Westinghouse Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-94-622

May 17, 1994

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

ATTENTION: MR. R. W. BORCHARDT

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: ADDITIONAL INFORMATION IN SUPPORT OF WESTINGHOUSE RESPONSE TO RAI 952.44 - 952.46

Dear Mr. Borchardt:

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

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10CFR Section 2.790, Affidavit AW-94-622 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

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

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-94-622 and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo, Manager
Nuclear Safety Regulatory And Licensing Activities

/nja

cc: Kevin Bohrer NRC 12H5

1688A

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PROPRIETARY INFORMATION NOTICE

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

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

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

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

Brian A. McIntyre, Manager
Advanced Plant Safety & Licensing

Sworn to and subscribed
before me this 24th day
of May, 1994

Lorraine M. Piplica
Notary Public

Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 1995
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety and Licensing, in the Advanced Technology Business Area, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(v) Enclosed is Letter NTD-NRC-94-4114, May 17, 1994, being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, N. J. Liparulo (W), to Mr. R. W. Borchardt, Office of NRR. The proprietary information as submitted for use by Westinghouse Electric Corporation is in response to questions concerning the AP600 plant and the associated design certification application and is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of licensing advanced nuclear power plant designs.

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

(a) Demonstrate the design and safety of the AP600 Passive Safety Systems.

(b) Establish applicable verification testing methods.

(c) Design Advanced Nuclear Power Plants that meet NRC requirements.

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

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

Further this information has substantial commercial value as follows:

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

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

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

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

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

Further the deponent sayeth not.

Question 952.44

Provide the following information to assist the staff in developing TRAC AP600 plant models for large break loss-of-coolant accident analysis:

a. Provide the reactivity coefficients for this core design. This should include the sensitivity to reactor coolant temperature, fuel rod temperature, void fraction (two-phase density change), and boron concentration.

b. Provide the control rod reactivity insertion as a function of time after scram.

c. Provide check valve characteristics, specifically the check valves associated with the core makeup tank and accumulator injection and core makeup tank pressure balance line from pressurizer (pressure differentials required for opening and closing, rate of opening and closing, and full-open area).

Response:

a. The reactivity feedback model used in the WCOBRA/TRAC code is provided below:

The total reactivity, TRIPL, is calculated as a function of time, t, as:

$$TRIPL = \rho_{init} + FRHO(WDENS, PPM, FRHOBU) + DOP(T_{fuel}) + RODS + RHOZ$$

where:

ρ_{init} = initial reactivity (input as 0.0)

FRHO = reactivity (defined as $\ln\Delta k/k_o$)

specified as a polynomial function of the water density, WDENS, boron concentration, PPM, and average burnup, FRHOBU

k_o is k at ρ_{H2O} = 0.7 gm/cm^3

DOP_{fuel} = Doppler feedback as a function of T_{fuel}, the average fuel temperature (°F) and the input multiplier (FDOP), which is input as 1.00.

[ ]^{a,c}

RODS = the control rod contribution.

RHOZ = bias calculated at t=0 such that TRIPL = ρ_{init}

The functional form of FRHO is given in Table 1. The coefficients were generated to fit the multiplication factor prediction for 17x17 V5H fuel. Units used in the polynomial fit are density (gm/cm^3), boron concentration (ppm), burnup (MWD/MTU). At t=0.0, the code calculates the value of FRHOBU such that:

$$\frac{\partial FRHO(WDENS_{t=0}, PPM_{t=0}, FRHOBU)}{\partial(WDENS)} = 0.0$$

b. No credit is taken for control rod insertion in the Westinghouse AP600 LBLOCA model. Figures 15.0.5-1 through 15.0.5-3 of the AP600 SSAR provide the requested information for non-LOCA events, however, this information is not applicable to LBLOCA analyses.

c. The requested information will be provided in the revised response to RAI 210.28, which will be provided by June 30, 1994. Note that subsequent to the receipt of this RAI, a design change was implemented which eliminated the line from each CMT to the pressurizer. Accordingly, the check valves in these lines were eliminated.

Table 1
WCOBRA/TRAC Moderator Reactivity Feedback Fit Coefficient Data

(a,c)

USAGE: $\Delta k(\rho, PPM, BU) = \sum_{n=1}^{30} A_n \rho^{i_n} \cdot PPM^{j_n} \cdot BU^{k_n} - \sum_{n=1}^{30} A_n \rho_{ref}^{i_n} PPM_{ref}^{j_n} BU^{k_n}$

Question 952.45

Provide the following steady-state and transient calculation assumptions from the WCOBRA/TRAC 80-percent cold-leg break loss-of-coolant-accident analysis to ensure that the initial and boundary conditions used by the staff are the same as those used by Westinghouse.

Provide a detailed noding diagram and model description, and nodal locations to which all the steady-state values provided in response to this request can be referenced. Identify the location for each plot relative to the noding diagram.

Provide the following information:

a. trip set points and delay times (time from receipt of trip signal to time of component or system activation)

b. core radial, azimuthal, and axial power distribution

c. maximum linear power-generation rate (kW/ft) for all modelled fuel rods

d. primary coolant mass flow

e. primary system hot- and cold-leg temperatures

f. feedwater mass flow and inlet temperature

g. steam exit pressure and temperature

h. core mass flows for all modelled fuel rods

i. core inlet and outlet temperature

j. core bypass flows (rod and thimble flow, reflector block flow, core cavity flow, downcomer upper head flow, hot-leg leakage, upper-head guide-tube flow, upper head drain hole flow)

k. upper head temperatures

l. reflector-block cooling flow outlet temperatures

m. boron concentration in primary coolant system and in safety injection systems

Response:

A detailed noding diagram and model description of the COBRA vessel nodalization in the AP600 WCOBRA/TRAC model is presented in Appendix 15C, Proprietary Volume 3 of the SSAR.

Figure 1 is a detailed nodalization for the one-dimensional components in the AP600 WCOBRA/TRAC model. The AP600 model consists of a number of PIPE, VALVE, TEE and STGEN components connected via junctions in a network with a reactor VESSEL component. Note that the break location for the cold leg breaks is in one of the cold legs connected to a core makeup tank; the pressure balance line is assumed to remain connected on the vessel side of the break. [Note: The CMT-Pressurizer balance line has been deleted from the current AP600 design] Further model description of the one-dimensional TRAC components is available in Appendix 15C in Proprietary Volume 3 of the SSAR.

The following information is provided in response to the specific requests for steady-state WCOBRA/TRAC values:

a. The containment HI pressure setpoint is attained at one second after the large break LOCA event initiates, generating an "S" signal which leads to all subsequent system actuations.

   For simplicity, because this signal is so fast and maintaining a hot secondary side is conservative for large break LOCA events, steam generator feedwater and steam lines are isolated at time zero, and startup feedwater is not modeled. A 1.2 second delay is assumed in core makeup tank outlet valve opening, so the CMT flow paths are assumed to begin to open at 2.2 seconds of the transient. The PRHR heat exchanger is not actuated in the transient. [Note: In the current AP600 design, the PRHR heat exchanger is actuated on an "S" signal] Control rod insertion into the core is not modeled, so the core shuts down due to other negative reactivity insertions, particularly core voiding. The automatic reactor coolant pump trip occurs 17.2 seconds after the break initiation.

b. Axial power profiles for the hot rod (Rod No.1), hot assembly average rod (Rod No.2) and core average power rods in open hole and guide tube locations (Rods No. 3 and 4) are provided in Appendix 15C. Note that the rod power level in the guide tube channel 26 (Rod No.4) and open hole channel 25 (Rod No.3) are set to [ ]$^{(a,c)}$ times the core average channel power, while the peripheral channel 24 rod (Rod No.5) power is [ ]$^{(a,c)}$ times the core average power rod.

c. Based on 102% of licensed core power (1933 MWt*1.02) operation, the maximum linear power generation rate of each rod (in kW/ft) equals [ ]$^{(a,c)}$ kW/ft for the hot rod, [ ]$^{(a,c)}$ kW/ft for the hot assembly rod, [ ]$^{(a,c)}$ kW/ft for the open hole and guide tube region fuel rods, and [ ]$^{(a,c)}$ kW/ft for the peripheral rod.

d. Primary coolant mass flow equals 20484 lbm/second in all loops combined.

e. The hot leg and cold leg temperatures at the above total mass flow and 102% power equal 600.8°F and 529.9°F in components 2/9 and 5/6/12/13, respectively.

f. The feedwater flow is 3964 lbm/second at a temperature of 439°F.

g. The steam generator exit pressure and temperature are 778.7 psia and 515.1°F respectively.

h. The core mass flow at the entrance of each channel is [ ]$^{(a,c)}$ lbm/second in the peripheral channel, [ ]$^{(a,c)}$ lbm/second in the open holes channel, [ ]$^{(a,c)}$ lbm/second in the guide tube channel, and [ ]$^{(a,c)}$ lbm/second in the hot assembly channel.

i. The inlet fluid temperature of each channel is [ ]$^{(a,c)}$ °F. Core outlet temperatures of the various channels are [ ]$^{(a,c)}$ °F for the peripheral channel, [ ]$^{(a,c)}$ °F for the open holes channel, [ ]$^{(a,c)}$ °F for the guide tube channel, and [ ]$^{(a,c)}$ °F for the hot assembly channel.

j. Core bypass flows, expressed as a percentage of total loop flow are [ ]$^{(a,c)}$ % upper head cooling flow, [ ]$^{(a,c)}$ % flow through the radial reflector, and [ ]$^{(a,c)}$ % thimble and reactor cavity bypass flow.

k. Upper head temperatures vary among the fluid channels. Specifically, the end of steady-state temperatures for channels 70, 71, 72, 73, 74, 75, 76, and 77 are [ ]$^{(a,c)}$ °F respectively. This provides a representation of the incomplete mixing situation expected in the AP600 vessel upper head region.

l. The reflector region cooling flow outlet temperature is [ ]$^{(a,c)}$ °F.

m. The reactor coolant system initial boron concentration is 950 ppm. The safety injection system boron concentration is 2500 ppm.

(a,c)

Figure 1 - AP600 Large Break LOCA model topology

Question 952.46

Provide the WCORBRA/TRAC 80-percent large break loss-of-coolant-accident (LBLOCA) calculation results to support a comparison of the TRAC and WCOBRA/TRAC results.

Provide plots of the following parameters as a function of time for the most current LBLOCA. Identify the location for each plotted transient parameter relative to the noding diagram requested in Q952.43.

Note: where two-phase conditions exist, provide both vapor and liquid parameters.

a. pressurizer pressure and mass flows

b. upper-plenum pressure

c. break mass flows, integrated break mass flows, and exit void fractions for both vessel-side and pump-side break locations

d. hot leg mass flows and temperatures at reactor vessel exit

e. cold leg mass flows and temperatures at reactor vessel inlet

f. core inlet and outlet mass flows

g. core makeup tank flows for each train

h. accumulator mass flows for each train

i. core makeup tank pressure balance line mass flows from both cold leg and pressurizer

j. pump speeds, mass flows, and void fractions

k. reactor power

l. core inlet boron concentration

m. fuel clad temperatures at selected core elevations for all modelled fuel rods (average and hot rods)

n. core voiding as function of core height for all modeled fuel rods (average and hot rods)

o. liquid levels and voiding in low plenum, core region, upper plenum, and upper head

p. steam generator feedwater flow and steam flow

q. steam generator secondary-side pressure

r. steam generator secondary-side liquid level and temperatures, and

s. mass flows from upper head through (1) guide tubes, (2) upper head drain holes, and (3) downcomer spray cooling holes.

Response:

The SSAR Revision 0 large break LOCA case analyzed with WCOBRA/TRAC (SSAR section 15.6.5) is a 100% cold leg guillotine break. The requested plots for this case are provided as Figures 2-102. Note that time equals 30 seconds is the end of the steady-state computation/the time of the break.

The AP600 1-D topology, used to model the large break LOCA, is shown on Figure 1(see response to RAI 952.45). The location of each plotted parameter is noted below relative to the noding diagram

a. **pressurizer pressure and mass flows**

Figure 2 Pressurizer pressure (psia) vs. Time
Figure 3 Pressurizer mass flow (lbm/sec) vs. Time

The plot location is the bottom cell of pressurizer PIPE component 16.

b. **upper plenum pressure**

Figure 4 Upper head pressure (psia) vs. Time
Figure 5 Upper head pressure (psia) vs. Time [expanded Y scale]

The plot location is the top channel of the reactor VESSEL component.

c. **break mass flows, integrated break mass flows, and exit void fractions for both vessel-side and pump-side break locations**

Figure 6 Vessel-side break mass flow rate (lbm/sec) vs. Time
Figure 7 Integrated vessel-side break mass discharge (lbm) vs. Time
Figure 8 Vessel-side break energy flow rate (BTU/sec) vs. Time
Figure 9 Vessel-side break integral energy release (BTU) vs. Time
Figure 10 Loop-side break mass flow rate (lbm./sec) vs. Time
Figure 11 Loop-side break energy flow rate (BTU/sec) vs. Time
Figure 12 Integrated loop-side break mass discharge (lbm) vs. Time
Figure 13 Loop-side break integral energy release (BTU) vs. Time

The plot locations are the first cell of TEE component 61 primary pipe (vessel side break), and the last cell of PIPE component 60 (loop side break).

d. **hot leg mass flows and temperatures at reactor vessel exit**

Figure 14 Hot leg A mass flow (lbm/sec) vs. Time
Figure 15 Hot leg B mass flow (lbm/sec) vs. Time

The plot locations are the first cells of hot leg TEE components 22 and 23.

e. **cold leg mass flows and temperatures at reactor vessel inlet**

Figure 16 Cold leg A-1 mass flow (lbm/sec) vs. Time
Figure 17 Cold leg A-2 mass flow (lbm/sec) vs. Time
Figure 18 Intact cold leg mass flow in the broken loop (lbm/sec) vs. Time

The plot locations are the first cells of PUMP component 5, 6 and 13.

f. **core inlet and outlet mass flows**

Figure 19 Core liquid flow in node 2, all channels (lbm/sec) vs. Time
Figure 20 Core liquid flow in node 15, all channels (lbm/sec) vs. Time
Figure 21 Core entrained flow in node 2, all channels (lbm/sec) vs. Time
Figure 22 Core entrained flow in node 15, all channels (lbm/sec) vs. Time
Figure 23 Core vapour flow in node 2, all channels (lbm/sec) vs. Time
Figure 24 Core vapour flow in node 15, all channels (lbm/sec) vs. Time

The plot locations are the bottom and top cell of the reactor VESSEL core channels.

g. **core makeup tank flows for each train**

Figure 25 CMT B-1 drain flow, component 19 (lbm/sec) vs. Time
Figure 26 CMT 1 top mass flow rate (lbm/sec) vs. Time
Figure 27 CMT B-2 drain flow, component 20 (lbm/sec) vs. Time
Figure 28 CMT 2 top mass flow rate (lbm/sec) vs. Time

The plot location for drain flow is at the bottom of the core makeup PIPE components 19 and 20. Core makeup tank top flows, the balance line flows from the pressurizer and the cold leg to the two CMT trains are represented by the calculated flows at the three junctions of TEE components 44 and 84.

h. **accumulator mass flows for each train**

Figure 33 Accumulator 1 mass flow (lbm/sec) vs. Time
Figure 34 Accumulator 2 mass flow (lbm/sec) vs. Time

The plot locations for mass flows out the bottom of the accumulator are ACCUM components 17 and 18.

i. **core makeup tank pressure balance line mass flows from both cold leg and pressurizer**

Figure 29 CL to CMT 1 balance line flow (lbm/sec) vs. Time
Figure 30 CL to CMT 2 balance line flow (lbm/sec) vs. Time
Figure 31 PRZ to CMT 1 balance line flow (lbm/sec) vs. Time [Note: This line has been removed from the current AP600 design]
Figure 32 PRZ to CMT 2 balance line flow (lbm/sec) vs. Time [Note: This line has been removed from the current AP600 design]

Core makeup tank top flows, the balance line flows from the pressurizer and the cold leg to the two CMT trains are represented by the calculated flows at the three junctions of TEE components 44 and 84

j. **pump speeds, mass flows, and void fractions**

Figure 35 Pumps A-1 and A-2 Inlet Void Fractions (-) vs. Time
Figure 36 Pumps B-1 and B-2 Inlet Void Fractions (-) vs. Time
Figure 37 Pumps A-1 and A-2 mass flowrate, components 5 and 6 (lbm/sec) vs. Time
Figure 38 Pumps A-1 and A-2 mass flowrate, components 5 and 6 (lbm/sec) vs. Time [focused Y scale]
Figure 39 Pump B-1 mass flowrate, component 12 (lbm/sec) vs. Time
Figure 40 Pump B-1 mass flowrate, component 12 (lbm/sec) vs. Time [focused Y scale]
Figure 41 Pump B-2 mass flowrate, component 13 (lbm/sec) vs. Time
Figure 42 Pump B-2 mass flowrate, component 13 (lbm/sec) vs. Time [focused Y scale]
Figure 43 Pump A-1 head (psi) vs. Time
Figure 44 Pump A-1 head (psi) vs. Time [focused Y scale]
Figure 45 Pump A-2 head (psi) vs. Time
Figure 46 Pump A-2 head (psi) vs. Time [focused Y scale]
Figure 47 Pump B-1 head (psi) vs. Time
Figure 48 Pump B-2 head (psi) vs. Time

k. **reactor power**

Figure 49 Reactor Power (MWth) vs. Time

l. **core inlet boron concentration**

The core inlet boron concentration equals the 950 ppm initial value for the first 40 seconds of the transient, and 2500 ppm thereafter. As noted in RAI952.45 response, the steam generator is isolated at the time of the break such that both the feedwater and steam flows are zero instantaneously.

m. **fuel clad temperatures at selected core elevations for all modelled fuel rods (average and hot rods)**

Figure 50 Rod 1 cladding temperature, 0.0 ft (deg. F) vs. Time
Figure 51 Rod 1 cladding temperature, 4.1 ft (deg. F) vs. Time
Figure 52 Rod 1 cladding temperature, 7.75 ft (deg. F) vs. Time
Figure 53 Rod 1 cladding temperature, 12.00 ft (deg. F) vs. Time
Figure 54 Rod 2 cladding temperature, 0.0 ft (deg. F) vs. Time
Figure 55 Rod 2 cladding temperature, 4.1 ft (deg. F) vs. Time
Figure 56 Rod 2 cladding temperature, 7.75 ft (deg. F) vs. Time
Figure 57 Rod 2 cladding temperature, 12.00 ft (deg. F) vs. Time
Figure 58 Rod 3 cladding temperature, 0.0 ft (deg. F) vs. Time
Figure 59 Rod 3 cladding temperature, 4.1 ft (deg. F) vs. Time
Figure 60 Rod 3 cladding temperature, 7.75 ft (deg. F) vs. Time
Figure 61 Rod 3 cladding temperature, 12.00 ft (deg. F) vs. Time
Figure 62 Rod 4 cladding temperature, 0.0 ft (deg. F) vs. Time
Figure 63 Rod 4 cladding temperature, 4.1 ft (deg. F) vs. Time
Figure 64 Rod 4 cladding temperature, 7.75 ft (deg. F) vs. Time
Figure 65 Rod 4 cladding temperature, 12.00 ft (deg. F) vs. Time
Figure 66 Rod 5 cladding temperature, 0.0 ft (deg. F) vs. Time
Figure 67 Rod 5 cladding temperature, 4.1 ft (deg. F) vs. Time
Figure 68 Rod 5 cladding temperature, 7.75 ft (deg. F) vs. Time
Figure 69 Rod 5 cladding temperature, 12.00 ft (deg. F) vs. Time
Figure 70 Peak Cladding Temperature (deg. F) vs. Time, all elevations

Figure 71 PCT Location (ft) vs. Time [relative to bottom of core]

Fuel cladding temperatures are supplied at four core locations (0.0, 4.1, 7.75 and 12 feet) for four rods. Rod 1 is the hot rod of the core, Rod 2 is the hot assembly average rod, Rod 3 is the core average rod in an open hole location, Rod 4 is the core average rod in a guide tube location and Rod 5 is a peripheral assembly rod.

n. **core voiding as function of core height for all modeled fuel rods (average and hot rods)**

Figures 72 through 87 provide the void fractions in the core peripheral channel, open hole, guide tube and hot assembly channels at the top, 7.75 ft, 4.1 ft and bottom elevations as identified in the following table:

	12.0 feet	7.75 feet	4.1 feet	0.0 feet
Core peripheral channel	Fig. 72	Fig. 73	Fig. 74	Fig. 75
open hole channel	Fig. 76	Fig. 77	Fig. 78	Fig. 79
guide tube channel	Fig. 80	Fig. 81	Fig. 82	Fig. 83
hot assembly channel	Fig. 84	Fig. 85	Fig. 86	Fig. 87

o. **liquid levels and voiding in low plenum, core region, upper plenum, and upper head**

Liquid levels are provided in Figures 88-95 for the downcomer below the DVI line entrance and elsewhere, the upper head, the inner and outer upper plenum regions and the core hot assembly, open hole and guide tube regions.

Figure 88 Downcomer collapsed level, below DVI point (ft) vs. Time
Figure 89 Downcomer collapsed level (ft) vs. Time
Figure 90 Upper head collapsed level (ft) vs. Time
Figure 91 Inner globe collapsed level (ft) vs. Time
Figure 92 Outder globe collapsed level (ft) vs. Time
Figure 93 Hot assembly channel collapsed level (ft) vs. Time
Figure 94 Open hole channe. llapsed level (ft) vs. Time
Figure 95 Guide tube channel collapsed level (ft) vs. Time

p. **steam generator feedwater flow and steam flow**

Steam generator feedwater flow and steam line flow are set to zero at the time of the break.

q. **steam generator secondary-side pressure**

Figure 101 Steam generator secondary side pressure (psia) vs. Time

Steam generator secondary side parameters are provided for the top cell of the secondary side of STGEN components 3 and 10.

r. **steam generator secondary-side liquid level and temperatures**

Figure 102 Steam generator secondary side liquid temperatures (deg. F) vs. Time

Steam generator secondary side parameters are provided for the top cell of the secondary side of STGEN components 3 and 10. Steam generator secondary side liquid levels are not available.

s. **mass flows from upper head through (1) guide tubes, (2) upper head drain holes, and (3) downcomer spray cooling holes.**

Mass flows are provided in Figures 96-100 for upper head flow paths.

Figure 96 Upper head to downcomer entrained flow (lbm/s) vs. Time
Figure 97 Upper head to downcomer vapor flow (lbm/s) vs. Time
Figure 98 Upper head to downcomer liquid flow (lbm/s) vs. Time
Figure 99 Guide tube liquid flow (lbm/s) vs. Time
Figure 100 Liquid flow through upper support plate (lbm/s) vs. Time

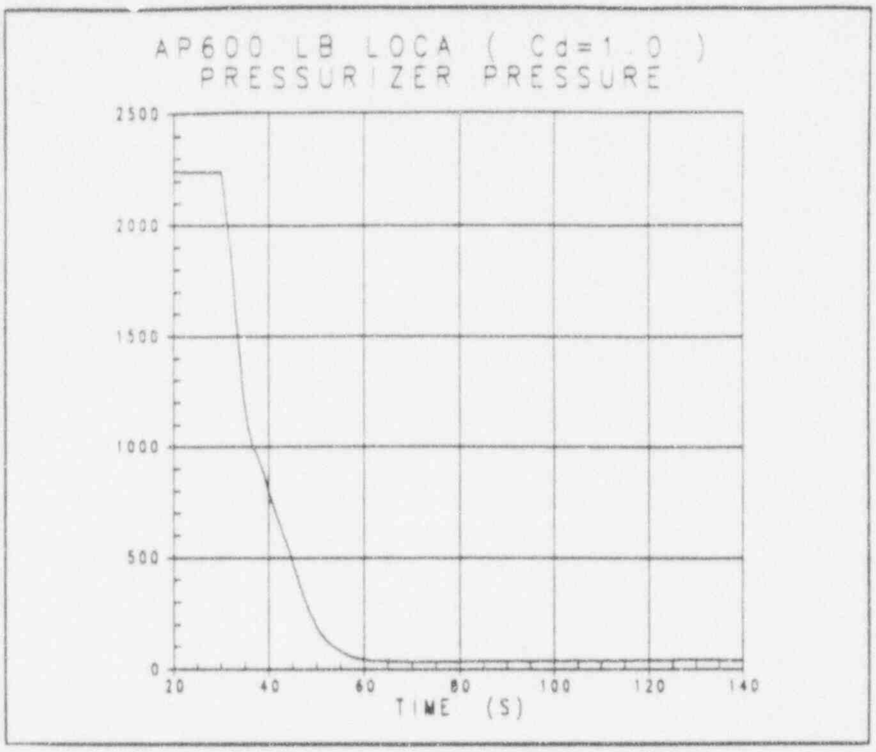

Figure 2 Pressurizer pressure (psia) vs. Time

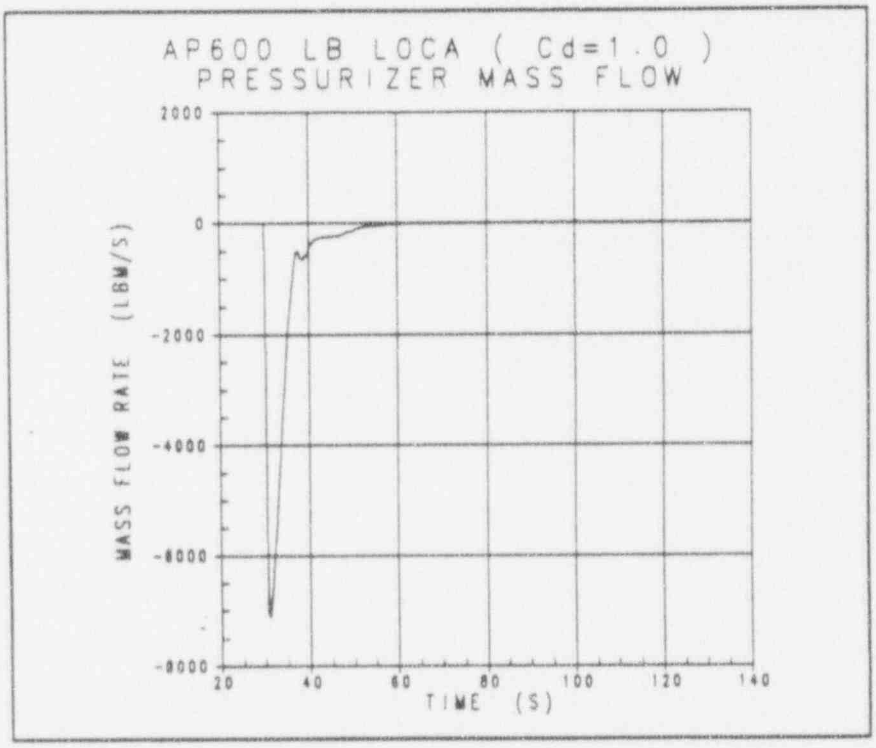

Figure 3 Pressurizer mass flow (lbm/sec) vs. Time

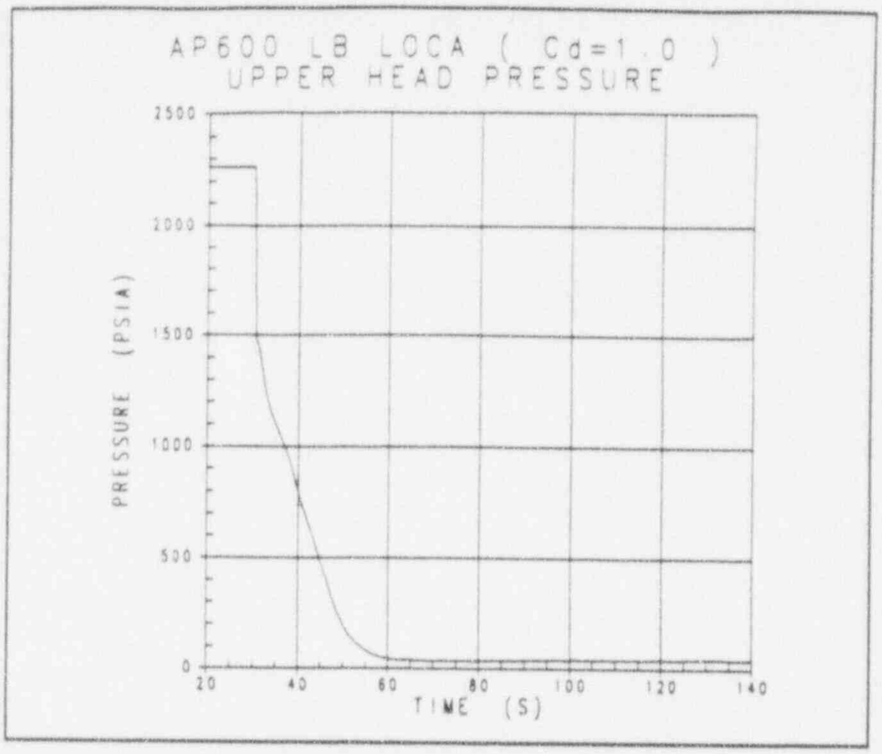

Figure 4 Upper head pressure (psia) vs. Time

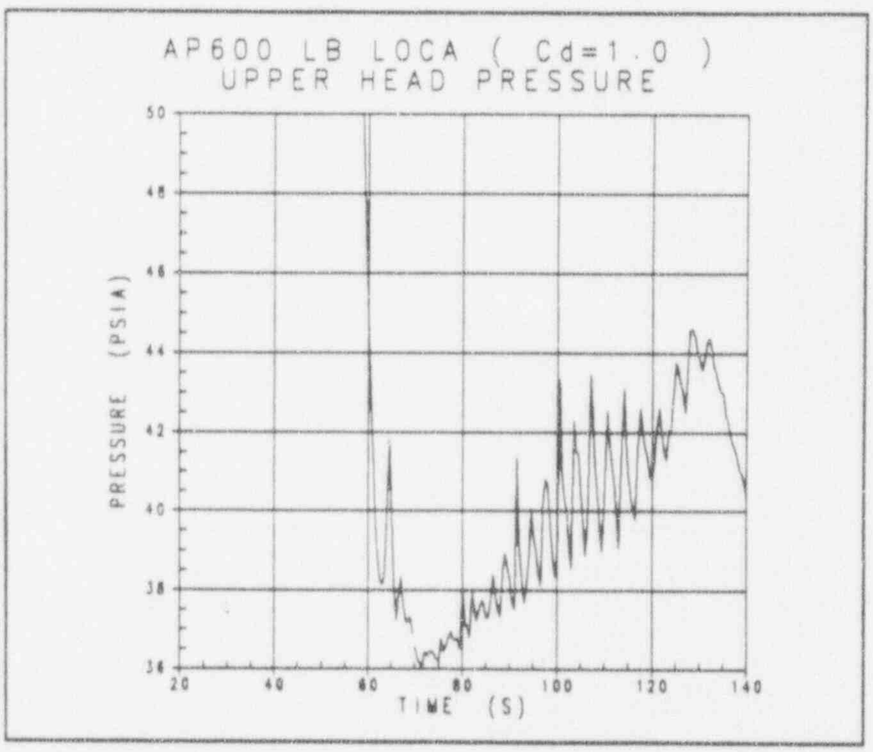

Figure 5 Upper head pressure (psia) vs. Time [expanded Y scale]

