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Multiloop Integral System Test (MIST): Final Report

Test Group 35, Noncondensibles and Venting

Prepared by J. R. Gloudemans/B&W

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U.S. Nuclear Regulatory
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and
Electric Power Research Institute
and
Babcock & Wilcox Owners Group

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ABSTRACT

The multiloop integral system test (MIST) was part of a multiphase program started in 1983 to address small-break loss-of-coolant accidents (SBLOCAs) specific to Babcock & Wilcox-designed plants. MIST was sponsored by the U.S. Nuclear Regulatory Commission, the Babcock & Wilcox Owners Group, the Electric Power Research Institute, and Babcock & Wilcox. The unique features of the Babcock & Wilcox design, specifically the hot leg U-bends and steam generators, prevented the use of existing integral system data or existing integral system facilities to address the thermal-hydraulic SBLOCA questions. MIST and two other supporting facilities were specifically designed and constructed for this program, and an existing facility -- the once-through integral system (OTIS) -- was also used. Data from MIST and the other facilities will be used to benchmark the adequacy of system codes, such as RELAP-5 and TRAC, for predicting abnormal plant transients. The MIST program is reported in 11 volumes. The program is summarized in Volume 1; Volumes 2 through 8 describe groups of tests by test type; Volume 9 presents inter-group comparisons; Volume 10 provides comparisons between the calculations of RELAP5 MOD2 and MIST observations, and Volume 11 presents the later, "Phase 4" tests. This is Volume 7 pertaining to Test Group 35. The six Group 35 tests dealt with noncondensibles and venting. The specifications, conduct, observations, and results of these tests are described herein.

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EXECUTIVE SUMMARY

Introduction

The multiloop integral system test (MIST) was a scaled 2-by-4 (2 hot legs and 4 cold legs) physical model of a Babcock & Wilcox (B&W), lowered-loop, nuclear steam supply system (NSSS). MIST was designed to operate at typical plant pressures and temperatures. Experimental data obtained from this facility during post-small-break loss-of-coolant accident (SBLOCA) testing are used for computer code benchmarking. The MIST interactions are of intrinsic interest because they may provide insight into expected plant behavior. MIST was necessarily atypical of a plant in certain important respects, however. The MIST interactions therefore are not to be applied directly to a plant.

MIST consisted of two 19-tube, once-through steam generators, a reactor, a pressurizer, 2 hot legs, and 4 cold legs with scaled reactor coolant pumps. Other loop components included a closed secondary system, 4 simulated reactor vessel vent valves (RVVVs), a pressurizer power-operated relief valve (PORV), hot leg and reactor vessel upper head vents, high-pressure injection (HPI), core flood system, and critical flow orifices for scaled leak simulation. Guard heaters, used in conjunction with passive insulation to reduce model heat loss, were used on all primary system components as well as the steam generator secondaries. MIST is illustrated in Figure 1.

Boundary Systems

The MIST boundary systems were sized to power-scale the plant boundary conditions. HPI and auxiliary feedwater (AFW) characteristics were based on composite plant characteristics. Scaled model vents were included in both hot legs and in the reactor vessel upper head. Leaks were located in the cold leg suction and discharge piping, and the upper and lower elevations of steam generator B (for tube rupture simulation). The desired vent and leak flows were obtained using power-scaled restrictors.

Heat Losses and Guard Heaters

MIST was designed to minimize heat losses from the reactor coolant system. Fin effects (instrument penetrations through the insulation) were minimized by using 1/4-inch penetrations for most of the instrumentation. Heat losses due to conduction through component supports were minimized by designing the supports to reduce the cross-sectional area and placing insulating blocks between load-bearing surfaces. The reactor coolant system piping and vessels were covered with passive insulation, active insulation (or guard heaters), and an outer-sealed jacket (to prevent chimney effects). The guard heaters were divided into 42 zones, each controlled by a zonal temperature difference and pipe metal temperature.

Instrumentation

MIST had approximately 850 instruments. These instruments were interfaced to a computer-controlled, high-speed data acquisition system. MIST instrumentation consisted of measurements of temperature, pressure, and differential pressure. Fluid level and phase indications were provided by optical viewports, conductivity probes, differential pressures, and gamma densitometers. Mass flow rates at the system boundaries were measured using Coriolis flowmeters and weigh scales. Loop mass flow rates were measured using venturis or turbines.

Transient Test Program

The MIST transient tests were defined to generate integral system data for code benchmarking. The transient test series was divided into the following seven groups:

- Mapping
- Boundary systems
- Leak-HPI configuration
- HPI-PORV cooling (feed and bleed)
- Steam generator tube rupture
- Noncondensible gas (NCG) and venting
- Reactor coolant pump (RCP) operation

The mapping tests were intended to examine the initial post-SBLOCA transient interactions. In these tests, the primary system inventory was carefully controlled and slowly varied to allow the examination of the normally rapid and overlapping post-SBLOCA events. The boundary system controls, such as guard heating and steam generator secondary level controls, were varied in Test Group 31. The leak size, location, and isolation status, as well as HPI capacity, were varied singly in Test Group 32. Test Group 33 addressed HPI-PORV cooling. Tube ruptures were examined in Test Group 34.

Test Group 35 concerned noncondensibles and venting. Group 35 Test 2 involved gas injection without venting to determine the threshold volume -- the volume at which a facility limit was encountered. The threshold volume was determined to be 60 standard cubic feet (scf). This was the facility maximum gas metering capacity rather than a thermal-hydraulic limit of the system. Gas injection was observed to inhibit BCM heat transfer and thus to elevate the primary system pressure.

Of the five transient tests, Test 1 used continuous hot leg venting without NCG. Venting obtained a relatively symmetric interruption, enhanced primary system depressurization, and hastened primary system refill. The four remaining transient tests (Test 3, 5, 7, and 8) varied venting, NCG species, break location, and break isolation status. Venting had little impact on the loop gas burdens. Break location had a relatively strong impact, however. Early in the transients, as the downcomer level descended to the elevation of the cold leg nozzles, the cold leg discharge breaks began to discharge noncondensibles, ultimately reducing the total loop burden of NCG by approximately one-half. However, only approximately 10 scf (versus 60 scf injected) were discharged out of a cold leg suction break. As the hot leg refilled, the cold leg piping voided. Gas effects then became particularly evident in the two tests having cold leg suction leaks. The noncondensibles impeded the heating of the HPI fluid. The lower downcomer and core inlet fluid cooled to almost the HPI supply temperature.

The interactions using nitrogen were almost indistinguishable from those using helium, implying that convective effects overwhelmed buoyant effects. Leak isolation indirectly enhanced the rate of discharge of NCGs. As the leak was closed, the primary system repressurized and the SCM increased. The operator opened the PORV to control the SCM. Whereas the rate of gas discharge had been quite small using vents alone, on the order of 1 scf/h, it increased approximately threefold upon PORV actuation.

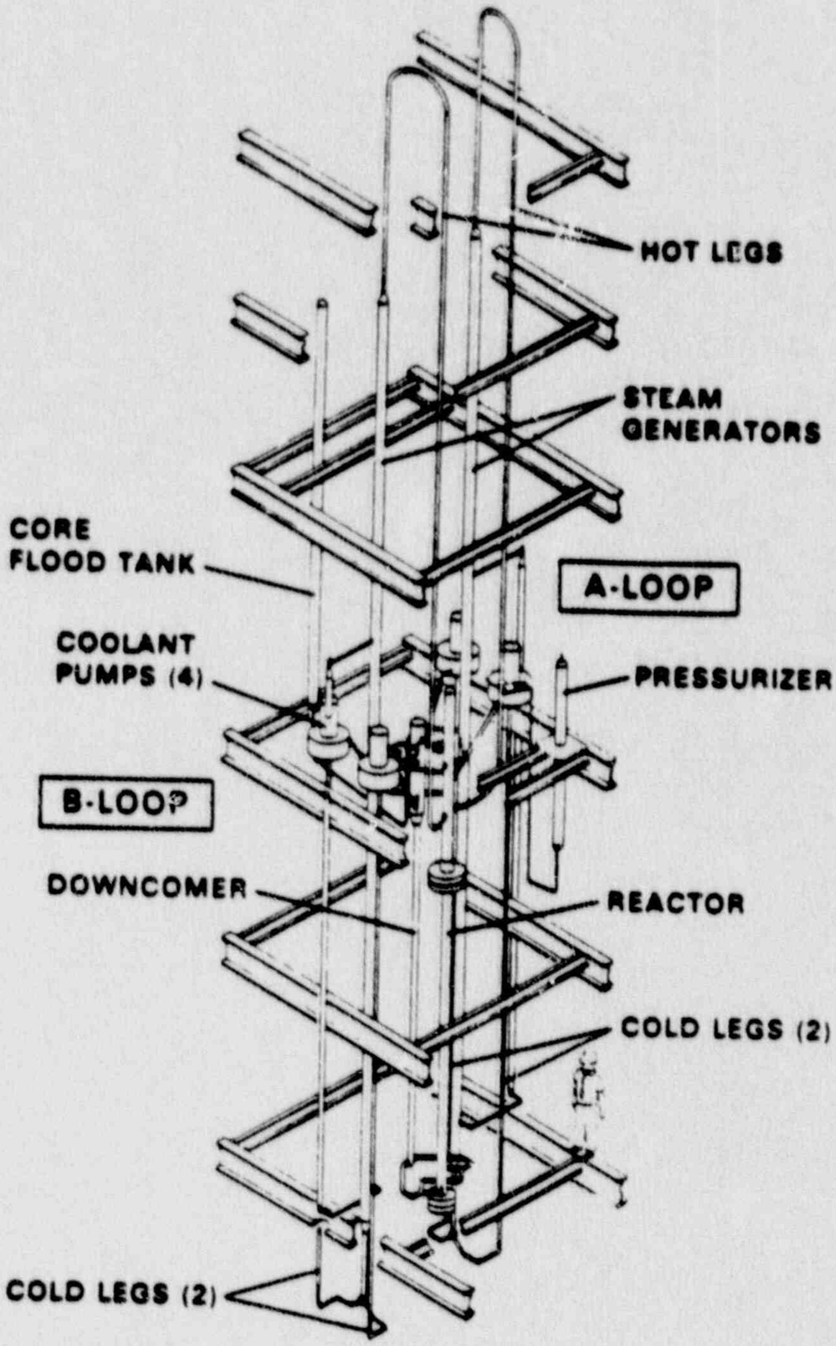

Figure 1. Reactor Coolant System -- Multiloop Integral System Test (MIST)

1. INTRODUCTION

The multi-loop integral system test (MIST) was a scaled 2-by-4 (2 hot legs and 4 cold legs) physical model of a Babcock & Wilcox (B&W), lowered-loop, nuclear steam supply system (NSSS). MIST was sponsored by the U.S. Nuclear Regulatory Commission, the B&W Owners Group, the Electric Power Research Institute, and B&W. The MIST results are presented in the following eleven volumes:

1. Summary
2. Mapping Tests, Group 30
3. SBLOCA Tests With Varied Boundary Conditions, Group 31
4. SBLOCA Tests With Altered Leak and HPI Configurations, Group 32
5. HPI-PORV Cooling Tests, Group 33
6. Steam Generator Tube Rupture Tests, Group 34
7. Noncondensible Gas and Venting Tests, Group 35
8. Pump Operation Tests, Group 36, and Core Uncovery Test 3801
9. Inter-Group Comparisons
10. RELAP5/MOD2 Calculations Versus MIST Observations
11. Phase 4 Tests

The MIST design, features, and instruments are outlined in section 2. The test specifications for Group 35 are provided in section 3. The Group 35 tests dealt with noncondensibles and venting. Continuous hot leg venting without noncondensible gases (NCG) was employed in one test. The maximum volume of NCG was determined in a second test. This maximum NCG volume corresponded to the maximum MIST NCG measuring capability, rather than to a limiting thermal-hydraulic response. The remaining four transient tests varied hot leg venting, leak location, NCG species, and leak isolation status.

The control of these tests and instrument performance are described in section 4. Section 5 provides observations for each test, inter-test comparisons, and a summary of major observations. Key data plots are provided with each test. A complete plot set is provided for each test in the enclosed microfiche. These plot sets are described and indexed in Appendix A of Volume 9. Figures 1.1 through 1.6 provide an overview of the test transients. Major events and timings are shown on traces of primary system pressure versus primary system total fluid mass.

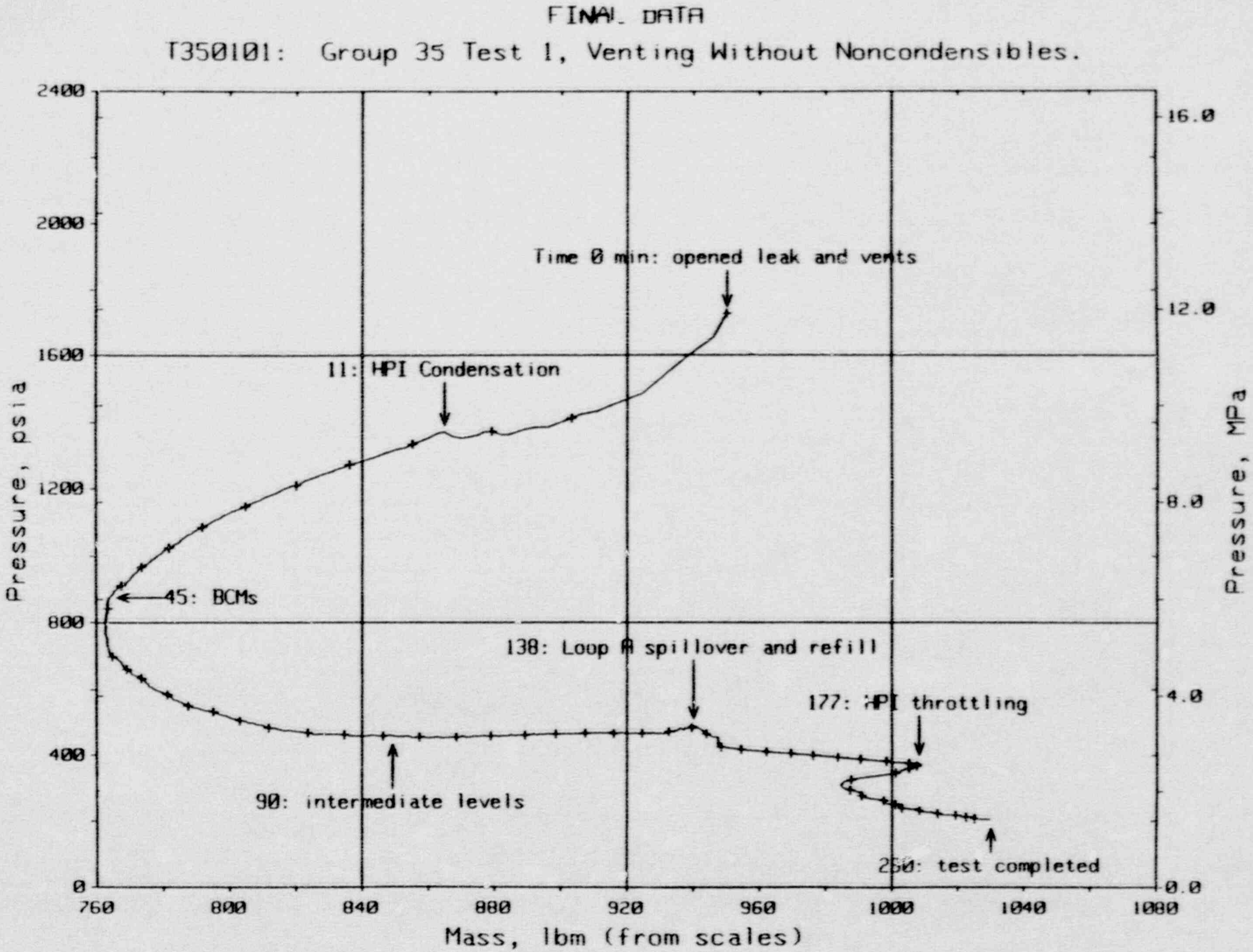

Figure 1.1 Primary System Pressure Vs Primary System Total Fluid Mass

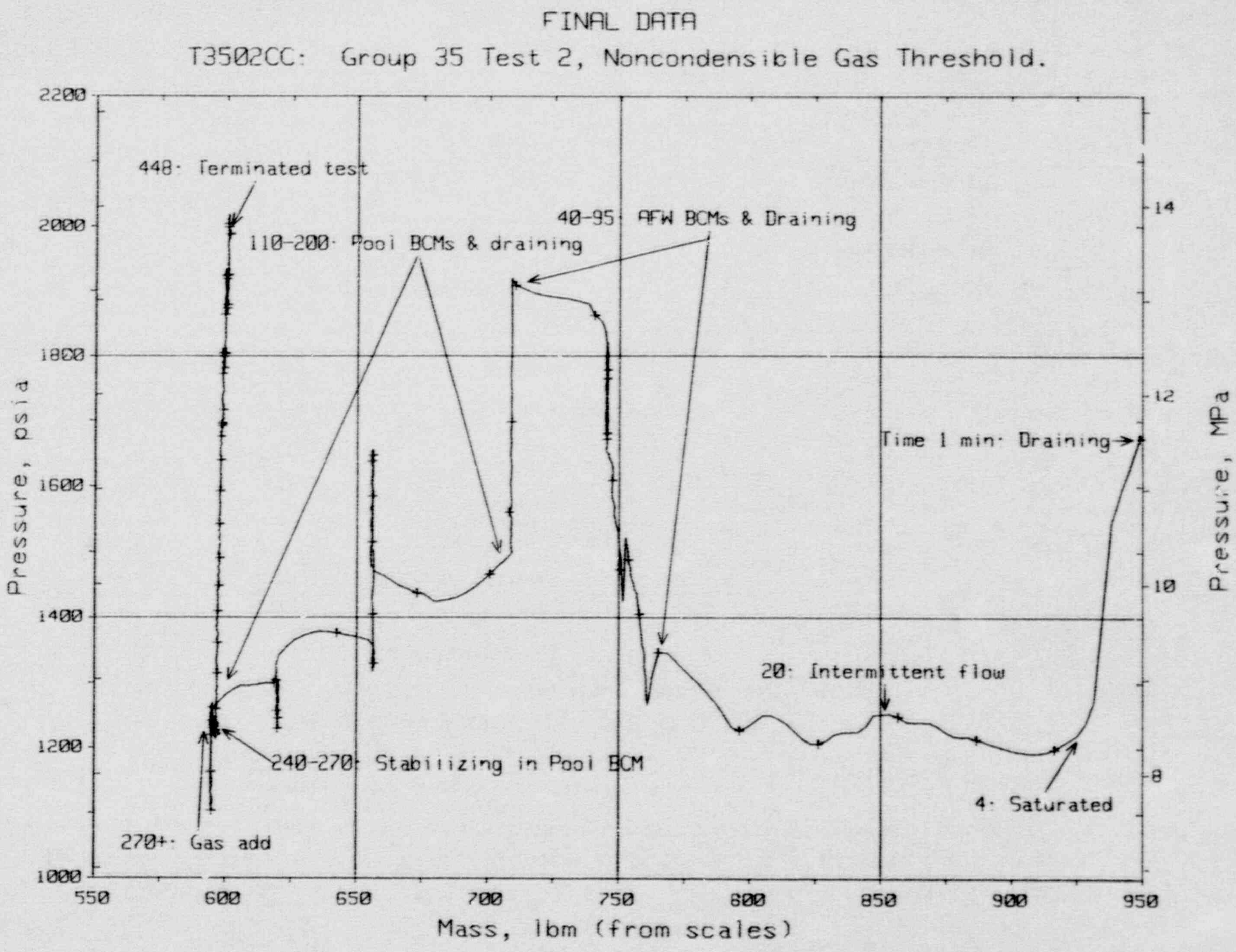

Figure 1.2 Primary System Pressure Vs Primary System Total Fluid Mass

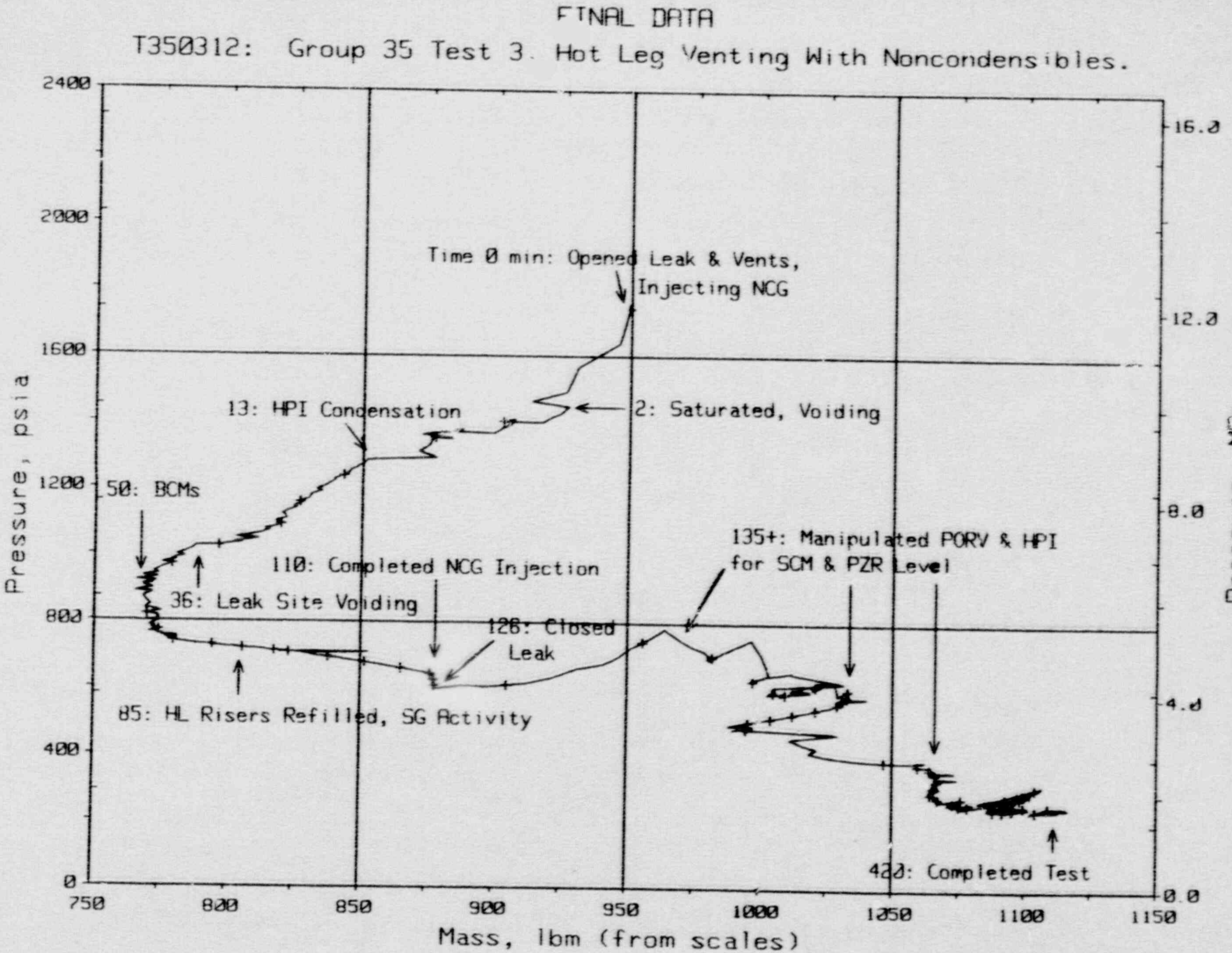

Figure 1.3 Primary System Pressure Vs Primary System Total Fluid Mass

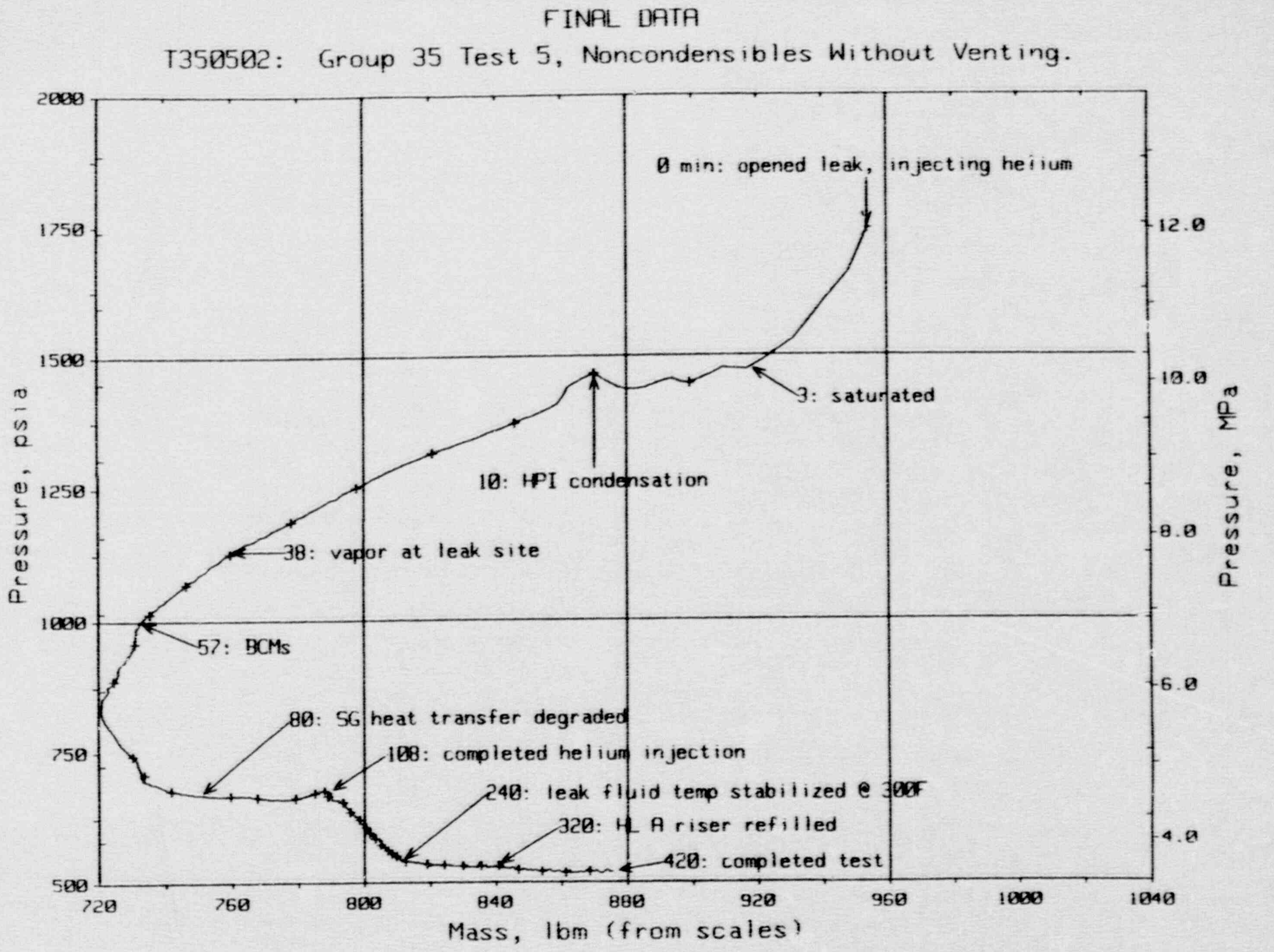

Figure 1.4 Primary System Pressure Vs Primary System Total Fluid Mass

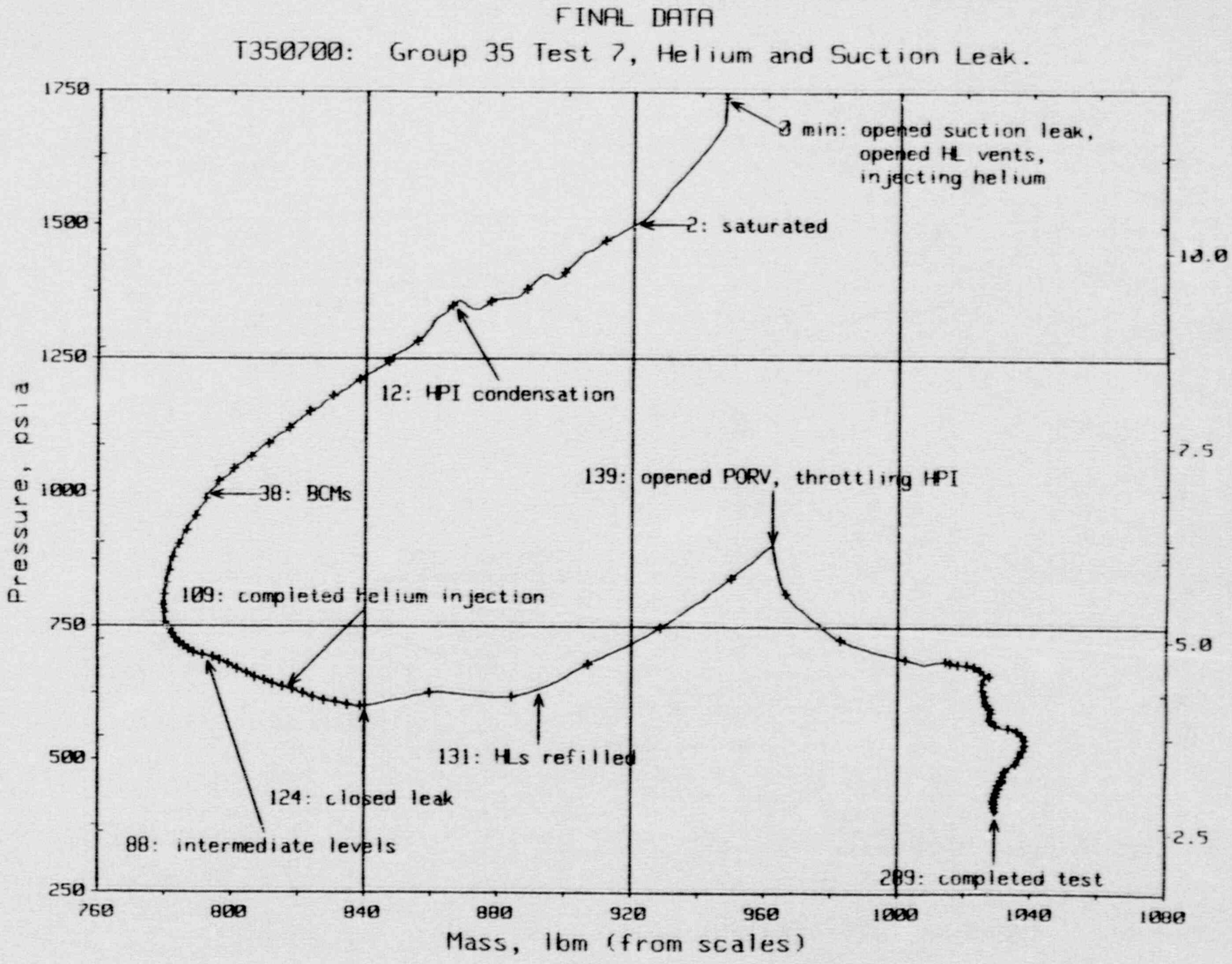

Figure 1.5 Primary System Pressure Vs Primary System Total Fluid Masss

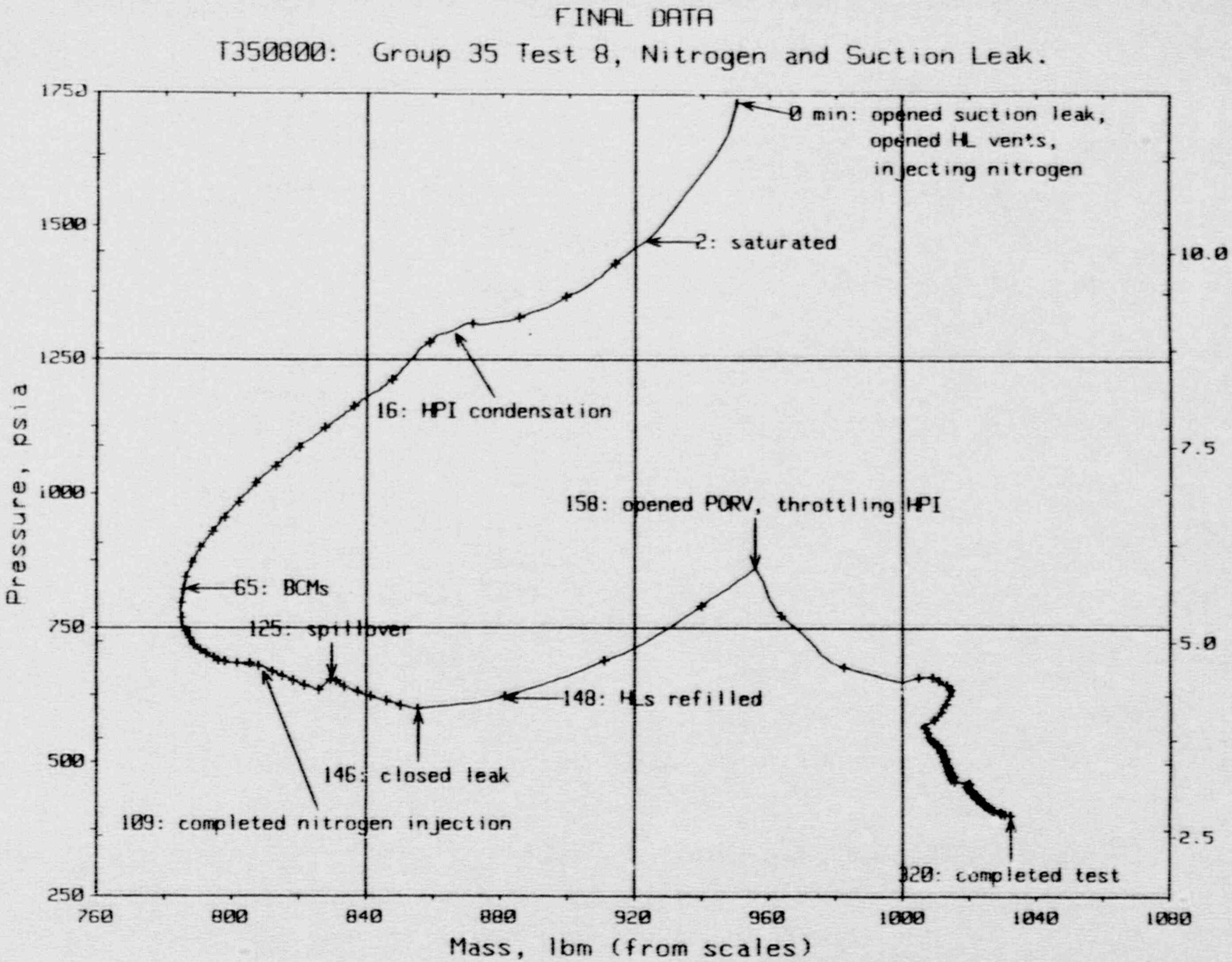

Figure 1.6 Primary System Pressure Vs Primary System Total Fluid Masss

2. FACILITY DESCRIPTION

2.1. Introduction

MIST was a scaled, 2-by-4 (2 hot legs and 4 cold legs) model of a B&W, lowered-loop, nuclear steam supply system (NSSS). MIST was designed to operate at typical plant pressures and temperatures. Experimental data obtained from this facility during post-SBLOCA testing are used for computer code benchmarking.

The reactor coolant system of MIST was scaled according to the following criteria, listed in order of decreasing priority: elevation, post-SBLOCA flow phenomena, component volume, and irrecoverable pressure drop. MIST consisted of two 19-tube, once-through steam generators; reactor; pressurizer; 2 hot legs; and 4 cold legs, each with a scaled reactor coolant pump.

Other loop components in MIST included a closed secondary system, 4 simulated reactor vessel vent valves (RVVVs), a pressurizer power-operated relief valve (PORV), hot leg vents and reactor vessel upper-head vents, high-pressure injection (HPI), core flood system, and critical flow orifices for scaled leak simulation. Guard heaters, used in conjunction with passive insulation to reduce model heat loss, were included on the steam generator secondaries and on all primary coolant components. The system was also capable of noncondensible gas addition at selected loop sites.

The approximately 850 MIST instruments were interfaced to a computer-controlled, high-speed data acquisition system. MIST instrumentation consisted of measurements of temperature, pressure, and differential pressure. Fluid level and phase indications were provided by optical viewports, gamma densitometers, conductivity probes, and differential pressures. Mass flow rates in the circulation loop were measured using venturis and a cooled thermocouple, and at the system boundaries using Coriolis flowmeters and weigh scales.

2.2. MIST Design

MIST was a scaled, full-pressure, experimental facility arranged to represent the B&W lowered-loop plant design. Like the plant, MIST was a 2-by-4 arrangement with 2 hot legs and 4 cold legs, as shown in Figure 2.1. MIST was designed for prototypical fluid conditions, with emphasis on being leak-tight and minimizing heat loss.

The scaling of MIST followed the approach and priorities used for OTIS[1]: that is, elevation, post-SBLOCA phenomenon, component and piping volumes, and irrecoverable pressure losses. MIST retained full plant elevations throughout the primary system and the steam generator secondaries. Only the elevations of several non-flow regions were compromised, primarily to optimize power-to-volume scaling. Key interfaces were maintained -- these included the hot leg U-bend spillover, upper and lower tubesheets of the steam generator (secondary faces), cold leg low point, pump discharge, cold and hot leg nozzles, core (throughout), and points of emergency core cooling system (ECCS) injection.

Two-phase behavior during voiding of the hot leg U-bend and flow interruption was sufficiently prototypical; that is, both the plant and the model were expected to encounter phase separation early in the post-SBLOCA transient. The MIST hot leg pipes were large enough to admit bubbly flow.

Fluid volume was 40% larger than power-to-volume scaling would dictate; the hot legs, cold legs, and upper downcomer were oversized. This atypicality was imposed by the previously described two-phase requirements and by considering component irrecoverable pressure losses. The excess volume of the hot leg slowed the rate of level decrease for power-scaled draining and similarly retarded the rate of level increase for power-scaled injection. Although the excess volume of loop fluid delayed system heatup and cooldown, this effect was usually minor compared to the long-term impact on system energy of leak-HPI cooling. The concentration of excess volume in the piping runs decreased fluid velocities in the hot legs and cold legs and therefore lengthened the transit time of loop fluid. Irrecoverable pressure drops were well preserved.

The MIST core and steam generators were full-length subsections of their plant counterparts. As shown on Figure 2.2, the core consisted of a 7-by-7 array of 45 full-length, 0.430-inch-diameter heater rods and four simulated incore guide tubes. Plant-typical fuel pin pitch and grid geometry were used. The simulated rods were capable of full-scale power output but were limited to approximately 10% of scaled power for the planned MIST testing. (The ratio of plant power to MIST power was 817:1.) A fixed, axial heat flux profile and a flat, radial heat flux profile were used. The axial peak-to-average flux ratio was 1.25:1.

The steam generators, shown in Figure 2.3, each contained 19 full-length tubes. The tubing diameter (5/8-inch OD), material, and triangular pitch of the tube bundle (7/8 inch, tube centerline to centerline) were prototypical. The geometry of the tube support plates (TSPs) was similar to that of the plant TSPs and provided equivalent flow areas and irrecoverable pressure losses. The MIST steam generators contained 16 TSPs, versus 15 in the plant. The flow holes of the MIST TSPs were drilled rather than broached. Also, the thicknesses of the MIST and plant steam generator tubesheets were unequal.

The hot legs used 2.5-inch, schedule-80 piping (2.32-inch ID). This diameter admitted bubbly flow and approximated the irrecoverable pressure loss of a plant hot leg. With the schedule-80 piping, the metal-to-fluid volume ratio in MIST was only 20% greater than that of the plant. The horizontal runs in the hot leg were approximately 1 foot long to accommodate the gamma densitometers. The pipe diameters of the hot leg U-bends maintained the pipe diameters of the hot leg risers and stubs. The radii of curvature of the hot leg U-bends were 1.61 ft. This curvature was chosen to match the horizontal displacement between the riser and stub while preserving the elevation of the U-bend spillover and approximating a power-scaled U-bend volume. Phase separation at the U-bend was predicted to occur at and below approximately 18% of scaled full power in MIST, versus 8% in the plant.[2] Beyond the U-bend, the hot leg piping in the model extended 12 feet, versus 1.5 feet in the plant, to span the height of the inlet plenum for the plant steam generator.

The four cold legs preserved elevation throughout. Two-inch, schedule-80 piping (1.939-inch ID) was used primarily to match irrecoverable pressure drop. This piping size also preserved the cold-leg Froude number, which influenced the mixing of the HPI and RVVV fluid streams. The cold leg horizontal piping runs were shortened, but the slope of the plant cold leg discharge piping was approximately maintained. HPI was injected into the sloping pipes at the appropriate elevation; the diameter of the model HPI nozzle was selected to preserve the ratio of fluid momentum between the cold leg and HPI.

A model reactor coolant pump was mounted in each cold leg. Suction and discharge orientations were prototypical. The pumps delivered single-phase scaled flows at plant-typical heads, allowed for simulated pump bumps by matching the plant pump spinup and coastdown times, and permitted operation under single- and two-phase conditions. The specific speeds of the model pumps were only one-tenth of those of the plant pumps. Therefore, the two-phase characteristics of the model pumps did not simulate those of the plant pumps.

The MIST reactor vessel employed an external annular downcomer. Inter-cold leg coupling was restricted toward that of a plant by using fins in the downcomer annulus to form quadrants, as shown in Figure 2.4. The annular gap was 1.4 inches and the gap at each fin was 0.4 inches. Each downcomer quadrant was connected to a separate RVVV simulation and a cold leg. The two core flood tank nozzles were each located at an interface between two downcomer quadrants.

The geometry of the model downcomer was annular down to the elevation of the top of the core. Just above the top of the core, the downcomer was gradually reconfigured to form a single pipe for the remaining elevation. The lower downcomer region obtained approximately the power-scaled fluid volume over the elevation of the core. Four model RVVVs were used to simulate eight plant valves. The MIST RVVVs could be controlled individually or in unison. Individual controllers provided automatic actuation of the valves on the upper plenum to downcomer-quadrant pressure differences. The MIST RVVVs thus approximated the head-flow response of the plant valves.[3] However, partially open operation was not possible in MIST; therefore, the detailed valve dynamics of the plant swing check valves were absent.

The MIST pressurizer was power-to-volume scaled. It contained heaters, spray, and a PORV. The lower pressurizer elevations were prototypical, as were those of the surge line. The model pressurizer height was reduced from that of the plant to increase its diameter, thus lessening atypical fluid stratification and the likelihood of spray impinging on the vessel wall.

One core flood tank was used in MIST. This tank was power-to-volume scaled to represent the two plant tanks. The model tank was installed vertically, with the bottom of the tank at a prototypical elevation. The injection line from the tank to the nozzles on the downcomer was sized to preserve plant-typical irrecoverable losses, and the nozzles were sized to maintain the plant ratio of (core-flood) injected fluid momentum to the downcomer fluid momentum.

2.3. Boundary Systems

The MIST boundary systems were sized to power-scale the plant boundary conditions. HPI and auxiliary feedwater (AFW) head-flow characteristics were based on composite plant characteristics. Model vents were included in both hot legs and in the reactor vessel upper head. Controlled leaks were located in the cold leg suction and discharge piping and at the upper and lower elevations of steam generator B (for tube rupture simulation). The desired vent and leak flow rates were obtained using critical flow orifices of power-scaled areas.

A steam generator tube rupture was simulated by opening a flow circuit across either the upper or the lower tubesheet of steam generator B. This circuit is shown in Figure 2.5. It consisted of a flow control orifice, isolation valves, and measurements of fluid temperature and differential pressure. The tube rupture simulation flow circuit did not preserve the complex flow path geometry of an actual tube rupture.

2.4. Heat Losses and Guard Heaters

MIST was designed to minimize heat losses from the reactor coolant system. Fin effects (instrument penetrations through the insulation) were minimized by using 1/4-inch penetrations for most of the instrumentation. Heat losses due to conduction through component supports were minimized by designing the supports to reduce the cross-sectional area and by placing ceramic blocks between load-bearing surfaces. The reactor coolant system piping and components were covered with passive insulation, guard heaters, and a sealed outer jacket (to prevent chimney effects). The insulation arrangement is illustrated in Figure 2.6. The guard heaters were divided into 42 zones, each controlled by a zonal temperature difference and a pipe metal temperature. This system provided differential temperature control as a function of temperature. A detailed finite-difference analysis of the insulation system indicated that heat loss was strongly dependent on metal temperature and weakly related to fluid state. The control temperature difference required to minimize heat losses was determined experimentally at several loop temperatures.

However, the guard heaters did not compensate for all the loop heat losses. For example, large local losses at the gamma densitometers and viewports were not compensated. Had these local losses been compensated, the requisite increased metal temperatures would have generated atypically large metal stored energies as well as undesirable local effects. The total MIST primary system heat loss at 650F was approximately 18 kW or 0.55% of scaled full power. The post-trip core power commonly simulated in MIST ranged from 3.5 down to 1% of scaled full power; the uncompensated heat losses of 0.55% of scaled full power thus represented from 16 to 55% of these post-trip power levels. Core power was increased to offset these uncompensated heat losses.

2.5. Instrumentation

The MIST instrumentation was selected and distributed based on the input from experimenters and code analysts. This instrument selection process considered the needs of code benchmarking, indications of thermal-hydraulic phenomena, and system closure.

The approximately 850 MIST instruments were interfaced to a computer-controlled, high-speed, data acquisition system. MIST instrumentation consisted of measurements of temperature, pressure, and differential pressure. Fluid level and phase indications were provided by optical viewports, conductivity probes, differential pressures, and gamma densitometers. Mass flow measurements at the system boundaries were made using Coriolis flowmeters and weigh scales. Mass flow rate measurements in the loop were performed with venturis or turbines. Tables 2.1 and 2.2 provide a summary of the MIST instrumentation by component and instrument type.

The largest grouping of instrumentation was in the two steam generators. About 250, or 30%, of the instruments were located in these two components. The steam generator instrumentation provided for the measurement of fluid temperature, metal and differential temperature, total guard heater power, differential pressure, gauge pressure, and conductivity (for void determination). The allocation of instruments to the steam generators resulted from the judgement that observations of AFW wetting effects and steam generator heat transfer were of major importance. Several other local and multidimensional phenomena were also of considerable interest: noncondensible gas blanketing of primary tubes, intermittent radial advancement of condensation fronts in the region of the AFW nozzle, and boiler-condenser heat transfer in the region of the secondary pool.

The core and RVVV instrumentation measured fluid temperature, metal and differential temperature, total guard heater and core power, conductivity (for void determination), and gauge and differential pressures. The core instrument distribution concentrated on the axially varying parameters. A flat, radial heat flux profile was used in the core, and radial maldistribution of inlet flow was expected to result in only minor variations of enthalpy. Therefore, the majority of the incore temperature instrumentation was located in a single, interior flow channel. Radial temperature variations at the core outlet were recorded, but with a limited number of instruments. The core instrument allocation provided core heat input, inlet and exit fluid properties, and fluid gradients within the reactor vessel. In addition, collapsed levels and regional void fractions were available. The vent valve mass flow rates were obtained by synthesizing RVVV differential pressures, valve positions, and indications of fluid state.

Downcomer instruments measured fluid temperature, metal and differential temperature, total guard heater power, and differential pressures. Forty fluid thermocouples were concentrated in the upper downcomer, detailing mixing information for the RVVV, core flood, and cold leg fluid streams. Six additional fluid thermocouples were spaced uniformly in the lower downcomer to indicate the extent of mixing as the fluid left the upper downcomer. The downcomer flow rate was measured using a venturi and a cooled thermocouple probe.

Table 2.1 MIST Instrumentation by Component

Component	Number of Instruments
Cold legs	164
Core flood	7
Hot legs	121
Pressurizer	25
Primary boundary systems	72
Reactor vessel and core	169
Steam generators	249
Steam generator feedwater and steam circuit	44
TOTAL	851

Table 2.2 MIST Instrumentation by Measurement Type

Measurement Type	Number of Instruments
Conductivity probes	36
Cooled thermocouple	12
Differential pressure	133
Differential temperature	42
Fluid temperature	381
Gamma densitometer	12
Limit switches	79
Mass flow	9
Metal temperature	69
Miscellaneous	17
Power	48
Pressure	9
Volumetric flow	4
TOTAL	851

Cold leg instrumentation provided fluid and metal temperatures, differential temperatures, total guard heater power, and differential pressures. Gamma densitometers indicated pump suction fluid density. Cold leg flow rates were measured using venturis located in the suction piping of each cold leg. For tests requiring full forced flow, turbine meters were used in place of the venturis. In addition, the reactor coolant pump power, speed, and head rise were measured. Thermocouple rakes were installed in the cold legs, upstream and downstream of the HPI injection points, to indicate thermal stratification and counterflow near the junctions of the cold legs and downcomer.

Hot leg instrumentation measured fluid and metal temperatures, differential temperatures, total guard heater power, and differential pressures. Void measurements using gamma densitometers and conductivity probes were also made. In addition, viewports provided visual data to assess the local flow regimes. The placement of the hot leg instruments provided detailed fluid temperature gradients, local void fractions, and overall collapsed level. A conductivity probe, combined with local differential pressures in the hot leg U-bend region, provided additional information regarding loop refill and spillover. Gamma densitometers in the hot leg horizontals, downstream of the reactor vessel outlet nozzles, and viewports at the 29-foot elevation and at the U-bend high points, provided information regarding fluid state and flow conditions. Viewports in the hot leg horizontals near the densitometers probed the developing flow regimes upstream of the hot leg risers.

The boundary systems, which included HPI, leaks, vents, and gas addition, were provided with fluid thermocouples, absolute and differential pressure transmitters, mass flowmeters, and weigh scales. These instruments provided mass and energy closure for the facility. Additional information regarding the design and instrumentation of MIST may be found in the Facility Specification[2] and in the Instrument Report.[4]

2.6. Conversion Factors

The key MIST conversion factors are listed below.

Power: 1% of scaled full power (2700. mW)

= 33. kW = 31.3 Btu/s

Primary Flow Rate (Total Primary System):

1% of scaled full flow ($135. \times 10^6$ lbm/h)

= 0.46 lbm/s = 1660. lbm/h = 0.21 kg/s

Secondary Flow Rate (Total Secondary System, i.e., 2 steam generators)

1% of scaled full flow (11.3×10^6 lbm/h)

= 0.0384 lbm/s = 138. lbm/h = 0.0174 kg/s

MIST piping was larger than power-to-volume scaled in consideration of two-phase phenomena and hydraulic losses. Whereas the plant-to-MIST power scaling factor was 817, the corresponding volume scaling factor was 620 for the total primary system volume (CFT excluded), and 600 for the primary system excluding the pressurizer.

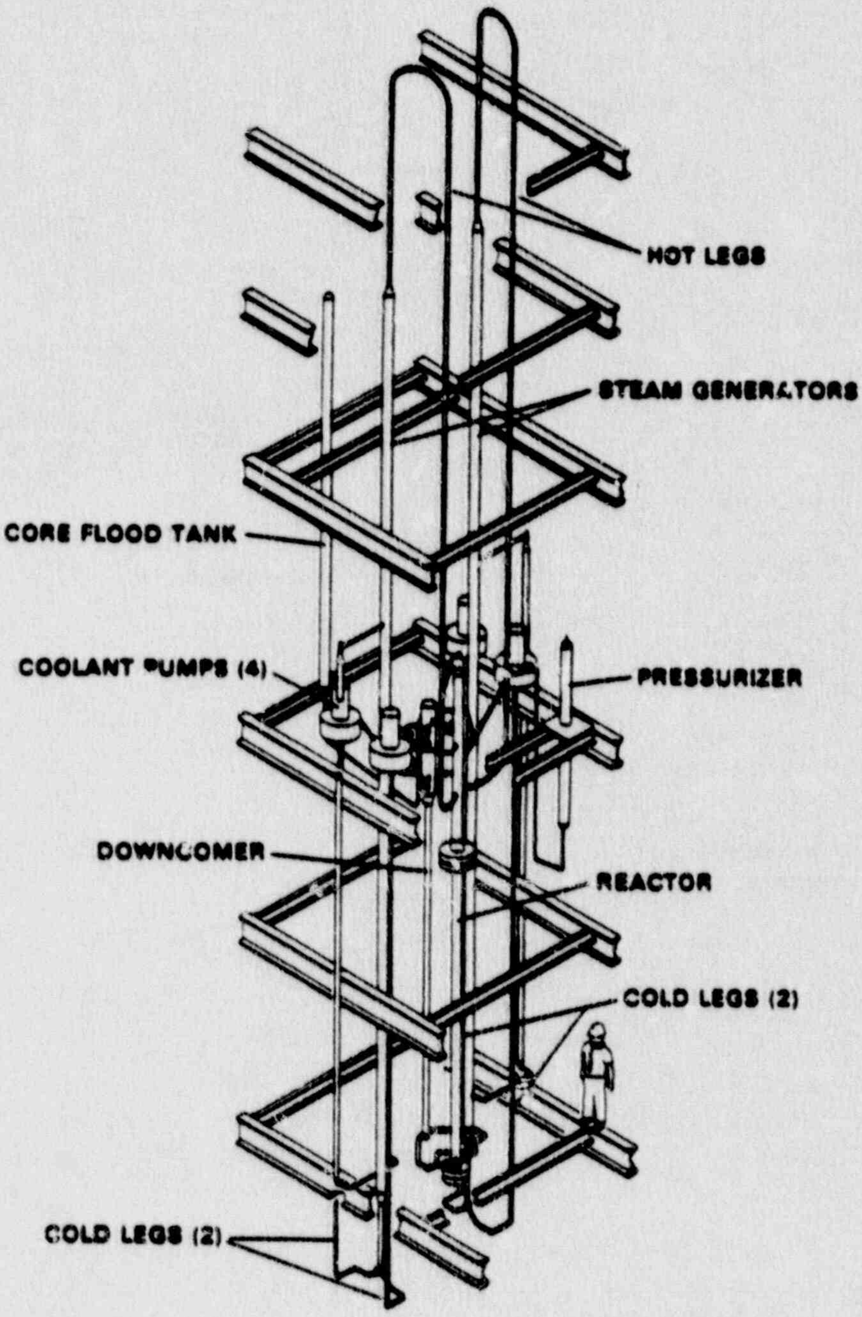

Figure 2.1. Reactor Coolant System -- MIST

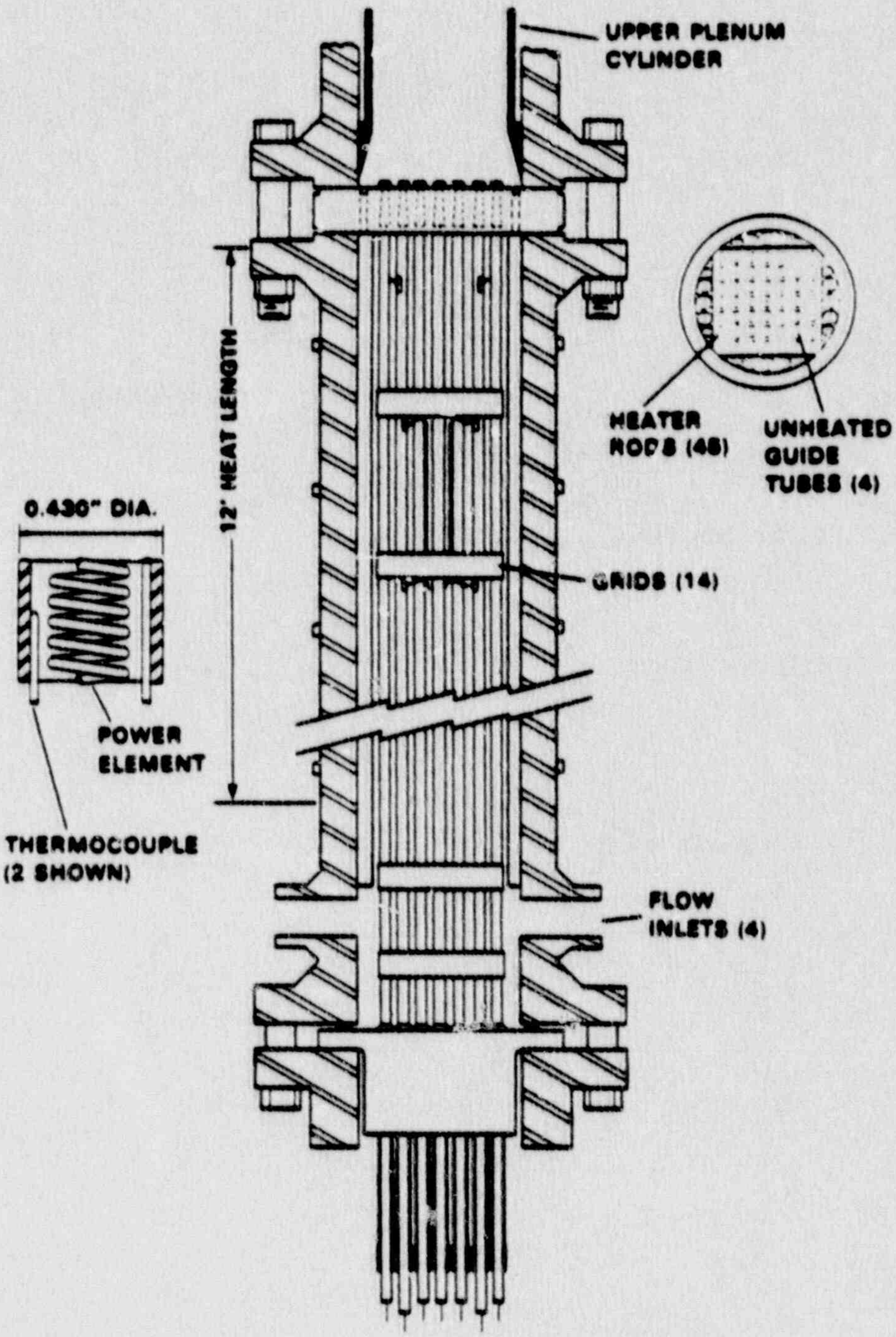

Figure 2.2. MIST Core Arrangement

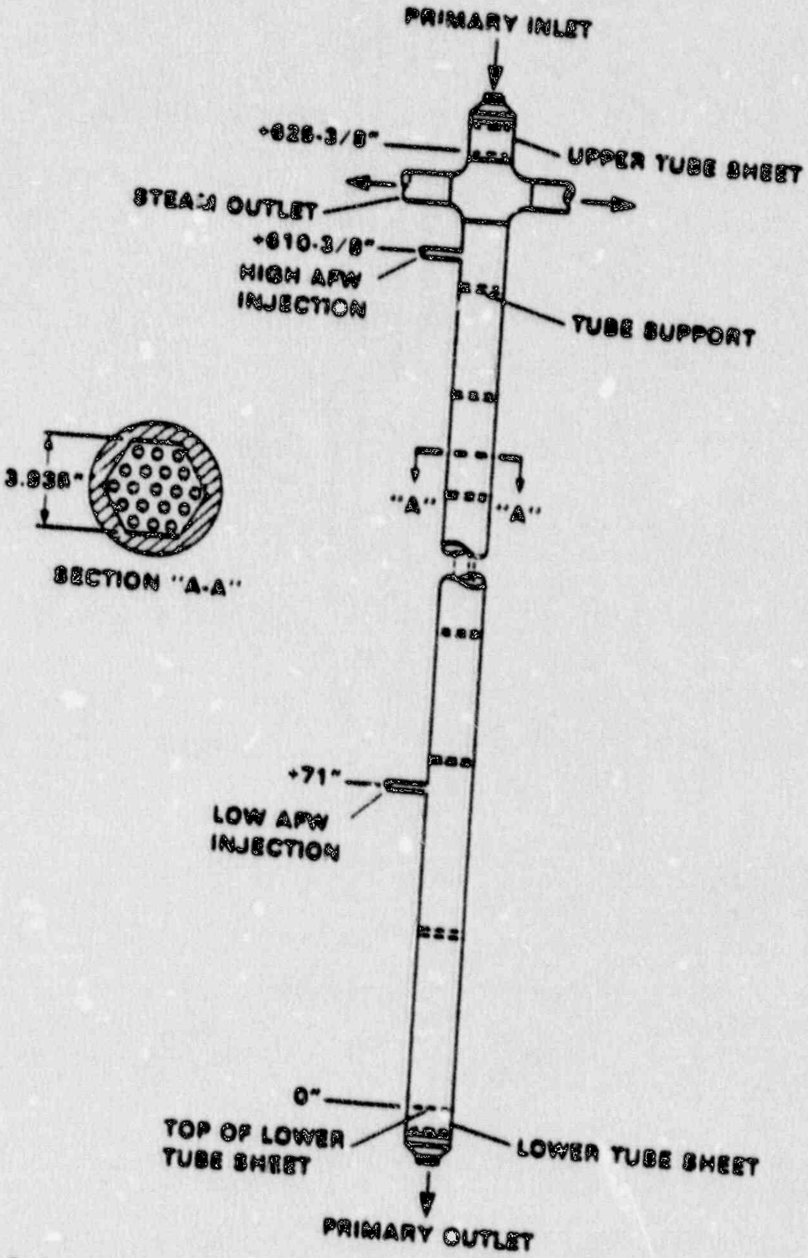

Figure 2.3. Nineteen-Tube, Once-Through Steam Generator

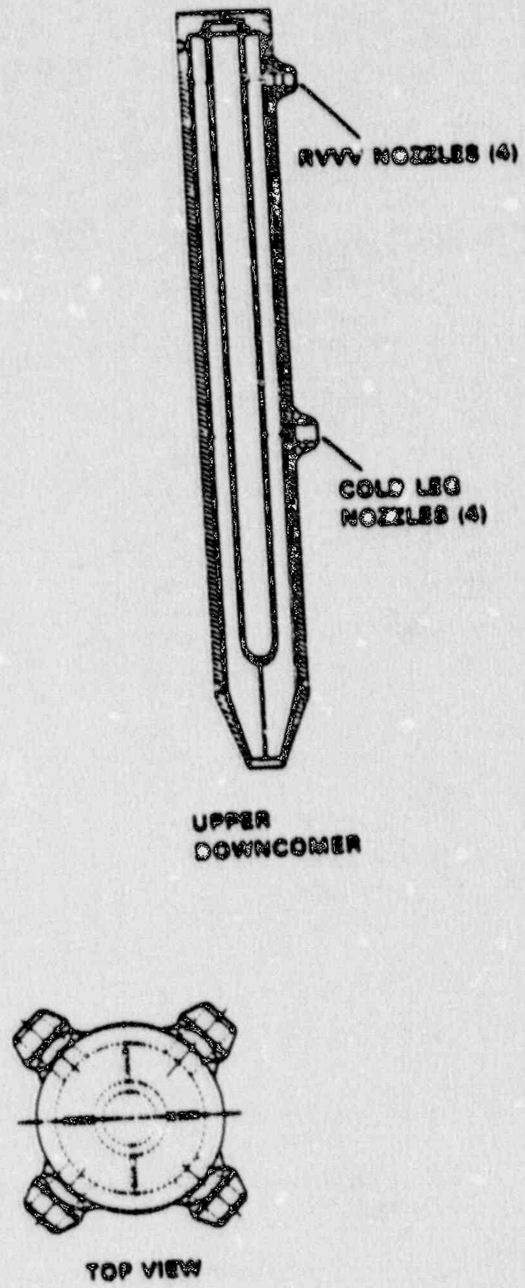

Figure 2.4. Upper Downcomer Arrangement

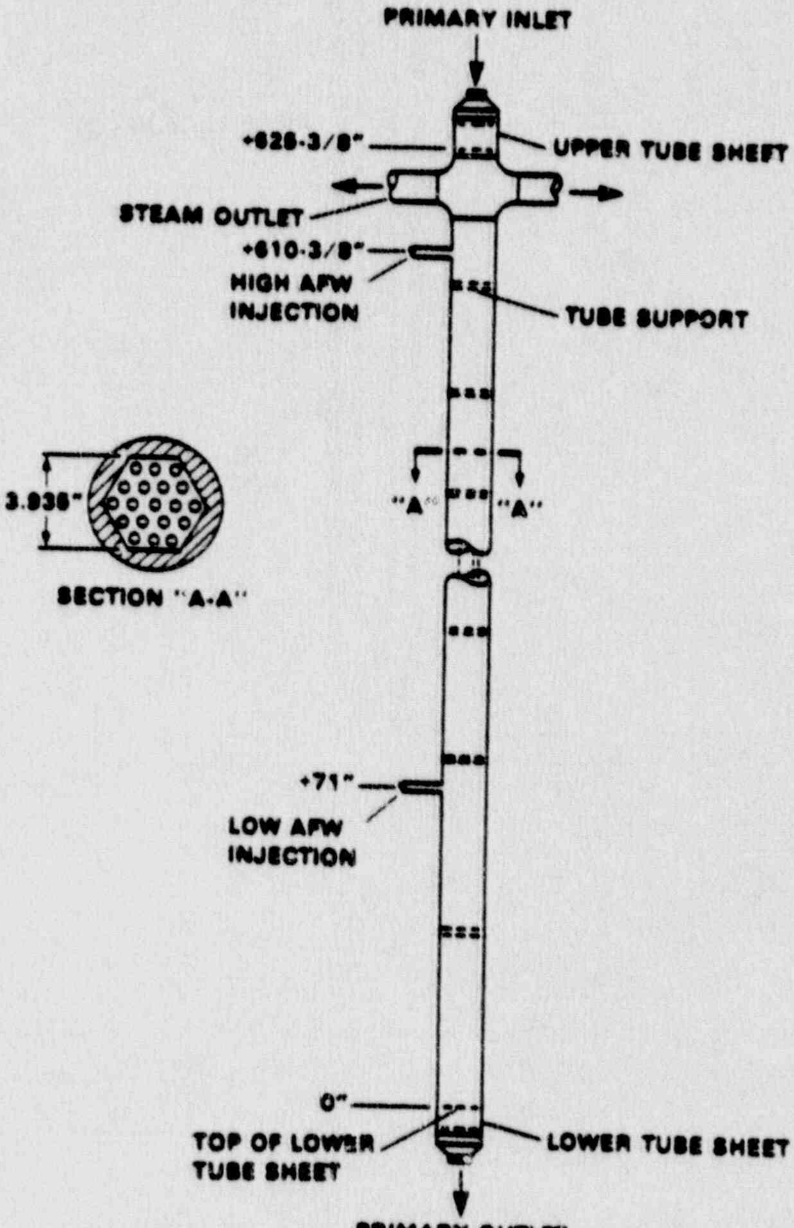

Figure 2.3. Nineteen-Tube, Once-Through Steam Generator

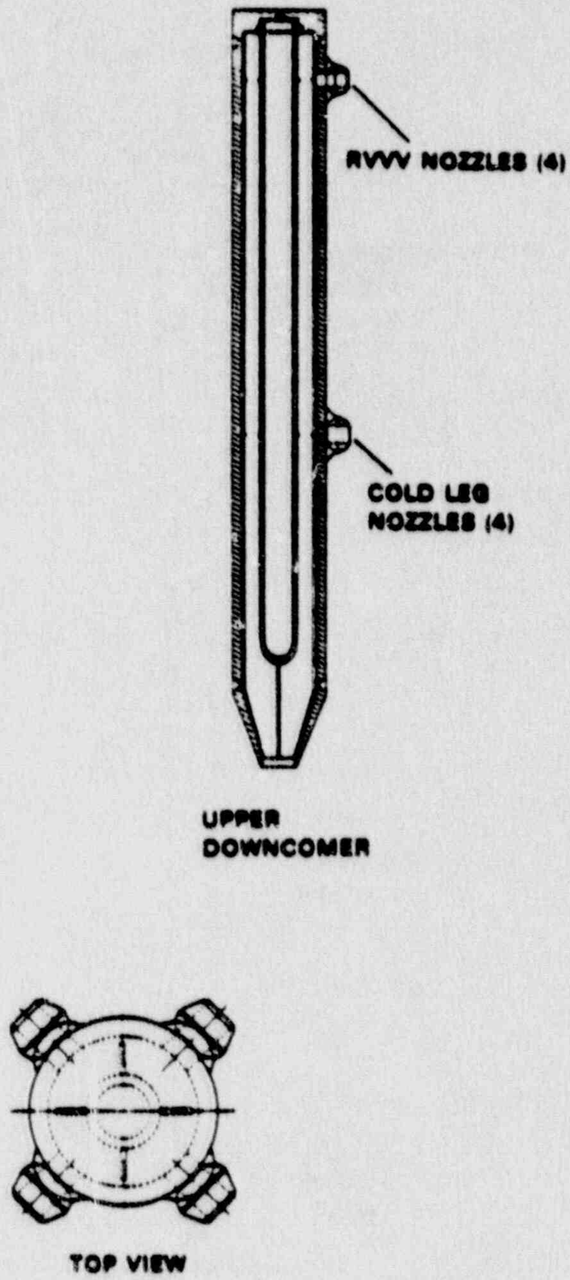

Figure 2.4. Upper Downcomer Arrangement

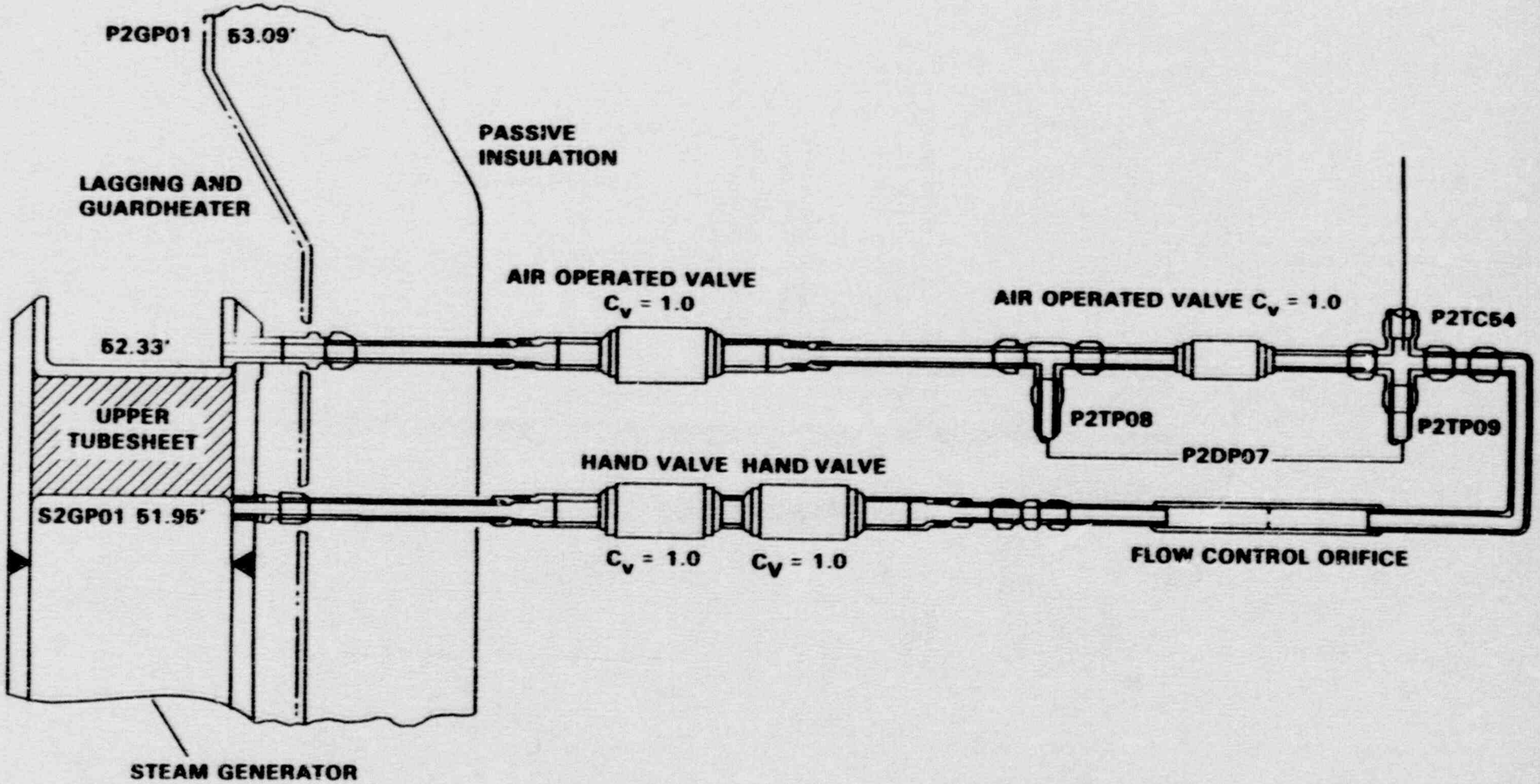

Figure 2.5 Primary-to-Secondary Tube Leak at Upper Tubesheet (Similar Arrangement at Lower Tubesheet)

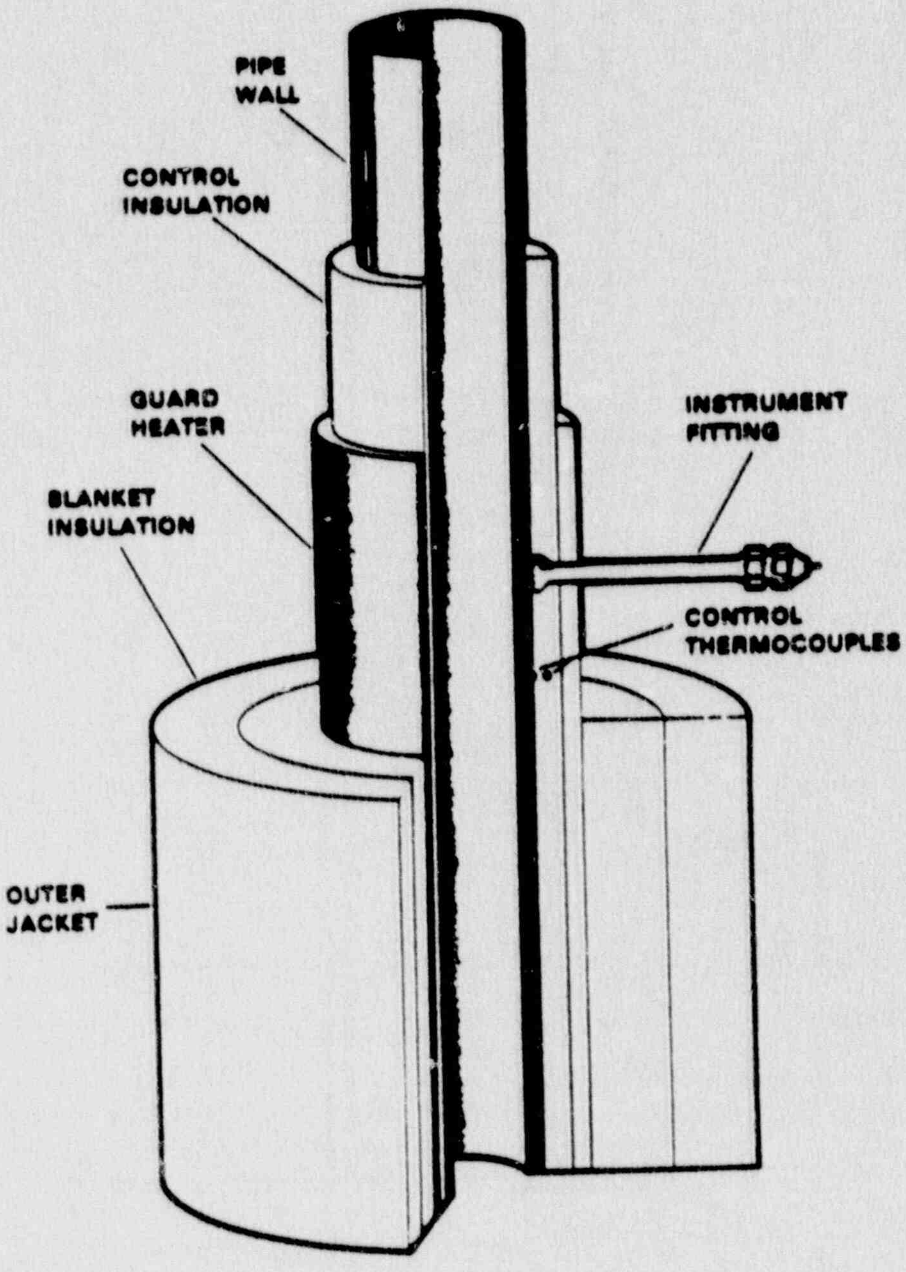

Figure 2.6 MIST Insulation Arrangement

3. TEST SPECIFICATIONS

The specifications of the Group 35 Tests has been excerpted from section 9 of the MIST Test Specifications.[5] These specifications were developed prior to testing, as is reflected in their tense. Several Group 35 Tests were deleted and added as testing progressed. The specifications herein apply to the Group 35 Tests which were conducted, rather than to the originally specified set.

3.1. Introduction

The six tests of Group 35 explore the effects of venting and noncondensible gases. Test 1 is a repeat of the Nominal Test (3109AA) but with vent actuation. The hot leg high-point vents (HLHPVs) are operated continuously and symmetrically throughout most of the test. Late in the loop refill phase, the venting is to be performed asymmetrically.

The NCG threshold is determined in Test 2. This is the maximum amount of noncondensibles that can be withstood before encountering a facility limit. The facility limits include high primary system pressure, high core-region fluid and heater-sheath temperatures, low reactor vessel collapsed liquid level, high primary-to-secondary pressure difference, and maximum noncondensible gas collection capacity.

The threshold amount is determined based on effects rather than on the simulation of particular plant sources of gas. This threshold amount of NCG is then applied in the remaining transient tests. In these tests, the NCG is injected at the rate needed to obtain the threshold amount during the time in which the BCM could occur. Each of these tests generally uses the conditions and controls of the Nominal Test (3109AA). No venting is used in Test 5; Test 3 uses continuous HLHPV actuation (as in Test 1 which had no NCG). A cold leg suction break is used in Tests 7 and 8, and Test 8 also uses nitrogen rather than helium. The ability of the hot leg vents to remove NCG from the reactor vessel head is also examined in several tests. The features of the Group 35 tests are summarized in Table 3.1.

3.2. Venting (Without NCG), Test 1 (350101)

Purpose

Test 1 uses symmetric hot leg high-point venting with conditions and controls that are otherwise identical to those of the Nominal Test (3109AA). As described below, the effects of venting on the symmetry of the conditions at the hot leg U-bends (HLUBs) will be obtained. Venting may suppress repressurization during refill and hasten the completion of loop refill. Asymmetric venting is used during the later stages of loop refill. This asymmetric vent operation is exaggerated to highlight its impact.

Conduct

Both HLHPVs are to be opened simultaneously and initially kept open in Test 1. The vents are to be actuated at the same time as the leak is opened (to obtain their maximum impact on the transient). Transfer from symmetric to asymmetric venting at the time or conditions at which the vents are to be opened in the customary transient tests. Summarizing this specification, begin venting asymmetrically at the time determined from the Nominal Test transient, or when both of the following conditions are met: (1) the core exit fluid is at least 50F subcooled, and (2) the hot leg levels are less than full.

Asymmetric venting uses a time-based schedule. First open (intact loop) HLHPV A while leaving the HLHPV B closed. After 20 minutes with HLHPV A open, alternate vents: simultaneously close the HLHPV A and open the HLHPV B. After 20 minutes with HLHPV B open, again exchange vents: simultaneously close B and open HLHPV A. Continue this periodic vent operation, alternating vents at 20-minute intervals, for the duration of the test. (The venting time intervals were chosen to enhance the vent-driven asymmetries while allowing sufficient time between vent transfers to observe their impact.) The specifications of Test 1 are otherwise the same as those of the Nominal Test. Test 1 is to be completed in 8 hours.

3.3. NCG Threshold, Test 2 (3502CC)

Purpose

Test 2 is used to determine the threshold level of loop NCG, the maximum volume of noncondensible gases which the system can withstand before challenging a facility limit. This threshold level is to be used in the subsequent transient tests with NCG injection. The slowly evolving NCG effects will also be of intrinsic interest.

Conduct

The NCG threshold determination is to be based on the pseudo-steady conditions obtained toward the end of Mapping Test 4. These conditions include core power = 1.0% plus losses to ambient, no leak or HPI, automatic/independent RVVV control with settings of 0.125 and 0.04 psi, SG level = 31.6 ft, and reactor coolant pumps (RCPs) off.

Repeat Mapping Test 4 through the loop stabilization in BCM (either in AFW-BCM, if stabilization is achieved there, or in Pool BCM). Accelerate the rate of inventory depletion to hasten the achievement of stable BCM, at the discretion of the Test Engineer and based on the observations made during the Mapping Test. After approximately 30 minutes of BCM, begin the NCG injections while maintaining the existing boundary system controls and setpoints.

Inject NCG at the core entrance. Use helium as the noncondensible species if the test loop has been found to be able to contain helium (i.e., if the loop helium loss rate is less than 10% of its total helium inventory per hour). Otherwise, use nitrogen rather than helium. Use an injection rate of approximately 20 scf/h. Adjust the gas addition system to obtain this rate ($\pm$10%) at the existing conditions in BCM. Attempt to maintain this setting for the duration of the test, allowing the gas addition rate to vary in response to the primary system pressure and, hence, the driving differential pressure. The gas addition rate of 20 scf/h is equivalent to 0.25 ft^3/h (1.25% of the total primary system volume per hour) at the PORV lift conditions, based on a compression factor of approximately 80. This injection rate is intended to be small enough to cause gradual NCG effects and yet large enough to obtain a significant loop burden of gas within a limited testing time.

Continue the NCG injection until a facility limit is encountered. If the PORV should actuate on overpressure, allow it to reseat at 2300 psia. If a facility limit is not encountered after 8 hours of testing with continuous gas injection, terminate testing at the discretion of the Test Engineer. The maximum test duration is 14 hours, which includes 4 hours to attain BCM, 8 hours of NCG injection, and 2 hours of post-injection stabilization and measurements.

At test termination, enter the termination time in the log and allow the system to approach equilibrium: deenergize the core and all guard heaters, and halt the NCG injections. Maintain this configuration for 1 hour. This one-hour quiescent period will permit the vapor species to segregate by density; the vapor-region temperature profiles will be used to qualitatively estimate the NCG concentrations throughout the voided regions of the system. This method of estimating gas volumes is conceptually sound but crude in practice. Its usefulness is impaired by the finite distance between fluid temperature measurements, by inhomogeneities of the loop metal mass and heat losses (which generate local natural circulation cells within the components), and by the extremely slow approach to equilibrium gas concentrations in a near-stagnant system.

After 1 hour, refill the loop expeditiously using the PORV and vents as convenient. Attempt to use these discharge sites independently to give insight into the volume of NCG that resided in each region. The volume of NCG in the system may exceed the capacity of the collection system, approximately 60 scf. In this case, allow the excess NCG to discharge to atmosphere but continue to vent independently and to condense and meter the vented water vapor; the NCG volumes can then be coarsely estimated by comparing the liquid volumes used during refill to the volume of steam condensed.

The required measurements and test acceptance criteria parallel those of the (nominal) Mapping Test. In addition, obtain gas closure (within the limits of the collection and measuring equipment). Separately measure the amount of gas injected, the amount discharged through the PORV during testing, if any, and the amounts displaced during refill, attempting to differentiate among venting sites. Following refill, obtain estimates of the actual NCG volume remaining in the loop, such as by sampling and/or selective venting.

3.4. Hot Leg Venting With NCG, Test 3 (350312)

Purpose

Test 3 investigates the effect of keeping the HLHPVs open with NCG in the loop. These results are to be compared to venting without NCG (Test 1), and the transient with NCG but with no venting (Test 5).

Conduct

Test 3 is to use hot leg venting and NCG injection. As in Test 1, open the HLHPVs simultaneously at test initiation and keep them open. Also, begin the NCG injection at test initiation step 1, when the 10-cm^2 B1 CLD leak is opened. Use a continuous NCG injection at the core inlet.

Determine this injection rate by dividing the amount determined in the NCG Threshold Test (Test 2) by the time interval from the results of the Nominal Test (3109AA). If the volume of NCG in Test 2 exceeded the capacity of the NCG collection system, then use the maximum collection volume (~60 scf) to set the injection rate in Test 3. The time interval is from the initiation of the Nominal Test until BCM could no longer have occurred, i.e., when the primary levels in both generators finally exceeded the elevation of the upper tubesheets. The resulting injection rate for Test 3 may be similar to that used in the NCG Threshold Test, on the order of 20 scf/h. As in the Threshold Test, adjust the gas addition system for the appropriate rate, and attempt to maintain a constant setting throughout the test.

Continue NCG injection until test termination or until the threshold volume (determined in Test 2) has been injected. Maintain the HLHPVs open. The test conduct is otherwise identical to that of the Nominal Test.

Begin the second phase of Test 3 after the hot legs have been refilled and natural circulation has been observed for approximately 10 minutes. To ensure that this phase is adequately explored, begin Phase 2 based on the following two criteria, should either be satisfied prior to loop refill: (1) less than 2 hours of testing remain, or (2) primary system pressure decreases below 600 psia.

Begin the second phase of Test 3 by isolating the leak. Maintain the status of the remaining systems. This includes HPI (full head-flow automatic throttling for 75F subcooling, manual throttling for pressurizer level), venting (both HLHPVs open), and NCG injection as previously described. The exception is PORV control. When the core exit fluid subcooling exceeds 70F, manually actuate the PORV to reduce the SCM from 70 to 60F, then close the PORV. Continue this method of incremental primary system depressurization by manual PORV actuation for the duration of the test.

The maximum test duration is 8 hours. In addition to the usual critical measurements, obtain NCG closure within the limits of the gas injection and collection systems and their measurements. Obtain the gas discharge amounts during post-termination refill of the loop. Estimate the amount of NCG remaining in the system.

3.5. NCG Without Venting, Test 5 (350502)

Purpose

Test 5 uses NCG with the Nominal Transient and without venting. The NCG effects on the transient system conditions will be obtained. The results will be compared to those of the Nominal Test (without NCG), Test 3109AA, and to those tests with NCG and using vent actuations.

Conduct

Test 5 is based on the Nominal Transient, Test 3109AA. Noncondensibles are to be injected, and the hot leg high-point vents are to remain closed, otherwise the specifications of the Nominal Test apply. As in Test 3 (Hot Leg Venting with NCG), begin the NCG injection during test initiation step 1, and continue injecting until test termination or until the threshold volume (determined in Test 2) has been injected. Also as in Test 3, determine this rate using the threshold NCG amount (limited by the collection capacity) and the time interval during which BCM can be sustained. The time for BCM is to be obtained from the Nominal Test (3109AA), and is to be measured from test initiation until the primary levels in both steam generators exceed the elevation of the upper tubesheets.

In addition to the standard critical measurements, obtain and record gas addition and gas collection closure (within the accuracy of the metering systems), and estimate the amount of NCG remaining in the system after refill by suitable venting and/or sampling. The maximum duration of Test 5 is 8 hours.

3.6. Cold Leg Suction Leak, Test 7 (350700)

Purpose

Test 7 uses a cold leg suction rather than a cold leg discharge leak, as well as NCG injection with continuous hot leg venting and, later in the test, leak isolation. The purpose of Test 7 is to examine the impact of noncondensibles discharged out the leak, and thereby the general effect of leak location on interactions.

Conduct

Test 7 uses hot leg venting, NCG injection, and a scaled 10-cm^2 leak located in the cold leg B1 suction piping. The leak is isolated during the test. Upon test initiation, open the scaled 10-cm^2 cold leg B1 suction leak. Other than this change of leak site, the specifications of Test 3 (350312) apply.

3.7. Nitrogen, Test 8 (350800)

Purpose

The purpose of Test 8 is to examine the impact of the noncondensible species on the integral system interactions.

Conduct

Test 8 uses hot leg venting, a scaled 10-cm^2 cold leg B1 suction leak, and nitrogen as the noncondensible gas species. The leak is isolated during the test. Begin the injection of nitrogen during test initiation, when the 10-cm^2 cold leg B1 suction leak is opened. With the exception of this change of noncondensible species, the conduct of Test 8 is to repeat that of Test 7.

Table 3.1. Group 35 Tests

Number		Title		Inter-Test Variations			
Short	Complete	Short	Complete	Leak Site	NCG Species	Venting	Break Status
1	350101	No NCG	Venting Without NCG	CLD	None	HL	Open
2	3502CC	Threshold	NCG Threshold	None	He	None	NA
3	350312	HL Venting	Hot Leg Venting With NCG	CLD	He	HL	Isolated
5	350502	No Venting	NCG Without Venting	CLD	He	None	Open
7	350700	Suction	Hot Leg Venting With NCG and Cold Leg Suction Leak	CLS	He	HL	Isolated
8	350800	Nitrogen	Hot Leg Venting With Nitrogen and Cold Leg Suction Leak	CLS	N_2	HL	Isolated

Notes

- Leak sites: "CLD" = Cold leg B1 discharge, "CLS" = Cold leg B1 suction (both scaled 10-cm^2).
- Venting: "HL" = Both hot leg high-point vents open throughout the test.
- Break status: "Isolated" = Break closed during test. Isolation times were test-dependent, and varied from 124 to 146 minutes.

4. PERFORMANCE

The acceptability of each test was determined by examining both the conduct of the test and the performance of the measurement systems. The acceptance criteria for each test were defined in the corresponding test procedure, which was based on the MIST Test Specifications.[5] Any condition, action, or measurement that did not meet the acceptance criteria was evaluated for its impact on test acceptability. The tests reported herein are only those that were determined to be acceptable. Any specific deviations of these tests from the acceptance criteria are described in this section.

The review of test conduct included the following checks for each test:

- System conditions and stability just prior to test initiation
- Sequence and timing of the test initiation actions
- Performance of the manual and automatic control functions
- Test termination criteria and the sequence of actions

The impact of out-of-specification conditions or actions was assessed. The deviations of those tests that were determined to be acceptable are described in section 4.1.

The following pretest and post-test data qualification checks were performed for each test:

- The acquisition of the critical measurements
- The operation of the measurement systems within their calibrated range
- The acquisition of instrument readings within their expected range of operation
- Self-consistent measurements, considering both comparable measurements and derived quantities

The appropriate measurement uncertainties were used to assess the individual measurements. The impact of the individual out-of-specification conditions was assessed. The deviations of the critical measurements of those tests that were determined to be acceptable are noted in section 4.2.

4.1. Conduct

The initial conditions were all acceptable except for the pressurizer surge line fluid temperature in Tests 350101 and 350700. These temperature deviations did not impact test acceptability. Test initiations and terminations were acceptable for all the tests. Noncondensible gas recovery was performed as specified. Operation of the control systems and manual interactions during the test transients were acceptable for all the tests with the following qualifications: During the initial fill of the steam generators in Tests 350312, 350502, 350700, and 350800, the auxiliary feedwater flow to generator B was lower than the required flow rate by up to 220 lb/h (30%). This was caused by a mispositioned pump bypass valve in the feedwater circuit. The error persisted through several tests because the problem was initially, incorrectly diagnosed as an obstruction in the feedwater circuit. Attempts to locate and remove the obstruction were unsuccessful. Testing proceeded following these unsuccessful attempts to correct the problem with the recognition that auxiliary feedwater flow rates during the initial fill may be different than specified as a result of this problem. It was our judgement that this difference would not invalidate the test results and their usefulness for code benchmarking, since the flow rates would be known and could be modeled by the code.

4.1.1. Initial Conditions

Initial conditions for the tests were defined by the governing test procedure, ARC-TP-737, and are repeated in Table 4.1 along with the actual values from each test. All initial conditions were met except for the pressurizer surge line fluid temperature in Tests 350101 and 350700. This temperature was specified to be within ± 5F of the hot leg fluid temperature, H1TC11. In Tests 350101 and 350700, the surge line fluid temperature at test initiation was 2.8F below and 1F above the specified tolerance, respectively. These values are underlined in the table to aid in their identification. These deviations did not impact test acceptability.

4.1.2. Test Initiation

The test initiation actions were performed acceptably for all the tests in this group In all the tests, with the exception of 3502CC for which these initiation activities did not apply, refill of both steam generator secondaries, activation of the HPI, activation of the core power decay ramp, switching the reactor vessel vent valve control, and activation of the abnormal transient operating guideline (ATOG) steam pressure control were performed, as required, to initiate the test. Secondary fill, HPI, and core power decay were verifiable from the data, and for each test were performed within 20 seconds of one another. HPI flow in these tests was not observed within the 20-second window. The delay in HPI flow initiation resulted from the time required to pressurize the accumulator in the HPI supply circuit.

4.1.3. Control During Testing

The controls for HPI, core flood tank, pressurizer main heaters, AFW to steam generators A and B, core power, PORV, steam pressure, and level control for steam generators A and B performed acceptably for all the tests in this group except as noted in the following text.

Steam Generator Secondary Level Control

Steam generator constant level control was used in all the tests except 3502CC to maintain the levels at 31.6 $\pm$ 1 ft. Steam generator constant level control was activated shortly after test initiation, when the generators were refilled to 31.6 ft. In Test 3502CC, activation of the steam generator constant level control was delayed until 96 minutes in order to establish boiler-condenser mode in the generators.

Steam generator A and B constant level controls performed acceptably during all the tests. There were isolated deviations above and below the desired control tolerance in all the tests. These deviations were short in duration, small in magnitude, and were observed during the loop transients. The longest of these deviations occurred during Test 350800 at about 20 minutes, and lasted for about 10 minutes. The level increased to about 33.7 ft during this period.

Steam Pressure Control

ATOG steam pressure control was used in all the tests except 3502CC. In Test 3502CC, constant pressure control of 1010 psia was specified in both generators. Performance of the ATOG steam pressure control was examined using the temperature difference between the core outlet and the maximum of the two steam generator secondary saturation temperatures. According to the temperature difference (DT), the following control was required during this test series:

1. If the DT was greater than or equal to 50F, secondary steam pressure control was maintained constant.

2. If the DT was less than 50 but greater than 0F, a secondary cooldown rate of 100F/h was activated and maintained until the DT increased to 50F, at which time constant pressure control was invoked.

The control system performed as intended in these tests. The isolated control anomalies are summarized below.

During long-term activation of control mode 1 in Tests 350101, 350502, and 350700, when the secondary was decoupled from the primary due to the absence of steam generator heat transfer, the secondary pressures decreased at a rate of up to about 30 psi/h in the generators. This depressurization resulted from a combination of factors, including a steam leakage that intermittently activated feedwater to maintain constant level control and heat losses not compensated for by guard heaters. In either instance, the net heat loss rate from the steam generators was small and amounted to less than 240 watts. Performance of control mode 1 was acceptable.

During activation of control mode 2, at a secondary pressure below about 120 psia, the cooldown of 100F/h was not achieved. At this low pressure, the pressure differential between the steam generator and condenser was too low to attain the steam flow rate required to cool at the rate of 100F/h. Performance of control mode 2 was acceptable. In Test 350700, control mode 2 performed properly during the early part of the test providing depressurization equivalent to a 100F/h cooldown, but actuation of this control mode was delayed toward the end of the test. In this instance, control mode 2 actuated when the differential temperature decreased to 46.5F, 3.5F less than the intended setpoint. This delay in actuation of control mode 2 was caused by the control system calculation error of the saturation temperature below 200 psia. These occurrences did not impact test acceptability. In Test 350800, control mode 2 was first activated during test initiation through 50 minutes. During this time, the steam generator depressurization rate was greater than 100F/h due to initial auxiliary feedwater overcooling. Control performance was acceptable.

Steam Generator Auxiliary Feedwater

The AFW control was to maintain the feedwater flow rate at the head/flow characteristic during the secondary fill transient. The AFW to generator A achieved the required flow rate during all the tests remaining within 10 to 18 lb/h (1.3 to 2.5%) of the required head/flow characteristic during the level increase from 5 to 31.6 ft.

In Tests 350312, 350502, 350700, and 350800, the AFW flow rate to generator B was not maintained within the desired head/flow characteristic during the secondary fill from 5 to 31.6 ft. At the time of AFW initiation, an apparent obstruction in generator B feedwater circuit resulted in a low AFW flow rate. AFW flow was low by about 220 lbm/h (30%) in Test 350312, 163 lbm/h (21%) in Test 350502, 100 lbm/h (14%) in Test 350700, and 90 lbm/h (12%) in Test 350800. The AFW flow remained below the desired AFW flow rate for about 8 to 10 minutes. This resulted in an asymmetric secondary fill with generator A attaining the control level of 31.6 ft earlier than generator B.

In Test 3502CC, while the secondary levels were increased to 31.6 ft, AFW to both generators was to be throttled to 25% of the nominal pump head/flow characteristic. At steam generator A and B secondary pressures of 1000 and 900 psia, respectively, the throttled flow rates should have been about 180 lbm/h for generator A and 150 lbm/h for generator B. Instead, the AFW flow rates were adjusted to 160 lbm/h for generator A and 150 lbm/h for generator B. Since stable boiler-condenser mode (BCM) was not achieved until after the secondary fill was completed, this deviation was not significant and did not affect test acceptability.

Power-Operated Relief Valve

In Tests 350101, 3502CC, and 350502, primary pressure remained below the actuation pressure of 2350 psia, and the PORV never opened. Performance of

Tests 350312, 350700, and 350800 consisted of two phases. During Phase I, the PORV was to remain in automatic control with actuation pressure of 2350 psia and during Phase II, the PORV was to be manually controlled to maintain the subcooling between 60 and 70F. The PORV remained closed during Phase I and was manually opened as required to maintain the subcooling during Phase II. Operation of the PORV was acceptable in all the tests.

High-Pressure Injection

With the exception of Test 3502CC, HPI was required in all the tests in this group. HPI control was performed as intended during these tests. In Test 3502CC, HPI was not used until after test termination. Automatic and manual control of HPI was performed according to the following:

1. Maintenance of the head/flow characteristic for all times when subcooling was less than 70F.

2. Automatic HPI throttling to control subcooling between 70 and 80F.

3. Manual HPI shut off when subcooling increased to 100F and returned to automatic when subcooling decreased to 50F (3 times). HPI was left on automatic subcooling control when subcooling reached 100F for the fourth time.

4. Manual throttling of HPI to maintain a pressurizer level of 21.4 ± 0.5 ft.

During activation of control mode 1 in all of the tests, the maximum deviation of the HPI flow rate from the head/flow characteristic was about 10 lb/h (1.5%). Control mode 2 was active in Tests 350101, 350700, and 350800. Control mode 3 was not activated in any of the tests in this group since core exit subcooling never reached 100F. Control mode 4 was active in Test 350312 and performed as required.

Core Flood Tank

The core flood tank (CFT) water inventory discharged to the loop during Tests 350101, 350312, 350502, and 350800. The CFT isolation valves opened when primary pressure was between 600 and 650 psia. The CFT was manually isolated during these tests with exception of Test 350502. In Test 350502, the CFT water inventory continued discharging to the loop until termination.

Isolation of the CFT was performed properly when the core exit subcooling exceeded 50F and the primary pressure was less than 715 psia. The only exception was in Test 350312. During this test, the CFT isolation valves were manually closed at a core exit subcooling of 22F. However, the required subcooling (50F) was achieved about 2 minutes thereafter. No impact on the test occurred since the loop pressure remained greater than the core flood tank during this period, thereby preventing discharge.

Pressurizer Main Heaters

The pressurizer main heaters were tripped off on low pressurizer level at test initiation for each test. The control for pressurizer main heater power (PZWM04) was manually set to zero power as required.

Core Power

The core power decay ramp was activated at test initiation in all the tests except 3502CC. Core power control was to remain constant at 46.2 kW in Test 3502CC. The core power control performed satisfactorily during each test. Core power was maintained within 2.1 kW (2.4%) of the intended core power decay curve throughout the tests. In Test 3502CC, core power control remained constant at 46.2 kW as required until test termination.

4.1.4. Termination

Test termination activities were acceptable for all the tests in this group. Tests 350101, 350700, and 350800 were terminated when the primary pressure decreased below 400 psia and the core exit subcooling was greater than 50F for more than 2 hours. Tests 350312 and 350502 were terminated on the basis of a maximum elapsed time of 7 hours. As specified in the test procedure, Test 3502CC was terminated when the facility limit of gas addition was reached. However, there was an error in the test procedure test termination criteria. The test specification called for the test to be continued for several hours after the completion of gas injection to observe slowly/evolving noncondensible gas effects. Instead, the test procedure called for test termination at the completion of gas addition. In all tests, the loop was refilled and the reactor vessel upper head void was removed prior to the termination of saving data. Noncondensible gas collection activities, initiated as part of primary loop refill, continued after test termination in all the tests except Test 350101, which contained no noncondensibles.

4.2. Instruments

Each of the six tests in the Group 35 series used a common set of instrumentation. The critical instruments in this set are defined in Table 4.2. The measurements obtained from the instrumentation were checked to assure acceptable operation during the tests. Checks on instrument measurements were performed by computer-automated data qualification activities, and manual examination of the analysis plots. Data qualification activities for each test in Group 35 were performed at steady-state, pre-test initial conditions, during the test transient, and after test termination as summarized below.

		Time of Performance		
Check	Purpose	Before Test	During Test	After Test
NOREAD	Definition of instruments not acquiring data	x	x	x
ANDCHK	Calibration check of the Analogic data acquisition system	x		x
ZEROS	Zero check of instrument transmitters	x		x
RANGE	Validity of instrument measurement as compared to expected range	x	x	x
CONSIS	Instrument and derived quantity consistency check	x	x	x

As a result of these manual and automatic data qualification checks applied to the measurements and derived quantities in the test data base, the critical instruments identified in Table 4.3 were determined to be invalid during all or part of the test. In most instances, there was sufficient redundancy in the group of critical instruments so that the individual failure did not violate the requirements of the Critical Instrument List. In the other cases, the existence of the failed critical instrument did not warrant repeating the test. For the 18 conductivity probes identified by Note 2, the measurement system error was not identified until after the test series was completed. In this instance, the void fraction obtained from neighboring differential pressure measurements provided sufficient backup except for the reactor vessel probes, RVCP01-04. The absence of these measurements did not warrant repeating the test.

Prior to and after completion of the test, a "zero" reading was obtained for all differential pressure and pressure transmitters, mass flowmeters, weigh tank load cells, and reactor core voltage and current measurements. For those critical instruments that failed the zero check (defined in the Immediate Report for each test), the magnitude of the failure was small enough that measurement performance was not degraded to a condition that warranted repeating the test. The instrumentation performance during these tests was fully acceptable based upon this check.

RVVV Performance

The behavior of the RVVVs was reviewed using limit switch data. The RVVVs performed asymmetrically in most of the Group 35 tests. RVVV A2 stayed open longer than the other RVVVs in Tests 1 and 5. RVVV B2 stayed open longer than the other RVVVs in Test 2; and in Test 8, RVVV A1 was less active than the other RVVVs and stayed closed more often. The characteristics of the RVVV differential pressure (DP) transmitters have been examined for each of the 6 tests of Group 35. The responses to the initial DP change were compared among the transmitters using high-speed data. The DP transmitter associated with the A2 RVVV appears to have been defective in each of the Group 35 tests. This transmitter apparently amplified an abrupt change of the actual DP, and responded relatively slowly to DP changes. These errors are expected to have caused RVVV A2 to open more frequently than the other RVVVs and to have stayed open longer, as was observed in Tests 1 (Venting Without Noncondensibles) and 5 (Noncondensibles Without Venting). It is concluded that the performance of the RVVVs was affected by the defective transducer in Tests 1 and 5. The impact of this asymmetric RVVV performance cannot readily be ascertained. It is perceived to have had little system-wide impact in most circumstances. The asymmetric performance of RVVV B2 in Test 2, Noncondensible Gas Threshold, may have affected the distribution of noncondensibles within the primary system.

Table 4.1. Test Initial Conditions

(Underlined entries indicate out-of-specification conditions, which are discussed in the text.)

						Actual Values					
System	Parameter	VTAB	Units	Desired	Tolerance	350101	3502CC	350312	350502	350700	350800
Primary											
	Pressure	RVGP01	psia	1750	*	1727	1763	1742	1742	1741	1735
	Hot leg subcooling	**	F	22.0	± 2	22.9	***	23.5	23.2	23.3	22.7
	Core power	RVWM20	kW	128.7 (test 3502CC at 46.2 kW)	± 1.65	127.8	46.2	129.4	128.6	129.3	128.1
	Pressurizer level	PZLV20	ft	23.0 (Test 3502CC at 20.5 ft) Level must be varying less than ±0.5 ft/h.	± 0.2	23.0 and steady	20.5 and steady	23.0 and steady	23.0 and steady	23.1 and steady	22.9 and steady
	Pressurizer surge line fluid temperature	PZTC01	F	Match H1TC11	± 5	H1TC11 - 7.8	H1TC11 + 3.6	H1TC11 + 0.2	H1TC11 + 0.02	H1TC11 + 6.0	H1TC11 + 0.25
	Fluid/metal temperatures	****	F	Varying less than 3F/h for fluid and 10F/h for metal during a 30-minute	acceptable	acceptable	acceptable	acceptable	acceptable	acceptable	acceptable

Table 4.1. Test Initial Conditions (Cont'd)

System	Parameter	VTAB	Units	Desired	Tolerance	Actual Values 350101	3502CC	350312	350502	350700	350800
Secondary											
	Pressure	S1GP01 S2GP01	psia	1010	± 10	1015 1015	1015 1015	1015 1015	1015 1016	1015 1016	1014 1016
	Level	S1LV20 S2LV20	ft	5.0	± 1.0 (Test 3502CC at 25.0 ft)	4.9 5.1	25.5 25.6	5.2 5.2	4.3 4.8	4.8 4.9	4.4 4.7
	Feedwater temperature	SFRT01 SFRT02	F	110	± 20	117.8 120.1	97.5 98.1	111.2 112.0	107.1 108.1	113.8 114.7	110.0 111.1
Core flood tank											
	Pressure	CFGP01	psia	600	± 10	605.0	595.0	607.0	609.1	600.3	602.2
	Level	CFLV20	ft	42.8	± 0.3	42.8	43.0	43.1	42.9	42.7	43.1

*For all the tests except 3502CC, pressure was adjusted to give a hot leg subcooling of 22 ± 2F. For Test 3502CC, this value was ± 25 psia.

**Hot leg subcooling was defined by the difference between H1TC11 and RVRF20 (the saturation temperature based on RVGP01).

***Not applicable for this test.

****The following fluid and metal temperature measurements were used to define steady state (minimum time interval of 30 minutes without test operator manual control adjustments):

Fluid: H1RT01, H2RT01, P1RT02, P2RT02.
Metal: P2MT01, C1MT04, C2MT04, C3MT04, C4MT04, RVMT24, RVMT25.

Table 4.2 Critical Instruments for the Group 35 Test Series

Component	Instrument Type	Critical Instruments	Additional for 350502
Reactor vessel	Ammeter	RVAM01	
	Conductivity probe	RVCP01-04	
	Differential pressure transmitter	RVDP01,RVDP03-09	RVDP02
	Differential temperature	RVDT01-04,-23	
	Pressure transmitter	RVGP01	
	Limit switch	RVLS01-04	
	Metal thermocouple	RVMT01-04,-23 RVMT05-22 (12 of 18)	RVMT24,-25
	Fluid thermocouple	RVTC01,-02 (1 of 2) RVTC16-20 RVTC03-15 (9 of 13) RVTC21-23 (2 of 3)	
	Voltmeter	RVVM01	
	Power controller	RVWM01-04,-23	
Hot legs	Conductivity probe	H1CP01-10 (5 of 10) H2CP01-10 (5 of 10)	
	Differential pressure transmitter	H1DP01,-04,-09-12,-14	H1DP02,-03,-05-08,-13,-15
		H2DP01,-04,-09-12,-14,-16	H2DP02,-03,-05-08,-13,-15
	Differential temperature	H1DT01-04 H2DT01-04	
	Limit switch	H1LS01,H2LS01	
	Metal thermocouple	H1MT01-04 H2MT01-04	
	Resistance temperature detector	H1RT01 or H1TC01, H2RT01 or H2TC01	
	Fluid thermocouple	H1TC02-09 (5 of 8) H2TC02-09 (5 of 8) H1TC10-12 (1 of 3) H2TC10-12 (1 of 3) H1TC13-19 (5 of 7) H2TC13-19 (5 of 7)	
	Power controller	H1WM01-04,H2WM01-04	
	Gamma densitometer	H1GD01,-02,H2GD01,-02	
Steam generator A	Differential pressure transmitter	P1DP04,S1DP01,S1DP03	S1DP02
	Differential temperature	S1DT01-05	
	Pressure transmitter	P1GP01,S1GP01	
	Metal thermocouple	S1MT01-05	P1MT01
	Resistance temperature detector	P1RT01,-02	

Table 4.2 Critical Instruments for the Group 35 Test Series (Cont'd)

Component	Instrument Type	Critical Instruments	Additional for 350502
	Fluid thermocouple	P1TC01-03,-13-16,-23-26, P1TC33-36 (10 of 15) P1TC18,-27,-28,-37,-38 (3 of 5) P1TC09-12,-19-22,-29-32 (8 of 12) S1TC01,-02,-26 (2 of 3) S1TC03-12 (7 of 10) S1TC13-23,-25 (8 of 12) S1TC24	
	Power controller		S1WM01-05
Steam generator B	Conductivity probe	S2CP01-12 (6 of 12)	
	Differential pressure transmitter	P2DP06,S2DP01,S2DP12 S2DP02-11 (5 of 10)	
	Differential temperature	S2DT01-05	
	Pressure transmitter	P2GP01,S2GP01	
	Metal thermocouple	S2MT01-05	P2MT01
	Resistance temperature detector	P2RT01,-02	
	Fluid thermocouple	P2TC01-13 (9 of 13) P2TC14-28 (10 of 15) P2TC29-43 (10 of 15) P2TC44-53 (7 of 10) S2TC01-08,-55 (6 of 9) S2TC09-19 (7 of 11) S2TC20-33,-54 (10 of 15) S2TC34-53 (13 of 20)	
	Power controller	S2WM01-05	
Cold legs (n=1,2,3,4)	Differential pressure transmitter	C1DP01,C2DP01,C2DP09 CnDP02-04,-06-08	
	Differential temperature	CnDT01-03	
	Gamma densitometer		CnGD03,04
	Metal thermocouple	CnMT01-03	CnMT04
	Resistance temperature detector	CnRT01,-02	
	Fluid thermocouple	CnTC02 CnTC03-06 (3 of 4) CnTC07-10 (3 of 4) CnTC11-14 (3 of 4)	
	Power controller		CnWM01-03
Reactor vessel downcomer	Differential pressure transmitter	DCDP01,-02,-05-08	
	Cooled thermocouple		DCCT02-04
	Differential temperature	DCDT01-03	

Table 4.2 Critical Instruments for the Group 35 Test Series (Cont'd)

Component	Instrument Type	Critical Instruments	Additional for 350502
	Metal thermocouple	DCMT01-03	DCMT04
	Resistance temperature detector	DCRT01	
	Fluid thermocouple	CTC01-04	
		DCTC05-12 (5 of 8)	
		DCTC13-40 (19 of 28)	
		DCTC41-46 (4 of 6)	
	Power controller		DCWM01-03
Pressurizer	Differential pressure transmitter	PZDP01,-02	
	Differential temperature	PZDT01,-02	
	Pressure transmitter	PZGP01	
	Metal thermocouple	PZMT01,-02	PZMT03
	Resistance temperature detector	PZRT01 or PZTC09	
	Fluid thermocouple	PZTC01,-02	
		PZTC04-08 (4 of 5)	
	Power controller	PZWM04	PZWM01-03
	Limit switch		
HPI	Differential pressure transmitter	HPDP01	
	Flowmeter	HPMM01-05	
	Fluid thermocouple	HPTC01	
Single-phase vent system	Load cell	V1LC01,-02	
	Limit switch	V1LS01,-02,-06	
	Fluid thermocouple	V1TC02	
	Flowmeter	V1MM01	
Leak quality system	Pressure transmitter	LQGP01	
	Flowmeter	LQMM01	
	Fluid thermocouple	LQTC01-04	
Two-phase vent system	Load cell	V2LC01-04	
	Limit switch	V2LS01-06	
	Flowmeter	V2MM01-03	
	Fluid thermocouple	V2TC01-04,-08,-09	
	Pressure transmitter	V2AP01*	
	Differential pressure transmitter	V2DP01-06*	
Core flood tank	Differential pressure transmitter	CFDP01	
	Pressure transmitter	CFGP01	
	Limit switch	CFLS01,-02 (1 of 2)	

Table 4.2 Critical Instruments for the Group 35 Test Series (Cont'd)

Component	Instrument Type	Critical Instruments	Additional for 350502
	Fluid thermocouple	CFTC01	CFTC02,03
Gas addition	Fluid thermocouple	GATC02-04**	
	Pressure transmitter	GAAP01*	
	Limit switch	GALS01-04*	
Feedwater circuit	Differential pressure	SFDP01-06	
	Resistance temperature detector	SFRT01,-02	
Steam circuit	Differential pressure transmitter	SSDP01-06	
	Resistance temperature detector	SSRT01,-02	
	Fluid temperature	SSTC01-03 (1 of 2) SSTC02,-04 (1 of 2)	
Miscel-laneous	Resistance temperature detector shunt	MSRF01	
	Reference oven temperature	MSTC01-07	

*These instruments are critical for all tests except Test 350101.

**For Test 350101, only 1 of 3 is required.

Table 4.3. Critical Instruments Not Available for the Group 35 Test Series

Instrument	Description	350101	3502CC	350312	350502	350700	350800	Backup Available
C1TC04	Pump suction fluid temperature at 2.36 ft	x	x	x	x	x	x	yes
C2GD04	Beam 2 loop B1 cold leg density at 21.25 ft				(8)			no
C3DP07	Differential pressure across loop A2 pump	x						no
C4DP07	Differential pressure across loop B2 pump	x						no
C4DT03	Guard heater zone 39 control at 23.47 ft		(1)	(1)	(1)	(1)	(1)	yes
DCTC03	Fluid temperature downstream of vent valve 3 at 24.16 ft		(9)	(9)	(9)	(9)	(9)	no
H1CP01,02	Hot leg fluid conductivity probes	(2)	(2)	(2)	(2)	(2)	(2)	yes
H1CP06	Hot leg fluid conductivity probe at 59.72 ft	x	x	x	x	x	x	yes
H1GD02	Beam 2 loop A hot leg fluid density at 21.25 ft		(8)	(8)	(8)	(8)	(8)	no
H2CP05	Hot leg fluid conductivity probe at 50.68 ft	x		x				yes
H2CP07	Hot leg fluid conductivity probe at 63.56 ft	x		x				yes
H2CP09	Hot leg fluid conductivity probe at 66.78 ft	x	x	x	x	x	x	yes
H2DT01	Guard heater zone 14 control at 29.63 ft		(3)					no
H2GD01	Beam 1 loop B hot leg fluid density at 21.25 ft			(8)	(4,8)	(8)	(8)	no
H2GD02	Beam 2 loop B hot leg fluid density at 21.25 ft			(8)	(8)			no
PZW03	Spray line guard heater total power				x			no
P1TC30	Generator A primary fluid temperature at 50.58 ft	x	x	x	x	x	x	yes
P1TC35	Generator A primary fluid temperature at 39.08 ft	x	x	x	x	x	x	yes
P2TC01	Generator B primary fluid temperature at 50.50 ft	x	x	x	x	x	x	yes
P2TC12	Generator B primary fluid temperature at 49.50 ft	x	x	x	x	x	x	yes
P2TC30	Generator B primary fluid temperature at 29.25 ft	x	x	x	x	x	x	yes
RVCP01-04	Reactor vessel fluid conductivity probes	(2)	(2)	(2)	(2)	(2)	(2)	no
RVTC07	Core fluid temperature (mid-bundle) at 13.15 ft	x	x	x	x	x	x	yes

Table 4.3. Critical Instruments Not Available for the Group 35 Test Series (Cont'd)

Instrument	Description	350101	3502CC	350312	350502	350700	350800	Backup Available
RVTC17	Fluid temperature upstream of vent valve 1 at 24.18 ft		(9)	(9)	(9)	(9)	(9)	no
SFRT01	Generator A inlet feedwater temperature at 50.28 ft	(5)						no
S1TC04	Generator A secondary fluid temperature at 11.07 ft	x	x	x	x	x	x	yes
S1TC16	Generator A secondary fluid temperature at 38.1[illegible] ft	x	x	x	x	x	x	yes
S2CP01-12	Generator B secondary conductivity probes	(2)	(2)	(2)	(2)	(2)	(2)	no
V1MM01	Single phase leak mass flowmeter		(6,10)		(10)		(10)	no
V2LC01	Load cell on RVHV/HPV weigh tank 1					(7)		no

(1) Metal temperature used for guard heater control in place of the differential temperature.

(2) Raw data obtained with these conductivity probes can not be processed due to a measurement problem observed after completing these tests.

(3) Unavailable from 321 to 350 minutes, from 394 to 395 minutes, from 435 to 452 minutes, from 486 to 537 minutes, and from 979 to 1047 minutes.

(4) Unavailable from 85 minutes to end of the test at 828 minutes.

(5) Unavailable from 280 to 300 minutes.

(6) Unavailable for one or two scans at 37 minutes 49 seconds, 65 minutes 9 seconds, 76 minutes 24 seconds, 88 minutes 54 seconds, 117 minutes 14 seconds, and 121 minutes 59 seconds. Unavailable for 4 to 8 scans at 52 minutes 24 seconds, 58 minutes 24 seconds, 84 minutes 34 seconds, and 163 minutes 39 seconds.

(7) This load cell was not used during the test.

(8) Approval for test performance without this instrument received per PMG Transmittal No. 557.

(9) Approval for test performance without this instrument received per PMG Transmittal No. 566.

(10) Presence of noncondensibles in the leak effluent affected flowmeter measurement.

5. OBSERVATIONS

Test Group 35 involved noncondensibles and venting. As discussed in section 5.1, the NCG species, leak location, and leak isolation were also varied among the tests.

Test 2, NCG Threshold, was conducted unlike the remaining five transient tests. In Test 2, the primary inventory was first depleted to obtain stable BCM, then gas was injected up to a facility limit. As described in section 5.2, injection was continued up to the maximum capacity of the facility gas metering system, approximately 60 scf. This volume of noncondensibles was more than 3 times the volume of MIST, or approximately 5% of the MIST volume at the final conditions.

Tests 1, 3, and 5 involved variations of hot leg venting and the presence or absence of noncondensibles. These three tests are described and compared in section 5.3. Much of the injected NCG was observed (by gas imbalance as well as by physical indications) to be discharged out the cold leg discharge break. The break location was varied in Tests 7 and 8. Test 7 is described and compared to Test 3 in section 5.4. A cold leg suction break and nitrogen were used in Test 8. Test 8 is described and compared to Test 7 in section 5.5.

Section 5.6 provides a summary of observations. General observations, the effects of inter-test variations, and noteworthy interactions are described.

5.1. Introduction

The tests of Group 35 are outlined in section 5.1.1. The system gas balances are discussed in section 5.1.2. Figures 1.1 through 1.6 and 5.1.1 through 5.1.6 provide overviews of the six Group 35 tests.

5.1.1. Description of Test Group 35

The Group 35 tests involved noncondensible gas and venting. Besides these primary inter-test variables, the NCG species, leak location, and leak isolation status were also varied among tests. The test specifications are given in section 3 herein, the test boundary-system conditions are summarized in Table 3.1.

The six tests of Group 35 involved four independent inter-test variables each having as many as three settings, as summarized in Table 5.1.1. Test 2, the threshold test, was conducted to determine the maximum system gas burden and was thus unlike the remaining five transient tests.

Venting Test 3 used a cold leg discharge leak, helium injection, continuous hot leg venting, and break isolation during the transient. Comparing the inter-test variations among the five transient tests, the conditions of Test 3 are convenient for separate inter-test comparisons with those of Tests 1, 5, and 7. Disregarding leak isolation, which occurred about 2 hours into the transients, Tests 3 and 1 were conducted with and without noncondensibles, Tests 3 and 5 varied hot leg venting, and Tests 3 and 7 varied the leak location. Test 8 is most comparable to Test 7, the inter-test variable being NCG species. These inter-test comparisons were selected for examination.

The timing of key controlled events is given in Table 5.1.2. The NCG injection was terminated in each case when the total injection reached the maximum metering value, approximately 60 scf, which was determined to be the most restrictive facility limit in Threshold Test 2. The injection rates were virtually identical among the tests so that the four gas injections were completed at 109 [illegible] minute.

The leak was [illegible] in Tests 3, 7, and 8. The following were the two criteria for isolation: (1) less than 2 hours of testing remained, or (2) the primary system pressure decreased below 600 psia. In each of the three tests, the leak was isolated based on primary system pressure rather than on remaining test time; the isolation times ranged from 124 to 146 minutes.

The PORV was actuated manually when the SCM increased to 70F following leak isolation. In the three tests using leak isolation, the SCM rise triggered PORV actuation in 12 ± 3 minutes after leak isolation.

5.1.2. Gas Balance

The NCG volumes were accounted for in an effort to obtain gas closure. The initial NCG volume plus the volume injected were compared to the volume collected plus that remaining. The results of these balances are listed in Table 5.1.3.

In each test, the volume injected far exceeded the initial inventory, which was about 0.3 scf. The proportion between the amount collected and the amount remaining varied among tests. In Test 2, there was neither venting nor a leak after gas injection was begun. Thus, the total amount resided in the loop at the end of the test. This amount was estimated by venting and by measuring the loop gas burden after test termination, and then by determining the remaining dissolved gas volume by chemical analysis of the loop fluid. In Test 2, the final plus collected gas volumes, 55 scf, was 4 scf less than the initial volume plus the volume injected. This difference, 7% of the injected volume, was attributable to both helium leakage and measurement inaccuracies.

The larger gas closure differences in Tests 3 and 5, 32 $\pm$ 1 scf, apparently reflected the gas discharged out the cold leg discharge leak during testing. The hot leg vent and PORV discharge streams were passed through a gas collection device but no such device was available for the cold leg leak discharge streams. The gas imbalances in Tests 3 and 5 were more than one-half of the amounts injected.

Cold leg suction leaks were used in Tests 7 and 8, and the gas closure imbalances decreased markedly from those of Tests 3 and 5, to 7 and 10 scf. Although there were several other inter-test differences among the Group 35 tests, notably the use of nitrogen in Test 8 versus helium in the others, the gas closure results provided the following insights:

- Without an unmetered discharge stream, gas closure was obtained within 10% of the injected amount.
- The large imbalances in tests having cold leg leaks reflected gas discharged out the leaks.
- Whereas significant amounts of gas were discharged by the cold leg

discharge leak, much smaller amounts were vented by the cold leg suction leaks.

The preceding gas balances provided estimates of the volume of NCG discharged by the leak, and thereby of the loop gas burden during testing. By approximately 2 hours, the gas injections had been completed in each test and leak isolation (in Tests 3, 7, and 8) was imminent, therefore 2 hours is a convenient time at which to estimate loop gas burden. Another convenient time at which to estimate is near the end of testing. The estimated loop NCG burdens at these two times are listed in Table 5.1.4. For Test 5, in which the leak was not isolated, it was assumed that the bulk of the leak discharge of NCG occurred early in the test, therefore the total leak discharged volume was used for both the 2-hour and the 280-minute estimates. For each of the tests, the leak discharge of NCG was taken to be the total volume difference obtained by the gas closure over the entire test, including many hours of venting and sampling beyond the standard termination of the test transient. Note that the total gas balance of Test 2, without discharges after gas injection, obtained closure to 4 scf. This magnitude of error is to be expected for the other gas tests.

Referring to the estimates of Table 5.1.4, the tests fall into 2 distinct groups: Tests 3 and 5 having cold leg discharge leaks had gas burdens between 20 and 30 scf, and Tests 7 and 8 having cold leg suction leaks had burdens between 40 and 50 scf. Venting alone had little impact on the total gas burden. PORV actuation (plus venting) removed about 20% of the total loop gas burden over 160 minutes. The change of NCG species from helium in Test 7 to nitrogen in Test 8 had virtually no effect. These NCG observations are discussed further in the descriptions of tests which follow.

Approximately 60 standard cubic feet (scf) of NCG (helium or nitrogen) were injected in each of the MIST tests involving NCG. This volume was equivalent to approximately 37,000 scf in a plant. This volume represents the sum of the following sources of NCG:

- Initial inventory, 600 scf;
- 2 hours of ECCS injection and radiolytic decomposition, 1100 scf;
- The fill and fission gas inventory of all the fuel rods, 1,300 scf; and

- The metal-water reaction of 8% of the total zirconium inventory, 33,000 scf

The ECCS injection source accounts for the NCG dissolved in the injection fluid, but does not consider the core flood tank (CFT) cover gas. The total volume of nitrogen contained in the 2 CFTs per plant is the equivalent of almost 30,000 scf.

Table 5.1.1. Comparisons Among Group 35 Test Conditions

	Leak Site	NCG Species	Hot Leg Venting	Break Status
Setting:				
0	Discharge	Helium	Yes	Open
1	Suction	Nitrogen	No	Isolated
2	None	None	--	(NA)
Test				
1 No NCG	0	2	0	0
2 Threshold	2	0	1	2
3 HL Venting	0	0	0	1
5 No Venting	0	0	1	0
7 Suction	1	0	0	1
8 Nitrogen	1	1	0	1

Table 5.1.2. Timing of Controlled Events, Transient Tests

Times are listed in minutes after test initiation.

	Test				
Event	1 No NCG	3 Venting	5 No Venting	7 Suction	8 Nitrogen
Opened both hot leg vents	0	0	NA	0	0
Began NCG injection	NA	0	0	0	0
Completed NCG injection	NA	110	108	109	109
Isolated leak	NA	126	NA	124	146
First actuated PORV	NA	135	NA	139	158
Completed test	290	420	420	289	320

Table 5.1.3. Gas Balances

Test	2 Threshold	3 HL Venting	5 No Venting	7 Suction	8 Nitrogen
Volumes, scf					
Initial plus injected	59	60	61	60	62
Final plus collected	55	29	28	53	52
Difference	4	31	33	7	10
Ratio: difference/ injected, %	7	52	56	12	17

Table 5.1.4. Gas Burdens During Testing

The total primary system gas burdens in standard cubic feet (scf) are shown at two times for the four Group 35 transient tests that used noncondensibles. The first time, 2 hours, was after the completion of gas injection and before both leak isolation and PORV actuation(s). The second time, 280 minutes, was just before the completion of the shortest test.

	Test			
	3 Venting	5 No Venting	7 Suction	8 Nitrogen
Gas Burden at 2 Hours				
Initial and injected	60	61	60	62
Collected*	2	0	3	2
Leak discharge**	31	33	7	10
Net	27	28	50	50
Gas Burden at 280 Minutes				
Initial and injected	60	61	60	62
Collected*	8	0	10	8
Leak discharge**	31	33	7	10
Net	21	28	43	44

*The "collected" entries are the total volumes of NCG separated and metered from the two-phase discharges, including hot leg high-point vents and the PORV, but not including the NCG discharged by the cold leg leak. The vents but not the PORV were active in Tests 3, 7, and 8 before the first entry at 2 hours; both the PORV and hot leg vents were active in Tests 3, 7, and 8 before the second entry at 280 minutes. Neither the hot leg vents nor the PORV were active in Test 5.

**The "leak discharge" entry was not measured, but was taken from the gas balance differences, cf. Table 5.1.3. The entries at 2 hours are just before the times of leak isolation in Tests 3, 7, and 8, the leak was not isolated in Test 5. The "leak discharge" entries reflect the total gas imbalances, i.e., the apparent leak discharge of NCG was not prorated based on the duration of the leak discharge.

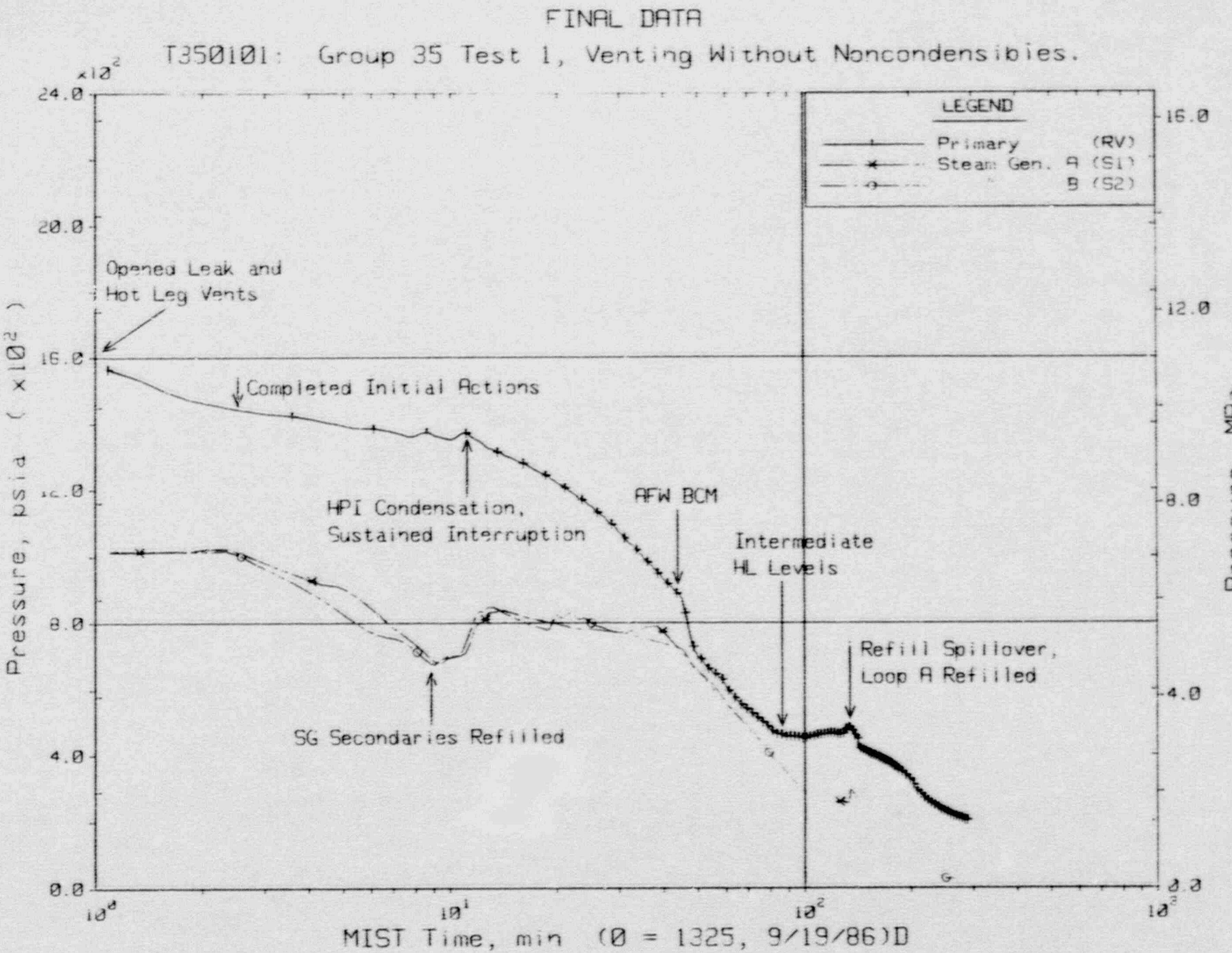

Figure 5.1.1 Primary and Secondary System Pressures (GP01s)

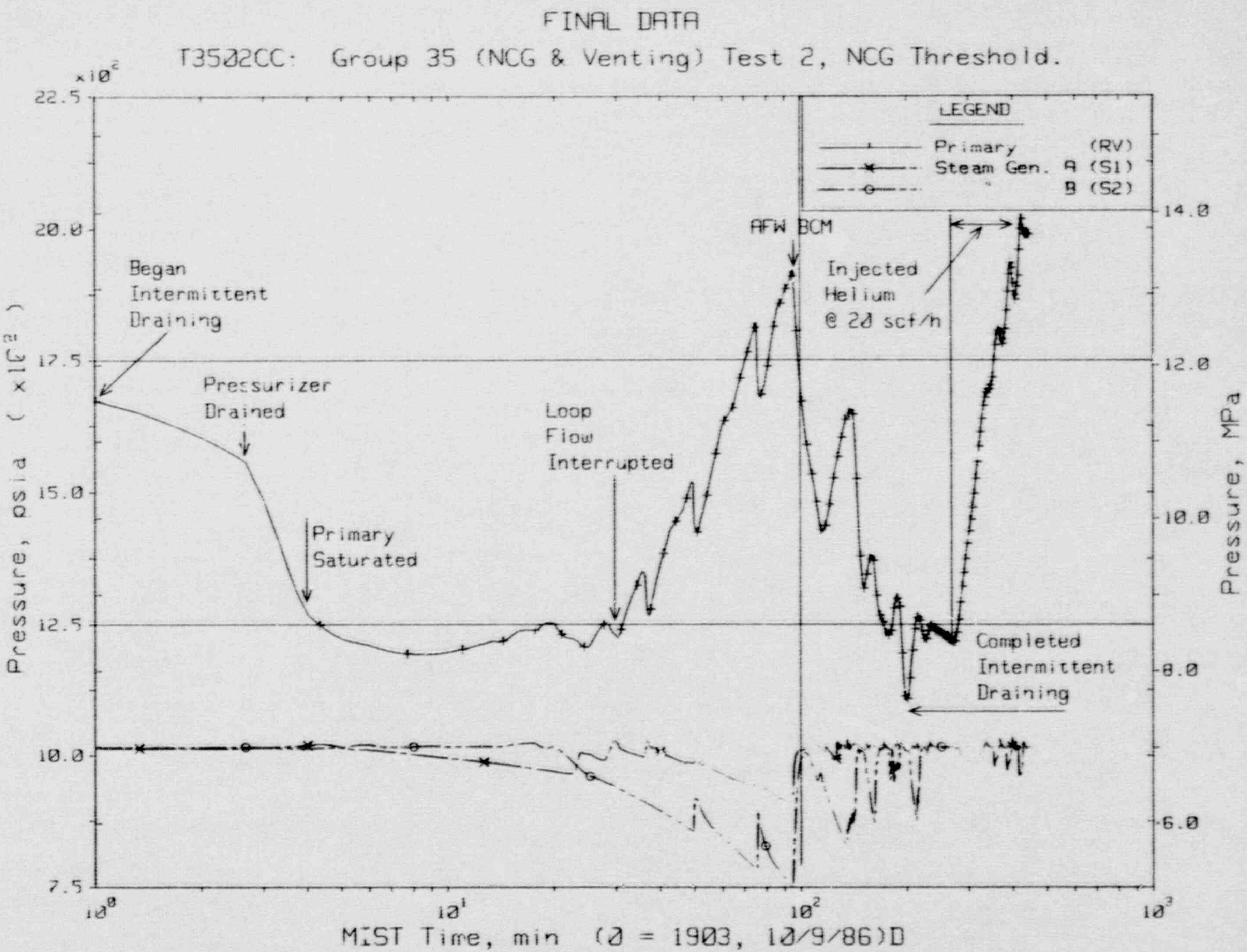

Figure 5.1.2 Primary and Secondary System Pressures (GPOIs)

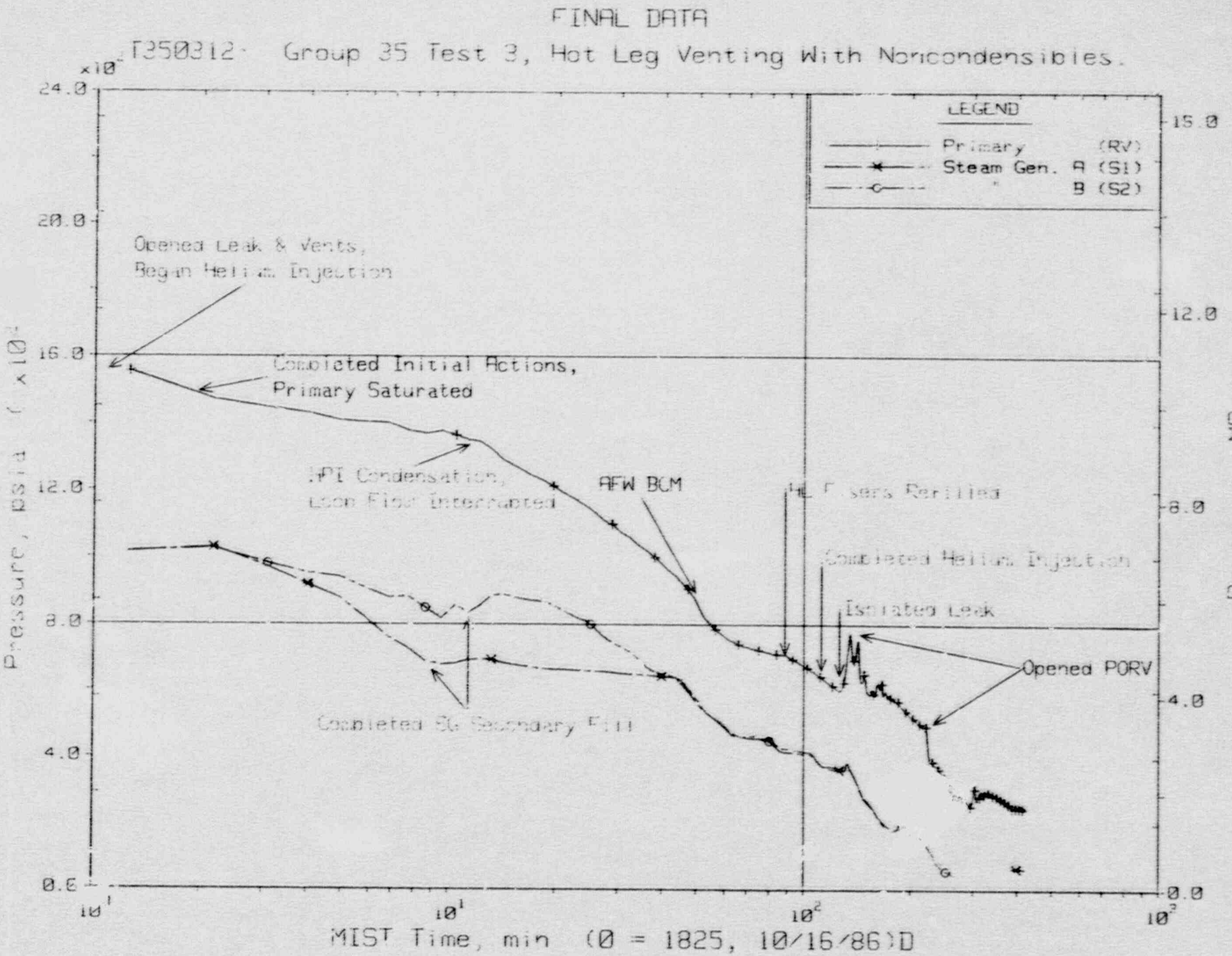

Figure 5.1.3 Primary and Secondary System Pressures (GPOls)

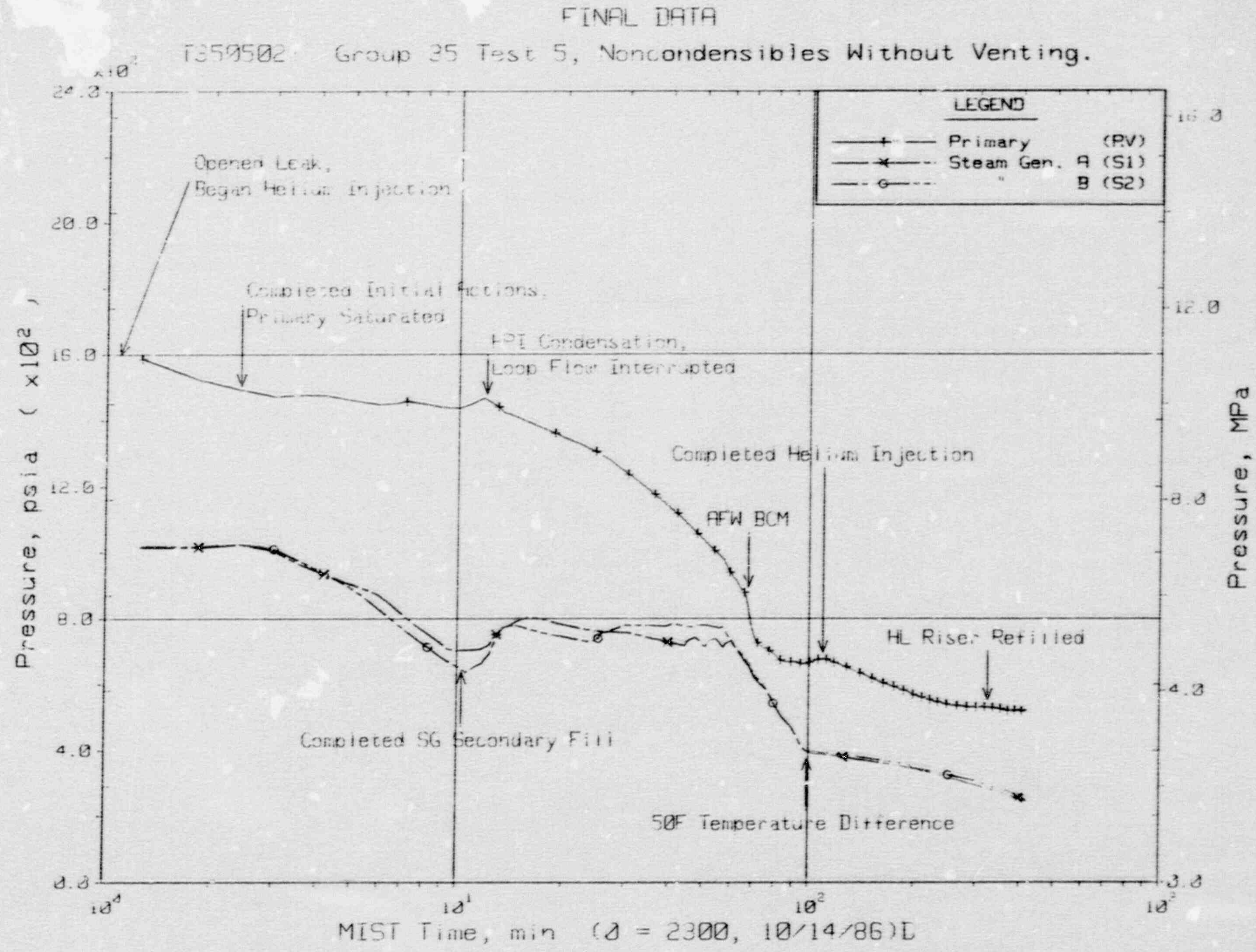

Figure 5.1.4 Primary and Secondary System Pressures (GP01s)

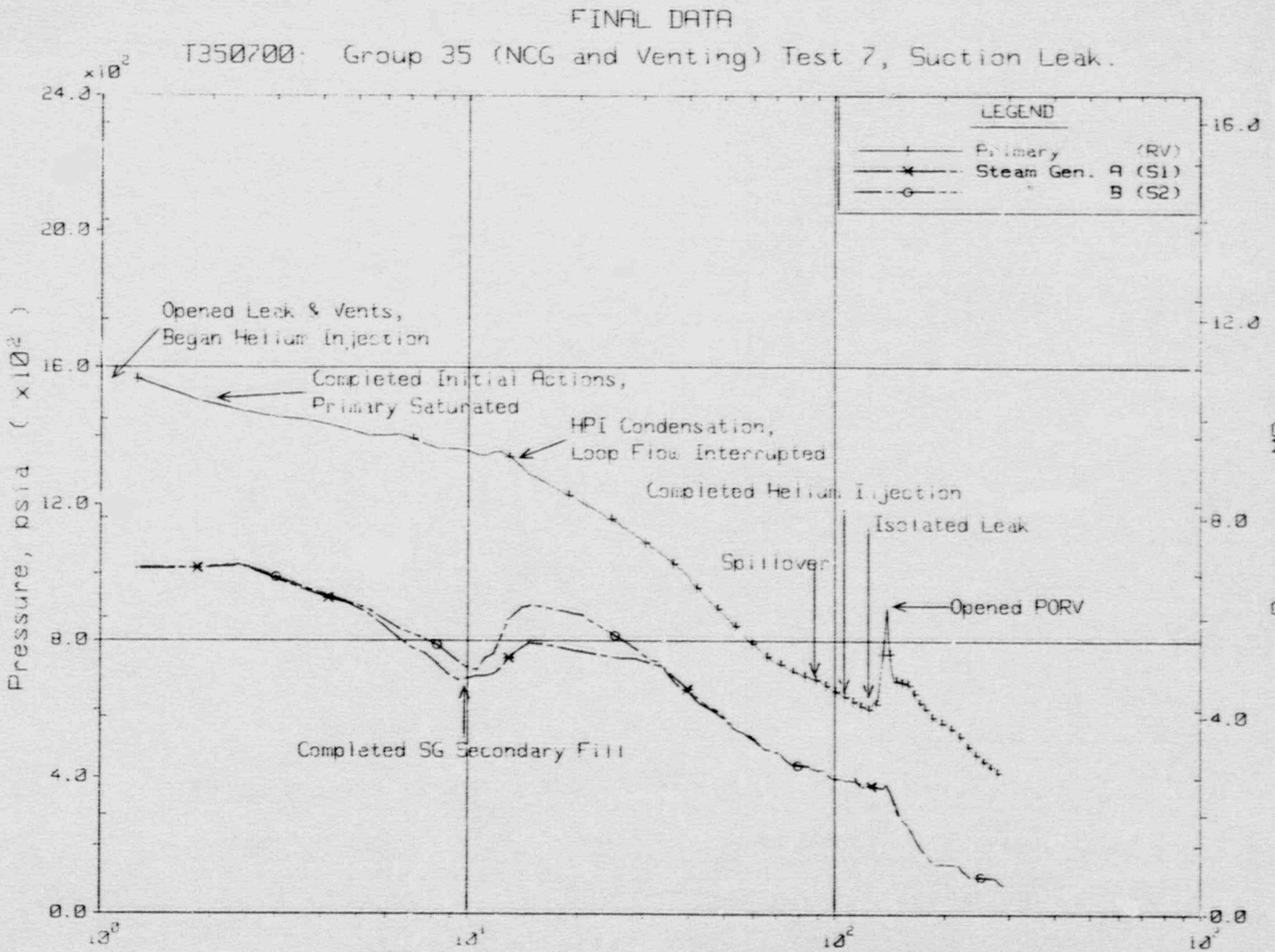

Figure 5.1.5 Primary and Secondary System Pressures (GP01s)

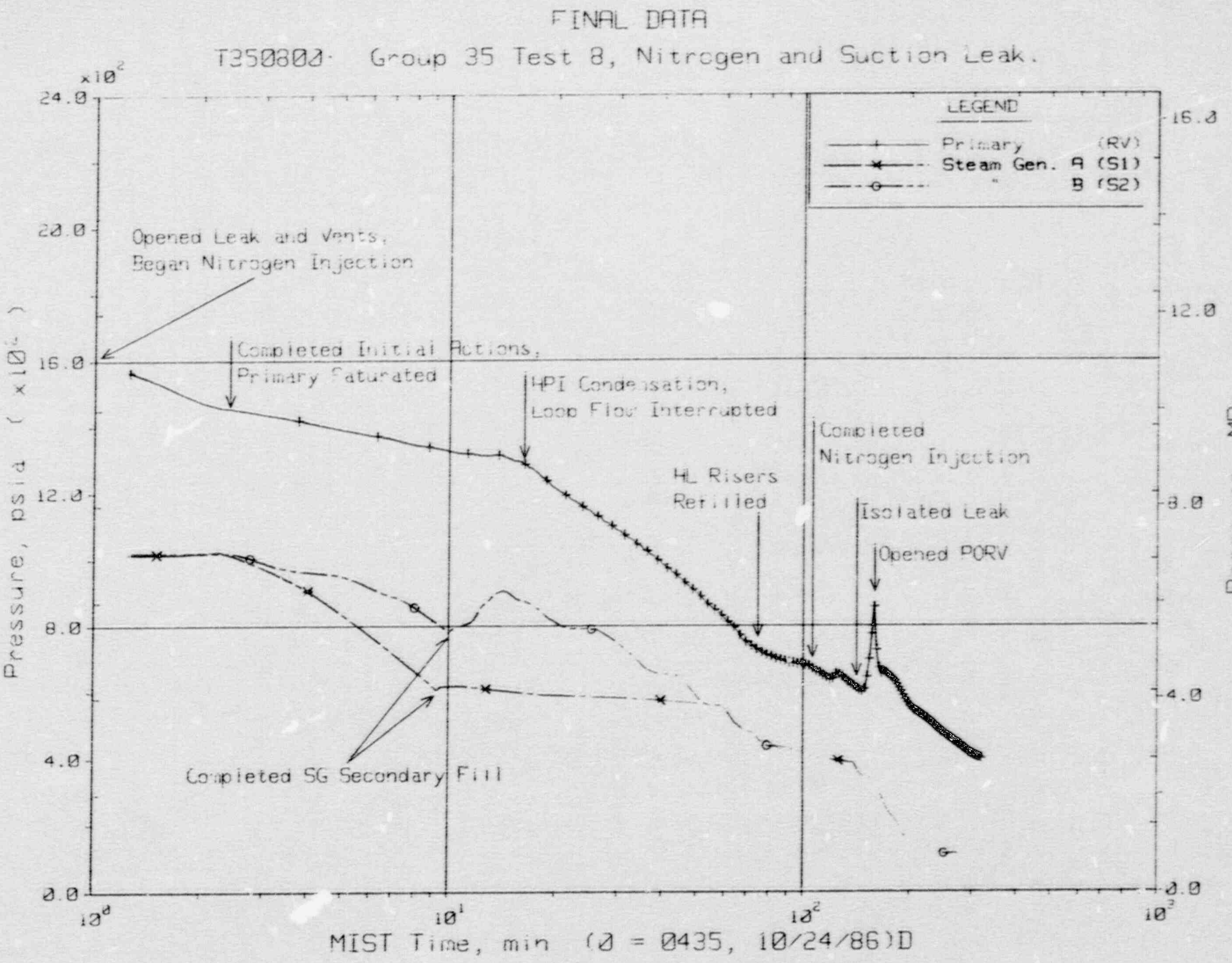

Figure 5.1.6 Primary and Secondary System Pressures (GP01s)

5.2. NCG Threshold, Test 2

Test 2 (3502CC) was the "threshold" test -- helium was injected into the reactor vessel lower piping with no leaking or venting. Injection was continued until a facility limit was encountered. The primary system pressure rose with the continuing gas injection, first rising almost linearly and then irregularly. The presence of the NCG was evidenced in the voided regions of the steam generator primaries and in the cold leg discharge piping. The test was terminated prematurely when the gas injection was completed, rather than allowing the primary system to continue repressurizing.

Test 2 was conducted in the following three phases:

1. Intermittent draining to obtain a stable pool BCM.
2. Helium injection (with no leaks or venting).
3. Post-termination gas recovery.

Gas closure to within approximately 7% of the total injected volume was obtained during the post-termination phase. The two earlier phases are discussed in sections 5.2.1 and 5.2.2.

5.2.1. Intermittent Draining

The leak effects began at 1 minute. The leak flow rate began to register (and indicated approximately 350 lbm/h, corresponding to the scaled 5-cm^2 lower downcomer leak, Figure 5.2.1), and the primary system began to depressurize from 1770 psia (Figure 5.2.2). The pressurizer drained at 4 minutes as indicated by the enhanced rate of primary system pressure decrease. At 5 minutes, the primary system pressure began to stabilize near 1225 psia, indicating saturation of the primary system fluid. Simultaneously, the core exit and hot leg fluid temperatures approached saturation (loop A first), and the loop A hot leg levels bracketing the U-bend began to descend (Figure 5.2.3). The steam generator A secondary feeding and steaming rates dwindled, whereas the steam generator B activity increased (Figure 5.2.4).

The reactor vessel fluid began to void at 9 minutes, reversing the downward trends of the loop A hot leg levels. The core region level approached that of the (full) downcomer at 14.5 minutes, then the levels in both of these components began to descend through the elevation of the RVVVs (Figure 5.2.5). The core region and downcomer levels stabilized near the nozzle elevation at 21 minutes, and the cold leg discharge piping began to void. Then, the loop B hot leg levels began to recede from the U-bend, and the loop A hot leg riser briefly refilled (Figure 5.2.3). The steam generator secondary activity mirrored this interchange of active loops, i.e., the steam generator B activity decreased whereas that of generator A briefly reactivated (Figure 5.2.4). Thus, a period of alternate loop activity was initiated. The fluid in the active loop contracted, causing its hot leg levels to recede from the U-bend, whereas the inactive loop levels continued to gradually rise.

Both hot leg riser levels remained below the U-bend spillover elevation between approximately 31 and 37 minutes (Figure 5.2.3). During this time, the collapsed liquid levels of the core region and downcomer descended toward the top of the core, and the primary system repressurized from 1230 to 1350 psia (Figure 5.2.2). At 38 minutes, the leak apparently plugged (Figure 5.2.1). The primary system total fluid mass, which had decreased by 20% of the initial fluid mass during the first 40 minutes, decreased by less than 2% during the second 40 minutes. Loop A activated and its hot leg levels immediately dropped below the elevation of the steam generator upper tube-sheet (Figure 5.2.3), initiating a brief period of BCM heat transfer. The core region and downcomer abruptly refilled to the nozzle elevation. The primary system pressure dropped to 1270 psia and then resumed its gradual increase. This sequence was repeated again at 51 minutes, but with a spillover in loop B. Also, the rate of primary system repressurization preceding the spillover had been attenuated by BCM heat transfer in loop A. The primary system pressure continued its overall increase (Figure 5.2.2) apparently because the vapor condensation corresponding to the steam generator A feed demand was insufficient to offset all of the core steam generation. A subsequent loop B spillover near 77 minutes depressurized the primary system from 1820 to 1685 psia. Steam generator B repressurized toward the secondary pressure setpoint during this heat transfer activity, but gradually depressurized between recoupling events (Figure 5.2.2), apparently due to heat loss and steam leakage.

The lower downcomer leak was actuated intermittently between 52 and 192 minutes. The earlier actuations were performed to clear the apparent blockage at the leak orifice, and the later actuations were performed to adjust the primary system total fluid mass downward to obtain a sustained pool BCM. As a result of these leak reductions, the primary system total fluid mass (Figure 5.2.6) varied as follows:

Time, min	Primary System Total Fluid Mass, lbm	Primary System Total Fluid Mass, % of initial (978 lbm)	Approximate (average) Mass Depletion Rate, lbm/h
80	767	78	
			85
92	750	77	
			345
96	727	74	
			~0
111	726	74	
			280
122	675	69	
			10
157	670	68.5	
			140
162	635	65	
			0
188	635	65	
			350
193	606	62	

Following the leak actuation from 92 to 96 minutes, the primary levels in both steam generators dropped below the AFW injection elevation, feed was supplied to both steam generators, and the primary system began to depressurize at 97 minutes from a maximum pressure of 1920 psia (Figure 5.2.7). Following the draindown ending at 122 minutes to 69% of the initial primary system total fluid mass, both steam generator primary levels briefly approached the secondary pool levels, both steam generator secondaries reactivated, and the primary system depressurized from 1650 psia at 142 minutes.

A final primary system drain was performed from 188 to 193 minutes. The intent of this drain, which reduced the primary system total fluid mass to 606 lbm, 62% of its initial value, was to obtain sustaining pool BCM. Intermittent and alternating pool BCM had been observed before this drain. After the drain, the steam generator primary levels became more stable (Figure 5.2.8) and the periods of pool BCM in one or the other of the steam generators were prolonged. The system was allowed to stabilize in this configuration from 227 to 267 minutes. The steam generator secondary feed and steam rates gradually stabilized (Figure 5.2.9) and the primary system pressure became nearly steady at 1200 psia, only some 200 psi greater than the secondary pressure (Figure 5.2.7).

5.2.2. Helium Injection

Beginning at approximately 270 minutes, helium was injected into the reactor vessel lower piping. The other primary boundary systems, including leaks and vents, were kept closed. At 277 minutes, the primary system pressure, which had been virtually constant, began to increase almost linearly at a rate of 8 psi/min (Figure 5.2.10). The loop A hot leg and steam generator primary levels decreased during the repressurization, whereas the corresponding loop B levels and the pressurizer level increased. The steam generator A primary level began to descend below the secondary pool level at 280 minutes (Figure 5.2.11) and continued down to 27.5 feet (5 feet below the secondary level), but the primary system repressurization continued. The steaming and feeding rates in steam generator A diminished near 280 minutes (Figure 5.2.12), apparently due to NCG effects.

The rate of primary system repressurization first subsided near 340 minutes (Figure 5.2.10). At this time, the steam generator B primary level descended to the pool level (Figure 5.2.11). the steam generator A primary level remained 5 feet below its secondary level, and the feeding and steaming rates in both steam generators increased (Figure 5.2.12). Thereafter, the primary system repressurized in an incremental fashion. Each period of rising pressure was punctuated by relatively intense activity in both steam generators, with both steam generator primary levels below the elevation of the secondary pool.

The overlapping vertical distance between the steam generator primary level and the secondary pool level, without primary-to-secondary heat transfer, indicated the extent of the NCG effects in the steam generator. Gas was injected at a nominally constant rate of 20 standard cubic feet (scf) per hour over the 3-hour injection period. The primary boundary systems (leaks, vents, and high-pressure injection) were inactive throughout this period. Thus, the total burden of primary system NCG increased linearly. The post-test gas venting and sampling confirmed gas closure to within about 7% of the total injected amount of 60 scf, supporting the assertion regarding a linearly increasing burden. The steam generator A minimum primary levels throughout this period, after the initial decrease to 27.5 ft, were notably constant (Figure 5.2.11). The indicated 27.5-ft steam generator primary level apparently corresponded to the 25.8-ft cold leg spillover elevation. The steam generator B primary level during the intermittent periods of steam generator activity did decrease, but the conditions in steam generator A rather than in B seem to have initiated each active period.

The initial drop of the steam generator A primary level, from the secondary level at 272 minutes to 5 feet below the pool level at 302 minutes, almost corresponded with the gas volume injected during this time. That is, the volume injected to time 302 minutes, when compressed to the current primary system pressure (and at saturation temperature), occupied almost exactly the primary volume corresponding to the exposed 5 feet of steam generator tube primary volume. Thus, the initial gas transport appears to have come directly from the core region, through hot leg A with the continuing vapor flow, and to the condensing site. Beyond the initial level drop at 302 minutes, however, some 50 scf more of NCG was injected. If this volume is converted to the primary system conditions at 450 minutes, 0.75 ft^3 of helium was as yet unaccounted for.

The presence of NCG can be inferred by the examination of system fluid temperatures, especially near the water-steam interfaces. Noncondensibles both lower the water-steam saturation temperature, and inhibit heat and mass transfer. The former effect is due to the partial pressure of NCG. The partial pressure of the water-steam component, in the presence of NCG, is less than the total pressure. The actual saturation temperature is correspondingly less than the apparent saturation temperature at total pressure. The latter effect, the inhibition by NCG of heat and mass transfer, is most evident in the voided regions of the steam generator primary. The NCG concentration above the liquid-vapor interface is increased by the condensation of steam. The accumulating noncondensibles tend to block the continuing introduction of steam. The temperature of the vapor in the NCG-affected regions thus decreases markedly from the primary saturation temperature. Based on the fluid temperatures throughout the system, the NCG apparently resided in two locations, namely the voided lengths of the steam generator primaries (Figure 5.2.13) and the cold leg discharge piping (Figure 5.2.14). The apparent saturation temperatures of the voided upper reactor vessel, upper downcomer, and hot legs showed little evidence of NCG.

The helium injection was terminated after 3 hours of injection. The total gas injection, approximately 60 scf, corresponded to the maximum NCG metering capacity of the test facility. The test was inadvertently terminated upon the completion of the gas injection, at 448 minutes, rather than allowing the primary system to continue repressurizing. The premature termination of this test has been corrected in the subsequent gas tests. Upon termination, the steam generators remained active (Figure 5.2.12), but the primary system pressure was continuing its irregular increase and had reached 2000 psia (Figure 5.2.10).

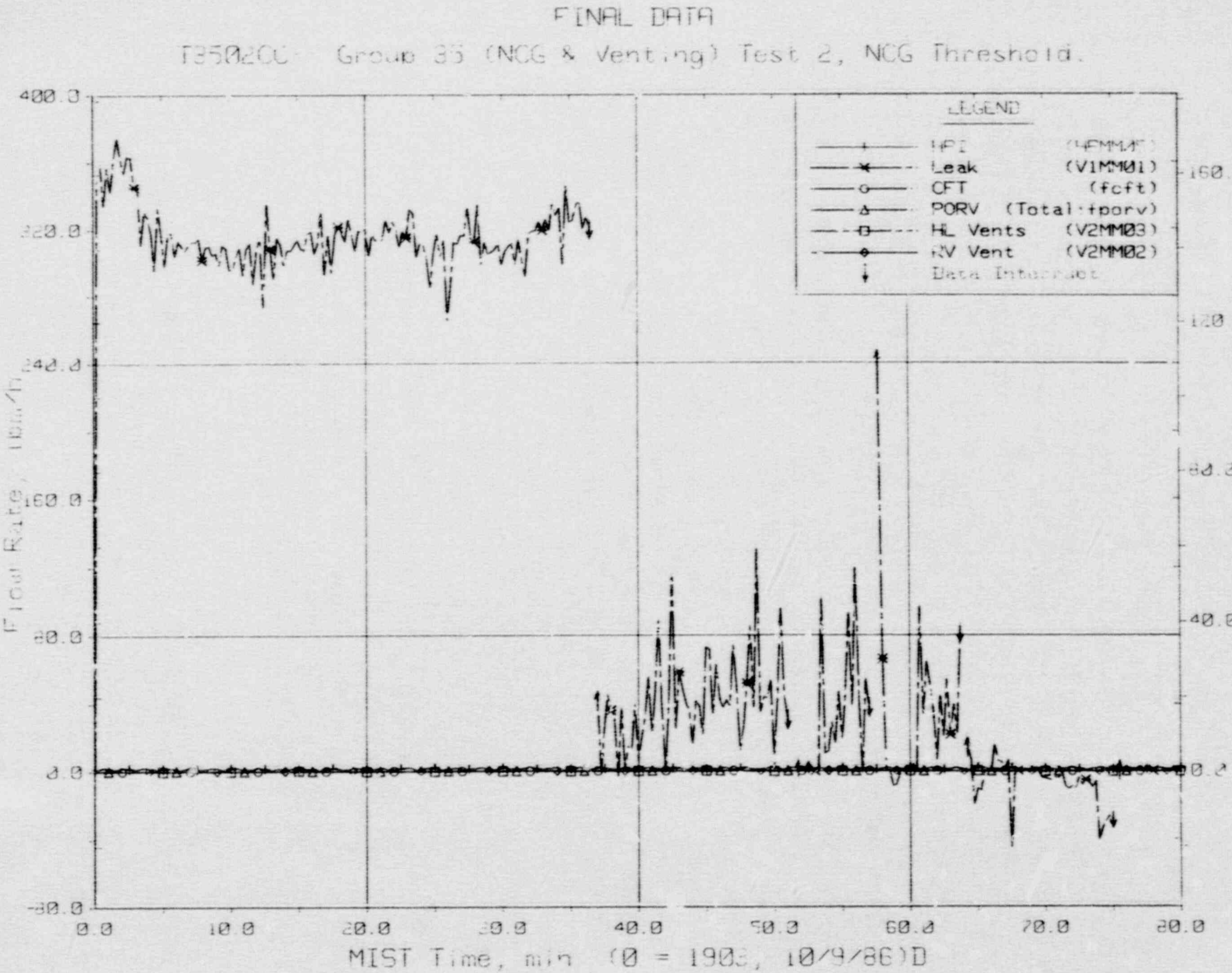

Figure 5.2.1 Primary System Boundary Flow Rates

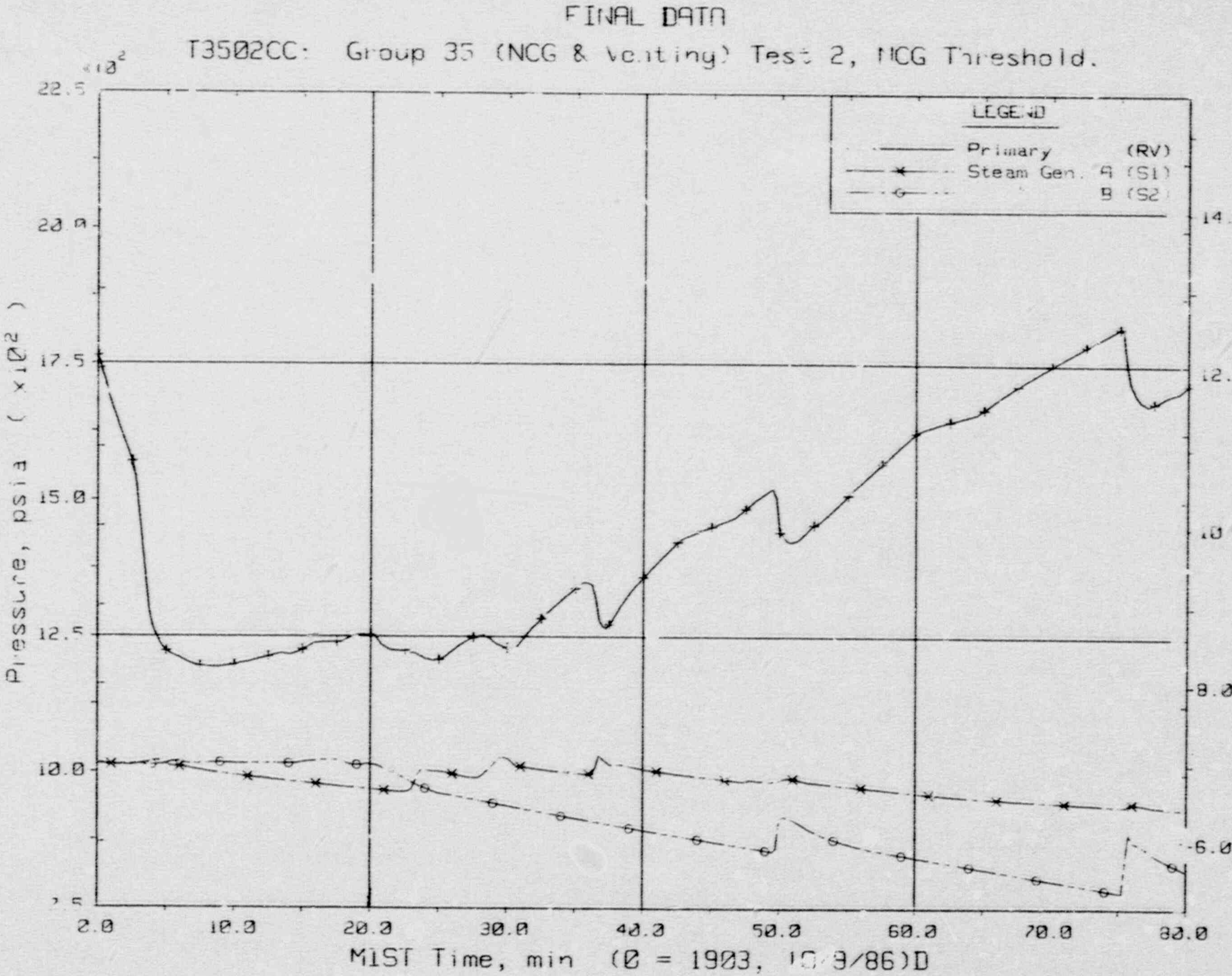

Figure 5.2.2 Primary and Secondary System Pressures (GP01s)

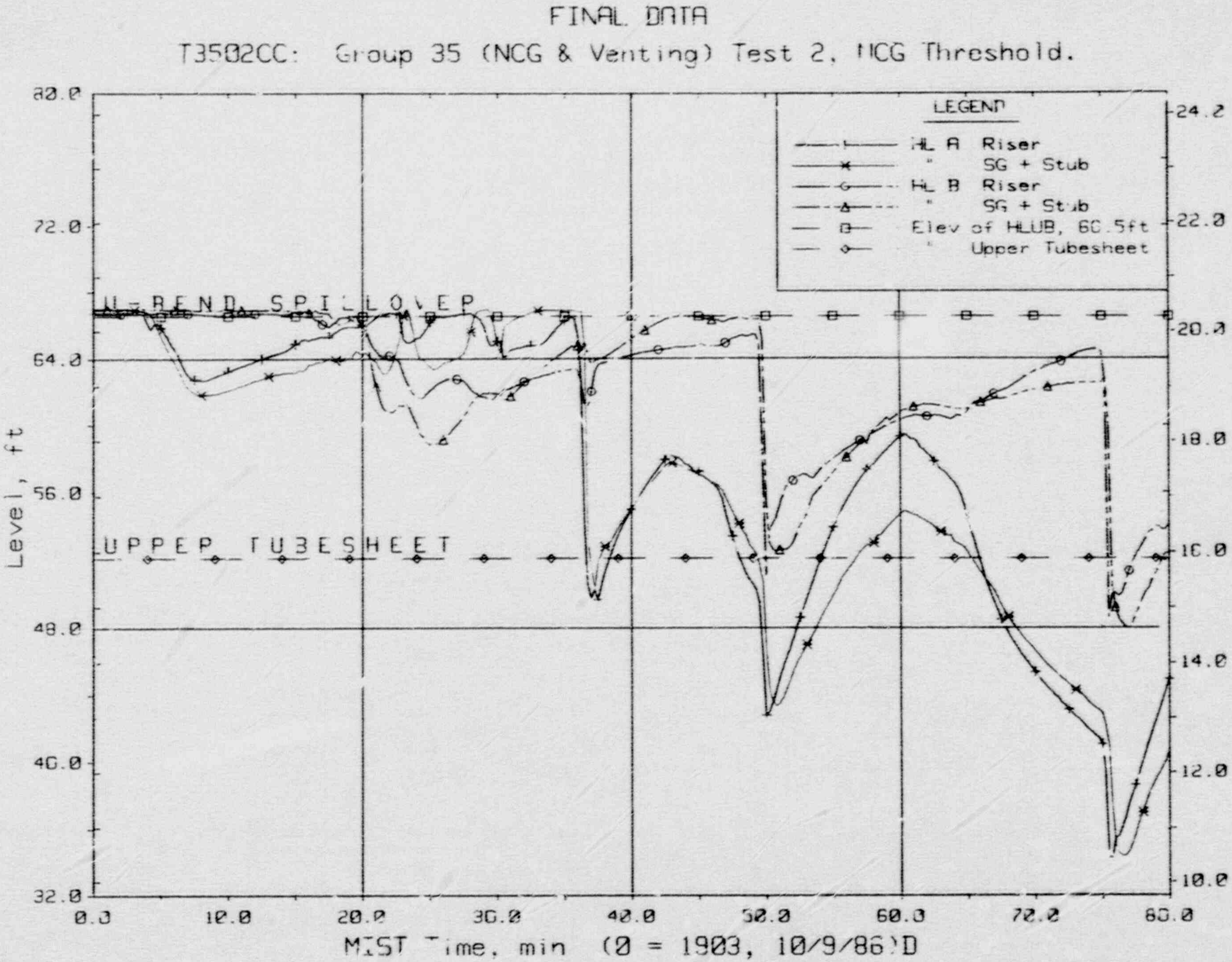

Figure 5.2.3 Hot Leg Riser and Stub Collapsed Liquid Levels

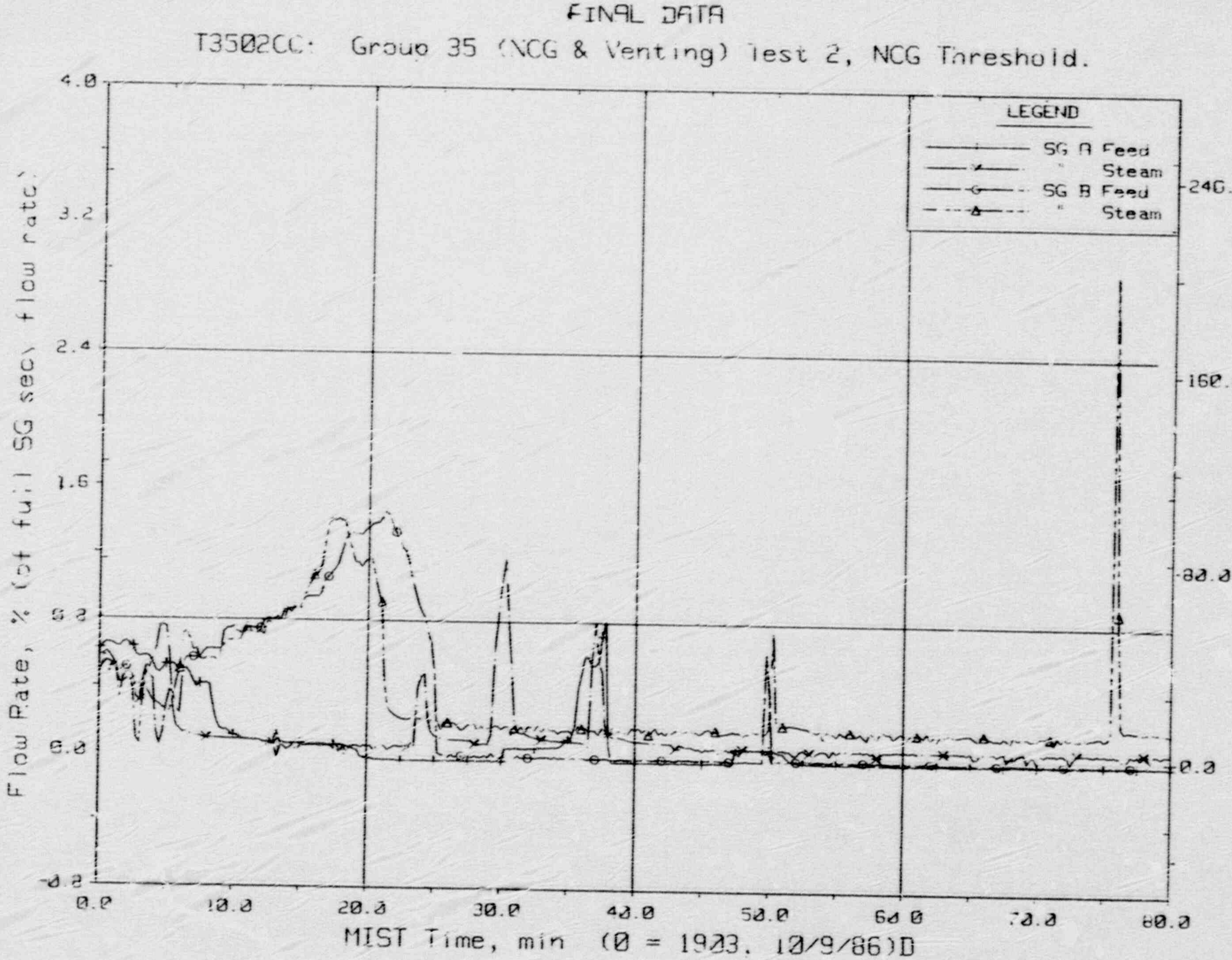

Figure 5.2.4 Secondary System Flow Rates

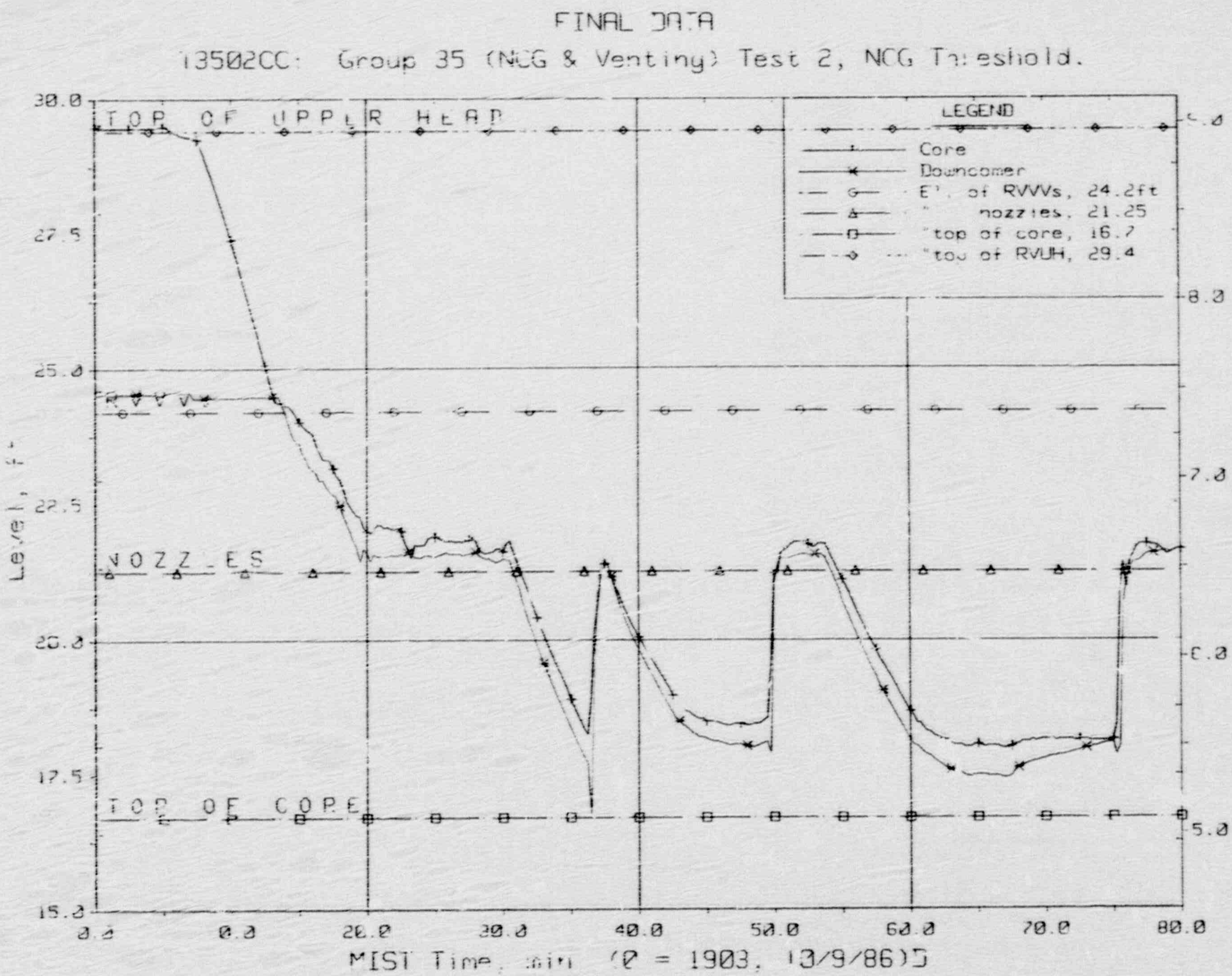

Figure 5.2.5 Core Region Collapsed Liquid Levels

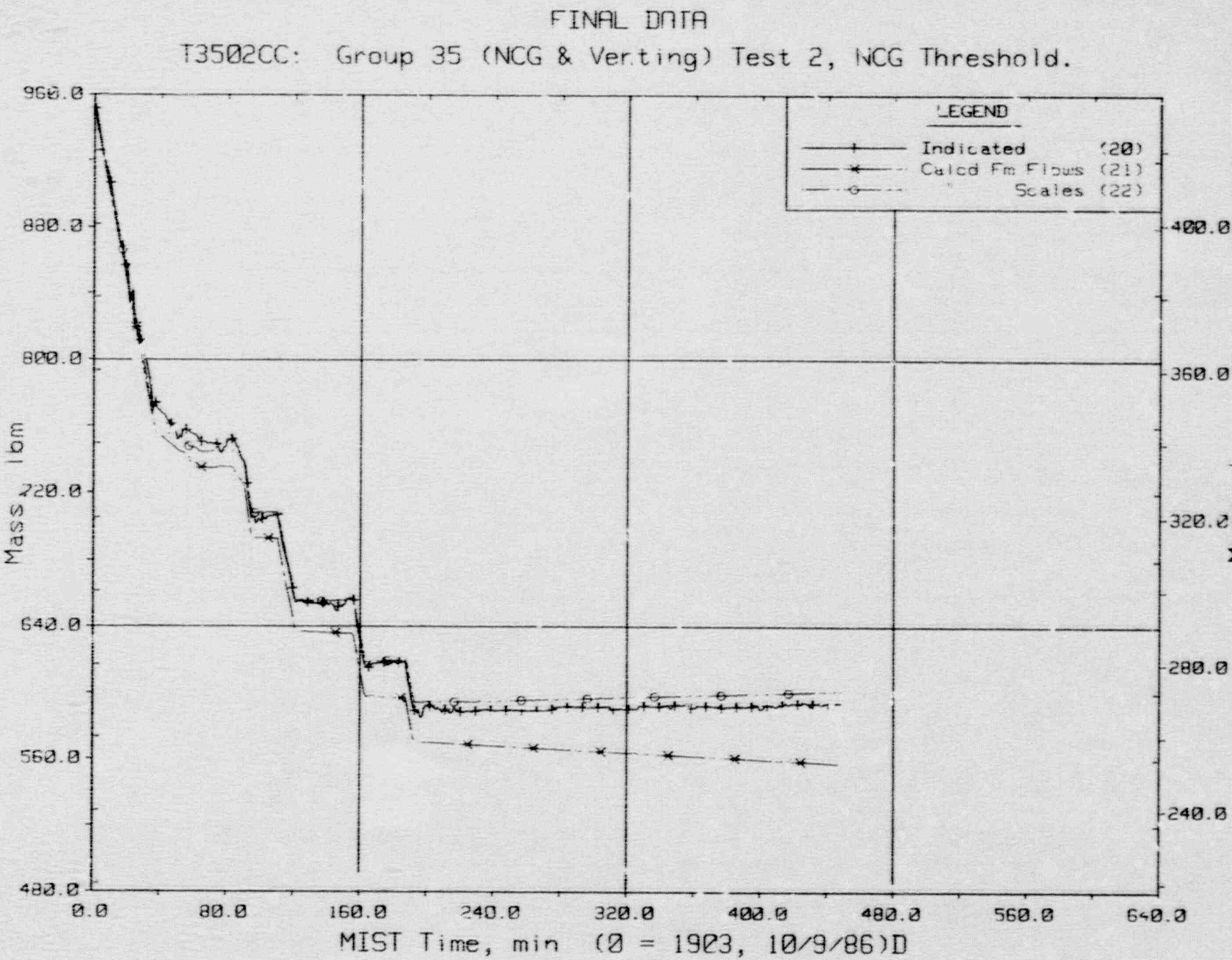

Figure 5.2.6 Primary System Total Fluid Mass (PLMLs)

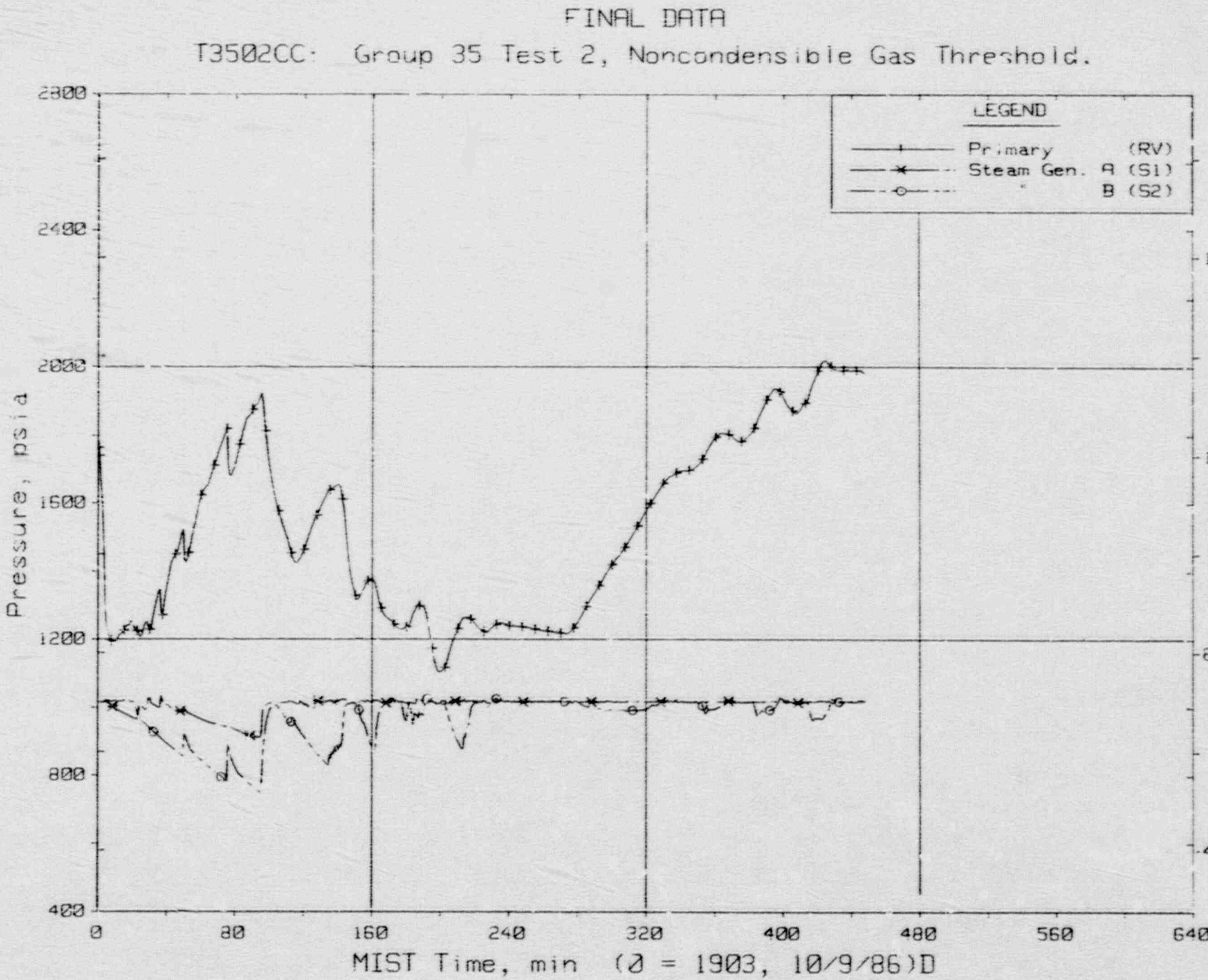

Figure 5.2.7 Primary and Secondary System Pressures (GPOls)

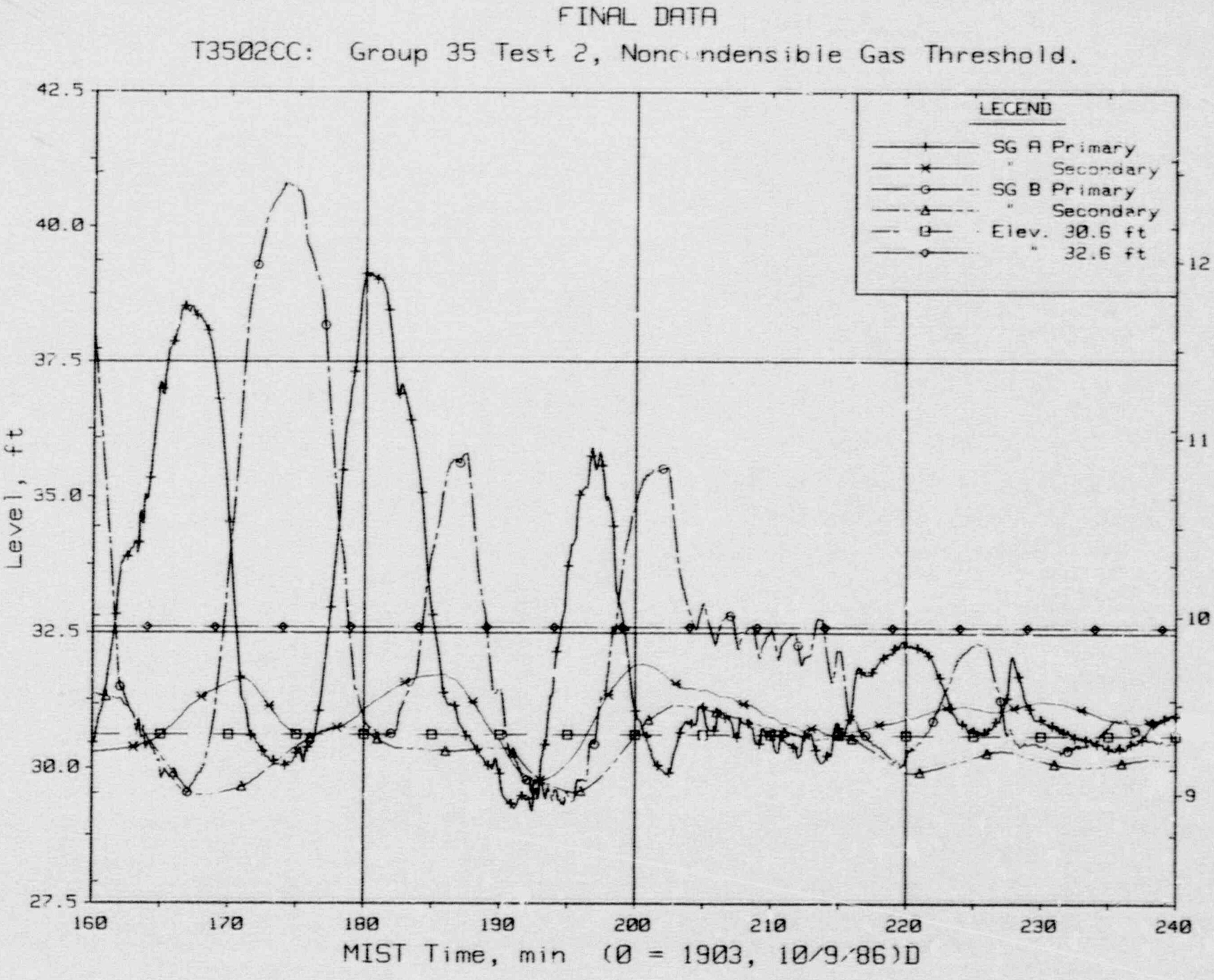

Figure 5.2.8 Steam Generator Collapsed Liquid Levels

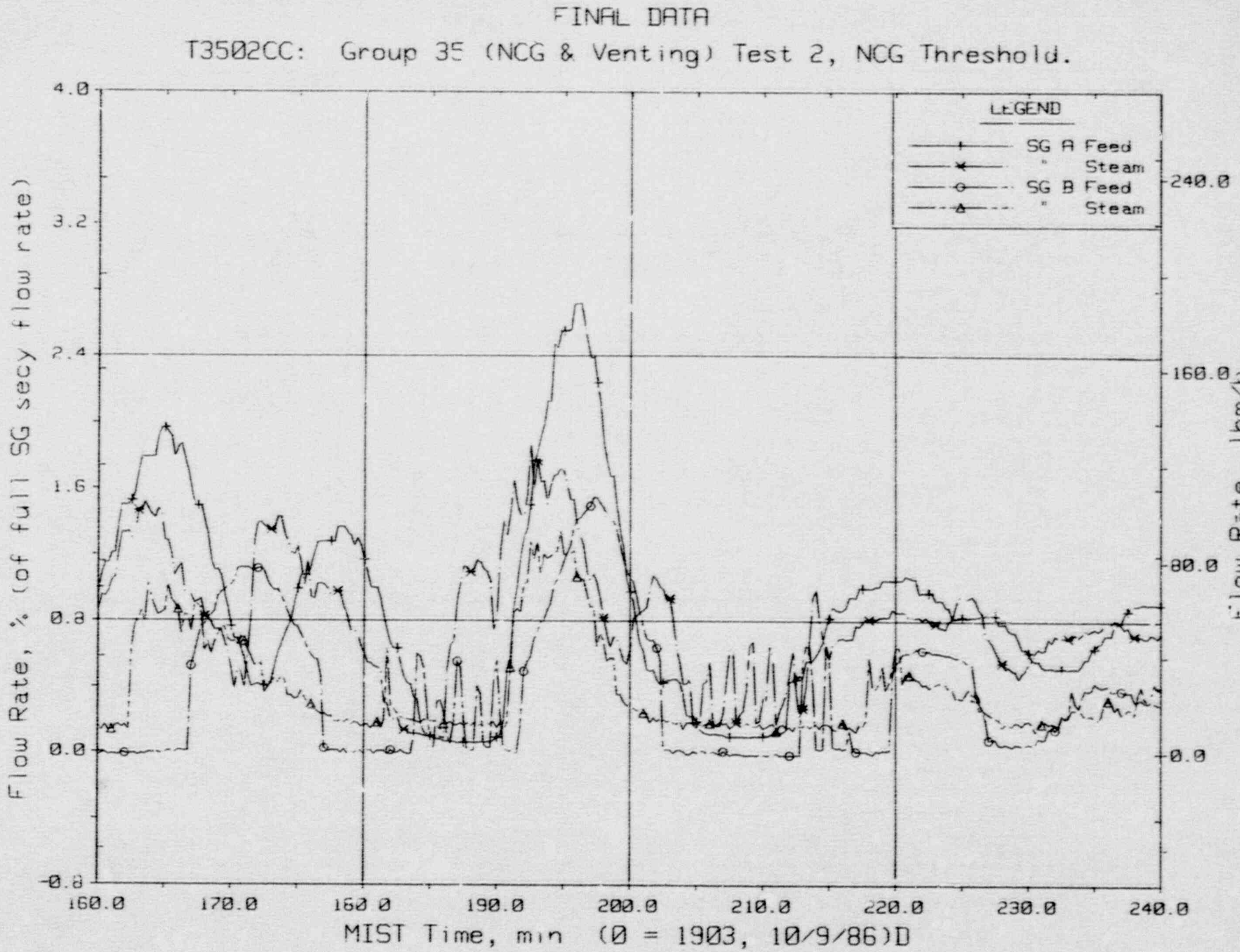

Figure 5.2.9 Secondary System Flow Rates

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IMAGE EVALUATION TEST TARGET (MT-3)

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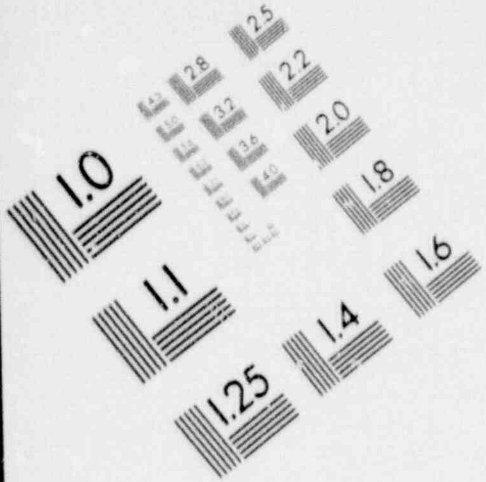
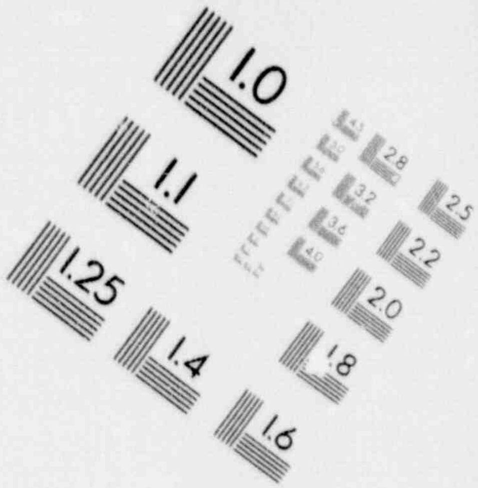
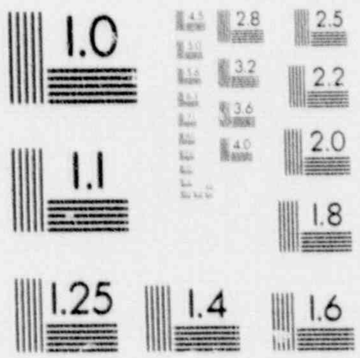
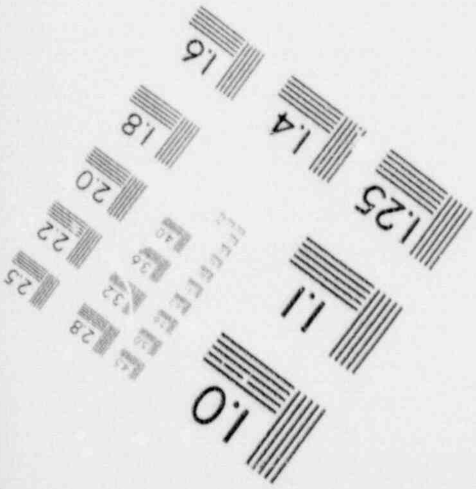
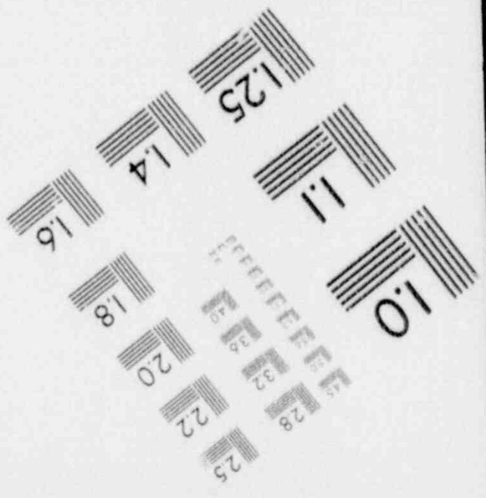
IMAGE EVALUATION TEST TARGET (MT-3)











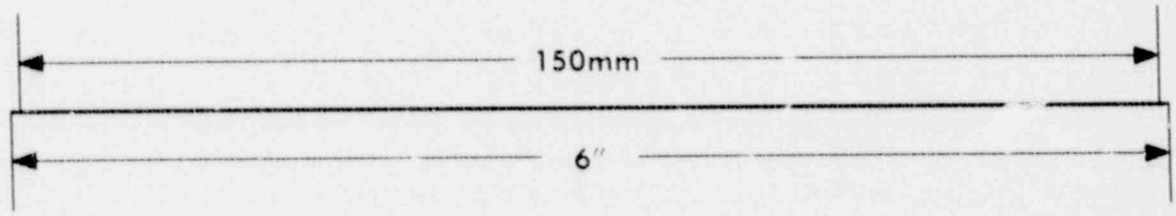


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IMAGE EVALUATION TEST TARGET (MT-3)

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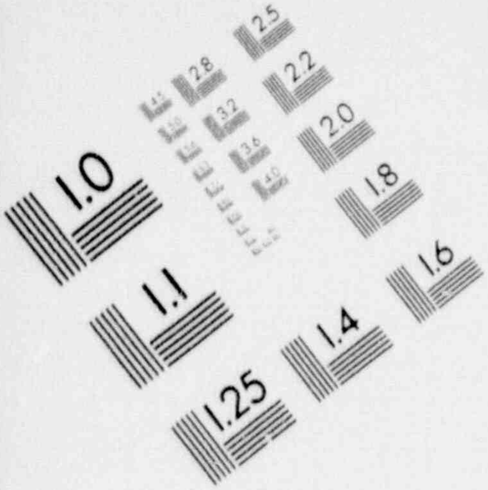
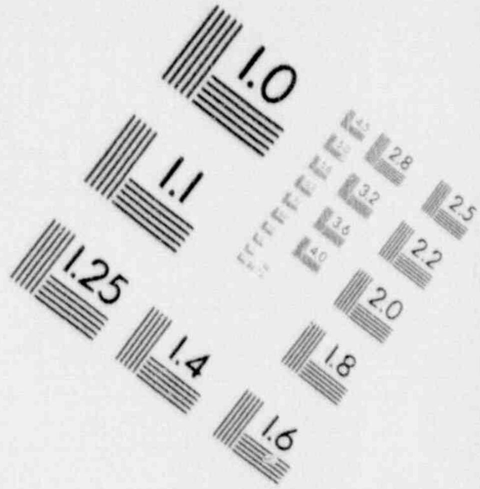
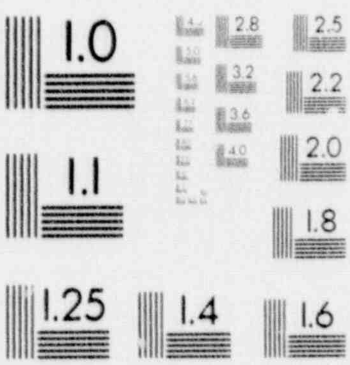
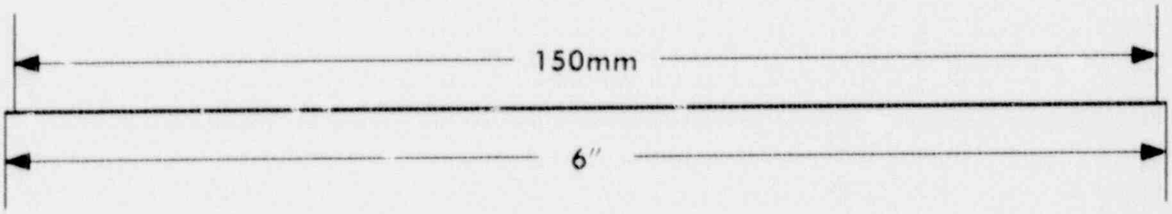
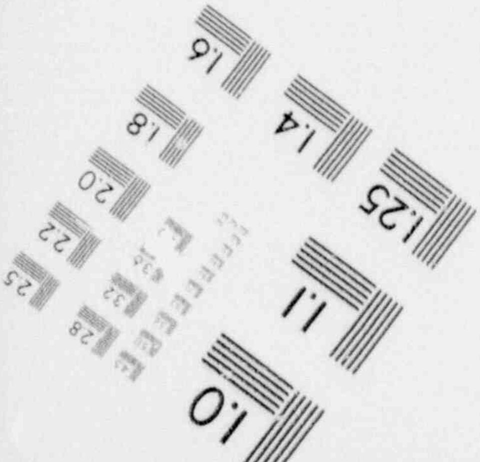
IMAGE EVALUATION TEST TARGET (MT-3)

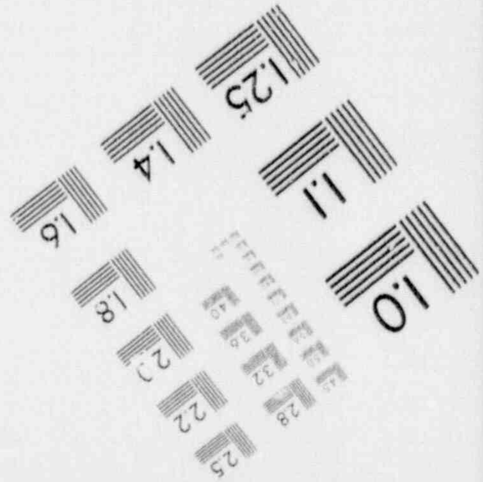












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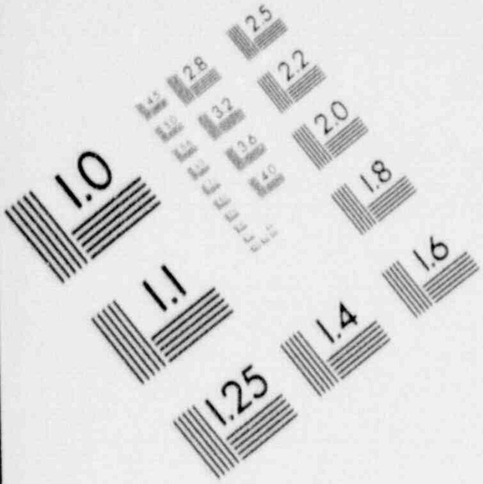

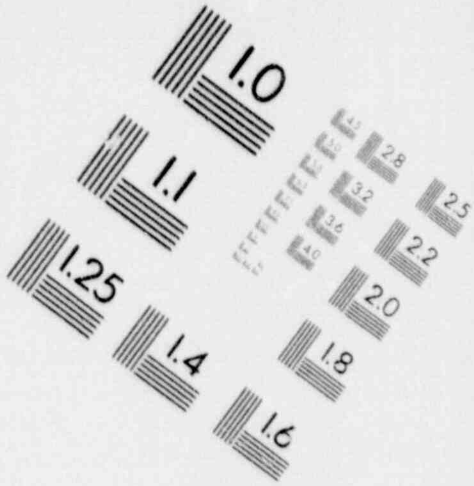

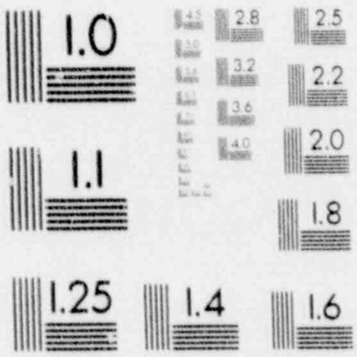

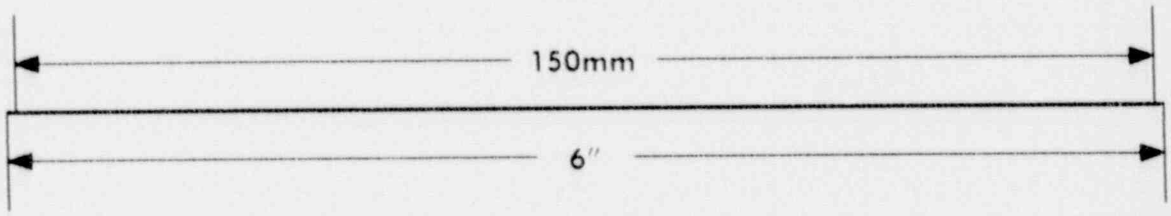

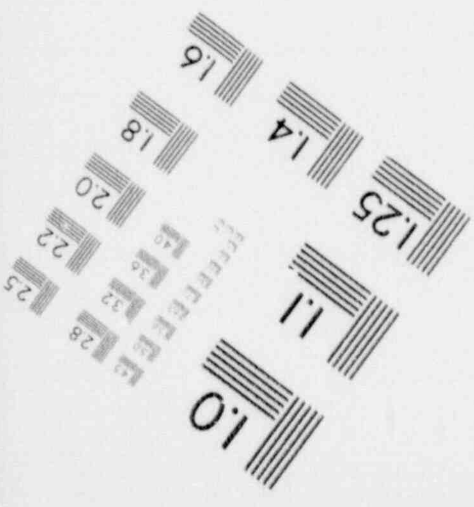

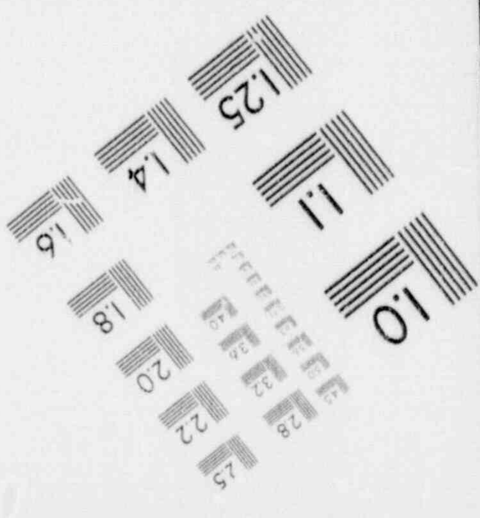

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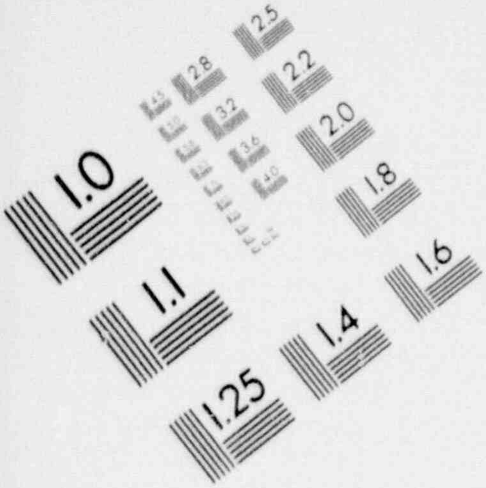

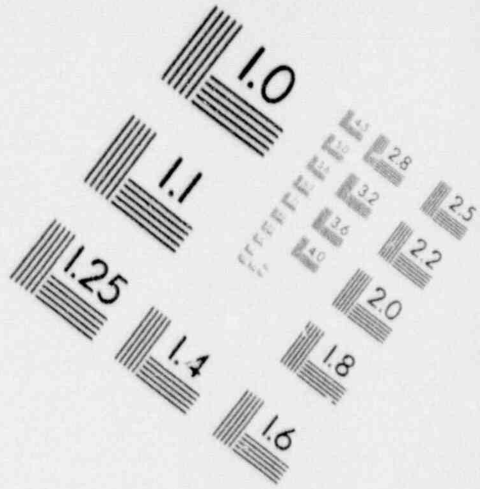

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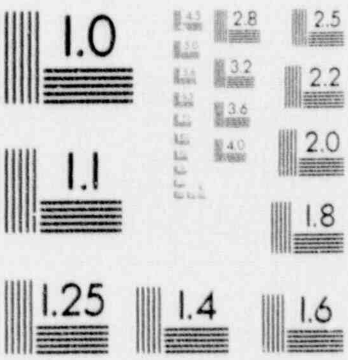
IMAGE EVALUATION TEST TARGET (MT-3)



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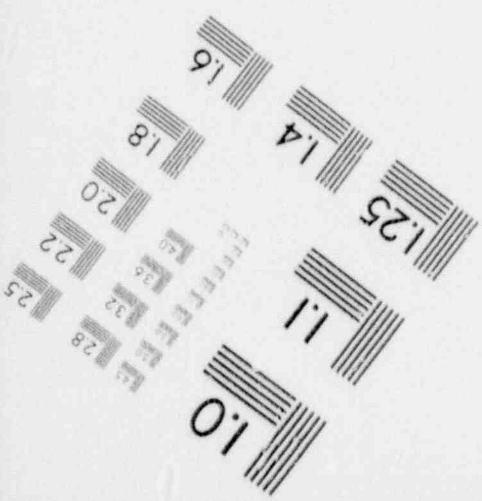

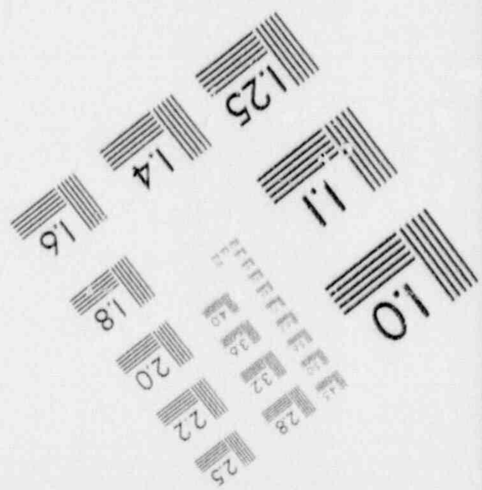

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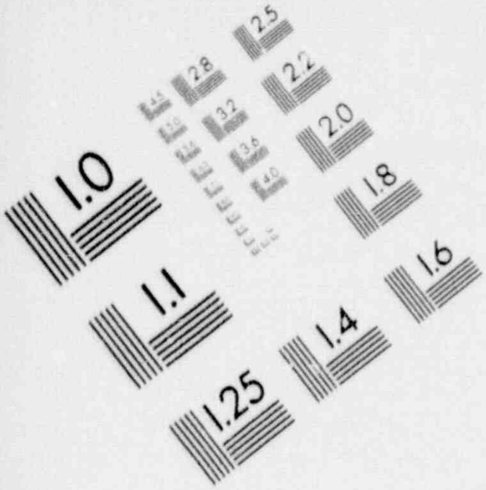
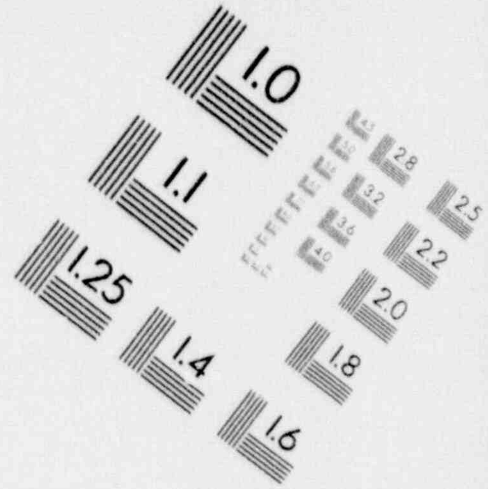
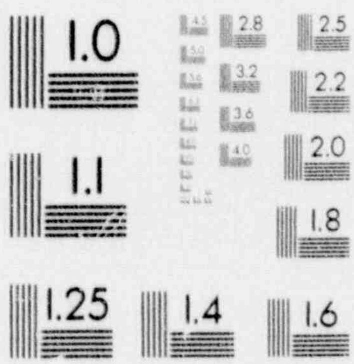
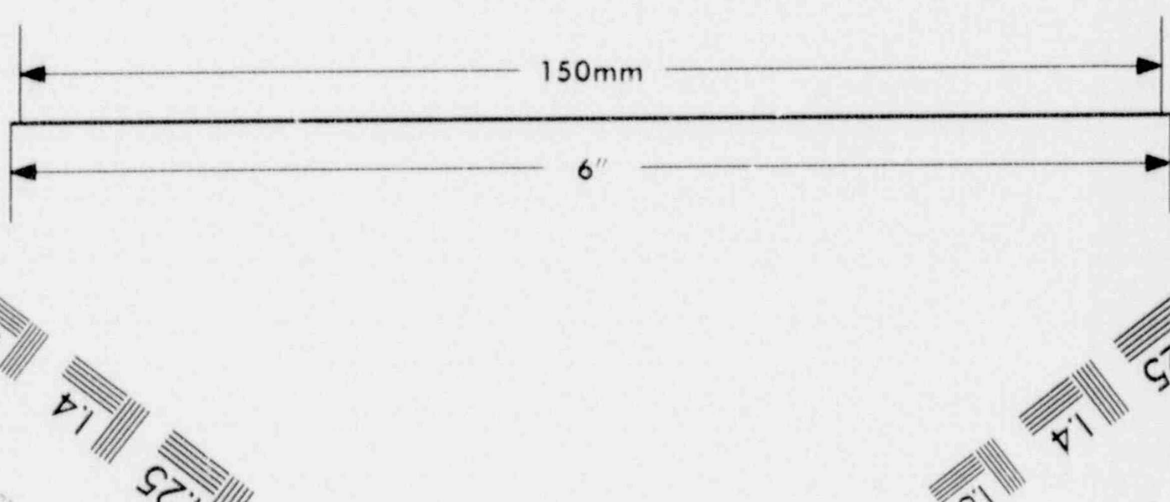
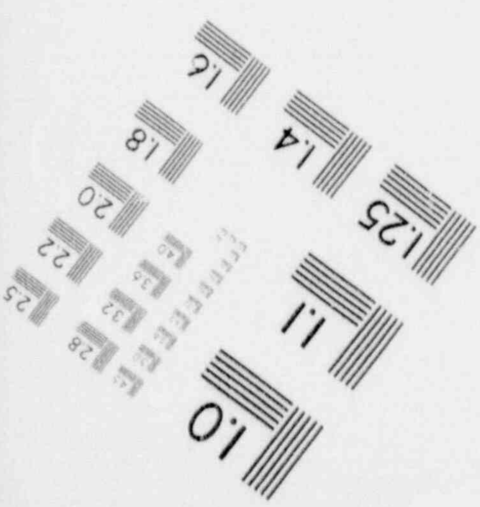
IMAGE EVALUATION TEST TARGET (MT-3)











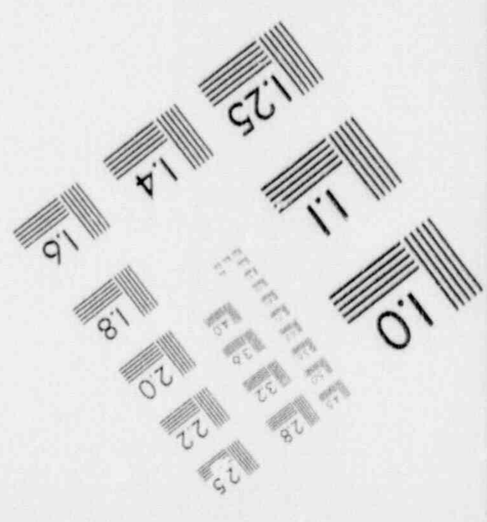


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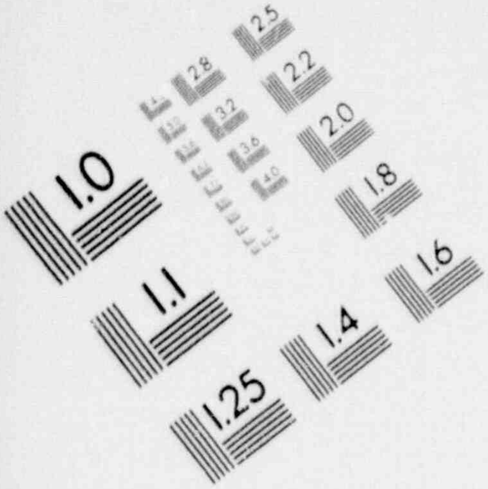
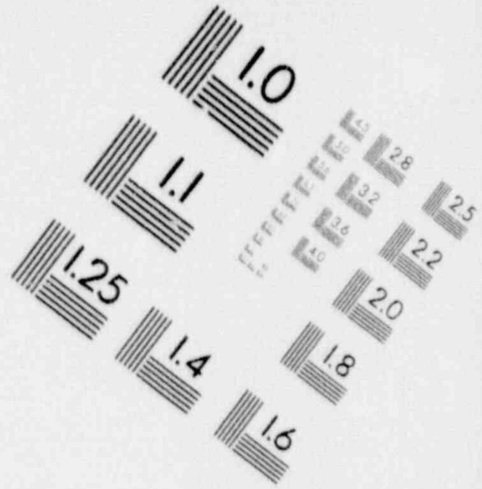
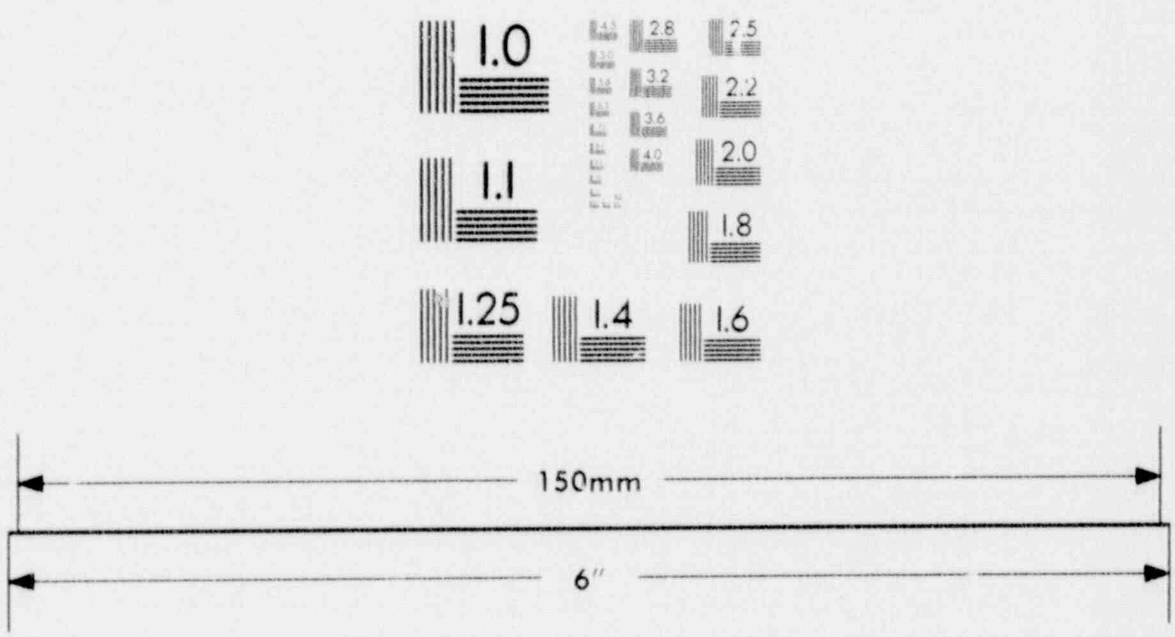
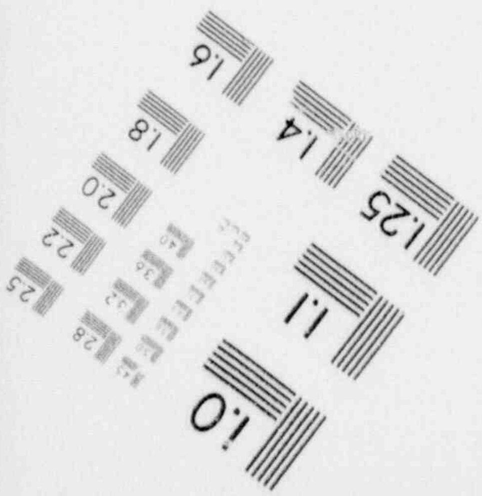
IMAGE EVALUATION TEST TARGET (MT-3)









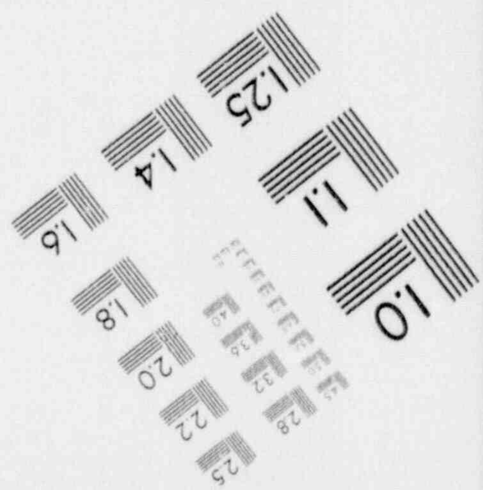


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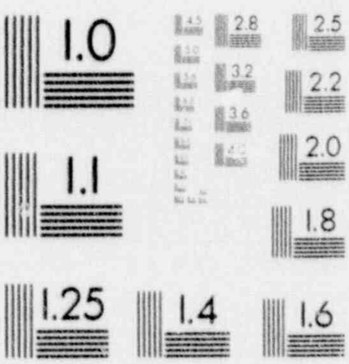
IMAGE EVALUATION TEST TARGET (MT-3)



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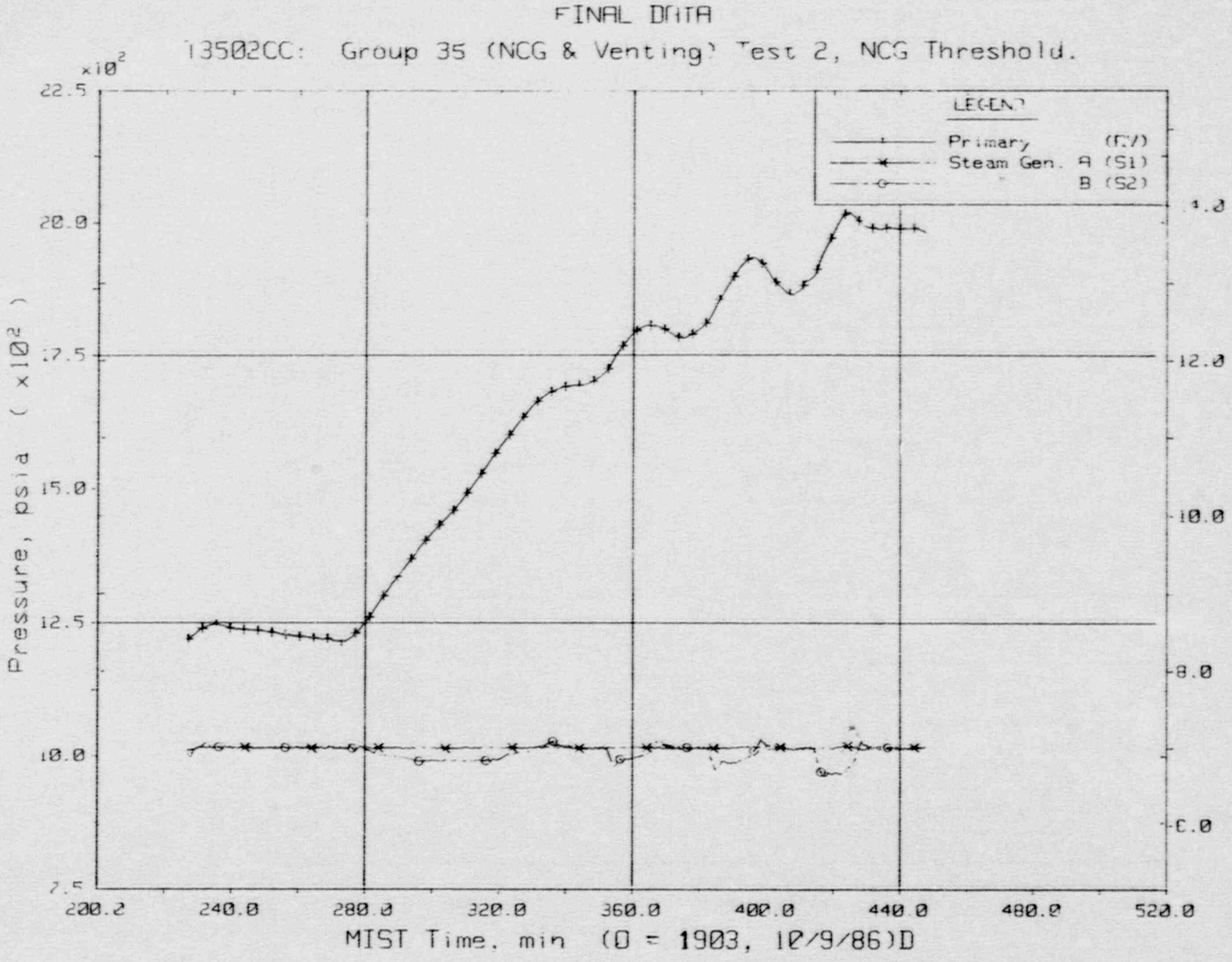

Figure 5.2.10 Primary and Secondary System Pressures (GP01s)

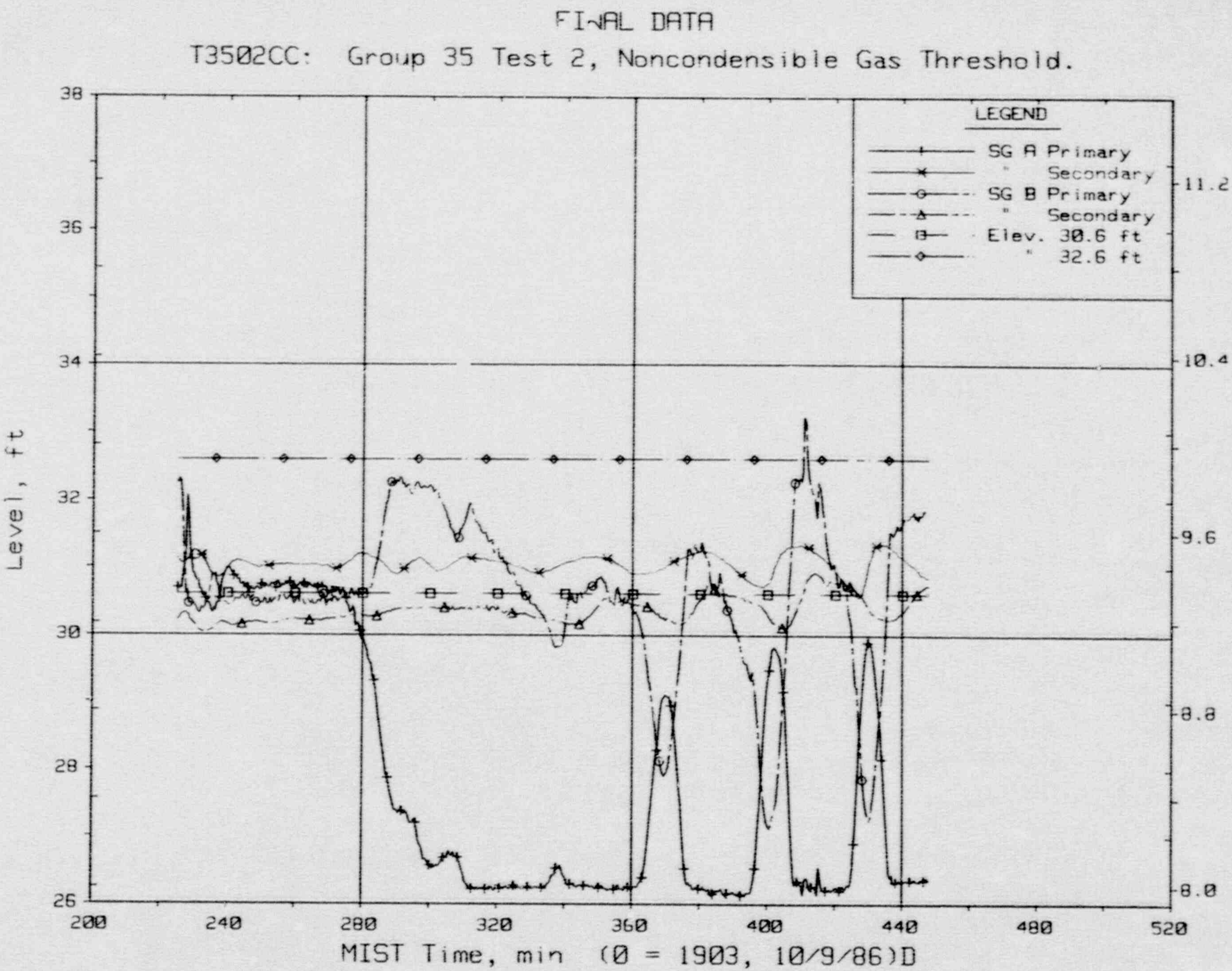

Figure 5.2.11 Steam Generator Collapsed Liquid Levels

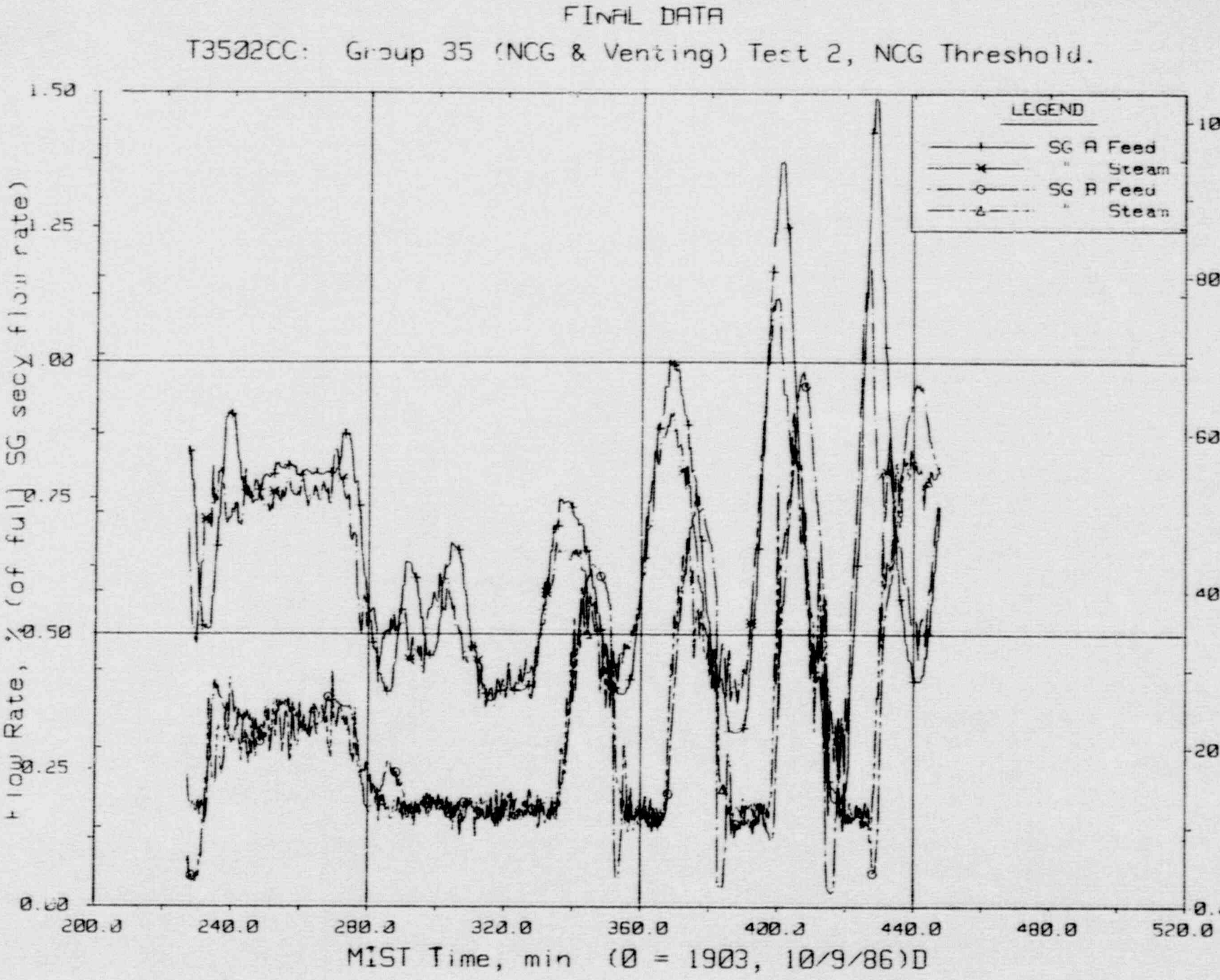

Figure 5.2.12 Secondary System Flow Rates

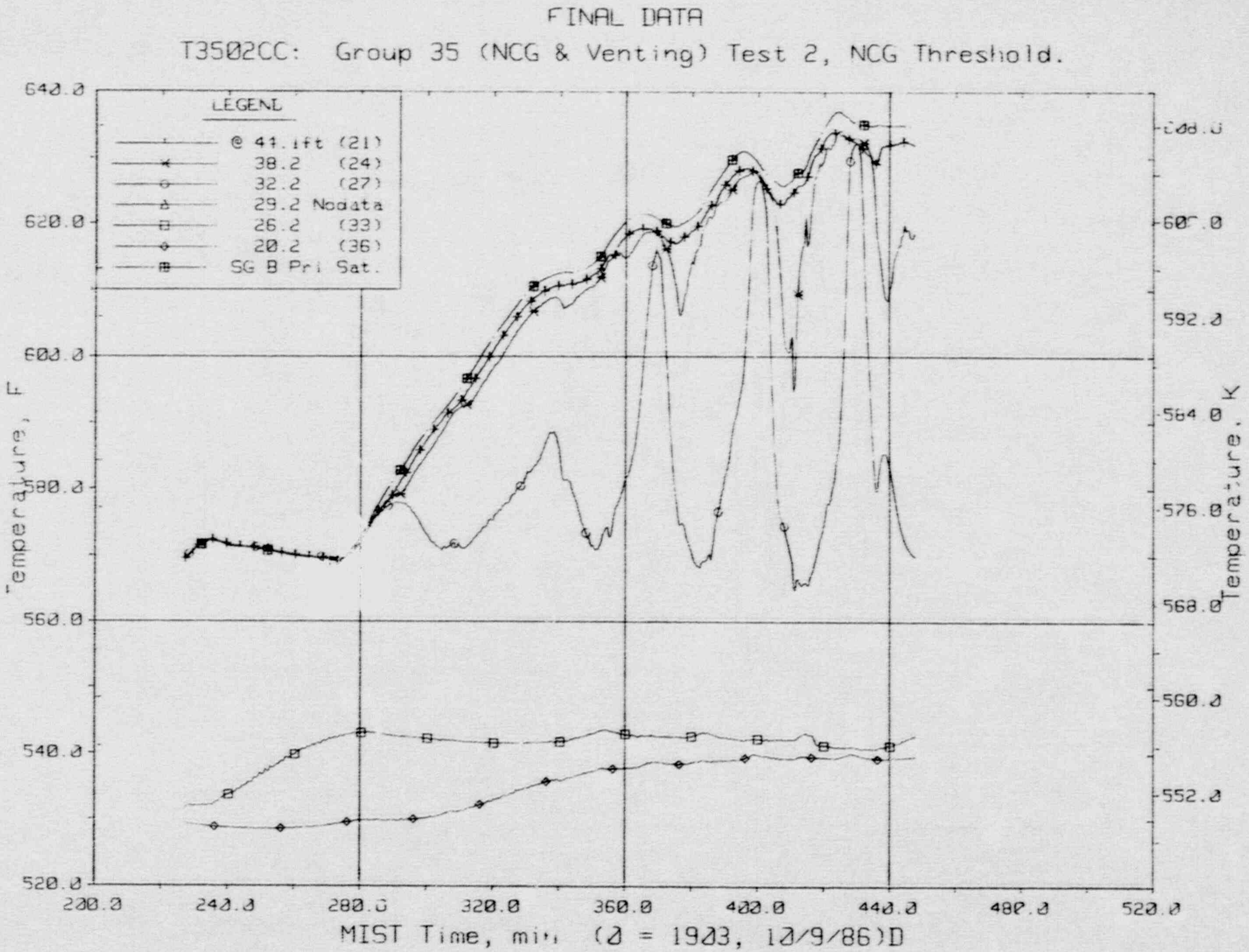

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Figure 5.2.13 Steam Generator B Central Tube (A) Mid-Elevation Primary Fluid Temperatures (P2TCs)

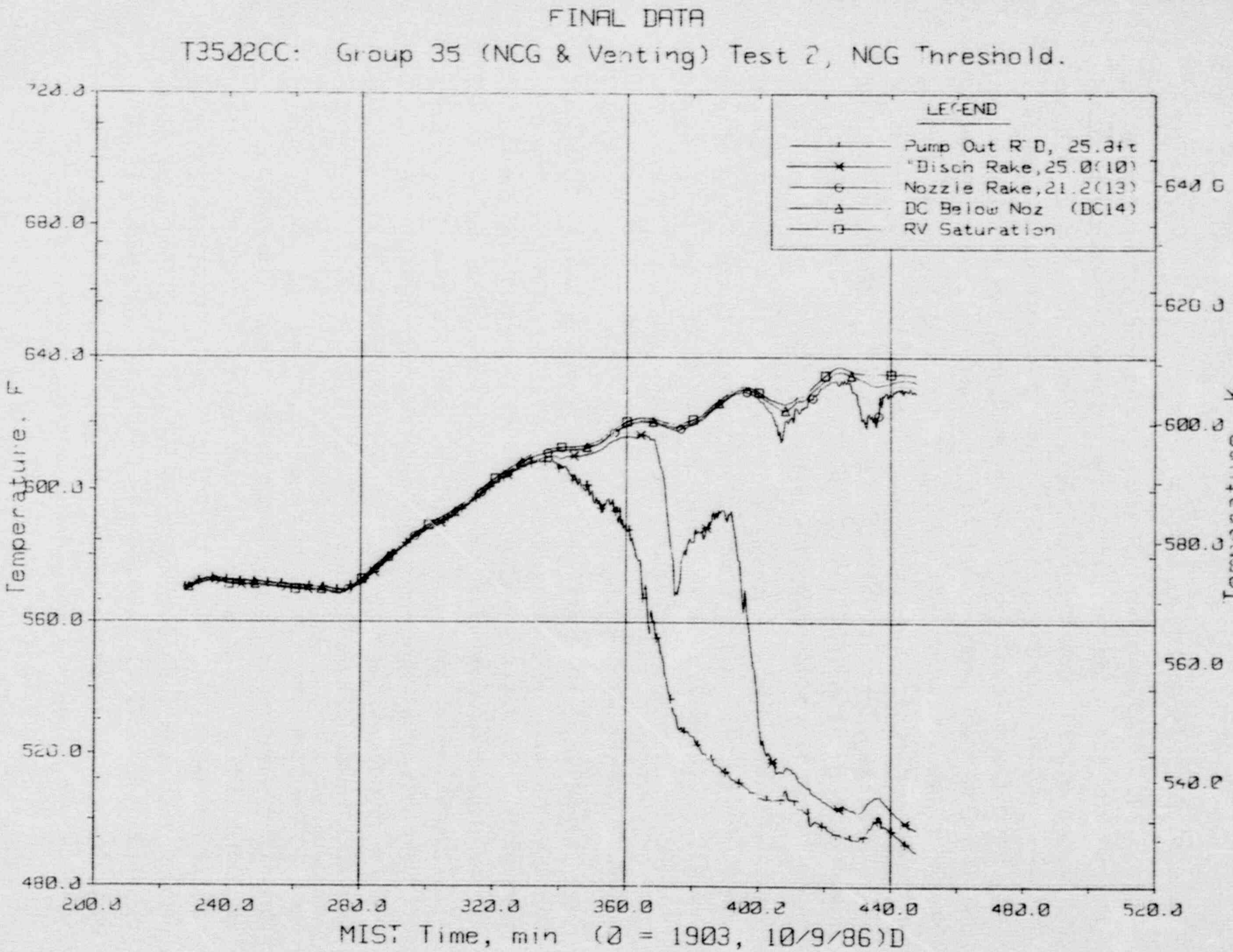


Figure 5.2.14 Cold Leg A1 Discharge Fluid Temperatures (C1TCs)

5.3. Hot Leg Venting, Tests 1, 3, and 5

Tests 1, 3, and 5 involved differences in noncondensibles and hot leg venting. In each of the three tests, the system was initialized in natural circulation without noncondensibles. A cold leg B1 scaled 10-cm^2 leak was opened to initiate each test. Both hot leg high-point vents were opened at test initiation in Tests 1 and 3, but the vents were kept closed in Test 5. Helium injection was begun at test initiation in Tests 3 and 5, but noncondensibles were not introduced in Test 1. The three tests thus involved different combinations of venting and noncondensibles. Test 1, Venting Without Noncondensibles, is described in section 5.3.1. Test 3, Venting With Noncondensibles, is described in section 5.3.2. Section 5.3.3 provides a description of Test 5, Noncondensibles Without Venting.

Inter-test comparisons are provided in section 5.3.4. Tests 1 and 3, compared in section 5.3.4.1, both used venting but with and without noncondensibles. Noncondensibles were used in both Tests 3 and 5, which are compared in section 5.3.4.2, but with and without venting.

5.3.1. Venting Without NCG, Test 1

Both of the hot leg high-point vents were kept open in Test 1 (35010[illegible]), and noncondensible gases were not employed. The resulting transient, compared to those with similar boundary conditions but with no venting, was more benign. The hot legs drained relatively symmetrically, the voided hot leg U-bend fluid cooled during the depressurization phase, the primary system was refilled, and circulation was reactivated relatively rapidly. An unusual RVVV configuration was encountered. The conditions that would have triggered asymmetric hot leg venting were not met.

The Test 1 transient was similar to those without venting during the earlier portions of the transient, but diverged as the transient progressed. The voided U-bend fluid cooled rather than remaining at an approximately constant temperature, and the hot legs refilled rapidly. One spillover event occurred with the vents open. The perturbation of the system conditions accompanying this single spillover was less pronounced than has been commonly observed. Owing to the earlier refill with the vents open, the primary system depressurization and subsequent test completion were similarly advanced.

Depressurization, Saturation, and Voiding

The primary system depressurized at 180 psi/min upon leak and vent actuation, stabilizing below 1480 psia at 1.7 minutes (Figure 5.3.1). The second group of test-initiating actions was performed just before the saturation of the primary loop fluid, with their effects almost coinciding with saturation. The hot leg levels first receded from the elevation of the U-bends at 2 minutes (Figure 5.3.2). The subsequent trends in hot leg levels were not as asymmetric as those observed with no hot leg venting during the period of intermittent circulation. However, the riser level in the loop A hot leg did deplete more than that in loop B. The hot leg riser levels in both loops finally remained below the U-bends after 11 minutes. The core-region fluid began voiding at 3 minutes, coinciding with the saturation of the core exit fluid.

Intermittent Circulation

The core-region collapsed liquid level had descended to the RVVV elevation, and the downcomer had begun to void at 8.5 minutes (Figure 5.3.3). Then, the often observed interactions involving core exit subcooling occurred. The hot leg riser levels attained the U-bend spillover elevation at 8.5 minutes and again at 11 minutes (Figure 5.3.2). On both occasions, loop flow reactivated (Figure 5.3.4), causing the core exit fluid to subcool (Figure 5.3.5). The primary system depressurized slightly (Figure 5.3.1), the RVVVs closed with the interruption of core vapor generation (Figure 5.3.6), and the downcomer level decreased (whereas the core-region level stabilized) due to the depressurization flashing of the upper downcomer fluid (Figure 5.3.3). These interactions were reversed when the hot leg riser levels receded from the spillover elevation (Figures 5.3.1 through 5.3.6). That is, the loop flow rate diminished, the core exit fluid saturated, the primary system repressurized slightly, and the RVVVs reopened. Now, the rate of downcomer level decrease slowed whereas the core-region level declined.

HPI Condensation

These interactions were halted at 13 minutes. The downcomer level descended to the nozzle elevation at 11 minutes, providing an additional flow path for core-generated steam. The primary system repressurized slightly, the RVVVs reopened (and stayed open), the hot leg riser levels receded from the U-bend and remained depleted, loop flow stagnated near 12 minutes, and the core exit fluid remained saturated beyond 12.5 minutes. The primary system depressurization continued at some 15 psi/min, even though both steam generators were now largely inactive. Apparently, the condensation of core-generated vapor in the cold legs and downcomer, following the voiding of the upper downcomer and the actuation of the RVVVs, was key to the primary system volume balance, and hence, to the primary system pressure variations.

The refill of the steam generator secondaries was completed at 9 minutes. Both generators, then at 680 psia (Figure 5.3.1), repressurized following refill due to the continuing and intermittent primary-to-secondary heat transfer. Inter-cold leg flow began in loop B at 12.5 minutes (Figure 5.3.4). Backflow in cold leg B1 heated the leak site fluid, abruptly decreasing the leak flow rate at 13 minutes (Figure 5.3.7). The steam generator secondary systems remained generally inactive until 45 minutes. The continuing discharge from the hot leg high-point vents cooled the U-bend fluid at about 37F/h (Figure 5.3.8).

BCM

The steam generator control pressure had been reduced (at the equivalent of 100F/h) to the current secondary pressures at 40 minutes. The steam generators became active; the reactivated AFW condensed primary system vapor near the site of feed introduction (AFW-BCM), depressurizing the primary system from 875 psia at 45 minutes toward the secondary pressures (Figure 5.3.1). Before this activity, the steam generator A secondary pressure was somewhat higher than that of steam generator B, and thus, the loop A activity was greater than the loop B activity. The initial difference in pressures was apparently caused by the unequal steam generator primary levels, which had diverged gradually beyond approximately 20 minutes (Figure 5.3.2). The primary system depressurization beginning at 45 minutes triggered about 15 minutes of increased voiding in the cold leg B1 discharge piping. The leak site fluid approached saturation, the leak flow rate decreased, and the primary system began to gain fluid mass (Figure 5.3.7).

Refill

The hot legs refilled relatively rapidly, indicating the effects of continuous hot leg venting. After the steam generator primary levels exceeded the tubesheet elevation at 90 minutes, the hot leg riser and stub levels rose almost linearly (Figure 5.3.9) at 15 ft/h. The riser level in loop A achieved the spillover elevation at 138 minutes. The maximum primary system pressure preceding spillover was only 480 psia (Figure 5.3.10) versus more than 600 psia commonly observed without venting. Rather than multiple spillovers, loop A remained full and immediately began to circulate. The core region and downcomer refilled to the vicinity of the RVVVs and the core outlet fluid subcooled. However, the loop B hot leg levels decreased due to the following combined effects:

- Fluid diversion to other components.
- Fluid contractions with the general primary system cooldown.
- The increased rate of discharge out the (refilled) loop A vent.
- Flashing of the saturated loop B fluid upon primary system depressurization.

This loop B voiding was enhanced beyond 177 minutes (Figure 5.3.9). The core exit subcooling margin (SCM) reached the control point of 75F and automatic HPI throttling commenced. The performance of the RVVVs was noteworthy.

RVVV Behavior

The RVVVs had closed upon the reestablishment of circulation in loop A, but opened intermittently as the reactor vessel and downcomer levels varied near the RVVV elevation, causing the pressure difference across the valves to fluctuate between the opening and closing setpoints. RVVV A2 opened much more frequently than the other valves (Figure 5.3.11), apparently due to the minute differences among the valve actuation setpoints. At 176 minutes, HPI throttling was begun and the vent valve differential pressures abruptly stabilized between the actuation setpoints (Figure 5.3.12). However, RVVV A2 had opened just as the pressure difference stabilized. Thus, the valves ceased to actuate with 3 valves closed and 1 open (Figure 5.3.13). As the core region continued to slowly refill and subcool, the downcomer fluid beyond the open RVVV A2 cooled correspondingly (Figure 5.3.14), but that beyond the closed vent valves cooled much more slowly (Figure 5.3.15). The fluid temperature difference across the open vent valve remained near zero, but those across the closed vent valves decreased to as low as -38F (Figure 5.3.16). The maximum difference among downcomer fluid temperatures at the RVVV elevation peaked at 46F (Figure 5.3.17). This unusually large difference among circumferential RVVV discharge fluid temperatures dissipated locally within the downcomer. The maximum difference among the downcomer fluid temperatures immediately below the RVVVs increased only a few degrees (Figure 5.3.17).

The test was terminated at 290 minutes based on the dual criteria of less than 400 psia primary system pressure and more than 50F SCM for at least 2 hours. The loop B hot leg riser and stub levels were gradually increasing at 3.6 ft/h, but remained some 9 feet below the spillover elevation (Figure 5.3.9). Both of the hot leg high-point vents were kept open for virtually the entire test, and asymmetric venting was not employed.

5.3.2. Venting With NCG, Test 3

In Test 3 (350312), helium was injected at the lower reactor vessel and both hot leg high-point vents remained open. The scaled 10-cm^2 cold leg B1 discharge break remained open during the beginning phase of the test and was closed for the second phase. The initial interactions, although similar to those generally observed, were dissimilar in two ways. The loops saturated and interrupted relatively symmetrically, and the steam generator feed rates were unequal from the onset of the refill period. After leak isolation, PORV actuations and HPI throttling were used to control subcooling and pressurizer level.

Approximately 60 scf of helium were injected at a rate of 33 scf/h. Approximately one-half of the injected gas was apparently discharged out the cold leg discharge break. There were some indications of lingering NCG effects in the cold leg and downcomer regions. For example, after the refill of the hot legs, flow was reactivated in only one of the four cold legs. NCG effects notwithstanding, the system was readily cooled and depressurized.

Initiation

The test was begun by opening the scaled 10-cm^2 cold leg (B1) discharge leak, opening both hot leg high-point vents, and initiating the helium injection. Helium was introduced into the reactor vessel lower piping. At 1.5 minutes, the descending pressurizer level triggered the second set of test-initiating actions. The steam generator secondary control levels were reset to 31.6 ft, full-capacity HPI was activated, the core power decay ramp was activated, the RVVV controls were transferred to automatic/independent, and the steam generator secondary pressure controls were transferred from constant pressure to ATOG control. The feed rate to steam generator A increased to almost 12% of the scaled full feed rate, as intended, but the feed rate to generator B increased anomalously to only two-thirds of this value (Figure 5.3.18). This feed rate difference was confirmed by the steam generator secondary level rises. Steam generator A reached the control level of 31.6 feet at 9 minutes, whereas the refill in generator B was delayed until after 12 minutes (Figure 5.3.19).

The unequal steam generator feed rates may have affected the initial inter-loop asymmetries, which were less pronounced than have often been encountered. Both hot leg stub levels receded from the U-bend at 2.5 minutes, and both hot leg riser levels similarly receded at 12 minutes (Figure 5.3.20). During the refill of the steam generator secondaries, generator A depressurized to 675 psia and generator B depressurized only to 825 psia.

Many of the initial interactions were similar to those observed without NCGs and venting. The primary system depressurization slowed at 2 minutes and 1500 psia as the primary loop fluid saturated (Figure 5.3.21). The core-region collapsed liquid level began to decrease at 3 minutes as the uppermost reactor vessel volume began to evidence voiding. The core exit SCM first reached zero at 3 minutes, but the core exit fluid intermittently subcooled up to 13 minutes (Figure 5.3.22) when loop flow reactivated (Figure 5.3.23). From 9 to 13 minutes the RVVVs, which had been open, generally closed as the downcomer level descended toward the nozzle elevation (Figure 5.3.24).

NCG Migration

The initial gas collection rate was nearly 5 scf/h versus the addition rate of 33 scf/h (Figure 5.3.25). The excess of the addition rate over the venting rate was presumably going into solution and to the several expanding vapor zones within the primary system. The loop B1 cold leg suction and discharge piping first began to void at 25 minutes (Figures 5.3.25 and 5.3.27), and the loop B1 cold leg discharge level stabilized near the leak elevation at 36 minutes. As the loop B1 discharge piping began to void, the gas venting rate abruptly diminished to about 0.2 scf/h (Figure 5.3.28). Thus, the injected NCG appeared to be flowing through the core, out the RVVVs to the downcomer, upward through the loop B1 cold leg discharge piping, and out the break. The measured break flow rate became extremely variable beyond 40 minutes (Figure 5.3.29), supporting the observation that NCG was interspersed with the break flow. The loop vapor temperatures indicated no NCG effects, such as by the apparent depression of the saturation temperature. The NCG flow rate out the break necessary to satisfy gas closure was approximately 15 scf/h.

The leak-site fluid temperature gave a strong indication of NCG effects. Although the cold leg B1 discharge level reached the break elevation at 36 minutes, the break fluid temperature remained as much as 35F subcooled (Figure 5.3.30). The pressure change associated with this depression of the apparent saturation temperature indicated the local NCG concentration. For example, the saturation pressure at 36 minutes based on the total primary system pressure was 550F, but the leak site fluid temperature was 500F. The saturation pressures corresponding to these temperatures were 1045 and 681 psia. The difference between these pressures (364 psi) divided by the total pressure gave an estimate of the NCG concentration. By this method, the NCG concentration at the leak site was about 30% beyond 40 minutes.

BCM, Start of Refill

Both steam generator secondaries became active beyond 45 minutes, causing the rate of primary system depressurization to increase somewhat near 50 minutes (Figure 5.3.31). Both steam generator primary levels were several feet below the feed injection site (Figure 5.3.32), therefore the primary-to-secondary heat transfer and primary system depressurization reflected the AFW-BCM, the condensation of primary system vapor near the site of feed introduction.

As a result of the primary-to-secondary heat transfer beginning at approximately 50 minutes, the HPI mass flow rate began to exceed the combined mass flow rates of the leak and vents beyond approximately 55 minutes (Figure 5.3.29). Unlike the interactions observed in similar tests with no NCG, the void distribution shifted as the primary system began to refill. The core-region collapsed liquid level gradually increased from the nozzle elevation toward the RVVVs, but the downcomer level remained near the nozzles (Figure 5.3.33). The hot leg riser and steam generator primary levels of both loops began to rise (Figure 5.3.32), but the cold leg suction and discharge piping of all four cold legs continued to void (Figures 5.3.26 and 5.3.27). The loop A cold leg discharge piping drained completely by 60 minutes, the B2 by 65 minutes; the B1 discharge level remained near the break elevation.

NCG Indications

The upper downcomer fluid temperatures gave weak indications of NCG effects beyond approximately 90 minutes. The vapor temperature measurements dropped approximately 5F below the current saturation temperature (Figure 5.3.34). The corresponding saturation pressure reduction of 31 psi was approximately 5% of the current total pressure. The NCG concentration in the upper downcomer was thus approximately 5%. The compressed volume of the upper downcomer NCG was small, on the order of 0.01 ft^3; this corresponded to approximately 1/4 ft^3 at standard conditions. The core exit fluid SCM displayed an even smaller increase during the same period, reflecting a slight concentration of NCG at the core exit.

The hot leg riser levels in both loops indicated full at 85 minutes (Figure 5.3.35). The cold leg flow rates began to register. Near 85 minutes, both steam generator secondaries became active (Figure 5.3.36), the primary system depressurized more rapidly (Figure 5.3.37), and the cold leg suction piping began to refill from as low as 17 feet, 9 feet below the cold leg spillover elevation (Figure 5.3.38). The loop A cold leg suction piping refilled at 110 minutes and the cold leg flow rates increased briefly, but the indicated loop B cold leg suction levels stabilized about 4 feet below the cold leg spillover elevation. Also at 110 minutes, the helium injection was terminated as specified. A total of 59 scf had been injected. Before the NCG injection was terminated, and although the core region level remained just above the elevation of the hot leg nozzles (Figure 5.3.39), the SCM was slightly positive (Figure 5.3.40). This apparent subcooling abruptly vanished as the NCG injection was halted. The prior subcooling was apparently simply a partial-pressure effect -- the core exit fluid was saturated, but at a pressure less than the total reactor vessel pressure.

Leak Isolation, PORV Actuations

The primary system depressurized to 600 psia at 126 minutes (Figure 5.3.37), triggering the second phase of the test. The leak was closed (Figure 5.3.41) and PORV actuations were used to control SCM. Also, the HPI flow rate and control mode were adjusted to control pressurizer level, SCM permitting. These operator control actions are summarized in Table 5.3.1. The hot leg high-point vents were kept open during phase 2.

Upon leak closure, the primary system repressurized (Figure 5.3.37), the core exit fluid subcooled (Figure 5.3.40), and the RVVVs closed. The core-region collapsed liquid level rose above the RVVVs, and the downcomer level covered the cold leg nozzles (Figure 5.3.39). The cold leg suction piping (Figure 5.3.38) as well as the steam generator primaries quickly refilled. The mass flow rates of the hot leg vents increased (Figure 5.3.41) as the fluid at the vents subcooled. The SCM reached 75F by 135 minutes, precipitating operator control of the PORV and HPI (Table 5.3.1). The NCG venting rate, which had been almost negligible, approached 2 scf/h as the PORV was opened intermittently (Table 5.3.1 and Figure 5.3.42).

The cold leg levels and flow rates apparently reflected the lingering effects of NCG. The cold leg A1 flow rate stabilized at 5% of scaled full cold leg flow, whereas the other flow rates generally remained small and variable (Figure 5.3.43). The indicated cold leg discharge liquid levels, except A1, remained partially voided and variable (Figure 5.3.44). At 220 minutes, the operator increased the HPI flow rate to control pressurizer level. The SCM rapidly increased, triggering manual PORV actuation at 221 minutes. The PORV was kept open from 221 to 299 minutes; the NCG venting rate increased to as much as 7 scf/h, and averaged about 2.5 scf/h over the period during which the PORV was open (Figure 5.3.45). Beyond 306 minutes, the PORV was kept closed and the NCG venting rate decreased to about 0.5 scf/h.

The test was terminated at 420 minutes based on the maximum duration criteria. (Data acquisition was continued for more than 14 hours to record the NCG collection and sampling phase.) At test termination, the flow rate in cold leg A1 had stabilized near 5% of the scaled full flow, but the other cold legs remained largely inactive. Indications of voiding persisted in the inactive cold legs. The loop fluid temperatures were generally subcooled, therefore the remaining loop voids almost certainly contained NCG. The total amount of helium injected plus the initial volume was 60 scf. Approximately 9 scf were vented during testing, another 17 scf were vented following test termination, and about 5 scf remained dissolved in the loop fluid, based on sampling results. The difference, approximately 31 scf, was apparently discharged out the cold leg B1 discharge break.

Table 5.3.1. PORV and HPI Control During the Second Phase of Test 3 (350312)

Table entries give the time in minutes of the indicated action.

Opened PORV (SCM > 70F)	Throttled HPI (PZR Level > 21.4 ft)	Closed PORV (SCM < 60F)	HPI to auto (SCM < 50F)	HPI off
135	137	138	139	
142	141	145	146	144
149	147	151	153	
	155		158	161
166		167	164	166
			168	169
			173	174
			177	177
			180	181
			184	185
221		299	219	299
304		306	300	302
			307	309
			313	315
			321	323
			329	330

Table 5.3.1. PORV and HPI Control During the Second Phase of Test 3 (350312) (Cont'd)

Opened PORV (SCM > 70F)	Throttled HPI (PZR Level > 21.4 ft)	Closed PORV (SCM < 60F)	HPI to auto (SCM < 50F)	HPI off
	338		337	
	343		342	
	359		358	
			363	364
			376	377
			386	387
			391	391.1
			396	397
			403	404
			406	408
	417		416	

(Test terminated at 420 minutes)

5.3.3. NCG Without Venting, Test 5

Noncondensibles without (hot leg) venting were used in Test 5 (350502). Much of the injected NCGs was discharged out the cold leg discharge break. The primary system pressure gradually decreased and then stabilized, generally without steam generator heat removal. The NCG inhibited steam generator heat transfer even with primary levels conducive to the BCM.

Initiation

The gas injection was initiated upon leak actuation at time zero. The remaining test-initiating actions were conducted between 1.8 and 2.1 minutes as the pressurizer drained. These actions included increasing the steam generator secondary level setpoint, activating HPI, beginning the core power decay ramp, transferring the RVVV controls to automatic and independent, and transferring control of the steam generator secondary pressure to ATOG. The hot leg high-point vents were not opened in this test. The AFW flow rate increase (in response to the increase of the steam generator secondary level setpoints) was not symmetric, apparently reflecting a control system malfunction. The feed rate to steam generator A increased to 10% of the scaled full steam generator secondary flow, whereas the feed rate to steam generator B increased to only 8% and then gradually rose to 10% during the ensuing refill for the steam generator secondaries (Figure 5.3.46).

In response to leak actuation, the primary system depressurized to 1475 psia by 3 minutes. Pressure then stabilized in response to primary saturation (Figure 5.3.47). The primary system again depressurized beyond 12 minutes, at more than 10 psi per minute, as the downcomer level descended to the elevation of the cold leg nozzles (Figure 5.3.48), thus allowing condensation of core-generated steam on the relatively cold HPI fluid.

NCG Indications

Both hot leg U-bends voided intermittently and symmetrically until 12 minutes (Figure 5.3.49) and then voided continually thereafter. The steam generator secondaries became quite inactive after the initial refill of their secondary sides and remained inactive until nearly 1 hour (Figure 5.3.46). Cold leg voiding began during the first hour. The (broken) cold leg B1 discharge piping began voiding early in the transient, and voided down to the leak elevation between 29 and 38 minutes (Figure 5.3.50). The other cold legs voided extensively at approximately 1 hour (at which time the steam generators reactivated) and voided completely by 77 minutes. The measured leak flow rate became oscillatory beyond 5 minutes (Figure 5.3.51), corresponding to the initial voiding in the cold leg B1 discharge piping. The variability of the leak flow rate increased near 14 minutes as the voiding in the cold leg B1 discharge piping increased. This indication of NCG at the leak site had additional confirmation. For example, the post-test gas closure calculations indicated that about half of the total injection (plus initial volume) of 61 scf was discharged out the break. Also, the measured leak fluid temperature remained about 50F subcooled, even though the leak site was uncovered (and would have been exposed to saturated steam had there not been NCG effects) beyond 38 minutes (Figure 5.3.52).

Steam Generator Activity

The steam generators became active beyond 57 minutes. The controlled depressurization of the steam generators began as the core exit-to-steam generator saturation temperature difference approached 50F (in both steam generators). Thus, feed was reactivated with steam generator primary levels well below the elevation of feed injection (Figure 5.3.53). The primary system depressurized toward the steam generator secondary pressures at nearly 40 psi per minute (Figure 5.3.47). The primary depressurization slowed after only a few minutes, while the steam generator primary levels remained below the feed-injection elevation, apparently reflecting the inhibition of heat transfer by noncondensibles.

Refill

The gas injection was completed at 108 minutes. The steam generator secondaries remained virtually inactive beyond 100 minutes (Figure 5.3.54), after the temperature difference (core exit less steam generator secondary saturation) of 50F had been established. The steam generator primary levels remained below the upper tubesheet elevation until approximately 5 hours, but the primary system pressure virtually stabilized at 700 psia (Figure 5.3.55). The HPI flow had first exceeded the leak flow rate near 1 hour (Figure 5.3.51) in response to the earlier primary system depressurization, during the BCM. The leak flow rate gradually increased with the subcooling of the leak fluid, stabilizing approximately 100 lbm/h below the HPI flow rate beyond 3 hours. The excess of HPI over leak flow rate gradually refilled the loop. The hot leg A riser level refilled to the U-bend spillover elevation at 308 minutes, contracted about 4 feet, and then regained the spillover elevation and remained there beyond approximately 320 minutes (Figure 5.3.56). The riser level variations of hot leg B paralleled those of hot leg A, but lagged by approximately 8 feet; the hot leg B riser level reached the spillover elevation near test termination at 7 hours. The hot leg levels beyond the U-bend (the steam generator primary levels) remained about 15 feet below their respective riser levels. The system response to the hot leg refill was mild compared with those that have been observed without NCG. Most notably, the steam generators remained virtually inactive, and the primary system pressure remained constant (Figure 5.3.55). The loop A cold leg suction levels began to slowly rise following the hot leg spillover.

The RVVVs operated asymmetrically during the later portions of the test (Figure 5.3.57), apparently reflecting the effects of both NCG and the unequal valve actuation setpoints. All four RVVVs remained open until 160 minutes, then the RVVVs became active. RVVV A1 first closed at 160 minutes, but RVVVs B1 and B2 did not become active until 212 minutes. RVVV A2 generally remained open. The downcomer fluid temperatures did not cool nearly as much as has been observed in certain NCG tests, such as those having a cold leg suction rather than a discharge leak. The lower downcomer and core inlet fluid temperatures decreased regularly beyond 1 hour. The lower downcomer and core inlet fluid temperatures approached 240F (Figure 5.3.58), and the core fluid temperature rise reached 220F. The test was terminated at 7 hours based on the maximum test duration.

5.3.4. Comparisons

Tests 1 and 3 are compared in section 5.3.4.1, Tests 3 and 5 are compared in section 5.3.4.2. The first comparison involves tests using hot leg venting, but with and without noncondensibles. The second comparison involves tests using noncondensibles, but with and without hot leg venting.

5.3.4.1. Venting With and Without Noncondensibles, Tests 1 and 3

A scaled 10-cm^2 cold leg B1 discharge leak as well as continuous hot leg venting were used in both Tests 1 and 3. Approximately 60 scf of helium were injected in Test 3, but noncondensibles were not introduced in Test 1. Also, the leak was isolated midway in the Test 3 transient, but was kept open in Test 1.

Tests 1 and 3 were initiated almost identically. Their primary system depressurizations were similar (Figure 5.3.59), and the initiation timings and flow rate magnitudes of the primary system boundary streams -- leak, vents, and HPI were almost exactly equal (Figure 5.3.60). This inter-test similarity was marred by feed control differences, however. The timing of the initial steam generator secondary feed and steam system changes was coincident, but the steam generator B feed rate in Test 3 increased to less than full scaled head-flow (Figure 5.3.61). The Test 3 steam generator B secondary level increased more slowly than the rest (Figure 5.3.62), and the steam generator B secondary system feed-depressurization was mitigated (Figure 5.3.63). The hot leg riser levels initially receded from the U-bend spillover elevation quite symmetrically between loops in both Tests 1 and 3 (Figure 5.3.64). An inter-test difference gradually developed, however -- the loop B riser level descended less rapidly in Test 3 than in Test 1. This difference may have been due to the noncondensibles used in Test 3, or to the asymmetric feeding in Test 3. The steam generator A and B primary levels decreased approximately equally in Test 1 but in Test 3, the steam generator A level descended more rapidly than the steam generator B level.

The downcomer levels approached the elevation of the cold leg nozzles beyond 10 minutes in both tests (Figure 5.3.65). As the noncondensible gas reached the leak site in Test 3, the leak mass flow rate became relatively variable (Figure 5.3.66). In both tests, the leak fluid temperature increased toward saturation near 14 minutes (Figure 5.3.67) in response to downcomer fluid heating.

The cold leg discharge levels declined in Test 3, with noncondensibles, but they generally remained full in Test 1 (Figure 5.3.68). In Test 3 the cold leg B1 discharge level reached the leak elevation near 35 minutes, completing the direct path for noncondensibles from the core, through the RVVVs, down the downcomer to the broken cold leg, and out the break.

The inter-test differences among steam generator activity persisted after refill of the steam generator secondaries. The steam generator A secondary pressure remained below 700 psia in Test 3 while both generators repressurized above 800 psia in Test 1 (Figure 5.3.69). The renewed steam generator activity near 45 minutes depressurized the primary system in both tests (Figure 5.3.70), but to a greater extent in Test 1. This difference was apparently caused by the relatively low steam generator A primary level in Test 1 (Figure 5.3.71), which favored depressurization through primary vapor condensation near the site of AFW injection (AFW-BCM). The primary system depressurization obtained system refill in both tests (Figure 5.3.72), but their refill behavior was distinctly different. The hot leg and steam generator primary levels remained near the elevation of the steam generator upper tubesheets in Test 1. In Test 3 with noncondensibles, the hot leg riser and stubs ascended (Figure 5.3.73) as the cold leg suction levels descended (Figure 5.3.74). This hot leg refill trend of Test 3 culminated in riser refill near 80 minutes. Unlike the responses seen without noncondensibles, hot leg refill had little effect in Test 3. The steam generator secondary systems became only mildly active (Figure 5.3.75), the primary system depressurized only gradually (Figure 5.3.76), and the lower downcomer fluid continued to cool (Figure 5.3.77). The hot leg stub levels were more than 10 feet below the U-bend (Figure 5.3.78), and the cold leg spillover voiding persisted (Figure 5.3.74).

Beyond 2 hours, the gas injection was completed and the leak was isolated in Test 3 (Figure 5.3.79). In Test 1, the hot leg riser levels achieved the U-bend spillover elevation and the system reactivated. Subsequent events were thus completely different between tests.

5.3.4.2. Noncondensibles With and Without Venting, Tests 3 and 5

Both hot leg high-point vents were opened at test initiation and were kept open in Test 3, but were not actuated in Test 5 The remaining controls were the same for both tests. A scaled 10-cm^2 cold leg B1 discharge leak and helium injection were used. The leak was isolated midway in Test 3, but was kept unisolated in Test 5.

Except for the vent actuation in Test 3 only, the tests were initiated almost identically (Figure 5.3.80). Although their initial conditions and actuation sequences were alike, the primary system depressurized more readily from the outset in Test 3 with venting (Figure 5.3.81).

The steam generator A and B feed rates were asymmetric in both tests (Figure 5.3.82). The steam generator B feed rates initially increased to less than full scaled flow. In Test 3, the steam generator B feed rate remained about constant but it gradually increased in Test 5, obtaining a 3-minute spread among the steam generator secondary refill times (Figure 5.3.83). The steam generator B secondary depressurized less during feeding in Test 3 than steam generator A, and than either steam generator in Test 5 (Figure 5.3.84). The downcomer levels attained the elevation of the cold leg nozzles simultaneously in the two tests, just before 12 minutes (Figure 5.3.85). The leak mass flow rates determined using turbine meters became relatively variable as the leak began to discharge noncondensible gas (Figure 5.3.80). This variability occurred in both tests, but, because of the absence of the turbine meter data in Test 5, it has been replaced with a calculationally smoothed flow rate derived from load cell readings. The leak fluid temperatures increased near 15 minutes in both tests (Figure 5.3.86) in response to the downcomer fluid heating by RVVV discharge. In both tests, however, the leak fluid remained highly subcooled even after the cold leg B1 discharge level descended to the leak elevation (Figure 5.3.87), attesting to the presence of noncondensibles.

The steam generator secondaries remained inactive in Test 5, without venting (Figures 5.3.88 and 5.3.89). As a result, the primary system pressure remained higher through the first hour (Figure 5.3.90), the leak-HPI flow rate imbalance remained larger (Figure 5.3.91), and the hot leg and steam generator primary levels descended more rapidly (Figures 5.3.92 and 5.3.93) in Test 5 without venting than in Test 3. Primary system refill began at approximately 45 minutes in Test 3, but was delayed until 65 minutes in Test 5. In both tests, the start of refill was obtained after the primary had depressurized sufficiently to reactivate the steam generator secondaries. Also in both tests, the steam generator primary levels were sufficiently low to promote AFW-BCM when the steam generators reactivated -- approximately 48 ft in Test 3 and 40 ft in Test 5 (Figure 5.3.93). The cold leg suction levels declined as the hot leg riser and stub levels rose.

The test transients with and without venting became increasingly disparate as the transients progressed. Following the steam generator activity near 1 hour, the leak mass flow rate in Test 5 increased to the HPI flow rate (Figure 5.3.94) although refill continued in Test 3. Their primary system pressures (Figure 5.3.95) and leak fluid temperatures (Figure 5.3.96) were equal near 100 minutes -- in both tests, although their cold leg B1 discharge levels remained near the elevation of the leak (Figure 5.3.97), the leak fluid temperatures indicated highly subcooled. In Test 5 without venting, the steam generator primary liquid levels stabilized approximately 3 ft below the upper tubesheet, and lingered below the tubesheet through 350 minutes (Figure 5.3.98). The noncondensibles in Test 5 apparently inhibited steam generator heat transfer, causing the steam generators to remain virtually inactive (Figure 5.3.99). Even when the hot leg riser levels achieved the U-bend spillover elevation beyond 300 minutes in Test 5 (Figure 5.3.100), the hot leg stubs and cold leg spillovers remained voided and the steam generators evidenced little response.

The gas injection was completed near 2 hours in both tests and, in Test 3 only, the leak was isolated. The Test 3 interactions beyond 2 hours thus reflected leak closure -- primary repressurization, HPI throttling, and PORV actuations to control SCM and pressurizer level.

