R_{dvi1} ; Line resistance from IRWST to vessel through DVI line 1	9.206e-6 ft/gpm^2	

Westinghouse

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

a,c

Parameter	AP1000	APEX
R_{dvi2} ; Line resistance from IRWST to vessel through DVI line 2	1.035e-5 ft/gpm^2	
L_{dvi1} ; Line length from IRWST to vessel through DVI line 1	85.19 ft	
L_{dvi2} ; Line length from IRWST to vessel through DVI line 2	111.50 ft	
$\Delta Z_{irwst\text{-}dvi}$; Elevation change from bottom of IRWST to DVI line centerline	3.43 ft	
ΔZ_{irwst} ; IRWST minimum level (referenced from bottom of IRWST tank)	343 in	

R_{ads1} ; ADS-4-1 line resistance (single valve failure)	6.114e-07 ft/gpm^2	
R_{ads1} ; ADS-4-1 line resistance (no failure)	1.705e-07 ft/gpm^2	
R_{ads2} ; ADS-4-2 line resistance (single valve failure)	6.221e-07 ft/gpm^2	
R_{ads2} ; ADS-4-2 line resistance (no failure)	1.574e-07 ft/gpm^2	
$\Delta z_{ads\text{-}boc}$; Elevation difference between ADS-4 discharge to containment and bottom of active core	31.36 ft	
L_{ads1} ; Length of Loop 1 ADS-4 piping	14.86 ft	
L_{ads2} ; Length of Loop 2 ADS-4 piping	18.90 ft	
$\Delta Z_{sump\text{-}boc}$; Elevation difference between maximum sump level (determined by curb height) and bottom of active core	29.53 ft	

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Appendix 2

Email dated 1/28/2004
"NOTRUMP vs NRC05"

Gongaware, Jacqueline J.

February 2, 2004

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:33 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP vs NRC05

From: Vijuk, Ronald P.
Sent: Wednesday, January 28, 2004 6:36 PM
To: 'Joseph Colaccino'; 'Jennifer Uhle'; 'Bajorek, Steve'
Cc: 'John Segala'
Subject: NOTRUMP vs NRC05

nrc05_25p2.doc

Here are the comparisons for the beyond design basis test. We will generate the additional breakdown of ADS4 flows and integrals and send separately.

Ron

OSU AP1000 NT vs Test NRC-05
Pressurizer Pressure

Figure-1

OSU AP1000 NT vs Test NRC-05
Downcomer Pressure

Figure-2

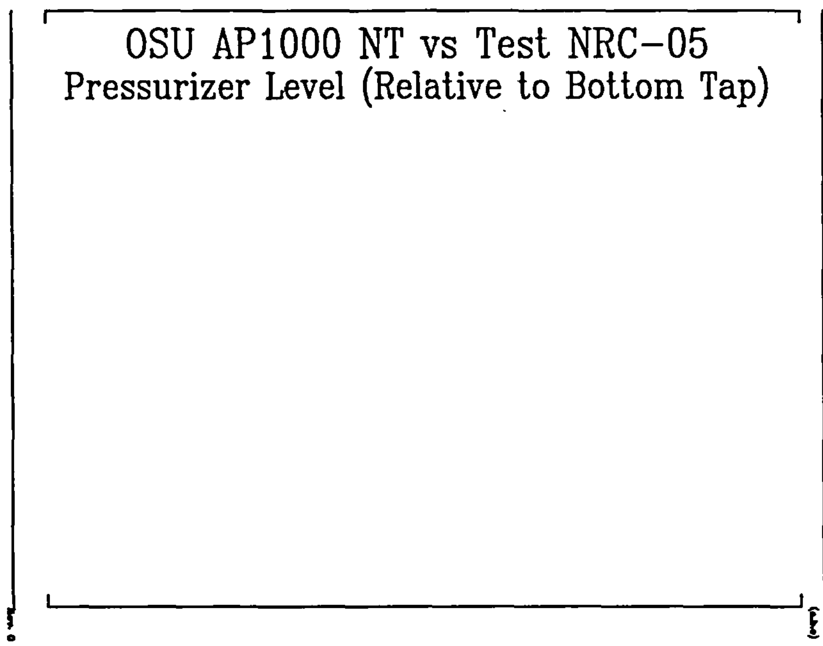

Figure-3

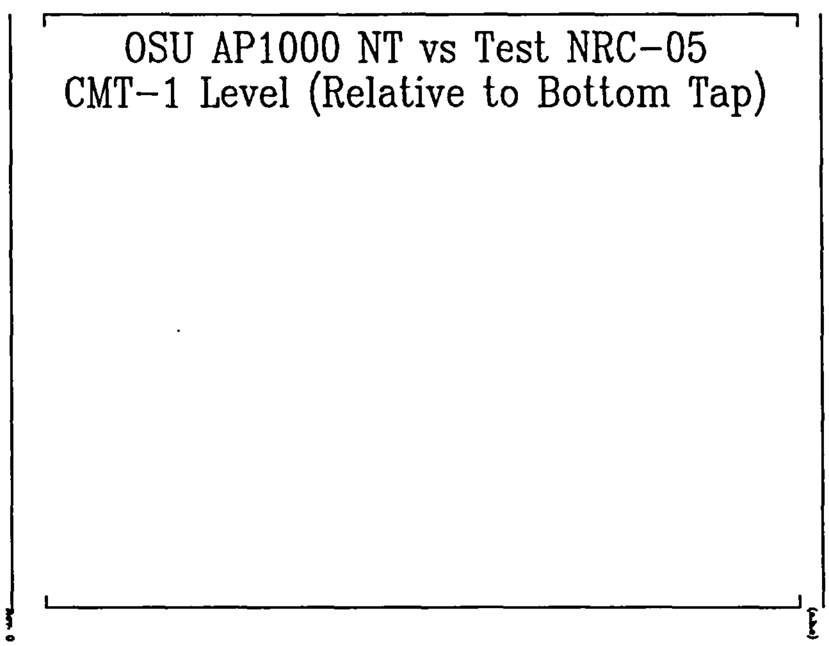

Figure-4

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OSU AP1000 NT vs Test NRC-05
CMT-2 Level (Relative to Bottom Tap)

Figure-5

OSU AP1000 NT vs Test NRC-05
CMT-1 Injection Line Mass Flow

Figure-6

Appendix 2
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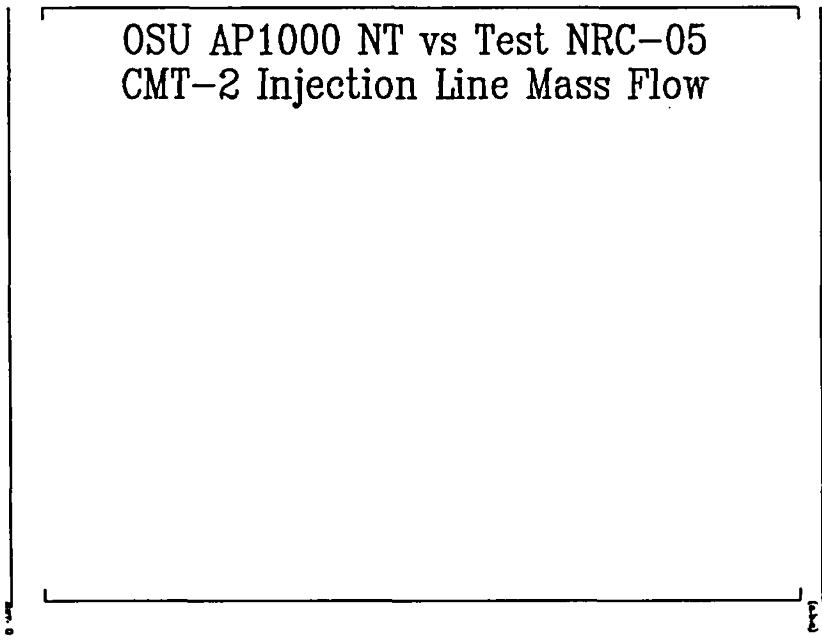

Figure-7

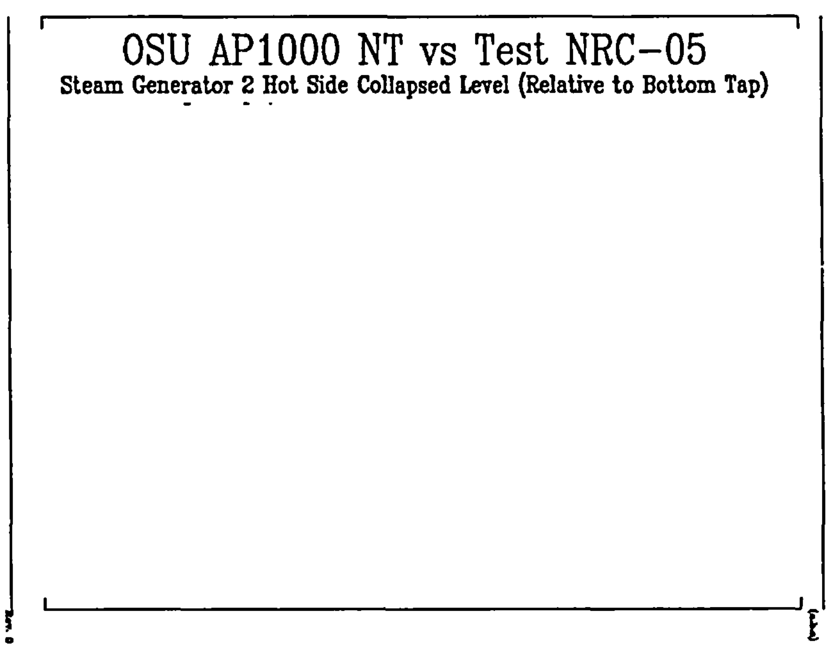

Figure-8

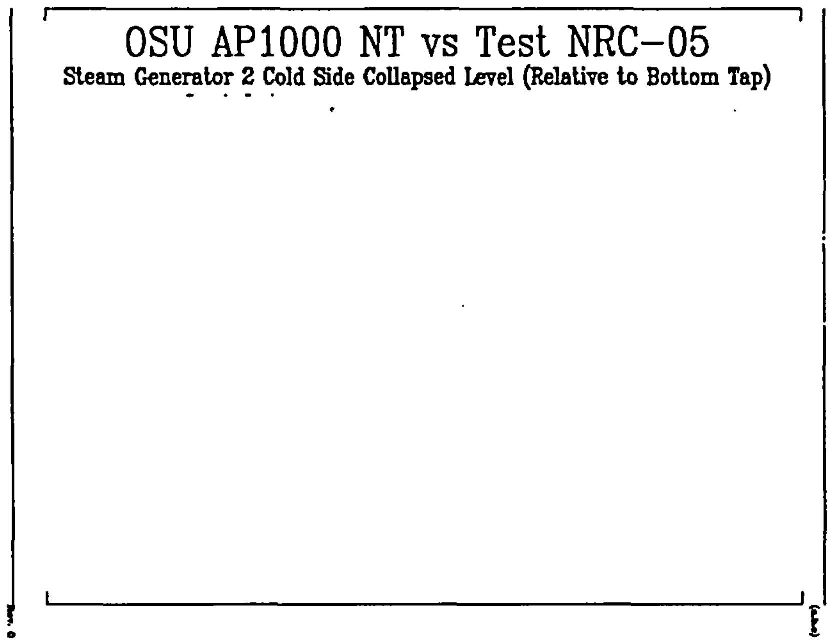

Figure-9

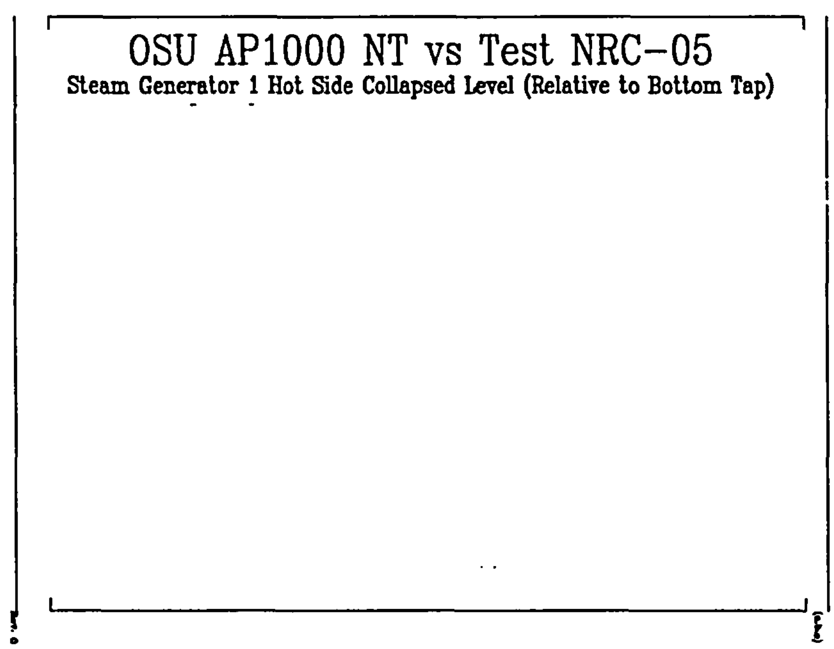

Figure-10

OSU AP1000 NT vs Test NRC-05
Steam Generator 1 Cold Side Collapsed Level (Relative to Bottom Tap)

Figure-11

OSU AP1000 NT vs Test NRC-05
ACC-1 Level (Relative to Bottom tap)

Figure-12

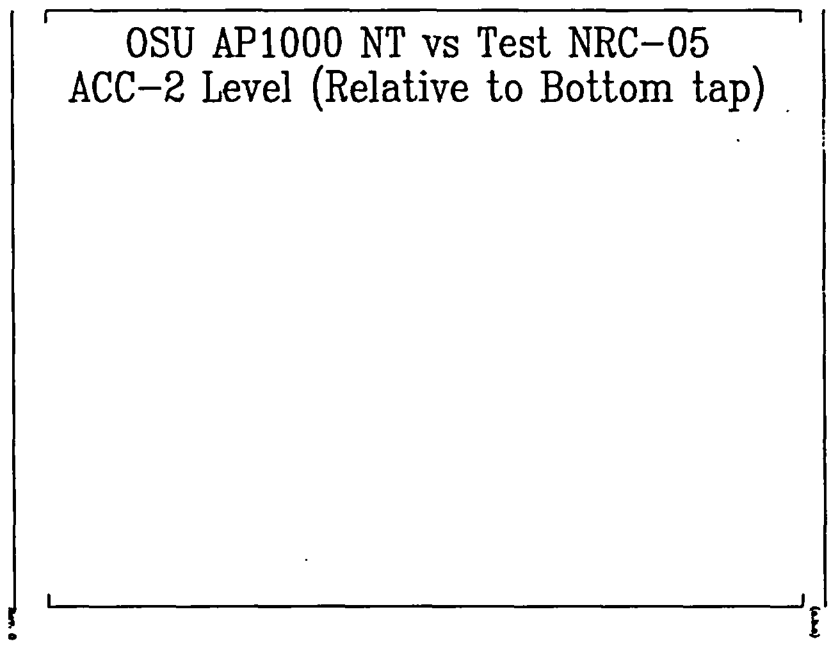

Figure-13

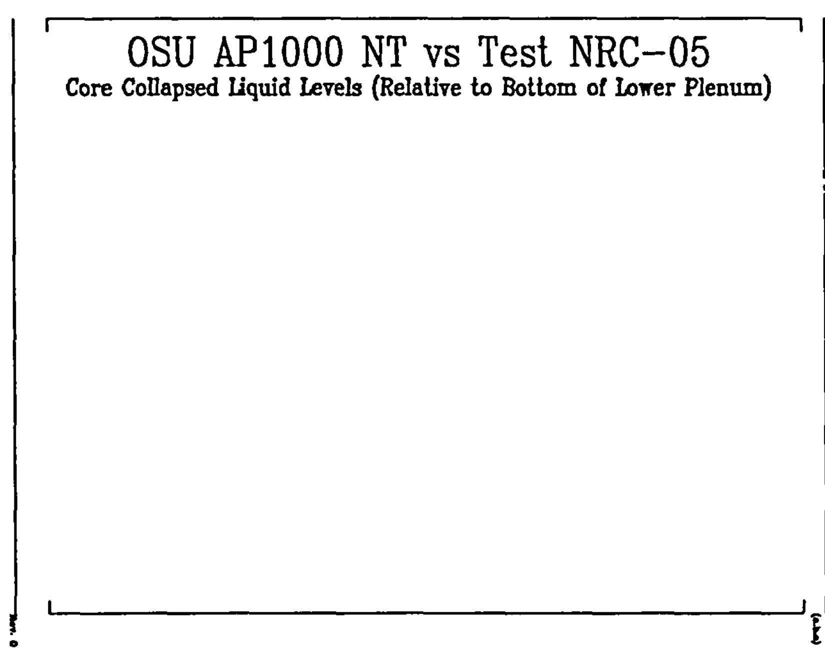

Figure-14

OSU AP1000 NT vs Test NRC-05
Average Core Void Fraction

Figure-15

OSU AP1000 NT vs Test NRC-05
Upper Plenum Collapsed Levels (Relative to Bottom of Lower Plenum)

Figure-16

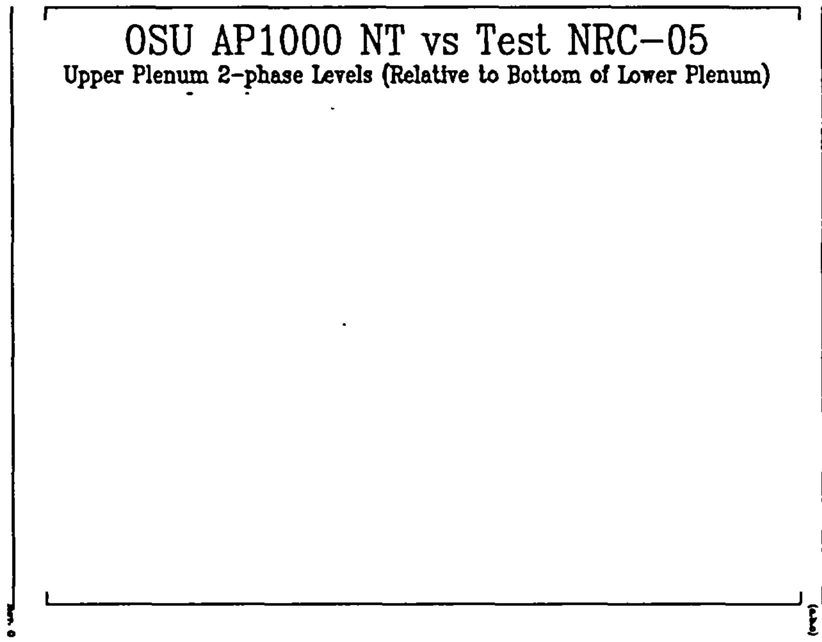

Figure-17

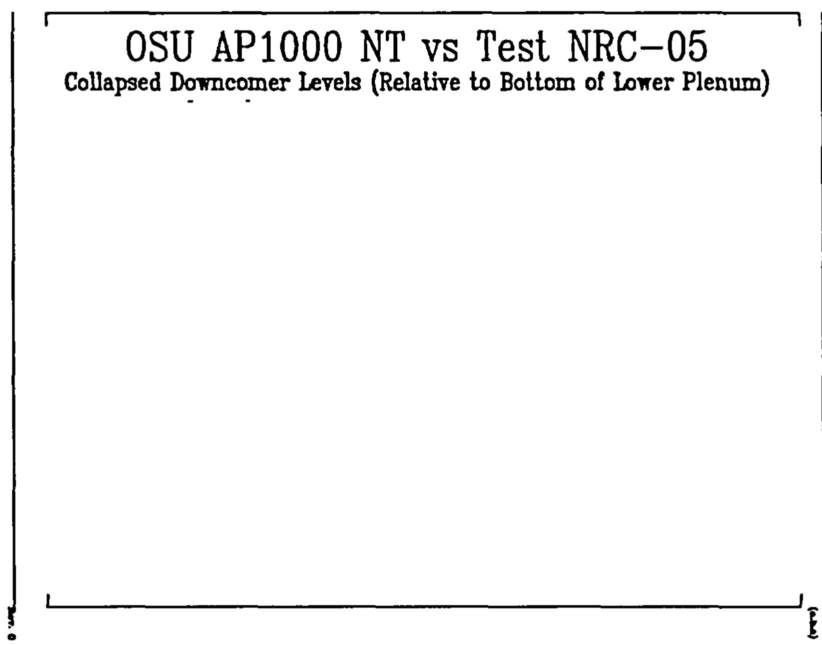

Figure-18

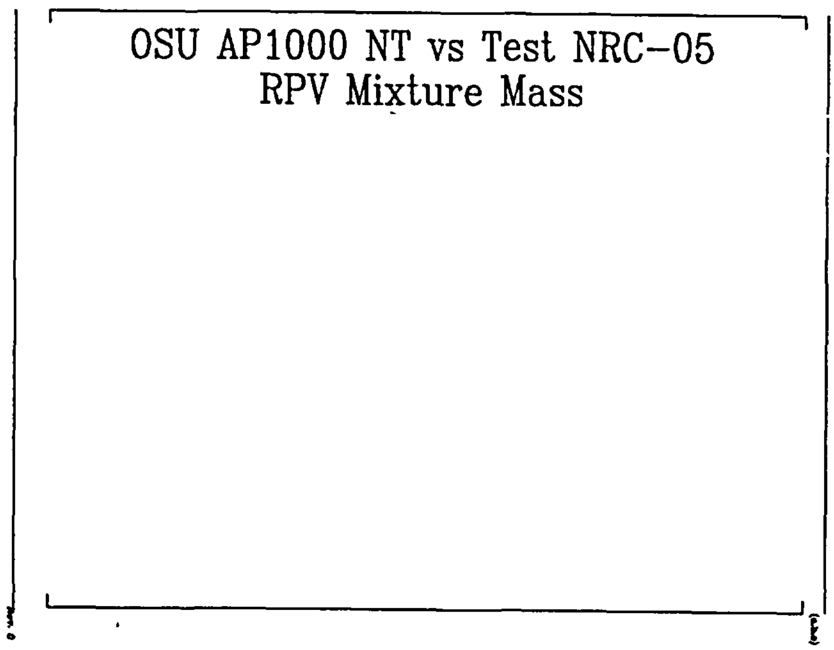

Figure-19

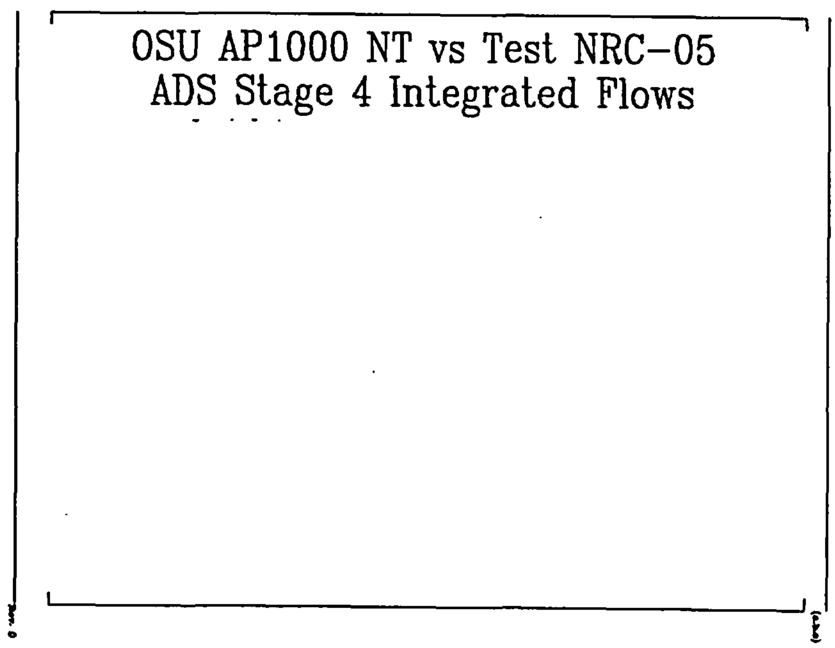

Figure-20

OSU AP1000 NT vs Test NRC-05
Vessel Side Integrated Break Flow

Figure-21

OSU AP1000 NT vs Test NRC-05
Total DVI Line 1 Flow

Figure-22

OSU AP1000 NT vs Test NRC-05
Total DVI Line 2 Flow

Figure-23

OSU AP1000 NT vs Test NRC-05
Core Inlet Temperatures

Figure-24

OSU AP1000 NT vs Test NRC-05
Core Outlet Temperatures

Figure-25

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Appendix 3

Email dated 1/29/2004
"NOTRUMP vs NRC05 ADS4 plots"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:31 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP vs NRC05 ADS4 plots

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 9:38 AM
To: 'Joseph Colaccino'; 'Jennifer Uhle'; 'Bajorek, Steve'
Cc: 'John Segala'
Subject: NOTRUMP vs NRC05 ADS4 plots

Folks,

nrc05_steve.doc

Here are the ADS4 plots Steve requested.

Ron

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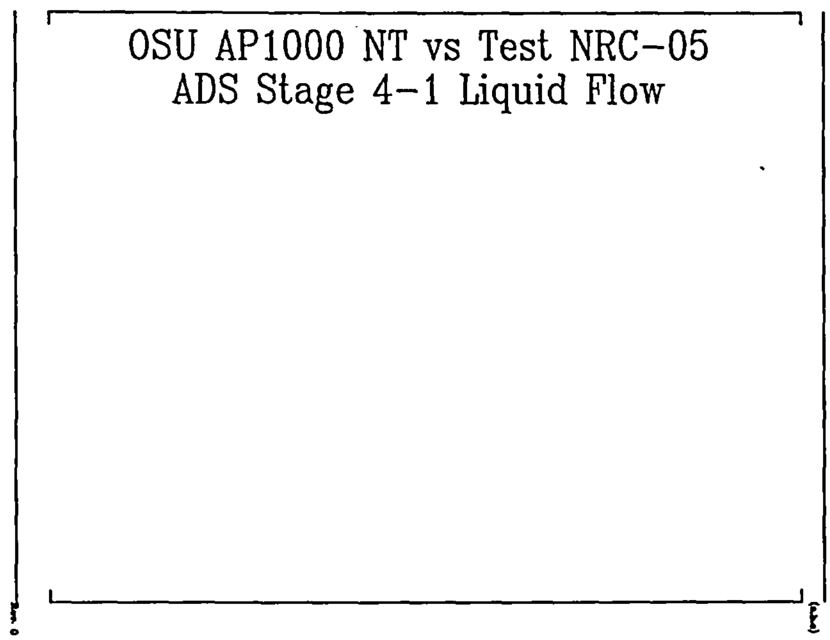

Figure-1 Test NRC-05, ADS 4-1 Liquid Discharge

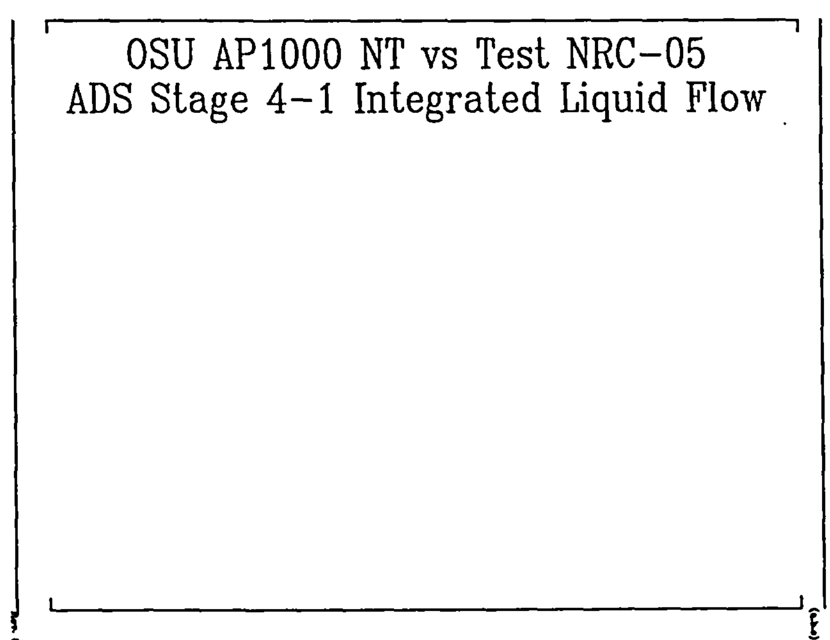

Figure-2 Test NRC-05, ADS 4-1 Integrated Liquid Discharge

OSU AP1000 NT vs Test NRC-05
ADS Stage 4-1 Vapor Flow

Figure-3 Test NRC-05, ADS 4-1 Vapor Discharge

OSU AP1000 NT vs Test NRC-05
ADS Stage 4-1 Integrated Vapor Flow

Figure-4 Test NRC-05, ADS 4-1 Integrated Vapor Discharge

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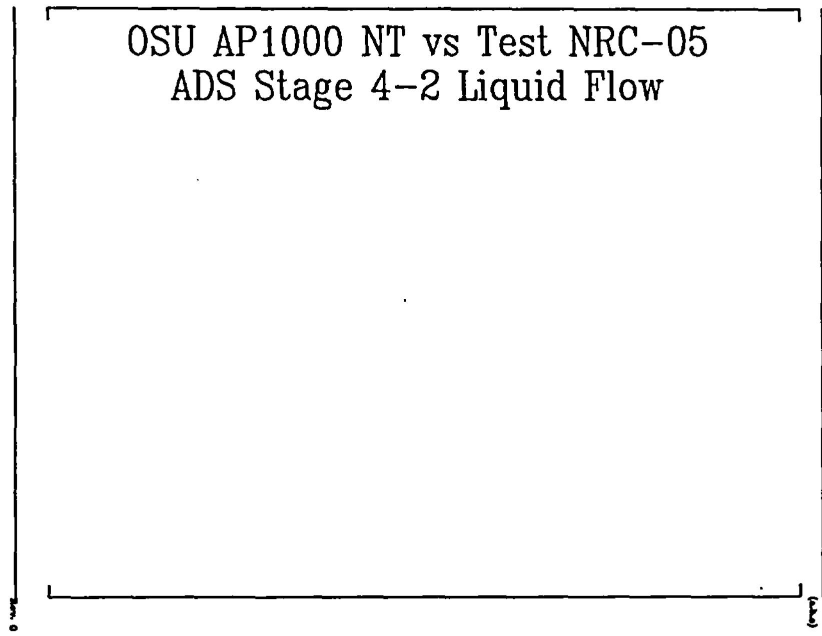


Figure-5 Test NRC-05, ADS 4-2 Liquid Discharge

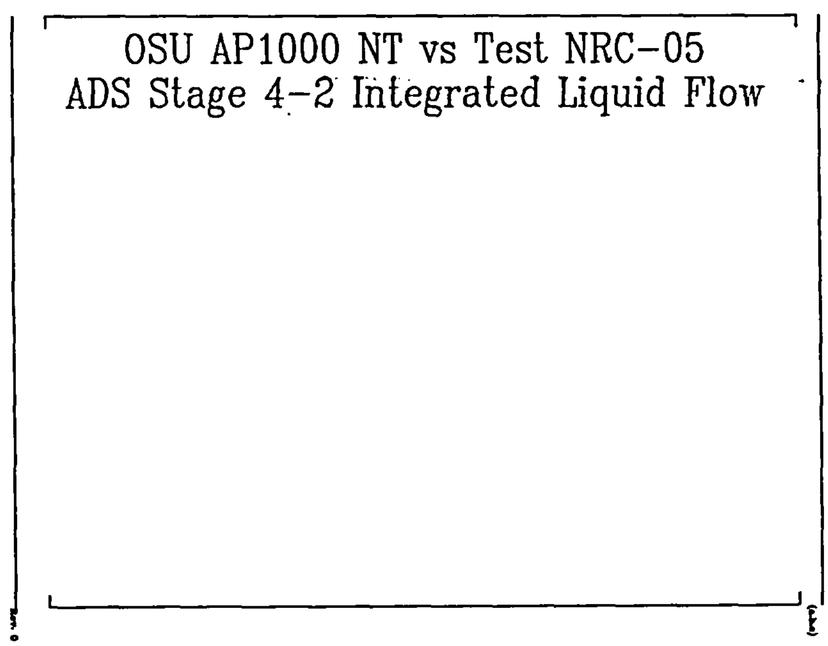


Figure-6 Test NRC-05, ADS 4-2 Integrated Liquid Discharge

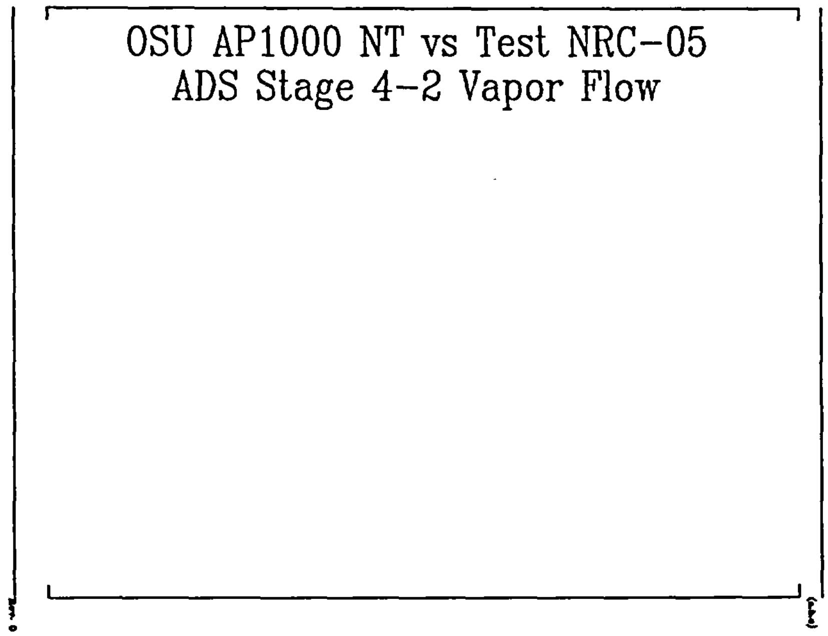


Figure-7 Test NRC-05, ADS 4-2 Vapor Discharge

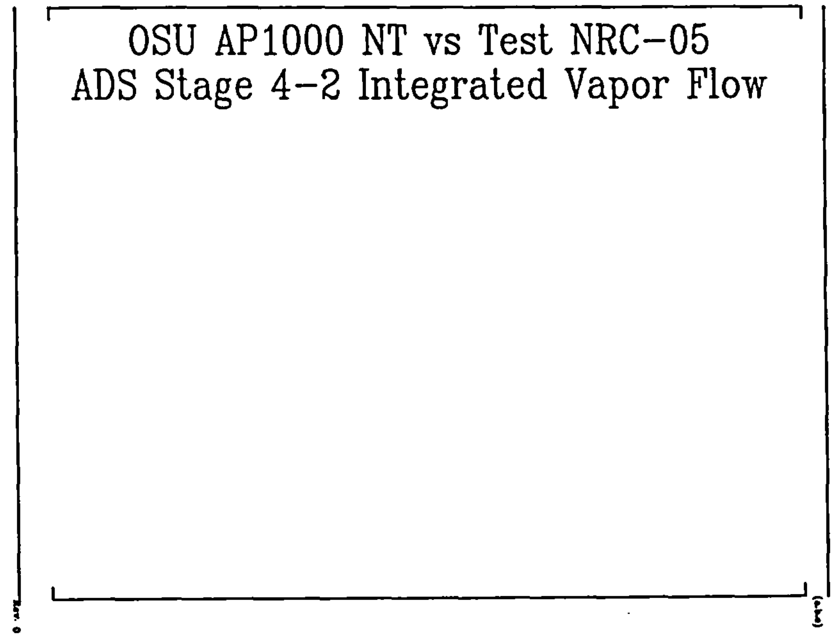


Figure-8 Test NRC-05, ADS 4-2 Integrated Vapor Discharge

DCP/NRC1678
Docket No. 52-006

February 2, 2004

Appendix 4

Email dated 1/27/04

"ADS4 DP"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:37 AM
To: Gongaware, Jacqueline J.
Subject: FW: ADS4 DP

From: Vijuk, Ronald P.
Sent: Tuesday, January 27, 2004 4:23 PM
To: 'John Segala'; 'Jennifer Uhle'
Cc: 'Joseph Colaccino'; Schulz, Terry L.; Cummins, Ed
Subject: ADS4 DP

John, Jennifer,

The file below is an AP600 RAI response that provides a good description of the detailed ADS4 pressure drop calculation (that we call FLOAD4) that we use to come up with the NOTRUMP adjustment factor to ADS4 resistance to account for momentum flux terms. Reviewing this has helped our understanding of how we should be estimating the ADS4 pressure drop if we had single phase steam. When Terry and Len discussed this they were calculating single phase steam DP by applying Darcy (using the incompressible resistance from Crane and an average steam density between inlet and exit conditions) and then adding another pressure loss term for acceleration. This added term for acceleration results in double counting because the acceleration DP due to area change is already in the incompressible resistance and because using the average density in Darcy accounts for acceleration due to compressibility effect. Our conclusion is that the Darcy term alone, using the incompressible resistance from Crane and an average steam density between inlet and exit conditions, is an appropriate method. Alternatively the Crane paper provides a Darcy equation that includes a Y factor to account for the acceleration due to compressibility. This Crane compressible method is compared to the detailed FLOAD4 calculation for single phase steam in the AP600 RAI file below and shows the detailed model compares well to the Crane compressible method. Terry's understanding is that using one of these two methods should help Len's evaluation show acceptable results for the DEDVI with bounding assumptions of 14.7 psia exit pressure and 192 F injection water temperature..

We would like to have a conference call to discuss this further.

Ron

OITS 6441.pdf

Question 440.796F Part a (OITS - 6441)

The following commitments were made by Westinghouse at the conclusion of the December 10, 1997 ACRS T/H Subcommittee meeting and must be fulfilled.

a. Momentum flux - Deficiencies (in the NOTRUMP model) are to be benchmarked against additional detailed calculations using actual two phase flow equations that include the effects of compressibility, including the condition of constant entropy.

RESPONSE:

In section 1.7.5 of the Final Validation Report for NOTRUMP[1], an assessment was performed of the effect of ignoring the momentum flux terms. This initial assessment indicated that while the ADS1-3 valves and piping would experience a small effect due to fluid acceleration, in the ADS4 piping the effect could be significant. To further evaluate whether the lack of momentum flux terms for this component in NOTRUMP could lead to erroneous results, a detailed pipe model was developed. The model integrates the momentum and energy equations along a detailed mesh representing the ADS4 piping from the hot leg to the squib valves, where the minimum area occurs. First, the model of the ADS4 piping will be described. A comparison will then be made with flows calculated by NOTRUMP.

Detailed model of the ADS4 piping

Figures 440.796f-1 and 440.796f-2 show two views of the ADS4 valves and their piping. A pipe of inner diameter 10.125 inches (0.56 sq. ft area) is connected to the top of the hot leg. An elbow turns the pipe to a horizontal configuration. About 7 feet downstream, a horizontal tee diverts some of the flow into the 8.5 inch (0.39 sq. ft area) piping leading to one of the two valve packages (the pipe from the tee to the valves is designated "branch 2" in this response). Downstream of the tee in the main pipe, a reducer leads to the 8.5 inch diameter piping which will lead to the other valve package (the main piping and this valve package are designated "branch 1").

The flow resistance (irrecoverable losses due to friction and form loss) through this piping network has been conservatively established for incompressible flow. Bounding assumptions have been used for pipe lengths (about 46 feet total, in contrast to the typical configuration shown in Figure 440.796f-1), and fittings (a total of 6 elbows are assumed in branch 1, and 7 elbows in branch 2, compared with the smaller number in the typical configuration). The total irrecoverable loss coefficient for this conservative configuration was estimated as 4.2, based on the nominal flow area through both branches (2*0.39 sq. ft), assuming complete turbulence (constant) friction factors.

This piping network was simulated with a total of 442 cells, as illustrated in Figure 440.796f-3. In this figure, each "+" represents one cell boundary or node. The cell length is 0.25 feet, with smaller increments taken at area changes in the reducer and gate valve (there are also area changes at the tees from the hot leg into branch 1, and from branch 1 to branch 2, but these are treated with special models as discussed below).

Momentum and Energy Equations

The momentum and energy equations to be integrated along the piping network are simplified equations in which steady state, equilibrium, homogeneous, adiabatic conditions have been assumed. The assumption of homogeneity (zero slip) results in a high estimate of the effect of acceleration on the pressure gradient, as pointed out in Section 1.7.4 of the NOTRUMP Final Validation report. The momentum and energy equations in this form are:

$$\frac{dP}{dz} = -\frac{f v_f}{2D}\left(\frac{W}{A}\right)^2 \Phi_{lo}^2 - \frac{W}{A}\frac{du}{dz}$$

$$\frac{d}{dz}\left(h + \frac{u^2}{2}\right) = 0 \qquad 1(a,b)$$

where h and u are the mixture enthalpy and velocity, W is the mixture flow rate, v_f is the liquid specific volume, Φ_{lo}^2 is the two phase multiplier, f is the friction factor and D and A are the pipe diameter and area.

Since:

$$W = \frac{uA}{v} \qquad 2$$

where v is the mixture specific volume, and W is constant, this substitution can be made into equations 1 and 2. In addition, since for homogeneous flow:

$$h = h_f + xh_{fg}$$
$$v = v_f + xv_{fg} \qquad 3(a,b)$$

where x is the flow quality W_v/W, equations 1 and 2 can be set up in terms of pressure and quality. After some manipulation,

$$\frac{dx}{dz} = \frac{G^2 v^2 \frac{1}{A}\frac{dA}{dz} - \left(\frac{\partial h}{\partial P} + G^2 v \frac{\partial v}{\partial P}\right)\frac{dP}{dz}}{h_{fg} + G^2 v v_{fg}} = \frac{a}{c}\frac{1}{A}\frac{dA}{dz} - \frac{b}{c}\frac{dP}{dz} \qquad 4$$

$$\frac{dP}{dz} = \frac{-\frac{f v_f}{2D} G^2 \Phi_{lo}^2 + \frac{g}{v}\frac{dy}{dz} + G^2\left(v - v_{fg}\frac{a}{c}\right)\frac{1}{A}\frac{dA}{dz}}{1 + G^2\left(\frac{\partial v}{\partial P} - v_{fg}\frac{b}{c}\right)} \qquad 5$$

where dy/dz is the elevation gradient.

Friction and form losses

Friction and form losses are calculated using two phase multipliers developed by Collier and others[2]. The two phase multiplier for losses in both pipes and fittings takes the basic form:

$$\Phi_{lo}^2 = (1-x)^2 \Phi_l^2$$
$$\Phi_l^2 = 1 + \frac{C}{X} + \frac{1}{X^2} \qquad 6(a,b)$$

where C is a value which depends on the fitting or pipe, and on the fluid conditions, and where X is the Lockhart-Martinelli parameter, defined by:

$$X = \left(\frac{\left(\frac{dP}{dz} \right)_l}{\left(\frac{dP}{dz} \right)_v} \right)^{1/2} \cong \frac{1-x}{x} \sqrt{\frac{v_f}{v_g}} \qquad 7$$

In equations 6 and 7 above, it has been assumed that the single phase loss coefficient and/or friction factors are independent of Reynolds number (mass velocities are sufficiently high such that this assumption is reasonable).

Tees

Tees require special treatment because flow splitting and phase separation will occur. Methods summarized in Lahey (1984)[3] were used to calculate pressure losses. These methods attribute pressure changes in the main pipe due to momentum change (modified by a pressure recovery term K_{1-2}), defined by (equations [19] and [20] of Reference 2):

$$\Delta P_{1-2} = \frac{K_{1-2}}{2} \left(v_2' G_2^2 - v_1' G_1^2 \right)$$

$$K_{1-2} = .11 + \frac{5.0}{\left(\frac{G_1 D_1}{\mu_f} \right)^{.17}} \qquad 8(a,b)$$

where 1 denotes the main pipe upstream of the tee, 2 denotes the main pipe downstream of the tee, and (assuming homogeneous conditions):

$$v_1' = v_f + x_1 v_{fg}$$

$$v_2' = v_f + x_2 v_{fg} \qquad 9(a,b)$$

where x_1 and x_2 are the flow qualities upstream and downstream of the tee (see below).

The pressure change into the branch (denoted as 1) consists of an acceleration change and a form loss. The form loss is calculated as described in the previous section. The acceleration change is given by (equation [13] of Reference 3 for homogeneous flow):

$$\Delta P_{1-3} = \frac{1}{2}\left(v_3^{'} G_3^2 - \frac{v_1^{'2} G_1^2}{v_3^{'}}\right) \quad 10$$

The assumption is made that the flow is locally incompressible at the tee junction.

The flow split at the tee is calculated using correlations recommended by Seeger (1986)[4]. These correlations describe the quality into the branch (3) in terms of:

$$\frac{x_3}{x_1} = f\left(\frac{G_3}{G_1}\right) \quad 11$$

The functional form depends on the tee orientation. For the vertical tee (from the hot leg), equation [2] of Reference 4 is applied, while for the horizontal tee, equation [8] of Reference 4 is applied.

Critical flow at the squib valve

By careful integration of the momentum and energy equation, it is possible to find the maximum flowrate (choked flow) in a pipe, by finding the point at which the denominator in the momentum equation approaches zero. Because the last valve in each branch is the minimum flow area (a design requirement), choking is likely to occur at this valve (this was confirmed by later calculations). The HEM was applied at the last cell in each branch, using as reservoir conditions (for branch 1, for example):

$$h_{01} = h_{j1} + \frac{u_{j1}^2}{2} \quad 12$$

$$s_{01} = s_f + x_{j1} s_{fg}$$

where j1 is the next to last node in branch 1. The flow was assumed to be adiabatic and frictionless from this point to the squib valve minimum area. A similar calculation was performed for branch 2.

Calculated results

The equations above were implemented in a small computer program; the flowrate through ADS4 was calculated for a range of pressures (20 to 80 psia in the hot leg, 14.7 psia at the exit) and qualities (20% to 100% in the hot leg). The model was benchmarked to the incompressible total loss coefficient by running a case with a hot leg pressure of 15 psia and 100% quality. At this low pressure difference, effects of compressibility and acceleration are minimal and the predicted loss should agree with the incompressible value. An adjustment of approximately 10 percent in the overall resistance was required to achieve good agreement with the loss coefficient of 4.2. It was also assumed that all the hot leg flow entered the ADS4, for maximum acceleration. Figures 440.796f-4 and 5 show the static pressure and fluid velocity in the piping for a hot leg pressure of 50 psia and a flow quality of 100%. There is an immediate 5 psi pressure drop at the entrance, then a pressure loss followed by a pressure recovery at the tee, then additional losses along the pipe and at each elbow. At the first valve, there is a pressure loss, then recovery, followed by a pressure loss (the irrecoverable loss due to the valve is applied at the valve exit). Figure 440.796f -5 shows that the fluid velocity within the pipe is highest at the hot leg entrance, reaching nearly 800 ft/s. Most of the acceleration occurs, however, at the squib valve.

Figures 440.796f -6 to 8 show conditions when the flow quality is 20%. In this case, phase separation occurs at the tee, with a higher quality mixture flowing into branch 2 (Figure 440.796f -8). Calculations assuming no separation occurs show that this phenomenon has a negligible effect on the amount of vapor which can be vented.

Vapor flow versus hot leg pressure for a range of flow qualities predicted by the model are shown in Figure 440.796f-9. The 100 percent quality data show good agreement with points estimated from a handbook, shown in Figure 1.7-9 of Reference 1. At approximately 40 psia, critical flow is calculated to occur at the squib valve, and the model and handbook data begin to diverge.

The model calculated data were used to generate a response surface which were then used to calculate ADS4 vapor flow, given hot leg pressure and quality from NOTRUMP. This comparison is shown in Figure 440.796f -10 for the time period between ADS4 opening and IRWST injection. These figures show good agreement between NOTRUMP and the detailed model, as long as critical flow conditions exist prior to 3000 seconds. The good agreement during choked flow indicates that the flow resistance upstream of the squib valve has a minor impact on the flow, even with the relatively high fluid velocities noted. When the flow becomes sub-critical, NOTRUMP predicts a higher vapor flow of about 20 percent (corresponding roughly to a 35 percent lower flow resistance). Overall, the total vapor vented is underpredicted by NOTRUMP soon after opening, then is overpredicted, as seen in Figure 440.796f-11. However, the NOTRUMP total vapor released is only about 5 percent higher at the time the IRWST comes on. Comparison of NOTRUMP and model details indicates that the difference during sub-critical flow can be attributed to:

a) Underestimation of the two phase pressure drop through fittings. The large number of elbows assumed in the ADS4 piping, for example, contributes to a 20 percent increase in flow resistance.
b) Underestimation of the acceleration terms. Even if the flow is no longer critical, fluid acceleration and expansion at low quality will contribute to increased pressure drop.

Conclusion

The over prediction by NOTRUMP of ADS4 vapor flow near the end of the transient is not considered to be a significant problem because of the bounding nature of the ADS4 piping which was modelled. As shown in Figure 440.796f-1, the number of elbows and lengths of piping in actual designs will be substantially less than what was assumed in the NOTRUMP calculation. In addition, pressure losses due to acceleration were maximized by assuming homogeneous fluid conditions.

REFERENCES:

[1] WCAP-14807,Revision 3.
[2] Collier, J. G., Convective Boiling and Condensation, 3rd Edition, Oxford-Clarendon press, 1994.
[3] Lahey, R. T., Nematollah, S., "The Analysis of Phase Separation Phenomena in Branching Conduits", Int. J. Multiphase Flow, Vol. 10, No. 1, 1984.
[4] Seeger, W., et al., "Two-Phase Flow in a T-Junction with a Horizontal Inlet", Int. J. Multiphase Flow, Vol. 12, No. 4, 1986.

Figure 440.796f-1. Typical AP600 ADS4 piping layout. View 1.

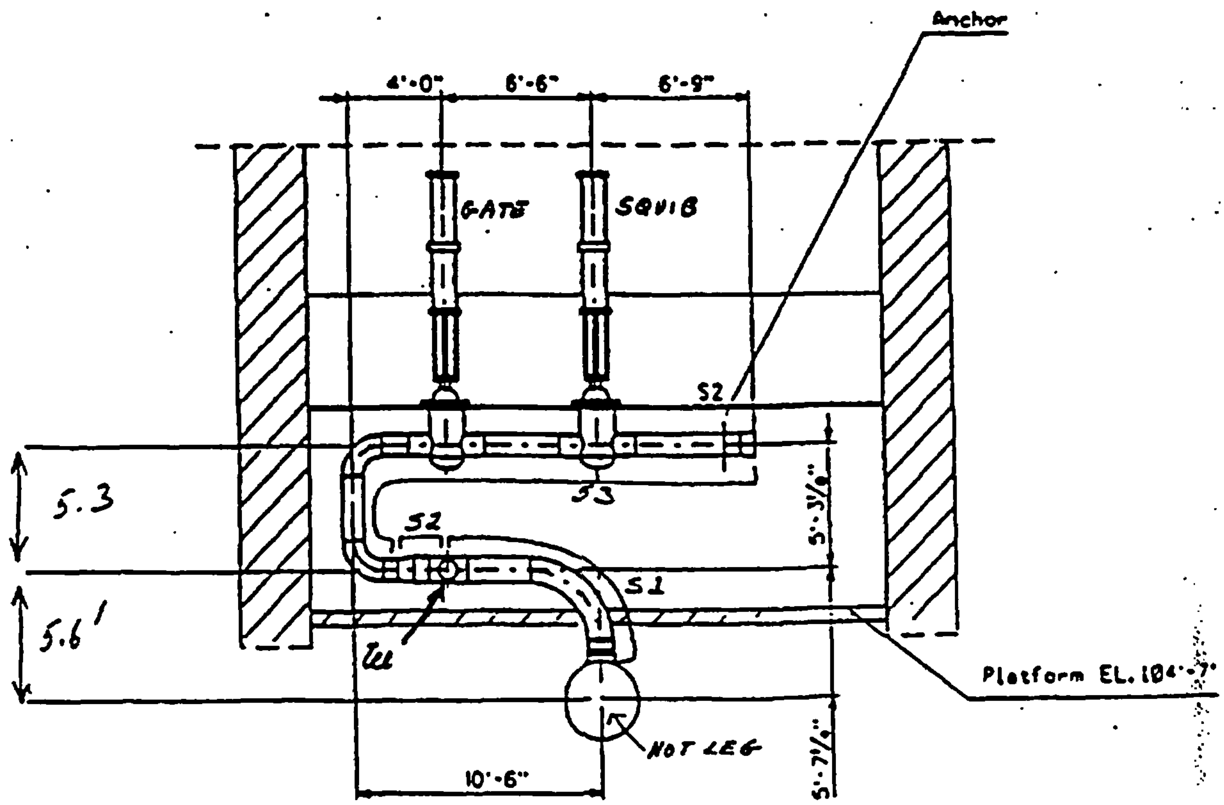


Figure 440.796f-2. Typical AP600 ADS4 piping layout. View 2.

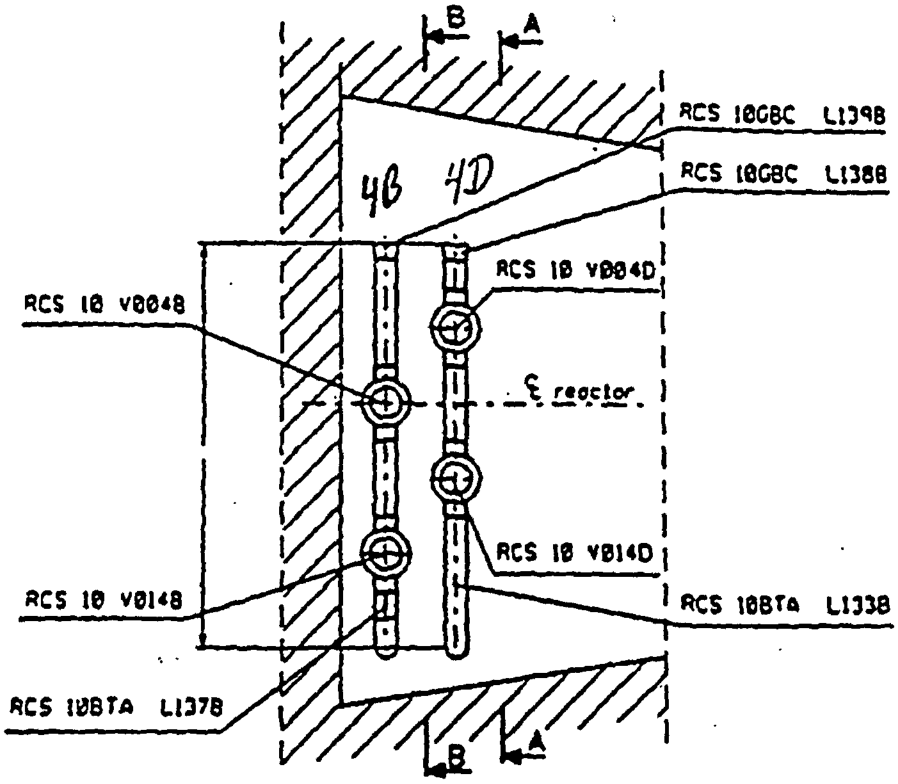


Figure 440.796f-3. ADS4 piping flow area distribution

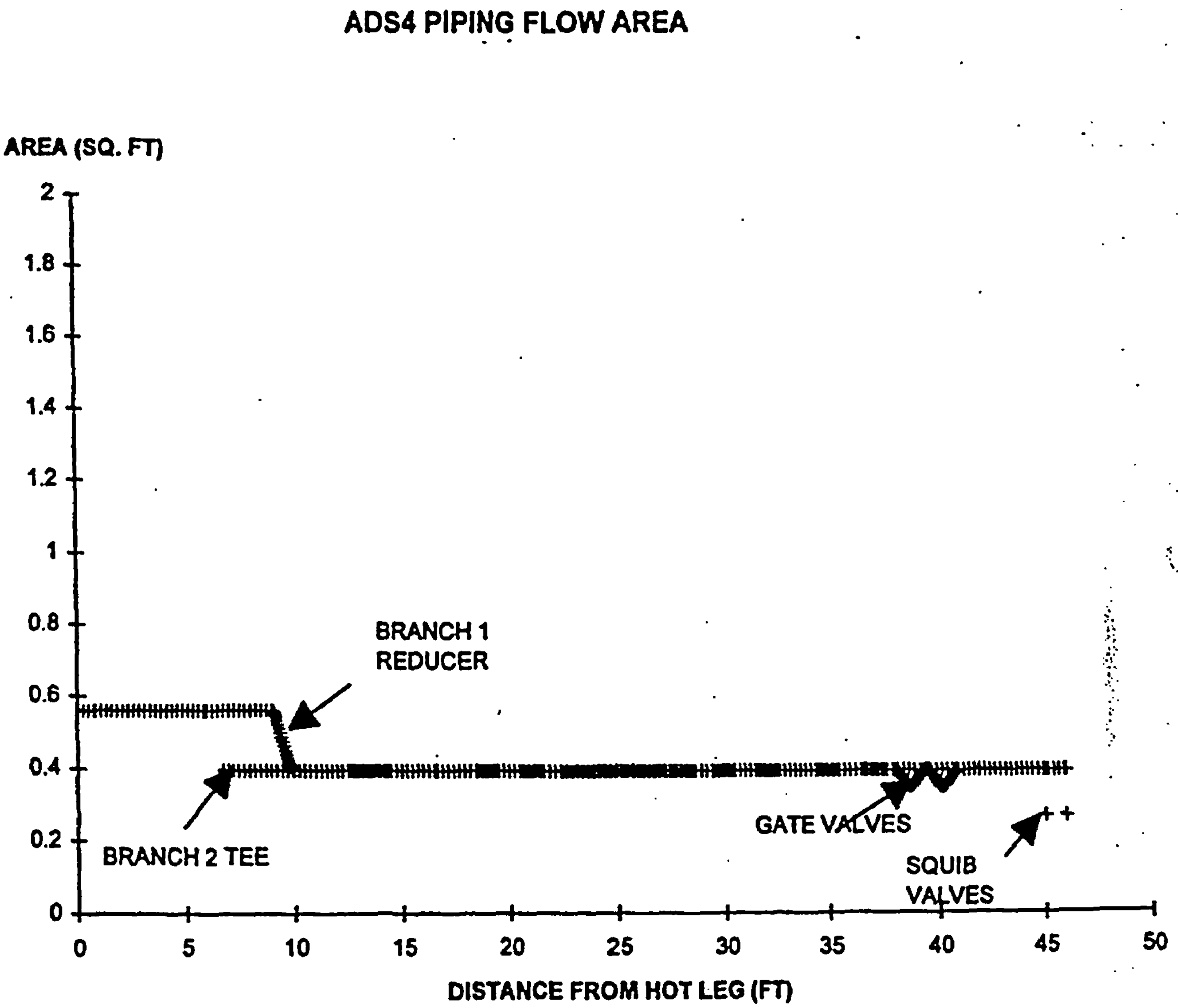


Figure 440.796f-4. Static pressure in ADS4 piping for hot leg pressure = 50 psia, quality = 100%.