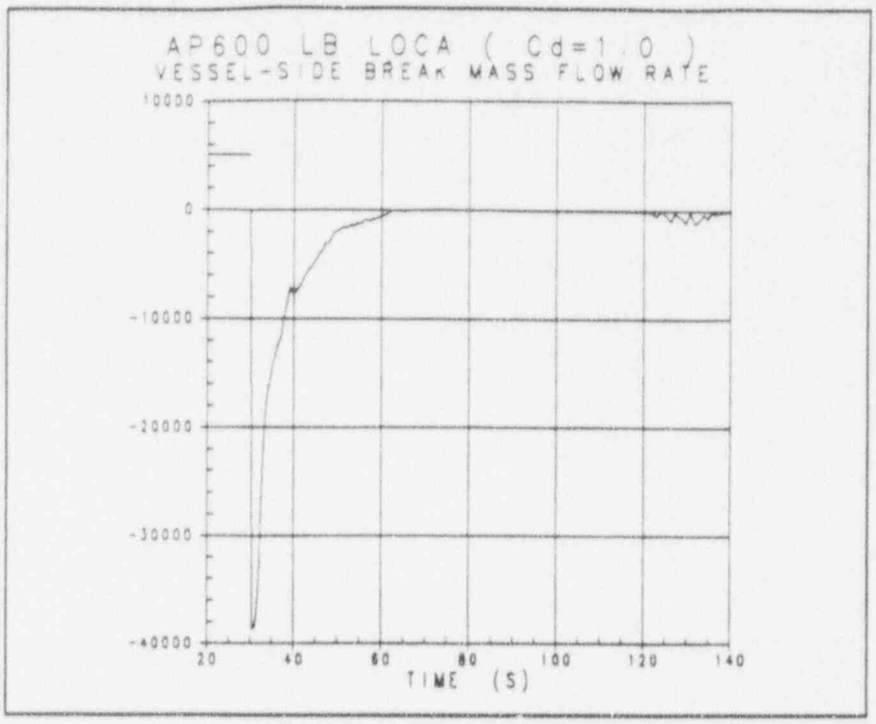

Figure 6 Vessel-side break mass flow rate (lbm/sec) vs. Time

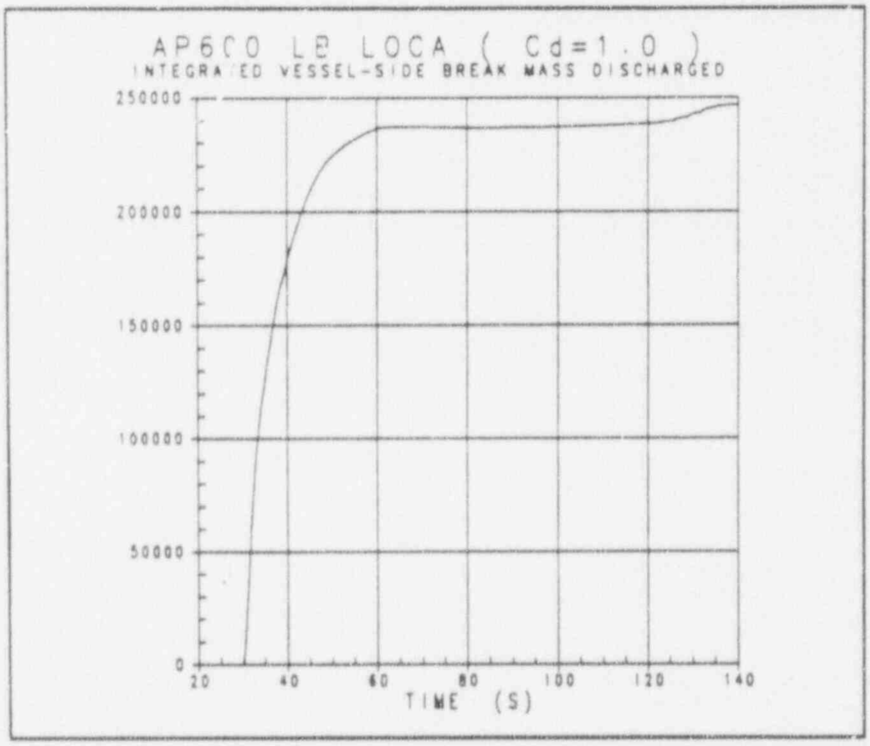

Figure 7 Integrated vessel-side break mass discharge (lbm) vs. Time

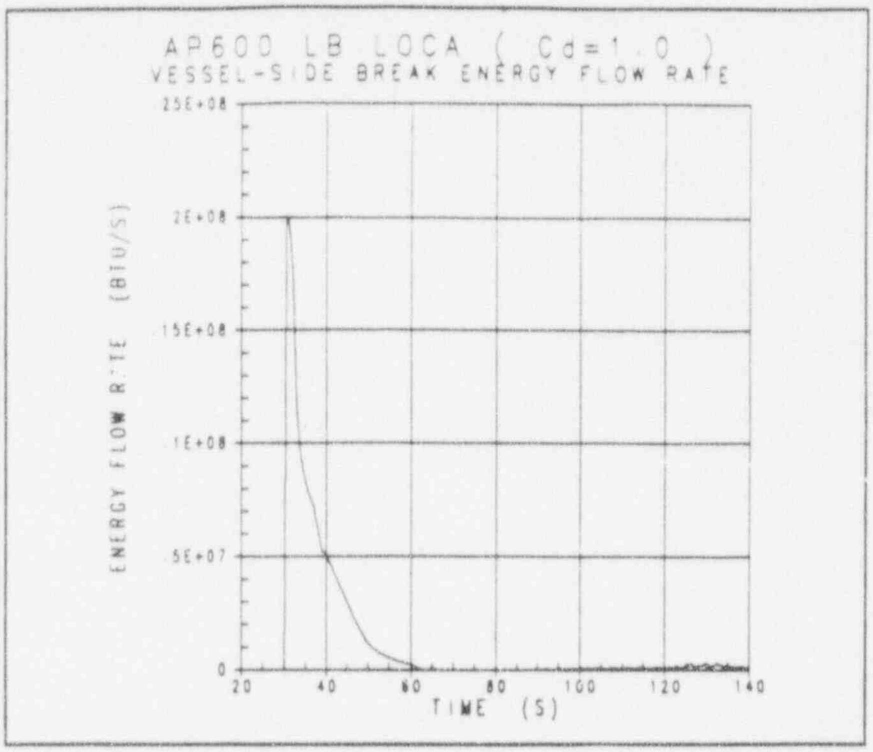

Figure 8 Vessel-side break energy flow rate (BTU/sec) vs. Time

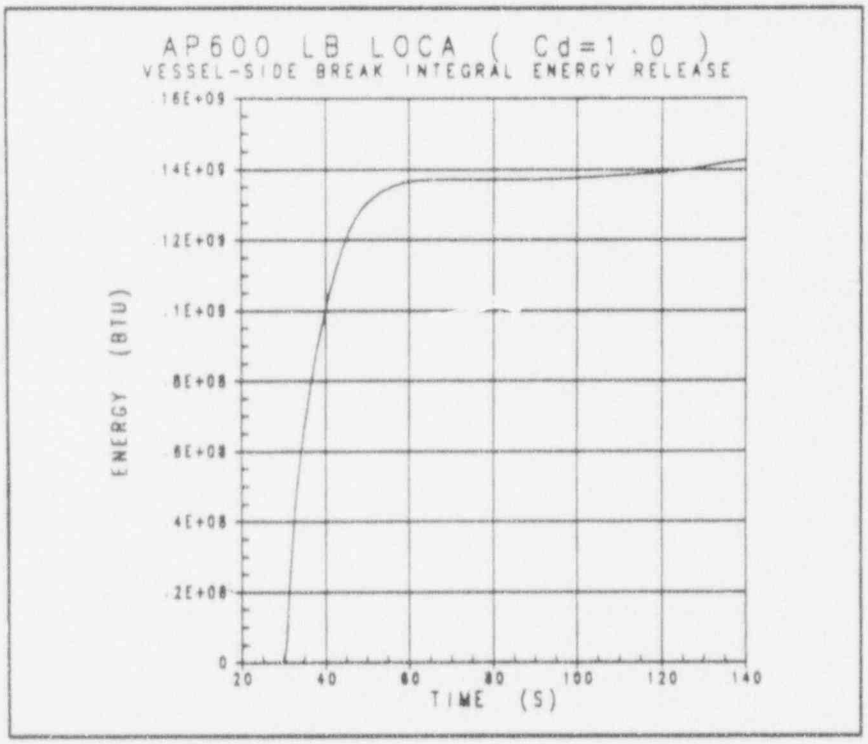

Figure 9 Vessel-side break integral energy release (BTU) vs. Time

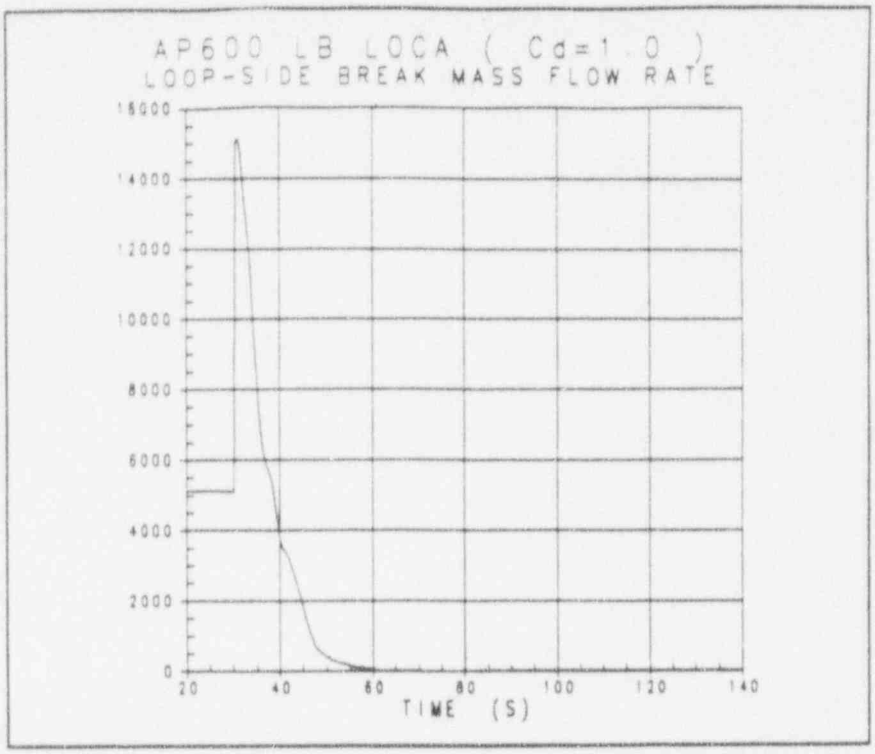

Figure 10 Loop-side break mass flow rate (lbm./sec) vs. Time

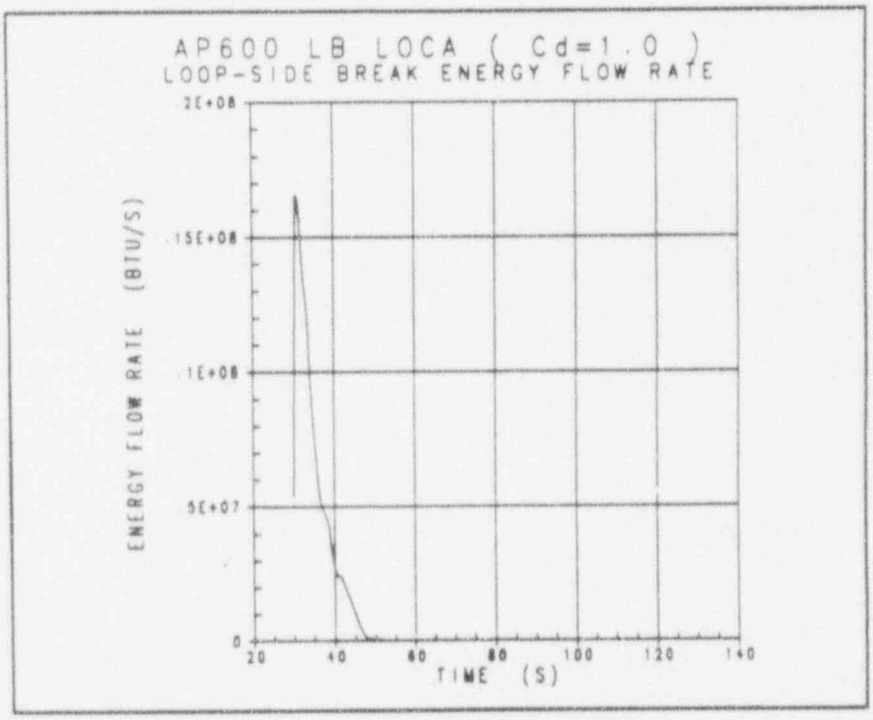

Figure 11 Loop-side break energy flow rate (BTU/sec) vs. Time

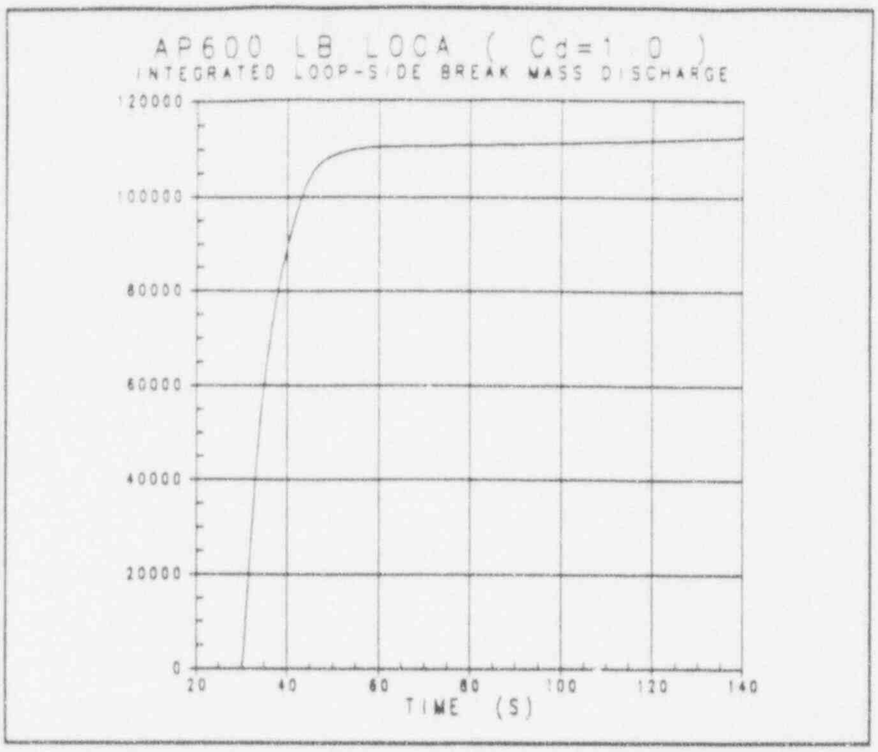

Figure 12 Integrated loop-side break mass discharge (lbm) vs. Time

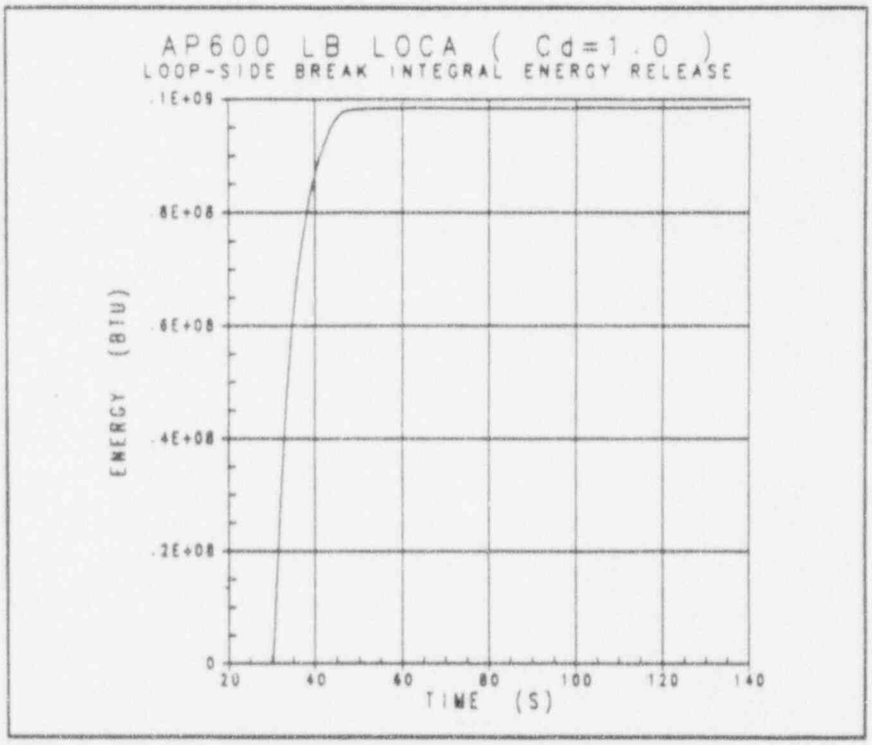

Figure 13 Loop-side break integral energy release (BTU) vs. Time

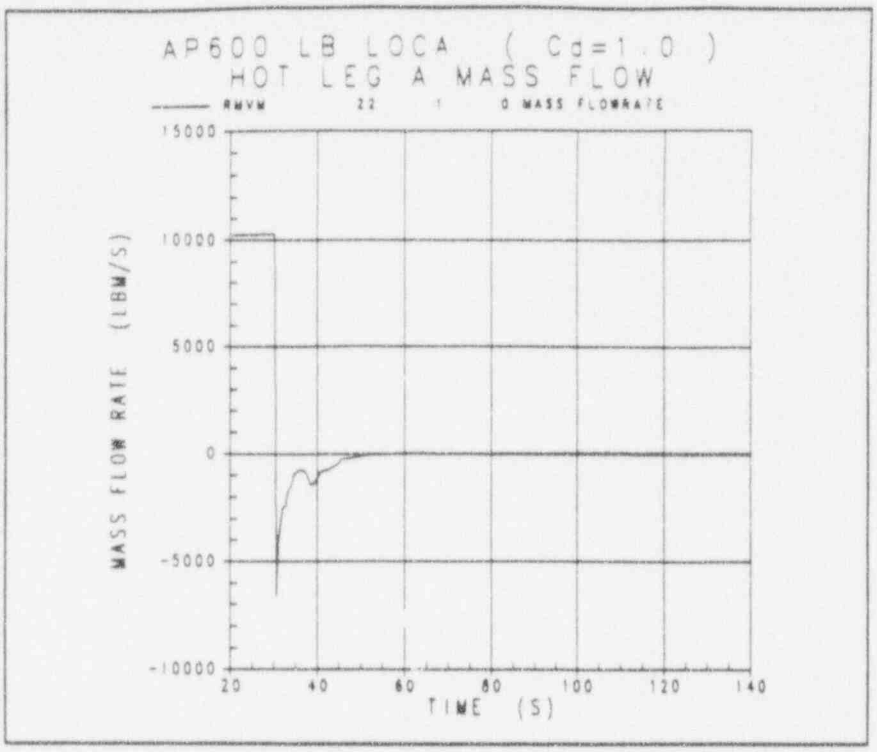

Figure 14 Hot leg A mass flow (lbm/sec) vs. Time

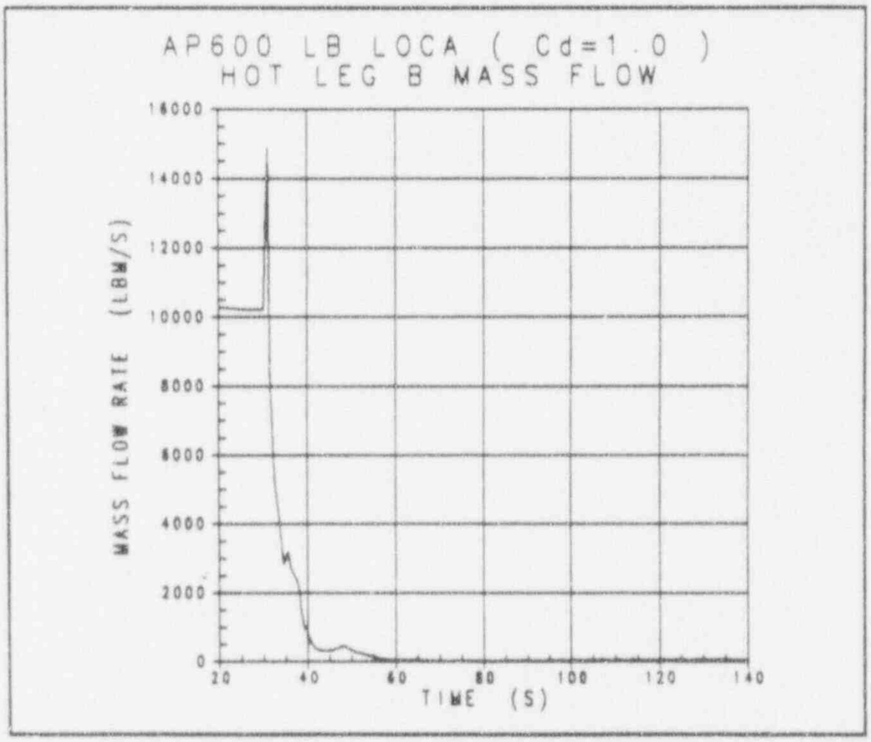

Figure 15 Hot leg B mass flow (lbm/sec) vs. Time

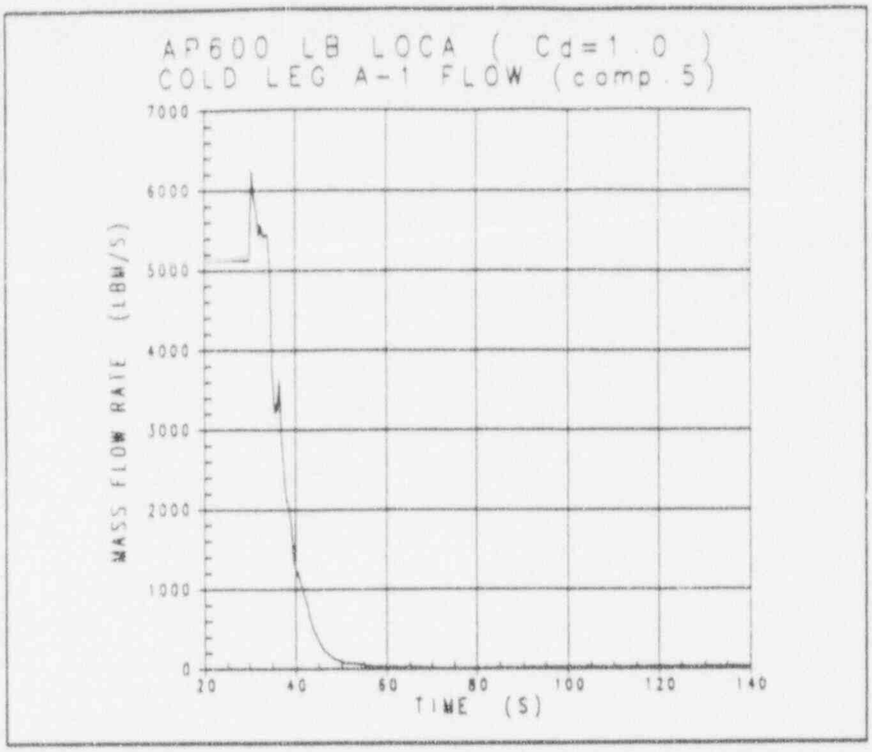

Figure 16 Cold leg A-1 mass flow (lbm/sec) vs. Time

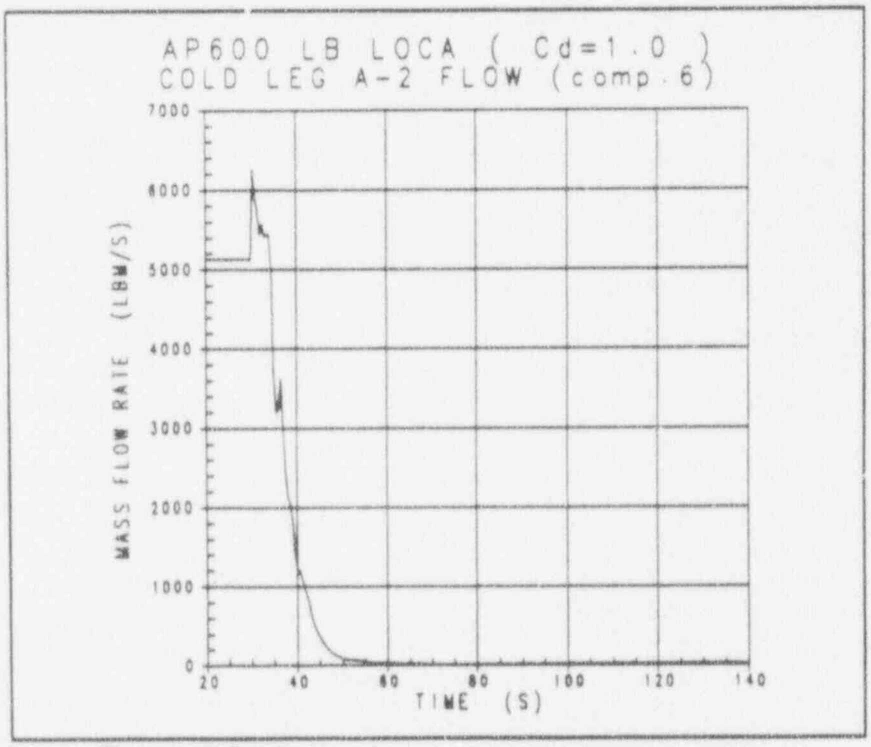

Figure 17 Cold leg A-2 mass flow (lbm/sec) vs. Time

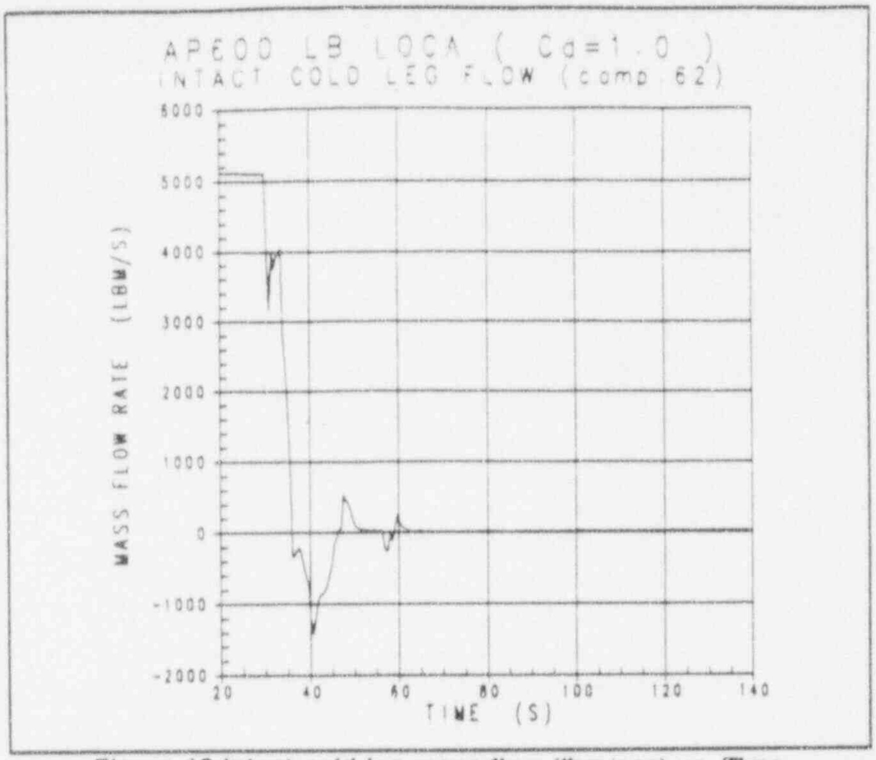

Figure 18 Intact cold leg mass flow (lbm/sec) vs. Time

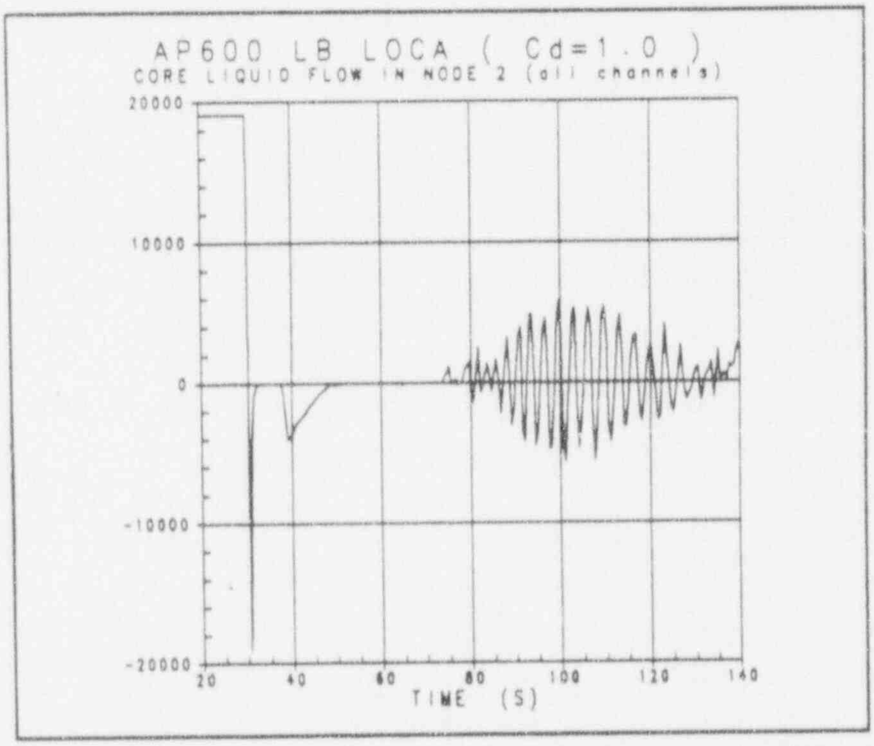

Figure 19 Core liquid flow in node 2, all channels (lbm/sec) vs. Time

