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INTERNAL TECHNICAL REPORT

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Organization: Semiscale Program

LOFT Test Support Branch

Author: J. L. Wambach

NRC Research and Technical Assistance Report

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LOFT TECHNICAL REPORT

Title	EXPERIMENTAL DATA REPORT FOR TRANSIENT FLOW CALIBRATION FACILITY TESTS IIIA101, IIIA102, IIIA201, AND IIIA202	LTR No.	LO-00-80-118
Author	J. L. Wambach *J L Wambach*	Released By LOFT CDCS	
Performing Organization	LOFT Test Support Facility	Date	March 26, 1980 *JL*
LOFT Review and Approval	*JJM WJJ* (LTSB Mgr.) *LP Leach* (Mgr., Semiscale Program)	Project System Engineer	

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LTR LO-00-80-118

EXPERIMENTAL DATA REPORT FOR TRANSIENT FLOW CALIBRATION FACILITY TESTS IIIA101, IIIA102, IIIA201, AND IIIA202

(INTACT LOOP COLD LEG SIMULATION WITH DTT RAKE AND/OR ECC PITOT TUBE RAKE INSTALLED)

By:

J. L. Wambach J. L. Wambach

Approved By: G. L. Martinell

W. J. Quapp

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ABSTRACT

Thermal-hydraulic response data are presented for the transient performance tests of an ECC pitot tube rake (IIIA201, IIIA202) and both an ECC pitot tube rake and modular drag disc-turbine transducer (DTT) rake (IIIA101, IIIA102). The tests were conducted in a system which provided full scale simulation of the pressure vessel and intact loop cold leg piping of the Loss of Fluid Test Facility (LOFT). A load cell system was used to provide a reference mass flow rate measurement.

SUMMARY

This report presents the results of transient blowdown tests of the LOFT ECC pitot tube rake and a modular Drag-Disc-Turbine Transducer rake, performed at the Transient Flow Calibration Facility at Wyle Laboratories in Norco, California. The facility was configured to provide a full scale simulation of the pressure vessel and intact loop cold leg of the Loss of Fluid Test Facility (LOFT). The test system was supported on load cells which provided a reference mass flow rate measurement to assess the theoretical model and calibration of the DTT and ECC pitot tube rakes. Density, pressure, differential pressure, and temperature data were also taken to aid in evaluating the response of the DTT and ECC pitot tube rakes.

Preliminary analysis of the test data indicates that the blowdown transients were repeatable and that the reference mass flow rate can be accurately determined from the load cell data. The response of the DTT rake, ECC rake, and gamma densitometers indicate that homogeneous liquid, homogeneous and stratified two-phase, and homogeneous single phase steam flow regimes were simulated during the test. The data can be used for assessment of instrument performance and evaluation of modeling techniques.

CONTENTS

FIGURES

TABLES

I. INTRODUCTION

A major objective of the Loss of Fluid Test (LOFT) program is to provide a data base for use in evaluating computer codes used to predict the response of a pressurized water reactor system to a hypothesized loss of coolant accident. In order to provide an effective data base, the LOFT instrumentation must be modeled, calibrated, and tested to establish the response, accuracy, and reliability of the measurement systems. Previous instrument models and analytical techniques based on scale model and single phase calibrations have not been effective in reducing data from diverse instrument systems to a reliable, consistent mass flow measurement during transient blowdown conditions. For this reason, a system was constructed to provide full scale LOFT geometry blowdown transients with a reference mass flow measurement system independent of local flow geometry. The requirements for the test program are detailed in Reference 1.

The independent mass flow measurement was achieved by supporting a simulated LOFT pressure vessel on load cells, and recording the weight transient during blowdown. Although the load cell system is subject to spurious mechanical loads, preliminary analysis of the test data has shown the system to be reliable, repeatable, and accurate within ±1.0% of system fluid weight, as required. This report presents the results obtained from a series of blowdown tests which were performed with the modular Drag disc - Turbine - Transducer rake (DTT) and/or an ECC pitot tube rake in the intact loop cold leg configuration.

II. TEST EQUIPMENT AND CONFIGURATION

1. PRESSURE VESSEL AND UTILITY PIPING

The pressure vessel for the transient flow calibration test (Figure 1) is made from carbon steel, with a volume of approximately 5.4 cubic metres (190 cubic feet). The vessel is equipped with a removable flanged upper head and a flanged discharge nozzle, bored and threaded to mate with a 14-inch, 1500 lb, Sch. 160 bore raised face flange. The discharge nozzle is located on the side of the vessel, 200 inches above the bottom of the inside of the lower vessel head. Flanged utility penetrations are provided at the top and bottom of the vessel for filling, venting, heating, and pressurizing the vessel, and for instrument penetrations. For these tests, the vessel was equipped with a removable carbon steel flow skirt to simulate the LOFT downcomer. Additional tapped holes are provided up the side of the vessel for thermocouples, pressure taps and a downcomer vent.

The pressure vessel is supported vertically from three equally spaced cantilever lugs located at the outlet nozzle centerline. The lugs support the full weight of the vessel, through the load cells. The load cells are mounted on steel pads on a concrete wall around the top of the concrete lined pit containing the bulk of the vessel.

The primary heatup line to the vessel is a 2-inch Sch. 160 carbon steel pipe which runs from the accumulator, at top of the pit wall, to the branch side of a 6-inch flanged tee bolted to the lower vessel penetration (see schematic, Figure 2). The run side of the tee is used for liquid level probe penetrations. The accumulator has a volume of 0.11 m^3 (4.0 ft^3) and is used to store hot water which is forced into the vessel for final pre-test pressurization. A 1-inch

Sch. 160 pressure relief line and a 2-inch Sch. 160 vent line join the 2-inch heatup line near the top of the pit wall. The top of the vessel is equipped with a 1-inch Sch. 160 vent line.

2. TEST PIPING AND SUPPORTS

The test piping consists of the vessel outlet elbow, the instrument test section, a shutoff gate valve, burst disc assembly, and discharge assembly. A perspective view of the test piping installation is shown in Figure 3.

The vessel outlet spool is a 14-inch Sch. 160 carbon steel 45^{o} elbow with a 14-inch, 1500 lb rated flange on the vessel end, and a Rocky Mountain Nuclear clamp-type hub on the other. A 3/8-inch NPT pressure tap is provided at the bottom center of the elbow.

The instrument test section is made from 14-inch Sch. 160 300-series stainless steel pipe with a Rocky Mountain Nuclear clamp-type hup upstream and a 1500 lb rated 14-inch flange downstream (see Figure 4). Penetration flanges are available for mounting both the modular DTT rake and the ECC Pitot tube rake. A 4-inch orifice plate was mounted inside the pipe, downstream from the DTT rake port. Several pressure taps are provided along the length of the test spool. Lugs, mounting pads, and holes are provided on the outside of the spool for mounting two densitometers and an accelerometer.

The shutoff gate valve is a 1[illegible]nch, 1500 lb unit fitted with a 14-inch, 1500 lb flange upstream (12-inch Sch. 160 bore), and a 10-inch, 1500 lb flange downstream. The 10-inch flange is specially machined to mate with the burst disc assembly. The burst disc assembly consists of two Inconel burst discs sandwiched between three steel rings with a clear diameter of 15.2 cm (six inches). The center ring has a pressure port to control the operation of the burst discs. The assembly has small bolts for holding the unit together for assembly, but the main clamping force is supplied by the 10-inch flange bolts.

The discharge assembly is a 10-inch Sch. 80 carbon steel pipe with a 1500 lb, special face flange upstream, and a flow splitting "tee" at the discharge. The tee is made from two long radius 90^0 10-inch tube bends, sectioned and welded together.

The test piping is supported by the vessel outlet flange and by a load cell at the downstream end of the discharge assembly. The loadcell rests on a 4100 Kg concrete reaction mass which is supported on four 30.5 cm. diameter air springs. In addition to the flexibility of the air springs, the reaction mass has rollers at the pipe support points to allow for axial thermal expansion.

3. INSTRUMENTATION

Instrumentation for the transient flow tests consists of reference instruments for determining the system weight, vessel mass inventory, and fluid conditions in the vessel and test section, and test instruments which are those being evaluated, with some instruments performing a dual role. All instruments used in the cold leg DTT/pitot tube rake tests are listed in Reference 1, and shown schematically in Figures 5 and 6.

The primary transducers for determining the system weight are the system load cells. The vessel load cells are a precision low profile shear web design with a rated capacity of 222 KN each (50,000 lb), with a rated accuracy of 0.1% full scale or better. The discharge assembly load cell is of the same design, with a rated capacity of 111 KN (25,000 lb). The load cells are highly resistant to spurious loads, and are temperature compensated to 46^{o}C (115^{o}F). To further guarantee the accuracy of the load cell readings, the vessel load cells were mounted on precision-leveled steel pads with a 5-cm thick steel load ring above the cells to isolate them from transverse loads, and 0.5 m long hollow stainless steel columns between the load ring and vessel support lugs for thermal isolation. The discharge assembly load cell was mounted on the concrete reaction mass. A reaction link connected to the end of the discharge tee provided support for the horizontal impulse load due to fluid acceleration in the piping at blowdown initiation. All other support/restraint members are either fitted with rollers to allow expansion, or are backed off the pipe during tests.

In addition to the factory calibration, the load cell system was given an in-place calibration by filling the vessel with cold water metered through a calibrated turbine meter. Details of the results of the calibration are listed in Reference 3.

A second reference vessel mass inventory measurement is provided by the top-to-bottom vessel differential pressure measurement (DP-V-2) and the vessel outlet-to-bottom differential pressure (DP-V-1). The pressure taps are located in the upper vessel head penetration flange, in the vessel wall 46 cm. below the outlet nozzle centerline, and in the 2-inch lower vessel fill line, approximately 33 cm. below the lower vessel flange. Dual differential pressure cells are provided for the vessel top-to-bottom differential pressure measurement with ranges of 75 and 350 KPa. The transducers are located below both pressure taps, at the bottom of the vessel pit. The instrument lines are 1/4-inch o.d. stainless steel. The lower sense line is water cooled near the vessel. The upper sense line has a 1.5-meter horizontal run from the pressure tap before starting the vertical run.

In addition to the vessel differential pressure measurements, additional pressure and differential pressure measurements are provided with locations and ranges as noted in Table I and Figures 1, 4, 5, and 6. All pressure taps except those noted have water jacketed pressure probes, which bring the cooling water flow within 0.32 cm. of the inner surface of the pipe. One exception is the pressure tap directly below the 14-inch outlet flange which was fitted with an external cooling jacket (to within 10 cm. of the vessel outer wall).

Fluid temperature measurements are taken with ISA type K grounded junction thermocouples, as noted in Table I and Figures 4, 5, and 6.

The primary flow instruments to be evaluated from these tests are the LOFT ECC Pitot tube rake and a modular drag disc turbine rake (DTT). The ECC rake consists of a flange and a mounting stalk which houses 4 sense lines with stagnation probes. The pitot tube openings are flush with the end of the kiel shields, see Figure 7. The differential pressure transducers are low range (± 42 KPA) and are located on an instrument panel directly below the test spool. The reference leg is set at the test spool center elevation, as is one of the pitot tubes (DP-ECC-3). Instrument lines are water cooled and the sense lines are continuously purged by 70^{o}F water (see Figure 8), which is at a pressure slightly above system pressure. For Test IIIA201, the purge system was not used. The sense lines were bled prior to testing and then closed off to prevent blowdown.

In addition to the pitot tubes, there are fluid temperature thermocouples mounted on the rake. The thermocouples are standard type K grounded junction thermocouples. For an instrument reference drawing, see Reference 4.

For two of the tests (IIIA101 and IIIA102), the modular DTT rake was also tested. The DTT rake consists of three individual DTT units. Each DTT has a shroud housing a drag disc, a turbine meter, and a thermocouple, in that order. The drag disc force is translated to an electrical output using a leaf spring and a variable reluctance transducer. The turbine meter uses an eddy current transducer for a pickup. The thermocouple is a standard type K grounded junction thermocouple. A cross section of the DTT rake installation is shown in Figure 9. Reference drawing is listed in Reference 5.

A six beam gamma densitometer is mounted upstream of the DTT penetration. The six-beam gamma densitometer consists essentially of two three-beam units (Reference 6) mounted on a common clamp, one on each side of the pipe. Each densitometer consists of a radioactive gamma ray source, a collimator flask, and three separate scintillation detector and photomultiplier units. The shielded gamma ray source casks contain approximately 30 curies of cesium 137. Air lines are provided to the source casks to move the sources to the collimators, to expose the sources for operation. The photomultiplier tube housings are water cooled to make the unit readings more uniform and repeatable. The six beam densitometer assembly is shown in Figure 10. The calibration of the six beam densitometer is discussed in Reference 7. In addition to the six beam densitometer, a three beam densitometer is mounted near the discharge of the test spool. See Figure 11.

In addition to the primary objective of evaluating the response of the DTT and pitot tube rakes, these tests also provide data to evaluate the response of the liquid level probes in the vessel and downcomer annulus.

4. SIGNAL CONDITIONING AND DATA ACQUISITION

Data acquisition channels for the transient tests consist of low and high level signals, with different signal conditioning for each type. The low level signals, came from thermocouples and bridge circuits (pressure, differential pressure, etc.) and were routed directly to the Wyle computer room for amplification (x 1000, x 333, or 1). High level signals originated with special EG&G instruments (gamma-densitometers, DTT rake, etc.). The high level signals were routed to special instrument-unique amplifiers and conditioning equipment in the EG&G trailer before being routed to the Wyle computer room for final amplification (x 10, x 2, or x 1) as required. Channels for recording on analog tape were also amplified to a 10 volt full scale level.

Instrument cables are of the twisted pair, shielded type, and are contained in protective trays from the test area to the instrument trailer, and from the trailer to the computer room. Instrument standard wire connectors are used at the instrument connections, and the signal leads are hard-wired at the signal conditioning amplifiers.

All data channels for digital recording were filtered at 10 Hz, digitized with 14 bit resolution, and recorded on a disc at a sample rate of 50 samples per second. Precision voltage calibration steps were inserted into the data immediately prior to and after testing.

Data channels for analog recording were sent to a buffer amplifier, and recorded, unfiltered, on 14-track analog tape. The voltage calibration steps were also fed to the analog system. Additional data acquisition system requirements and data formats are detailed in Reference 8.

III. TEST PROCEDURE

Prior to the start of each test, all systems were checked for operability, and for adequate supplies of fuel, coolant, etc. The instrument sense lines were filled and bled, using the purge system (Figure 8), and the load cell readings were evened by adjusting the air spring pressures. Cooling water flow was initiated to the pressure probes and gamma densitometers. A sample of the vessel water was taken for subsequent analysis. See Table II for results of the water chemistry analysis. A voltage insertion was performed to check data acquisition system performance.

The system was heated and filled to operating conditions by introducing steam into the bottom of the empty vessel through the 2-inch heatup line. A uniform temperature distribution was promoted during the condensation process by venting the system through vent lines at the top of the vessel, at the top of the downcomer annulus, and just upstream of the burst disc assembly. The heatup steam circulated through the accumulator to provide a supply of hot water for later use in bringing the system to test pressure. Data scans were taken periodically during heatup to check progress and verify instrument integrity.

After the vessel was heated to nominal test temperature, the steam flow was reduced, and the system was allowed to stabilize for approximately one hour to provide a more uniform temperature distribution in the system. When the temperature distribution was acceptable, all vents were closed, and the high pressure charging pump was started to force additional hot water into the system to raise the pressure to a moderately subcooled condition for taking the pre-test gamma densitometer calibration scans. After these data scans were taken and reviewed, the system was pumped up to test pressure and a final data scan was taken and reviewed to assure system readiness to test. Initial conditions for these tests are summarized below.

Test IIIA101

Pressure	-	15.6 $\pm$ 0.2 MPa
Temperature	-	564 $\pm$ 2 K
Liquid Level	-	System full

Test IIIA102

Pressure	-	15.5 $\pm$ 0.2 MPa
Temperature	-	564 $\pm$ 2 K
Liquid Level	-	System full

Test IIIA201

Pressure	-	15.6 $\pm$ 0.2 MPa
Temperature	-	562 $\pm$ 2 K
Liquid Level	-	System full

Test IIIA202

Pressure	-	15.6 $\pm$ 0.2 MPa
Temperature	-	565 $\pm$ 2 K
Liquid Level	-	System full

With the system conditions approved for testing, the analog tape recorders were started and allowed to warmup, the digital data acquisition system was started, and the pre-test voltage insertion calibration was run. When data acquisition was verified, blowdown was initiated by venting the cavity between the burst discs.

Approximately 90 seconds after blowdown initiation the post-test voltage insertion calibration was performed, and data acquisition was terminated. The shutoff valve was closed and a post-test gamma densitometer calibration was performed. The system was placed in a shutdown mode and a low pressure nitrogen purge was introduced to the vessel. See Table III for a synopsis of the timing for each test.

IV. DATA REDUCTION

After completion of each test, the test data was transferred from the magnetic disc to magnetic tape in the same basic format as the data was recorded. The format was a single string of characters with data points for the various individual transducers repeating in a fixed sequence. See Reference 8 for a complete description of the data format. The first step in reducing the data was to convert from the recorded 16-byte words to 60-byte words using the program BITPIK.[9] The data were then sorted into files to allow access to individual transducers output without sorting through the whole data set. The sorting was performed with the MODMAC program (Reference 10), which also converted the data from the digital signal level, "counts", to the final form in "engineering units" using polynomial calibrations. Some channels which required additional processing were converted only to digital signal level, "volts" at this time (i.e., density and load cells). Plotting, analysis, and calibration corrections were done with the MACRAN time series data analysis system (Reference 11).

The reported data include computed parameters which were calculated from one or more of the experimentally measured parameters using analytical techniques more sophisticated than a simple polynominal calibration. These computed parameters include mass flow measurements and flow density measurements. Calculation of these parameters is described in the following paragraphs.

The primary reference mass flow measurement was computed from the load cell data by filtering and differentiating the sum of the load cell readings. This technique and associated uncertainty are discussed in detail in Reference 3.

Experimental mass flow measurements were calculated from the drag disc and turbine data, and the ECC pitot tube data, in conjunction with the gamma densitometer readings.

Two sets of computer programs were used in these calculations, DPROF3 and EMDOT3 (See Reference 12). One set estimates a density profile from chordal average density measurements. A second set estimates either a velocity or a momentum flux profile from a linear array of local measurements (the rake), and combines it with the previously calculated density profile to calculate the mass flow rate.

One experimental mass flow was computed by combining the turbine meter and densitometer data using the equation,

$$\dot{m} \quad \iint [\rho(\vec{r})\ v\ (\vec{r})]\ dA$$

where

ρ is the fluid density from 6-beam densitometer

r is the position vector

v is the fluid velocity from turbine meters

$\iint dA$ is the integral over the fluid flow area.

The second experimental mass flow was computed from the drag disc and densitometer data using the equation,

$$m = \iint [\rho(\vec{r})\ p\ (\vec{r})]^{1/2}\ dA$$

where

ρ is the fluid density measured by the six-beam densitometer

$\vec{r}$ is the position vector

p is the momentum flux (ρV^2) measured by the drag disc

$\iint dA$ is the integral over the fluid flow area.

The mass flow from the ECC pitot tube rake and densitometer was calculated using the equation,

$$\dot{m} = \iint [\rho(\vec{r})\ p\ (\vec{r})]^{1/2}\ dA$$

where the terms are as above, with the momentum flux being derived from the measured ΔP_{stag}, the differential pressure, by removing initial elevation head differences.

Note: Tests where densitometer beams failed or saturated, (DE-2-B for Tests IIIA201 and IIIA202), the average density program was adjusted for a five-beam fit.

Reference density values were calculated for each individual densitometer beam according to the following equations, based on an in-place calibration:

$$\rho = \frac{1}{a} \ln \left(\frac{b}{V_m - V_o}\right)$$

$$a = \frac{1}{\rho_L - \rho_A} \ln \left(\frac{V_a - V_o}{V_L - V_o}\right)$$

$$b = (V_A - V_o)\ e^a\ \rho_A$$

where

ρ = measured density

V_m = measured signal voltage

ρ_L = known density (liquid)

ρ_A = known density (vapor)

V_o = combined signal offset voltage (source stored) and bias voltage (opposite source exposed)

V_L = signal voltage for liquid full system

V_A = signal voltage for vapor-full system.

V. EXPERIMENTAL RESULTS

The results of the transient DTT and ECC Pitot tube rake tests in the intact loop cold leg configuration are presented in Appendices A, B, C, and D for data from Tests IIIA101, IIIA102, IIIA201, IIIA202, respectively. The data are presented in the form of single measurement plots in engineering units, with time as the abscissa. Certain computed parameters, calculated from one or more of the experimental measurements are also presented. Comparisons of integrated mass flow rates from the reference system and the DTT and densitometer, and the ECC rake and densitometer combinations are also plotted.

Scales for the plot ordinates were chosen to most effectively present the bulk of the data, and sometimes truncated initial spikes at the initiation of blowdown.

The differential pressure cells were set to read zero with the sense lines isolated from the transducers and cross vented at the manifold valves. The cells were oriented to give a positive reading when the pressure in the sense line connected to the tap mentioned first in the instrument description and figure title had the higher pressure. The data for differential pressure measurements are corrected for line pressure sensitivity but not for velocity or elevation head. Differential pressure data for measurements in the pipe are adjusted for elevation head differences in the sense lines at blowdown initiation. Pressure transducers were set to read zero with the system cold and depressurized, and should be interpreted as gauge pressure. Momentum flux from drag discs was corrected for thermal sensitivity.

Uncertainties estimated for each measurement are presented in Table 1. Uncertainties associated with the instrumentation are calculated using procedures outlined in Reference 13. Uncertainties

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associated with the data acquisition system are estimated from Neff crosstalk and comparison of known input voltages with measured output voltages from the calibration steps recorded immediately prior to the initiation of blowdown for each measurement. The average data acquisition system uncertainty is estimated to be 0.13% range + 0.20% reading.

The total uncertainty for each measurement is computed by combining the instrument uncertainty and the acquisition system uncertainty using the root sum square (RSS) technique.

Measurements presented in the Appendices were reviewed to verify that they were consistent and reasonable. Instrument channel outputs were compared against corresponding parameter channels from each test using overlays. Those measurements that were determined to be within their associated uncertainties were labeled qualified engineering units data with comments supplied as shown in Table I. This review process followed procedures outlined in Reference 14.

Calculated parameters including average density, reference mass flow rate, and mass flow rate computed from the DTT rake/densitometer combinations were reviewed but not qualified. Technical analysis and review of that data was out of scope for this report.

Experimental data for evaluating liquid level probe performance was also acquired using the analog system during these tests. That data will be presented in a separate experimental data report following data processing and review.

Data which was recorded but not reviewed, for these tests are listed in Figures 5 and 6. These included spoolpiece pressures, differential pressures, and temperatures, among others.

VI. CONCLUSIONS

The following conclusions are based on preliminary processing, reduction, and analysis of the test data presented in this report.

(1) The load cell system provides a repeatable reference measurement for mass flow rate for performance evaluation of the ECC pitot tube and DTT rakes in the simulated LOFT cold leg, intact loop geometry and blowdown environment.

(2) The densitometer data indicate a certain degree of flow stratification due to inertial effects such as gravity and acceleration caused by flow through the elbow region.

(3) Existing models for calculating mass flow rate from the DTT or ECC pitot tube rake and densitometer combinations are reasonable for the flow regimes encountered in these tests. (More refined analysis may show better agreement between measured and reference values plotted.)

(4) Comparison of ECC pitot tube and DTT rake computed mass flows indicate an acceptable repeatability in the mass flowrate computation model used. Because no assumption is made regarding homogeneous flow, this model is useful in other flow regimes in addition to homogeneous two-phase flow.

(5) Measurement repeatability from these tests ensures a valuable data base for instrument performance research in two phase flow.

VII. REFERENCES

1. H. S. Crapo, Test Requirements for Transient Performance Testing of LOFT Flow Instrumentation, ES-60274, Rev. A, April 1979.

2. EG&G Drawing, LOFT Transient Two-Phase Flow Instrument Test Spool, 411065, November 1978.

3. R. R. Good, and T. R. Meachum, Analysis of the Transient Load Measuring System, LTR LQ-87-80-132, March 17, 1980

4. INEL-LOFT ECC Type 1 T/C and Pitot Tube Rake, Science Applications DWG. 200131J.

5. Wyle Three MDTT Rake Assembly and Details, EG&G DWG 209243.

6. G. D. Lassahn, LOFT Three Beam Densitometer Data Interpretation, TREE-NUREG-1111, October, 1977.

7. R. R. Good, Six-Beam Test (For Gamma Densitometer), LTR 141-122, August 1979.

8. E. Deaton, LOFT Data Acquisition Format for Offsite Data Acquisition, L DAF-ODA-0, September 1978.

9. E. B. Henry, Baseline Program Document, BLPD-BITPIK-0, August 1977.

10. E. B. Henry, MODMAC IBM 360/75 Computer Program, CPD-MODMAC-1, May 1978.

11. Applications Manual, MAC/RAN III Time Series Data Analysis System, University Software Systems, Agabian Associates, Copyright 1974.

12. G. D. Lassahn, User's Manual for DPROF3 and EMDOT3, GDL-3-79, letter to L. D. Goodrich, July 24, 1979.

13. G. L. Biledeau et al., LOFT Experimental Measurements Uncertainty Analysis, LTR 141-39, September 1975.

14. C. M. Nightengale, L. D. Goodrich, et al., LOFT Nonnuclear Data Reduction and Qualification Manual, LTR 141-63, May 1979.

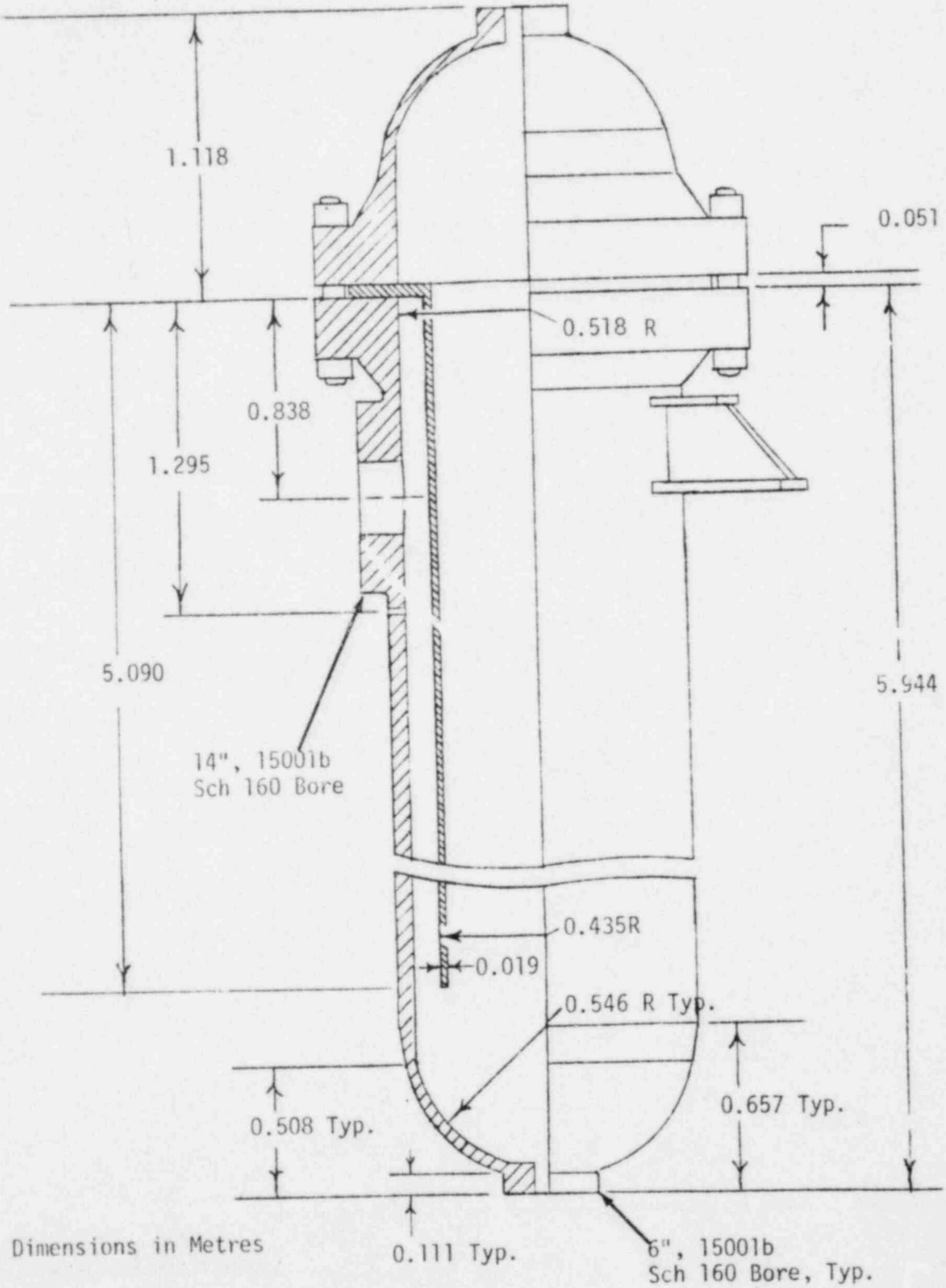


Figure 1. Pressure Vessel for Transient Performance Tests

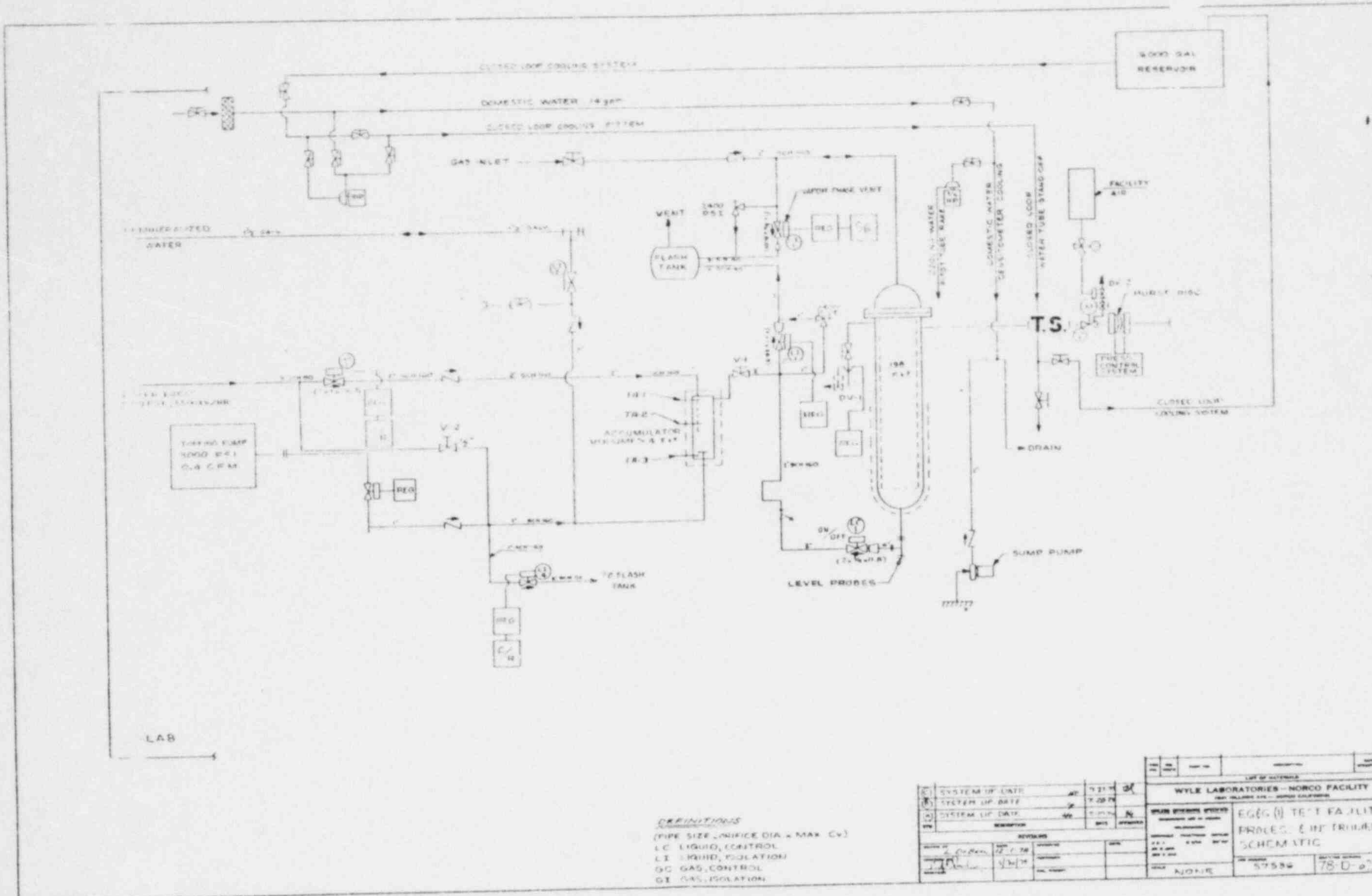


Figure 2. Transient Flow Calibration Facility Process and Instrumentation Schematic

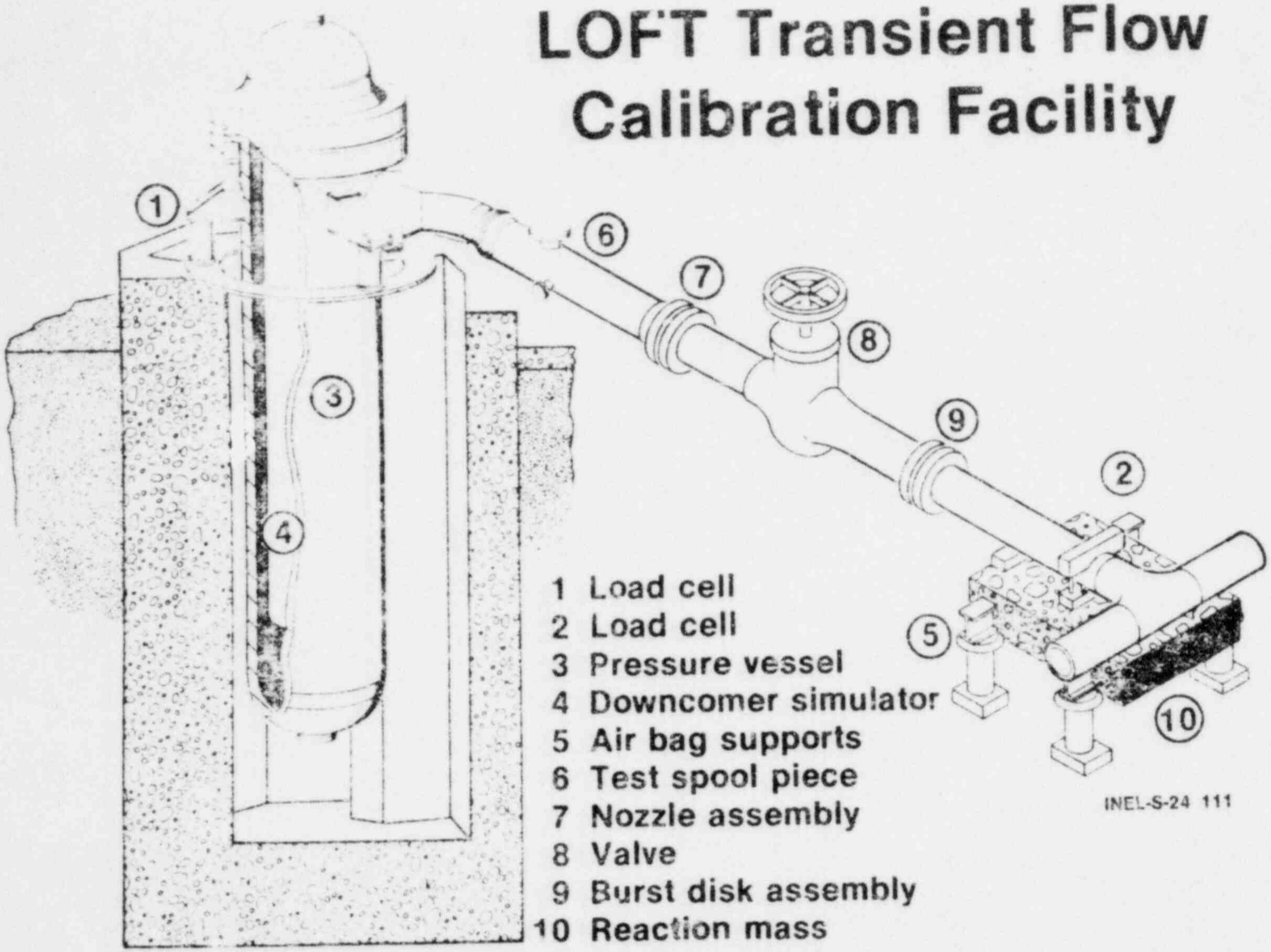
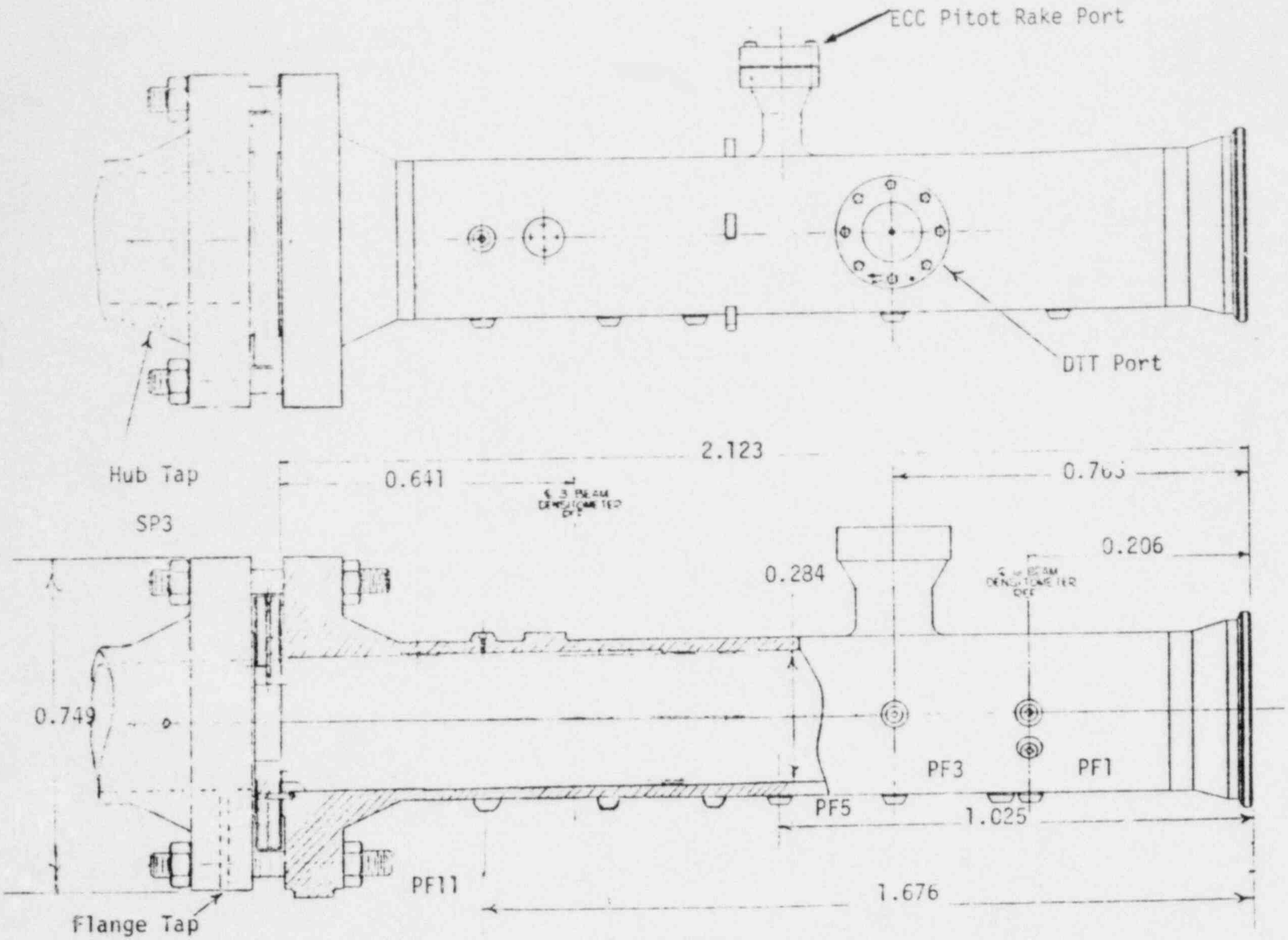


Figure 3. Test Vessel and Piping Simplified Perspective



Dimensions in metres.