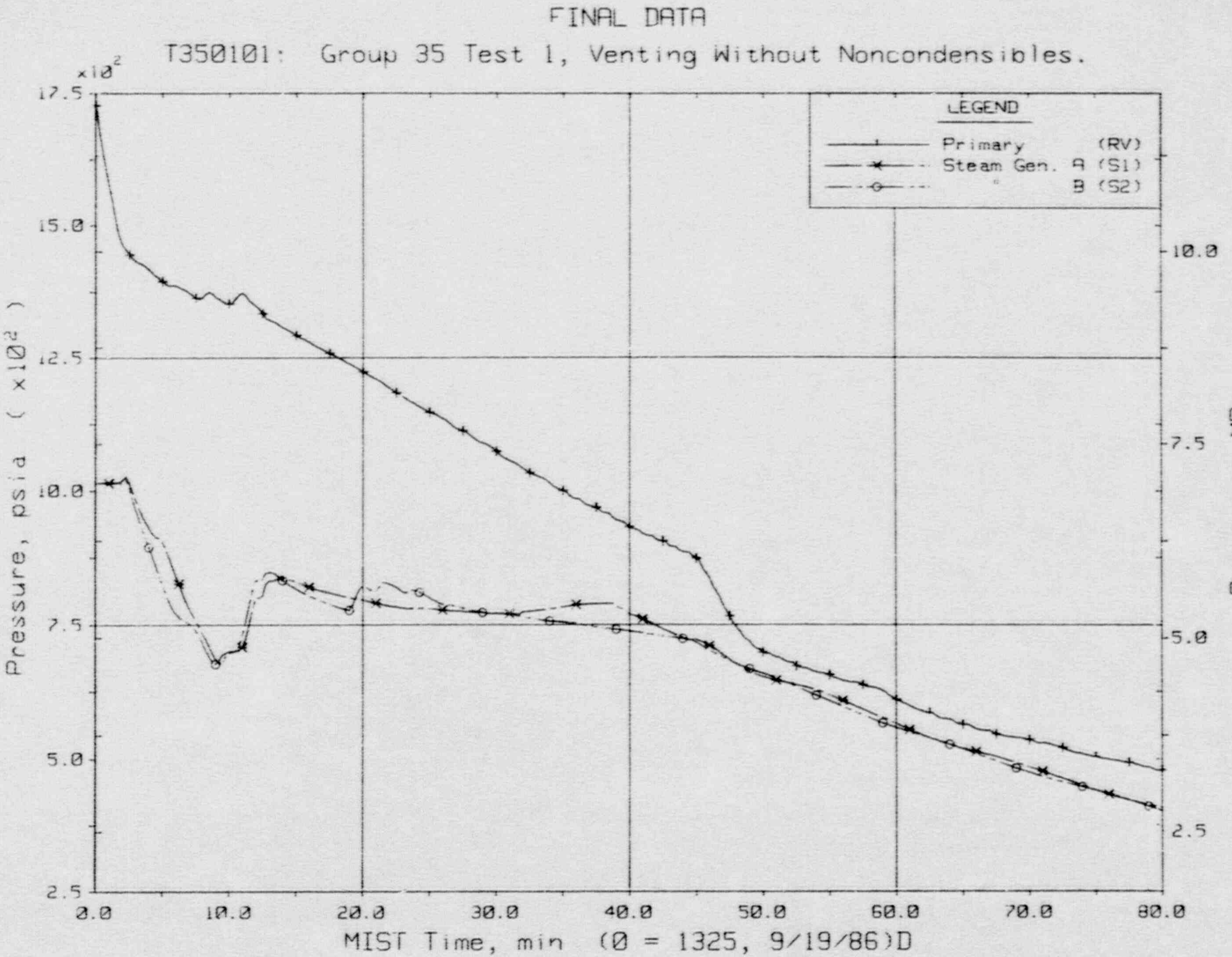


Figure 5.3.1 Primary and Secondary System Pressures (GP01s)

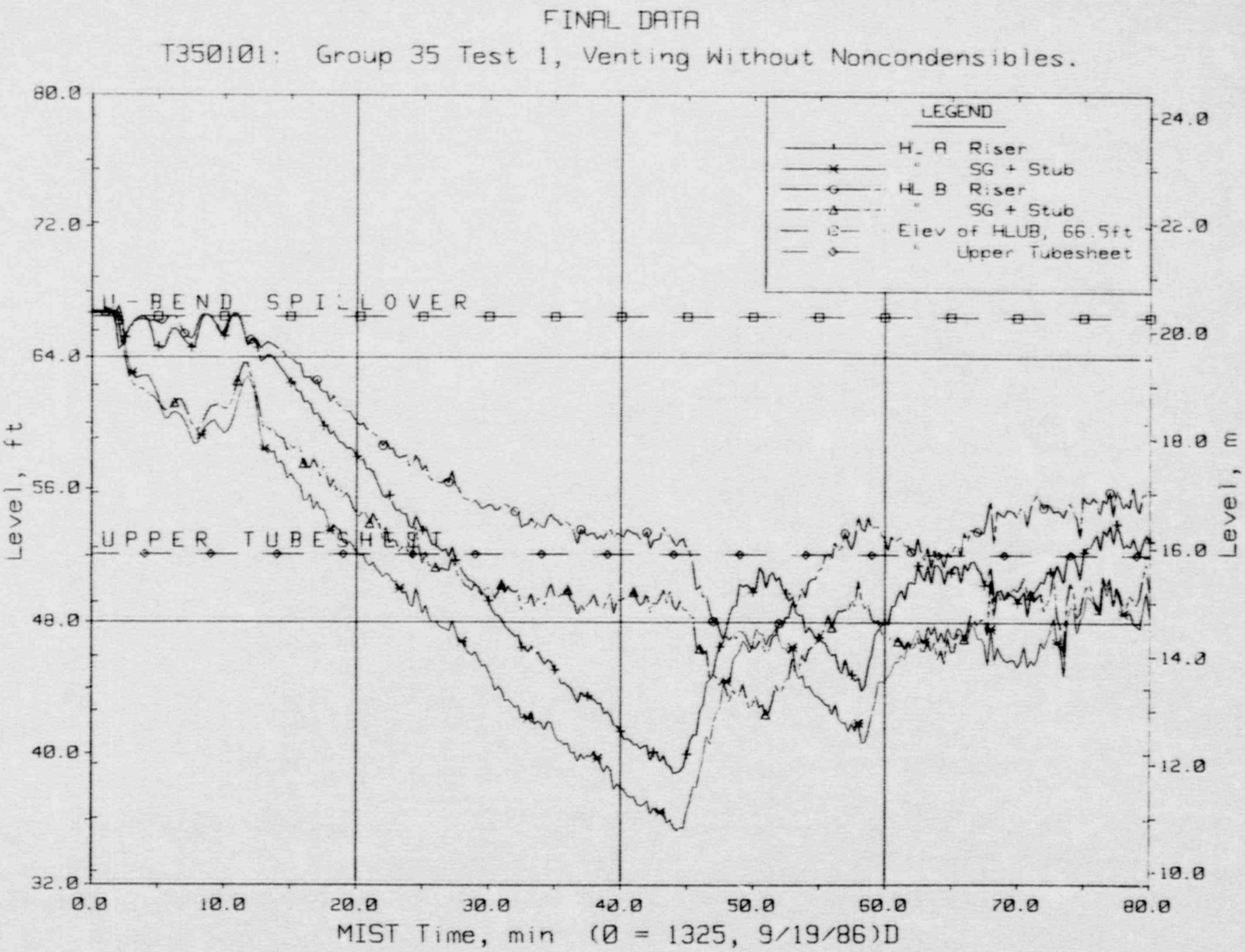


Figure 5.3.2 Hot Leg Riser and Stub Collapsed Liquid Levels

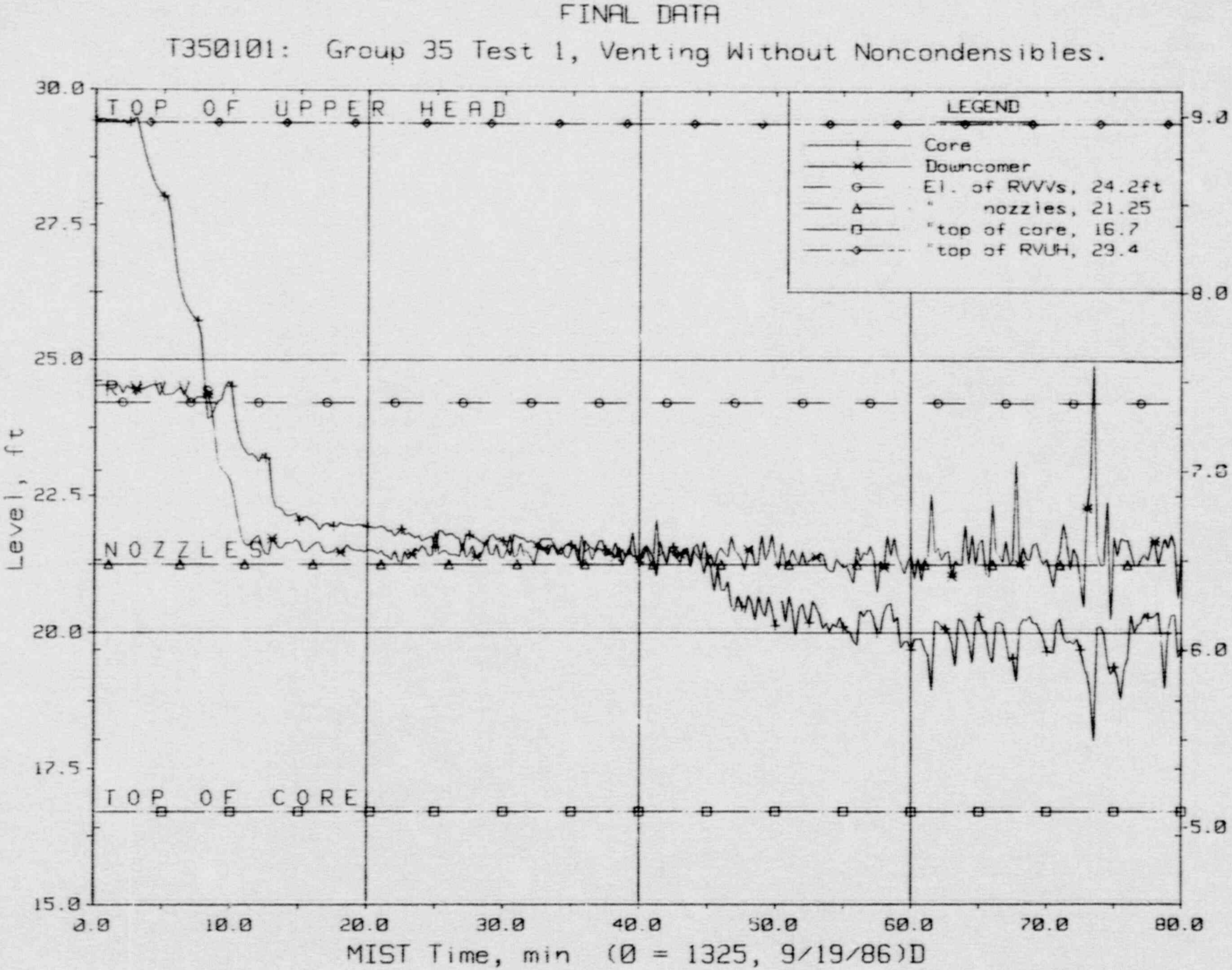


Figure 5.3.3 Core Region Collapsed Liquid Levels

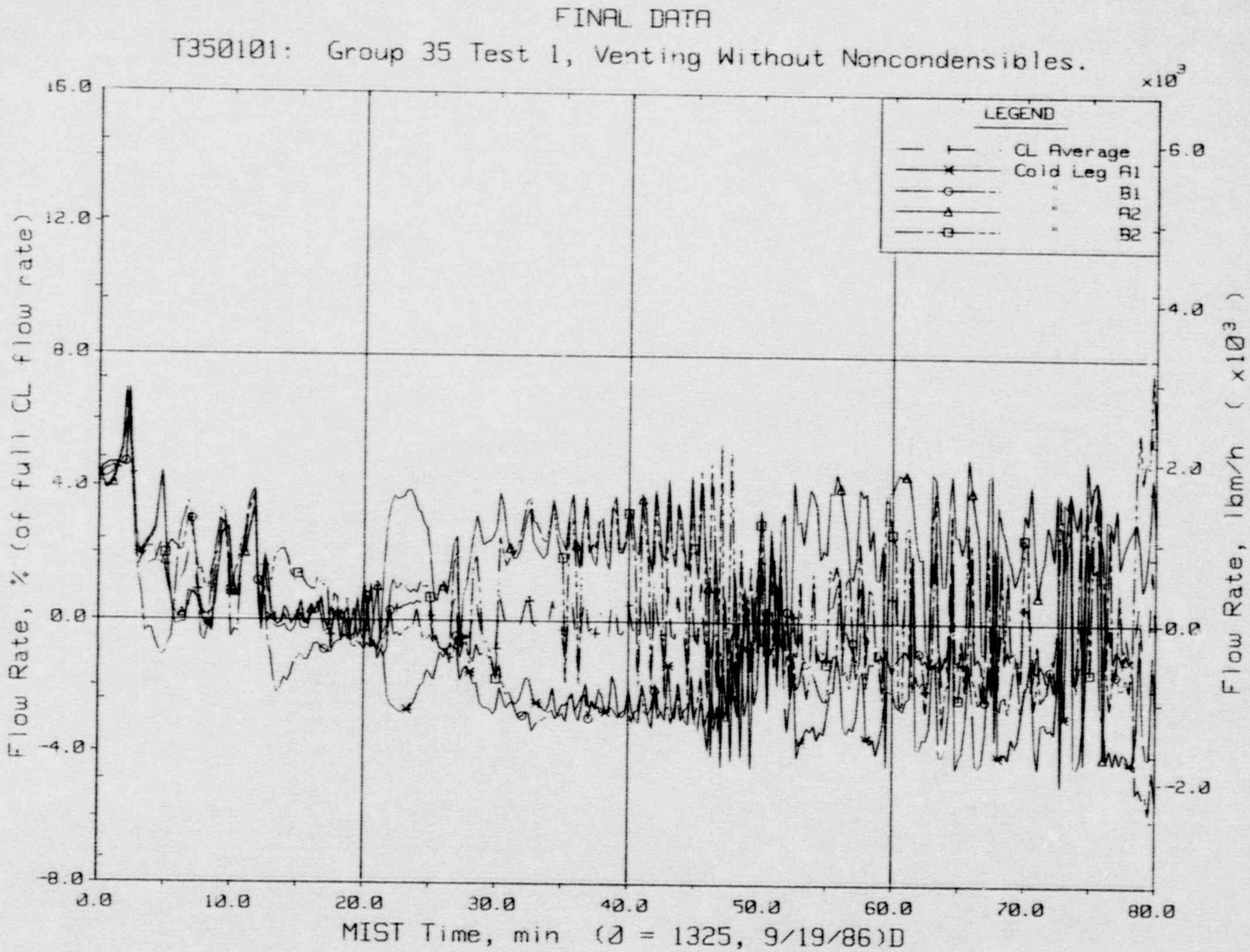


Figure 5.3.4 Cold Leg (Venturi) Flow Rates

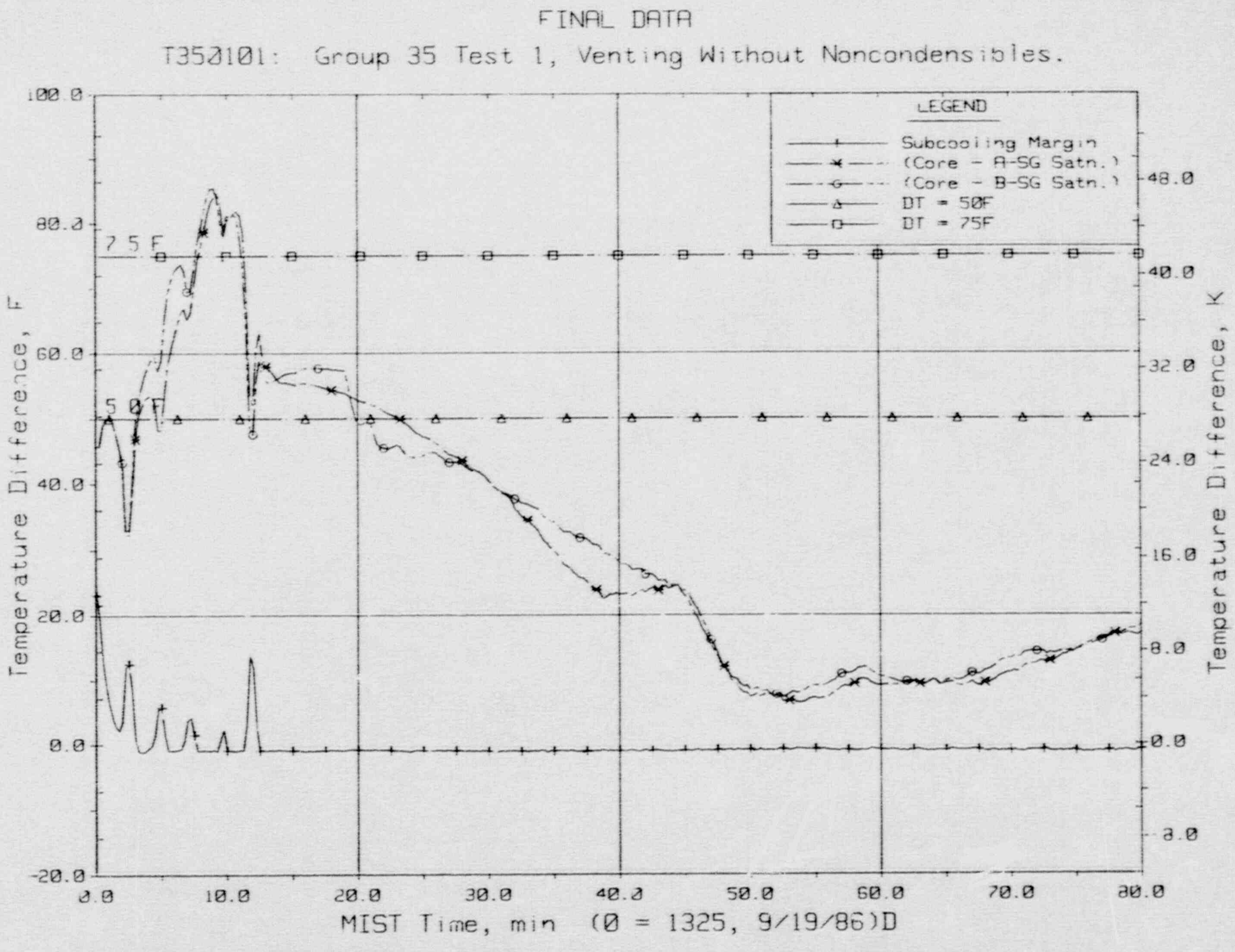


Figure 5.3.5 Control Temperature Differences

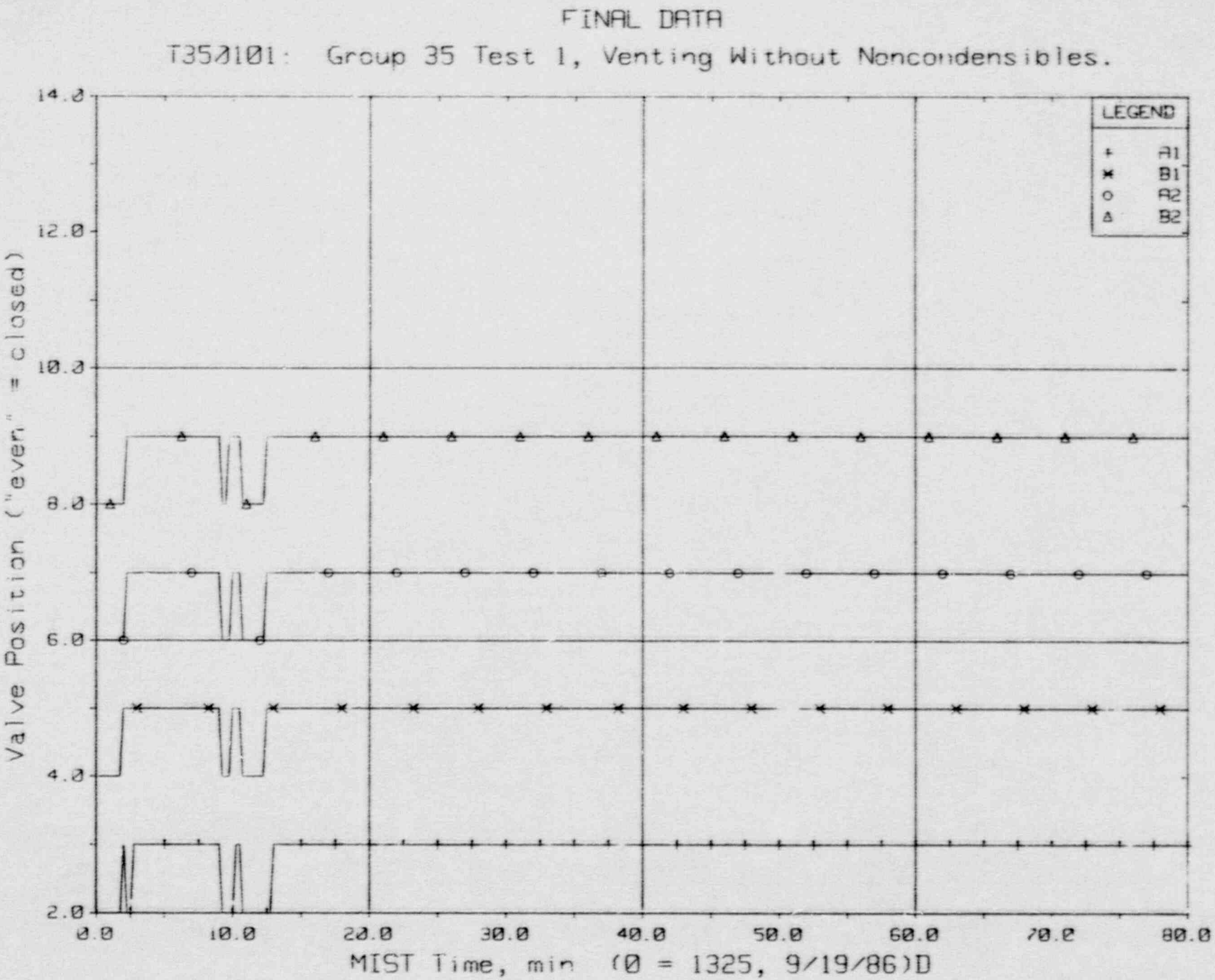


Figure 5.3.6 Reactor Vessel Vent Valve Positions

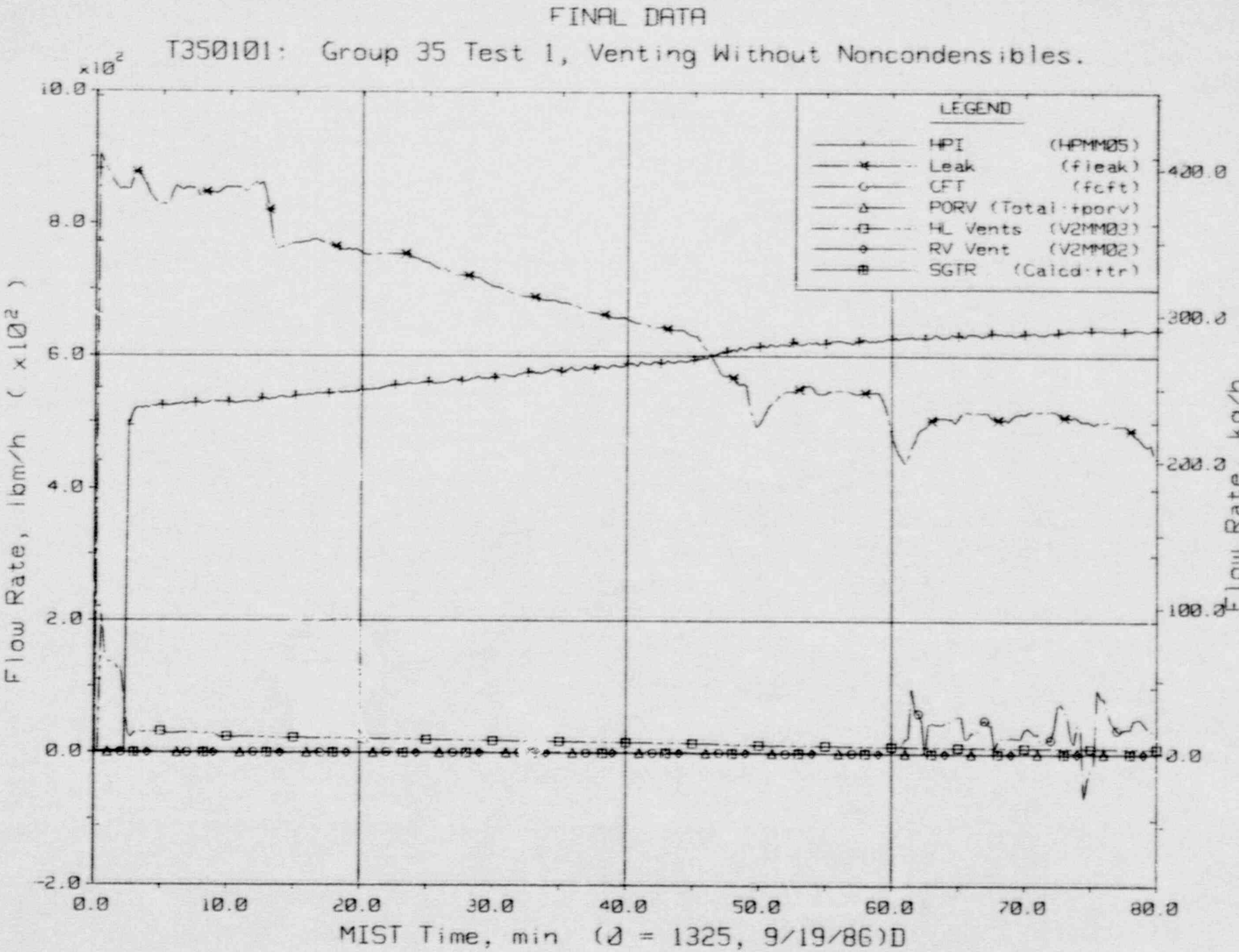


Figure 5.3.7 Primary System Boundary Flow Rates

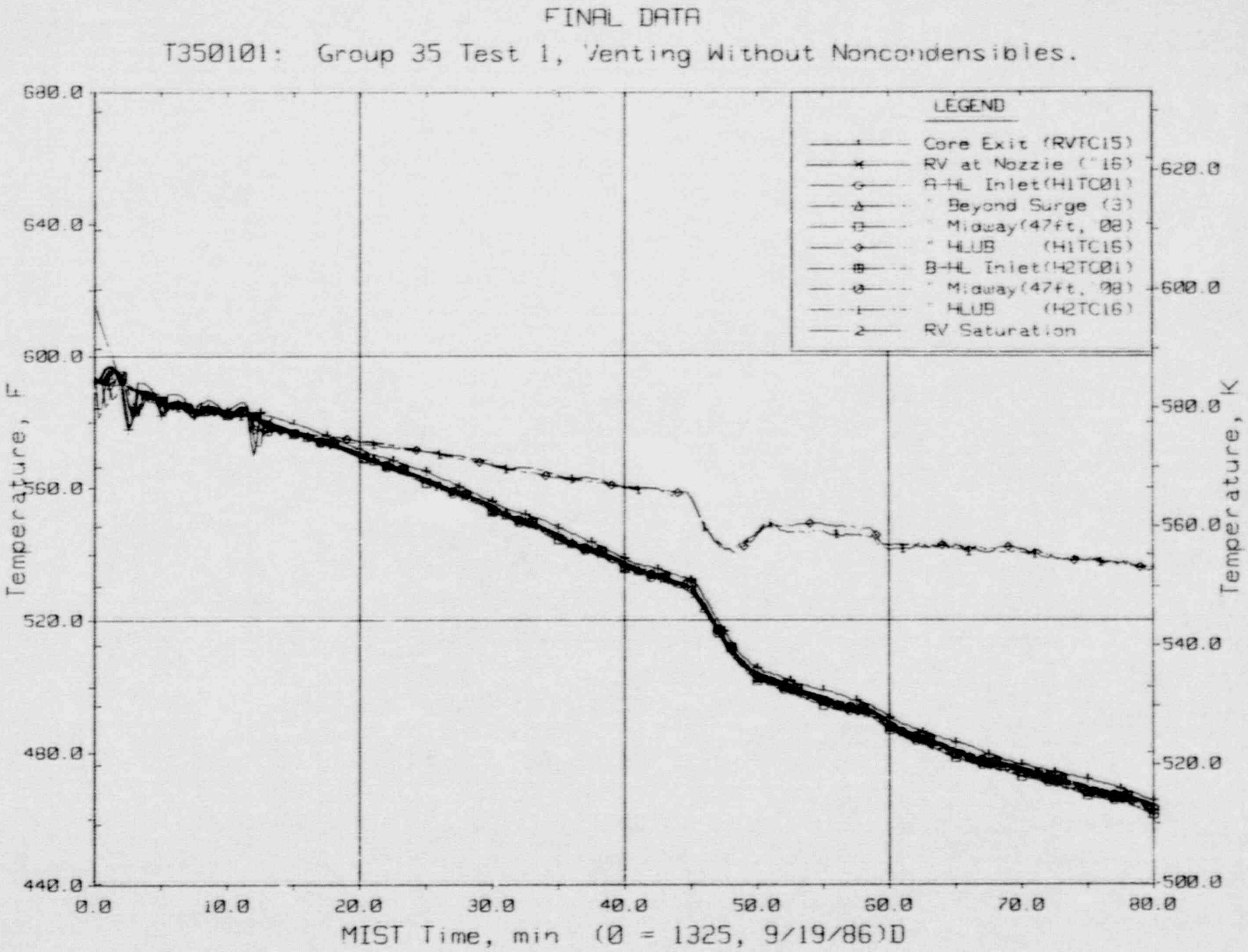


Figure 5.3.8 Composite Core Exit and Hot Leg Fluid Temperatures

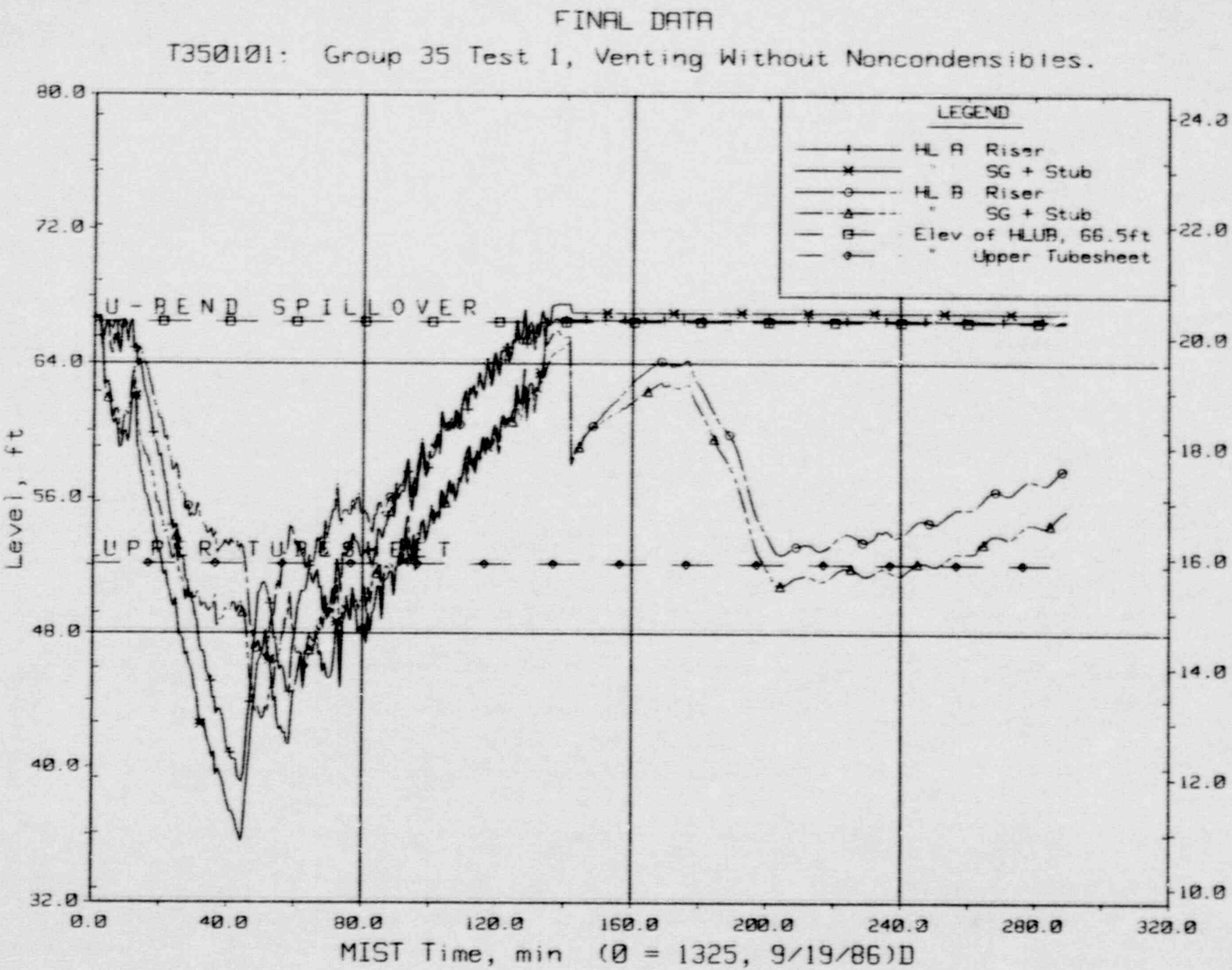


Figure 5.3.9 Hot Leg Riser and Stub Collapsed Liquid Levels

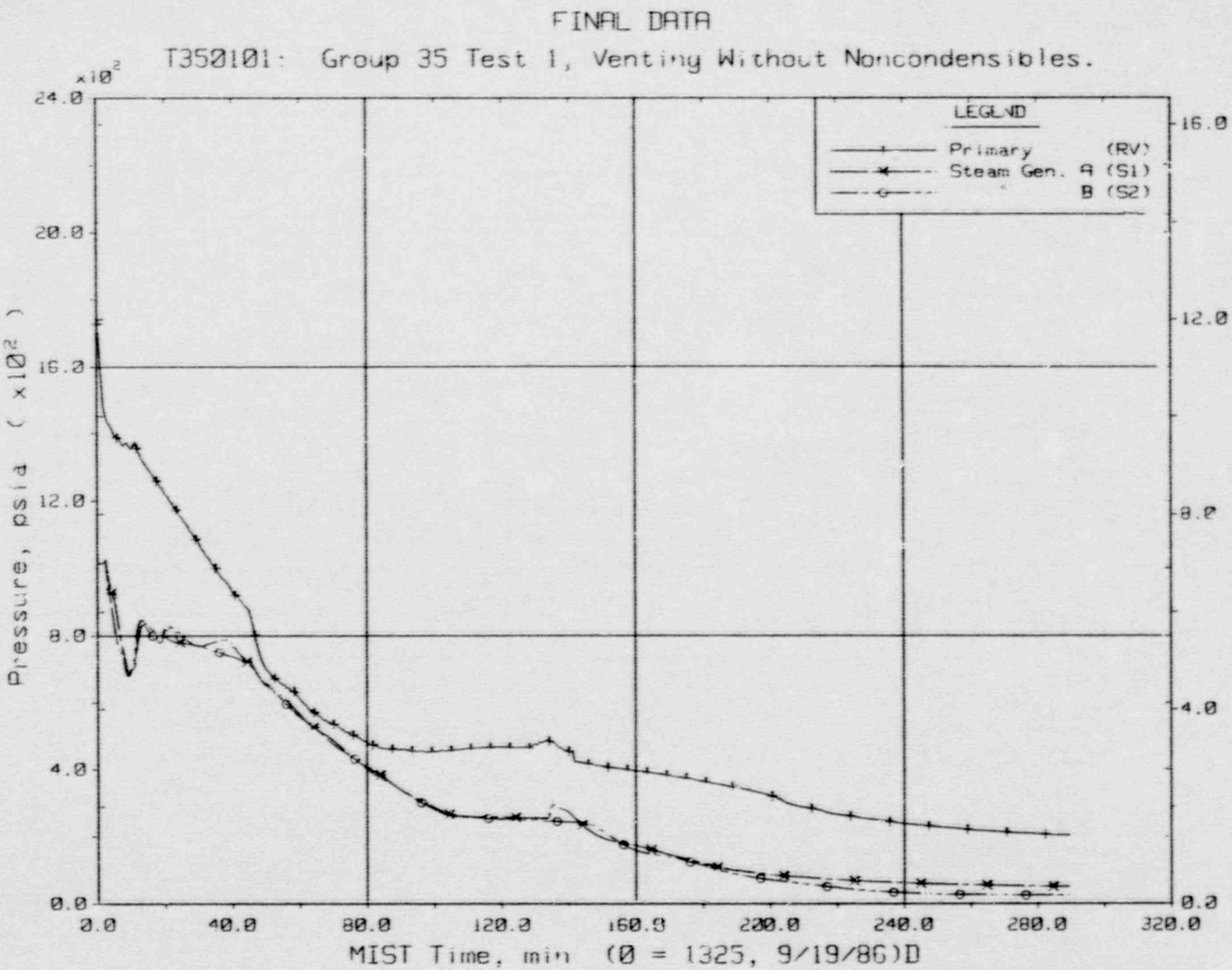


Figure 5.3.10 Primary and Secondary System Pressures (GP01c)

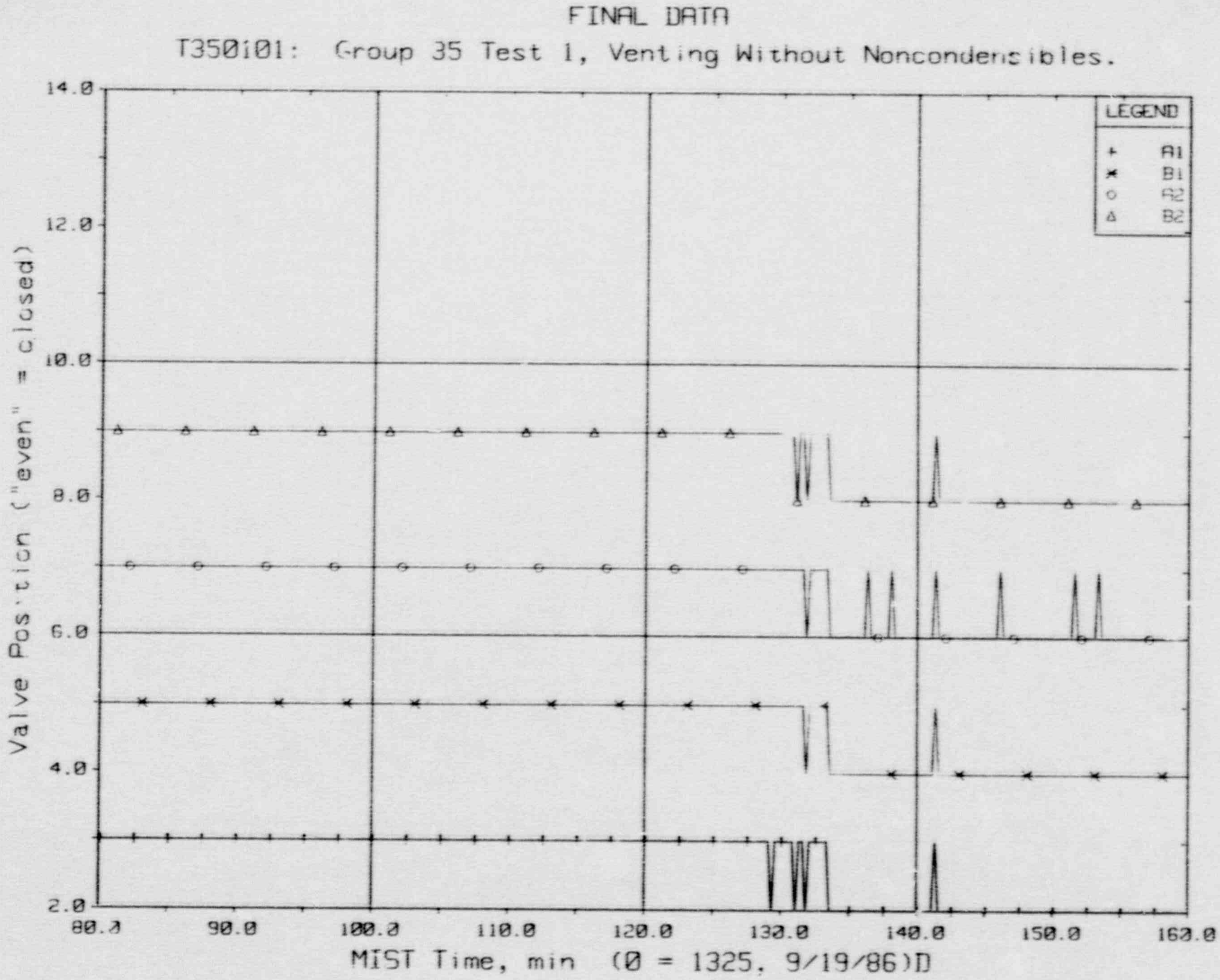
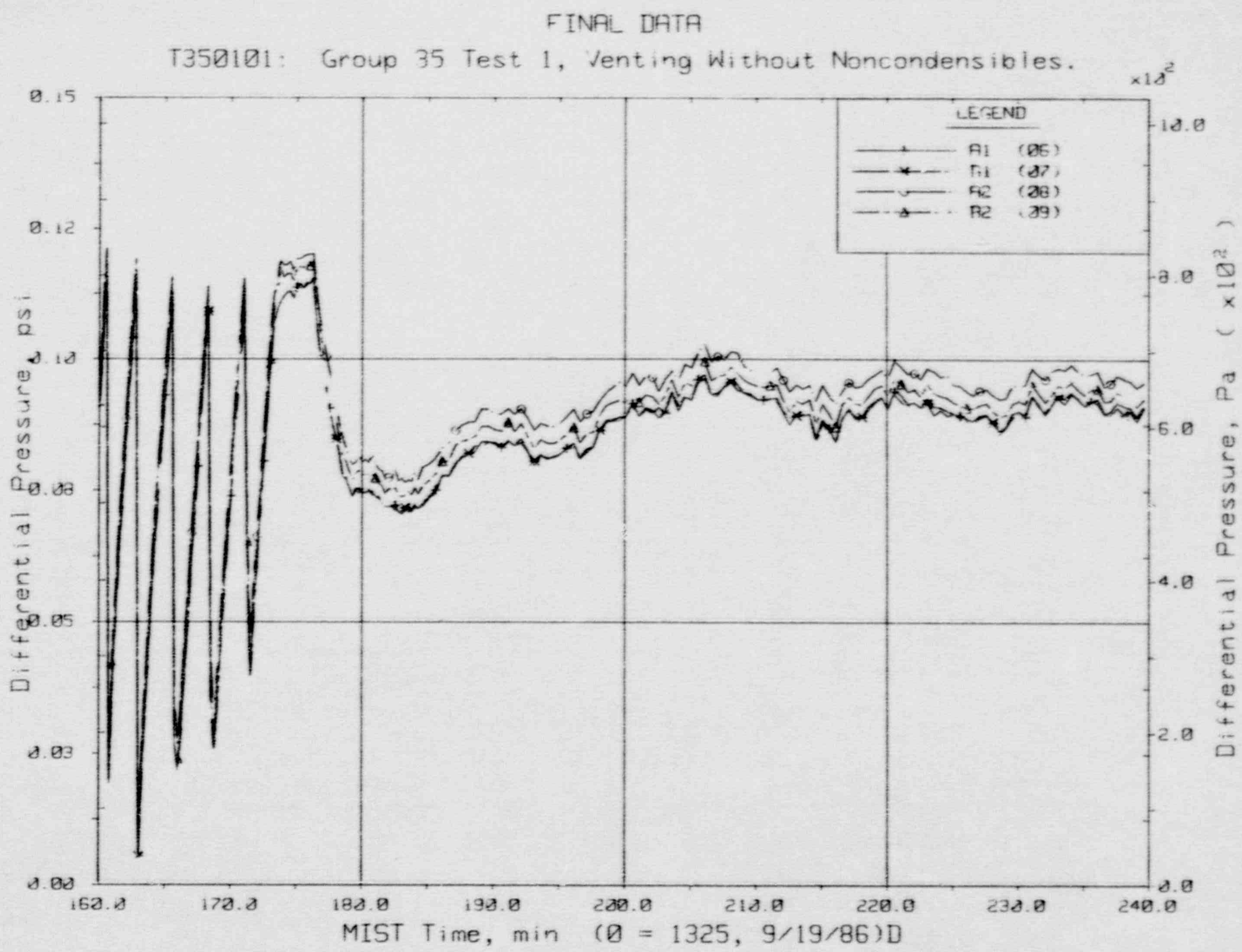


Figure 5.3.11 Reactor Vessel Vent Valve Positions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A1 (07)
A2 (08)
A2 (09)
Differential Pressure, psi
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0.12
0.10
0.08
0.05
0.03
0.00
Differential Pressure, Pa (x10²)
x10²
10.0
8.0
6.0
4.0
2.0
0.0
160.0
170.0
180.0
190.0
200.0
210.0
220.0
230.0
240.0
MIST Time, min (0 = 1325, 9/19/86)D

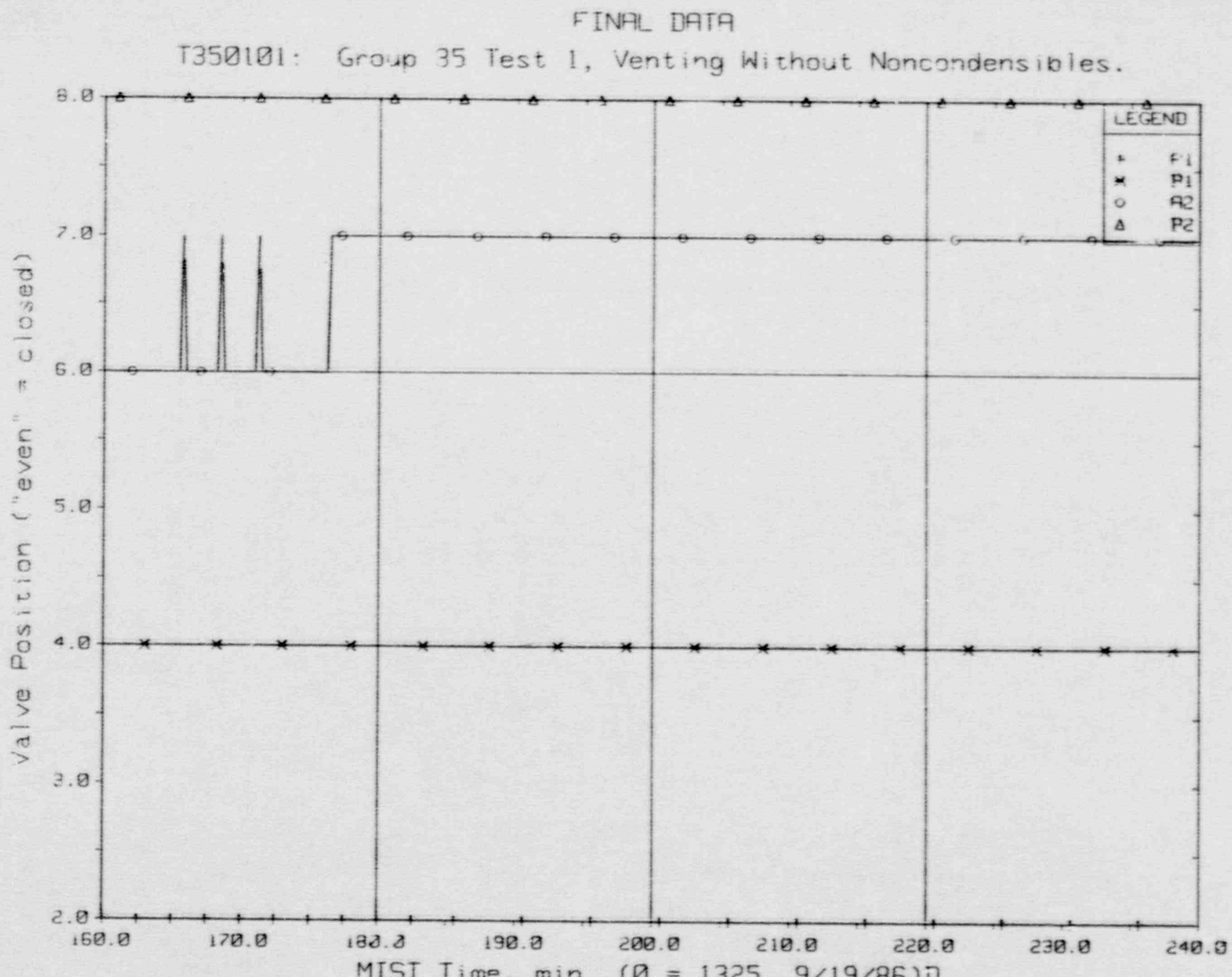


Figure 5.3.13 Reactor Vessel Vent Valve Positions

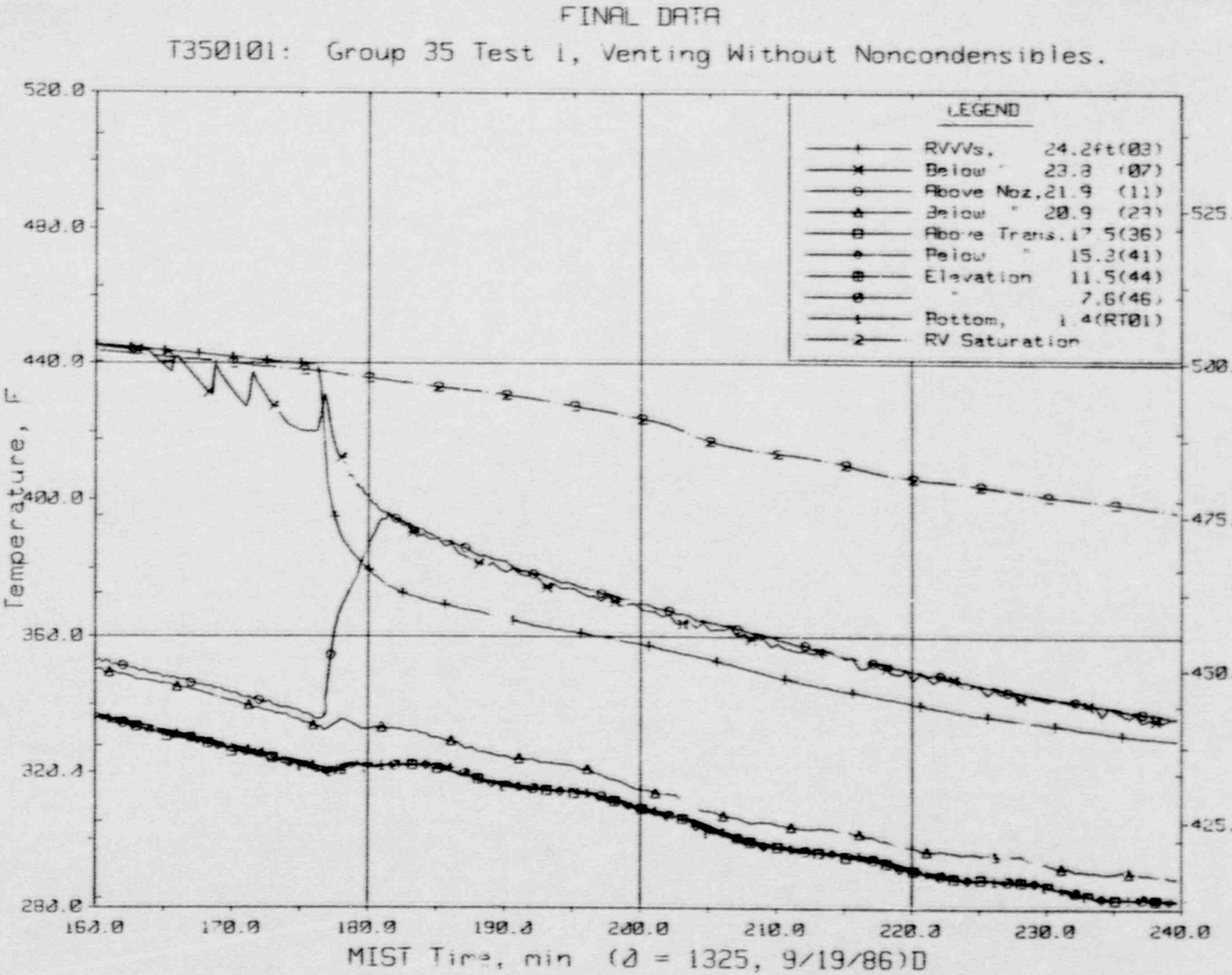


Figure 5.3.14 Downcomer Quadrant A2 Fluid Temperatures (DCTCs)

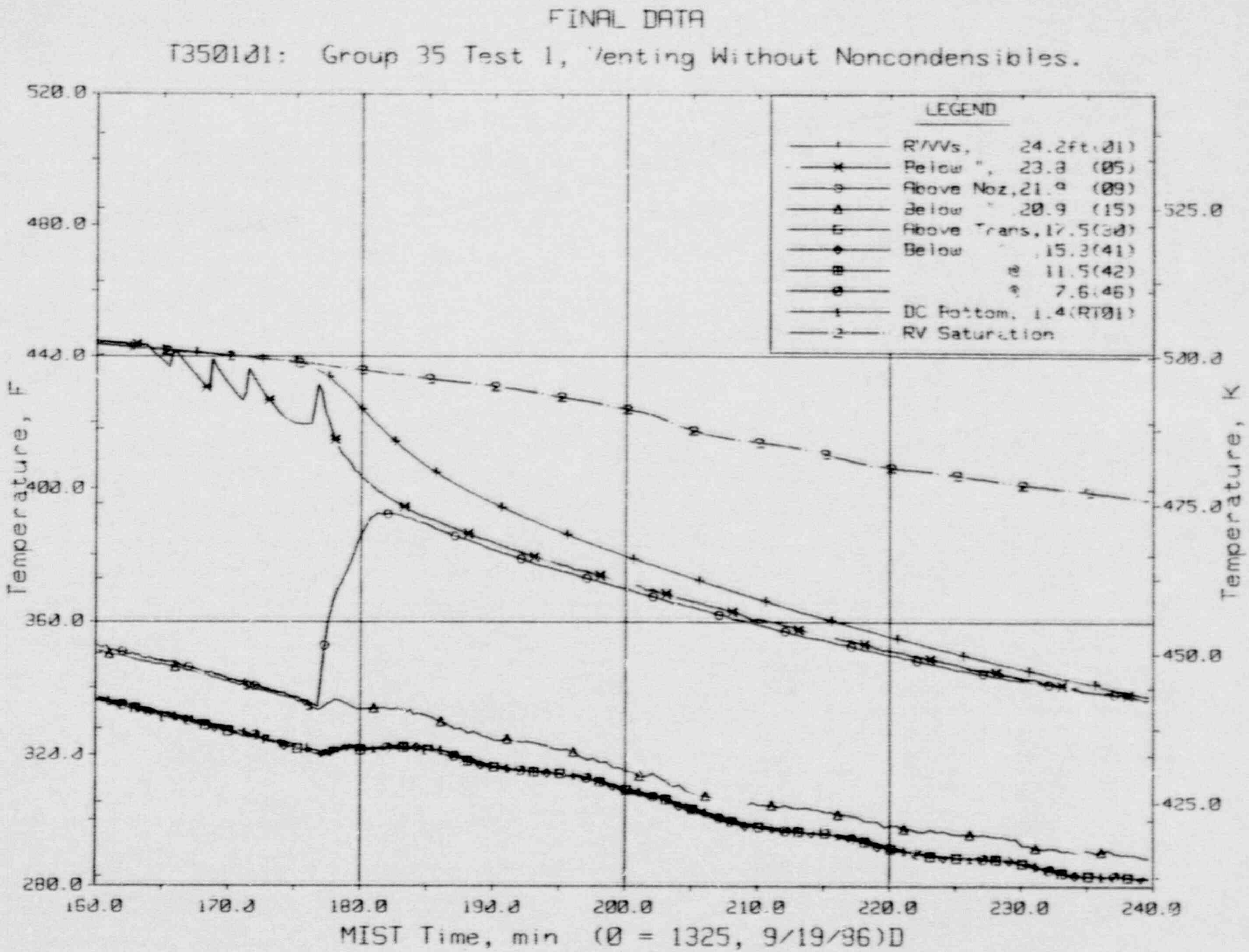


Figure 5.3.15 Downcomer Quadrant A1 Fluid Temperatures (DCTCs)

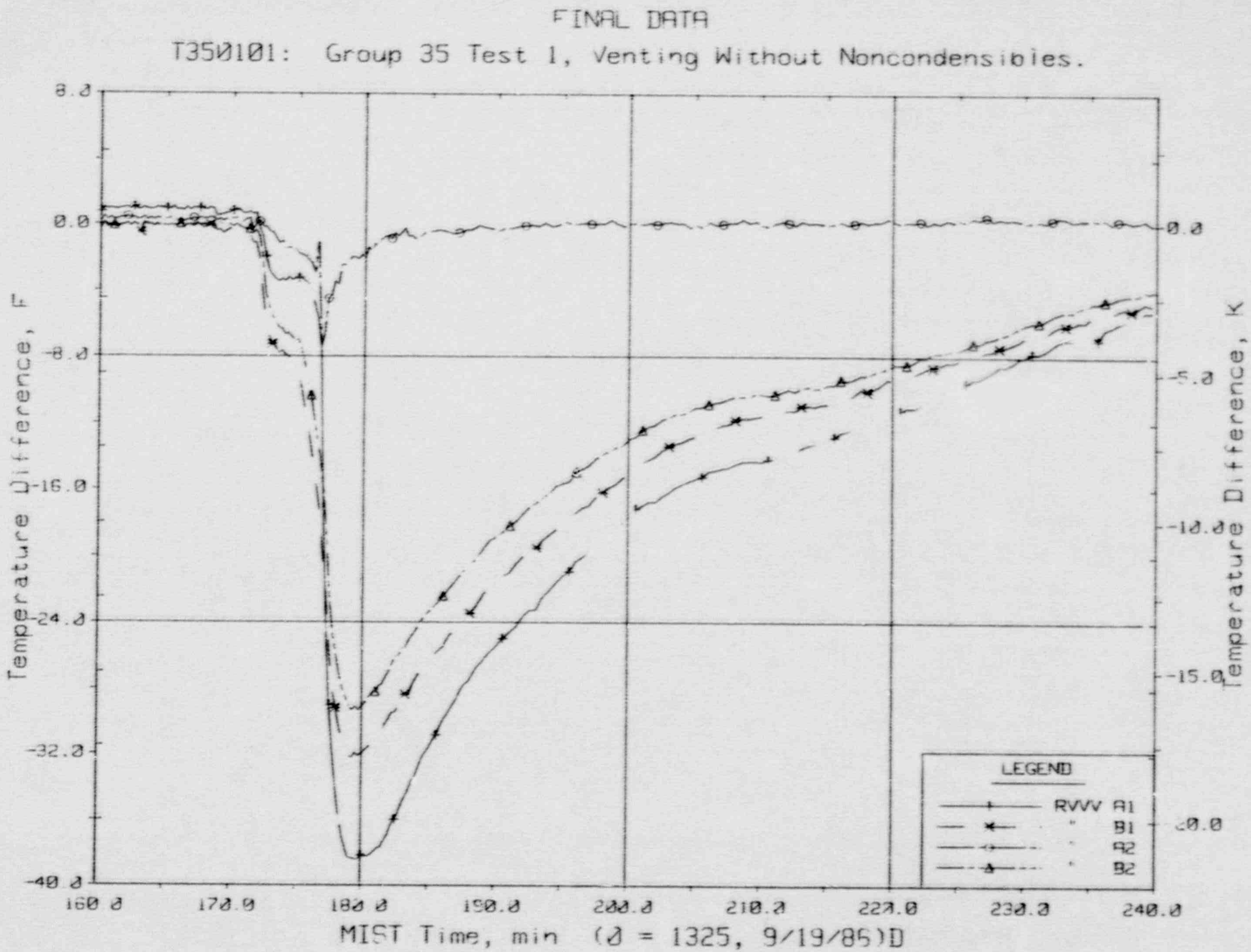


Figure 5.3.16 Temperature Differences Across Vent Valves

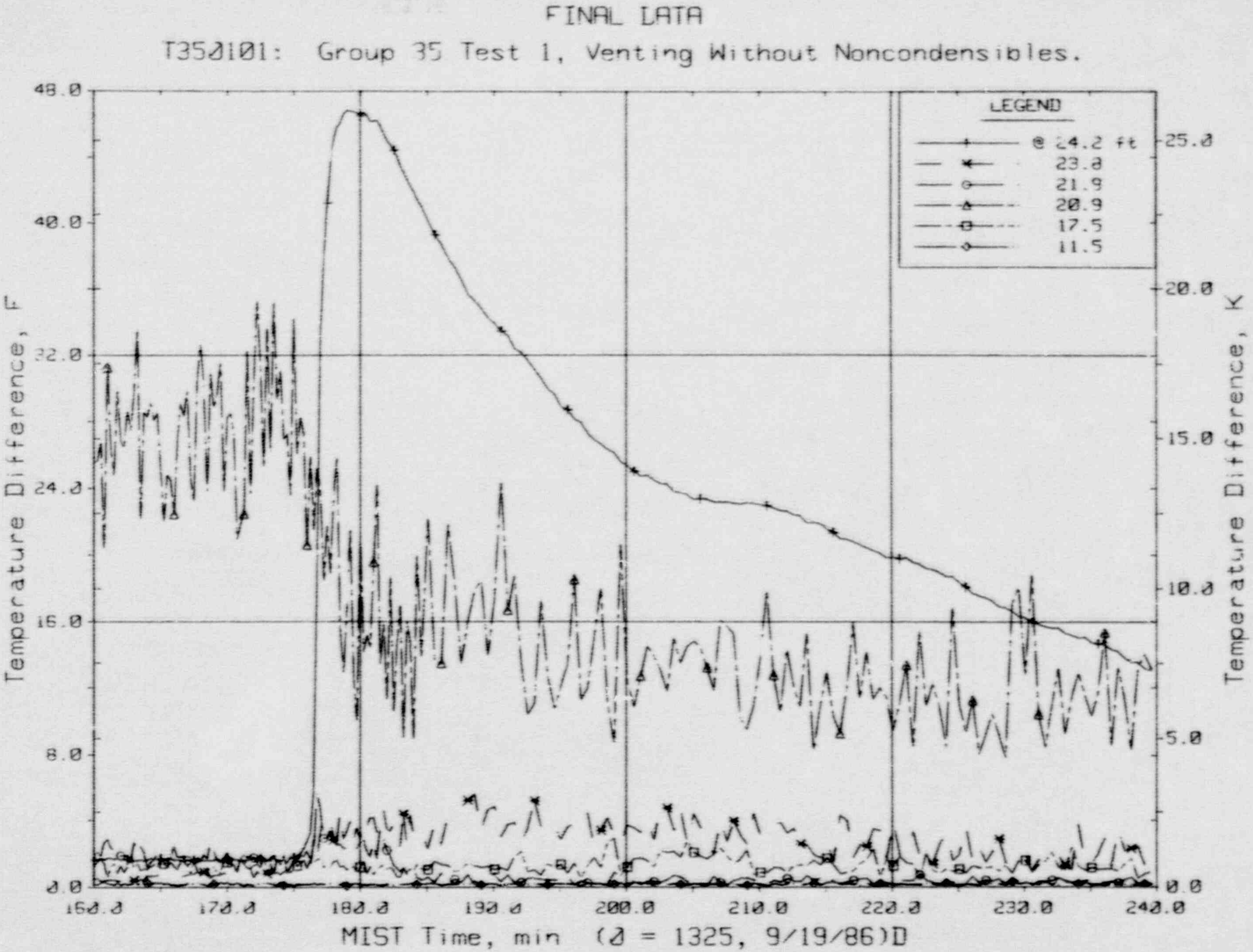
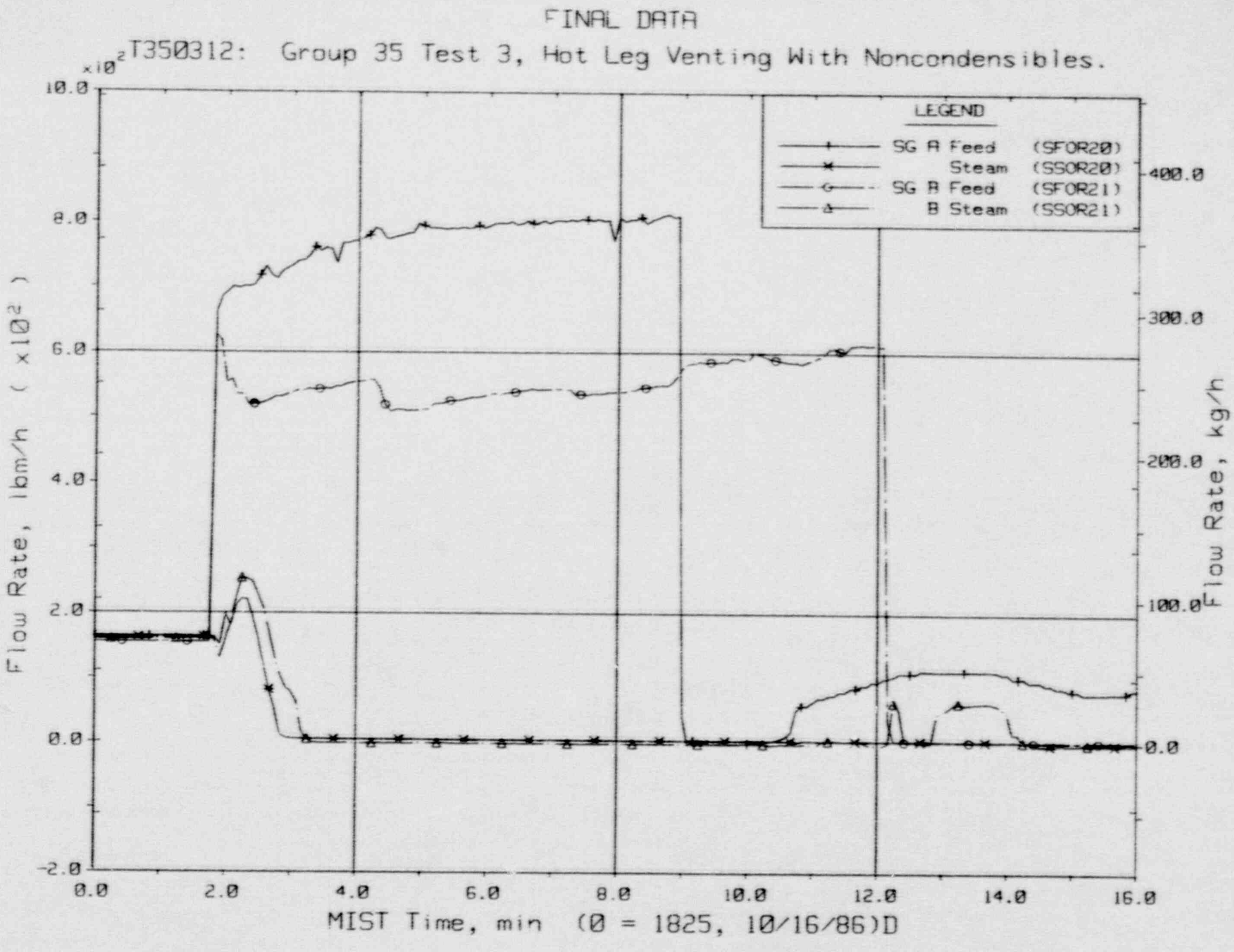


Figure 5.3.17 Maximum Differences Among Coplanar Downcomer Fluid Temperatures



5-69

Figure 5.3.18 Steam Generator Secondary Flow Rates

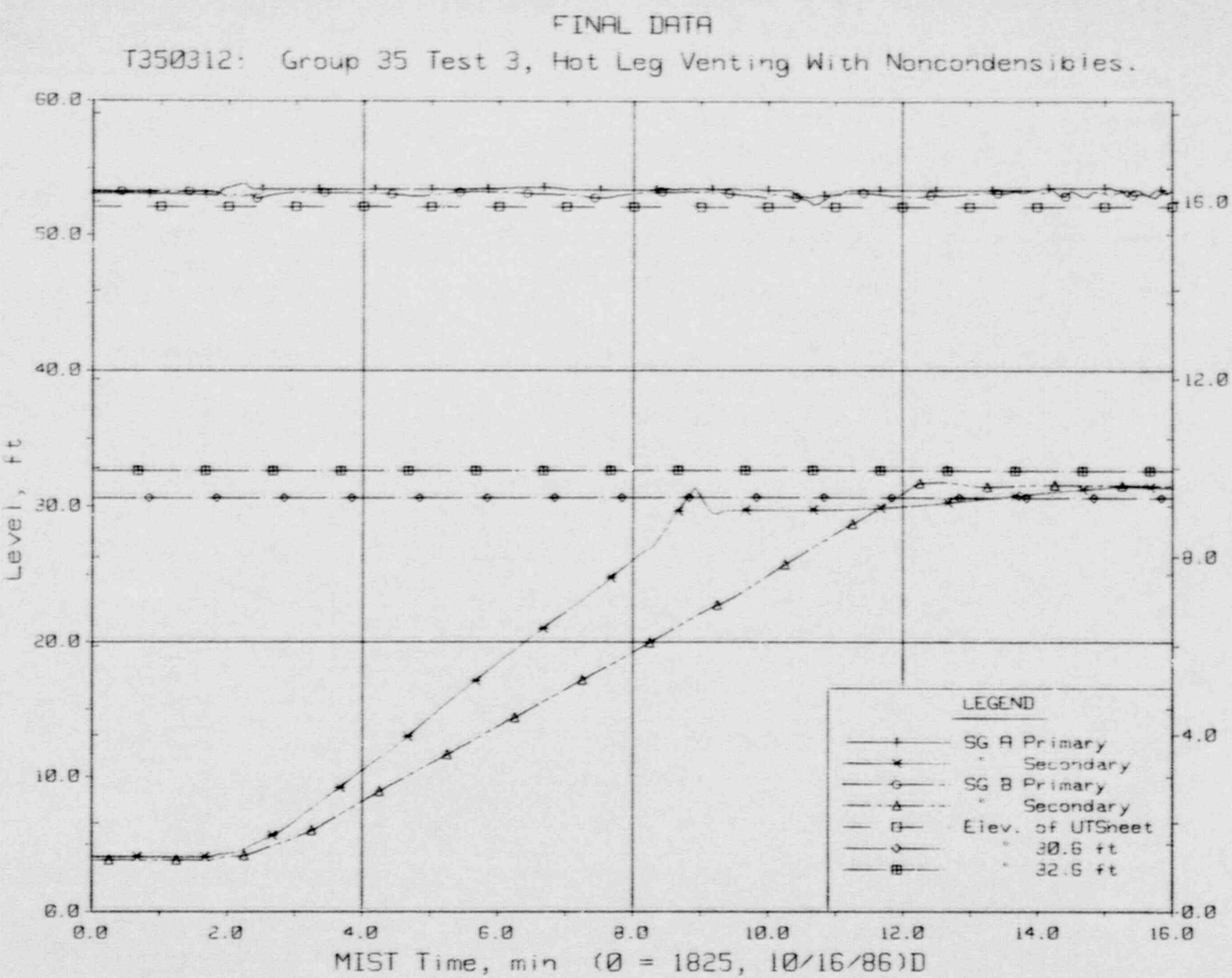


Figure 5.3.19 Steam Generator Collapsed Liquid Levels

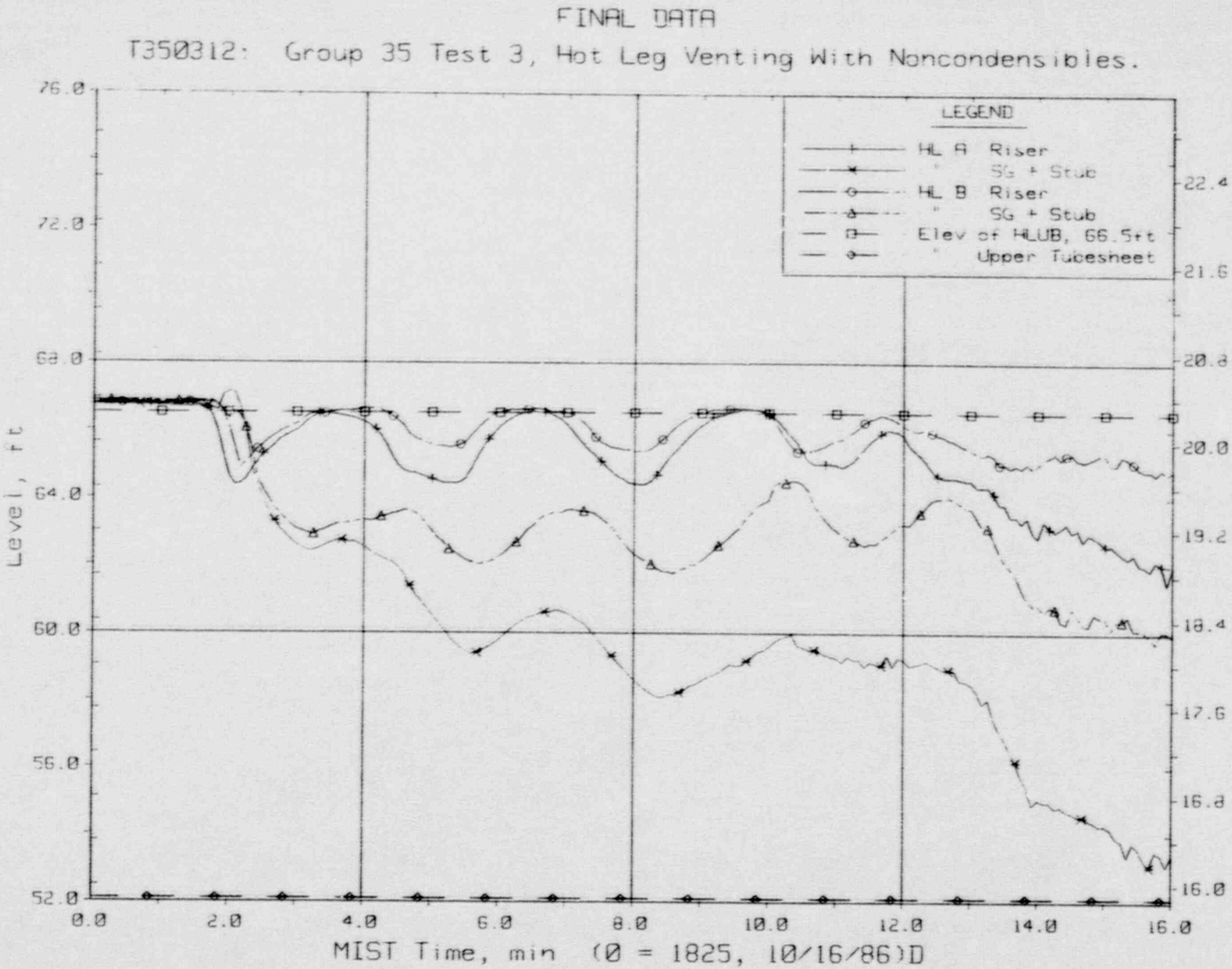


Figure 5.3.20 Hot Leg Riser and Stub Collapsed Liquid Levels

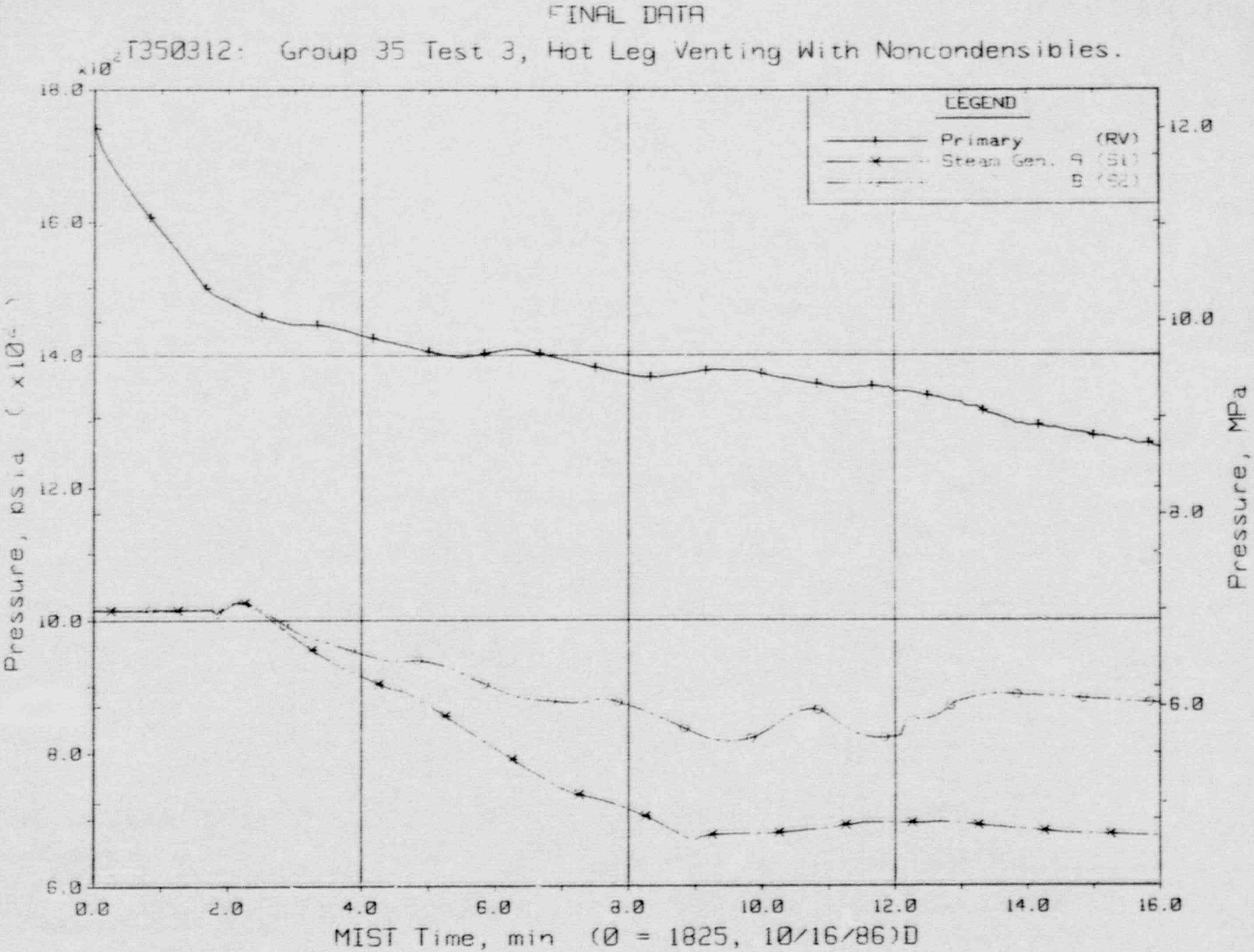


Figure 5.3.21 Primary and Secondary System Pressures (GPOIs)

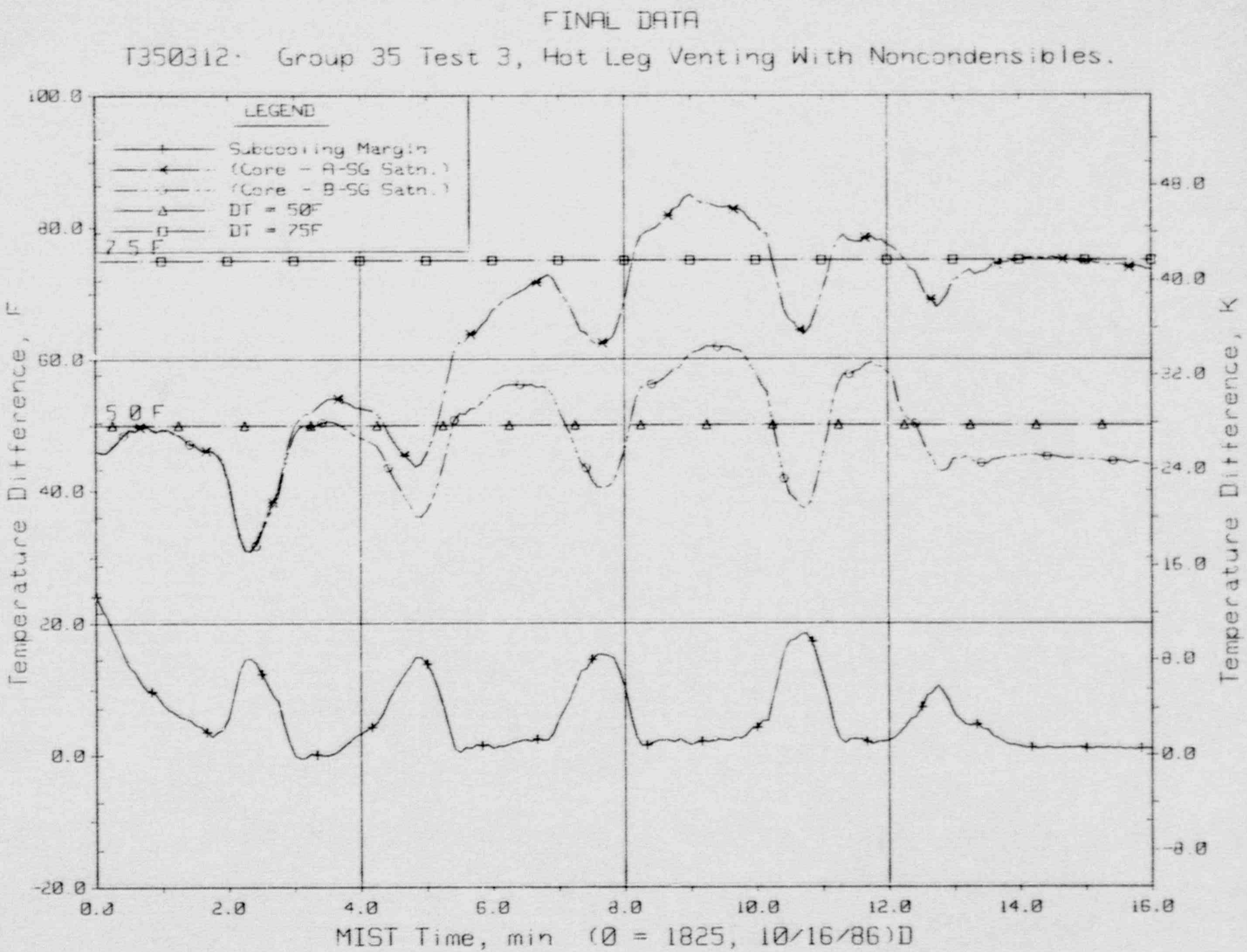


Figure 5.3.22 Control Temperature Differences

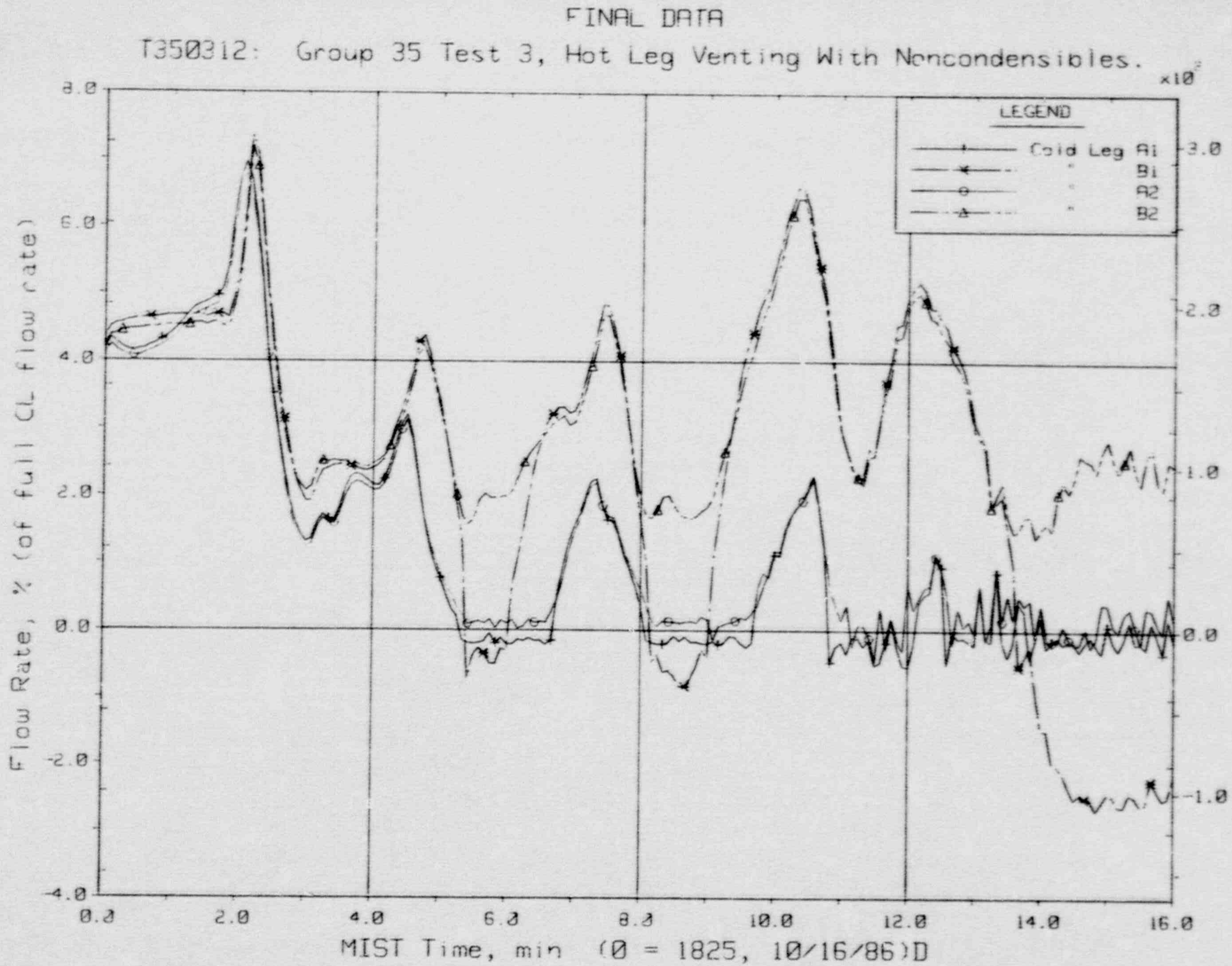


Figure 5.3.23 Cold Leg (Venturi) Flow Rates

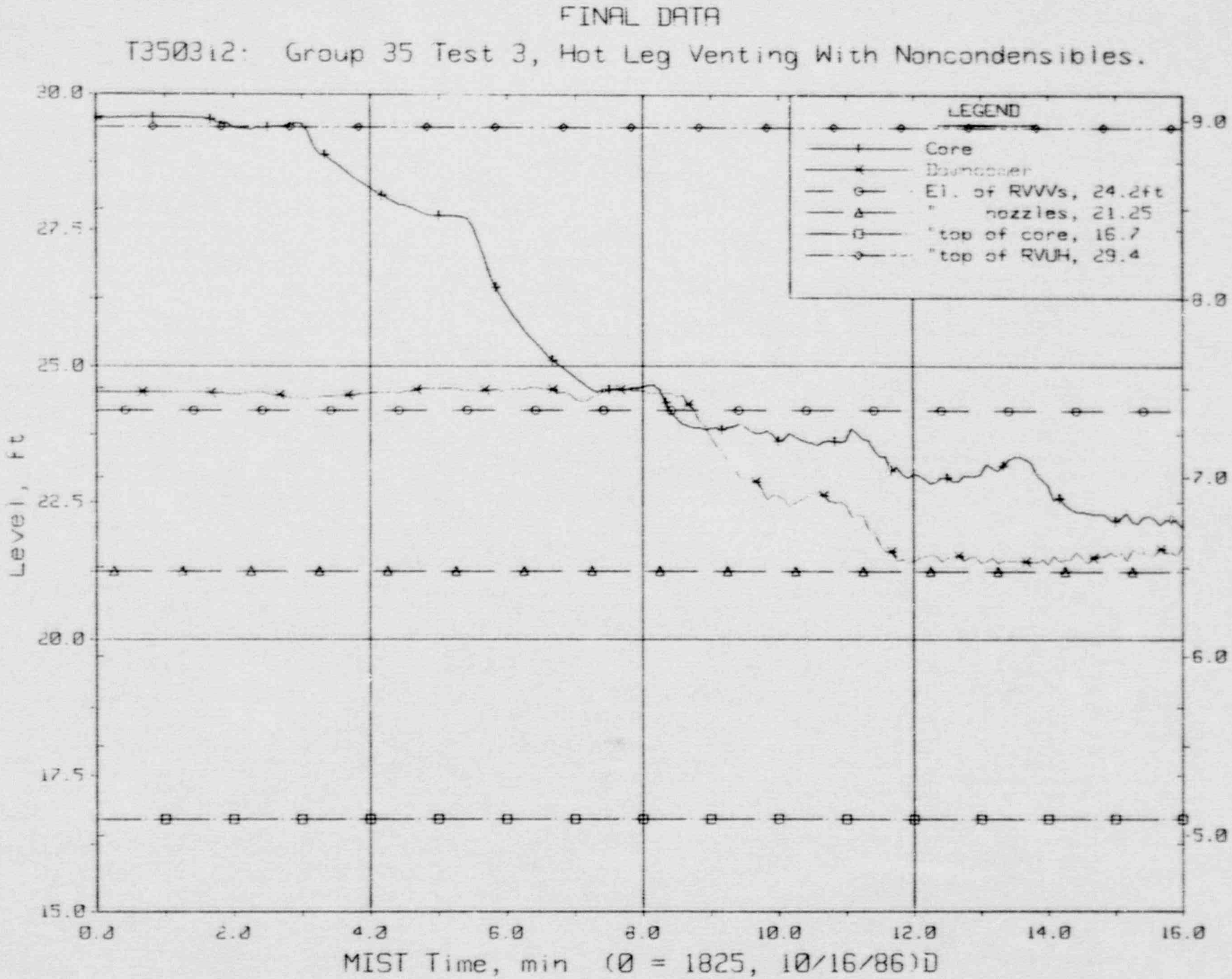


Figure 5.3.24 Core Region Collapsed Liquid Levels

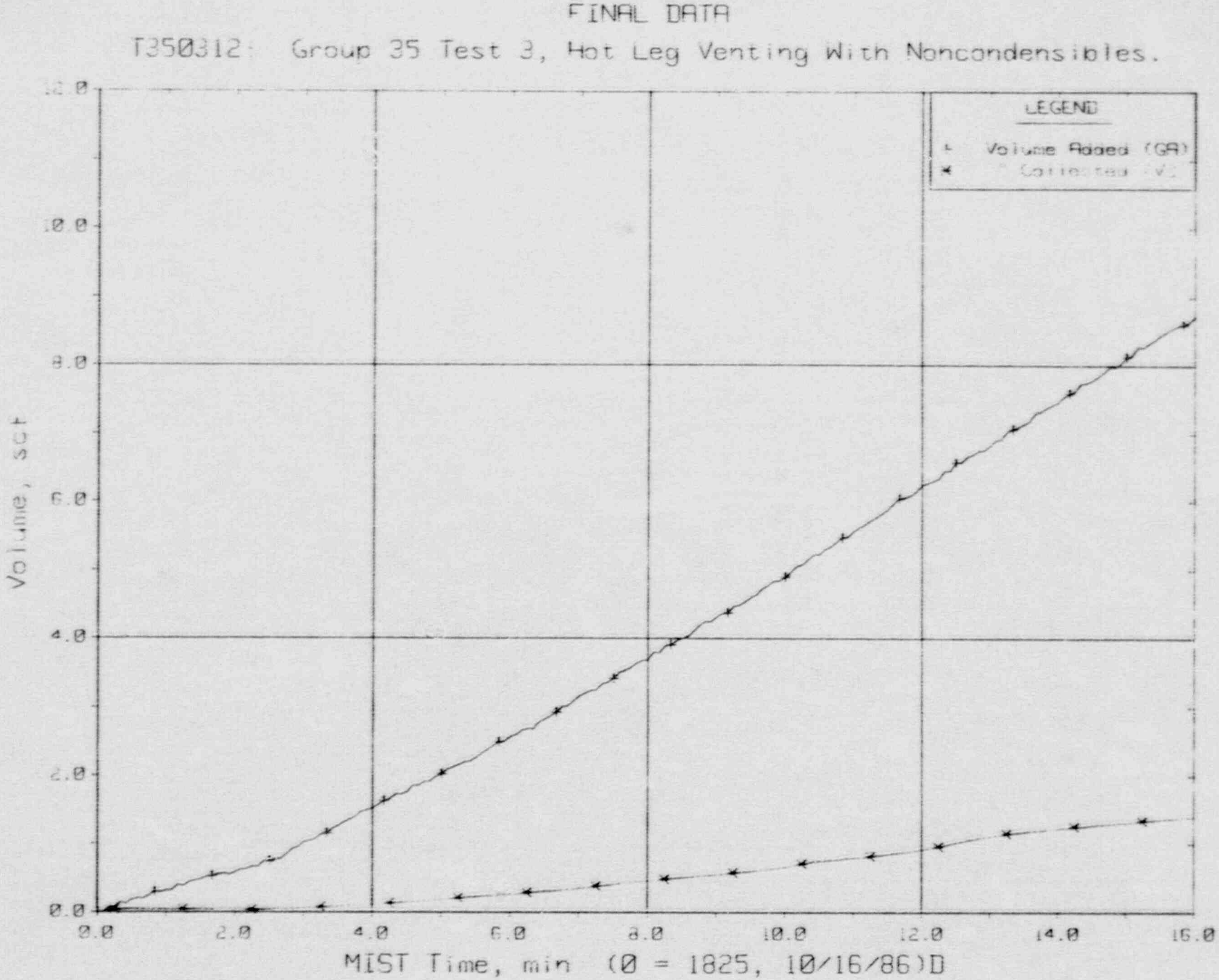


Figure 5.3.25 Noncondensibles Gas Volumes

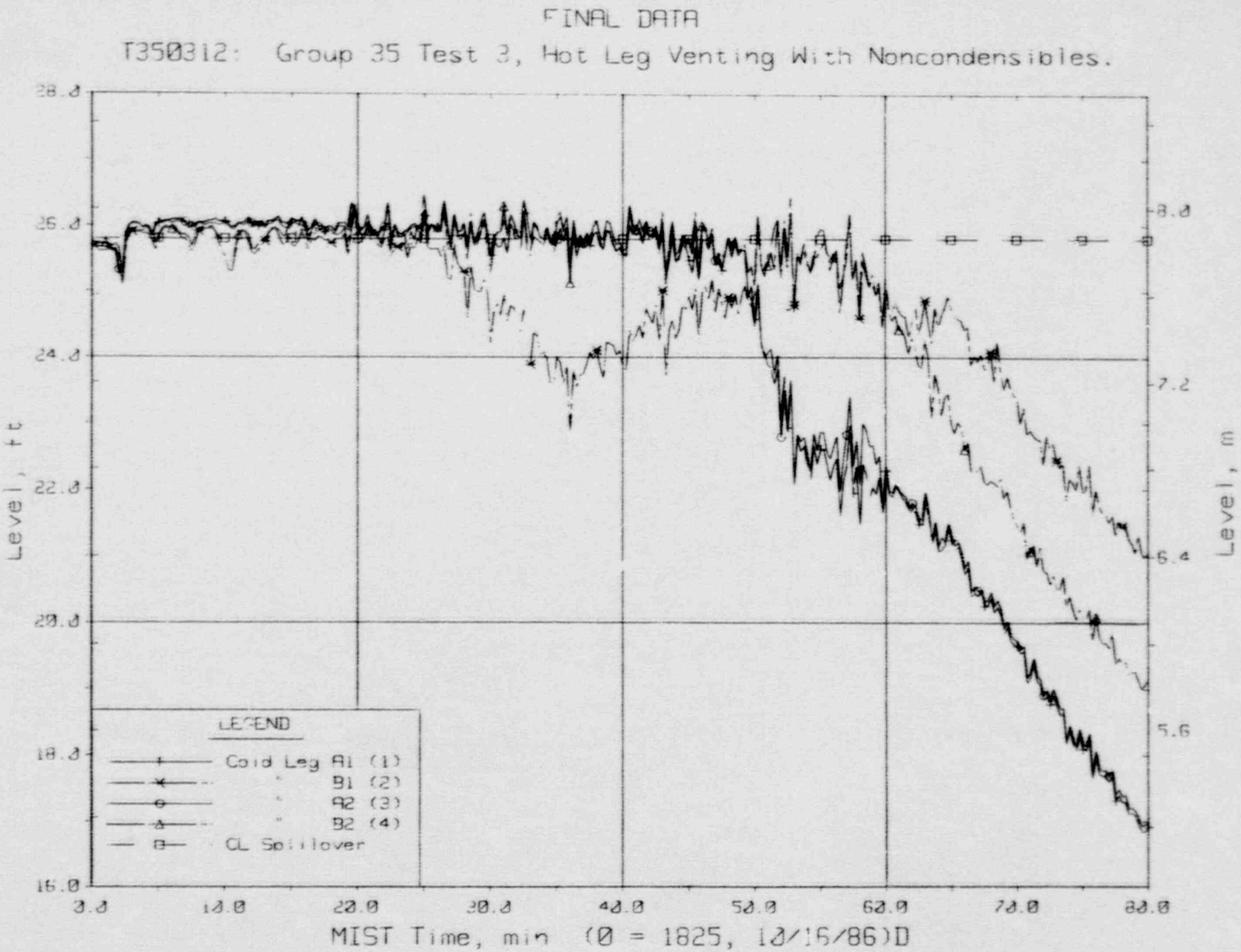


Figure 5.3.26 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

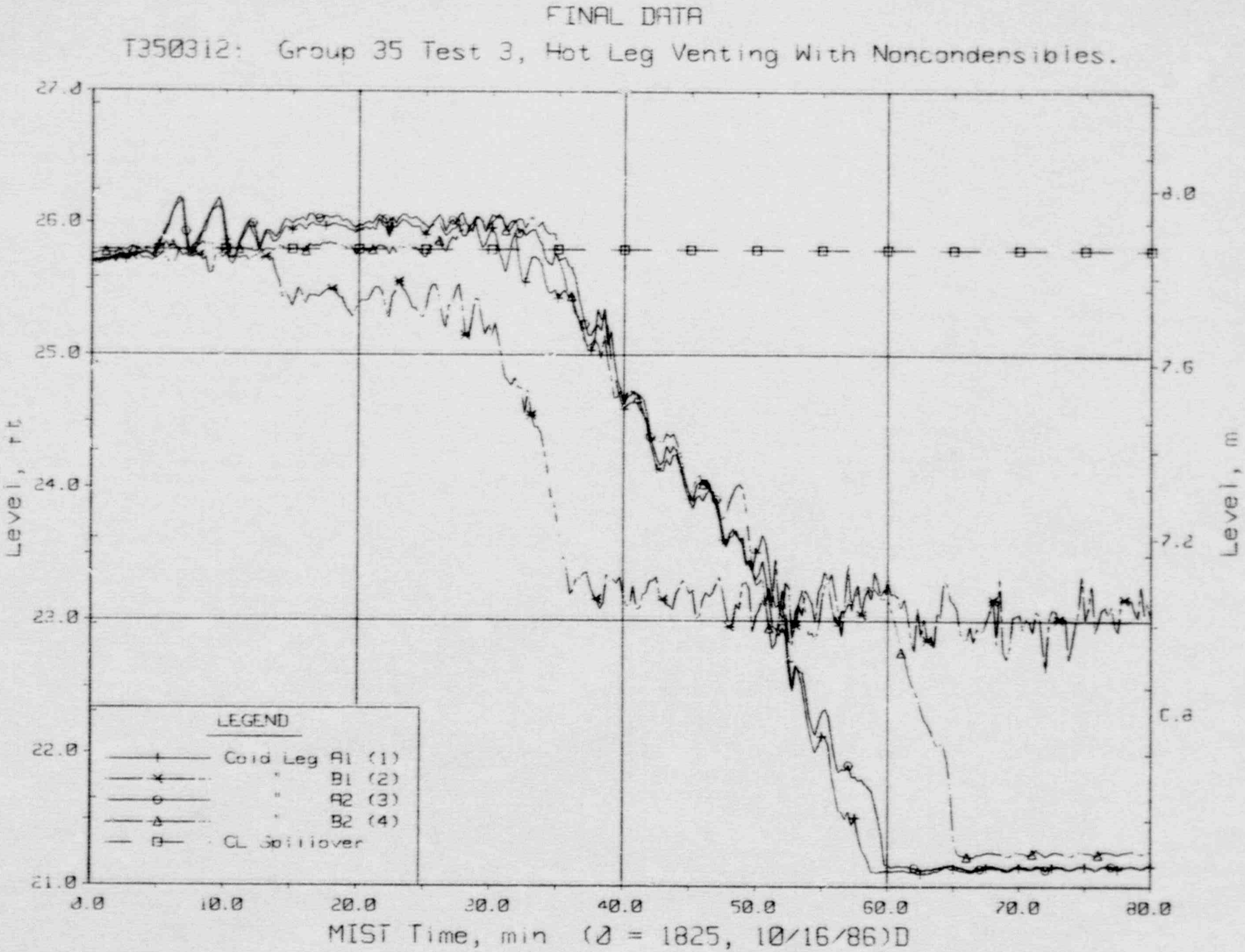


Figure 5.3.27 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

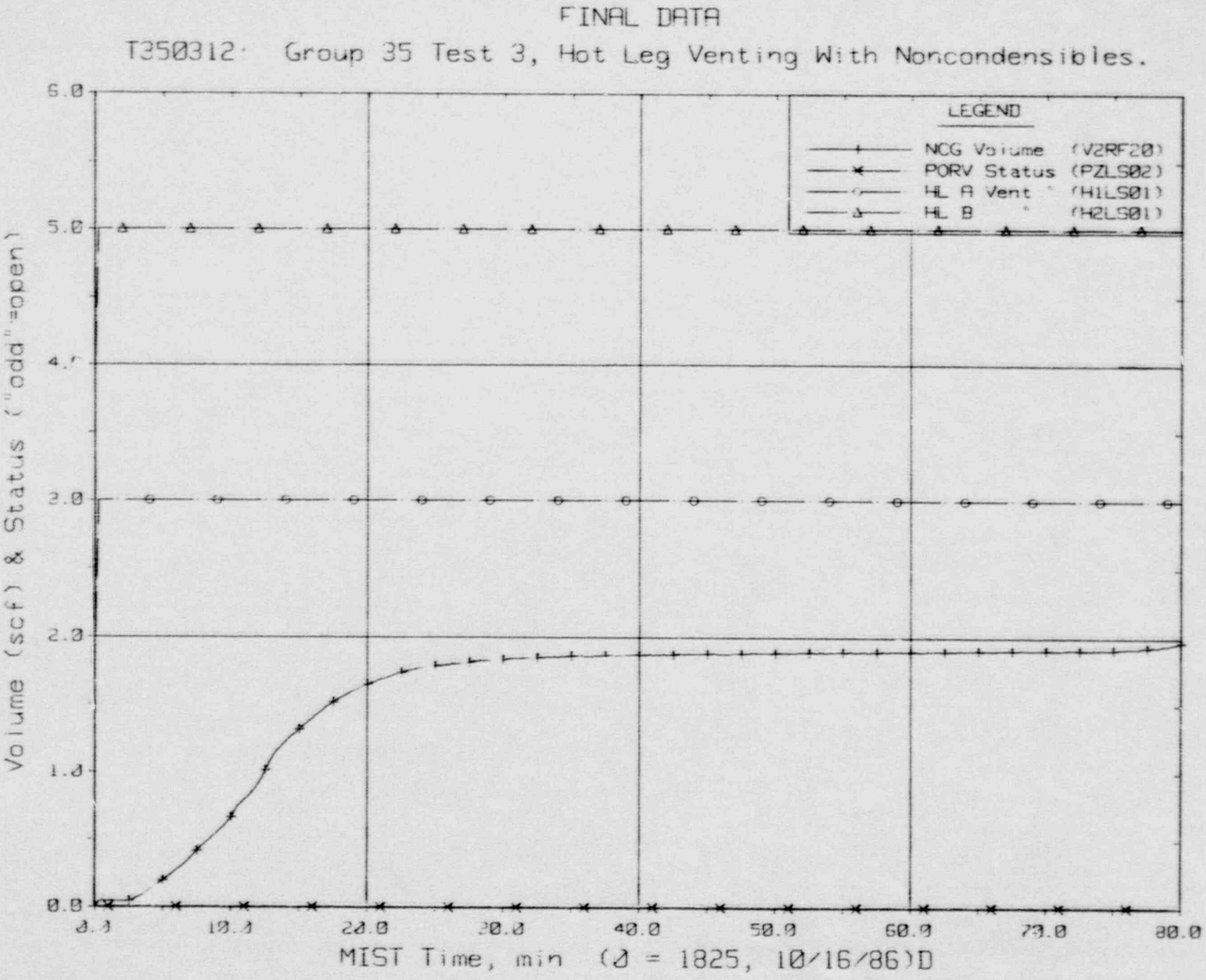


Figure 5.3.28 Noncondensibles Collected and Discharge Valve Status

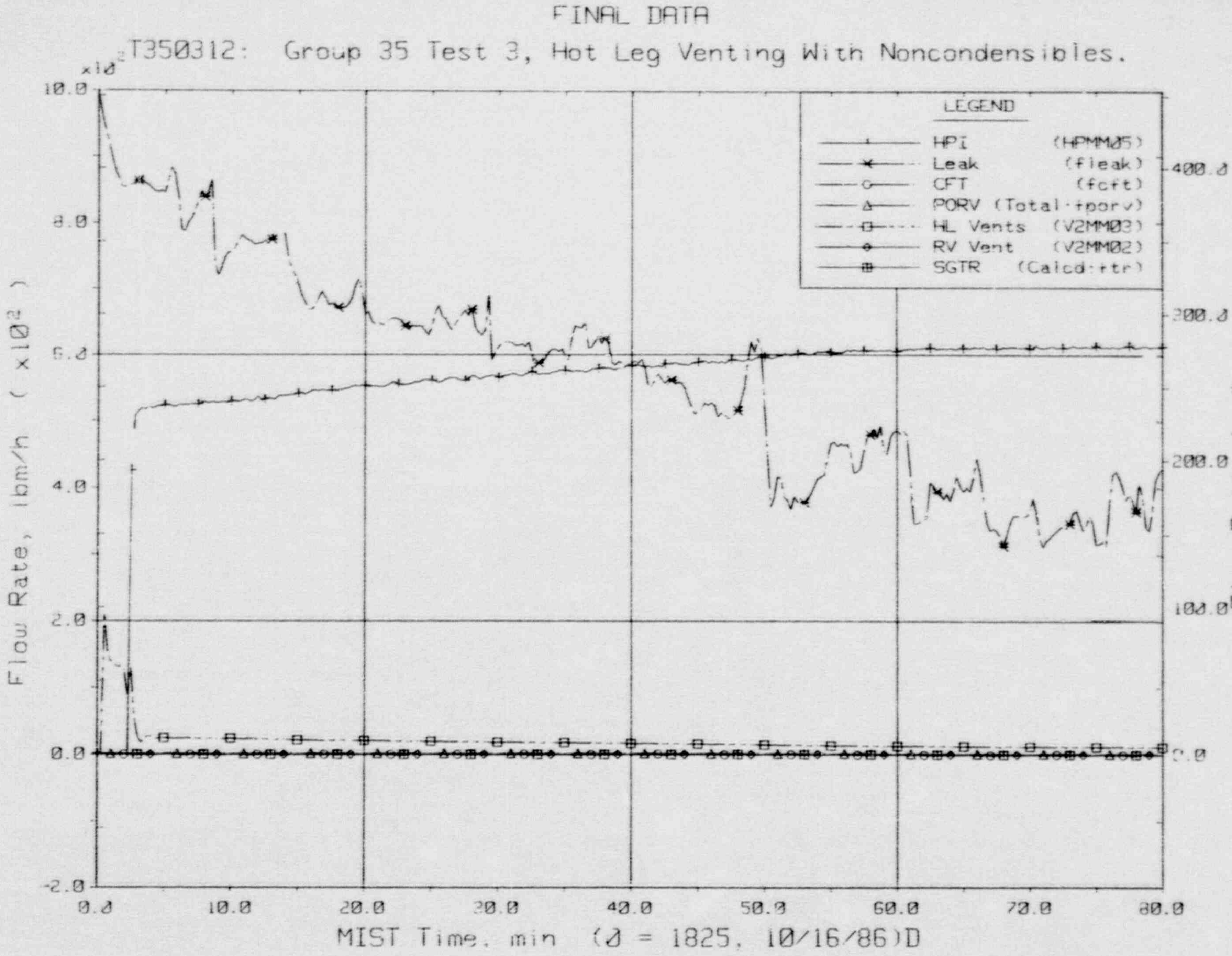


Figure 5.3.29 Primary System Boundary Flow Rates

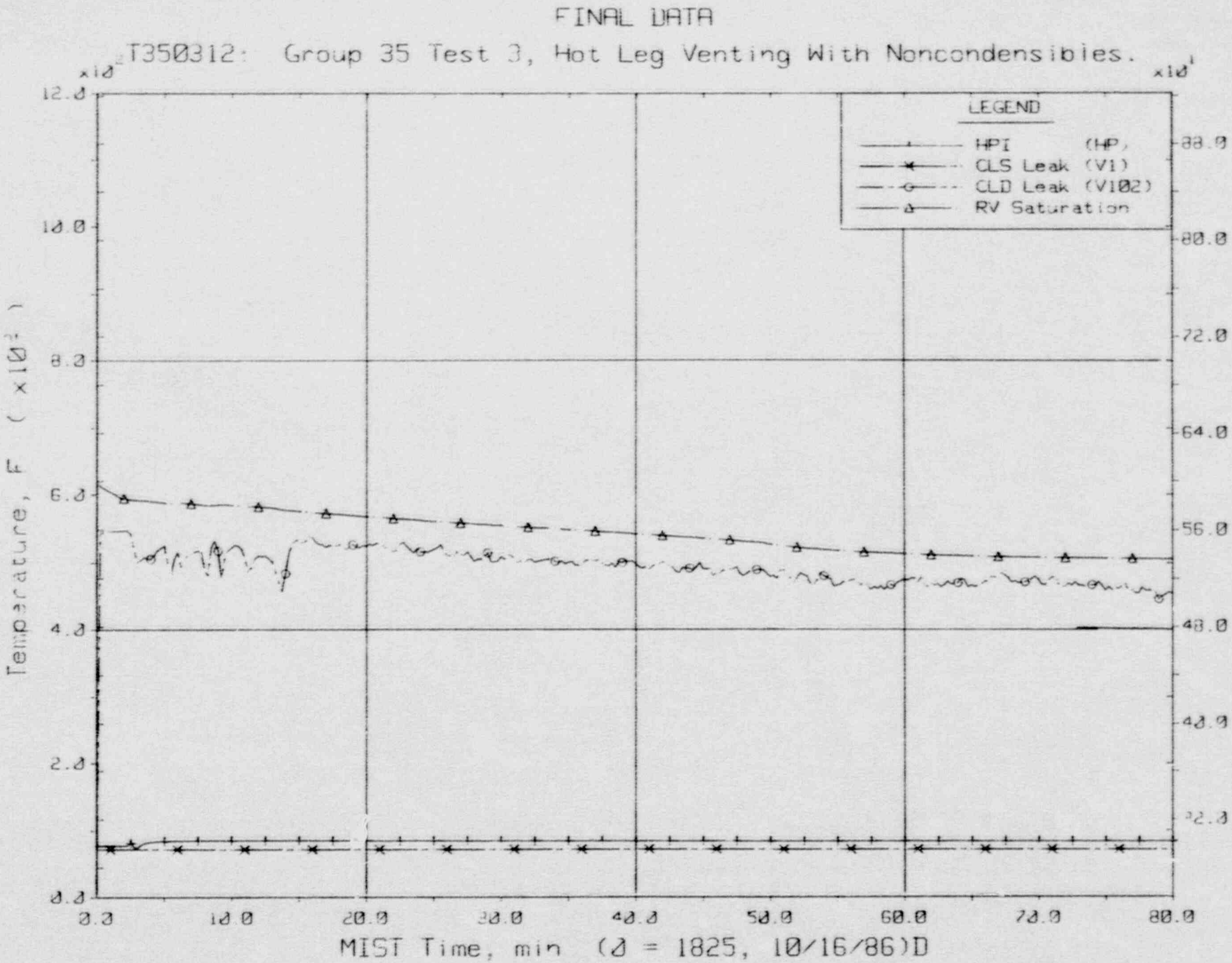


Figure 5.3.30 Single-Phase Discharge and HPI Fluid Temperatures (TC01s)

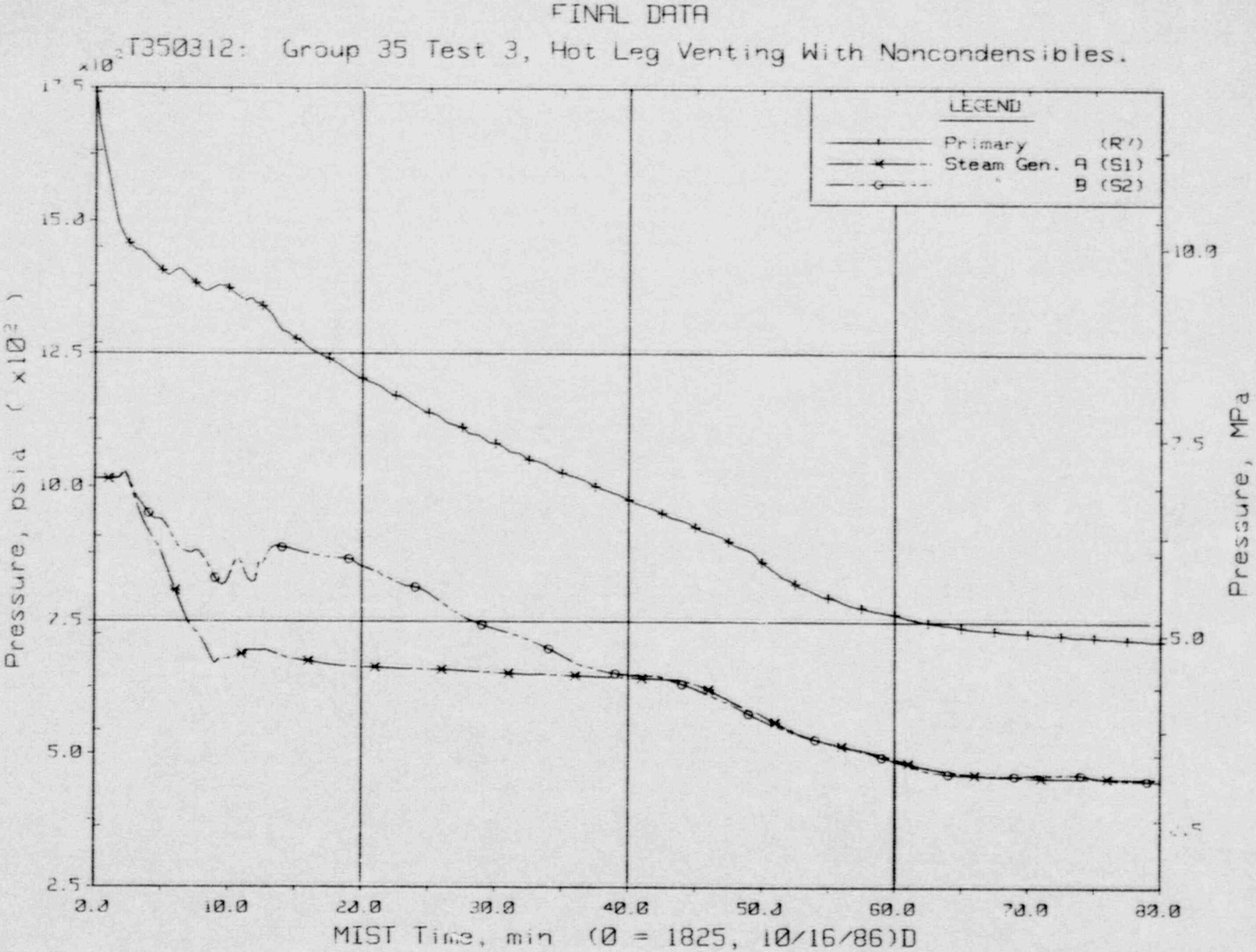


Figure 5.3.31 Primary and Secondary System Pressures (GP01s)

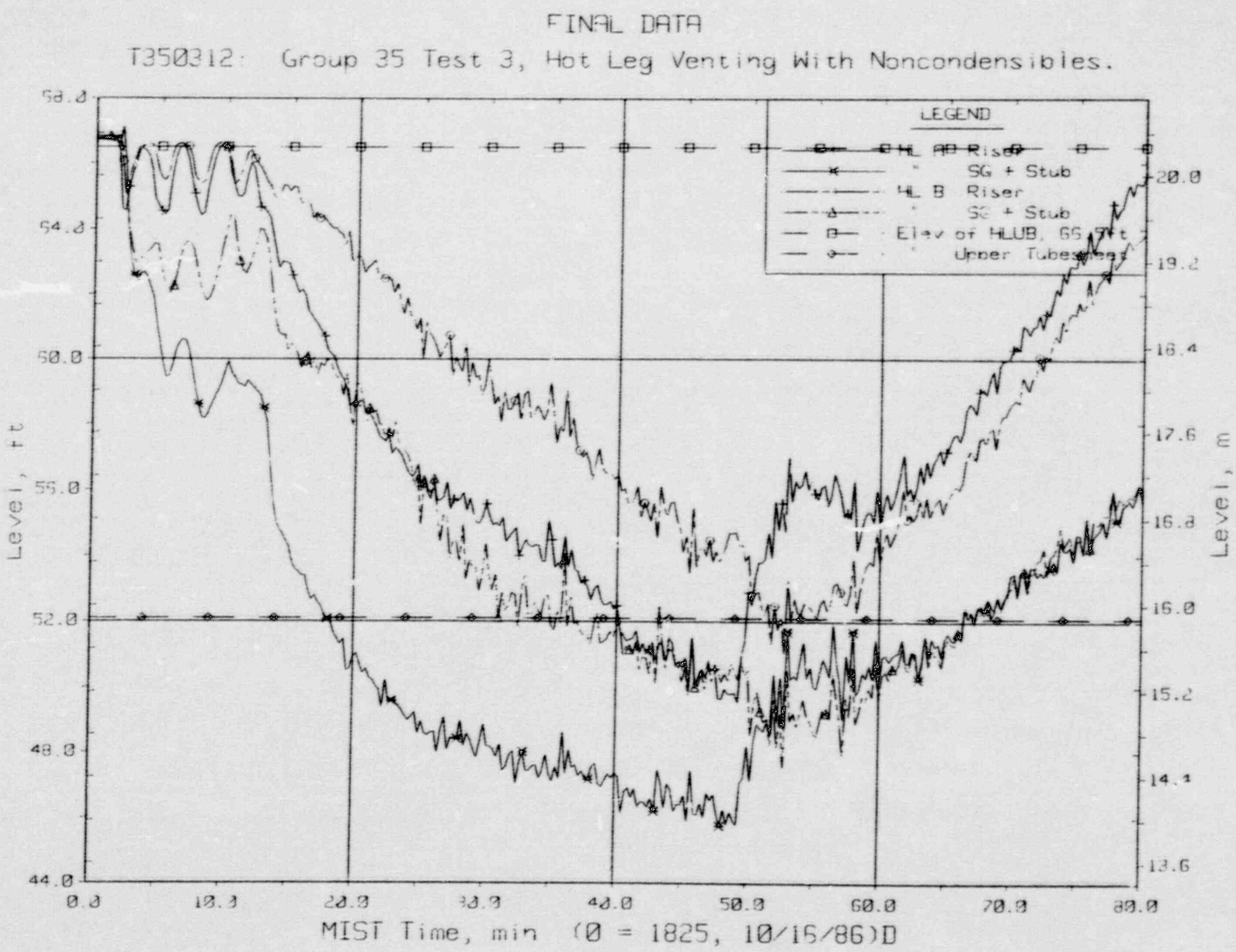


Figure 5.3.32 Hot Leg Riser and Stub Collapsed Liquid Levels

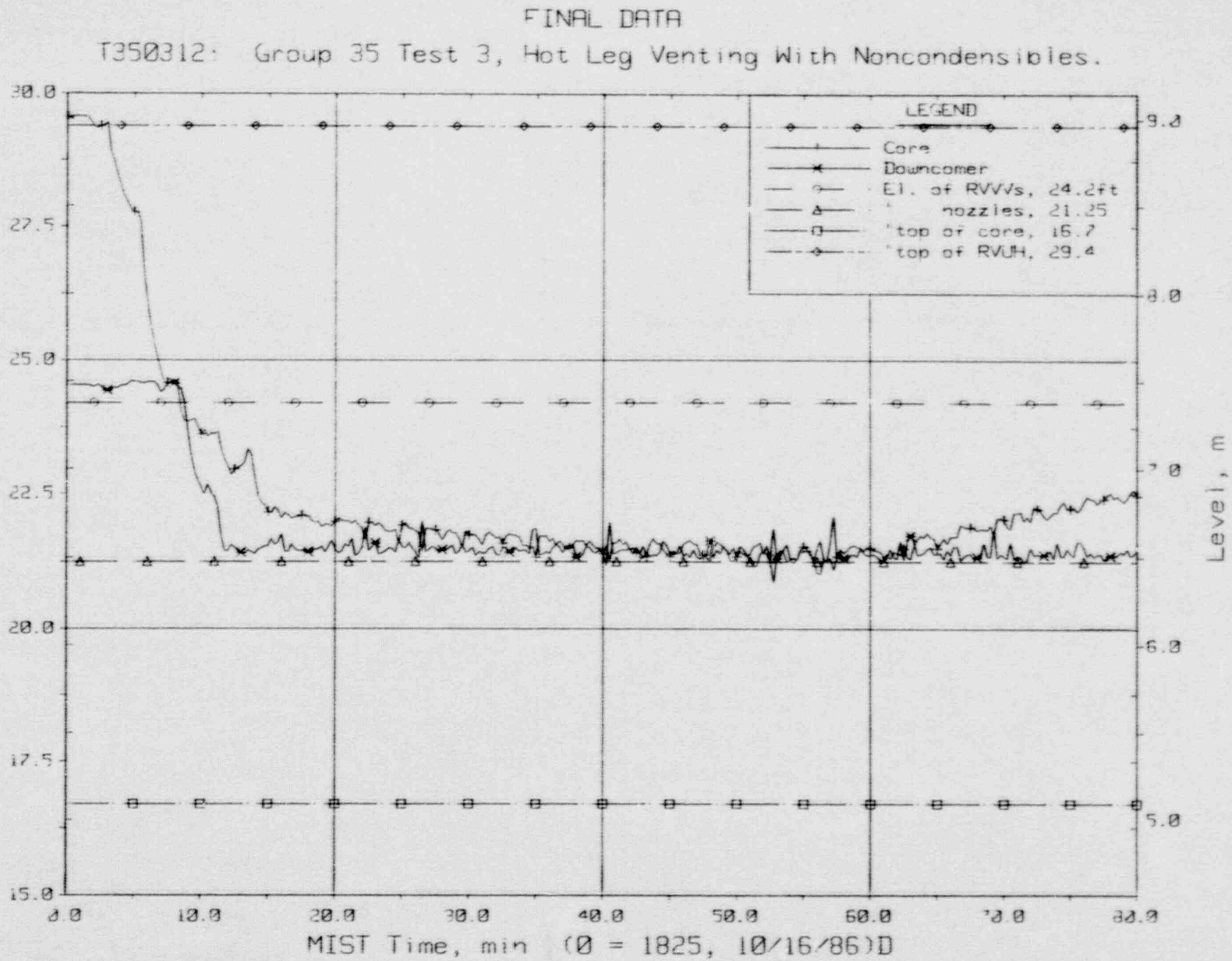


Figure 5.3.33 Core Region Collapsed Liquid Levels

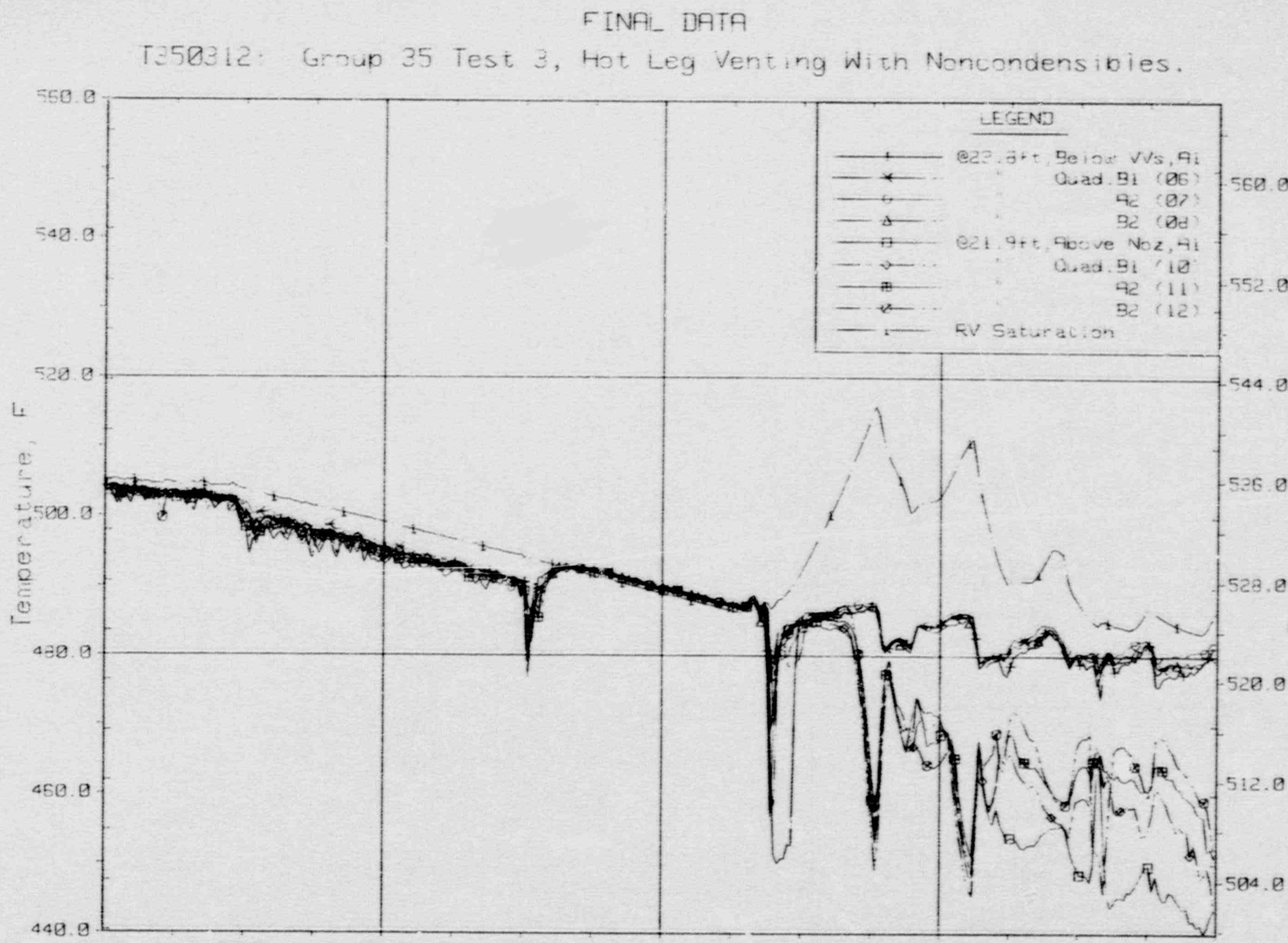


Figure 5.3.34 Downcomer Upper-Elevation Fluid Temperatures (DCTCs)

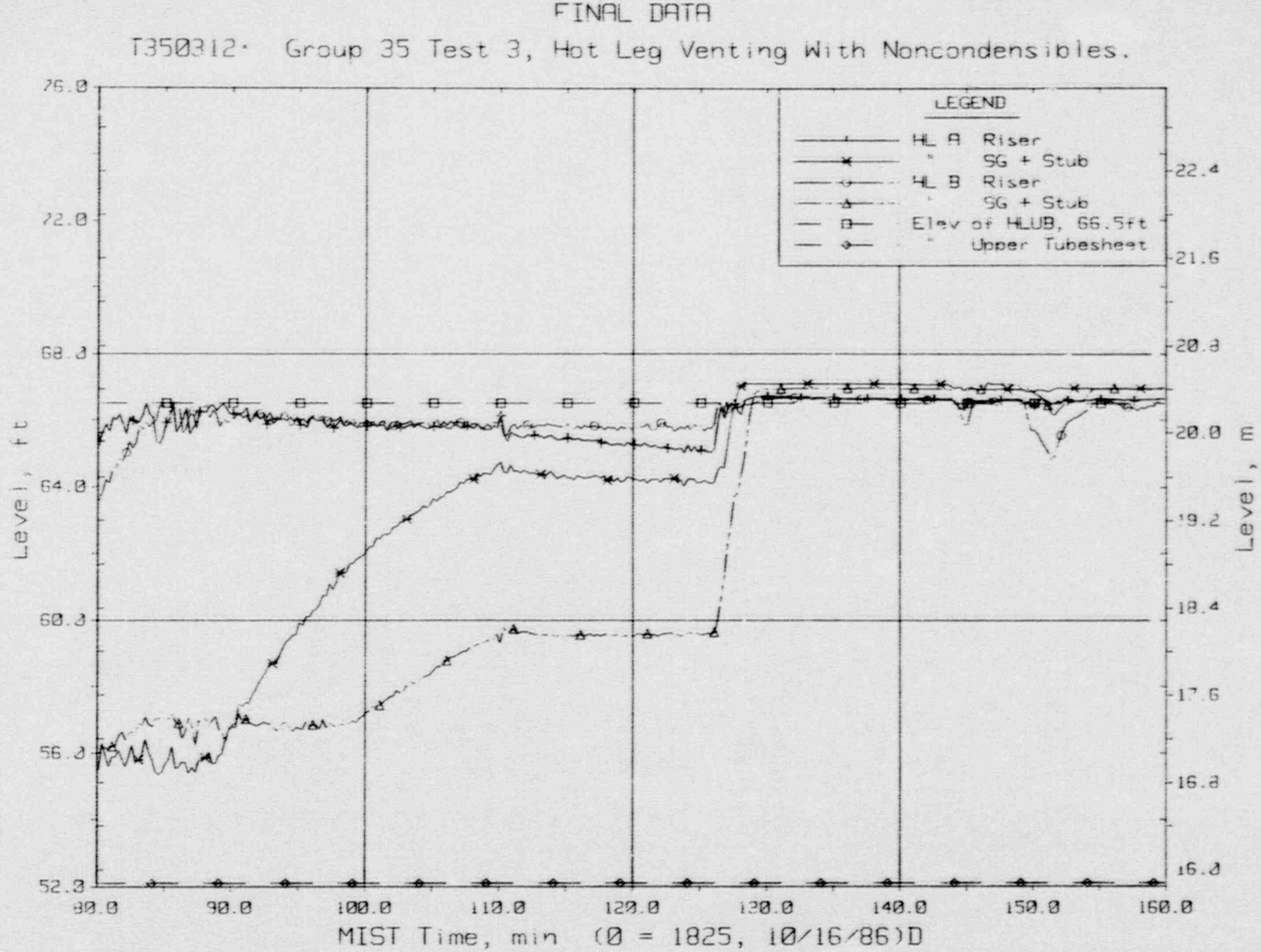


Figure 5.3.35 Hot Leg Riser and Stub Collapsed Liquid Levels

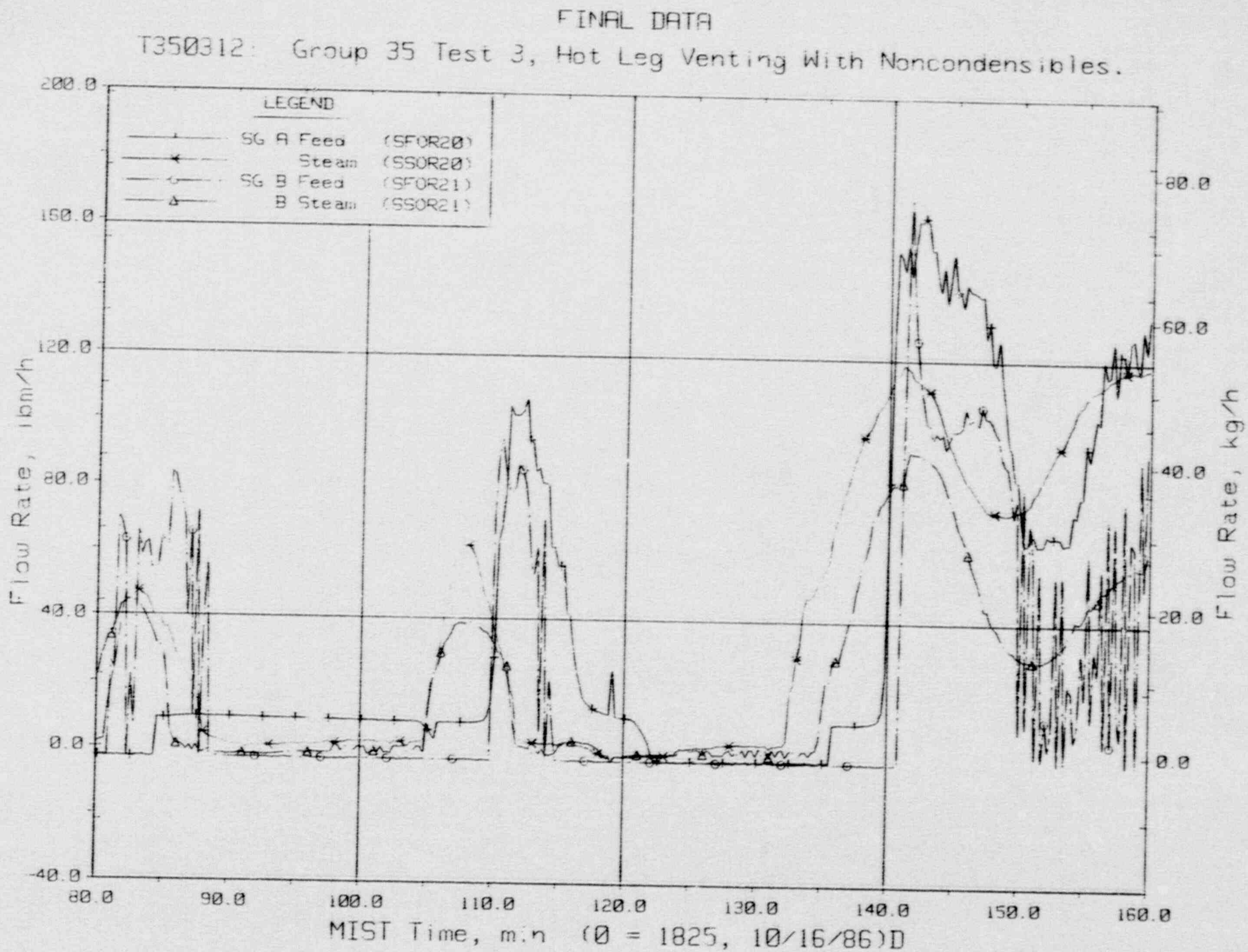


Figure 5.3.36 Steam Generator Secondary Flow Rates

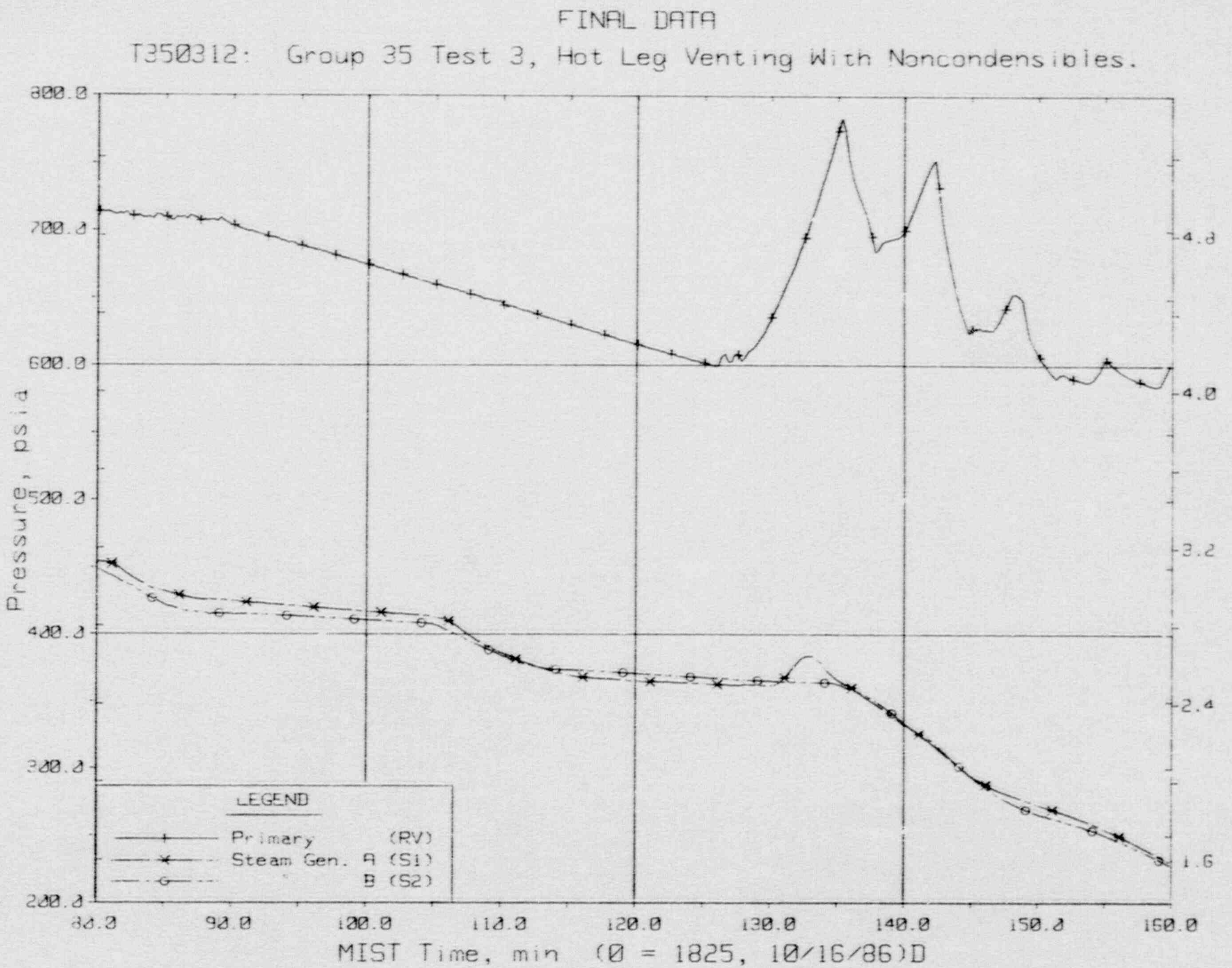


Figure 5.3.37 Primary and Secondary System Pressures (GP01s)

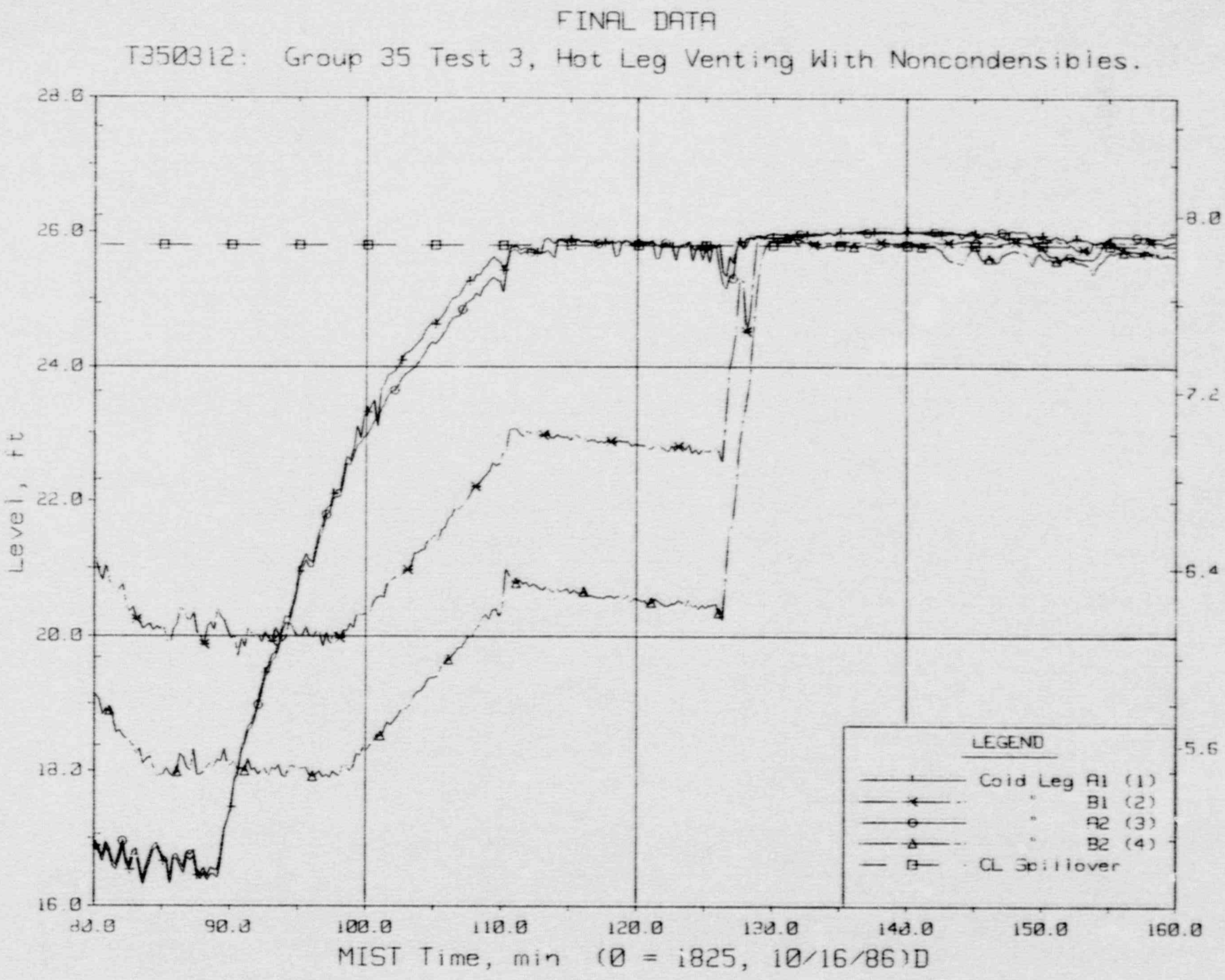


Figure 5.3.38 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

FINAL DATA

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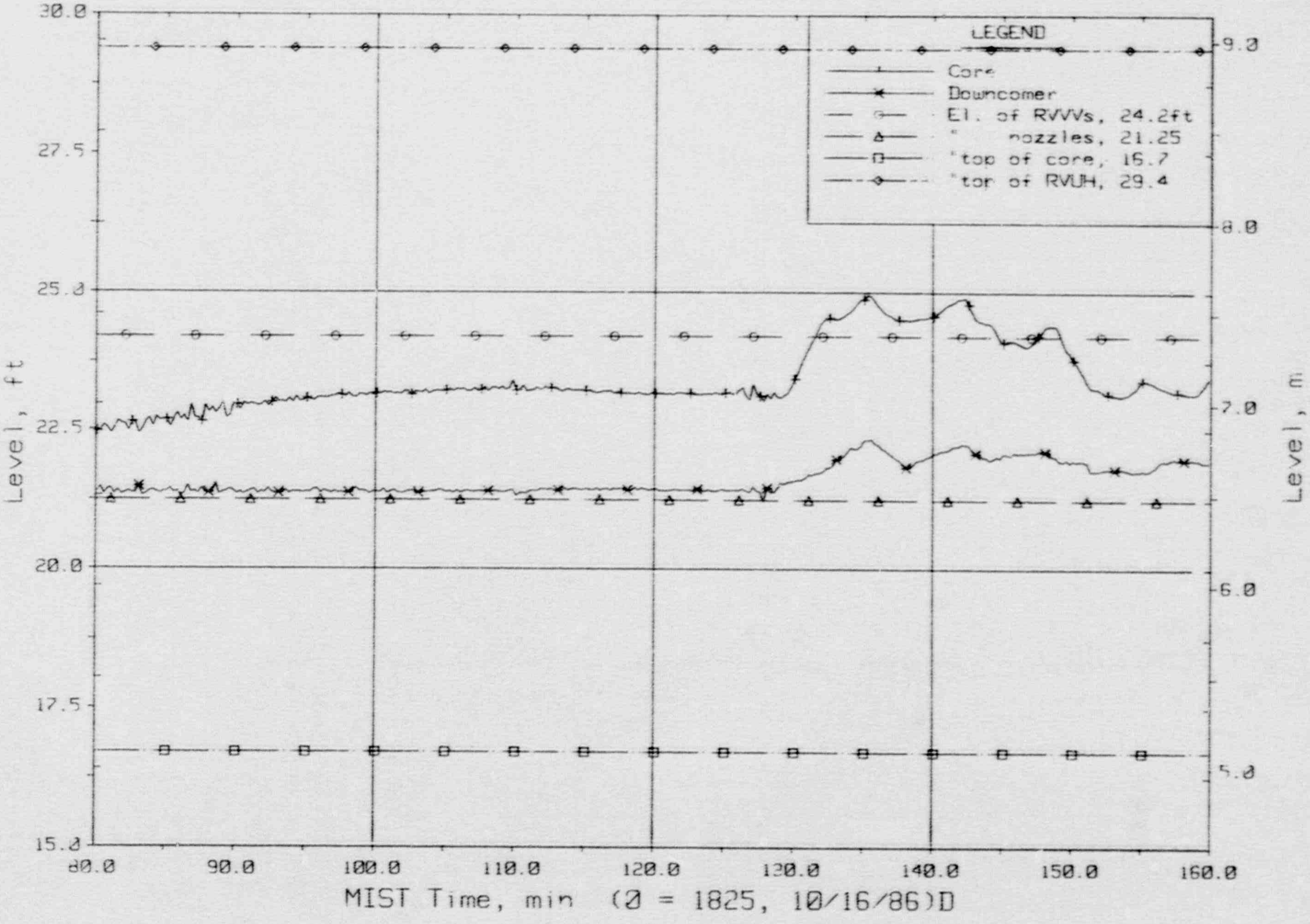


Figure 5.3.39 Core Region Collapsed Liquid Levels

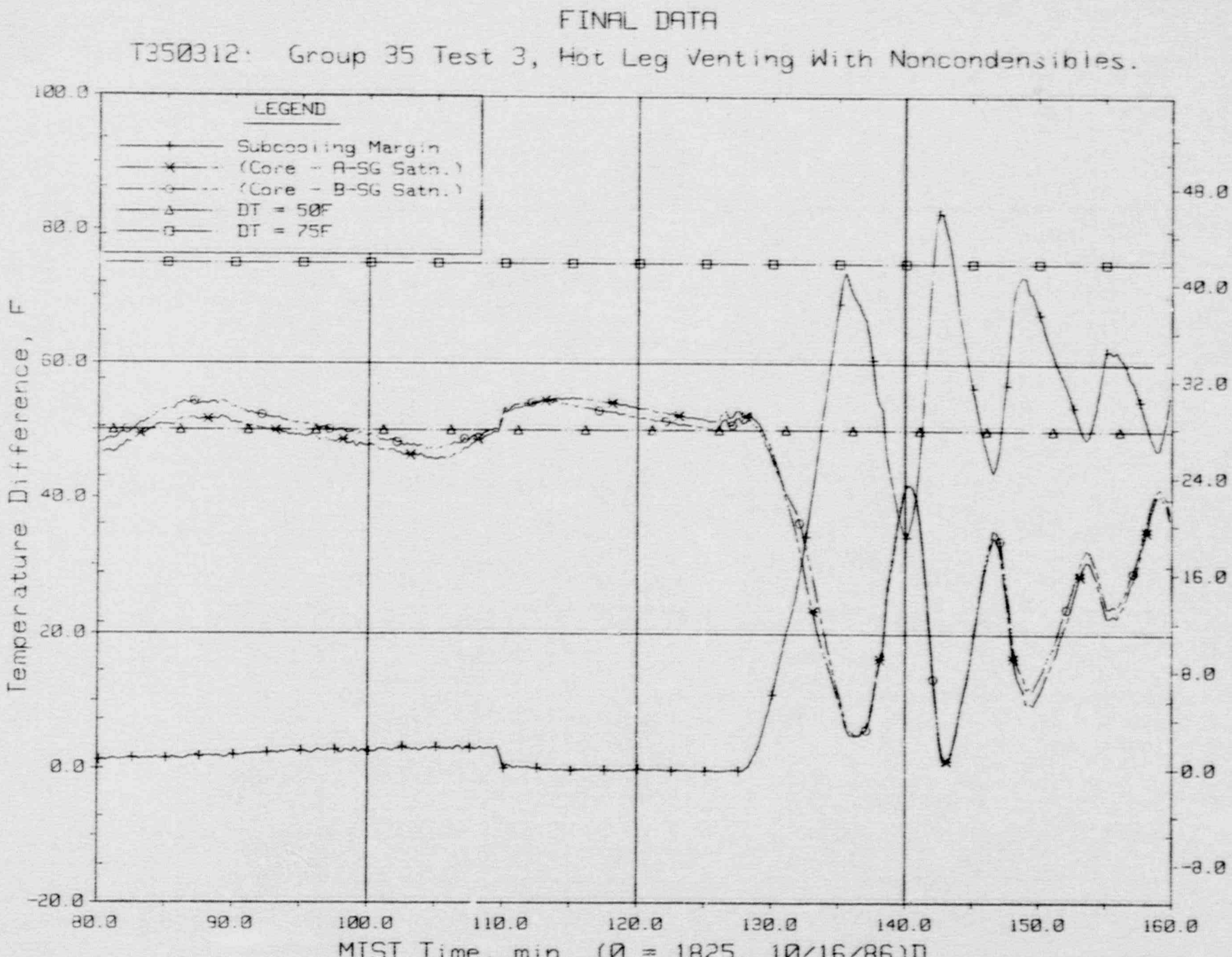


Figure 5.3.40 Control Temperature Differences

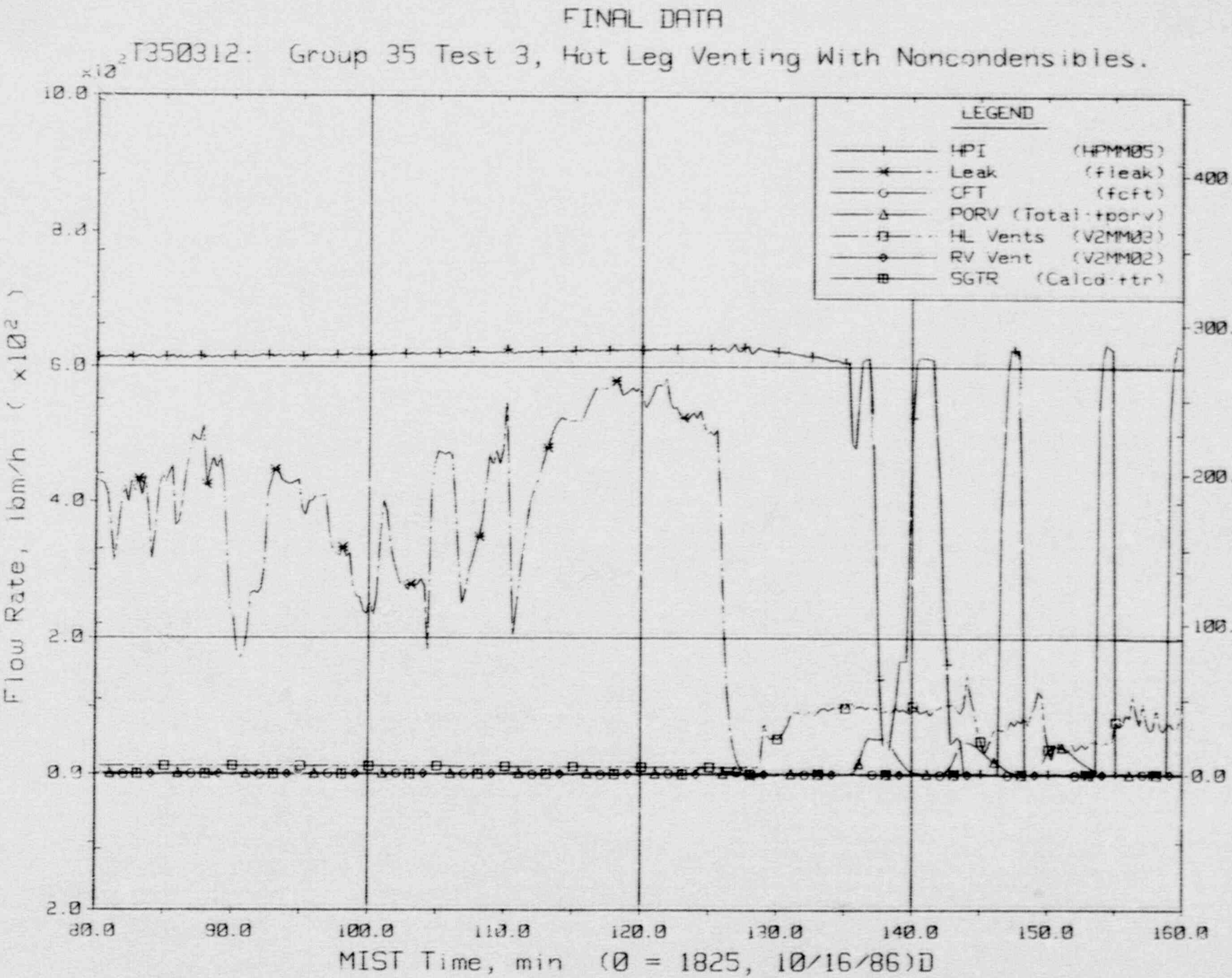


Figure 5.3.41 Primary System Boundary Flow Rates

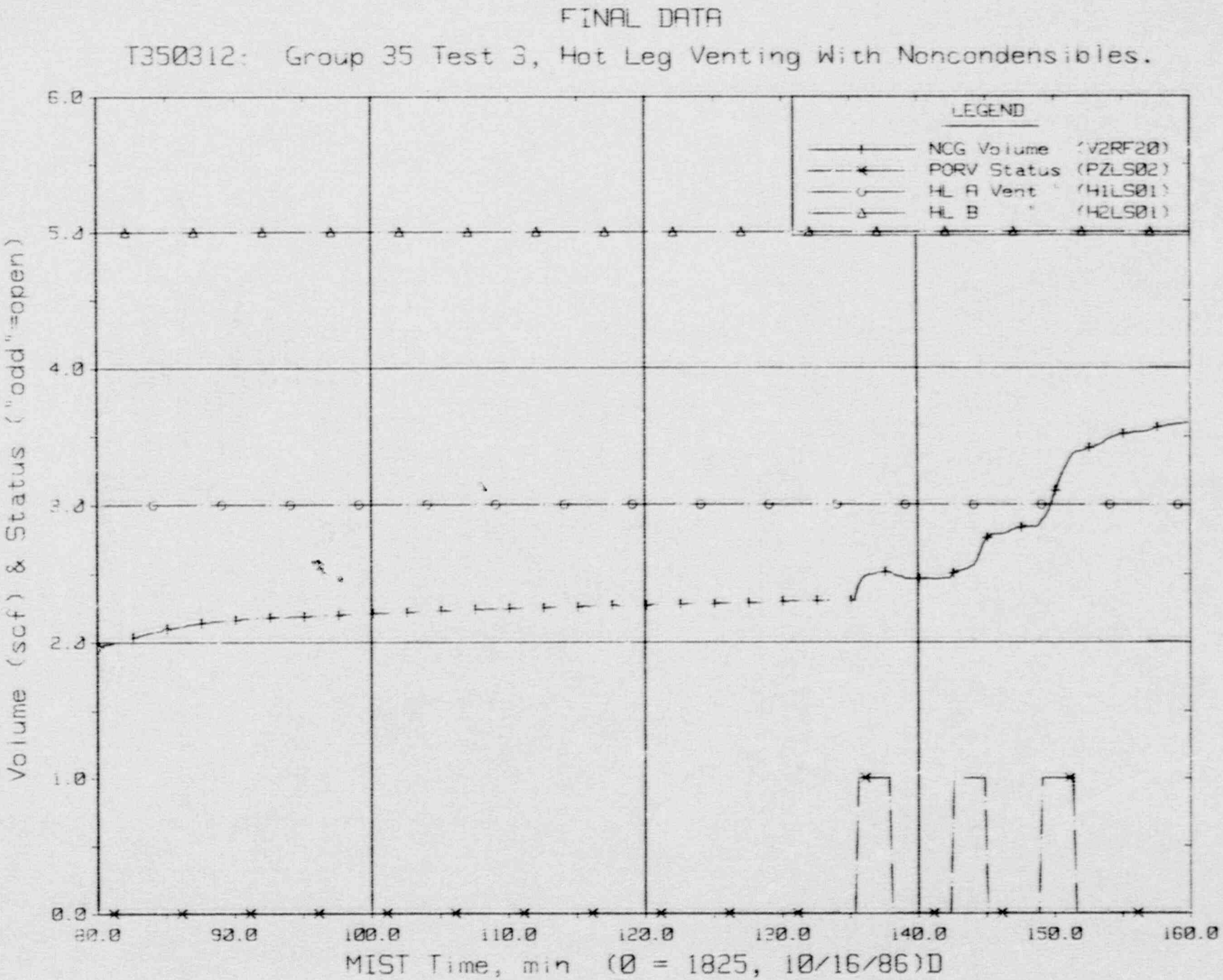


Figure 5.3.42 Noncondensibles Collected and Discharge Valve Status

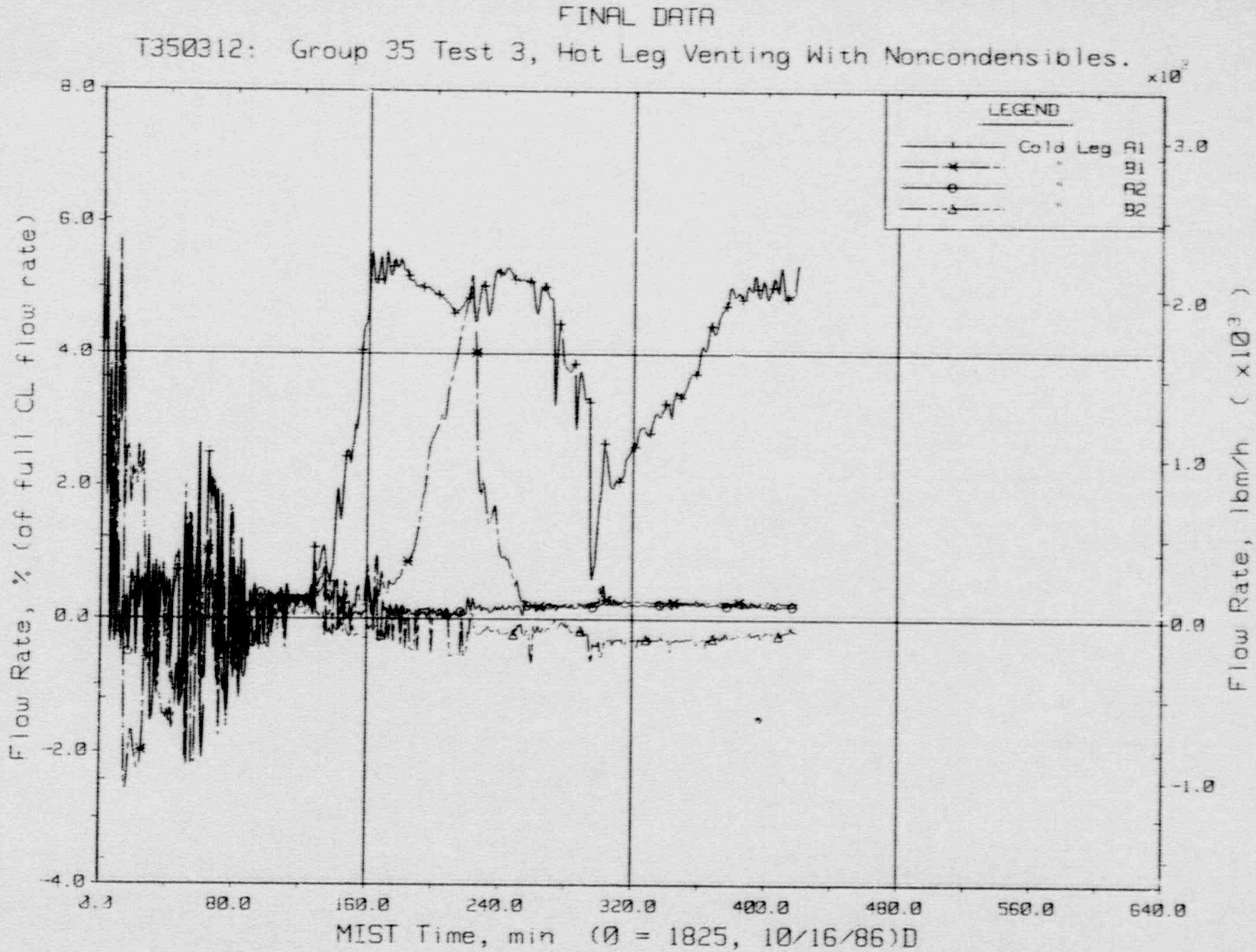


Figure 5.3.43 Cold Leg (Venturi) Flow Rates

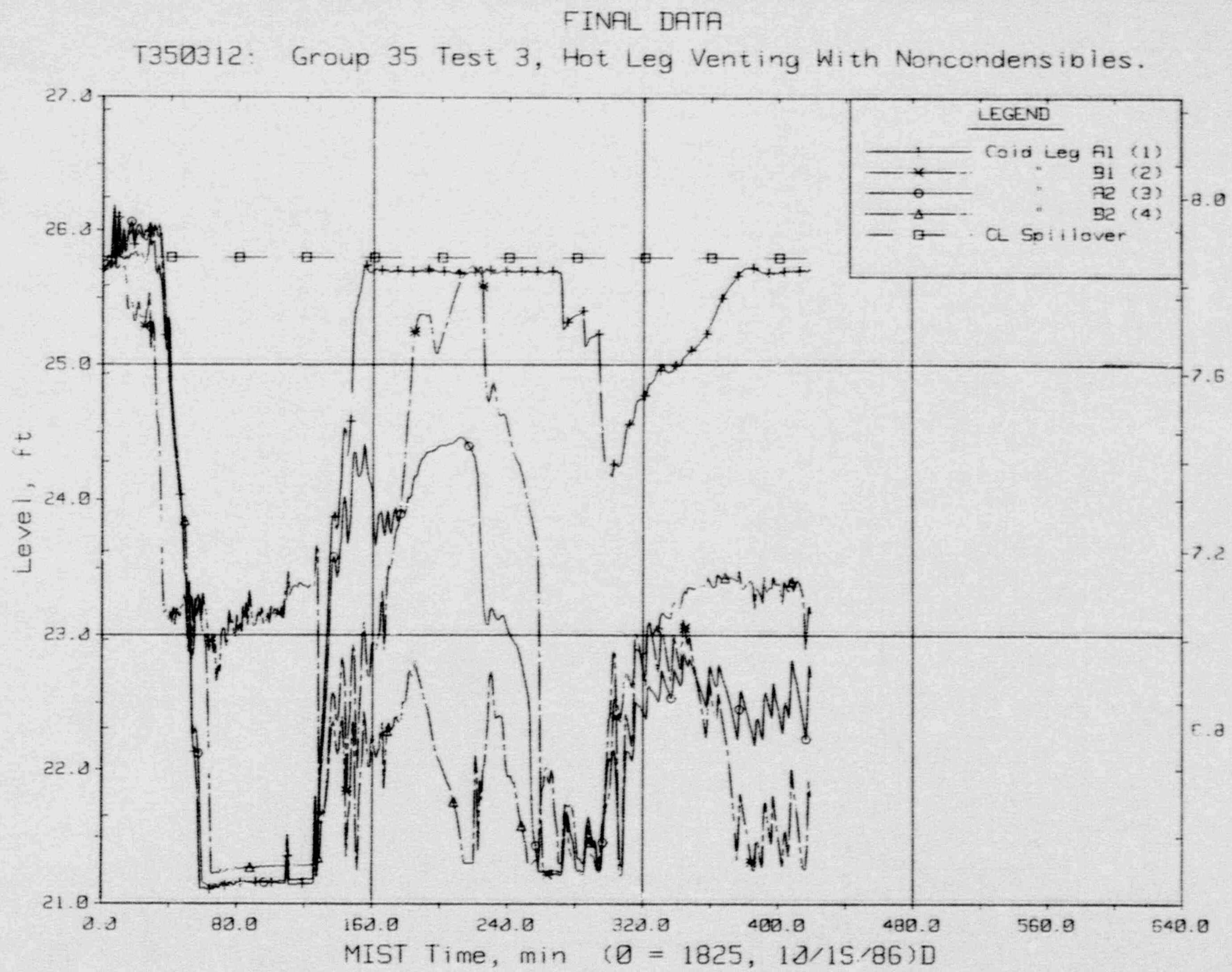


Figure 5.3.44 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

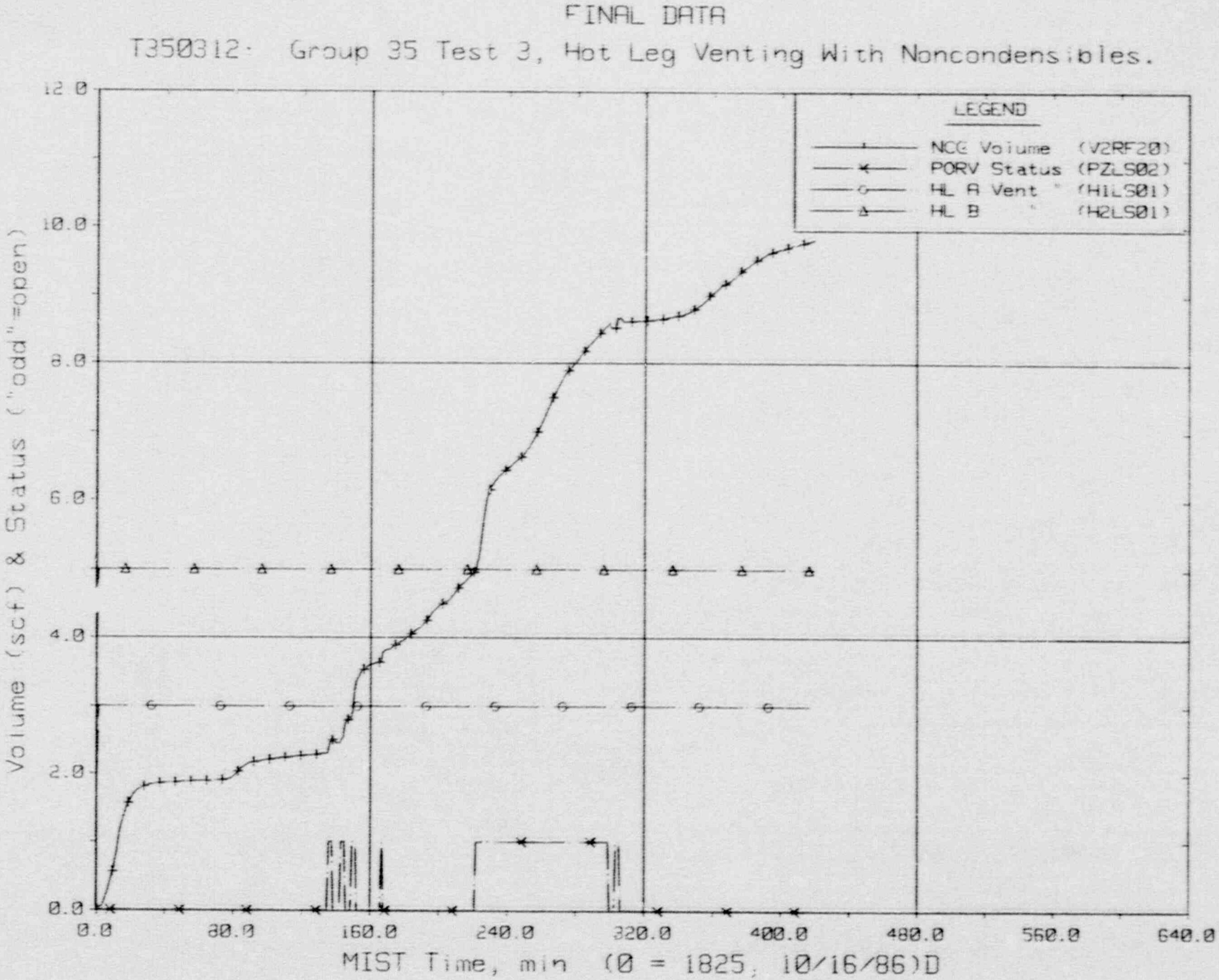


Figure 5.3.45 Noncondensibles Collected and Discharge Valve Status

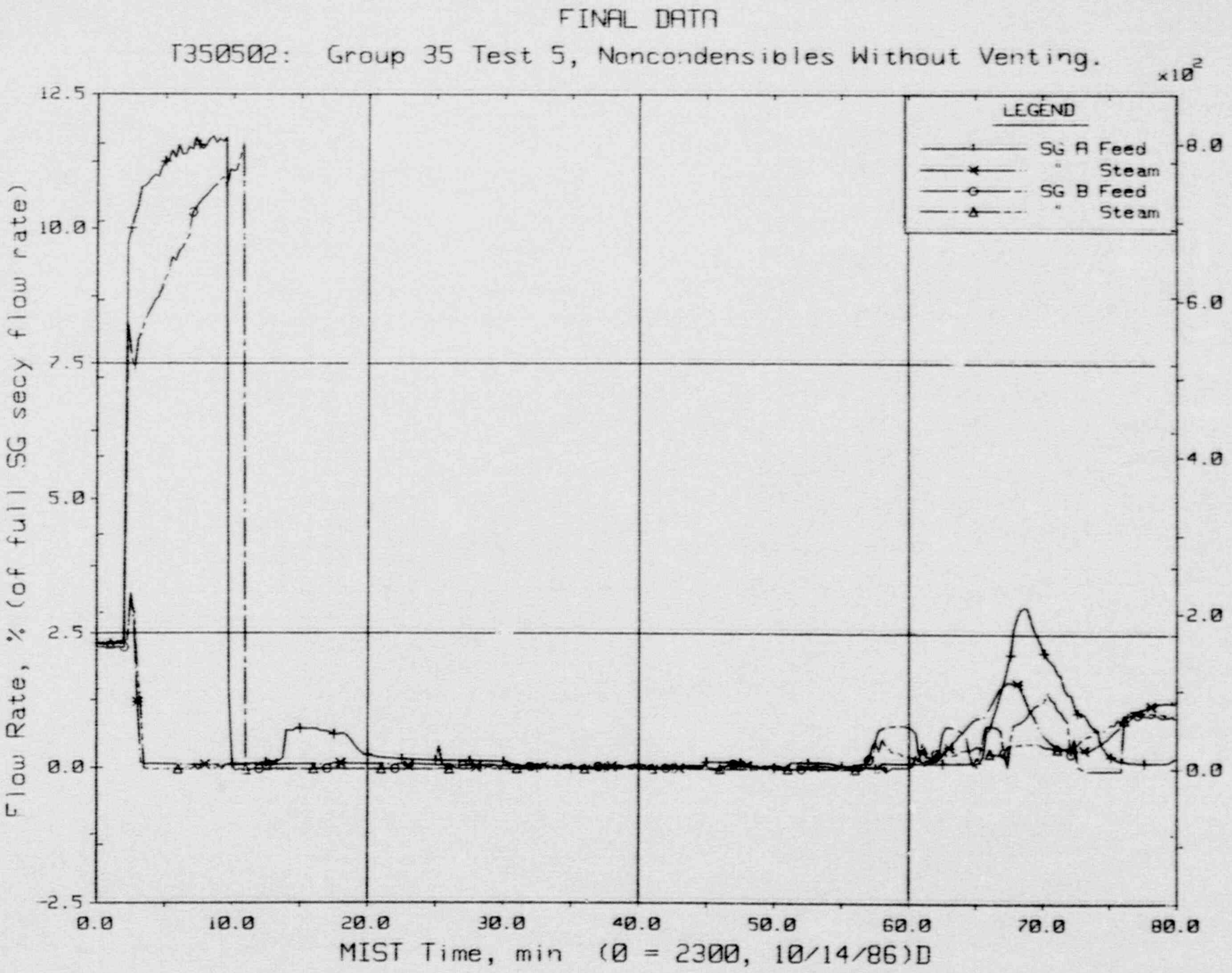


Figure 5.3.46 Secondary System Flow Rates

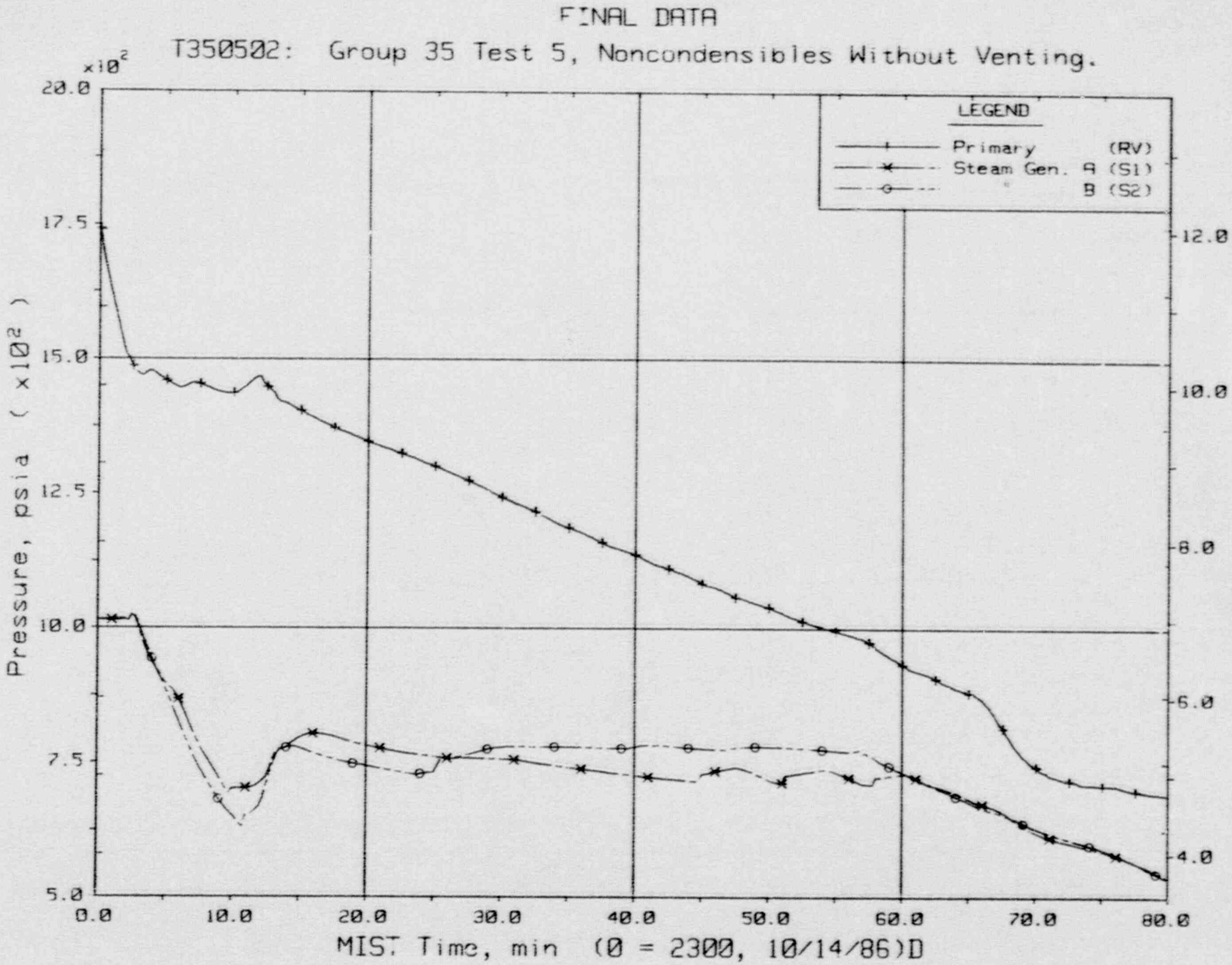


Figure 5.3.47 Primary and Secondary System Pressures (GP01s)

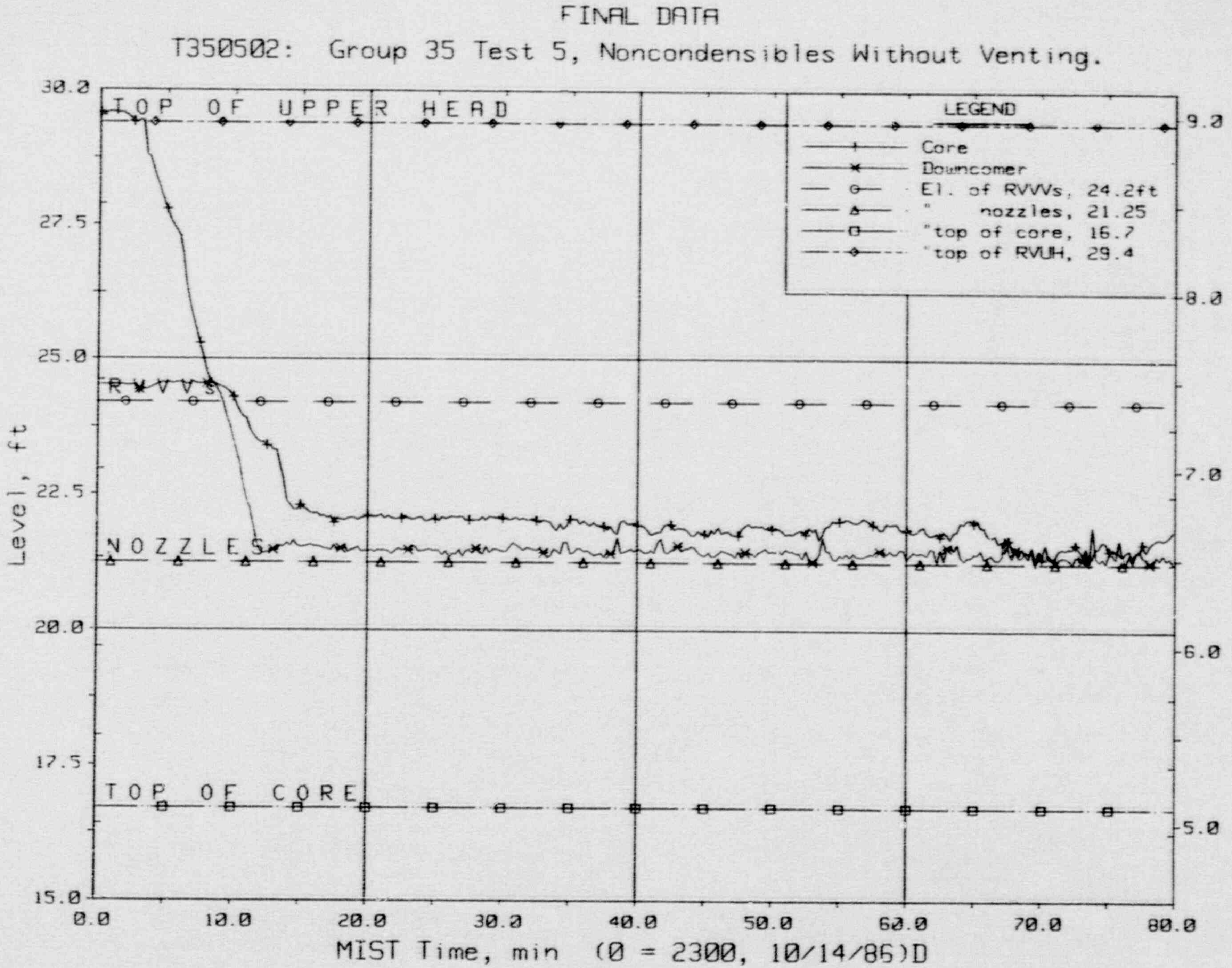


Figure 5.3.48 Core Region Collapsed Liquid Levels

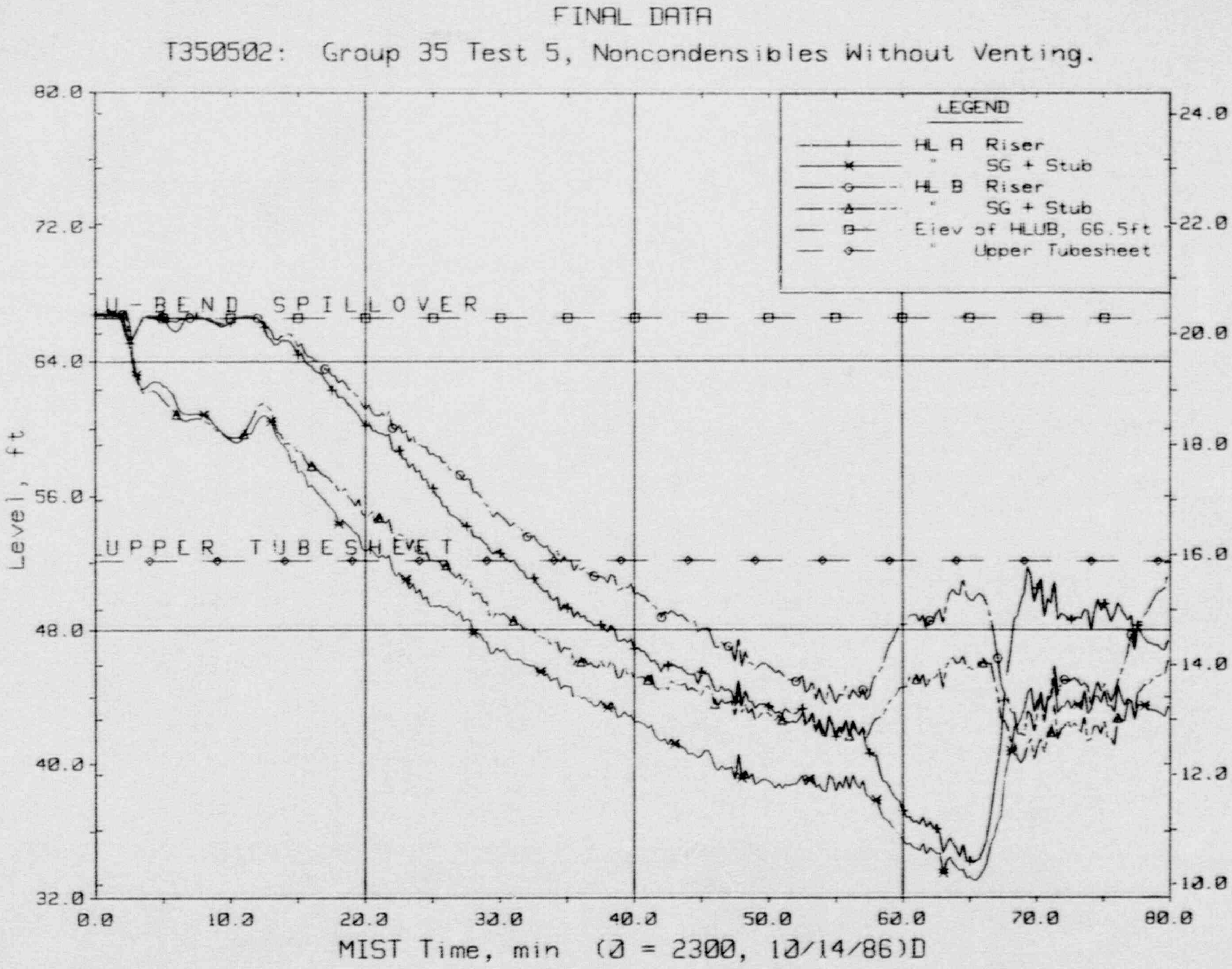


Figure 5.3.49 Hot Leg Riser and Stub Collapsed Liquid Levels

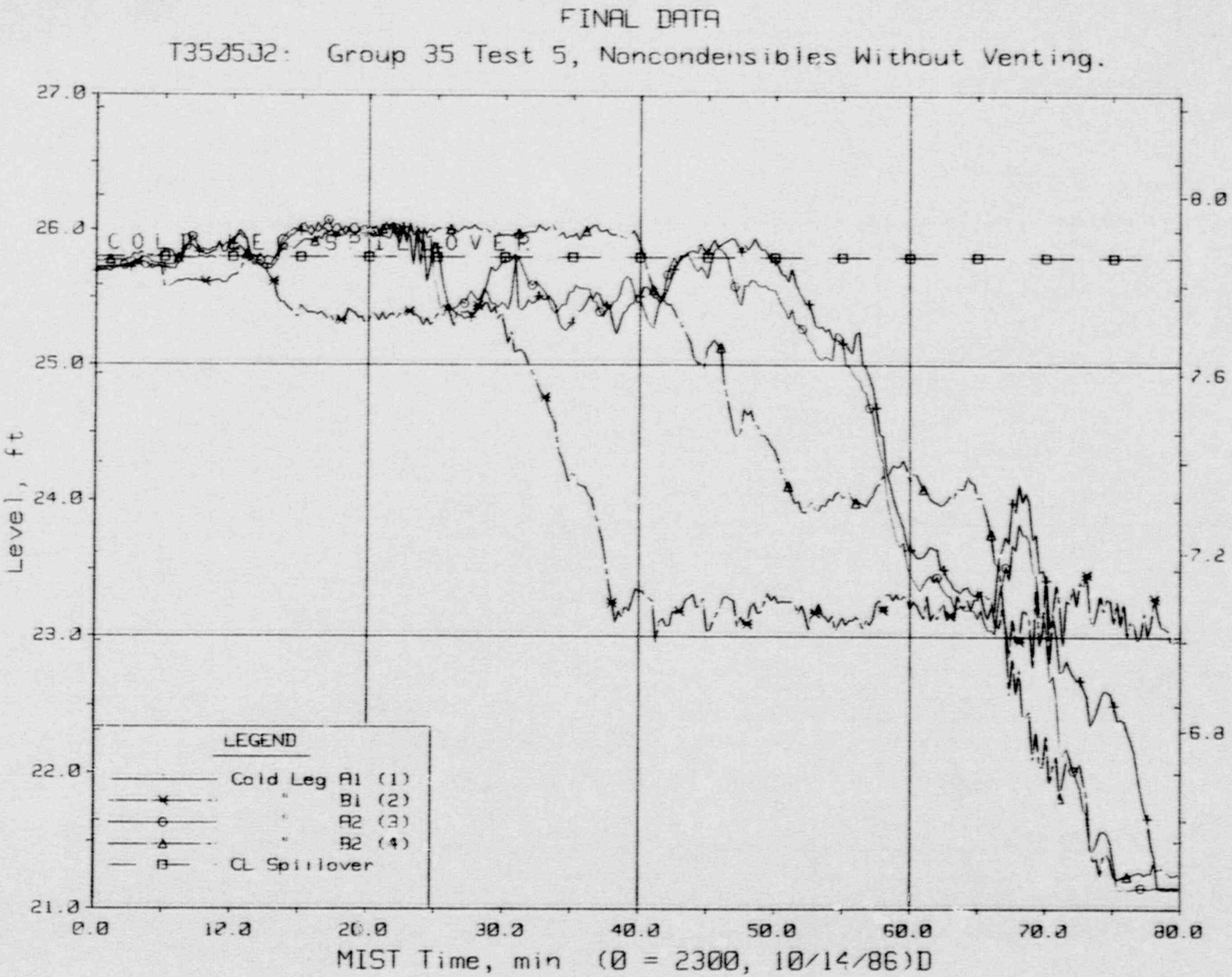


Figure 5.3.50 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

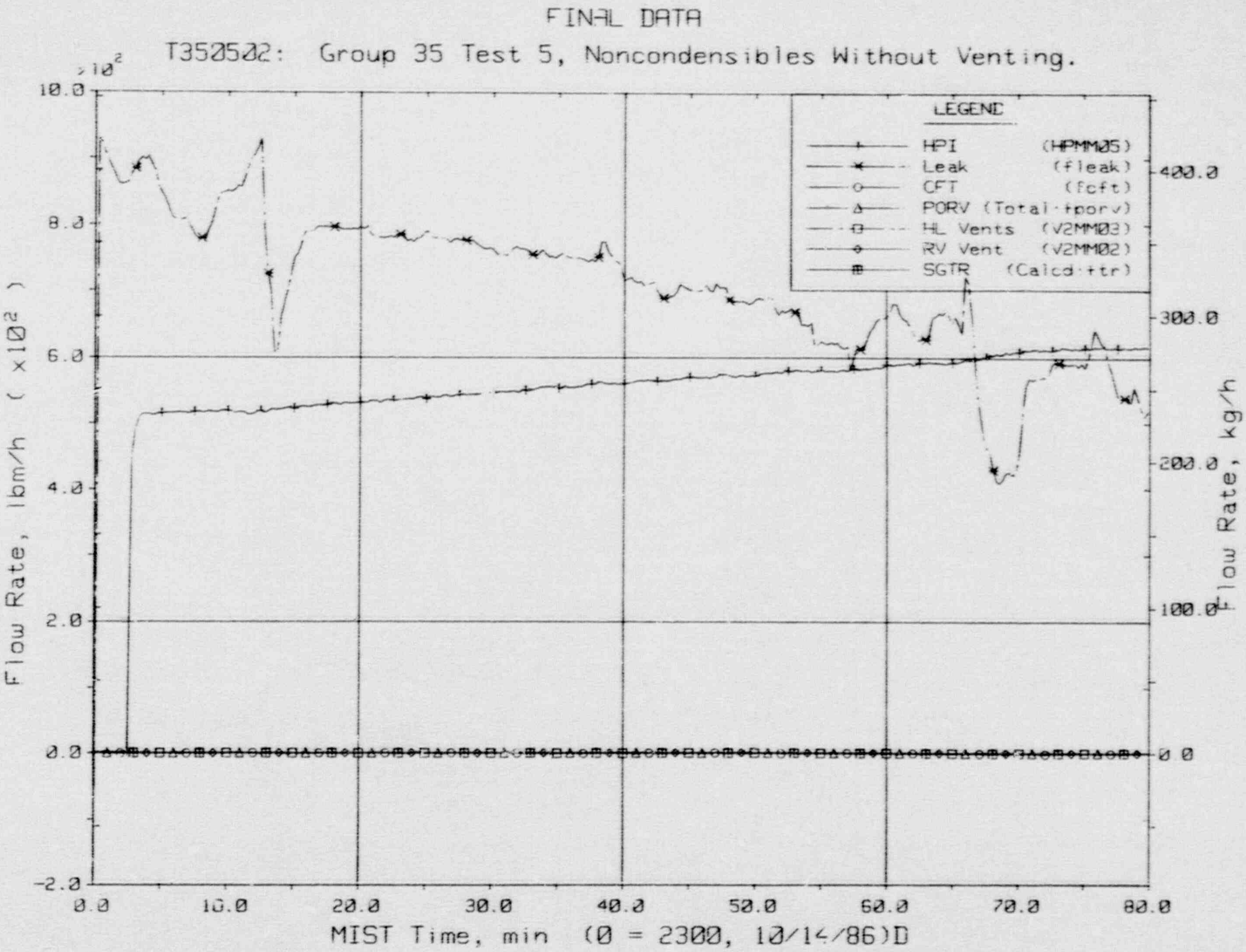


Figure 5.3.51 Primary System Boundary Flow Rates

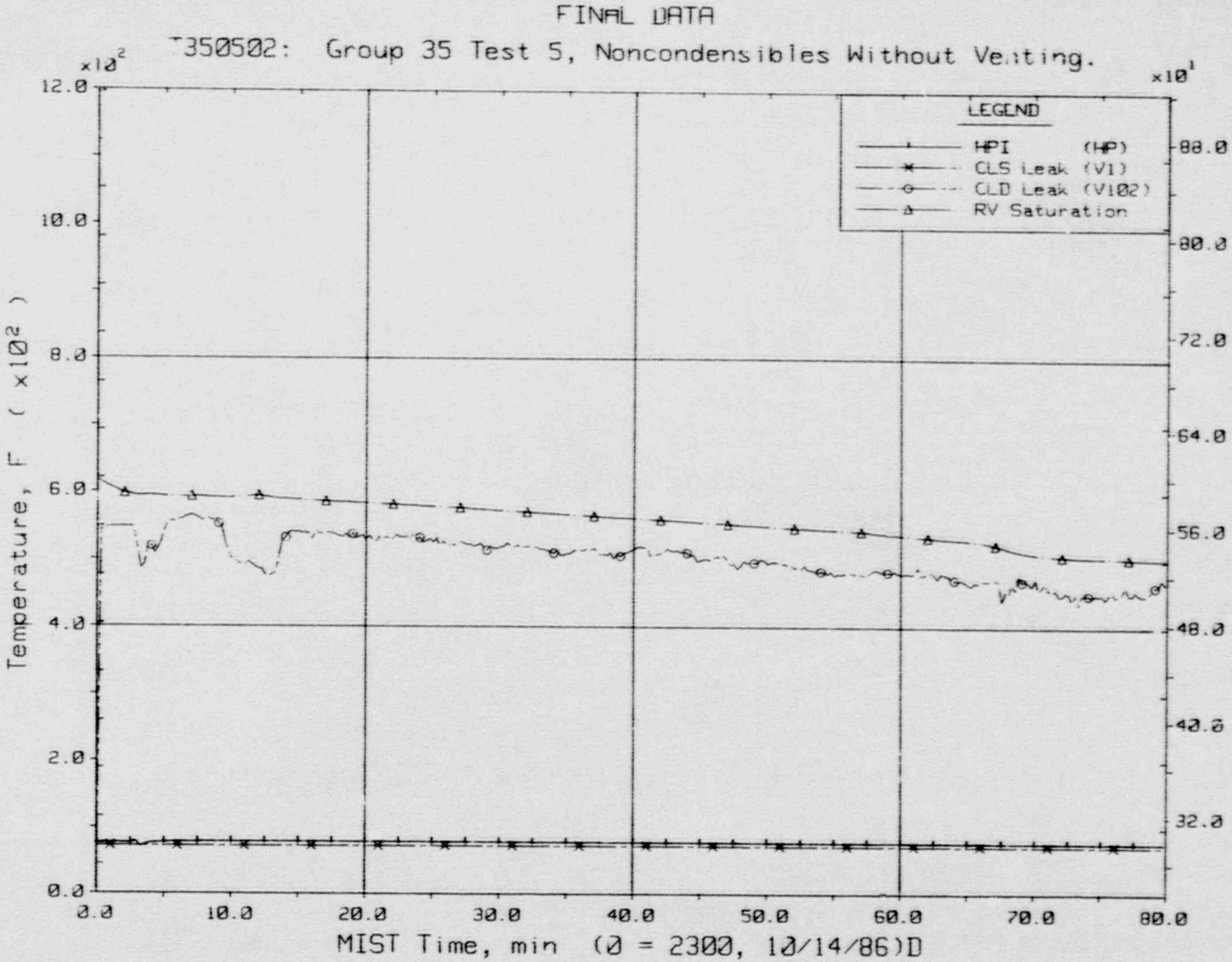


Figure 5.3.52 Single-Phase Discharge and HPI Fluid Temperatures (TC01s)

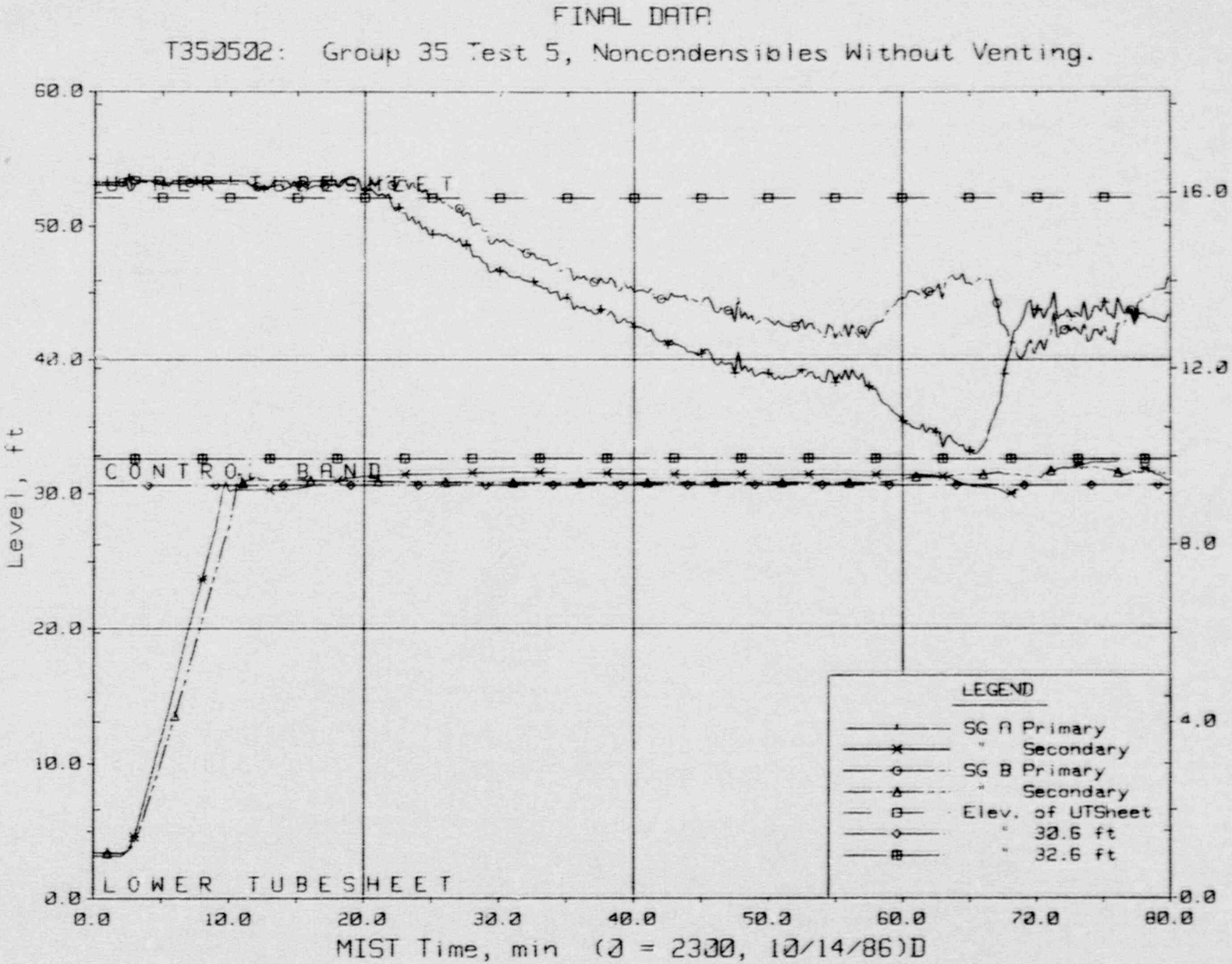


Figure 5.3.53 Steam Generator Collapsed Liquid Levels

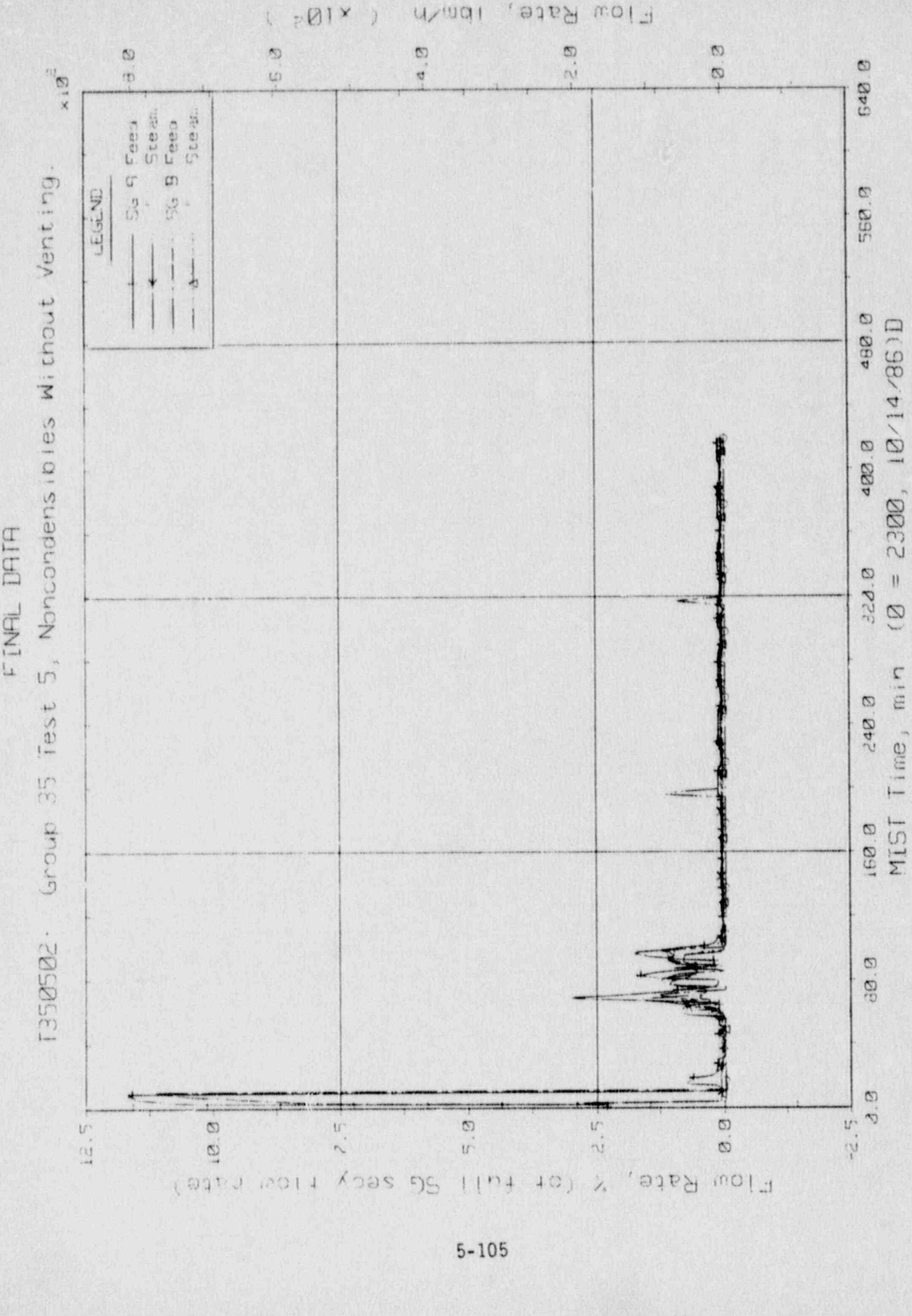


Figure 5.3.54 Secondary System Flow Rates

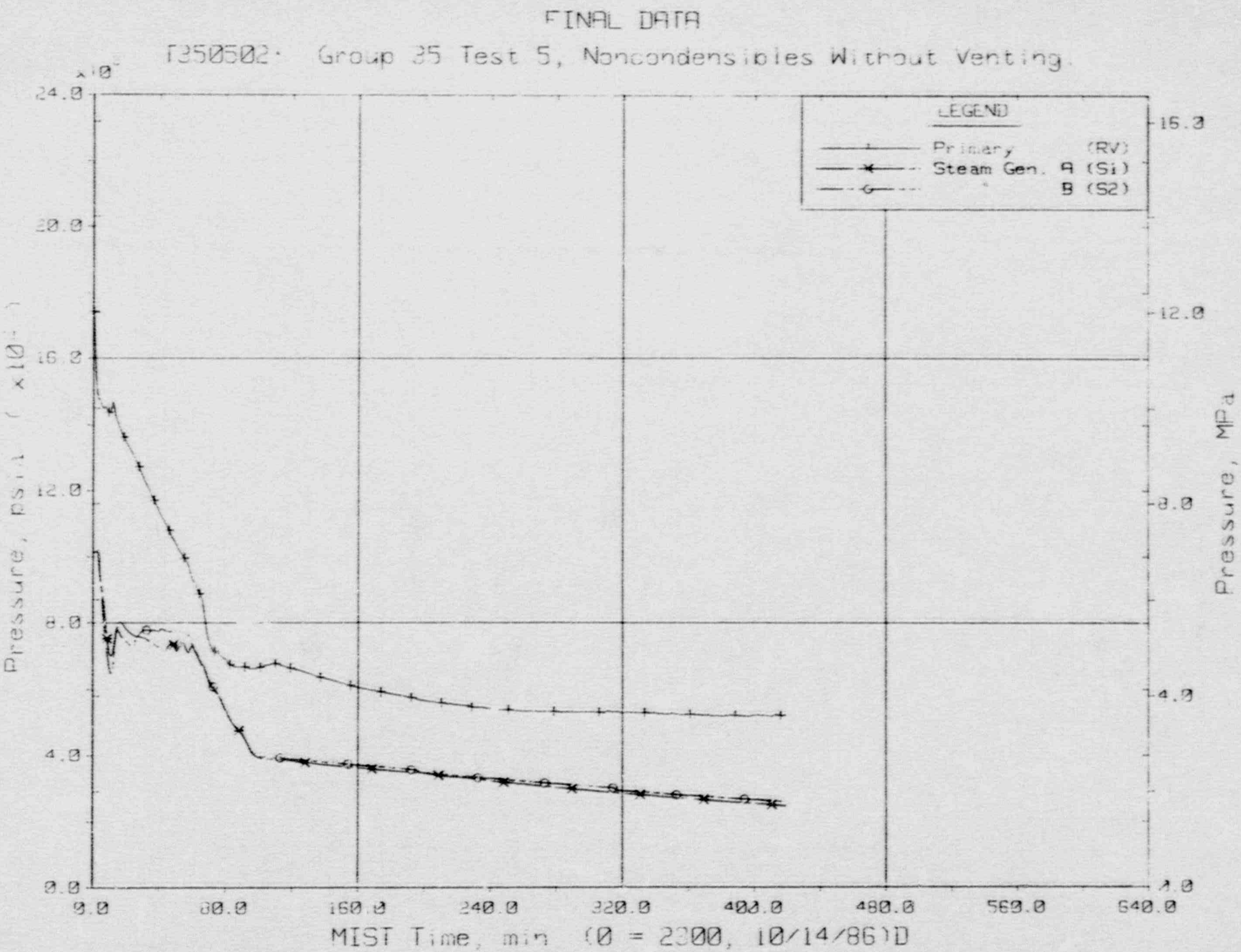


Figure 5.3.55 Primary and Secondary System Pressures (GP01s)

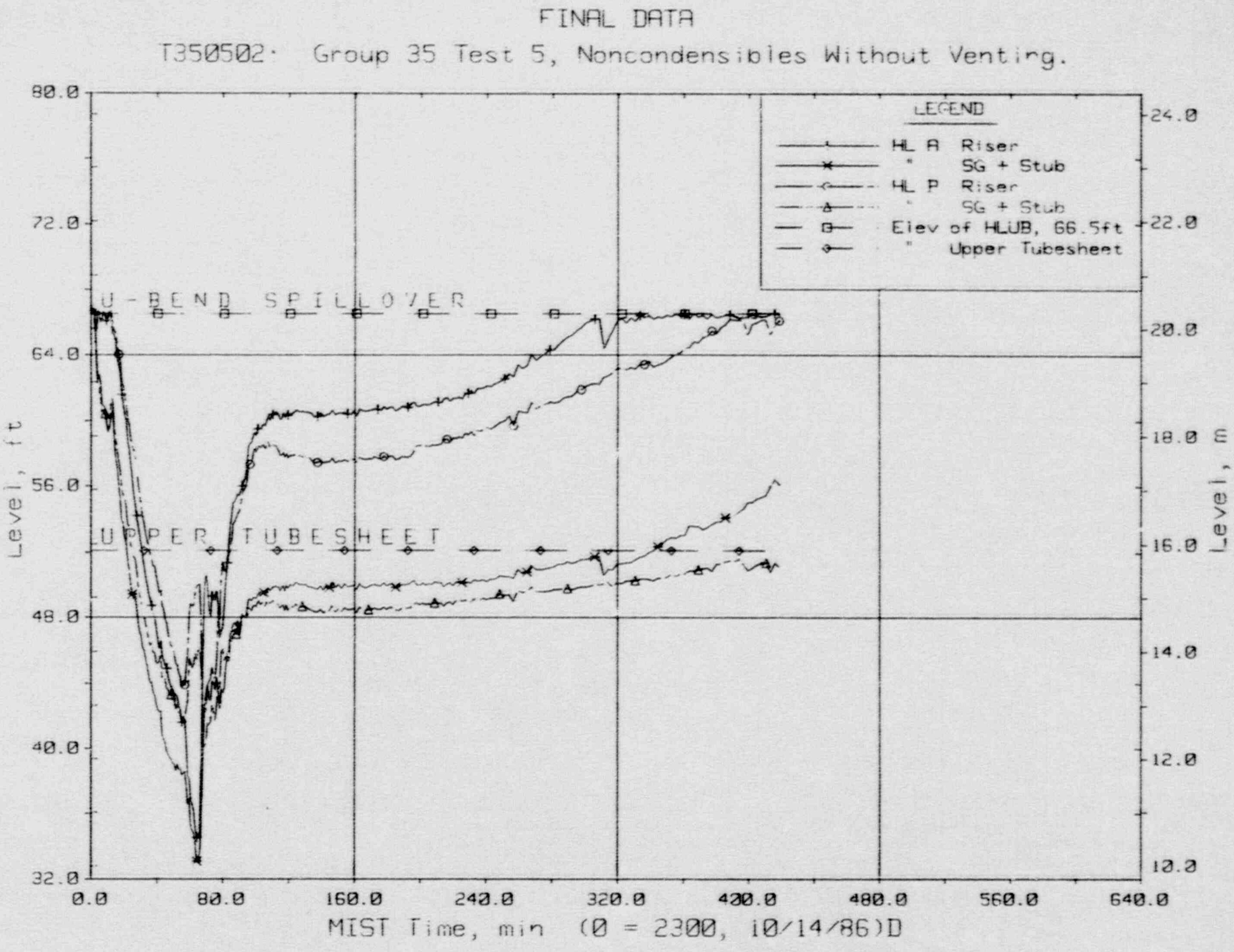


Figure 5.3.56 Hot Leg Riser and Stub Collapsed Liquid Levels

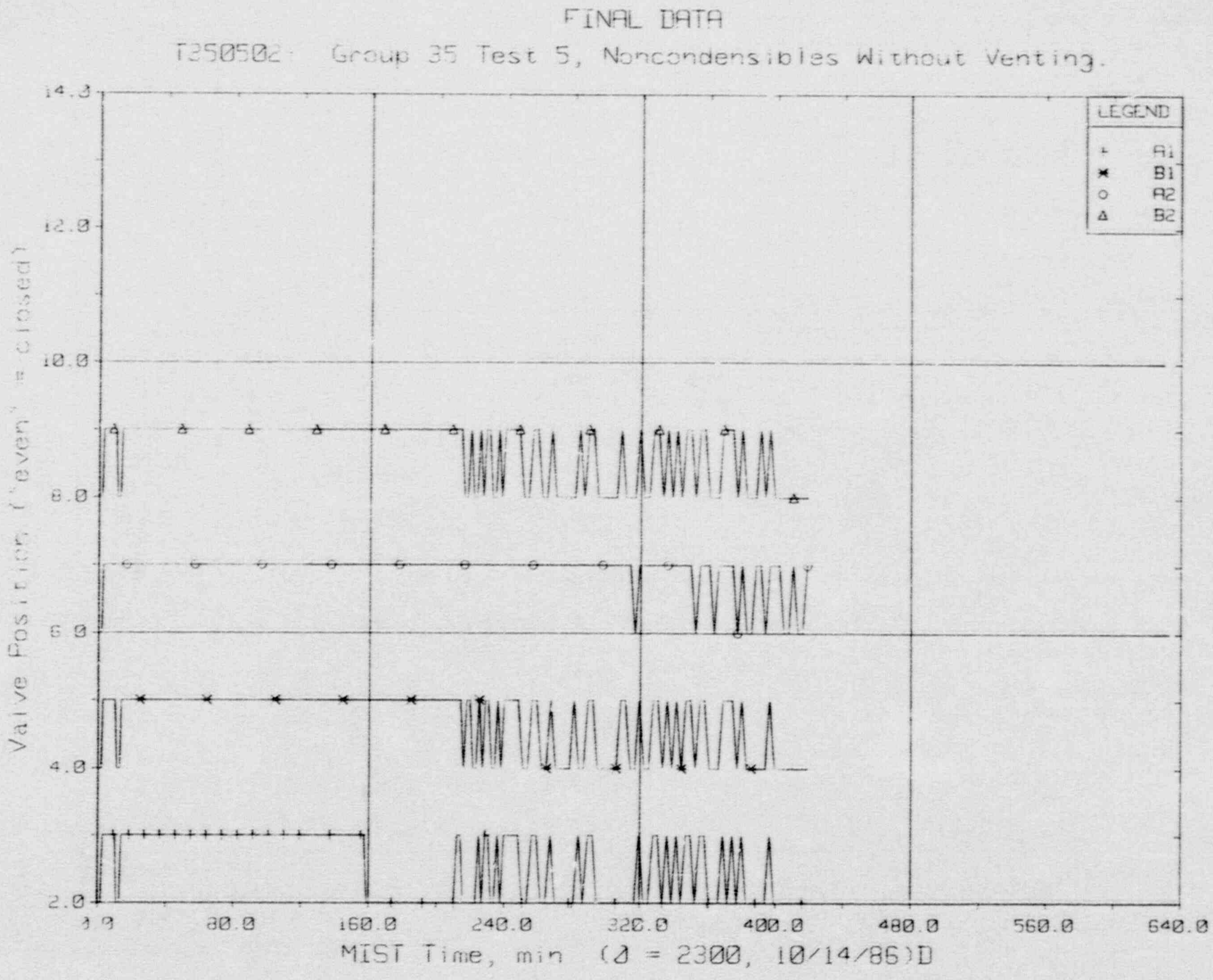


Figure 5.3.57 Reactor Vessel Vent Valve Positions

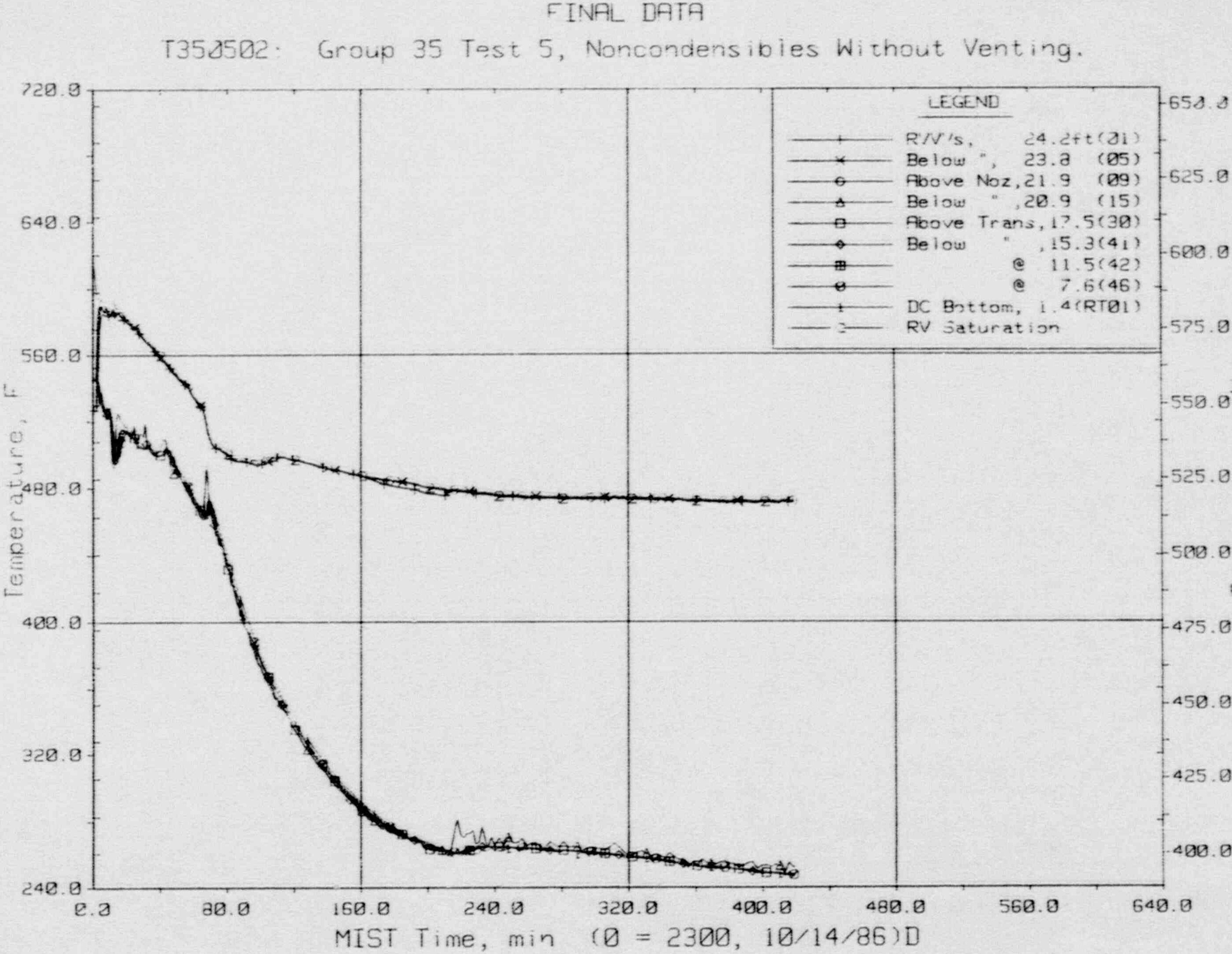


Figure 5.3.58 Downcomer Quadrant A1 Fluid Temperatures (DCTCs)

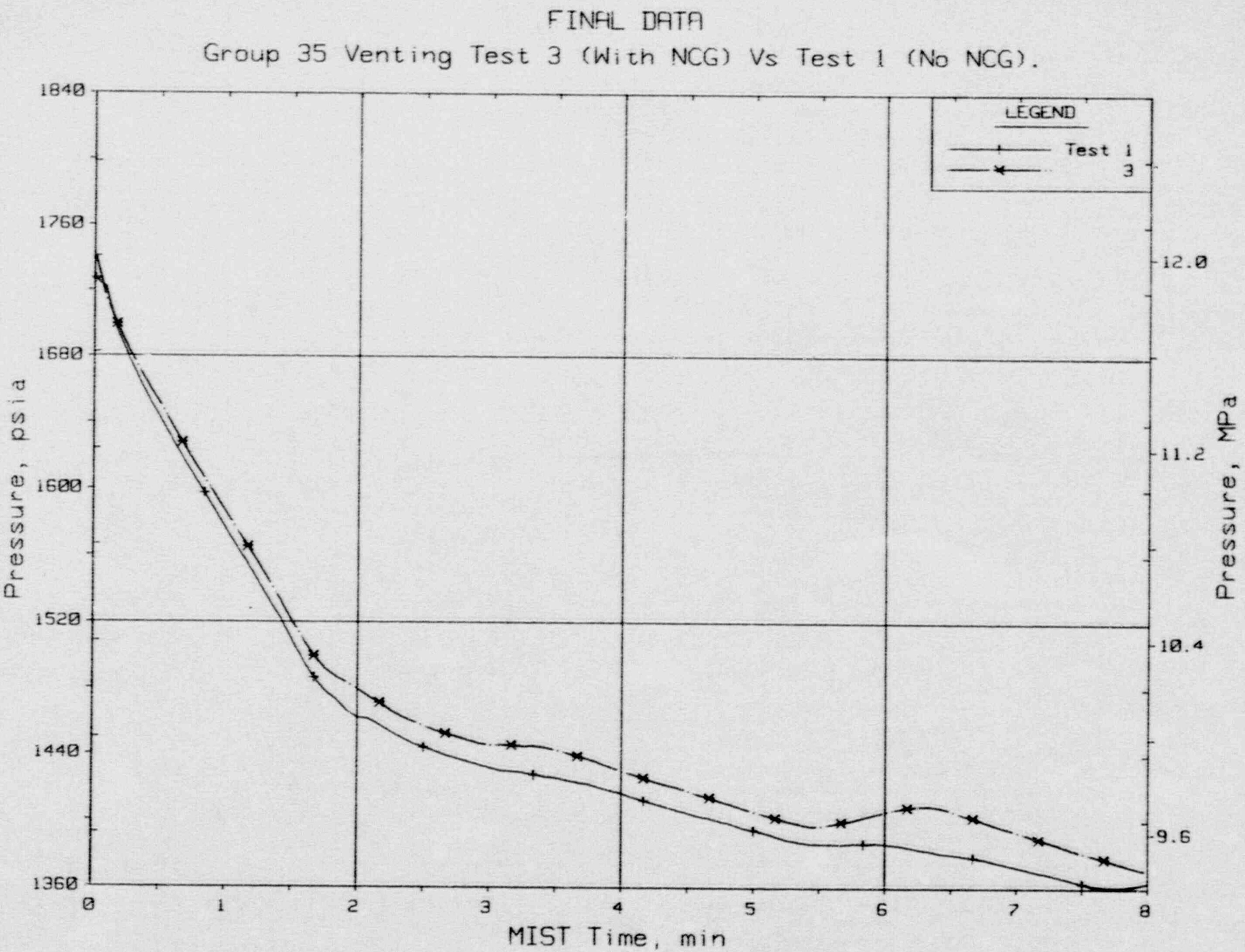


Figure 5.3.59 Primary System Pressure (RVDP01)

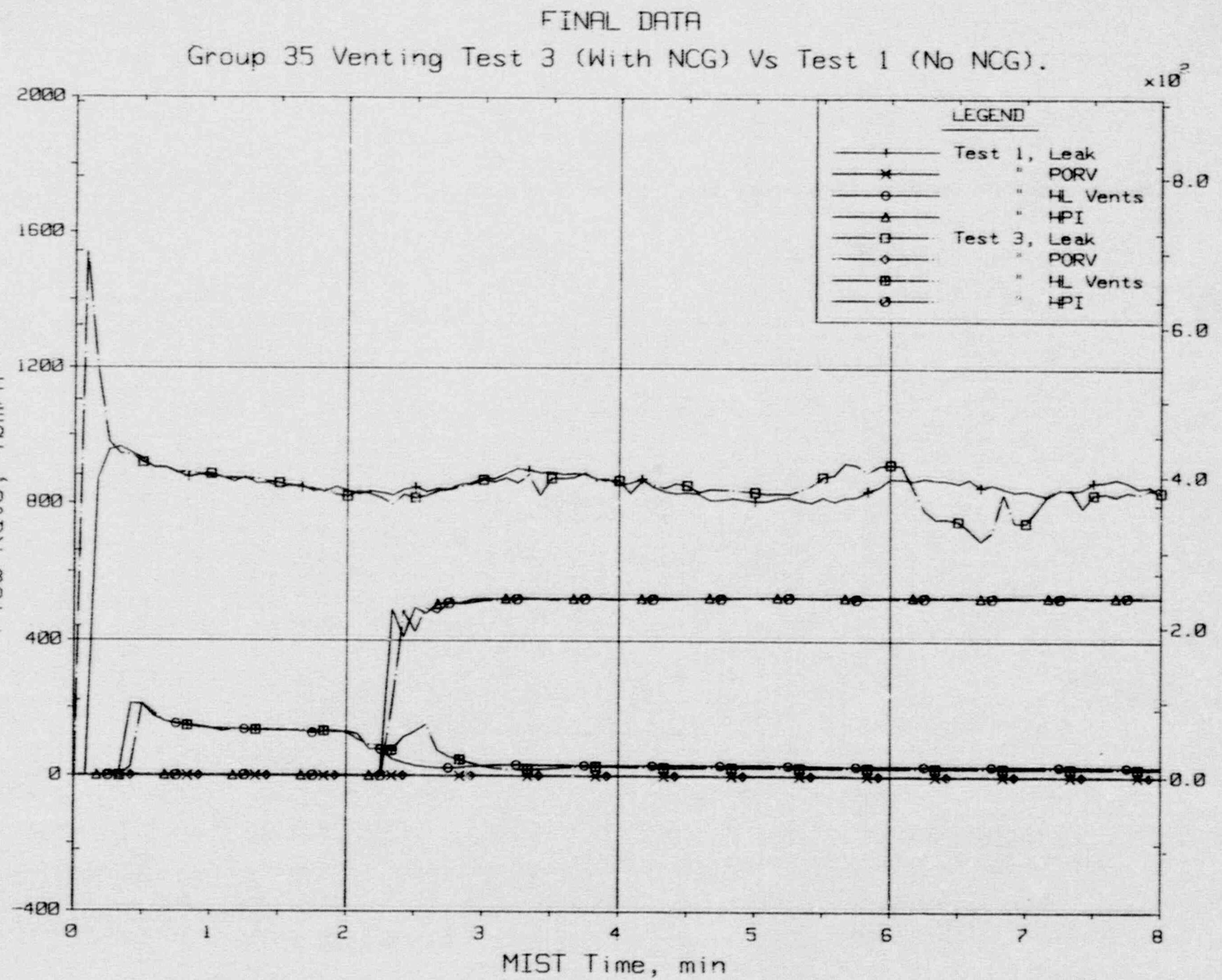


Figure 5.3.60 Primary System Boundary Mass Flow Rates

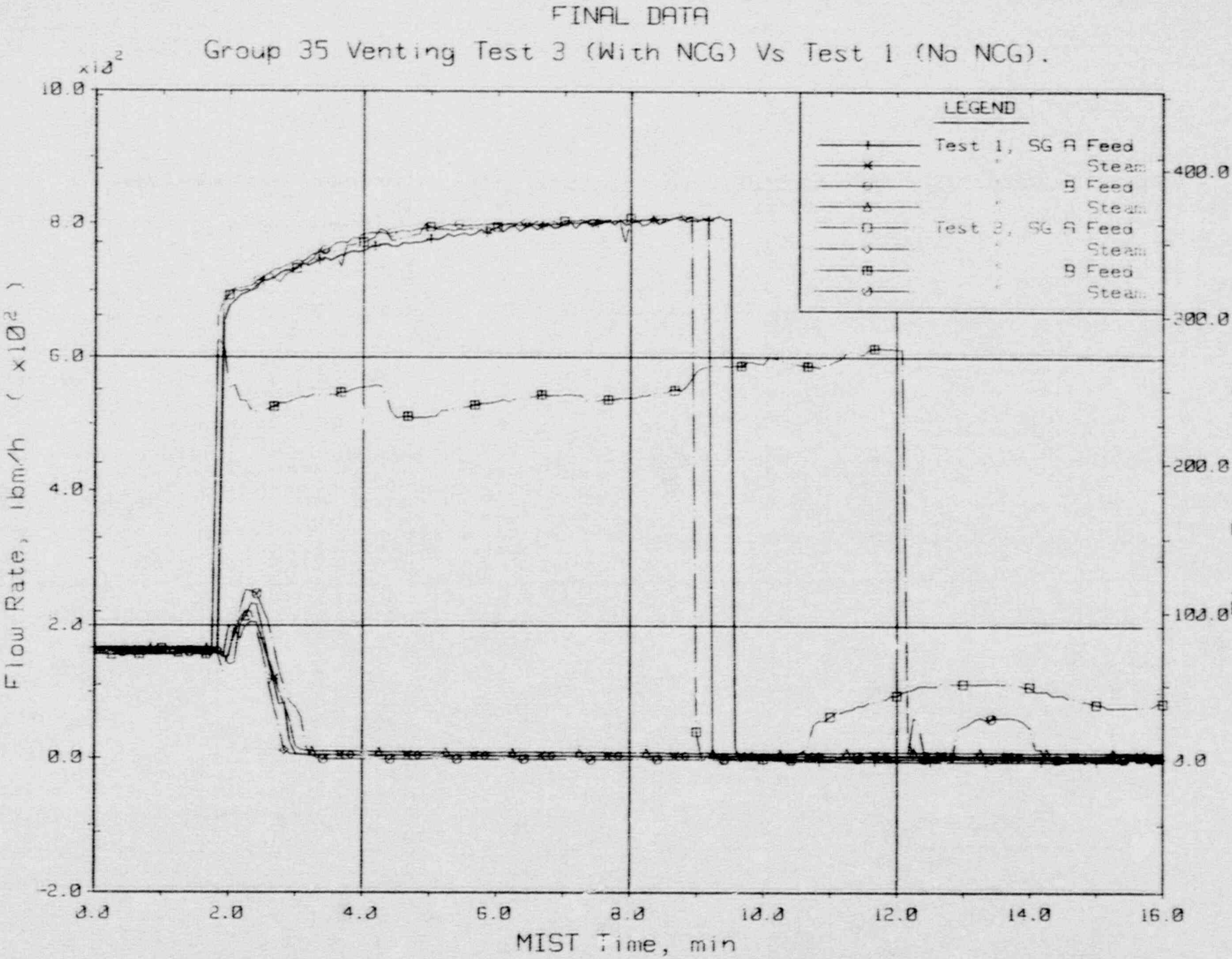


Figure 5.3.61 Steam Generator Secondary Flow Rates

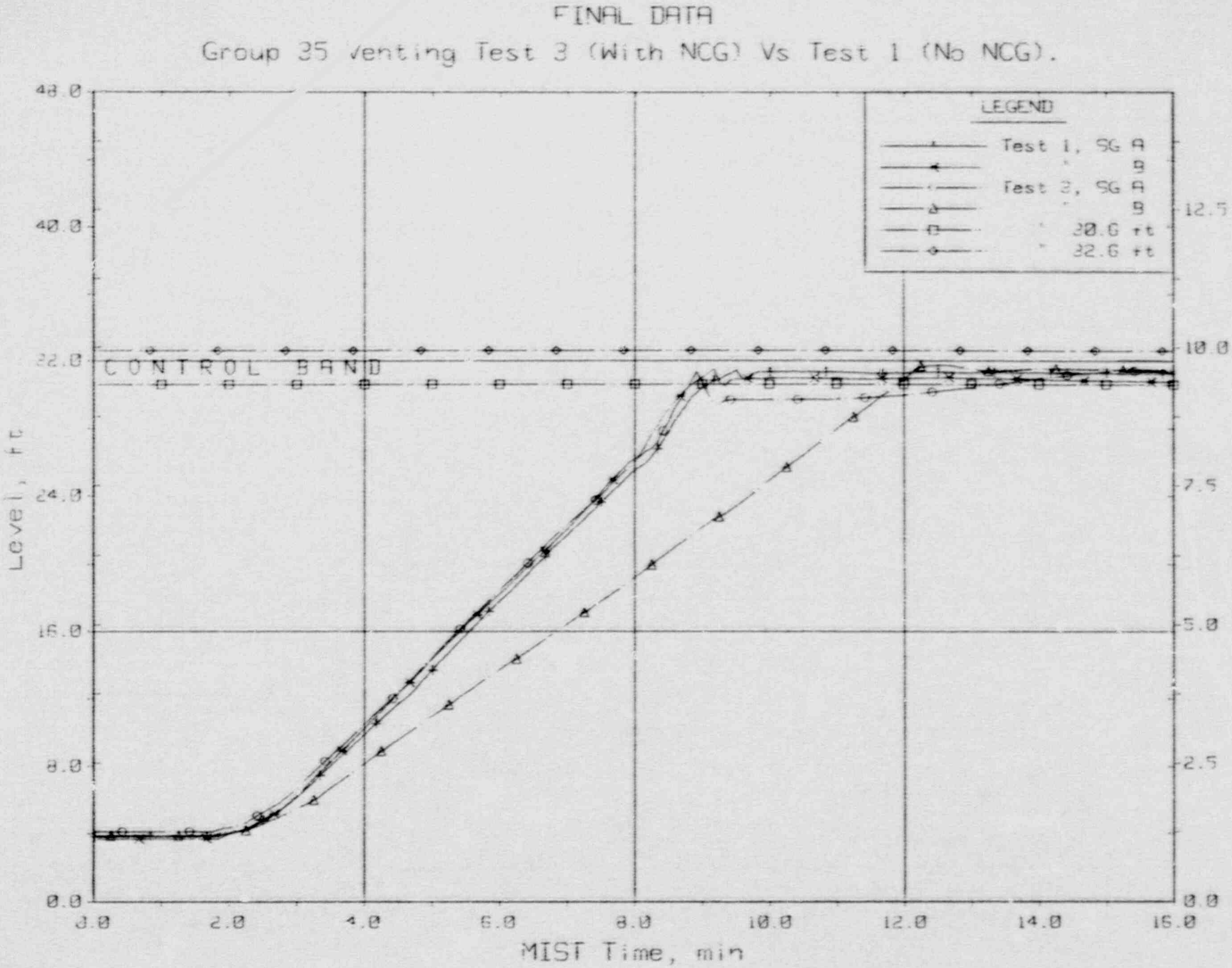


Figure 5.3.62 Steam Generator Secondary Collapsed Liquid Levels

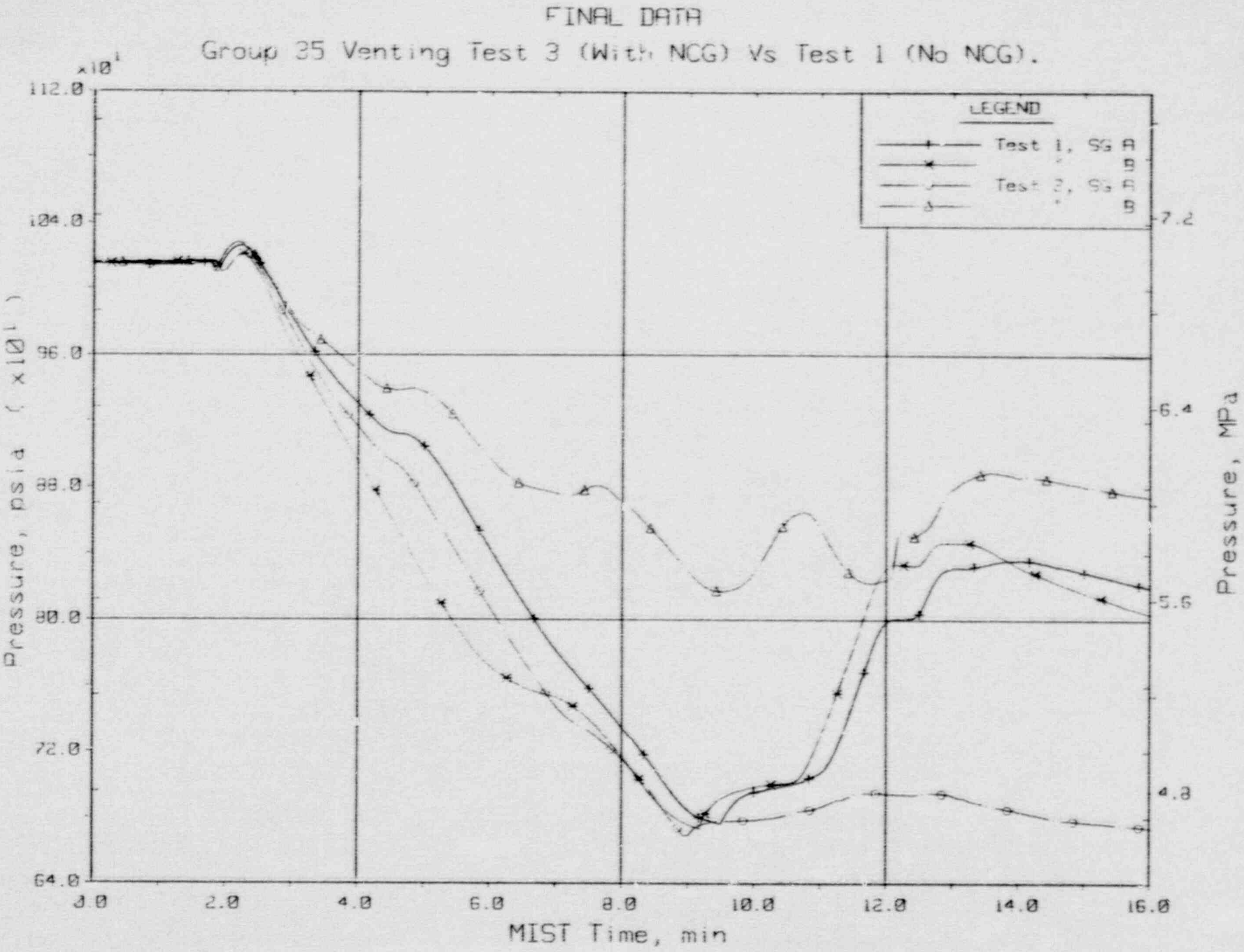


Figure 5.3.63 Steam Generator Secondary Pressures (SnGP01s)

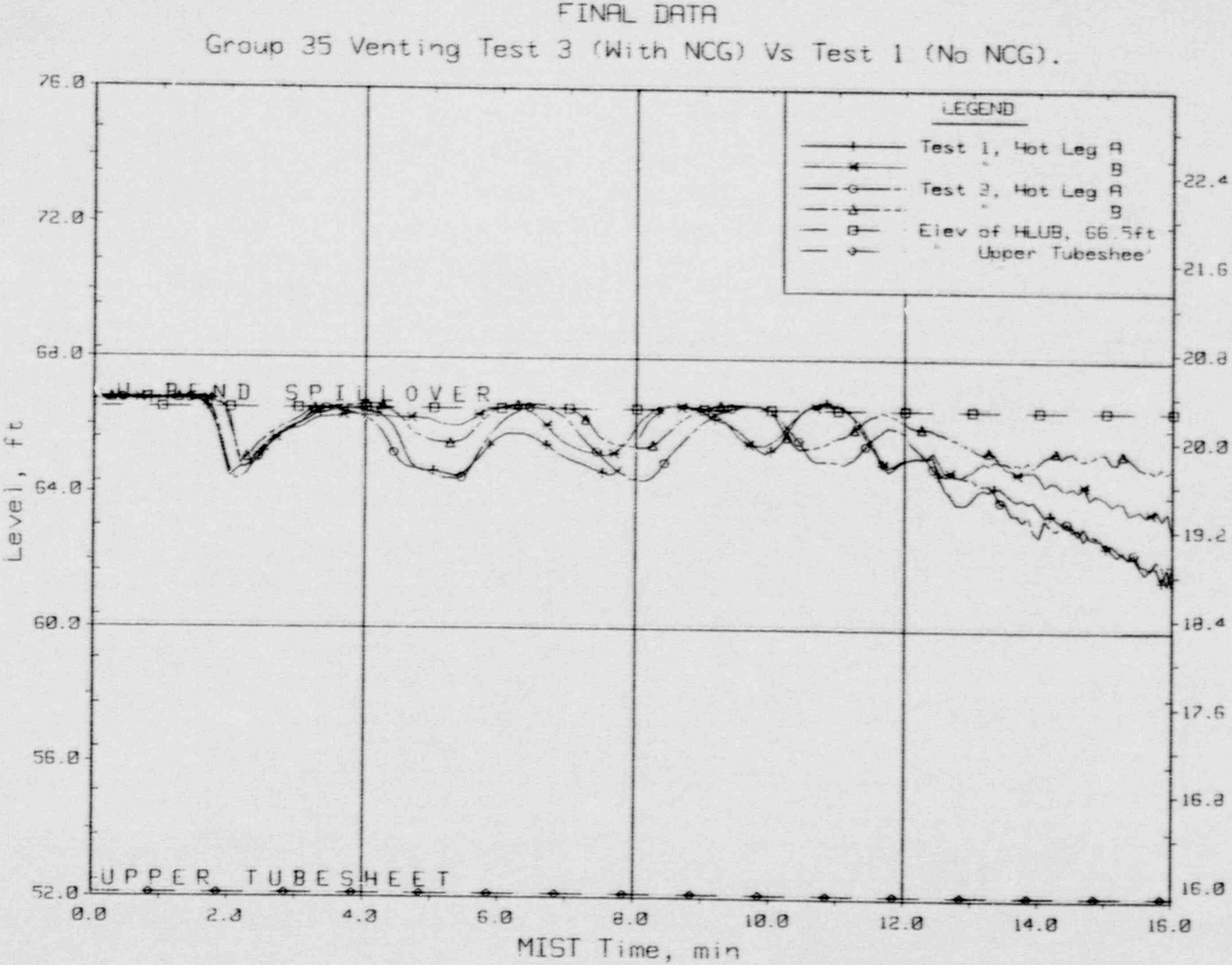


Figure 5.3.64 Hot Leg Riser Collapsed Liquid Levels

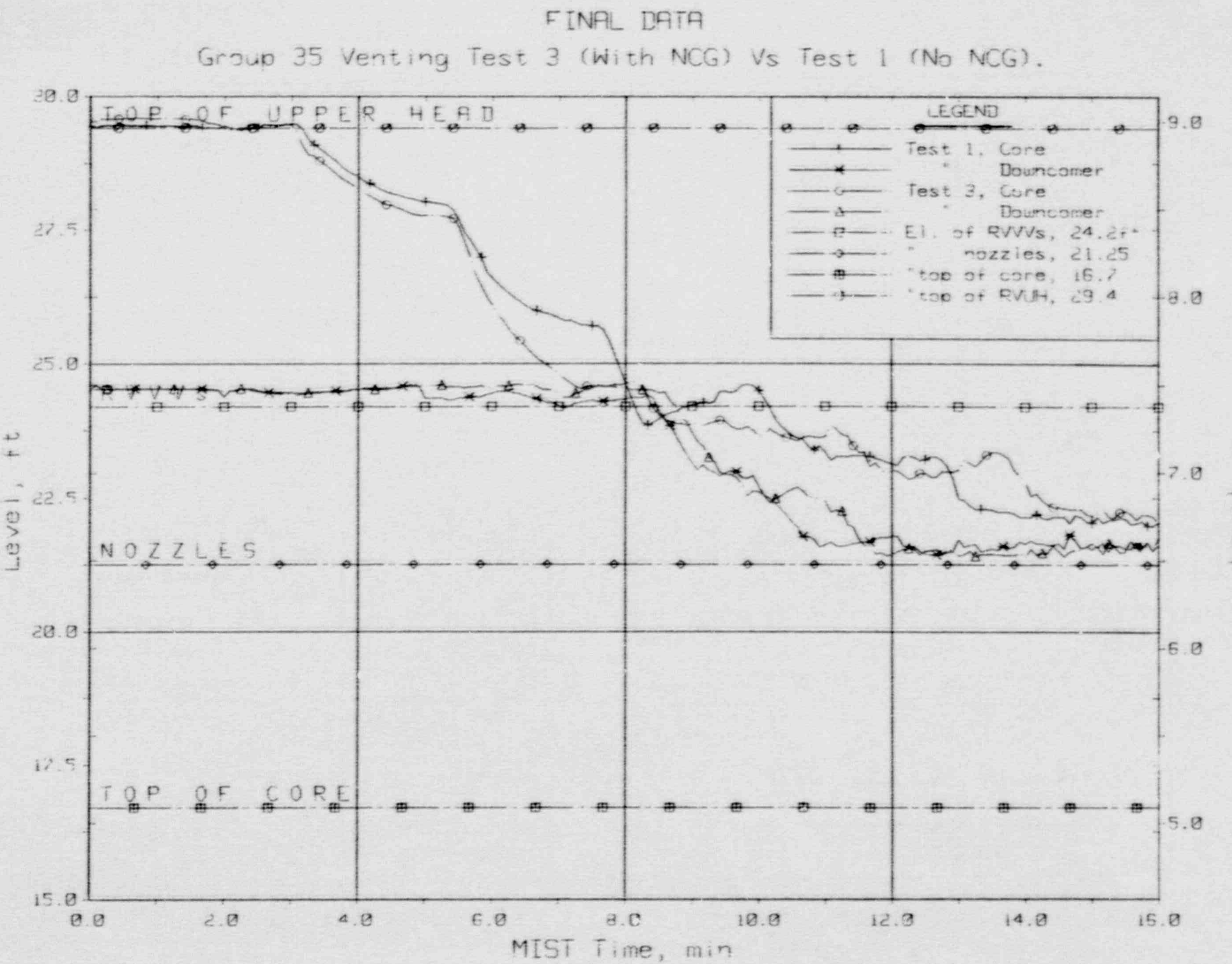


Figure 5.3.65 Core Region Collapsed Liquid Levels

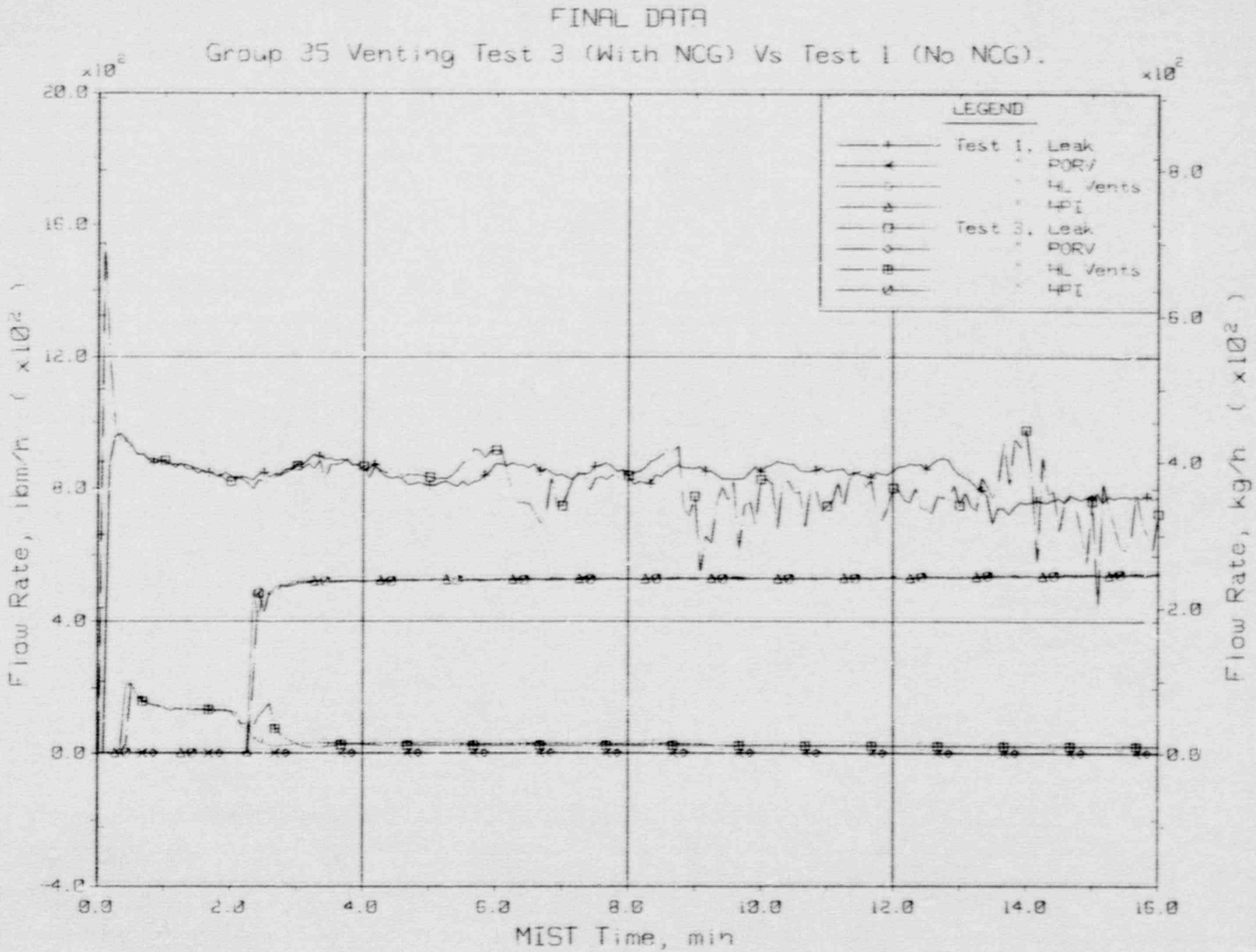


Figure 5.3.66 Primary System Boundary Mass Flow Rates

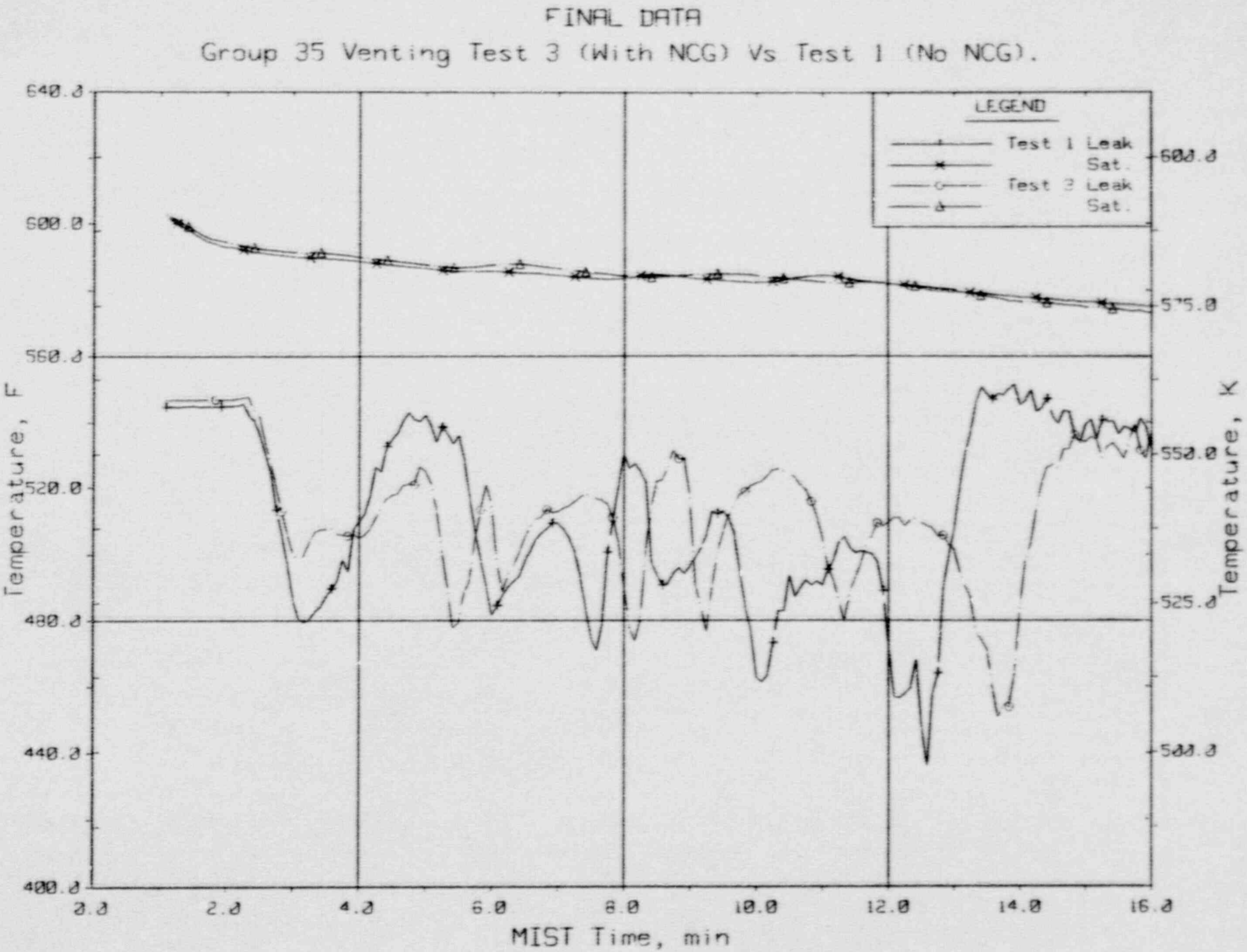


Figure 5.3.67 Leak and HPI Fluid Temperatures (TC01s)

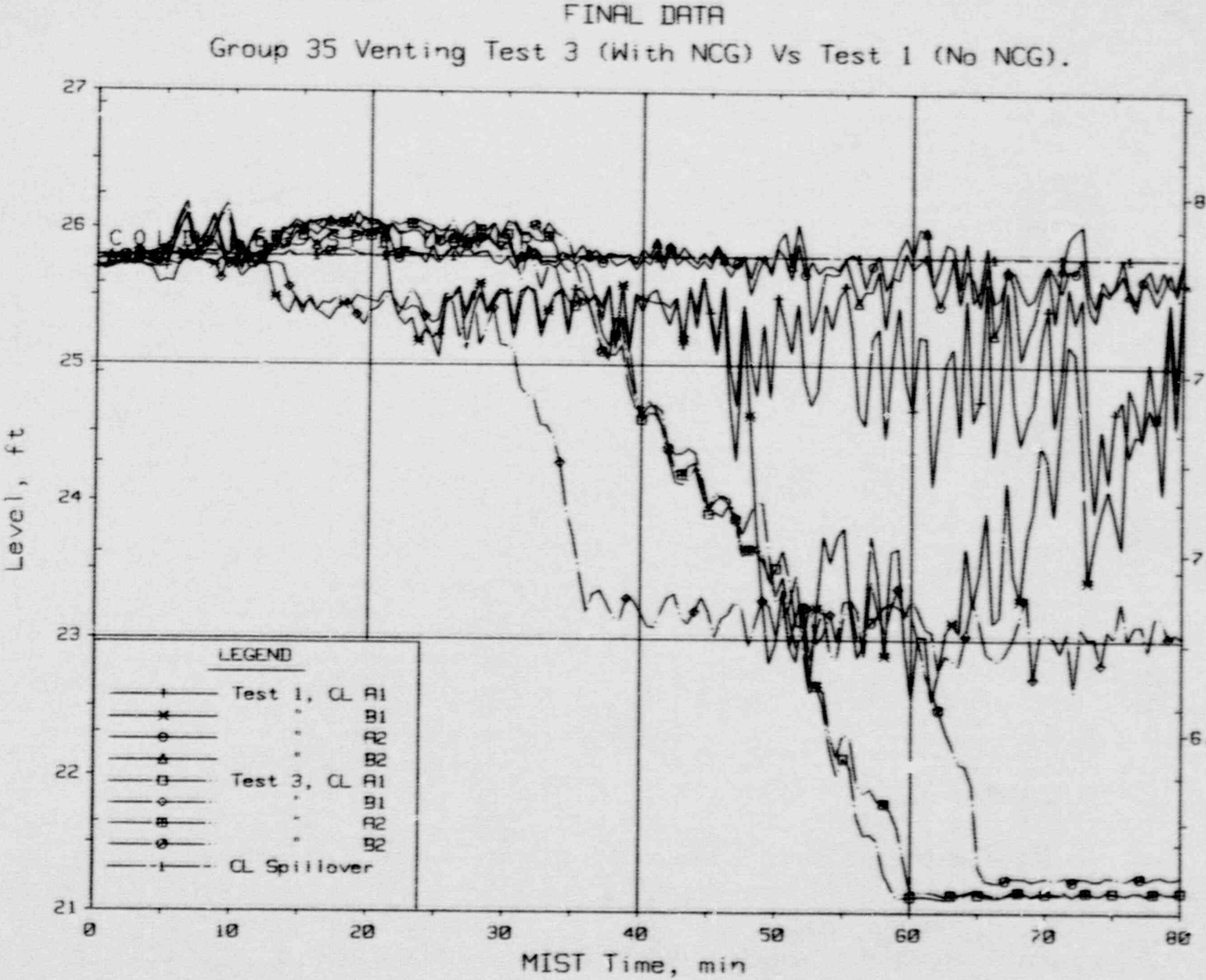
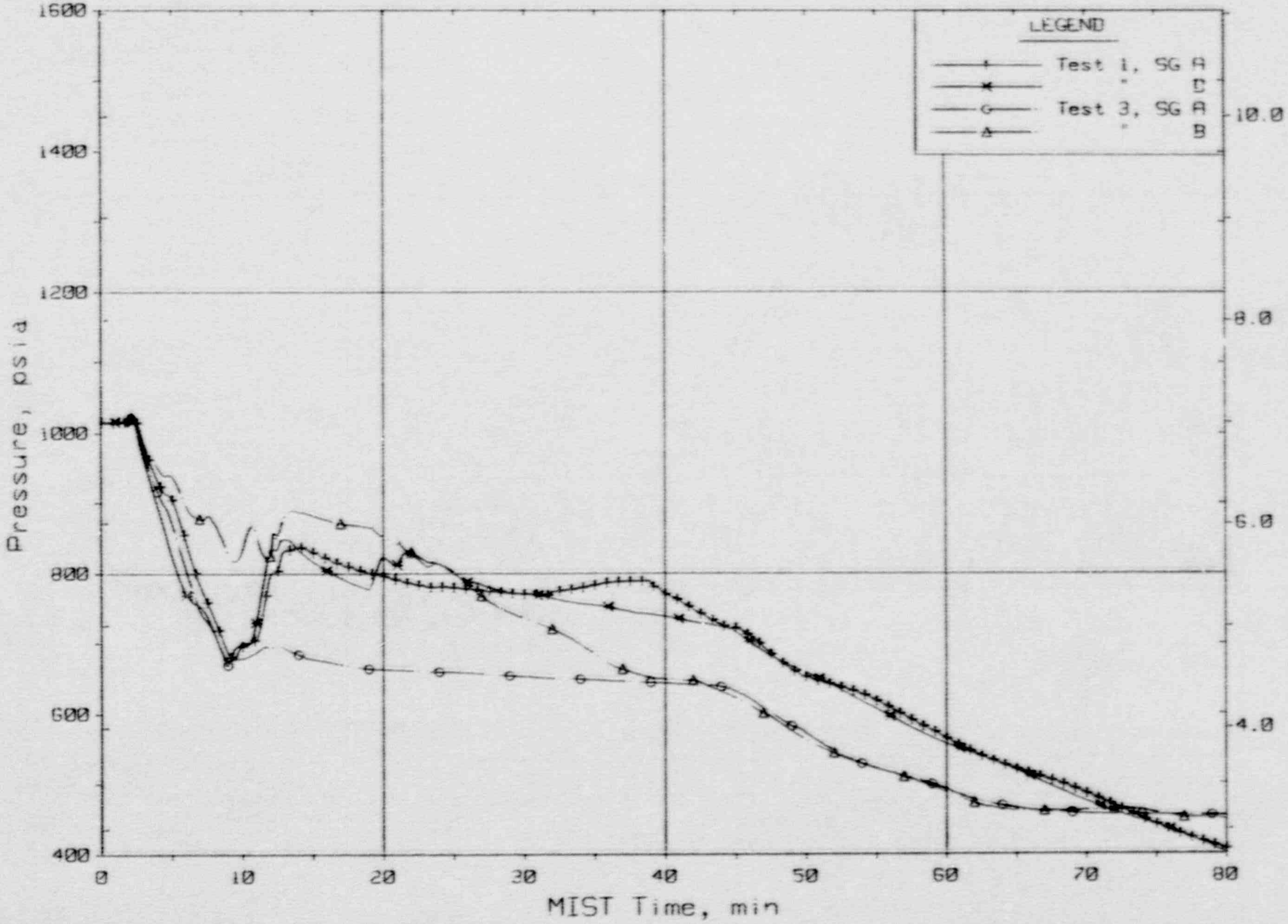


Figure 5.3.58 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

FINAL DATA

Group 35 Venting Test 3 (With NCG) Vs Test 1 (No NCG).



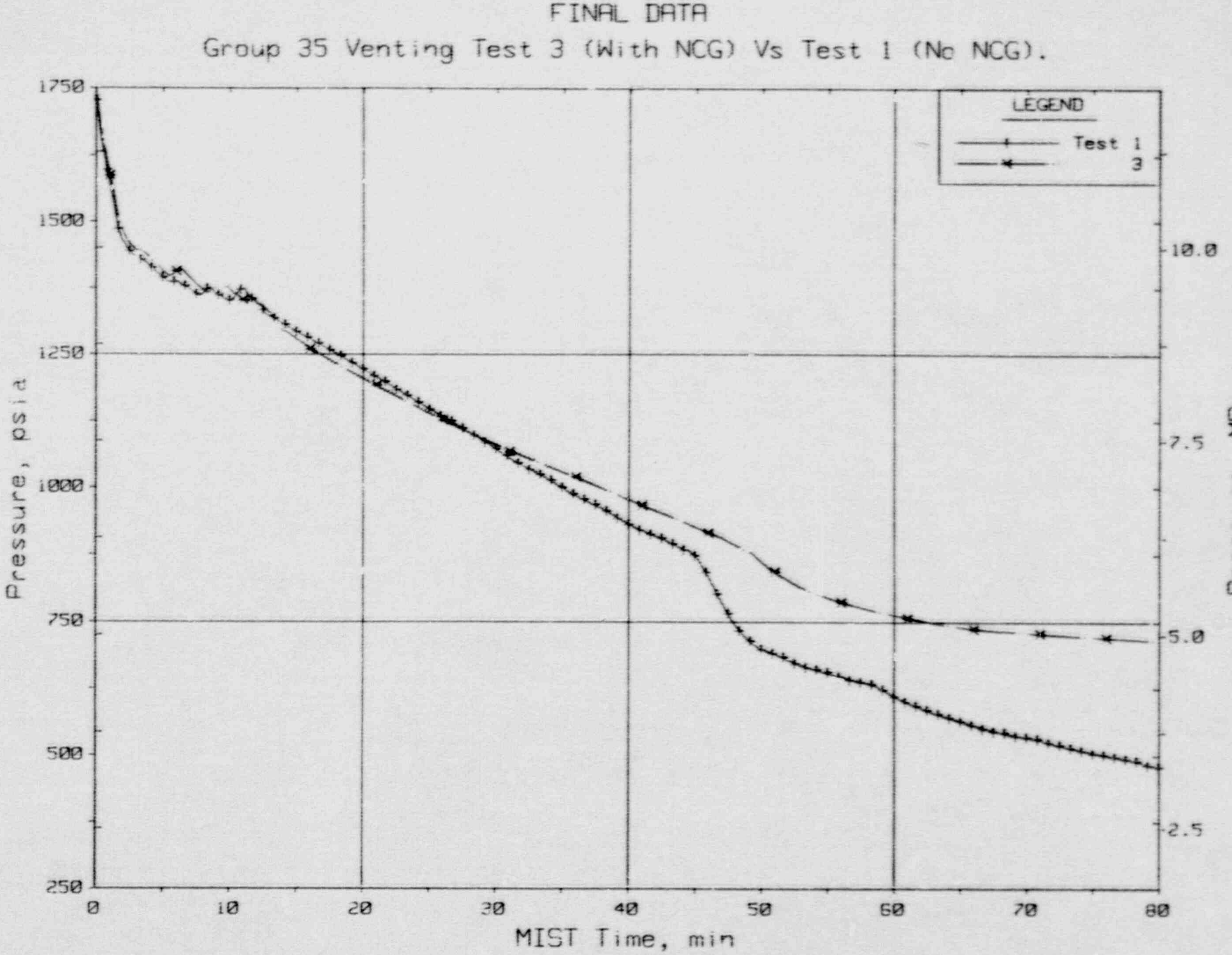


Figure 5.3.70 Primary System Pressure (RVGP01)

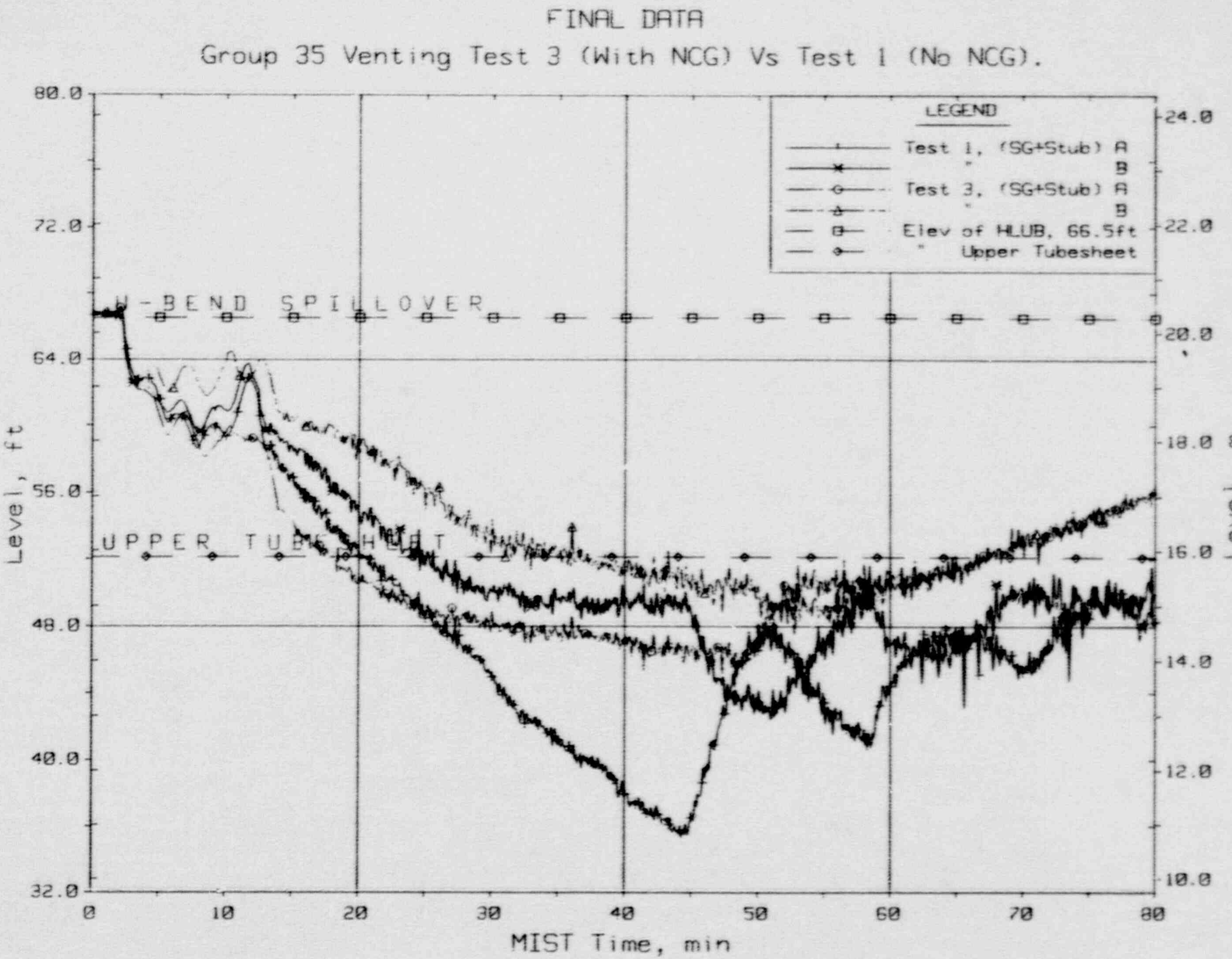


Figure 5.3.71 Steam Generator Primary and Stub Collapsed Liquid Levels

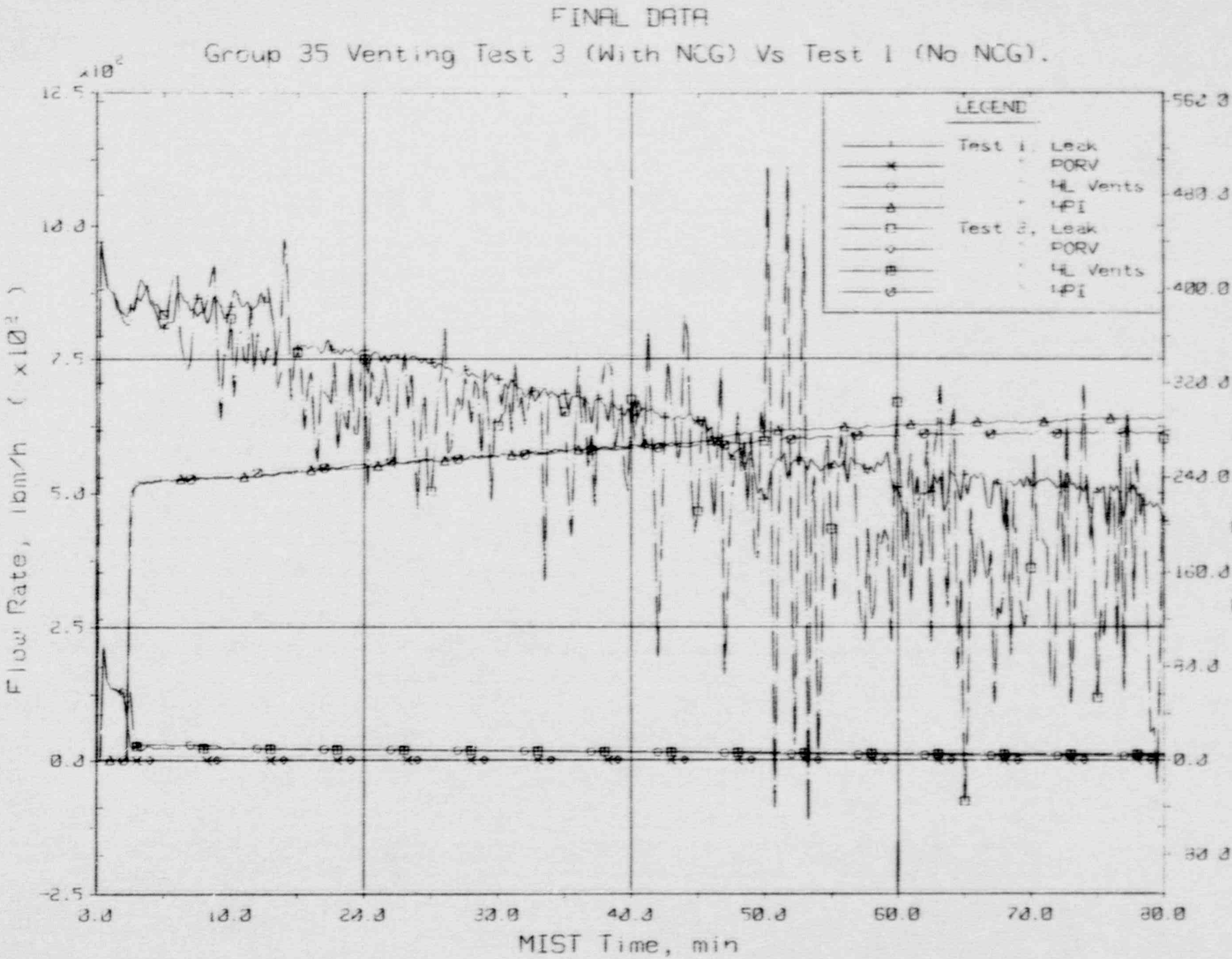


Figure 5.3.72 Primary System Boundary Mass Flow Rates

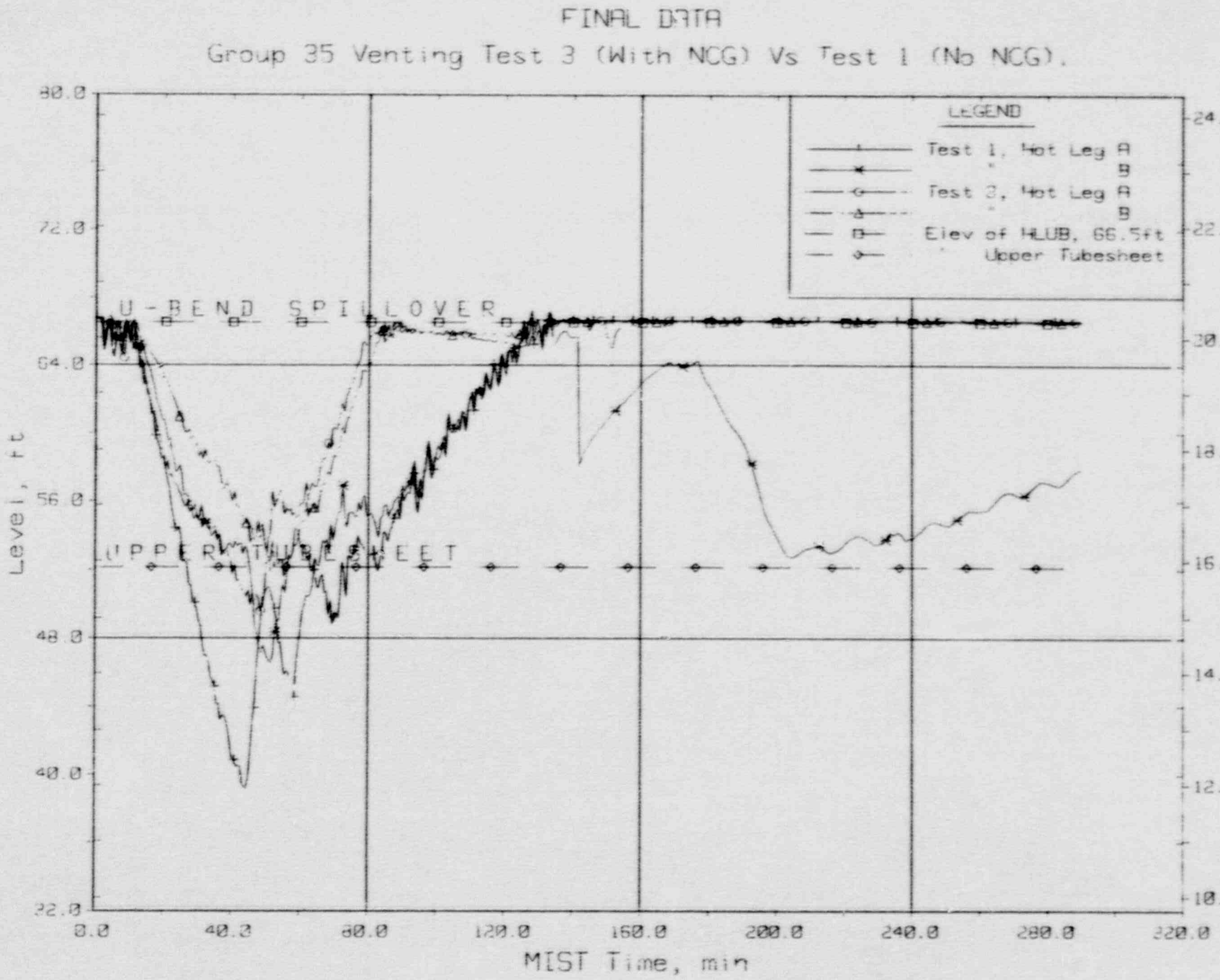


Figure 5.3.73 Hot Leg Riser Collapsed Liquid Levels

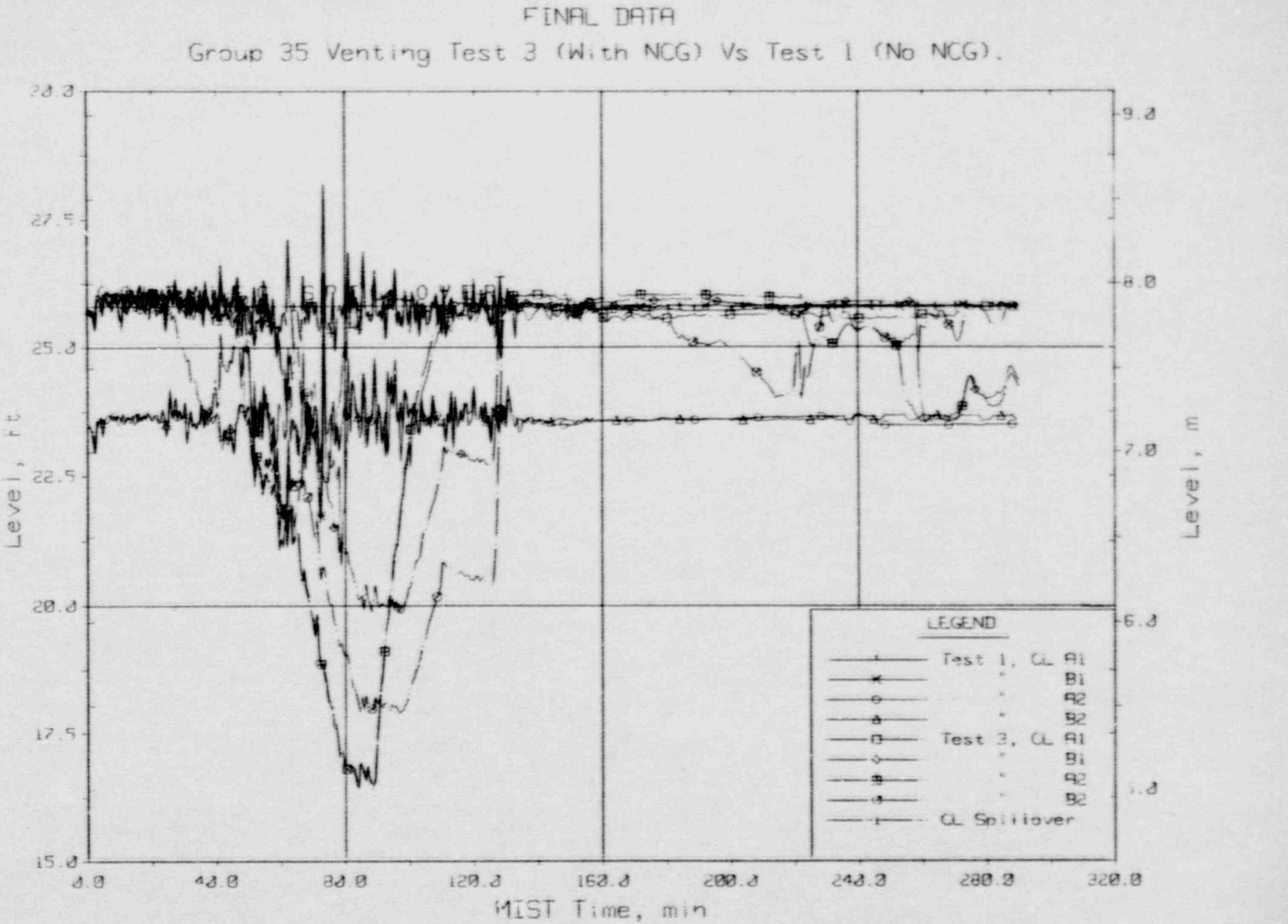


Figure 5.3.74 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

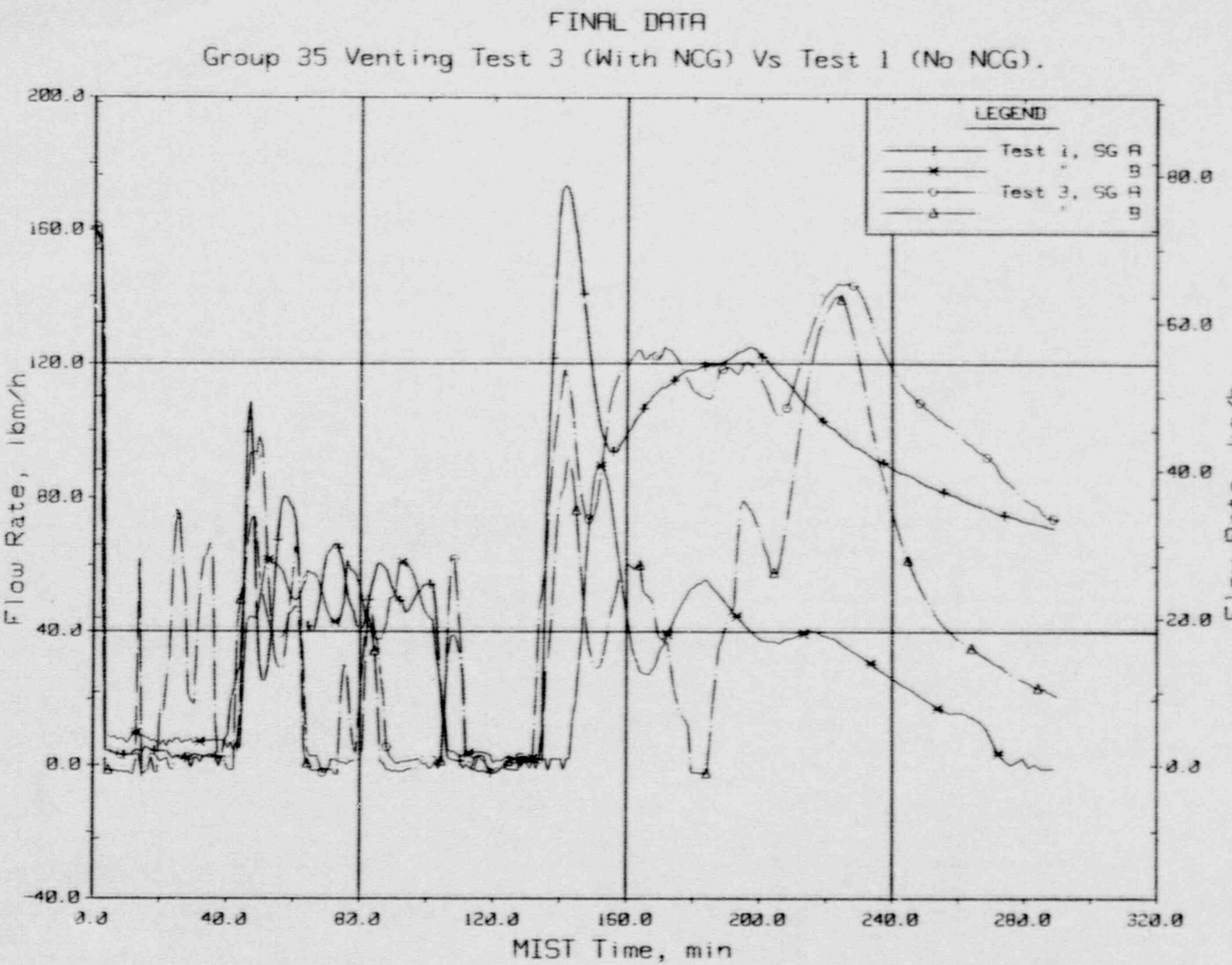


Figure 5.3.75 Steam Generator Secondary Steam Flow Rates

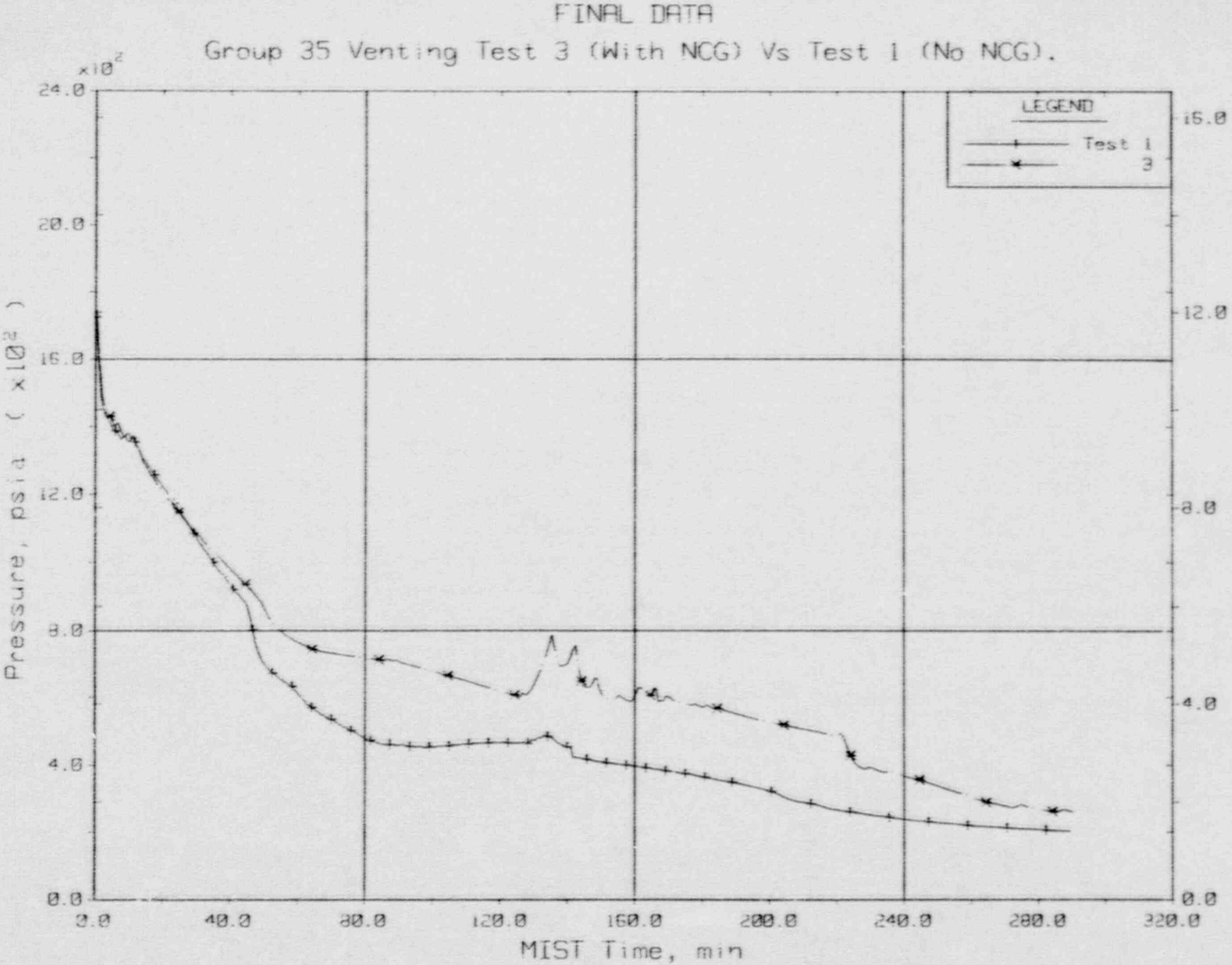


Figure 5.3.76 Primary System Pressure (RVGP01)

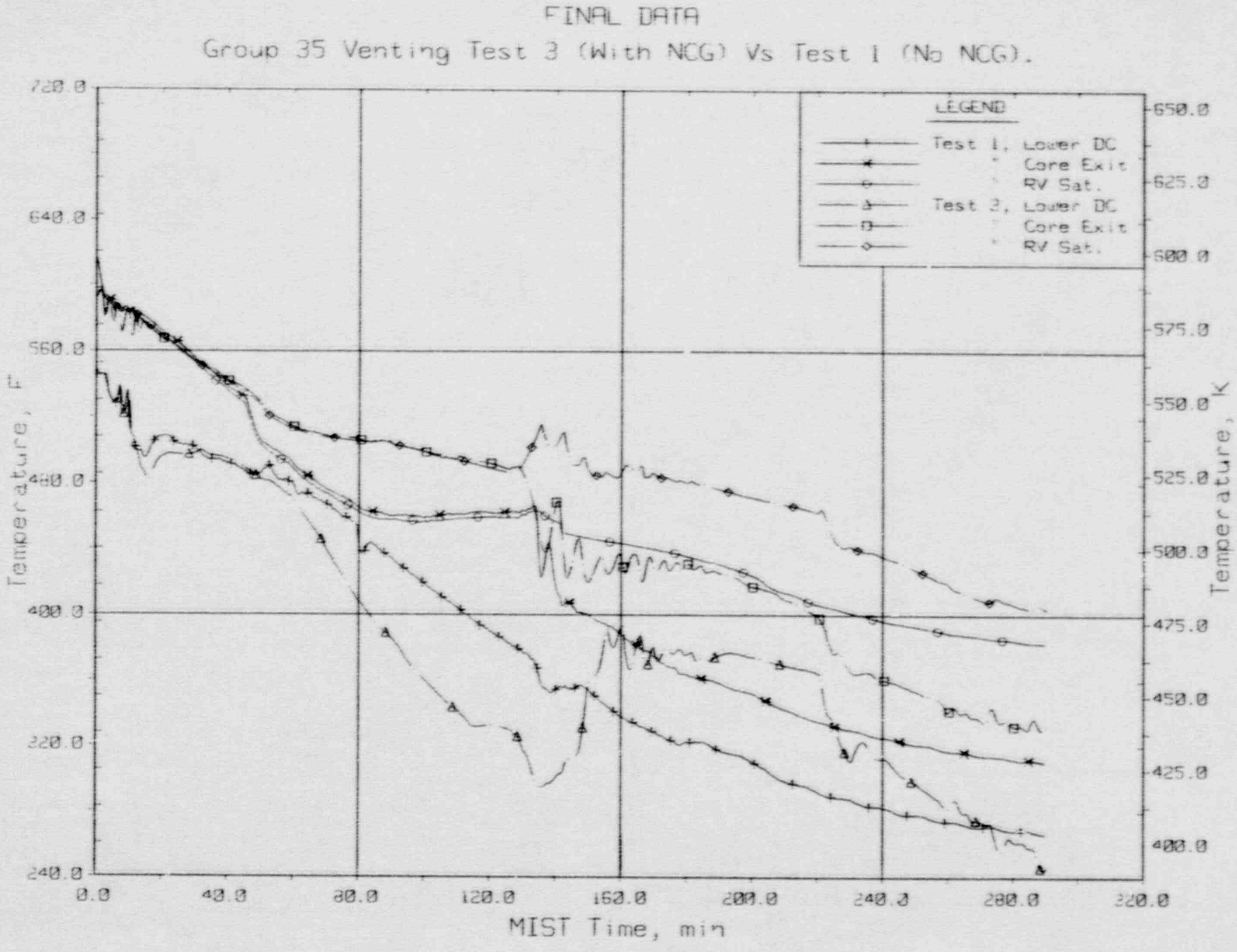


Figure 5.3.77 Core Bracketing Fluid Temperatures

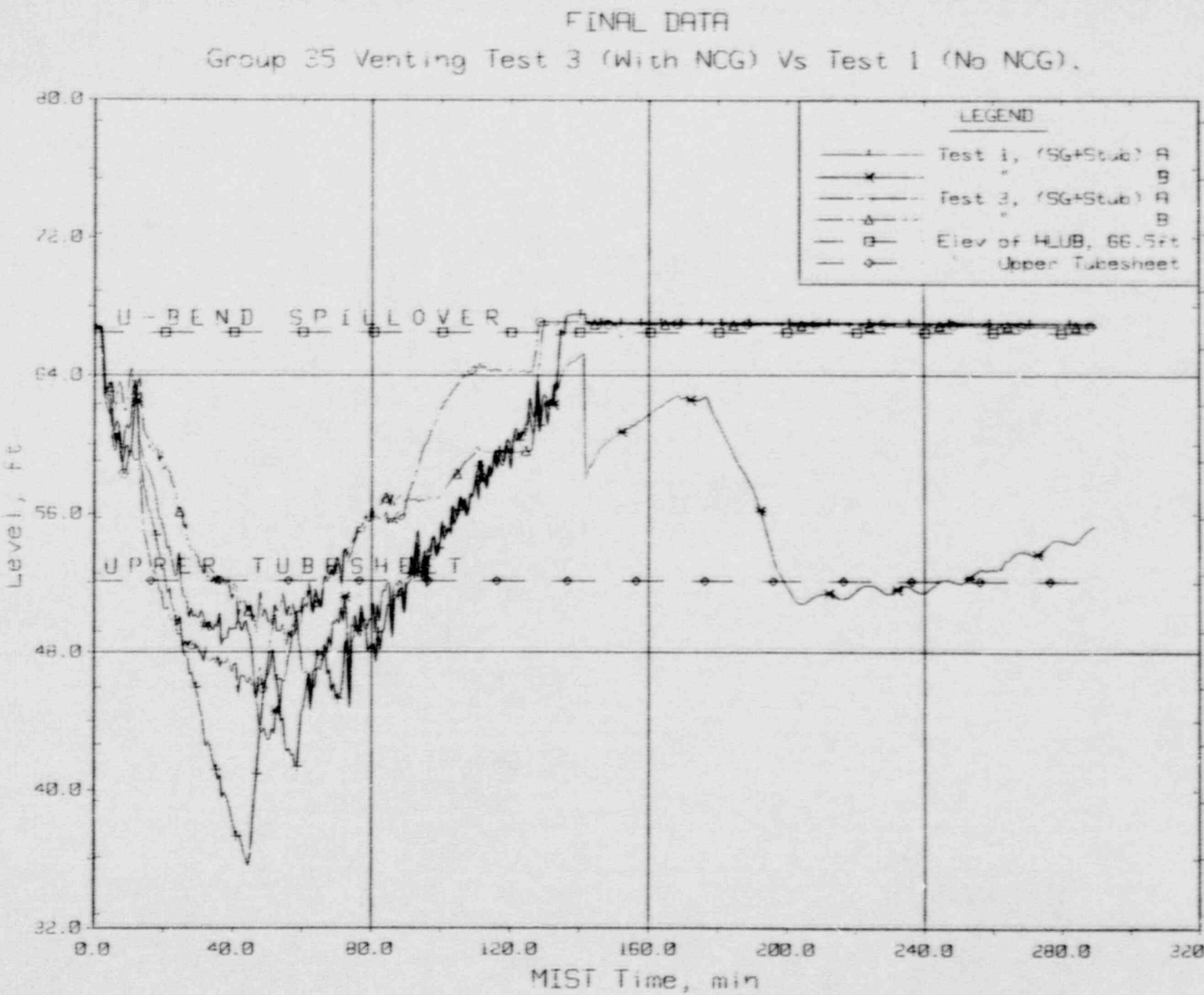


Figure 5.3.78 Steam Generator Primary and Stub Collapsed Liquid Levels

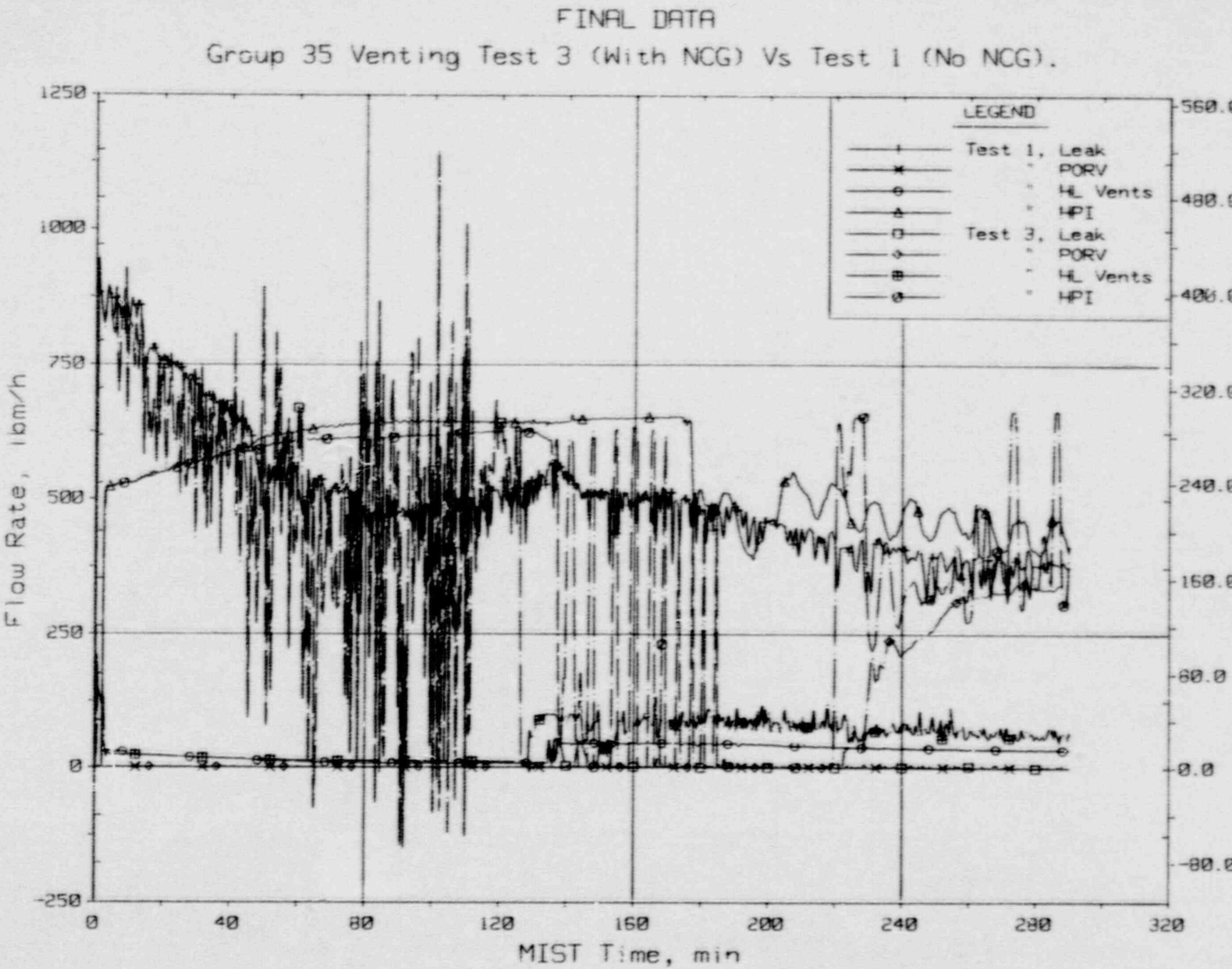


Figure 5.3.79 Primary System Boundary Mass Flow Rates

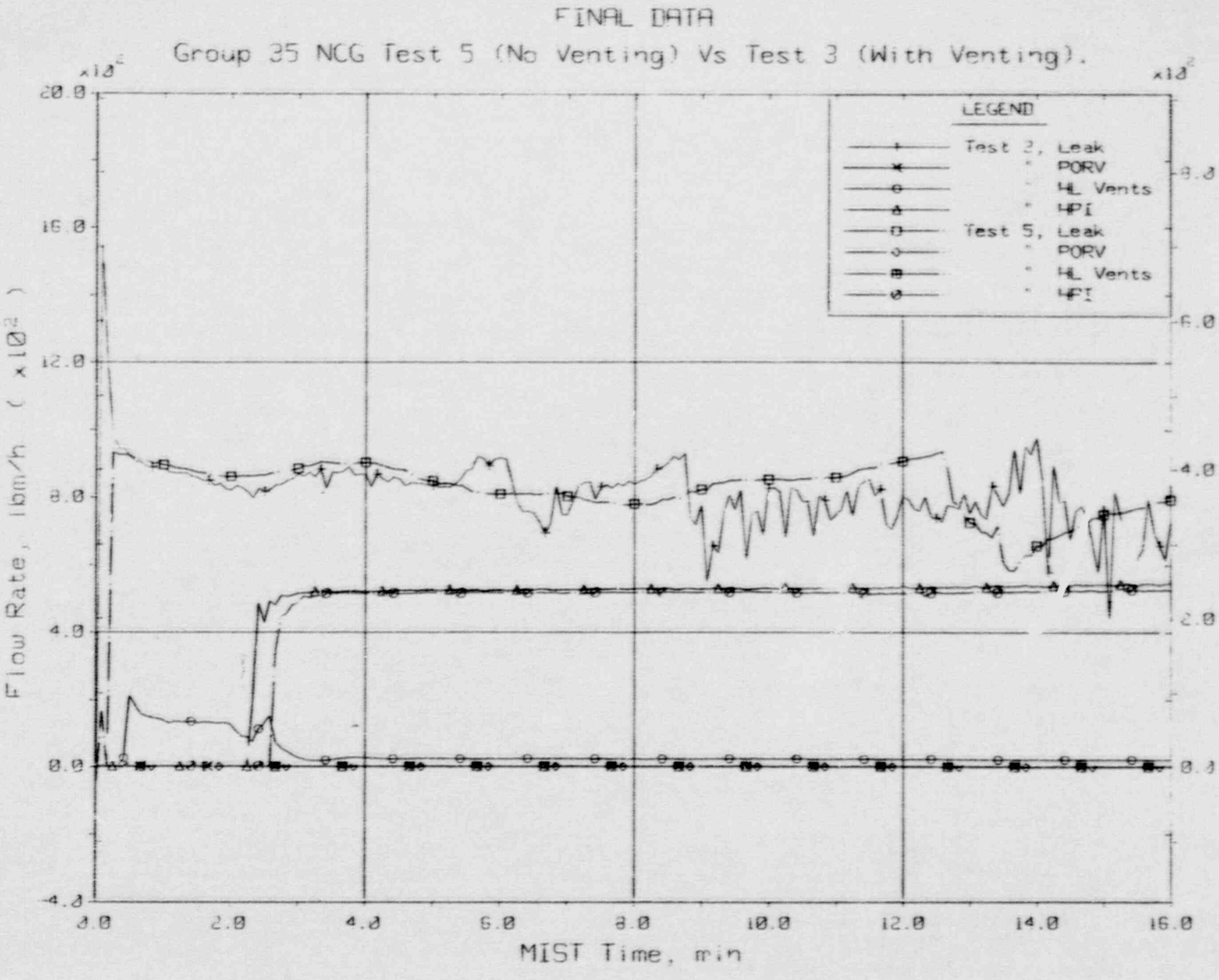


Figure 5.3.80 Primary System Boundary Mass Flow Rates

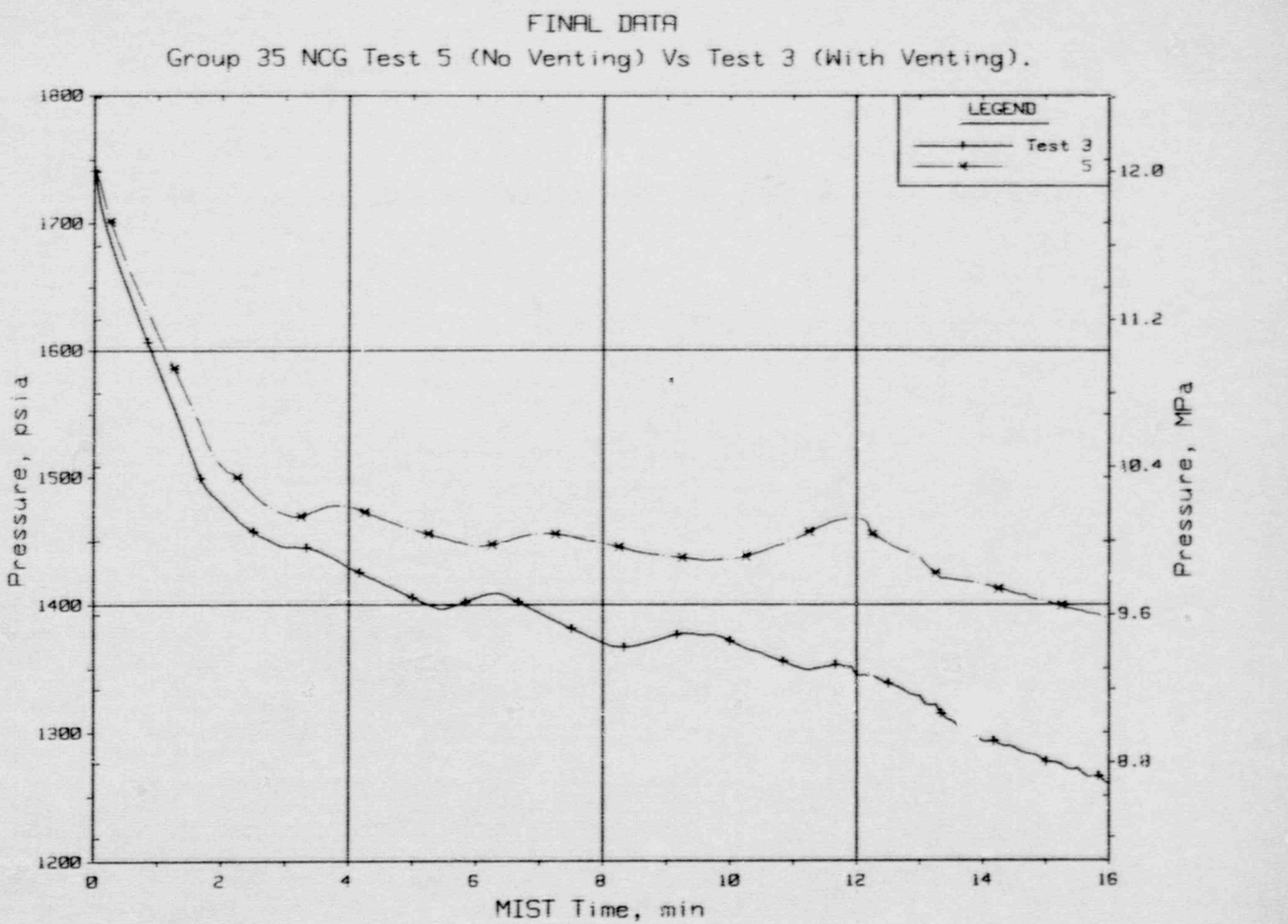


Figure 5.3.81 Primary System Pressure (RVGP01)

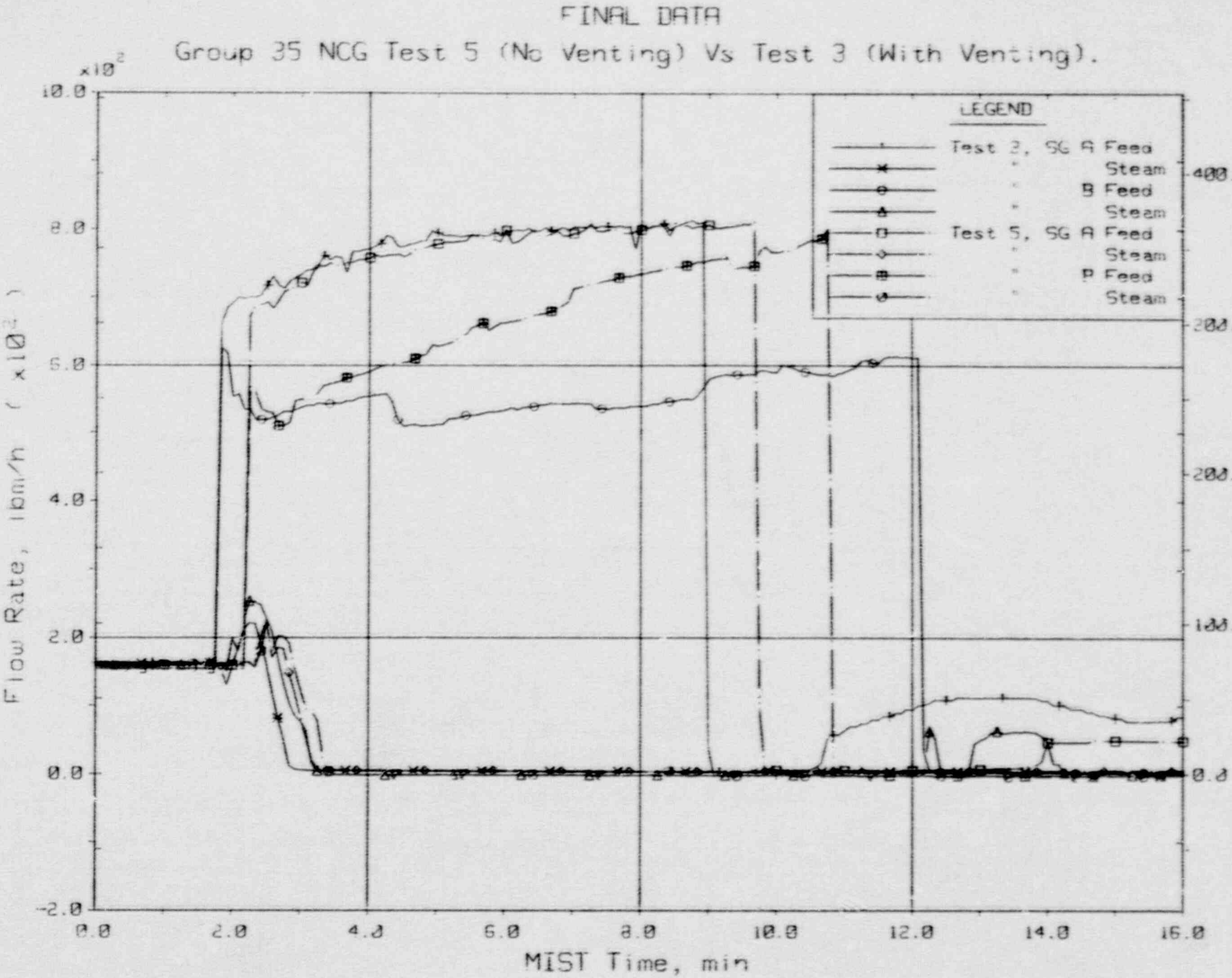


Figure 5.3.82 Steam Generator Secondary Flow Rates

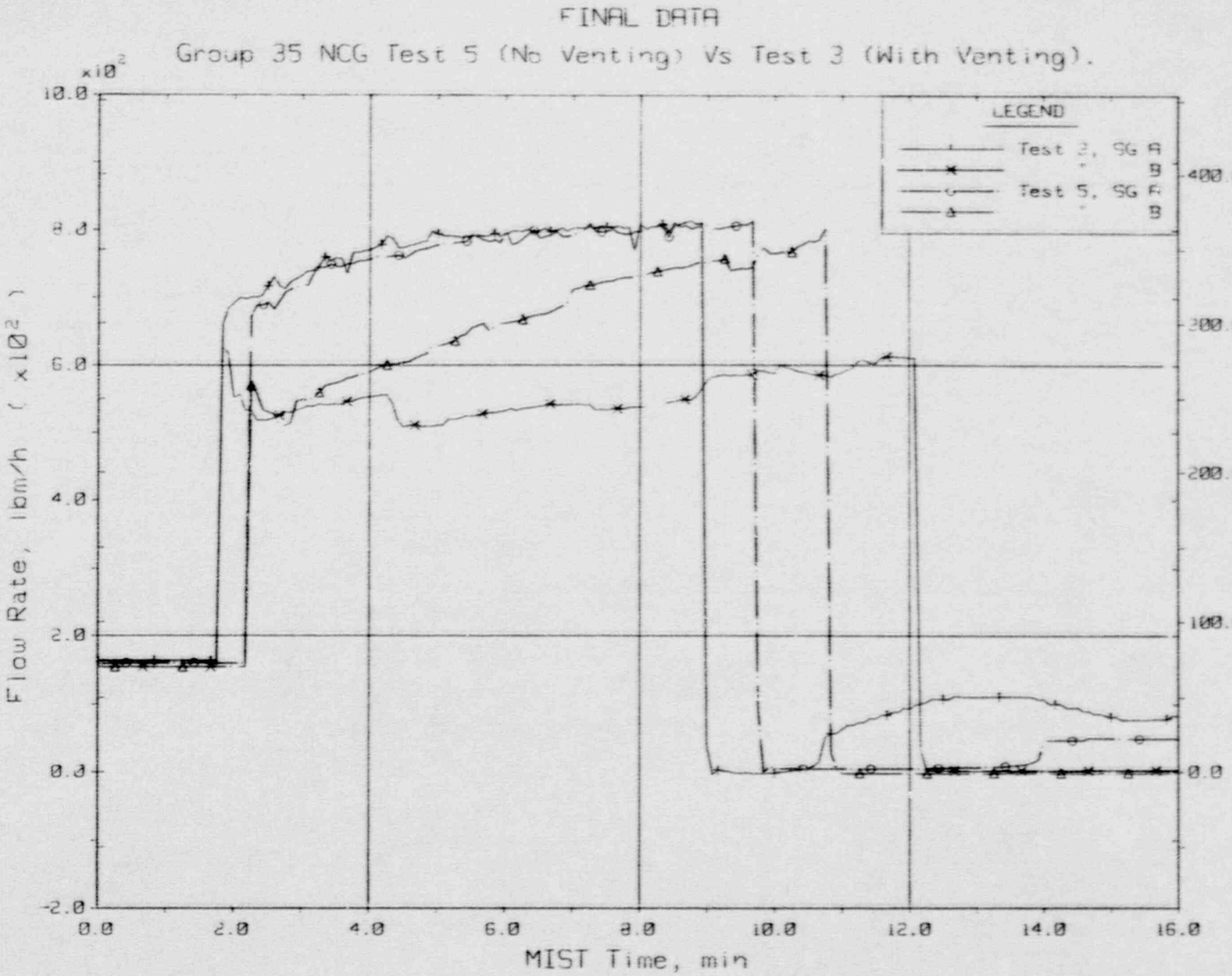


Figure 5.3.83 Steam Generator Secondary Feed Flow Rates

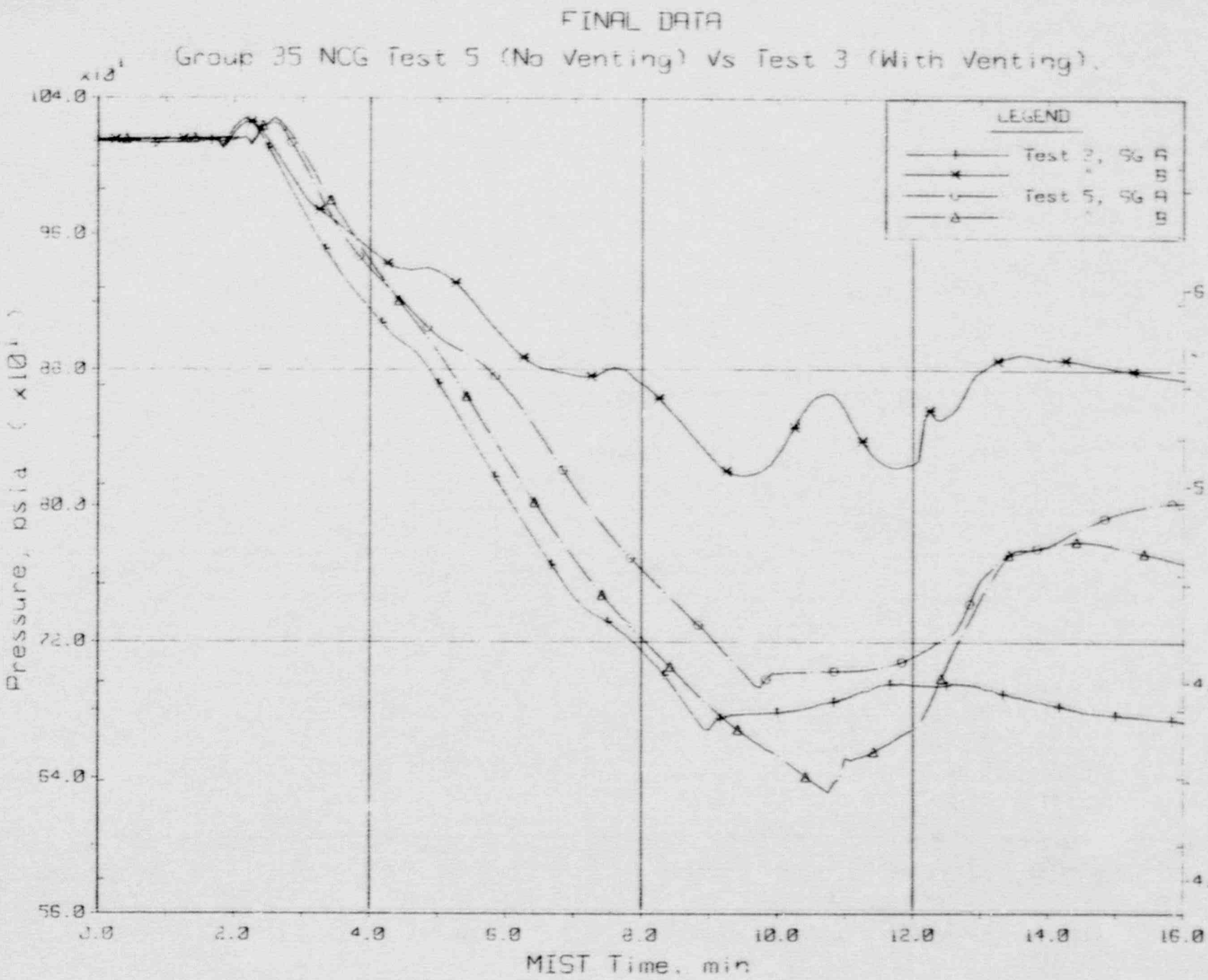


Figure 5.2.84. Steam Generator Secondary Pressures (SpGP01s)

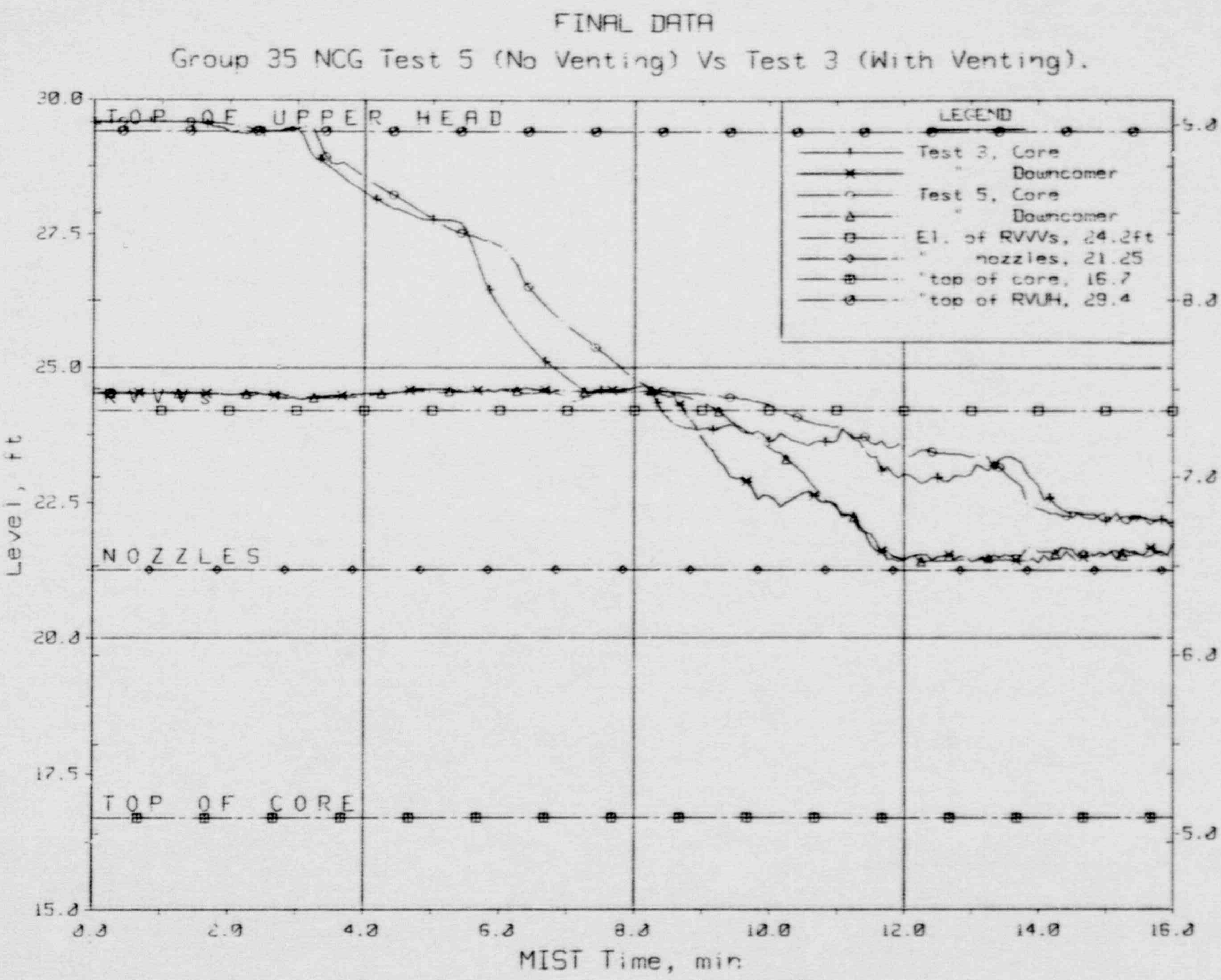


Figure 5.3.85 Core Region Collapsed Liquid Levels

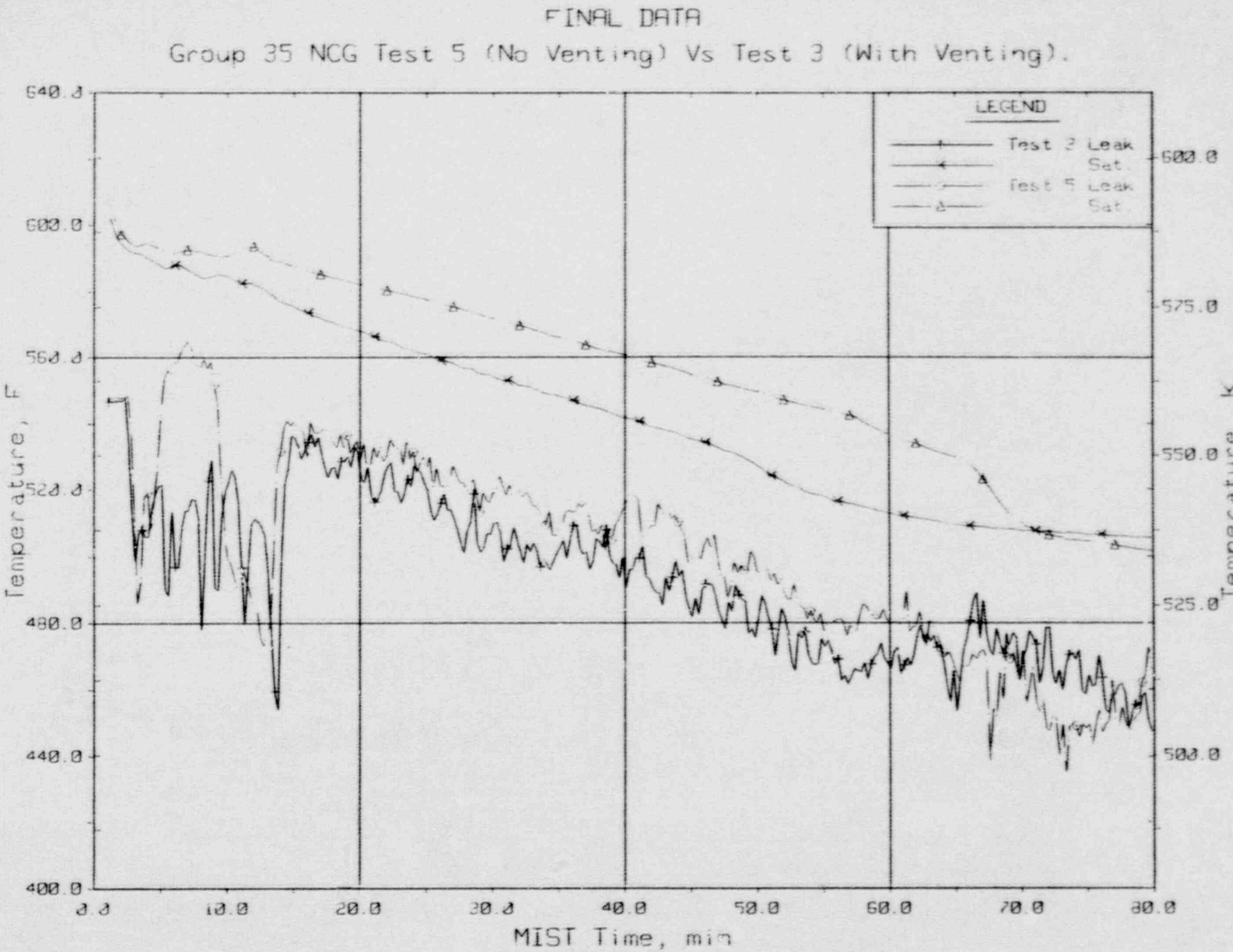


Figure 5.3.86 Leak and HPI Fluid Temperatures (TC01s)