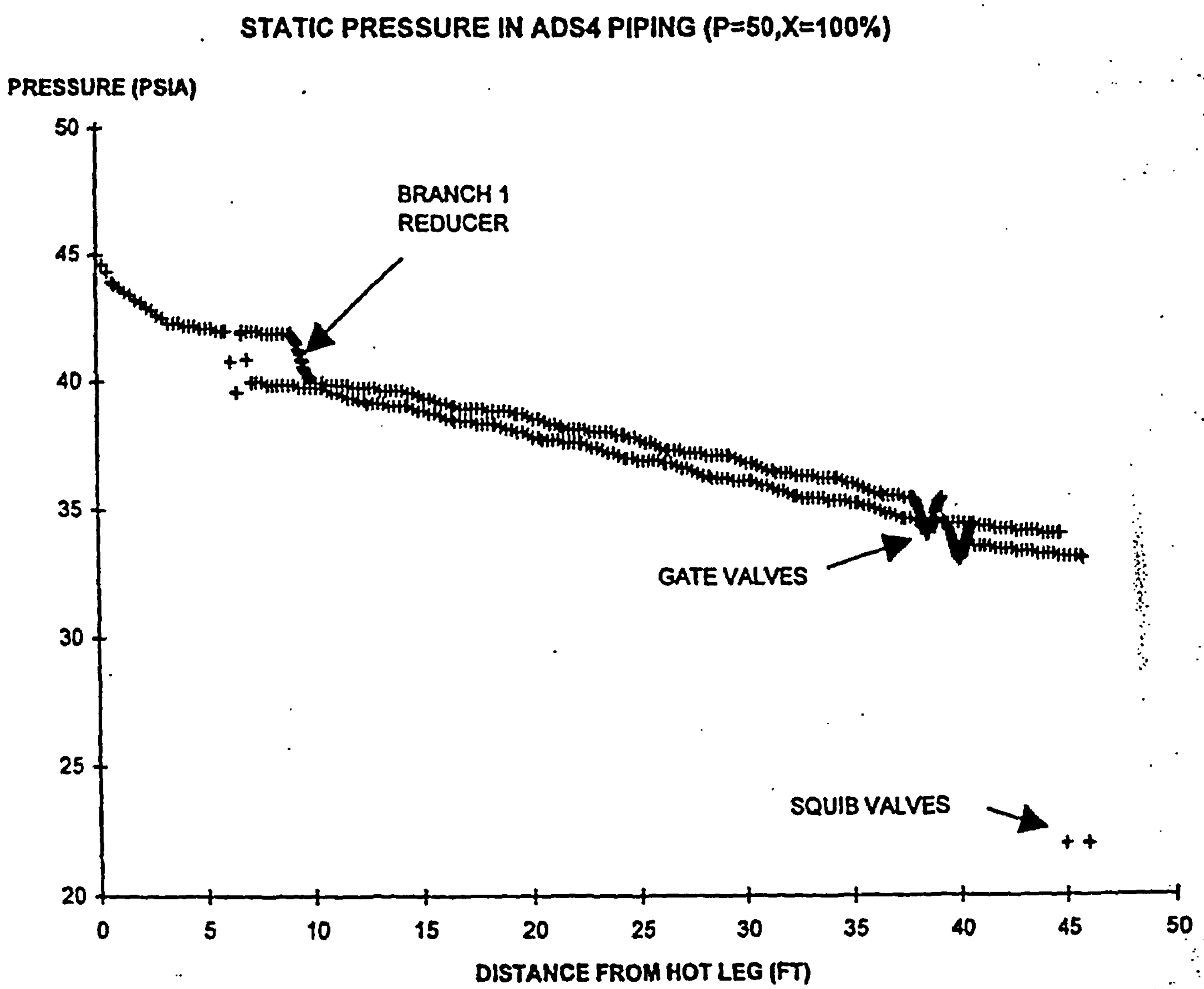


Figure 440.796f-5. Fluid velocity in ADS4 piping for hot leg pressure = 50 psia, quality = 100%.

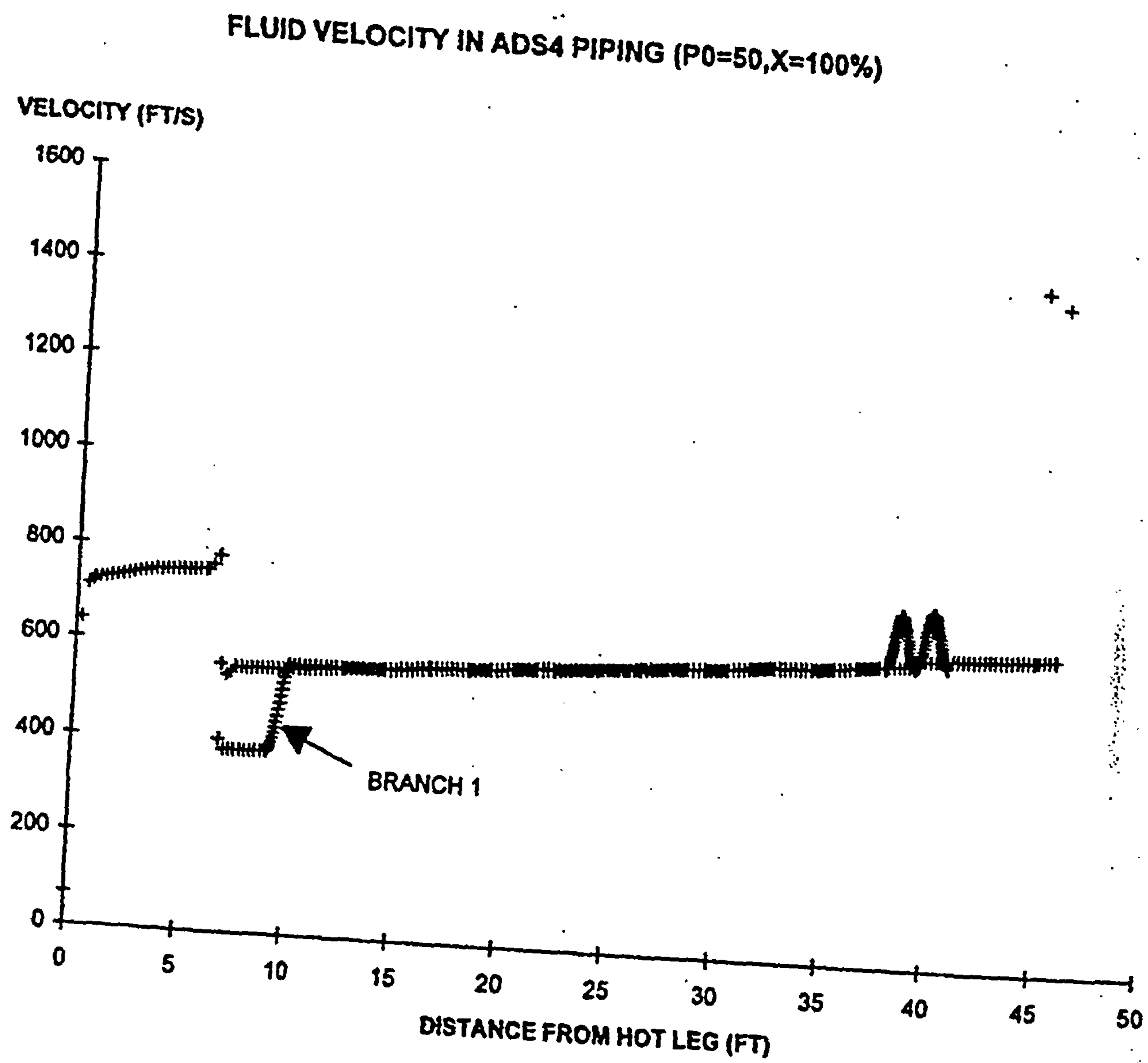


Figure 440.796f-6. Static pressure in ADS4 piping for hot leg pressure = 50 psia, quality = 20%.

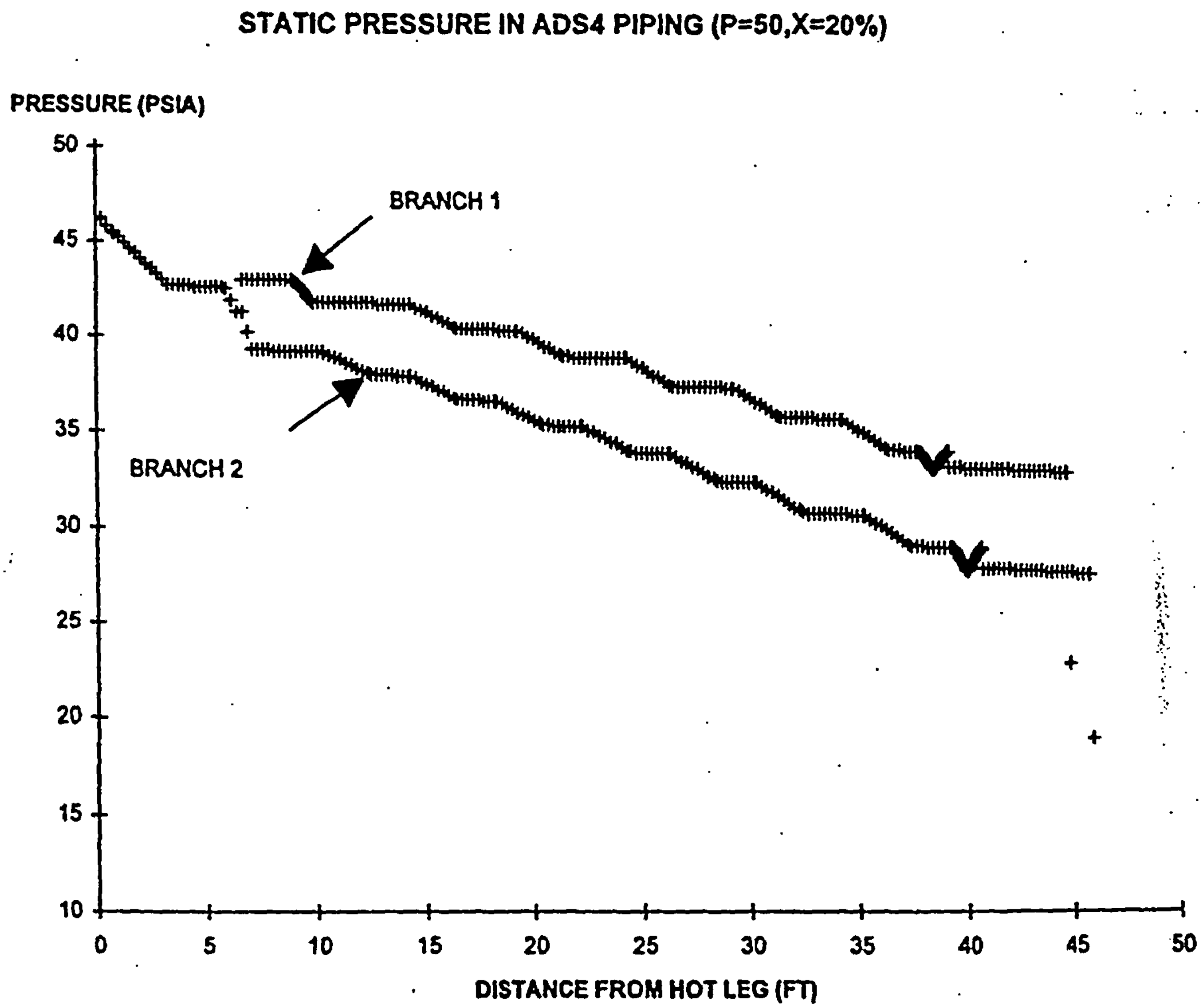


Figure 440.796f-7. Fluid velocity in ADS4 piping for hot leg pressure = 50 psia, quality = 20%.

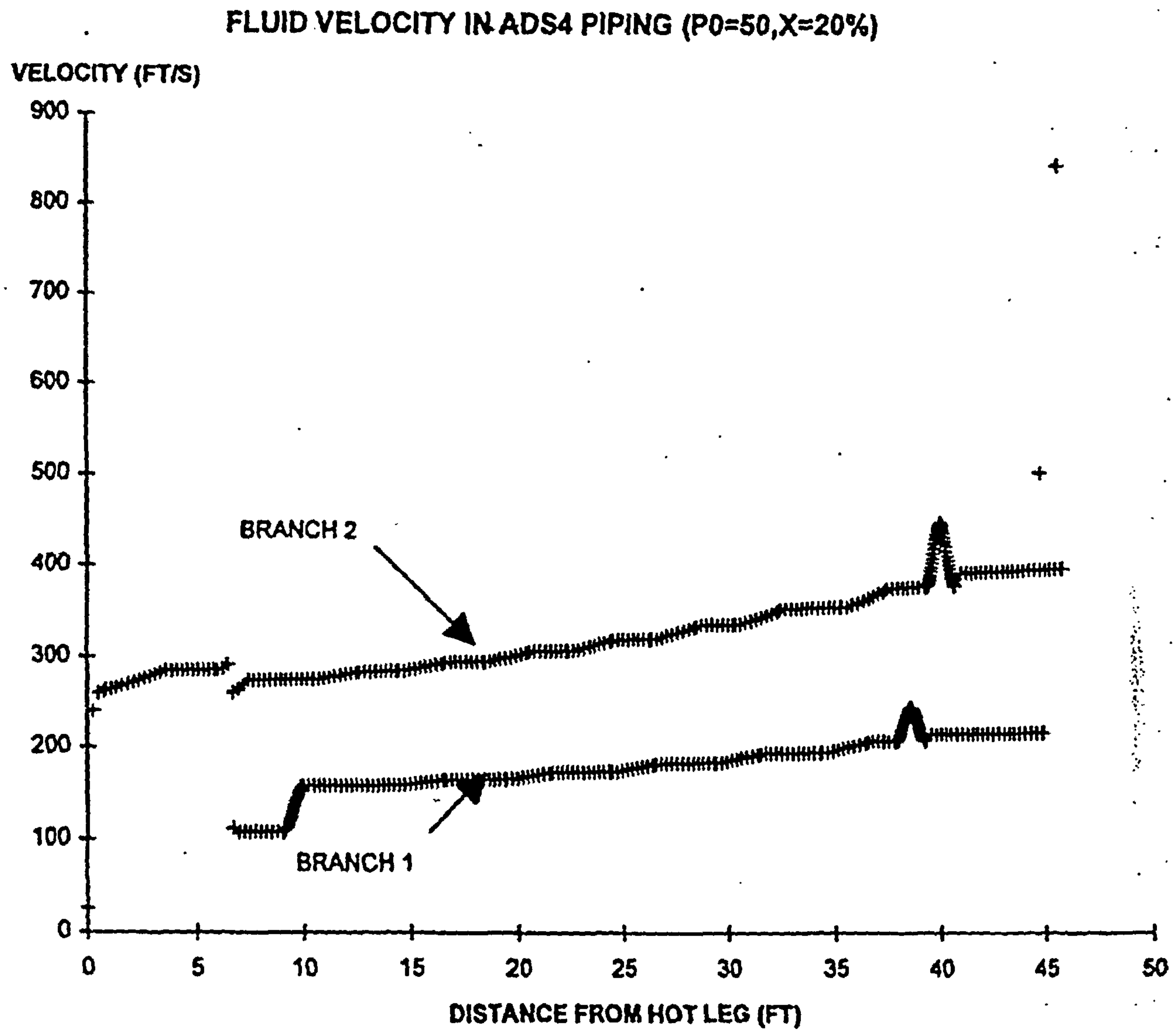


Figure 440.796f-8. Flow quality in ADS4 piping for hot leg pressure = 50 psia, quality = 20%.

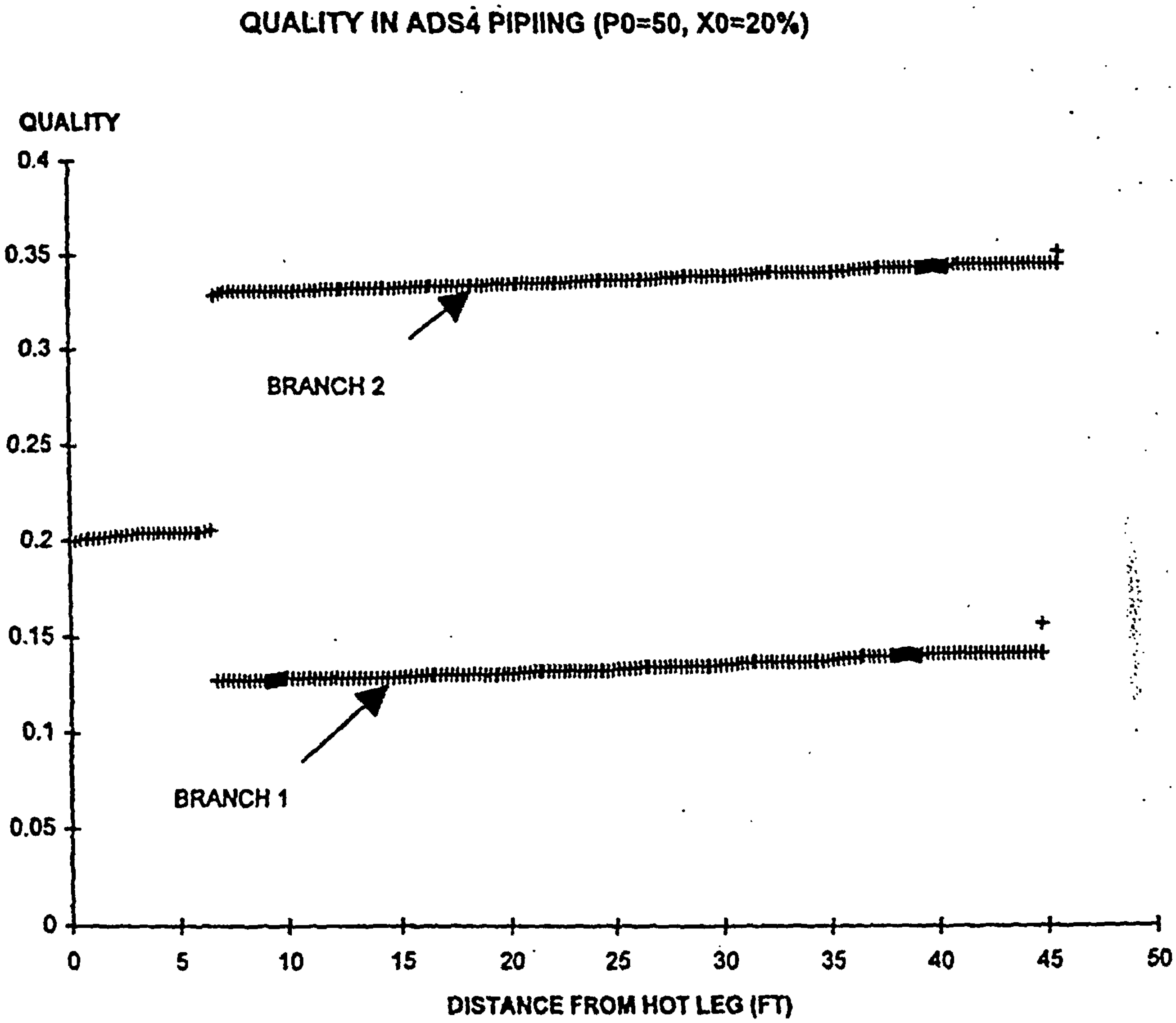


Figure 440.796f-9. Vapor flow vs hot leg pressure and quality predicted by pipe model.

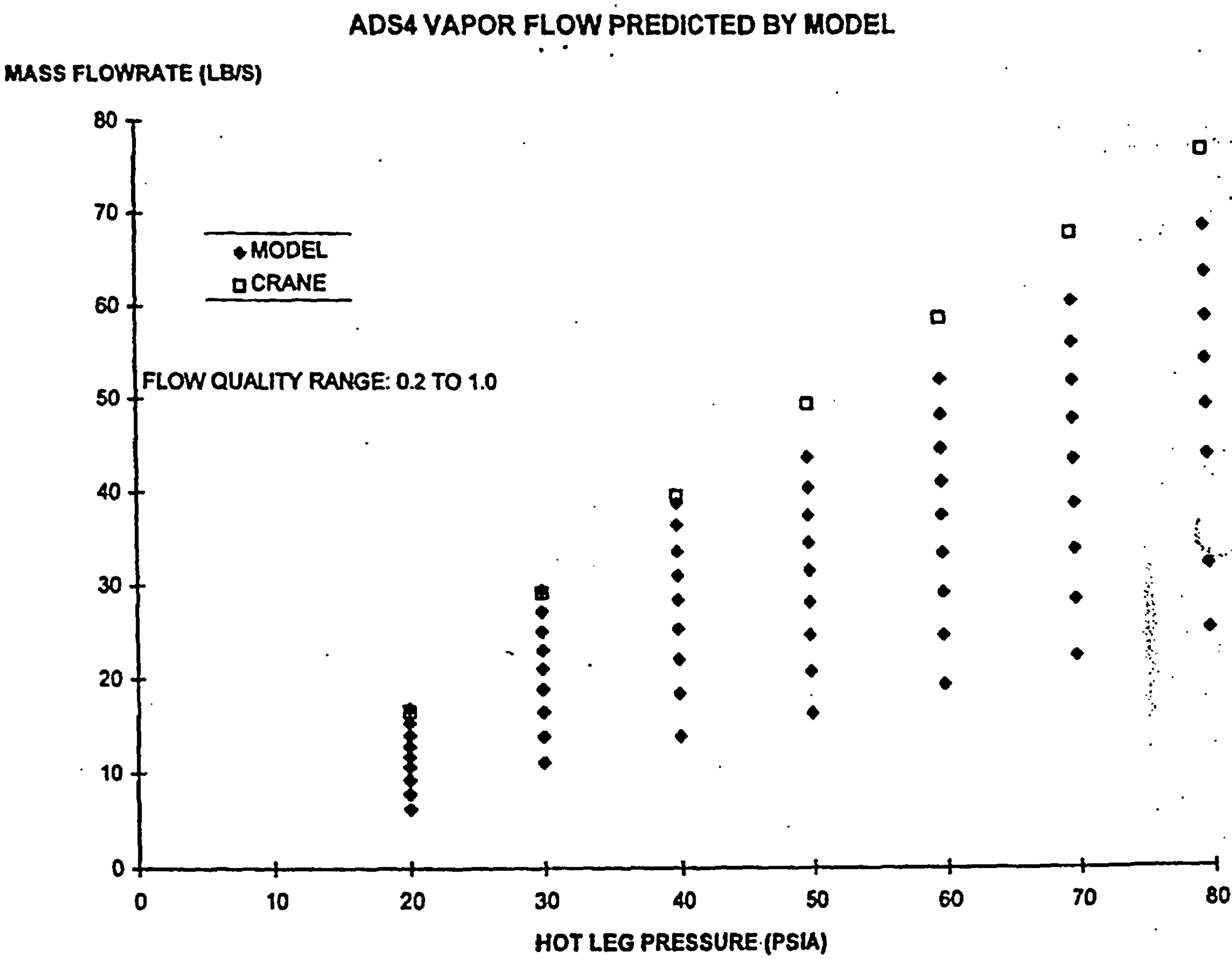


Figure 440.796f-10. Comparison of NOTRUMP and pipe model vapor flows

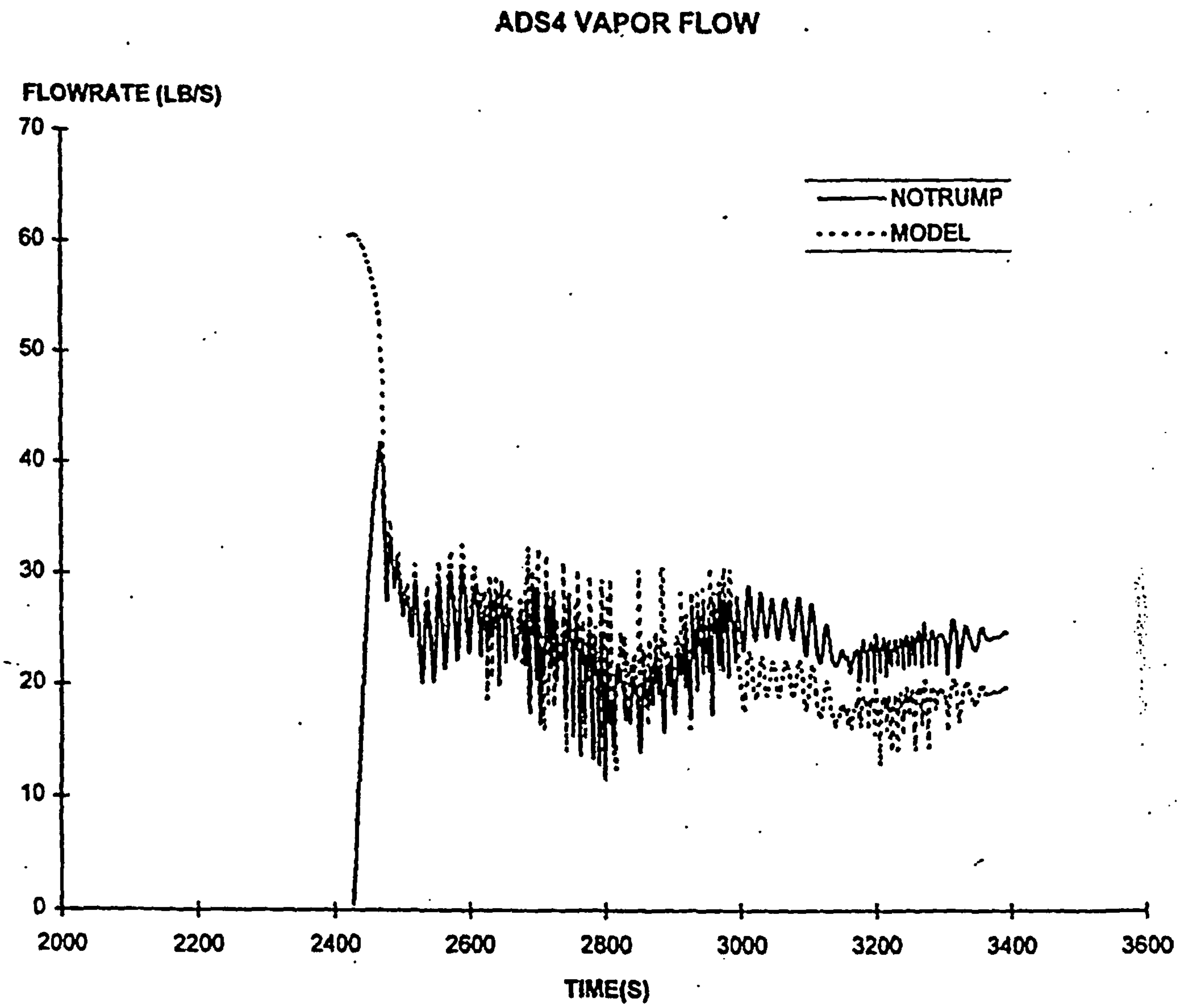
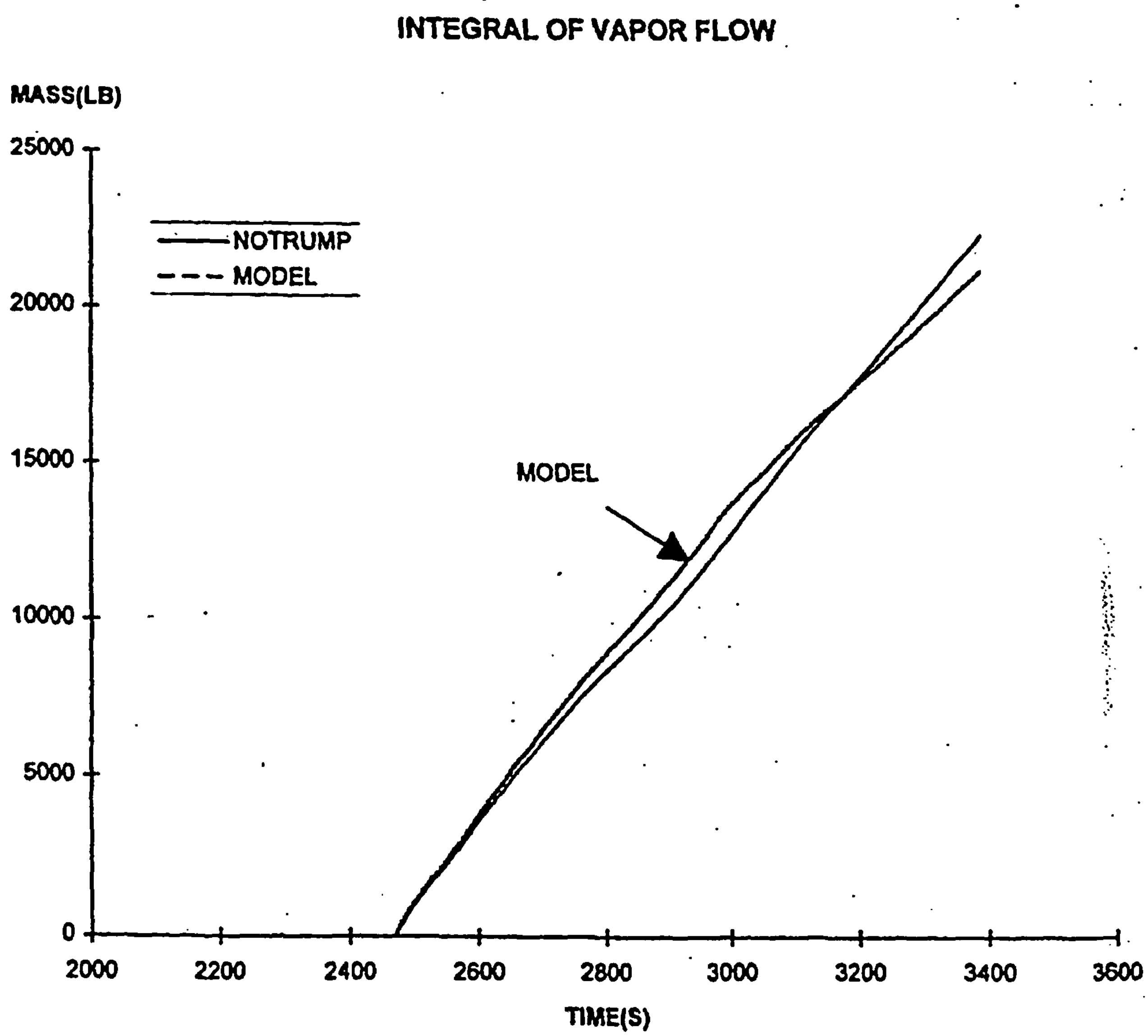


Figure 440.796f-11. Comparison of NOTRUMP and pipe model vapor flows (integral)



Appendix 5

Email dated 1/28/2004

"LTC at 20 psia"

Gongaware, Jacqueline J.

~~February 2, 2004~~

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:32 AM
To: Gongaware, Jacqueline J.
Subject: FW: LTC at 20 psia

From: Vijuk, Ronald P.
Sent: Wednesday, January 28, 2004 7:19 PM
To: 'Joseph Colaccino'; 'Jennifer Uhle'
Cc: 'John Segala'
Subject: LTC at 20 psia

LTC at 20 psia.doc

Here is the WCOBRA/TRAC continuous case for the 20 psia cont pressure scenario.

15.6.5.4C.1 Long-Term Cooling Analysis Methodology

The AP1000 safety-related systems are designed to provide adequate cooling of the reactor indefinitely. Initially, this is achieved by discharging water from the IRWST into the vessel. When the low-3 level setpoint is reached in the IRWST, the containment recirculation subsystem isolation valves open and water from the containment reactor coolant system (RCS) compartment can flow into the vessel through the PXS piping. The water in containment rises in temperature toward the saturation temperature. Long-term heat removal from the reactor and containment is by heat transfer through the containment shell to atmosphere. The purpose of the long-term cooling analysis is to demonstrate that the passive systems provide adequate emergency core cooling system performance during the IRWST injection/containment recirculation time scale. The long-term cooling analysis is performed using the WCOBRA/TRAC computer code to verify that the passive injection system is providing sufficient flow to the reactor vessel to cool the core and to preclude boron precipitation.

The AP1000 long-term cooling analysis is supported by the series of tests at the Oregon State University AP600 APEX Test Facility. This test facility is designed to represent the AP600 reactor safety-related systems and nonsafety-related systems at quarter-scale during long-term cooling. The data obtained during testing at this facility has been shown to apply to the AP1000 (Reference 25). These tests were modeled using WCOBRA/TRAC with an equivalent noding scheme to that used for AP600 (Reference 17) in order to validate the code for long-term cooling analysis.

Reference 24 provides details of the AP1000 WCOBRA/TRAC modeling. The coarse reactor vessel modeling used for AP600 has been replaced with a detailed noding like that applied in the large-break LOCA analyses described in subsection 15.6.5.4A. The reactor vessel noding used in the AP1000 long-term cooling analyses in core and upper plenum regions is equivalent to that used in full-scale test simulations (see Reference 24).

A DEDVI line break is analyzed because it is the most limiting long-term cooling case in the relationship between decay power and available liquid driving head. Because the IRWST spills directly onto the containment floor in a DEDVI break, this event has the highest core decay power when the transfer to sump injection is initiated. In postulated DEDVI break cases, the compartment water level exceeds the elevation at which the DVI line enters the reactor vessel, so water can flow from the containment into the reactor vessel through the broken DVI line; this in-flow of water through the broken DVI line assists in the heat removal from the core. The steam produced by boiling in the core vents to the containment through the ADS valves and condenses on the inner surface of the steel containment vessel. The condensate is collected and drains to the IRWST to become available for injection into the reactor coolant system. The WCOBRA/TRAC analysis presented analyzes the DEDVI small-break LOCA event from a time (3000 seconds) at which IRWST injection is fully established to beyond the time of containment recirculation. During this time, the head of water to drive the flow into the vessel for IRWST injection decreases from the initial level to its lowest value at the containment recirculation switchover time. PXS Room B is the location of the break in the DVI line. At this break location, liquid level in containment at the time of recirculation is a minimum.

A continuous analysis of the post-LOCA long term cooling is provided from the time of stable IRWST injection through the time of sump recirculation for the DEDVI break. Maximum design resistances are applied in WCOBRA/TRAC for both the ADS Stage 4 flow paths and the IRWST injection and containment recirculation flow paths.

The break modeled is a double-ended guillotine rupture of one of the direct vessel injection lines. The long-term cooling phase begins after the simultaneous opening of the isolation valves in the IRWST DVI lines and the opening of ADS Stage 4 squib valves, when flow injection from the IRWST has been fully established. Initial conditions are taken from the NOTRUMP DEDVI case at 20 psia containment pressure reported in subsection 15.6.5.4B.

15.6.5.4C.2 DEDVI Line Break with ADS Stage 4 Single Failure, Passive Core Cooling System Only Case; Continuous Case

This subsection presents the results of a DEDVI line break analysis during IRWST injection phase continuing into sump recirculation. Initial conditions at the start of the case are prescribed based on the NOTRUMP DEDVI break results to allow a calculation to begin shortly after IRWST injection begins in the small break long-term cooling transient. The WCOBRA/TRAC calculation is then allowed to proceed until a quasi-steady-state is achieved. At this time, the predicted results are independent of the assumed initial conditions. This calculation uses boundary conditions taken from a WGOTHIC analysis of this event. During the calculation, which is carried out for 10,000 seconds until a quasi-steady-state sump recirculation condition has been established, the IRWST water level is decreased continuously until the sump recirculation setpoint is reached.

In the analysis, one of the two ADS Stage 4 valves in the PRHR loop is assumed to have failed. The initial reactor coolant system liquid inventory and temperatures are determined from the NOTRUMP calculation. The core makeup tanks do not contribute to the DVI injection during this phase of the transient. Steam generator secondary side conditions are taken from the NOTRUMP calculation (at the beginning of long-term cooling). The reactor coolant pumps are tripped and not rotating.

The levels and temperatures of the liquid in the containment sump and the containment pressure are based on WGOTHIC calculations of the conservative minimum pressure during this long-term cooling transient, including operation of the containment fan coolers. Small changes in the RCS compartment level do not have a major effect on the predicted core collapsed liquid level or on the predicted flow rate through the core. The minimum compartment floodup level for this break scenario is 107.8 feet or greater.

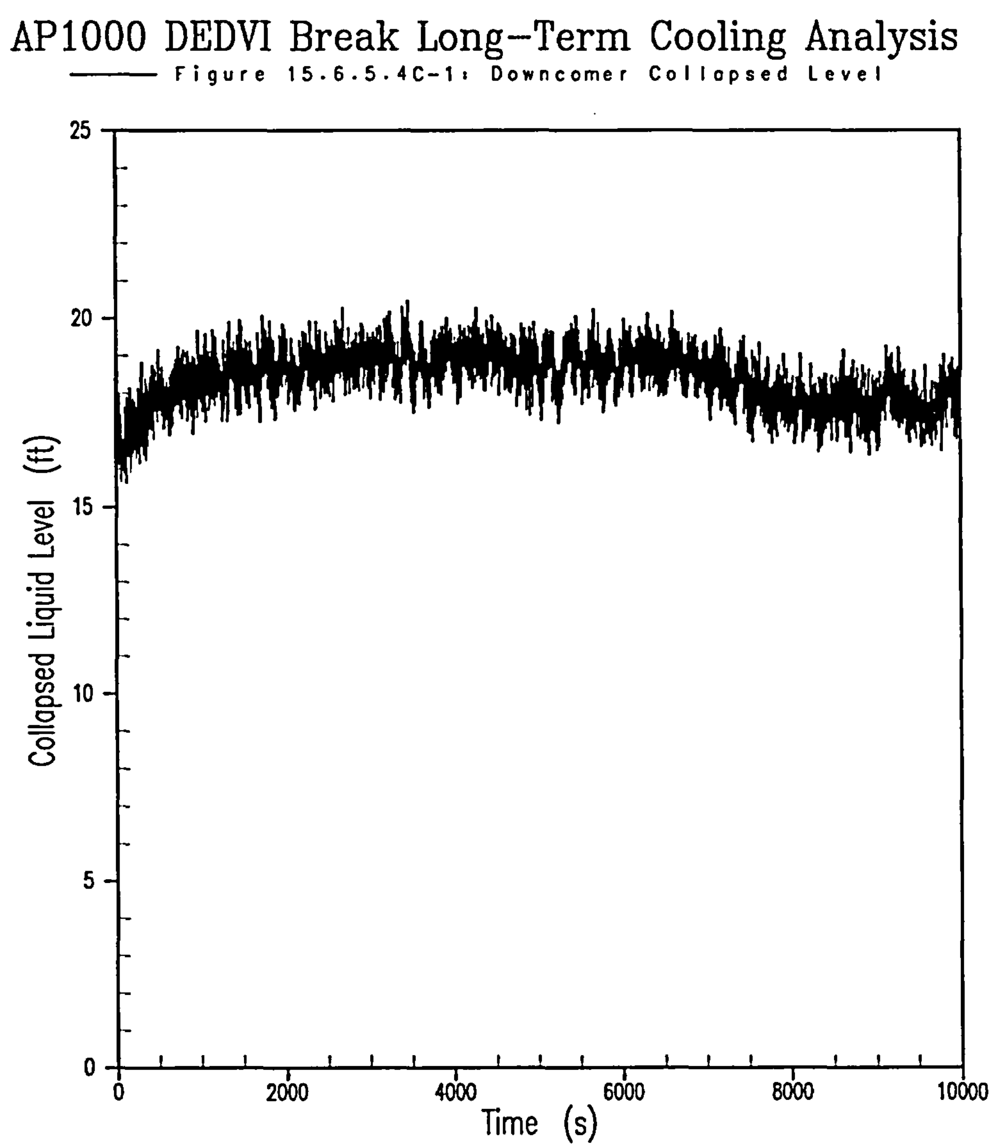
In this transient, the IRWST provides a hydraulic head sufficient to drive water into the downcomer through the intact DVI nozzle. Also, water flows into the downcomer from the RCS loop compartment through the broken DVI line once the liquid level is adequate to support flow. The water flows down the downcomer and up through the core, into the upper plenum. Steam produced in the core and liquid flow out of the reactor coolant system via the ADS Stage 4 valves. There is little flow out of ADS Stages 1, 2, and 3 even when the IRWST liquid level falls below the sparger elevation, so they are not modeled in this calculation. The venting provided by the ADS-4 paths enables the liquid flow through the core to maintain core cooling.

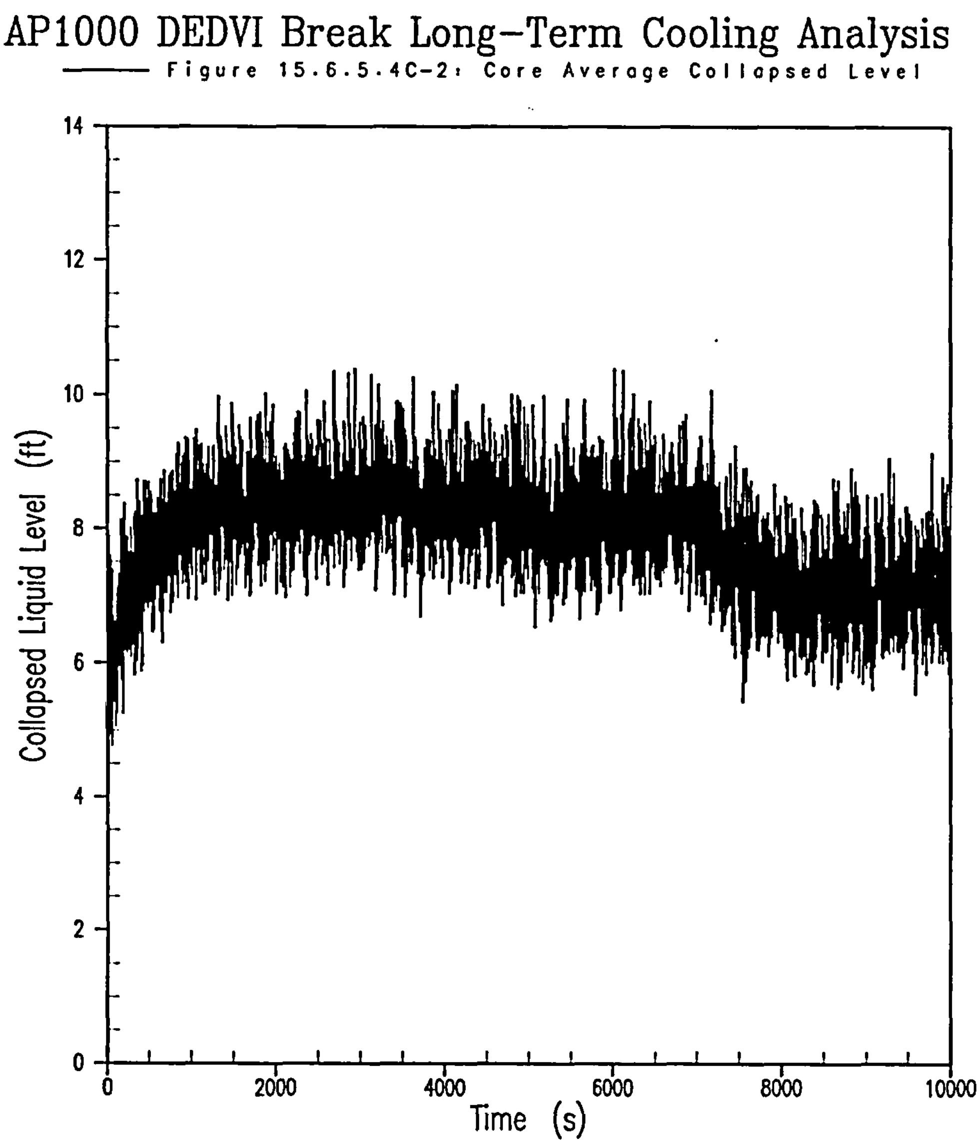
Approximately 500 seconds of WCOBRA/TRAC calculation are required to establish the quasi-steady-state condition associated with IRWST injection at the start of long-term cooling and so are ignored in the following discussion. The hot leg levels are such that during the IRWST injection phase the quality of the ADS Stage 4 mass flows varies as water is carried out of the hot legs. This periodically increases the pressure drop across the ADS Stage 4 valves and the upper plenum pressure. The higher pressure in the upper plenum reduces the injection flow. This cycle of pressure variations due to changing void fractions in the flow through ADS Stage 4 is consistent with test observations and is expected to recur often during long-term cooling.

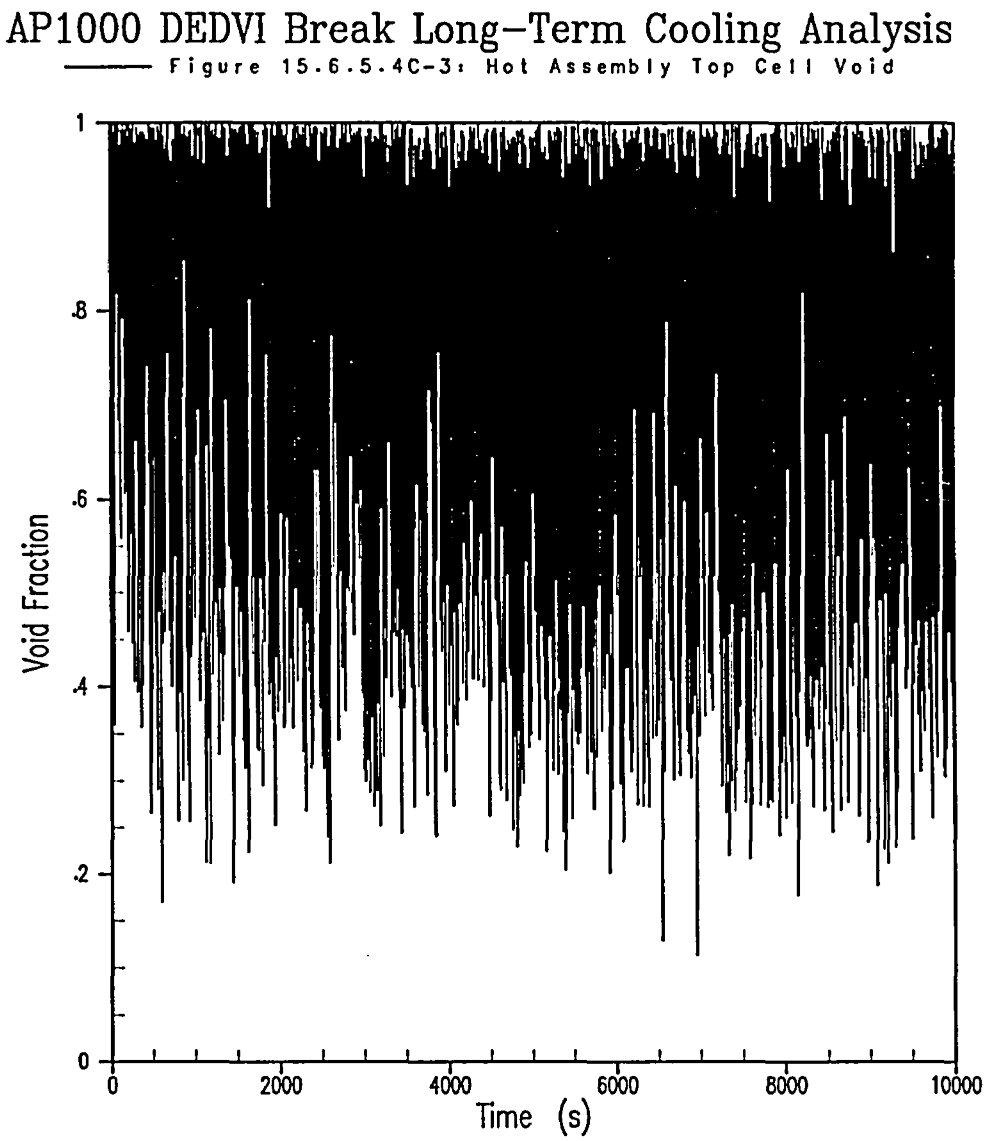
The head of water in the IRWST causes a flow of subcooled water into the downcomer at an approximate rate of 170 lbm/s through the intact DVI nozzle at the start of long-term cooling. The downcomer level at the end of the code initiation (the start of long-term cooling) is about 18.0 feet (Figure 15.6.5.4C-1). Note that the time scale of this and other figures in subsection 15.6.5.4C.2 is offset by 2500 seconds; that is, a time of 500 seconds on the Figure 15.6.5.4C-1 axis equals 3000 seconds transient time for the DEDVI break. All of the injection water flows down the downcomer and up through the core. The accumulators have been fully discharged before the start of the time window and do not contribute to the DVI flow.

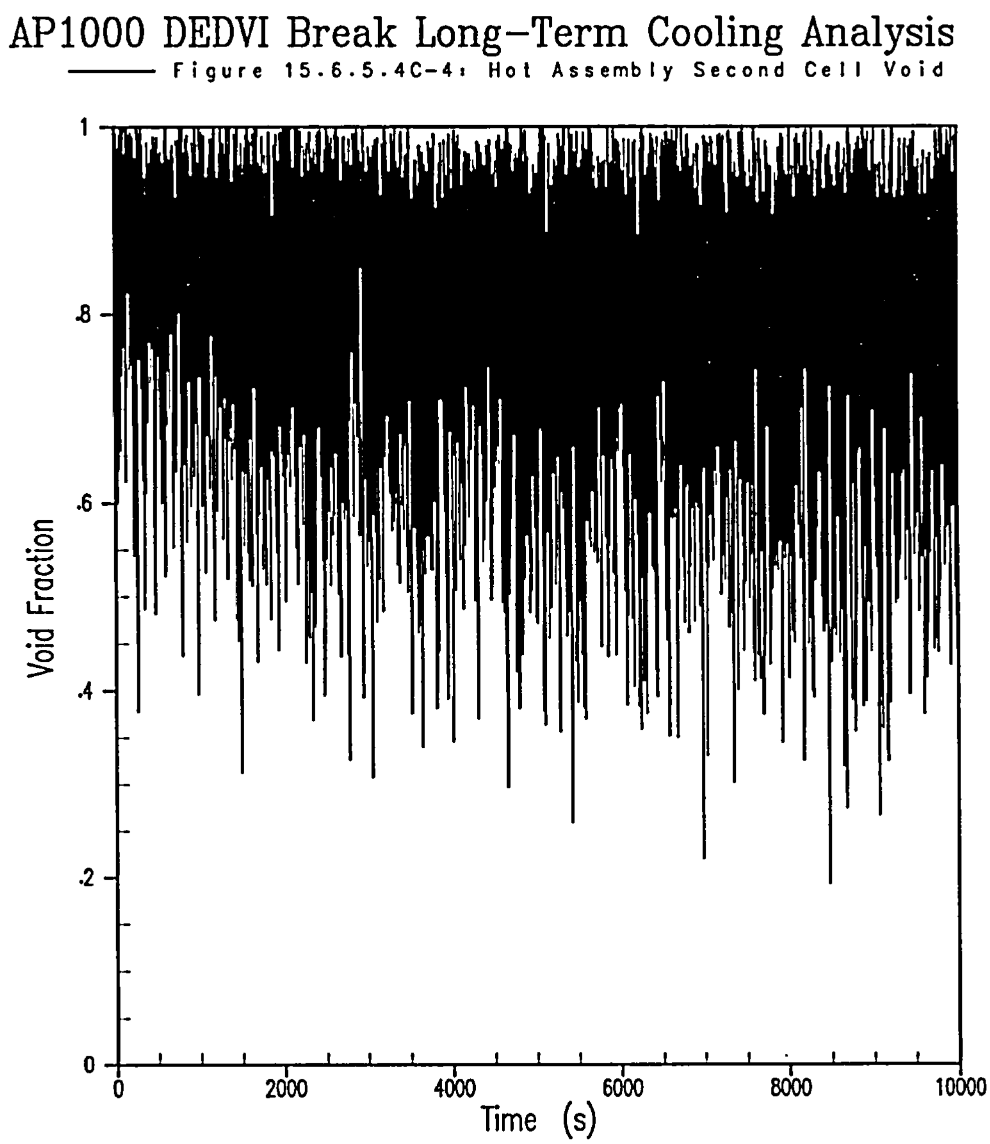
Boiling in the core produces steam and a two-phase mixture, which flows into the upper plenum. The core is 14 feet high, and the core average collapsed liquid level (Figure 15.6.5.4C-2) is shown from the start of long-term cooling. The boiling process causes a variable rate of steam production and resulting pressure changes, which in turn causes oscillations in the liquid flow rate at the bottom of the core and also variations in the core collapsed level and the flow rates of liquid and vapor out of the top of the core. In the WCOBRA/TRAC noding, the core is divided both axially and radially as described in Reference 24. The void fractions in the top two cells of the hot assembly are shown as Figures 15.6.5.4C-3 and -4. The average void fraction of these upper core cells is about 0.8 during long-term cooling, during IRWST injection, and into the containment recirculation period. There is a continuous flow of two-phase fluid into the hot legs, and mainly vapor flow toward the ADS Stage 4 valve occurs at the top of the pipe. The collapsed liquid level in the hot leg varies between 0.8 feet to 1.6 feet (Figure 15.6.5.4C-5). The hot legs on average are more than 50-percent full. Vapor and liquid flows at the top of the core are shown in Figures 15.6.5.4C-6 and 15.6.5.4C-7, the upper plenum collapsed liquid level in Figure 15.6.5.4C-8. Figures 15.6.5.4C-9 and 15.6.5.4C-10 are ADS stage 4 mass flowrates.

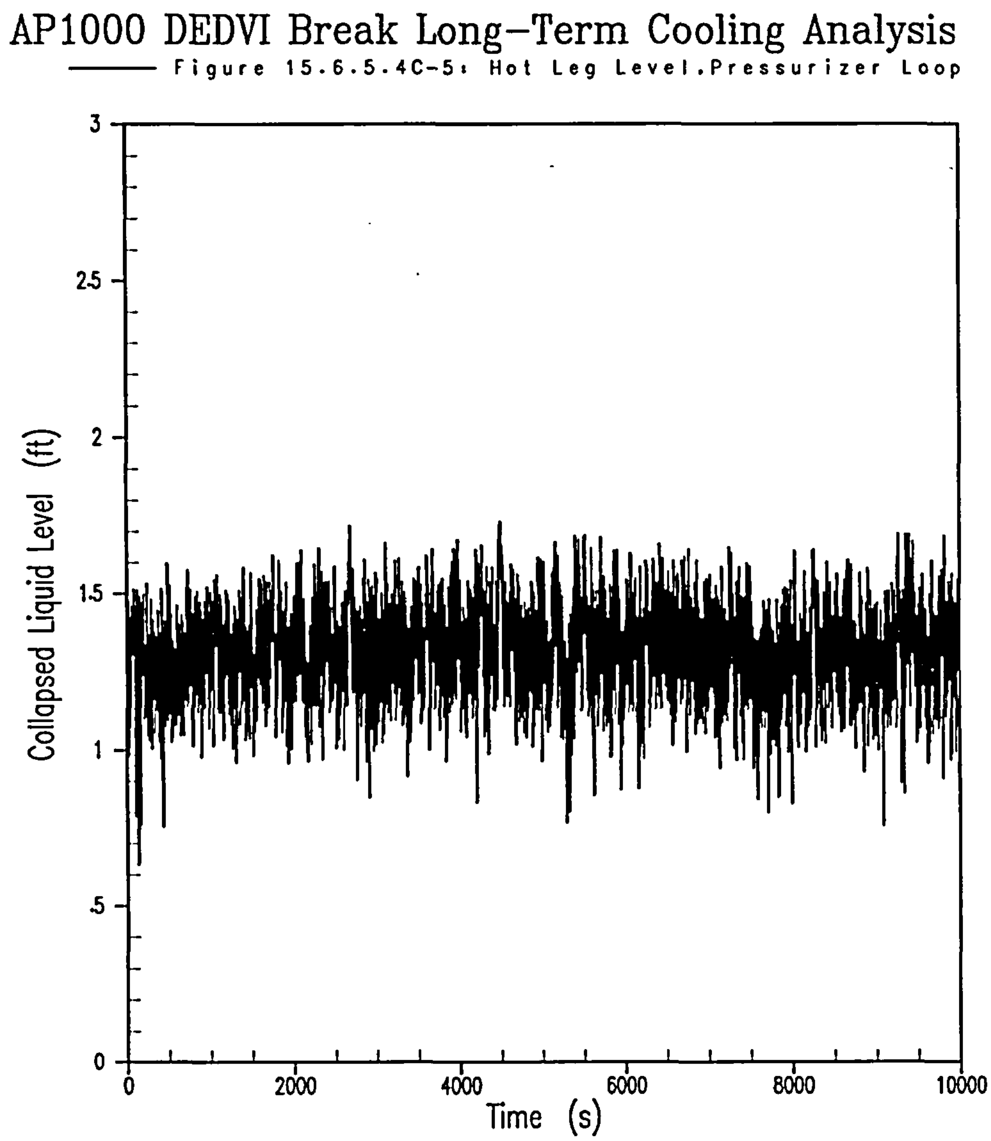
The pressure in the upper plenum is shown in Figure 15.6.5.4C-11. The upper plenum pressure fluctuation that occurs is due to the ADS Stage 4 water discharge. The PCT of the hot rod follows saturation temperature (Figure 15.6.5.4C-12), which demonstrates that no uncovery and no cladding temperature excursion occurs. A small pressure drop is calculated across the reactor vessel, and injection rates through the DVI lines into the vessel are presented in Figures 15.6.5.4C-13 and -14. Figure 15.6.5.4C-14 shows the flow is outward through the broken DVI line at the start of the long-term cooling period, and it increases to a maximum average value of about 52 lbm/s after the compartment water level has increased above the nozzle elevation to permit liquid injection into the reactor vessel. In contrast, the intact DVI line flow falls from 170 lbm/s with a full IRWST to about 65 lbm/s flow from the containment at the end of the calculation. The recirculation core liquid throughput is more than adequate to preclude any boron buildup on the fuel.