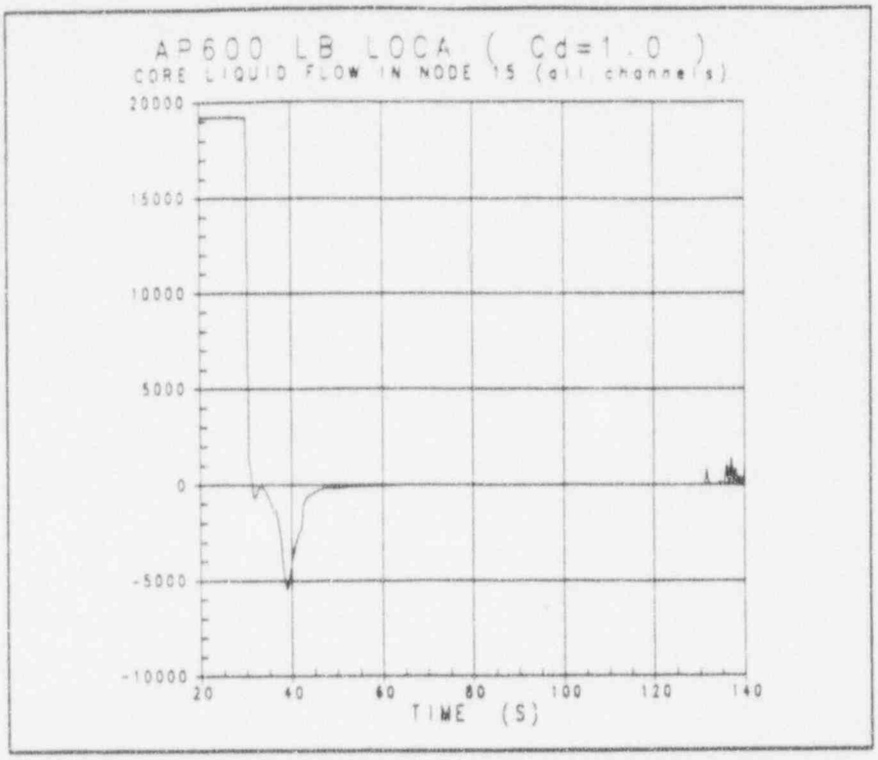

Figure 20 Core liquid flow in node 15, all channels (lbm/sec) vs. Time

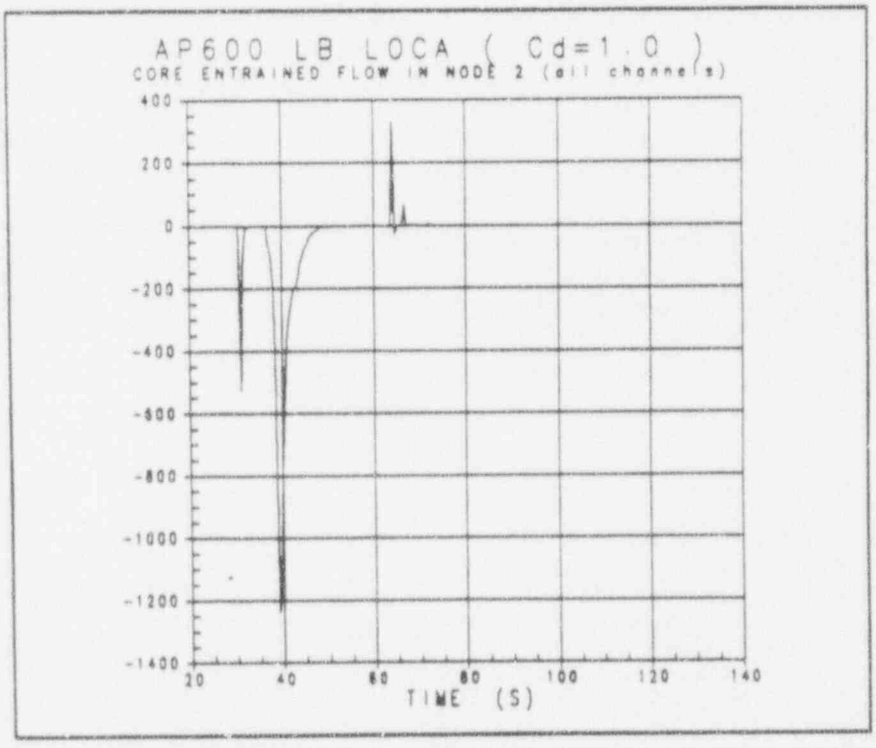

Figure 21 Core entrained flow in node 2, all channels (lbm/sec) vs. Time

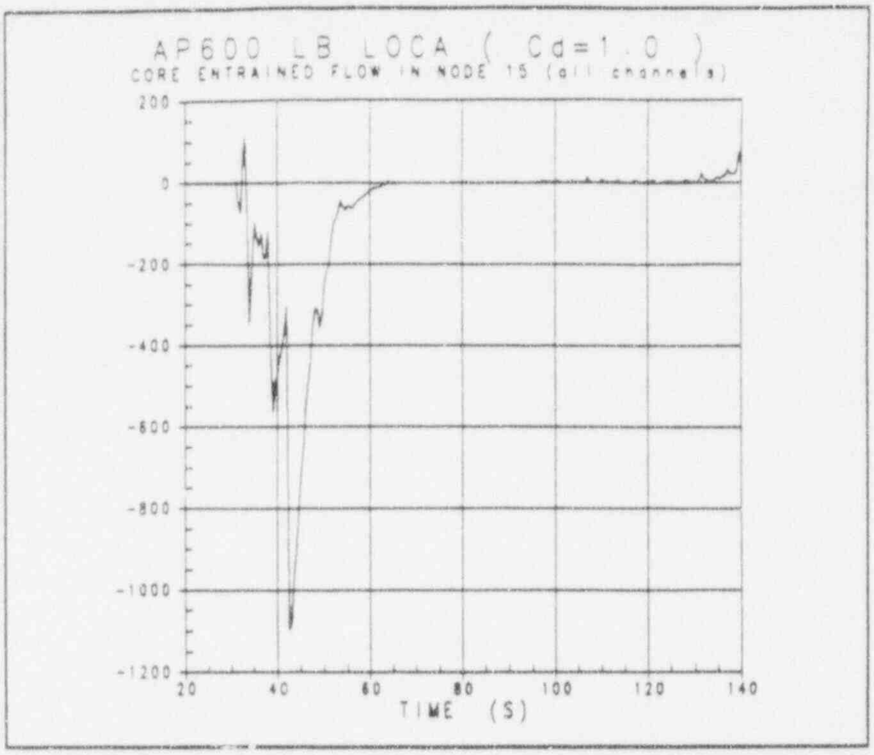

Figure 22 Core entrained flow in node 15, all channels (lbm/sec) vs. Time

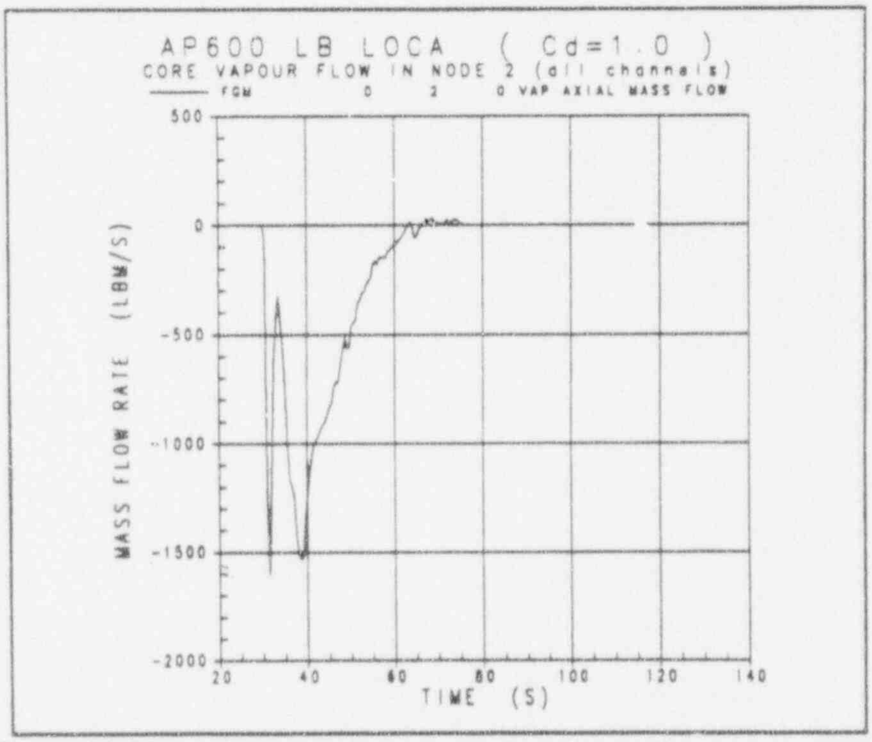

Figure 23 Core vapour flow in node 2, all channels (lbm/sec) vs. Time

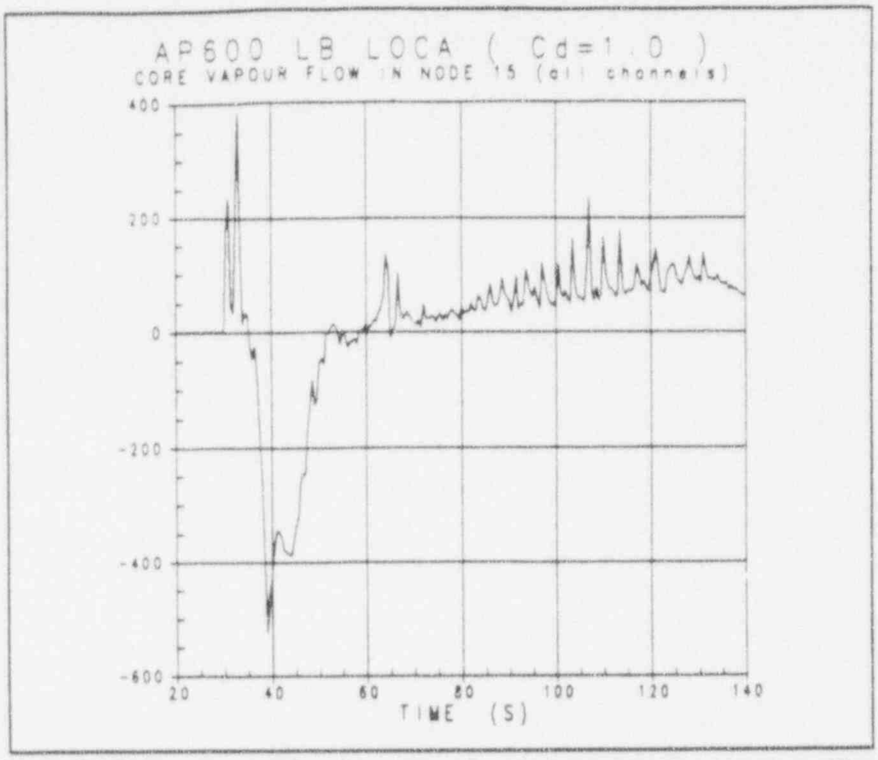

Figure 24 Core vapour flow in node 15, all channels (lbm/sec) vs. Time

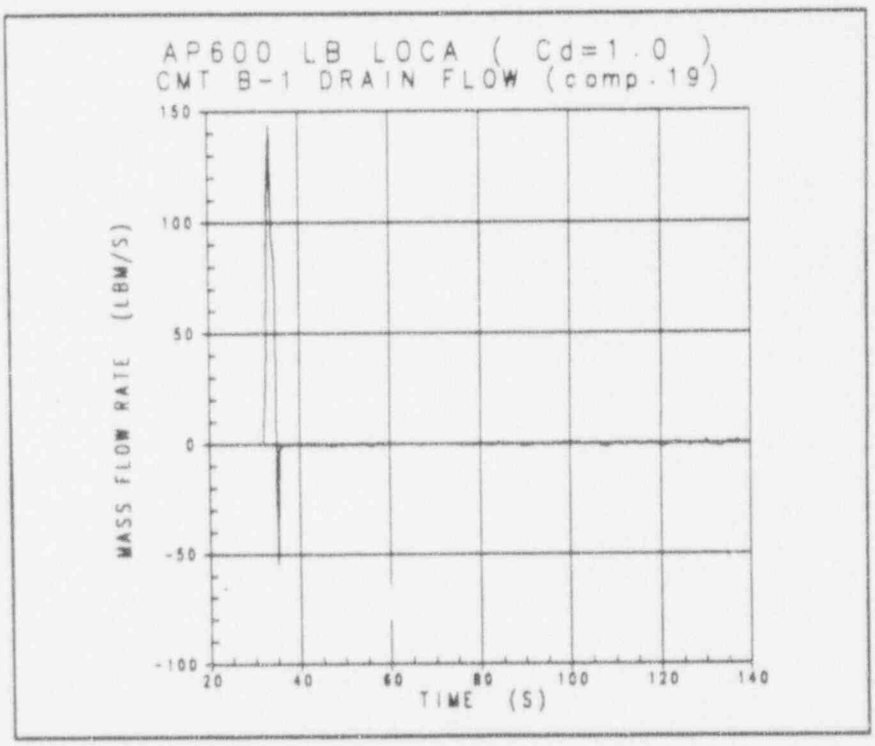

Figure 25 CMT B-1 drain flow, component 19 (lbm/sec) vs. Time

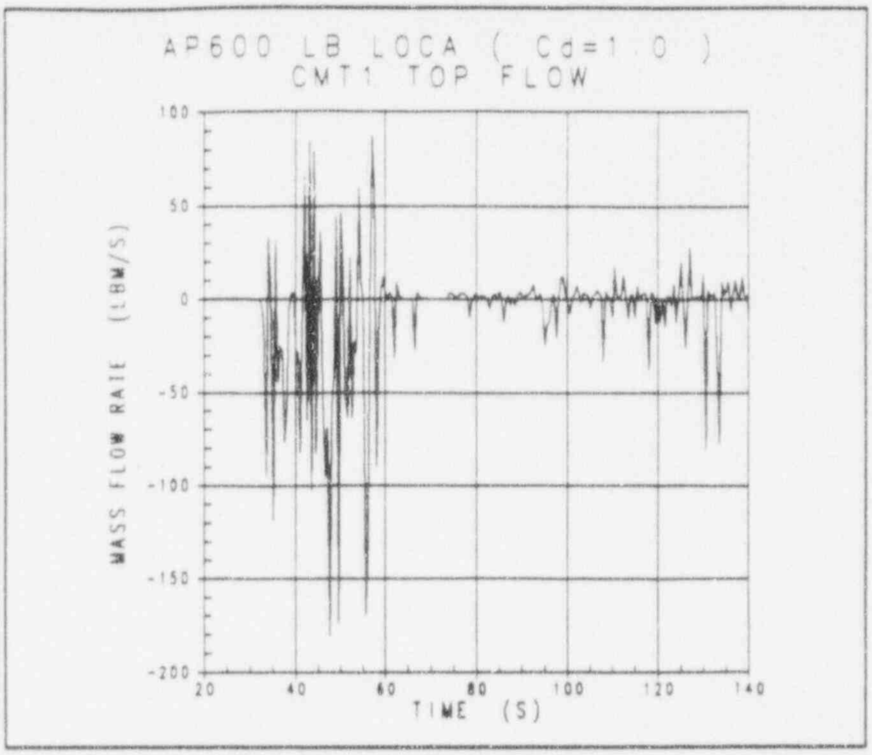

Figure 26 CMT 1 top mass flow rate (lbm/sec) vs Time

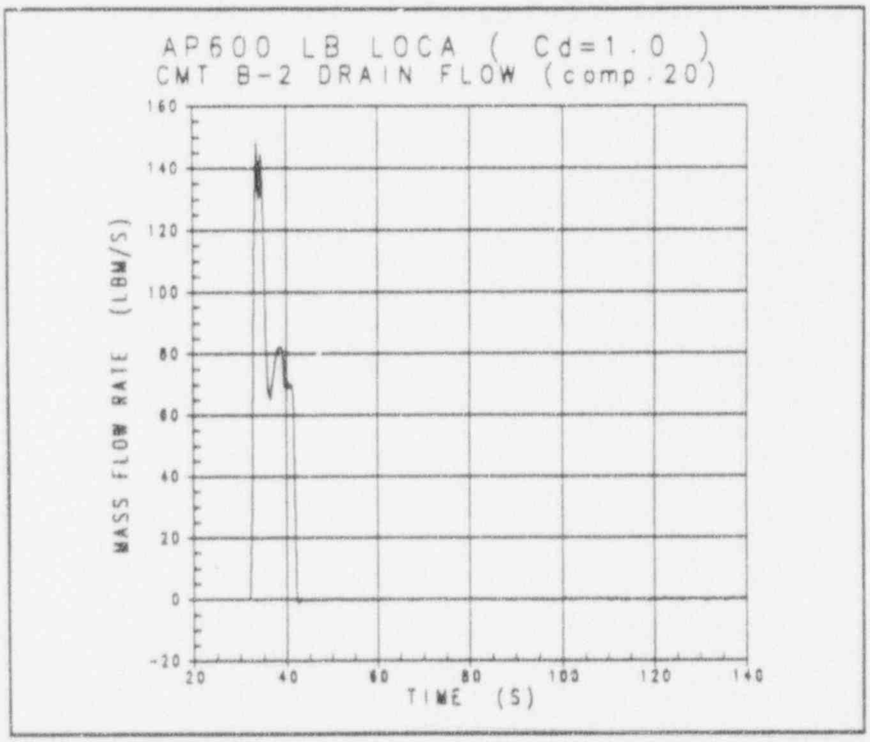

Figure 27 CMT B-2 drain flow, component 20 (lbm/sec) vs. Time

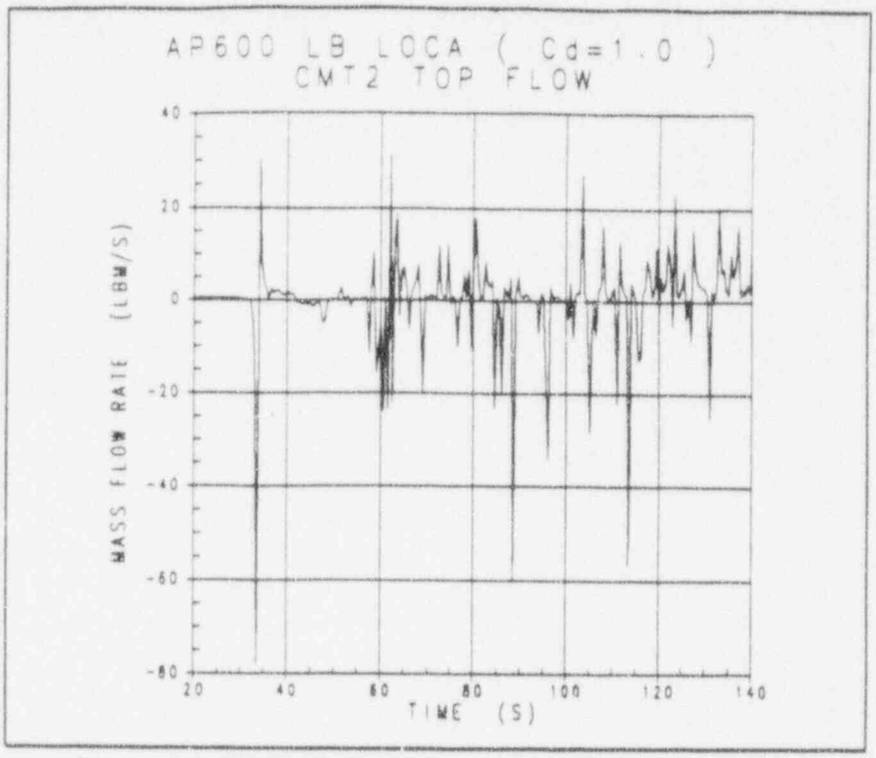

Figure 28 CMT 2 top mass flow rate (lbm/sec) vs. Time

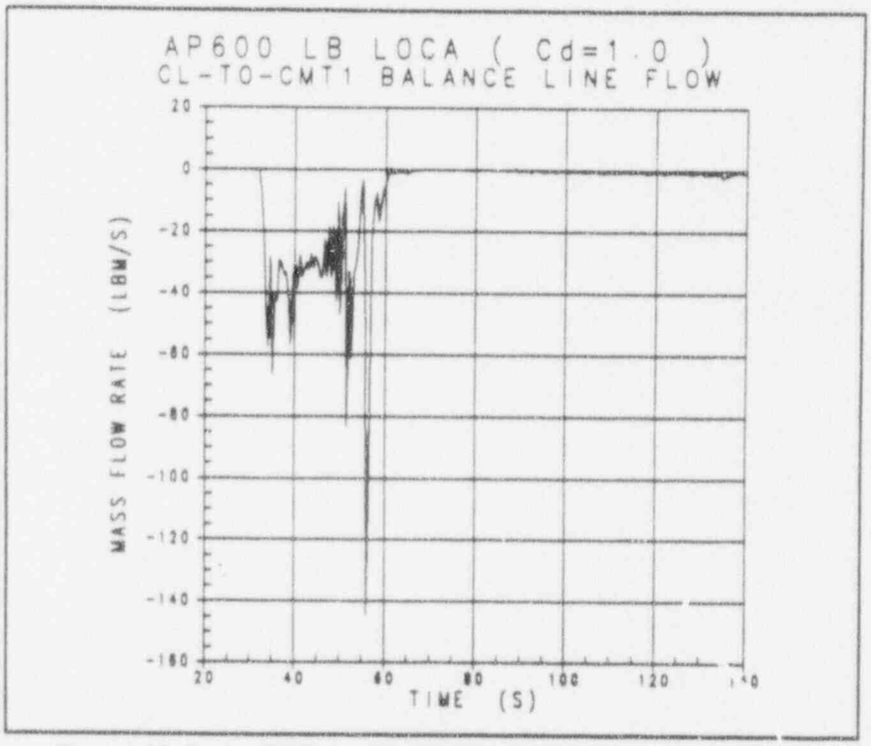

Figure 29 CL to CMT 1 balance line flow (lbm/sec) vs. Time

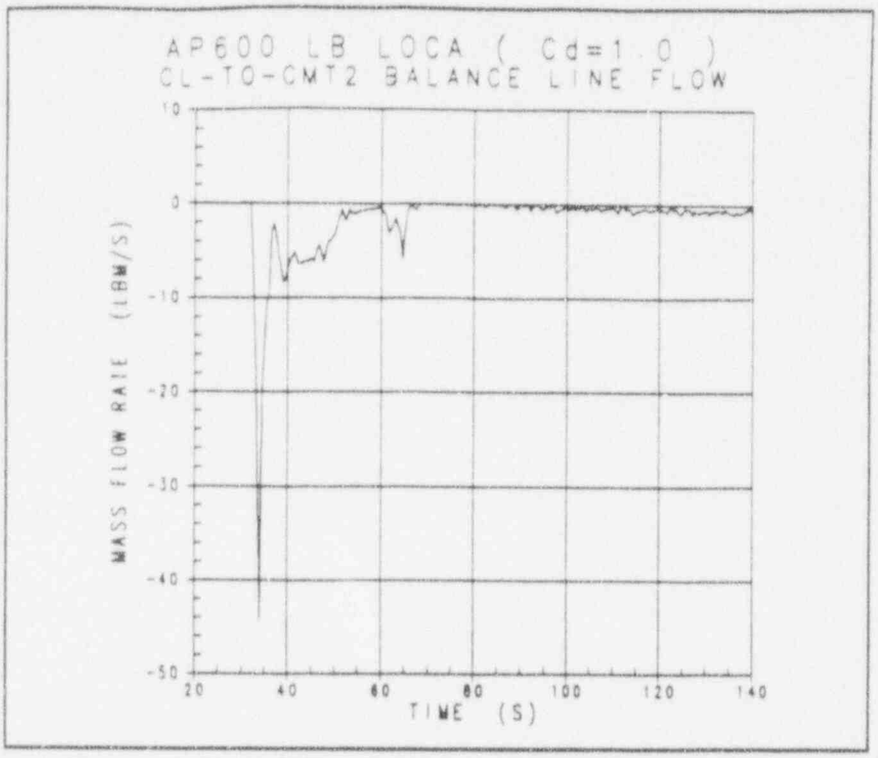

Figure 30 CL to CMT 2 balance line flow (lbm/sec) vs. Time

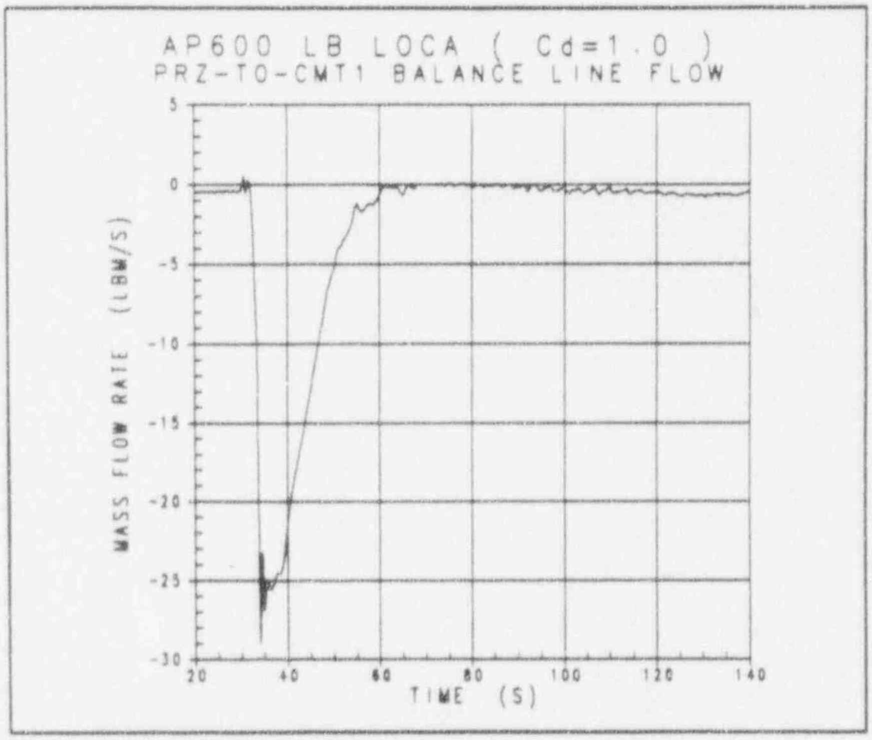

Figure 31 PRZ to CMT 1 balance line flow (lbm/sec) vs. Time

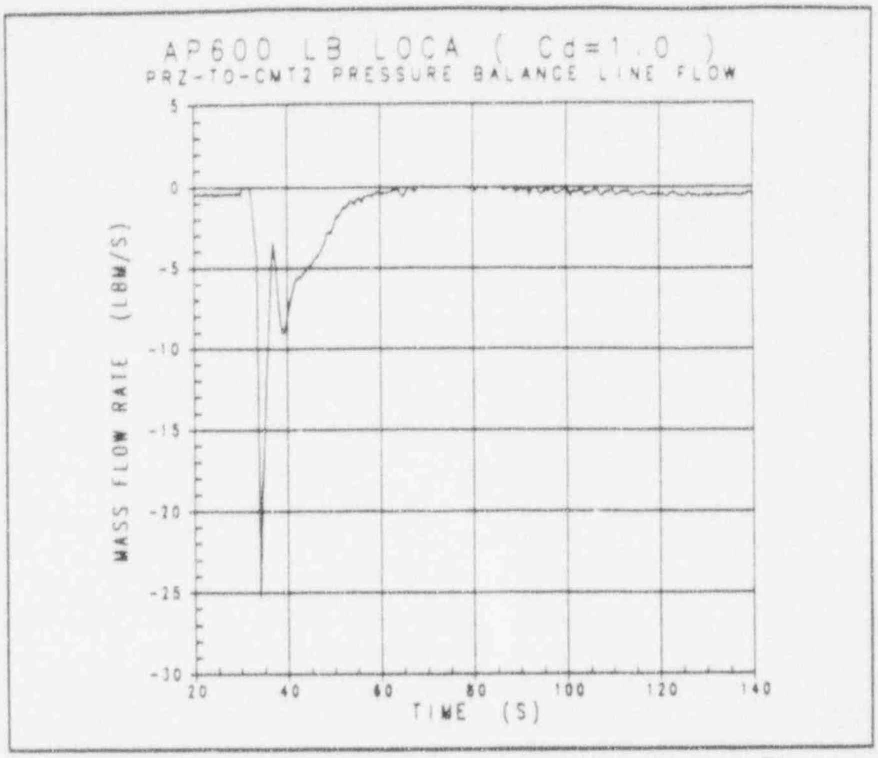

Figure 32 PRZ to CMT 2 balance line flow (lbm/sec) vs. Time

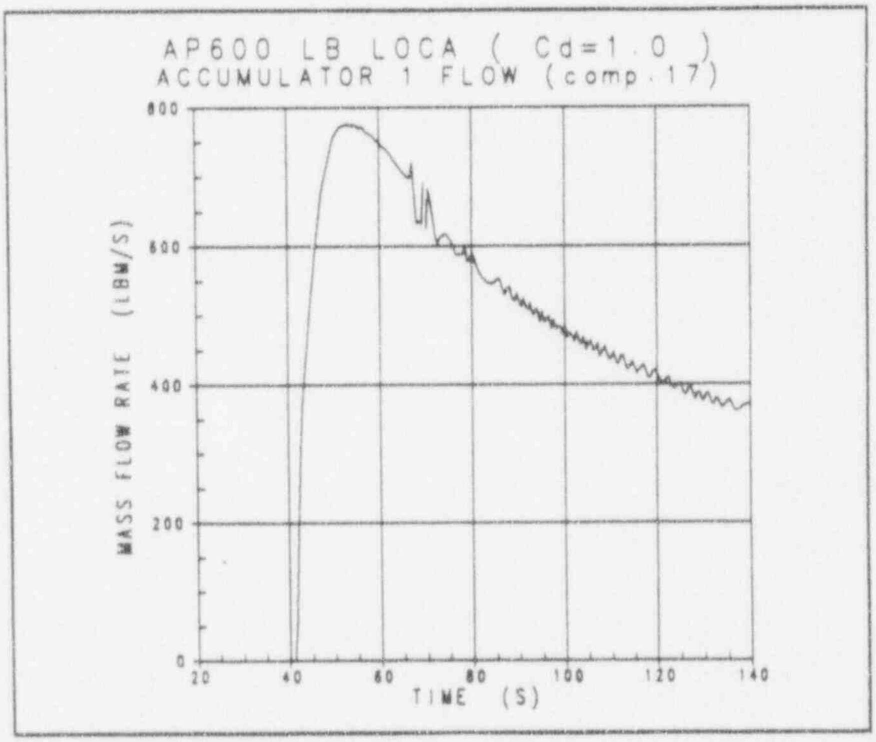