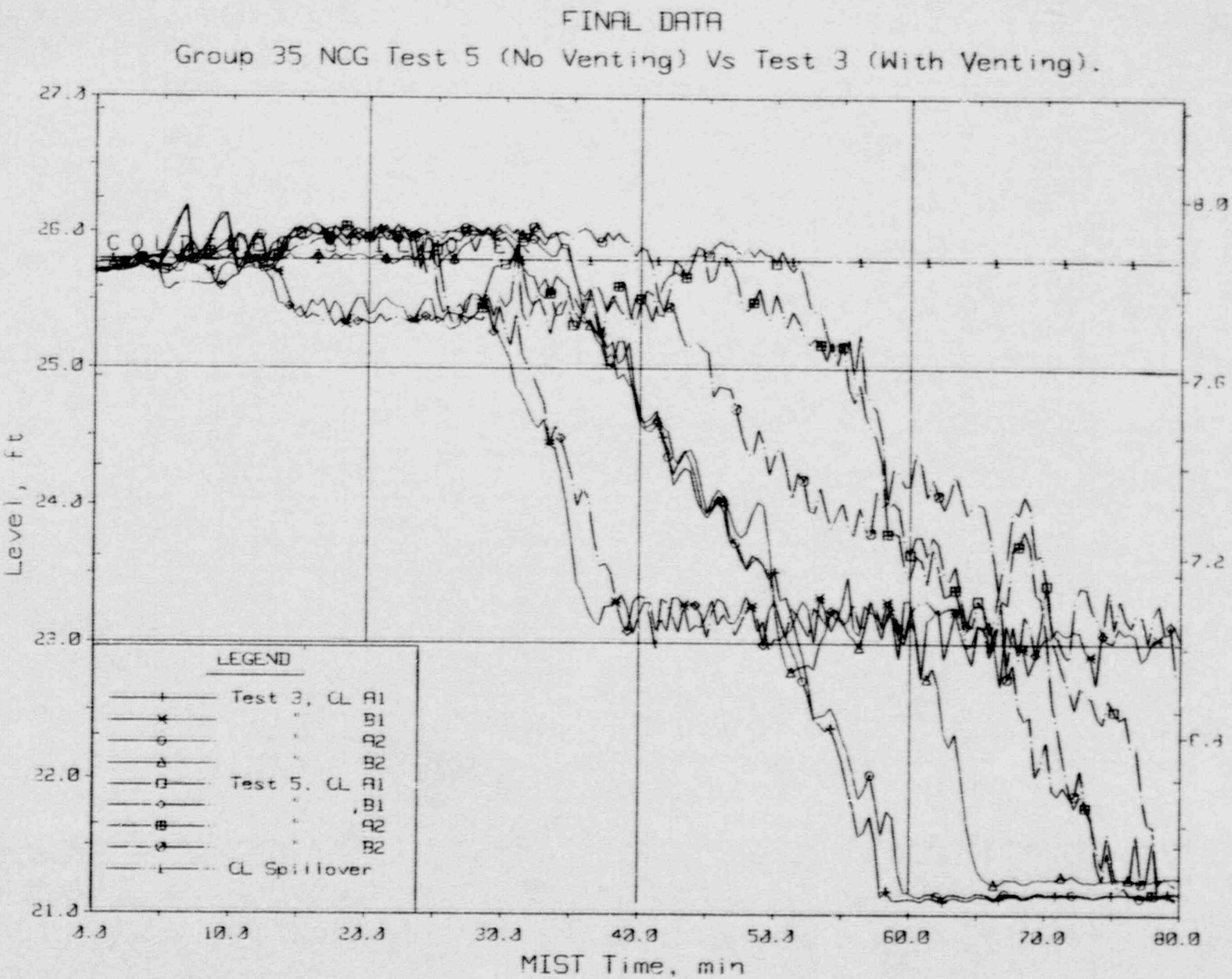


Figure 5.3.87 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

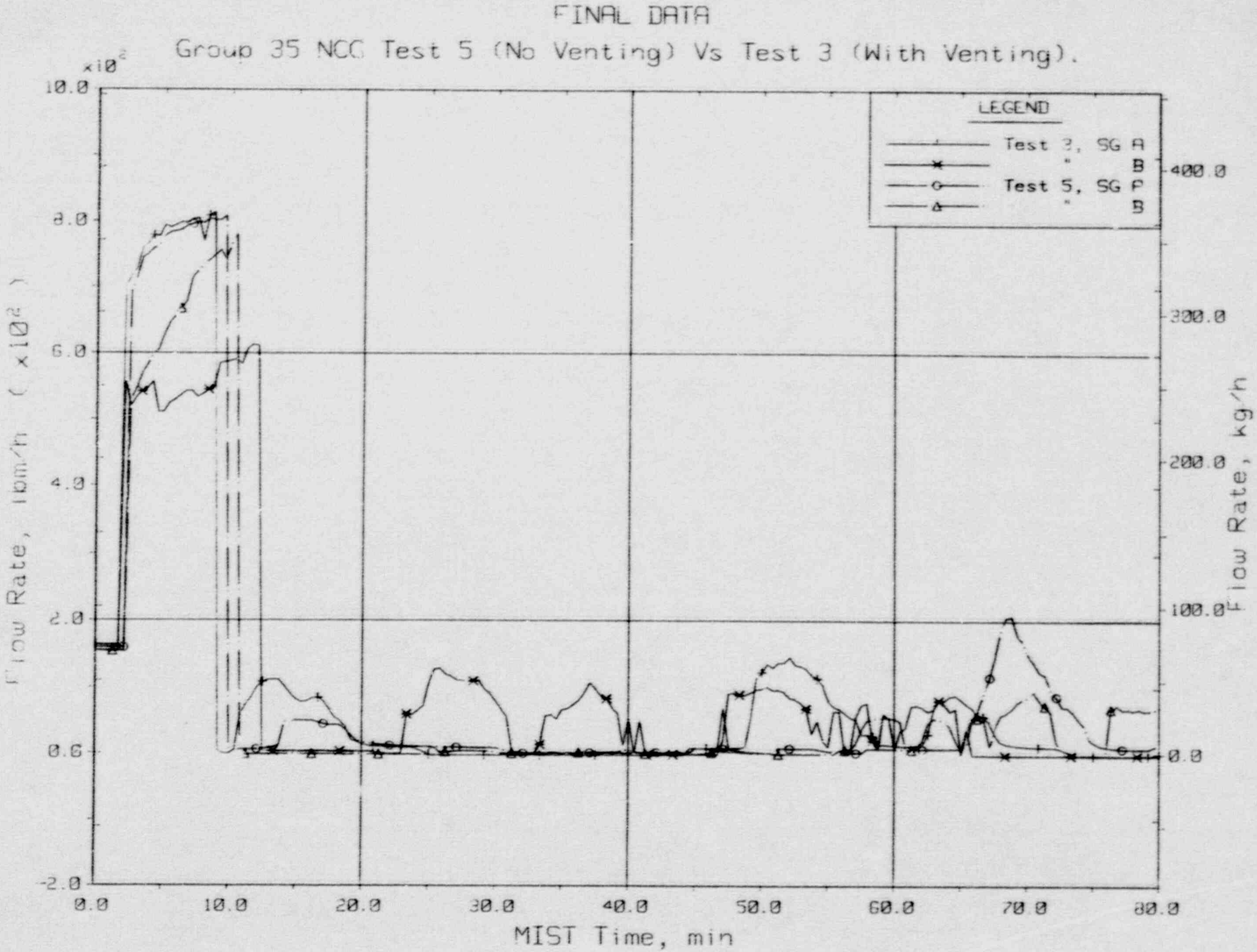


Figure 5.3.88 Steam Generator Secondary Feed Flow Rates

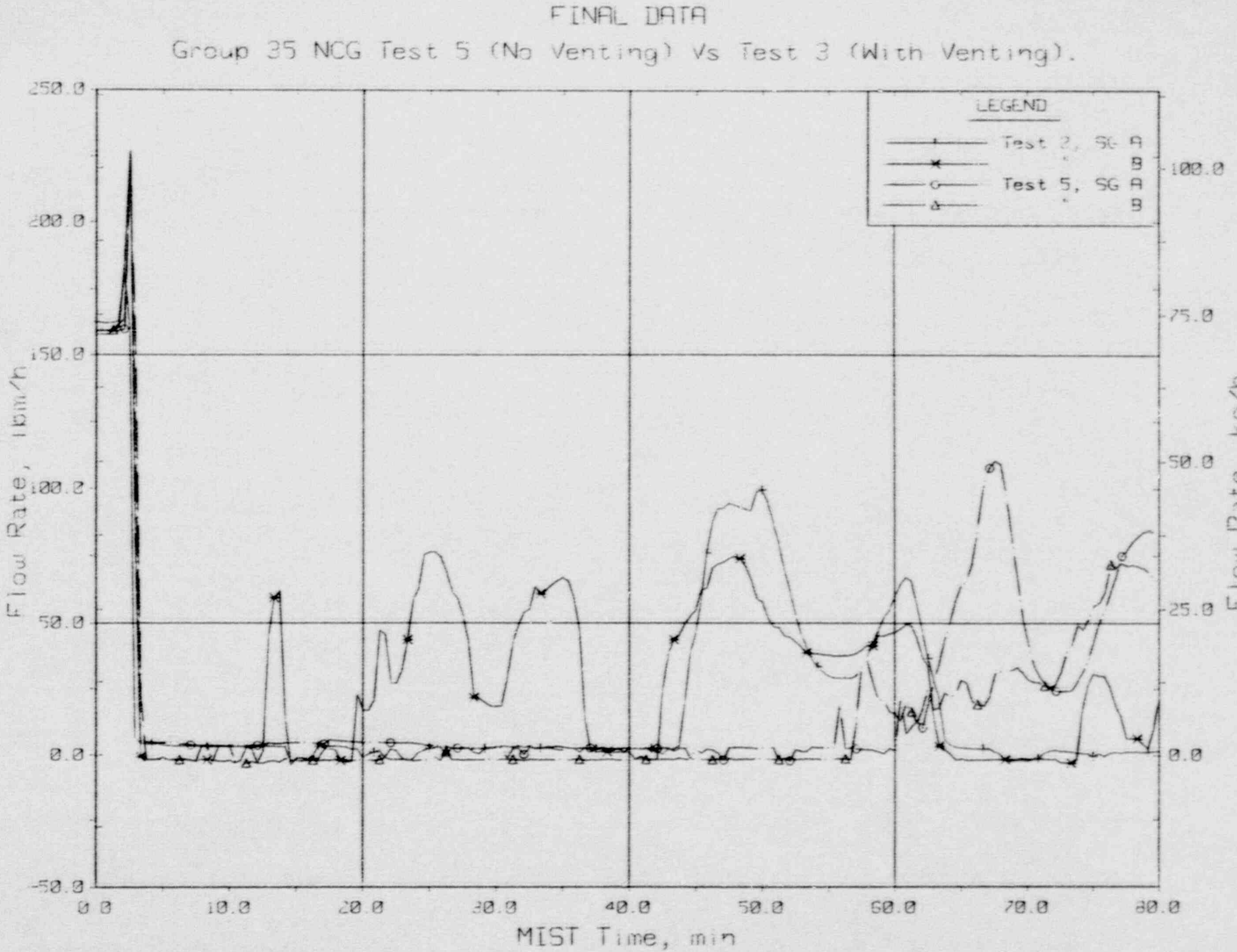


Figure 5.3.89 Steam Generator Secondary Steam Flow Rates

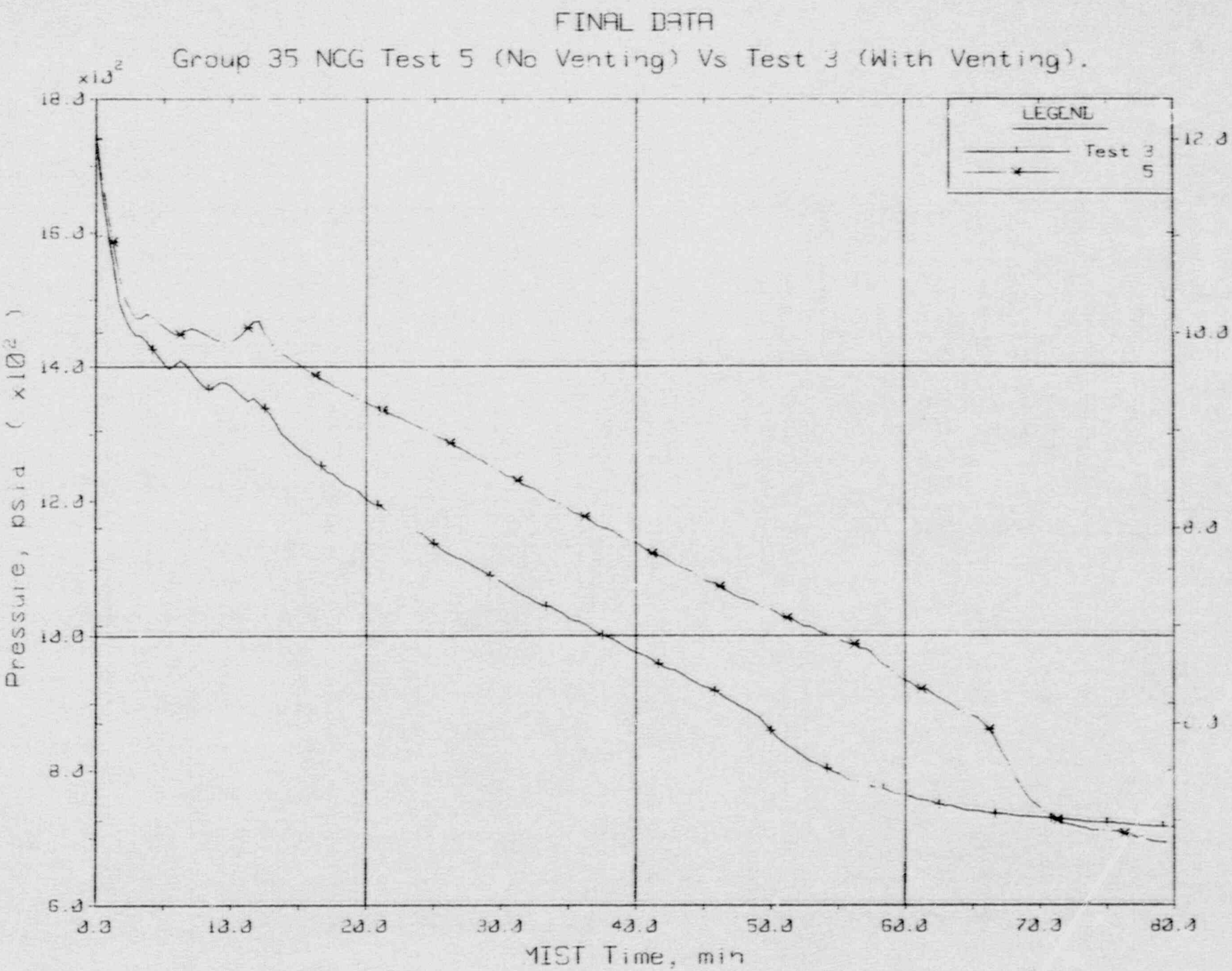


Figure 5.3.90 Primary System Pressure (RVGP01)

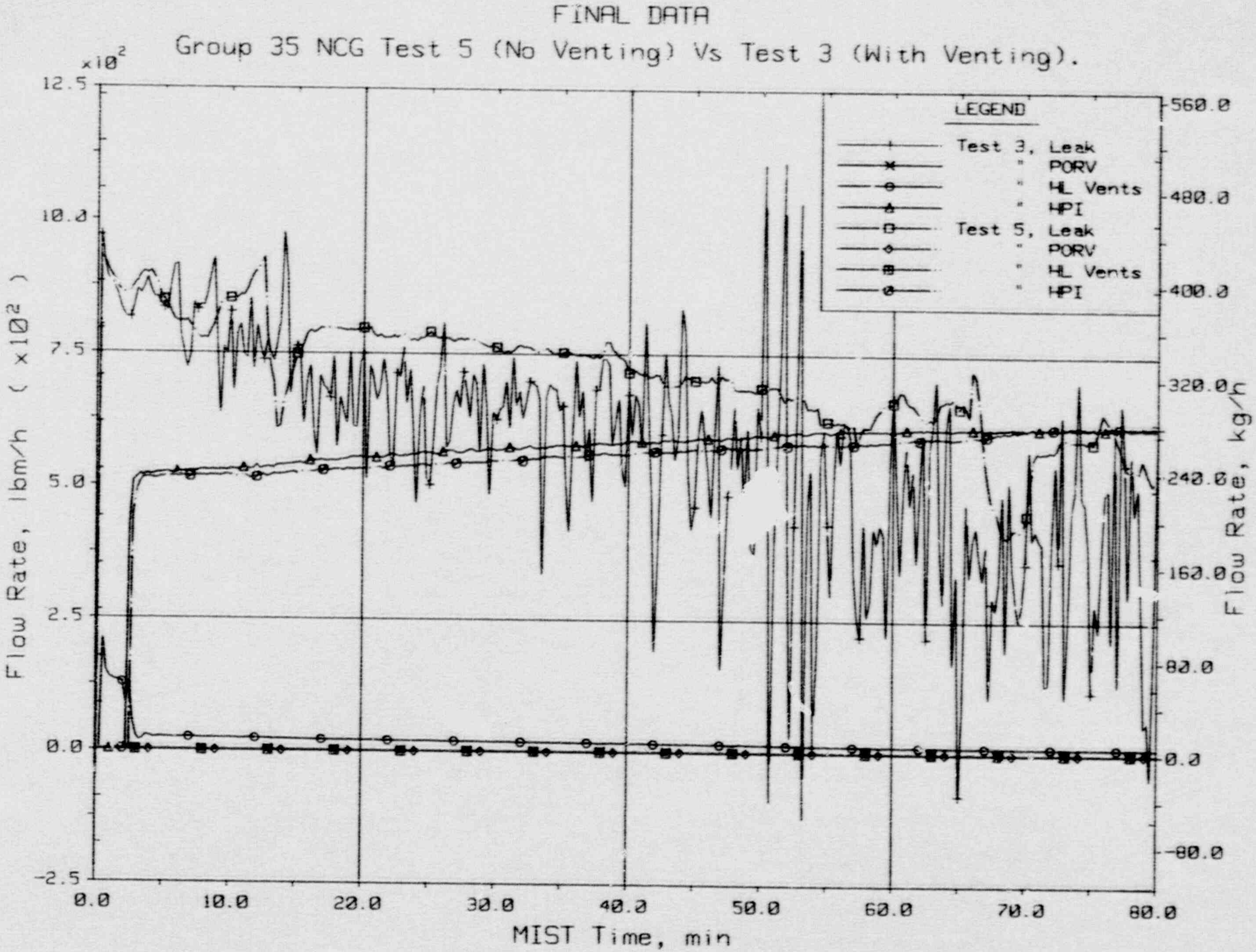


Figure 5.3.91 Primary System Boundary Mass Flow Rates

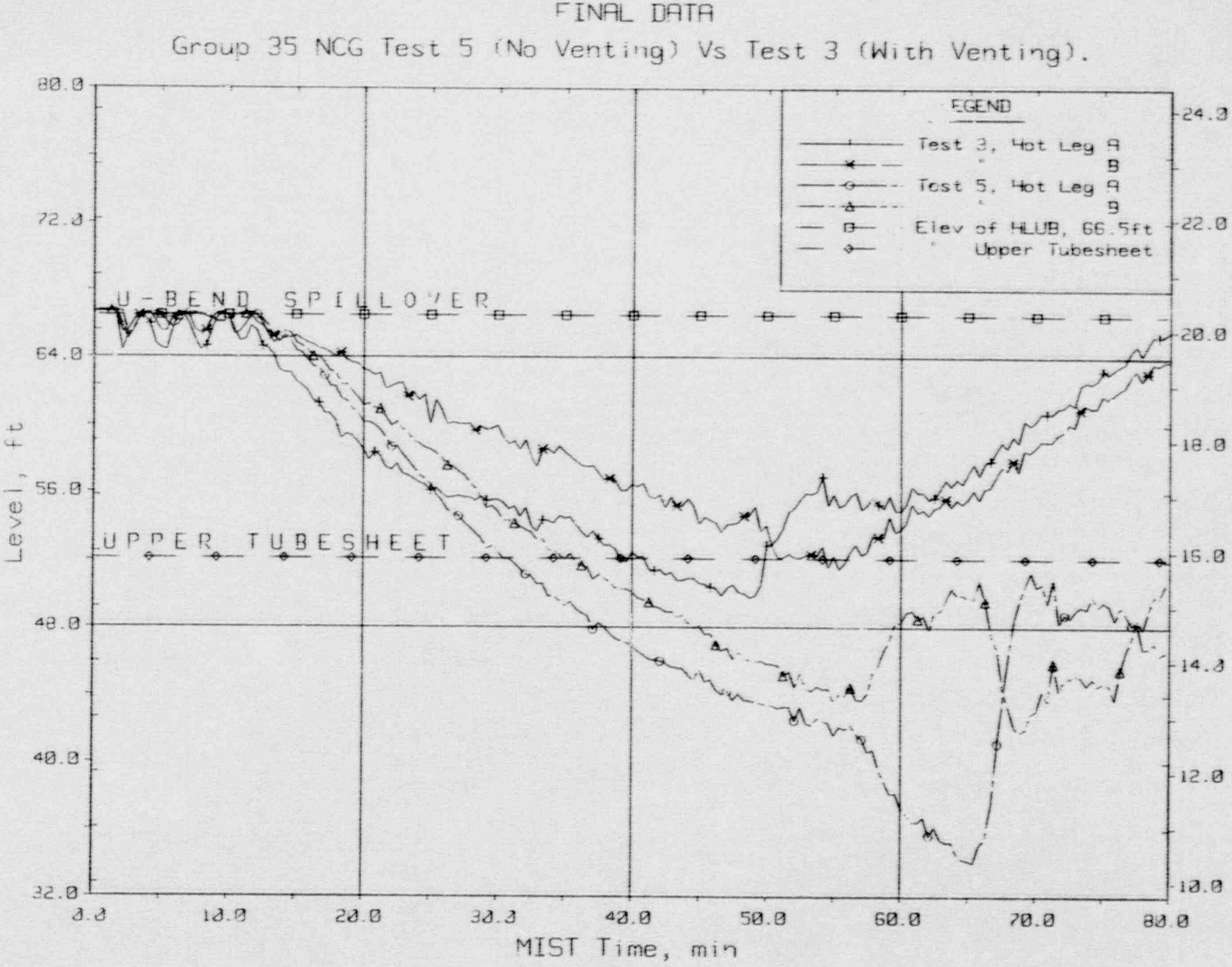


Figure 5.3.92 Hot Leg Riser Collapsed Liquid Levels

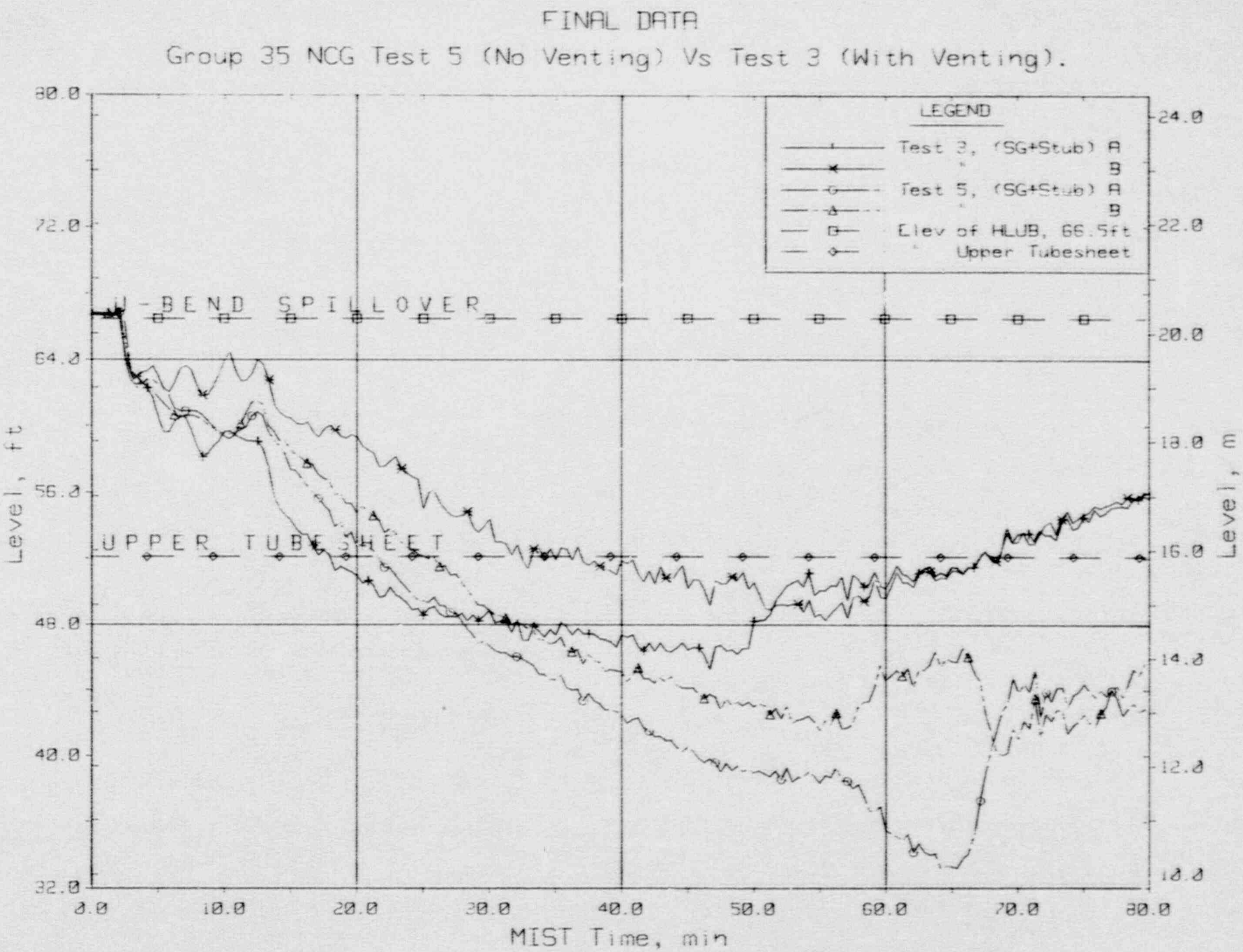


Figure 5.3.93 Steam Generator Primary and Stub Collapsed Liquid Levels

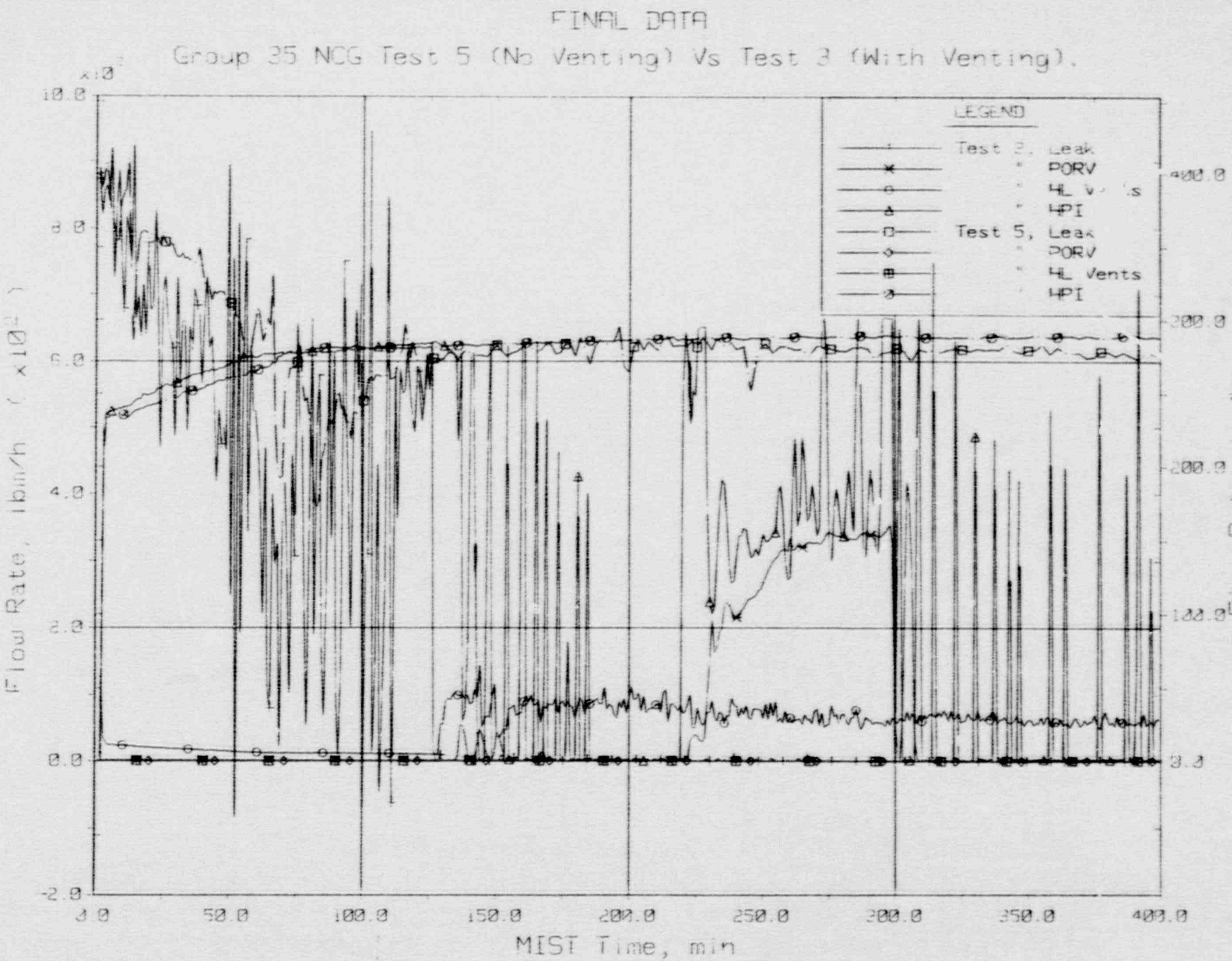


Figure 5.3.94 Primary System Boundary Mass Flow Rates

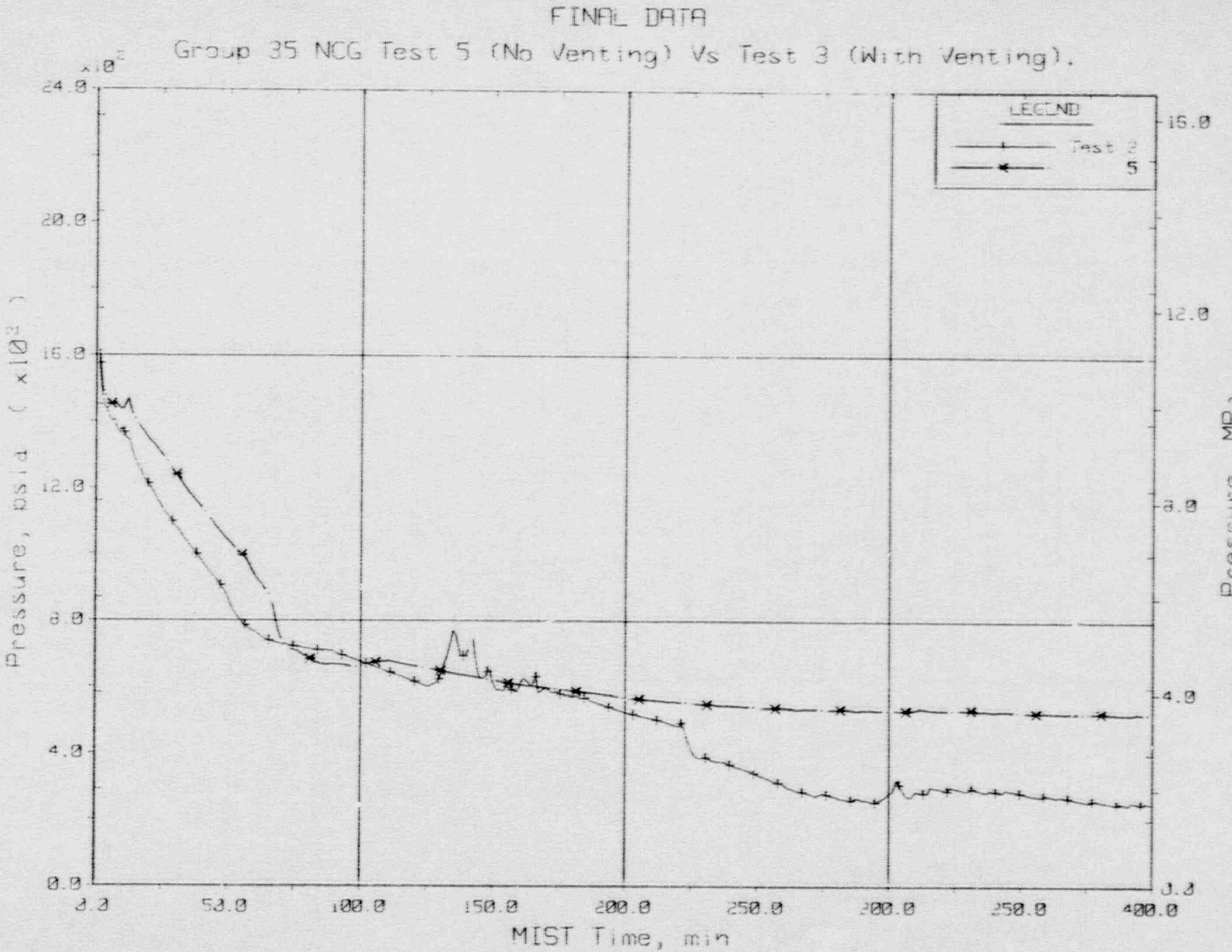


Figure 5.3.95 Primary System Pressure (RVGP01)

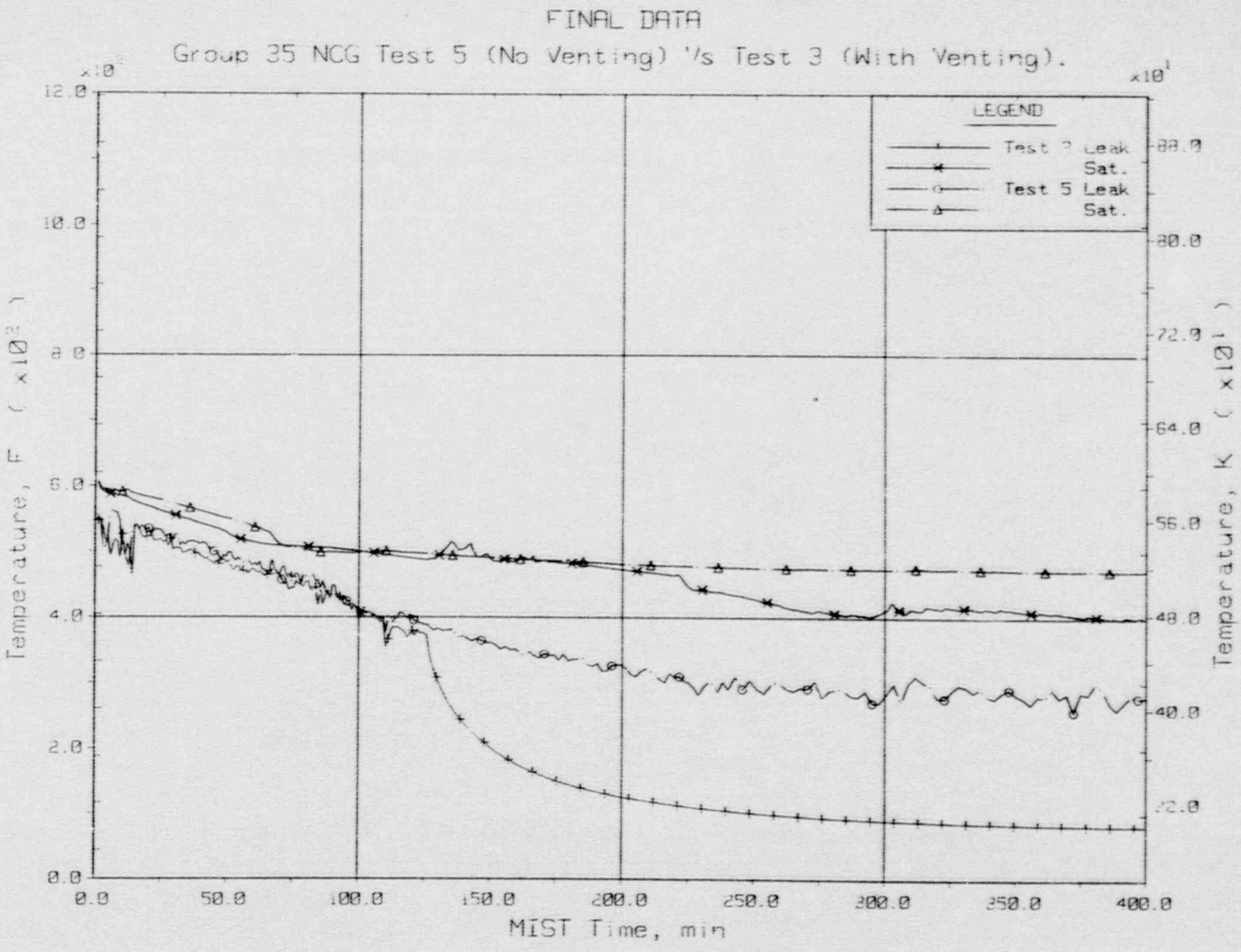


Figure 5.3.96 Leak and HPI Fluid Temperatures (TC01s)

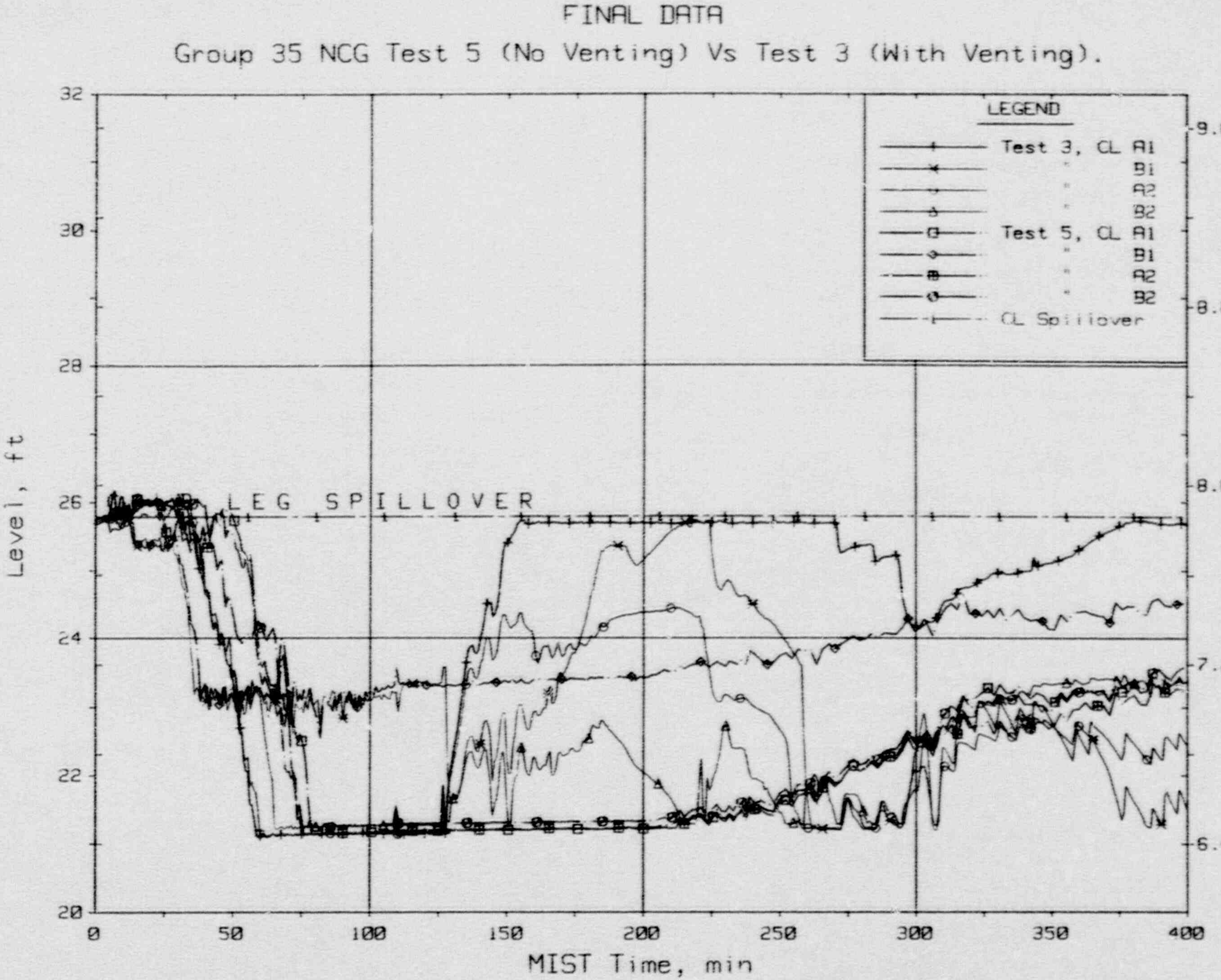


Figure 5.3.97 Cold leg Discharge Collapsed Liquid Levels (CnLV23s)

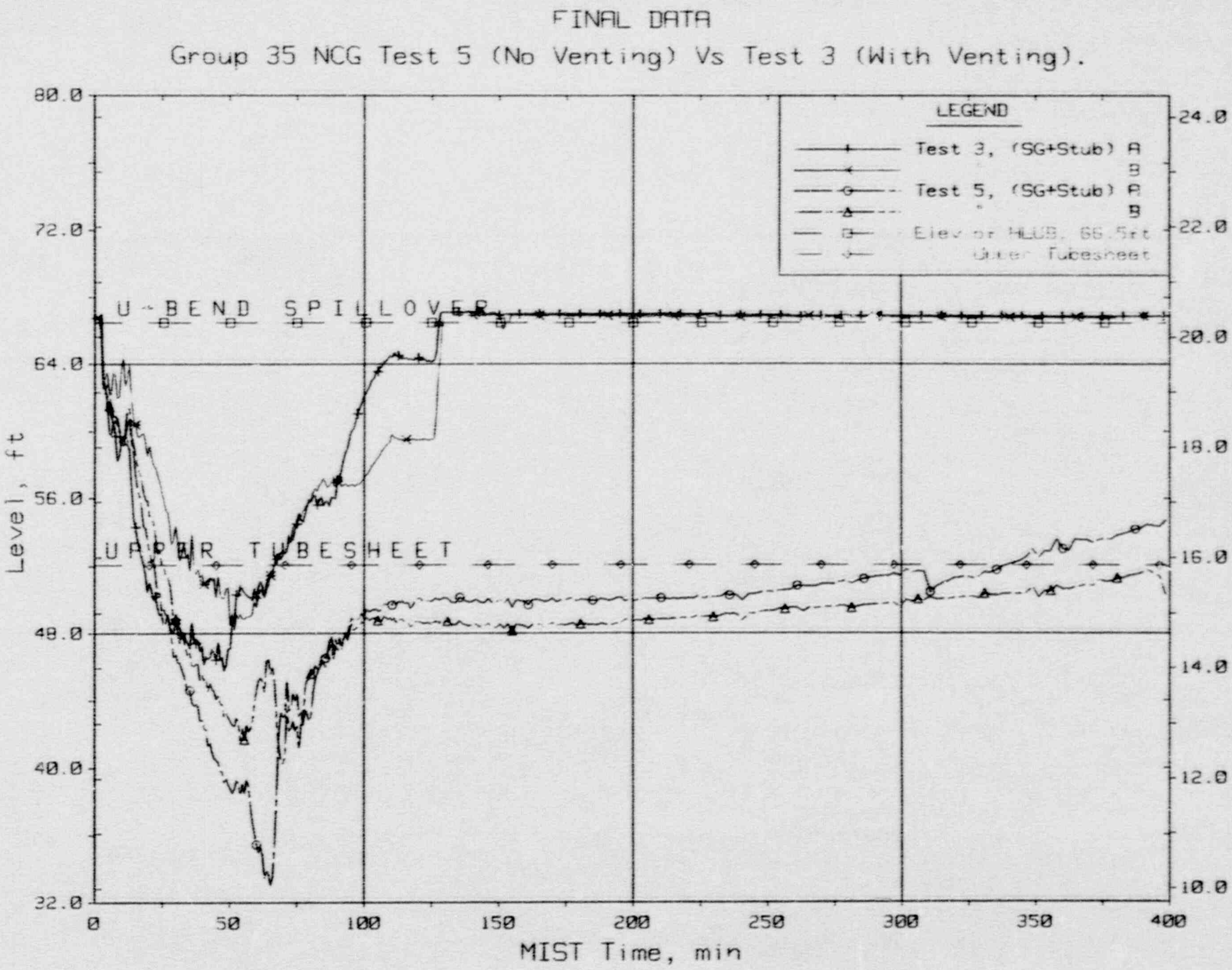


Figure 5.3.98 Steam Generator Primary and Stub Collapsed Liquid Levels

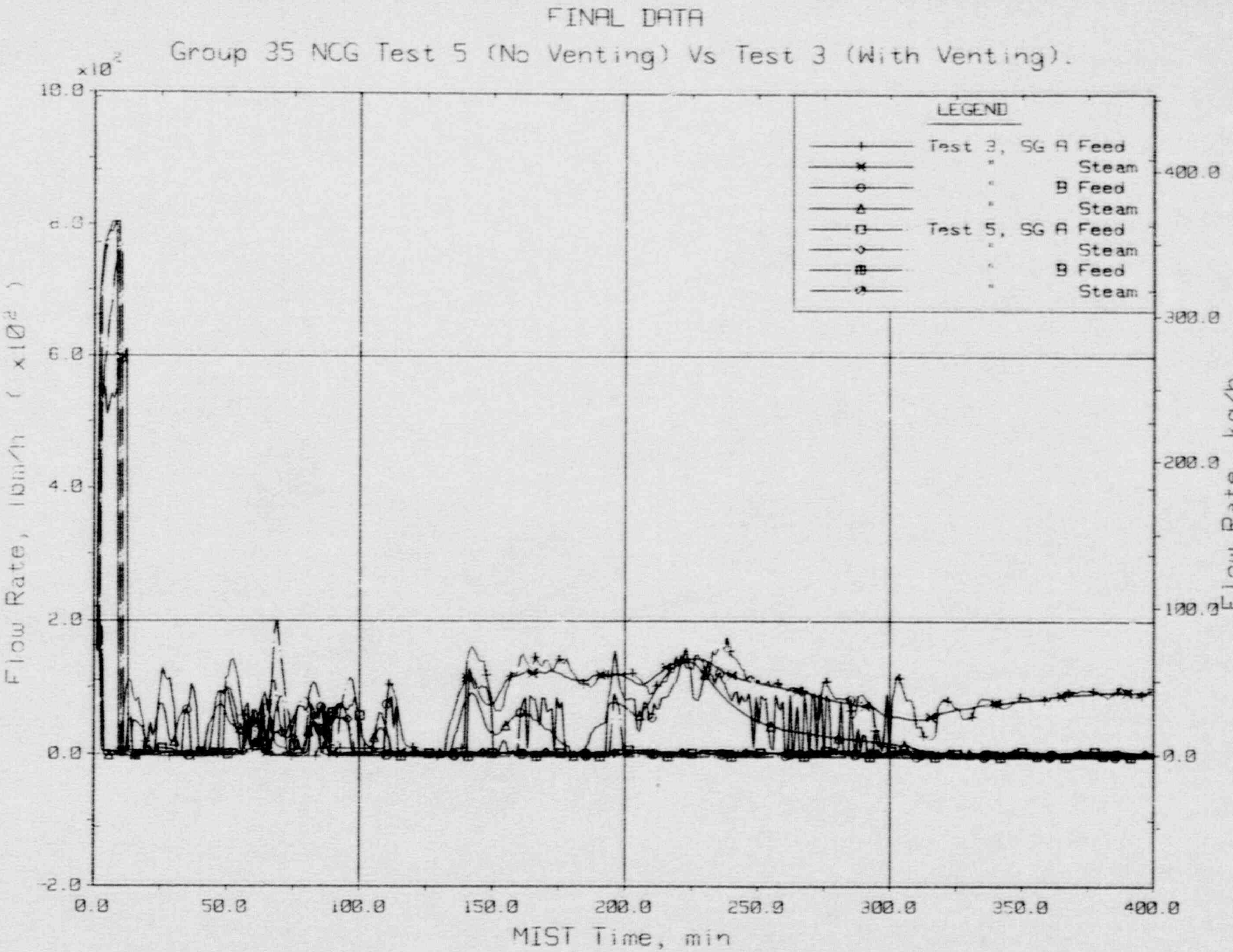


Figure 5.3.99 Steam Generator Secondary Flow Rates

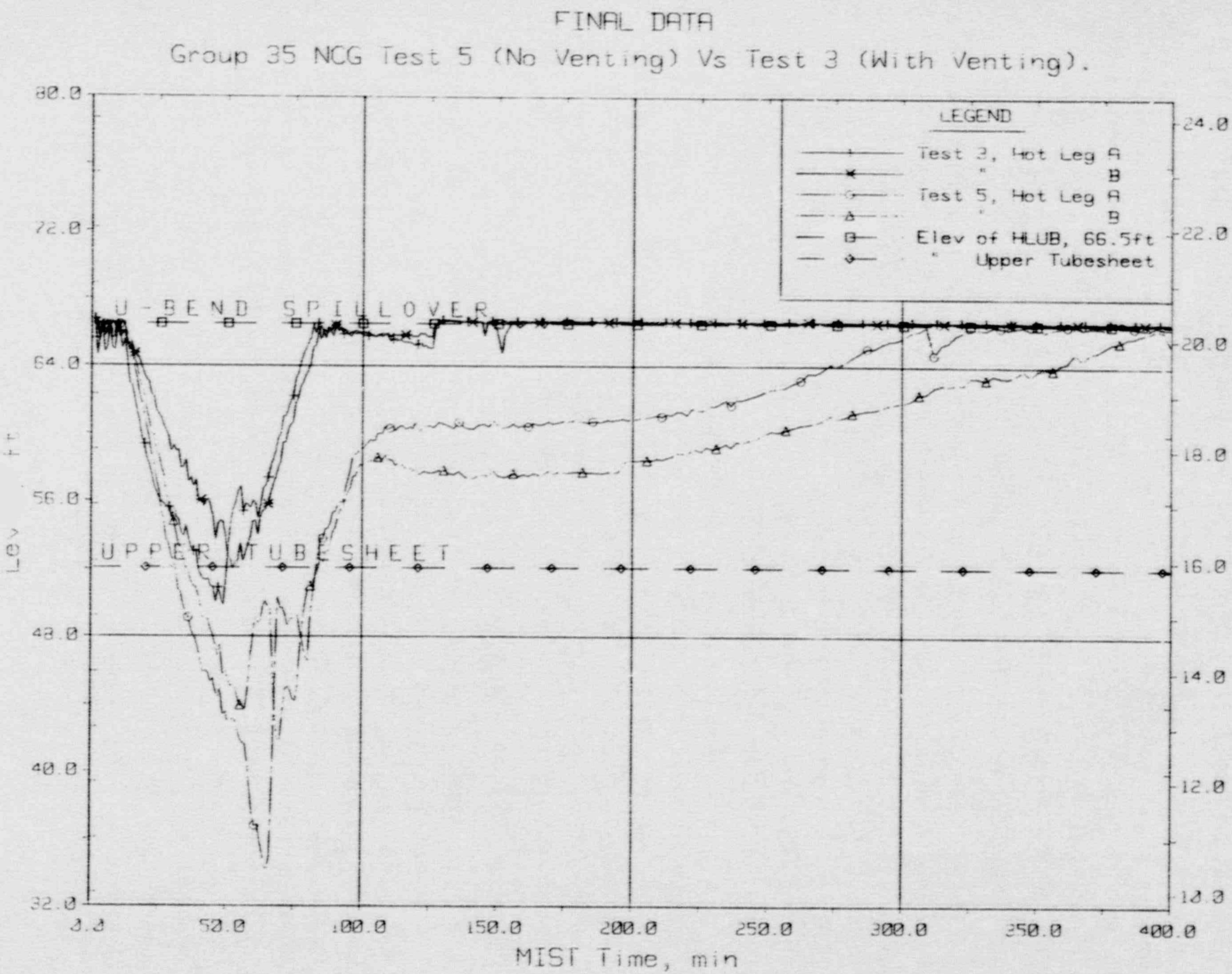


Figure 5.3.100 Hot Leg Riser Collapsed Liquid Levels

5.4. Leak Location, Tests 3 and 7

Tests 3 and 7 both used continuous hot leg venting, helium, and a scaled 10-cm^2 cold leg B1 leak. The leak was located in the discharge piping in Test 3, but in the suction piping in Test 7. Test 7 is described in section 5.4.1, Test 3 has already been described in section 5.3.2. Tests 3 and 7 are compared in section 5.4.2.

5.4.1. Cold Leg Suction Leak, Test 7

A cold leg suction leak was used in Test 7 (350700). The leak was closed for the second phase of the test. Helium was injected at the core inlet at a rate of 33 scf/h. The gas injection was terminated after 60 scf were injected. Little gas was discharged out the leak, and approximately 40 scf of the helium remained within the primary system at test termination. The hot leg vents were kept open throughout the test; the PORV was opened to control the SCM after the leak had been closed.

The NCG effects were most apparent in the upper downcomer and cold leg discharge piping after the BCM was precluded by the rising steam generator primary levels. The fluid temperatures in the vapor region indicated subcooling, and the cold leg nozzle fluid temperatures indicated little warming of the entering HPI fluid. The lower downcomer and core-inlet fluid temperatures also approached the HPI supply fluid temperature.

Initiation, Depressurization to Saturation

Test 7 was begun by opening the scaled 10-cm^2 cold leg B1 suction leak, opening both hot leg high-point vents, and injecting helium into the reactor vessel lower piping. The helium injection rate was approximately 33 scf/h. The other standard test-initiating actions were also performed. Immediately, the leak mass flow rate increased to more than 800 lbm/h (Figure 5.4.1), the primary system began to depressurize from 1740 psia (Figure 5.4.2), and the hot leg vent discharge flow rate began to increase toward a value commensurate with liquid at the vent site (Figure 5.4.1). The cold leg flow rates increased from 1 to 2 minutes and then began to subside. The RVVVs opened at 1.4 minutes. At 1.5 minutes, the HPI isolation valves opened and the steam generator feed rates began to increase; the feed rate to steam generator A increased to the full head/flow value but the feed rate to steam generator B increased to only approximately 85% of this value (Figure 5.4.3). Bubbles were observed through the hot leg riser viewports as early as 1.2 minutes in loop A and 1.7 minutes in loop B (Figure 5.4.4). The observations through the hot leg horizontal viewports (Figure 5.4.5) indicated later, less pronounced, and more asymmetric activity, perhaps reflecting the asymmetric placement of these viewports.

The primary system saturated at 2 minutes. The rate of the primary system depressurization slowed (Figure 5.4.2), the levels downstream of both hot leg U-bends began to decrease (Figure 5.4.6), and the hot leg venting rates abruptly decreased (Figure 5.4.1) as the fluid at the venting sites saturated and then voided. Indications of spillovers rather than all liquid were observed through the hot leg A U-bend viewport at 2.1 minutes, and through the hot leg B U-bend viewport at 2.4 minutes (Figure 5.4.7). The lower-elevation viewports indicated decreased voiding at this time (Figures 5.4.4 and 5.4.5). The hot leg riser collapsed liquid levels (Figure 5.4.6) receded from full by approximately 1 ft as spillovers were first observed, and the cold leg and downcomer flow rates peaked near 6% of scaled full flow (Figures 5.4.8 and 5.4.9). The reactor vessel began to void at 3 minutes (Figure 5.4.10). Also at this time, the indicated HPI flow rate stabilized at the full head/flow capacity.

Between 4 and 5 minutes, increased voiding was again observed through the hot leg horizontal and riser viewports of both loops (Figures 5.4.4 and 5.4.5), but the U-bend viewports indicated continuing spillovers (Figure 5.4.7). The hot leg riser collapsed liquid levels refilled briefly (Figure 5.4.6) and the loop flow rates again increased and then subsided (Figure 5.4.9).

The hot leg A U-bend was first observed to void completely near 6 minutes, but the viewport indications of spillover continued in loop B (Figure 5.4.7). The measured hot leg levels seemed slightly out of phase with these visual observations -- the levels receded from full before 6 minutes, but had refilled by 6.4 minutes (Figure 5.4.6). The changes of the loop flow rates seemed to correspond to the measured level. The cold leg and downcomer flow rates achieved a broad minimum near 5.8 minutes (Figure 5.4.9), 0.4 minutes after the minimum hot leg riser collapsed liquid level, and similarly peaked just after the hot leg riser levels indicated full. The cold leg flow rates intermittently stalled (Figure 5.4.8) but the downcomer flow rate, augmented by RVVV flow, generally remained above 2% of scaled full flow.

At 9.3 minutes, the hot leg A U-bend indications of complete voiding were observed to transfer to a spillover (Figure 5.4.7). This observed transition corresponded to full hot leg riser level indications (Figure 5.4.6) and to increasing loop flow rates (Figure 5.4.9), but the riser viewports continued to indicate bubbly flow (Figure 5.4.4). The quasi-periodicity of the variations of riser level, loop flow, and viewport indications was altered when the core-region levels descended to the nozzle elevation.

HPI Condensation

The secondary side refill was completed at 9 minutes in steam generator A and at 10.5 minutes in B. The core-region collapsed liquid level approached the elevation of the RVVVs at 9 minutes (Figure 5.4.10), the downcomer began to void, and the RVVVs, which had remained open, began to actuate as the core exit fluid intermittently subcooled. This activity continued until 12 minutes. At this time, the descending downcomer level reached the cold leg nozzles, exposing the upper downcomer vapor to the HPI-cooled cold leg fluid. The primary system began to depressurize from 1350 psia (Figure 5.4.2), the reactor vessel collapsed liquid level began to descend toward the hot leg nozzles and the riser levels in both hot legs receded from the U bends (Figure 5.4.6). The regional void fraction distribution (obtained from differential pressure measurements) for the reactor vessel varied in an unusual manner (Figure 5.4.11). The volume above the RVVVs remained completely voided beyond 9 minutes. The void fraction between the nozzles and the RVVVs reached 50% at 13 minutes, but then receded to approximately zero at 15 minutes as the core exit void fraction increased. The hot leg A horizontal and both hot leg riser viewports (Figure 5.4.4 and 5.4.5) indicated increased voiding as the core-region level approached the nozzle elevation, followed by decreased voiding. Both hot leg U-bend viewports indicated complete voiding beyond 15 minutes (Figure 5.4.7), which confirmed the receding hot leg riser levels. The viewport indications became quite constant after this time, indicating stratified flow at the hot leg horizontals, a medium concentration of bubbles in the risers, and complete voiding at the U-bends (Figures 5.4.12 through 5.4.14).

The primary level in steam generator A descended much more rapidly than the level in B (Figure 5.4.15), even though U-bend flow was interrupted and the break was in loop B. Cold leg B1 began to backflow at 14 minutes and reached more than 1000 lbm/h, which exceeded the break mass flow rate, at 16 minutes (Figure 5.4.16). This flow reversal was accompanied by an unusually large temperature change in both loop B cold legs. For example, the fluid temperature at the pump discharge for cold leg B1 dropped from 520 to 360F and returned to 525F within 2 minutes (Figure 5.4.17). This propagation of relatively cold fluid may have reflected the interference of noncondensibles with HPI condensation. As the colder fluid reached the leak site, the leak mass flow rate increased discernibly.

The gas venting rate diminished as the hot legs voided and as the steam generator primary levels entered the steam generators. Whereas the gas injection rate was maintained within about 10 scf/h of the average 33 scf/h, the initial venting collection rate was approximately 9 scf/h. The gas collection rate slowed beyond 15 minutes, becoming virtually zero beyond 35 minutes (Figure 5.4.18).

Start of Refill

The primary level in steam generator A decreased below the upper tubesheet elevation at 25 minutes, while that in steam generator B attained the tubesheet elevation at 41 minutes (Figure 5.4.15). The steam generator secondary control and actual pressures became equal near 34 minutes, both steam generator secondaries became mildly active (Figure 5.4.19), and the primary system depressurization rate increased slightly (Figure 5.4.20). The relatively mild BCM depressurization apparently reflected NCG effects.

The HPI mass flow rate began to exceed the combined leak and venting mass flow rates beyond approximately 35 minutes (Figure 5.4.21). The hot leg riser levels began an irregular increase, but the cold leg suction and discharge levels began to recede between 30 and 40 minutes. The loop A cold leg discharge levels decreased markedly at 45 minutes. The cold leg B2 discharge level evidenced a similar decrease at 55 minutes, but the (broken) cold leg B1 discharge level remained near the cold leg spillover elevation (Figure 5.4.22).

Effects of Noncondensibles

As both steam generator primary levels rose above the elevation of the upper tubesheets, there were indications of noncondensible gas migration toward the reactor vessel and downcomer. The steam generator A primary level had exceeded the upper tubesheet elevation at 70 minutes; this occurred at 88 minutes in steam generator B (Figure 5.4.23). The hot leg B U-bend viewport began to evidence a spillover beyond 80 minutes (Figure 5.4.14). The upper downcomer fluid (vapor) temperatures, which had followed the primary system saturation temperature, now began to diverge and to indicate apparent subcooling (Figure 5.4.24). The degree of apparent subcooling was a direct albeit approximate indication of the local NCG concentration. The apparent subcooling of the upper downcomer fluid temperatures increased with time and was larger at the lower (voided) elevations -- the apparent subcooling of the (cold leg) nozzle-region temperatures ultimately reached 150F. Also at 90 minutes, the cold leg B1 discharge piping quickly voided, completing the voiding of all four cold leg discharges, and the nozzle rake fluid temperatures began to diverge. For example, at the cold leg A1 nozzle, the upper three thermocouple rake fluid temperatures merged near 400F, whereas the lowest rake thermocouple indication rapidly decreased and approached the HPI fluid temperature (Figure 5.4.25).

The gas injection was completed at 109 minutes, with a total injection of approximately 60 scf of helium. Approximately 3 scf had been vented, and the post-test gas balance calculations indicated that less than 7 scf had been discharged by the cold leg suction break. Therefore, approximately 50 scf remained within the primary system at the completion of the injection. This resident volume of NCG occupied about 3 ft^3, or 15% of the total primary system volume, at the current primary system conditions.

The reactor vessel vent valves performed in a most unusual and asymmetric manner near the end of the gas injection phase (Figure 5.4.26). For example, just beyond 109 minutes, RVVV B1 closed whereas RVVV A2 opened. The indicated RVVV differential pressures (Figure 5.4.27) supported these opposed actuations. The origins of the indicated pressure changes are unknown.

Leak Isolation

The cold leg suction leak was closed at 124 minutes (Figure 5.4.28), as specified. Immediately, the primary system began to repressurize (Figure 5.4.29) and fill due primarily to the continuing HPI flow. The pressurizer level began to increase, and both the cold leg suction piping (Figure 5.4.30) and the hot leg risers (Figure 5.4.23) refilled. The combined mass flow rates of both vents increased at 126 minutes and again at 131 minutes (Figure 5.4.28), apparently corresponding to the refill of the hot leg B U-bend followed by the A. The core-region collapsed liquid level exceeded the elevation of the RVVVs at 133 minutes (Figure 5.4.31), the core exit subcooling increased, and the operator manually opened the PORV at 139 minutes, as specified, to control the SCM. The pressurizer level began to increase relatively rapidly at 139 minutes and indicated full at 146 minutes; the PORV discharge first began to indicate flow at 140 minutes, and indicated increased flow commensurate with subcooling at the PORV site at 147 minutes (Figure 5.4.28). The gas (venting and PORV) discharge collection rate increased with the PORV actuation (Figure 5.4.32), approaching 5 scf/h. The lower downcomer and core-region fluid continued to cool in response to the HPI-PORV cooling. The core exit SCM thus remained above 70F and the PORV was kept open. The HPI fluid was virtually unheated when it entered the downcomer. Primary-to-secondary heat transfer had been largely supplanted by HPI-PORV cooling. Thus, there was little flow through the cold legs. The upper downcomer remained voided (Figure 5.4.31), apparently reflecting NCG effects. Because the core had been subcooled, the RVVVs remained closed, thus precluding HPI heating via mixing with the vent valve effluent. The lower downcomer and core-inlet fluid cooled to approximately 100F (Figure 5.4.33). Automatic HPI throttling (for 75F SCM) began at 138 minutes. The reduced HPI flow rate approximately equalled the combined PORV and vent flow rates (Figure 5.4.28), thus stabilizing the total primary system fluid mass. The test was terminated at 289 minutes based on the dual criteria of primary system pressure of less than 400 psia and SCM greater than 50F for at least 2 hours.

5.4.2. Comparison

A cold leg B1 suction break was imposed in Test 7 versus the usual cold leg B1 discharge piping break, such as used in Test 3. Tests 3 and 7 were otherwise controlled in the same fashion. Both tests used a scaled 10-cm^2 leak, helium injection at the lower reactor vessel piping, continuous hot leg venting, and leak isolation midway through the test transients.

Tests 3 and 7 were begun from virtually identical initial conditions. Their initial depressurization rates were similar (Figure 5.4.34). In Test 3 having a cold leg discharge break, the leak fluid temperatures were slightly less than those of Test 7 (Figure 5.4.35), obtaining a slightly higher initial leak mass flow rate (Figure 5.4.36). The responses to the test-initiating actions were recorded within sequential data scans between the tests, thus the timing of these actions was nominally identical. In both tests, the initial feed rate to steam generator A increased to full head flow but those to steam generator B were less than full head flow (Figure 5.4.37), obtaining a 3-minute spread among the times required to refill the steam generator secondaries (Figure 5.4.38). As a result, the steam generator secondary system depressurizations due to feeding were dissimilar (Figure 5.4.39).

The gas injections were first recorded just after time zero, and the gas collections began to register beyond approximately 2 minutes (Figure 5.4.40). The Test 7 gas injection and collection rates slightly exceeded those of Test 3 over the first 12 minutes, but both inter-test differences were quite small and, with particular reference to gas collection, may have been due to metering inaccuracies and deadbands. (The "collected" volumes were obtained from the two-phase effluent streams, the vents, and later the PORV; the cold leg leak effluent gas volumes were not collected.)

In both tests, the primary system pressure stabilized near 1500 psia upon primary saturation just as the HPI flow began to register (at approximately 2 minutes). The hot leg riser levels began to recede symmetrically in both tests (Figure 5.4.41) and, within 1 minute, the core-region level began to reflect voiding (Figure 5.4.42). Perhaps in response to the unequal feed rates to steam generators A and B, the steam generator primary levels began to differ (Figure 5.4.43), being higher in the steam generator receiving less feed. The downcomer began to void at approximately 9 minutes in both tests, descending to the elevation of the cold leg nozzles at 12 minutes (Figure 5.4.42). The leak fluid temperature increased at 15 minutes in Test 3, but not until 20 minutes in Test 7 (Figure 5.4.44). In both tests, the leak fluid remained approximately 50F subcooled. The broken cold leg B1 discharge piping began to void at 15 minutes in both tests (Figure 5.4.45). Although the gas injection rates were 32 scf/h in both tests, the initial gas collection rates were only 6 scf/h, and slightly higher in Test 7 than in Test 3 (Figure 5.4.46). In both tests, the gas venting and collection rates began to dwindle beyond 15 minutes as the (broken) cold leg B1 piping began to void; these collection rates became negligible by 30 minutes. In Test 3, the measured leak mass flow rate became increasingly erratic as the test progressed, apparently reflecting the influence of noncondensible gas; the Test 7 lead mass flow rate remained quite stable by comparison (Figure 5.4.47).

The primary system depressurized continually (Figure 5.4.48) after the downcomer level had reached the nozzle elevation in both tests. The steam generator A was depressurized to maintain the primary-to-secondary temperature difference of 50F at 20 minutes (Figure 5.4.49), followed by steam generator B at 35 minutes in Test 3 but not until 45 minutes in Test 7. The steam generator steam and feed systems thus became intermittently active beyond 20 minutes (Figure 5.4.50), generally earlier in Test 3. The steam generator primary levels descended below the elevation of the upper tubesheets between 18 and 40 minutes (Figure 5.4.51), again a few minutes earlier in Test 3 than in Test 7. Although the conditions were appropriate for BCM, the noncondensibles apparently inhibited steam generator primary-to-secondary heat transfer. The primary system did depressurize more rapidly than it had been, coincident with steam generator secondary activity starting at 50 minutes in Test 3, but this enhanced depressurization quickly subsided (Figure 5.4.48). There was similar steam generator activity in Test 7, but without affecting the primary system depressurization rate.

The HPI mass flow rate began to exceed the total discharge mass flow rate beyond approximately 45 minutes in both tests (Figure 5.4.47). The hot leg and steam generator primary levels began to rise but the cold leg levels declined (Figure 5.4.45). The cold leg B1 discharge level declined to the elevation of the discharge break relatively early in Test 3, but remained nearly full in Test 7.

Near 2 hours in both tests, the gas injection was completed (Figure 5.4.52) and the leak was isolated shortly thereafter (Figure 5.4.53). The primary system began to repressurize (Figure 5.4.54) and the SCM to increase, prompting HPI throttling and PORV actuation. The PORV was actuated intermittently and infrequently in Test 3, but continually in Test 7 (Figure 5.4.55). In every instance, PORV actuation enhanced the gas collection rate (Figure 5.4.56). Whereas only 2 to 3 scf were collected during the first 2 hours with the hot leg high-point vents open continually, approximately 7 scf were collected during the succeeding 2-1/2 hours. The coincidence of the gas collection rate enhancements with the PORV actuations indicates that the PORV discharges were the major contributors.

Refill proceeded rapidly after break isolation. The hot leg riser levels, which had been just below the U-bend spillover elevation, quickly refilled (Figure 5.4.57). The steam generator primary and cold leg suction levels also refilled (Figures 5.4.58 and 5.4.59), but the cold leg discharge levels apparently reflected the lingering effects of noncondensibles. The cold leg A1 discharge piping indicated full near 155 minutes in Test 3, but the rest of the cold leg discharge levels in Test 3 indicated partial voiding. Those in Test 7 indicated complete voiding (Figure 5.4.60). Whereas in Test 3 the core inlet fluid temperature gradually increased beyond 140 minutes, in Test 7 the core inlet fluid temperature decreased toward the HPI fluid temperature (Figure 5.4.61); it stabilized near 90F beyond 4 hours, approximately 300F below the core exit fluid temperature, and 370F subcooled at the system total pressure.

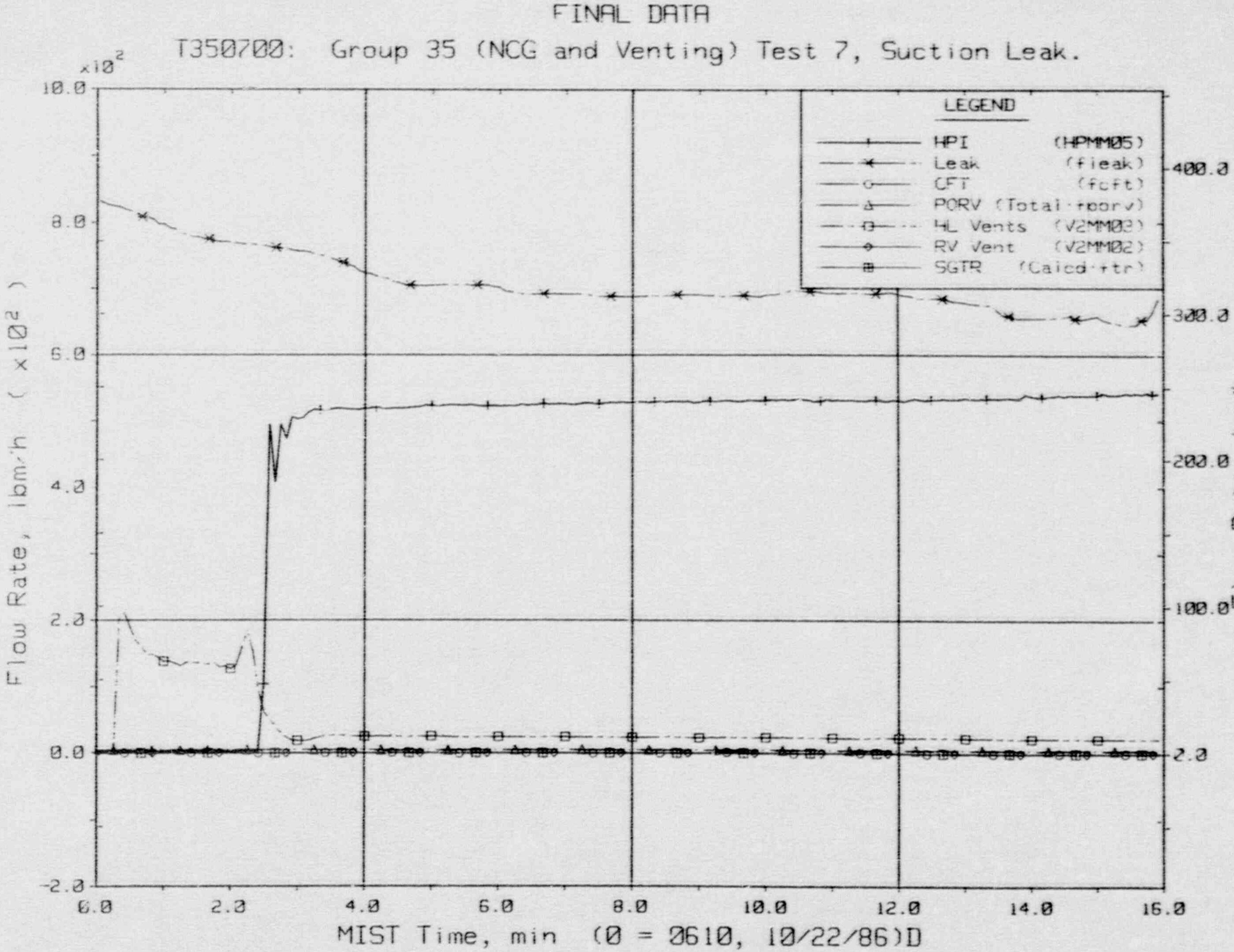


Figure 5.4.1 Primary System Boundary Flow Rates

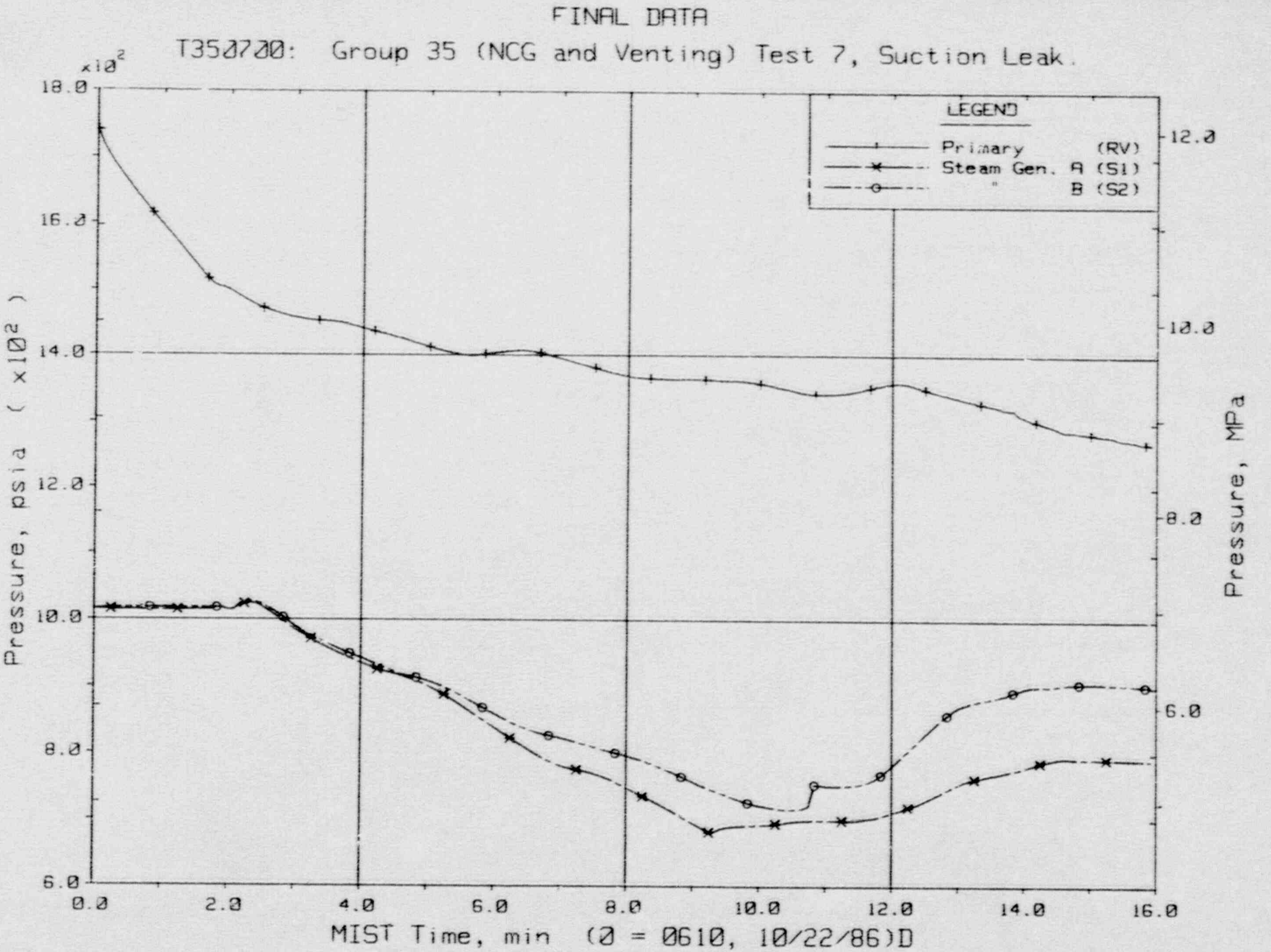


Figure 5.4.2 Primary and Secondary System Pressures (GPOIs)

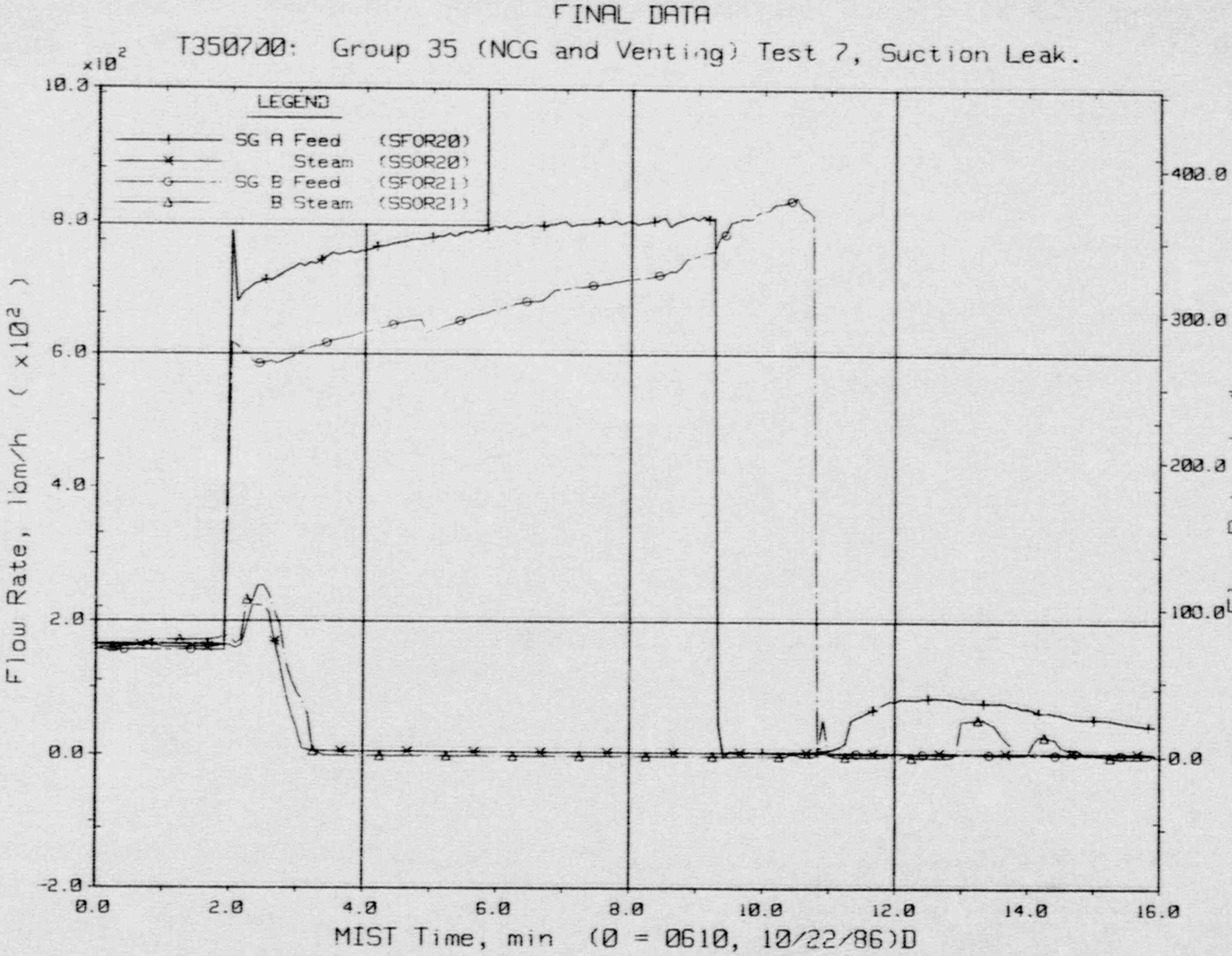


Figure 5.4.3 Steam Generator Secondary Flow Rates

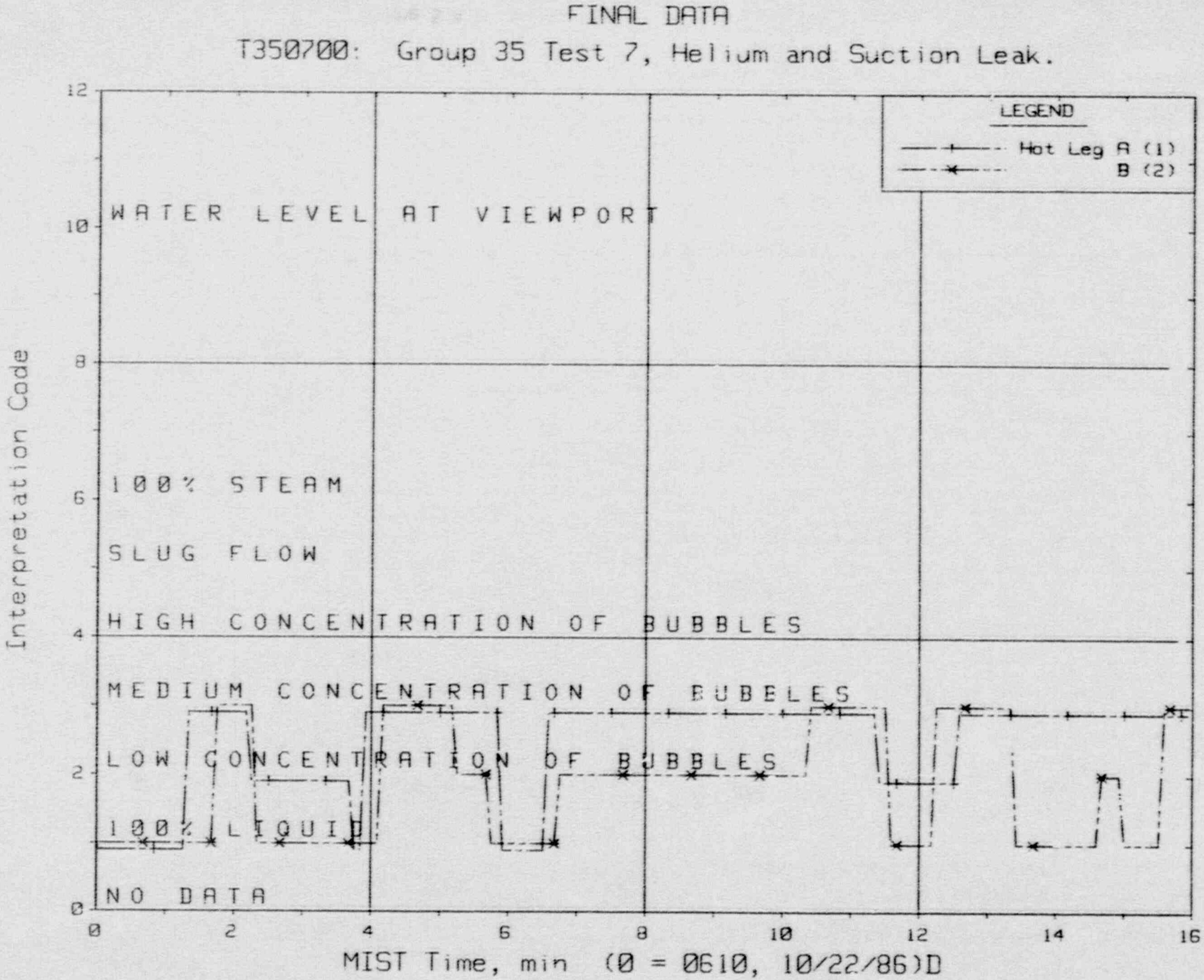


Figure 5.4.4 Hot Leg Riser Viewport Indications (HnMS02s)

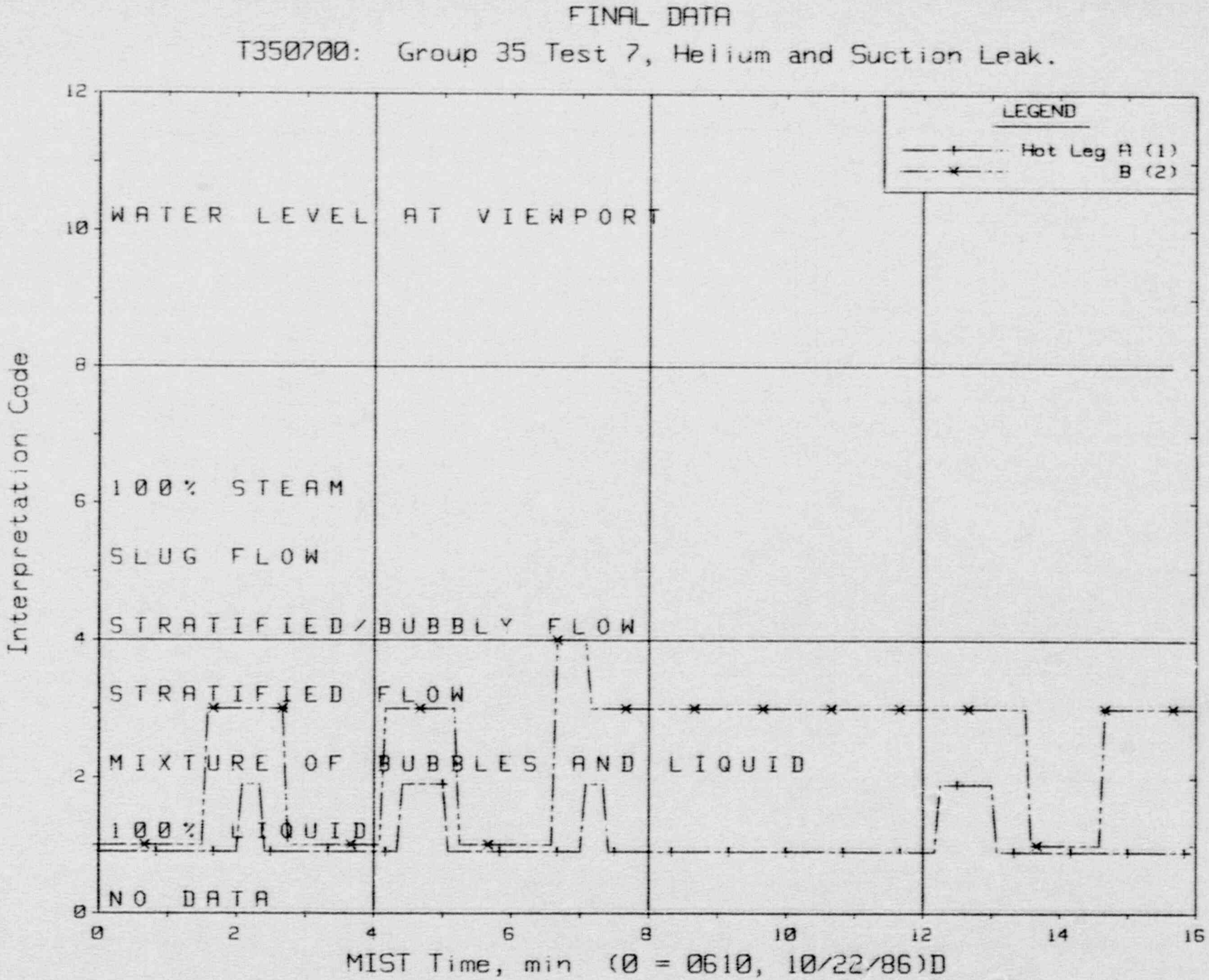


Figure 5.4.5 Hot Leg Horizontal Viewport Indications (HnMSO1s)

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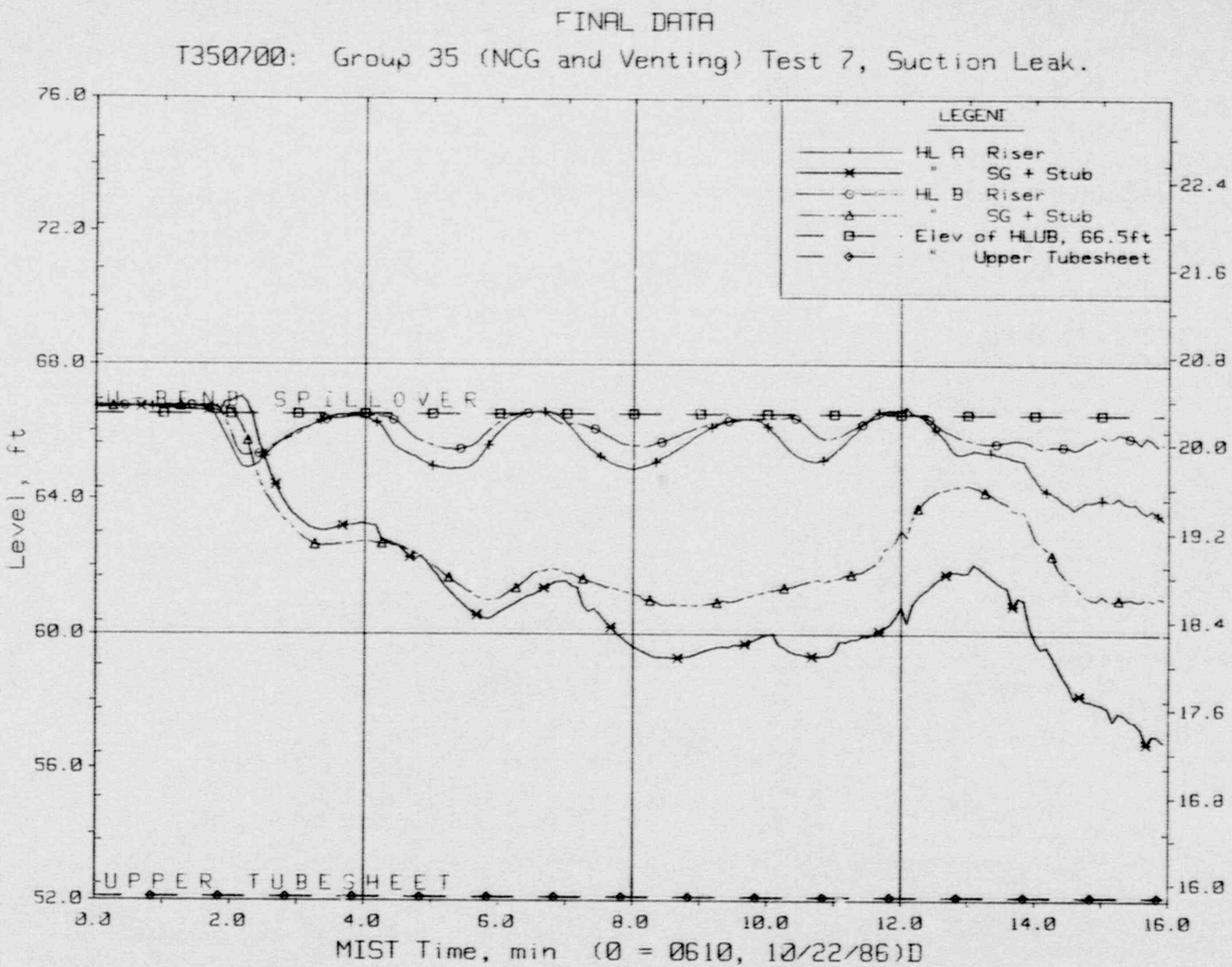

Figure 5.4.6 Hot Leg Riser and Stub Collapsed Liquid Levels

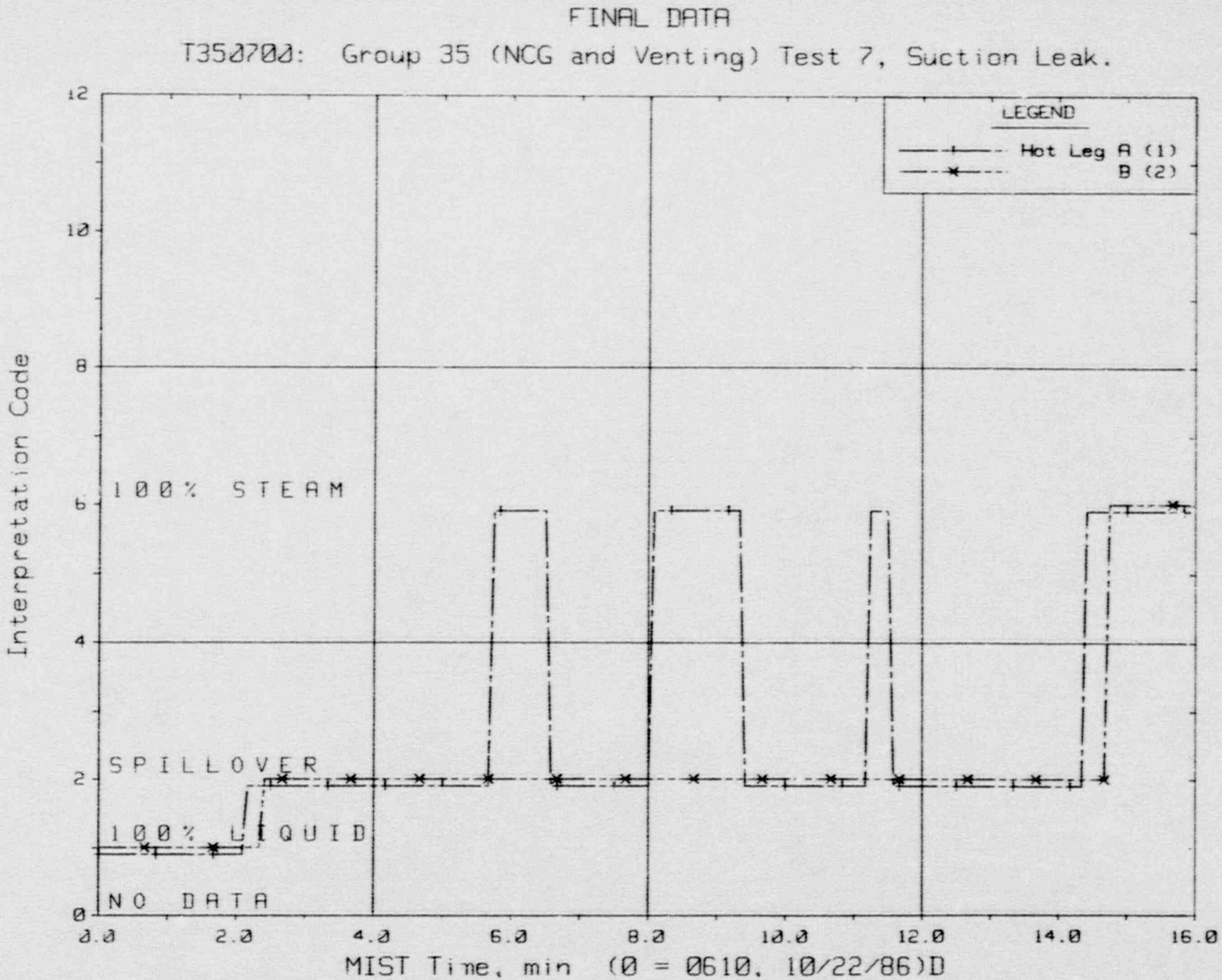

Figure 5.4.7 Hot Leg U-Bend Viewport Indications (HnMS03s)

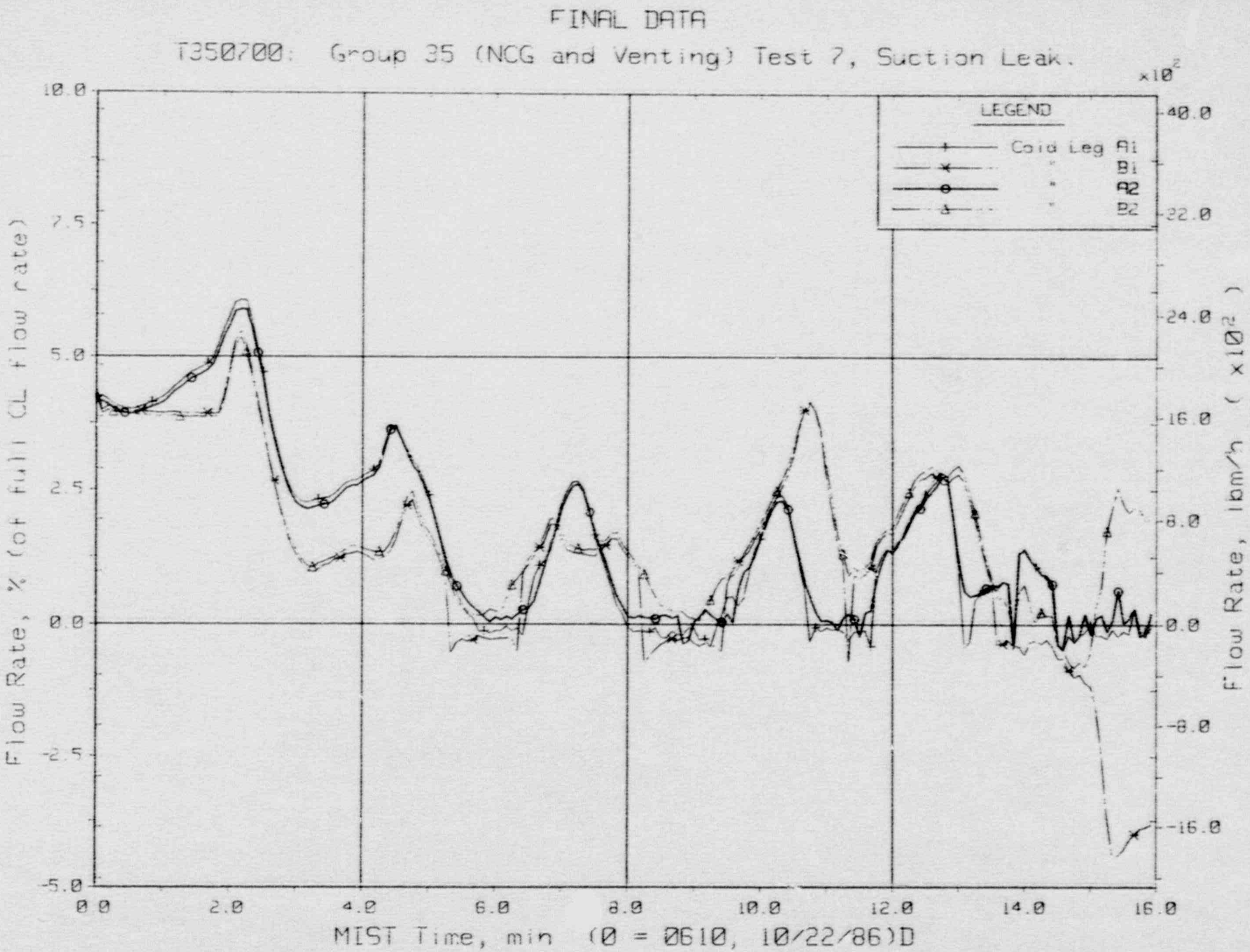

Figure 5.4.8 Cold Leg (Venturi) Flow Rates

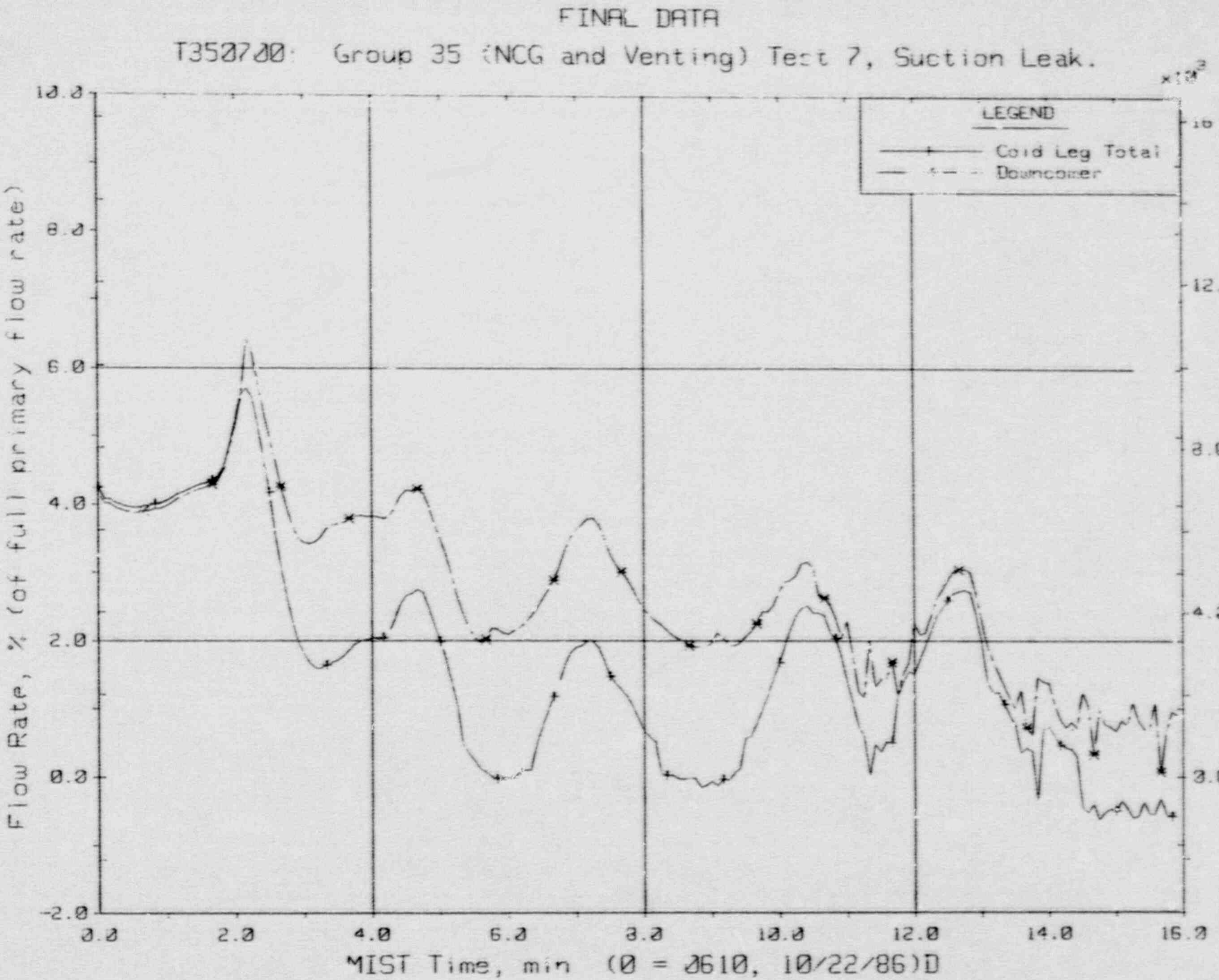

Figure 5.4.9 Primary System Venturi Flow Rates

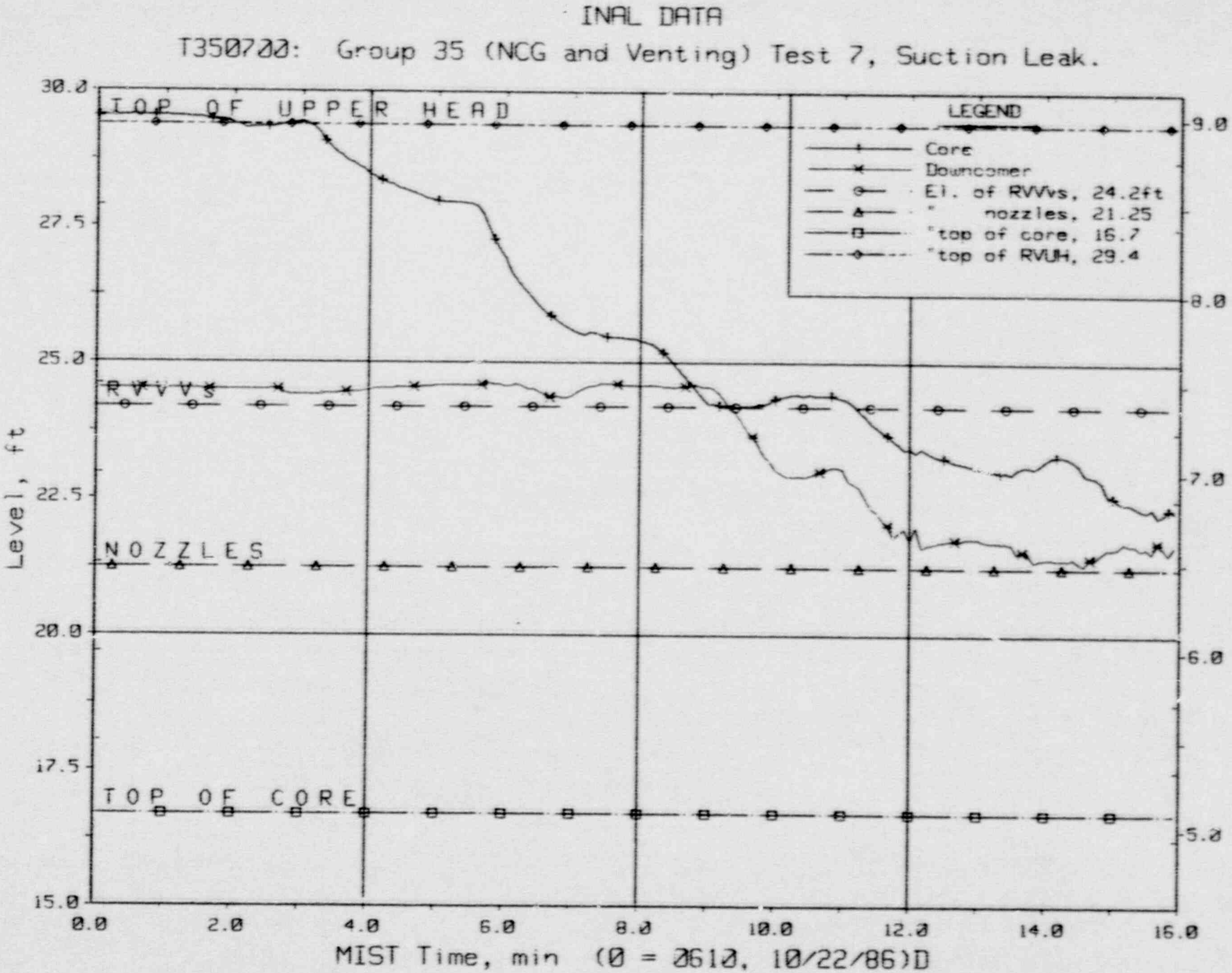

Figure 5.4.10 Core Region Collapsed Liquid Levels

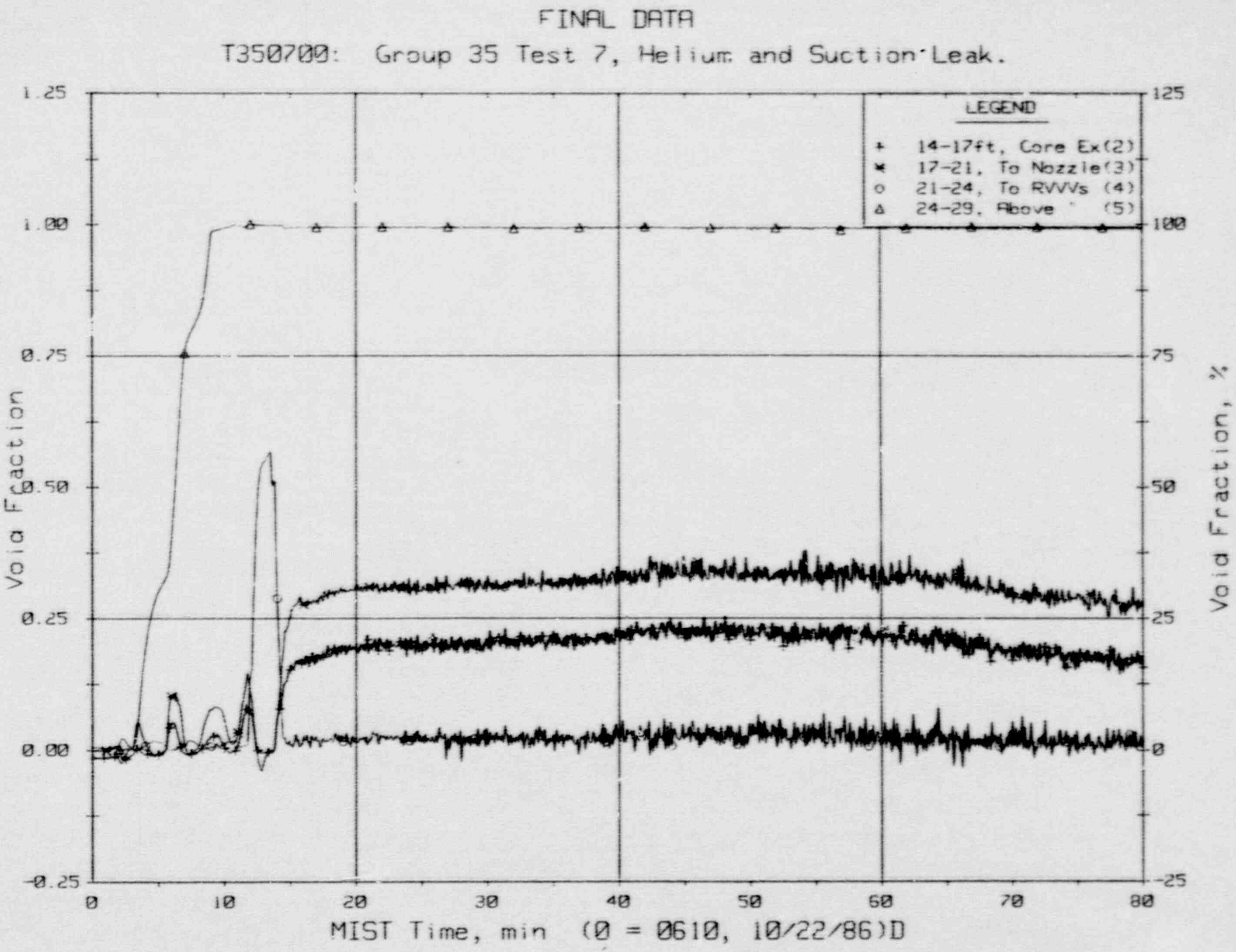

Figure 5.4.11 Reactor Vessel Void Fractions from Differential Pressures (RVVFs)

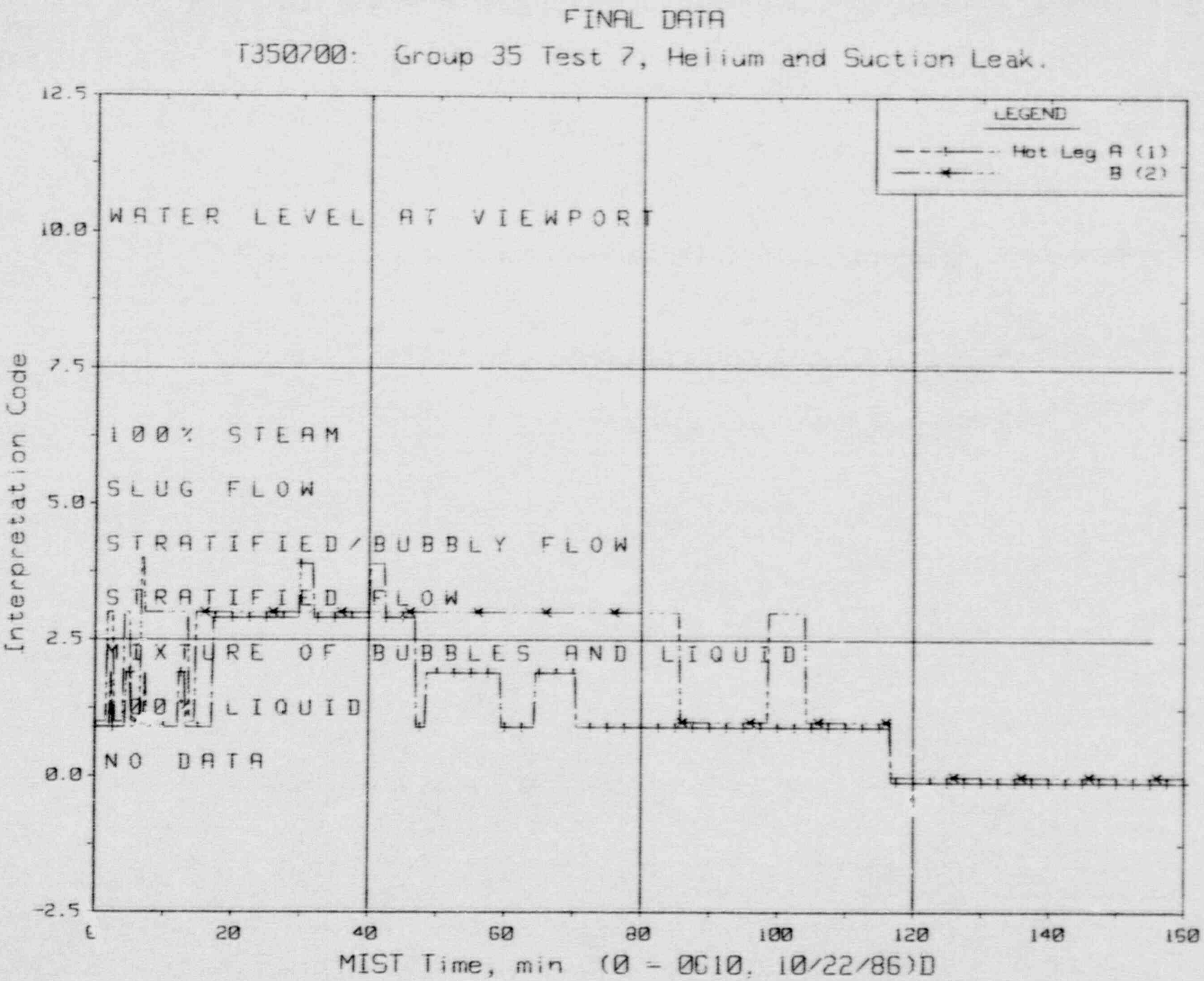

Figure 5.4.12 Hot Leg Horizontal Viewport Indications (HnMSOls)

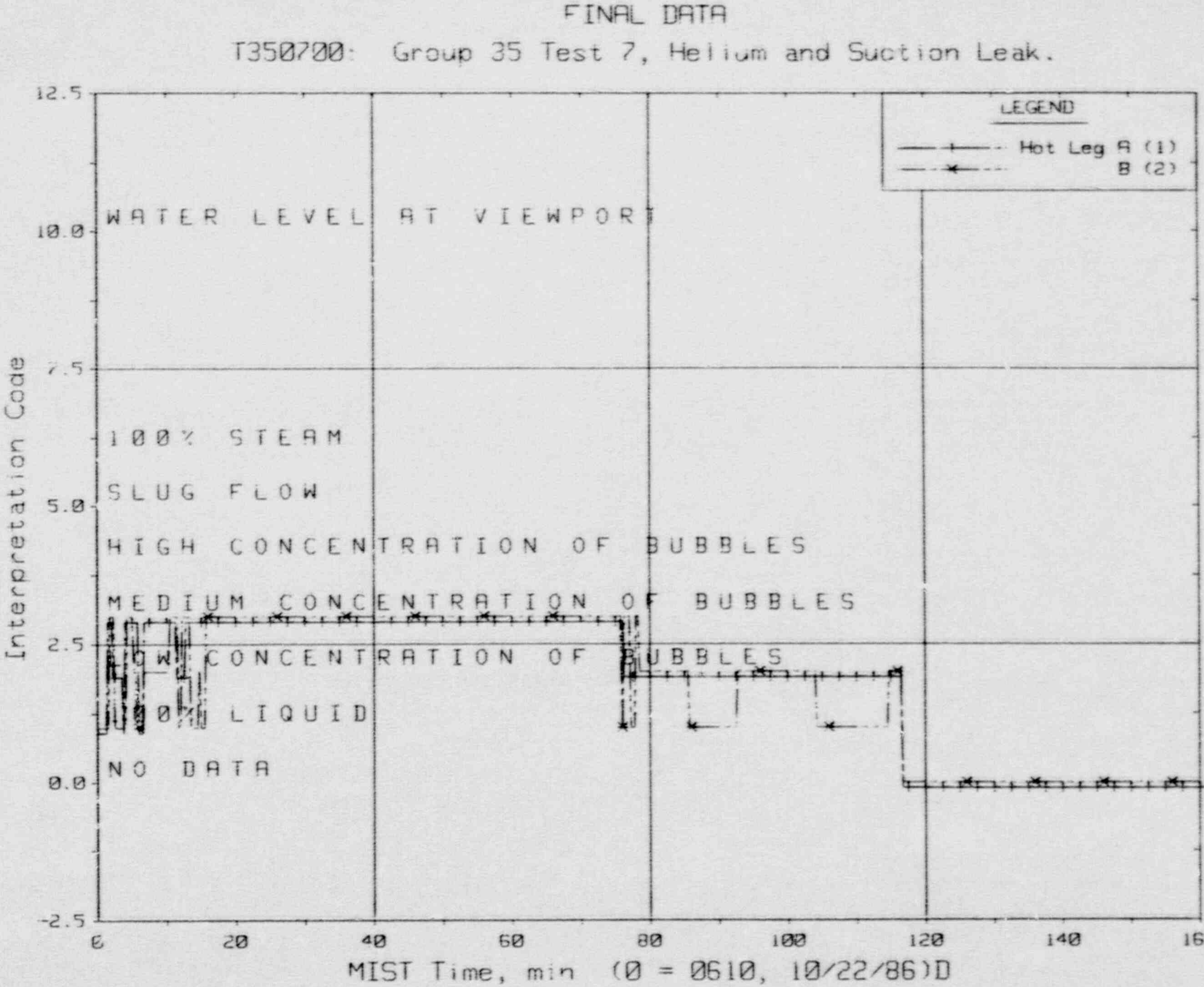

Figure 5.4.13 Hot Leg Riser Viewport Indications (HnMS02s)

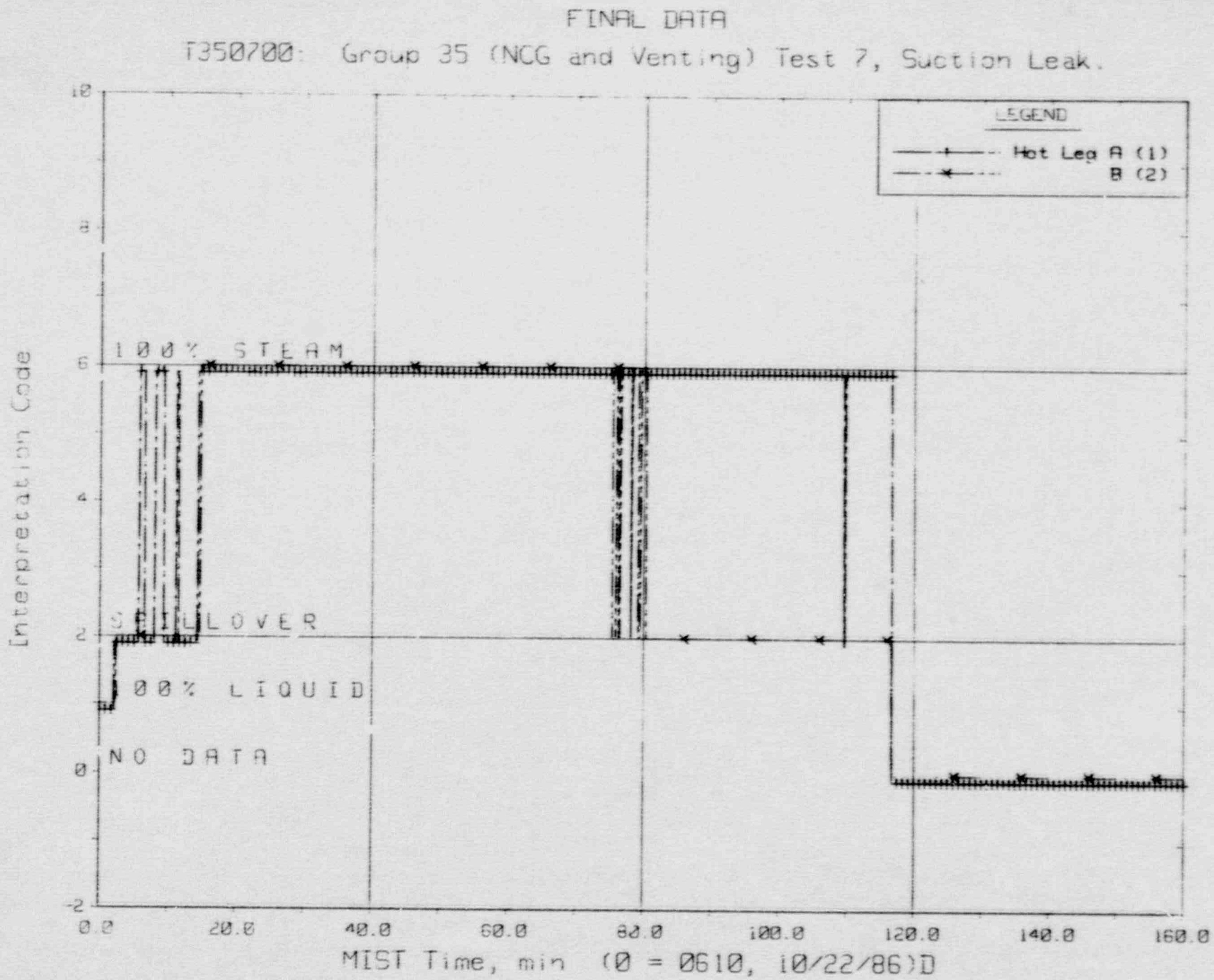

Figure 5.4.14 Hot Leg U-Bend Viewport Indications (HnMS03s)

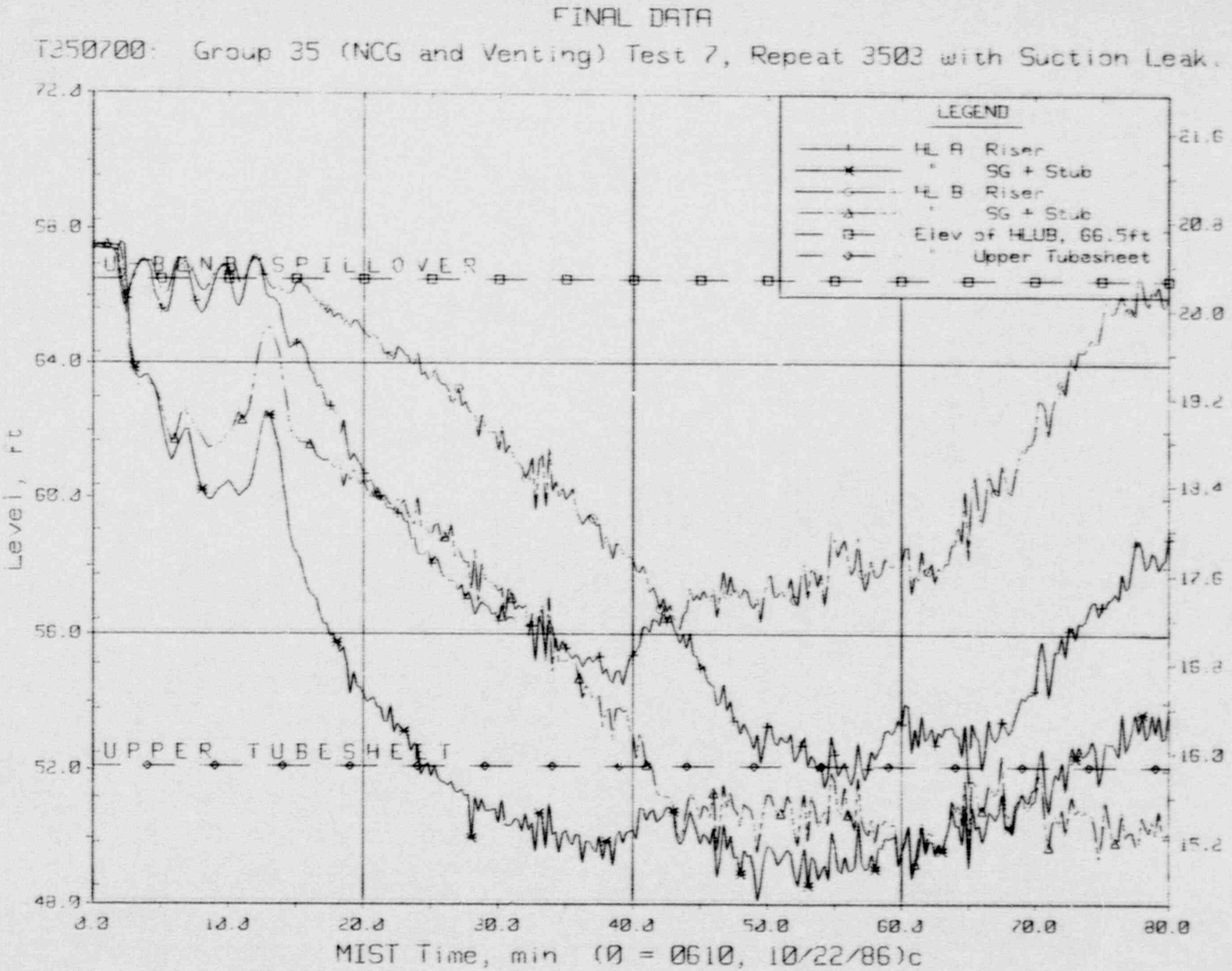

Figure 5.4.15 Hot Leg Riser and Stub Collapsed Liquid Levels

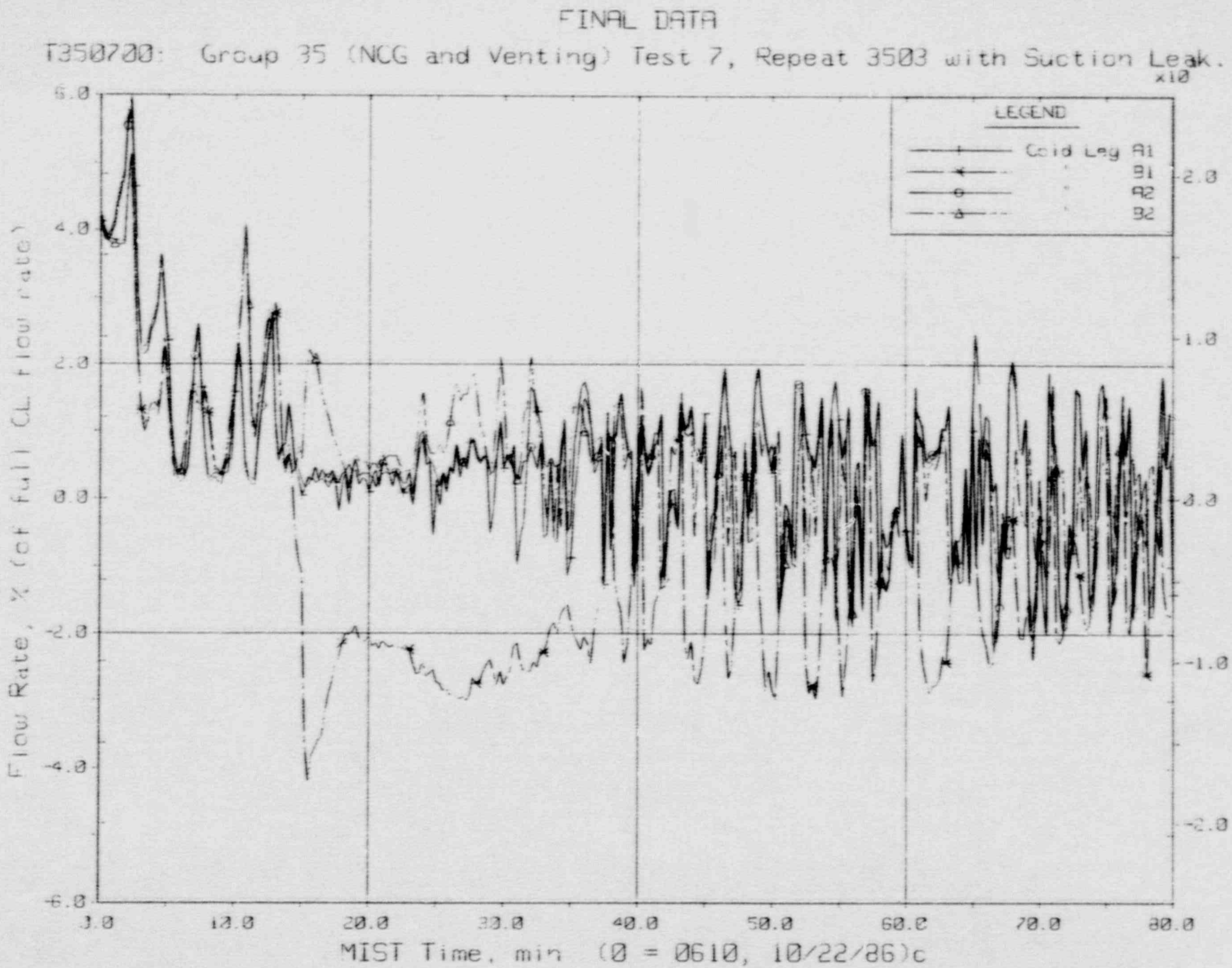

Figure 5.4.16 Cold Leg (Venturi) Flow Rates

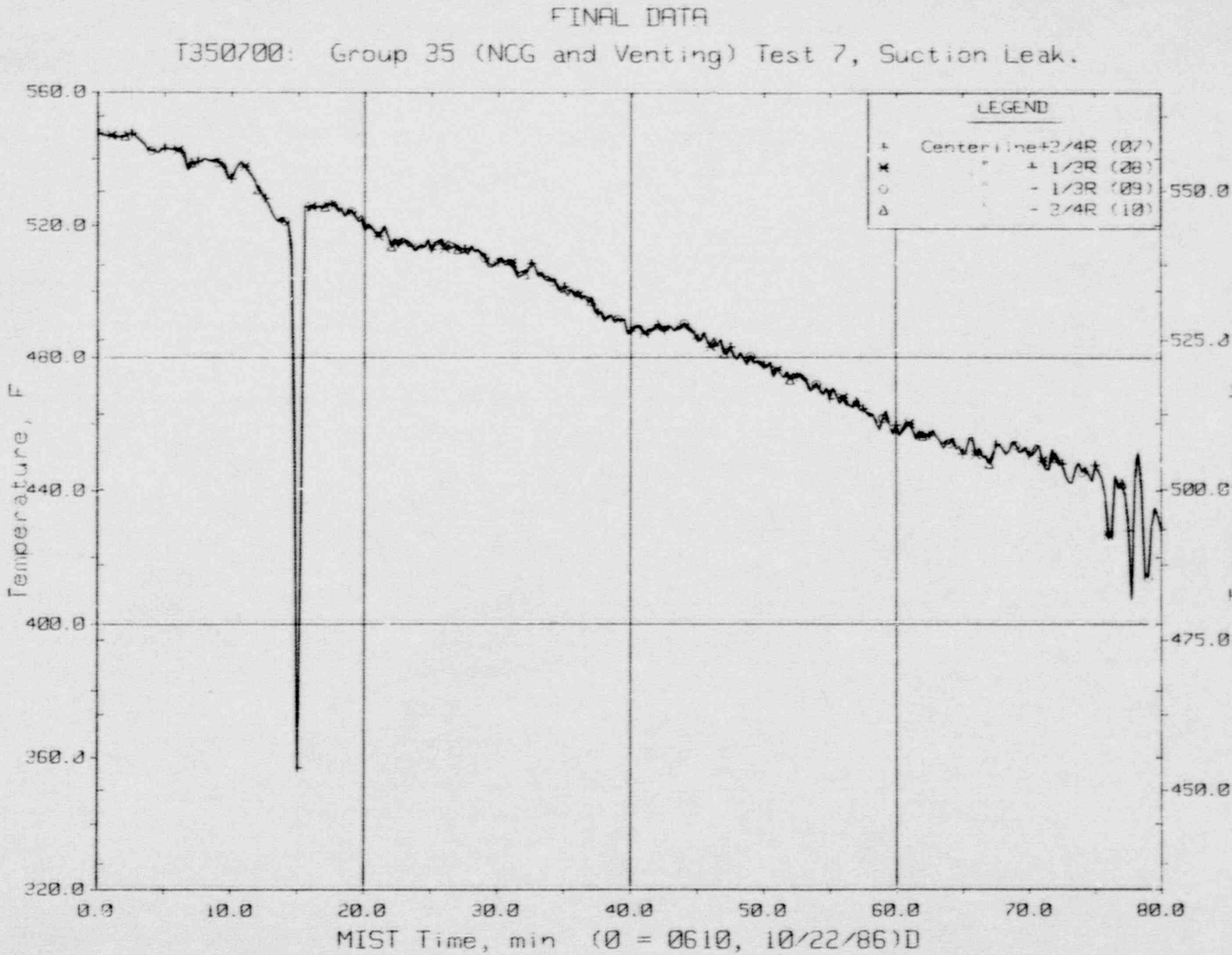

Figure 5.4.17 Cold Leg B1 Pump Discharge Rake Fluid Temperatures (25 ft, C2TCs)

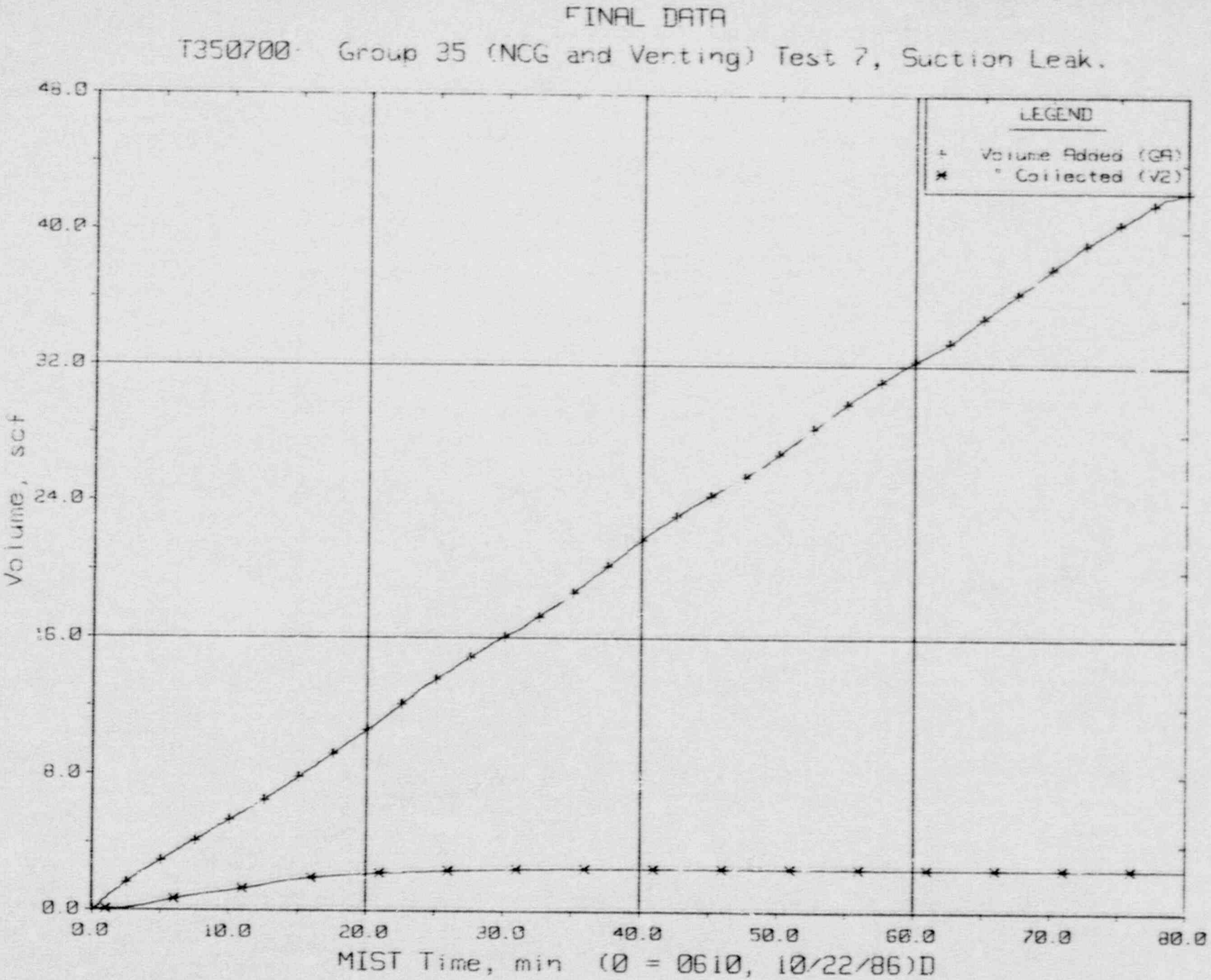

Figure 5.4.18 Noncondensibles Gas Volumes

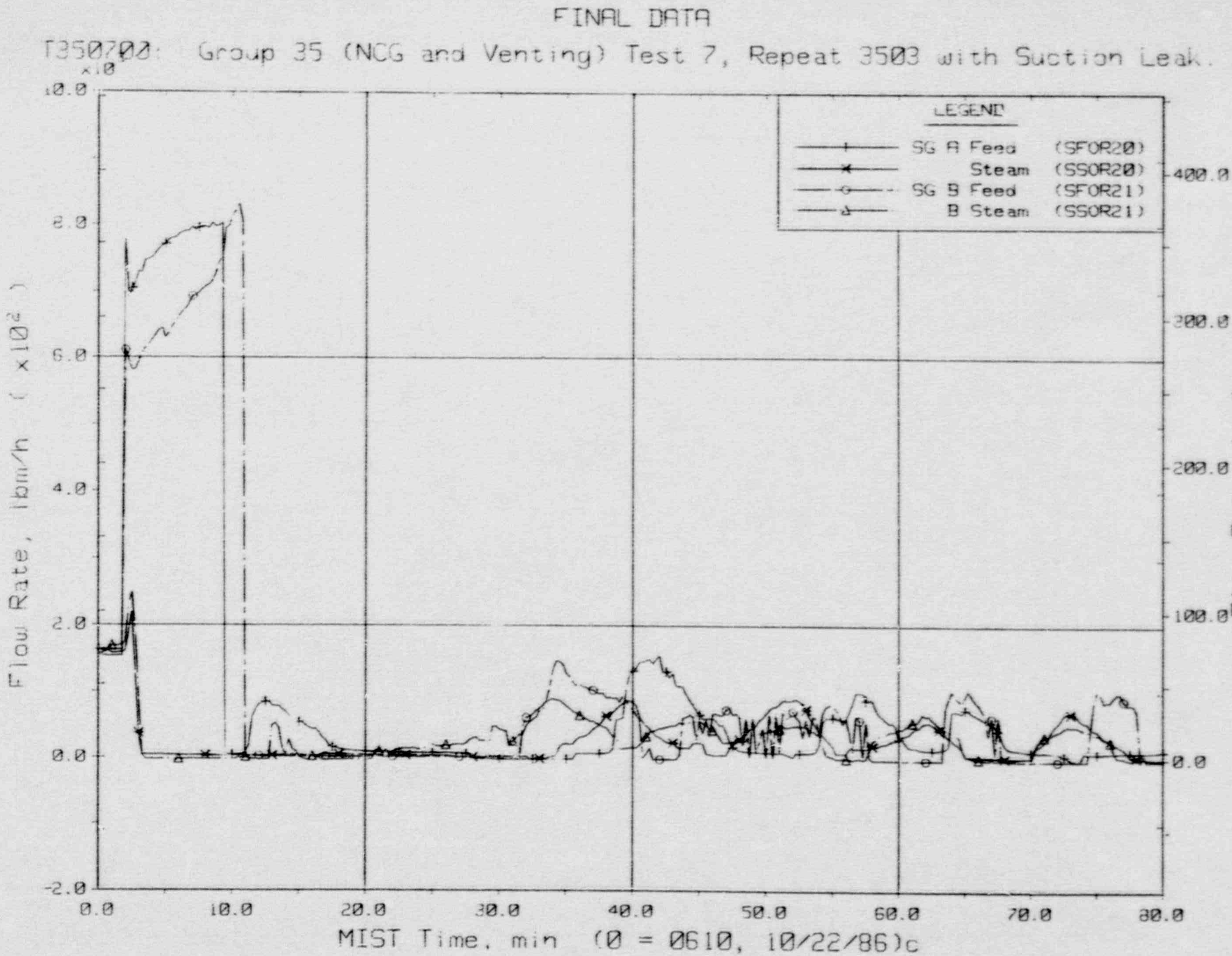

Figure 5.4.19 Steam Generator Secondary Flow Rates

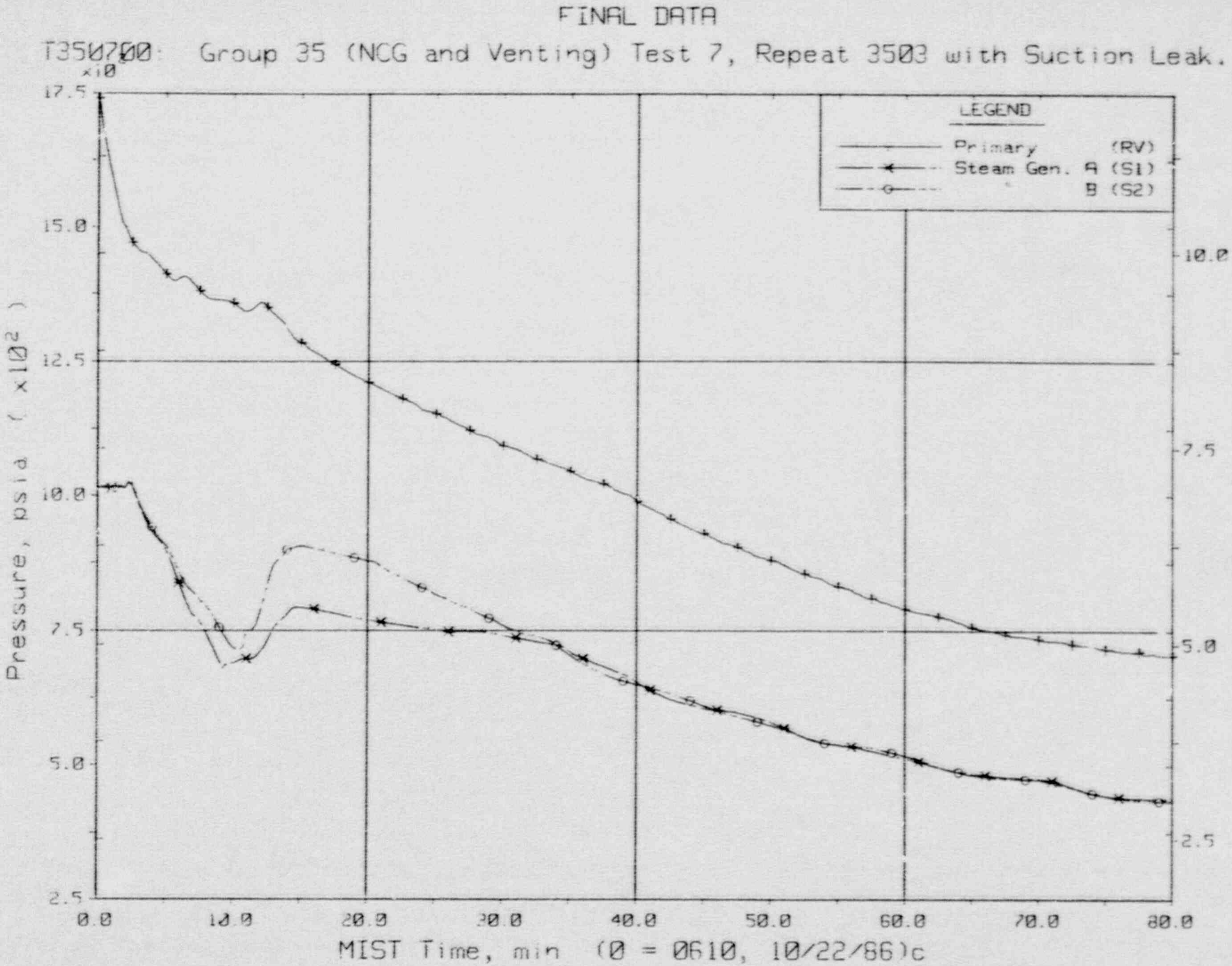

Figure 5.4.20 Primary and Secondary System Pressures (GP01s)

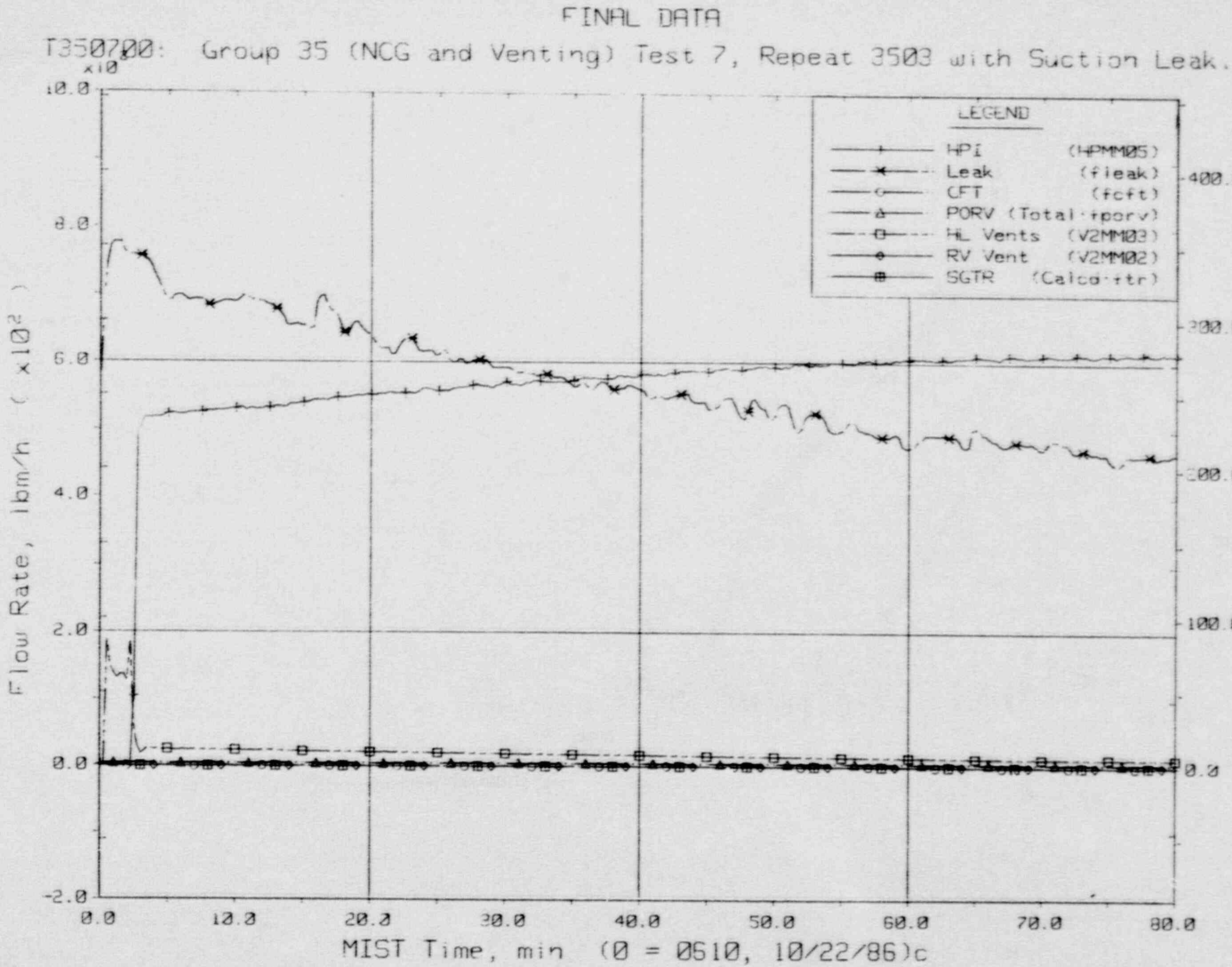

Figure 5.4.21 Primary System Boundary Flow Rates

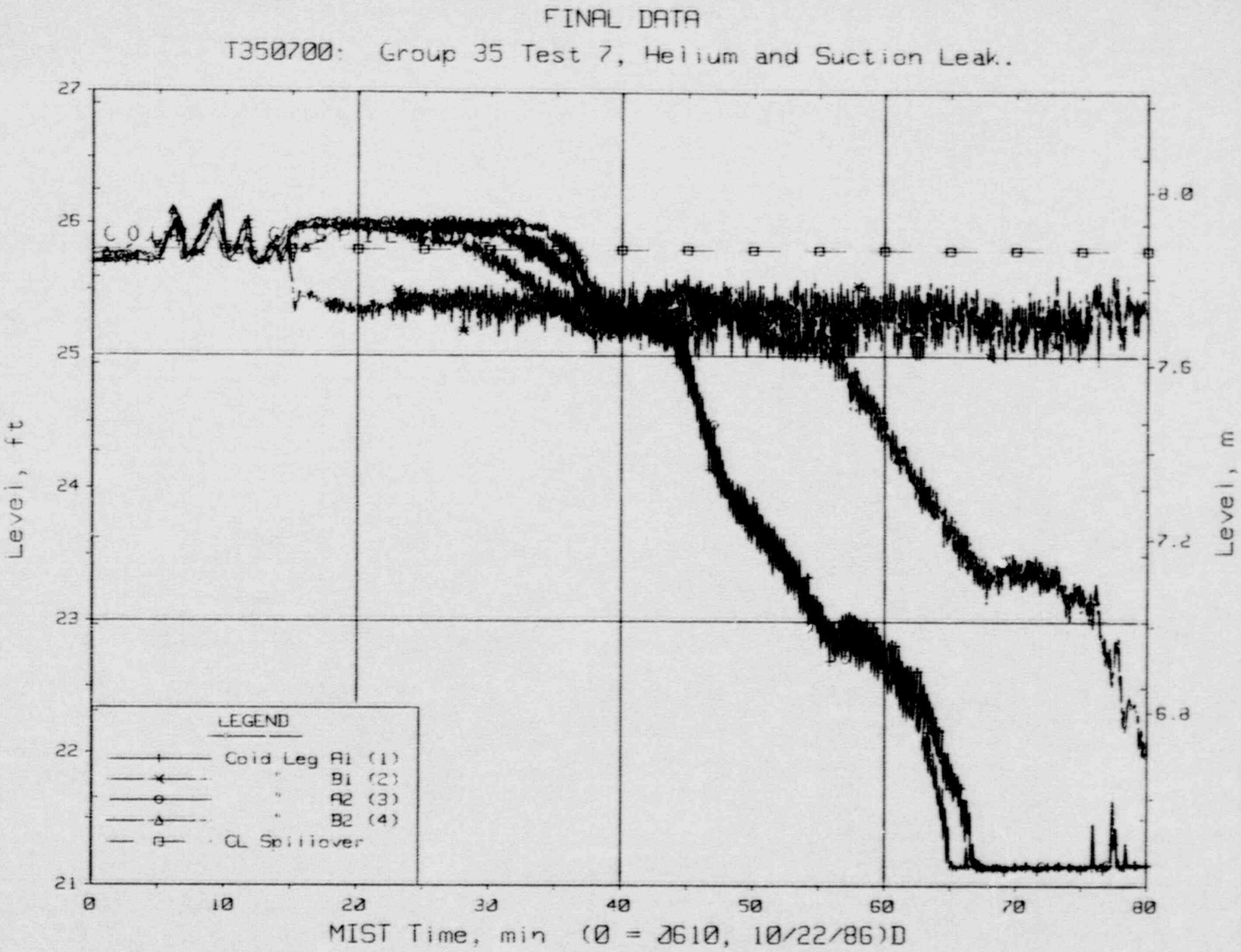

Figure 5.4.22 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

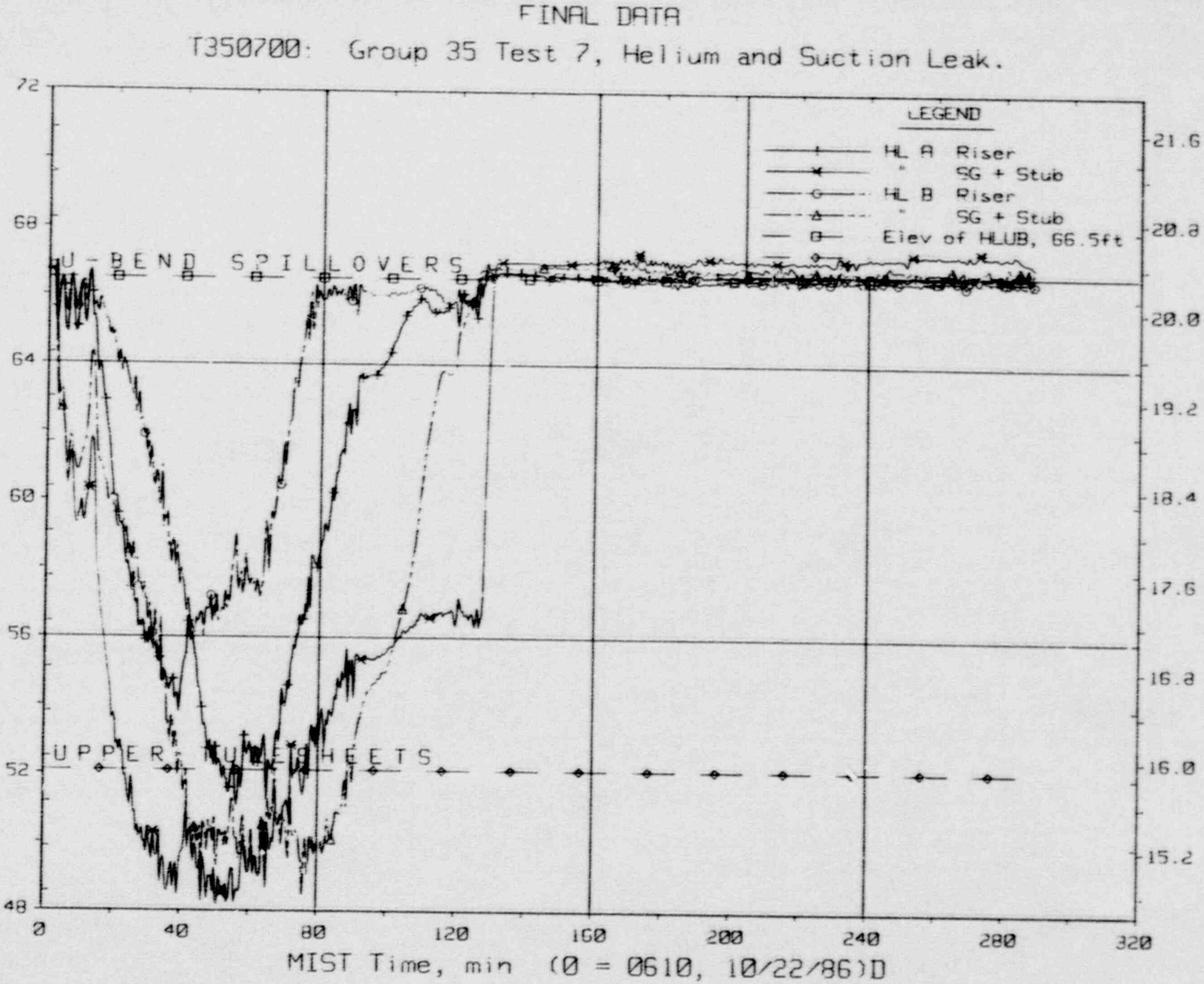

Figure 5.4.23 Hot Leg Riser and Stub Collapsed Liquid Levels

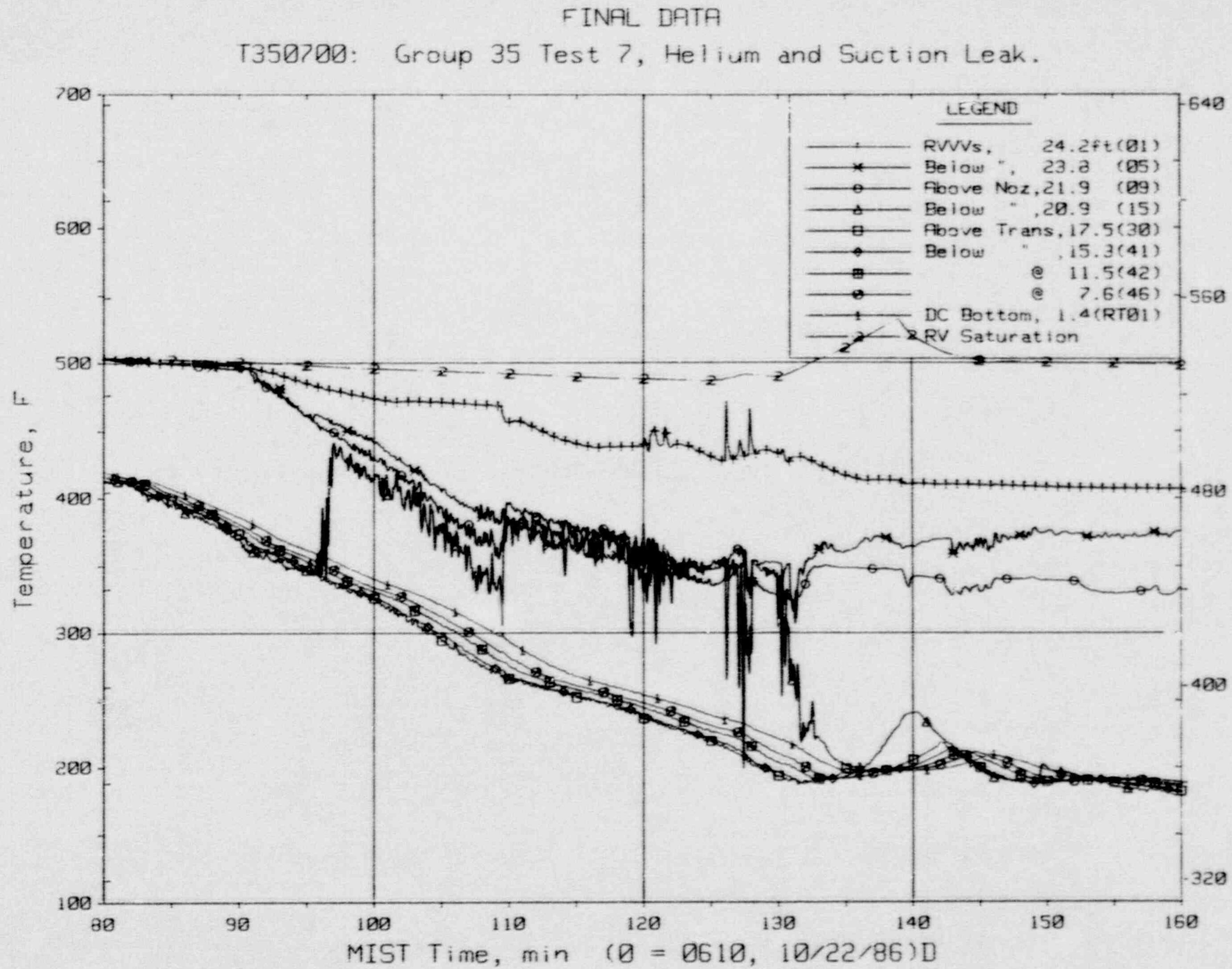

Figure 5.4.24 Downcomer Quadrant A1 Fluid Temperatures (DCTCs)

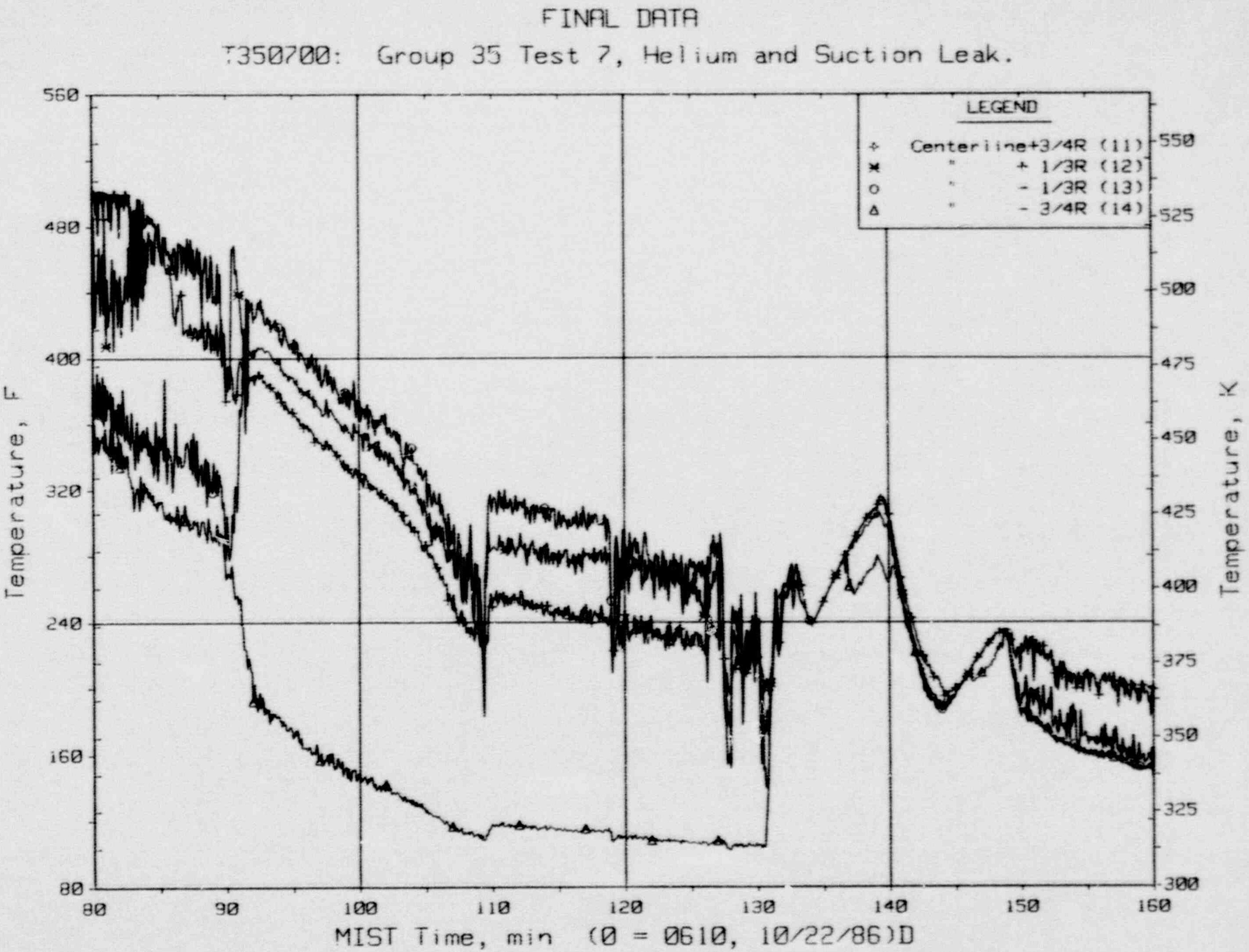

Figure 5.4.25 Cold Leg A1 Nozzle Rake Fluid Temperatures (21.2 ft, C1TCs)

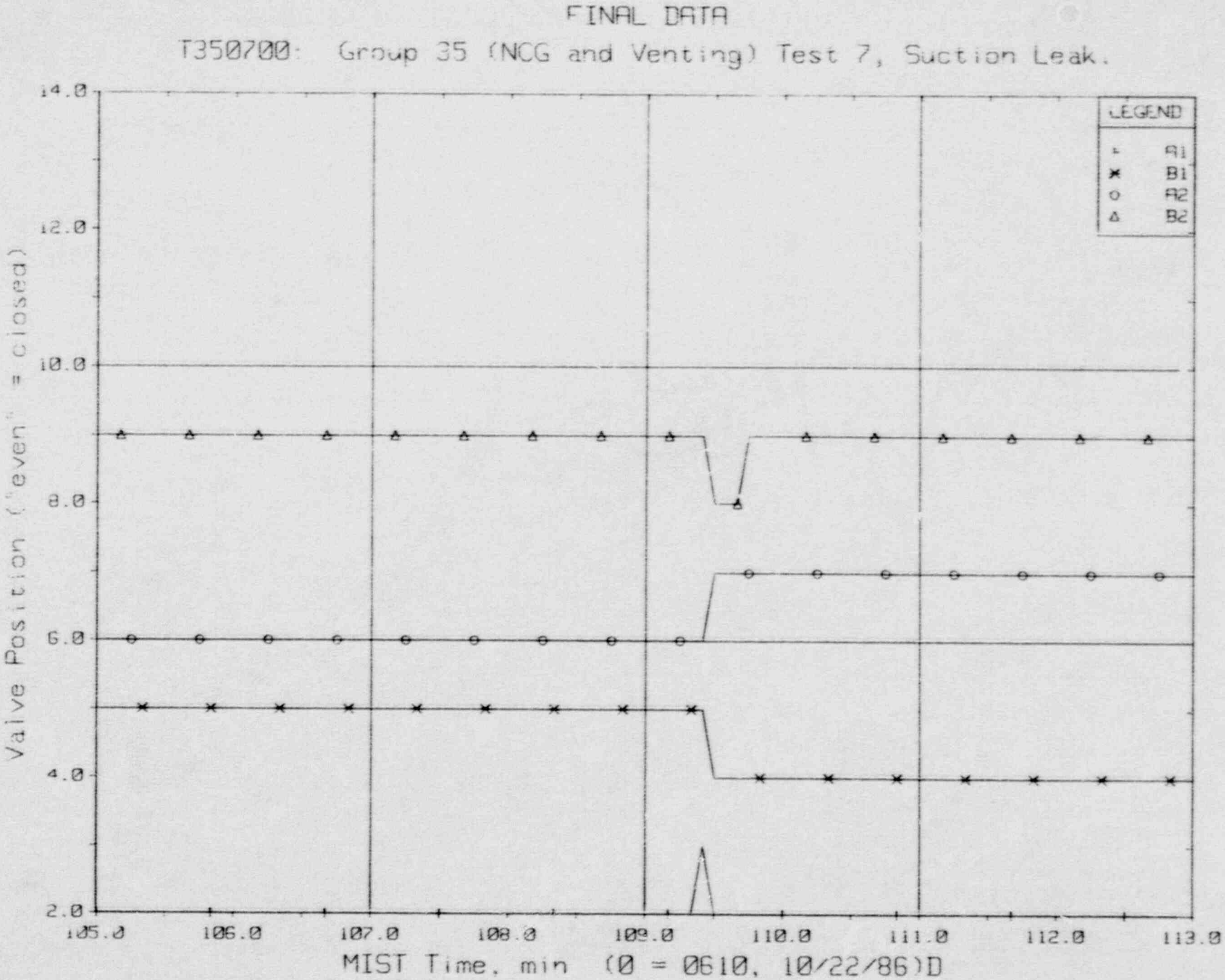

Figure 5.4.26 Reactor Vessel Vent Valve Positions

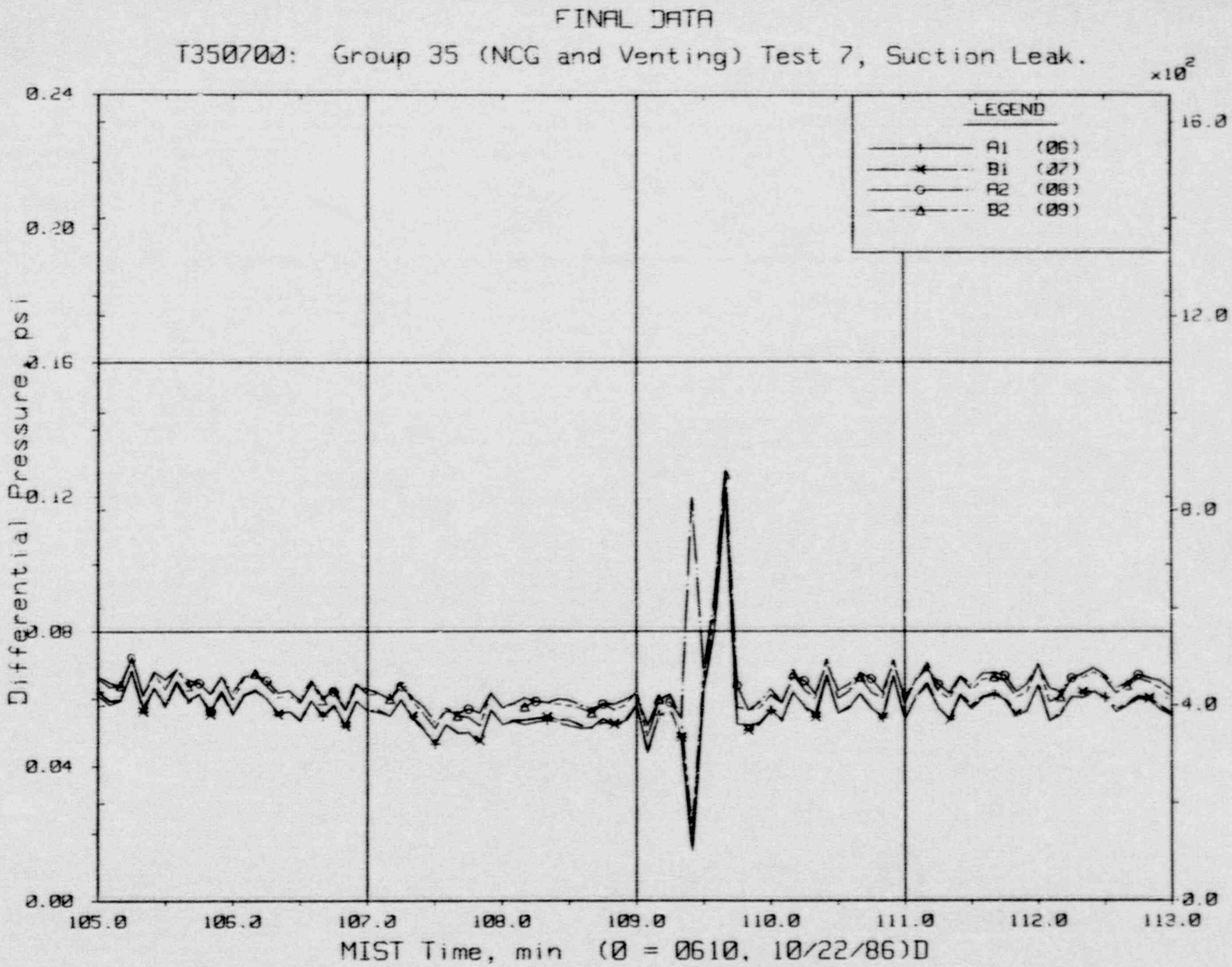

Figure 5.4.27 Reactor Vessel Vent Valve Differential Pressures (RVDPs)

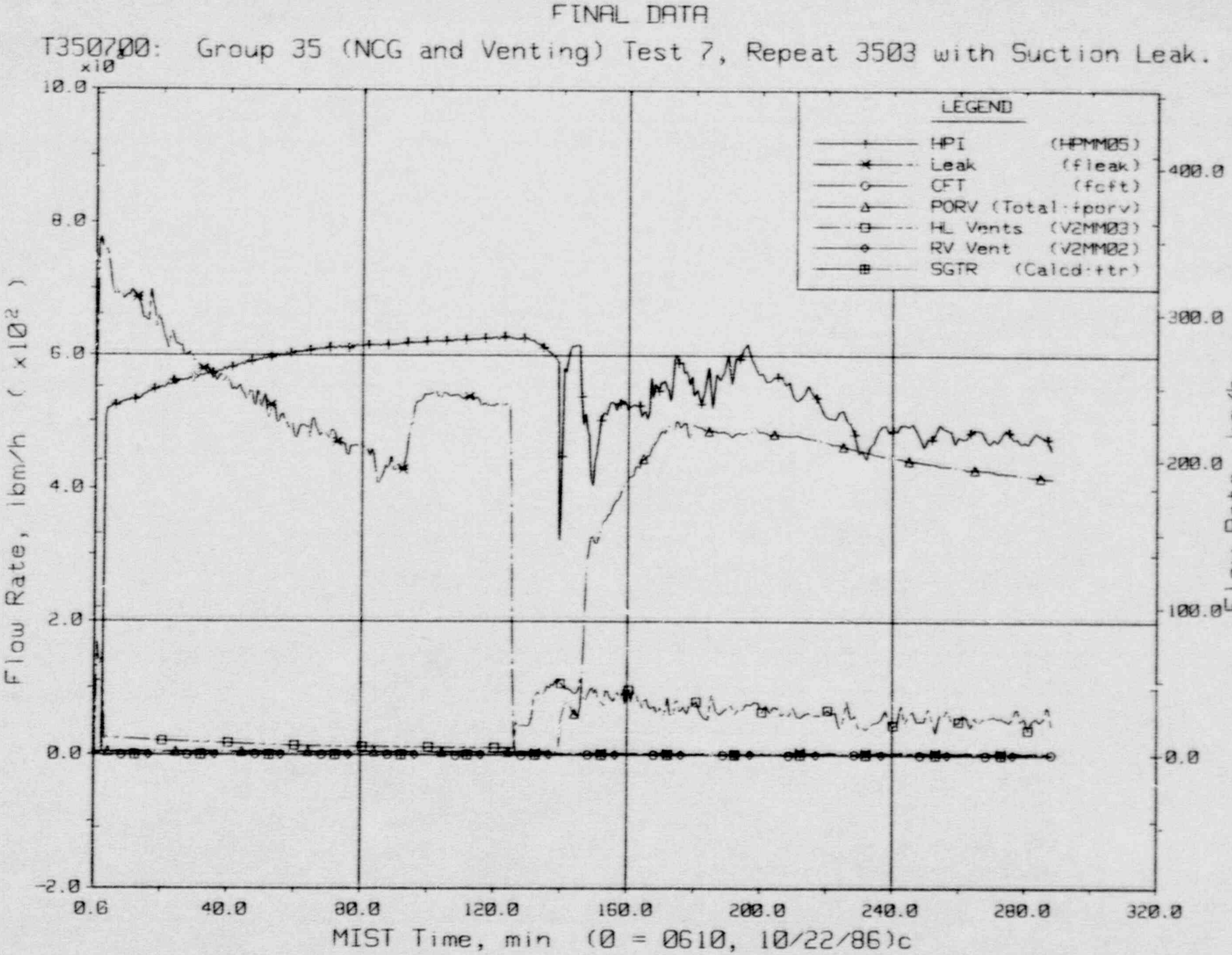

Figure 5.4.28 Primary System Boundary Flow Rates

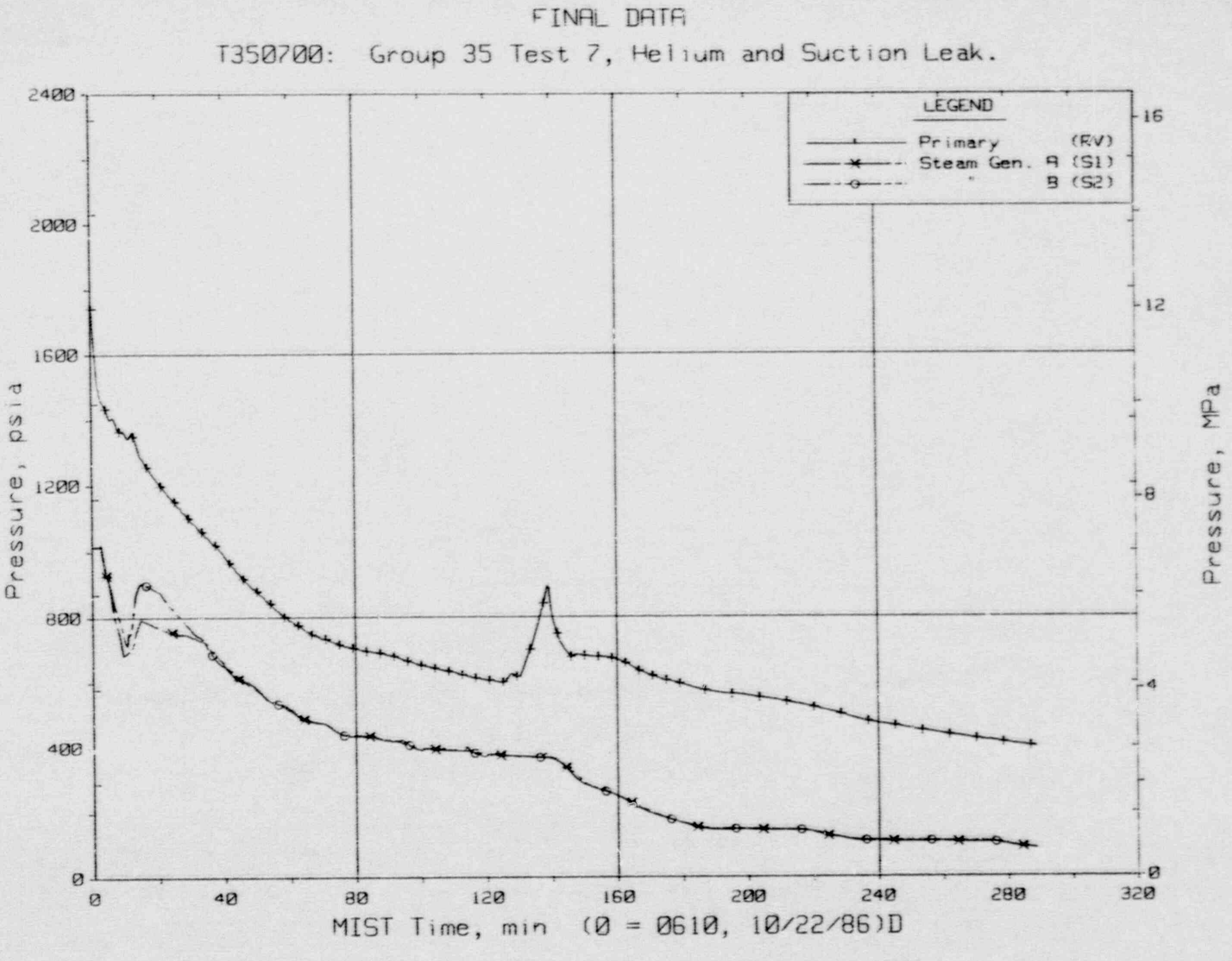

Figure 5.4.29 Primary and Secondary System Pressures (GP01s)

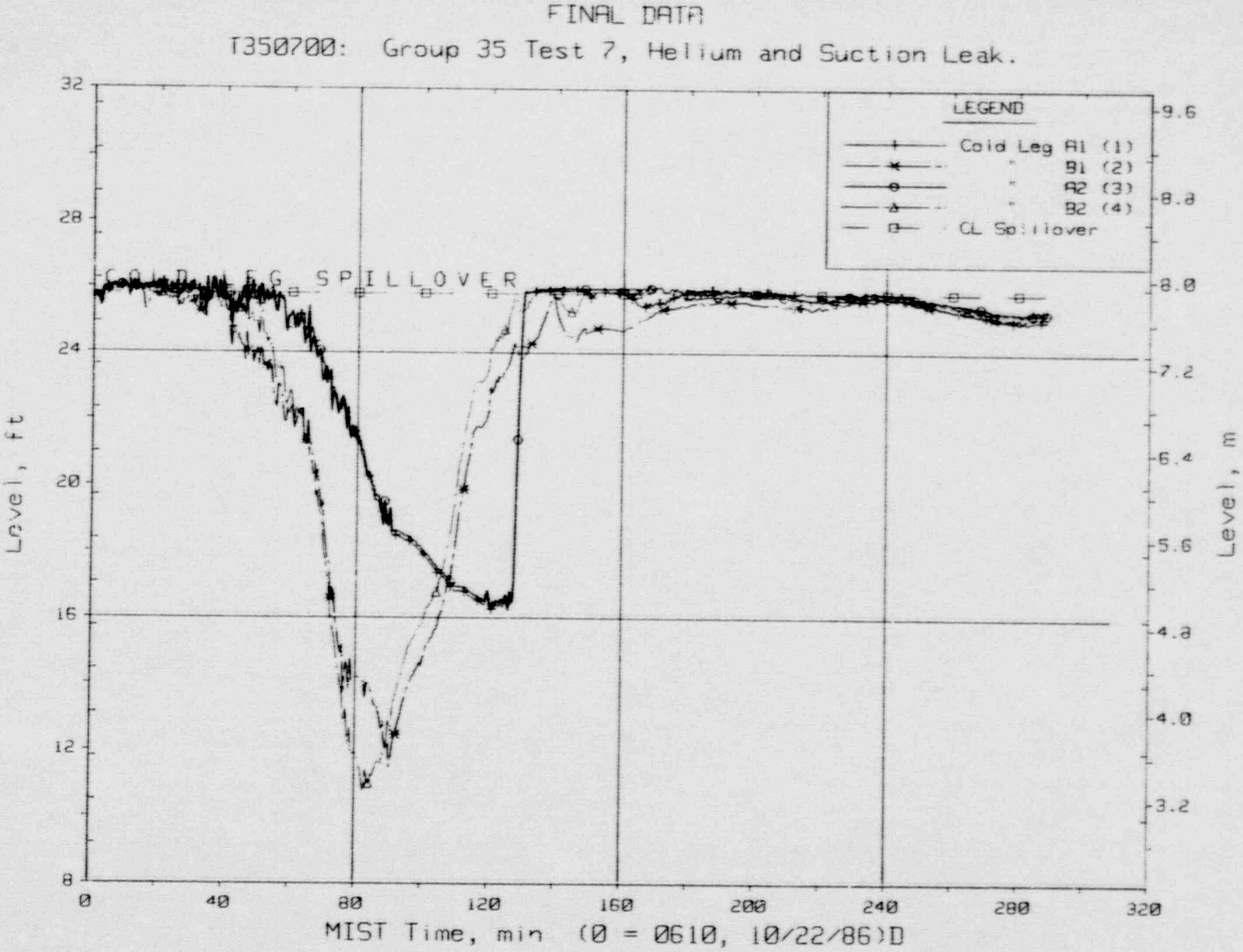

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Figure 5.4.30 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

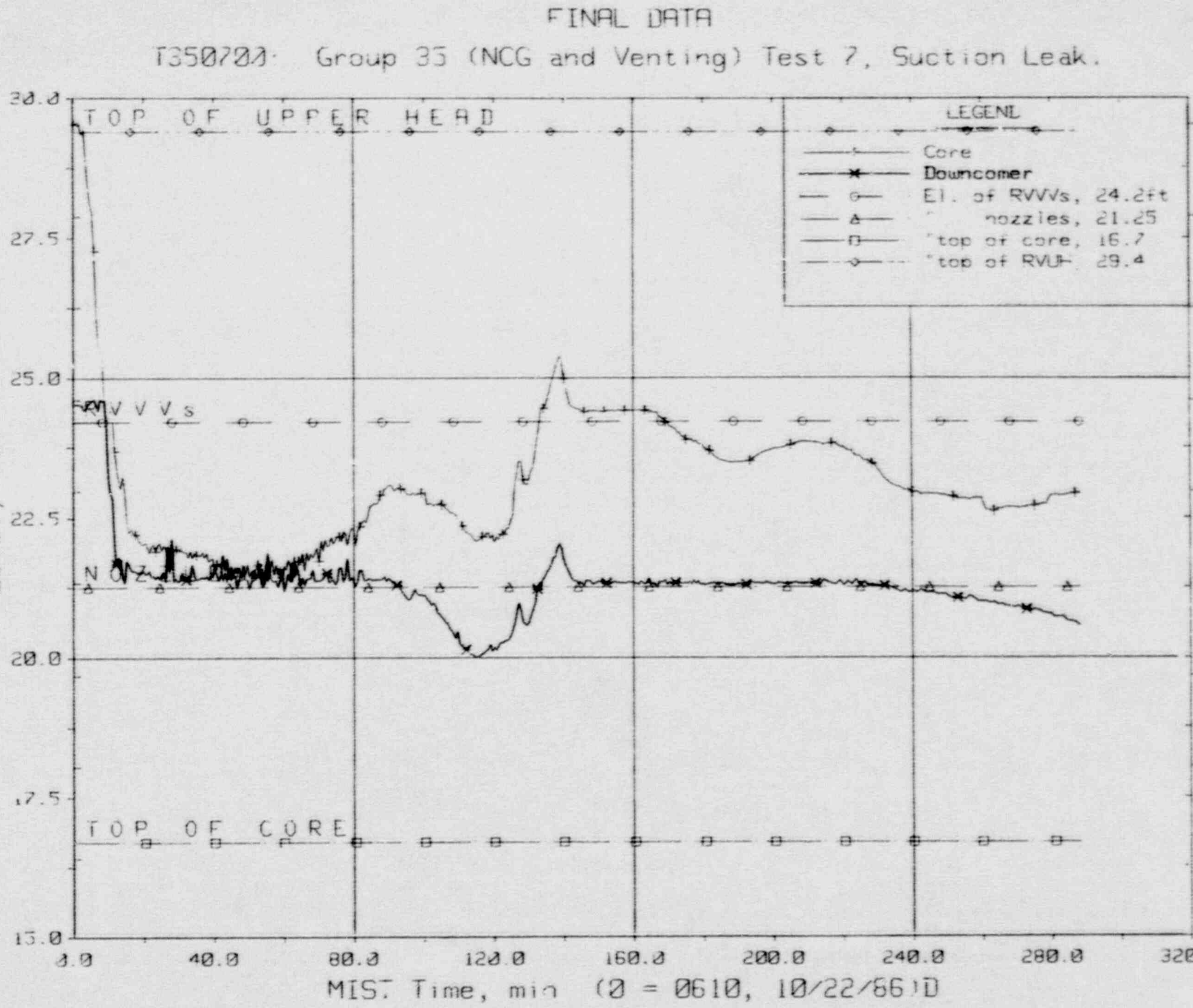

Figure 5.4.31 Core Region Collapsed Liquid Levels

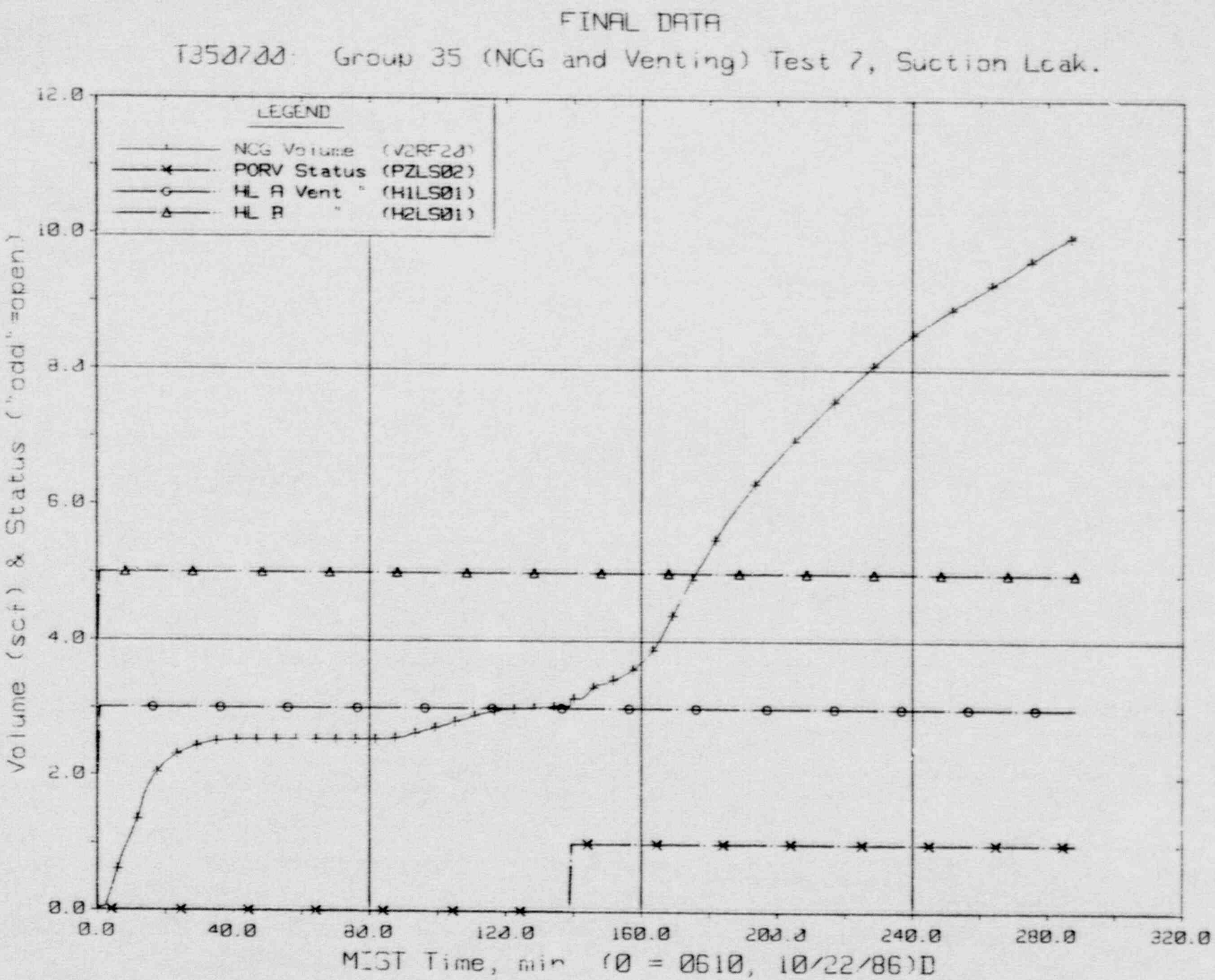

Figure 5.4.32 Noncondensibles Collected and Discharge Valve Status

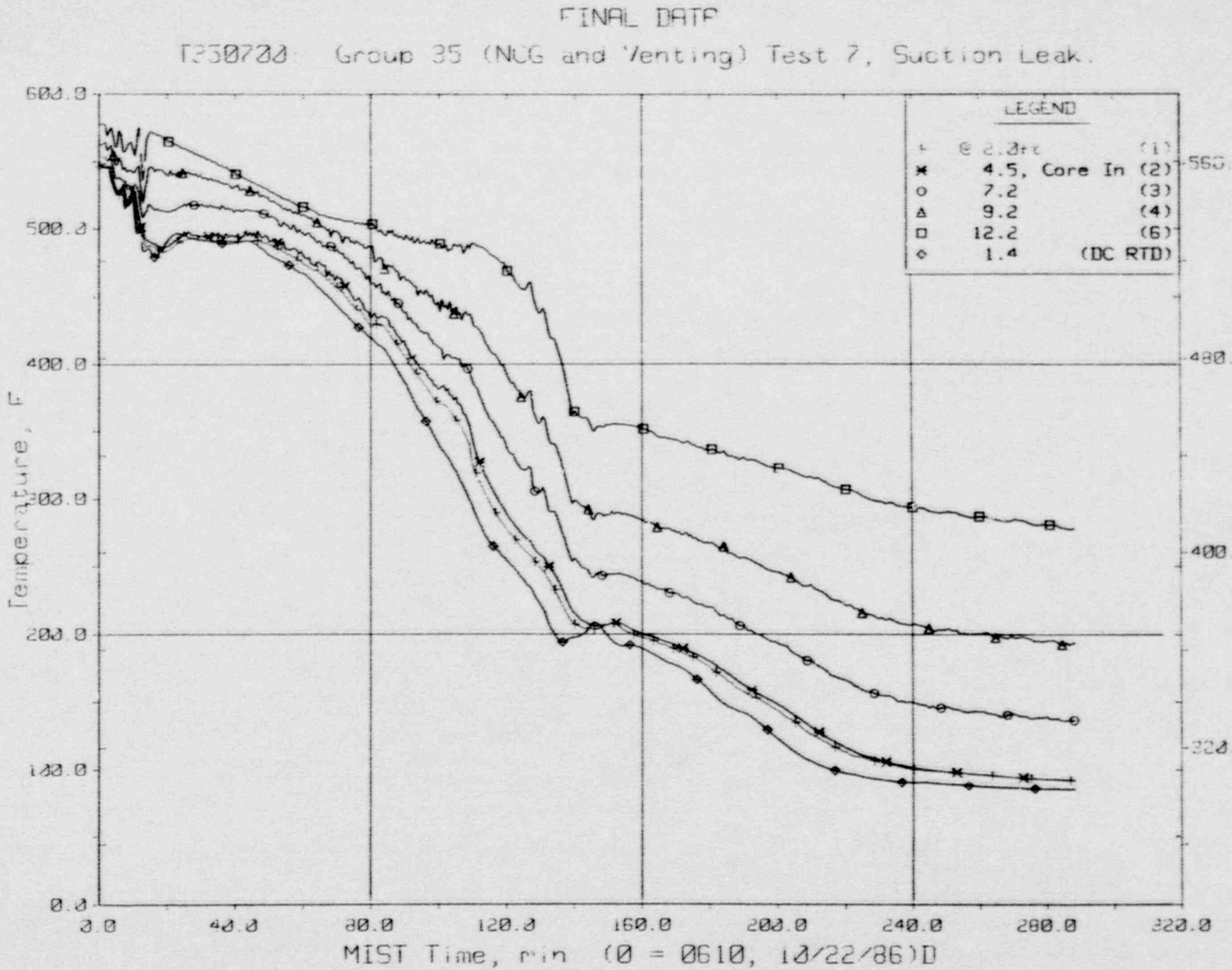

Figure 5.4.33 Reactor Vessel Lower-Elevation Fluid Temperatures (RVTCs)

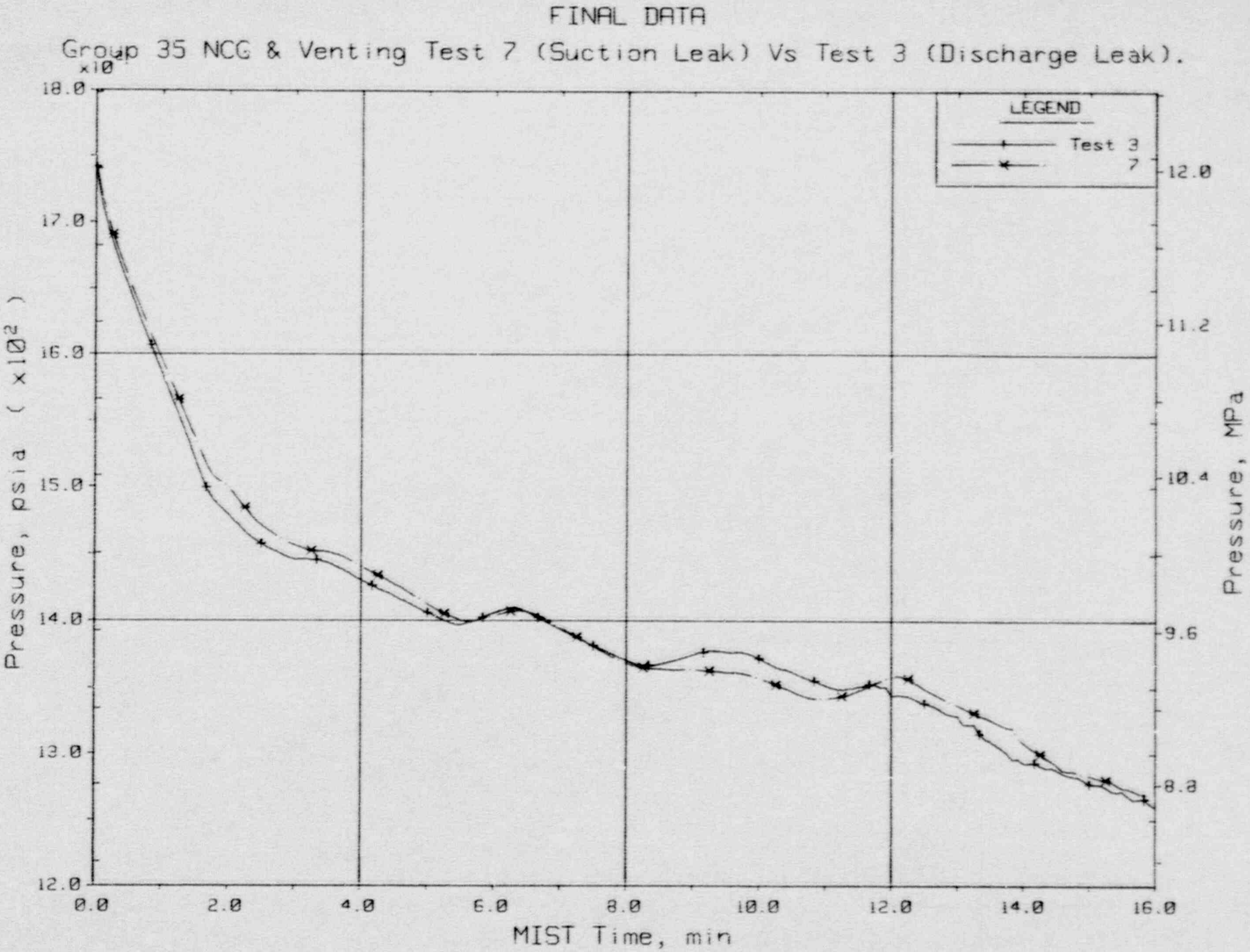

Figure 5.4.34 Primary System Pressure (RVGP01)

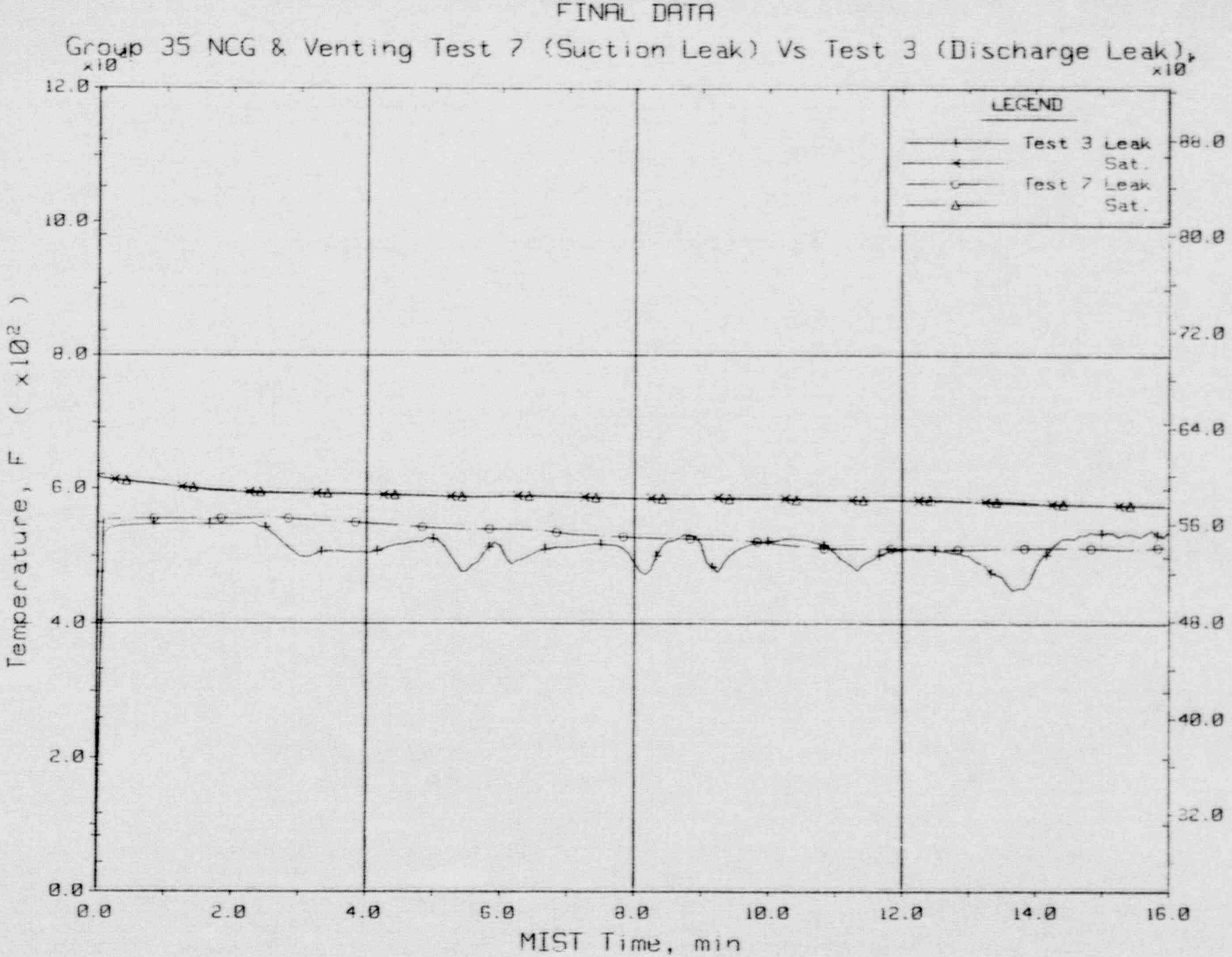

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Figure 5.4.35 Leak and HPI Fluid Temperatures (TC01s)

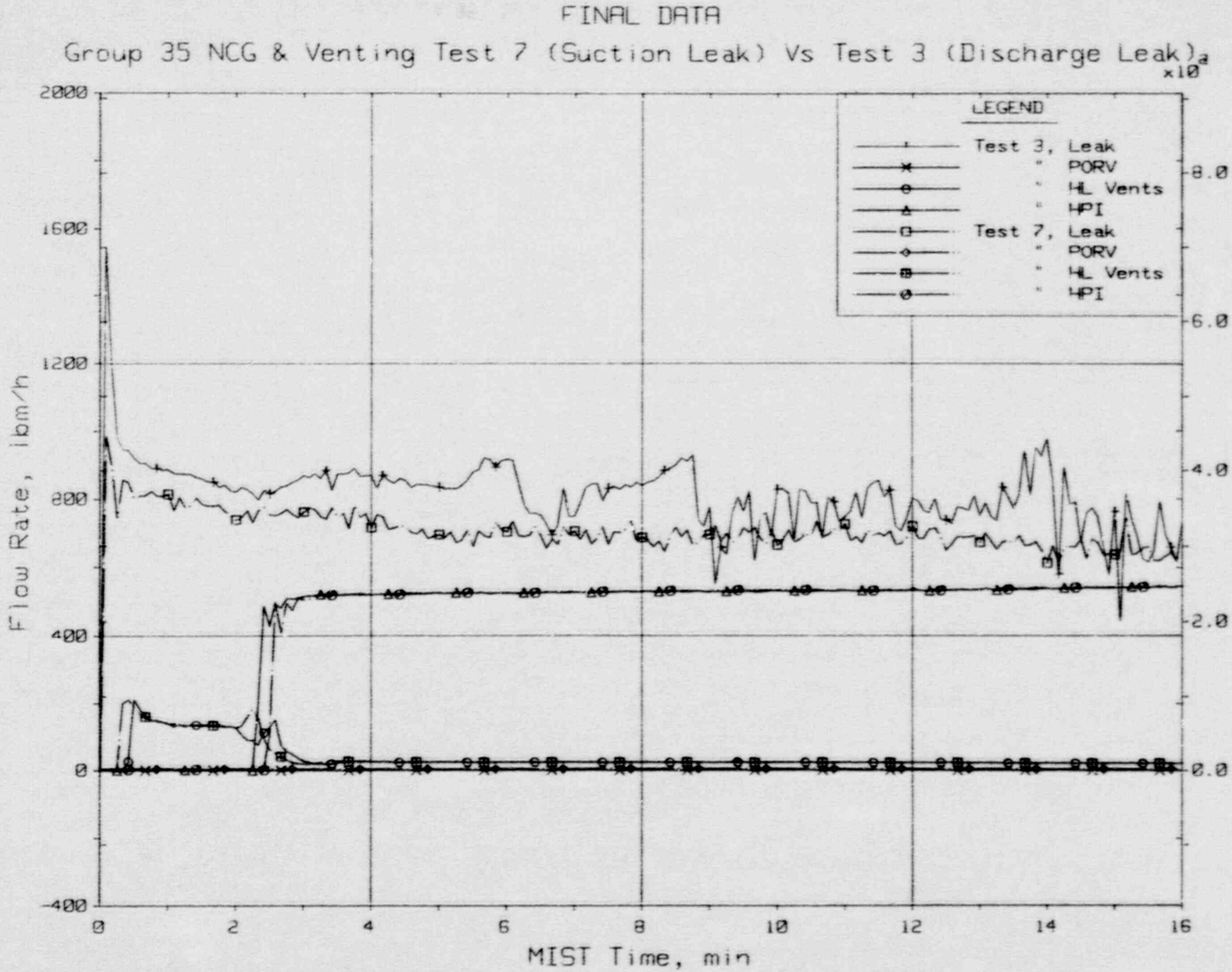

Figure 5.4.36 Primary System Boundary Mass Flow Rates

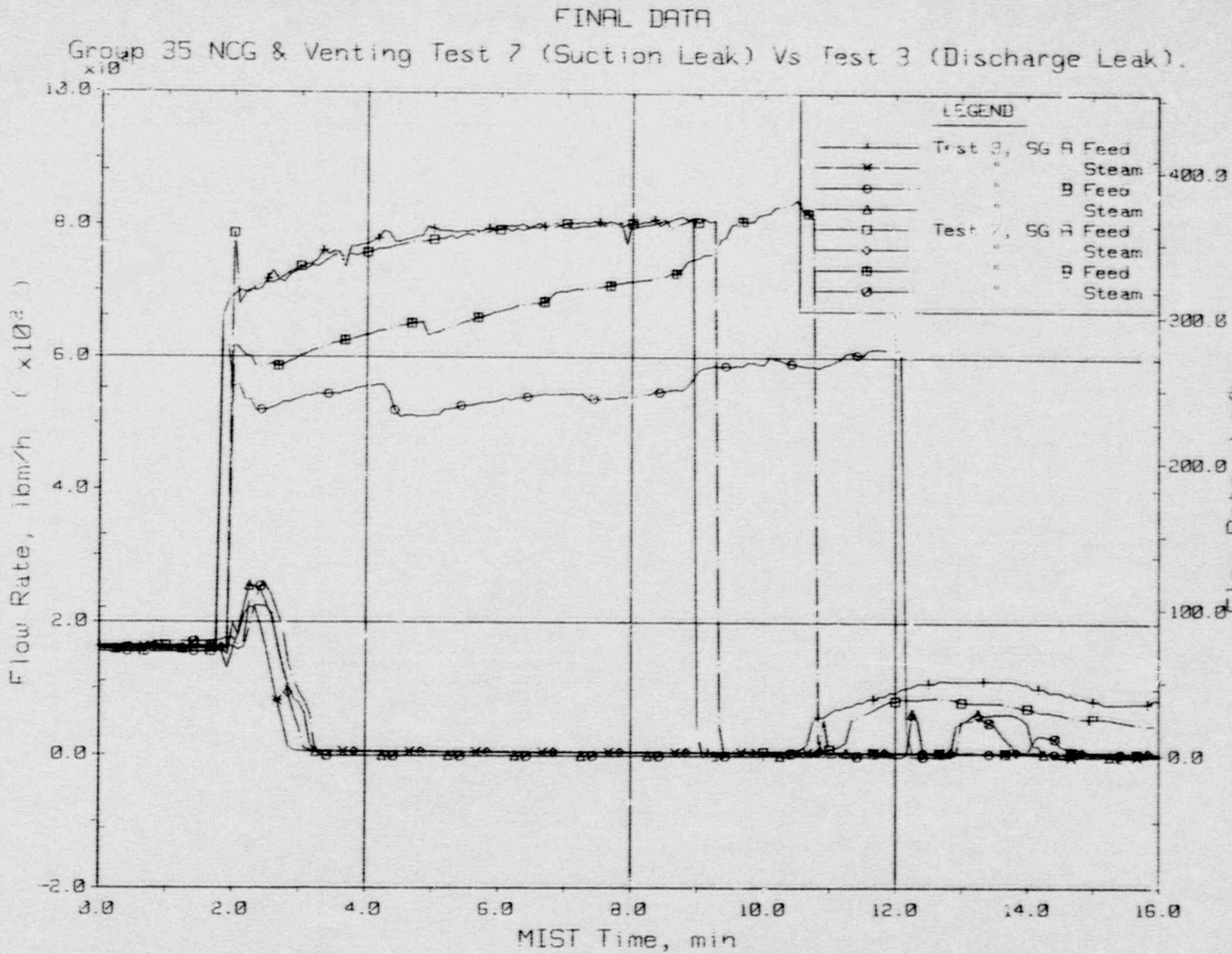

Figure 5.4.37 Steam Generator Secondary Flow Rates

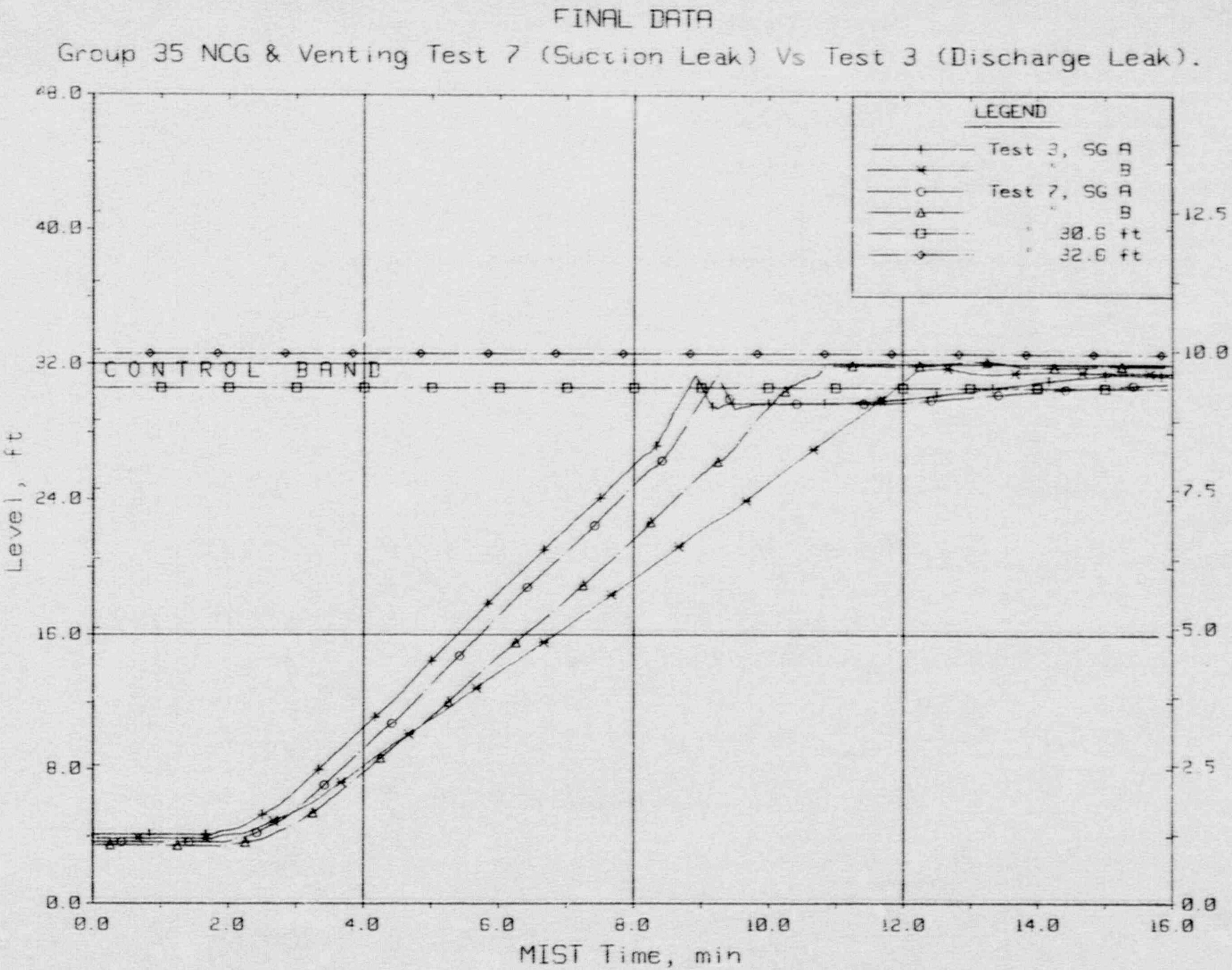

Figure 5.4.38 Steam Generator Secondary Collapsed Liquid Levels

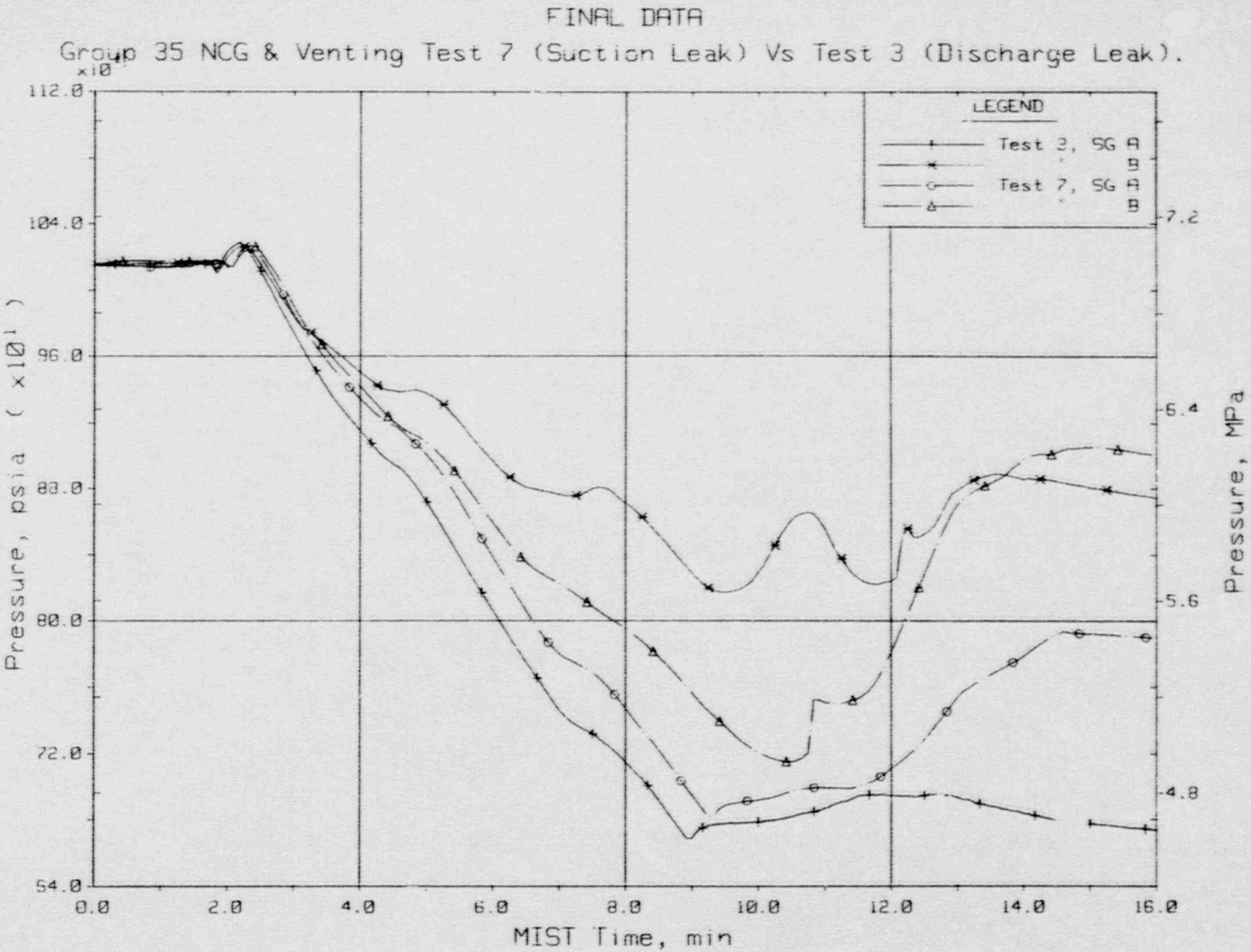

Figure 5.4.39 Steam Generator Secondary Pressures (SnGP01s)

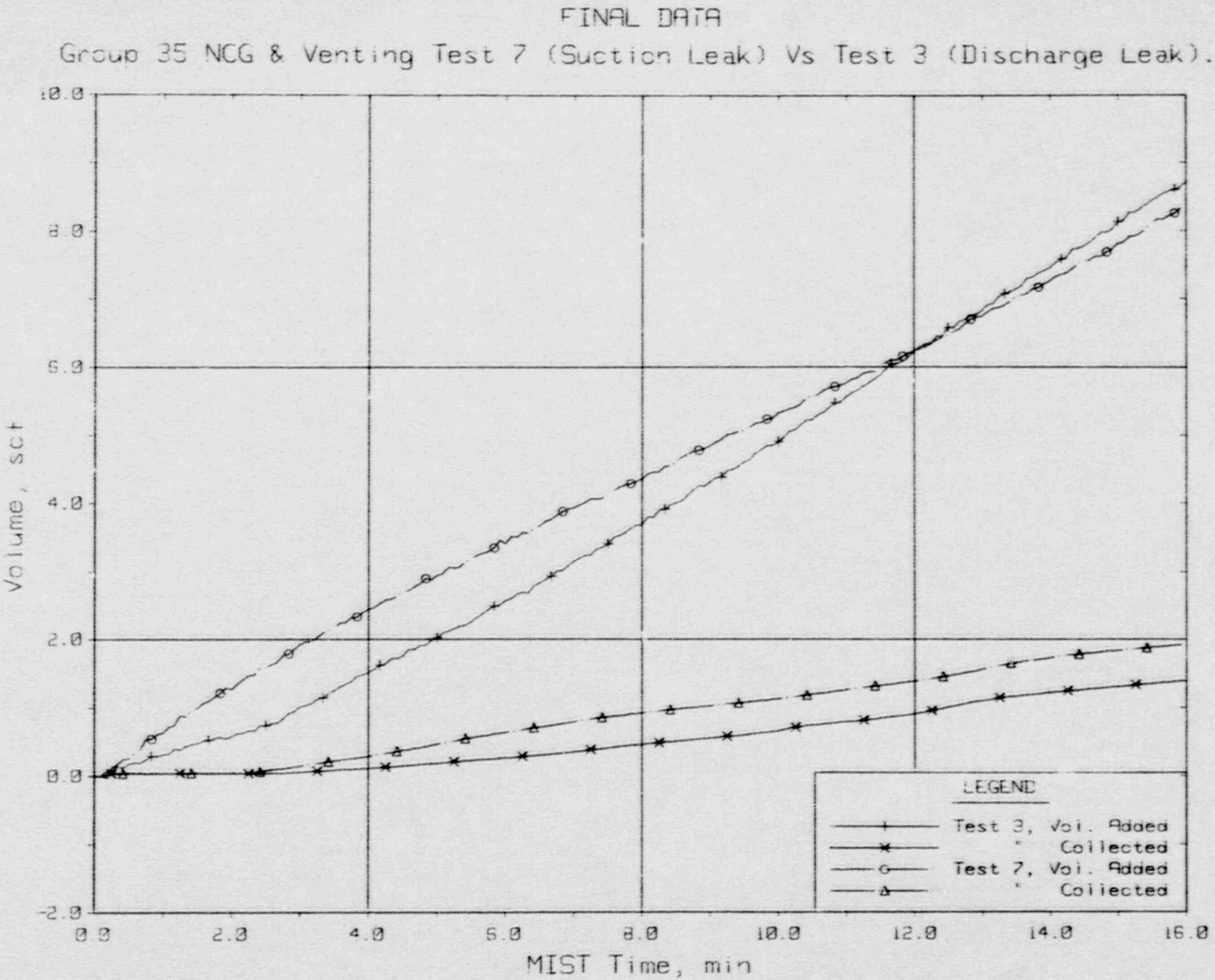

Figure 5.4.40 Noncondensibles Gas Volumes

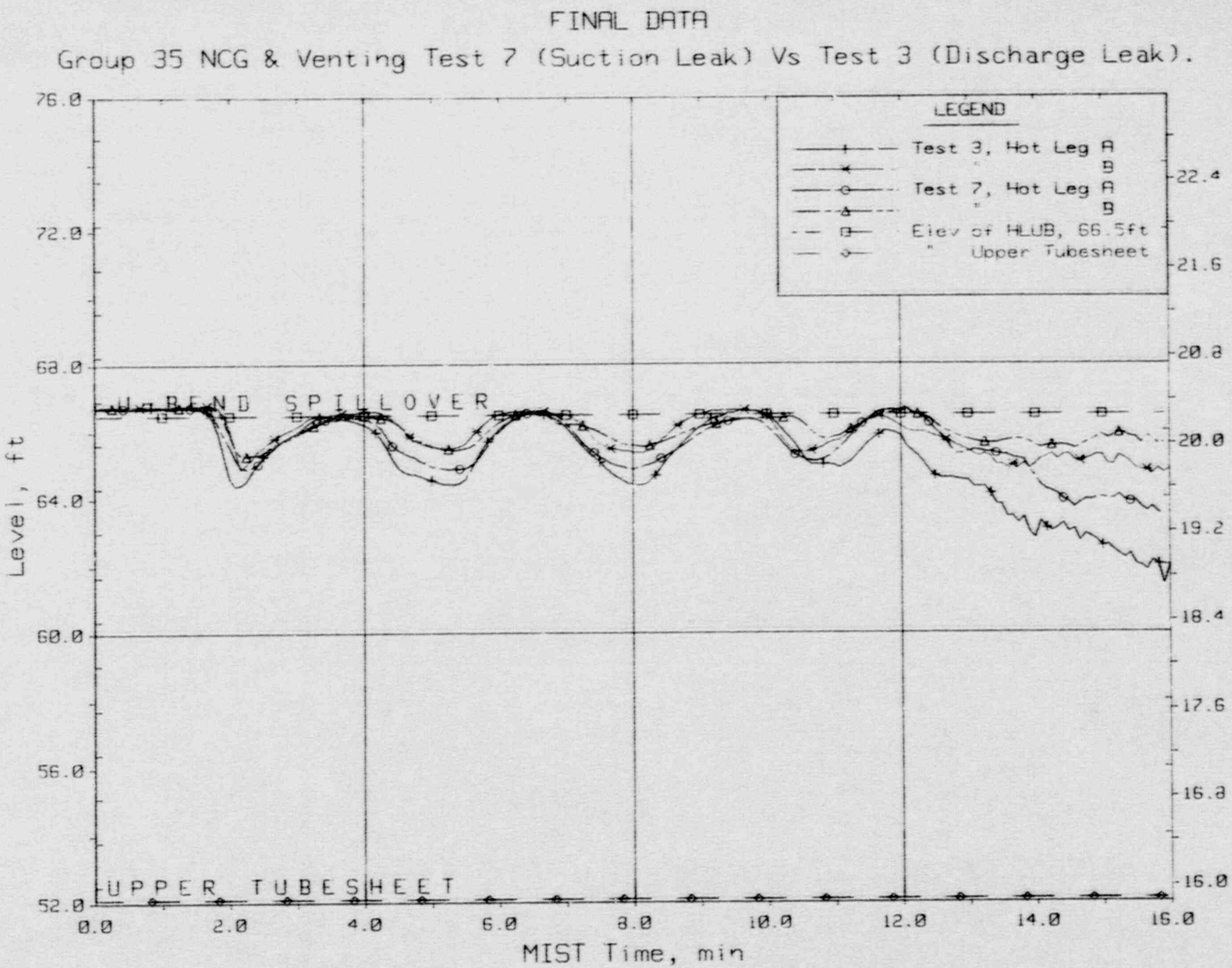

Figure 5.4.41 Hot Leg Riser Collapsed Liquid Levels

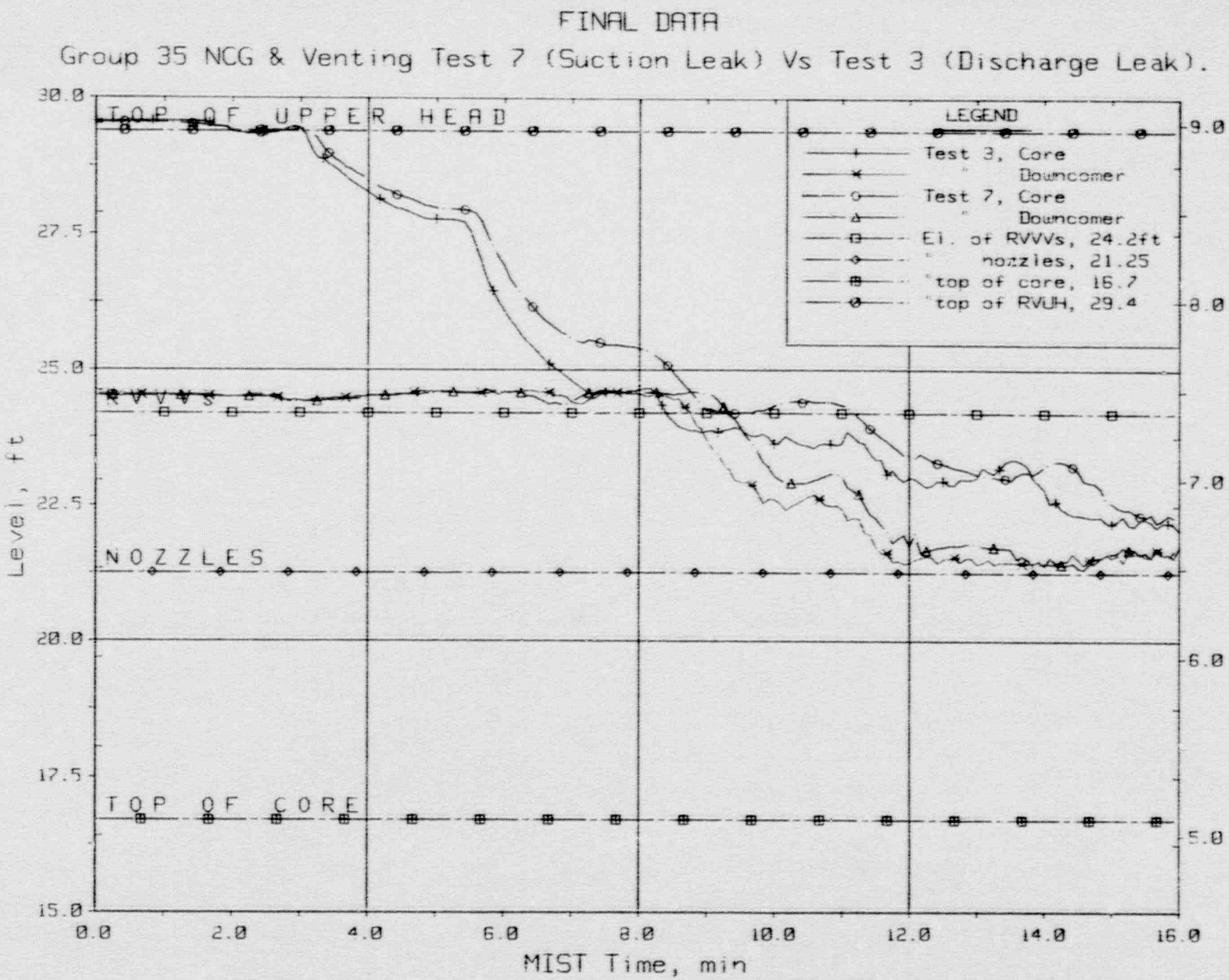

Figure 5.4.42 Core Region Collapsed Liquid Levels

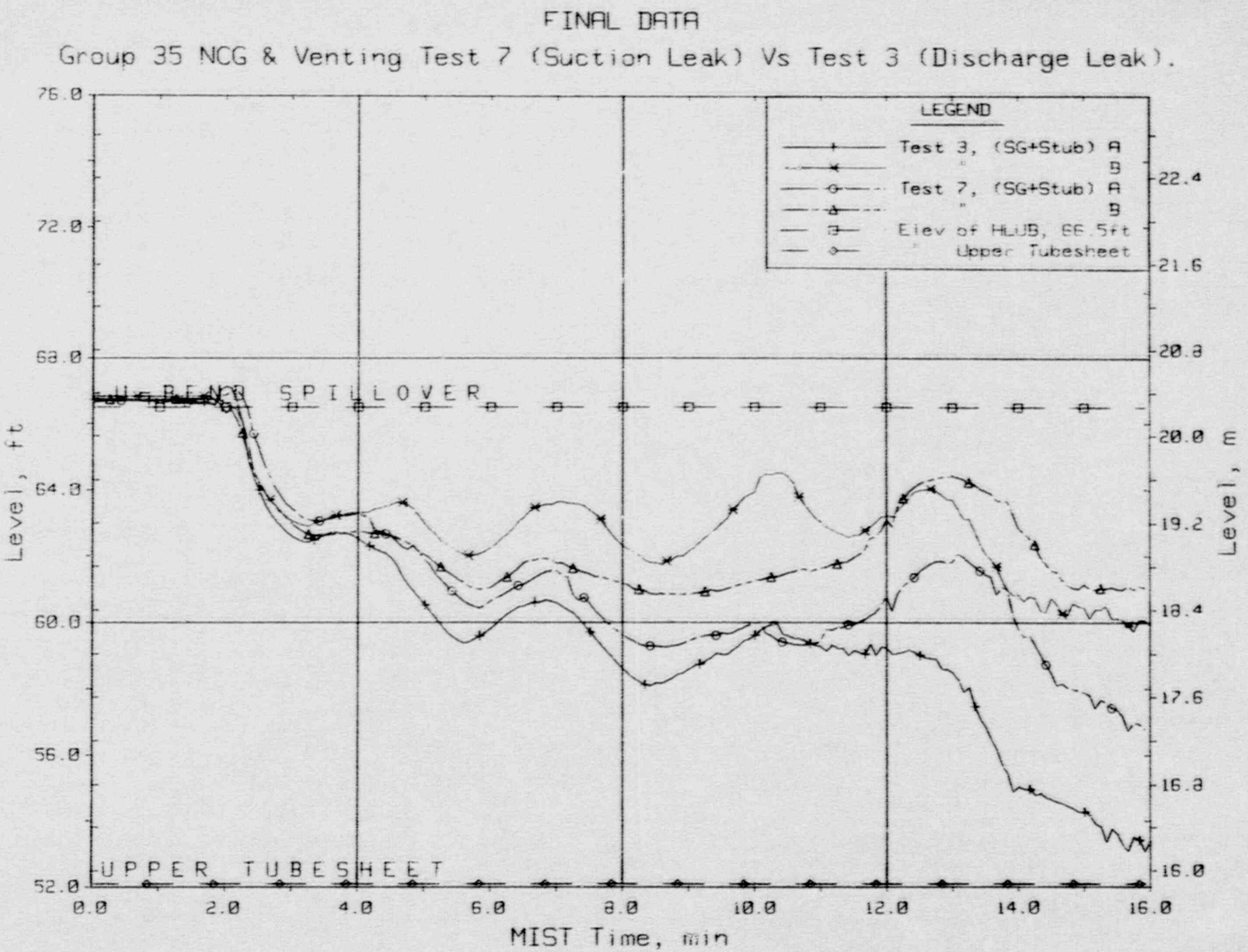

Figure 5.4.43 Steam Generator Primary and Stub Collapsed Liquid Levels

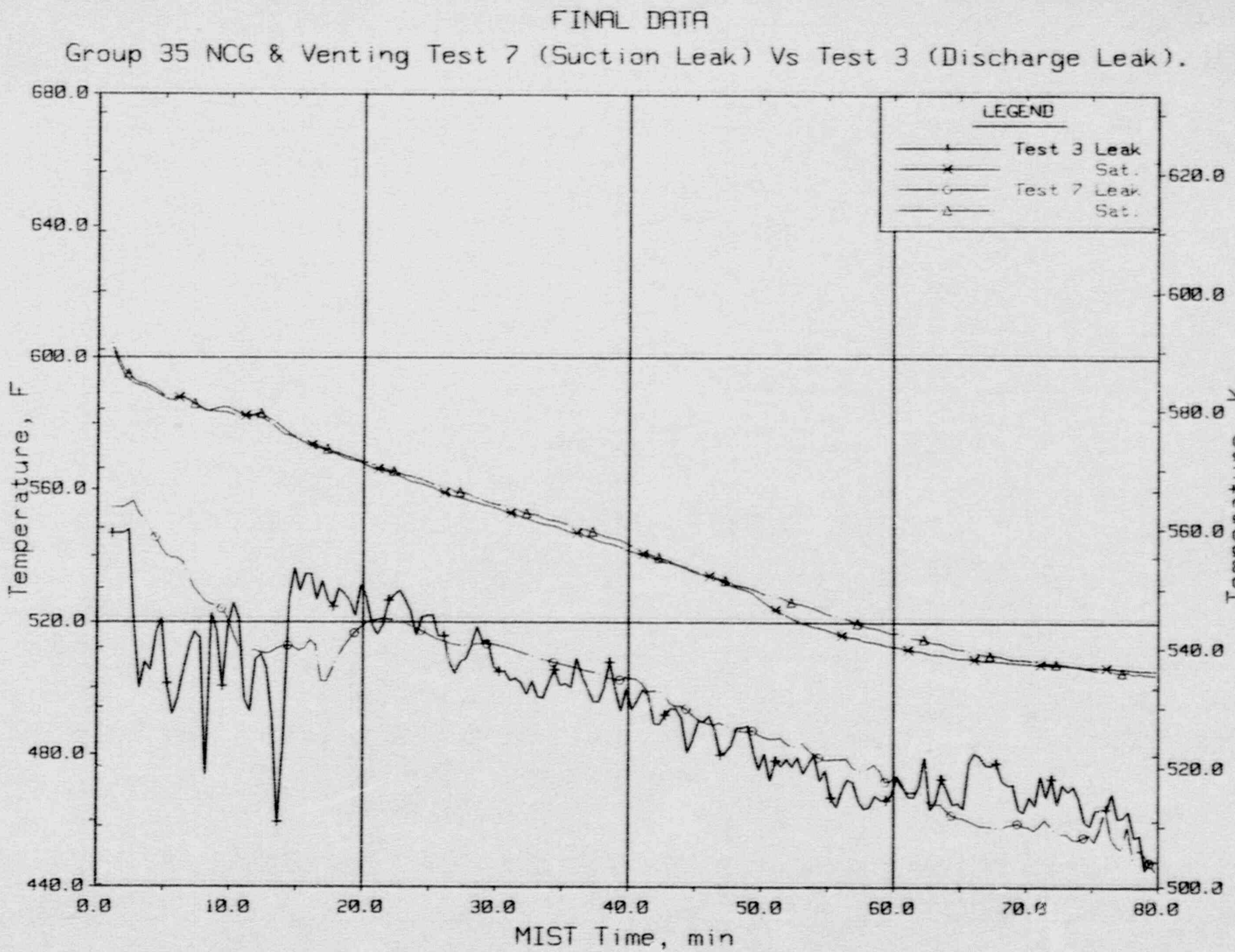

Figure 5.4.44 Leak and HPI Fluid Temperatures (TC01s)

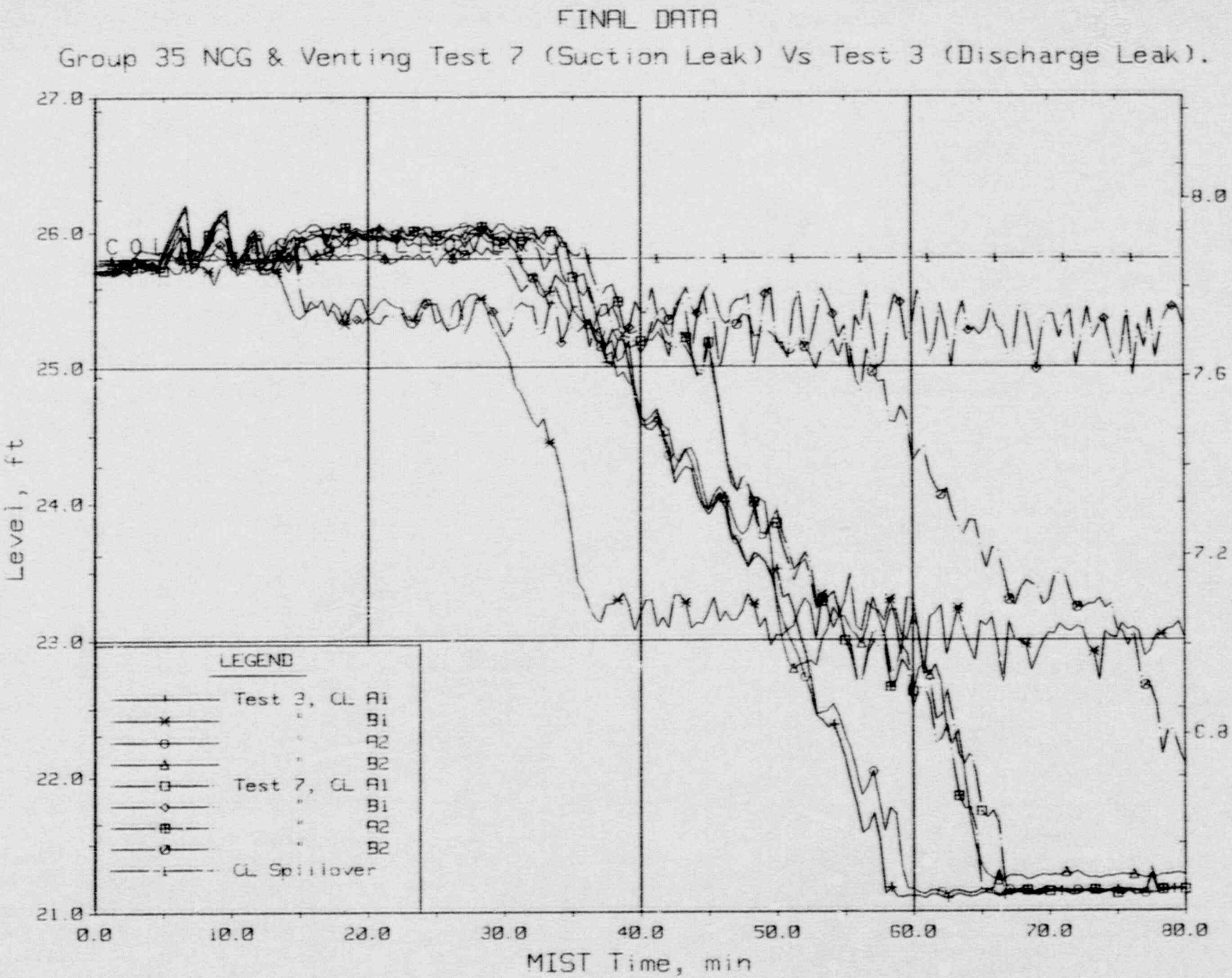

Figure 5.4.45 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

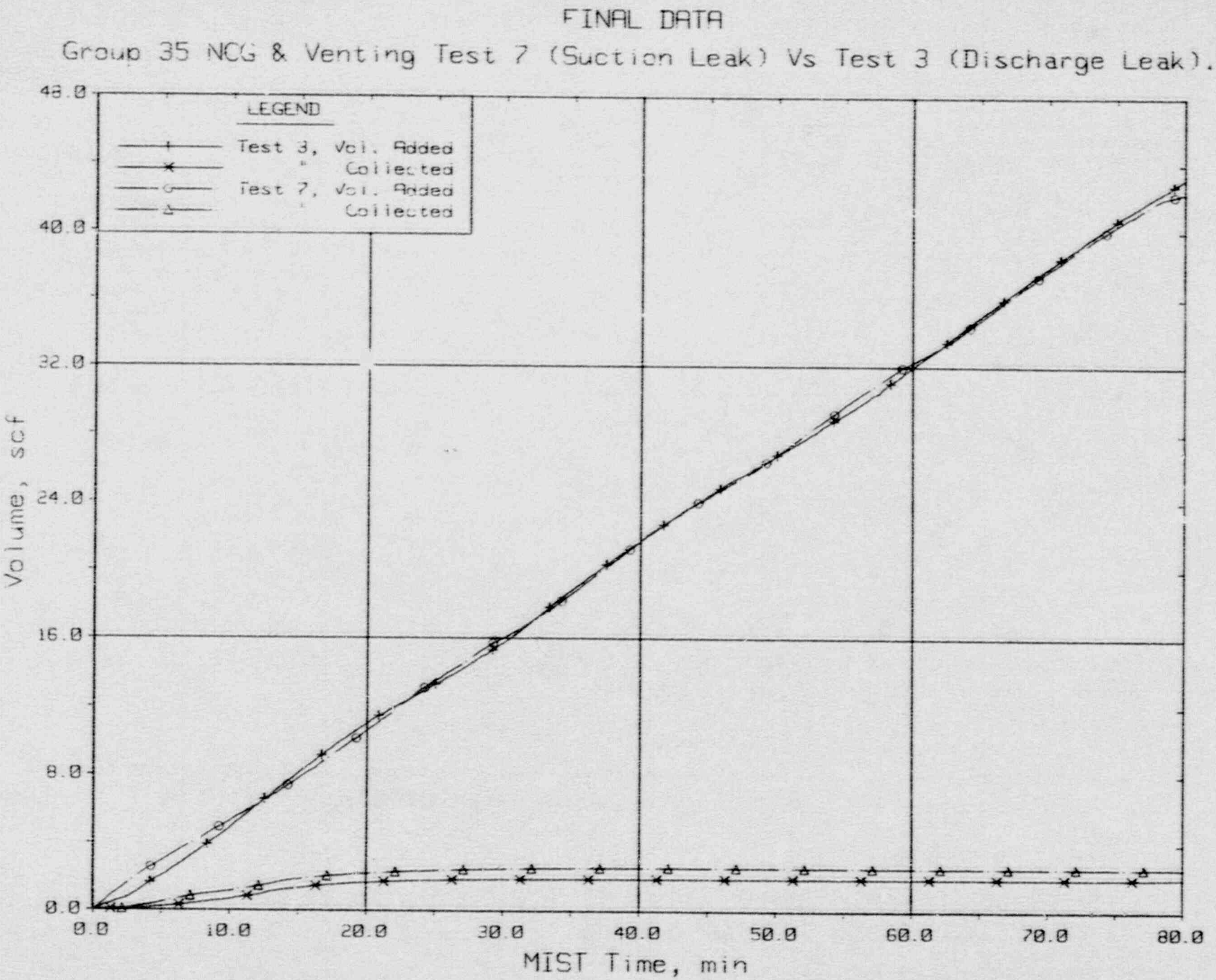

Figure 5.4.46 Noncondensibles Gas Volumes

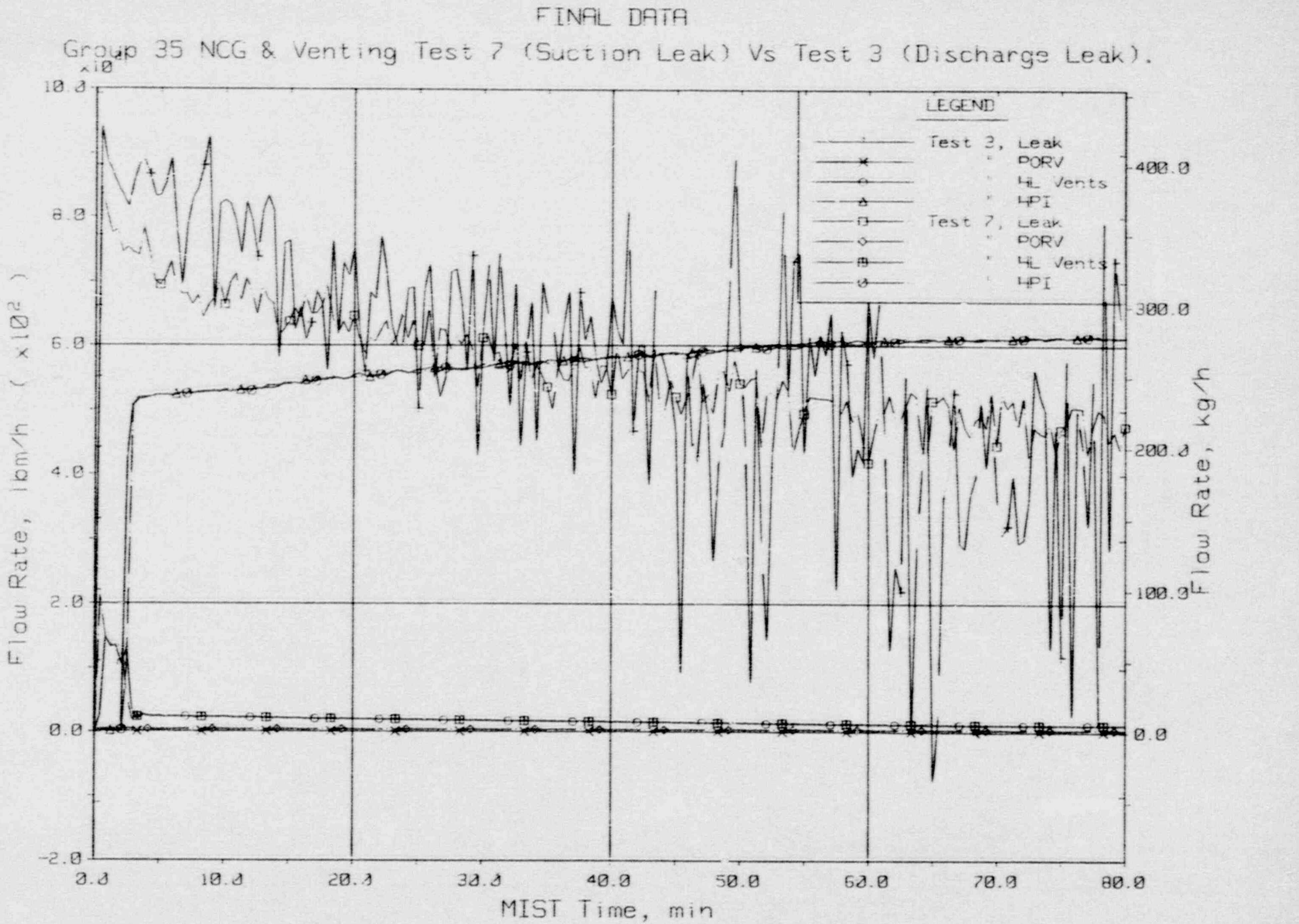

Figure 5.4.47 Primary System Boundary Mass Flow Rates

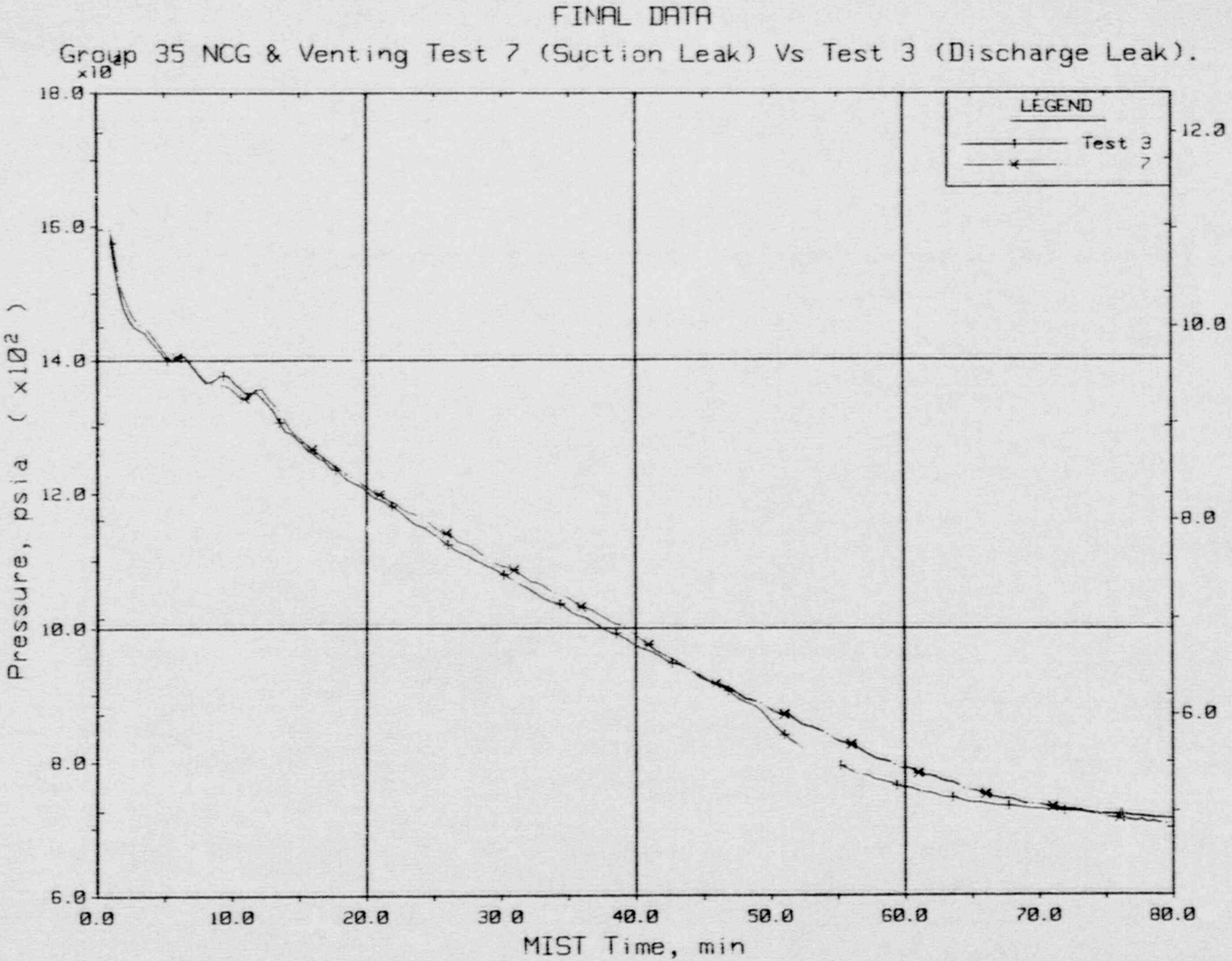

Figure 5.4.48 Primary System Pressure (RVGP01)

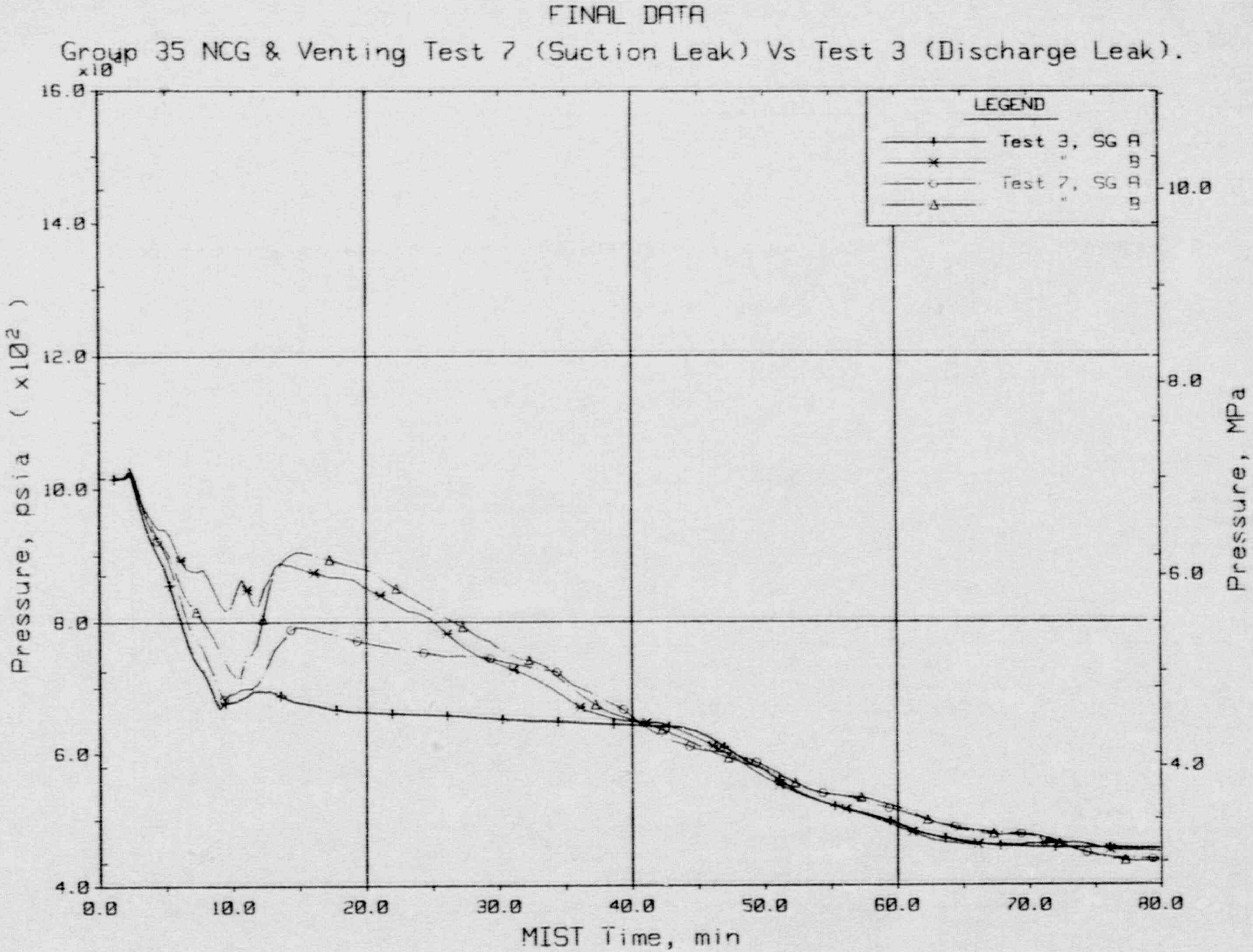

Figure 5.4.49 Steam Generator Secondary Pressures (SnGP01s)

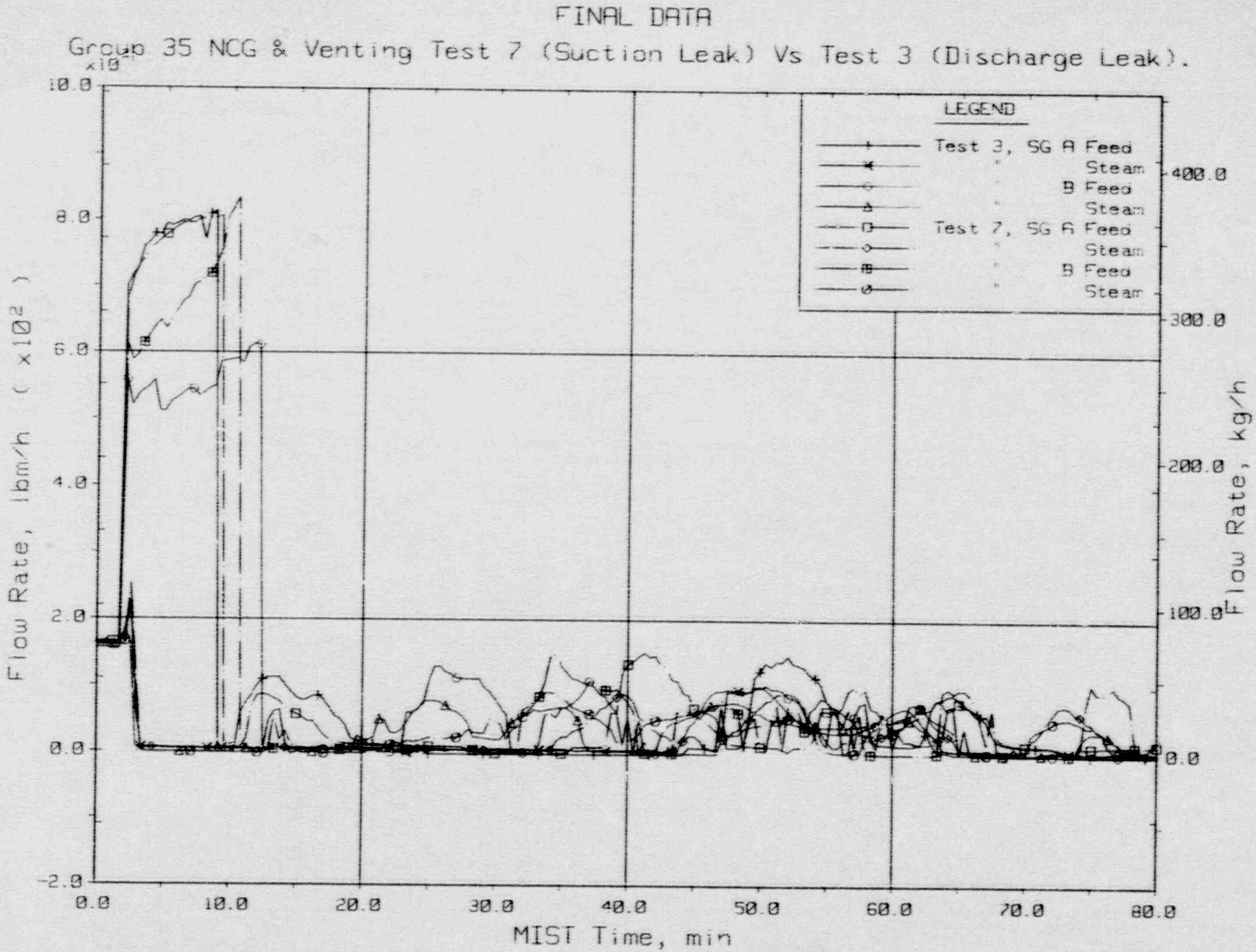

Figure 5.4.50 Steam Generator Secondary Flow Rates

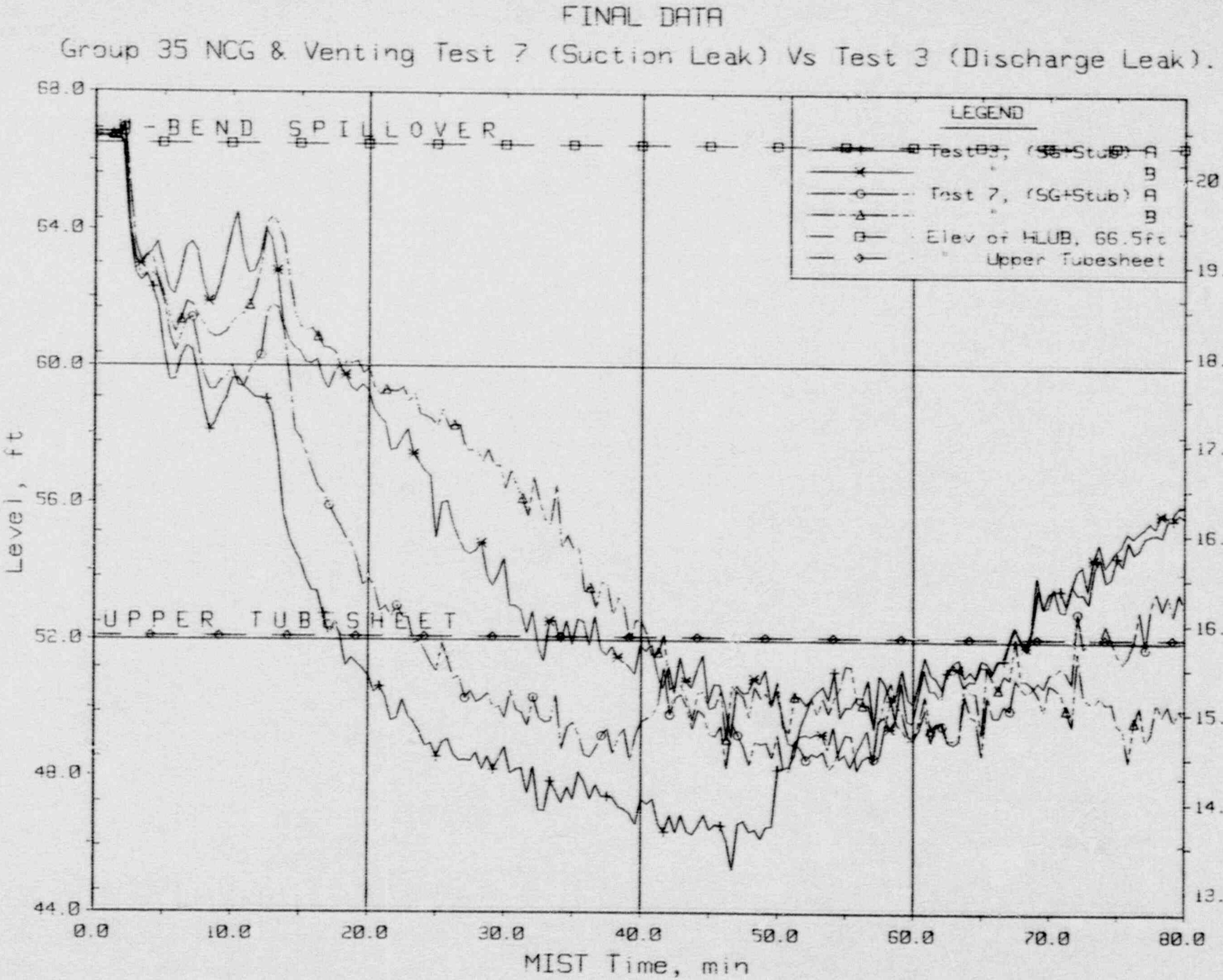

Figure 5.4.51 Steam Generator Primary and Stub Collapsed Liquid Levels

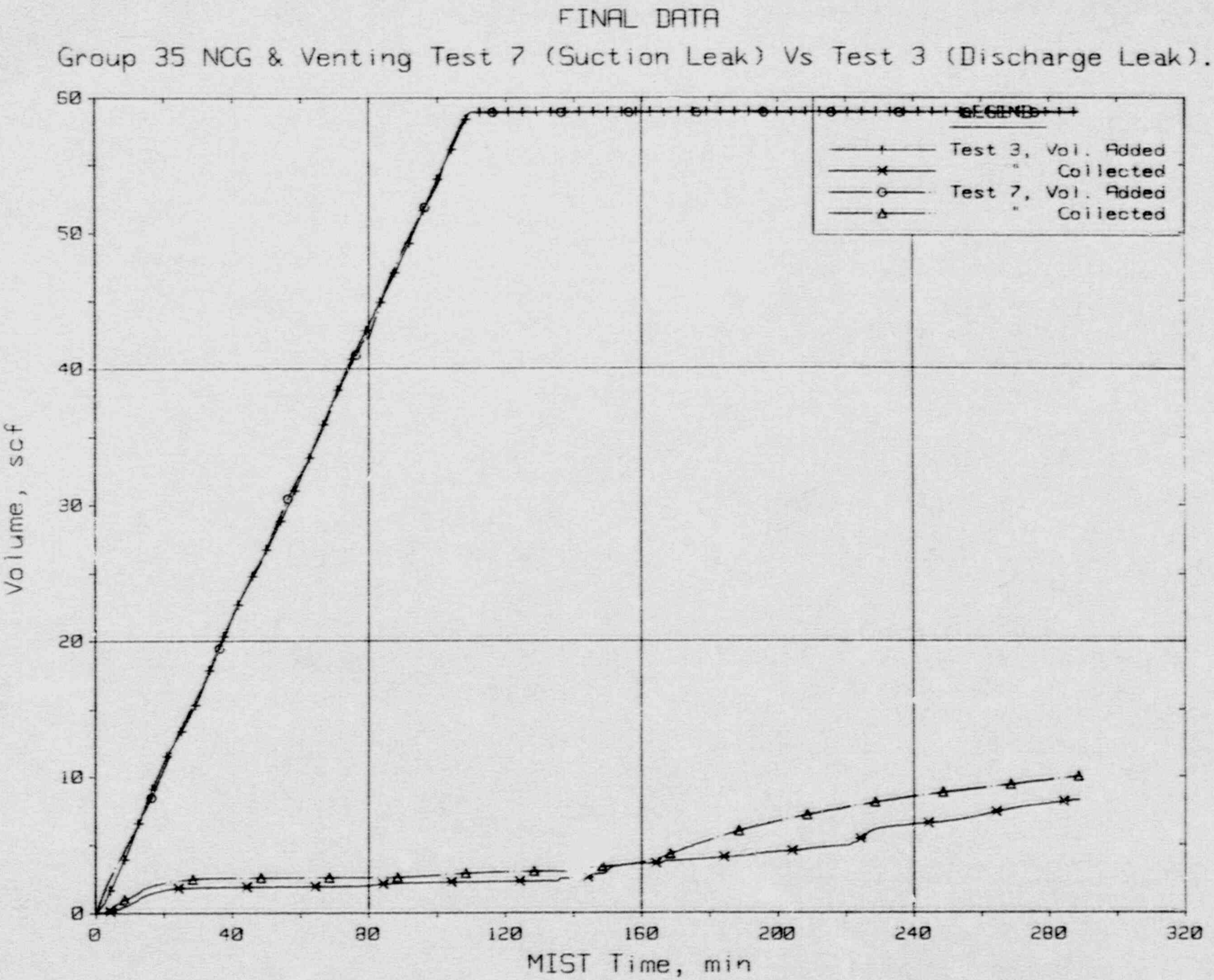

Figure 5.4.52 Noncondensibles Gas Volumes

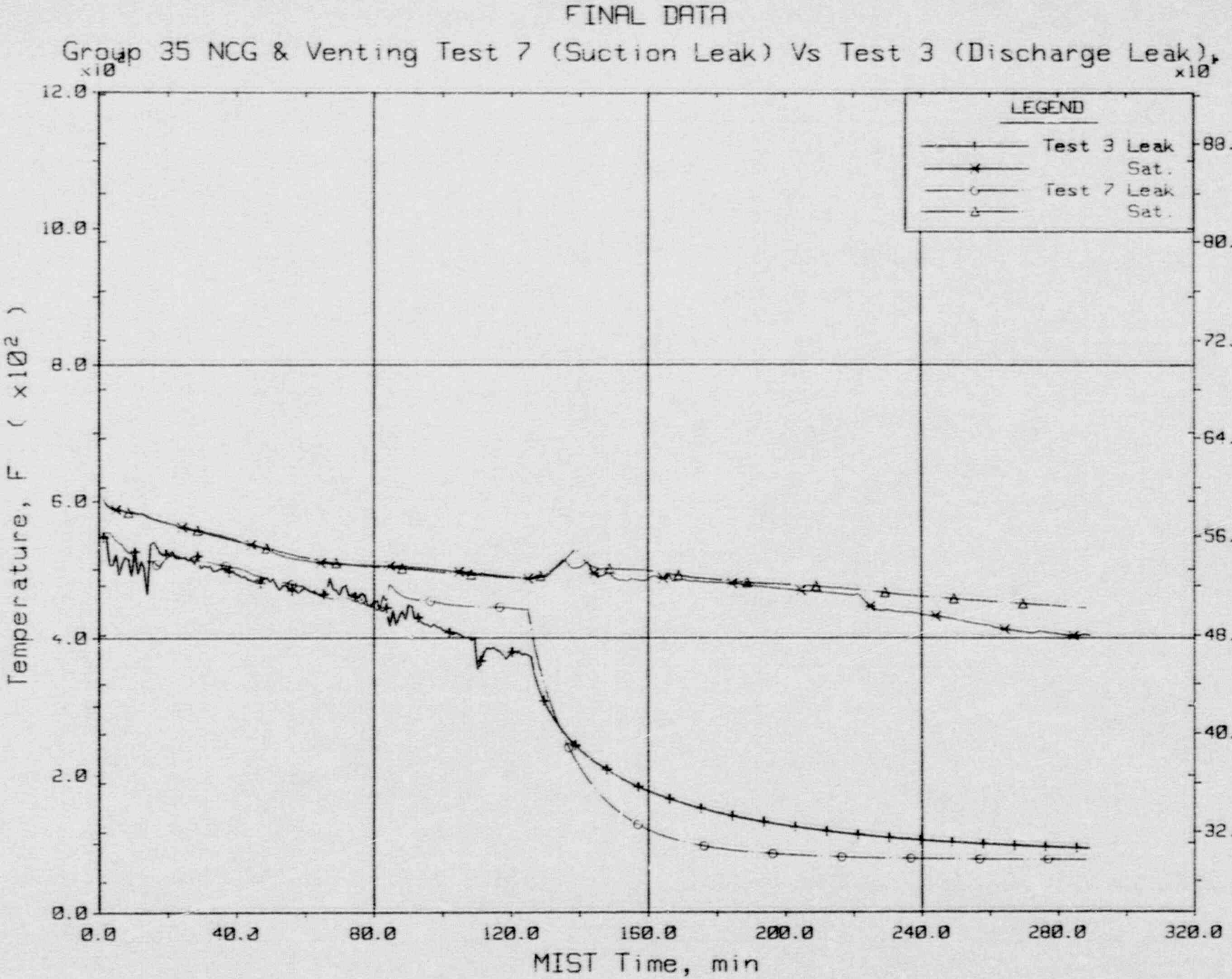

Figure 5.4.53 Leak and HPI Fluid Temperatures (TC01s)

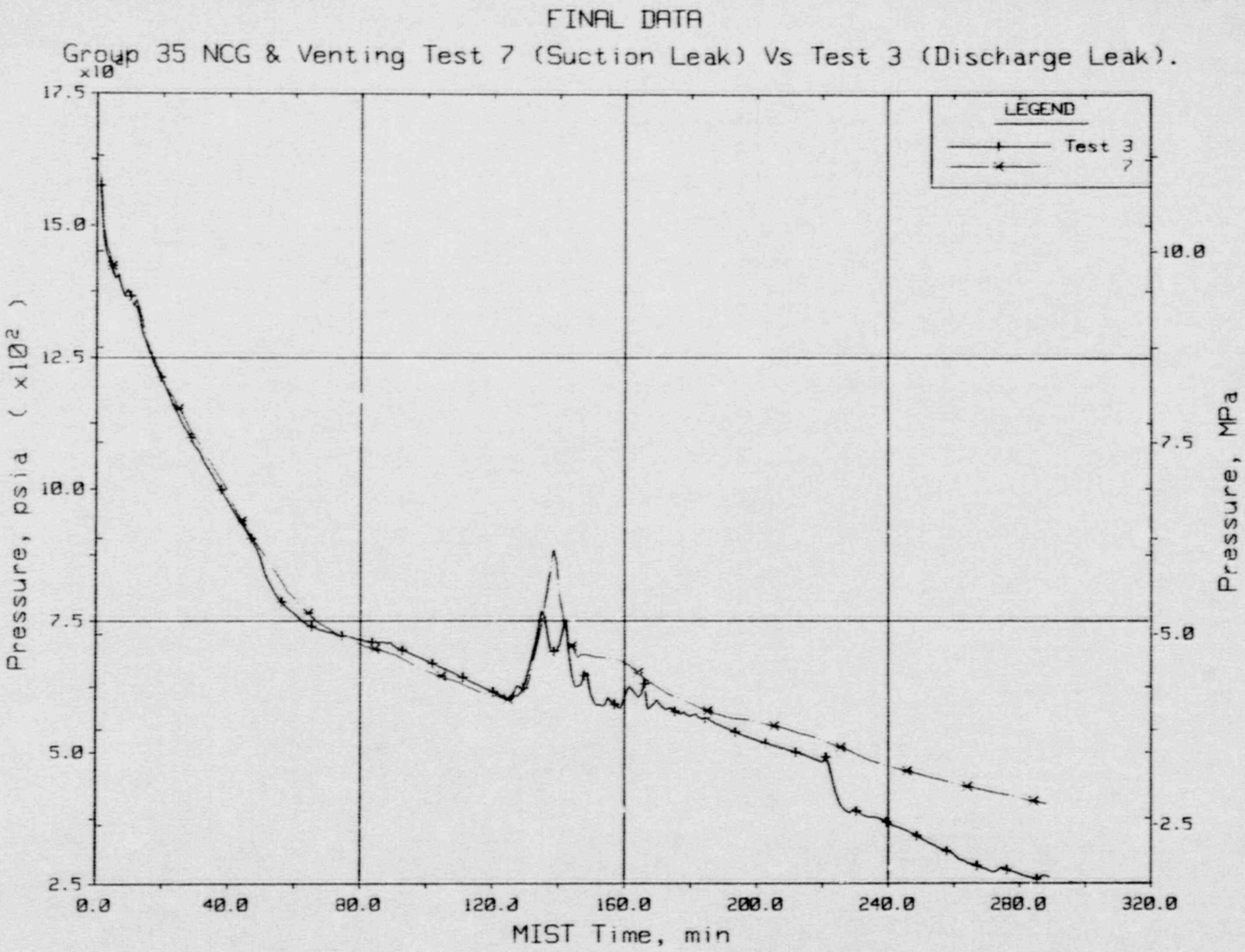

Figure 5.4.54 Primary System Pressures (RVGP01)

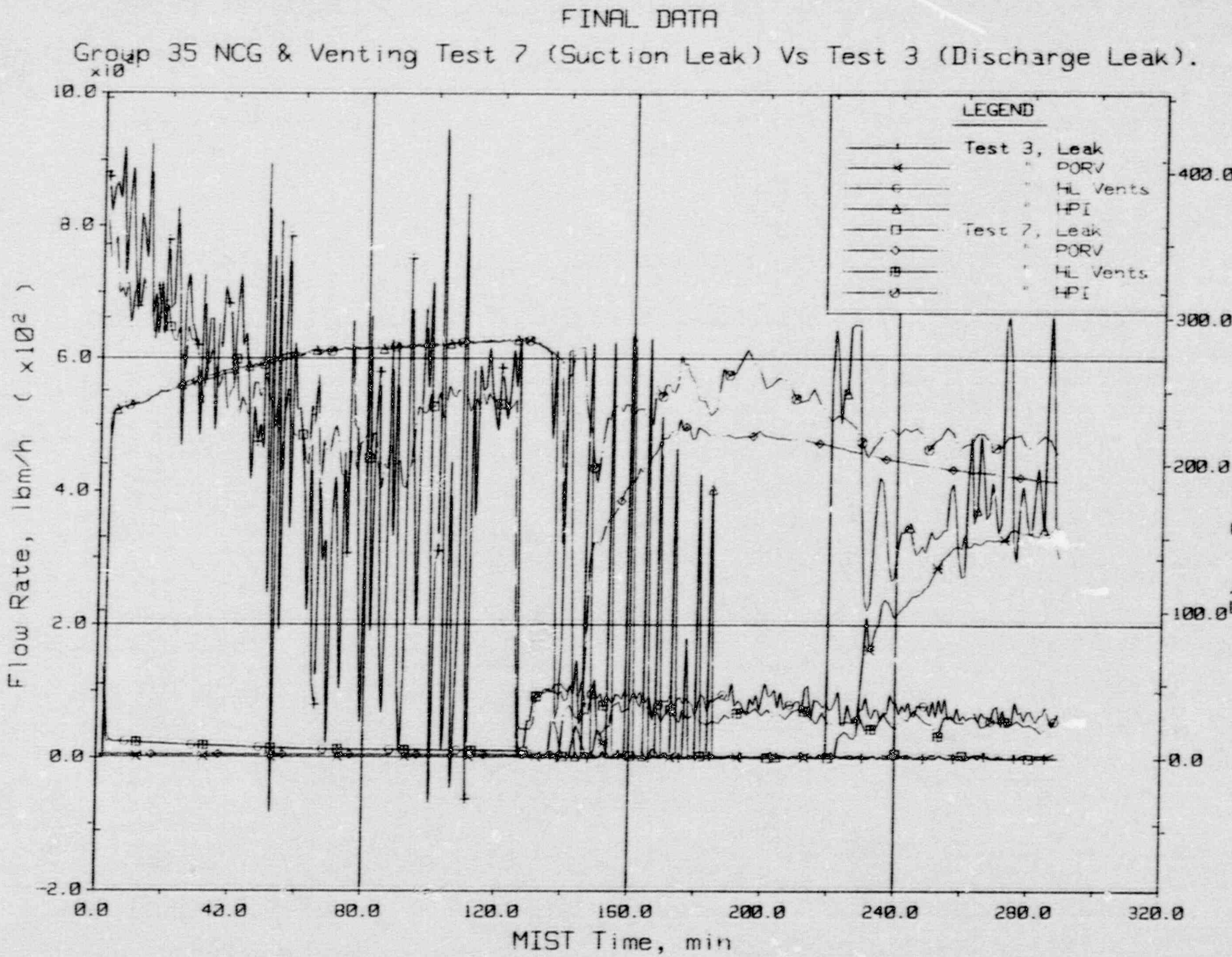

Figure 5.4.55 Primary System Boundary Mass Flow Rates

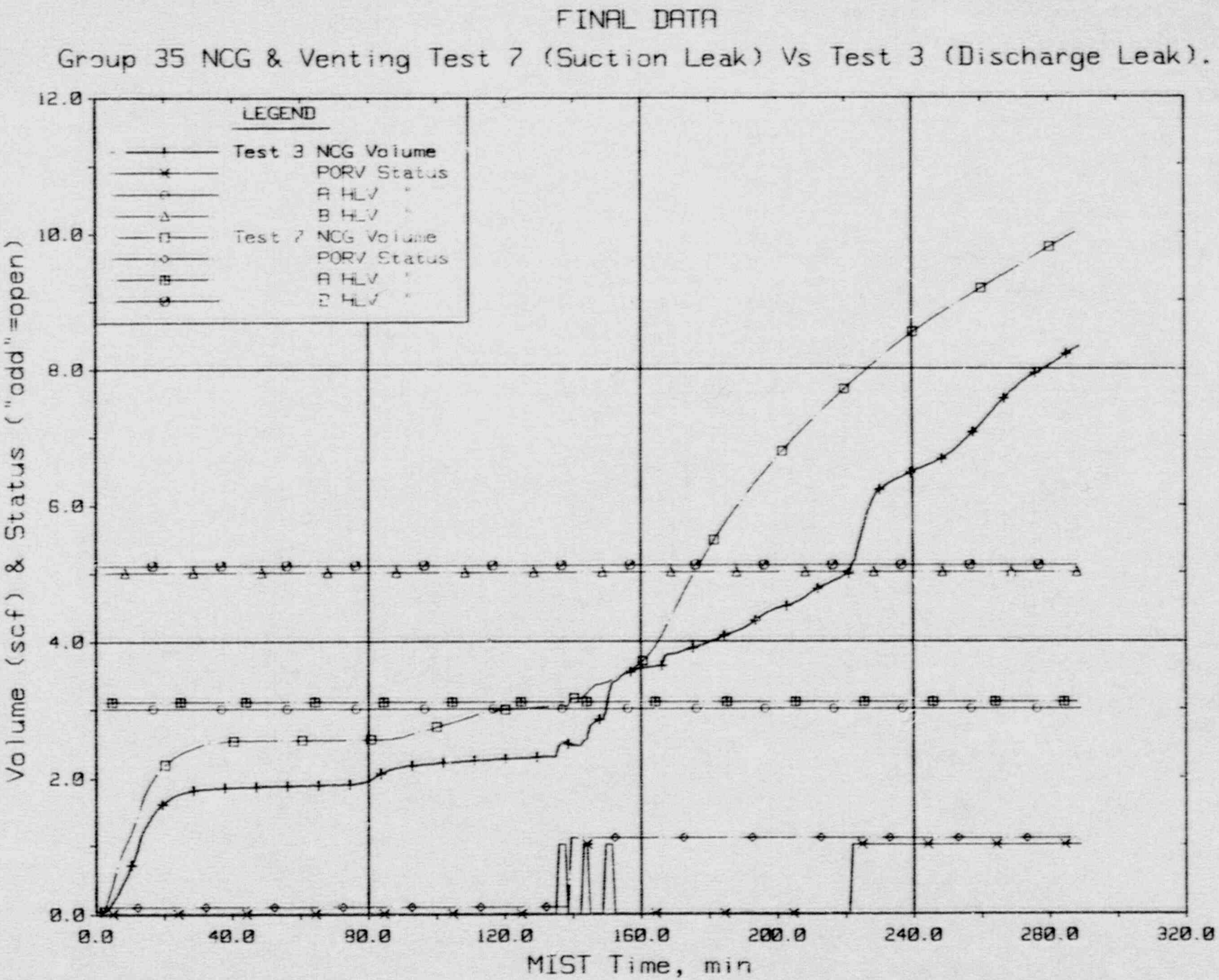

Figure 5.4.56 Noncondensibles Collected and Discharge Valve Status

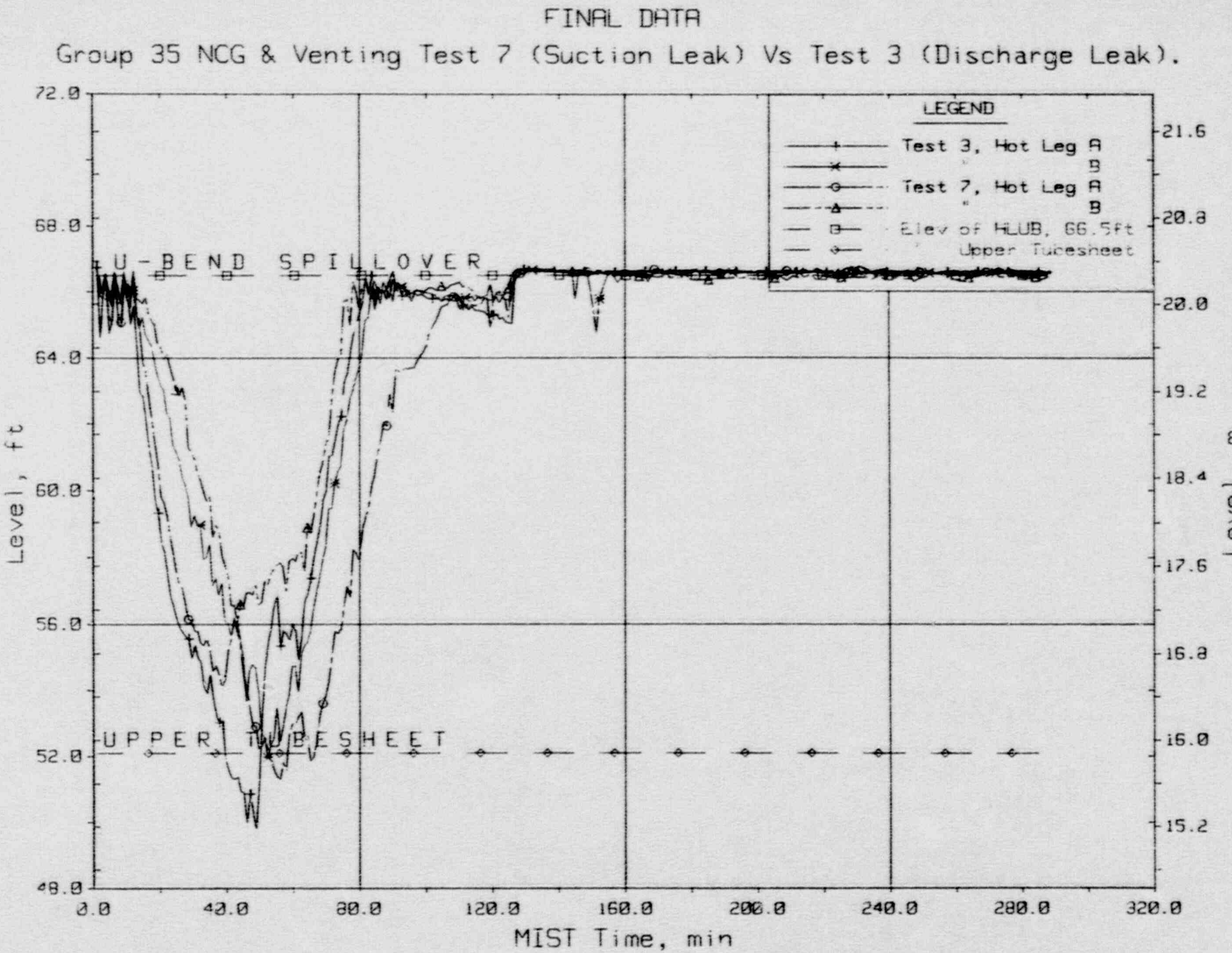

Figure 5.4.57 Hot Leg Riser Collapsed Liquid Levels

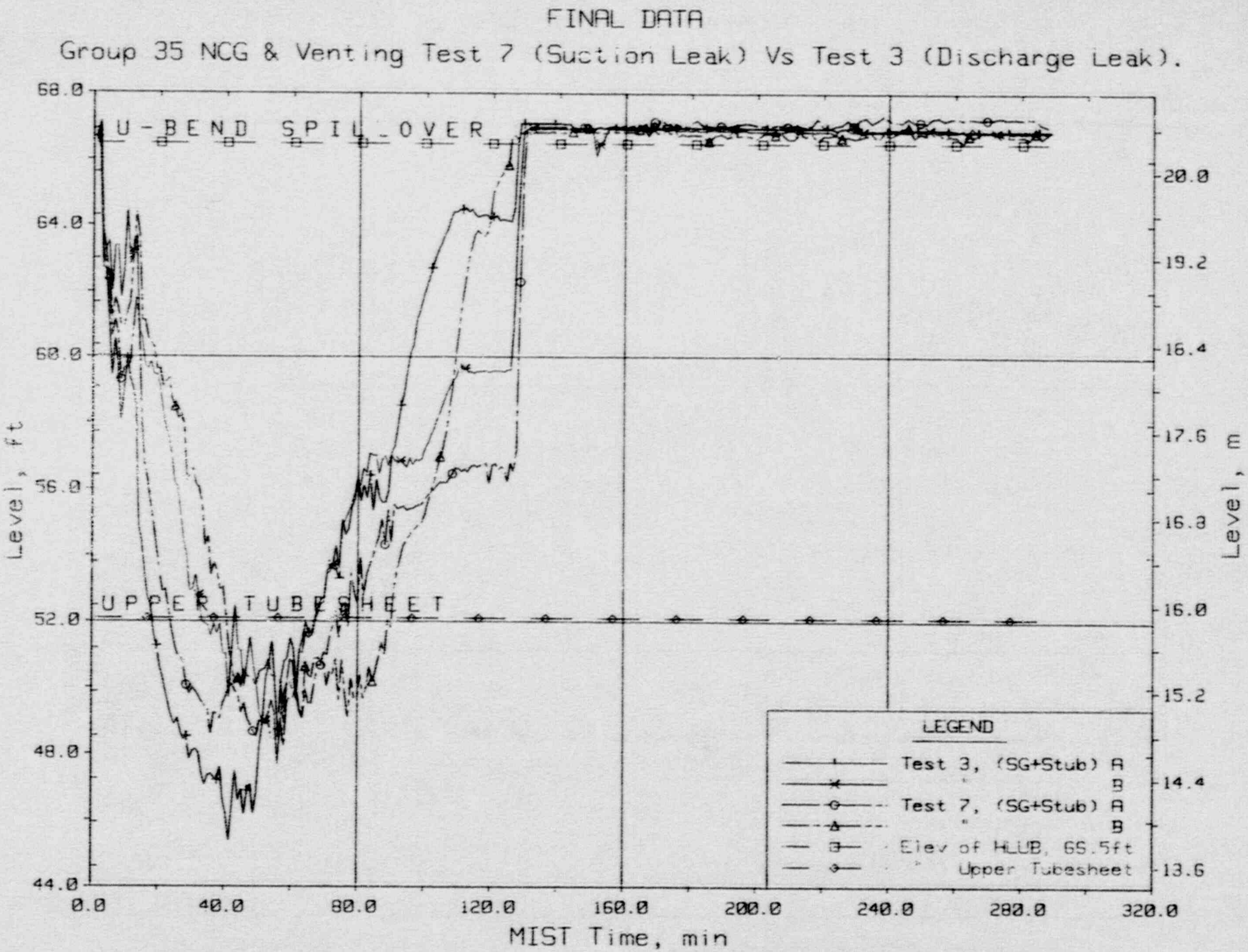

Figure 5.4.58 Steam Generator Primary and Stub Collapsed Liquid Levels

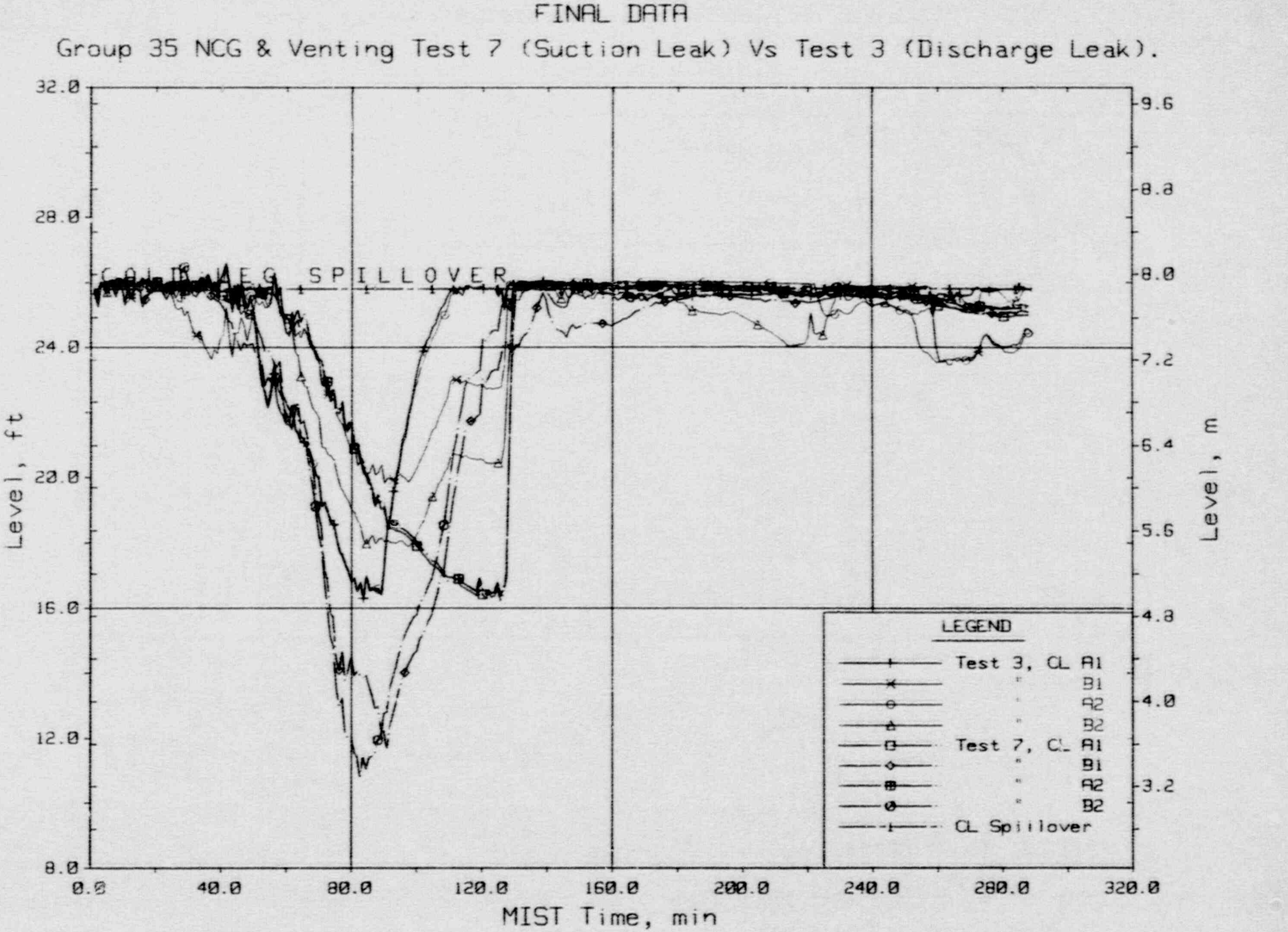

Figure 5.4.59 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

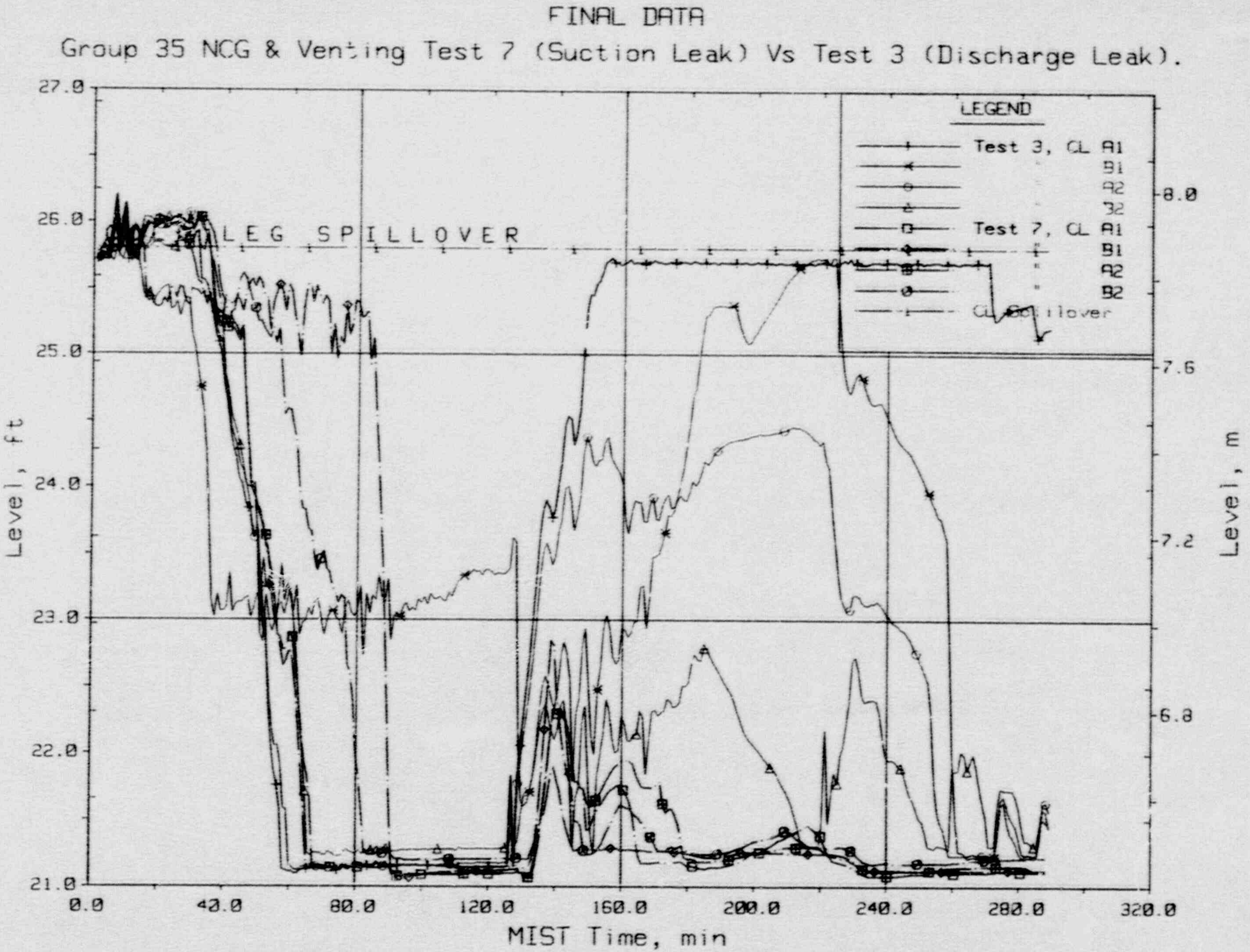

Figure 5.4.60 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

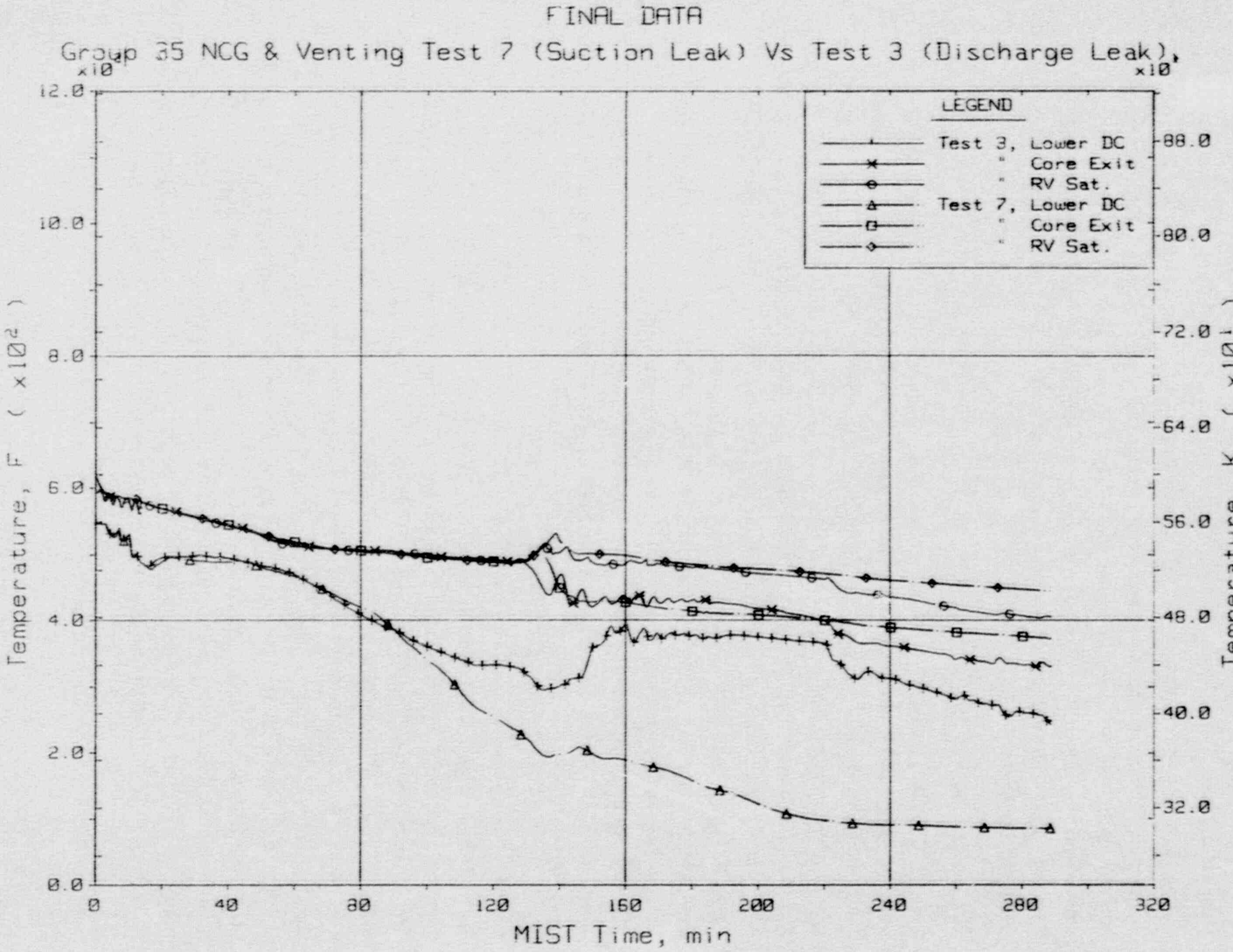

Figure 5.4.61 Core Bracketing Fluid Temperatures

5.5. NCG Species, Tests 7 and 8

Helium was injected in Test 7, and nitrogen was injected in Test 8. Tests 7 and 8 had otherwise the same boundary system controls: A scaled 10-cm^2 cold leg B1 suction leak, continuous hot leg venting, and leak isolation at approximately 2 hours. Test 7 has already been described in section 5.4.1. Section 5.5.1 provides a description of Test 8, and Tests 7 and 8 are compared in section 5.5.2.

5.5.1. Nitrogen, Test 8

Test 8 (350800) used nitrogen as the NCG species and a cold leg suction break. Both hot leg high-point vents were kept open throughout the test. The leak was closed midway through the test, then the PORV was opened manually to control the (apparent) core exit fluid subcooling. Little of the NCG was discharged out the break. The total NCG venting rate increased with PORV actuation, but most of the injected gas remained in the system at test termination. The NCG effects were most apparent in the cold legs and downcomer. Upon the establishment of HPI-PORV cooling, the RVVVs closed even though the upper downcomer and cold leg discharge piping remained voided. The HPI then entered the downcomer unheated. The cold leg nozzle, lower downcomer, and core inlet fluid temperatures approached the HPI supply fluid temperature.

Initiation

Test 8 was begun by opening a scaled 10-cm^2 cold leg B1 suction break, opening both hot leg high-point vents, and injecting nitrogen at the reactor vessel lower piping. Nitrogen was injected at a continuous rate of approximately 33.5 scf/h (Figure 5.5.1). The customary additional control changes were performed at test initiation, namely the transfer of the RVVV controls and the activation of the core power decay ramp. The second and final set of test-initiating actions was accomplished as the loop saturated and the rate of primary system depressurization slowed (Figure 5.5.2), approximately 2 minutes after test initiation. Upon resetting the steam generator secondary levels to 31.6 ft, the steam generator feeding rates were noticeably different (Figure 5.5.3), with steam generator B low. The early system interactions were otherwise similar to those commonly encountered during the initial phases of the small-break transient.

Inter-Cold Leg Flow

An uncommon event occurred at 10 minutes in the loop A cold legs (Figure 5.5.4) and at 20 minutes in the loop B cold legs. At these times, each of the four thermocouples composing a pump discharge rake dropped by as much as 200F and, within 1 minute, returned to their previous temperatures. These temperature spikes corresponded to the onset of inter-cold leg flow -- first between the loop A cold legs, then between the loop B legs (Figure 5.5.5). The magnitude of the temperature changes indicated that NCG briefly inhibited the condensation of RVVV discharged steam on the cold HPI fluid, allowing this cold fluid to be transported with relatively little heating.

Cold Leg Voiding

The hot leg risers and steam generators began to refill sporadically beyond 50 minutes (Figure 5.5.6), whereas the cold leg suction and discharge piping began to void (Figures 5.5.7 and 5.5.8). After voiding down to as low as 10 feet, the cold leg suction piping refilled beyond 100 minutes, but the cold leg discharge piping remained voided. The fluid temperatures in the cold leg discharge piping of each of the cold legs remained far below saturation (Figure 5.5.9), indicating a high concentration of NCG.

Leak Isolation

The nitrogen injection was terminated at 109 minutes, with just over 60 scf of the nitrogen having been injected. At 146 minutes, the second phase of the test was begun by closing the cold leg suction break (Figure 5.5.10). The primary system began to repressurize (Figure 5.5.11), the apparent core exit SCM began to rise, and the PORV was manually opened at 158 minutes to maintain 70F SCM. Automatic HPI throttling commenced shortly thereafter. The gas venting rate, which had averaged less than 1 scf/h, increased to more than 2 scf/h (Figure 5.5.12). However, most of the injected NCG remained in the loop and apparently resided predominantly in the upper downcomer and cold leg discharge regions.

NCG Inhibition of HPI Heating

The RVVVs remained closed beyond 150 minutes (Figure 5.5.13), although the upper downcomer remained voided below the nozzle elevation (Figure 5.5.14). The HPI fluid, apparently surrounded by NCG, entered the downcomer with little preheating. The cold leg nozzle and lower downcomer fluid temperatures dropped to 100F beyond 160 minutes, although the upper downcomer temperatures remained near 400F (Figures 5.5.15 and 5.5.16). This temperature disparity persisted through test termination at 320 minutes. The core inlet fluid temperature also decreased to the HPI fluid temperature (Figure 5.5.17). The test was terminated using the dual criteria of primary system pressure being less than 400 psia and more than 50F SCM for at least 2 hours.

5.5.2. Comparison

Nitrogen was injected in Test 8, versus helium in the other tests using noncondensible gas (such as Test 7). Tests 7 and 8 otherwise had identical boundary system controls. Both used a scaled 10-cm^2 cold leg B1 suction leak, continuous hot leg high-point venting, and break isolation midway into the transients.