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-1: Downcomer Collapsed Level
Collapsed Liquid Level (ft)
Time (s)
0
5
10
15
20
25
0
2000
4000
6000
8000
10000


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-2: Core Average Collapsed Level
Collapsed Liquid Level (ft)
Time (s)
0
2
4
6
8
10
12
14
0
2000
4000
6000
8000
10000

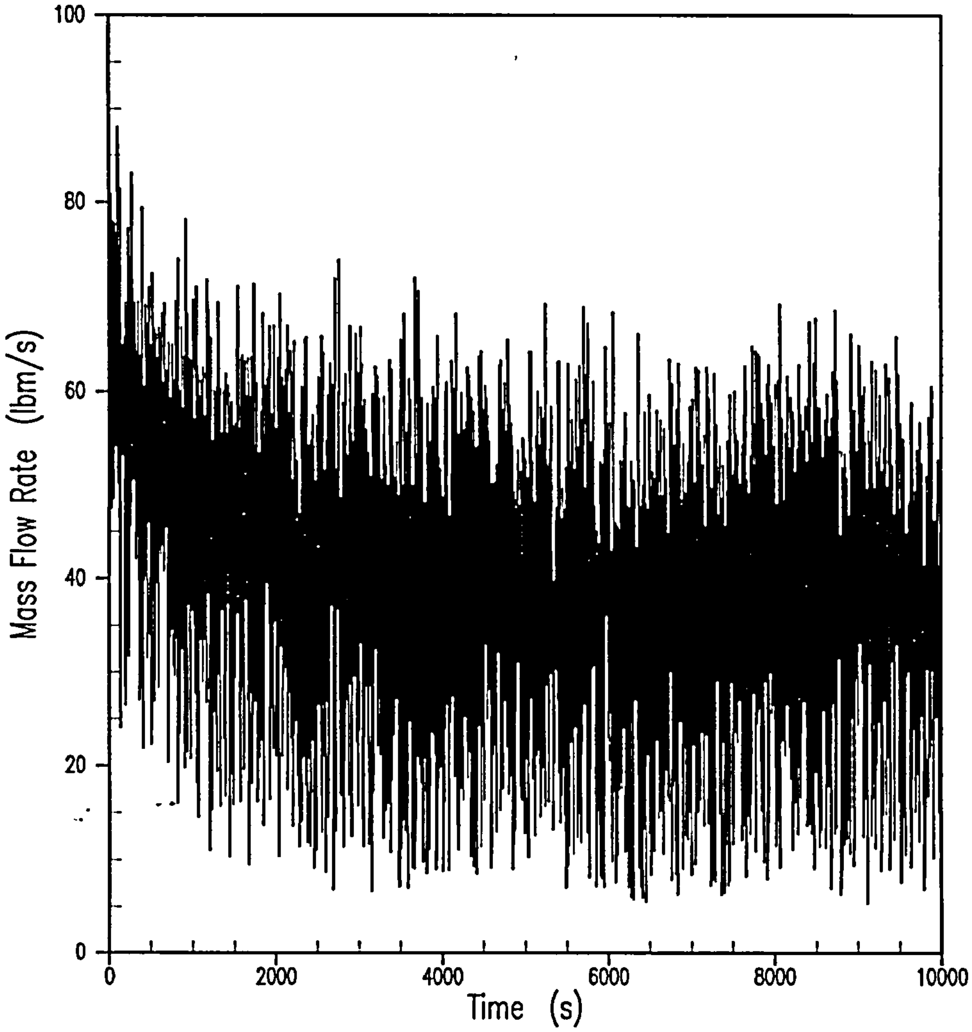

AP1000 DEDVI Break Long–Term Cooling Analysis
Figure 15.6.5.4C-3: Hot Assembly Top Cell Void
Void Fraction
0
.2
.4
.6
.8
1
Time (s)
0
2000
4000
6000
8000
10000


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-4: Hot Assembly Second Cell Void
Void Fraction
1
.8
.6
.4
.2
0
0
2000
4000
6000
8000
10000
Time (s)


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-5: Hot Leg Level,Pressurizer Loop
Collapsed Liquid Level (ft)
Time (s)
0
.5
1
1.5
2
2.5
3
0
2000
4000
6000
8000
10000

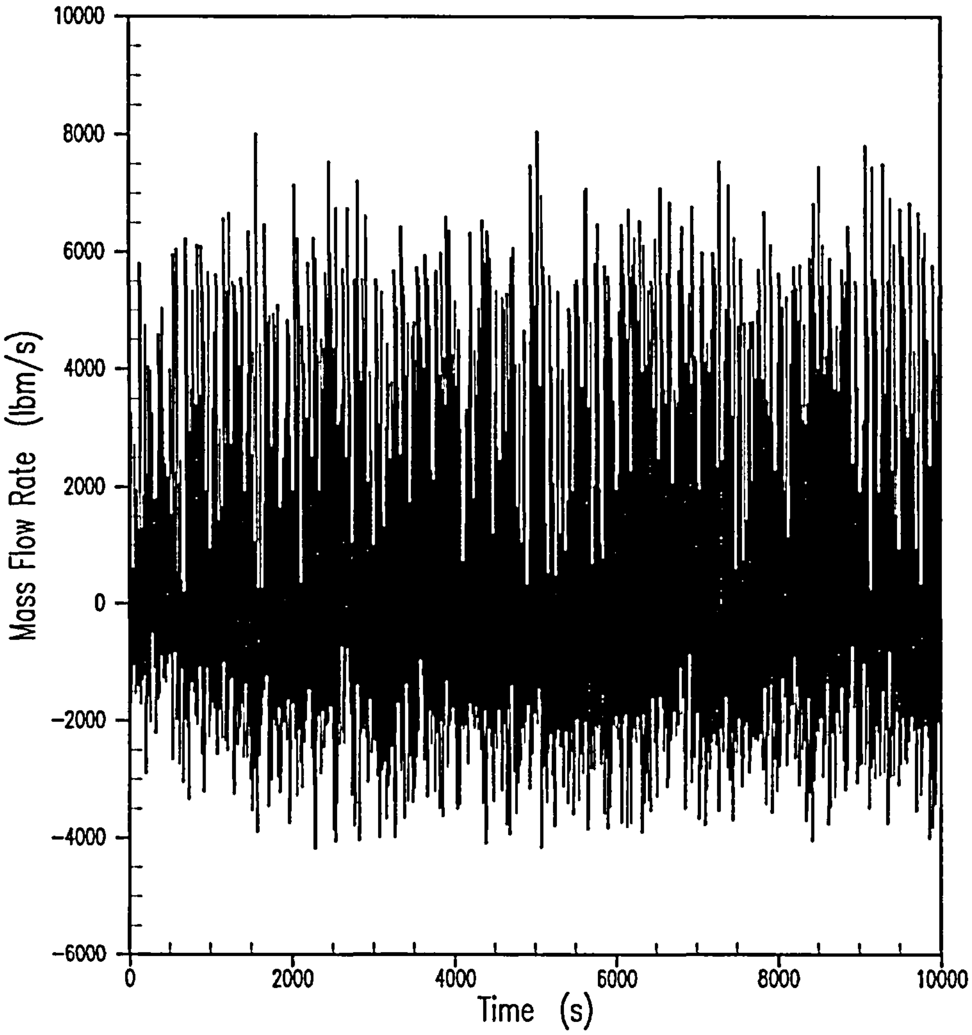
AP1000 DEDVI Break Long-Term Cooling Analysis

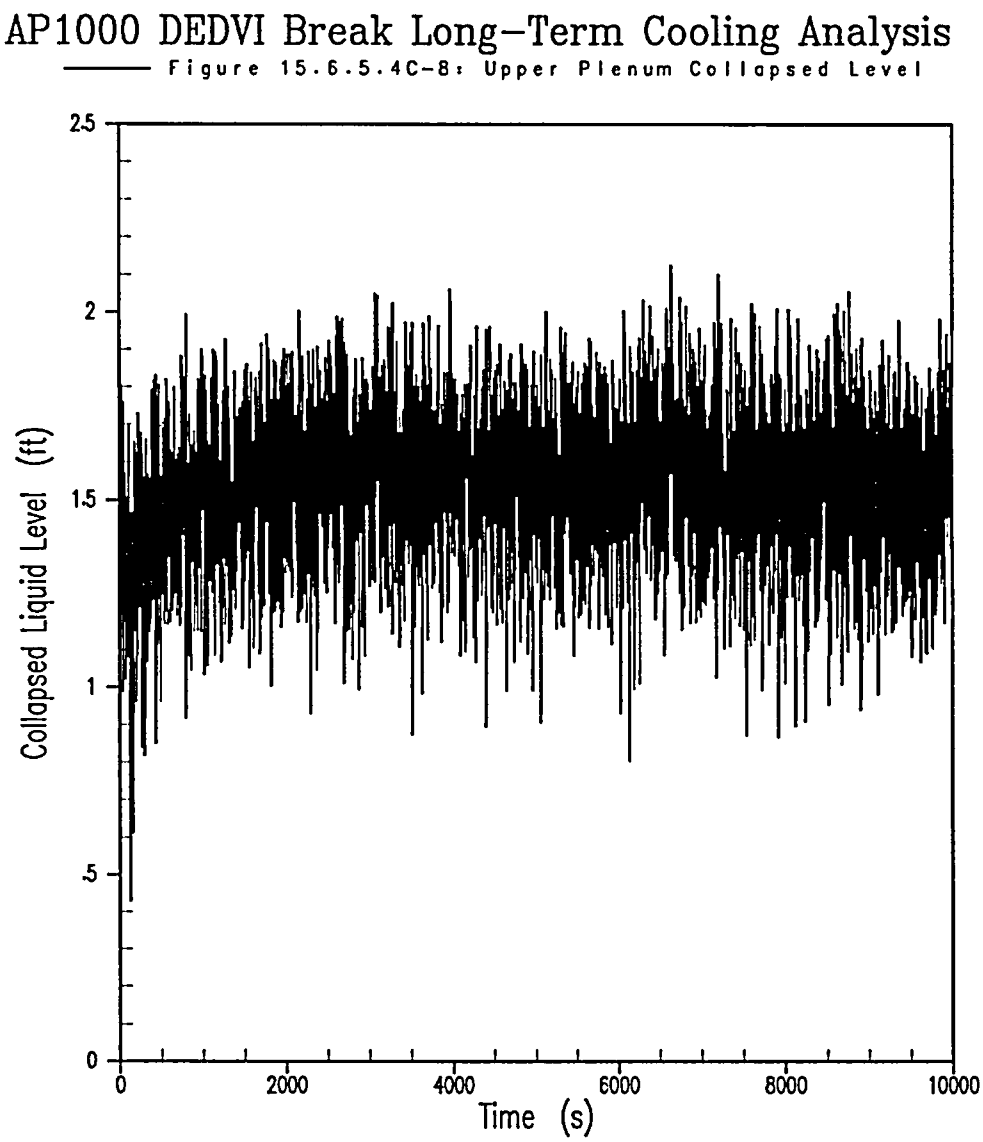
Figure 15.6.5.4C-6: Core Exit Vapor Flow Rate

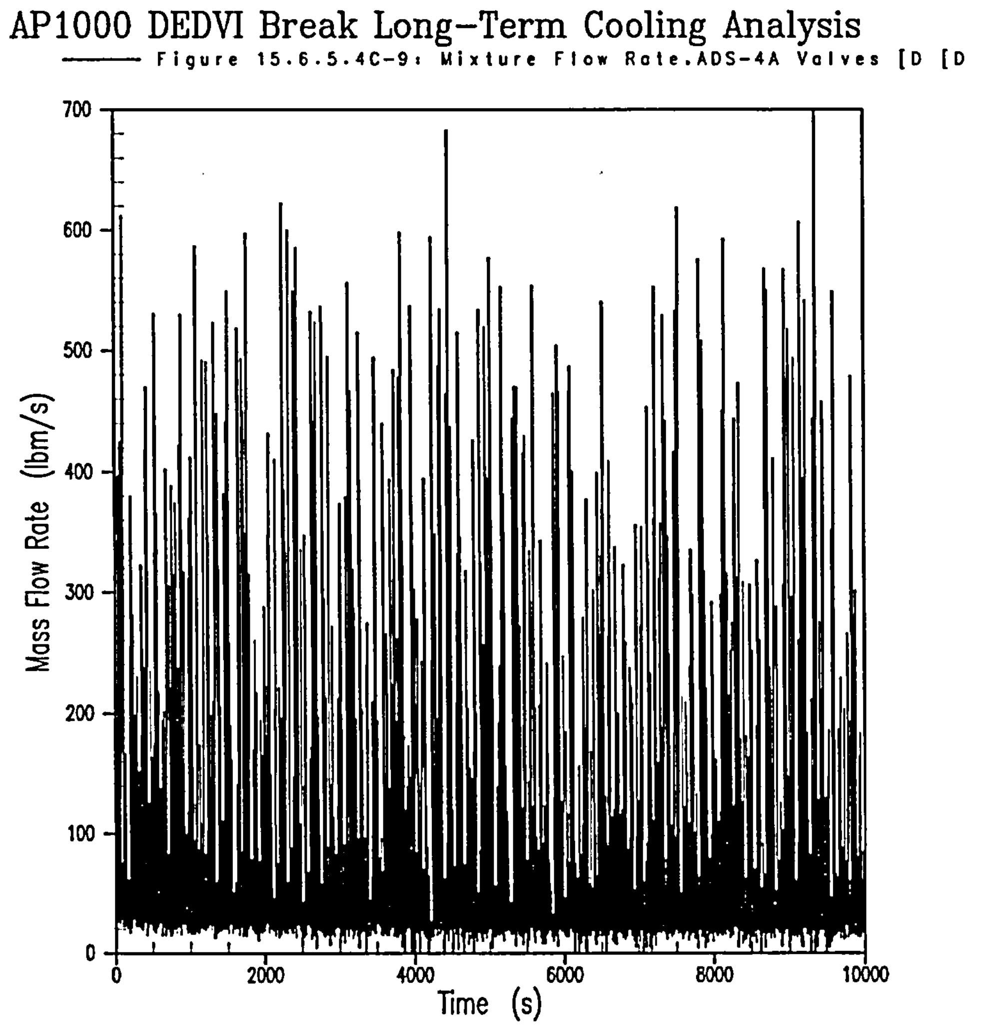


AP1000 DEDVI Break Long-Term Cooling Analysis

Figure 15.6.5.4C-7: Core Exit Liquid Flow Rate

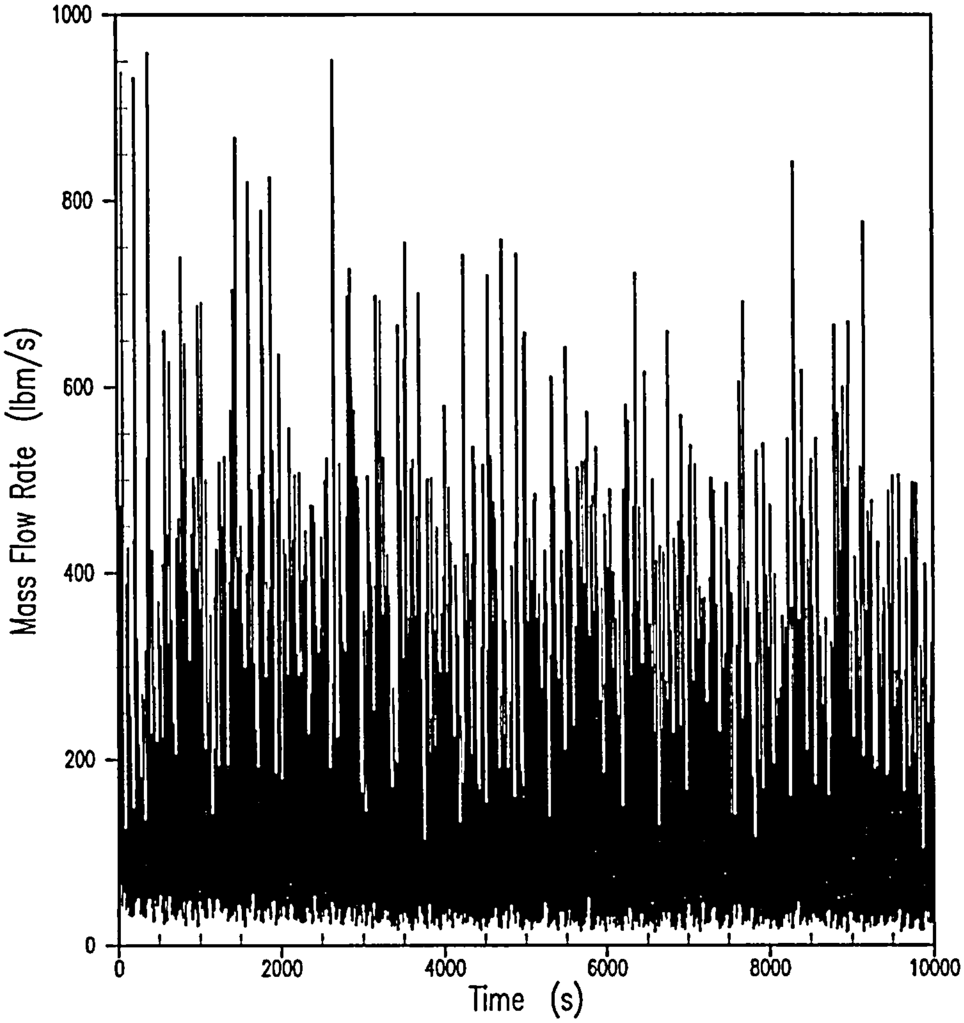


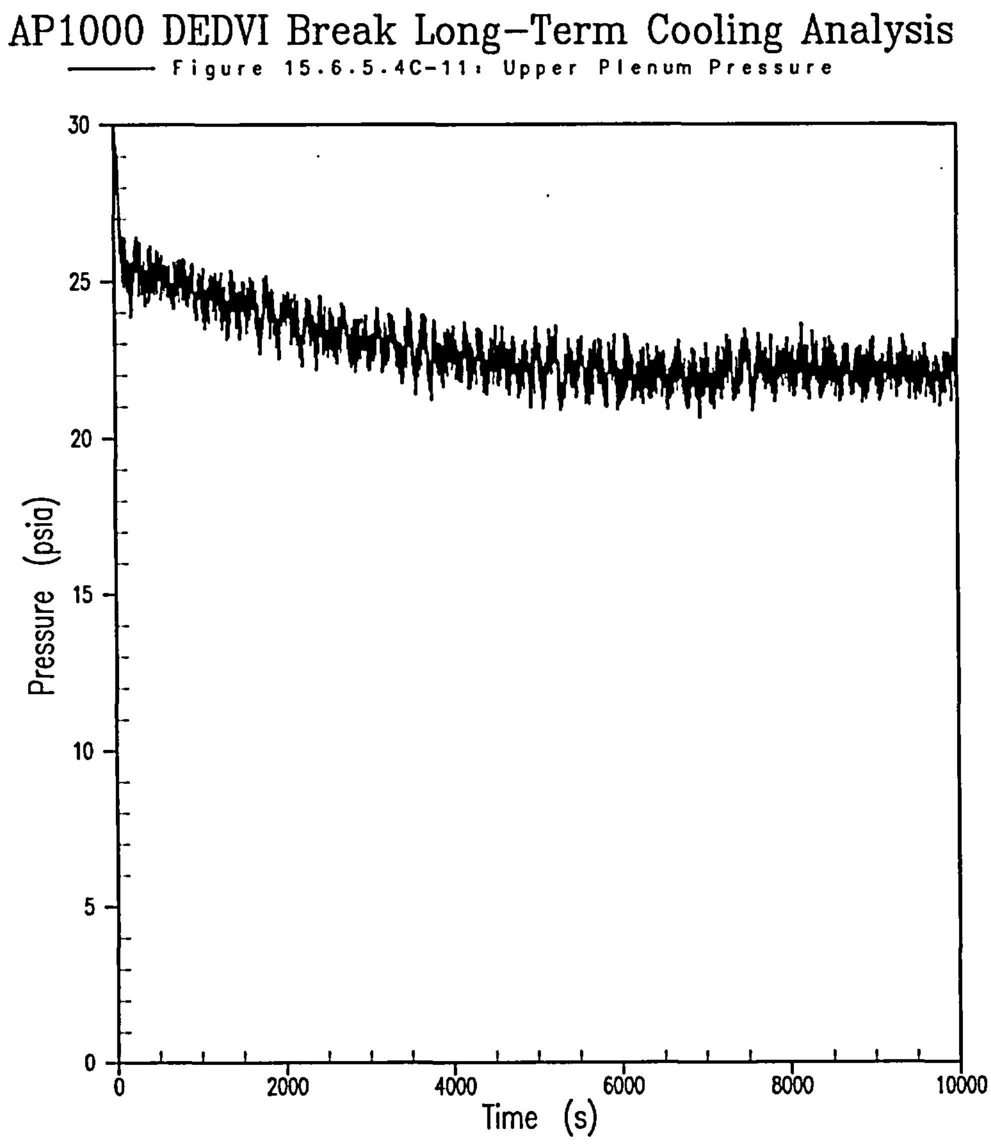

AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-8: Upper Plenum Collapsed Level
Collapsed Liquid Level (ft)
2.5
2
1.5
1
.5
0
0
2000
4000
6000
8000
10000
Time (s)

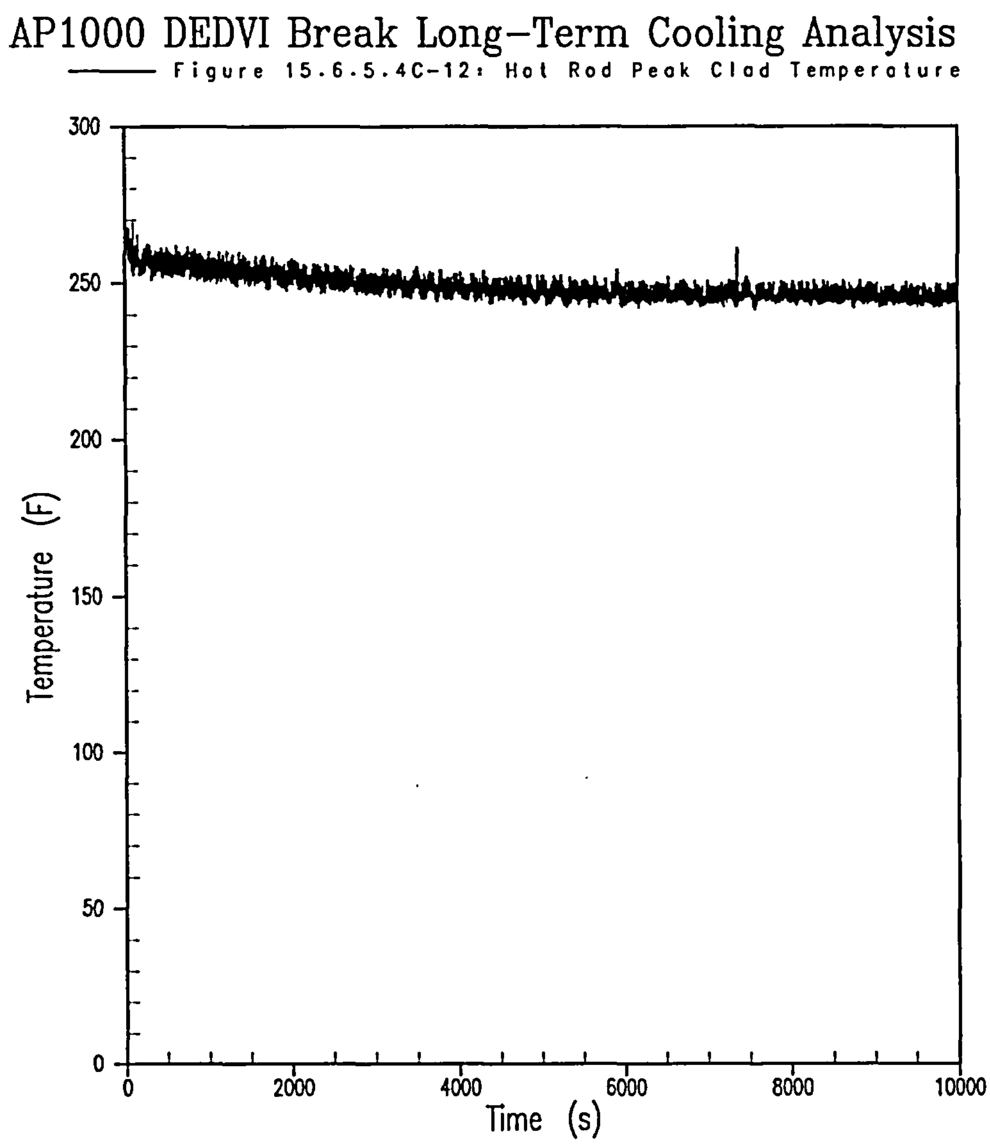

AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-9: Mixture Flow Rate.ADS-4A Valves [D [D [
Mass Flow Rate (lbm/s)
0
100
200
300
400
500
600
700
0
2000
4000
6000
8000
10000
Time (s)

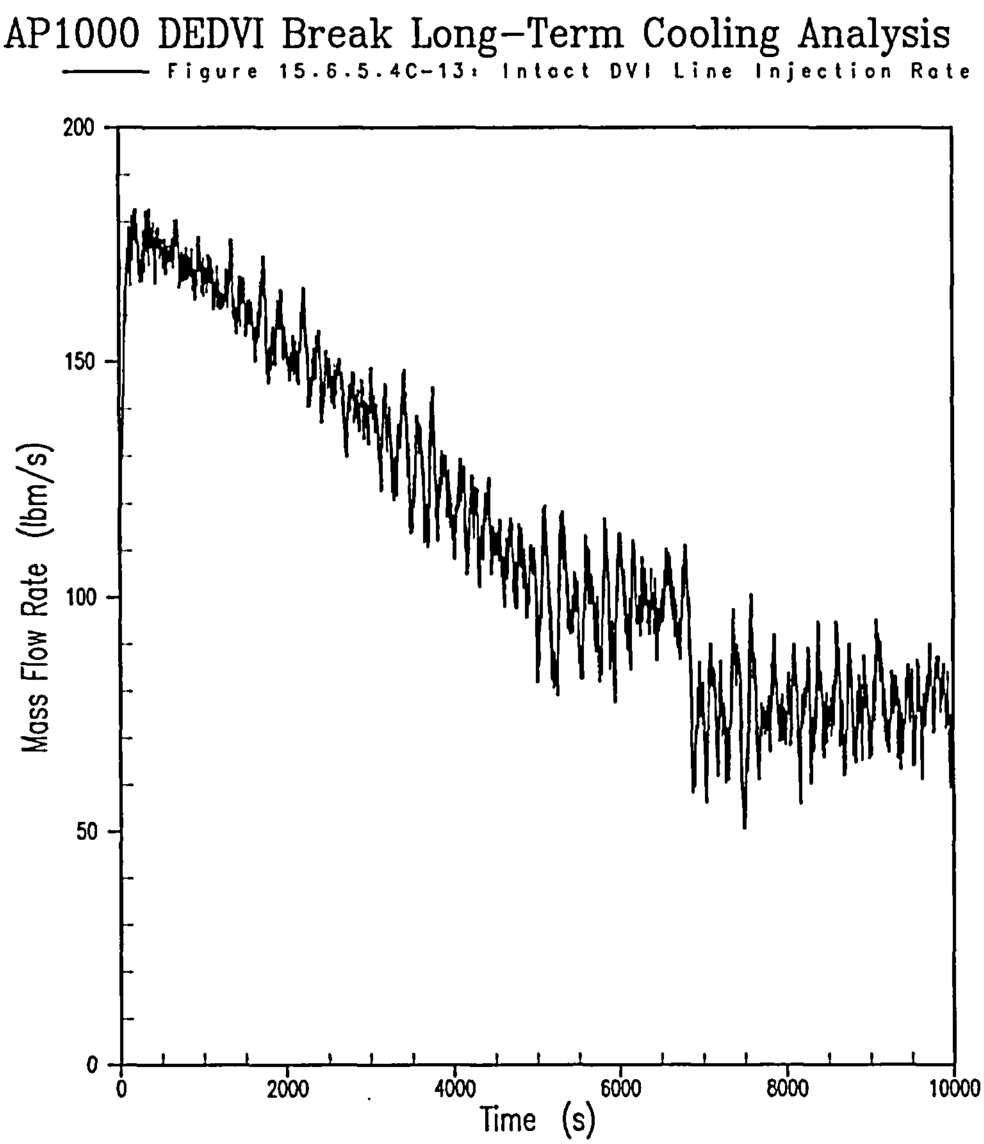
AP1000 DEDVI Break Long-Term Cooling Analysis

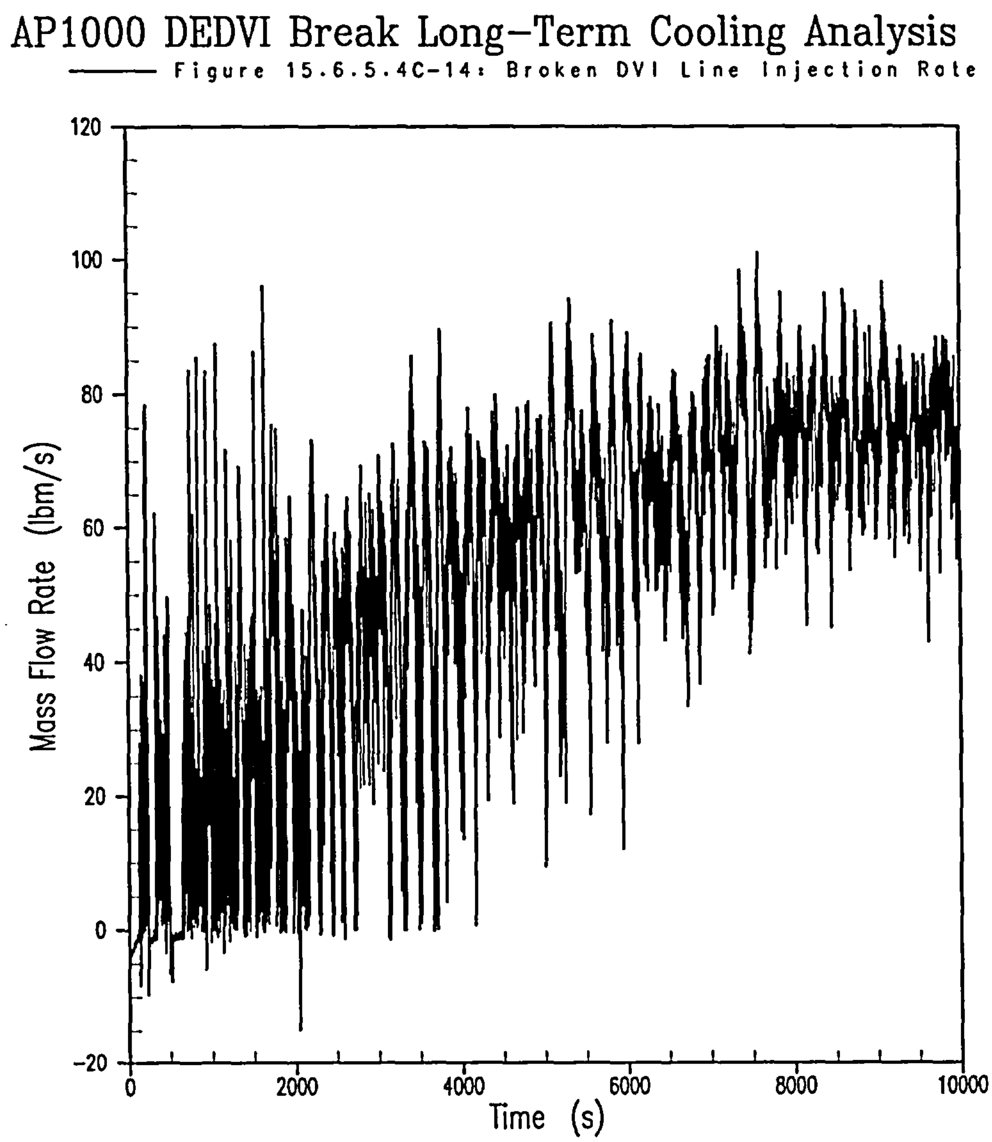
Figure 15.6.5.4C-10: Mixture Flow Rate,ADS-4B Valves




AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-11: Upper Plenum Pressure
Pressure (psia)
30
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
Time (s)


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-12: Hot Rod Peak Clad Temperature
300
250
200
150
100
50
0
Temperature (F)
0
2000
4000
6000
8000
10000
Time (s)


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-13: Intact DVI Line Injection Rate
Mass Flow Rate (lbm/s)
200
150
100
50
0
0
2000
4000
6000
8000
10000
Time (s)


AP1000 DEDVI Break Long-Term Cooling Analysis
Figure 15.6.5.4C-14: Broken DVI Line Injection Rate
Mass Flow Rate (lbm/s)
120
100
80
60
40
20
0
-20
0
2000
4000
6000
8000
10000
Time (s)

Appendix 6

Email dated 1/29/2004

"NOTRUMP homogeneous sensitivity case"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:31 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP homogeneous sesnsitivity case

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 10:46 AM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Gagnon, Andre F.
Subject: NOTRUMP homogeneous sesnsitivity case

20psi_homo_comp_figs.doc

Here is the NOTRUMP case at 20 psia with homogeneous flow assumption above the core - results are similar to 25 psia case previously provided in OI 21.5-1 response. The sensitivity case is compared to the the new 20 psia base case in these plots.

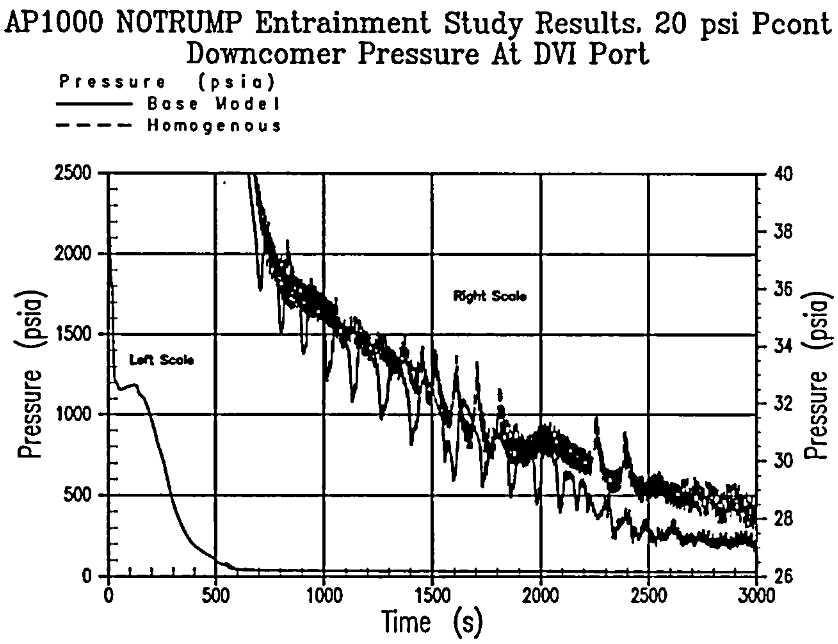


Figure-1 **Downcomer Pressure Comparison**

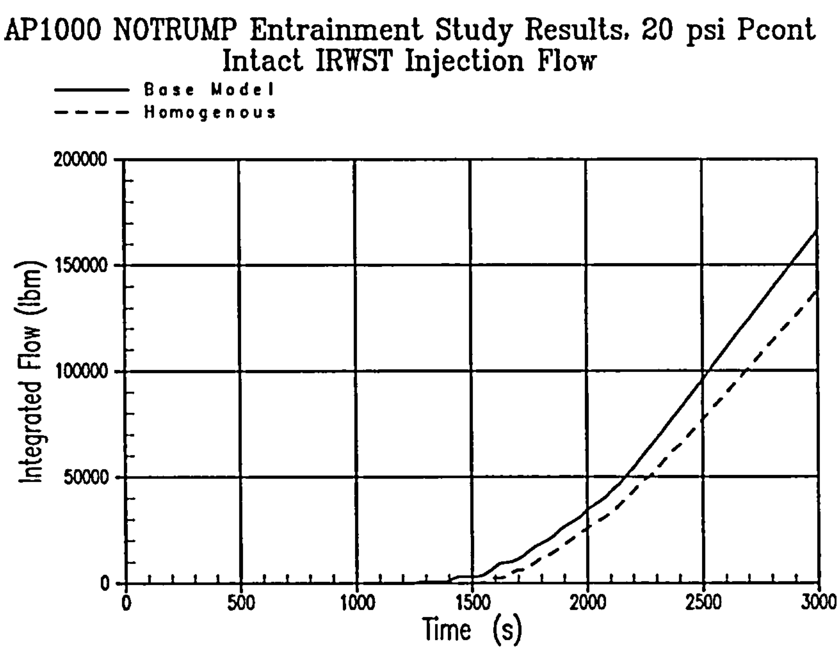


Figure-2 **Integrated Intact IRWST Injection Flow**

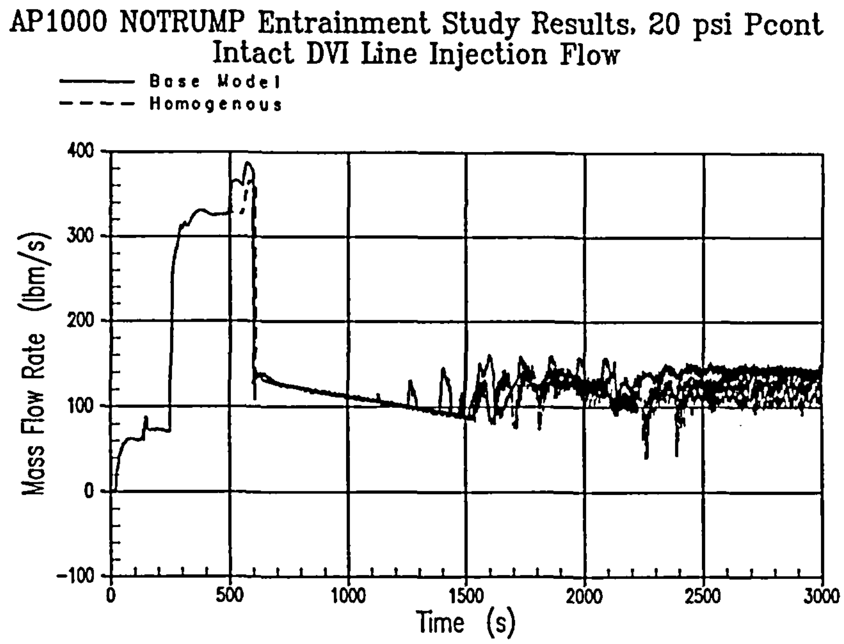


Figure-3 **Intact DVI Line Injection Flow**

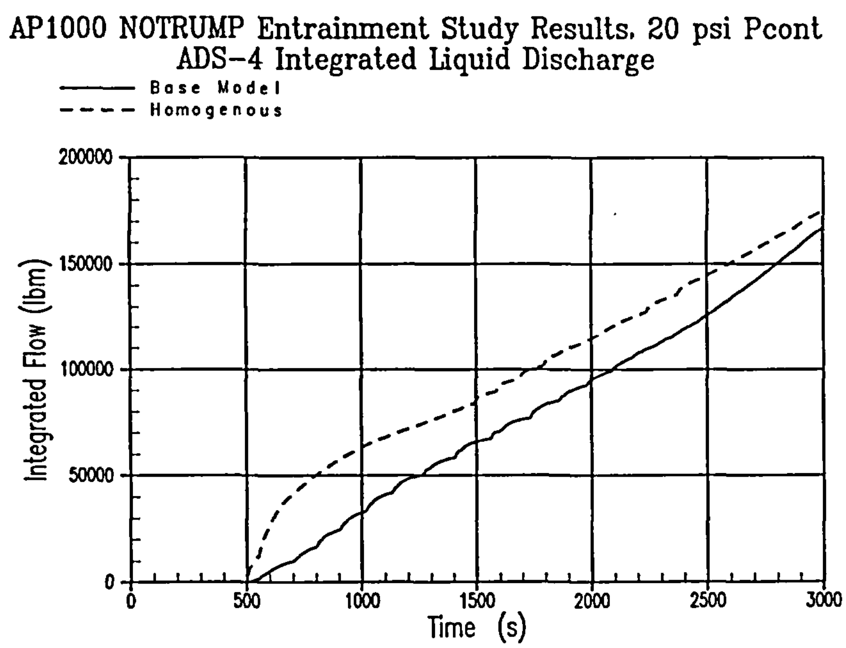


Figure-4 **ADS-4 Integrated Liquid Discharge Comparison**

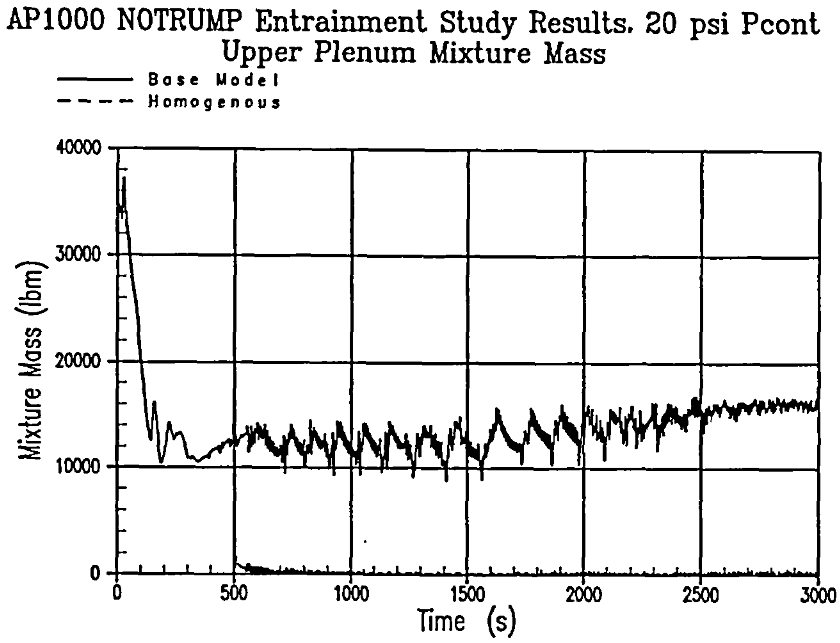


Figure-5 **Upper Plenum Mixture Mass Comparison**

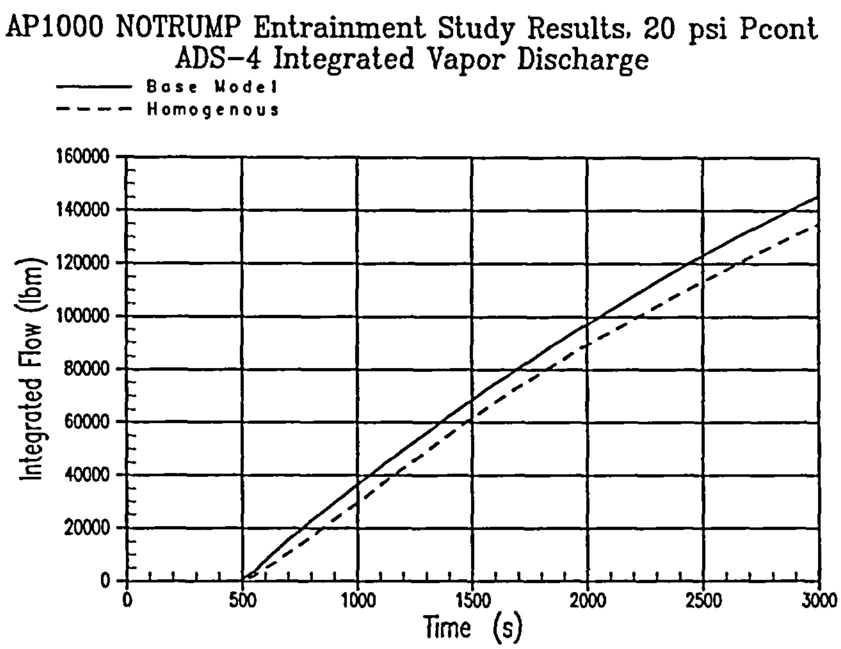


Figure-6 **ADS-4 Integrated Vapor Discharge Comparison**

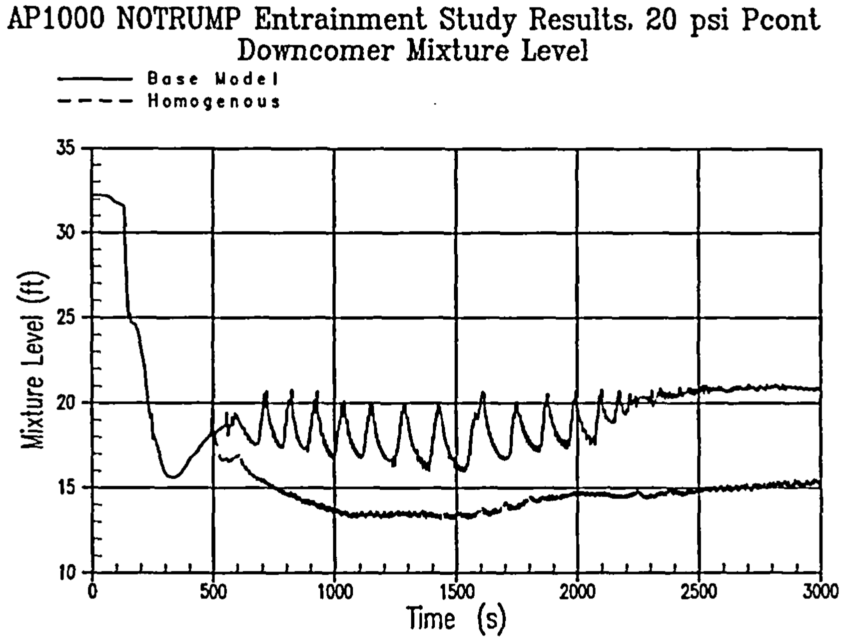


Figure-7 **Downcomer Region Mass Comparison**

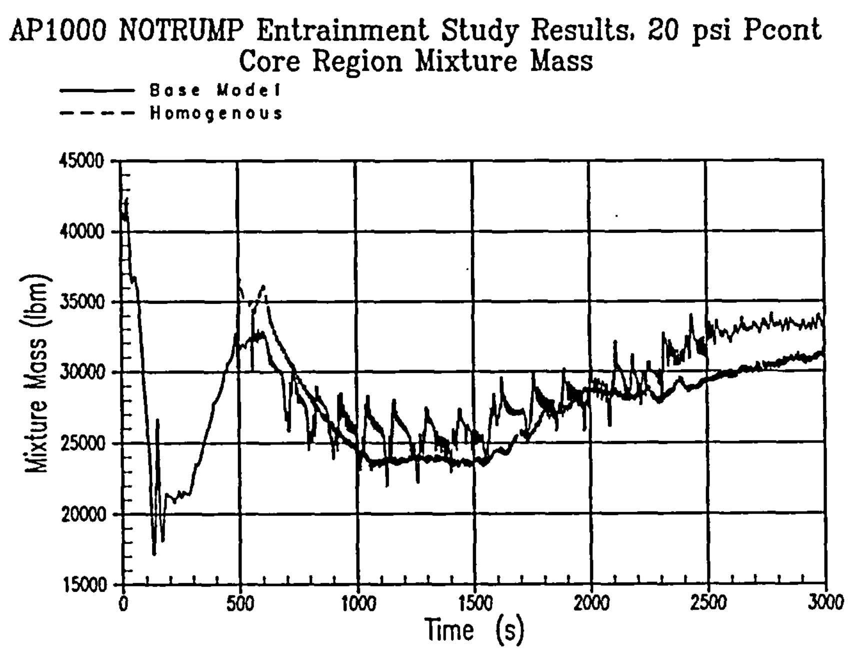


Figure-8 **Core Region Mass Comparison**

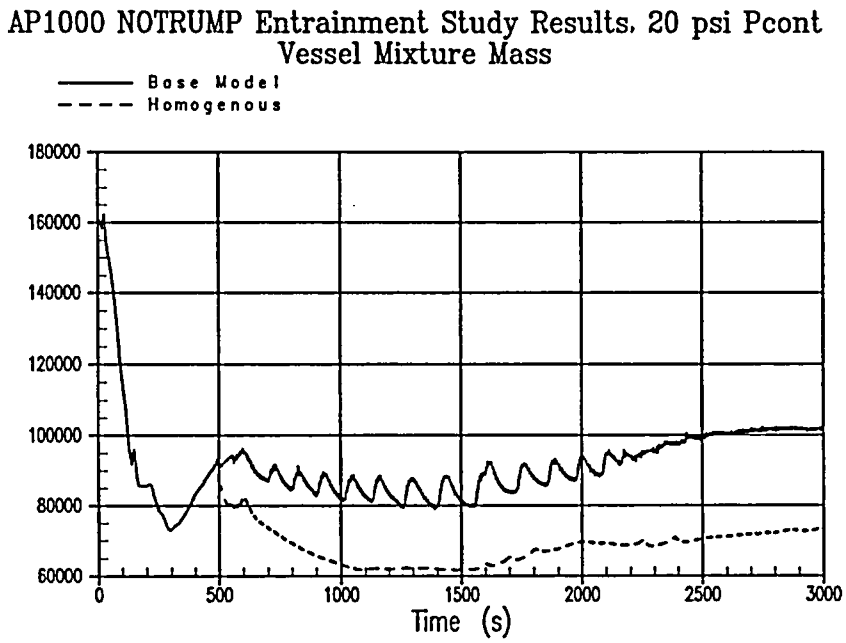


Figure-9 **Vessel Mixture Mass Comparison**

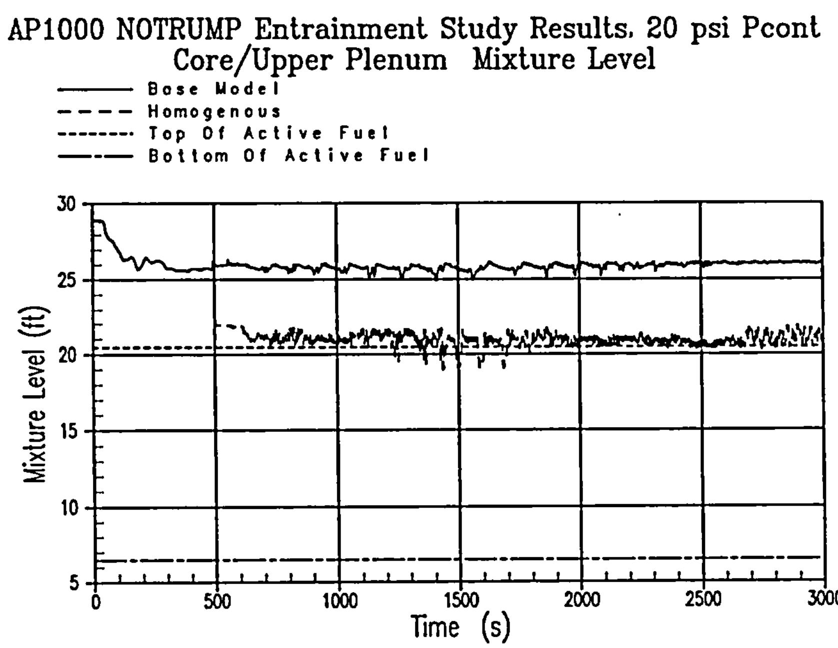


Figure-10 **Core/Upper Plenum Mixture Level Comparison**

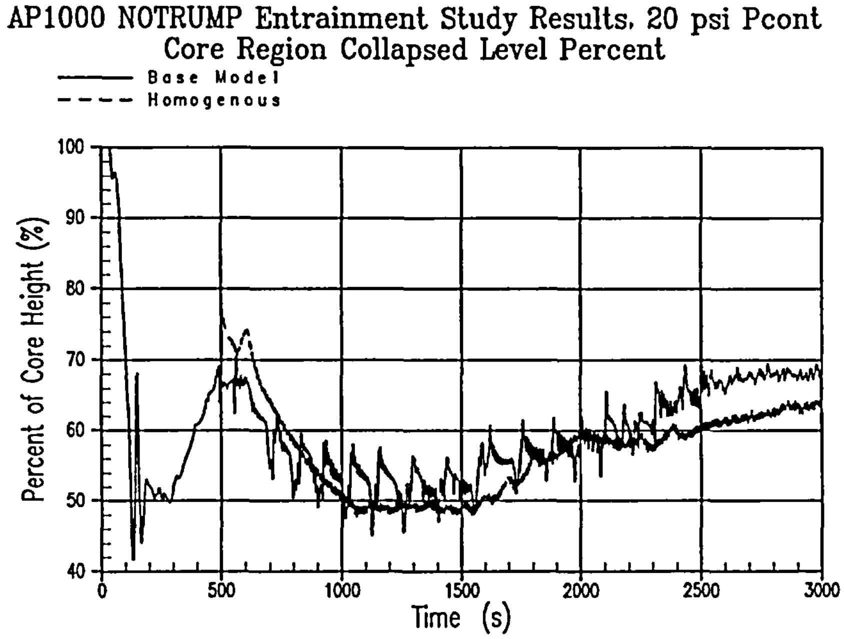


Figure-11 **Core Coverage Percentage Comparison**

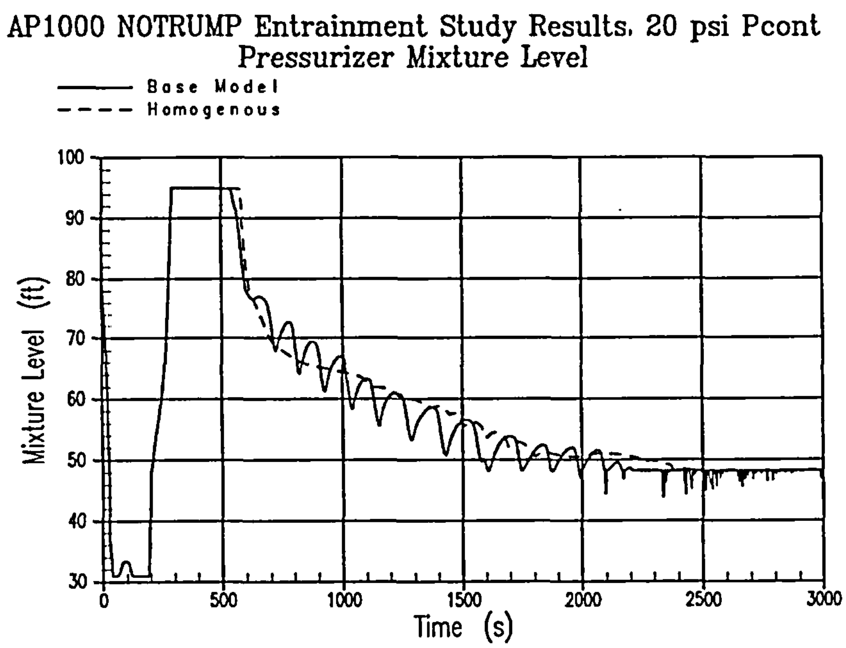


Figure-12 **Pressurizer Mixture Level Comparison**

DCP/NRC1678
Docket No. 52-006

February 2, 2004

Appendix 7

Email dated 1/29/2004
"10 inch break"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:31 AM
To: Gongaware, Jacqueline J.
Subject: FW: 10 inch break

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 12:49 PM
To: 'John Segala'; 'Jennifer Uhle'; 'Joseph Colaccino'
Subject: 10 inch break

10-inch LOCA m.doc

Here is additional discussion regarding the 10 inch break.

10-inch Small Break LOCA

The largest small break LOCA analyzed is the 10-inch cold leg break. NOTRUMP results for this break are shown in AP1000 DCD Figures 15.6.5.4B-56 through 78.

During the initial portion of the 10-inch break, the break in the cold leg draws fluid from the bottom of the core, and the vessel mixture level falls to a minimum and then recovers as accumulator flow enters the downcomer. During this time period a portion of the core exhibits the potential for core dryout to occur without the prediction of a traditional core uncovery period (for example, core two-phase mixture level dropping into the active fuel region). To conservatively account for this potential core dryout period, a composite core mixture level was created which collapses to the minimum of the actual core/upper plenum two-phase mixture level and the bottom of the lowest core node that exceeds the core dryout onset conditions. A 90-percent quality limit was chosen as the indicator of the onset of core dryout indicative of the critical heat flux. Dryout is assumed at core qualities above this value. To conservatively estimate the effects of this dryout period, an adiabatic heat-up calculation was performed, and the resulting peak cladding temperature is determined to be approximately 1370°F. Even under these conservative adiabatic heat-up assumptions, the AP1000 plant design exhibits large margins to the 10 CFR 50.46 Appendix-K limits for the 10-inch break.

The AP1000 response to a 10 inch LOCA during this early blowdown period is essentially the same as for conventional PWRs. Historically these intermediate size breaks have been shown to be bounded by the LBLOCA. After this early blowdown period, the AP1000 response to the 10-inch break is similar to other AP1000 small break LOCA events. However the post-blowdown recovery period for the 10-inch break is less limiting than the DEDVI LOCA because both DVI injection paths are available to supply core makeup, and their is no injection water lost directly to the containment. In addition, the long term recovery phase for the 10-inch break is less challenging than the other break sizes because the larger break aids depressurization.

These effects can be seen in the attached figures comparing the 10-inch break and DEDVI break results.