Figure 4. Test Spool

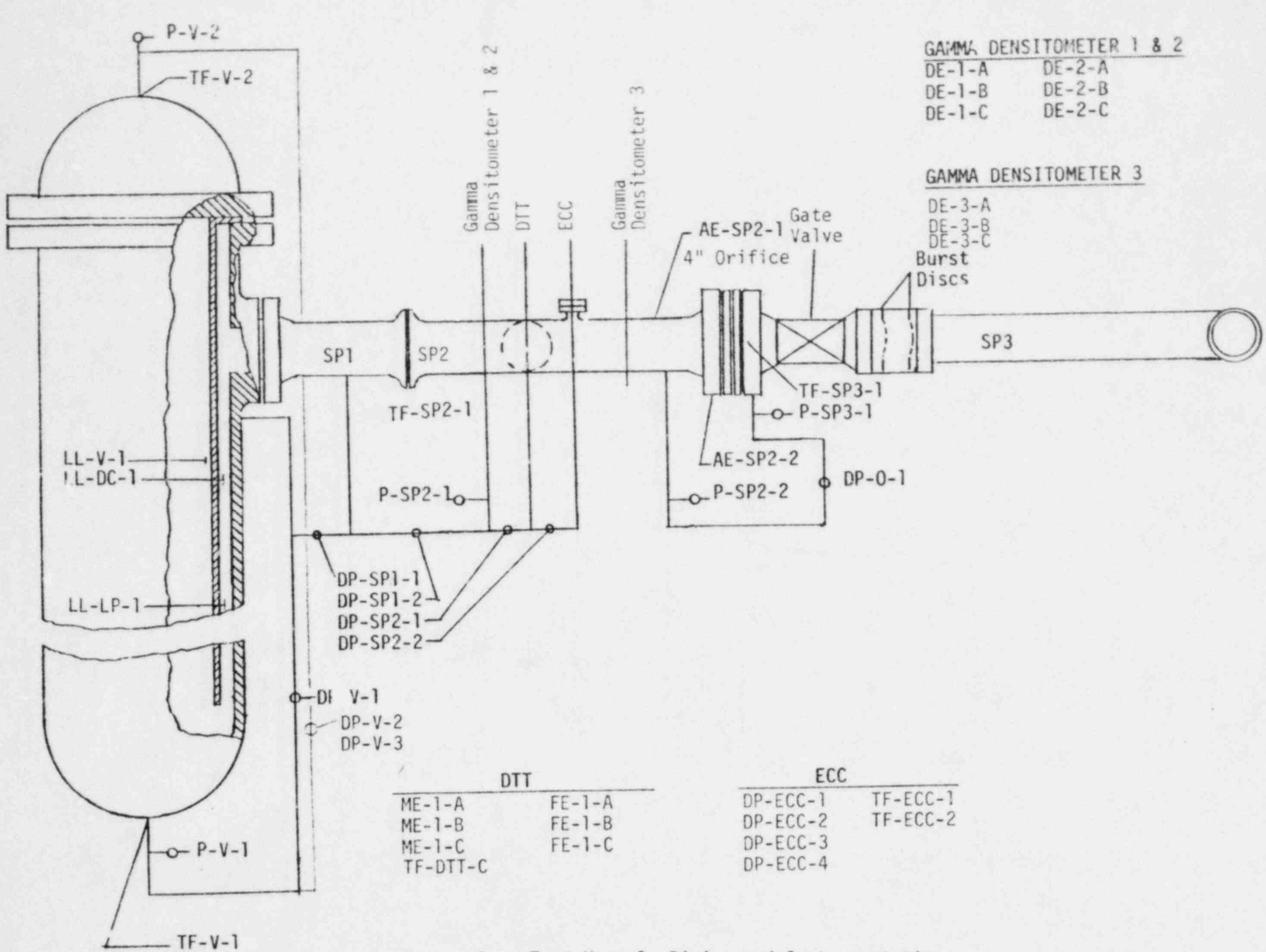


Figure 5. Test Vessel, Piping and Instrumentation Schematic - IIIA101, IIIA102

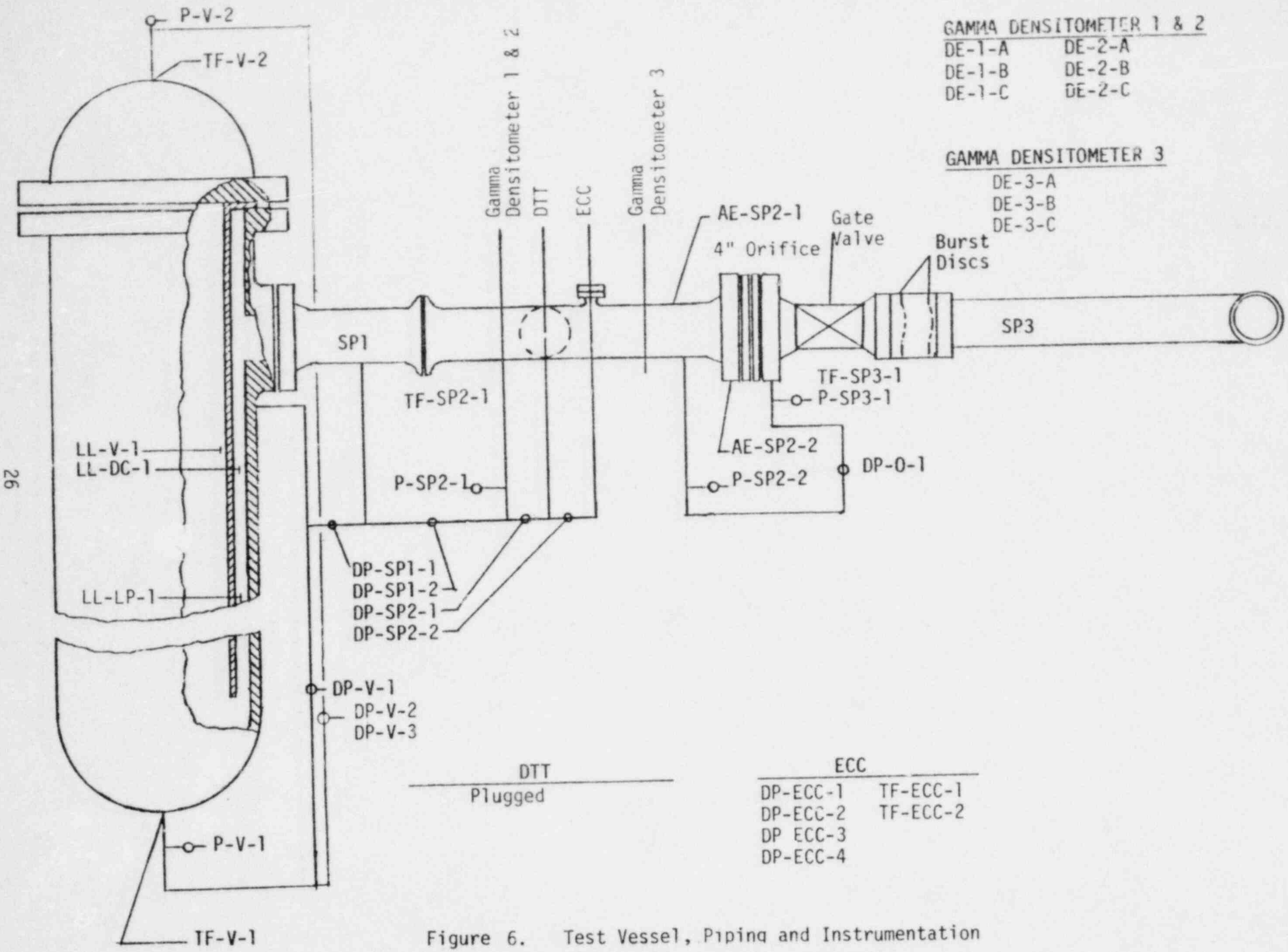


Figure 6. Test Vessel, Piping and Instrumentation Schematic - IIIA201, IIIA202

LOFT ECC T/C-Pitot Tube Rake

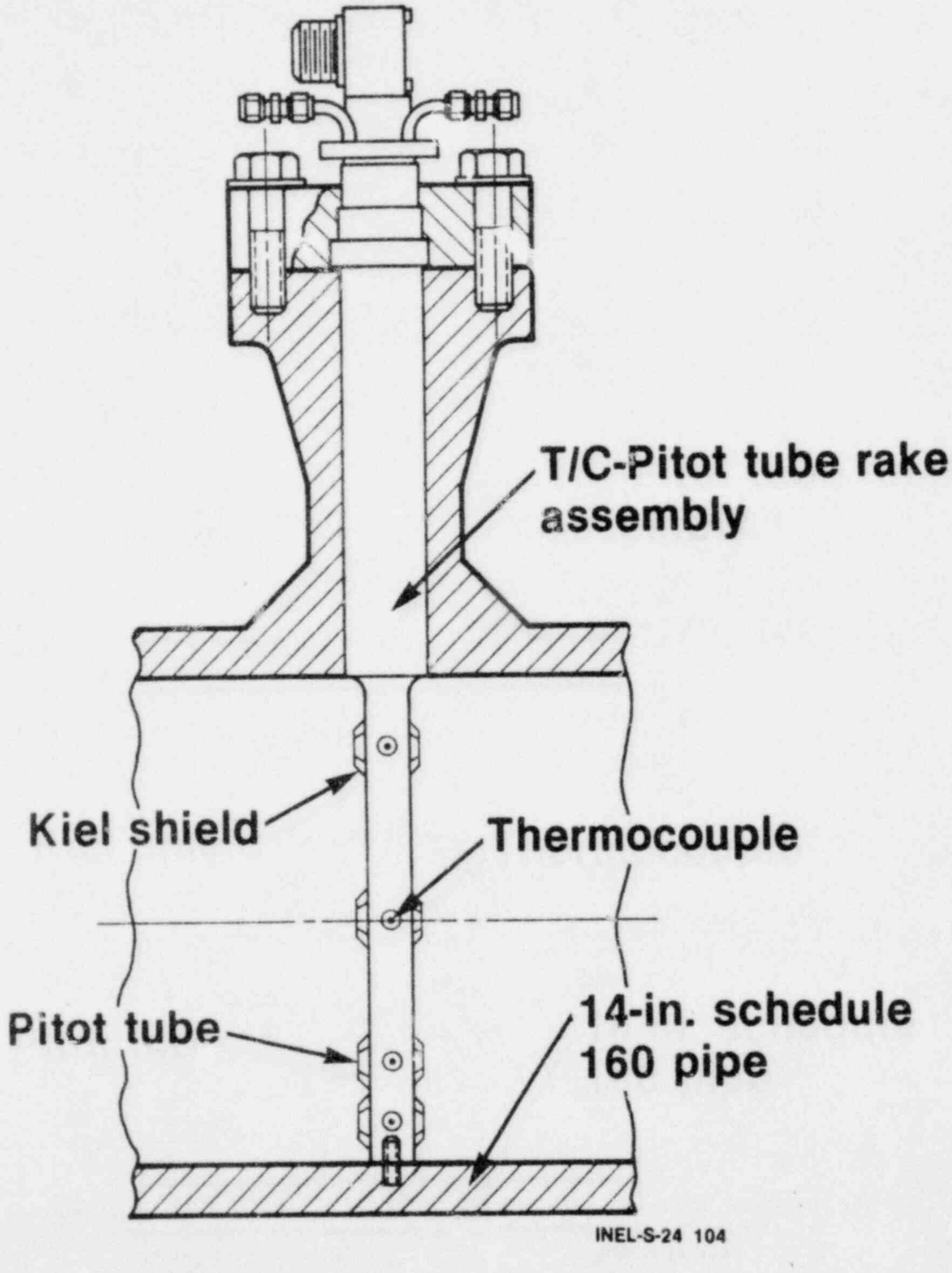


Figure 7. ECC Pitot Tube Rake - Cross Section of Installation

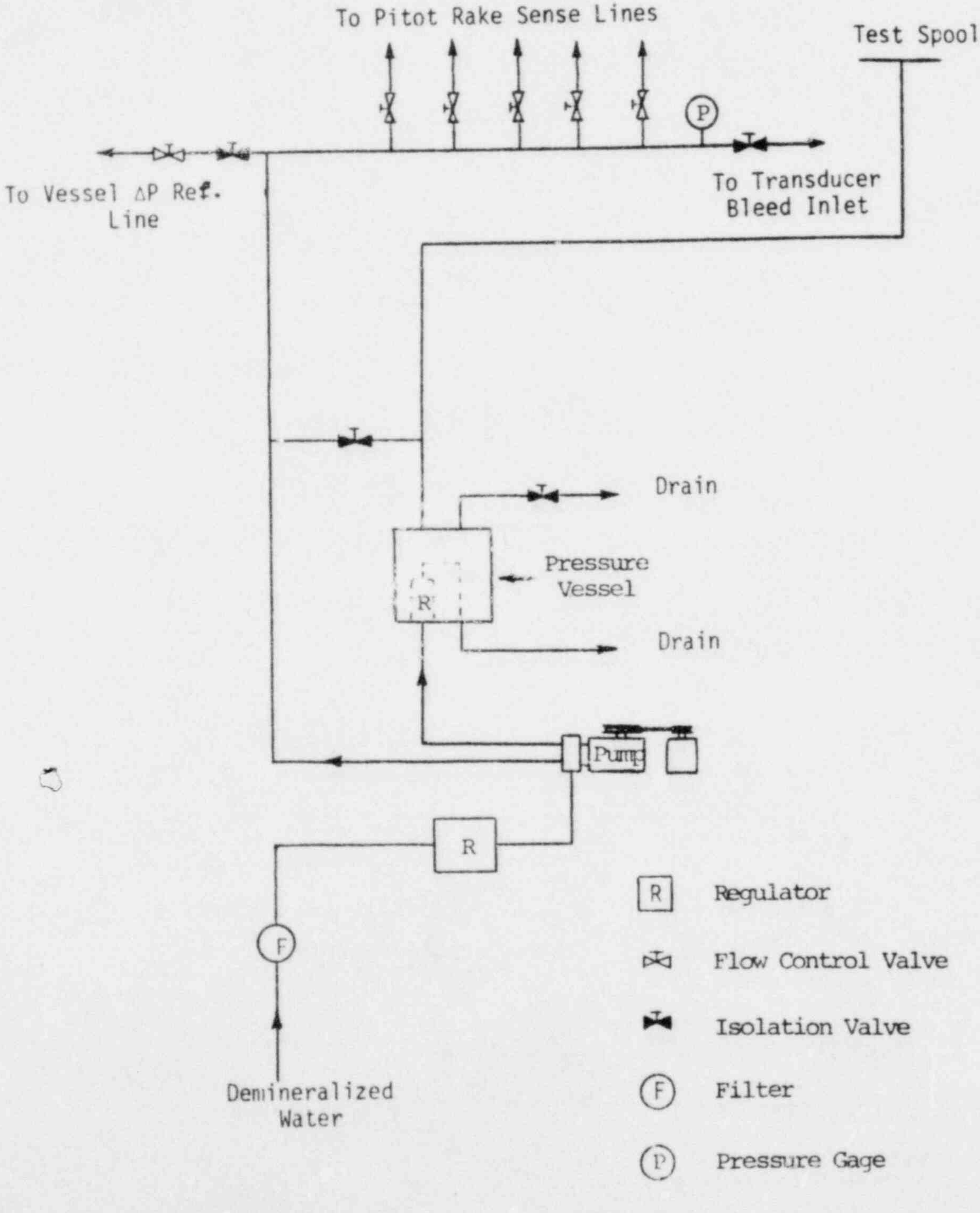


Figure 8. Schematic of Continuous Purge System

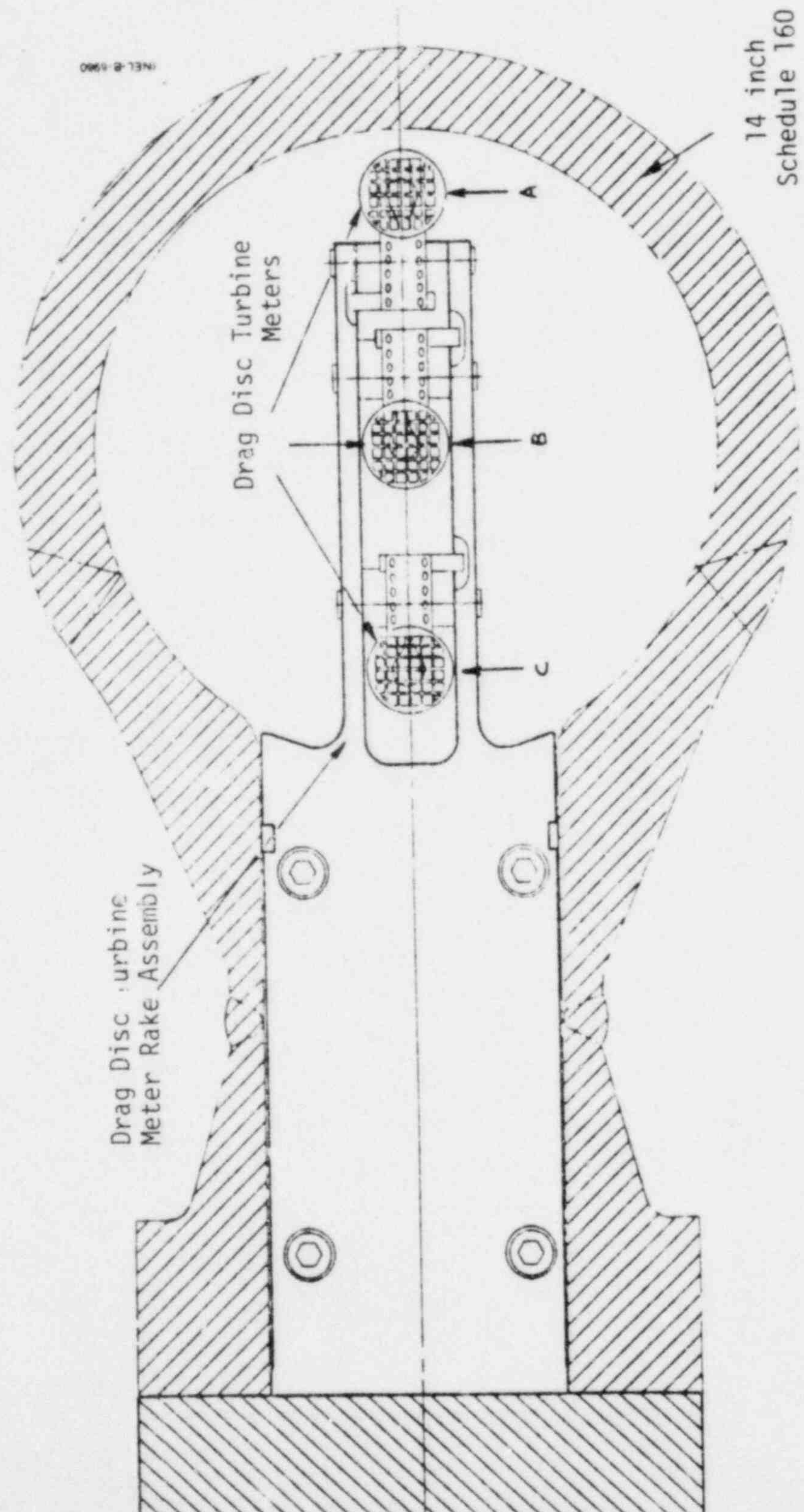


Figure 9. DTT Rake -- Cross Section of Installation

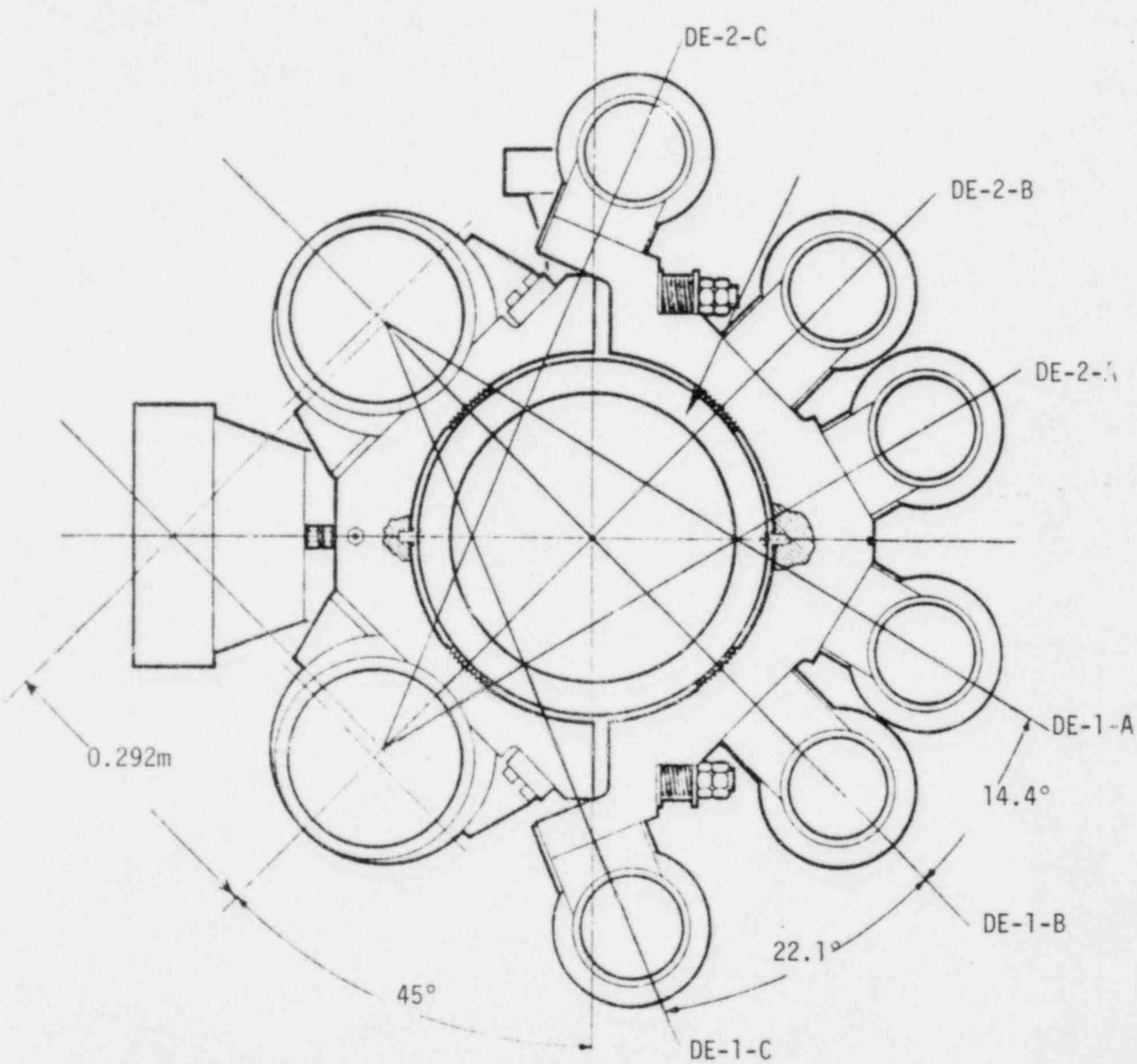


Figure 10. Six-Beam Densitometer -- Cross Section of Installation

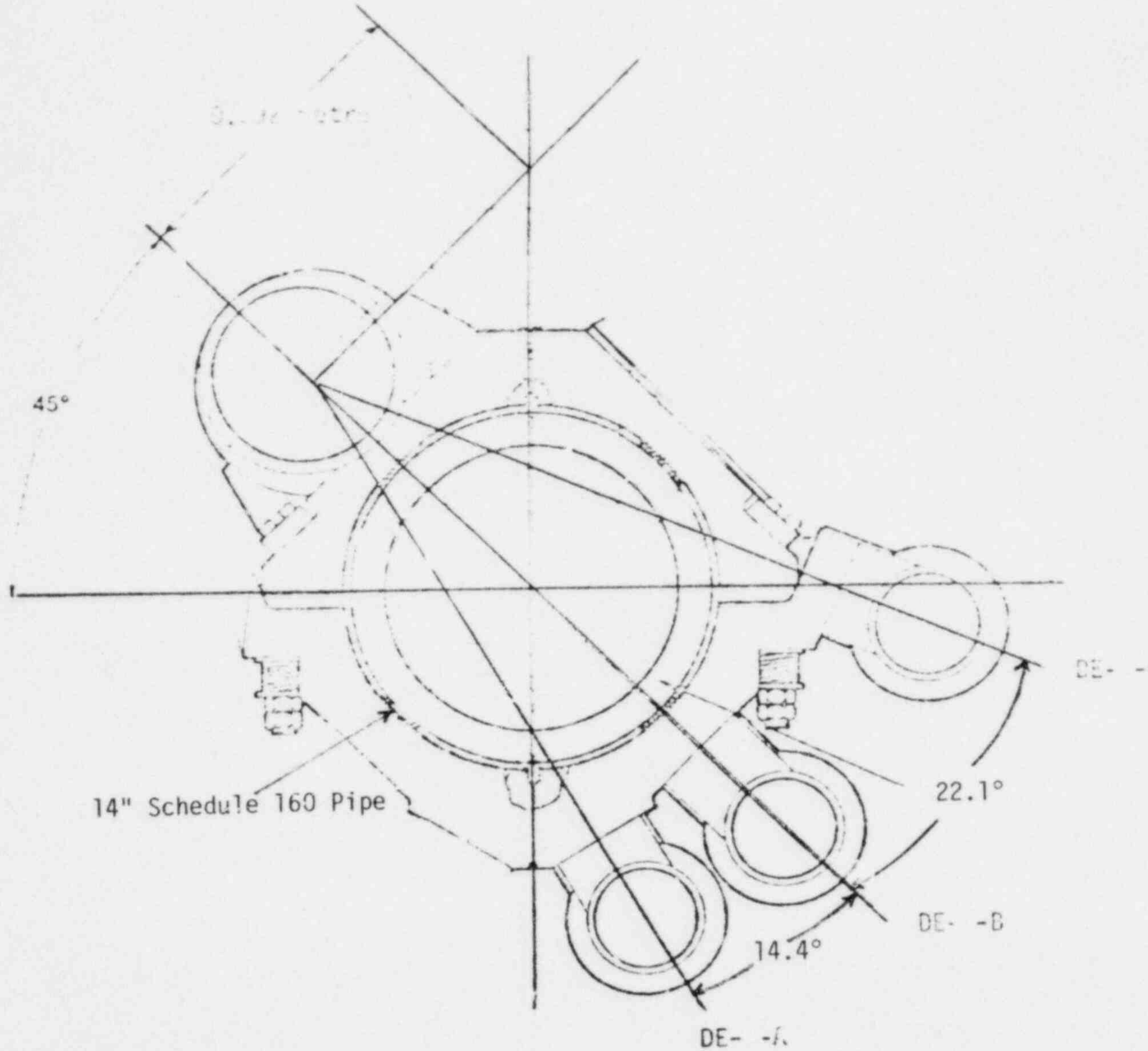
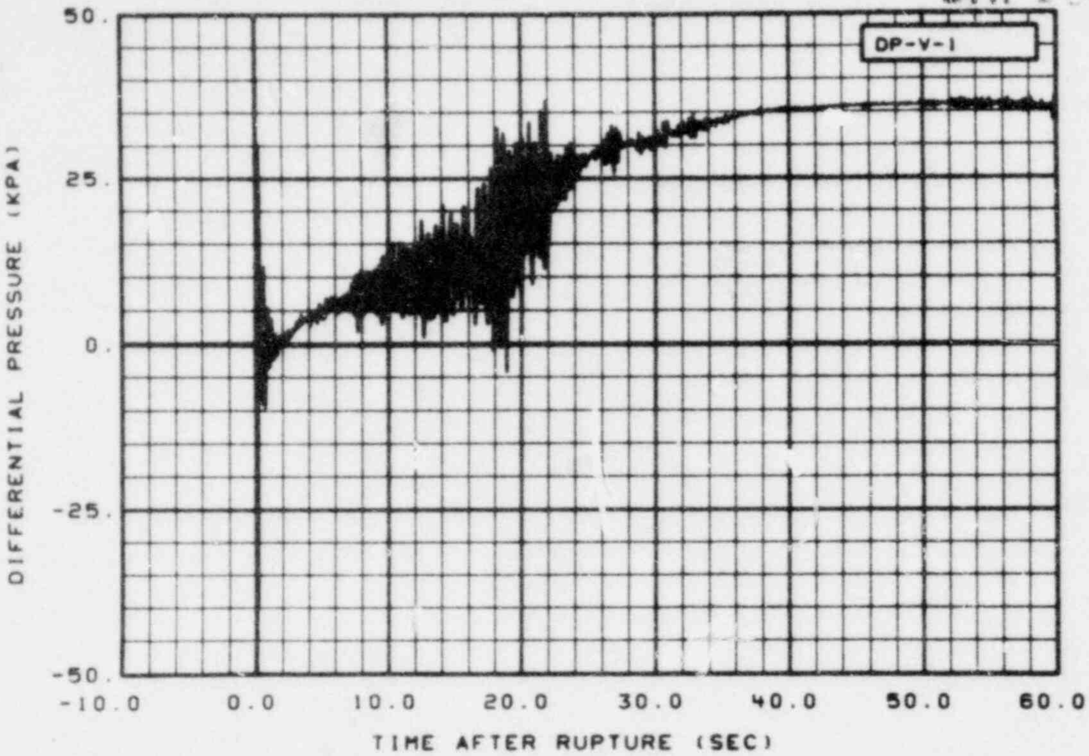


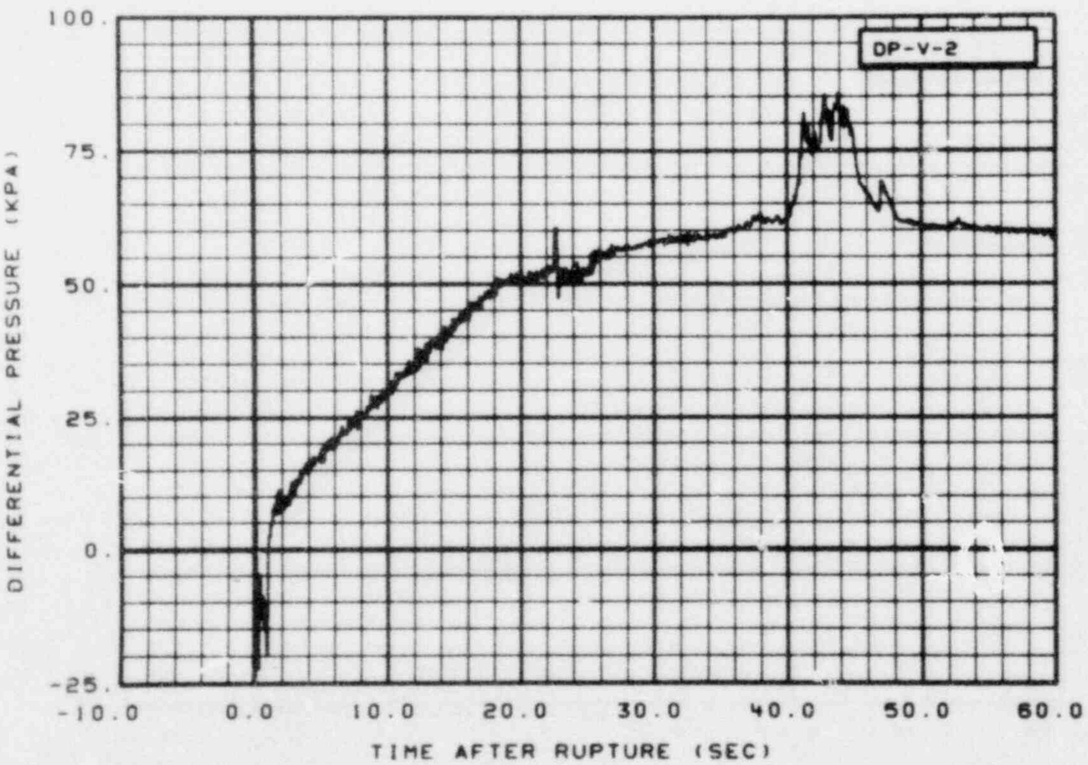
Figure 11. Three - Beam Densitometer--Cross Section of Installation.

APPENDIX A

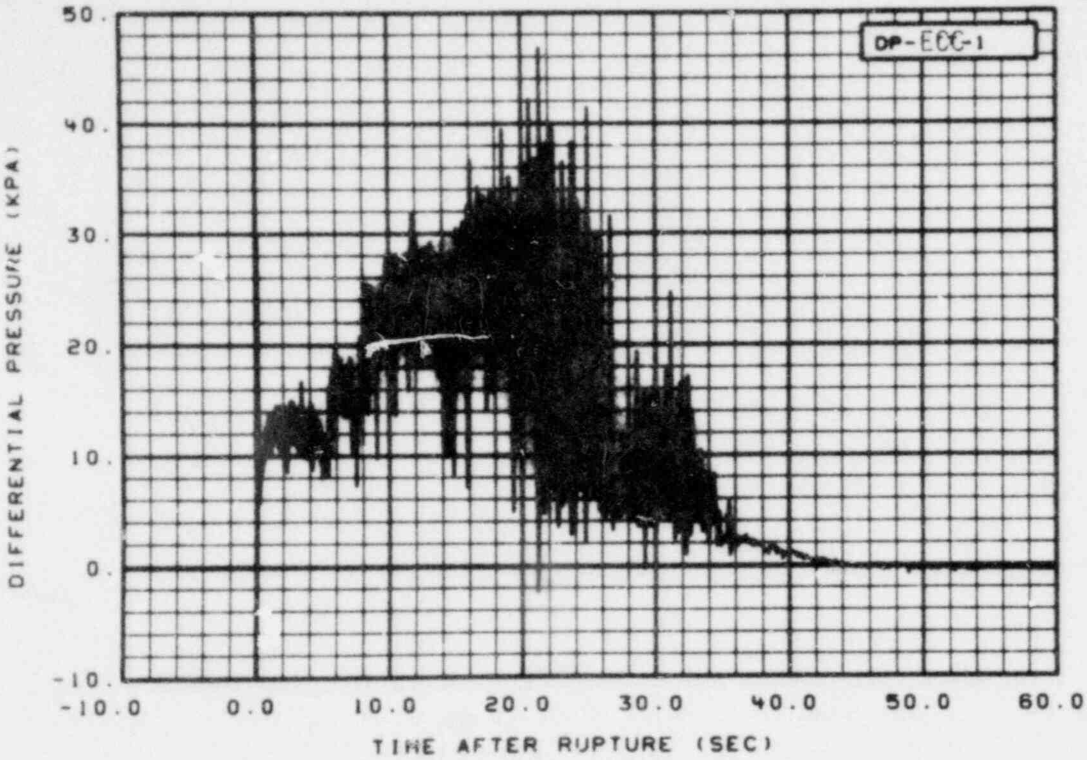
DATA FROM TEST IIIA101



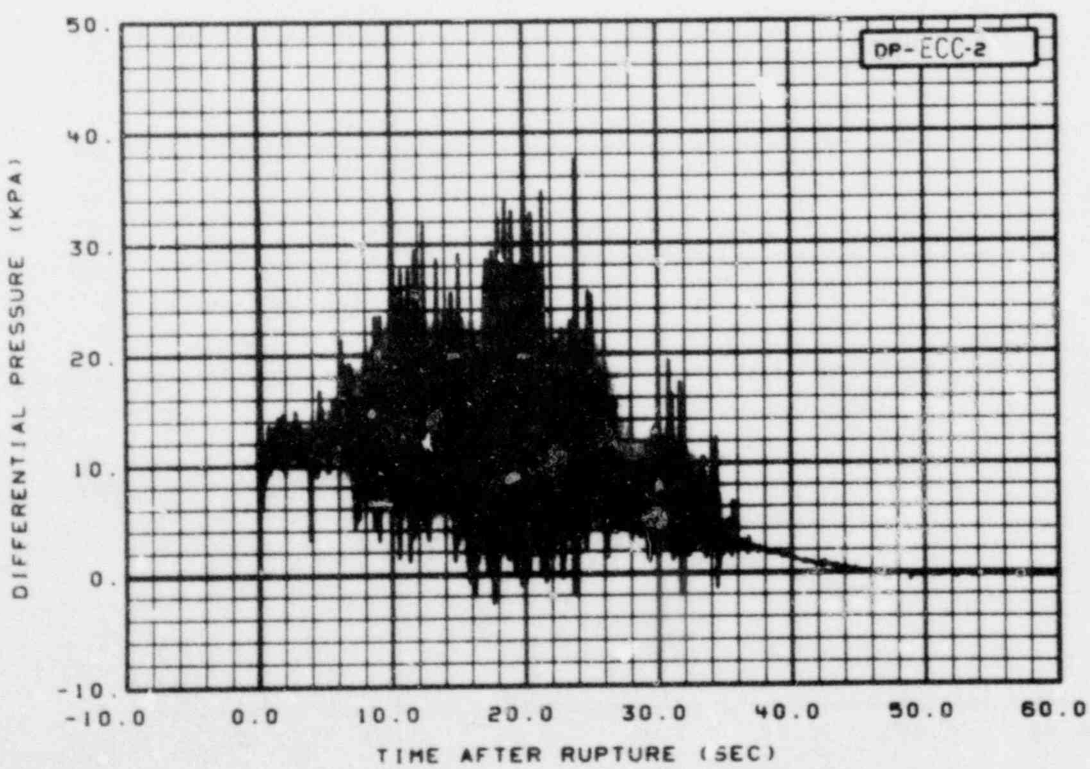
A-1 Differential pressure from vessel bottom to outlet nozzle tap -- (DP-V-1) -- Test IIIA101



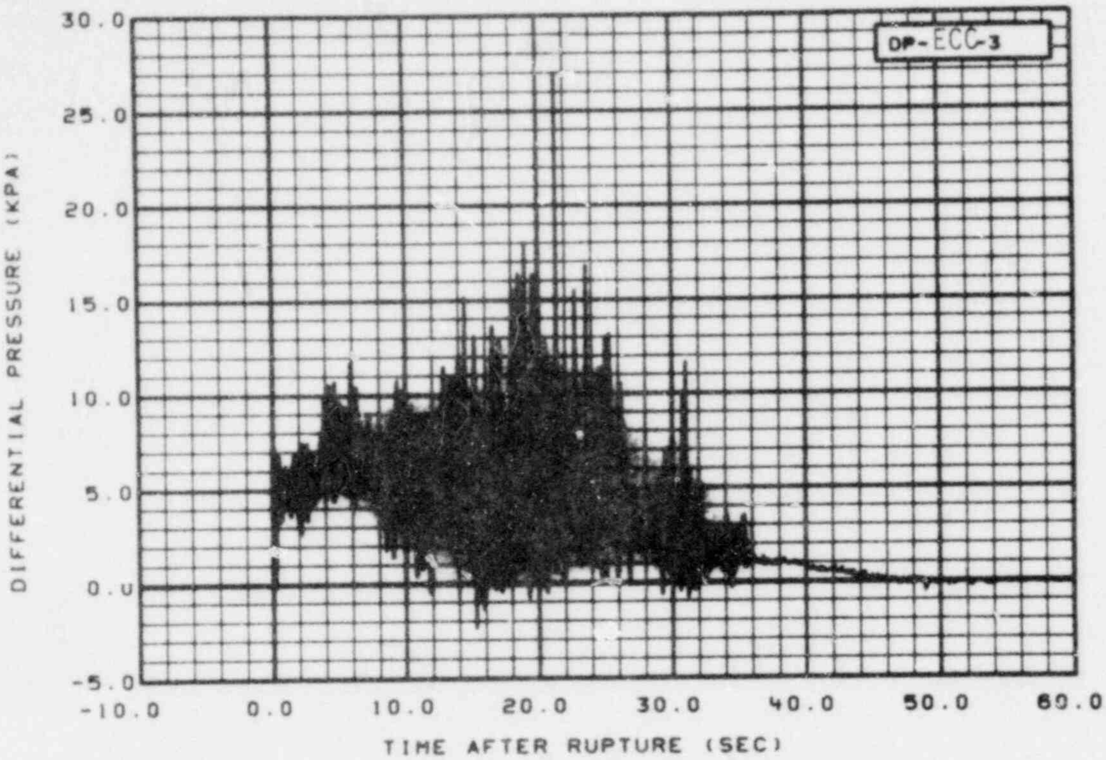
A-2 Differential pressure from vessel top vent to heatup line, low range -- (DP-V-2) -- Test IIIA101



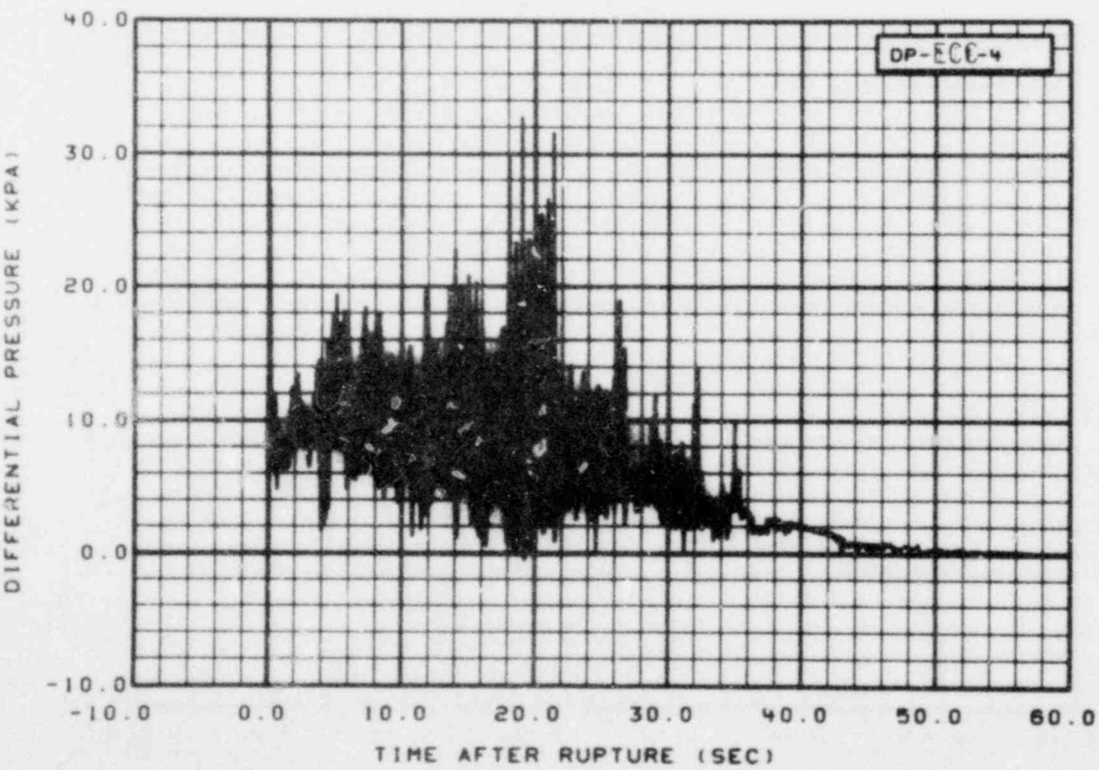
A-3 Differential pressure at bottom of ECC pitot tube rake -- (DP-ECC-1) -- Test IIIA101. . .



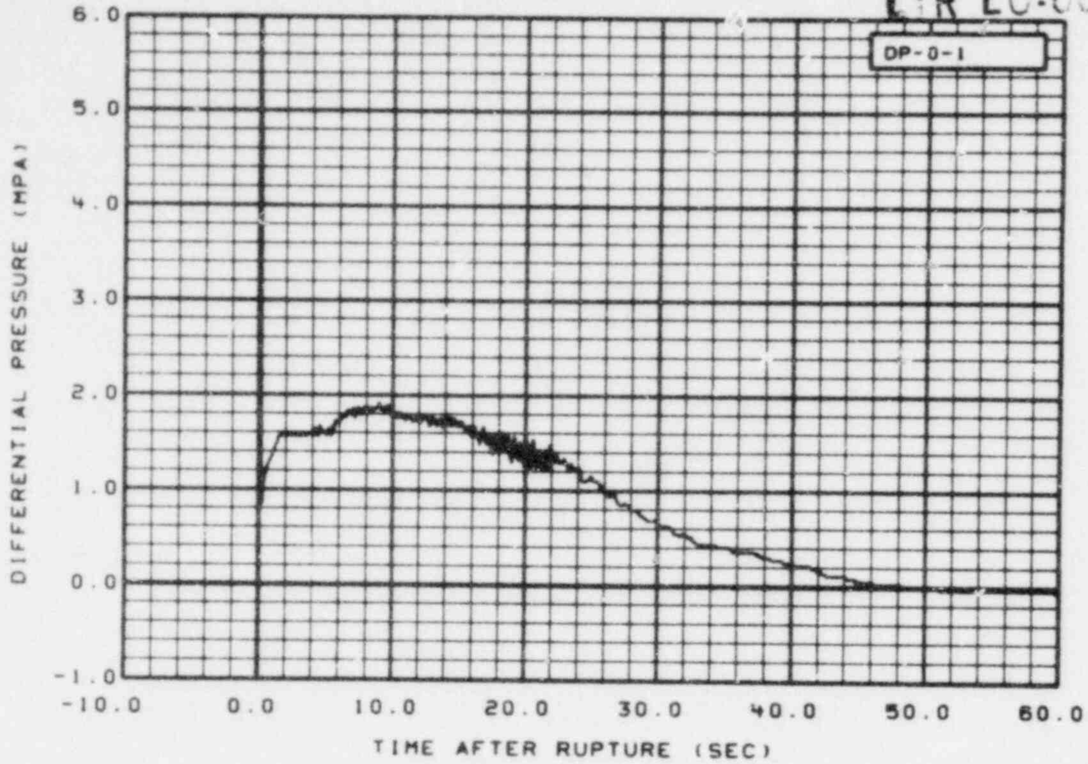
A-4 Differential pressure - ECC pitot tube rake (DP-ECC-2) -- Test IIIA101 . . . .



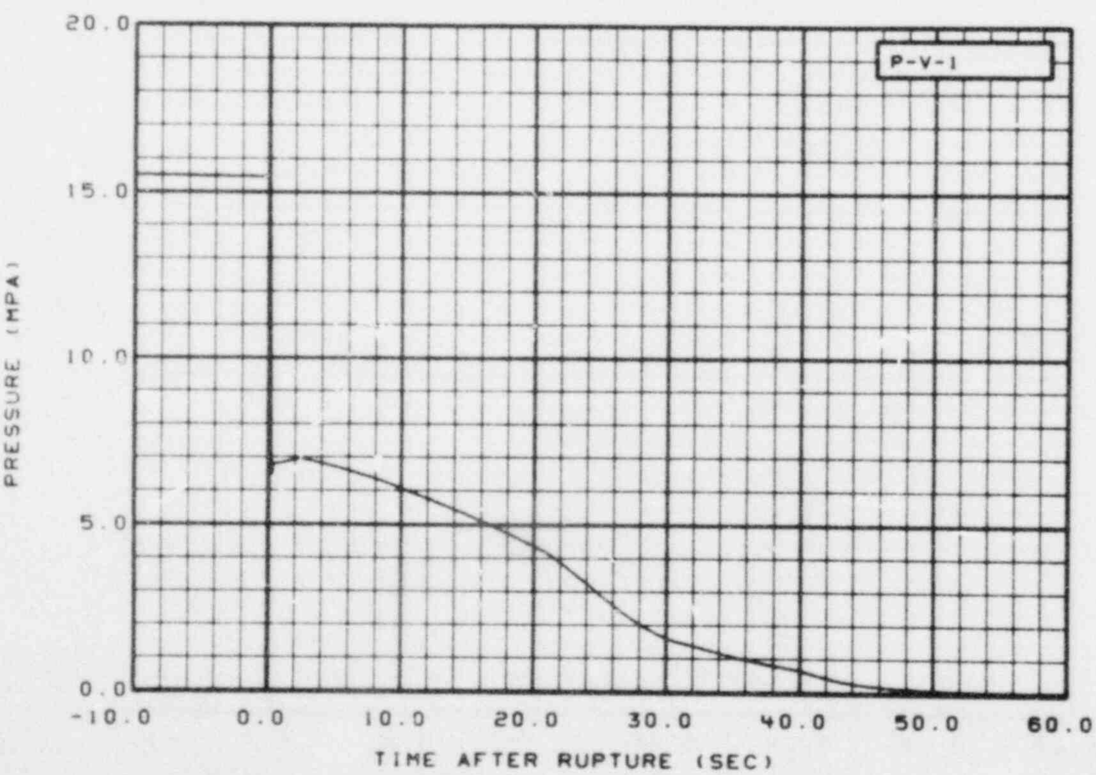
A-5 Differential pressure at center of ECC pitot tube rake -- (DP-ECC-3) -- Test IIIA101. . .



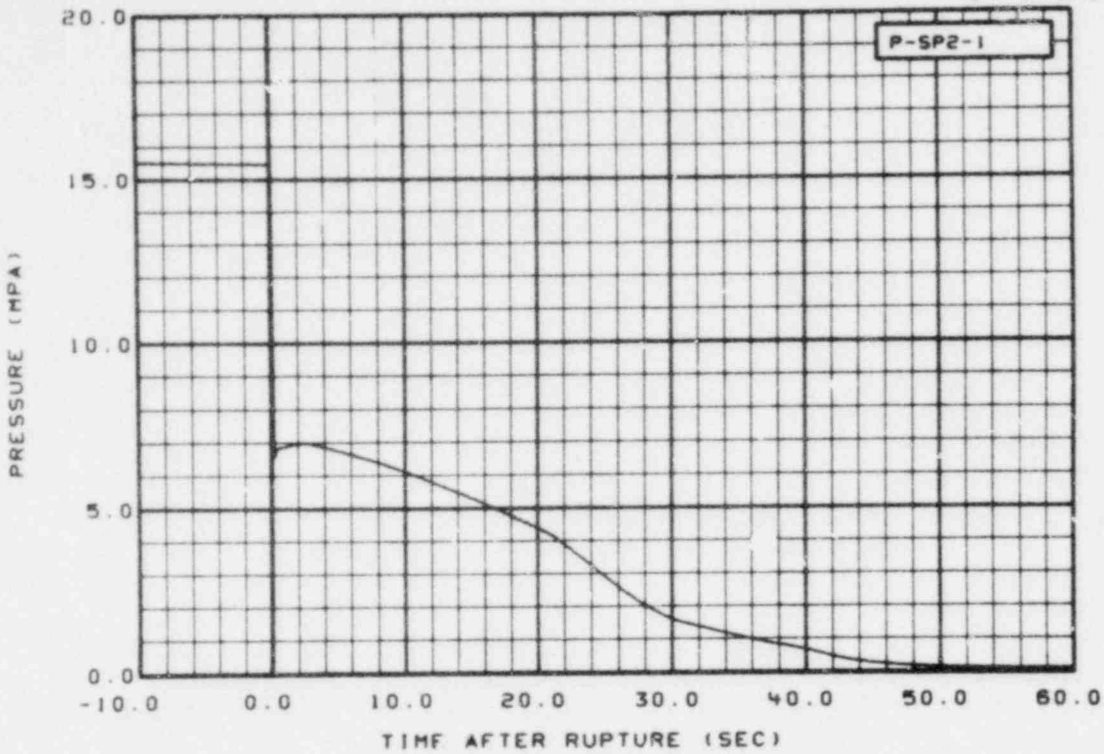
A-6 Differential pressure at top of ECC pitot tube rake -- (DP-ECC-4) -- Test IIIA101.



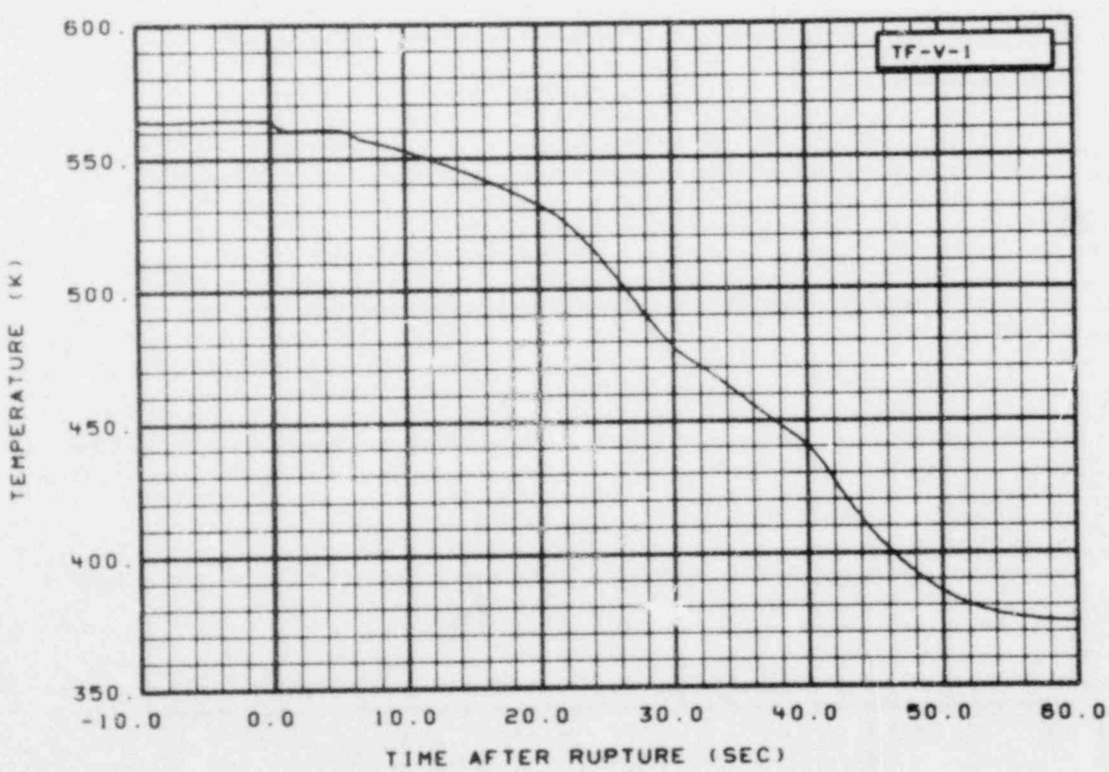
A-7 Differential pressure from test spool tap no. 11 to gate valve flanges -- (DP-0-1) -- Test IIIA101.



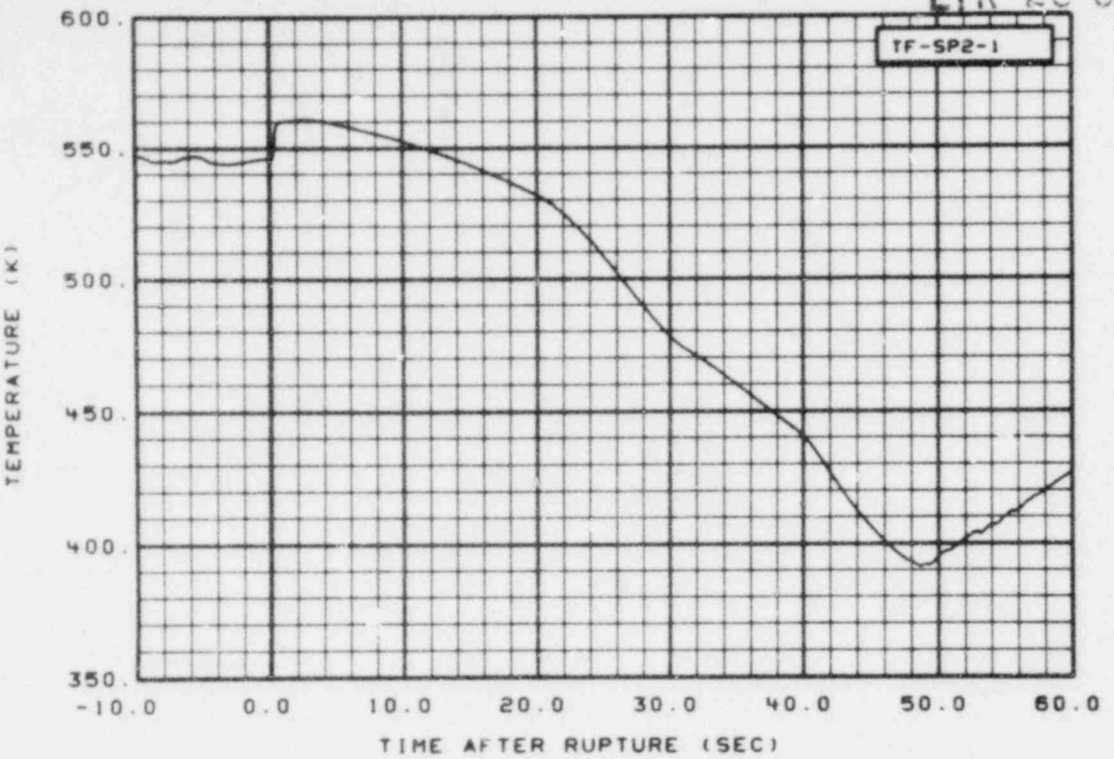
A-8 Pressure at bottom of vessel -- (P-V-1) -- Test IIIA101



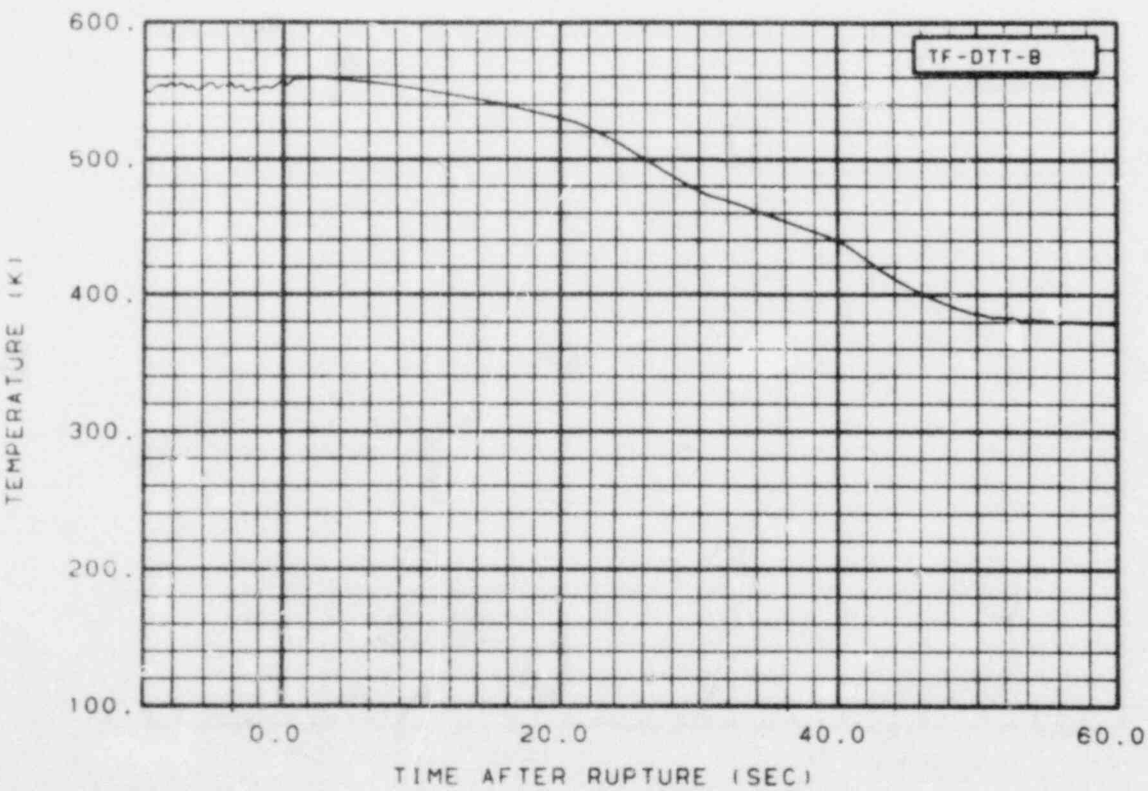
A-9 Pressure at test spool tap no. 11 -- (P-SP2-1)
Test IIIA101 . . . .



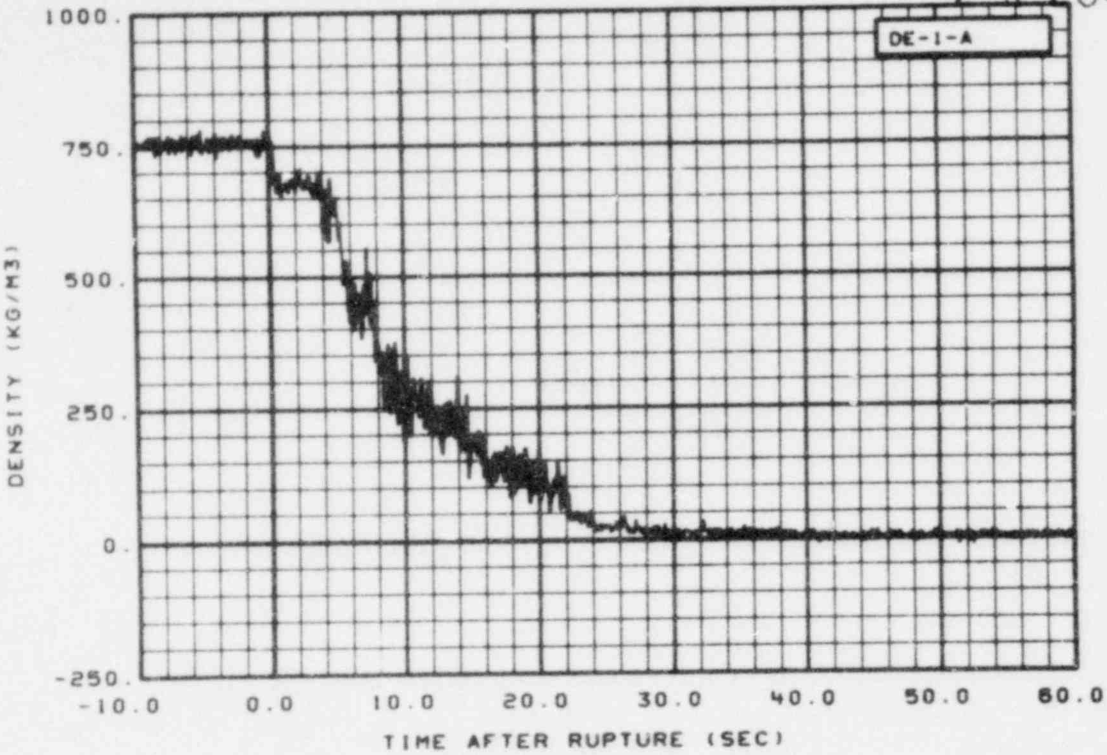
A-10 Fluid temperature at bottom of vessel -- (TF-V-1) --
Test IIIA101 . . . .



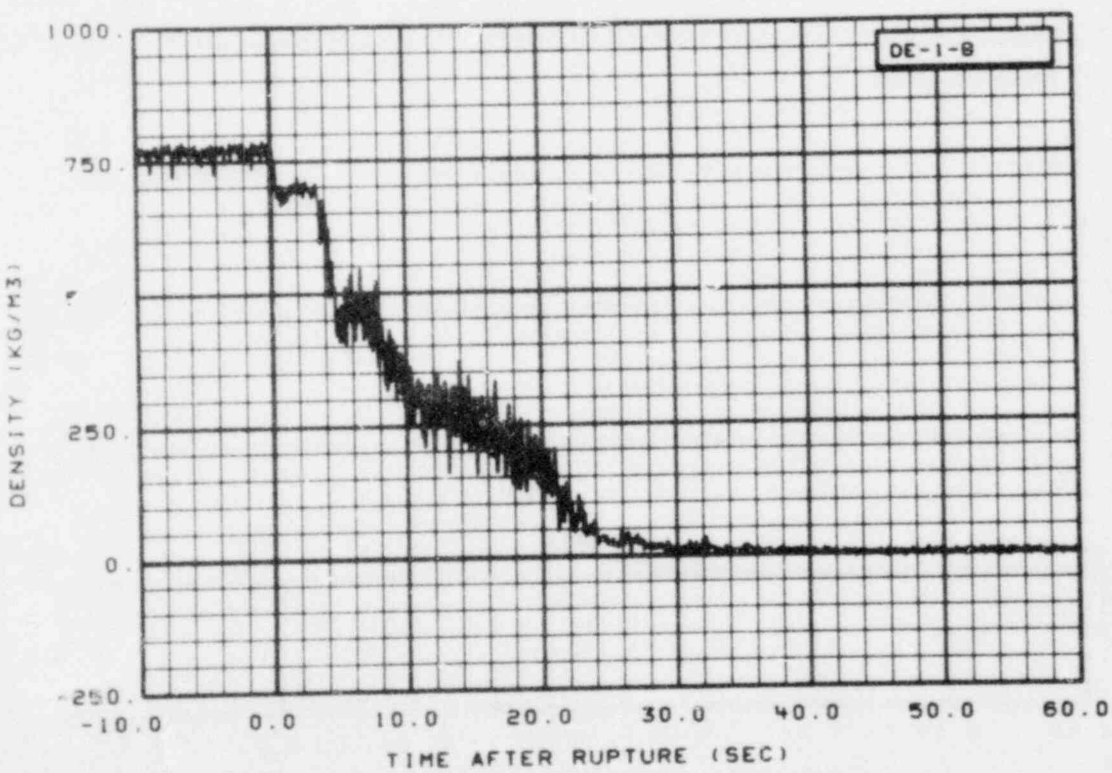
A-11 Fluid temperature at test spool tap no. 1 -- (TF-SP2-1) -- Test IIIA101 . . . .



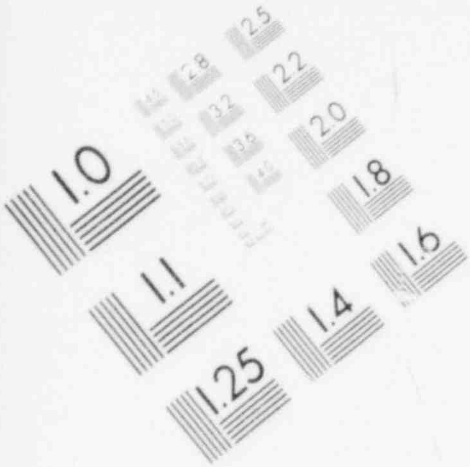
A-12 Fluid temperature at DTT port -- (TF-DTT-B) -- Test IIIA101 . . . .