Tests 7 and 8 were initiated identically, and had the same initial primary system depressurization rates (Figure 5.5.18). Their initial leak mass flow rates were also similar (Figure 5.5.19) -- the differences between the plotted leak mass flow rates reflect their different sources and the error, approximately 5% low, in the Test 7 leak mass flow rate obtained from the micro-motion flow meter (Figure 5.5.20). (The micro-motion measurements are not available for Test 8.)

Upon resetting the steam generator secondary levels triggering increased feed flow, the feed rate to steam generator B increased to less than the full head-flow value. This inter-steam generator difference was approximately preserved between tests (Figure 5.5.21). Discernible inter-test differences developed just after the saturation of the primary system at 2 minutes. The loops interrupted symmetrically in Test 7 but asymmetrically in Test 8 (Figure 5.5.22). Between 2 and 12 minutes, both loops reactivated intermittently in Test 7 whereas, in Test 8, loop A deactivated and loop B generally remained active. In Test 8, the steam generator B secondary depressurized relatively little due to feeding while the steam generator A secondary was depressurized to 600 psia (Figure 5.5.18). The core inlet fluid temperature decreased gradually in Test 8 but cyclically in Test 7 (Figure 5.5.23). As the loop flow rates intermittently stagnated in Test 7 (Figure 5.5.24), the core inlet fluid temperature rose, and the core void production apparently increased causing the core-region collapsed liquid level to decline relatively rapidly (Figure 5.5.25). Even though the primary system initially depressurized more rapidly in Test 8 than in Test 7 because of the continuing steam generator B heat transfer in Test 8, the flashing due to depressurization in Test 8 was exceeded by the core void production in Test 7, resulting in a lower core level in Test 7. The sustained loop B flow in Test 8 maintained its leak fluid temperature above that in Test 7 (Figure 5.5.26).

The downcomer level descended to the elevation of the cold leg nozzles at 12 minutes in Test 7, approximately 4 minutes earlier than in Test 8 (Figure 5.5.25). The earlier depressurization enhancement due to HPI condensation in Test 7 caused the primary system pressure in Test 7 to descend below that in Test 8 near 14 minutes (Figure 5.5.18).

The gas collection (venting) rates diminished as HPI condensation began, becoming virtually zero in both tests beyond 30 minutes. The earlier gas venting rates had been approximately 8 scf/h in Test 7 using helium versus 6 scf/h in Test 8 using nitrogen. Before the gas venting rates subsided, approximately 2.5 scf were vented in Test 7 versus 2 scf in Test 8 (Figure 5.5.27). The gas injection rates were similar for the tests (Figure 5.5.28).

The steam generator A primary level descended below the elevation of the upper tubesheet at 20 minutes in Test 8, and a few minutes later in Test 7 (Figure 5.5.29). The corresponding event in steam generator B was delayed until 40 minutes in both tests. Between 15 and 30 minutes, the steam generator B secondaries began to be depressurized (Figure 5.5.30) to maintain the primary-to-secondary temperature difference of 50F. However, the reactivation of the steam generator A secondary was somewhat delayed because of the prior depressurization due to feeding, particularly in Test 8. The steam generator primary levels and feed activity (Figure 5.5.31) were appropriate for AFW-BCM in both tests beyond 40 minutes in steam generator B, and beyond 65 minutes in both steam generators. The primary system continued to depressurize, but its depressurization rate was little affected by the steam generator activity (Figure 5.5.32), apparently reflecting NCG effects. The continuing primary system depressurization obtained the start of refill near 1 hour in both tests (Figure 5.5.33). Also in both tests, the hot leg riser (Figure 5.5.34) and steam generator primary levels rose, whereas the cold leg suction and discharge levels declined (Figures 5.5.35 and 5.5.36). The leak fluid temperatures remained highly subcooled, by approximately 50F (Figure 5.5.37), and the core inlet fluid temperatures gradually declined (Figure 5.5.38). The core inlet fluid temperatures in both tests achieved 200F just beyond 2 hours, versus 500F core outlet and saturation temperatures.

The hot leg riser levels approached the U-bend spillover elevation between 80 and 100 minutes (Figure 5.5.39), but the hot leg stub and steam generator primary levels remained some 10 feet below the U-bend (Figure 5.5.40). In both tests, the systems were unresponsive to hot leg refill (Figure 5.5.41) compared to the interactions seen in tests without noncondensibles.

The gas injections were completed near 115 minutes in both tests, with approximately 60 scf having been injected in each test (Figure 5.5.42). The cold leg B1 suction leak was isolated at 125 minutes in Test 7 and at 146 minutes in Test 8. In both tests, the hot leg vent mass flow rate increased, signalling liquid-full hot legs, almost simultaneously with leak closure (Figure 5.5.43). Also in both tests, the primary system rapidly repressurized upon leak isolation (Figure 5.5.41), raising the SCM and thereby triggering HPI throttling and PORV actuation. In both Test 7 using helium and Test 8 using nitrogen, the gas collection rate was immediately responsive to PORV actuation (Figure 5.5.44). Whereas approximately 3 scf of helium had been collected from the hot leg high-point vents during the first 2 hours of Test 7, and similarily 2 scf of nitrogen in Test 8, another 6 scf of the respective gases were collected during the second 2 hours with both the vents and PORV open continuously. The total volume collected was larger in Test 7 because the PORV was opened earlier than in Test 8, but the Test 8 collection rate remained slightly larger through the end of the period of inter-test comparison.

The inter-test similarities persisted through the later portions of the tests. In both tests, the cold leg suction piping refilled after leak closure but the cold leg discharge piping remained completely voided (Figure 5.5.45). The voids were apparently heavily laden with noncondensibles, inhibiting HPI heating through interaction with the warmer downcomer fluid. In both tests the lower downcomer and core inlet fluid cooled to less than 100F, virtually the HPI supply temperature, while the core exit fluid remained 70F subcooled at approximately 380F (Figure 5.5.46). At the end of the period of inter-test comparison, the primary and steam generator secondary pressures in both tests were approximately 400 psia and 100 psia (Figure 5.5.41). In summary, test 7 using nitrogen and test 8 using helium were generally quite similar. There were no major inter-test differences which were attributable to the particular species of NCG.

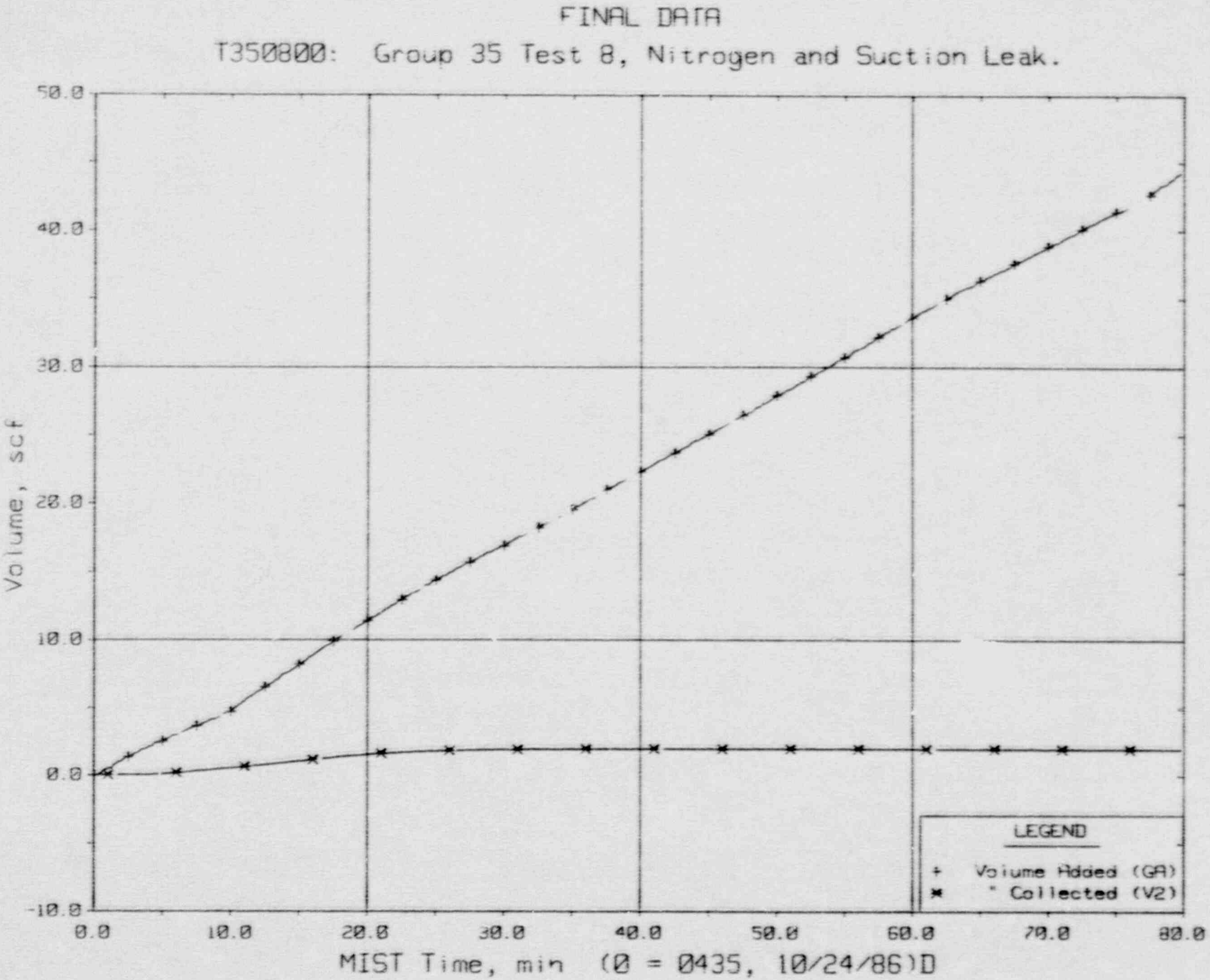

Figure 5.5.1 Noncondensibles Gas Volumes

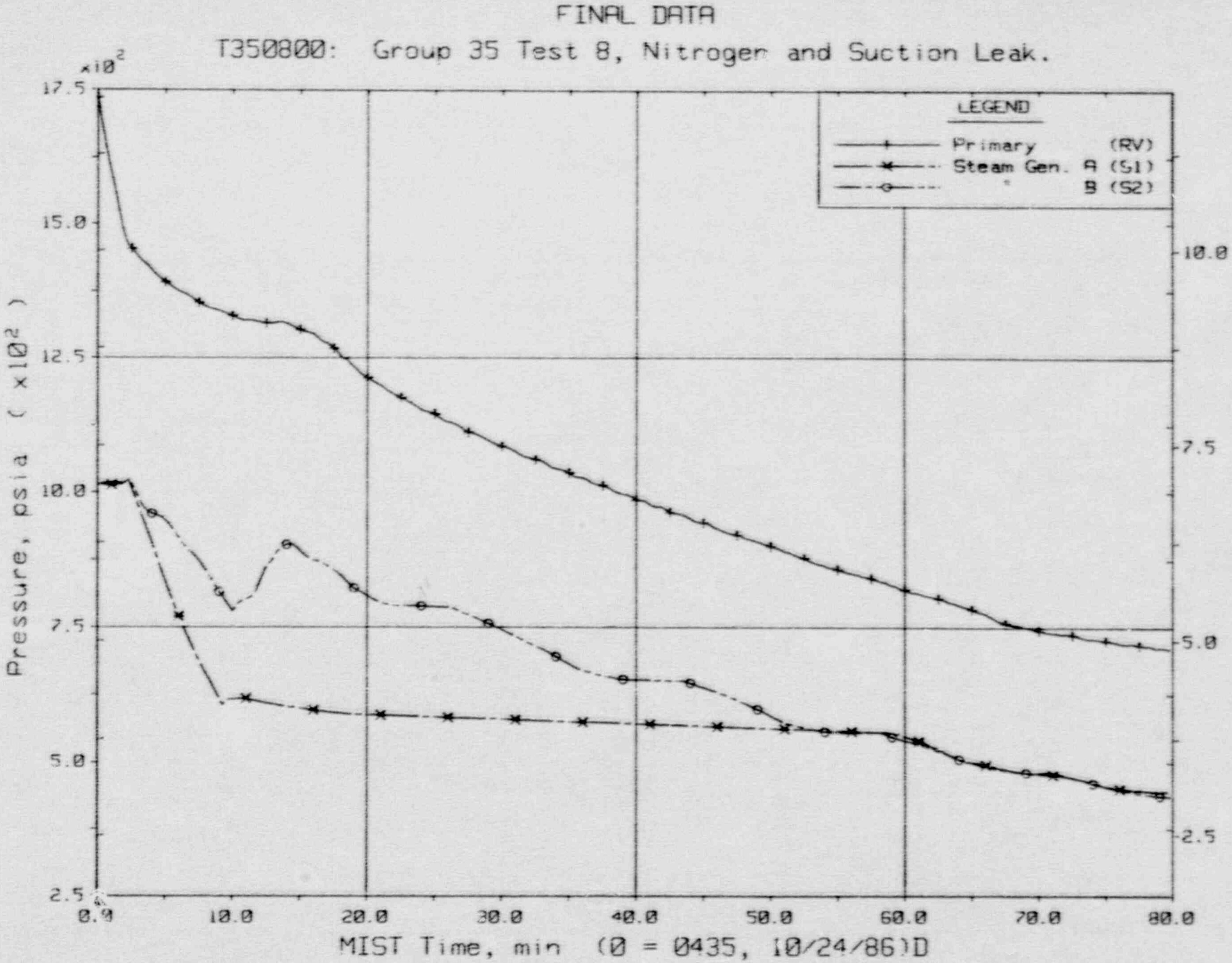

Figure 5.5.2 Primary and Secondary System Pressures (GPOIs)

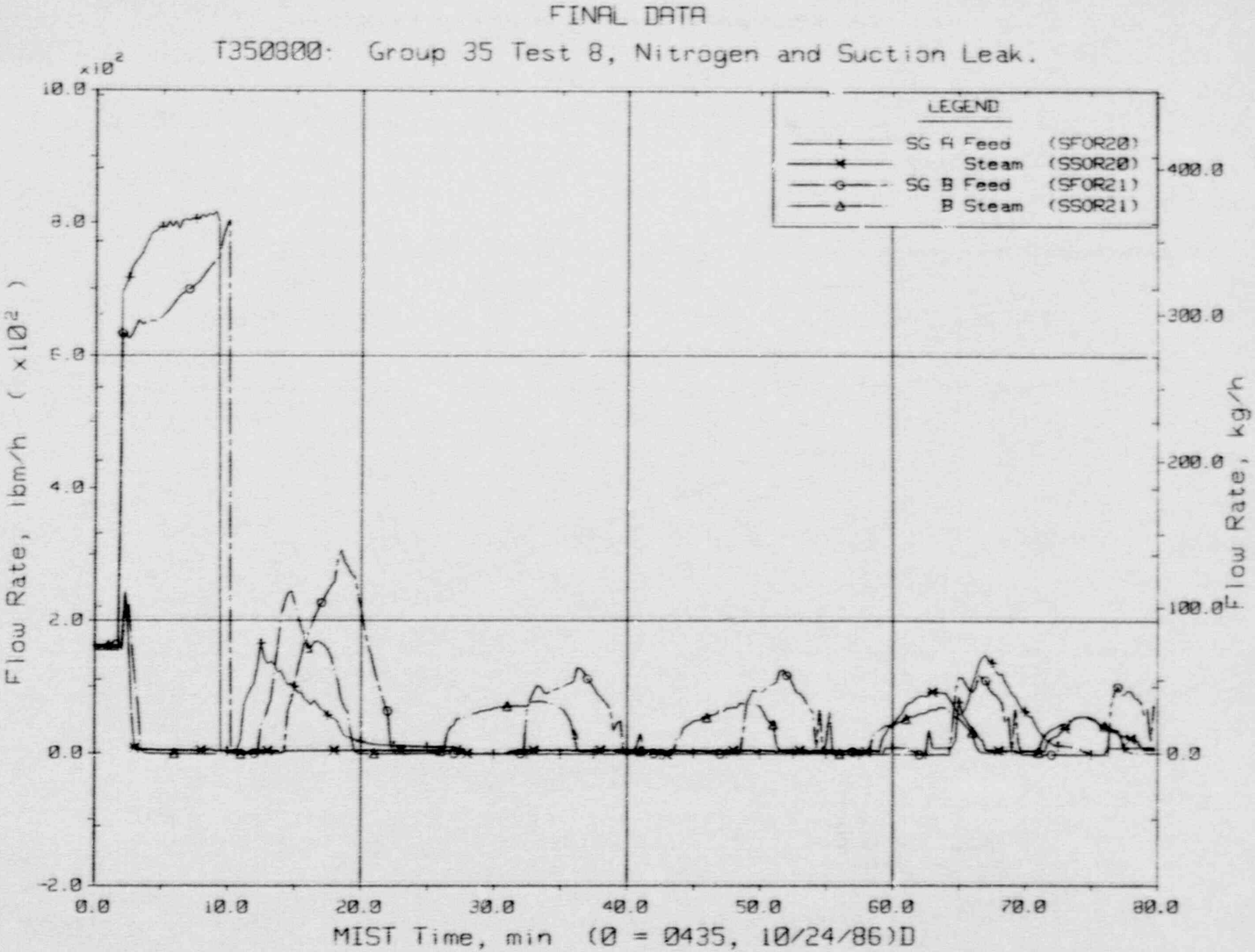

Figure 5.5.3 Steam Generator Secondary Flow Rates

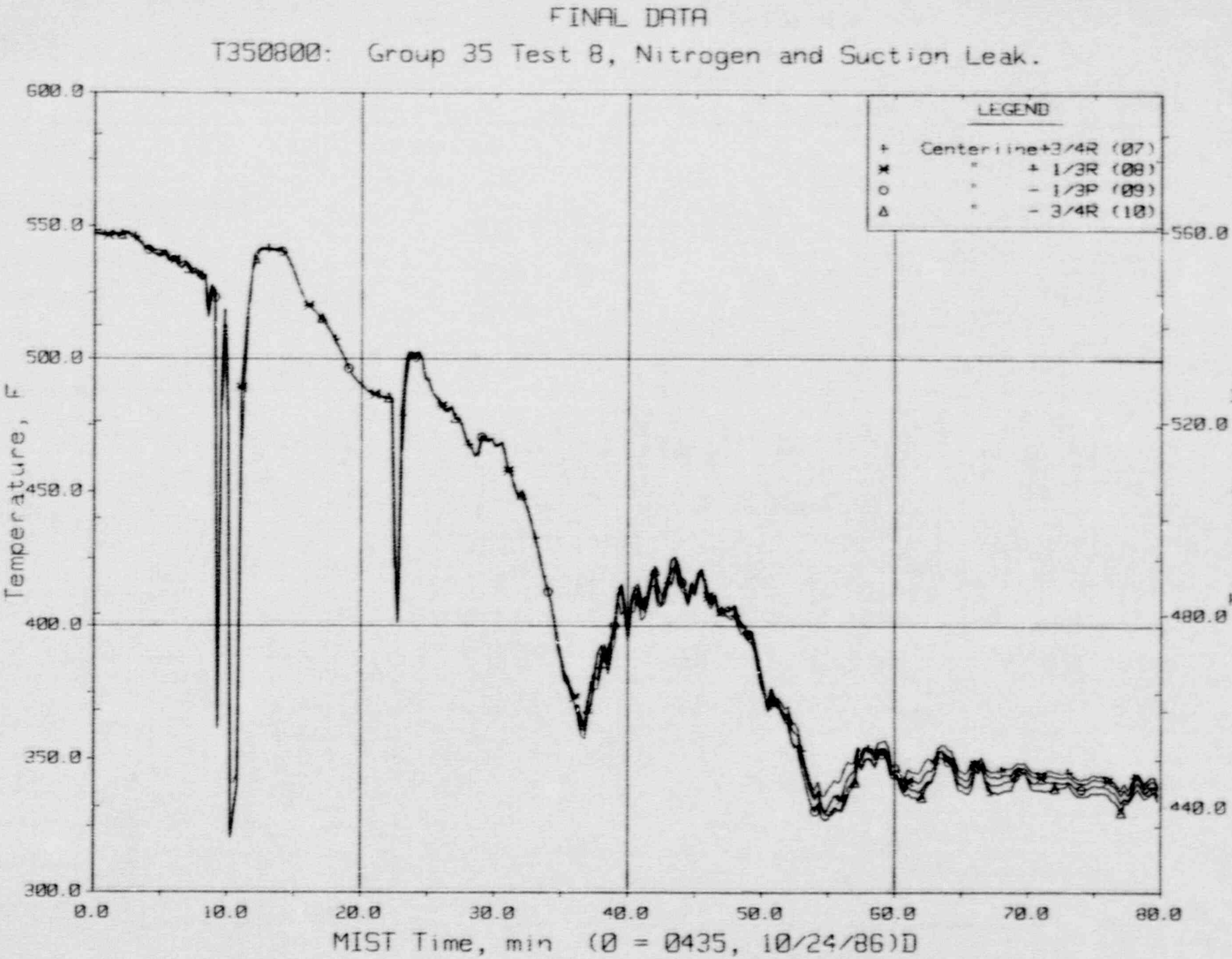

Figure 5.5.4 Cold Leg A2 Pump Discharge Rake Fluid Temperatures (25 ft, C3TCs)

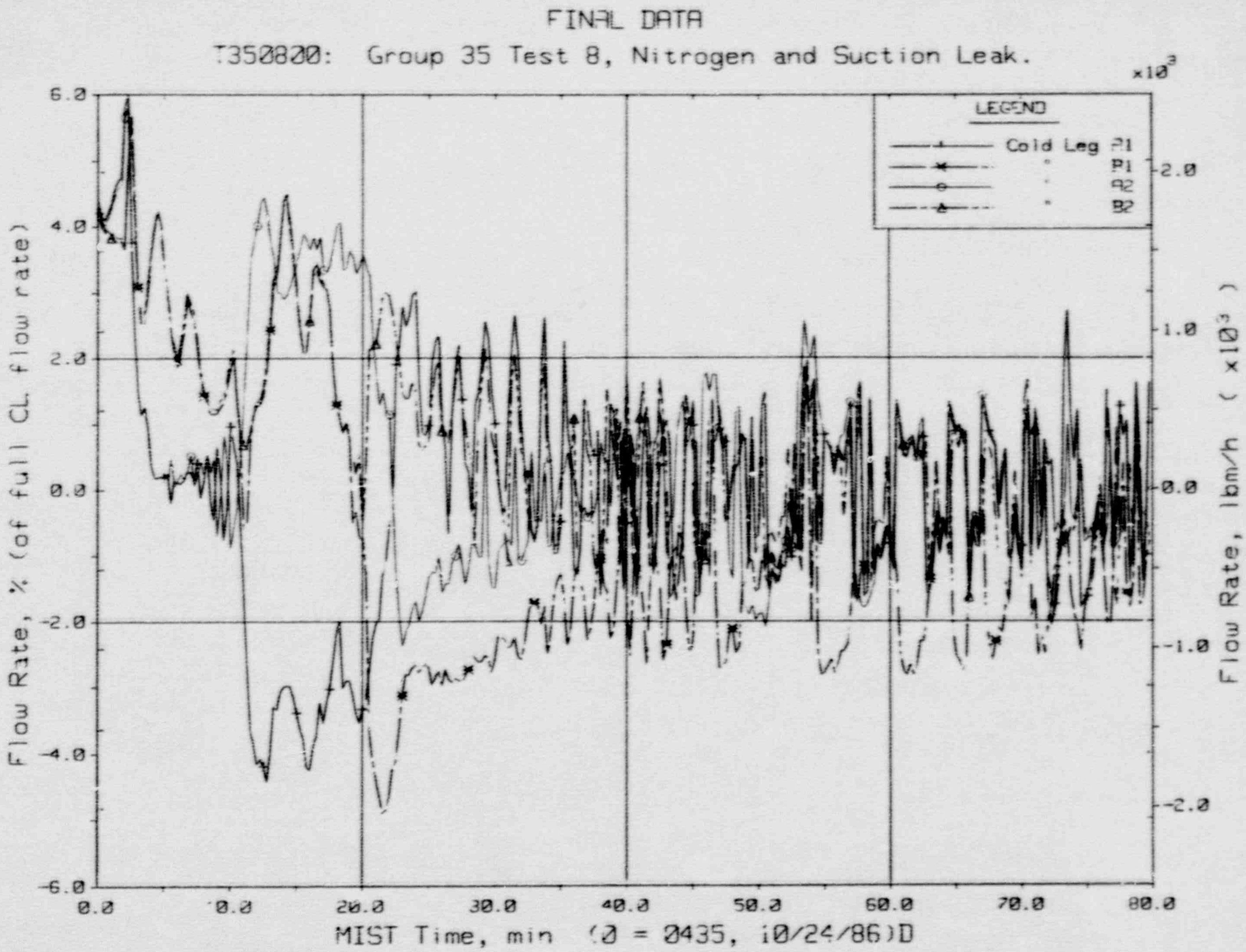

Figure 5.5.5 Cold Leg (Venturi) Flow Rates

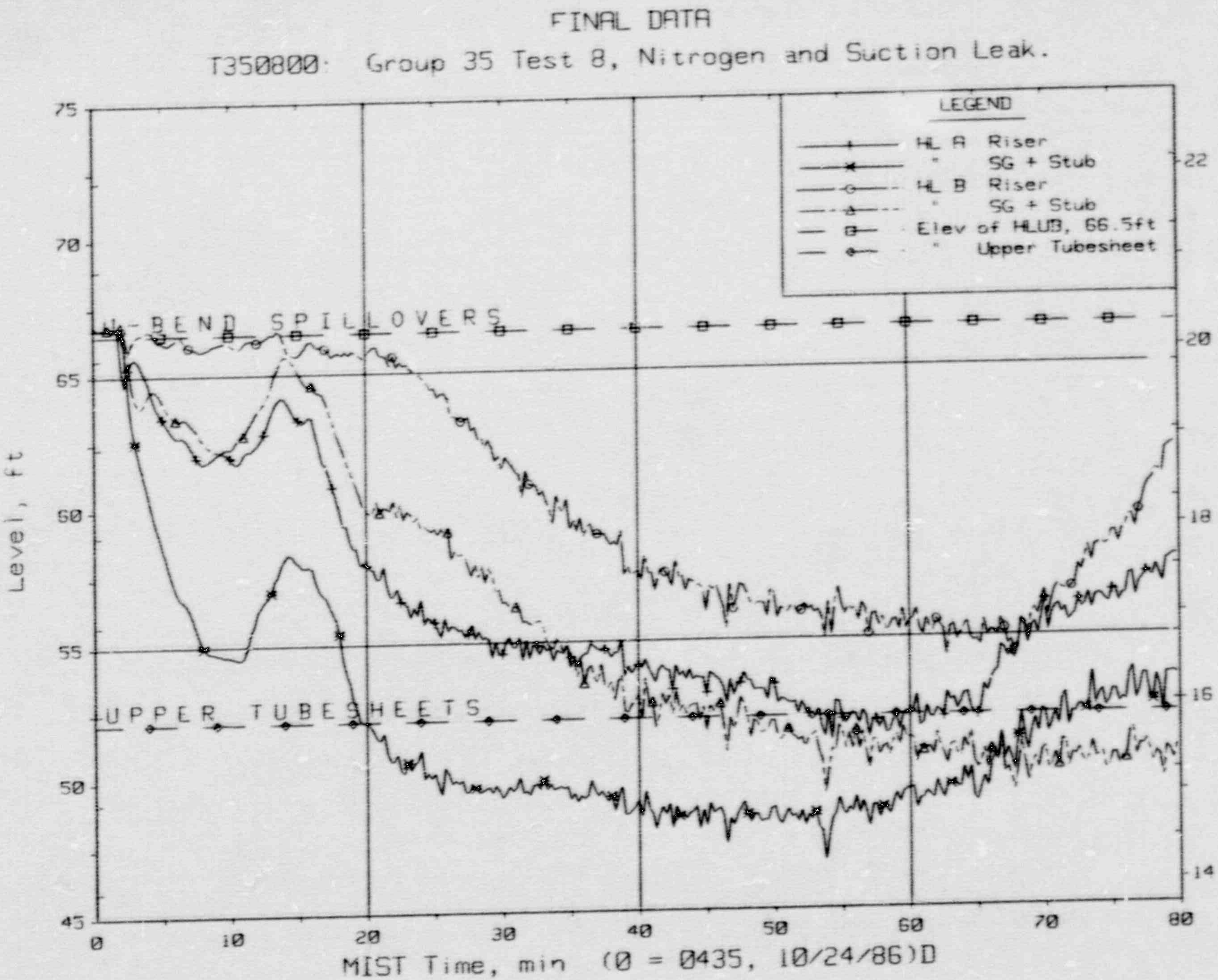

Figure 5.5.6 Hot Leg Riser and Stub Collapsed Liquid Levels

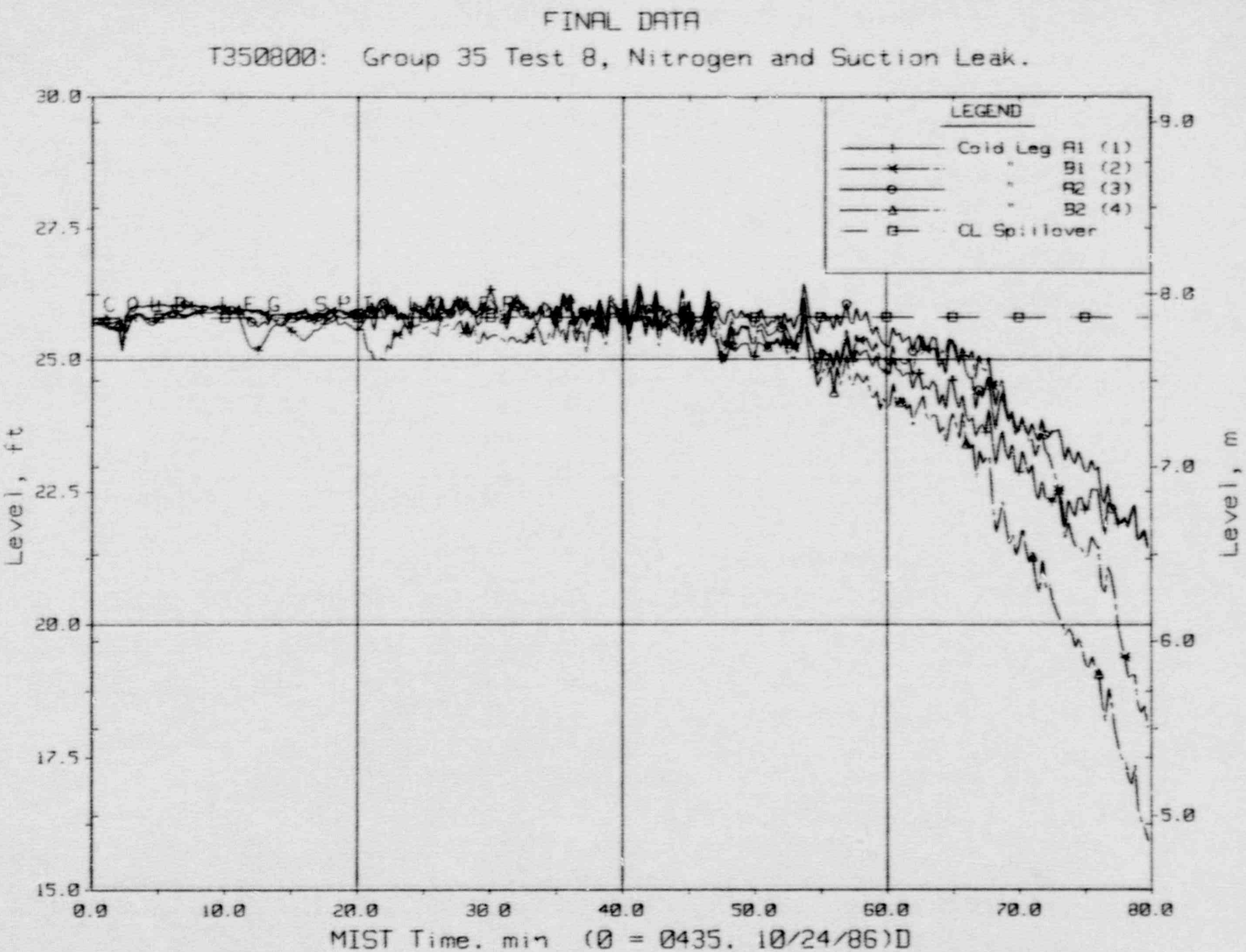

Figure 5.5.7 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

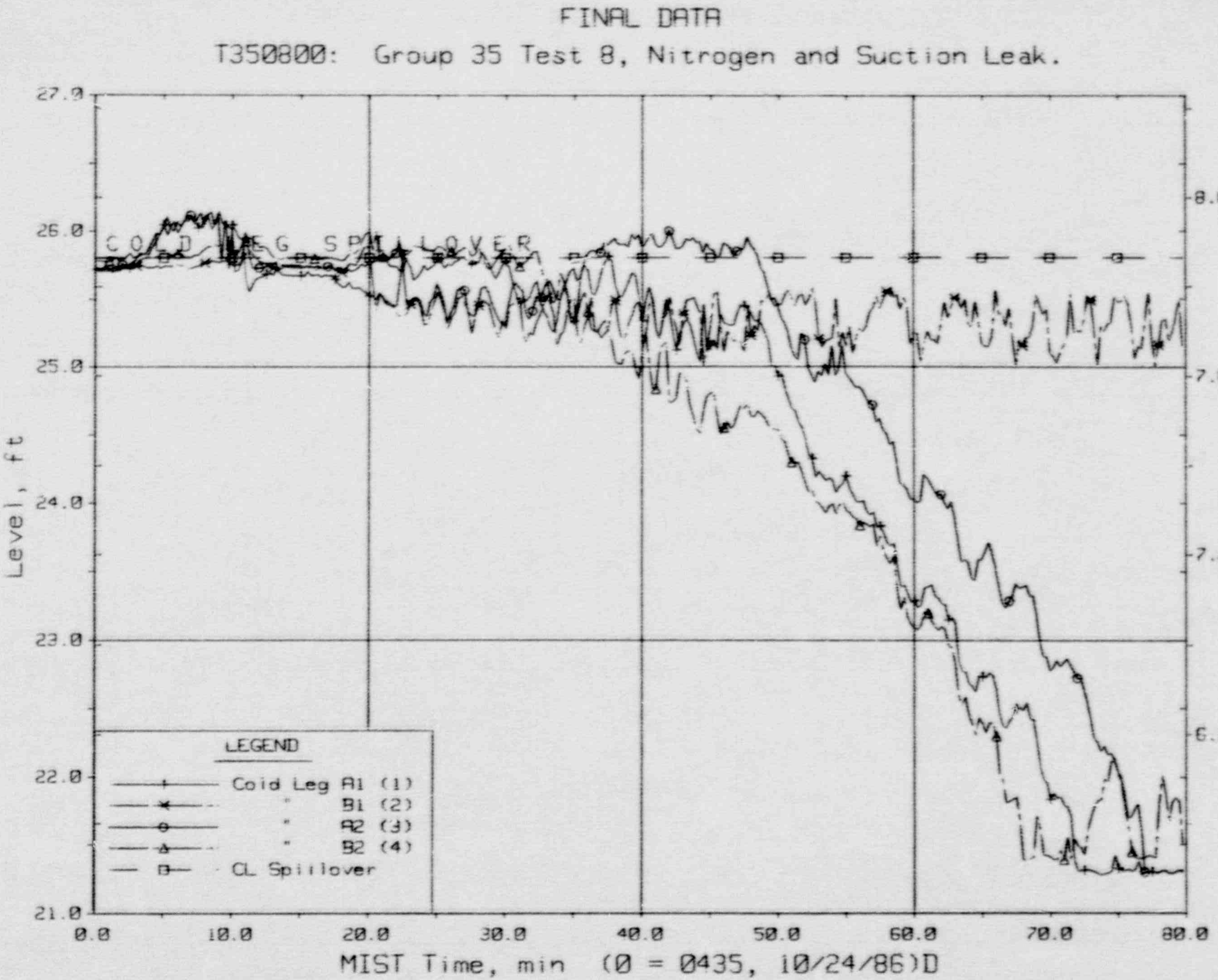

Figure 5.5.8 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

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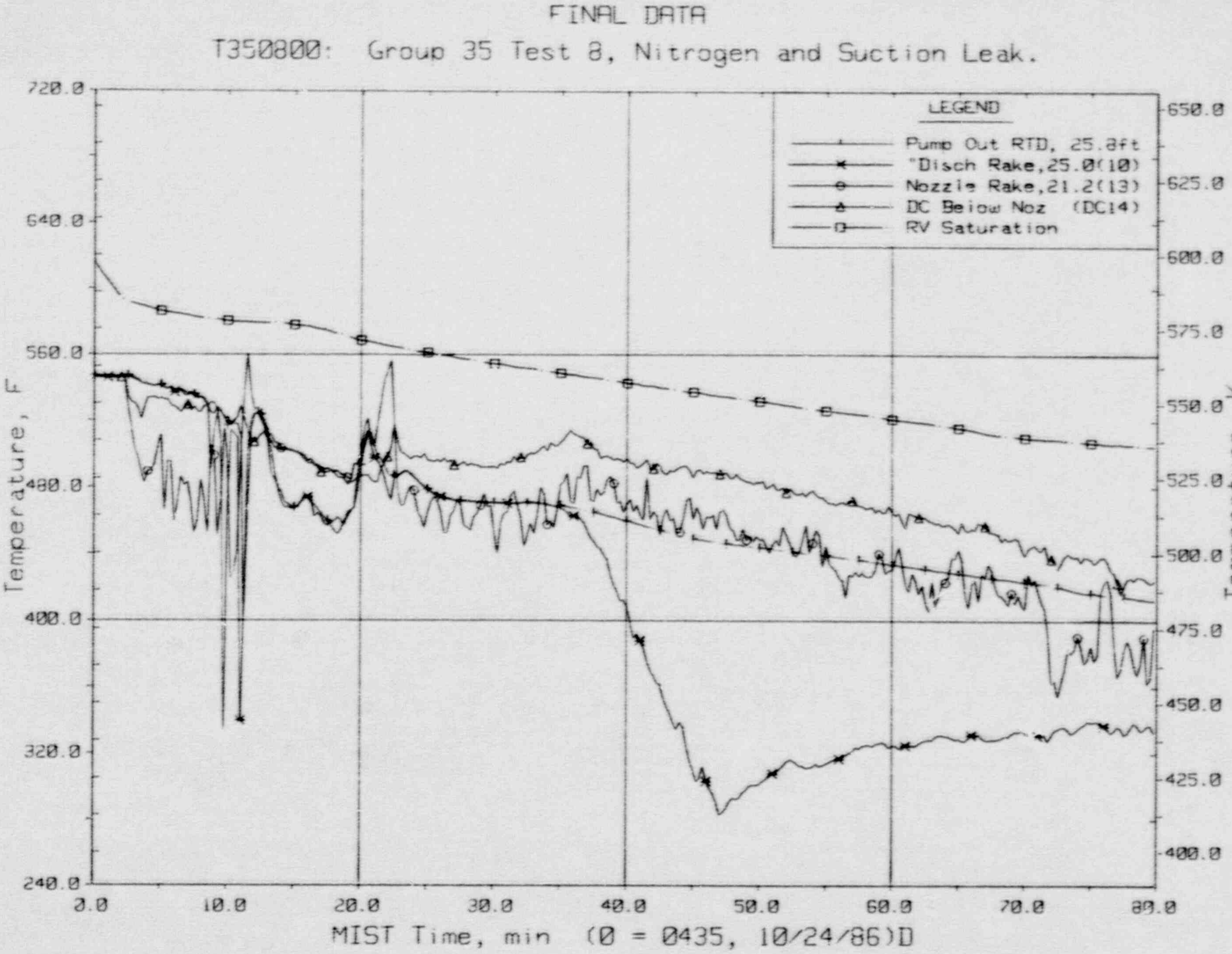

Figure 5.5.9 Cold Leg A1 Discharge Fluid Temperatures (CITCs)

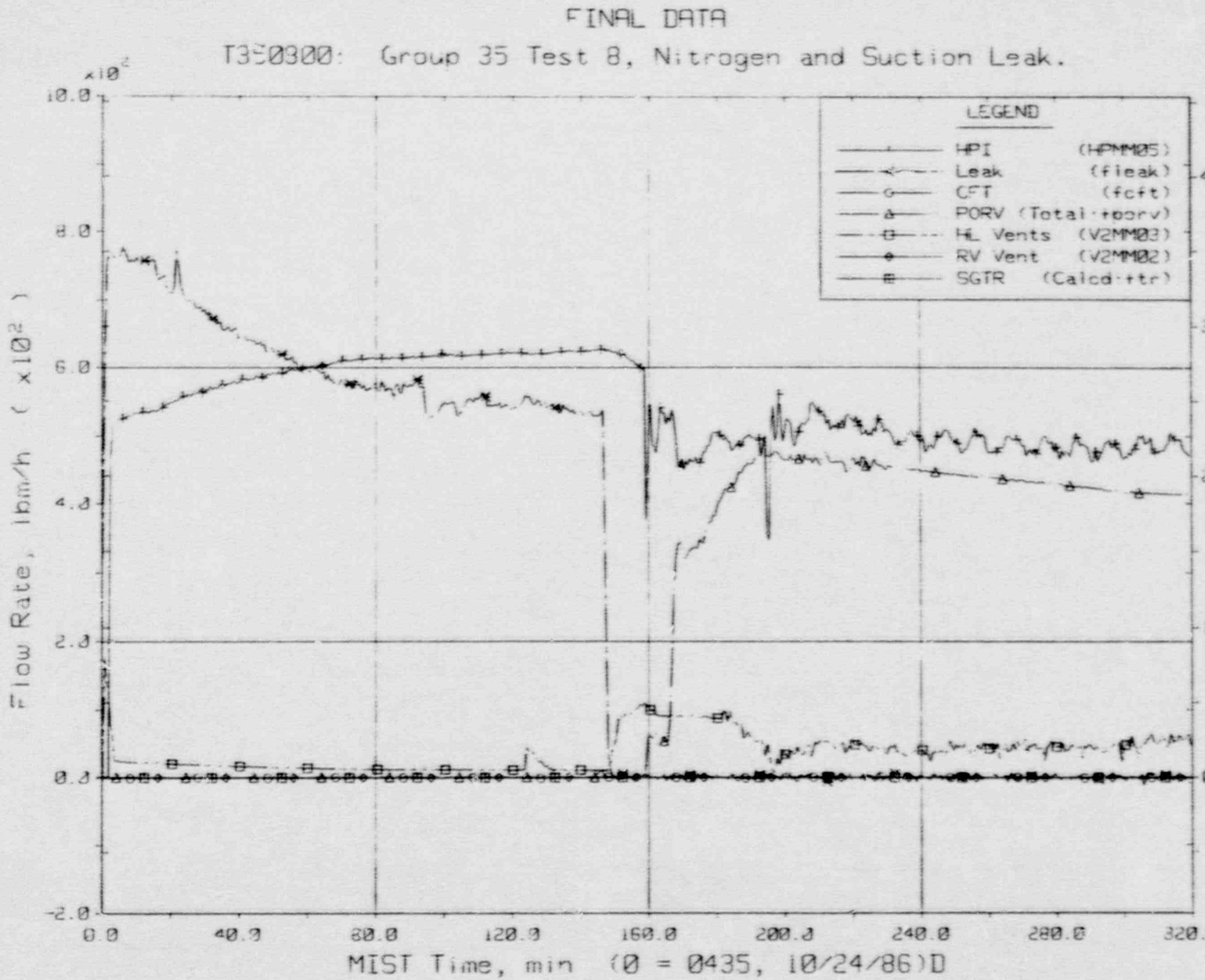

Figure 5.5.10 Primary System Boundary Flow Rates

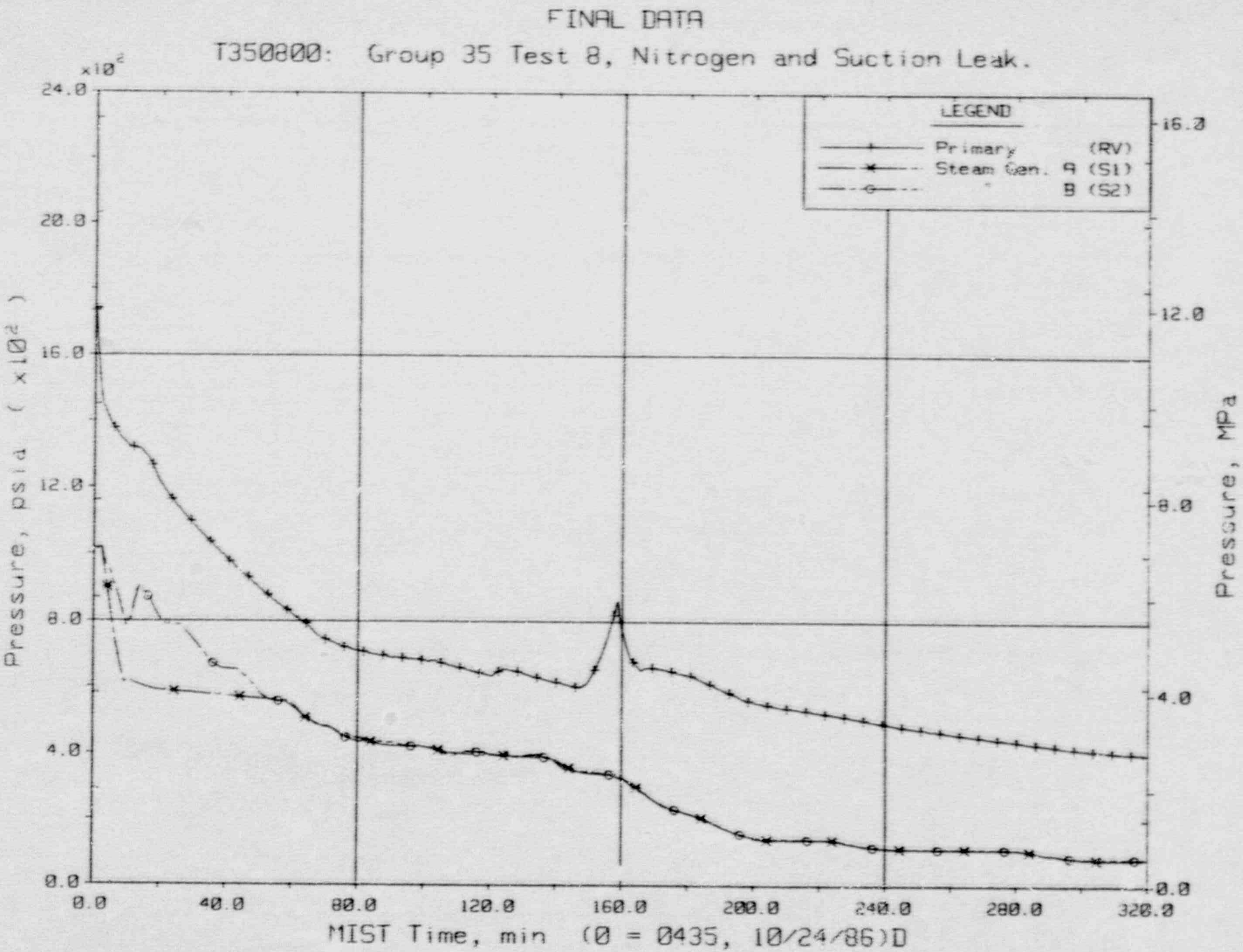

Figure 5.5.11 Primary and Secondary System Pressures (GP01s)

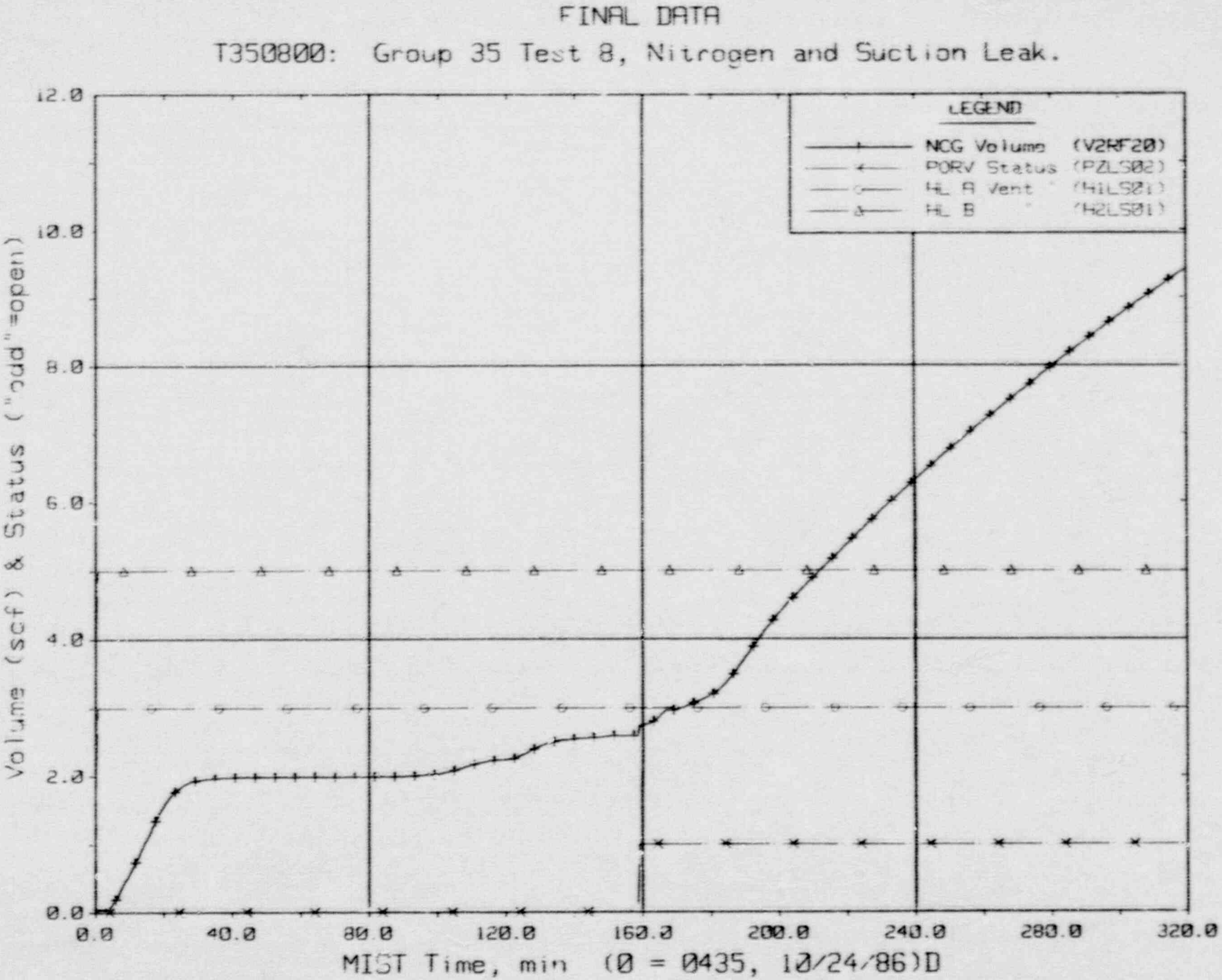

Figure 5.5.12 Noncondensibles Collected and Discharge Valve Status

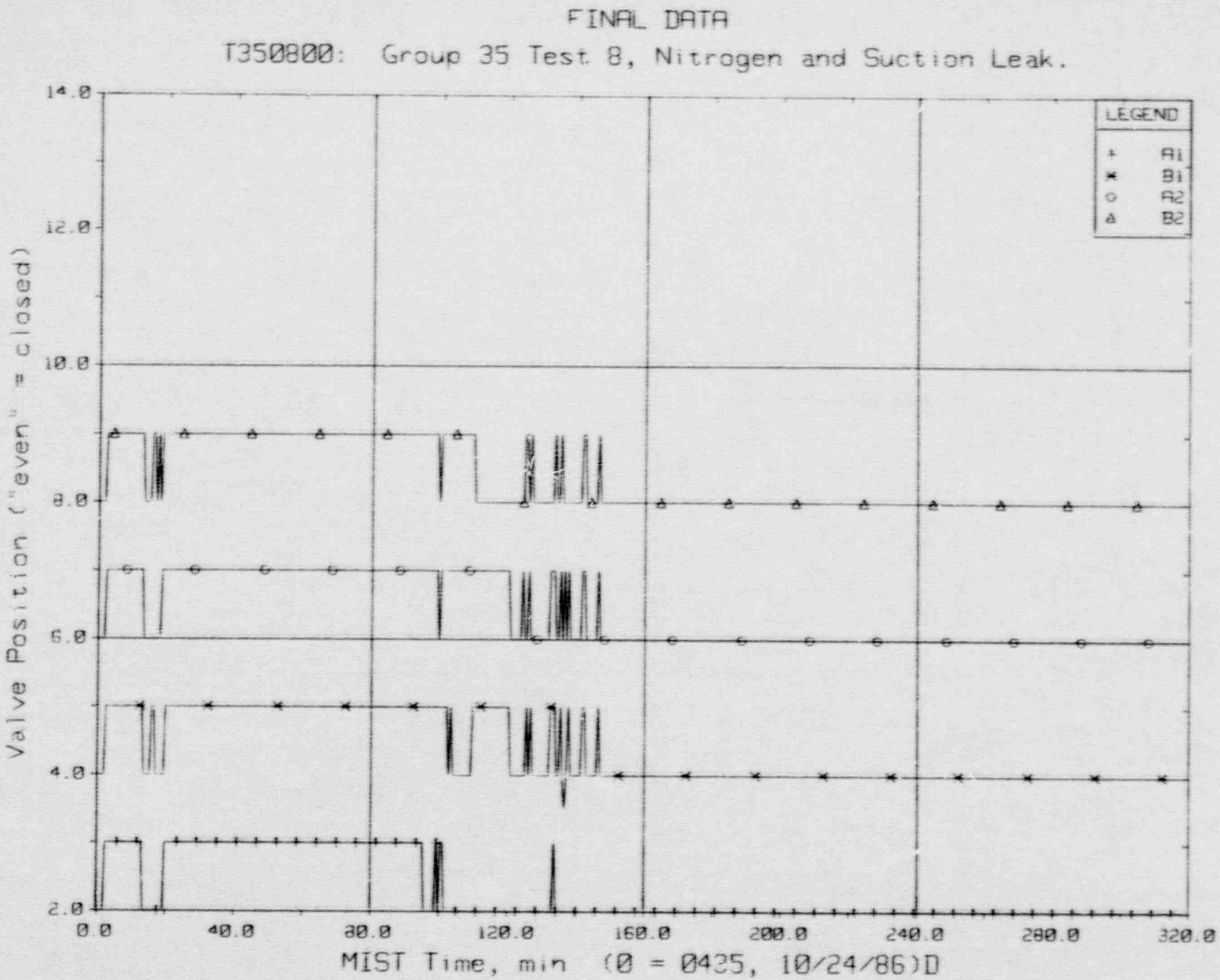

Figure 5.5.13 Reactor Vessel Vent Valve Positions

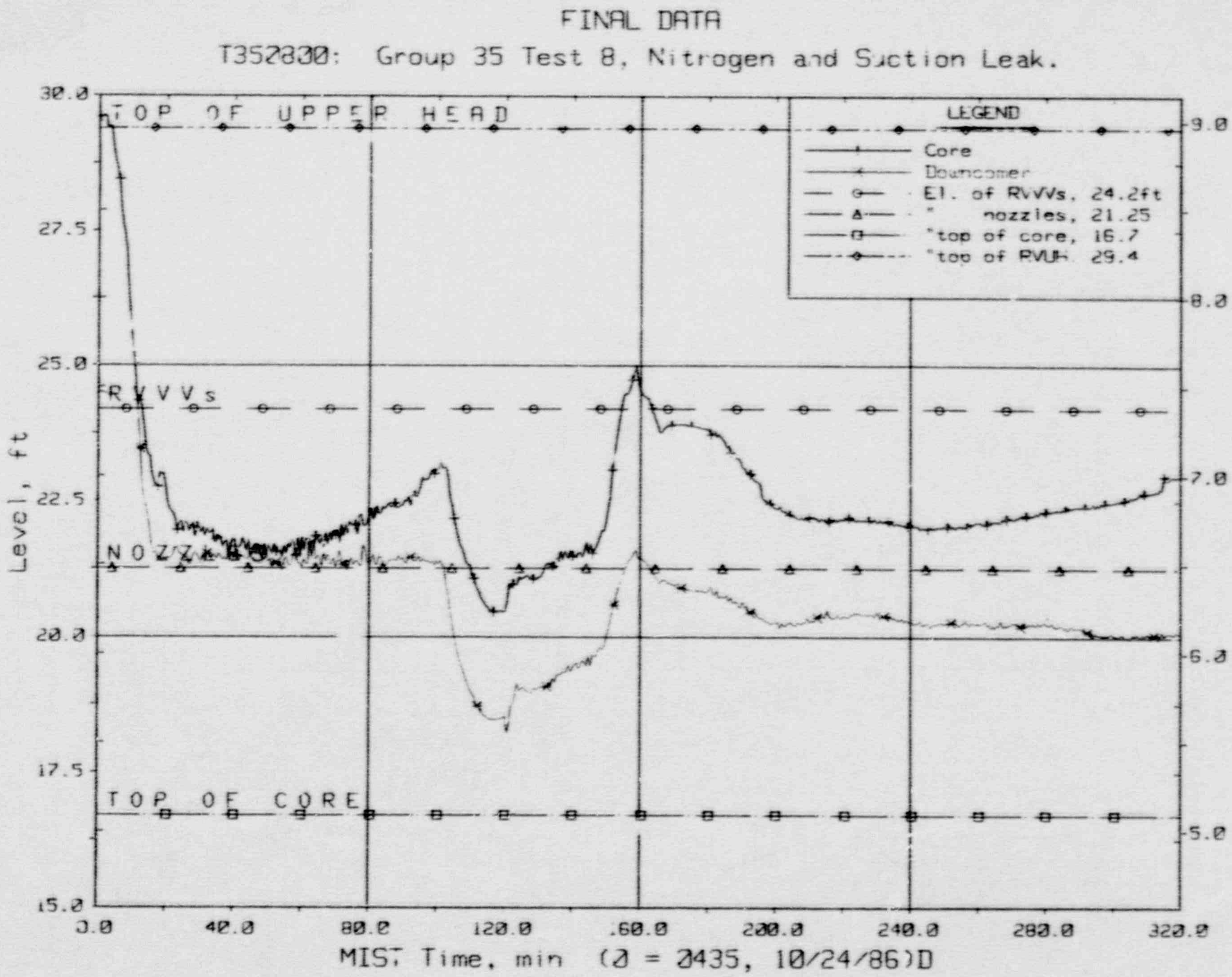

Figure 5.5.14 Core Region Collapsed Liquid Levels

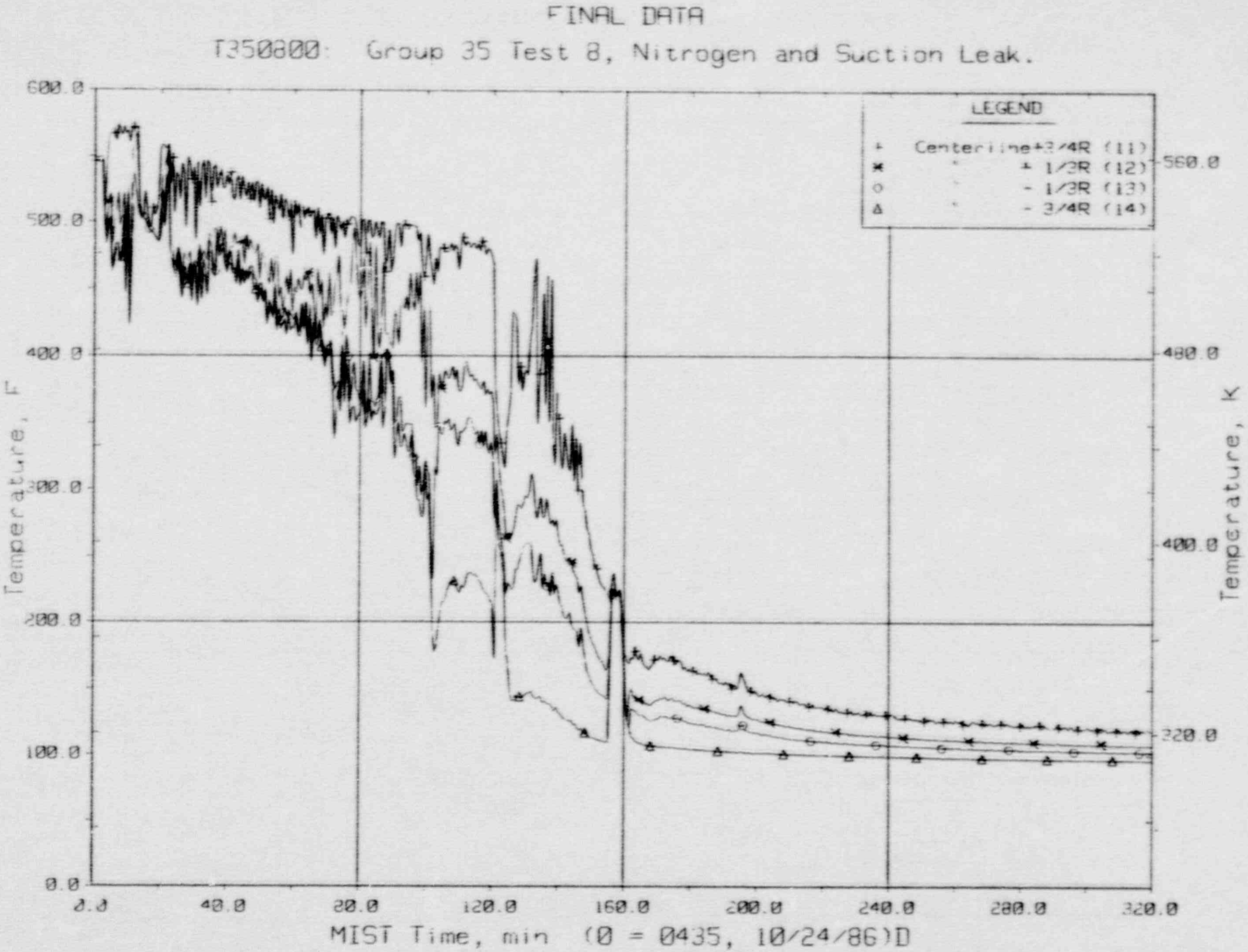

Figure 5.5.15 Cold Leg A1 Nozzle Rake Fluid Temperatures (21.2 ft, C1TCs)

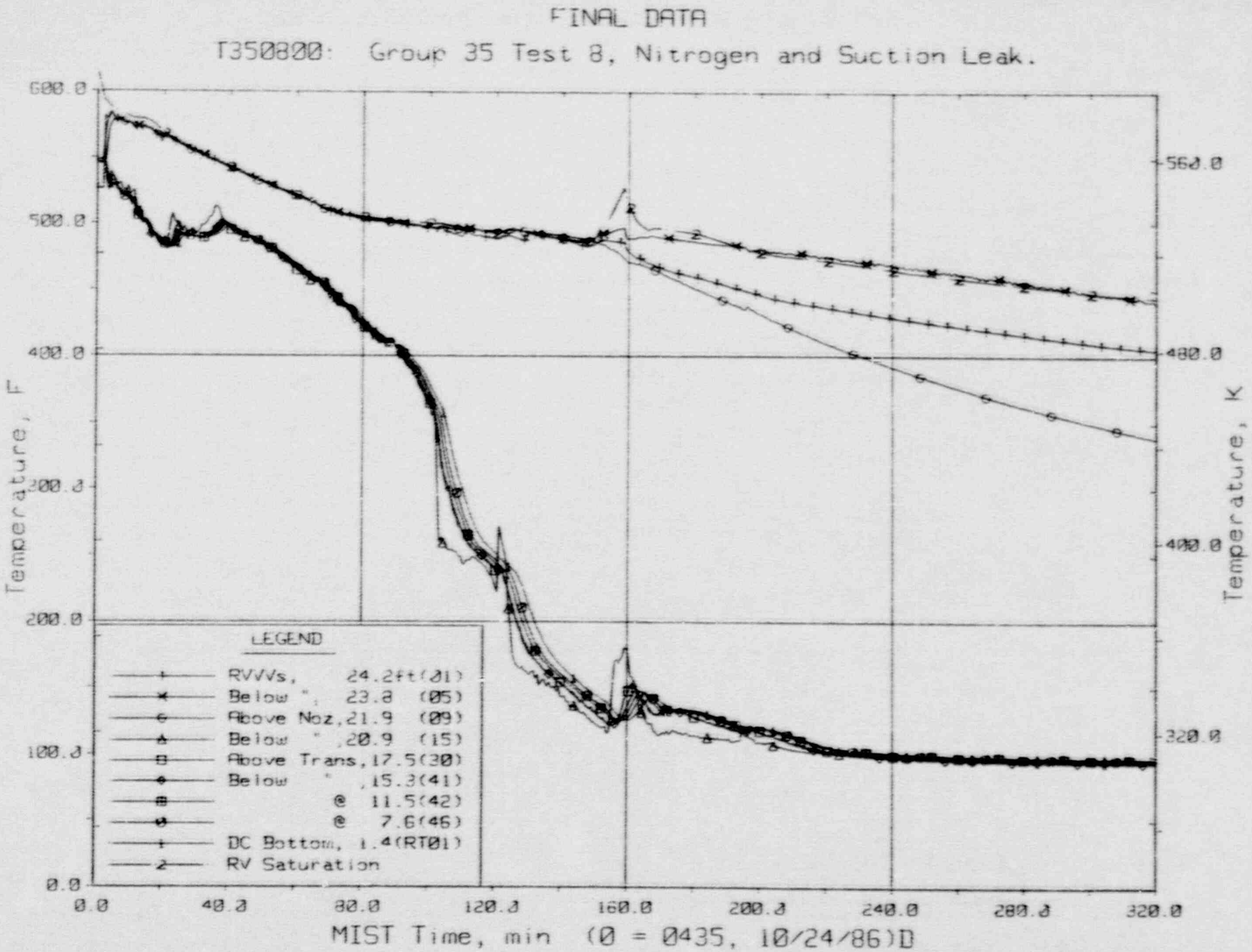

Figure 5.5.16 Downcomer Quadrant A1 Fluid Temperatures (DCTCs)

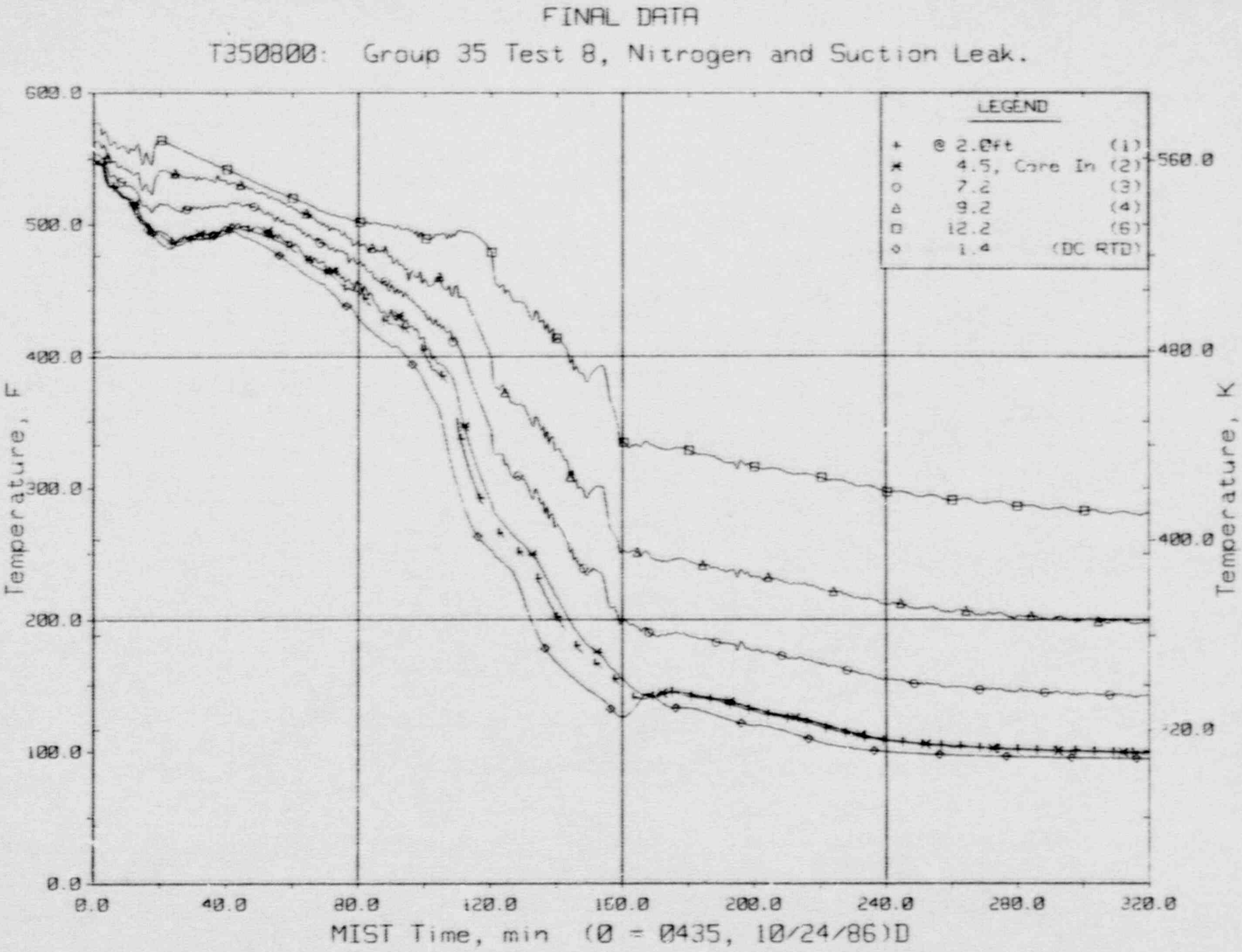

Figure 5.5.17 Reactor Vessel Lower-Elevation Fluid Temperatures (RVTCs)

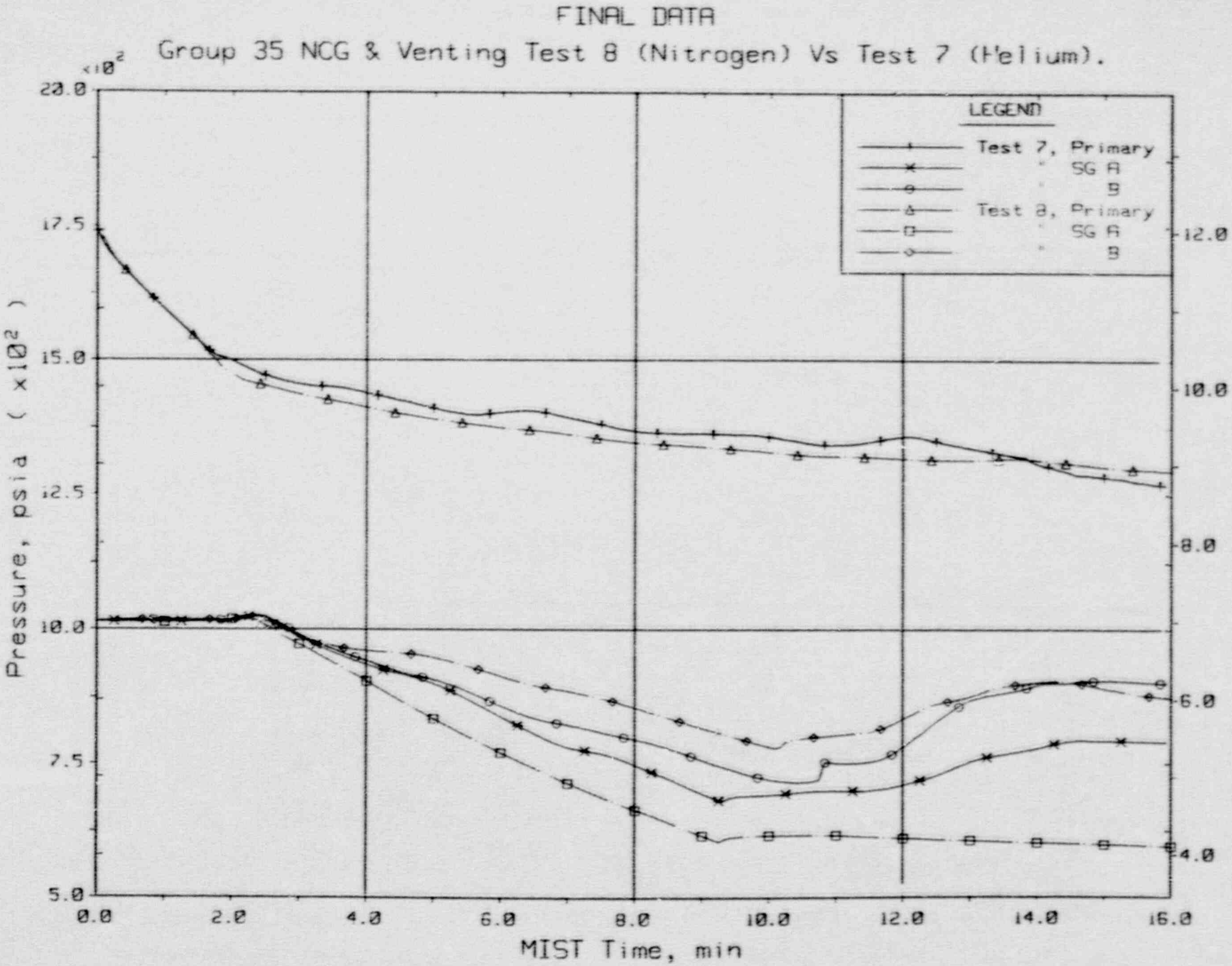

Figure 5.5.18 Primary and Secondary System Pressures (GPOIs)

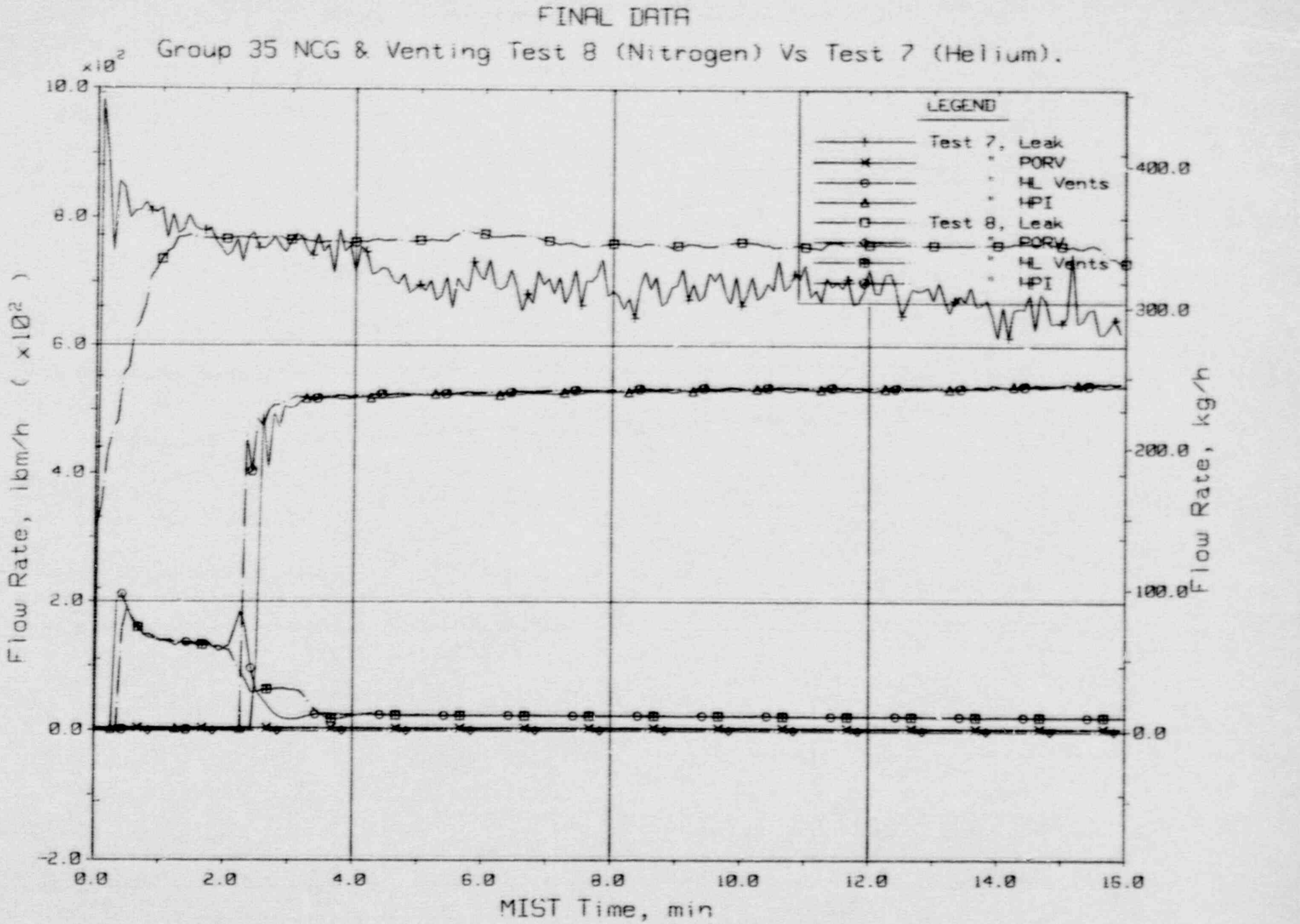

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Figure 5.5.19 Primary System Boundary Mass Flow Rates

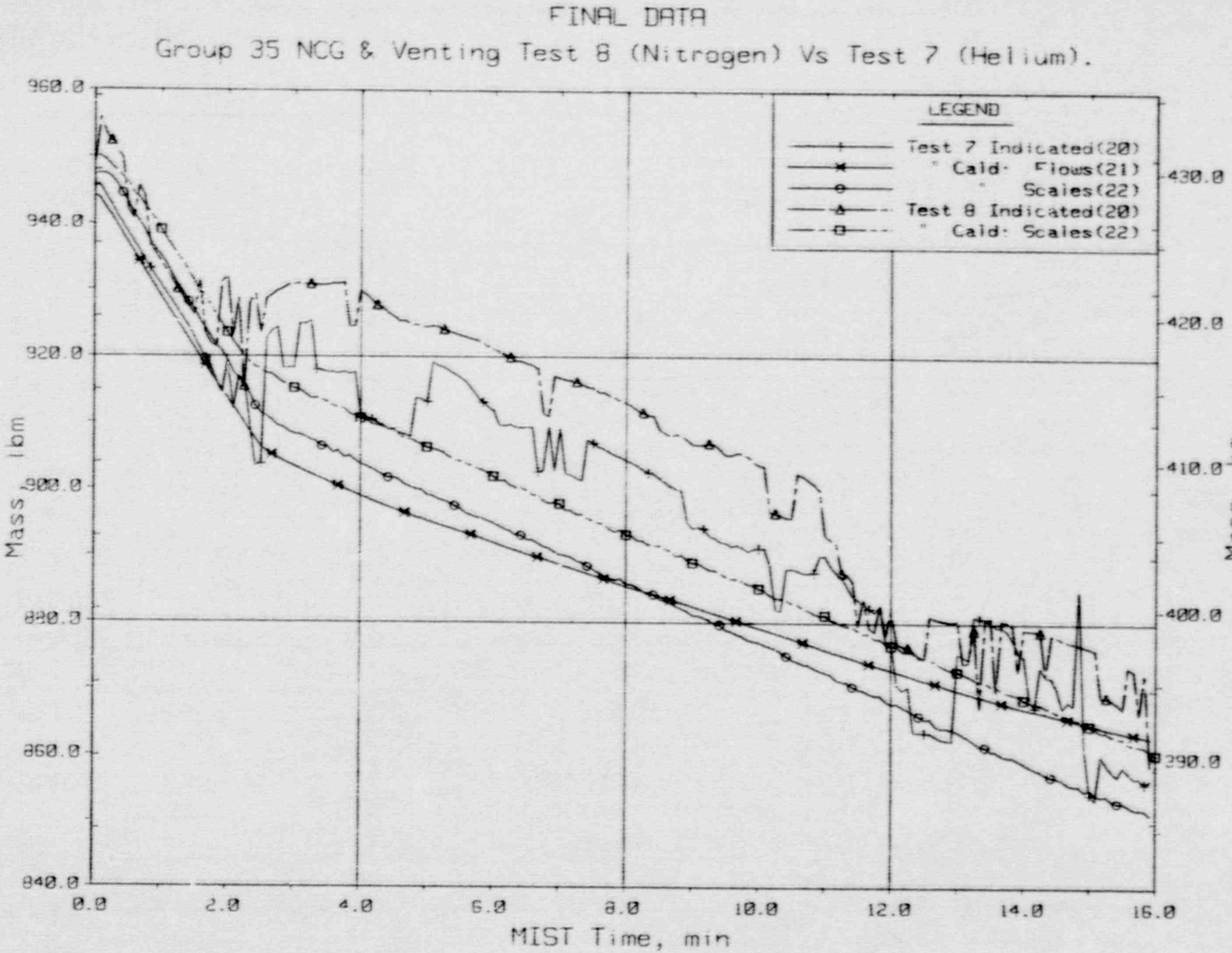

Figure 5.5.20 Primary System Total Fluid Mass (PLMLs)

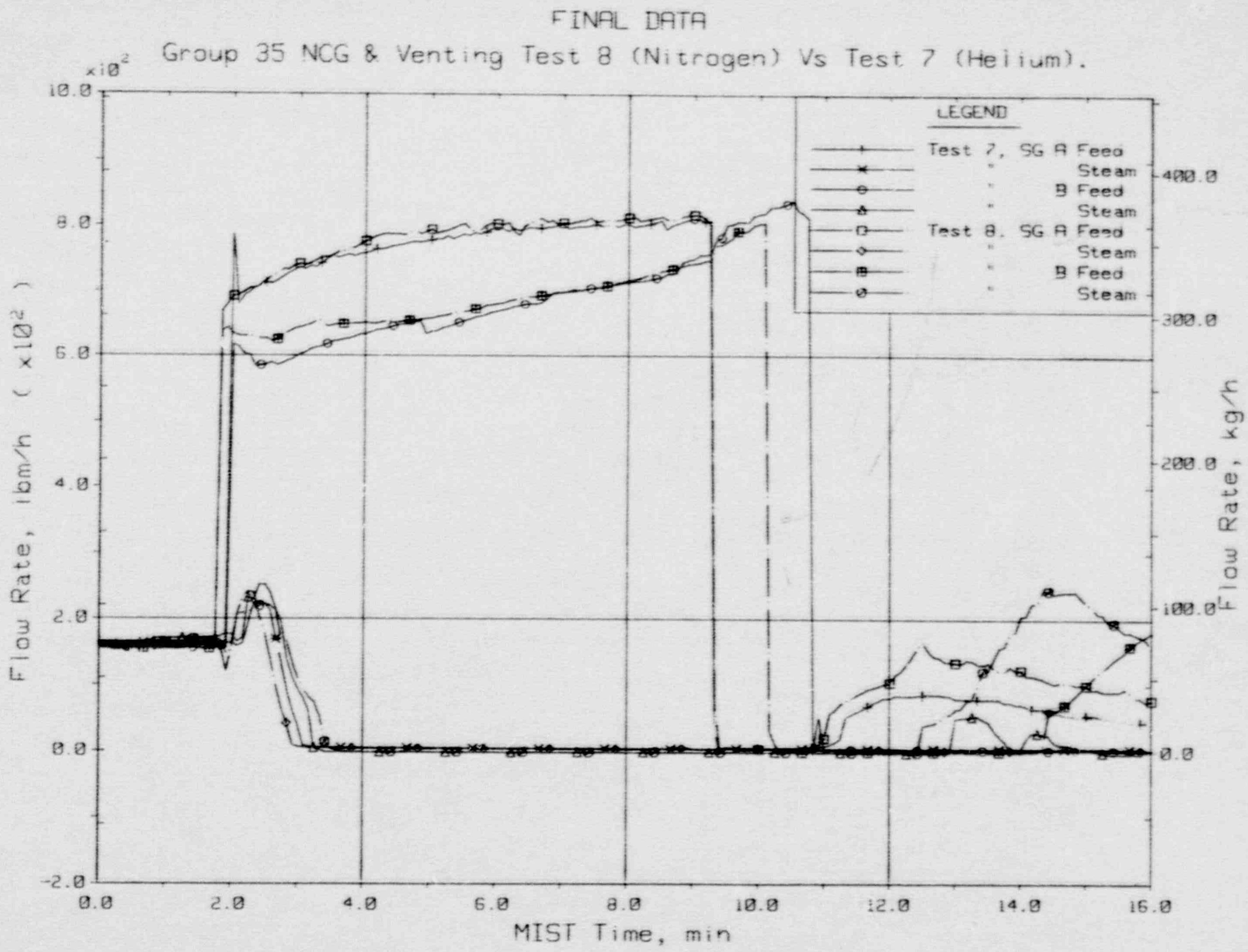

Figure 5.5.21 Steam Generator Secondary Flow Rates

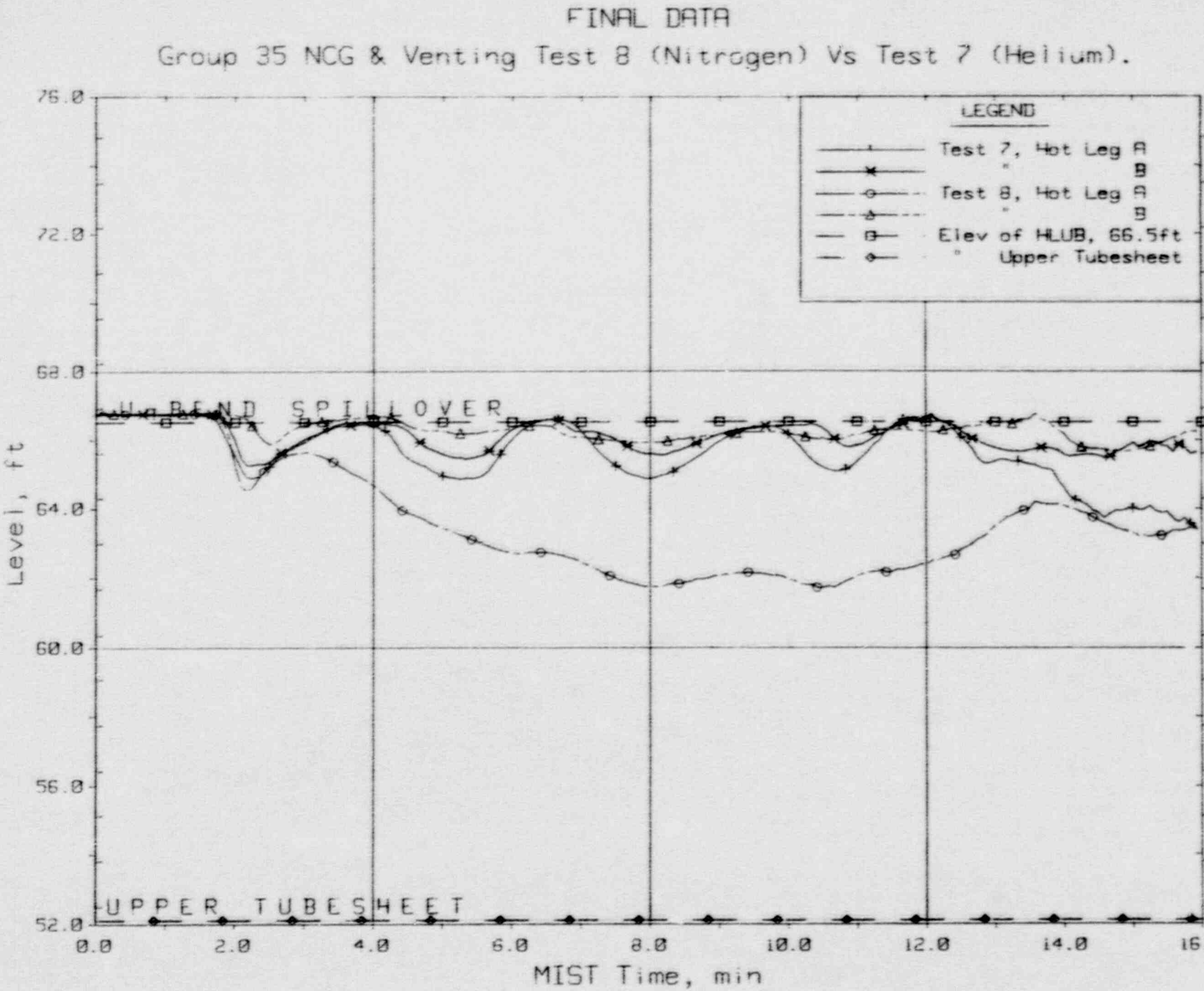

Figure 5.5.22 Hot Leg Riser Collapsed Liquid Levels

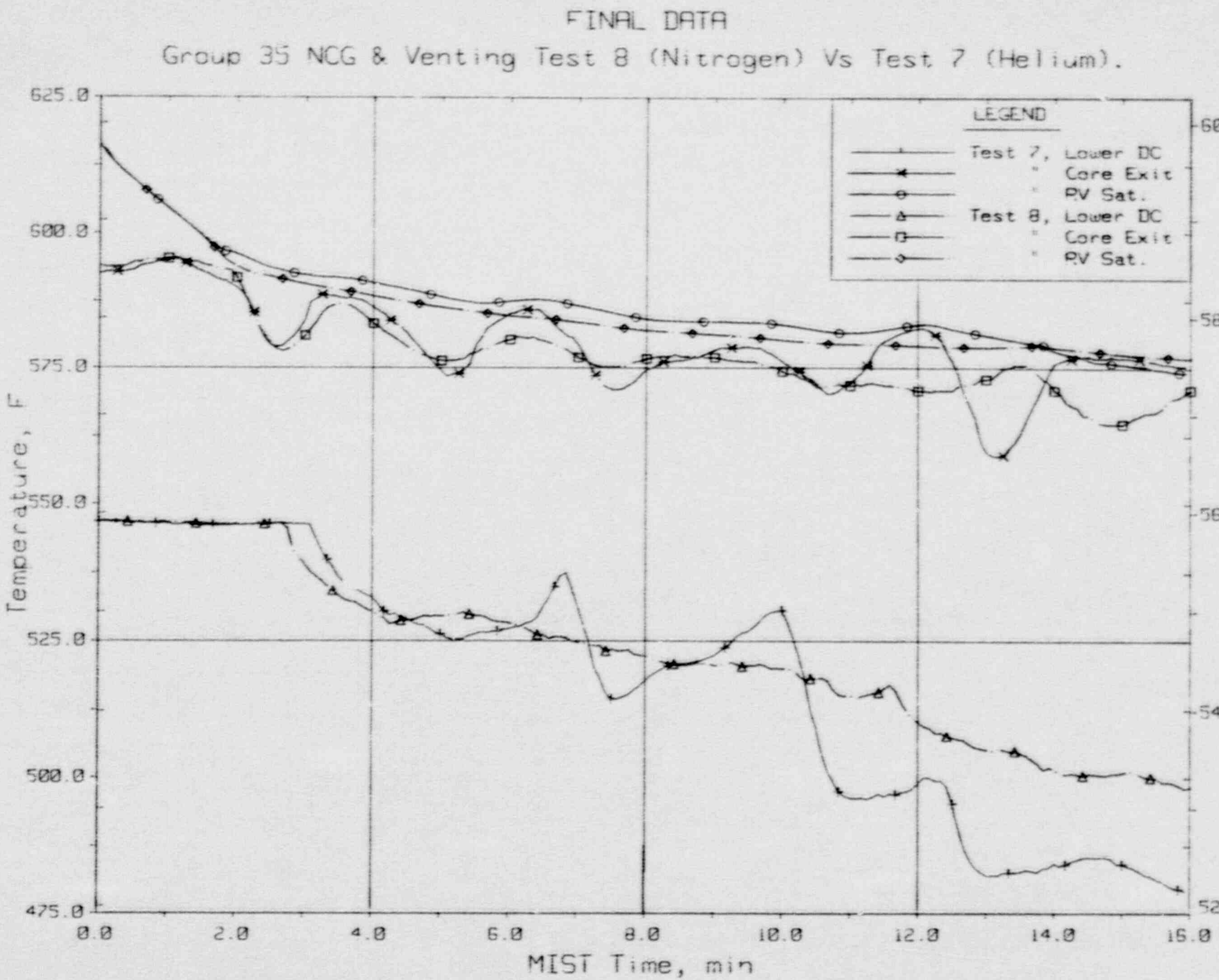

Figure 5.5.23 Core Bracketing Fluid Temperatures

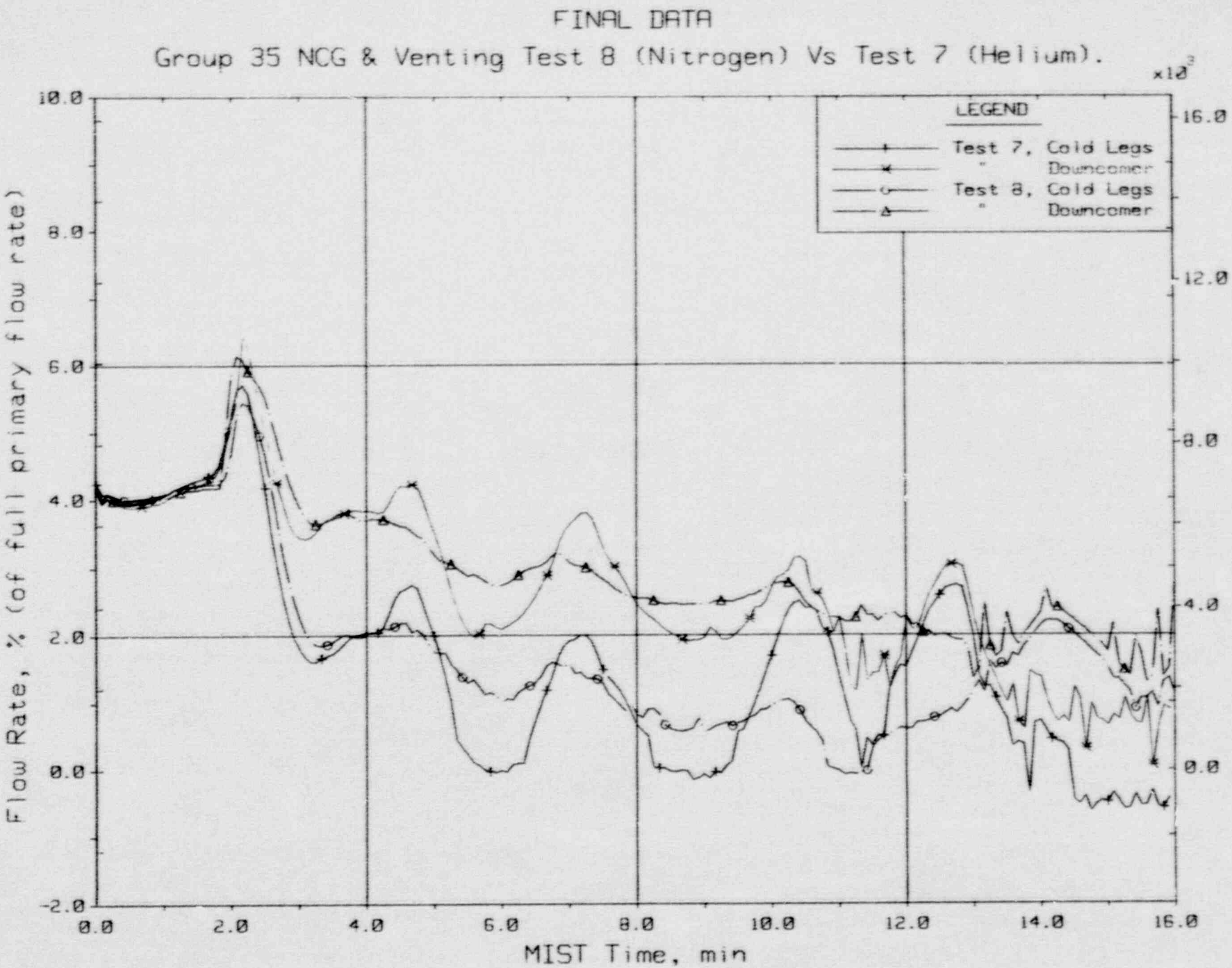

Figure 5.5.24 Primary System Venturi Flow Rates

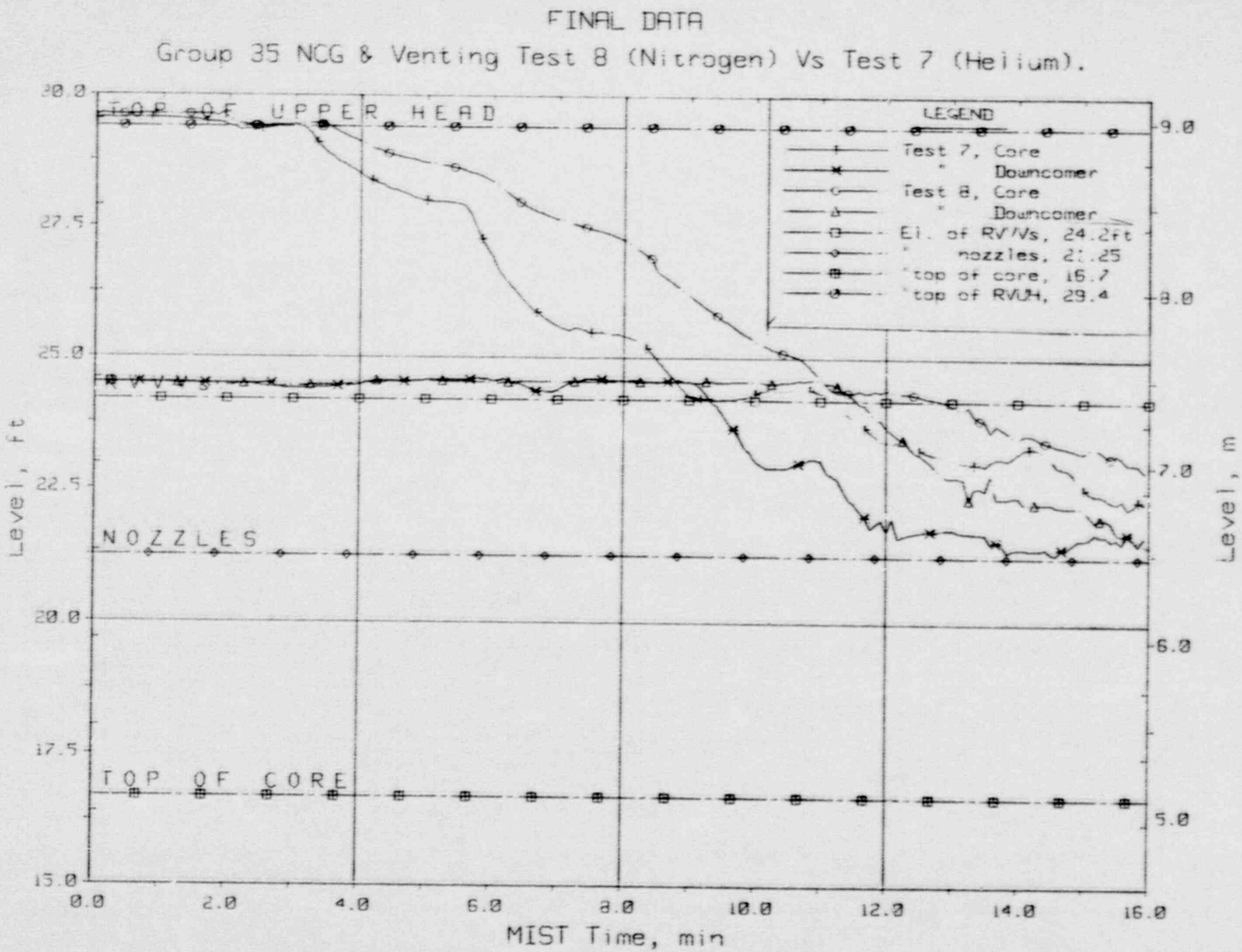

Figure 5.5.25 Core Region Collapsed Liquid Levels

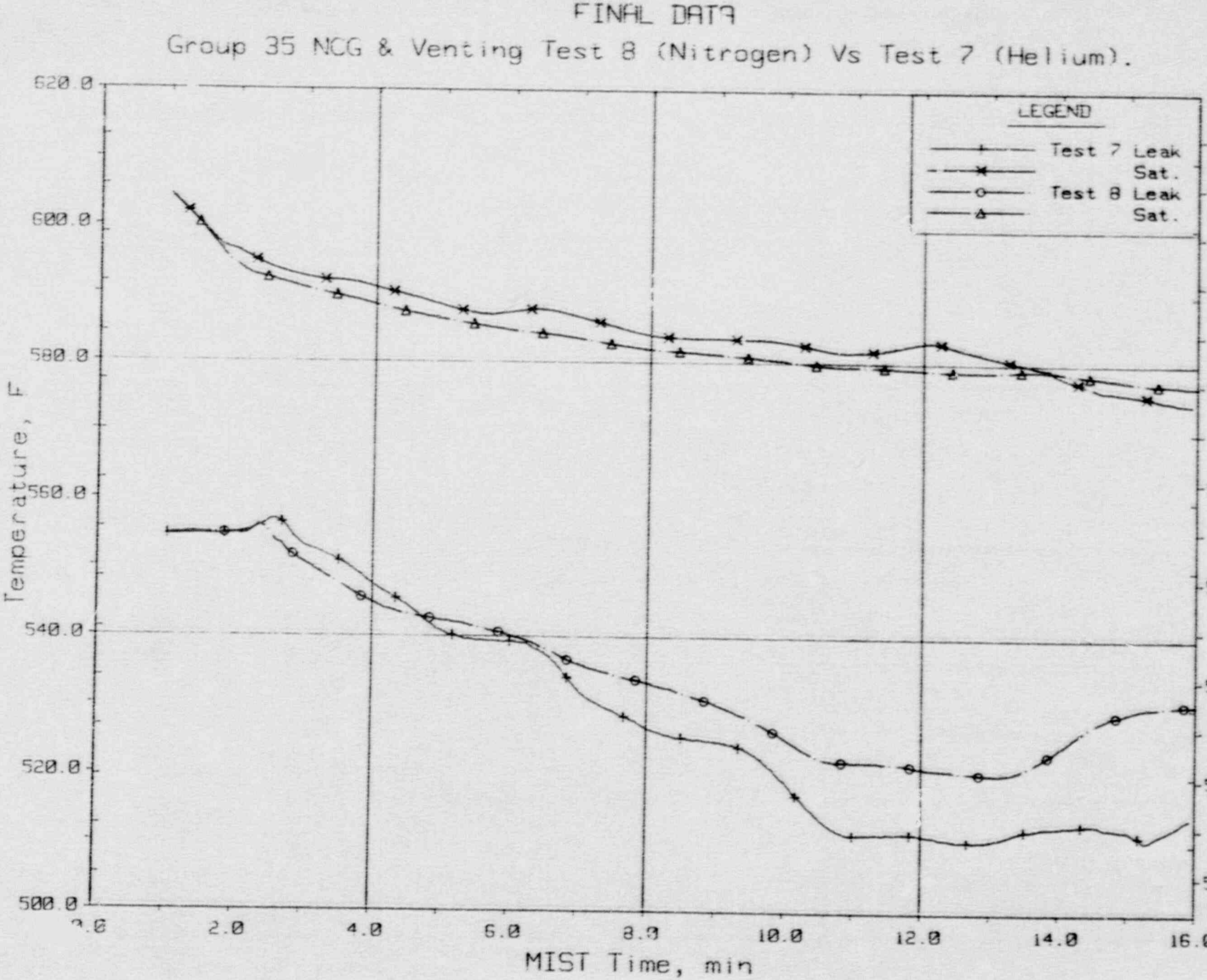

Figure 5.5.26 Leak and HPI Fluid Temperatures (TC01s)

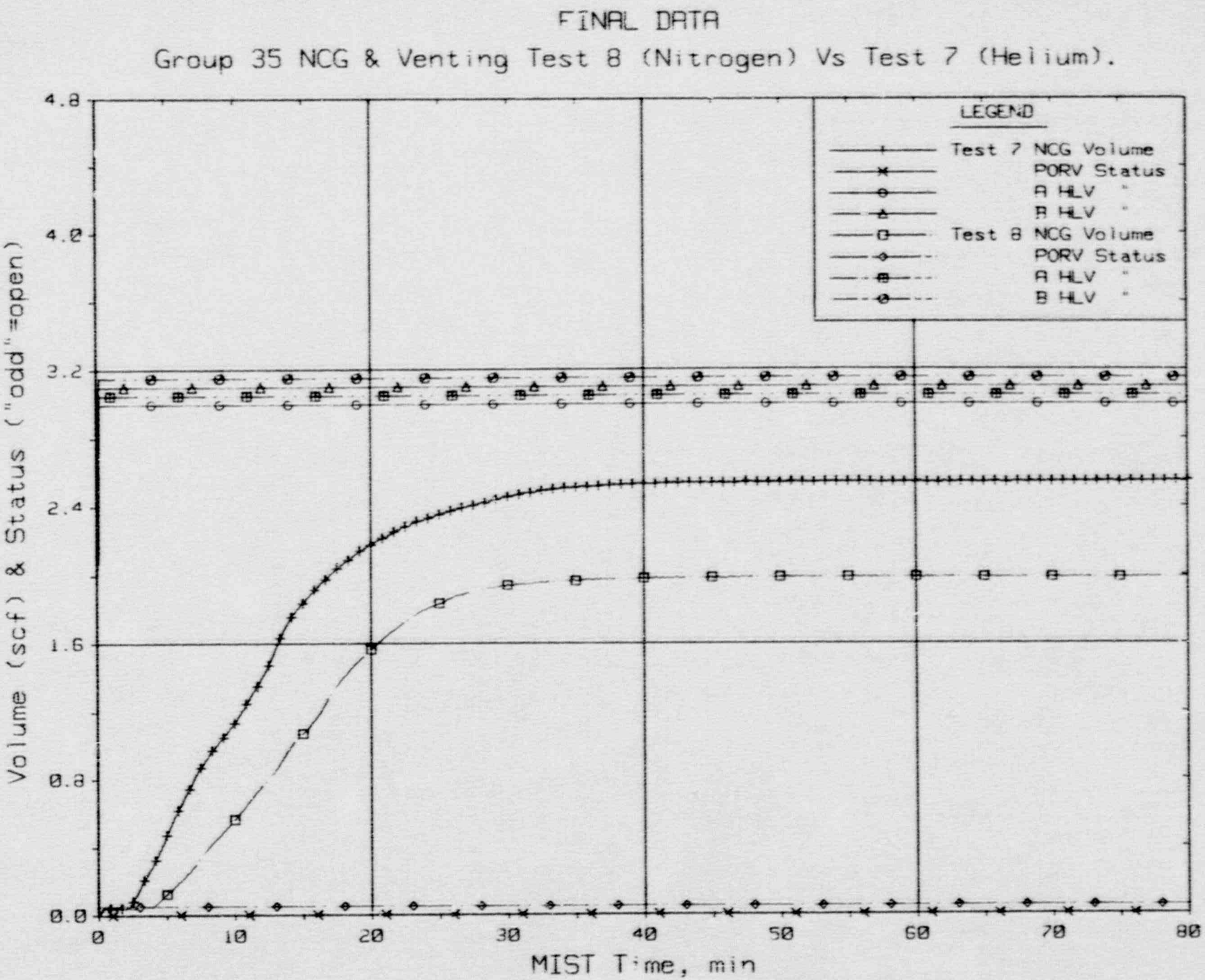

Figure 5.5.27 Noncondensibles Collected and Discharge Valve Status

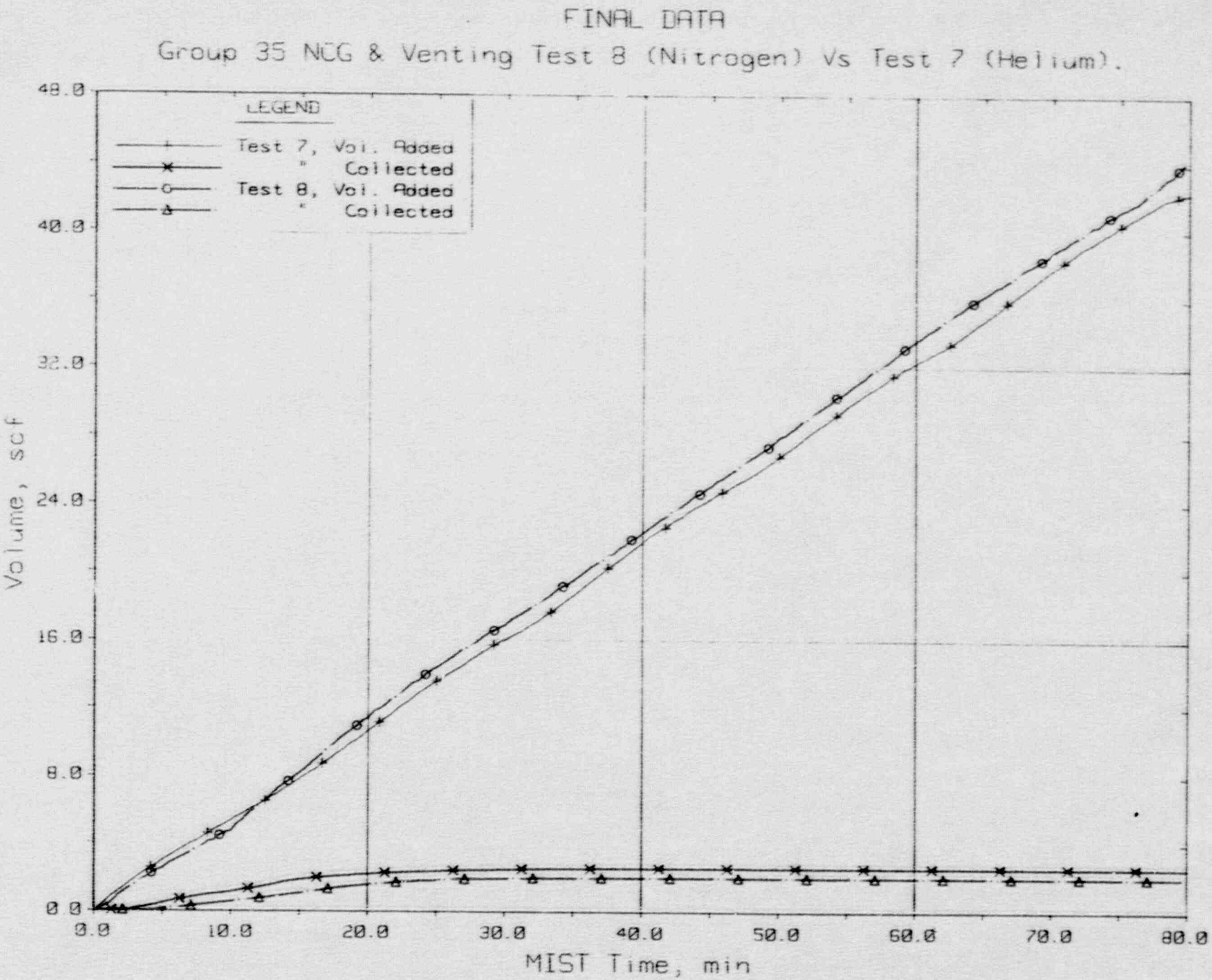

Figure 5.5.28 Noncondensibles Gas Volumes

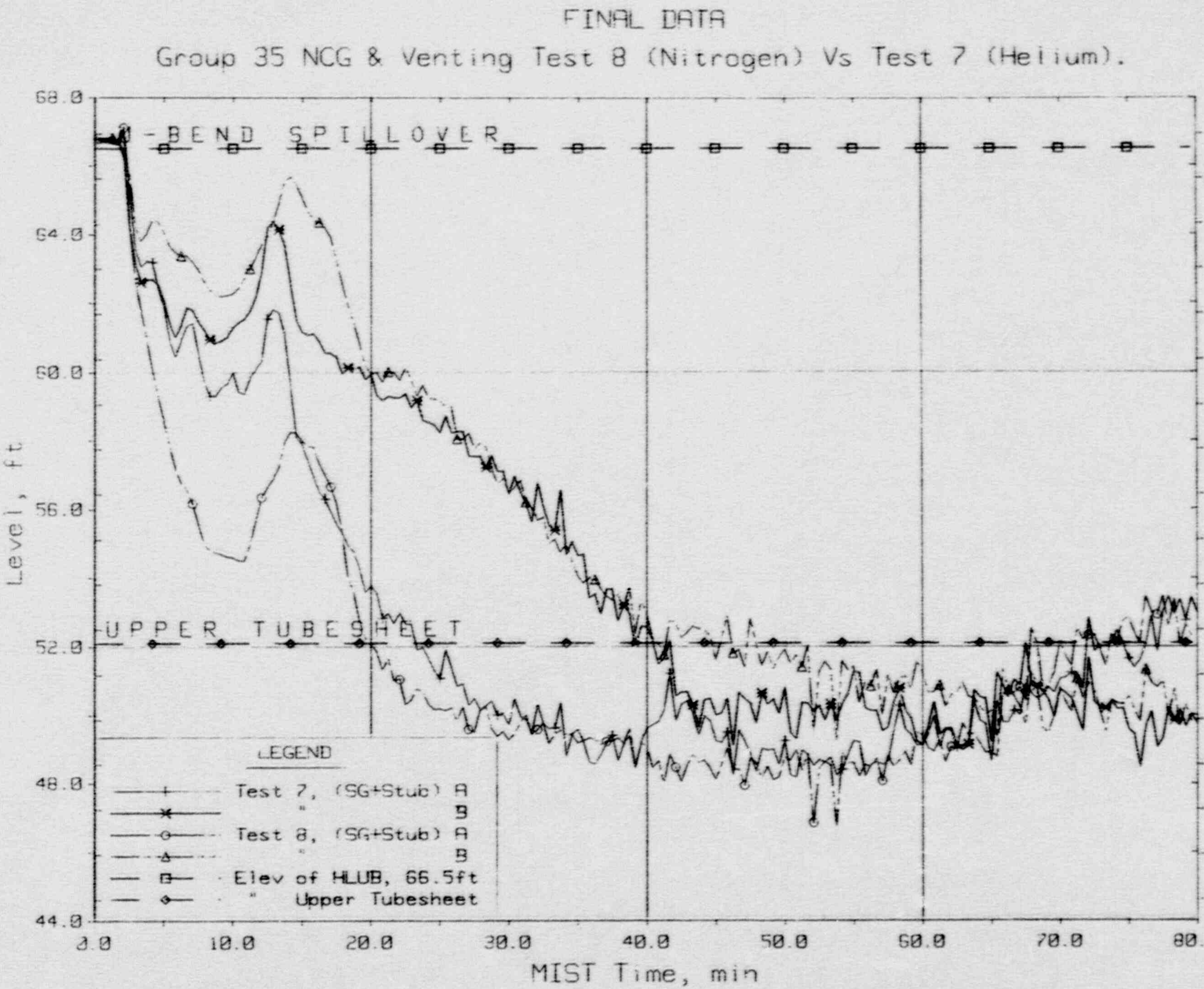

Figure 5.5.29 Steam Generator Primary and Stub Collapsed Liquid Levels

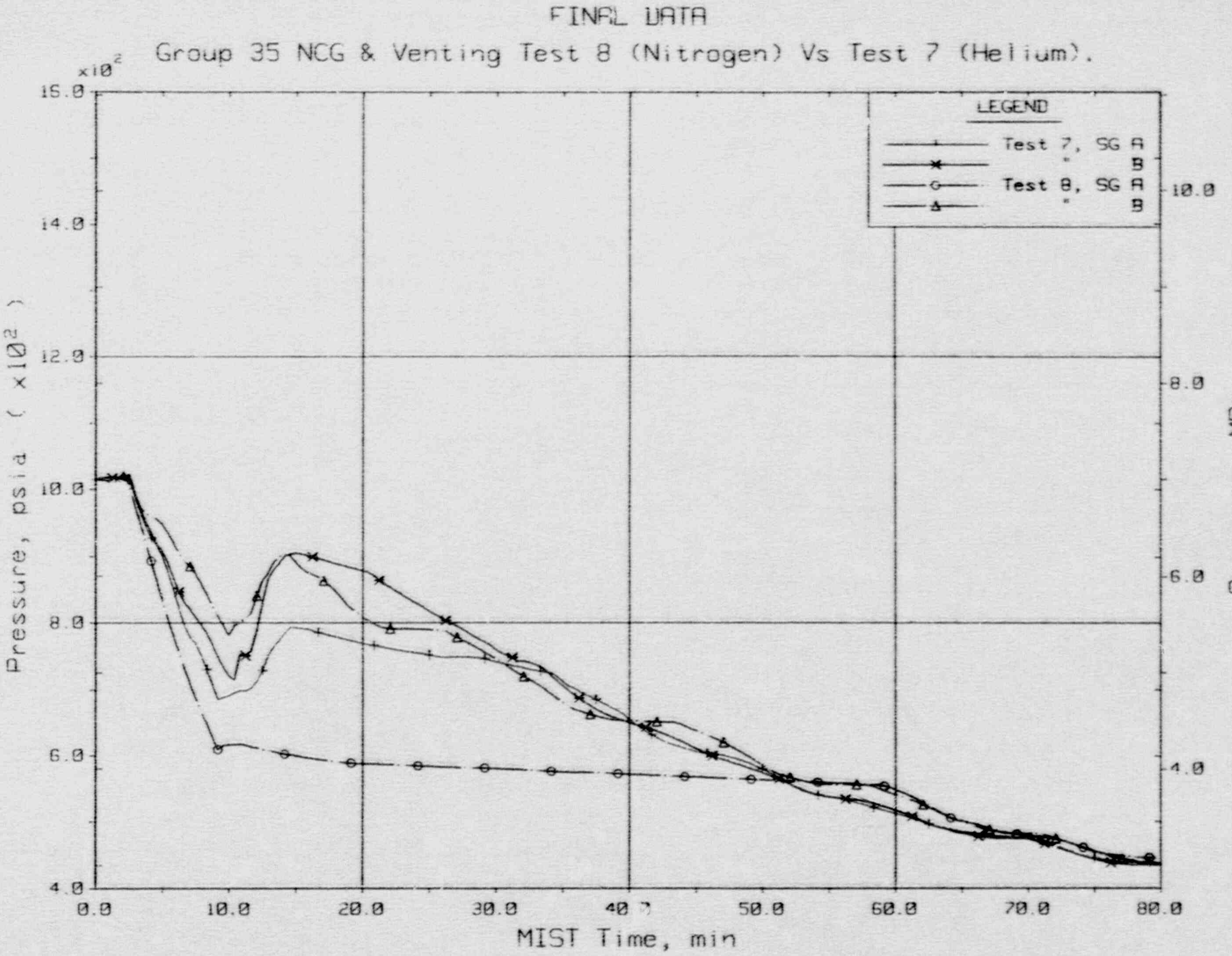

Figure 5.5.30 Steam Generator Secondary Pressures (SnGP01s)

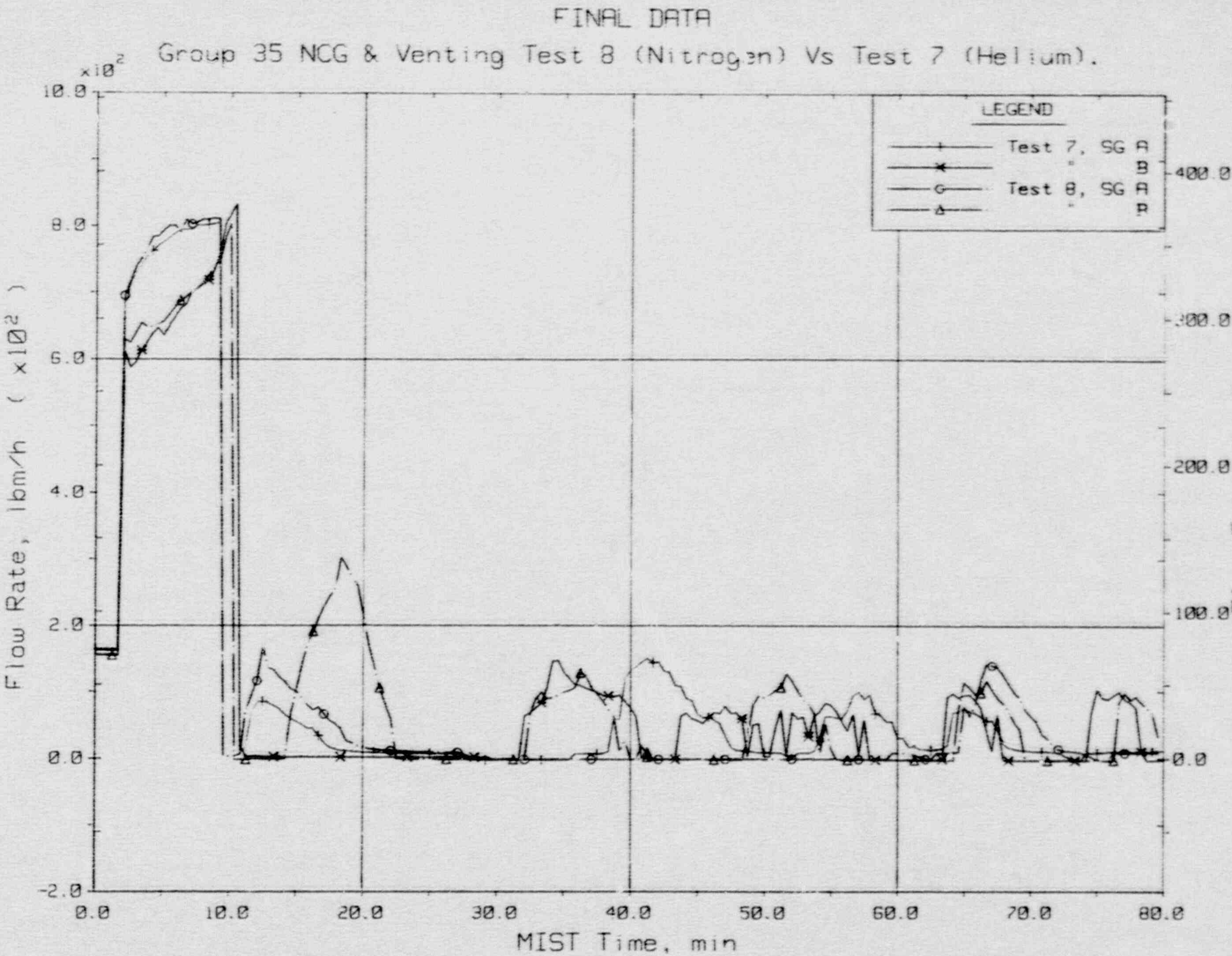

Figure 5.5.31 Steam Generator Secondary Feed Flow Rates

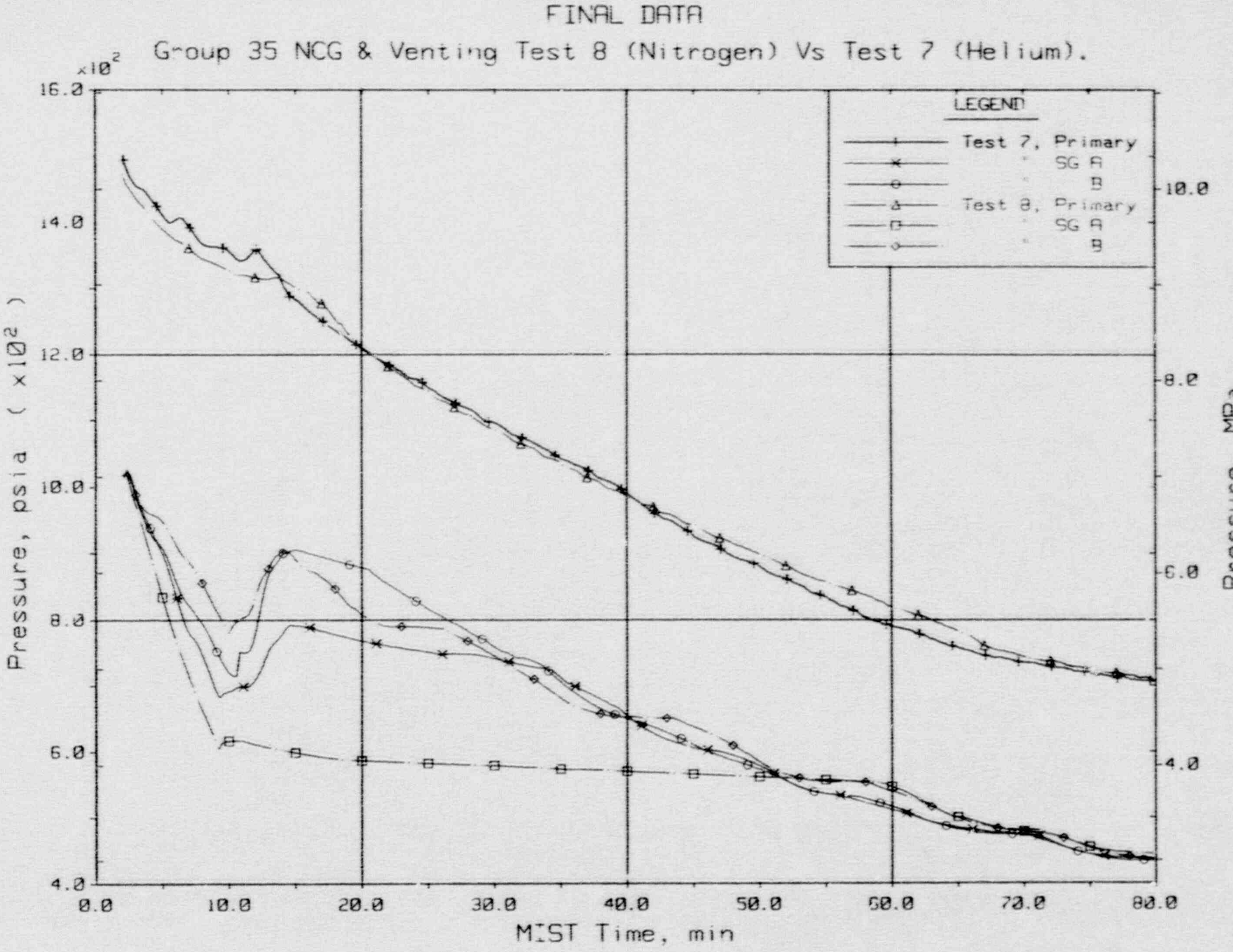

Figure 5.5.32 Primary and Secondary System Pressures (GP01s)

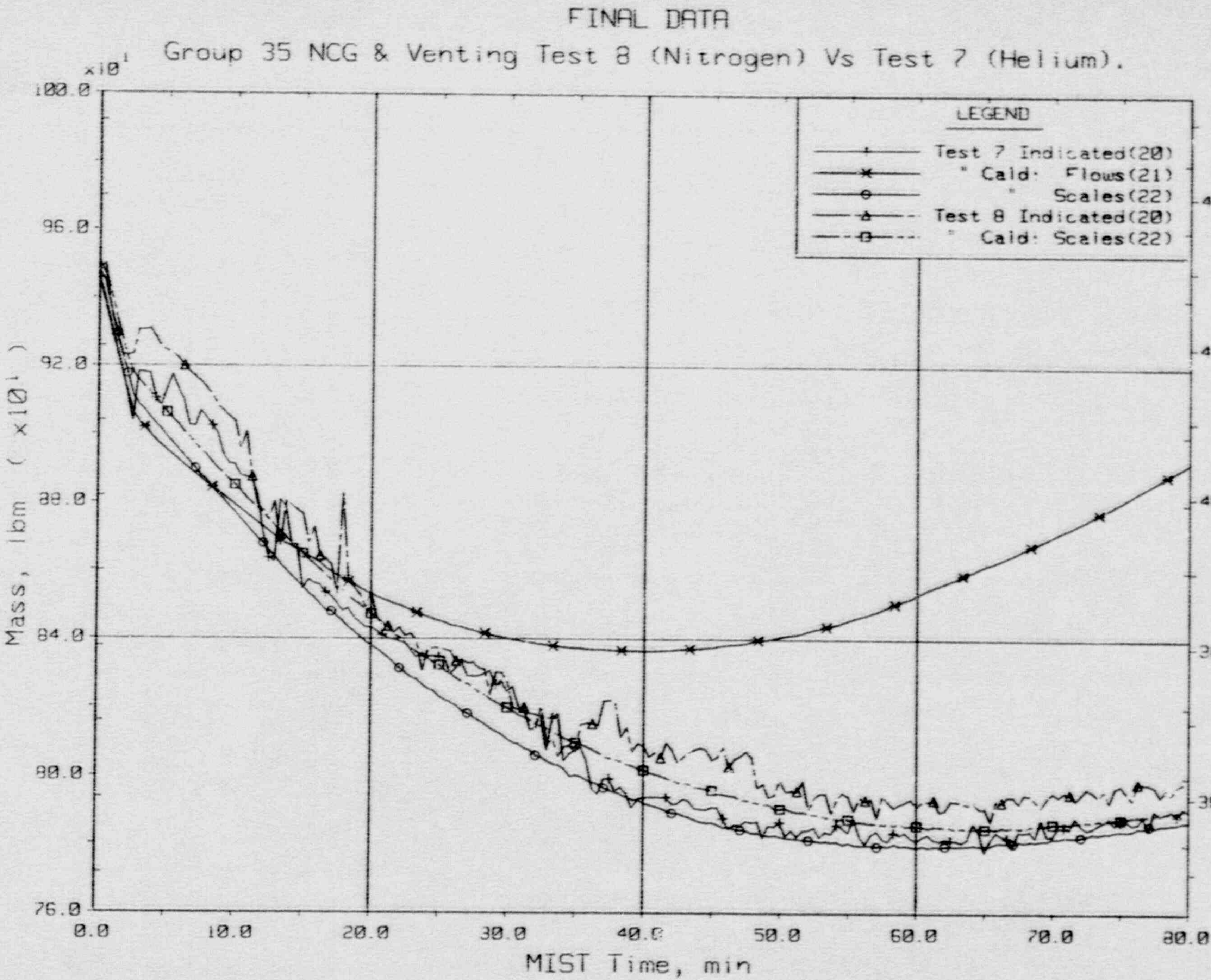

Figure 5.5.33 Primary System Total Fluid Mass (PLMLs)

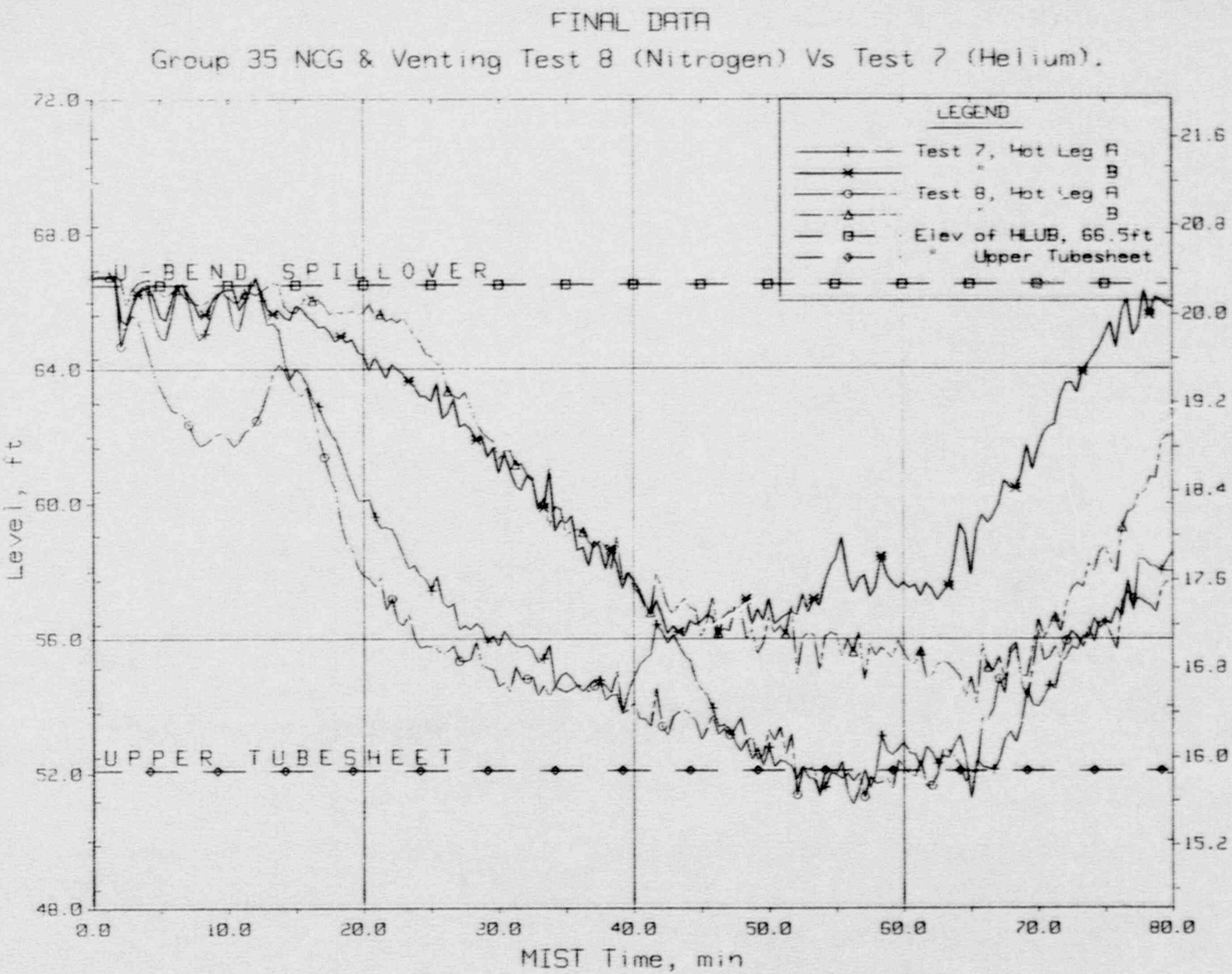

Figure 5.5.34 Hot Leg Riser Collapsed Liquid Levels

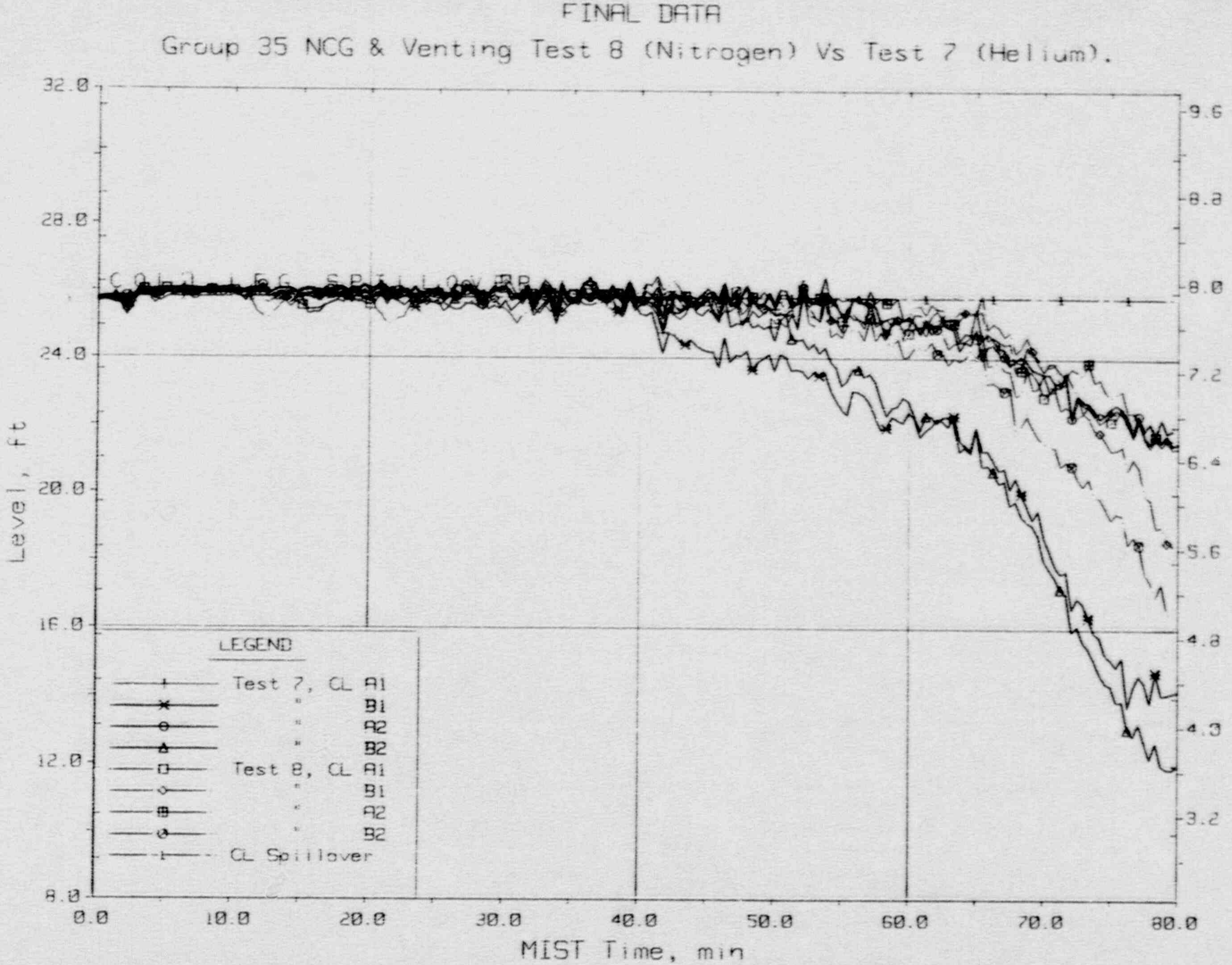

Figure 5.5.35 Cold Leg Suction Collapsed Liquid Levels (CnLV22s)

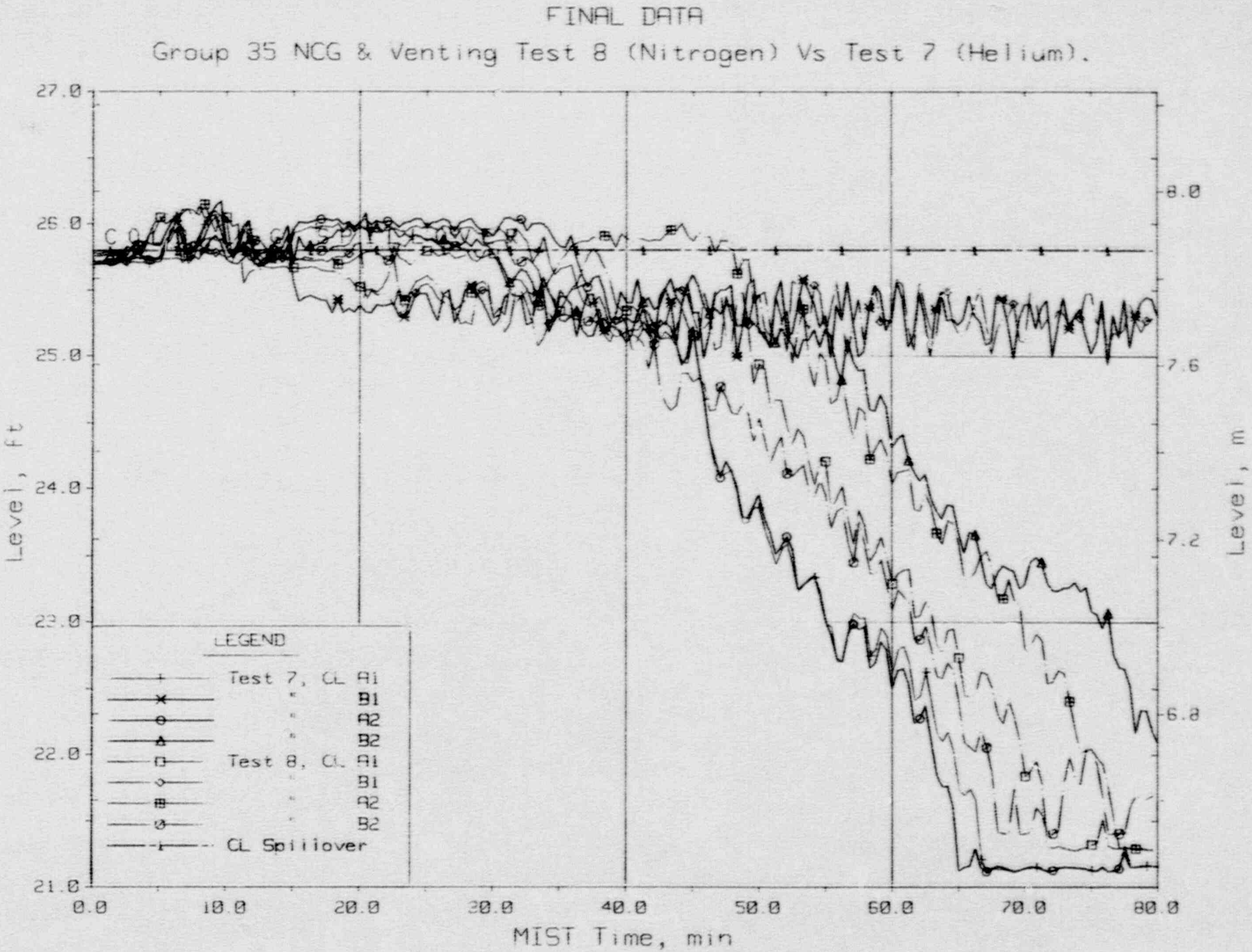

Figure 5.5.36 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

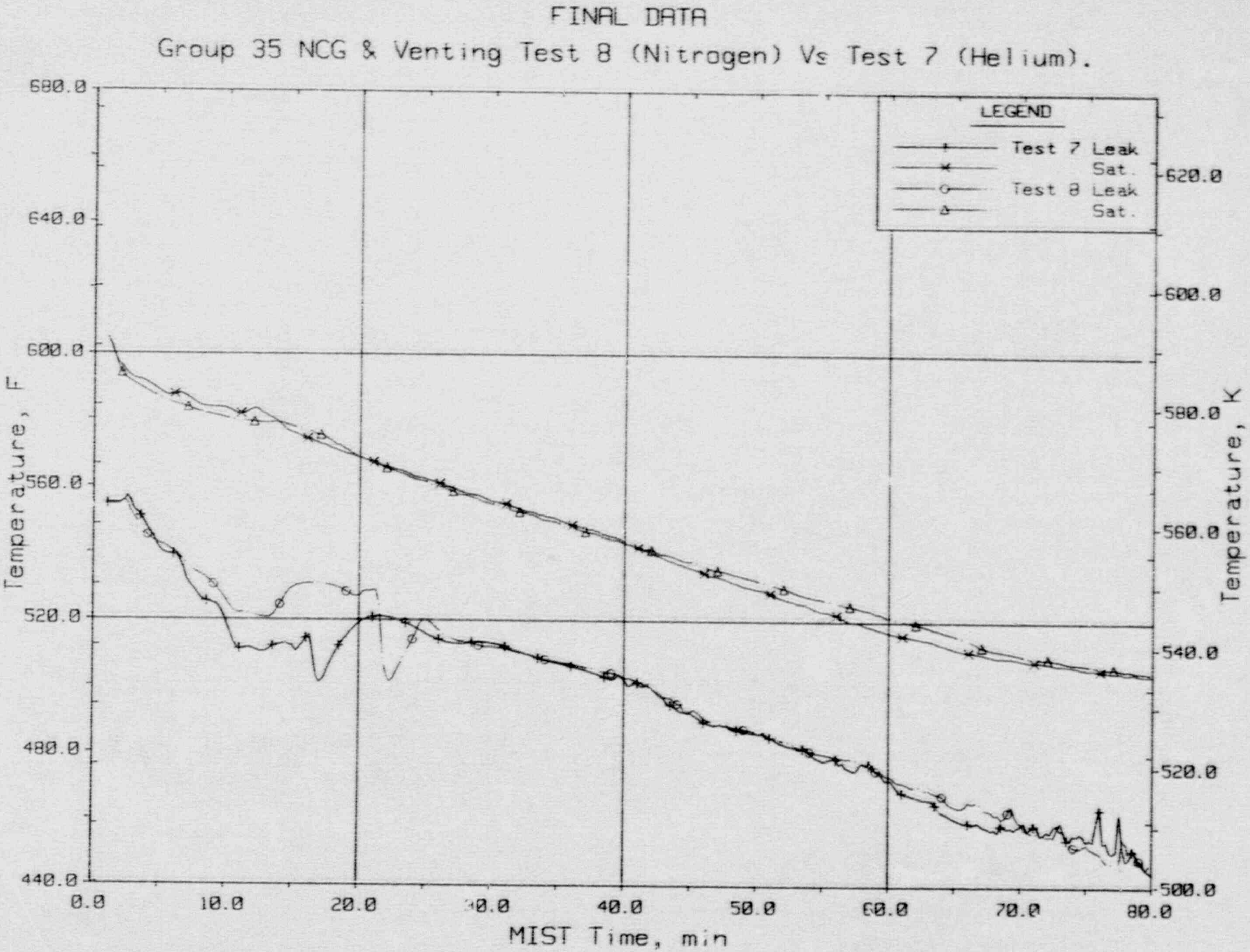

Figure 5.5.37 Leak and HPI Fluid Temperatures (TC01s)

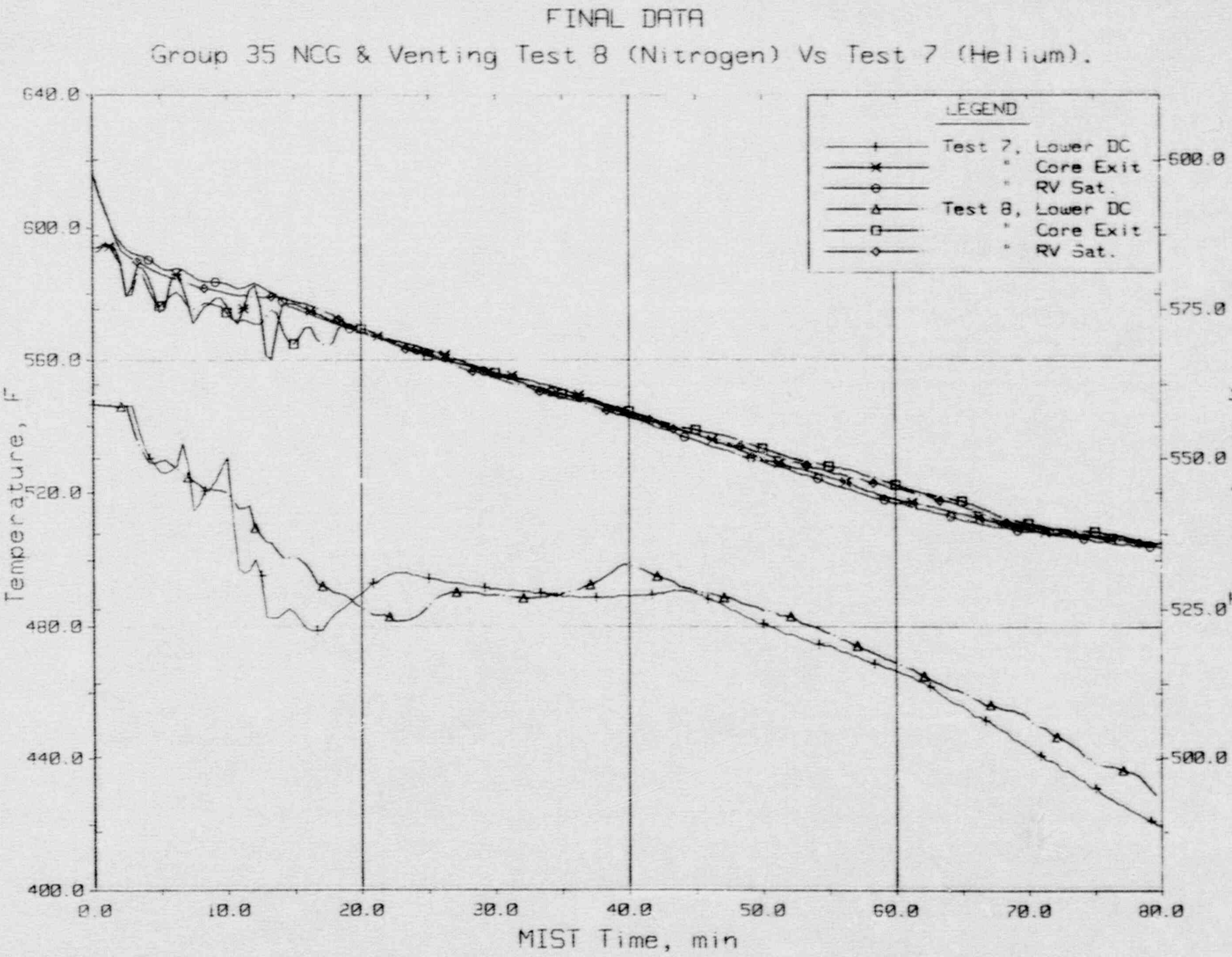

Figure 5.5.38 Core Bracketing Fluid Temperatures

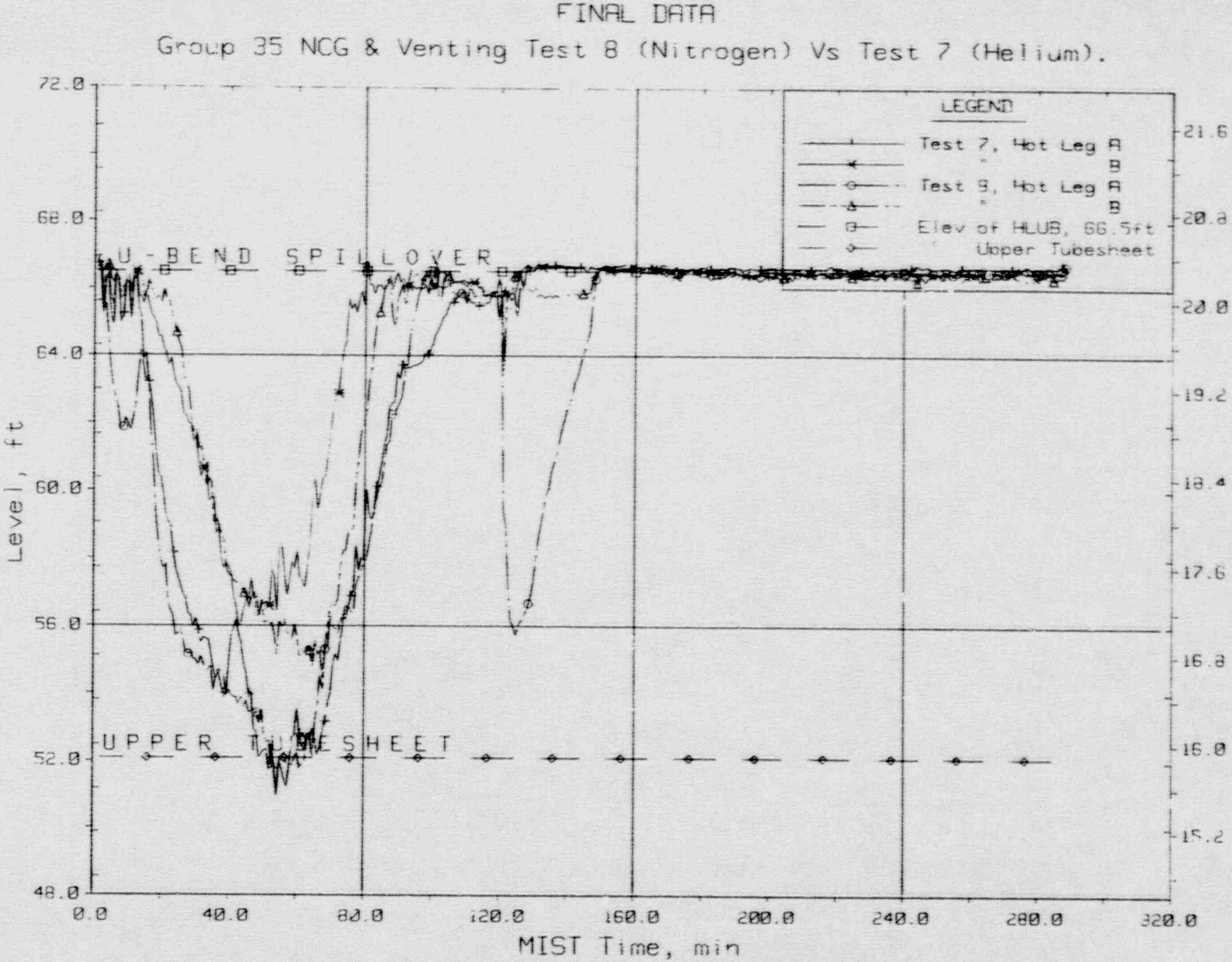

Figure 5.5.39 Hot Leg Riser Collapsed Liquid Levels

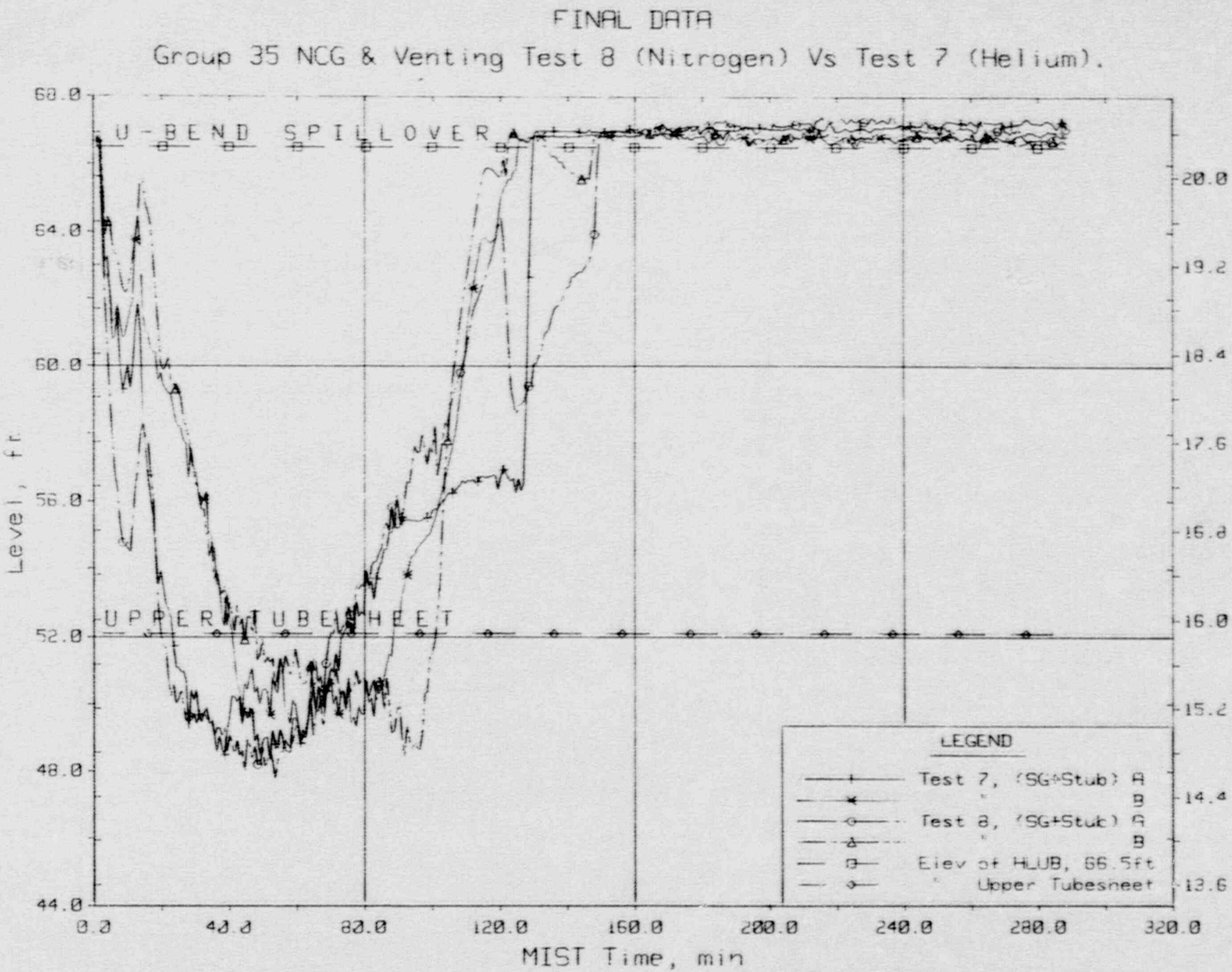

Figure 5.5.40 Steam Generator Primary and Stub Collapsed Liquid Levels

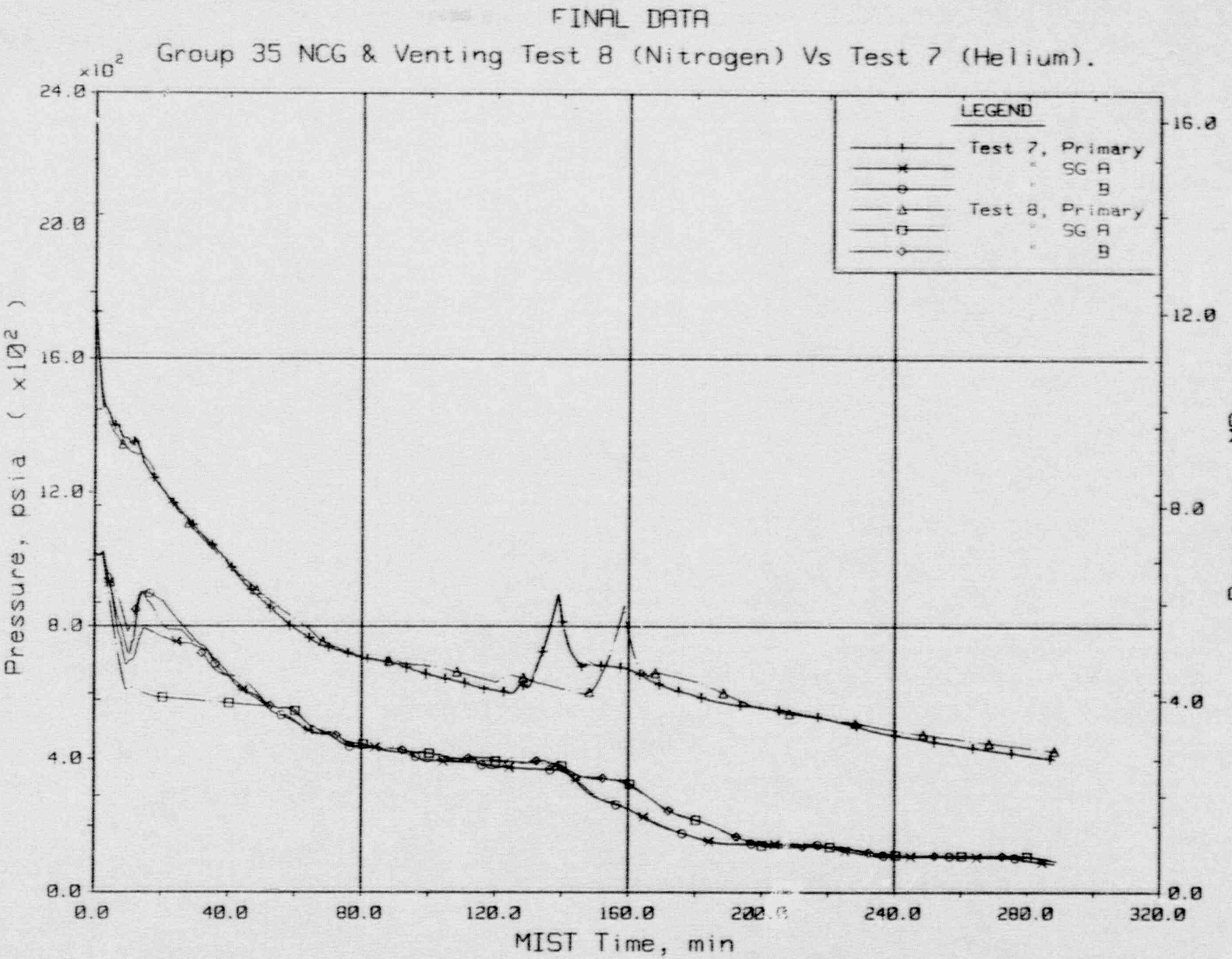

Figure 5.5.41 Primary and Secondary System Pressures (GP01s)

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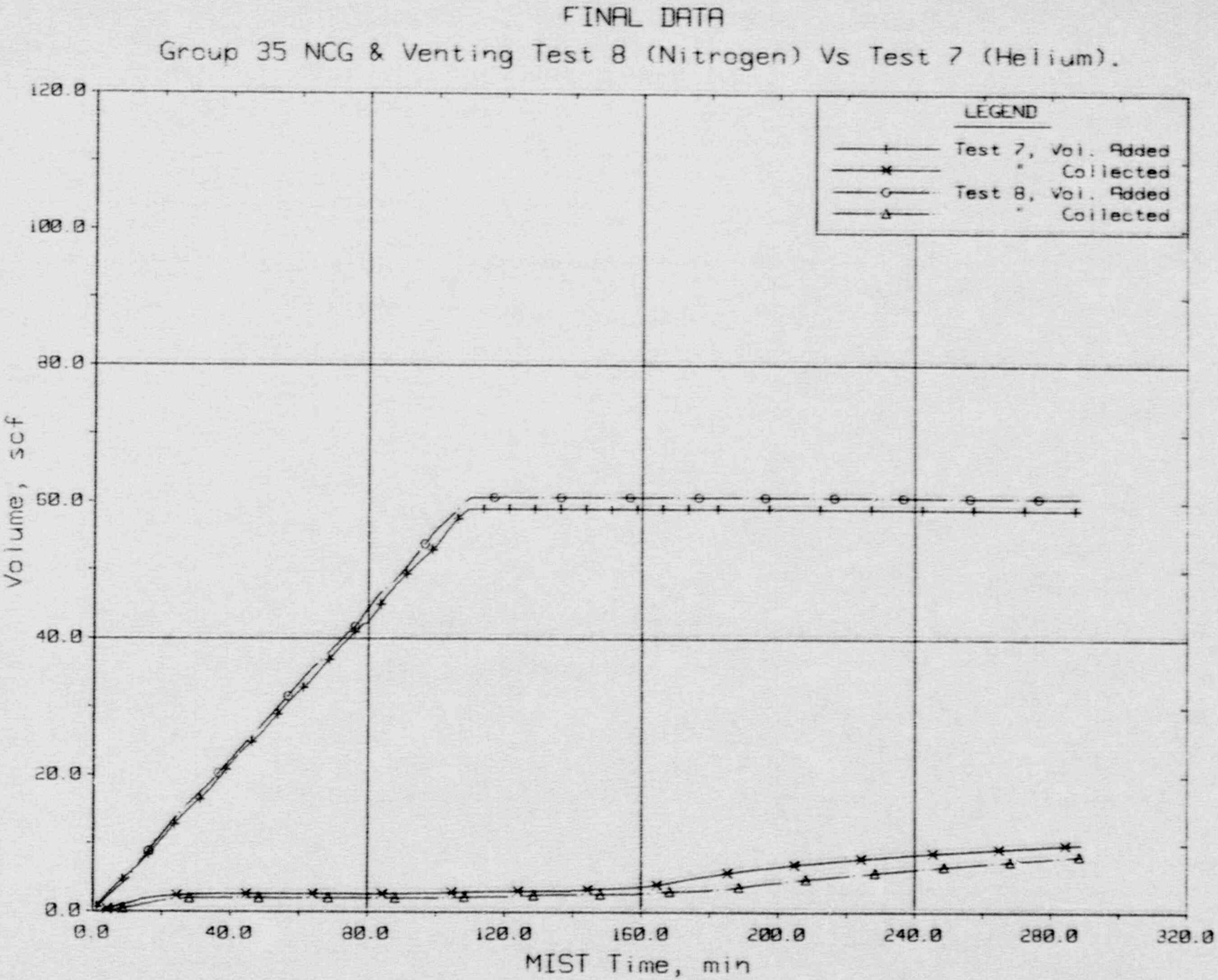

Figure 5.5.42 Noncondensibles Gas Volumes

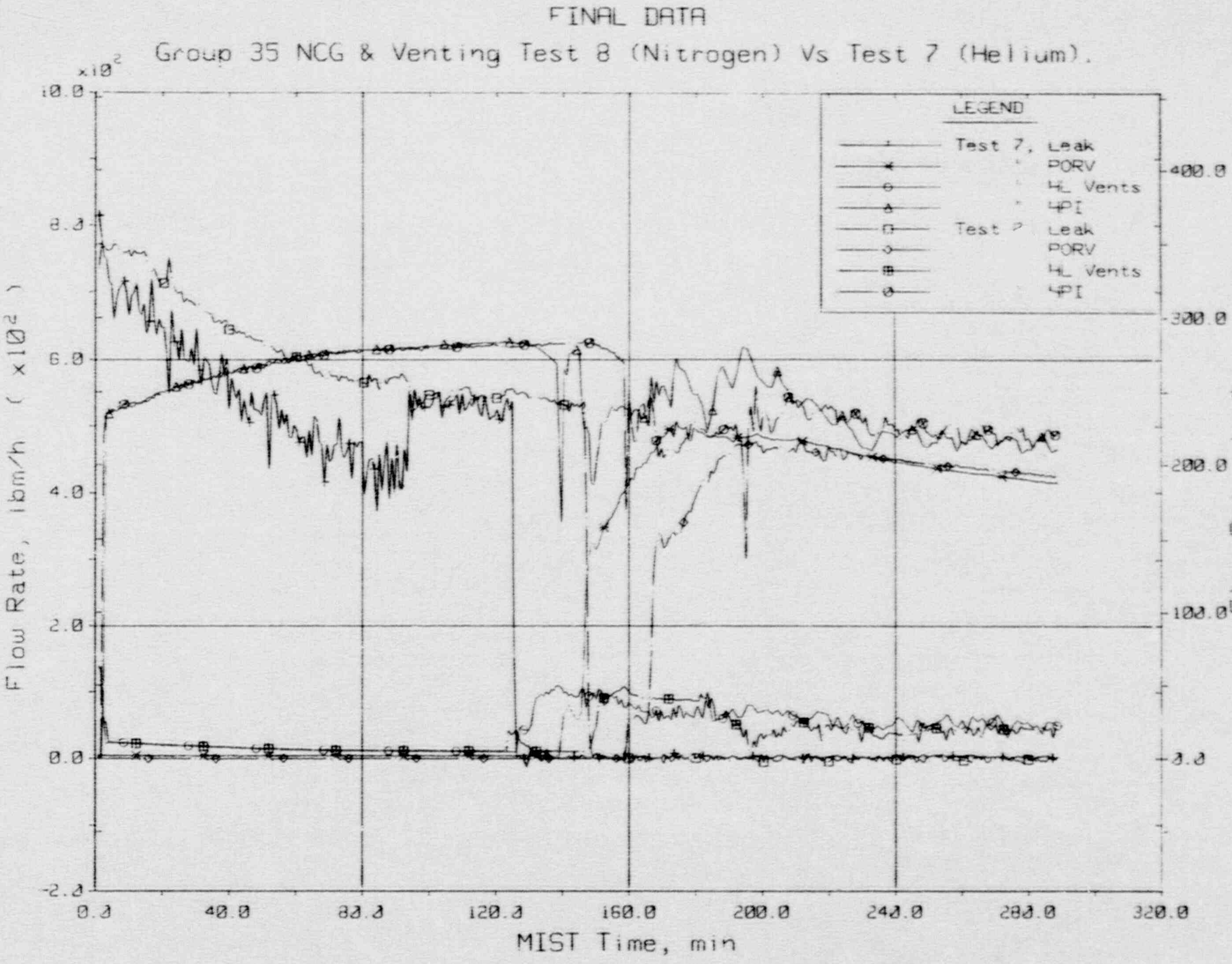

Figure 5.5.43 Primary System Boundary Mass Flow Rates

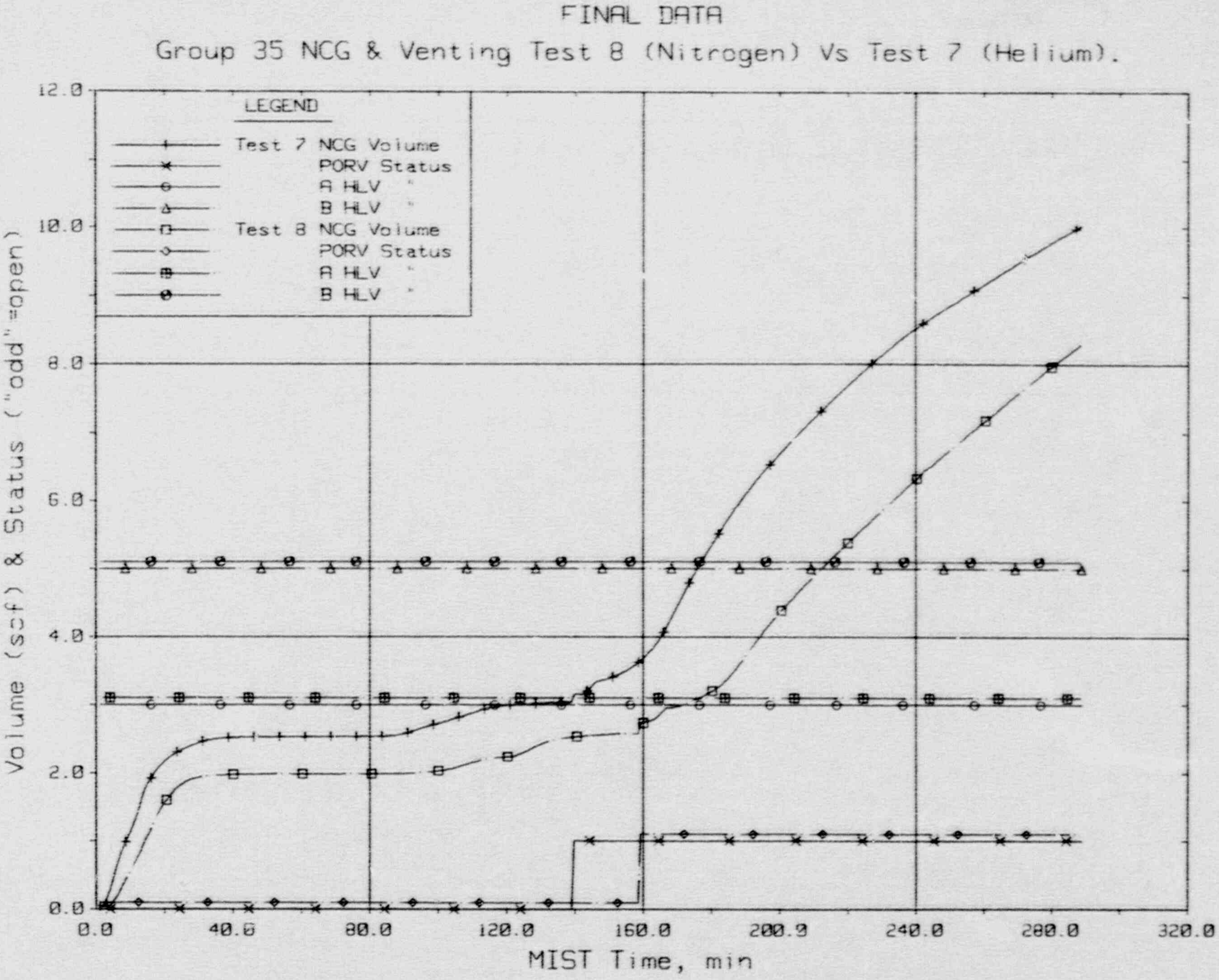

Figure 5.5.44 Noncondensibles Collected and Discharge Valve Status

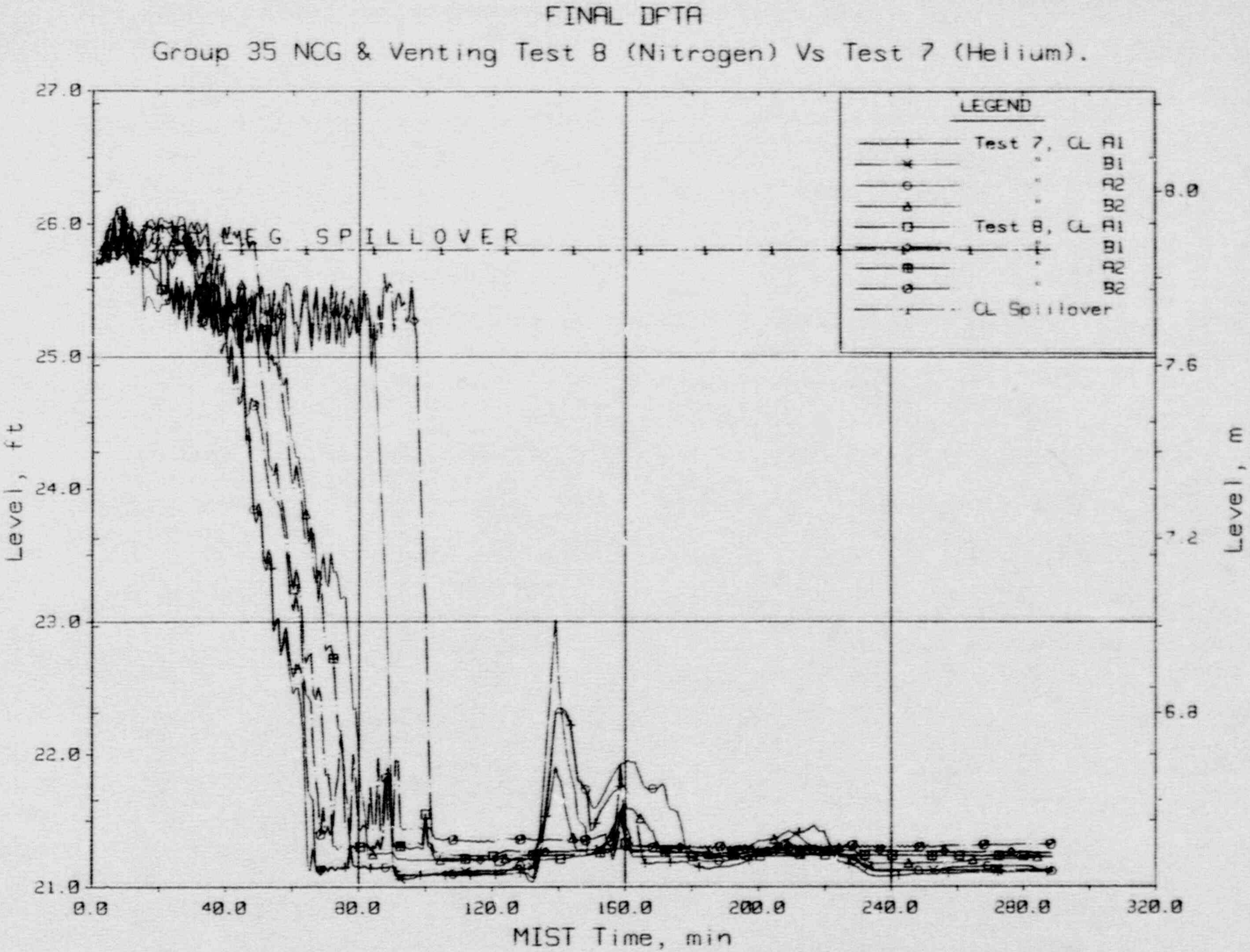

Figure 5.5.45 Cold Leg Discharge Collapsed Liquid Levels (CnLV23s)

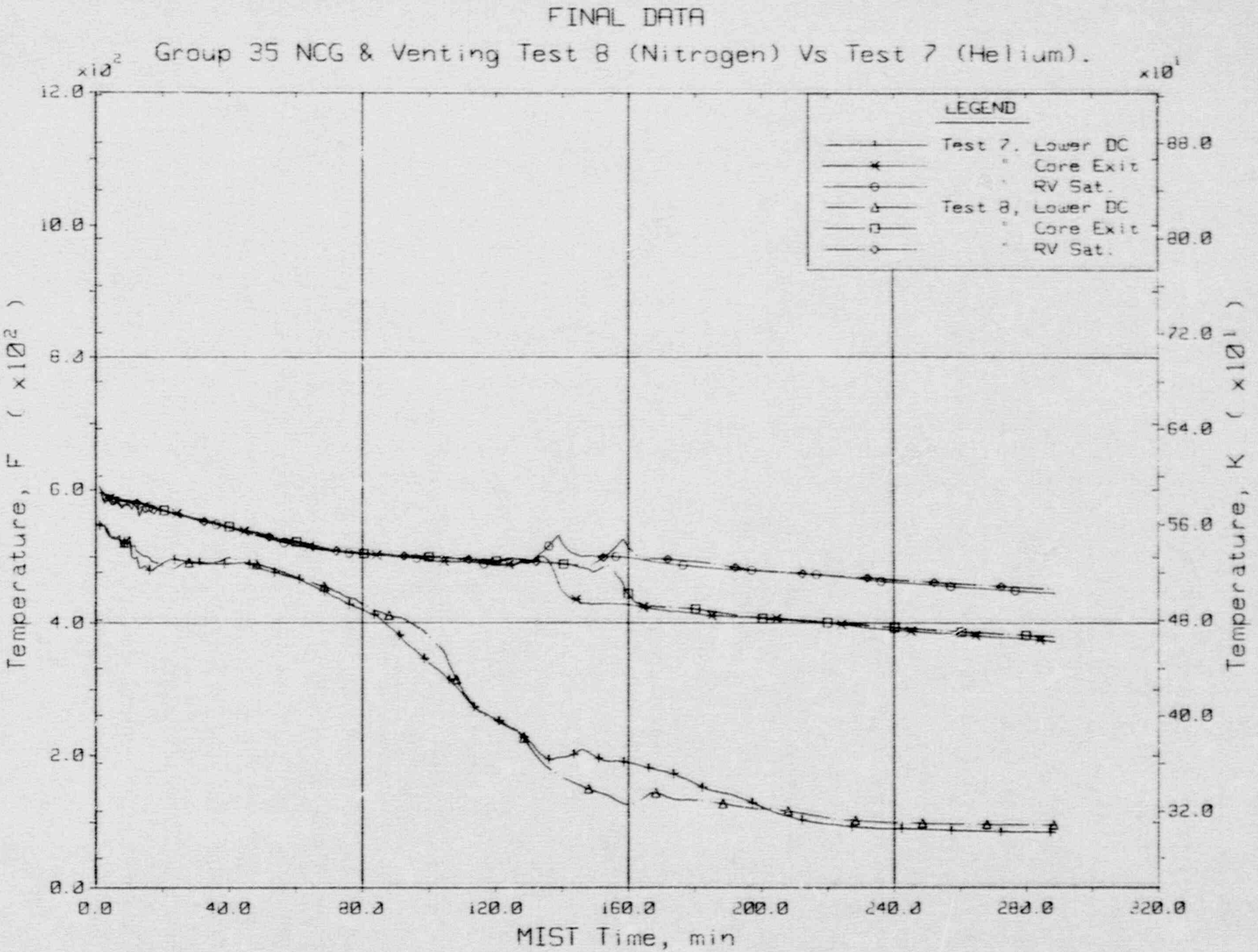

Figure 5.5.46 Core Bracketing Fluid Temperatures

5.6. Summary of Observations

Observations are summarized as follows:

- General observations
- Effects of inter-test variations
- Noteworthy interactions

5.6.1. General Observations

The following pre-test observations are discussed herein:

- Gas closure
- Discharge of NCG by the leak
- Gas discharge by the vents and PORV
- NCG threshold
- Venting without noncondensibles
- Venting with noncondensibles
- Cold leg suction break

Gas Closure

Gas closure using helium was obtained to approximately 4 scf versus 60 scf injected. With no controlled discharge after the helium injection was begun, this difference between the injected and collected volumes (accounting for the relatively small initial and remaining amounts) was attributable to uncontrolled leakage and to measurement inaccuracies.

Discharge of NCG By the Leak

In those tests with controlled leaks after noncondensible injection had begun, the gas closure imbalance was two to eight times larger than without a controlled leak, indicating NCG discharge by the leak. Comparing the apparent volumes discharged by the leaks, three to four times as much gas was discharged by a cold leg discharge leak as by a cold leg suction leak.

Gas Discharge By Vents and PORV

The collected NCG volumes reflected the gas discharged by the vents and PORV. The hot leg vents discharged relatively little NCG, and the initial gas venting rate quickly subsided as the cold legs and downcomer began to void. In comparisons of the collection rates before and after PORV actuation, three to four times as much NCG was discharged from the PORV as from the hot leg vents. For tests having cold leg suction leaks, the volume discharged by the leak was of the same magnitude as that collected from the vents and PORV. For these tests, more than two-thirds of the volume injected remained in the loop at test termination. However, with a cold leg discharge break, the break discharge of NCG was four times that discharged by the PORV and vents (in Test 3), and the volume remaining at the end of the test was about one-third of the 60 scf injected. These relative volumes showed little dependence on NCG species.

NCG Threshold, Test 2

Sustained pool BCM was obtained when the primary system total fluid mass had been depleted by approximately 40%. Upon helium injection with sustained pool BCM, the NCG apparently collected first within the steam generators and then in the cold legs. The primary system pressurized with the continuing NCG, although the steam generator primary levels remained sufficiently low for pool BCM. The maximum gas injection volume, 60 scf, was set by the system measuring capacity. This maximum volume was three times the volume of MIST or, when converted to operating pressure and temperature, approximately 5% of the total MIST volume. This volume approximately equalled the voided primary volumes of both steam generators when the primary levels had declined to the usual secondary control levels.

Venting Without Noncondensibles, Test 1

Continuous hot leg venting (without noncondensibles) obtained relatively symmetric inter-loop behavior, more rapid refill, and a milder spillover response than without venting. Upon the sustained interruption of loop flow, the primary system depressurized at some 15 psi/min through both HPI condensation and hot leg venting. Rather than multiple spillovers upon refill of the hot legs, loop A remained full and immediately began to circulate.

Venting With Noncondensibles, Test 3

The initial gas venting rate from the hot leg high-point vents approached 5 scf/h, versus the injection rate of more than 30 scf/h, but quickly subsided as the cold legs and downcomer began to void.

Gas discharge by the leak was evidenced by the gas closure imbalance, by the variability of the measured leak flow rate, and by the apparent subcooling of the voided leak site. The NCG impeded but did not prevent primary system depressurization through vapor condensation and primary-to-secondary heat transfer. As the primary system began to gain fluid inventory, the hot leg riser and steam generator primary levels rose but the cold leg suction and discharge piping voided. In the four transient tests using NCG, the system interactions upon hot leg refill were relatively mild.

Upon leak isolation, the primary system rapidly repressurized and the SCM increased, triggering manual PORV actuation. The NCG venting and collection rate increased markedly upon PORV actuation. The cold legs evidenced lingering NCG effects. The cold leg suction piping remained partially voided, and the cold leg flow rates were highly asymmetric.

<u>Cold Leg Suction Break, Test 7</u>

A cold leg suction rather than discharge leak was used in Test 7. The apparent leak discharge of NCG was much reduced from that observed with a discharge leak, the loop gas burden near test termination was 43 scf, more than two-thirds of the injected volume. As was observed in tests having cold leg discharge piping leaks, the hot leg vents discharged little of the loop NCG.

Test 7 was characterized by inhibited primary-to-secondary heat transfer and relatively cold lower downcomer and core inlet fluid temperatures. The BCM depressurization of the primary system was almost indiscernible. A spillover was observed through the hot leg B U-bend viewport near 80 minutes, as the hot leg riser levels approached full, but there was little evidence of increased primary-to-secondary heat transfer.

As the hot legs filled, the cold leg levels declined, as had occurred in tests having a cold leg discharge leak. But in Test 7 with a cold leg suction leak and thereby an increased loop burden of noncondensibles, noncondensible effects became much more apparent. The voided upper downcomer fluid temperatures indicated significant subcooling, and the noncondensibles apparently restricted HPI heating. In response to the continuing introduction of virtually unheated HPI, the lower downcomer and core inlet temperatures ultimately cooled to less than 100F, obtaining a core fluid temperature rise of almost 400F.

5.6.2. Effects of Inter-Test Variations

The effects of the following inter-test variations are discussed herein:

- Noncondensibles
- Venting
- Break Location
- NCG Species

Effects of Noncondensibles, Tests 1 and 3

Comparing Tests 1 and 3 without and with noncondensibles, the cold leg discharge levels quickly descended in Test 3, exposing the leak site to the NCG-laden vapor, whereas they remained full in Test 1. The BCM depressurization was attenuated in Test 3. Without noncondensibles, the hot leg riser and stub levels rose only slowly from the elevation of the upper tubesheets to the U-bend spillovers. However, with noncondensibles, the hot leg riser and stub levels ascended relatively rapidly but the cold leg piping voided. The hot leg spillovers produced little system activity. The leak was kept open in Test 1 but was isolated in Test 3 near 2 hours.

Venting Effects, Tests 3 and 5

Continuous hot leg venting was used in Test 3 but not in Test 5. Venting aided primary system depressurization and hastened the start of refill. The vents discharged less than 5% of the injected noncondensibles. In both Tests 3 and 5, approximately one-third of the total injected volume of NCG was apparently discharged by the cold leg discharge leak, thus their loop burdens of NCG were approximately equal. Some BCM depressurization was evident in both tests. BCM was delayed somewhat in Test 5 without venting, but the attendant primary system depressurization was stronger than in Test 3 with venting. Whereas the steam generator primary levels just entered the steam generators in Test 3, in Test 5 they dropped nearly 20 feet below the elevation of the upper tubesheet.

The leak was isolated near 2 hours in Test 3 but was kept open in Test 5. The hot leg A riser refilled in Test 5 near 300 minutes, but little primary-to-secondary heat transfer resulted.

Break Location Effects, Tests 3 and 7

A cold leg suction leak was used in Test 7, and a cold leg discharge leak in Test 3. Approximately half of the 60 scf of injected helium was discharged by the cold leg discharge leak, but only approximately 10 scf with the suction leak. The amounts vented and discharged by the PORV, approximately 9 scf, were similar in the two tests. Thus, the total gas burden remaining near test completion in Test 7 was approximately twice that in Test 3.

In both Tests 3 and 7, the primary system depressurization through BCM was inhibited by noncondensibles. The BCM effects were almost indiscernible in Test 7. In both tests, the cold leg discharge piping voided as the hot legs refilled. With a cold leg B1 discharge break, the cold leg B1 discharge piping level quickly descended to the break elevation, but it remained nearly full in Test 7, with a cold leg suction break.

Near 2 hours in both tests, the gas injection was completed, then the leak was isolated. The primary system repressurized, triggering PORV actuation to control the SCM. In both tests, the gas collection rate abruptly increased as the PORV was activated. The greater burden of NCG in Test 7 became increasingly apparent later in the test. Whereas the core inlet fluid temperature gradually increased in Test 3, in Test 7 it decreased toward the HPI supply fluid temperature.

Effects of NCG Species, Tests 7 and 8

Nitrogen was used as the NCG species in Test 8, versus helium in the other gas tests. Other than the noncondensible species, the boundary system controls of Test 8 were the same as those of Test 7. In both tests, most of the injected NCG remained in the system, rather than being discharged out the break as had occurred in the tests using a cold leg discharge break. Common to the other tests, the hot leg vents had little effect on the loop gas burden, and the gas collection rate was noticeably increased upon PORV actuation. In both Tests 7 and 8, the total loop gas burden of NCG near the completion of the tests was approximately 44 scf, and within 18 scf of the total injected volume.

The loops interrupted asymmetrically in Test 8 using nitrogen, rather than symmetrically as in Test 7. This interruption difference may have been due to the NCG species or to the inter-test differences of steam generator feed rate control. The asymmetries in Test 8 obtained continued loop B flow and primary-to-secondary heat transfer, enhanced primary system depressurization, and reduced core region voiding. These inter-test differences diminished when HPI condensation began somewhat earlier in Test 7 than in Test 8.

The gas injection rates were similar between the tests. The gas venting rates dwindled in both tests as the downcomer level descended to the cold leg nozzles and HPI condensation commenced.

The inter-test similarities continued as the tests progressed. The BCM depressurizations were slight. As observed in the tests having cold leg discharge leaks, the cold leg levels descended as the hot legs refilled. In both Tests 7 and 8, the systems were quite unresponsive to the achievement of hot leg refill.

Tests 7 and 8 responded similarly to leak isolation. Upon PORV actuation to control the SCM, the gas collection rate abruptly increased. During the 2 hours following PORV actuation the volumes of helium collected in Test 7, and of nitrogen collected in Test 8, were approximately twice those collected during the 2 previous hours using hot leg vents only. Also in the two tests using helium and nitrogen, HPI heating became increasingly inhibited so that the lower downcomer and cold leg inlet fluid temperatures approached the HPI supply temperature, versus the core exit fluid temperatures of 380F. The primary-to-secondary pressure difference remained near 300 psi at the completion of Tests 7 and 8.

5.6.3. Noteworthy Interactions

Gas Closure

MIST was demonstrated to provide gas closure to within approximately 4 scf, 7% of the total volume injected, using helium.

Leak Discharge of Gas

With a leak active, the degradation of the gas balance as well as several physical conditions indicated that a significant portion of the loop gas burden was discharged by the leak. The noncondensible gas evidently travelled up through the core, out the vent valves, down the downcomer, and into the broken cold leg. The gas volume discharged by the leak was much larger with a cold leg discharge leak than with a cold leg suction leak.

Gas Discharge By the Vents and PORV

The hot leg vents alone removed relatively little of the loop gas burden. With the PORV active, the combined gas discharged of the vents plus the PORV increased markedly over that using the vents only. The primary system depressurization through PORV actuation may have increased the gas venting rate but, because the traversed pressures had sometimes already been encountered, the enhanced gas discharge rate seems attributable to the PORV rather than to the vents.

Effects of NCG on BCM

Gas injection during BCM obtained primary system pressurization. The maximum MIST gas burden was set by the gas metering capacity rather than by limiting thermal-hydraulic conditions within the loop. The maximum NCG volume of 60 scf was 3 times the MIST total volume. Converted to operating pressure and temperature, the volume of the maximum NCG burden corresponded to approximately 5% of the total MIST volume. The noncondensibles apparently impeded but did not halt BCM heat transfer.

Effects of Venting Without NCG

Continuous hot leg venting promoted symmetric loop flow interruptions, enhanced the depressurization of the primary system, hastened the refill of the hot legs, and diminished the intensity of the system interactions upon refill

NCG Effects After Hot Leg Refill

Noncondensibles weakened the BCM depressurization. Noncondensibles also promoted cold leg voiding as the hot legs refilled, and inhibited the warming of the HPI fluid through either condensation of RVVV steam or mixing with warmer fluid. With the larger burdens of NCG, such as occurred in Tests 7 and 8 having cold leg suction breaks, the lower downcomer and core inlet fluid cooled to almost the HPI supply fluid temperature.

Increased Gas Discharge Upon Leak Isolation

Leak isolation led indirectly to an enhanced rate of gas discharge. The primary system repressurization due to leak isolation triggered PORV actuation to control the SCM. The (metered) gas discharge rate increased markedly upon opening the PORV.

Viewport Observations

The hot leg viewport observations, available in Test 7, generally corresponded to the observations deduced from supporting measurements such as levels, flow rates, and system pressure trends.

6. SUMMARY

Test Group 35 concerned noncondensibles and venting. The NCG were injected into the piping at the bottom of the reactor vessel. Group 35 Test 2 involved gas injection without venting to determine the threshold volume at which a facility limit was encountered. The threshold volume was determined to be 60 scf. This was the facility maximum gas metering capacity rather than a thermal-hydraulic limit of the system. The noncondensible gas inhibited BCM heat transfer and thus elevated the primary system pressure. The MIST interactions are of intrinsic interest because they may provide insight into expected plant behavior. MIST was necessarily atypical of a plant in certain important respects, however. The MIST interactions therefore not to be applied directly to a plant.

Of the five transient tests, Test 1 used continuous hot leg venting without NCG. Venting obtained a relatively symmetric interruption, enhanced primary system depressurization, and hastened primary system refill. The four remaining transient tests (Tests 3, 5, 7, and 8) varied venting, NCG species, break location, and break isolation status. Venting had little impact on the loop gas burdens. Break location had a relatively strong impact, however. Early in the transients, as the downcomer level descended to the elevation of the cold leg nozzles, the cold leg discharge breaks began to discharge noncondensibles, ultimately reducing the total loop burden of NCG by approximately one-half. With a cold leg suction break, on the other hand, only approximately 10 scf (versus 60 scf injected) were discharged out the break. As the hot leg refilled, the cold leg piping voided. Gas effects then became particularly evident in the two tests having cold leg suction leaks. The noncondensibles impeded the heating of the HPI fluid. The lower downcomer and core inlet fluid cooled to almost the HPI supply temperature.

The interactions using nitrogen were almost indistinguishable from those using helium, implying that convective effects overwhelmed buoyant effects.

Leak isolation indirectly enhanced the discharge rate of NCGs. As the leak was closed, the primary system repressurized and the SCM increased. The operator opened the PORV to control the SCM. Whereas the rate of gas discharge had been quite small using vents alone, on the order of 1 scf/h, it increased about threefold upon PORV actuation.

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Test Group 35, Noncondensibles and Venting

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J. R. Gloudemans

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3315 Old Forest Road
Lynchburg, VA 24506-0935

Babcock & Wilcox
Research & Development Division
Alliance Research Center
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Alliance, OH 44601

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Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Electric Power Research Institute
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Palo Alto, CA 94303

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P. O. Box 10935
Lynchburg, VA 24506-0935

10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

The Multiloop Integral System Test (MIST) is part of a multiphase program started in 1983 to address small-break loss-of-coolant accidents (SBLOCAs) specific to Babcock and Wilcox designed plants. MIST is sponsored by the U. S. Nuclear Regulatory Commission, the Babcock & Wilcox Owners Group, the Electric Power Research Institute, and Babcock and Wilcox. The unique features of the Babcock and Wilcox design, specifically the hot leg U-bends and steam generators, prevented the use of existing integral system data or existing integral facilities to address the thermal-hydraulic SBLOCA questions. MIST and two other supporting facilities were specifically designed and constructed for this program, and an existing facility--the Once Through Integral System (OTIS)--was also used. Data from MIST and the other facilities will be used to benchmark the adequacy of system codes, such as RELAP5 and TRAC, for predicting abnormal plant transients.

The MIST program is reported in 11 volumes. The program is summarized in Volume 1; Volumes 2 through 8 describes groups of tests by test type; Volume 9 presents inter-group comparisons; Volume 10 provides comparisons between the calculations of RELAP5/MOD2 and MIST observations, and Volume 11 presents the later Phase 4 tests. This Volume 7 pertains to Test Group 35, Noncondensibles and Venting. The specifications, conduct, observations, and results of these tests are described.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

Multiloop Integral System Test (MIST), Babcock and Wilcox
Small break loss-of-coolant accident, transient testing, reactor safety
steam generator (once through), feed and bleed
steam generator tube rupture, station black out
Two-phase flow, SBLOCA without HPI injection, RELAP5/MOD2 calculations

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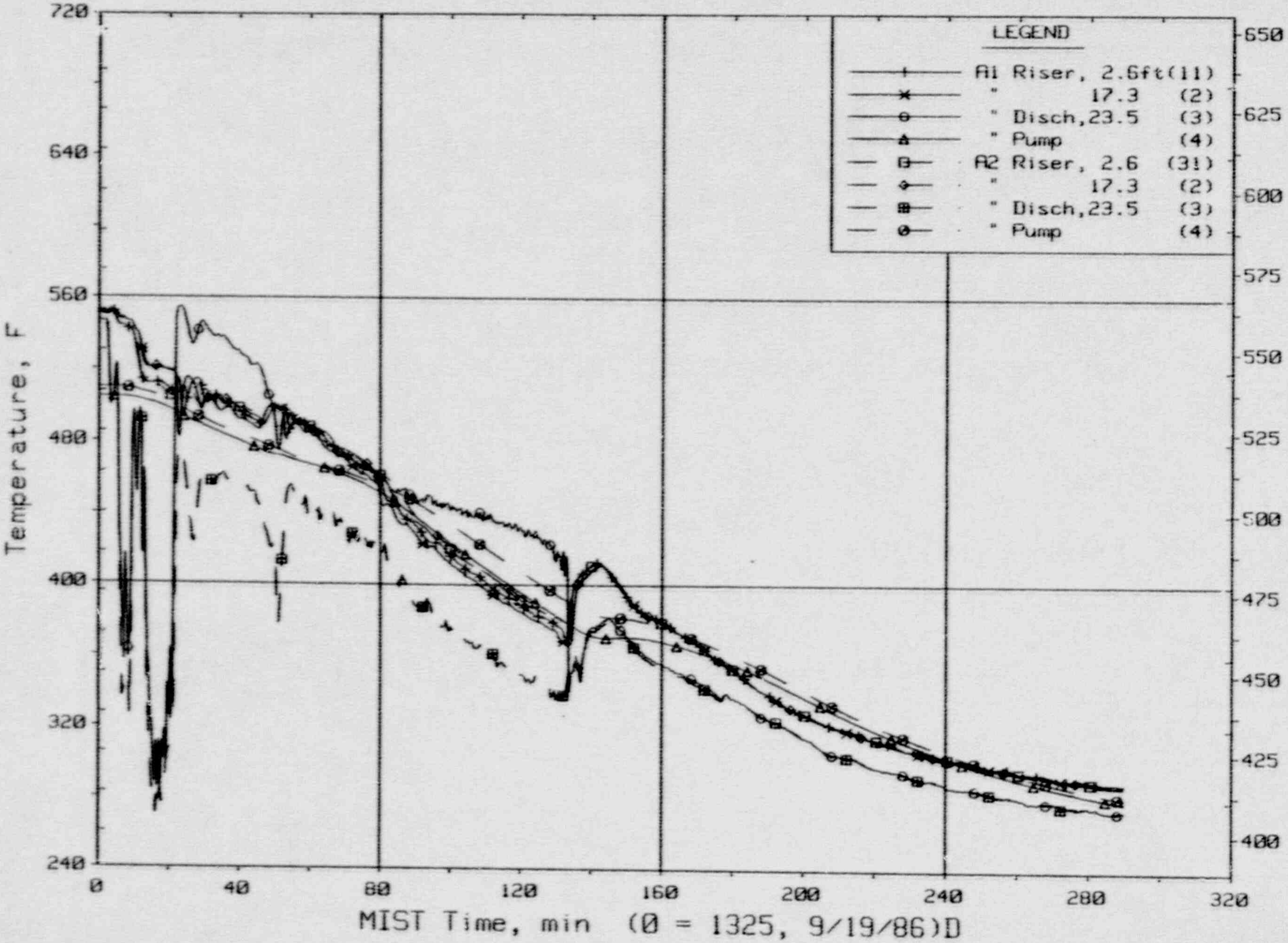
WASHINGTON DC 20555

T350101

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



Loop A Cold Leg Metal Temperatures (C1,3MTs).

Mon Jan 16 08:42:04 1989

C1MT1

FINAL DATA

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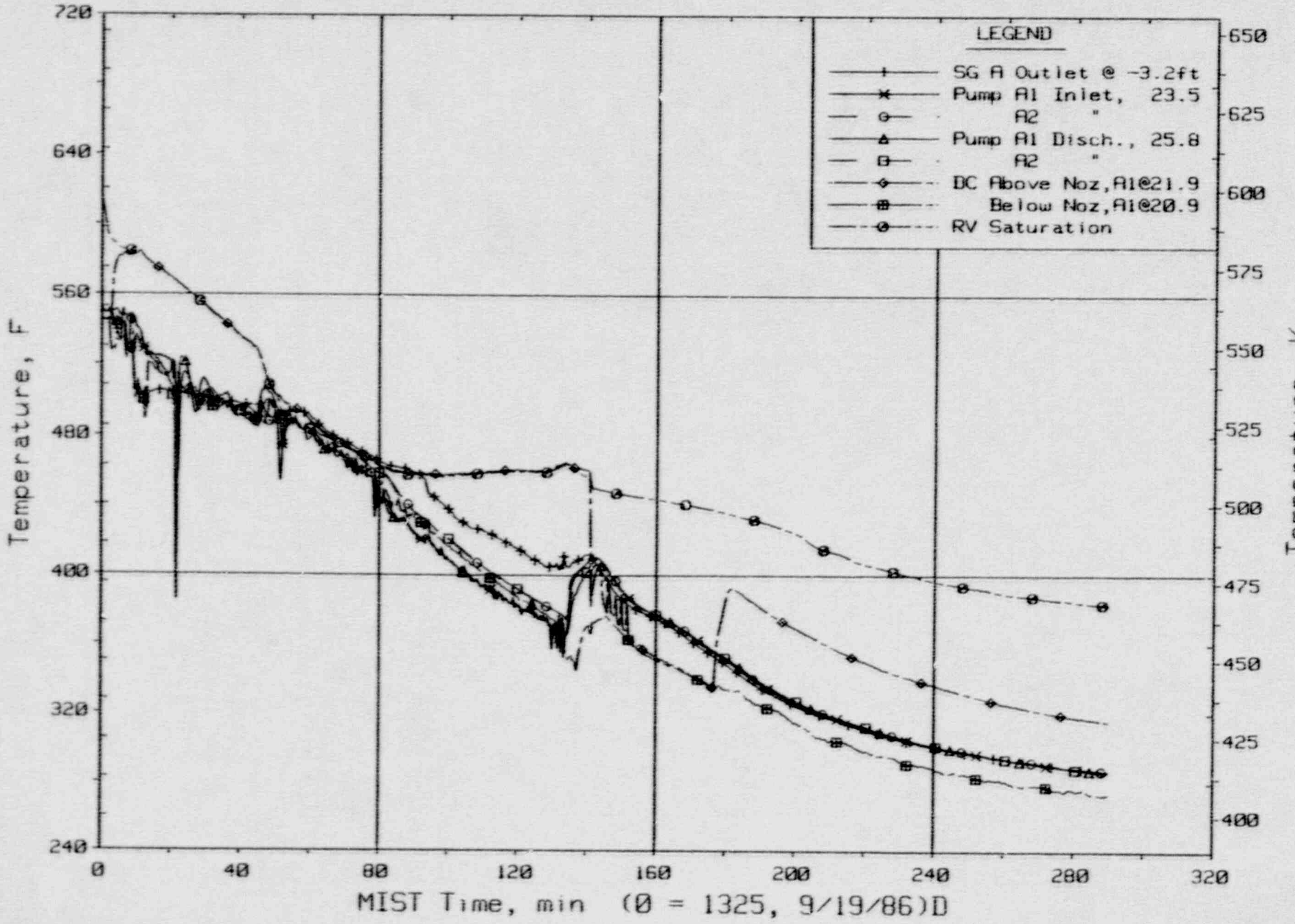

Loop A Cold Leg Fluid Temperatures (RTDs).

Mon Jan 16 08:47:05 1989

C1RT0

FINAL DATA

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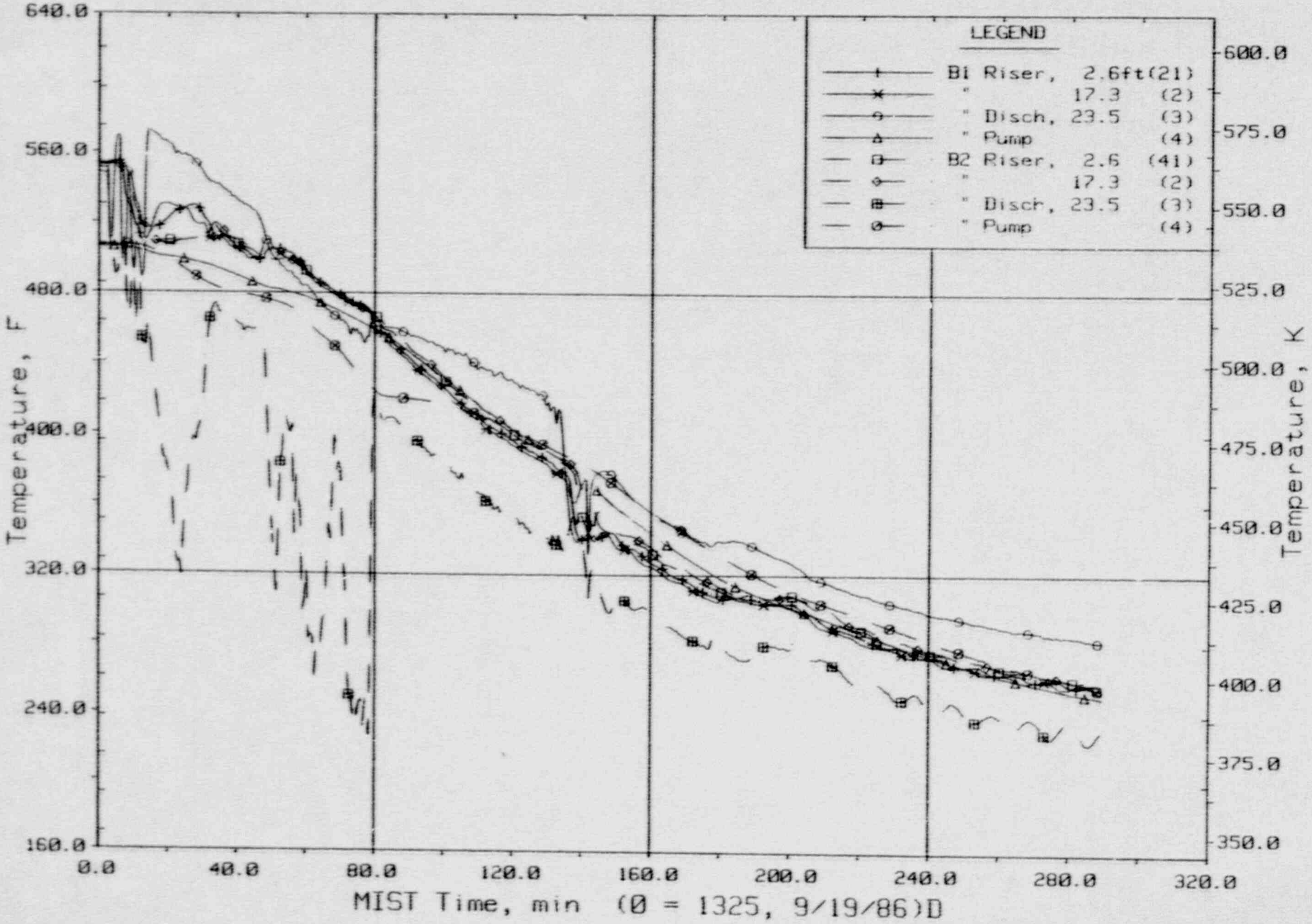
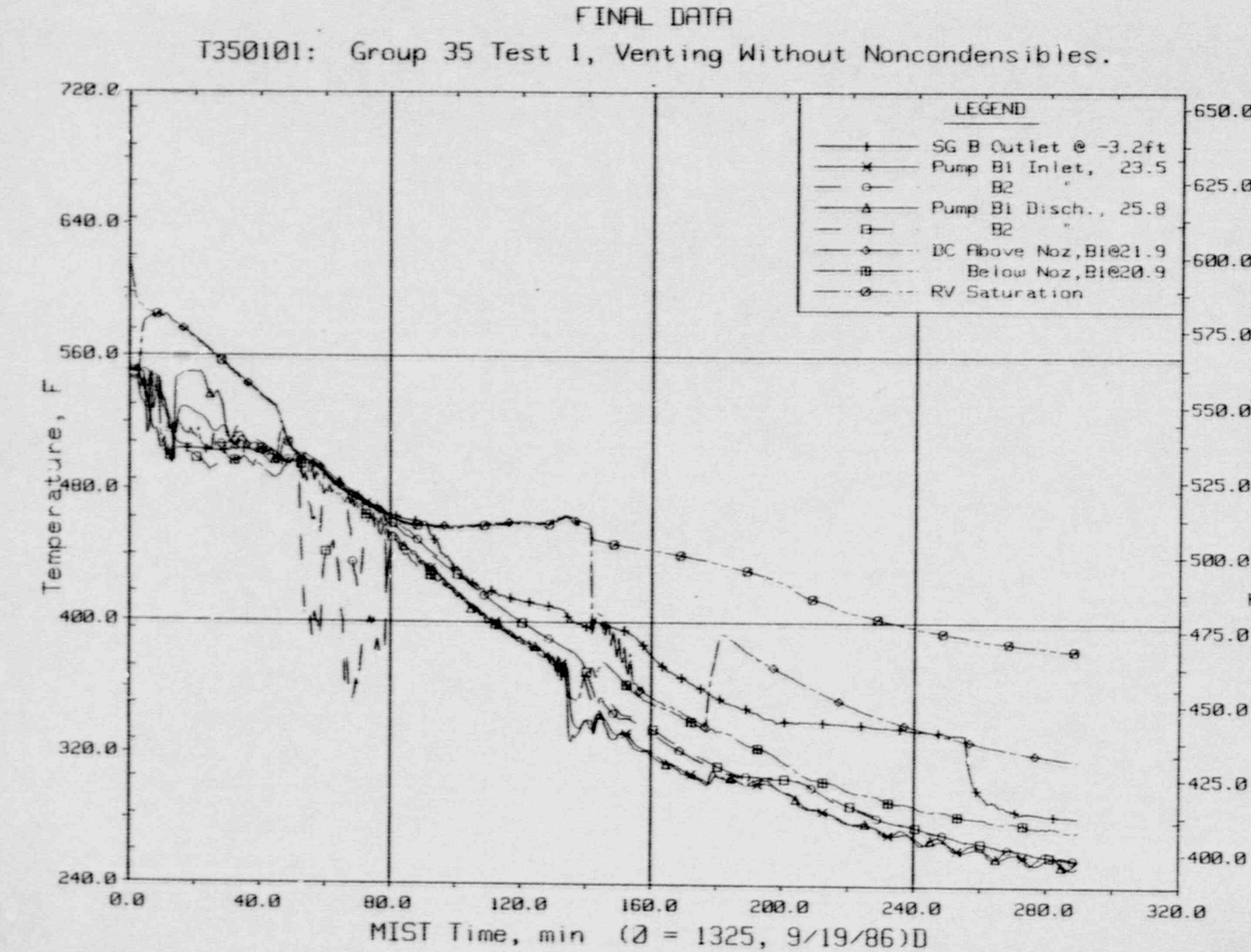


Loop B Cold Leg Metal Temperatures (C2,4MTs).

Fri Jun 3 09:19:07 1988

C2MT1



Loop B Cold Leg Fluid Temperatures (RTDs).

Fri Jun 3 09:24:01 1988

C2RT0

FINAL DATA

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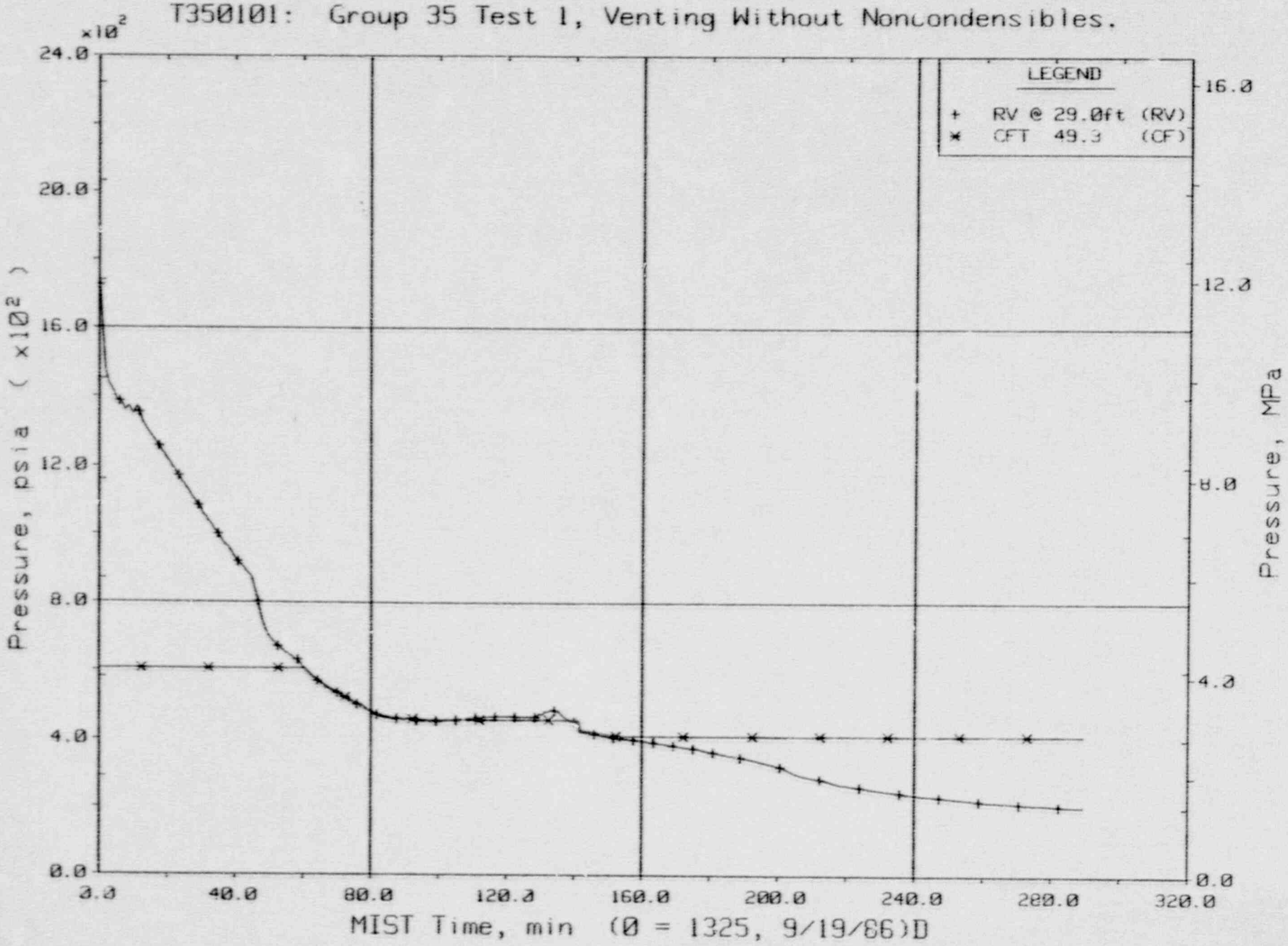


Primary System and Core Flood Tank Pressures (GP01s).

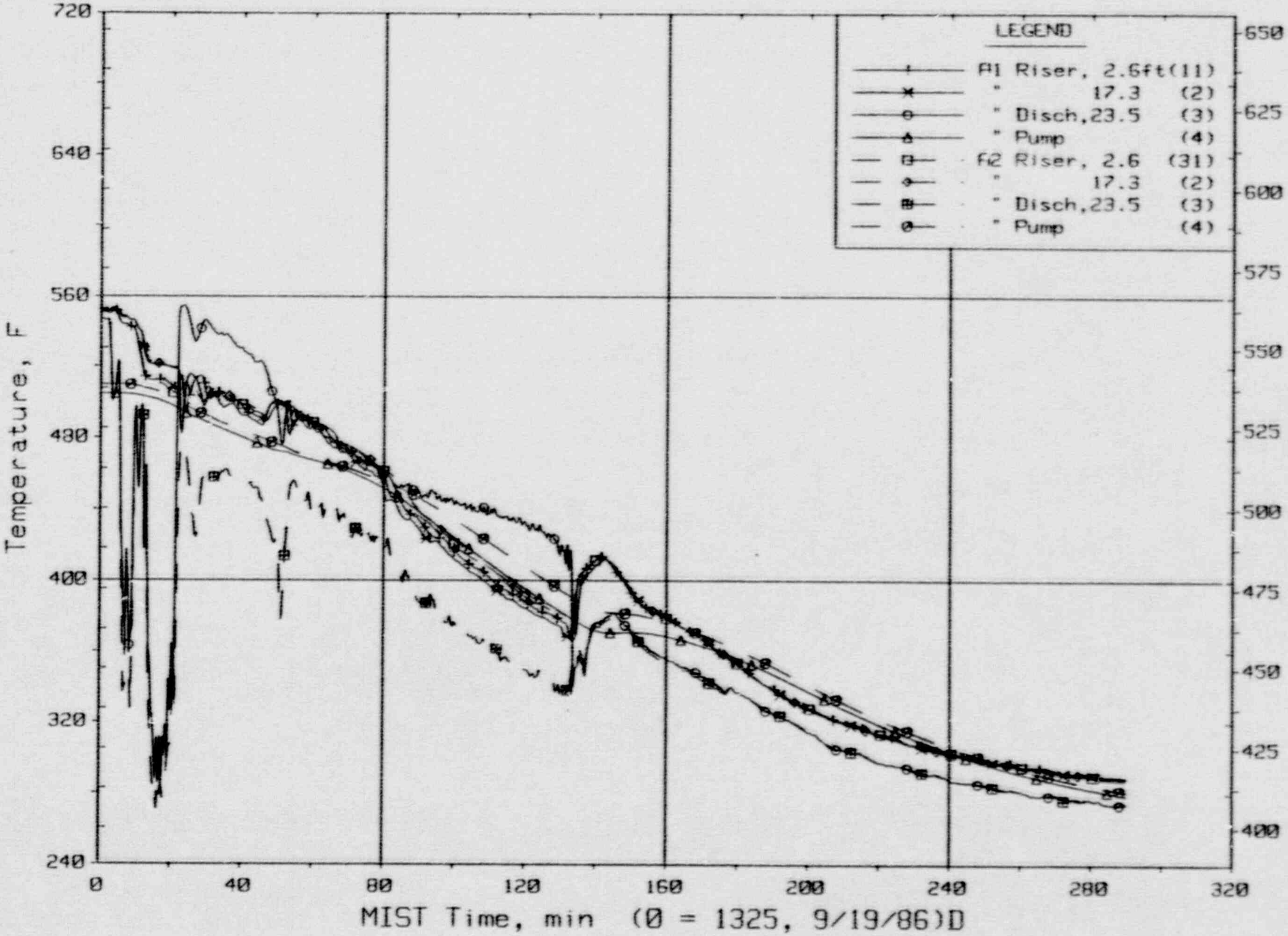
Fri Jun 3 09:27:28 1988

CFGP1

T350101

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



Loop A Cold Leg Metal Temperatures (C1,3MTs).

Mon Jan 16 08:42:04 1989

C1MT1

FINAL DATA

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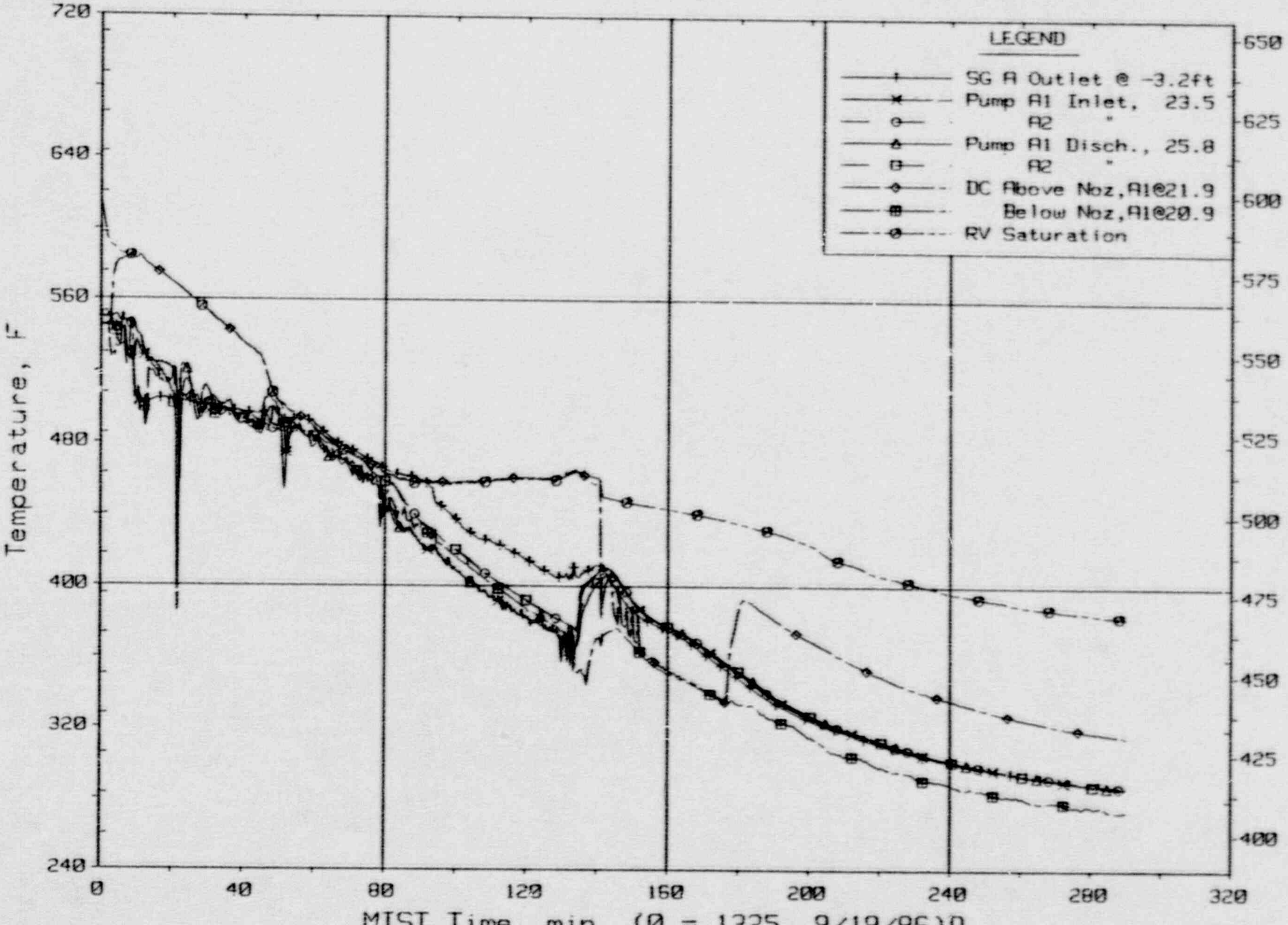

Loop A Cold Leg Fluid Temperatures (RTDs).

Mon Jan 16 08:47:05 1989

C1RT0

FINAL DATA

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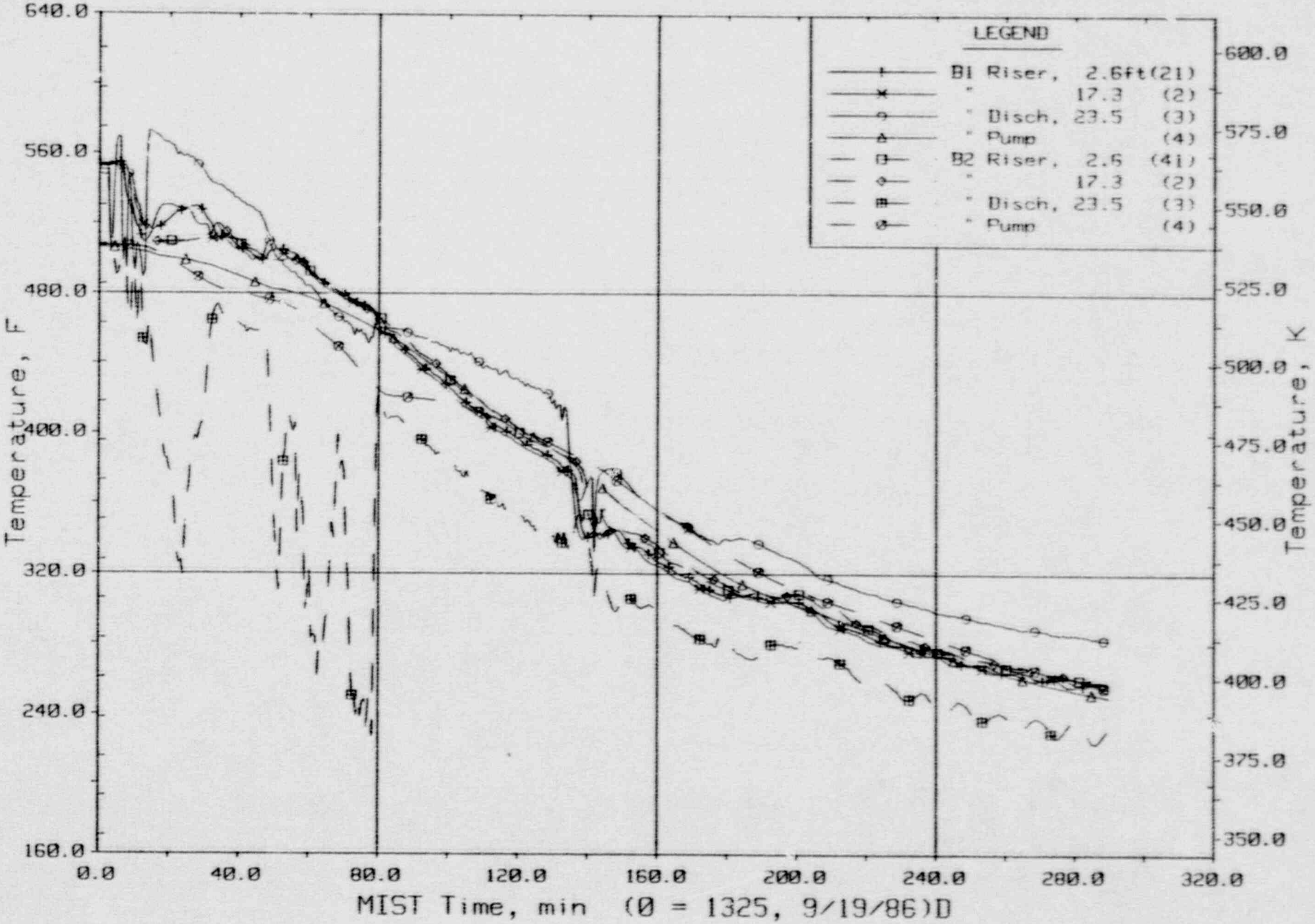


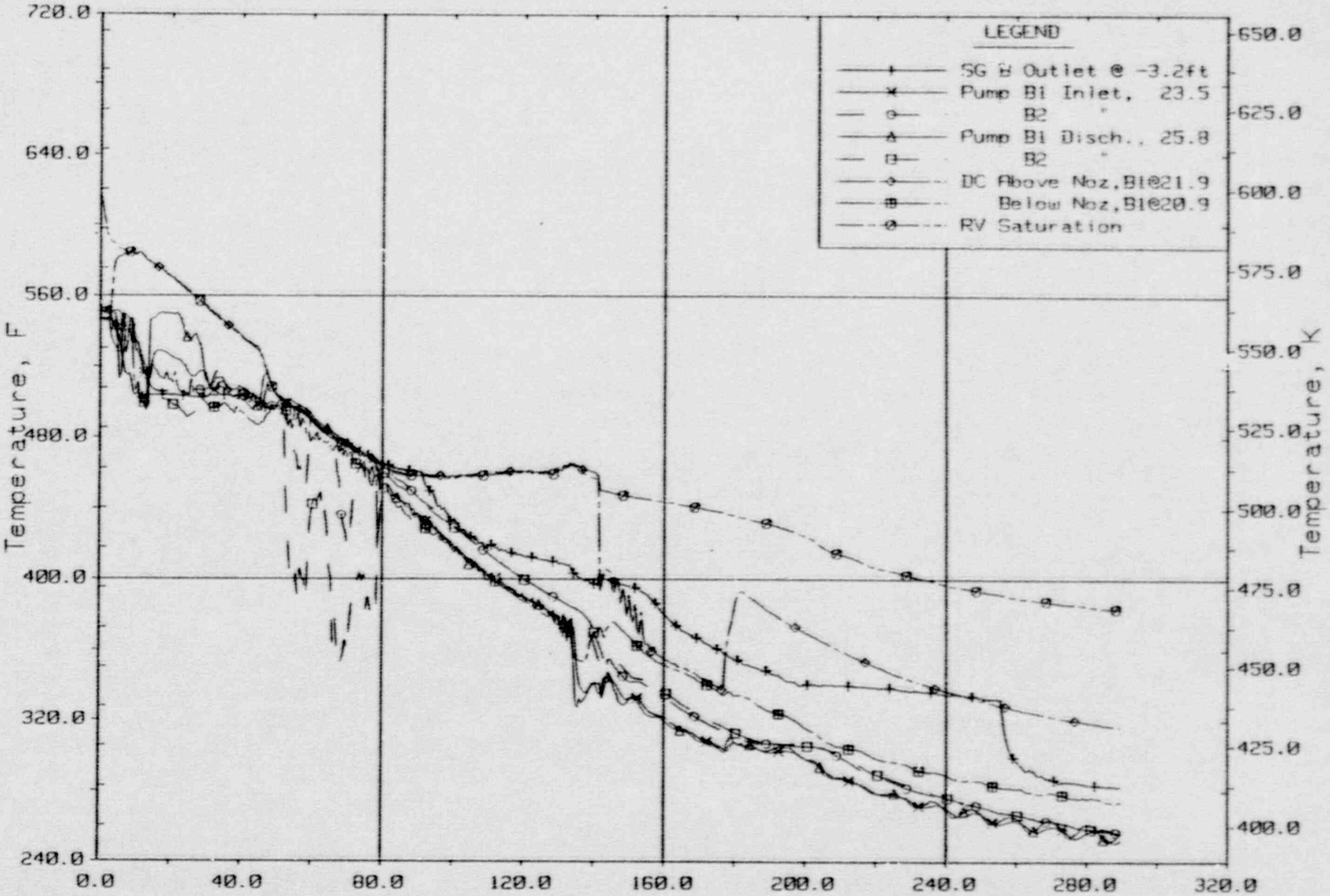
Loop B Cold Leg Metal Temperatures (C2,4MTs).

Fri Jun 3 09:19:07 1988

C2MT1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



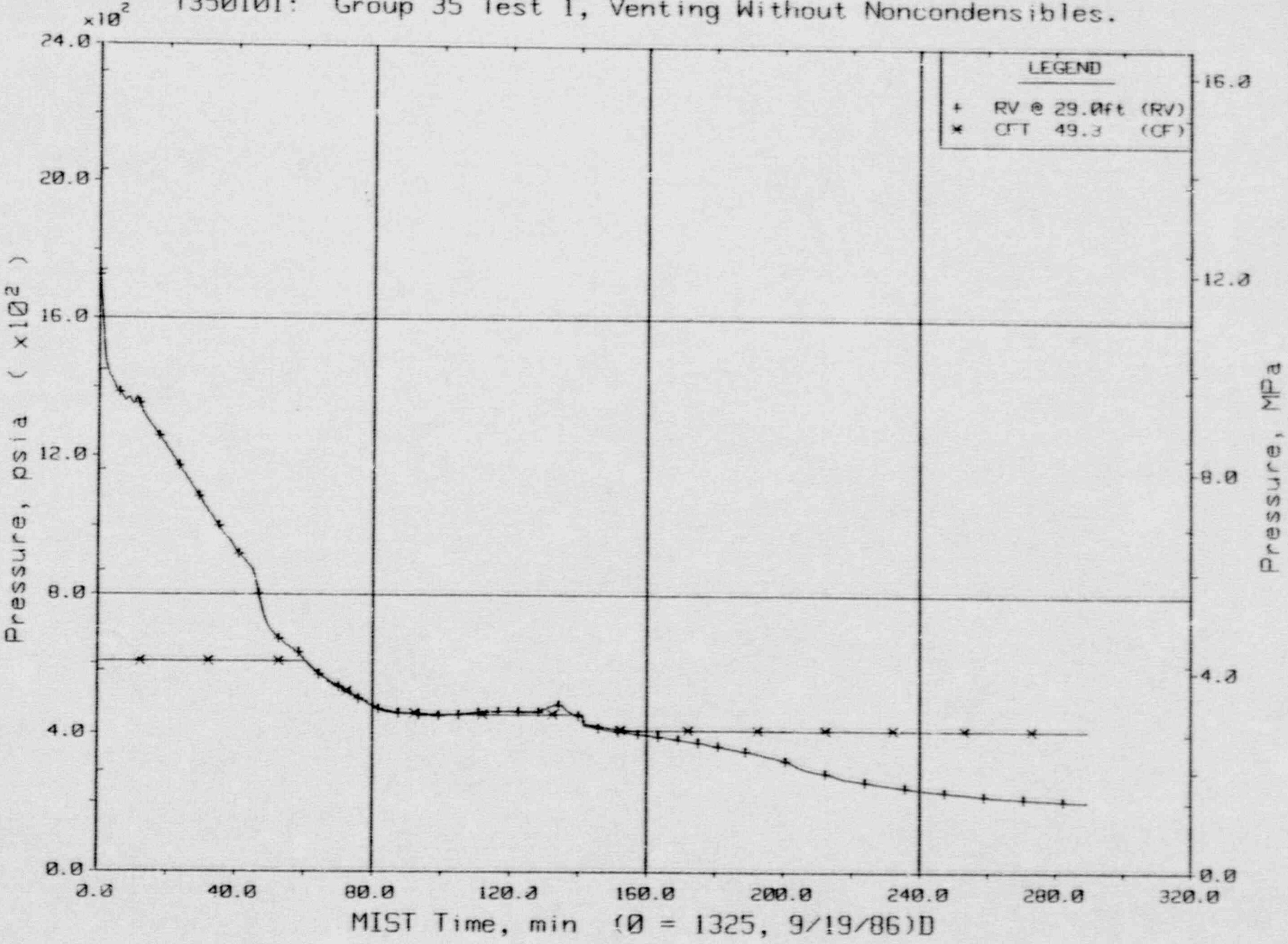
Loop B Cold Leg Fluid Temperatures (RTDs).

Fri Jun 3 09:24:01 1988

C2RT0

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



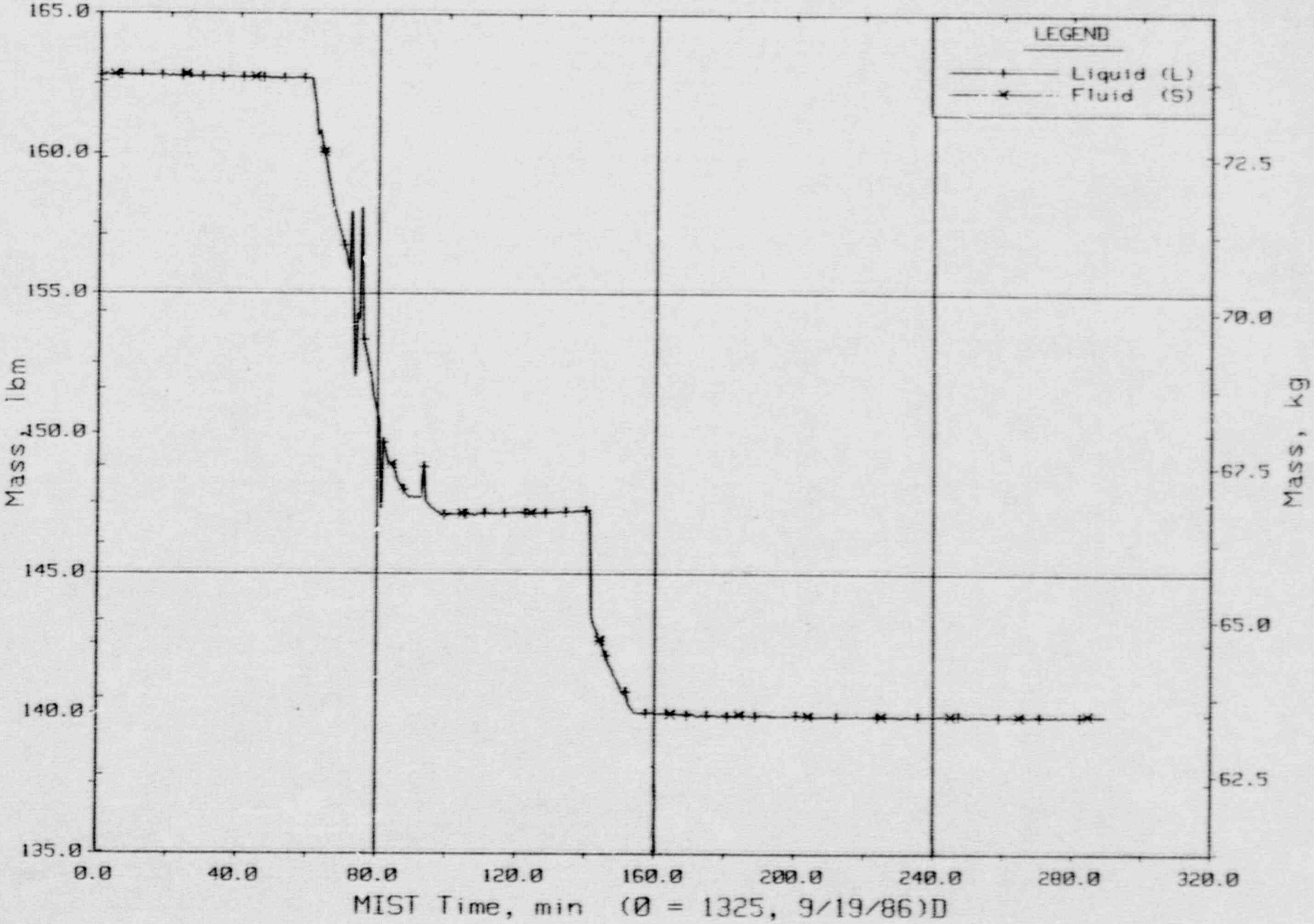
Primary System and Core Flood Tank Pressures (GP01s).

Fri Jun 3 09:27:28 1988

CFGP1

FINAL DATA

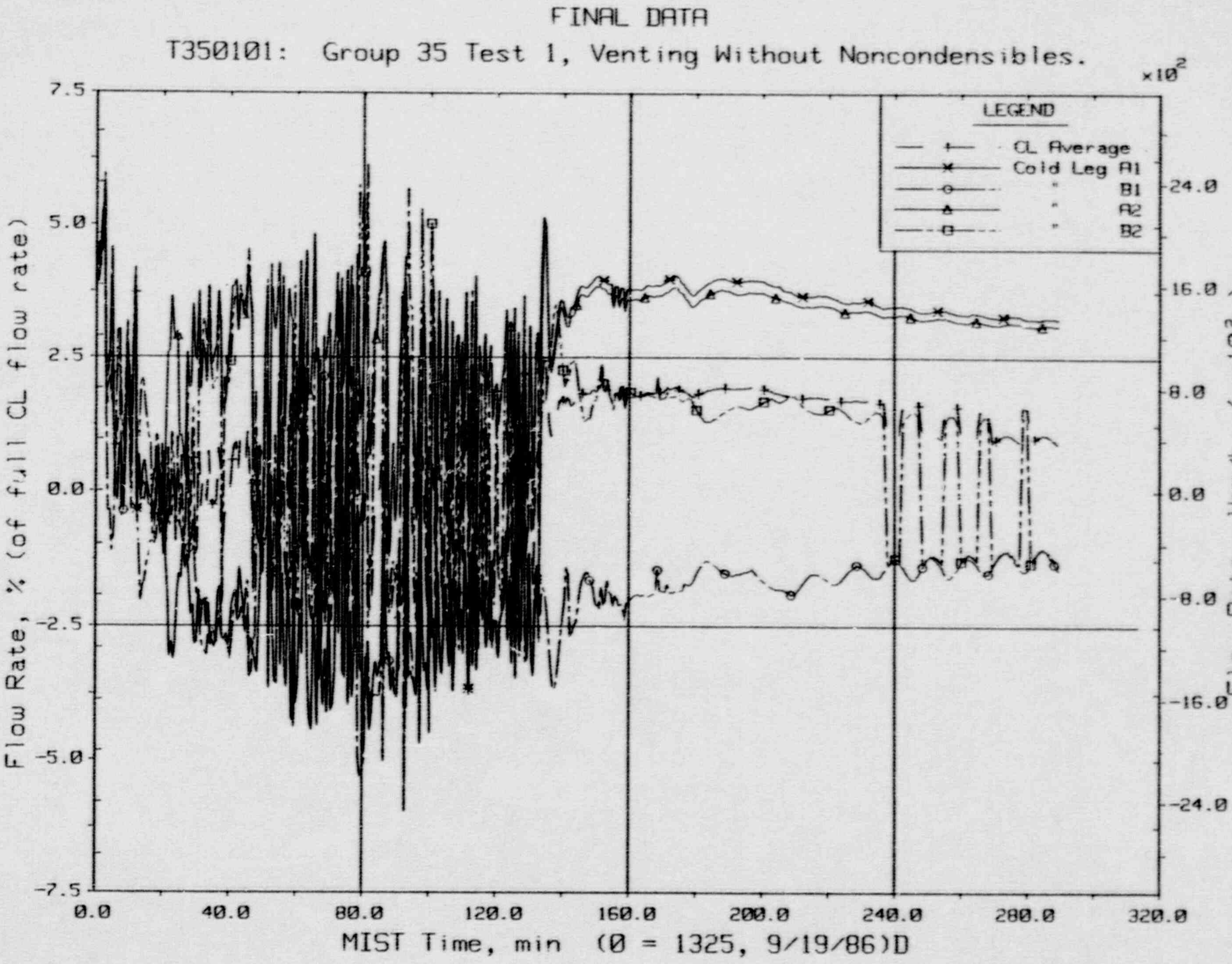
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Fri Jun 3 09:30:24 1988

CFML1



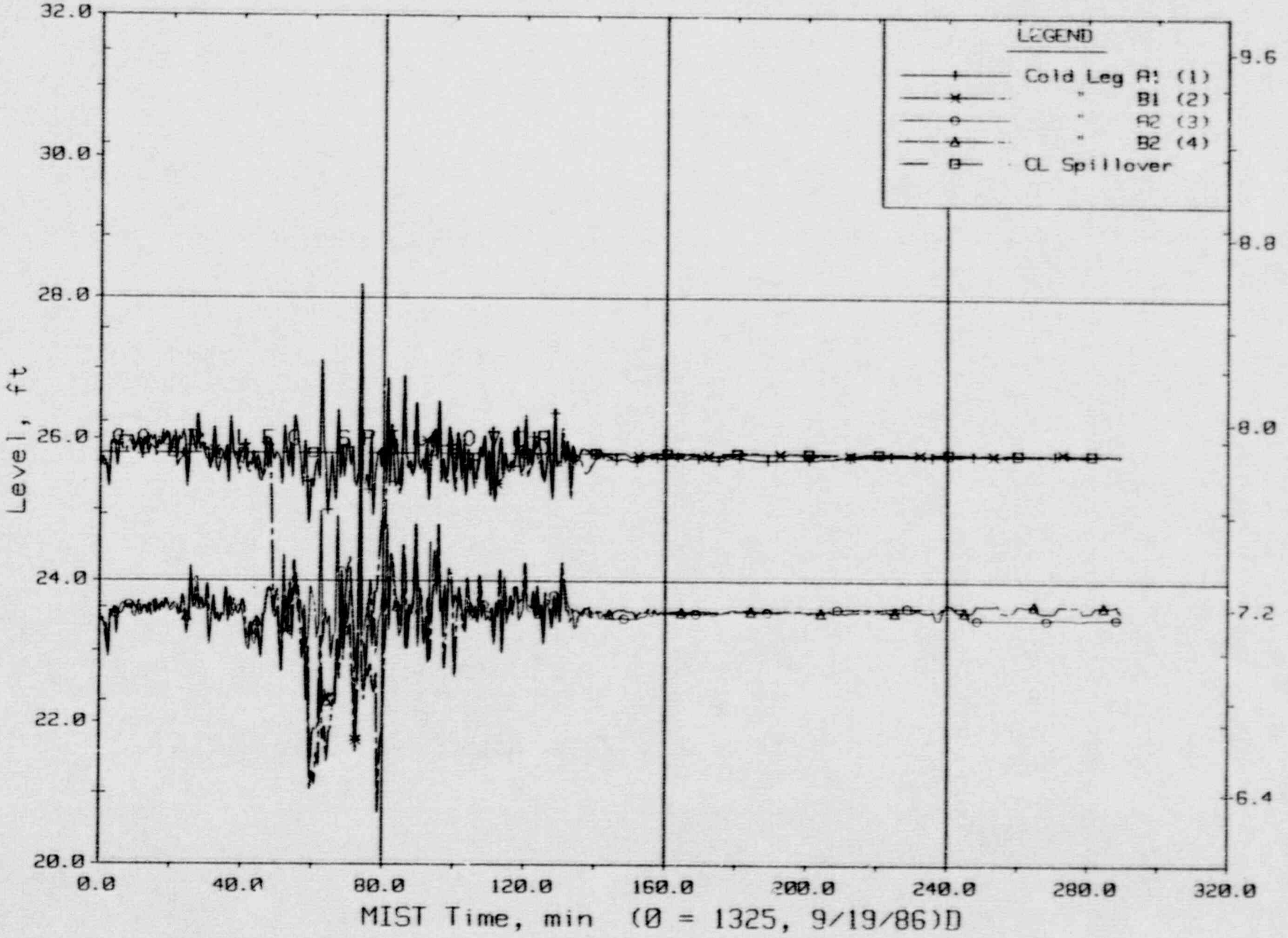
Cold Leg (Venturi) Flow Rates.

Mon Jun 6 10:40:13 1988

CLFL1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



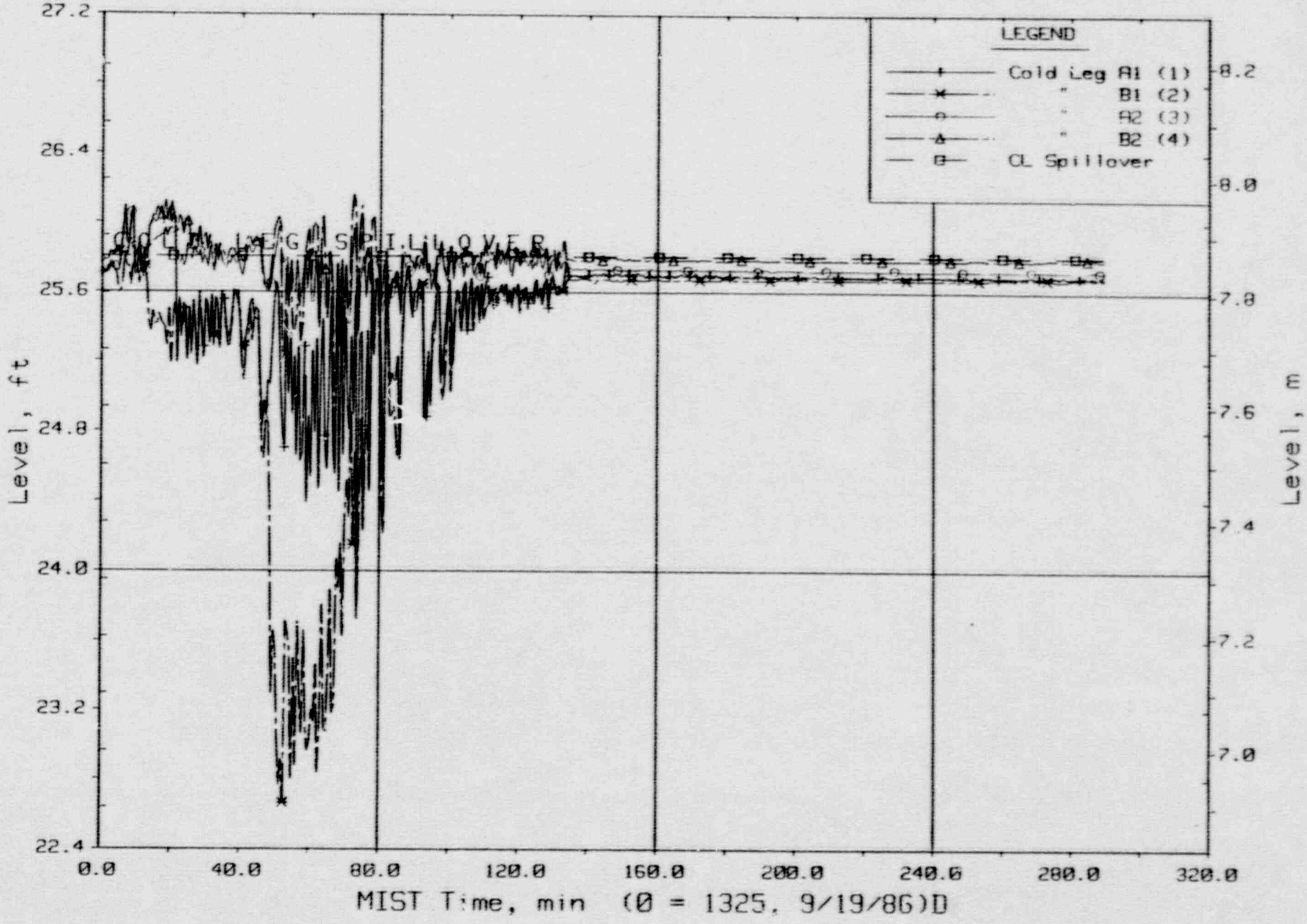
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Fri Jun 3 09:42:41 1988

CLLV4

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



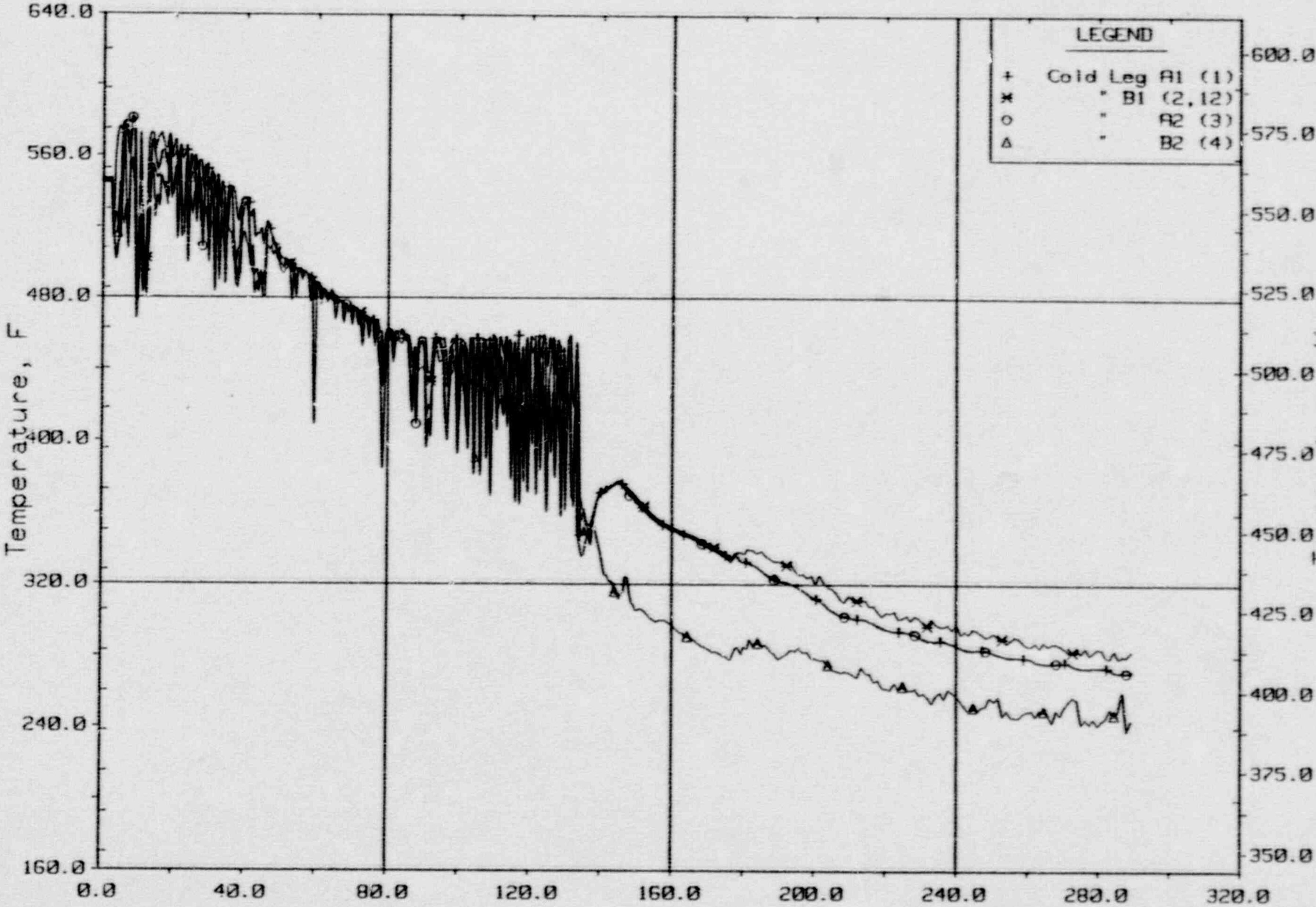
Cold Leg Discnarge Collapsed Liquid Levels (CnLV23s).

Fri Jun 3 09:46:45 1988

CLLV5

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



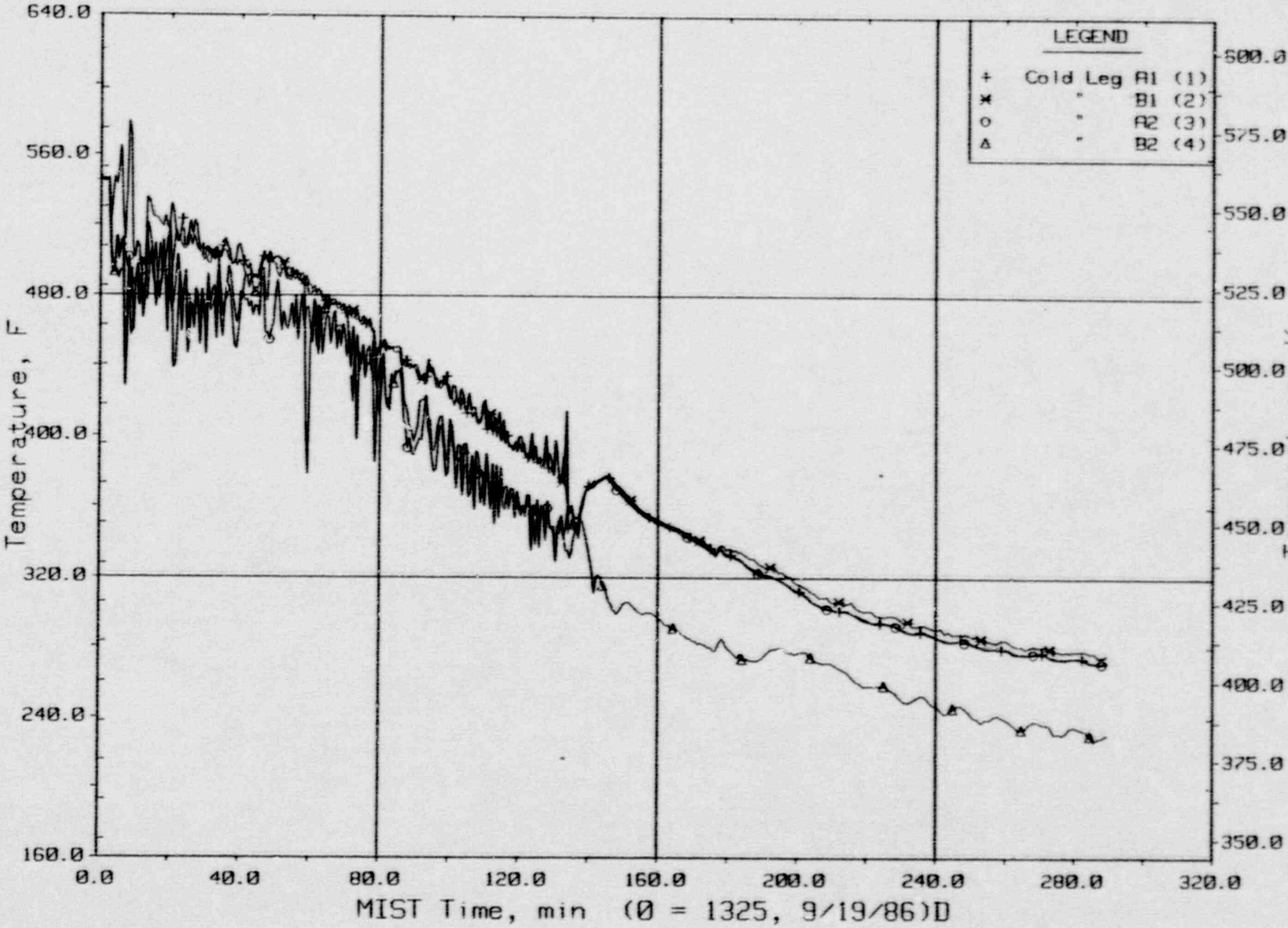
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Mon Jun 6 10:30:58 1988

CLTC1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



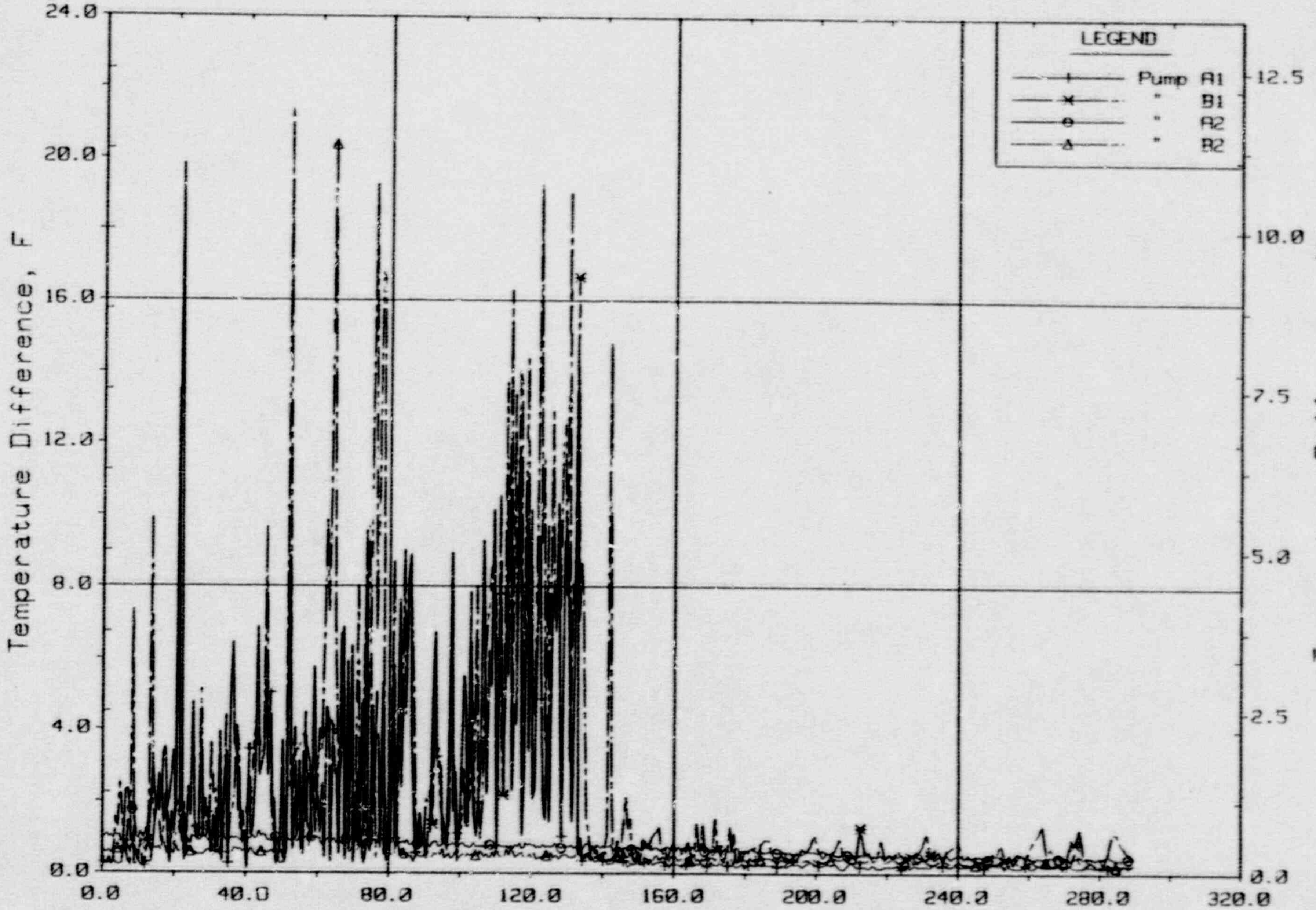
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Mon Jun 6 10:33:45 1988

CLTC2

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



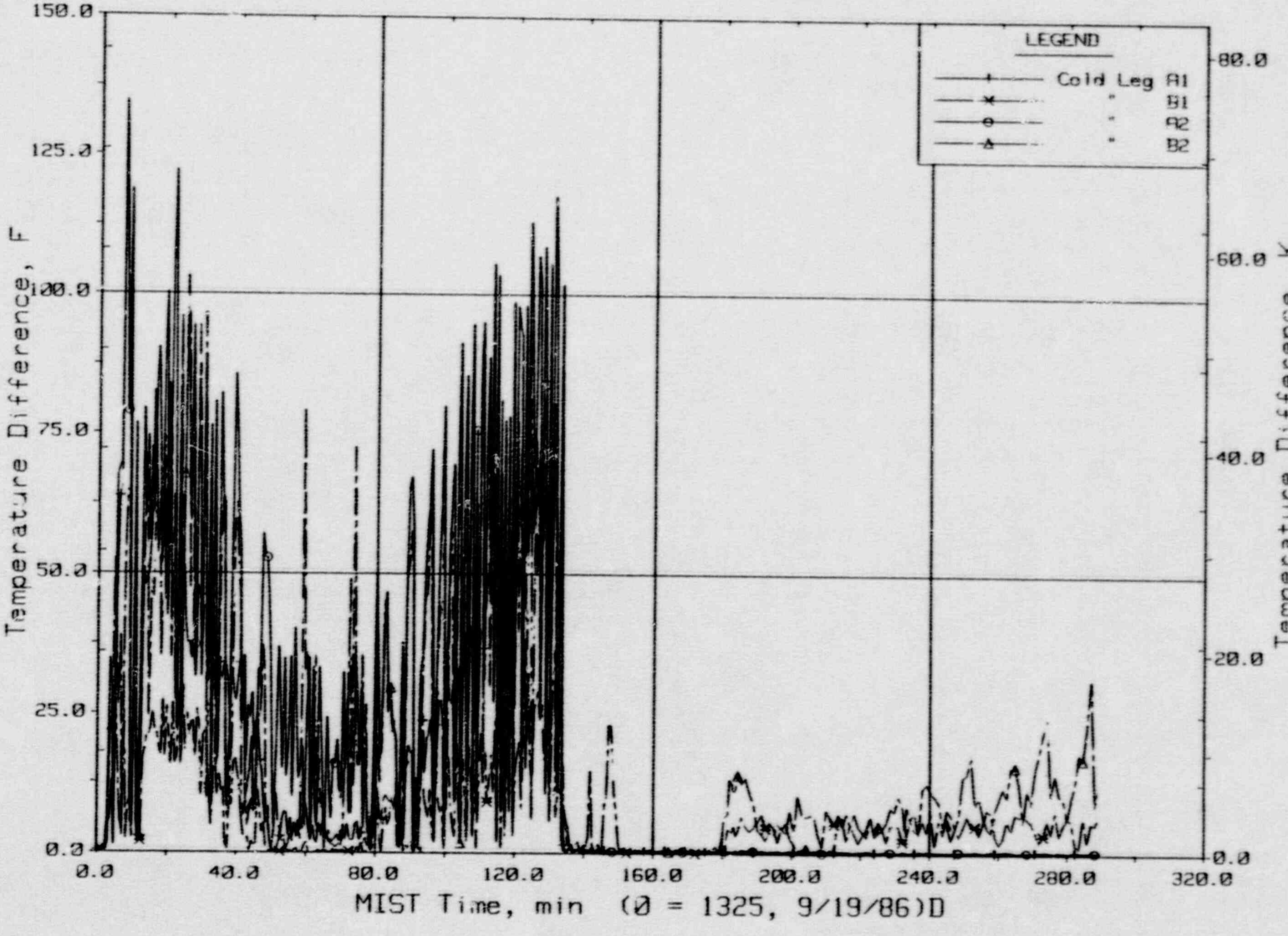
Maximum Differences Among RCP Rake Fluid Temperatures.

Mon Jun 6 10:37:33 1988

CLTD1

FINAL DATA

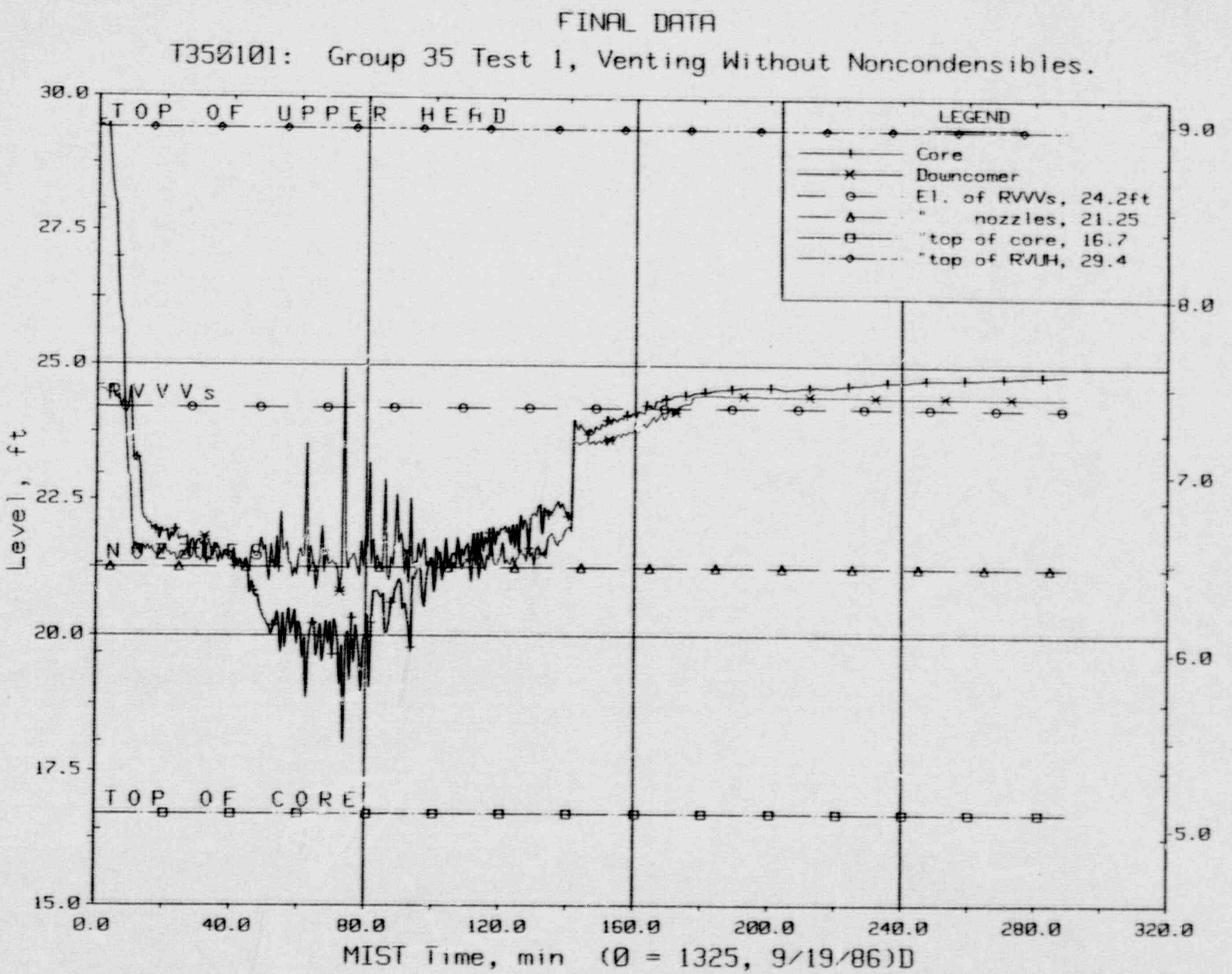
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Mon Jun 6 10:41:21 1988

CLTD2



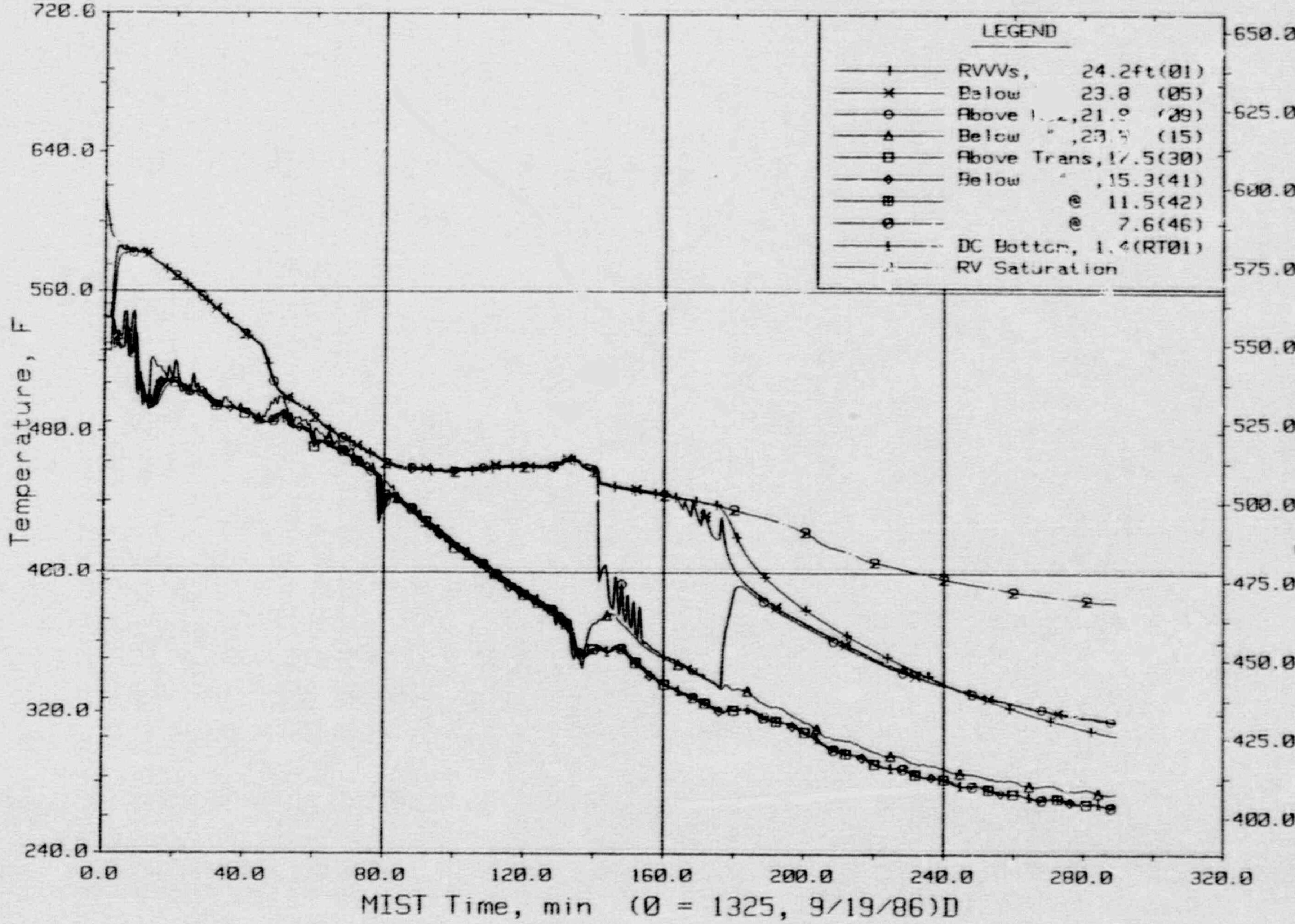
Core Region Collapsed Liquid Levels.

Fri Jun 3 10:15:55 1988

COLV1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



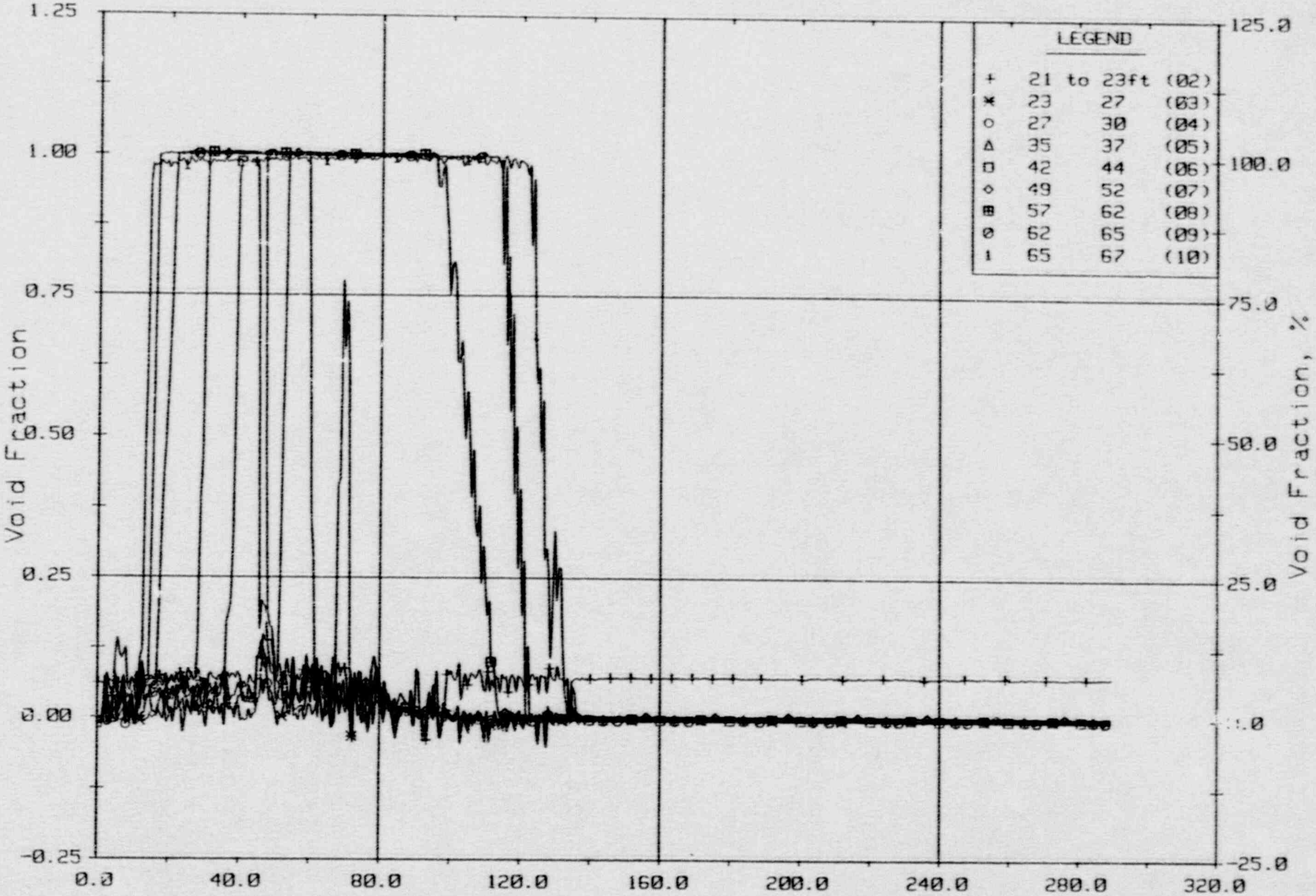
Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Fri Jun 3 10:25:45 1988

DCTC6

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



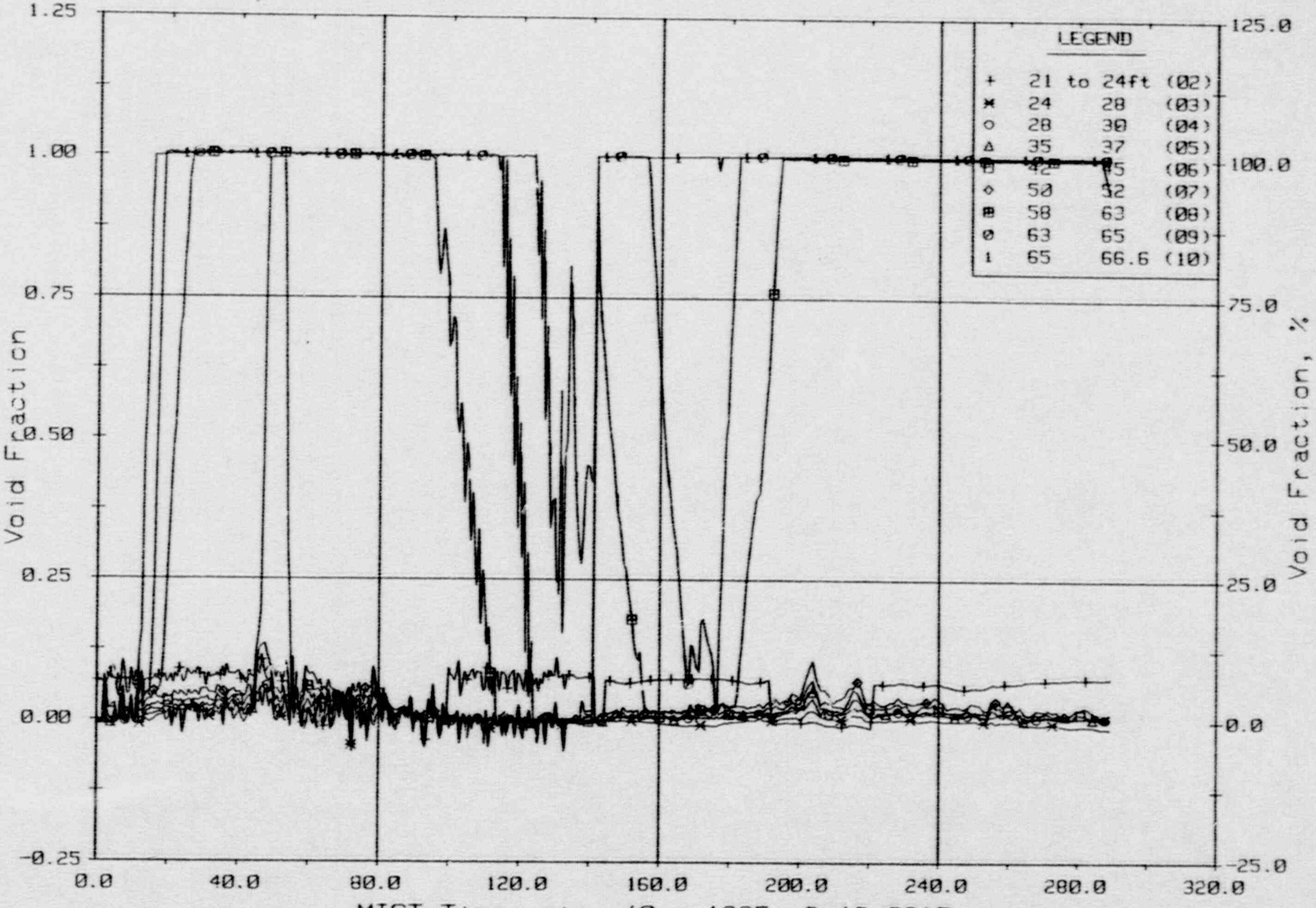
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Fri Jun 3 10:31:13 1988

H1VF1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



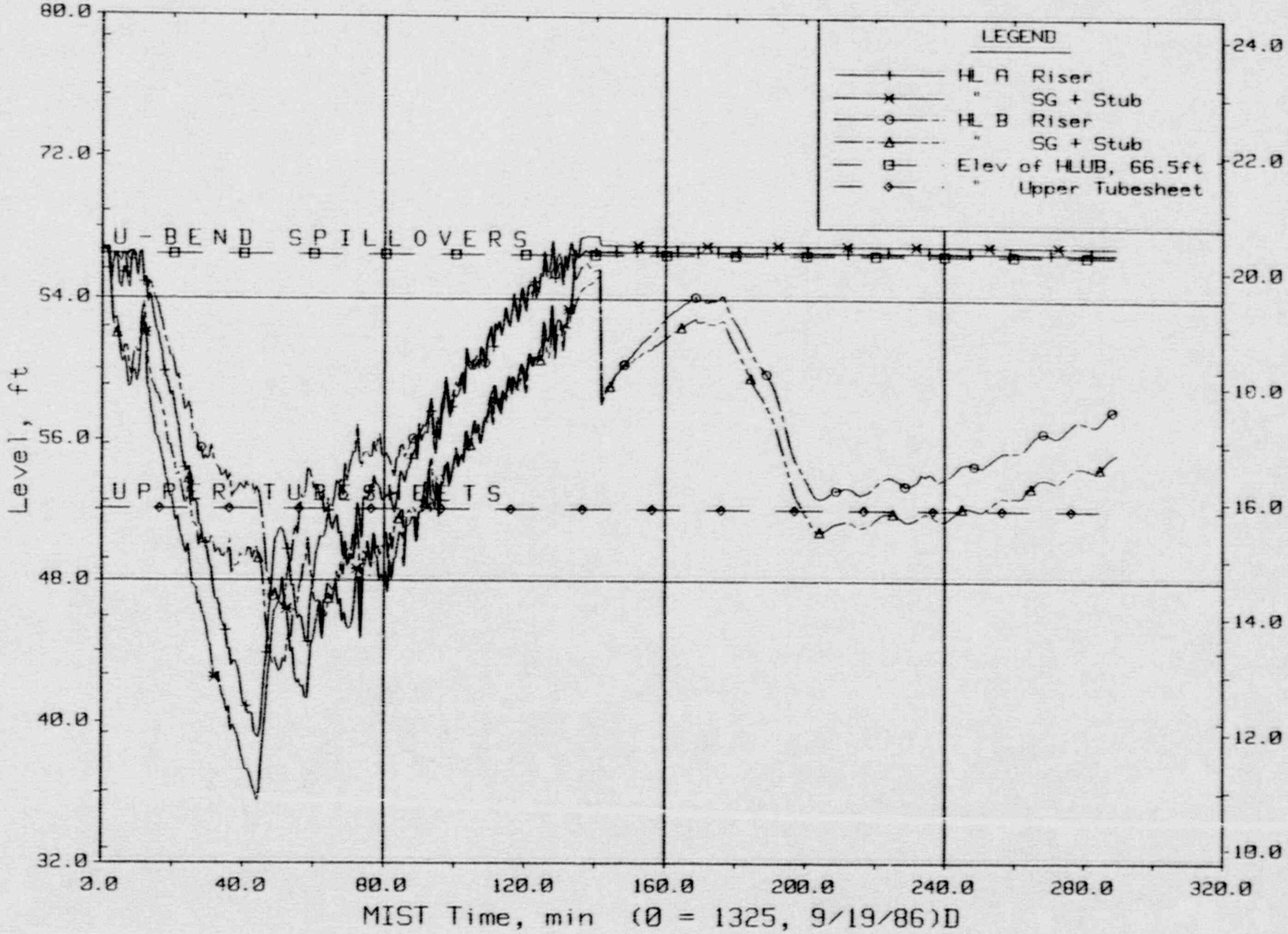
Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).

Fri Jun 3 10:35:52 1988

H2VF1

FINAL DATA

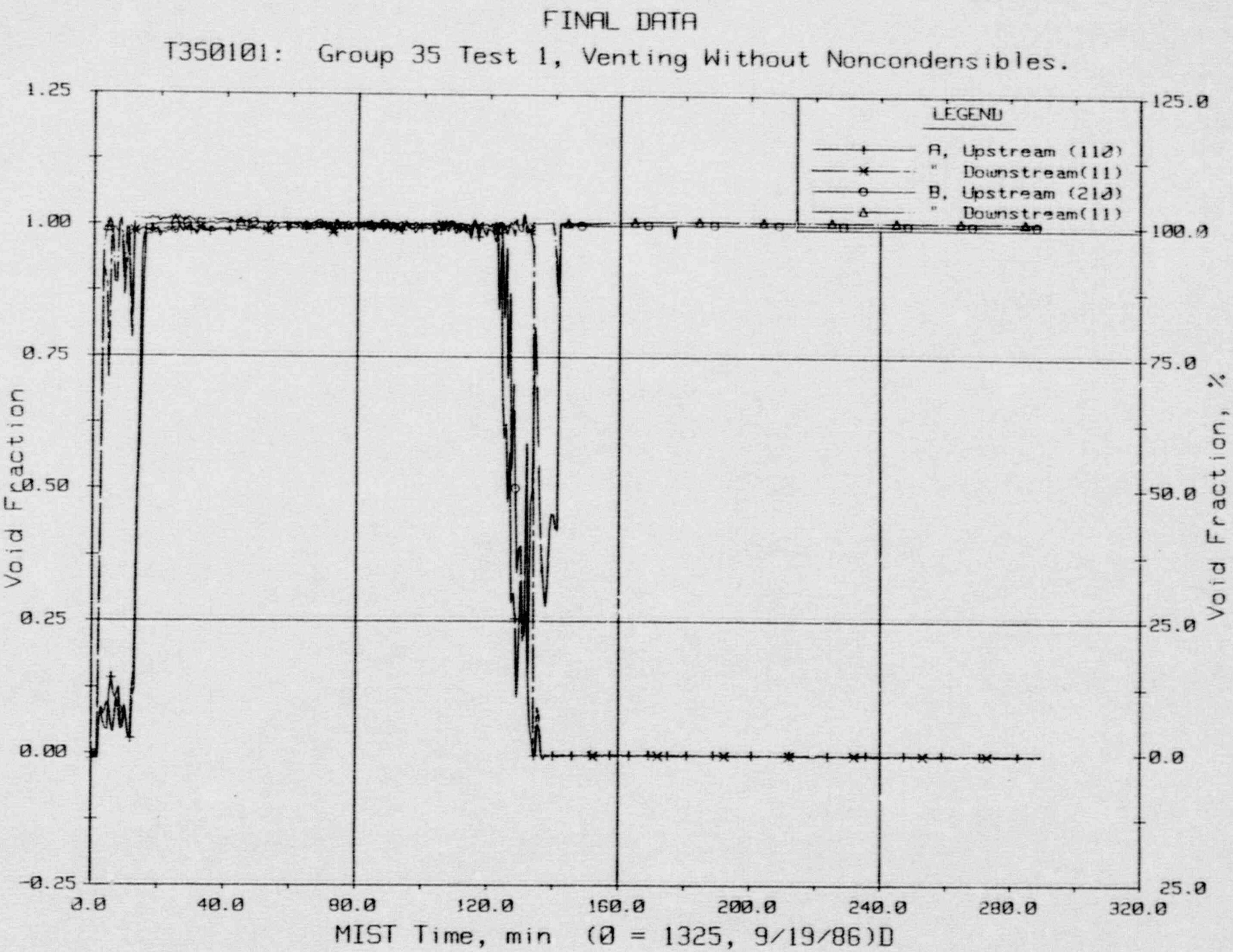
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Hot Leg Riser and Stub Collapsed Liquid Levels.

Fri Jun 3 10:40:21 1988

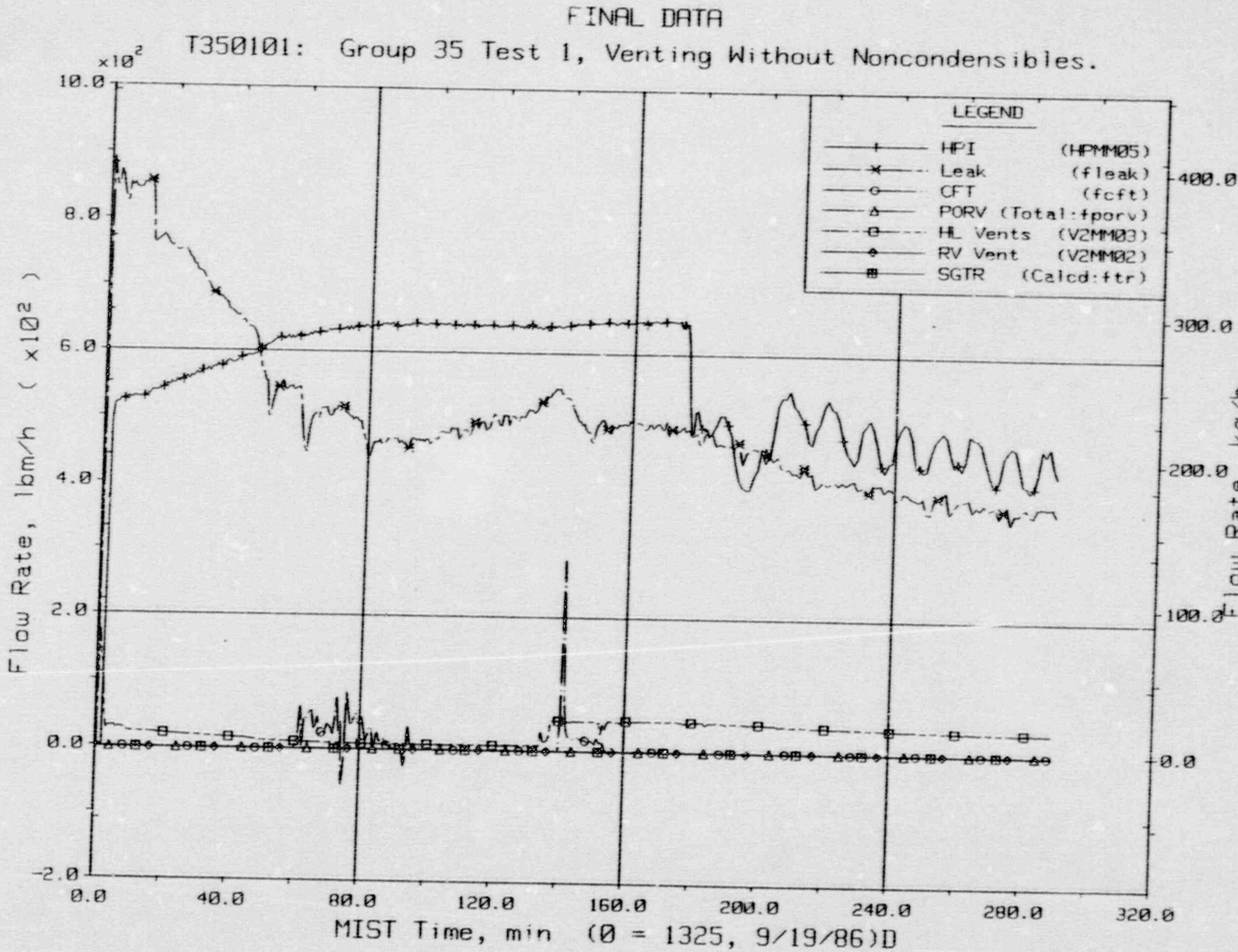
HLLV1



Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft, HnVFs).

Fri Jun 3 10:44:10 1988

HLVF1



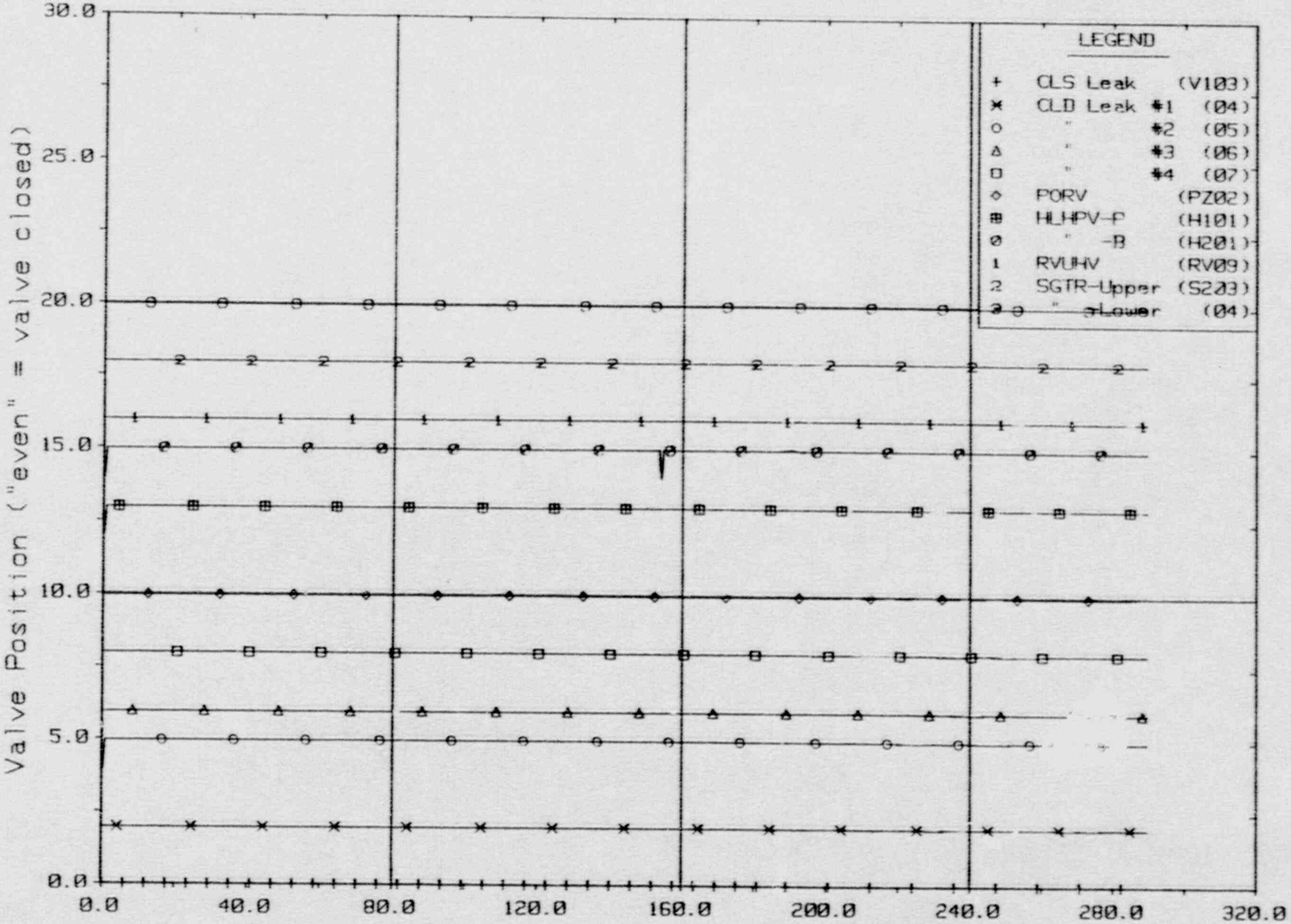
Primary System Boundary Flow Rates.

Fri Jun 3 10:48:48 1986

PBFL3

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



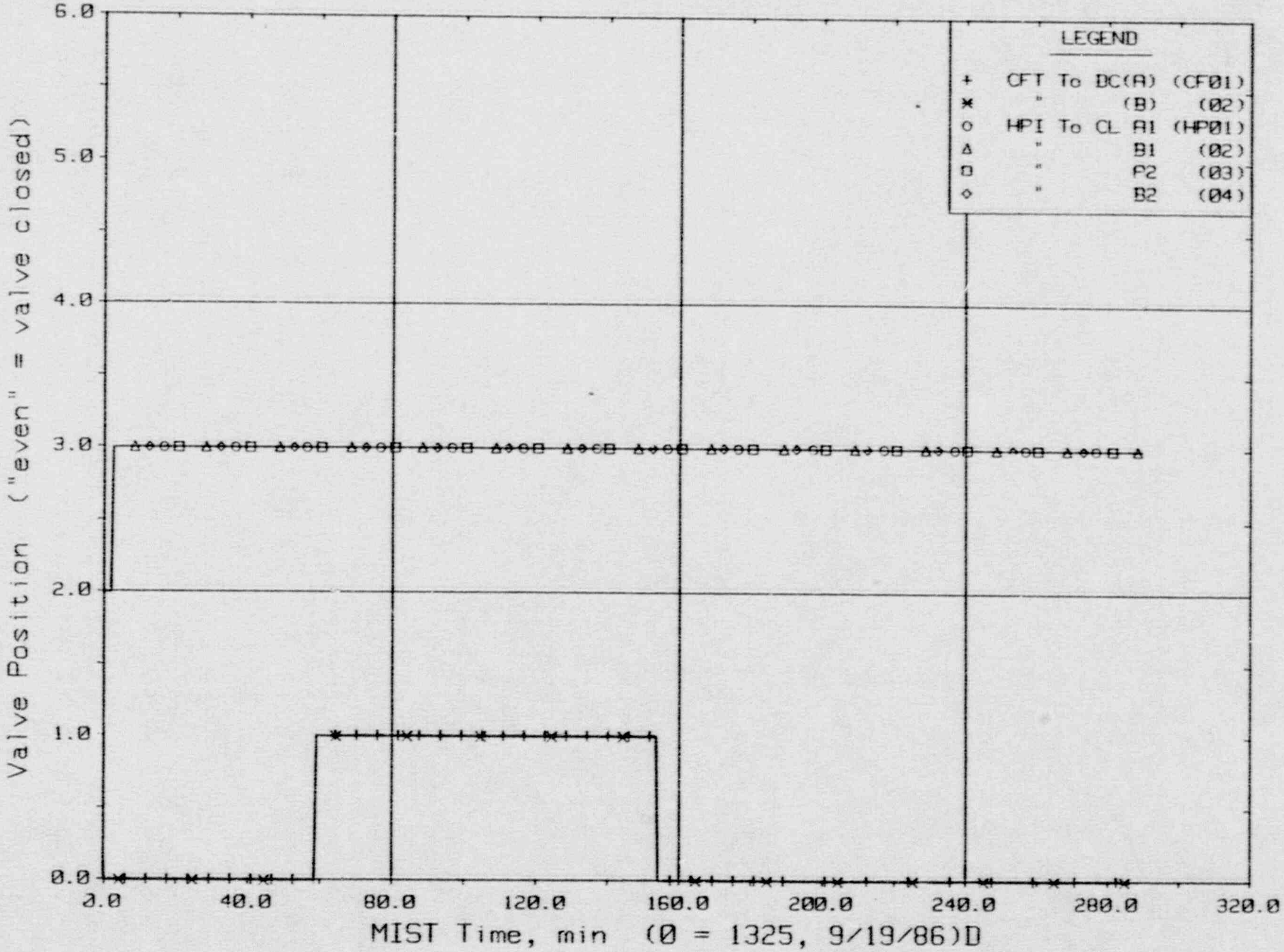
Primary System Discharge Limit Switch Indications (LSs).

Fri Jun 3 10:54:16 1988

PBLS1

FINAL DATA

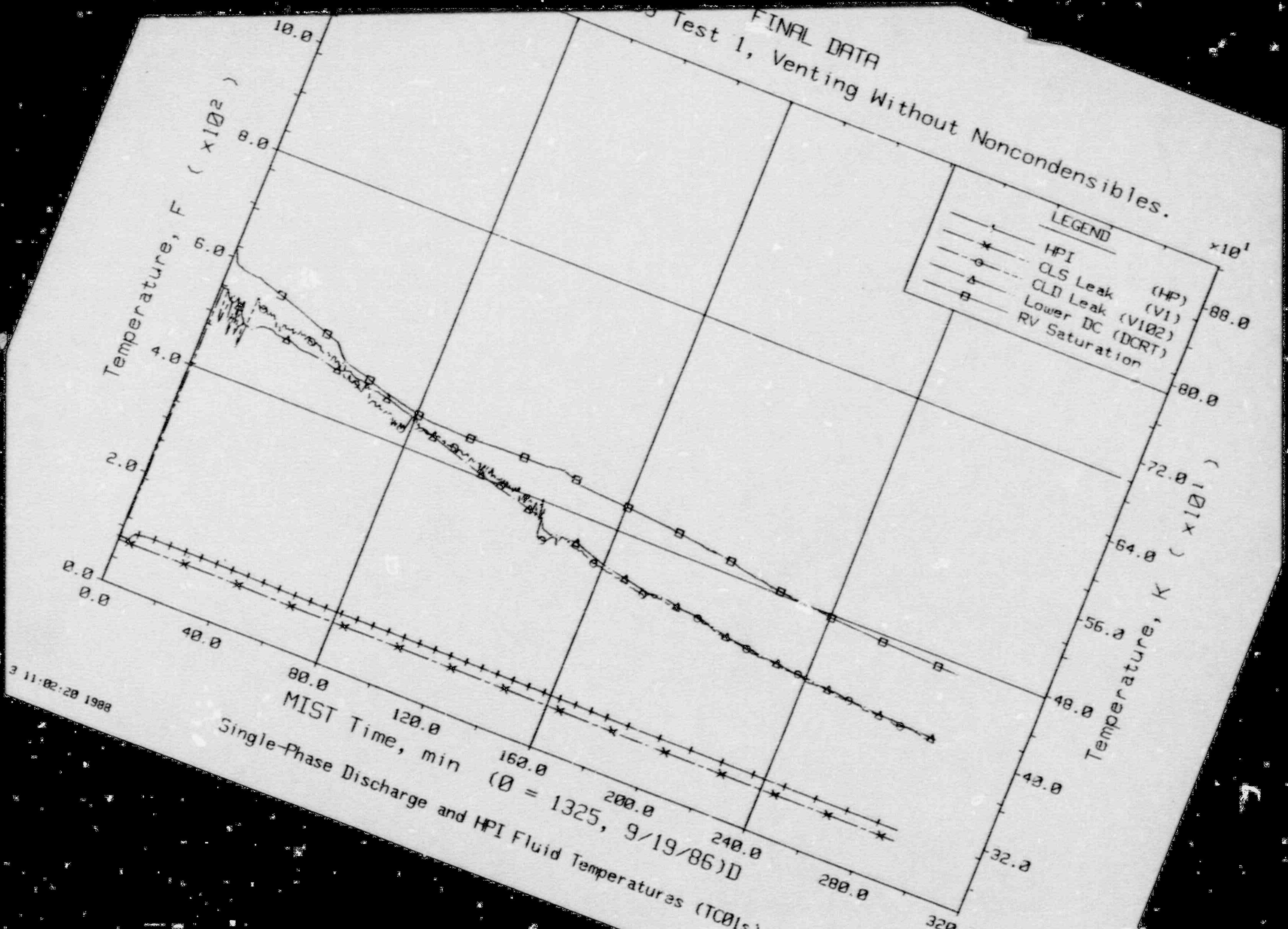
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Primary System Injection Limit Switch Indications (LSs).