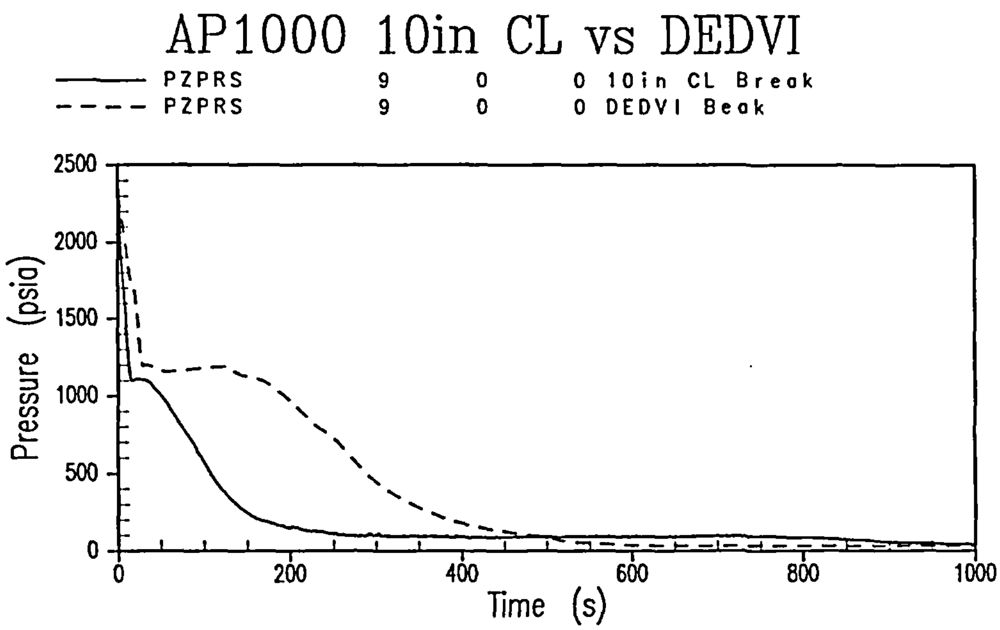


Figure 1: Pressurizer Pressure

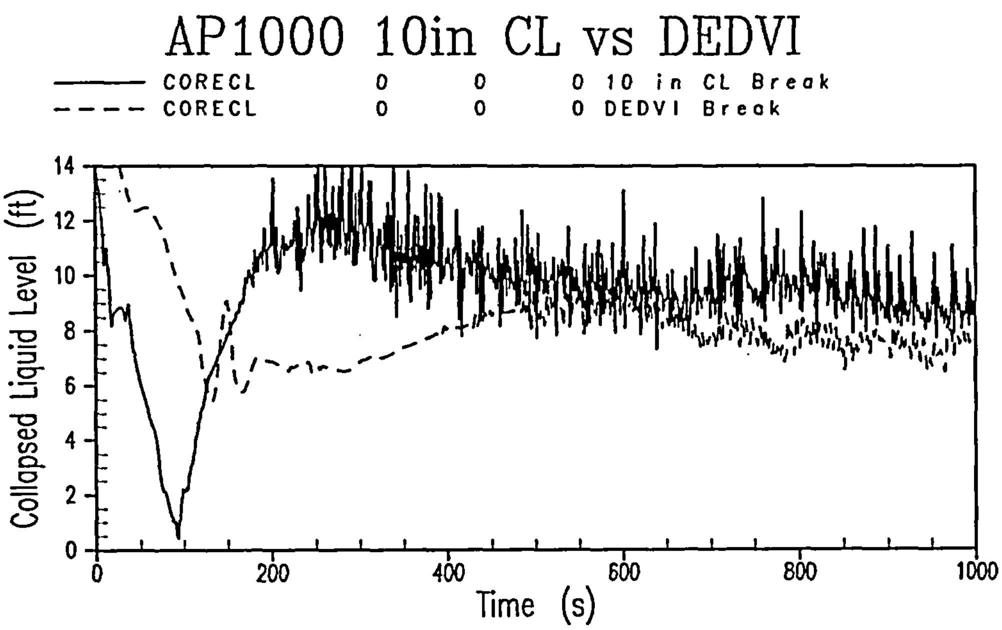


Figure 2: Core Collapsed Liquid Level

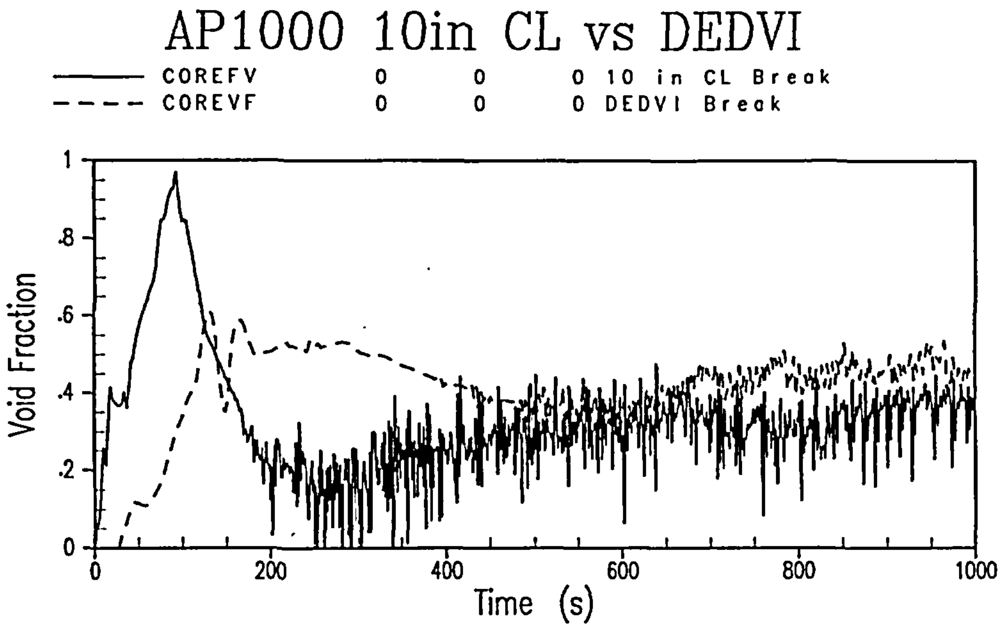


Figure 3: Core Average Void Fraction

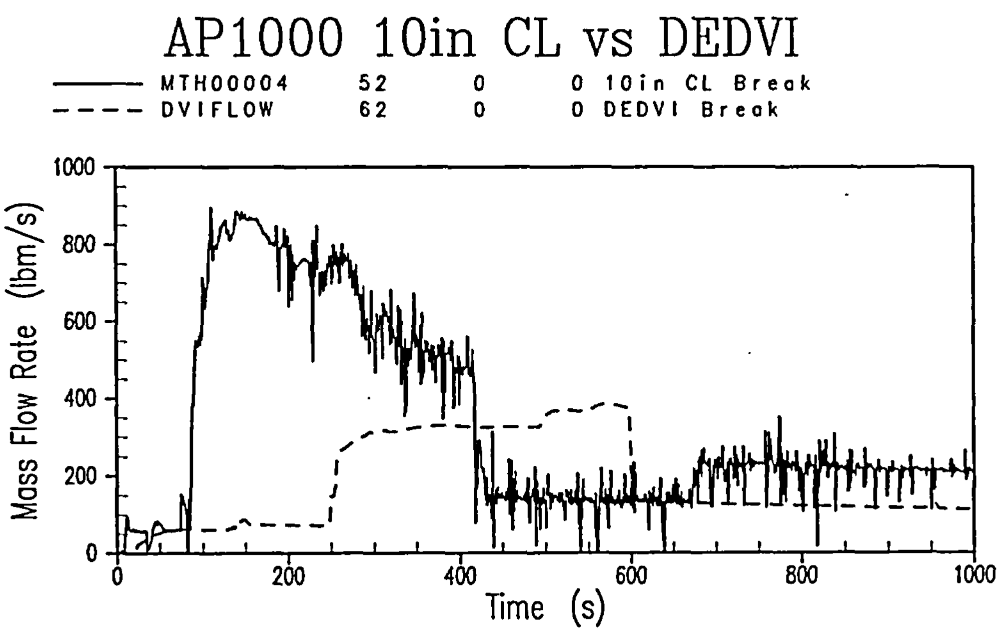


Figure 4: Direct Vessel Injection Flow

DCP/NRC1678
Docket No. 52-006

February 2, 2004

Appendix 8

Email dated 1/29/2004

"FLOAD4 & Crane calcs"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:31 AM
To: Gongaware, Jacqueline J.
Subject: FW: FLOAD4 & Crane calcs

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 1:46 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Subject: FLOAD4 & Crane calcs

FLOAD4-Crane.doc FLOAD4 fp-d.pdf FLOAD4 pz.pdf

Here are the FLOAD4 and Crane calcs for AP1000.

FLOAD4 and Crane Calculations

The attached figures give FLOAD4 calculated results for flow and pressure in the AP1000 ADS4 flow path on the non-pressurizer loop with both squib valves open. The FLOAD4 methods are described in the AP600 RAI response provided previously.

An independent calculation was performed for 100% steam flow using CRANE methods. CRANE lists the following equation (eqn 3-20) for compressible fluids:

$$w = 0.525\ Y\ d^2\ (\ DP\ /\ K\ v\ )^{0.5}$$

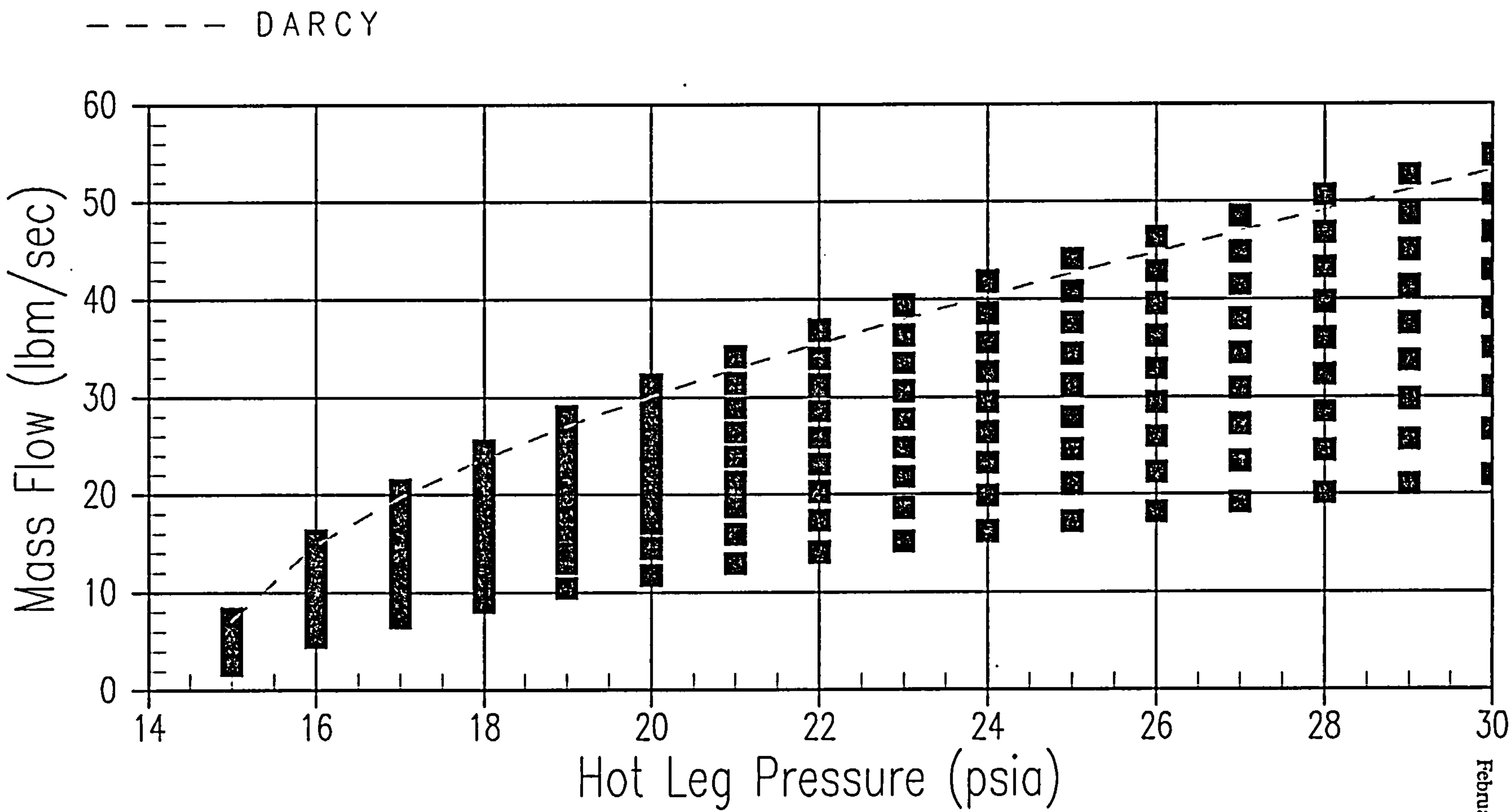
where w is the mass flow (lb/sec)
Y is a expansion factor from CRANE page A-22 for k = 1.3 (water, steam)
d is the pipe inside diameter (used to calc K)
DP is the differential pressure (psi)
K is the resistance coefficient, velocity head loss
v is the upstream mixture specific volume (ft3/lb)

As an example, for the AP1000 with a HL pressure of 20 psia and a containment pressure of 14.7 psia:

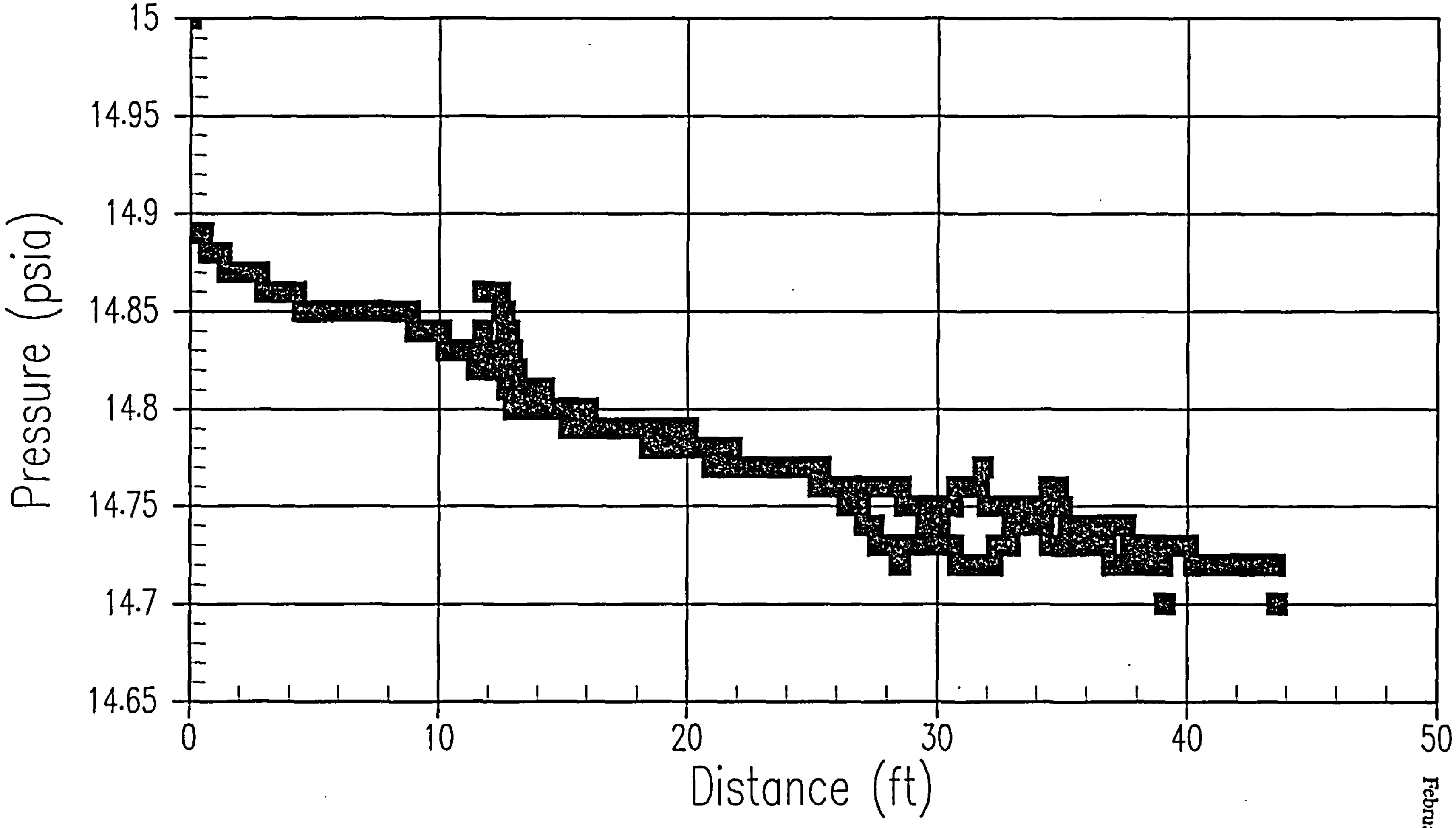
Y =	0.87 from CRANE p A-22 with the K shown below and a DP/P = 0.26
d =	15.82 in. (equivalent inside diameter of two ADS 4 branch lines, 14" sch 160)
DP =	5.3 psi (for listed RCS / containment pressure)
K =	3.81 (ADS 4 line B with both valves open)
v =	20.09 ft3/lb (saturated steam at 20 psia)
w =	30.08 lb/sec

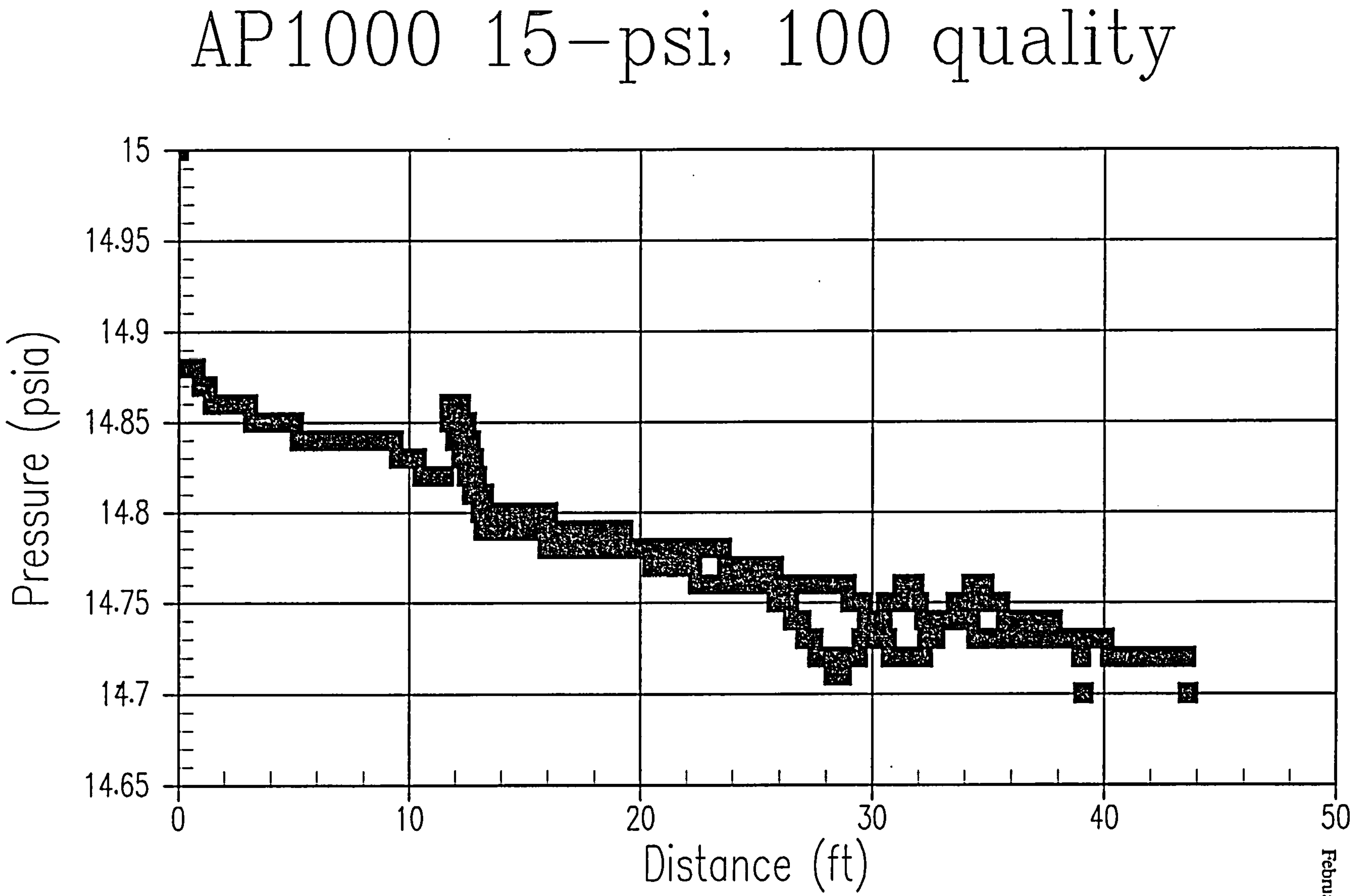
The results of this calculation are plotted against the FLOAD4 data. The FLOAD4 result with 100% steam compares well with this calculation using CRANE compressible flow equation.

AP1000 FLOAD4 Simulations As A Function Of Pressure/Quality

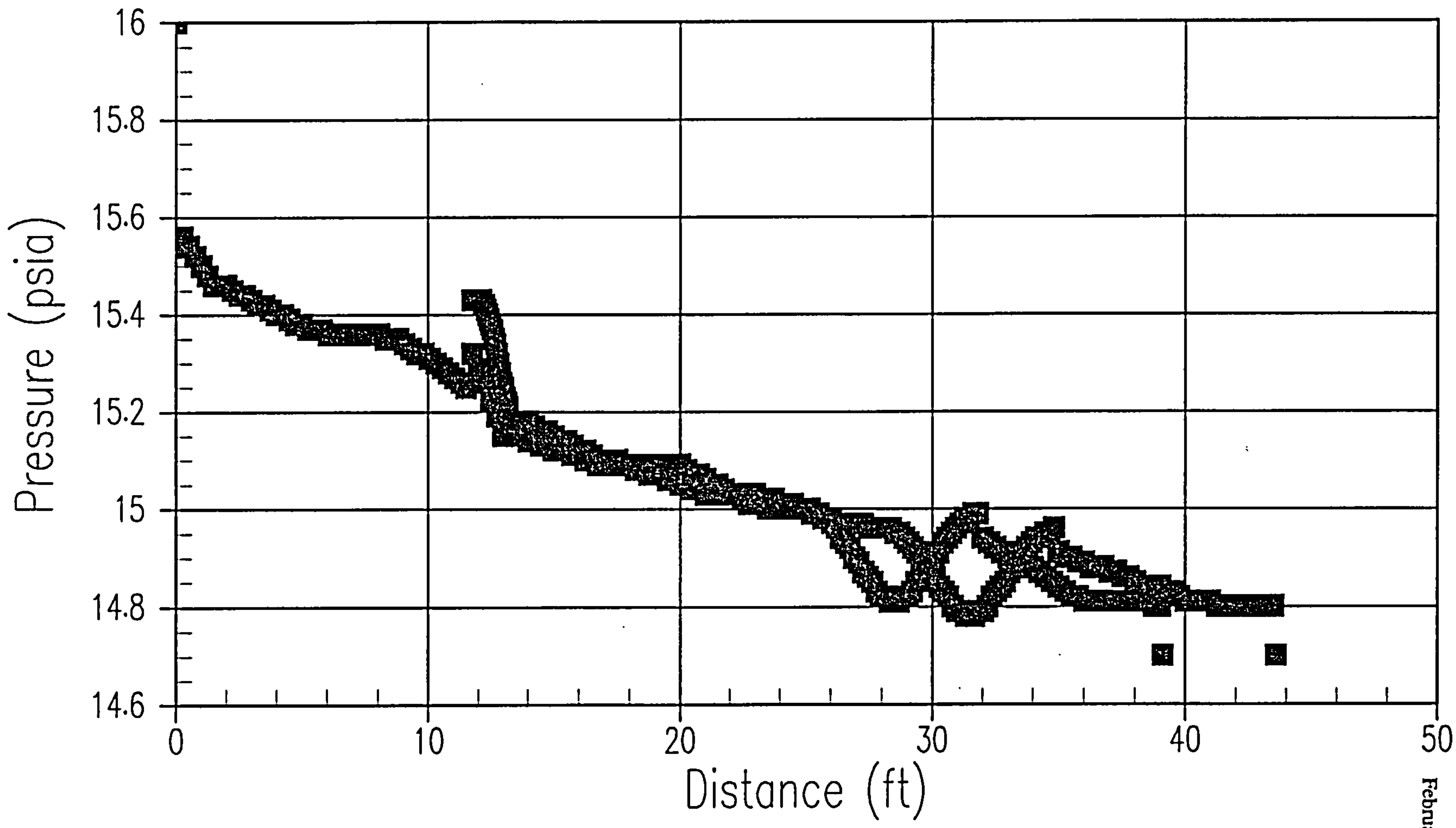


AP1000 15-psi, 90 quality

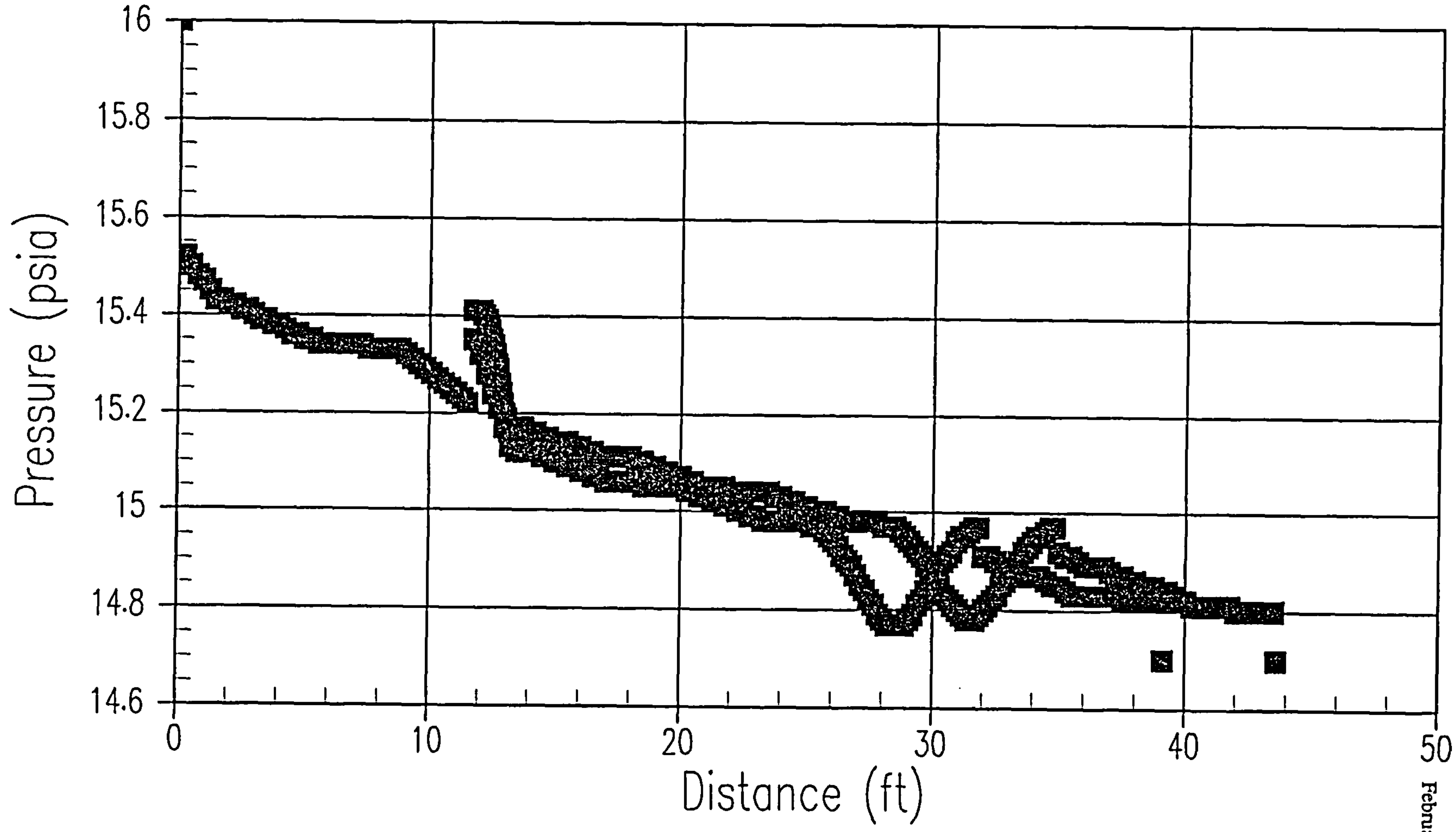



AP1000 15-psi, 100 quality
Pressure (psia)
15
14.95
14.9
14.85
14.8
14.75
14.7
14.65
Distance (ft)
0
10
20
30
40
50

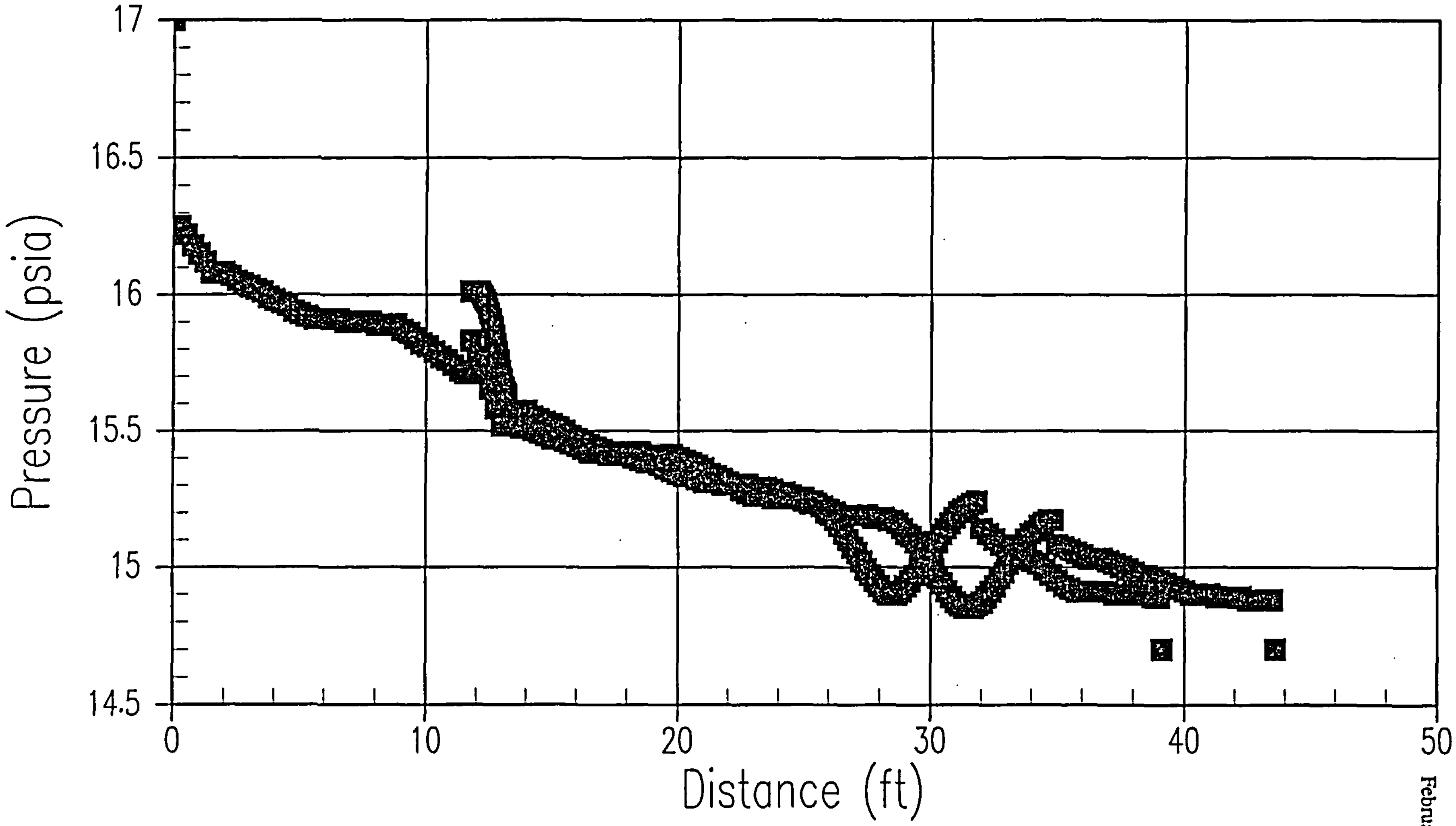
AP1000 16-psi, 90 quality



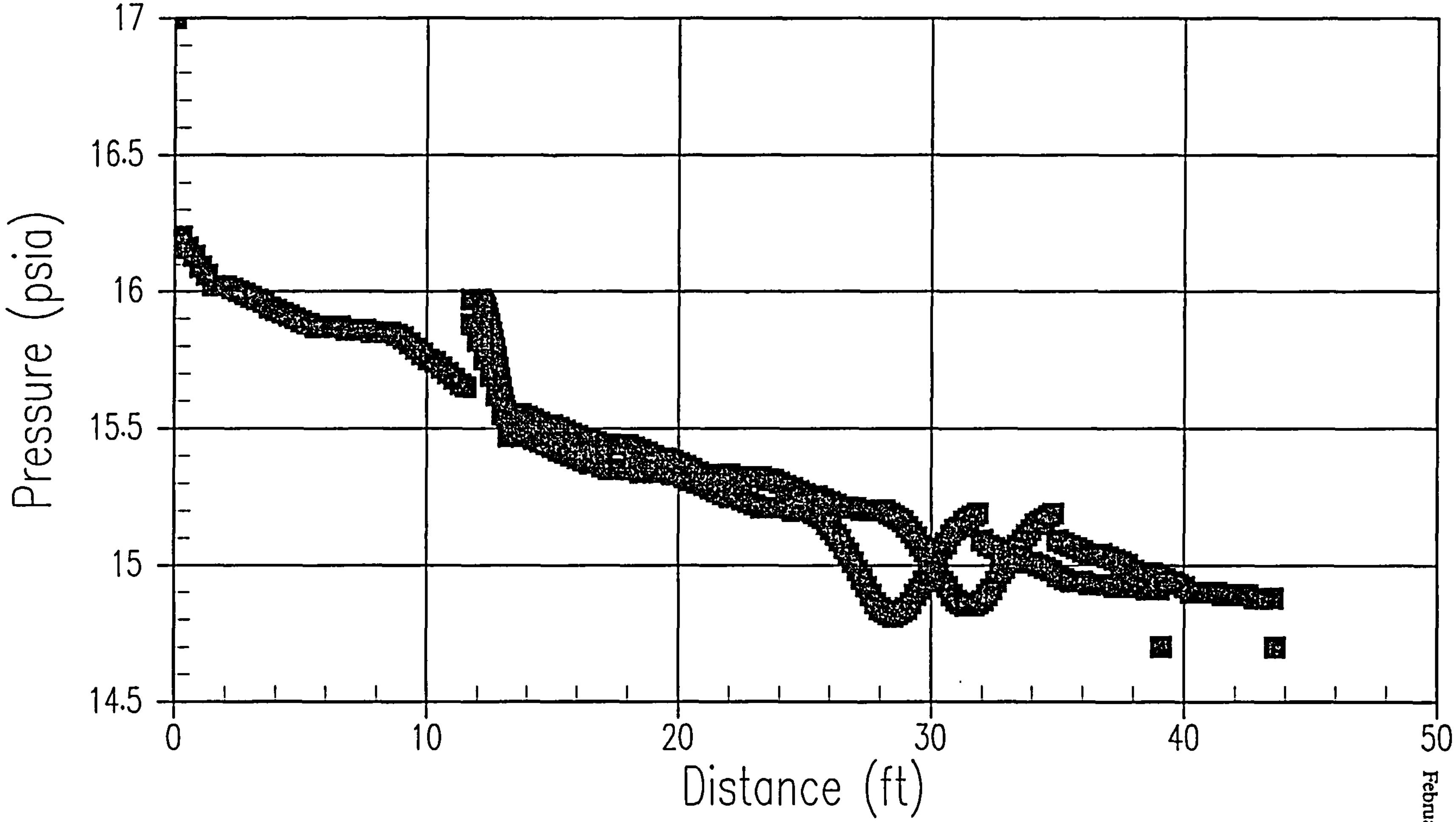
AP1000 16-psi, 100 quality



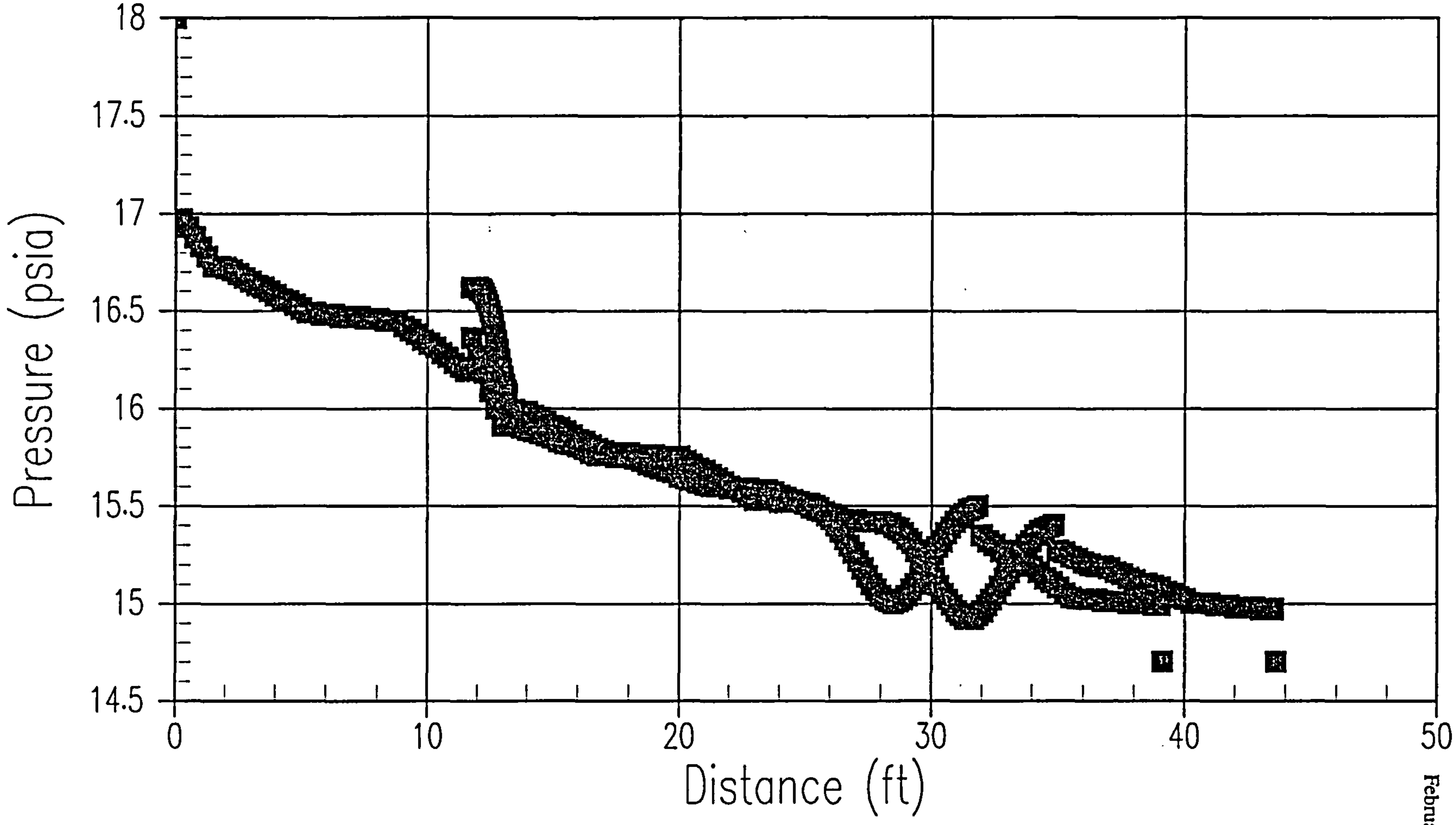
AP1000 17-psi, 90 quality



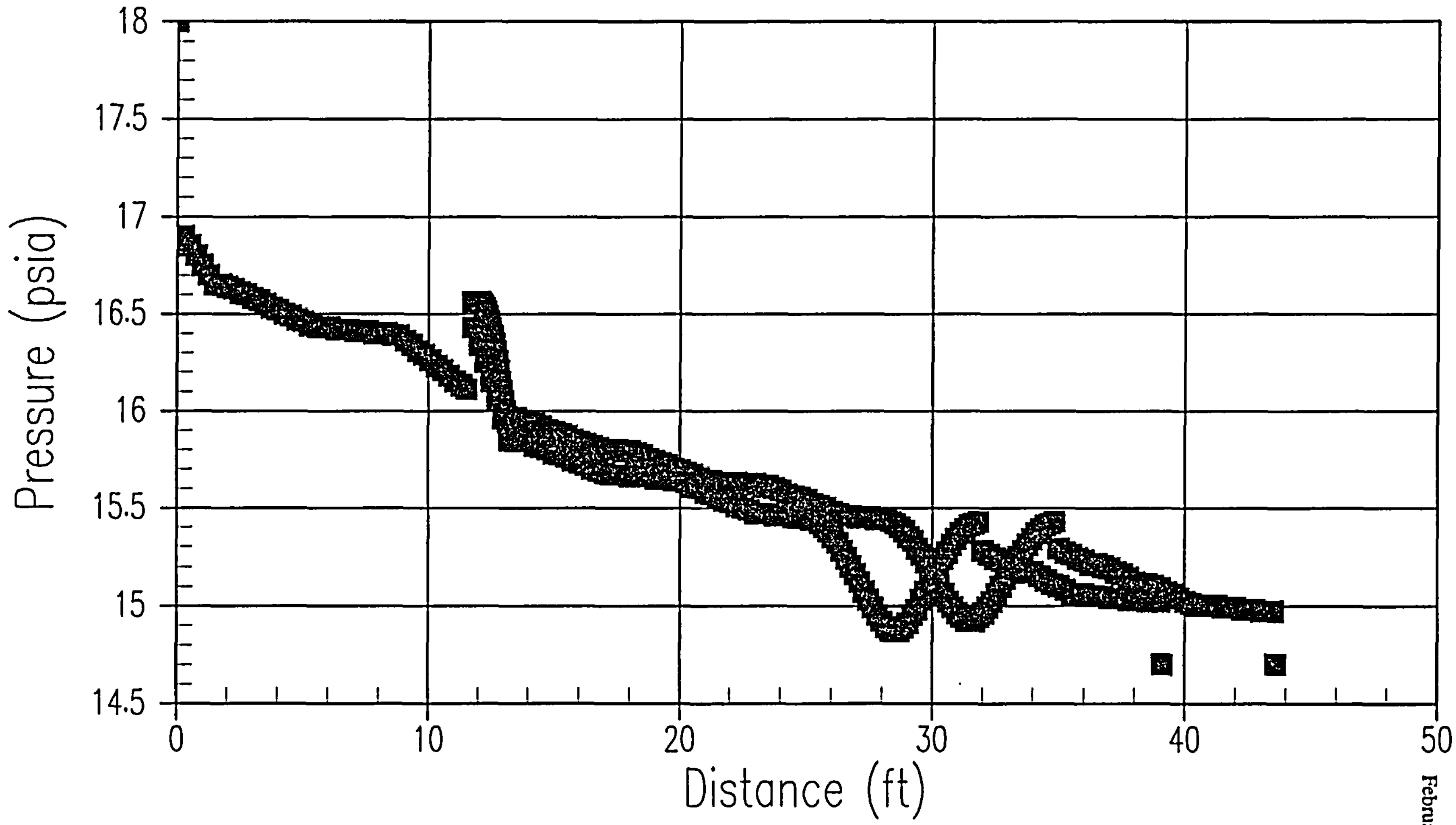
AP1000 17-psi, 100 quality



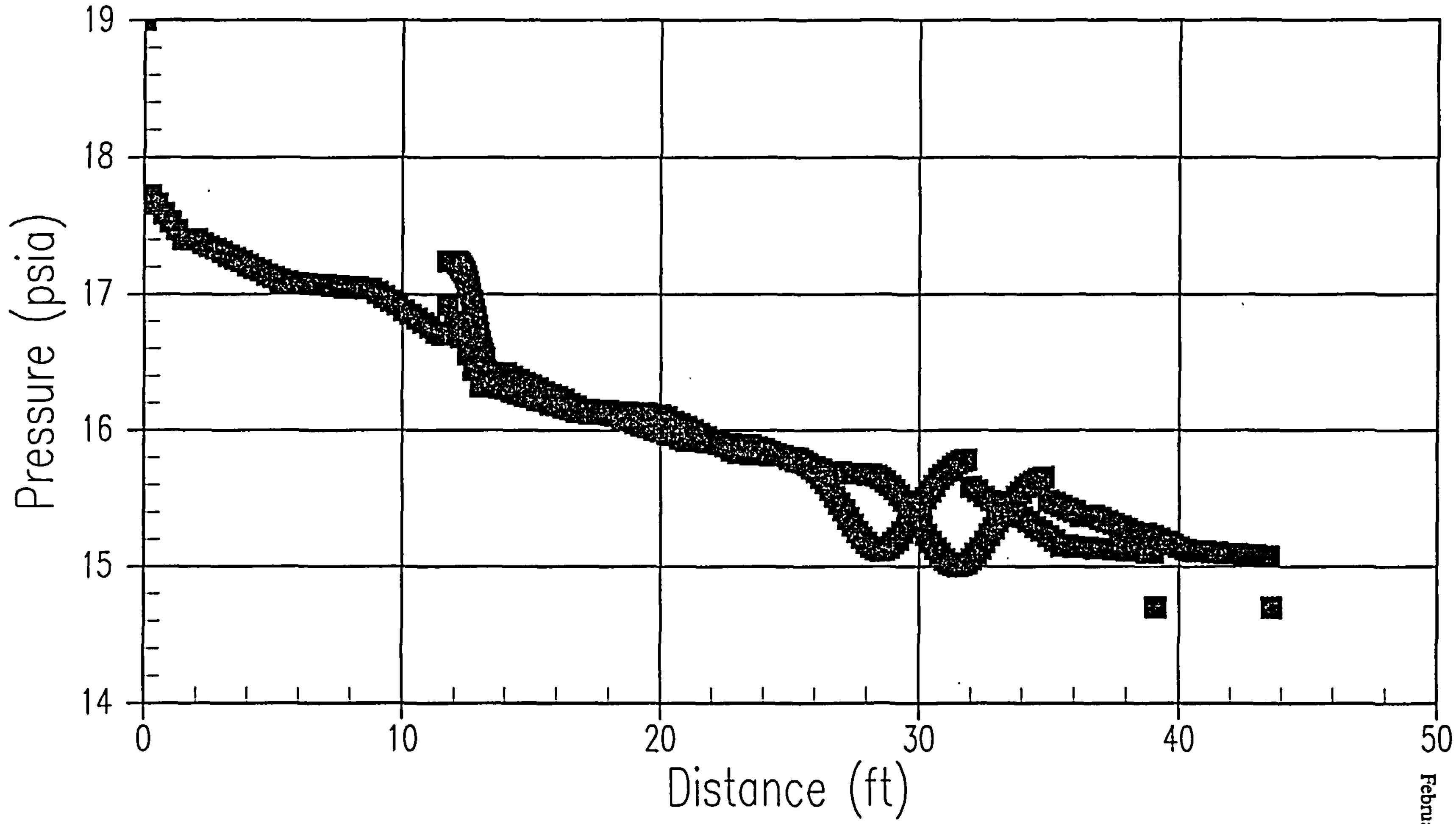
AP1000 18-psi, 90 quality



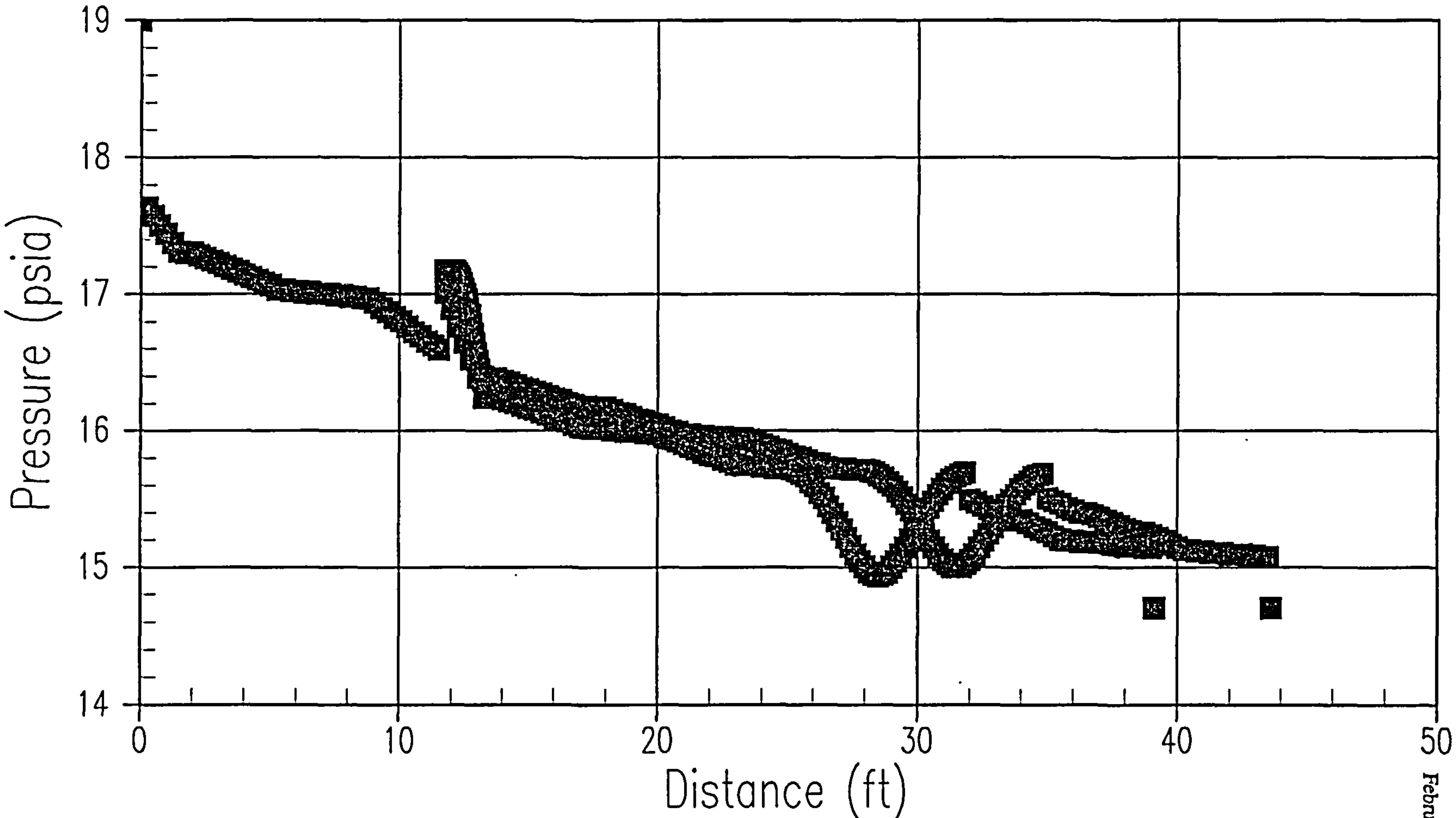
AP1000 18-psi, 100 quality



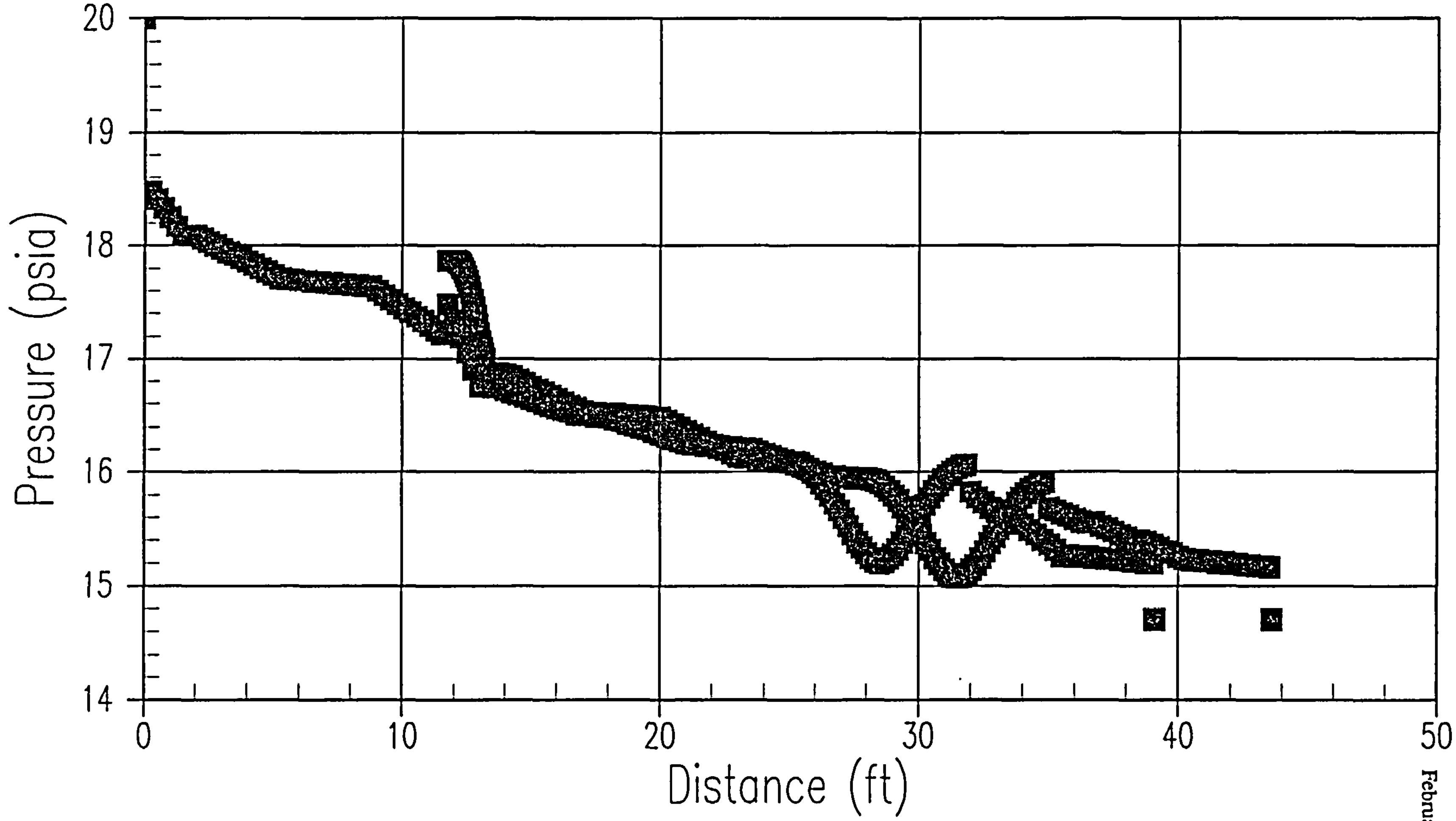
AP1000 19-psi, 90 quality

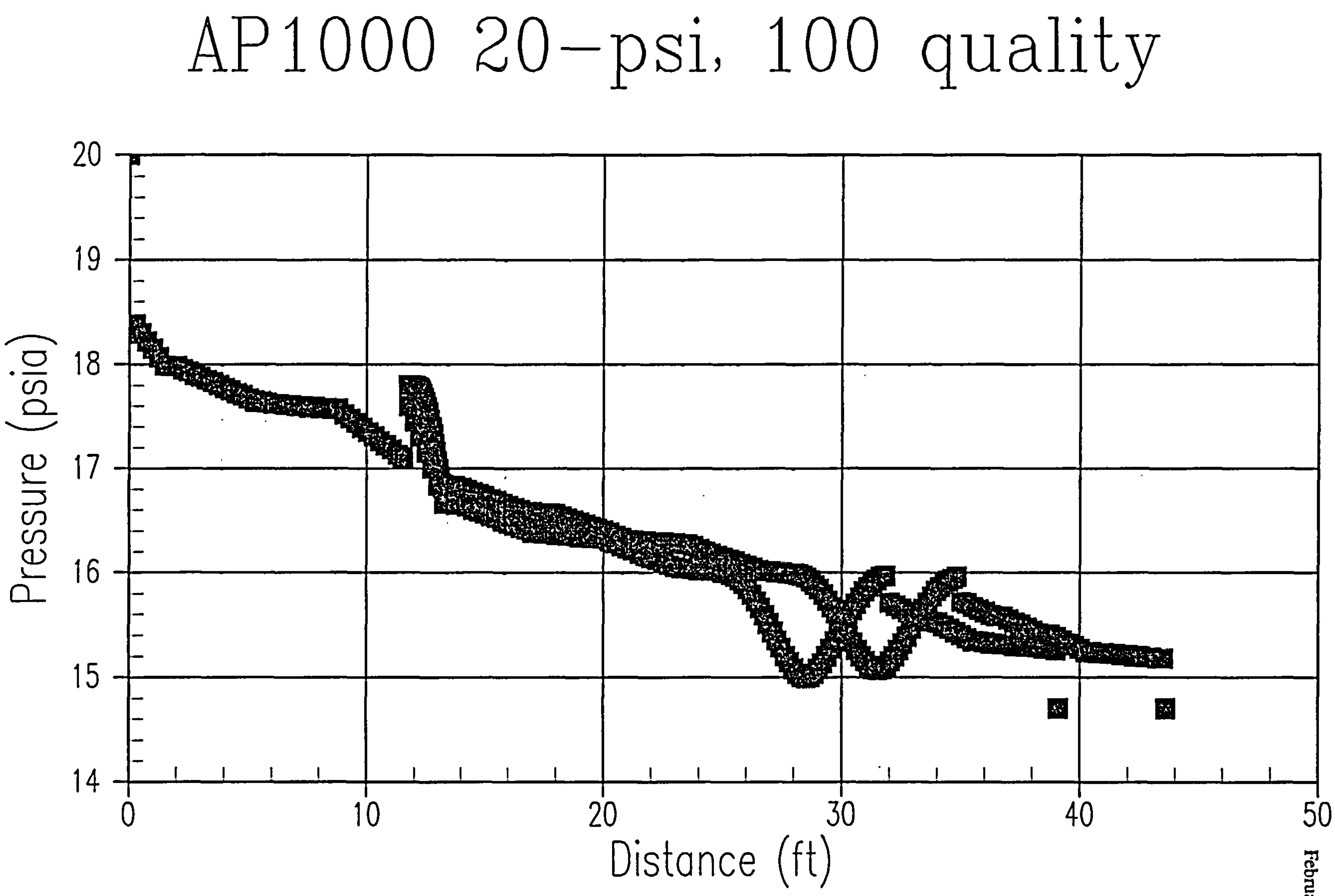


AP1000 19-psi, 100 quality

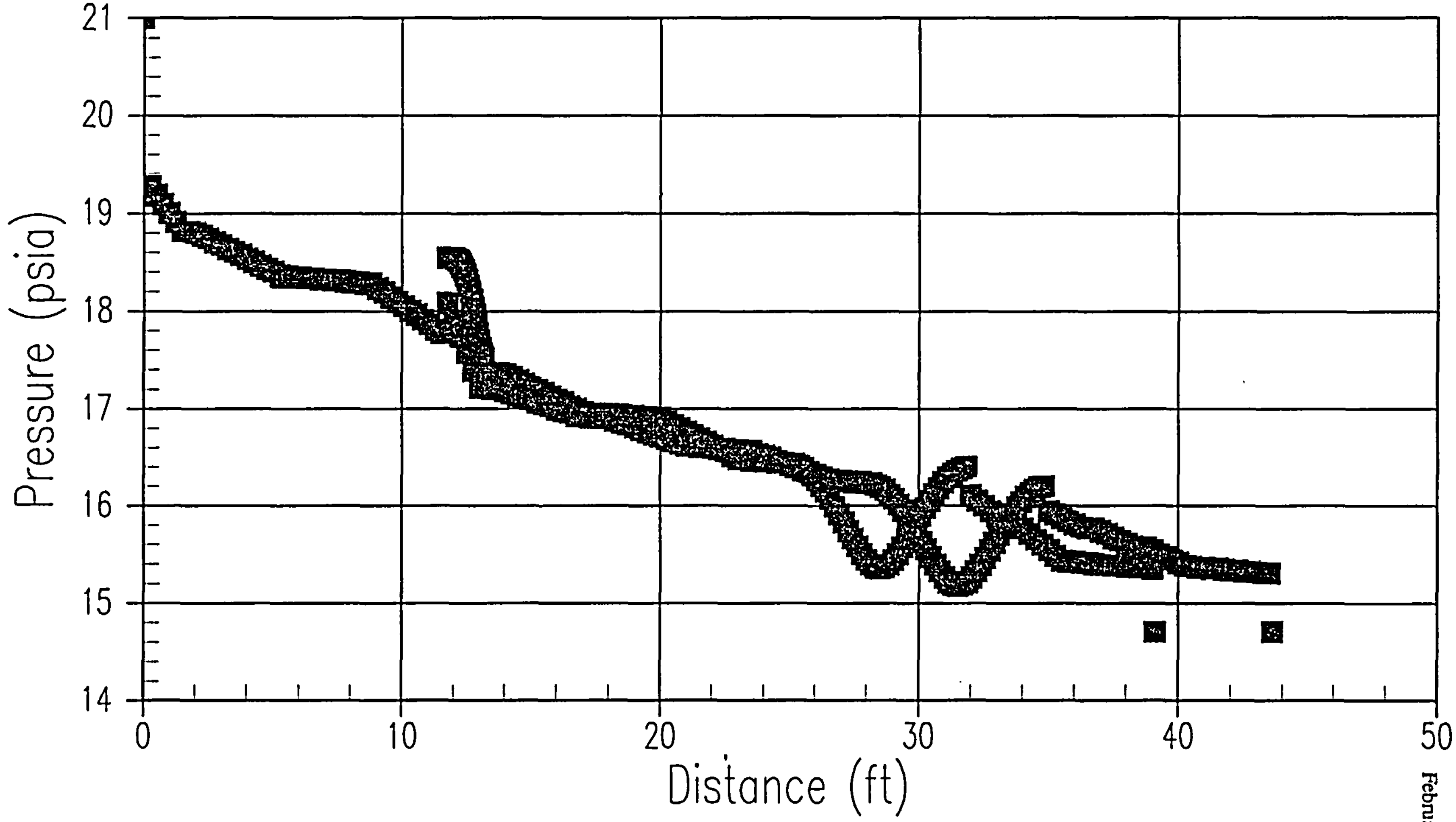


AP1000 20-psi, 90 quality

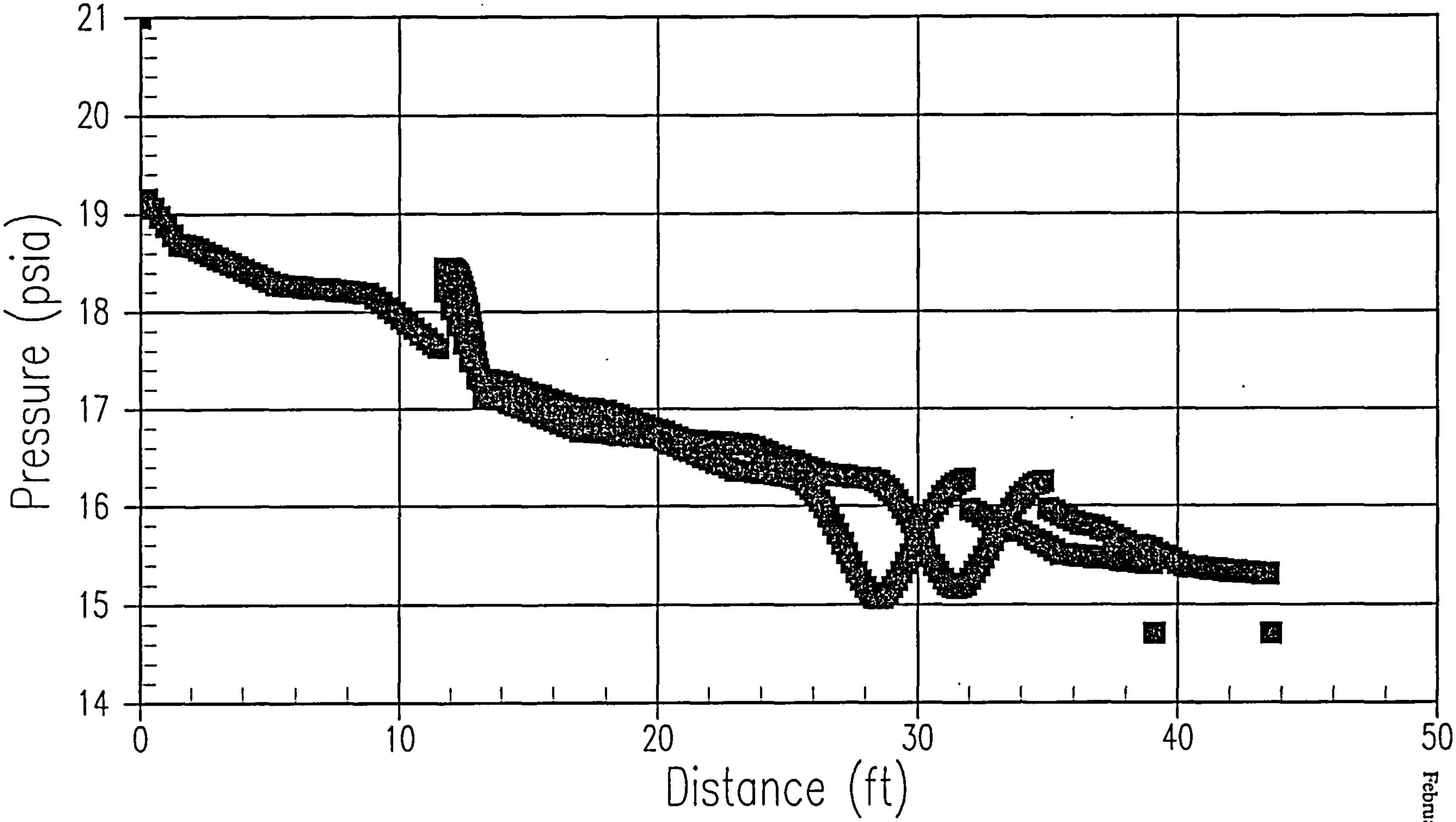



AP1000 20-psi, 100 quality
Pressure (psia)
20
19
18
17
16
15
14
Distance (ft)
0
10
20
30
40
50