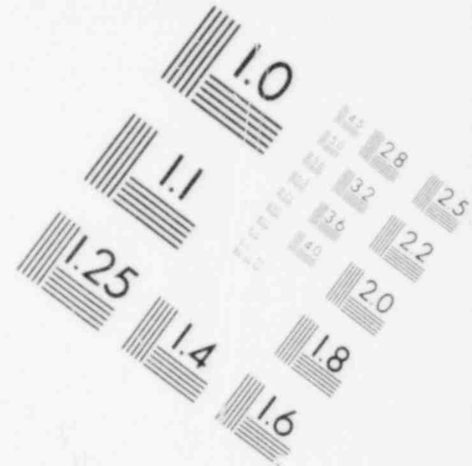


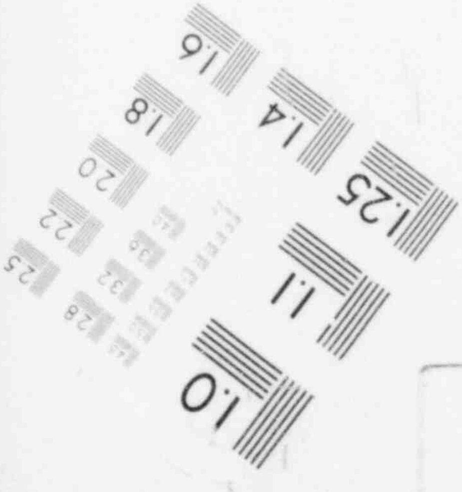
A-13 Density upstream from DTT, source 1, top beam -- (DE-1-A) -- Test IIIA101 . . . .



A-14 Density upstream from DTT, source 1, center beam -- (DE-1-B) -- Test IIIA101 . . . .







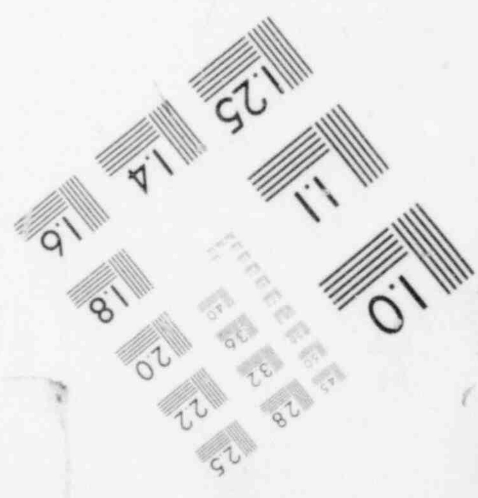
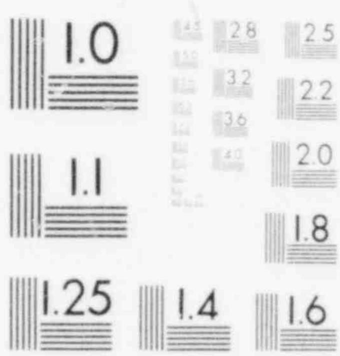
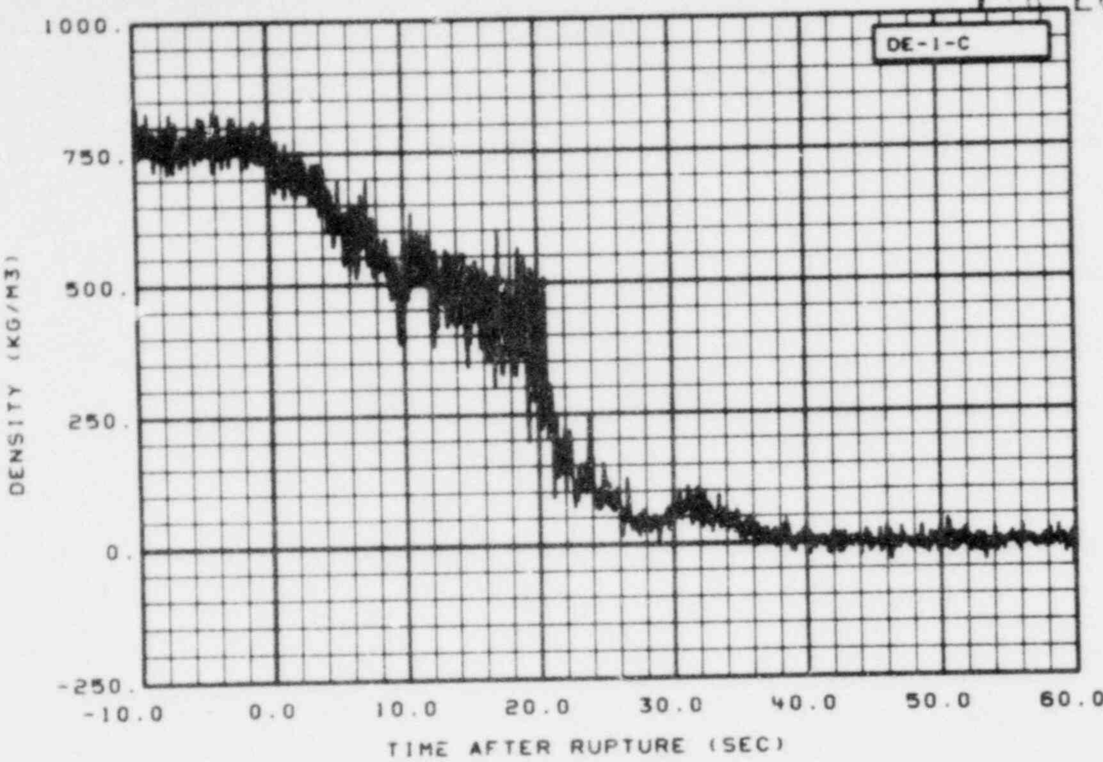


IMAGE EVALUATION TEST TARGET (MT-3)

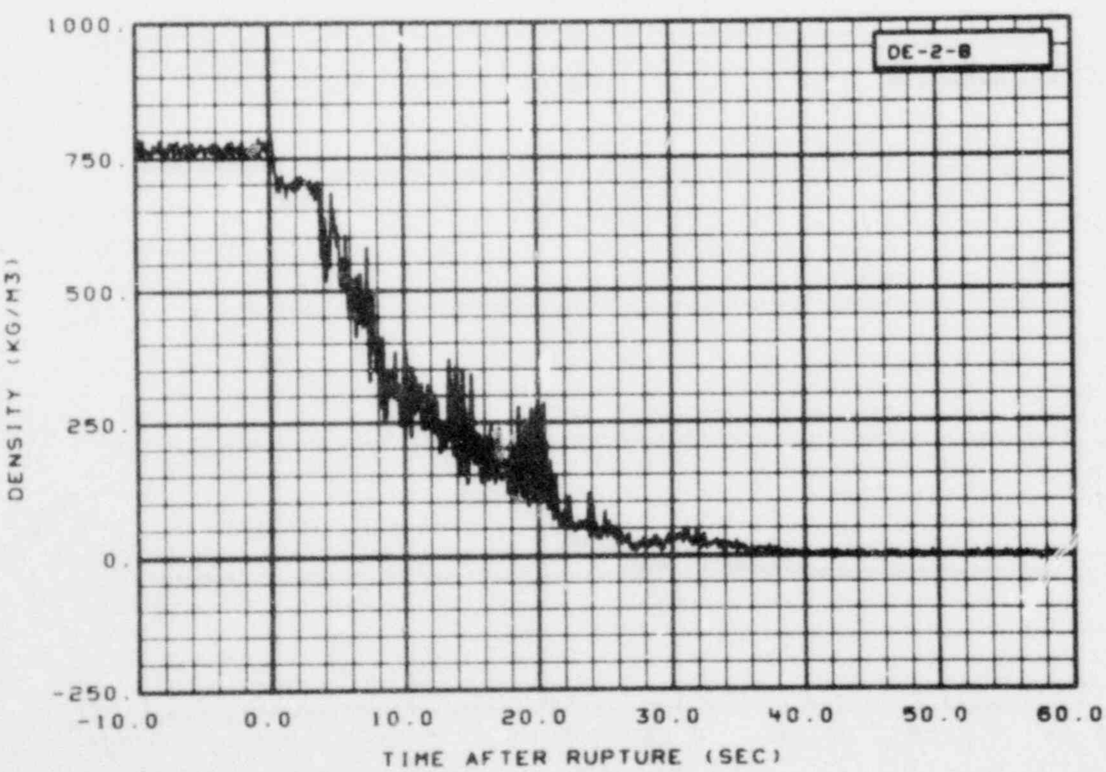


6″

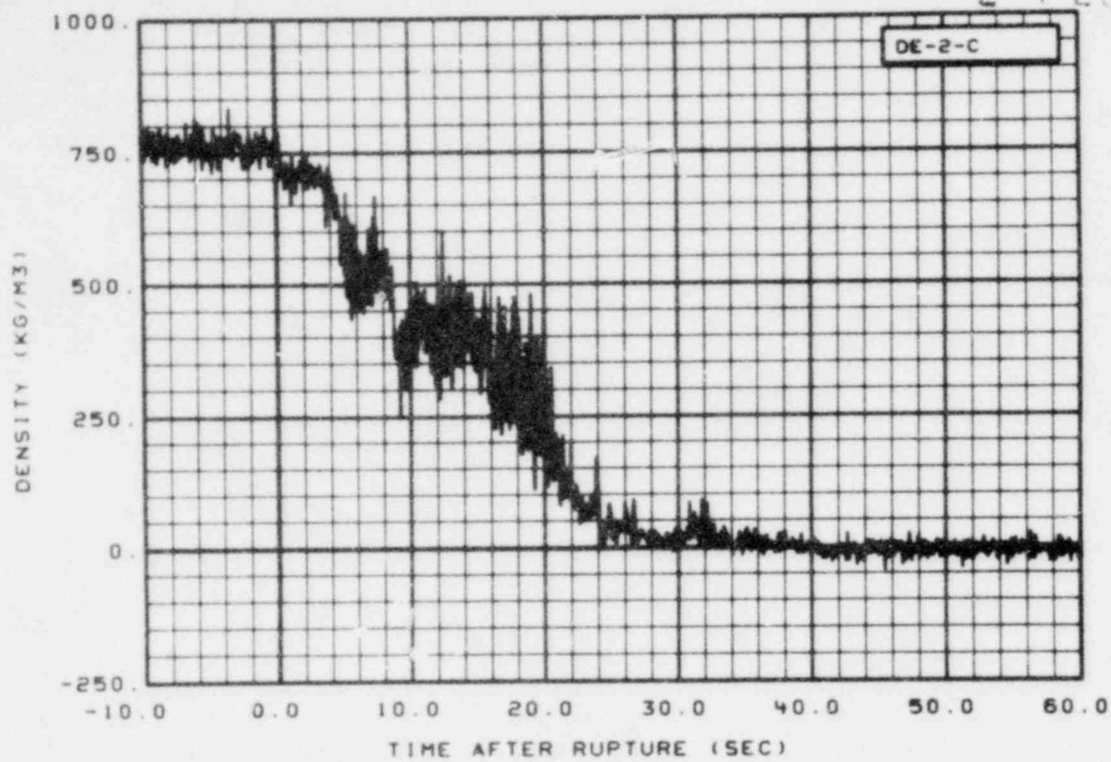
MICROCOPY RESOLUTION TEST CHART



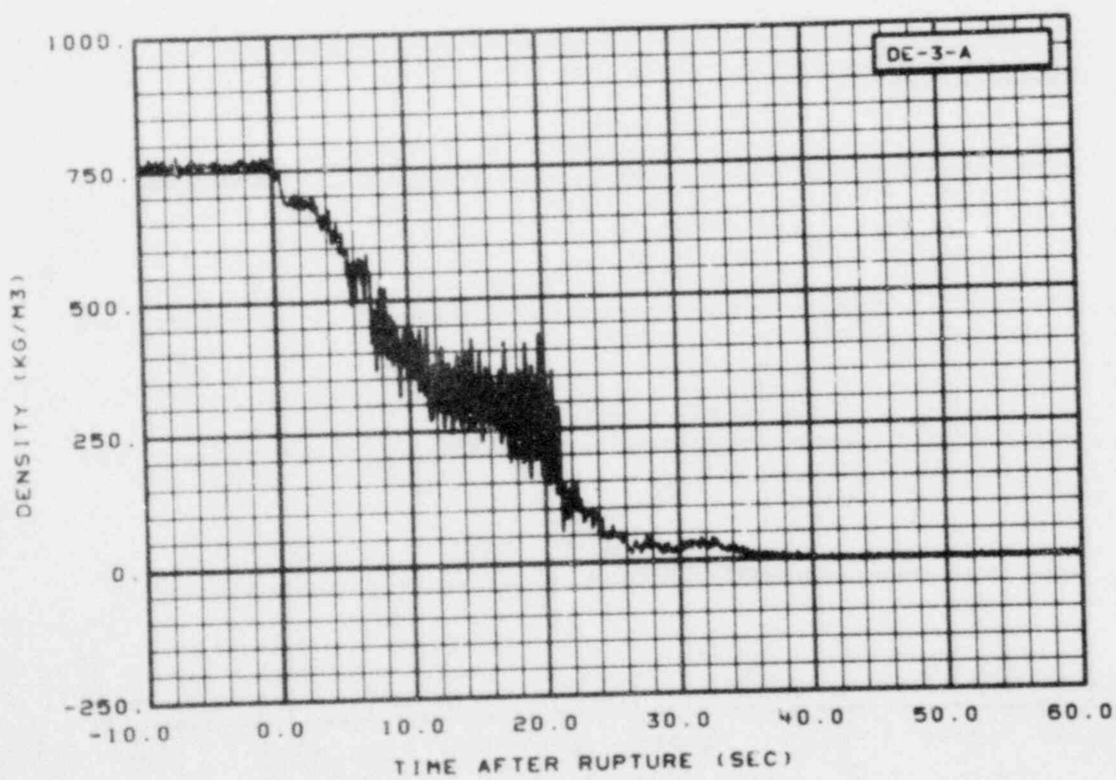
A-15 Density upstream from DTT, source 1, side beam -- (DE-1-C) -- Test IIIA101 . . . .



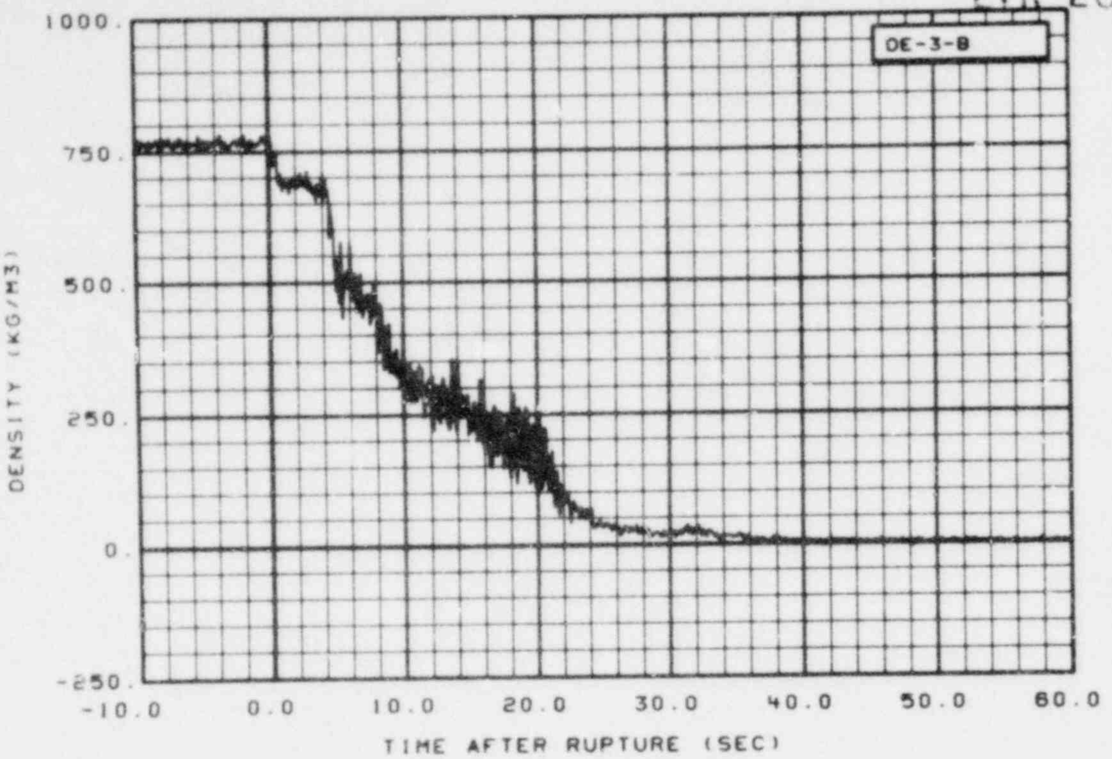
A-16 Density upstream from DTT, source 2, center beam -- (DE-2-B) -- Test IIIA101 . . . .



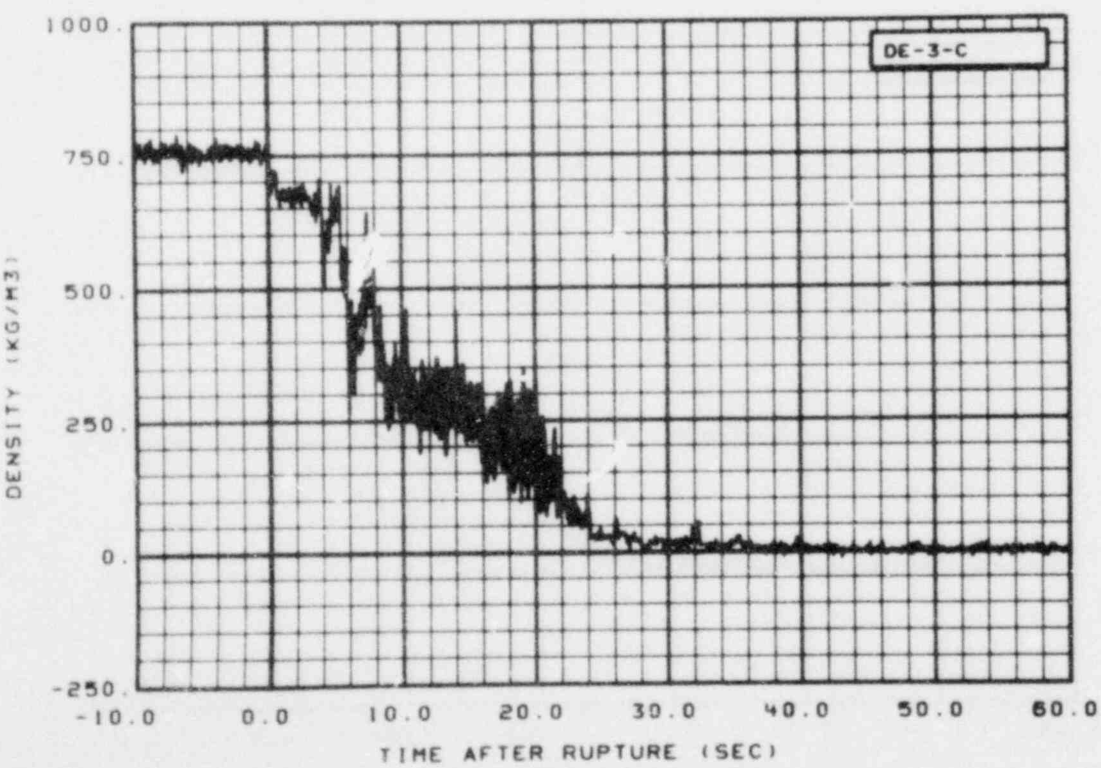
A-17 Density upstream from DTT, source 2, side beam -- (DE-2-C) -- Test IIIA201 . . . .



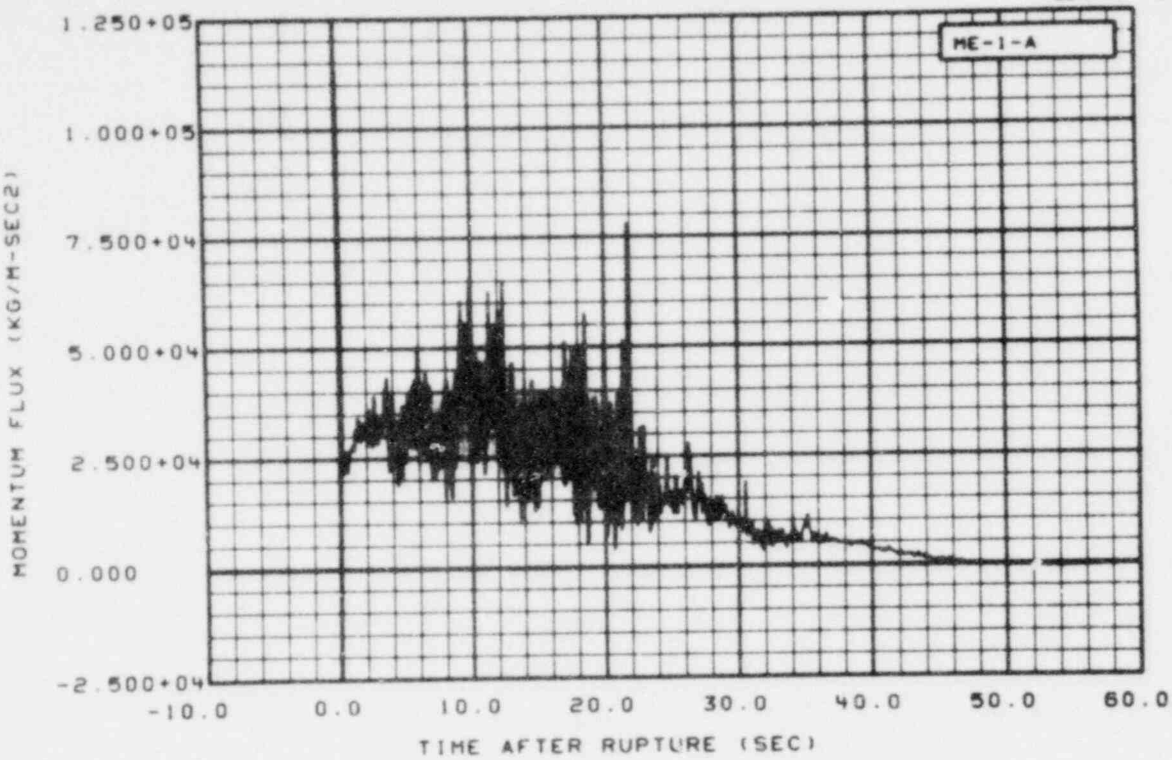
A-18 Density downstream from pitot rake, source 3 lower beam -- (DE-3-A) -- Test IIIA101 . . .



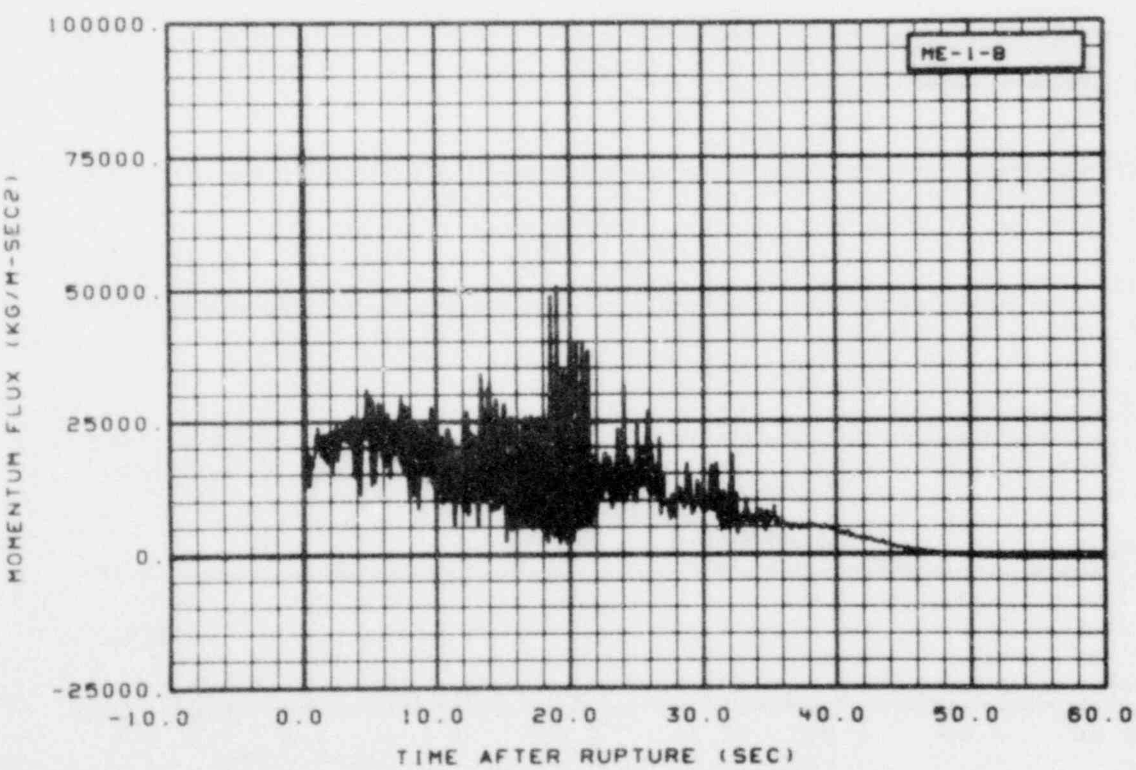
A-19 Density downstream from pitot rake, source 3 center beam -- (DE-3-B) -- Test IIIA101. . .



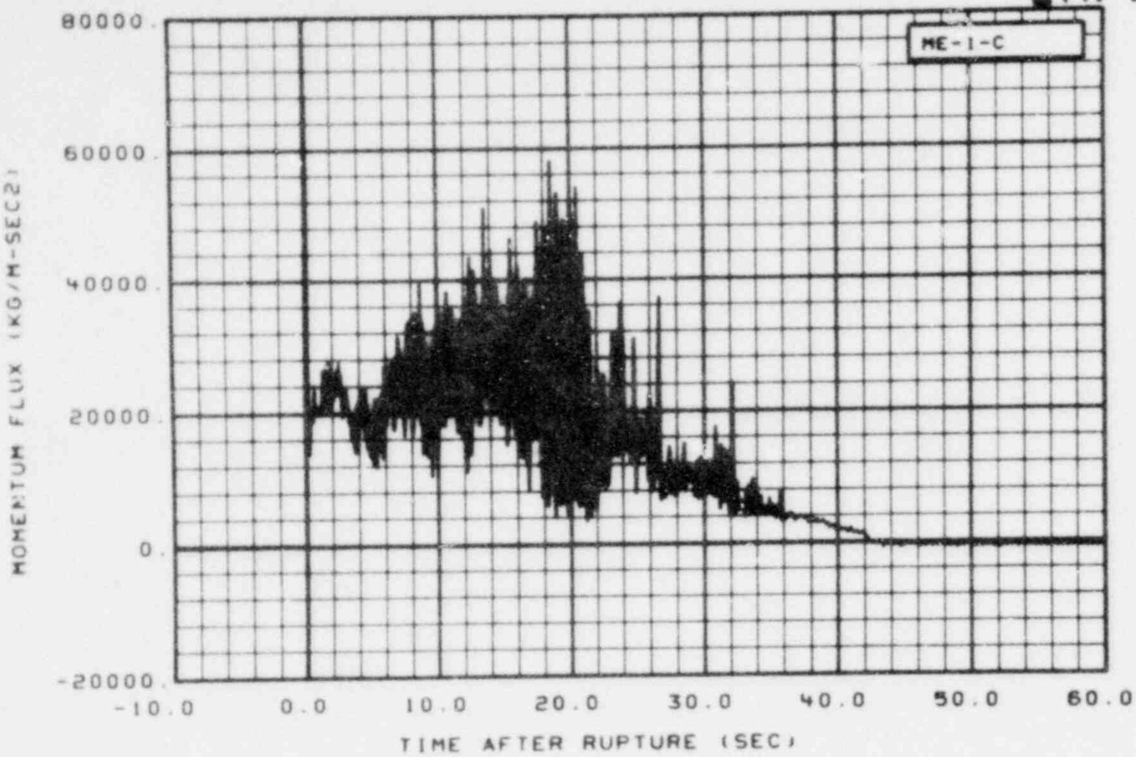
A-20 Density downstream from pitot rake, source 3 side beam -- (DE-3-C) -- Test IIIA101. . . .



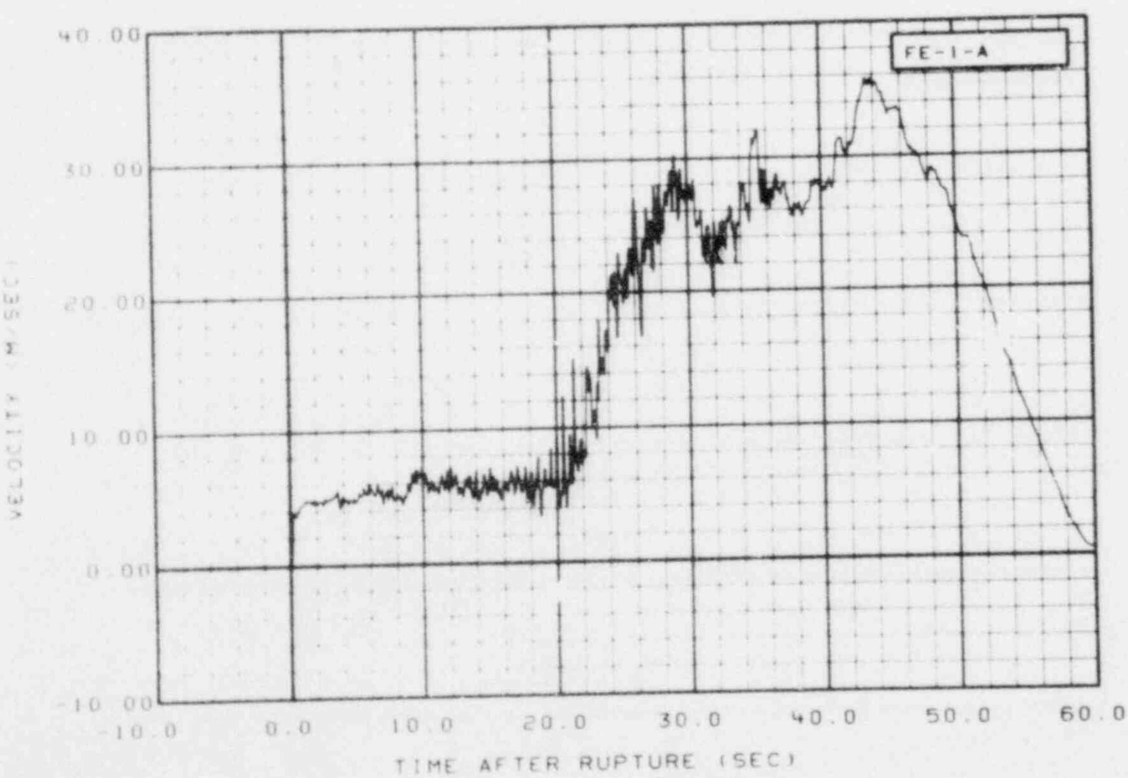
A-21 Momentum flux at free end of DTT -- (ME-1-A) -- Test IIIA101 . . . .



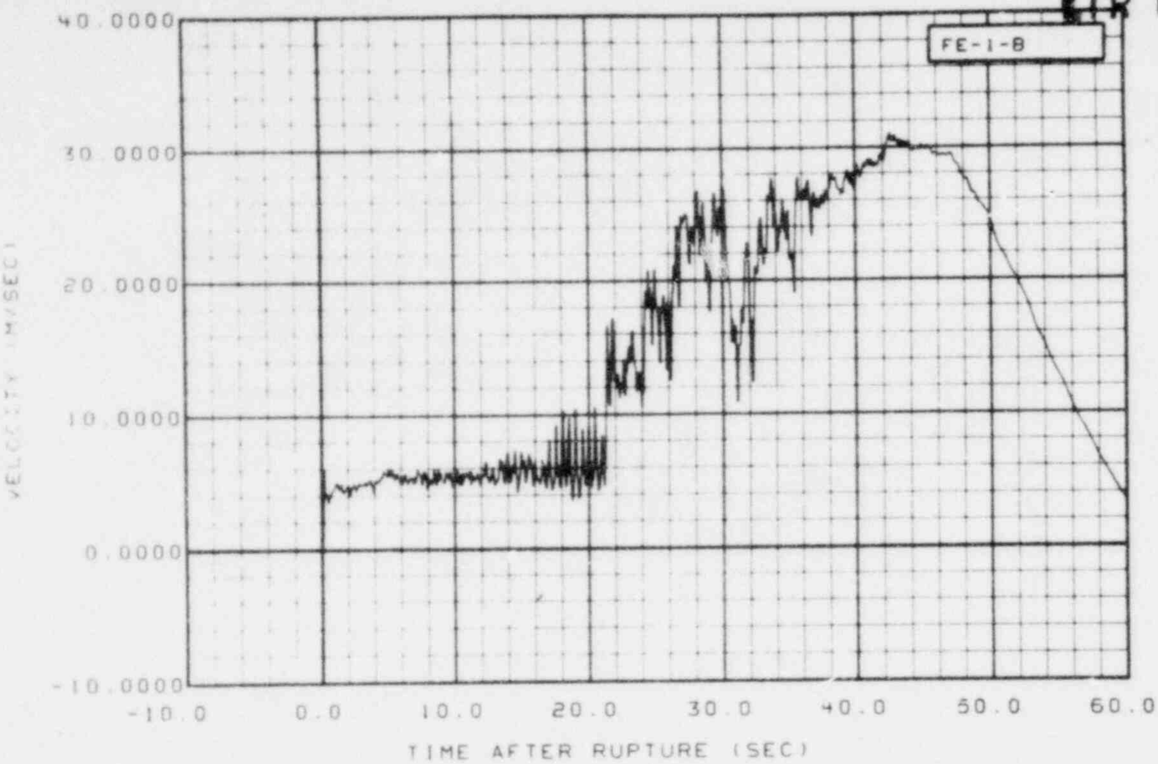
A-22 Momentum flux at center DTT -- (ME-1-B) -- Test IIIA101



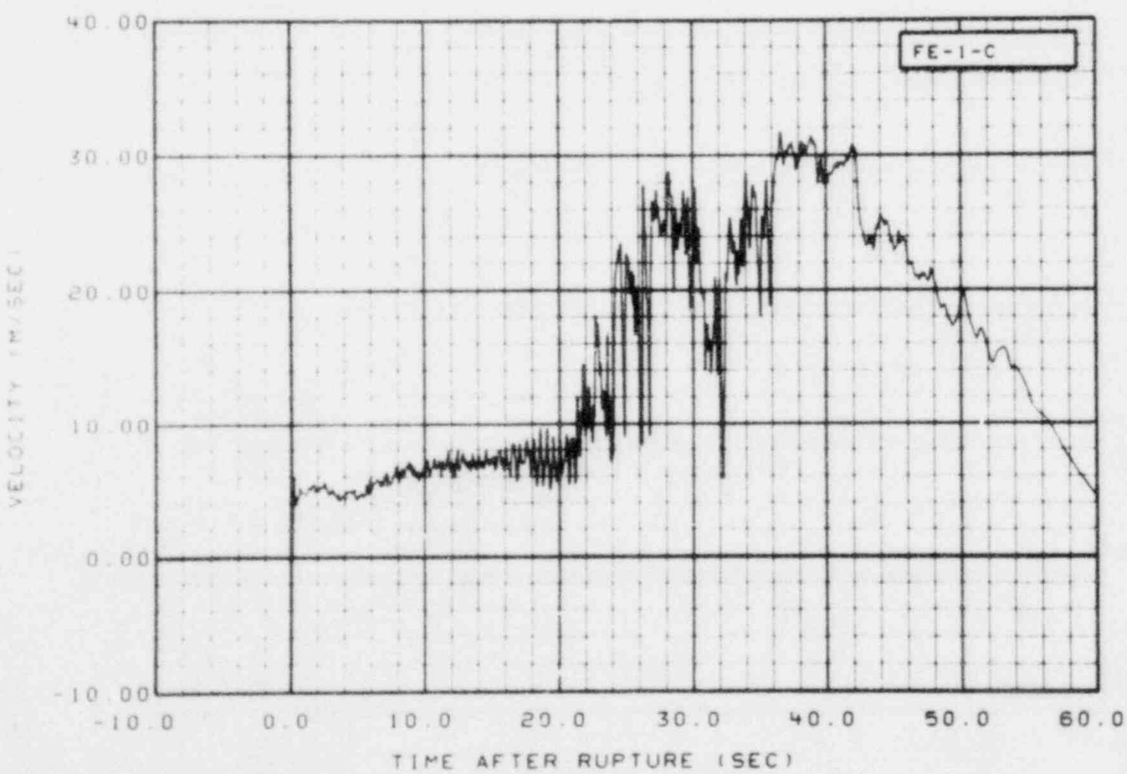
A-23 Momentum flux at flange end of DTT -- (ME-1-C) -- Test IIIA101 . . . .



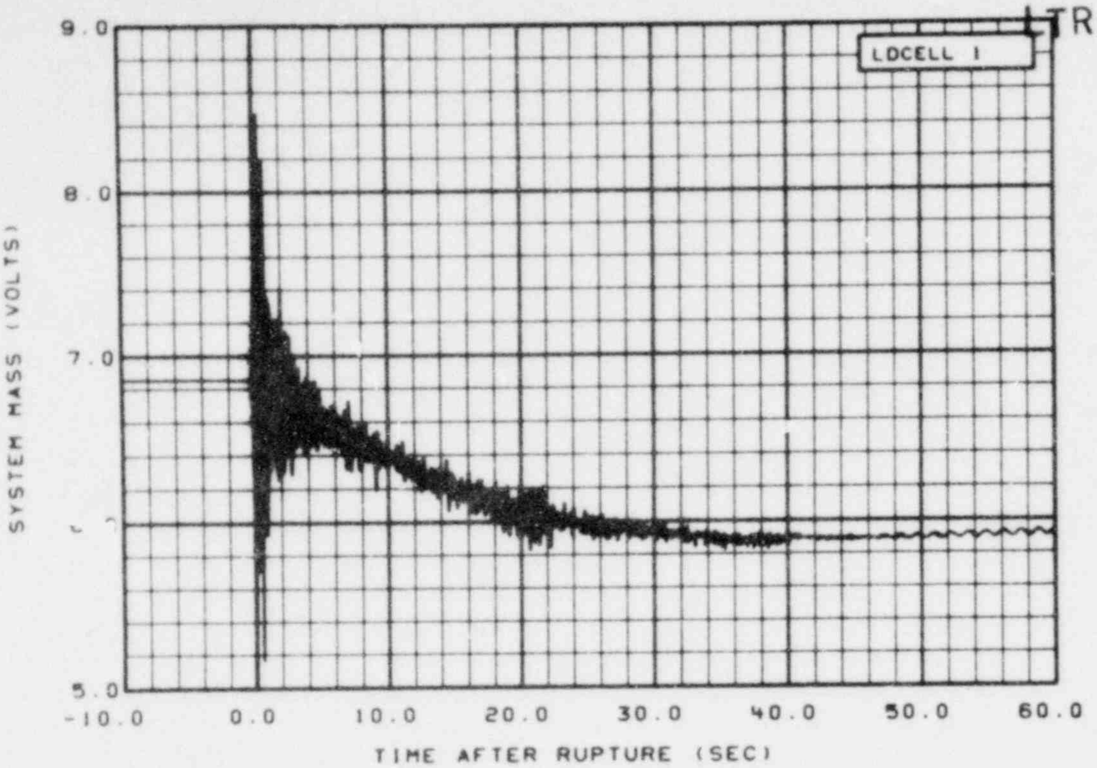
A-24 Fluid velocity at free end of DTT -- (FE-1-A) Test IIIA101 . . . .



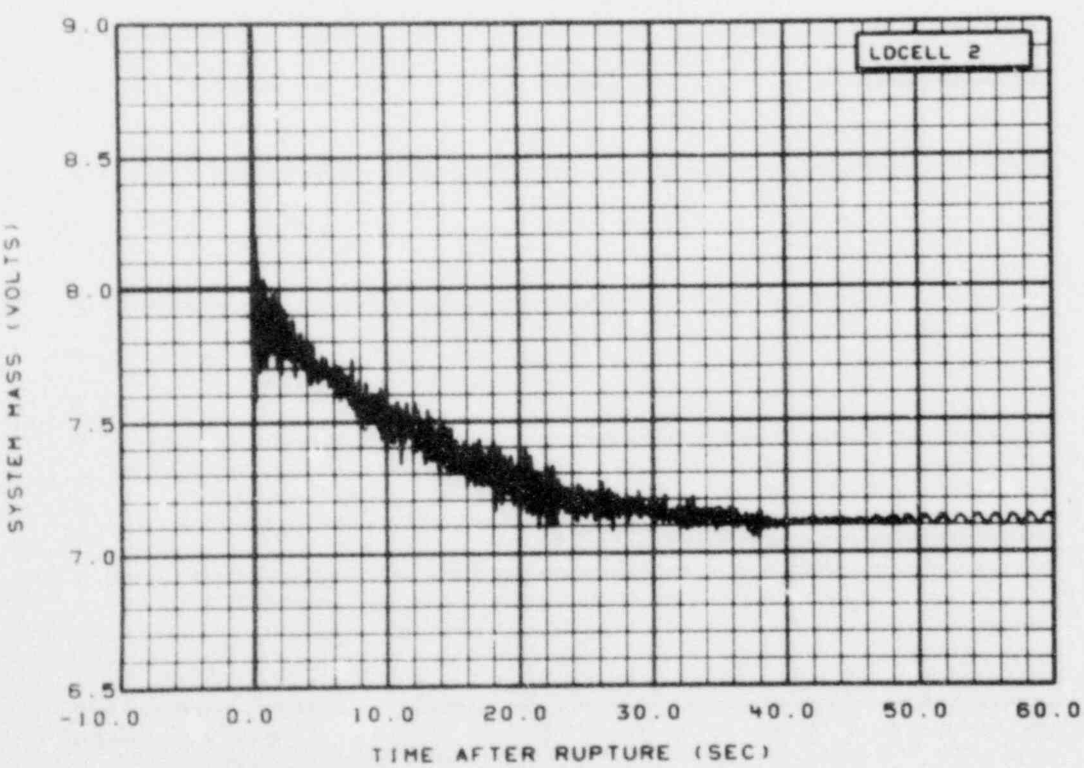
A-25 Fluid velocity at center DTT -- (FE-1-B) -- Test IIIA101 . . . .



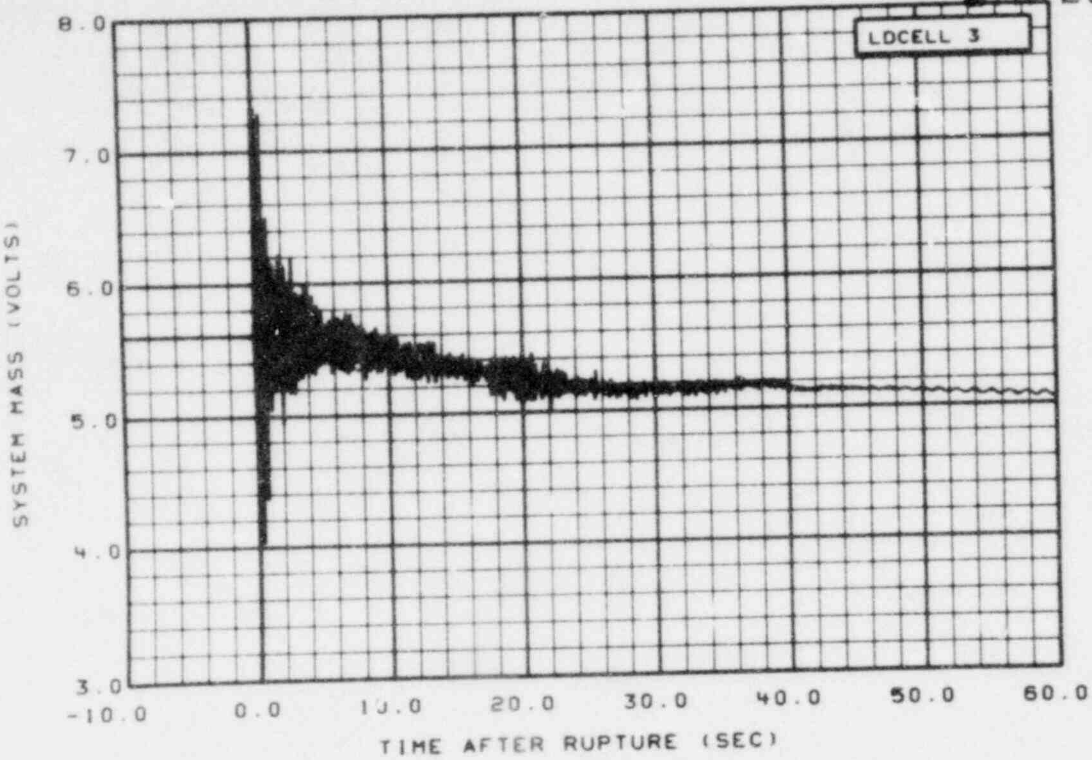
A-26 Fluid velocity at flange end of DTT -- (FE-1-C) -- Test IIIA101. . . . .



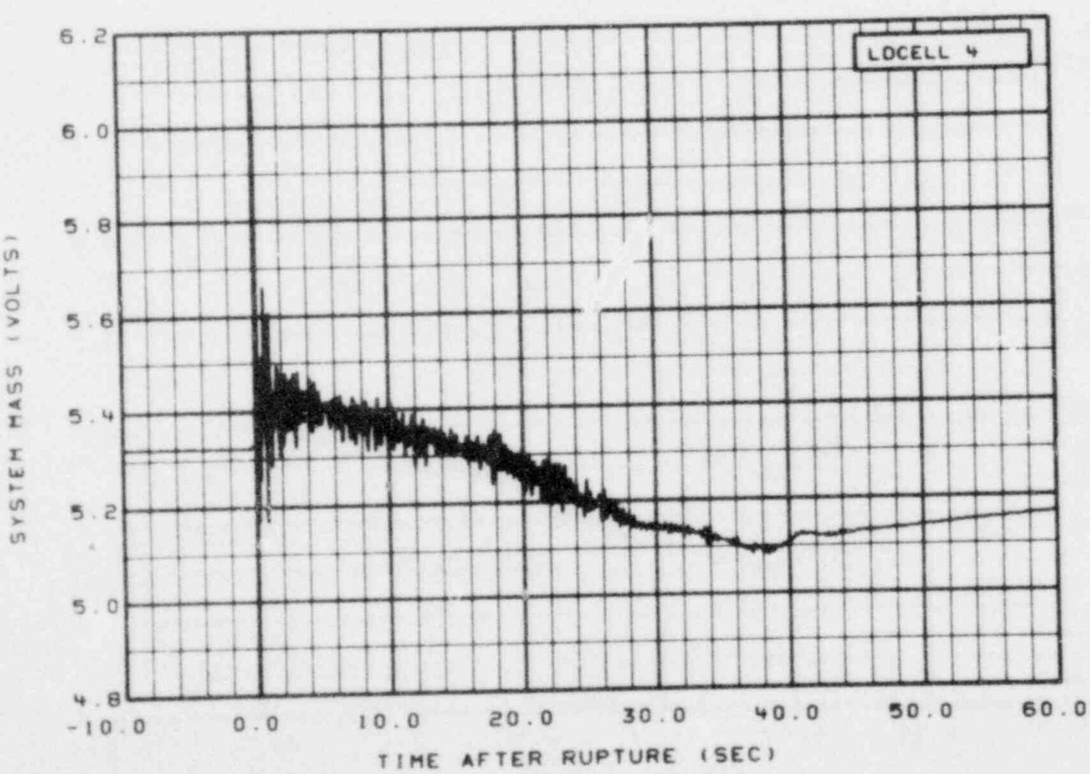
A-27 Load cell 1 -- Test IIIA101



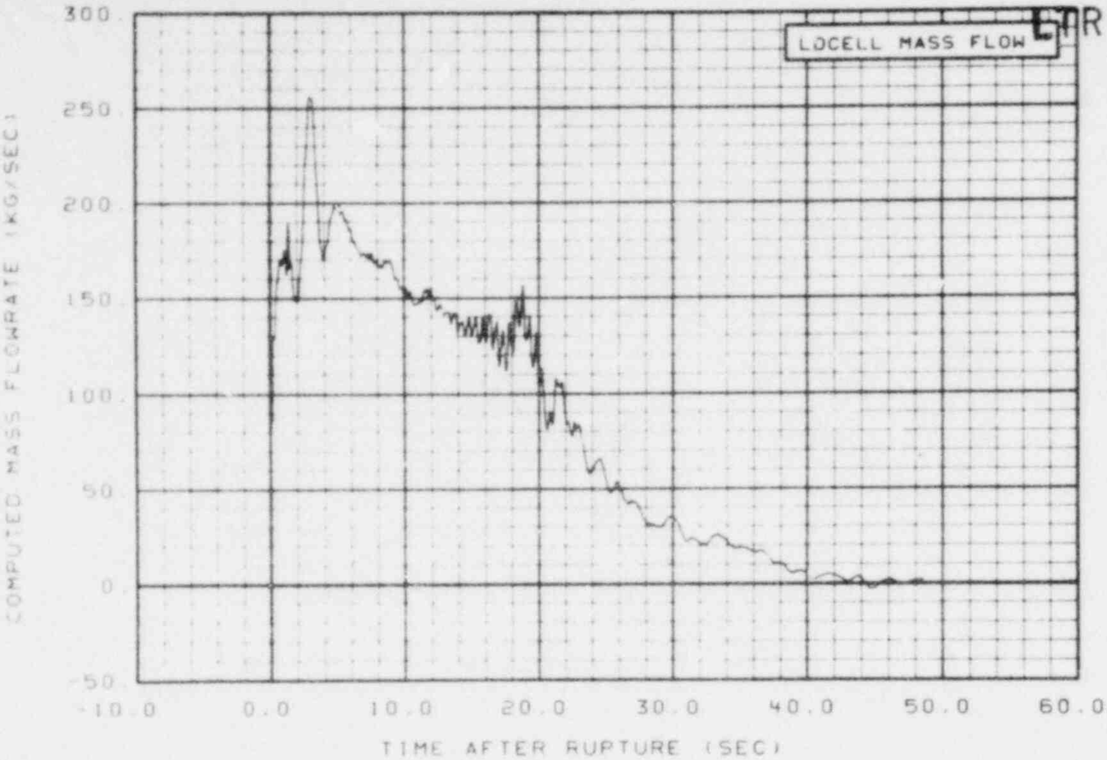
A-28 Load cell 2 -- Test IIIA101



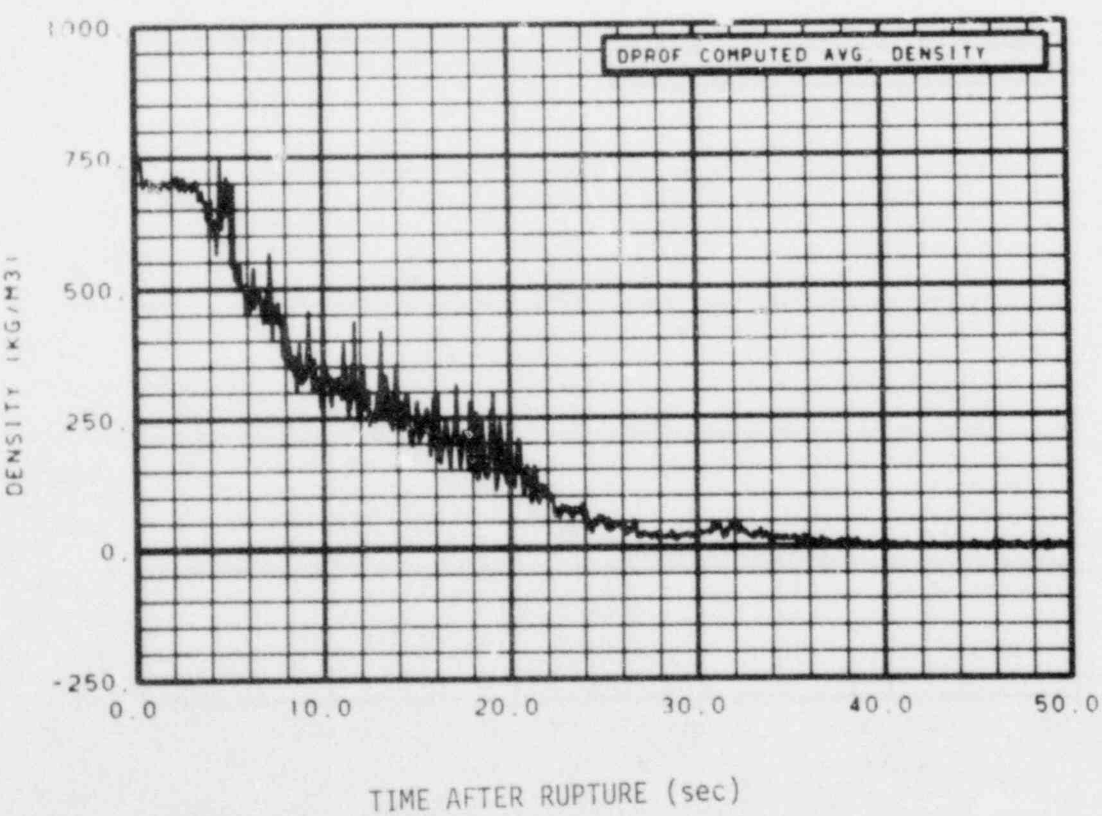
A-29 Load cell 3 -- Test IIIA101.