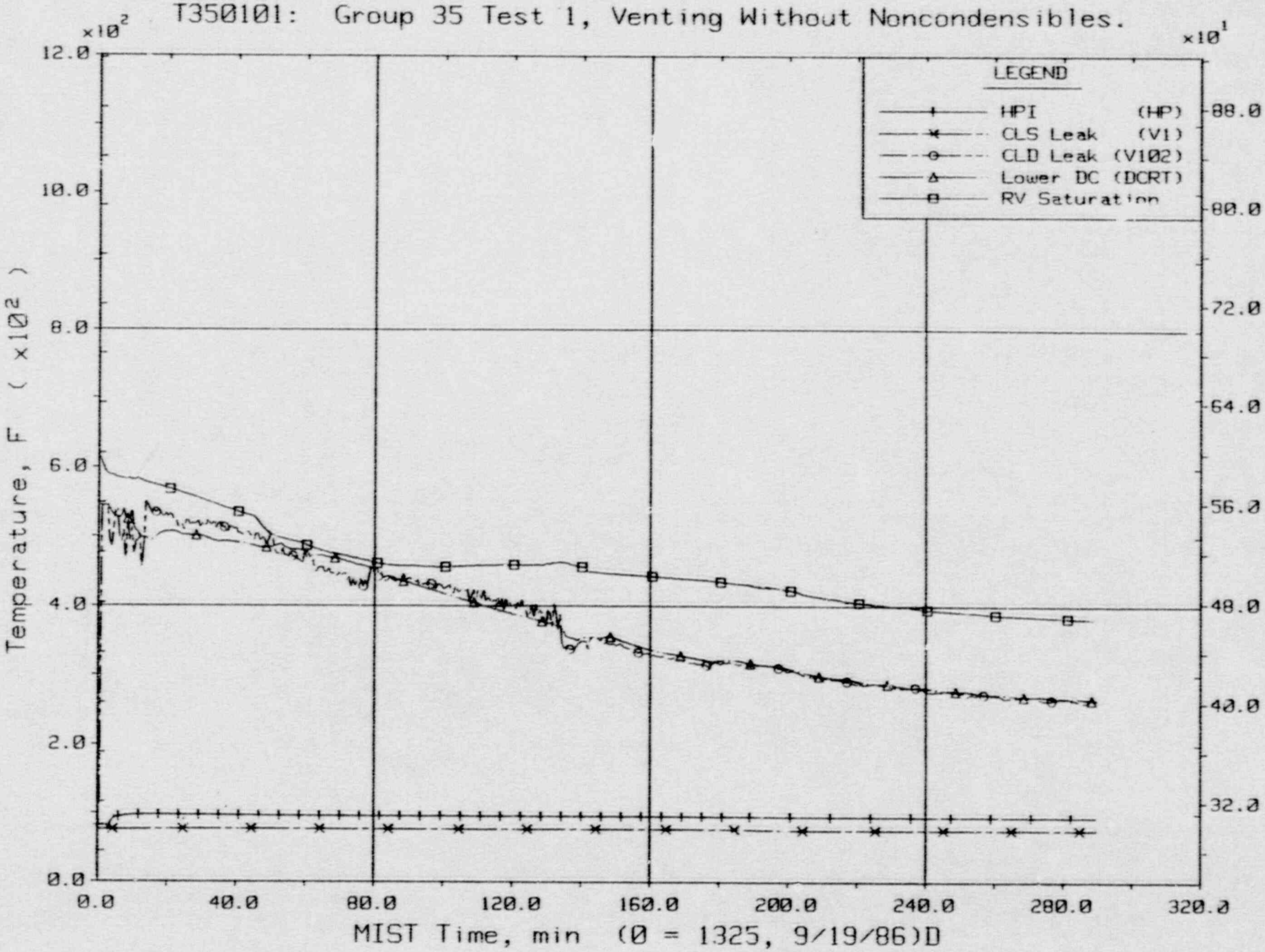
Fri Jun 3 10:58:32 1988

PBLS2



Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

FINAL DATA



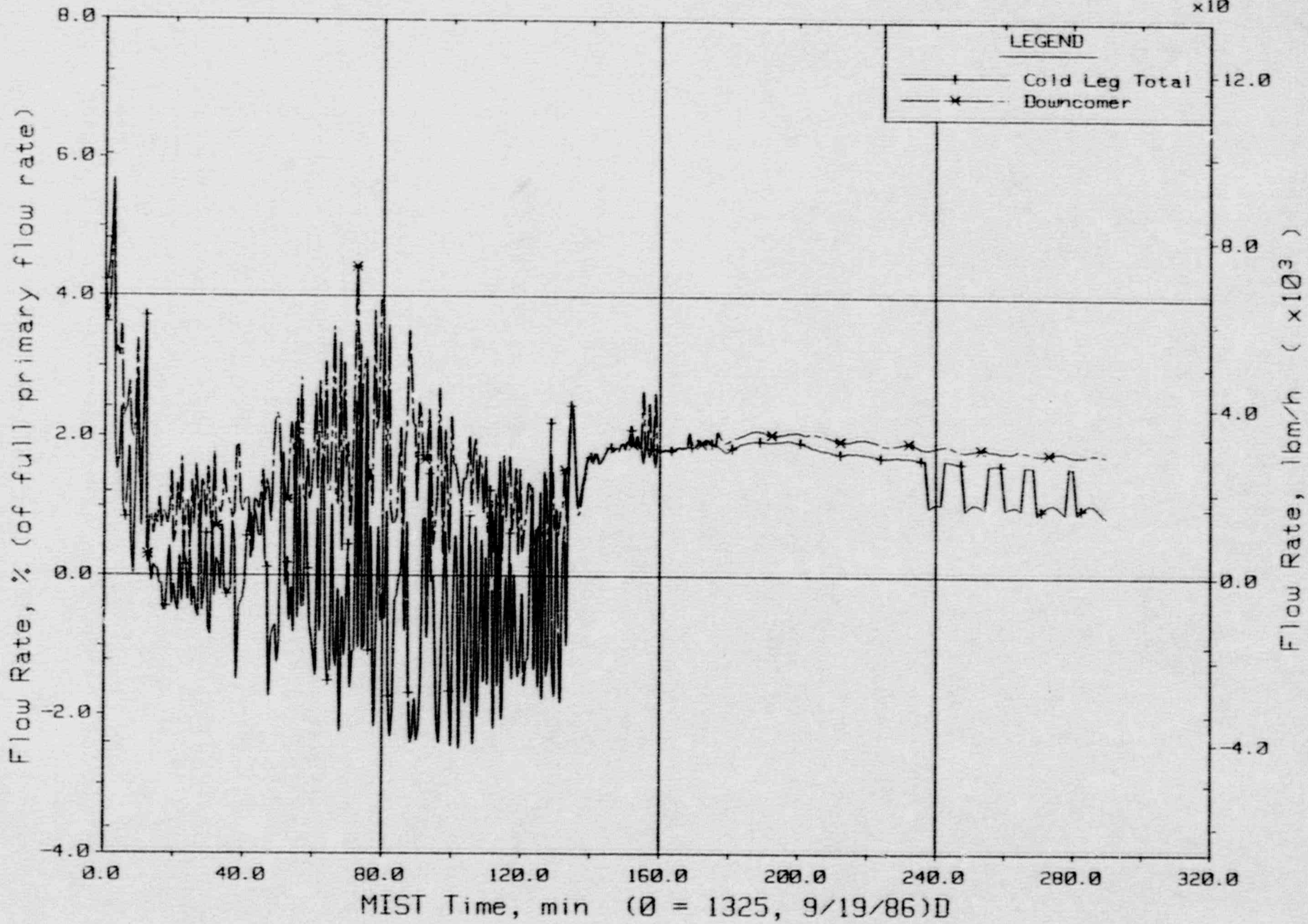
Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Fri Jun 3 11:02:20 1988

PBTC1p

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



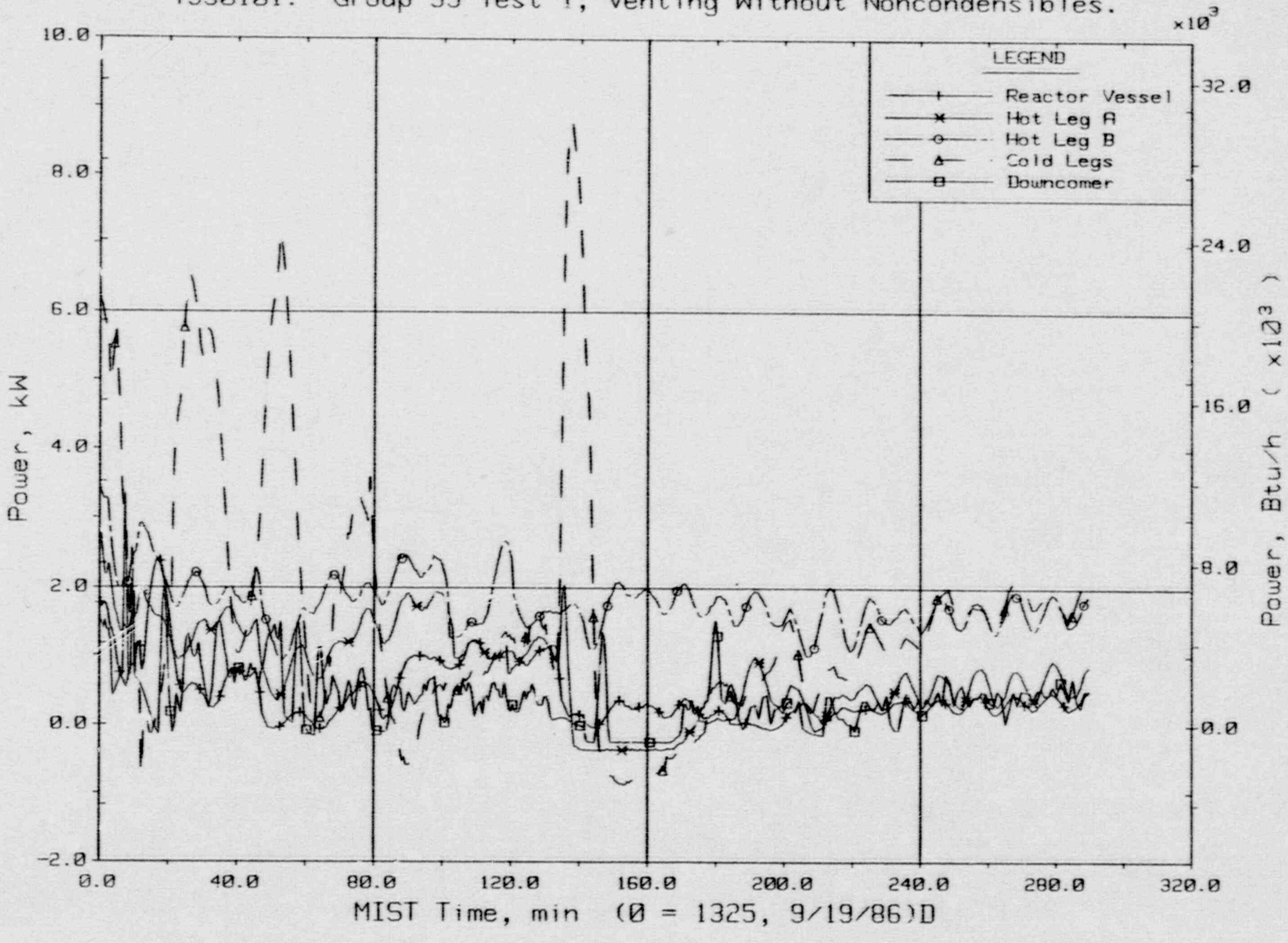
Primary System Venturi Flow Rates.

Fri Jun 3 11:?5:37 1988

PRFL7

FINAL DATA

TS50101: Group 35 Test 1, Venting Without Noncondensibles.



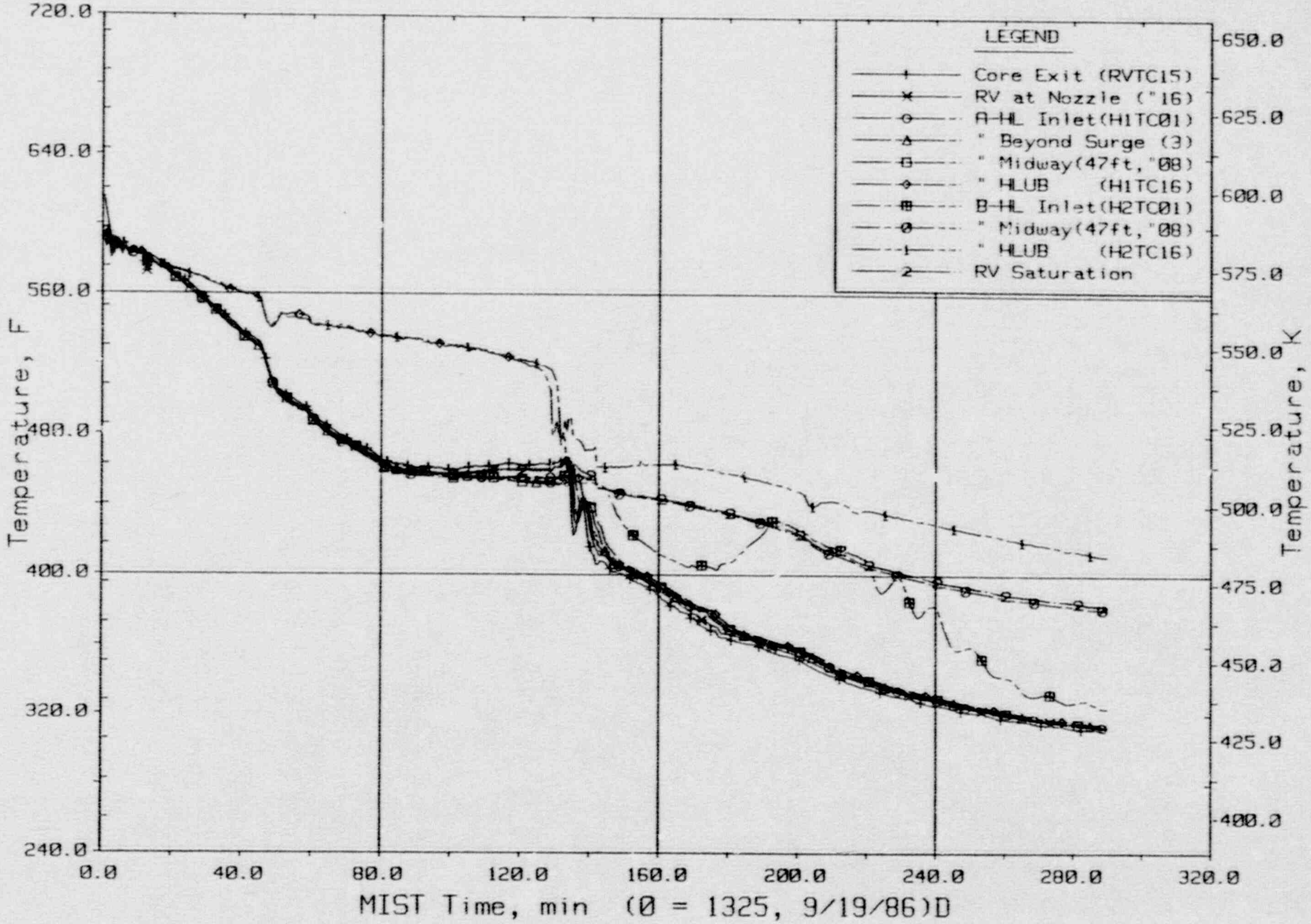
Guard Heater Specified Power Per Primary Component.

Fri Jun 3 11:11:15 1988

PRGQ1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



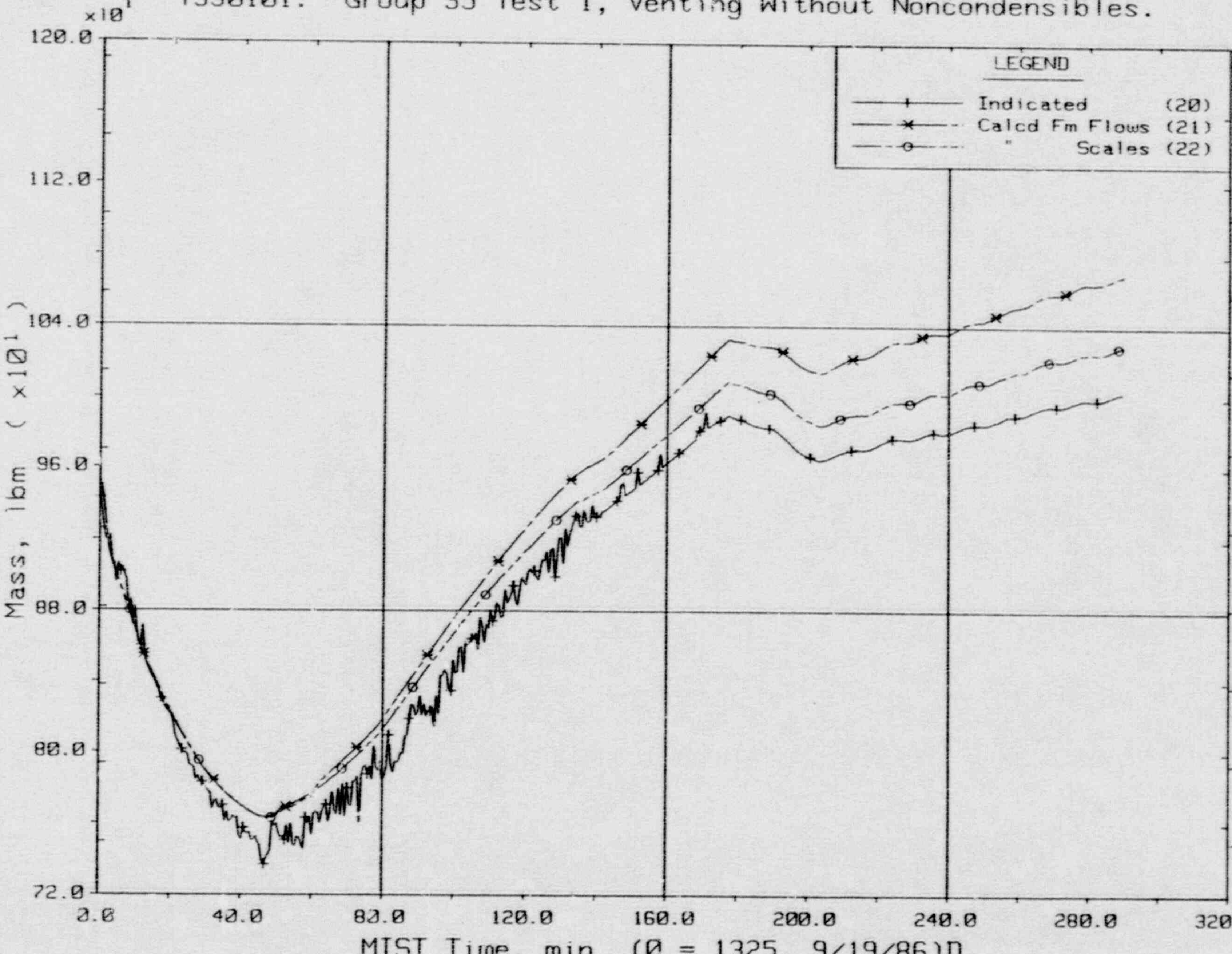
Composite Core Exit and Hot Leg Fluid Temperatures.

Fri Jun 3 11:16:16 1988

PRKT1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



Primary System Total Fluid Mass (PLMLs).

Fri Jun 3 11:19:49 1988

PRML2

FINAL DATA

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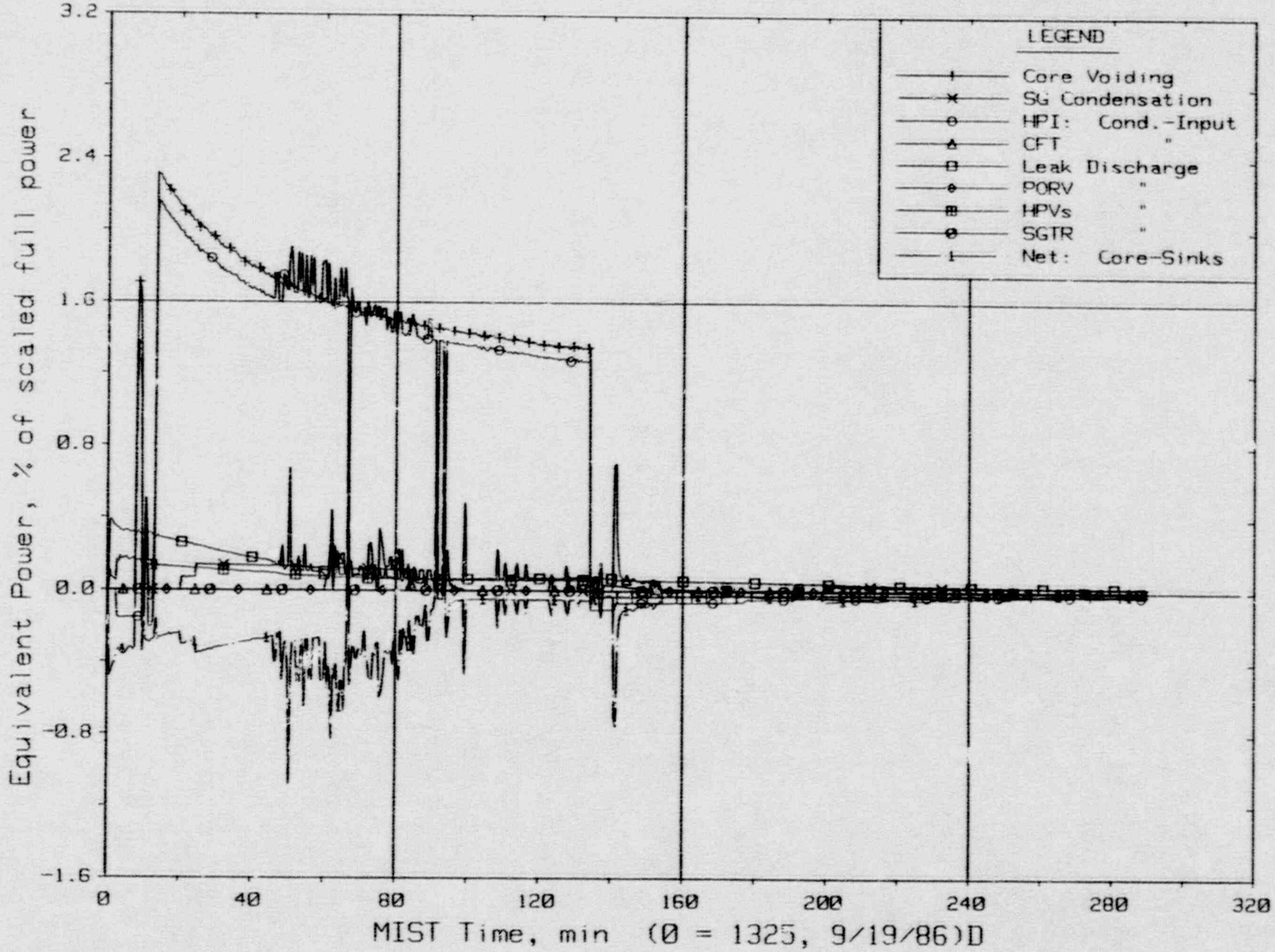

Primary Fluid Volume Changes By Components.

Mon Jan 16 08:52:03 1989

PRPA0

FINAL DATA

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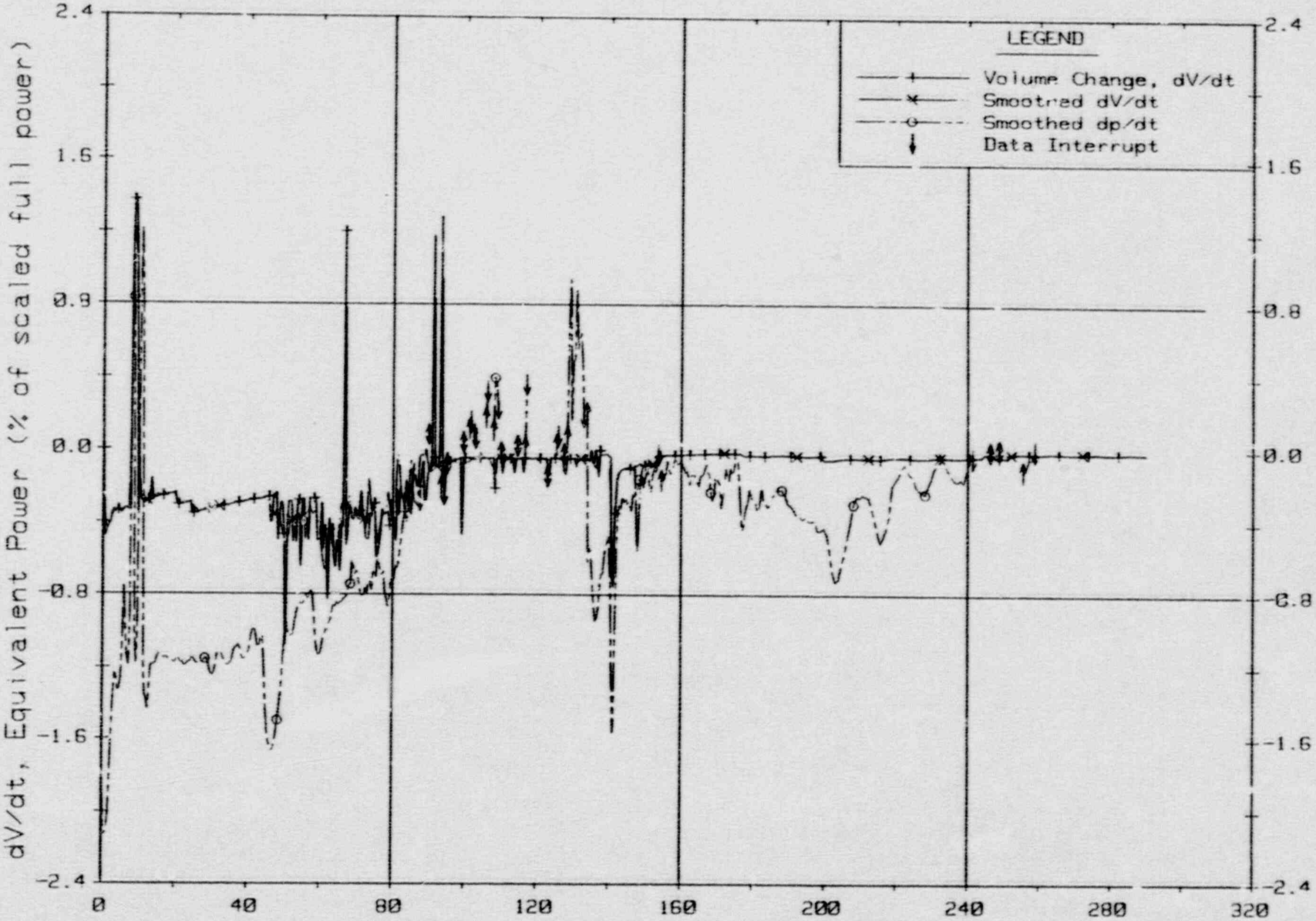


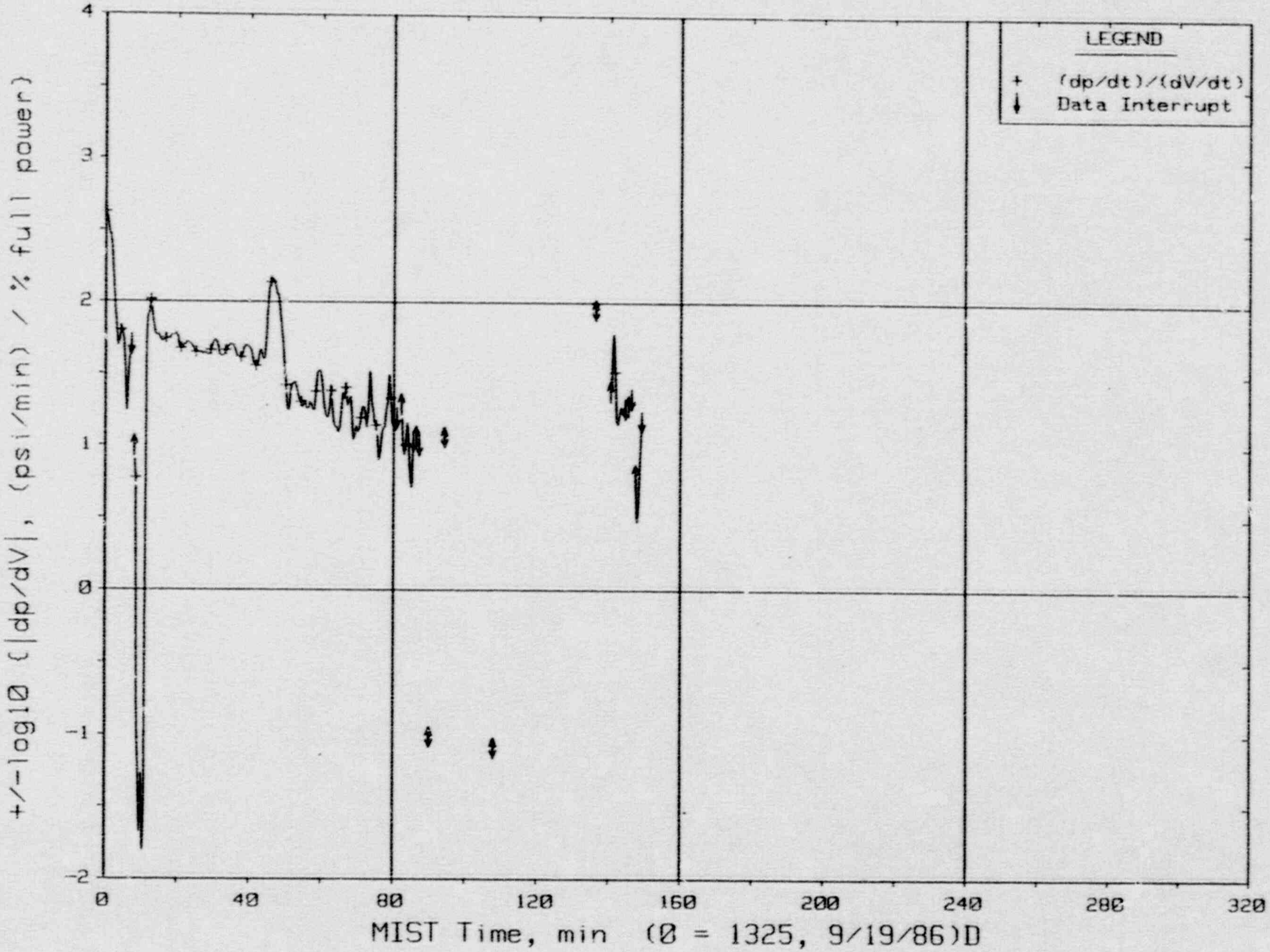
Primary Fluid Volume and Pressure Changes, dV/dt and dp/dt.

Mon Jan 16 08:55:14 1989

PRPA2

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



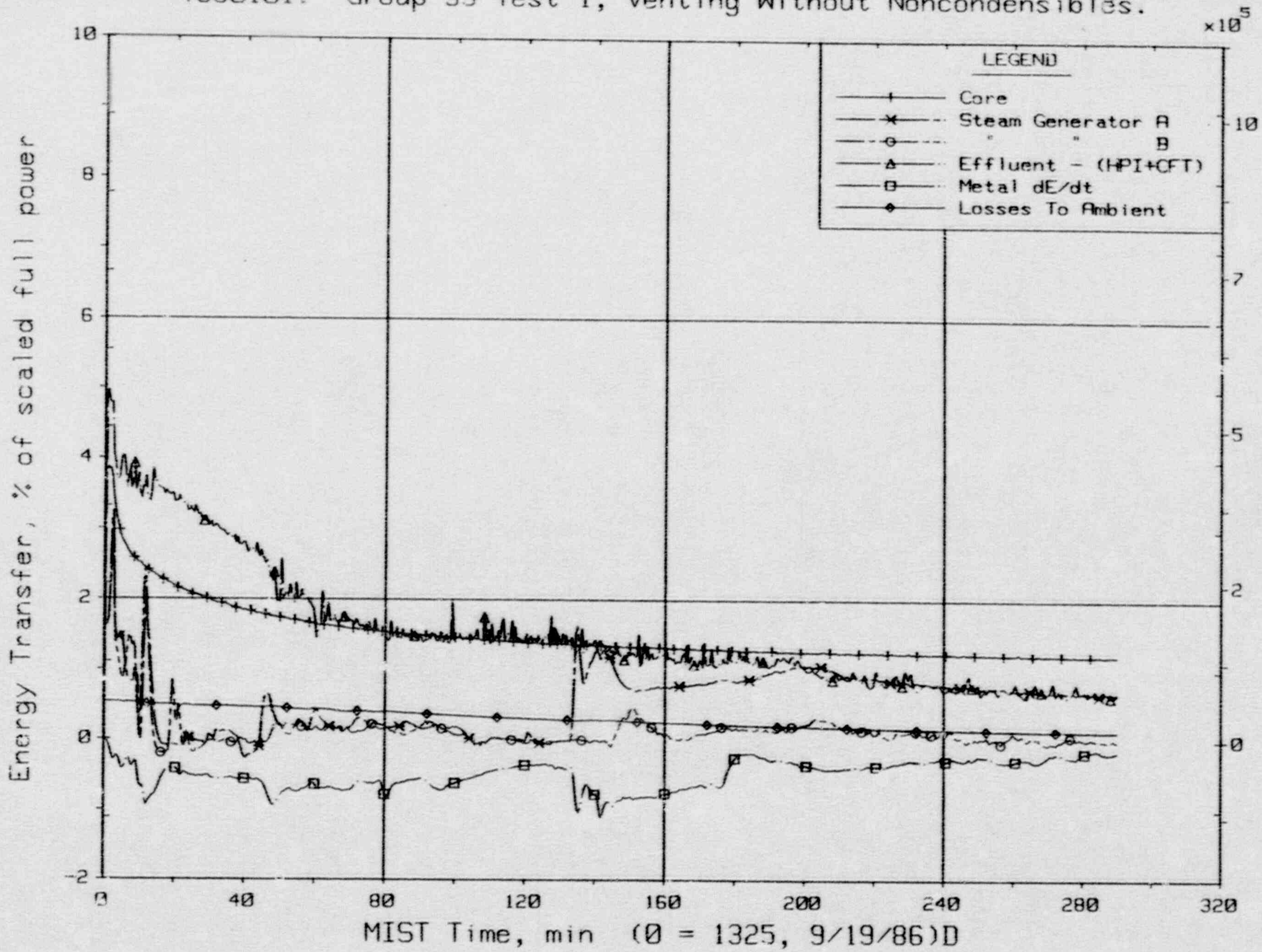
Primary System Response: dp/dt divided by dV/dt.

Mon Jan 16 08:57:35 1989

PRPA3

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



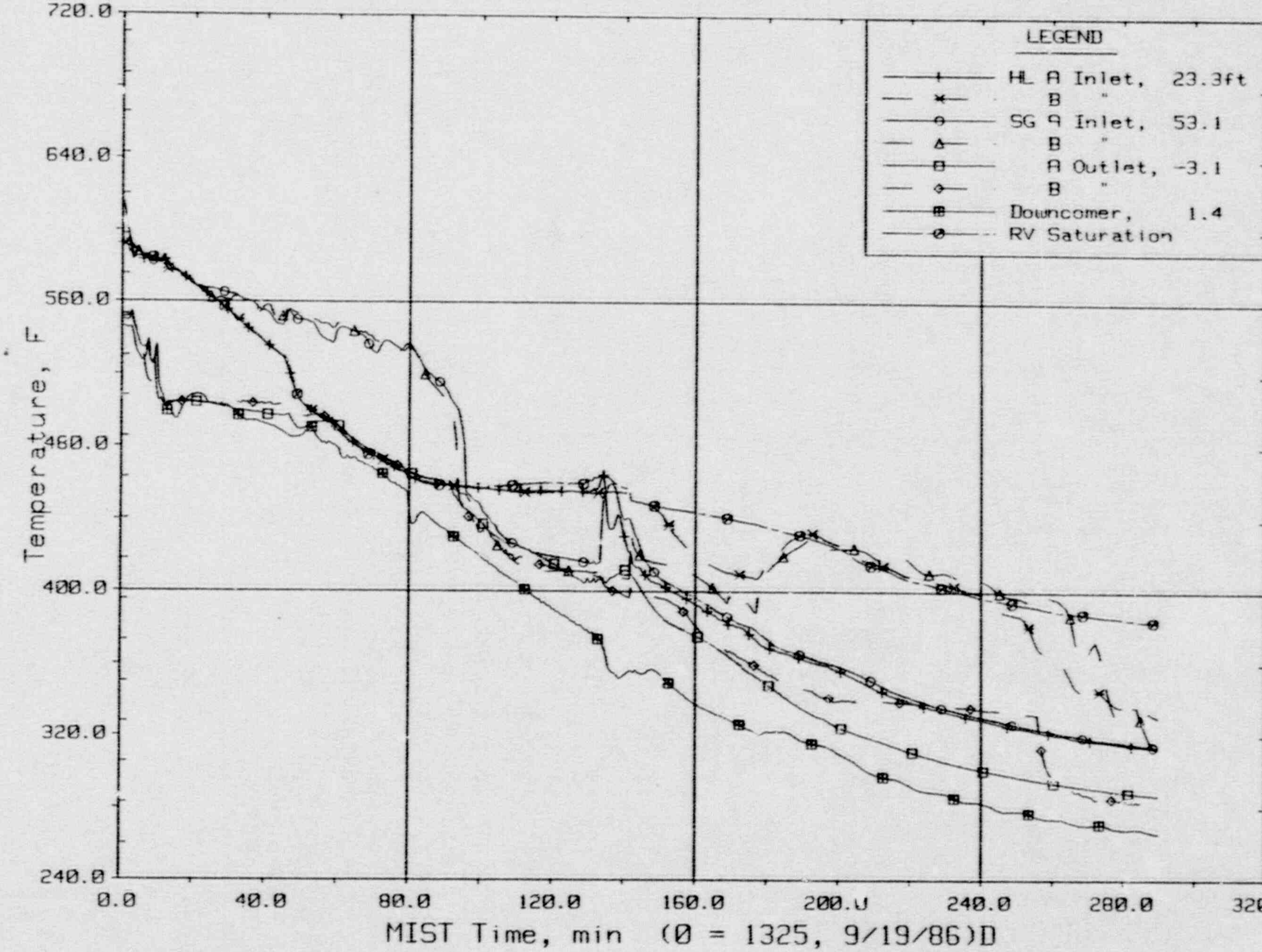
Primary System Energy Transfer.

Mon Jan 16 08:30:10 1989

PRQE2

FINAL DATA

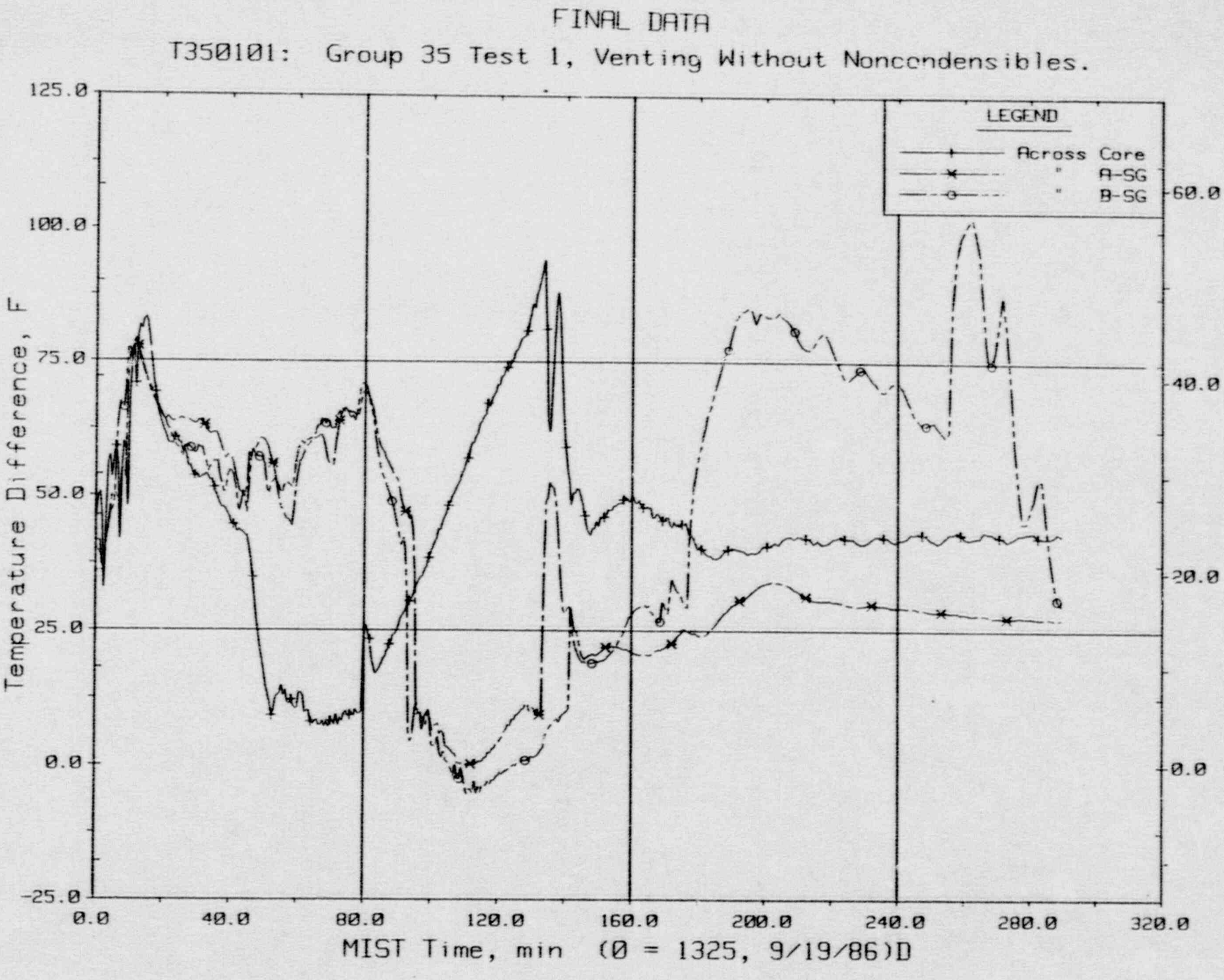
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Primary System Fluid Temperatures (RTDs).

Fri Jun 3 11:29:14 1988

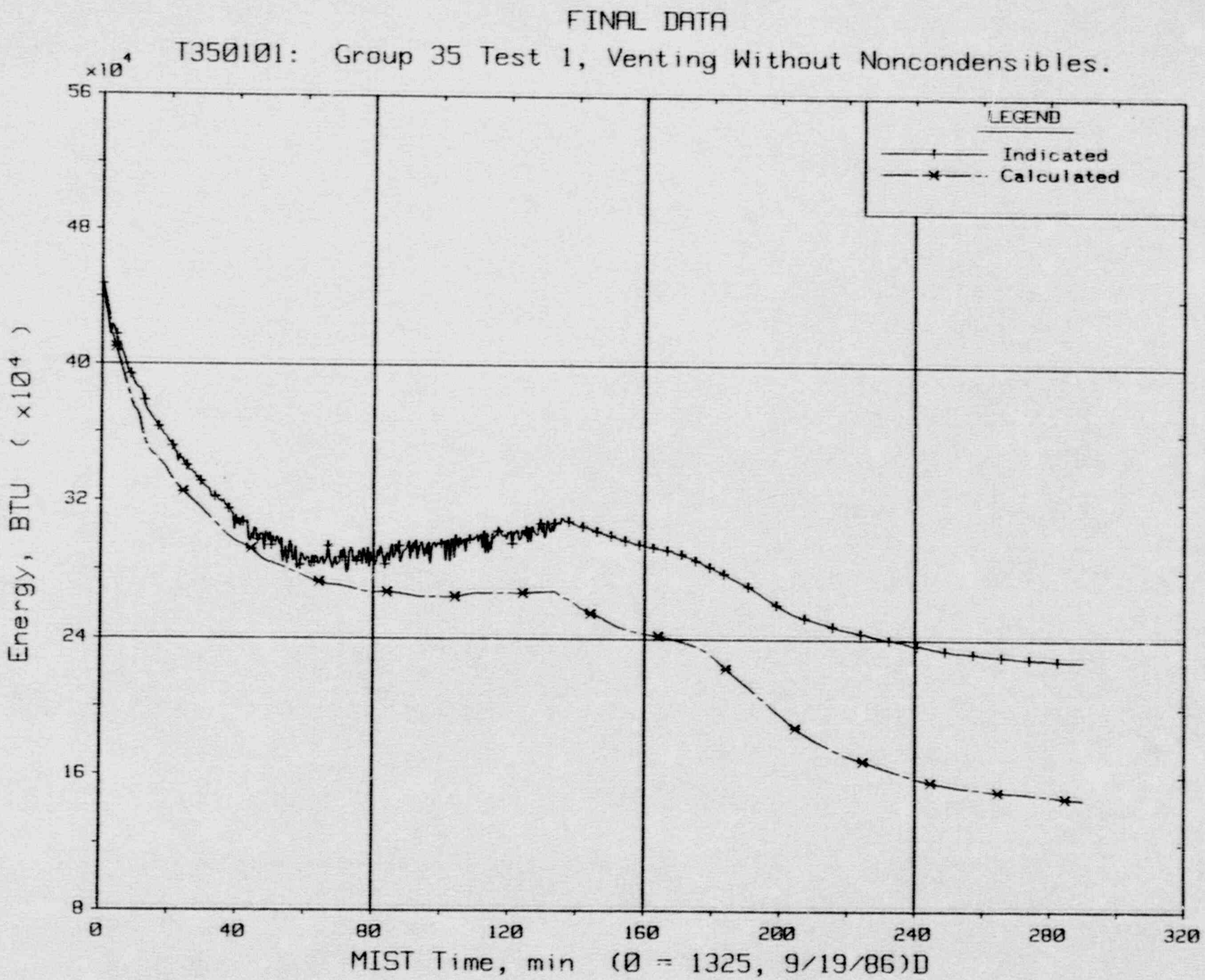
PRRT0



Key Temperature Differences.

Fri Jun 3 11:32:44 1988

PRTD2



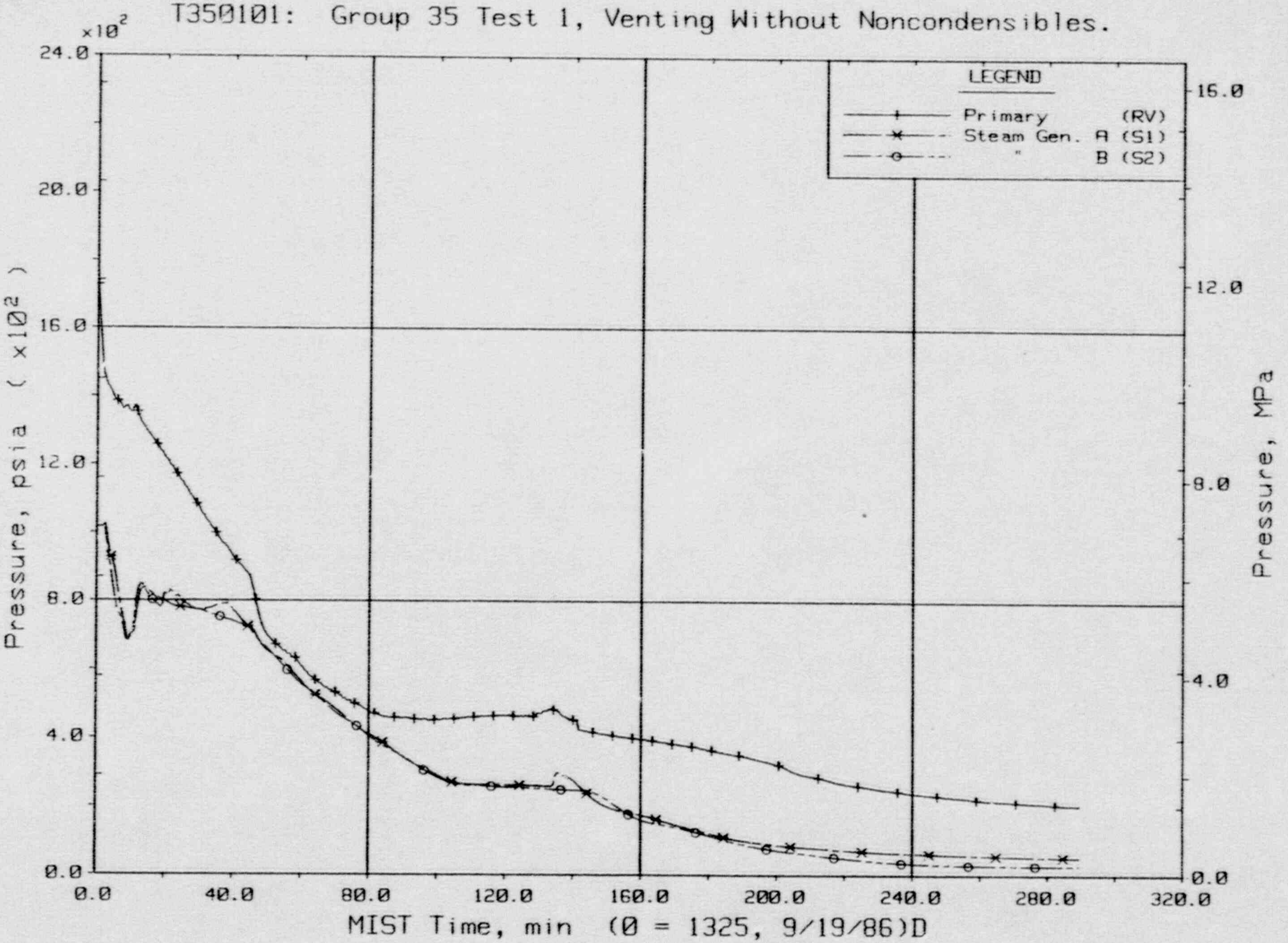
Primary System Total Fluid Energy.

Mon Jan 16 08:26:37 1989

PRTE2

FINAL DATA

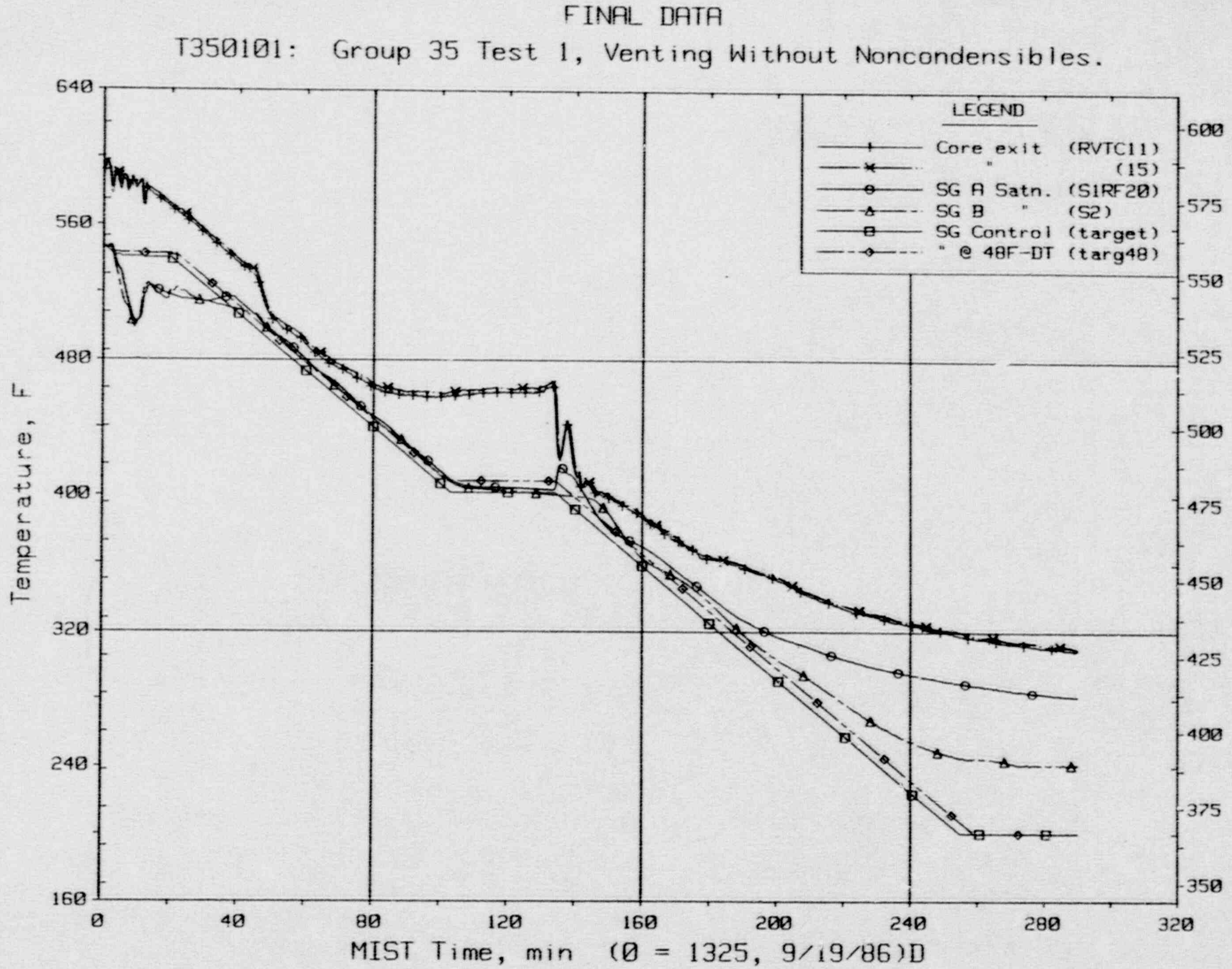
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Primary and Secondary System Pressures (GP01s).

Fri Jun 3 13:02:04 1988

PSGP1



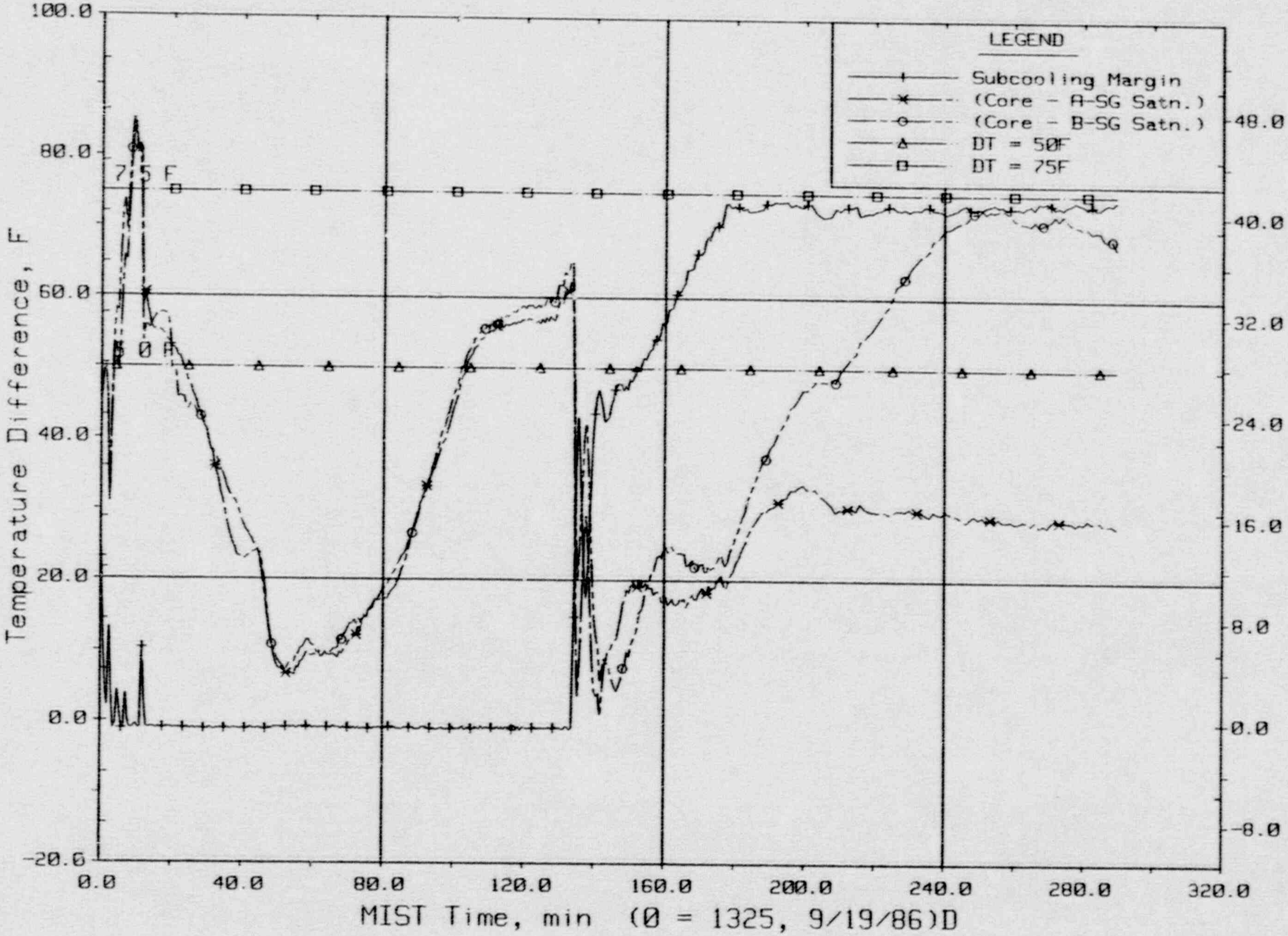
Steam Generator Secondary Saturation and Control Temperatures.

Thu Jan 5 13:01:06 1989

PSTC3

FINAL DATA

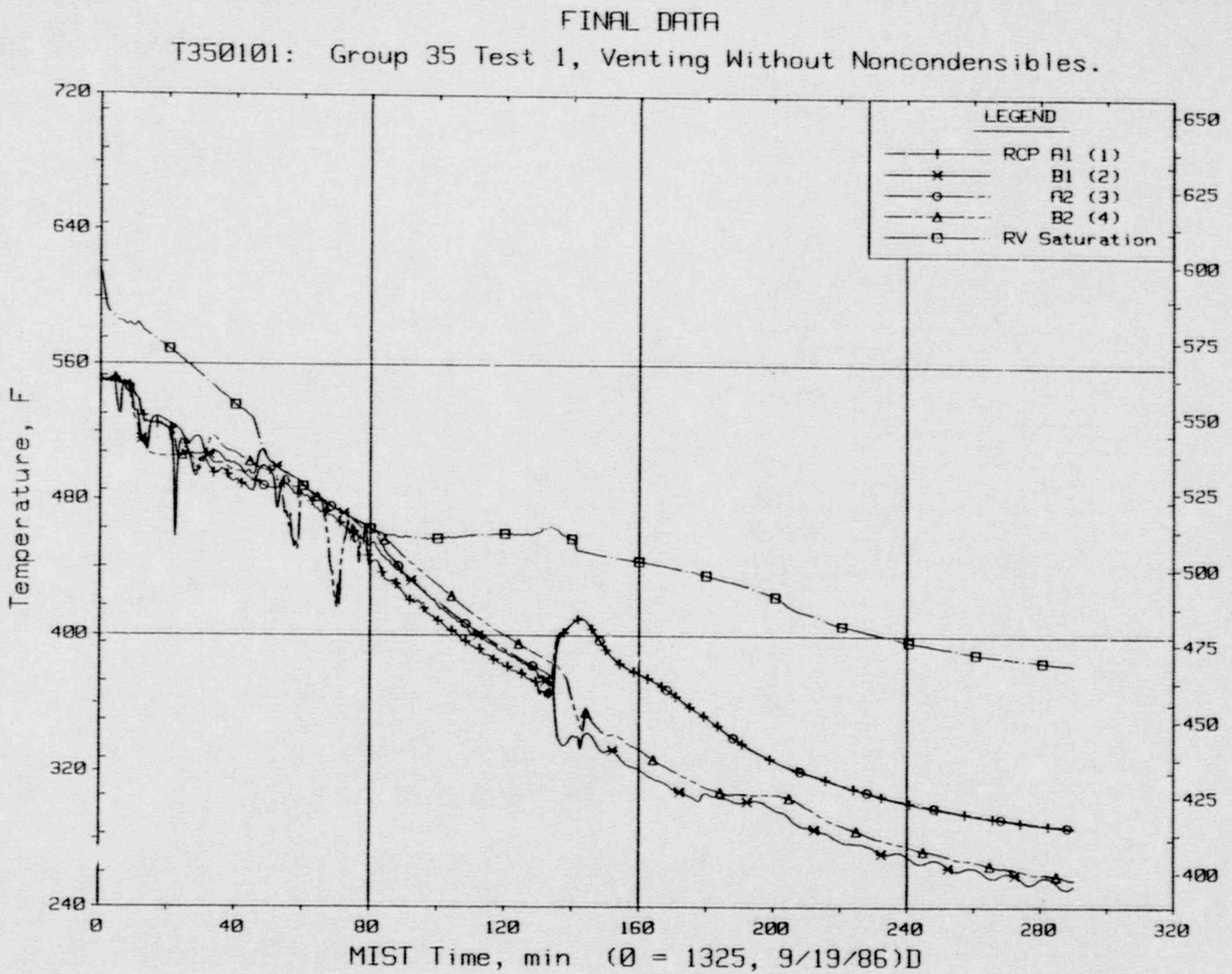
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Control Temperature Differences.

Fri Jun 3 13:09:32 1988

PSTD1



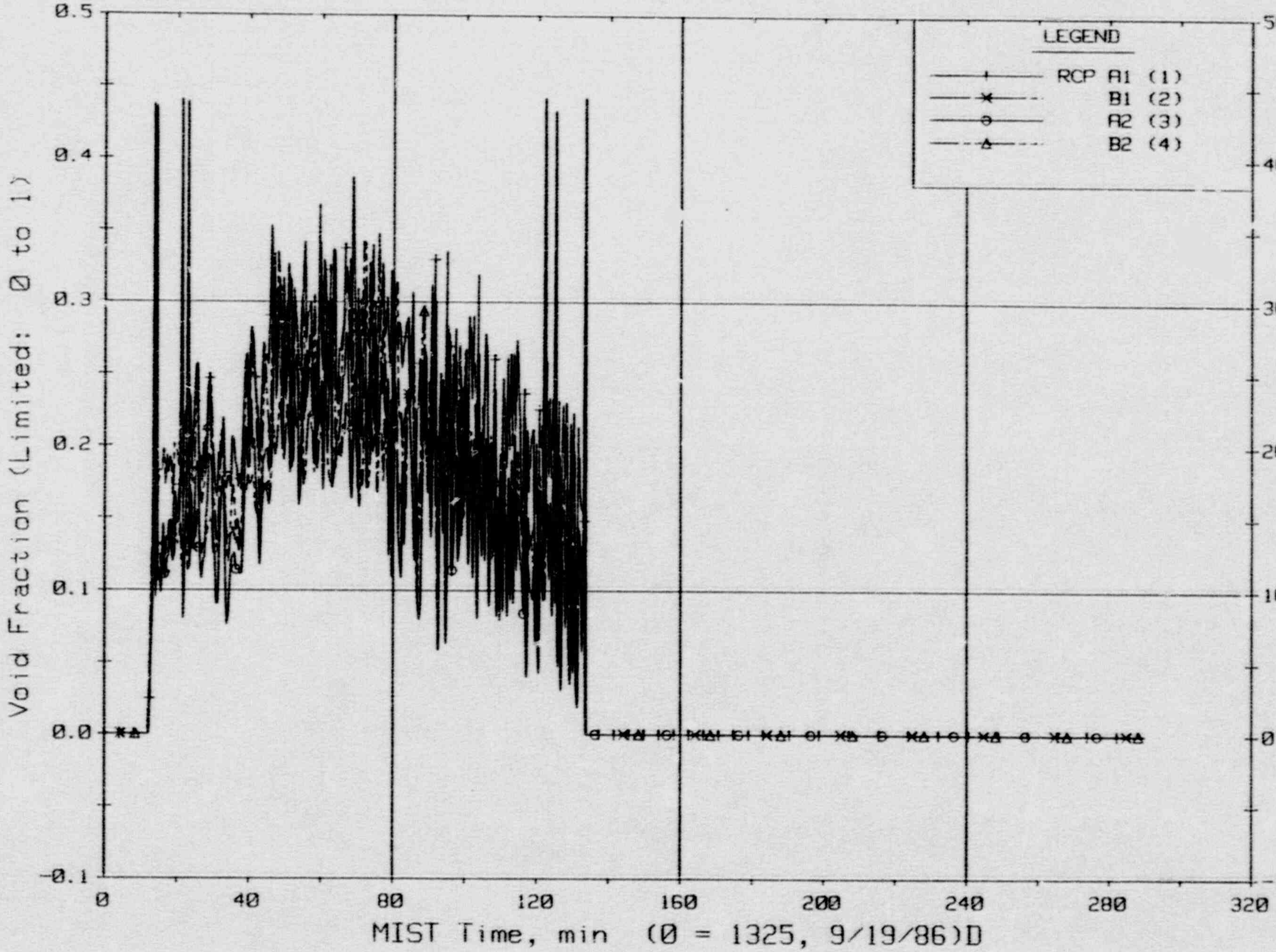
Pump Suction Fluid Temperature (CnRT01s).

Thu Jan 5 13:09:57 1989

PURT0

FINAL DATA

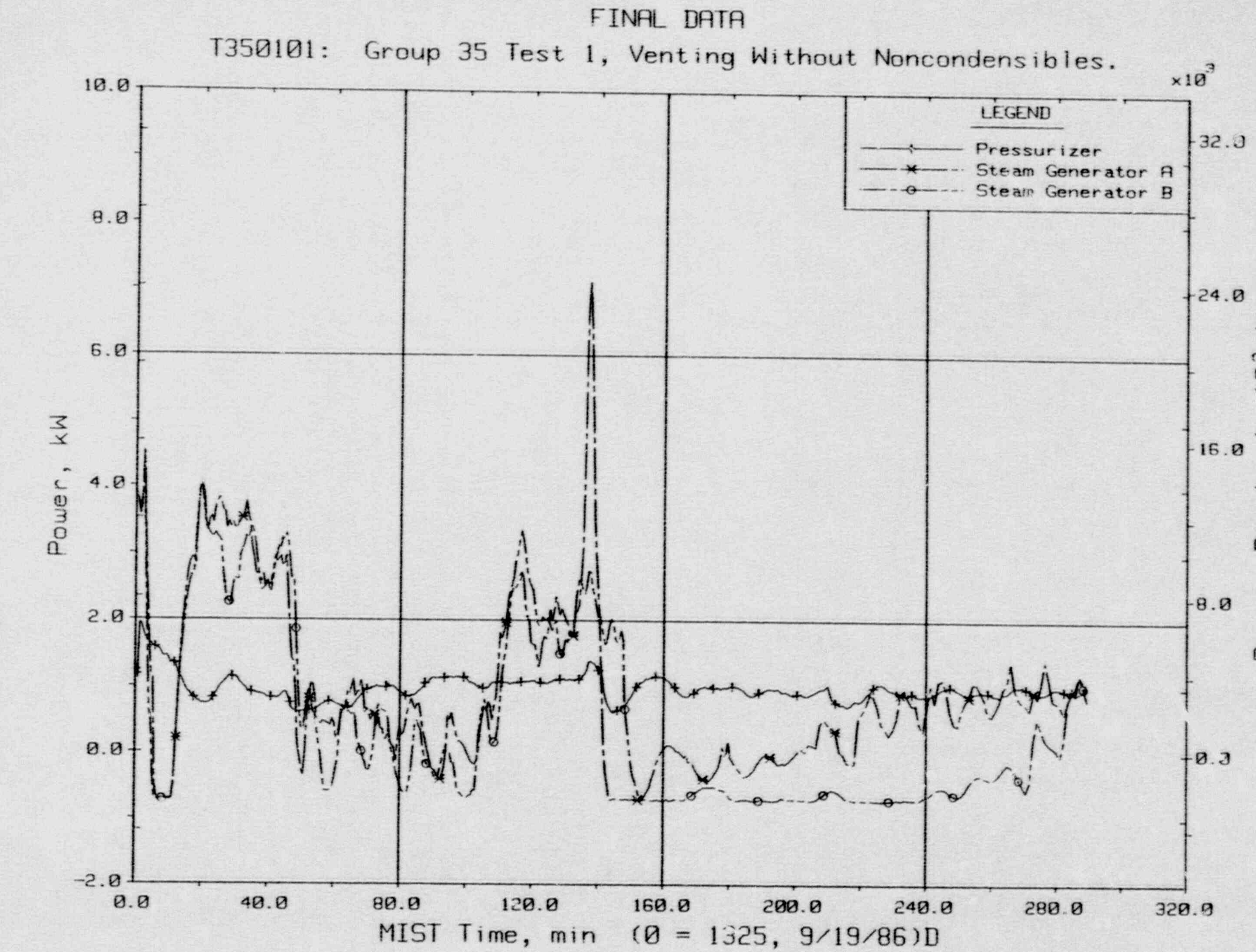
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

Thu Jan 5 13:14:32 1989

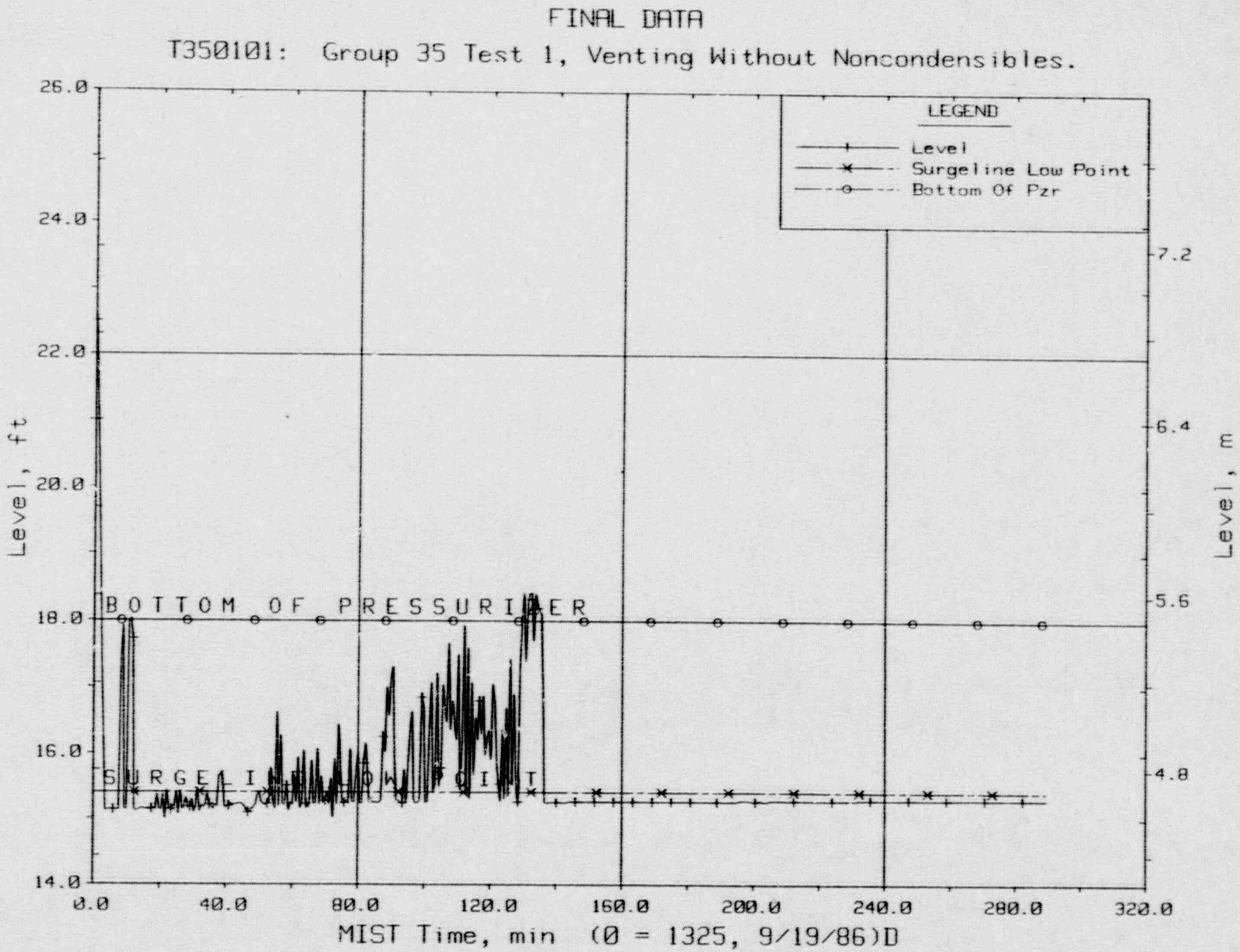
PUVF2



Guard Heater Specified Power, Pressurizer and Steam Generators.

Fri Jun 3 13:47:48 1988

PZGQ1



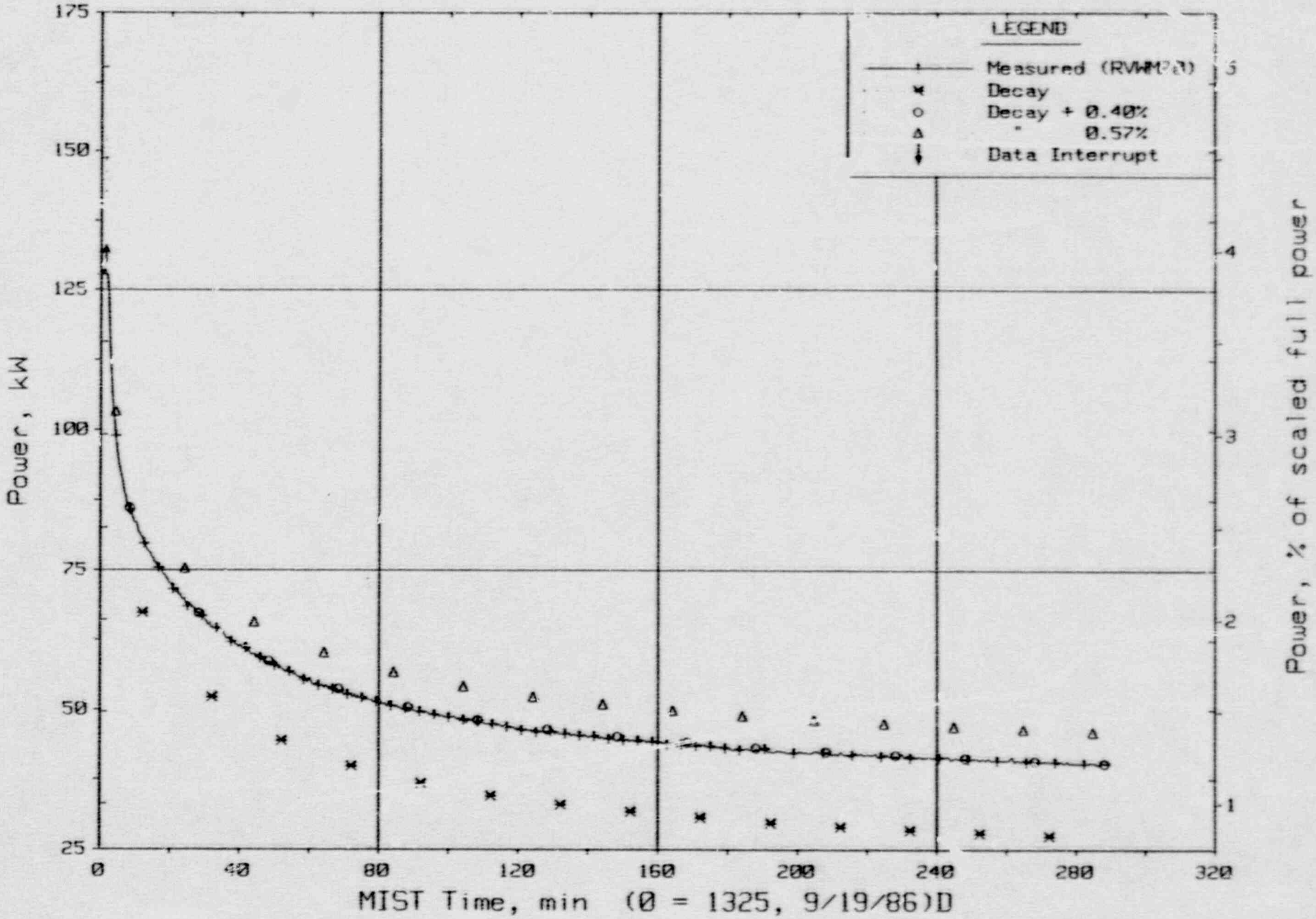
Pressurizer Collapsed Liquid Level (PZLV20).

Fri Jun 3 13:51:45 1988

PZLV1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



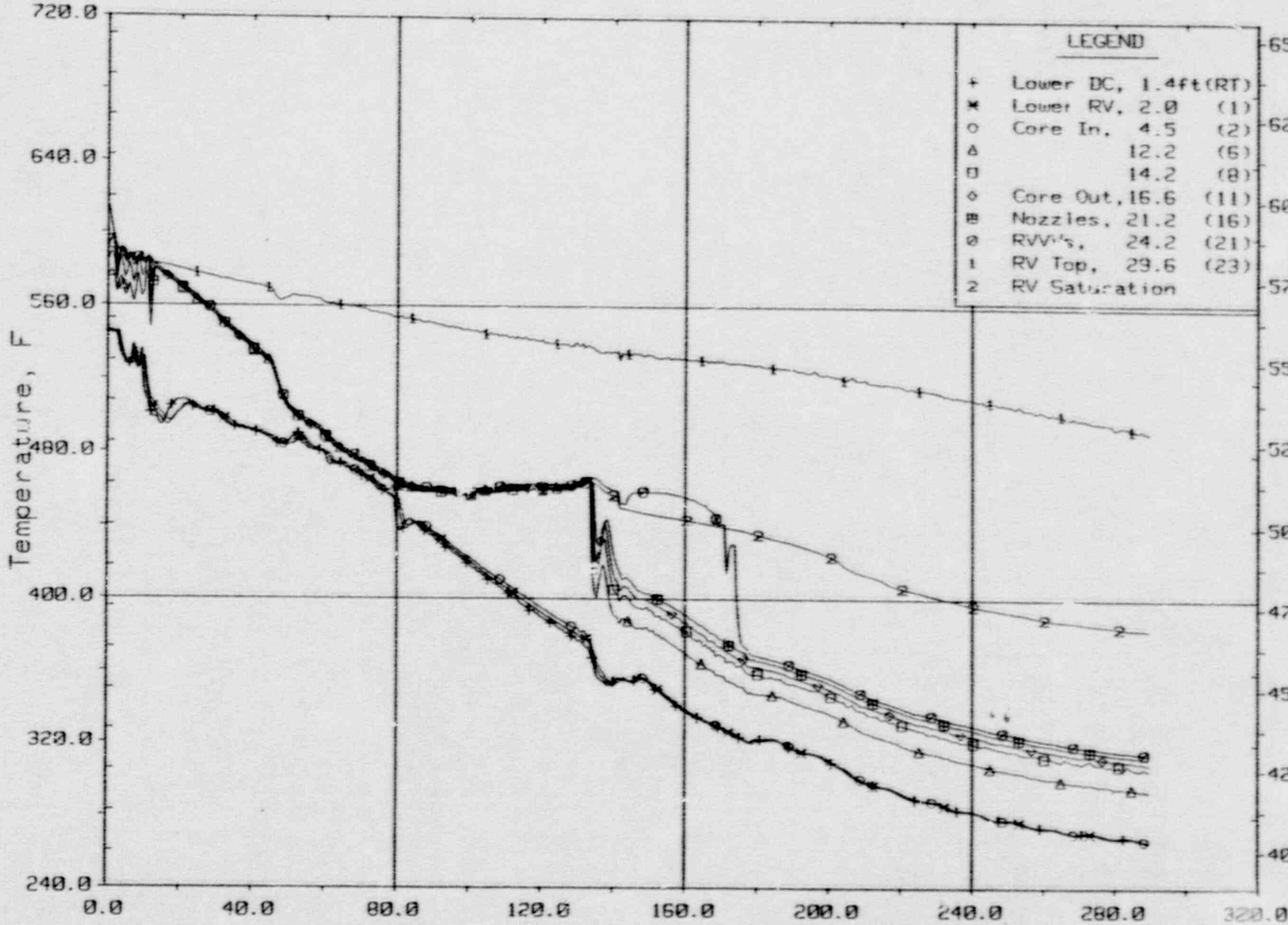
Core Power.

Thu Jan 5 13:05:20 1989

RVKW0

FINAL DATA

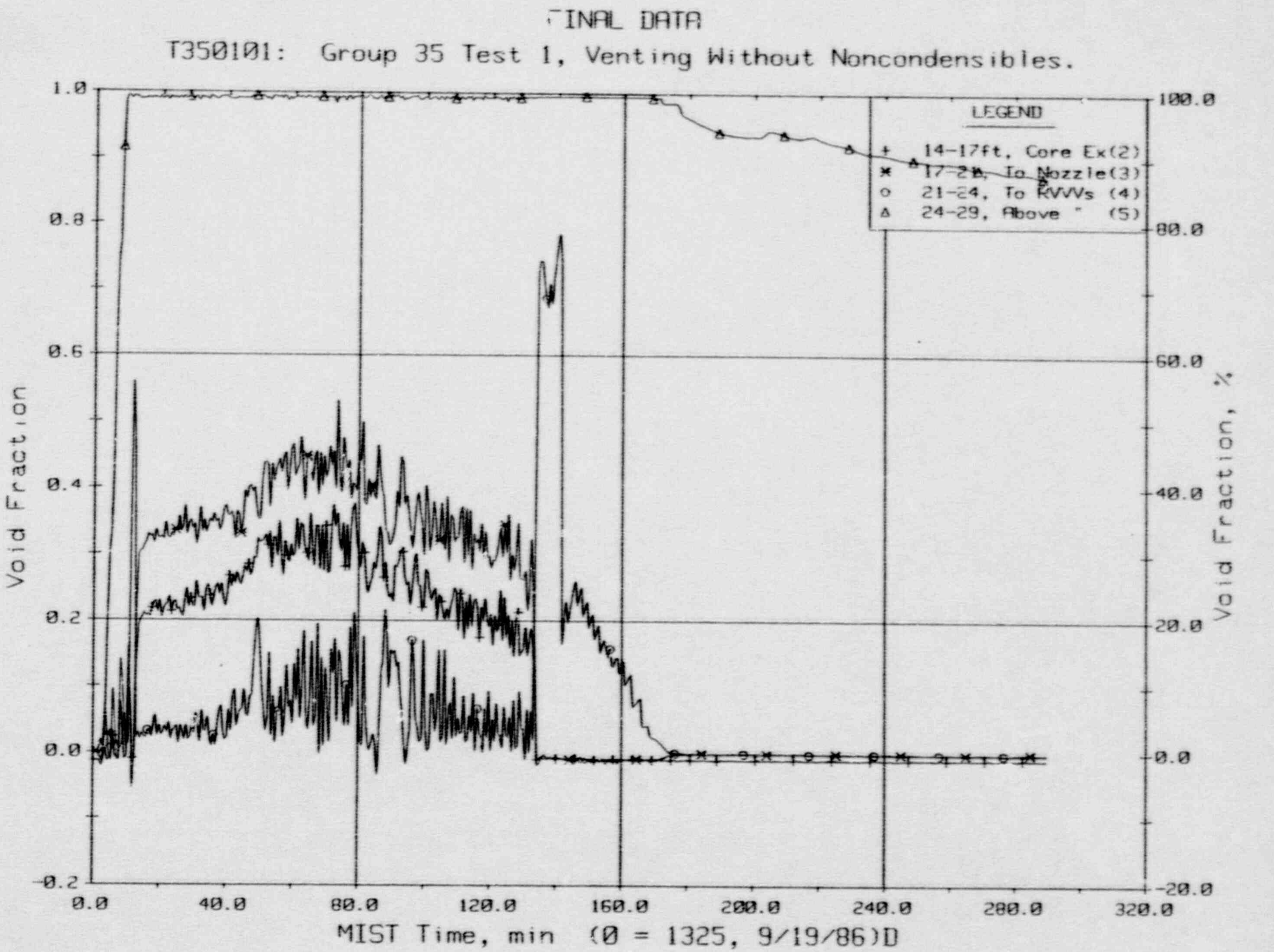
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

Fri Jun 3 14:14:46 1988

RVTCØ



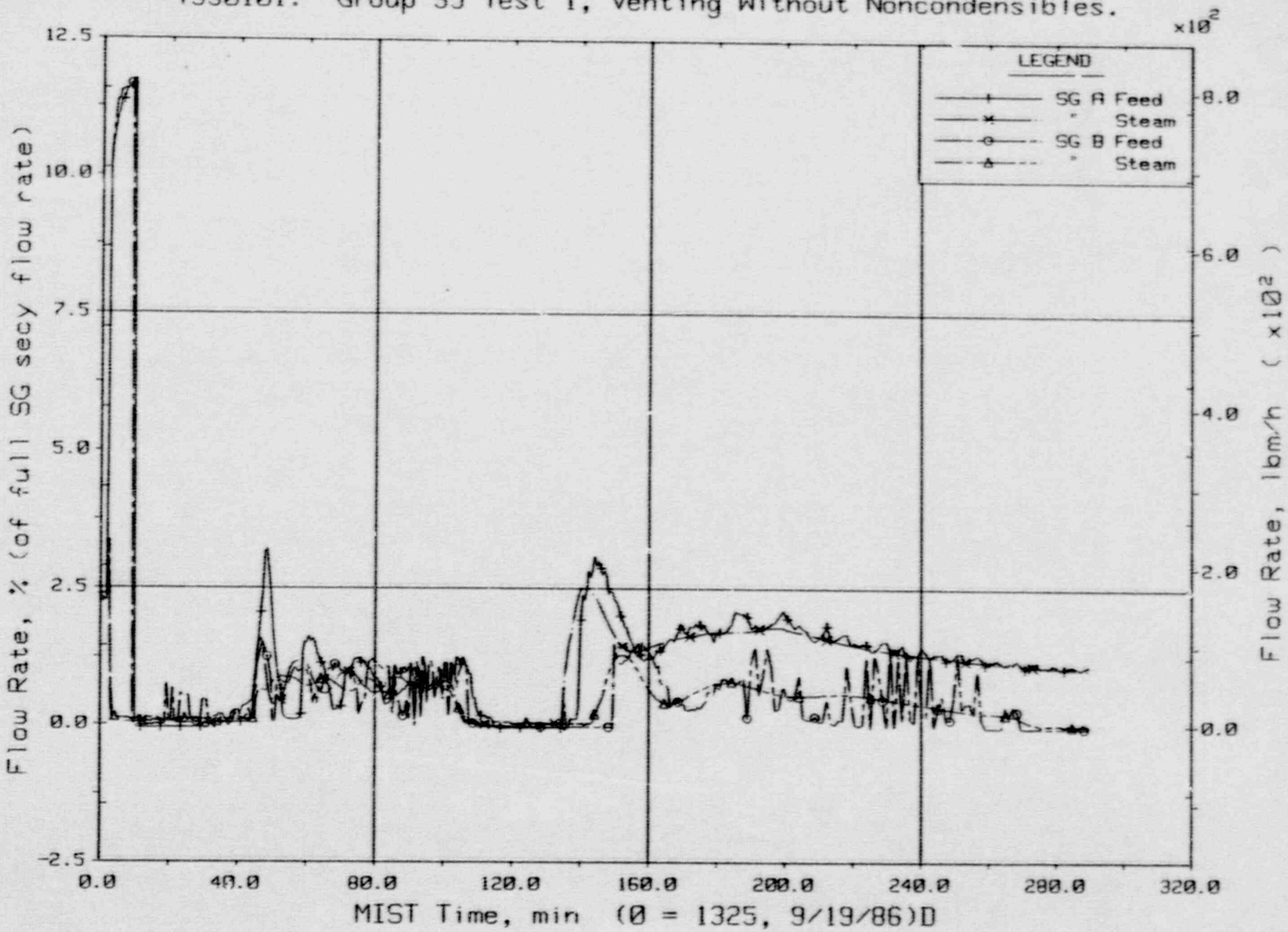
Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Fri Jun 3 14:21:49 1988

RVVF1

FINAL DATA

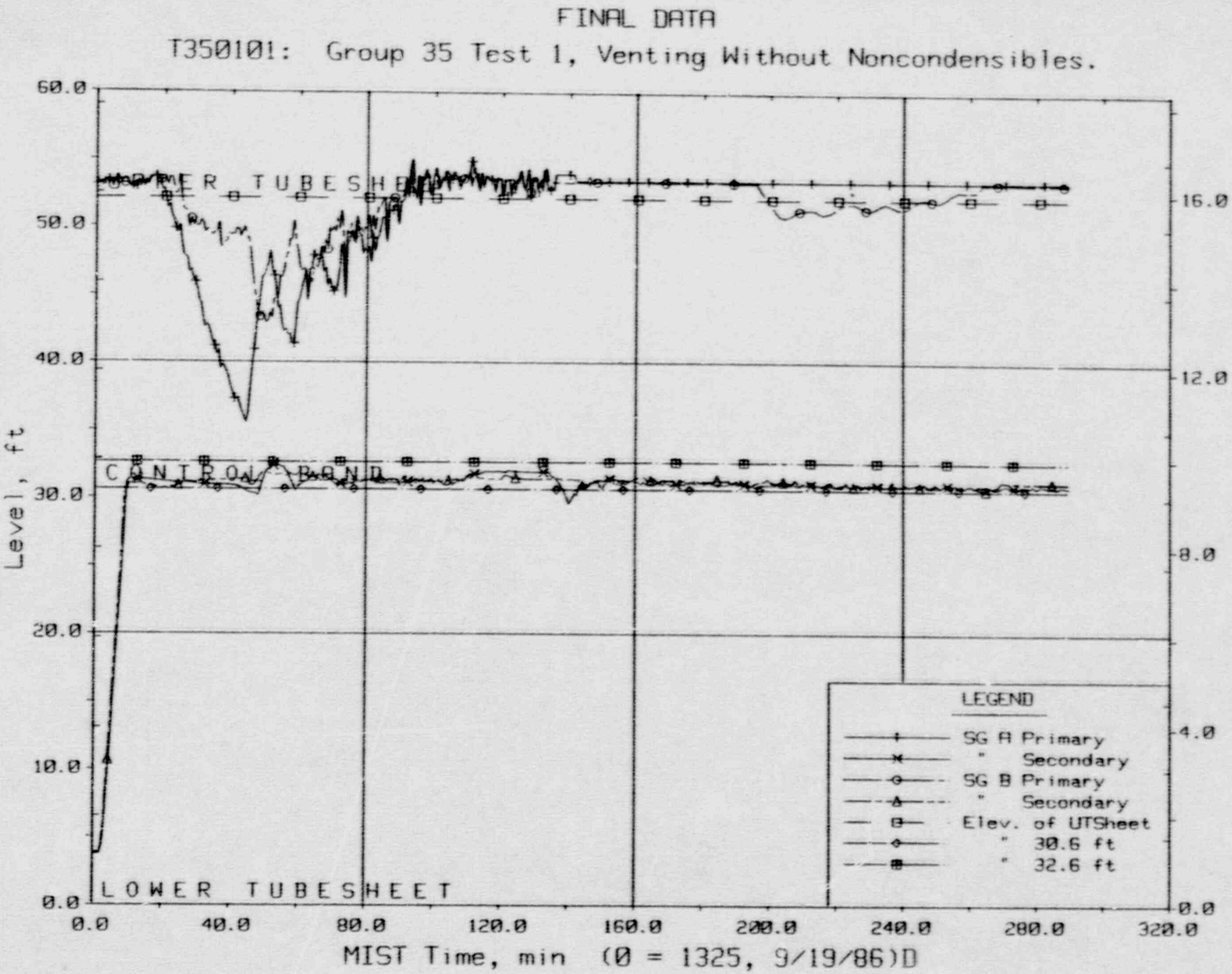
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Steam Generator Secondary System Flow Rates.

Fri Jun 3 14:25:57 1988

SGFL2



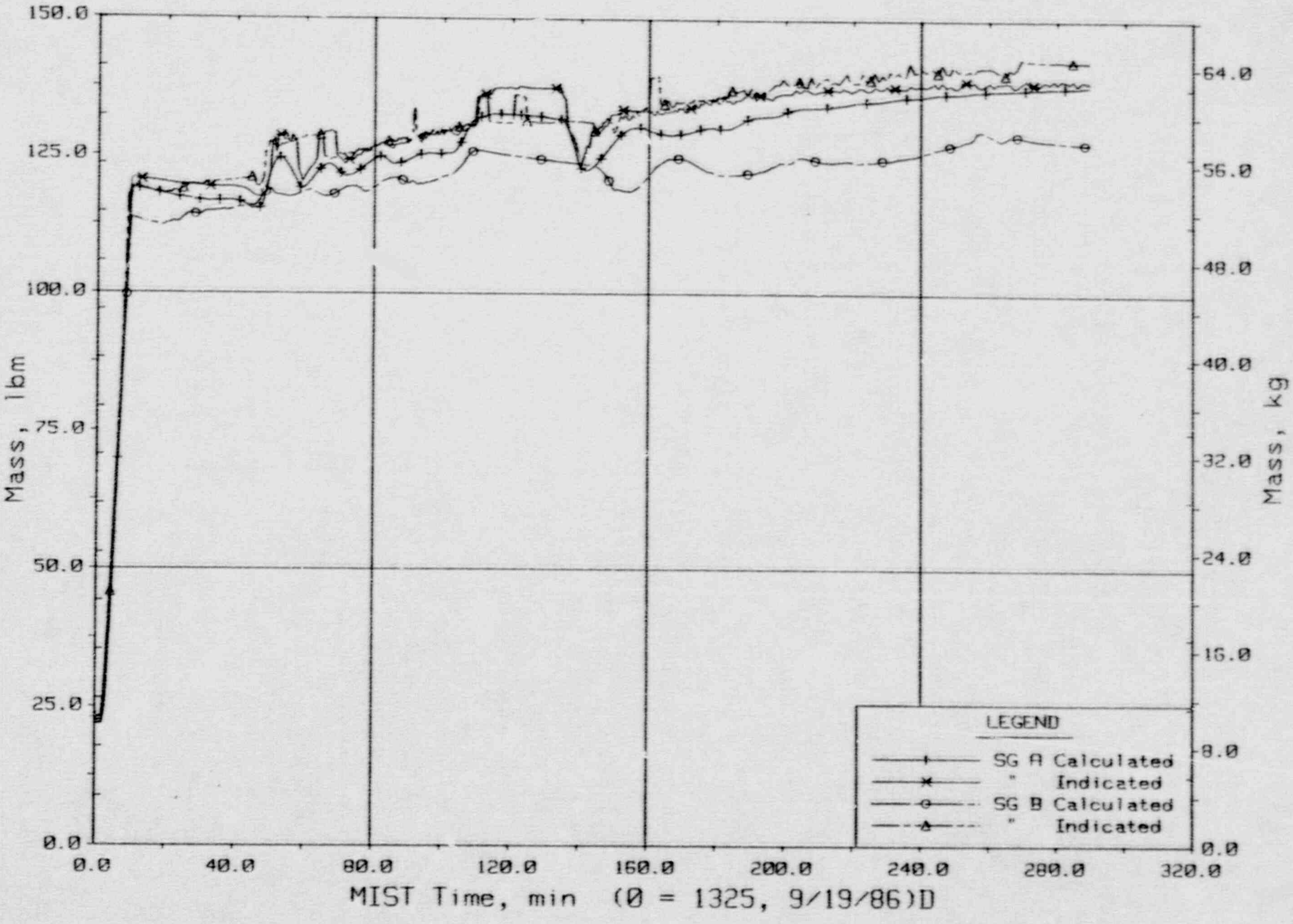
Steam Generator Collapsed Liquid Levels.

Fri Jun 3 14:29:44 1988

SGLV2

FINAL DATA

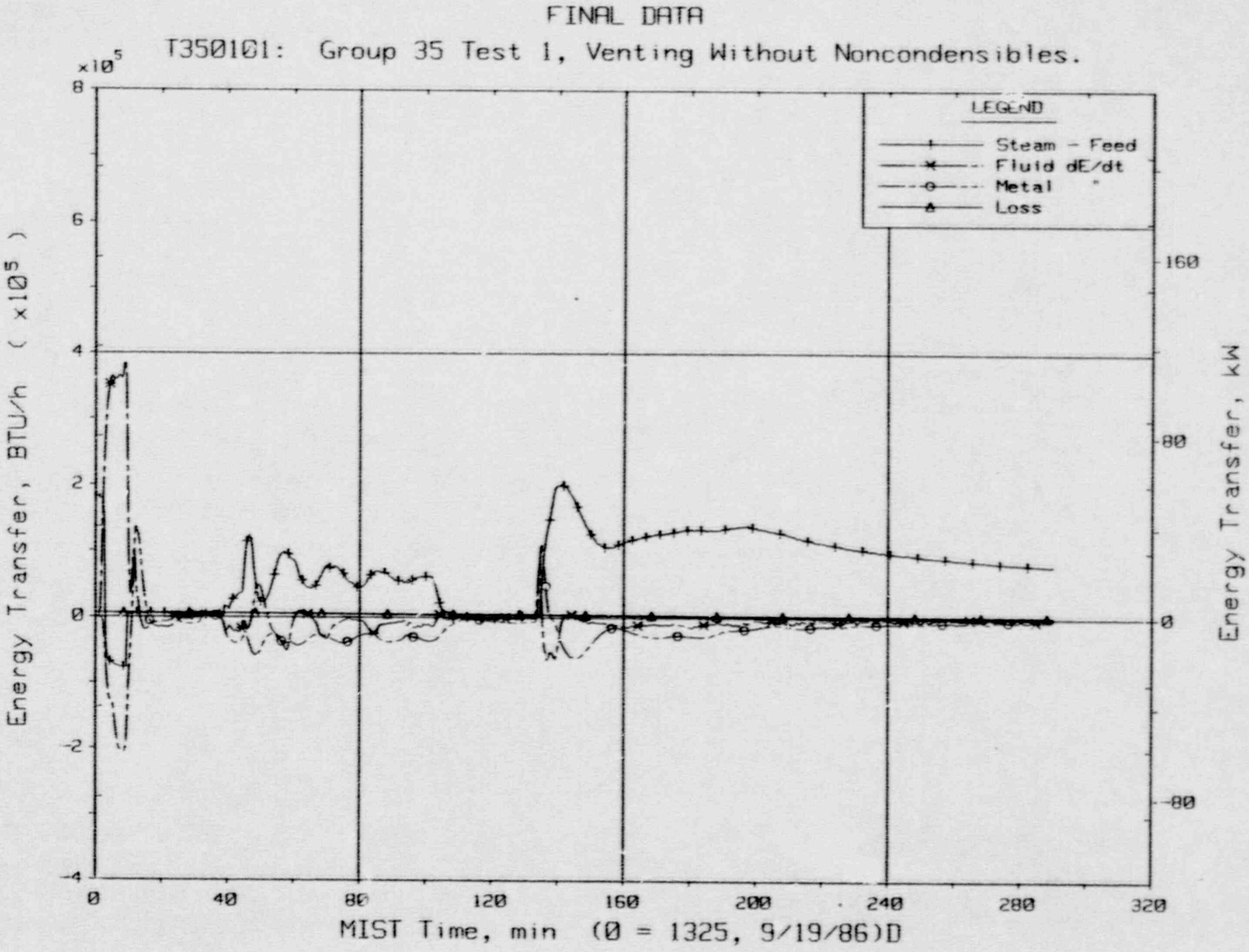
T350101: Group 35 Test 1, Venting Without Noncondensibles.



Steam Generator Secondary Fluid Mass Balances.

Fri Jun 3 14:32:58 1988

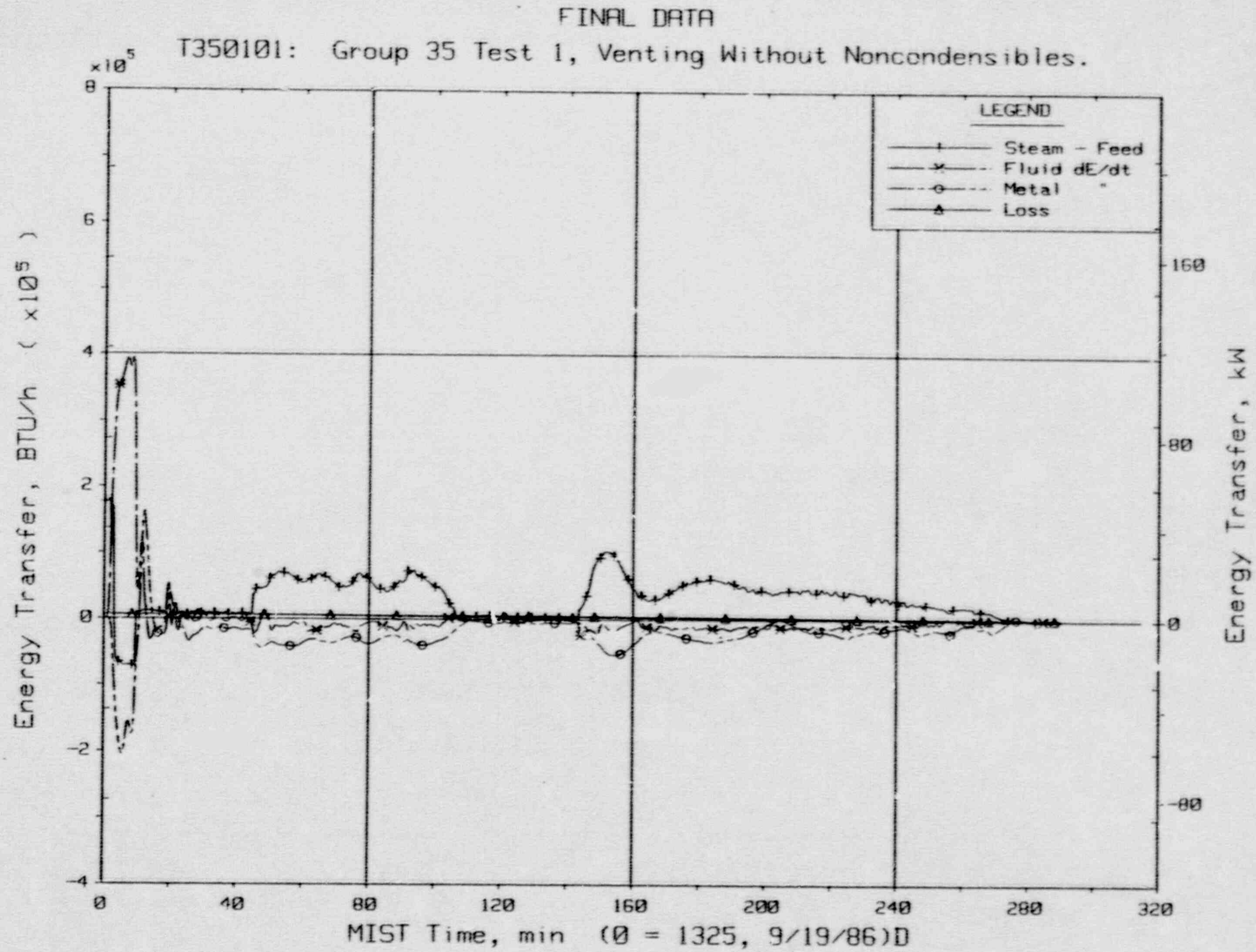
SGML1



Steam Generator A Energy Transfer.

Mon Jan 16 08:33:27 1989

SGQE3



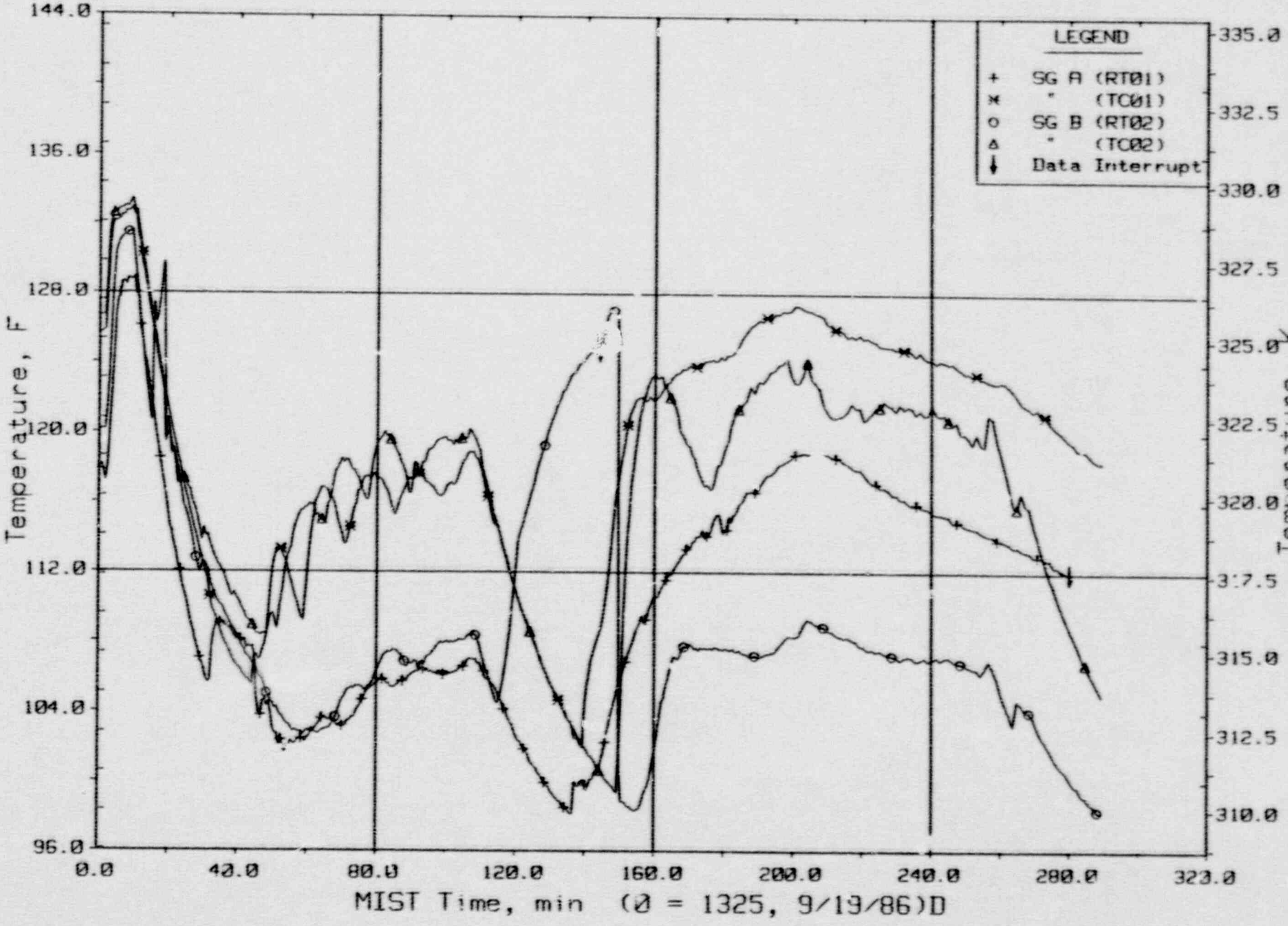
Steam Generator B Energy Transfer.

Mon Jan 16 08:36:34 1989

SGOE6

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



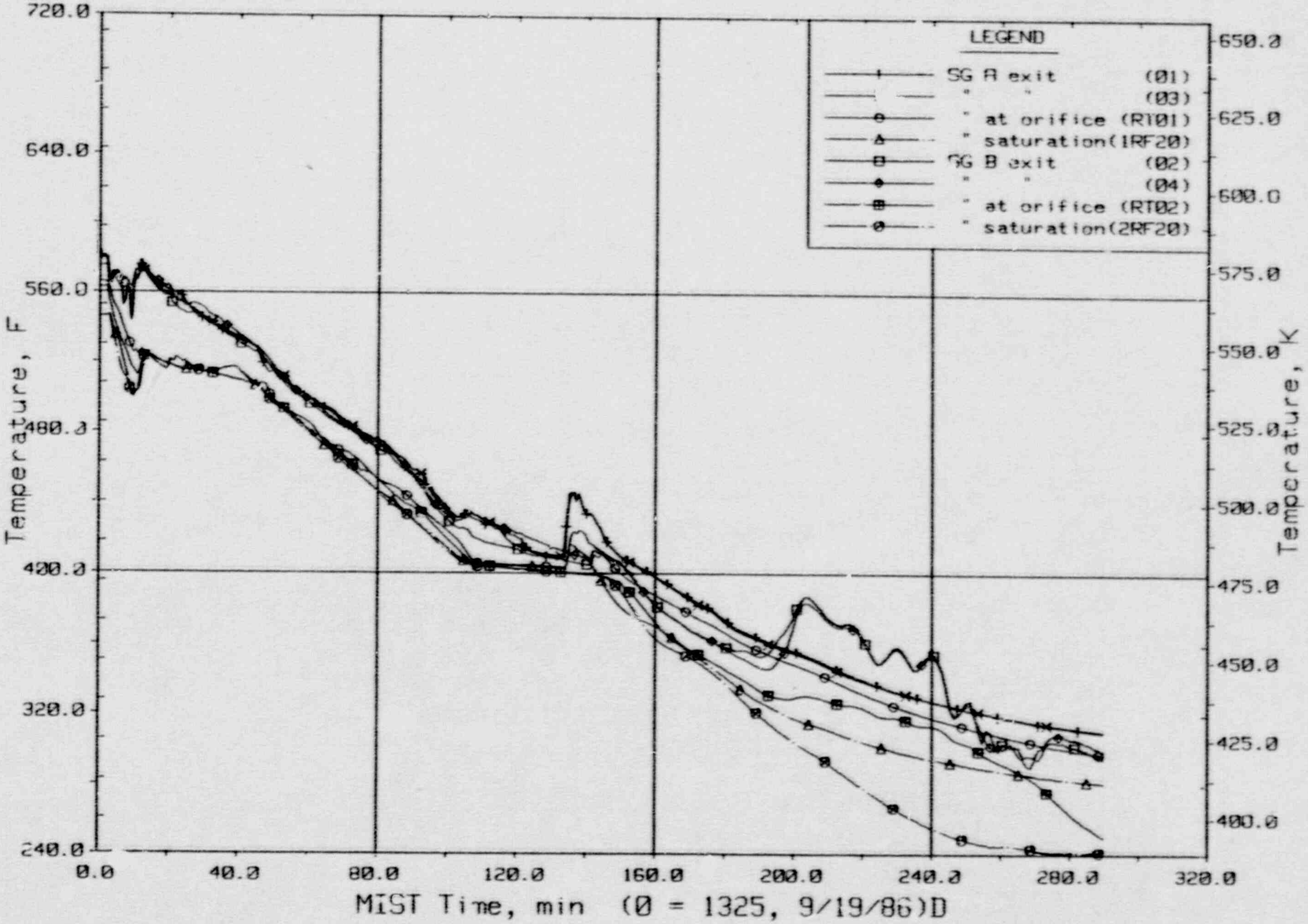
Feedwater Temperatures (SFs).

Mon Jun 6 08:09:48 1988

SGRT1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



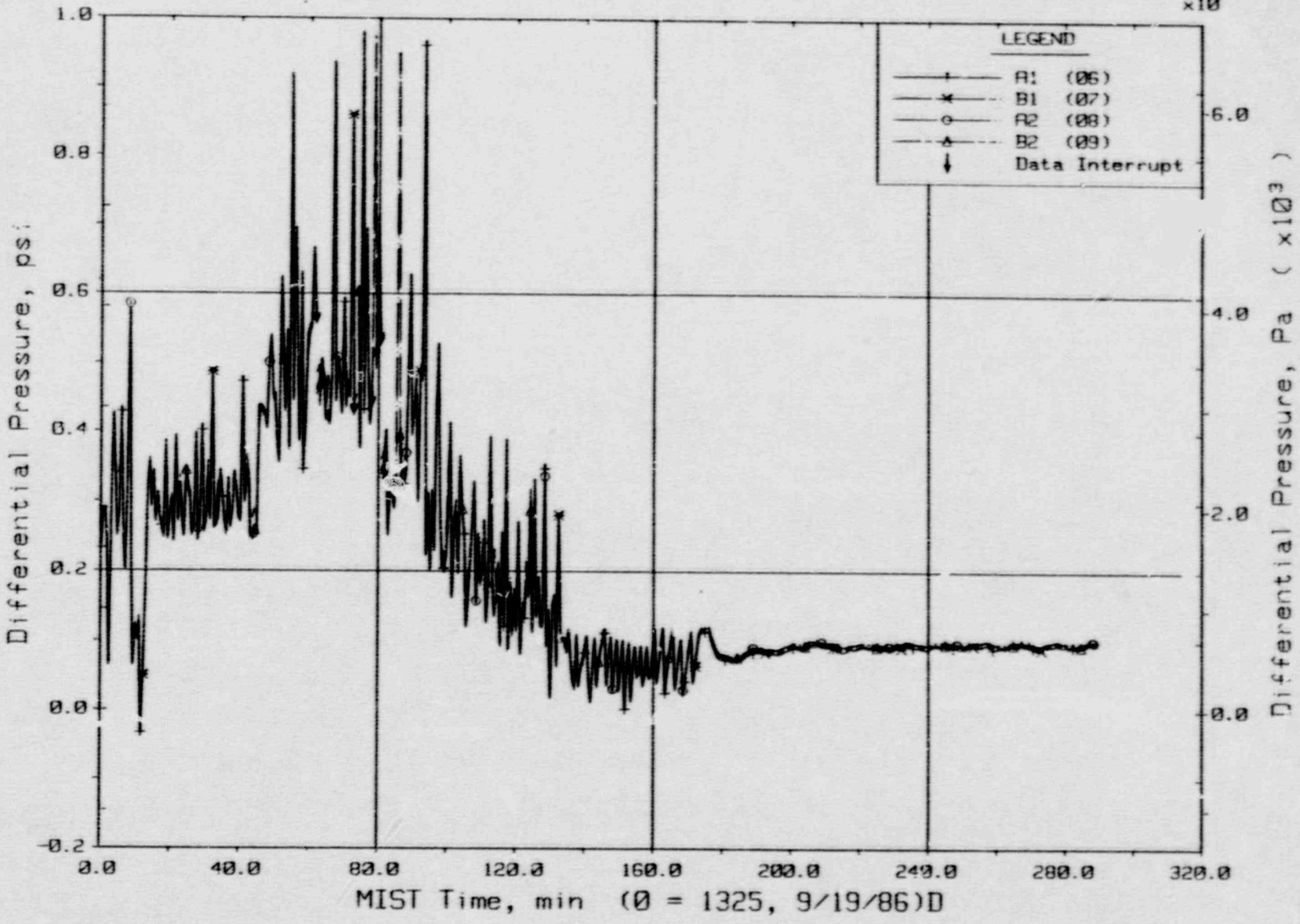
Steam Generator Steam Outlet Temperatures (SSTCs).

Mon Jun 6 08:28:51 1988

SGRT2

FINAL DATA

T350101: Group 35 Test 1 Venting Without Noncondensibles.



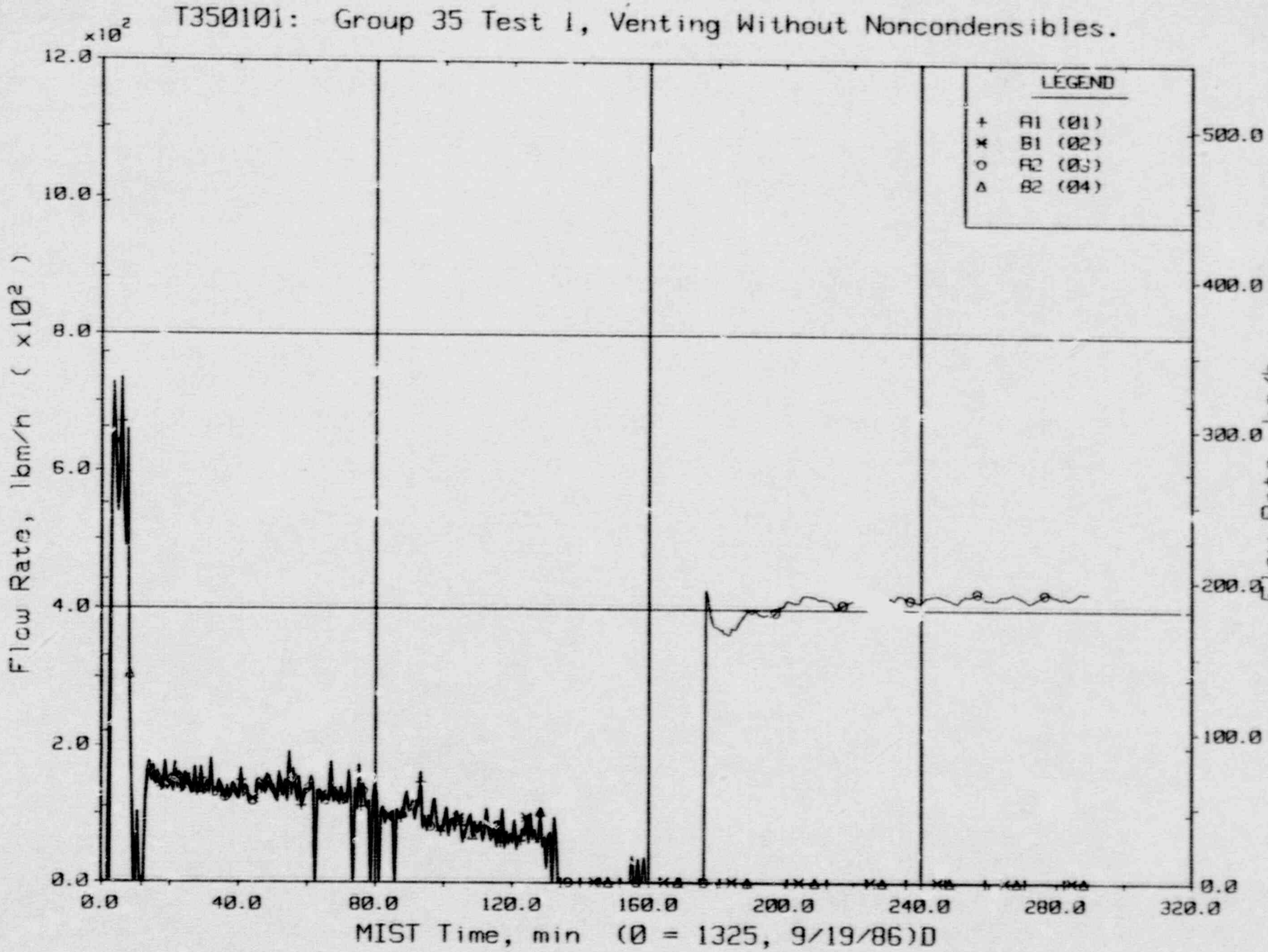
Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Mon Jun 6 08:34:16 1988

VVDP1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



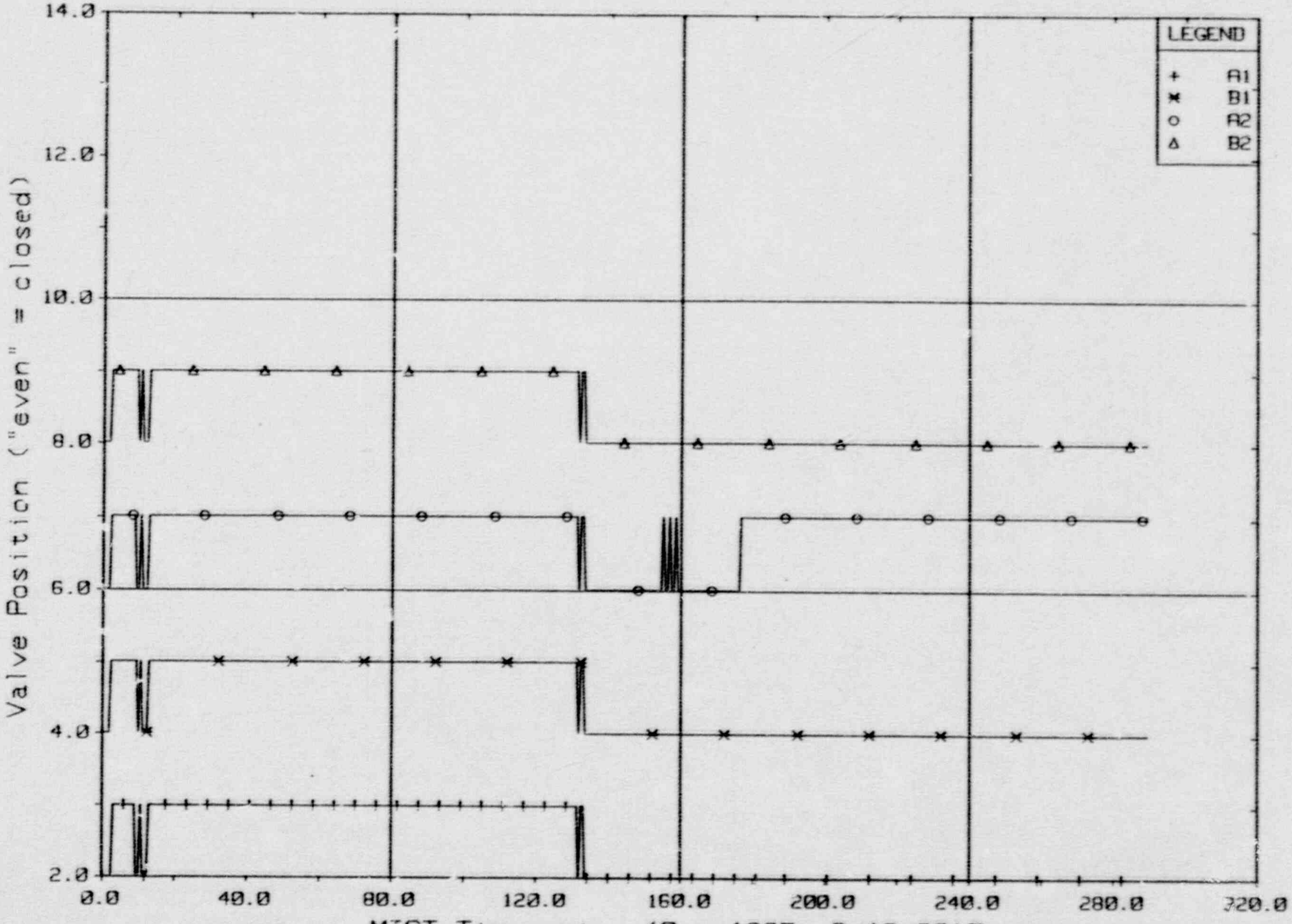
Reactor Vessel Vent Valve Flow Rates (RVORs).

Mon Jun 6 08:38:12 1988

VVFL1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.



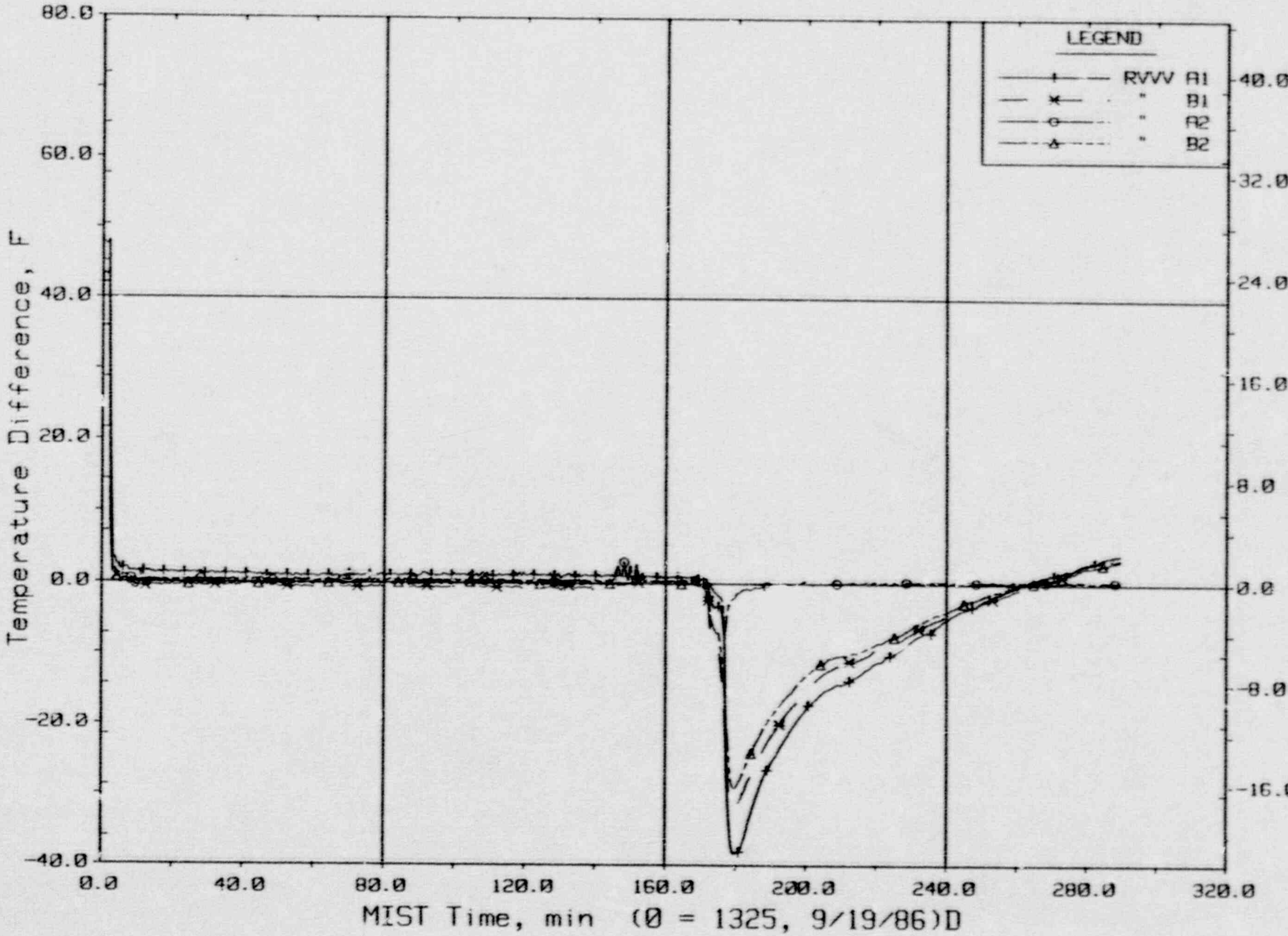
Reactor Vessel Vent Valve Positions.

Mon Jun 6 08:42:34 1988

VVLS1

FINAL DATA

T350101: Group 35 Test 1, Venting Without Noncondensibles.

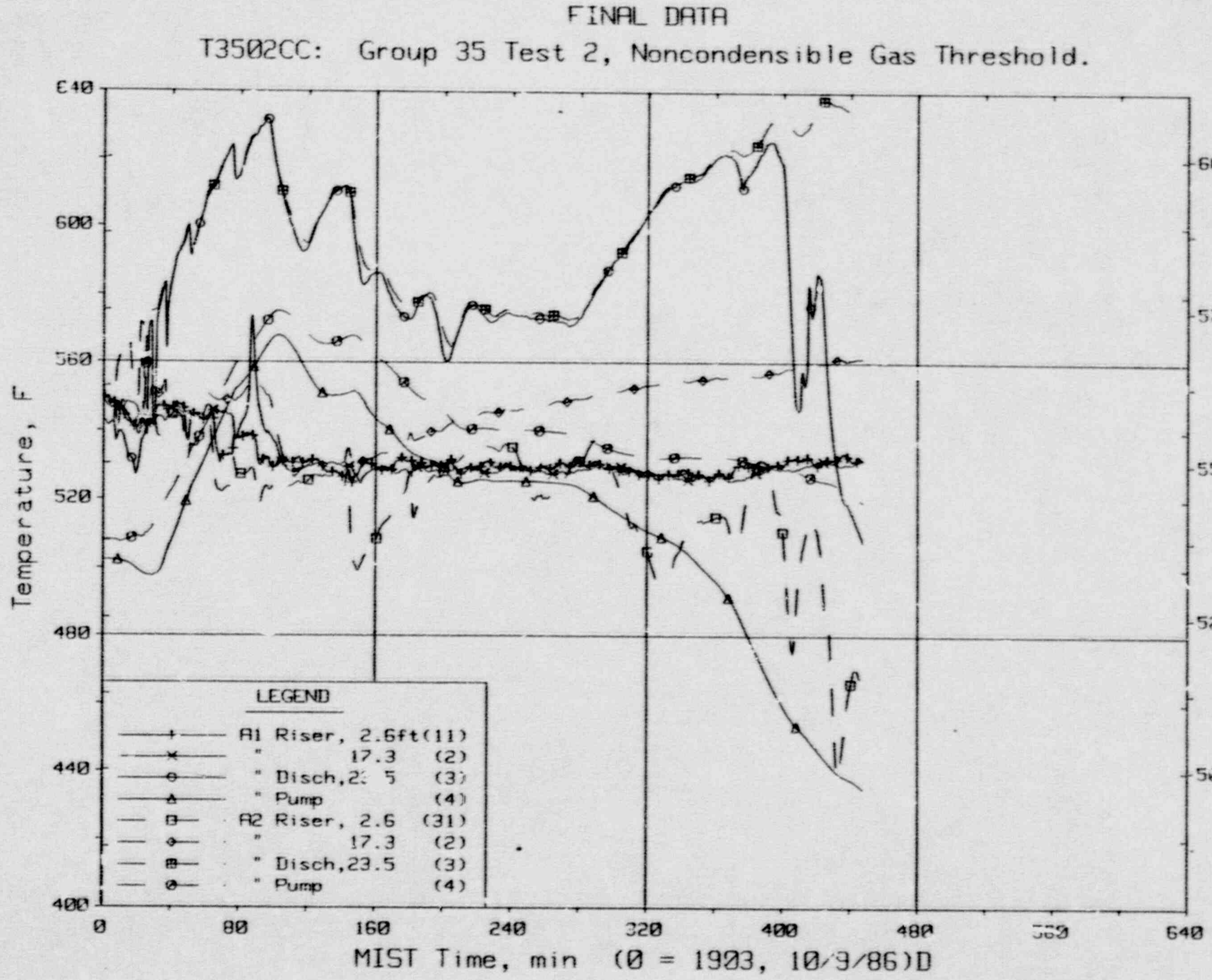


Temperature Differences Across Vent Valves.

Mon Jun 6 08:45:39 1988

VVTD1

T3502CC



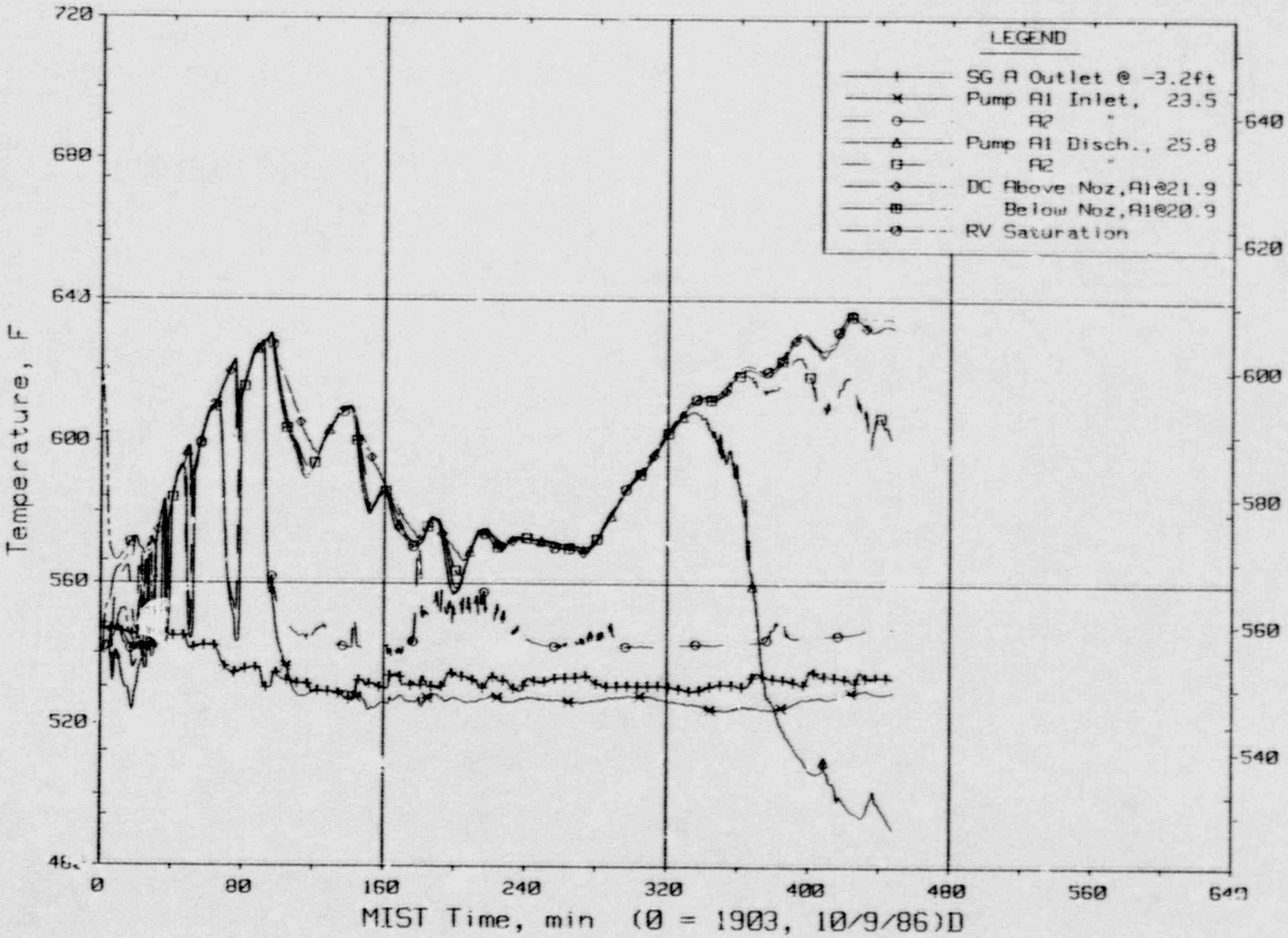
Loop A Cold Leg Metal Temperatures (C1,3MTs).

Fri Jan 6 08:59:43 1989

C1MT1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



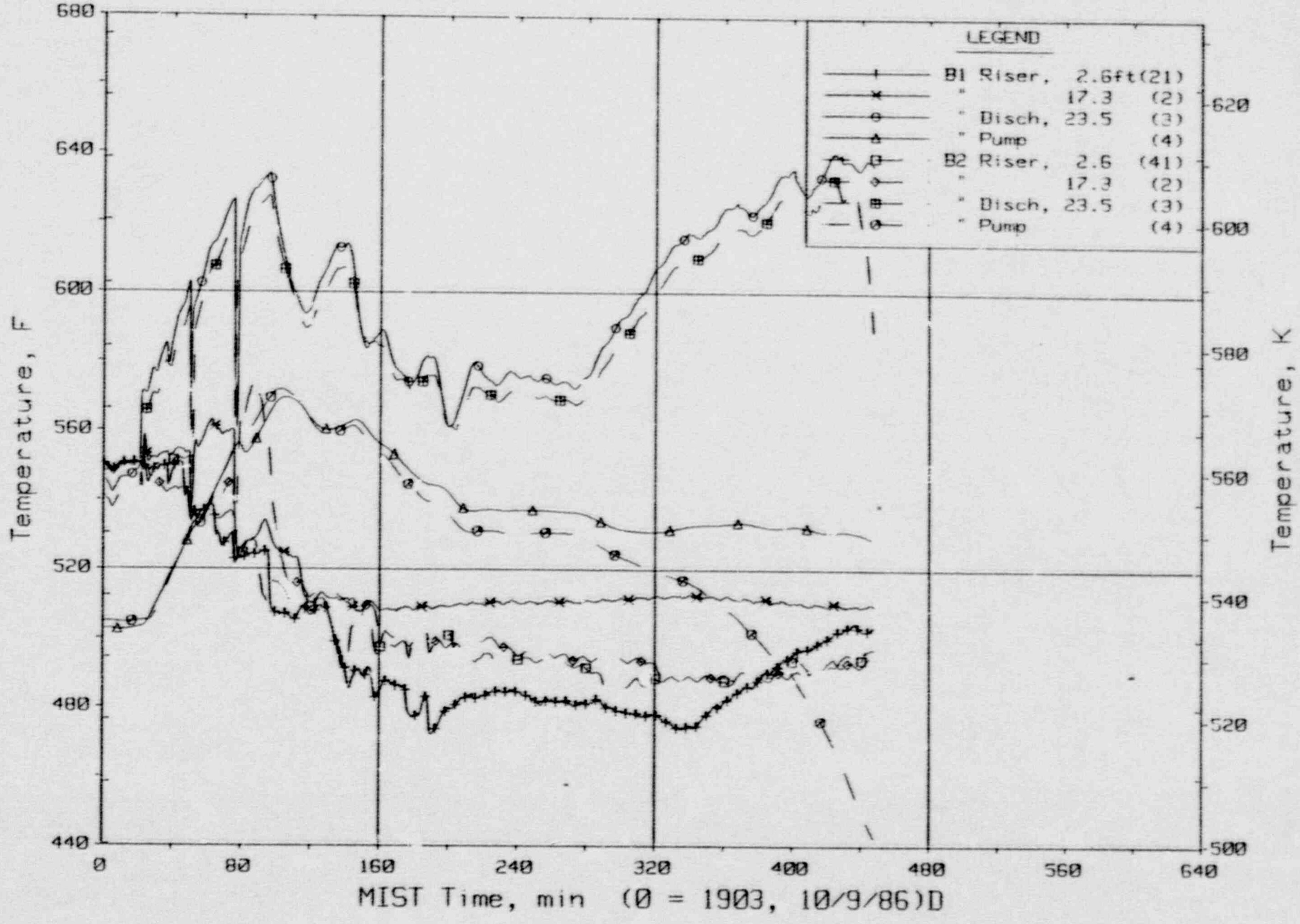
Loop A Cold Leg Fluid Temperatures (RTDs).

Fri Jan 6 09:05:29 1989

C1RT0

FINAL DATA

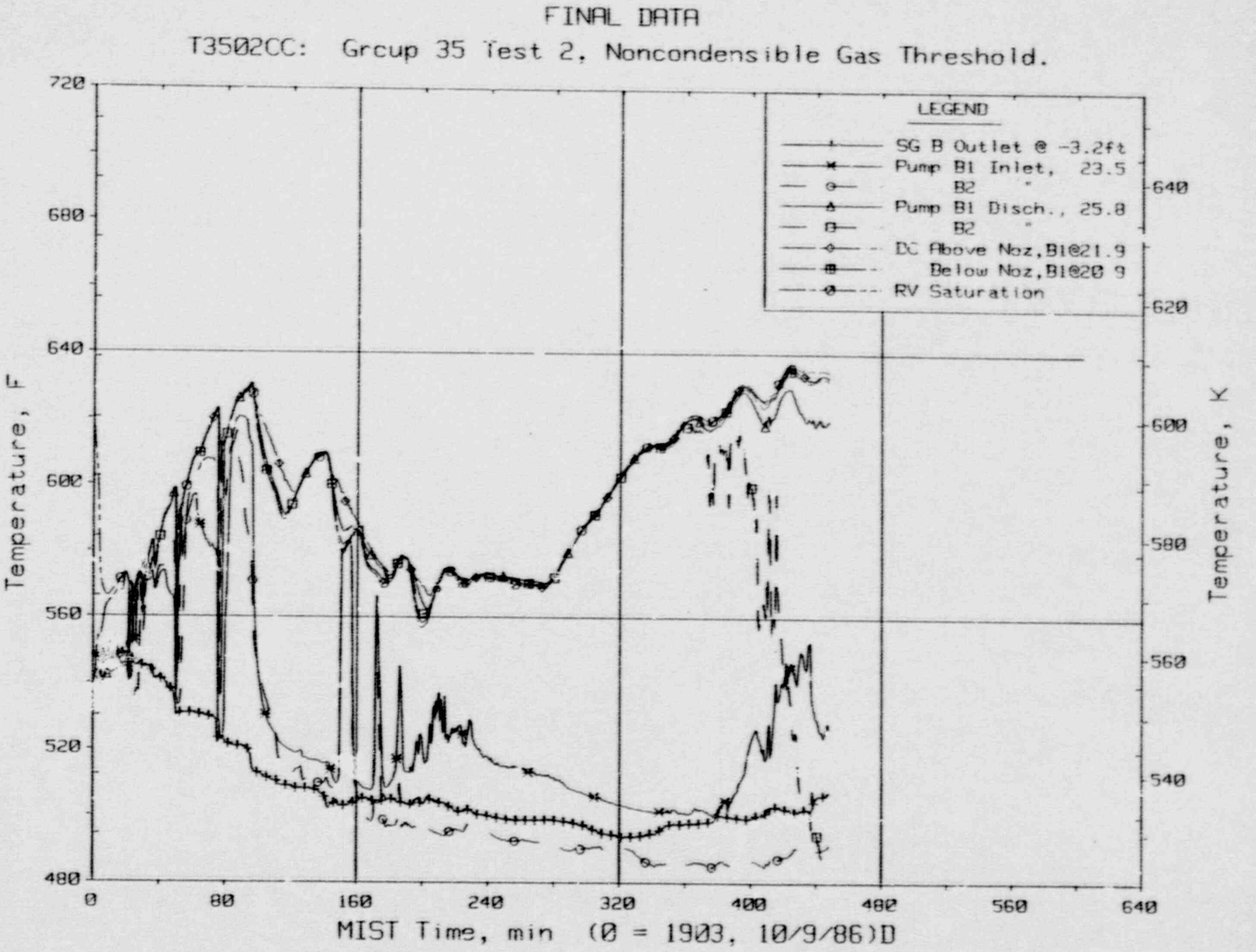
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



Loop B Cold Leg Metal Temperatures (C2,4MTs).

Fri Jan 6 09:10:27 1989

C2MT1



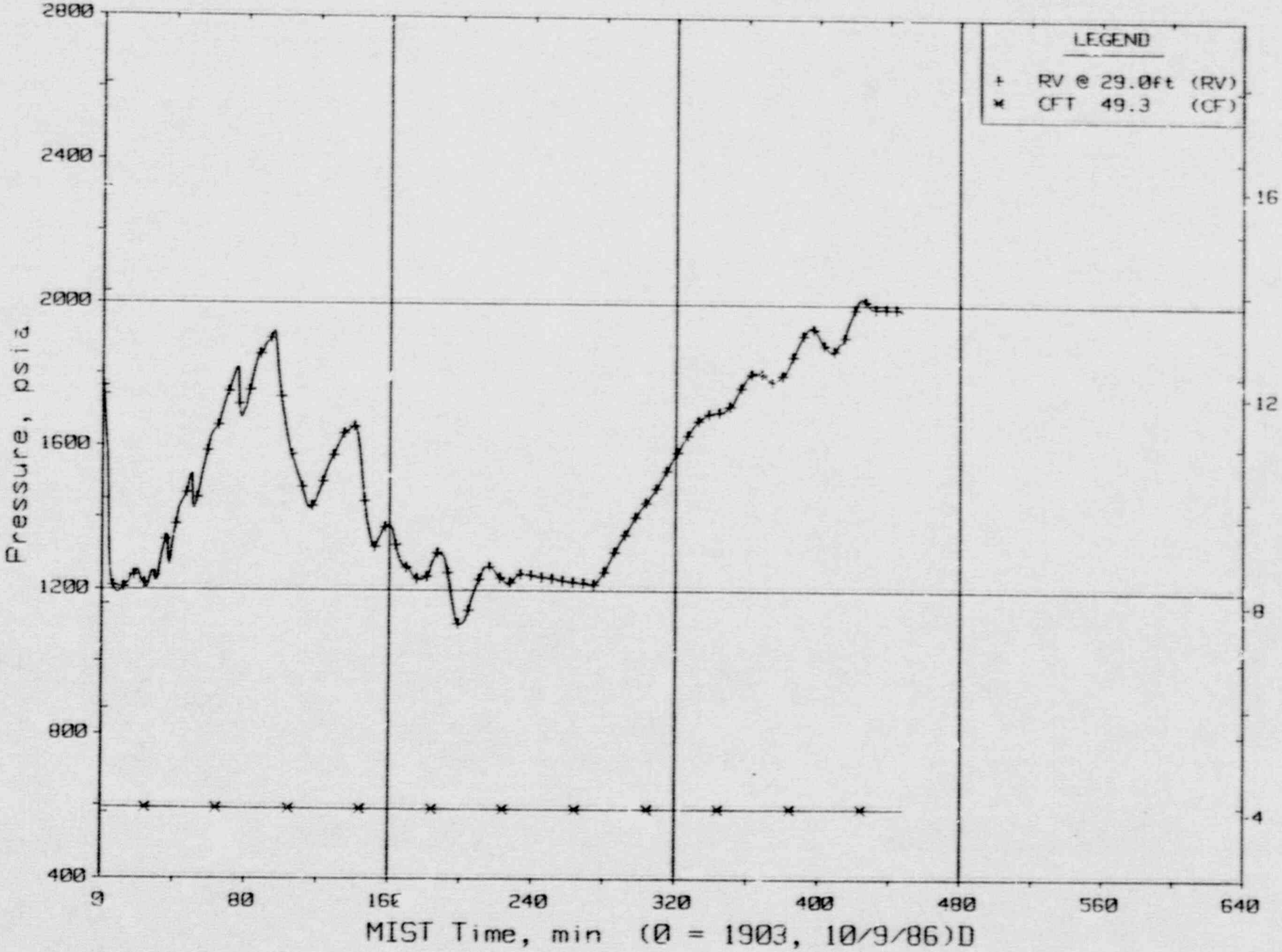
Loop B Cold Leg Fluid Temperatures (RTDs).

Fri Jan 6 09:16:13 1989

C2RT0

FIN^L DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



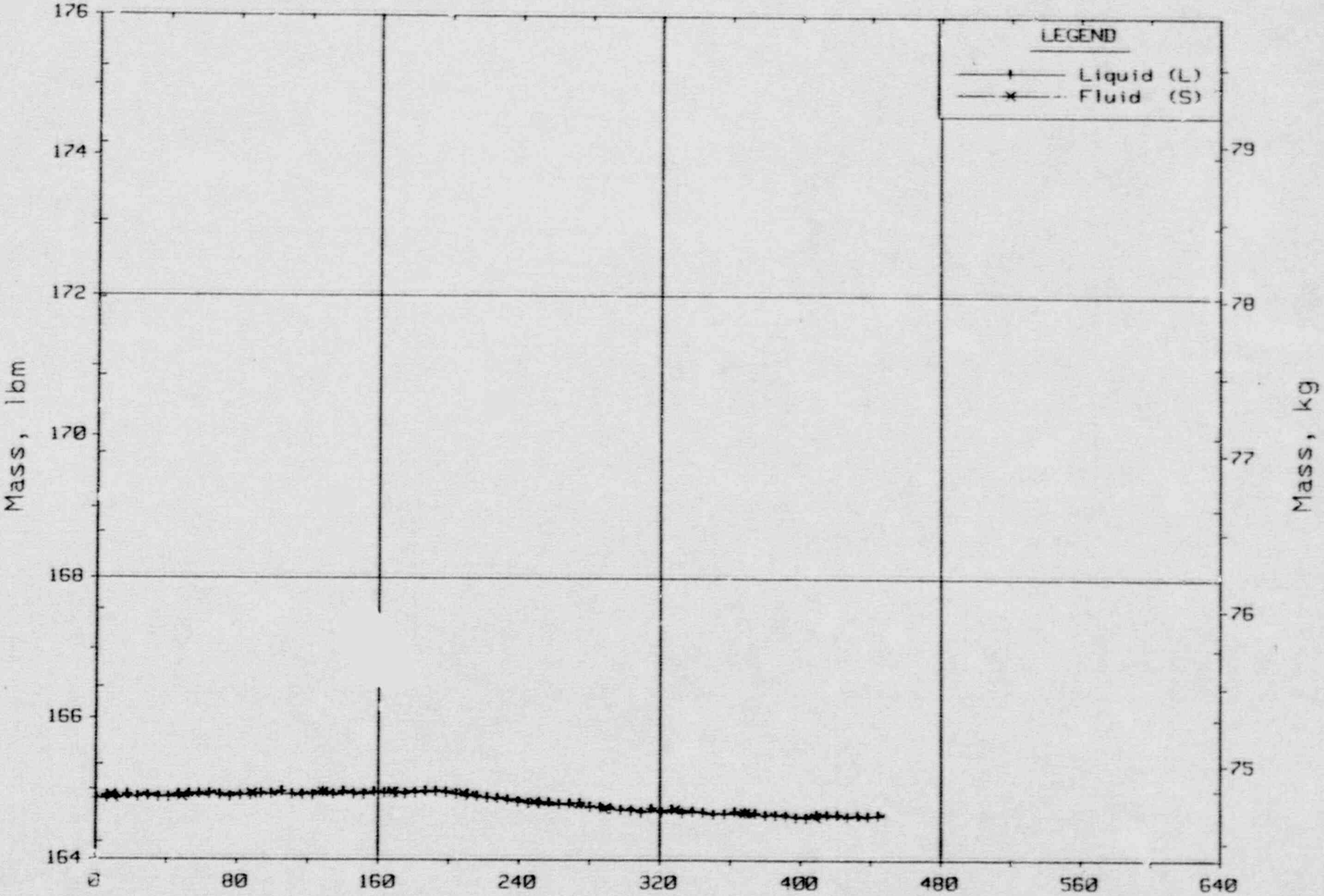
Primary System and Core Flood Tank Pressures (GP01s).

Fri Jan 6 09:20:49 1989

CFGP1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



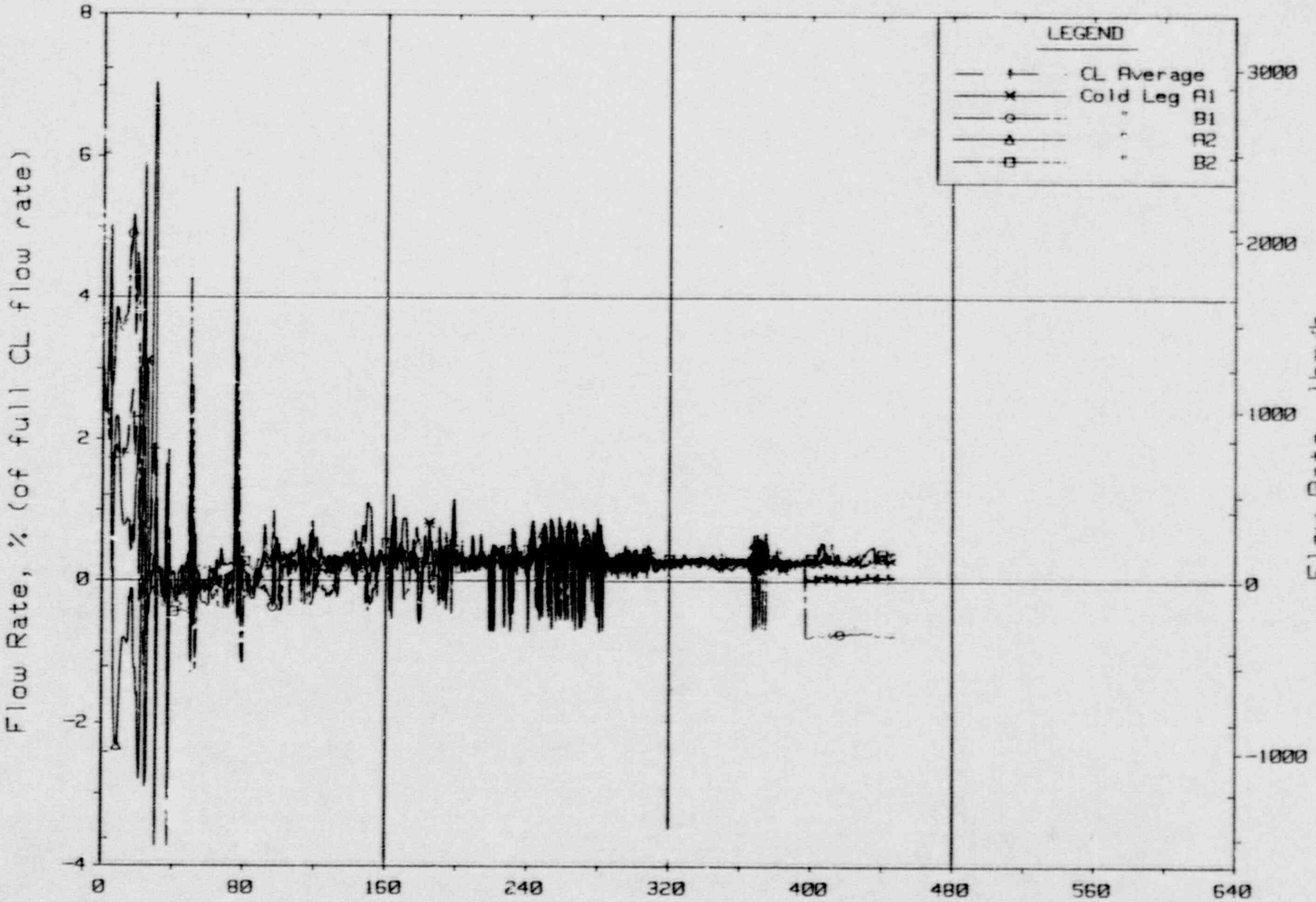
Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Fri Jan 6 09:23:29 1989

CFML1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



MIST Time, min (0 = 1903, 10/9/86)D

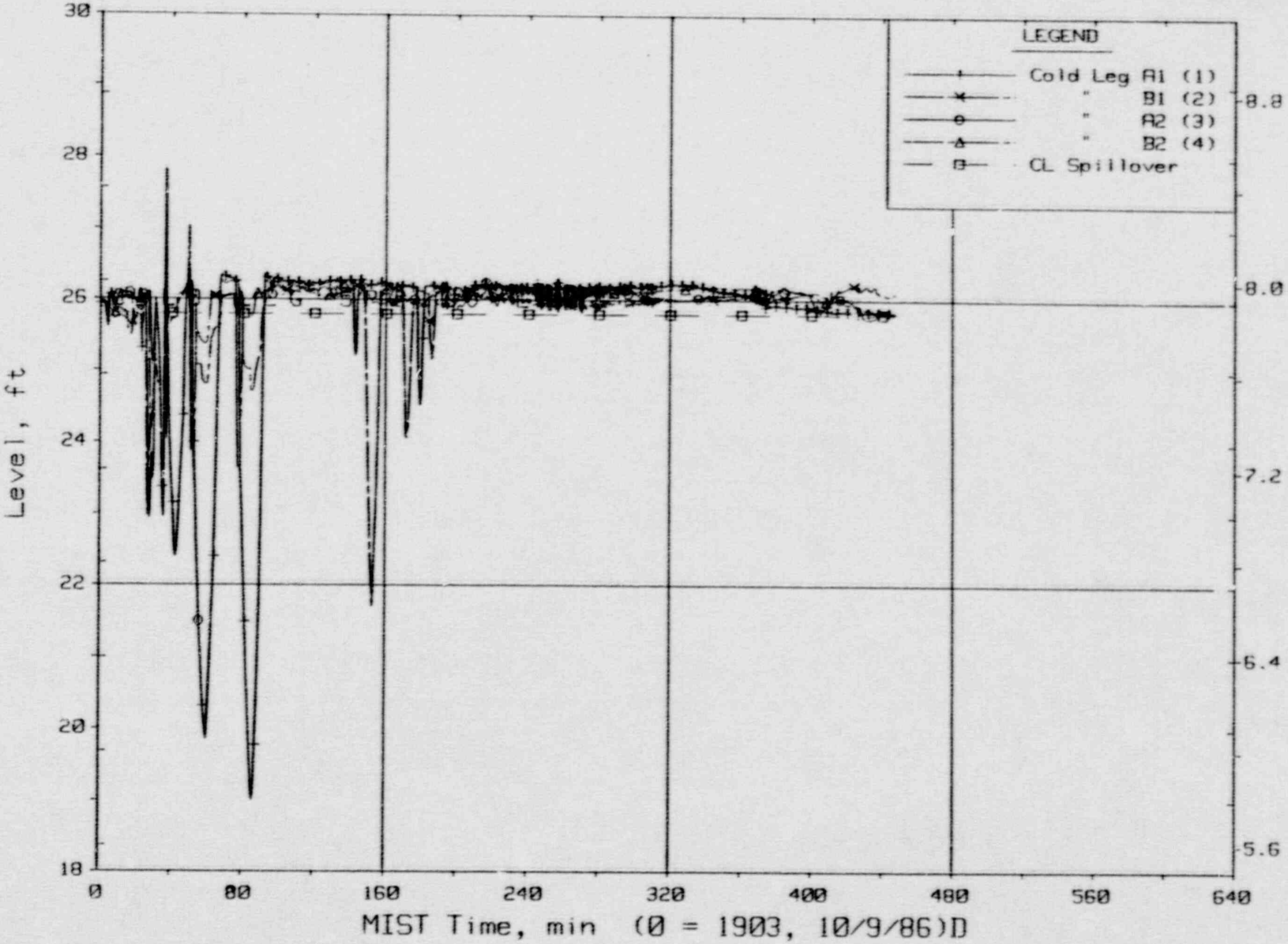
Cold Leg (Venturi) Flow Rates.

Fri Jan 6 03:28:21 1989

CLFL1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



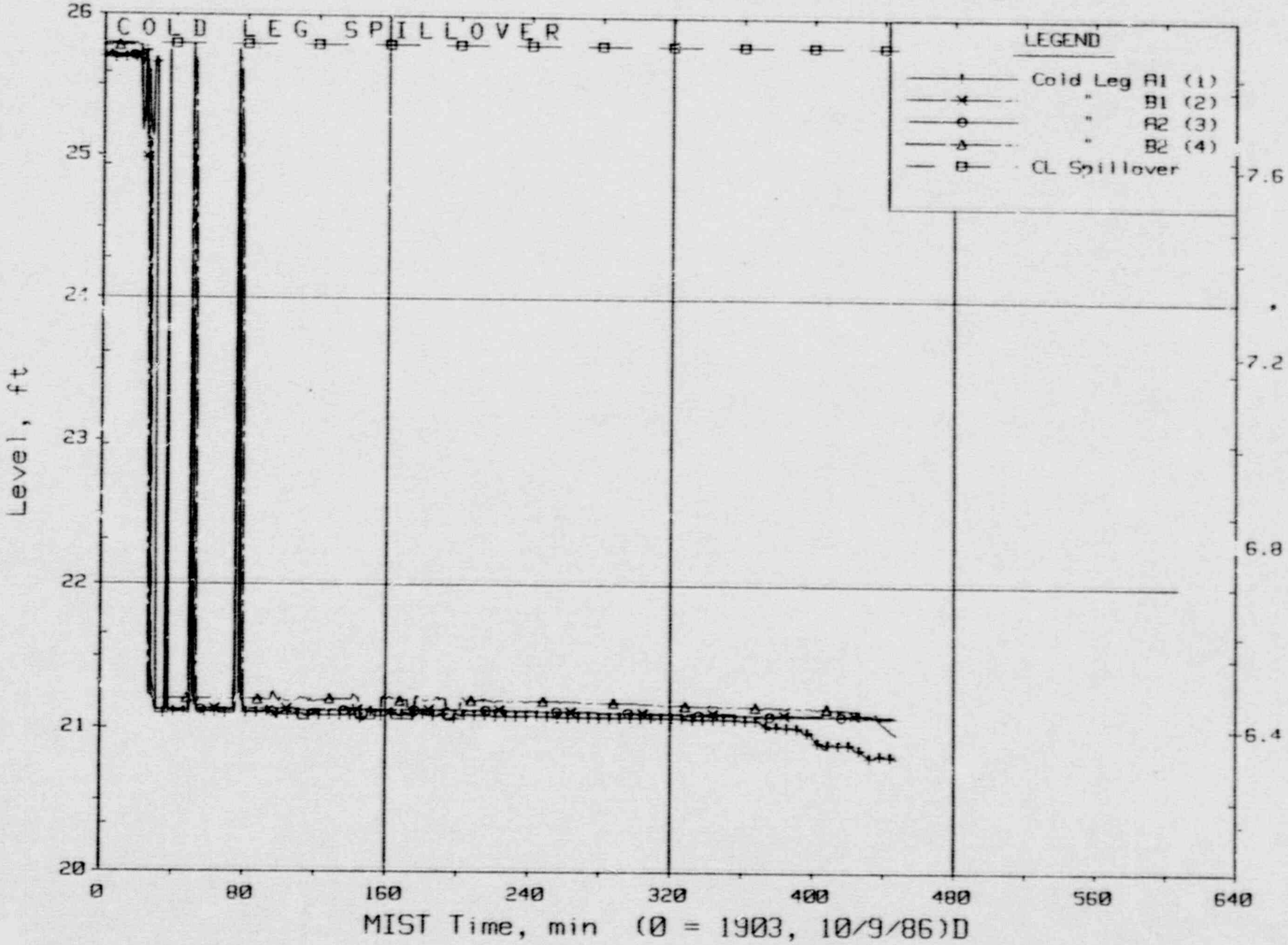
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Fri Jan 6 09:32:51 1989

CLLV4

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



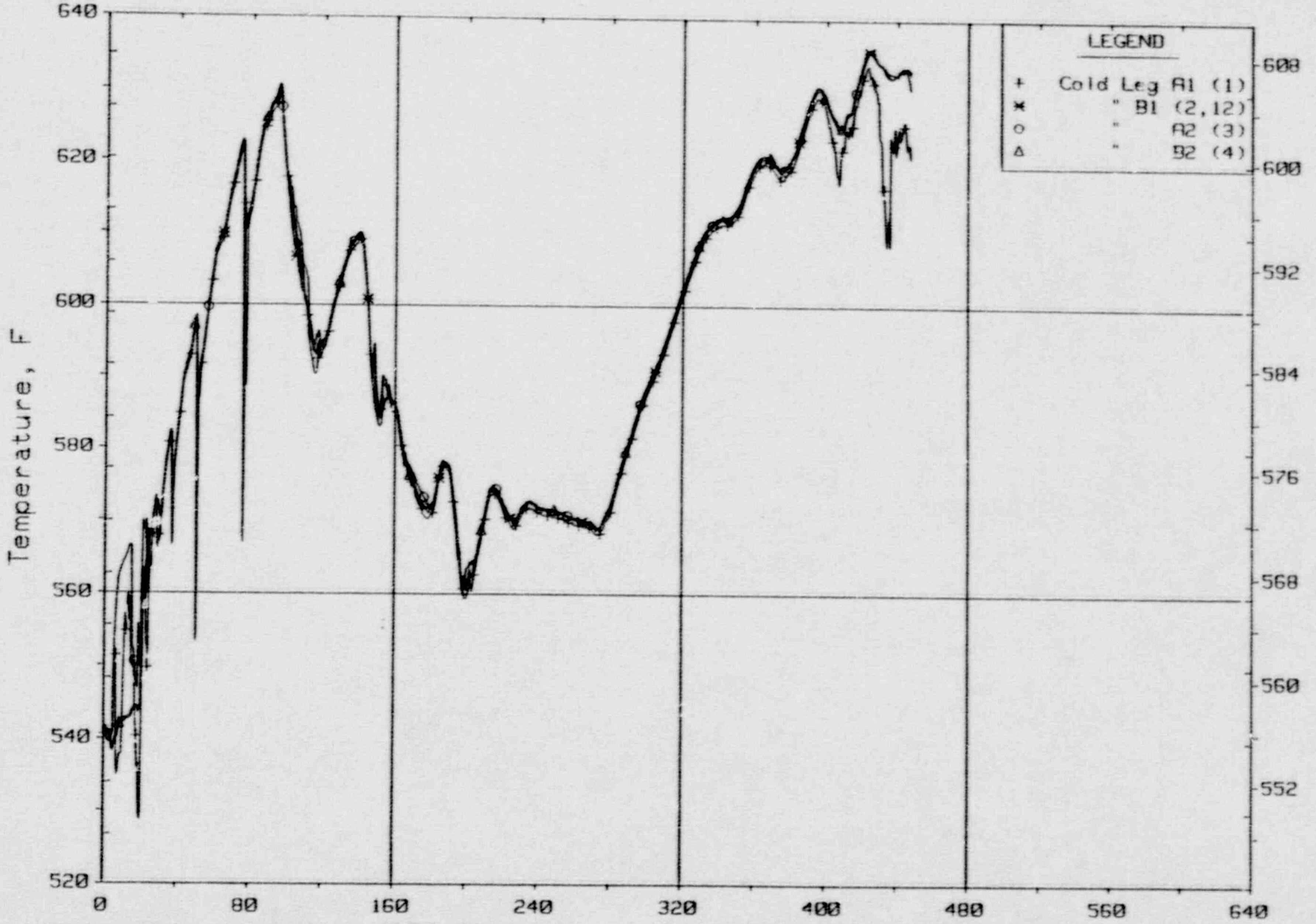
Cold Leg Discharge Collapsed Liquid Levels (CnLV23s).

Fri Jan 6 09:36:39 1989

CLLV5

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



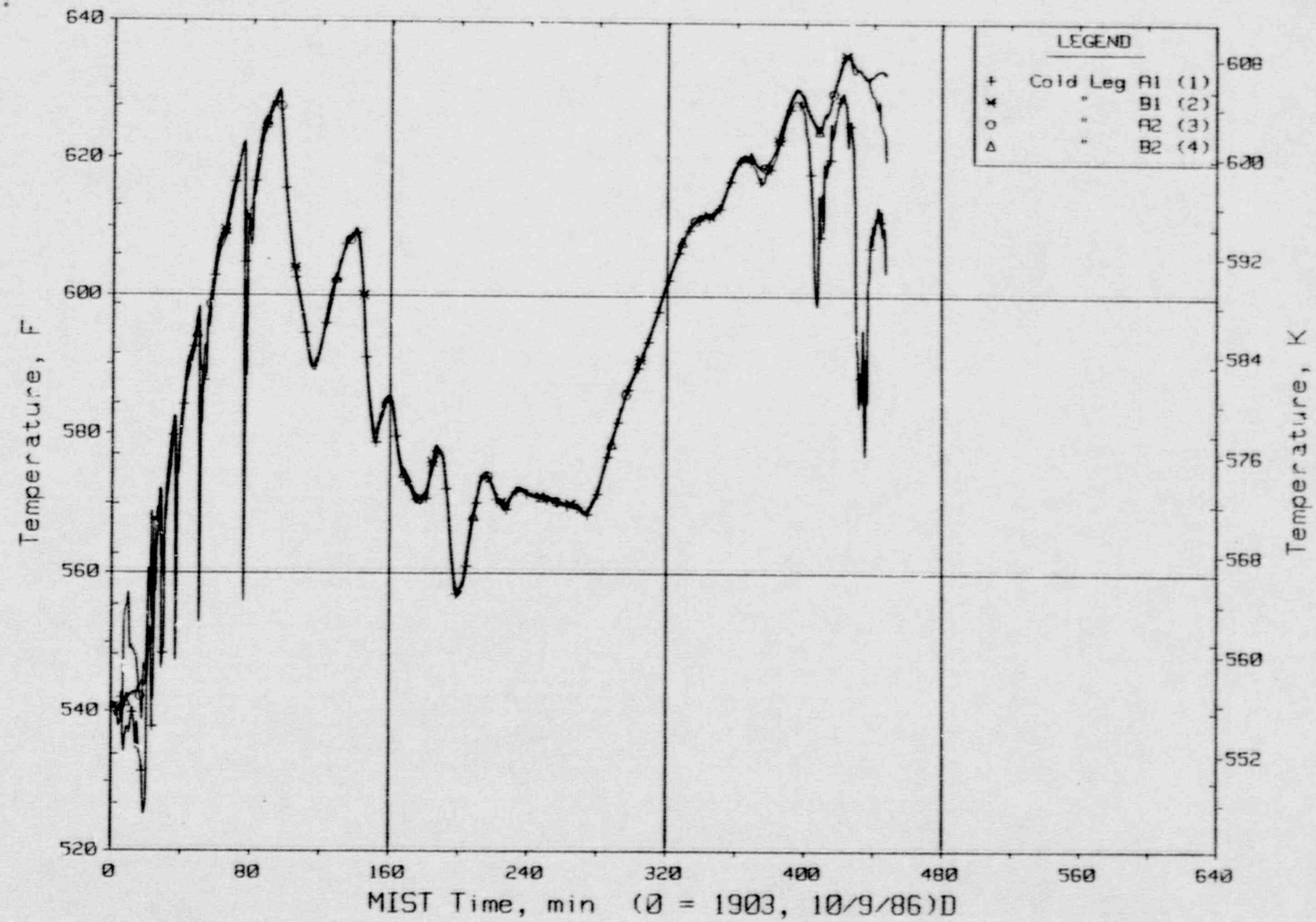
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Fri Jan 6 09:41:47 1989

CLTC1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



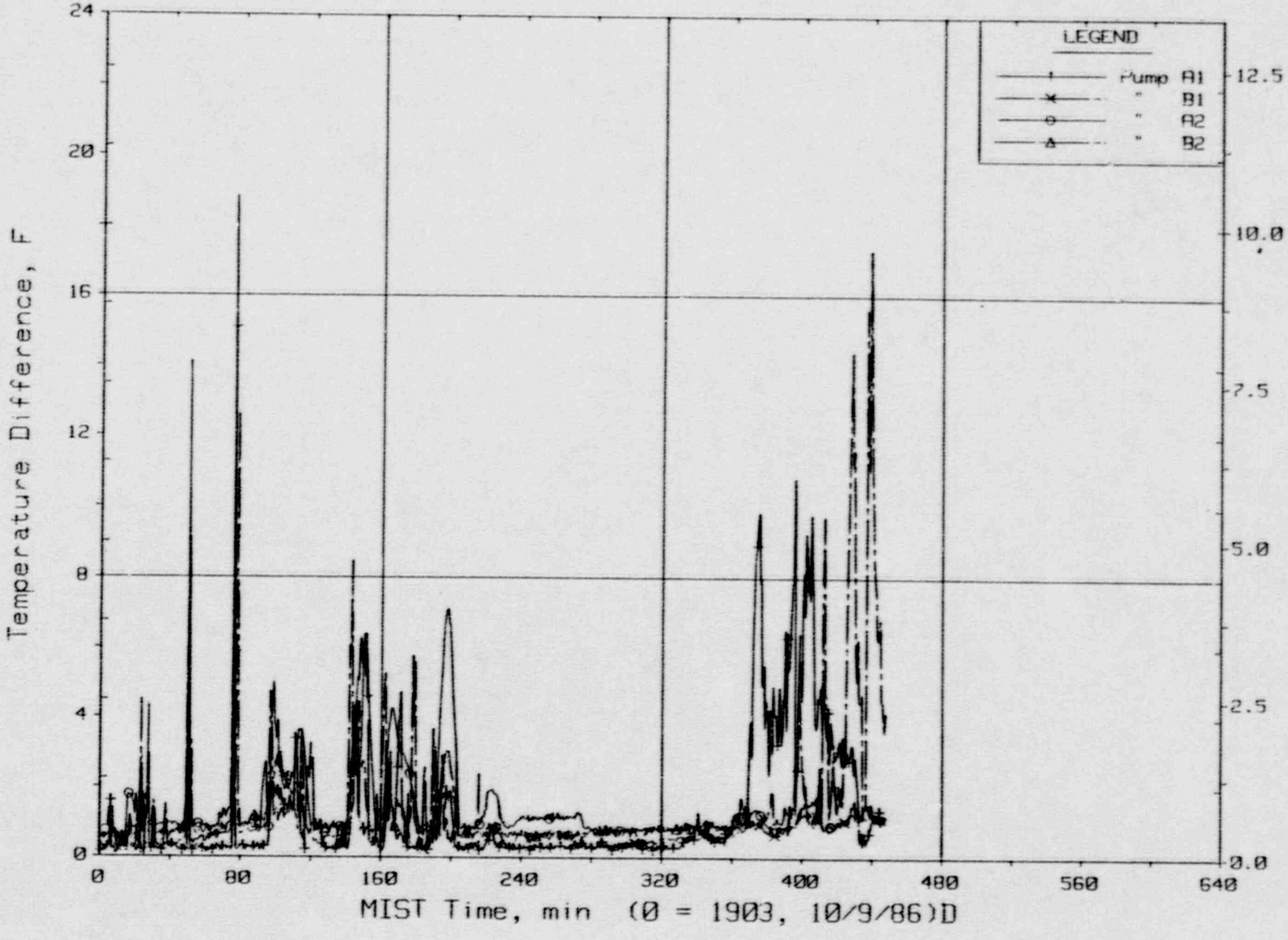
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Fri Jan 6 09:46:19 1989

CLTC2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



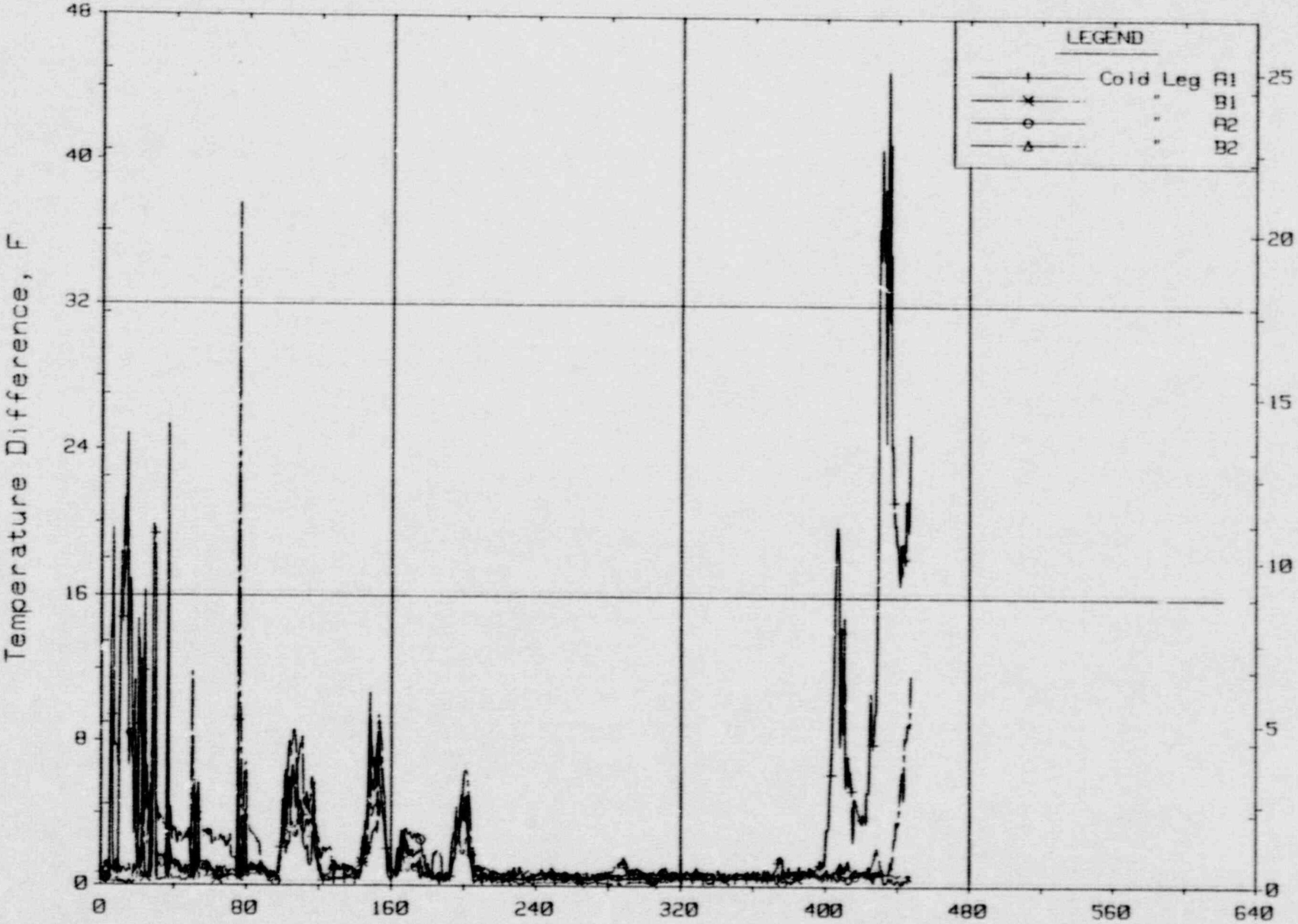
Maximum Differences Among RCP Rake FLuid Temperatures.

Fri Jan 6 09:50:24 1989

CLTD1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



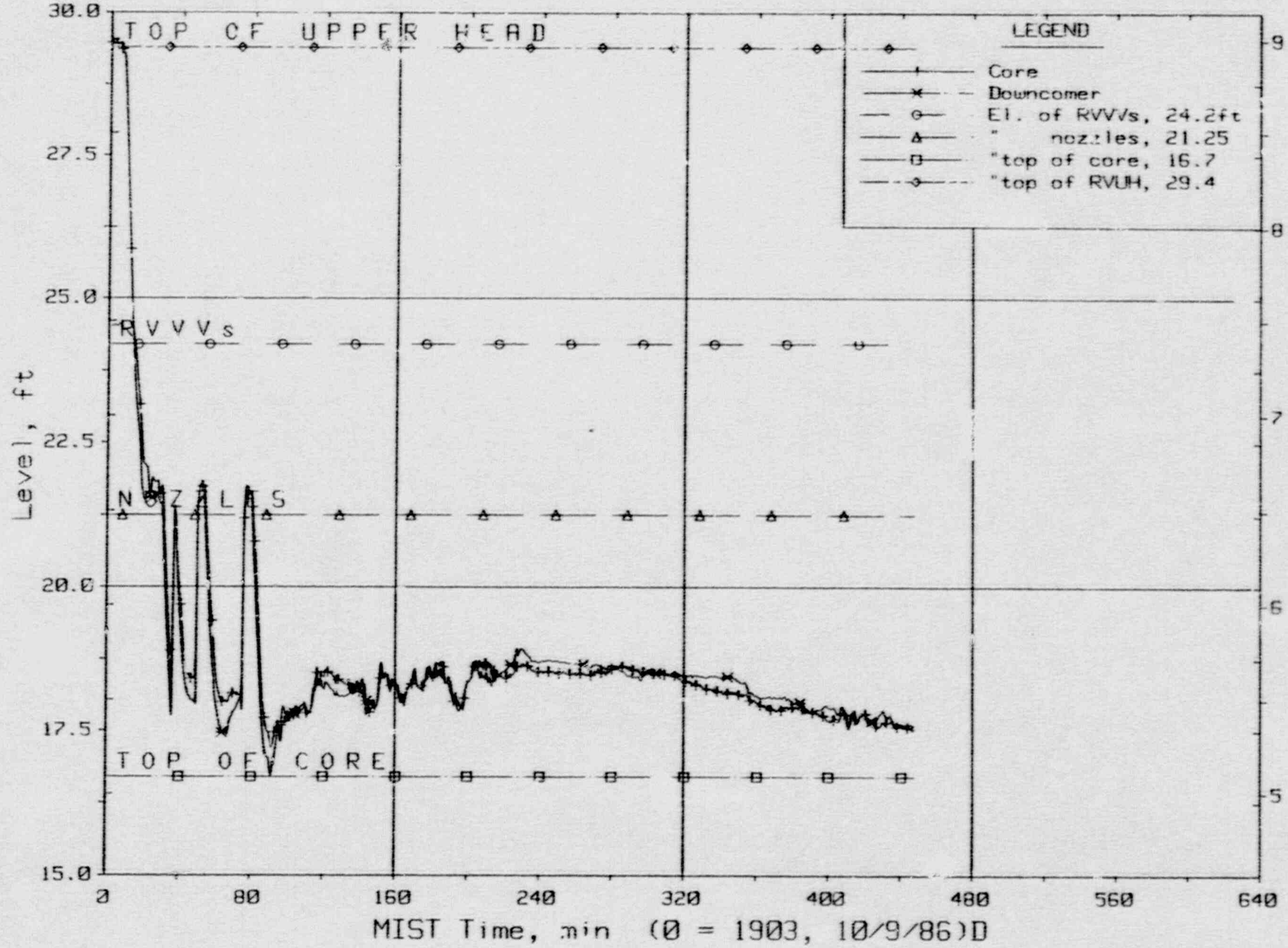
Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Fri Jan 6 09:54:14 1989

CLTD2

FINAL DATA

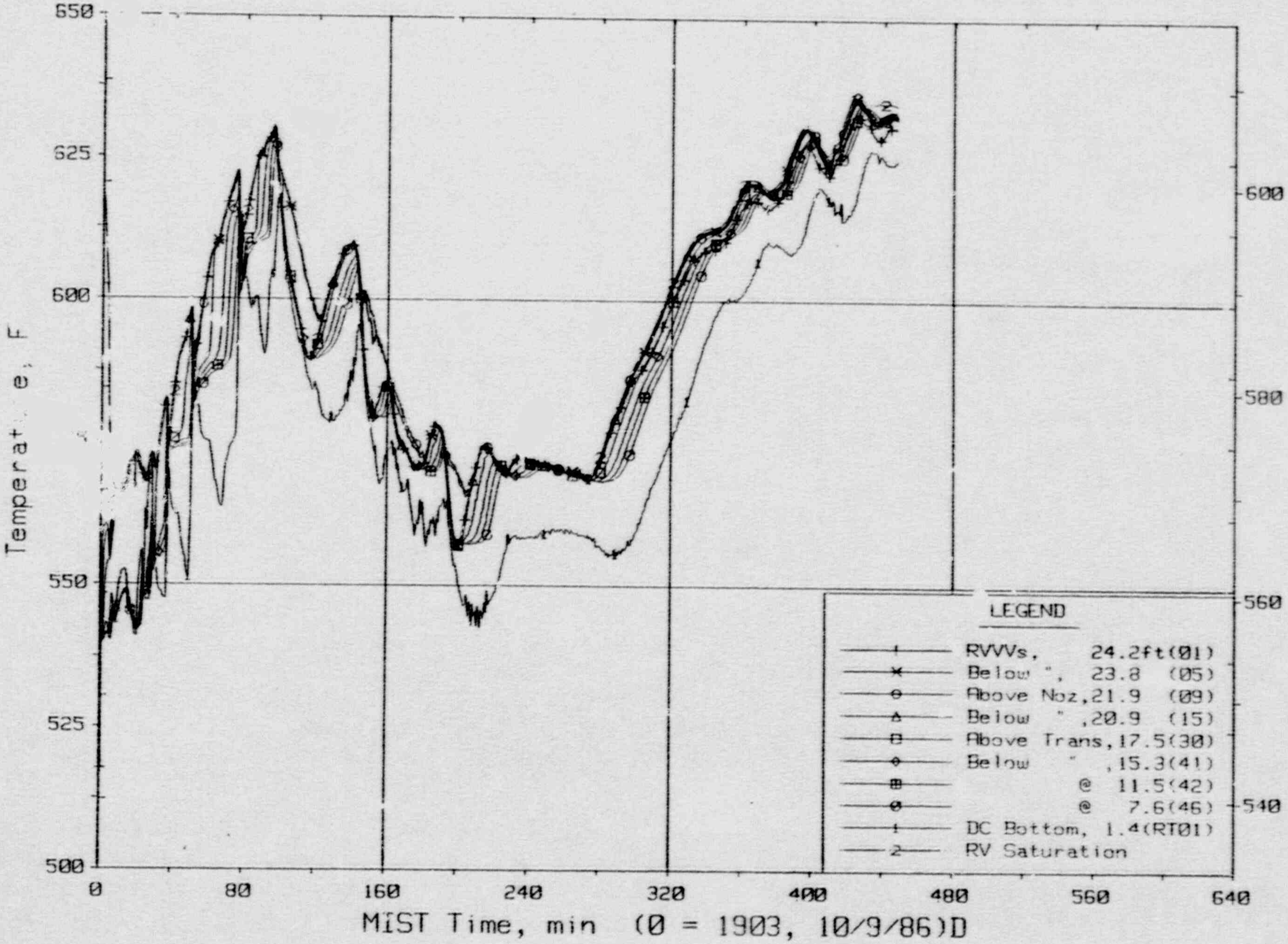
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



Core Region Collapsed Liquid Levels.

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



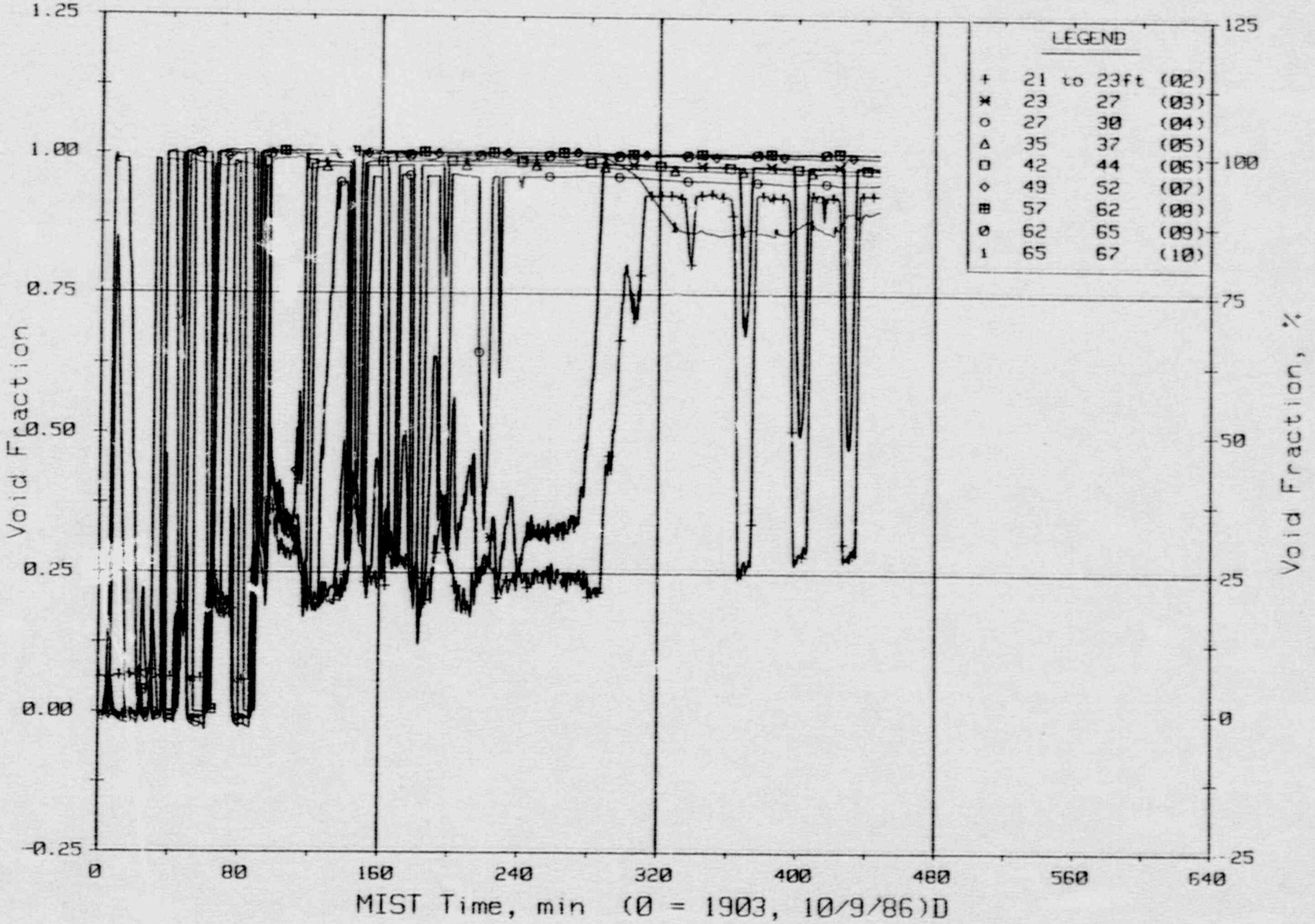
Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Fri Jan 6 10:09:34 1989

DCTC6

FINAL DATA

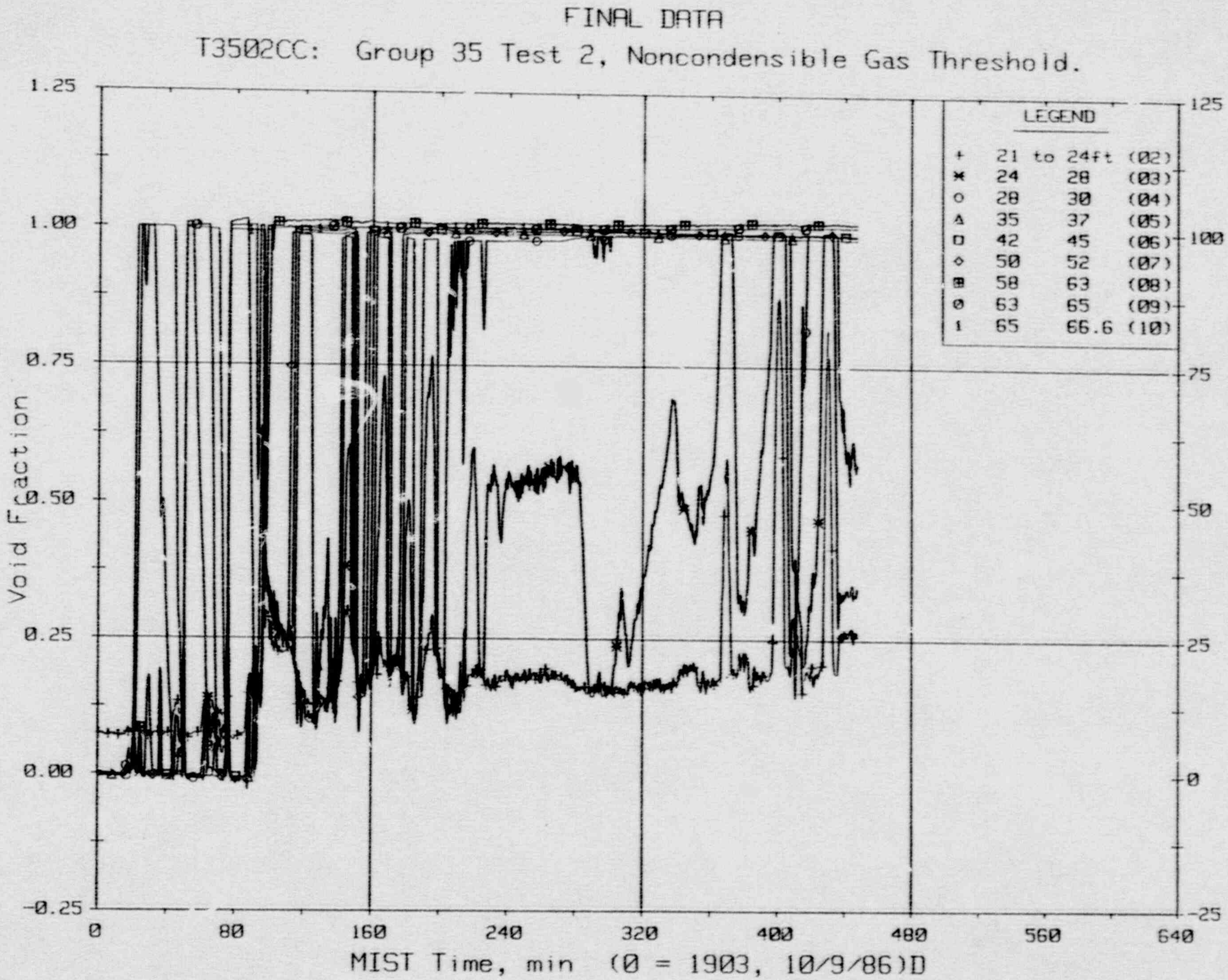
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



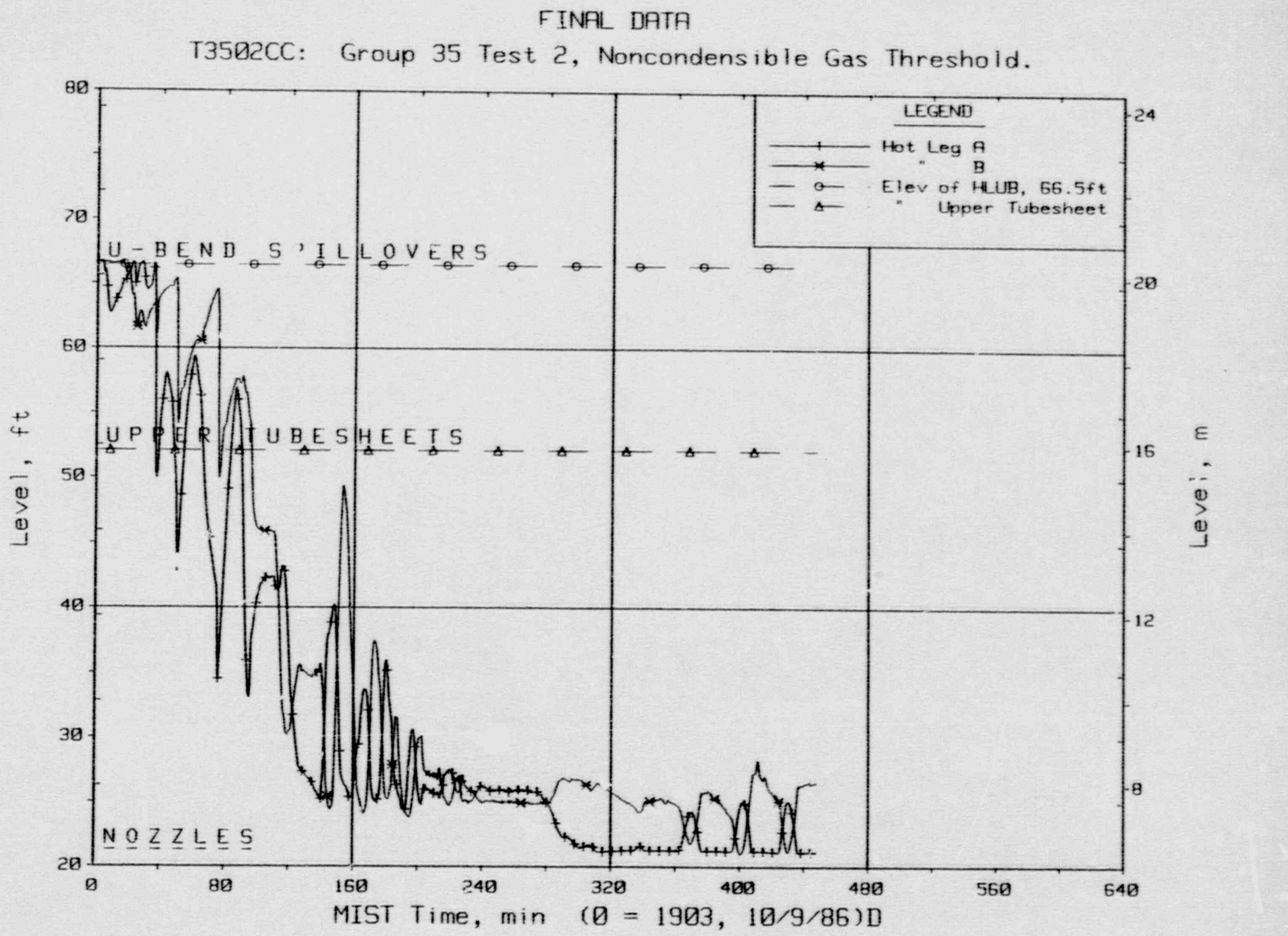
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Fri Jan 6 11:24:46 1989

H1VF1



Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).



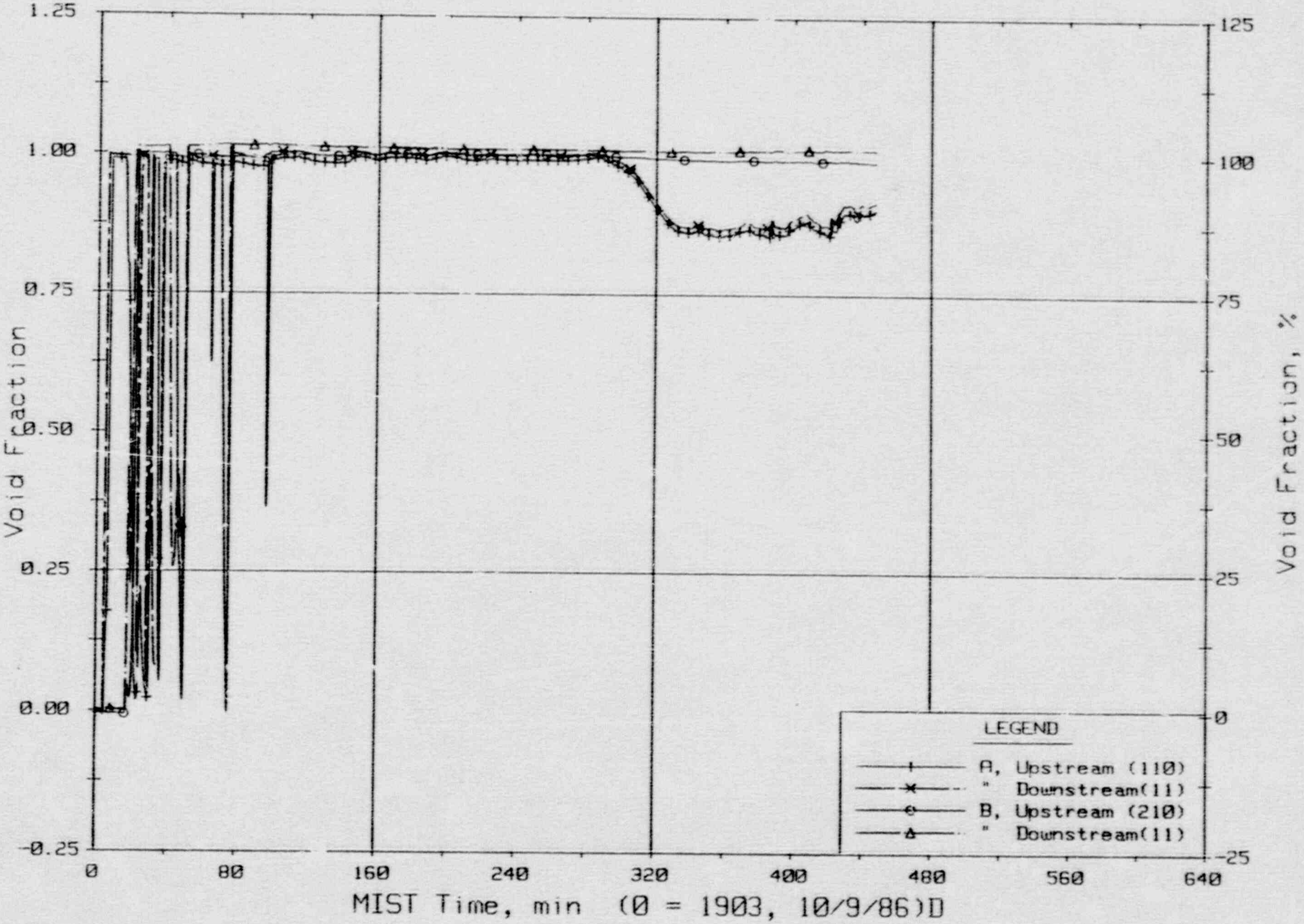
Hot Leg Riser Collapsed Liquid Levels.

Fri Jan 6 13:49:48 1989

HLLV0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



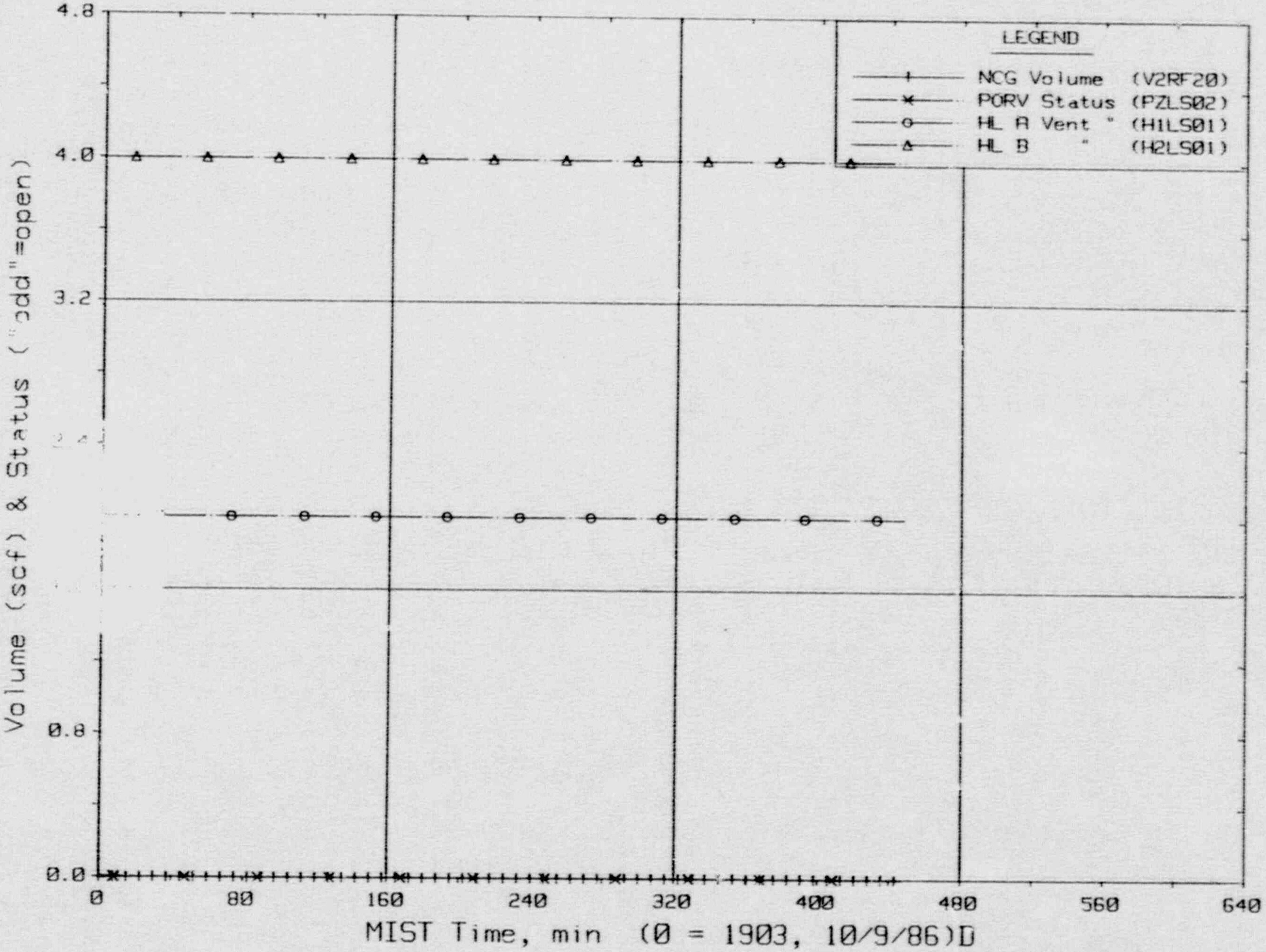
Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft, HnVFs).

Fri Jan 6 11:43:13 1989

HLVF1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



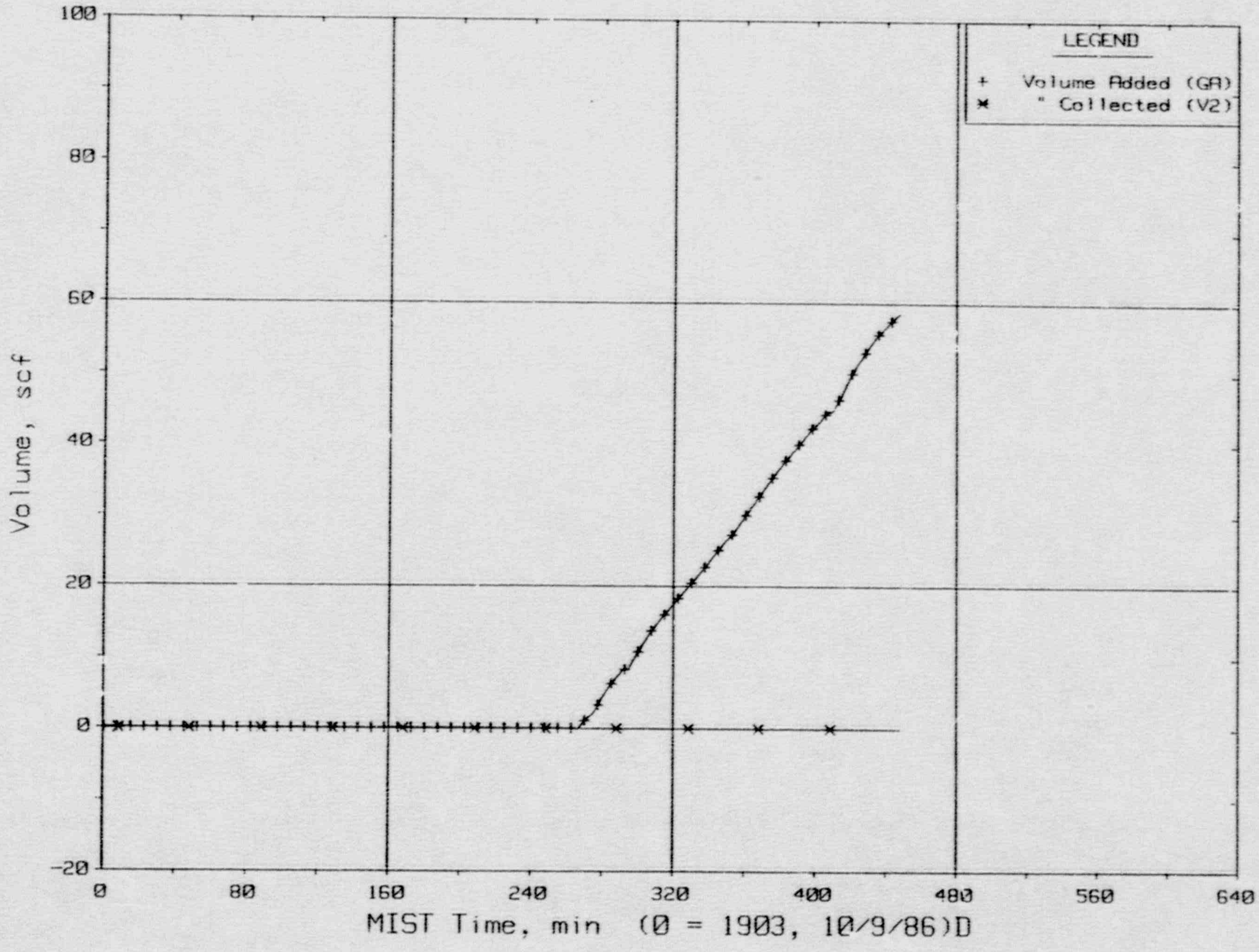
Noncondensibles Collected and Discharge Valve Status.

Thu Jan 5 17:55:26 1989

NCMS1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



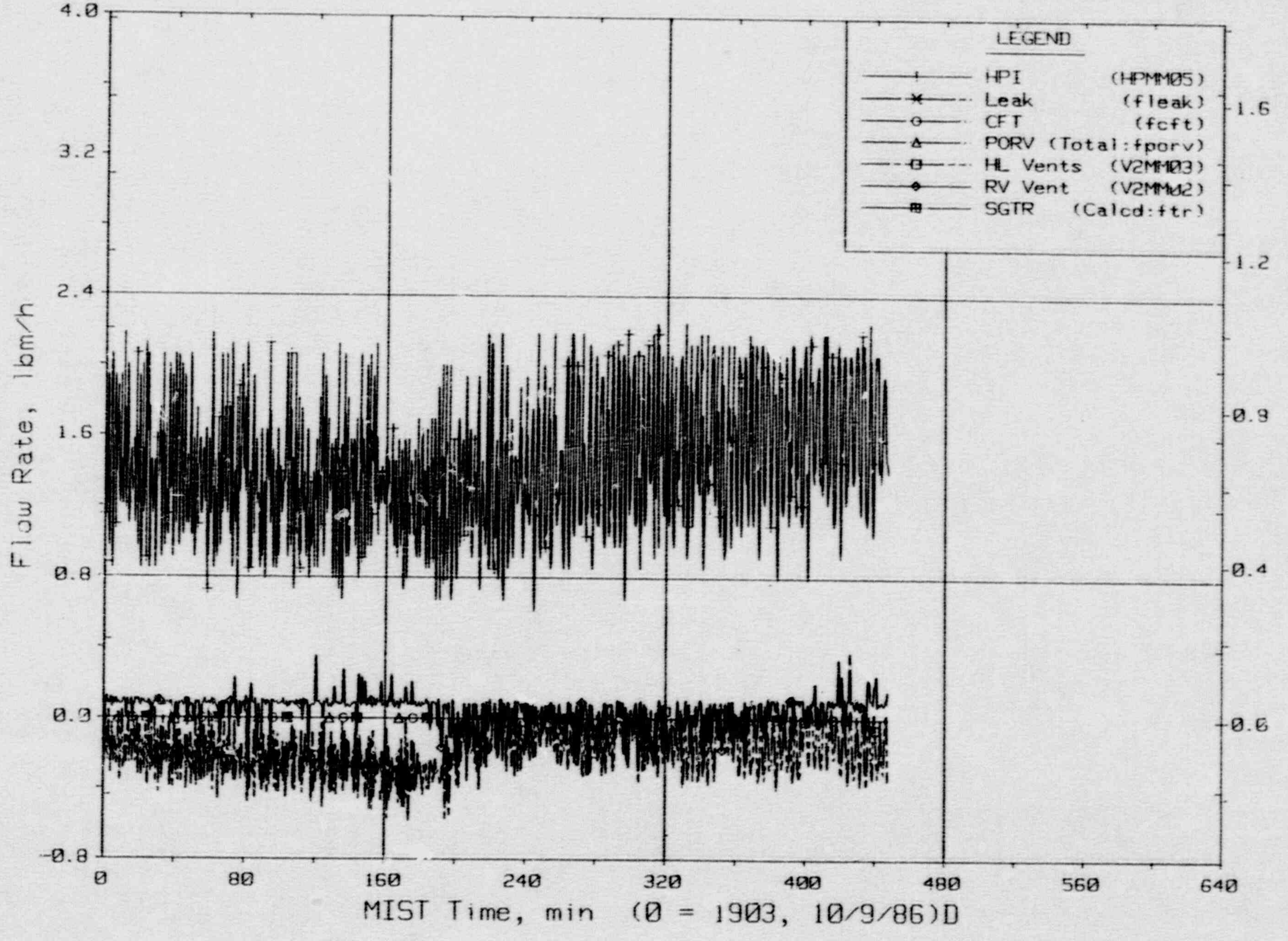
Noncondensible Gas Volumes.

Thu Jan 5 17:57:44 1989

NCMS2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



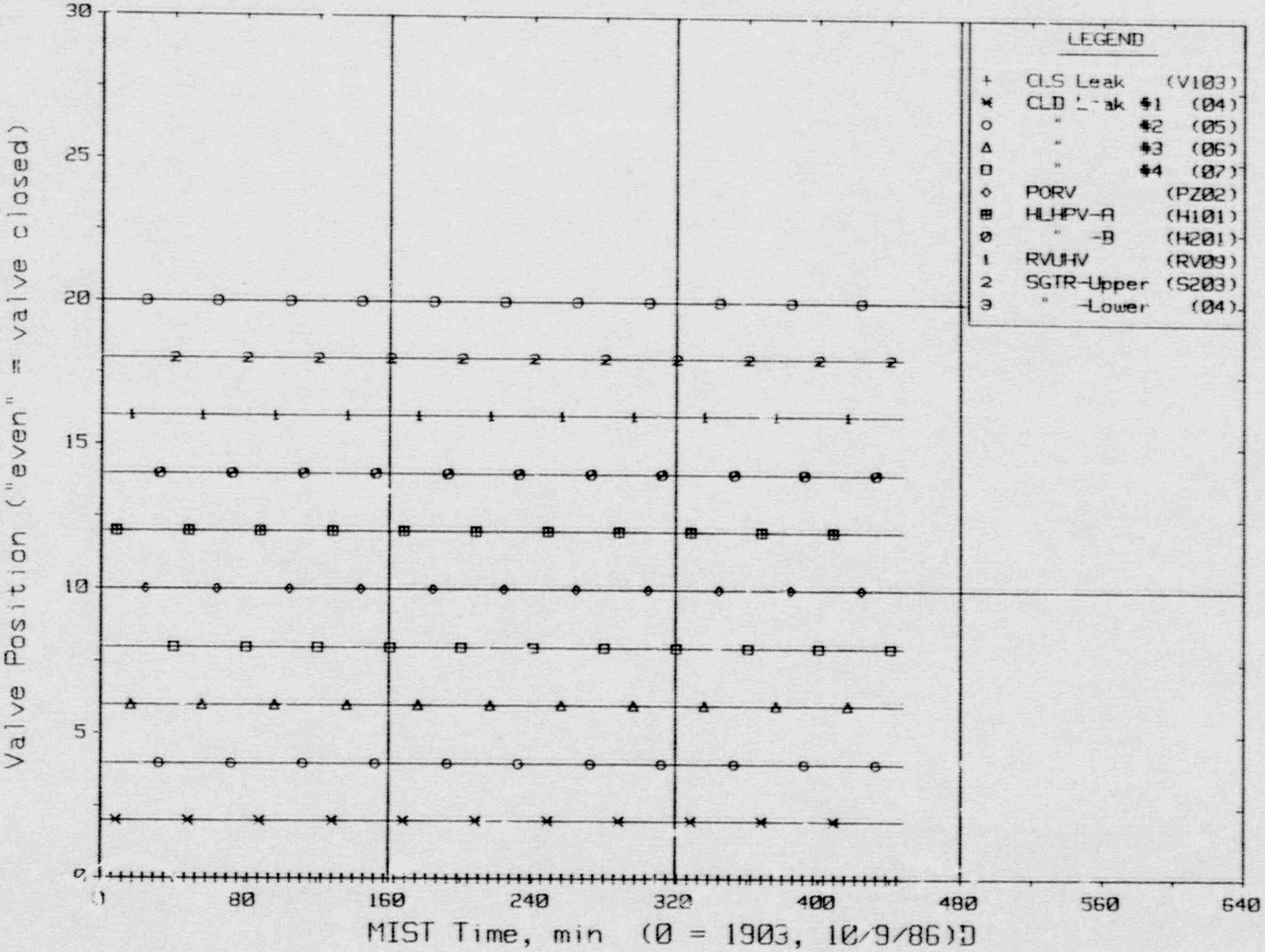
Primary System Boundary Flow Rates.

Fri Jan 6 11:49:08 1989

PBFL3

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



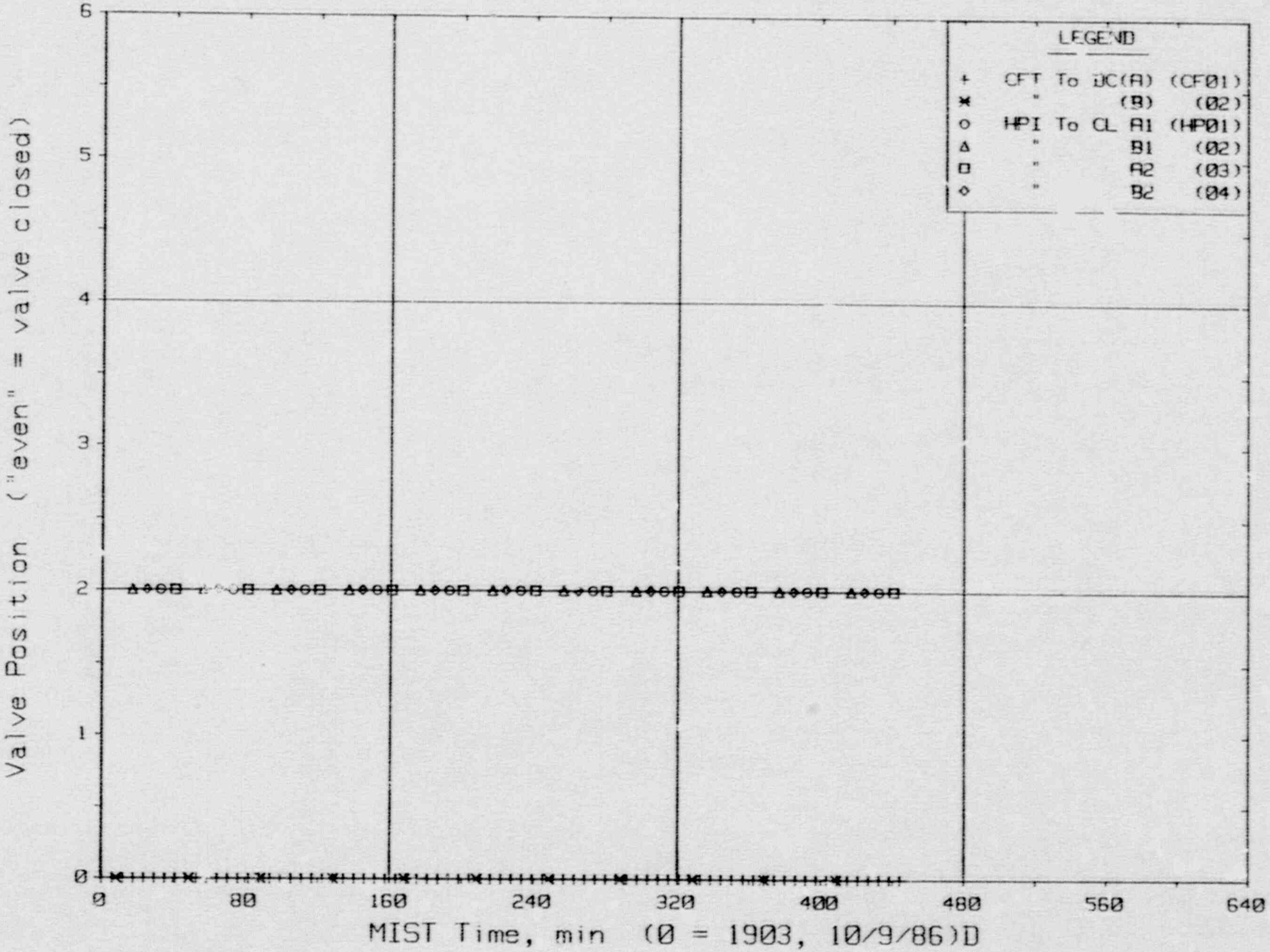
Primary System Discharge Limit Switch Indications (LSs).

Fri Jan 6 11:54:16 1989

PBLS1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



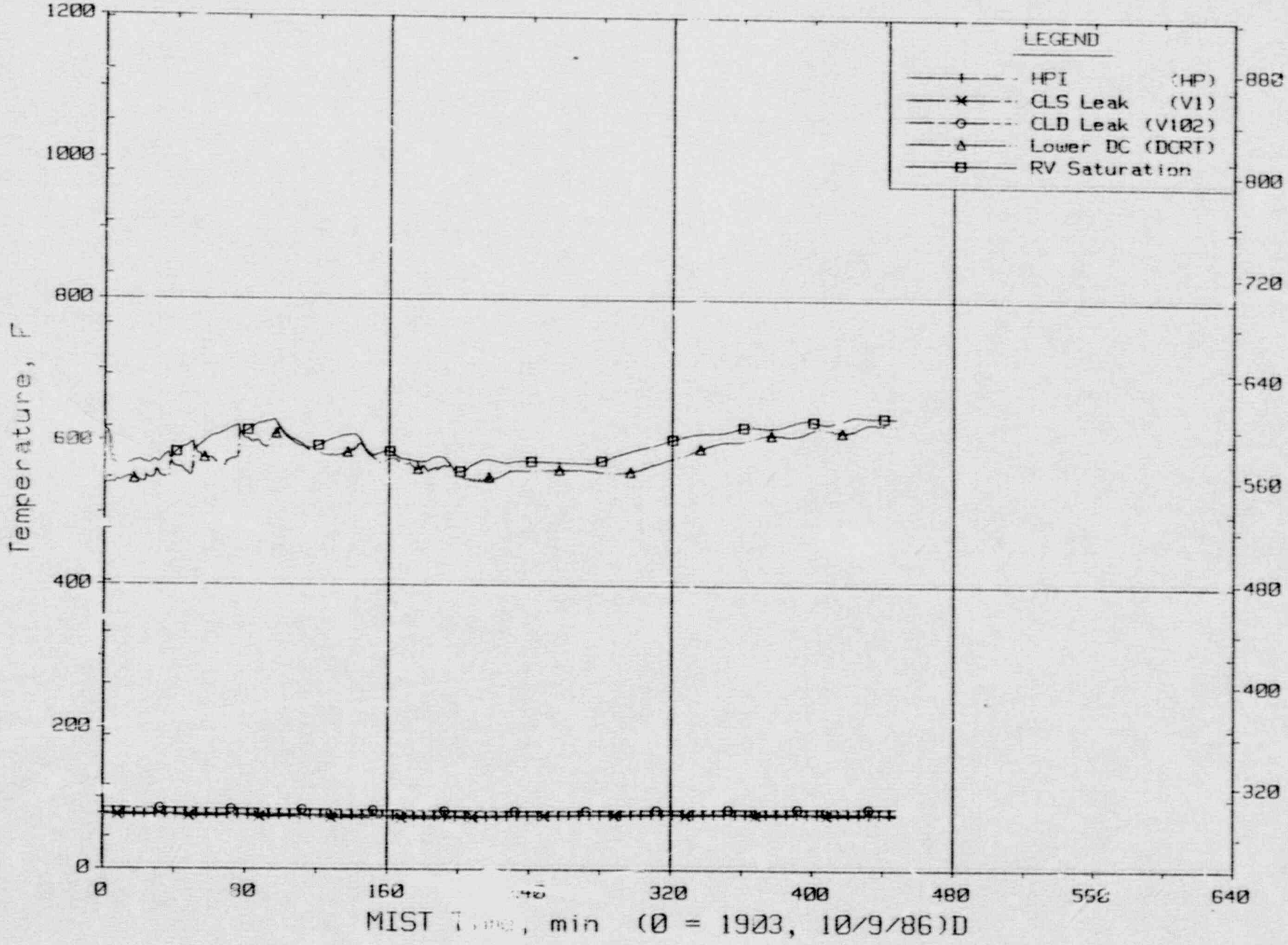
Primary System Injection Limit Switch Indications (LSs).

Fri Jan 6 11:57:55 1989

PBLS2

FINAL DATA

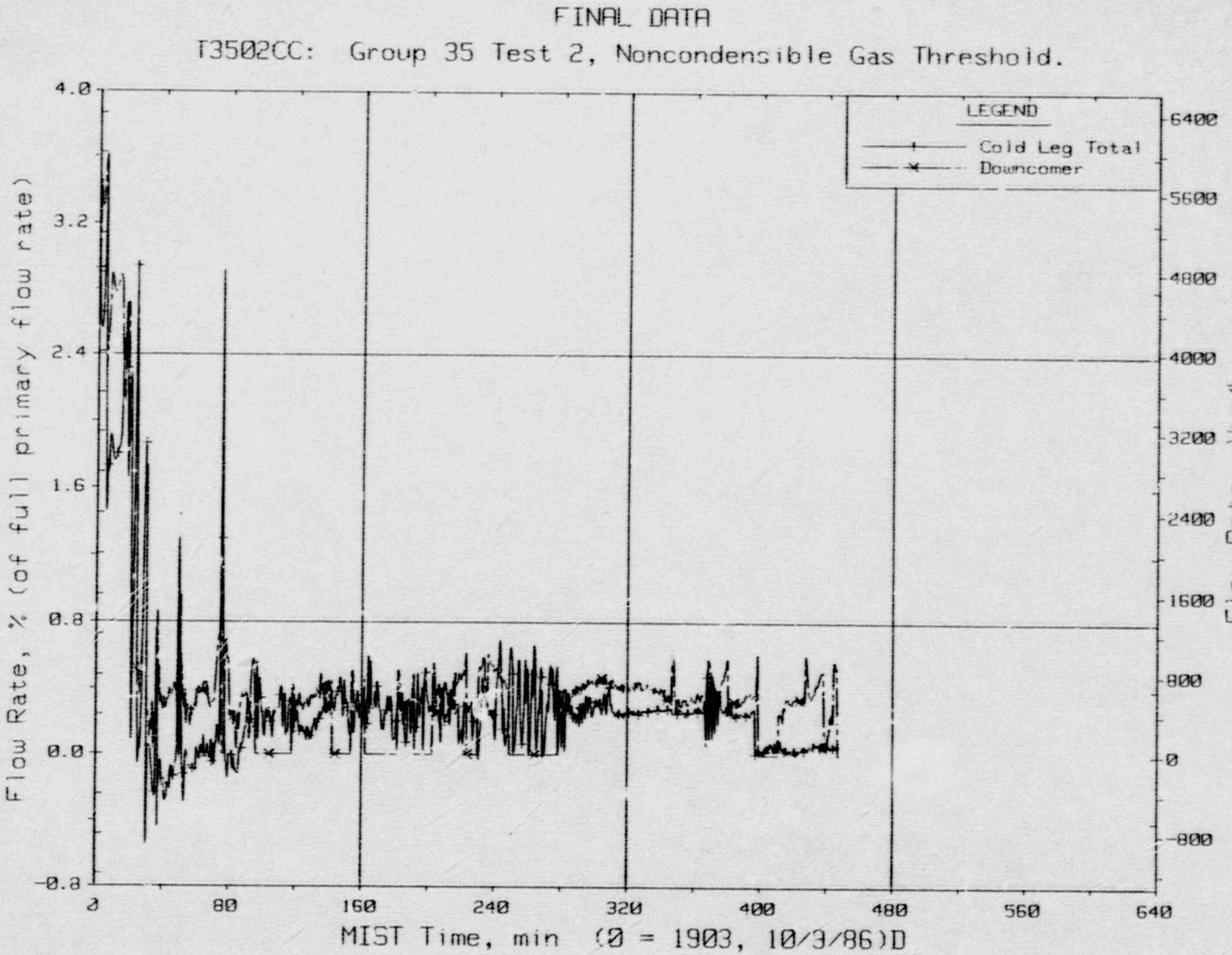
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Fri Jan 6 12:01:23 1989

PBTC1p



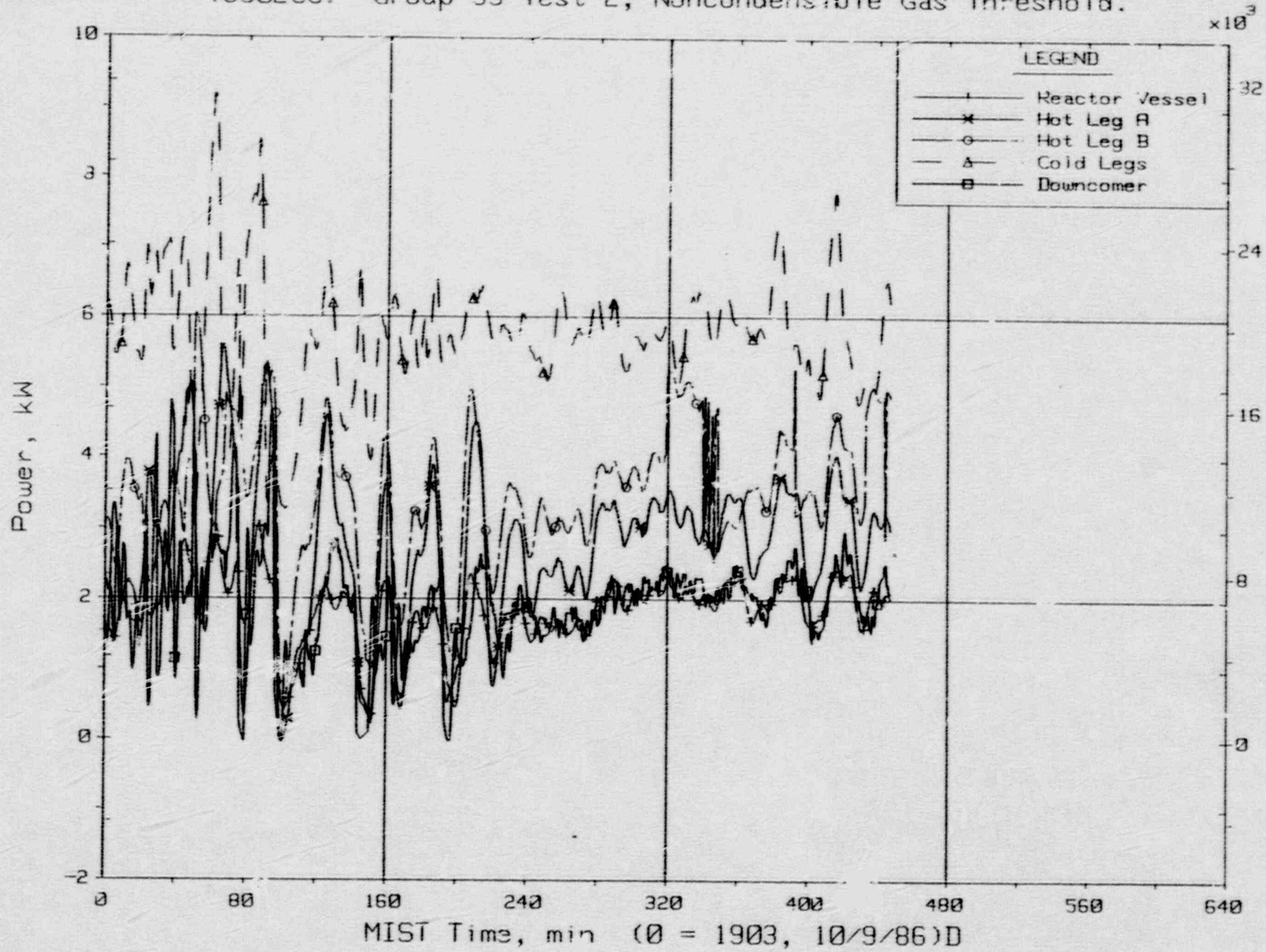
Primary System Venturi Flow Rates.

Fri Jan 6 12:04:17 1989

PRFL7

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



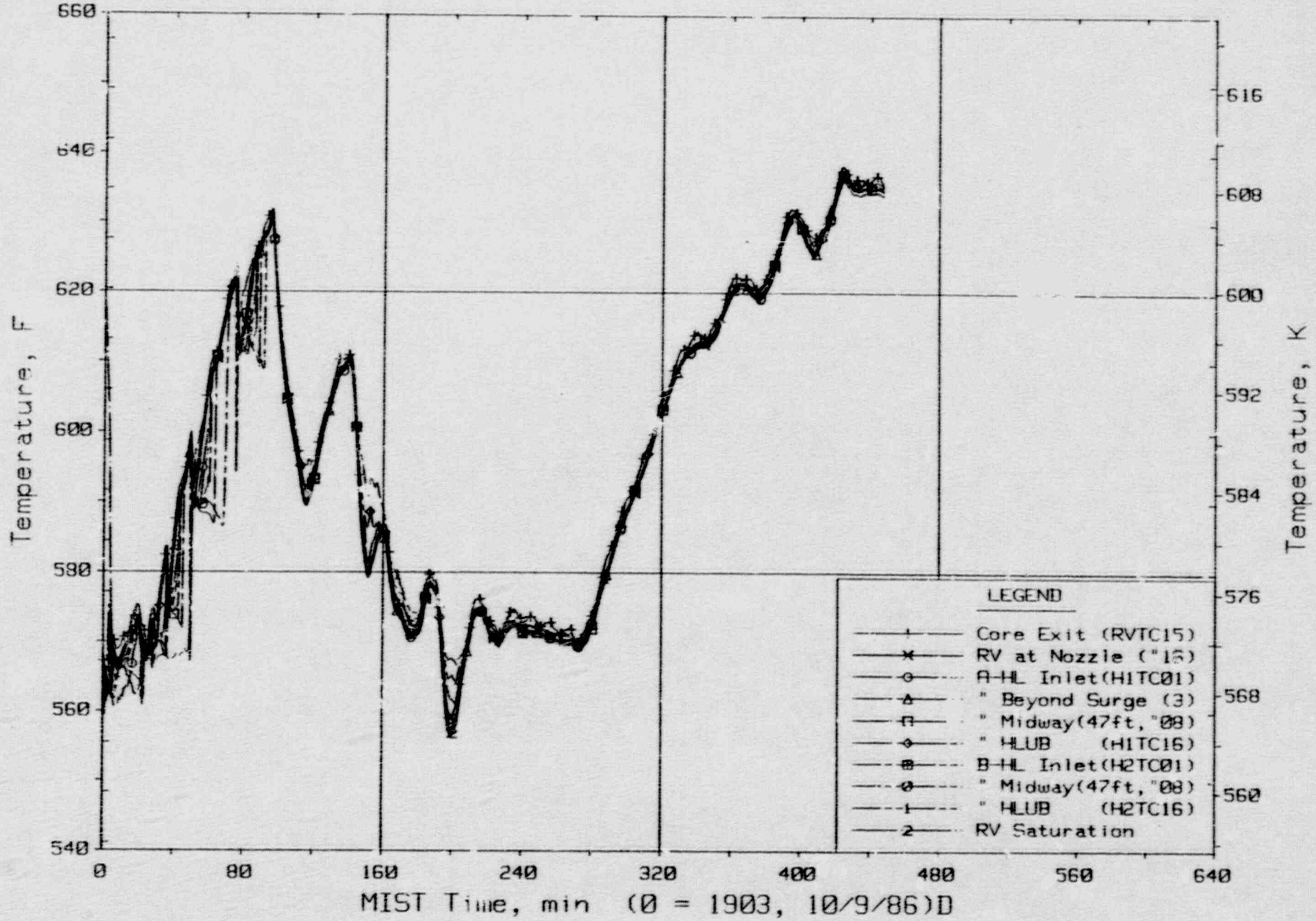
Guard Heater Specified Power Per Primary Component.

Fri Jan 6 12:08:28 1989

PRG01

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



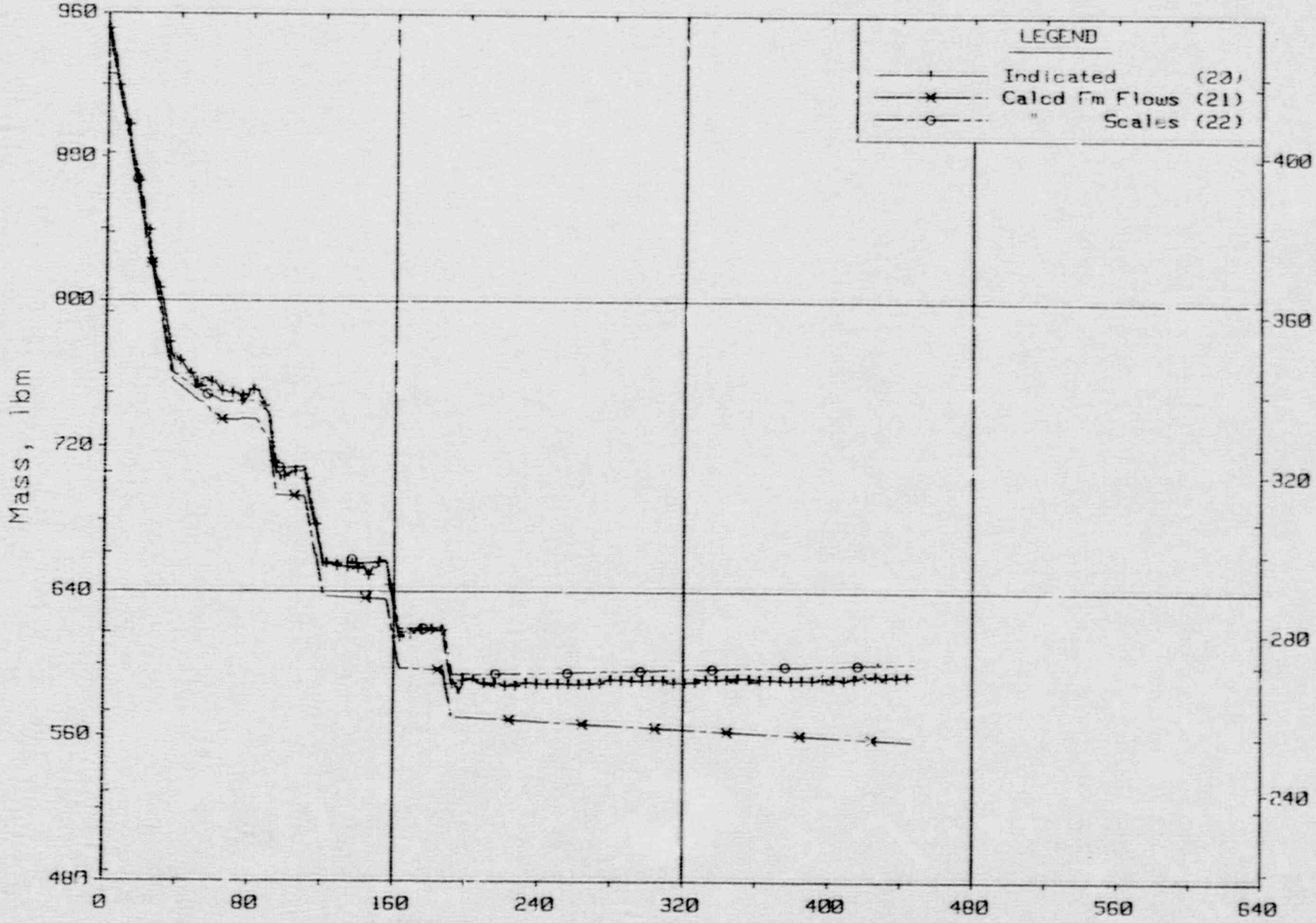
Composite Core Exit and Hot Leg Fluid Temperatures.

Fri Jan 6 12:15:10 1989

PRKT1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



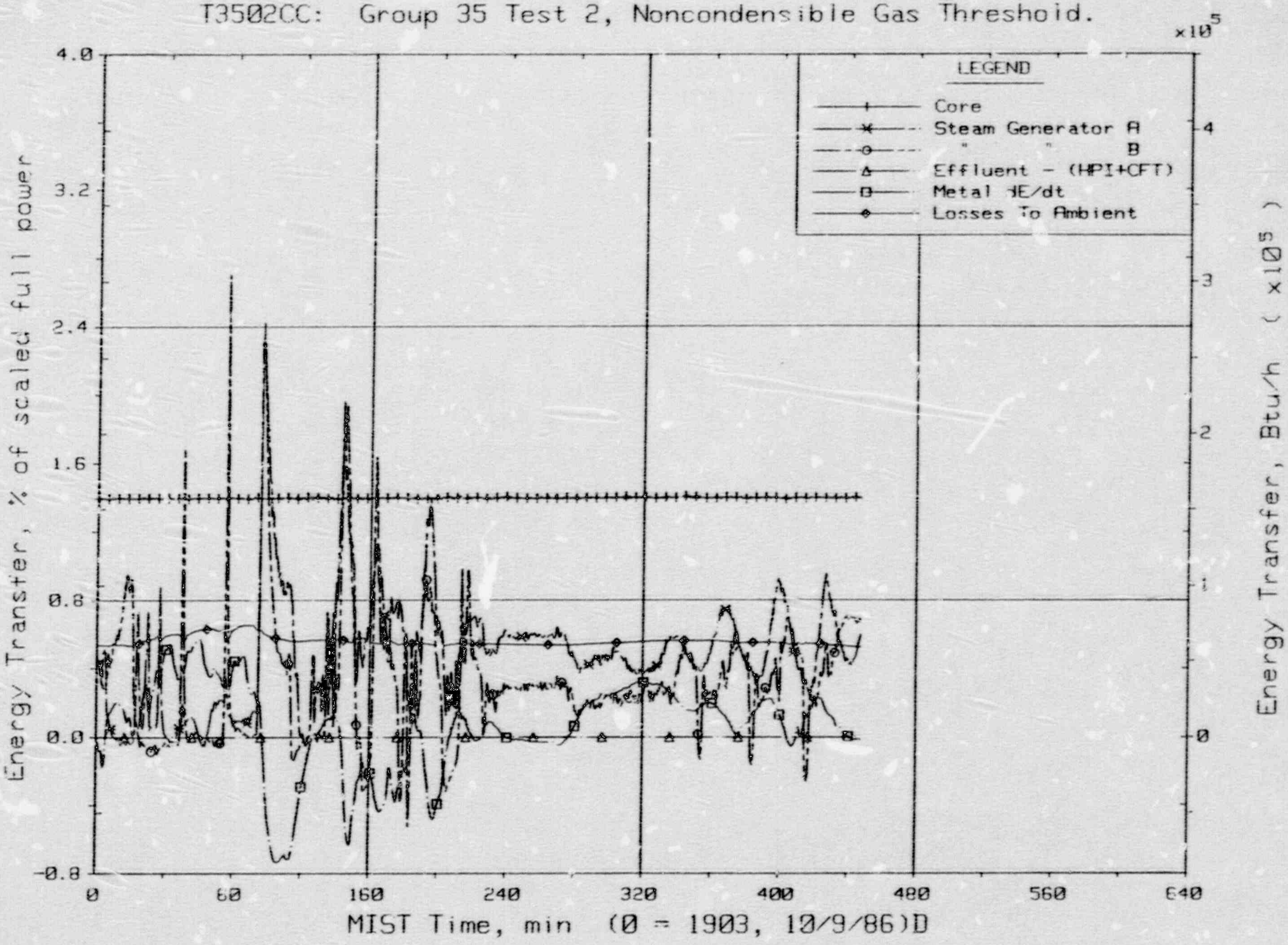
Primary System Total Fluid Mass (PLMLs).

Fri Jan 6 12:19:55 1989

PRML2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



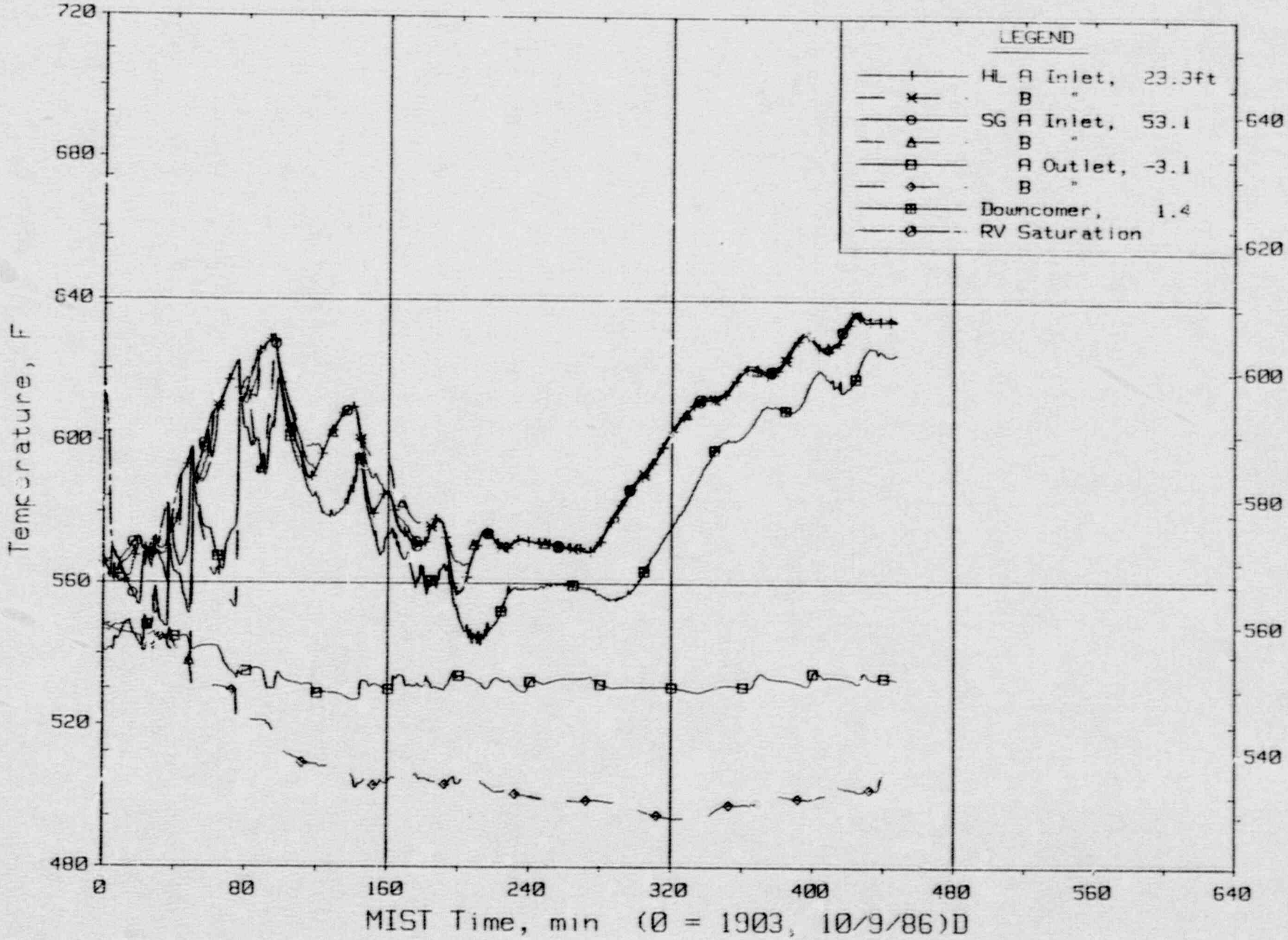
Primary System Energy Transfer.

Fri Jan 6 12:43:47 1989

PRQE2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



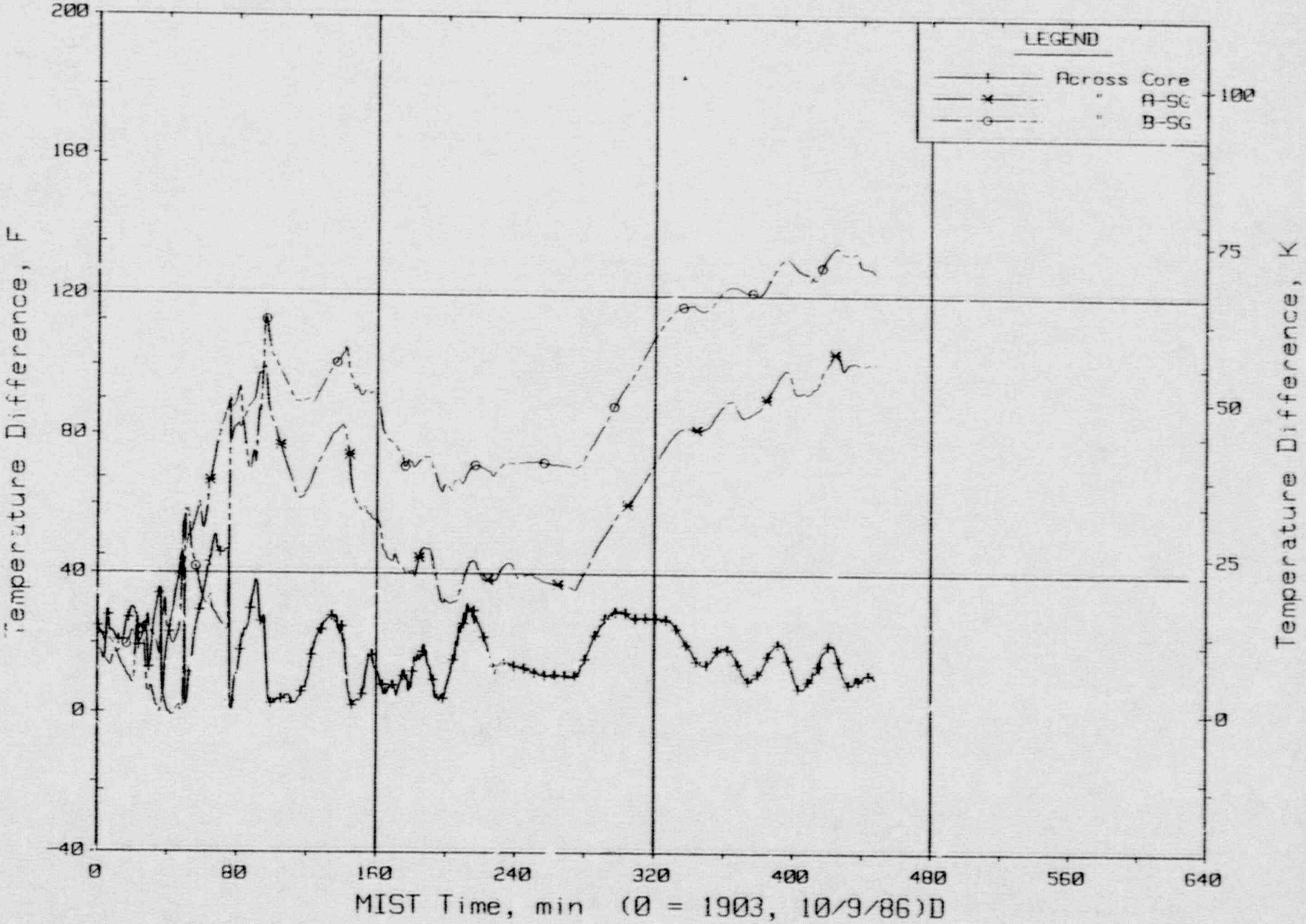
Primary System Fluid Temperatures (RTDs).

Fri Jan 5 12:23:36 1989

PRRT0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



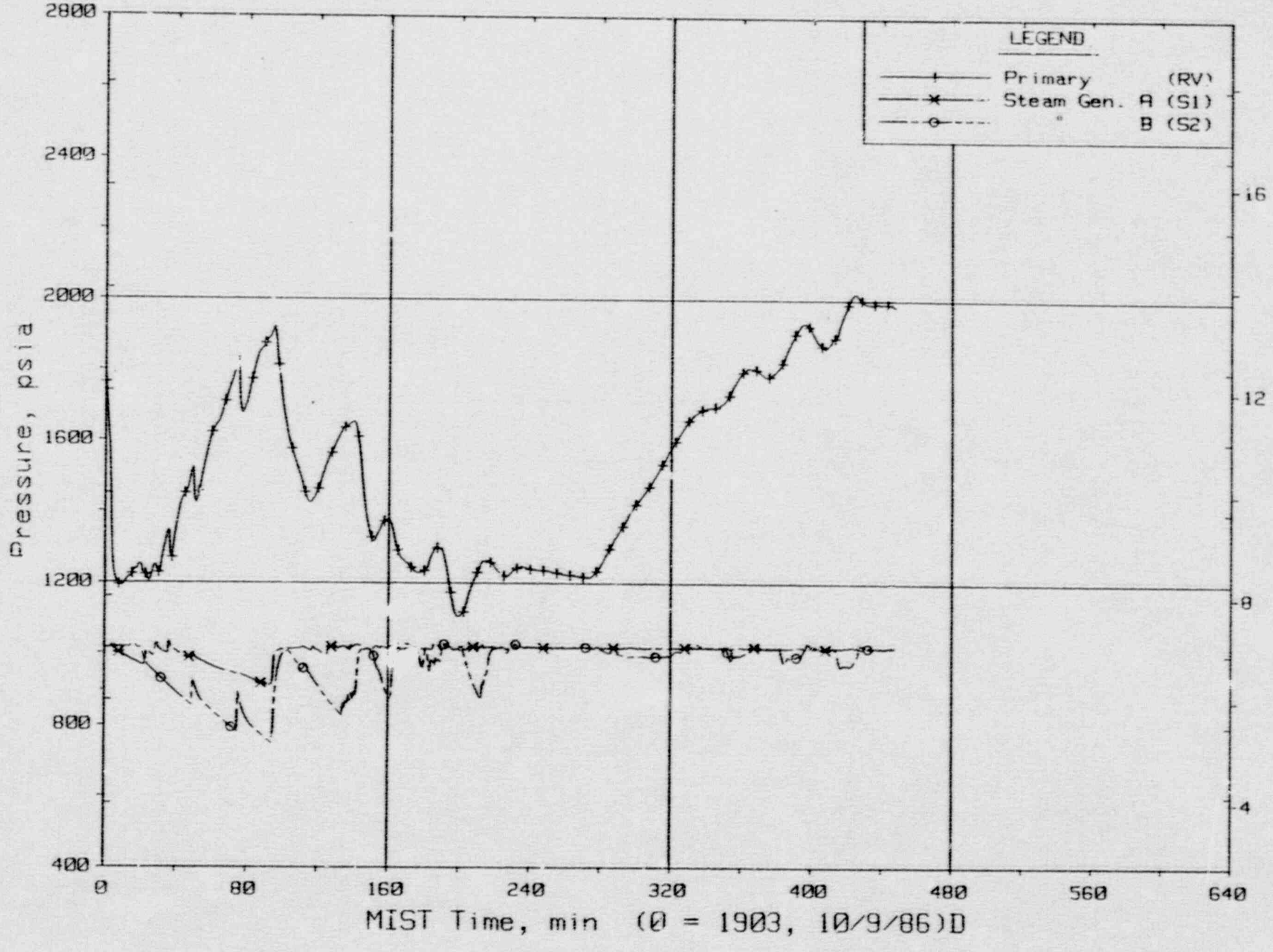
Key Temperature Differences.

Fri Jan 6 12:26:47 1989

PRTD2

FINAL DATA

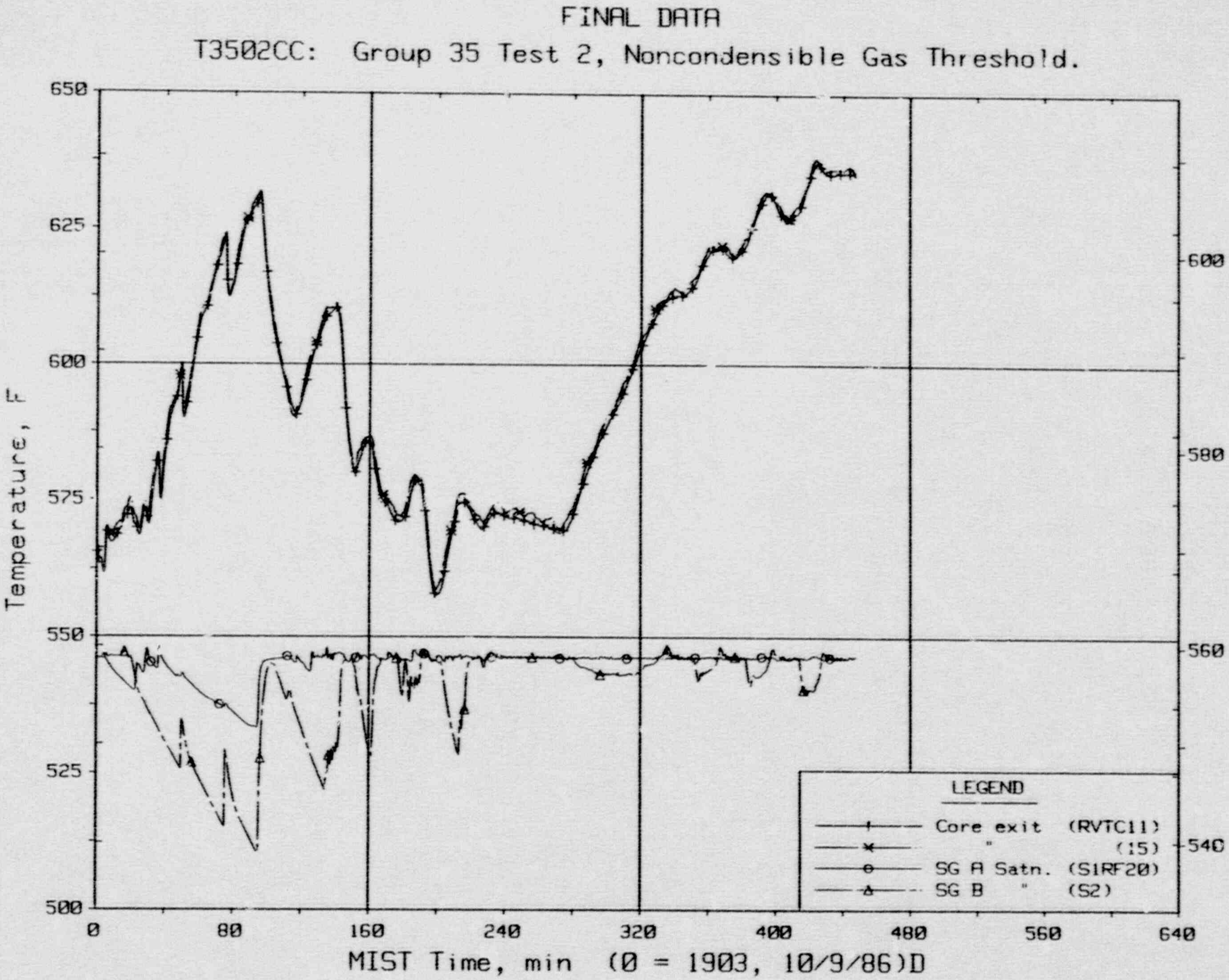
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



Primary and Secondary System Pressures (GP01s).

Mon Nov 7 10:19:03 1988

PSGP1



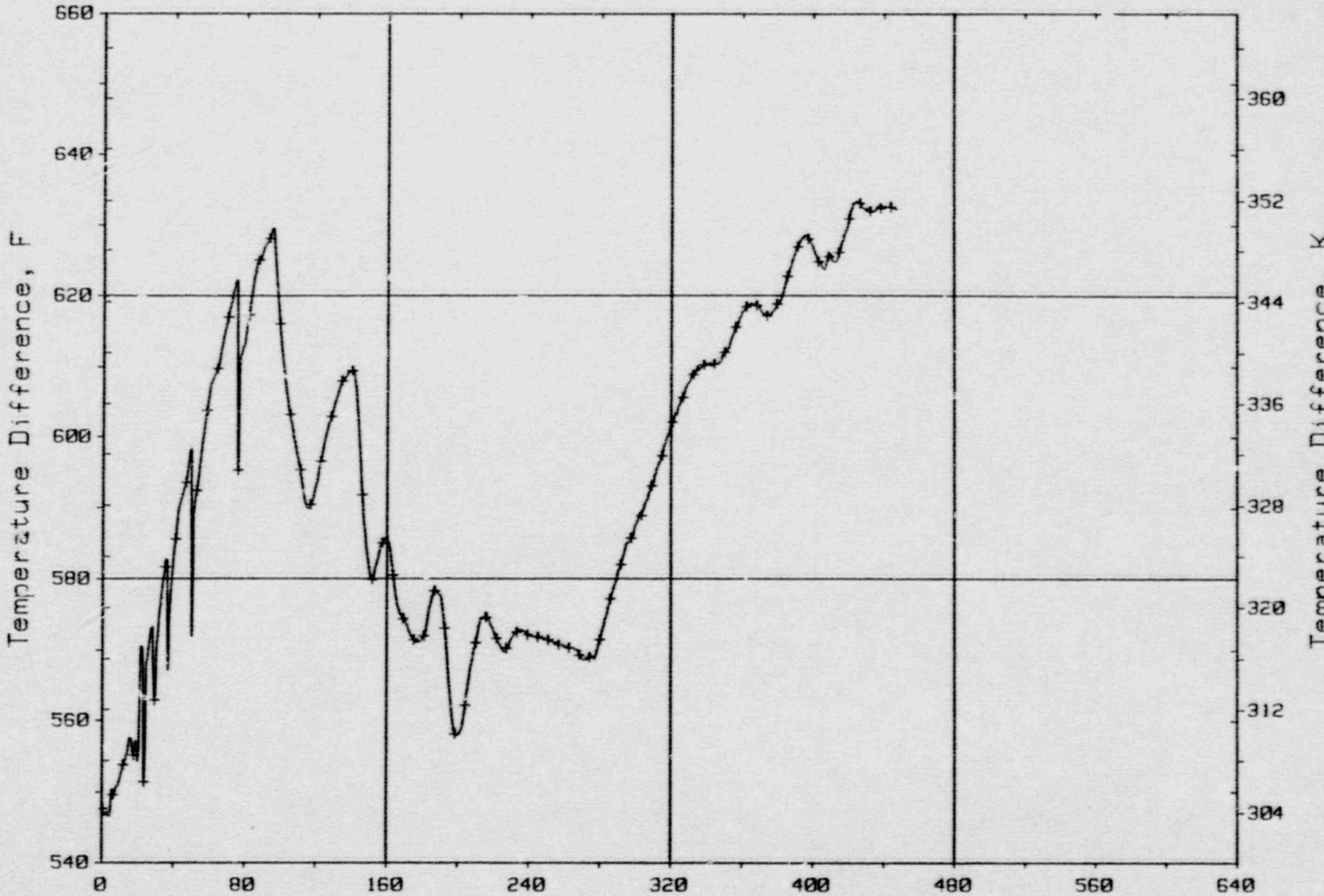
Core Exit and Steam Generator Secondary Saturation Temperatures.

Fri Jan 6 13:03:41 1989

PSTC3p

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



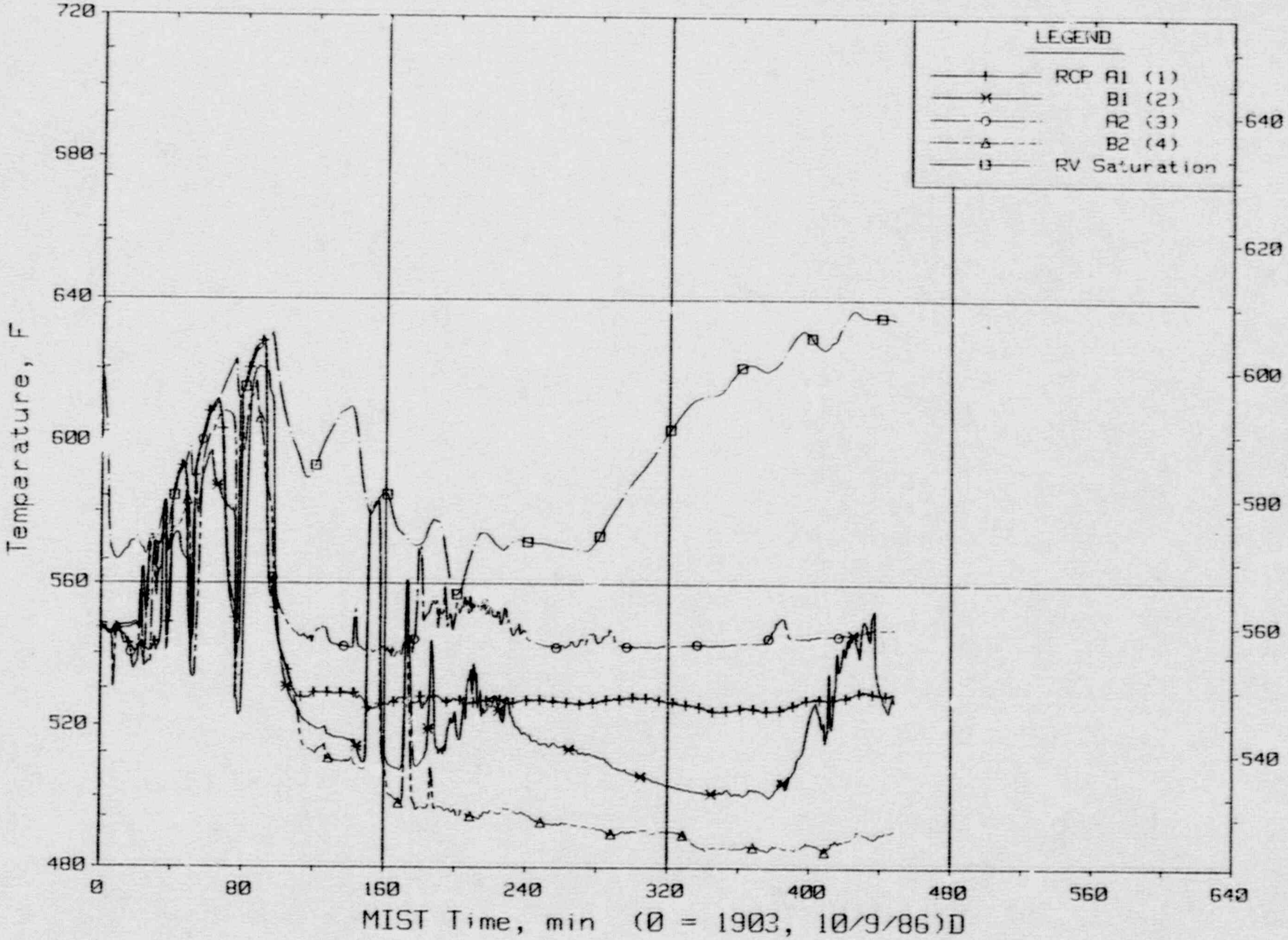
Core Exit Subcooling Margin.

Fri Jan 6 13:40:33 1989

PSTD0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



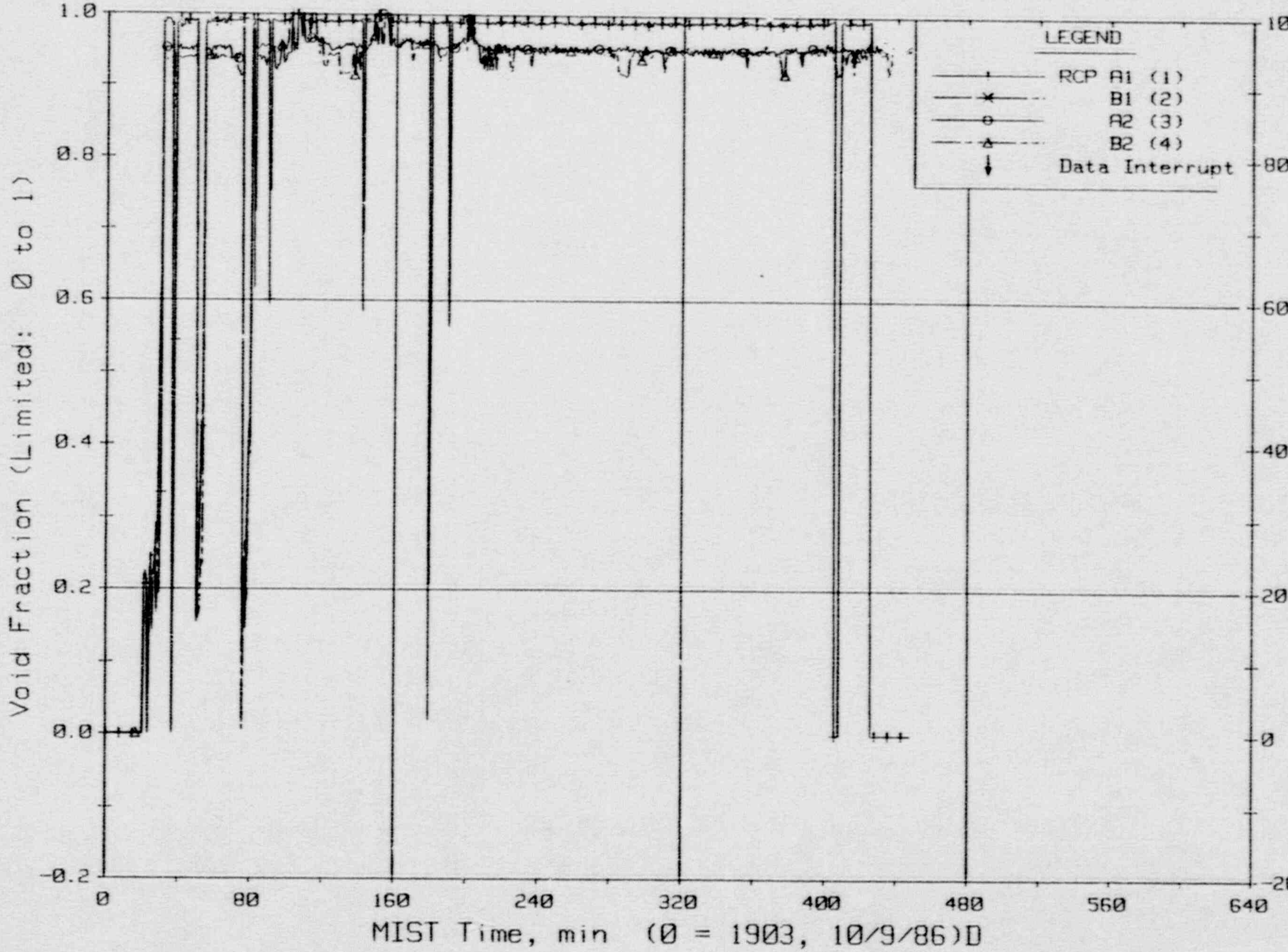
Pump Suction Fluid Temperature (CnRT01s).

Thu Jan 5 18:00:51 1989

PURT0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



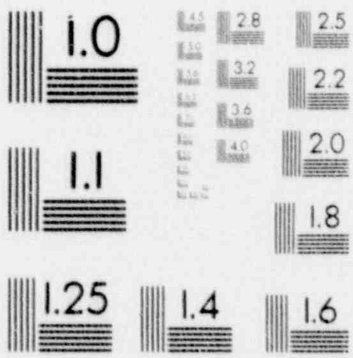
Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

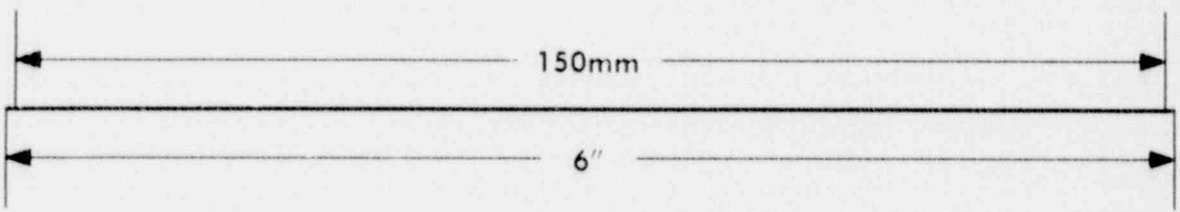
Thu Jan 5 18:03:47 1989

PUVF2

2

IMAGE EVALUATION TEST TARGET (MT-3)

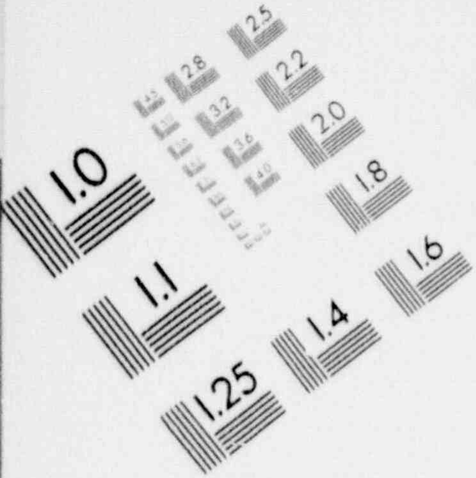


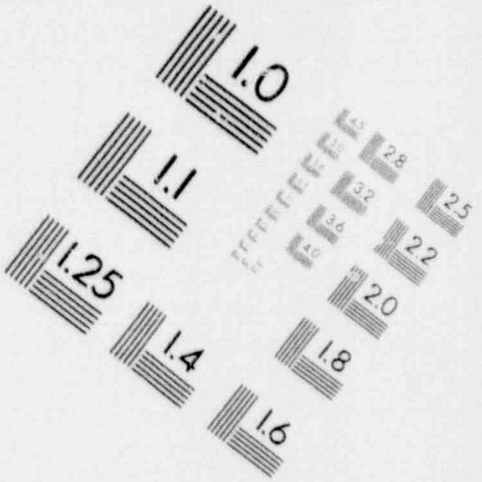


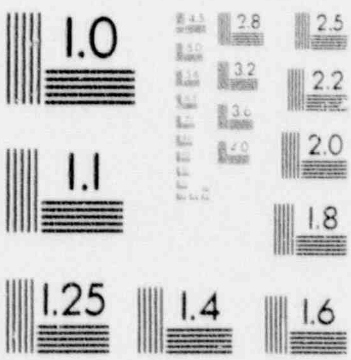
PHOTOGRAPHIC SCIENCES CORPORATION
770 BASKET ROAD
P.O. BOX 338
WEBSTER, NEW YORK 14580
(716) 265-1600

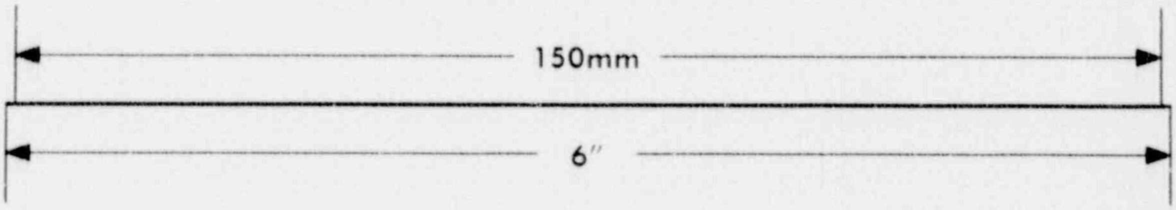
2

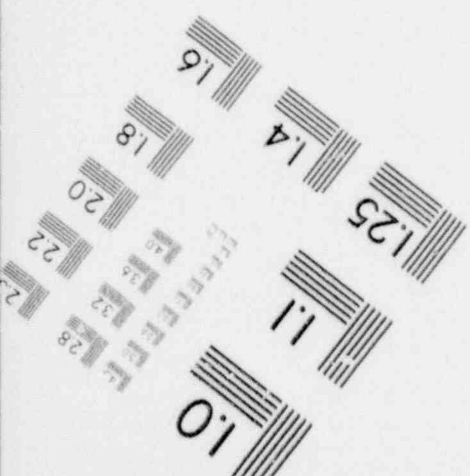
IMAGE EVALUATION TEST TARGET (MT-3)

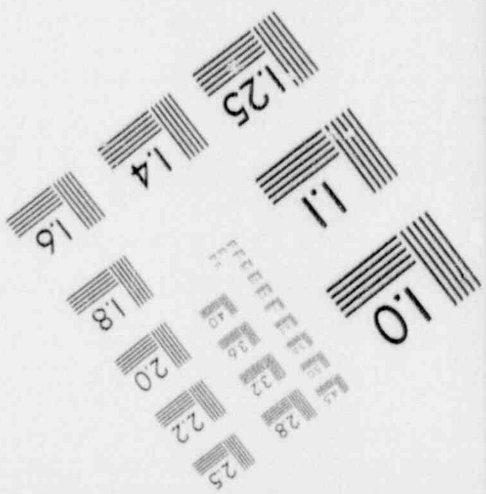












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(716) 265-1600

2

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

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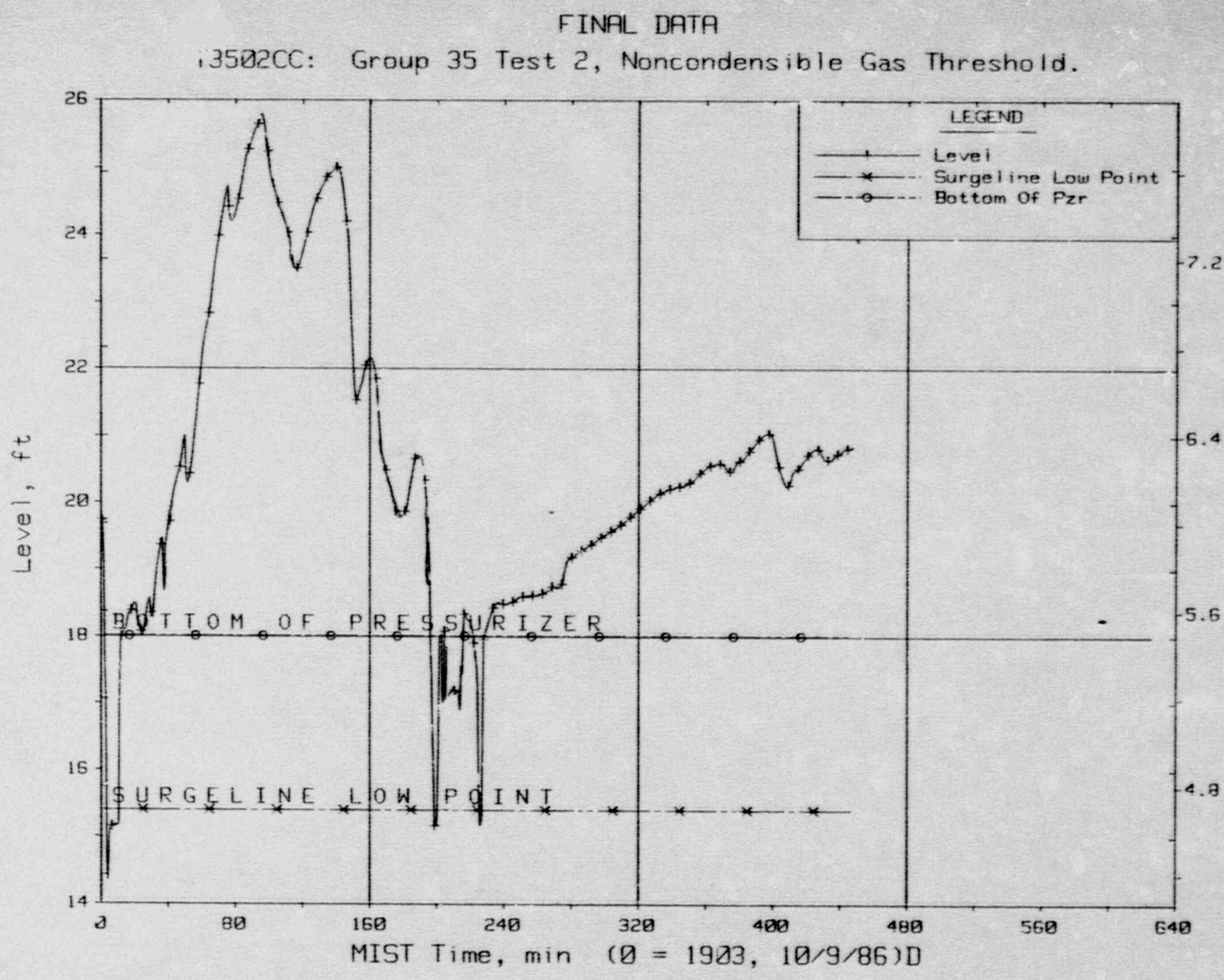
2

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"



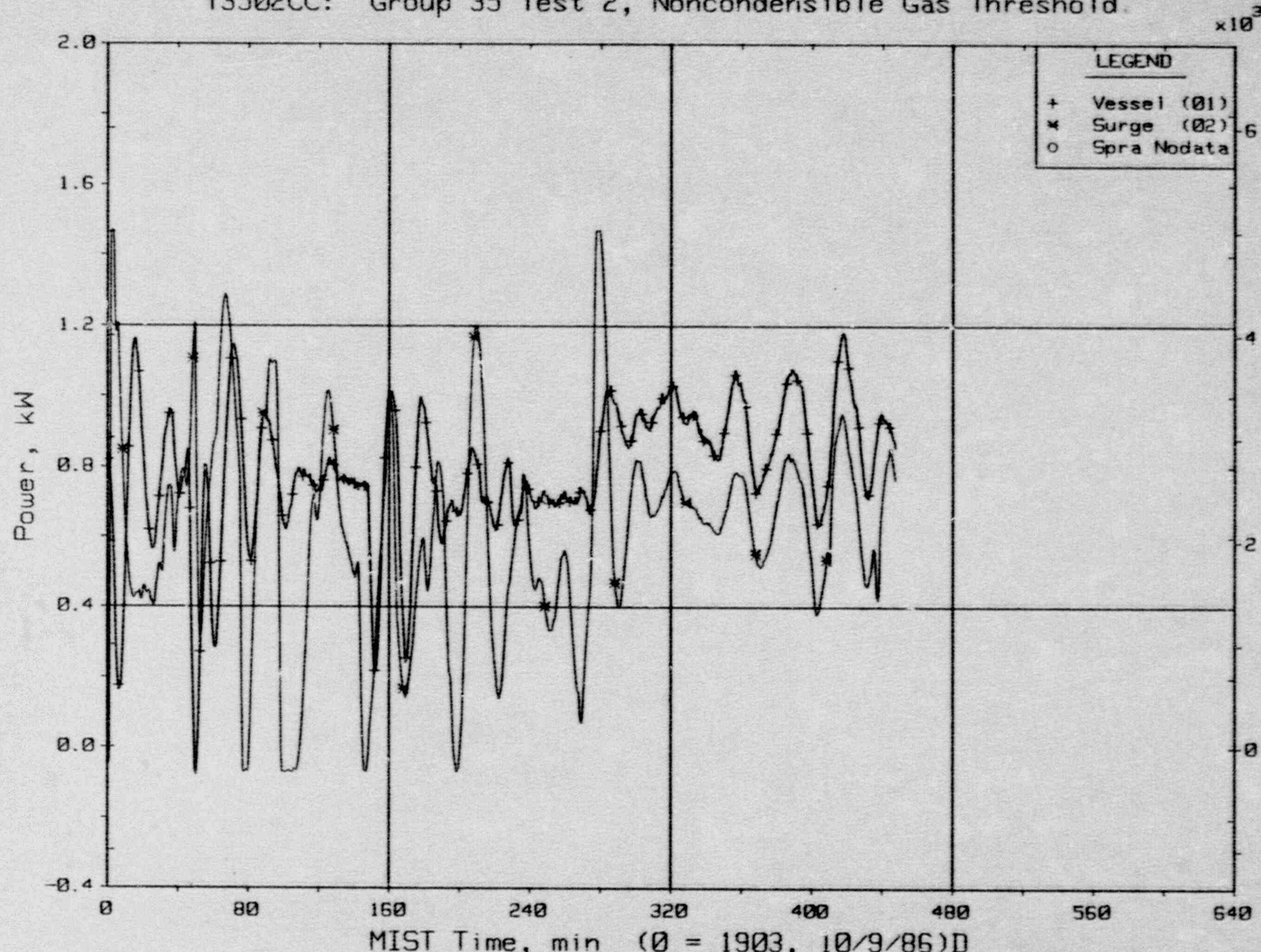
Pressurizer Collapsed Liquid Level (PZLV20).

Fri Jan 6 12:57:54 1989

PZLV1

FINAL DATA

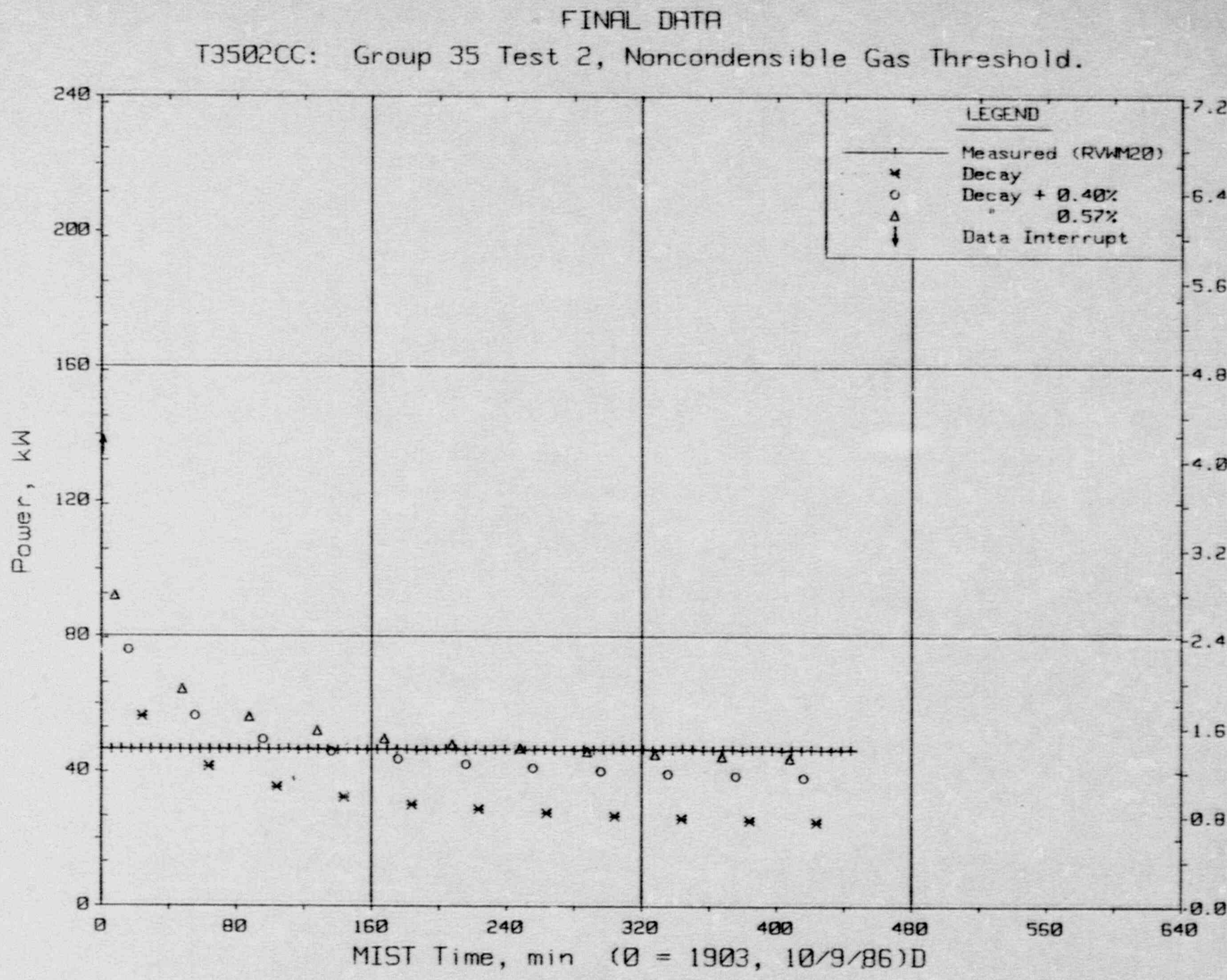
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold



Pressurizer Guard Heater Specified Power (PZWMs).

Fri Jan 6 13:56:42 1989

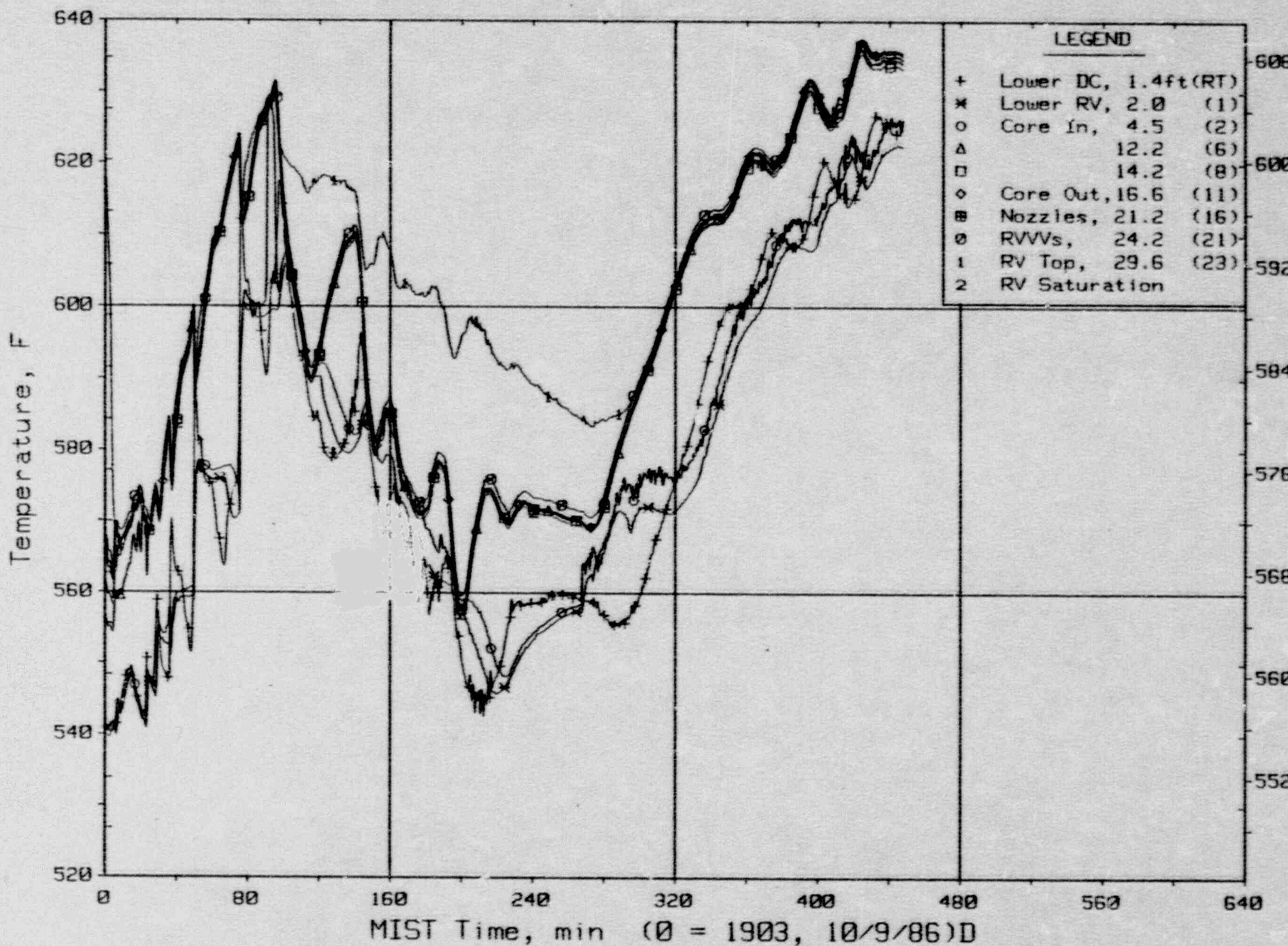
PZWM1


FINAL DATA
T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.
LEGEND
Measured (RVWM20)
Decay
Decay + 0.40%
" 0.57%
Data Interrupt
Power, kW
Power, % of scaled full power
MIST Time, min (0 = 1903, 10/9/86)D
0
40
80
120
160
200
240
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2
0
80
160
240
320
400
480
560
640

Core Power.

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



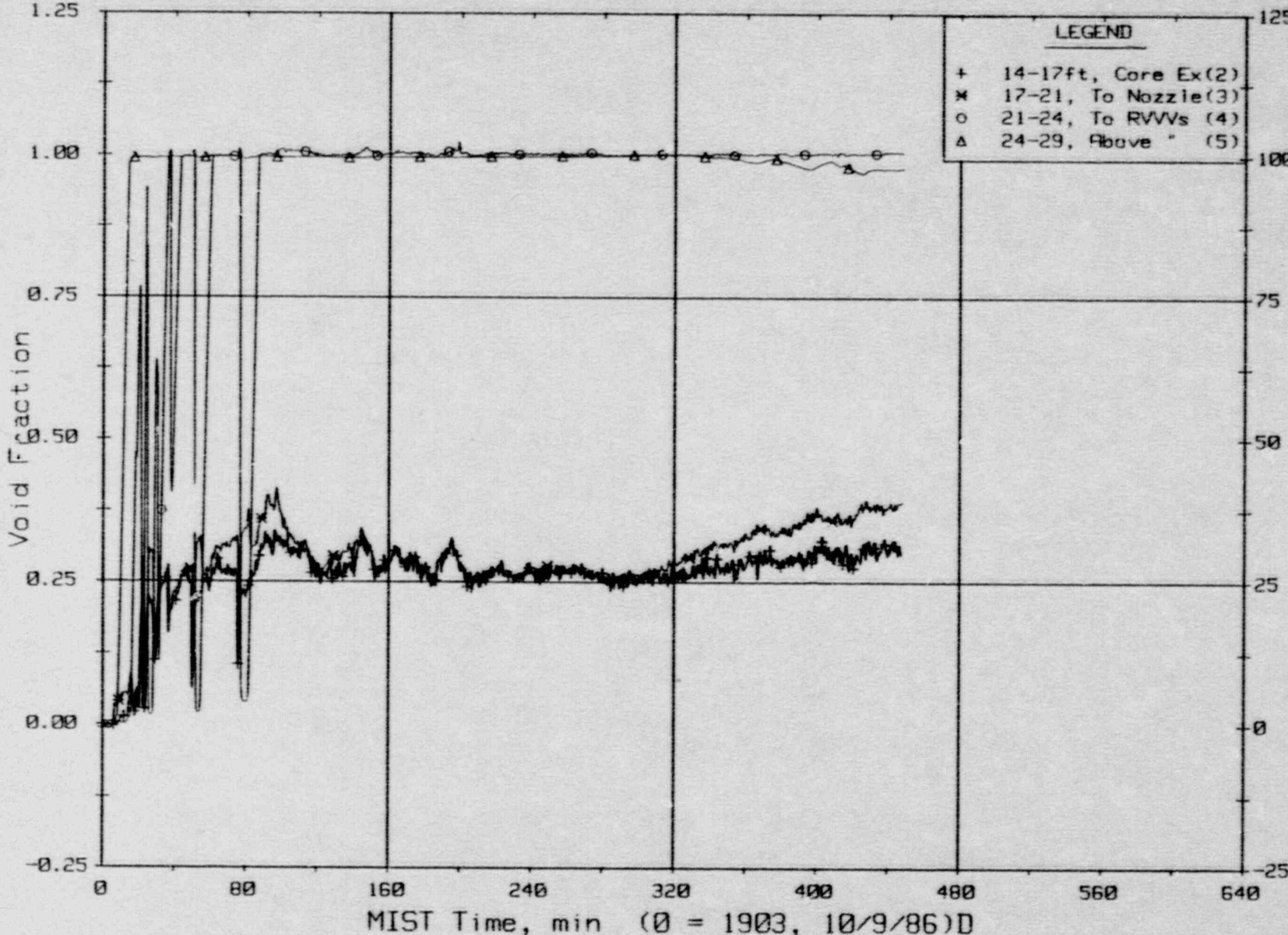
Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

Fri Jan 6 13:08:18 1989

RVTC0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



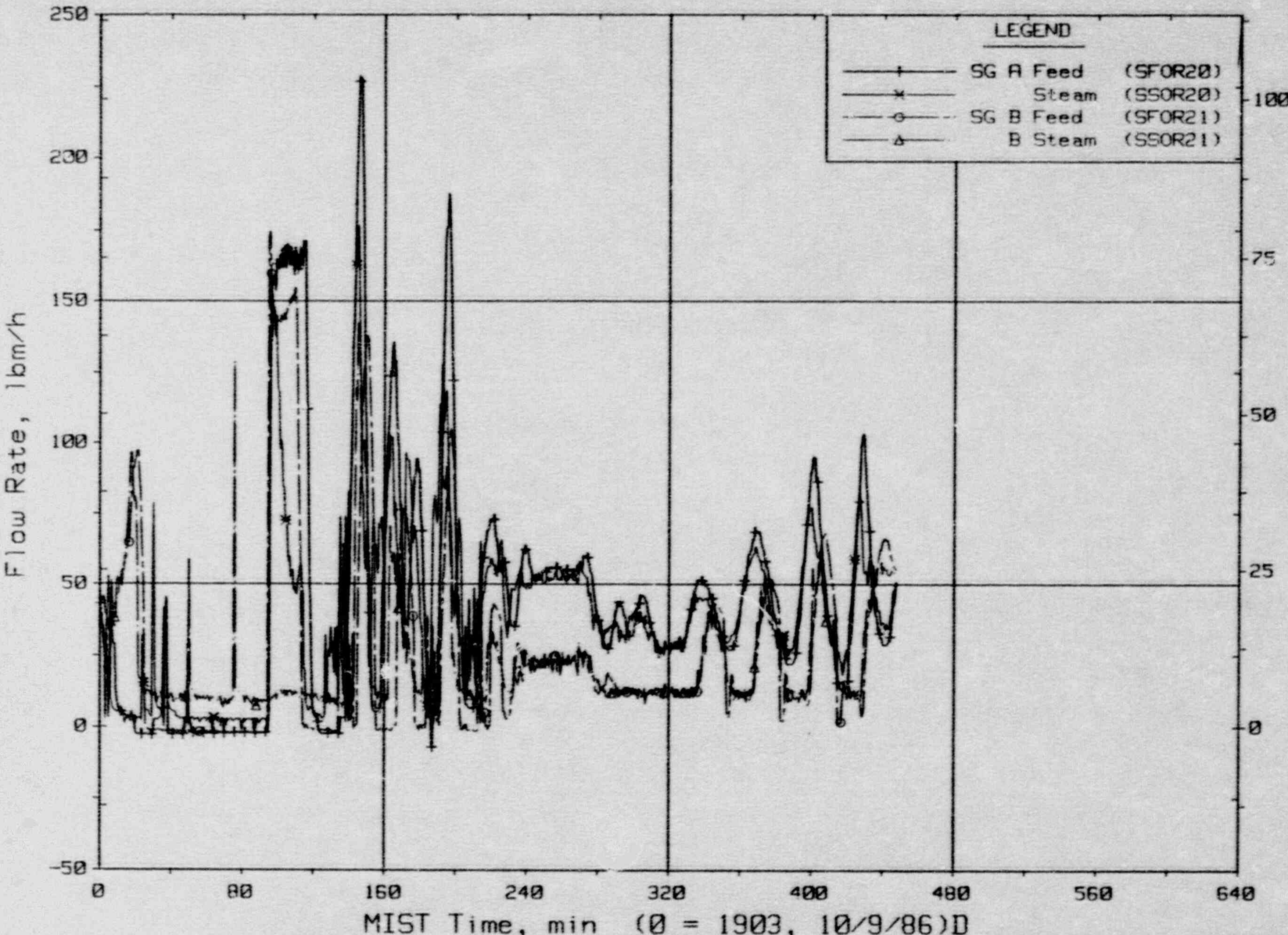
Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Fri Jan 6 13:11:46 1989

RVVF1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



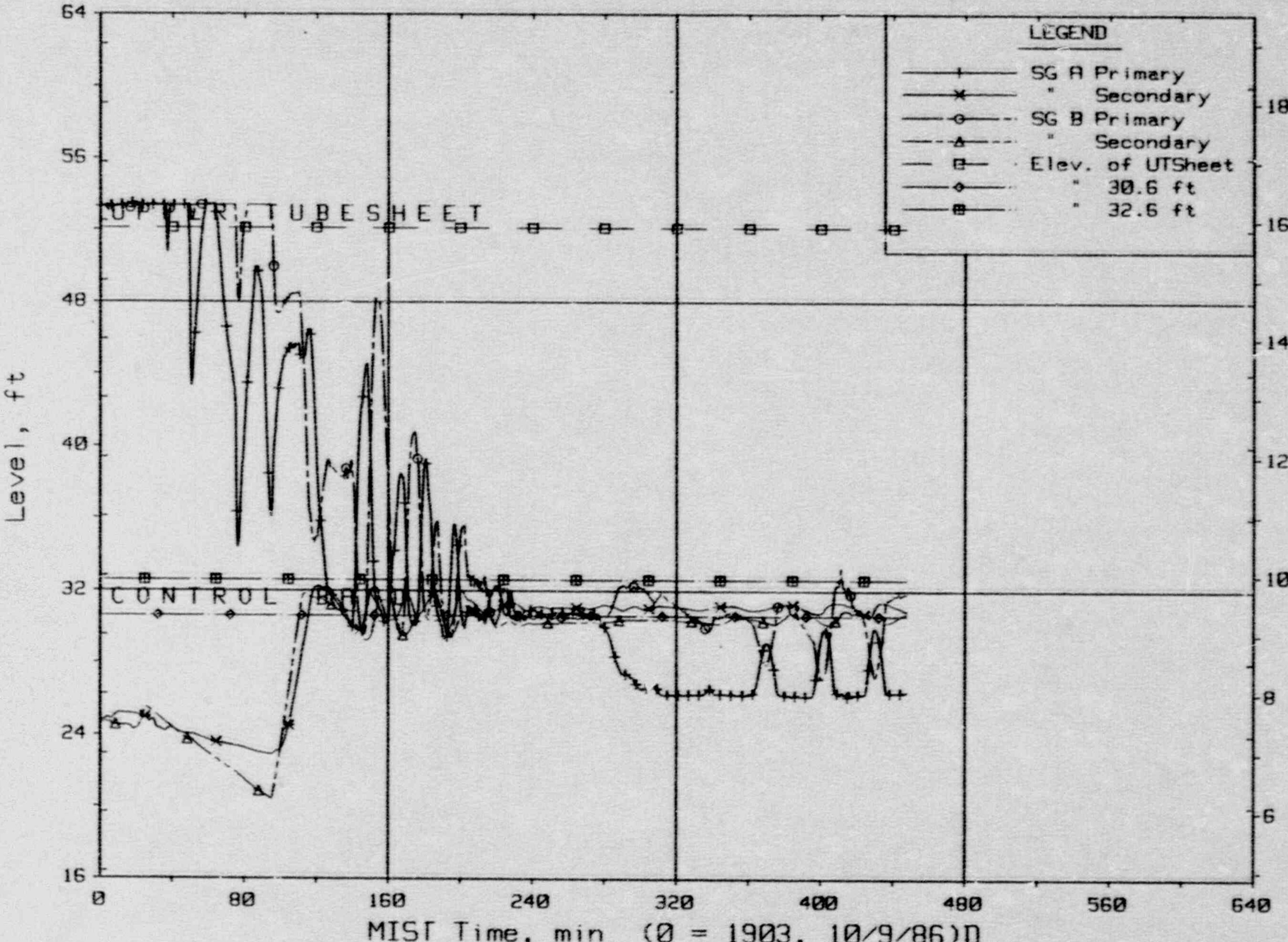
Steam Generator Secondary Flow Rates.