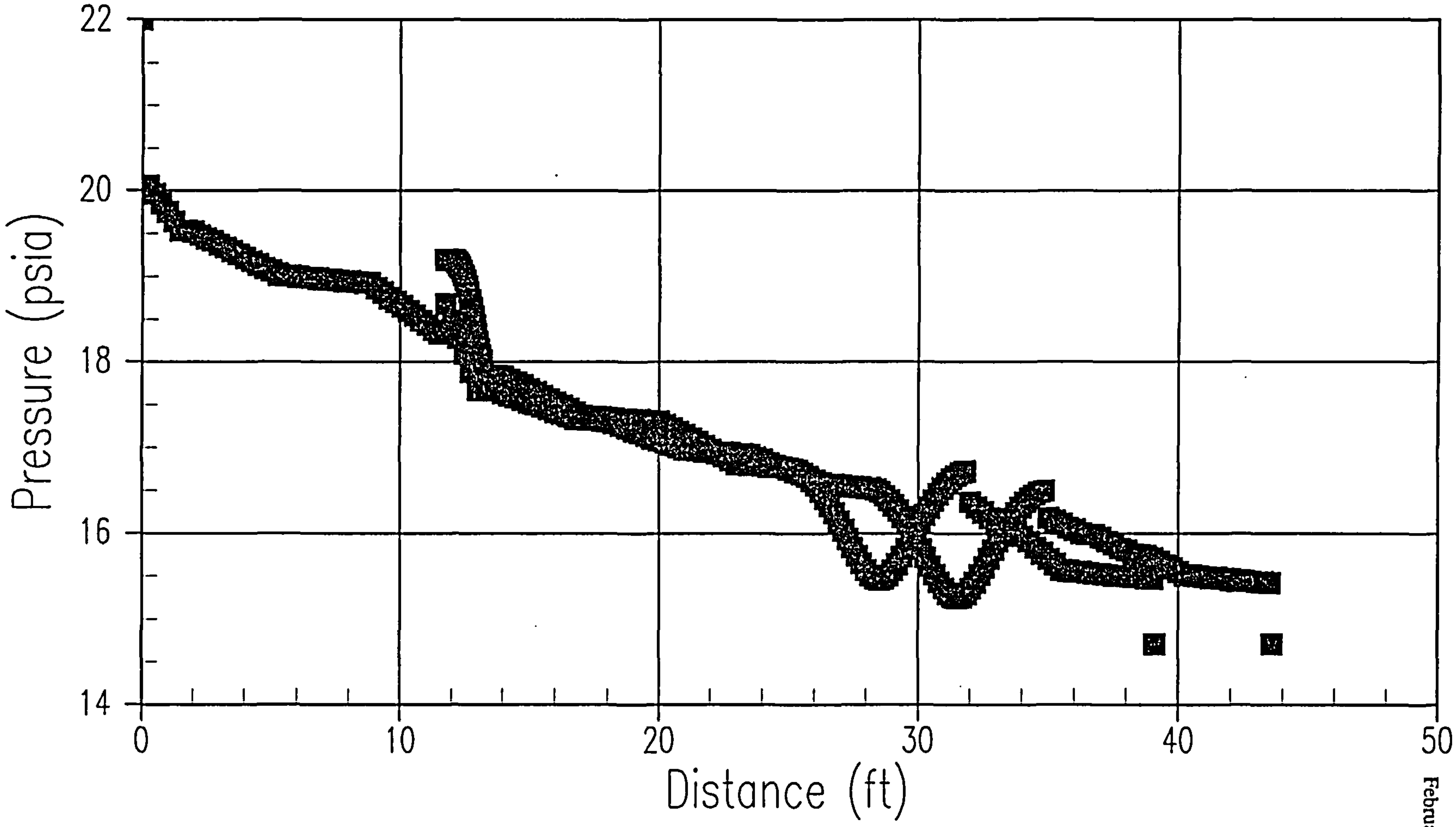
AP1000 21-psi, 90 quality



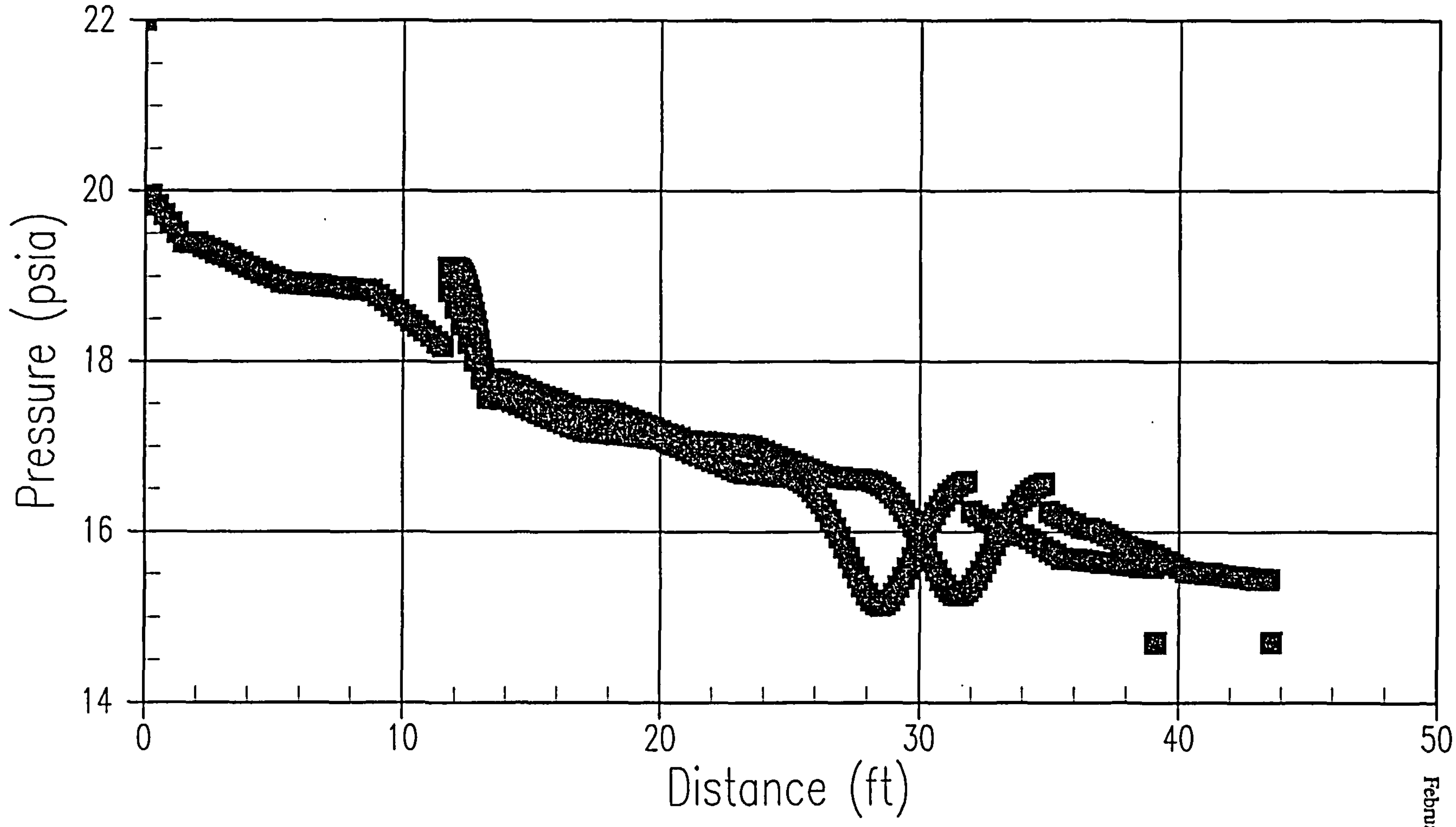
AP1000 21-psi, 100 quality



AP1000 22-psi, 90 quality



AP1000 22-psi, 100 quality



DCP/NRC1678
Docket No. 52-006

February 2, 2004

Appendix 9

Email dated 1/29/04

"NOTRUMP ADS4 sensitivity case"

Appendix 9
DCP/NRC1678
Docket No. 52-006

February 2, 2004

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:30 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP ADS4 sensitivity case

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 2:10 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Gagnon, Andre F.
Subject: NOTRUMP ADS4 sensitivity case

DEDVI_20ads4k.doc

Here is the NOTRUMP case at 20 psia with increased ADS4 form losses - results are similar to 25 psia case previously provided in OI 21.5-1 Item ADS4 K Sensitivity response, except that there is a brief period of uncovery in the revised sensitivity case. With adiabatic heatup during this uncovery the PCT would still be well under 1500F. The sensitivity case is compared to the the new 20 psia base case in these plots.

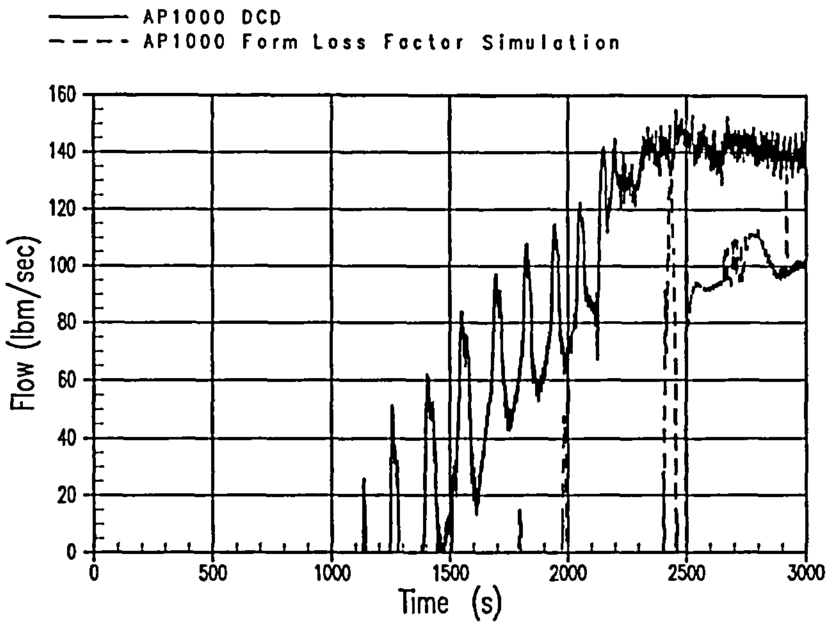


Figure-1 DEDVI 20 Psi Containment – IRWST Injection

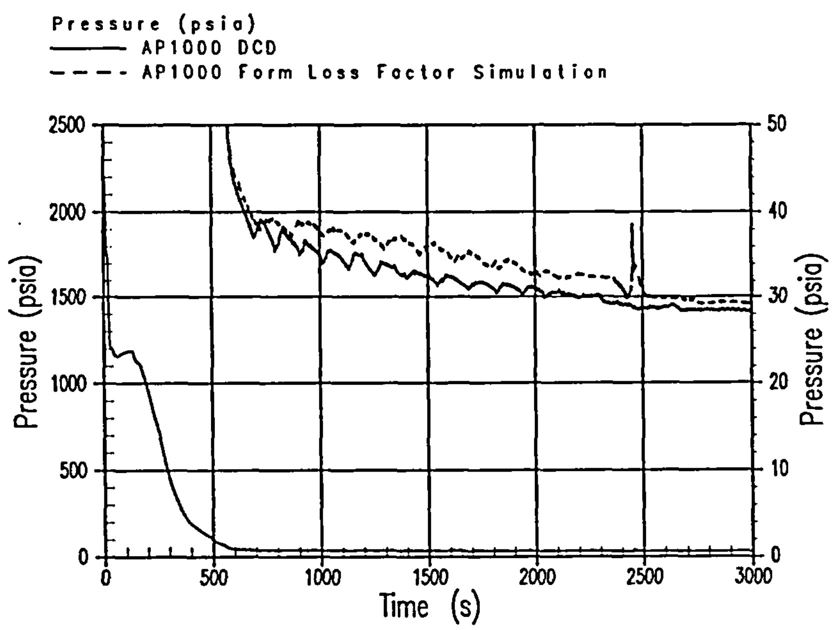


Figure-2 DEDVI 20 Psi Containment – Upper Plenum Pressure

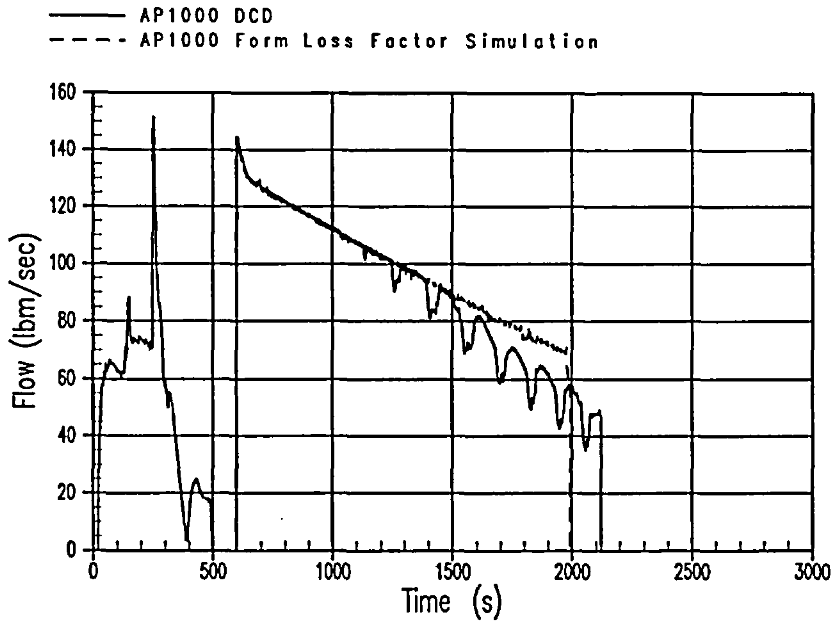


Figure-3 **DEDVI 20 Psi Containment – Intact CMT Injection Rate**

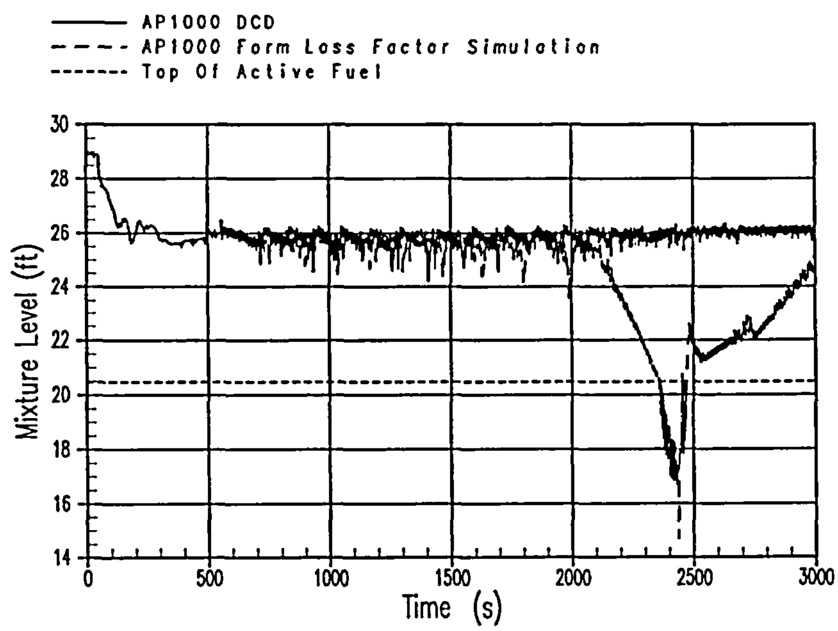


Figure-4 **DEDVI 20 Psi Containment – Core/Upper Plenum Mixture Level**

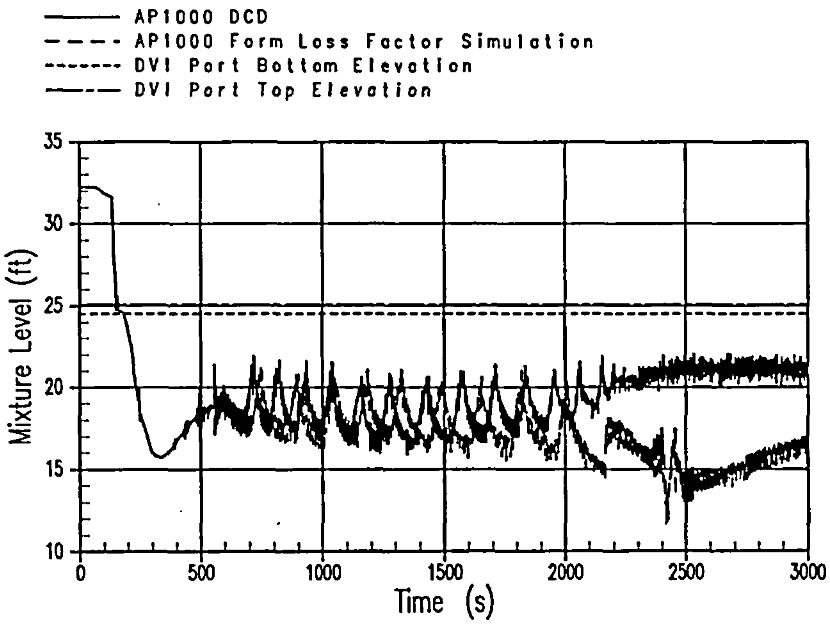


Figure-5 **DEDVI 20 Psi Containment – Downcomer Mixture Level**

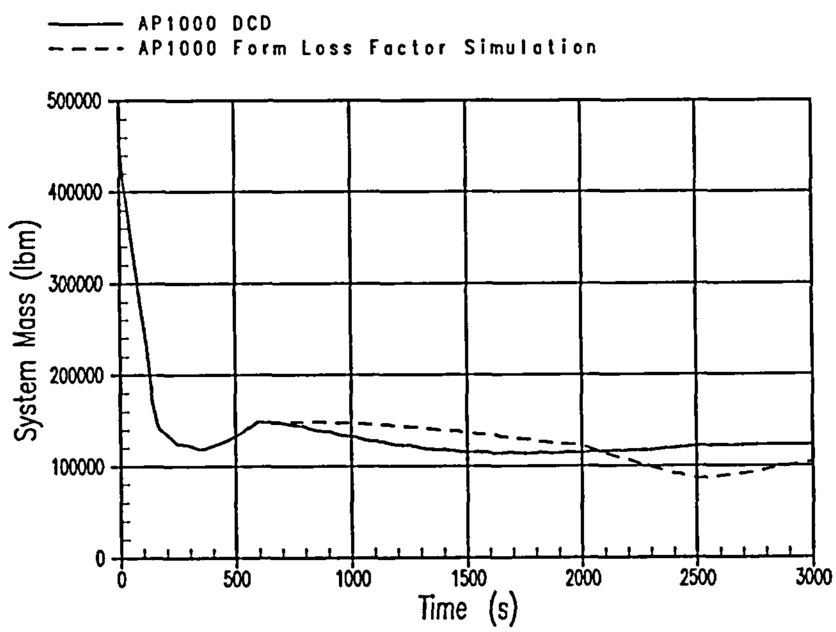


Figure-6 **DEDVI 20 Psi Containment – RCS System Inventory**

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February 2, 2004

Appendix 10

Email dated 1/29/04
"NOTRUMP PRA case"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:30 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP PRA case

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 4:13 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Subject: NOTRUMP PRA case

NOTRUMP PRA case.doc

Here is the NOTRUMP PRA case. Note that we used 22 psia for this case because it is a larger break than the DEDVI case where we use 20 psia. The results are core cooling success as was the previous Case B.

A5.5.1.3.2 Case B Results

Case B is a double-ended rupture of an 8.0-inch CMT balance line (inside diameter of 6.8 inches). This break is very much like a break in the RCS cold leg. Both CMTs are assumed to fail. In addition, the break is assumed to be in a location that prevents the faulted CMT from draining. Therefore, operation action to actuate the ADS must be assumed.

- Credit for PRHR HX operation
- Credit for 2 out of 2 accumulators
- ADS stages 1, 2, and 3 fail to open
- Credit for 4 out of 4 ADS stage 4 at 20 minutes (1200 seconds)
- Only 1 of 2 IRWST lines is assumed to inject. Further, failure of 1 of the 2 parallel paths in the IRWST line to open is assumed
- Credit for containment isolation; containment pressure assumed to be 22 psia, which was calculated for the DEDVI break with conservative design basis methods to minimize containment pressure but not considering fan cooler operation. Since the DE CMT balance line is a larger break, the 22 psia containment pressure is conservative for this case.

Figures A5.2-14 through A5.2-25 provide plots of the plant response and Table A5.2-2 provides the sequence of key events. Figures A5.2-16 and A5.2-17 show the liquid and steam break flow rates that lead to depressurization of the RCS, as seen in Figure A5.2-14, and draining of the RCS pressurizer (Figure A5.2-15). Due to the large size of the break and lack of CMT injection, the RCS rapidly depressurizes and accumulator injection begins at around 290 seconds. Both accumulators continue to inject until around 1350 seconds, providing adequate injection to keep the core covered. At 20 minutes, the operator opens all 4 ADS stage 4 valves, which results in a further depressurization down to less than 50 psi. The depressurization brought on by the opening of ADS stage 4 is sufficient to allow for IRWST injection, which begins at 1450 seconds (250 seconds after opening ADS stage 4). The IRWST injection rate is sufficient to prevent core uncovery, stabilizing at about 150 lbm/sec, which matches the losses out of the break and ADS. Since core uncovery does not occur for case UC2B, the clad does not experience a heat-up, and a clad heat-up calculation is not performed.

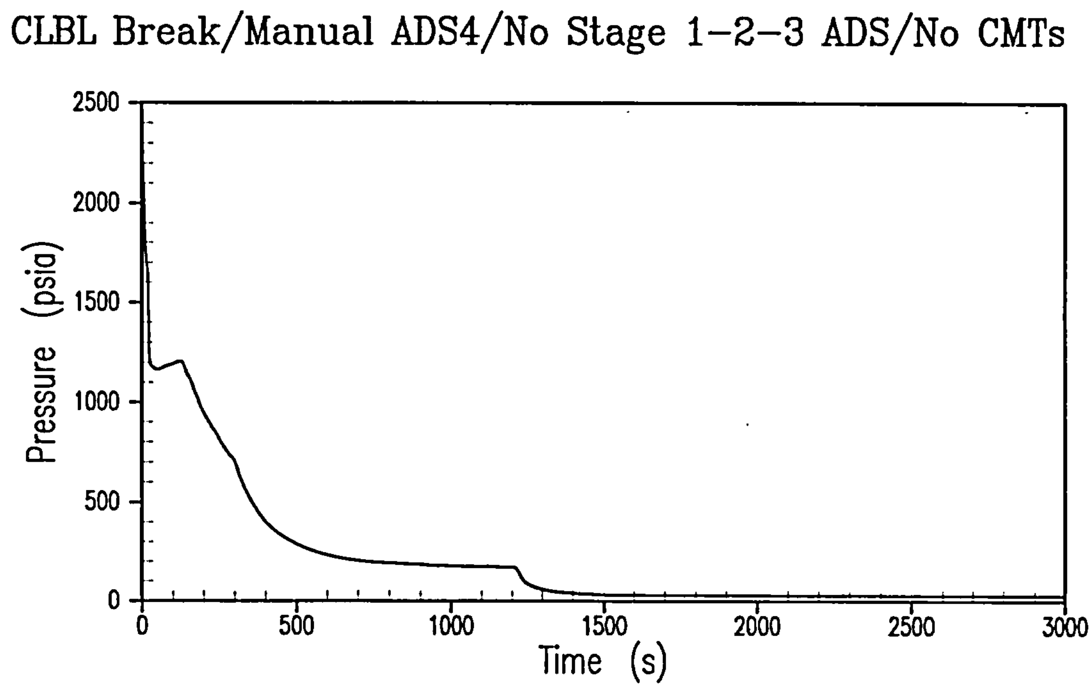

Figure A5.2-14

Case B – Pressurizer Pressure

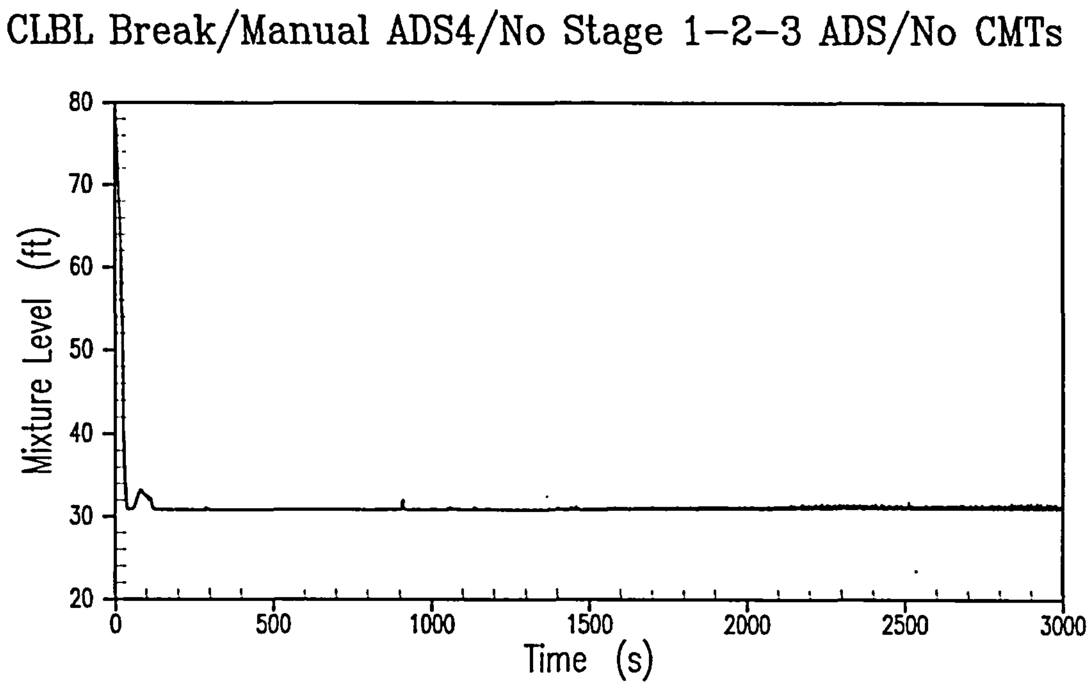

Figure A5.2-15

Case B – Pressurizer Level

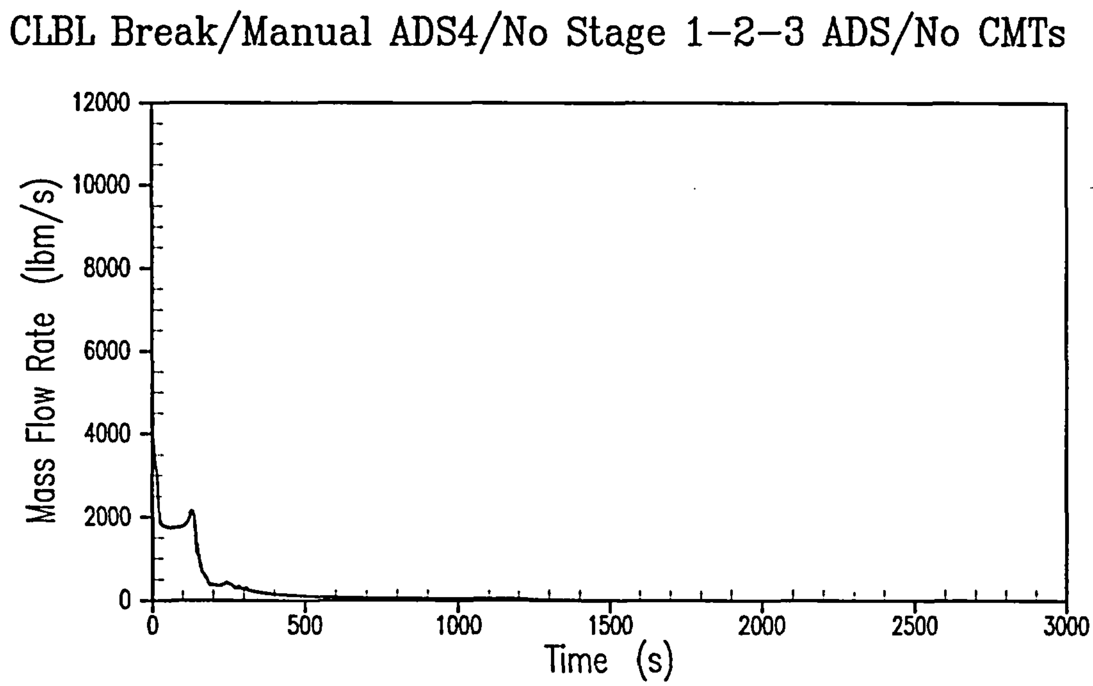

Figure A5.2-16

Case B – Break Liquid Flow

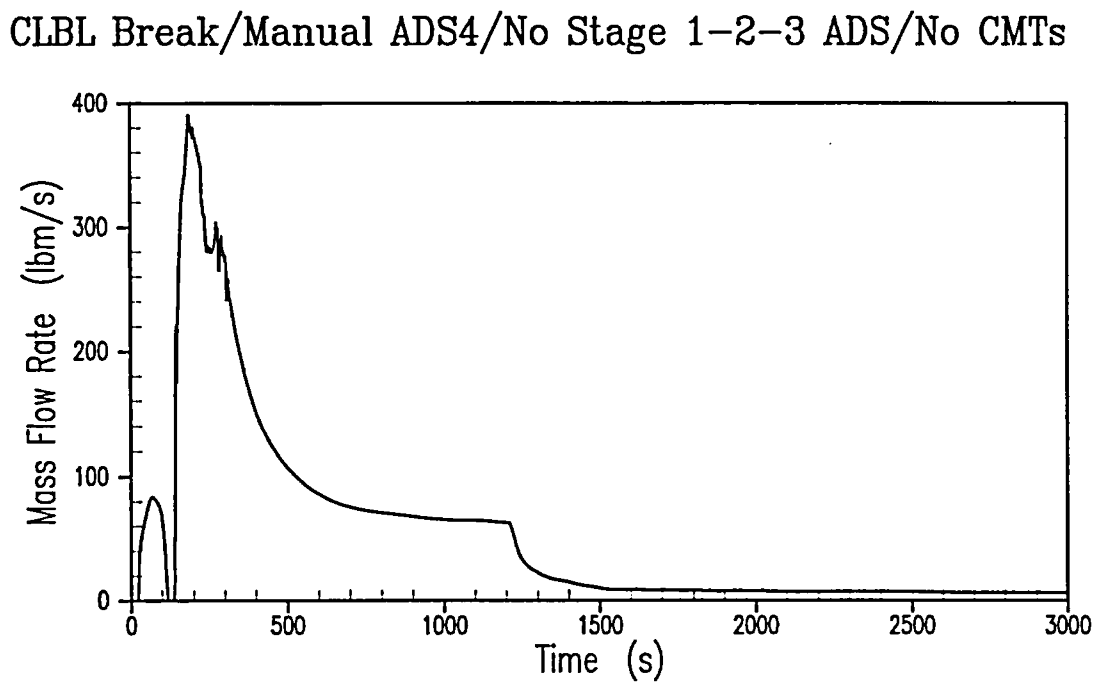

Figure A5.2-17

Case B – Break Vapor Flow

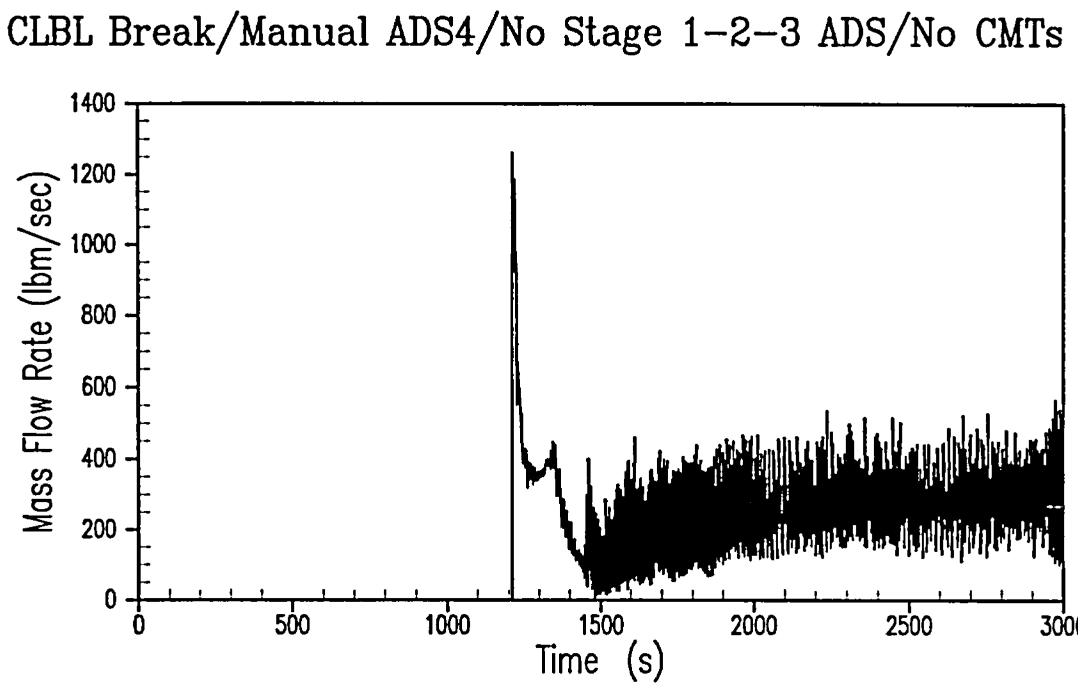

Figure A5.2-18

Case B – 4th Stage ADS Liquid Flow Through All Open Paths

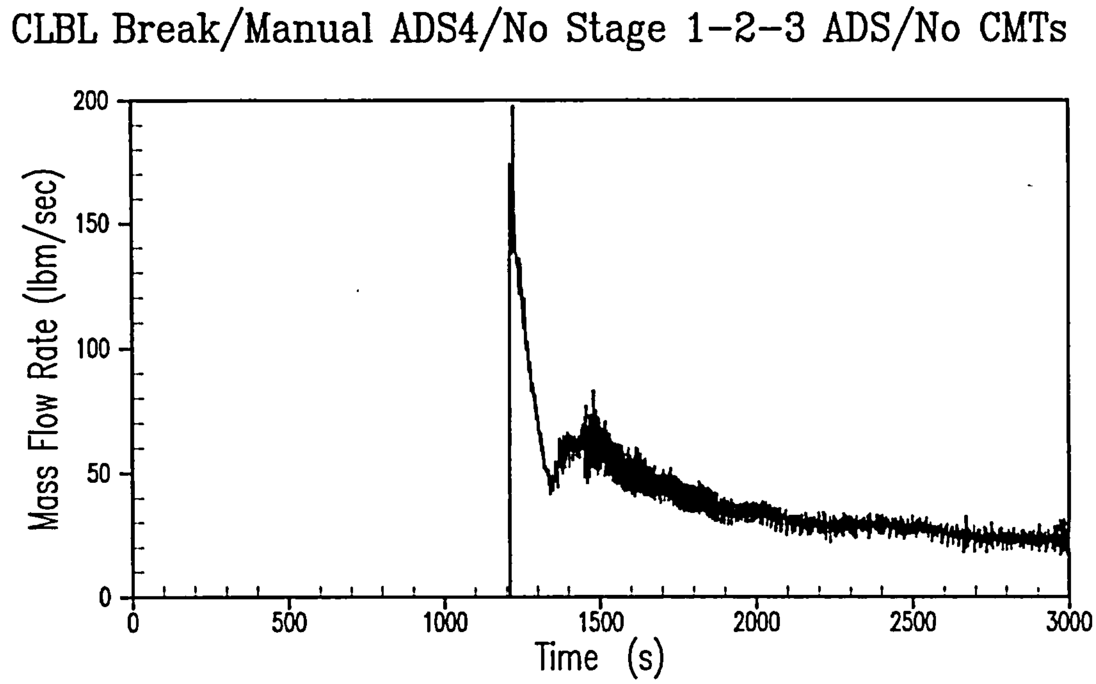

Figure A5.2-19

Case B – 4th Stage ADS Vapor Flow

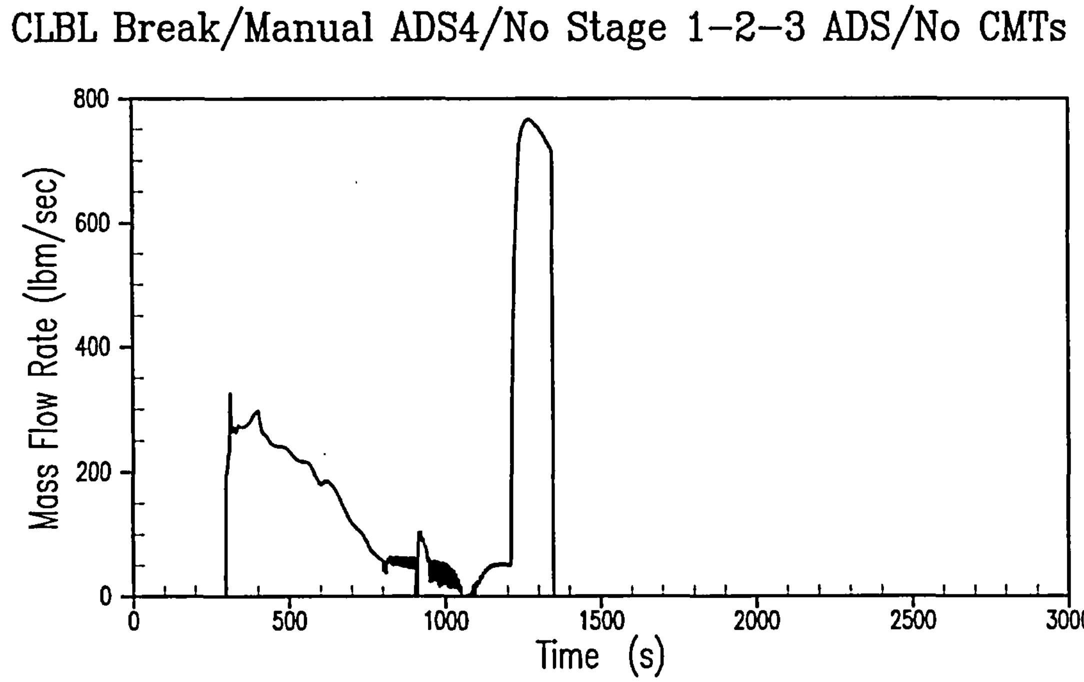

Figure A5.2-20

Case B – Accumulator Injection Flow

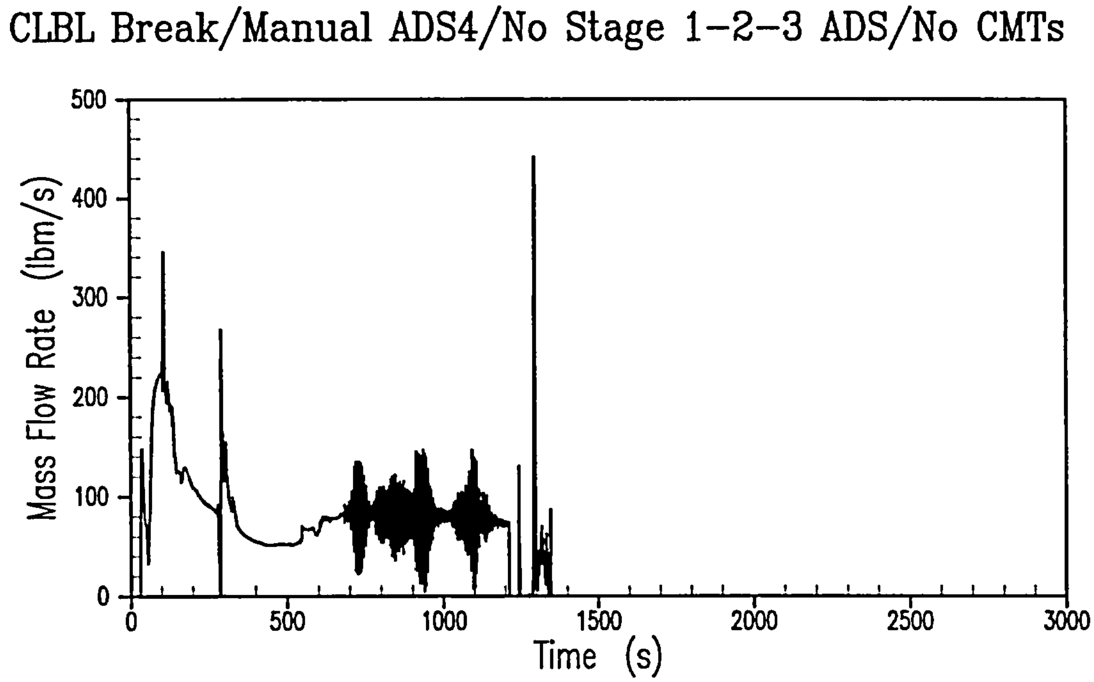

Figure A5.2-21

Case B – PRHR Discharge Flow

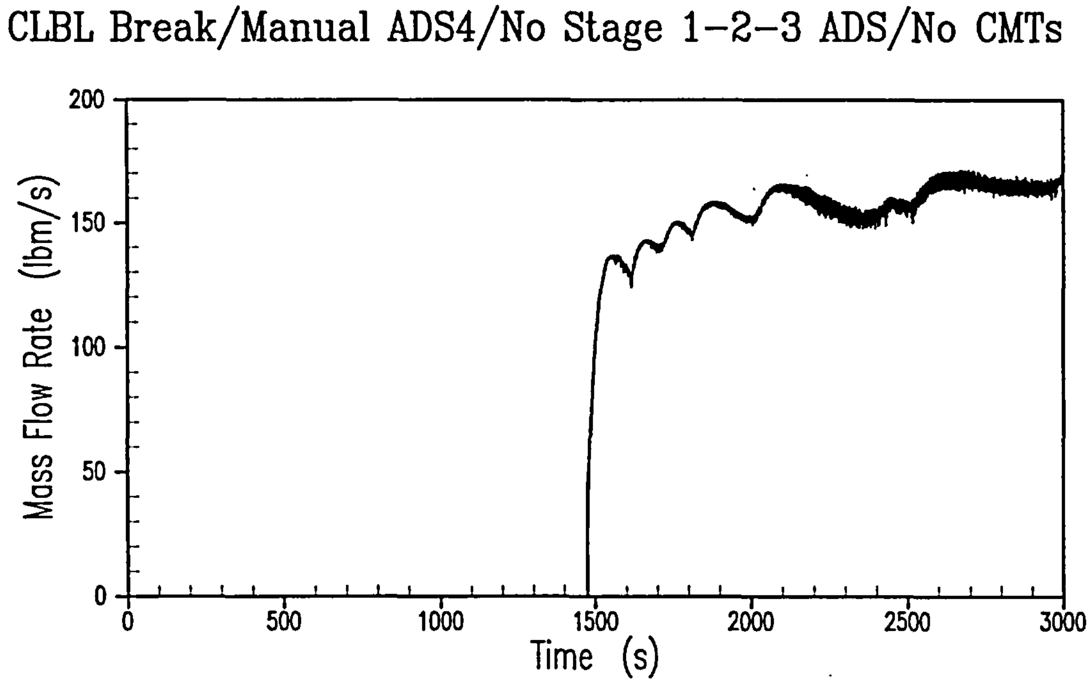

Figure A5.2-22

Case B – IRWST Injection Flow

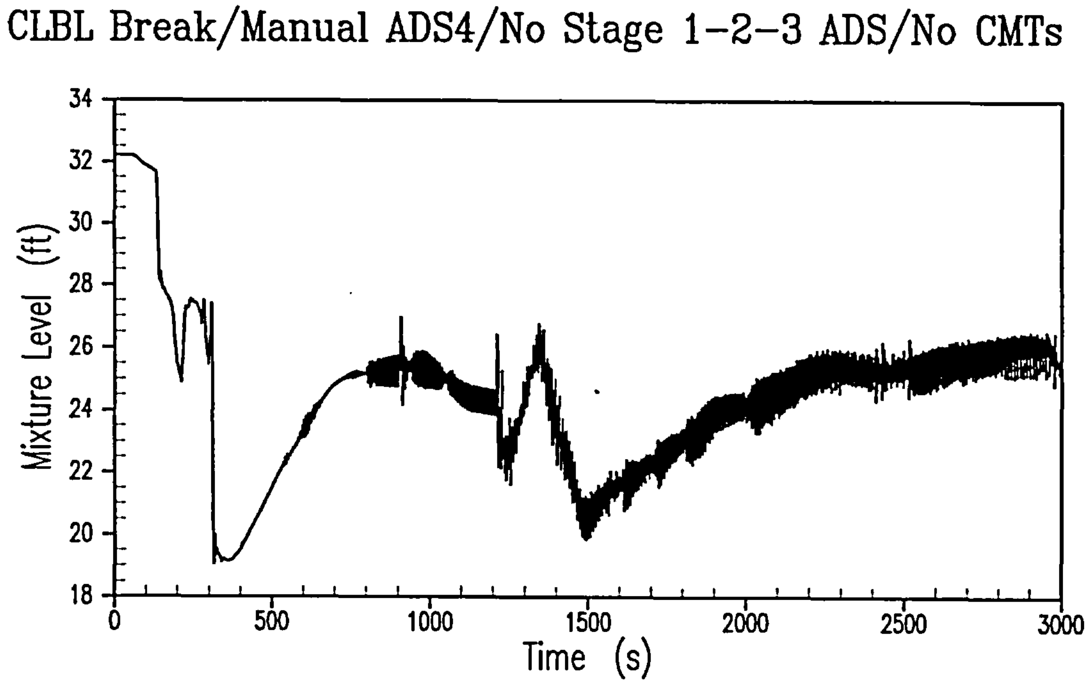

Figure A5.2-23

Case B – Downcomer Mixture Level

CLBL Break/Manual ADS4/No Stage 1-2-3 ADS/No CMTs

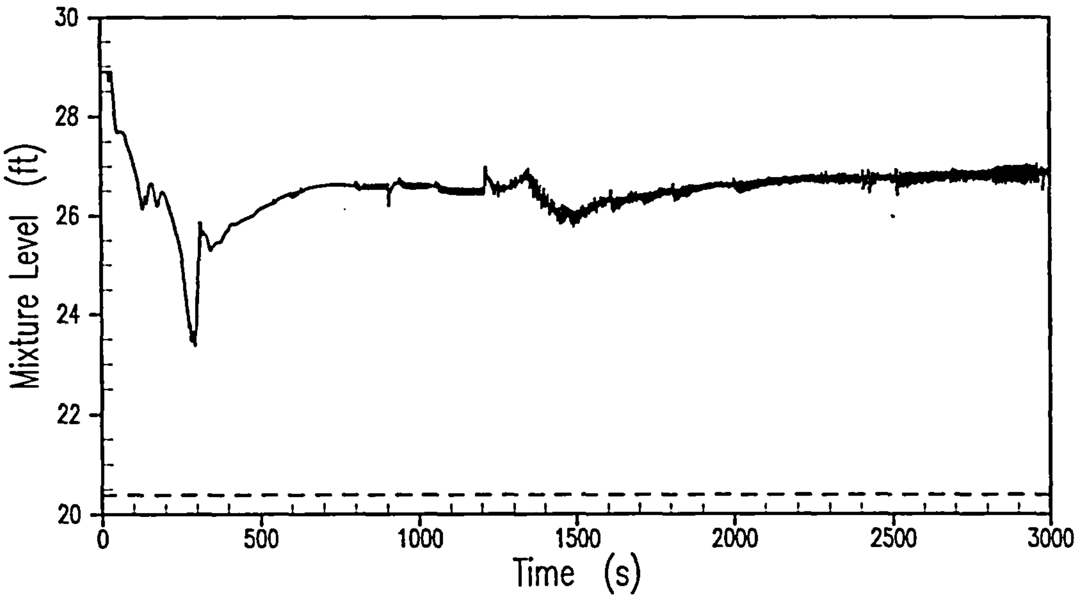

Figure A5.2-24

Case B – Upper Plenum and Core Mixture Level

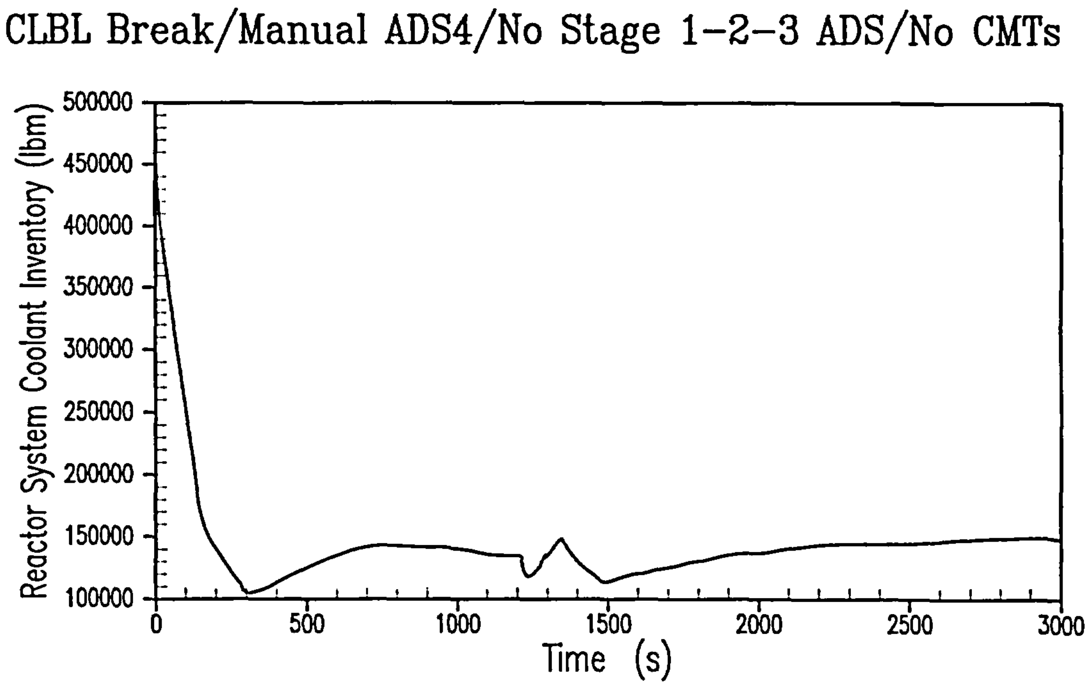

Figure A5.2-25

Case B – Reactor System Coolant Inventory

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February 2, 2004

Appendix 11

Email dated 1/29/04

"CHF Supplement"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:29 AM
To: Gongaware, Jacqueline J.
Subject: FW: CHF supplement

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 5:36 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Ohkawa, Katsuhiro
Subject: CHF supplement

bundle_chf.doc

Here is the additional comparison to rod bundle CHF.

Heat Transfer Assessment Supplement

The following supplements the heat transfer assessment provided in OI 21.5-2P Item 22 Rev 2 for the accumulator injection period of the DEDVI break.

Two additional Bundle CHF evaluations were performed using local quality based correlations. A correlation by Khabensky (1998) was developed for VVER/RBMK rod bundles which are ~3.6m height at very low upflow (G=0 to 300 kg/m2-s) conditions. The correlation is based on linear interpolation of a CCFL type CHF at zero flow and the local quality based CHF at higher flow end points. The correlation includes the pressure range suitable for AP1000 core conditions during the accumulator injection period (p=0.1 to 7 MPa).

Another one is by Holowach (2002). This was developed based on the data from a small diameter duct but has the local quality form suitable for a bundle CHF calculation. This correlation has been shown to be reasonably accurate at very low pressures (10 – 100 kPa) for small diameter channels.

Following is the evaluation of CHF based on AP1000 geometry and the fluid condition predicted by NOTRUMP during accumulator injection. NOTRUMP sensitivity analysis with higher core voiding during this period indicates that higher voiding does not greatly affect core flow conditions for CHF during the accumulator injection period.

Comparison with Khabensky's correlation:

$$q_{CHF} = (1-\frac{G}{300})q^T_{CHF} + \frac{G}{300}2A(p)(1-X)^{1.2} \text{ (MW/m}^2\text{)}$$

where G is the inlet mass flux in kg/m^2-s, p is the pressure in MPa, X is the quality. For p<1MPa,

$$A(p) = 1.16p^{0.15}$$

and,

$$q^T_{CHF} = 6.75*10^{-9}\frac{h_{fg}\sqrt{\rho_g}\{\sigma g(\rho_f-\rho_g)\}^{0.25}}{A_H\left\{1-\left(\frac{\rho_g}{\rho_f}\right)^{0.25}\right\}^2} \text{ (MW/m}^2\text{)}$$

A_H is the bundle heated area in m^2.