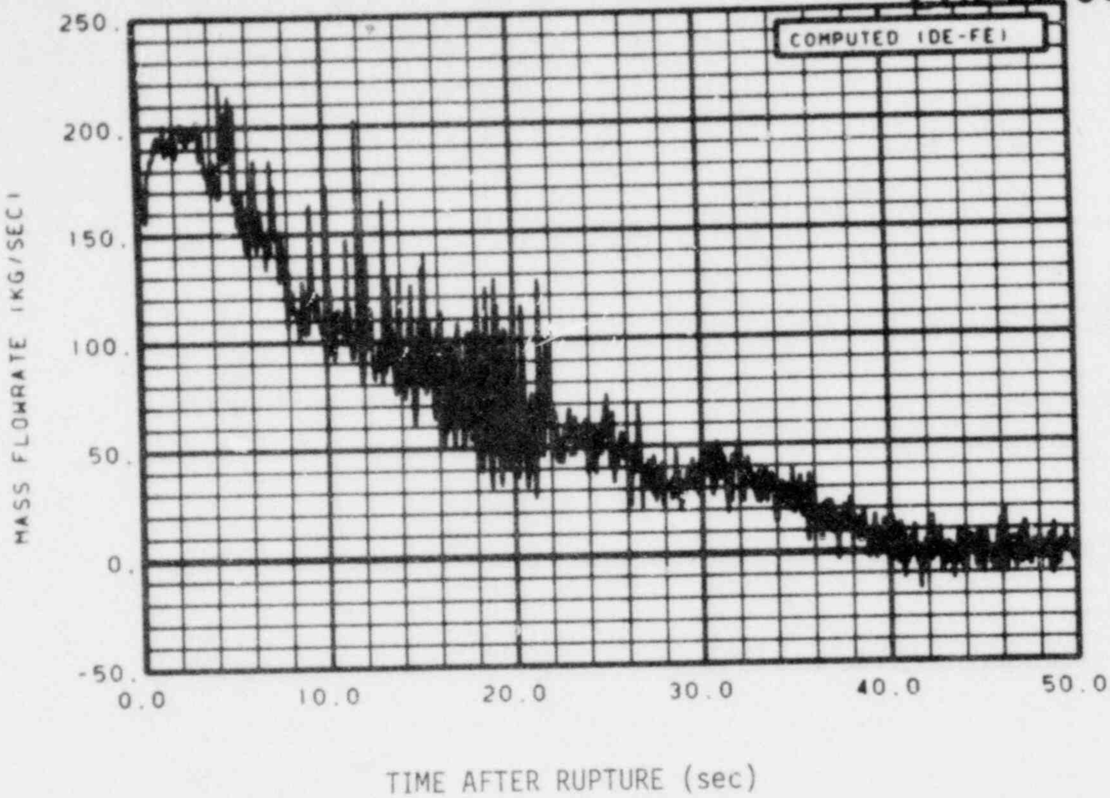
A-30 Load cell 4 -- Test IIIA101



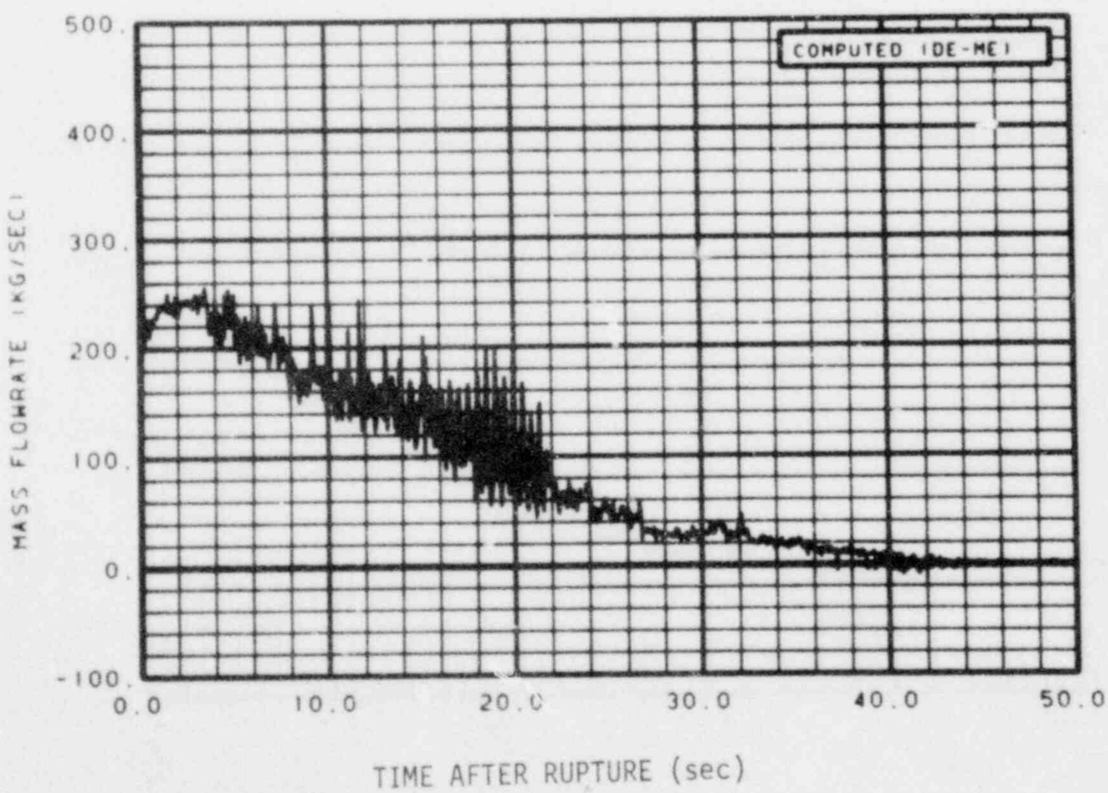
A-31 Mass flow rate computed from load cell readings -- Test IIIA101 . . . .



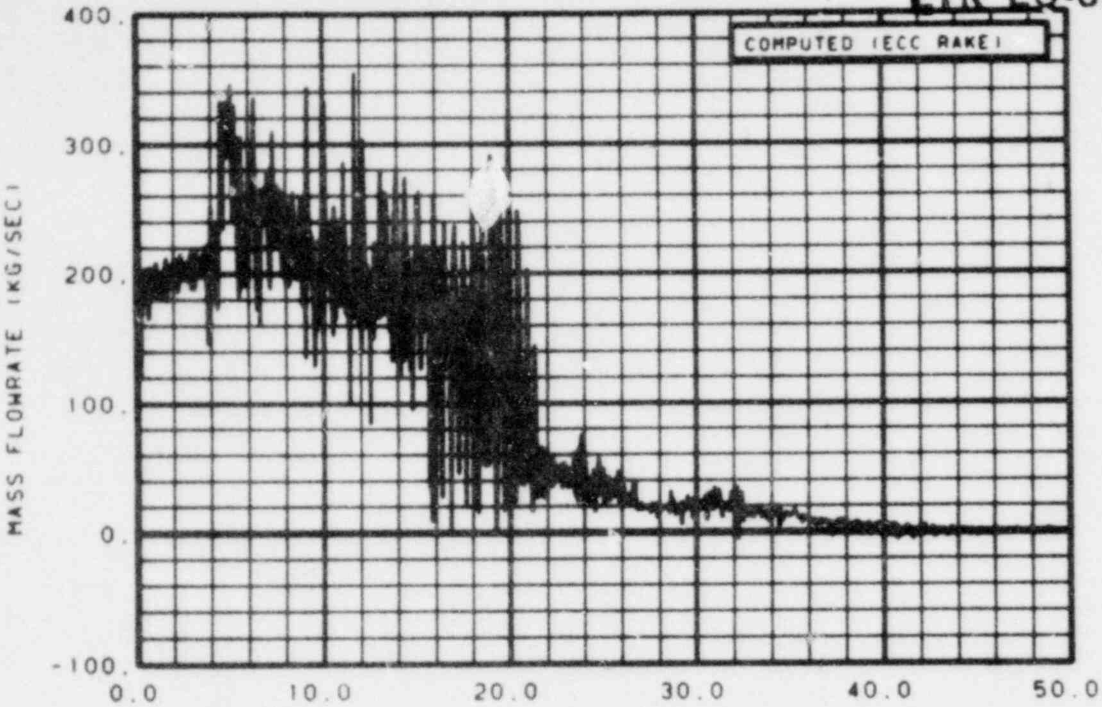
A-32 Average density computed from 6-beam gamma densitometer -- Test IIIA101 . . . .



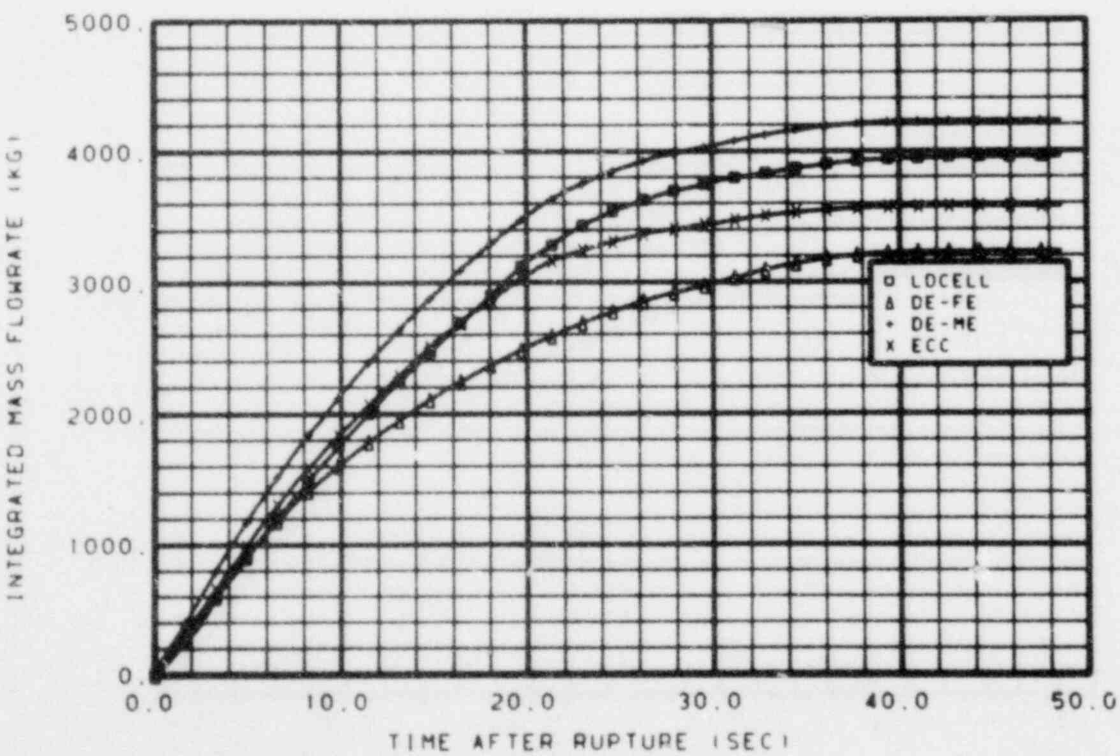
A-33 Mass flow rate computed from turbine meters and gamma densitometers -- Test IIIA101. .



A-34 Mass flow rate computed from drag discs and densitometers -- Test IIIA101. . . . . . .



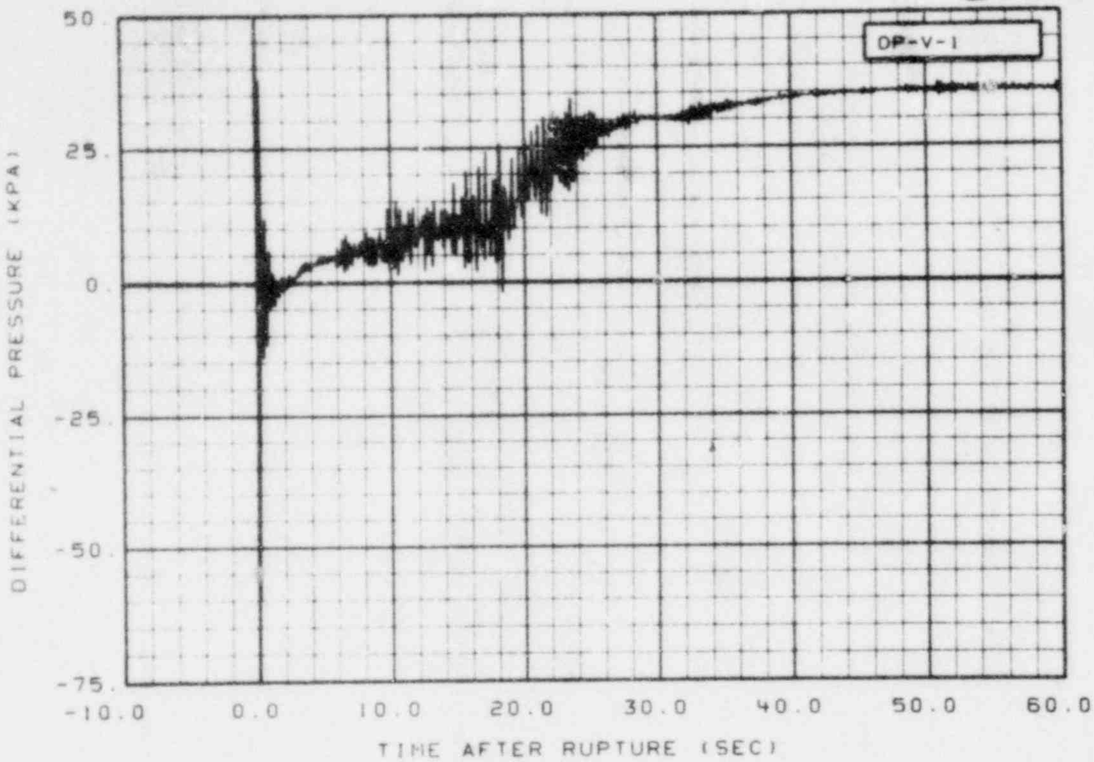
A-35 Mass flow rate computed from ECC pitot tube rake and gamma densitometers -- Test IIIA101. . . . .



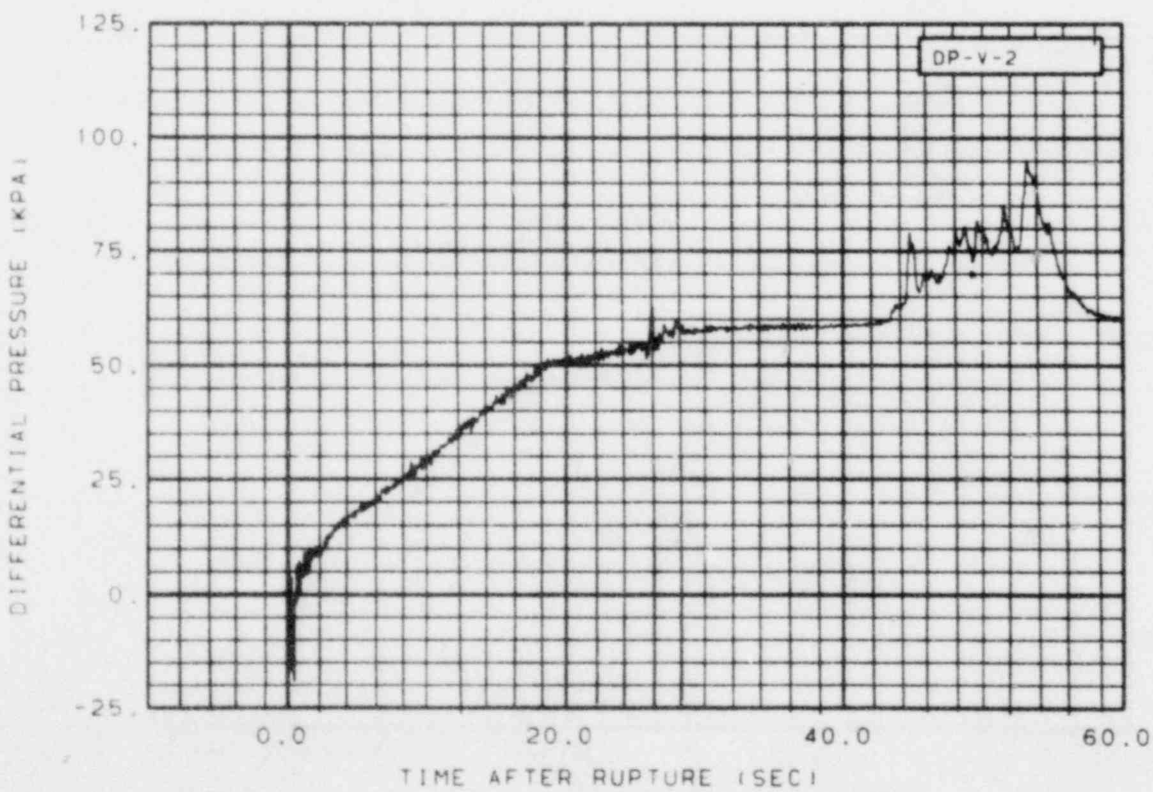
A-36 Integrated mass flowrate comparisons -- Test IIIA101

APPENDIX B

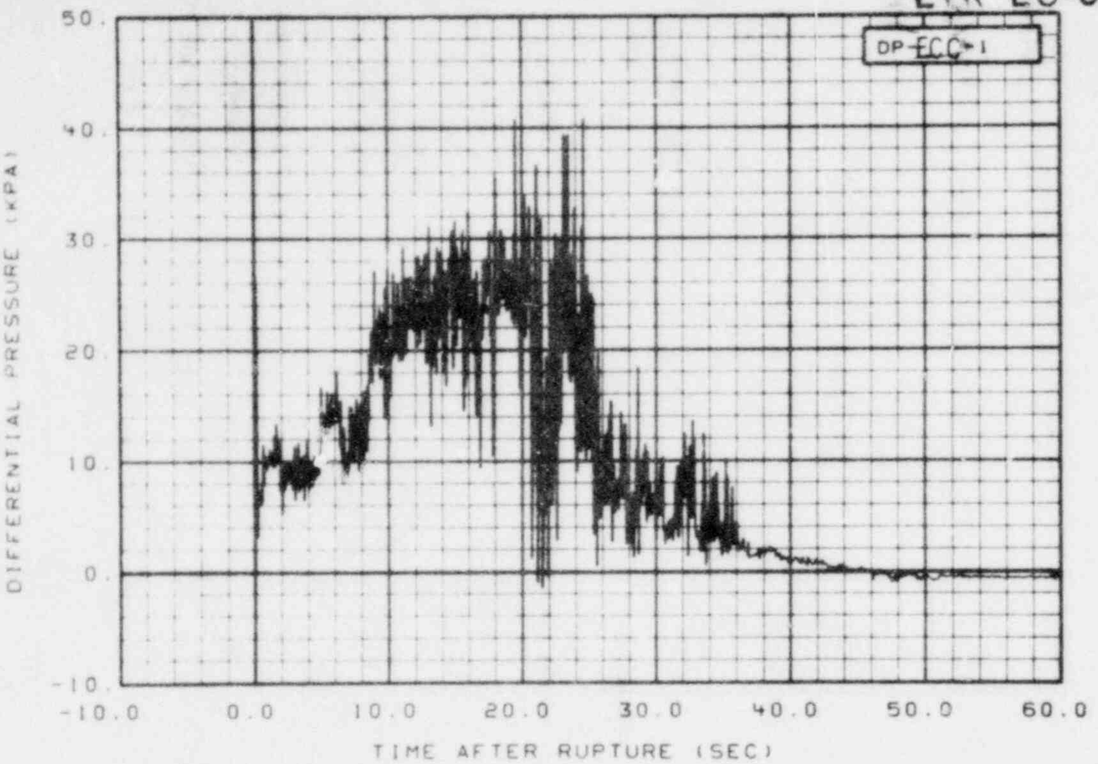
DATA FROM TEST IIIA102



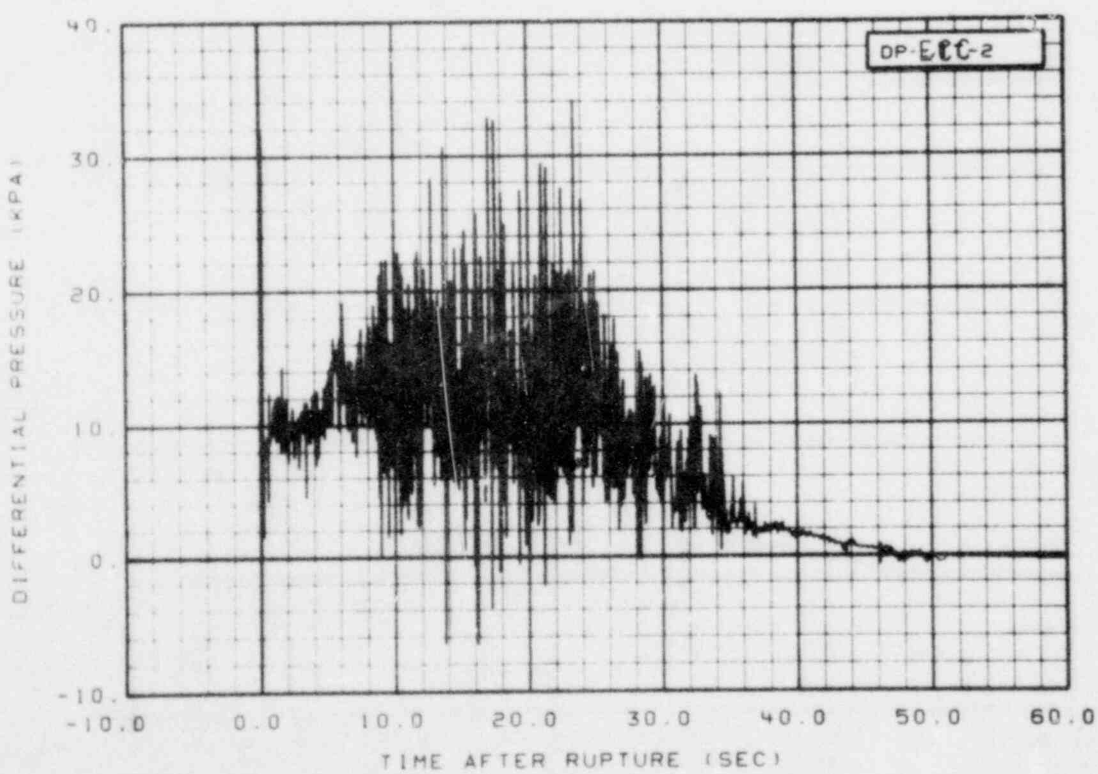
B-1 Differential pressure from vessel bottom to outlet nozzle tap -- (DP-V-1) -- Test IIIA102 . . . . . .



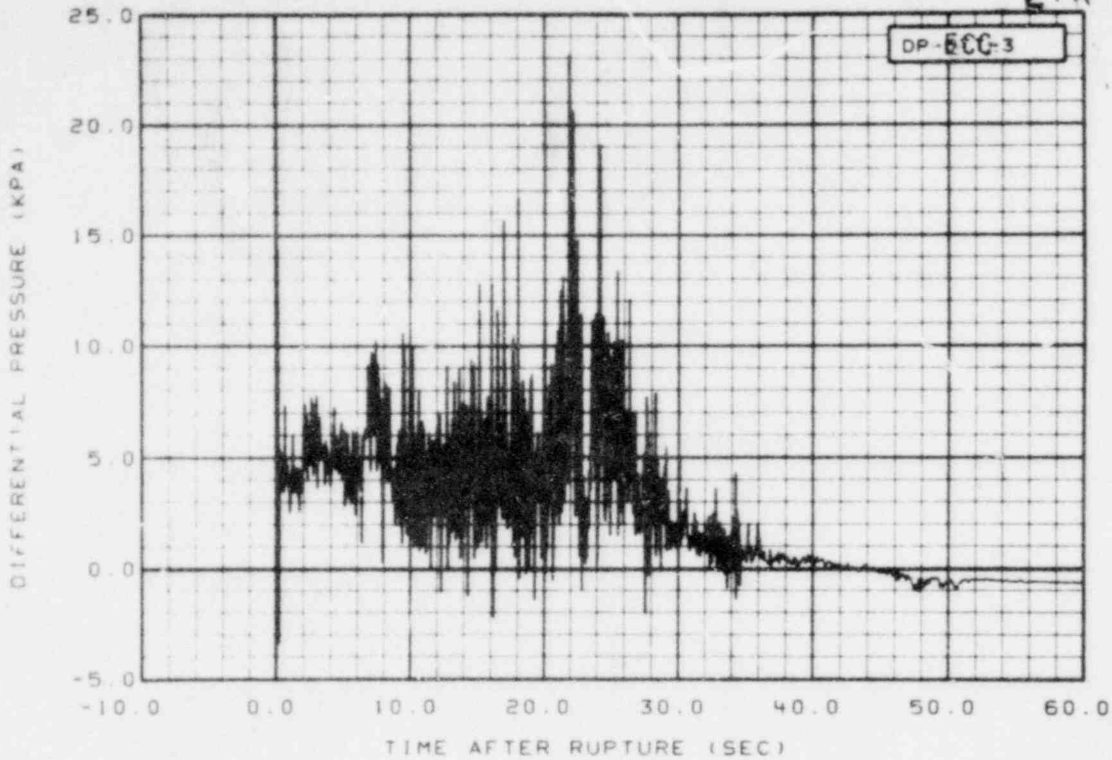
B-2 Differential pressure from vessel top vent to heatup line, low range -- (DP-V-2) -- Test IIIA102



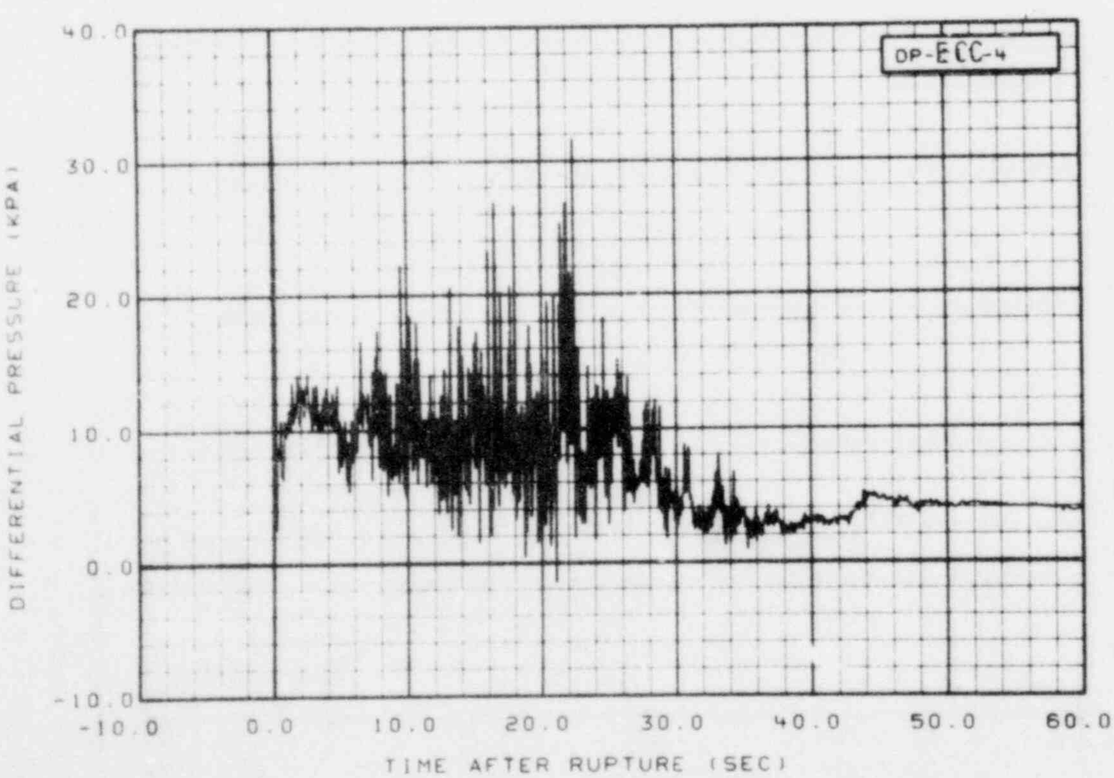
B-3 Differential pressure at bottom of ECC pitot tube rake -- (DP-ECC-1) -- Test IIIA102. . .



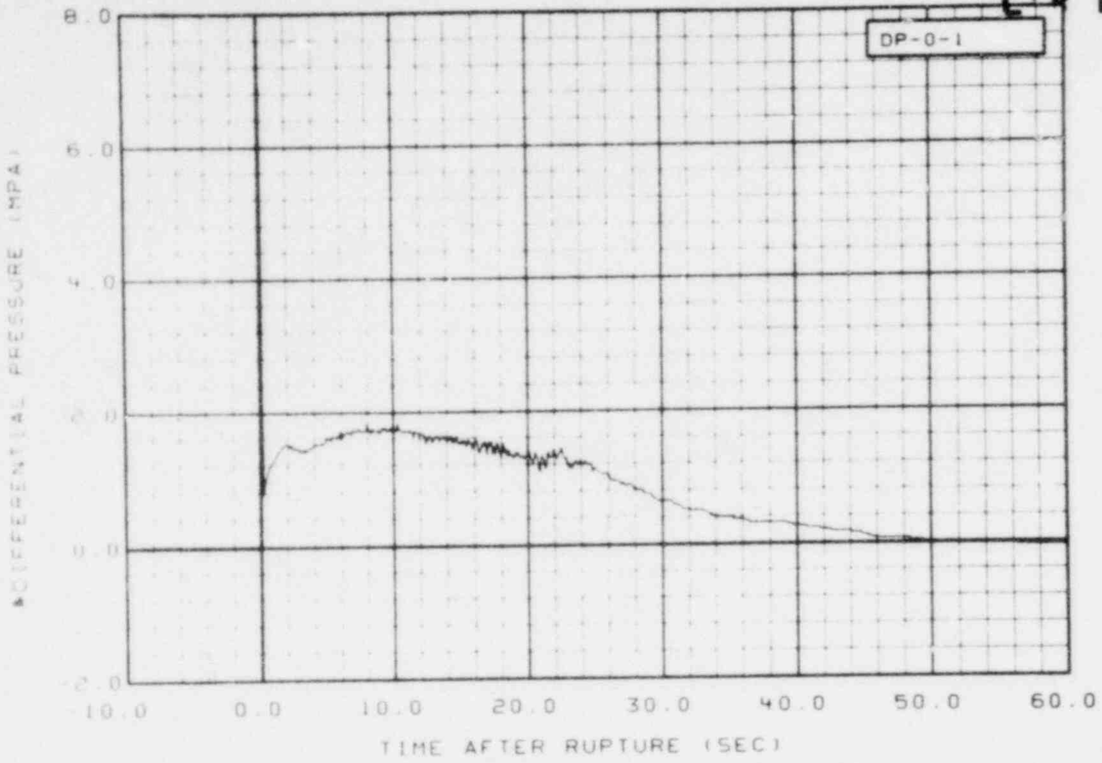
B-4 Differential pressure at ECC pitot tube rake -- (DP-ECC-2) -- Test IIIA102 . . . .



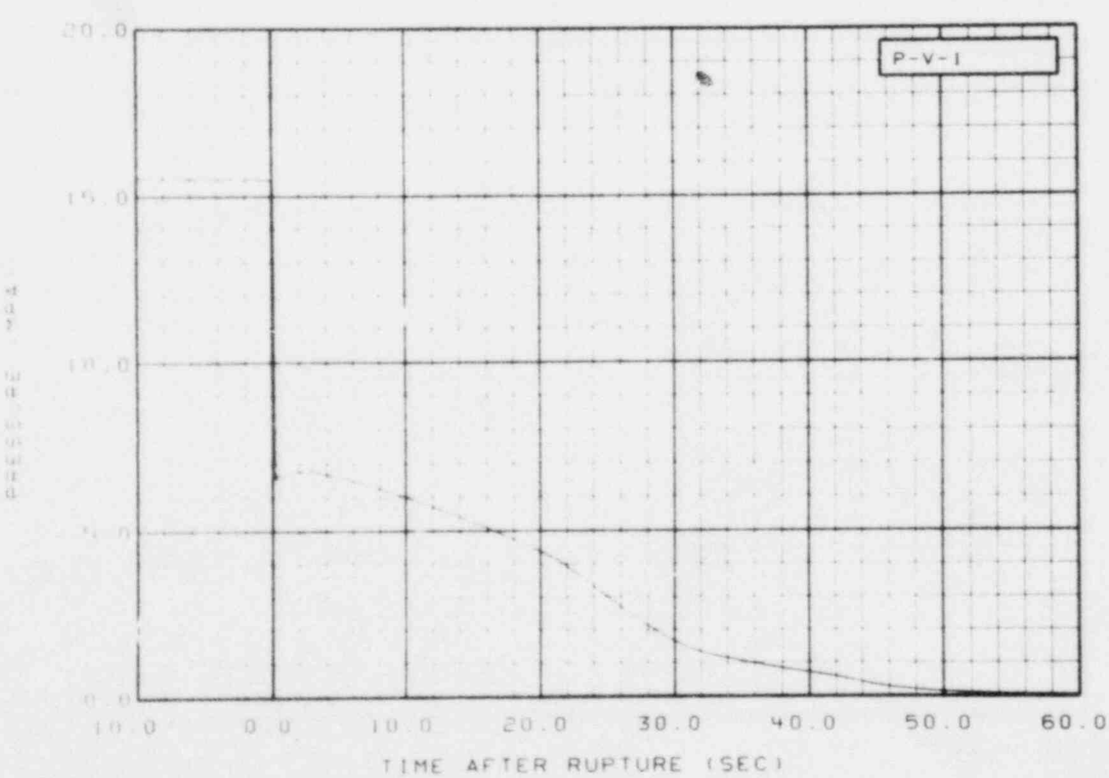
B-5 Differential pressure at center of ECC pitot tube rake -- (DP-ECC-3) -- Test IIIA102 . . . .



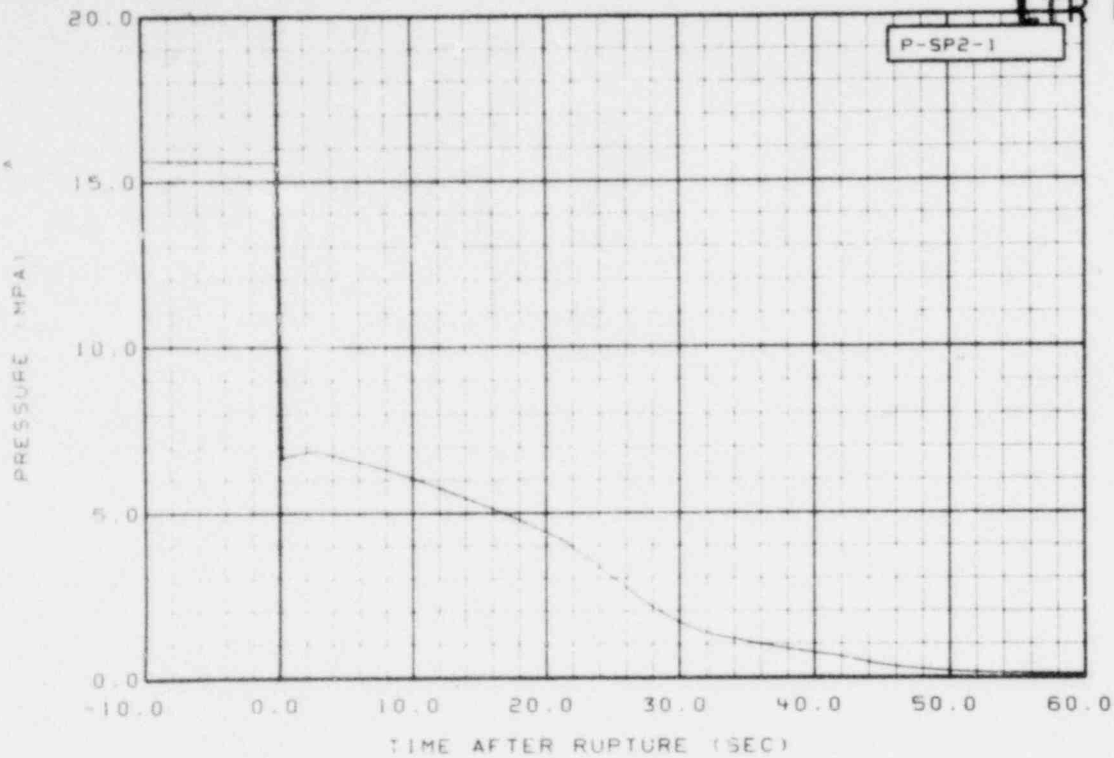
B-6 Differential pressure at top of ECC pitot tube rake -- (DP-ECC_4) -- Test IIIA102 . . . . . .



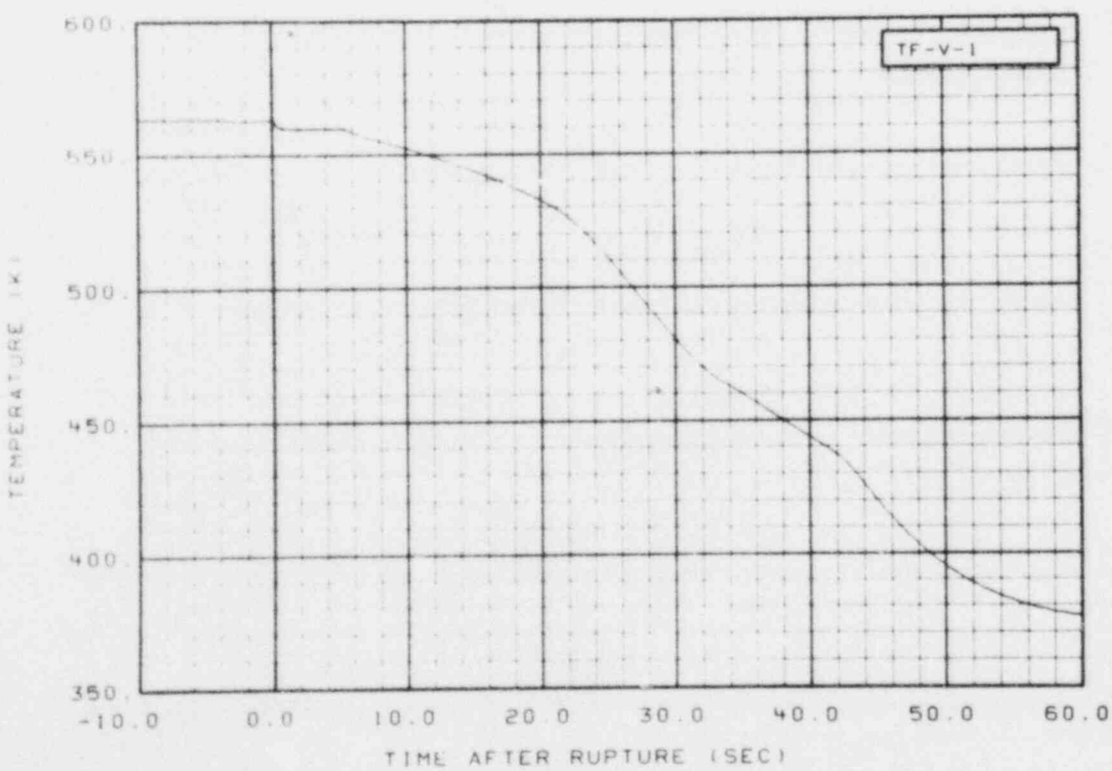
B-7 Differential pressure from test spool tap no. 11 to gate valve flange -- (DP-0-1) -- Test IIIA102



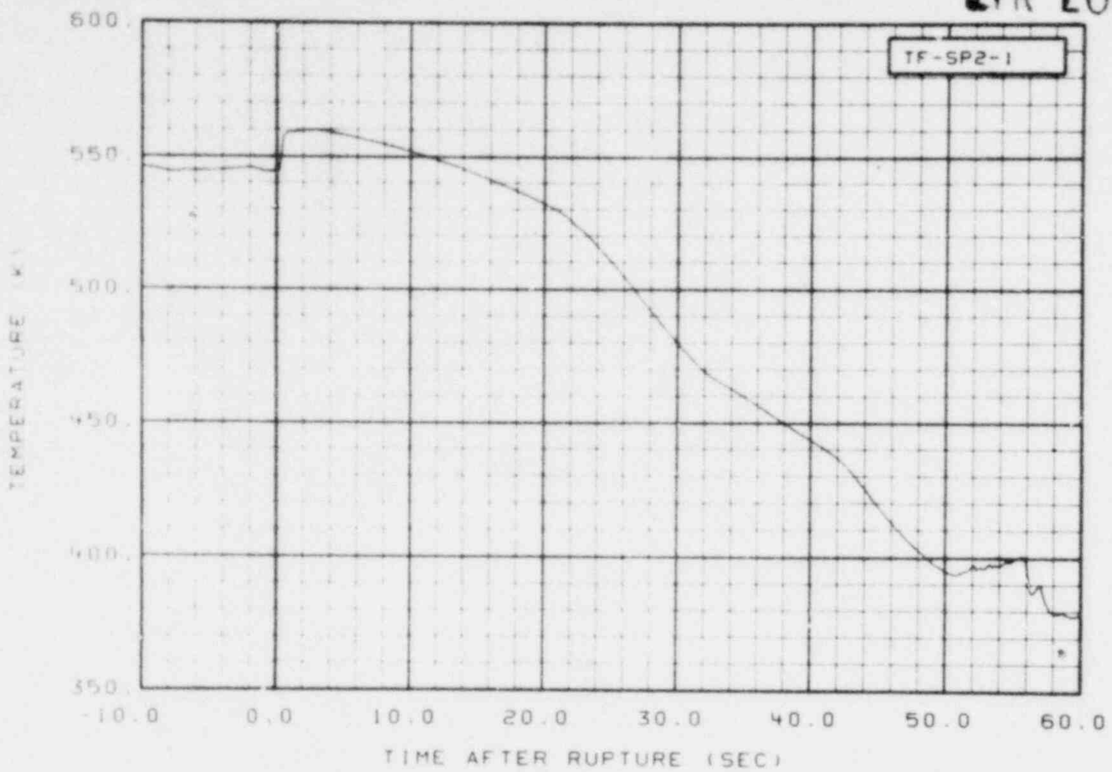
B-8 Pressure at bottom of vessel -- (P-V-1) -- Test IIIA102.



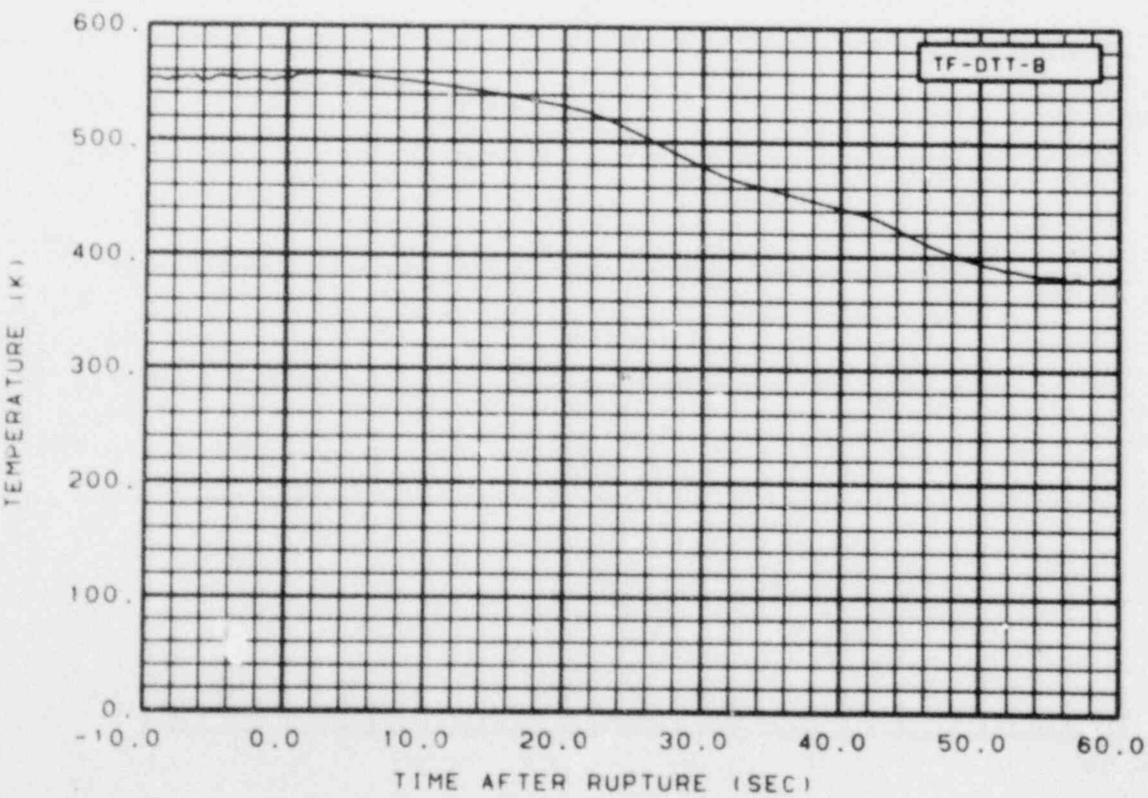
B-9 Pressure at test spool tap no. 11 -- (P-SP2-1) -- Test IIIA102 . . . .



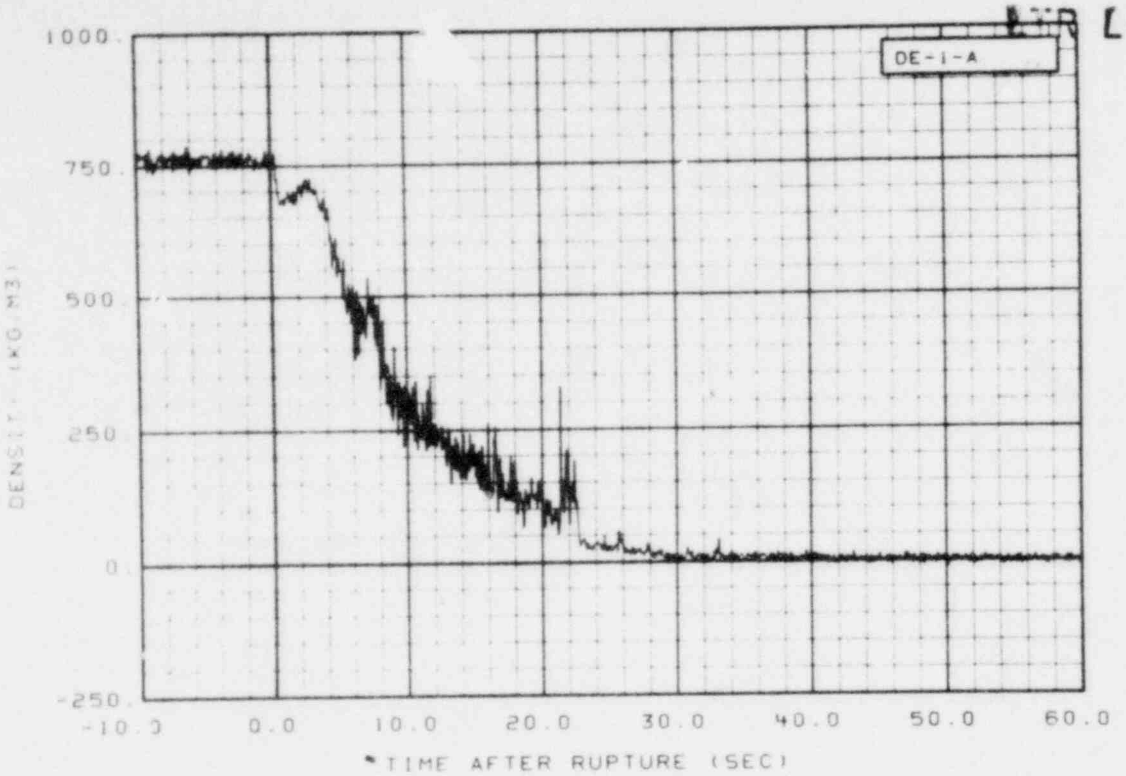
B-10 Fluid temperature at bottom of vessel -- (TF-V-1) -- Test IIIA102 . . . .



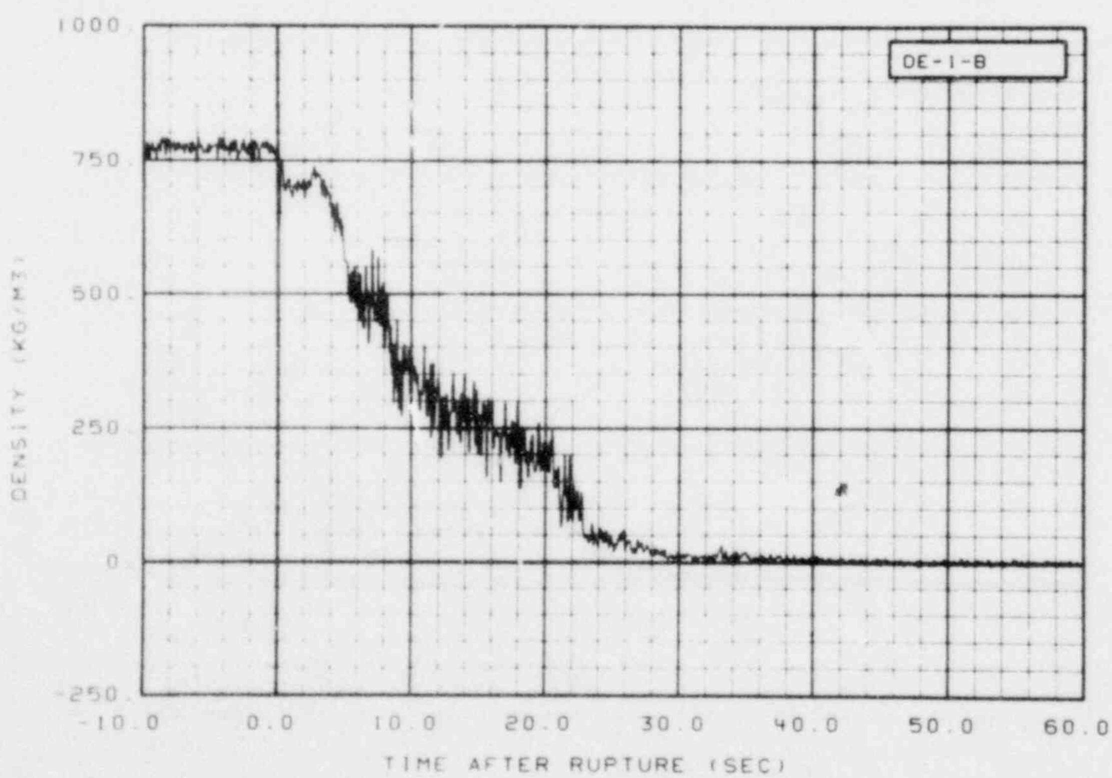
B-11 Fluid temperature at test spool tap no. 1 -- (TF-SP2-1) -- Test IIIA102 . . . .



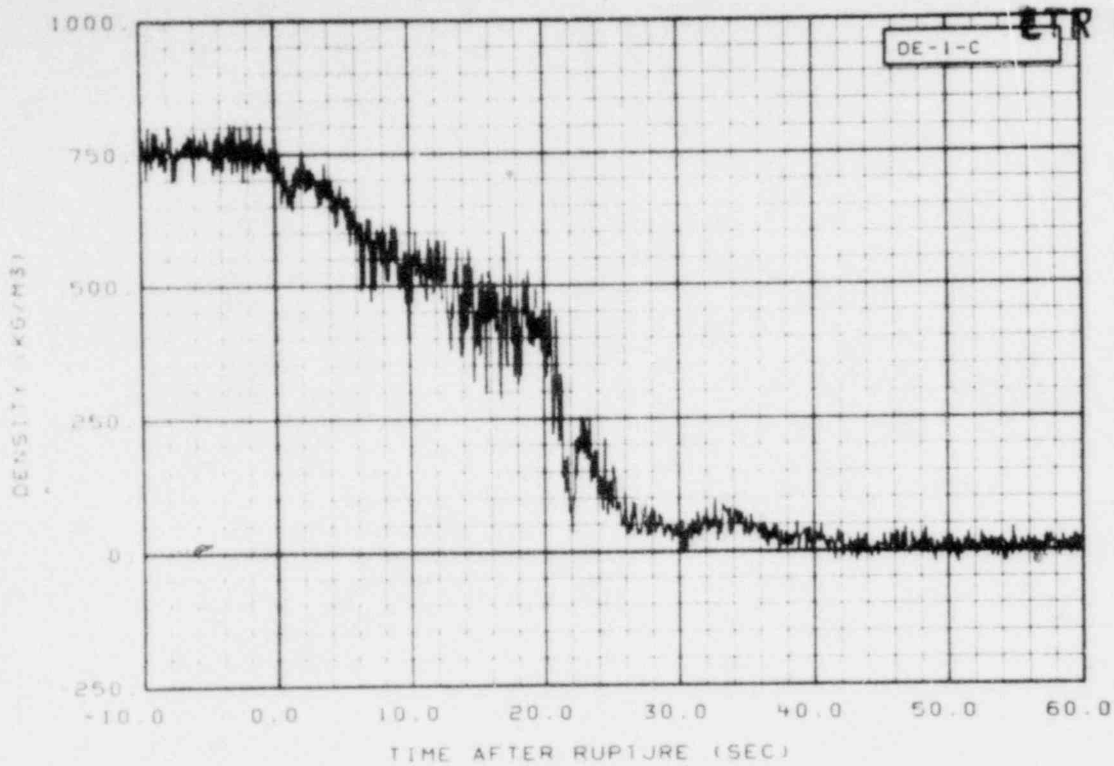
B-12 Fluid temperature at DTT port -- (TF-DTT-B) -- Test IIIA102 . . . .