Fri Jan 6 13:47:15 1989

SGFL0

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



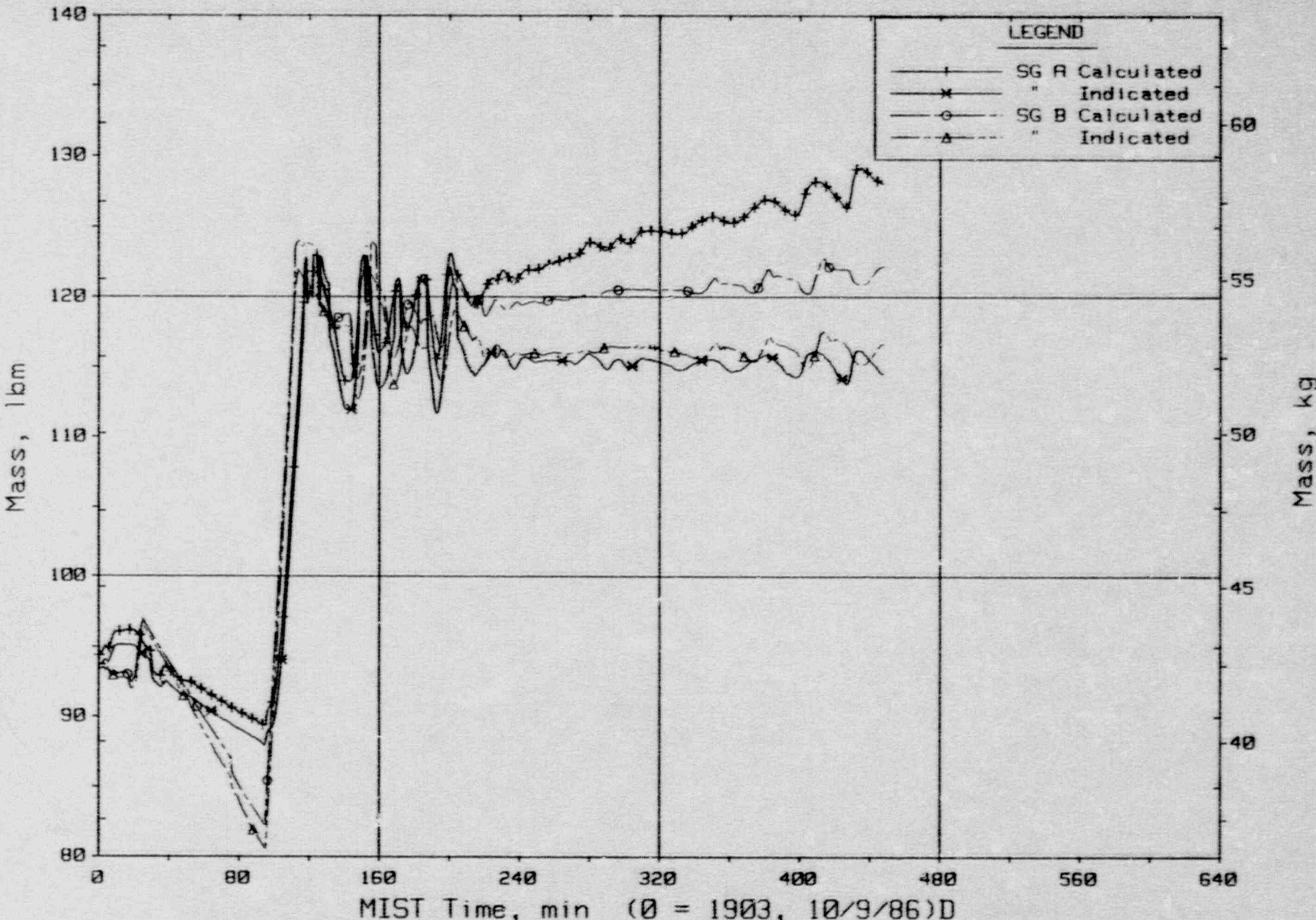
Steam Generator Collapsed Liquid Levels.

Fri Jan 6 13:19:18 1989

SGLV2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



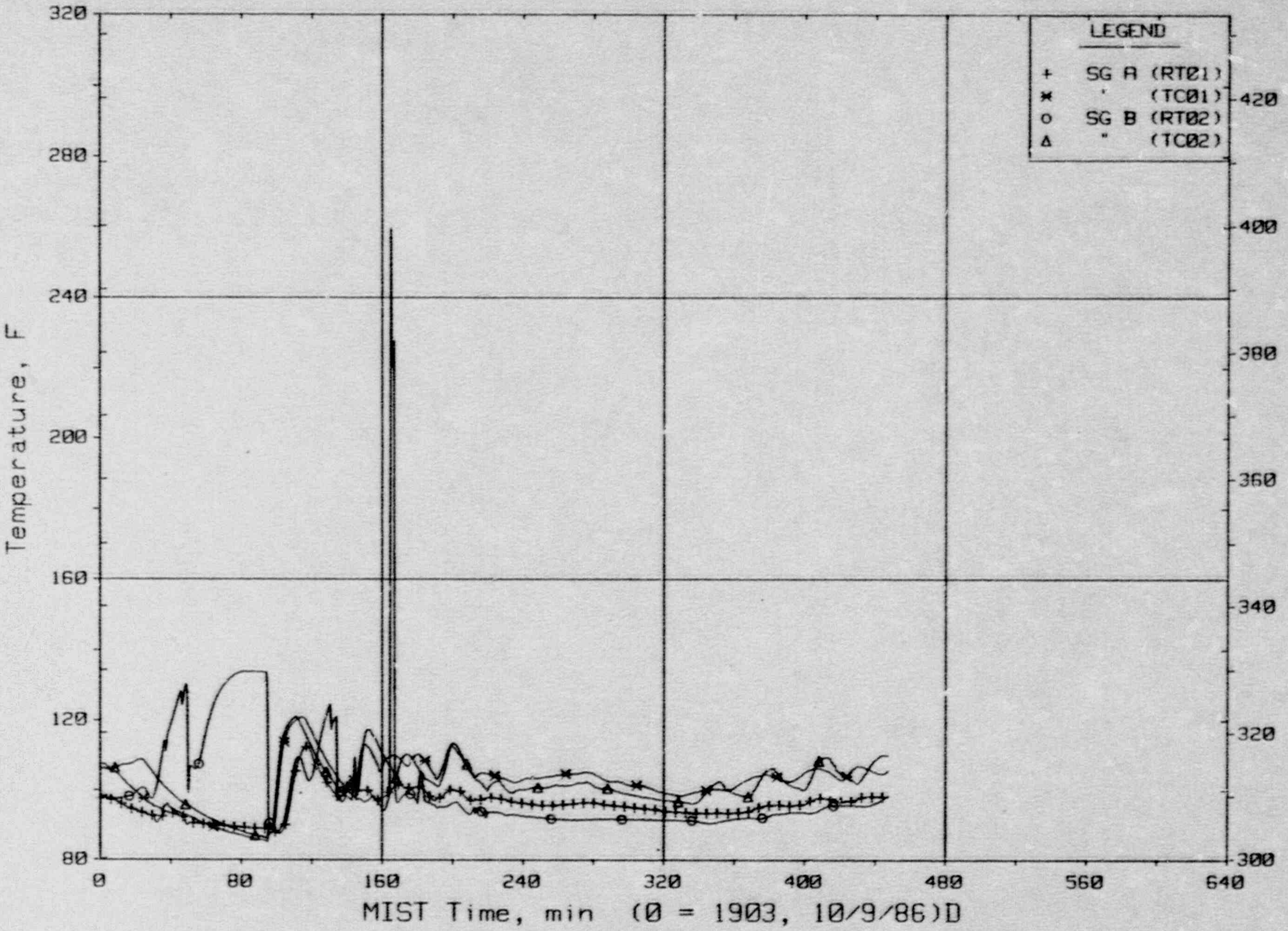
Steam Generator Secondary Fluid Mass Balances.

Fri Jan 6 09:02:09 1989

SGML1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



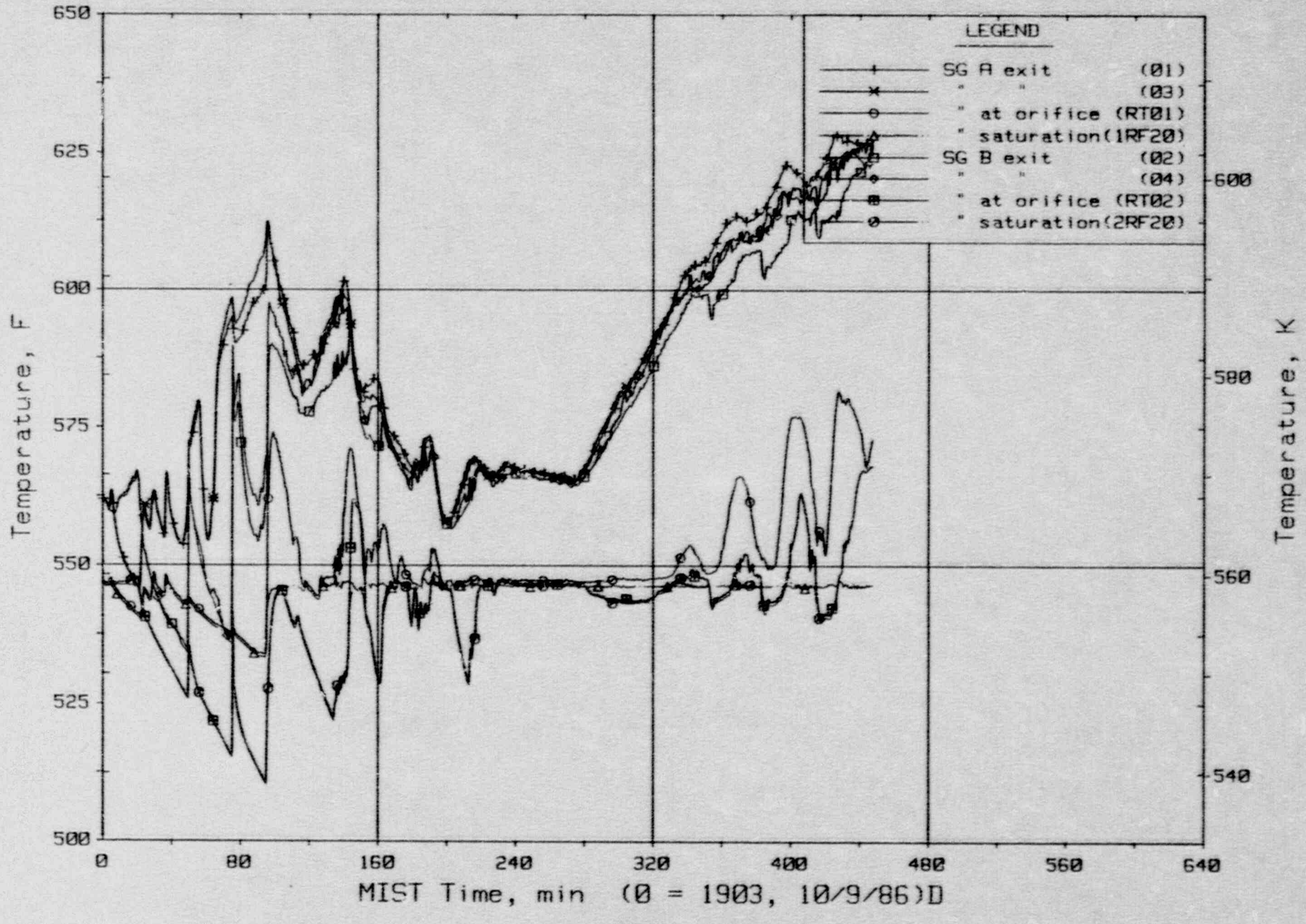
Feedwater Temperatures (SFs).

Fri Jan 6 09:06:27 1989

SGRT1

FINAL DnTn

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



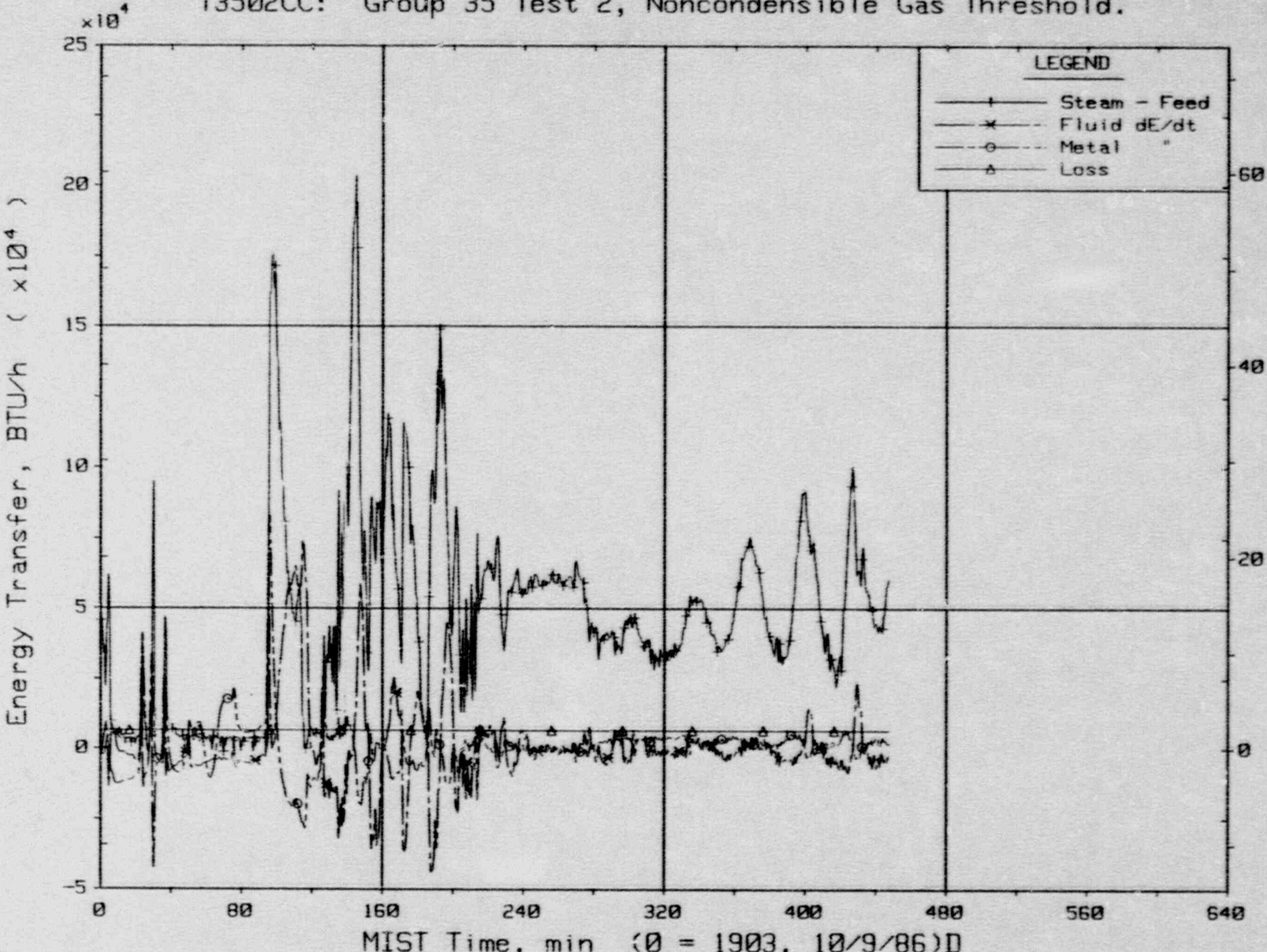
Steam Generator Steam Outlet Temperatures (SSTCs).

Fri Jan 6 09:12:29 1989

SGRT2

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



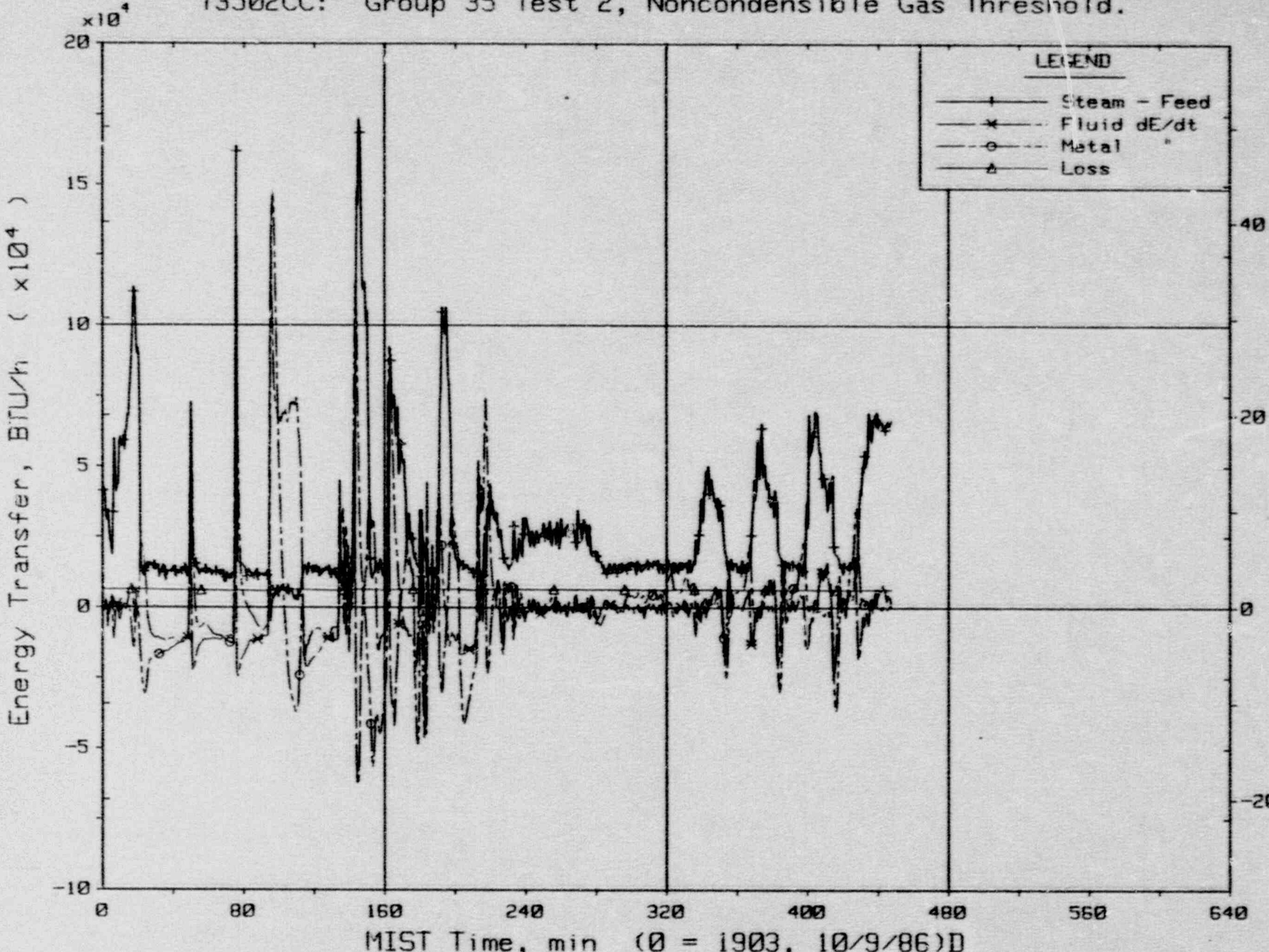
Steam Generator A Energy Transfer.

Fri Jan 6 12:52:17 1989

SGQE3

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



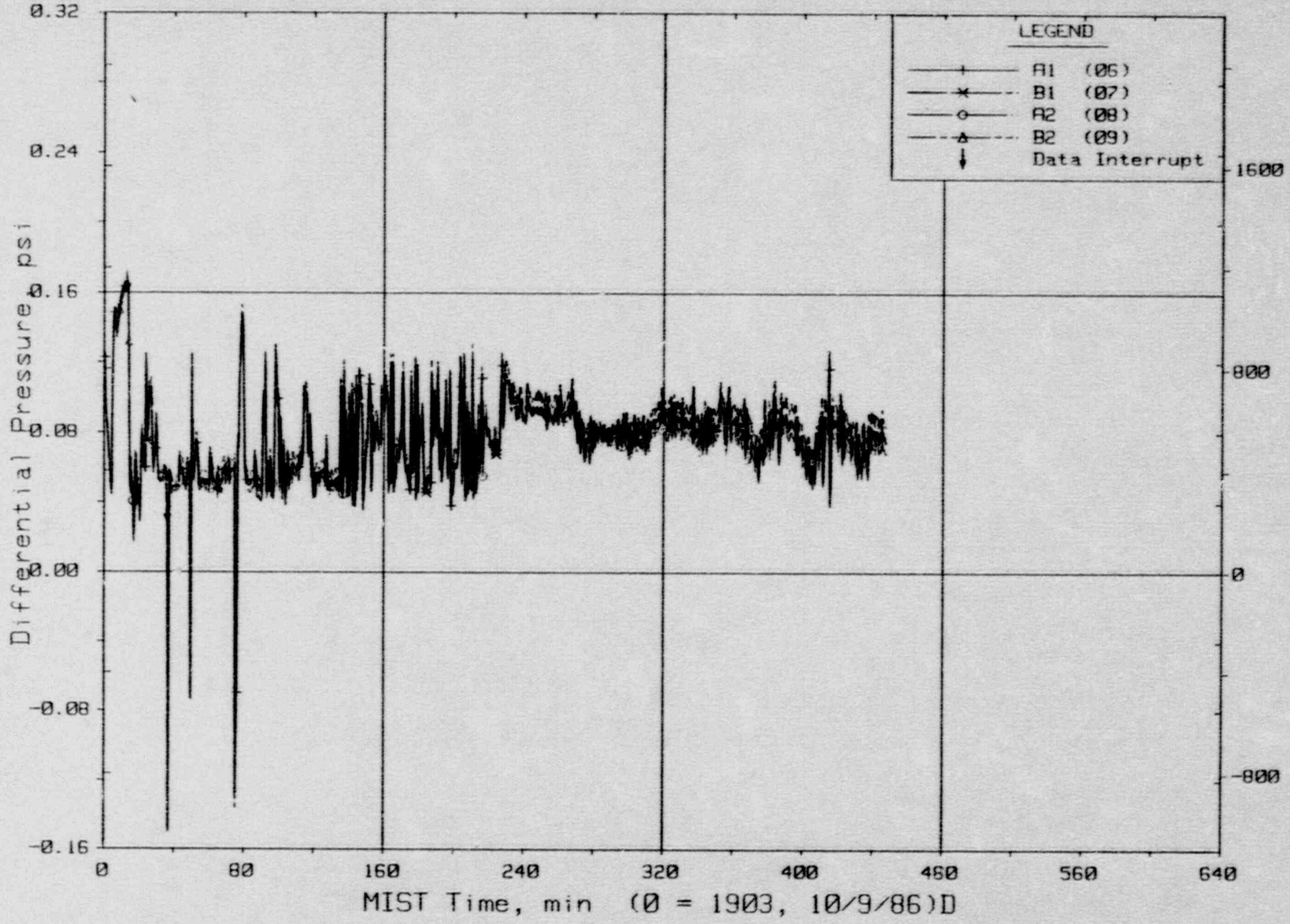
Steam Generator B Energy Transfer.

Fri Jan 6 12:57:01 1989

SGQE6

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



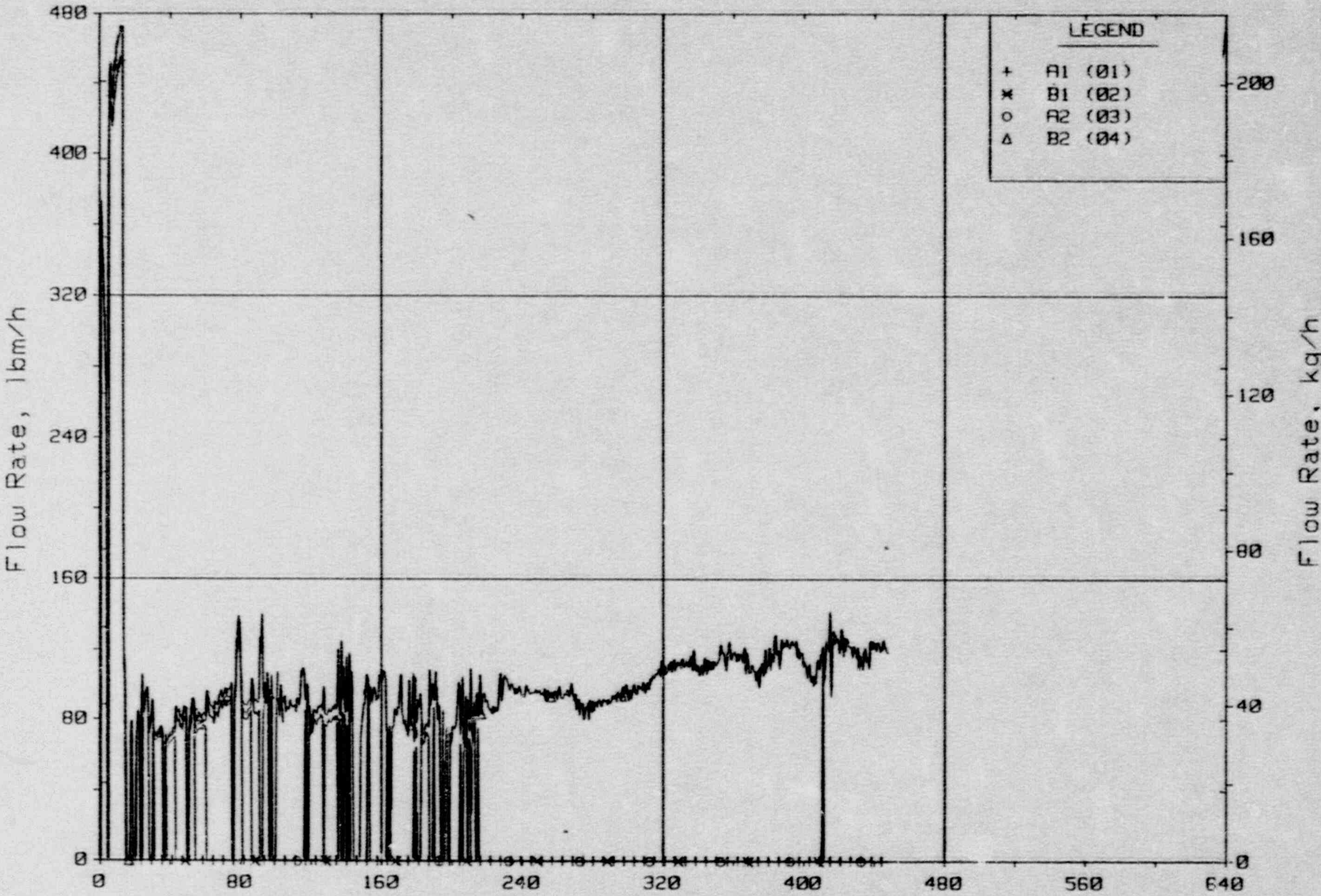
Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Fri Jan 6 09:18:14 1989

VVDP1

rINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



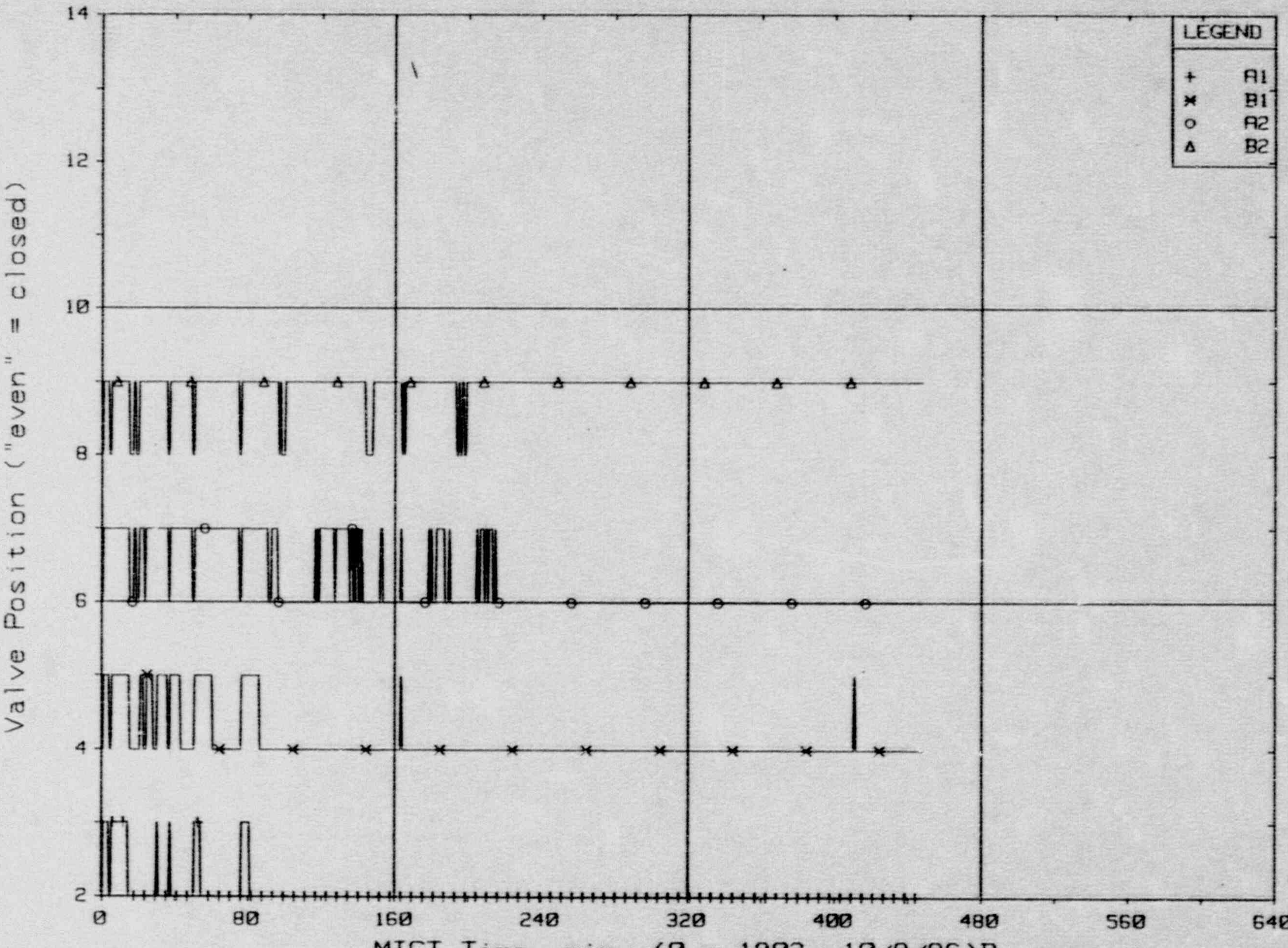
Reactor Vessel Vent Valve Flow Rates (RVORs).

Fri Jan 6 09:23:00 1989

VVFL1

-INAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



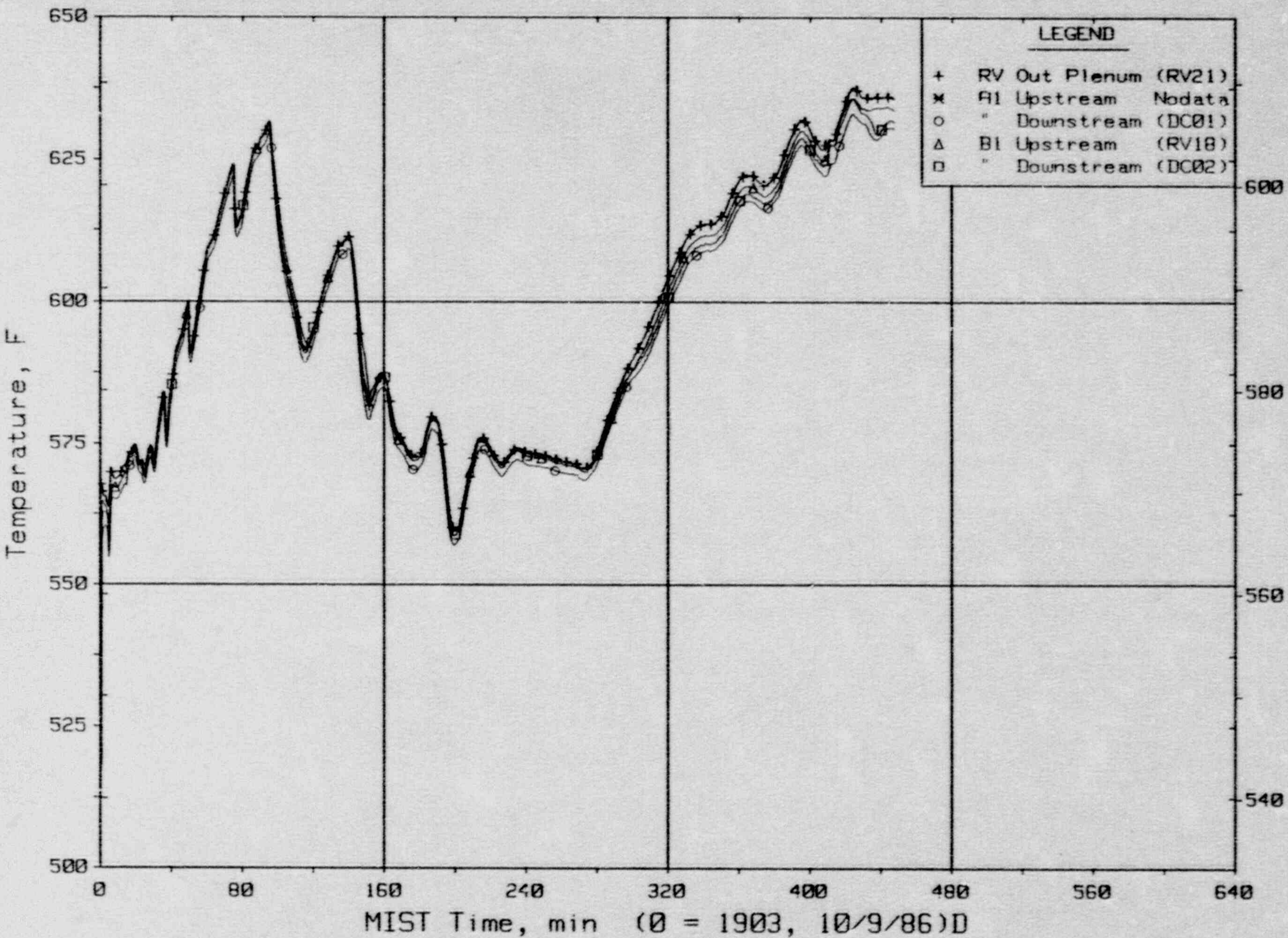
Reactor Vessel Vent Valve Positions.

Fri Jan 5 09:26:12 1989

VVLS1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



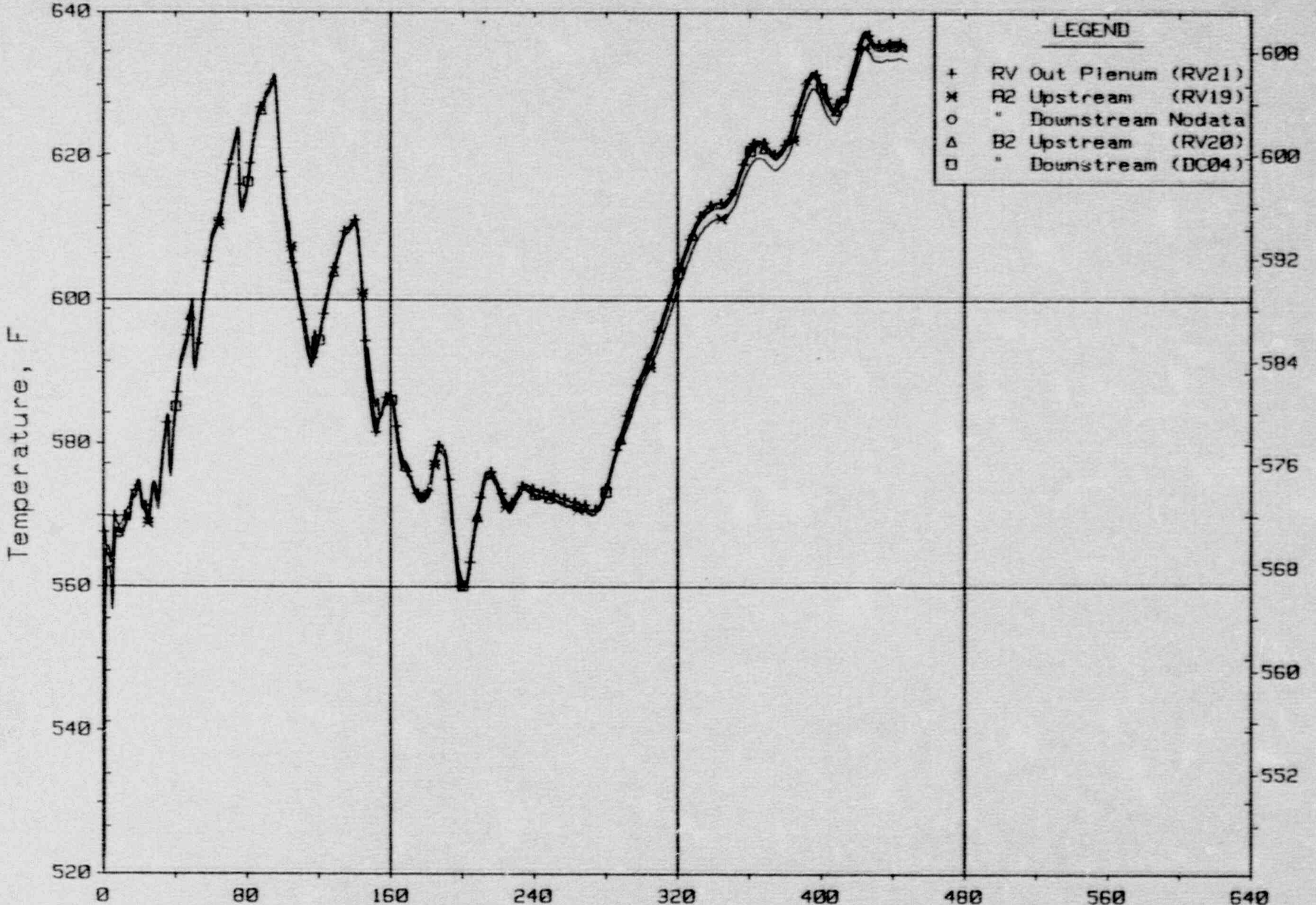
RVVVs A1 and B1 Bracketing Fluid Temperatures (TCs).

Fri Jan 6 10:32:20 1989

VVTC1

FINAL DATA

T3502CC: Group 35 Test 2, Noncondensible Gas Threshold.



RVVVs A2 and B2 Bracketing Fluid Temperatures (TCs).

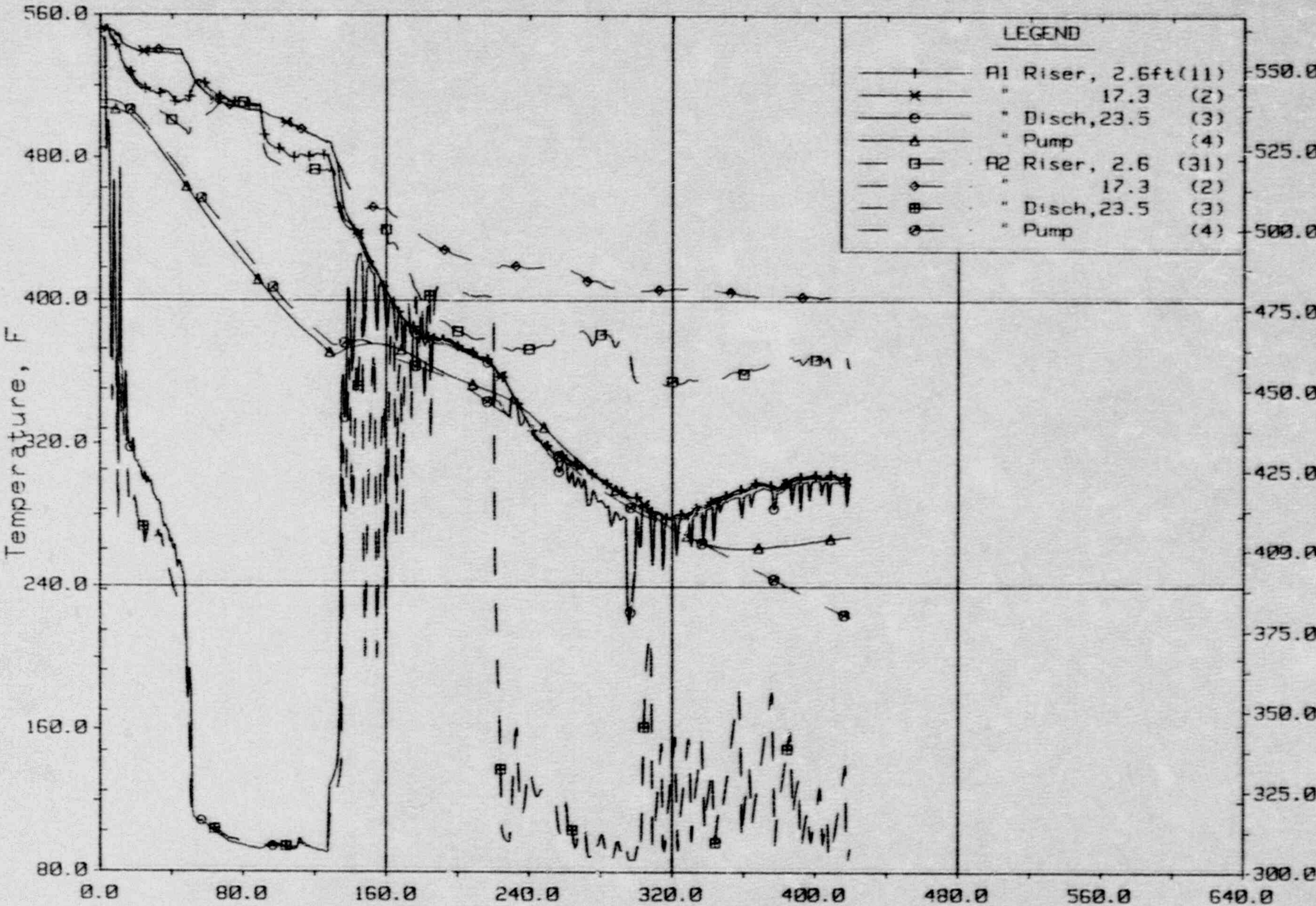
Fri Jan 6 11:34:56 1989

VVTC2

T350312

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



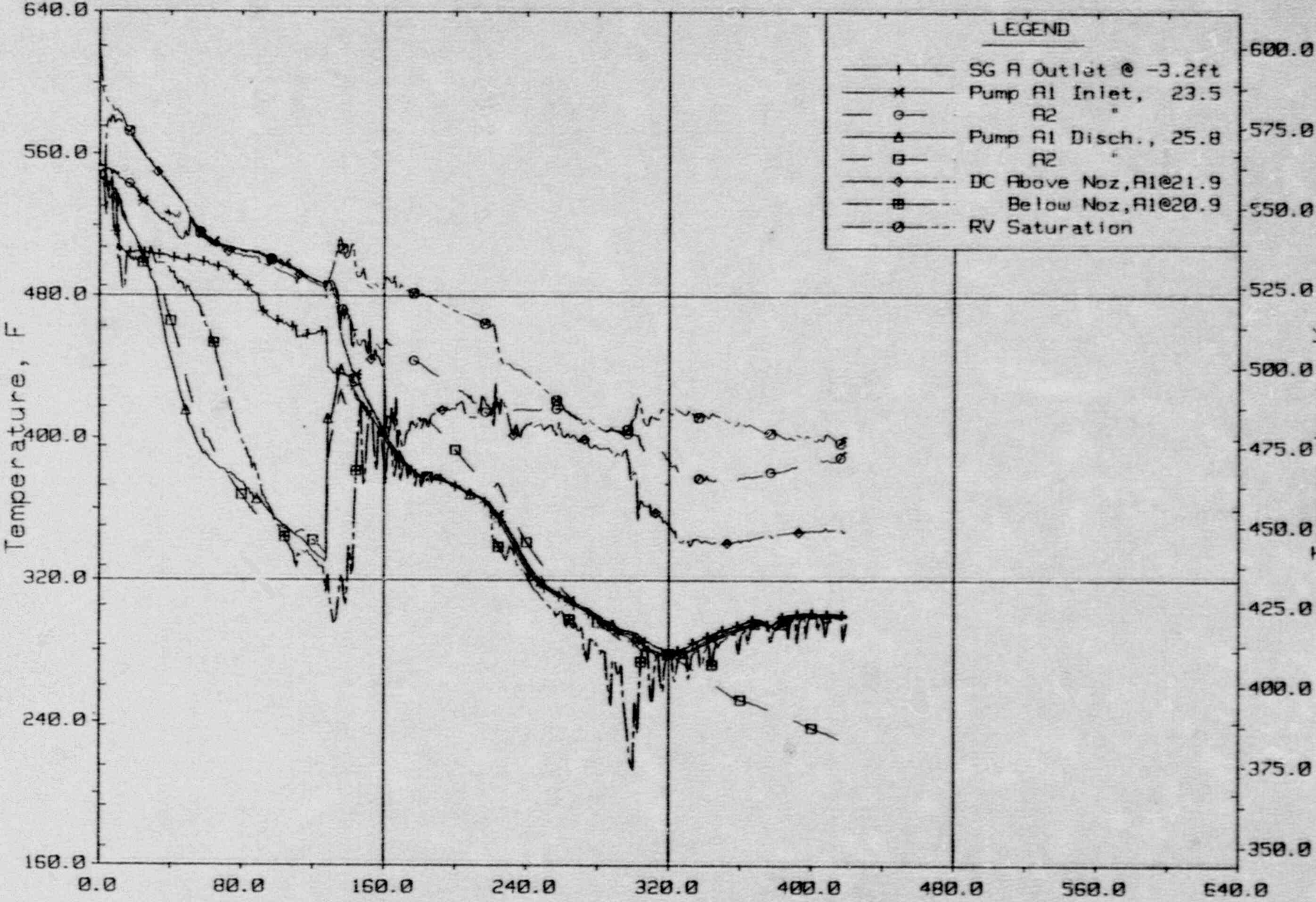
Loop A Cold Leg Metal Temperatures (C1,3MTs).

Wed May 25 10:32:00 1988

C1MT1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



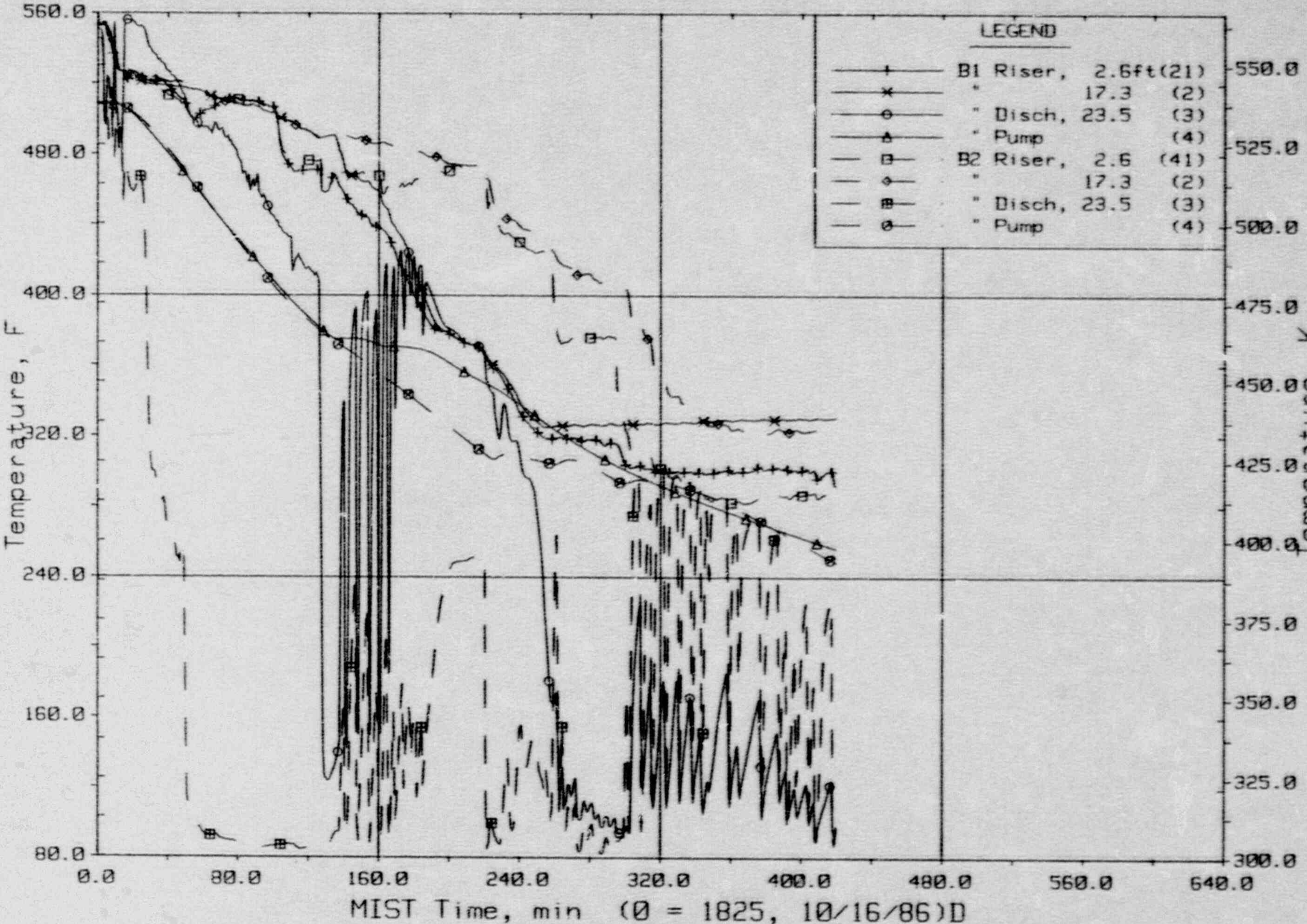
Loop A Cold Leg Fluid Temperatures (RTDs).

Wed May 25 10:37:19 1988

C1RT0

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



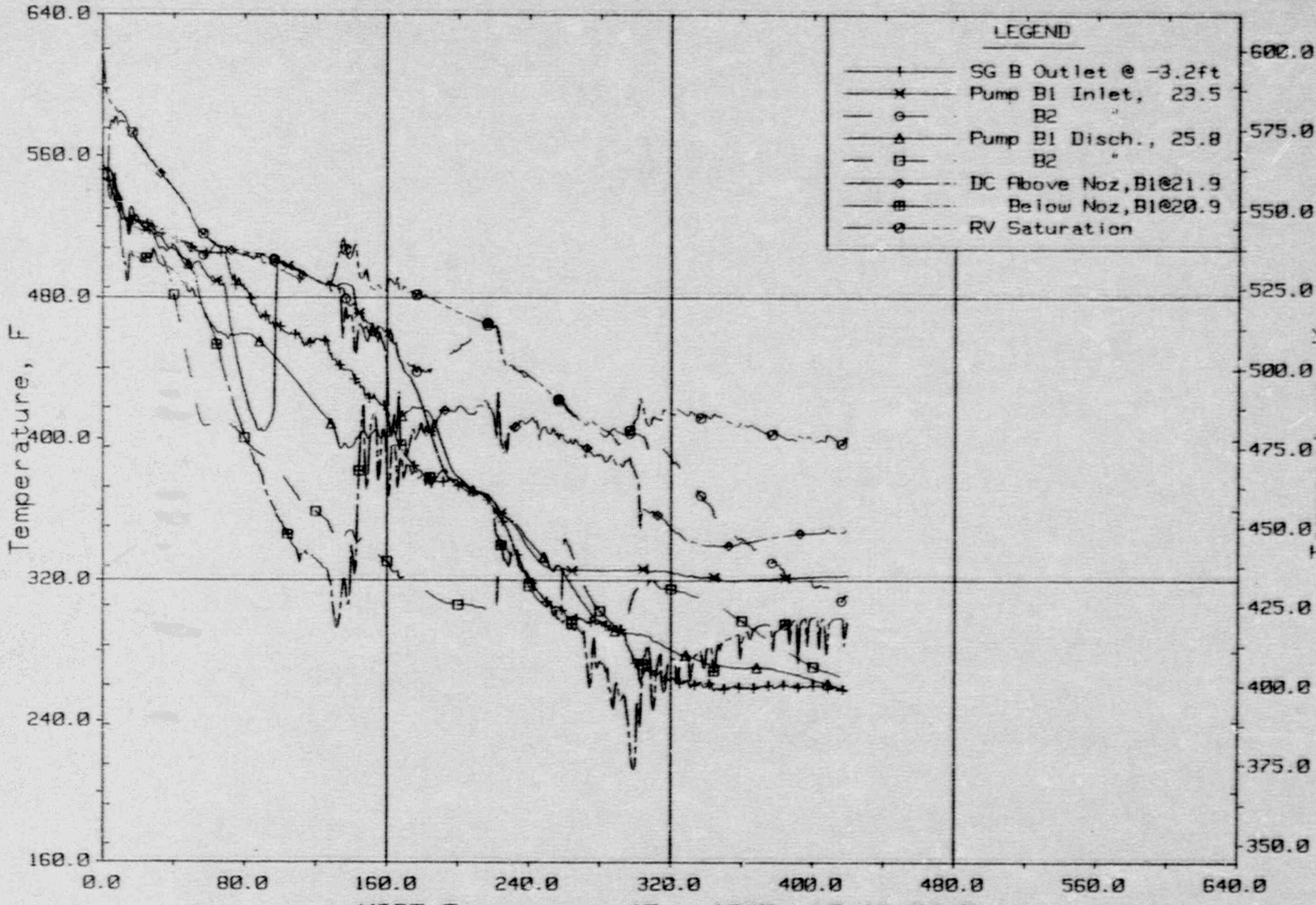
Loop B Cold Leg Metal Temperatures (C2,4MTs).

Wed May 25 10:44:13 1988

C2MT1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



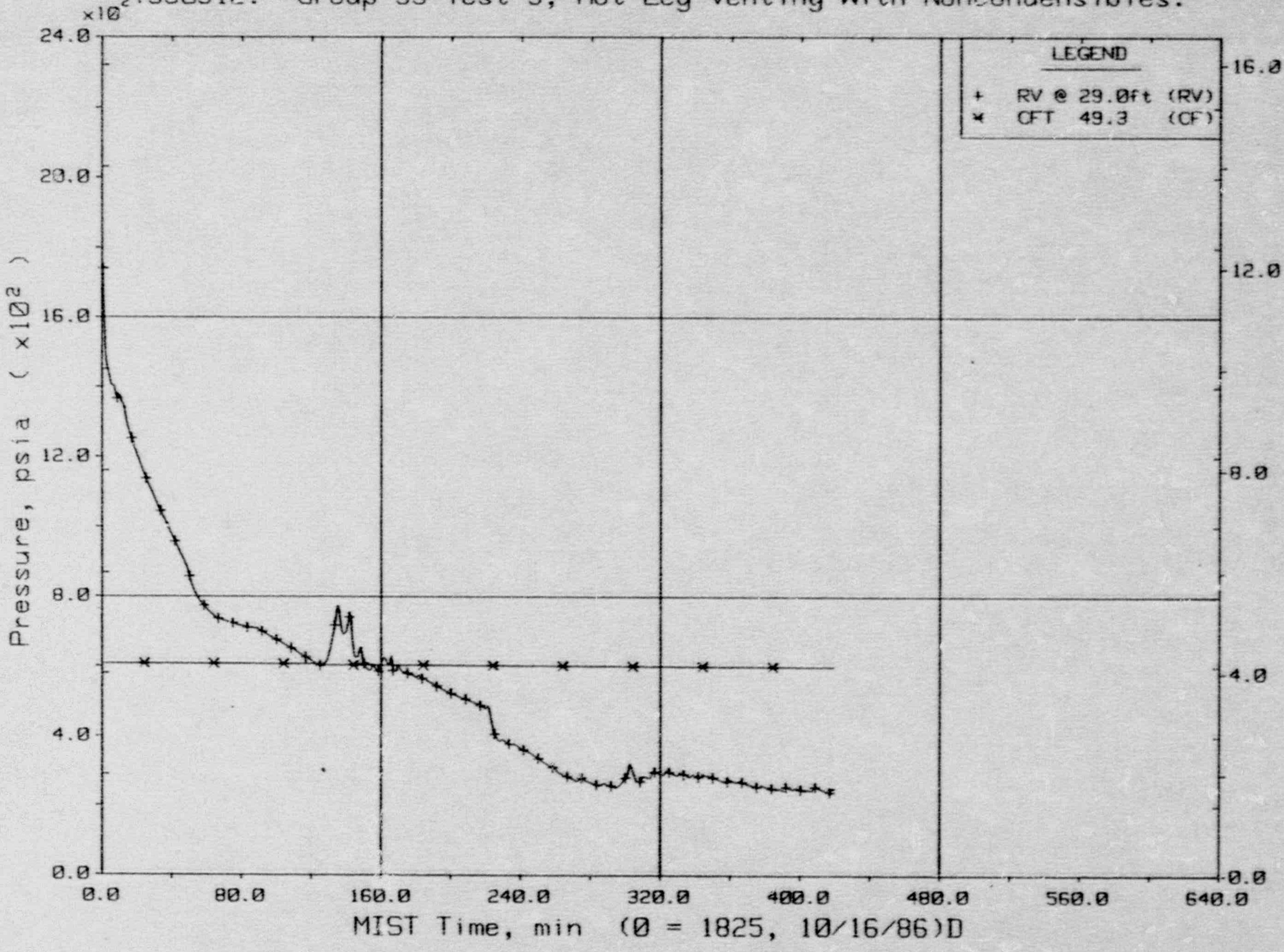
Loop B Cold Leg Fluid Temperatures (RTDs).

Wed May 25 10:49:23 1988

C2RT0

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



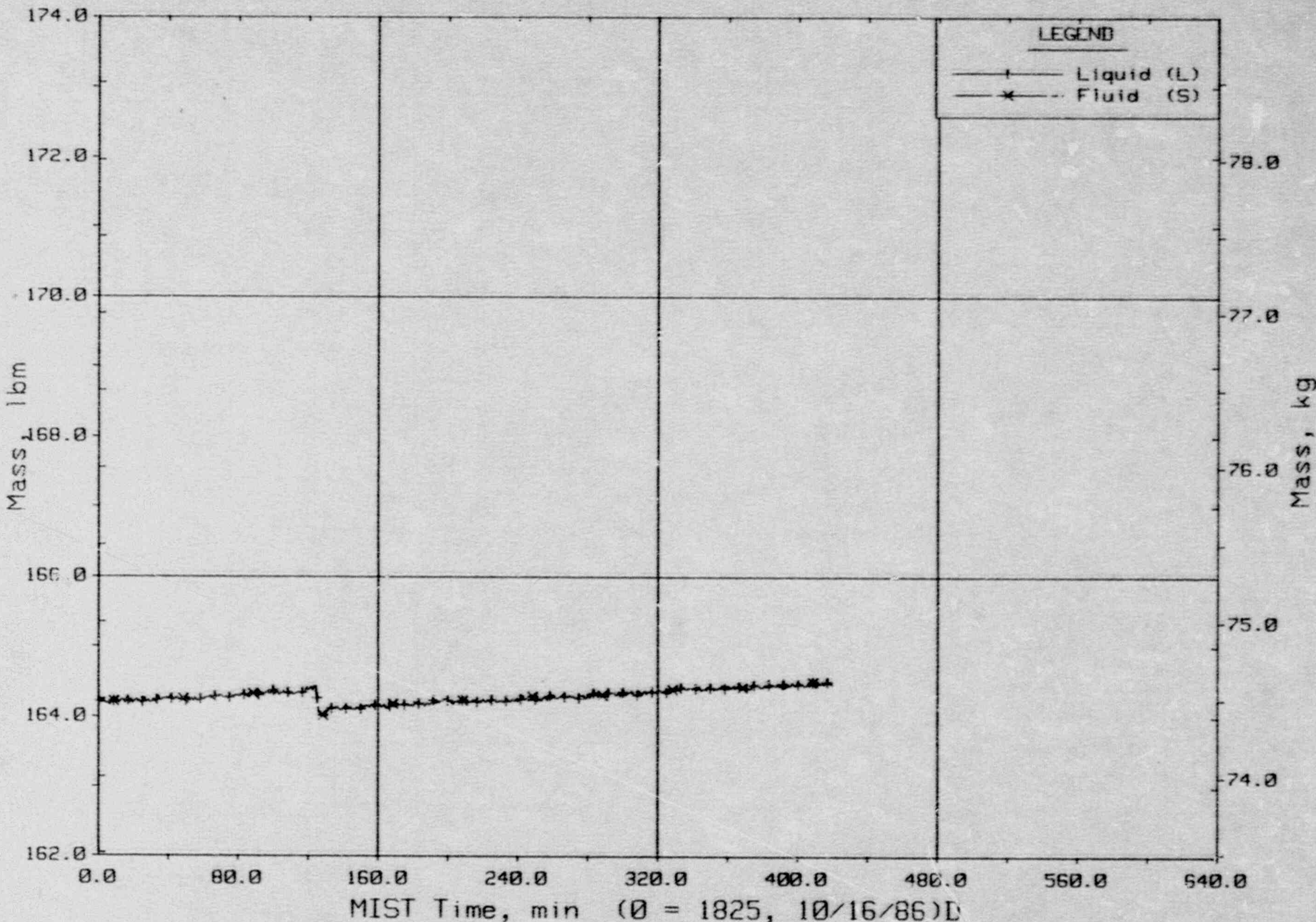
Primary System and Core Flood Tank Pressures (GP01s).

Wed May 25 10:53:20 1988

CFGP1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



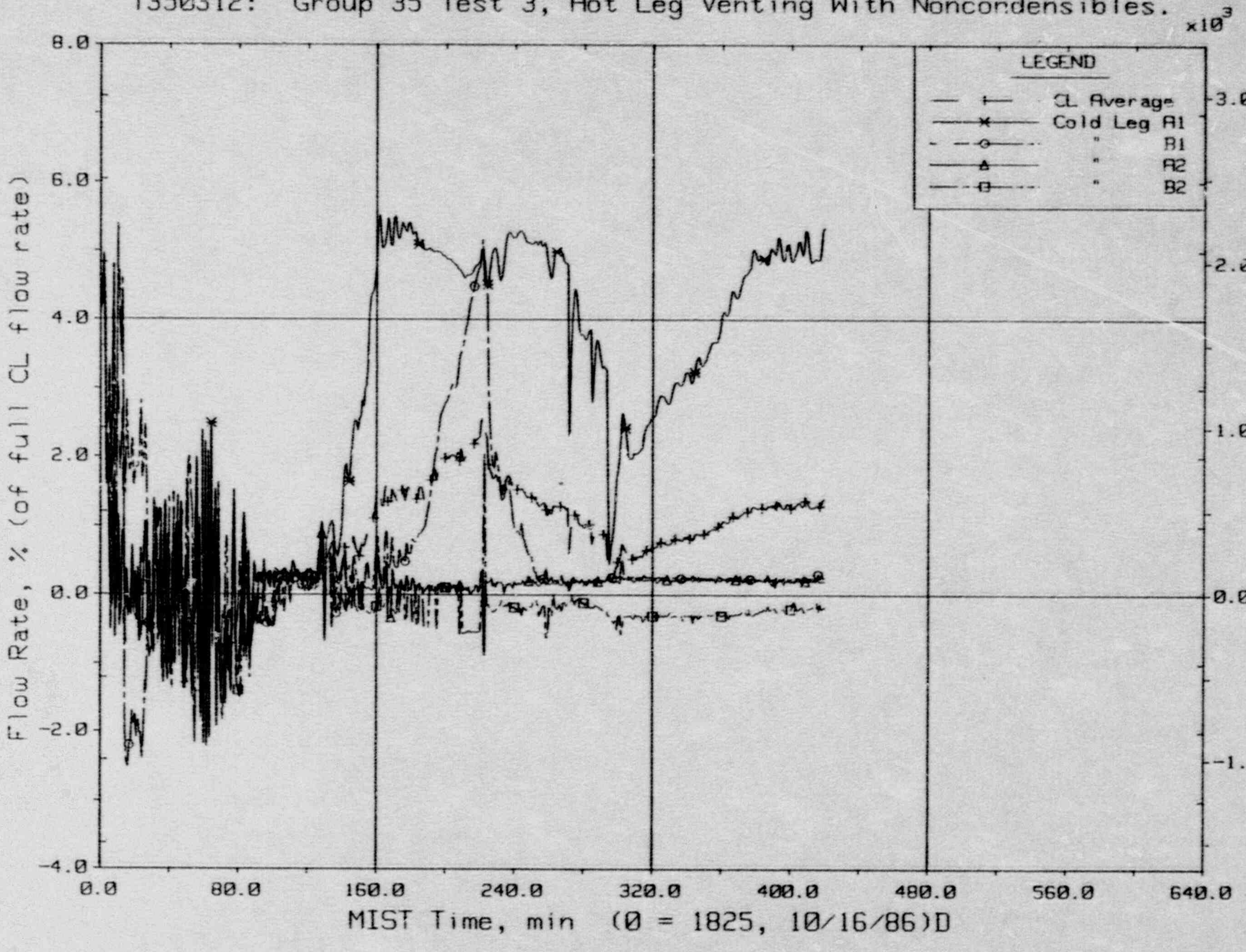
Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Wed May 25 10:58:29 1988

CFML1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



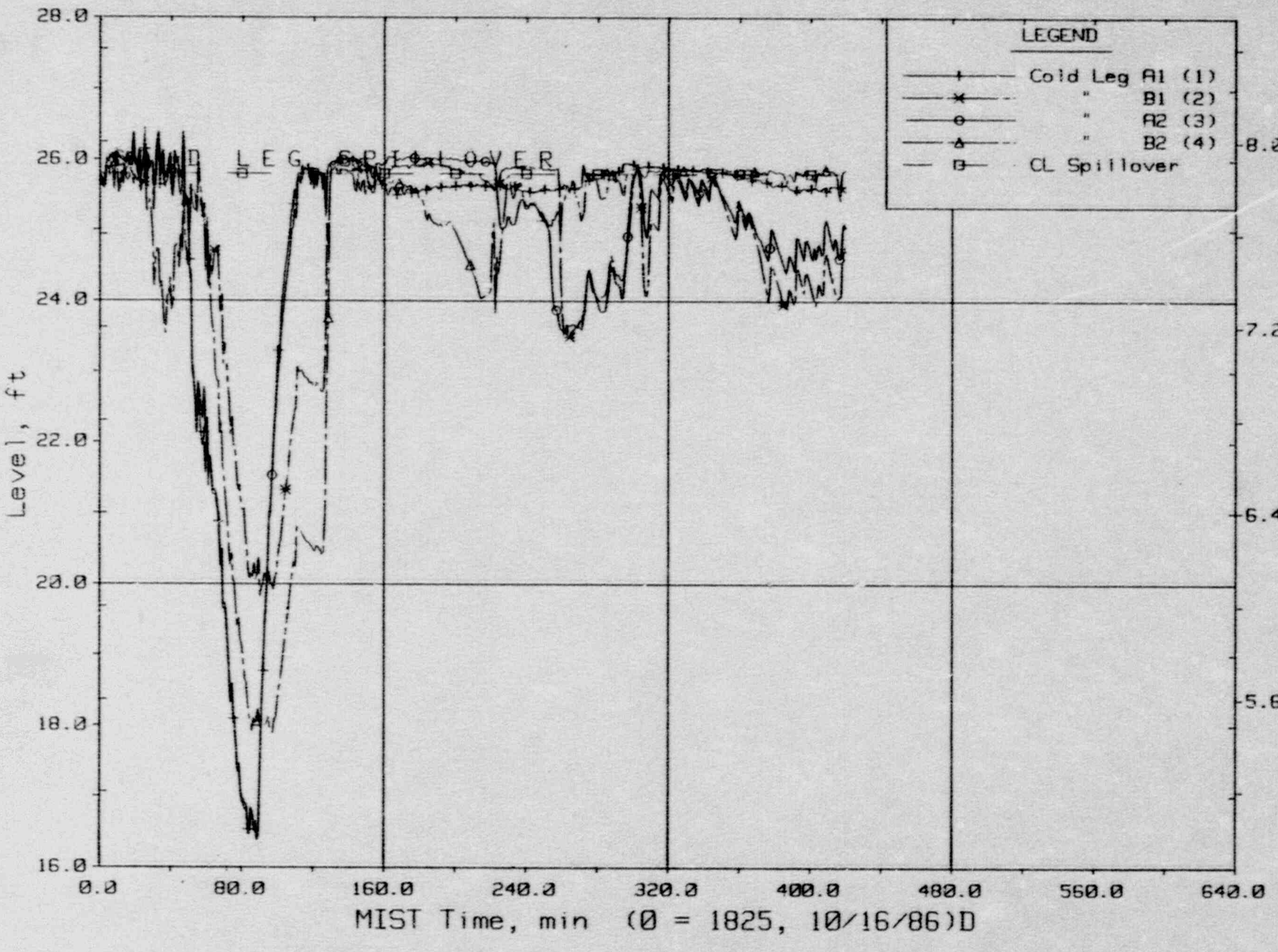
Cold Leg (Venturi) Flow Rates.

Wed May 25 11:04:12 1988

CLFL1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



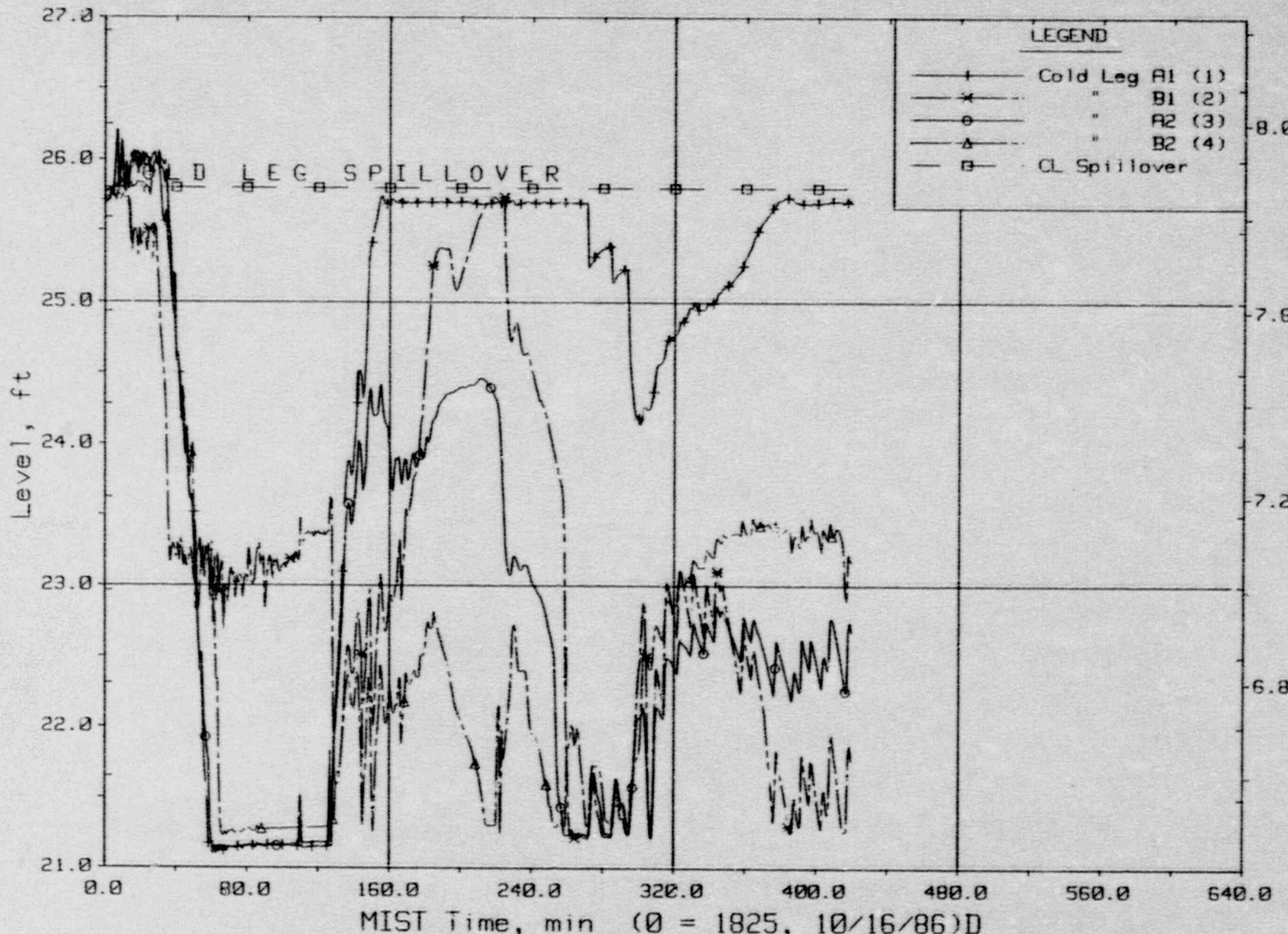
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Wed May 25 11:09:42 1988

CLLV4

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



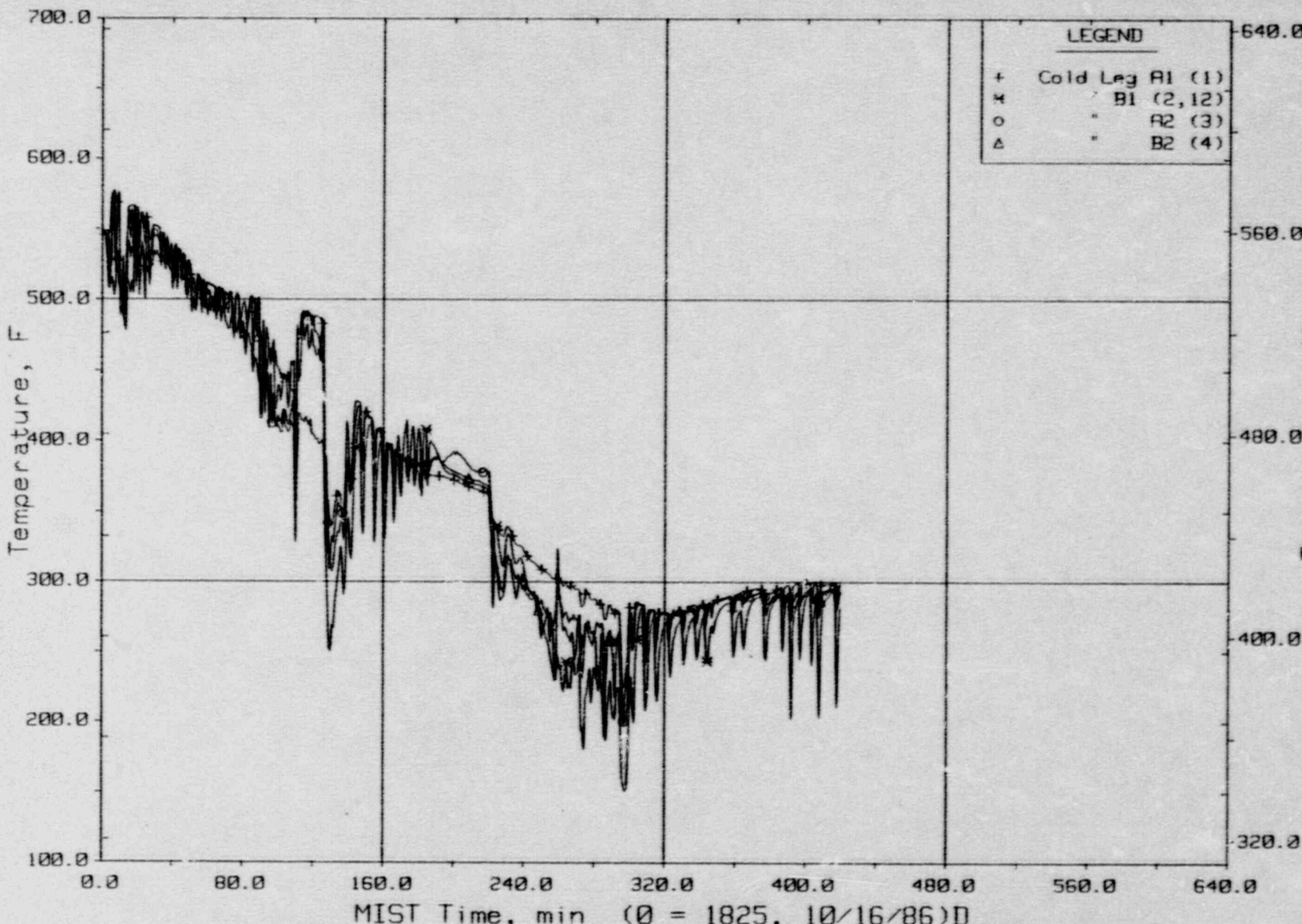
Cold Leg Discharge Collapsed Liquid Levels (CnLV23s).

Wed May 25 11:13:36 1988

CLLV5

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



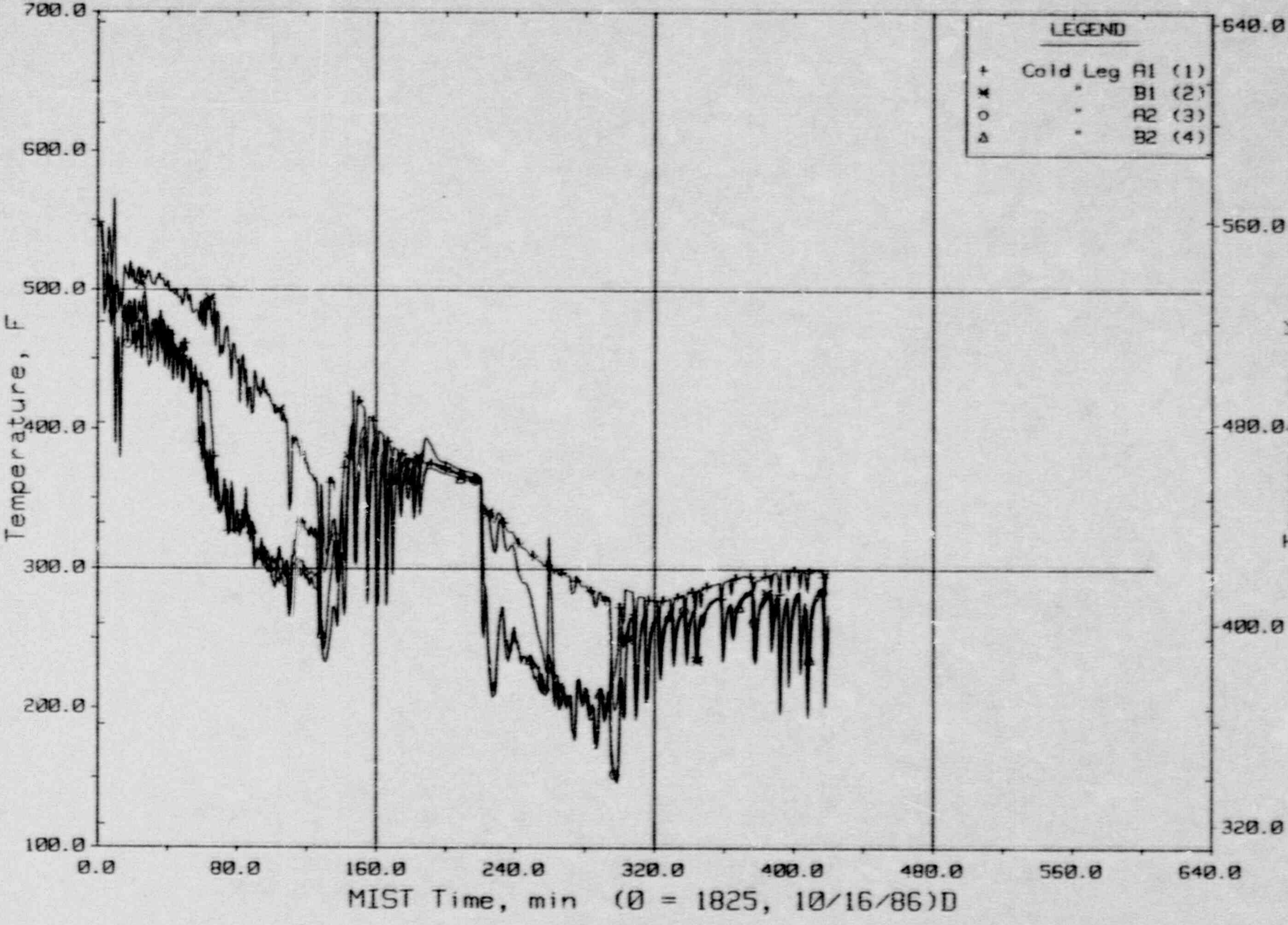
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Wed May 25 11:20:00 1988

CLTC1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



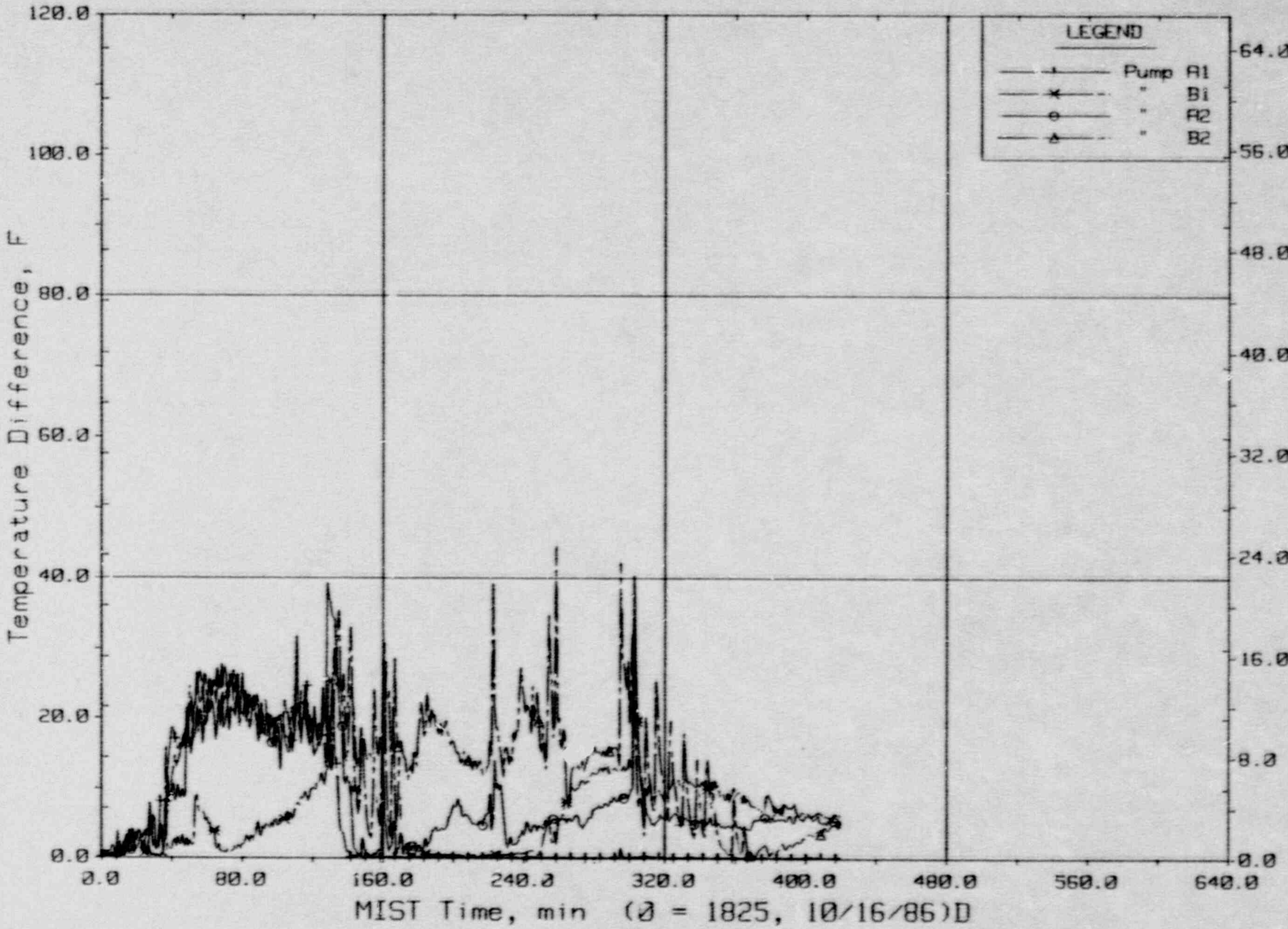
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Wed May 25 11:24:28 1988

CLTC2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



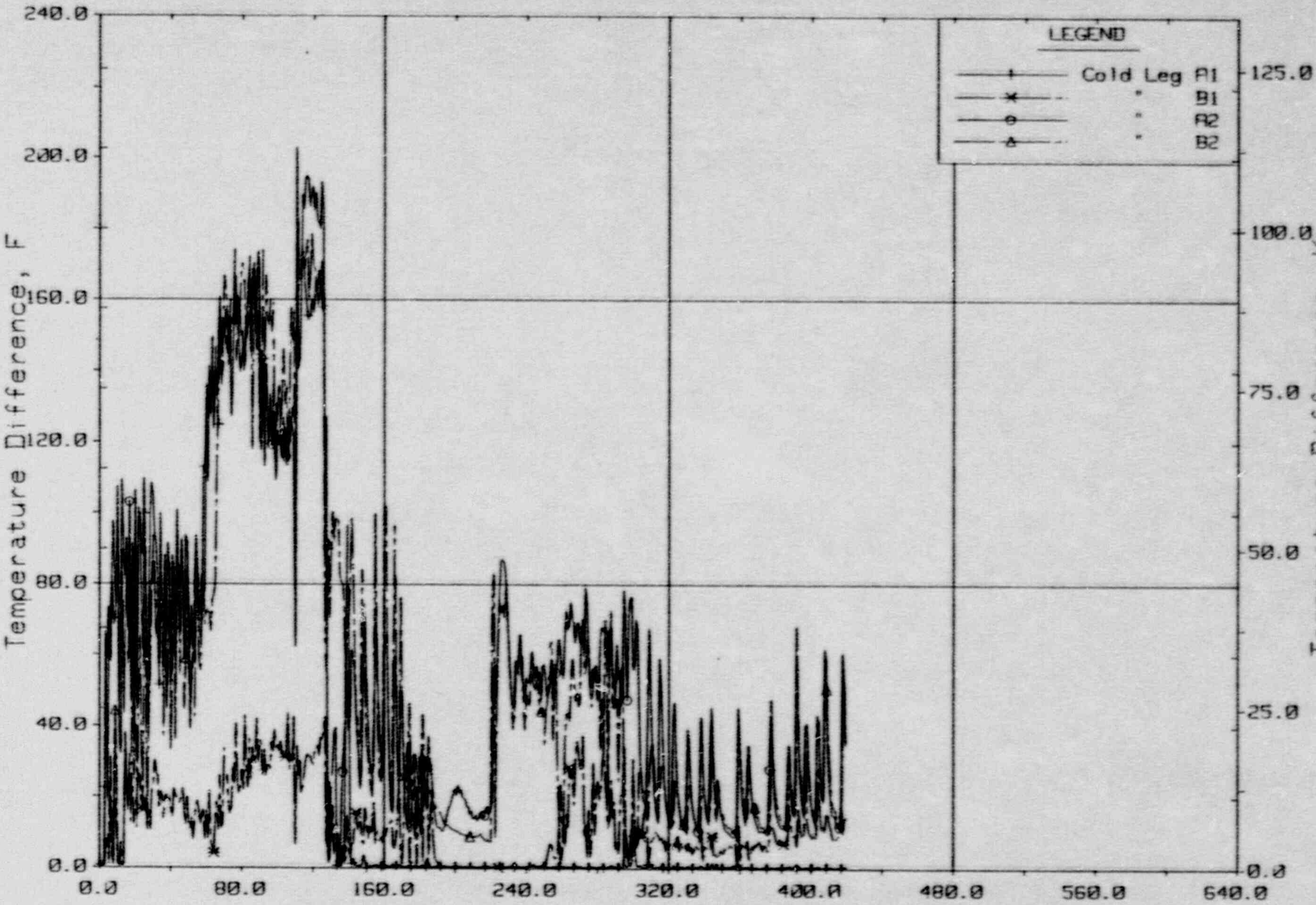
Maximum Differences Among RCP Rake FLuid Temperatures.

Wed May 25 11:28:12 1988

CLTD1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



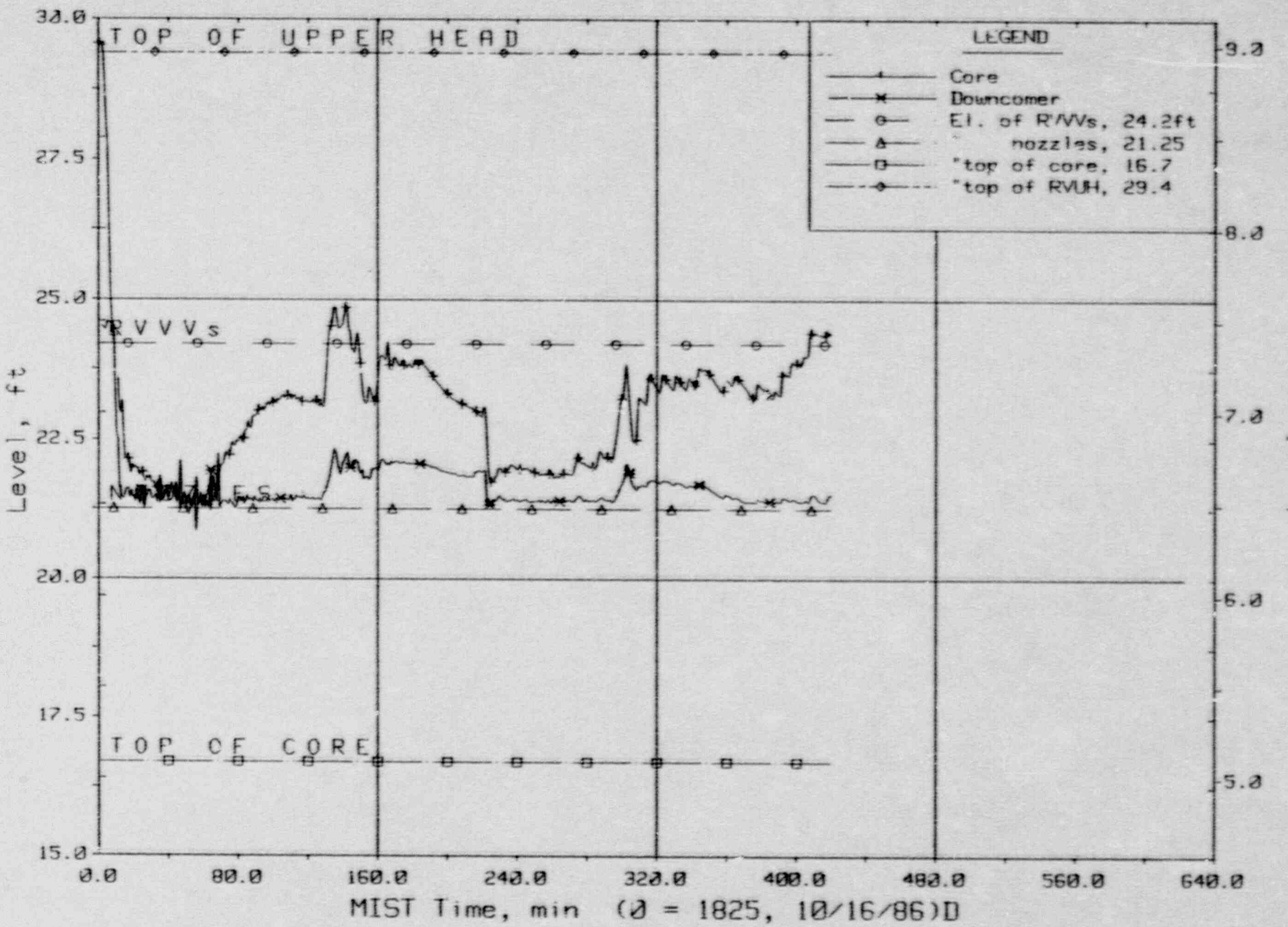
Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Wed May 25 11:32:40 1988

CLTD2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



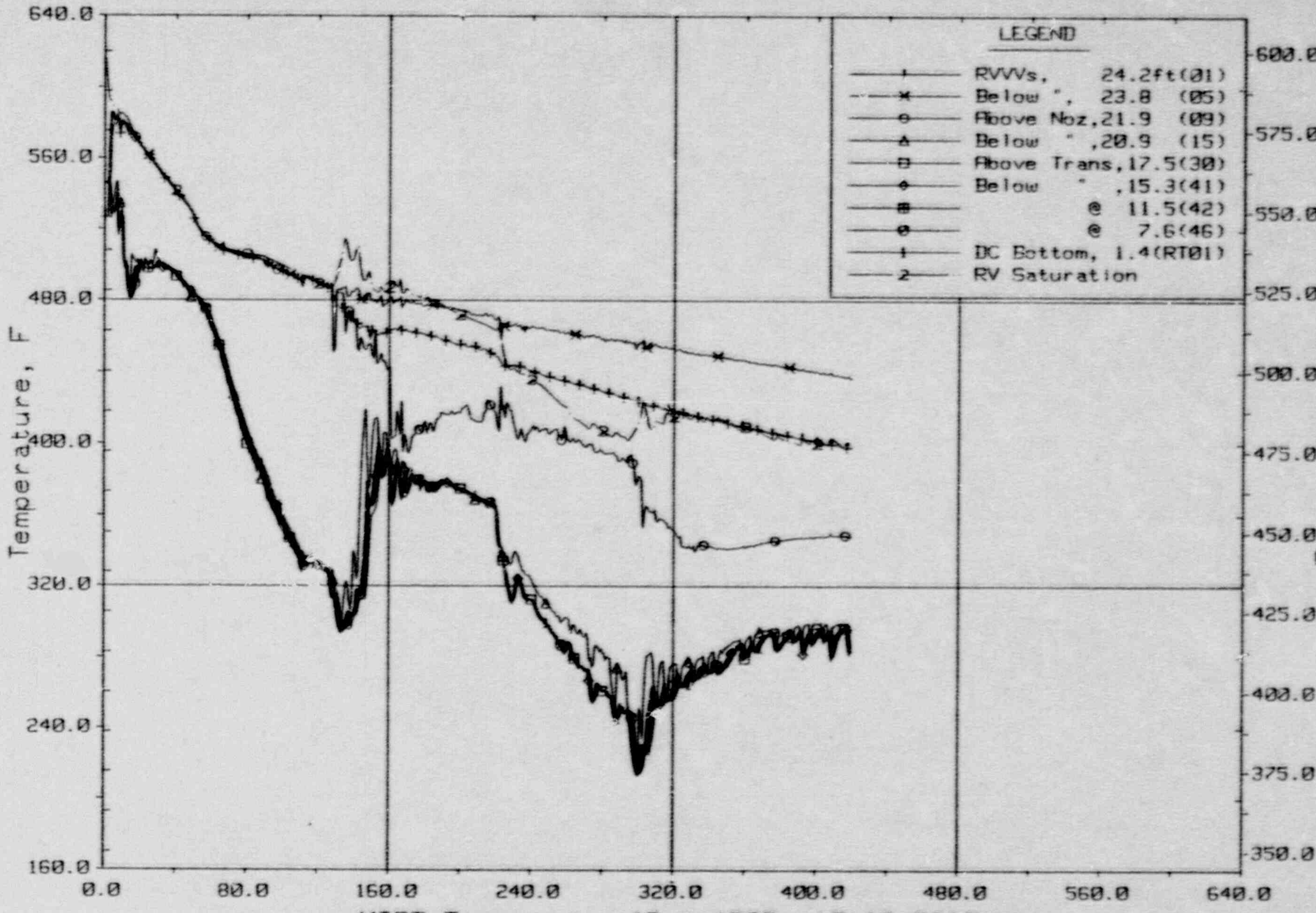
Core Region Collapsed Liquid Levels.

Wed May 25 11:37:29 1988

COLV1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



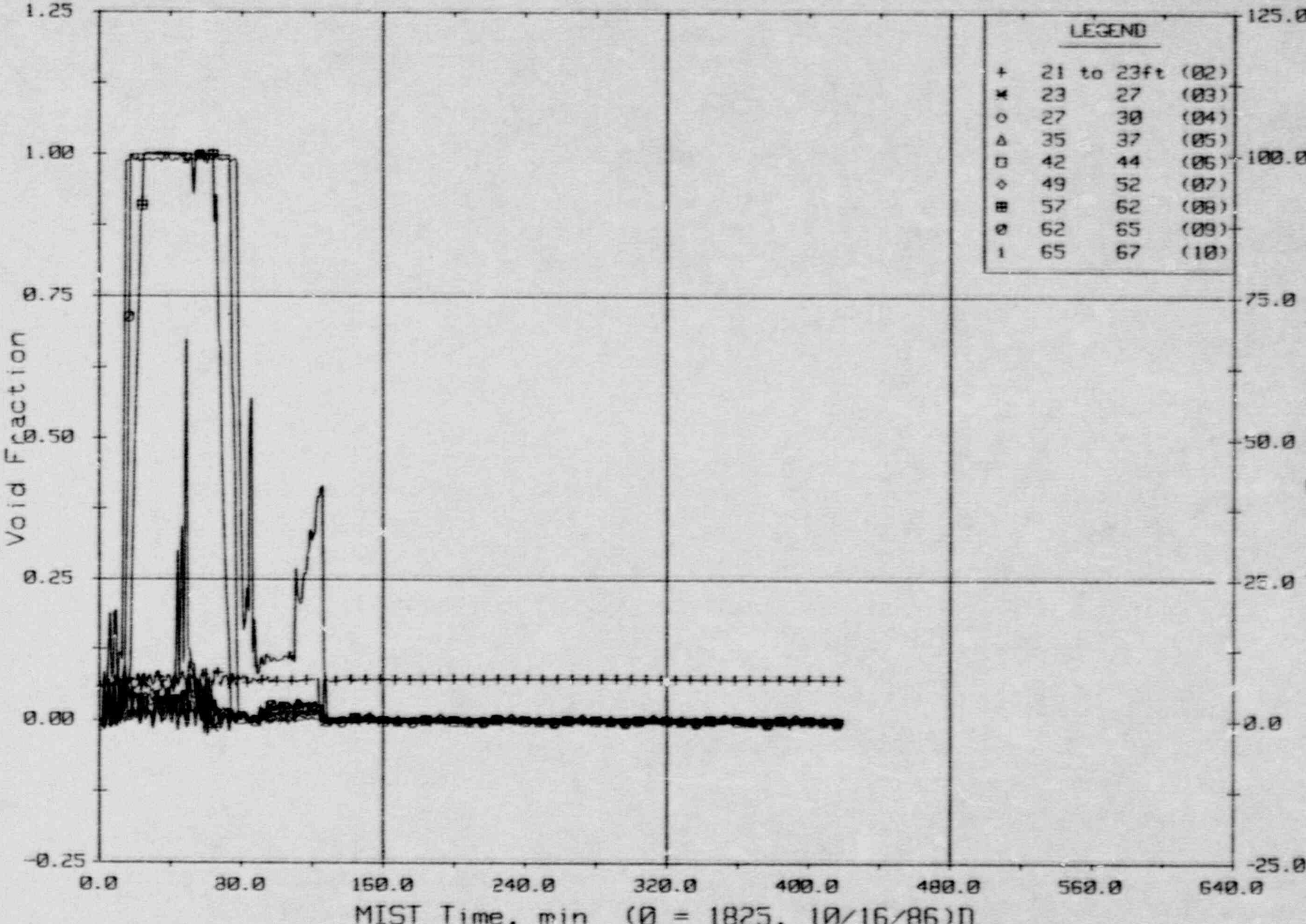
Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Wed May 25 11:53:56 1988

DCTC6

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



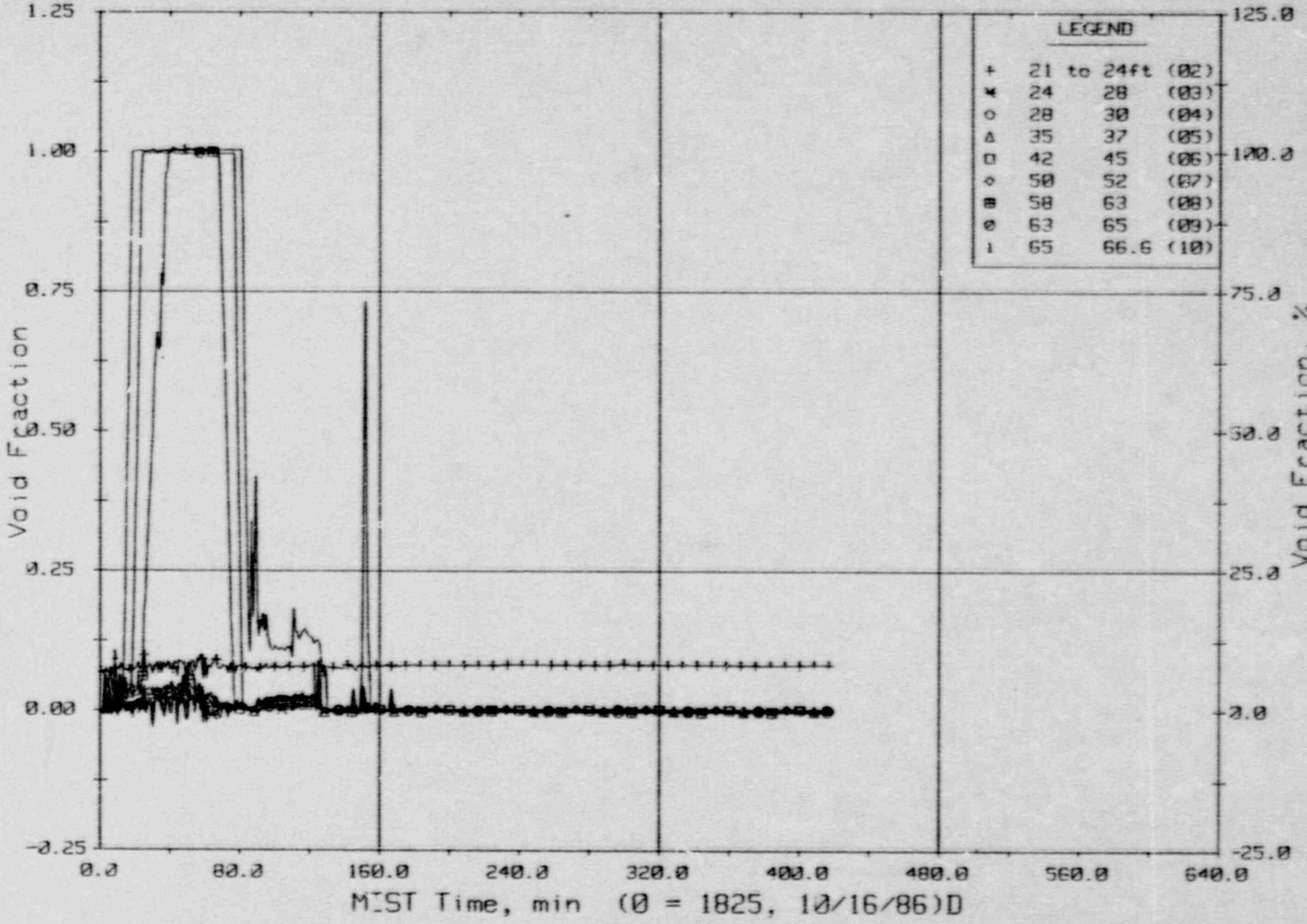
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Wed May 25 12:00:17 1988

H1VF1

FINAL DATA

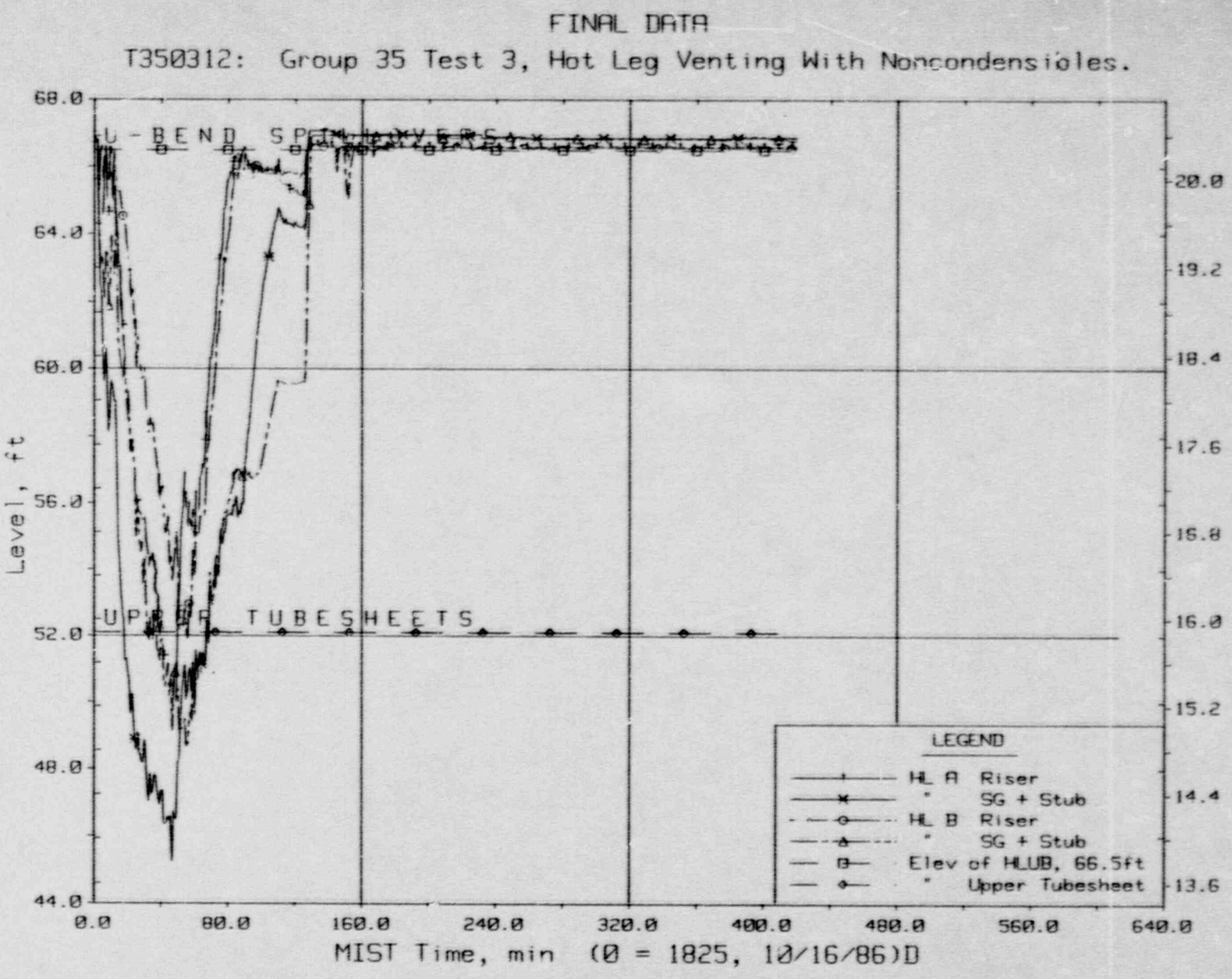
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).

Wed May 25 12:04:34 1988

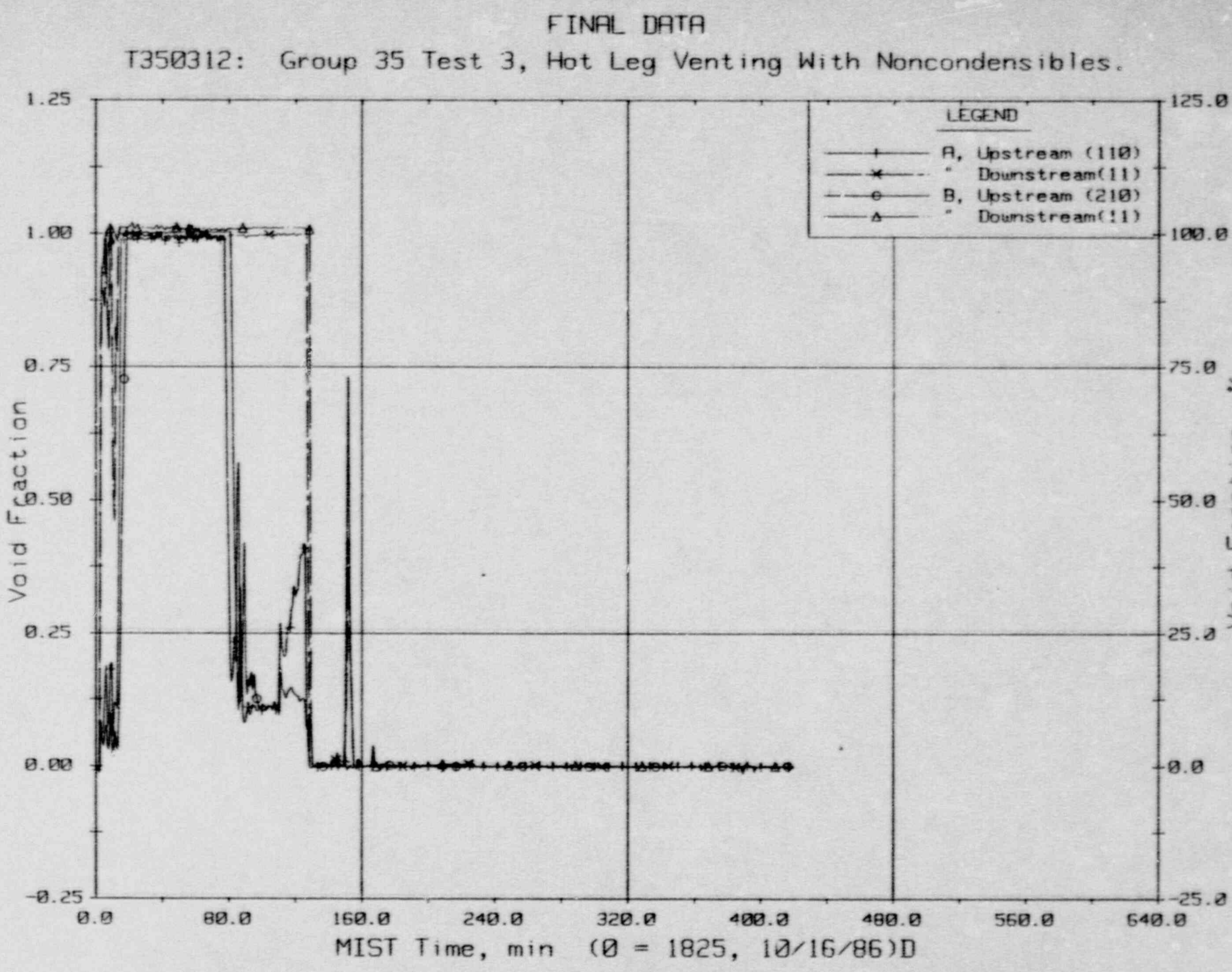
H2VF1



Hot Leg Riser and Stub Collapsed Liquid Levels.

Wed May 25 12:10:25 1988

HLLV1



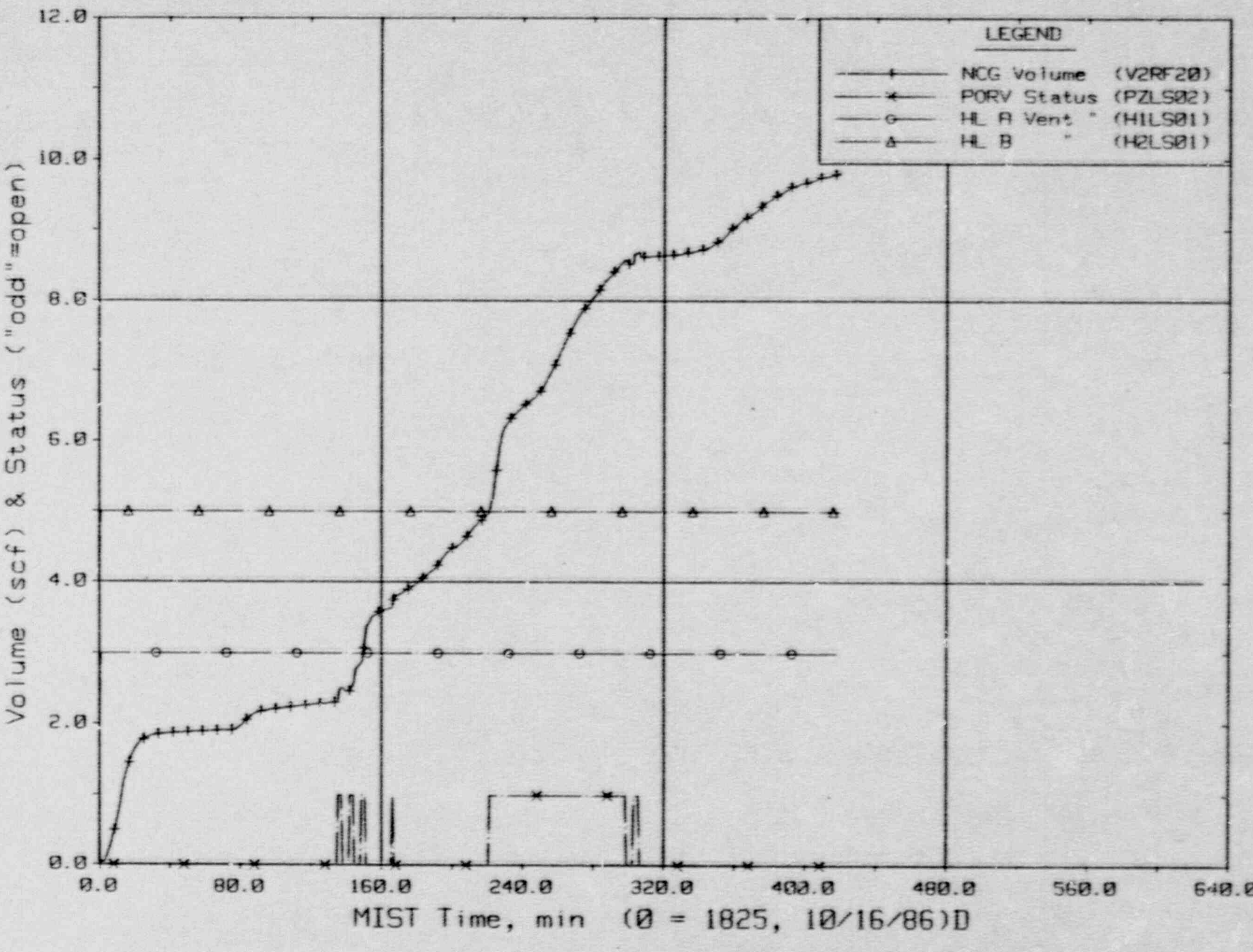
Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft, HnVFs).

Wed May 25 12:14:27 1988

HLVF1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



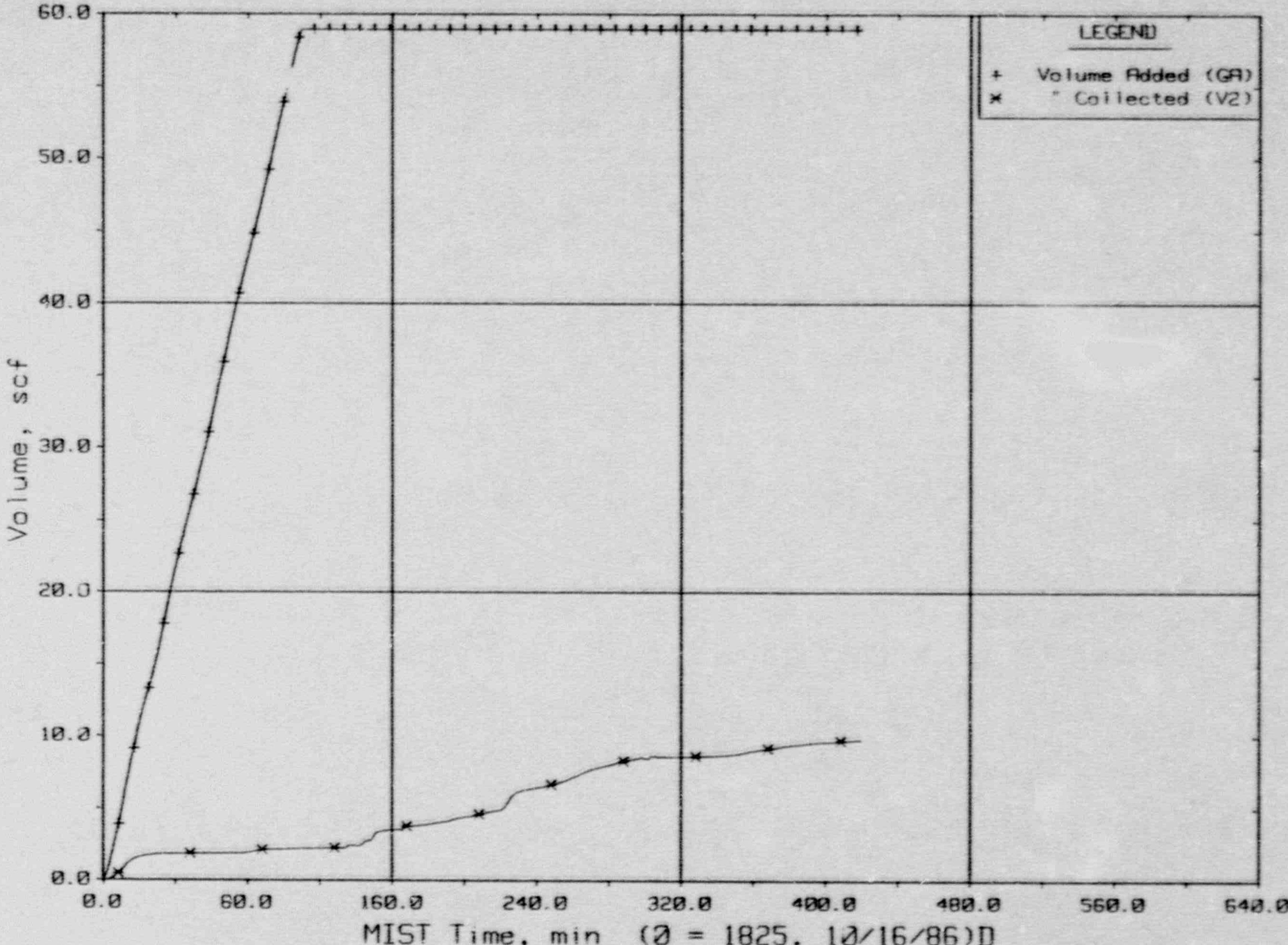
Noncondensibles Collected and Discharge Valve Status.

Wed May 25 14:30:12 1988

NCMS1

FINAL DATA

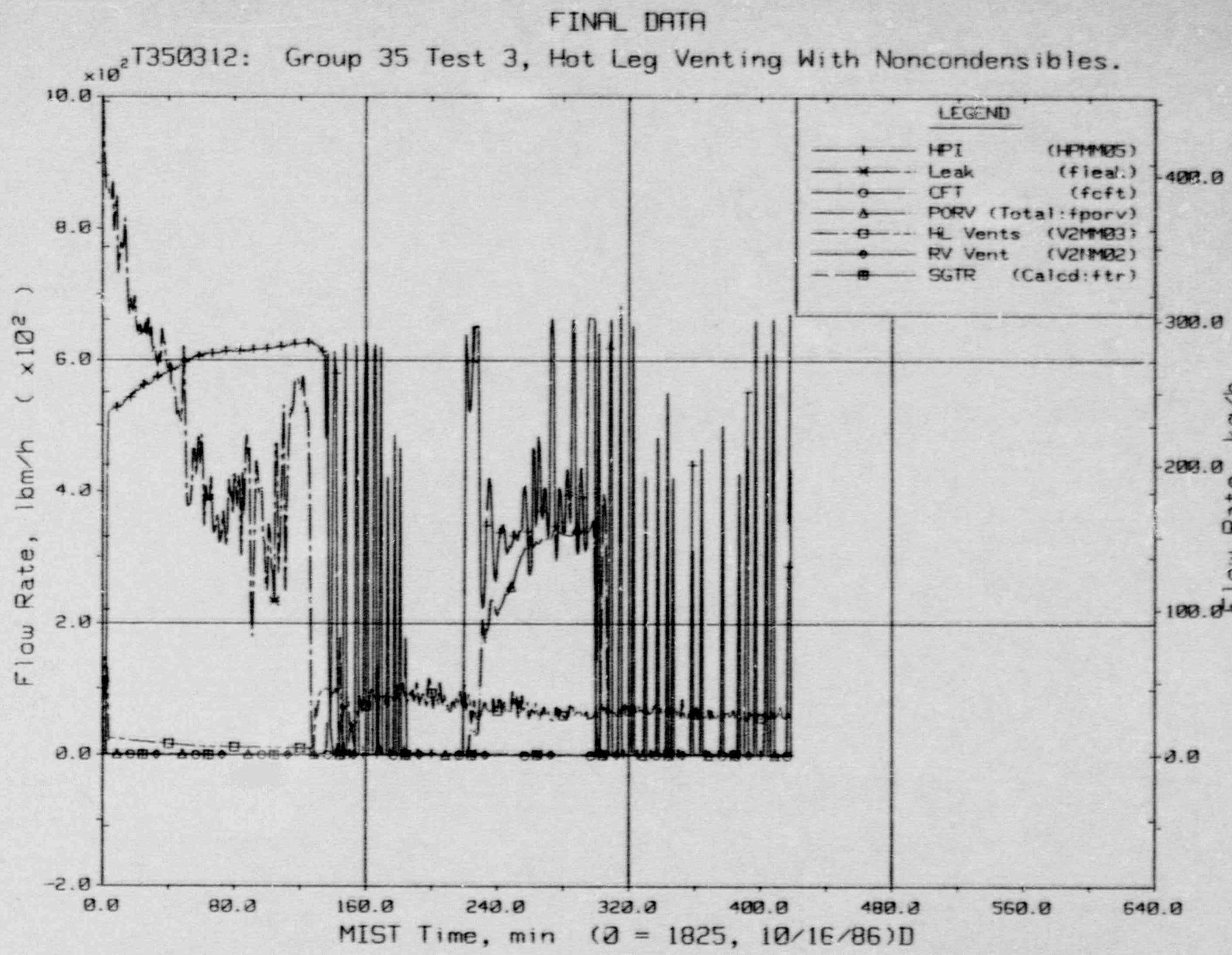
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Noncondensibles Gas Volumes.

Wed May 25 14:33:04 1988

NCMS2



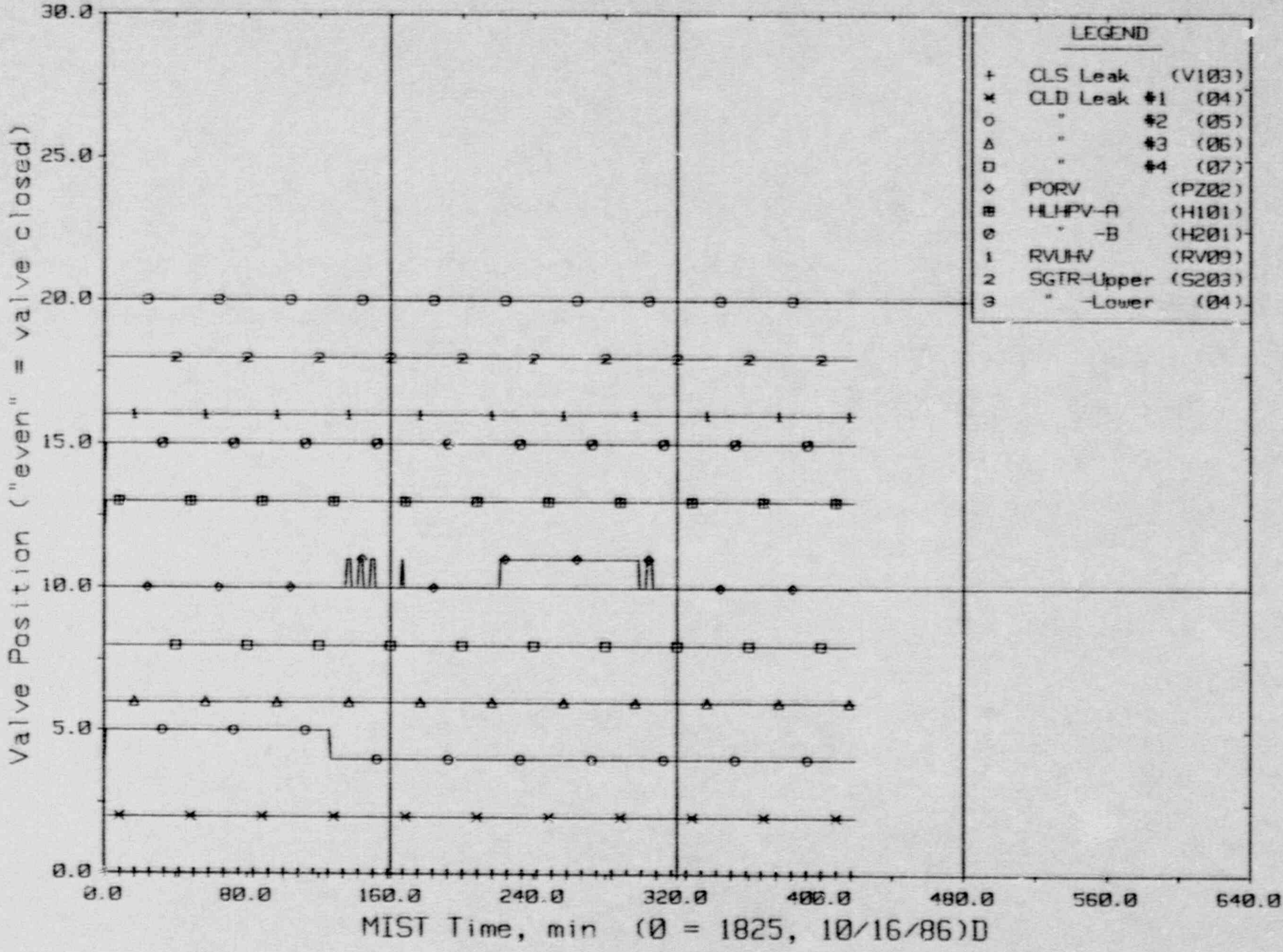
Primary System Boundary Flow Rates.

Wed May 25 12:18:52 1988

PBFL3

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



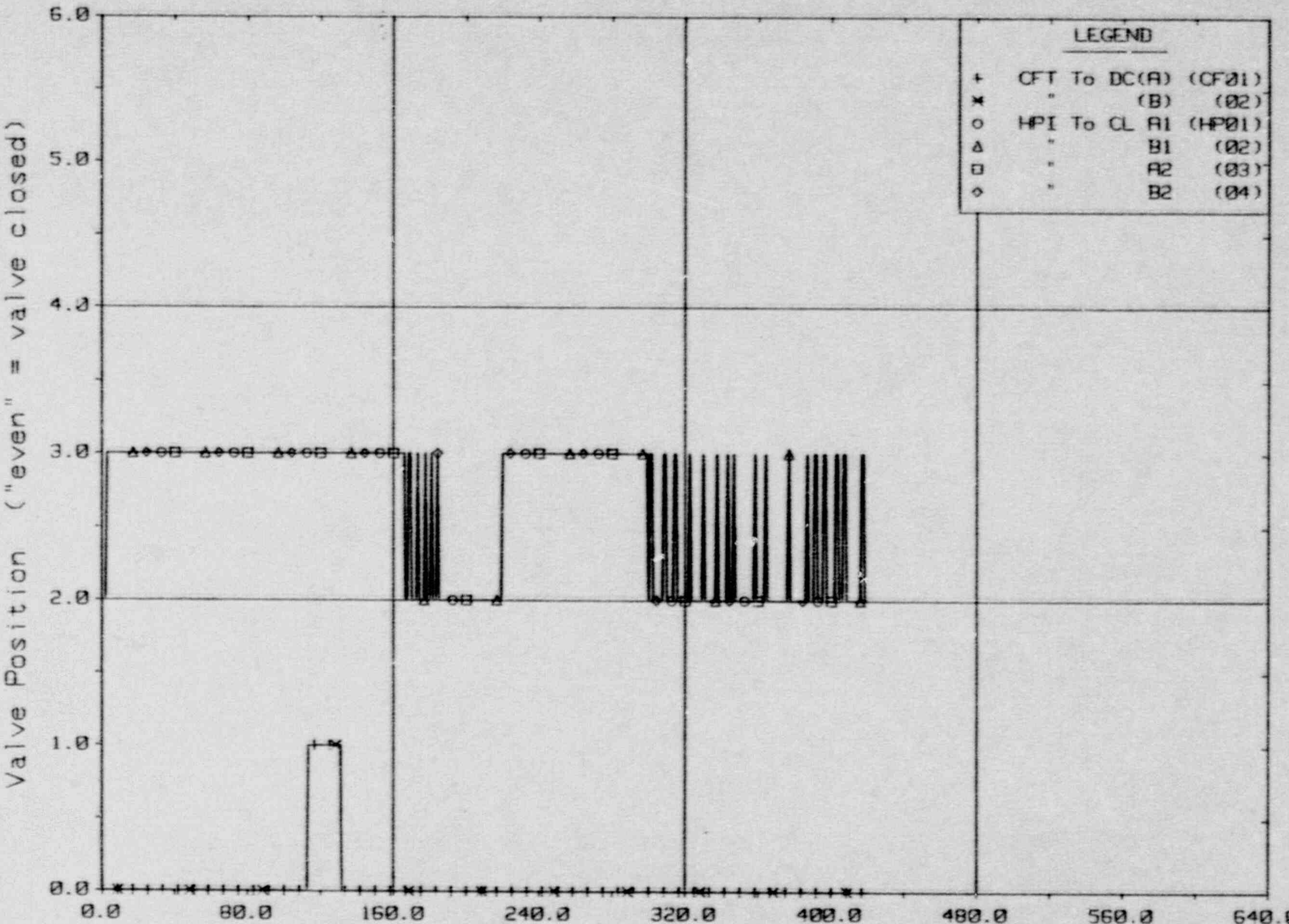
Primary System Discharge Limit Switch Indications (LSs).

Wed May 25 12:23:34 1988

PBLS1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



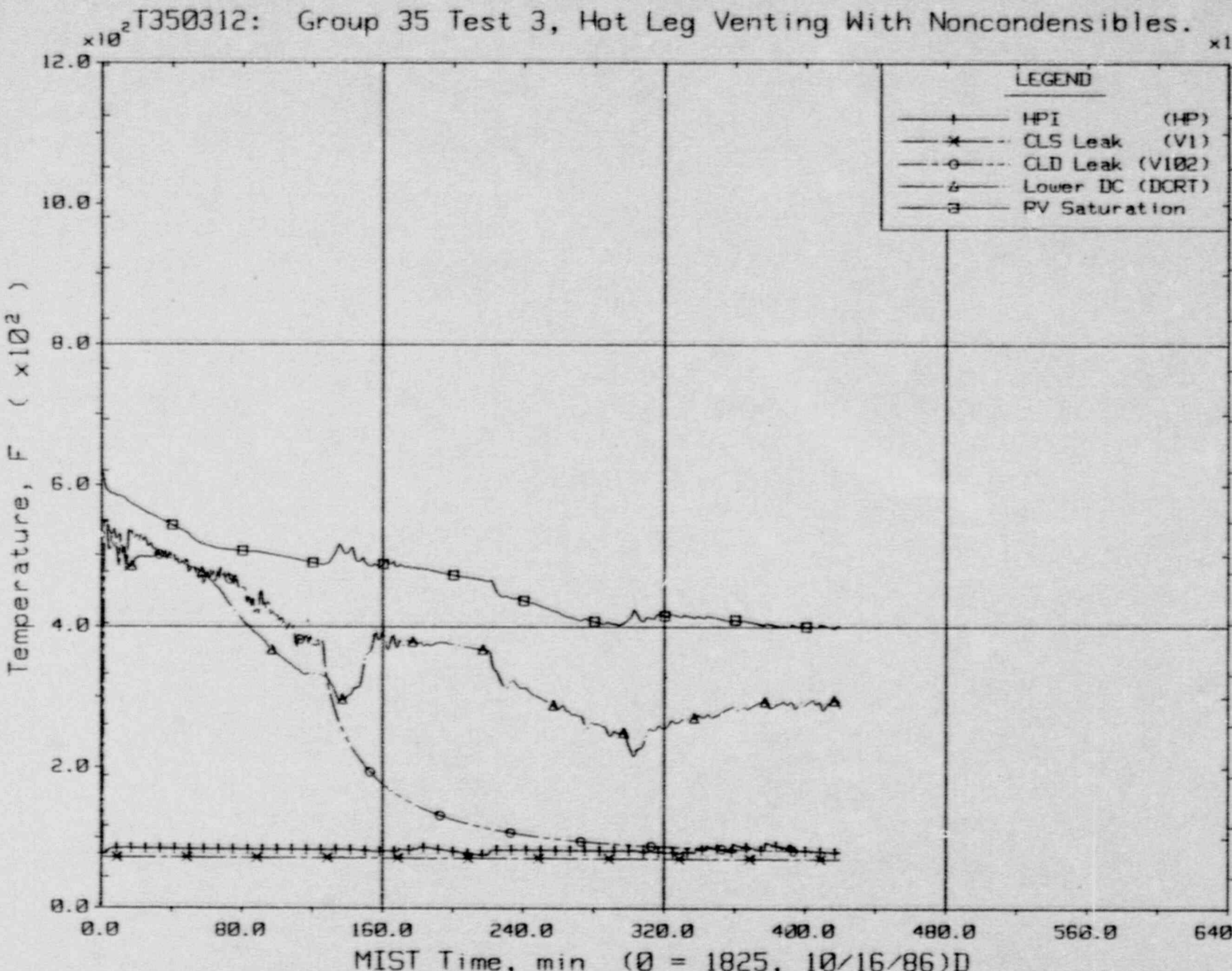
MIST Time, min (0 = 1825, 10/16/86)D

Primary System Injection Limit Switch Indications (LSs).

Wed May 25 12:26:55 1988

PBLS2

FINAL DATA



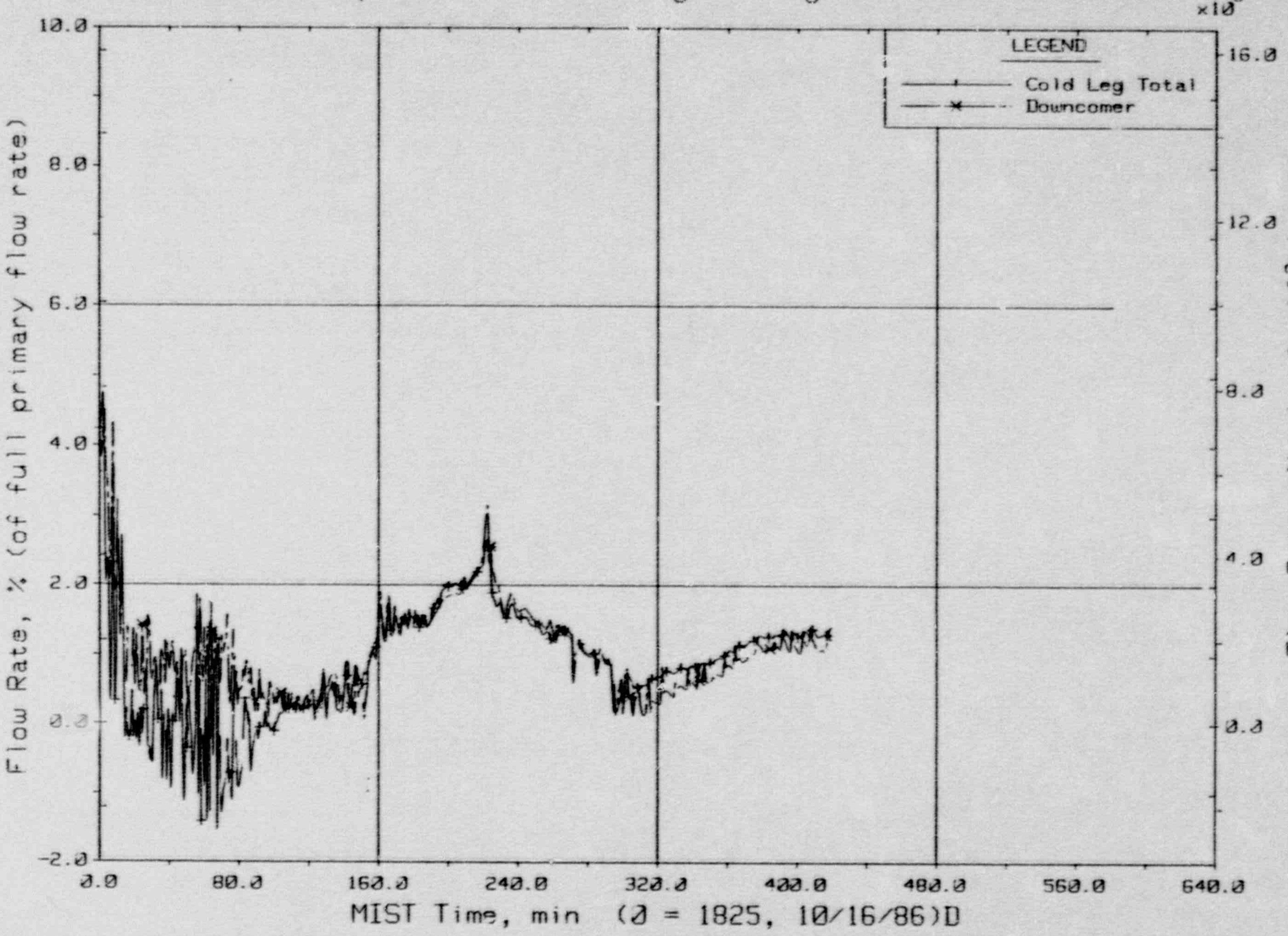
Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Wed May 25 12:30:03 1988

PBTC1p

FINAL DATA

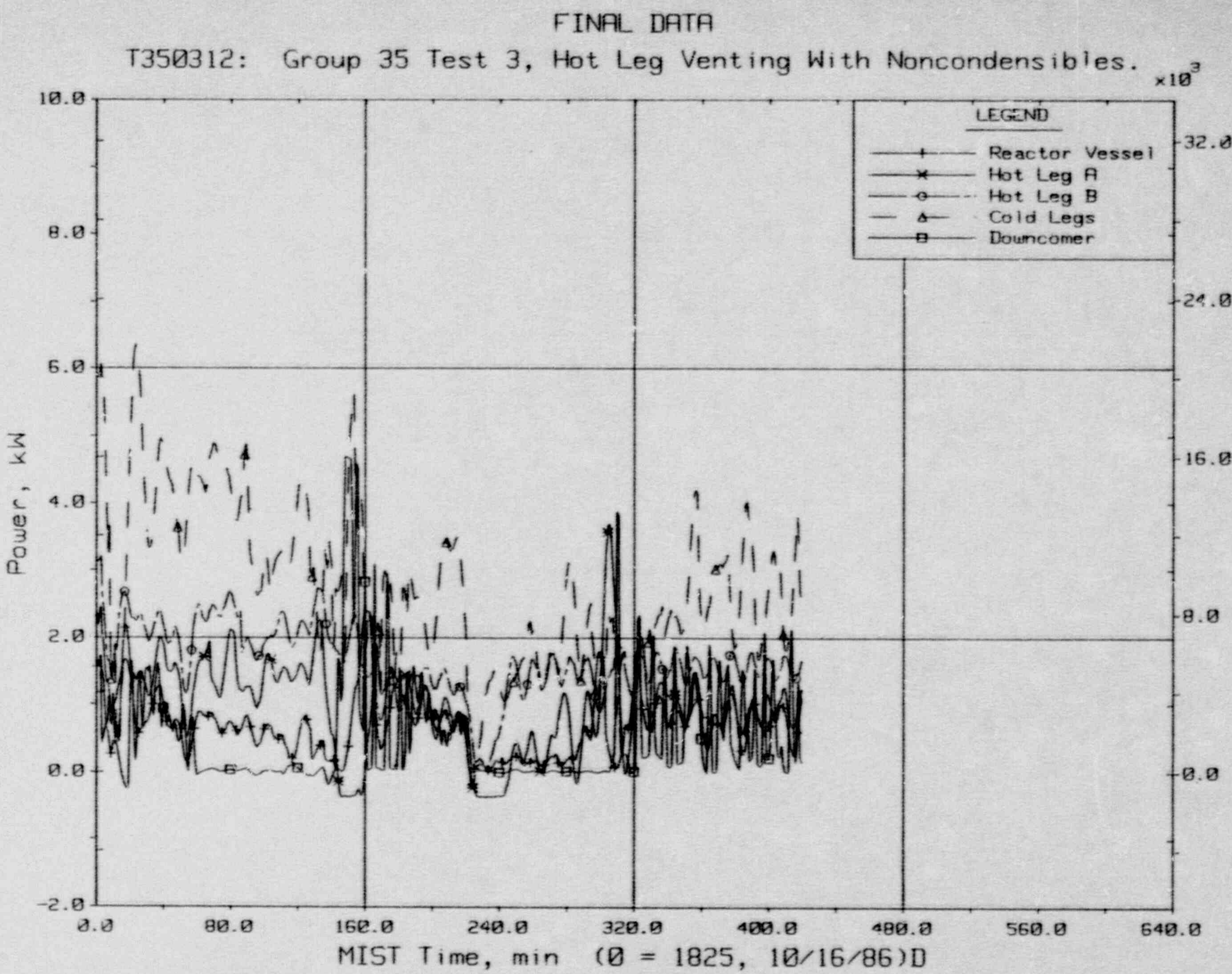
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Primary System Venturi Flow Rates.

Wed May 25 12:32:41 1988

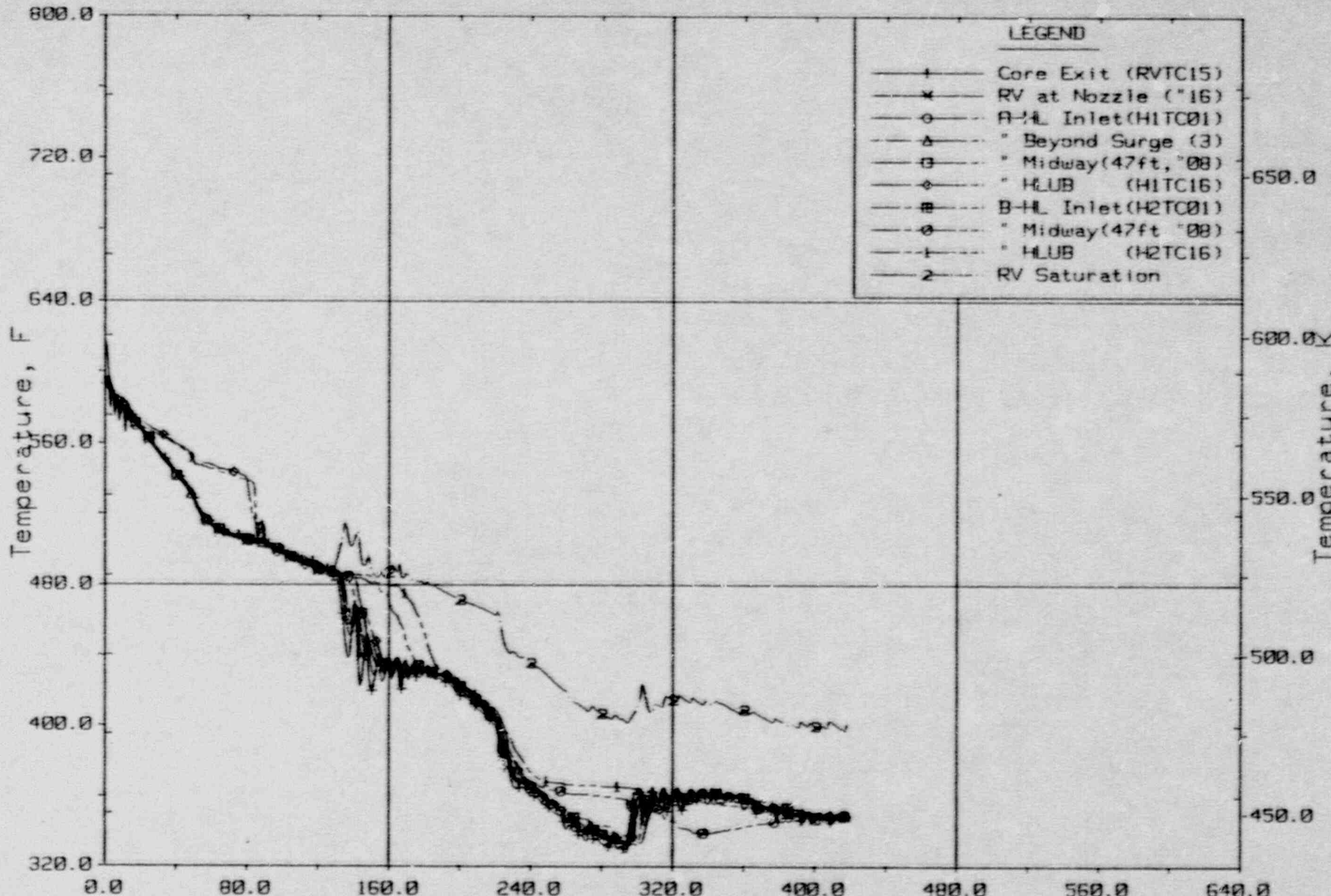
PRFL7



Guard Heater Specified Power Per Primary Component.

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



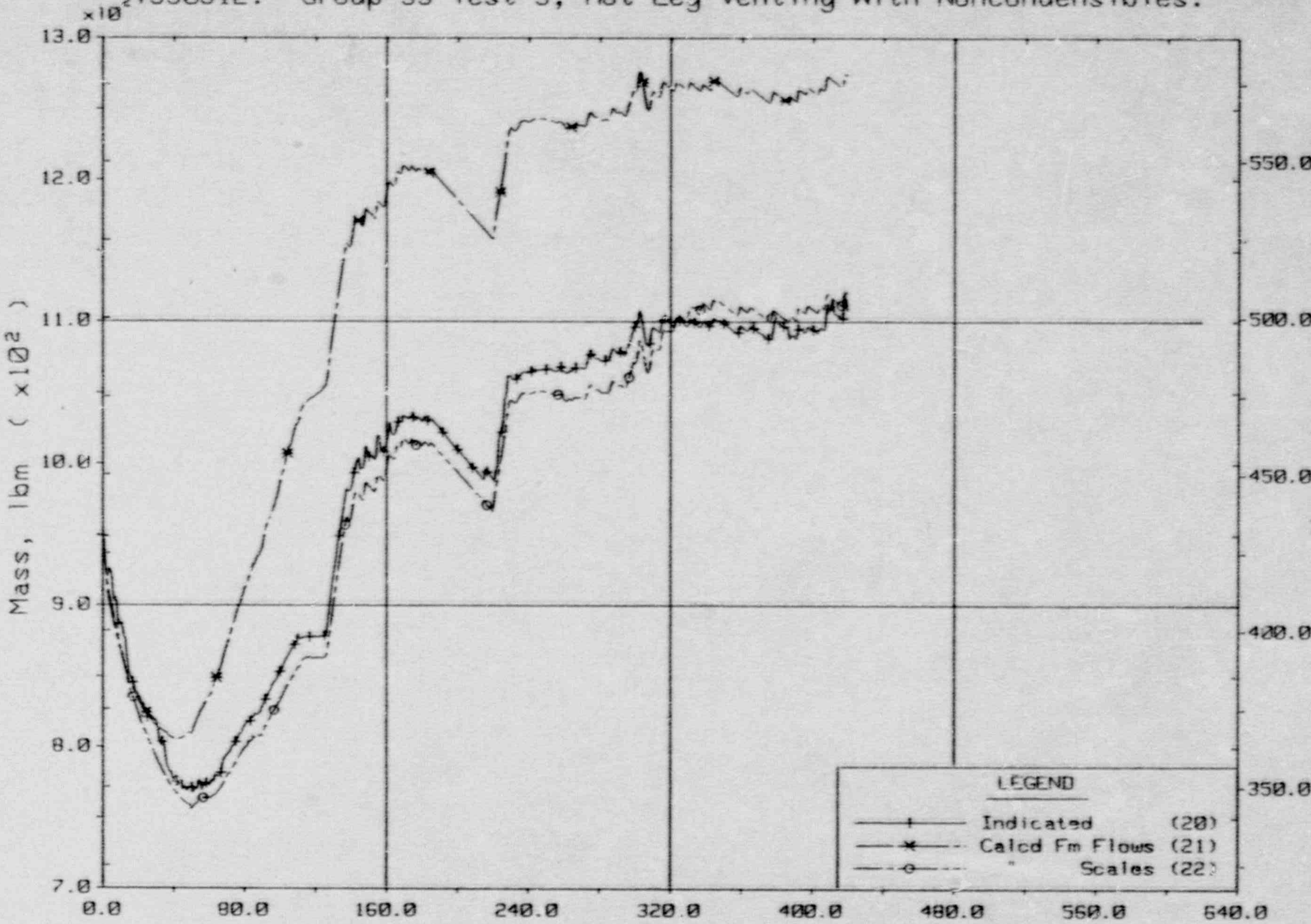
Composite Core Exit and Hot Leg Fluid Temperatures.

Wed May 25 12:40:44 1988

PRKT1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.

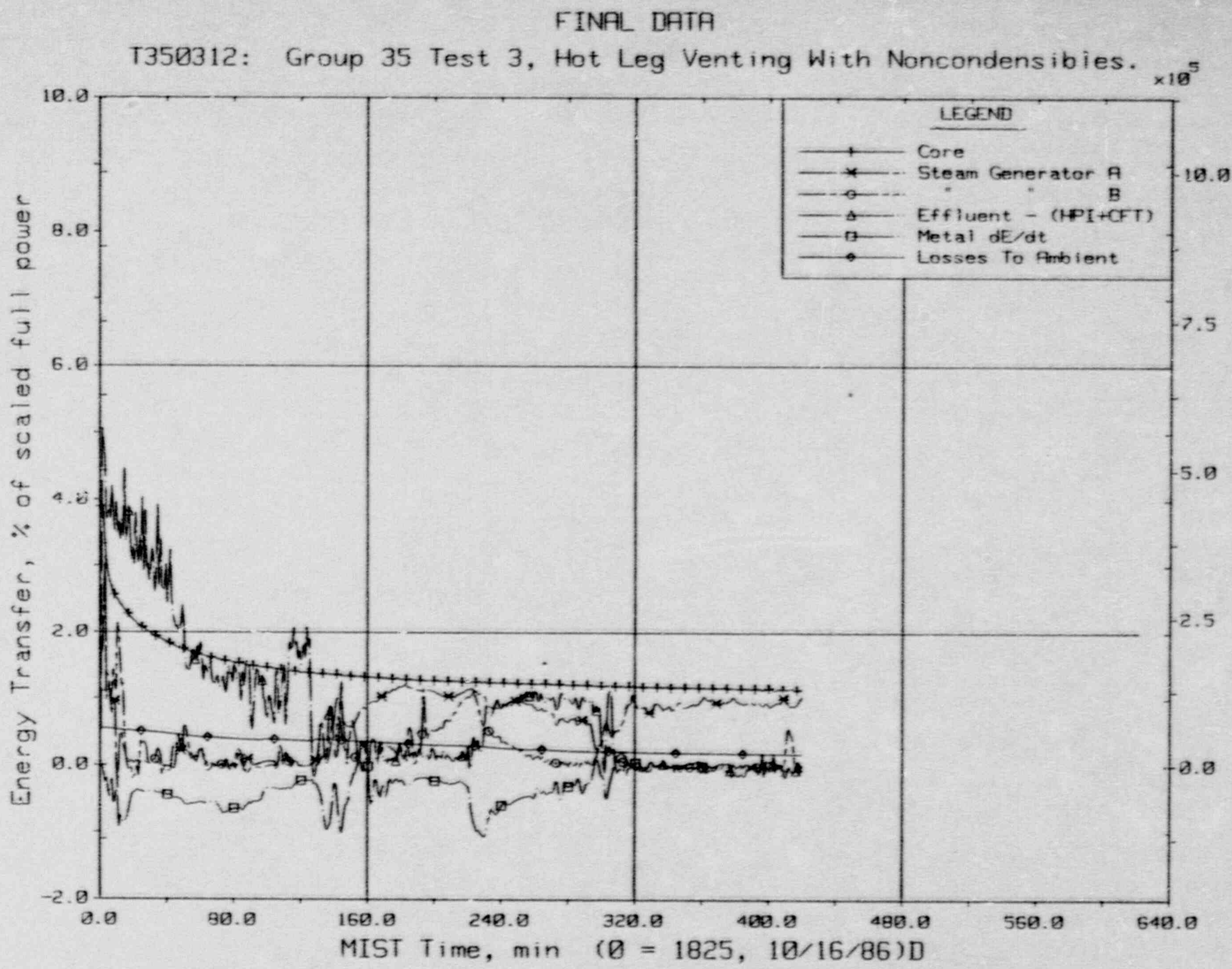


MIST Time, min (0 = 1825, 10/16/86)D

Primary System Total Fluid Mass (PLMLs).

Wed May 25 12:43:51 1988

PRML2



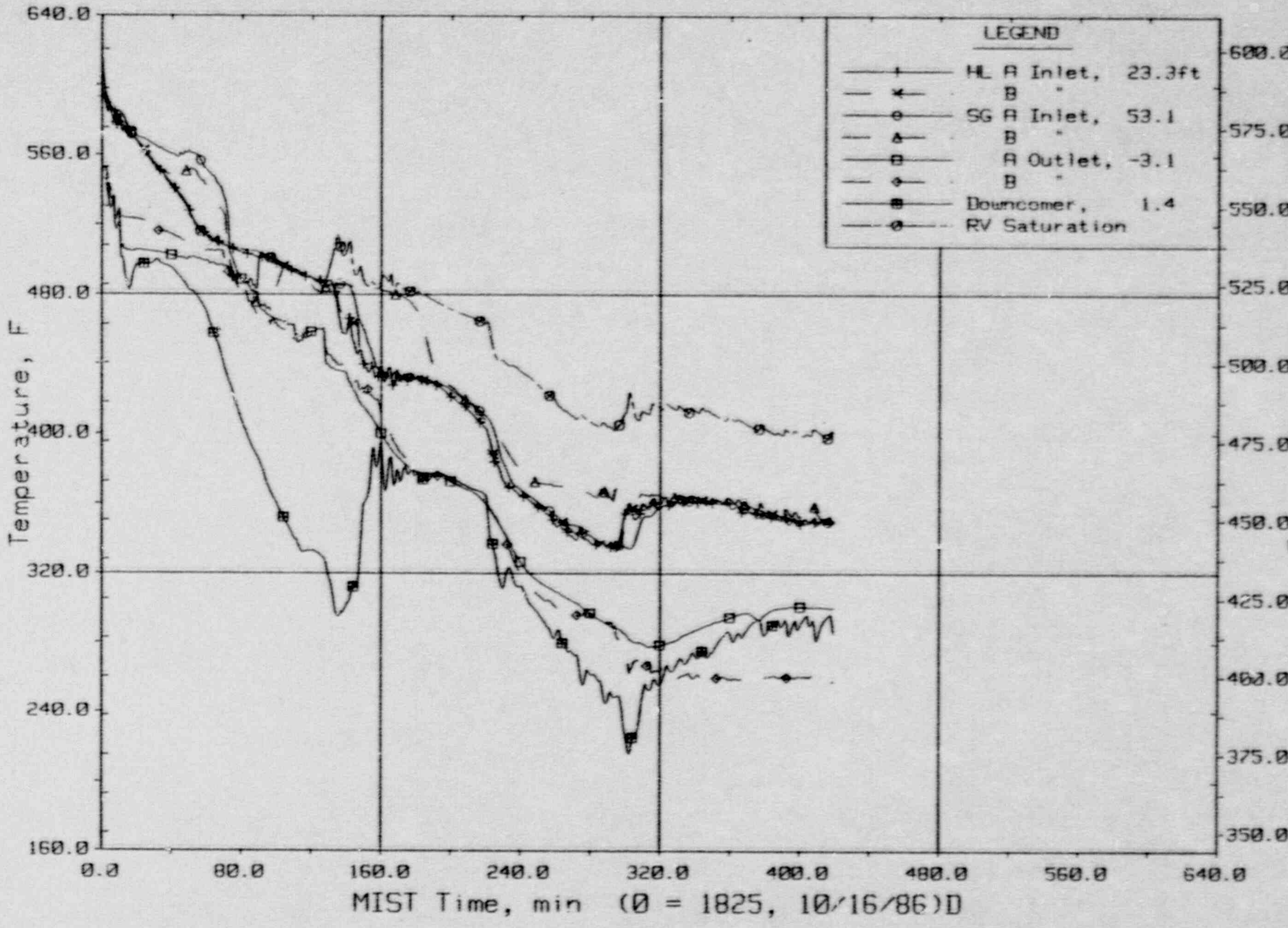
Primary System Energy Transfer.

Wed May 25 12:57:22 1988

PROE2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



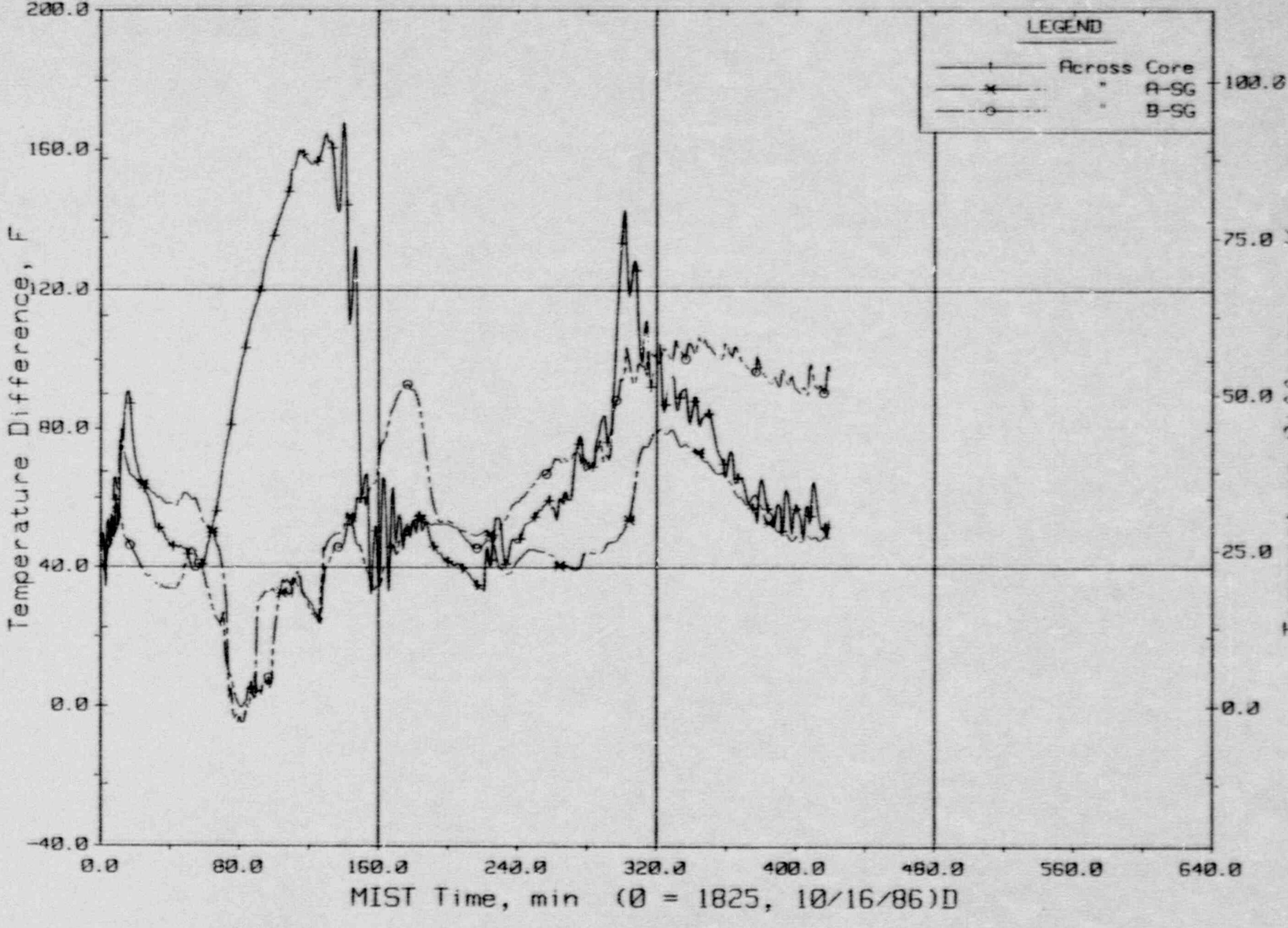
Primary System Fluid Temperatures (RTDs).

Wed May 25 13:01:16 1988

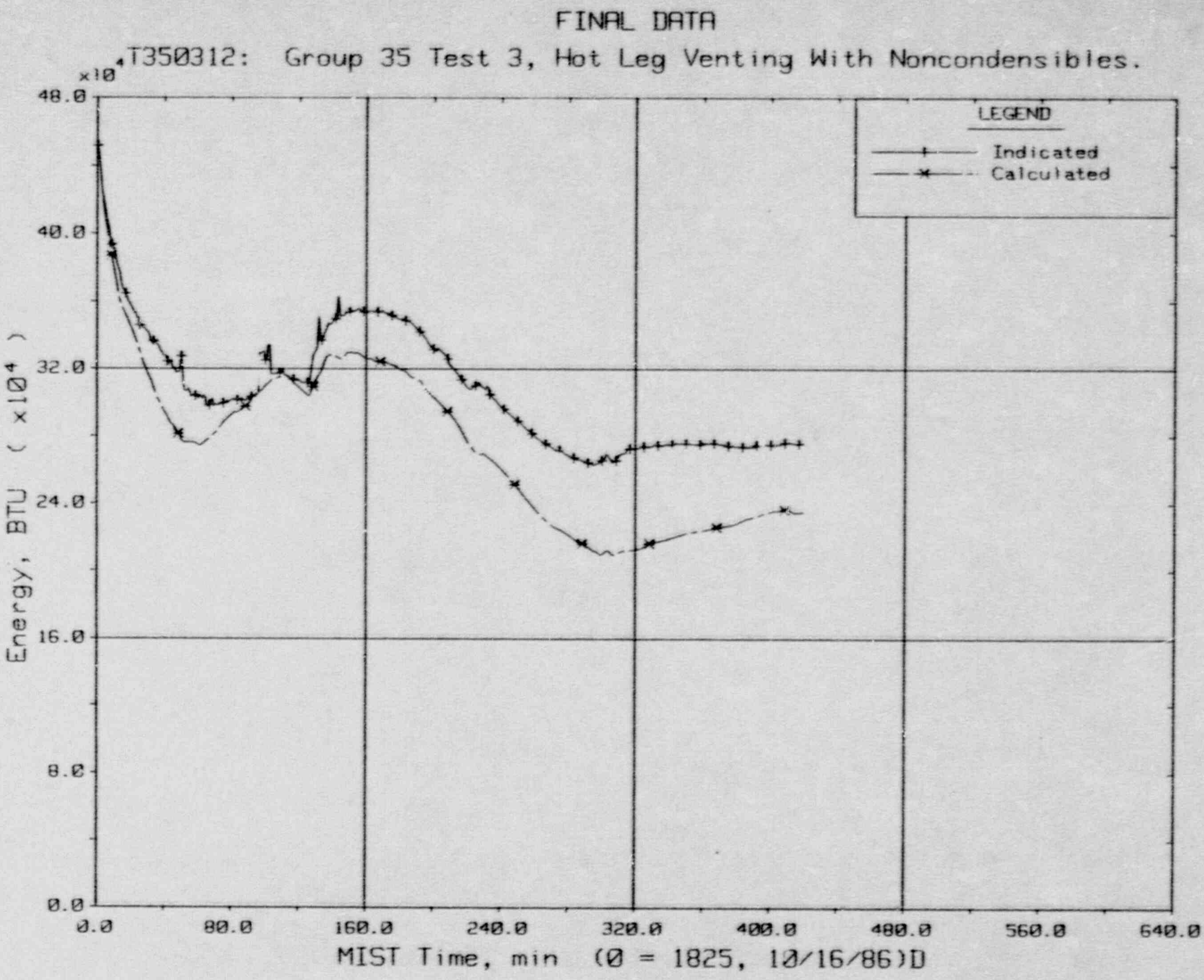
PRRT0

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Key Temperature Differences.



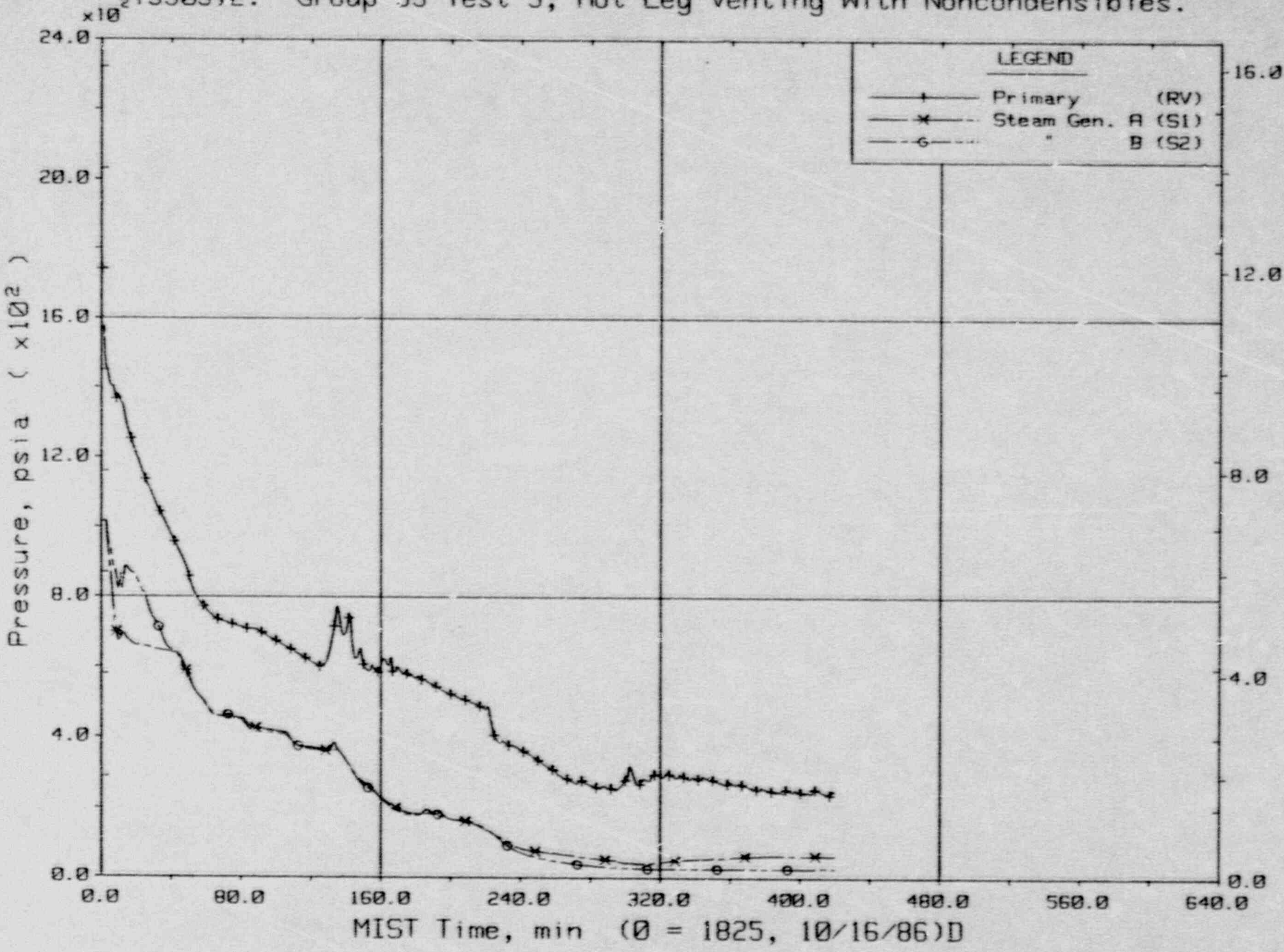
Primary System Total Fluid Energy.

Wed May 25 13:06:38 1988

PRTE2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



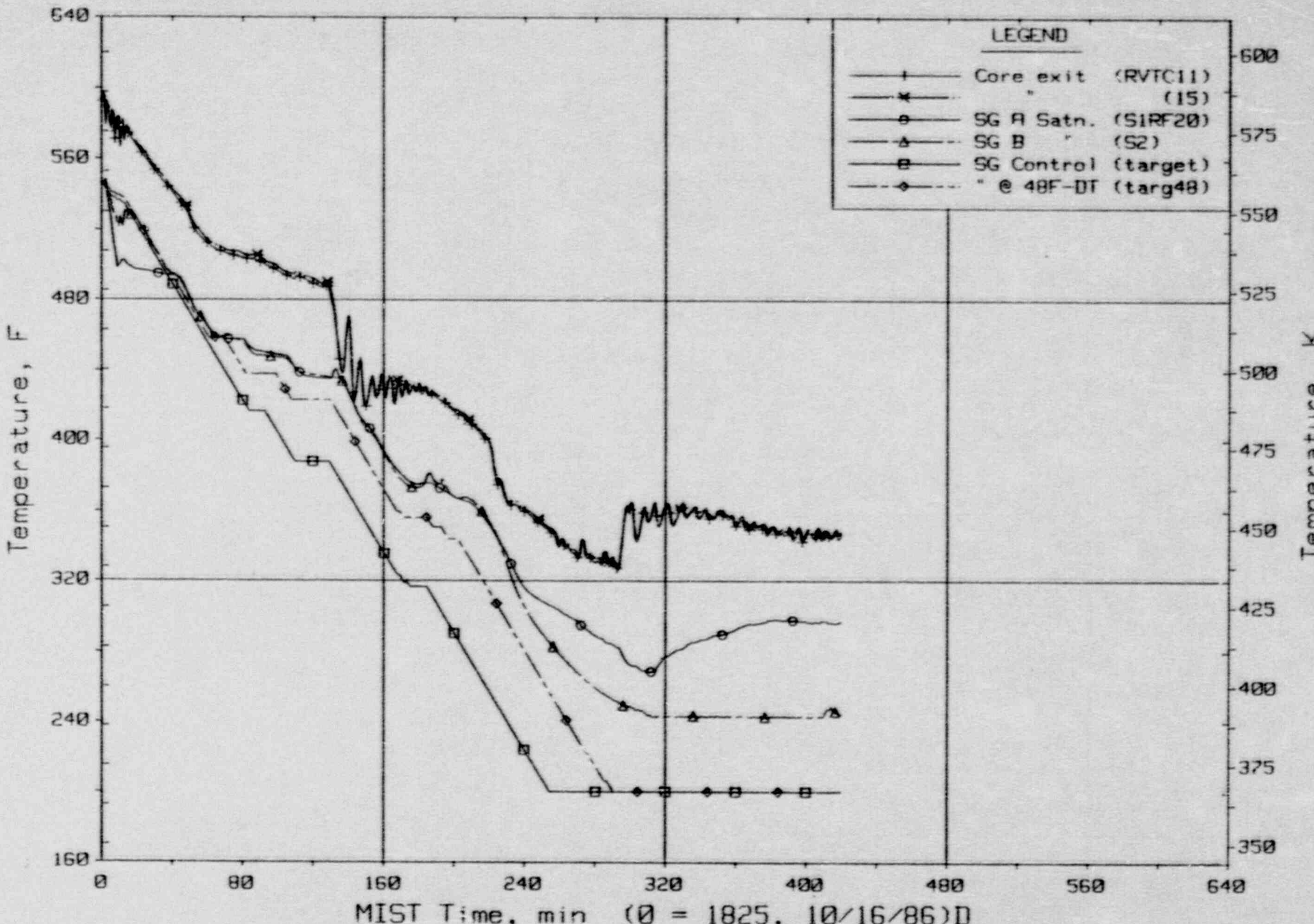
Primary and Secondary System Pressures (GP01s).

Wed May 25 13:09:06 1988

PSGP1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



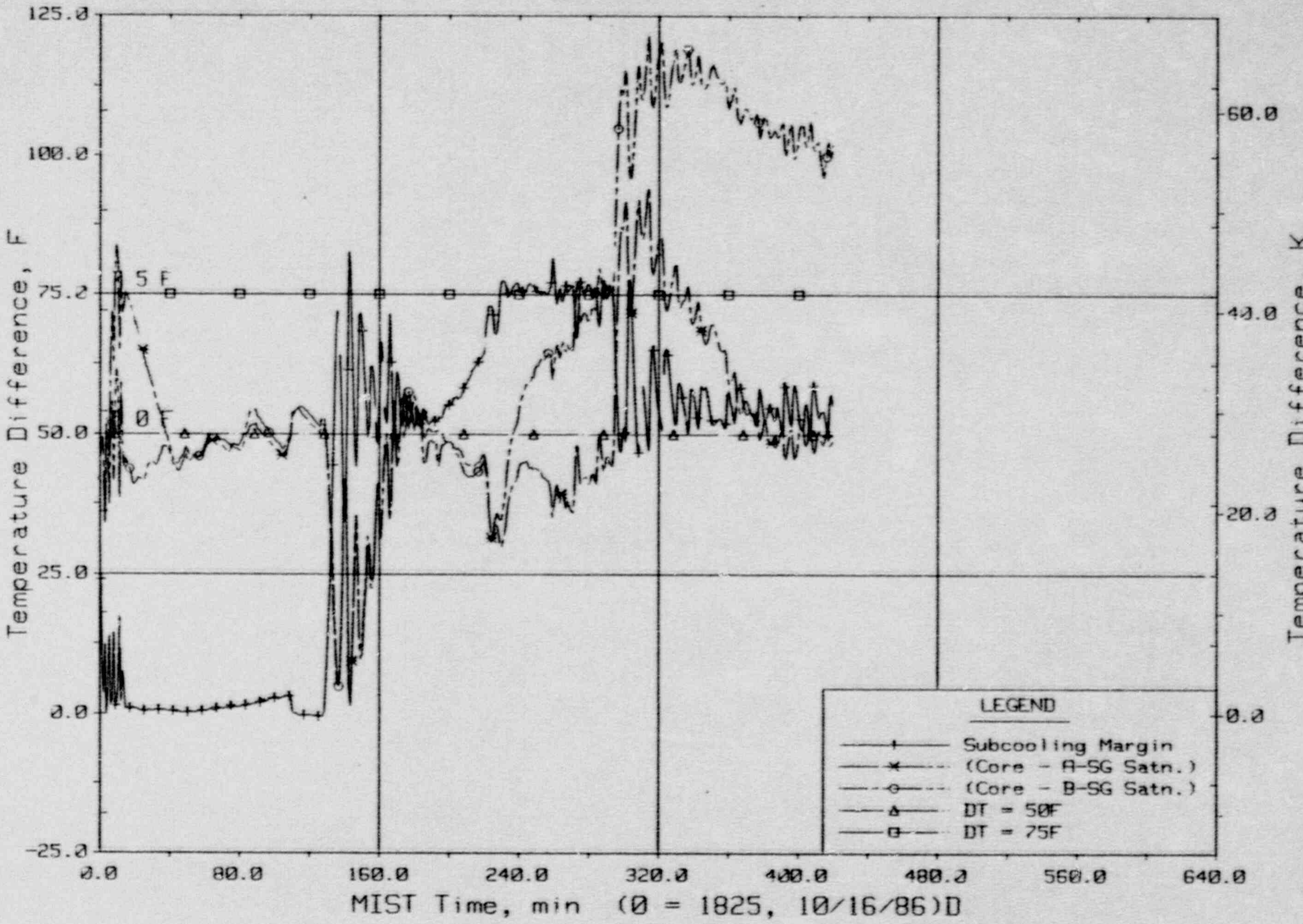
Steam Generator Secondary Saturation and Control Temperatures.

Fri Jan 6 11:13:16 1989

PSTC3

FINAL DATA

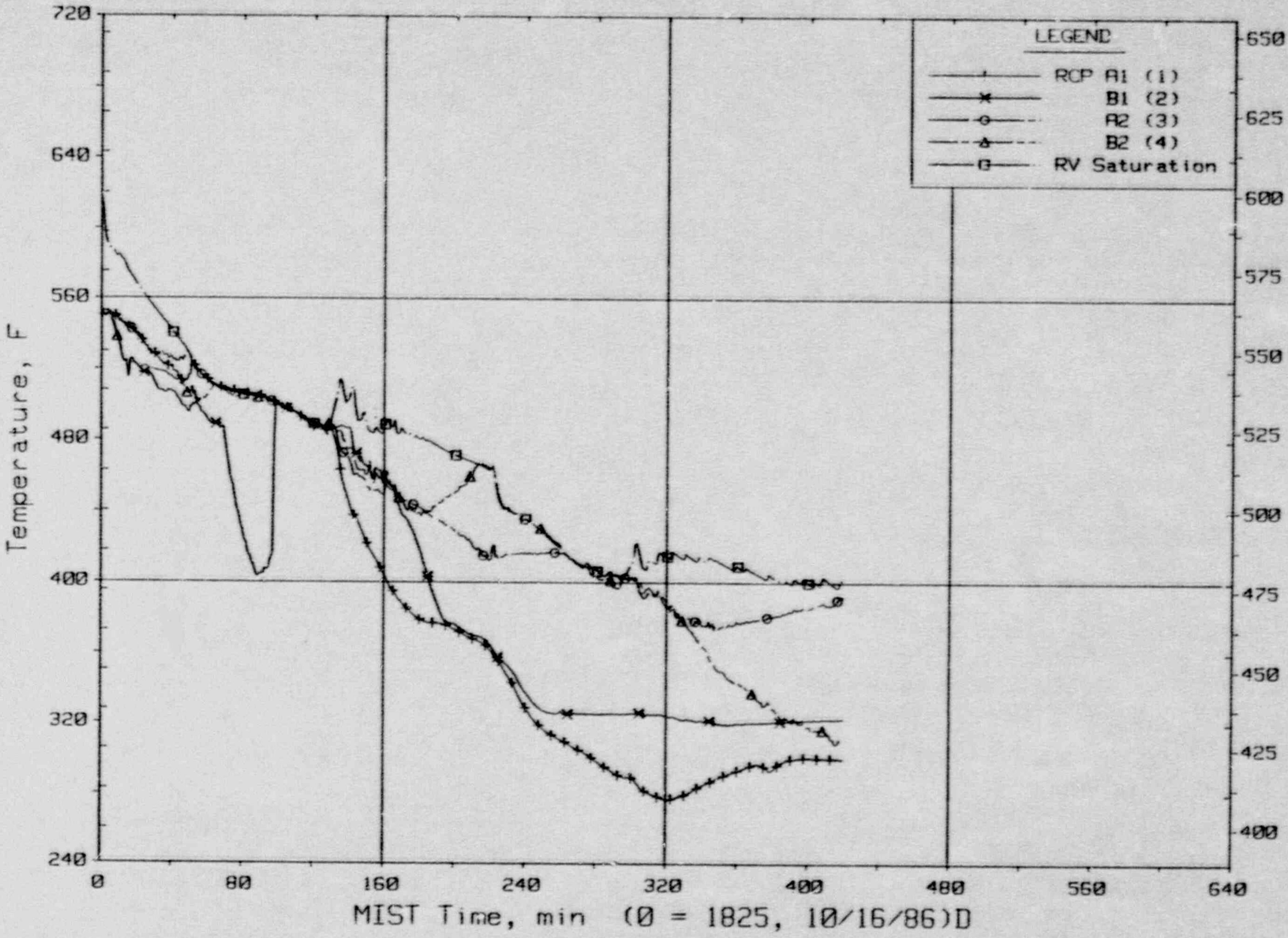
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Control Temperature Differences.

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



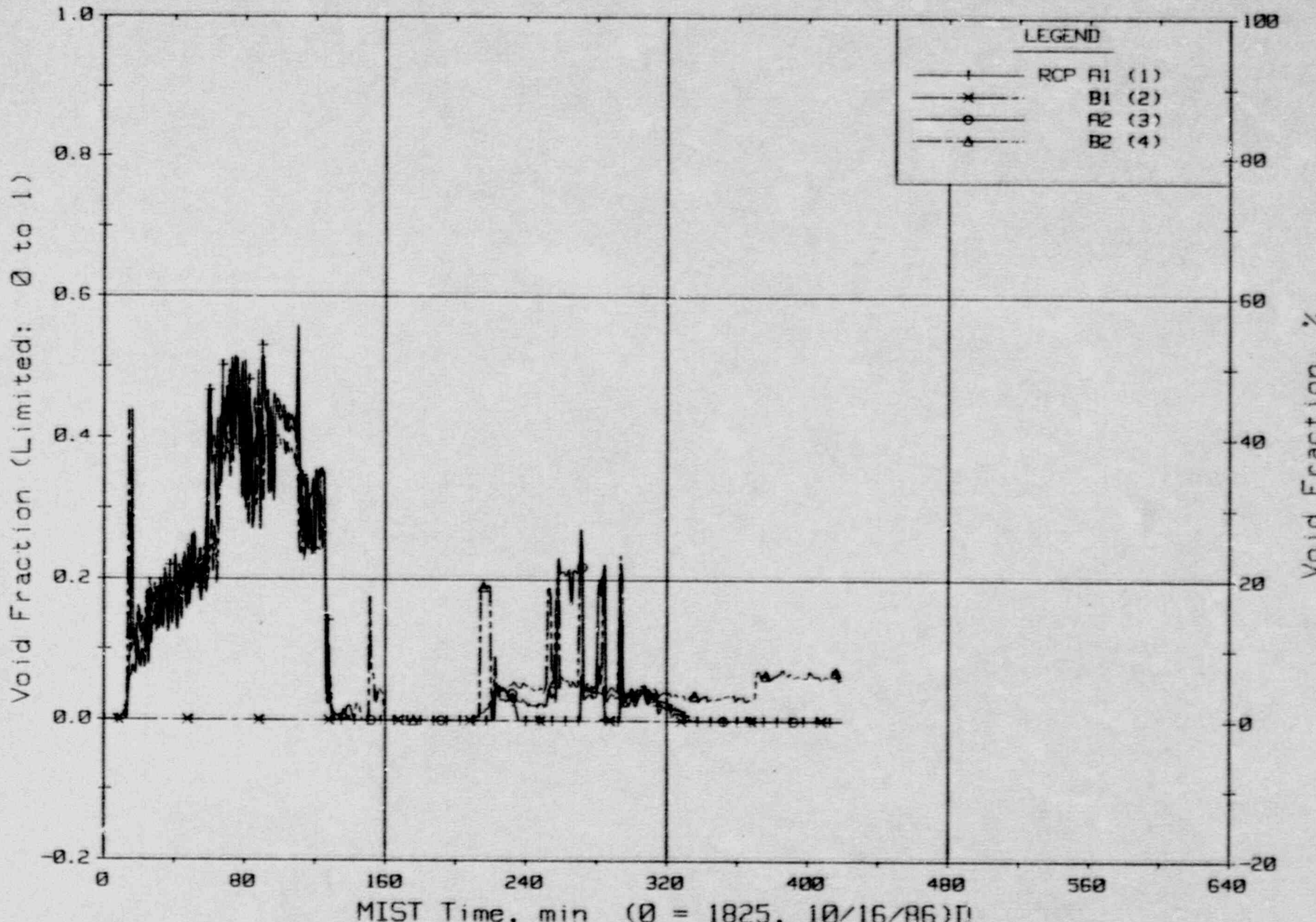
Pump Suction Fluid Temperature (CnRT01s).

Fri Jan 6 11:20:00 1989

PURT0

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



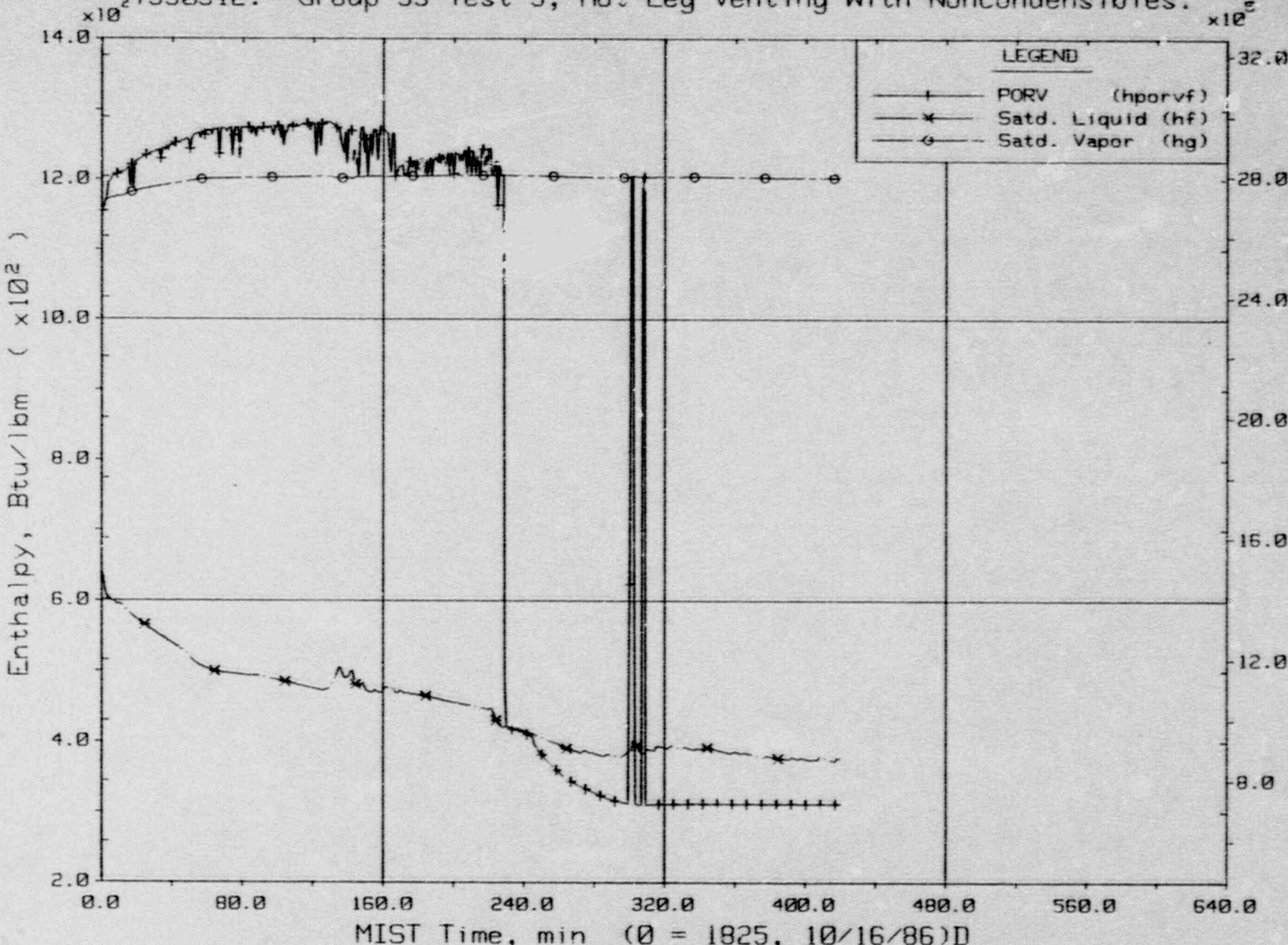
Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

Fri Jan 6 11:16:37 1989

PUVF2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



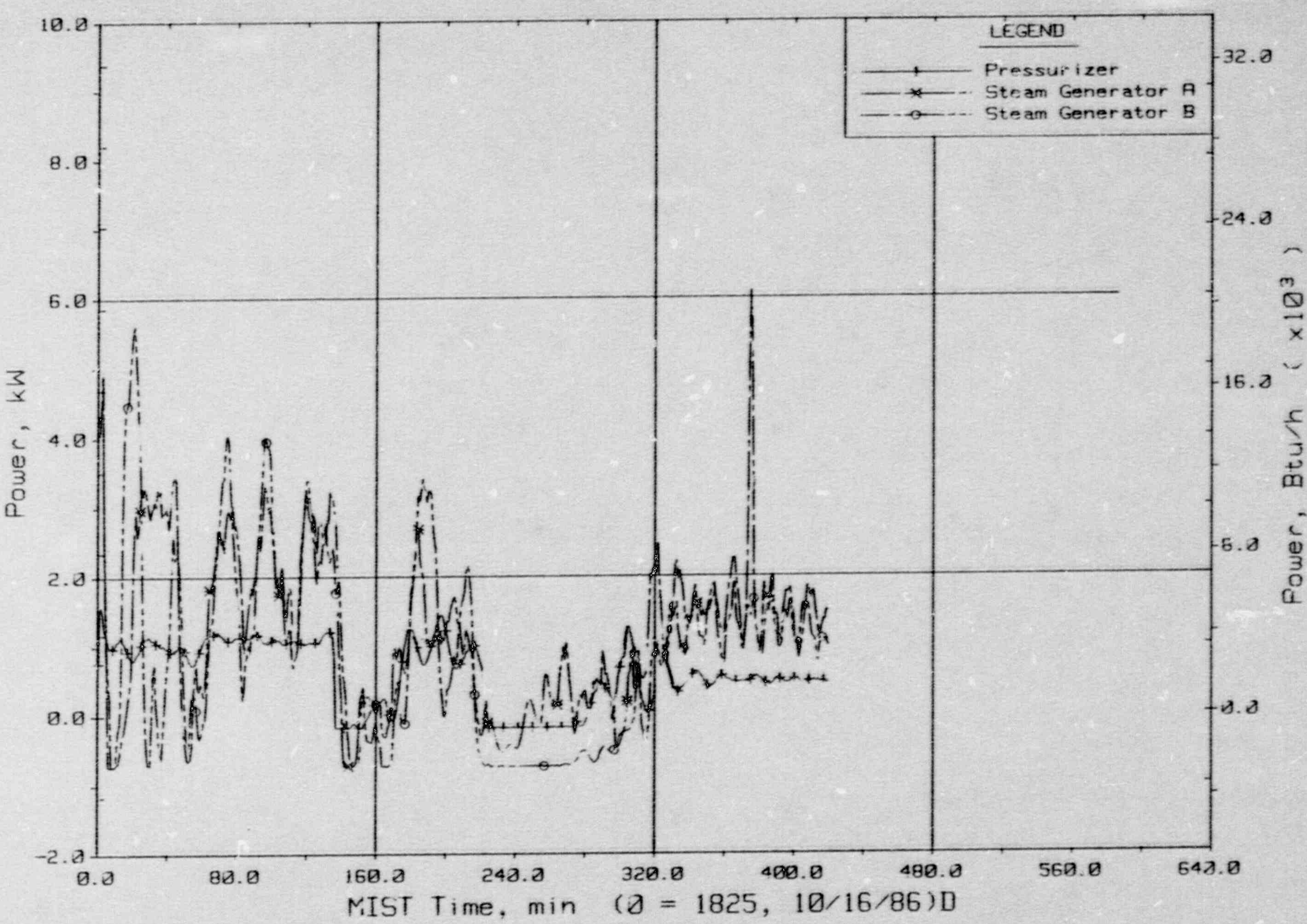
Power-Operated Relief Valve Enthalpy (Based On Flow Rate).

Wed May 25 13:20:21 1988

P7EN1

FINAL DATA

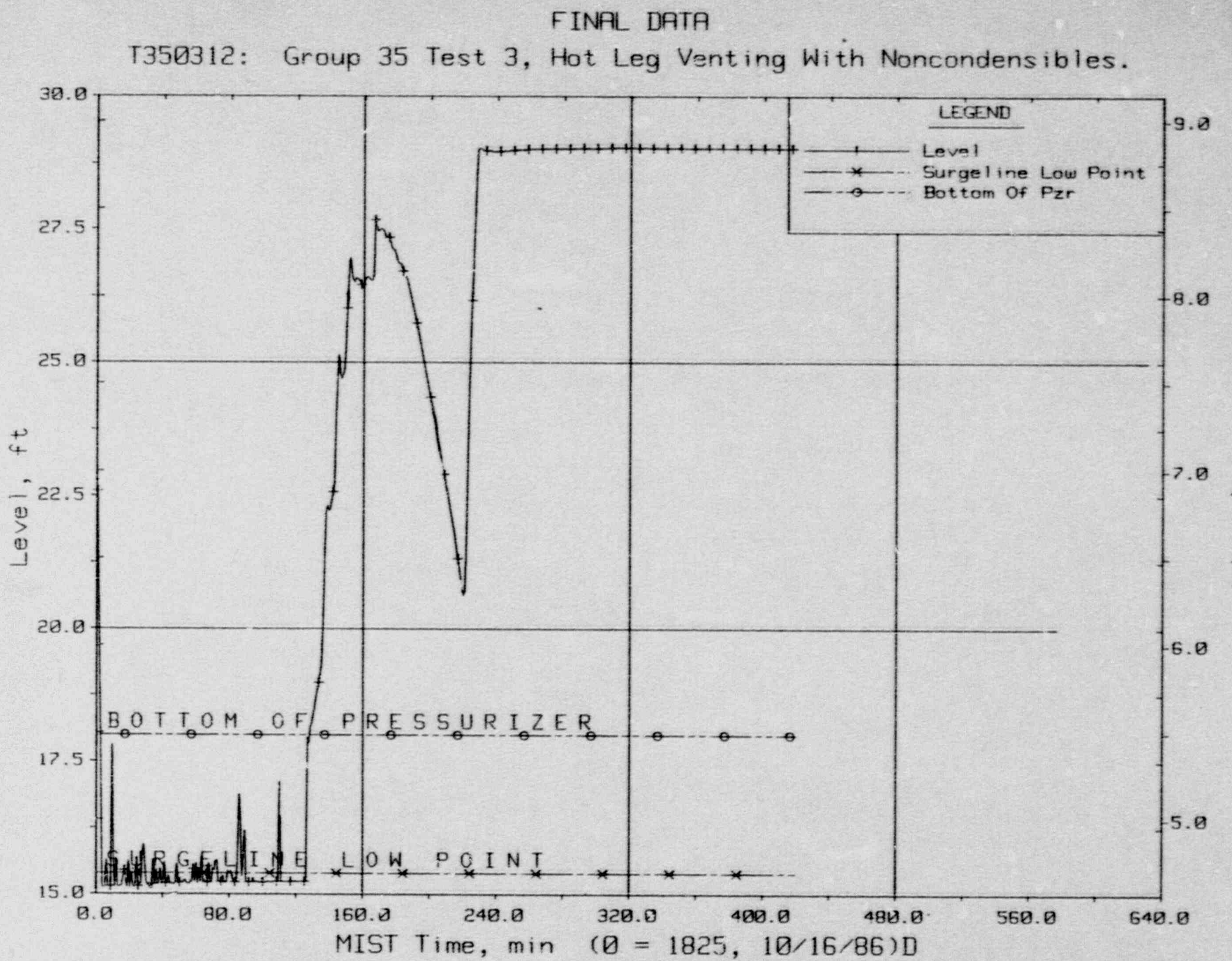
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Guard Heater Specified Power, Pressurizer and Steam Generators.

Wed May 25 13:24:29 1988

PZGQ1



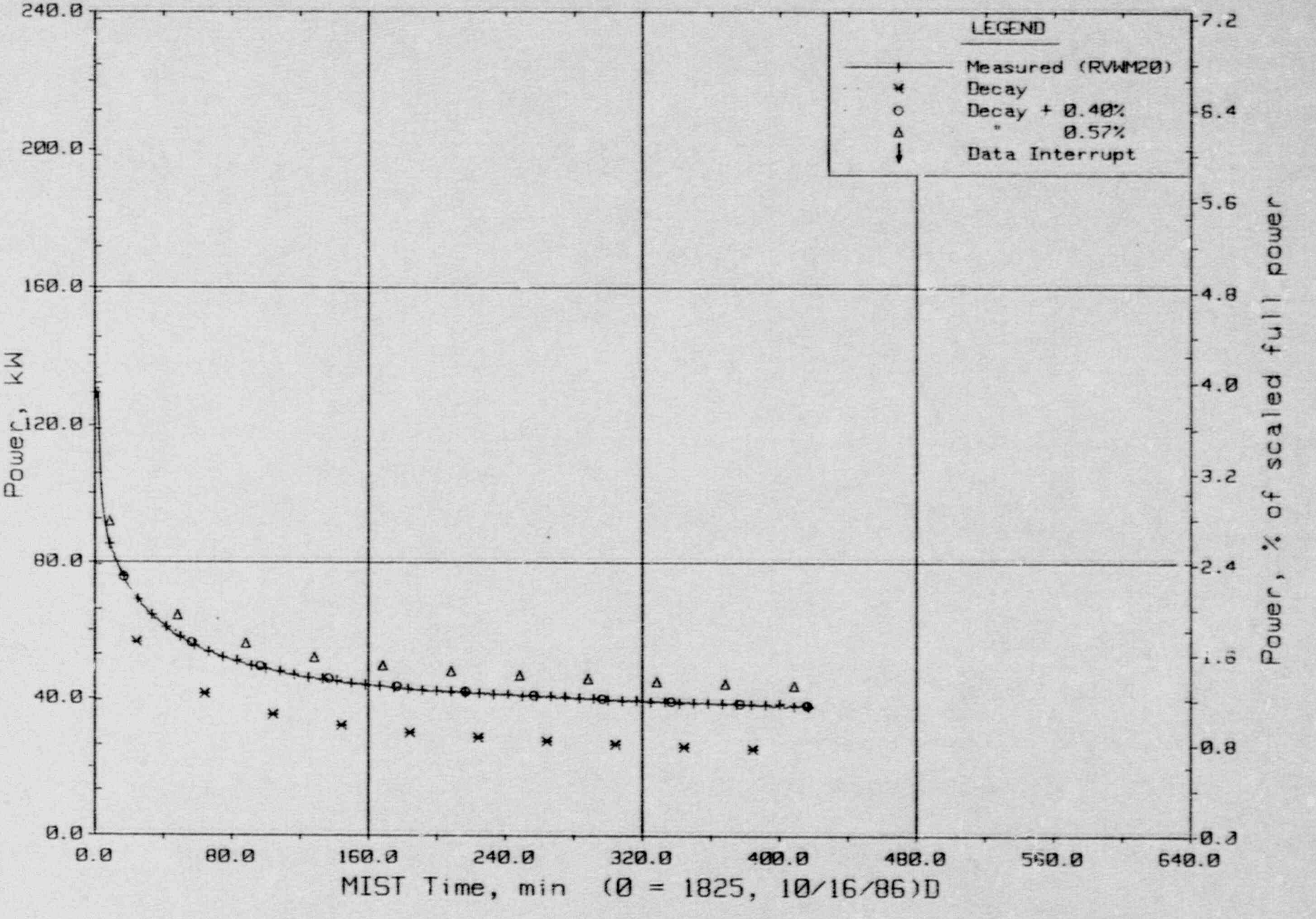
Pressurizer Collapsed Liquid Level (PZLV20).

Wed May 25 13:28:15 1988

PZLV1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



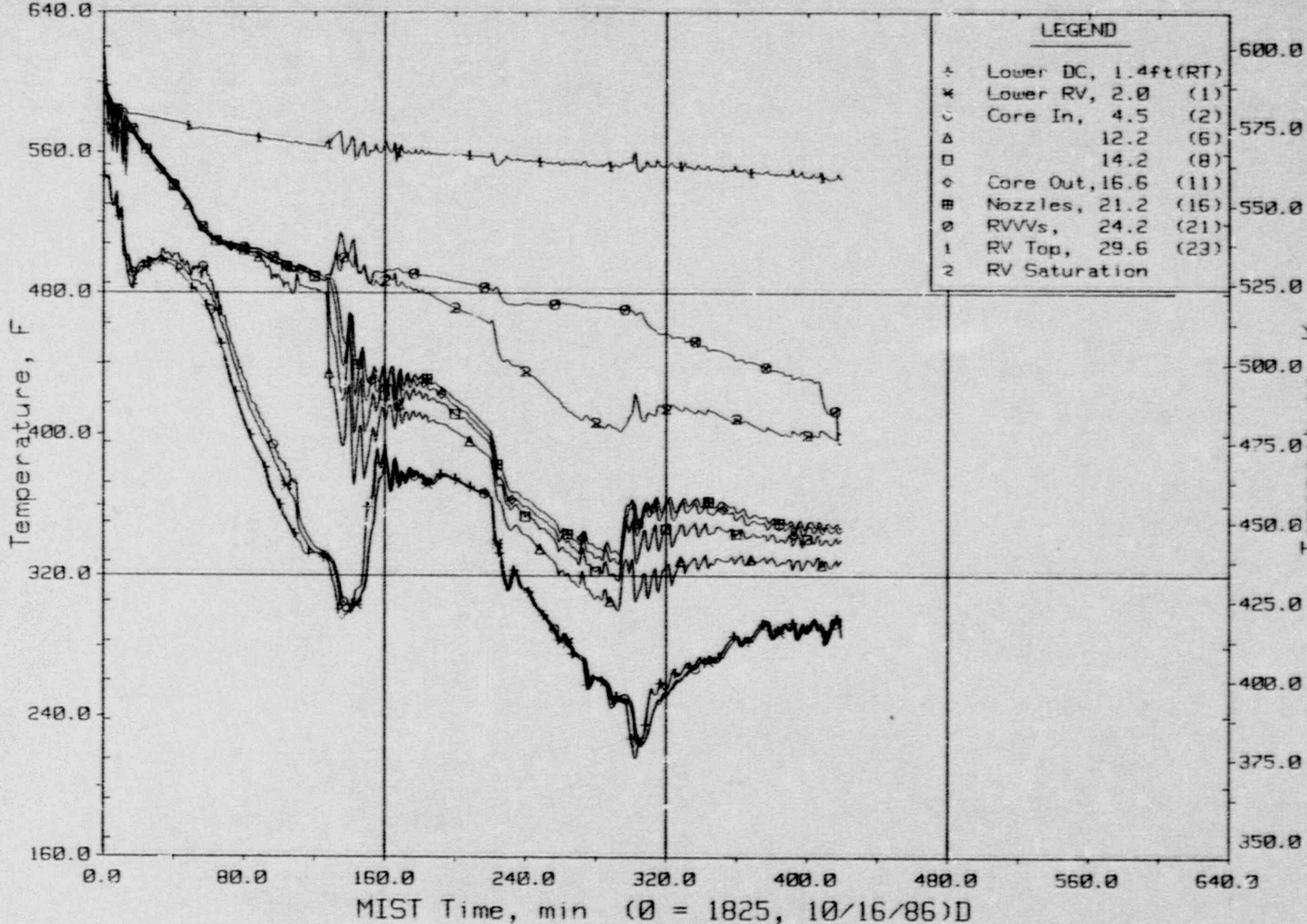
Core Power.

Wed May 25 13:31:26 1988

RVKW0

FINAL DATA

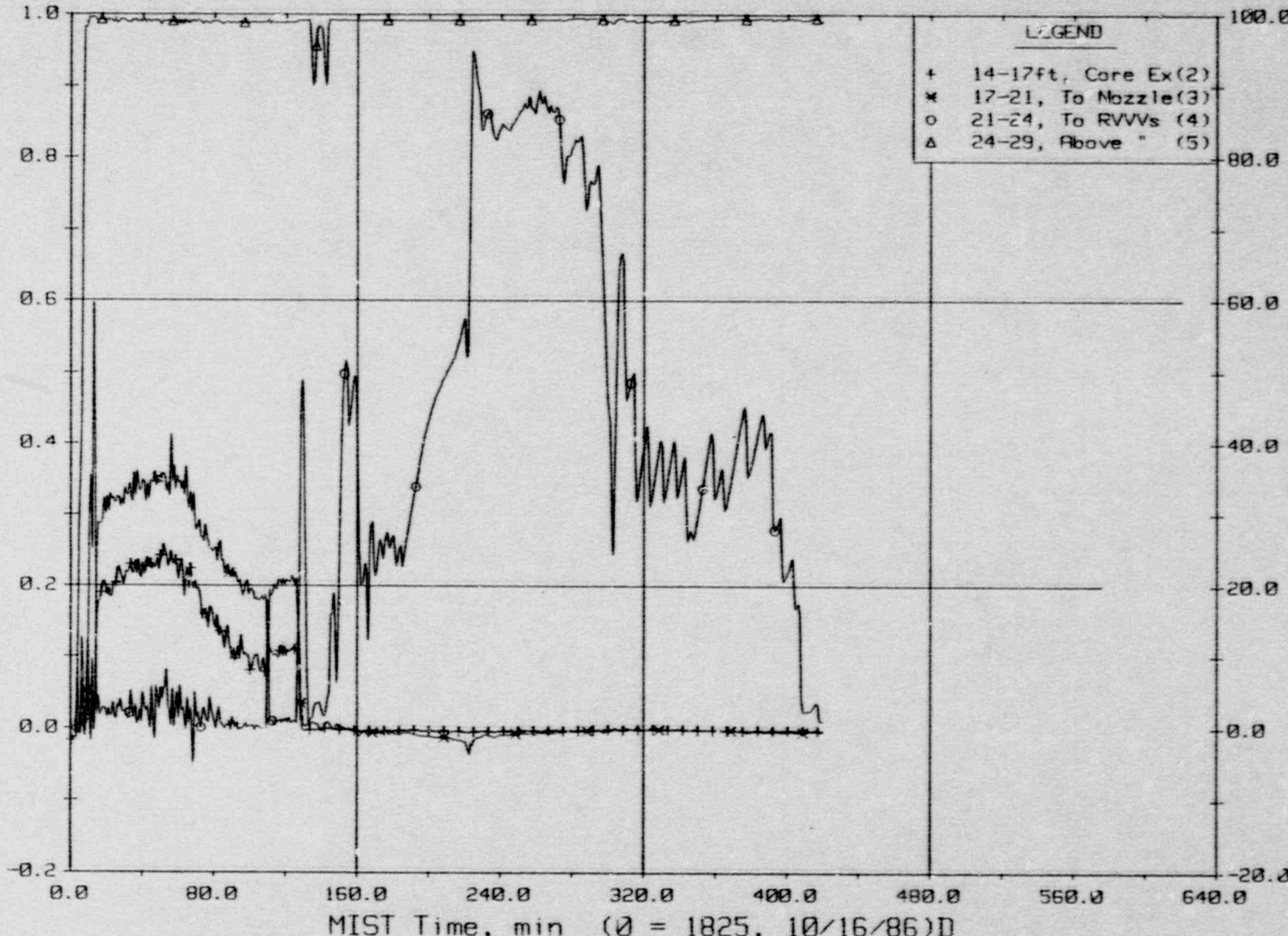
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



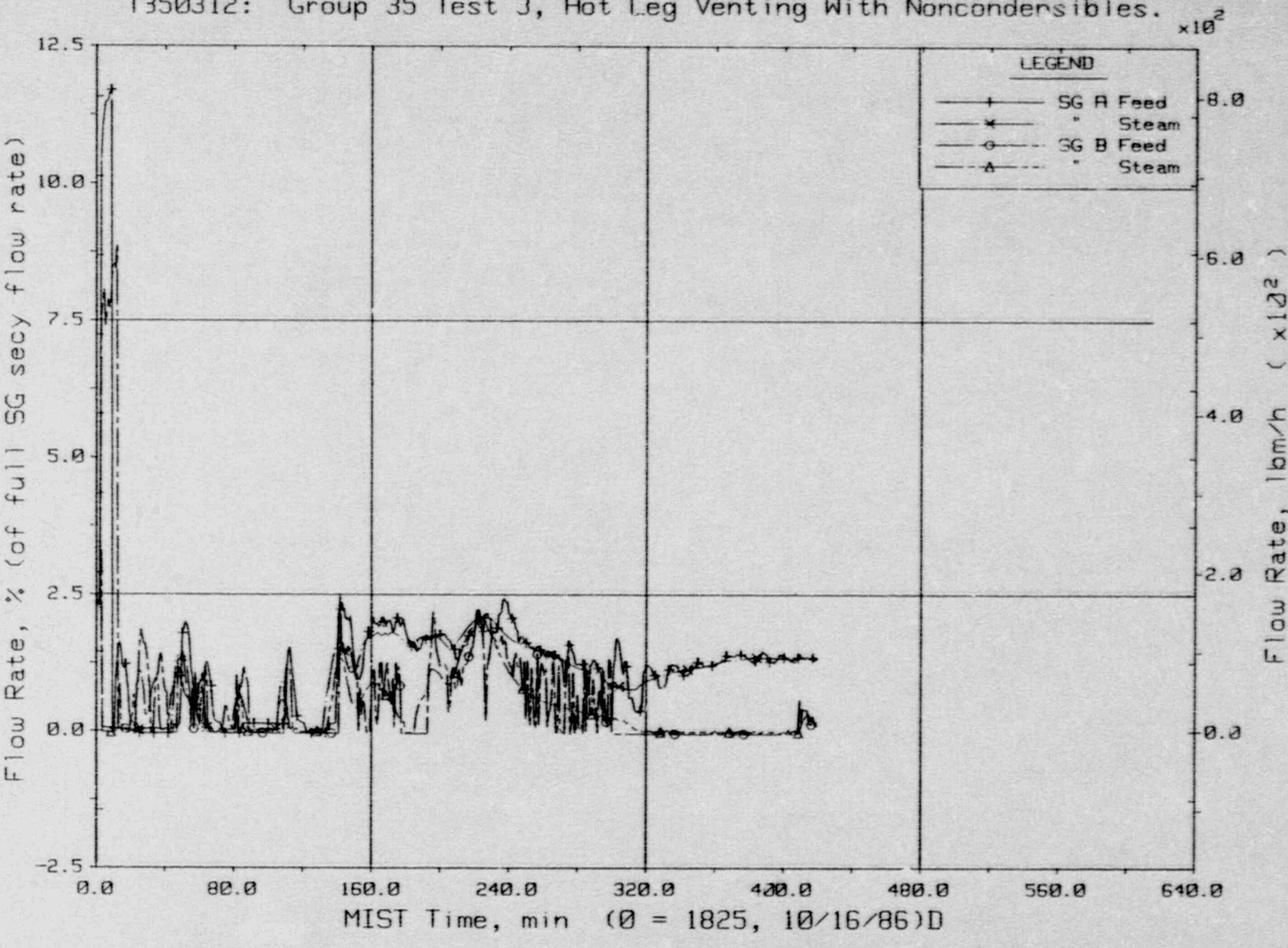
Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Wed May 25 13:40:05 1988

RVVF1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



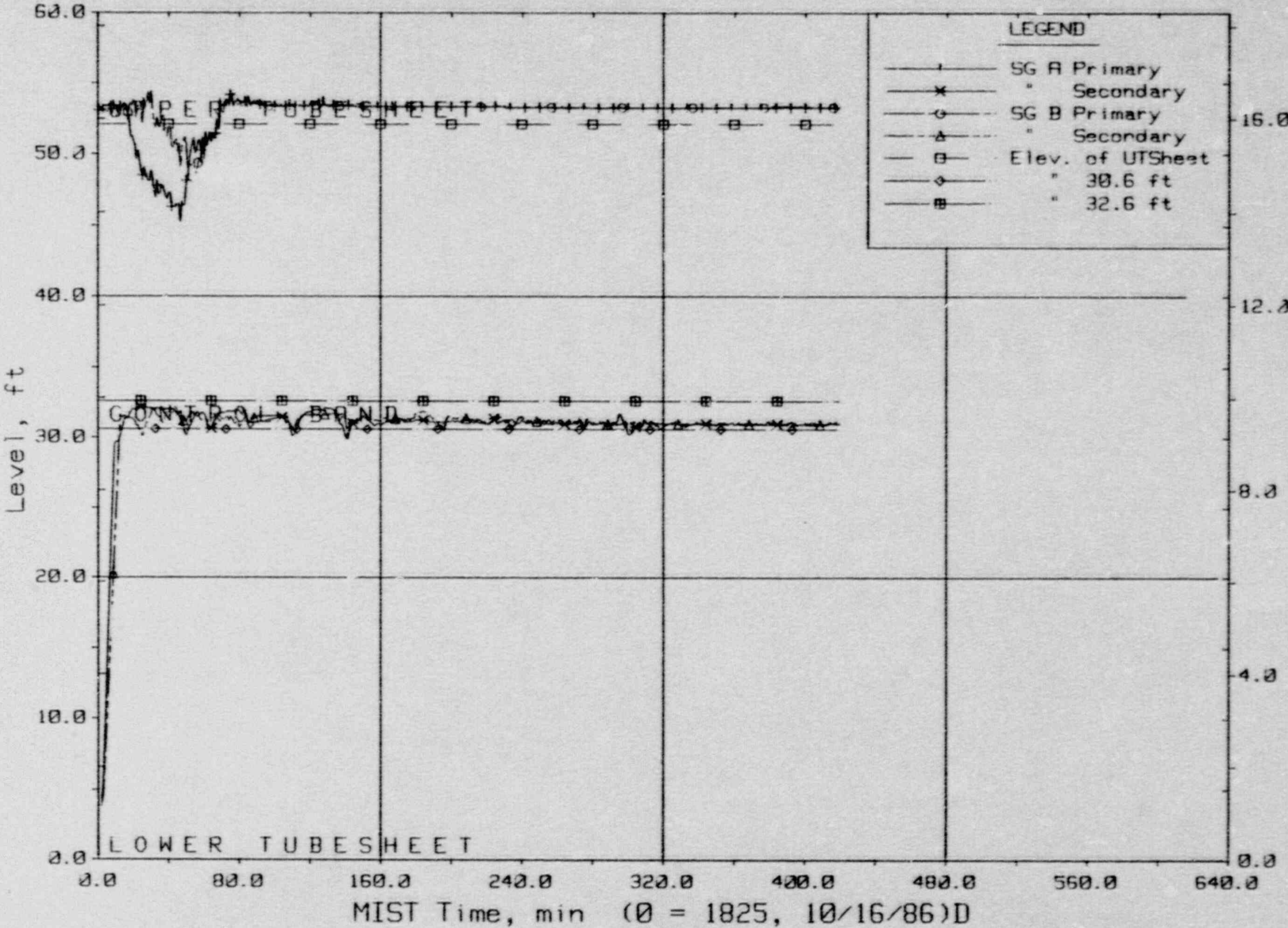
Steam Generator Secondary System Flow Rates.

Wed May 25 13:43:23 1988

SGFL2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



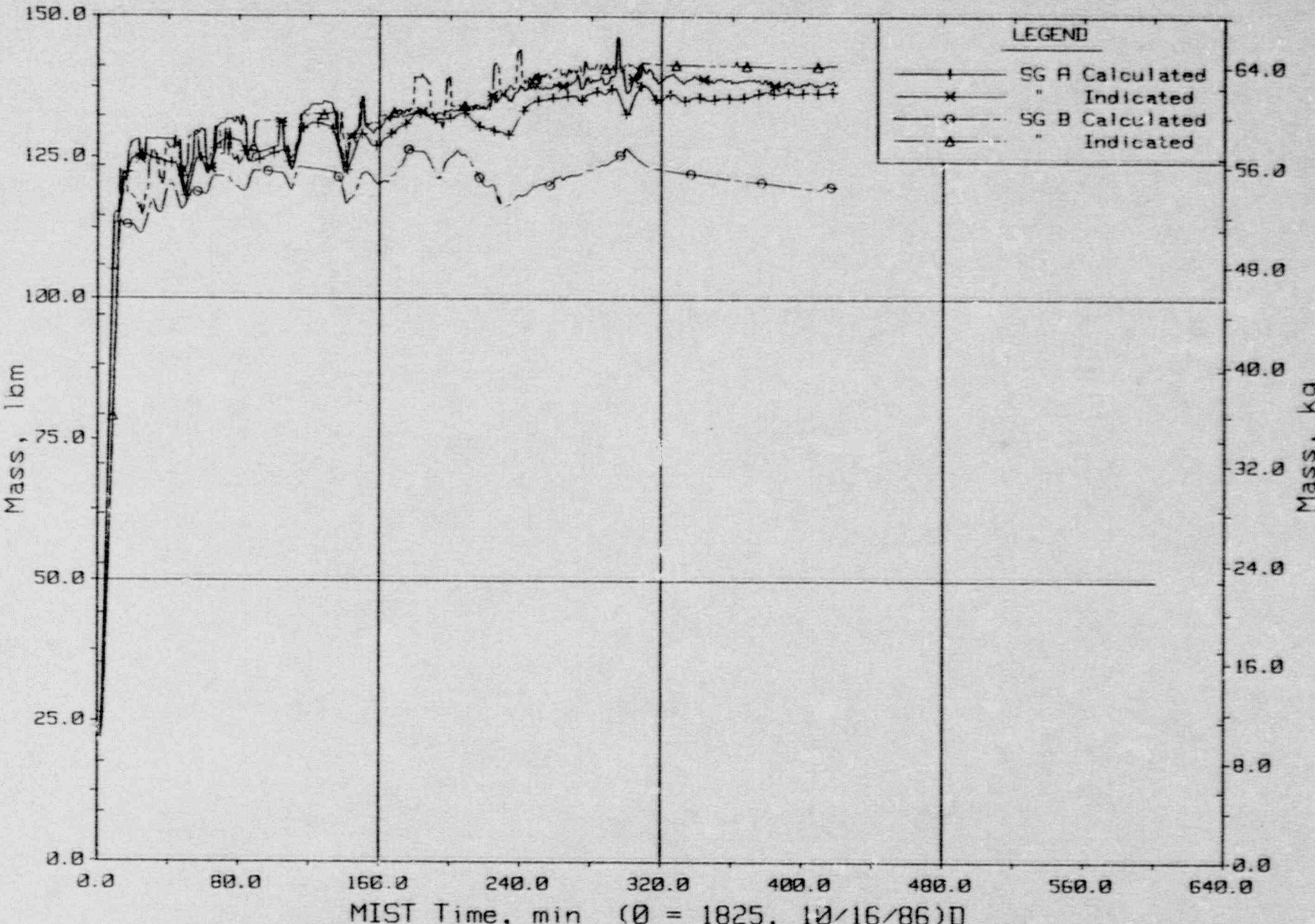
Steam Generator Collapsed Liquid Levels.

Wed May 25 13:47:07 1988

SGLV2

FINAL DATA

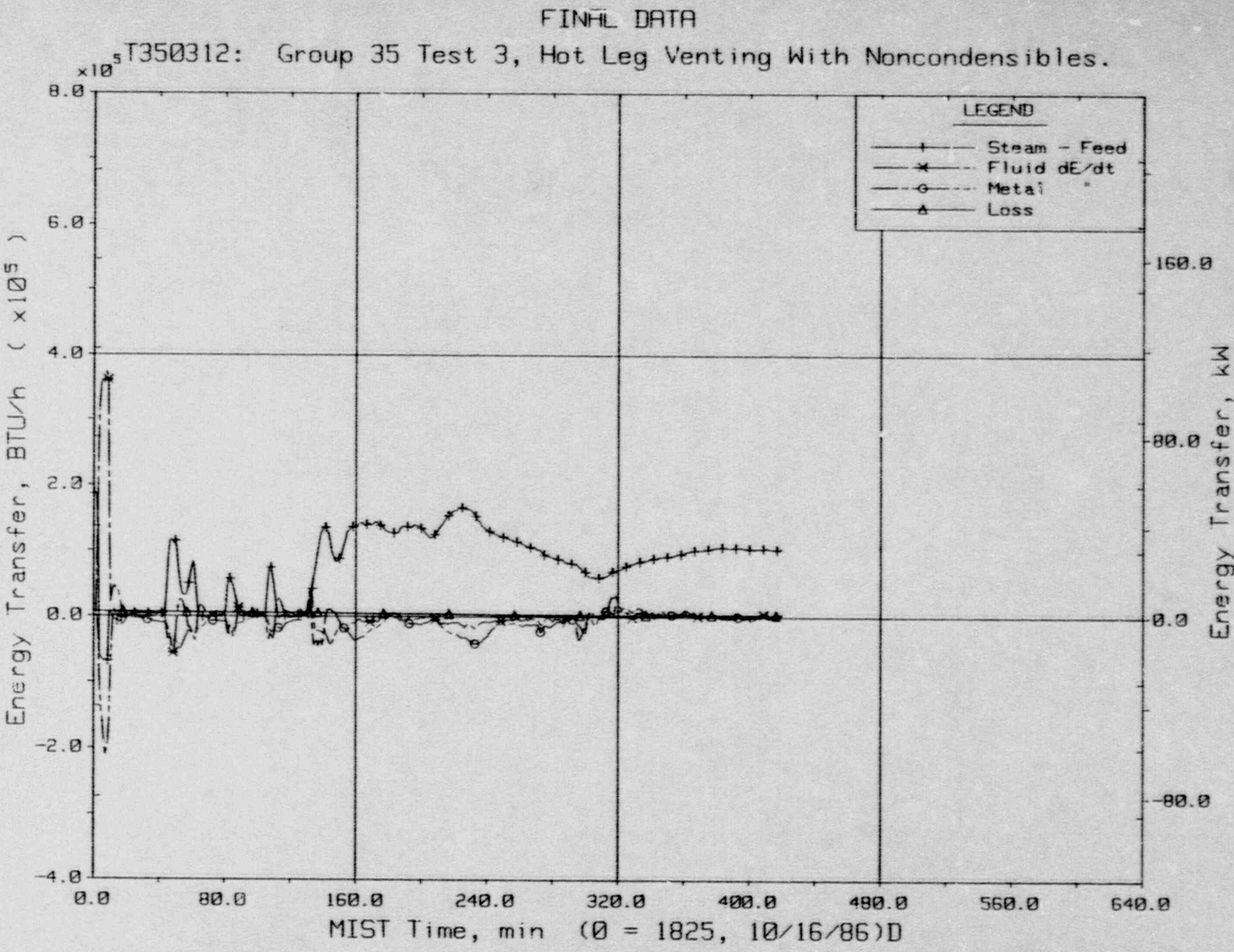
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Steam Generator Secondary Fluid Mass Balances.

Wed May 25 13:50:17 1988

SGML1



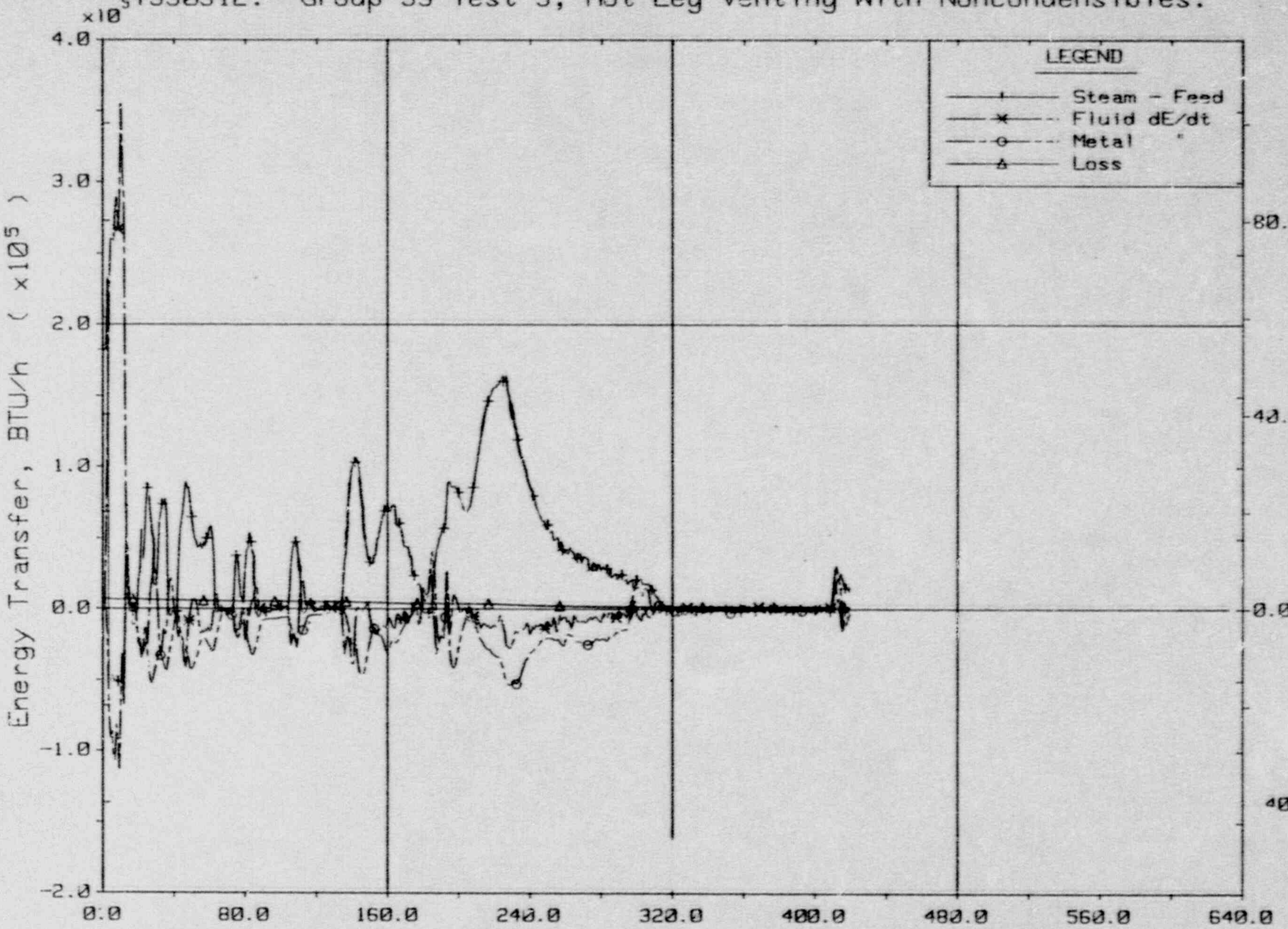
Steam Generator A Energy Transfer.

Wed May 25 13:53:41 1988

SGQE3

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



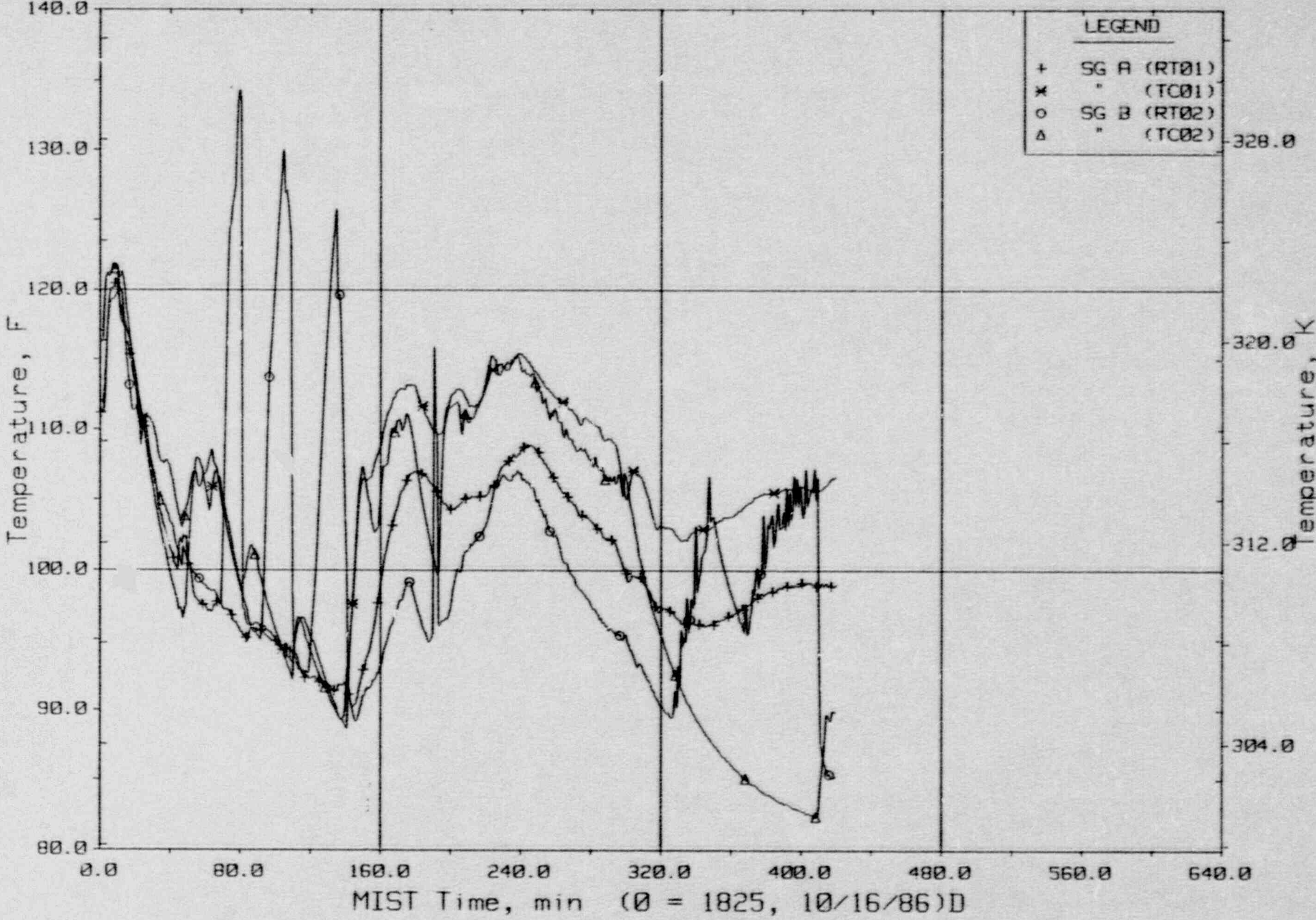
Steam Generator B Energy Transfer.

Wed May 25 13:57:01 1988

SGQE6

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



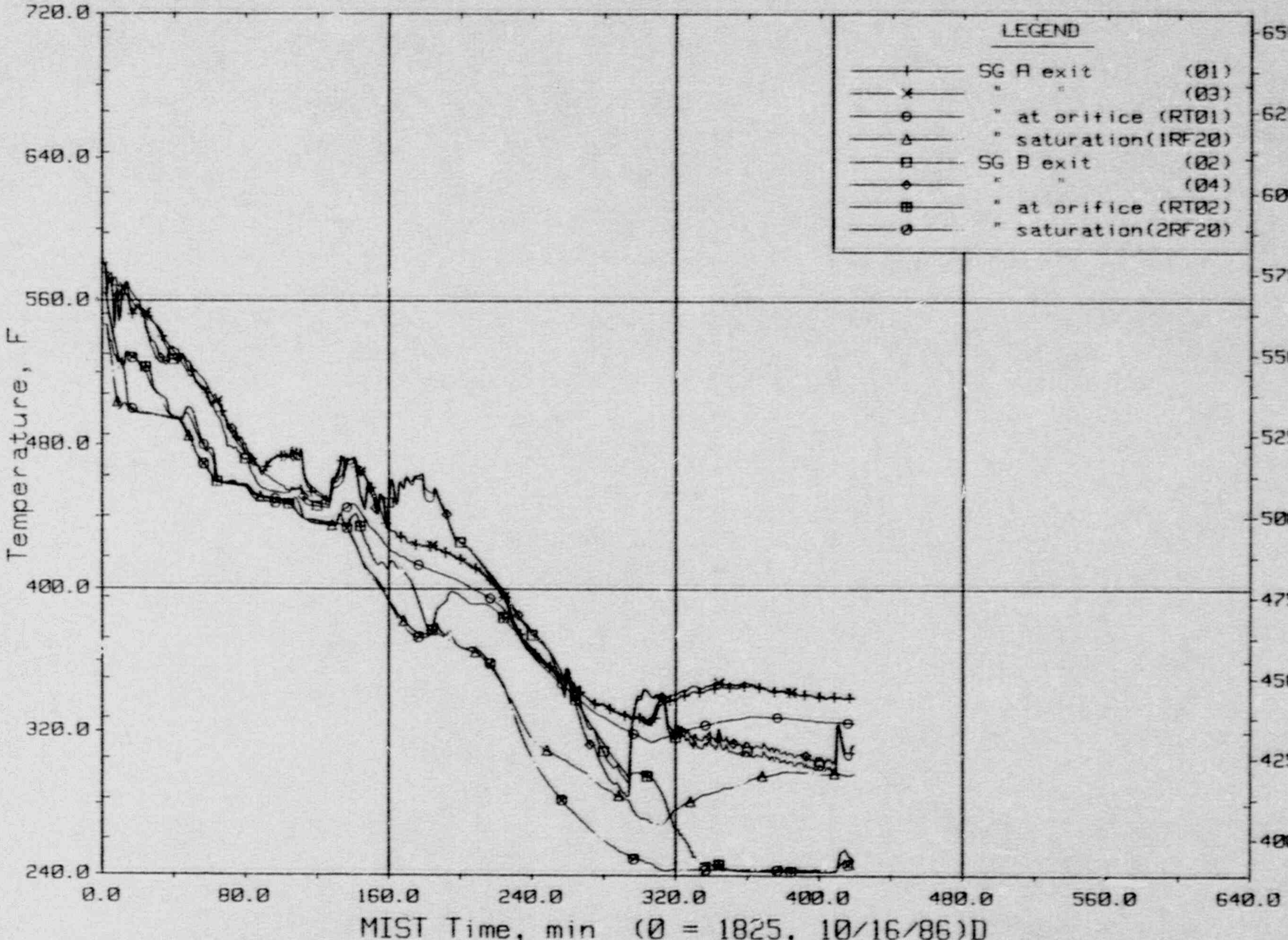
Feedwater Temperatures (SFs).

Wed May 25 13:59:54 1988

SGRT1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



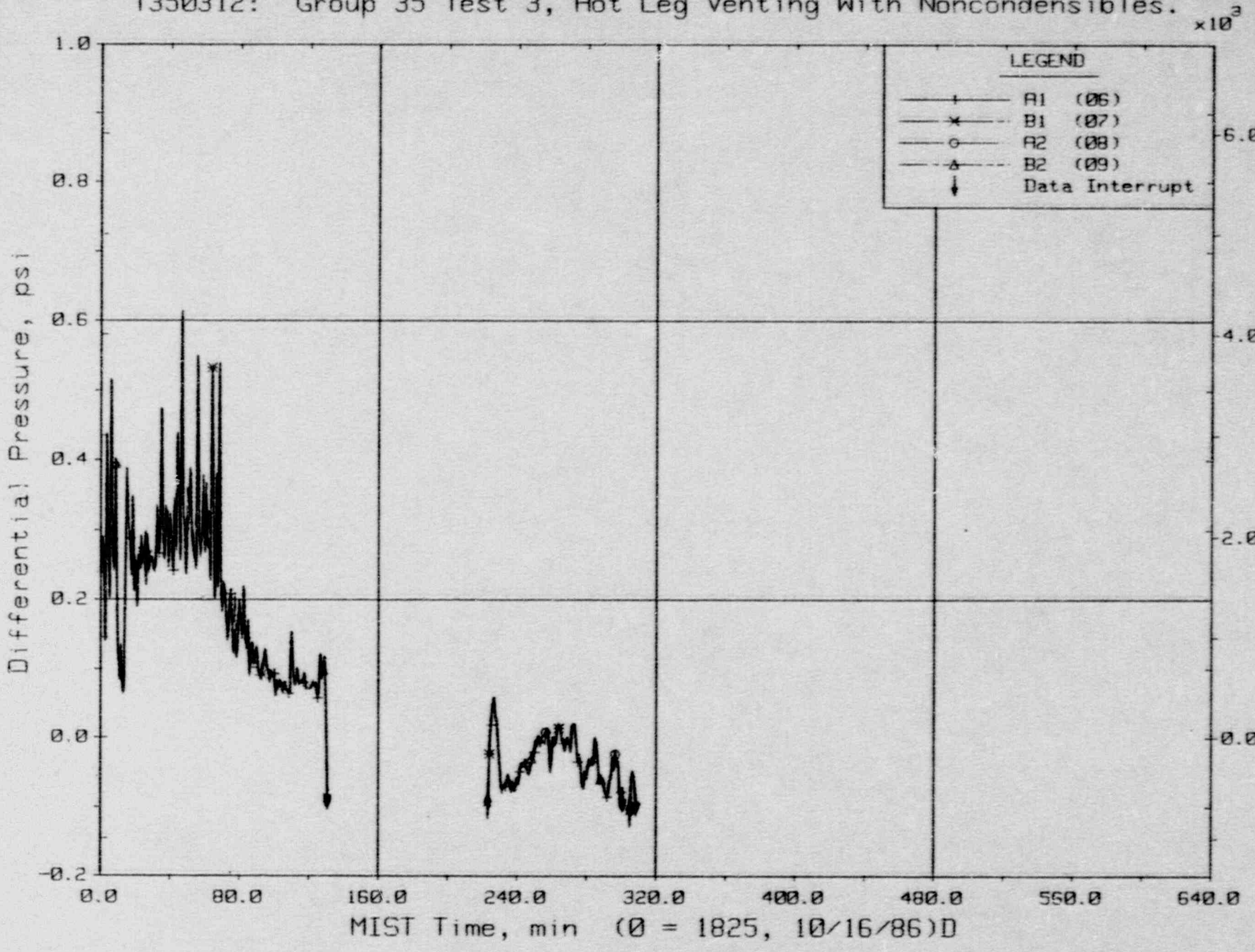
Steam Generator Steam Outlet Temperatures (SSTCs).

Wed May 25 14:03:33 1988

SGRT2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



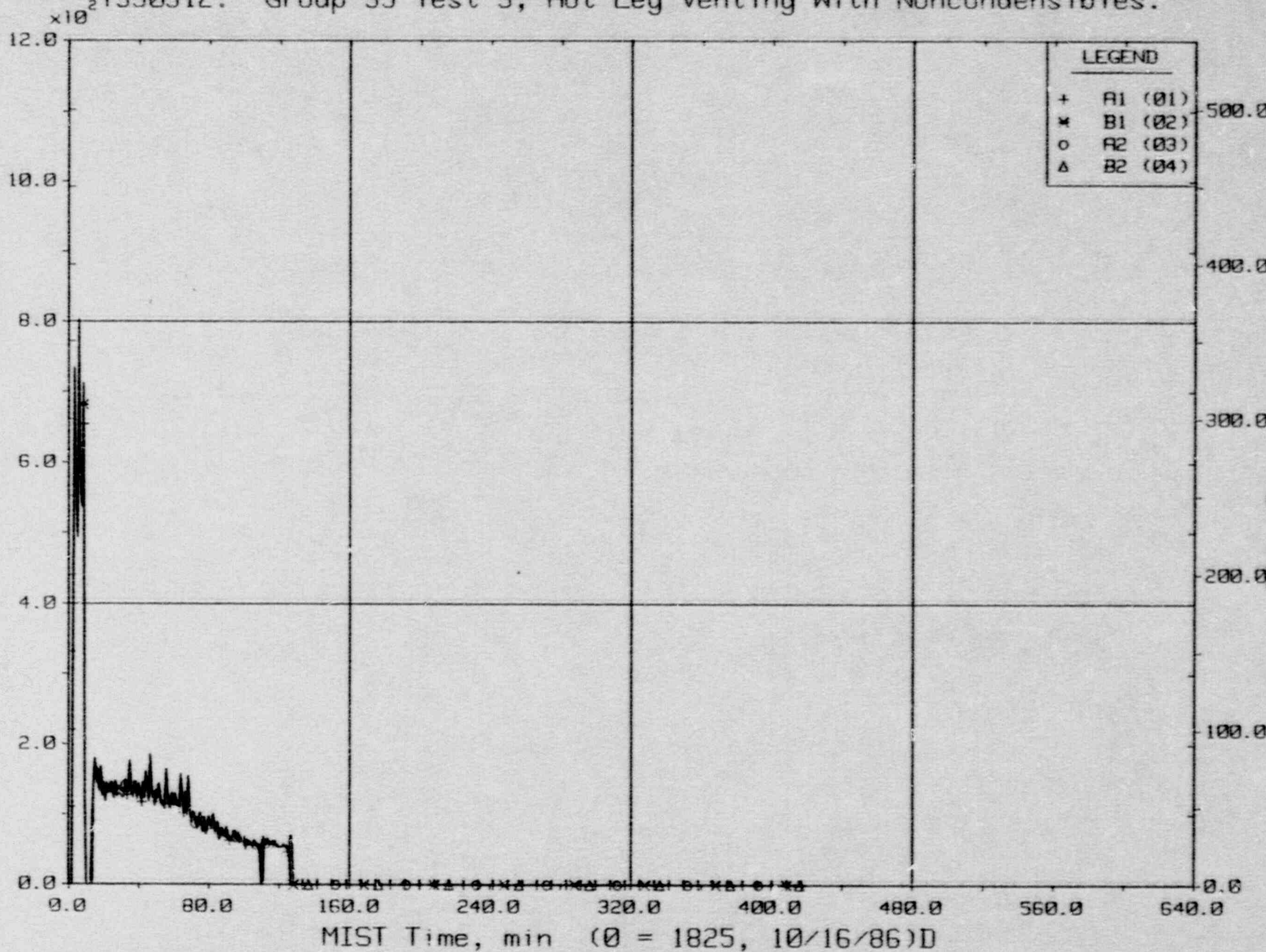
Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Wed May 25 14:07:00 1988

VVDP1

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



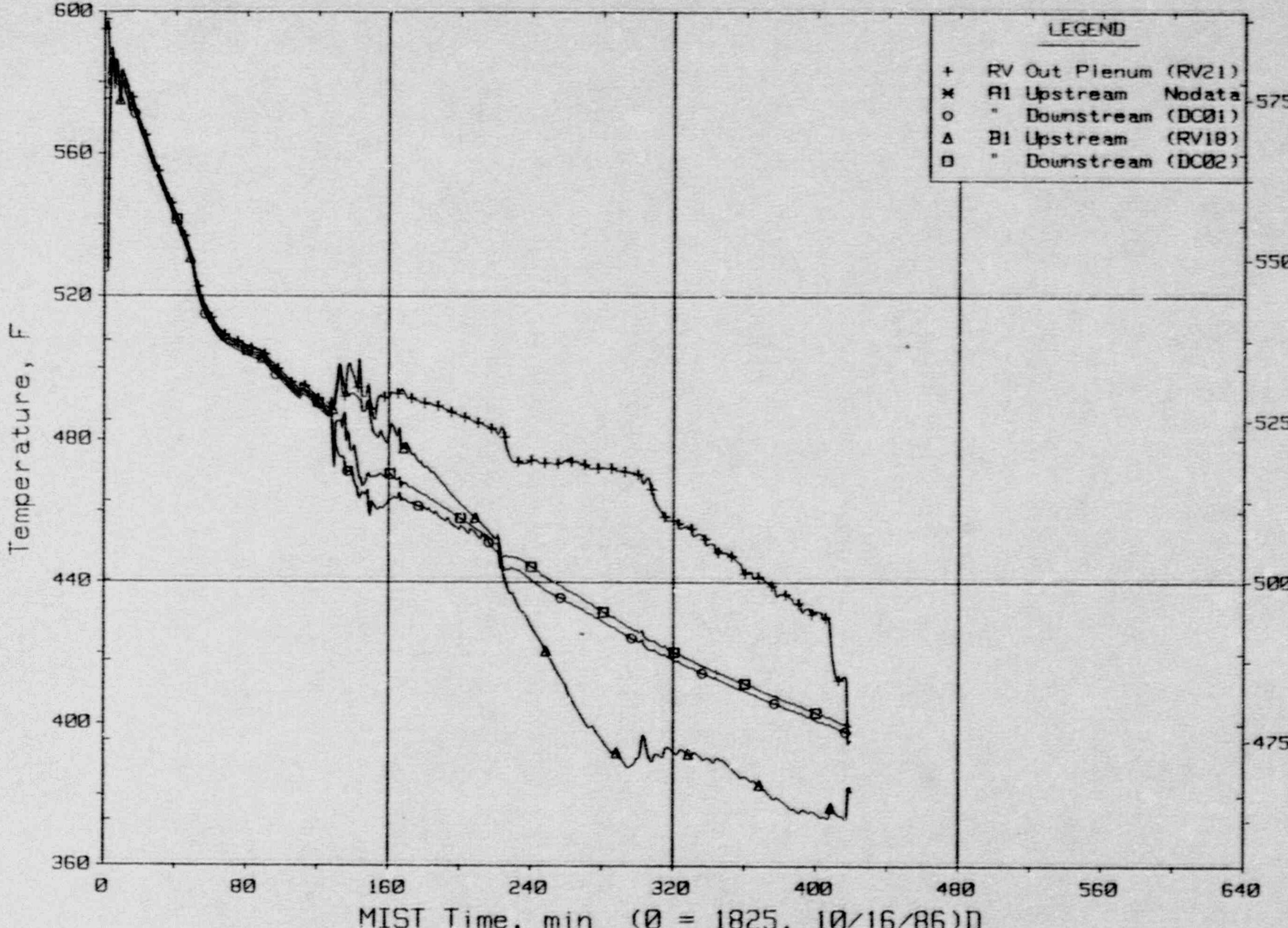
Reactor Vessel Vent Valve Flow Rates (RVORs).

Wed May 25 14:10:35 1988

VVFL1

FINAL DATA

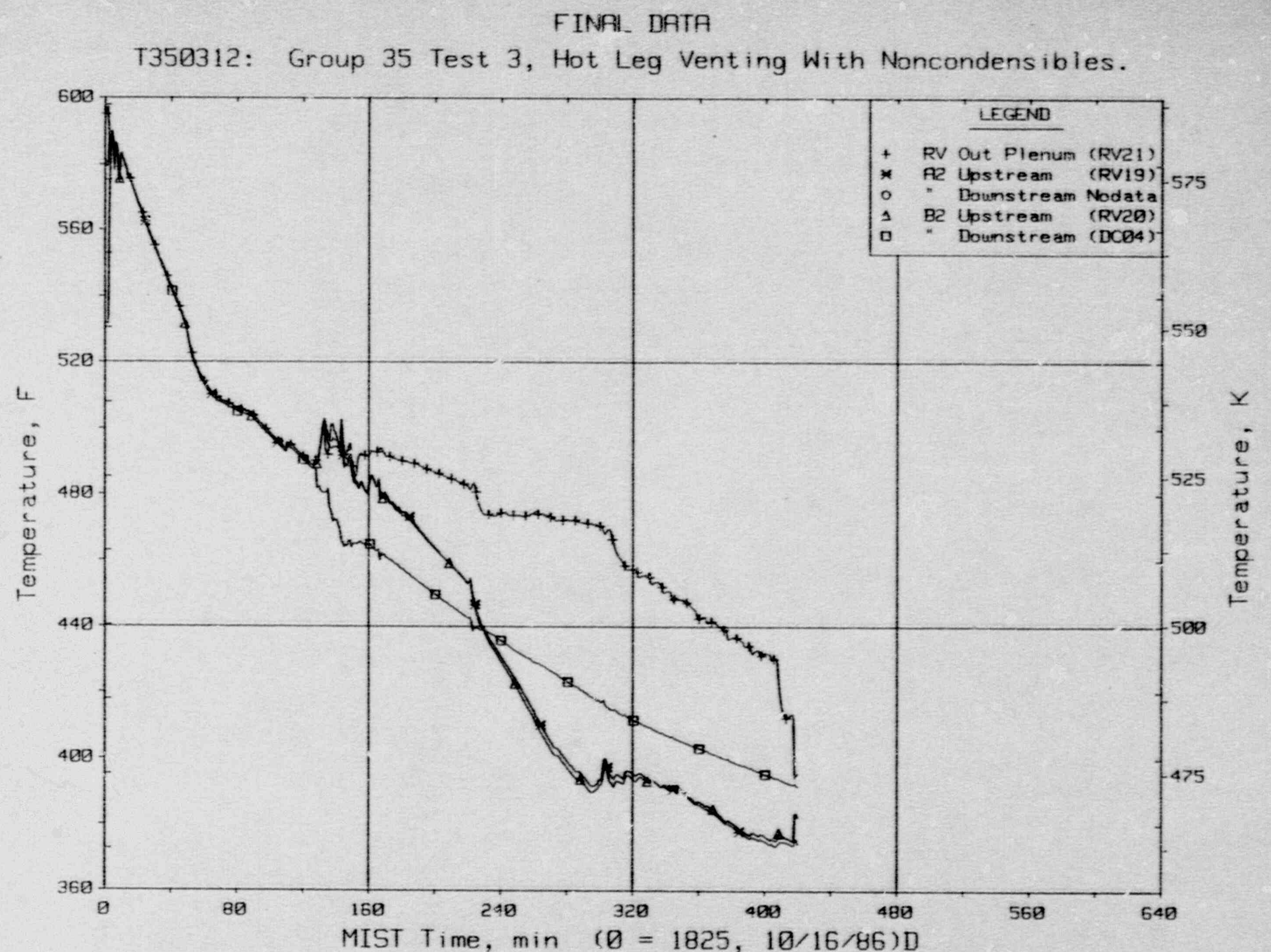
T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



RVVVs A1 and B1 Bracketing Fluid Temperatures (TCs).

Fri Jan 6 11:06:07 1989

VVTC1



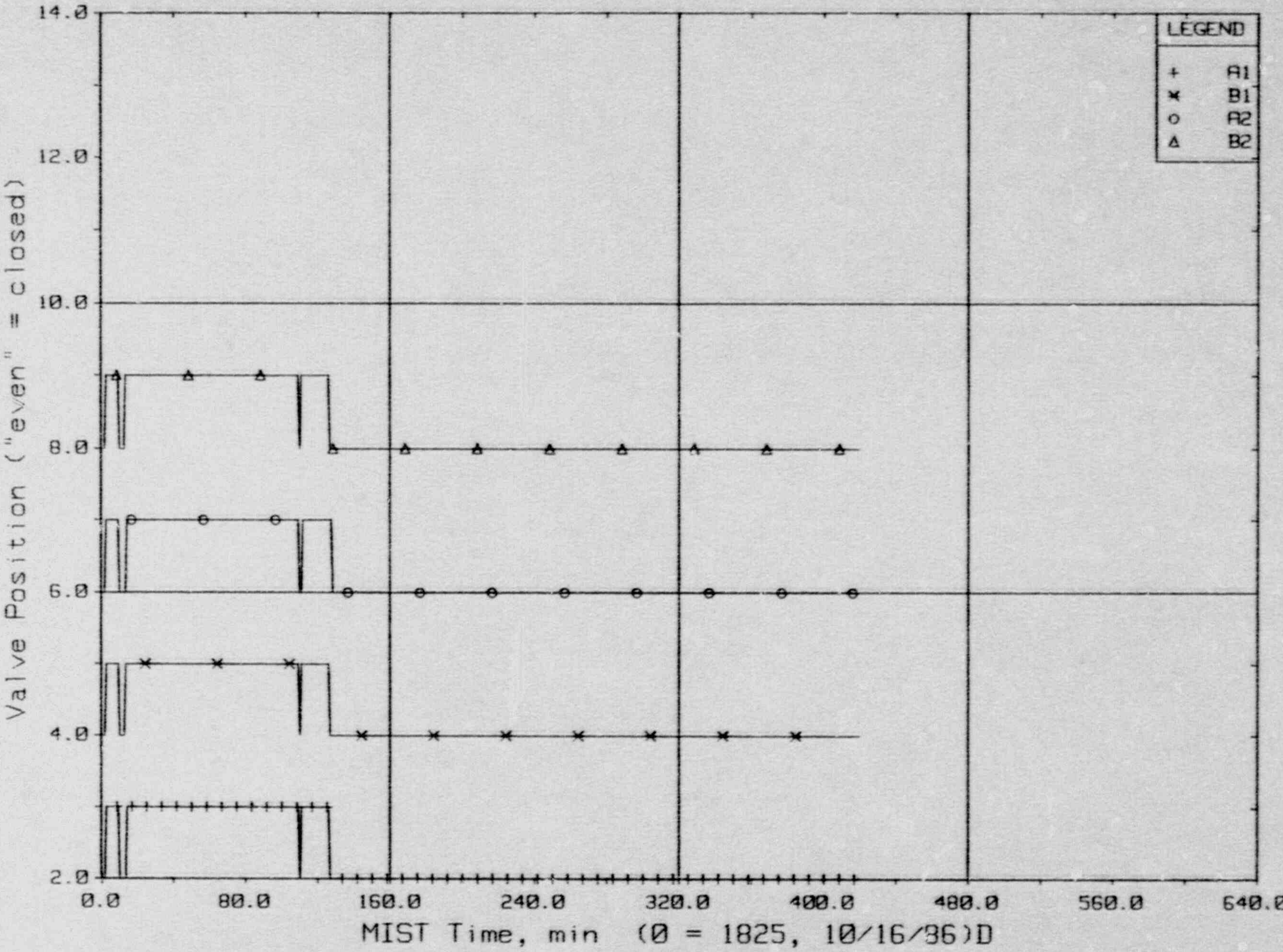
RVVs A2 and B2 Bracketing Fluid Temperatures (TCs).

Fri Jan 6 11:09:24 1989

VVTC2

FINAL DATA

T350312: Group 35 Test 3, Hot Leg Venting With Noncondensibles.



Reactor Vessel Vent Valve Positions.

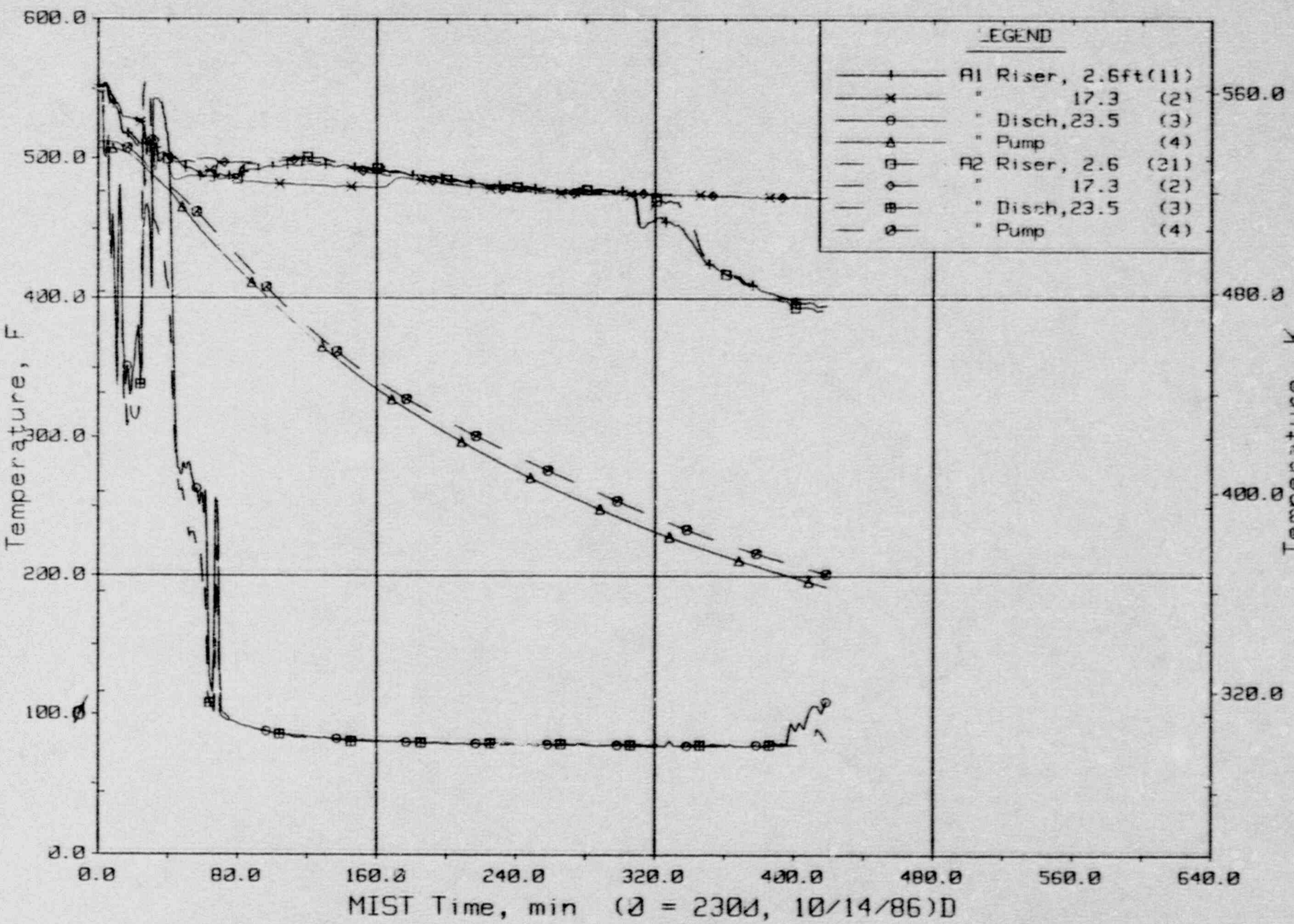
Wed May 25 14:13:41 1988

VVLS1

T350502

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



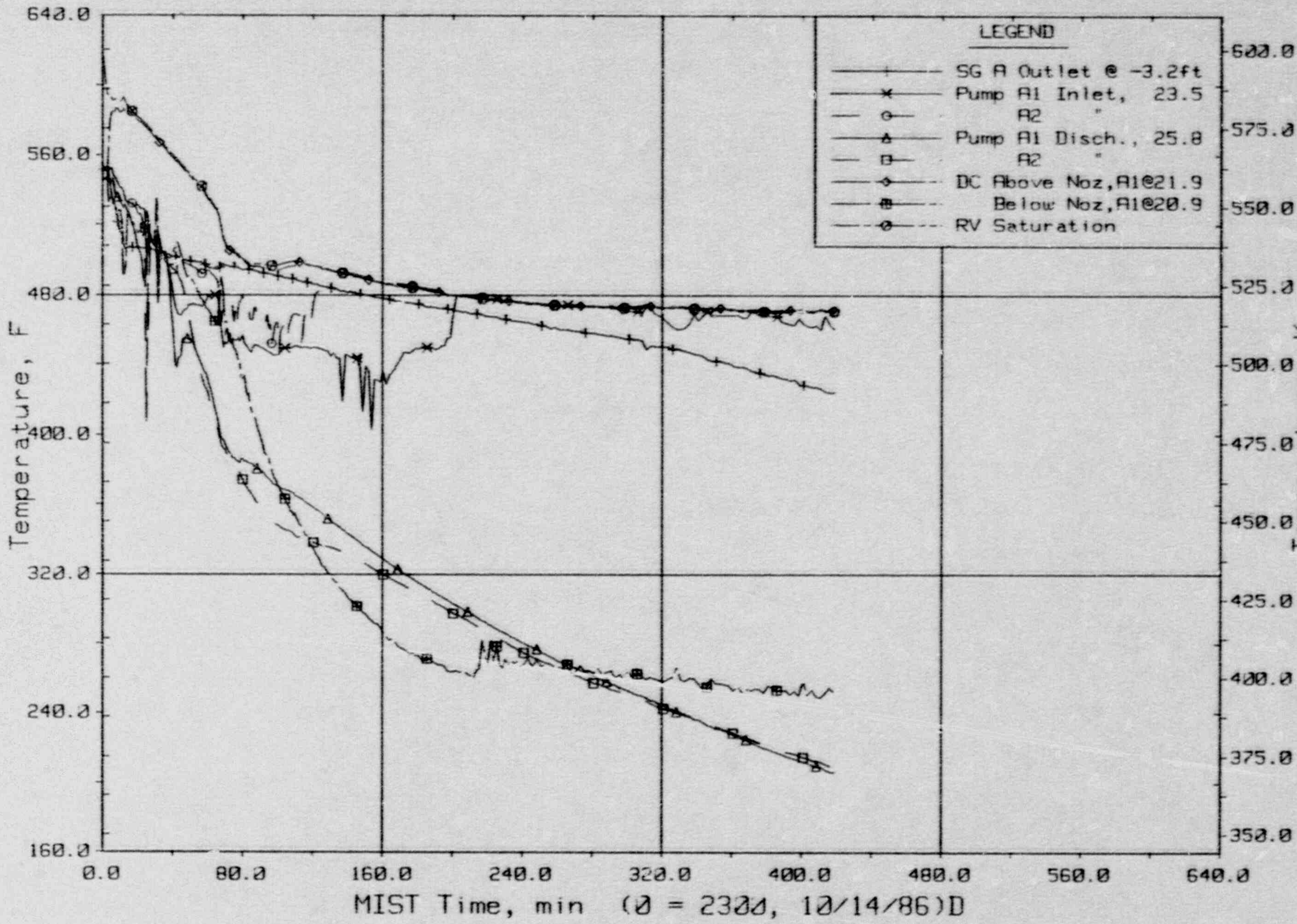
Loop A Cold Leg Metal Temperatures (C1,3MTs).

Wed May 25 14:42:32 1988

C1MT1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



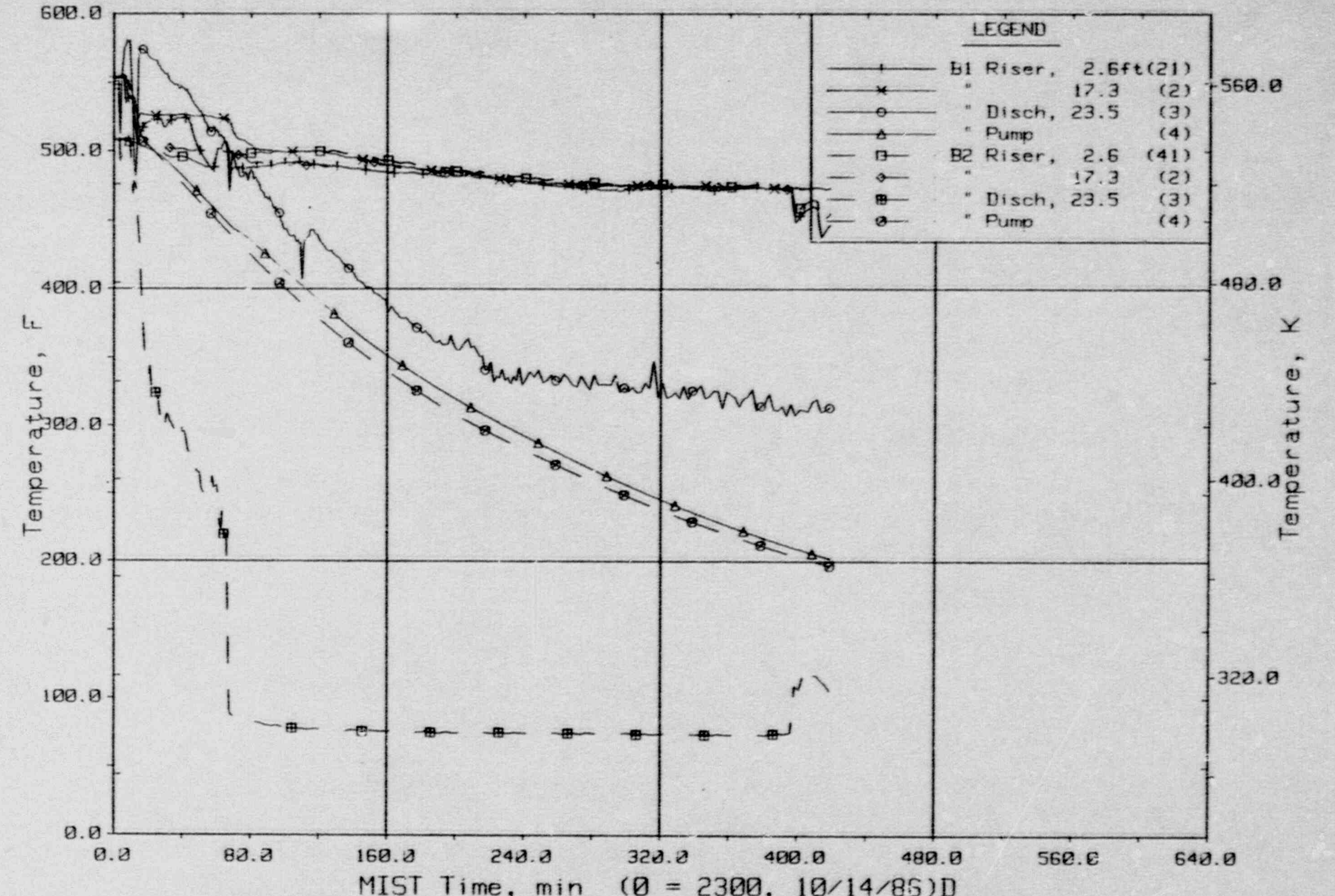
Loop A Cold Leg Fluid Temperatures (RTDs).

Wed May 25 14:46:52 1988

C1RT0

FINAL DATA

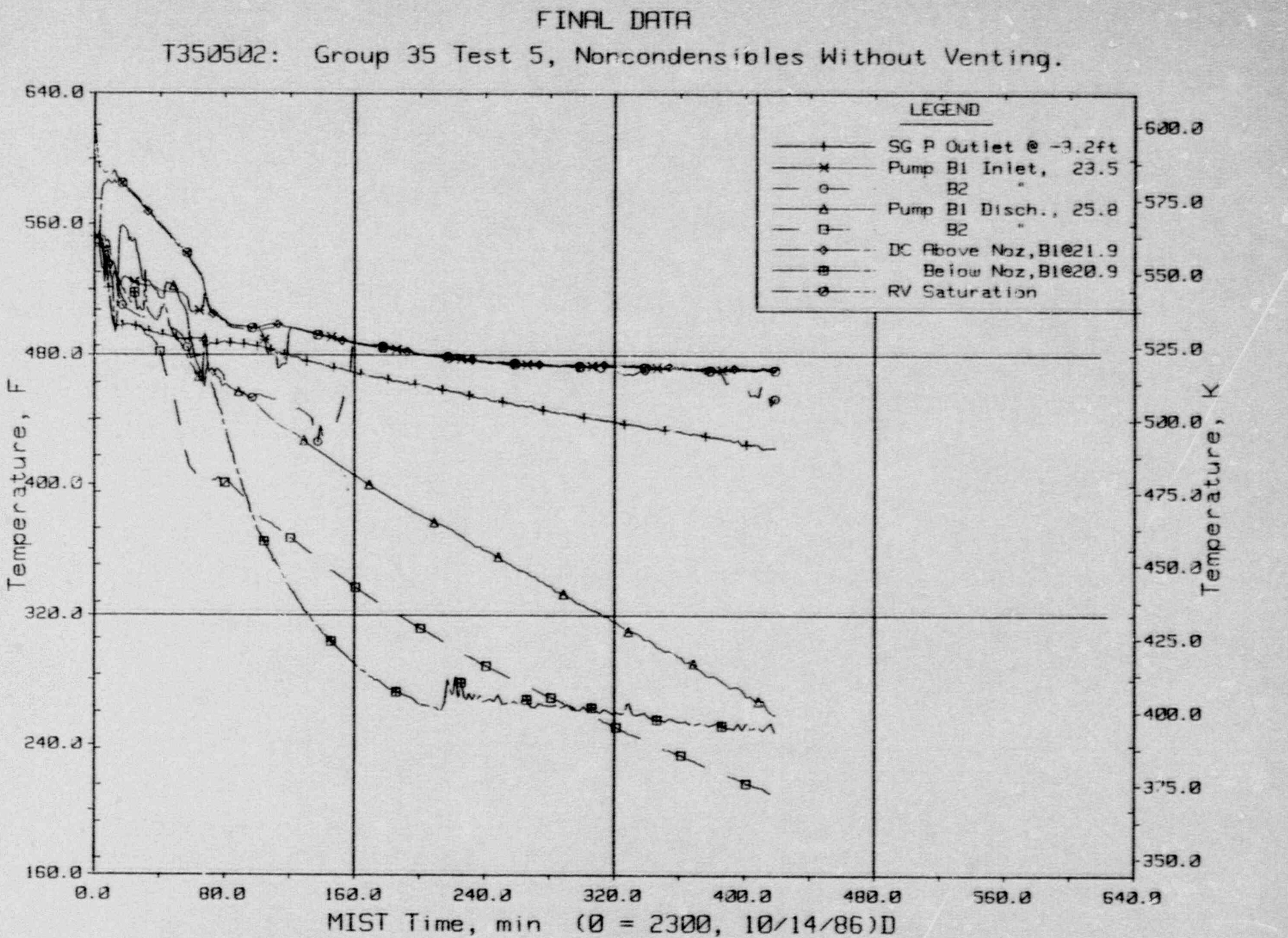
T350502: Group 35 Test 5, Noncondensibles Without Venting.



Loop B Cold Leg Metal Temperatures (C2,4MTs).

Wed May 25 14:50:12 1988

C2MT1



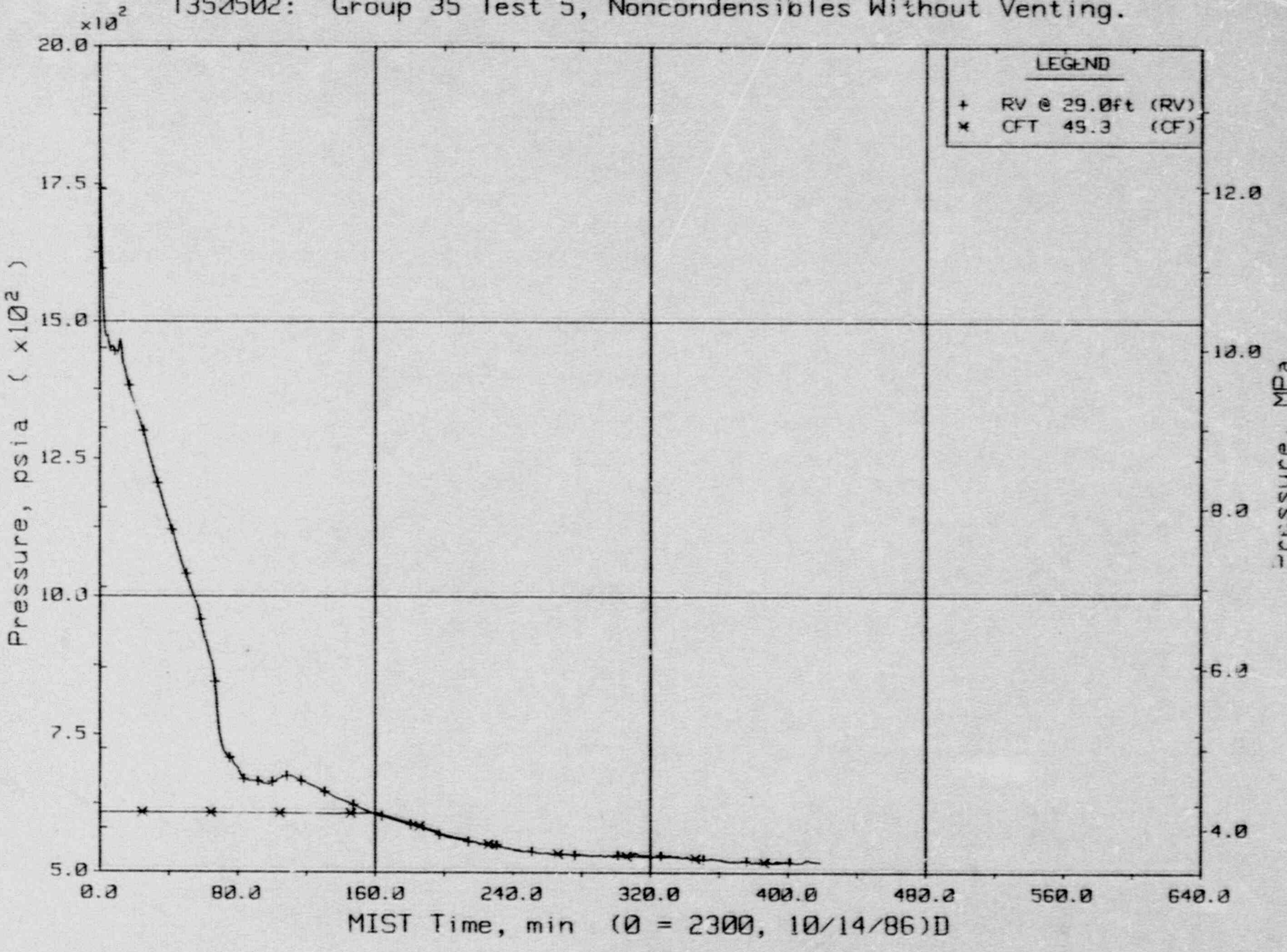
Loop B Cold Leg Fluid Temperatures (RTDs).

Wed May 25 14:53:26 1988

C2RT0

FINAL DATA

T352502: Group 35 Test 5, Noncondensibles Without Venting.



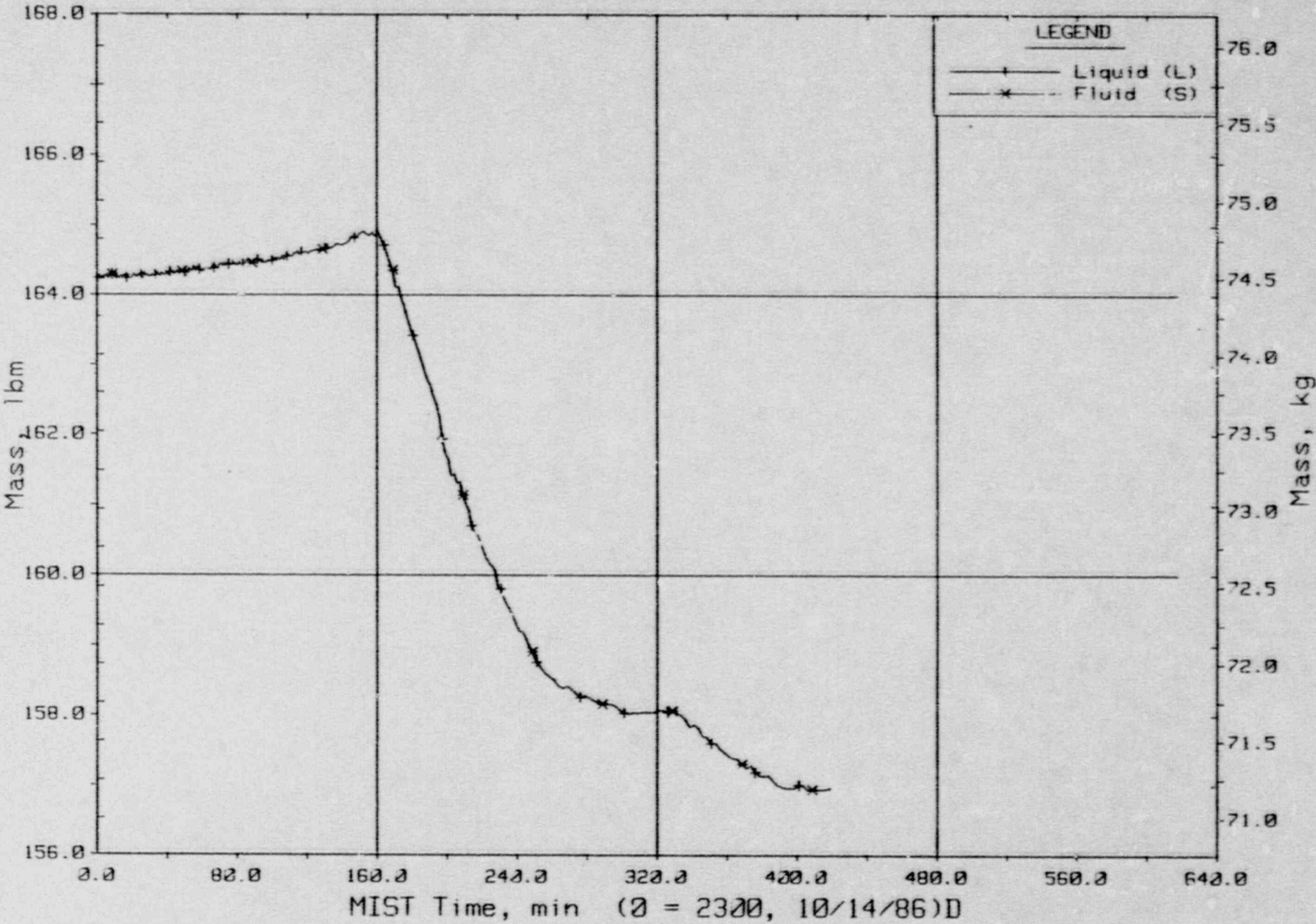
Primary System and Core Flood Tank Pressures (GP01s).

Wed May 25 14:56:06 1988

CFGP1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



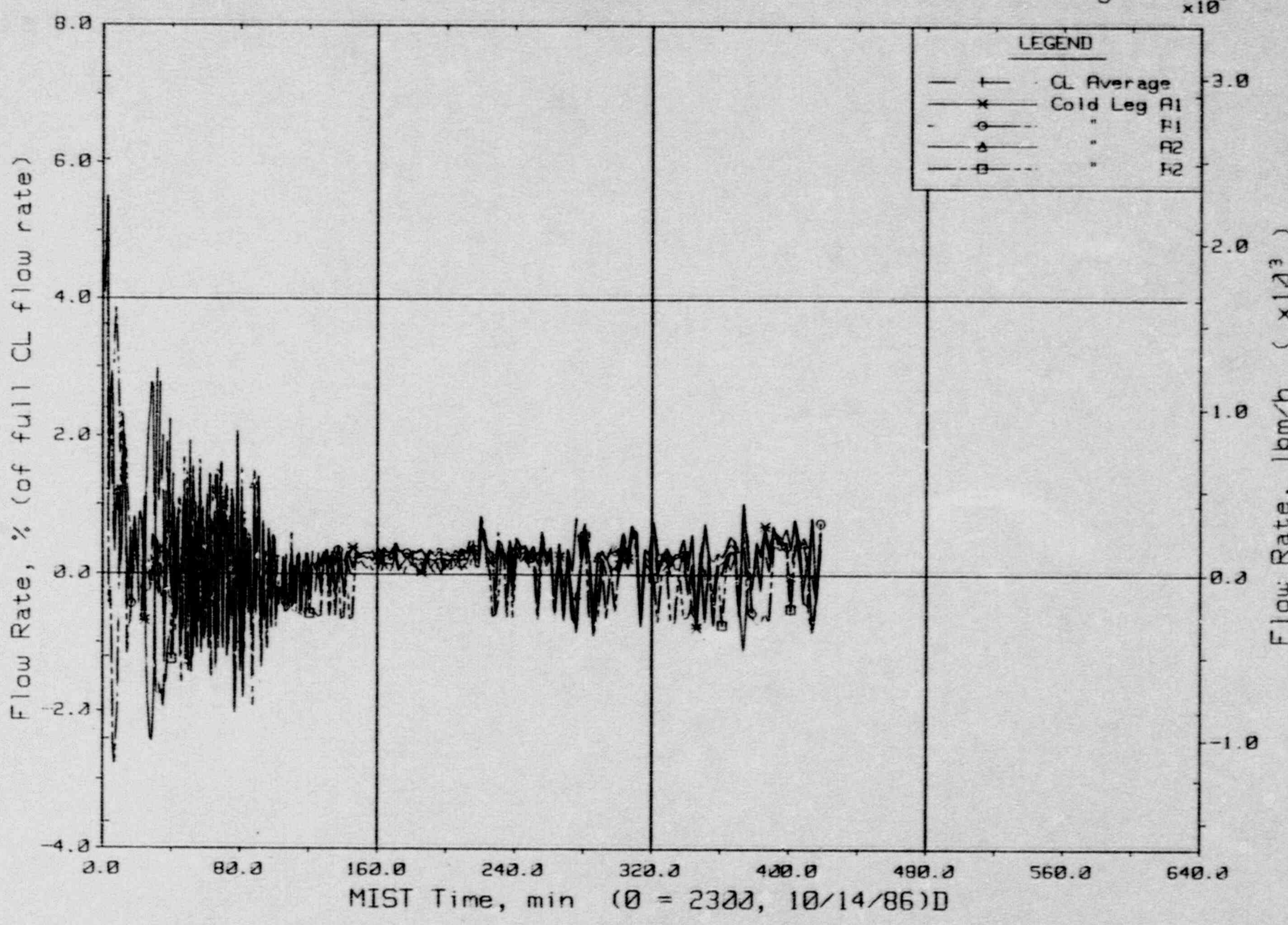
Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Wed May 25 14:58:30 1988

CFML1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



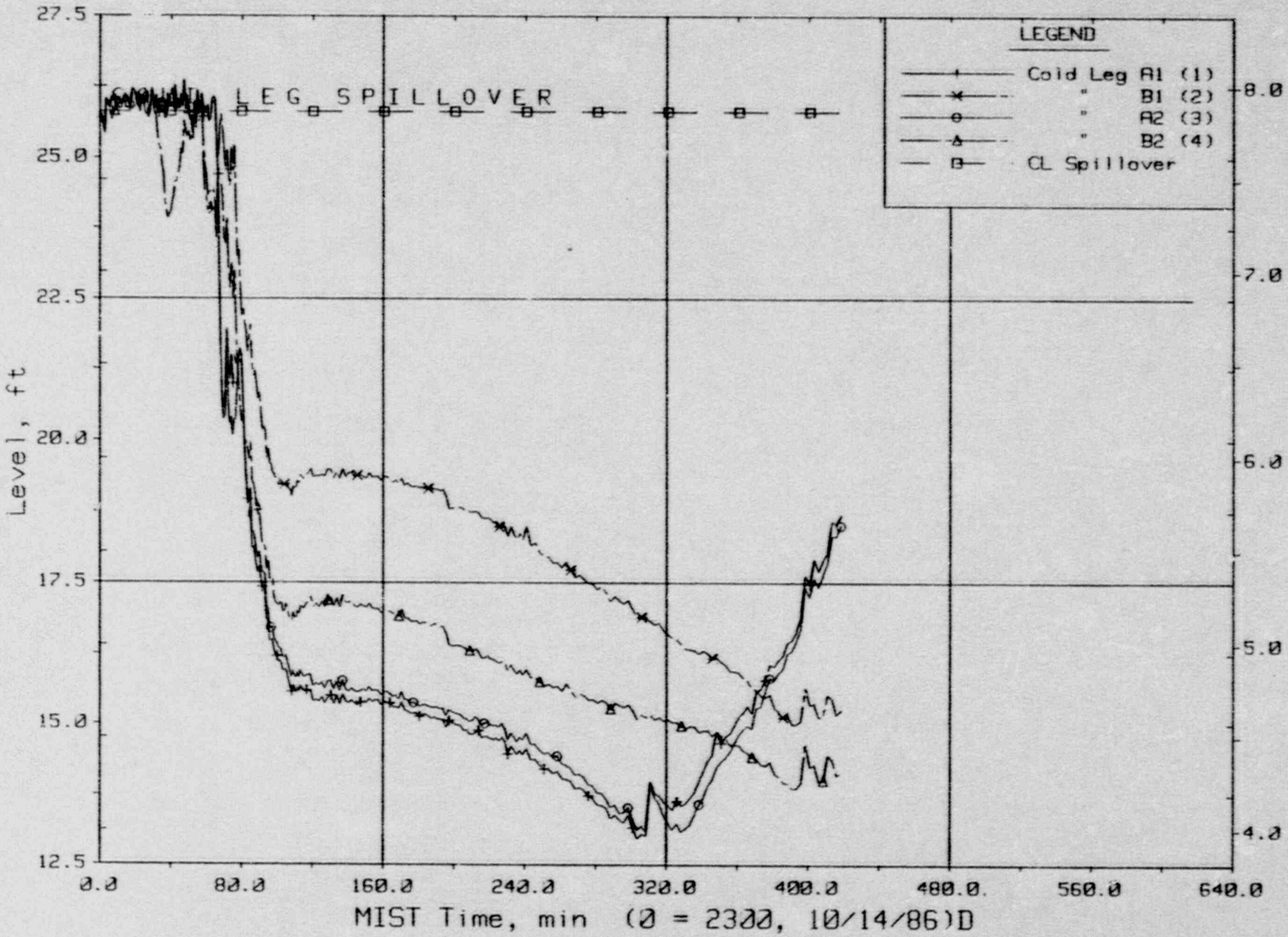
Cold Leg (Venturi) Flow Rates.

Wed May 25 15:02:27 1988

CLFL1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



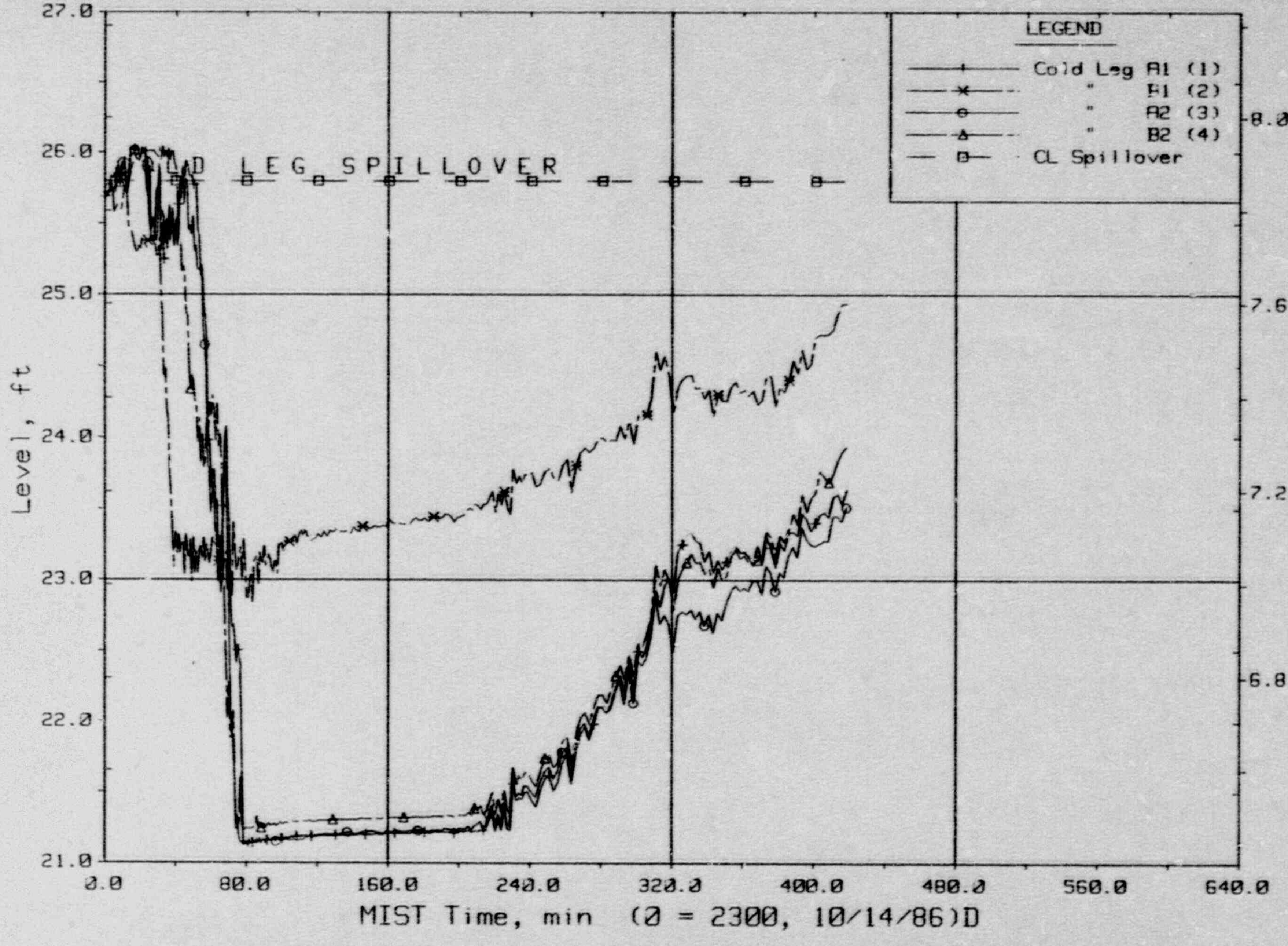
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Wed May 25 15:06:32 1988

CLLV4

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



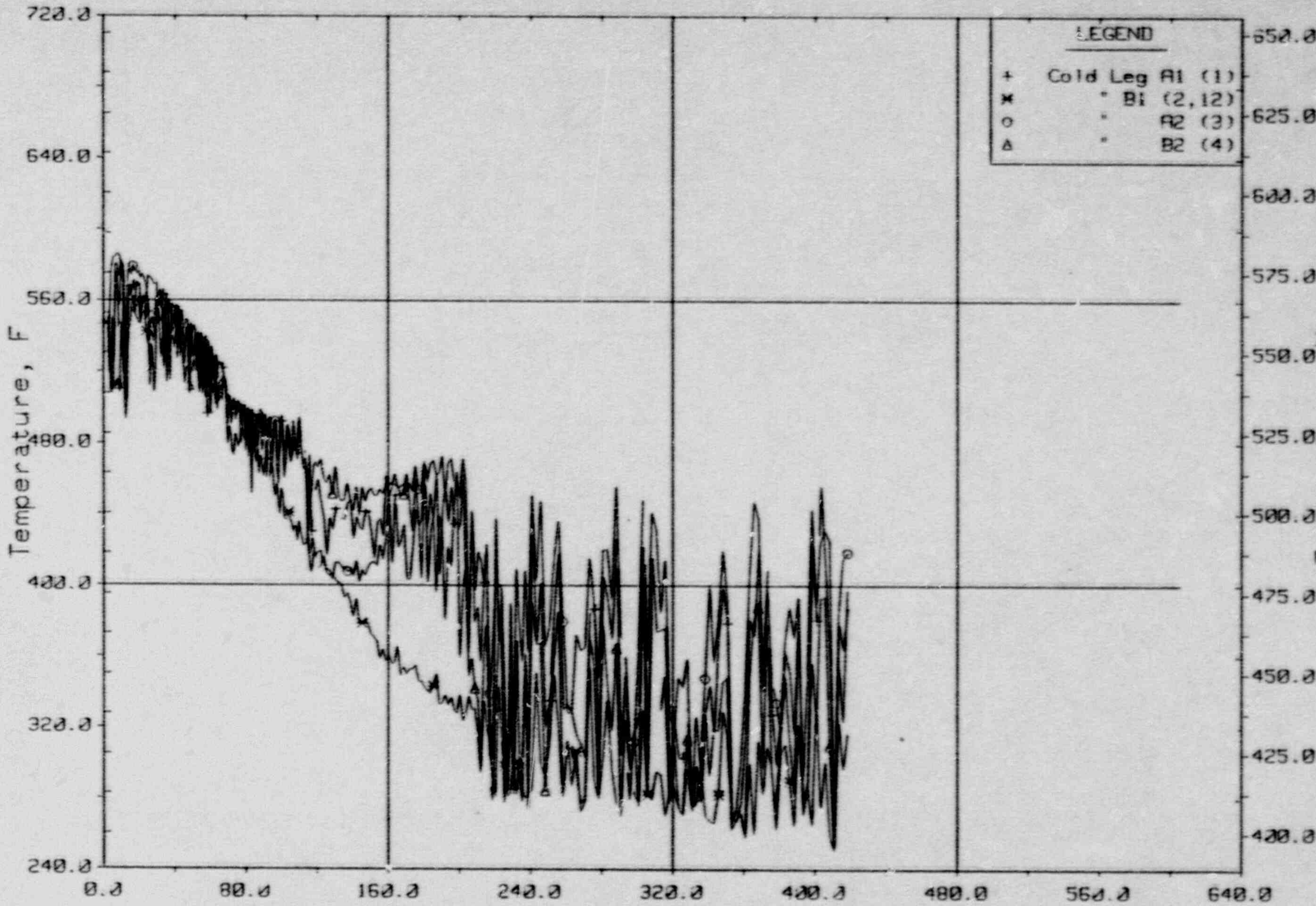
Cold Leg Discharge Collapsed Liquid Levels (CnLV23s).

Wed May 25 15:12:49 1988

CLLV5

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



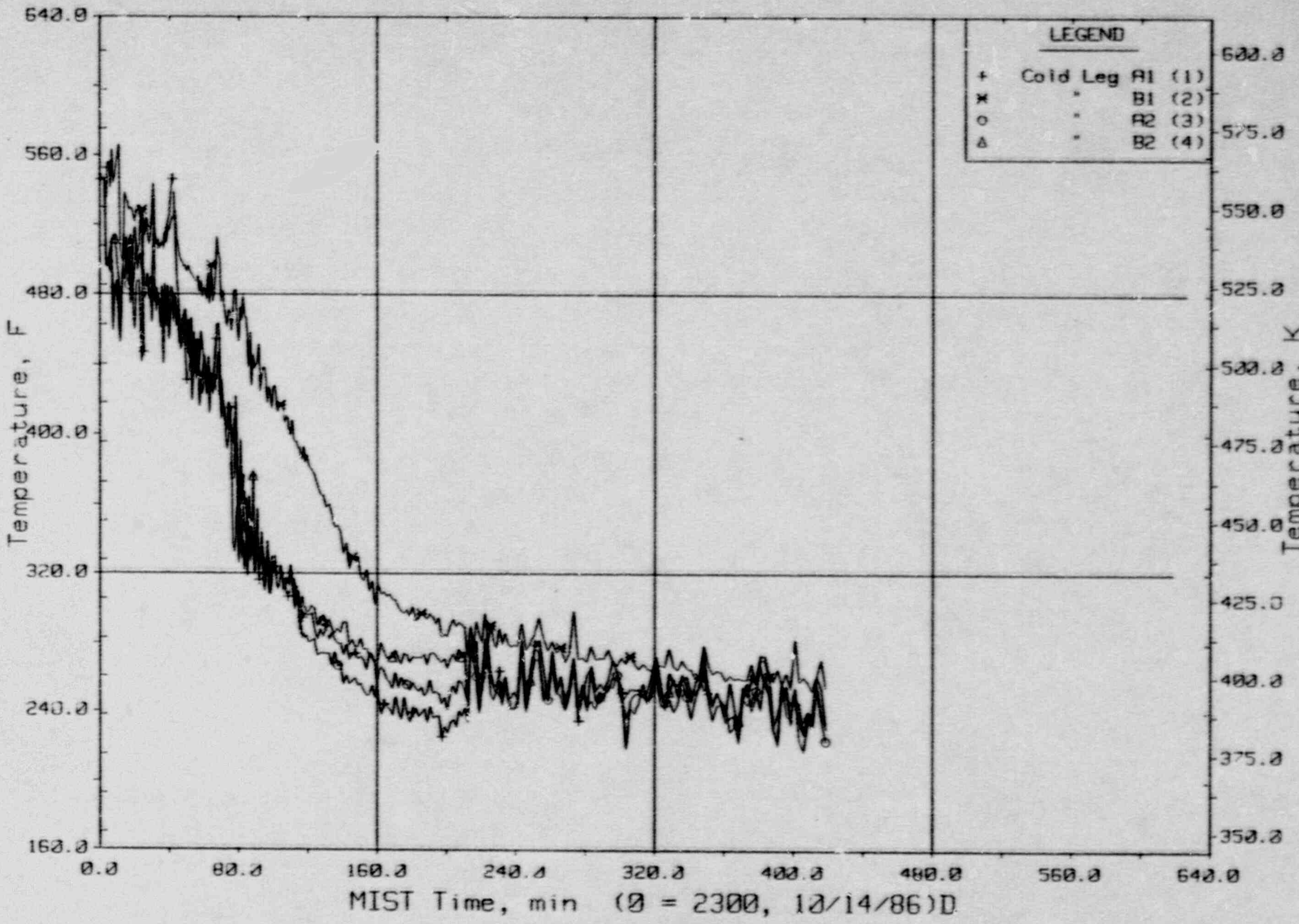
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Wed May 25 15:24:36 1988

CLTC:

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



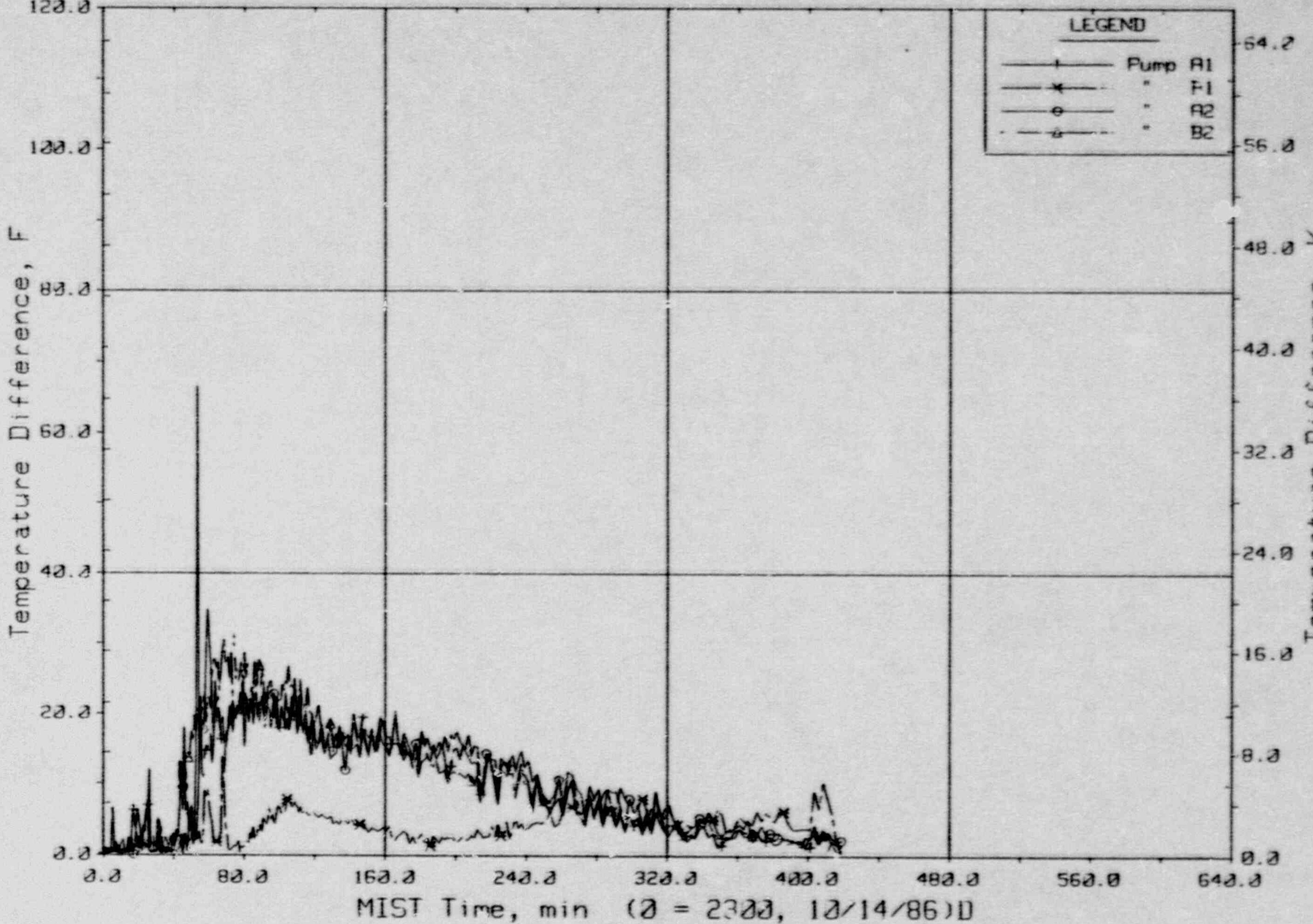
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Wed May 25 15:27:10 1988

CLTC2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



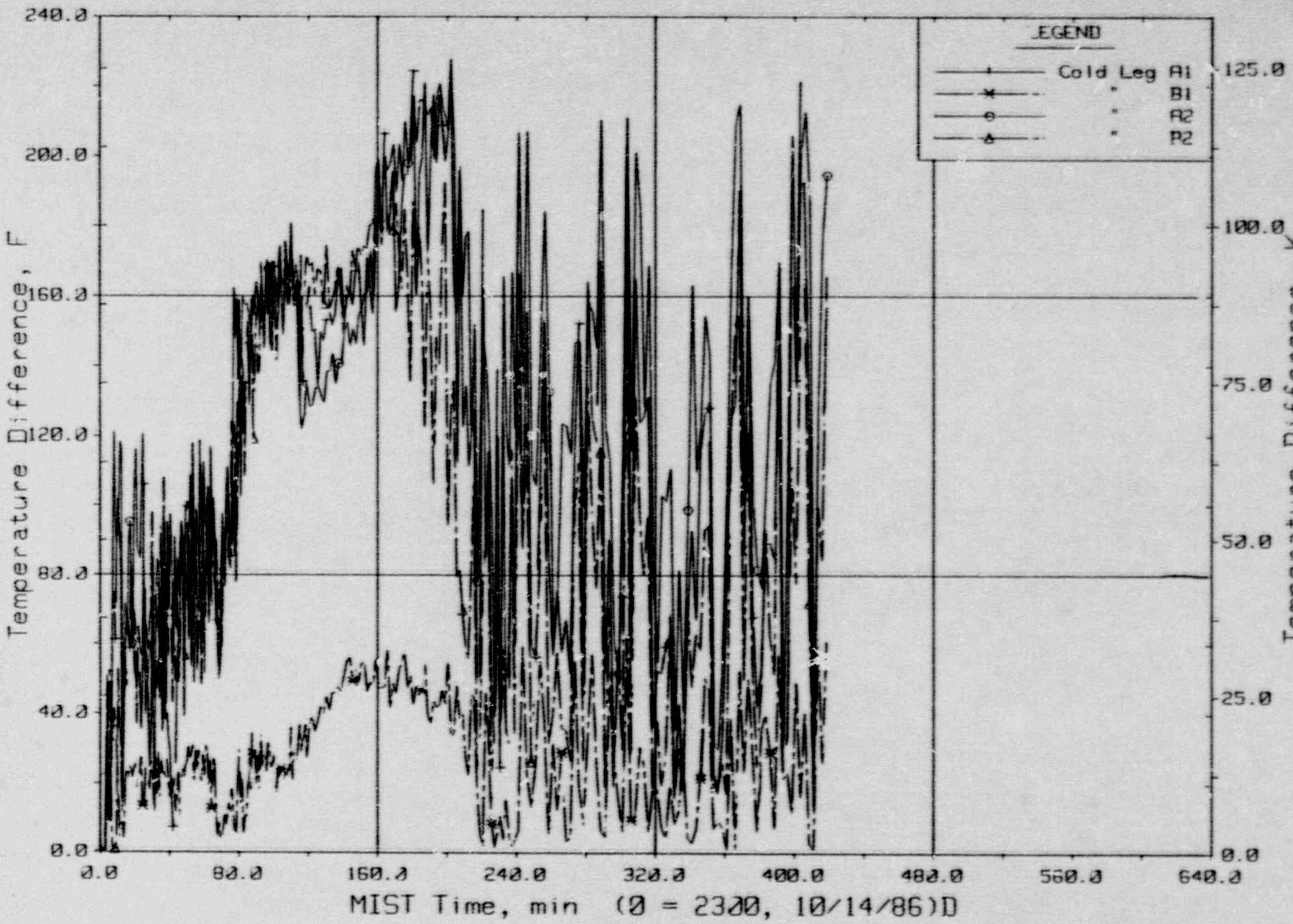
Maximum Differences Among RCP Rake Fluid Temperatures.