Figure 33 Accumulator 1 mass flow (lbm/sec) vs. Time

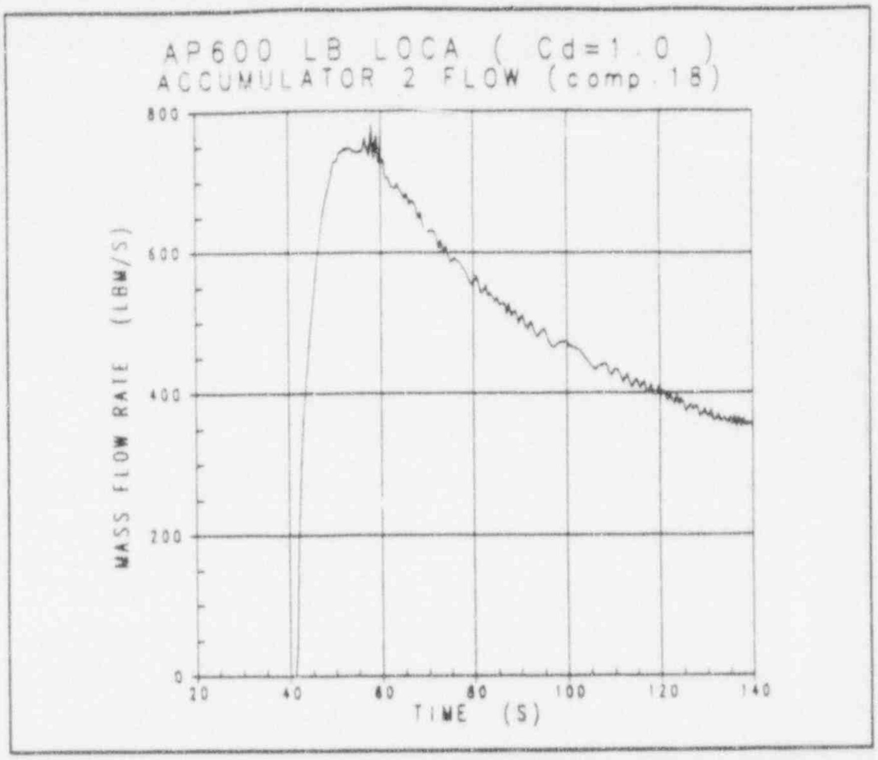

Figure 34 Accumulator 2 mass flow (lbm/sec) vs. Time

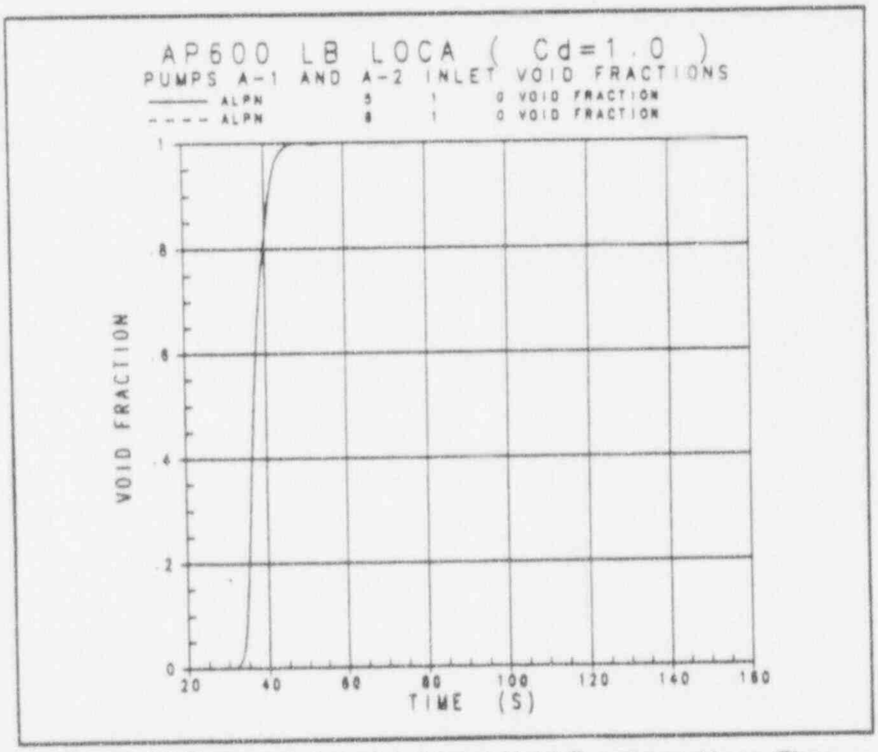

Figure 35 Pumps A-1 and A-2 inlet Void Fractions (-) vs. Time

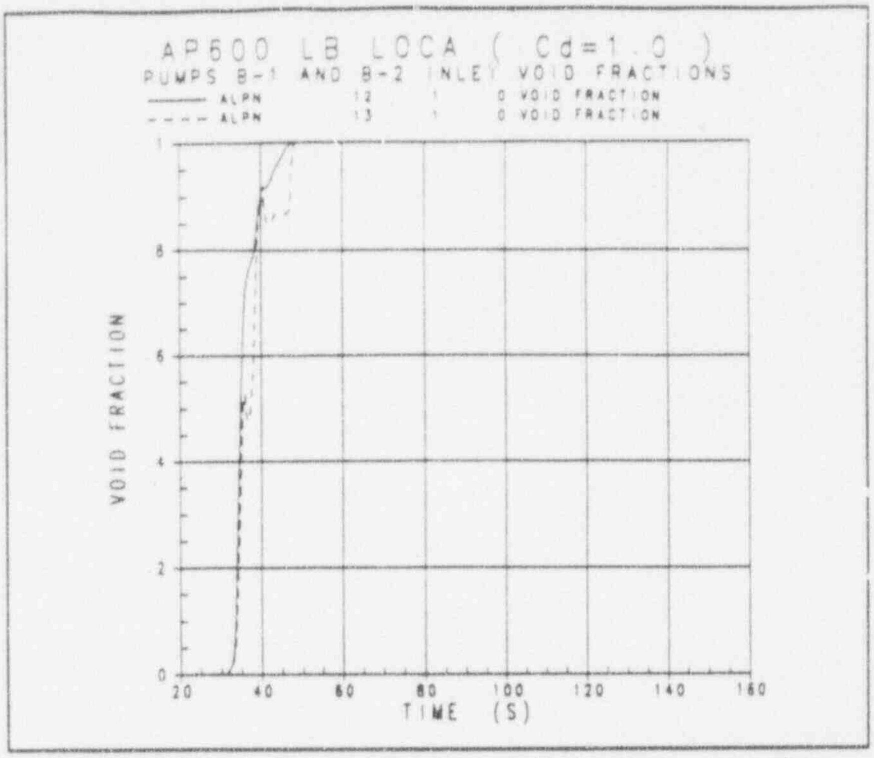

Figure 36 Pumps B-1 and B-2 Inlet Void Fractions (-) vs. Time

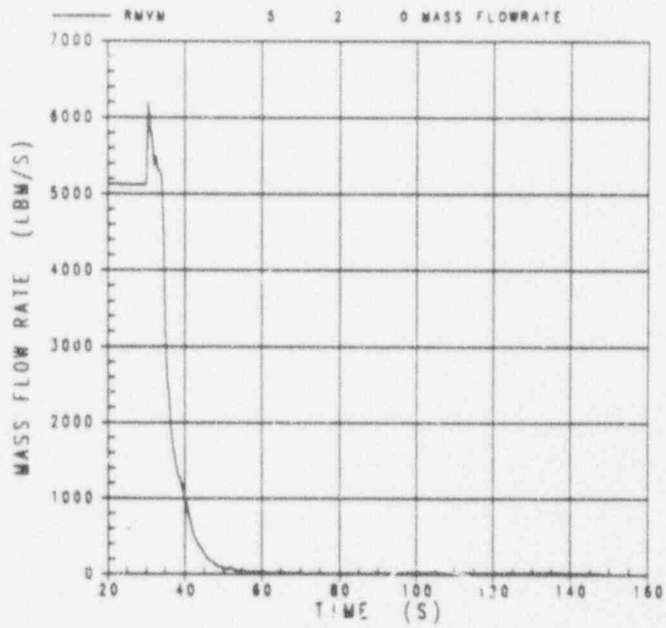

Figure 37 Pumps A-1 & A-2 mass flowrate, components 5&6 (lbm/sec) vs. Time

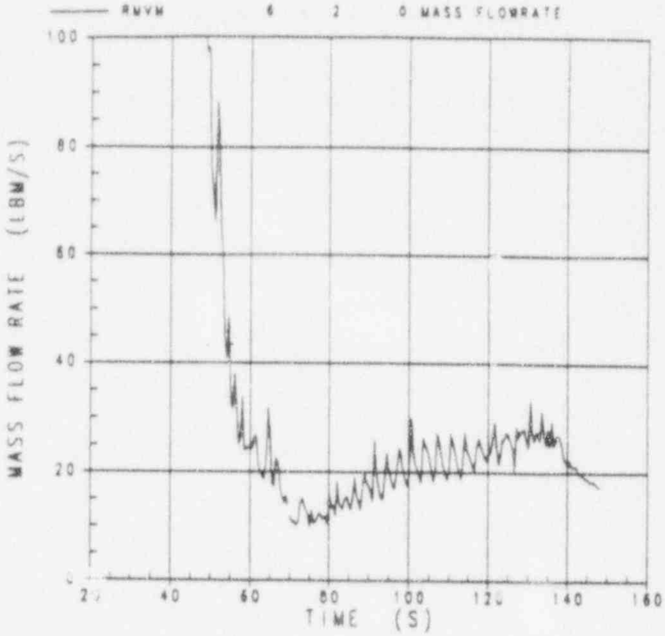

Figure 38 Pumps A-1 & A-2 mass flowrate, components 5&6 (lbm/sec) vs. Time [focused Yscale]

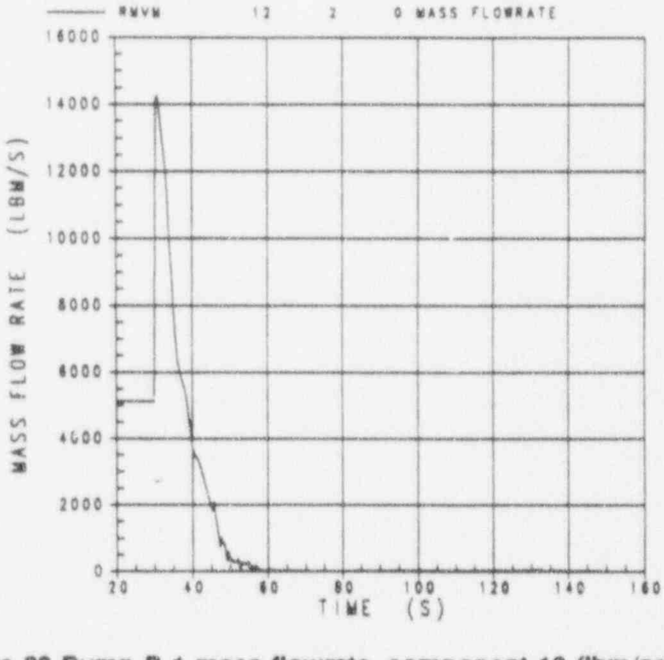

Figure 39 Pump B-1 mass flowrate, component 12 (lbm/sec) vs. Time

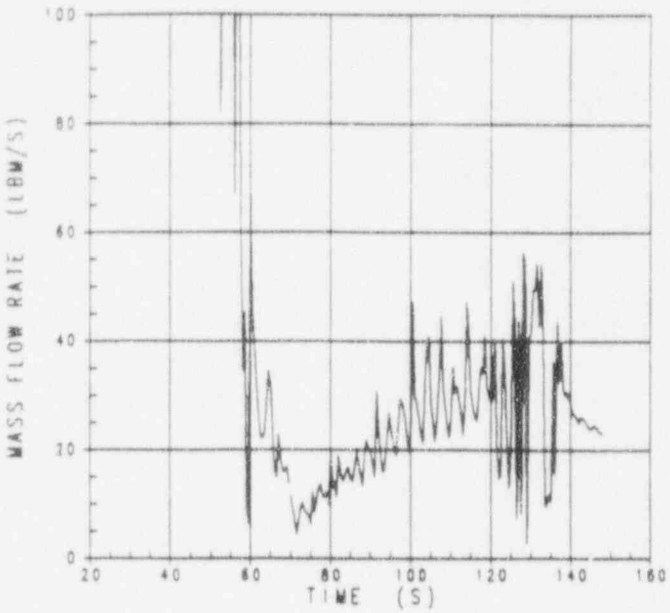

Figure 40 Pump B-1 mass flowrate, component 12 (lbm/sec) vs. Time [focused Y scale]

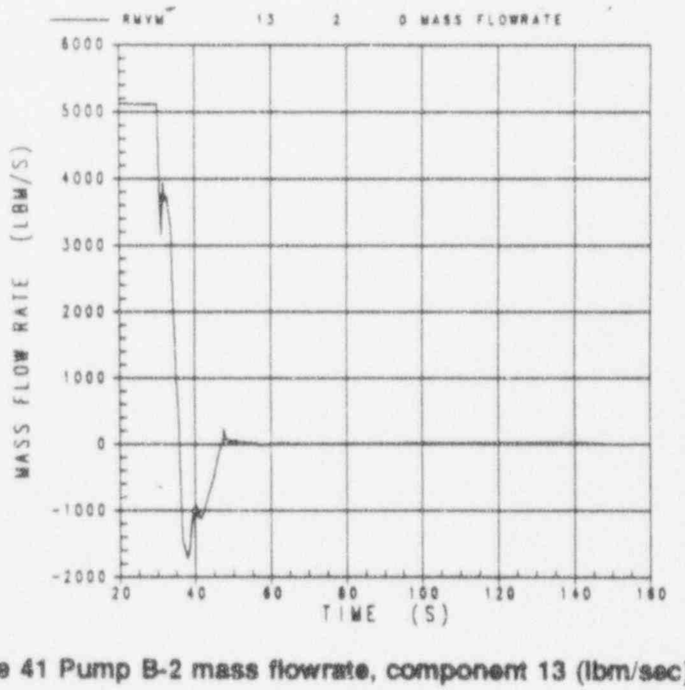

Figure 41 Pump B-2 mass flowrate, component 13 (lbm/sec) vs. Time

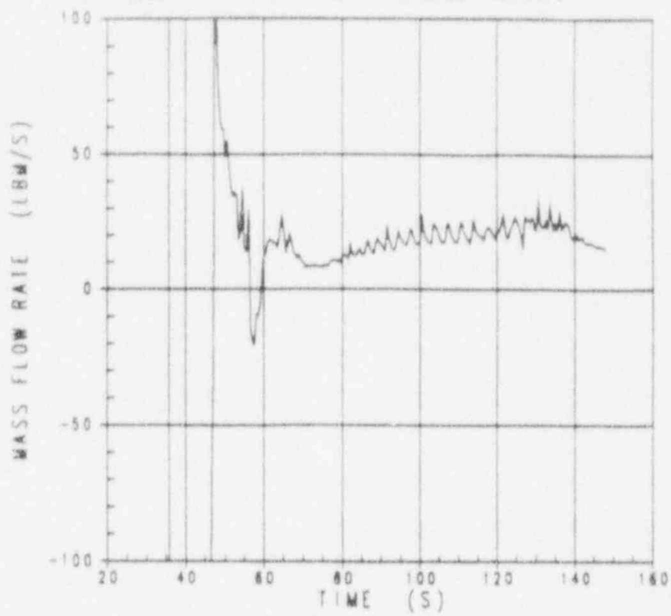

Figure 42 Pump B-2 mass flowrate, component 13 (lbm/sec) vs. Time [focused Y scale]

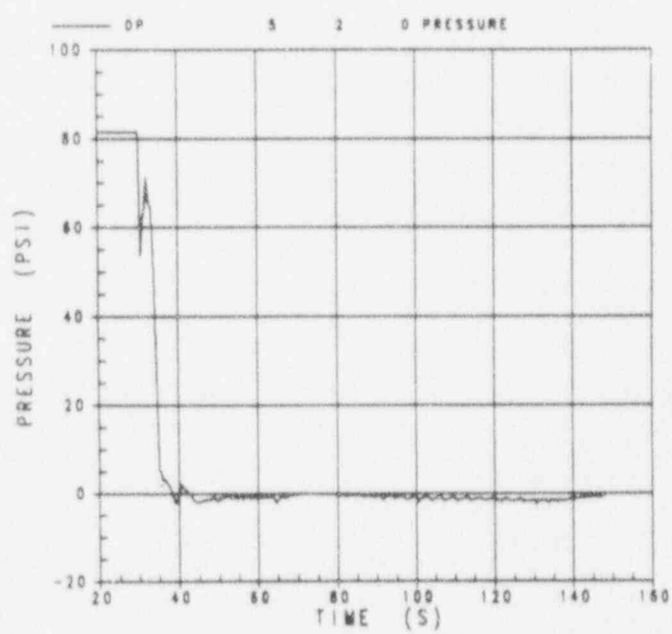

Figure 43 Pump A-1 head (psi) vs. Time

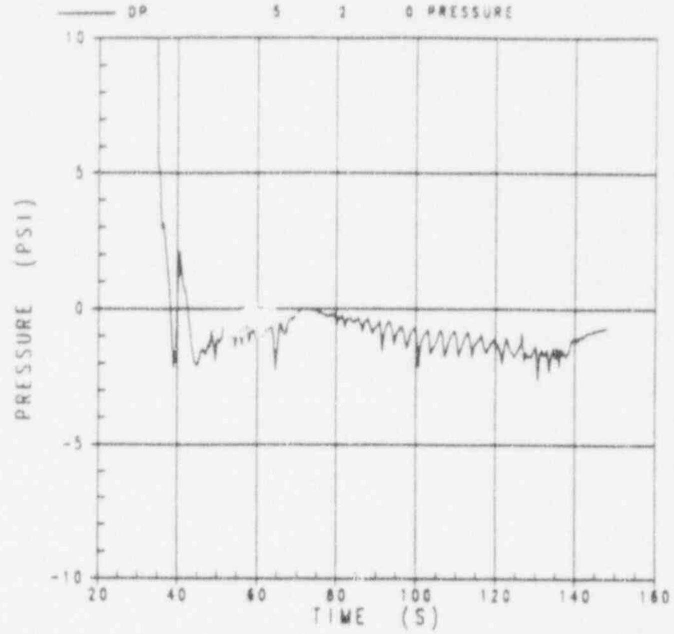

Figure 44 Pump A-1 head (psi) vs. Time [focused Y scale]

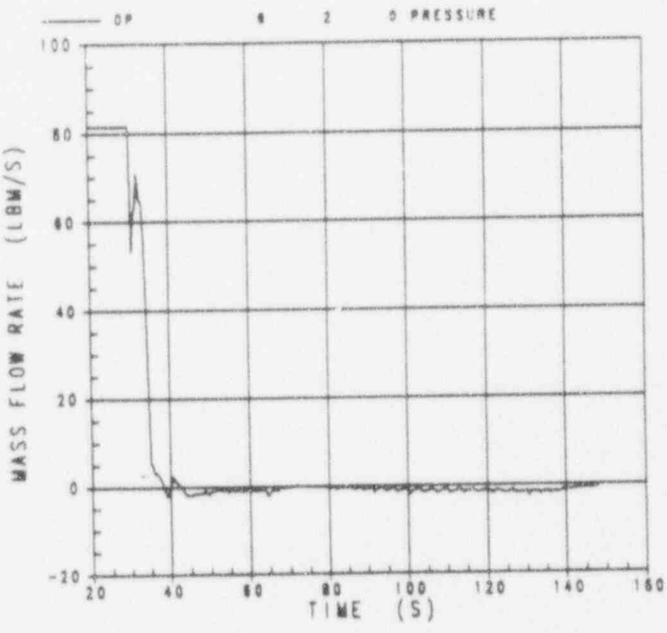

Figure 45 Pump A-2 head (psi) vs. Time

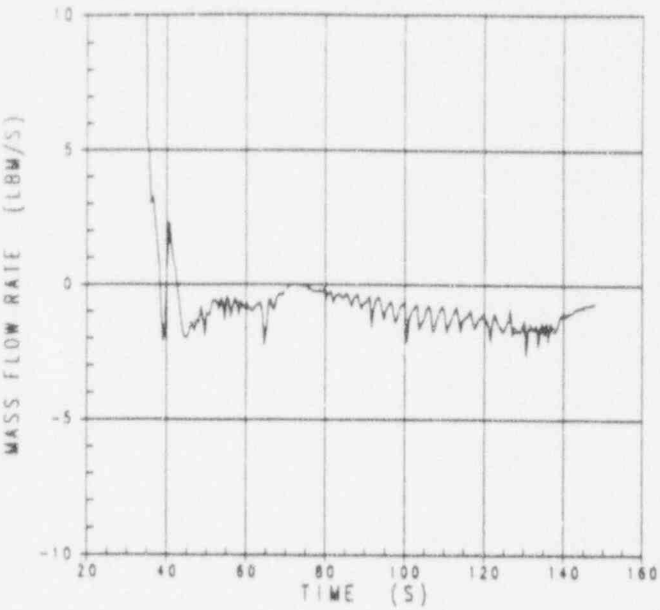

Figure 46 Pump A-2 head (psi) vs. Time [focused Y scale]