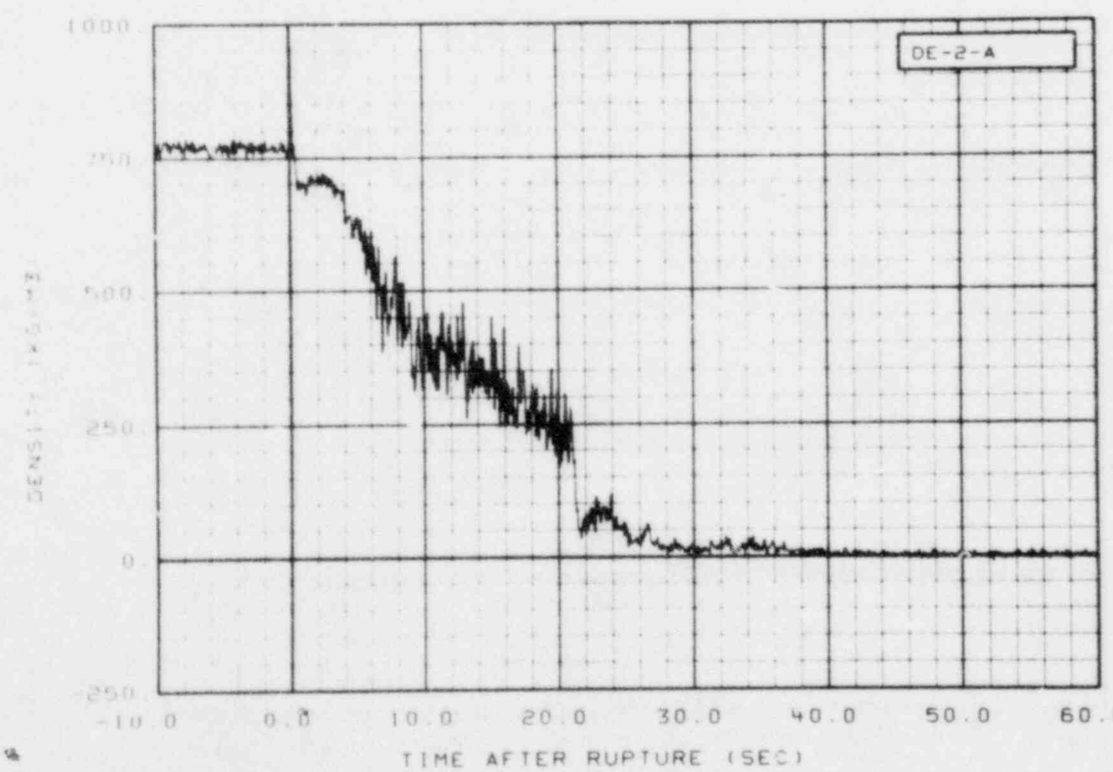
B-13 Density upstream from DTT, source 1, top beam -- (DE-1-A) -- Test IIIA102 . . . .



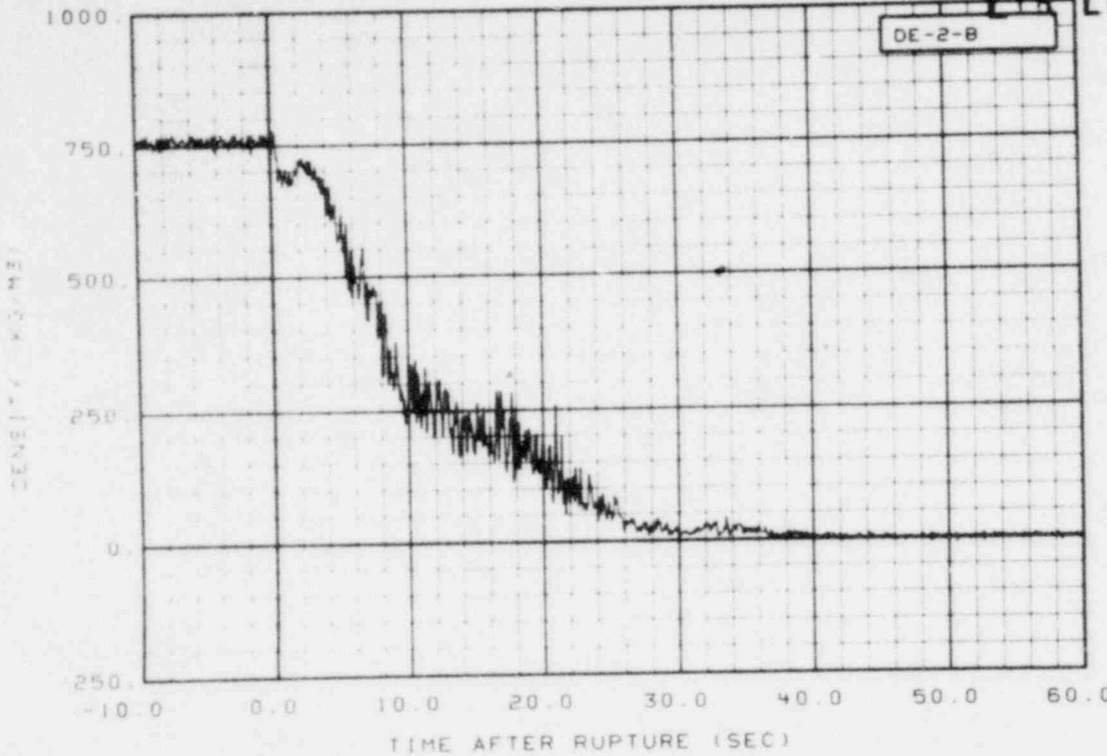
B-14 Density upstream from DTT, source 1, center beam -- (DE-1-B) -- Test IIIA102 . . . .



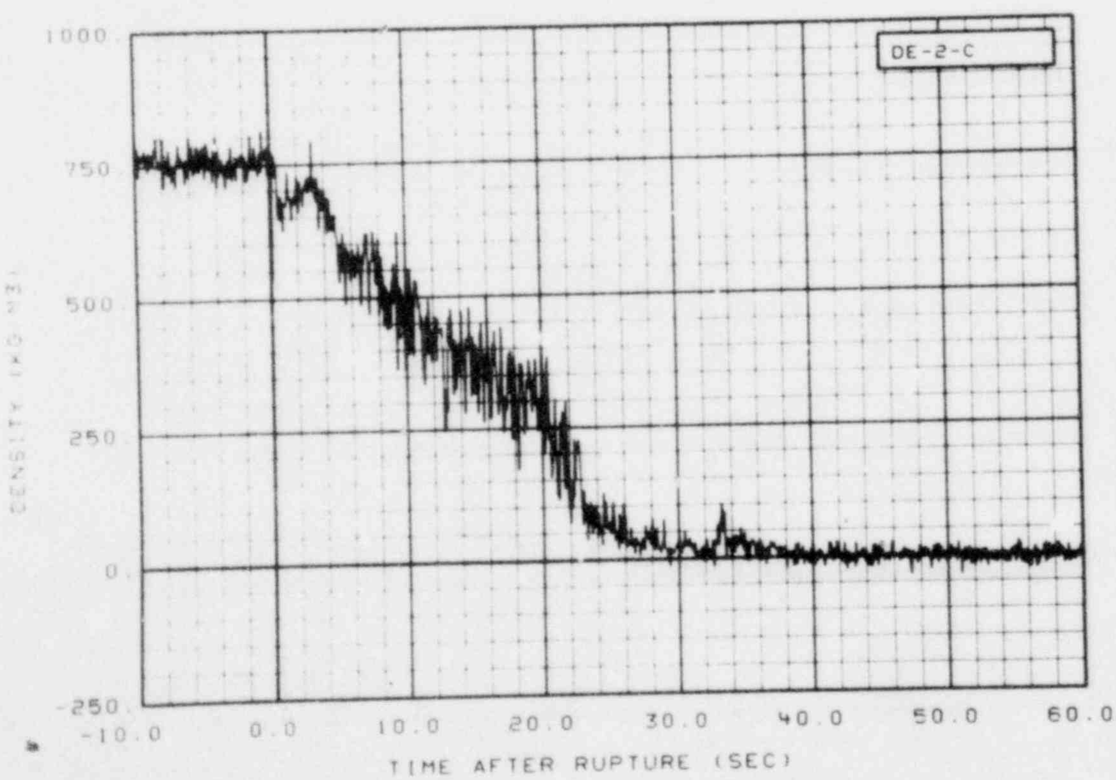
B-15 Density upstream from DTT, source 1, side beam -- (DE-1-C) -- Test IIIA102 . . . .



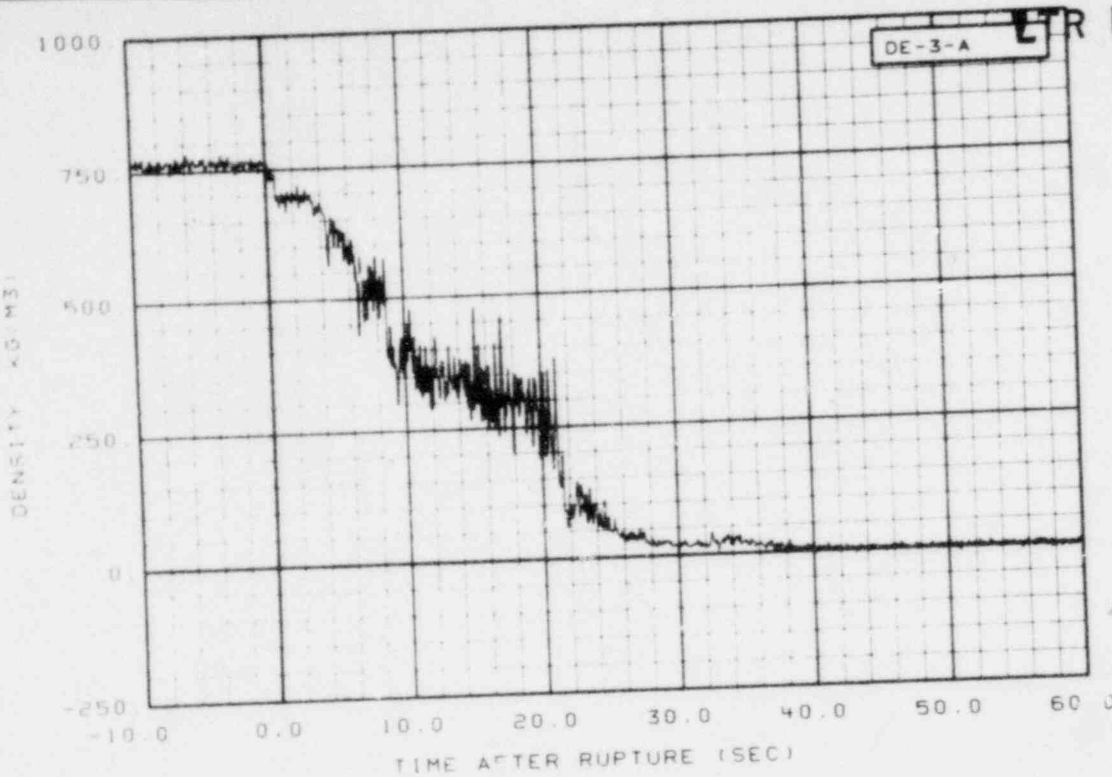
B-16 Density upstream from DTT, source 2, lower beam -- (DE-2-A) -- Test IIIA102 . . . .



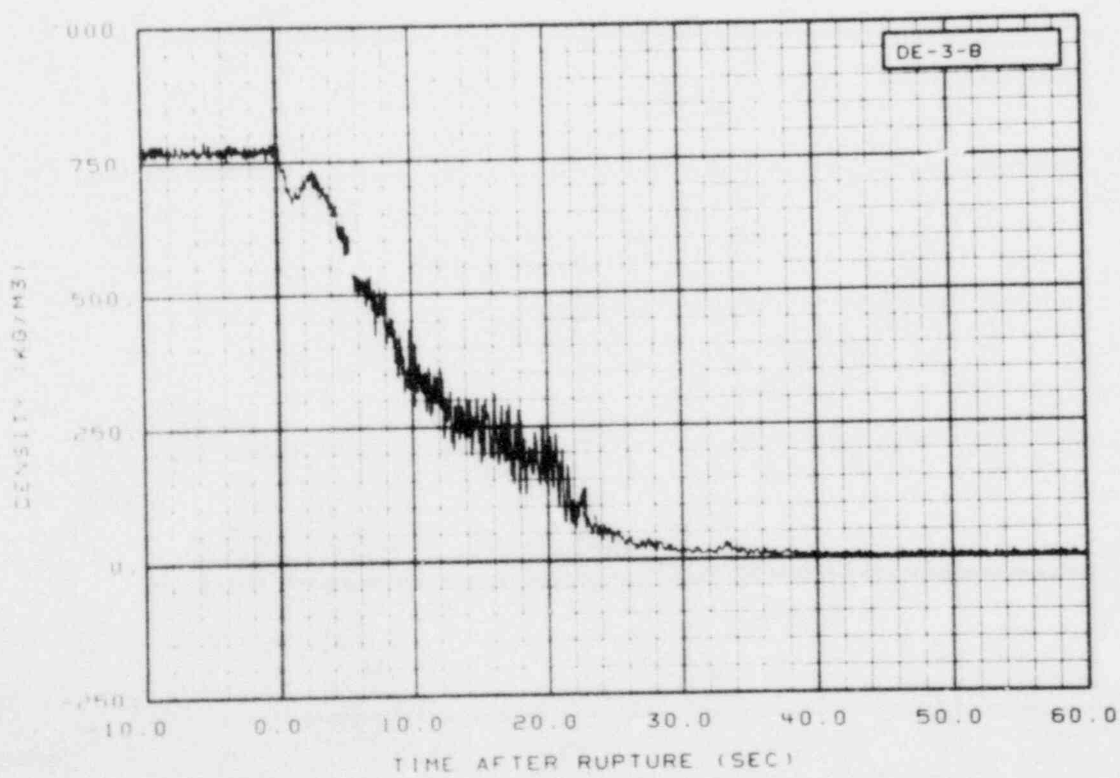
B-17 Density upstream from DTT, source 2, center beam -- (DE-2-B) -- Test IIIA102 . . . .



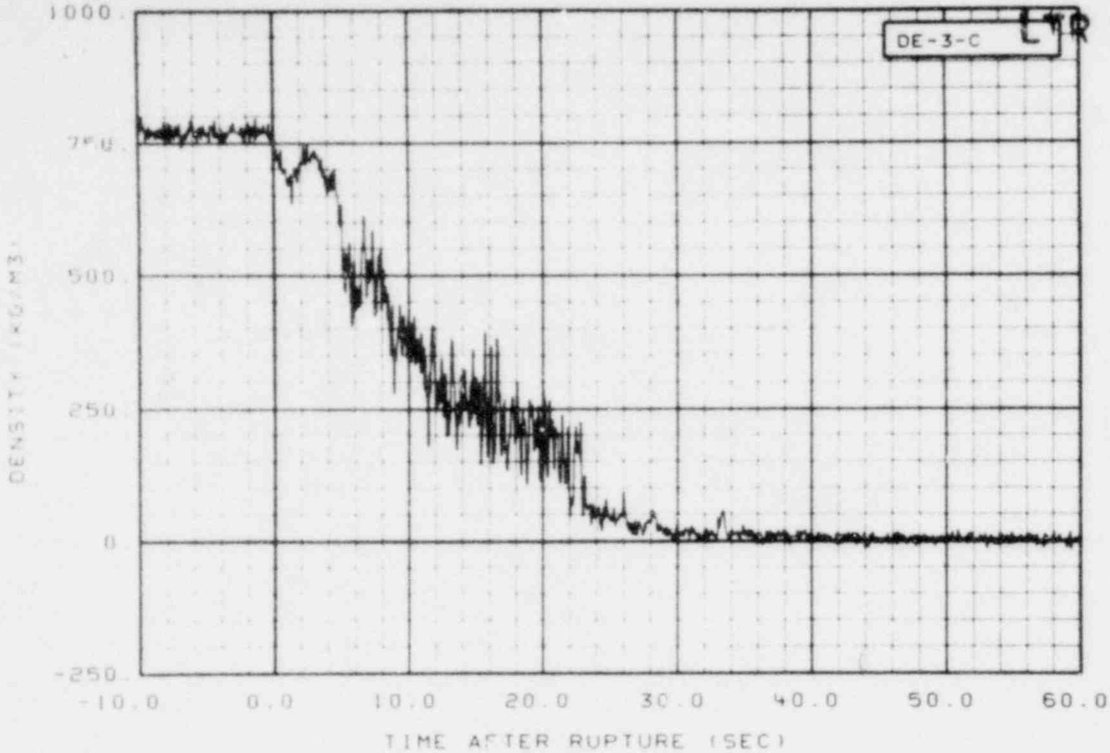
B-18 Density upstream from DTT, source 2, side beam -- (DE-2-C) -- Test IIIA102 . . . .



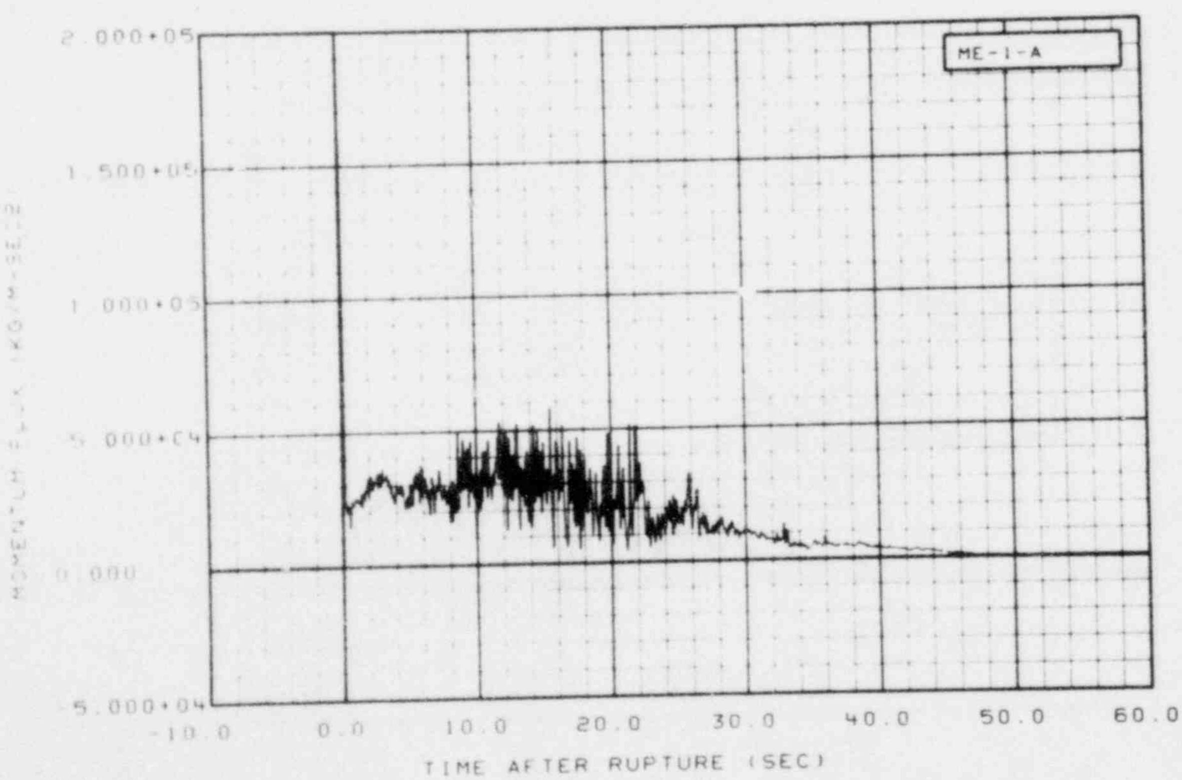
B-19 Density downstream from ECC rake, source 3, lower beam -- (DE-3-A) -- Test IIIA102 . . . .



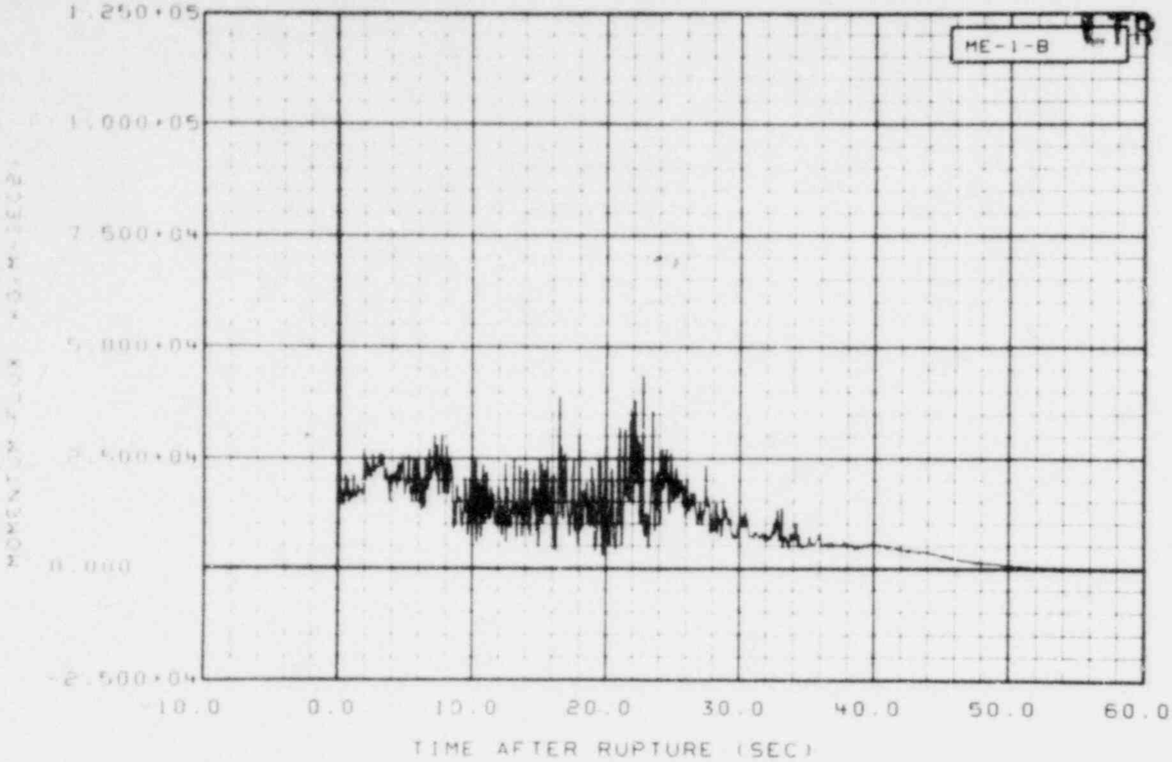
B-20 Density downstream from ECC rake, source 3, center beam -- (DE-3-B) -- Test IIIA102 . . . .



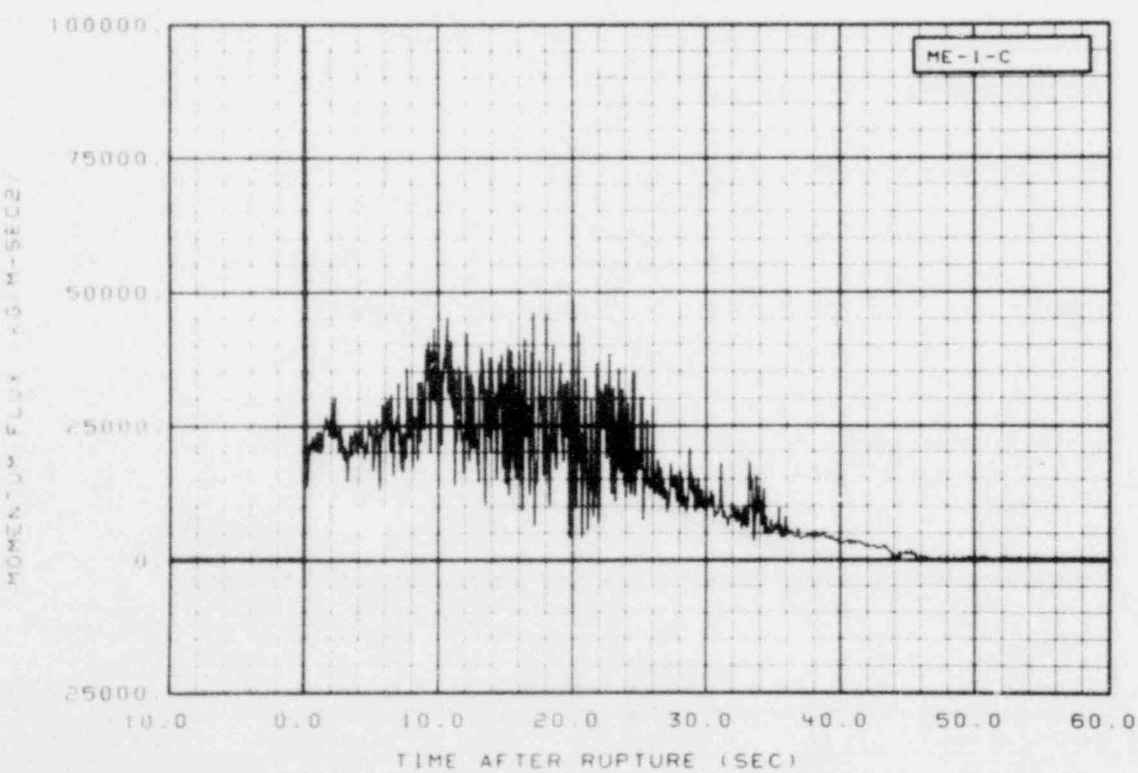
B-21 Density downstream from ECC rake, source 3, side beam -- (DE-3-C) -- Test IIIA102 . . . .



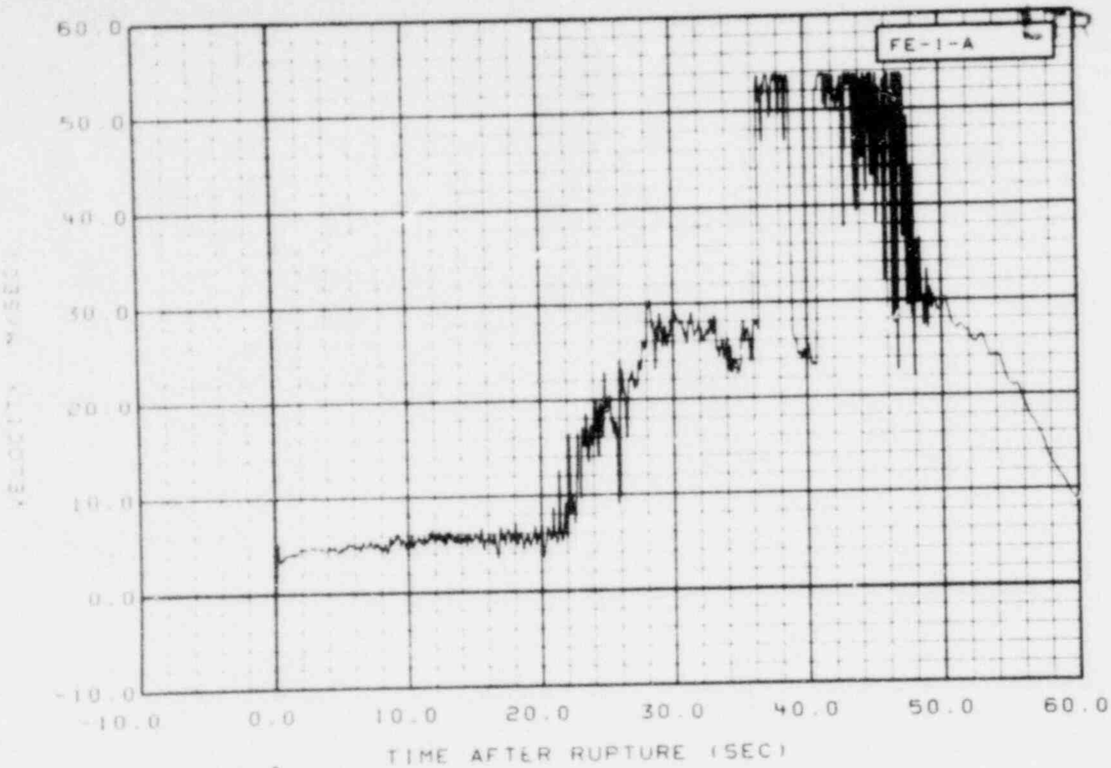
B-22 Momentum flux at free end of DTT -- (ME-1-A) -- Test IIIA102 . . . .



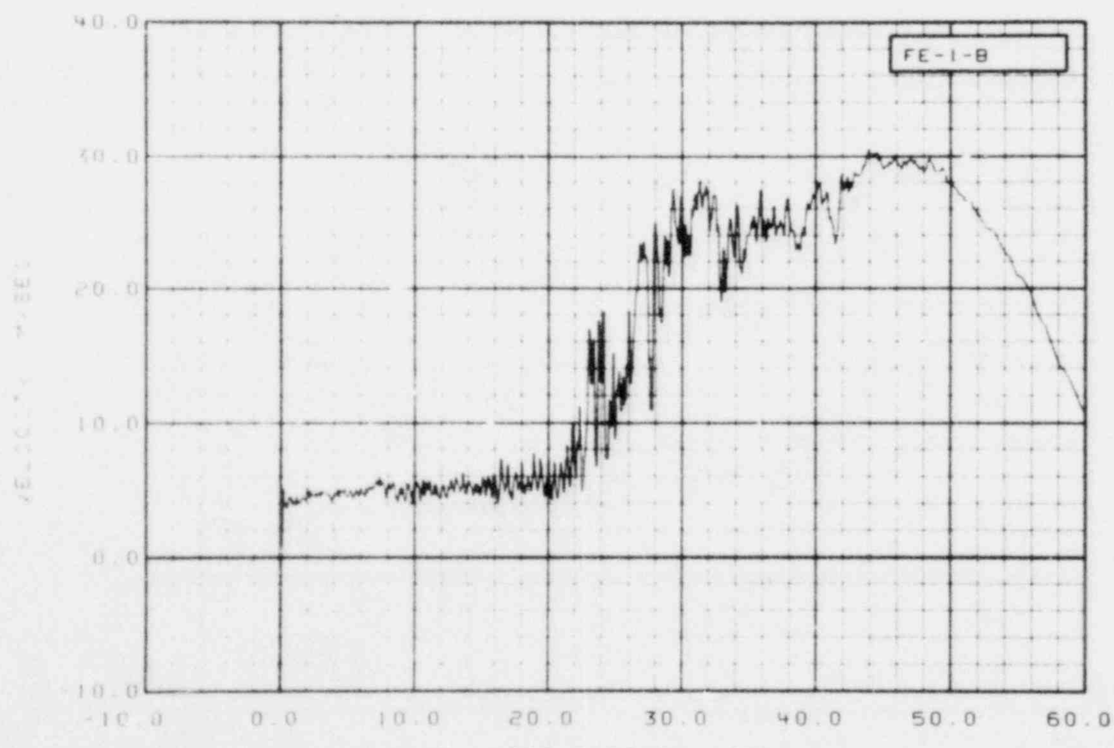
B-23 Momentum flux at center DTT -- (ME-1-B) -- Test IIIA102.



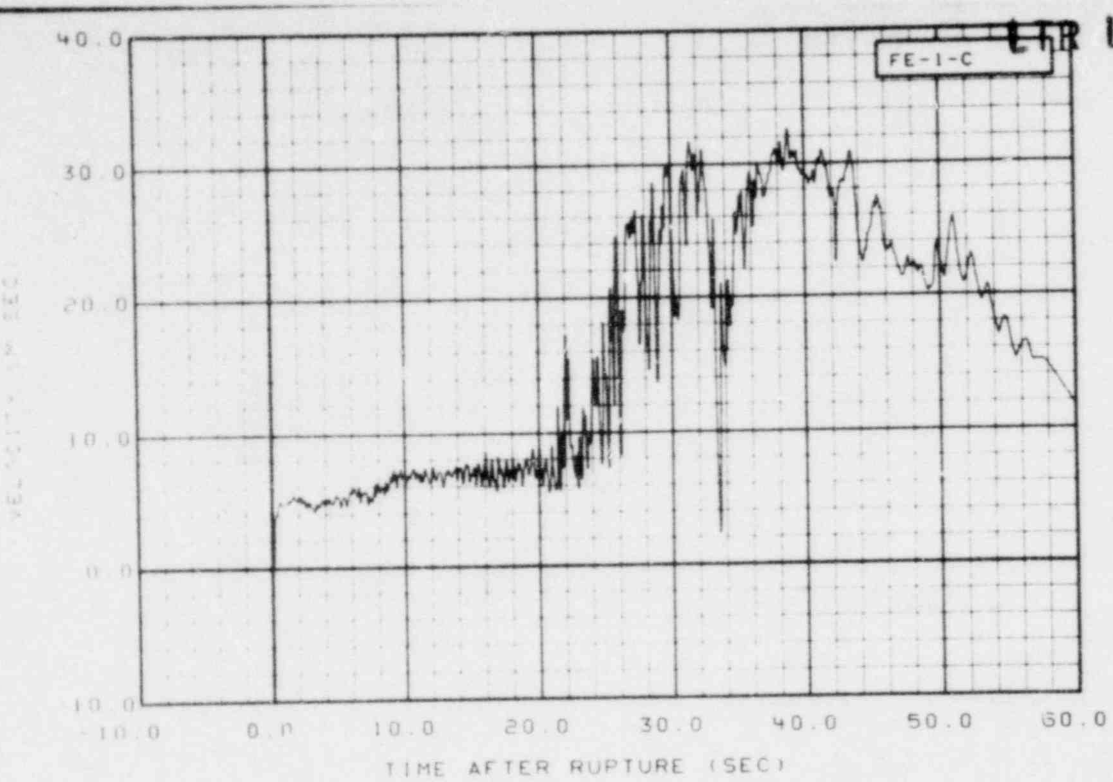
B-24 Momentum flux at flange end of DTT -- (ME-1-C) -- Test IIIA102 . . . .



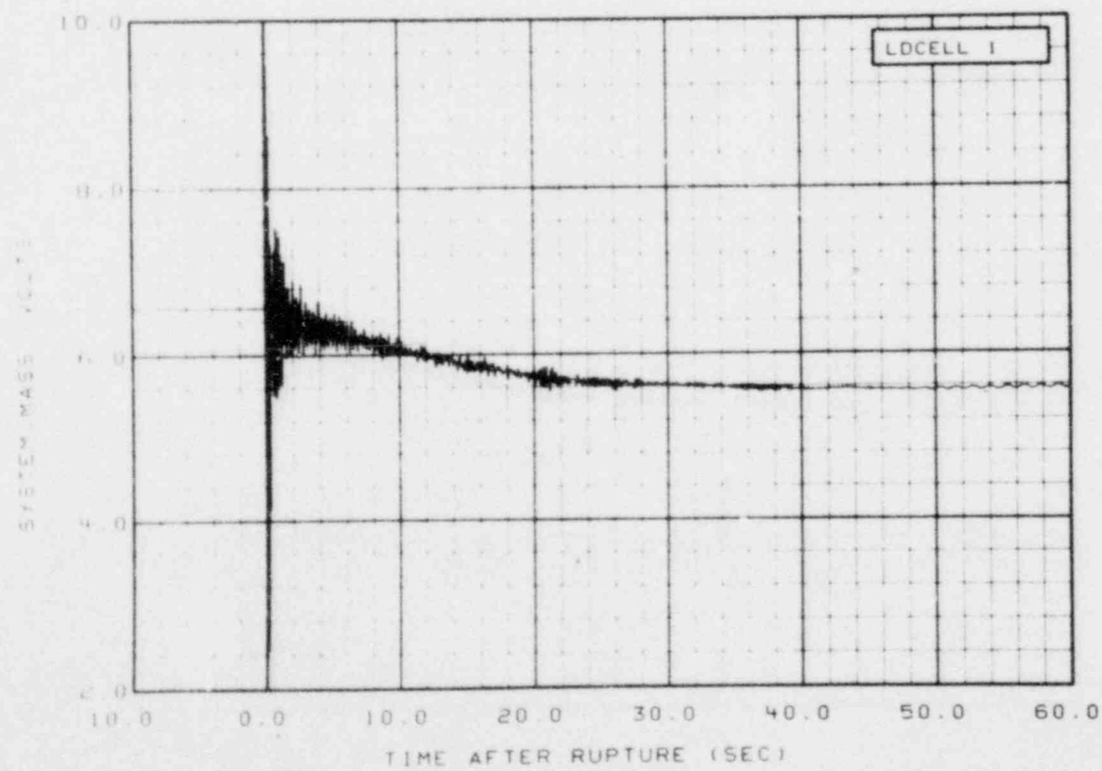
B-25 Fluid velocity at free end of DTT -- (FE-1-A) -- Test IIIA102 . . . .



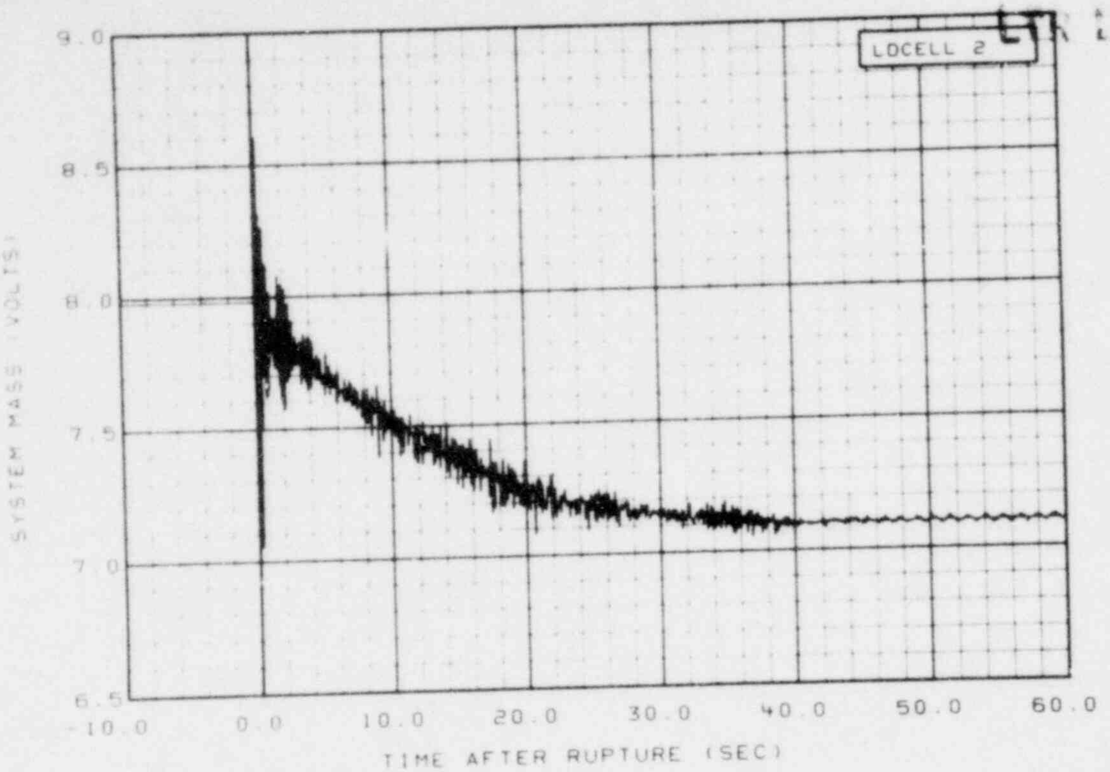
B-26 Fluid velocity at center DTT -- (FE-1-B) -- Test IIIA102 . . . .



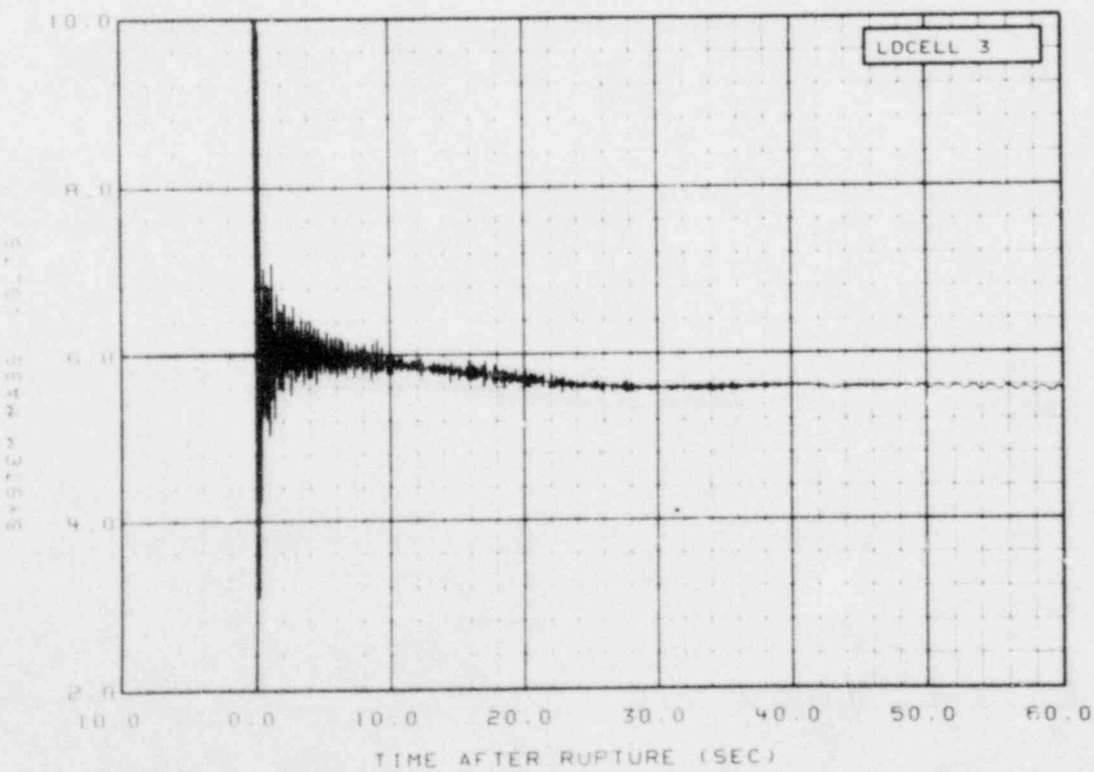
B-27 Fluid velocity at flange end of DTT -- (FE-1-C) -- Test IIIA102 . . . .



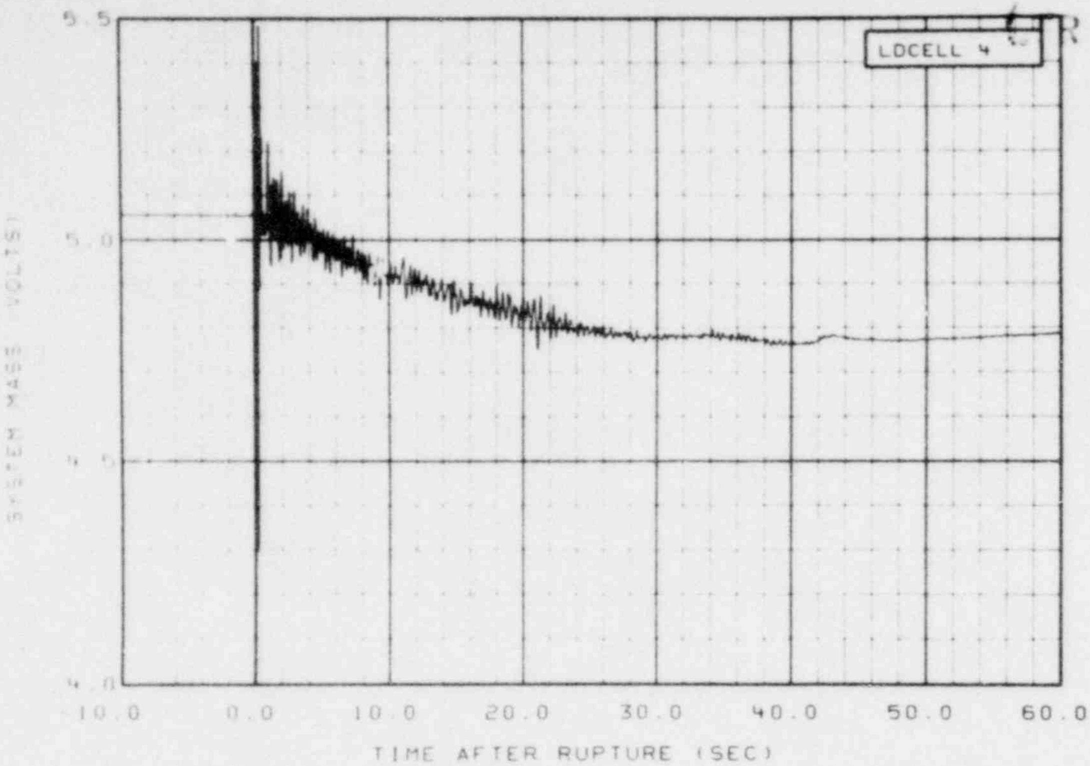
B-28 Load cell 1 -- Test IIIA102



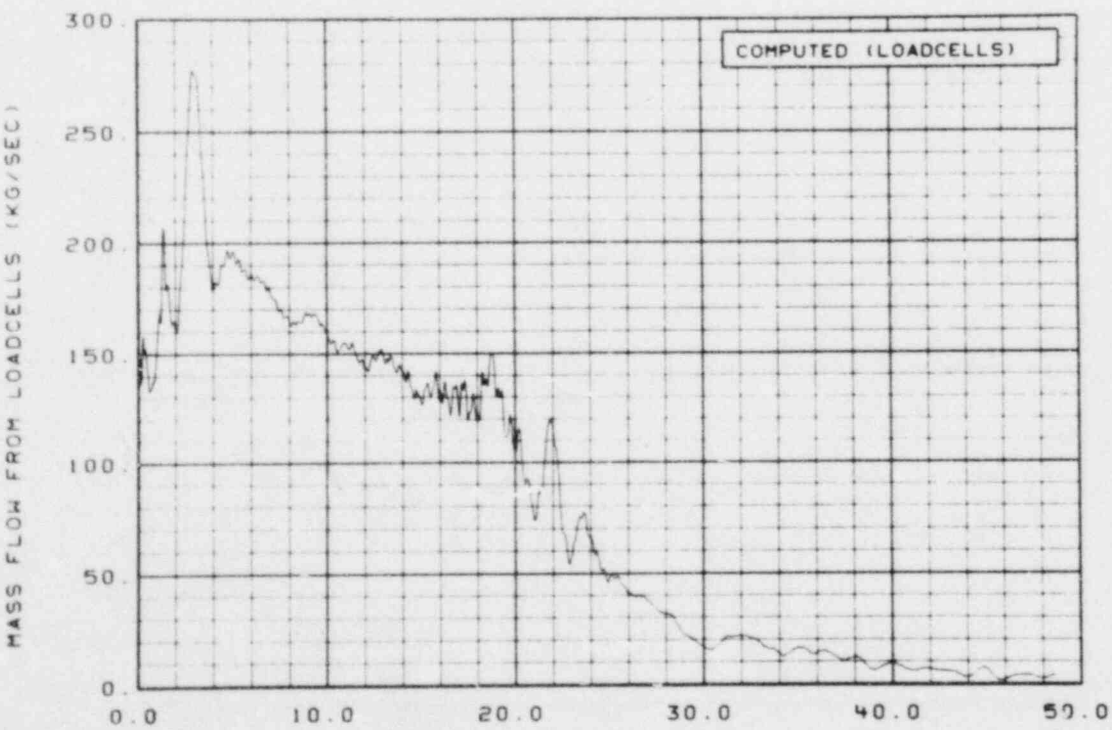
B-29 Load cell 2 -- Test IIIA102.



B-30 Load cell 3 -- Test IIIA102.

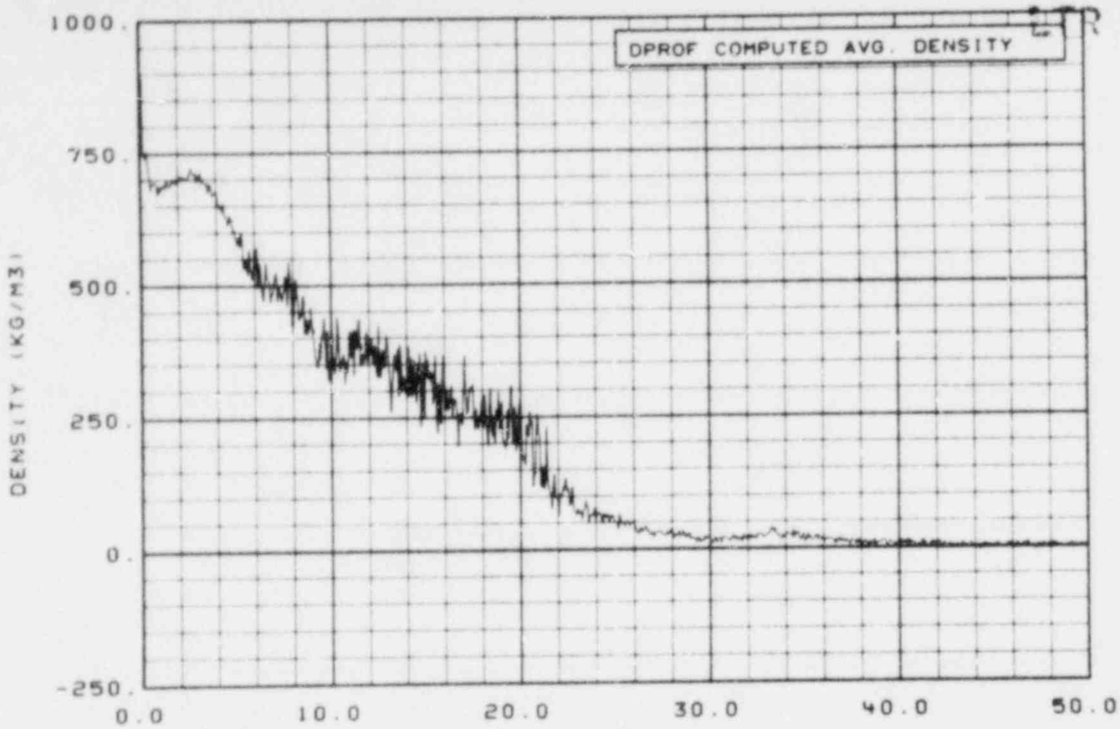


B-31 Load cell 4 -- Test IIIA102

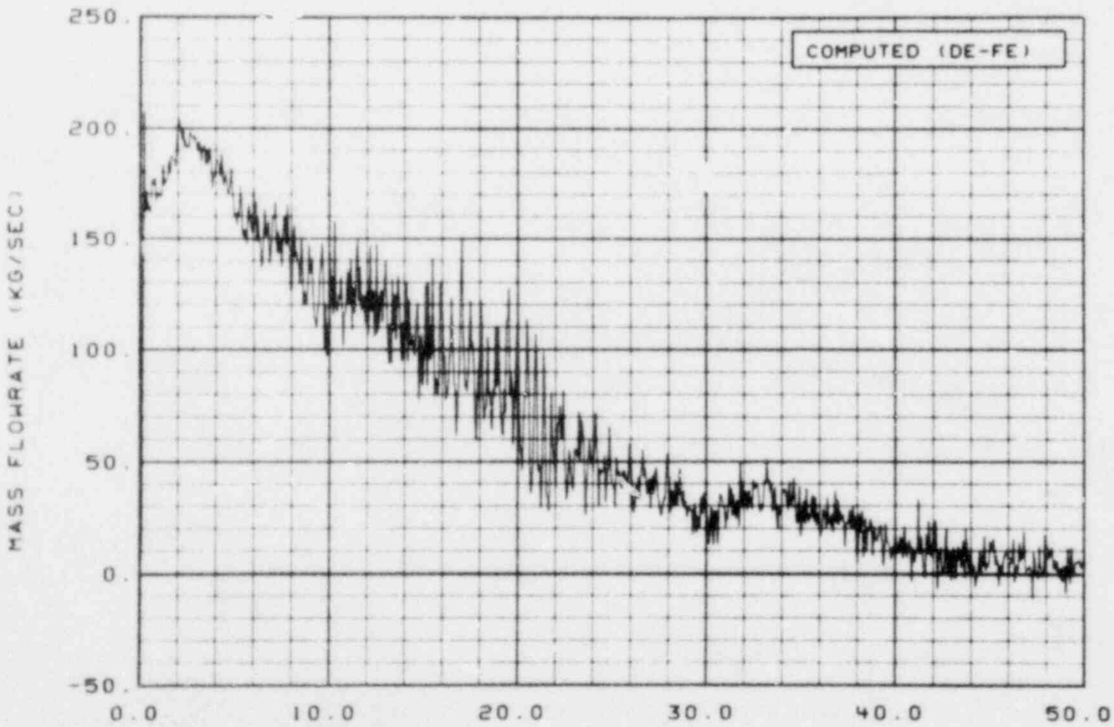


TIME AFTER RUPTURE (sec)

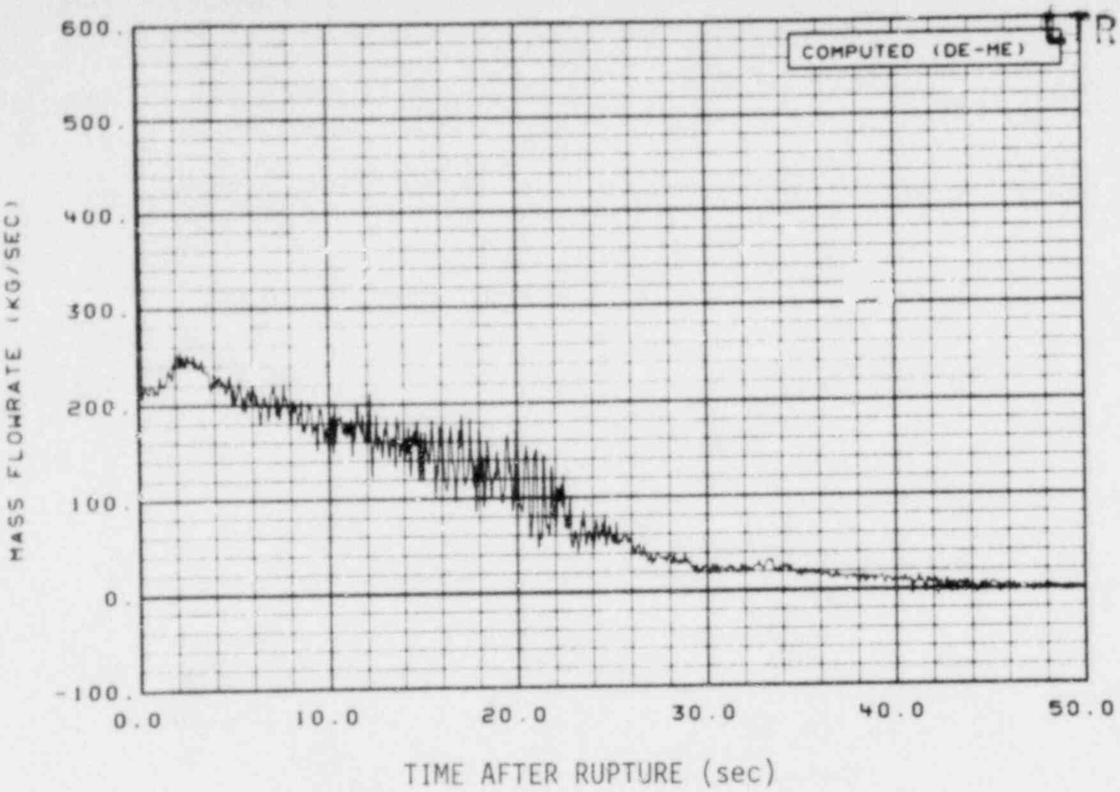
B-32 Mass flow rate computed from load cell readings -- Test IIIA102 . . . .