Wed May 25 15:29:49 1988

CLTD1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



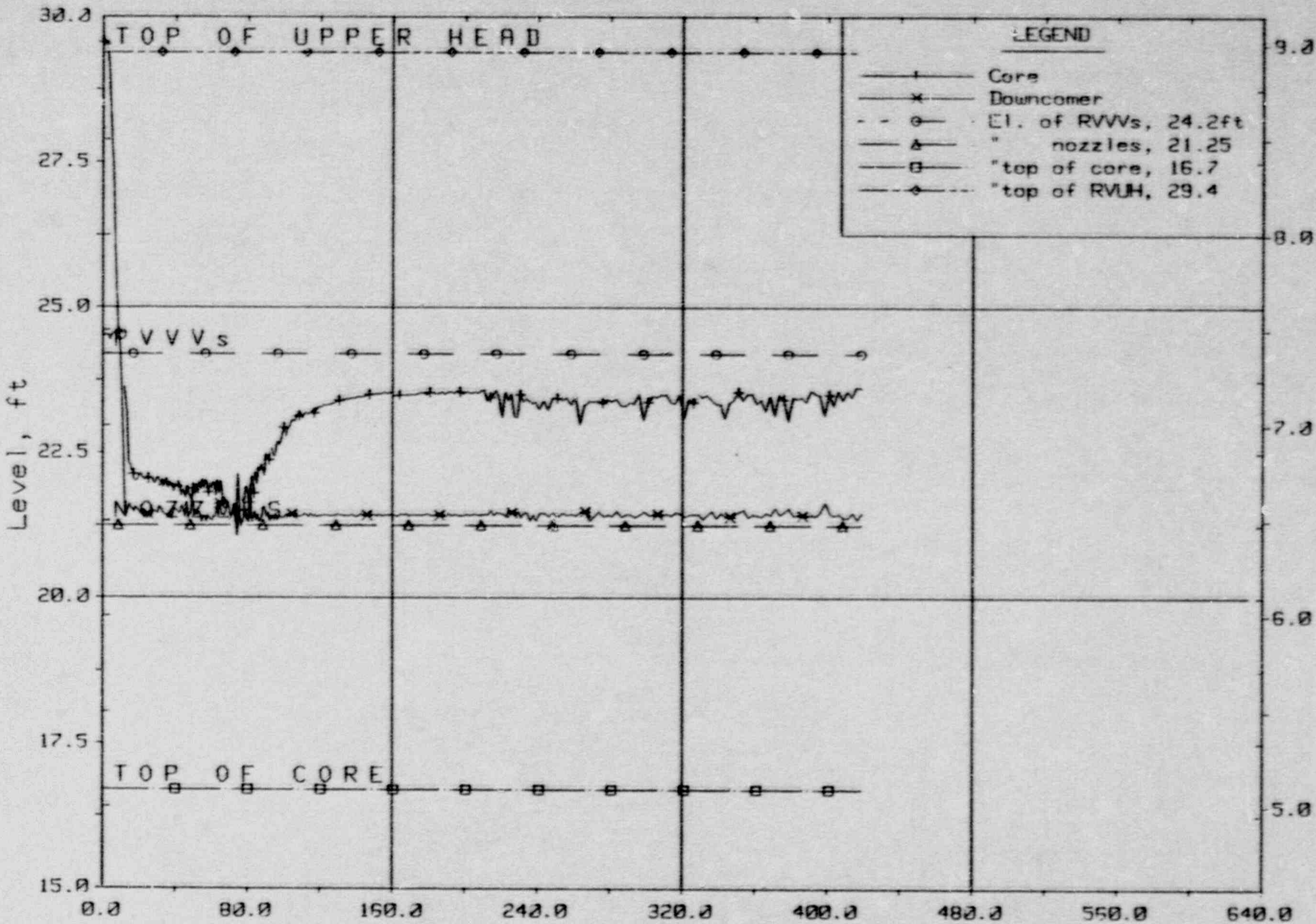
Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Wed May 25 15:33:04 1988

CLTD2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



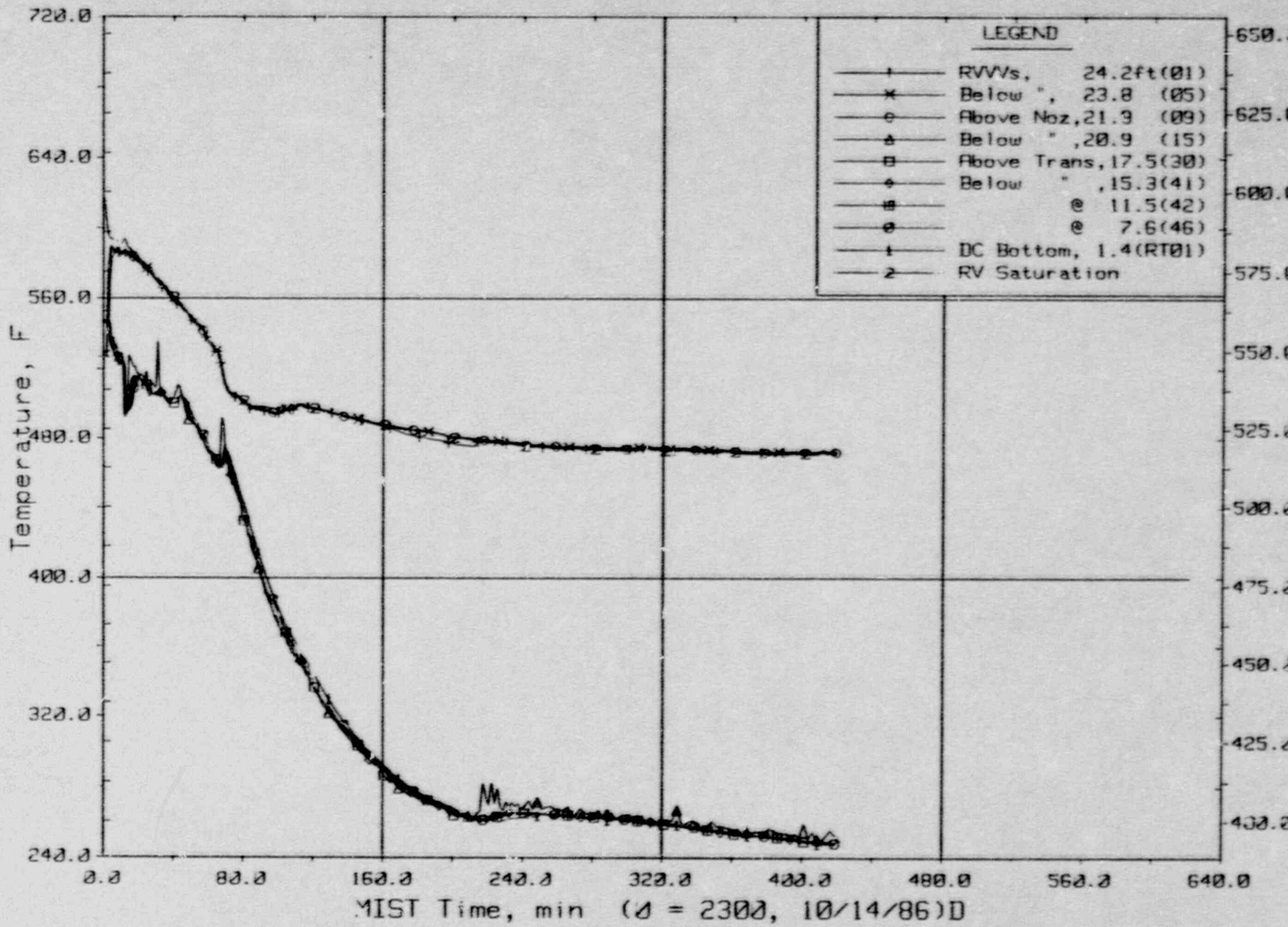
Core Region Collapsed Liquid Levels.

Wed May 25 15:37:02 1988

COLV1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



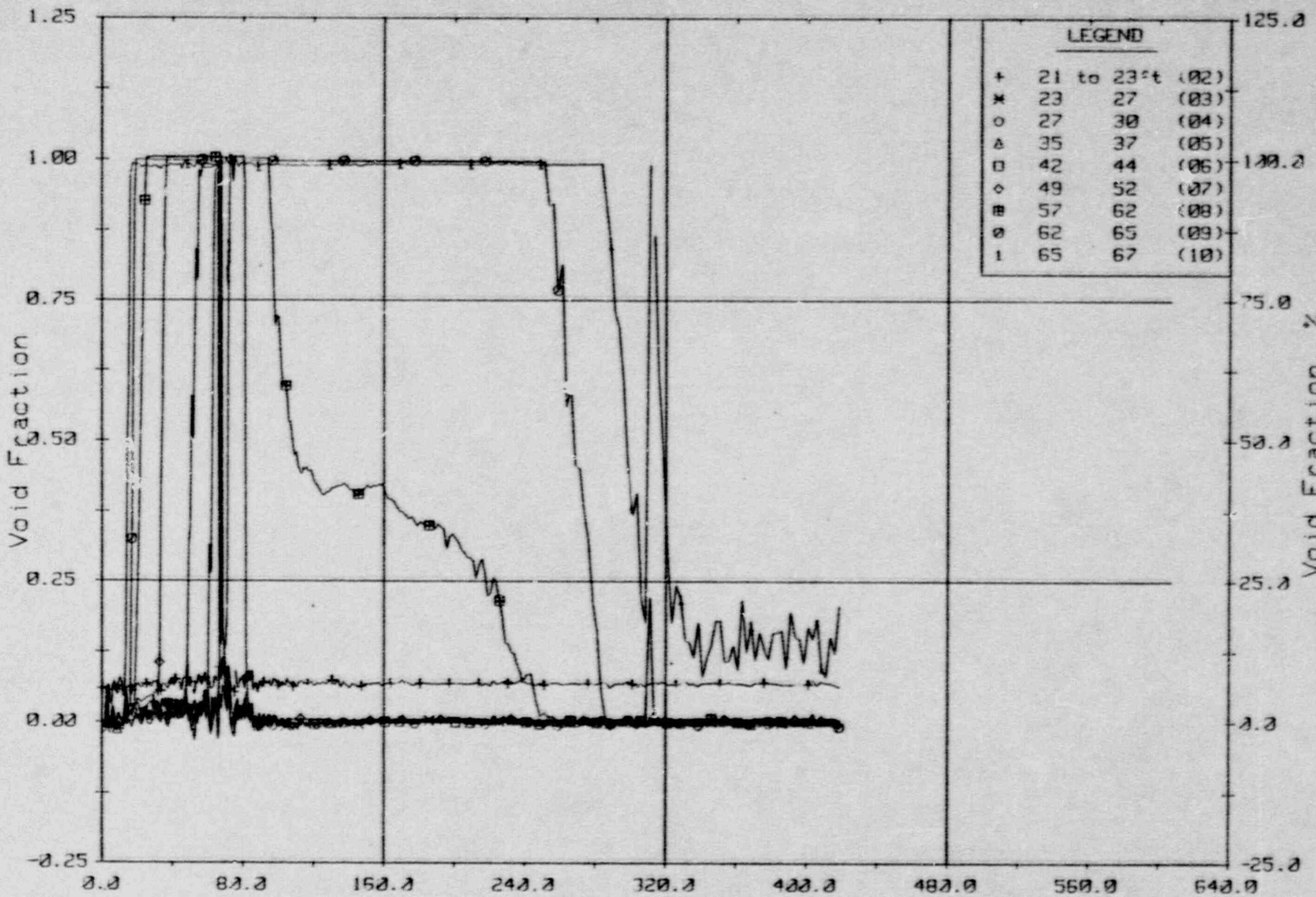
Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Wed May 25 15:43:41 1988

DCTC6

FINAL DATA

T350502: Group 35 Test 5, Nonconderisibles Without Venting.



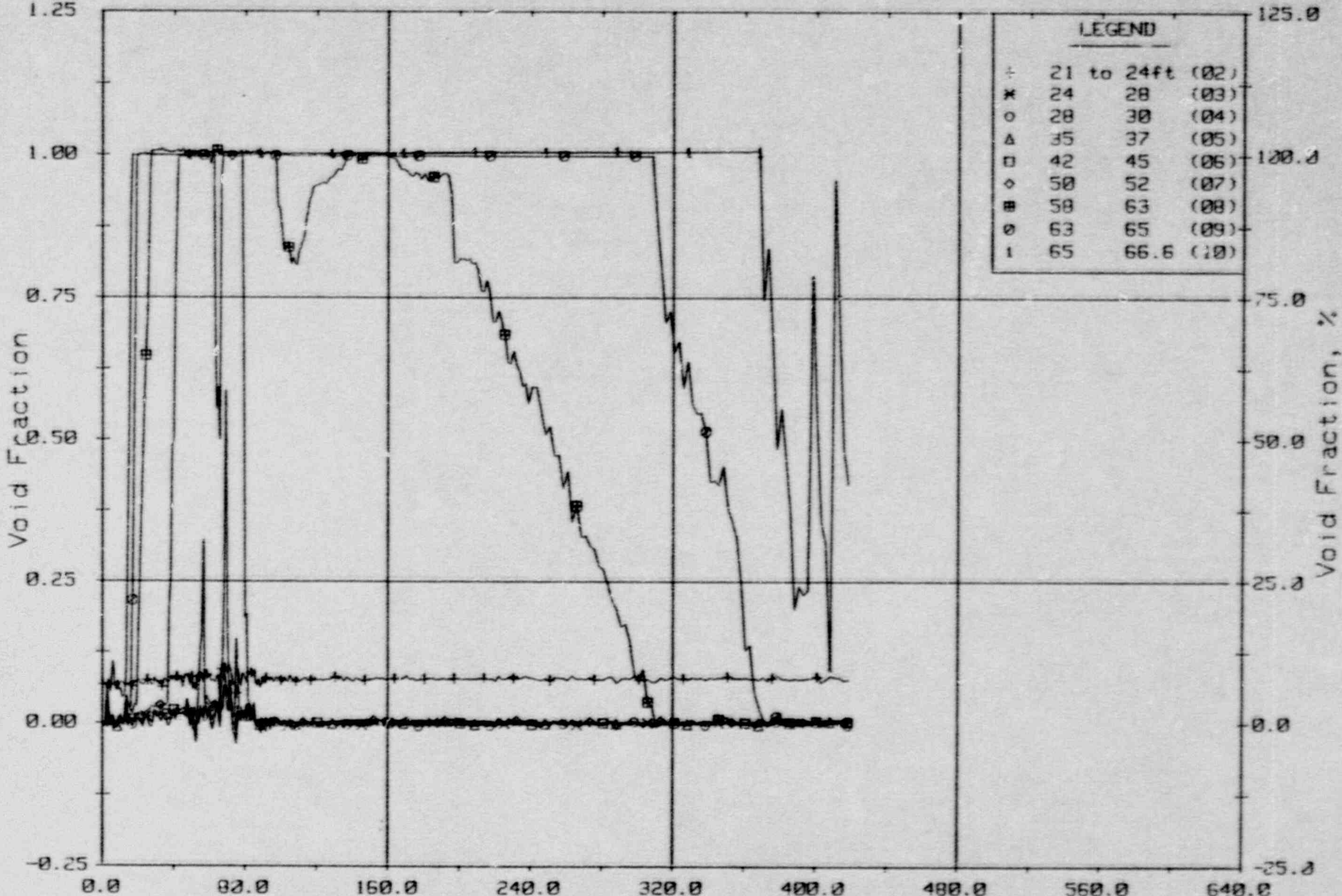
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Wed May 25 15:47:19 1988

H1VF1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



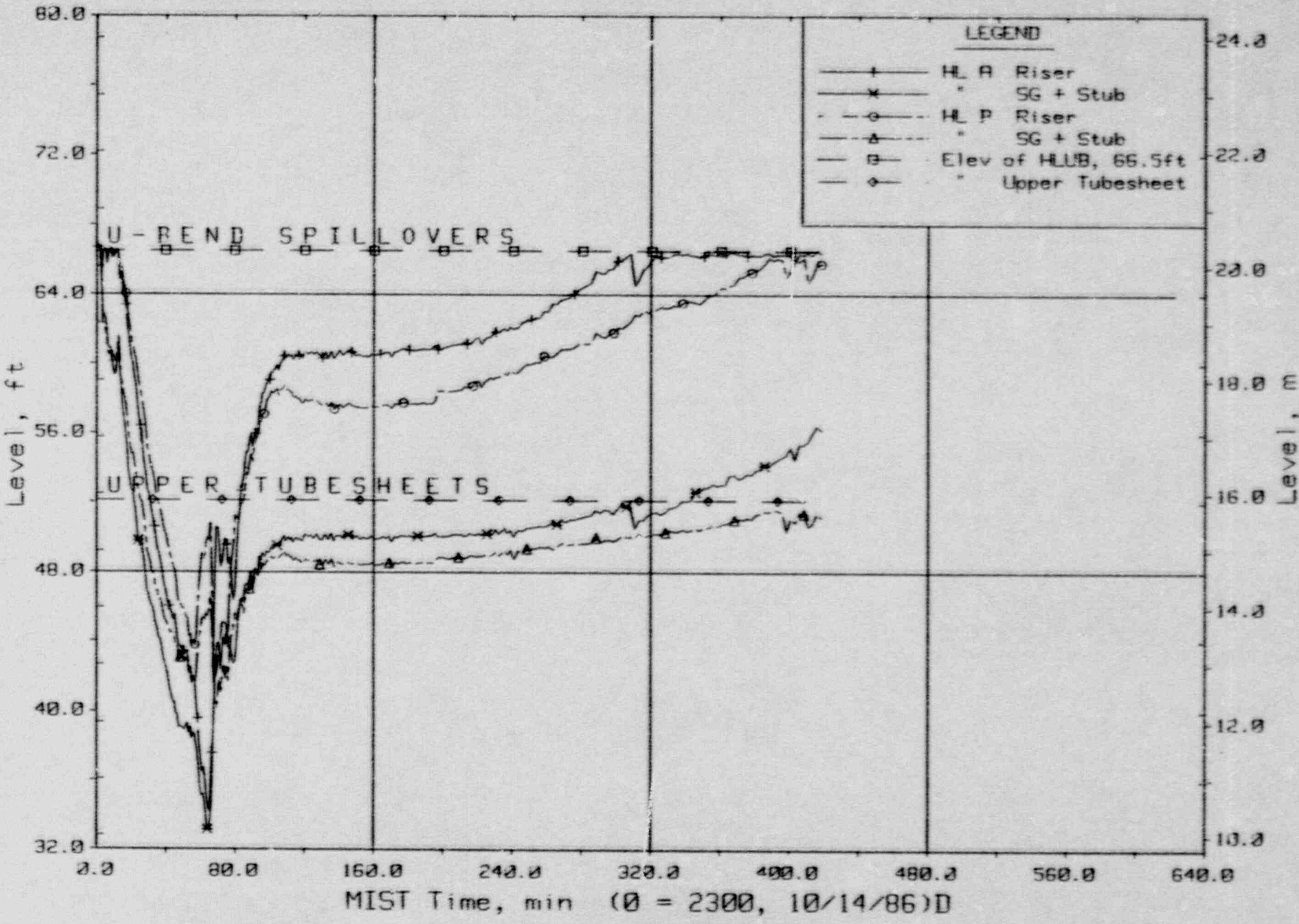
Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).

Wed May 25 15:50:33 1988

H2VF1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



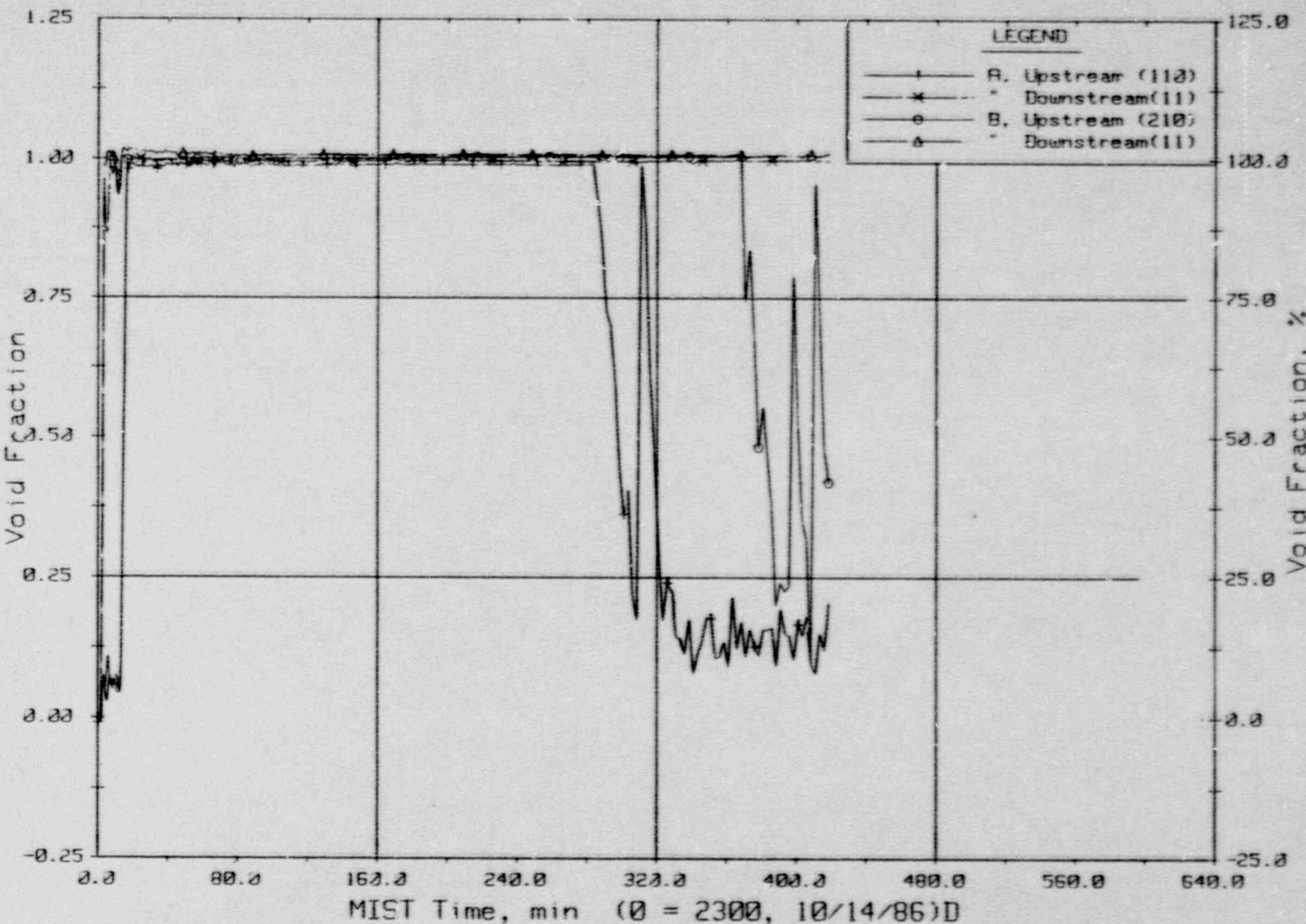
Hot Leg Riser and Stub Collapsed Liquid Levels.

Wed May 25 15:53:46 1988

HLLV1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



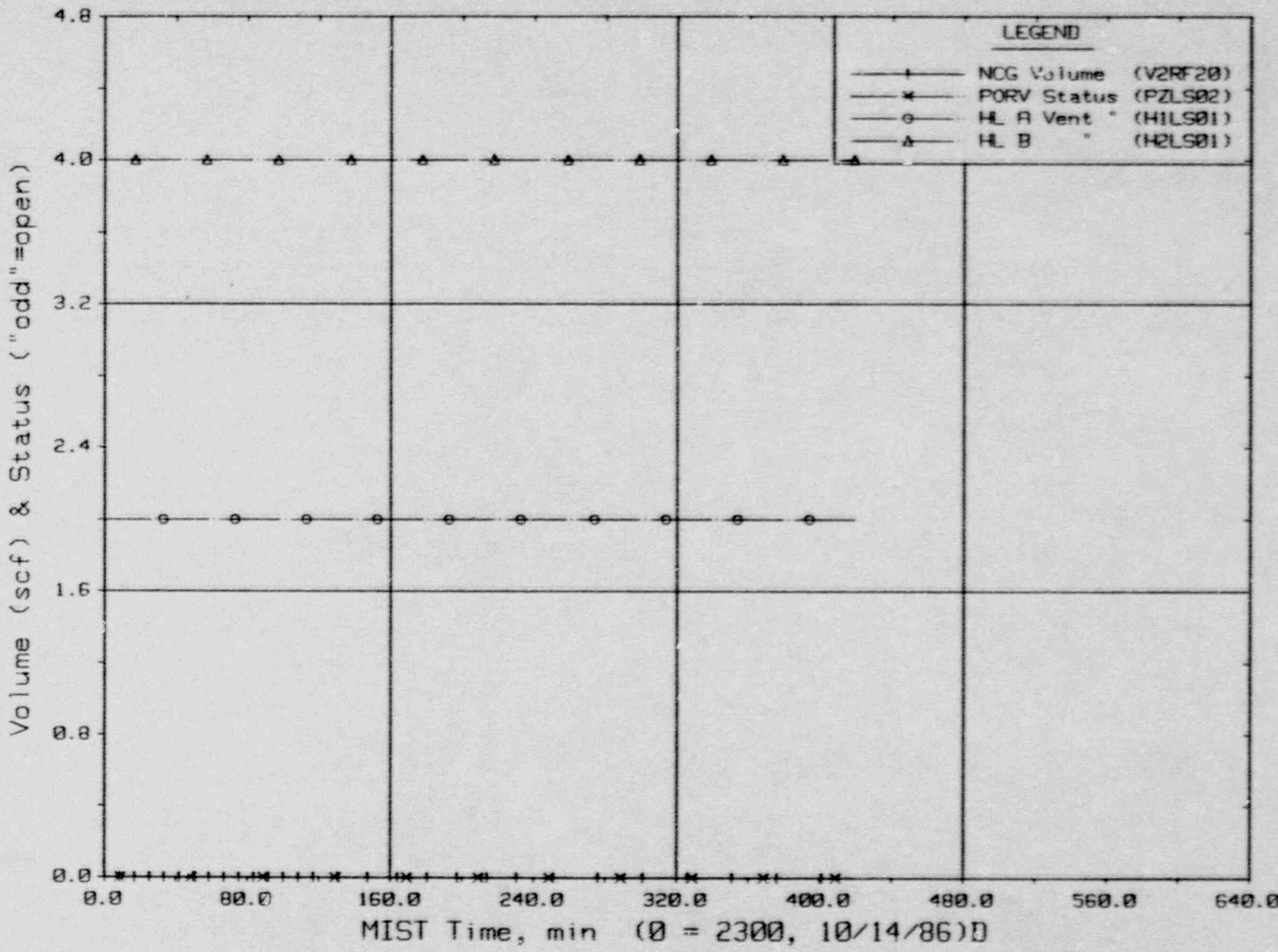
Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft. Hn'Fs).

Wed May 25 15:56:37 1988

HLVF1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



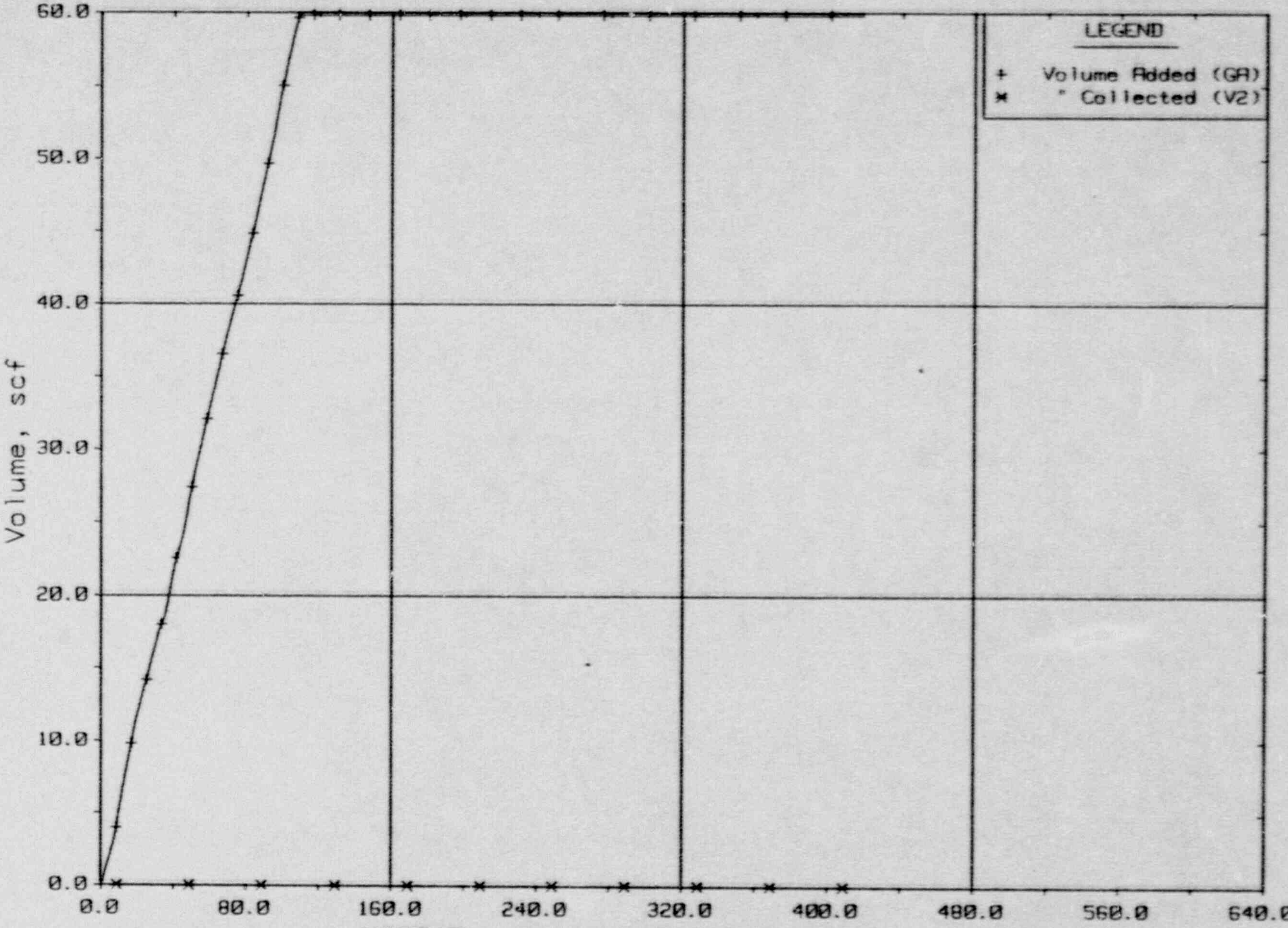
Noncondensibles Collected and Discharge Valve Status.

Thu May 26 10:20:26 1988

NCMS1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



MIST Time, min (0 = 2300, 10/14/86)D

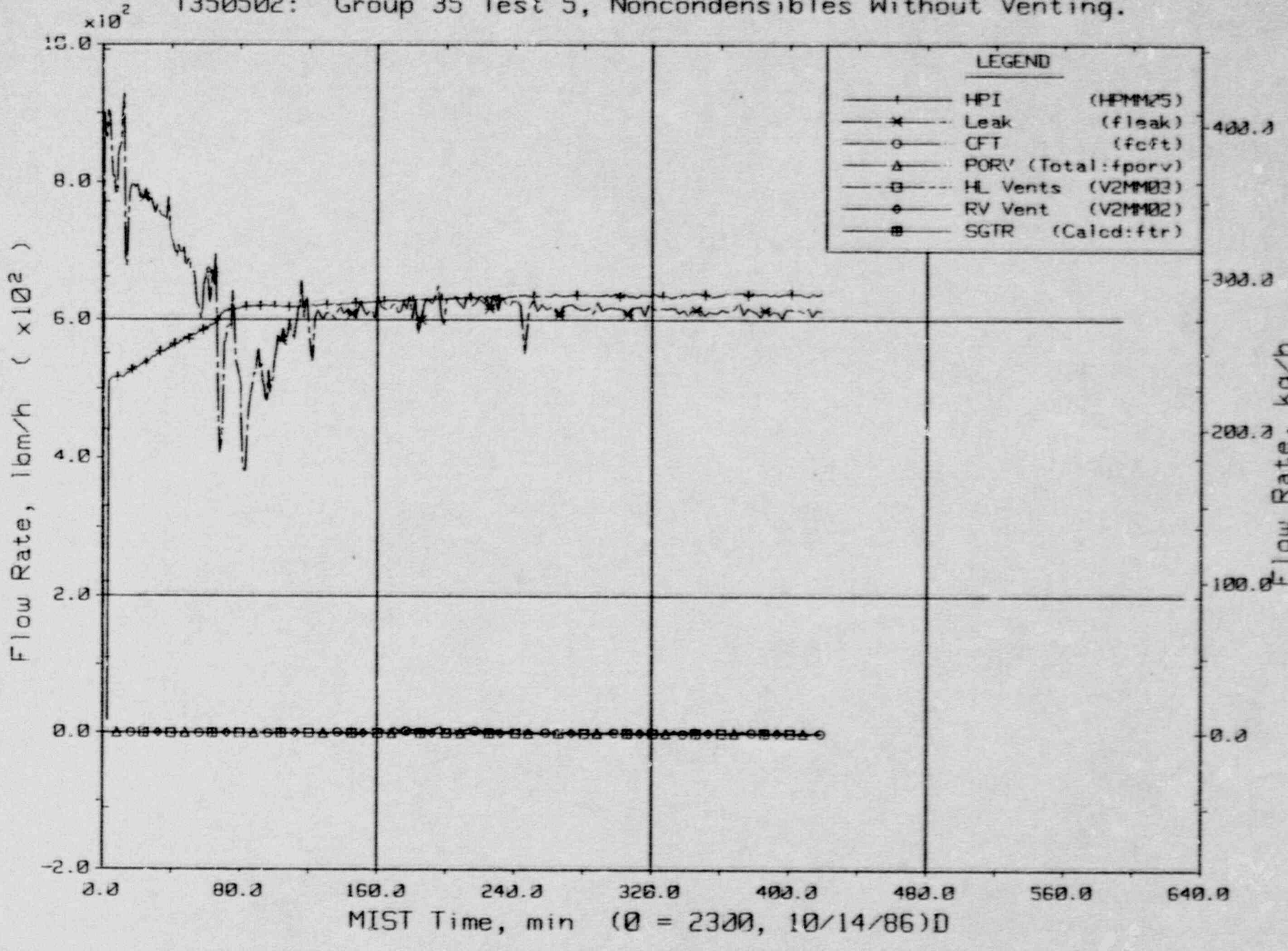
Noncondensibles Gas Volumes.

Thu May 26 10:27:57 1988

NCMS2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



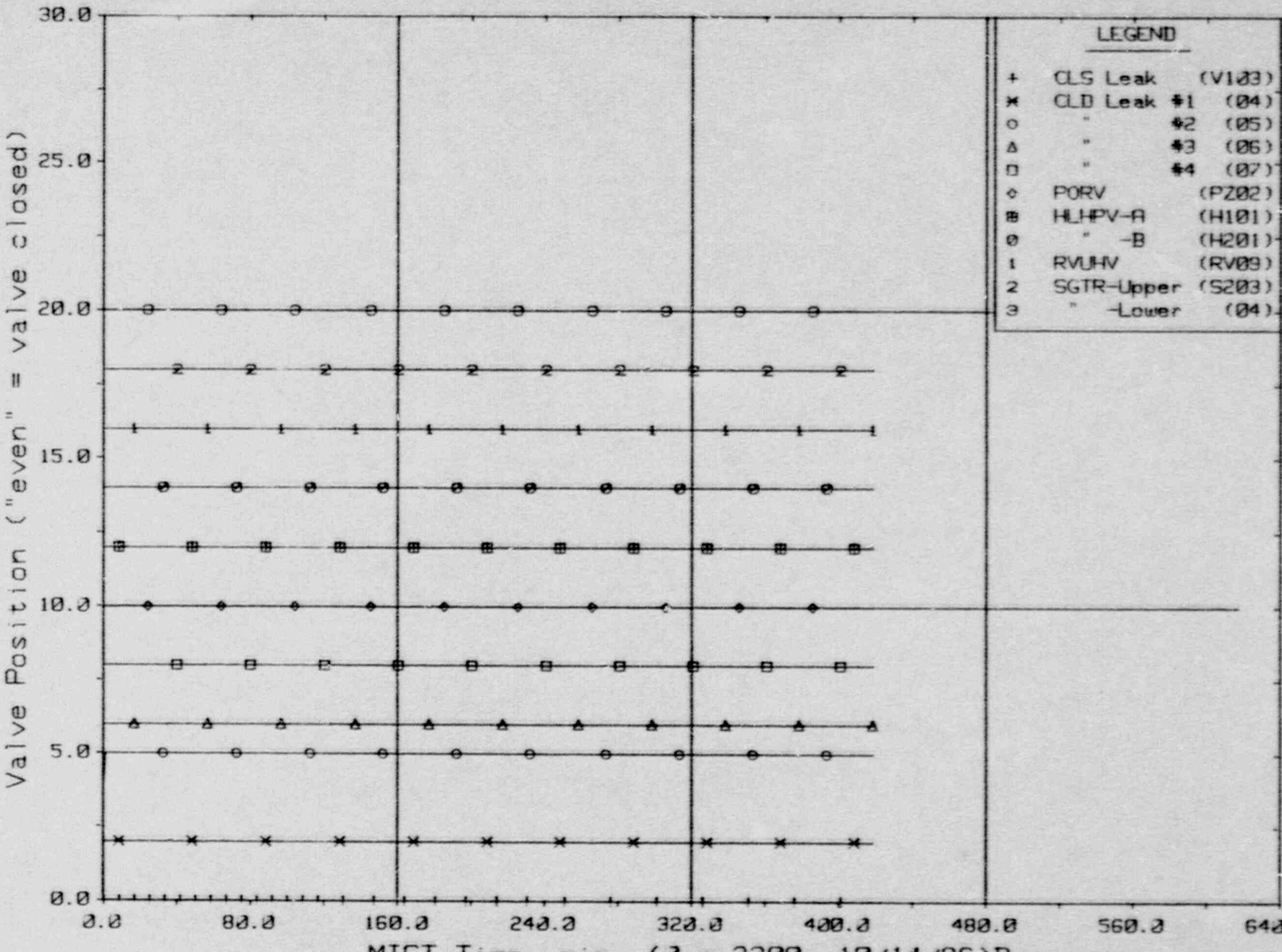
Primary System Boundary Flow Rates.

Wed May 25 16:02:26 1988

PHFL3

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



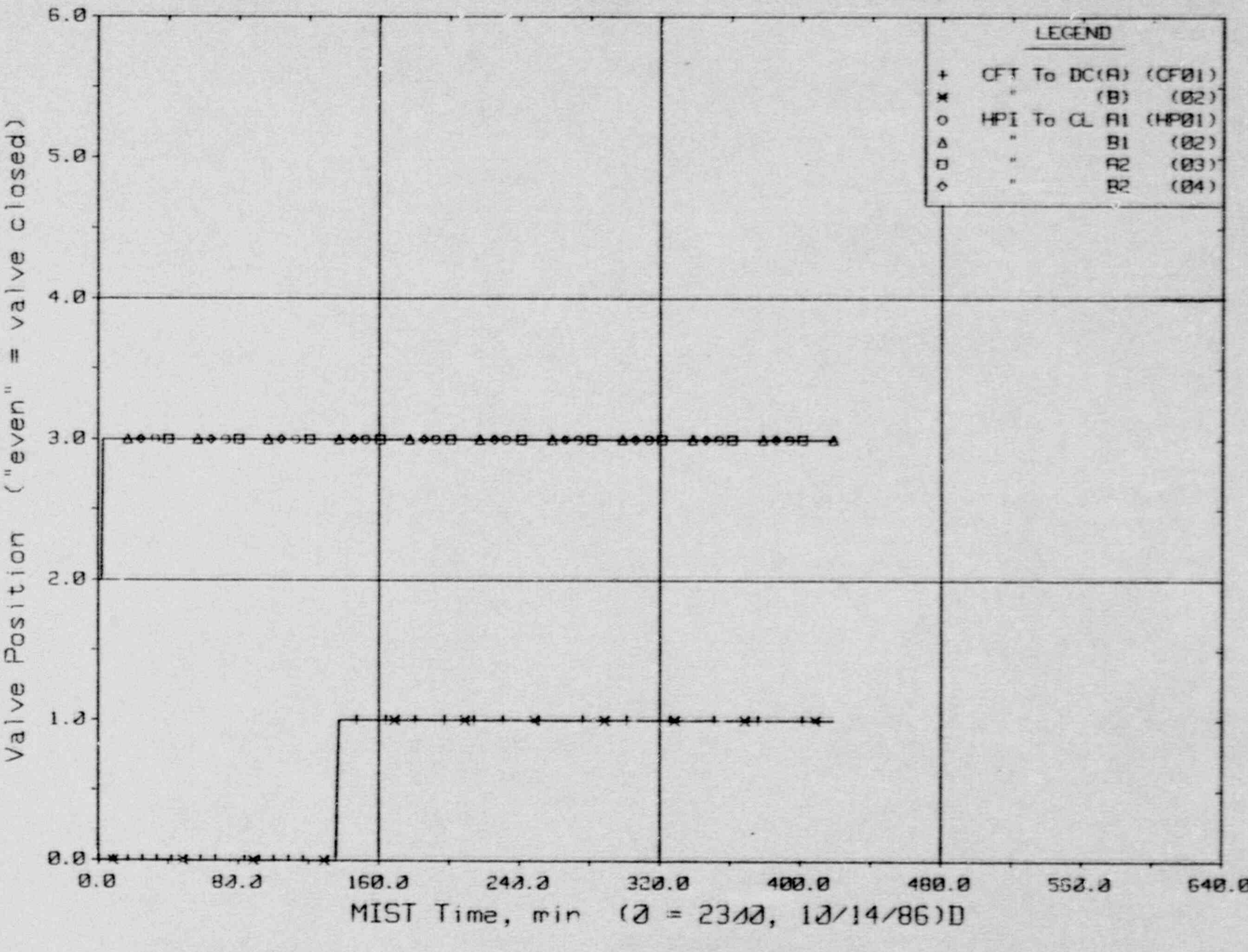
Primary System Discharge Limit Switch Indications (LSs).

Wed May 25 16:06:06 1988

PBLS1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



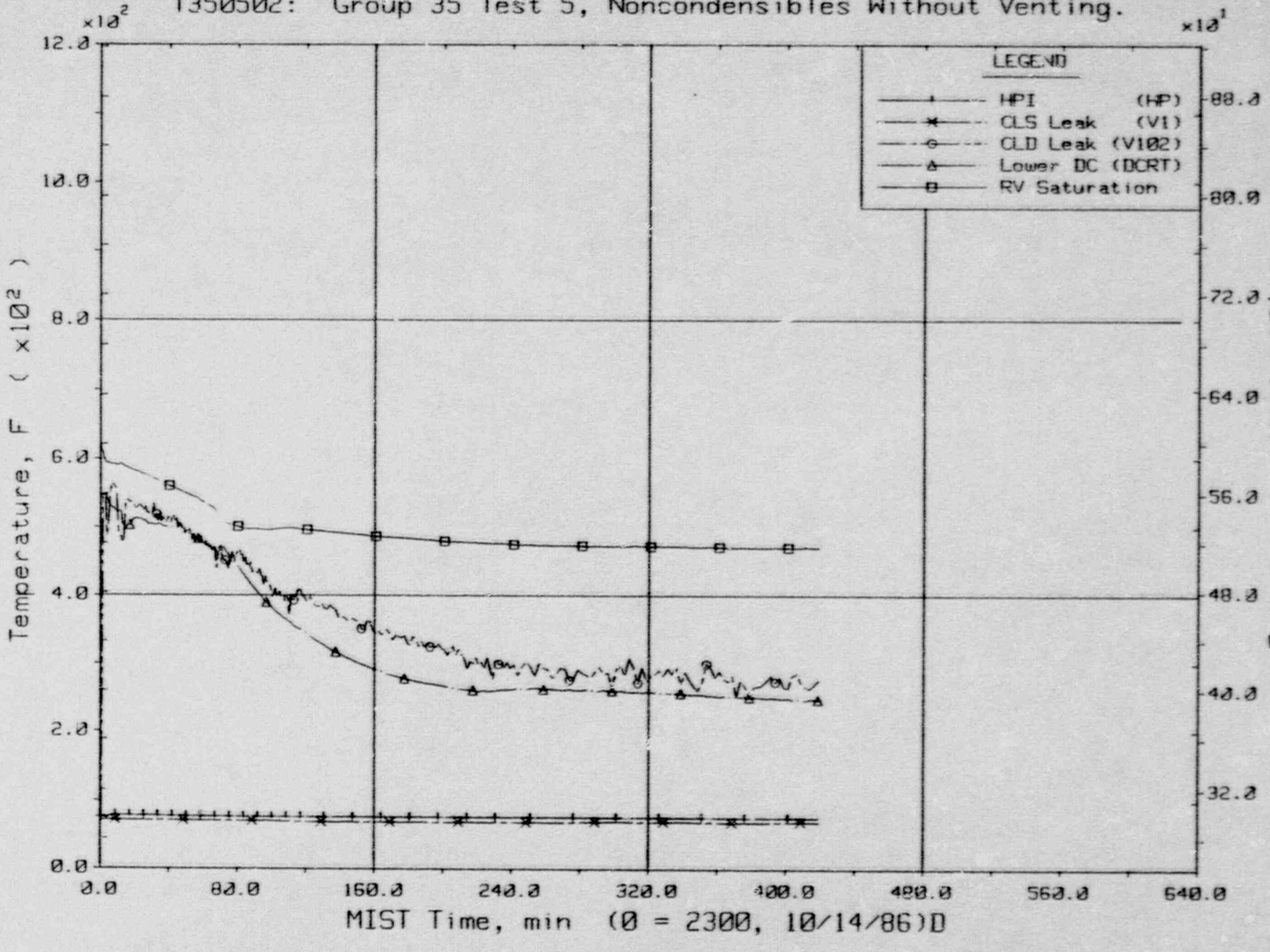
Primary System Injection Limit Switch Indications (LSs).

Wed May 25 16:09:19 1988

PRLS2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



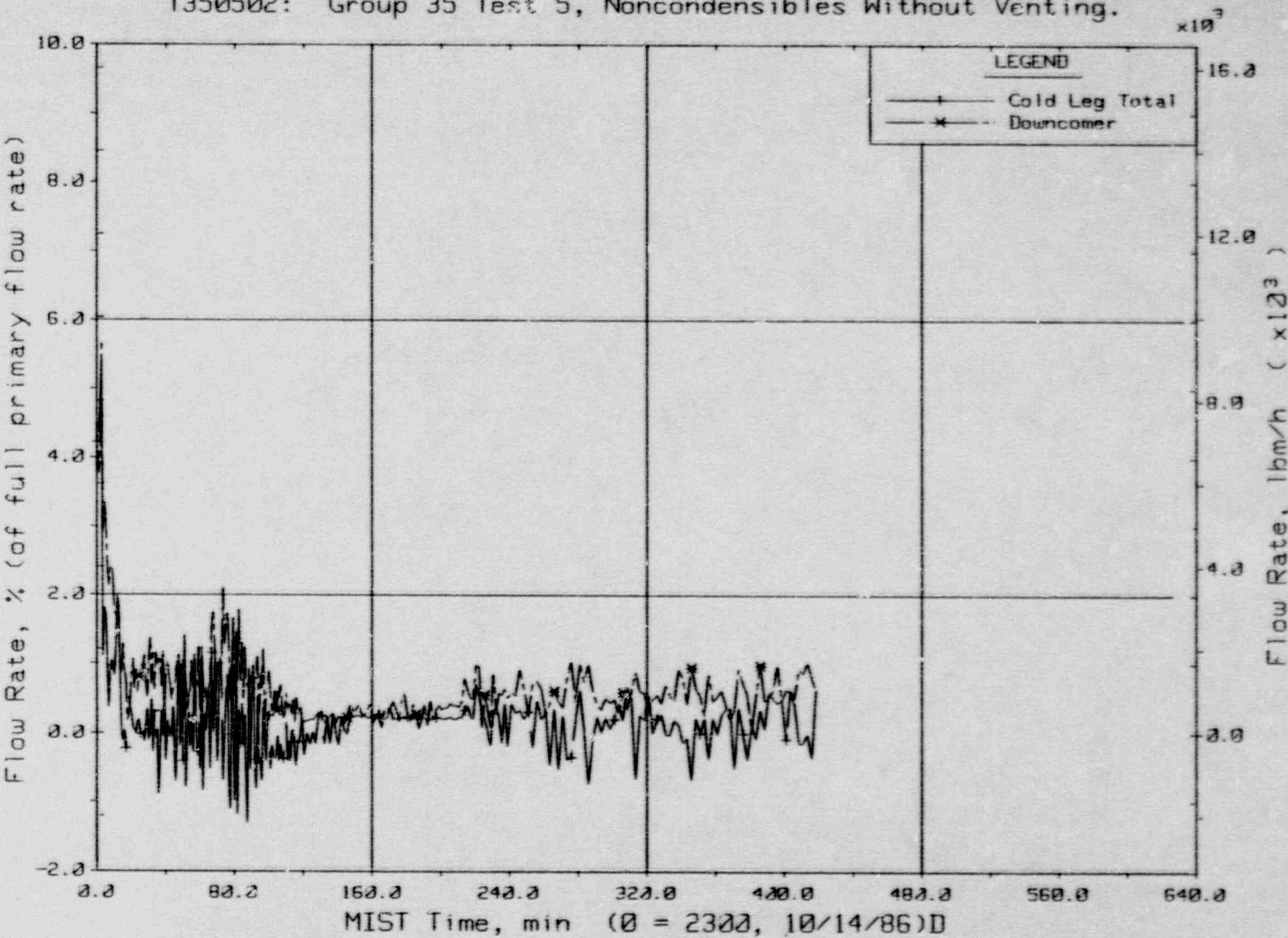
Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Wed May 25 16:12:36 1988

PBTC1p

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



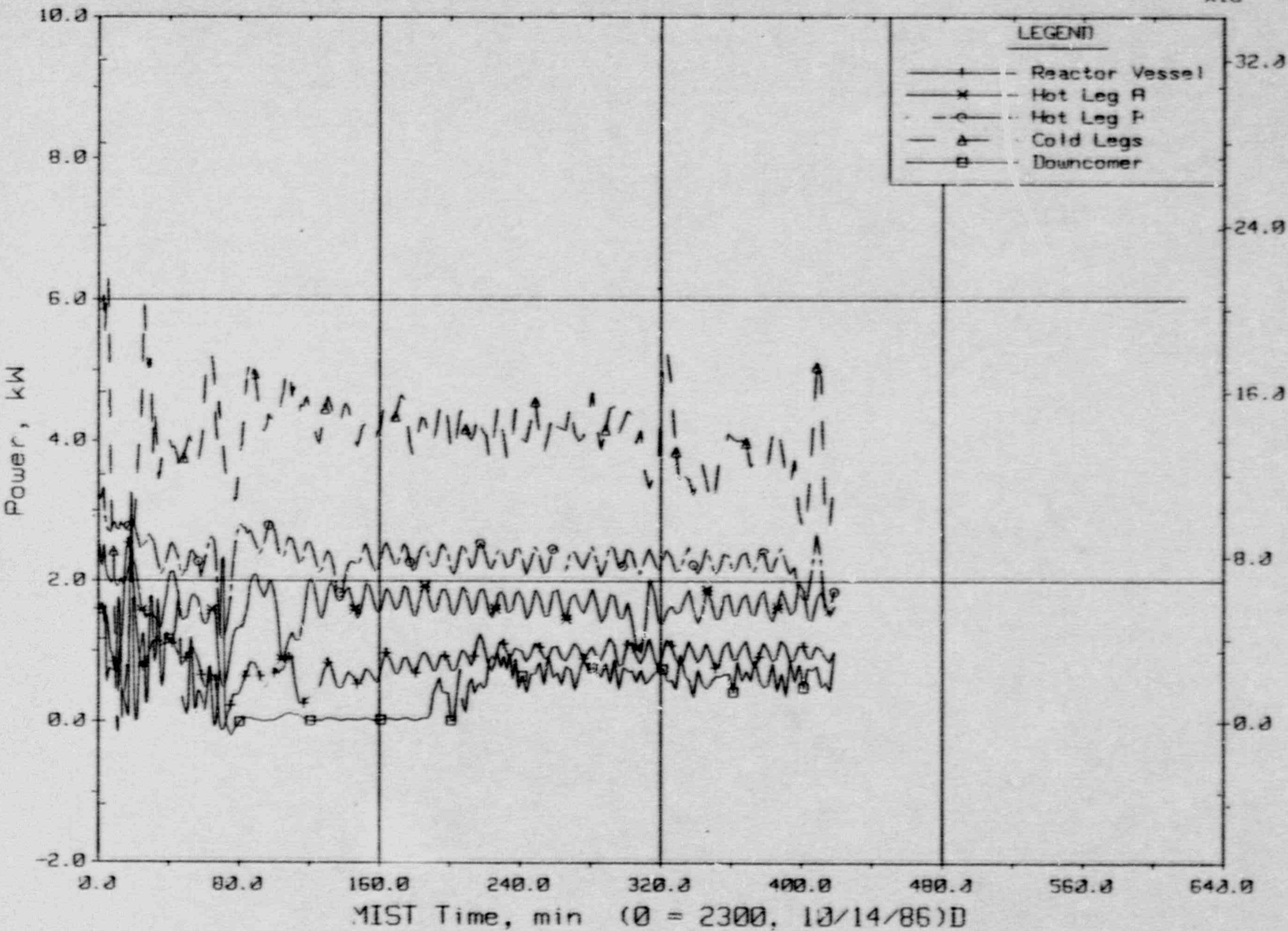
Primary System Venturi Flow Rates.

Wed May 25 16:15:09 1988

PRFL7

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



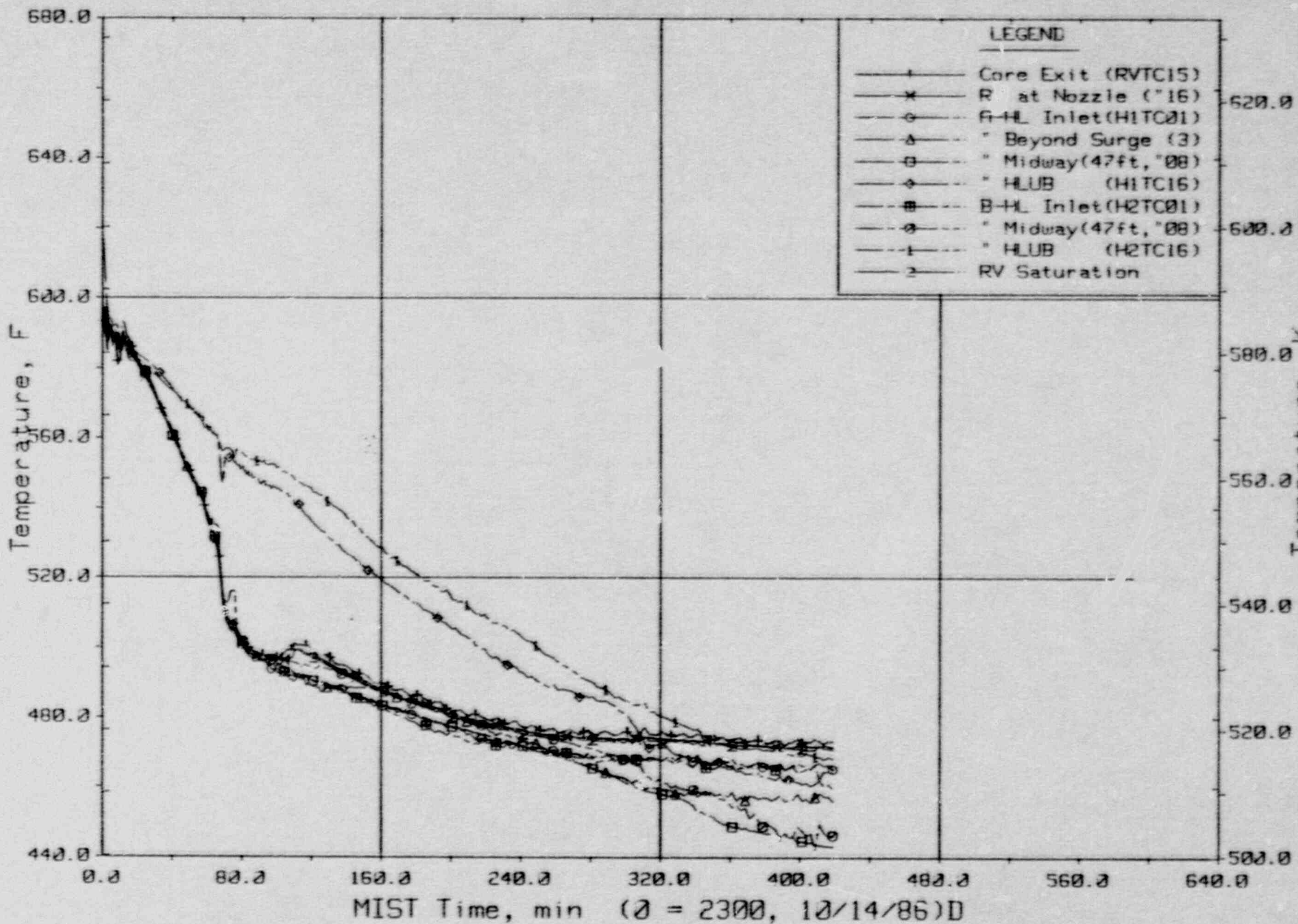
Guard Heater Specified Power Per Primary Component.

Wed May 25 16:18:17 1988

PRG01

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



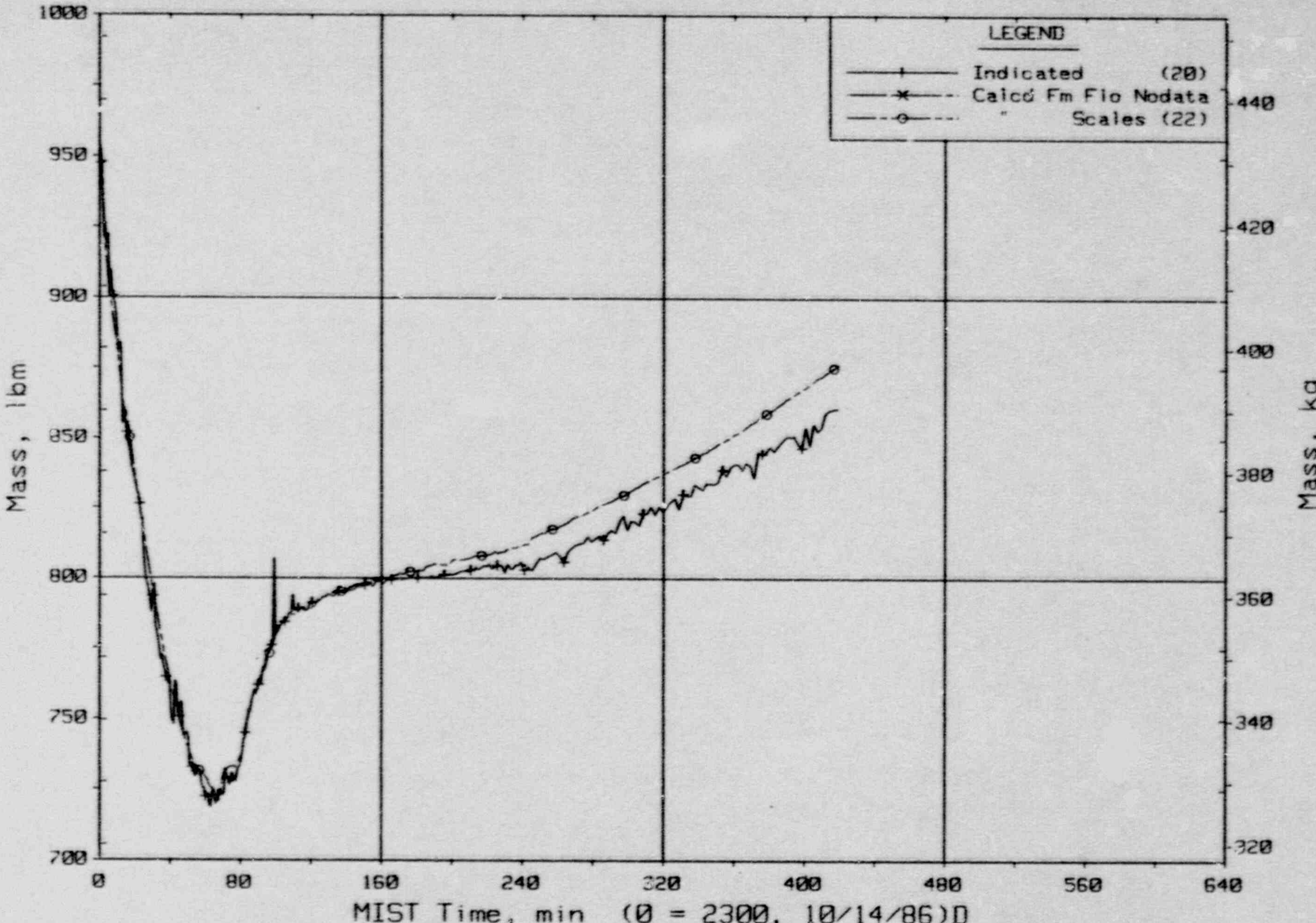
Composite Core Exit and Hot Leg Fluid Temperatures.

Wed May 25 16:24:53 1988

PRKT1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



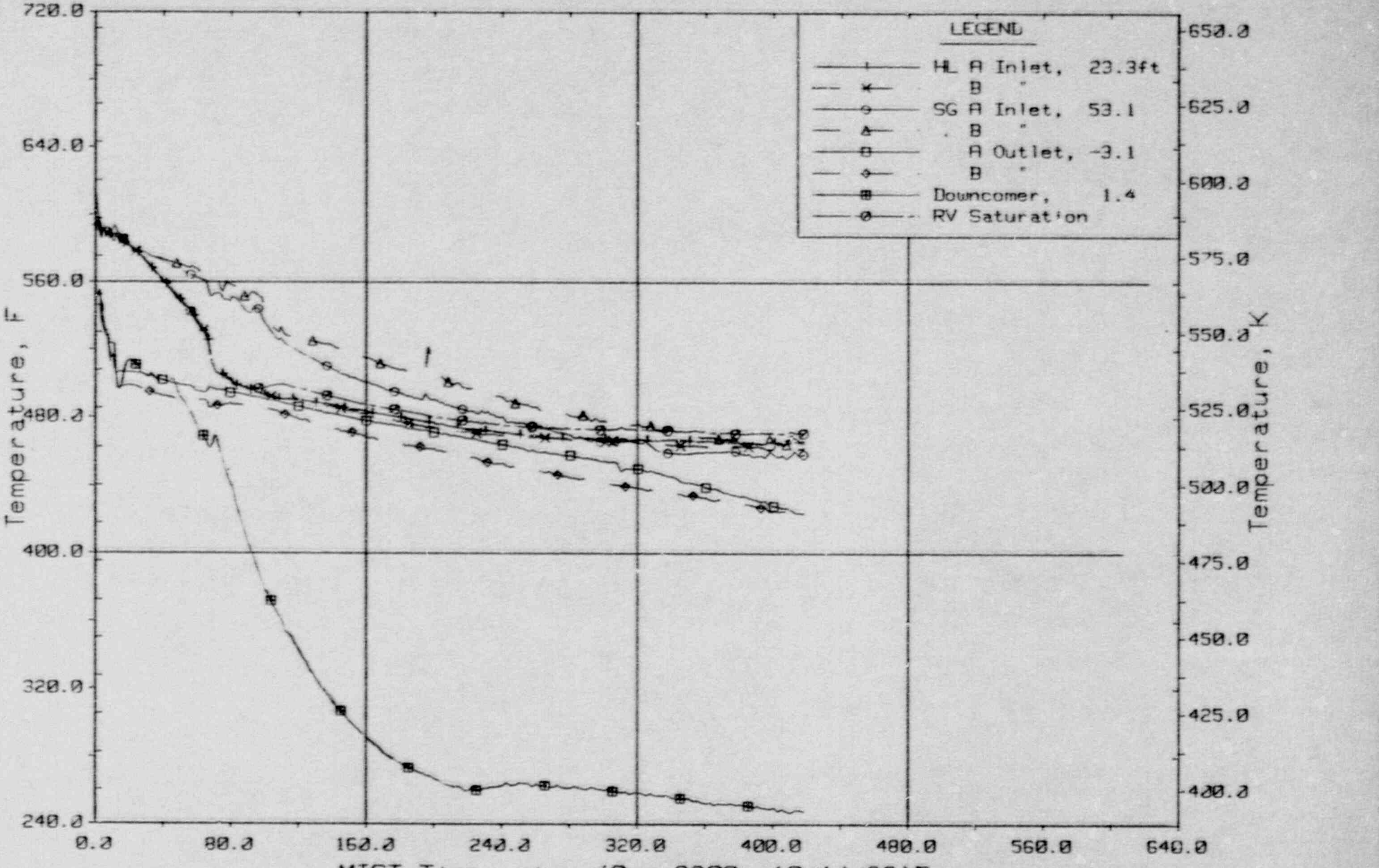
Primary System Total Fluid Mass (PLMLs).

Fri Jan 6 15:01:36 1989

PRML2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



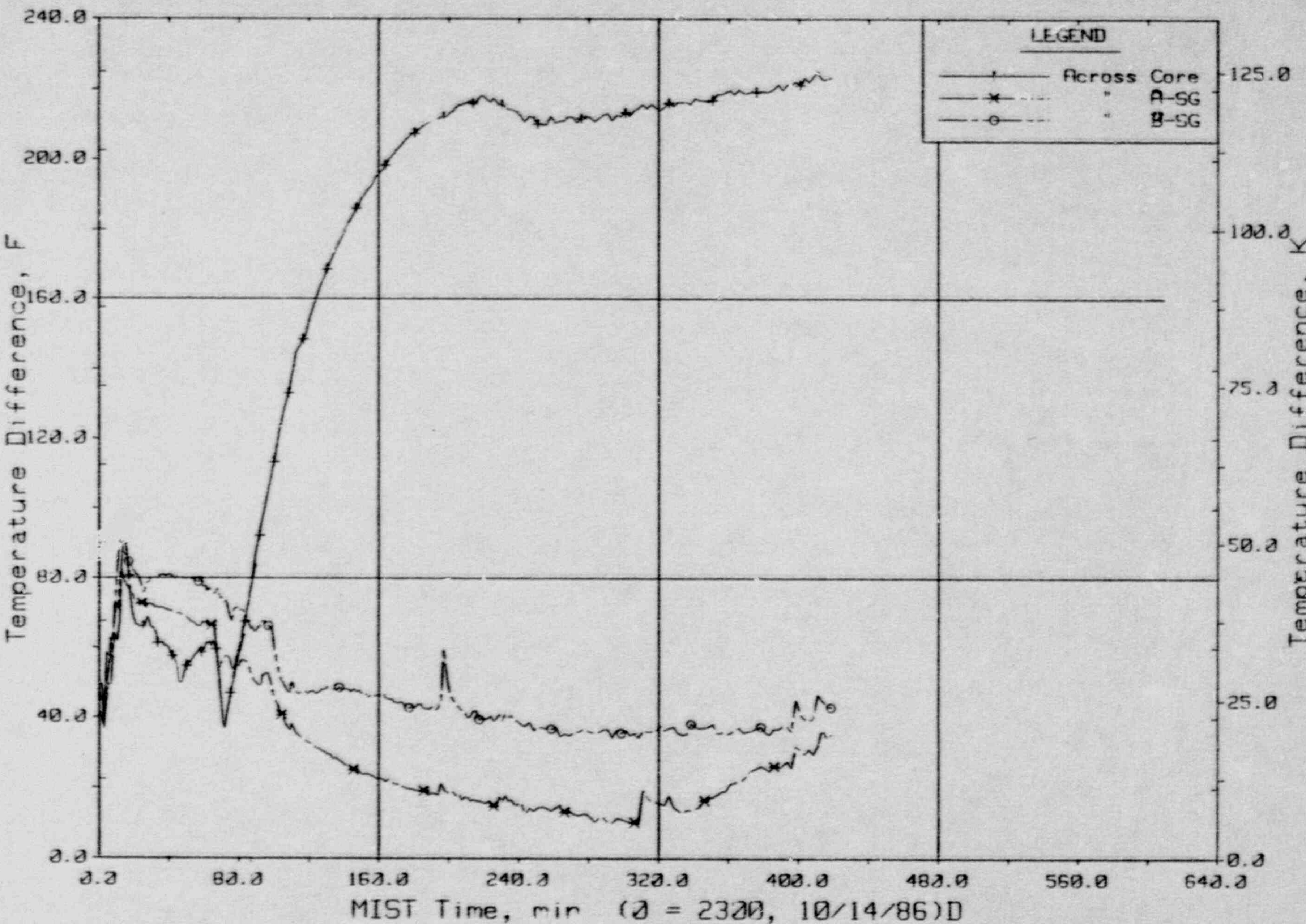
Primary System Fluid Temperatures (RTDs).

Wed May 25 15:58:25 1988

PRRT0

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



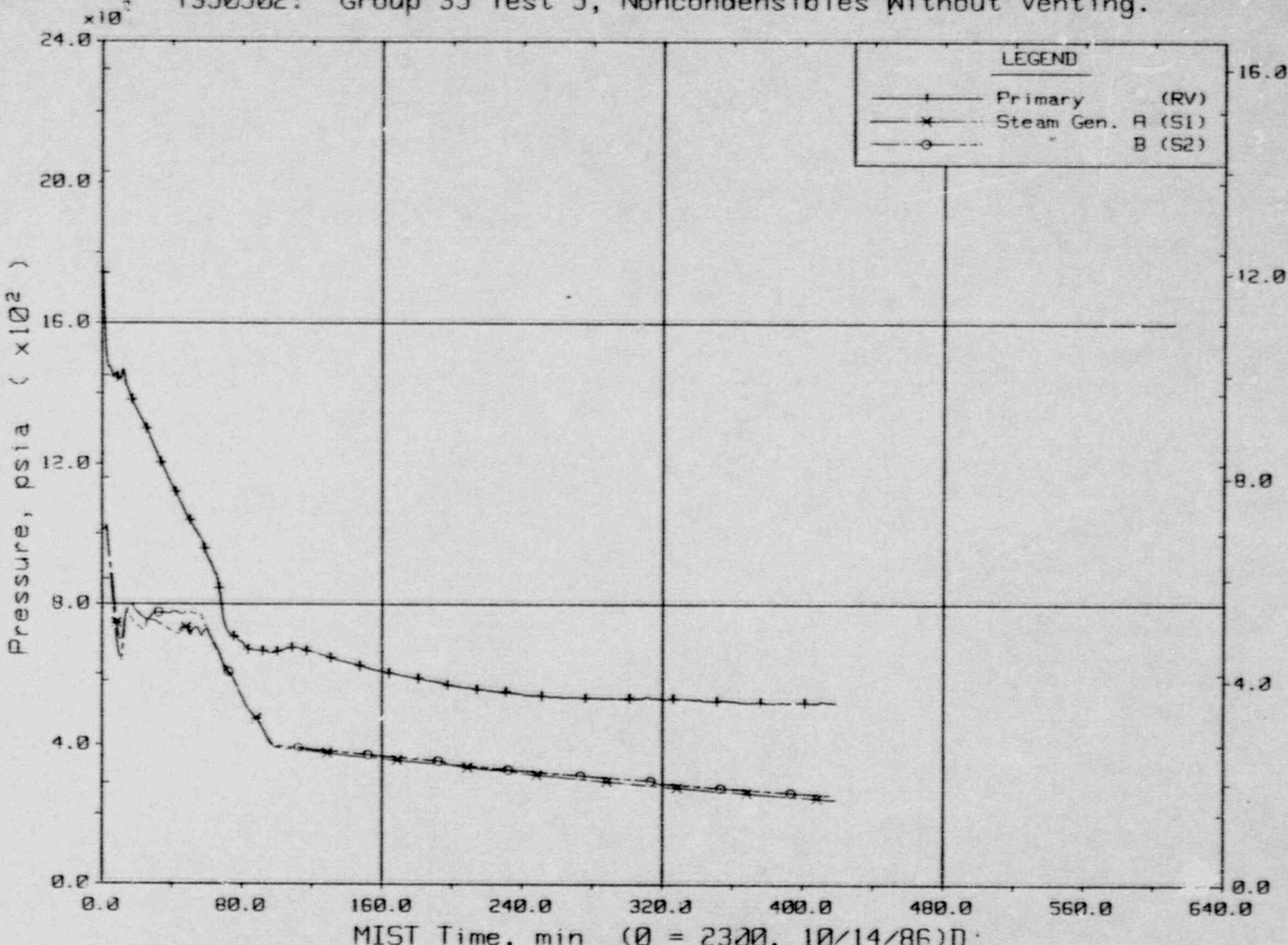
Key Temperature Differences.

Wed May 25 17:05:05 1988

PRTD2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



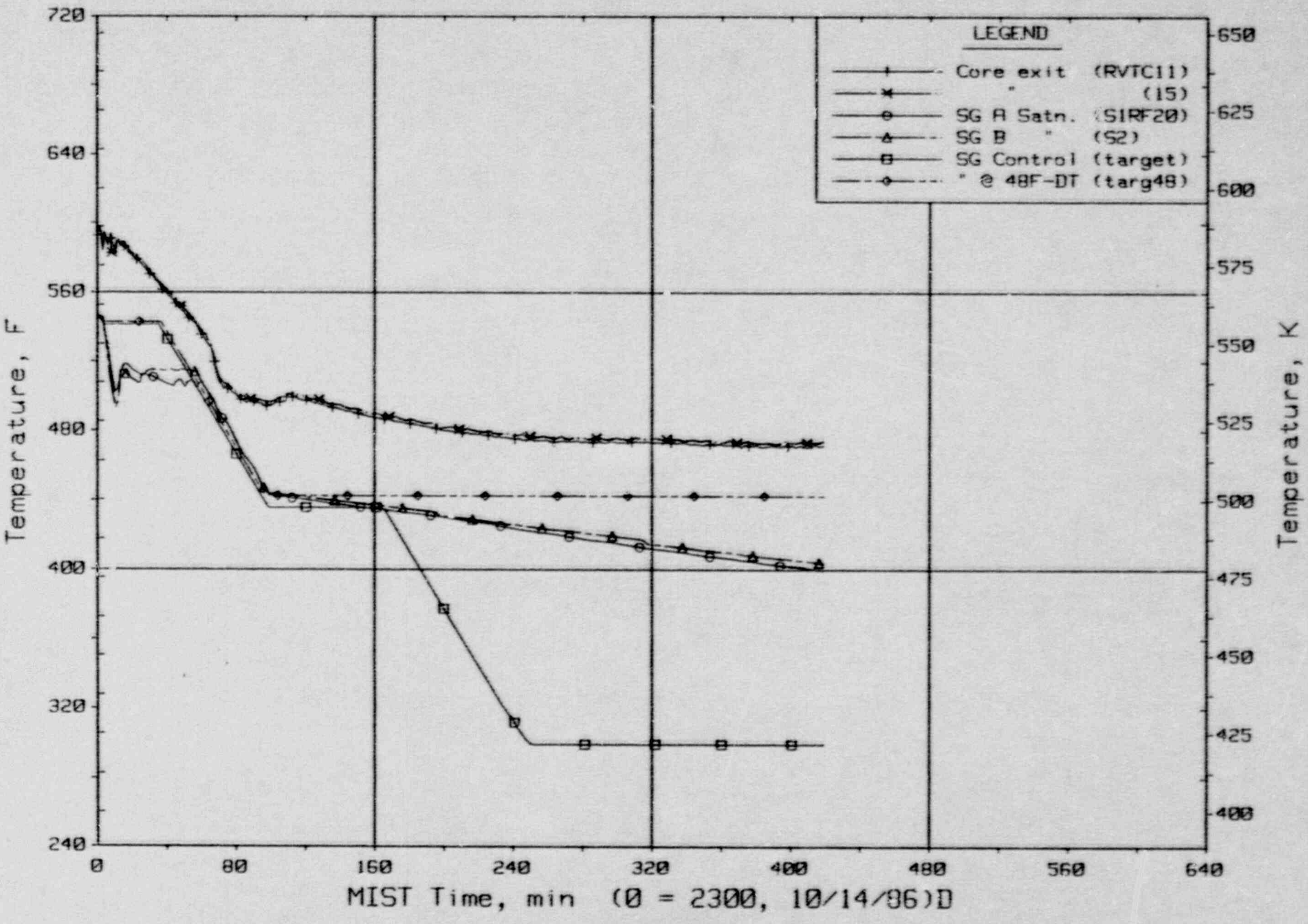
Primary and Secondary System Pressures (GP01s).

Wed May 25 17:14:51 1988

PSGP1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



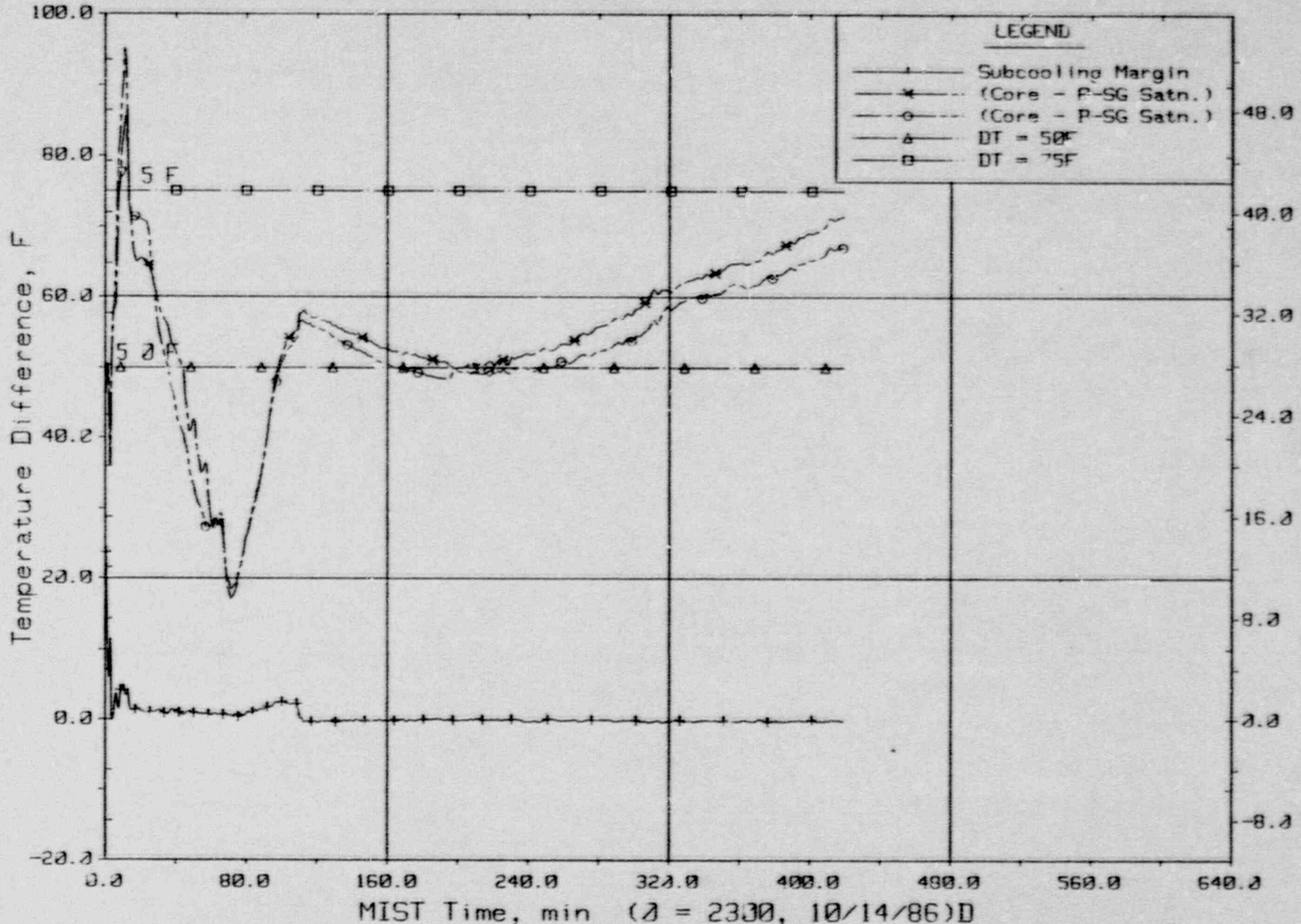
Steam Generator Secondary Saturation and Control Temperatures.

Fri Jan 6 14:42:35 1989

PSTC3

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



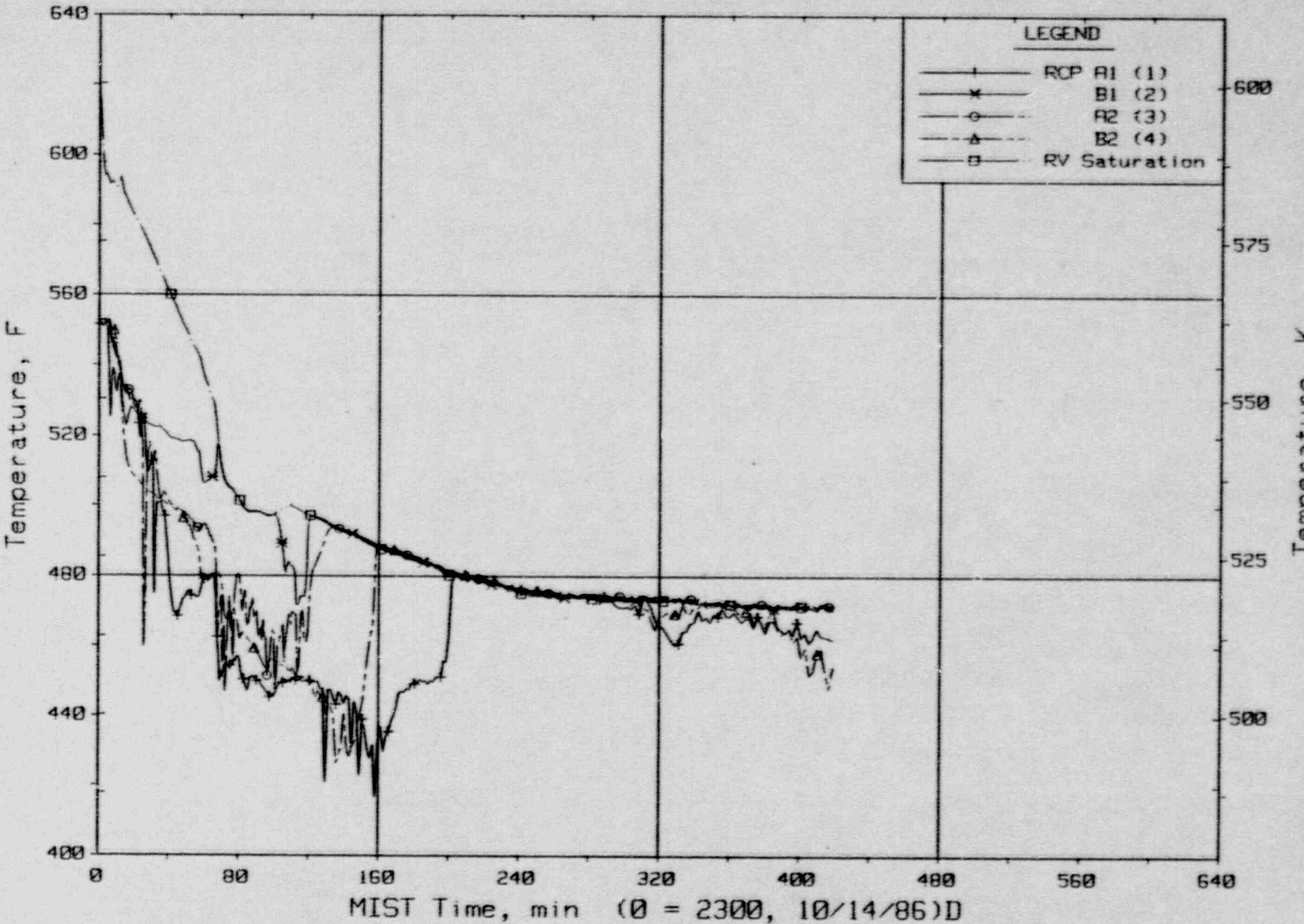
Control Temperature Differences.

Wed May 25 17:35:34 1988

PSTD1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



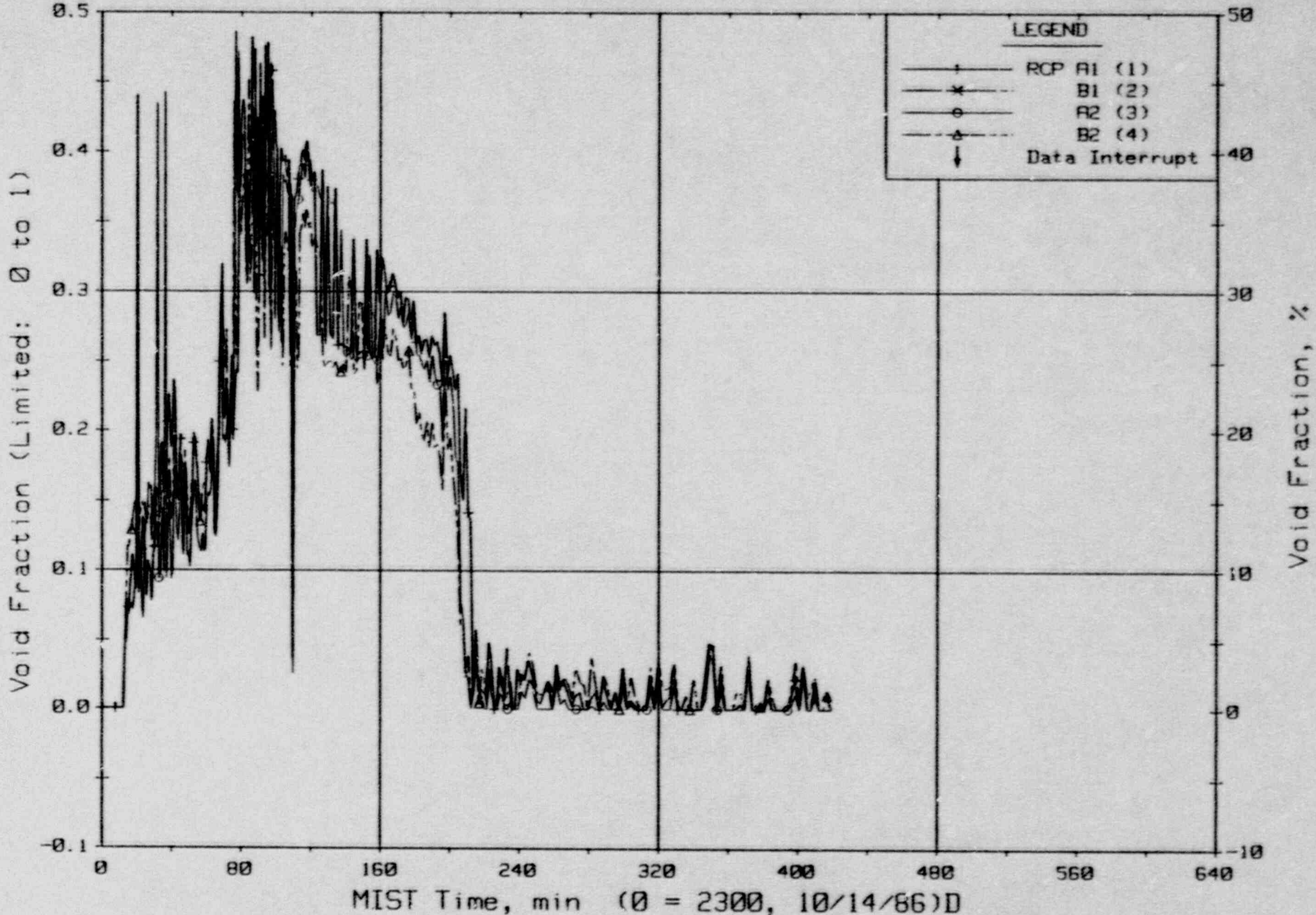
Pump Suction Fluid Temperature (CnRT01s).

Fri Jan 6 15:25:01 1989

PURT0

FINAL DATA

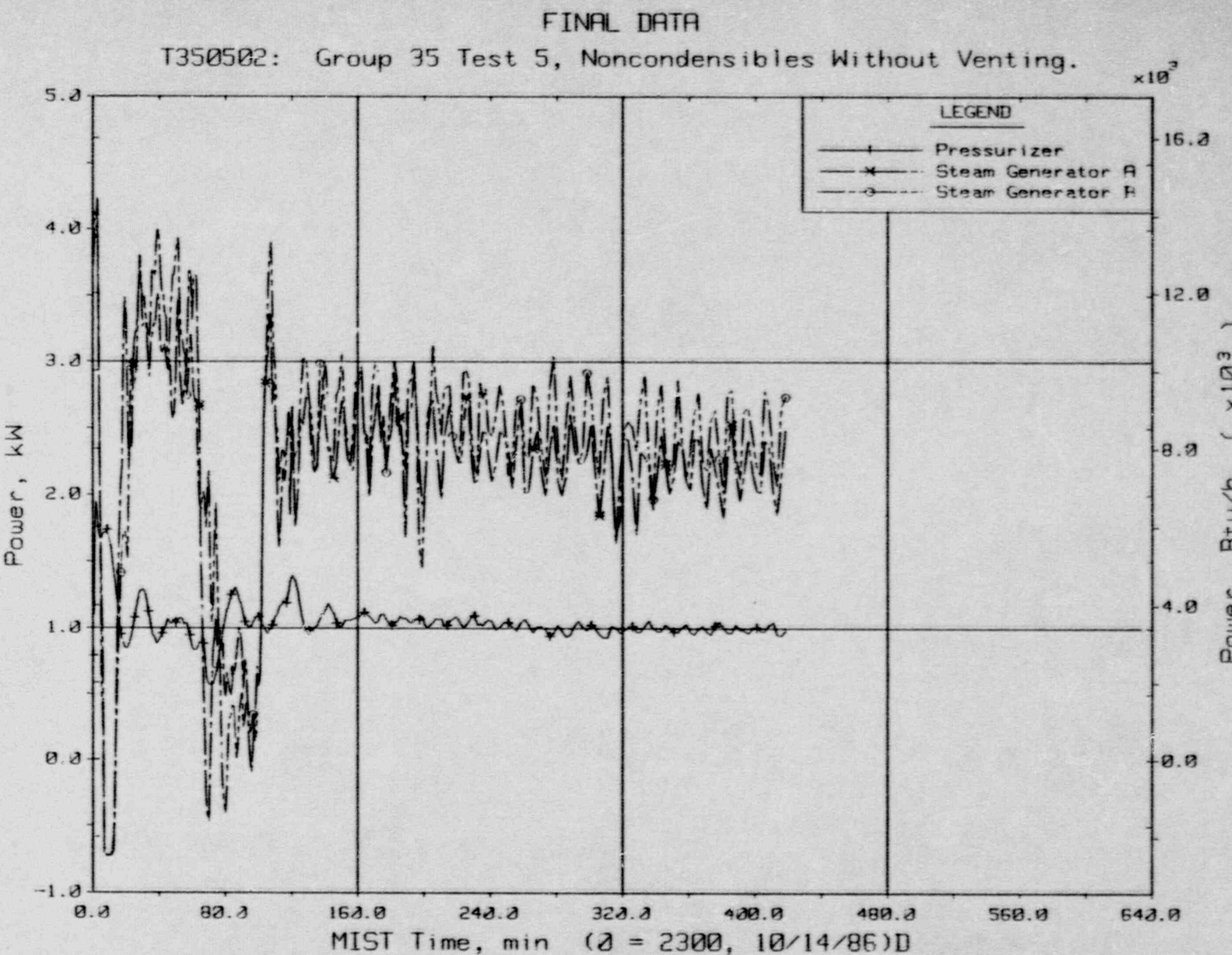
T350502: Group 35 Test 5, Noncondensibles Without Venting.



Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

Fri Jan 6 15:19:03 1989

PU/F2



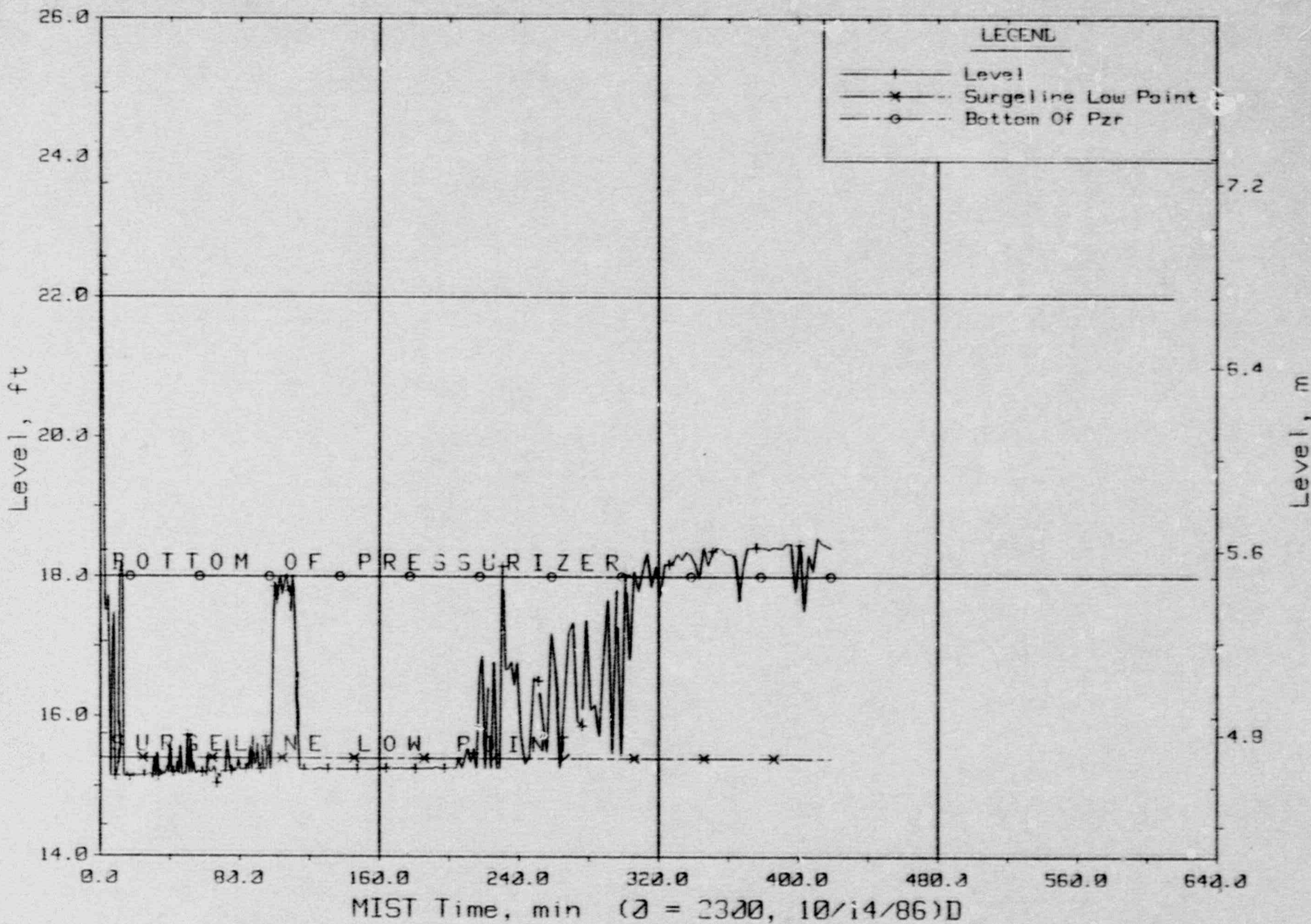
Guard Heater Specified Power, Pressurizer and Steam Generators.

Wed May 25 17:54:48 1988

PZG01

FINAL DATA

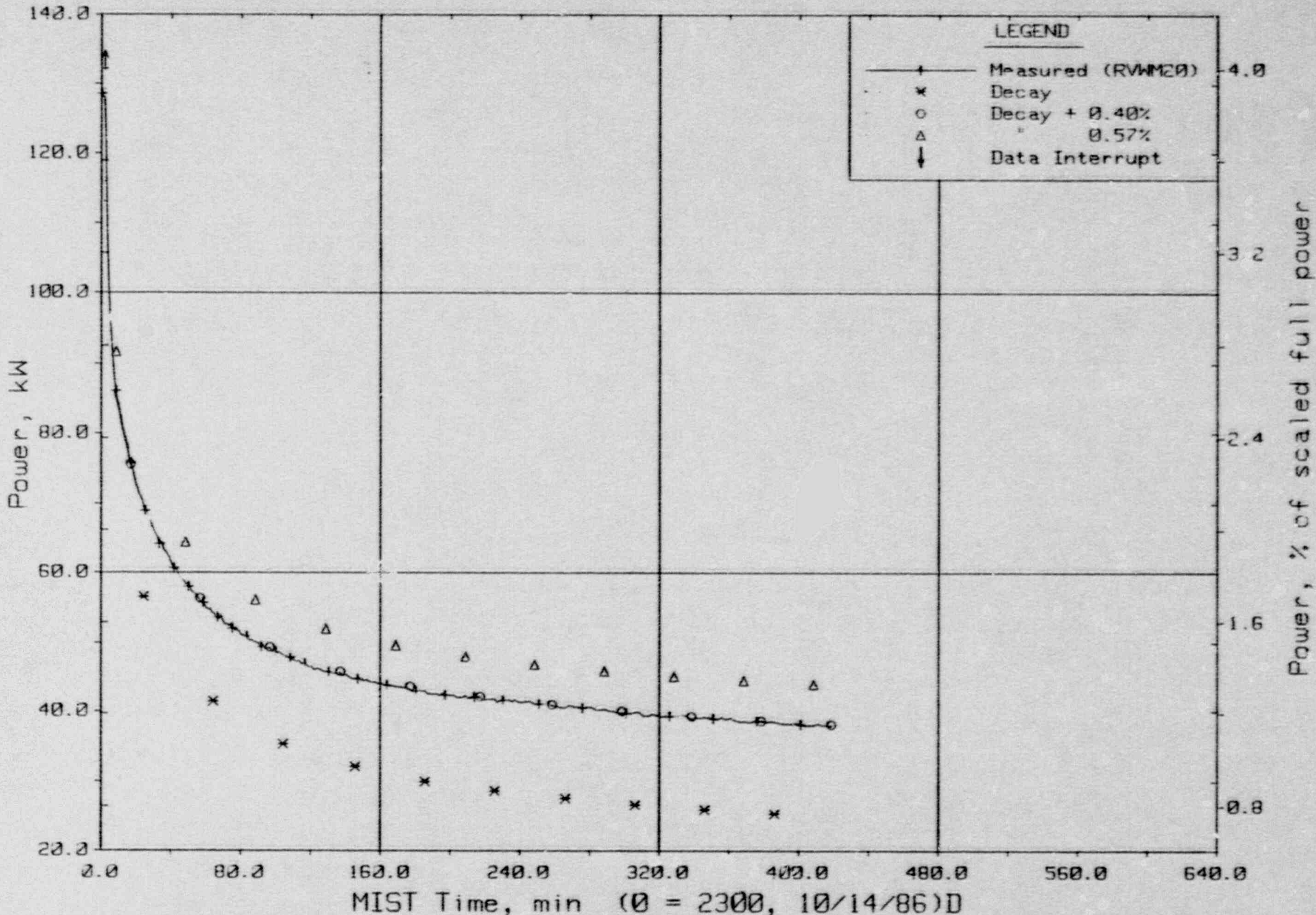
T350502: Group 35 Test 5, Noncondensibles Without Venting.



Pressurizer Collapsed Liquid Level (PZLV20).

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



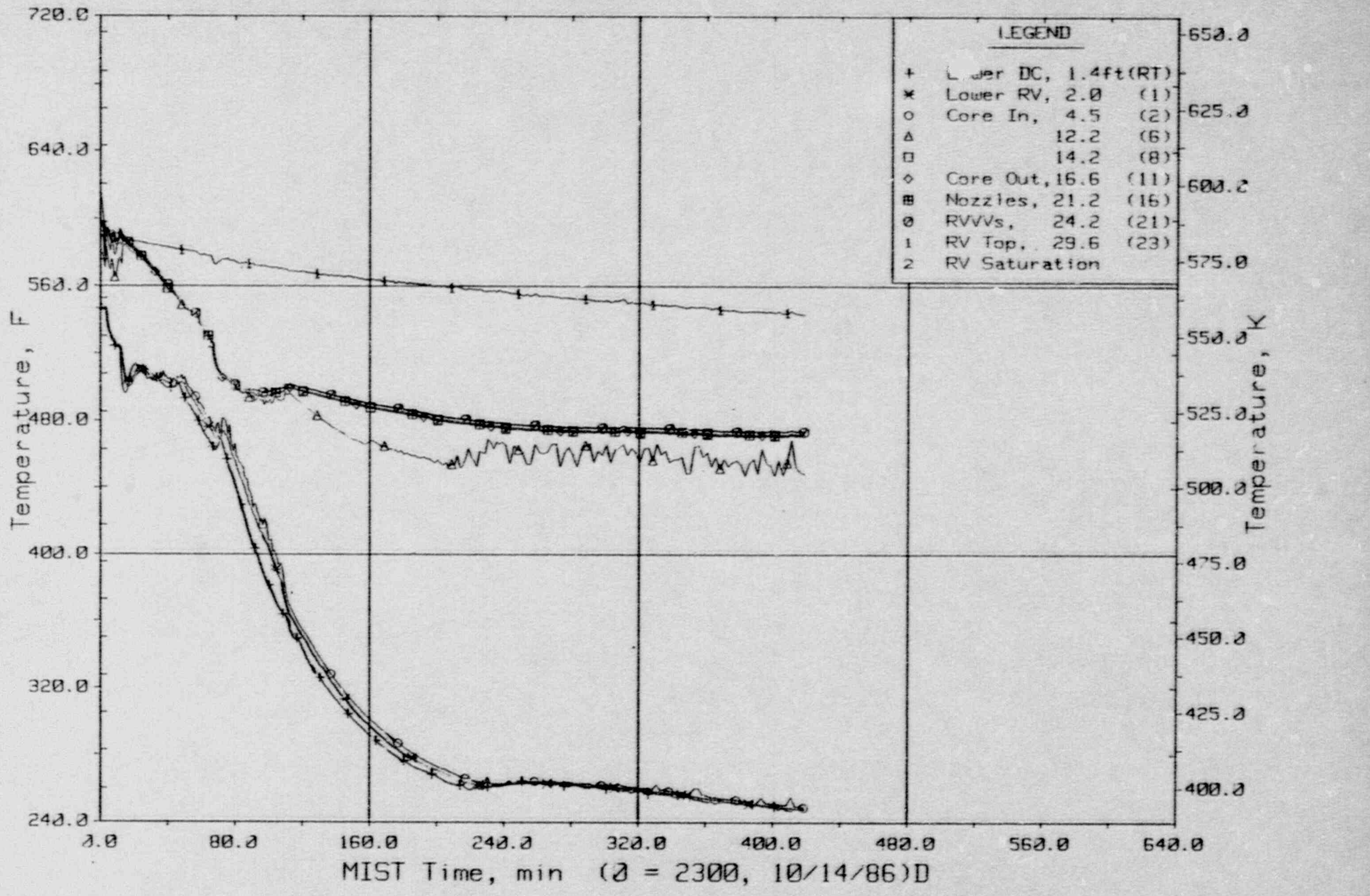
Core Power.

Wed May 25 18:07:07 1988

RVKW0

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



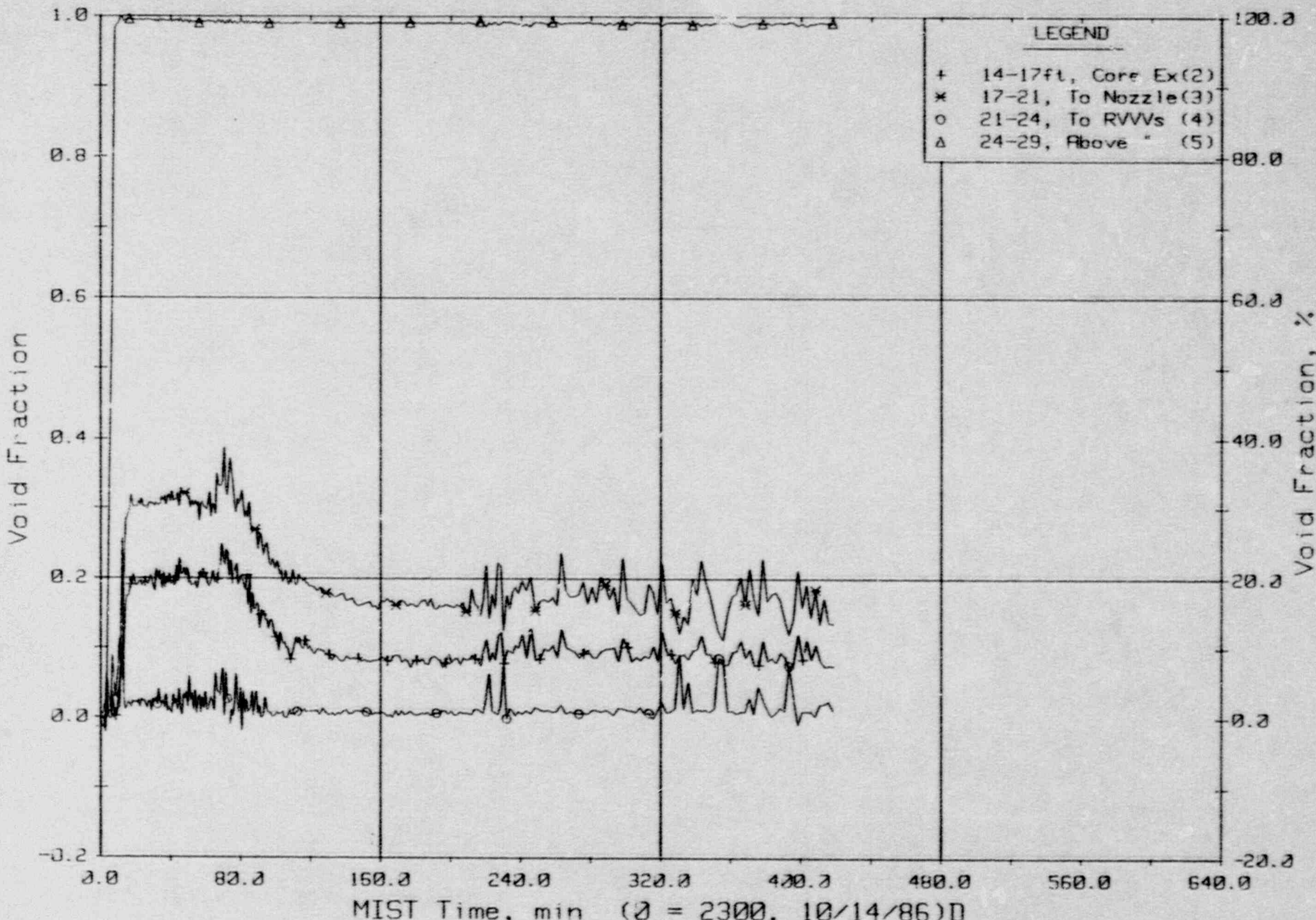
Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

Wed May 25 18:14:11 1988

RVTC0

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



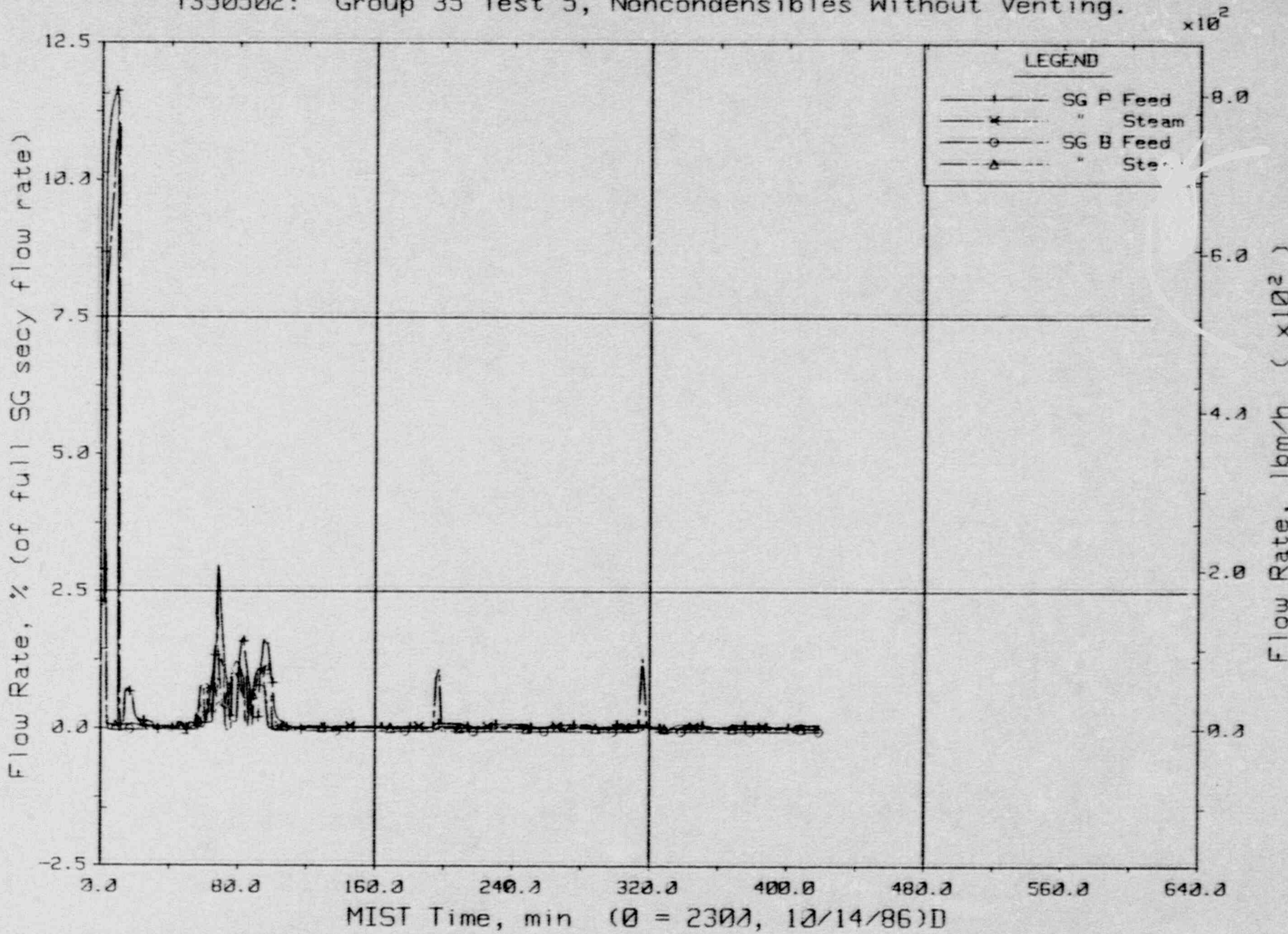
Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Wed May 25 18:16:22 1988

RVVF1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



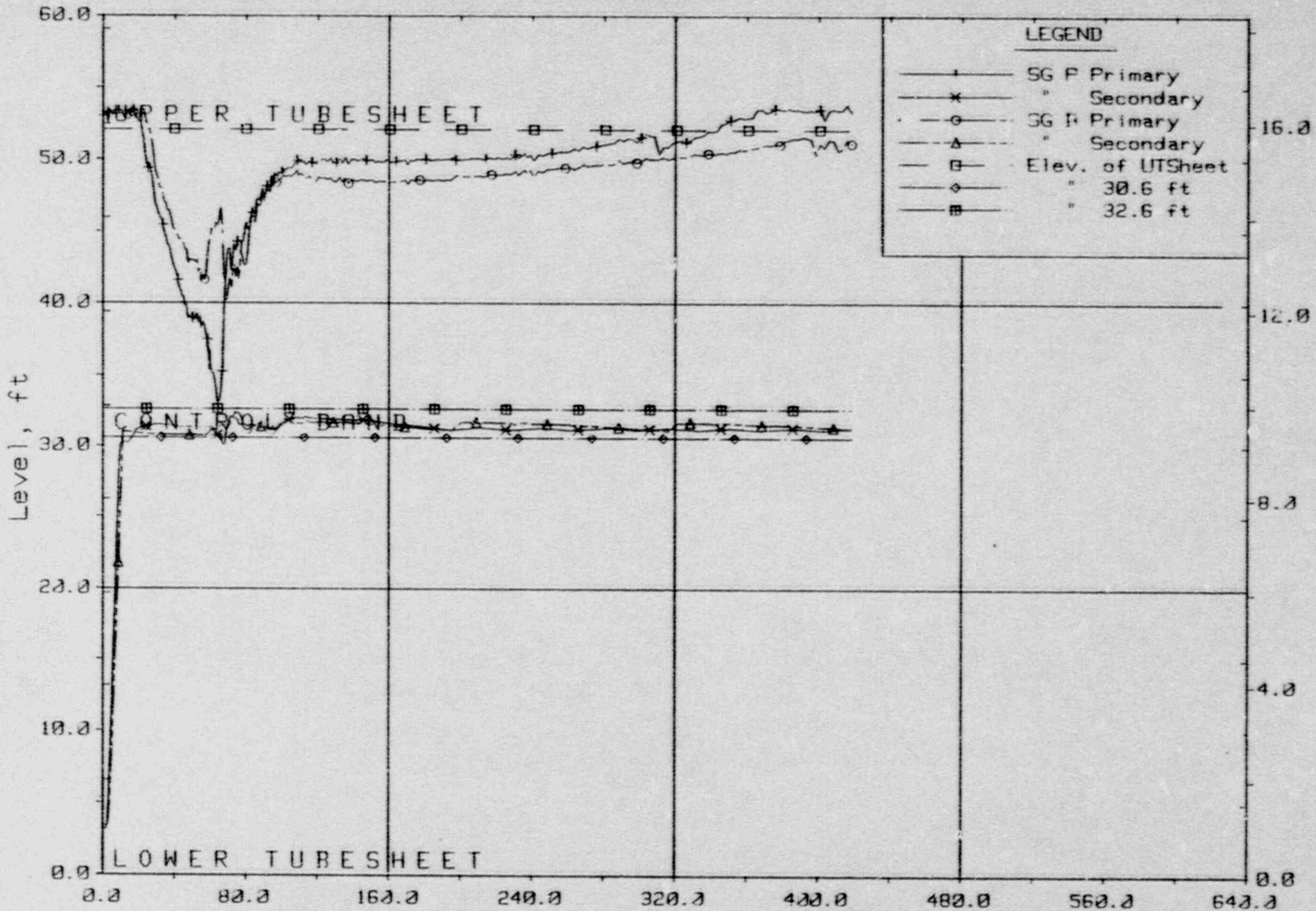
Steam Generator Secondary System Flow Rates.

Wed May 25 18:21:42 1988

SGFL2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



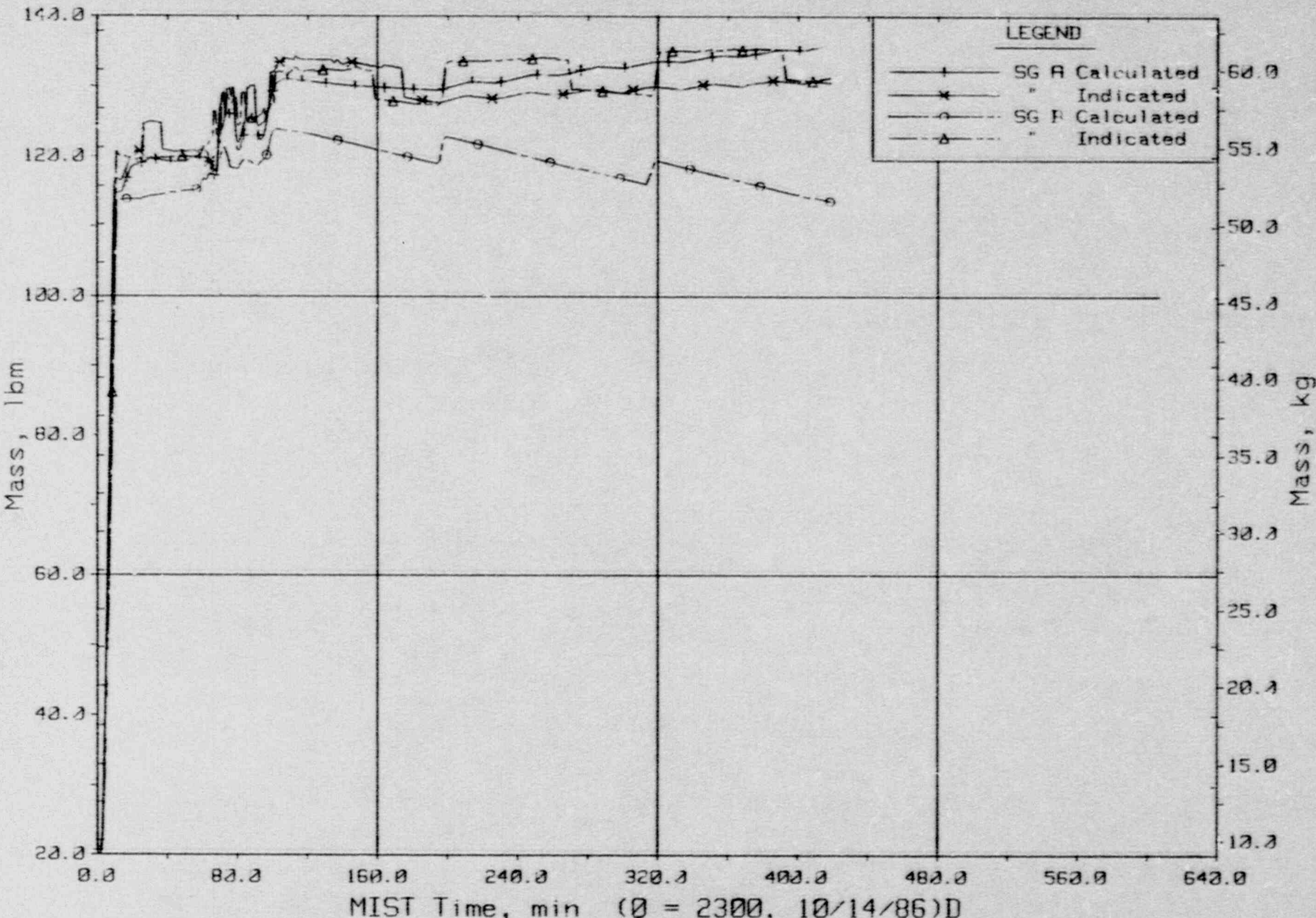
Steam Generator Collapsed Liquid Levels.

Wed May 25 18:25:16 1988

SGLV2

FINAL DATA

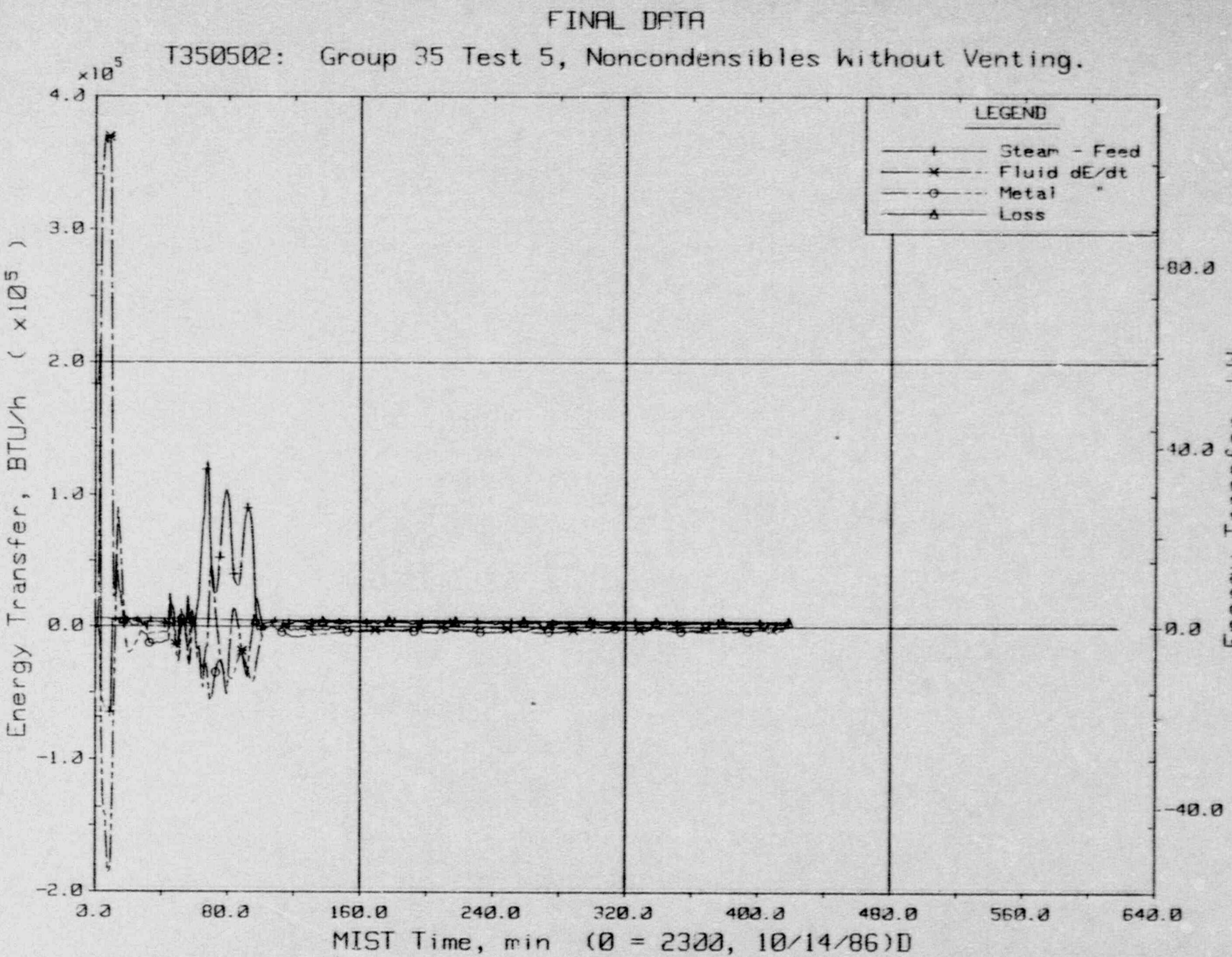
T350502: Group 35 Test 5, Noncondensibles Without Venting.



Steam Generator Secondary Fluid Mass Balances.

Wed May 25 18:29:28 1988

SGML1



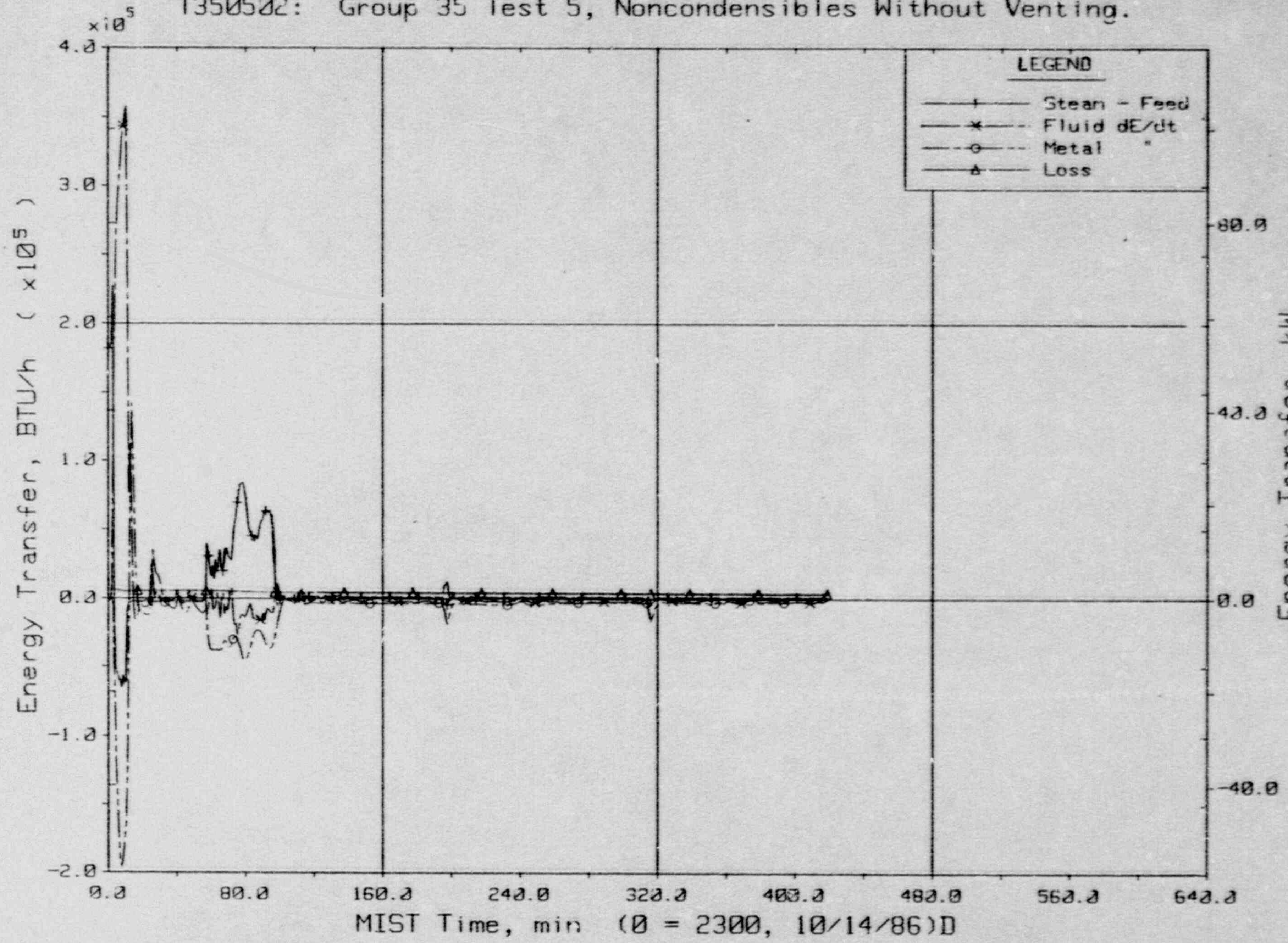
Steam Generator A Energy Transfer.

Wed May 25 18:32:41 1988

SGOE3

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



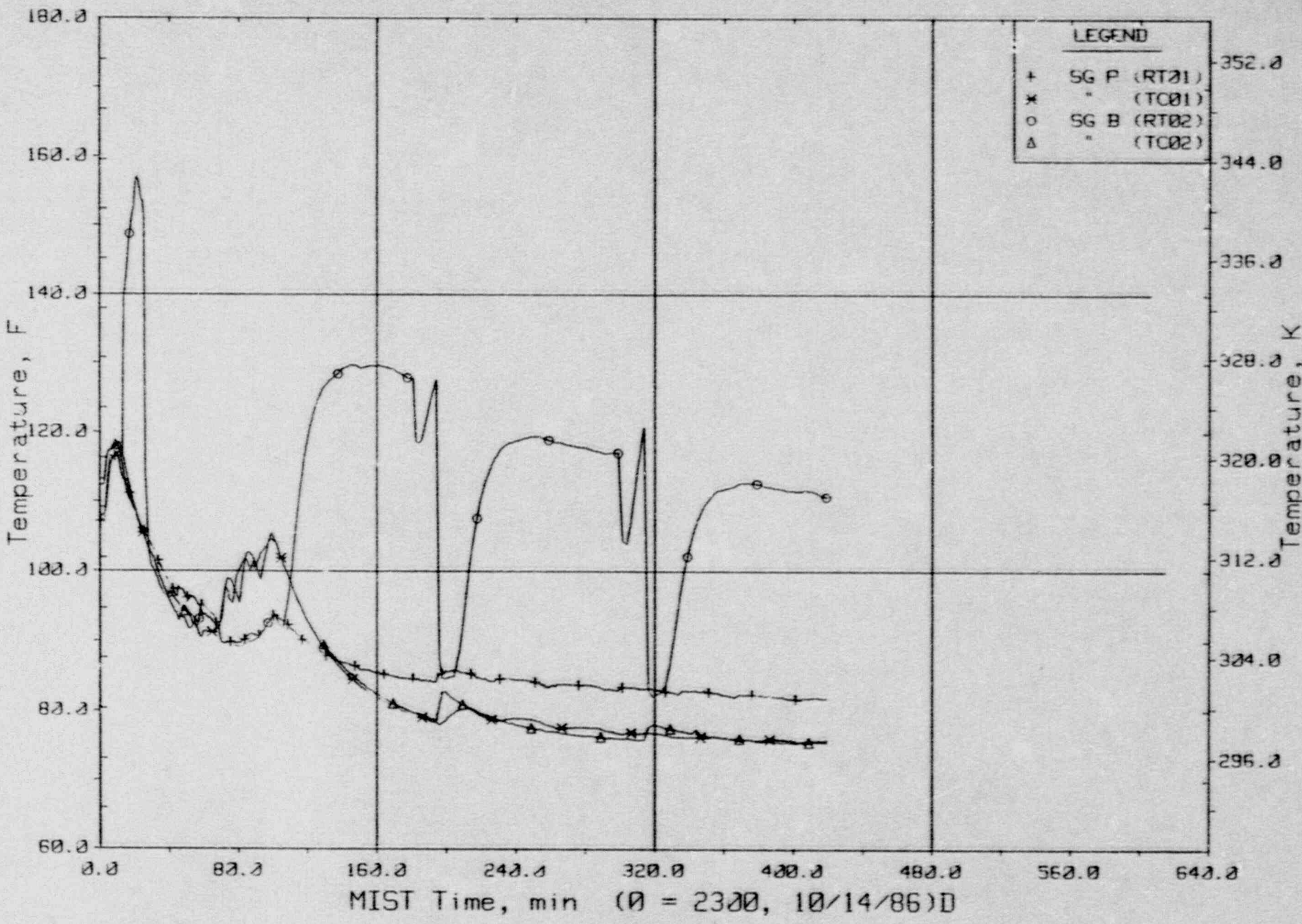
Steam Generator B Energy Transfer.

Wed May 25 18:35:39 1988

SGOE6

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



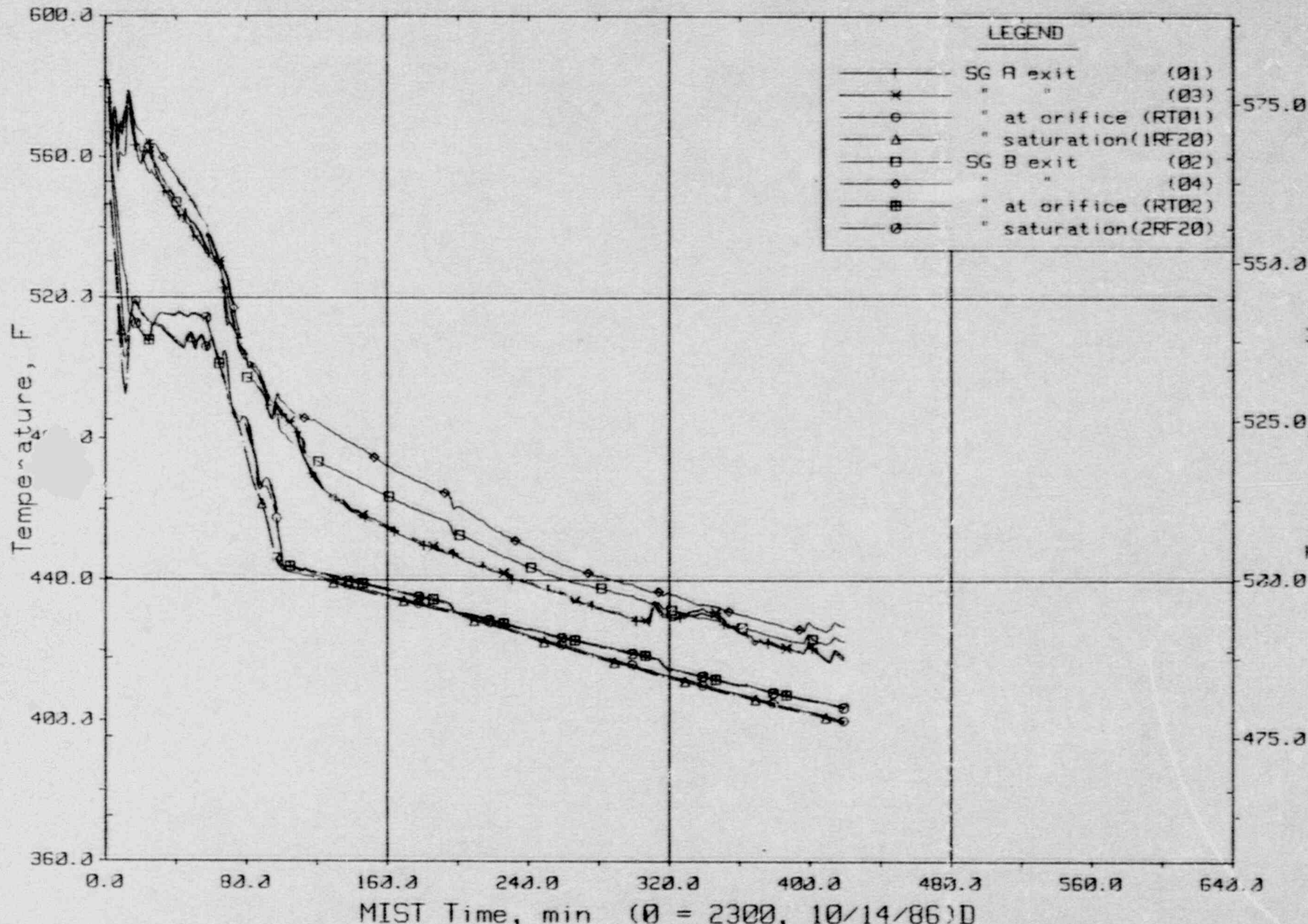
Feedwater Temperatures (SFs).

Wed May 25 18:37:59 1988

SGRT1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



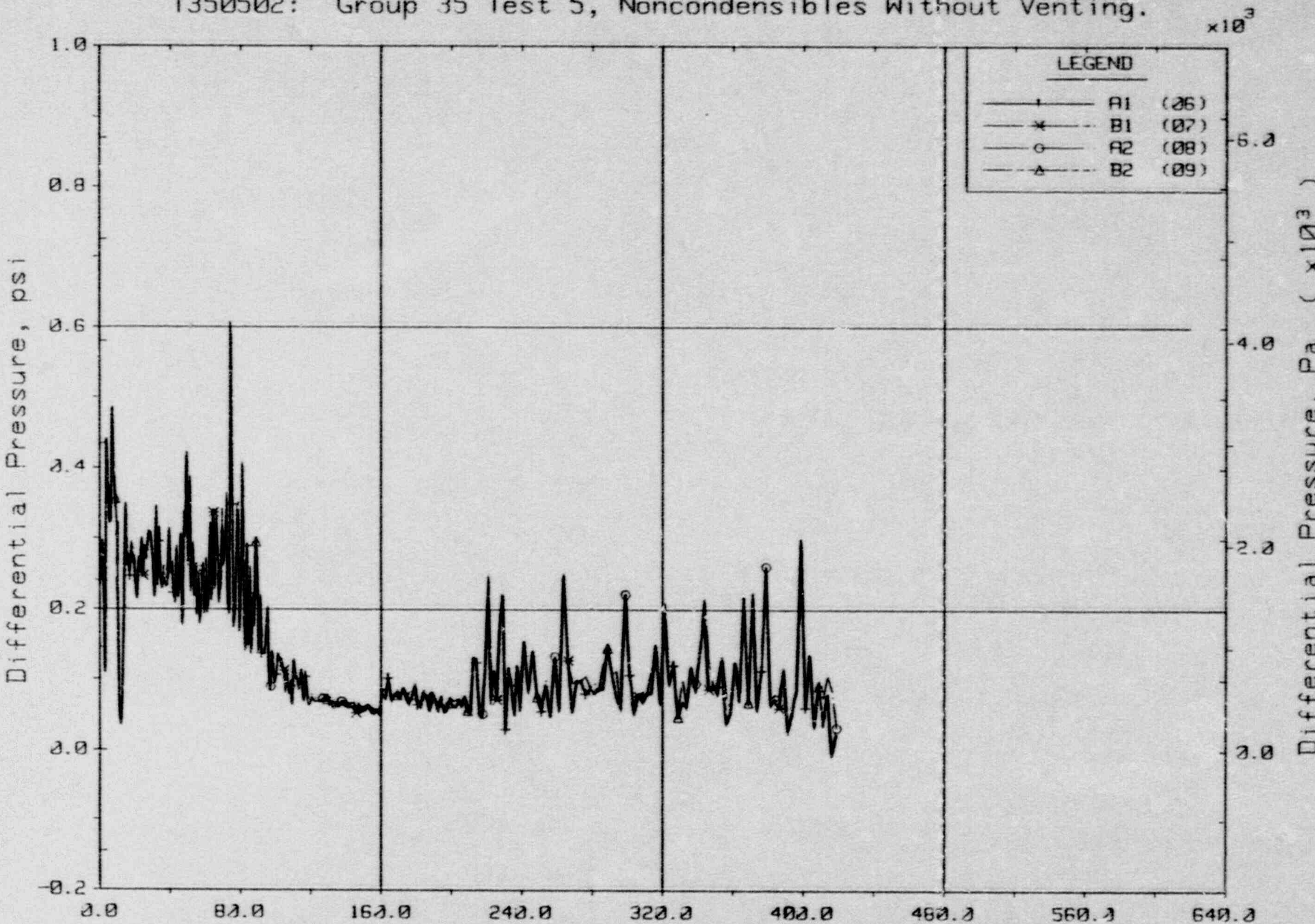
Steam Generator Steam Outlet Temperatures (SSTCs).

Wed May 25 18:40:54 1988

SGRT2

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



MIST Time, min (0 = 2300, 10/14/86)D

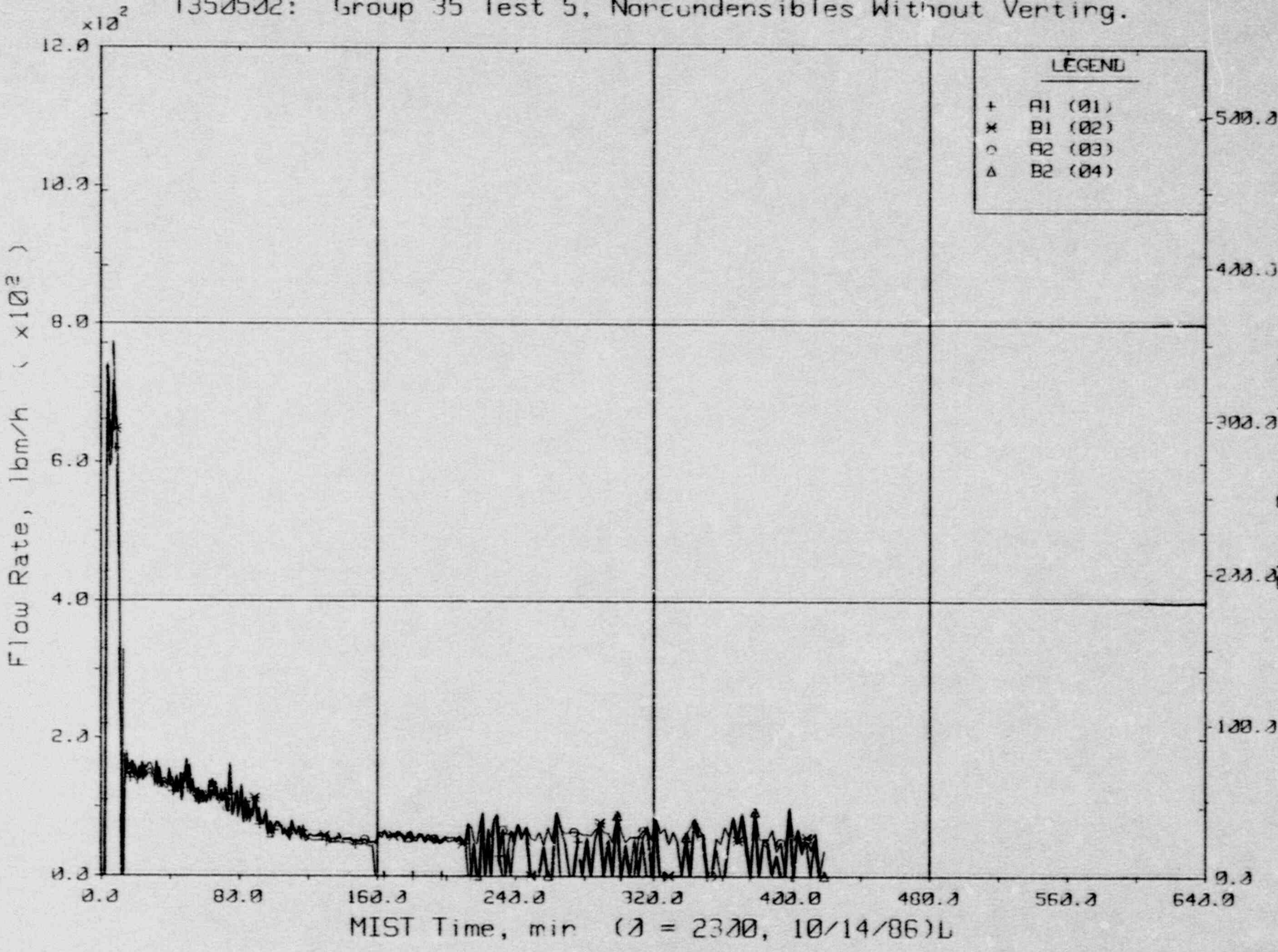
Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Wed May 25 18:44:16 1988

VVDP1

FINAL DATA

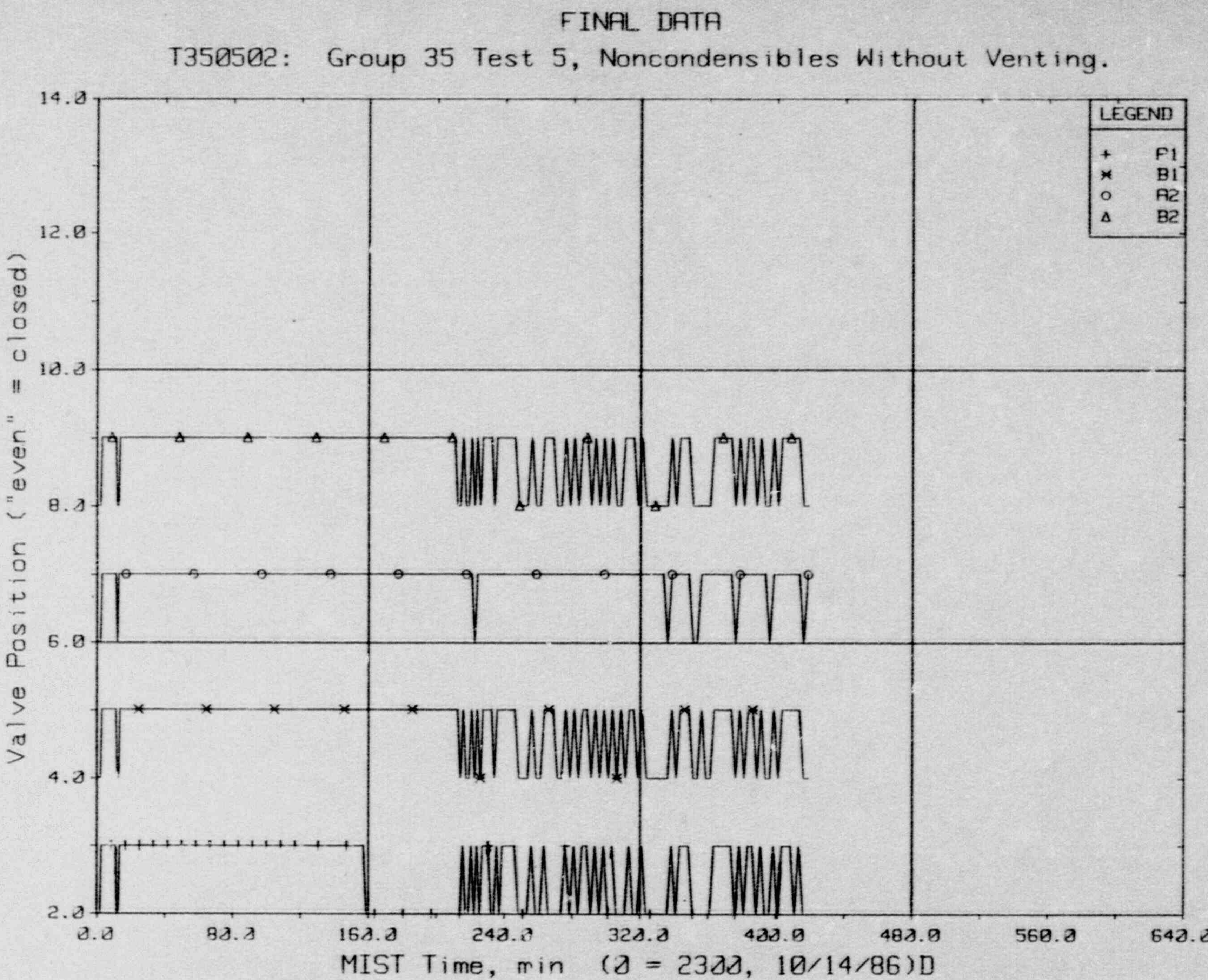
T350502: Group 35 Test 5, Noncondensibles Without Venting.



Reactor Vessel Vent Valve Flow Rates (R/ORs).

Wed May 25 19:47:21 1988

VVFL1



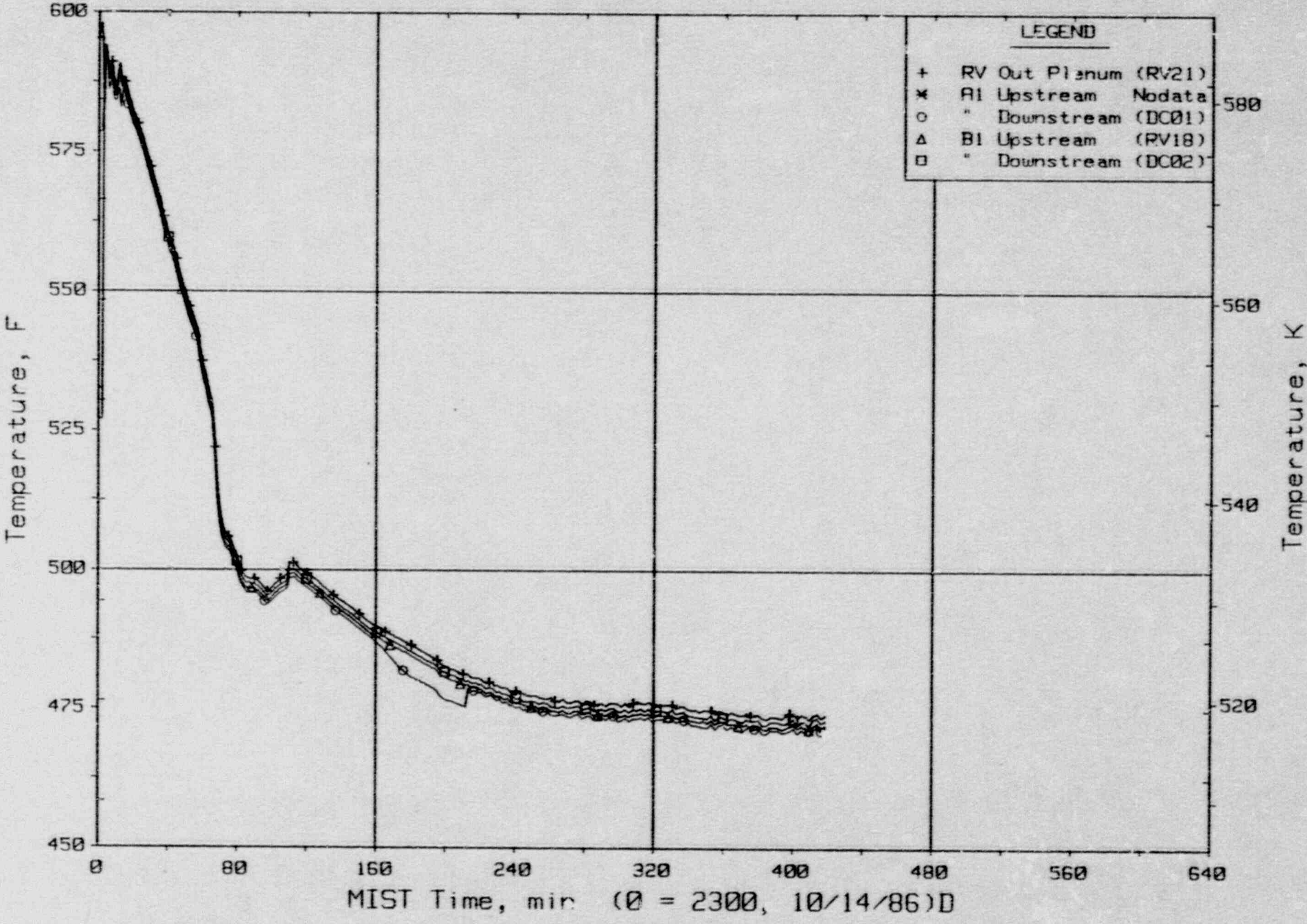
Reactor Vessel Vent Valve Positions.

Wed May 25 18:49:41 1988

VVLS1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



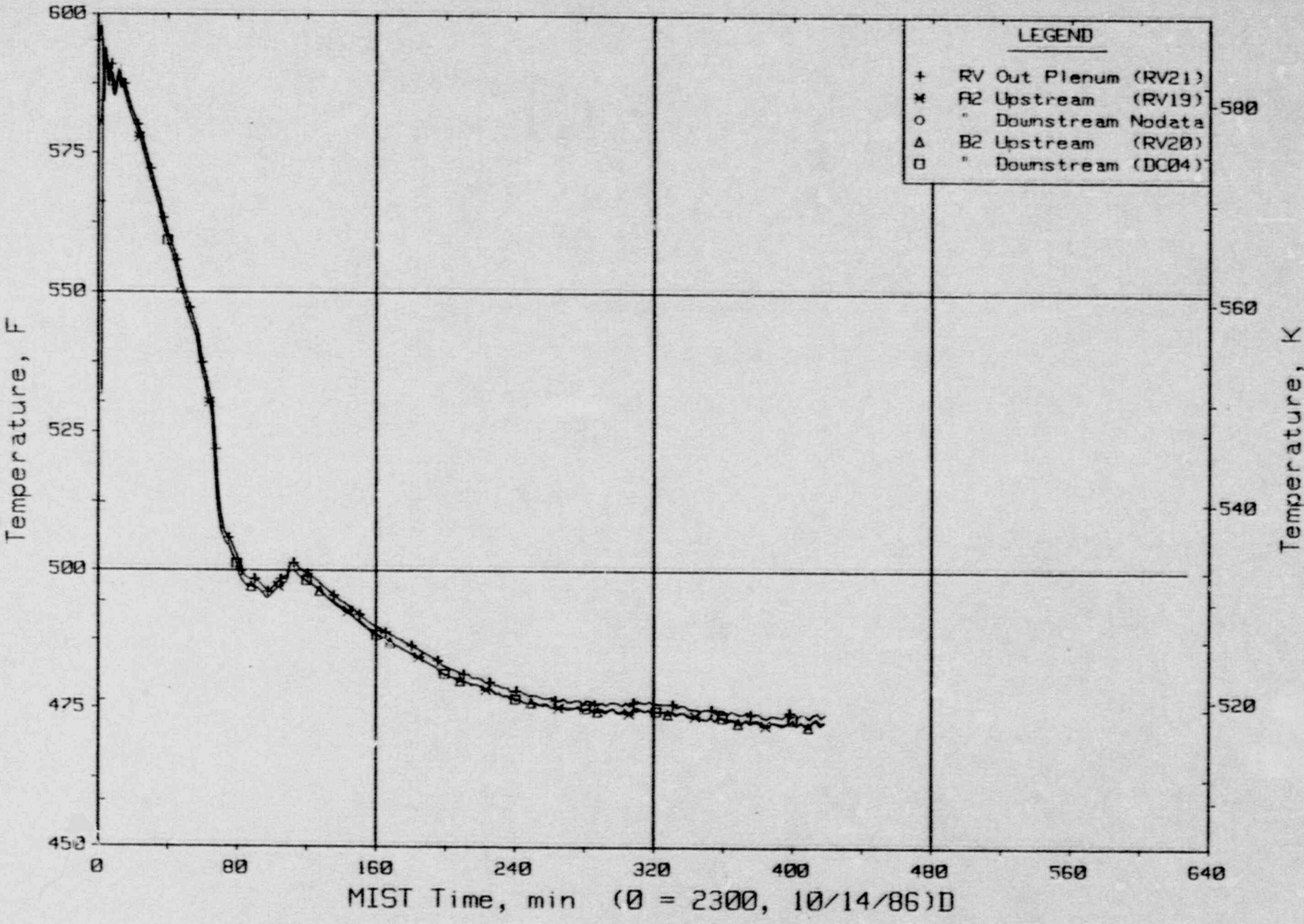
RVVVs A1 and B1 Bracketing Fluid Temperatures (TCs).

Fri Jan 6 16:08:06 1989

VVTC1

FINAL DATA

T350502: Group 35 Test 5, Noncondensibles Without Venting.



RVVVs A2 and B2 Bracketing Fluid Temperatures (TCs).

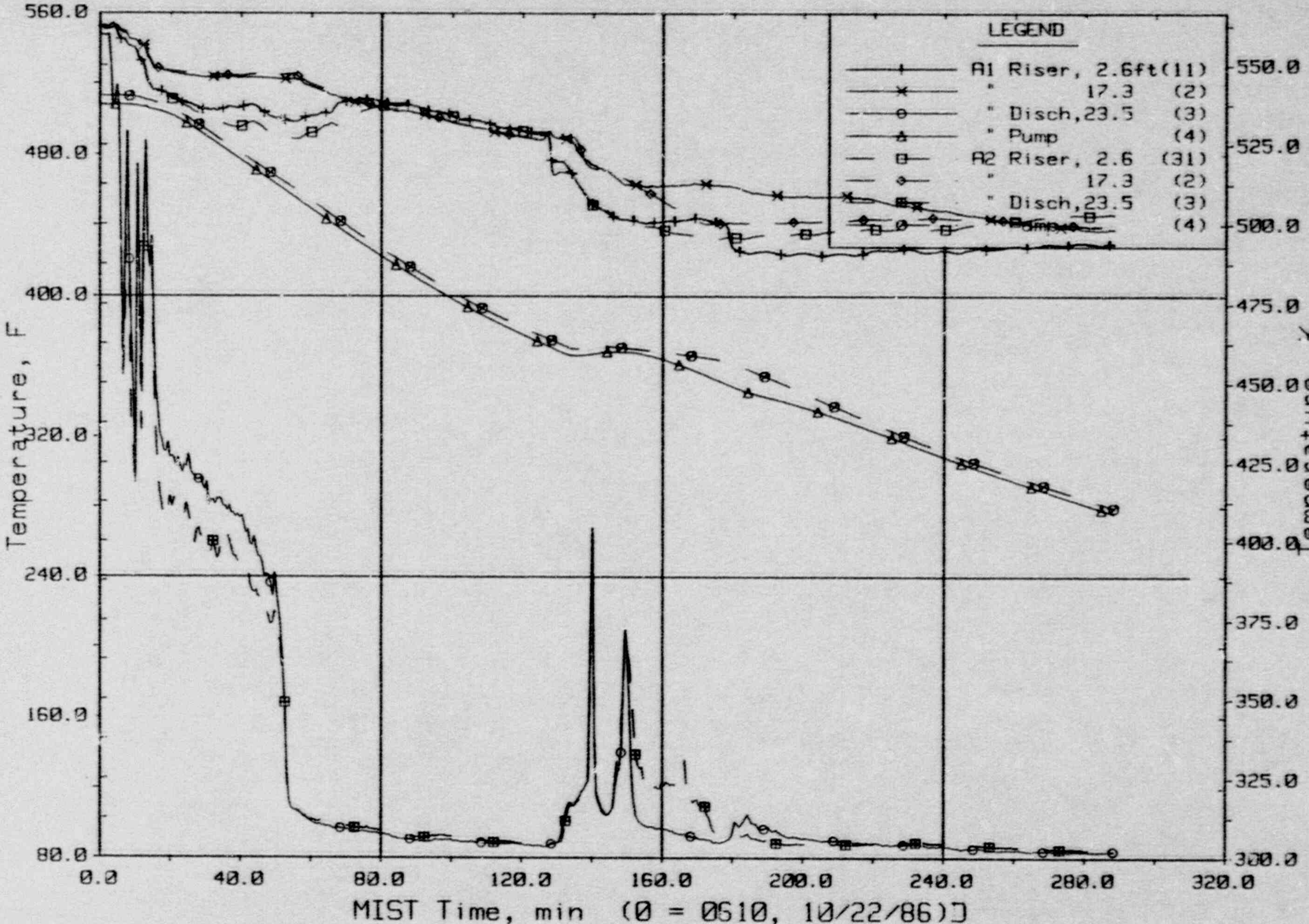
Fri Jan 6 16:10:42 1989

VVTC2

T350700

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



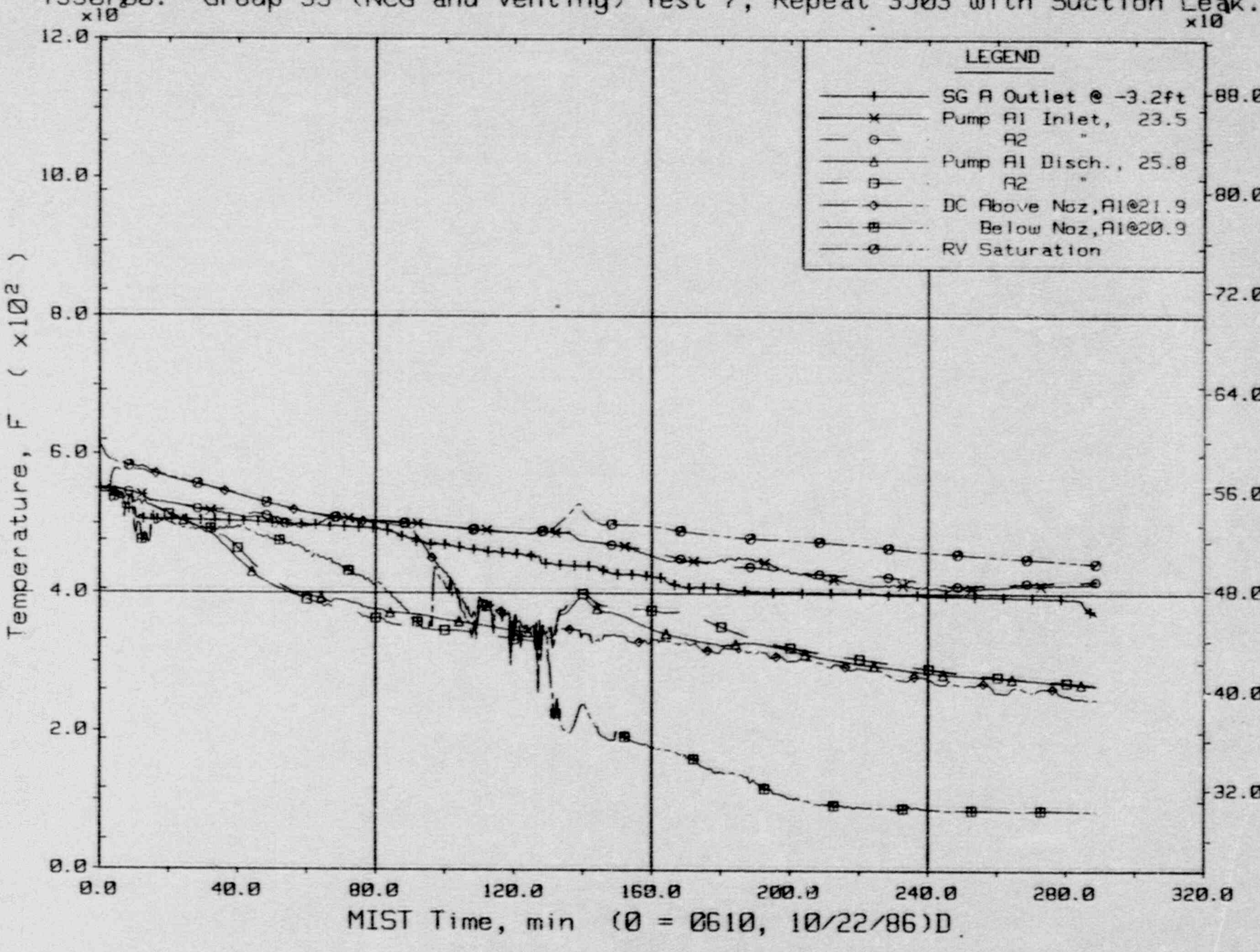
Loop A Cold Leg Metal Temperatures (C1,3MTs).

Thu May 26 08:09:47 1988

C1MT1

FINAL DATA

T350700: Group 35 (NCG and Venting) Test 7, Repeat 3503 with Suction Leak.



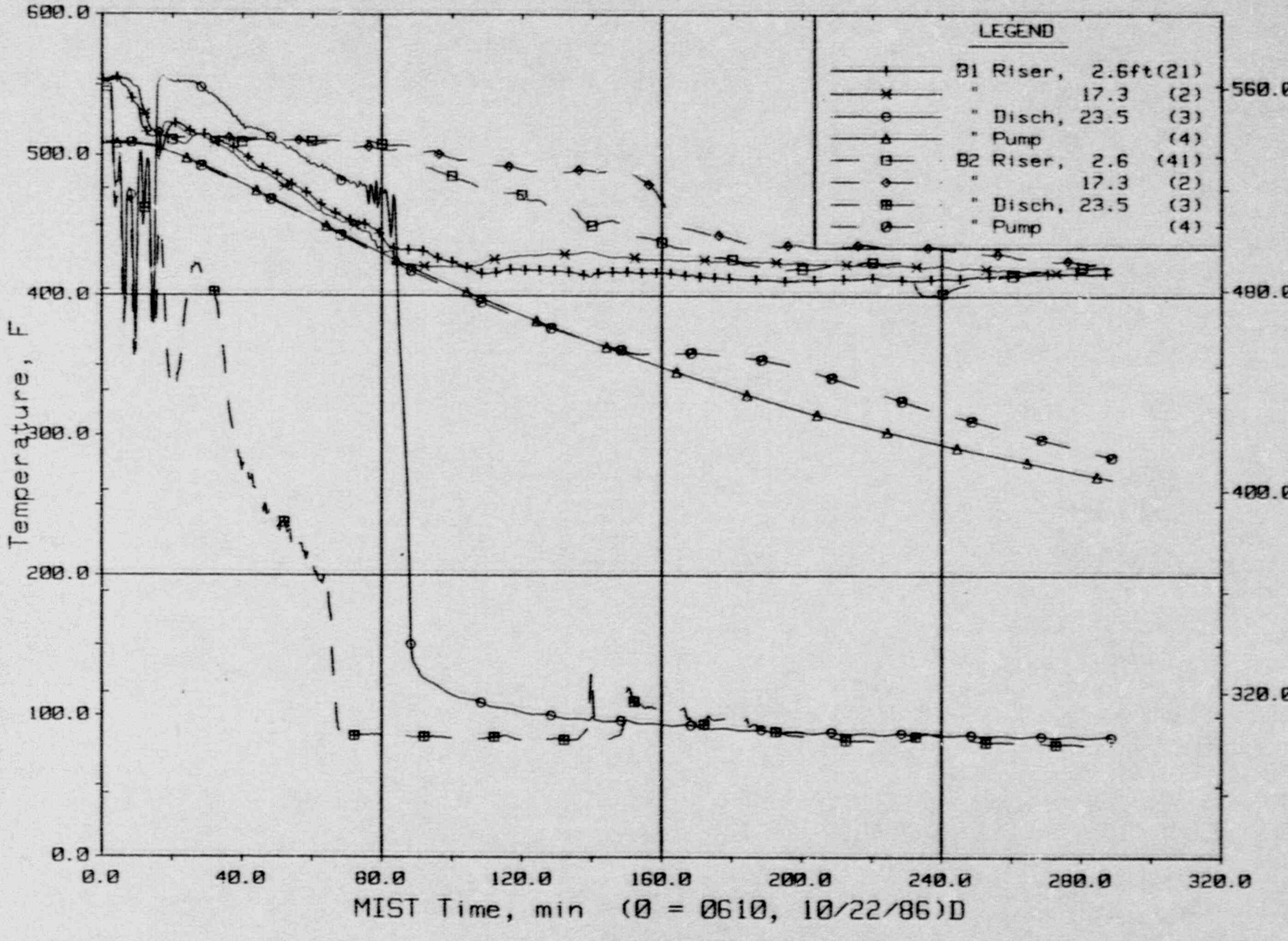
Loop A Cold Leg Fluid Temperatures (RTDs).

Fri Jan 6 16:23:21 1989

C1RT0

rInnL bATA

T350700: Group 35 (NCG and Venting) Test 7, Repeat 3503 with Suction Leak.



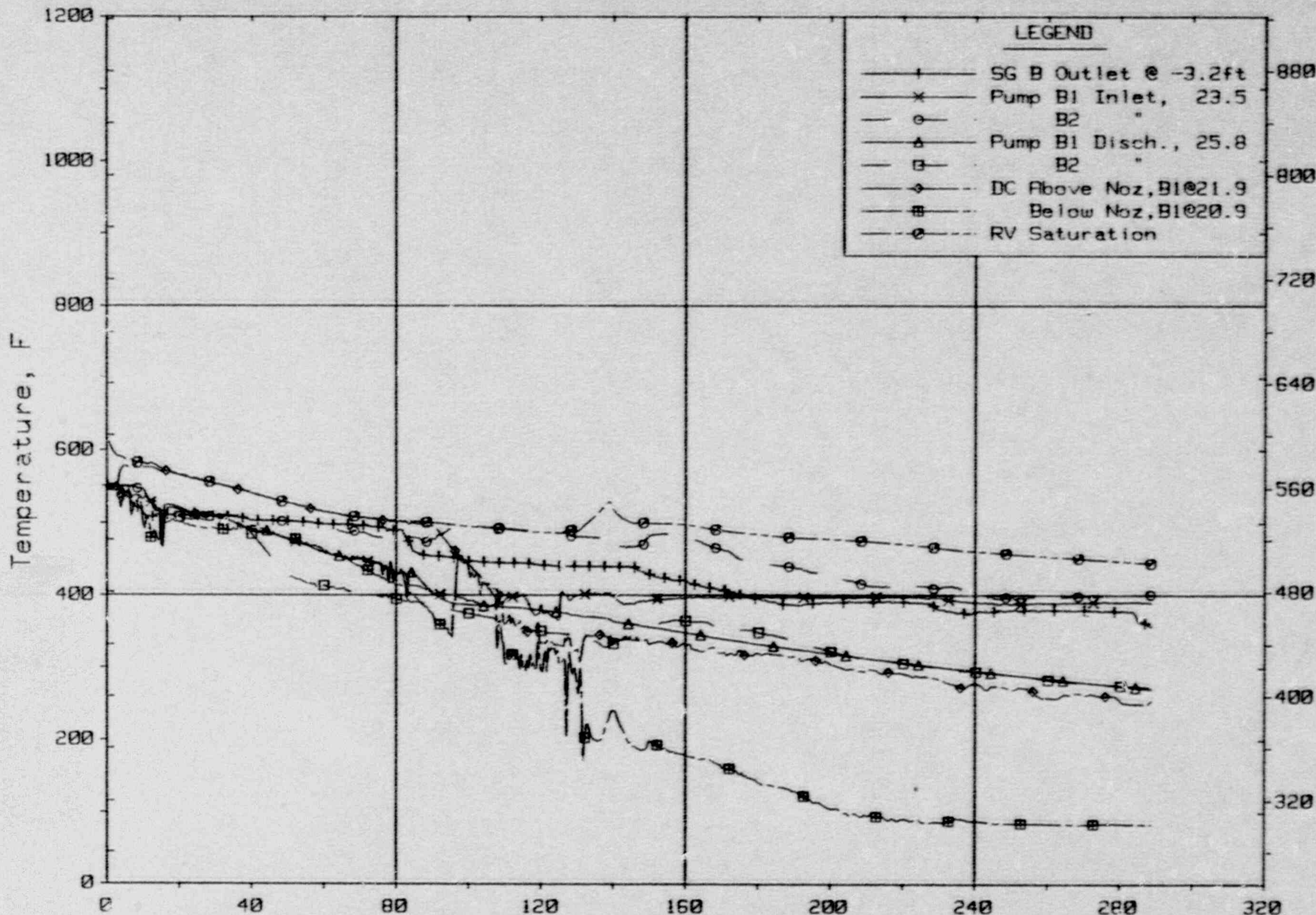
Loop B Cold Leg Metal Temperatures (C2,4MTs).

Fri Jan 6 16:28:54 1989

C2MT1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



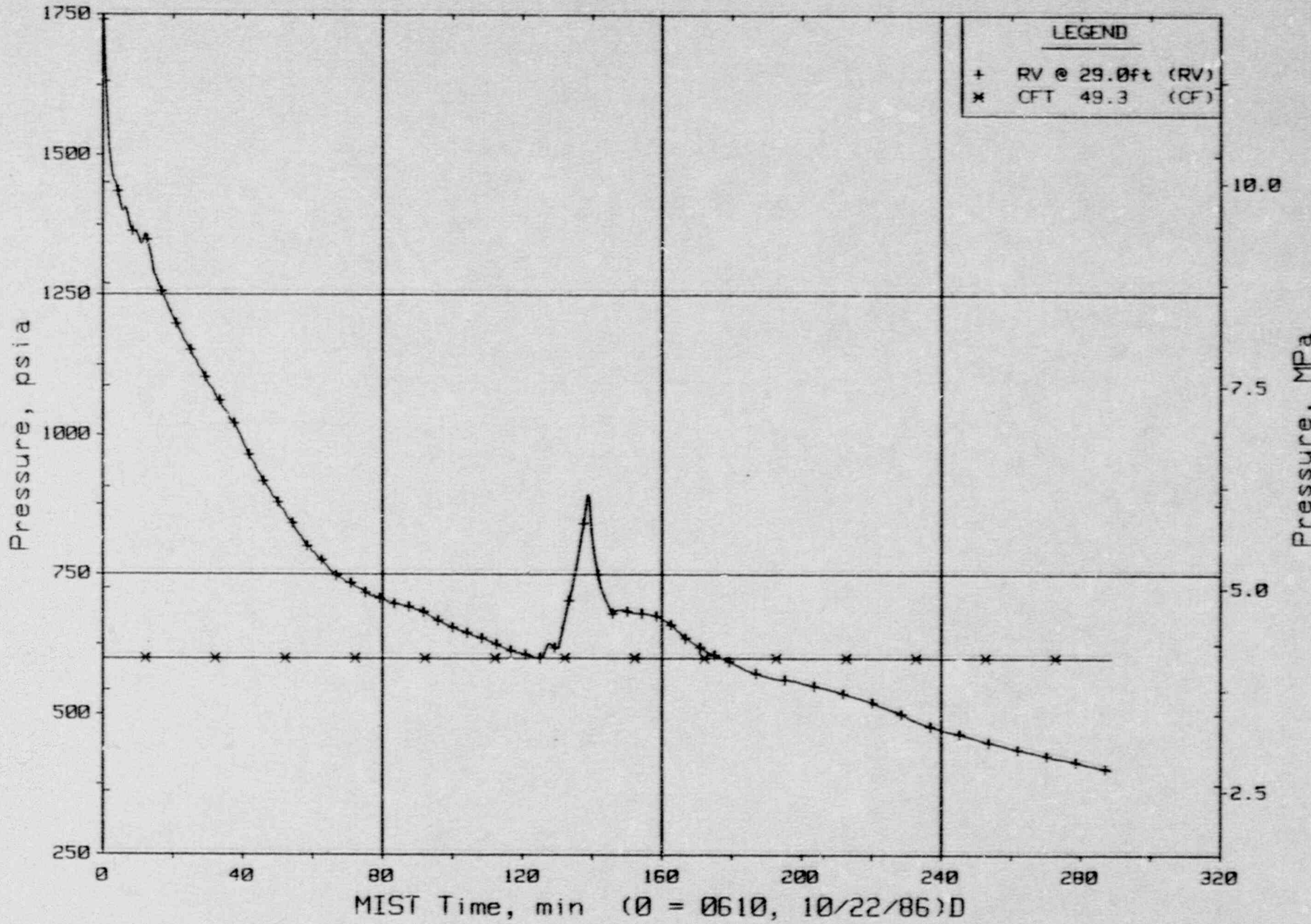
Loop B Cold Leg Fluid Temperatures (RTDs).

Fri Jan 6 16:33:07 1989

C2RT0

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



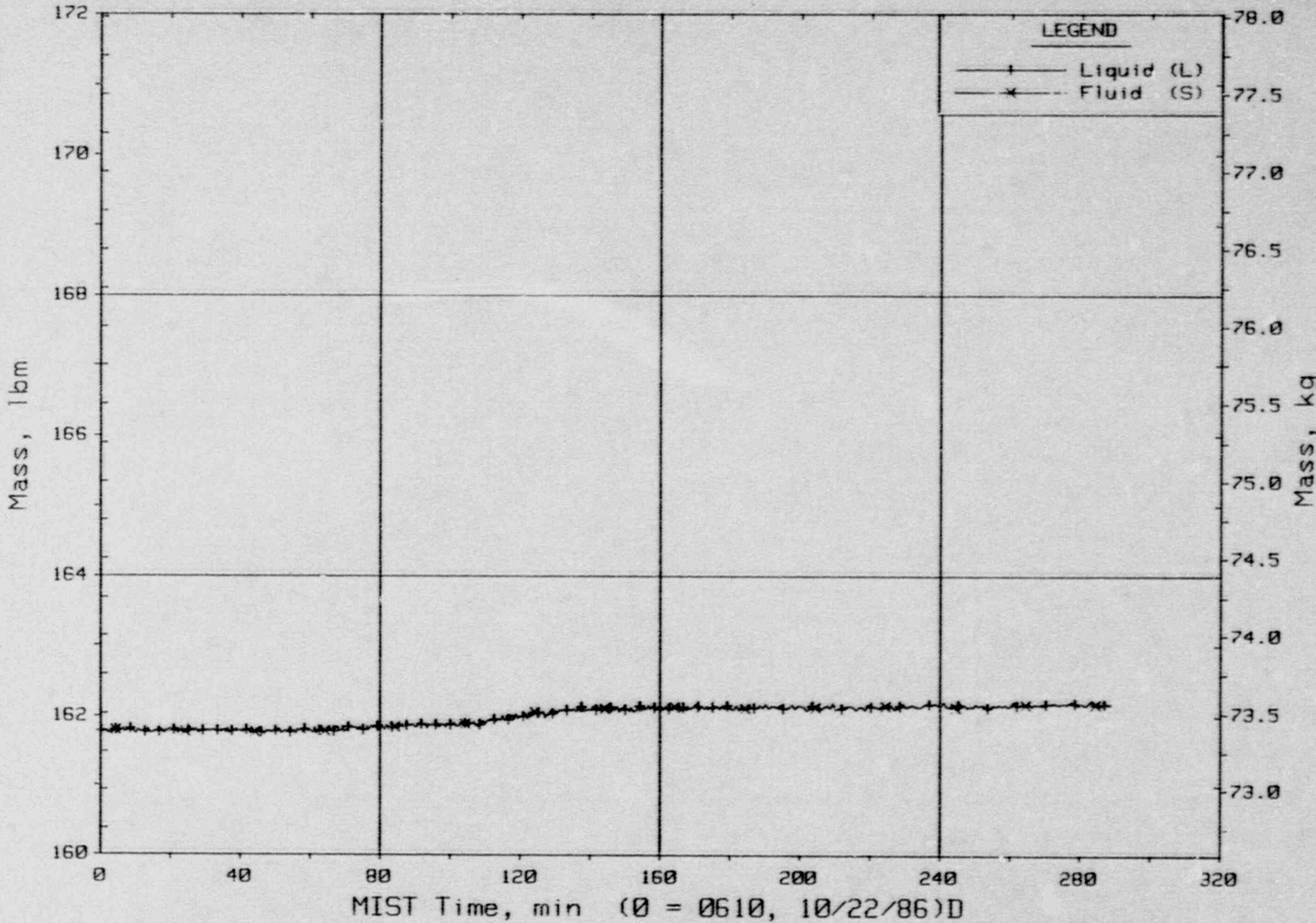
Primary System and Core Flood Tank Pressures (GP01s).

Fri Jan 6 16:36:22 1989

CFGP1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



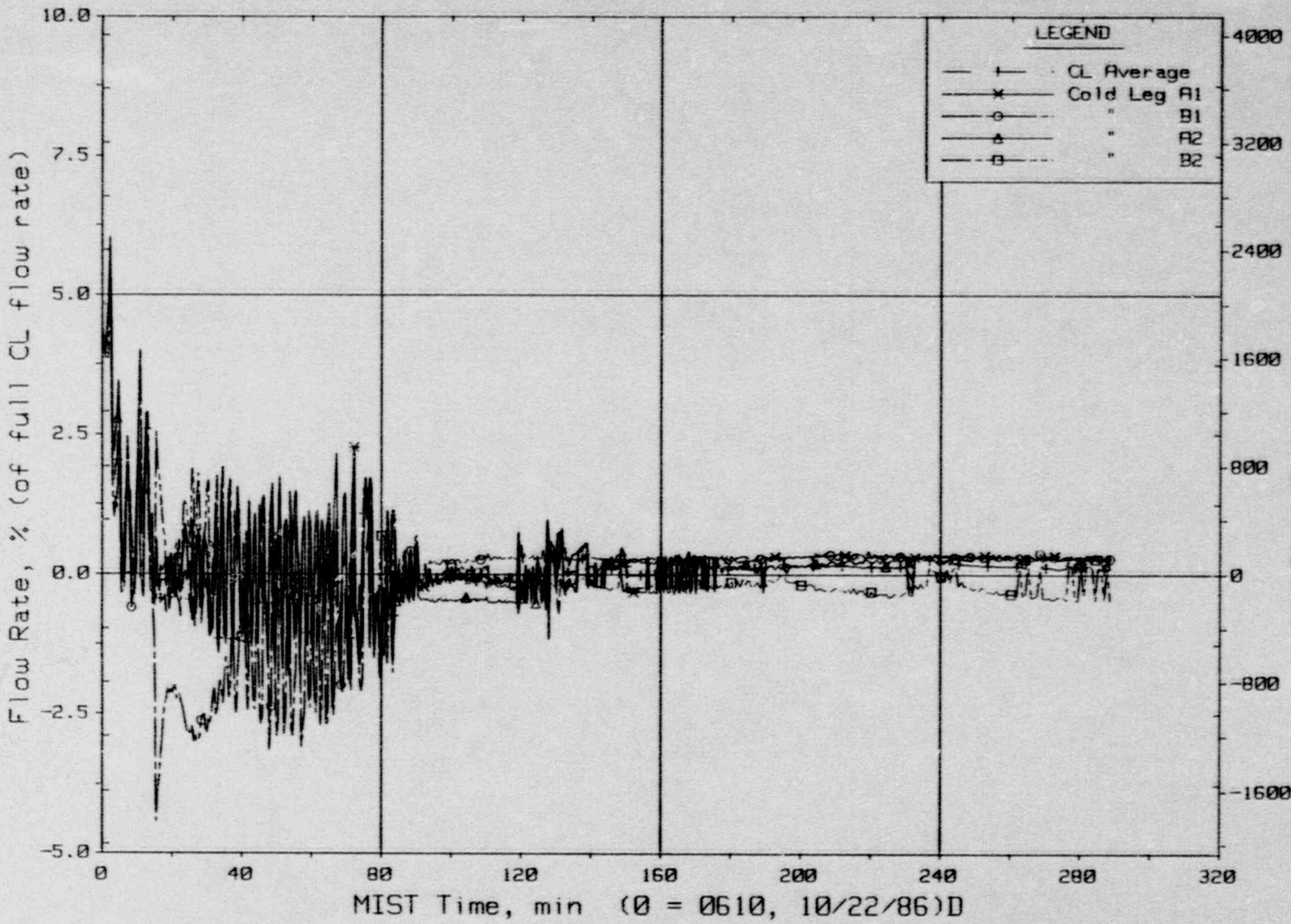
Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Fri Jan 6 16:38:51 1989

CFML1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



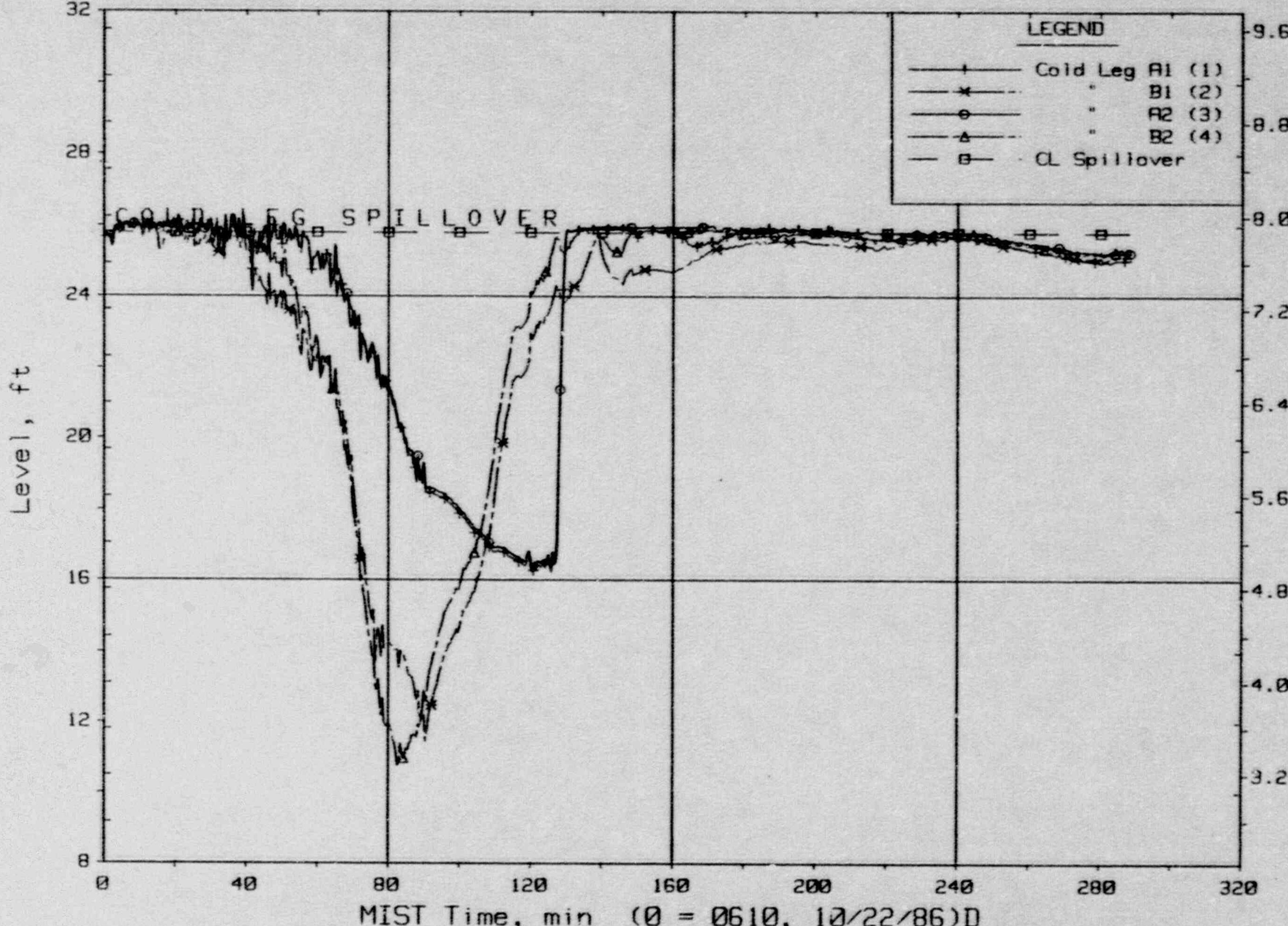
Cold Leg (Venturi) Flow Rates.

Fri Jan 6 16:43:21 1989

CLFL1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



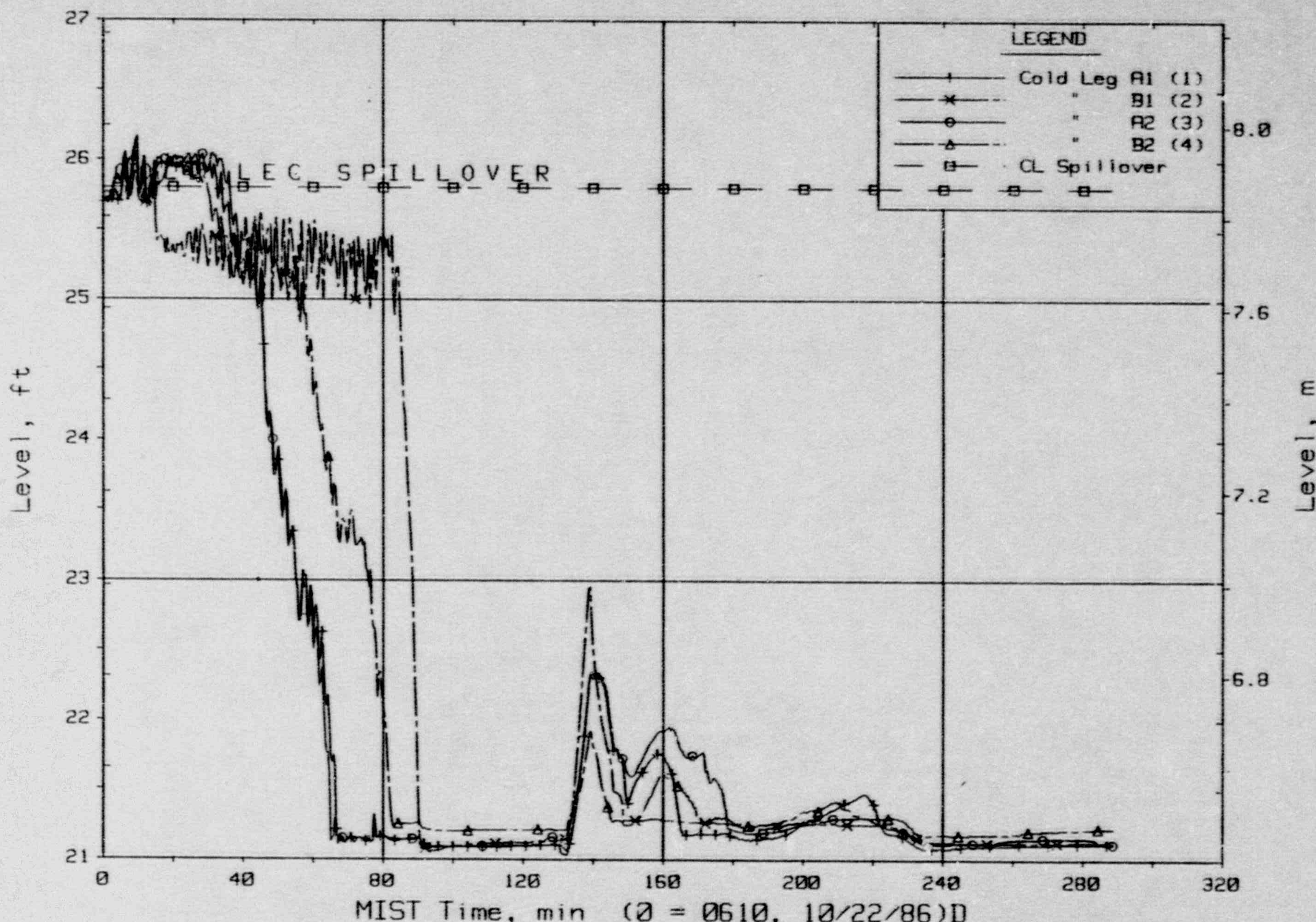
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Wed Jan 11 16:38:57 1989

CLLV4

FINAL DATA

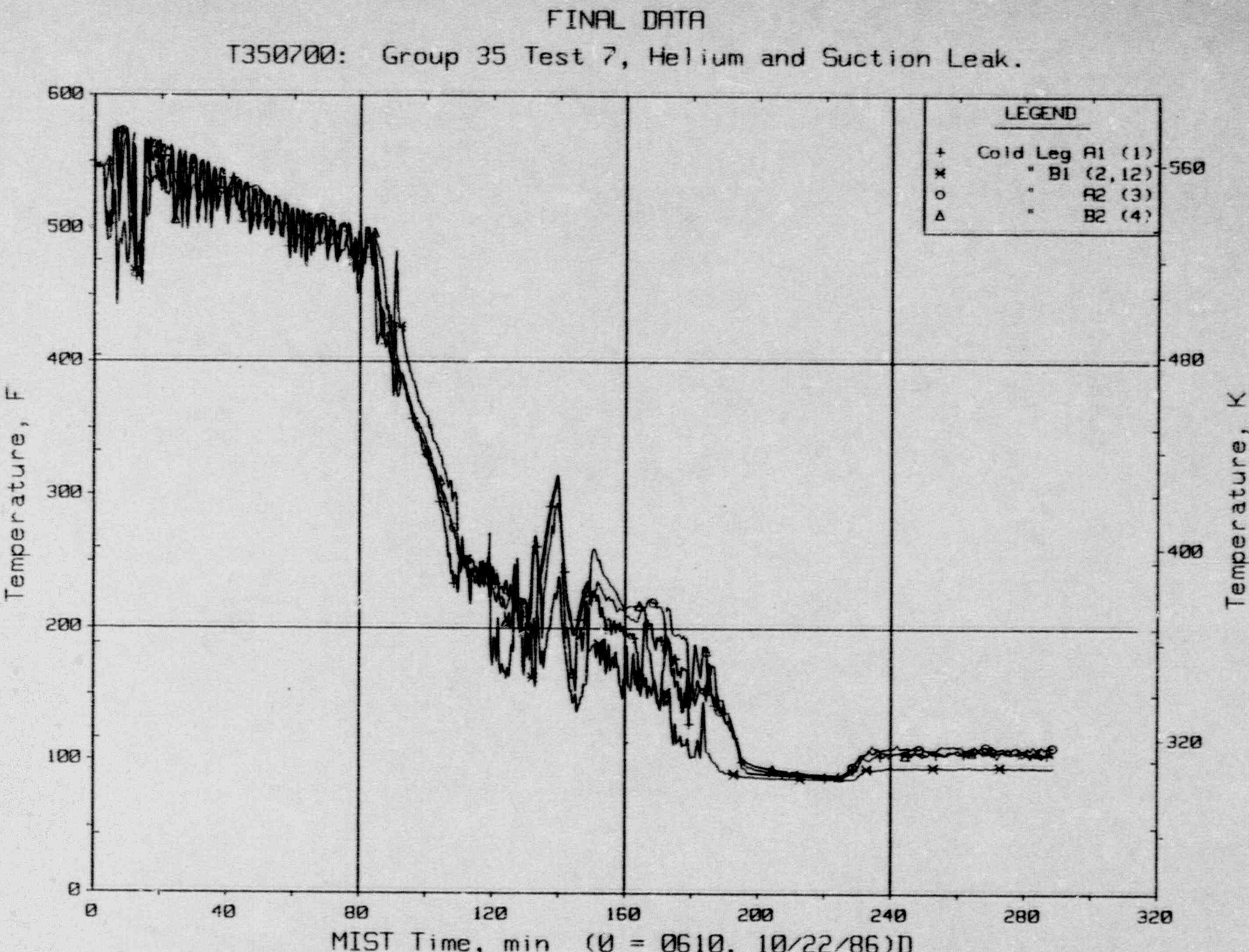
T350700: Group 35 Test 7, Helium and Suction Leak.



Cold Leg Discharge Collapsed Liquid Levels (CnLV23s).

Wed Jan 11 16:43:09 1989

CLLV5



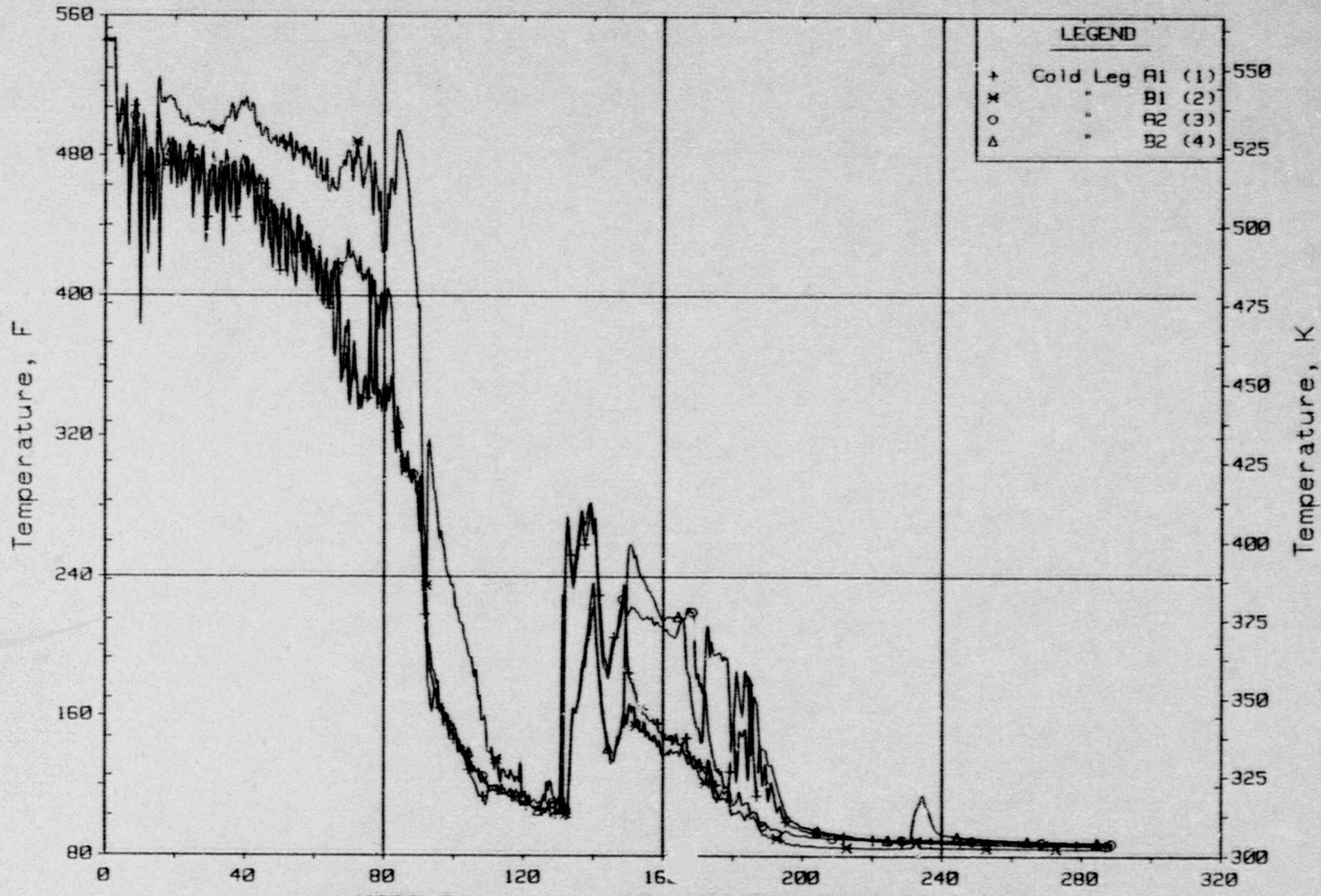
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Wed Jan 11 16:46:29 1989

CLTC1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



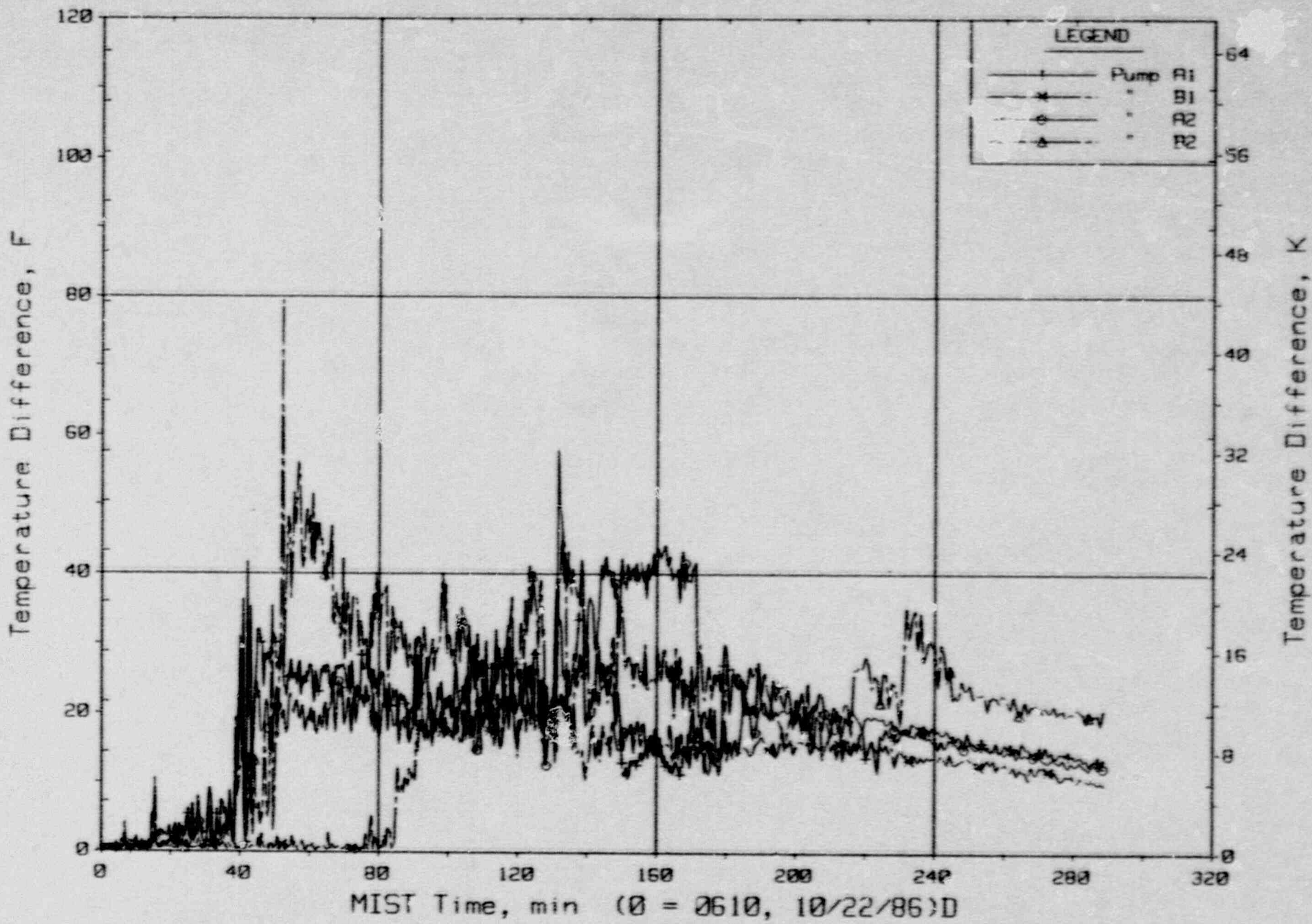
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Wed Jan 11 16:49:47 1989

CLTC2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



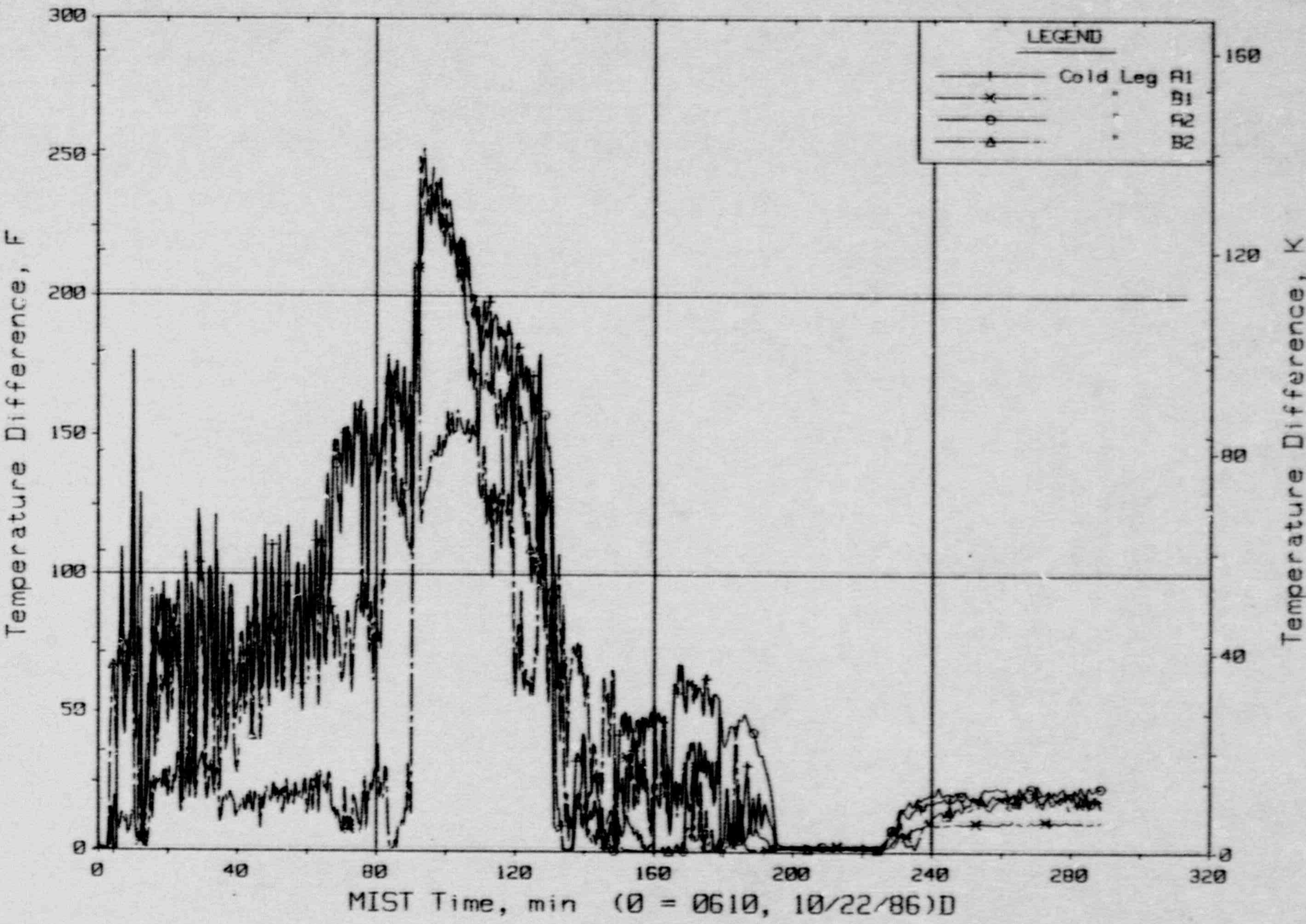
Maximum Differences Among RCP Rake Fluid Temperatures.

Wed Jan 11 16:53:17 1989

CLTD1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



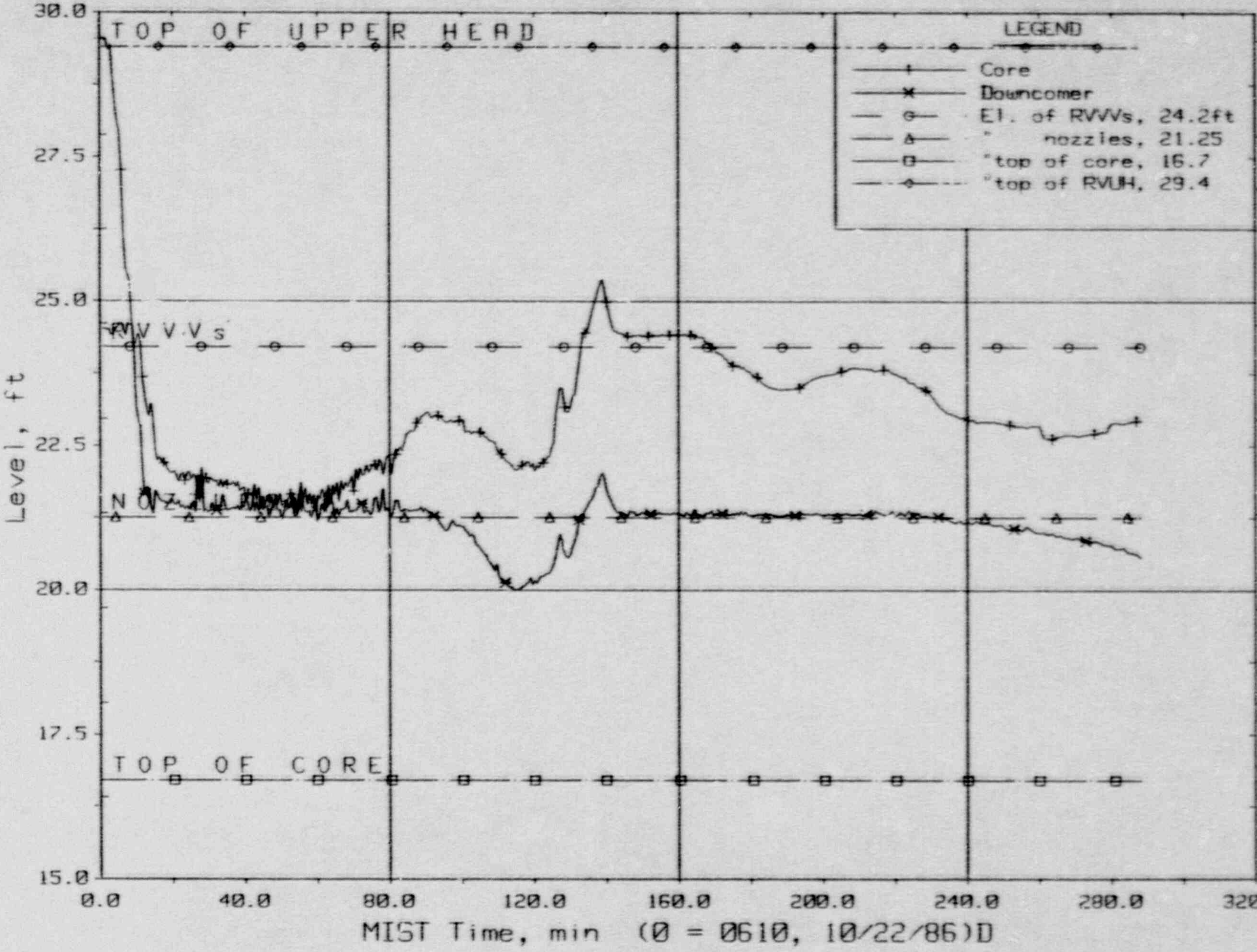
Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Wed Jan 11 16:57:20 1989

CLTD2

FINAL DATA

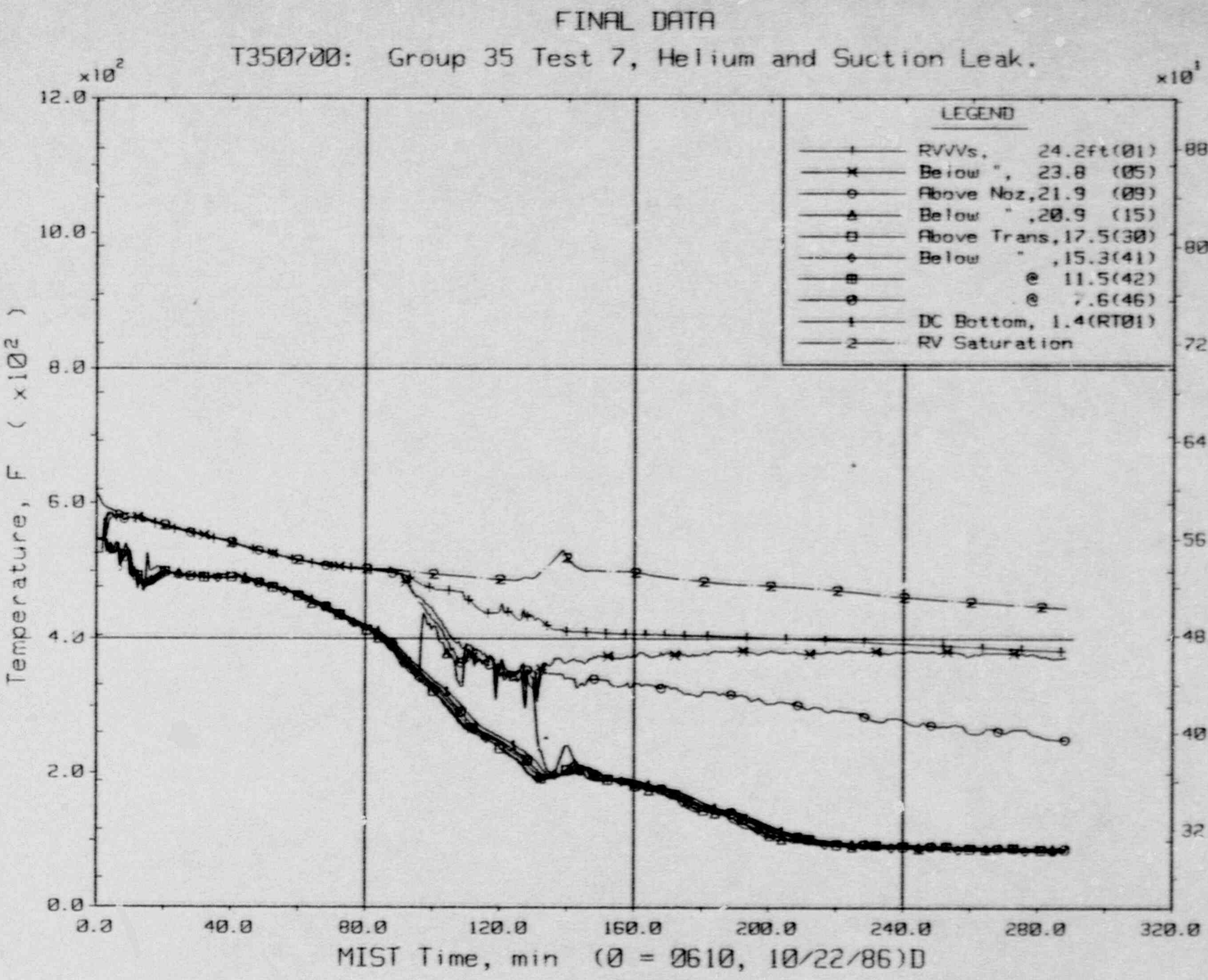
T350700: Group 35 Test 7, Helium and Suction Leak.



Core Region Collapsed Liquid Levels.

Thu May 26 08:32:28 1988

COLV1



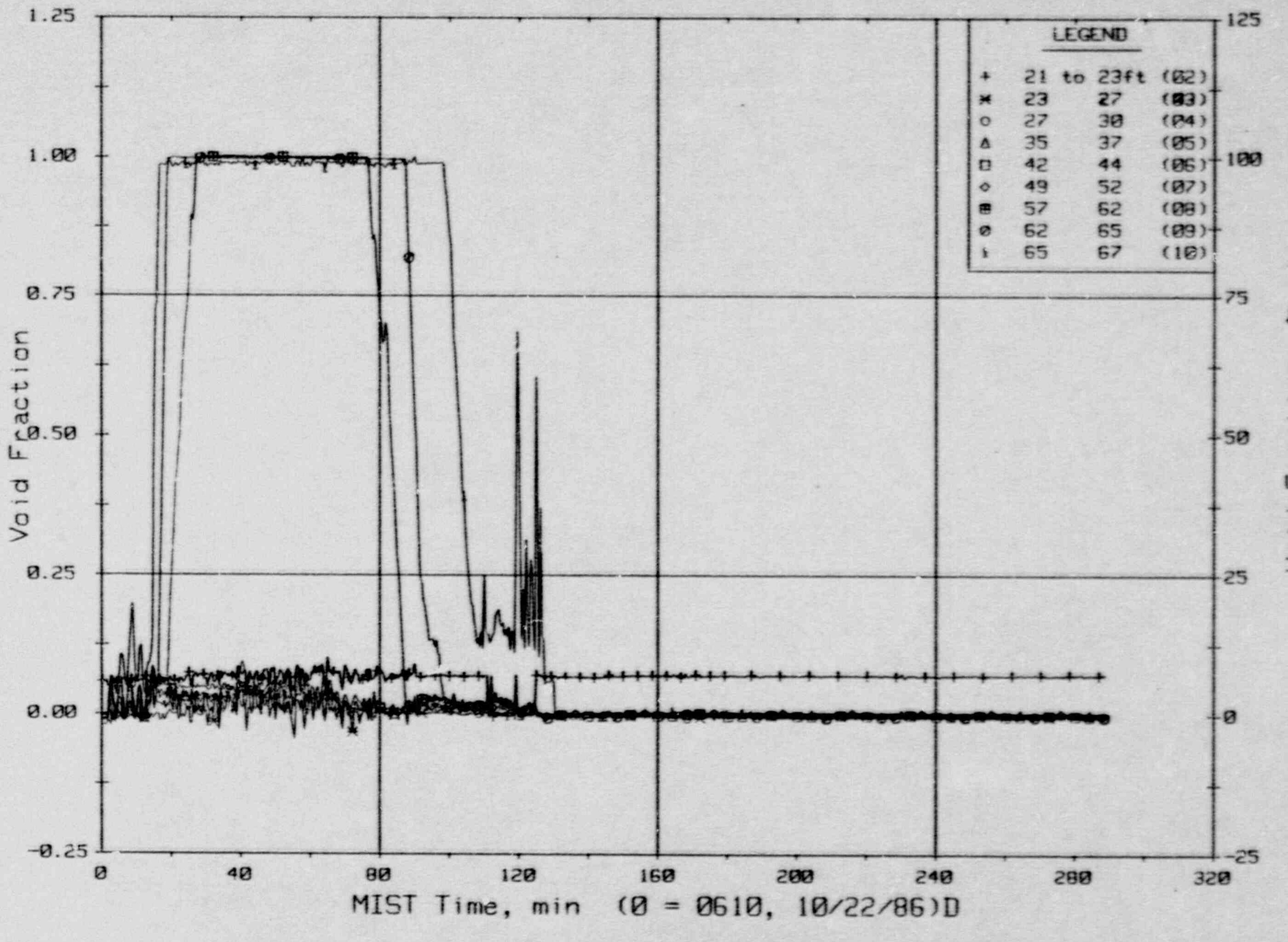
Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Thu May 26 08:49:28 1988

DCTC6

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



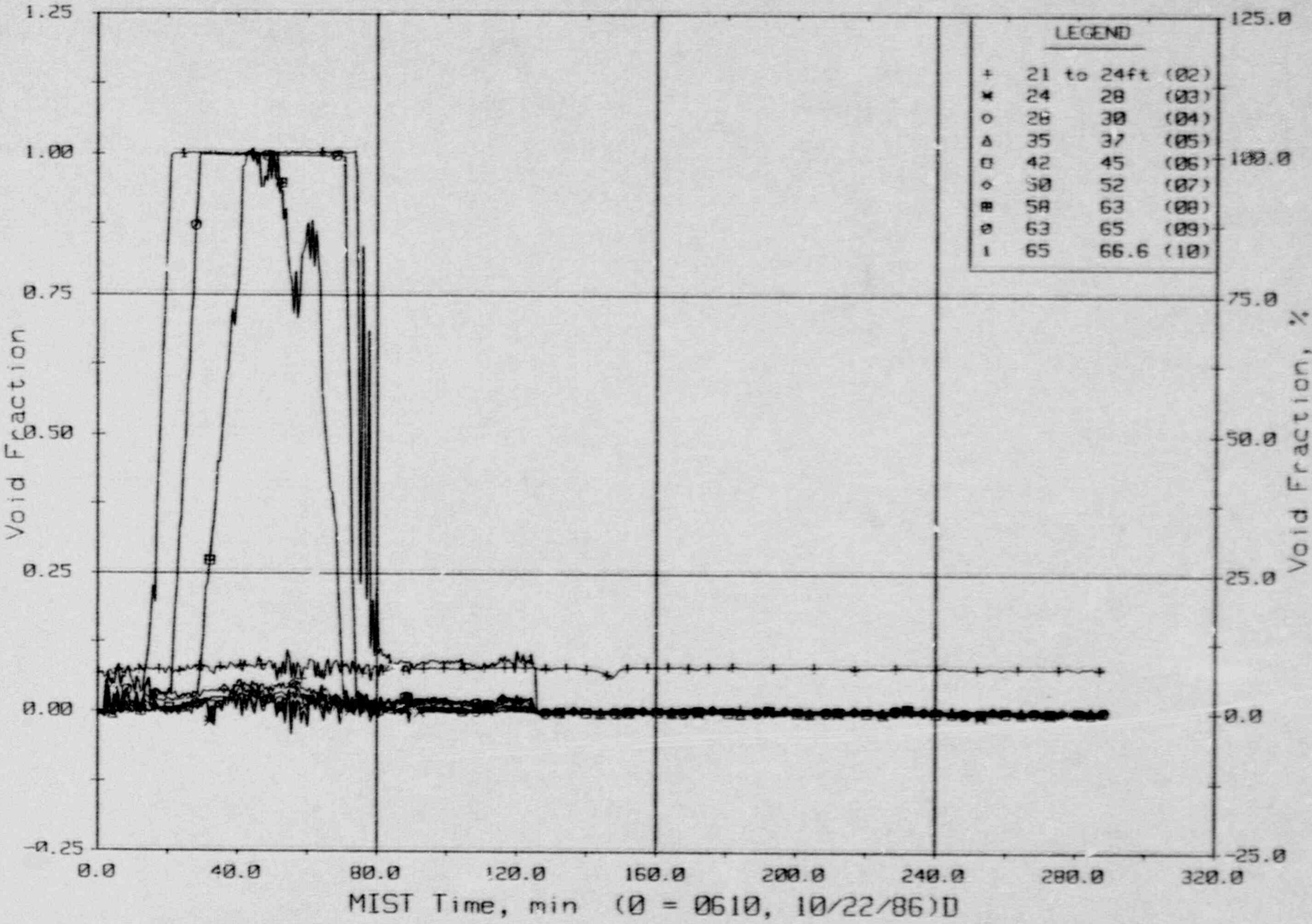
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Fri Jan 6 17:23:42 1989

H1VF1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



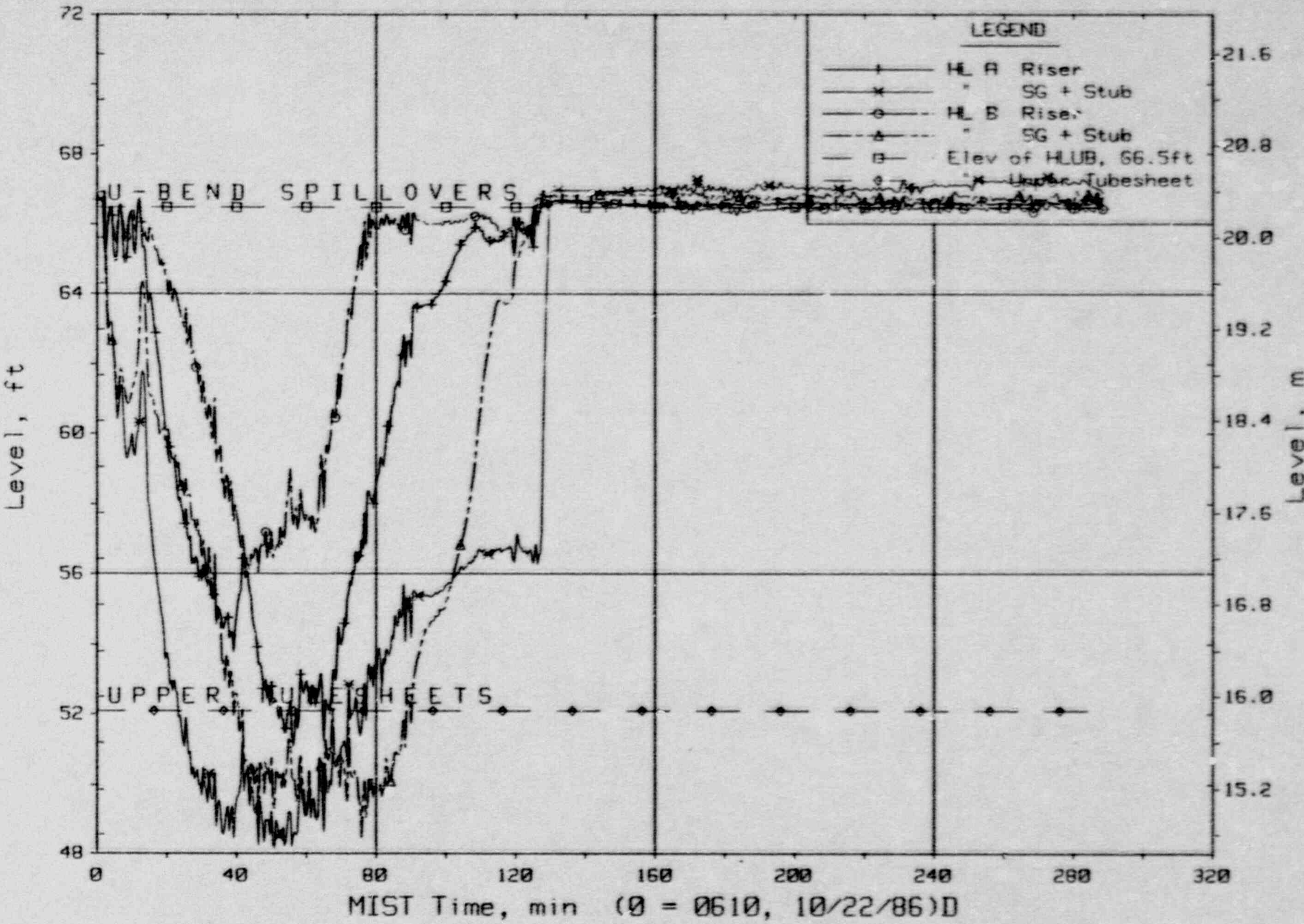
Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).

Thu May 25 08:57:16 1989

H2VF1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



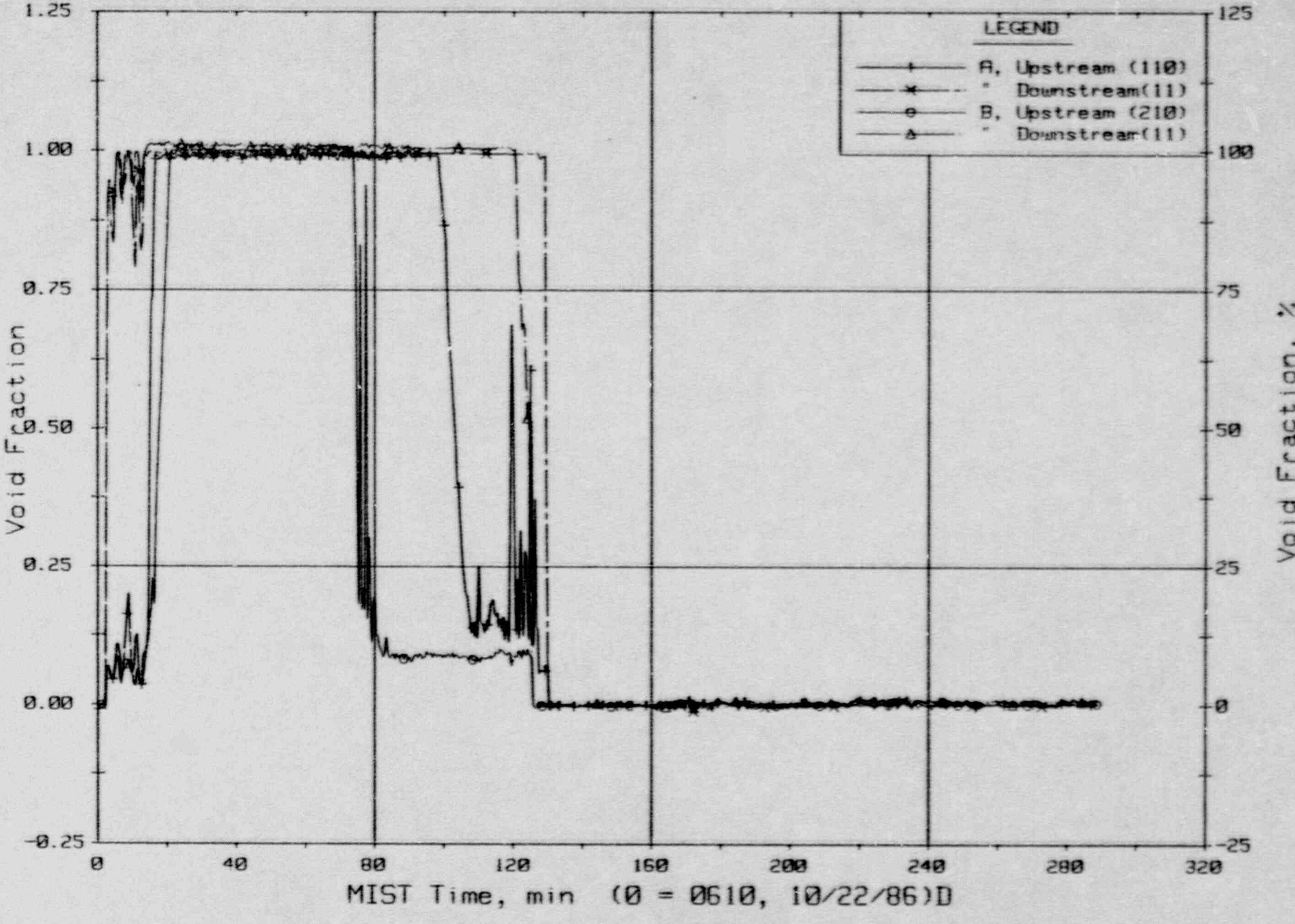
Hot Leg Riser and Stub Collapsed Liquid Levels.

Fri Jan 6 17:31:35 1989

HLLV1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



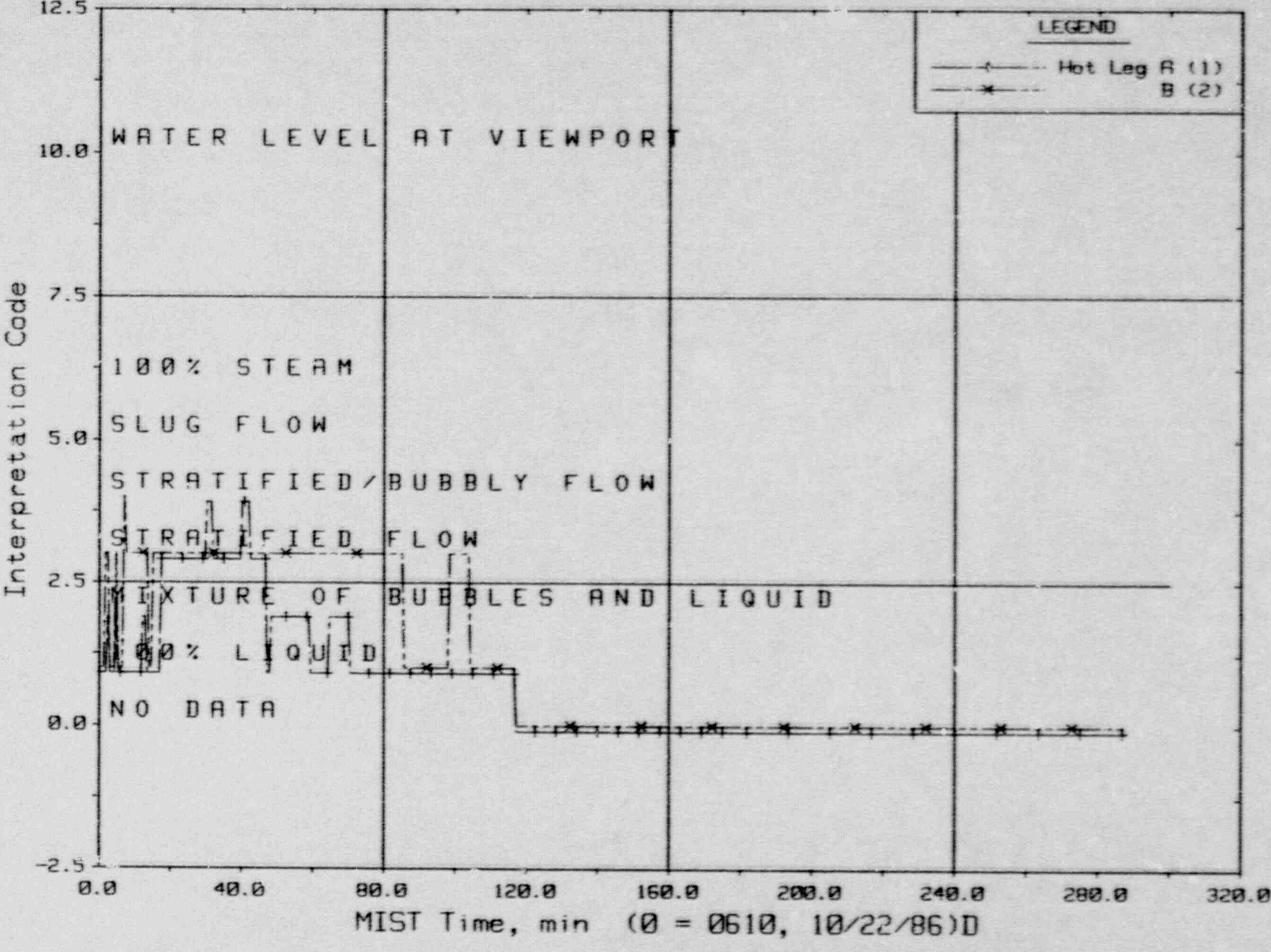
Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft, HnVFs).

Fri Jan 6 17:34:52 1989

HLVF1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



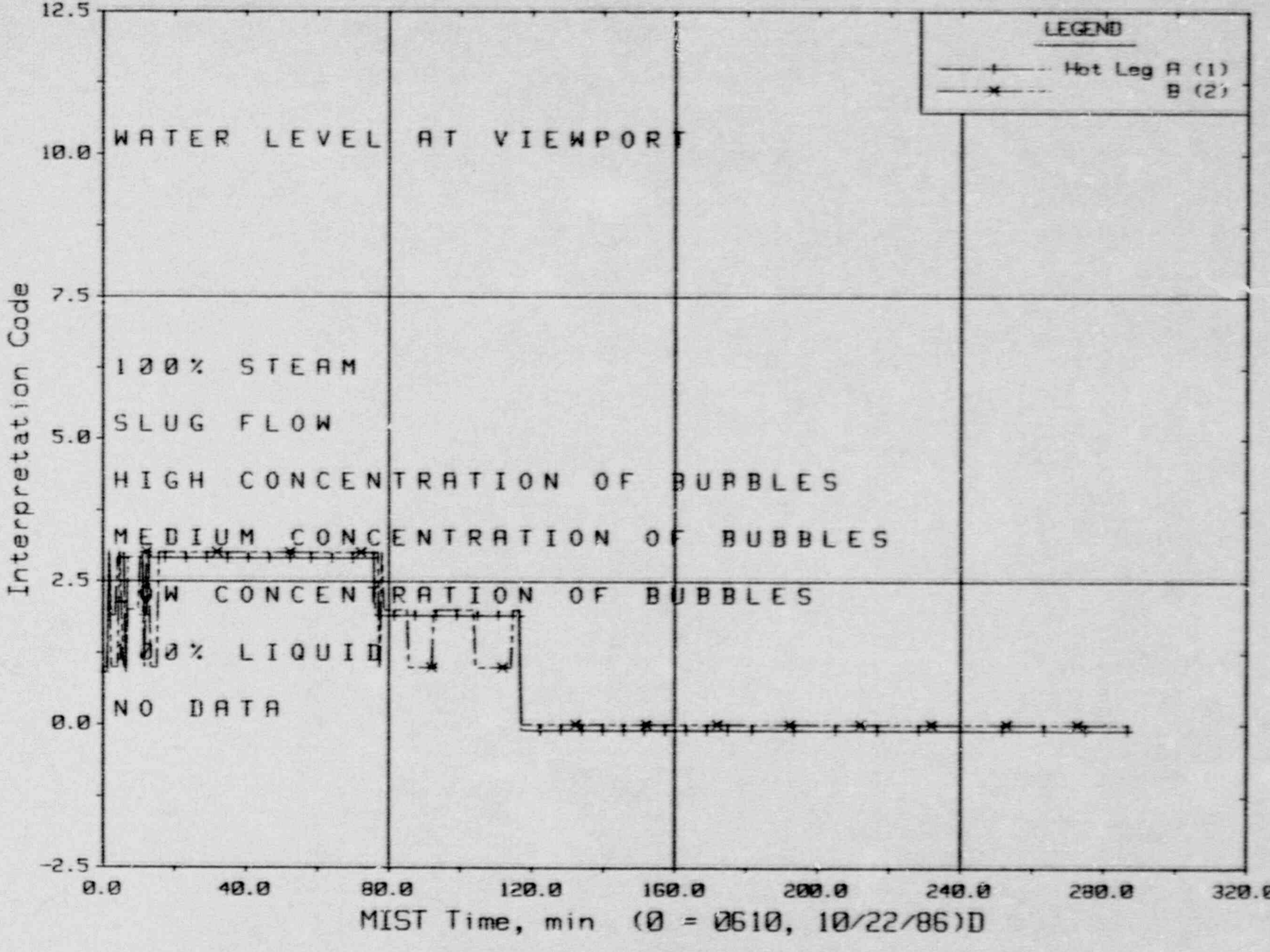
Hot Leg Horizontal Viewport Indications (HnMS01s).

Thu May 26 13:26:31 1988

HLVP2

FINAL DATA

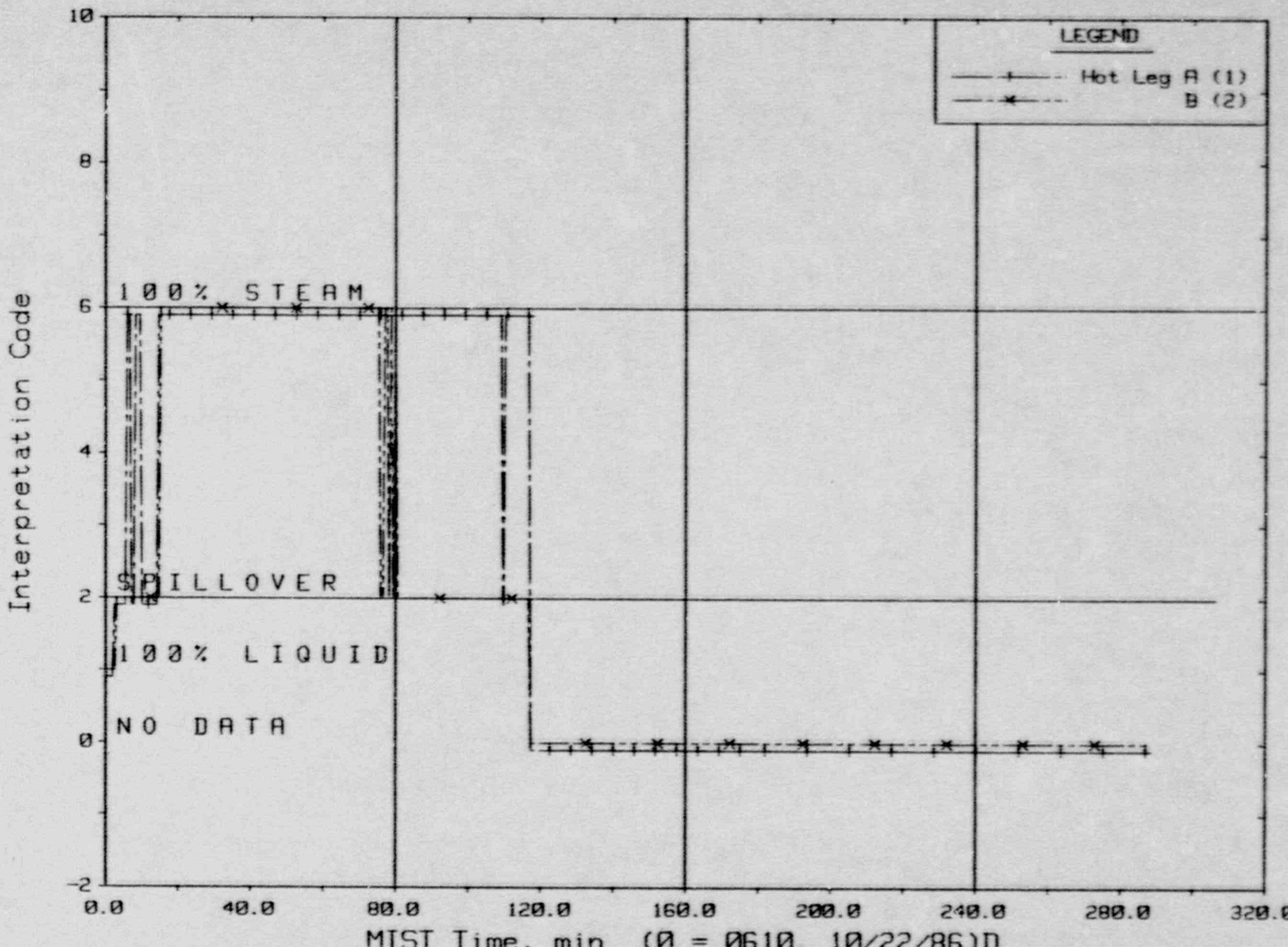
T350700: Group 35 Test 7, Helium and Suction Leak.



Hot Leg Riser Viewport Indications (HnMS02s).

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



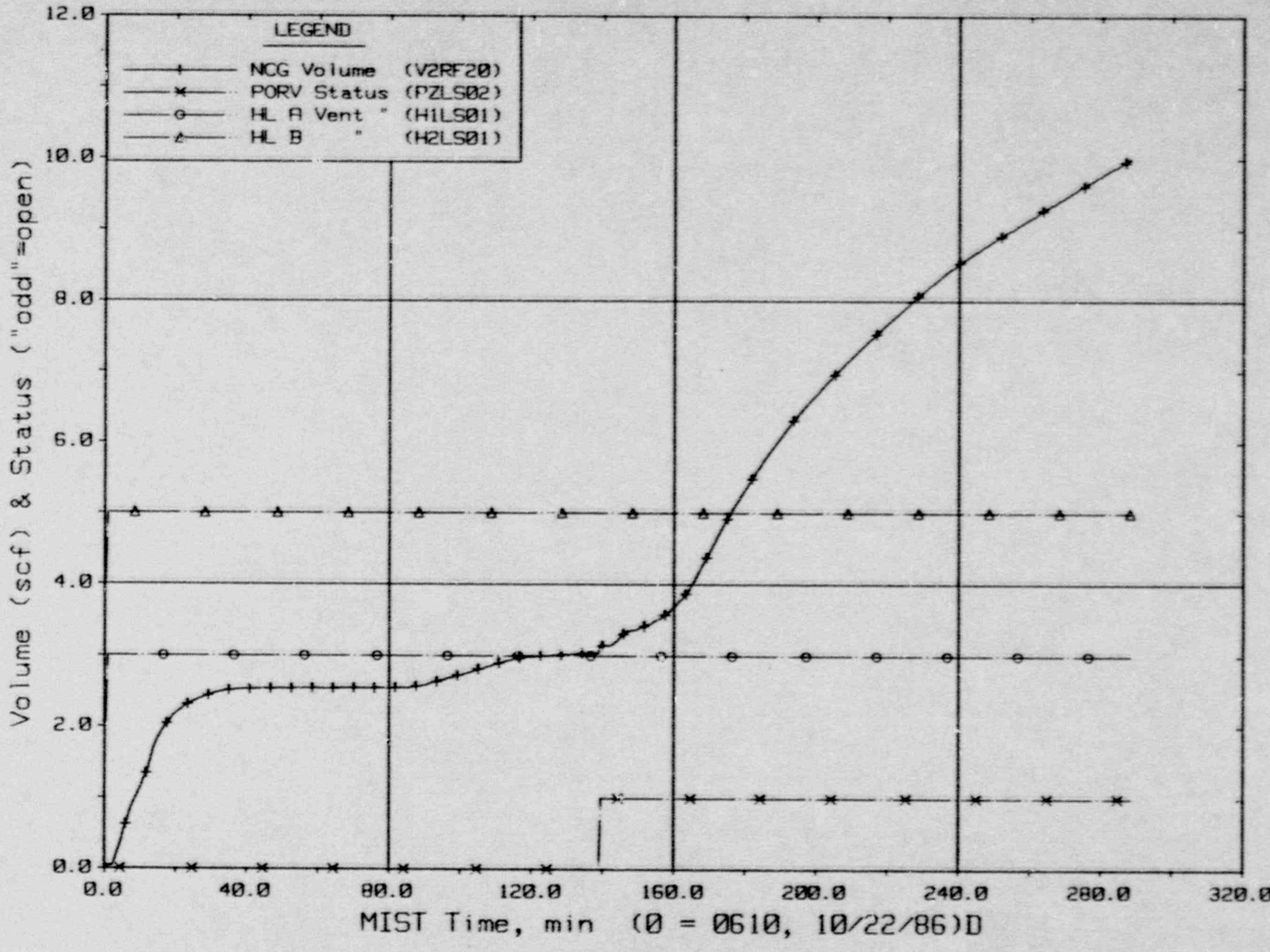
Hot Leg U-Bend Viewport Indications (HnMS03s).

Thu May 26 13:32:49 1988

HLVP4

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



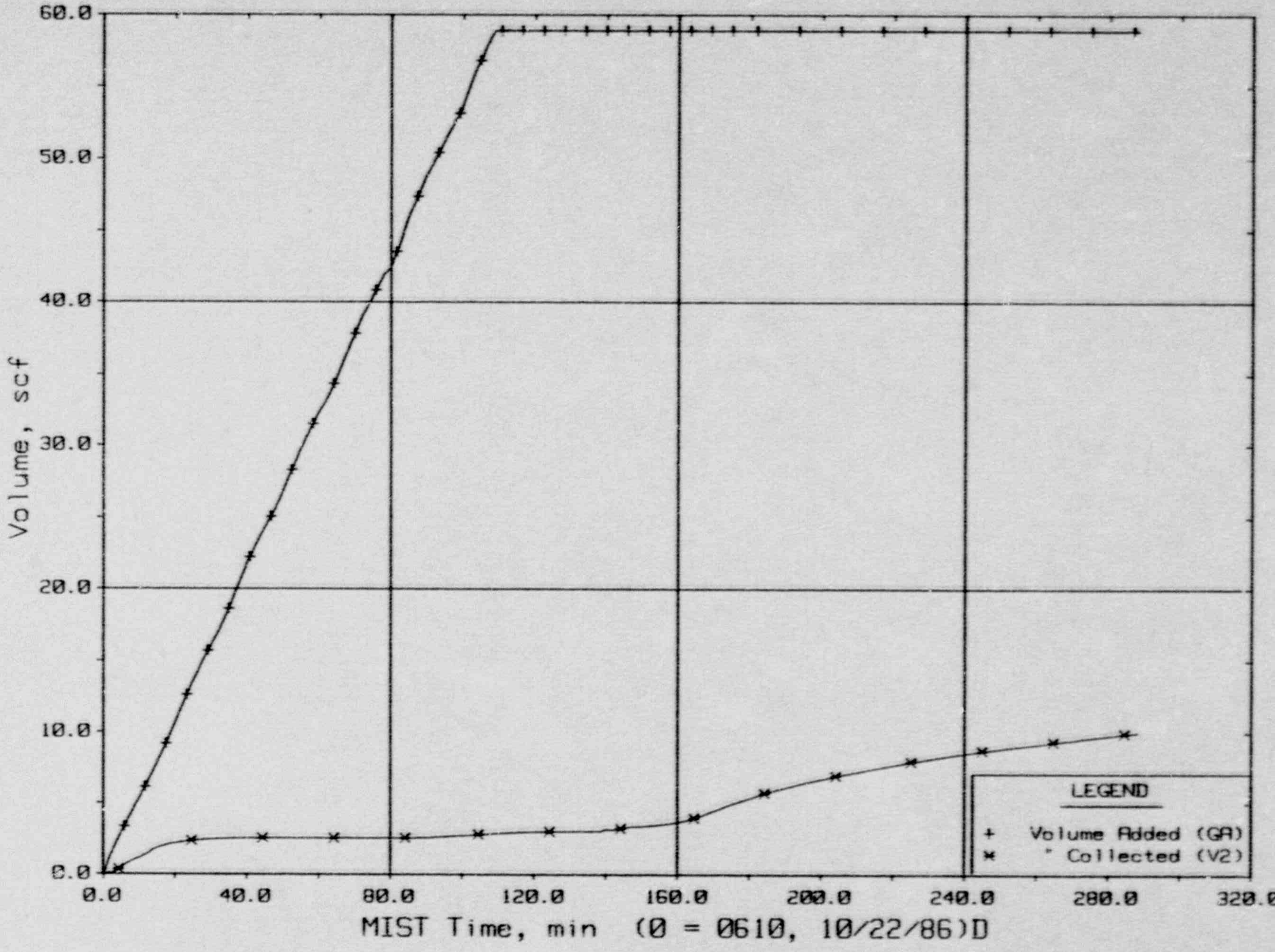
Noncondensibles Collected and Discharge Valve Status.

Thu May 26 13:19:22 1988

NCMS1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



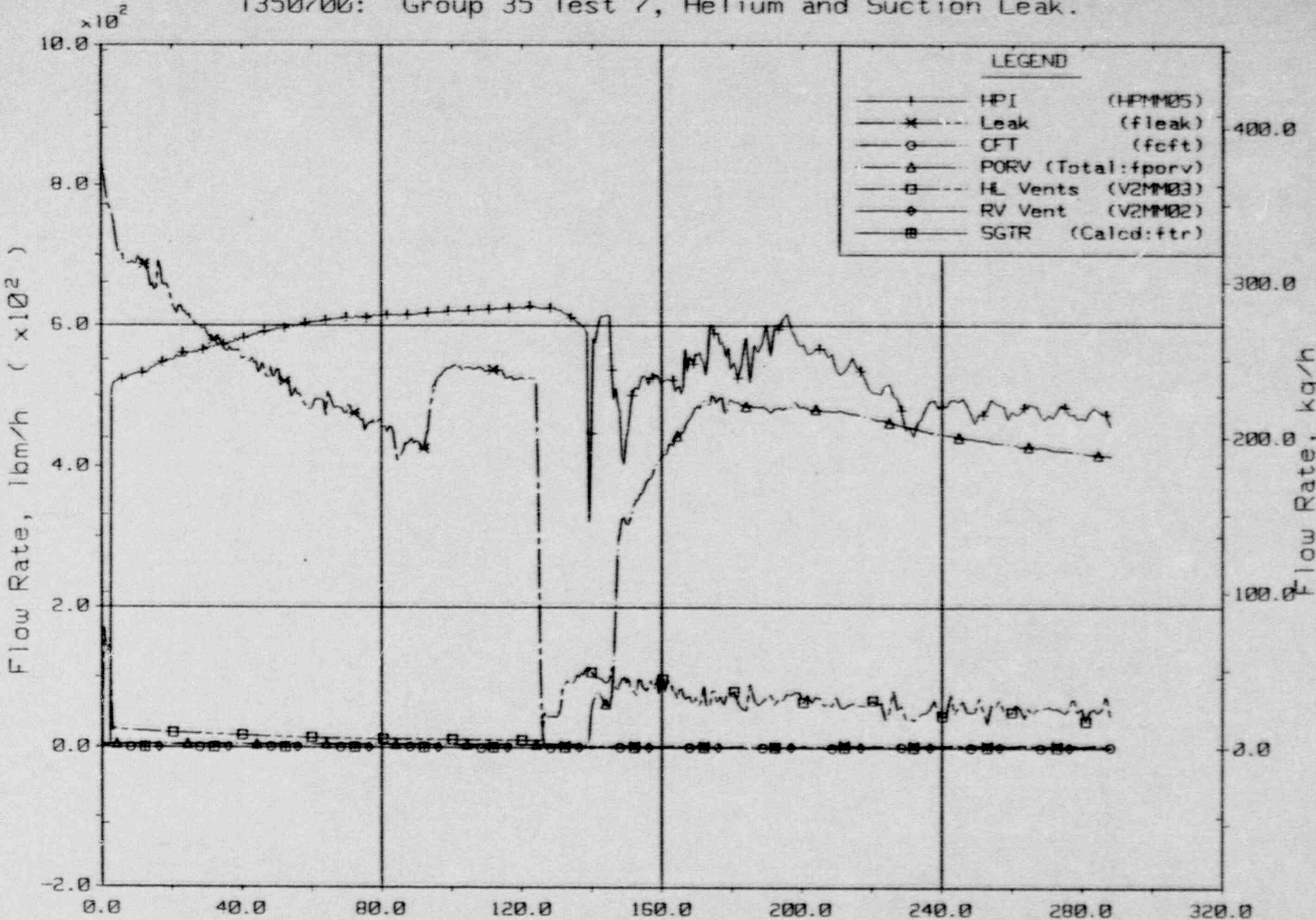
Noncondensibles Gas Volumes.

Thu May 26 13:21:34 1988

NCMS2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



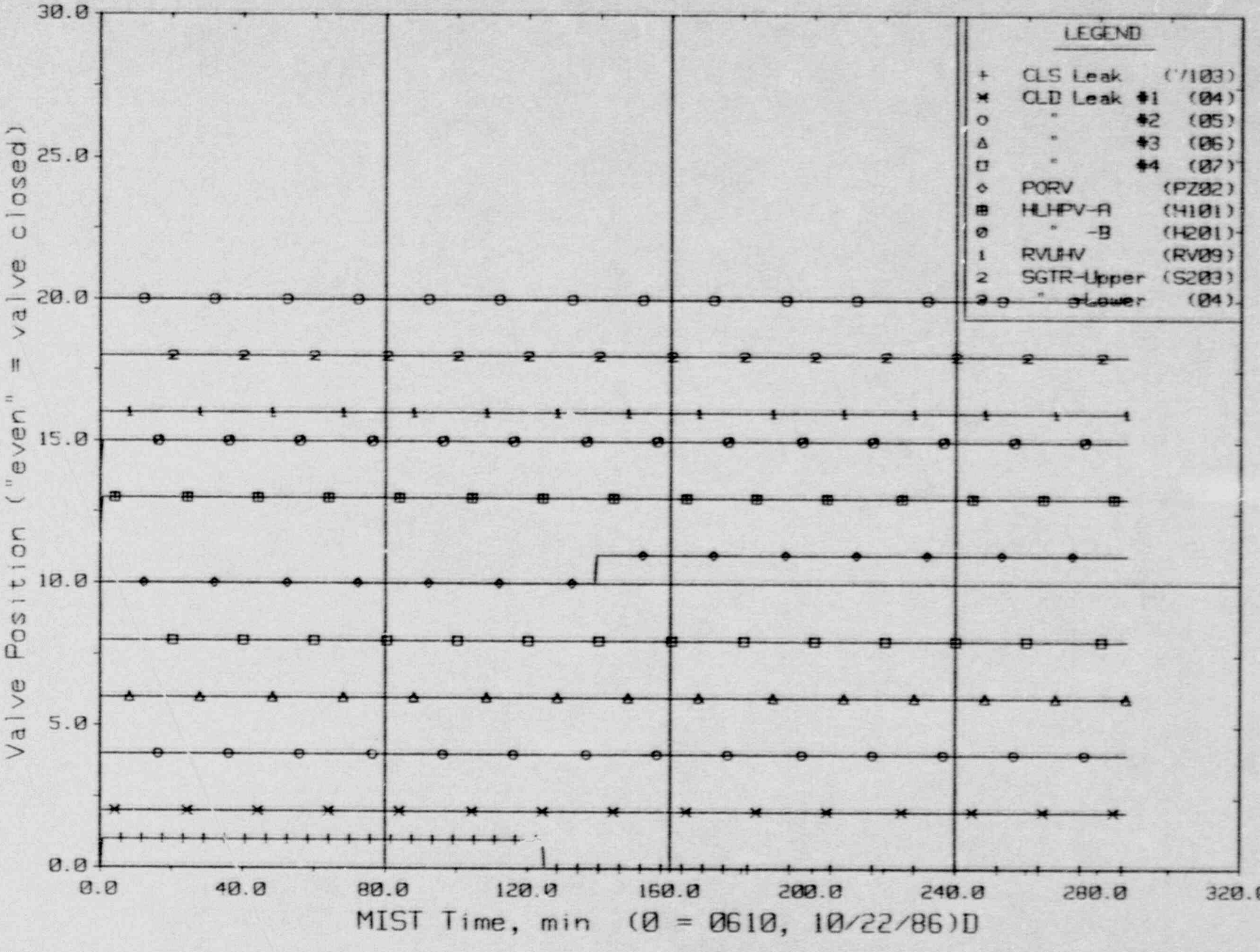
Primary System Boundary Flow Rates.

Thu May 26 09:09:31 1988

PBFL3

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



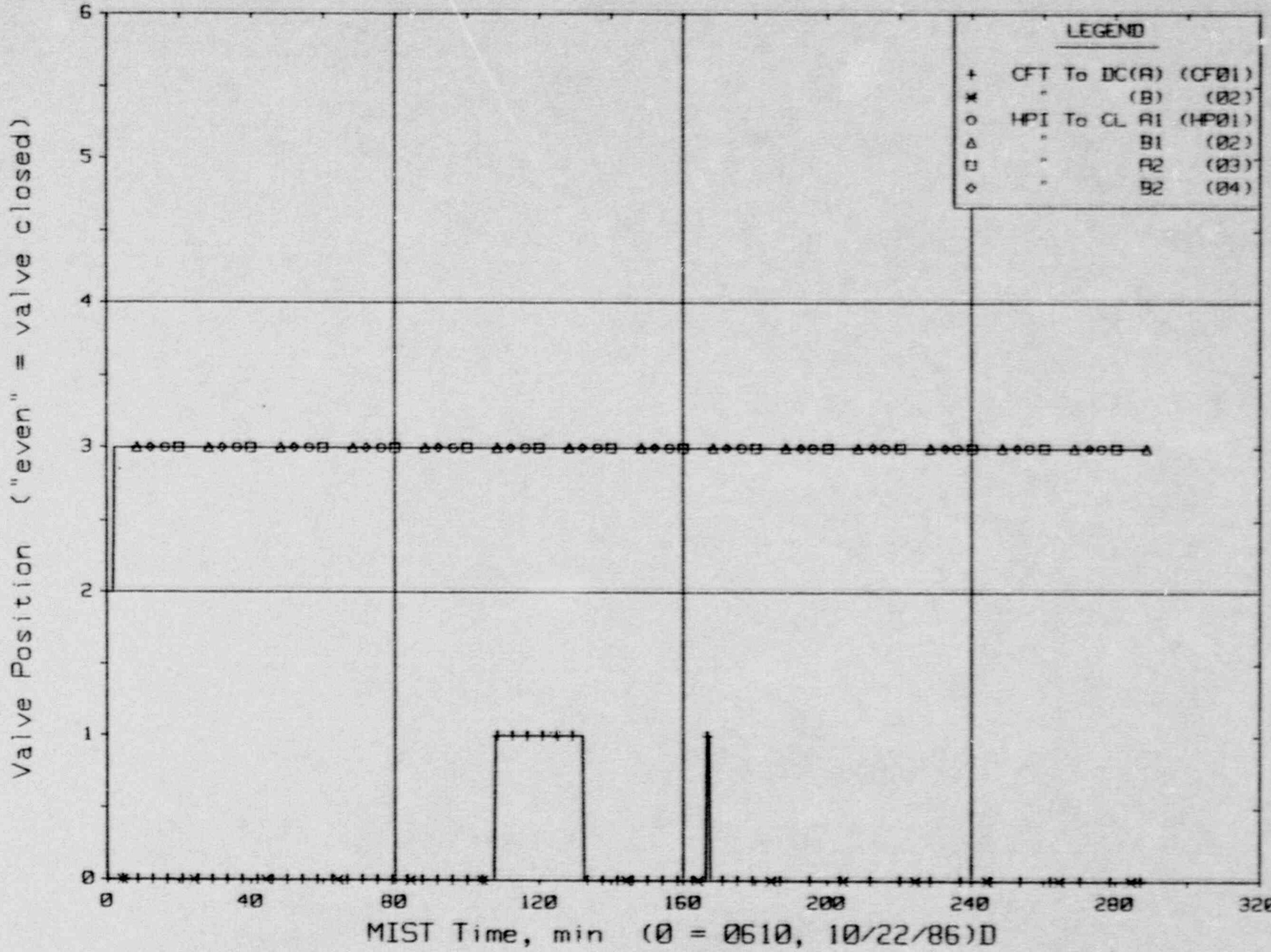
Primary System Discharge Limit Switch Indications (LSs).

Thu May 26 09:13:37 1988

PBLS1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



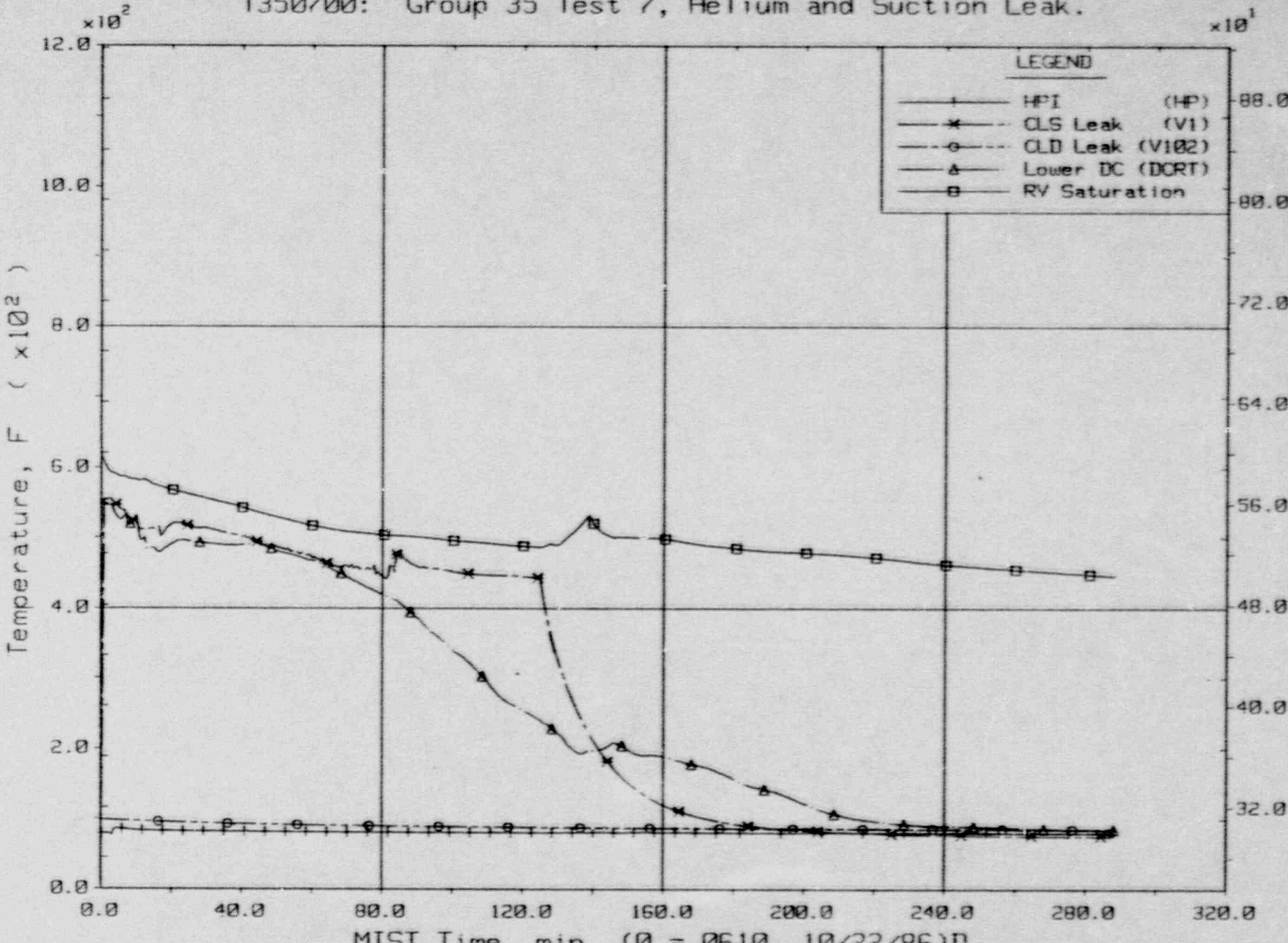
Primary System Injection Limit Switch Indications (LSs).

Fri Jan 6 17:46:22 1989

PBLS2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



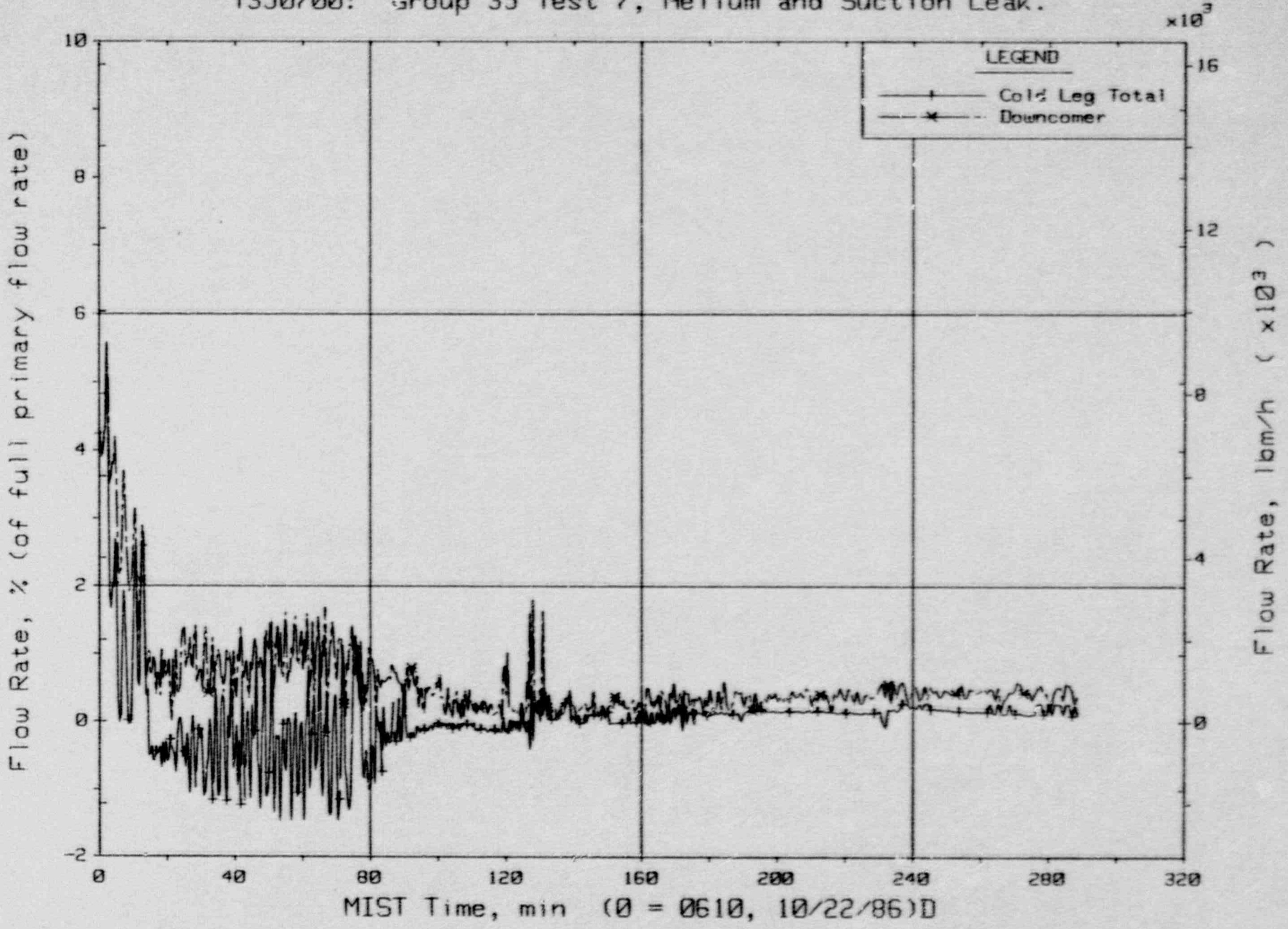
Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Thu May 26 09:19:34 1988

PBTC1p

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



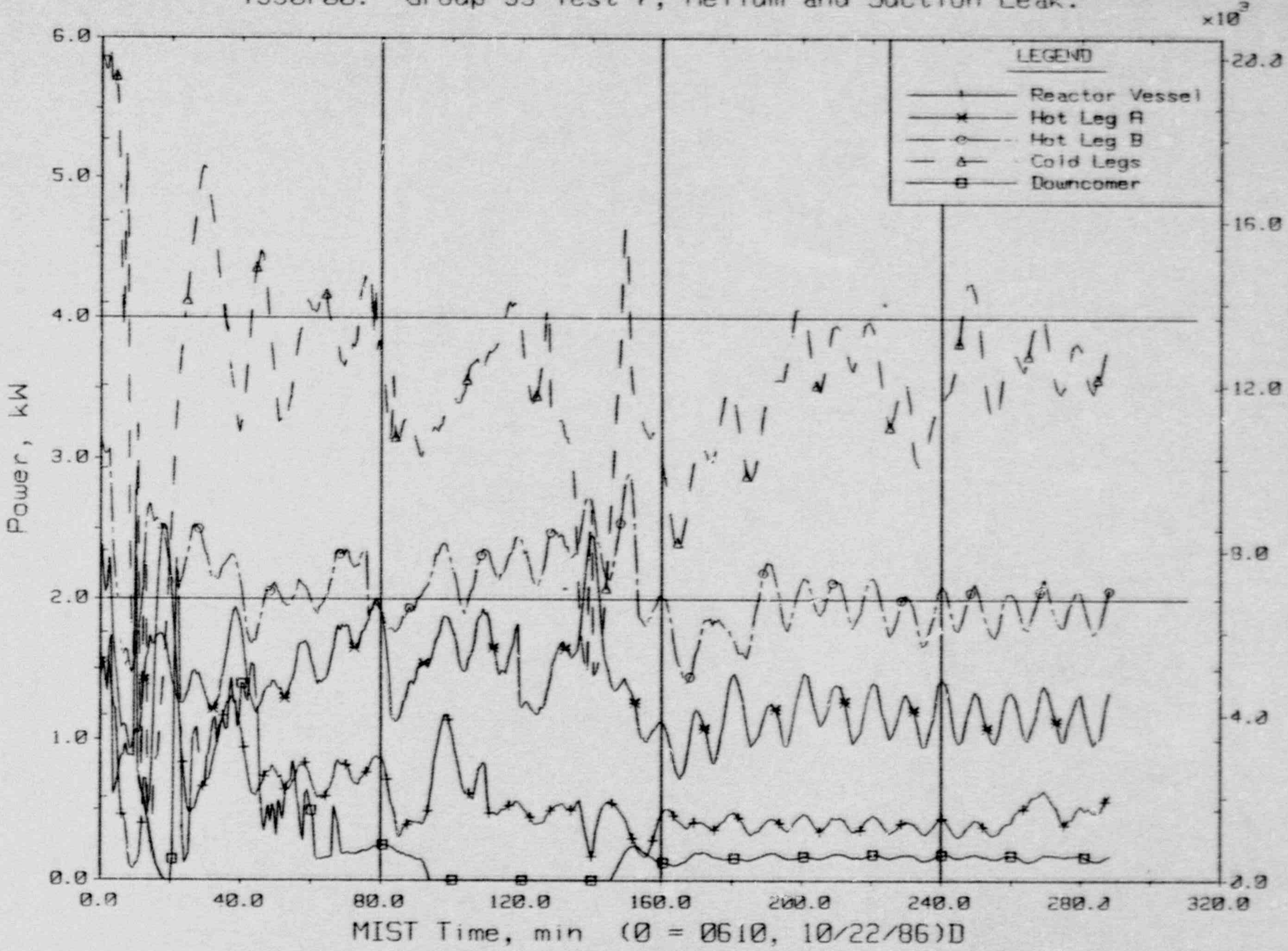
Primary System Venturi Flow Rates.

Fri Jan 6 17:51:58 1989

PRFL7

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



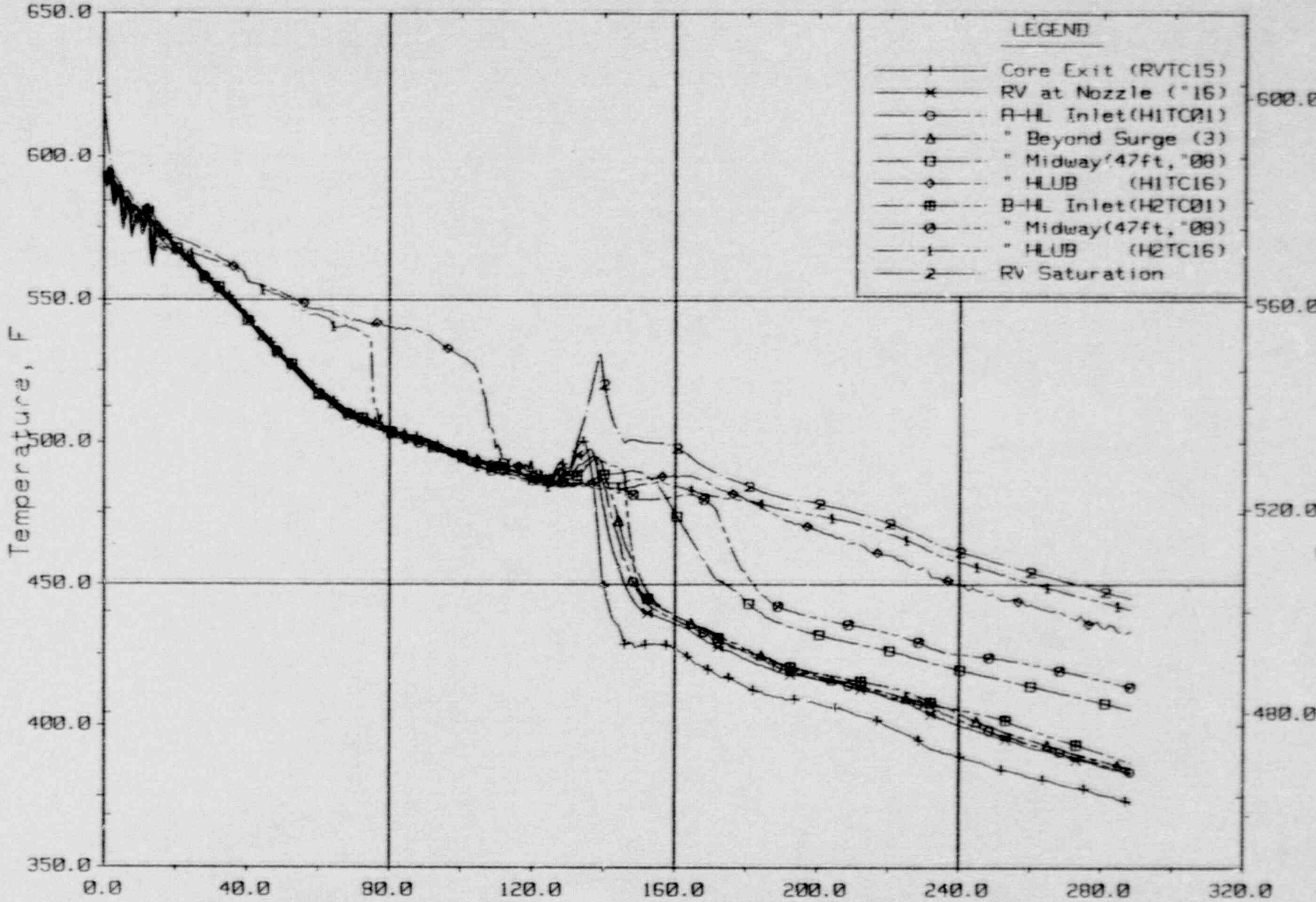
Guard Heater Specified Power Per Primary Component.

Thu May 26 09:25:20 1988

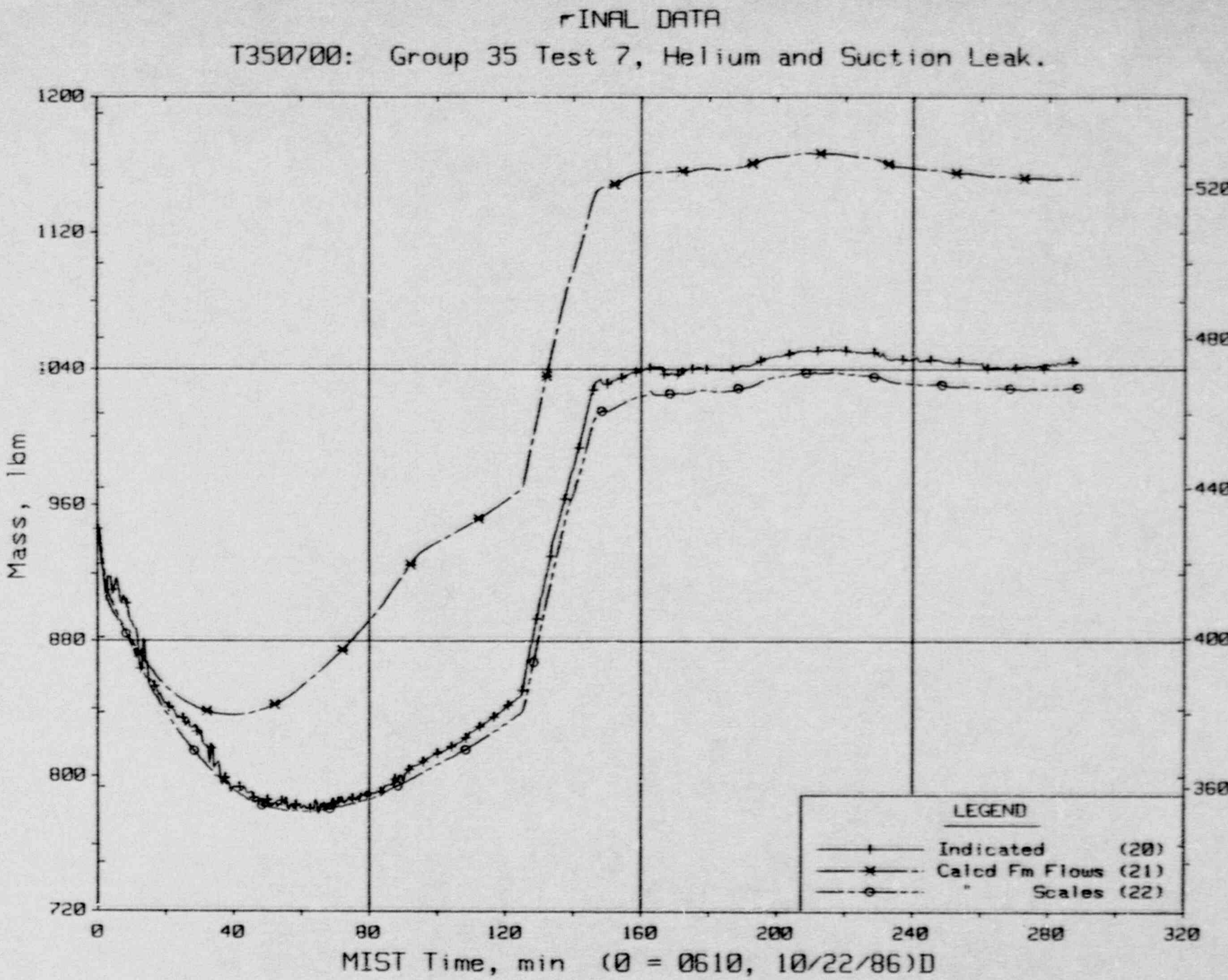
PRGQI

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



Composite Core Exit and Hot Leg Fluid Temperatures.



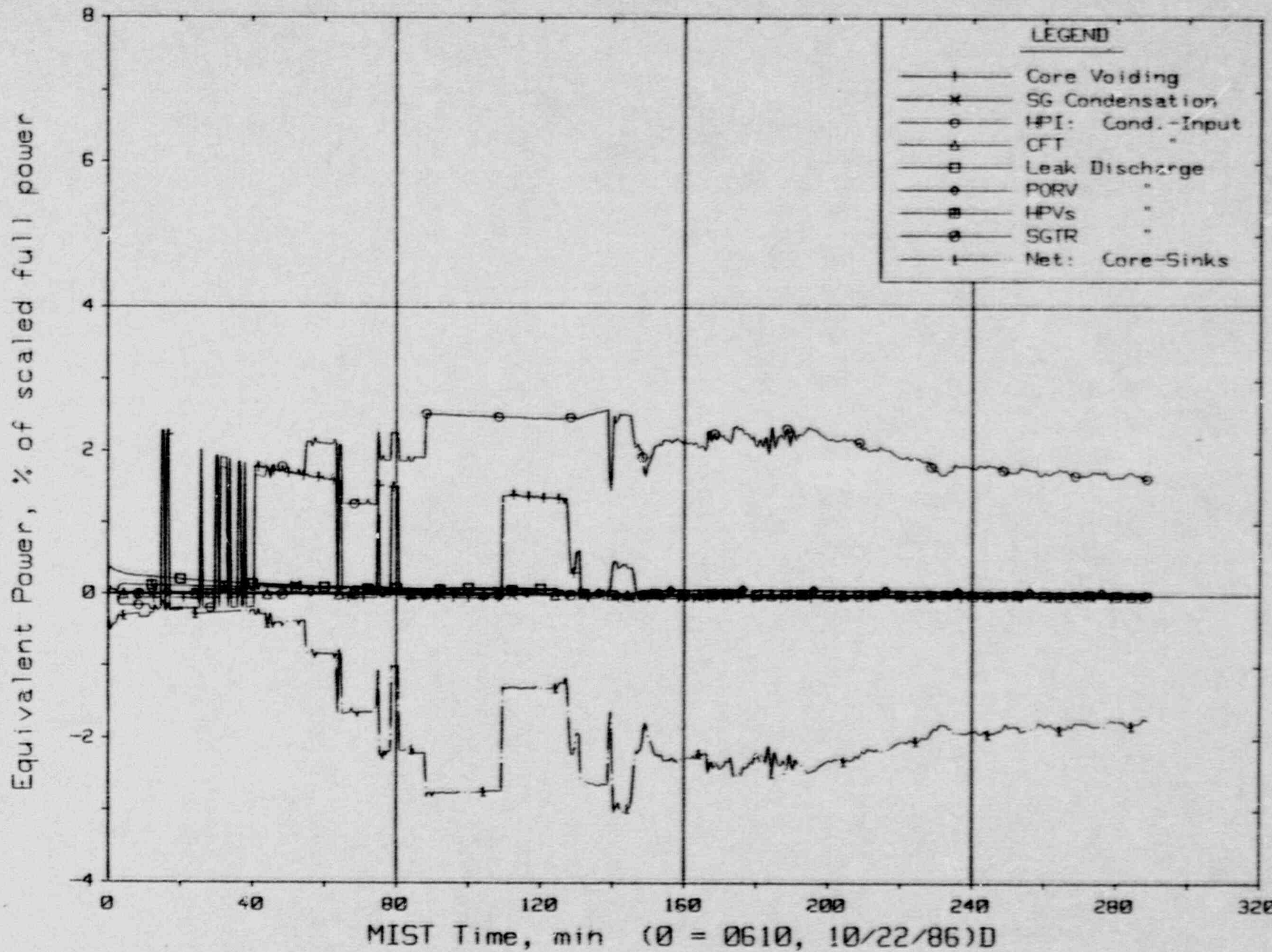
Primary System Total Fluid Mass (PLMLs).

Wed Jan 11 16:47:12 1989

PRML2

FINAL DATA

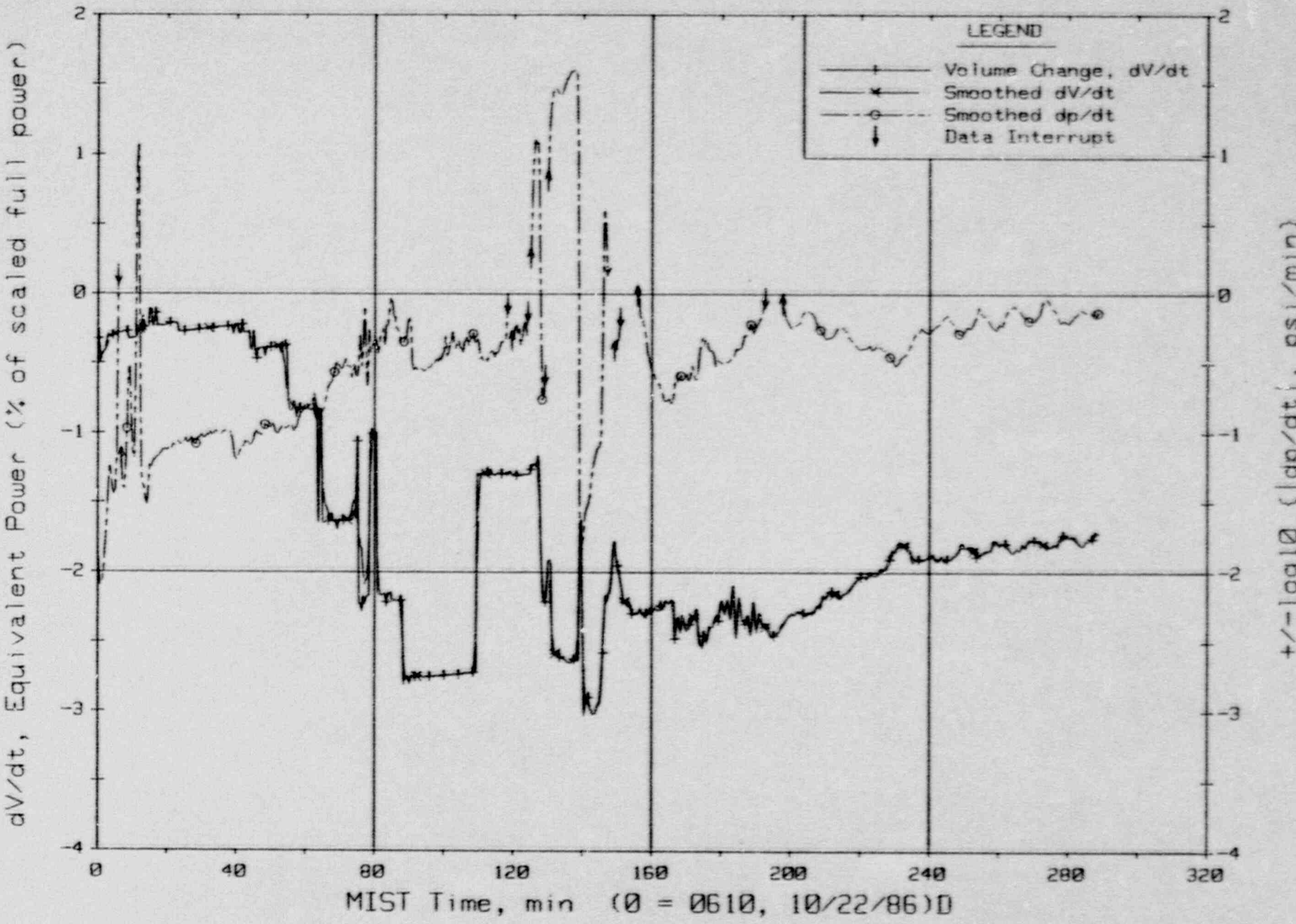
T350700: Group 35 Test 7, Helium and Suction Leak.



Primary Fluid Volume Changes By Components.

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



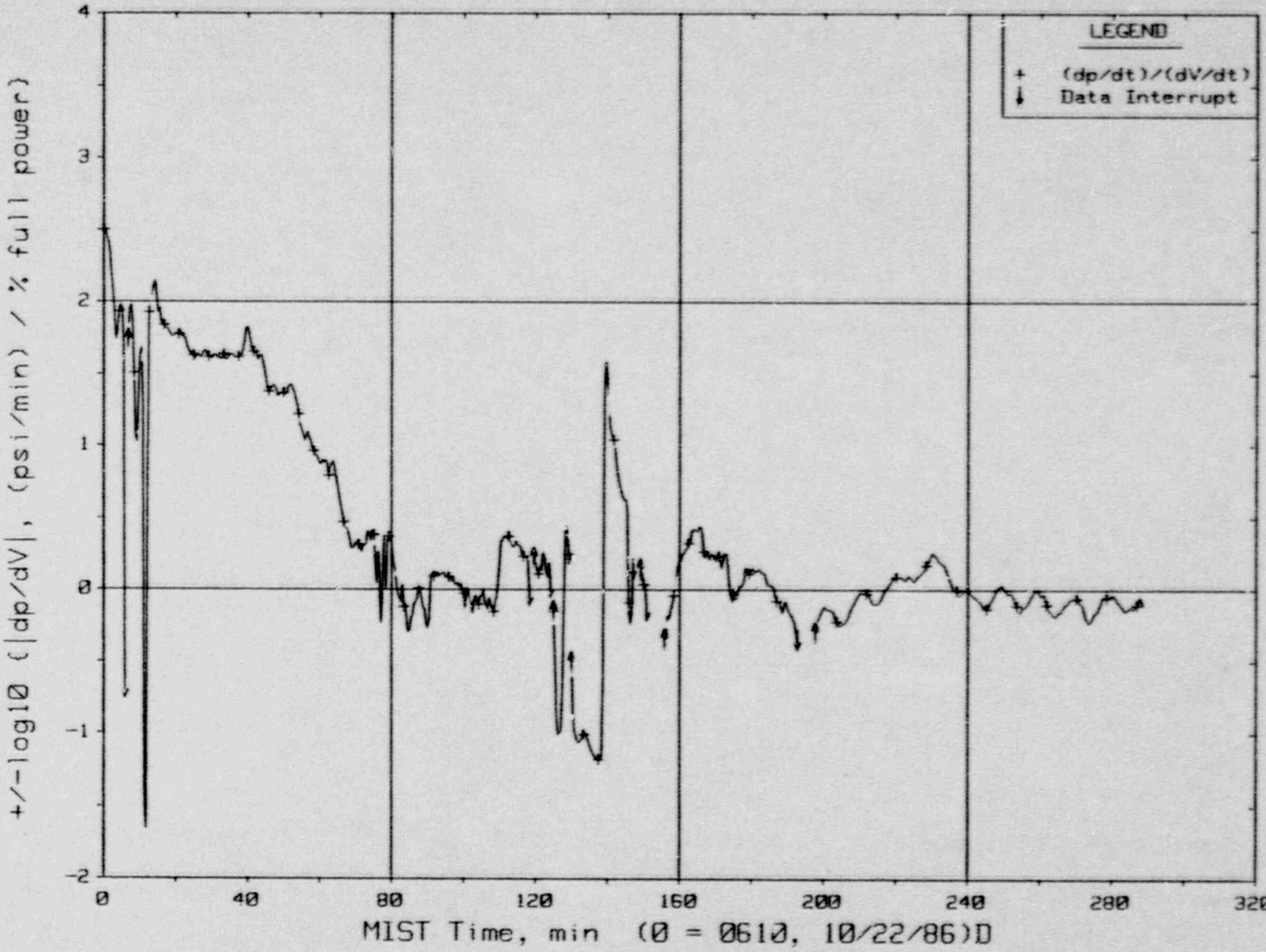
Primary Fluid Volume and Pressure Changes, dV/dt and dp/dt.

Fri Jan 6 18:09:43 1989

PRPA2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



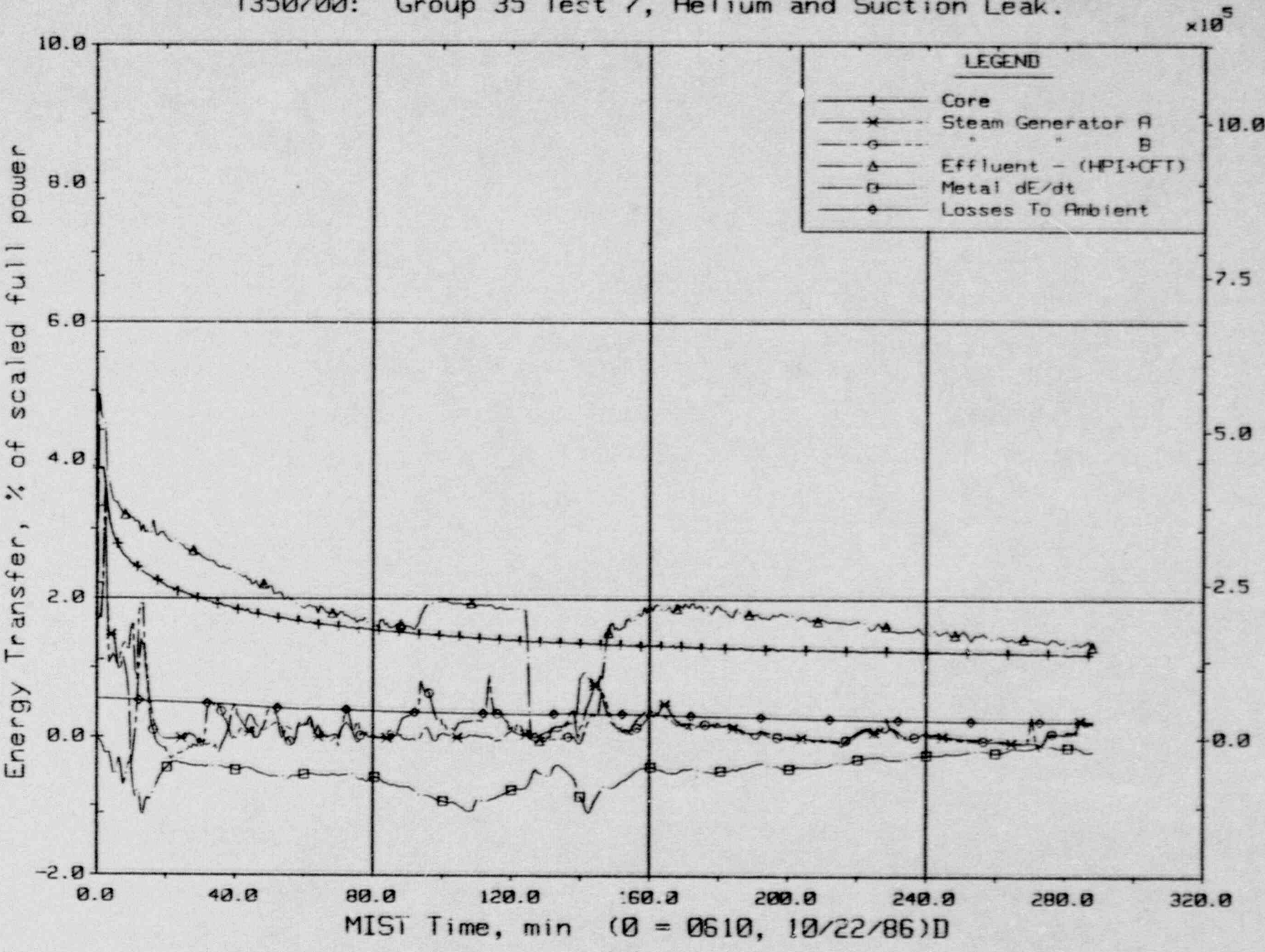
Primary System Response: dp/dt divided by dV/dt.

Wed Jan 11 16:59:38 1989

PRPA3

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



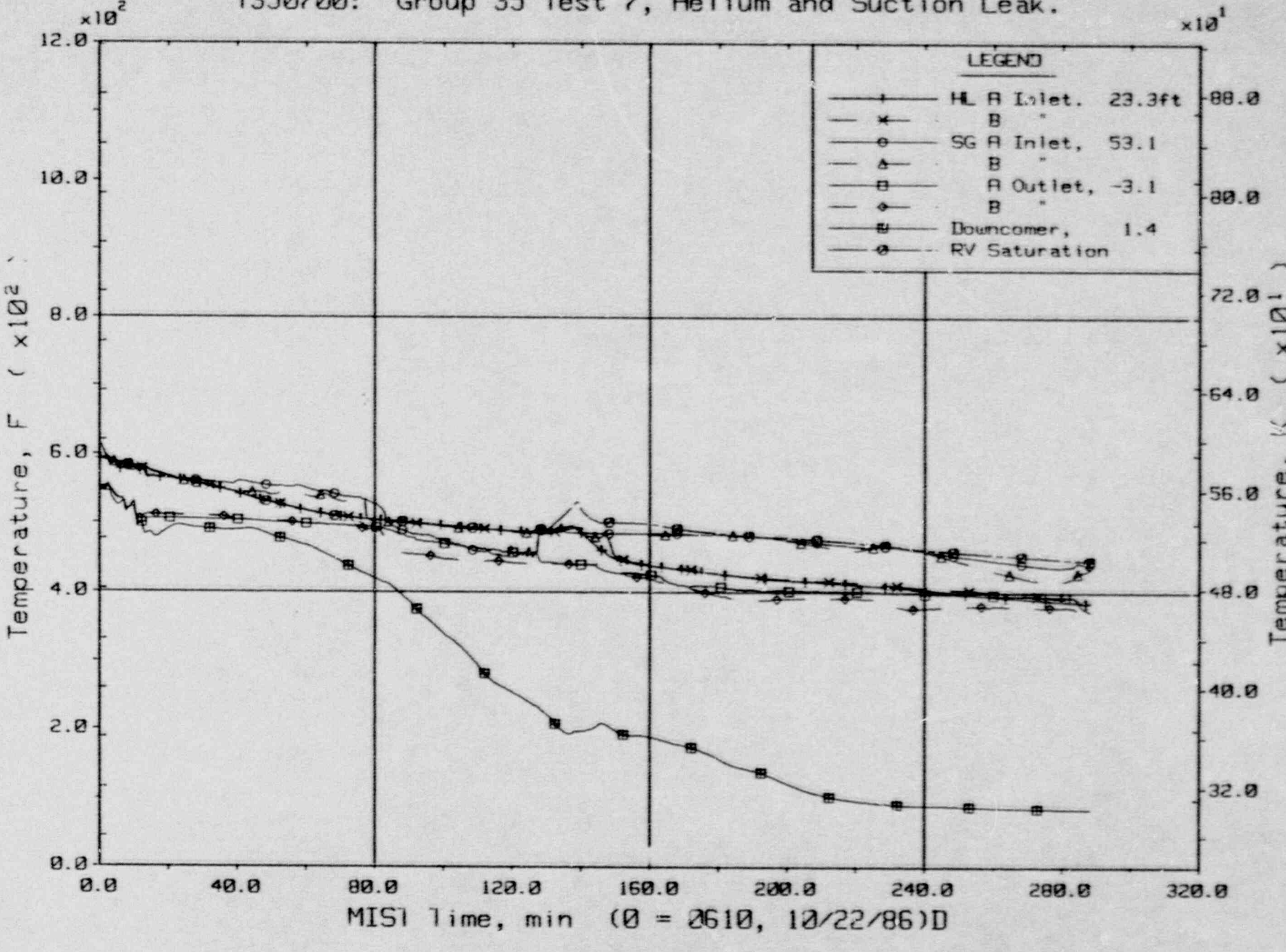
Primary System Energy Transfer.