This CCFL based zero flow CHF expression is missing the bundle flow area in the numerator which is apparently folded into the constant. Putting back the bundle flow area, A_F, and adjusting the constant to yield 0.01MW/m^2 (or 0.88Btu/ft2-s) at 0.1MPa, X=0.6, which is listed in Table 1 (author's calculation) for A_F=0.295ft2, A_H=345.7ft2 (VVER1000 bundle geometry), and changing the equation into British units,

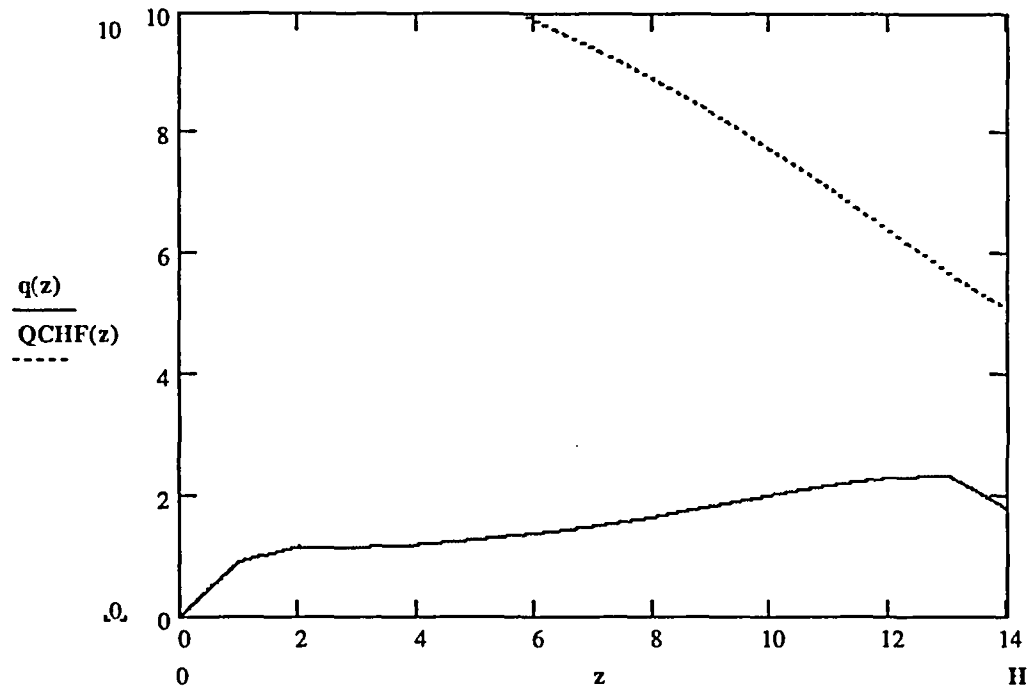
$$q^T_{CHF} = 1.882\frac{A_F h_{fg}\sqrt{\rho_g}\{\sigma g(\rho_f-\rho_g)\}^{0.25}}{A_H\left\{1-\left(\frac{\rho_g}{\rho_f}\right)^{0.25}\right\}^2} \text{ (Btu/ft2-s)}$$

$$q_{CHF} = (1-\frac{G}{61.4})q^T_{CHF} + \frac{G}{61.4}96.8p^{0.15}(1-X)^{1.2} \text{ (Btu/ft2-s)}$$

where G is in lbm/ft2-s, p is in psia, areas are in ft2, properties are in British units.
Now we put AP1000 geometry, A_F/A_H=7.3*10^{-4}. The zero flow CHF is 0.76 Btu/ft2-s (or 0.0086MW/m2). The worst condition during accumulator injection is p=40 psia, G=4.0lbm/ft2-s, X=0.57 at the top of core. q_{CHF}=4.98 Btu/ft2-s at the top of core.

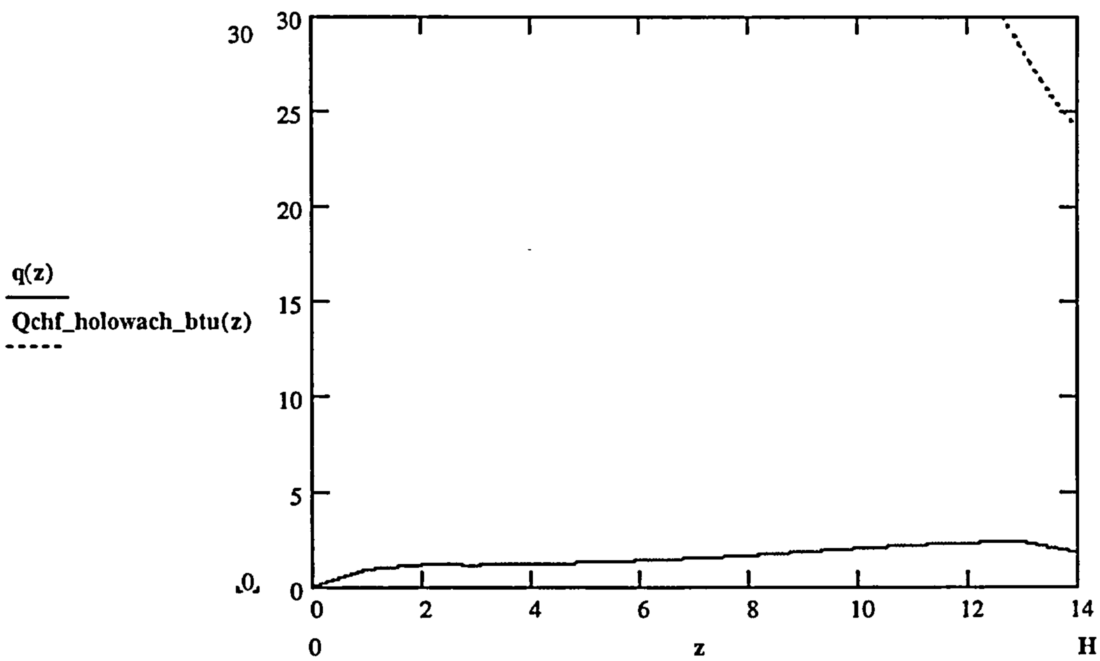
The first figure below shows the comparison of q_{CHF} and the top skewed heat flux at 600 sec which is the worst time during accumulator injection.

Comparison with Khabensky's correlation:



Comparison with Holowach's correlation:

$$q_{CHF} = \frac{h_{fg}\{\rho_g(\rho_f - \rho_g)\}^{0.5}}{1081\left\{1-\left(\frac{\rho_g}{\rho_f}\right)^{0.25}\right\}^2} 88\exp(-2.9X(z)) \text{ (Btu/ft2-s)}$$



Comparisons to local quality based correlations and to correlations based on tube geometry indicate that there is an adequate CHF margin during accumulator injection.

References:

V. B. Khabensky, S. D. Malkin, V. V. Shalia, B. I. Nigmatulin, "Critical heat flux in rod bundles under upward low mass flux densities," Nuclear Engineering and Design, 183 (1998) 249-259.
M. J. Holowach, L. E. Hochreiter, F. B. Cheung, D. L. Aumiller, "Critical heat flux during reflood transients in small-hydraulic-diameter geometries," Nuclear Technology, 140 (2002) 18-27.

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Docket No. 52-006

February 2, 2004

Appendix 12

Email dated 1/29/04
"DP data comparison"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:29 AM
To: Gongaware, Jacqueline J.
Subject: FW: DP data comparison

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 6:50 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Frepoli, Cesare; Schulz, Terry L.
Subject: DP data comparison

CESNEF1.doc

Here is our assessment realtive to the Italian pressure loss data.

Assessment of Two-Phase Frictional Pressure Drops in the ADS4 Line based on CESNEF-2 Data

Experimental pressure drop for two-phase flow in rectilinear ducts of any inclination was collected and structured in a Data Bank, named MIDA (Reference 1). The data base includes about 24000 pressure drop data points over a wide range of conditions. The data was correlated in the CESNEF-2 and CESNEF-3 correlations which are discussed in Reference 2. In the same reference it is claimed that, with respect to the data base, CESNEF-2 has an average error (MEM) of 8.9%.

Because of its accuracy, the correlation was used as reference data for the assessment of the ADS4 line frictional pressure drop contribution.

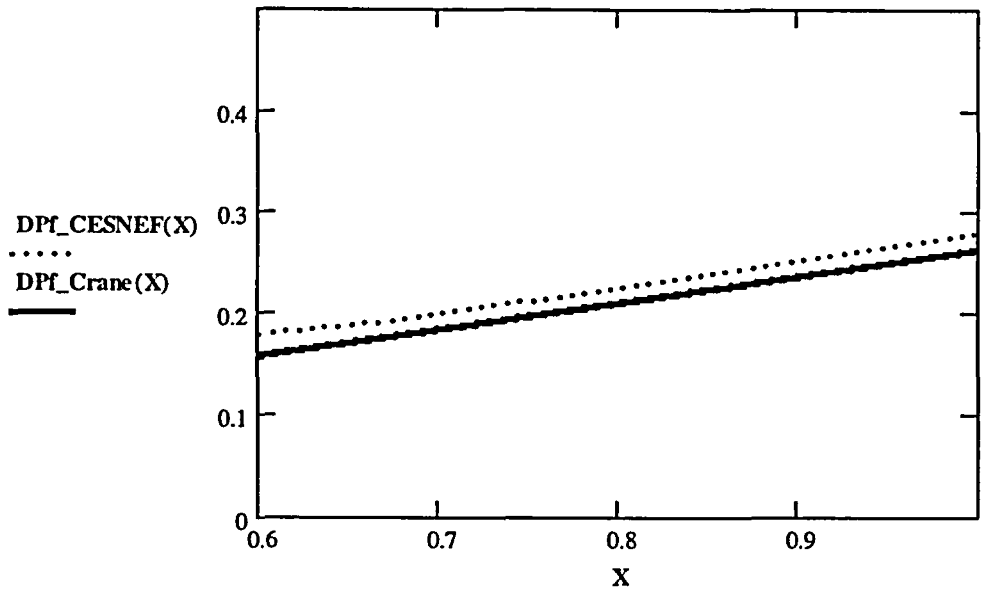
A simple test model representing the ADS 4 line straight pipe geometry was set up. The model is based on a 10 ft long, 14 in. Sch. 160 vertical pipe. This pipe is used to represent the geometry of the ADS4 line which goes from the tee branch to the valve. Note that, since the only purpose of this assessment is to benchmark the CESNEF frictional losses to other models, the length of the test section is arbitrary.

The following conditions were considered:

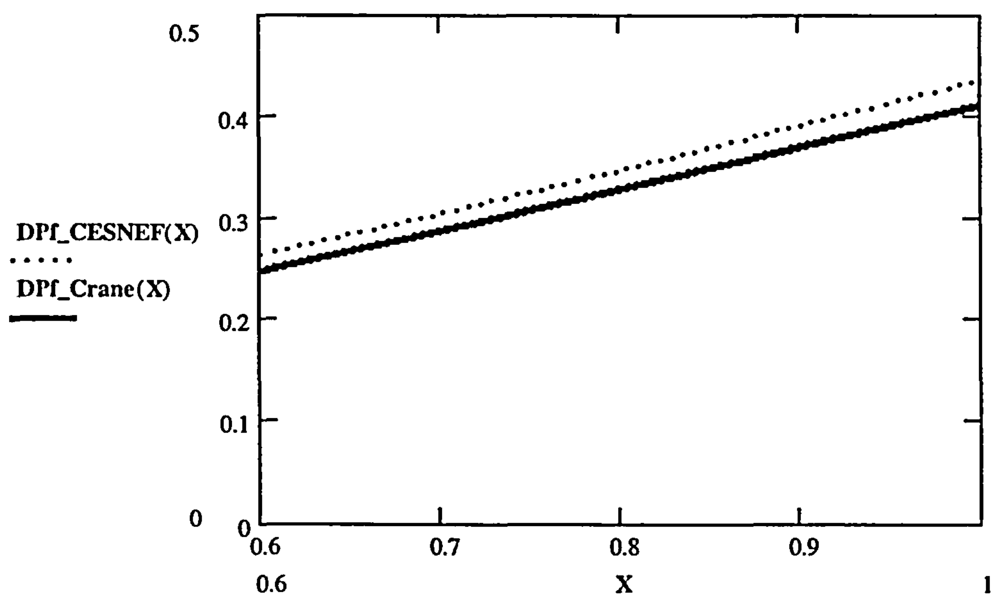
Hot Leg Pressure: from 20 to 30 psia
Mass Flow Rate: from 40 to 50 lb/s in the main pipe (20 to 25 lb/s in the test pipe)
Inlet Flow Quality: from 0.6 to 1.0

The following Figures shows the comparison between the calculated frictional pressure drops (in psi) obtained with the CESNEF-2 and the frictional pressure drops obtained with the Darcy formula (CRANE) for four cases which cover the conditions above. The calculation with Darcy formula is based on a fully turbulent friction factor f equal to 0.01314. This is the value that was reported in the response to DSER Open Item 15.2.7-1P for a 14 in. Sch. 160 pipe.

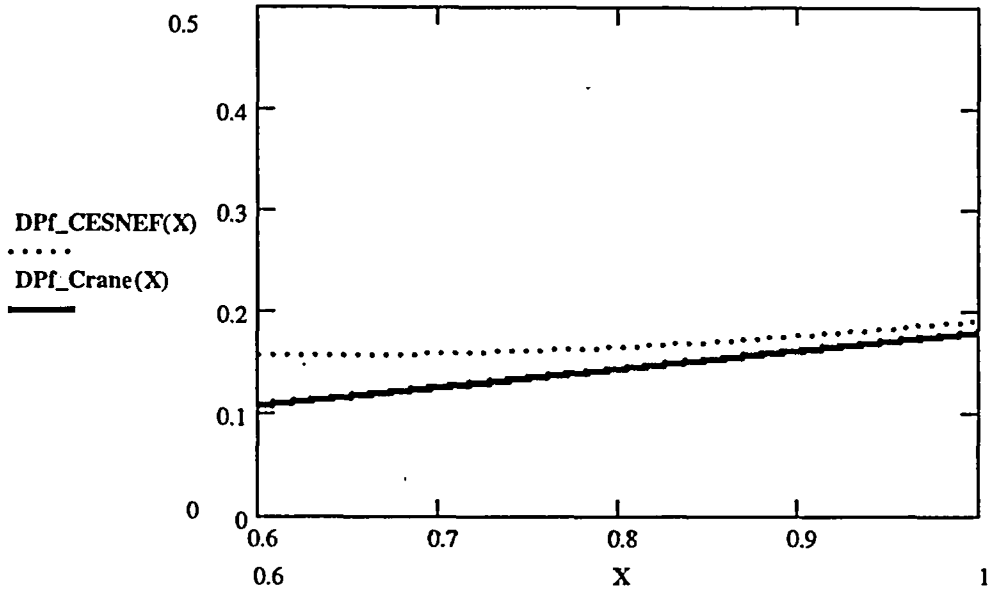
Pressure = 20 psia; Flow = 20 lb/s



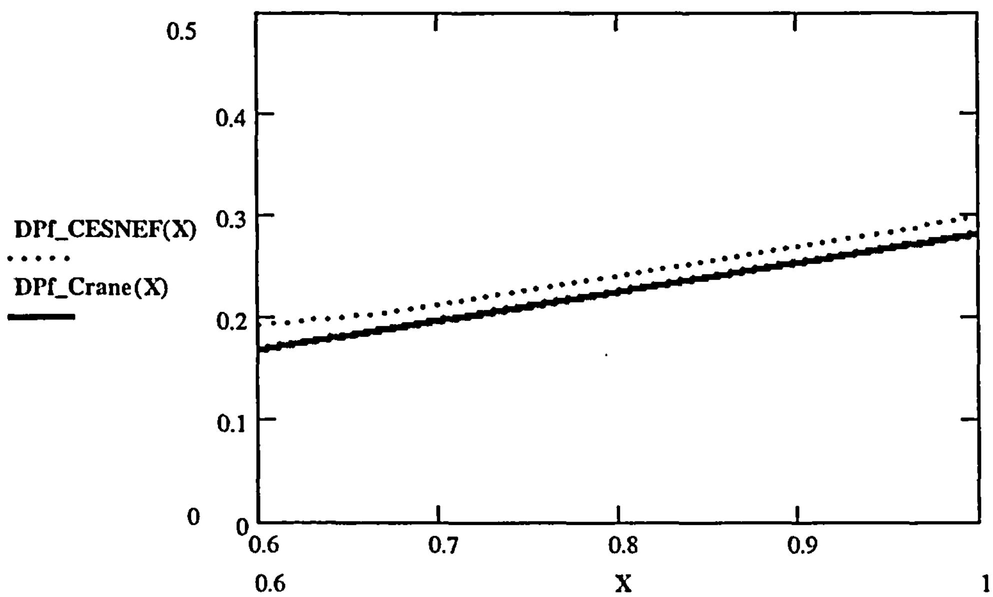
Pressure = 20 psia; Flow = 25 lb/s



Pressure = 30 psia; Flow = 20 lb/s



Pressure = 30 psia; Flow = 25 lb/s



For value of quality approaching unity, the Darcy formula (CRANE) is in good agreement with CESNEF-2.

In the following a calculation was performed on the full ADS4 piping system for several high quality 2-phase flows (100% - 80%) using CRANE methods. The approach used assumes that these high quality mixtures, flowing at high velocities, will act as homogenous fluids. The results of this analysis are compared with those from FLOAD4.

CRANE lists the following equation (eqn 3-20) for compressible fluids:

$$w = 0.525\ Y\ d^2\ (DP / K\ v)^{0.5}$$

where w is the mixture mass flow (lb/sec)
Y is a expansion factor from CRANE page A-22 for k = 1.3 (water, steam)
d is the pipe inside diameter (used to calc K)
DP is the differential pressure (psi)
K is the resistance coefficient, velocity head loss
v is the upstream mixture specific volume (ft3/lb)

As an example, for the AP1000 with a HL pressure of 20 psia and a containment pressure of 14.7 psia:

Y = 0.87 from CRANE p A-22 with the K shown below and a DP/P = 0.26
d = 15.82 in. (equivalent inside diameter of two ADS 4 branch lines, 14" sch 160)
DP = 5.3 psi (for listed RCS / containment pressure)
K = 3.81 (ADS 4 line B with both valves open)
v = 16.07 ft3/lb (80% quality mix water/steam at 20 psia)

w = 30.08 lb/sec (mix)
ws = 26.90 lb/sec (steam with 80% quality)

The results of this calculation are shown below compared with FLOAD4. The FLOAD4 results at 100%, 90% and 80% steam compare well with this calculation using the CRANE compressible flow equation.

	20.0 psia HL			25.0 psia HL			30.0 psia HL		
Quality	Ws	FLOAD4	Diff	Ws	FLOAD4	Diff	Ws	FLOAD4	Diff
	(lb/sec)	(lb/sec)		(lb/sec)	(lb/sec)		(lb/sec)	(lb/sec)	
100%	30.08	31.25	-3.7%	42.67	44.13	-3.3%	53.20	54.71	-2.8%
90%	28.54	28.72	-0.6%	40.48	40.75	-0.7%	50.47	50.63	-0.3%
80%	26.90	26.39	1.9%	38.16	37.59	1.5%	47.58	46.84	1.6%

Conclusions

The homogeneous mixture Darcy method compares well to data represented by the CESNEF-2 correlation for flow conditions representative of ADS4 flow conditions. Since the pressure losses in this data are dominated by pipe friction, this indicates the pipe friction losses are reasonably represented with homogeneous flow.

Application of the homogeneous mixture Darcy method to the ADS4 piping configuration results in reasonable comparison to the detailed FLOAD4 model.

References

[1] Brega, E., Brigoli, B., Carsana, C.G., Lombardi, C., Maran, L., "Data Bank of Pressure and Densities Data for Two-Phase Mixture Flowing in Rectilinear Ducts", 8th UIT Conference, Ancona, Italy (1990).

[2] Lombardi, C., Maran, L., Oriani, L., Ricotti, M., "CESNEF-3 Pressure Drop Correlation for Gas-Liquid Mixture Flowing Upflow in Vertical Ducts", ATTI XVIII Congresso Nazionale sulla Trasmissione del Calore (18th UIT National Heat Transfer Conference): Cernobbio 28-30 June 2000.

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Appendix 13

Email dated 1/29/2004

"DP data"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:28 AM
To: Gongaware, Jacqueline J.
Subject: FW: DP data

From: Vijuk, Ronald P.
Sent: Thursday, January 29, 2004 6:54 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Brown, William L.; Frepoli, Cesare; Schulz, Terry L.
Subject: DP data

Sudden Contraction Data Prediction.doc

Here is our assessment relative to sudden contraction pressure loss data that we located. We expect similar results relative to the data you provided.

Comparison to Pressure Drop Data for Sudden Contraction Area Changes Using Homogeneous Methods

Background

The ADS-4 flow paths in AP1000 contain sudden contraction area changes where the flow is accelerated in the ADS-4 piping and results in notable pressure drop. Experience from single phase flow indicates that pressure drop through a sudden contraction is largely due to a reversible acceleration pressure drop and an irreversible viscous loss due to momentum transfer in the downstream section. The largest area change in the AP1000 ADS-4 flow paths occurs at the entrance to the ADS-4 flow path from the hot leg. The area ratio of the AP1000 ADS-4 off-take to the hot leg is about 0.22.

It is desired to show that the pressure drop associated with sudden contractions can be acceptably predicted by comparison with single phase and two-phase sudden contraction data (see pressure drop data sources section below). For two-phase conditions, homogeneous based methods seem to provide acceptable prediction of pressure drop through sudden contractions. The following discussion presents pressure drop predictions of sudden contraction data for two-phase and single phase flow.

Pressure Drop Data Sources

Two sources of pressure drop data are presented:

1. Geiger and Rohrer, "Sudden Contraction Losses in Two-Phase Flow", Journal of Heat Transfer, 1966.

2. Schmidt and Friedel, "Two-Phase Pressure Drop Across Sudden Contractions in Duct Areas", Int. J. Multiphase Flow, 1997.

Two homogeneous methods are used to compare with the data:

Homogeneous Method Using Mechanical Energy Eqn.

$$\Delta p_{\substack{sudden \\ contraction}} = \frac{G_m^2}{2\rho_m}[1-\sigma^2 + K_{1\phi contraction}]$$

where ρ_m is homogeneous mixture density and σ is area ratio of sudden contraction.

Homogeneous Method Using Momentum Eqn.

$$\Delta p_{\substack{sudden \\ constraction}} = \frac{G_m^2}{\rho_m}[1-\sigma]$$

Results

Results applying the homogeneous methods are shown in Figures 1 through 5 below. Figure 6 shows comparison against single phase data. The homogeneous mechanical energy method generally predicts the two-phase data reasonably well. The homogeneous momentum method tend to predict pressure losses higher than the two-phase data.

Conclusions

Homogeneous methods provide acceptable prediction of pressure drop across sudden contractions. Therefore code calculations of sudden contraction pressure drop based upon homogeneous models should provide acceptable results.

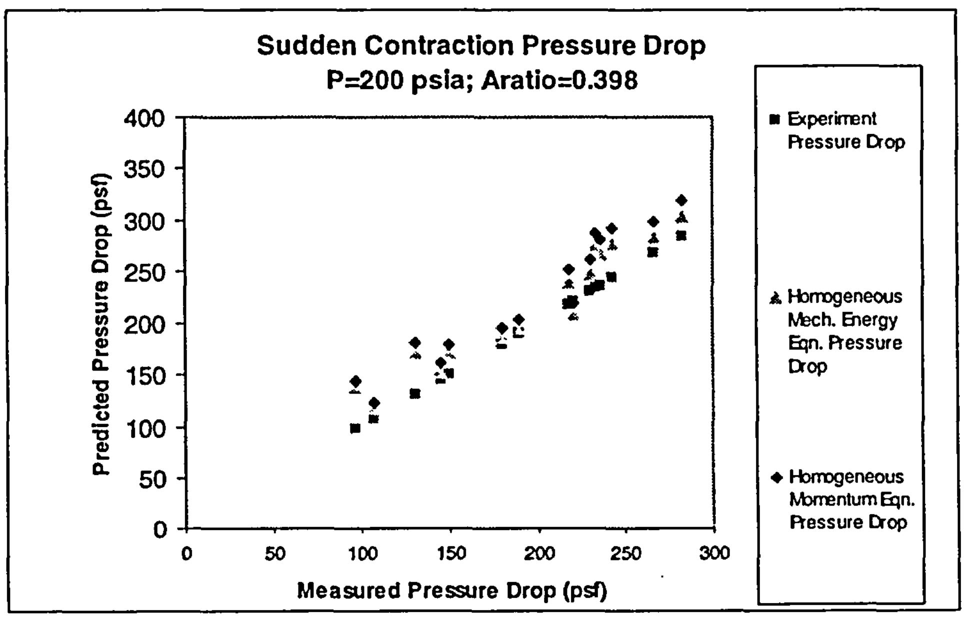

Figure 1. Steam-Water Data, Quality Range X=0.0117-0.211

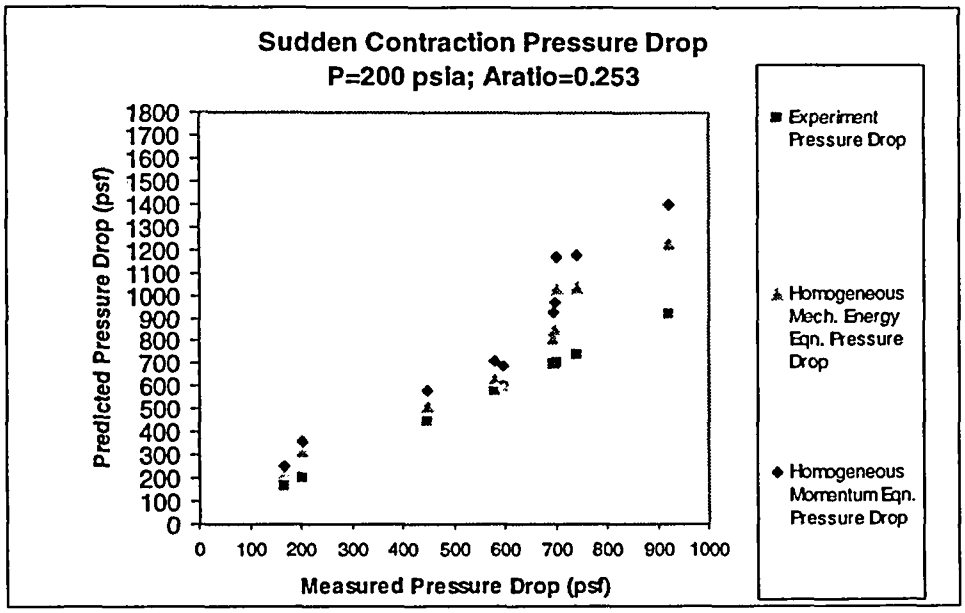

Figure 2. Steam-Water Data, Quality Range X=0.0001-0.193

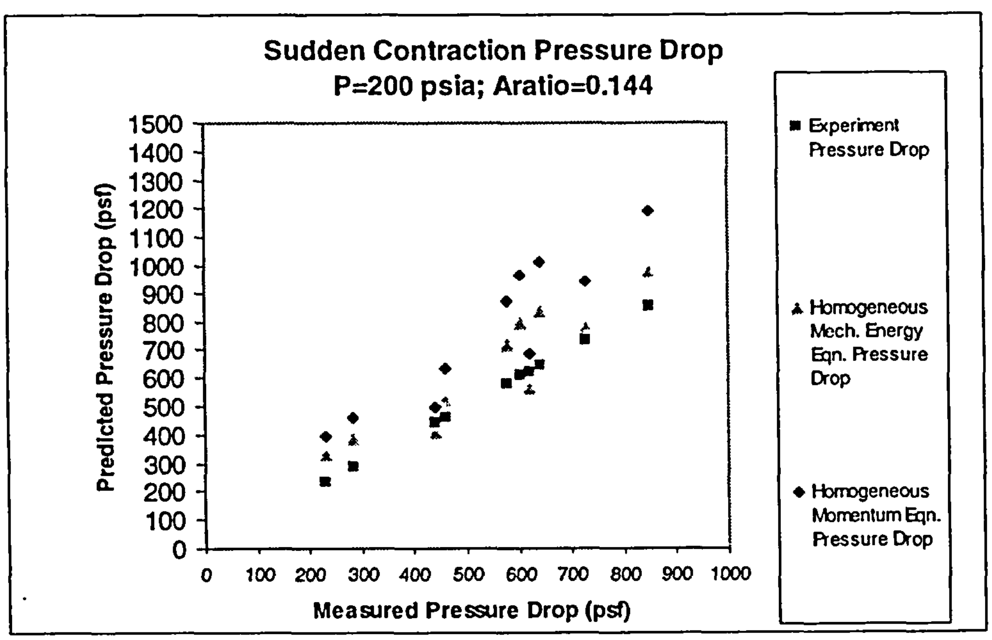

Figure 3. Steam-Water Data, Quality Range X=0.0001-0.0858

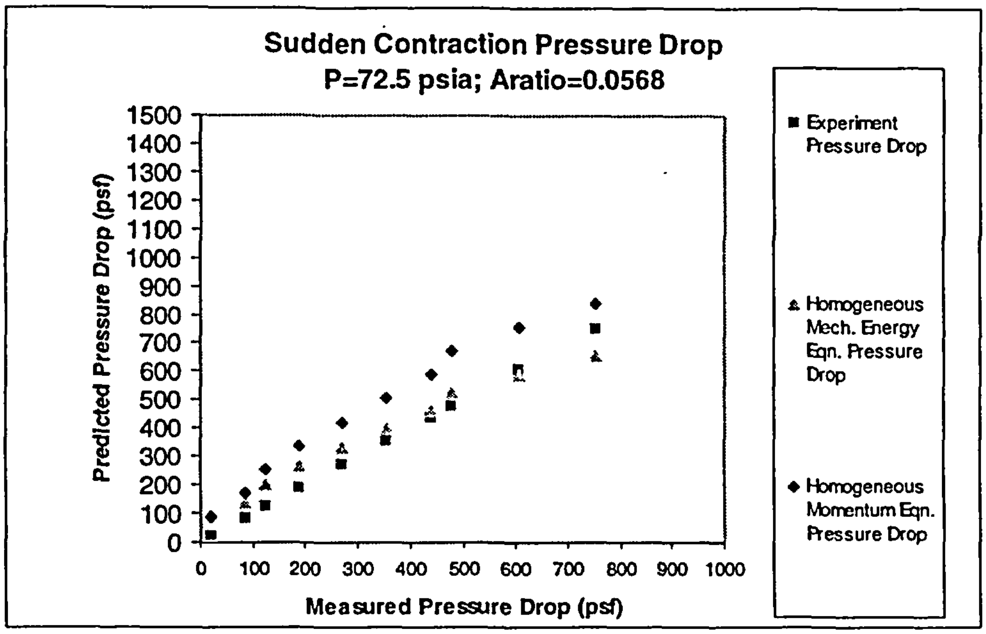

Figure 4. Air-Water Data, Quality Range X=0.1-1.0

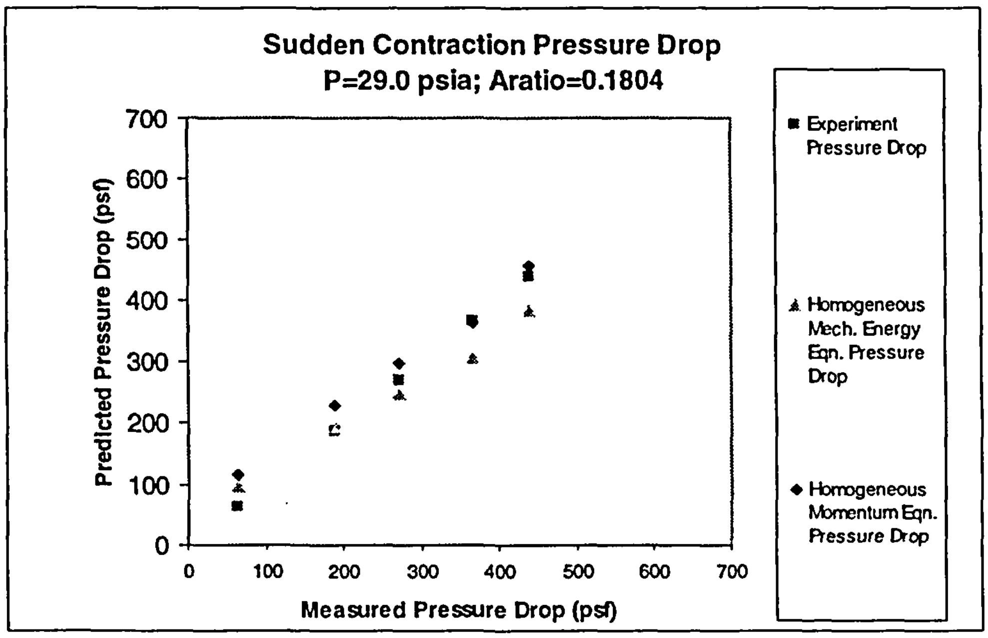

Figure 5. Air-Water Data, Quality Range X=0.25-1.0

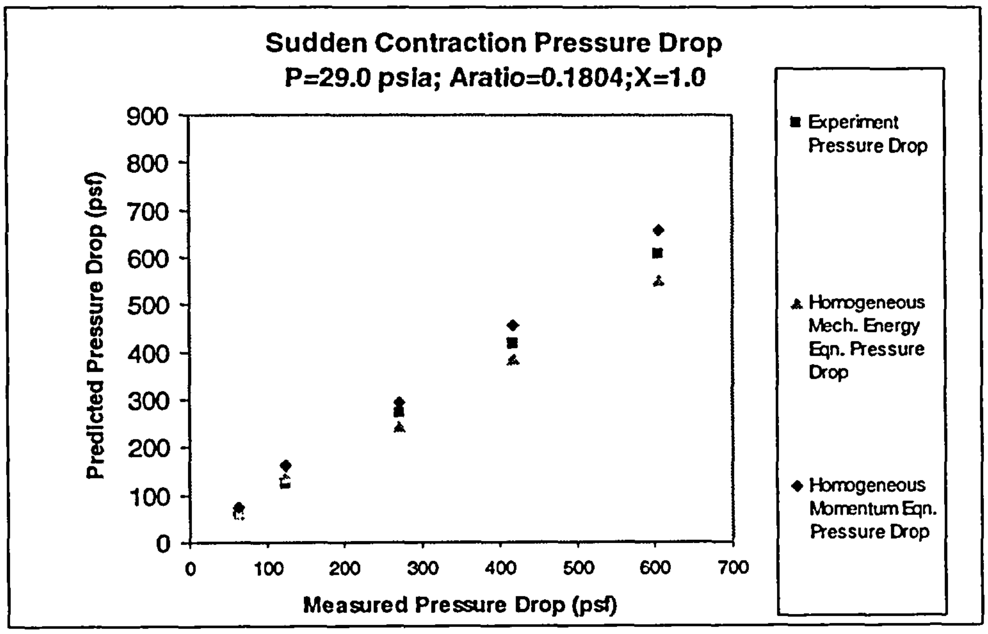

Figure 6. Air Data

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Appendix 14

Email dated 1/29/04

"Convergence at x = 1"

Gongaware, Jacqueline J.

From:	Vijuk, Ronald P.
Sent:	Monday, February 02, 2004 8:28 AM
To:	Gongaware, Jacqueline J.
Subject:	FW: Convergence at x =1

From:	Vijuk, Ronald P.
Sent:	Thursday, January 29, 2004 6:58 PM
To:	'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc:	Cummins, Ed; Brown, William L.; Schulz, Terry L.; Frepoli, Cesare
Subject:	Convergence at x =1

Equations_.doc

Here is an exercise that shows homogeneous multiplier method converges to Darcy at quality of 1.0.

Two-Phase Pressure drop Formulation @ χ=1.0

Starting from two-phase pressure drop,expression based upon "liquid only" multiplier it can be shown to be equivalent to Darcy at χ=1 for smooth pipe.

$$\Delta p = \frac{\Phi_{lo}^2 f_{lo} L}{D} \frac{G_m^2}{2\rho_f} \qquad G_m = \rho_g j_g + \rho_f j_f$$

where

$$\Phi_{lo}^2 = \left[1+\chi\left(\frac{\rho_f}{\rho_g}-1\right)\right]\left[1+\chi\left(\frac{\mu_f}{\mu_g}-1\right)\right]^{-0.25}$$

represent a homogeneous "liquid only" multiplier based upon mixture viscosity proposed by McAdams, et al.

$$\frac{\mu_{TP}}{\mu_f} = \left[1+\chi\left(\frac{\mu_f}{\mu_g}-1\right)\right]^{-1}$$

and that two-phase friction factor, f_{TP}, has same Re dependence as single phase friction factor, f_{lo}; where:

$$f = 0.316 R_e^{-0.25} \quad \text{where } R_e = \frac{G\,D}{\mu}$$

$C_1 = 0.316$ and $n = 0.25$

Blasius relation of turbulent friction factor for smooth pipe

$$\frac{f_{TP}}{f_{lo}} = \frac{C_1 / Re_{TP}^n}{C_1 / R_{lo}^n} \Rightarrow \left(\frac{\mu_{TP}}{\mu_f}\right)^n = \left(\frac{\mu_{TP}}{\mu_f}\right)^{0.25}$$

and

$$f_{lo} \sim \left(\frac{\mu_f}{D\,G_m}\right)^n \Rightarrow f_{lo} \sim \left(\frac{\mu_f}{D\,G_m}\right)^{0.25}$$

For conditions where χ=1.0, the following simplifications can be made:

$$\Phi_{lo}^2 = \left(\frac{\rho_f}{\rho_g}\right)\left(\frac{\mu_f}{\mu_g}\right)^{-0.25}$$

$G_m \Rightarrow G_g$ as $G_m \Rightarrow \rho_g j_g$ @ χ=1.0 (i.e., $\rho_f j_f = G_f = 0$)

Substituting conditions @ χ=1.0

$$\Delta p = \left(\frac{\rho_f}{\rho_g}\right)\left(\frac{\mu_f}{\mu_g}\right)^{-0.25}\left(\frac{\mu_f}{D\,G_g}\right)^{0.25}\frac{L}{D}\frac{G_g^{\ 2}}{2\,\rho_f}$$

$$= \left(\frac{\mu_g}{D\,G_g}\right)^{0.25}\frac{L}{D}\frac{G_g^{\ 2}}{2\,\rho_g} = \left(\frac{f_g L}{D}\right)\frac{G_g^{\ 2}}{2\,\rho_g}$$

where

$$\left(\frac{\mu_g}{D\,G_g}\right)^{0.25} \sim f_g$$

The above result is equivalent to Darcy @ χ=1.0

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Appendix 15

Email dated 1/30/04

"Sudden Contraction Rev. 1"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:26 AM
To: Gongaware, Jacqueline J.
Subject: FW: Sudden Contraction DP

From: Vijuk, Ronald P.
Sent: Friday, January 30, 2004 5:04 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Brown, William L.
Subject: Sudden Contraction DP

Here is some additional DP comparisons for some of the data NRC provided.

From: Brown, William L.
Sent: Friday, January 30, 2004 5:01 PM
To: Vijuk, Ronald P.
Subject: Sudden Contraction Rev.1

Sudden Contraction Data PredictionRev1.d

Ron

I copied the latest plot showing comparison to Ferrell&McGee data sent by NRC into the attached revision of the Sudden Contraction Data Prediction writeup we sent yesterday.
The plot is shown as Figure 7 at the end of the writeup. The comparison was performed for 117 psia conditions and three run groups of different massflux G (G=111,221,276 lbm/ft^2-sec). The area ratio was 0.608. Quality ranged from 0 to 32.3%.

W. Brown

Pressure Drop Data Prediction of Sudden Contraction Area Changes Using Homogeneous Methods

Background

The ADS-4 flow paths in AP1000 contain significant sudden contraction area changes where the flow is accelerated in the ADS-4 piping and results in notable pressure drop in the core exit region flow path. Experience from single phase flow indicates that pressure drop through a sudden contraction is largely due to a reversible acceleration pressure drop and an irreversible viscous loss due to momentum transfer in the downstream section. The largest area change in the AP600 and AP1000 ADS-4 flow paths occurs at the entrance to the ADS-4 flow path from the hot leg. The area ratio of the AP600 ADS-4 off-take to the hot leg (A_{ads4}/A_{hleg}), for example, is about 0.11 and for AP1000 is about 0.22.

It is desired to show that the pressure drop associated with sudden contractions can be acceptably predicted by comparison with single phase and two-phase sudden contraction data (see pressure drop data sources section below). For two-phase conditions, homogeneous based methods seem to provide acceptable prediction of pressure drop through sudden contractions whereas attempts using more sophisticated separated flow based models have offered little or no improvement over homogeneous based models. It has been postulated that this may the case as the two-phase flow regardless of flow regime upstream of the sudden contraction is forced to mix (liquid and vapor phases exchange momentum) or homogenize as it encounters the flow contraction. The following discussion presents pressure drop predictions of sudden contraction data for two-phase and single phase flow.

Pressure Drop Data Sources

Three sources of pressure drop data are presented:

1. Geiger and Rohrer, "Sudden Contraction Losses in Two-Phase Flow", Journal of Heat Transfer, 1966.
2. Schmidt and Friedel, "Two-Phase Pressure Drop Across Sudden Contractions in Duct Areas", Int. J. Multiphase Flow, 1997.
3. Ferrell and McGee, "Two-Phase Flow Through Abrupt Expansions and Contractions", 1966.

Homogeneous Method Using Mechanical Energy Eqn.

$$\Delta p_{\substack{sudden \\ contraction}} = \frac{G_m^2}{2\rho_m}[1-\sigma^2 + K_{1\phi contraction}]$$

where ρ_m is homogeneous mixture density and σ is area ratio of sudden contraction.

Homogeneous Method Using Momentum Eqn.

$$\Delta p_{\substack{sudden \\ constraction}} = \frac{G_m^2}{\rho_m}[1-\sigma]$$

Results

Results applying the homogeneous methods are shown in Figures 1 through 5 below. Figure 6 shows comparison against single phase data. The homogeneous mechanical energy method generally predicts the two-phase data reasonably well. The homogeneous momentum method provides a conservative prediction of the two-phase data.

Conclusions

Homogeneous methods provide acceptable prediction of pressure drop across sudden contractions. Therefore code calculations of sudden contraction pressure drop based upon homogeneous models should provide acceptable results.

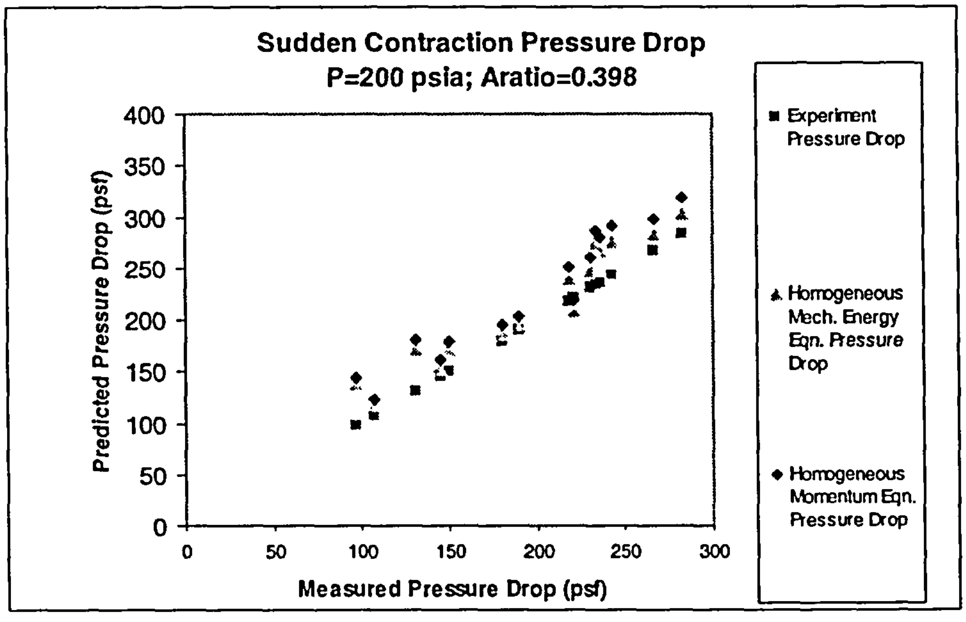

Figure 1. Steam-Water Data, Quality Range X=0.0117-0.211

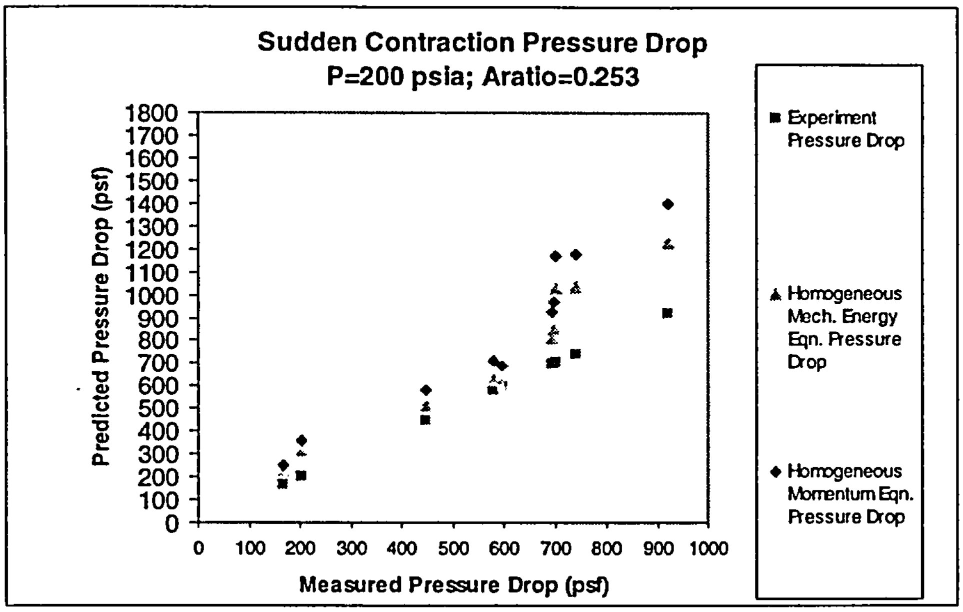

Figure 2. Steam-Water Data, Quality Range X=0.0001-0.193

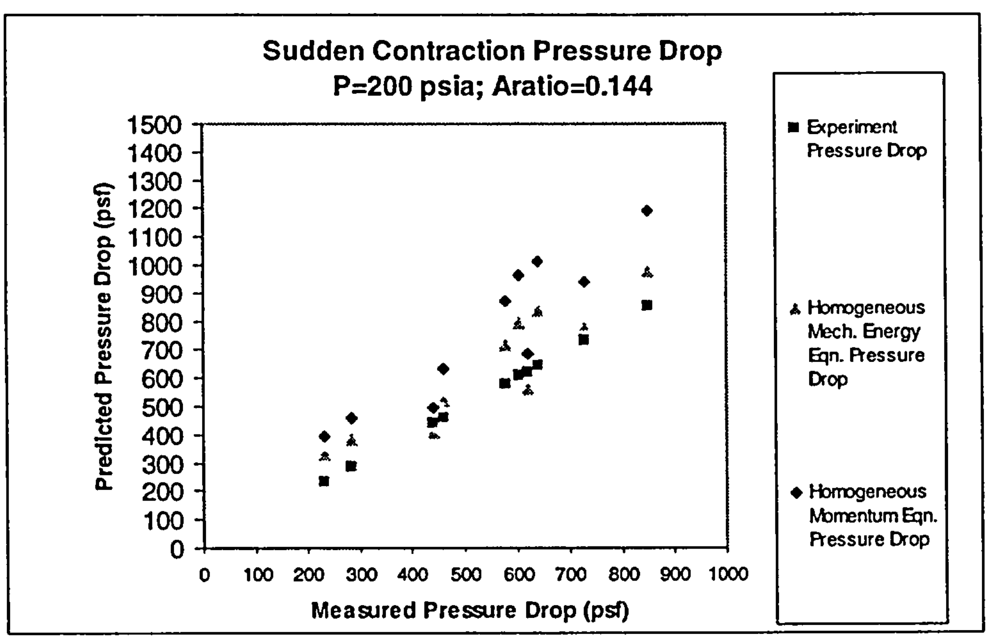

Figure 3. Steam-Water Data, Quality Range X=0.0001-0.0858

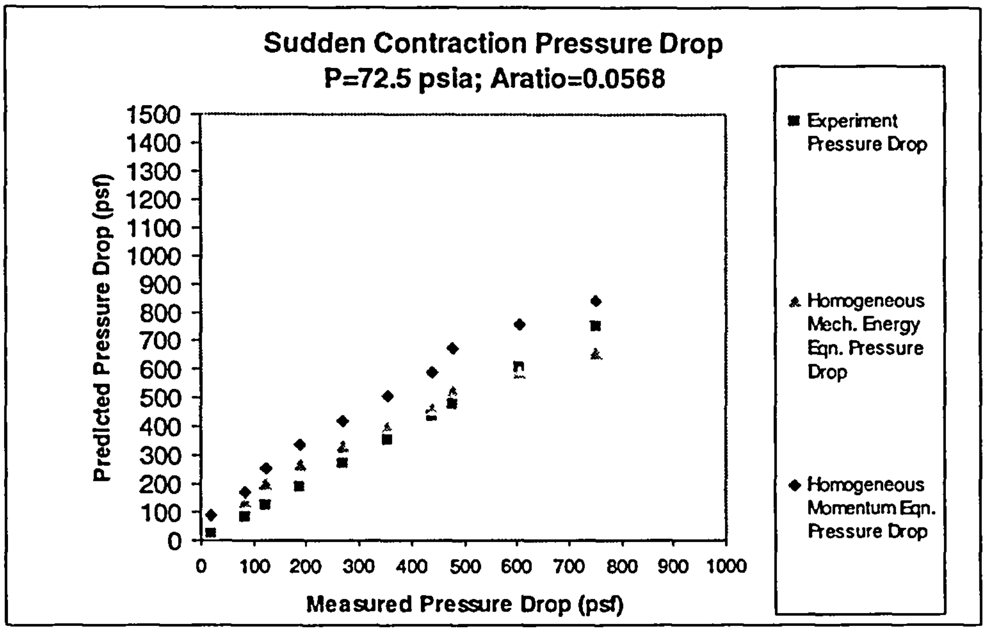

Figure 4. Air-Water Data, Quality Range X=0.1-1.0

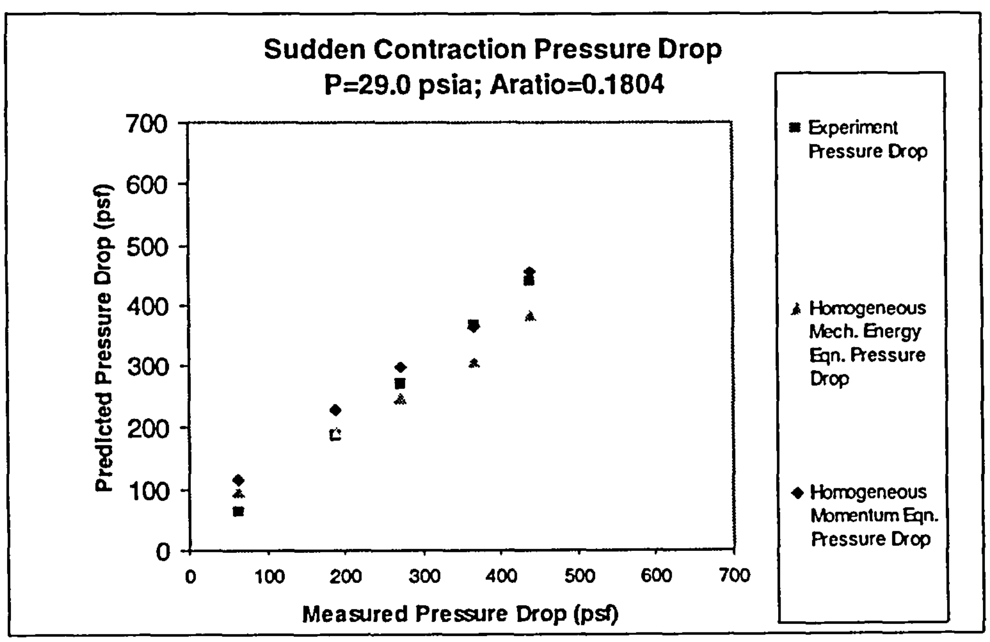

Figure 5. Air-Water Data, Quality Range X=0.25-1.0

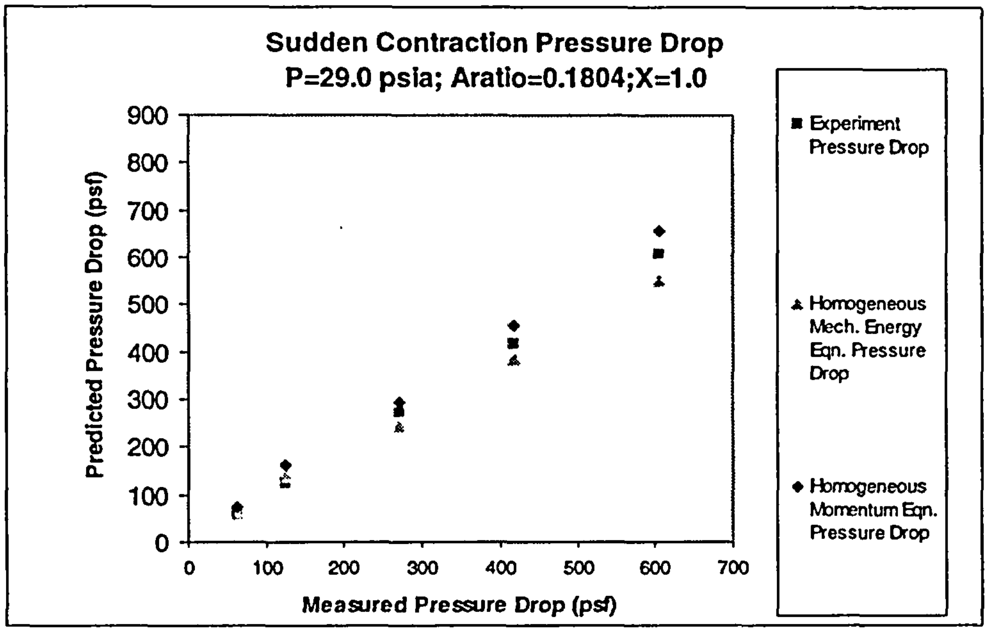

Figure 6. Air Data

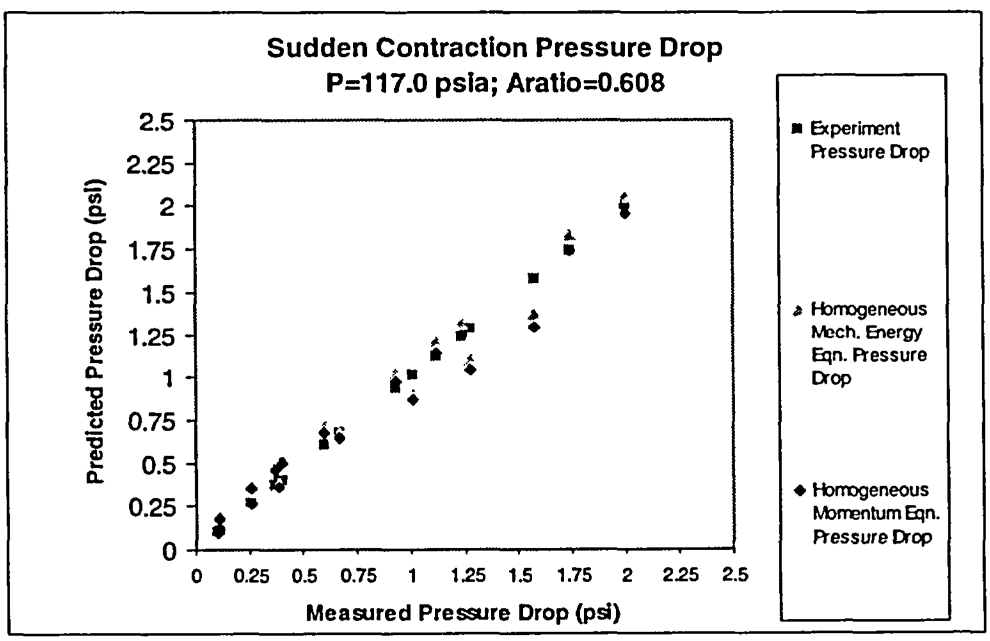

Figure 7. Ferrell and McGee Data

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Appendix 16

Email dated 1/30/2004
"NOTRUMP cases"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:27 AM
To: Gongaware, Jacqueline J.
Subject: FW: NOTRUMP cases

From: Vijuk, Ronald P.
Sent: Friday, January 30, 2004 5:31 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Gagnon, Andre F.
Subject: NOTRUMP cases

DBA02 Y-C.doc   dvi20_cosi.doc

Here are NOTRUMP cases for DBA02 and for AP1000 DEDVI with artificially increased downcomer condensation heat transfer to compensate for lack of 2D downcomer thermal mixing. For the DBA02 case the artificially high condensation is turned off at 300 seconds. For the AP1000 case the high condensation is on throughout. The NOTRUMP comparison for the core void during early time is better but still lower than data. The AP1000 case plots compare to the DCD 20 psia case in Figures 1 throuhg 19, anf Figure 20 provides the core average void fraction for the high condensation case.