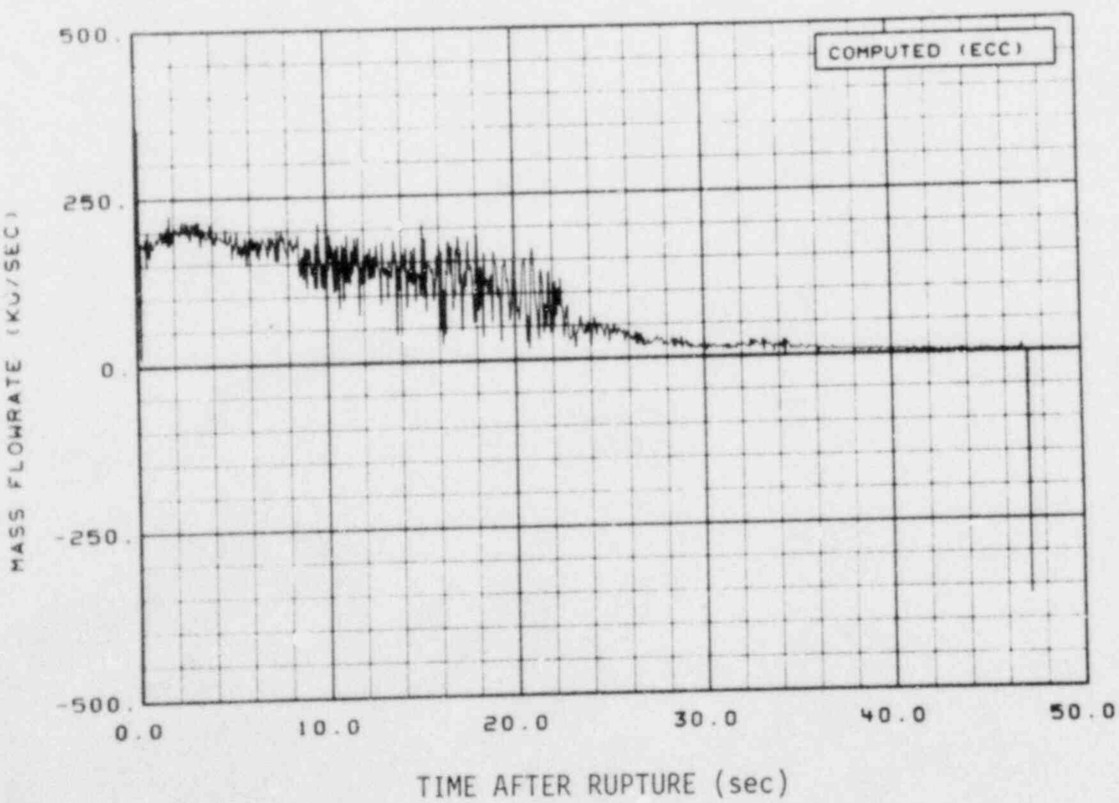
B-33 Average density computed from 6-beam gamma densitometer -- Test IIIA102 . . . .



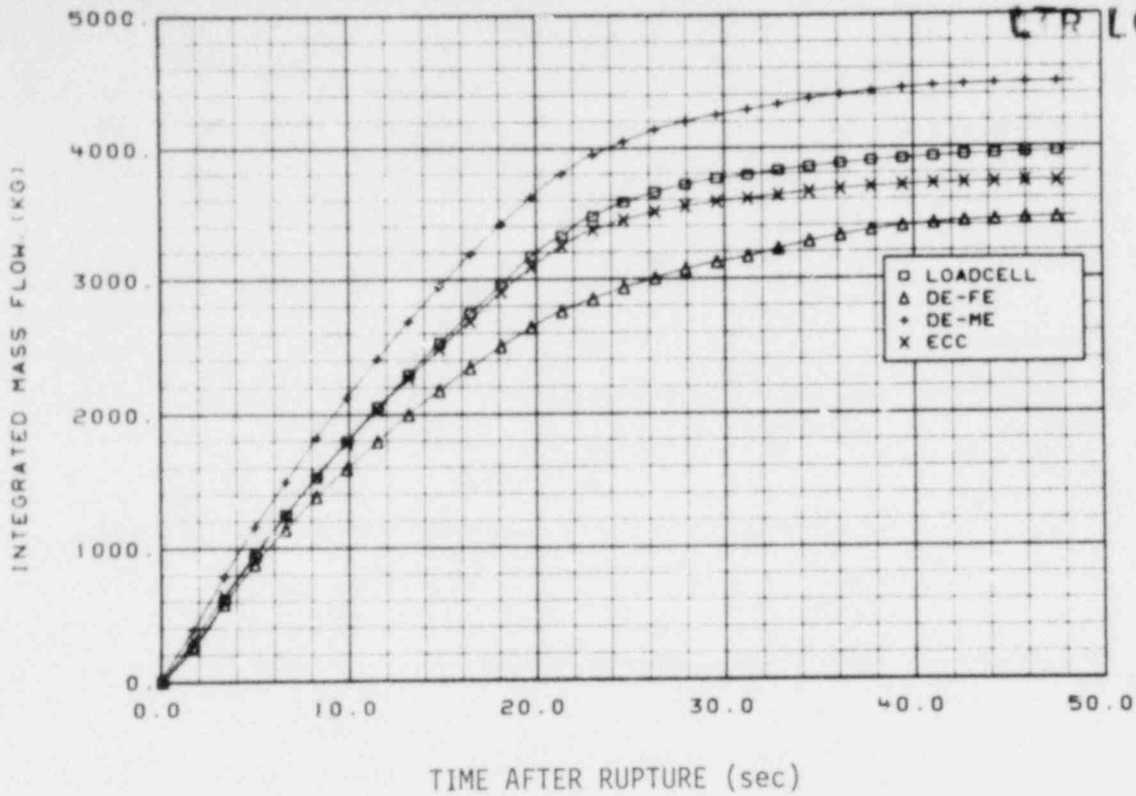
B-34 Mass flow rate computed from turbine meters and gamma densitometers -- Test IIIA102. . . . .



B-35 Mass flow rate computed from drag discs and densitometers -- Test IIIA102. . . . .



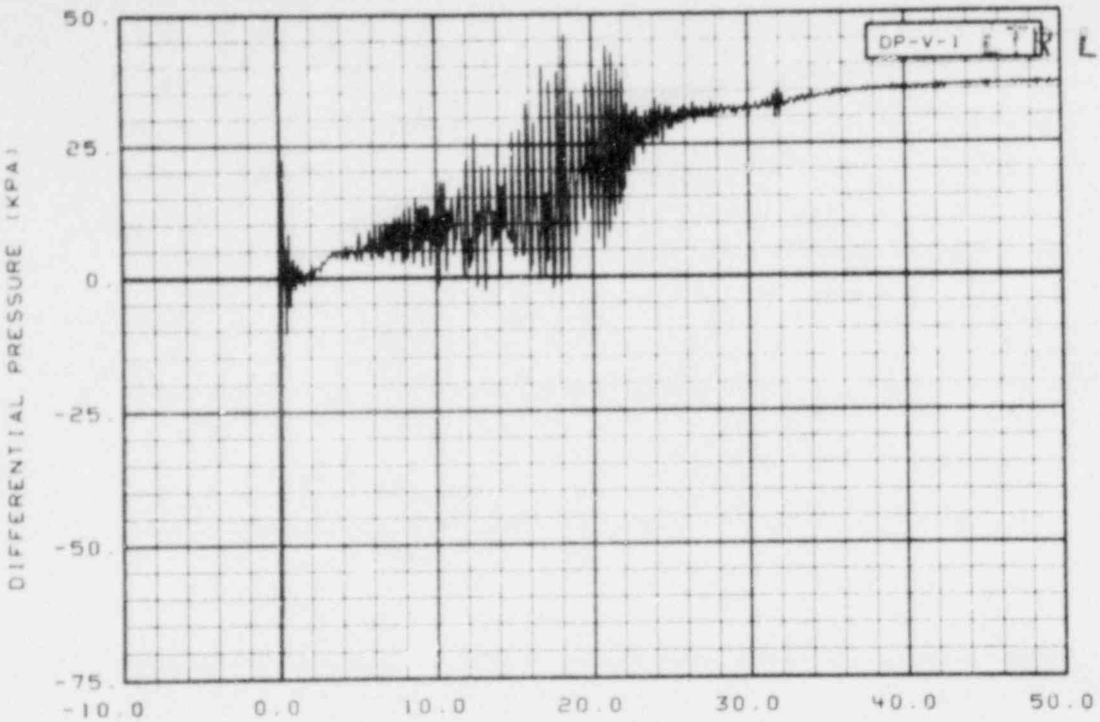
B-36 Mass flow rate computed from ECC pitot tube rake and densitometers -- Test IIIA102. . . . .



B-37 Integrated mass flowrate comparison -- Test IIIA102

APPENDIX C

DATA FROM TEST IIIA201



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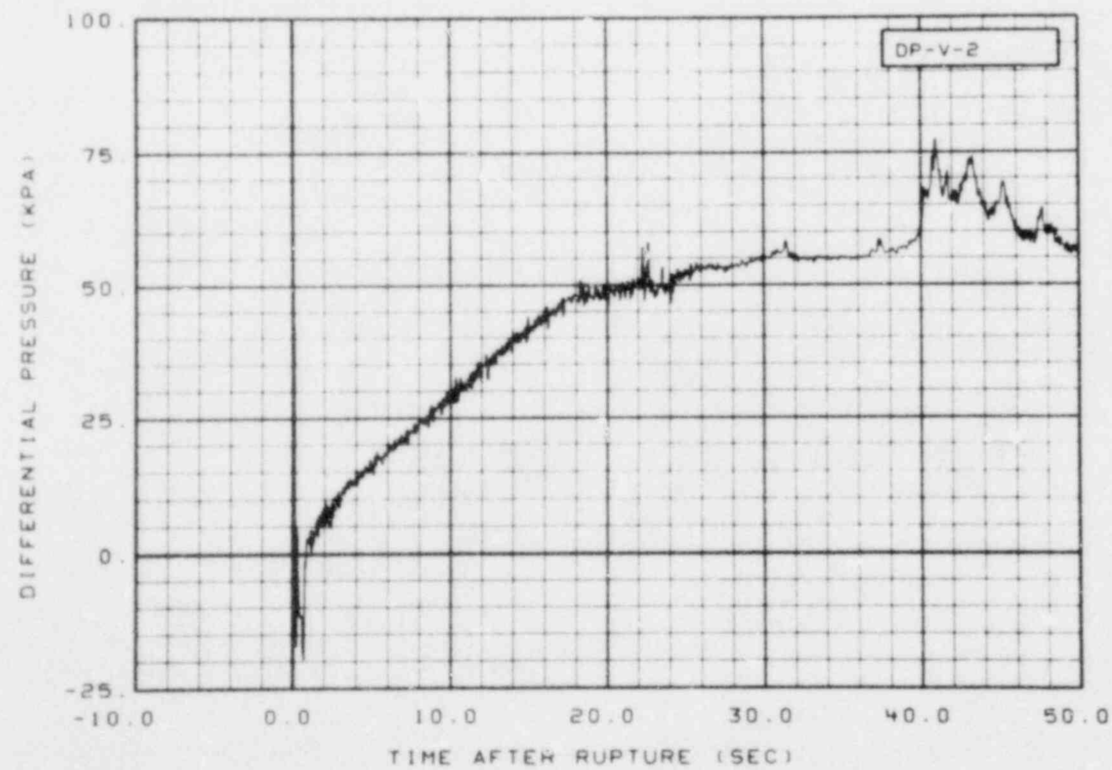
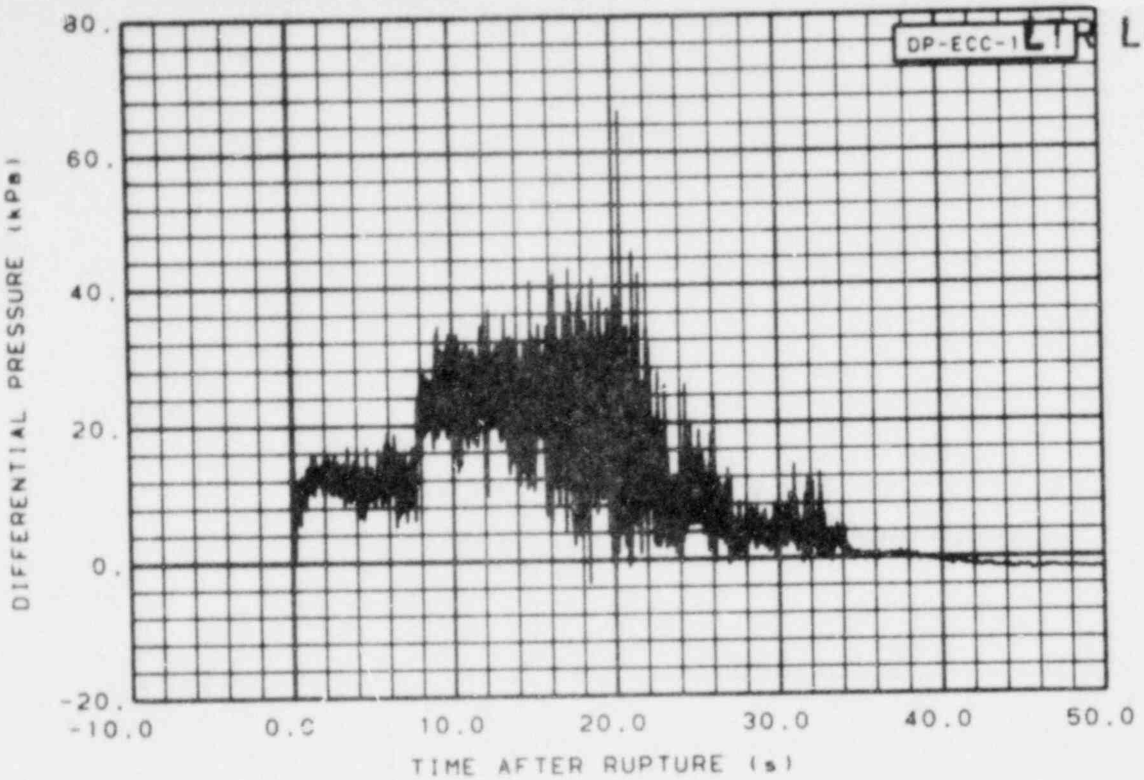
TIME AFTER RUPTURE (sec)

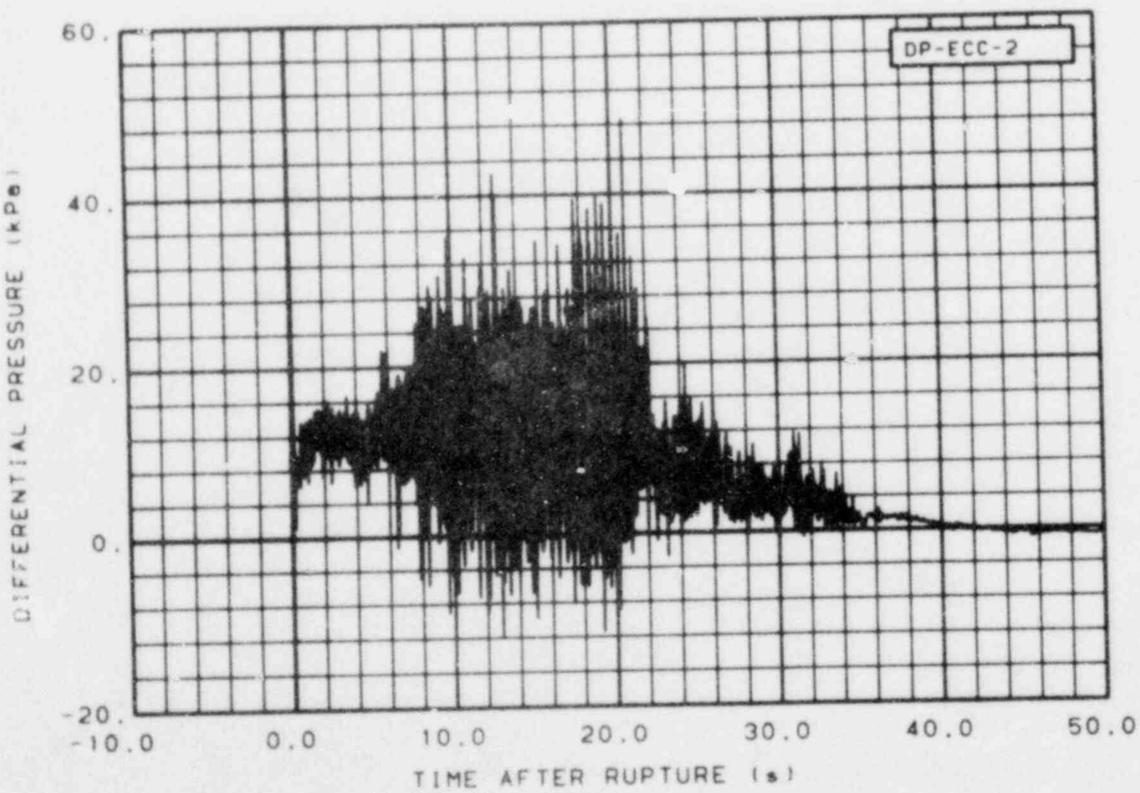
C-1 Differential pressure from vessel bottom to outlet nozzle tap -- (DP-V-1) -- Test IIIA201 . . . . . .



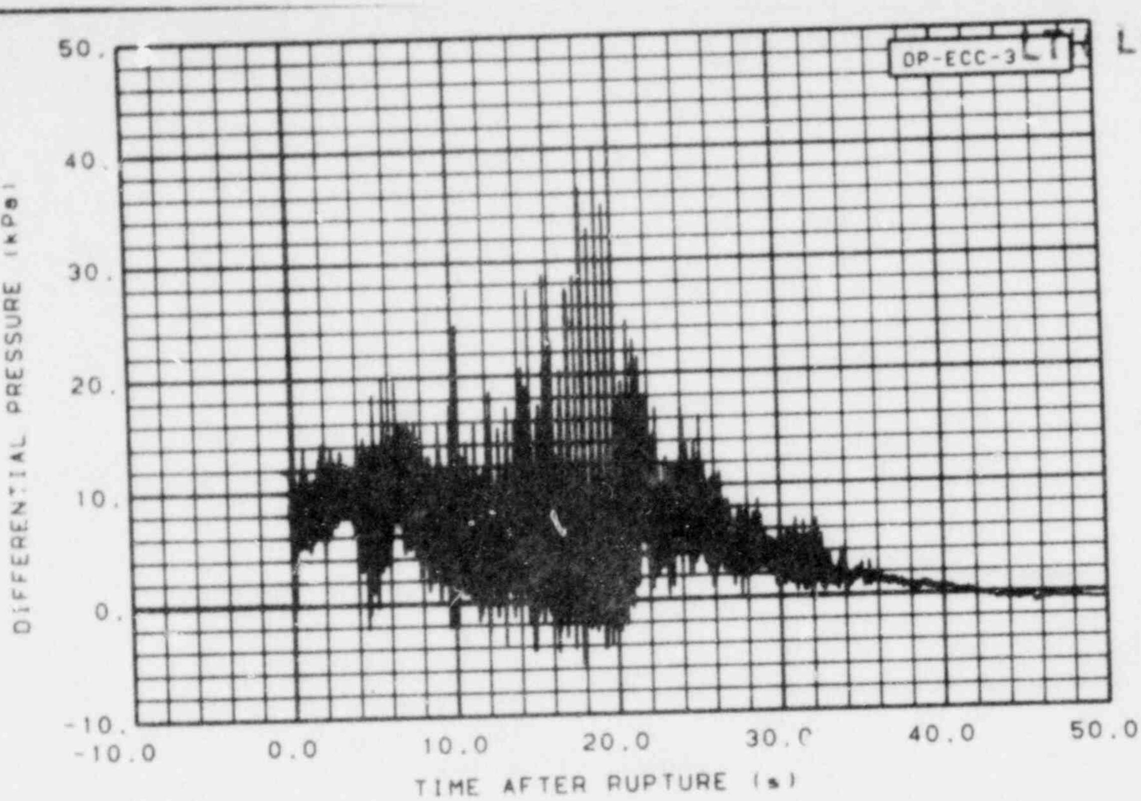
C-2 Differential pressure from vessel top vent to heatup line, low range -- (DP-V-2) -- Test IIIA201



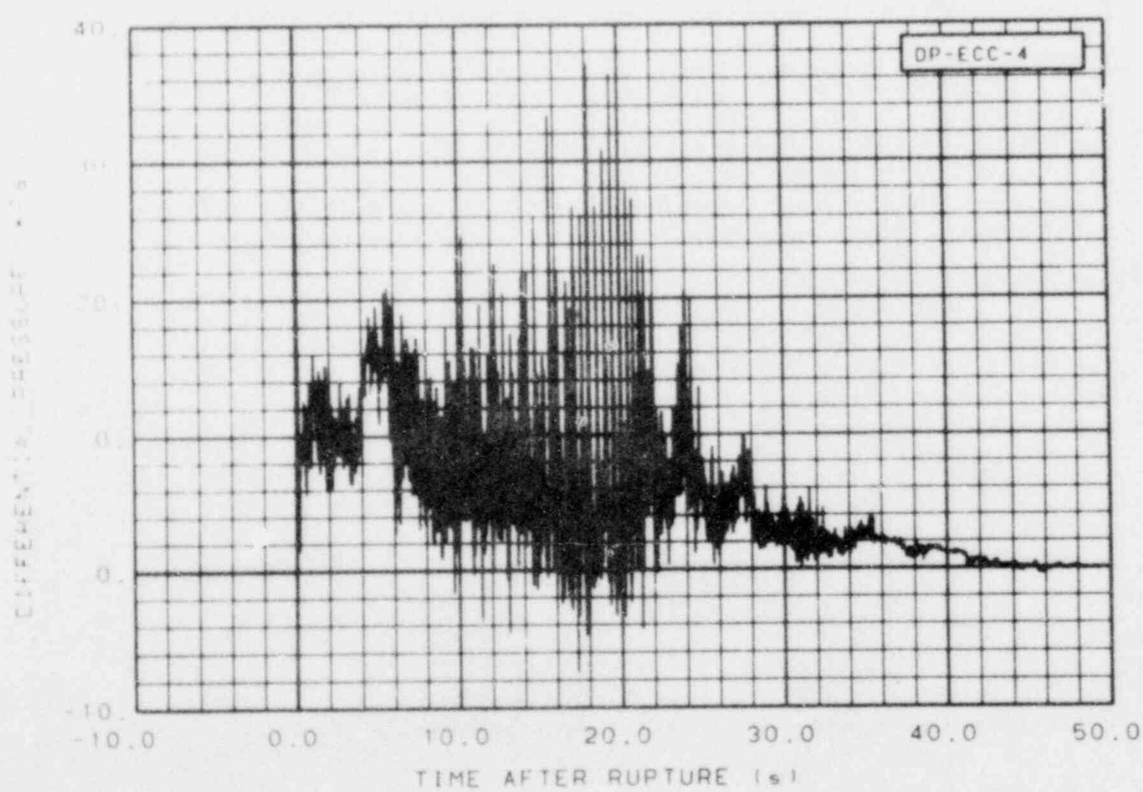
C-3 Differential pressure at bottom of ECC pitot tube rake -- (DP-ECC-1) -- Test IIIA201 . . . .



C-4 Differential pressure at ECC pitot tube rake -- (DP-ECC-2) -- Test IIIA201 . .



C-5 Differential pressure at center of ECC pitot tube rake -- (DP-ECC-3) -- Test IIIA201. . .



C-6 Differential pressure at top of ECC pitot tube rake -- (DP-ECC-4) -- Test IIIA201 . . . . . .

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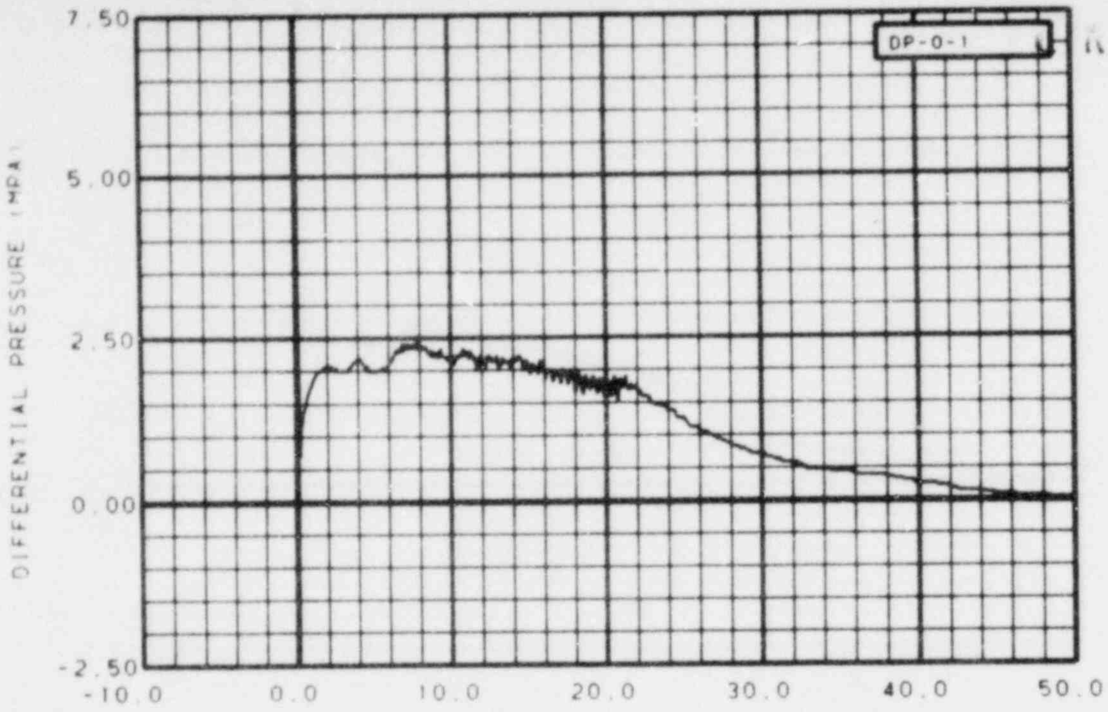
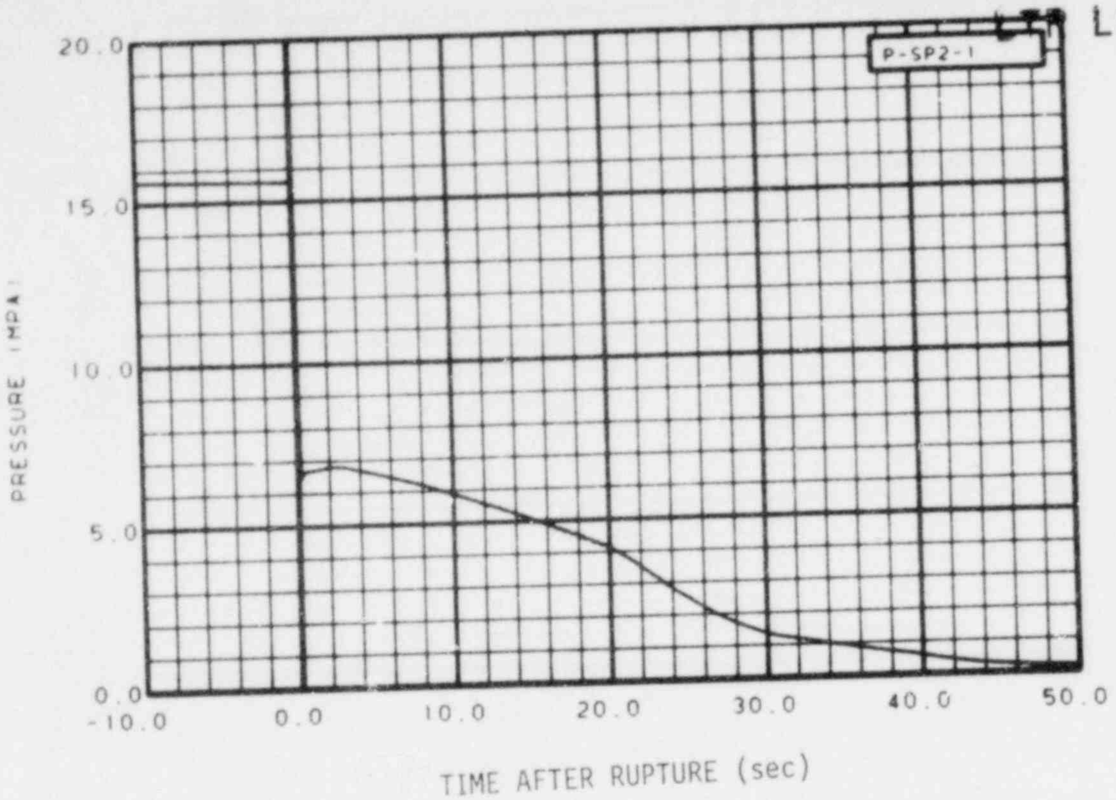


TIME AFTER RUPTURE (sec)

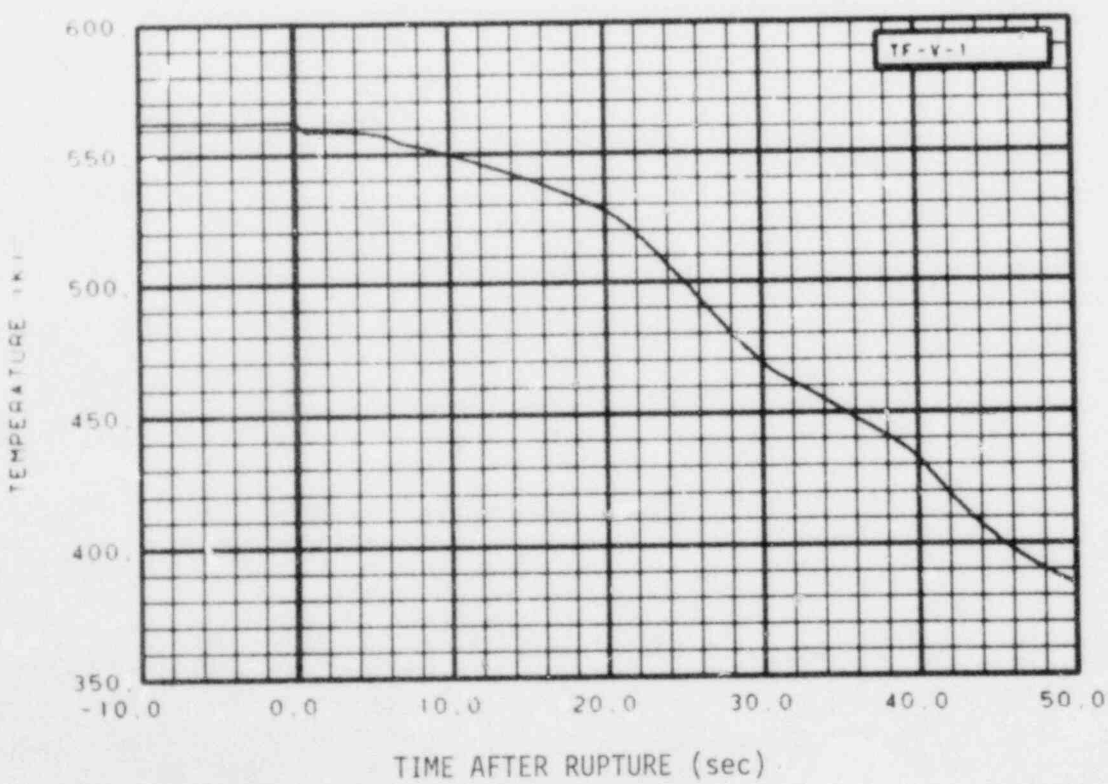
C-7 Differential pressure from test spool tap no. 11 to gate valve flange -- (DP-0-1) -- Test IIIA201

TIME AFTER RUPTURE (sec)

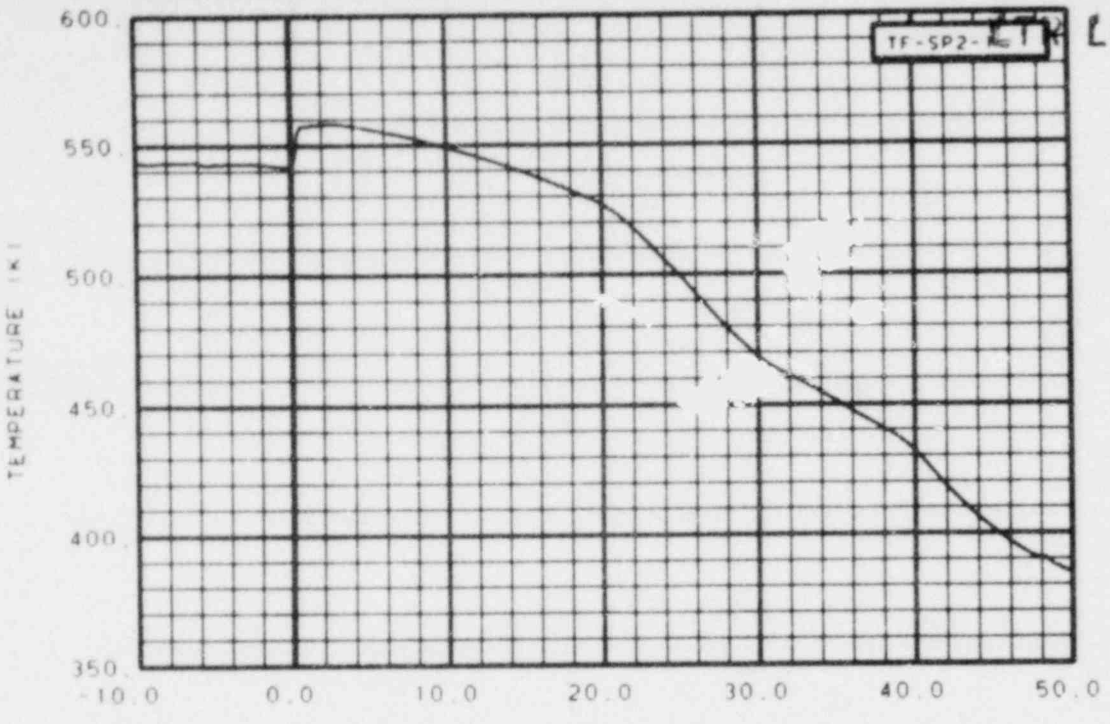
C-8 Pressure at bottom of vessel -- (P-V-1) -- Test IIIA201



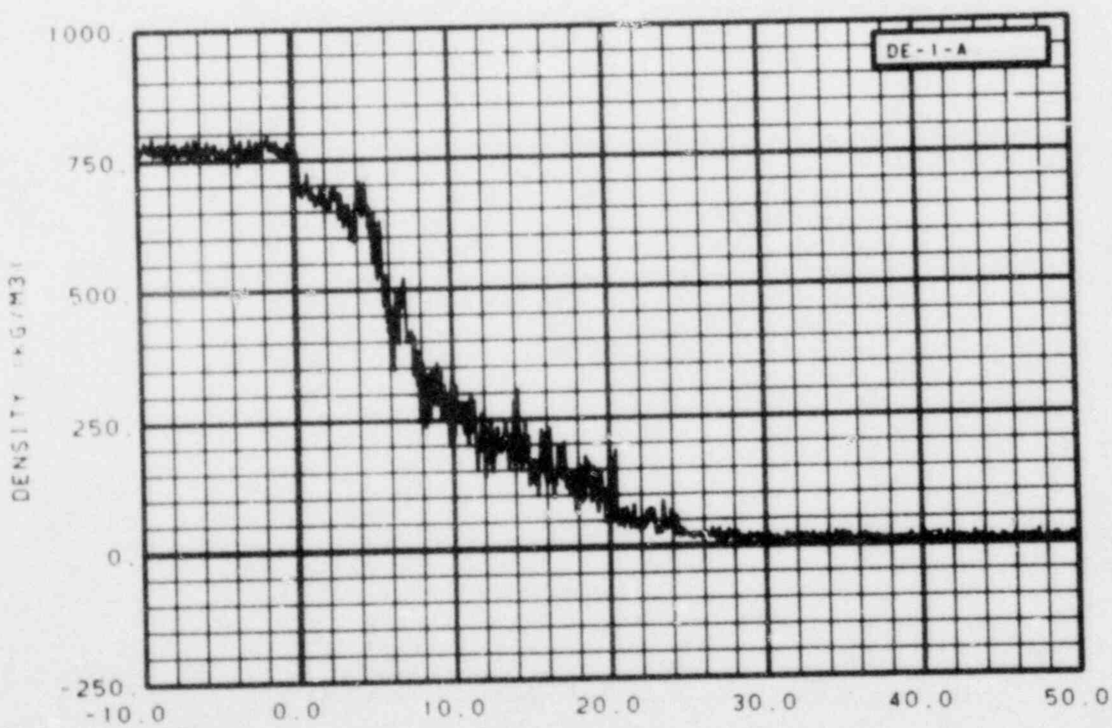
C-9 Pressure at test spool tap no. 11 -- (P-SP2-1) -- Test IIIA201 . . . .



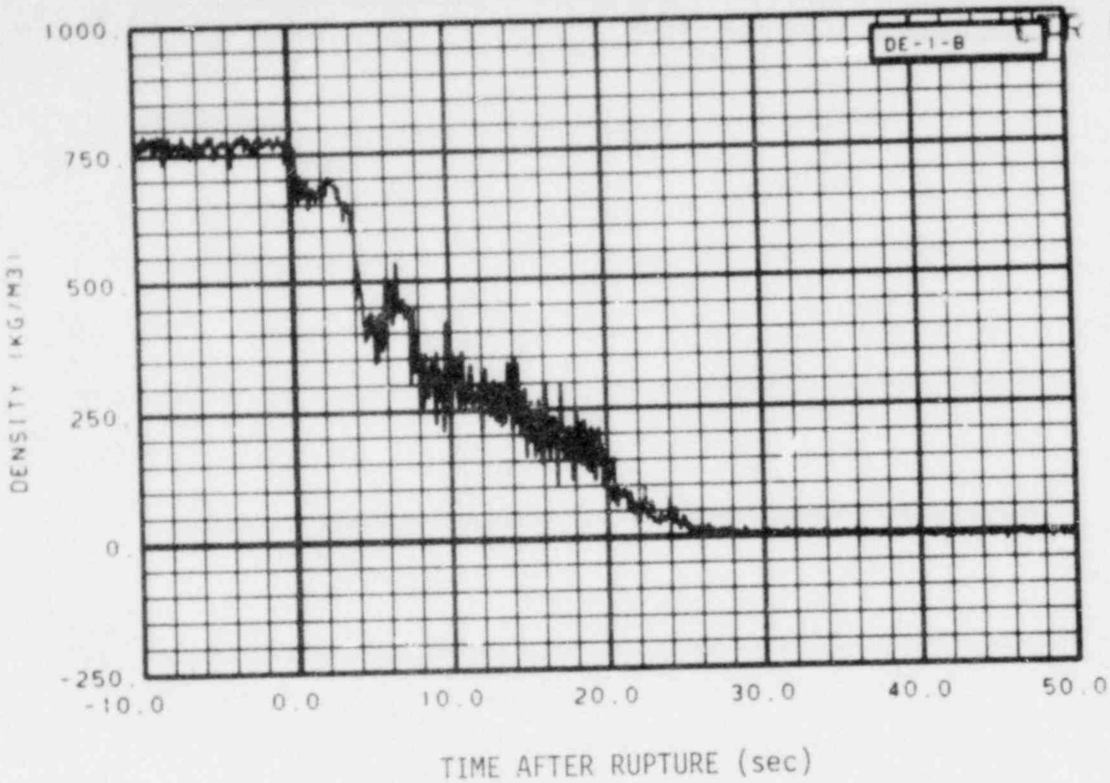
C-10 Fluid temperature at bottom of vessel -- (TF-V-1, -- Test IIIA201 . . . .



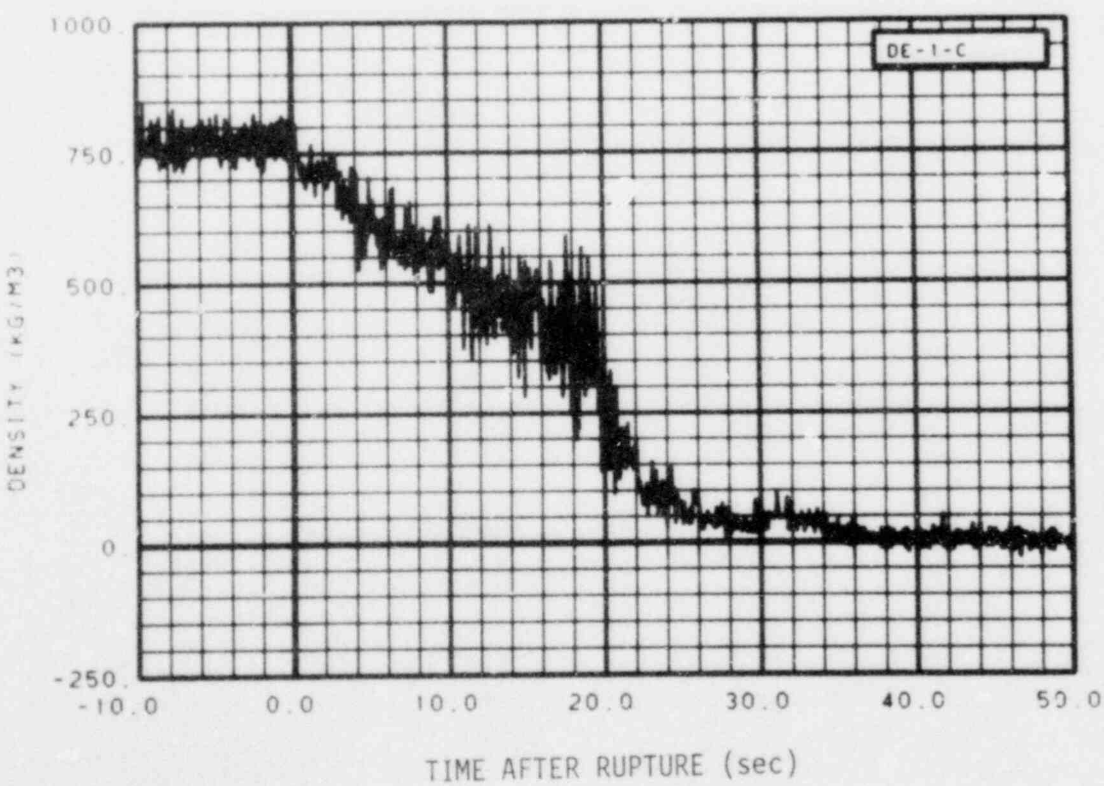
C-11 Fluid temperature at test spool tap no. 1 -- (TF-SP2-1) -- Test IIIA201 . . . .



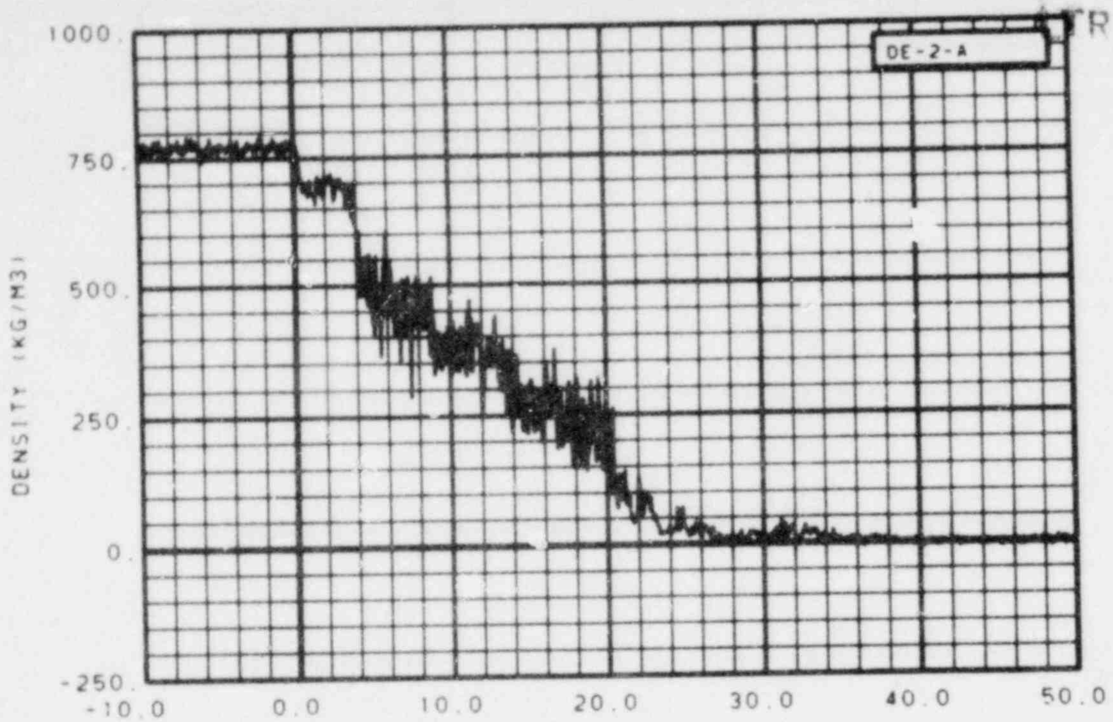
C-12 Density upstream from DTT, source 1, top beam -- (DE-1-A) -- Test IIIA201 . . . .



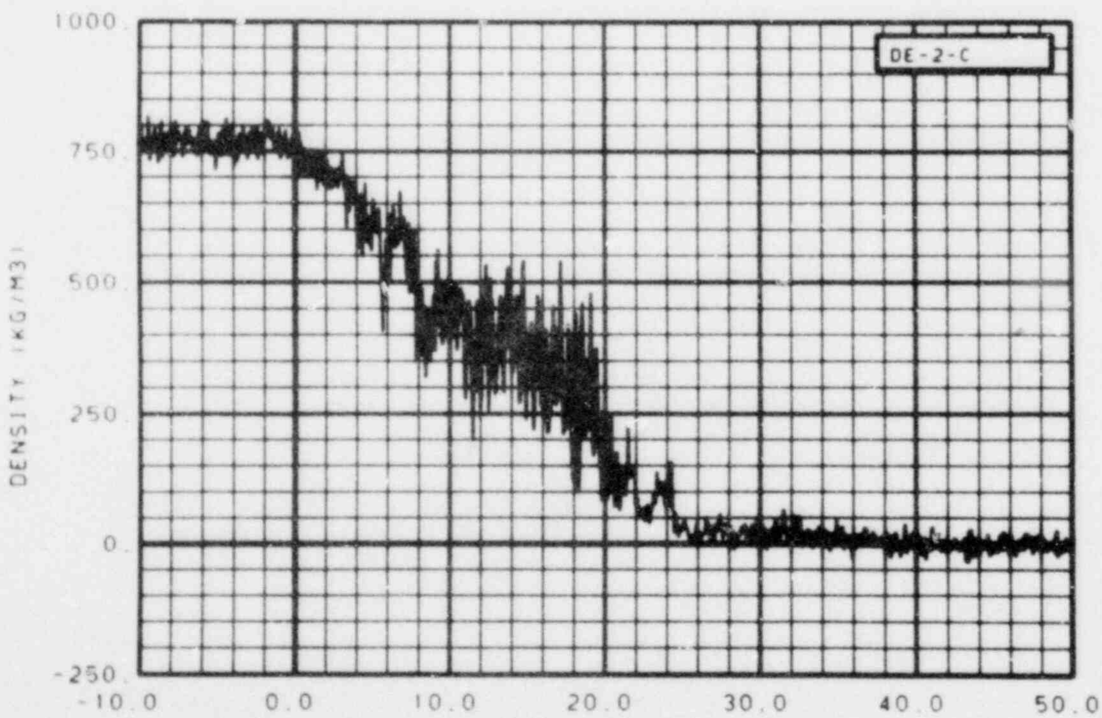
C-13 Density upstream from DTT, source 1, center beam -- (DE-1-B) -- Test IIIA201 . . . .



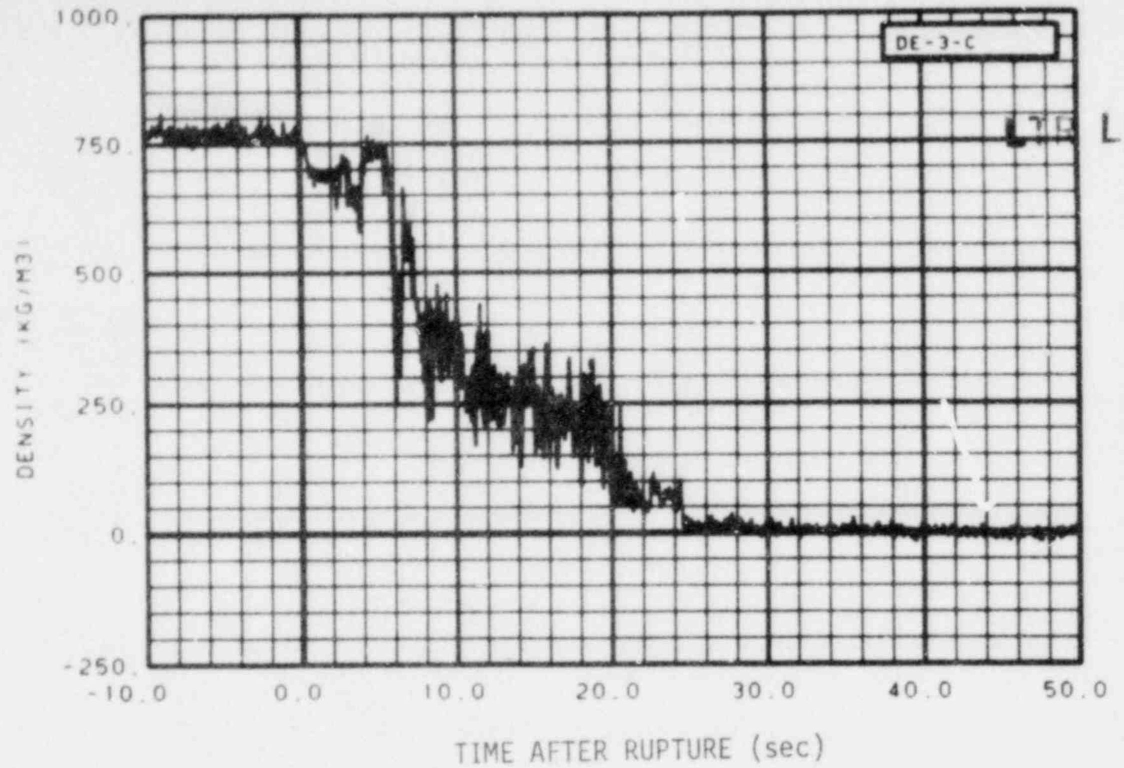
C-14 Density upstream from DTT, source 1, side beam -- (DE-1-C) -- Test IIIA201 . . . .