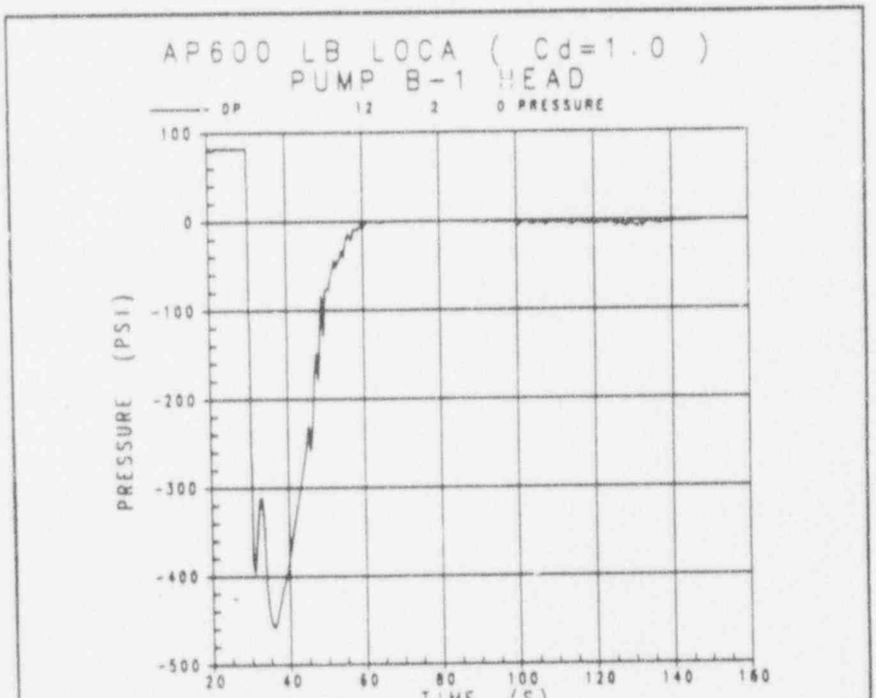

Figure 47 Pump B-1 head (psi) vs. Time

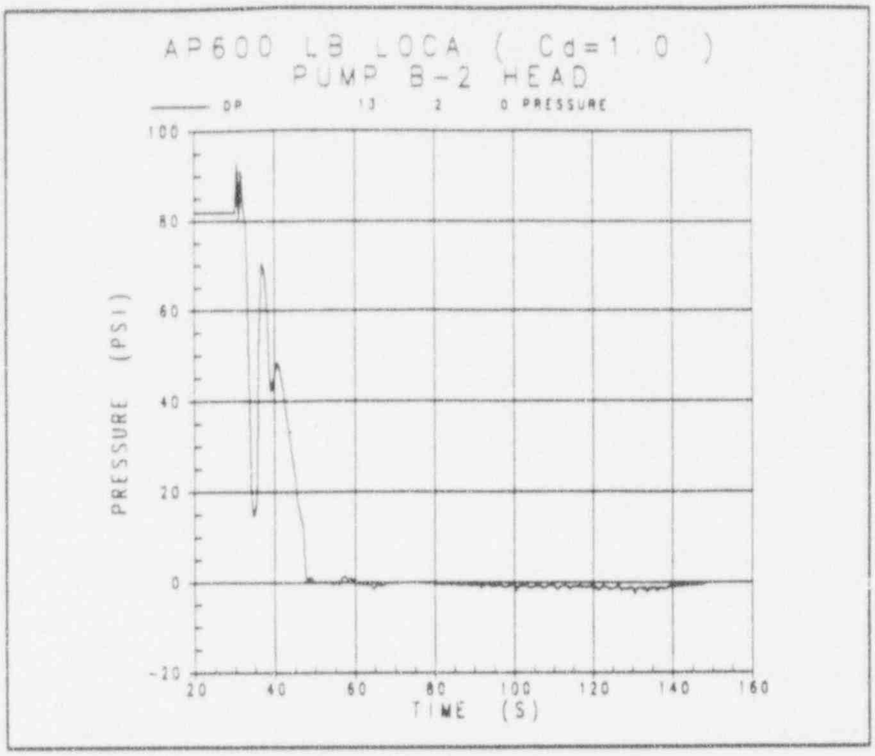

Figure 48 Pump B-2 head (psi) vs. Time

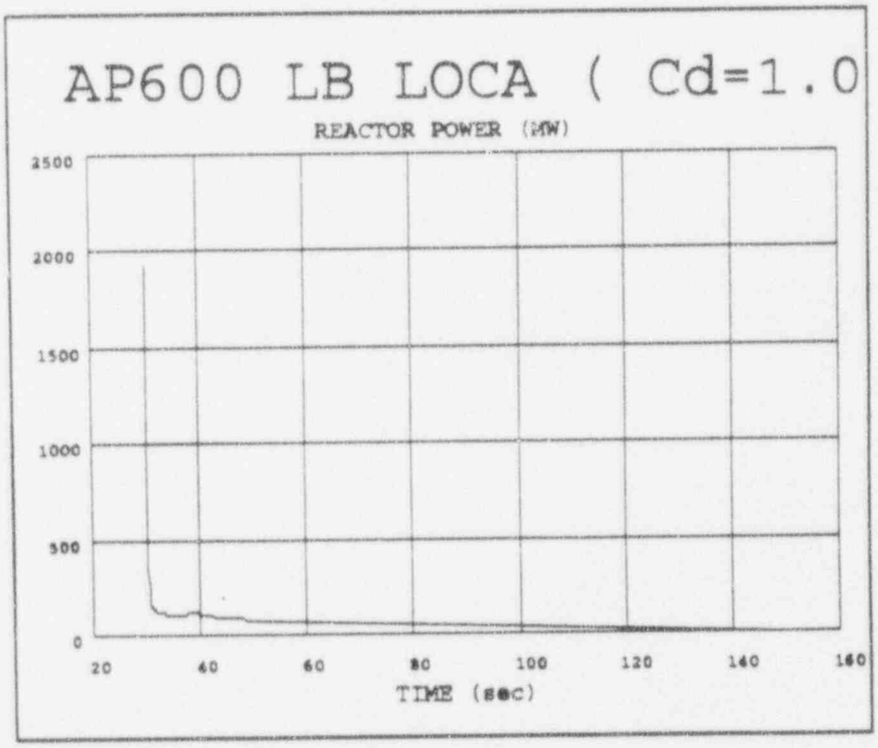

Figure 49 Reactor Power (MWth) vs. Time

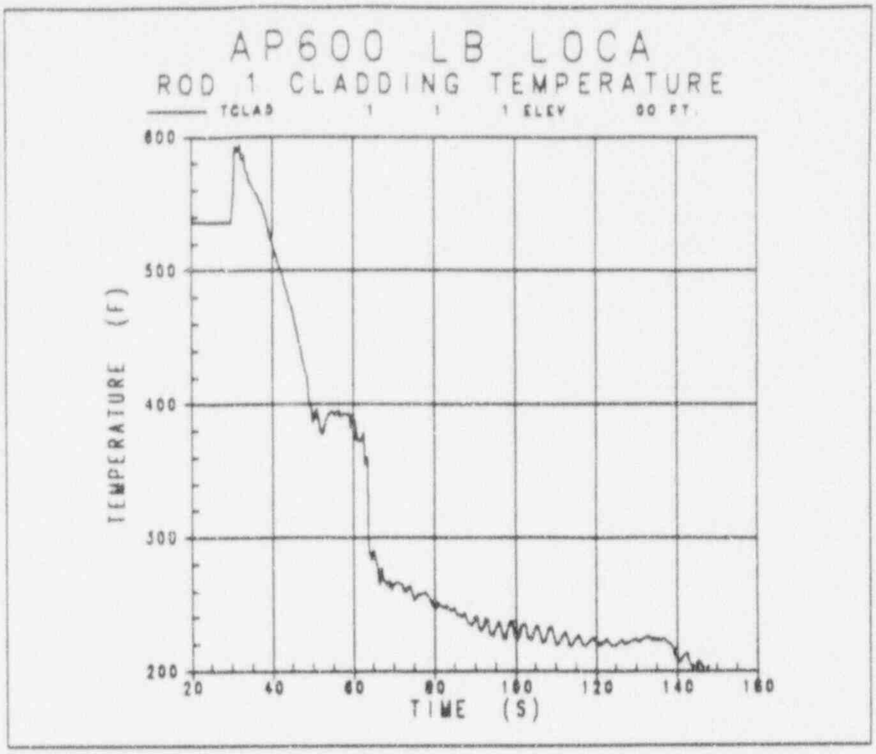

Figure 50 Rod 1 cladding temperature, 0.0 ft (deg. F) vs. Time

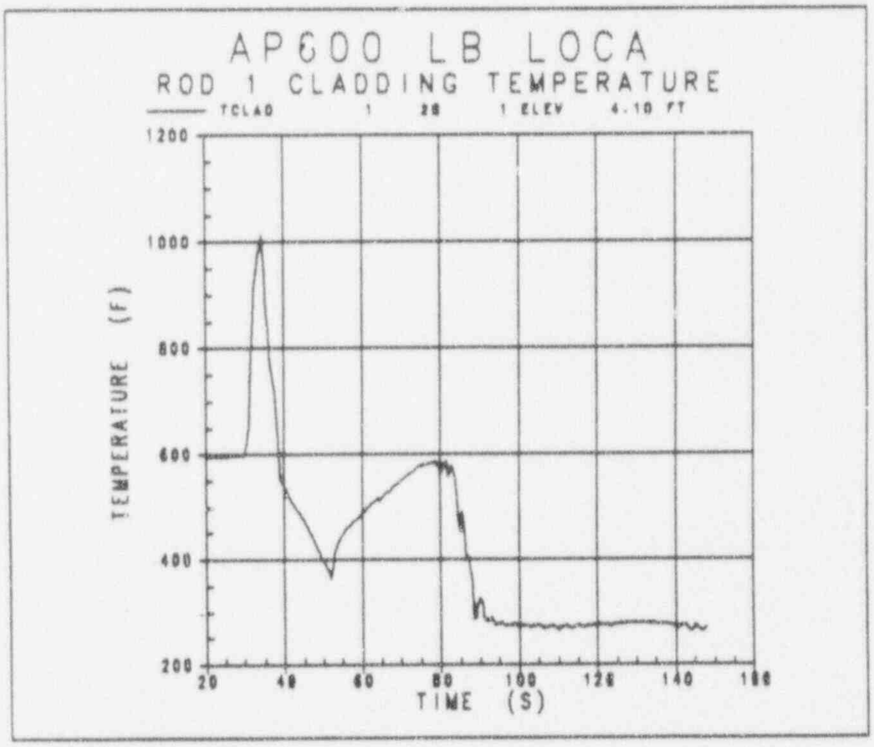

Figure 51 Rod 1 cladding temperature, 4.1 ft (deg. F) vs. Time

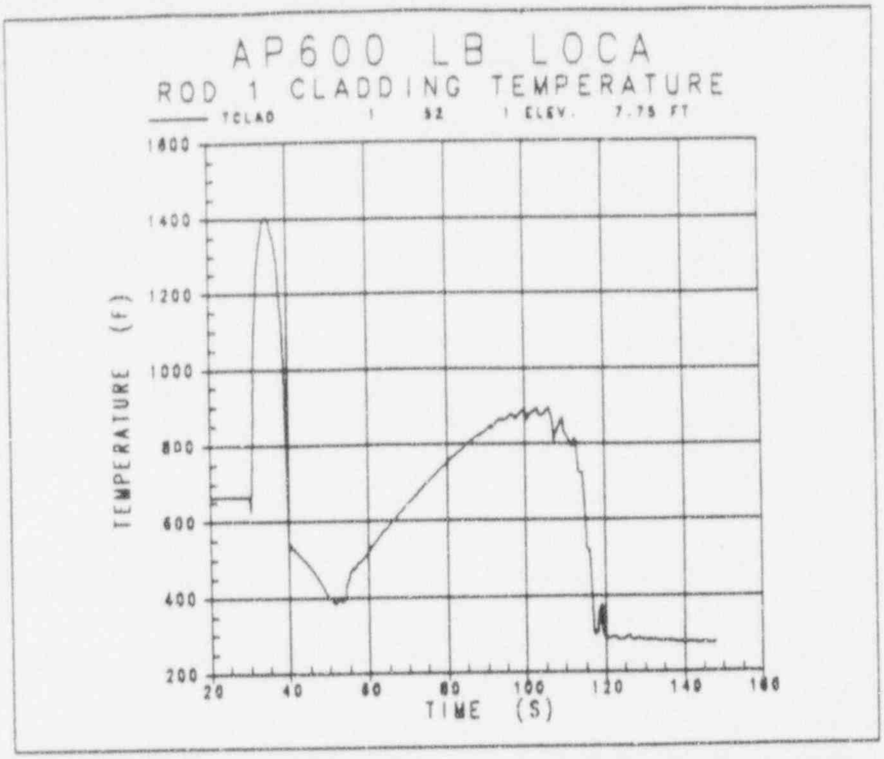

Figure 52 Rod 1 cladding temperature, 7.75 ft (deg. F) vs. Time

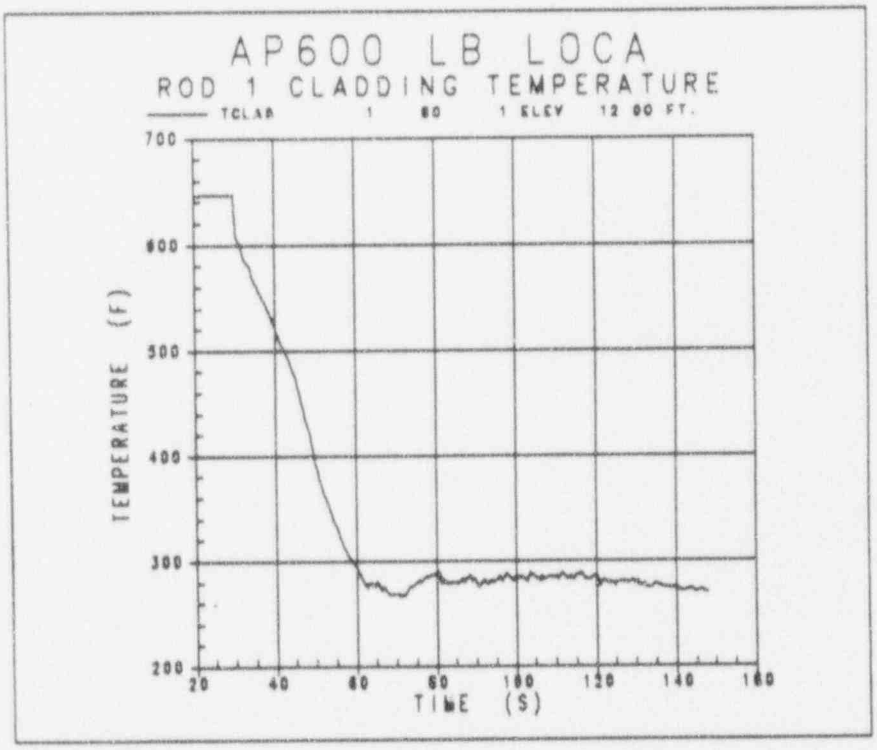

Figure 53 Rod 1 cladding temperature, 12.00 ft (deg. F) vs. Time

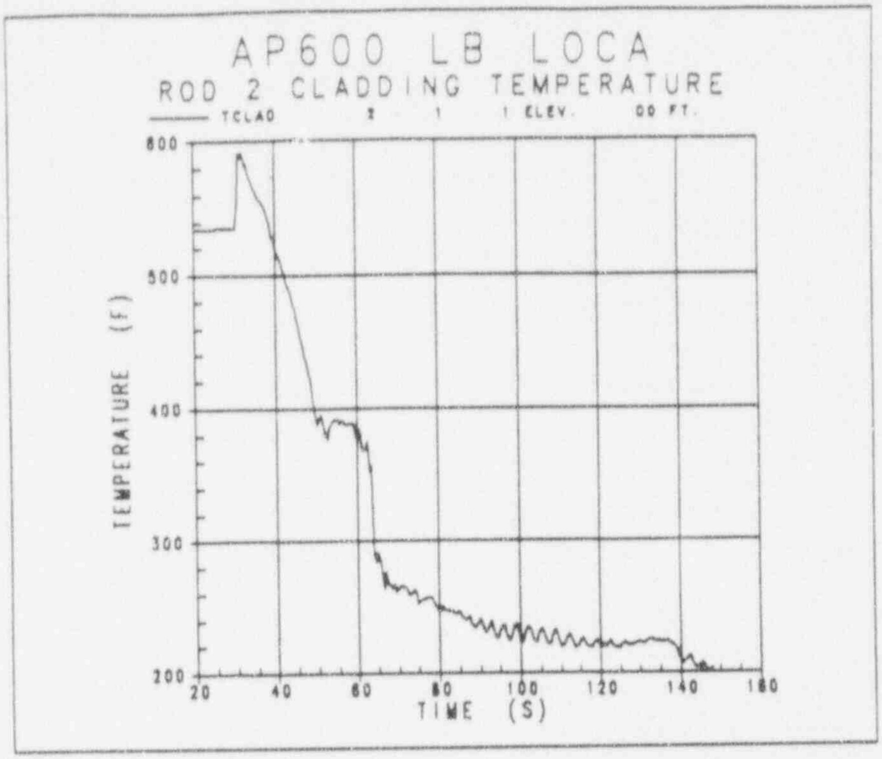

Figure 54 Rod 2 cladding temperature, 0.0 ft (deg. F) vs. Time

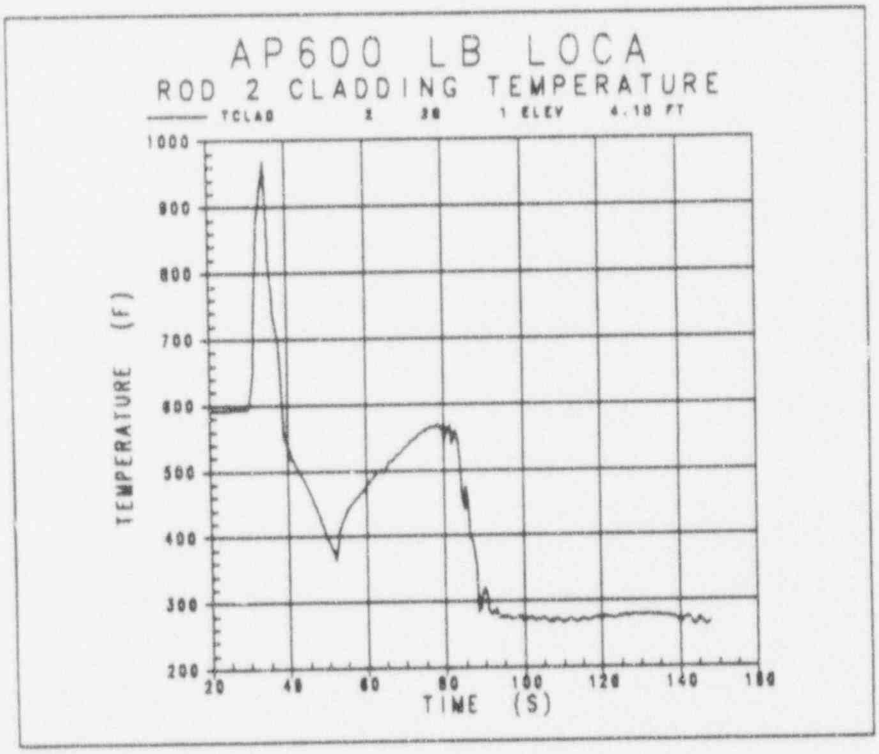

Figure 55 Rod 2 cladding temperature, 4.1 ft (deg. F) vs. Time

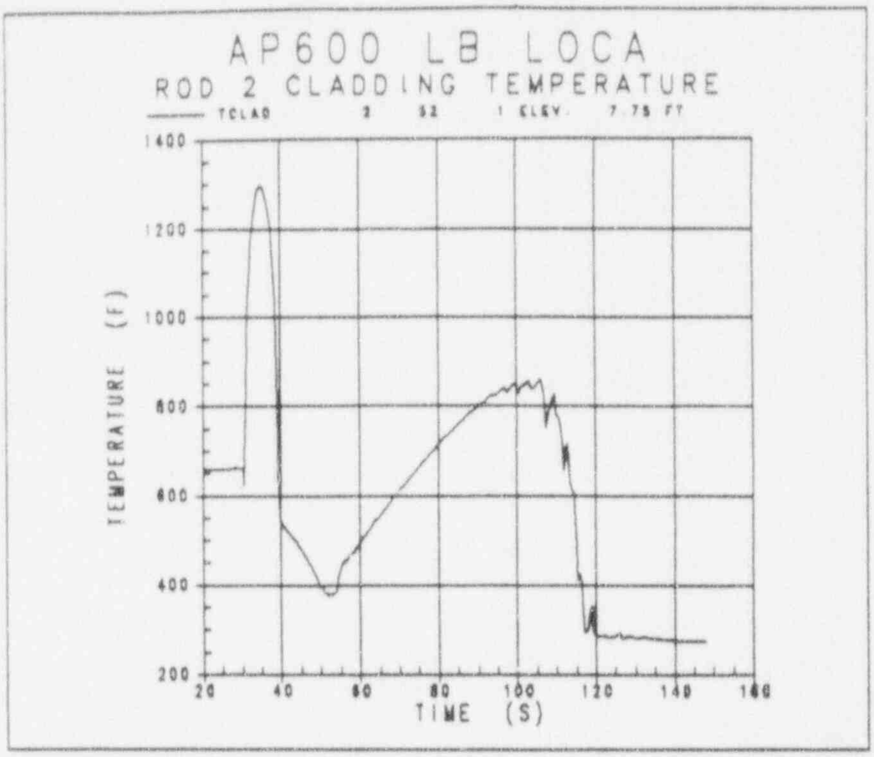

Figure 56 Rod 2 cladding temperature, 7.75 ft (deg. F) vs. Time

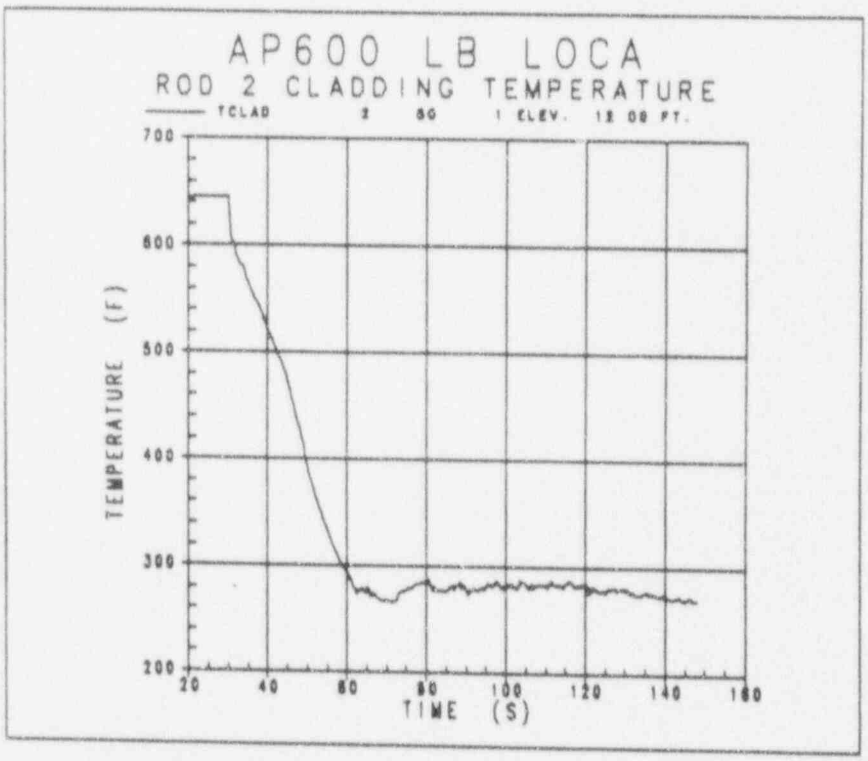

Figure 57 Rod 2 cladding temperature, 12.00 ft (deg. F) vs. Time

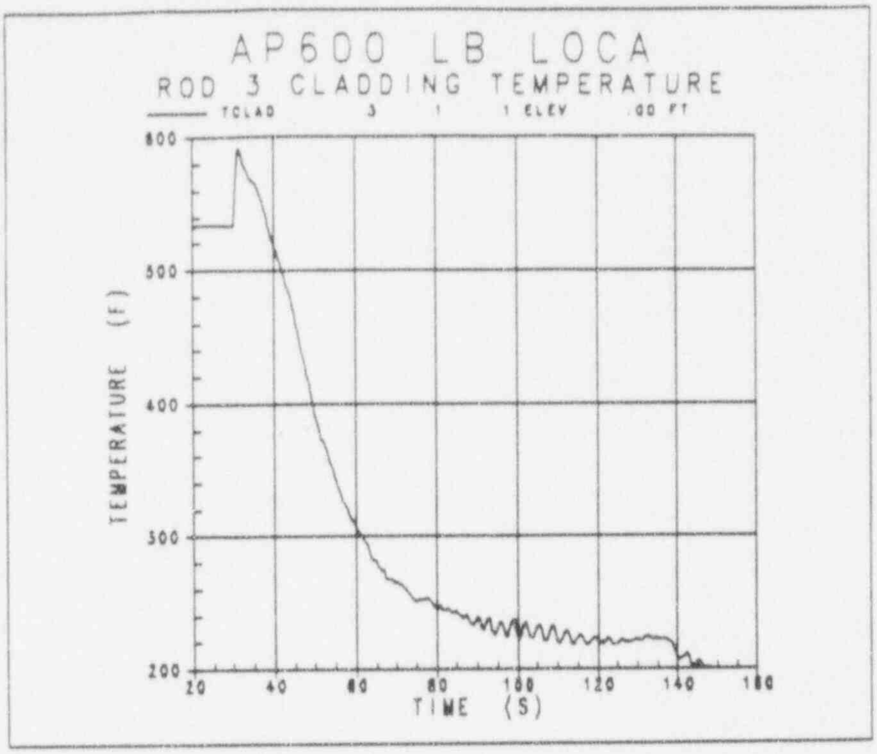

Figure 58 Rod 3 cladding temperature, 0.0 ft (deg. F) vs. Time

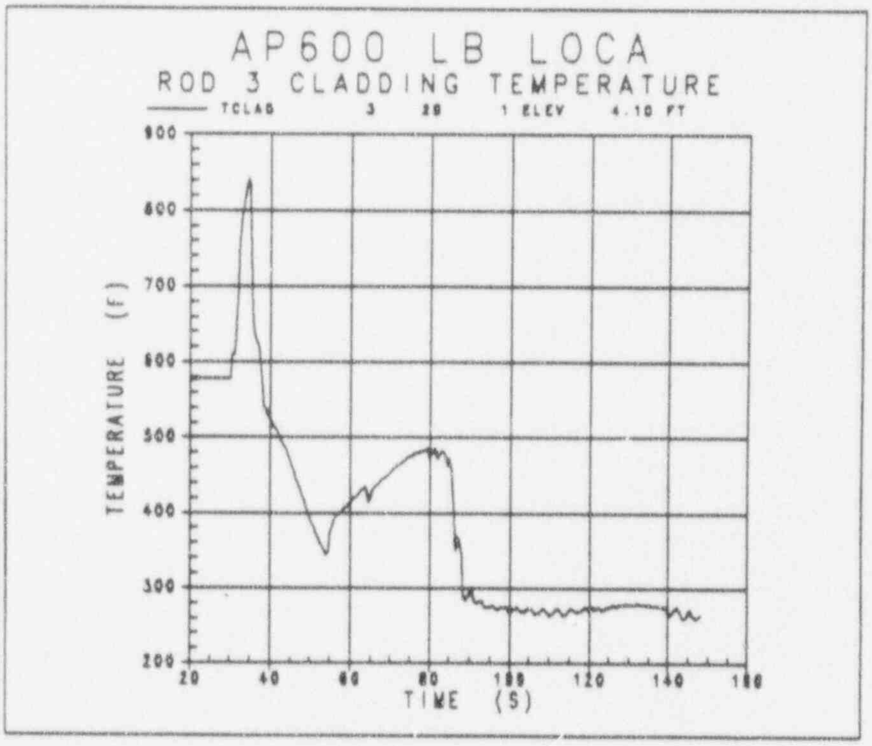

Figure 59 Rod 3 cladding temperature, 4.1 ft (deg. F) vs. Time