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OSU AP1000 NT vs Test DBA-02
Pressurizer Pressure

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02
Downcomer Pressure

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02
Pressurizer Level (Relative to Bottom Tap)

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
CMT-1 Level (Relative to Bottom Tap)

OSU AP1000 NT vs Test DBA-02
CMT-2 Level (Relative to Bottom Tap)

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02
CMT-1 Injection Line Mass Flow

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
CMT-2 Injection Line Mass Flow

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OSU AP1000 NT vs Test DBA-02

Steam Generator 2 Hot Side Collapsed Level (Relative to Bottom Tap)

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OSU AP1000 NT vs Test DBA-02

Steam Generator 2 Cold Side Collapsed Level (Relative to Bottom Tap)

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OSU AP1000 NT vs Test DBA-02

Steam Generator 1 Hot Side Collapsed Level (Relative to Bottom Tap)

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02

Steam Generator 1 Hot Side Collapsed Level (Relative to Bottom Tap)

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02

Steam Generator 1 Cold Side Collapsed Level (Relative to Bottom Tap)

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OSU AP1000 NT vs Test DBA-02
ACC-1 Level (Relative to Bottom tap)

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02
ACC-2 Level (Relative to Bottom tap)

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
Core Collapsed Liquid Levels (Relative to Bottom of Lower Plenum)

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
Average Core Void Fraction

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02

Upper Plenum Collapsed Levels (Relative to Bottom of Lower Plenum)

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02

Upper Plenum 2-phase Levels (Relative to Bottom of Lower Plenum)

Rev. 0

(a,b,c)

OSU AP1000 NT vs Test DBA-02

Collapsed Downcomer Levels (Relative to Bottom of Lower Plenum)

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
RPV Mixture Mass

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
ADS Stage 4 Integrated Flows

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OSU AP1000 NT vs Test DBA-02
Vessel Side Integrated Break Flow

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
Total DVI Line 1 Flow

Rev. 0

(a,b,c)

February 2, 2004

OSU AP1000 NT vs Test DBA-02
Total DVI Line 2 Flow

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
Total DVI Line 2 Flow

Rev. 0

(a,b,c)

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OSU AP1000 NT vs Test DBA-02
Core Inlet Temperatures

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OSU AP1000 NT vs Test DBA-02
Core Outlet Temperatures

Rev. 0

(a,b)

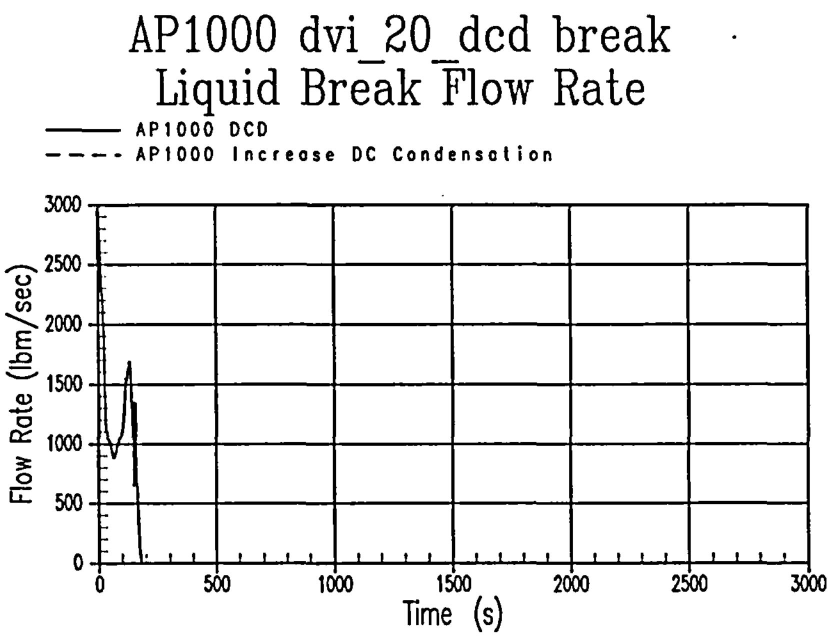
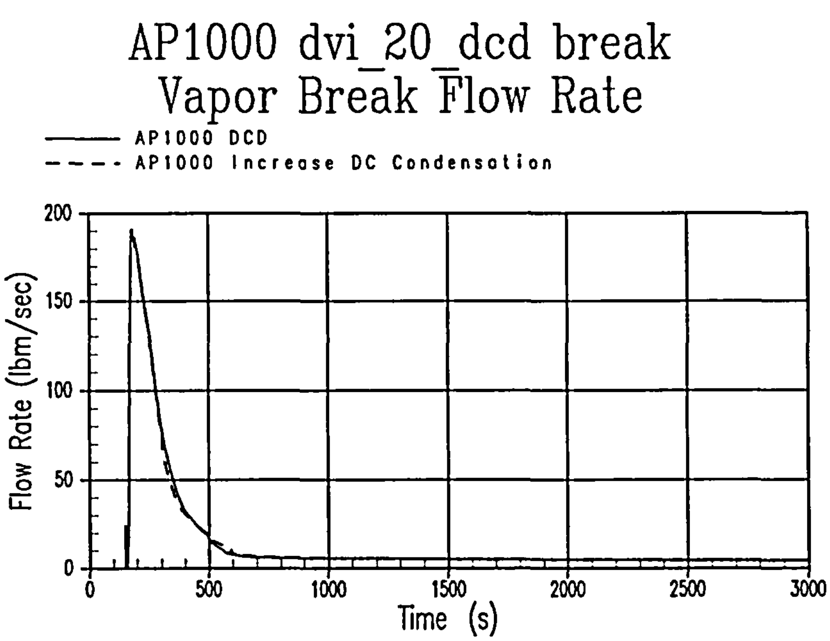


Figure-1



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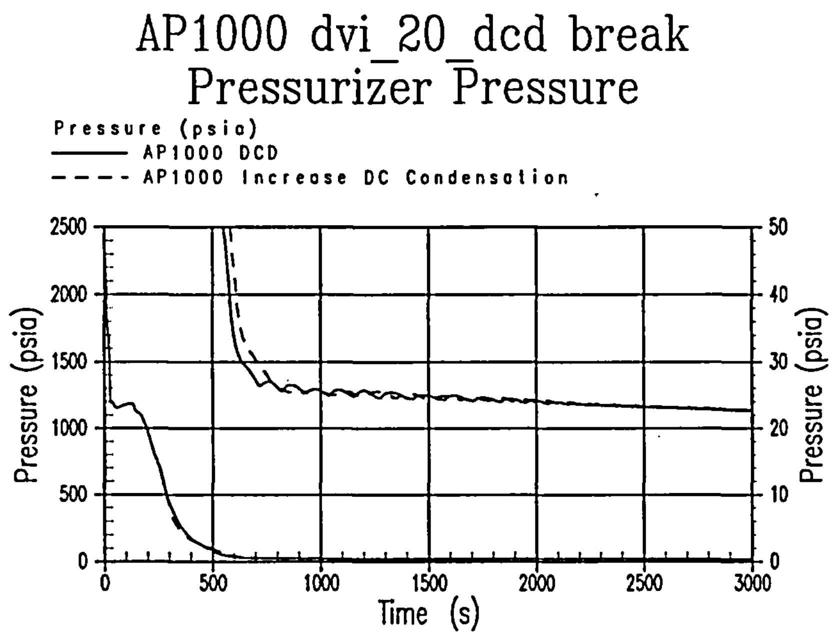

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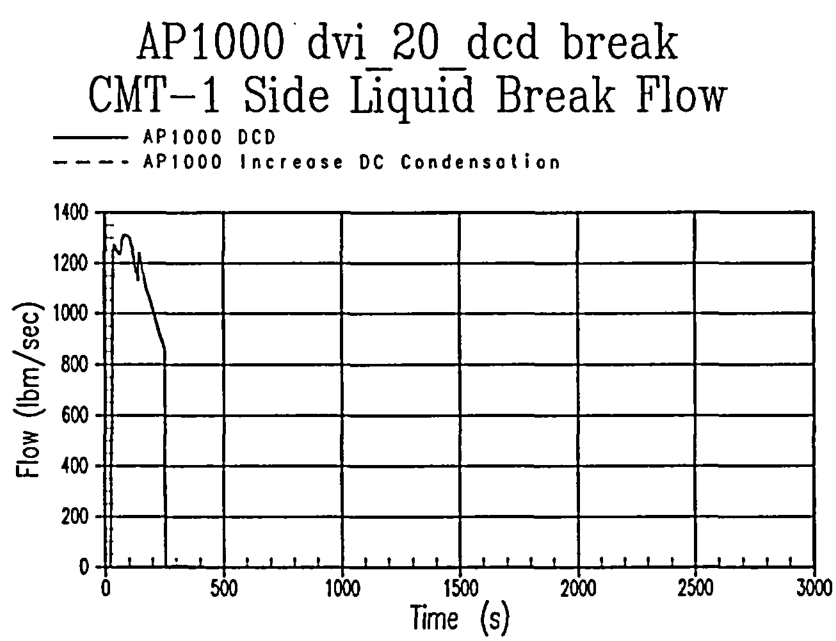

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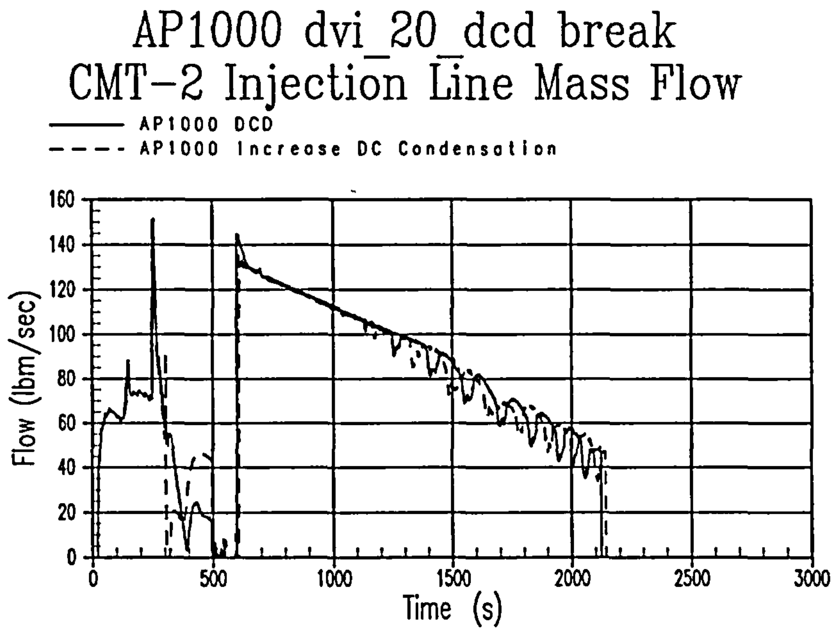

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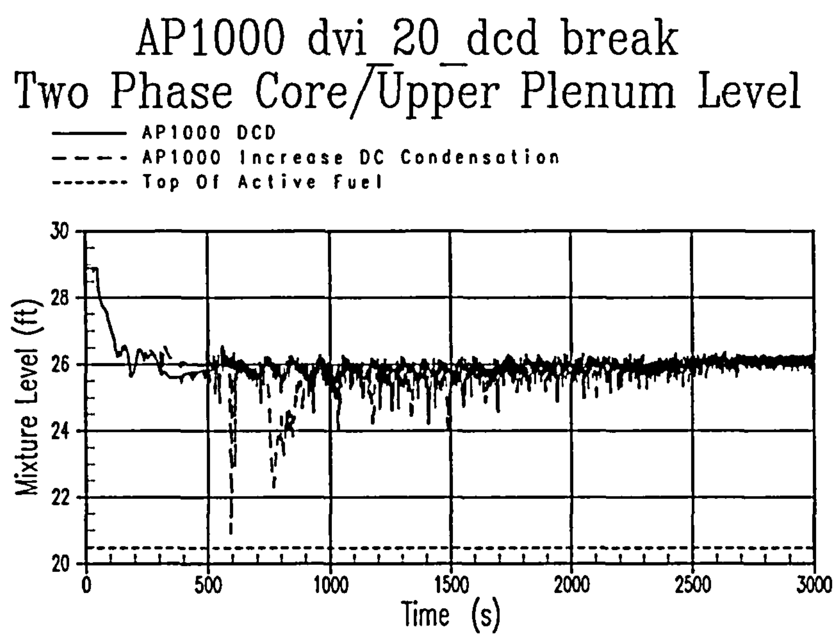

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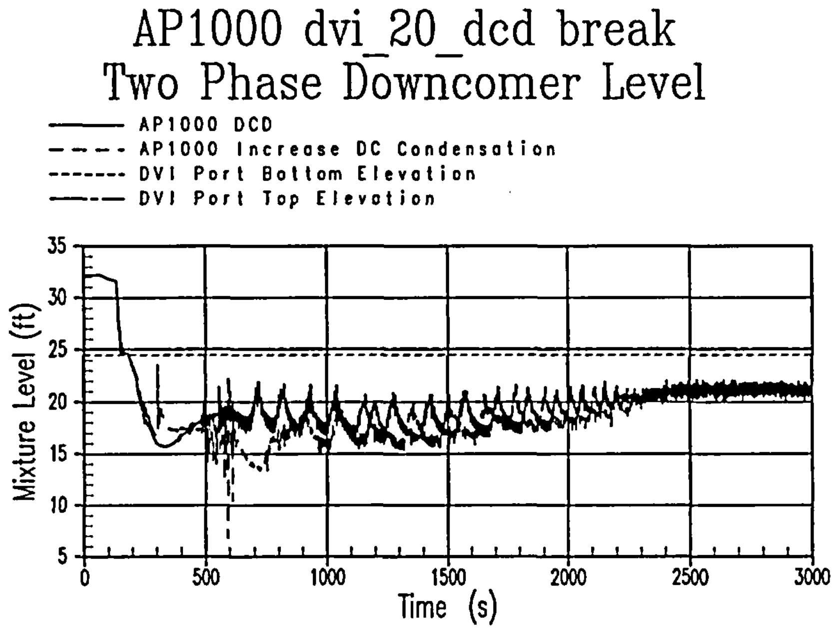

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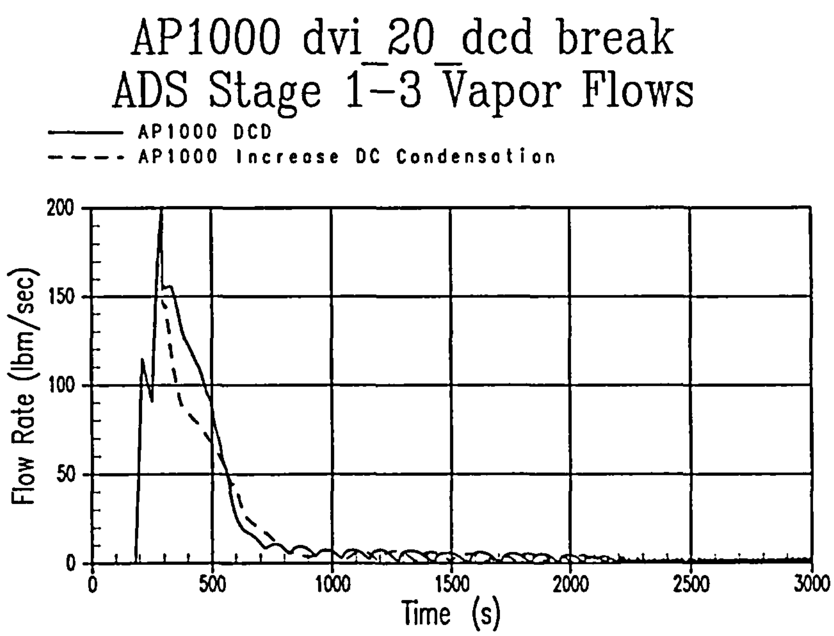

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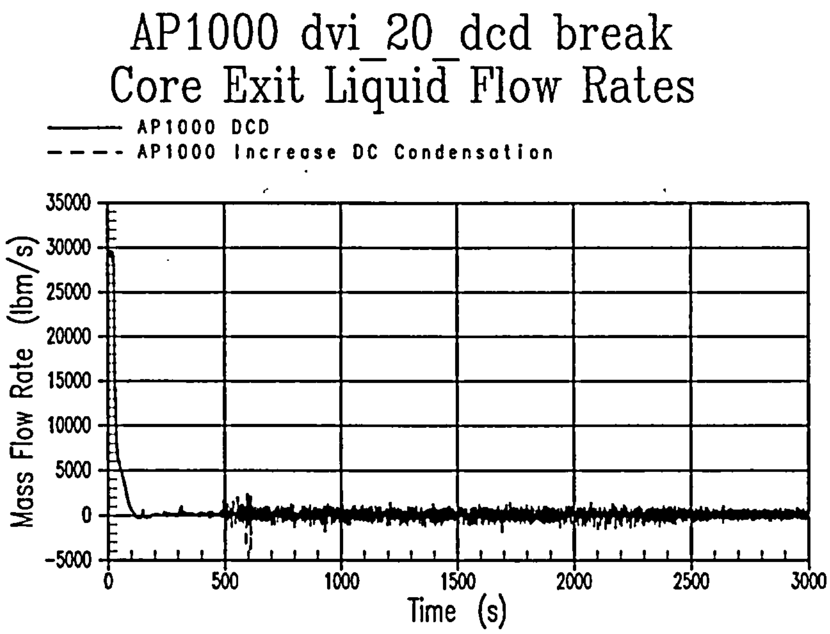
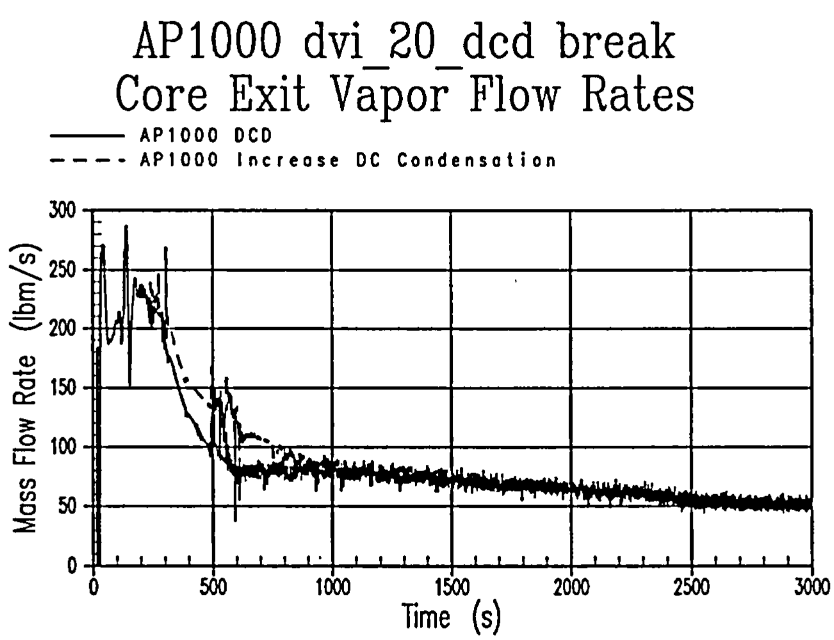


Figure-9



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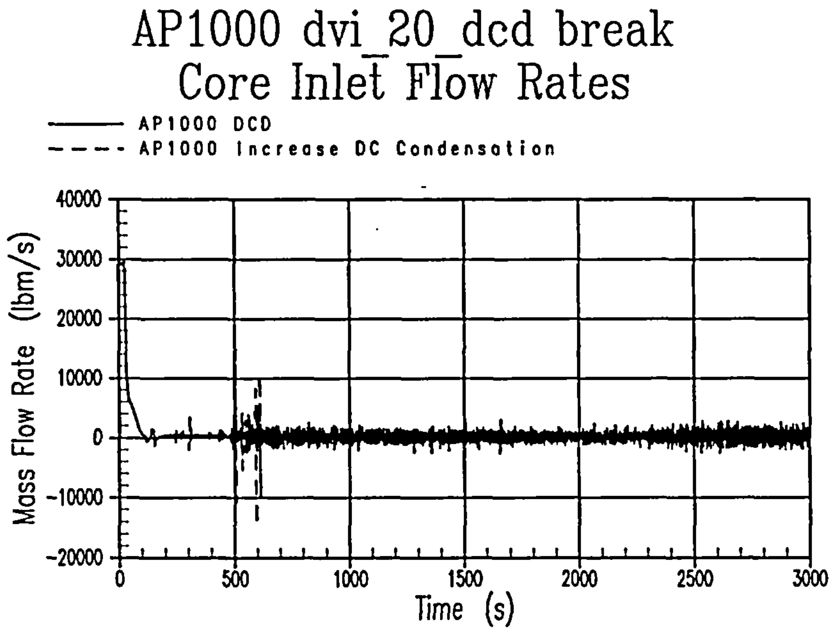

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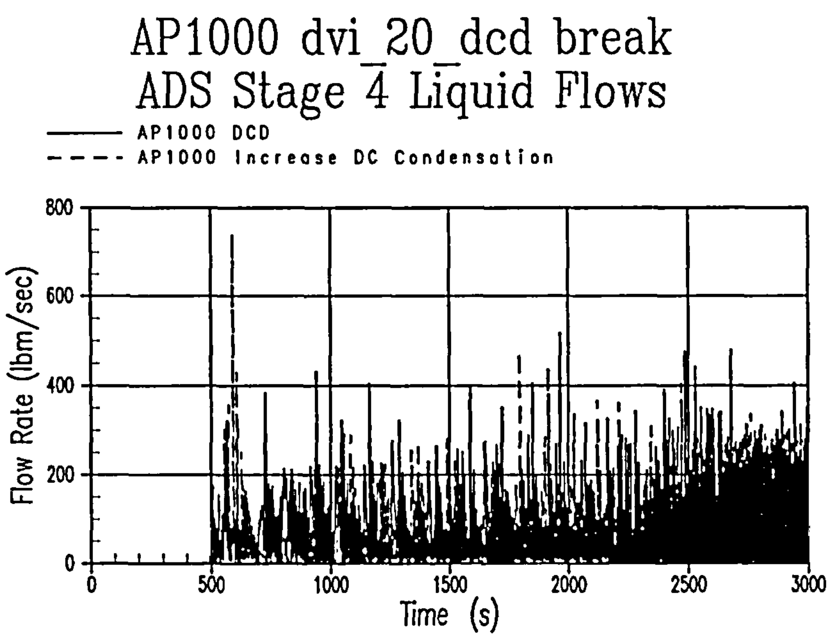

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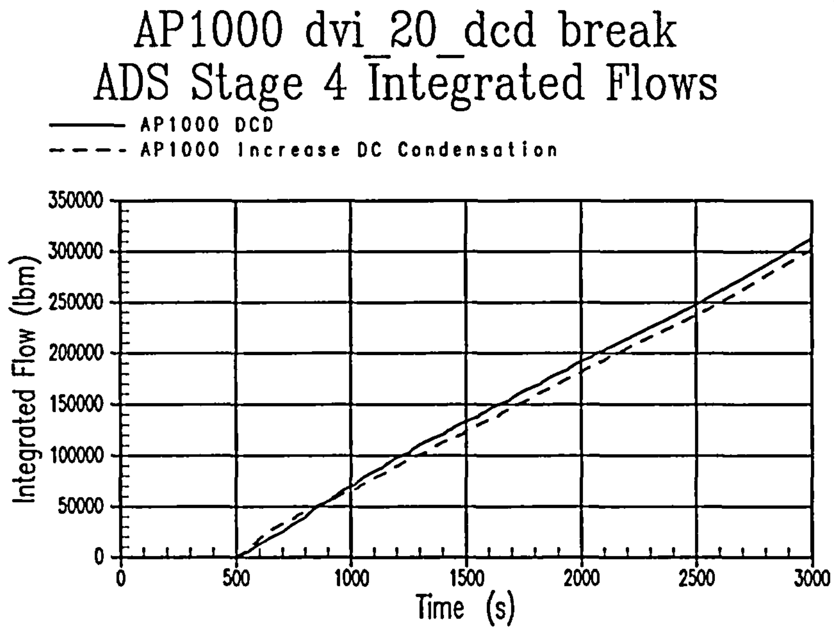

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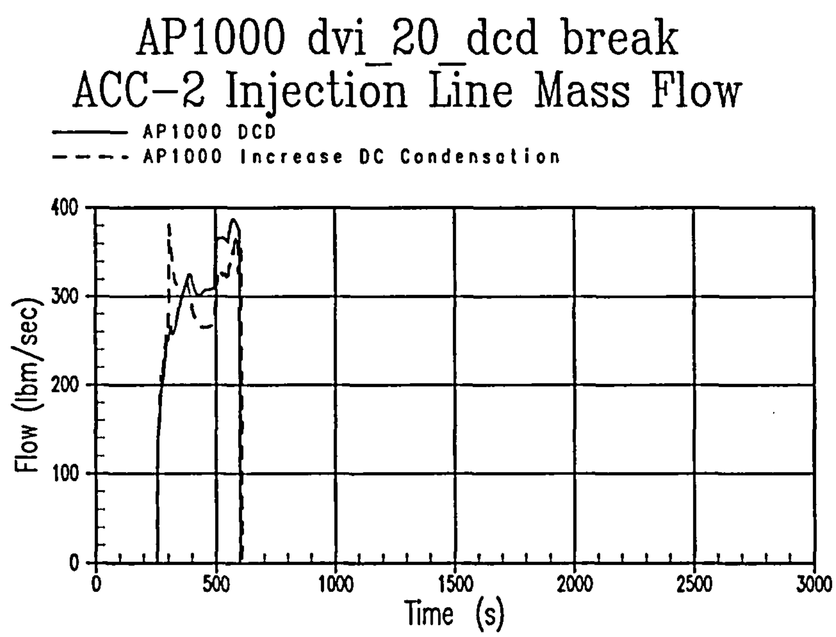
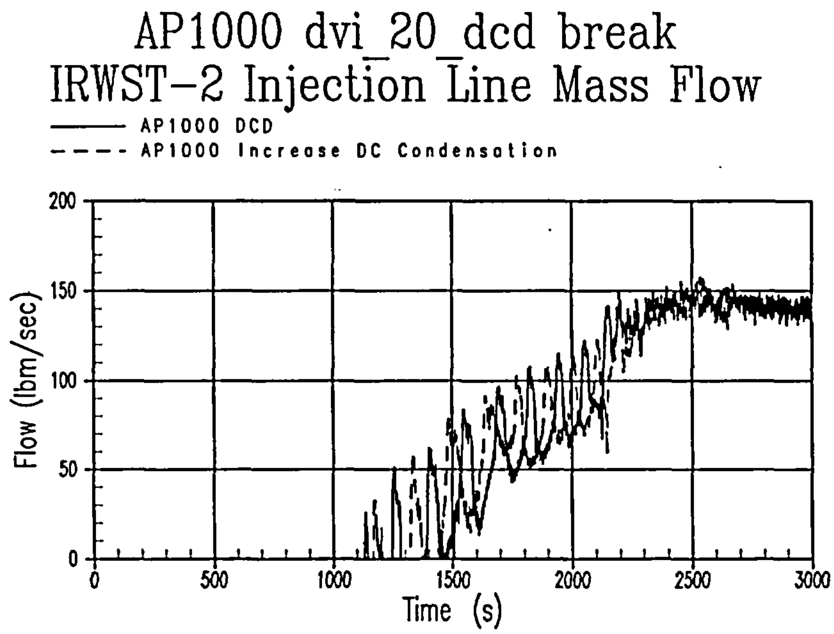


Figure-14



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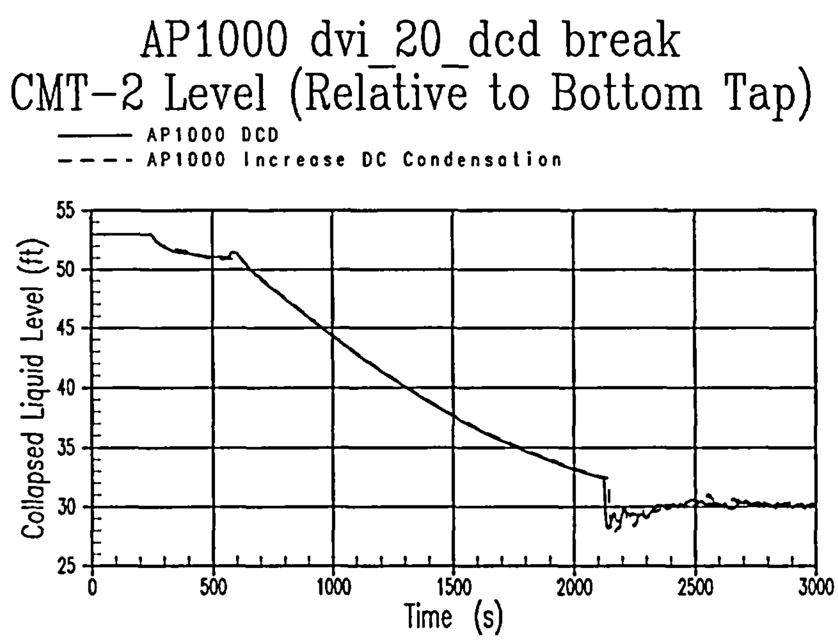

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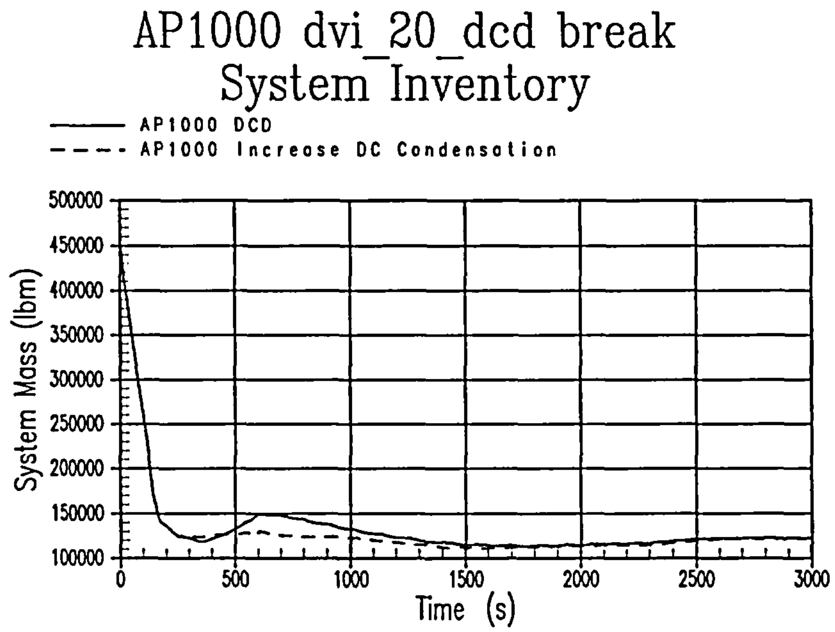

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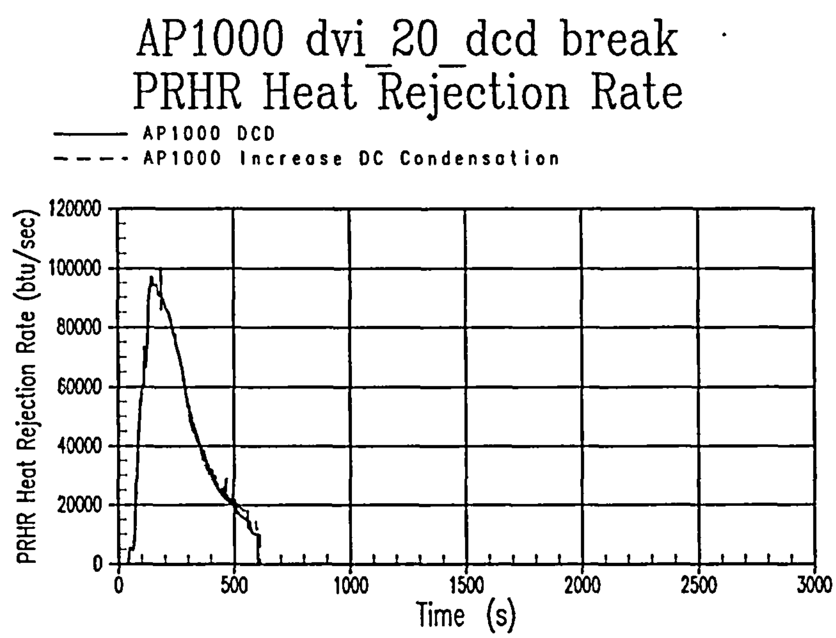

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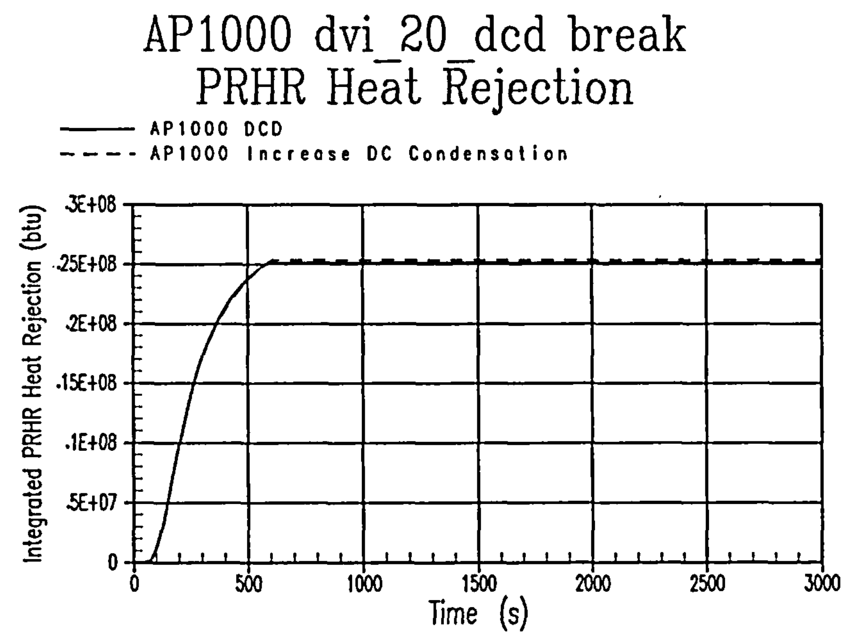

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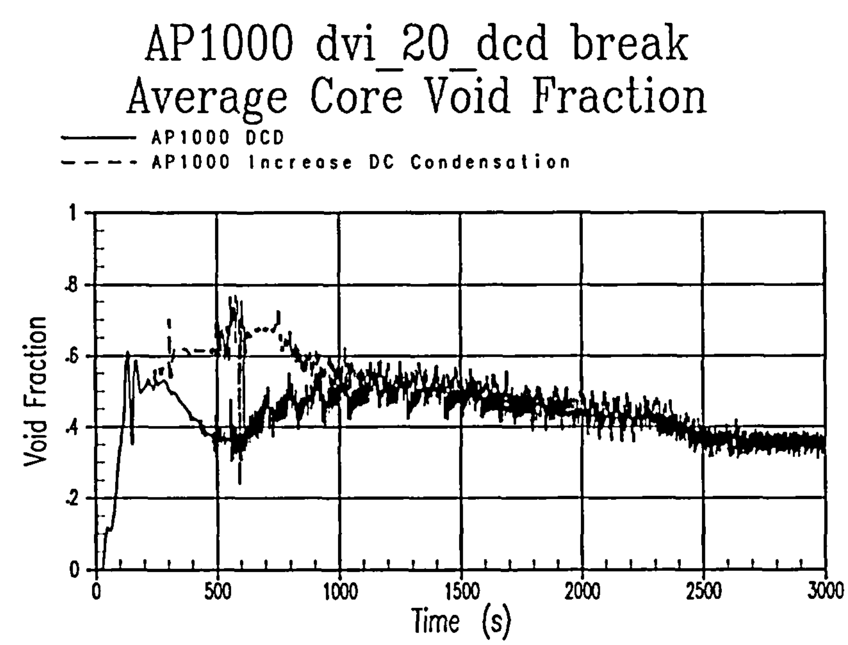

Figure-20

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Appendix 17

Email dated 2/2/2004

"DBA02 NOTRUMP / data plots"

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 9:08 AM
To: Gongaware, Jacqueline J.
Subject: FW: DBA02 NOTRUMP / data plots

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 9:07 AM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'; 'Bajorek, Steve'
Cc: Cummins, Ed; Gagnon, Andre F.
Subject: DBA02 NOTRUMP / data plots

dba02_ads4_details.doc

Here are the plots that we think Steve was requesting in his 1/31 email.

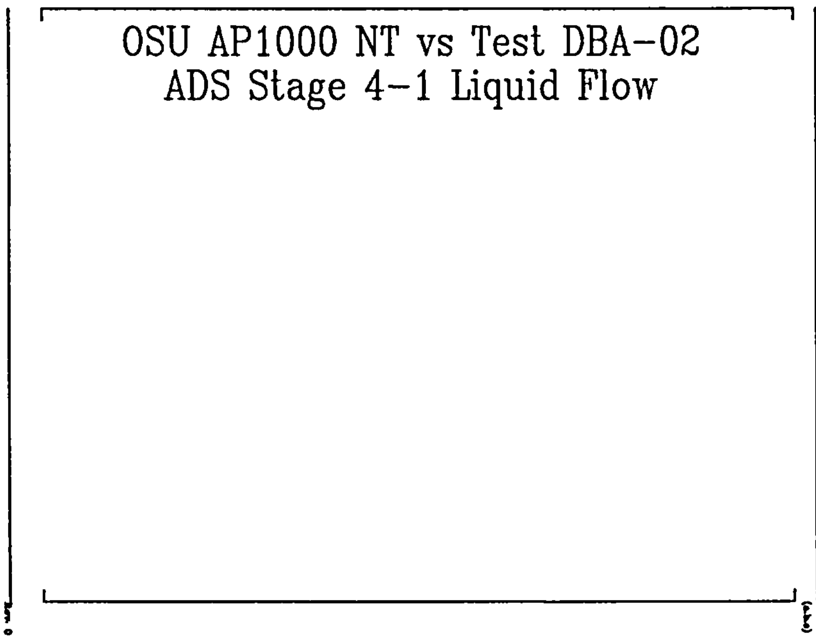

Figure-1

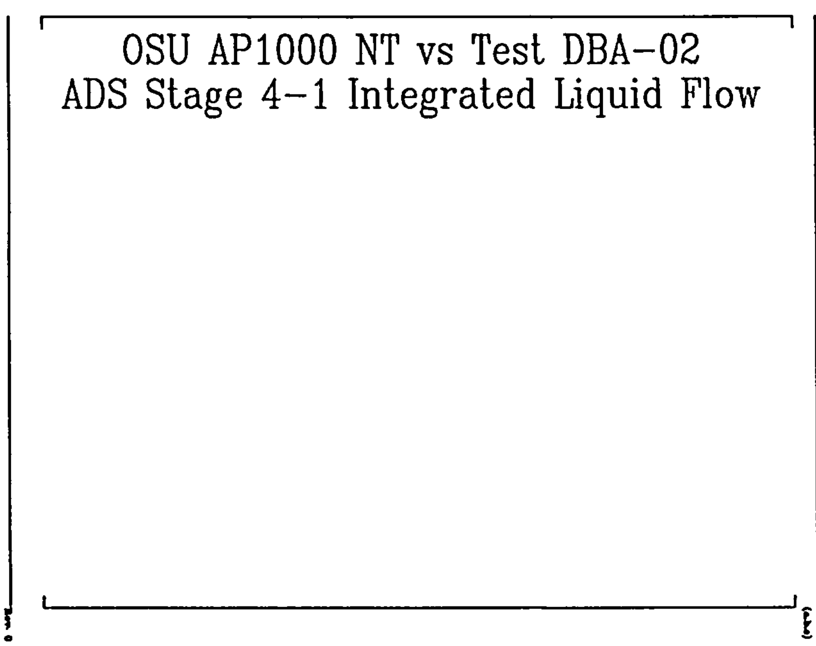

Figure-2

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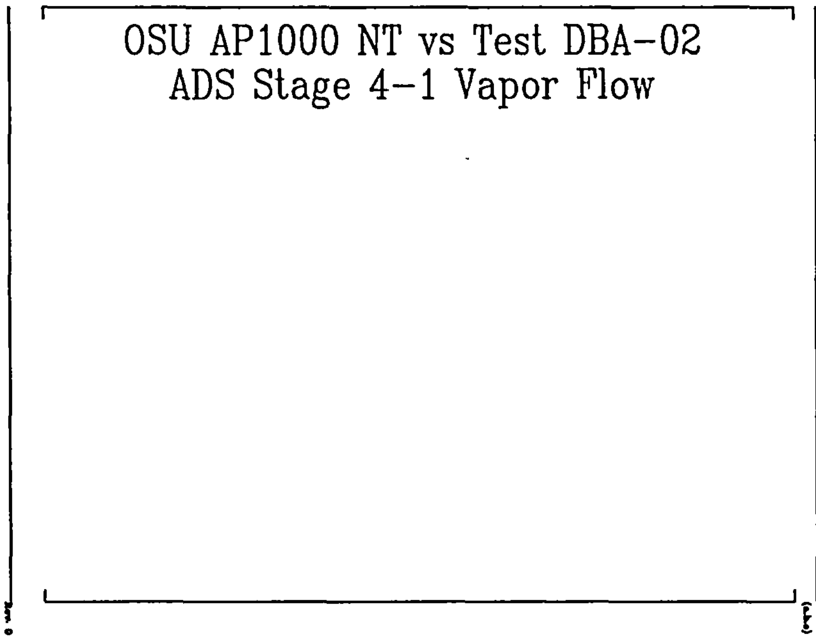
February 2, 2004



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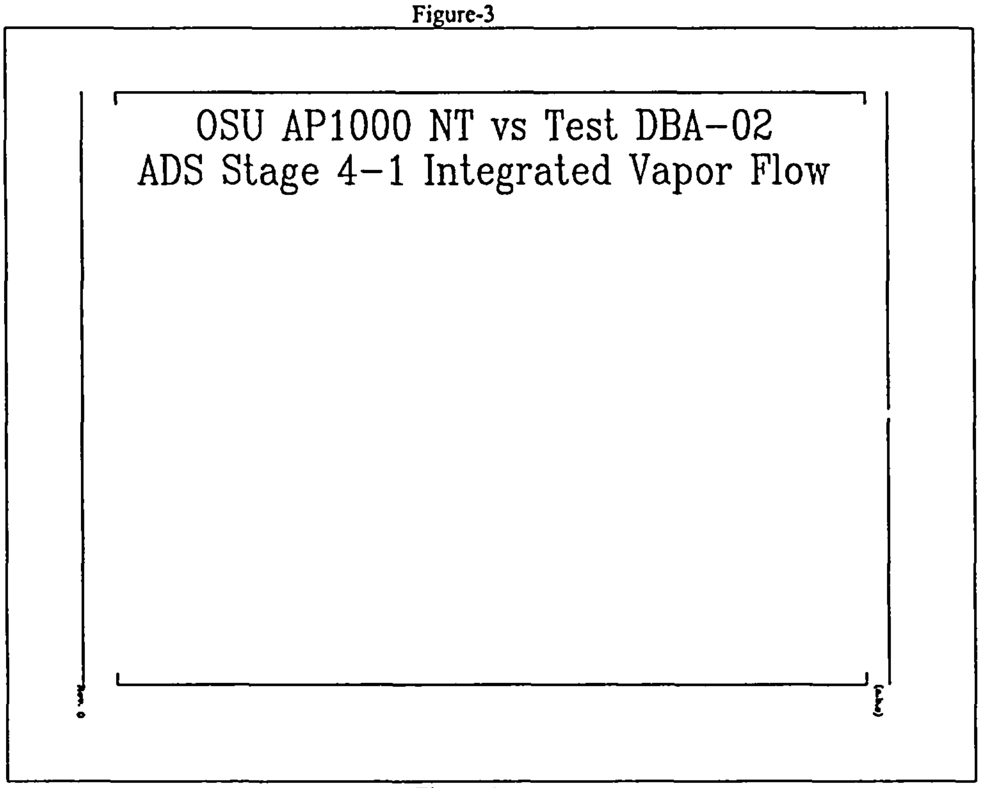
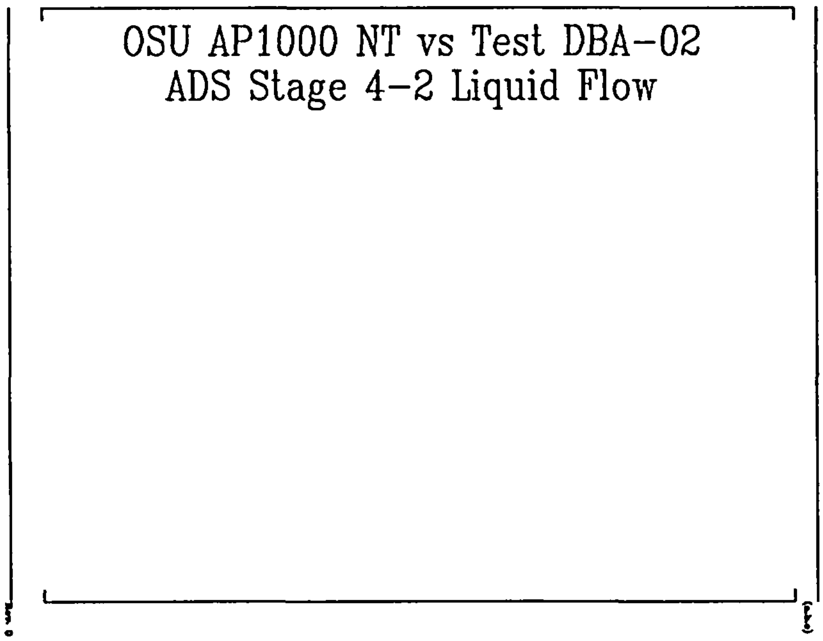


Figure-4

February 2, 2004



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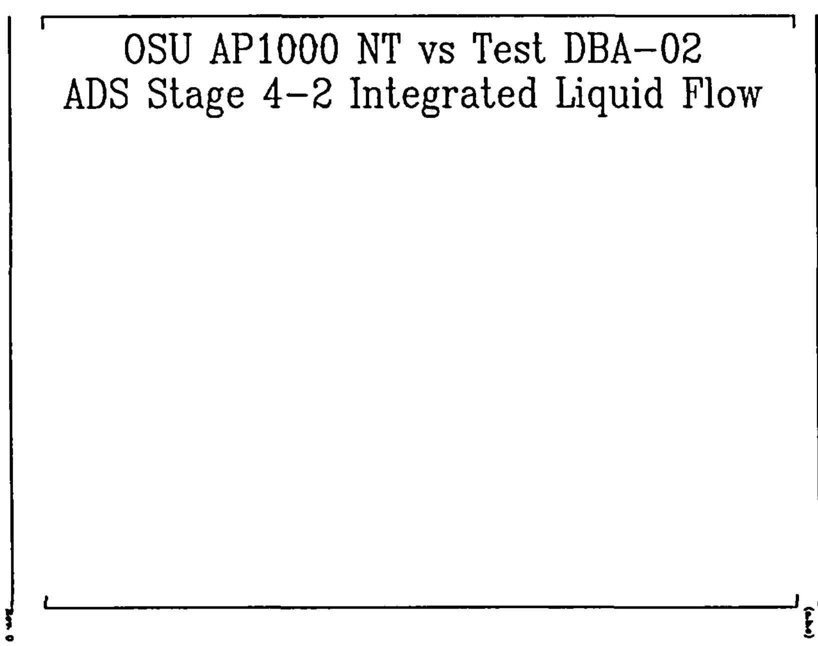

Figure-6

OSU AP1000 NT vs Test DBA-02
ADS Stage 4-2 Vapor Flow

Figure-7

OSU AP1000 NT vs Test DBA-02
ADS Stage 4-2 Integrated Vapor Flow

Figure-8

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Appendix 18

Email dated 2/2/2004
"New NOTRUMP cases"

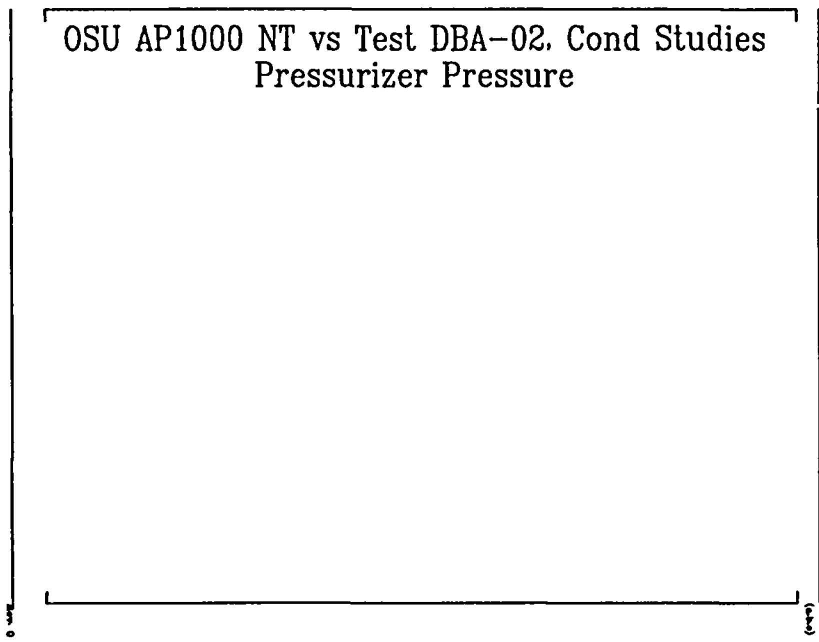
Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 1:26 PM
To: Gongaware, Jacqueline J.
Subject: FW: New NOTRUMP cases

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 1:25 PM
To: 'Joseph Colaccino'; 'John Segala'; 'Jennifer Uhle'
Cc: Cummins, Ed; Gagnon, Andre F.
Subject: New NOTRUMP cases

dba02_cosisw.doc dvi_20_cosisw_cosi_code.doc

Here are new NOTRUMP cases for DBA02 and for AP1000 DEDVI with artificially increased downcomer condensation heat transfer and using EPRI drift flux model for the core stack to compensate for lack of 2D downcomer thermal mixing. For the DBA02 case the artificially high condensation and EPRI drift flux are turned off at 300 seconds, reverting to the Yeh model and nominal condensation. For the AP1000 case the high condensation and EPRI drift flux are turned off at 500 seconds, reverting to the Yeh model and nominal condensation. The NOTRUMP comparison to DBA02 for the core void during early time is now close to the data.



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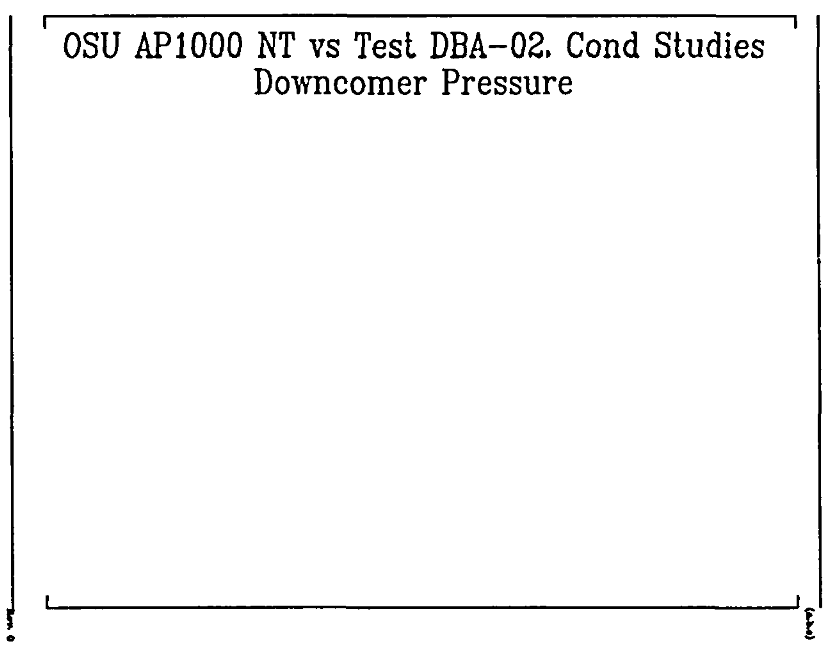


Figure-2

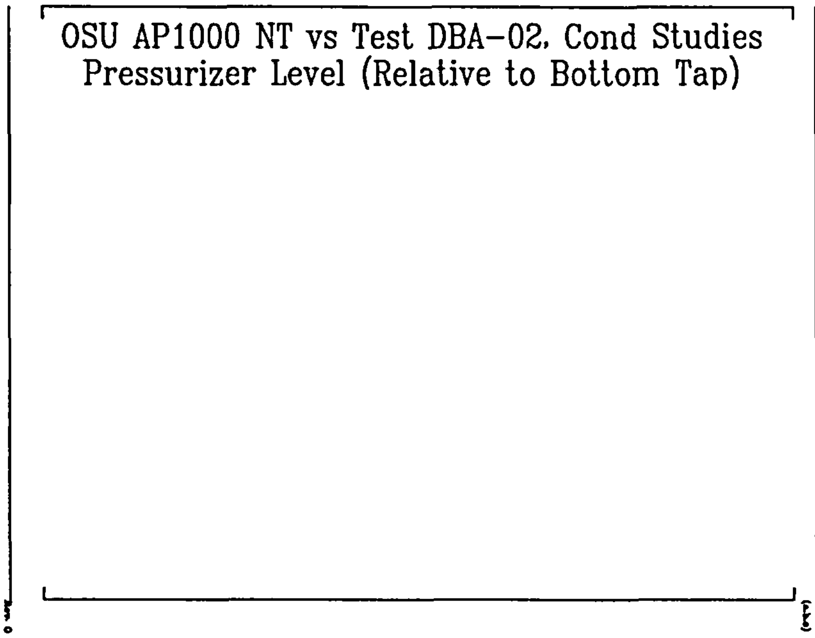


Figure-3

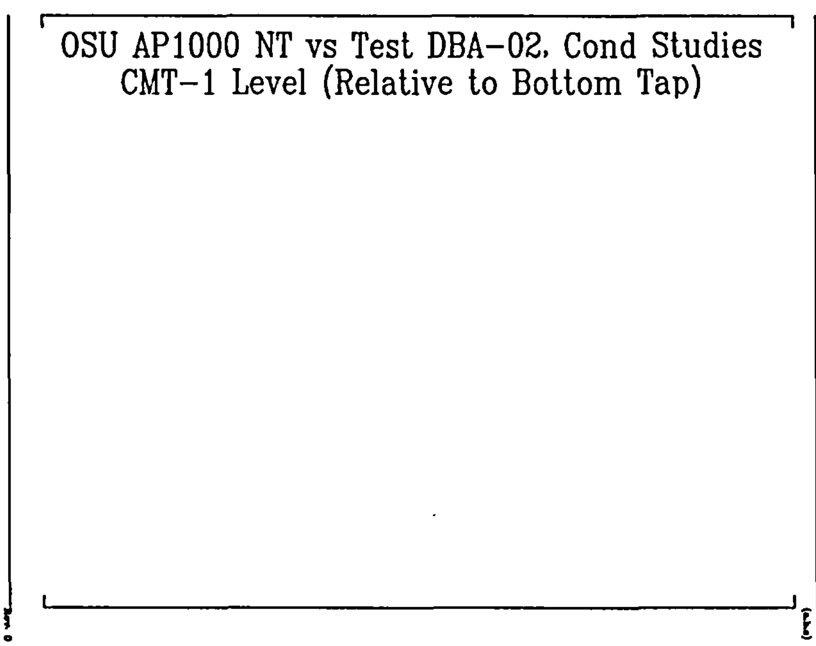


Figure-4

OSU AP1000 NT vs Test DBA-02, Cond Studies
CMT-2 Level (Relative to Bottom Tap)

Figure-5

OSU AP1000 NT vs Test DBA-02, Cond Studies
CMT-1 Injection Line Mass Flow

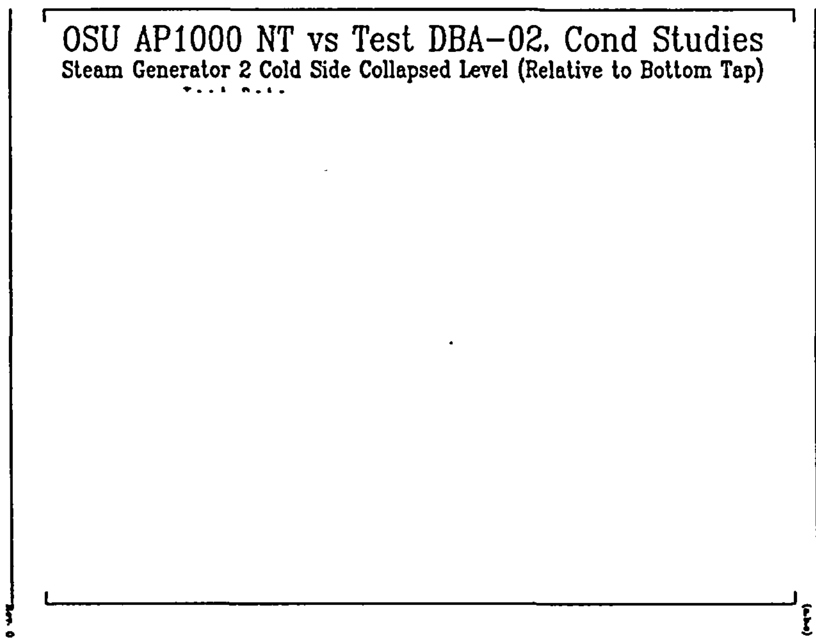
Figure-6

OSU AP1000 NT vs Test DBA-02, Cond Studies
CMT-2 Injection Line Mass Flow

Figure-7

OSU AP1000 NT vs Test DBA-02, Cond Studies
Steam Generator 2 Hot Side Collapsed Level (Relative to Bottom Tap)

Figure-8



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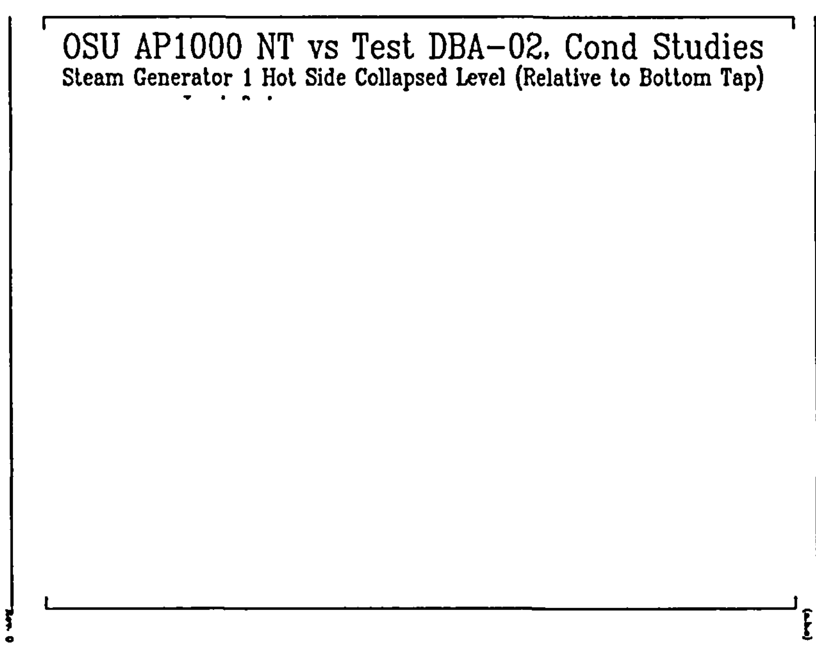

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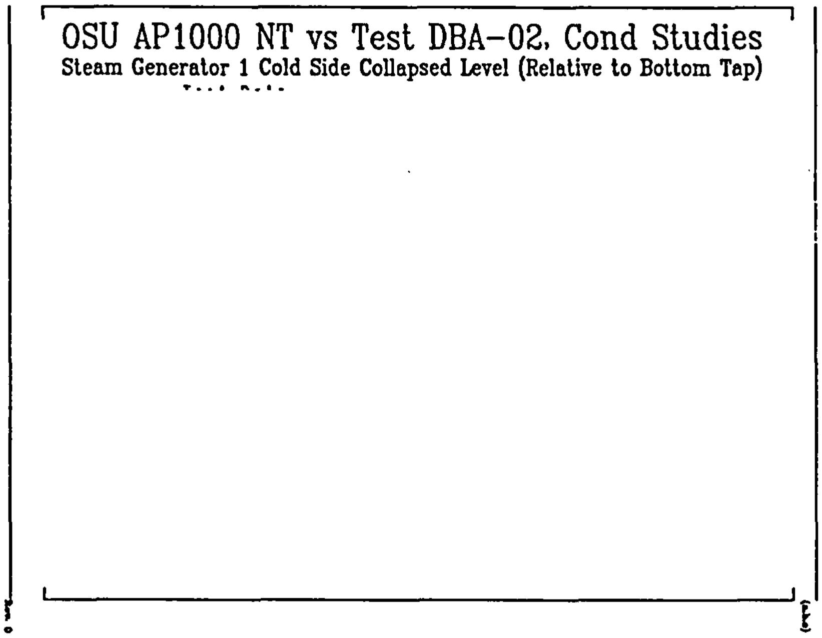

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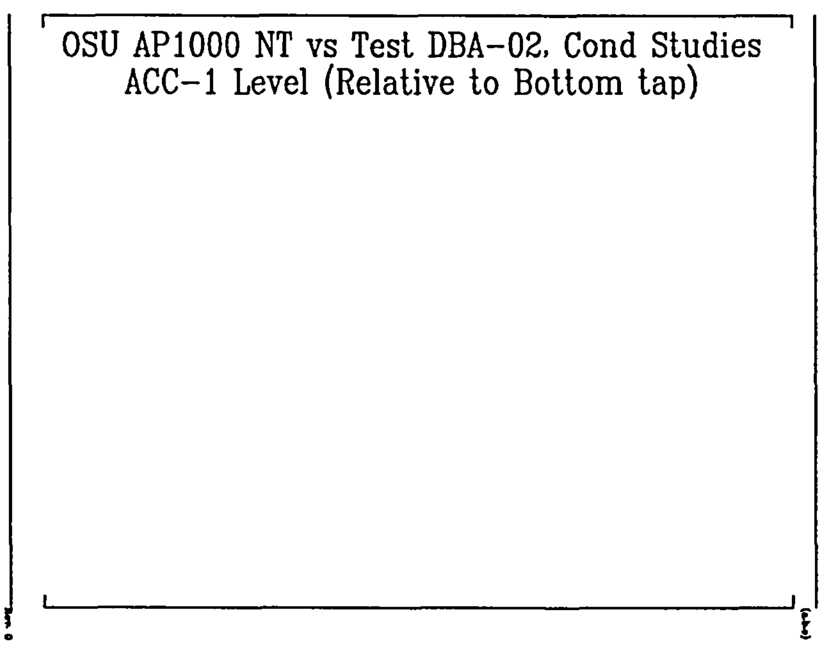