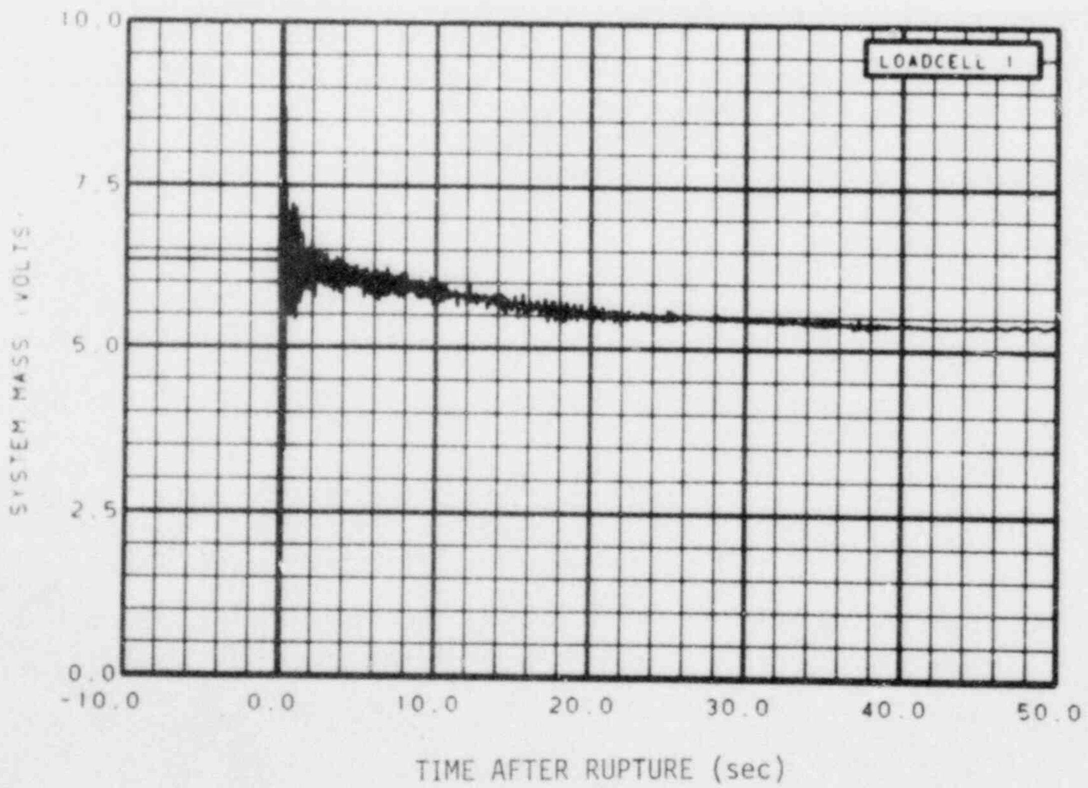
C-15 Density upstream from DTT, source 2, lower beam -- (DE-2-A) -- Test IIIA201 . . . .



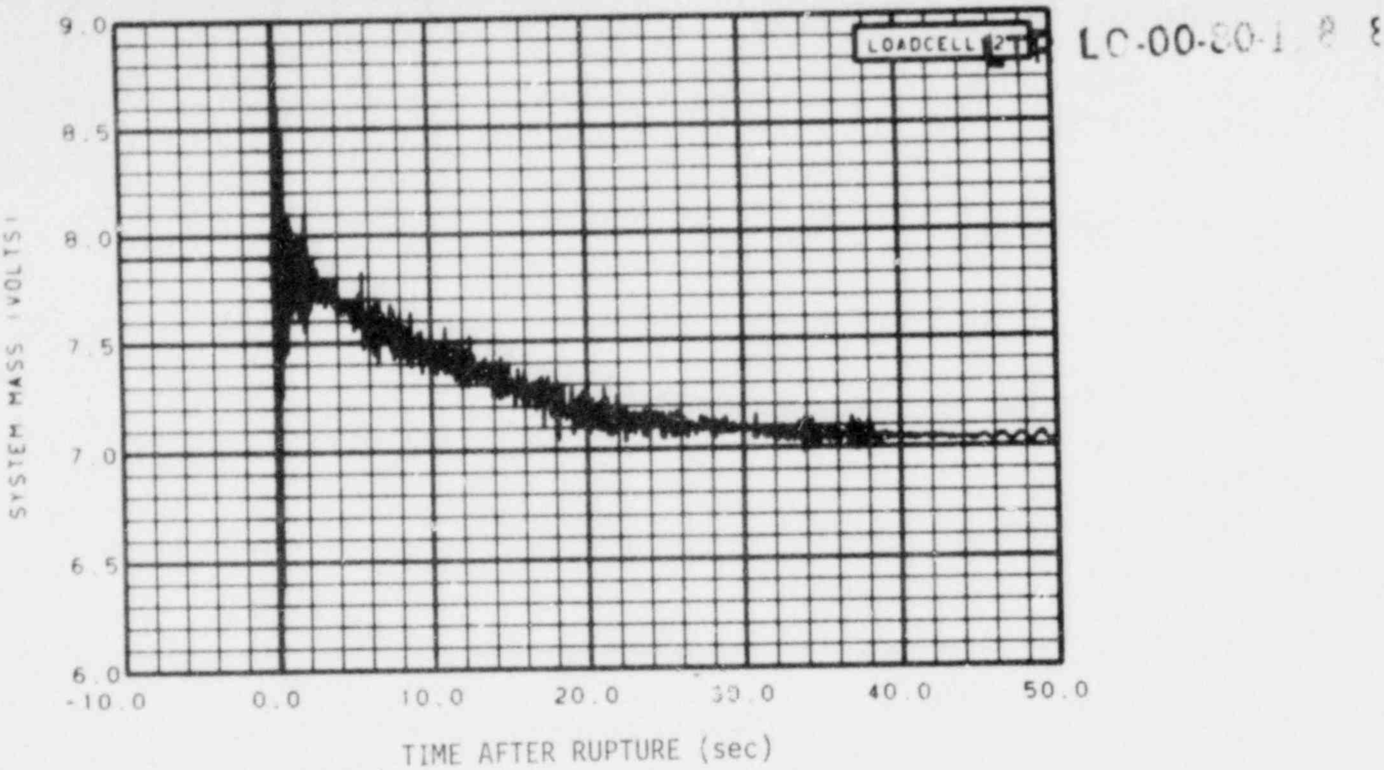
C-16 Density upstream from DTT, source 2, top beam -- (DE-2-C) -- Test IIIA201 . . . .



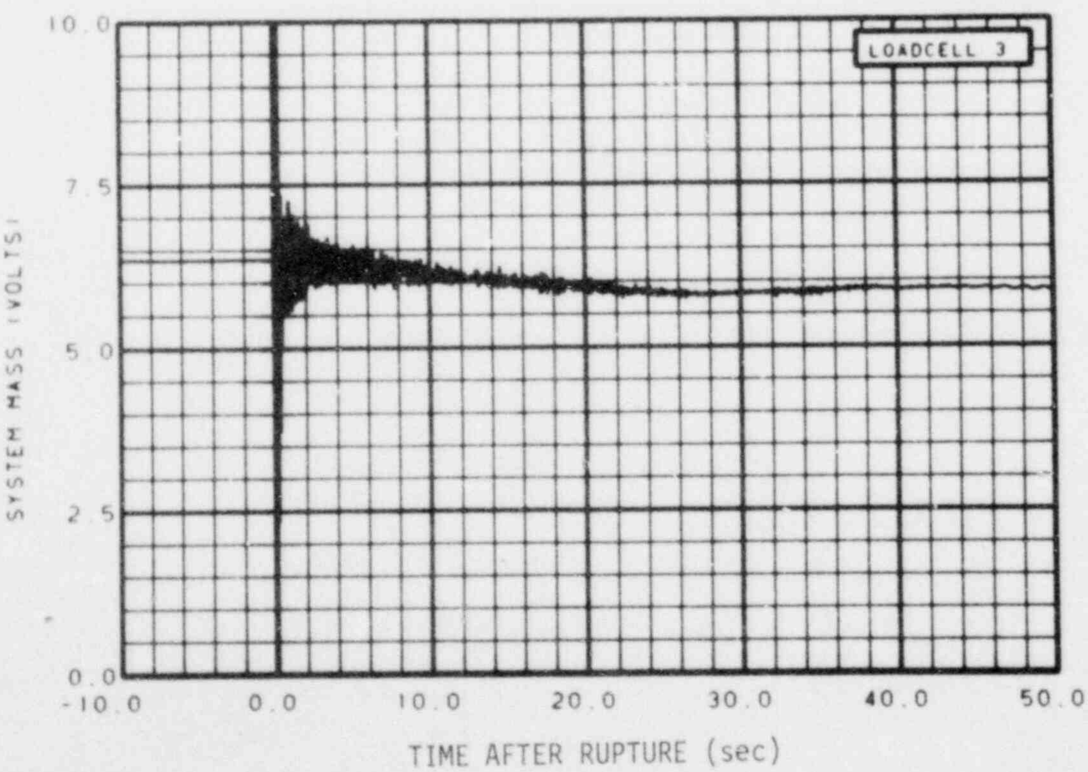
C-17 Density downstream from ECC rake, source 3, lower beam -- (DE-3-C) -- Test IIIA201 . . . .



C-18 Load cell 1 -- Test IIIA201.



C-19 Load cell 2 -- Test IIIA201.



C-20 Load cell 3 -- Test IIIA201.

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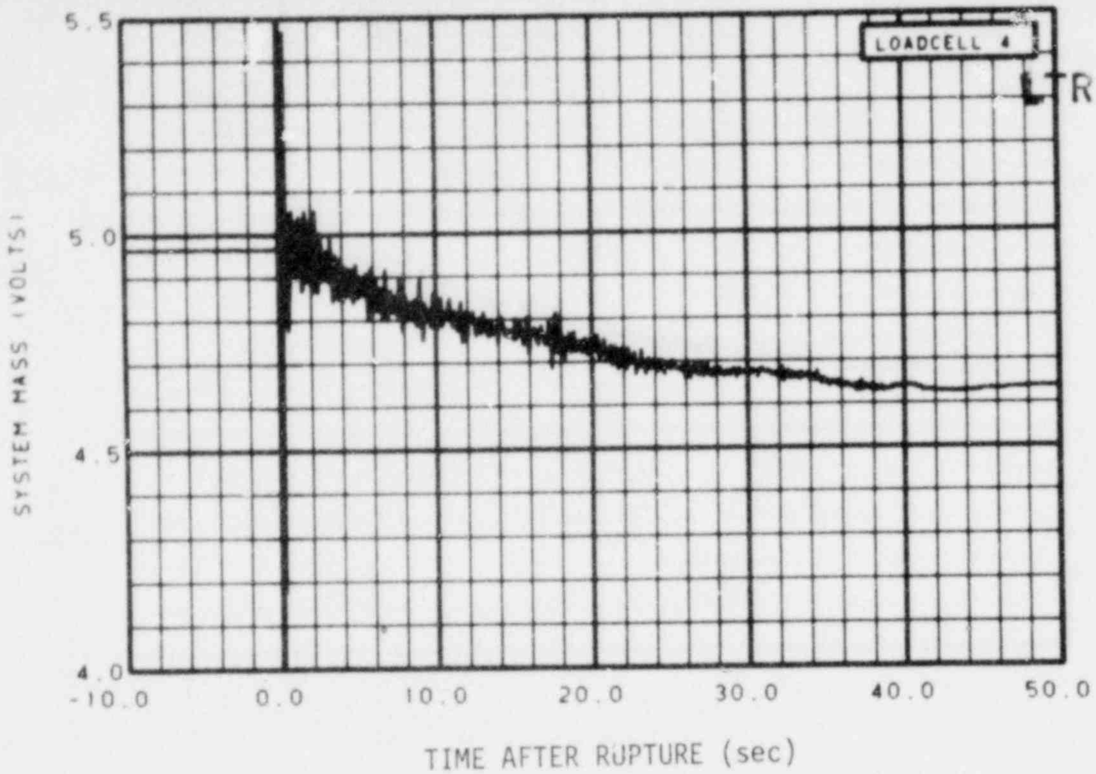
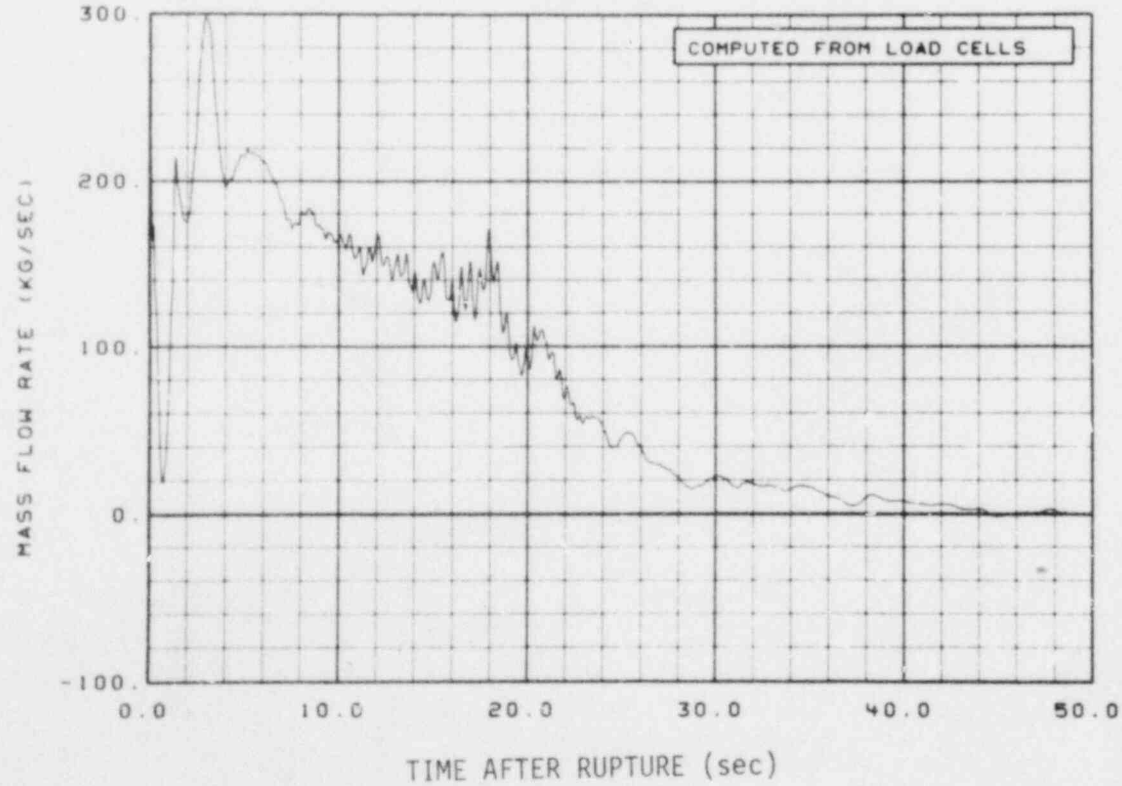
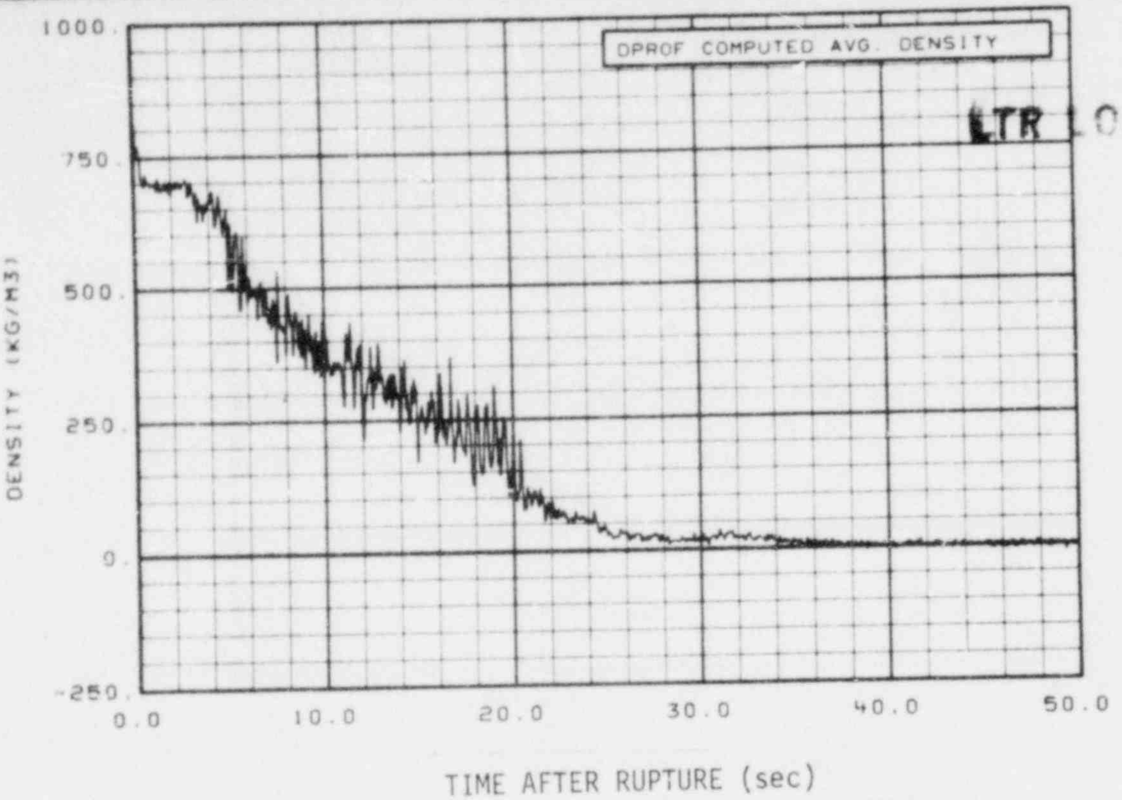


C-21 Load cell 4 -- Test IIIA201.

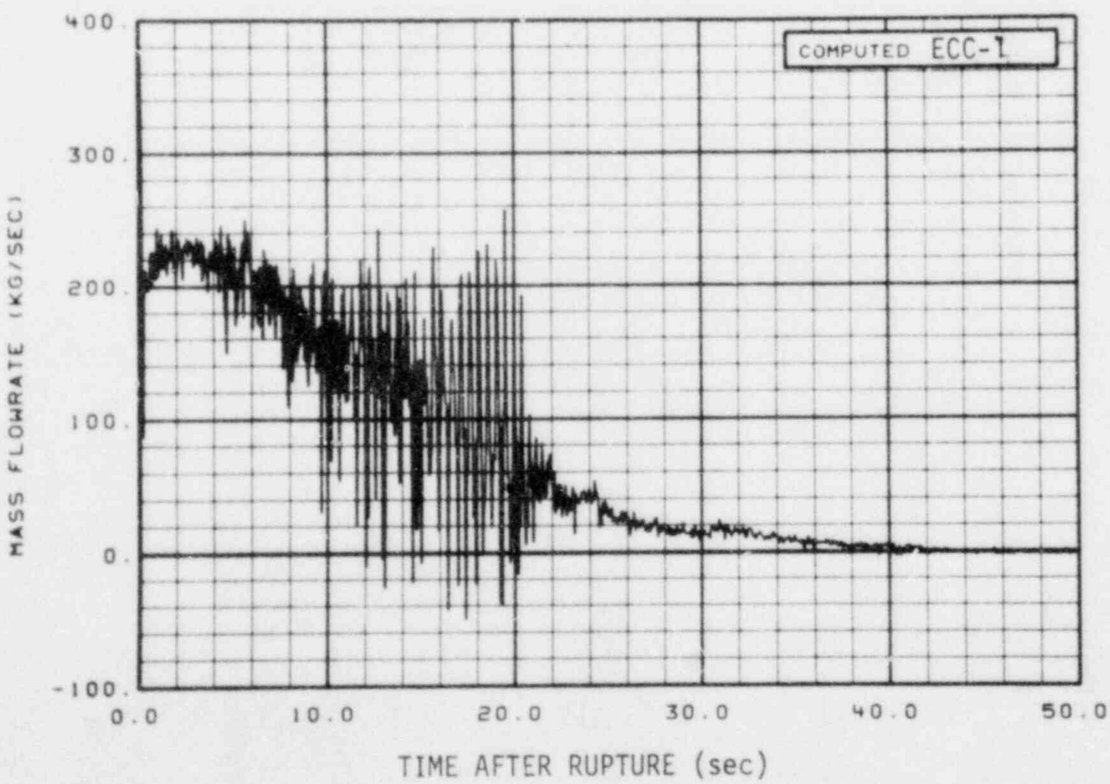


C-22 Mass flow rate computed from load cell readings -- Test IIIA201 . . . .

LTR 10-00-80-118

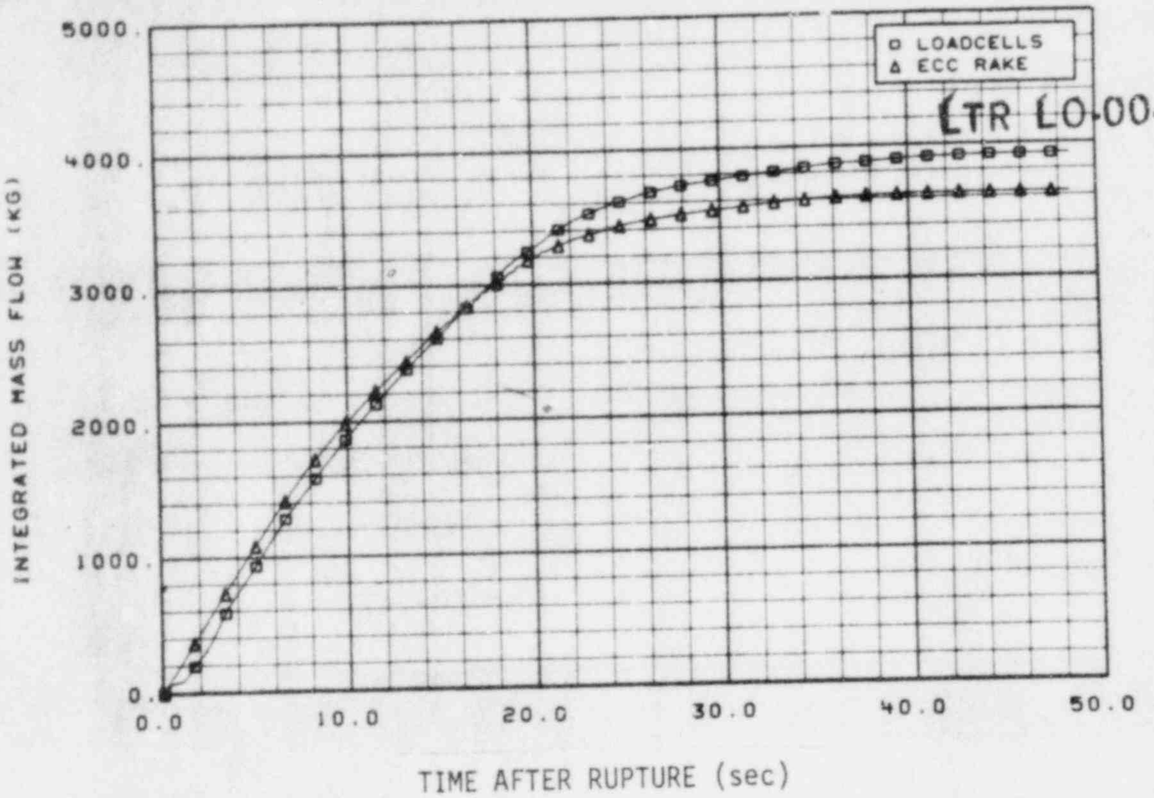


C-23 Average density computed from 6-beam gamma densitometer -- Test IIIA201



C-24 Mass flow rate computed from ECC pitot tube rake and gamma densitometers -- Test IIIA201. . . . .

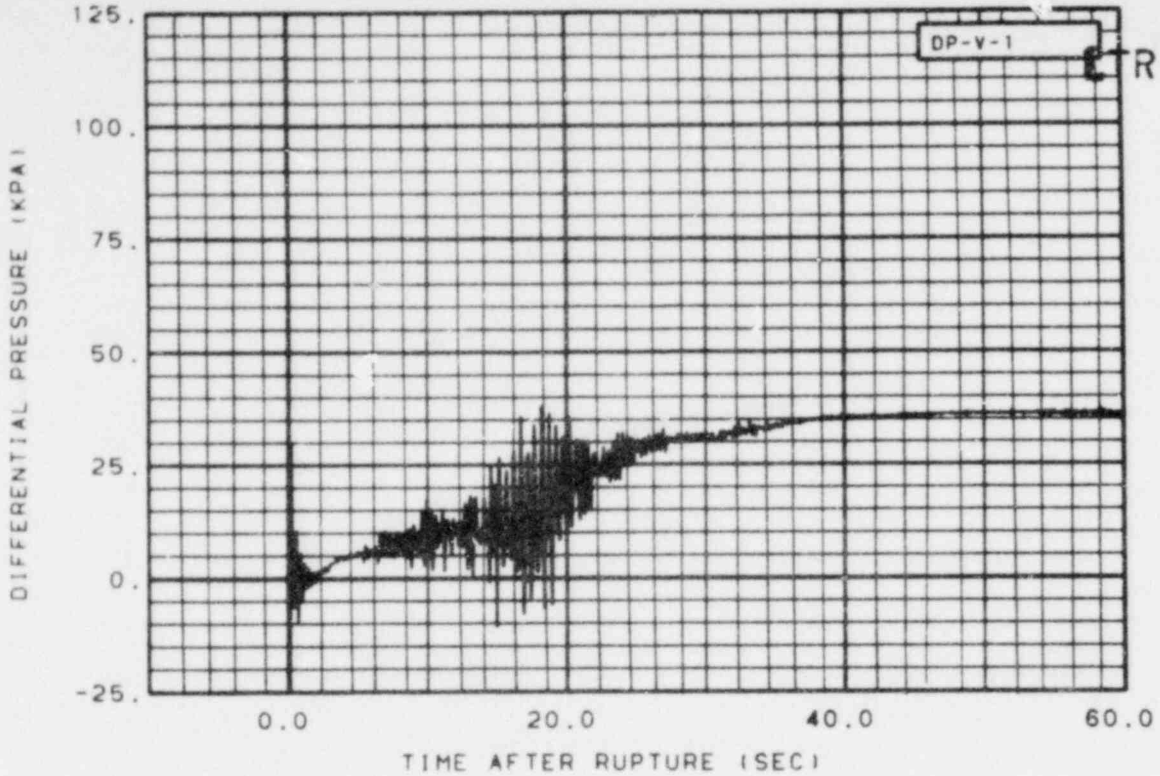
LTR LO-00-80-118



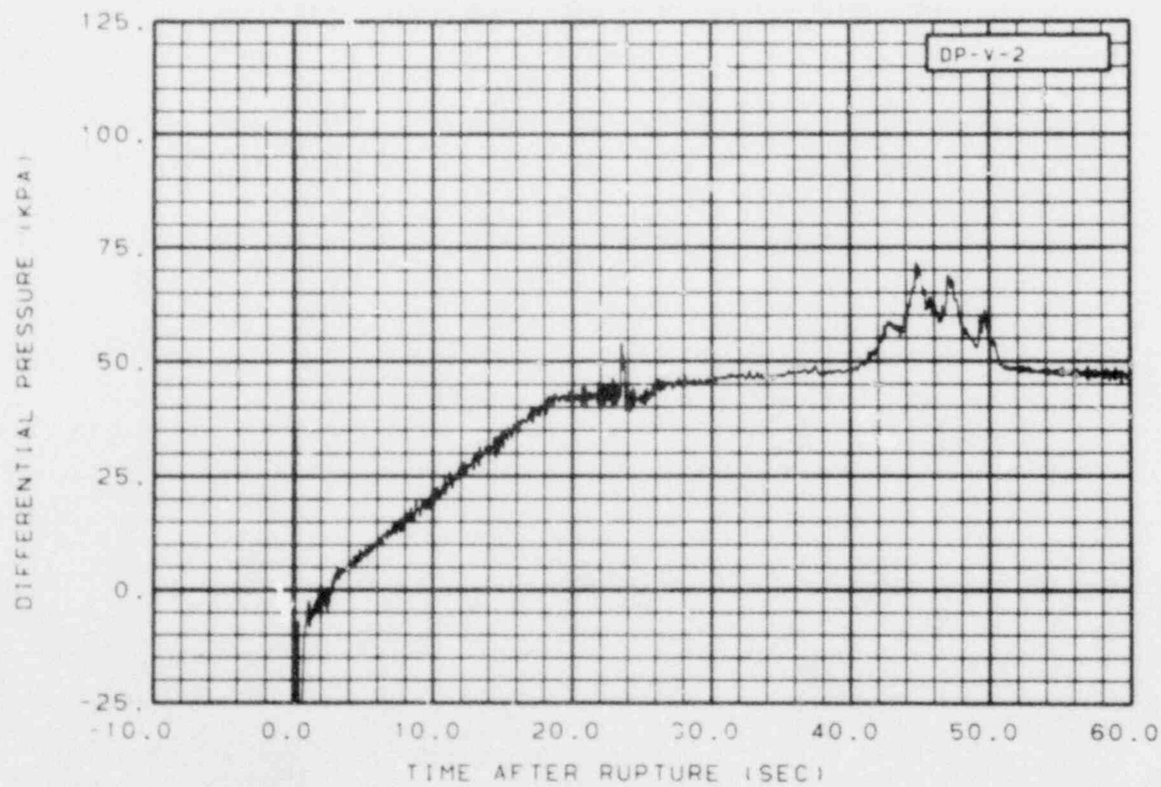
C-25 Integrated mass flowrate comparison -- Test IIIA201

APPENDIX D

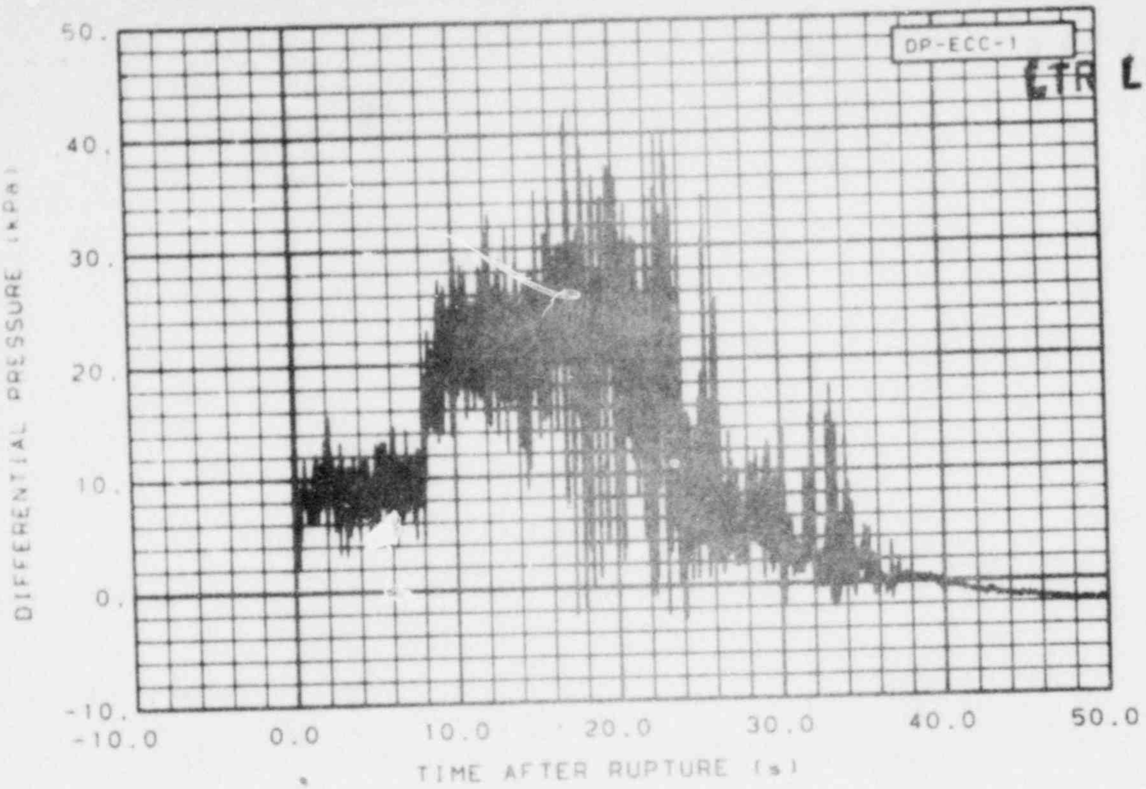
DATA FROM TEST IIIA202



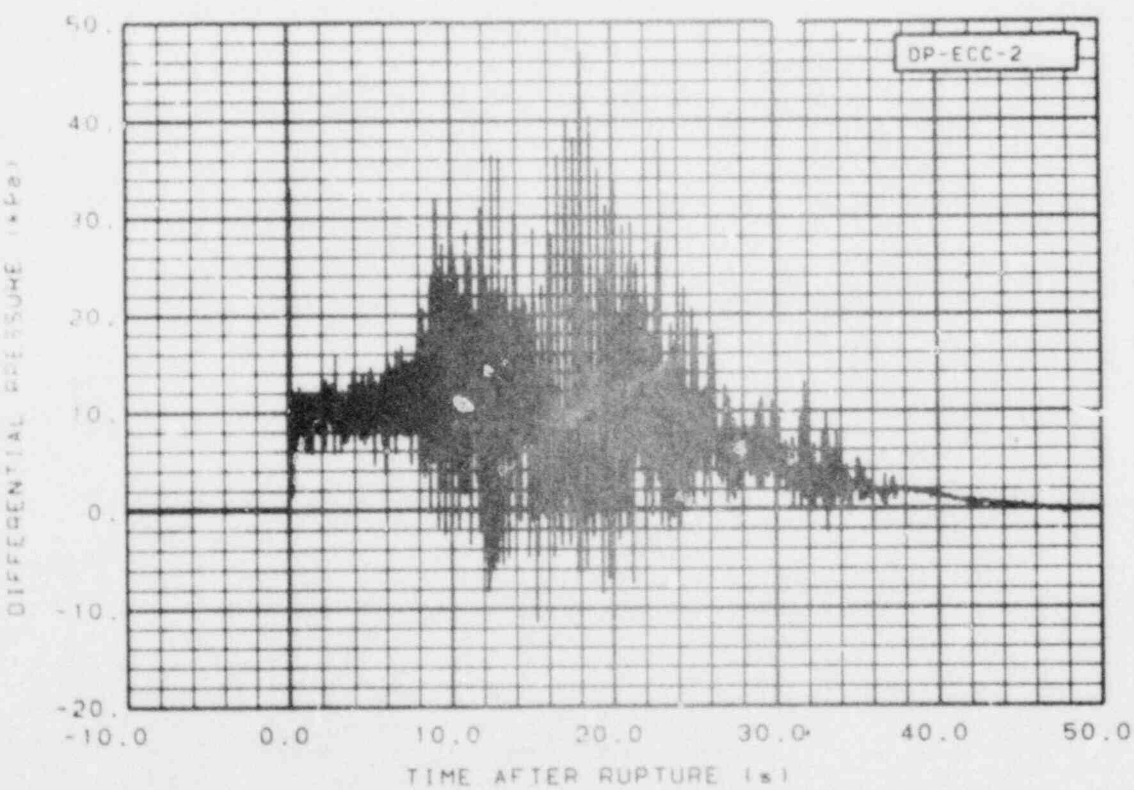
D-1 Differential pressure from vessel bottom to outlet nozzle tap -- (DP-V-1) -- Test IIIA202 . . . . . .



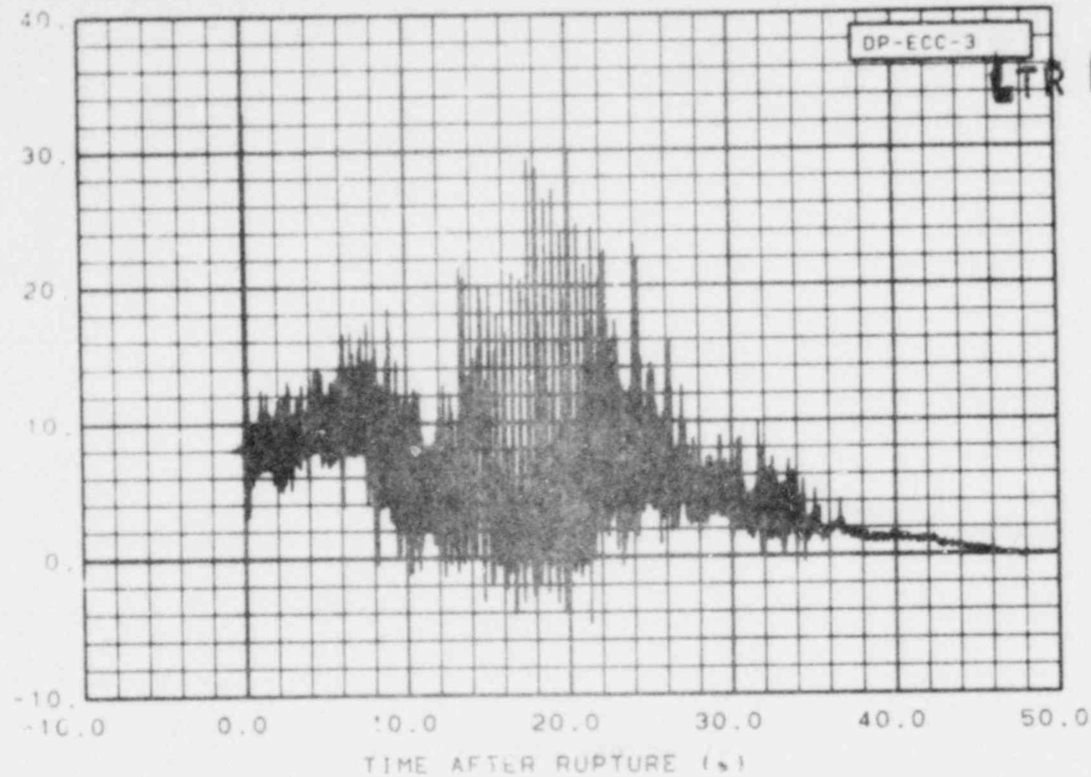
D-2 Differential pressure from vessel top vent to heatup line, low range -- (DP-V-2) -- Test IIIA202



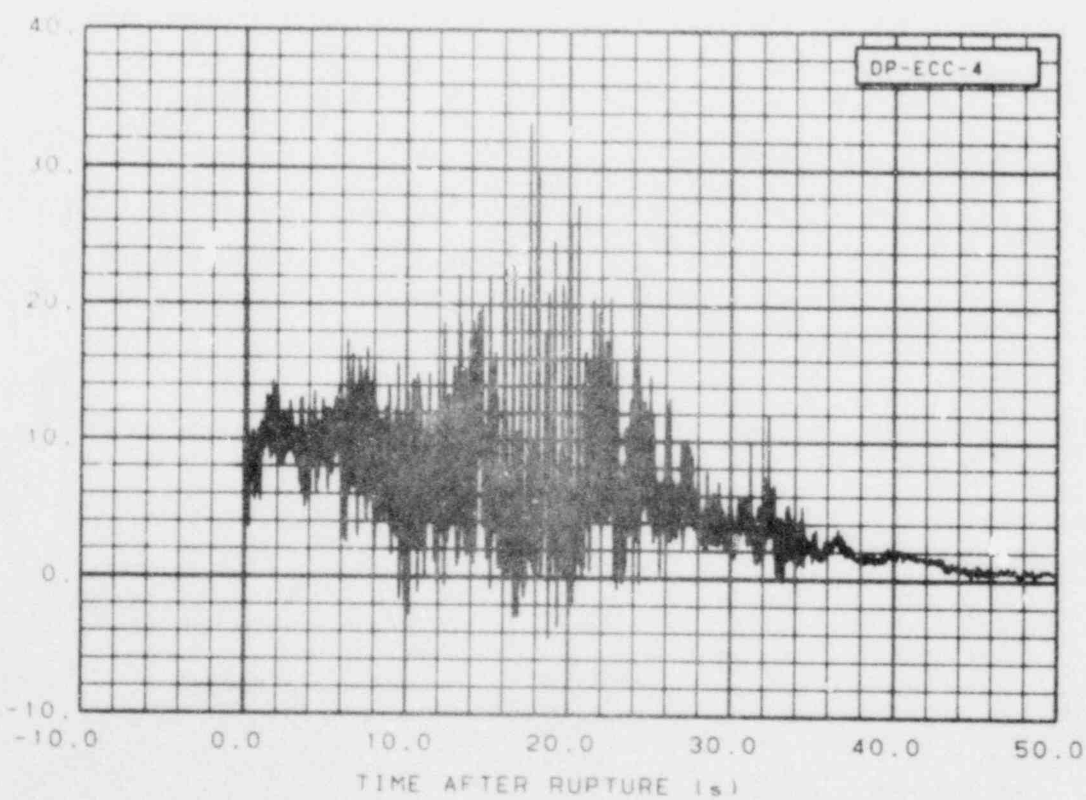
D-3 Differential pressure at bottom of ECC pitot tube rake -- (DP-ECC-1) -- Test IIIA202 . . . .



D-4 Differential pressure at ECC pitot tube rake -- (DP-ECC-2) -- Test IIIA202 . .

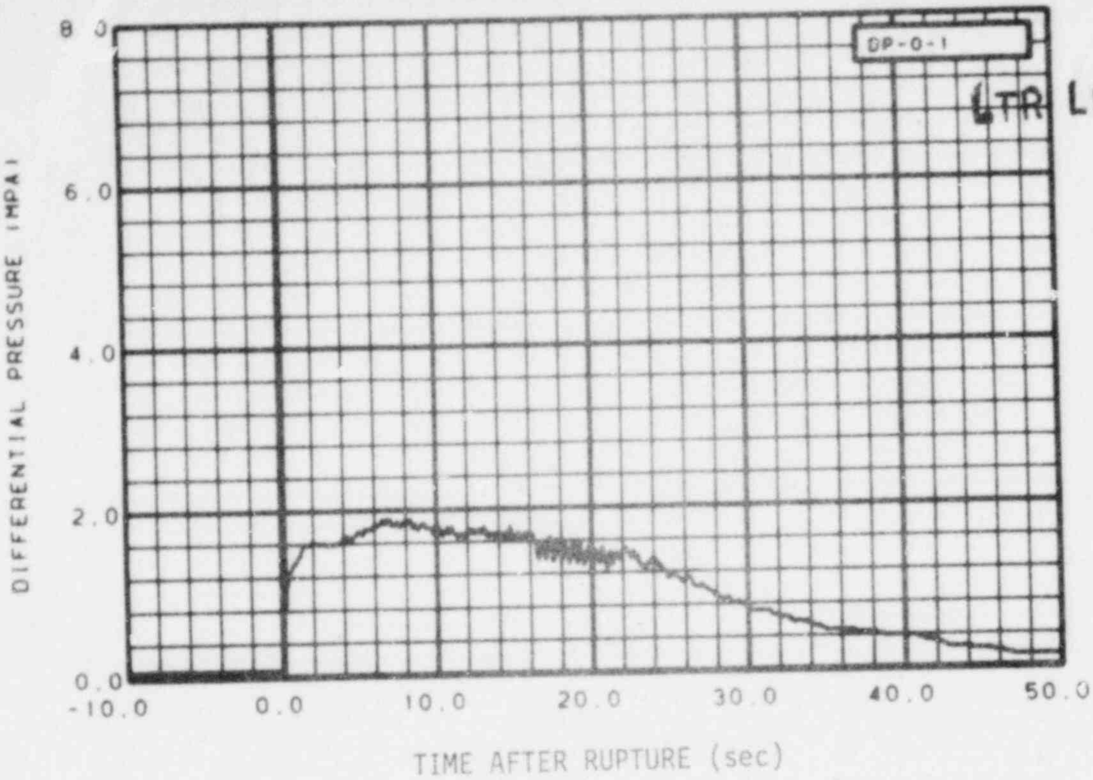


D-5 Differential pressure at center of ECC pitot tube rake -- (DP-ECC-3) -- Test IIIA202. . .

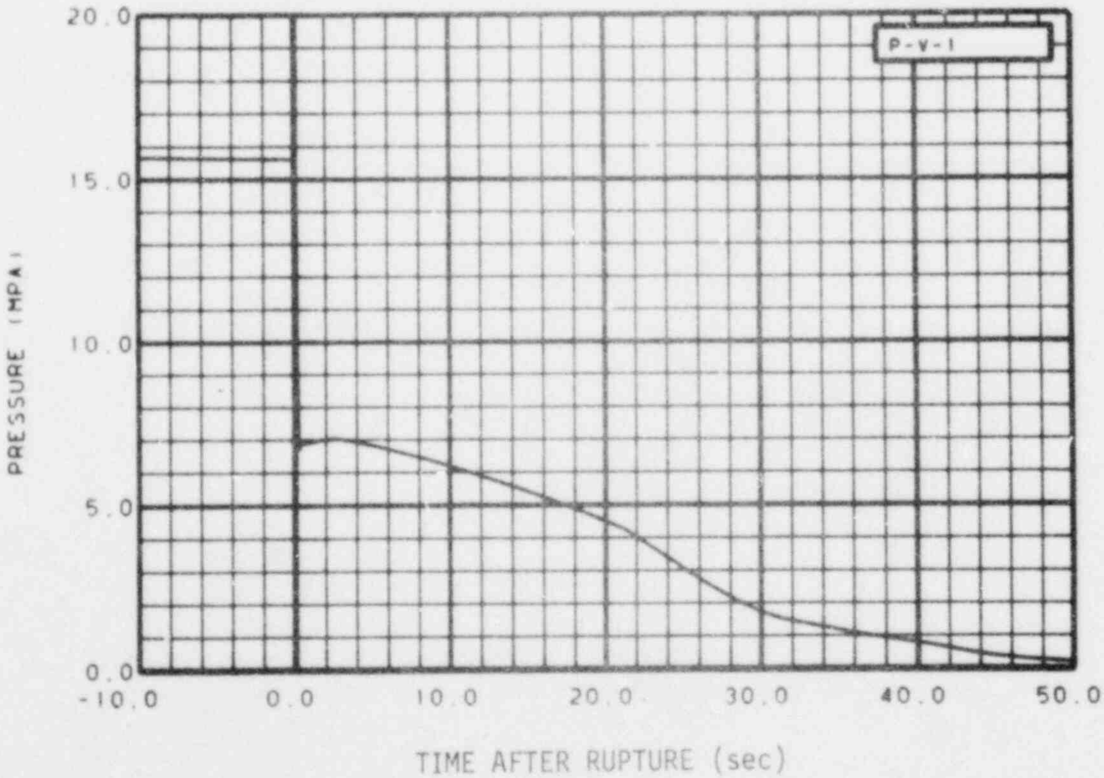


D-6 Differential pressure at top of ECC pitot tube rake -- (DP-ECC-4) -- Test IIIA202 . . . . . .

LTR LO-00-80-118

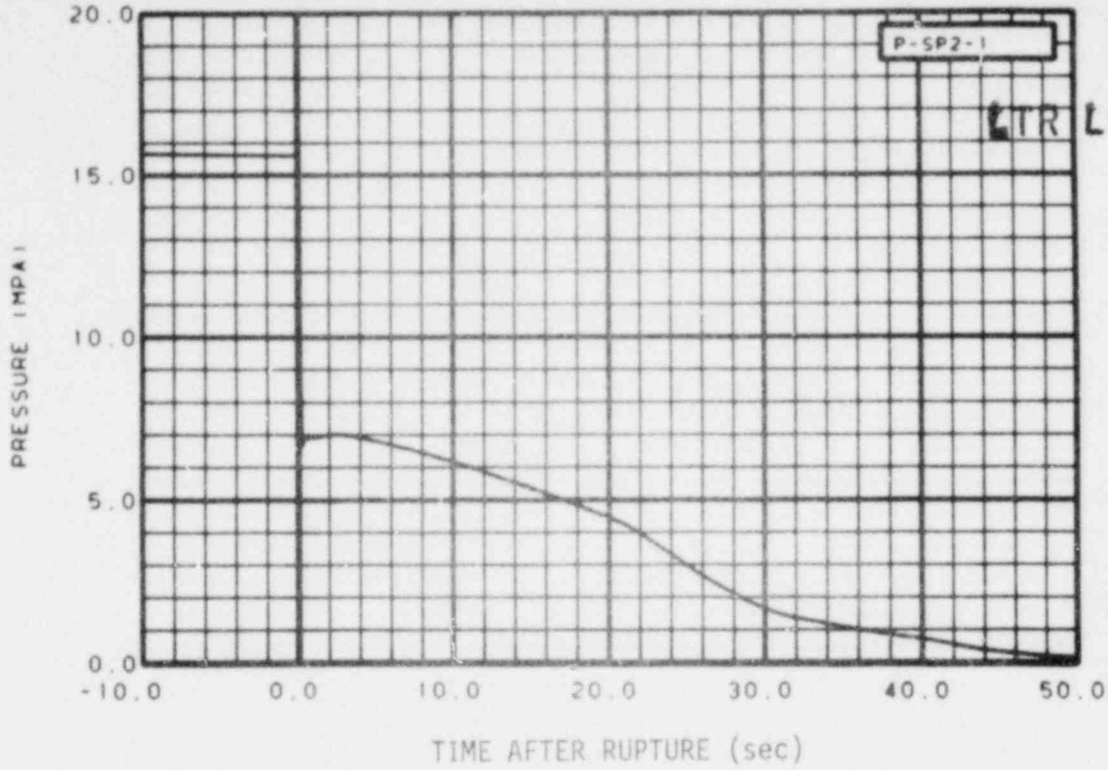


D-7 Differential pressure from test spool tap no. 11 to gate valve flange -- (DP-0-1) -- Test IIIA202

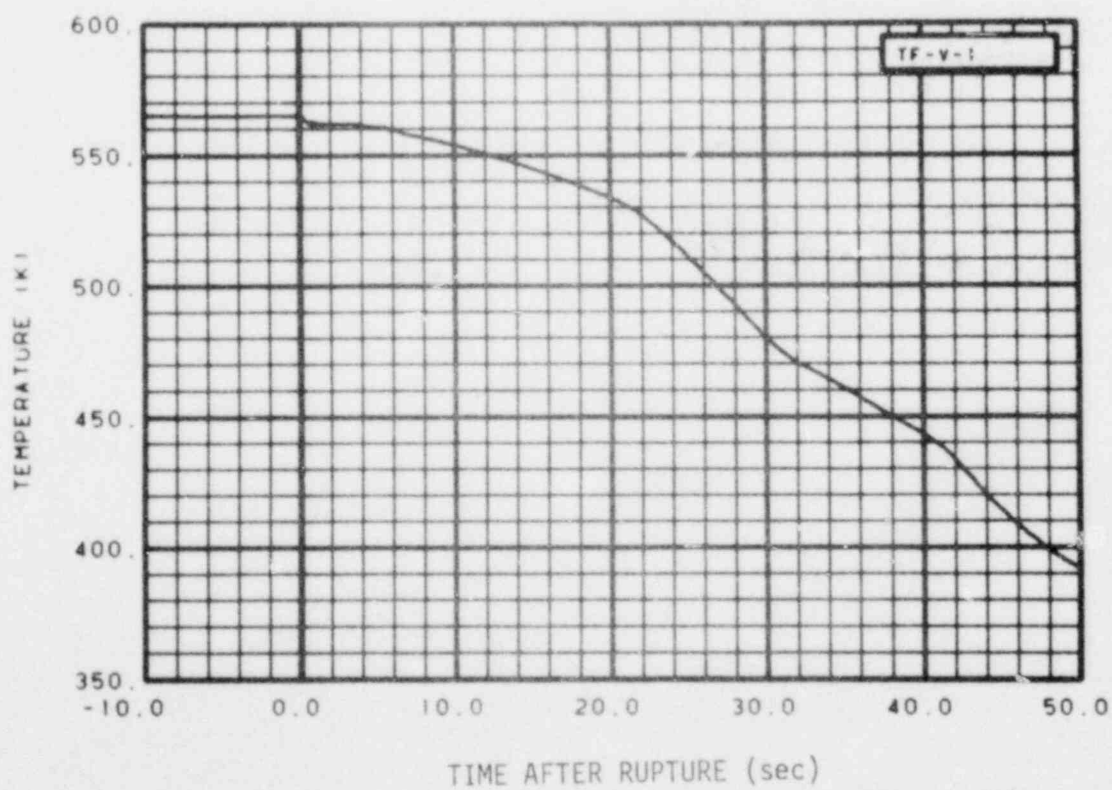


D-8 Pressure at bottom of vessel -- (P-V-1) -- Test IIIA2?2.

LTR LO-00-80-118



D-9 Pressure at test spool tap no. 11 -- (P-SP2-1) -- Test IIIA202 . . . .



D-10 Fluid temperature at bottom of vessel -- (TF-V-1) -- Test IIIA202 . . . .