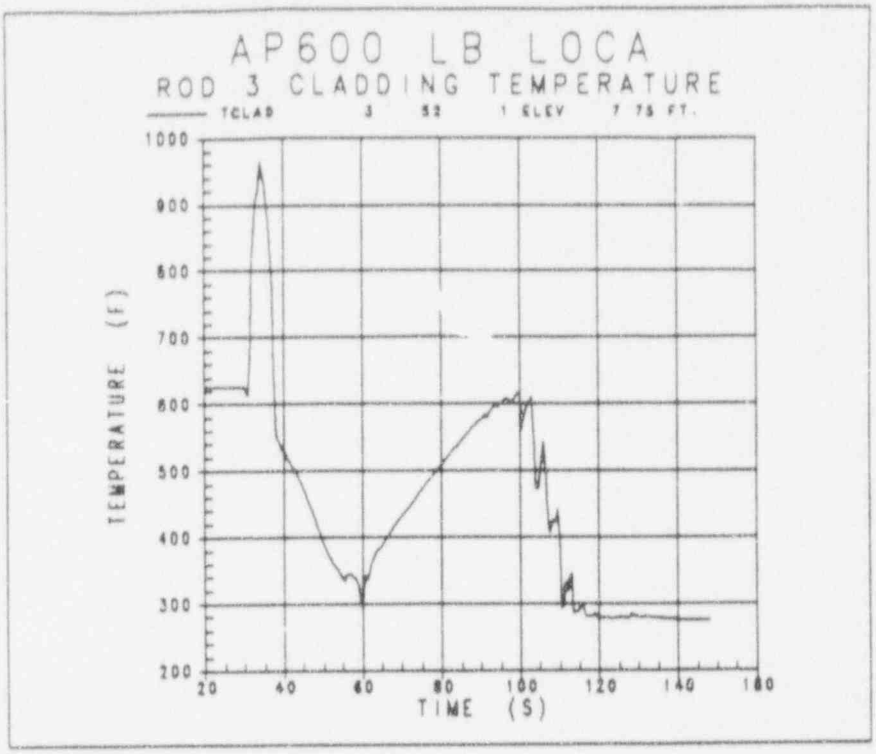

Figure 60 Rod 3 cladding temperature, 7.75 ft (deg. F) vs. Time

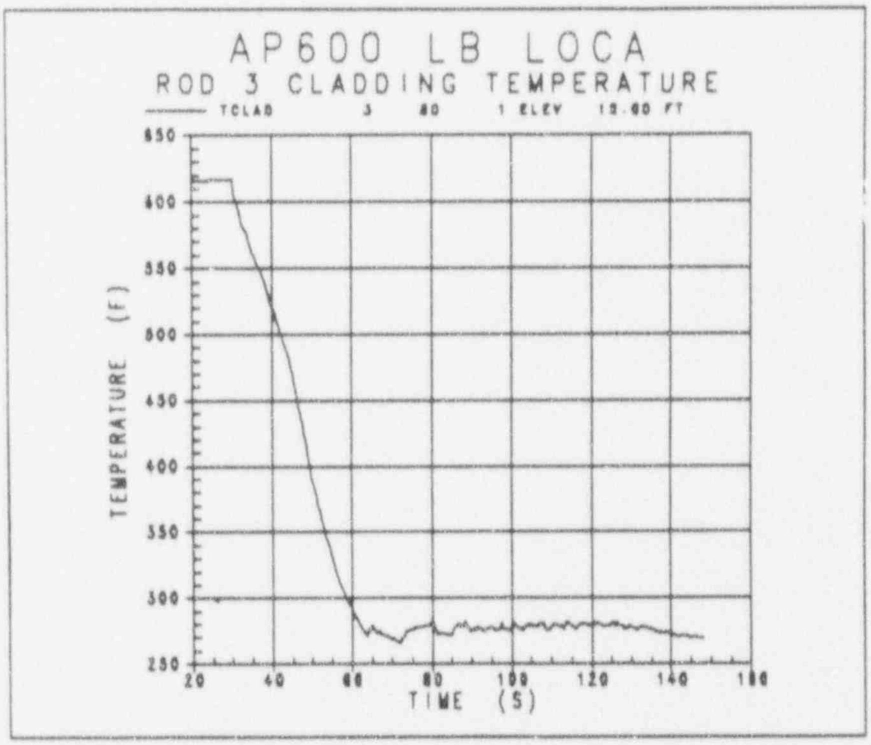

Figure 61 Rod 3 cladding temperature, 12.00 ft (deg. F) vs. Time

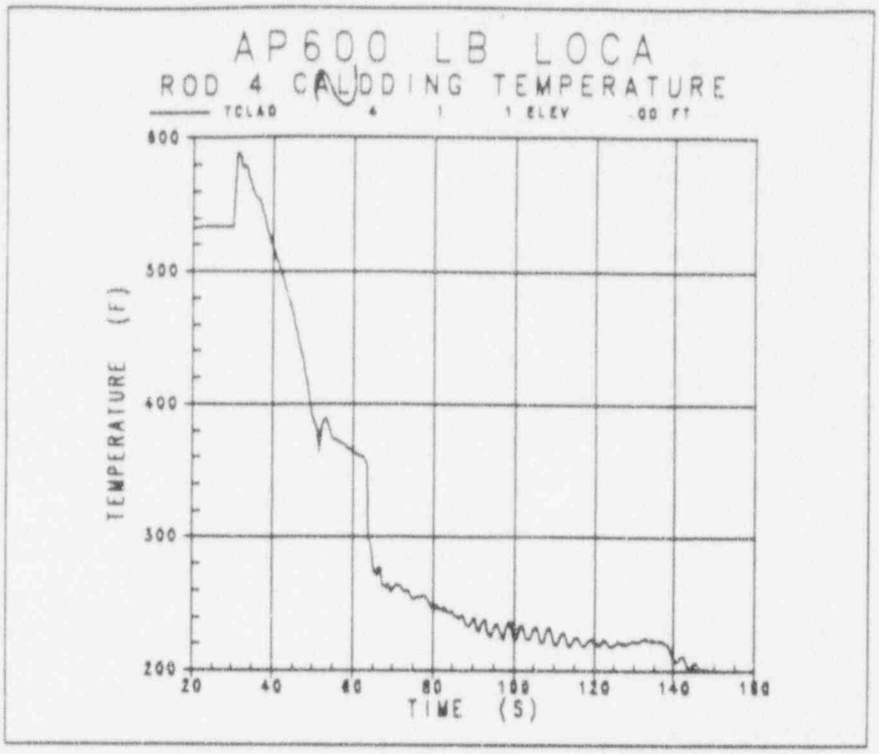

Figure 62 Rod 4 cladding temperature, 0.0 ft (deg. F) vs. Time

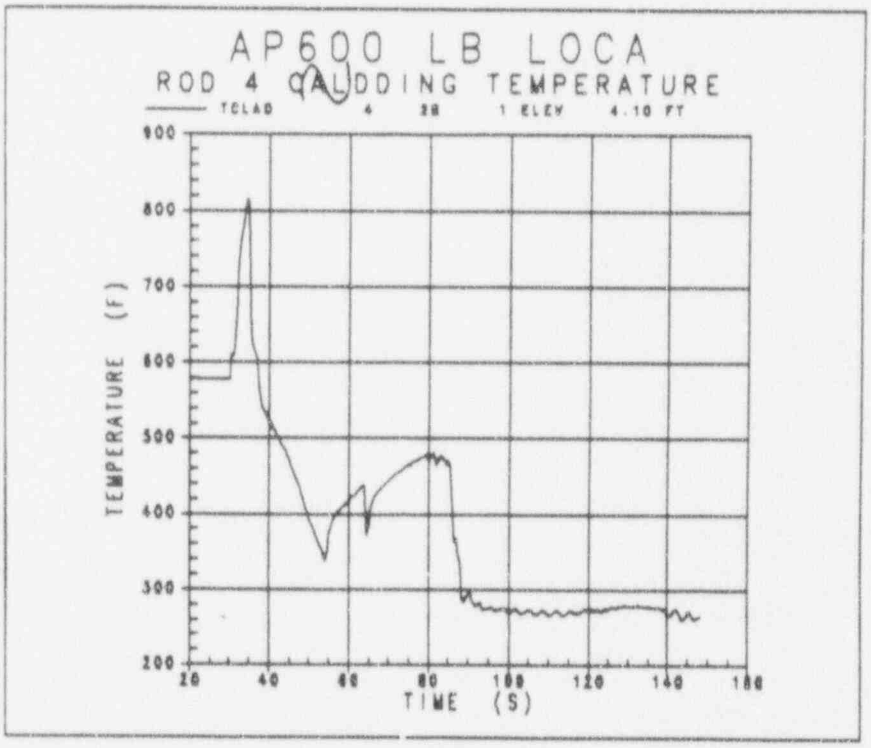

Figure 63 Rod 4 cladding temperature, 4.1 ft (deg. F) vs. Time

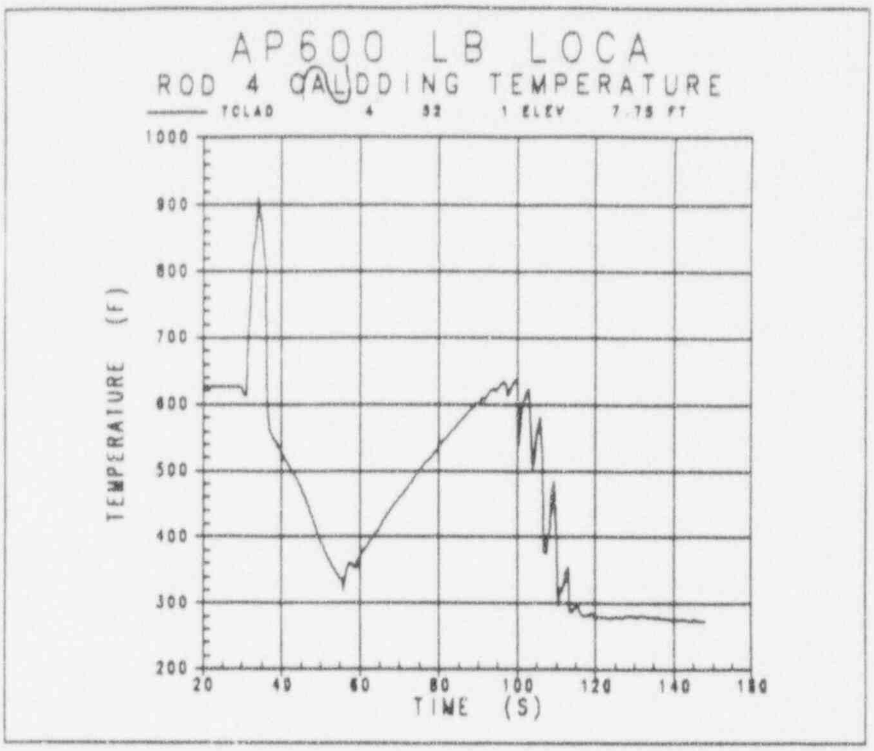

Figure 64 Rod 4 cladding temperature, 7.75 ft (deg. F) vs. Time

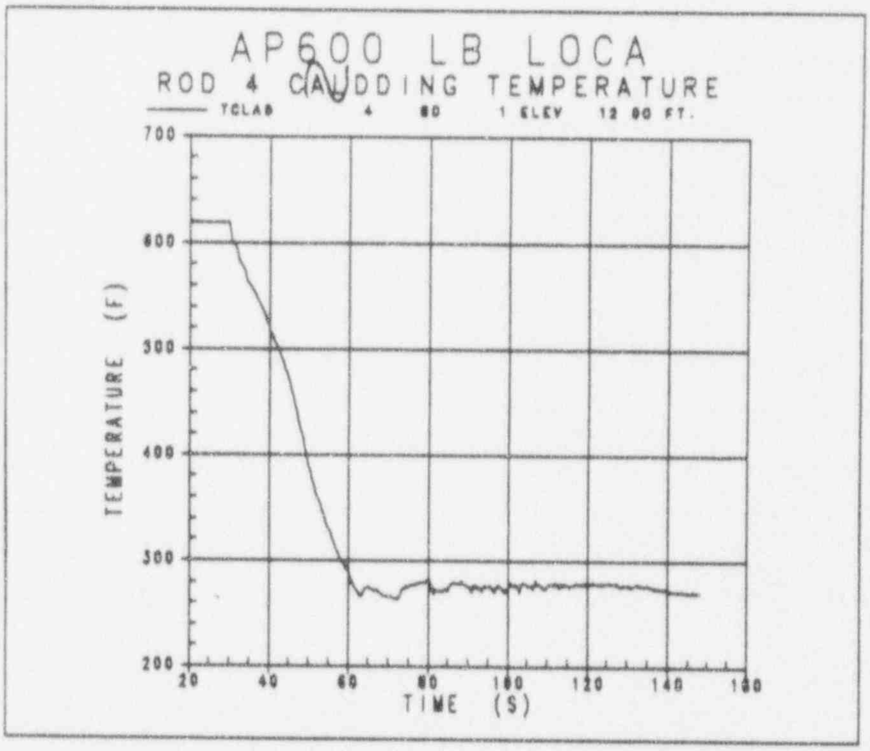

Figure 65 Rod 4 cladding temperature, 12.00 ft (deg. F) vs. Time

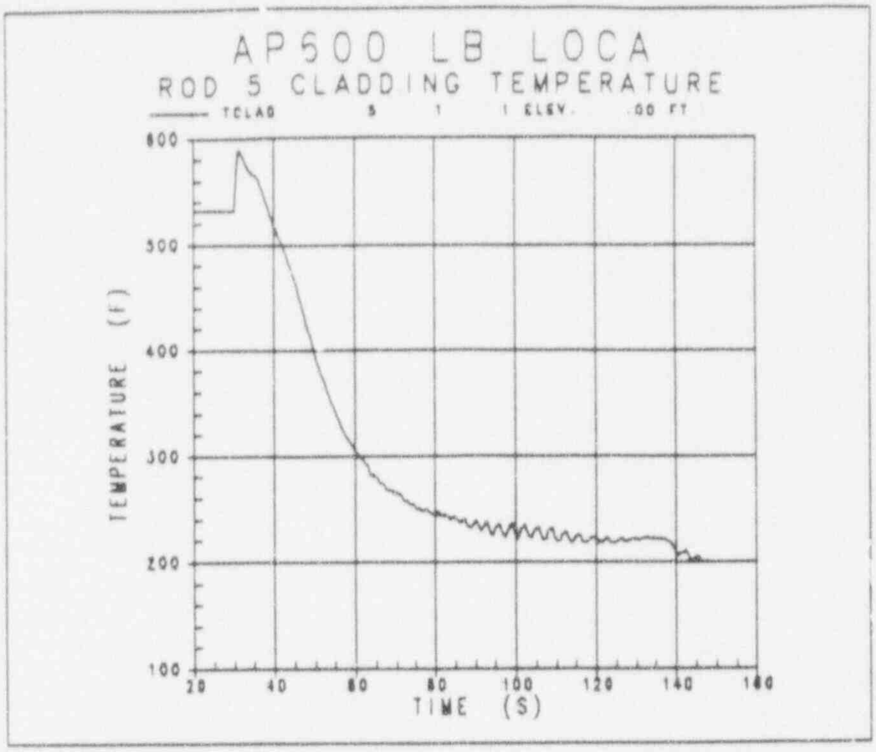

Figure 66 Rod 5 cladding temperature, 0.0 ft (deg. F) vs. Time

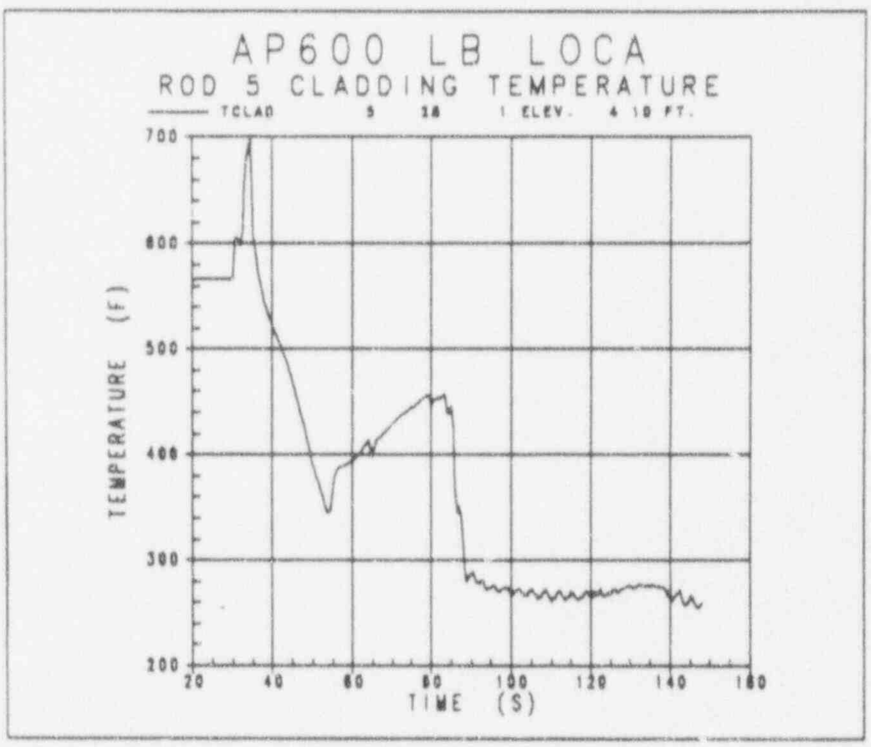

Figure 67 Rod 5 cladding temperature, 4.1 ft (deg. F) vs. Time

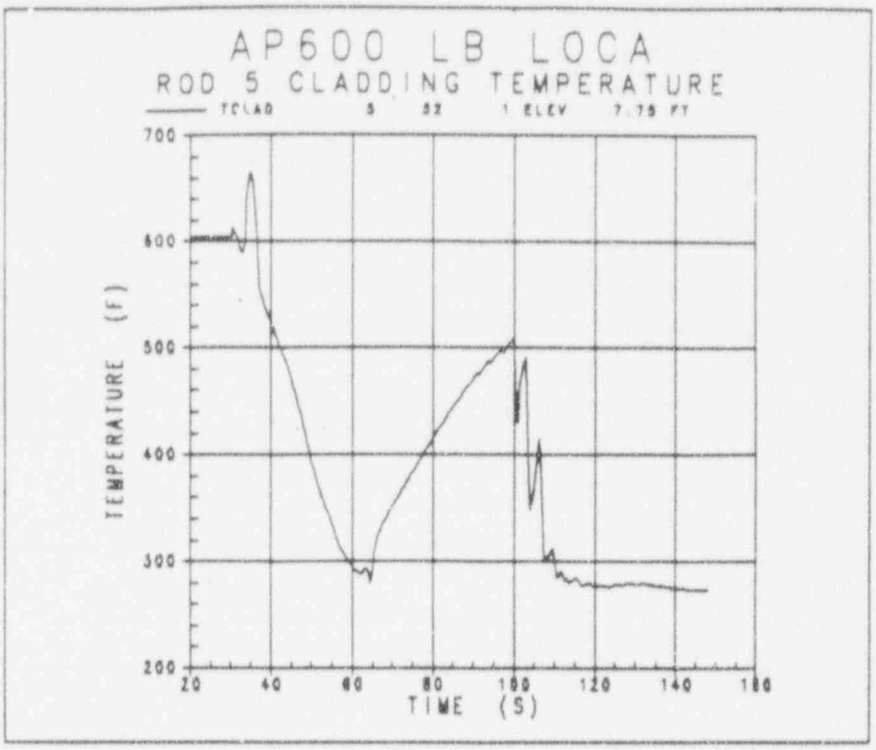

Figure 68 Rod 5 cladding temperature, 7.75 ft (deg. F) vs. Time

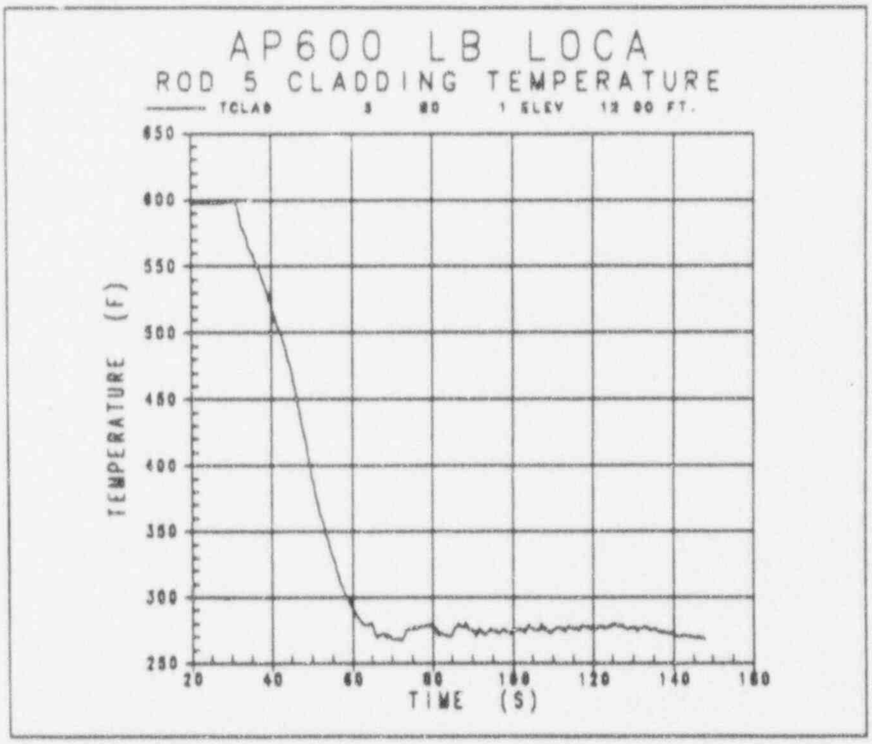

Figure 69 Rod 5 cladding temperature, 12.00 ft (deg. F) vs. Time

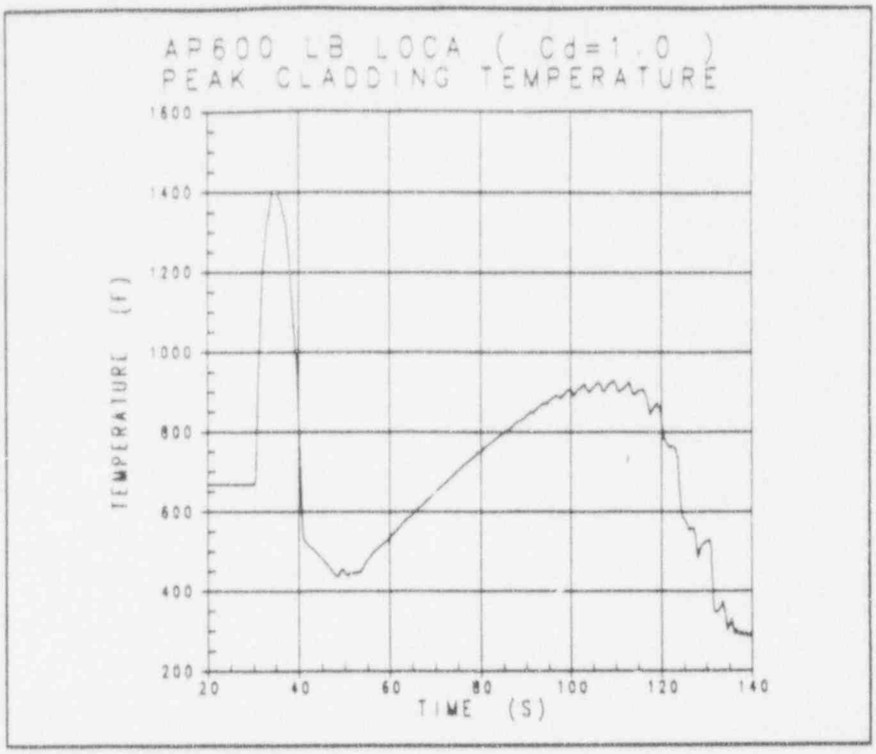

Figure 70 Peak Cladding Temperature (deg. F) vs. Time

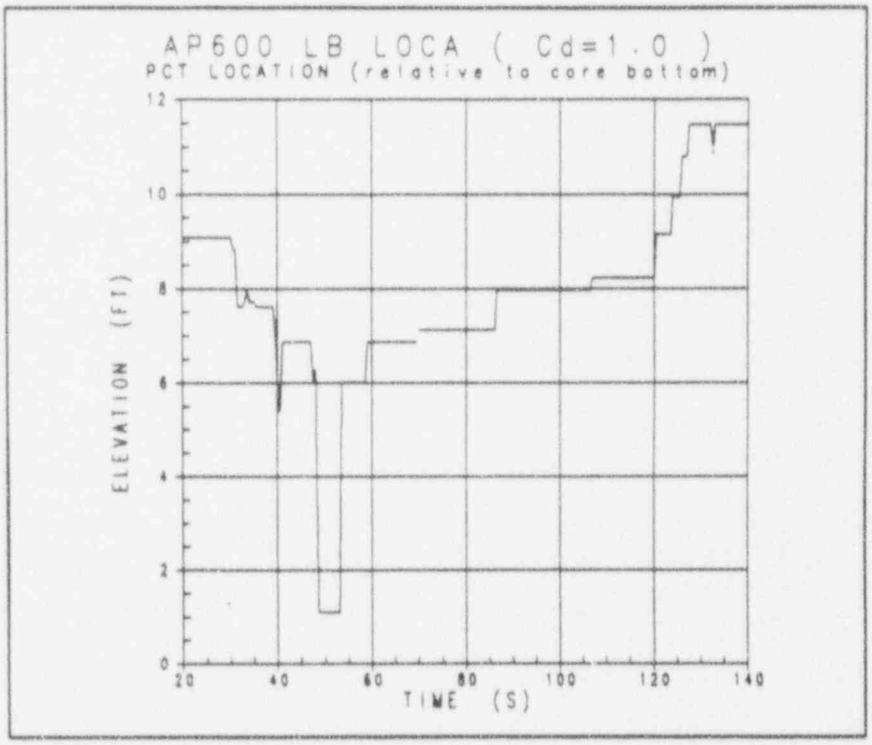

Figure 71 PCT Location (ft) vs. Time [relative to bottom of core]