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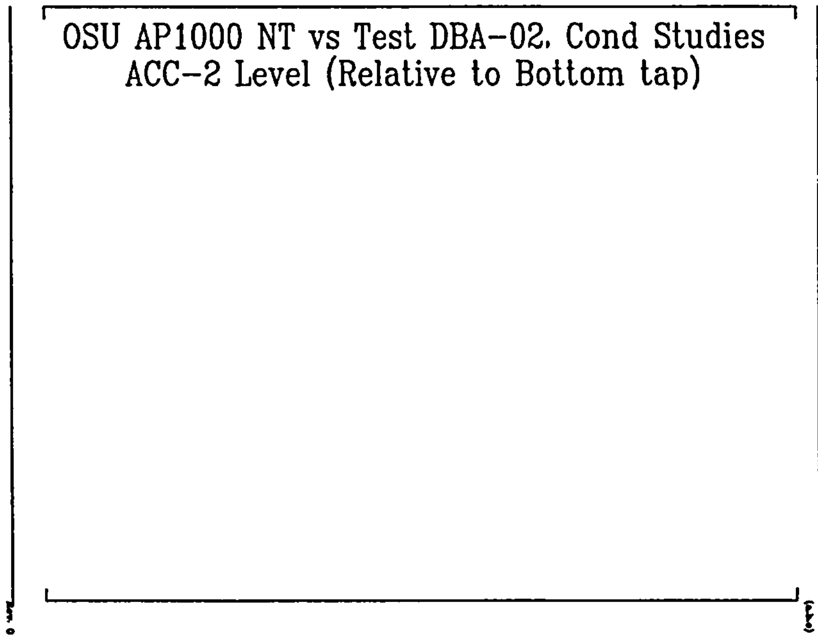

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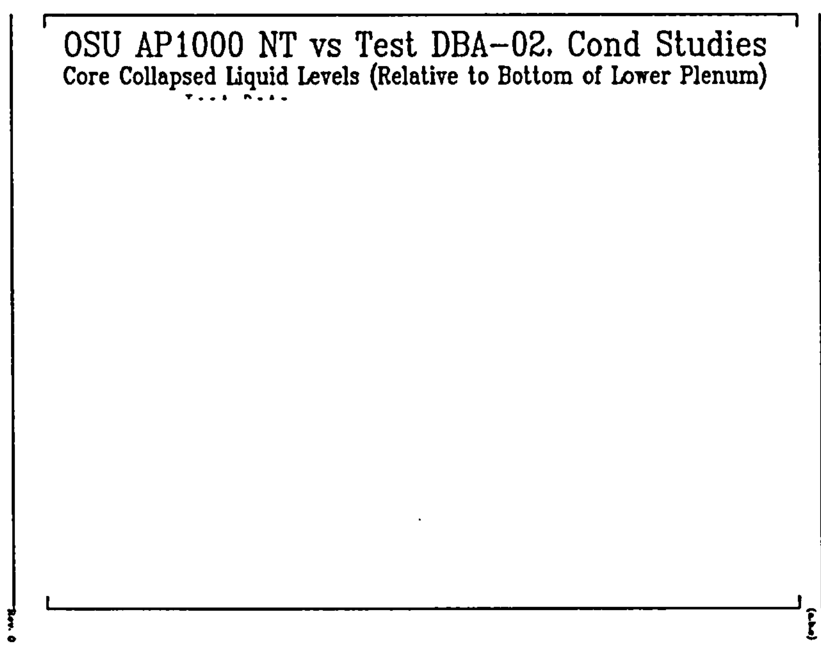

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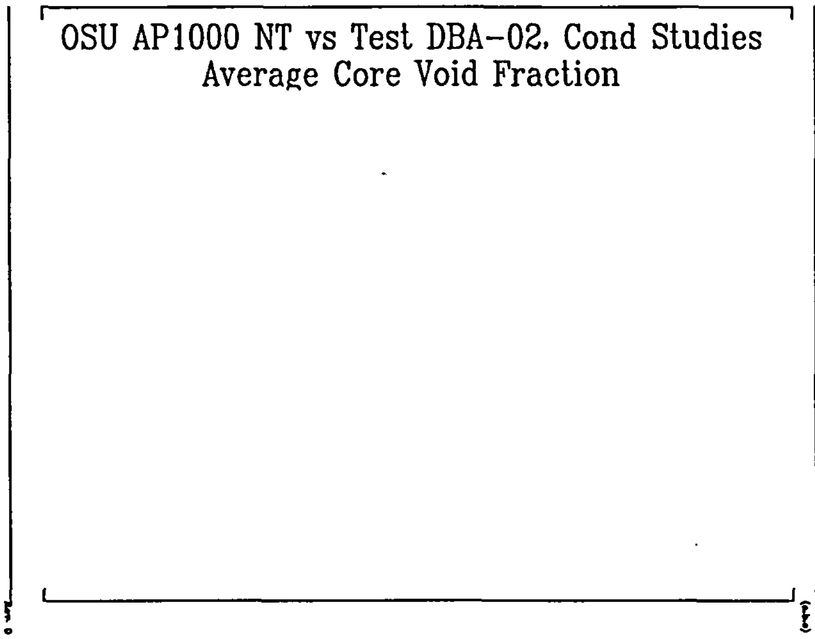

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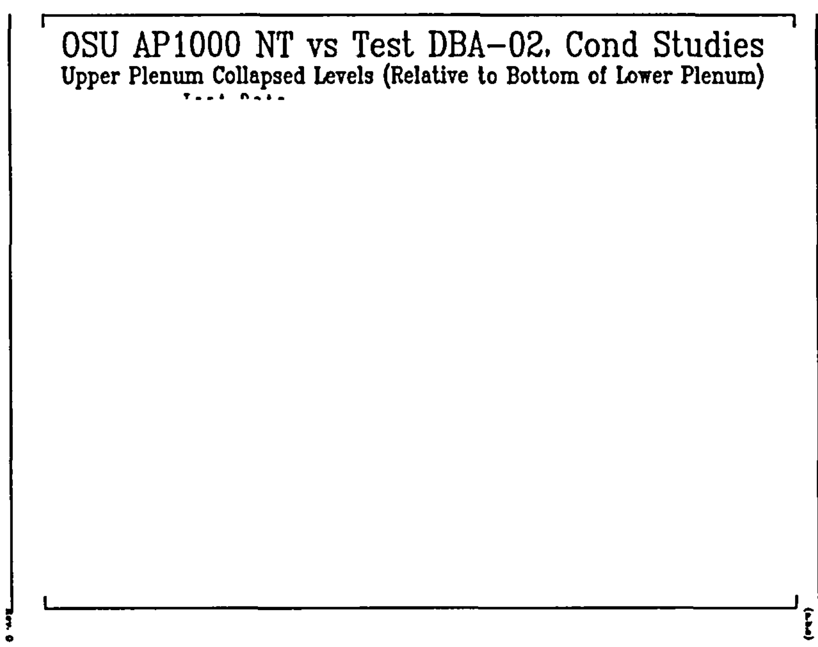

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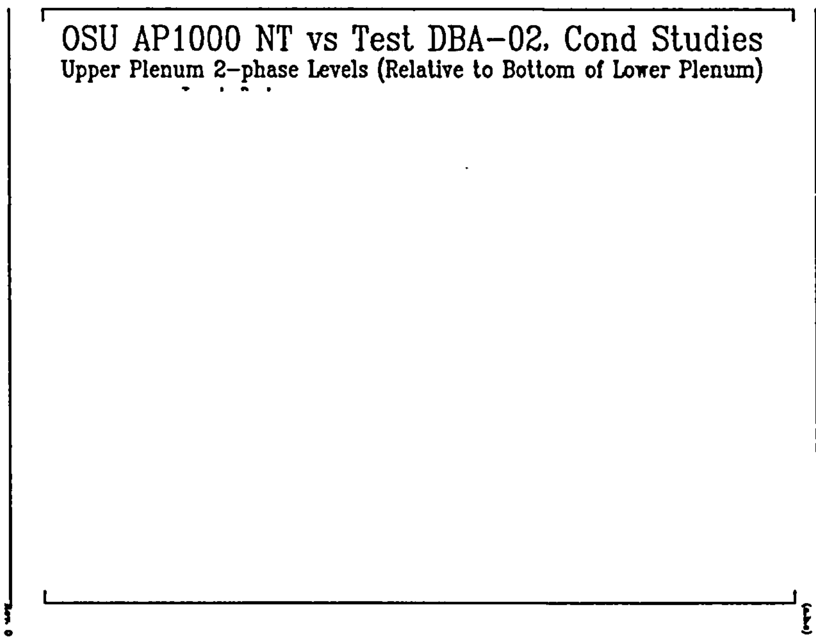

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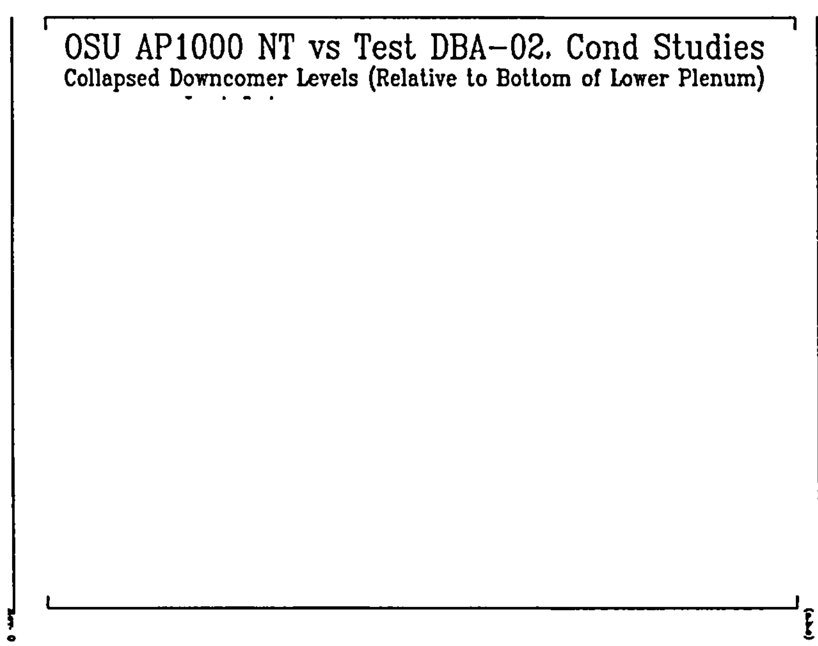

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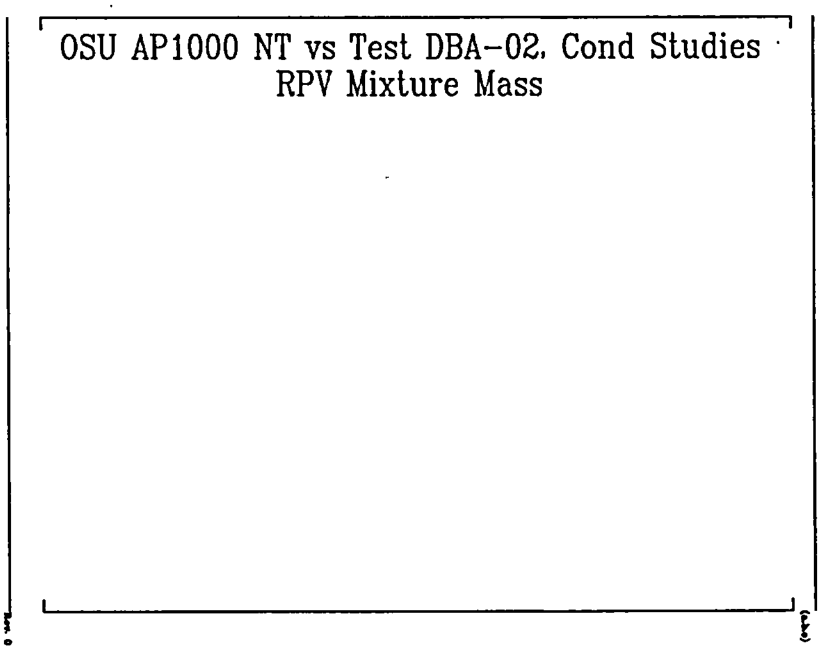

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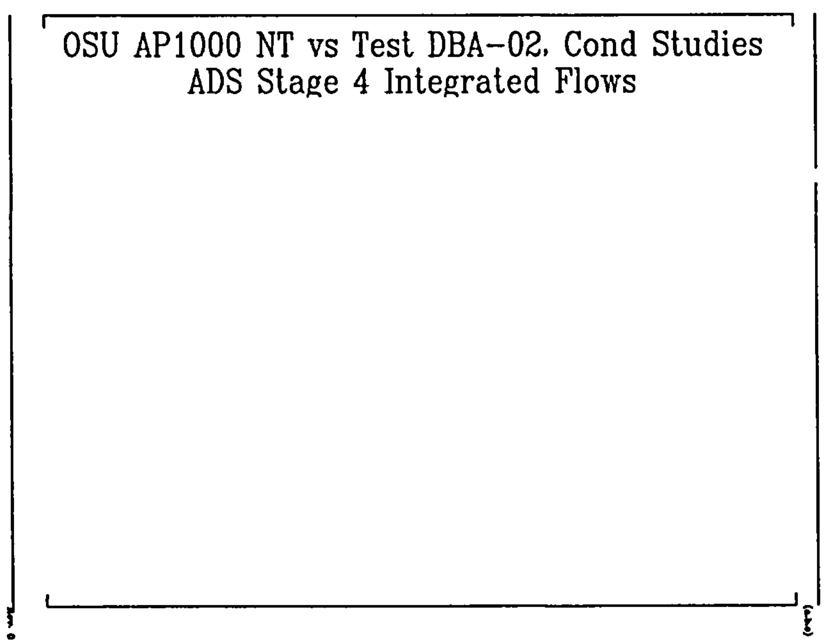

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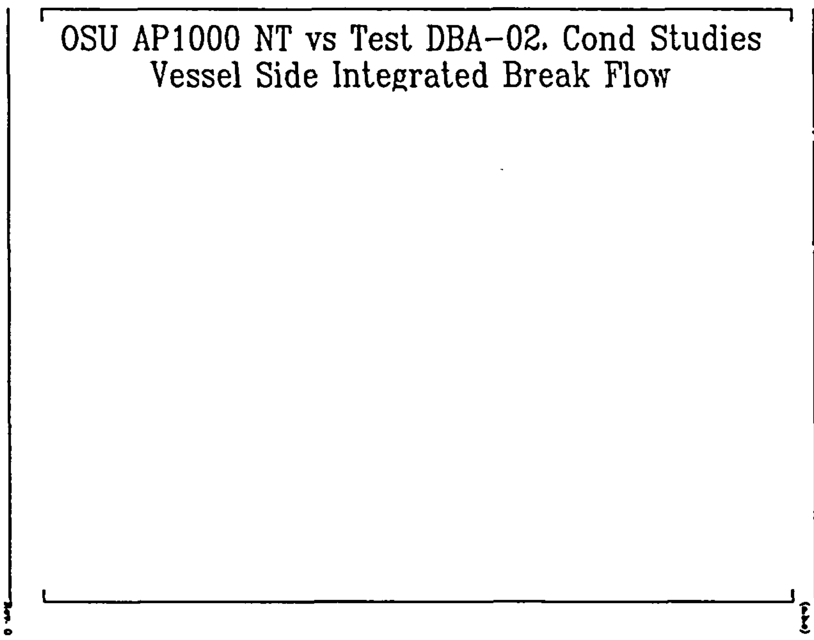

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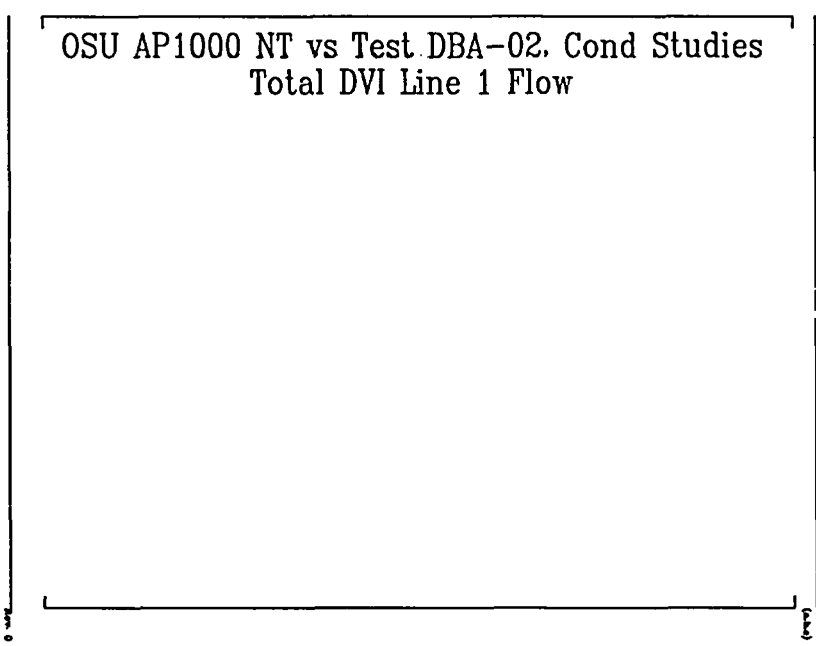

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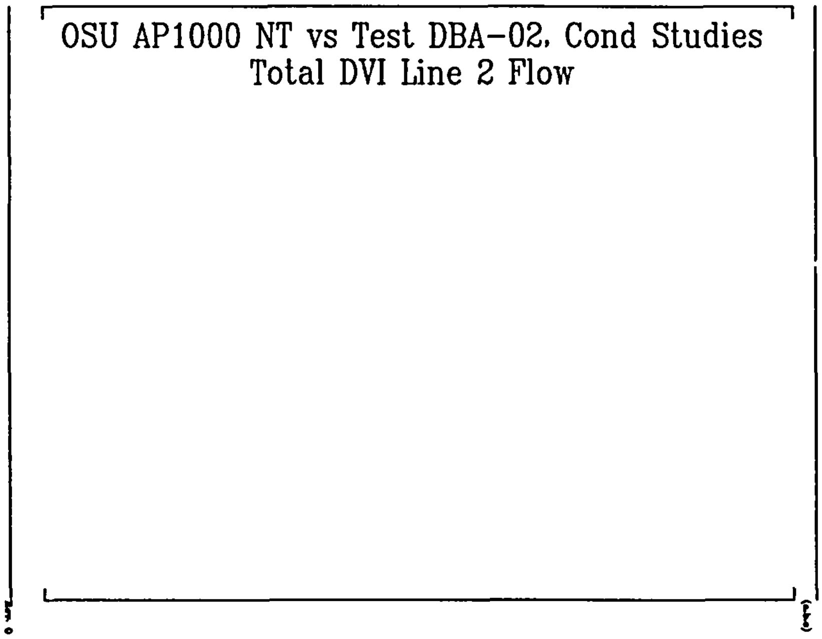

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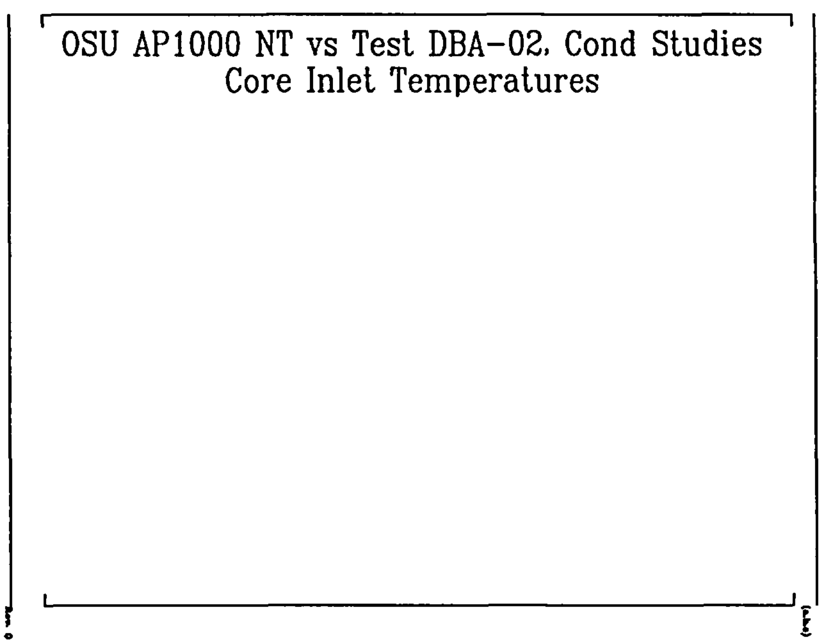

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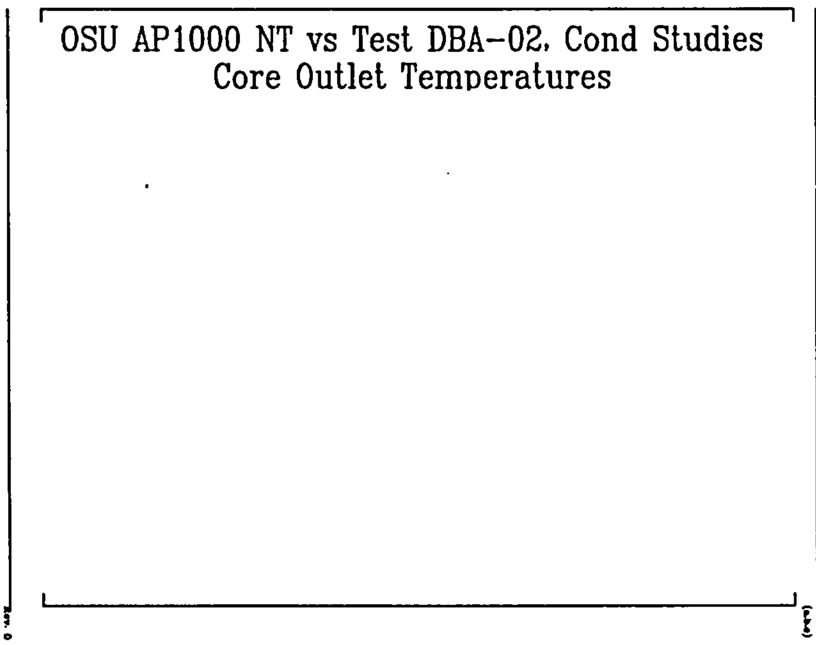
OSU AP1000 NT vs Test DBA-02, Cond Studies
Core Outlet Temperatures

Figure-25

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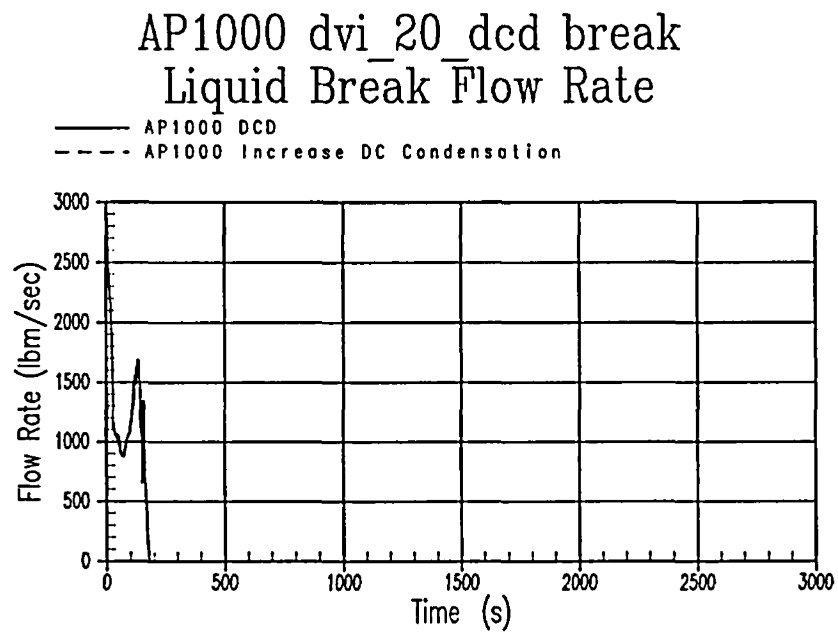

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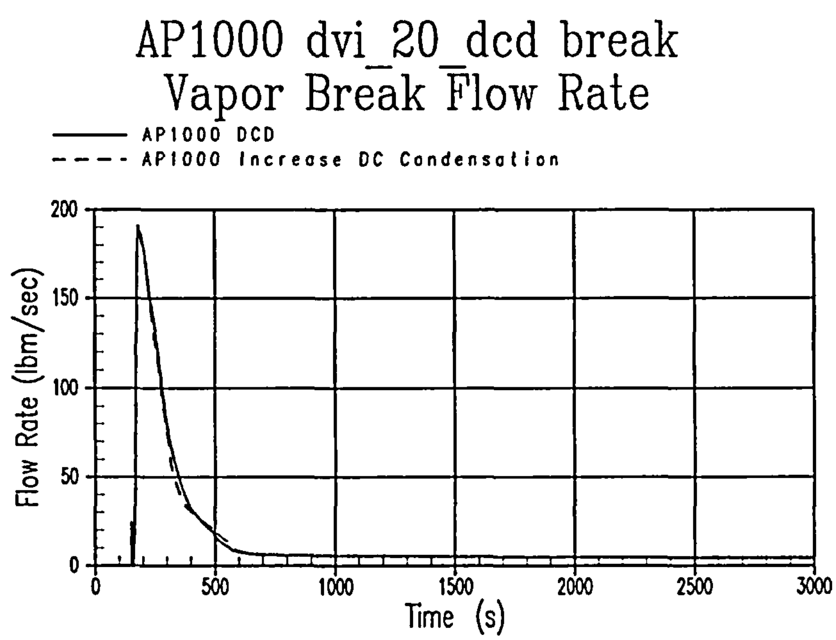

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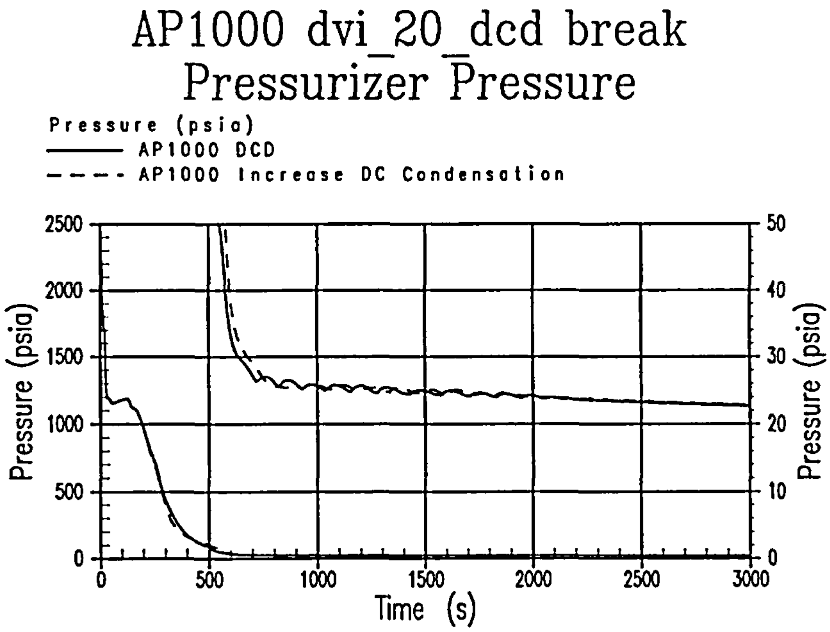

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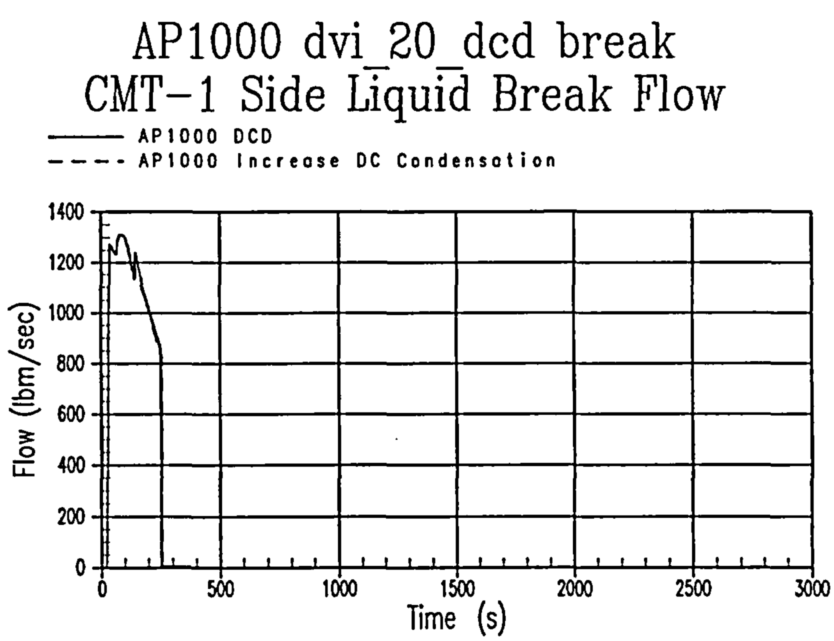

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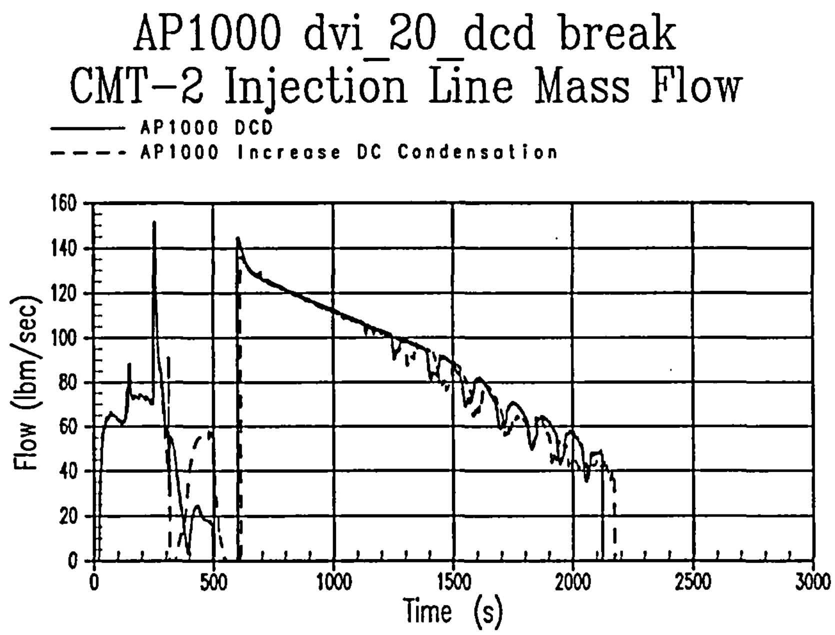

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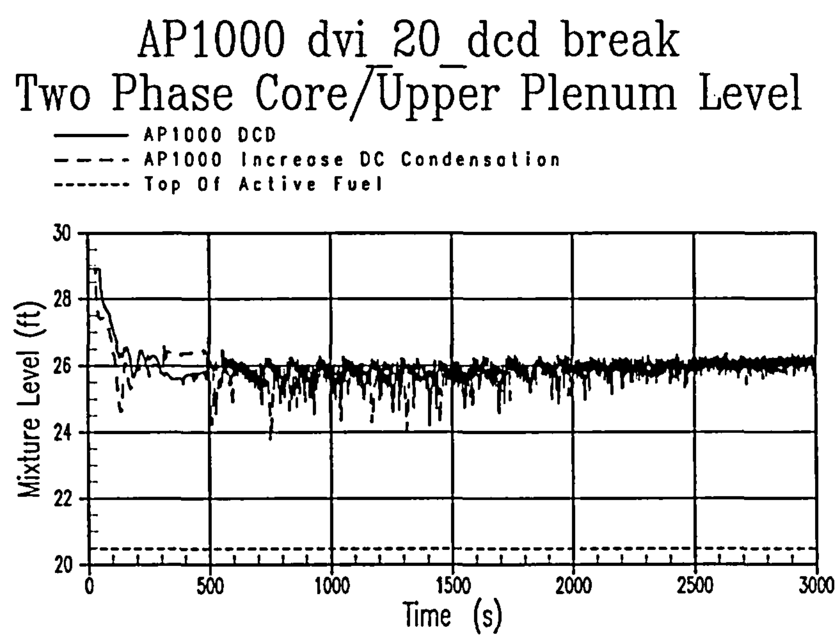

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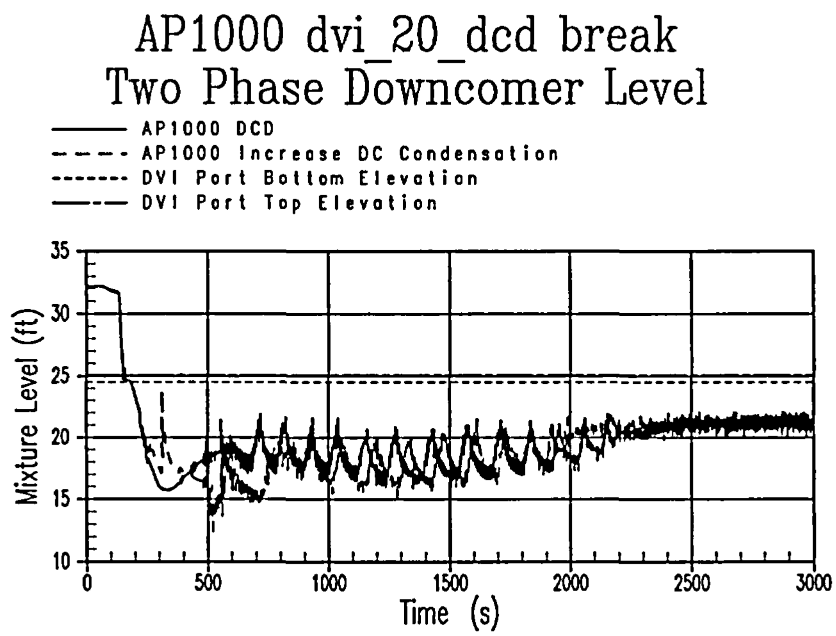

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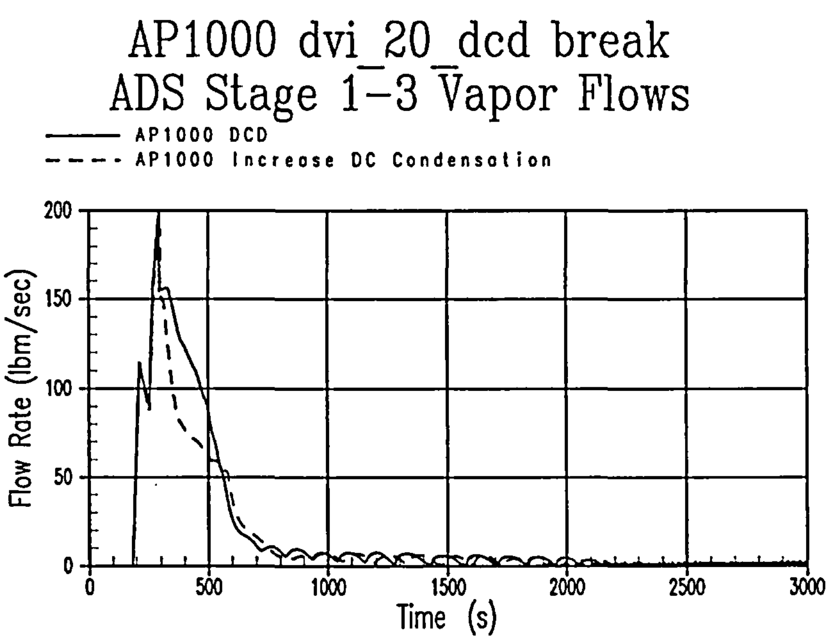

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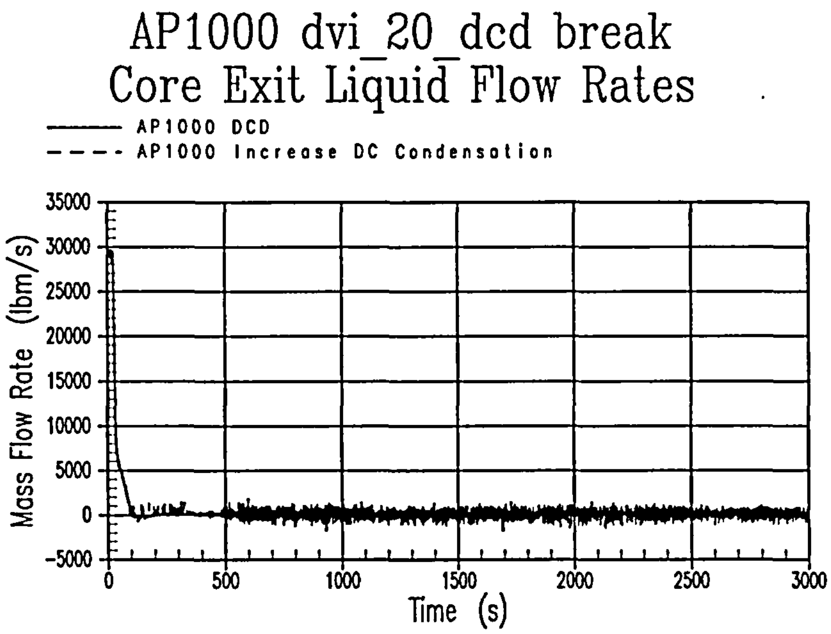

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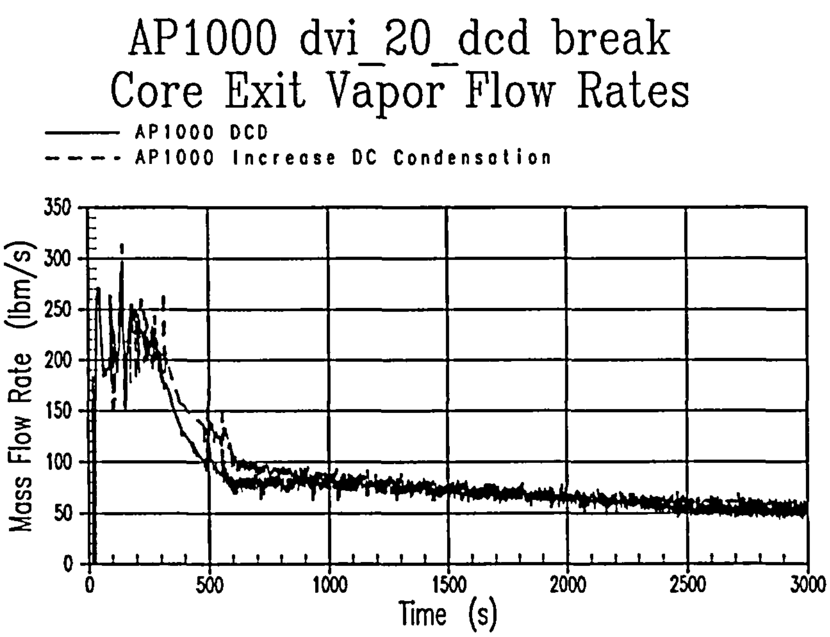

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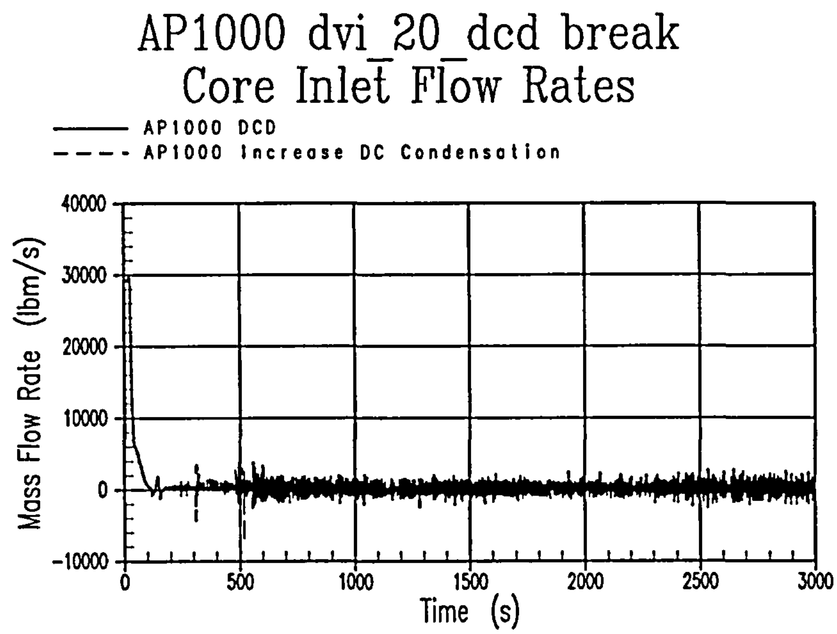

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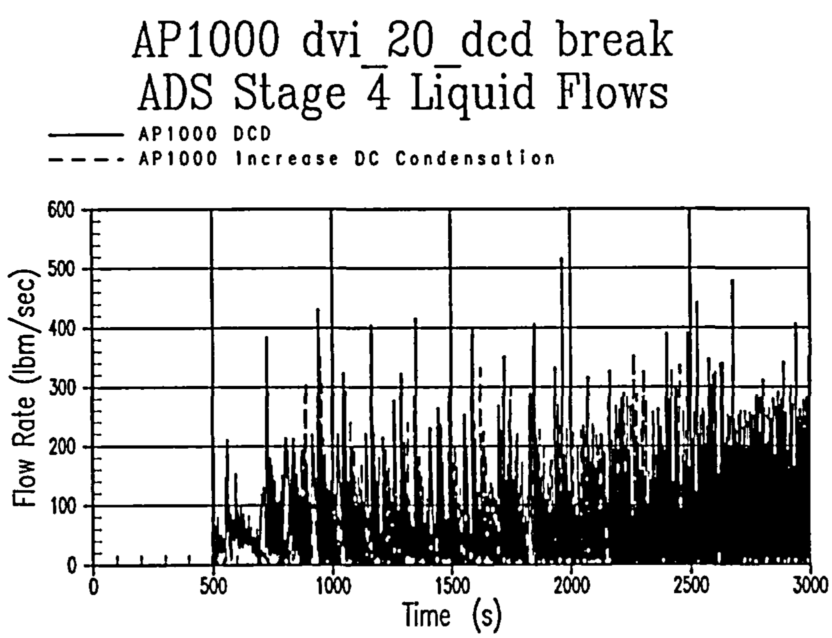

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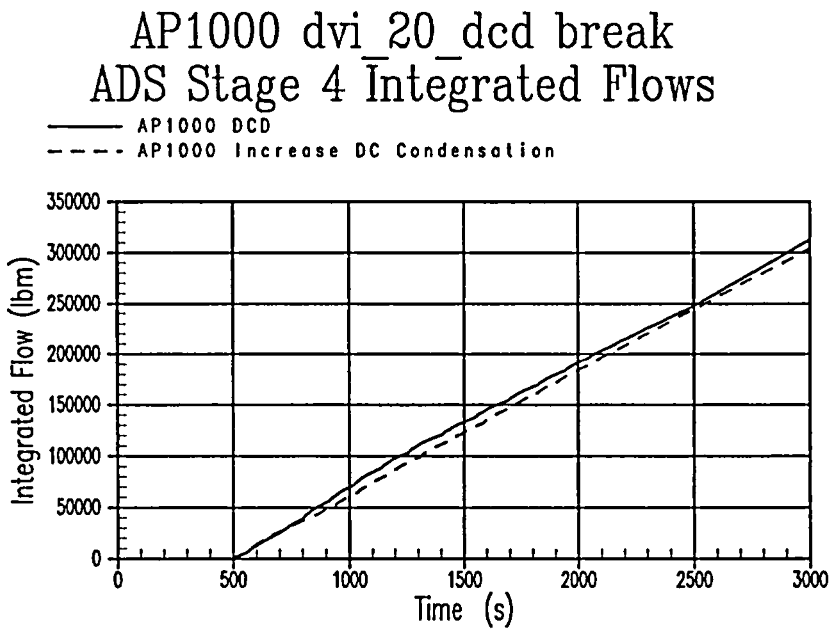

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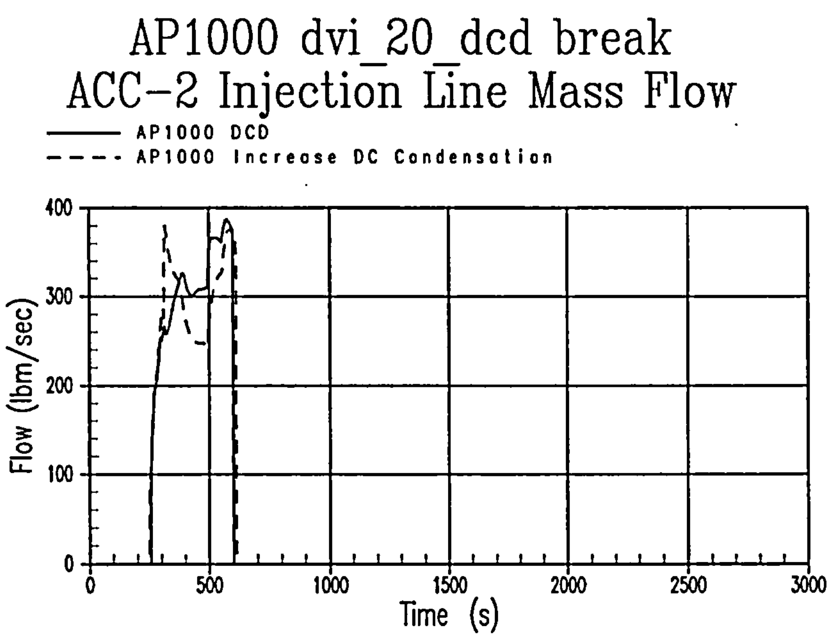

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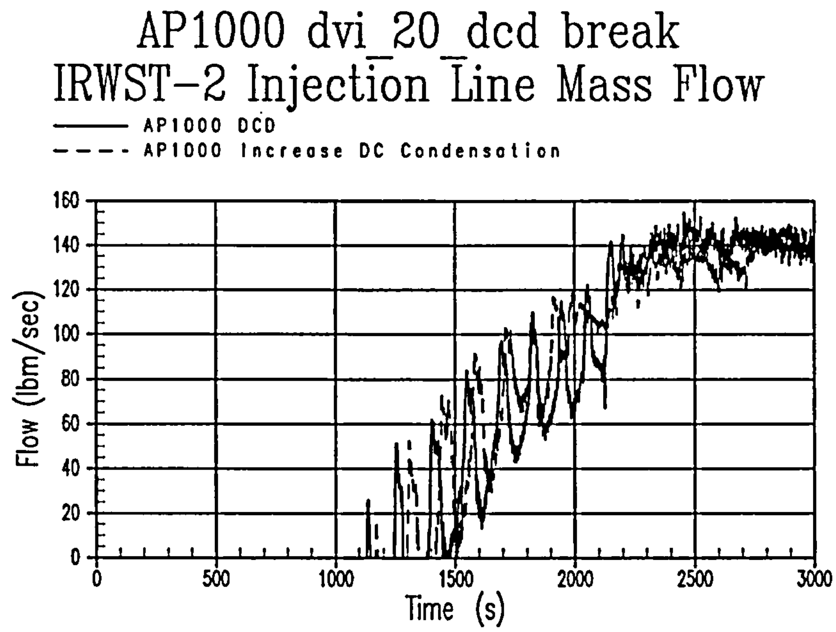

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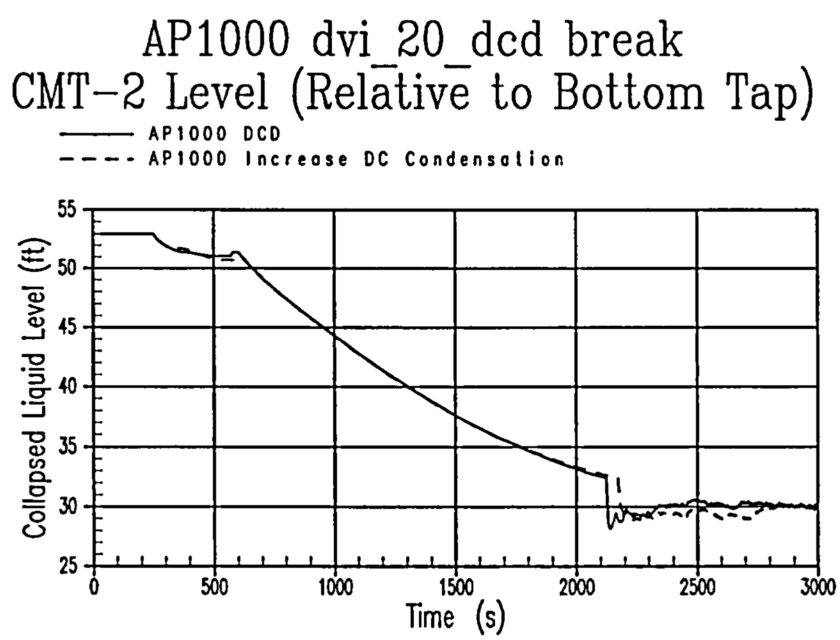

Figure-16

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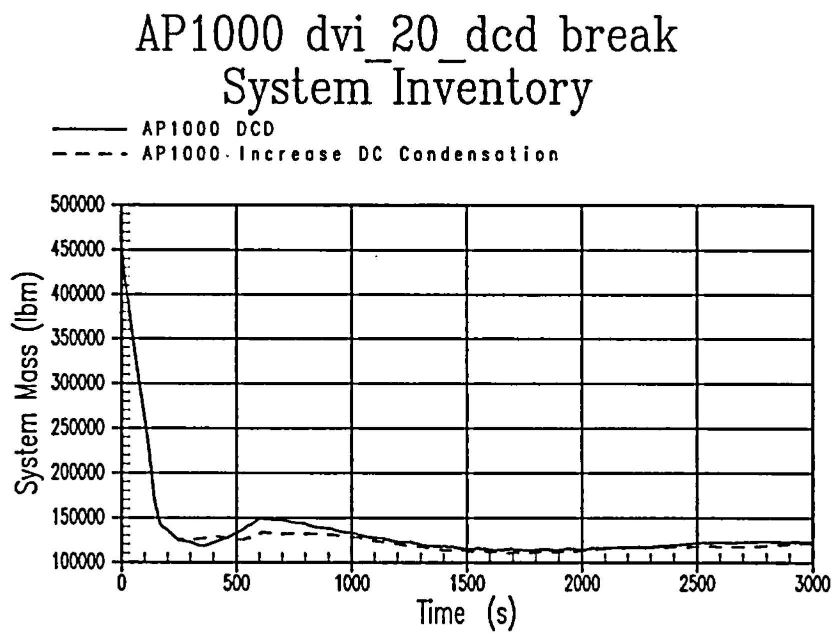
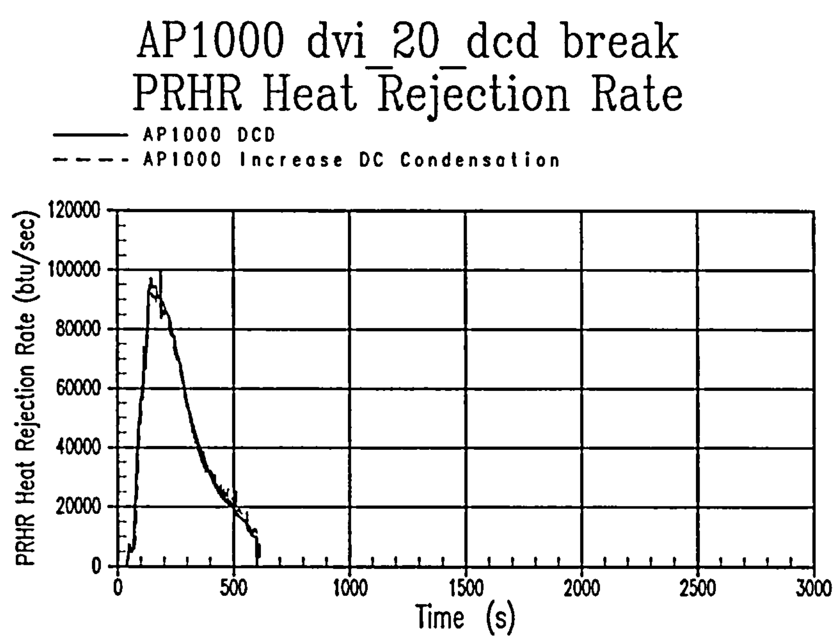


Figure-17



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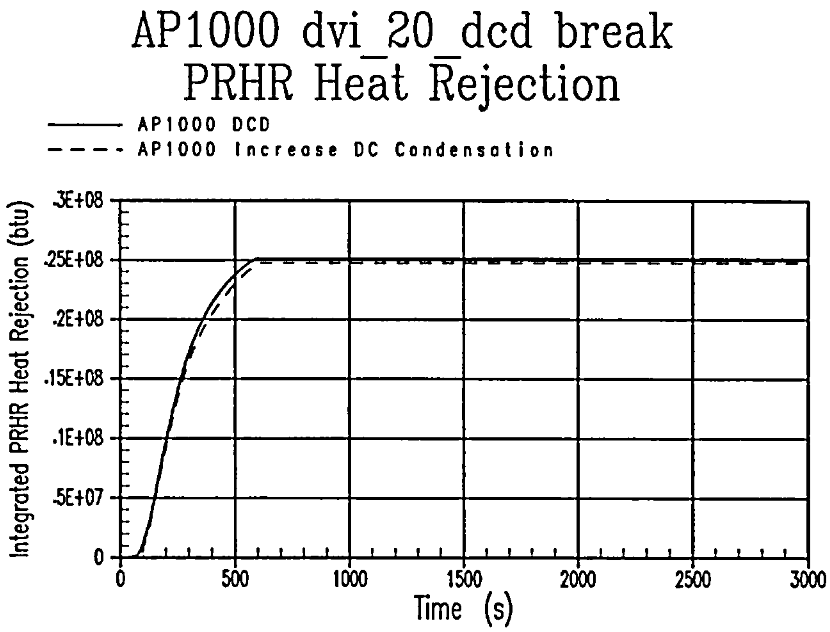

Figure-19

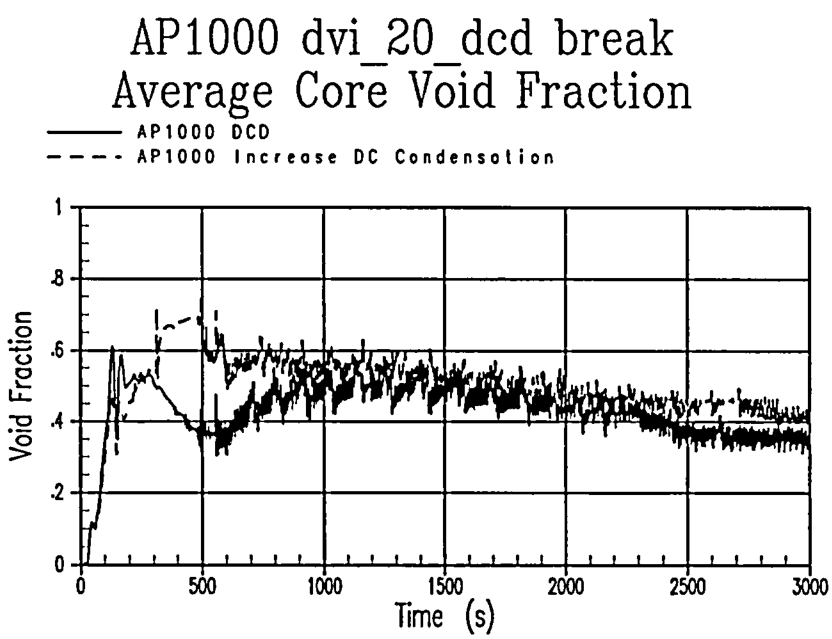

Figure-20

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Appendix 19

Email dated 1/28/2004

"OI 21.5-2P, Item 22 R1 (Jan 2 response)

Gongaware, Jacqueline J.

From: Vijuk, Ronald P.
Sent: Monday, February 02, 2004 8:26 AM
To: Gongaware, Jacqueline J.
Subject: FW: Re: OI 21.5.-2P, Item 22 R1 (Jan 2 response)

From: Vijuk, Ronald P.
Sent: Wednesday, January 28, 2004 11:01 AM
To: 'Jennifer Uhle'; 'John Segala'; 'Bajorek, Steve'
Cc: 'Joseph Colaccino'; Wright, Richard F.; Gagnon, Andre F.; Cummins, Ed
Subject: RE: Re: OI 21.5.-2P, Item 22 R1 (Jan 2 response)

John, Jennifer, Steve,

Here is our response to Steve's points.

> Figure 21 is correct for the modeling methodology applied for the APEX test facility. In the NOTRUMP model of the APEX test facility, the top of core is actually the top of the heater rods. In the NOTRUMP simulations, for both the plant and APEX facilities, the region above the active fuel is lumped into the upper plenum; therefore, the change in drain rate below the core plate is not observed.
>
> Note that for the plant entrainment studies with homogeneous flow above the core, this region was re-noded such that the upper core plate represents the boundary between the upper plenum and core stack. This was presented in DSER Open Item response 21.5-1P. The APEX simulations, for test SB18, performed therein did not re-node the core/upper plenum region but simply homogenized the region above the active fuel.
>
> Regarding Figure 23, NOTRUMP core exit steam temperature was used because it was conveniently available. The point of the comparison was to show that NOTRUMP shows degraded cooling at the top of the core at about the same time as it happens in the test.
>
> Figure 22 is the same NOTRUMP mis-prediction of core void during the accumulator injection period we have seen in all the DEDVI cases. This results from the 2D downcomer effects as discussed in our Item 22 response. We will send a more detailed explanation of the 2D behavior and the CHF heat transfer assessment we have sent last week. This comparison to NRC05 shows that even though NOTRUMP doesn't get enough core voiding early, this does not propagate to the later period when mixture level drops into the core.

We have also checked the items John gave me this morning regarding entries in our 1/9/04 submittal:

> The upper plenum volume for APEX should be 3.3 cu ft. (volume from top of heated length to the bottom of upper support plate).
>
> The elevation distance from the DVI centerline to the bottom of active fuel for AP1000 should be 18.327 ft.
>
> We will double check the other entries in the table for item 10.

Ron

> **From:** Jennifer Uhle(SMTP:JXU1@nrc.gov)
> **Sent:** Monday, January 26, 2004 4:25 PM
> **To:** vijukrp@westinghouse.com
> **Subject:** Fwd: Re: OI 21.5.-2P, Item 22 R1 (Jan 2 response)

<<Message: Re: OI 21.5.-2P, Item 22 R1 (Jan 2 r...>>
Here is Steve's issue.

J