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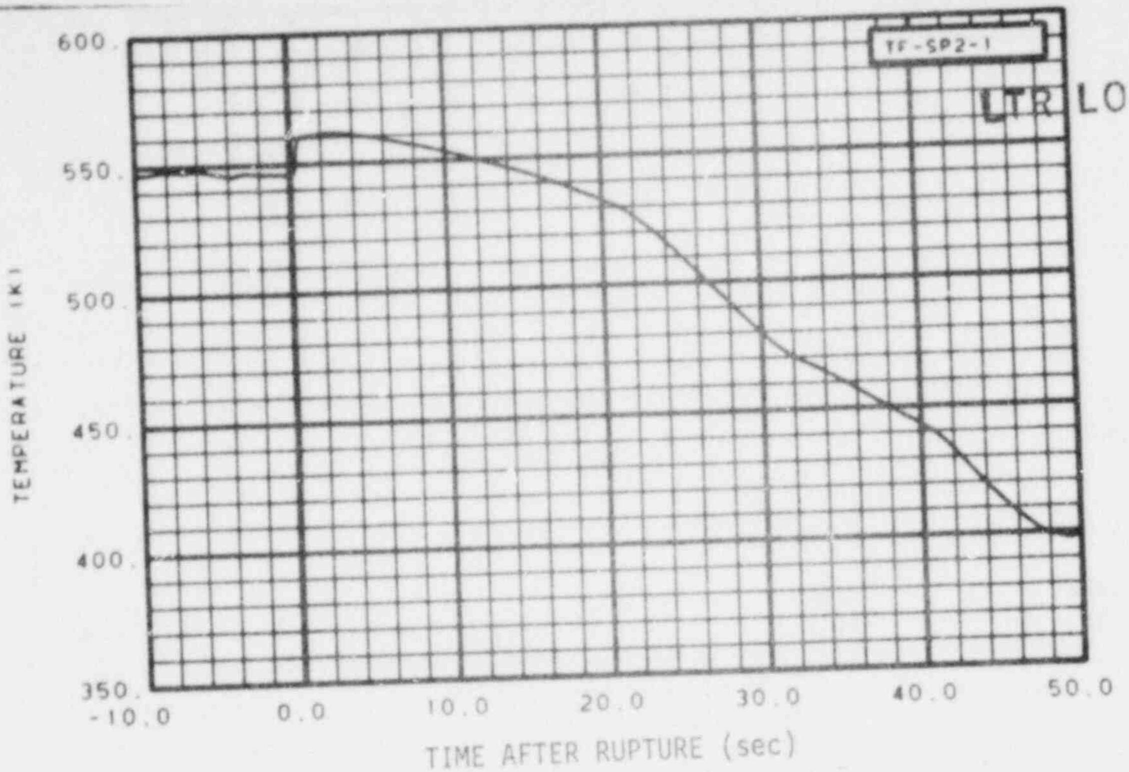
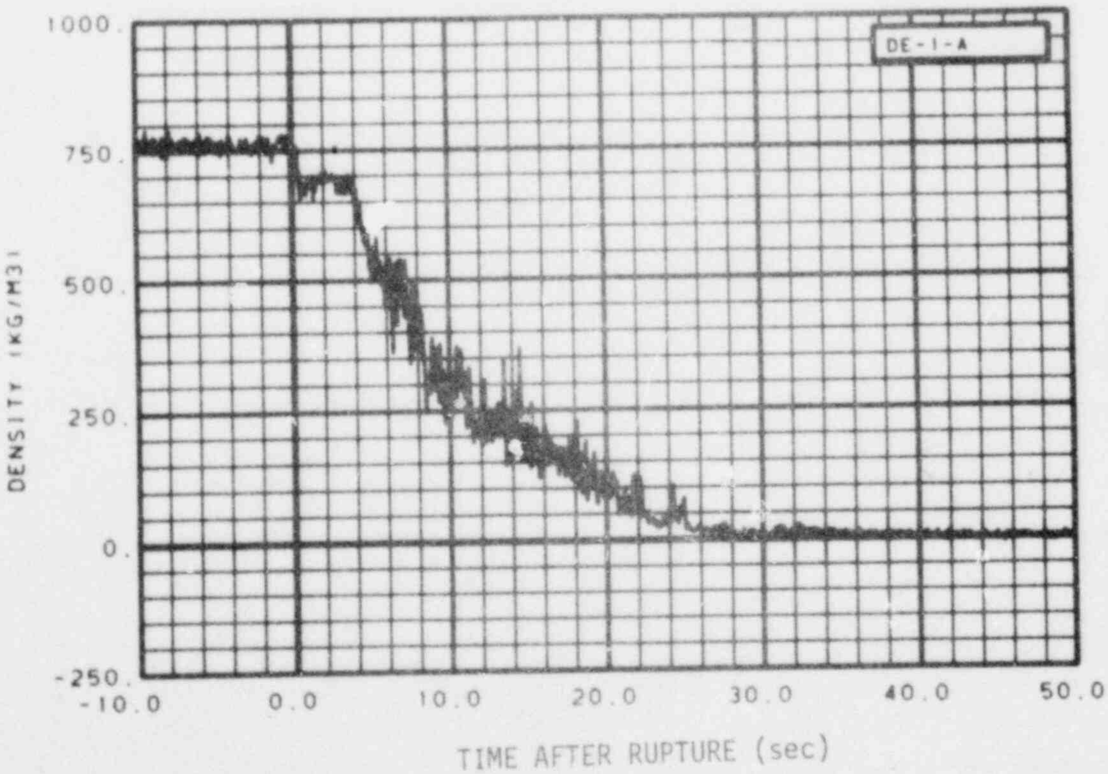
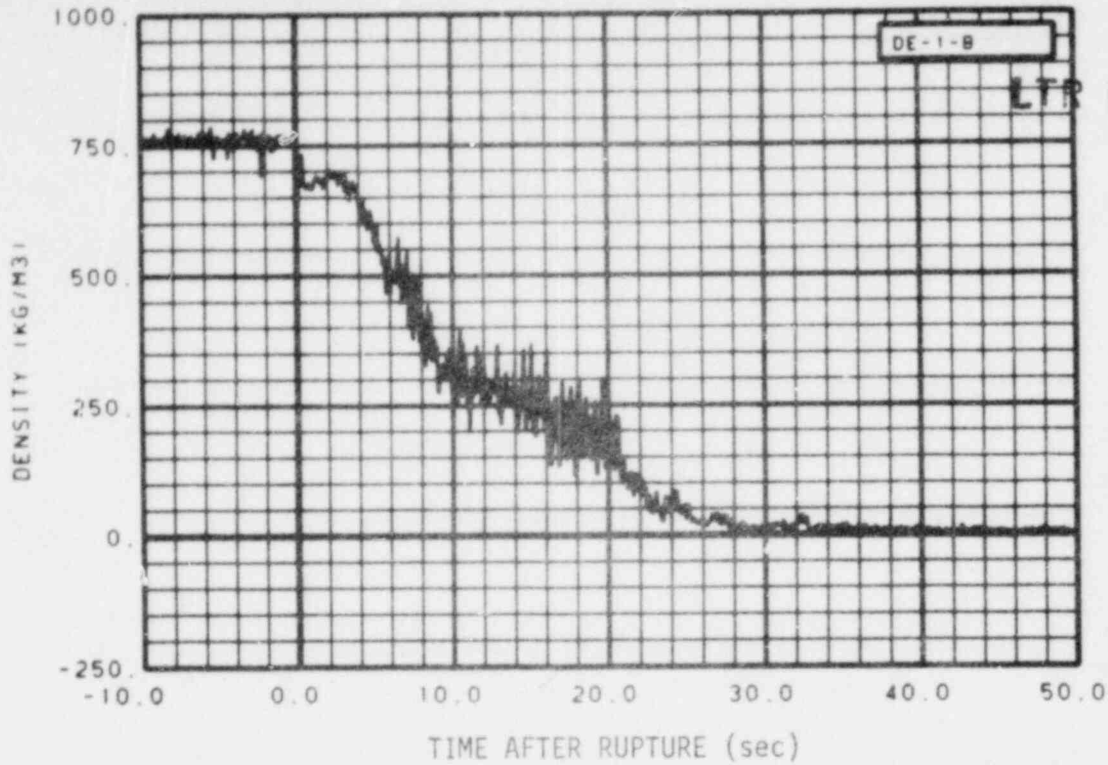


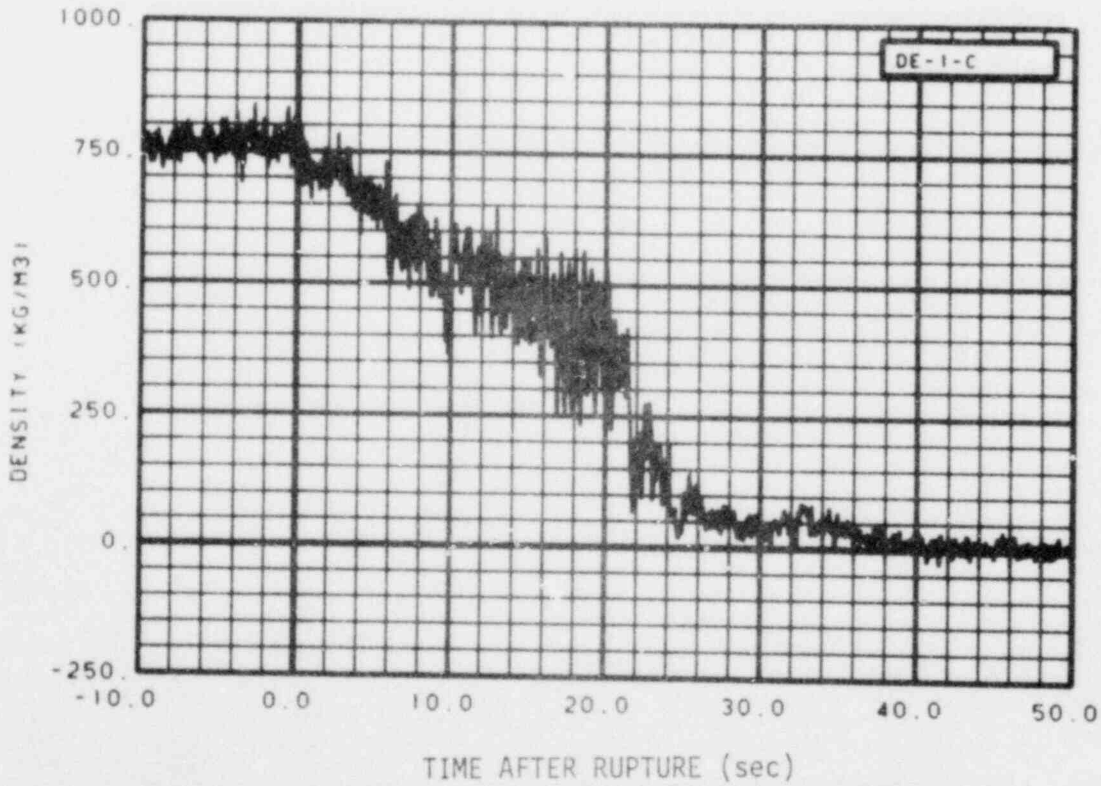
D-11 Fluid temperature at test spool tap no. 1 -- (TF-SP2-1) -- Test IIIA202 . . . .



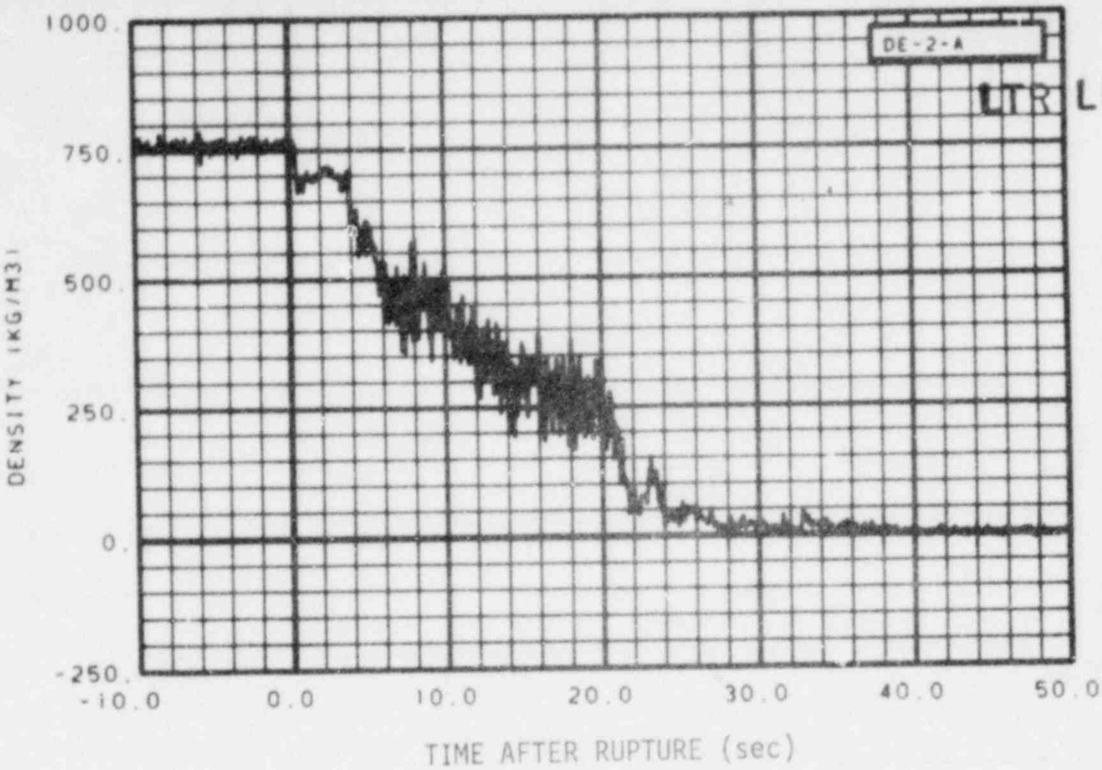
D-12 Density upstream from DTT, source 1, top beam -- (DE-1-A) -- Test IIIA202 . . . .



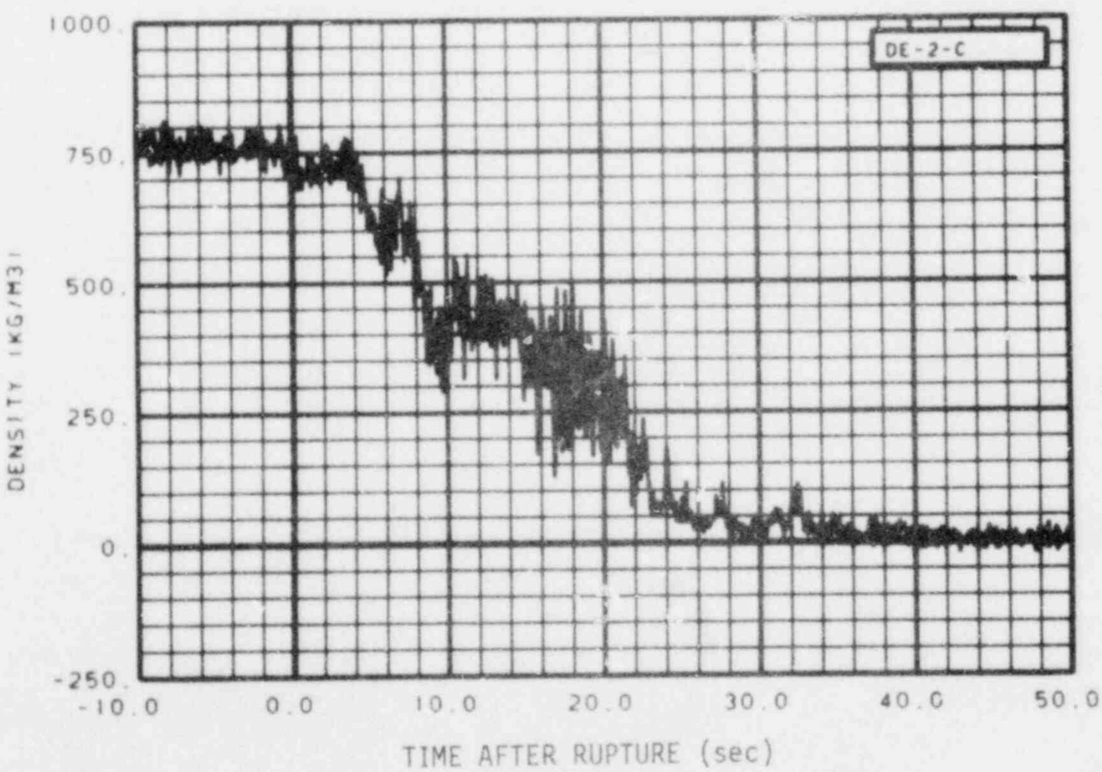
D-13 Density upstream from DTT, source 1, center beam -- (DE-1-B) -- Test IIIA202 . . . .



D-14 Density upstream from DTT, source 1, side beam -- (DE-1-C) -- Test IIIA202 . . . .



D-15 Density upstream from DTT, source 2, lower beam -- (DE-2-A) -- Test IIIA202 . . . .



D-16 Density upstream from DTT, source 2, side beam -- (DE-2-C) -- Test IIIA202 . . . .

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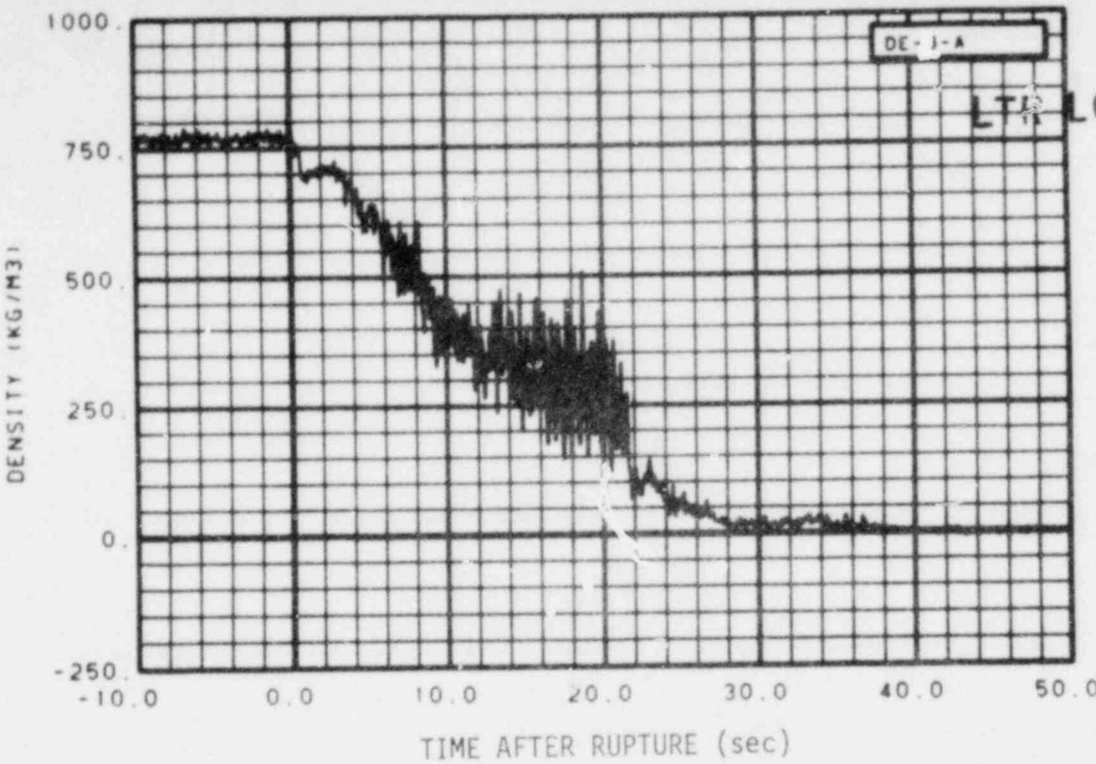
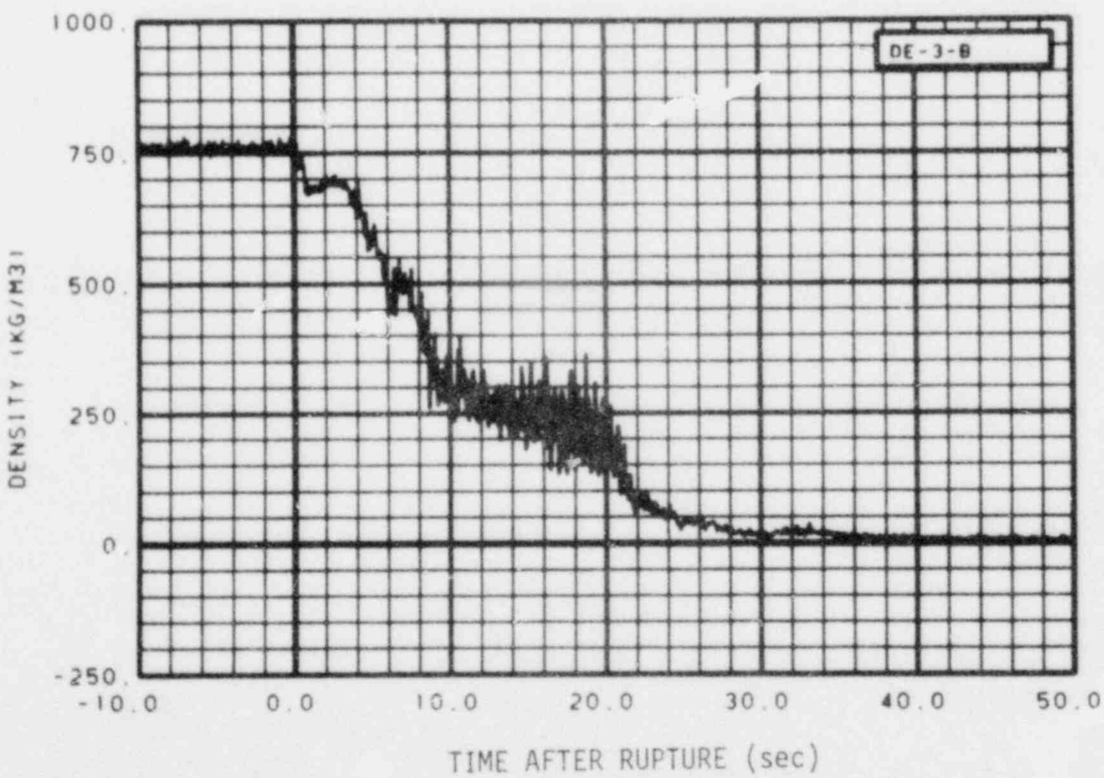
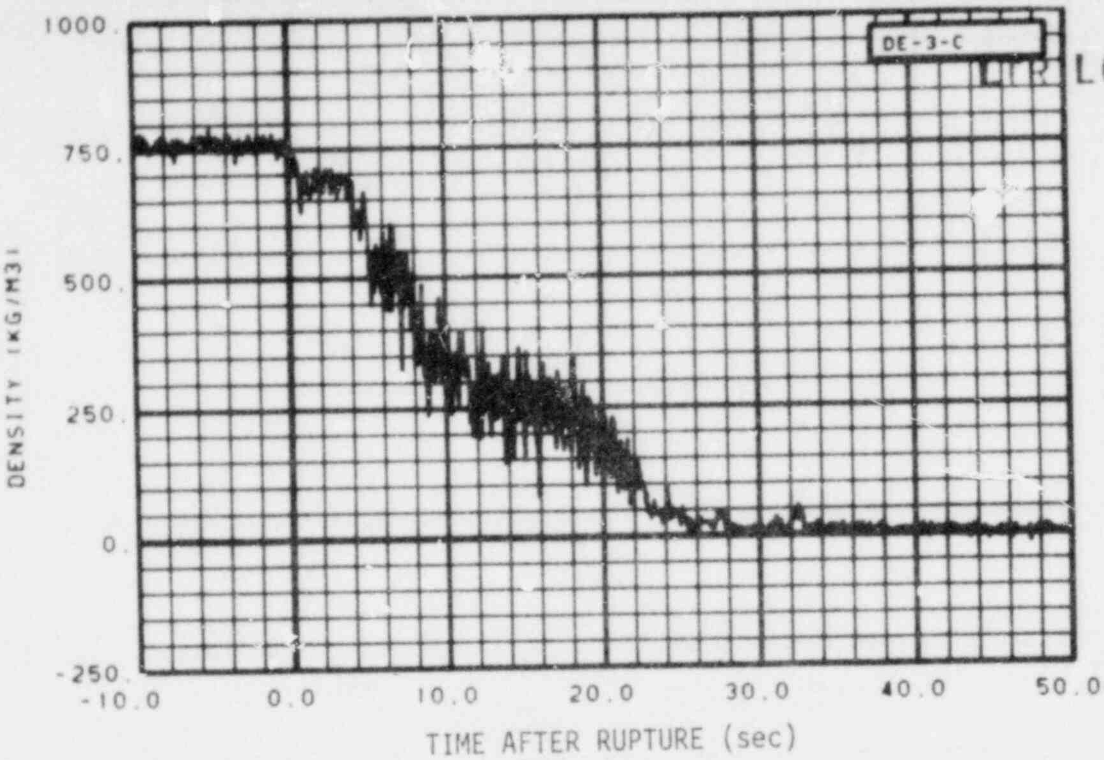


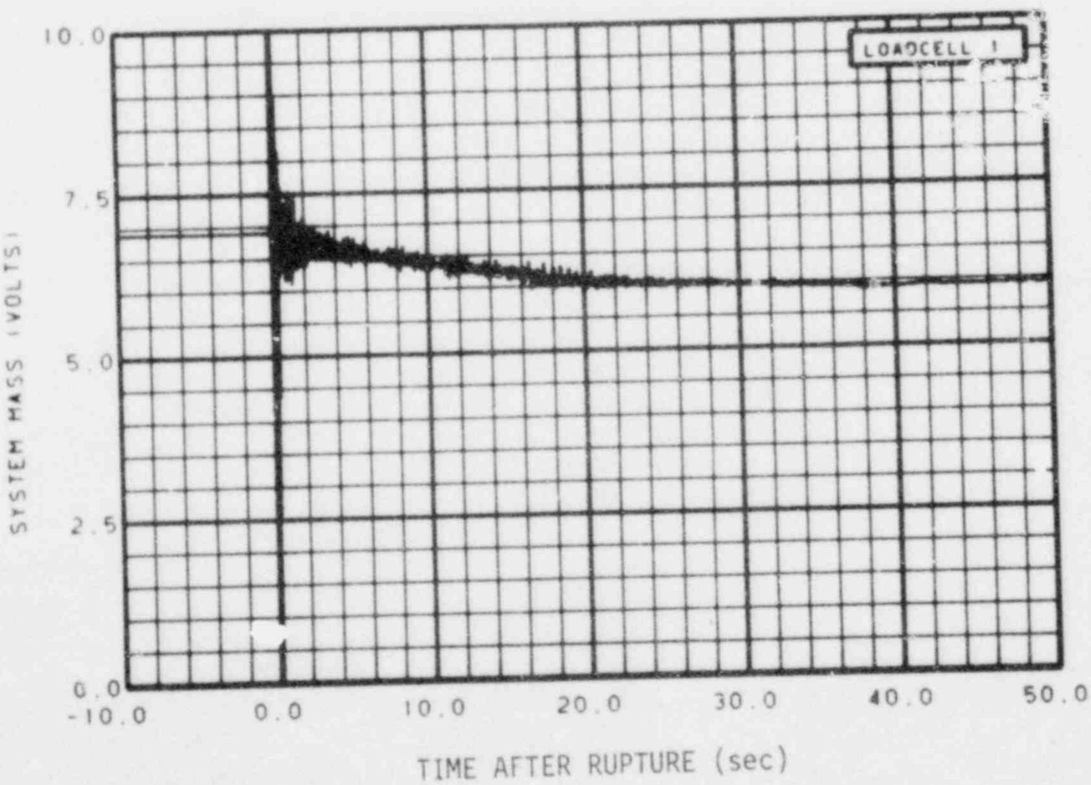
D-17 Density downstream from ECC rake, source 3, bottom beam -- (DE-3-A) -- Test IIIA202 . . . .



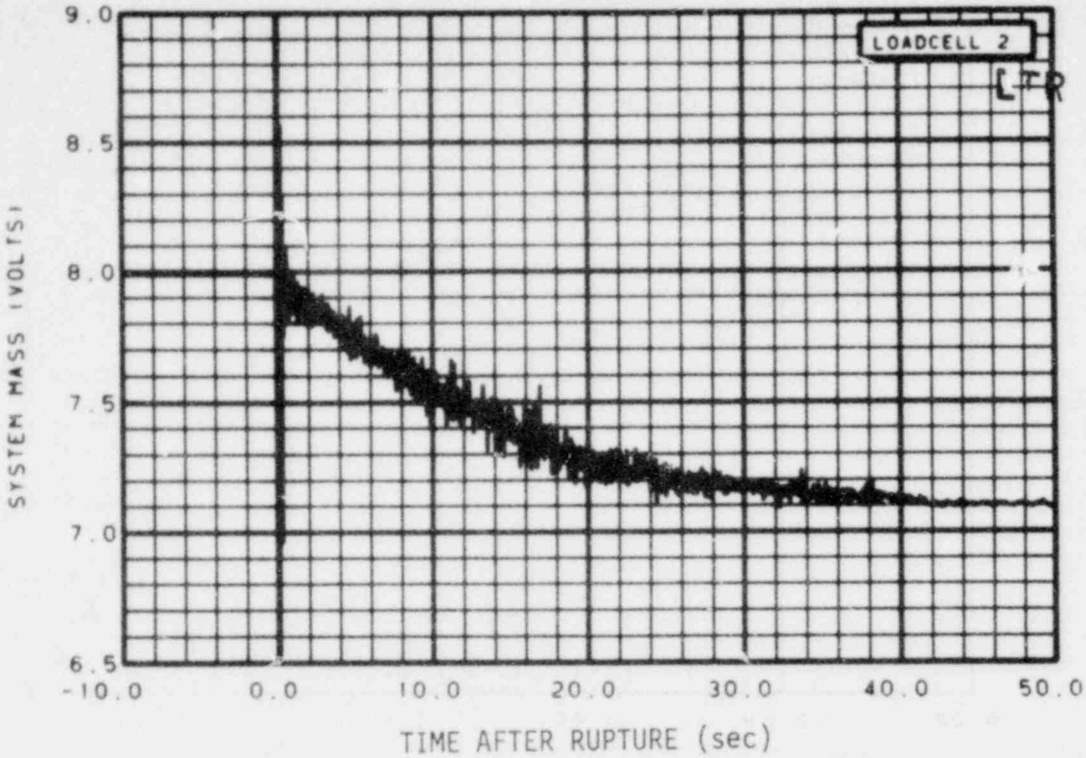
D-18 Density downstream from ECC rake, source 3 center beam -- (DE-3-B) -- Test IIIA202. .



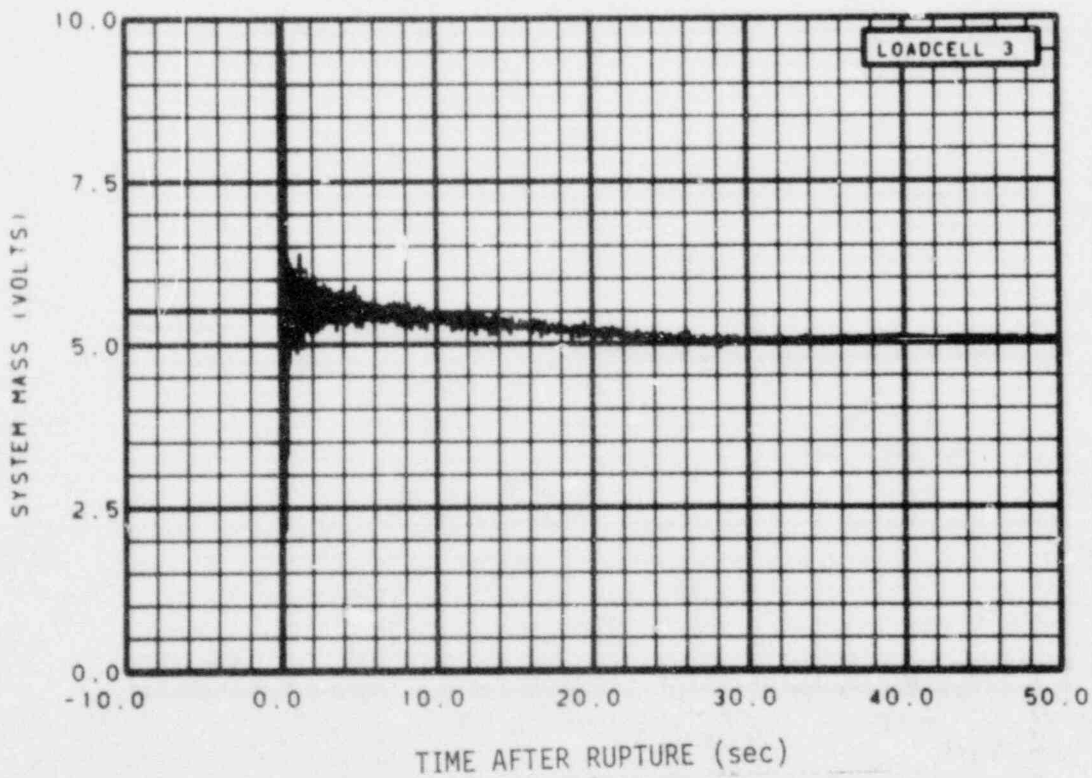
D-19 Density downstream from ECC rake, source 3 top beam -- (DE-3-C) -- Test IIIA202 . . .



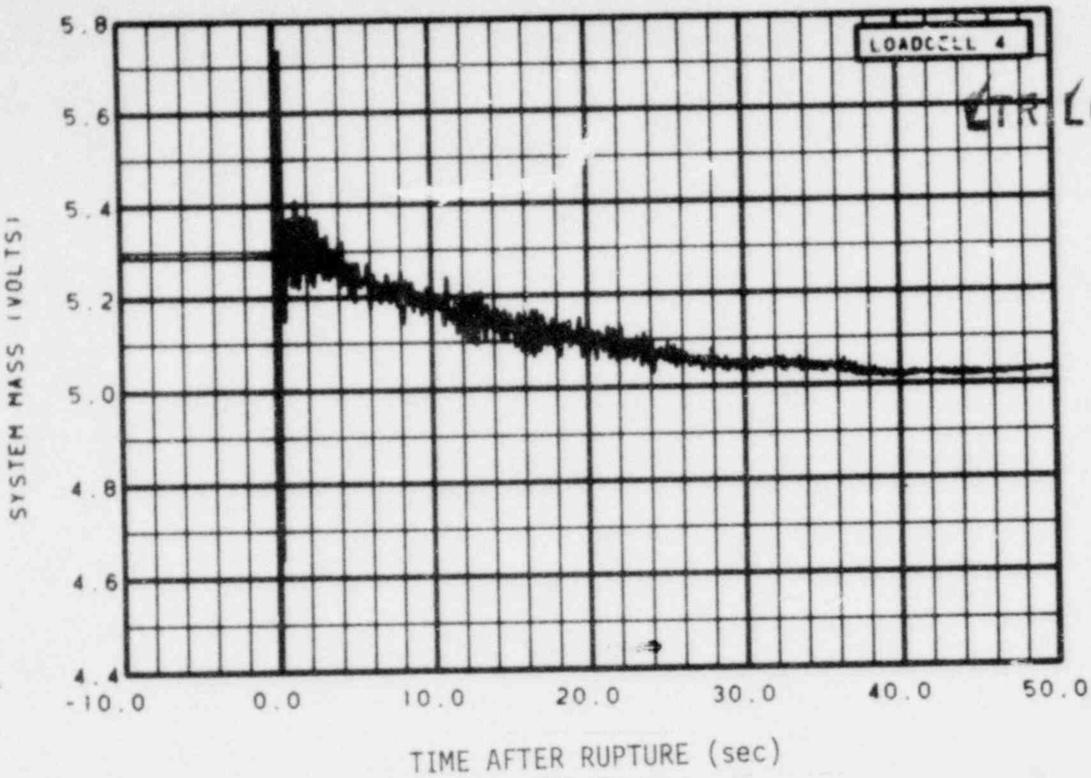
D-20 Load cell 1 -- Test IIIA202.



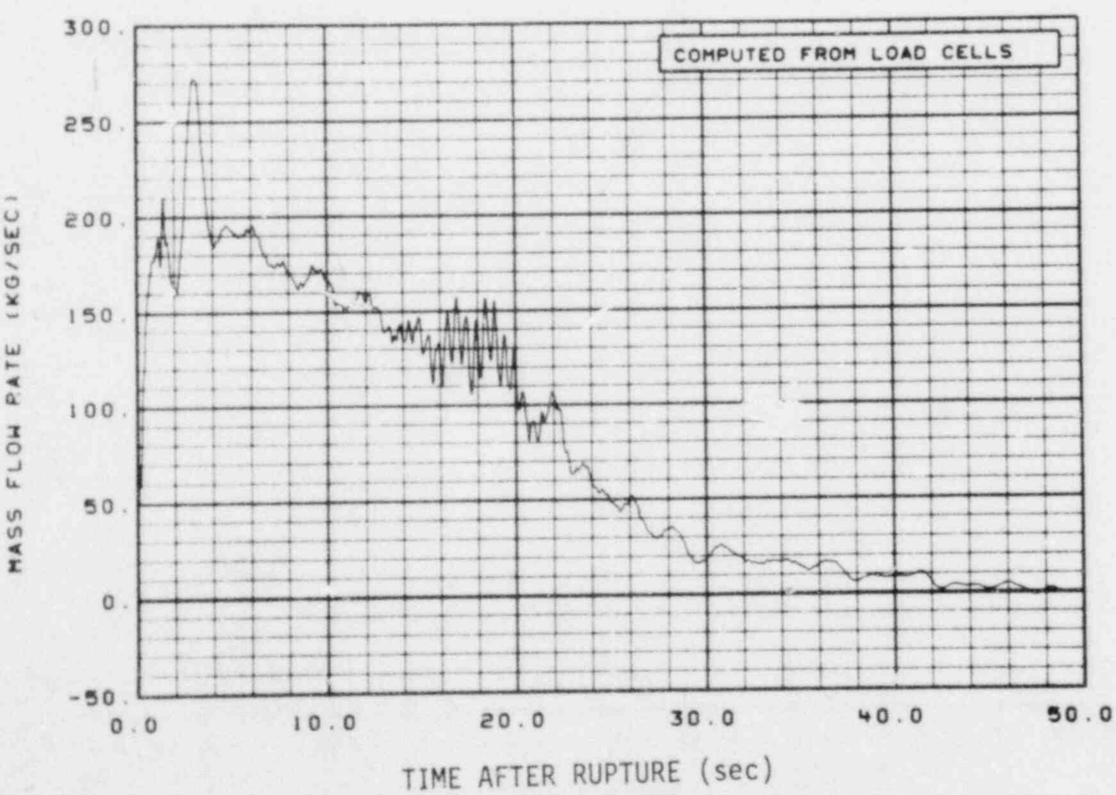
D-21 Load cell 2 -- Test IIIA202.



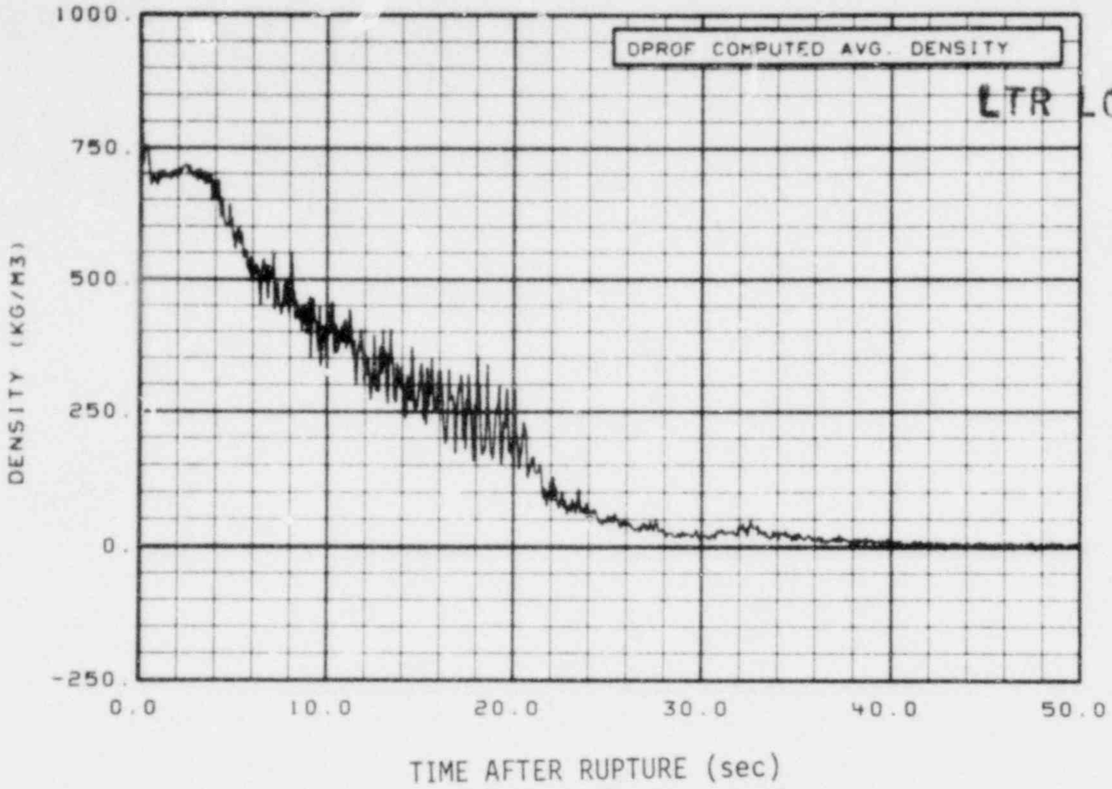
D-22 Load cell 3 -- Test IIIA202.



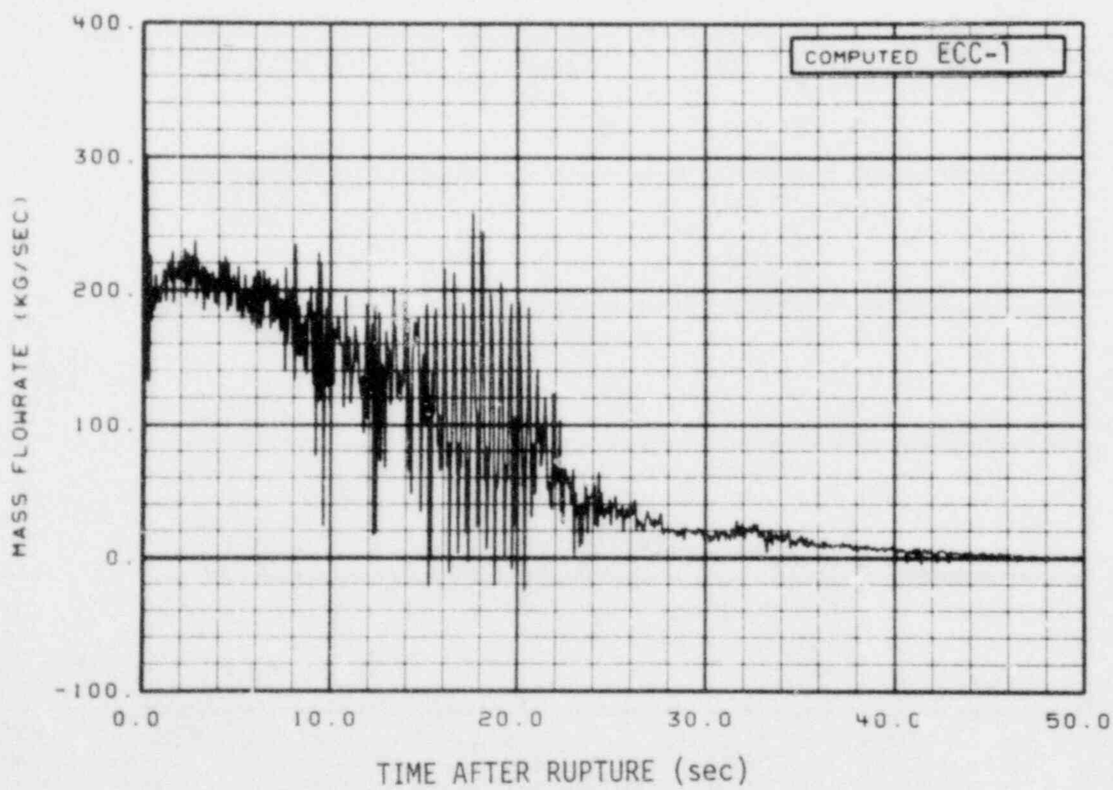
D-23 Load cell 4 -- Test IIIA202.



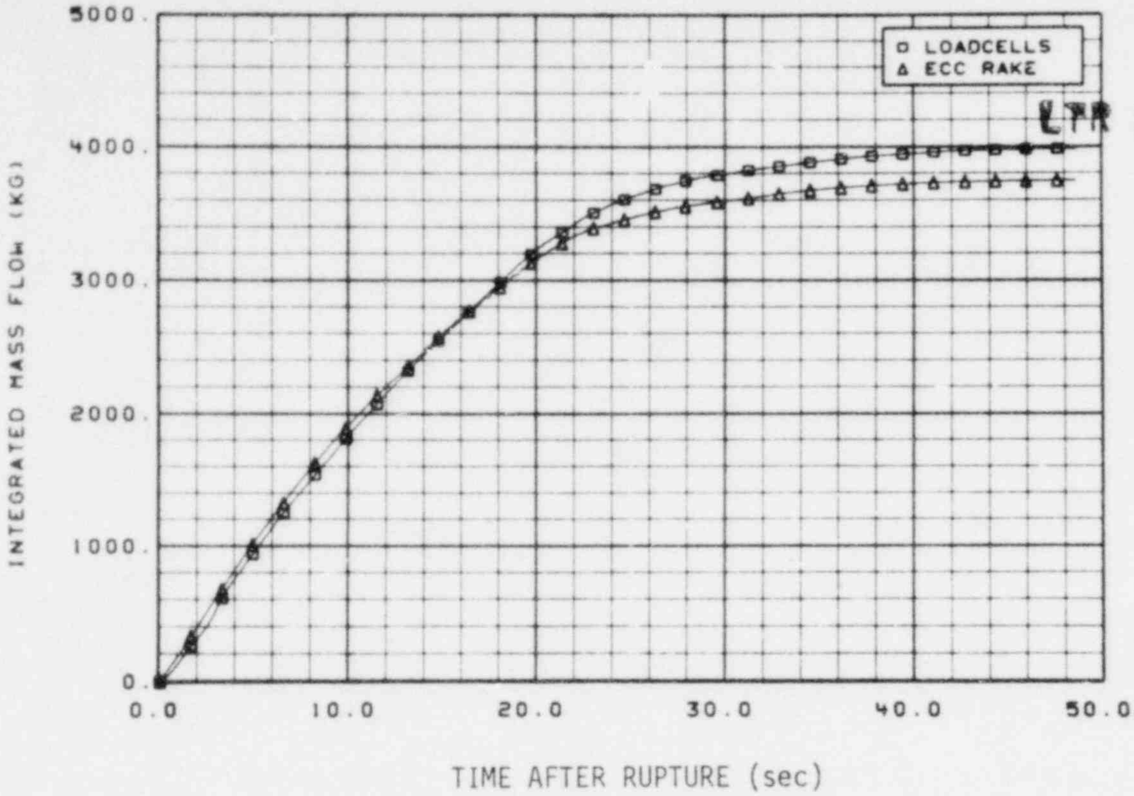
D-24 Mass flow rate computed from load cell readings -- Test IIIA202 . . . .



D-25 Average density computed from 6-beam gamma densitometer -- Test IIIA202 . . . .



D-26 Mass flow rate computed from ECC pitot tube rake and gamma densitometers -- Test IIIA202. . . . .



D-27 Integrated mass flowrate comparison -- Test IIIA202

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TABLE I

INSTRUMENTATION FOR TRANSIENT FLOW TEST

Parameter System Detector	Location	Range	Measurement Uncertainty*	Data Fig. No.	Comments
DIFFERENTIAL PRESSURE					
Vessel DP-V-1	Vessel bottom to outlet	± 69 KPA	5.6% Rd + .72% Rg	A-1, B-1, C-1, D-1	Qualified[a]
Vessel DP-V-2	Vessel top to bottom	± 75 KPA	5.0% Rd + .72% Rg	A-2, B-2, C-2, D-2	Reviewed but not qualified
ECC Rake DP-ECC-1	ECC rake - bottom	± 42 KPA	4.0% Rd + 1.22% Rg	A-3, B-3, C-3, D-3	Qualified[j]
ECC Rake DP-ECC-2	ECC rake	± 42 KPA	4.0% Rd + 1.12% Rg	A-4, B-4, C-4, D-4	Qualified
ECC Rake DP-ECC-3	ECC rake - pipe center	± 42 KPA	4.0% Rd + 1.07% Rg	A-5, B-5, C-5, D-5	Qualified
ECC Rake DP-ECC-4	ECC rake - top	± 42 KPA	4.0% Rd + .77% Rg	A-6, B-6, C-6, D-6	Qualified[b]
Nozzle DP-O-1	PF11 to bottom of valve flange	± 10 MPa	4.0% Rd + .72% Rg	A-7, B-7, C-7, D-7	Qualified
PRESSURE (GAUGE)					
Vessel P-V-1	Vessel bottom	0 - 21 MPa	4.1% Rd + .45% Rg	A-8, B-8, C-8, D-8	Qualified
Spool Piece P-SP2-1	PF11	0 - 17 MPa	4.1% Rd + .75% Rg	A-9, B-9, C-9, D-9	Qualified[c]

TABLE I (CONTINUED)

Parameter System Detector	Location	Range	Measurement Uncertainty*	Data Fig. No.	Comments
FLUID TEMPERATURE					
Vessel TF-V-1	Bottom of vessel	360 - 590 K	4.3% Rd + 0.13% Rg	A-10, B-10, C-10, D-10	Qualified
Spool Piece TF-SP2-1	SP2-1 top	360 - 590 K	4.3% Rd + 0.13% Rg	A-11, B-11, C-11, D-11	Qualified(d)
DTT Rake TF-DTT-B	DTT rake	360 - 590 K	4.3% Rd + 0.13% Rg	A-12, B-12	Qualified(d)
CHORDAL DENSITY					
Left Source DE-1-A	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 2.38% Rg	A-13, B-13, C-12, D-12	Qualified
Left Source DE-1-B	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 2.38% Rg	A-14, B-14, C-13, D-13	Qualified
Left Source DE-1-C	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 2.38% Rg	A-15, B-15, C-14, D-14	Qualified
Right Source DE-2-A	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 1.77% Rg	B-16, C-15, D-15	Qualified(e)
Right Source DE-2-B	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 1.77% Rg	A-16, B-17	Qualified(f)
Right Source DE-2-C	Upstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 7.19% Rg	A-17, B-18, C-16, D-16	Qualified

TABLE I (CONTINUED)

Parameter System Detector	Location	Range	Measurement Uncertainty*	Data Fig. No.	Comments
Spool Piece DE-3-A	Downstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 1.27% Rg	A-18, B-19, D-17	Qualified (f)
Spool Piece DE-3-B	Downstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 1.27% Rg	A-19, B-20, D-18	Qualified (g)
Spool Piece DE-3-C	Downstream of DTT on SP2	800 - 1000 Kg/m^3	.20% Rd + 1.27% Rg	A-20, B-21, C-17, D-19	Qualified (h)
MOMENTUM FLUX					
Spool Piece ME-1-A	SP2, bottom MDTT	3 - 75 $mg/m\text{-}sec^2$	.20% Rd + 16 % Rg	A-21, B-22	Qualified
Spool Piece ME-1-B	SP2, center MDTT	3 - 75 $mg/m\text{-}sec^2$	.20% Rd + 16 % Rg	A-22, B-23	Qualified
Spool Piece ME-1-C	SP2, top MDTT	3 - 75 $mg/m\text{-}sec^2$	.20% Rd + 16 % Rg	A-23, B-24	Qualified
FLUID VELOCITY					
FE-1-A	SP2, bottom MDTT	2.3 - 45 m/sec	.20% Rd + 7.8 % Rg	A-24, B-25	Qualified (i)
FE-1-B	SP2, center MDTT	2.3 - 46 m/sec	.20% Rd + 7.8 % Rg	A-26, B-26	Qualified
FE-1-C	SP2, top MDTT	2.3 - 46 m/sec	.20% Rd + 7.8 % Rg	A-26, B-27	Qualified

TABLE I (CONTINUED)

Parameter System Detector	Location	Range	Measurement Uncertainty*	Data Fig. No.	Comments
SYSTEM MASS					
Load Cell 1	180° +	222 Kn	Static uncertainty of weighing system	A-27, B-28, C-18, D-20	Qualified
Load Cell 2	300° +	222 Kn	is .59% of fluid weight range	A-28, B-29, C-19, D-21	Qualified
Load Cell 3	60° +	222 Kn	(Reference 5)	A-29, B-30, C-20, D-22	Qualified
Load Cell 4	Discharge assembly	111 Kn		A-30, B-31, C-21, D-23	Qualified

\+ Nozzle outlet at 0°

* Total uncertainty, consists of transducer plus data acquisition system uncertainties

(a) IIIA101 and IIIA102 - qualified; IIIA201 and IIIA202 - reviewed but not qualified

(b) IIIA101 qualified from -10 to 50 seconds; IIIA102 qualified from -10 to 40 seconds, IIIA201 and IIIA202 qualified from -10 to 50 seconds

(c) IIIA101, IIIA102 and IIIA202 qualified from -10 to 50 seconds; IIIA201 qualified from -10 to 60 seconds

(d) IIIA101, IIIA102, IIIA201 and IIIA202 qualified from 0 to hot wall effect (≈ 50 seconds)

(e) IIIA101 - failed; IIIA102, IIIA201 and IIIA202 - qualified

(f) IIIA101 and IIIA102 - qualified; IIIA201 and IIIA202 - failed

(g) IIIA101, IIIA102 and IIIA202 - qualified; IIIA201 - failed

(h) IIIA101, IIIA102 and IIIA201 - qualified; IIIA202 - failed

(i) IIIA101, IIIA201 and IIIA202 qualified from -10 to 50 seconds; IIIA102 qualified from 0 to 35 and 50 to 60 seconds

(j) **The comment "qualified" with** no superscript indicates that the data from all four tests are qualified from -10 to 50 seconds

TABLE II

WATER CHEMISTRY

Item	Test Number			
	IIIA101	IIIA102	IIIA201	IIIA202
pH	9.9	10.0	9.9	10.0
Chlorides (ppm)	0.05	0.0	0.15	0.1
Conductivity (ms/cm)	145	120	85	140
Dissolved O_2 (ppb)	<100	<100.0	<100	<100
Suspended Solids (ppm)	0	<10.0	<10.0	40.0
Dissolved iron (ppm)	0.05	0.05	0.1	0.35

TABLE III

SEQUENCE OF EVENTS

Item	Test Number			
	IIIA101	IIIA102	IIIA201	IIIA202
Start Heatup	-5:00	-5:00	-5:00	-5:00
Water Sample	-4:30	-4:30	-4:30	-4:30
Reach 555 K	-1:00	-1:00	-1:00	-1:00
Start γ-Dens. Cal.	-0:32	-0:32	-0:32	-0:32
Final Data Scan	-0:06	-0:06	-0:06	-0:06
Start Analog Tapes	-0:02	-0:02	-0:02	-0:02
Start Digital Recorder	-0:01	-0:01	-0:01	-0:01
Blowdown	0:00	0:00	0:00	0:00
Close MOV	+0:03	+0:03	+0:03	+0:03
Start Post-test γ-Dens. Cal.	+0:03	+0:03	+0:03	+0:03