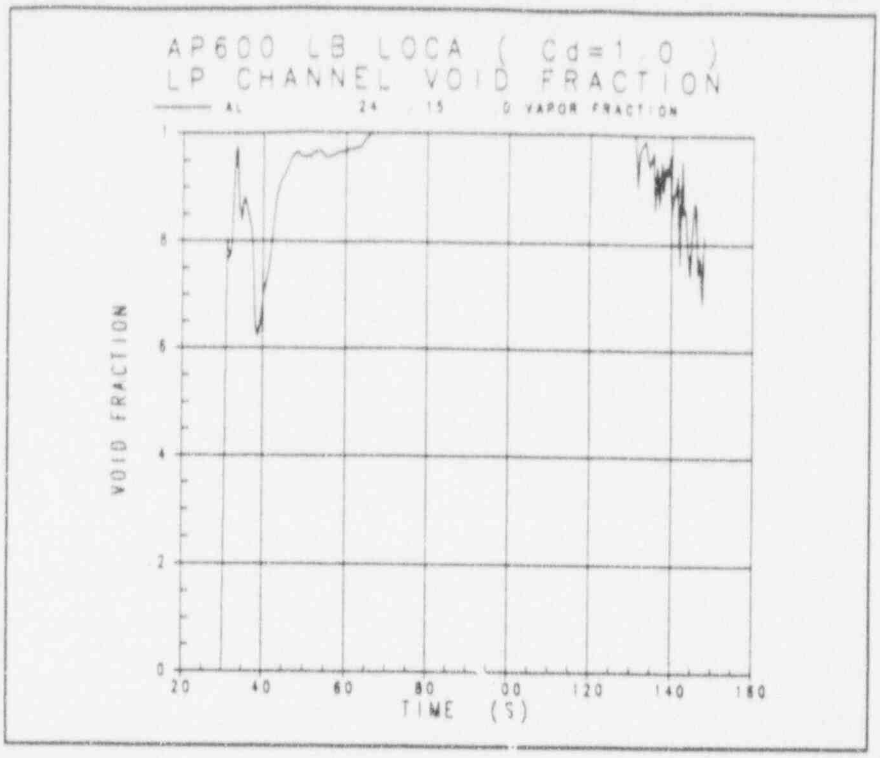

Figure 72 Void Fraction, Core peripheral channel, 12.0 ft elevation vs. Time

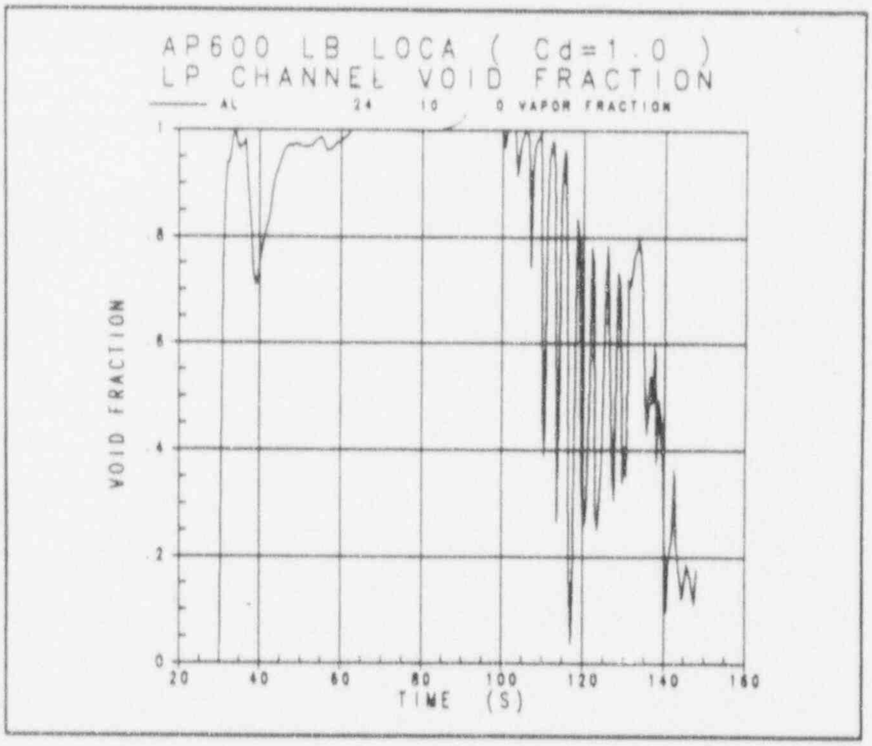

Figure 73 Void Fraction, Core peripheral channel, 7.75 ft elevation vs. Time

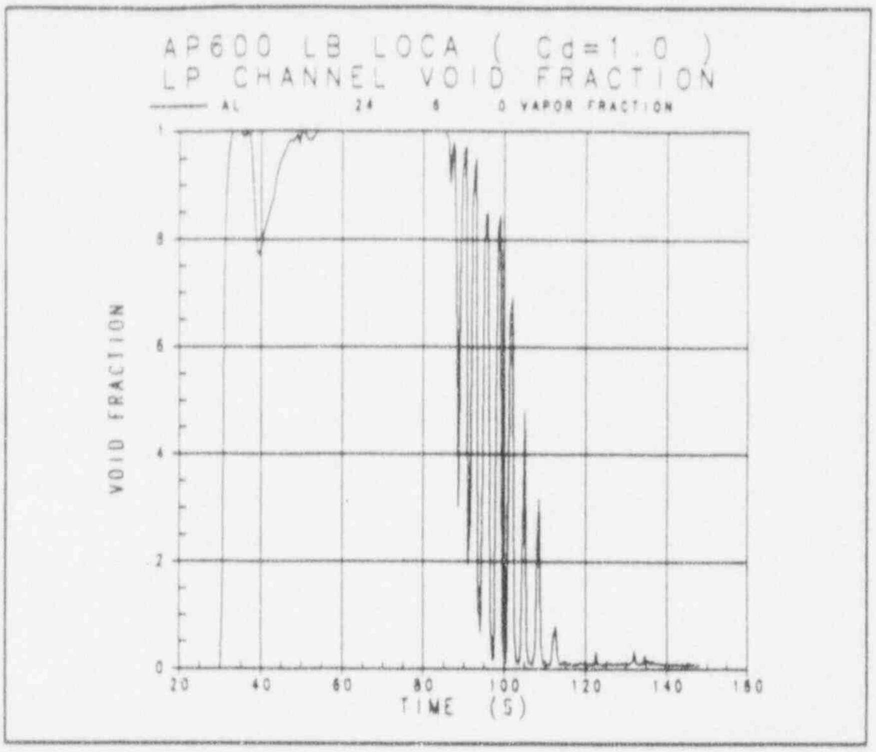

Figure 74 Void Fraction, Core peripheral channel, 4.1 ft elevation vs. Time

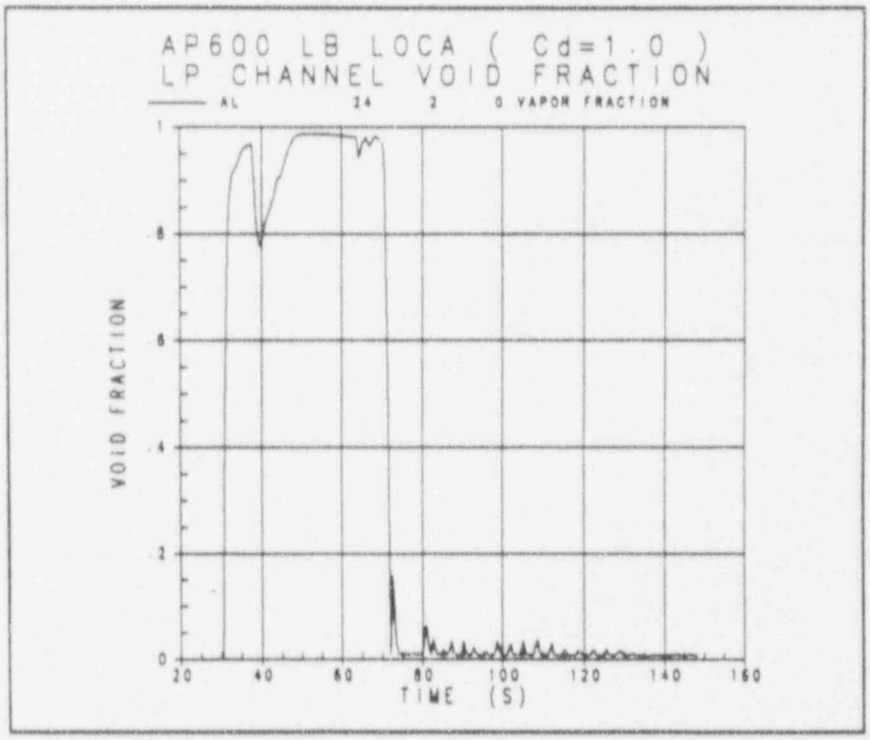

Figure 75 Void Fraction, Core peripheral channel, 0.0 ft elevation vs. Time

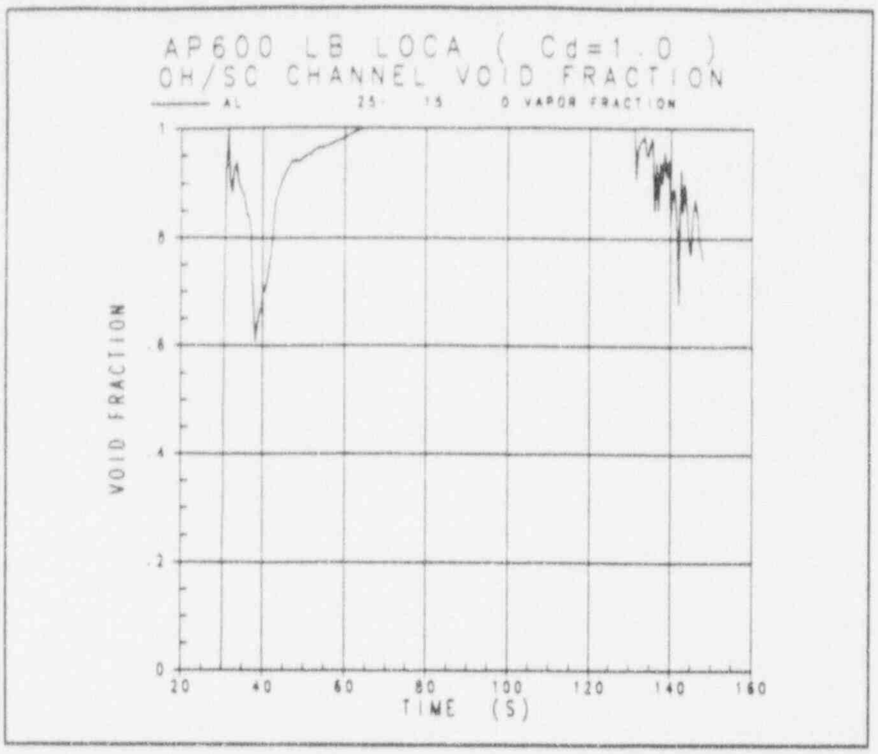

Figure 76 Void Fraction, Open hole channel, 12.0 ft elevation vs. Time

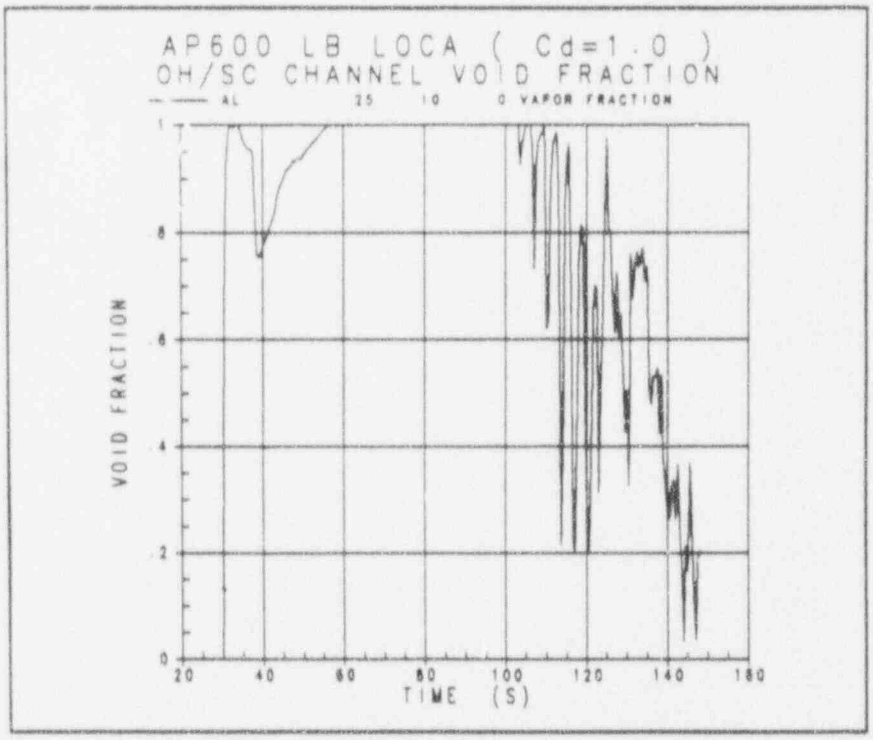

Figure 77 Void Fraction, Open hole channel, 7.75 ft elevation vs. Time

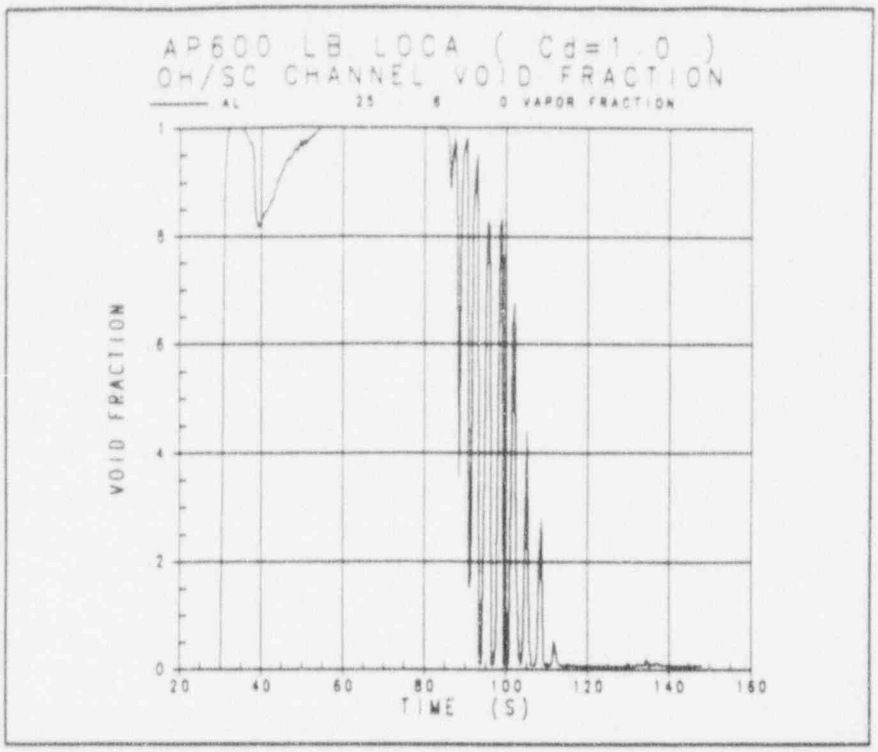

Figure 78 Void Fraction, Open hole channel, 4.1 ft elevation vs. Time

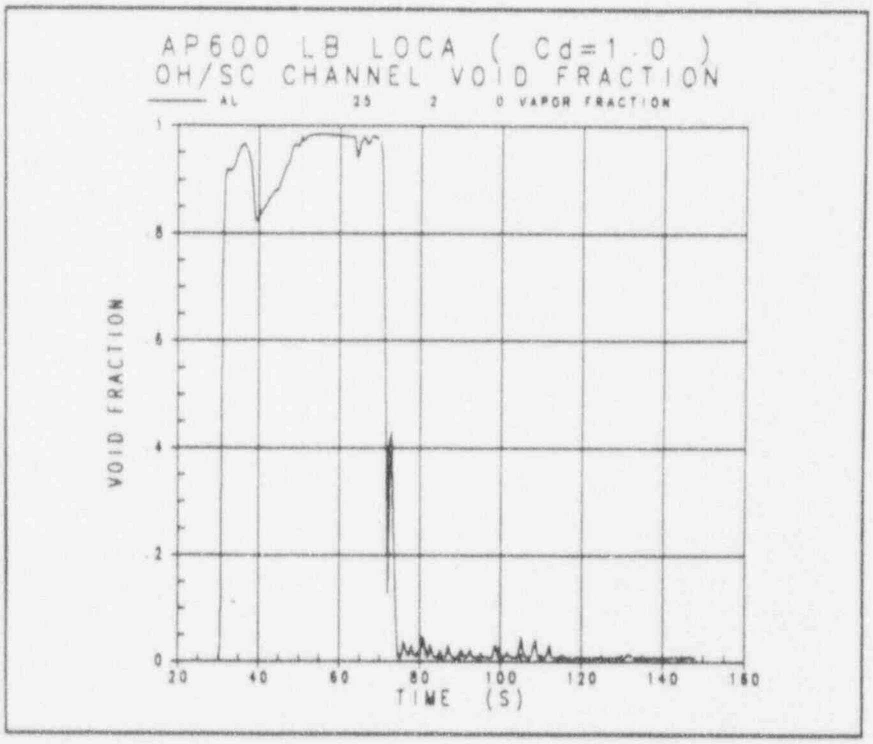

Figure 79 Void Fraction, Open hole channel, 0.0 ft elevation vs. Time

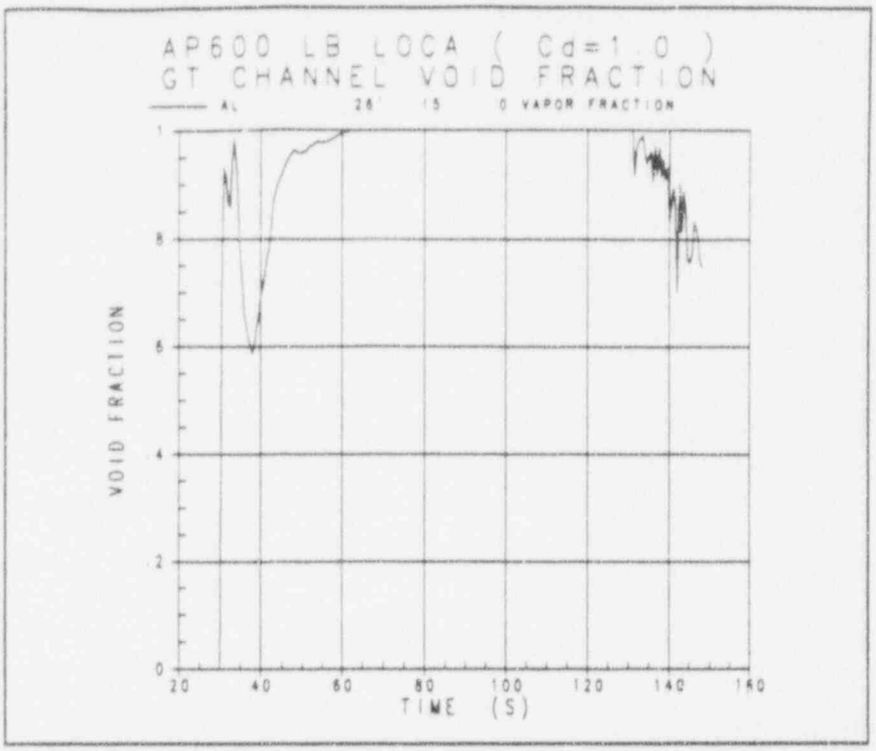

Figure 80 Void Fraction, Guide tube channel, 12.0 ft elevation vs. Time

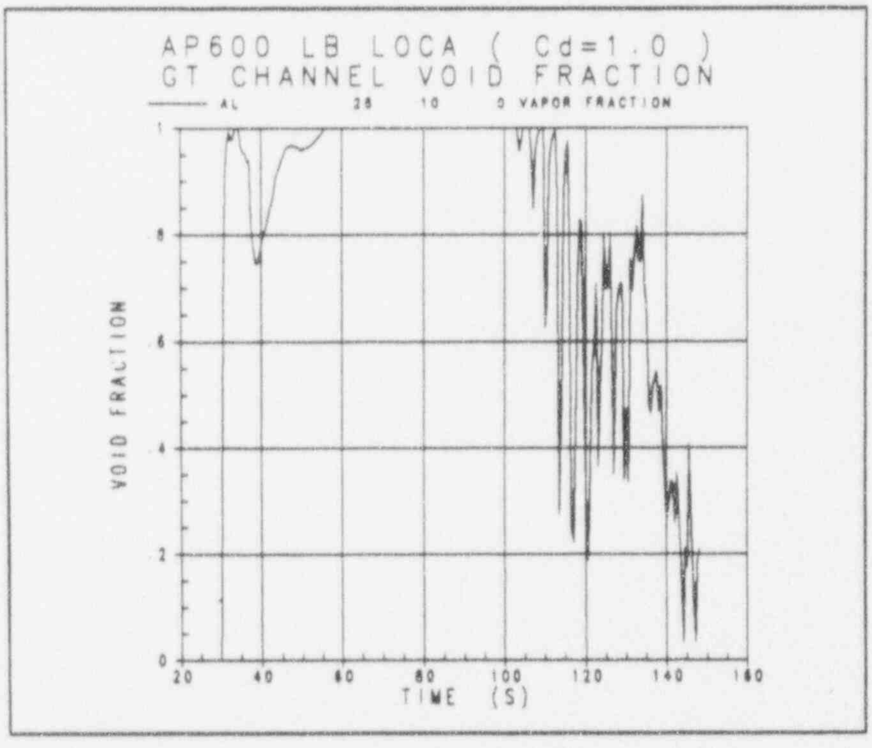

Figure 81 Void Fraction, Guide tube channel, 7.75 ft elevation vs. Time

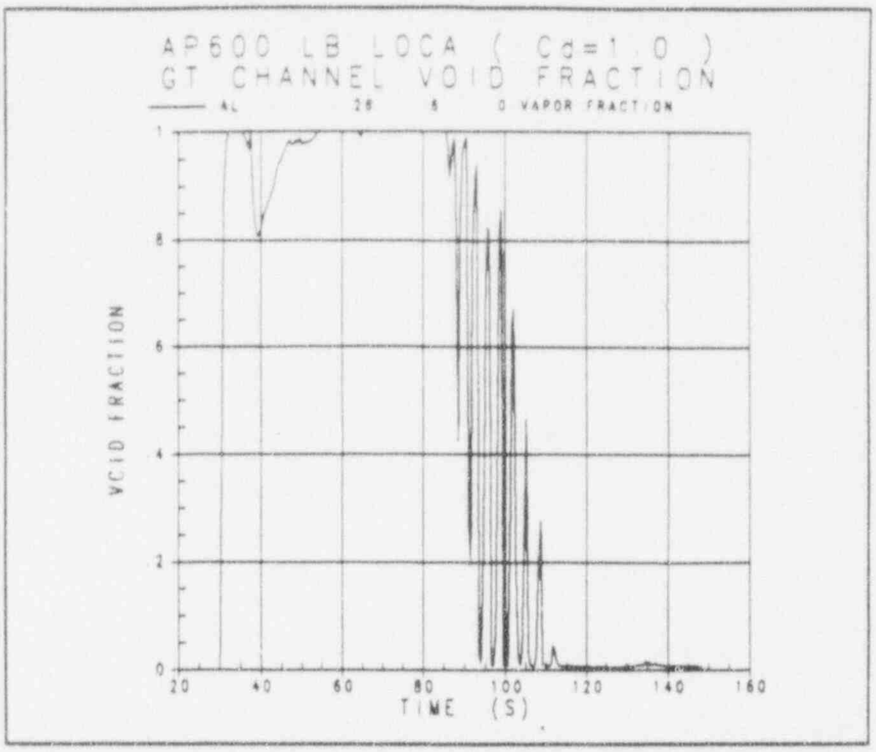

Figure 82 Void Fraction, Guide tube channel, 4.1 ft elevation vs. Time

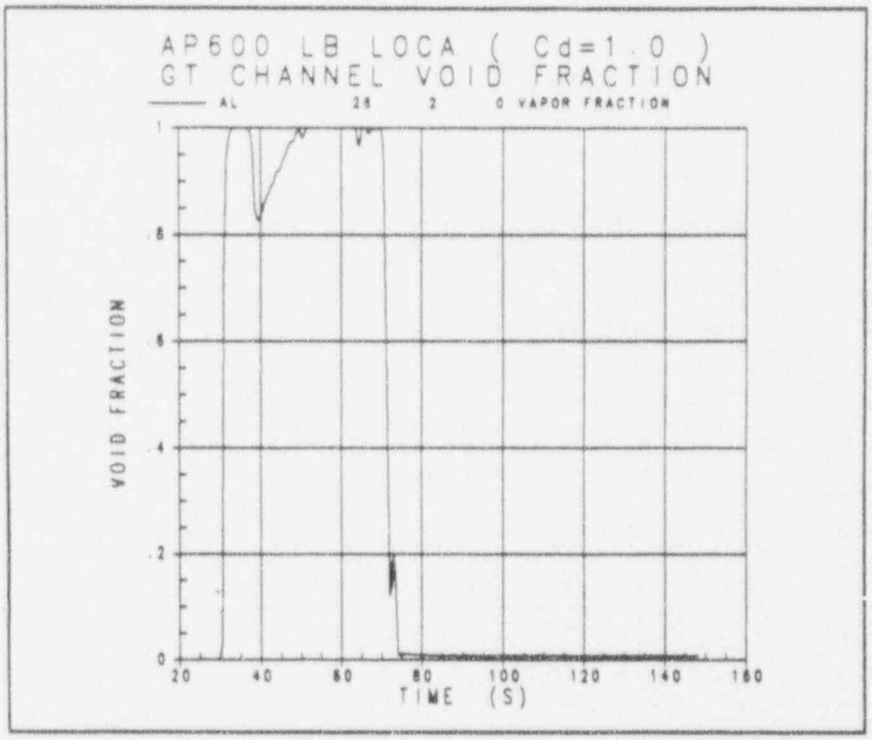

Figure 83 Void Fraction, Guide tube channel, 0.0 ft elevation vs. Time

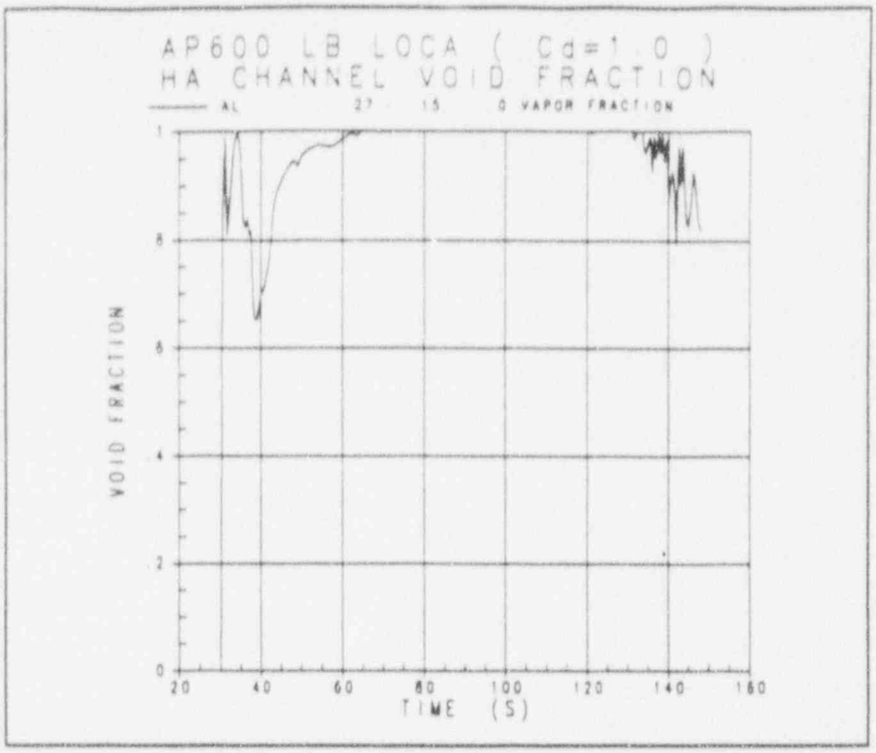

Figure 84 Void Fraction, Hot assembly channel, 12.0 ft elevation vs. Time

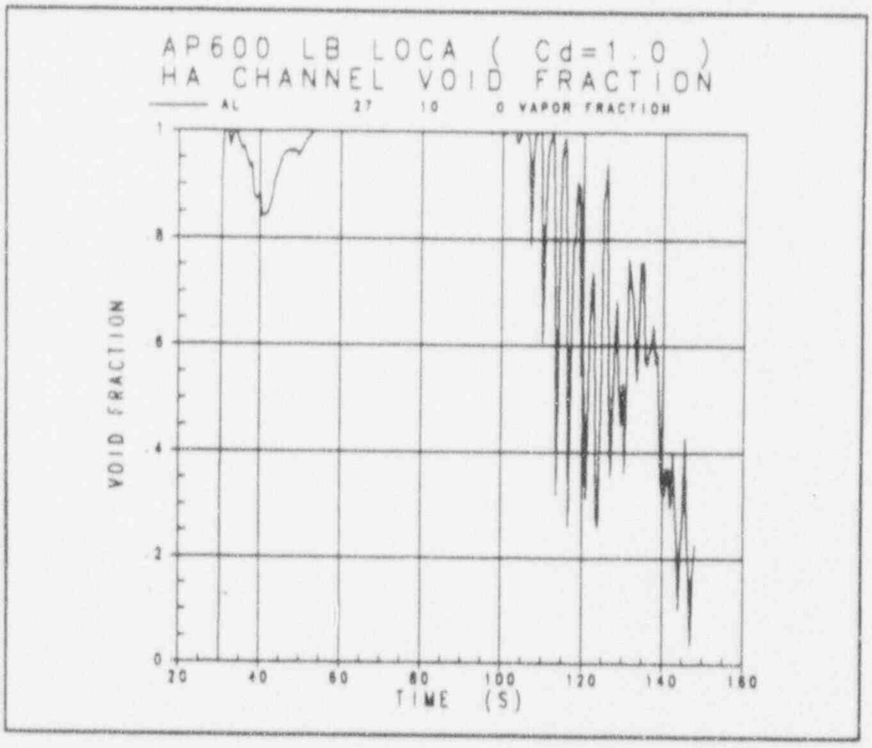

Figure 85 Void Fraction, Hot assembly channel, 7.75 ft elevation vs. Time

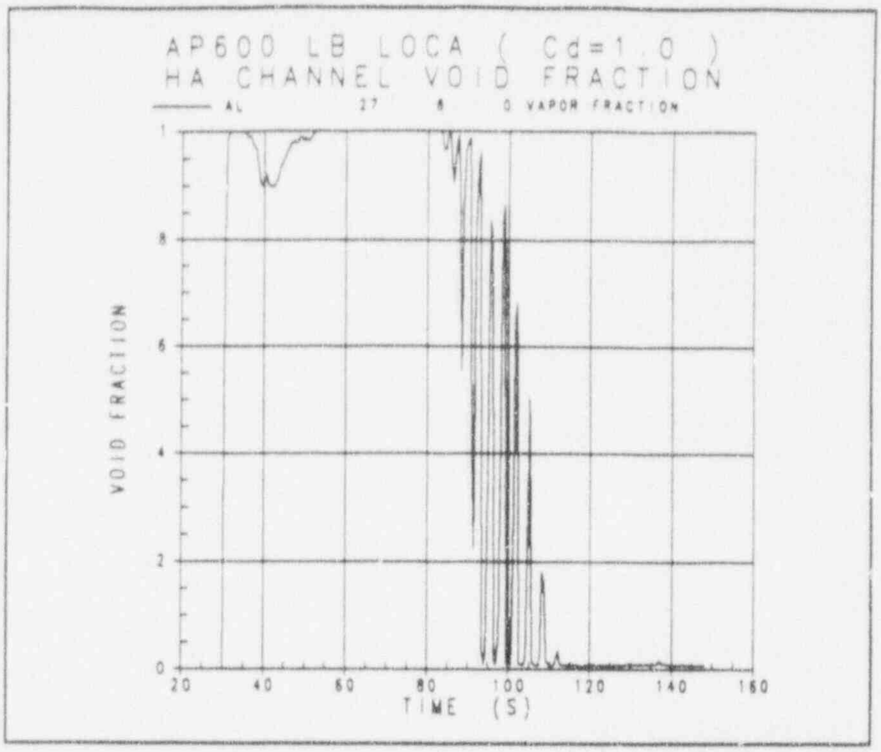

Figure 86 Void Fraction, Hot assembly channel, 4.1 ft elevation vs. Time

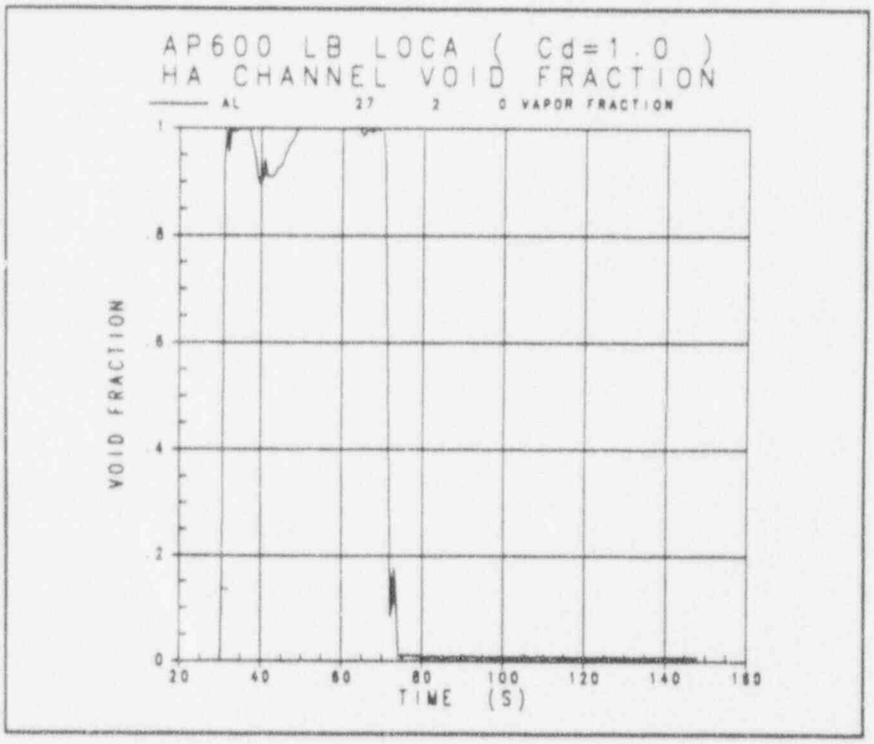

Figure 87 Void Fraction, Hot assembly channel, 0.0 ft elevation vs. Time

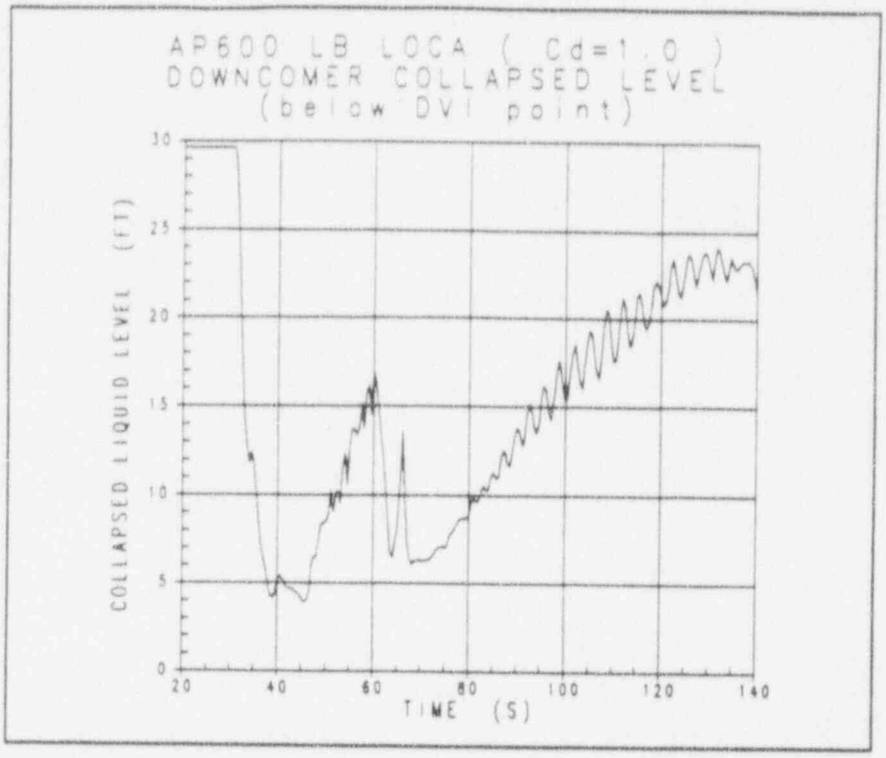

Figure 88 Downcomer collapsed level, below DVI point (ft) vs. Time

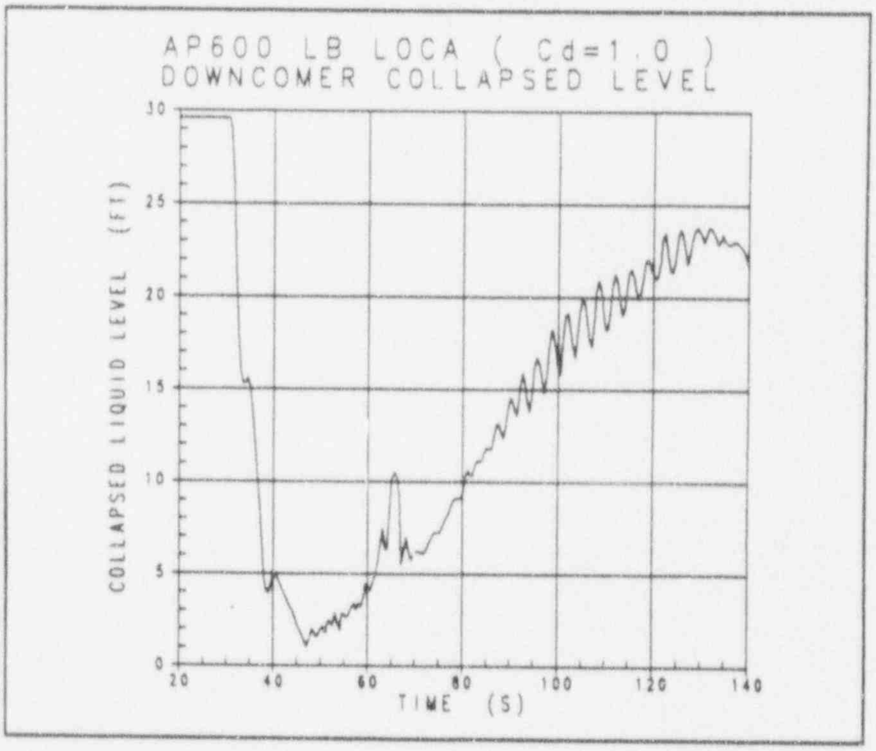

Figure 89 Downcomer collapsed level (ft) vs. Time

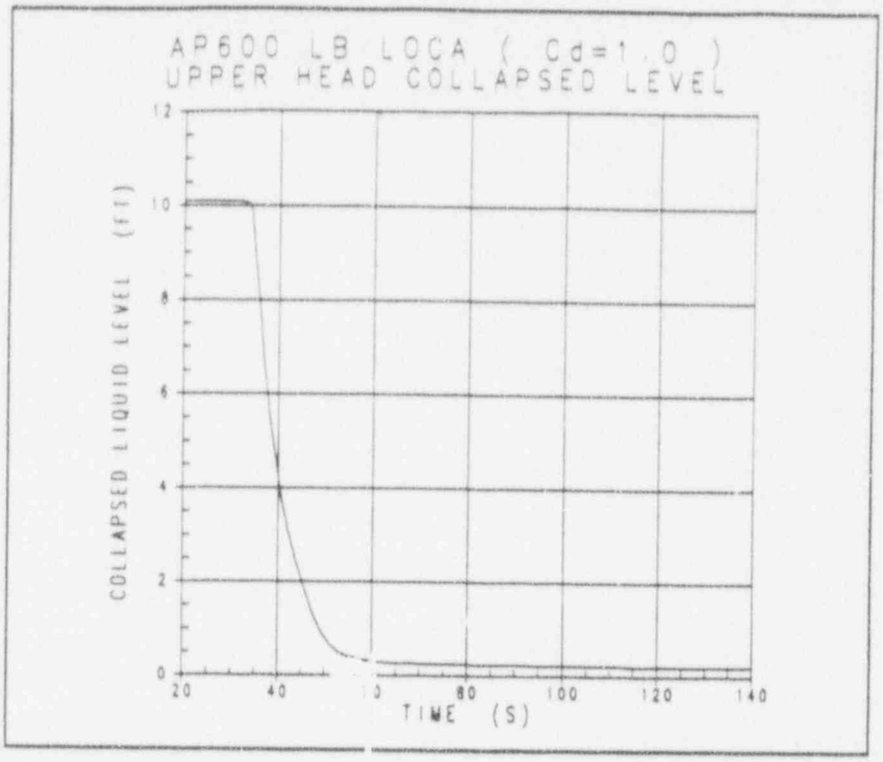

Figure 90 Upper head collapsed level (ft) vs. Time

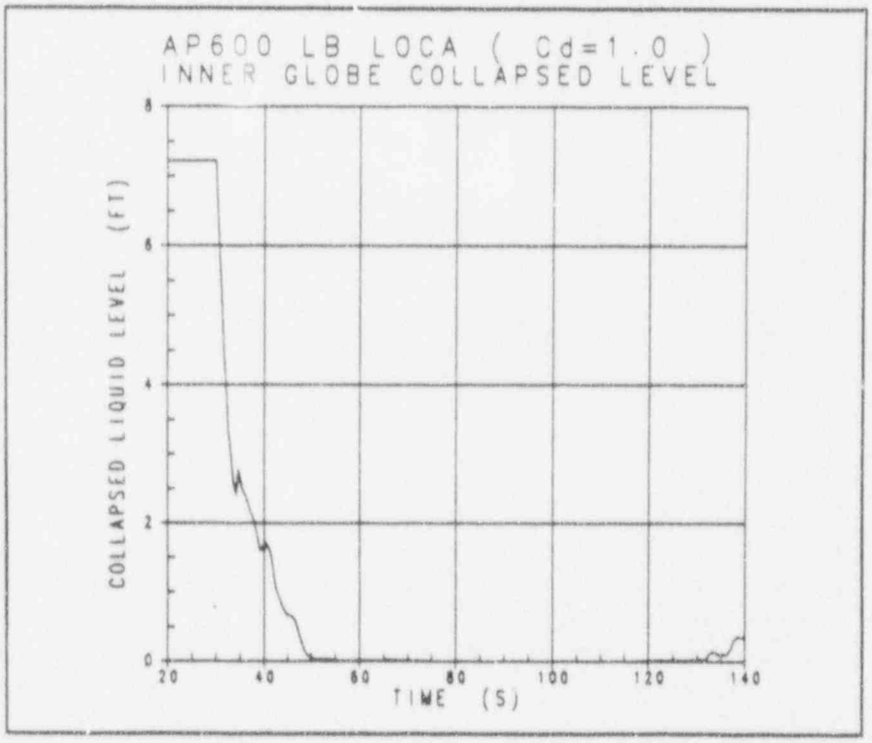

Figure 91 Inner globe collapsed level (ft) vs. Time

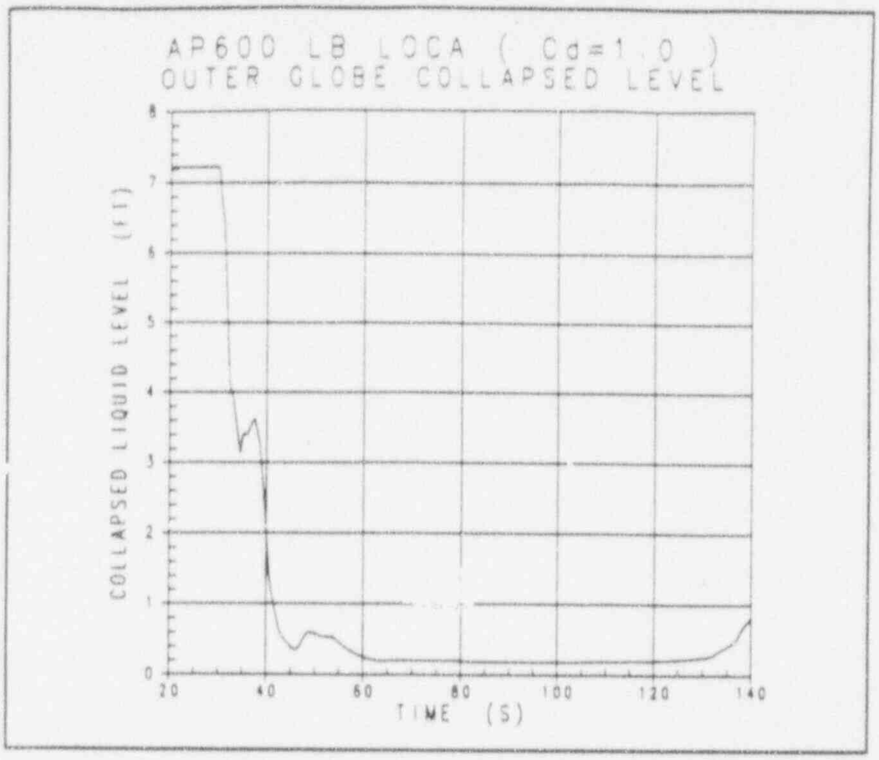

Figure 92 Outder globe collapsed level (ft) vs. Time

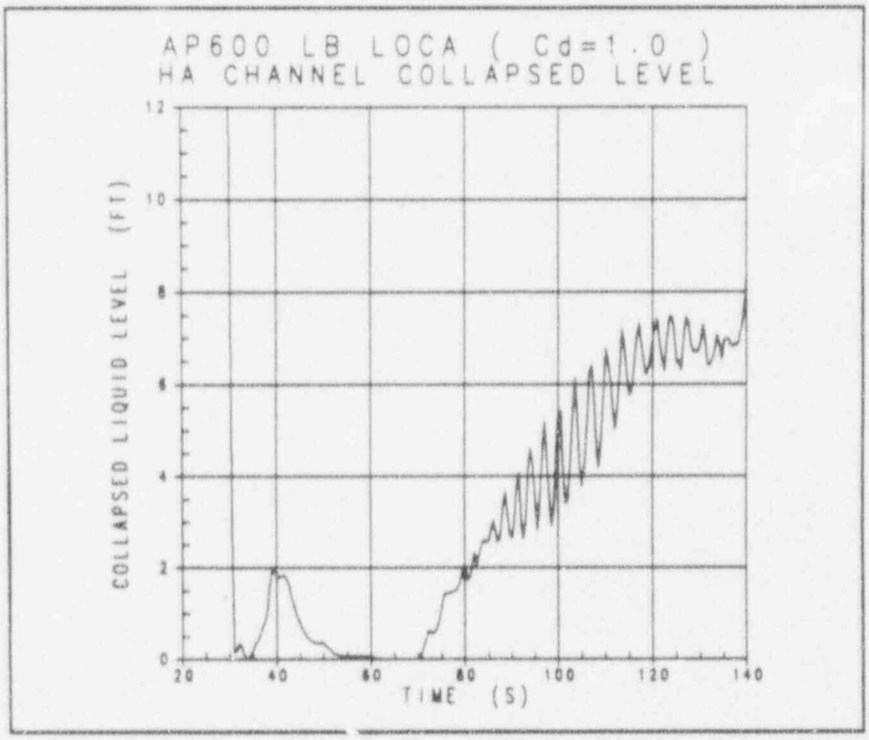

Figure 93 Hot assembly channel collapsed level (ft) vs. Time

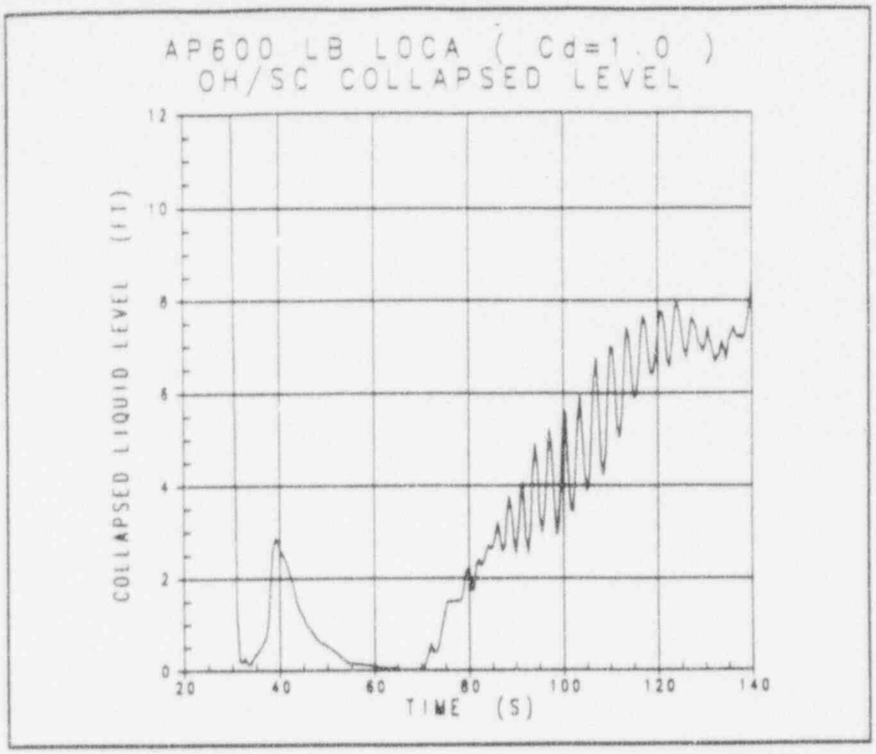

Figure 94 Open hole channel collapsed level (ft) vs. Time

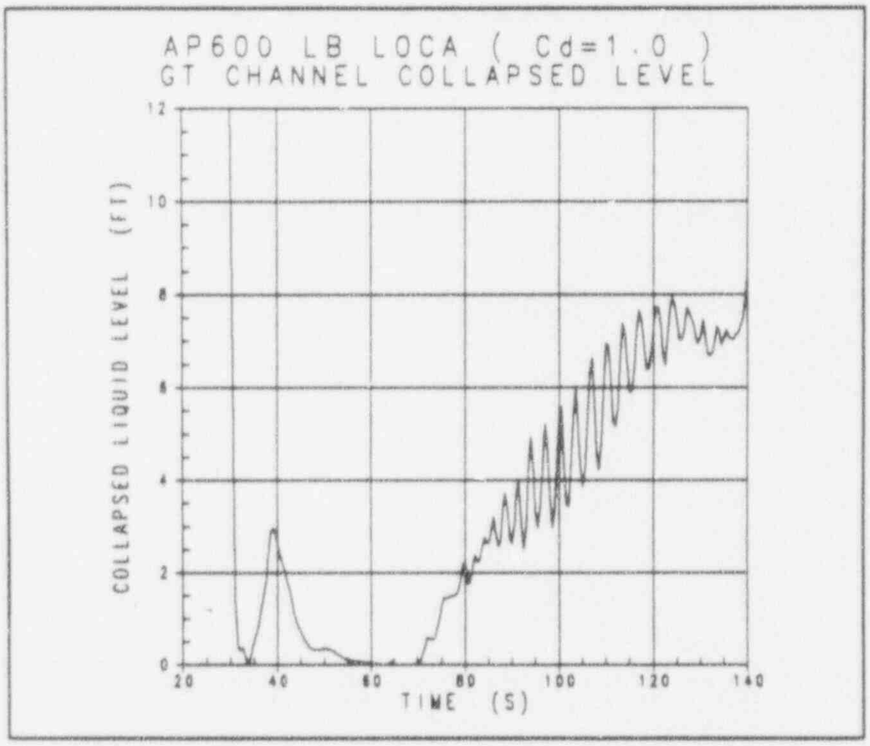

Figure 95 Guide tube channel collapsed level (ft) vs. Time

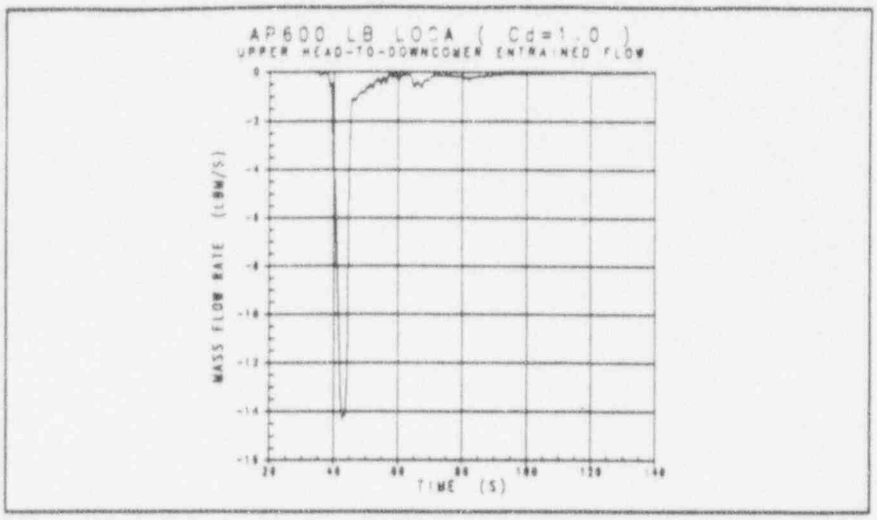

Figure 96 Upper head to downcomer entrained flow (lbm/s) vs. Time

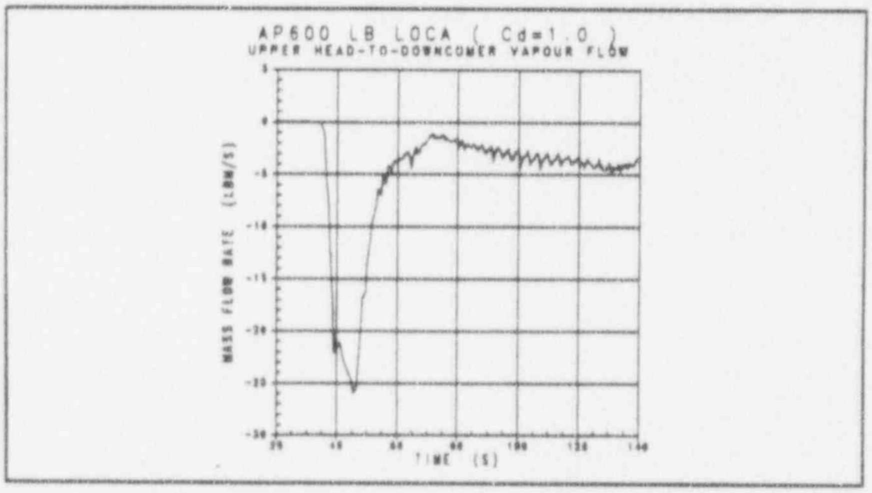

Figure 97 Upper head to downcomer vapor flow (lbm/s) vs. Time

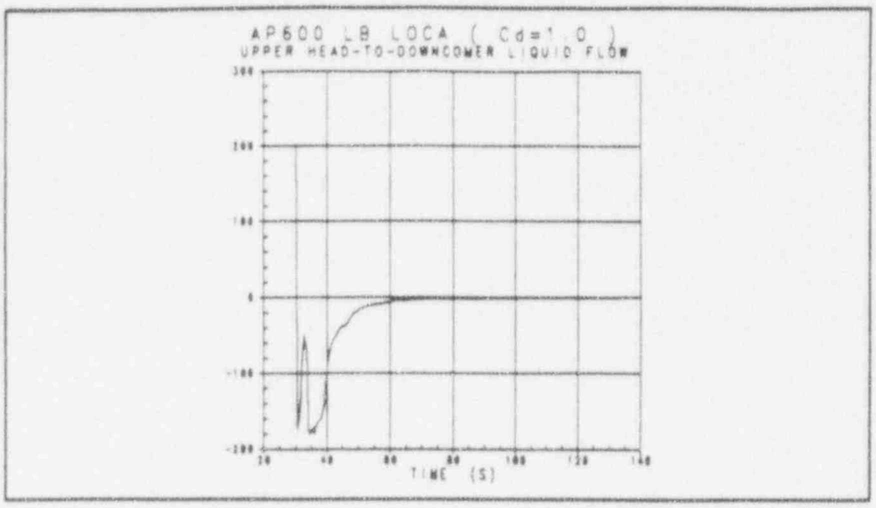

Figure 98 Upper head to downcomer liquid flow (lbm/s) vs. Time

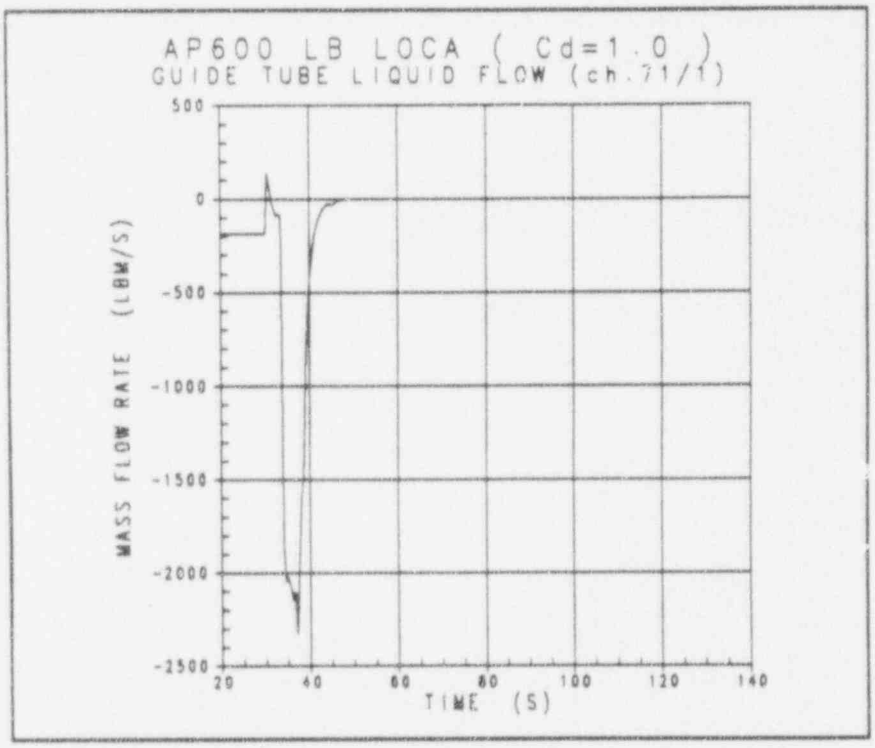

Figure 99 Guide tube liquid flow (lbm/s) vs. Time

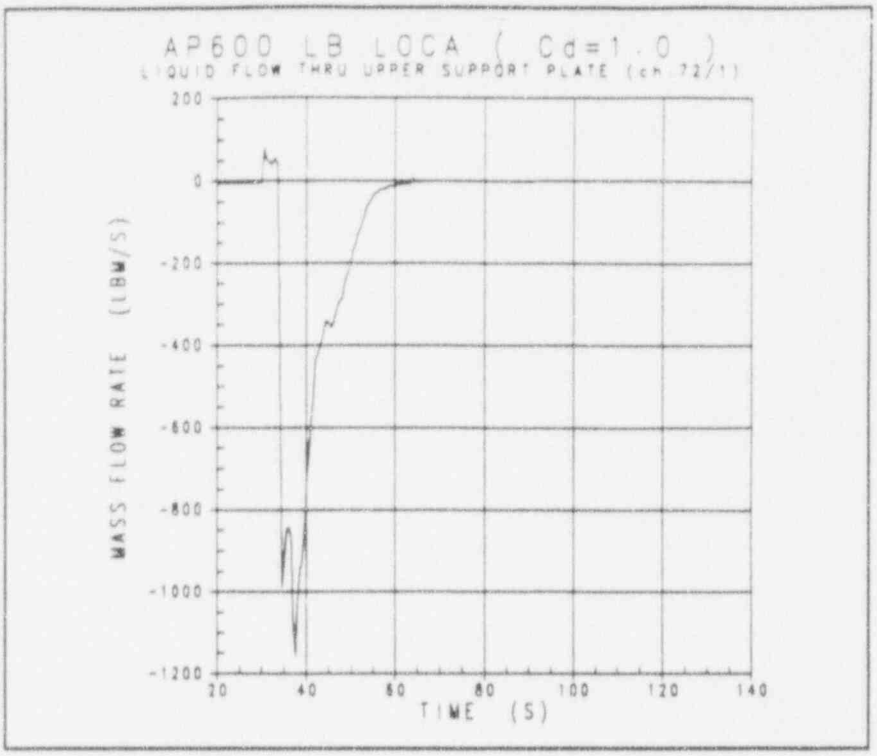

Figure 100 Liquid flow through upper support plate (lbm/s) vs. Time

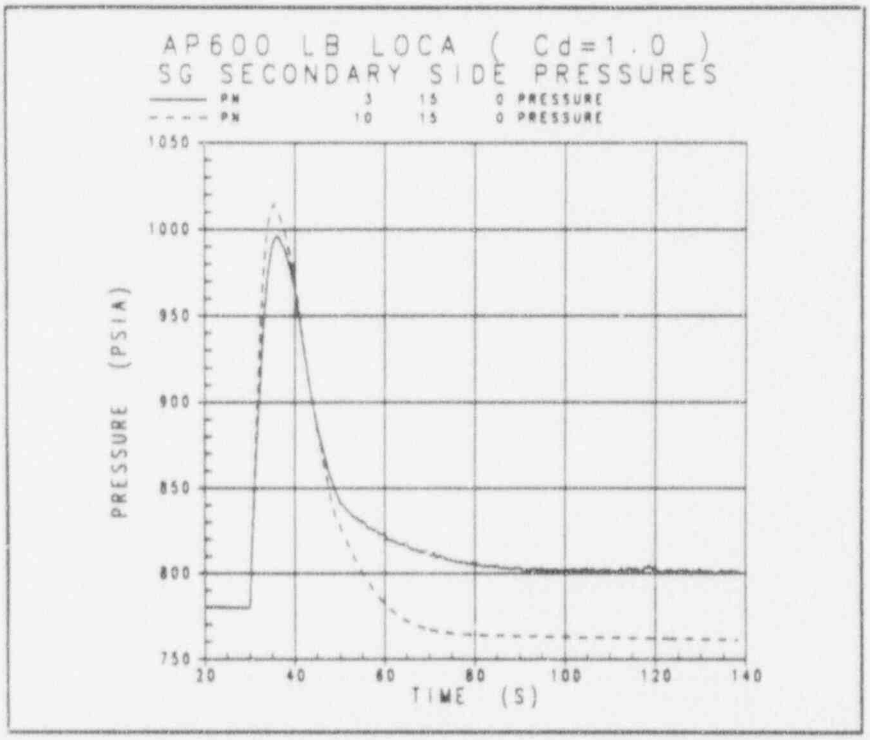

Figure 101 Steam generator secondary side pressure (psia) vs. Time

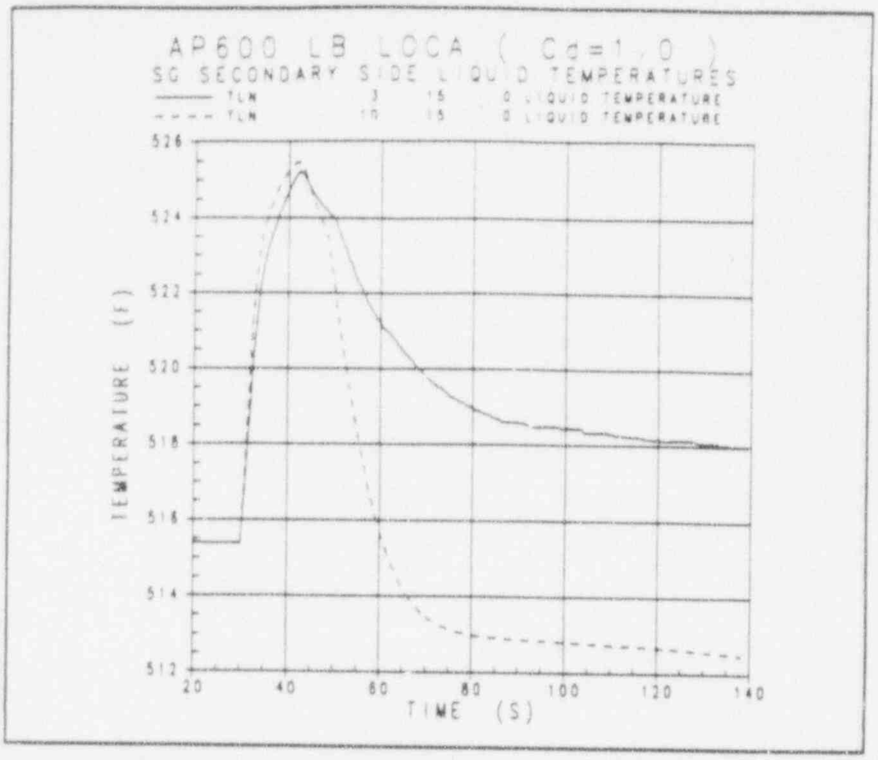

Figure 102 Steam generator secondary side liquid temperatures (deg. F) vs. Time