Thu May 26 09:53:01 1988

PRQE2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



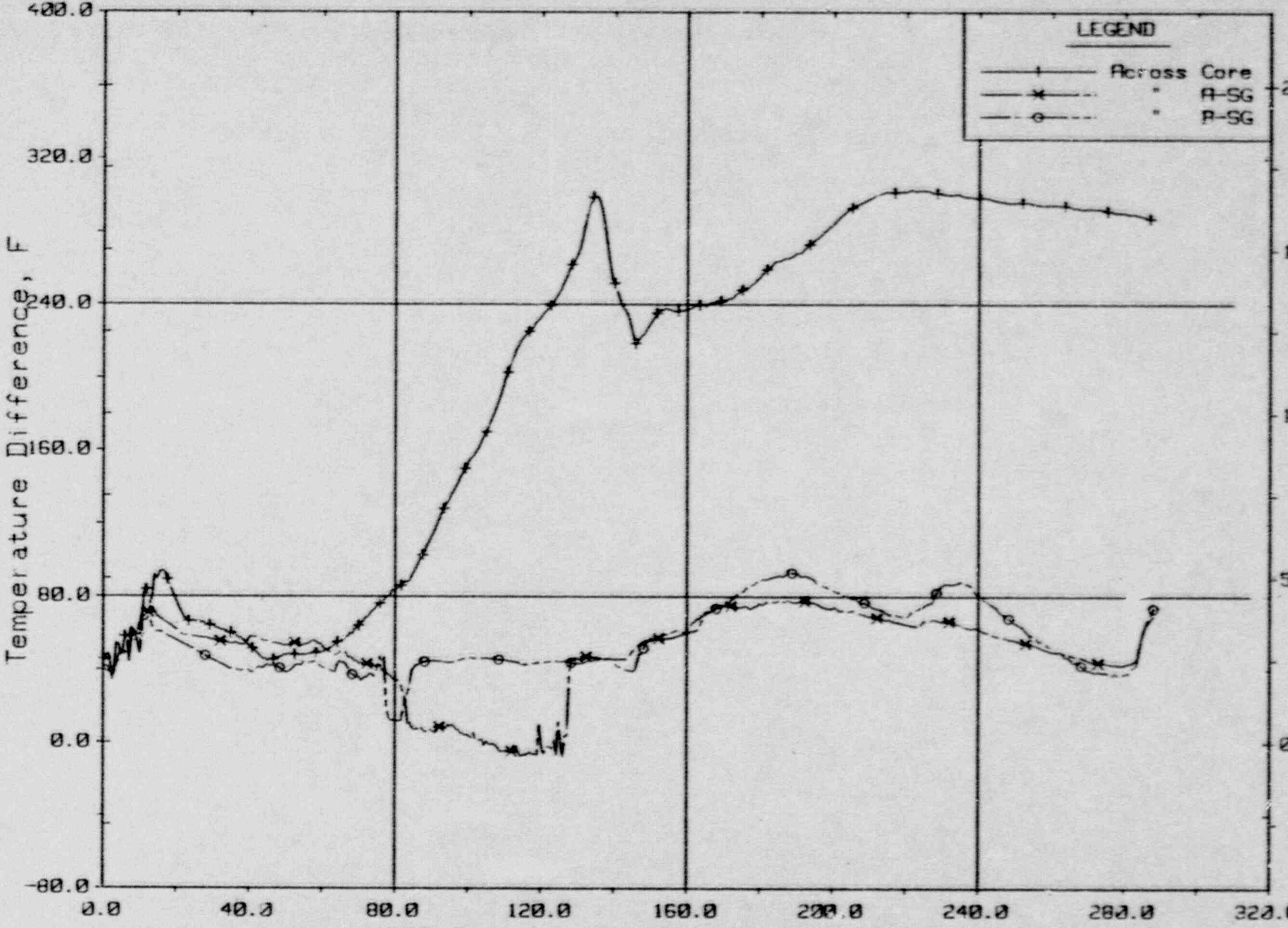
Primary System Fluid Temperatures (RTDs).

Thu May 26 09:58:02 1986

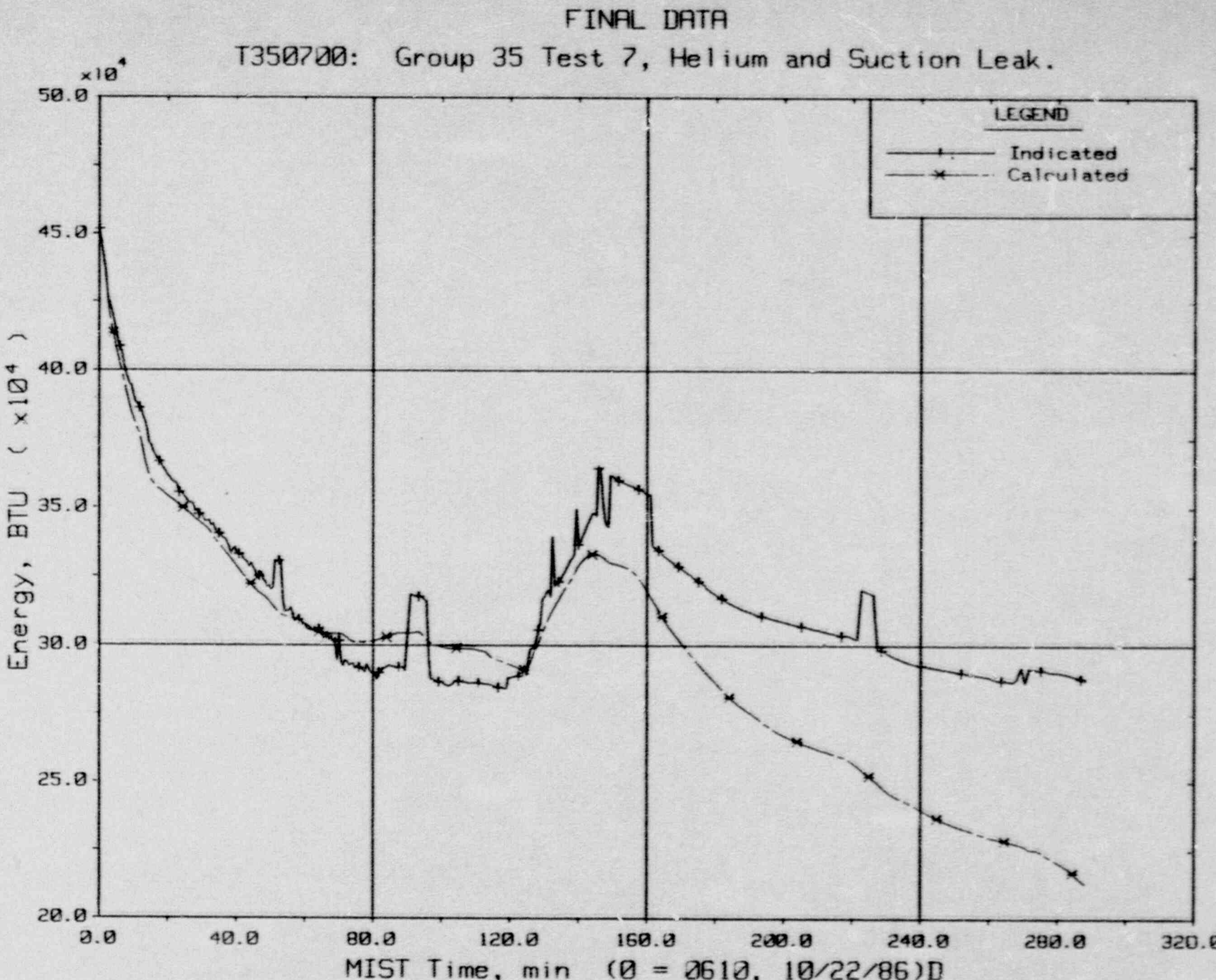
PRRT0

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



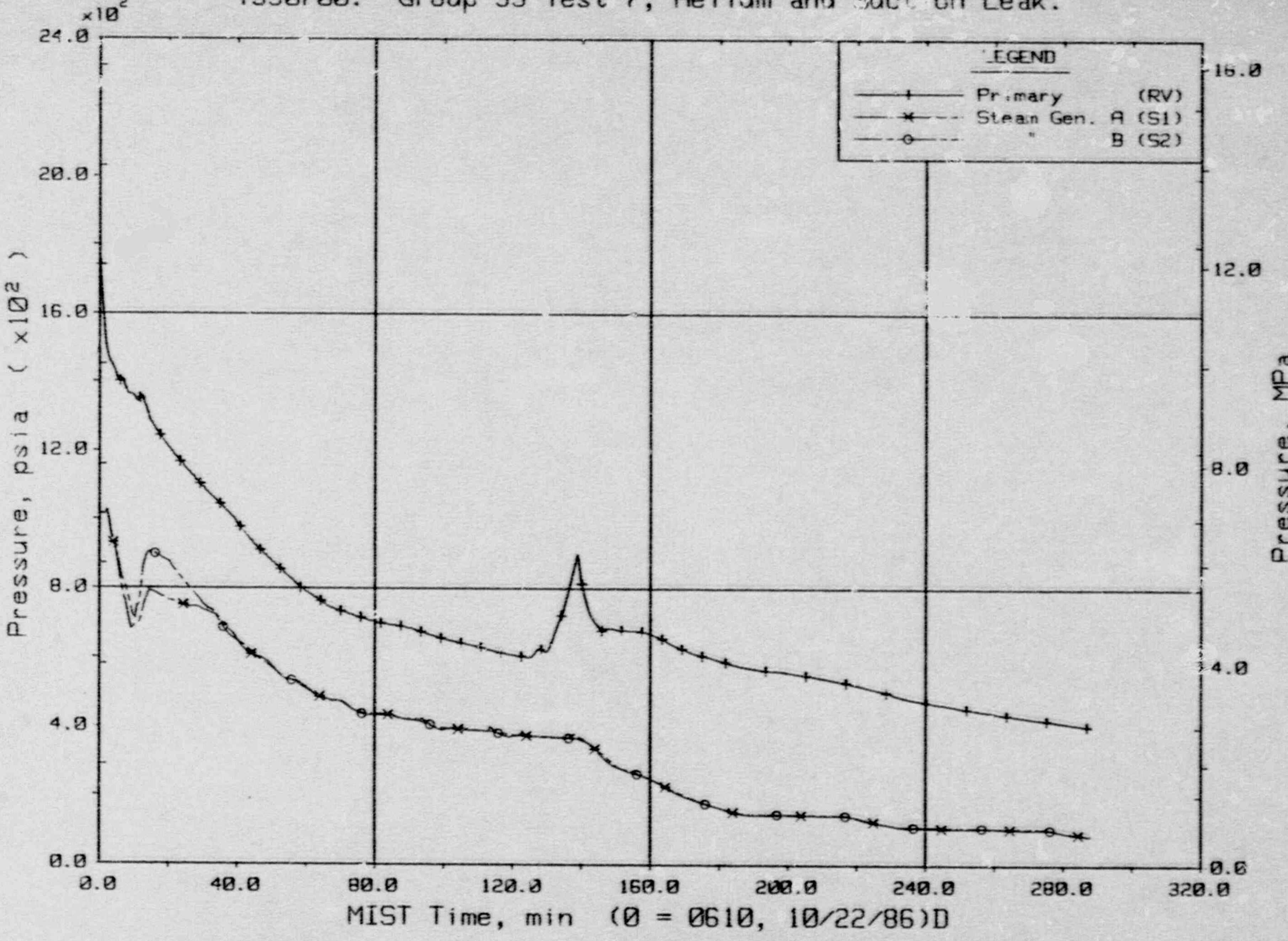
Key Temperature Differences.



Primary System Total Fluid Energy.

FINAL DATA

T350700: Group 35 Test 7, Helium and Suct on Leak.



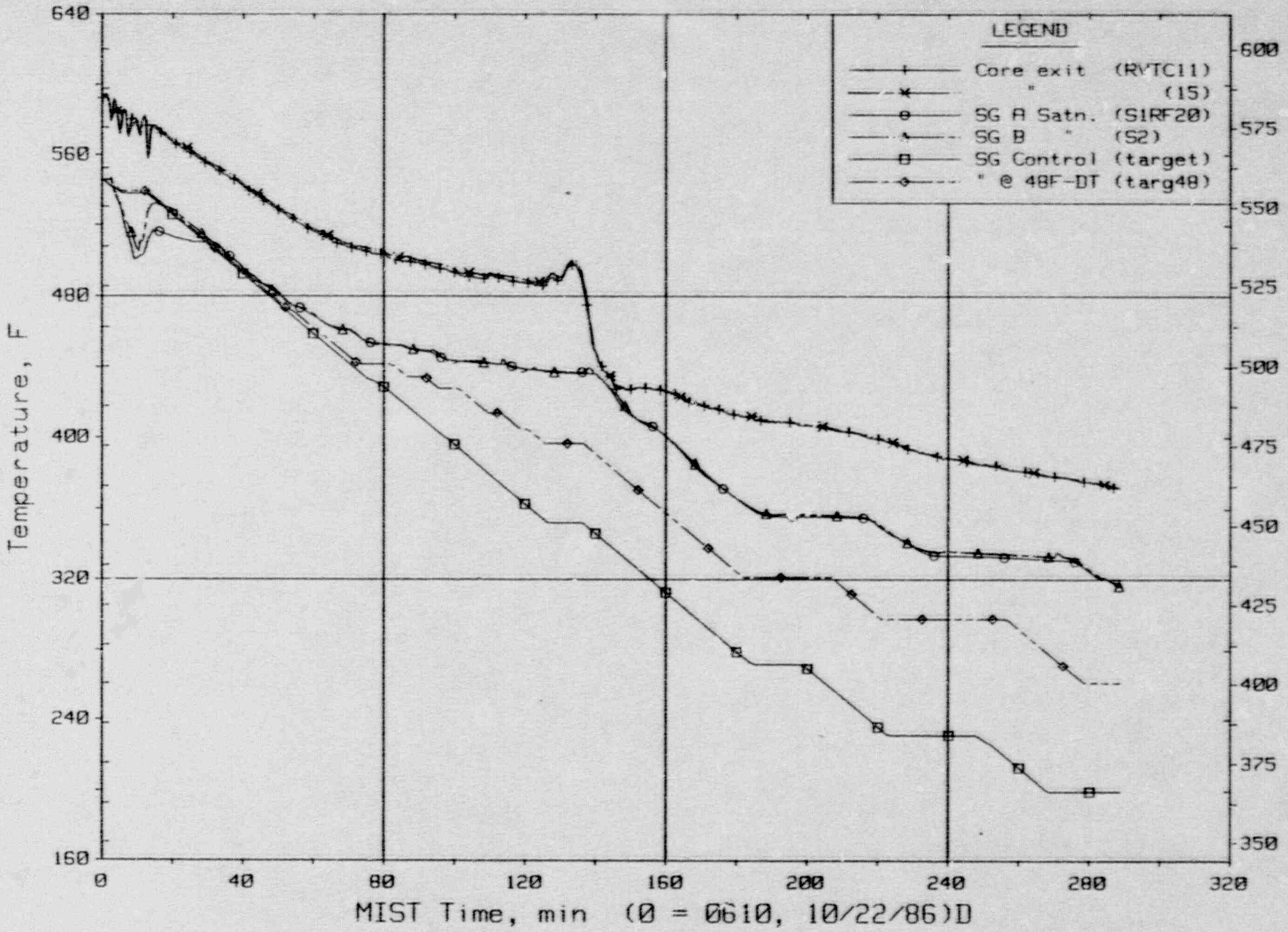
Primary and Secondary System Pressures (GP01s).

Thu May 26 10:10:08 1988

PSGP1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



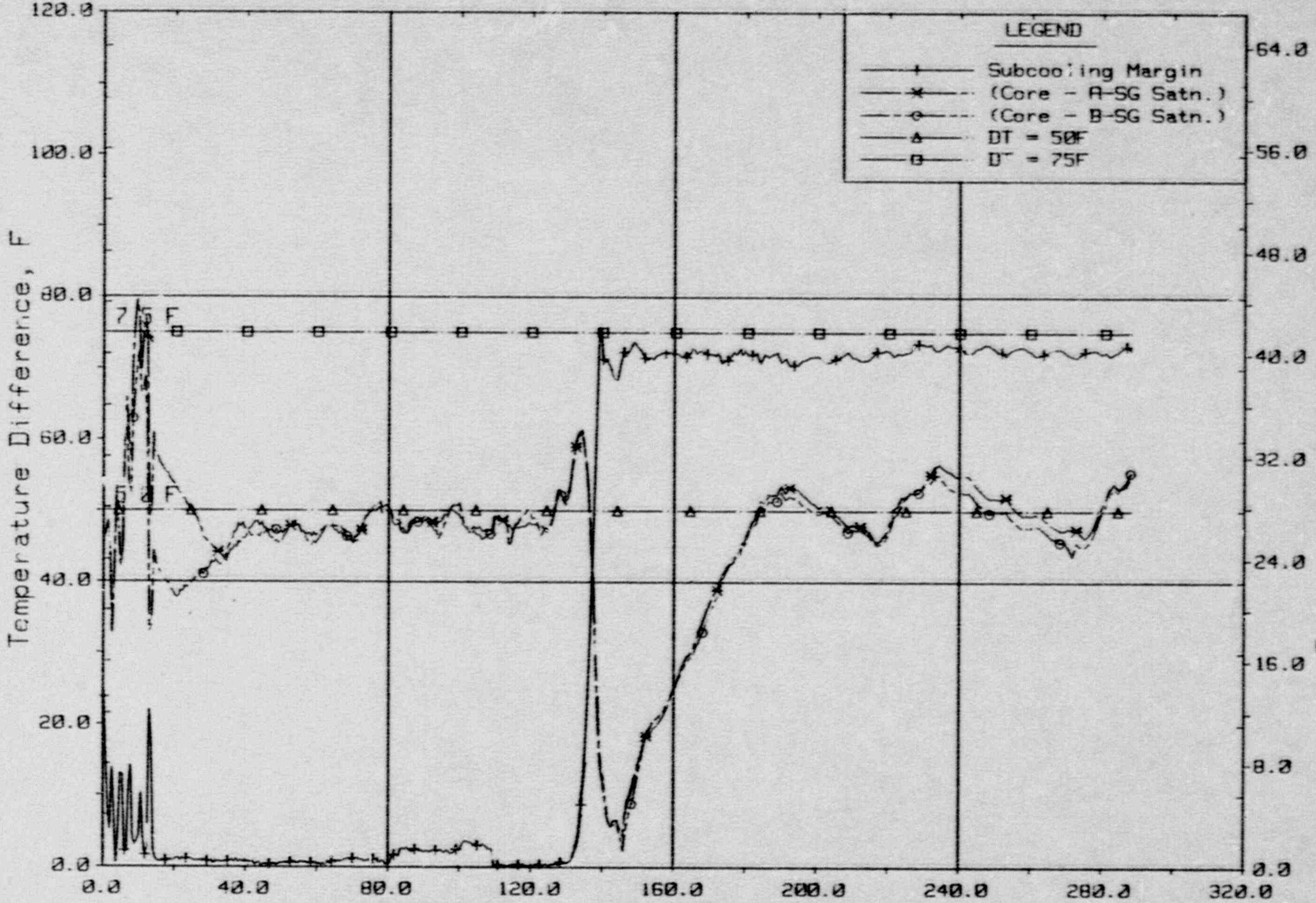
Steam Generator Secondary Saturation and Control Temperatures.

Fri Jan 6 18:32:35 1989

PSTC3

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



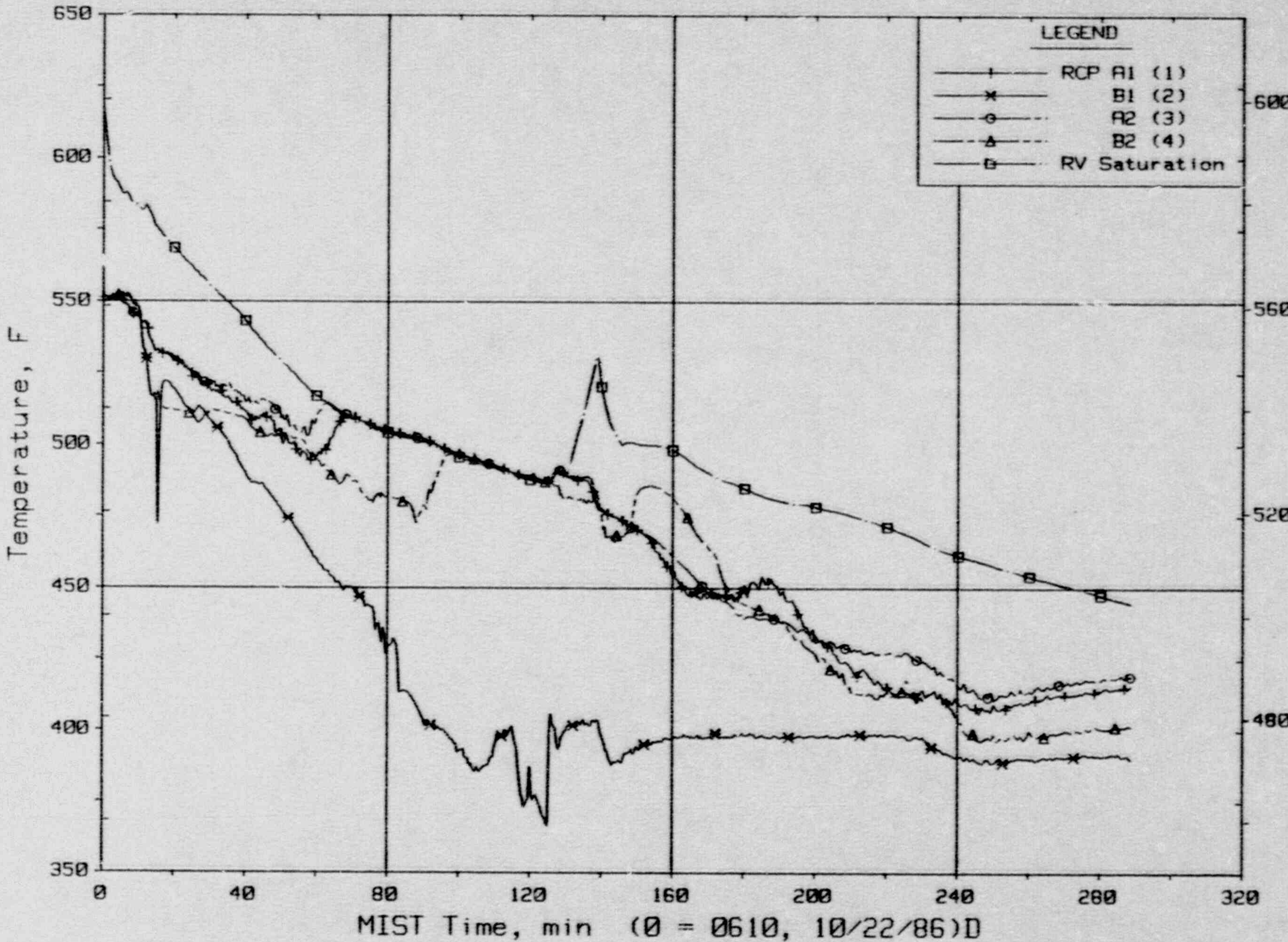
Control Temperature Differences.

Thu May 26 10:27:00 1988

PSTD1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



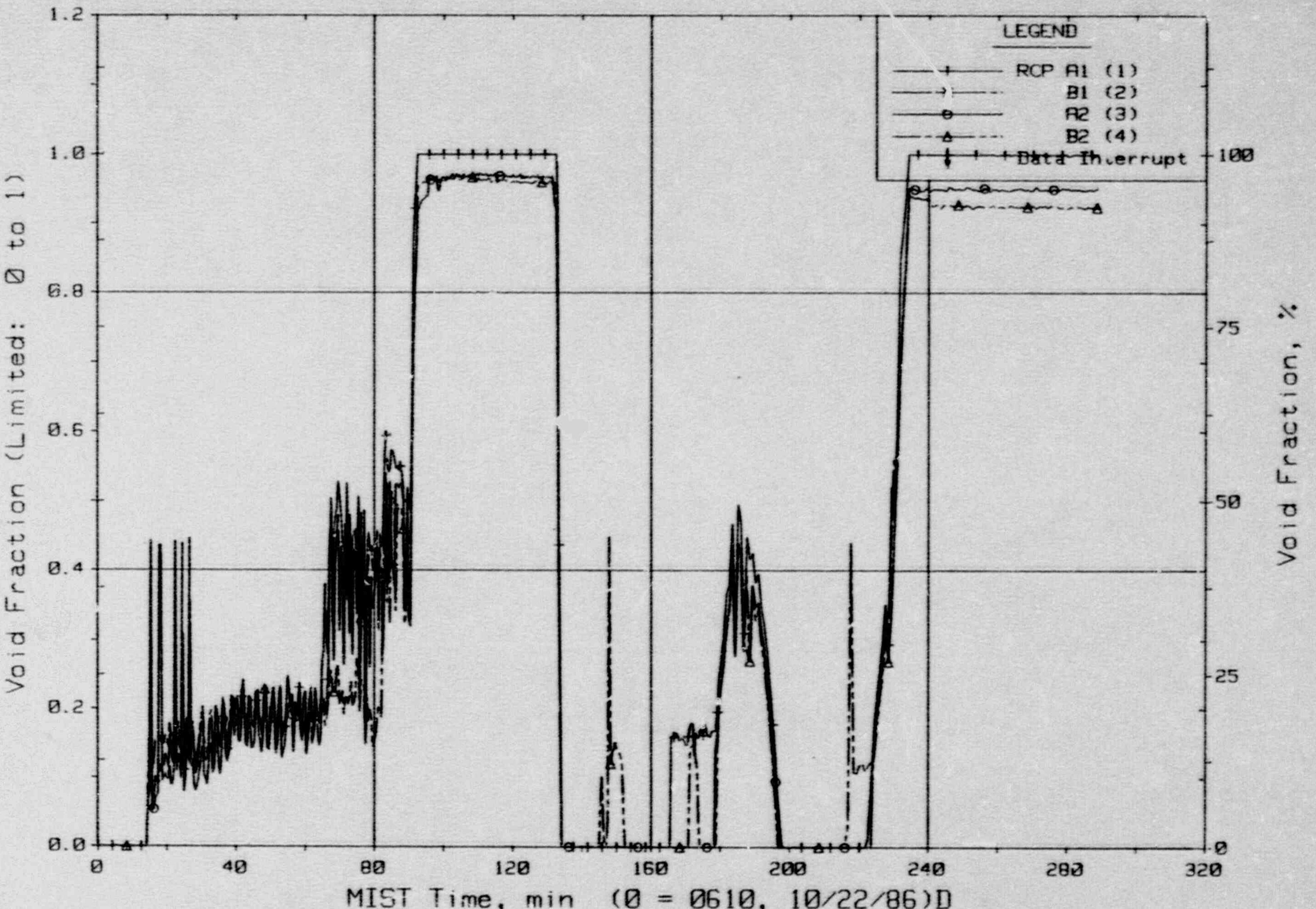
Pump Suction Fluid Temperature (CnRT01s).

Wed Jan 11 16:17:06 1989

PURT0

rINAL DATA

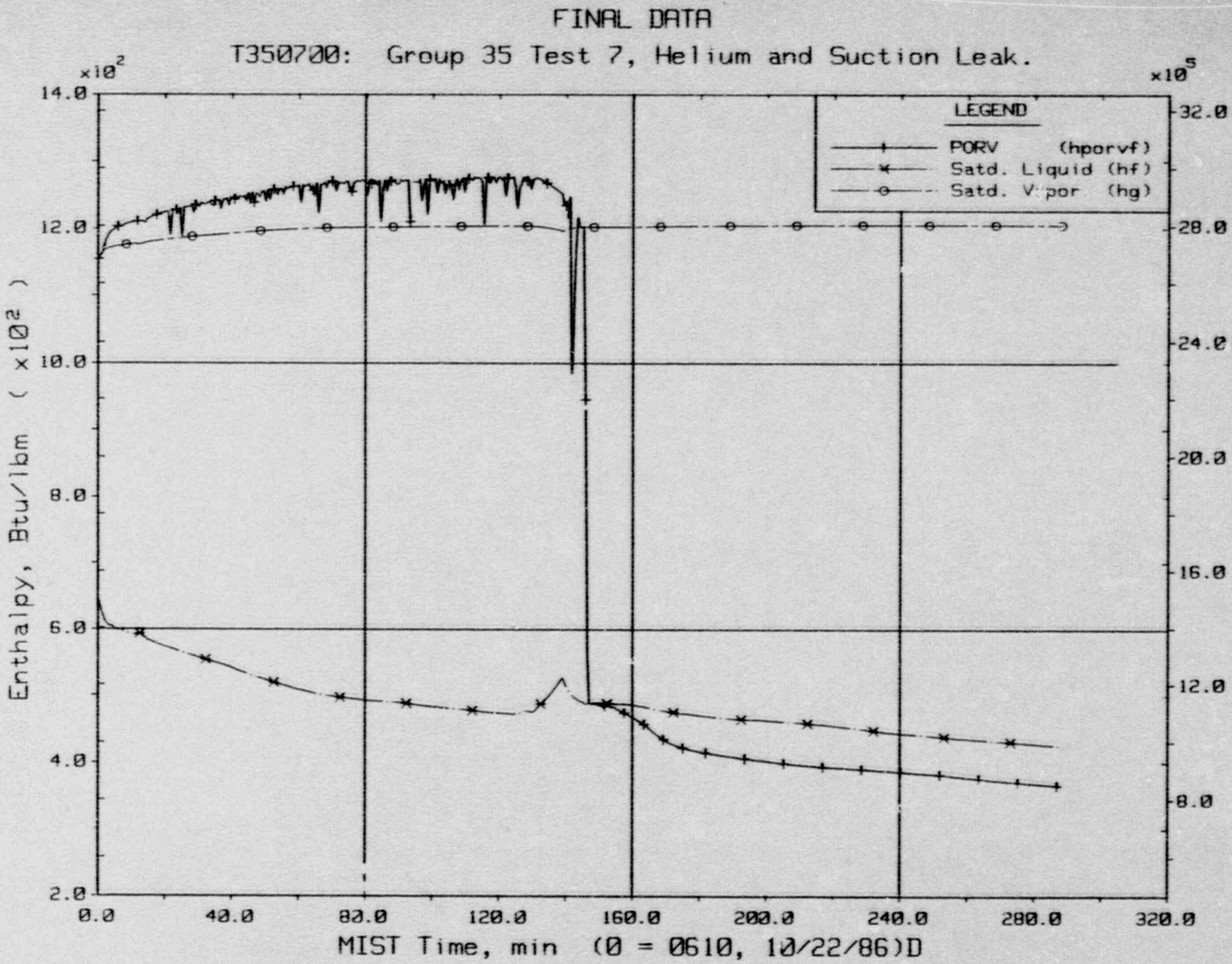
T350700: Group 35 Test 7, Helium and Suction Leak.



Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

Wed Jan 11 16:36:52 1989

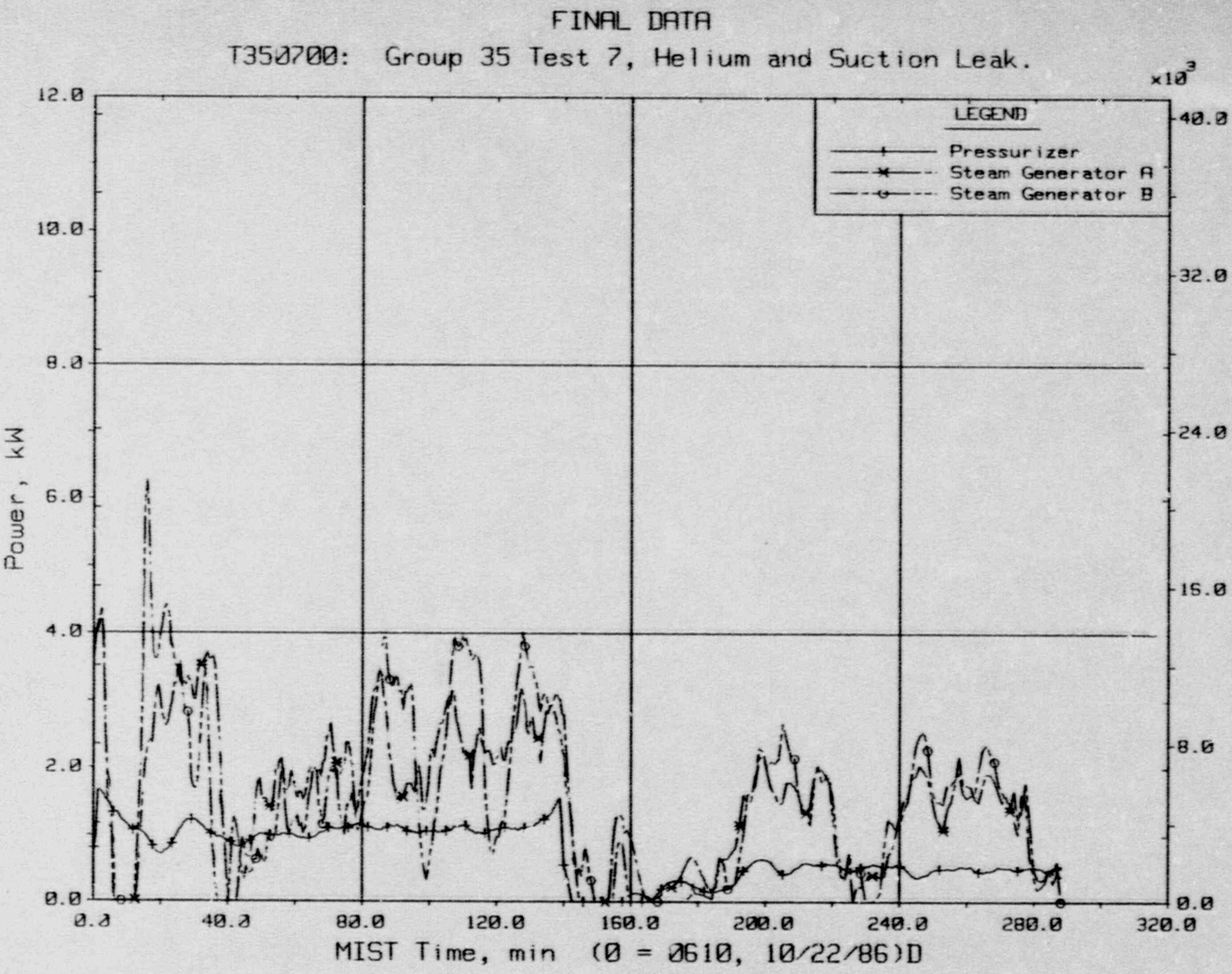
PUVF2



Power-Operated Relief Valve Enthalpy (Based On Flow Rate).

Thu May 26 10:30:39 1988

PZEN1



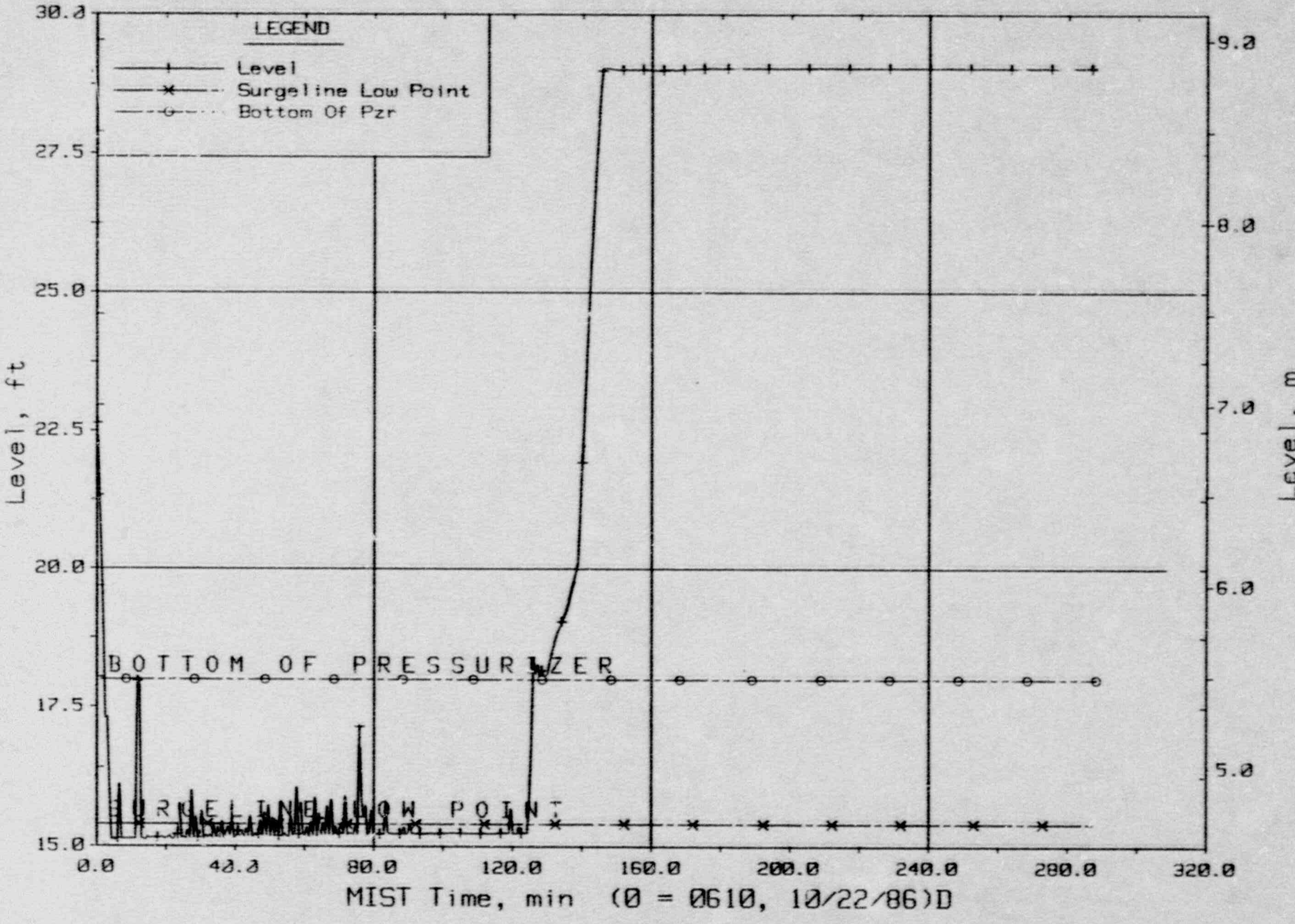
Guard Heater Specified Power, Pressurizer and Steam Generators.

Thu May 25 10:33:38 1989

PZGQ1

FINAL DATA

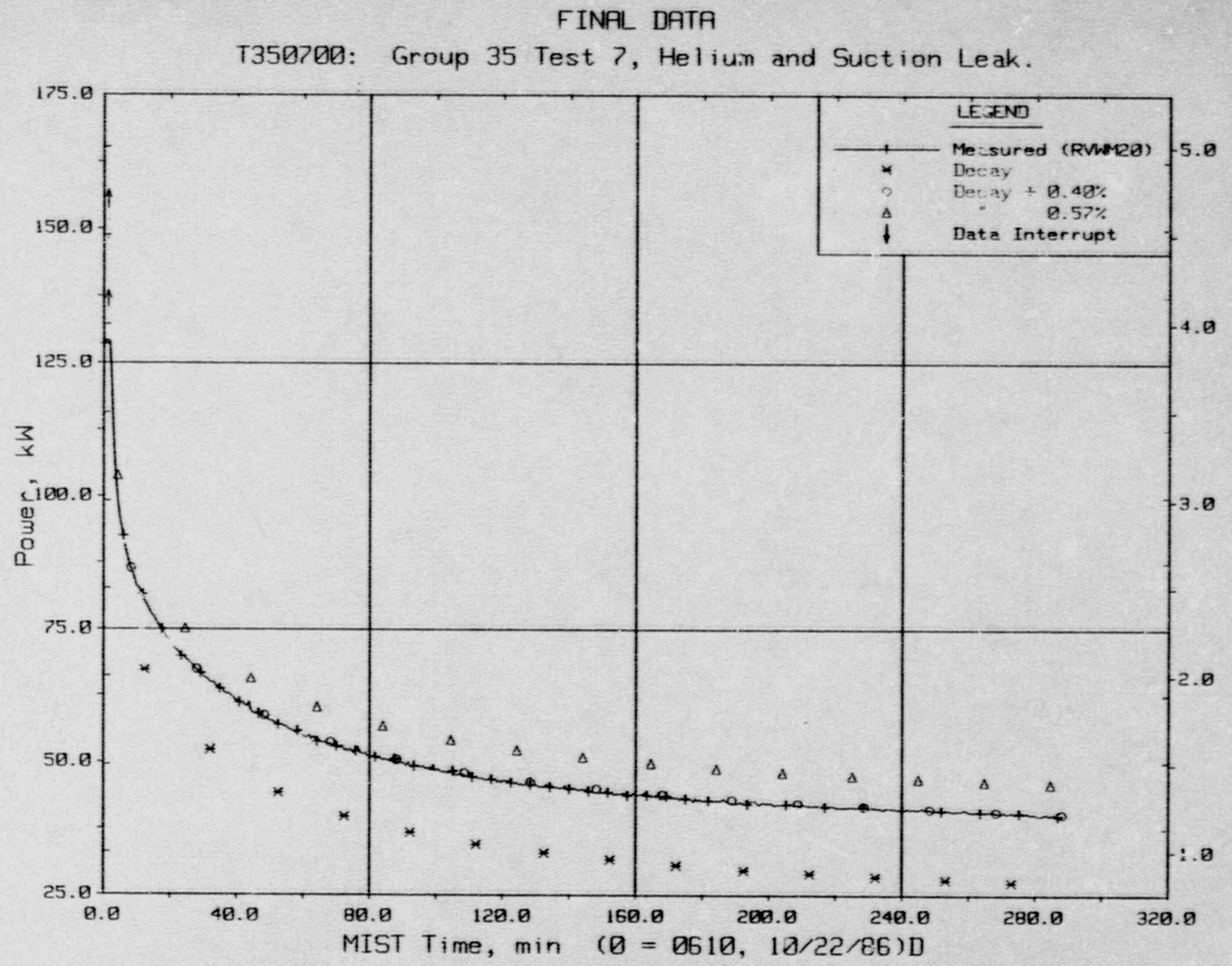
T350700: Group 35 Test 7, Helium and Suction Leak.



Pressurizer Collapsed Liquid Level (PZLV20).

Thu May 26 10:37:40 1988

PZLV1



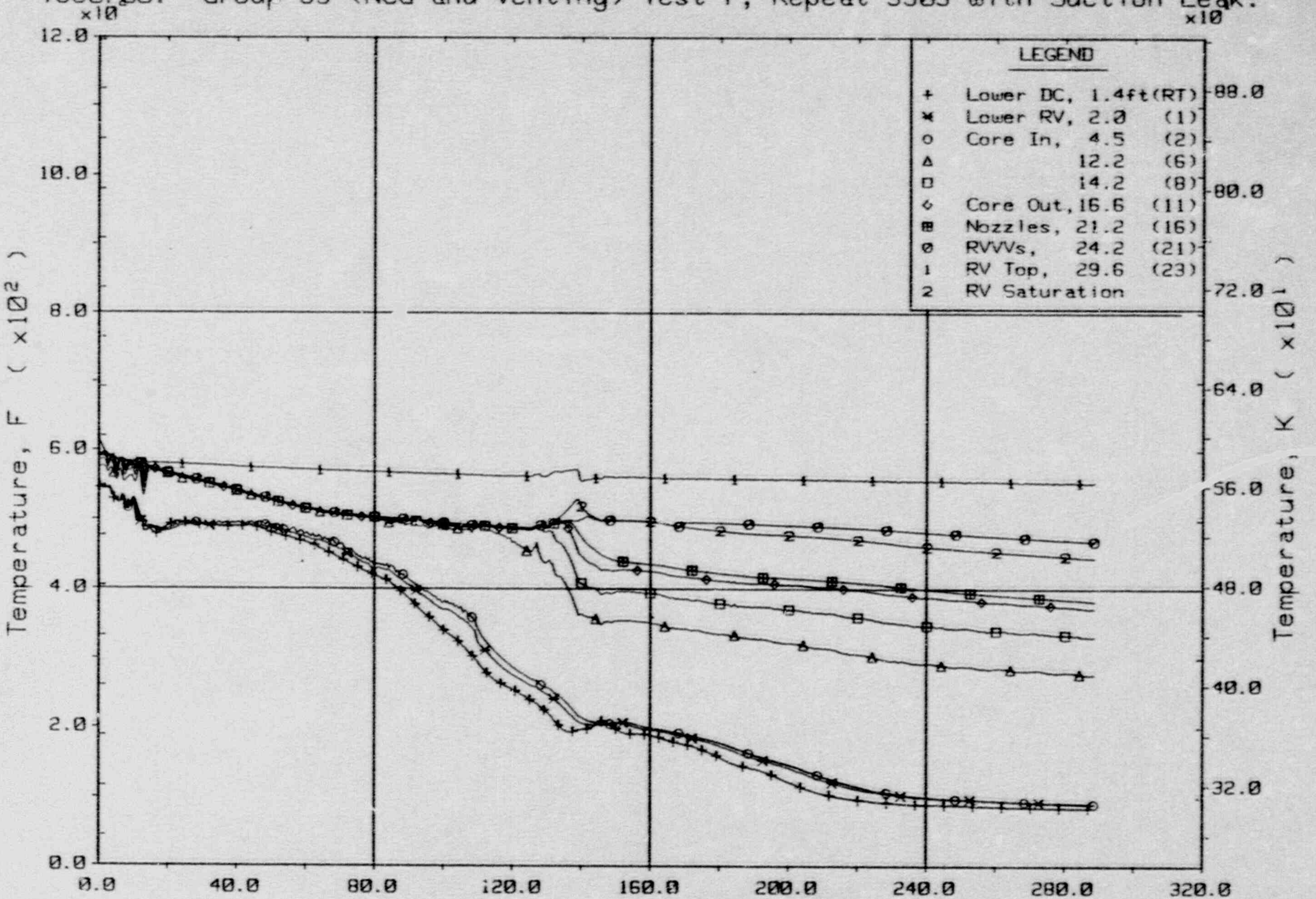
Core Power.

Thu May 26 10:45:55 1988

RVKW0

FINAL DATA

T350700: Group 35 (NCG and Venting) Test 7, Repeat 3503 with Suction Leak.



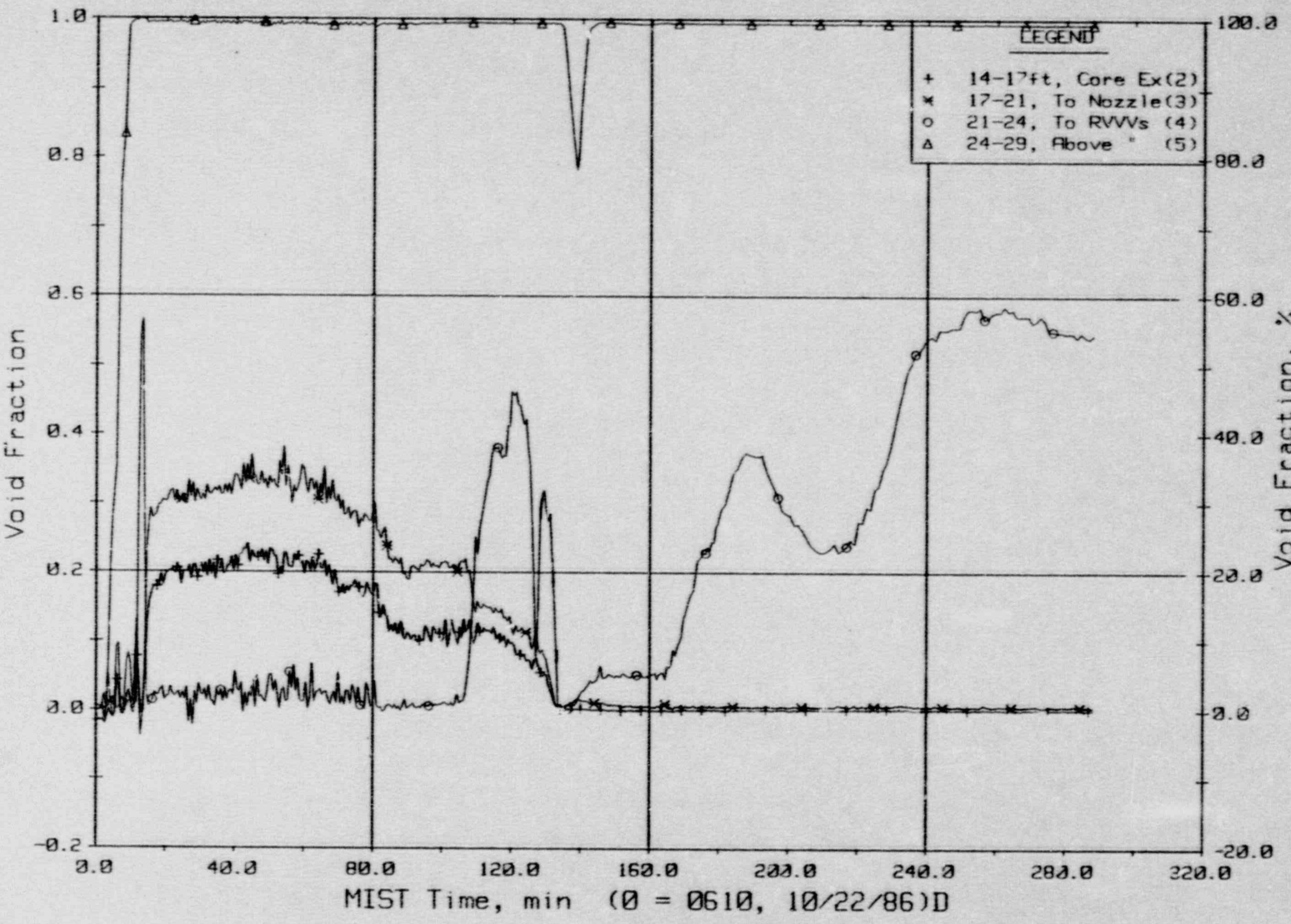
Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

Fri Jan 6 16:21:44 1989

RVTC0

FINAL DATA

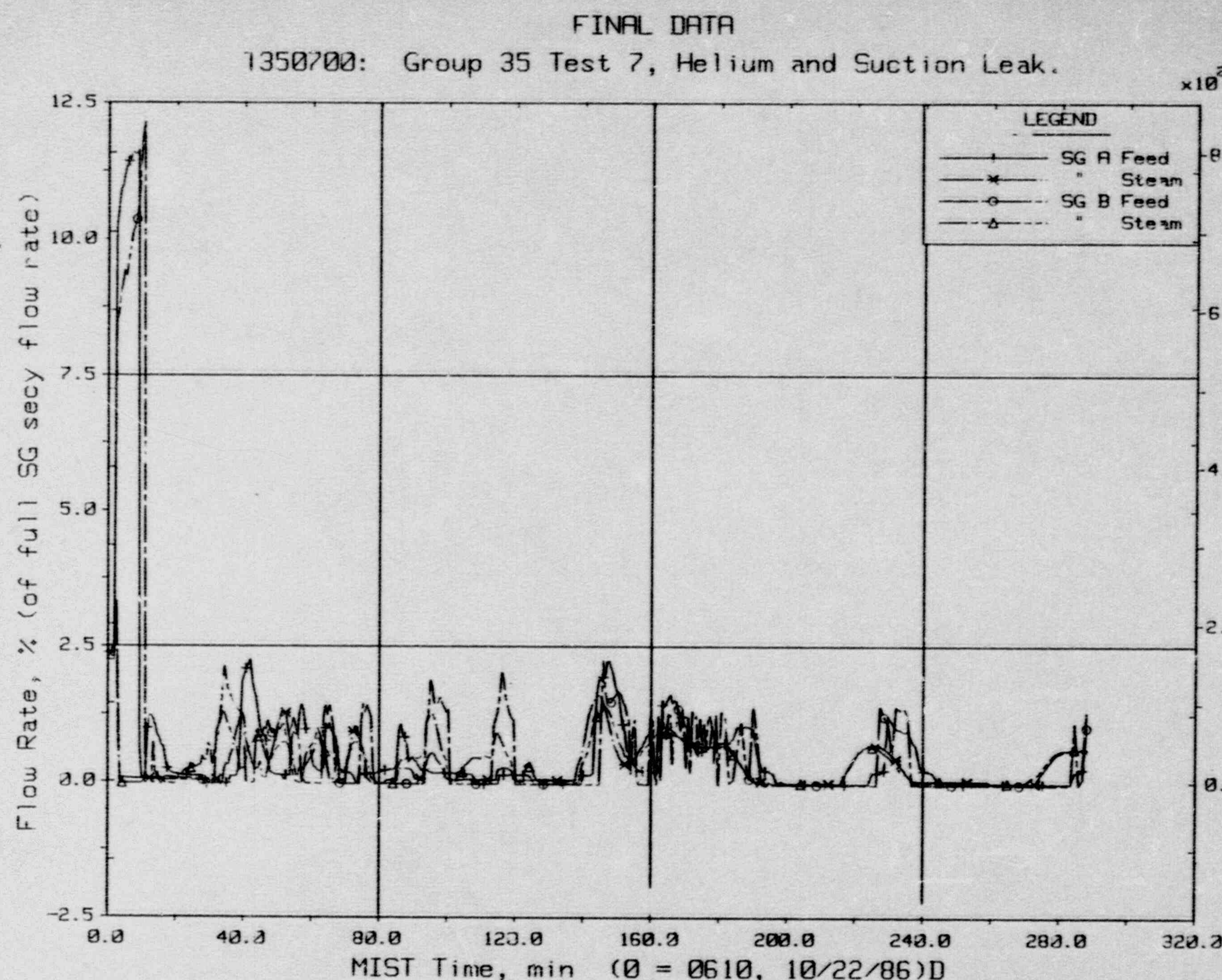
T350700: Group 35 Test 7, Helium and Suction Leak.



Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Thu May 26 11:09:56 1988

RVVF1



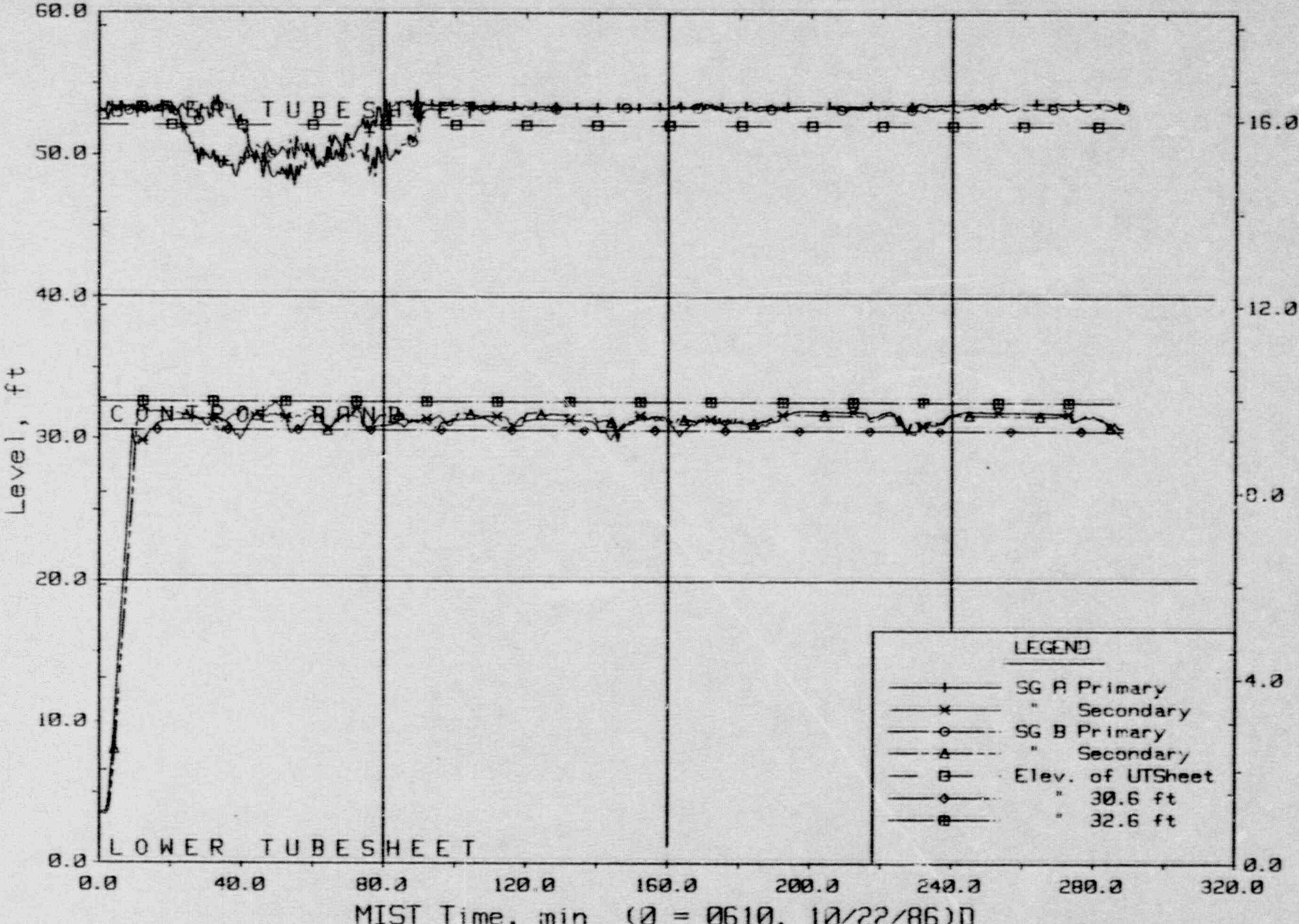
Steam Generator Secondary System Flow Rates.

Thu May 26 11:19:46 1988

SGFL2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



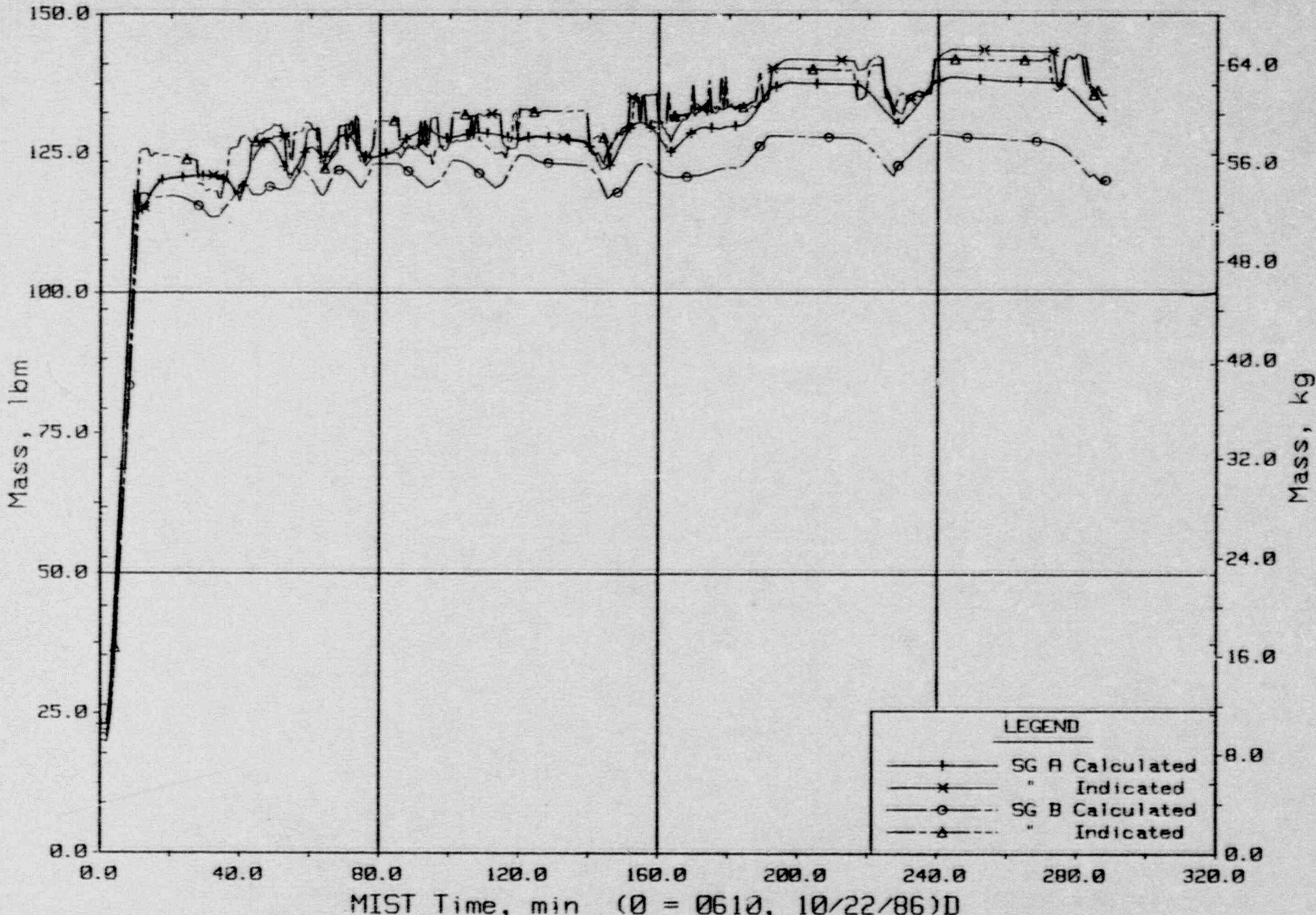
Steam Generator Collapsed Liquid Levels.

Thu May 26 11:37:34 1988

SGLV2

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



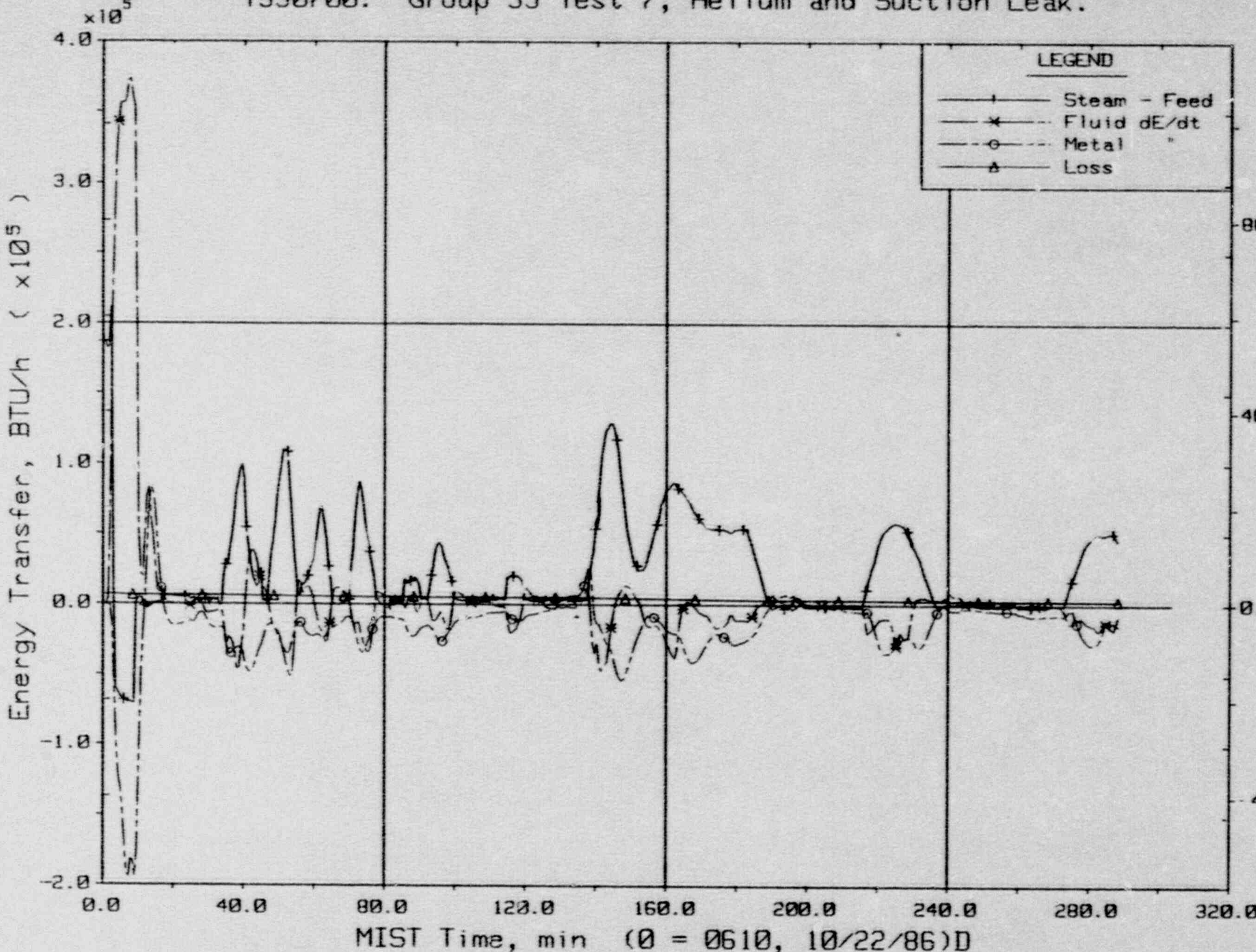
Steam Generator Secondary Fluid Mass Balances.

Thu May 26 11:41:39 1988

SGML1

FINAL DATA

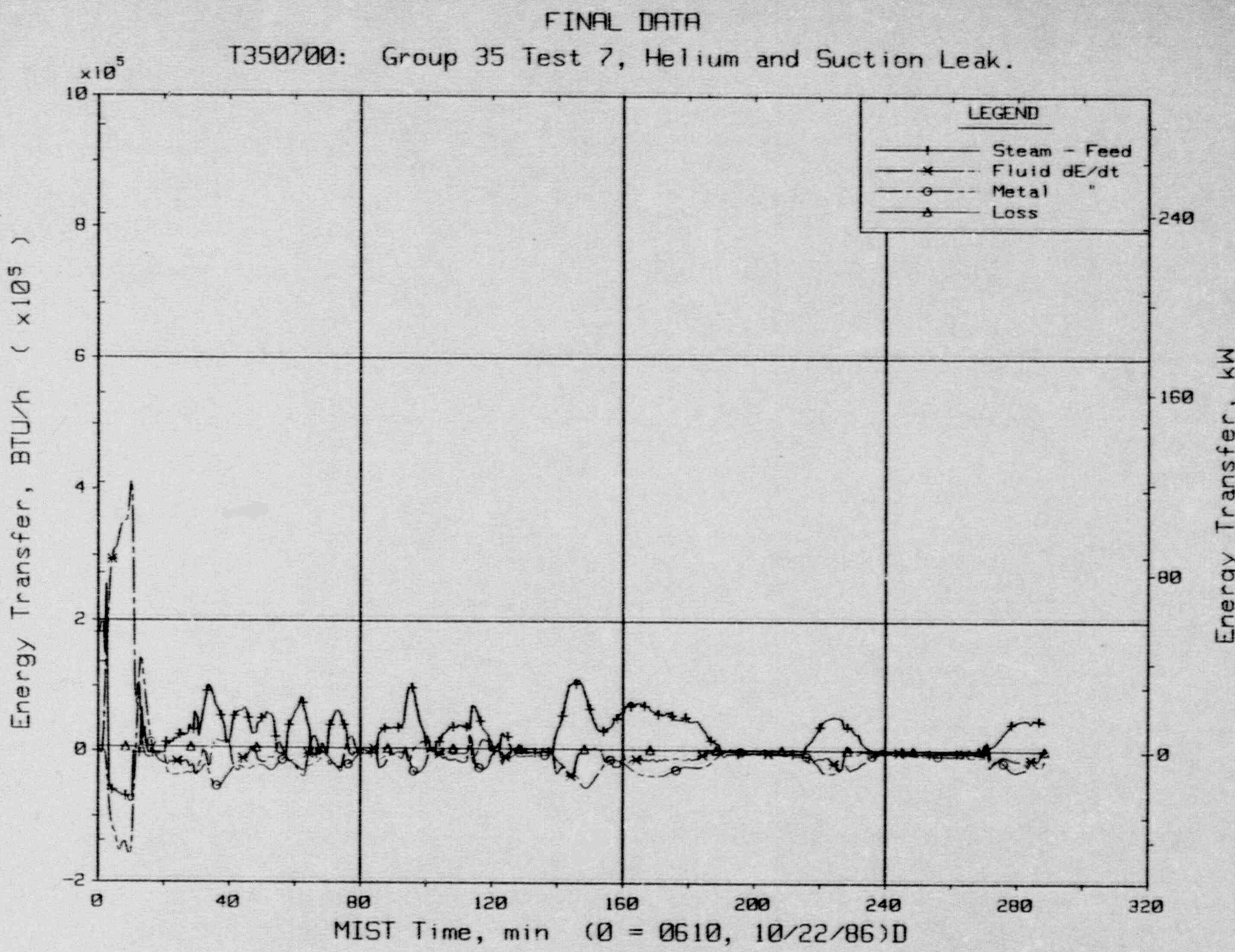
T350700: Group 35 Test 7, Helium and Suction Leak.



Steam Generator A Energy Transfer.

Thu May 26 11:45:38 1988

SGQE3



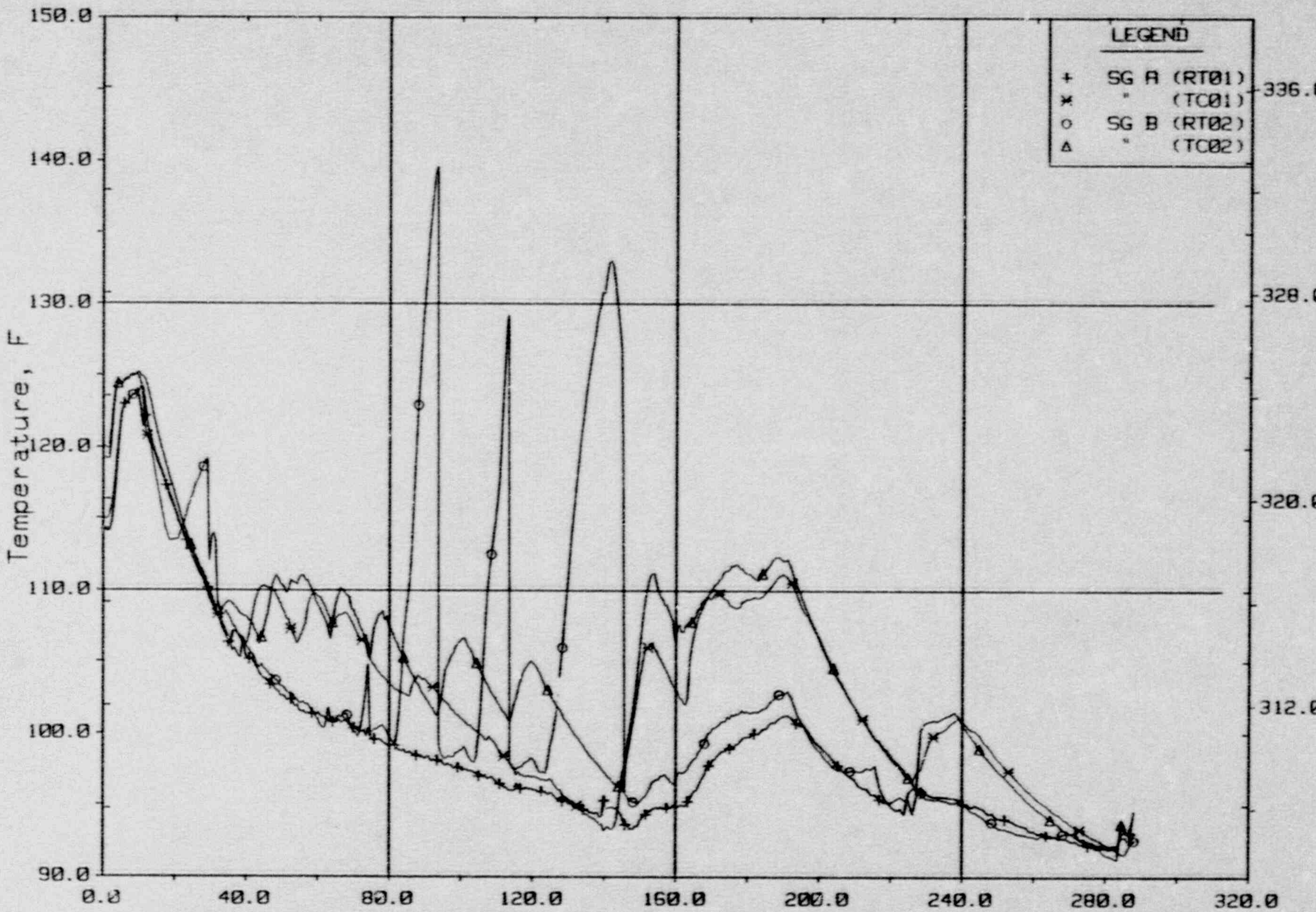
Steam Generator B Energy Transfer.

Fri Jan 6 16:47:49 1989

SGQE6

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



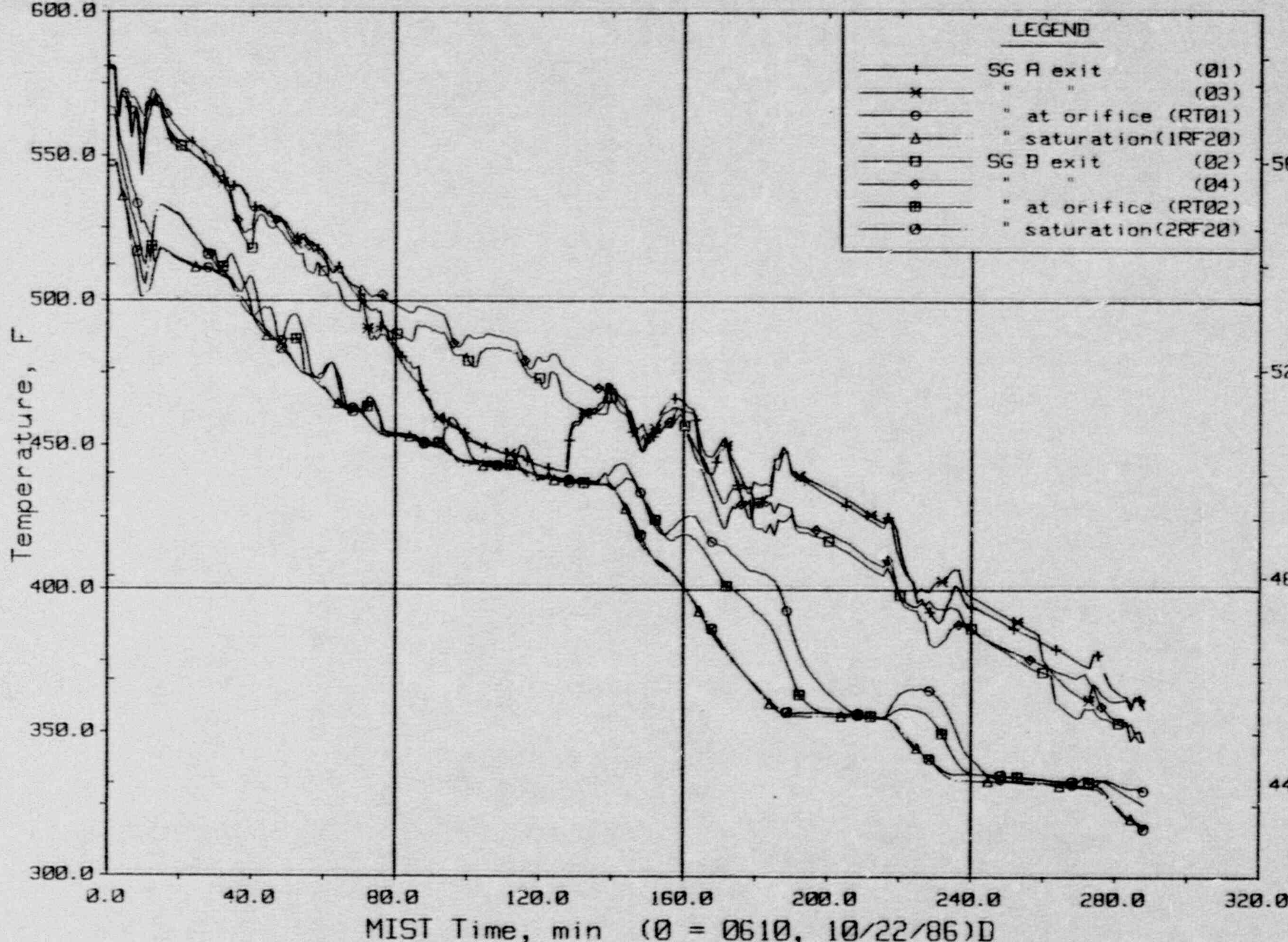
Feedwater Temperatures (SFs).

Thu May 26 11:59:21 1988

SGRT1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



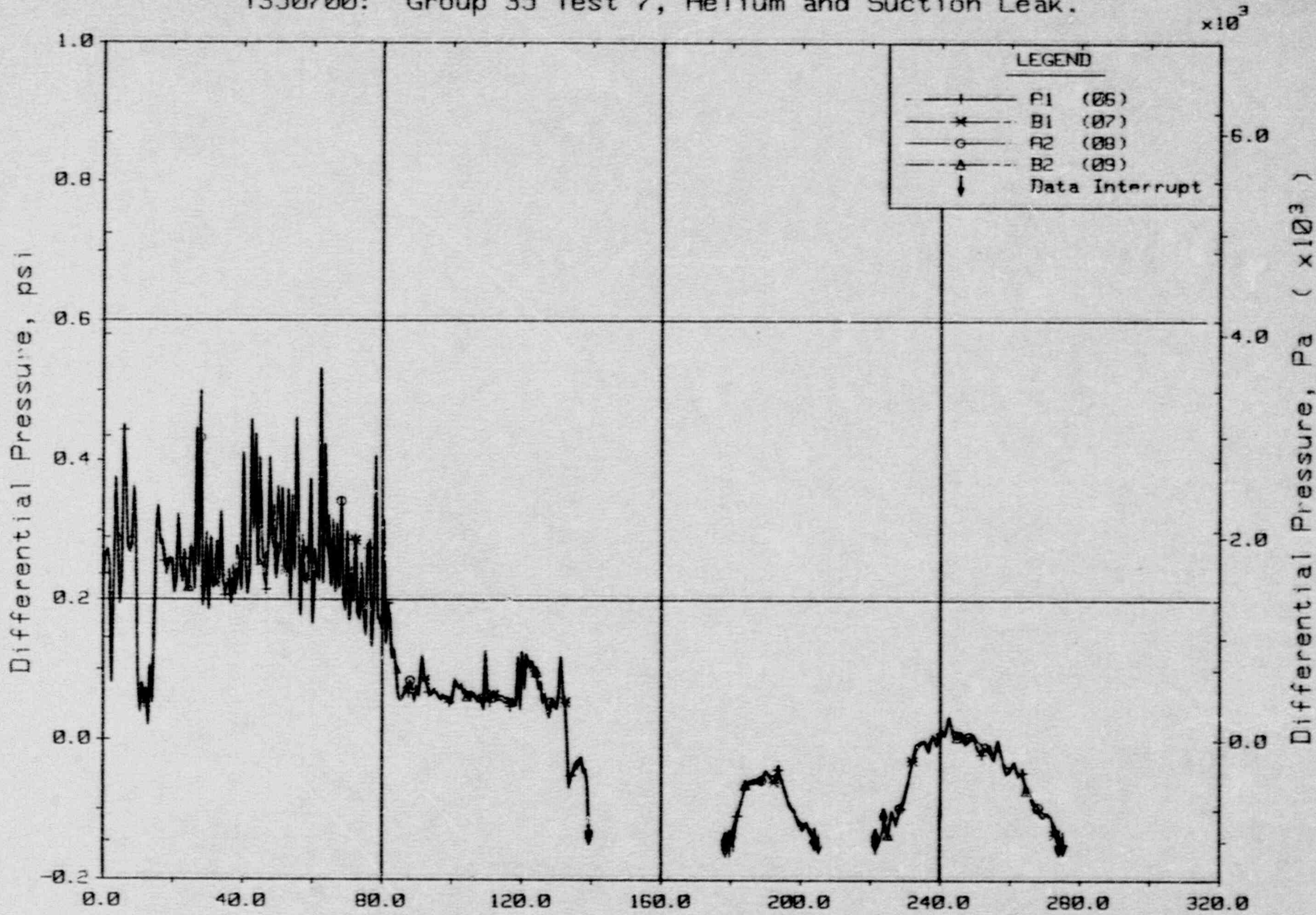
Steam Generator Steam Outlet Temperatures (SSTCs).

Thu May 26 12:03:44 1988

SGRT2

FINAL DATA

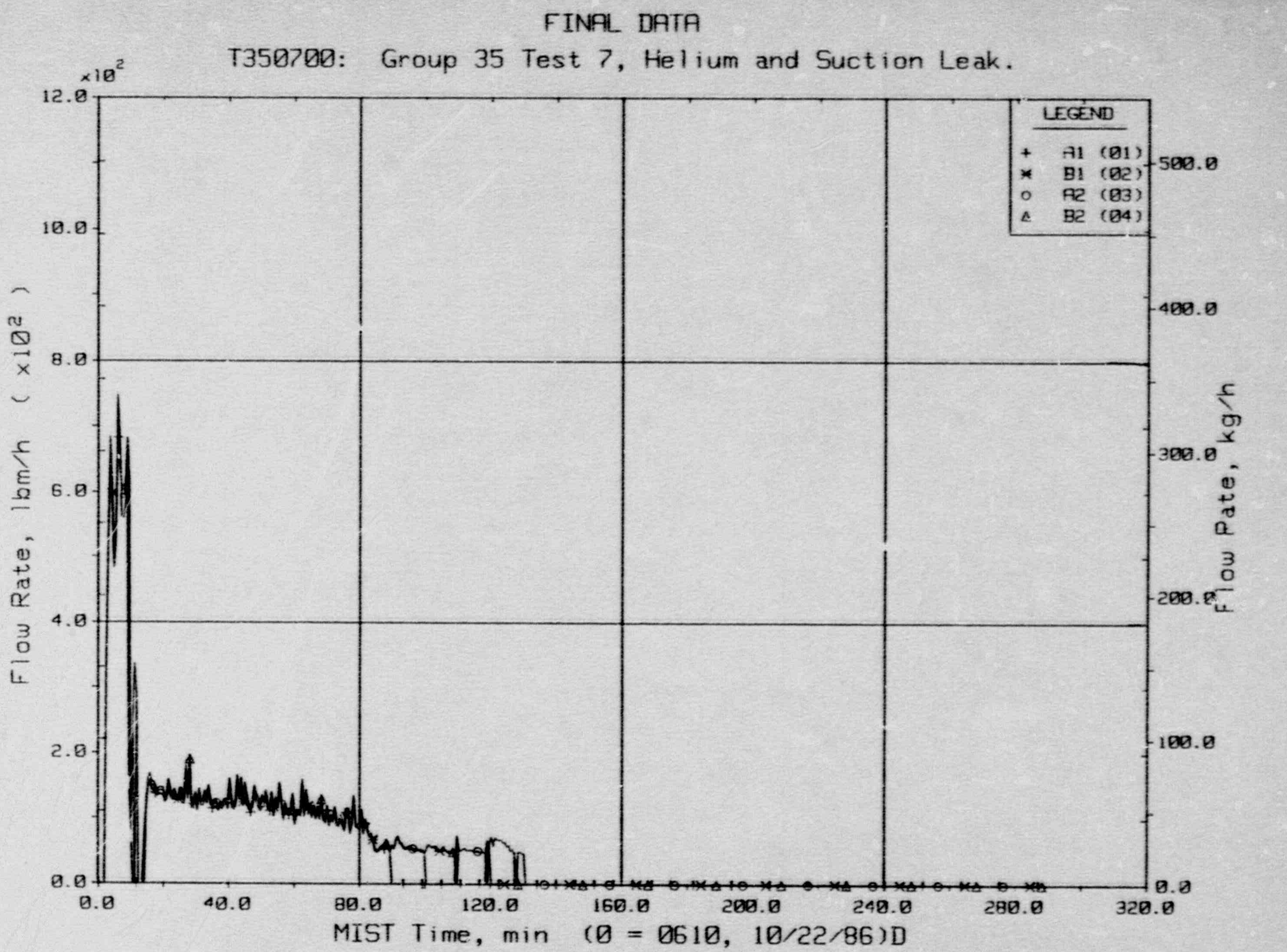
T350700: Group 35 Test 7, Helium and Suction Leak.



Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Thu May 26 12:07:24 1988

VVDP1



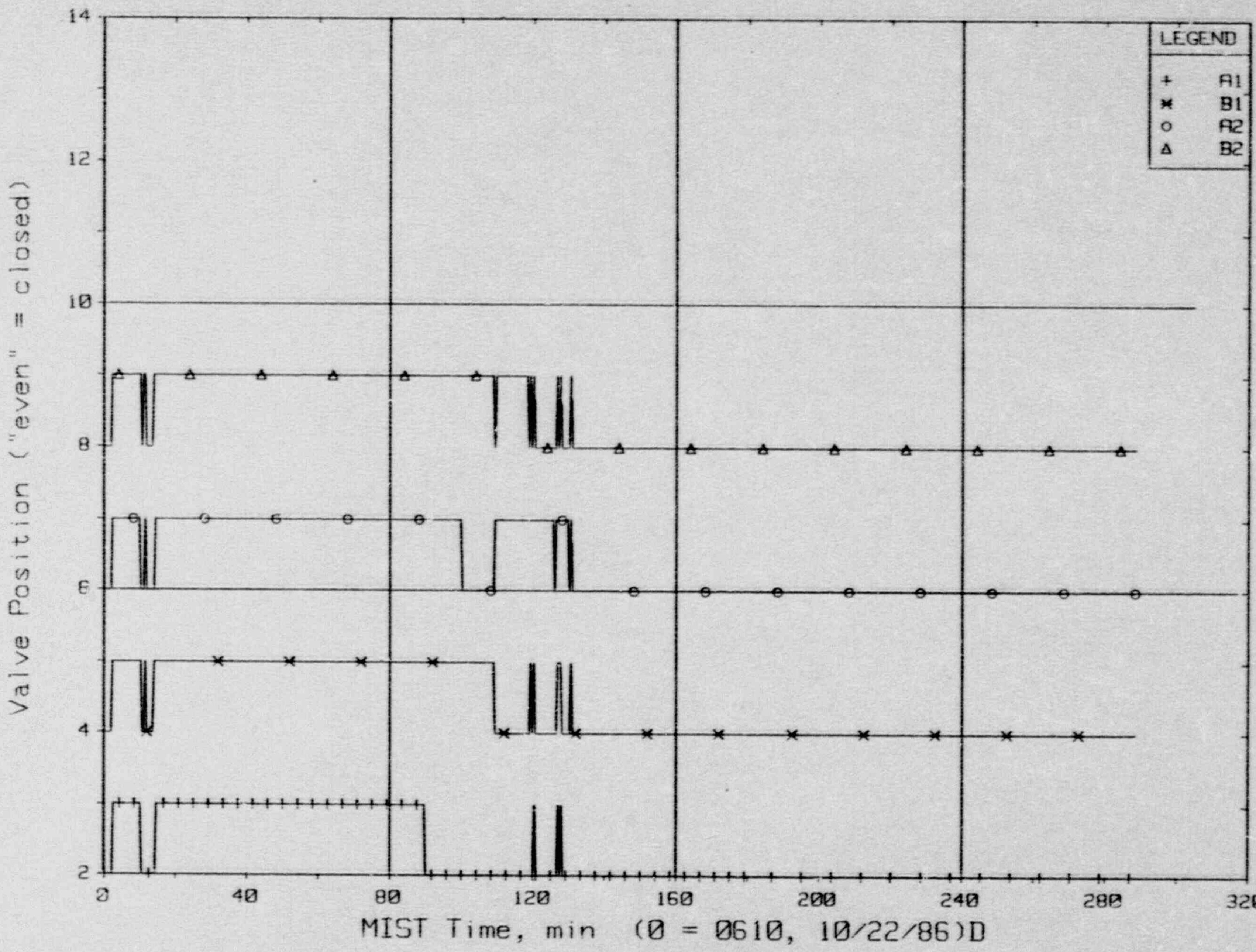
Reactor Vessel Vent Valve Flow Rates (RVORs).

Thu May 26 12:10:46 1988

VVFL1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



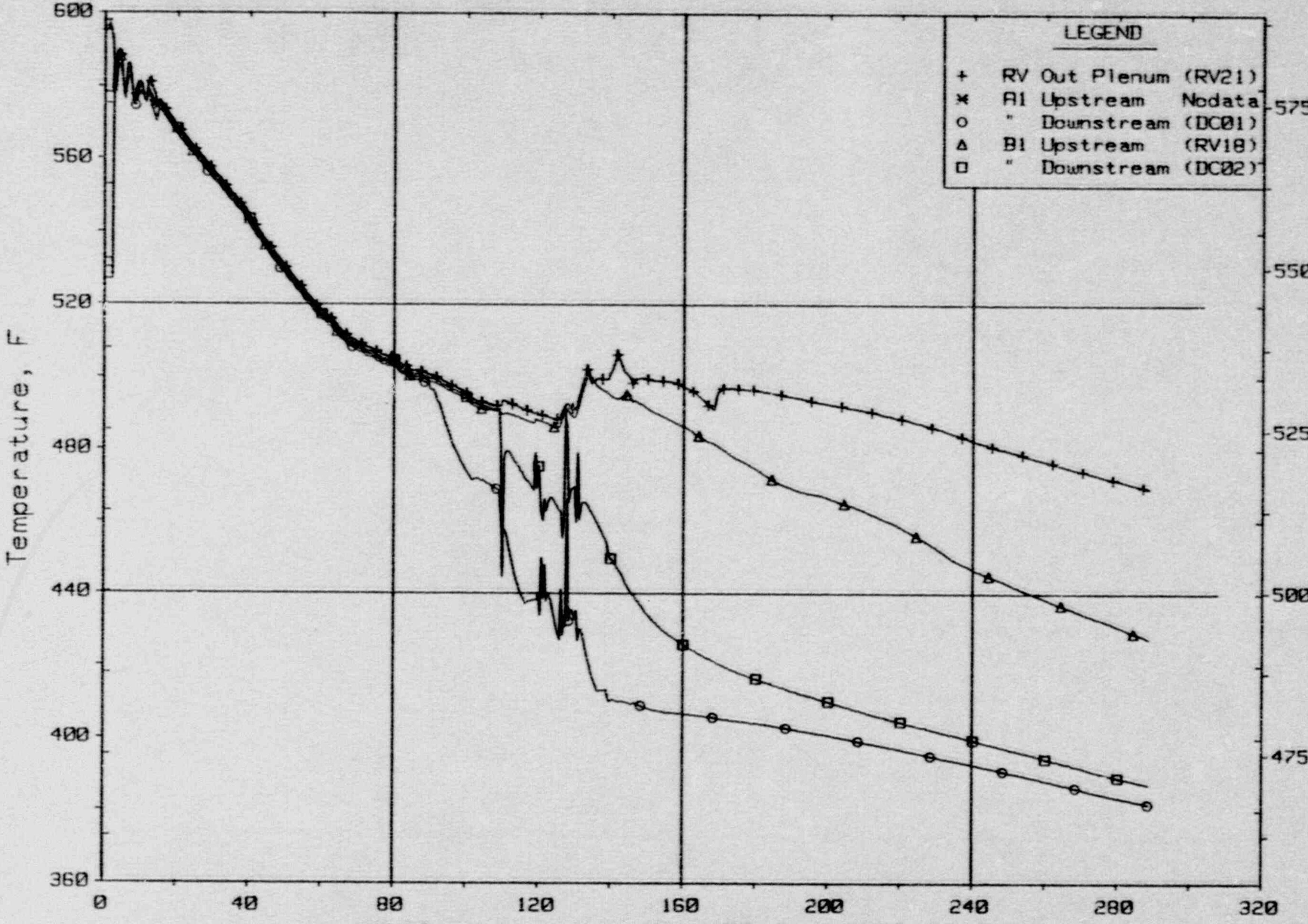
Reactor Vessel Vent Valve Positions.

Fri Jan 6 17:08:37 1989

VVLS1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



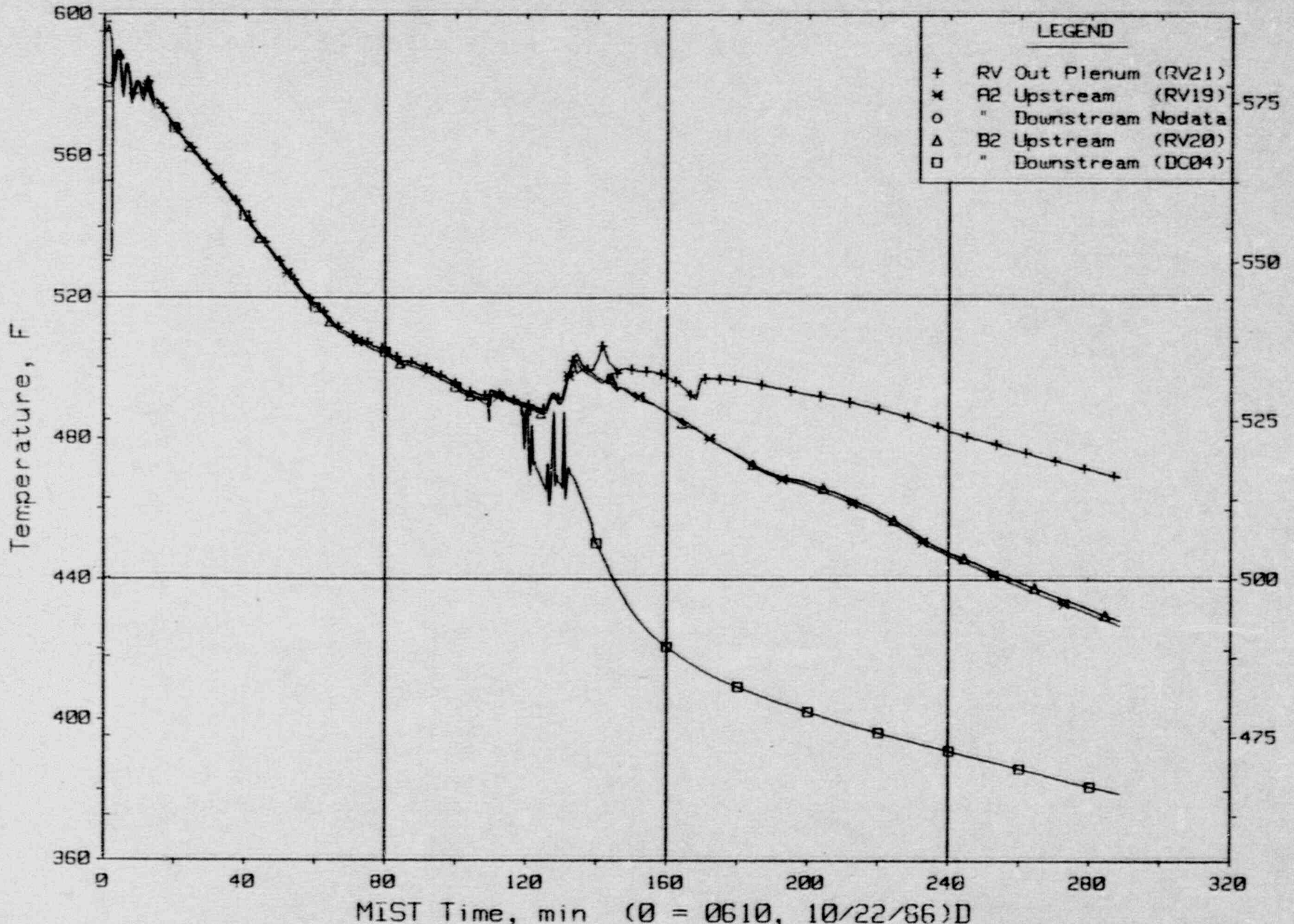
RVVVs A1 and B1 Bracketing Fluid Temperatures (TCs).

Wed Jan 11 16:13:00 1989

VVTC1

FINAL DATA

T350700: Group 35 Test 7, Helium and Suction Leak.



RVVVs A2 and B2 Bracketing Fluid Temperatures (TCs).

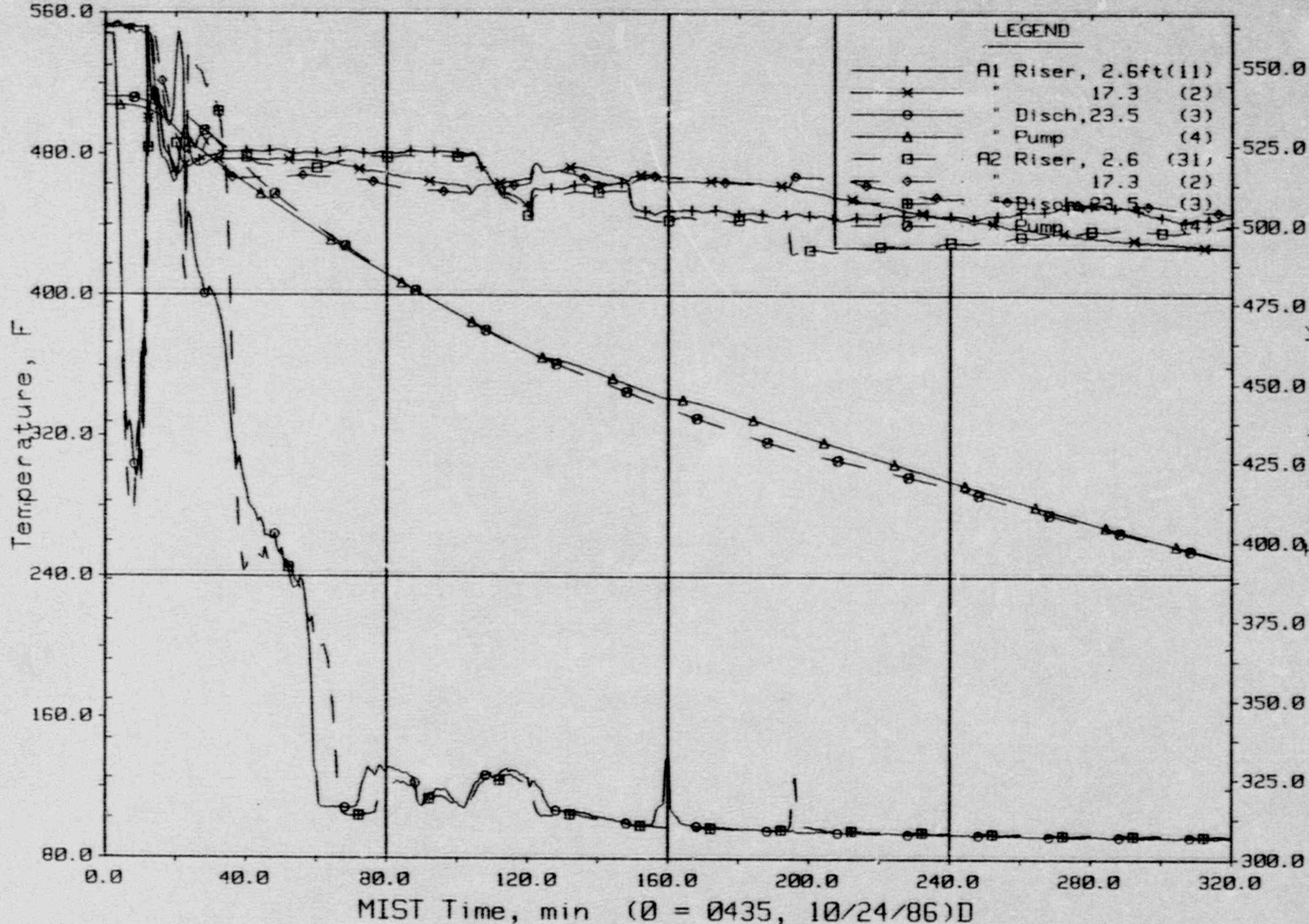
Wed Jan 11 16:16:02 1989

VVTC2

T350800

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



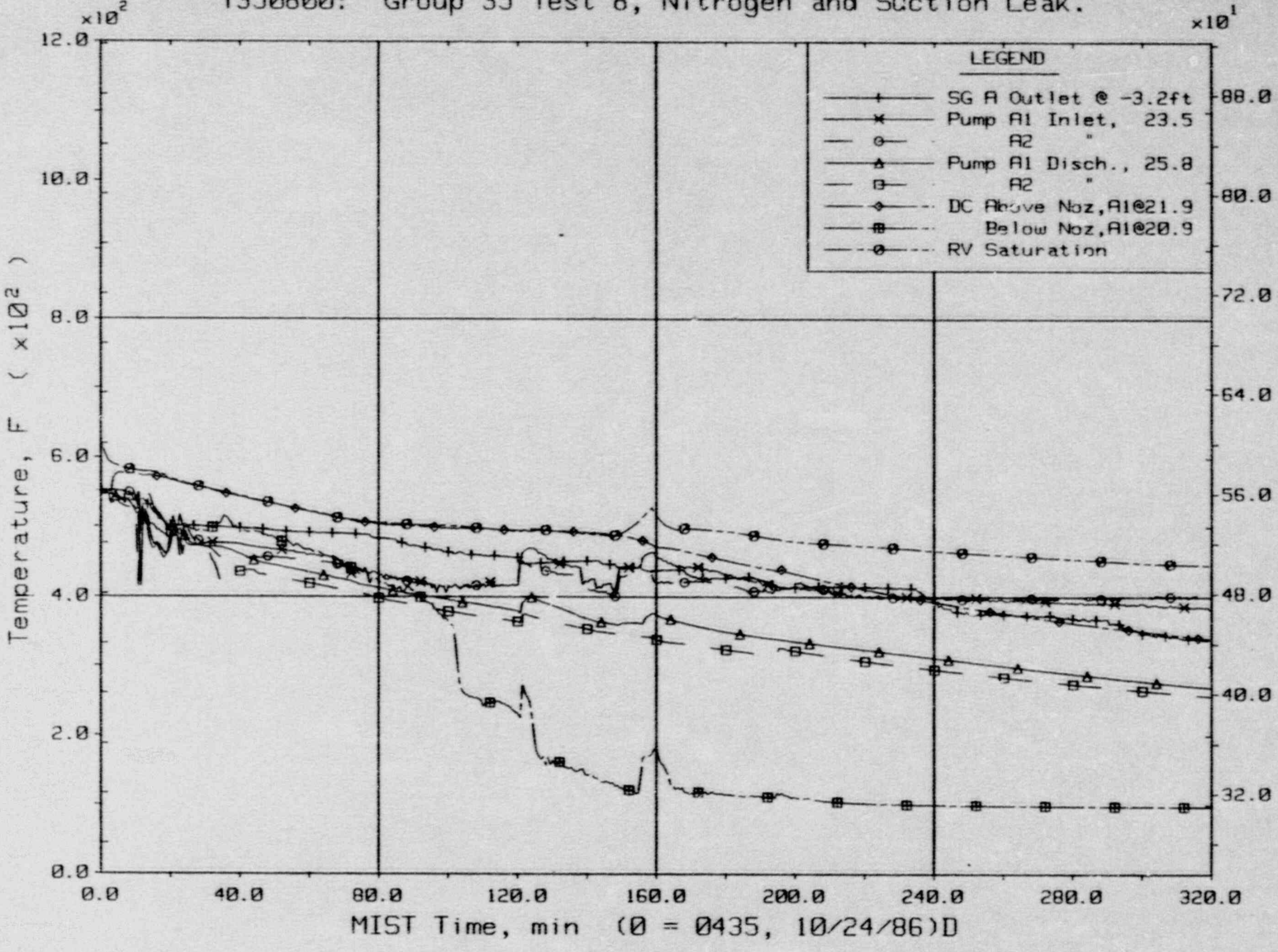
Loop A Cold Leg Metal Temperatures (C1,3MTs).

Thu May 26 10:37:04 1988

C1MT1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



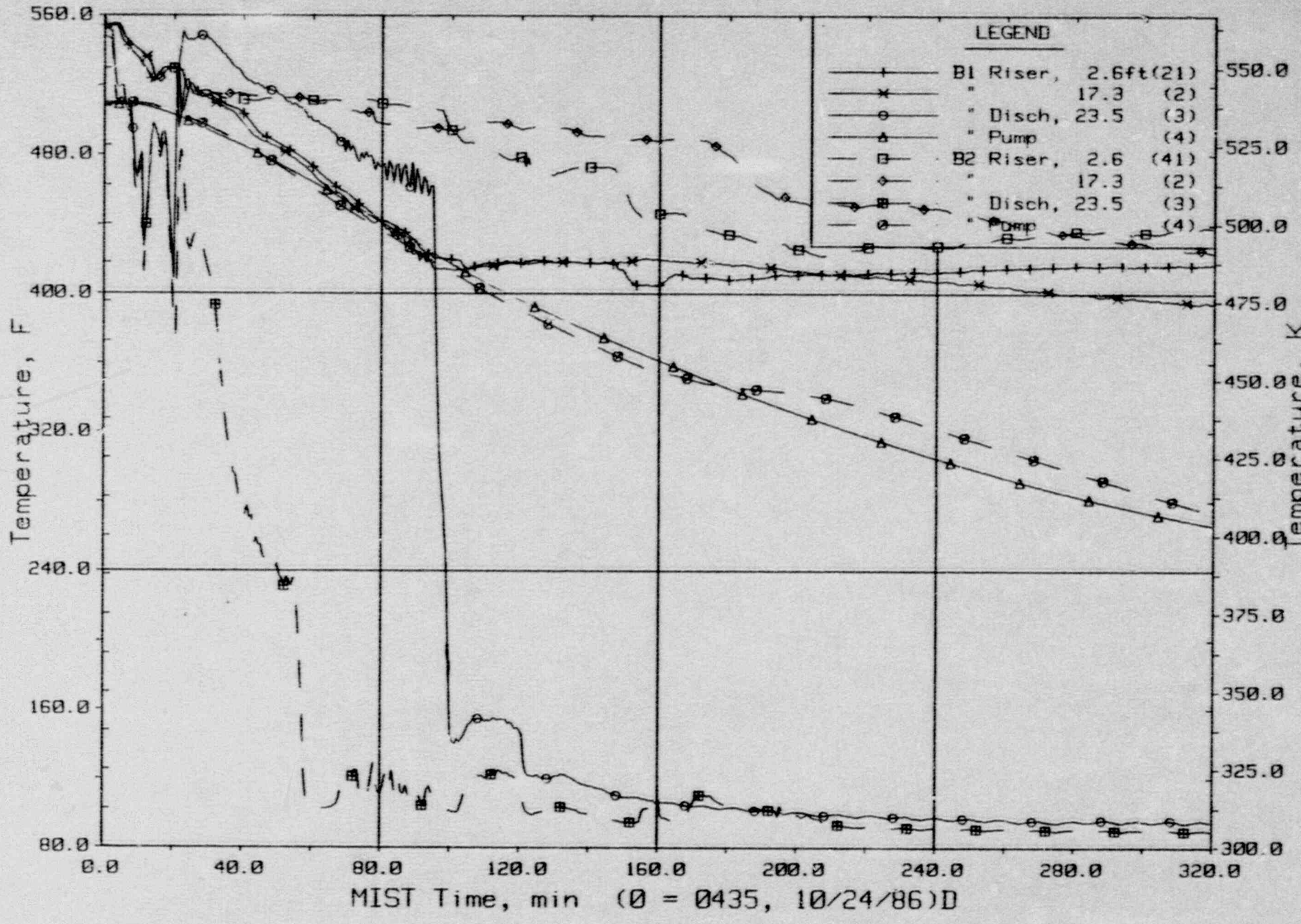
Loop A Cold Leg Fluid Temperatures (RTDs).

Thu May 26 10:47:25 1988

C1RT0

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



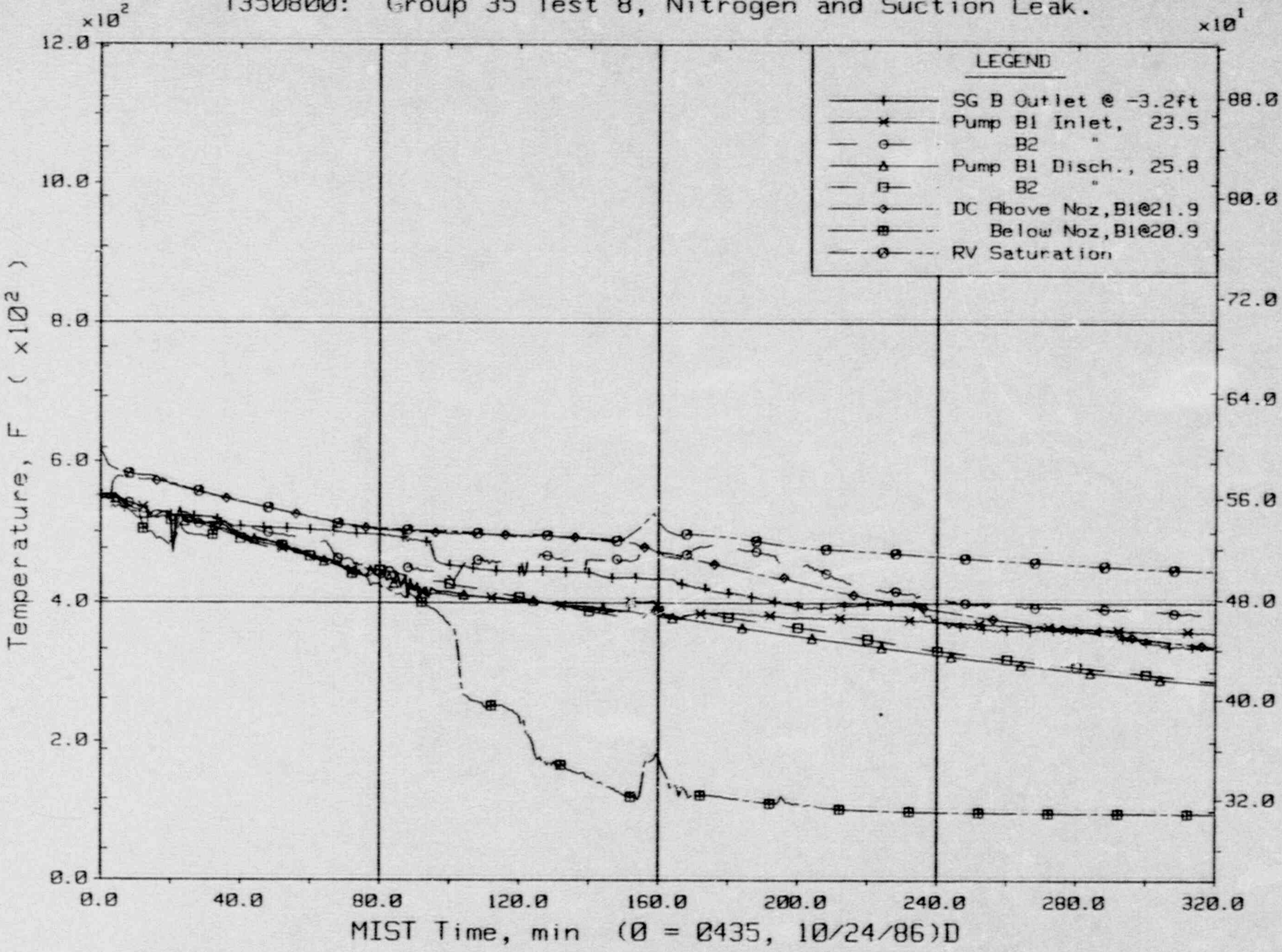
Loop B Cold Leg Metal Temperatures (C2,4MTs).

Thu May 26 10:58:45 1988

C2MT1

FINAL DATA

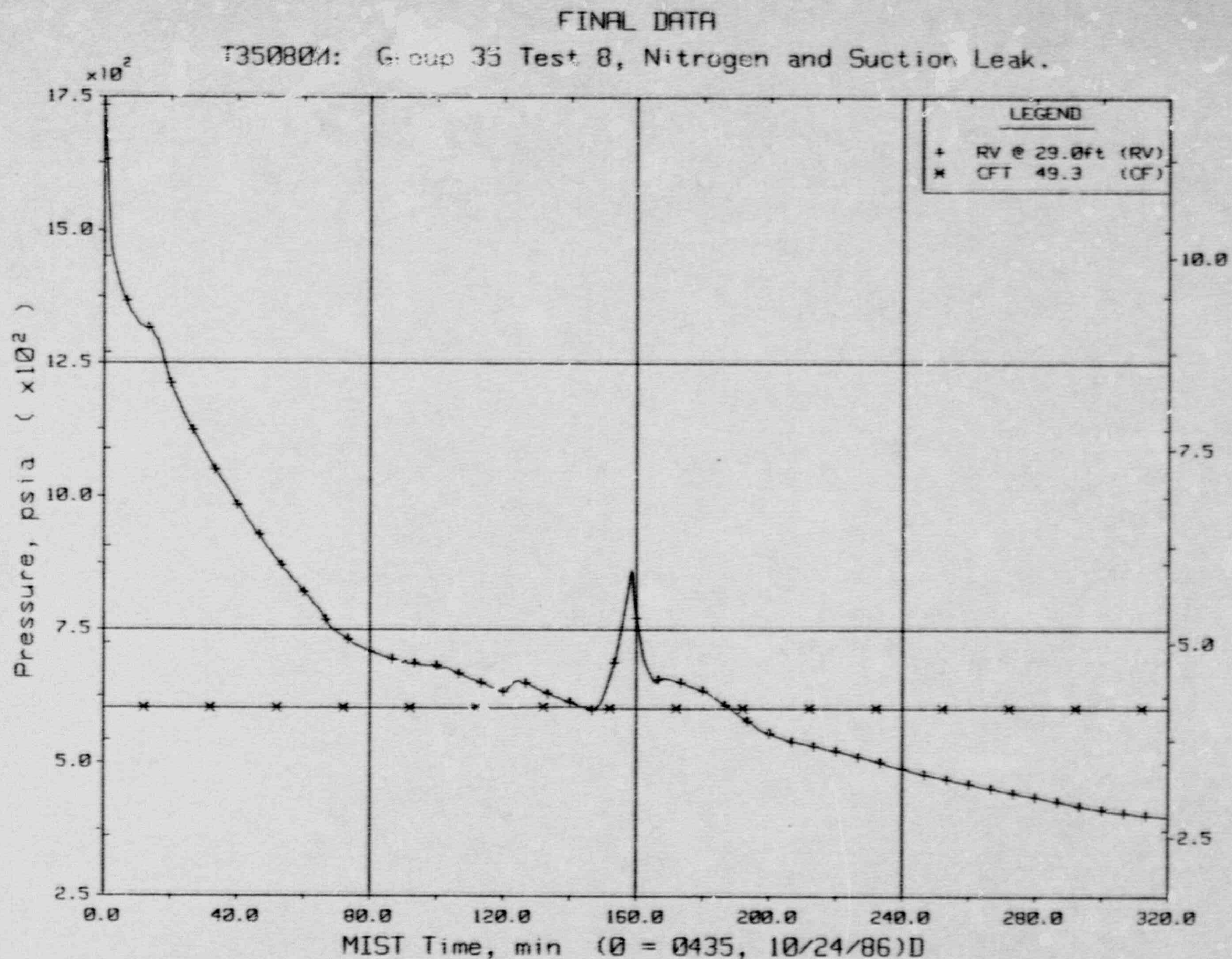
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Loop B Cold Leg Fluid Temperatures (RTDs).

Thu May 26 11:11:45 1988

C2RT0



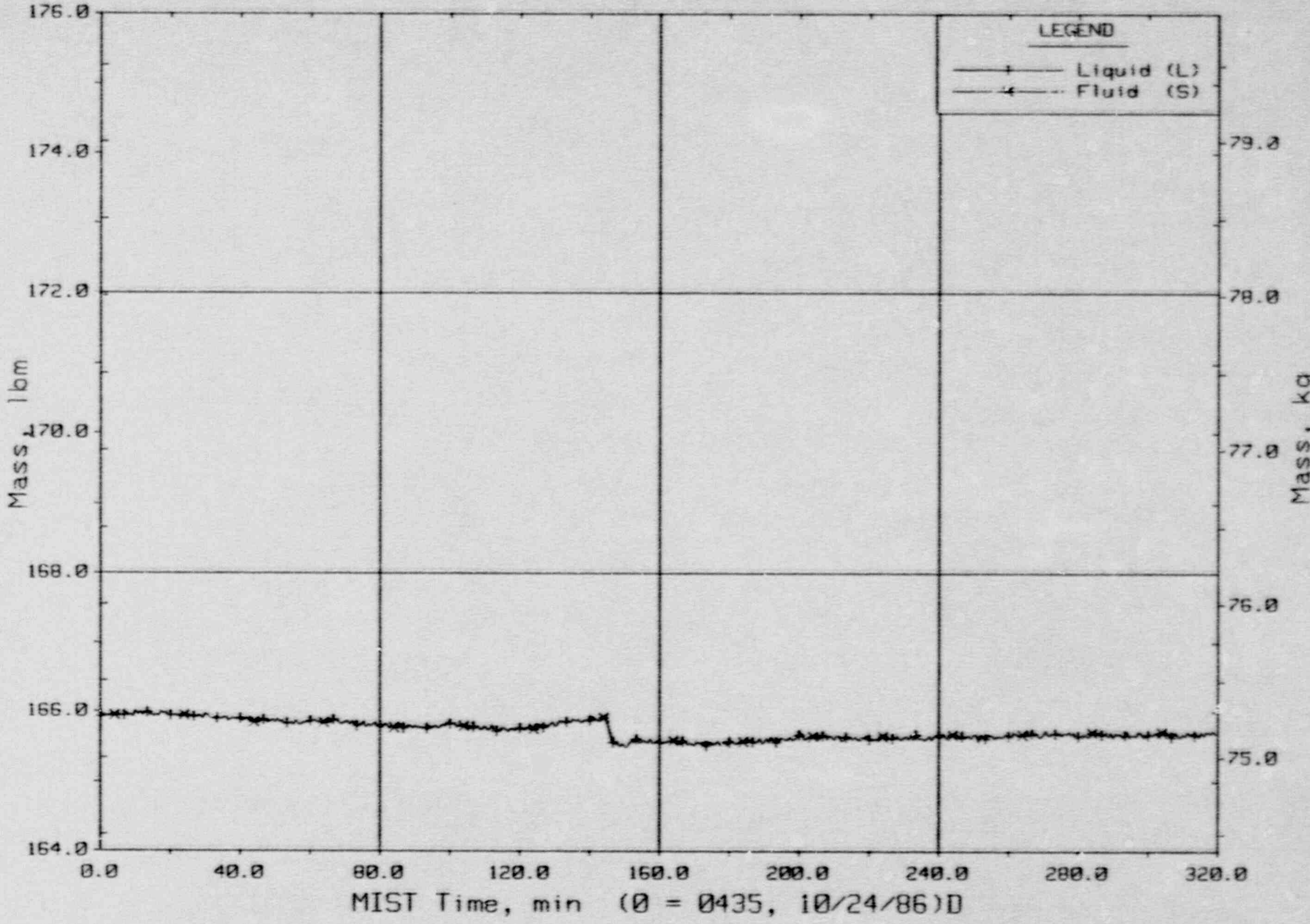
Primary System and Core Flood Tank Pressures (GP01s).

Thu May 26 11:15:22 1988

CFGP1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



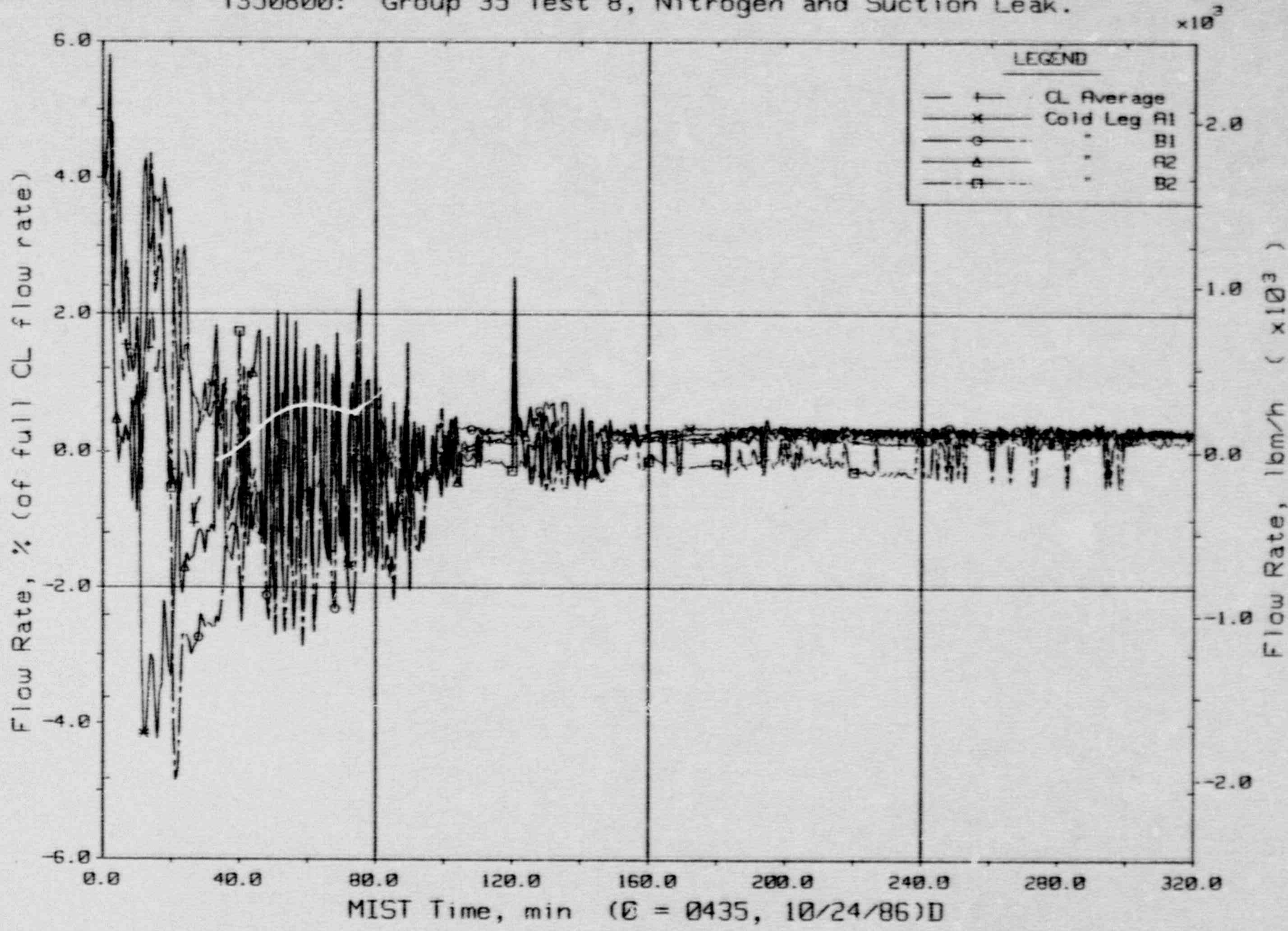
Core Flood Tank Liquid and Fluid Mass (CFMa20s).

Thu May 26 11:31:06 1988

CFML1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



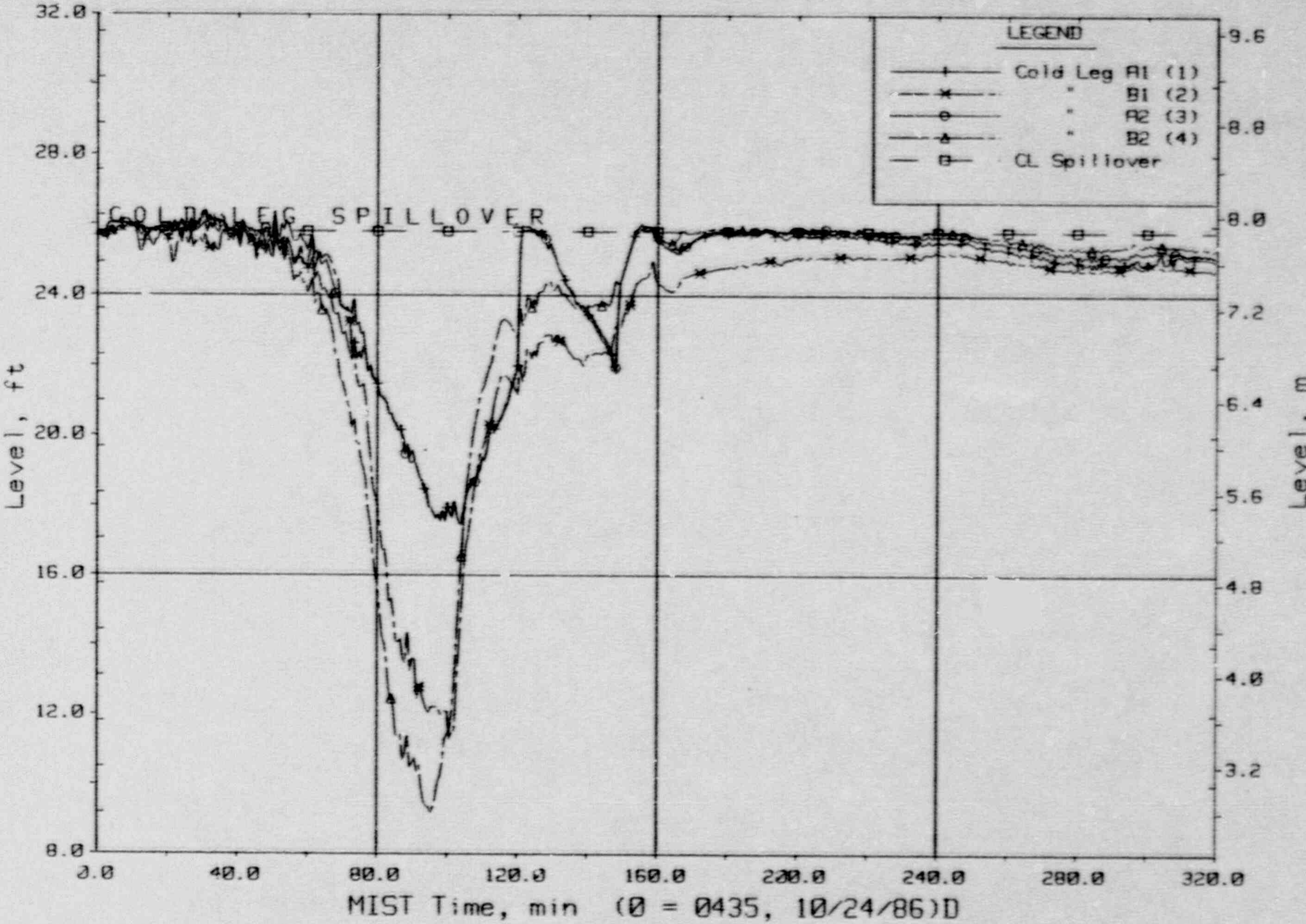
Cold Leg (Venturi) Flow Rates.

Thu May 26 11:38:31 1988

CLFL1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



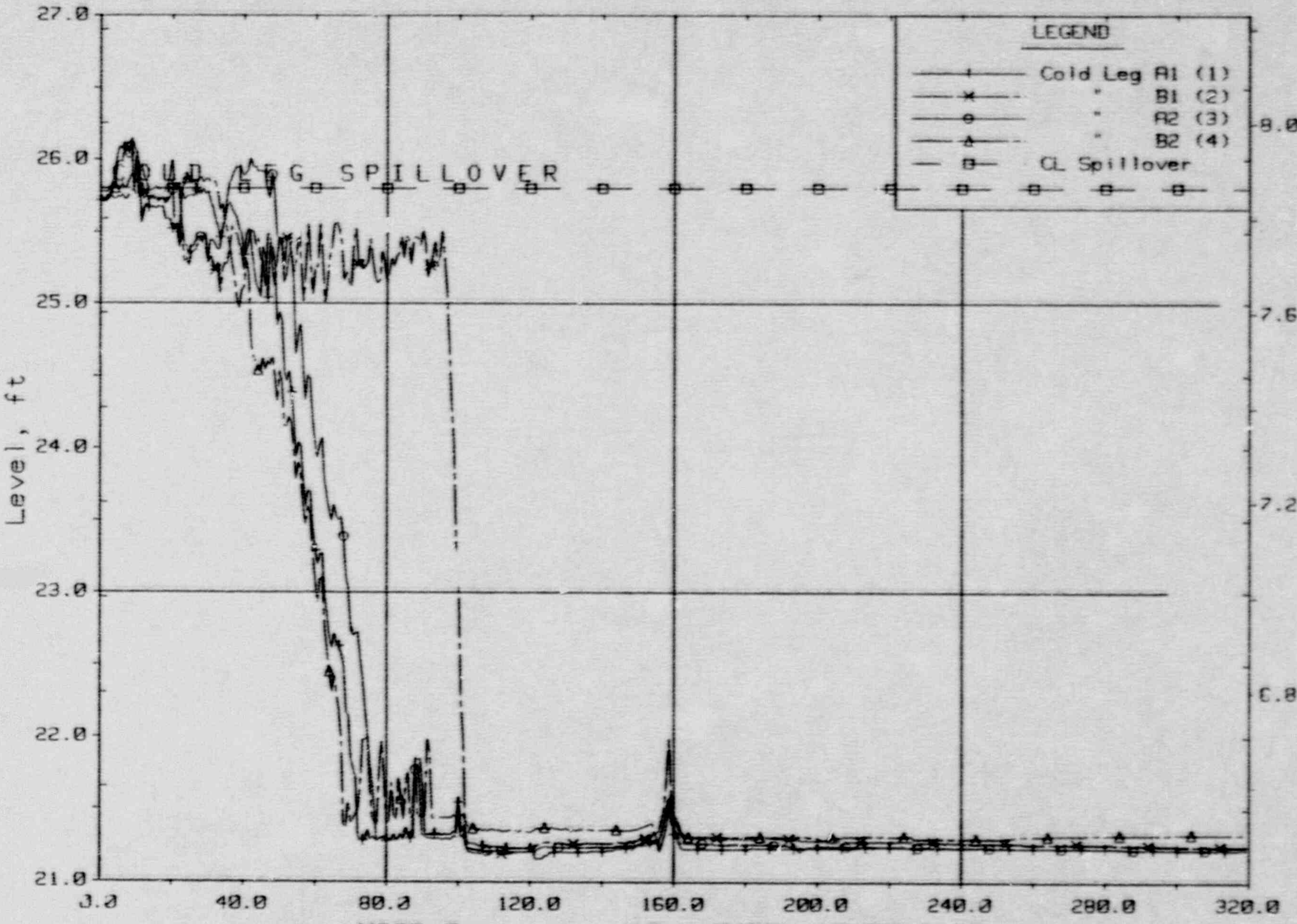
Cold Leg Suction Collapsed Liquid Levels (CnLV22s).

Thu May 26 11:43:30 1988

CLLV4

FINAL DATA

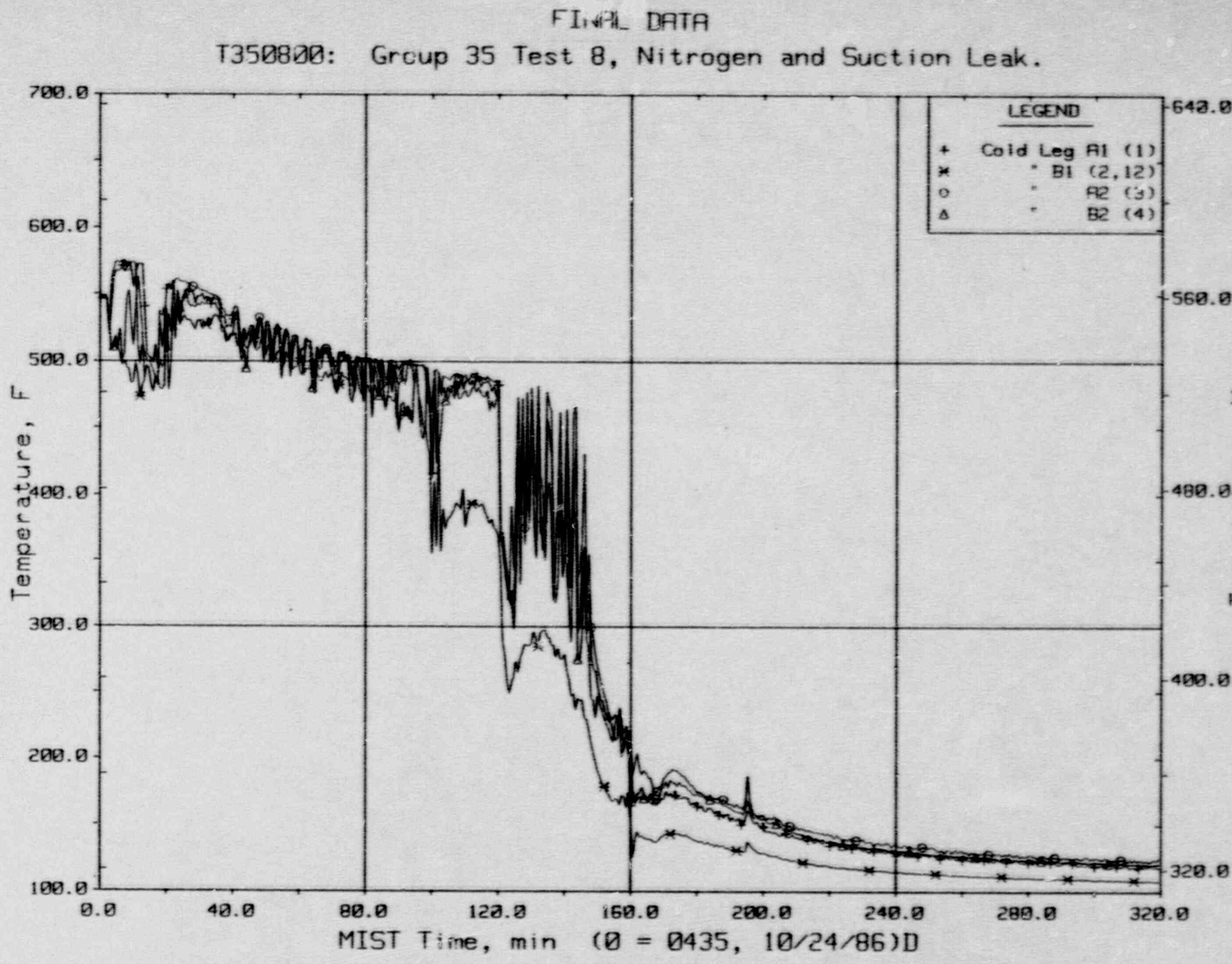
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Cold Leg Discharge Collapsed Liquid Levels (CnL*23s).

Thu May 26 11:48:09 1988

CLLV5



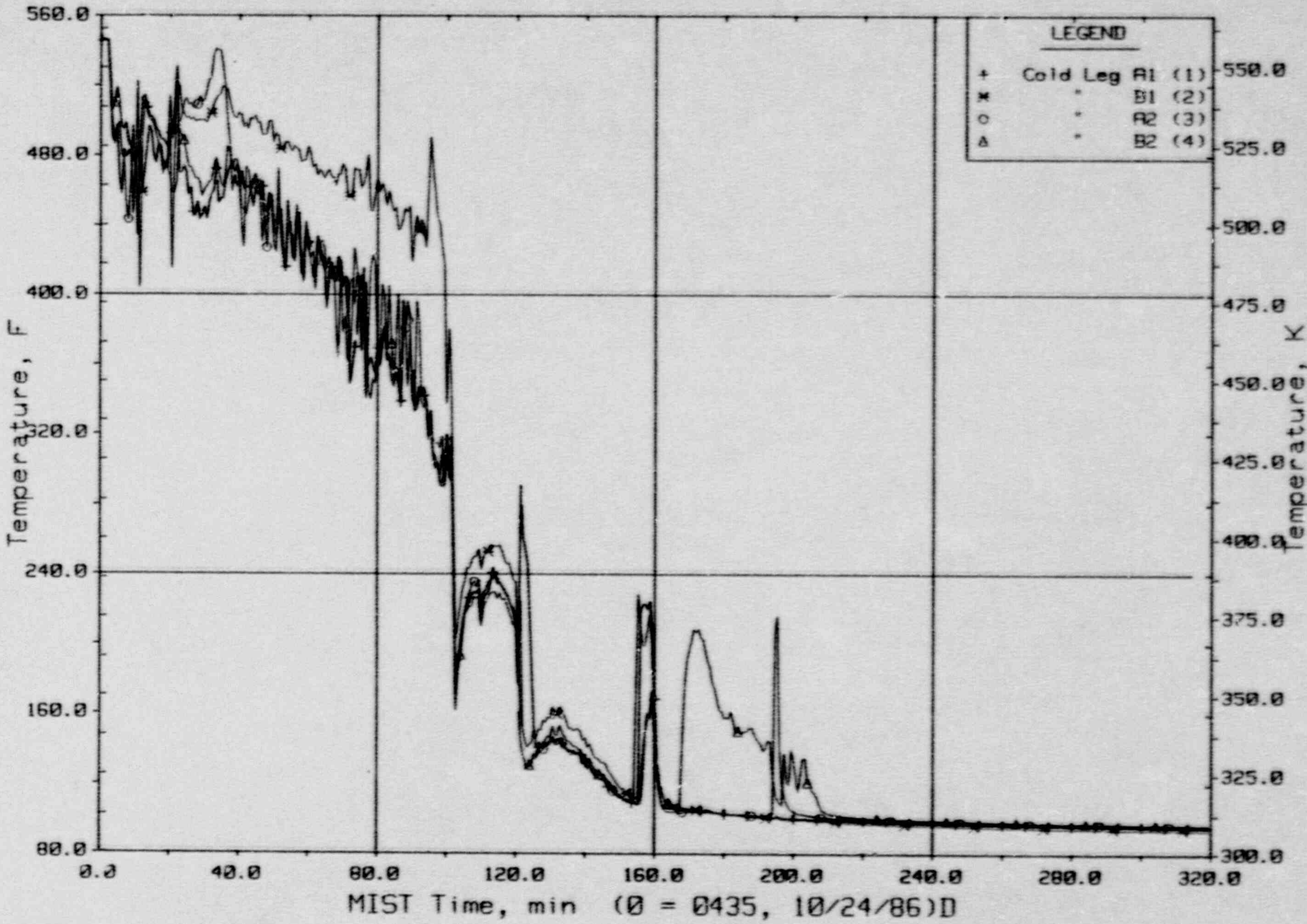
Cold Leg Nozzle Fluid Temperatures, Top of Rake (21.3ft, CnTC11s).

Thu May 26 16:57:10 1988

CLTC1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



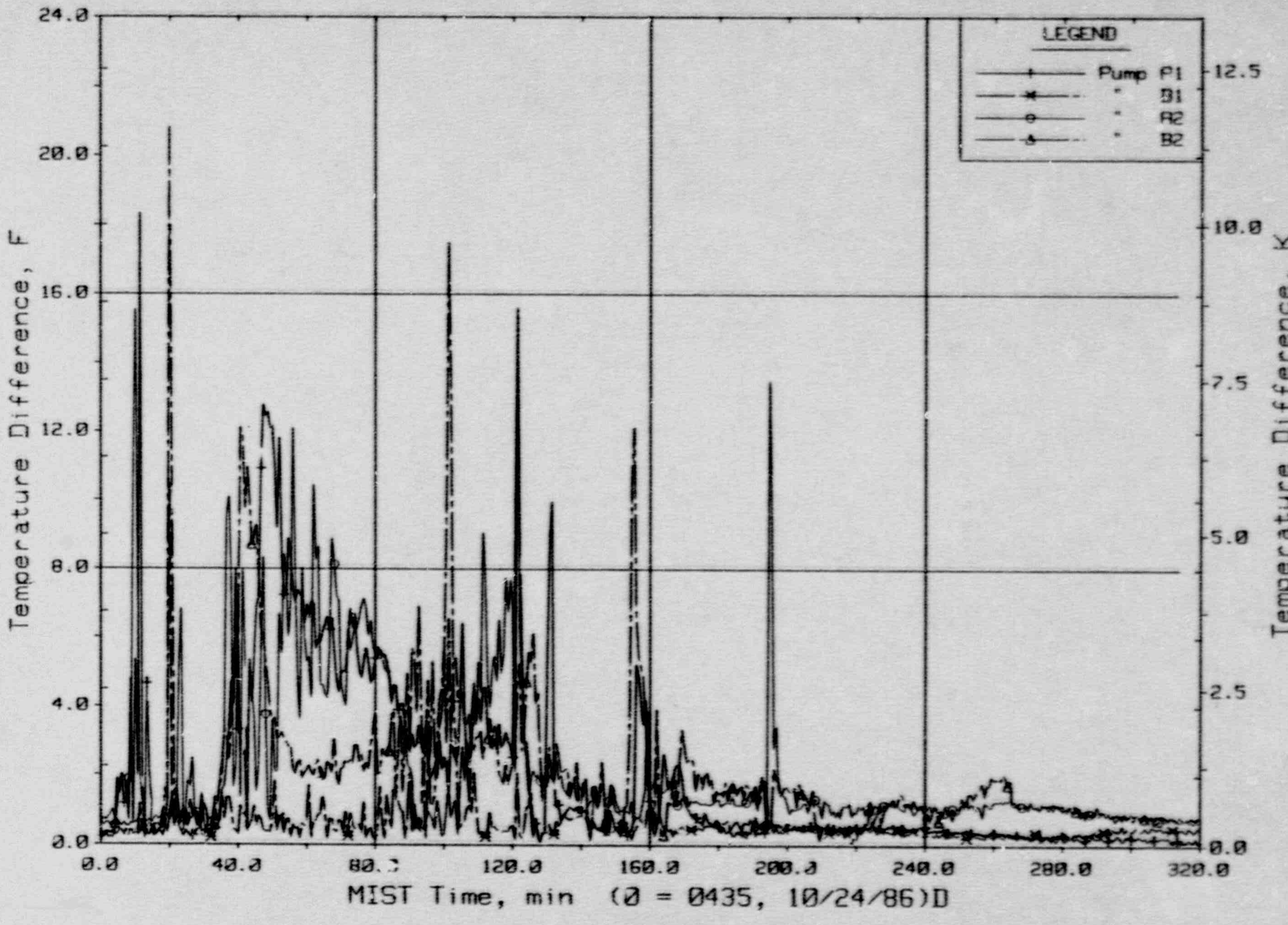
Cold Leg Nozzle Fluid Temperatures, Bottom of Rake (21.2ft, CnTC14s).

Thu May 26 17:02:42 1988

CLTC2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



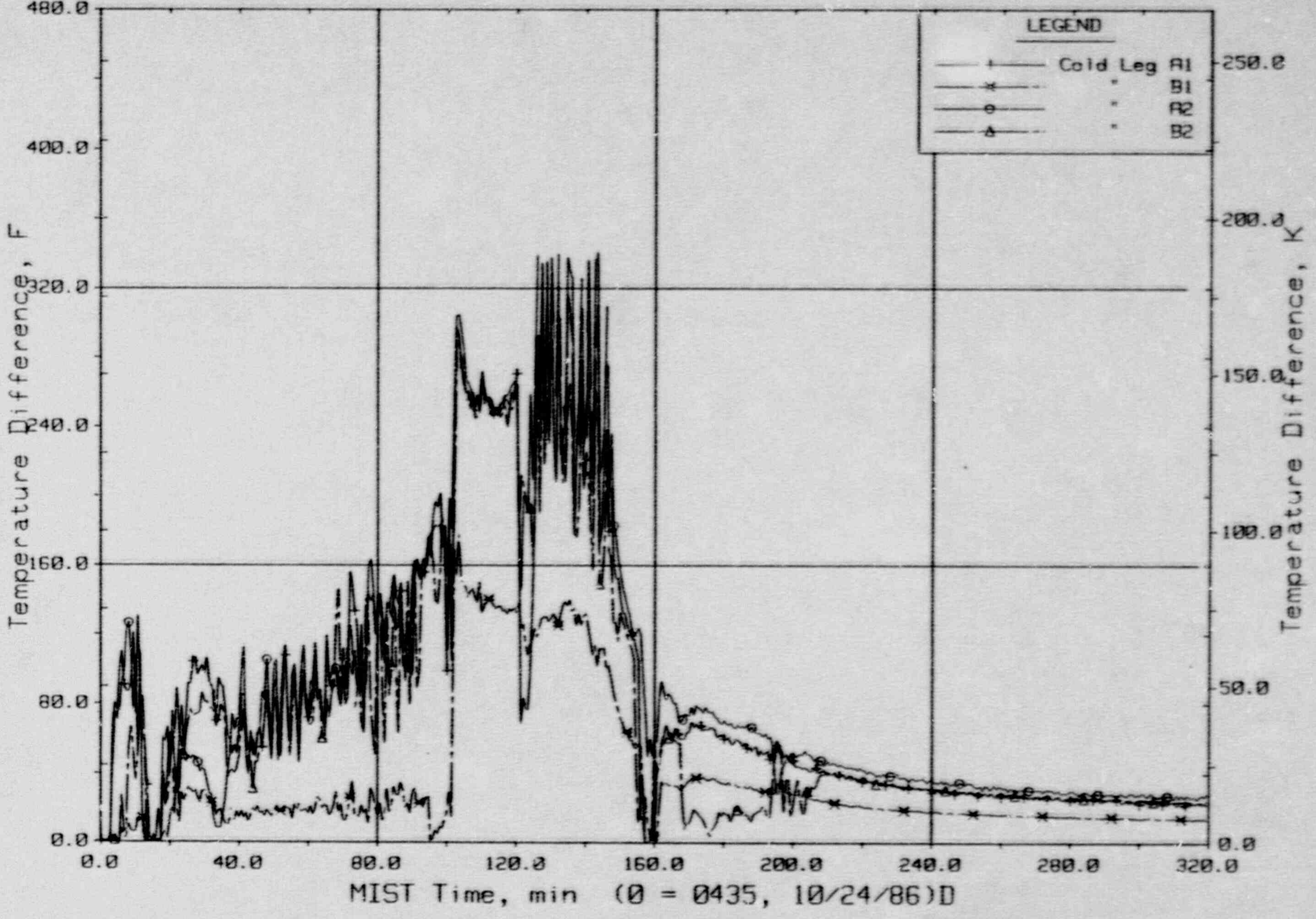
Maximum Differences Among RCP Rake Fluid Temperatures

Thu May 26 17:06:54 1988

CLTD1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



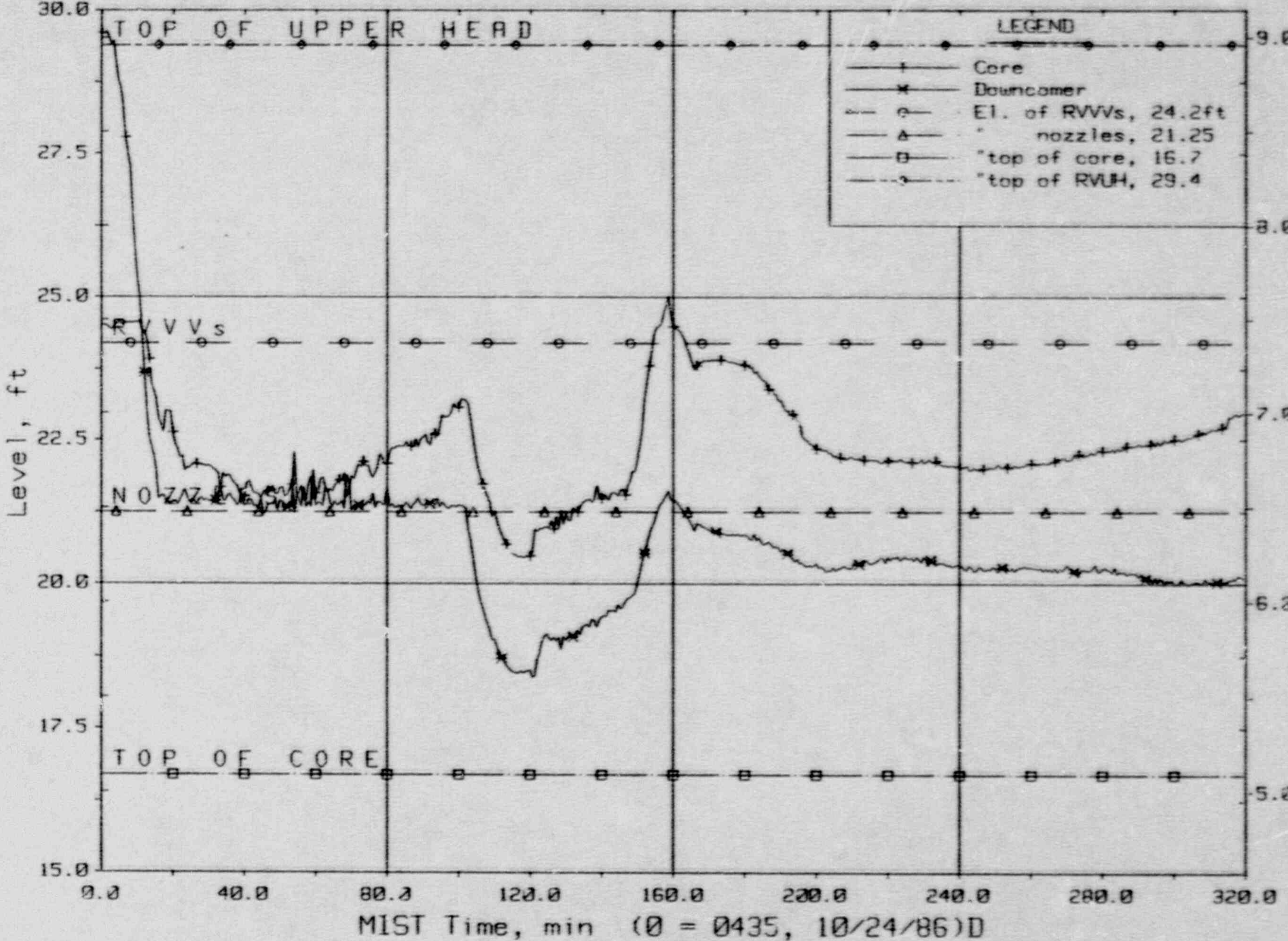
Maximum Differences Among CL Nozzle Rake Fluid Temperatures.

Thu May 26 17:10:51 1988

CLTD2

FINAL DATA

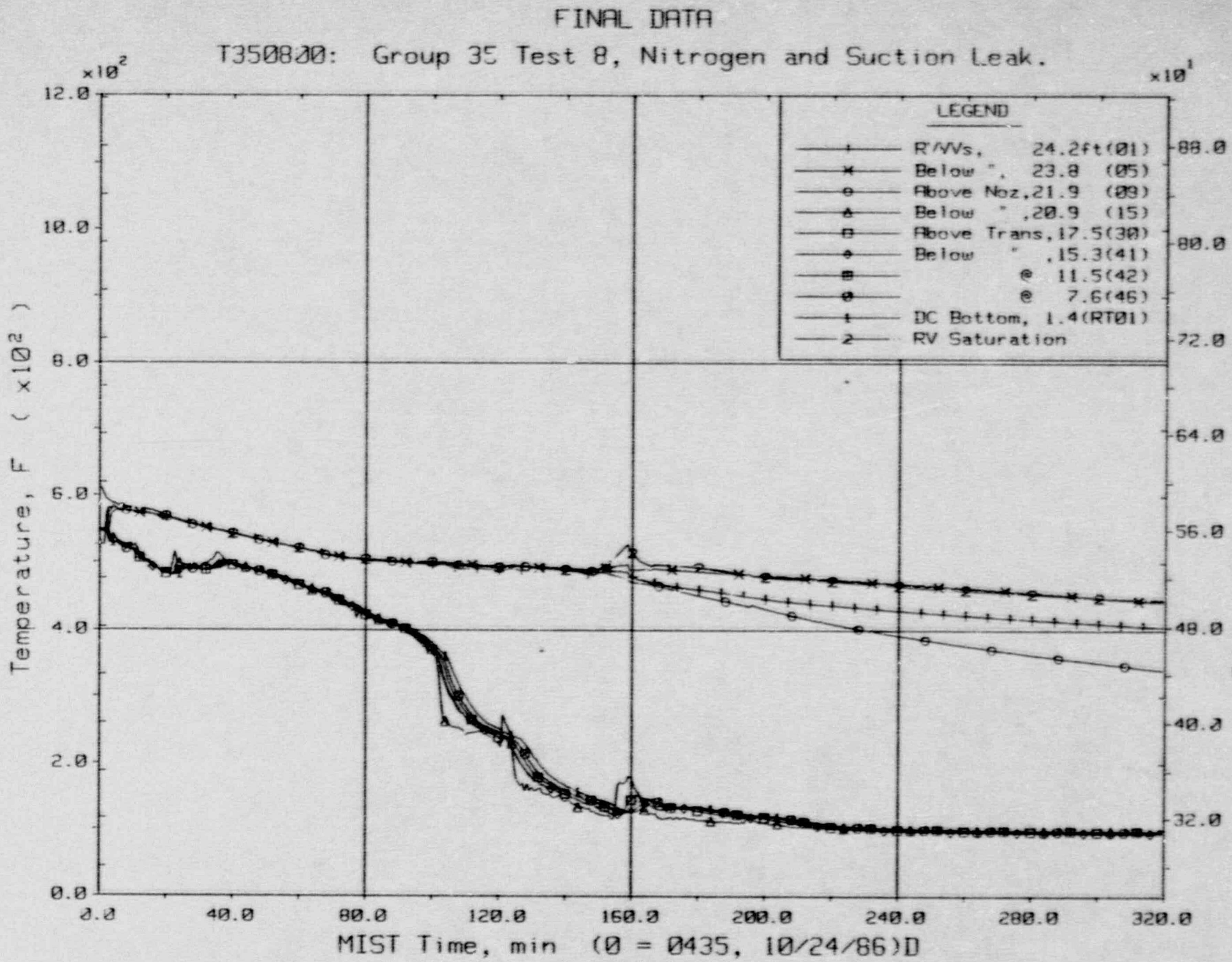
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Core Region Collapsed Liquid Levels.

Thu May 26 17:15:23 1988

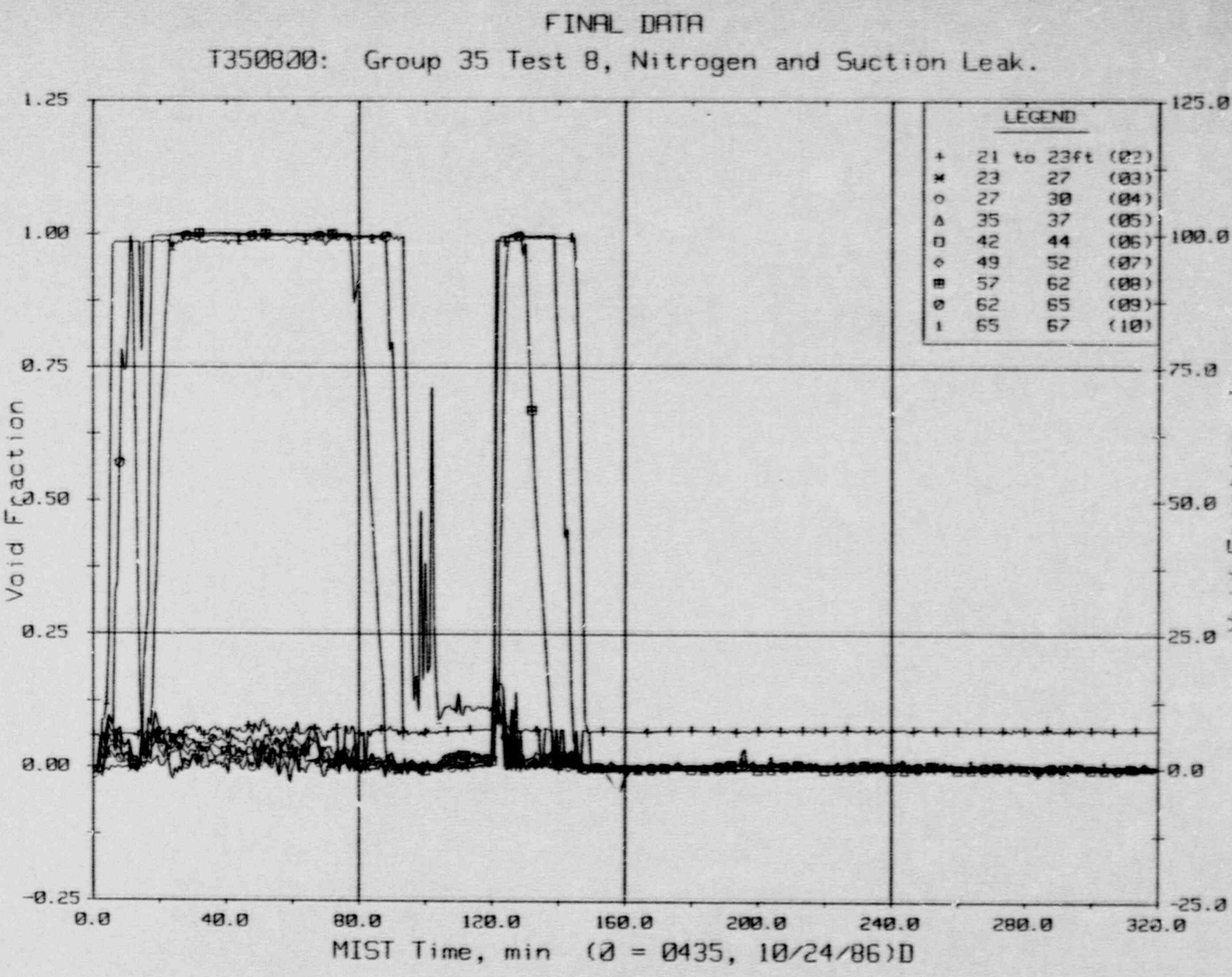
COLV1



Downcomer Quadrant A1 Fluid Temperatures (DCTCs).

Thu May 26 17:25:05 1988

DCTC6



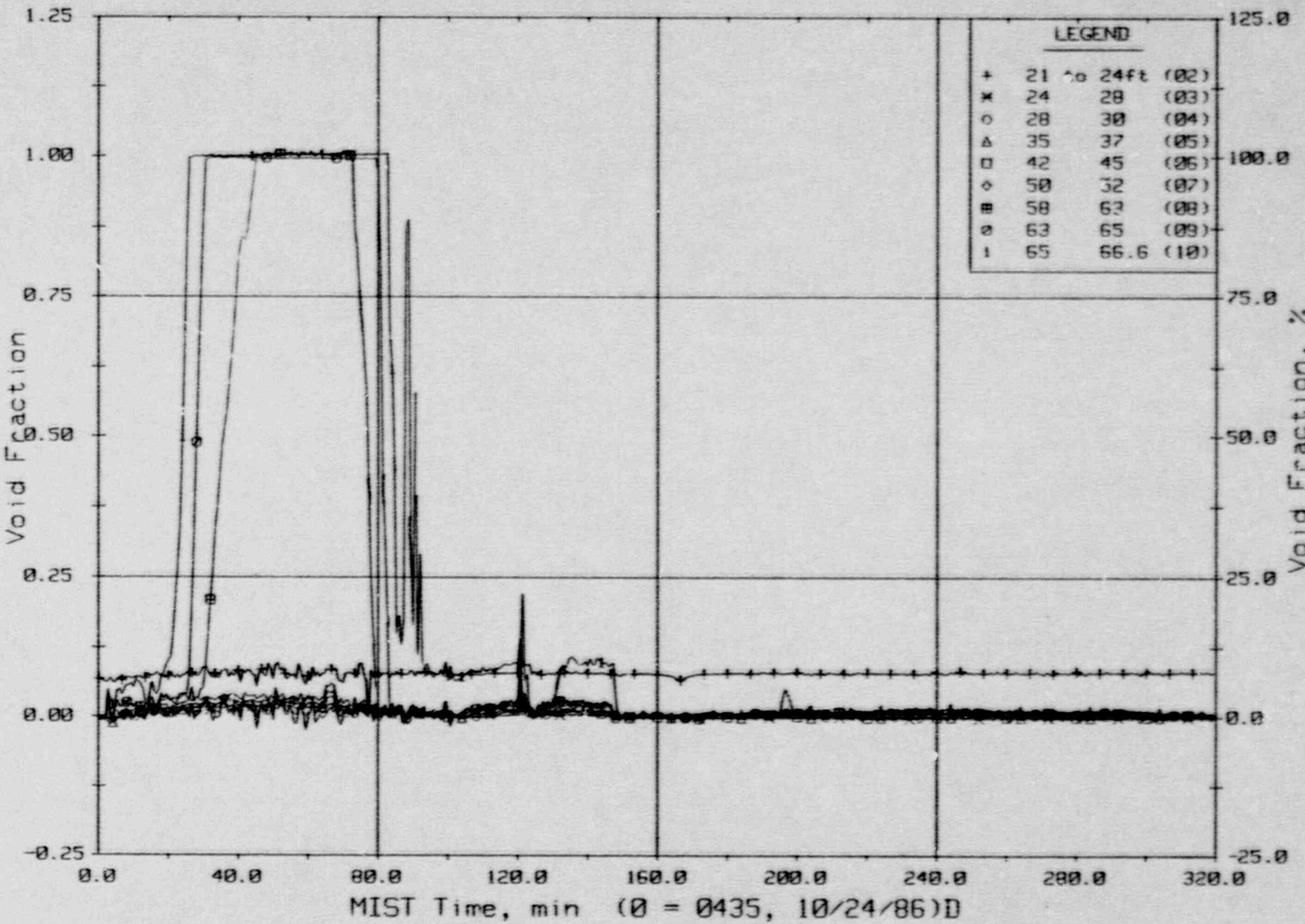
Hot Leg A Riser Void Fractions From Differential Pressures (H1VFs).

Thu May 26 17:30:33 1988

H1VF1

FINAL DATA

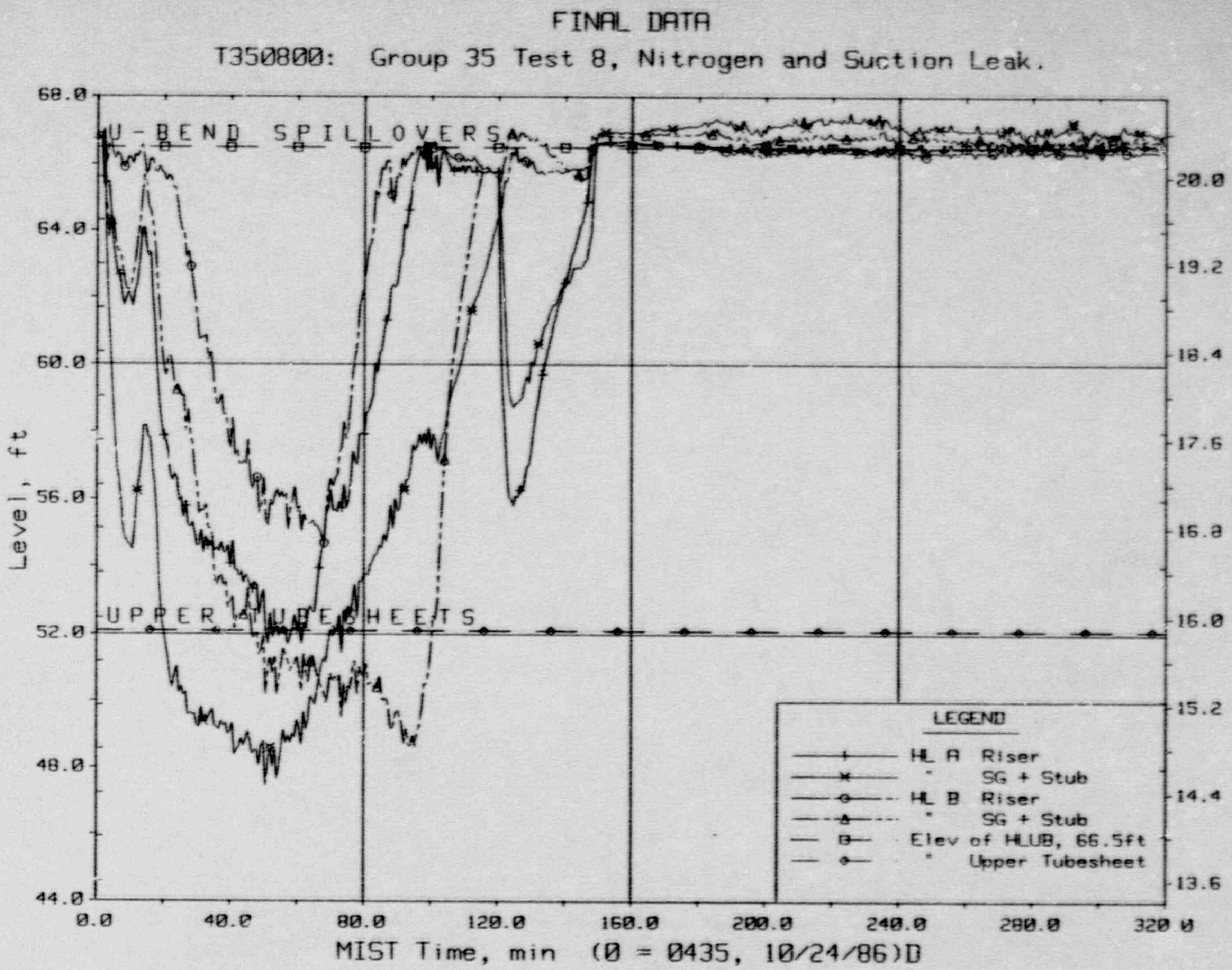
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Hot Leg B Riser Void Fraction From Differential Pressures (H2VFs).

Fri May 27 11:07:12 1988

H2VF1



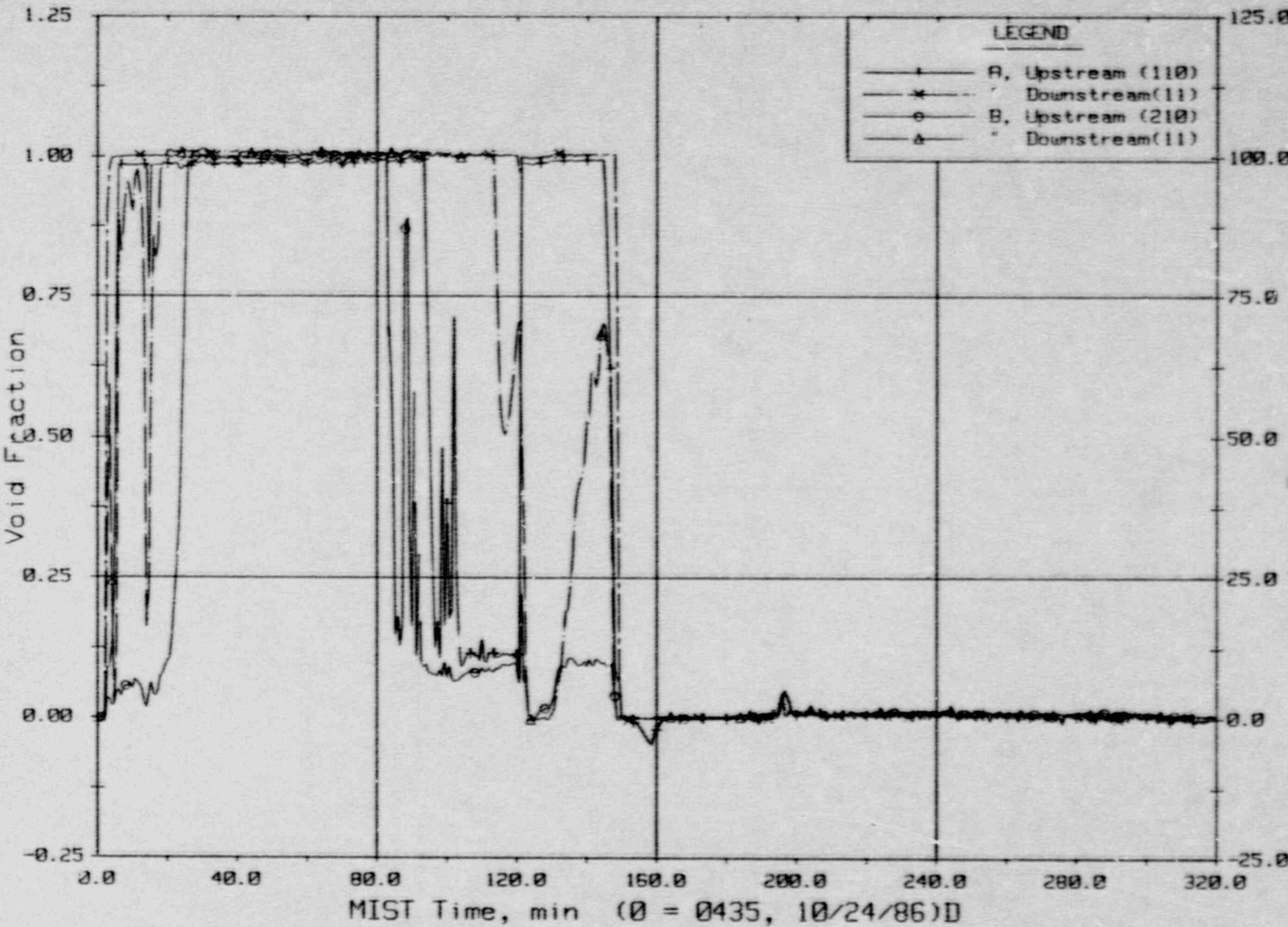
Hot Leg Riser and Stub Collapsed Liquid Levels.

Fri May 27 11:11:35 1988

HLLV1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



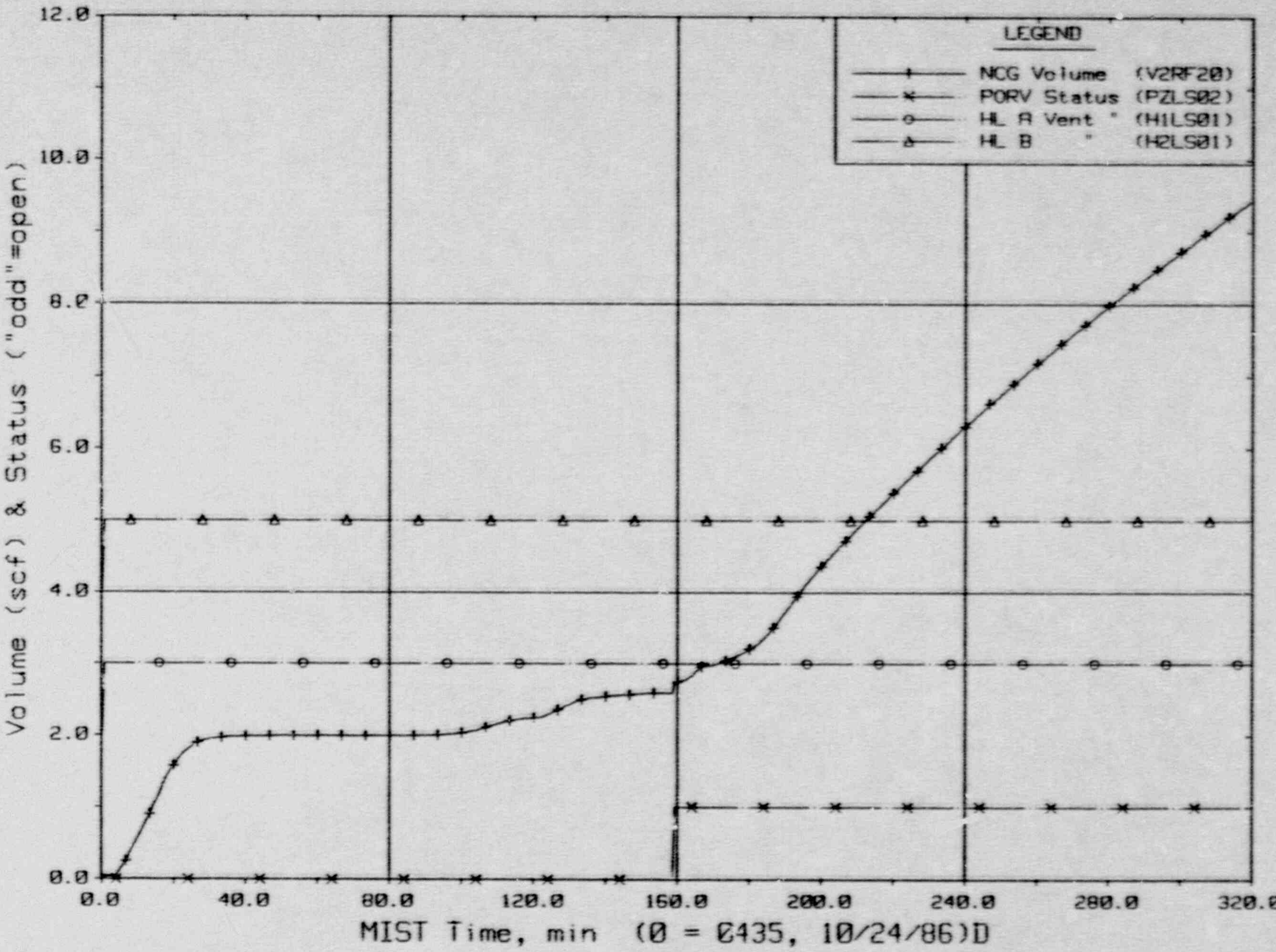
Hot Leg U-Bend Void Fractions From Diffl. Pressures (64.8 to 66.6 ft, HnVFs).

Fri May 27 11:15:25 1988

HLVF1

FINAL DATA

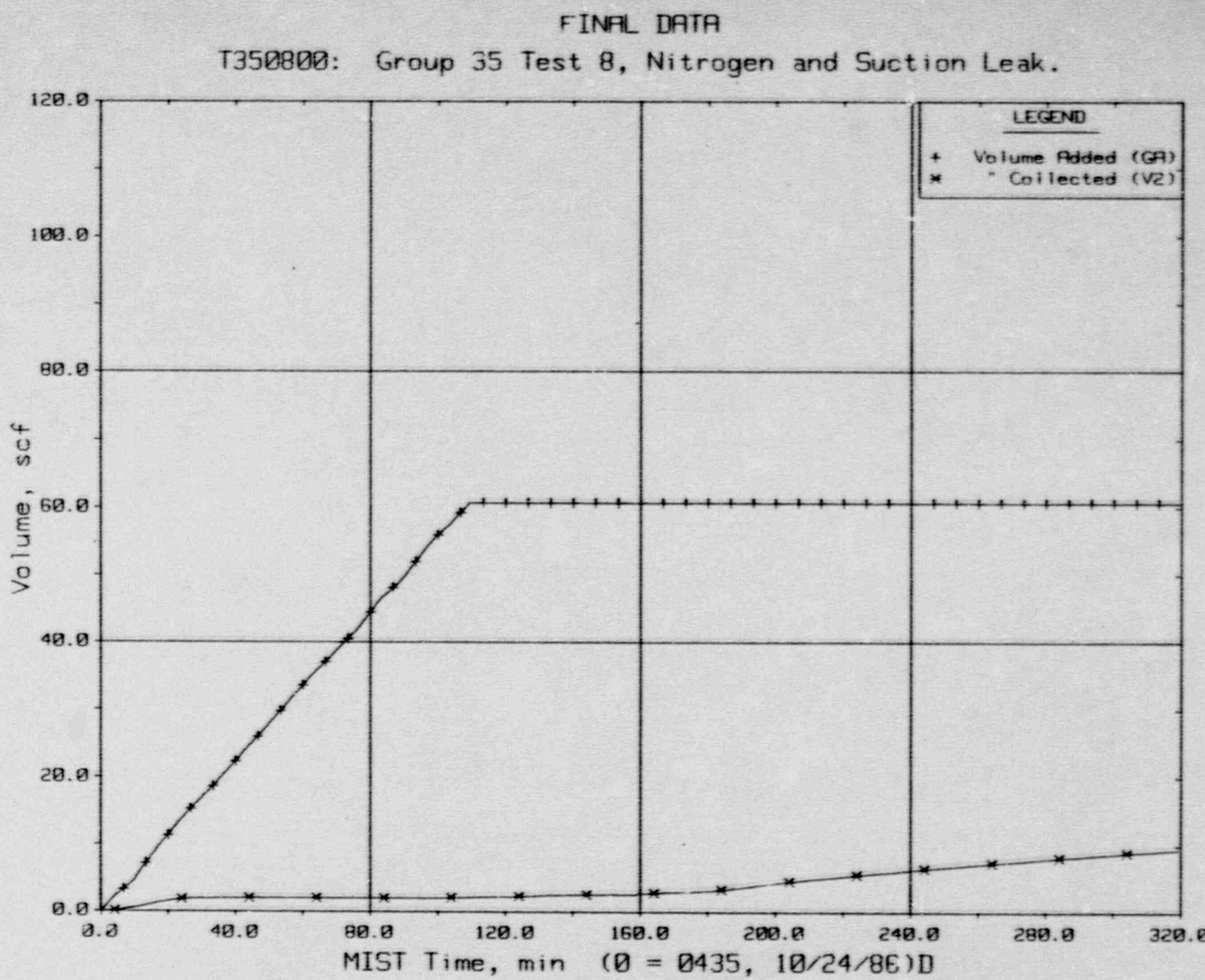
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Noncondensibles Collected and Discharge Valve Status.

Fri May 27 10:31:19 1988

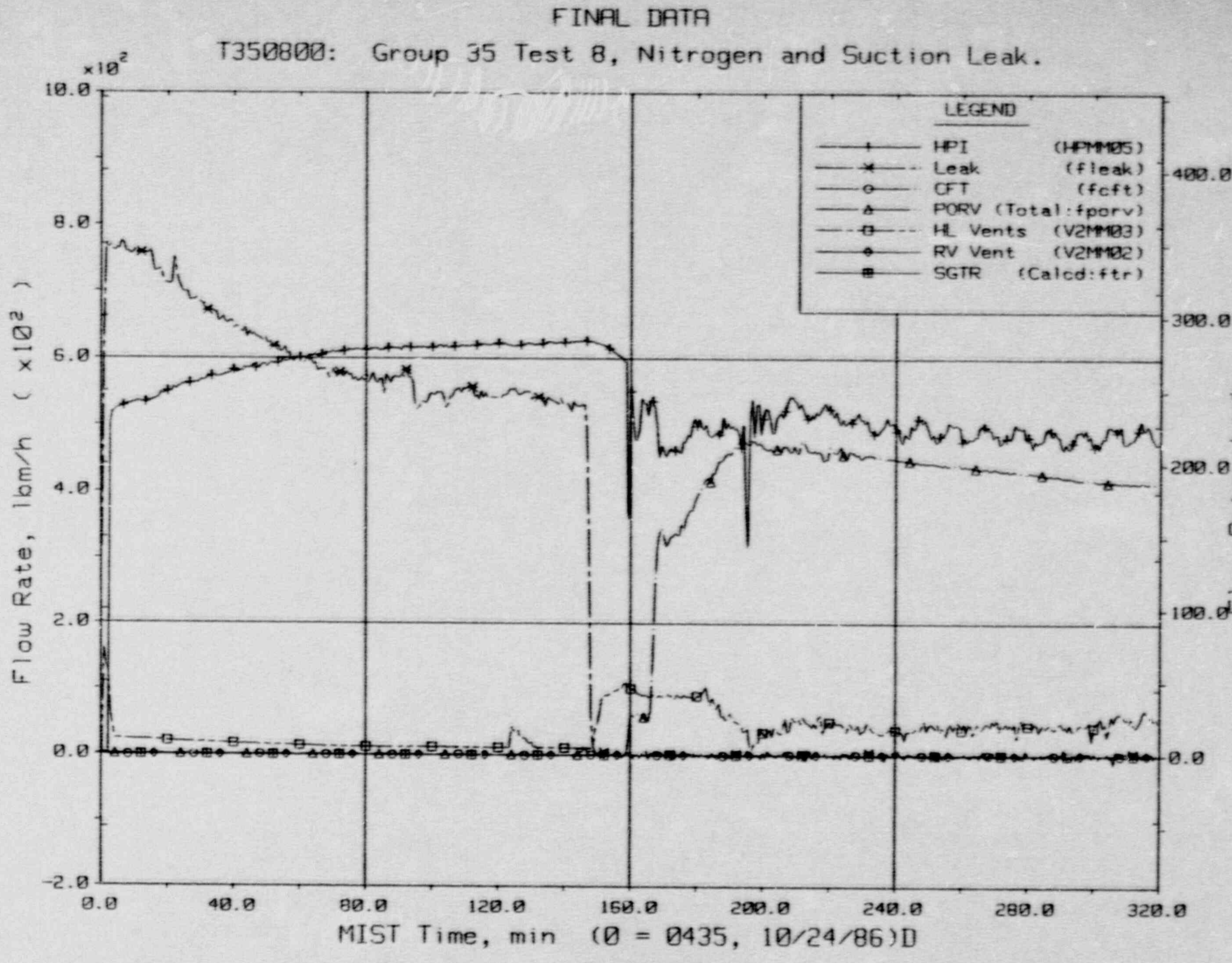
NCMS1



Noncondensibles Gas Volumes.

Fri May 27 10:42:49 1988

NCM52



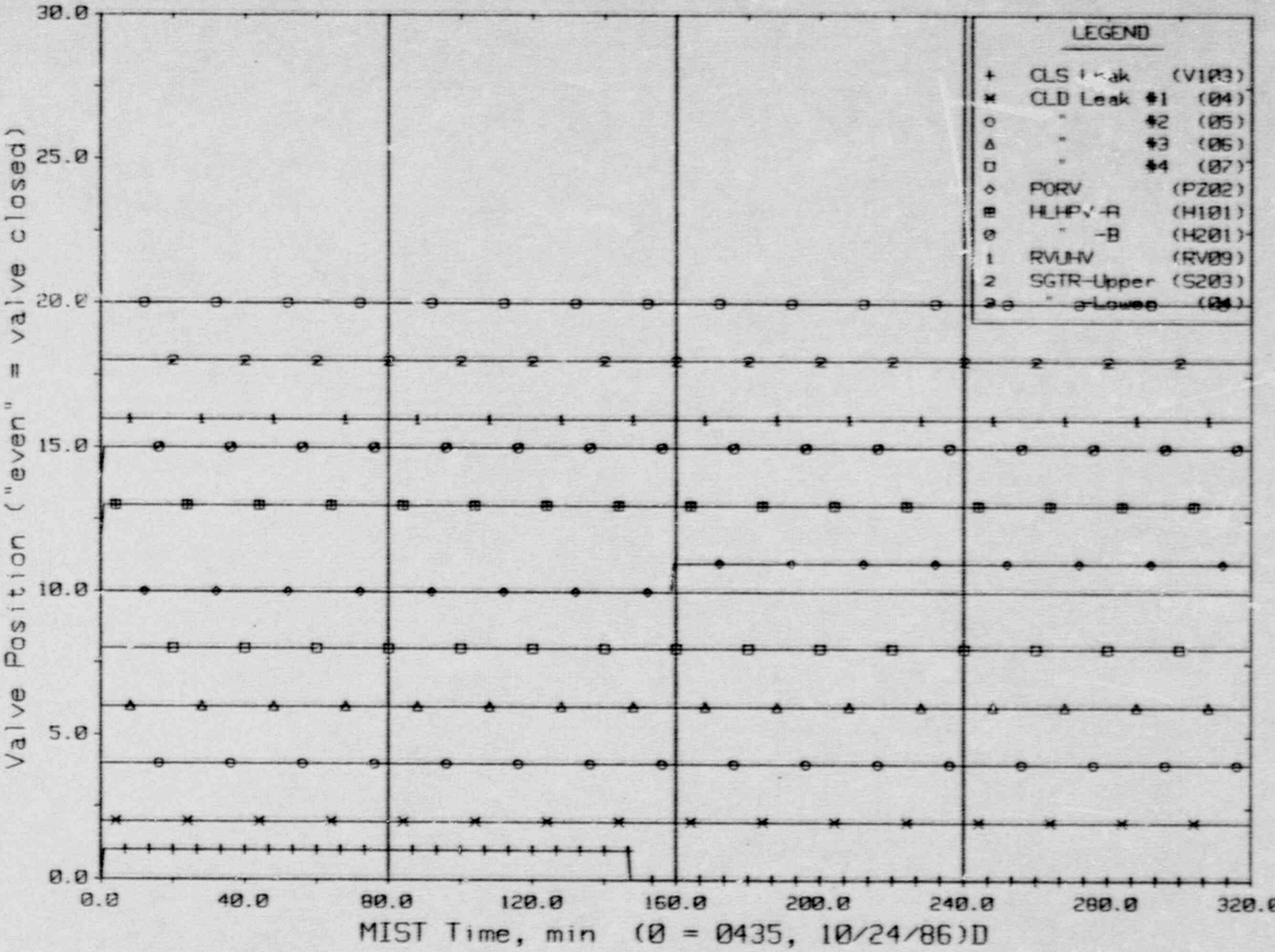
Primary System Boundary Flow Rates.

Fri May 27 06:07:30 1988

PBFL3

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



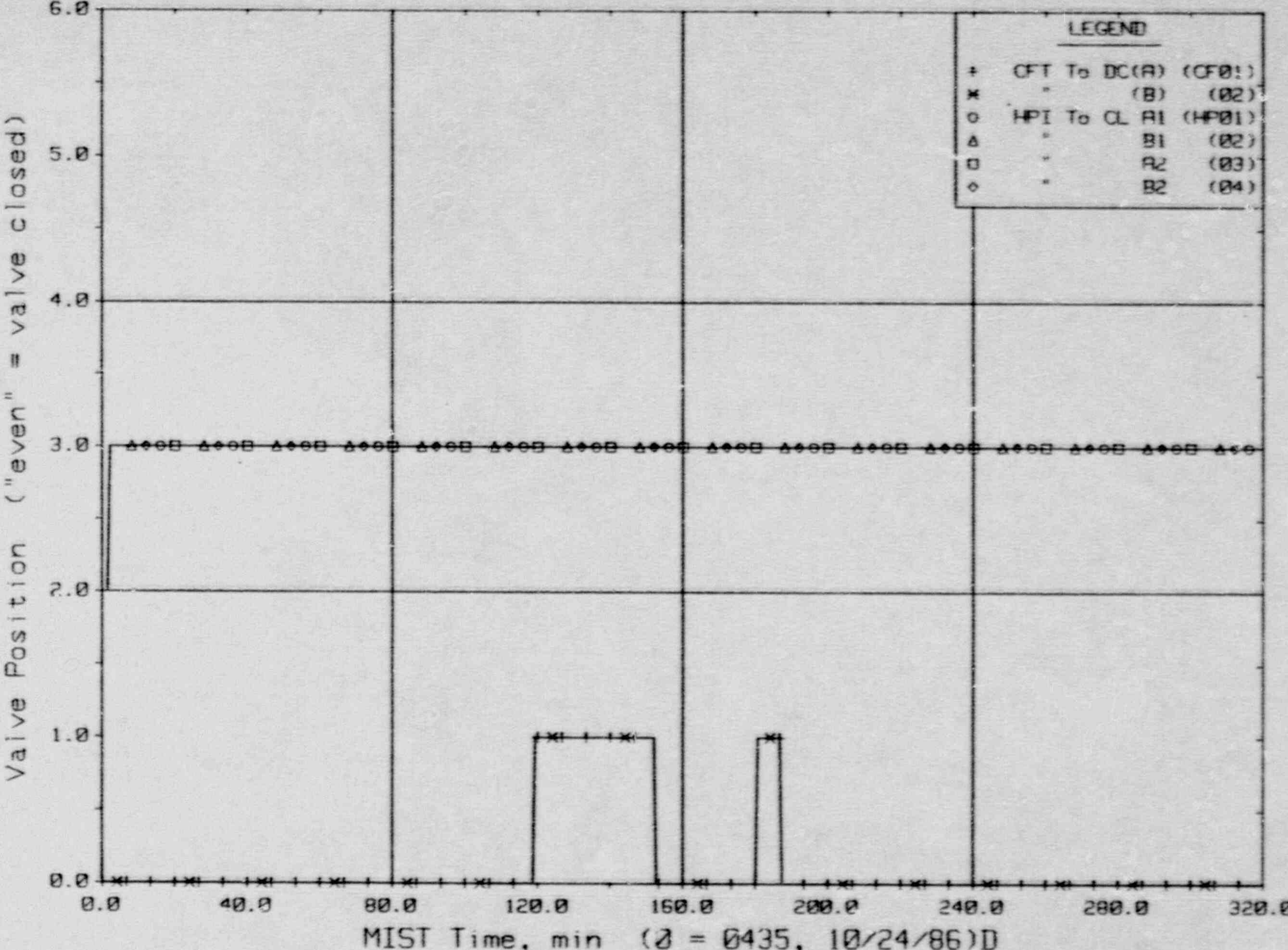
Primary System Discharge Limit Switch Indications (LSs).

Fri May 27 08:11:46 1988

PBLS1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



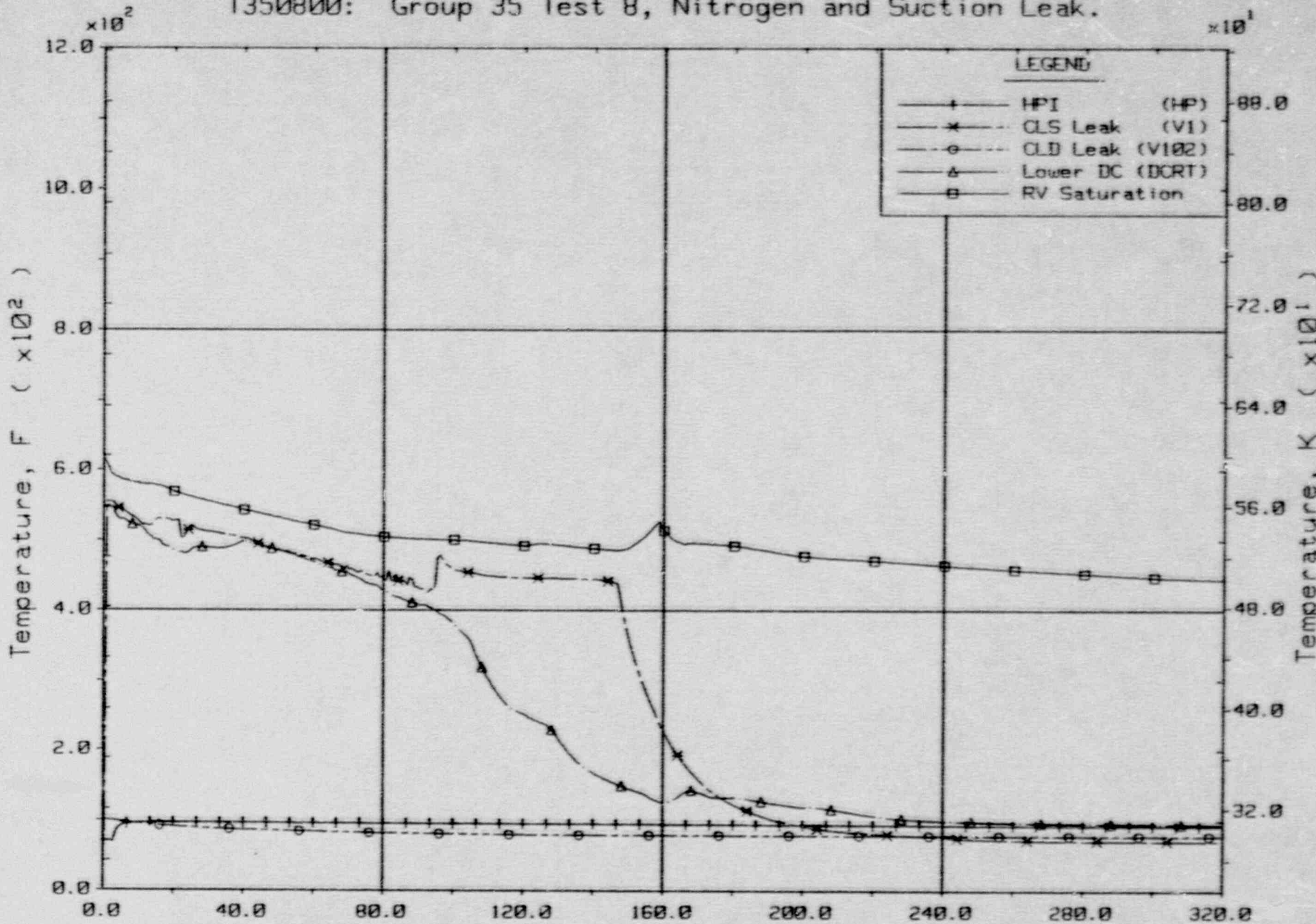
Primary System Injection Limit Switch Indications (LSs).

Fri May 27 08:14:54 1988

PBLS2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



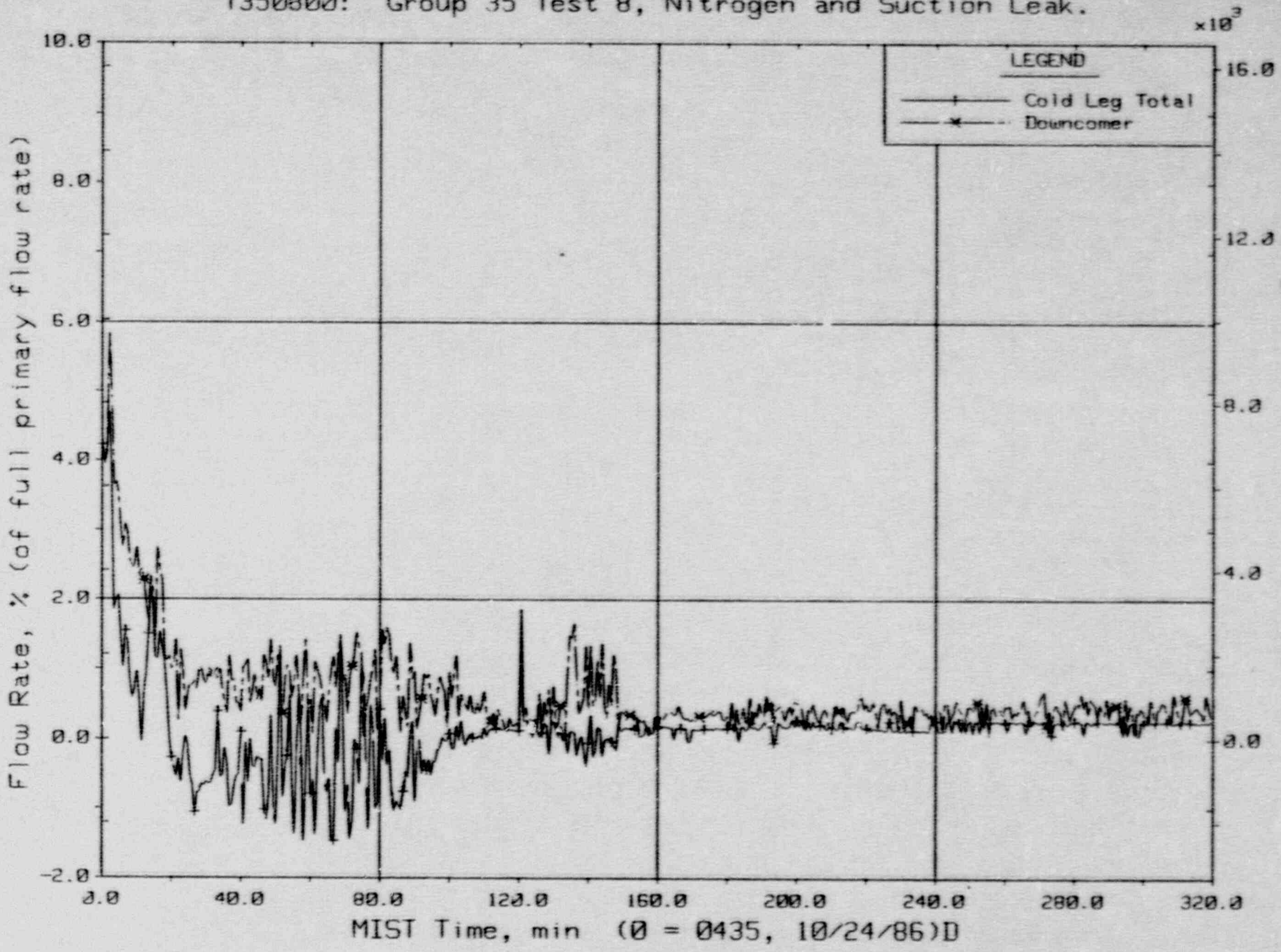
Single-Phase Discharge and HPI Fluid Temperatures (TC01s).

Fri May 27 08:17:53 1988

PBTC1p

rINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



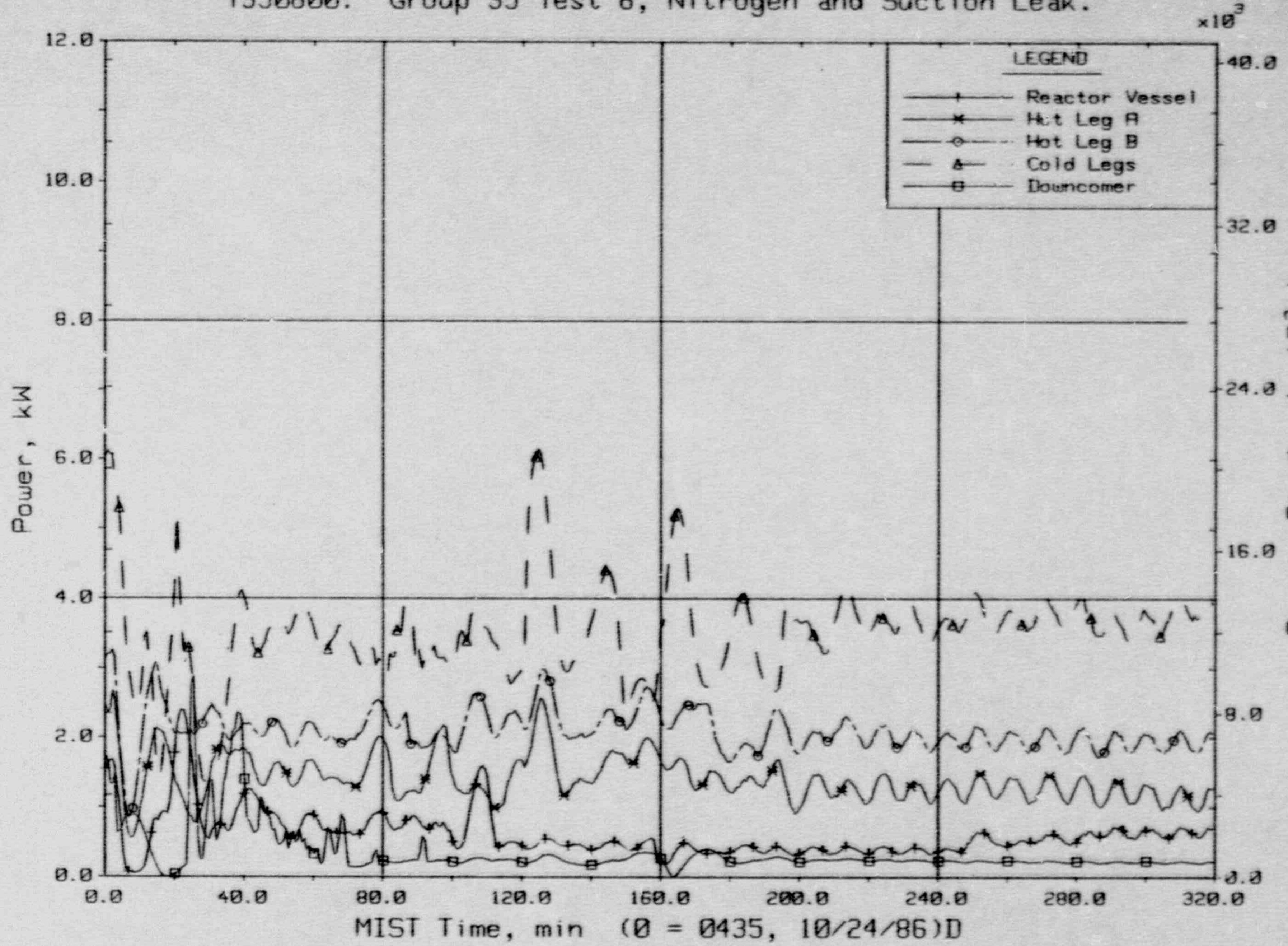
Primary System Venturi Flow Rates.

Fri May 27 08:20:35 1988

PRFL7

FINAL DATA

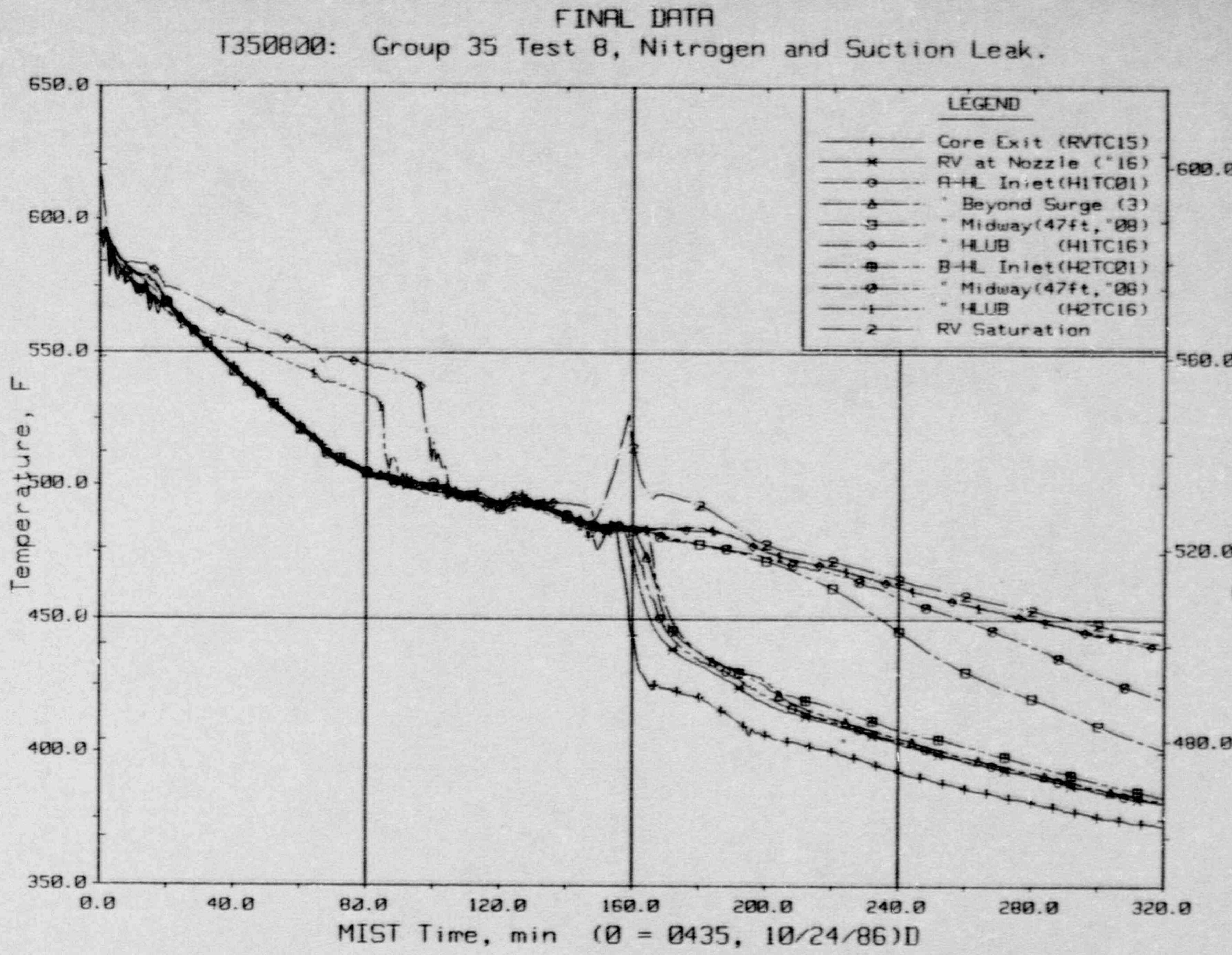
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Guard Heater Specified Power Per Primary Component.

Fri May 27 08:23:51 1988

PRGQ1



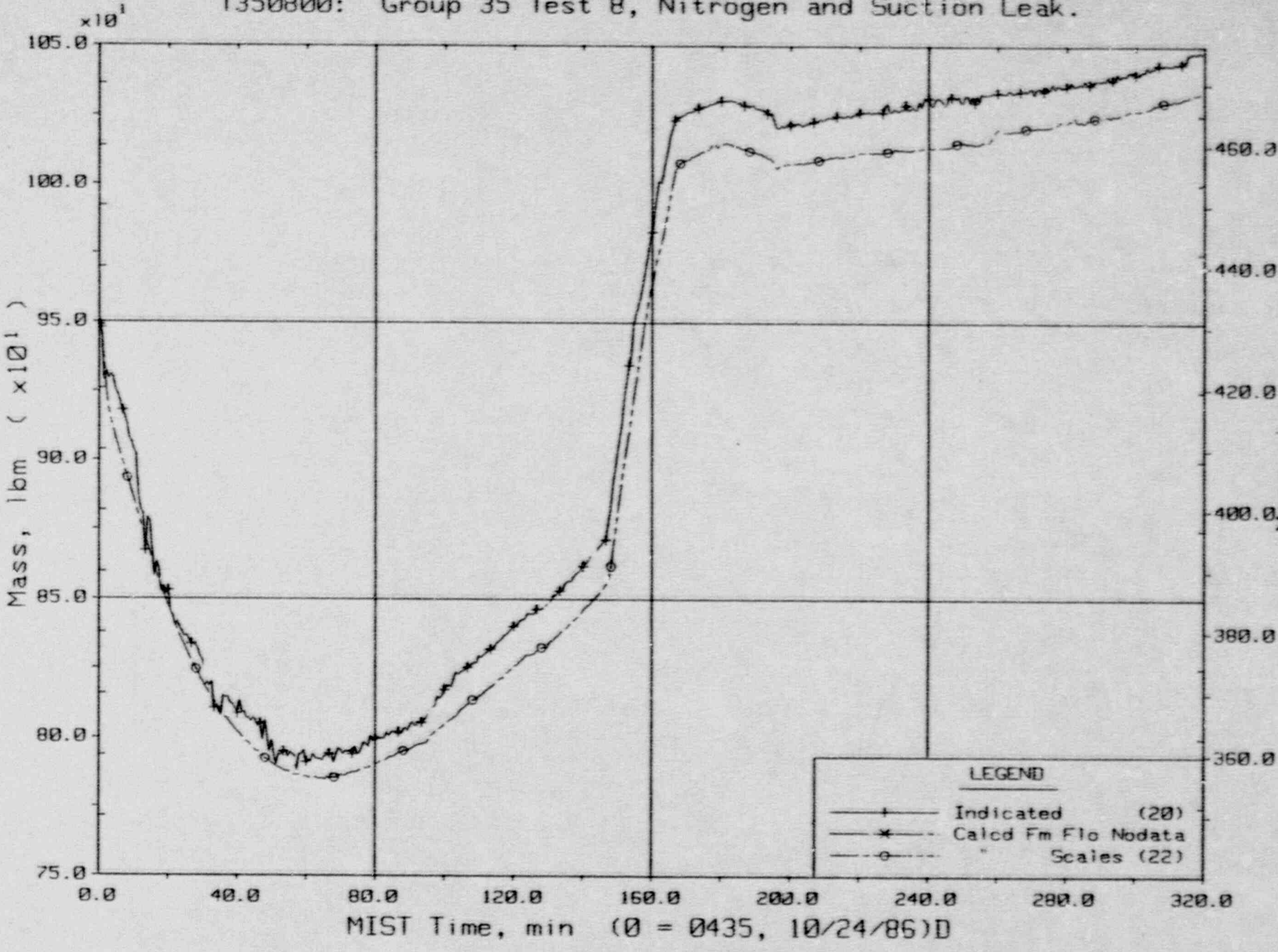
Composite Core Exit and Hot Leg Fluid Temperatures.

Fri May 27 08:28:24 1988

PRKT1

FINAL DATA

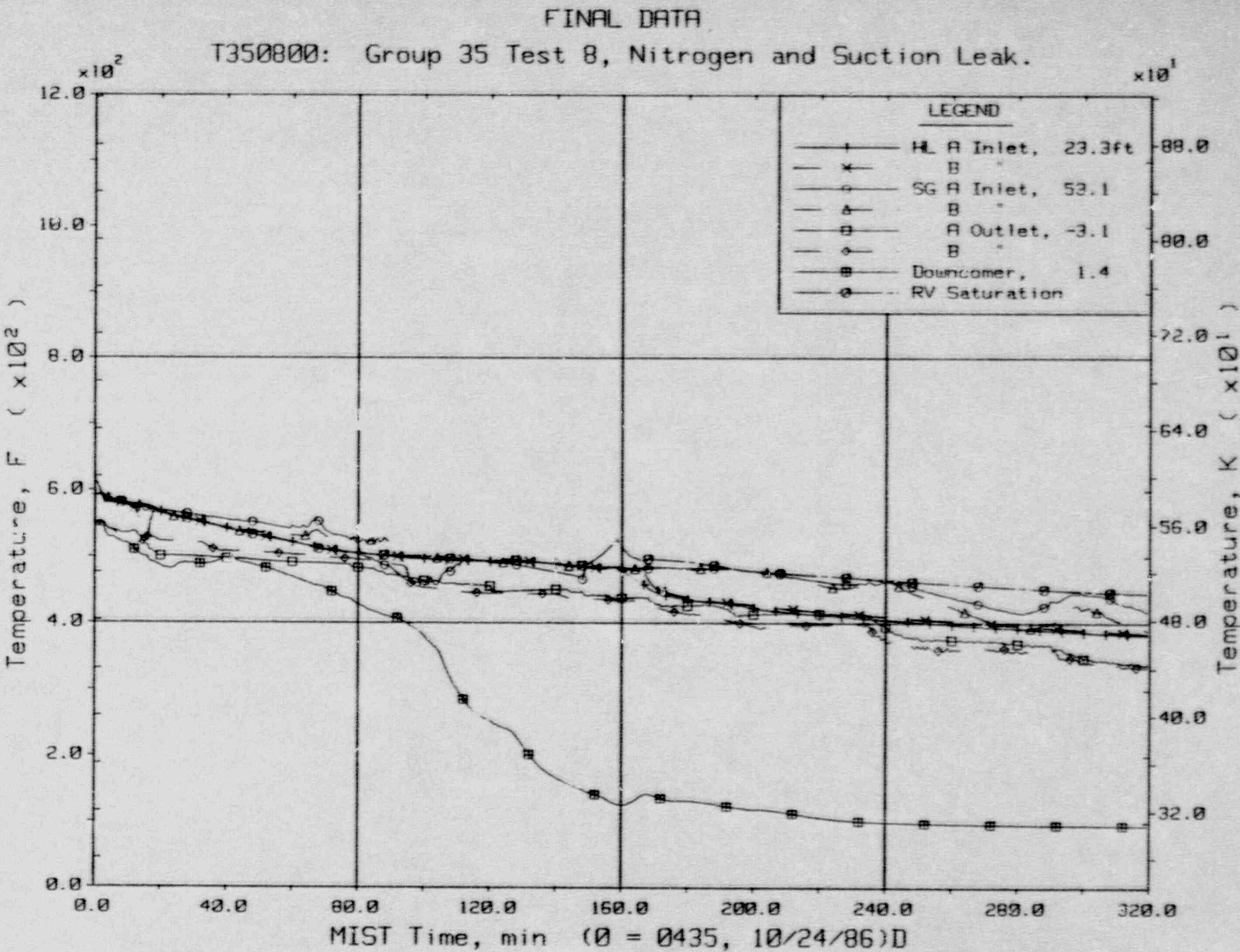
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Primary System Total Fluid Mass (PLMLs).

Fri May 27 08:31:11 1988

PRML2



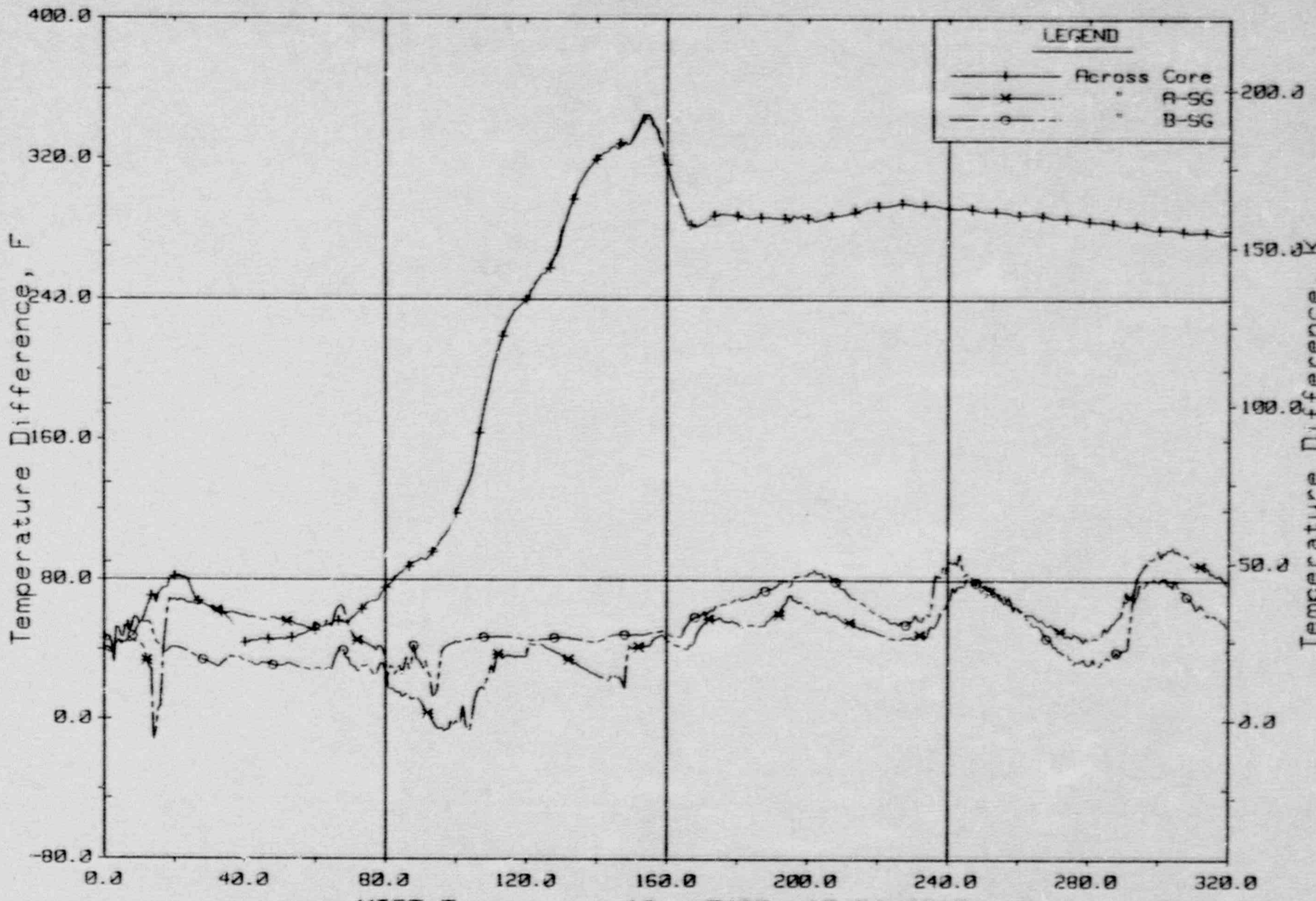
Primary System Fluid Temperatures (RTDs).

Fri May 27 08:52:07 1988

PRRT0

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



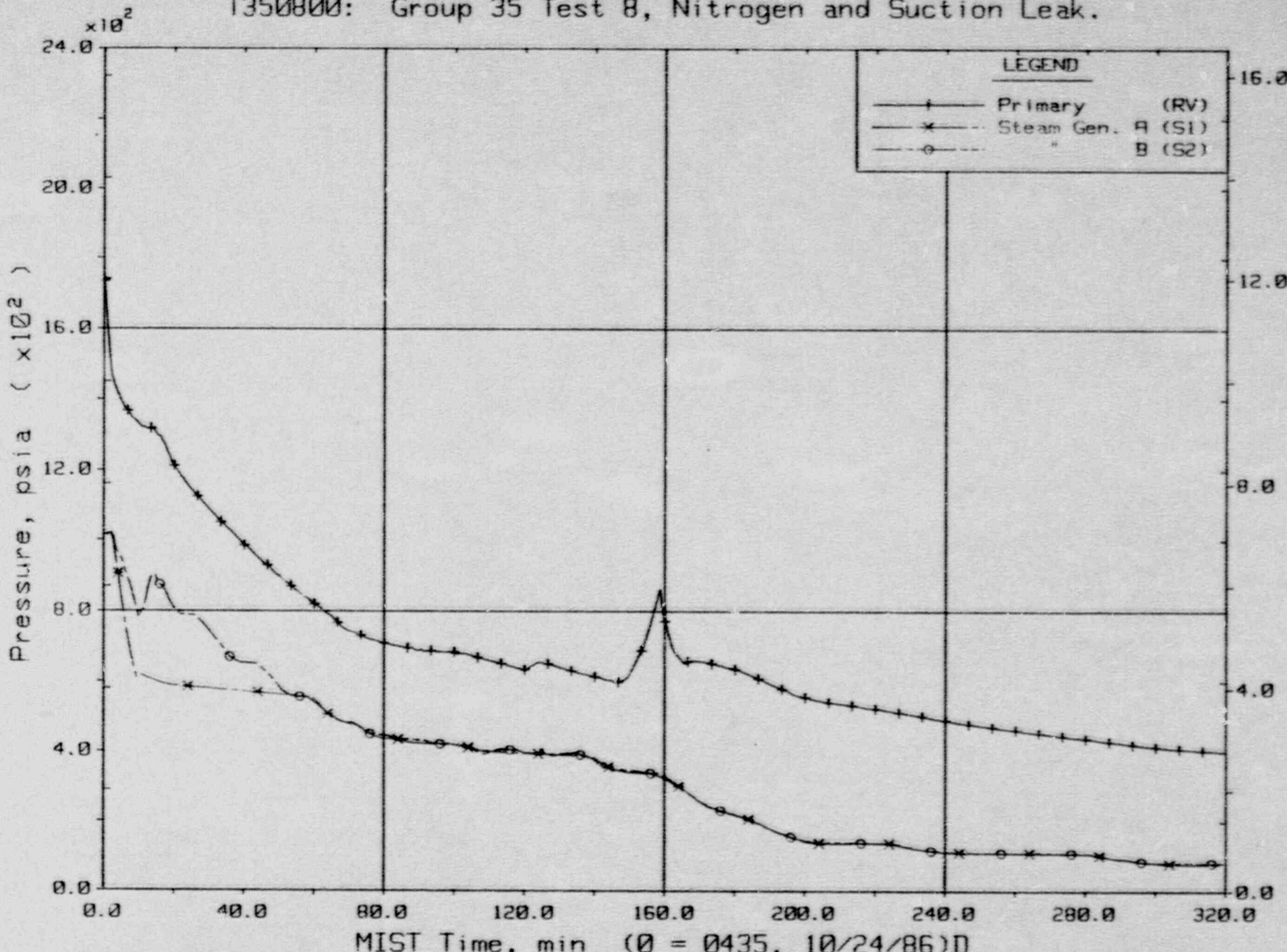
Key Temperature Differences.

Fri May 27 08:56:51 1988

PRTD2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



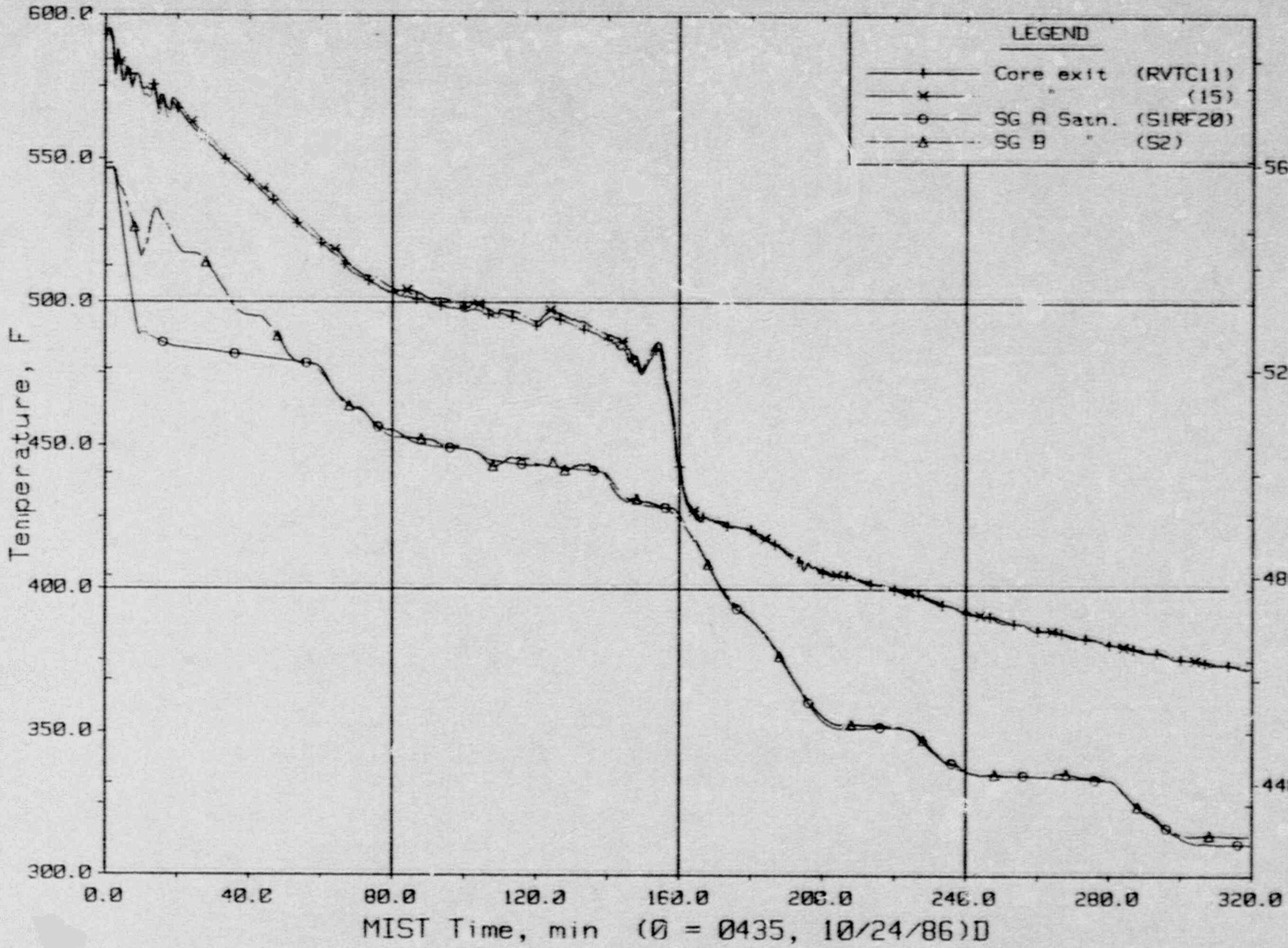
Primary and Secondary System Pressures (GP01s).

Fri May 27 09:03:05 1988

PSGP1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



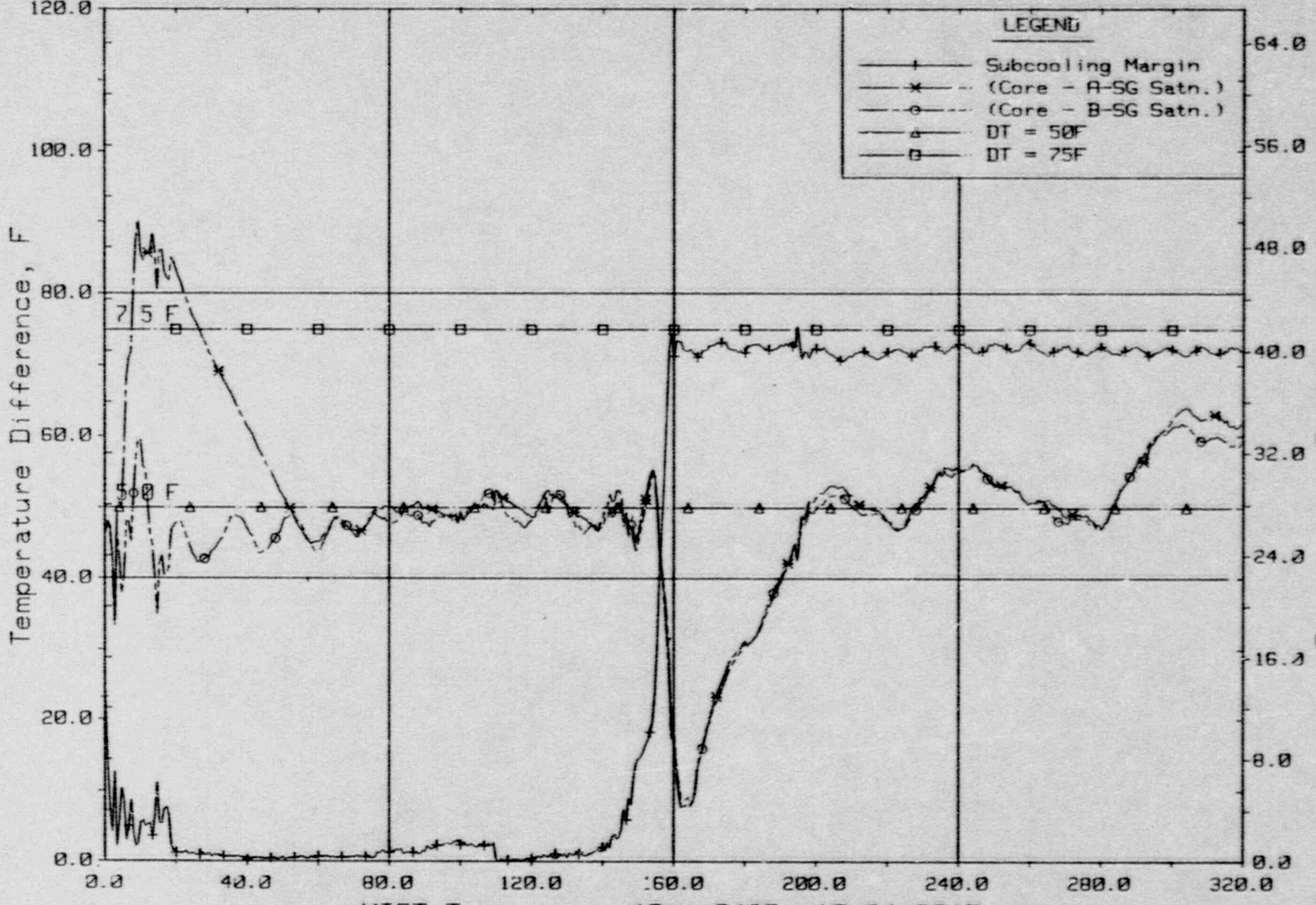
Core Exit and Steam Generator Secondary Saturation Temperatures.

Fri May 27 09:06:55 1988

PSTC3p

FINAL DATA

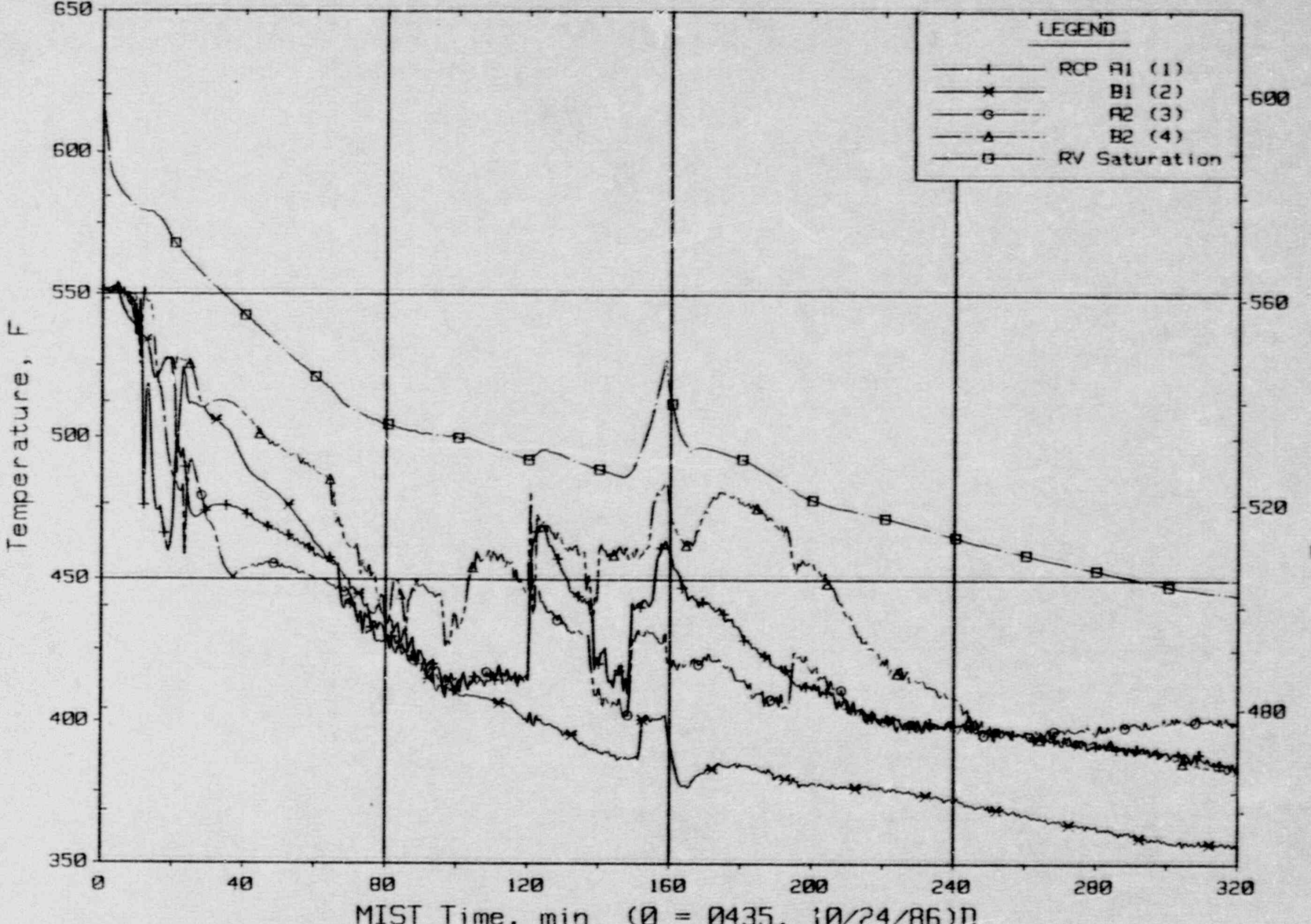
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Control Temperature Differences.

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



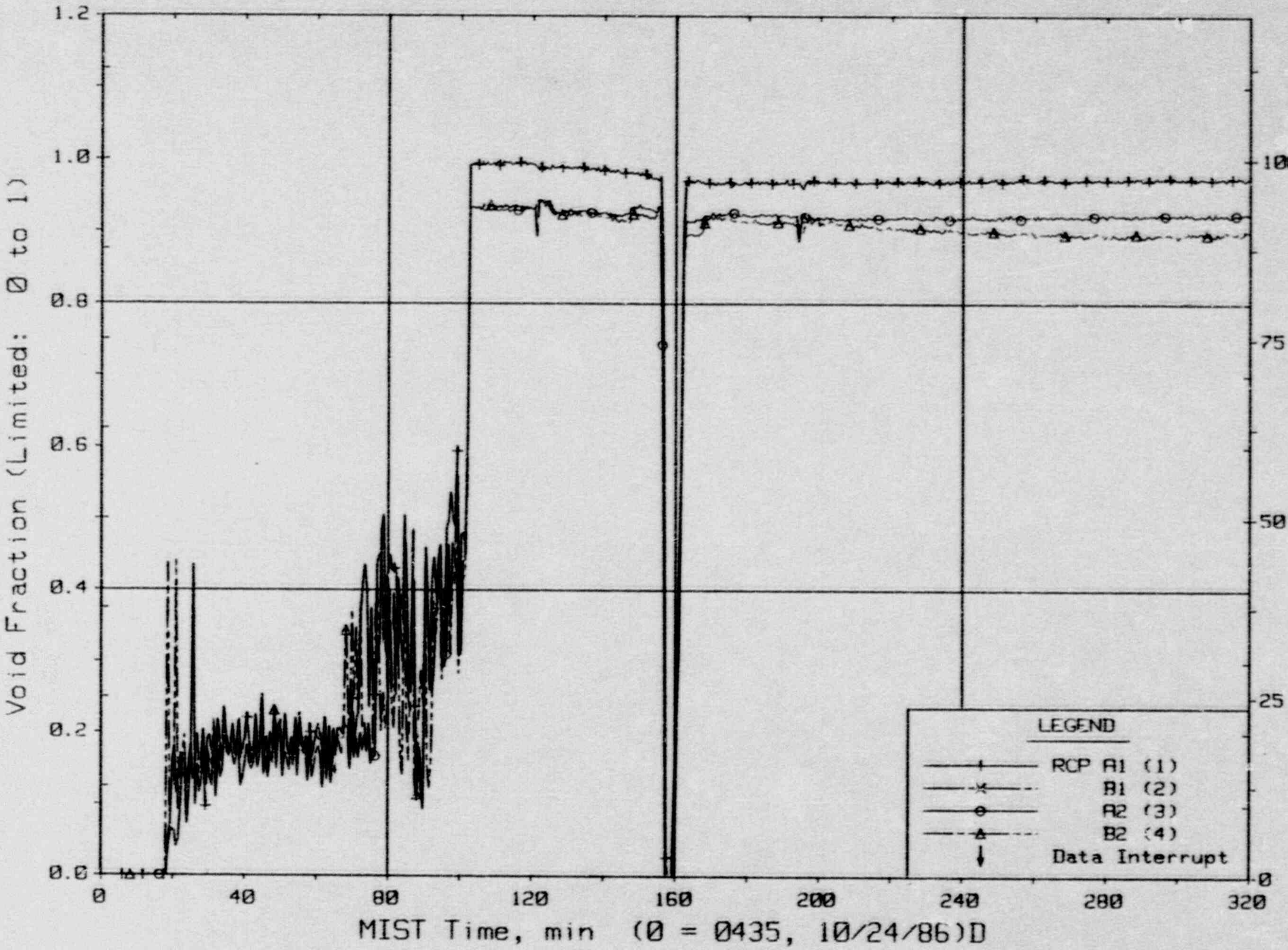
Pump Suction Fluid Temperature (CnRT01s).

Mon Jan 16 12:14:39 1989

PURT0

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.

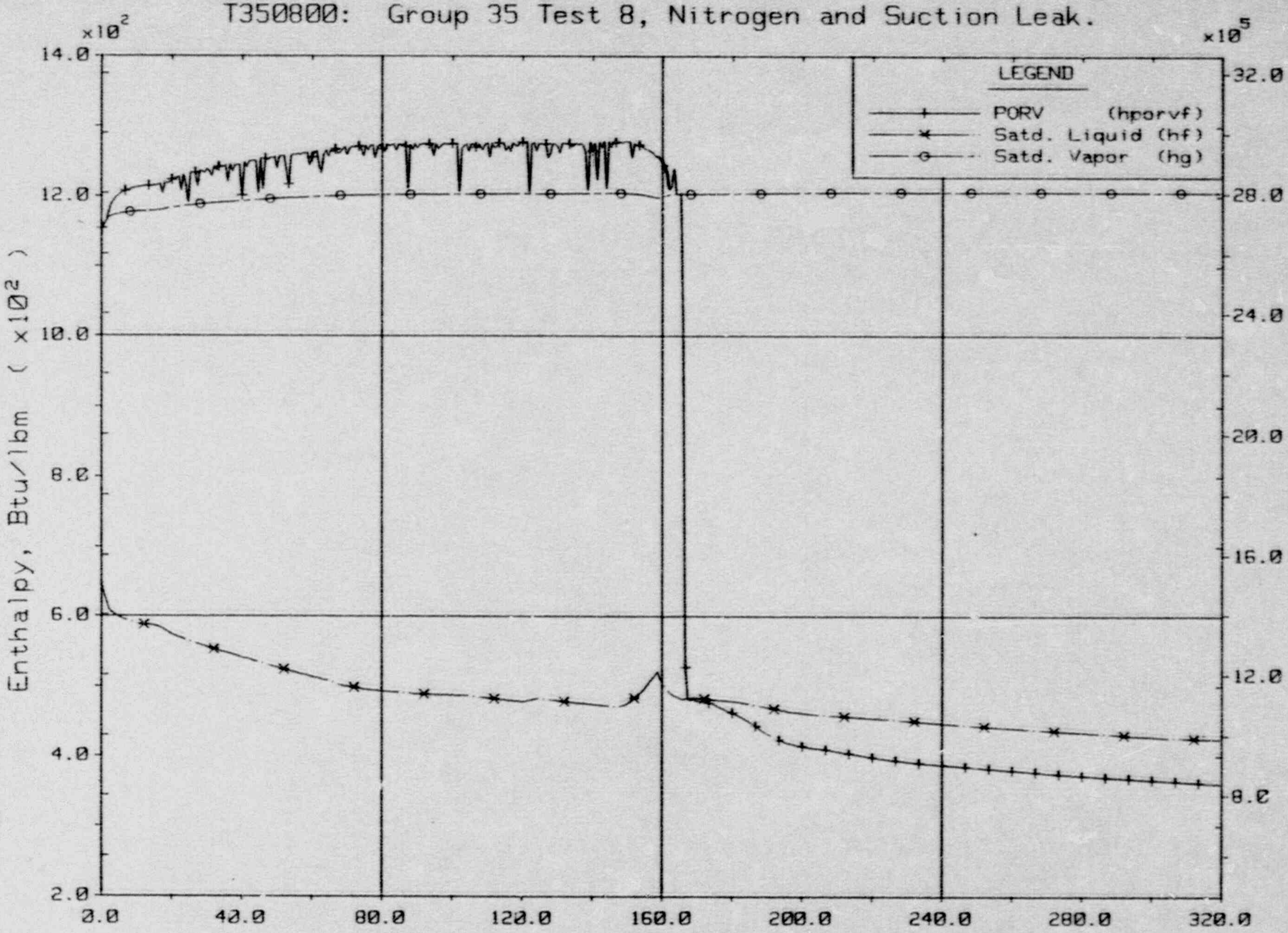


Pump Suction Void Fraction From Gamma Densitometers (CnGD21).

Mon Jan 16 12:10:37 1989

PUVF2

FINAL DATA



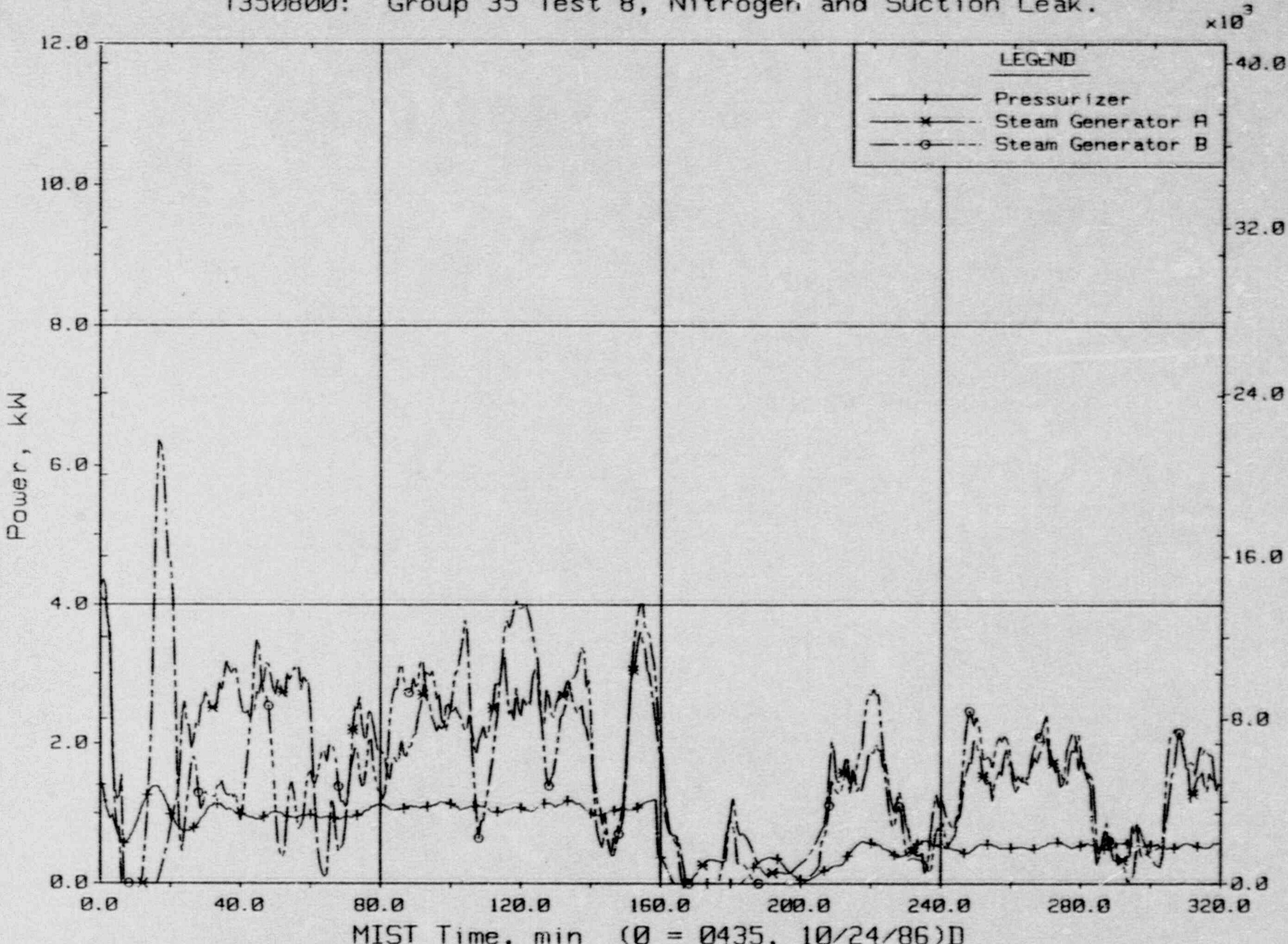
Power-Operated Relief Valve Enthalpy (Based On Flow Rate).

Fri May 27 03:16:16 1988

PZEN1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



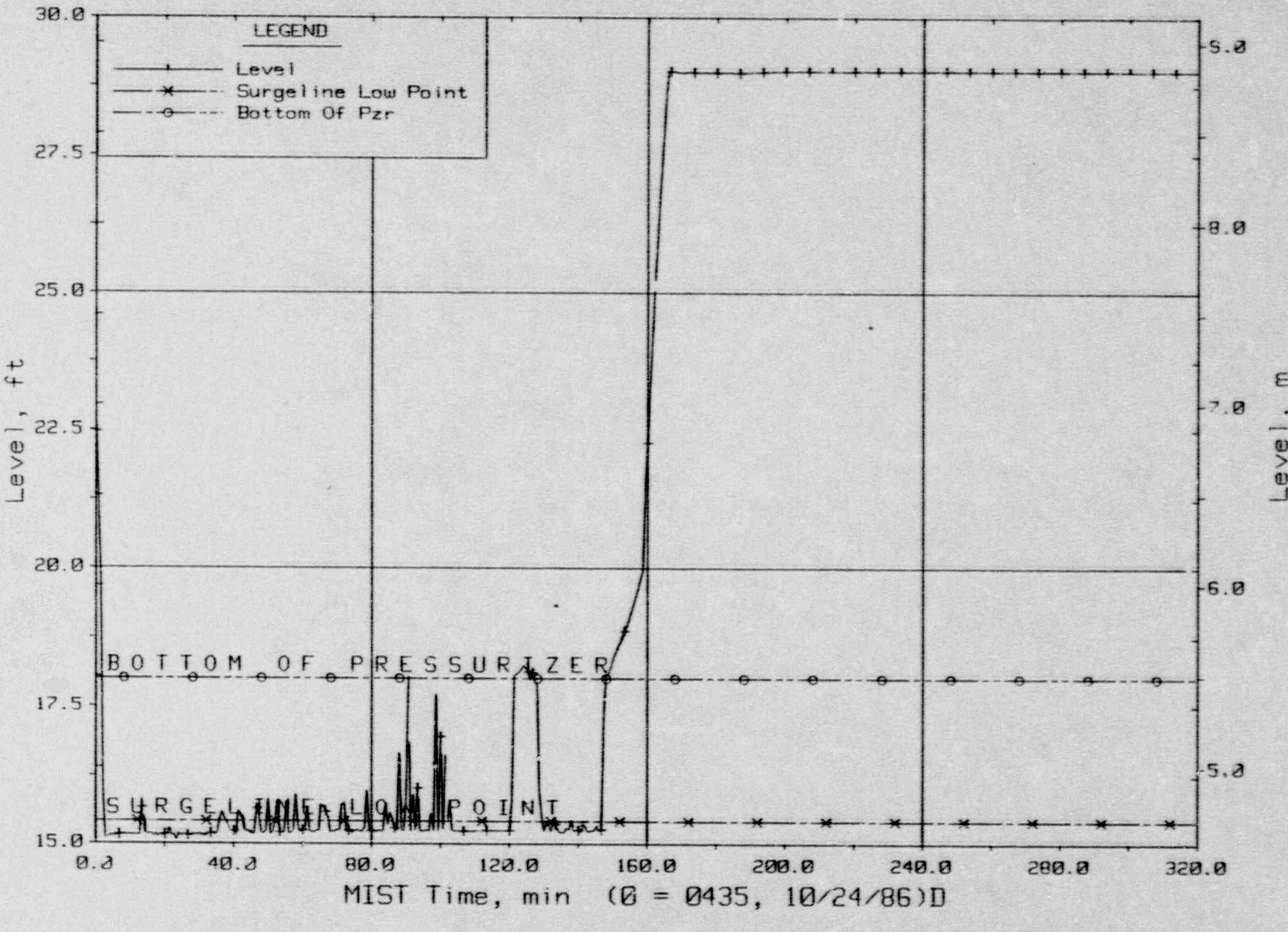
Guard Heater Specified Power, Pressurizer and Steam Generators.

Fri May 27 09:20:42 1988

PZGQ1

FINAL DATA

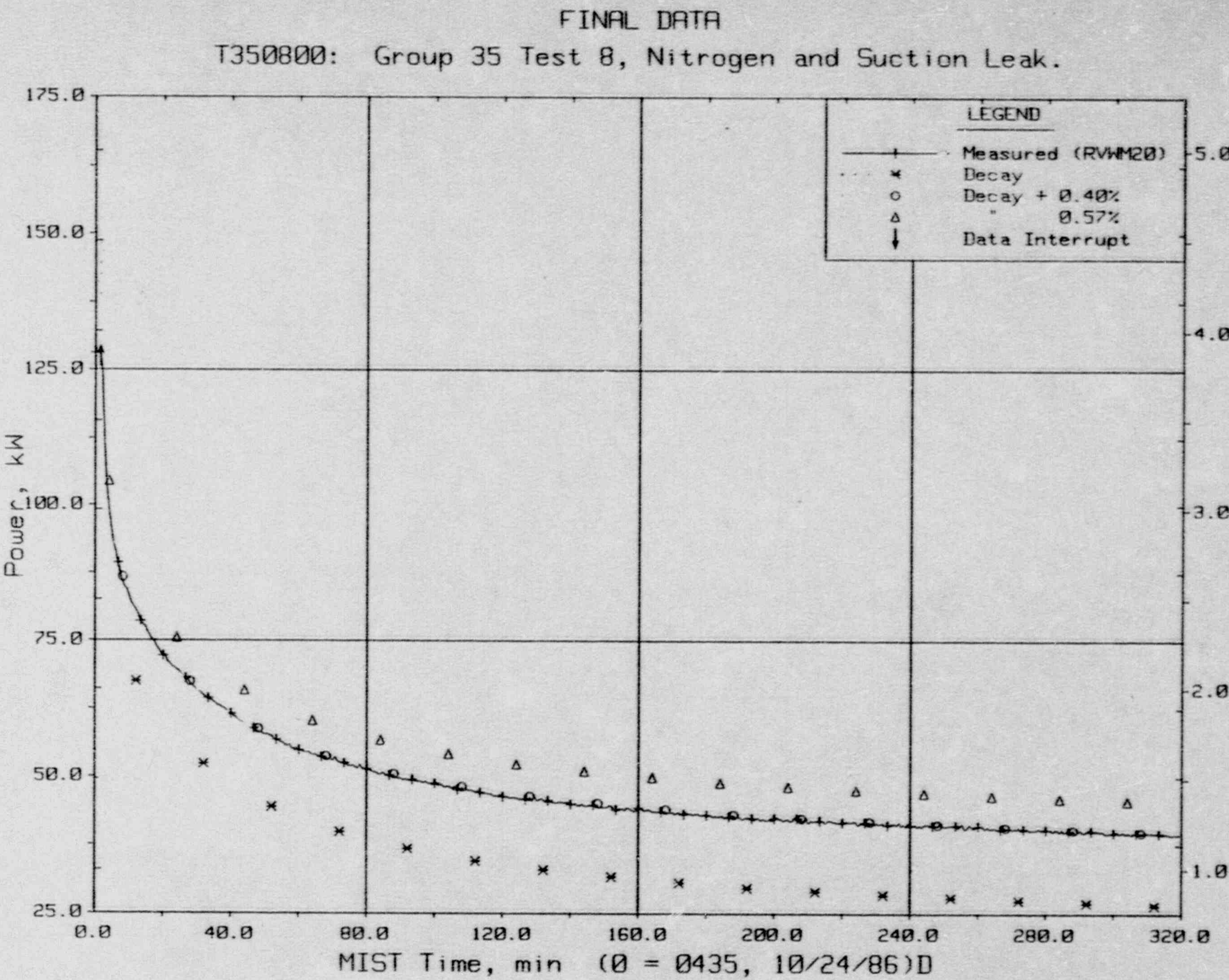
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Pressurizer Collapsed Liquid Level (PZLV20).

Fri May 27 09:24:35 1988

PZLV1



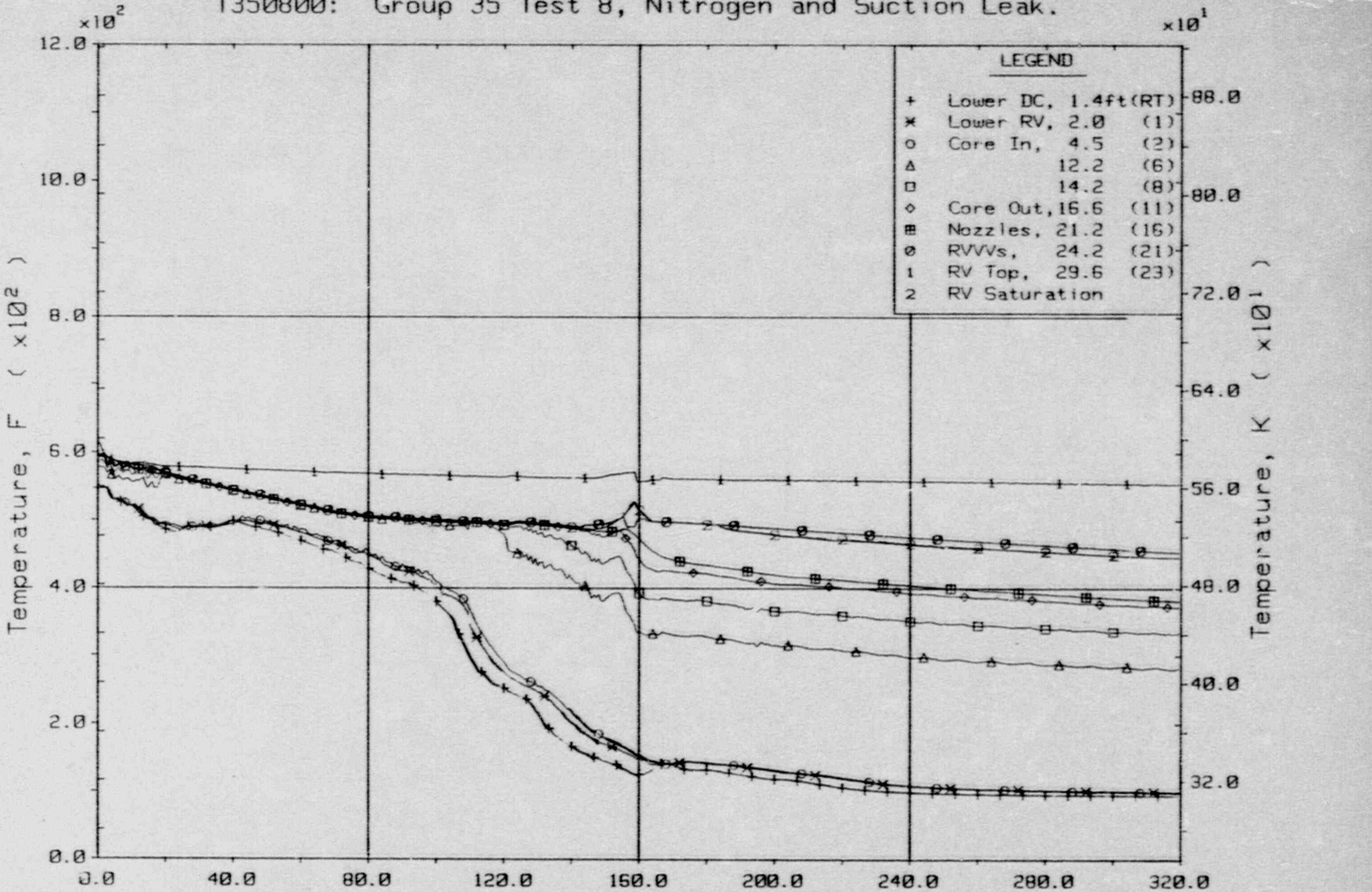
Core Power.

Fri May 27 09:28:30 1988

RVKW0

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



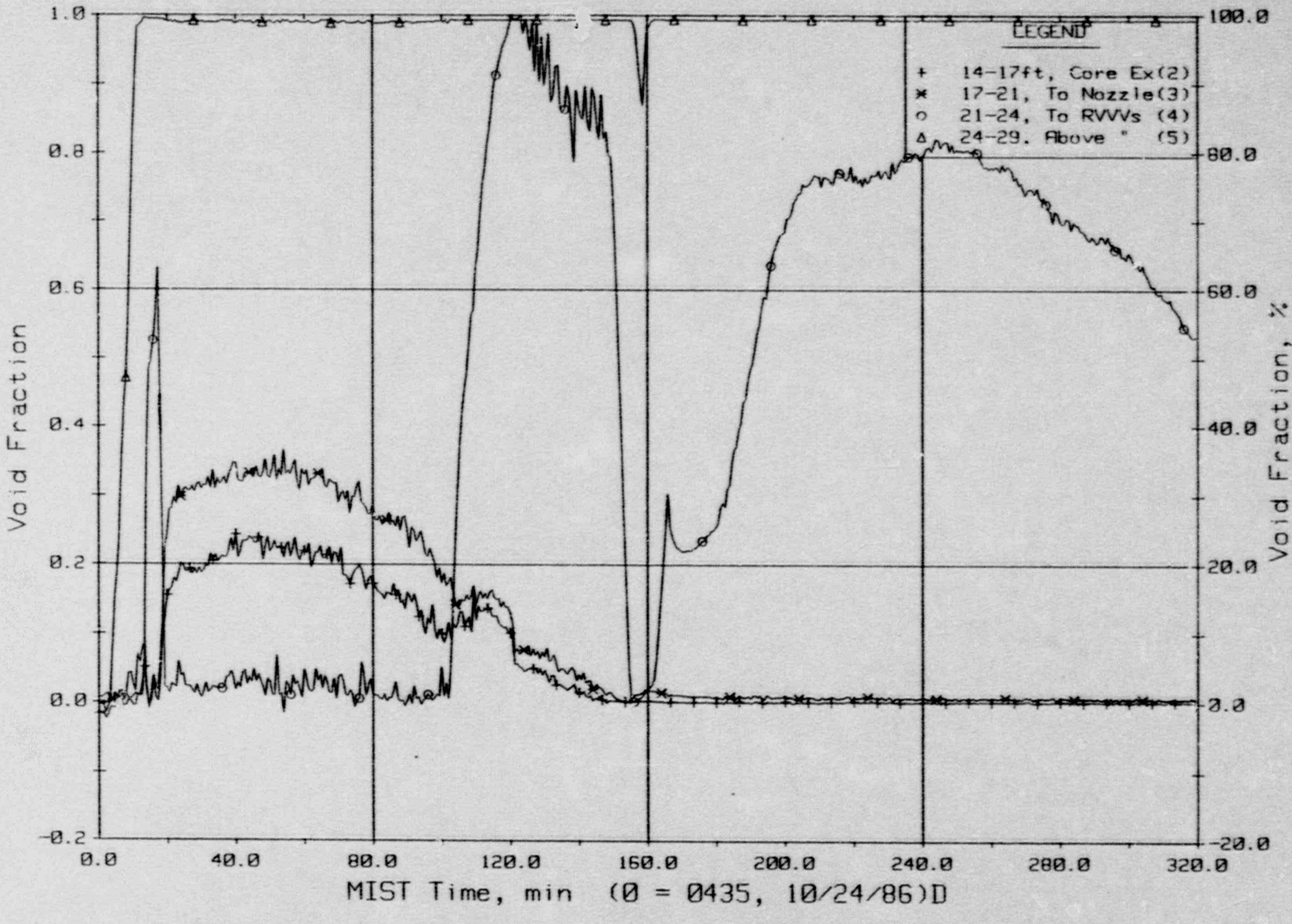
Core Unit Cell and Reactor Vessel Fluid Temperatures (RVTCs).

Fri May 27 09:34:06 1988

RVTC0

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



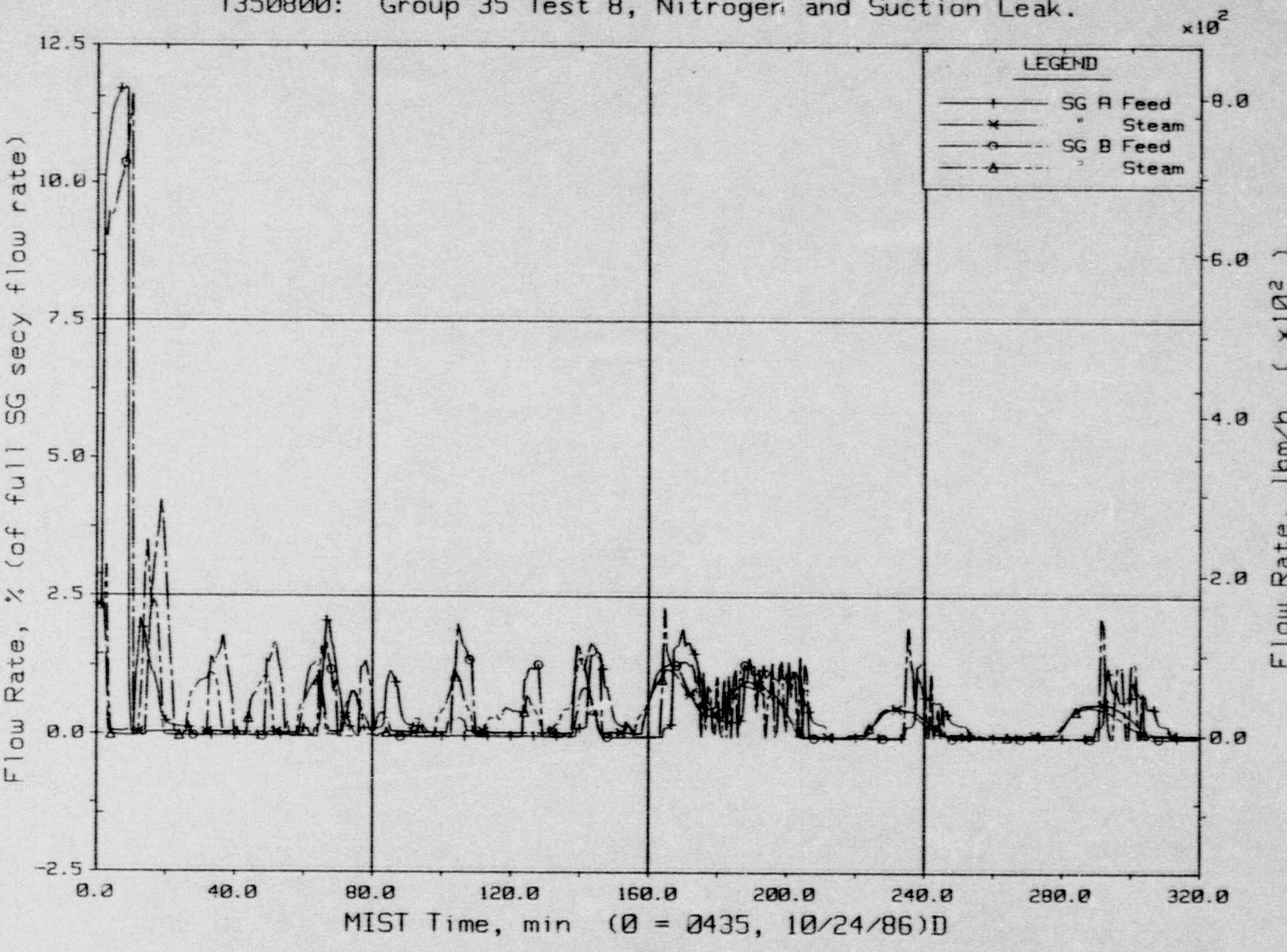
Reactor Vessel Void Fractions From Differential Pressures (RVVFs).

Fri May 27 09:37:19 1988

RVVF1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



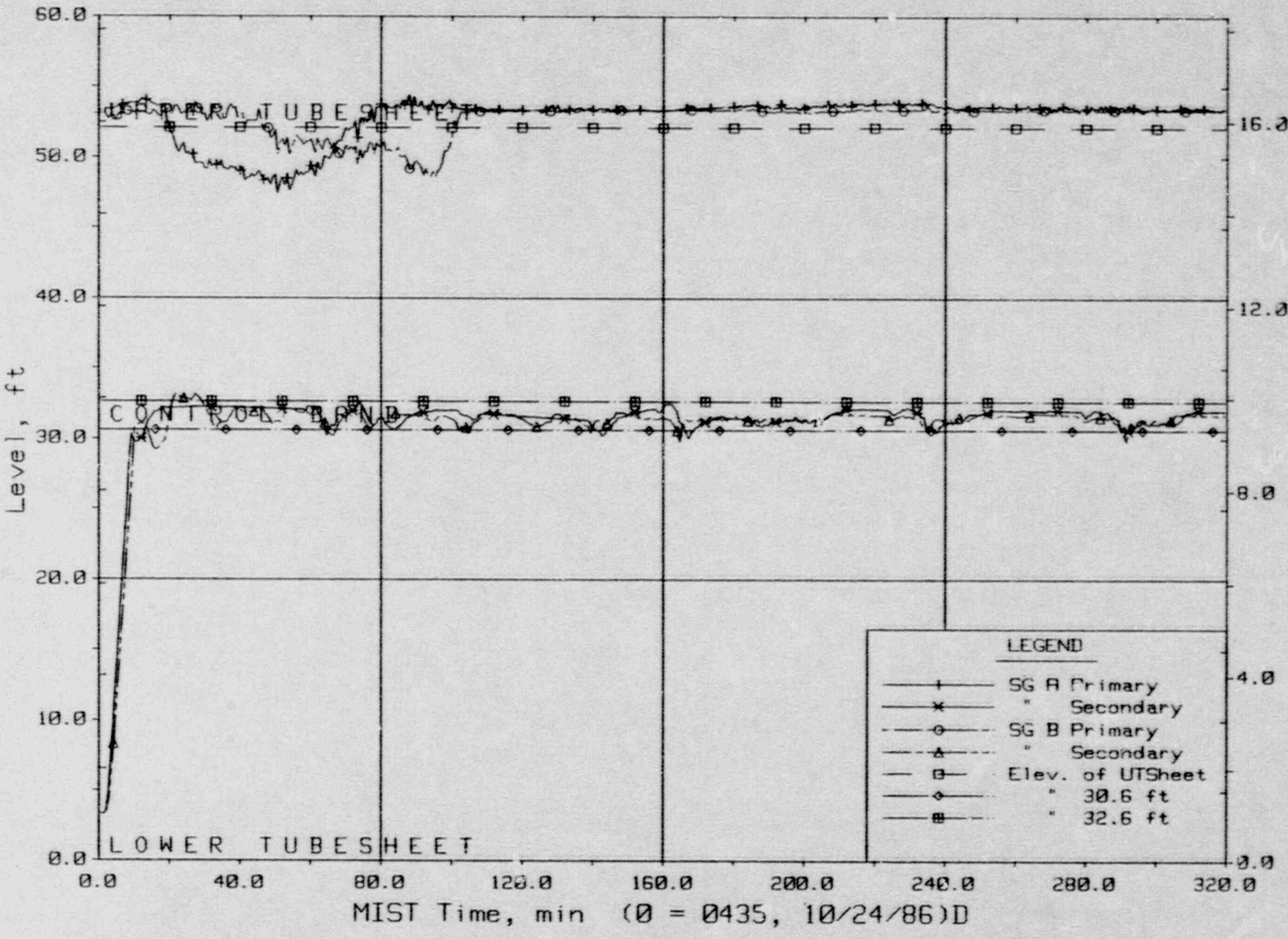
Steam Generator Secondary System Flow Rates.

Fri May 27 09:41:31 1988

SGFL2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



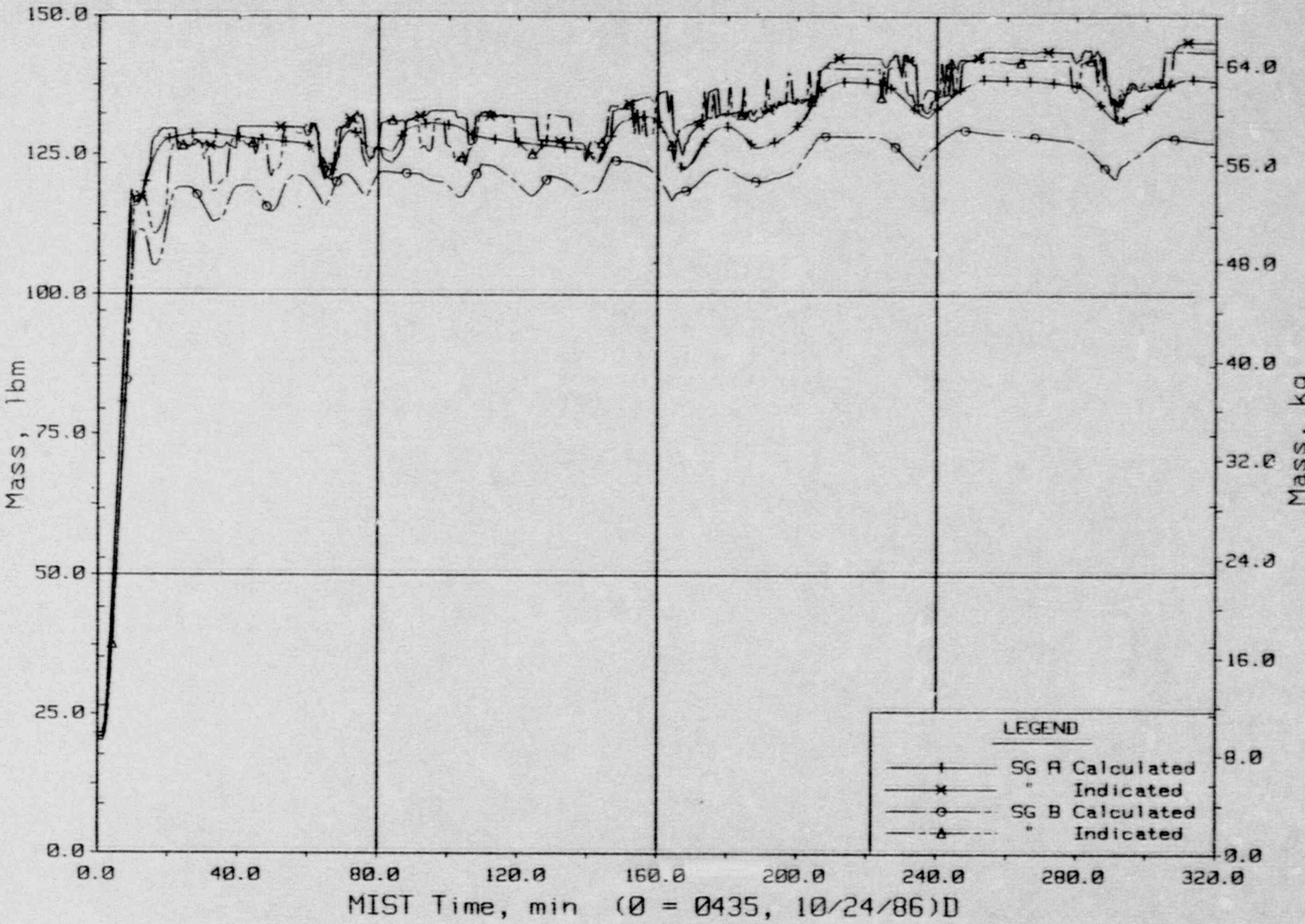
Steam Generator Collapsed Liquid Levels.

Fri May 27 09:45:50 1988

SGLV2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



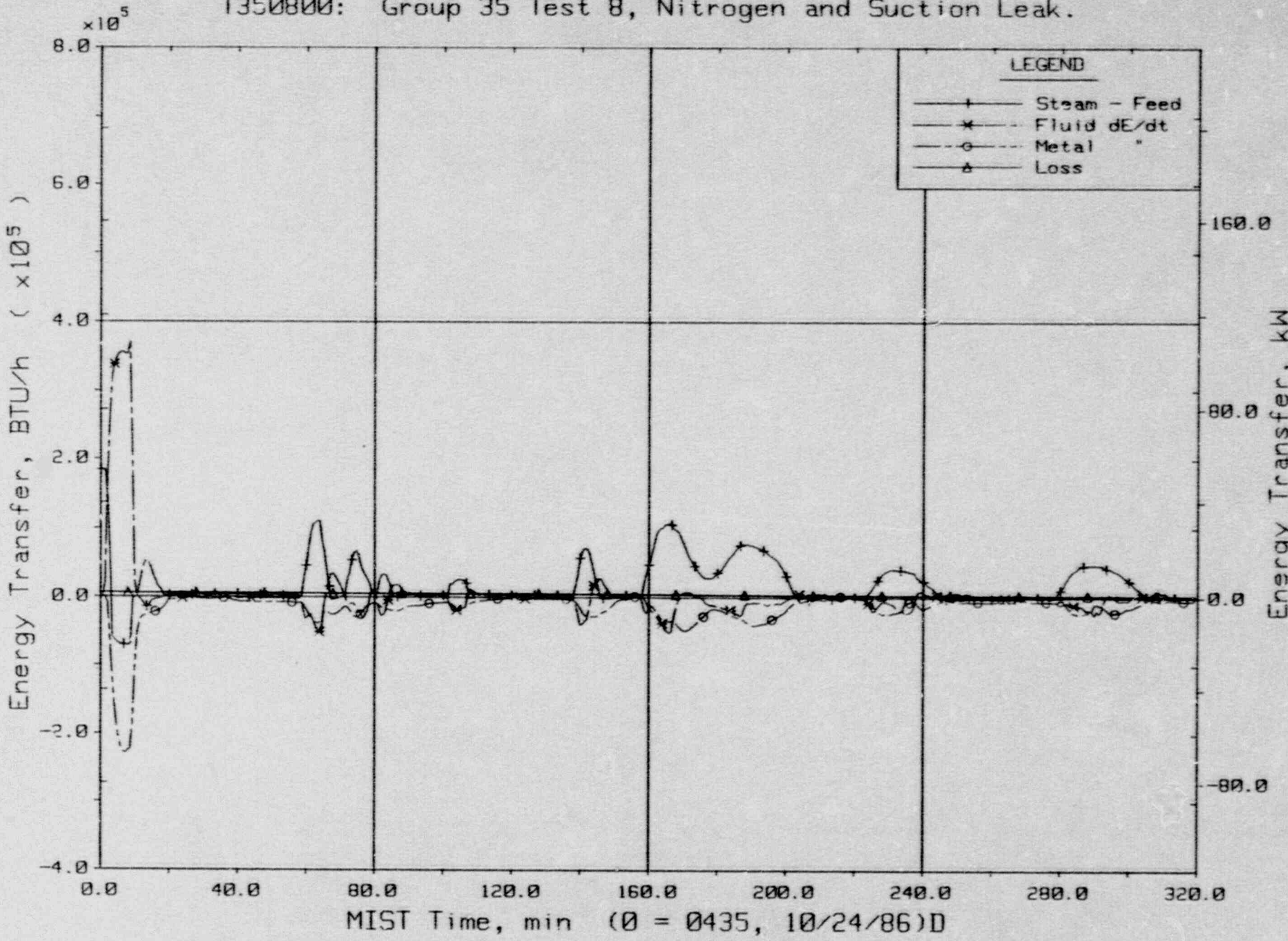
Steam Generator Secondary Fluid Mass Balances.

Fri May 27 09:50:42 1988

SGML1

FINAL DATA

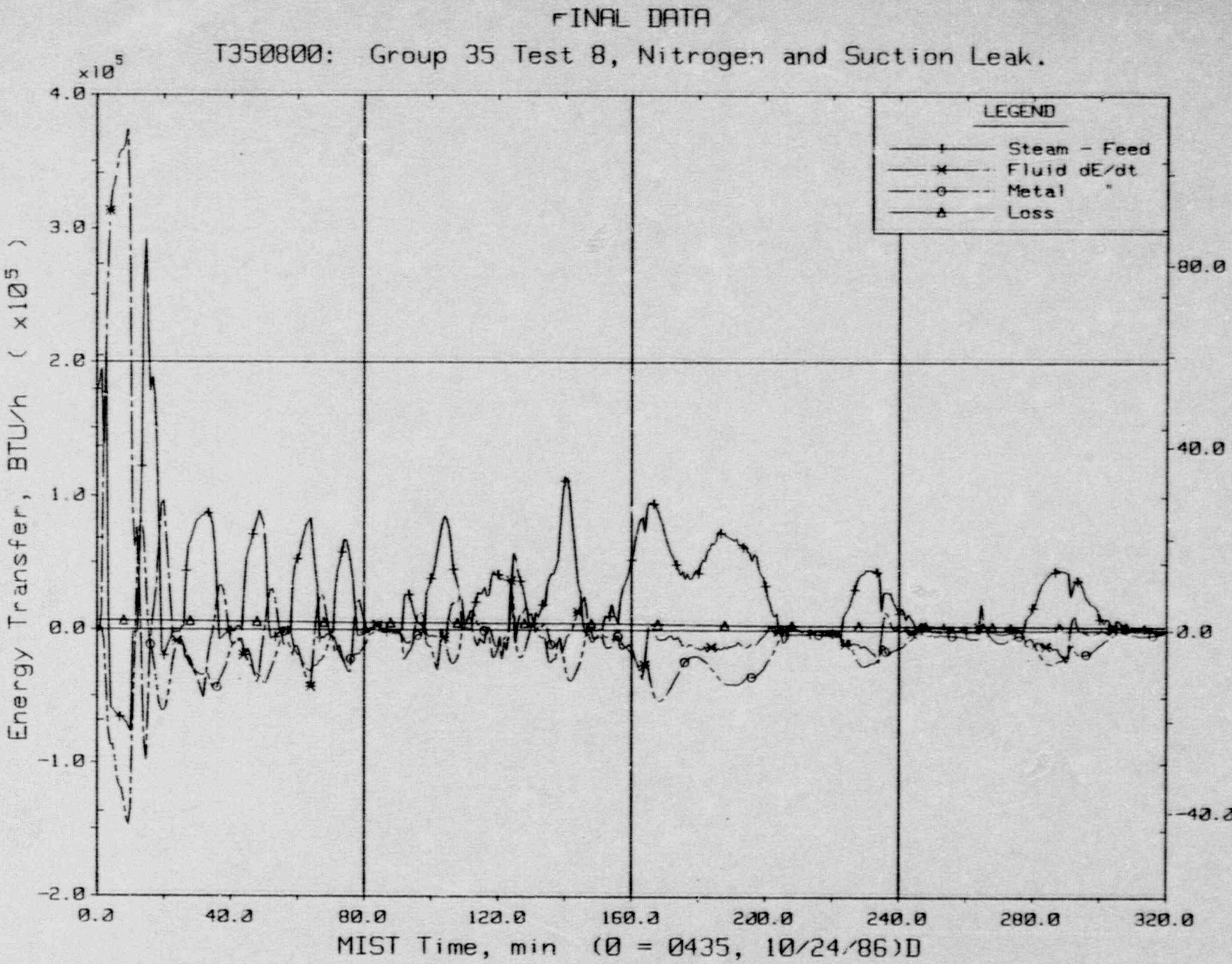
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Steam Generator A Energy Transfer.

Fri May 27 09:54:48 1988

SGQE3



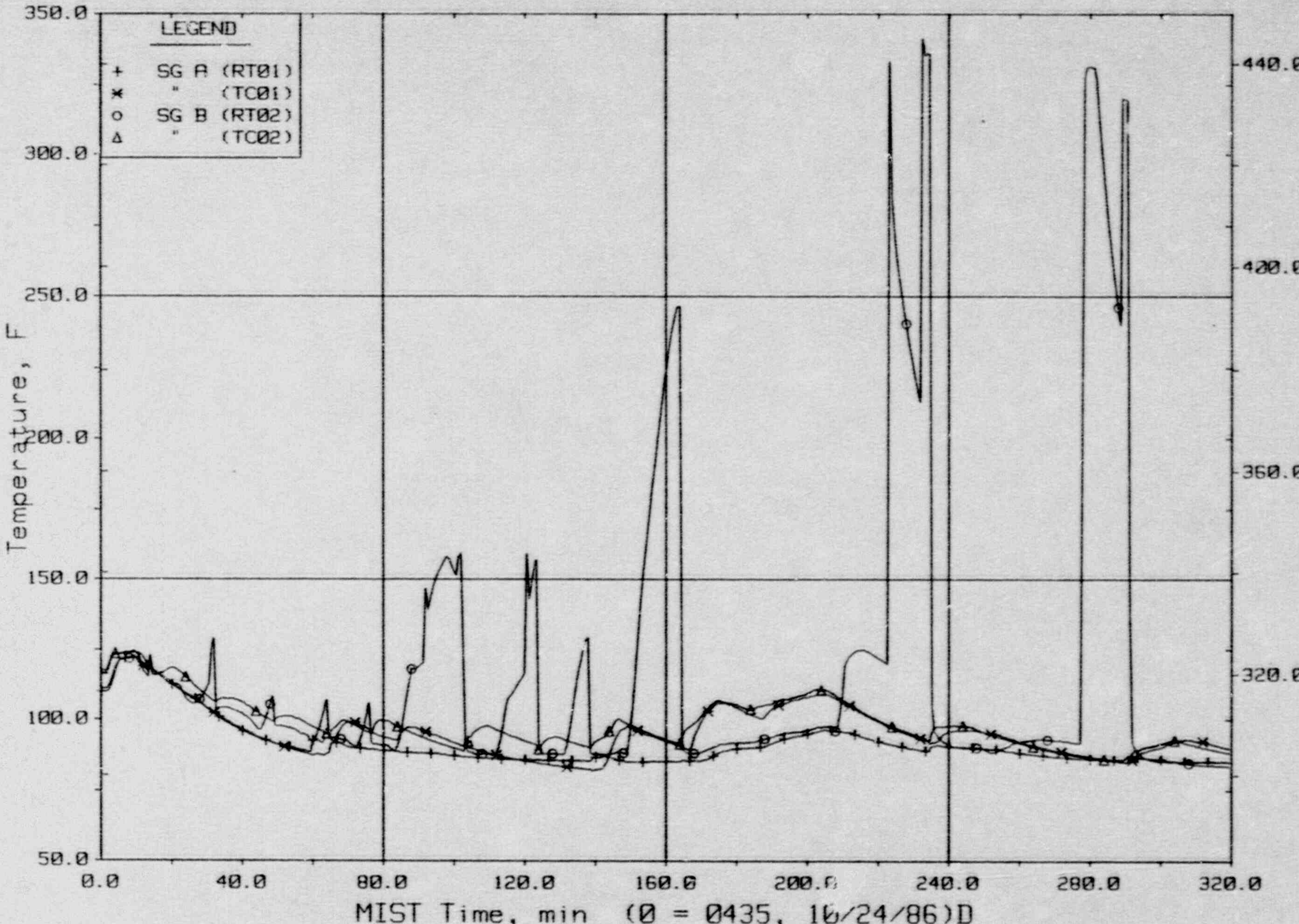
Steam Generator B Energy Transfer.

Fri May 27 09:59:12 1988

SGQE6

FINAL DATA

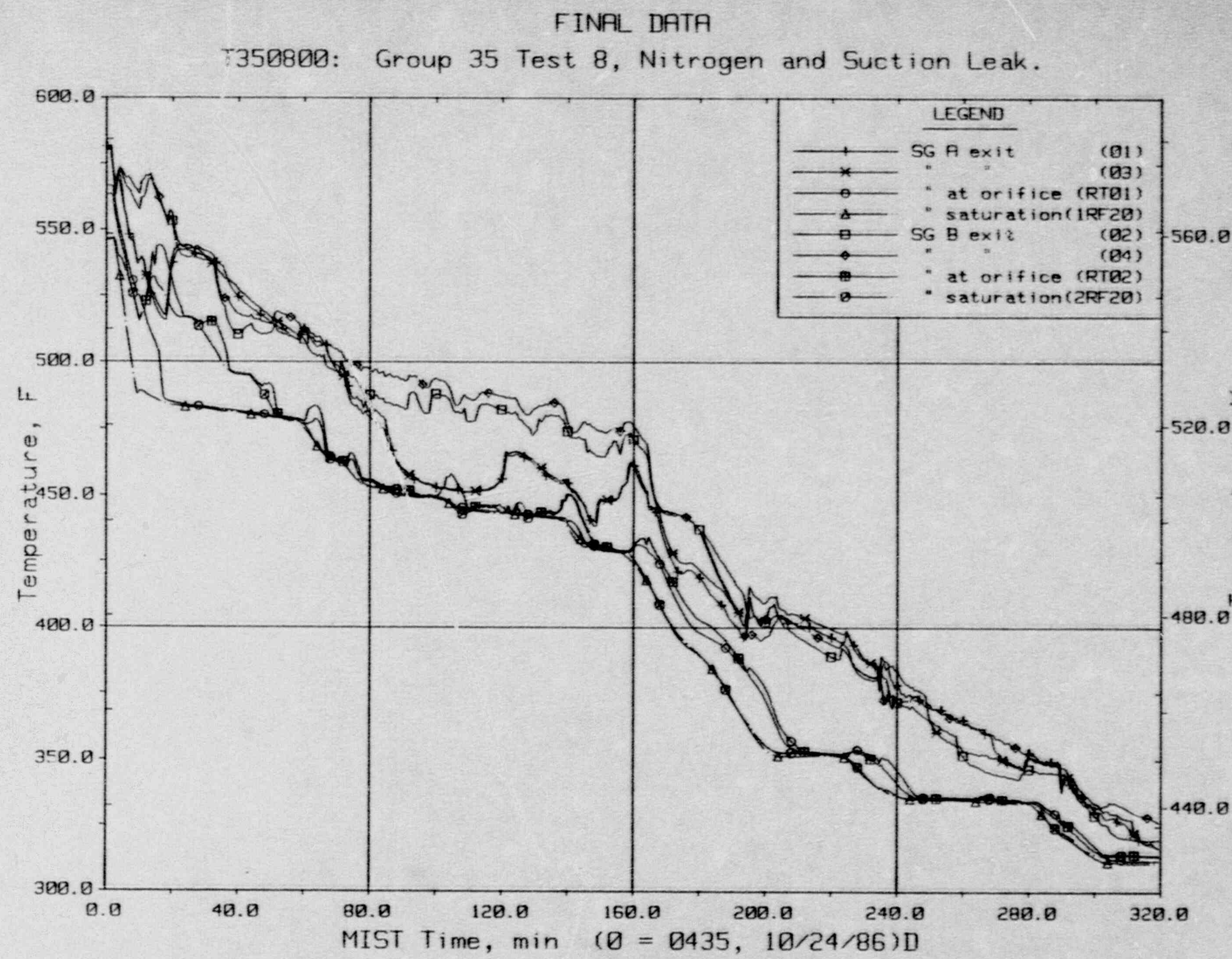
T350800: Group 35 Test 8, Nitrogen and Suction Leak.



Feedwater Temperatures (SFs).

Fri May 27 10:03:07 1988

SGRT1



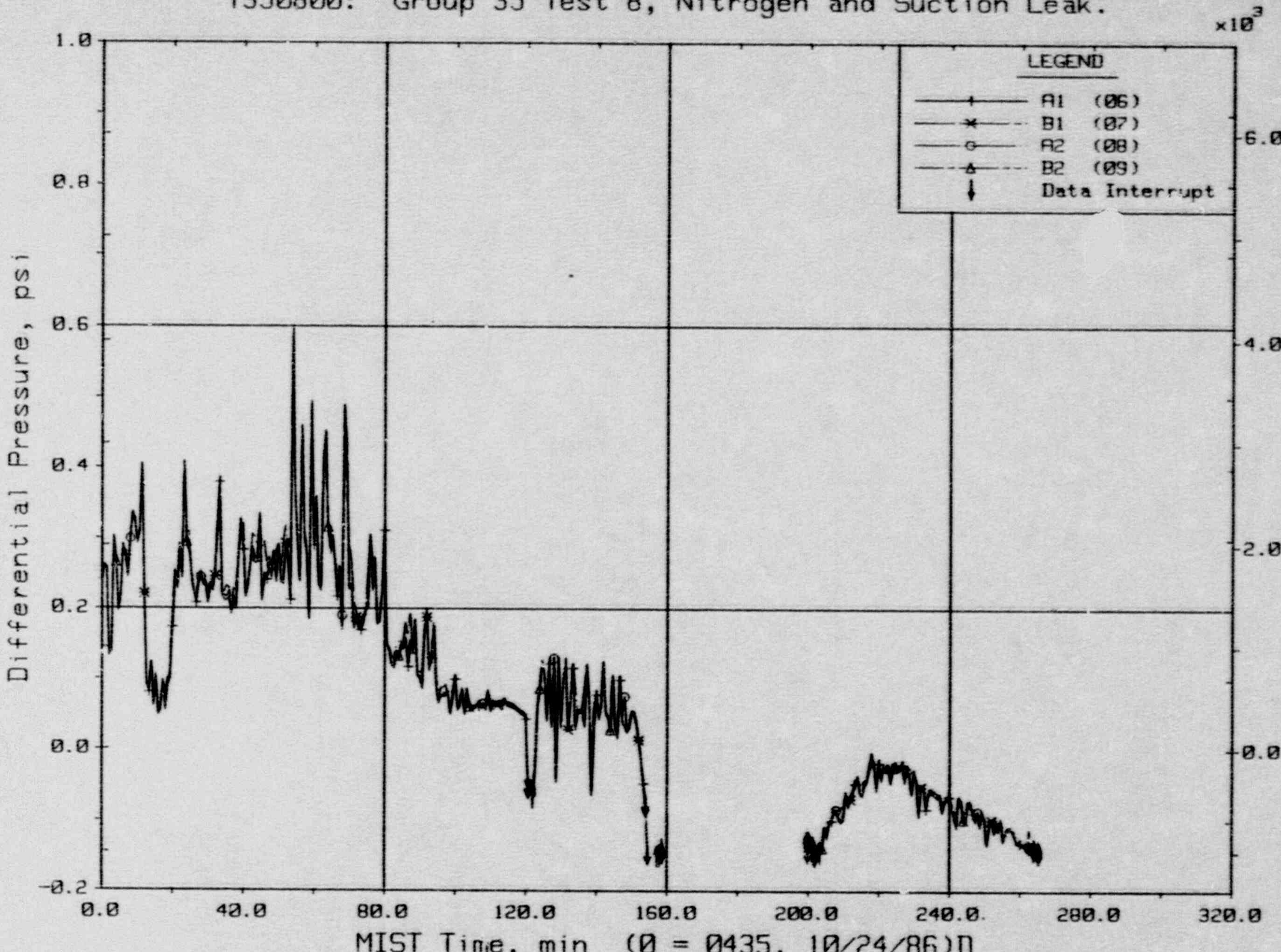
Steam Generator Steam Outlet Temperatures (SSTCs).

Fri May 27 10:08:35 1988

SGRT2

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



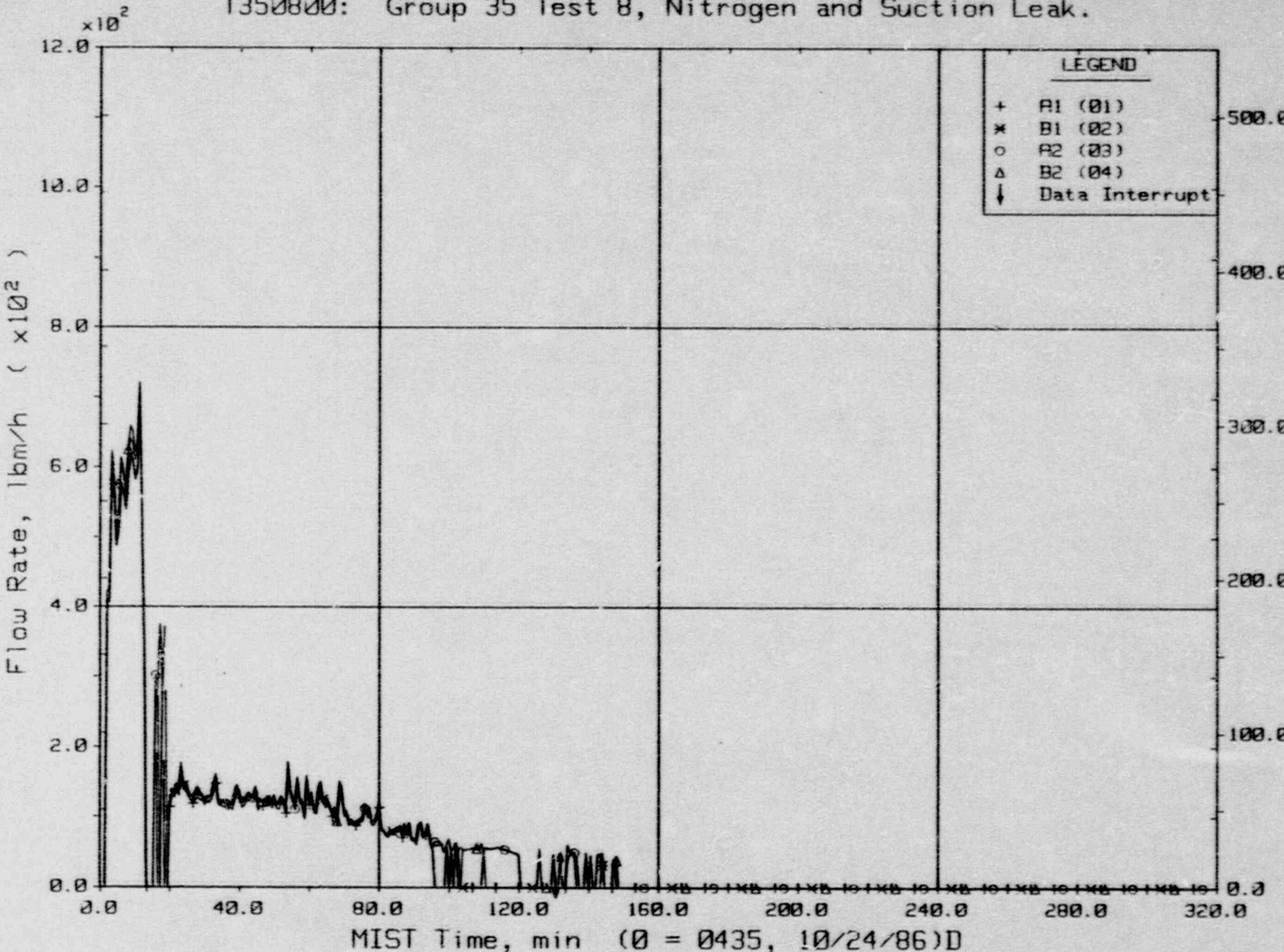
Reactor Vessel Vent Valve Differential Pressures (RVDPs).

Fri May 27 10:13:30 1988

VVDP1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



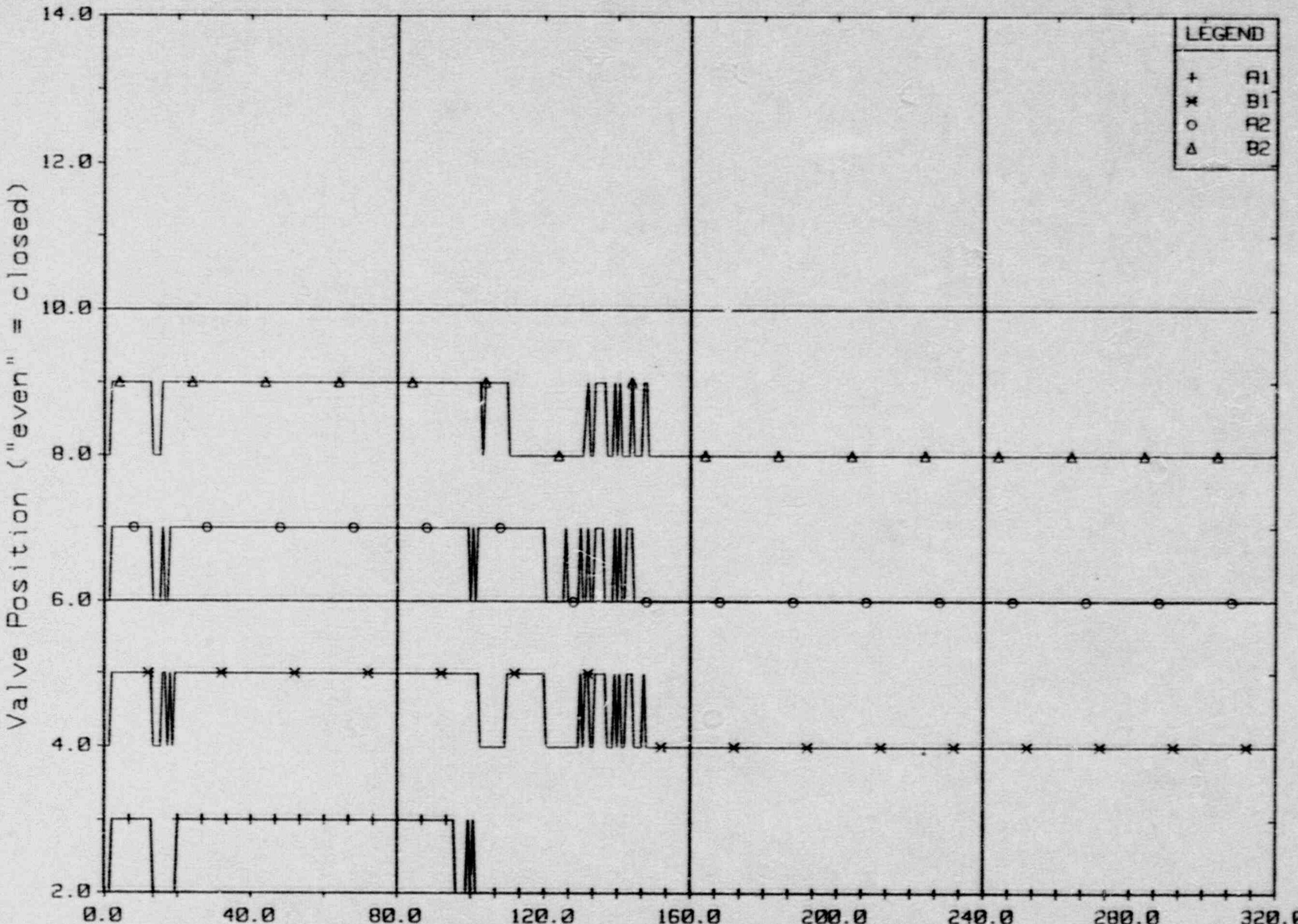
Reactor Vessel Vent Valve Flow Rates (RVORs).

Fri May 27 10:17:37 1988

VVFL1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



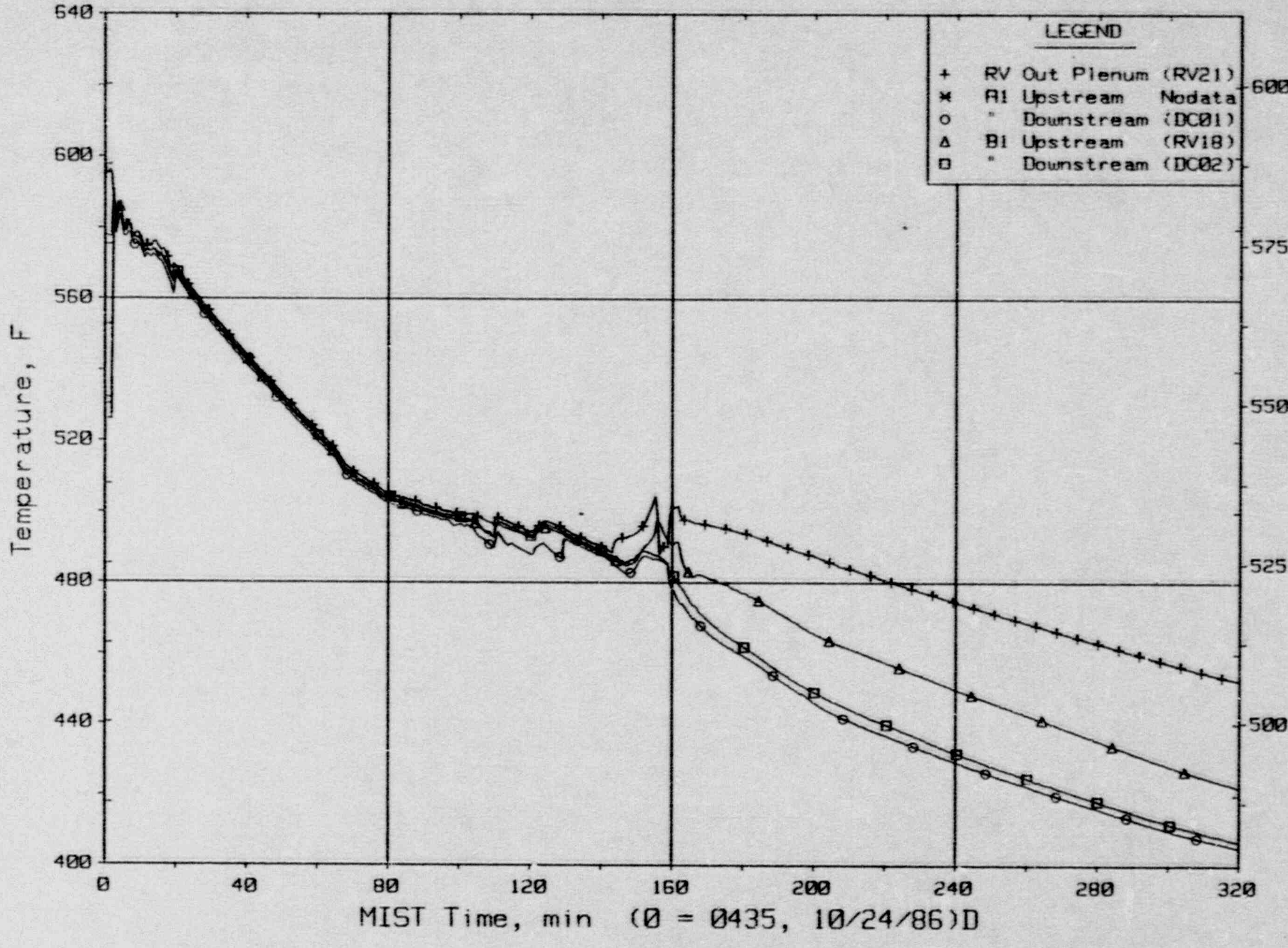
Reactor Vessel Vent Valve Positions.

Fri May 27 10:21:04 1988

VVLS1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



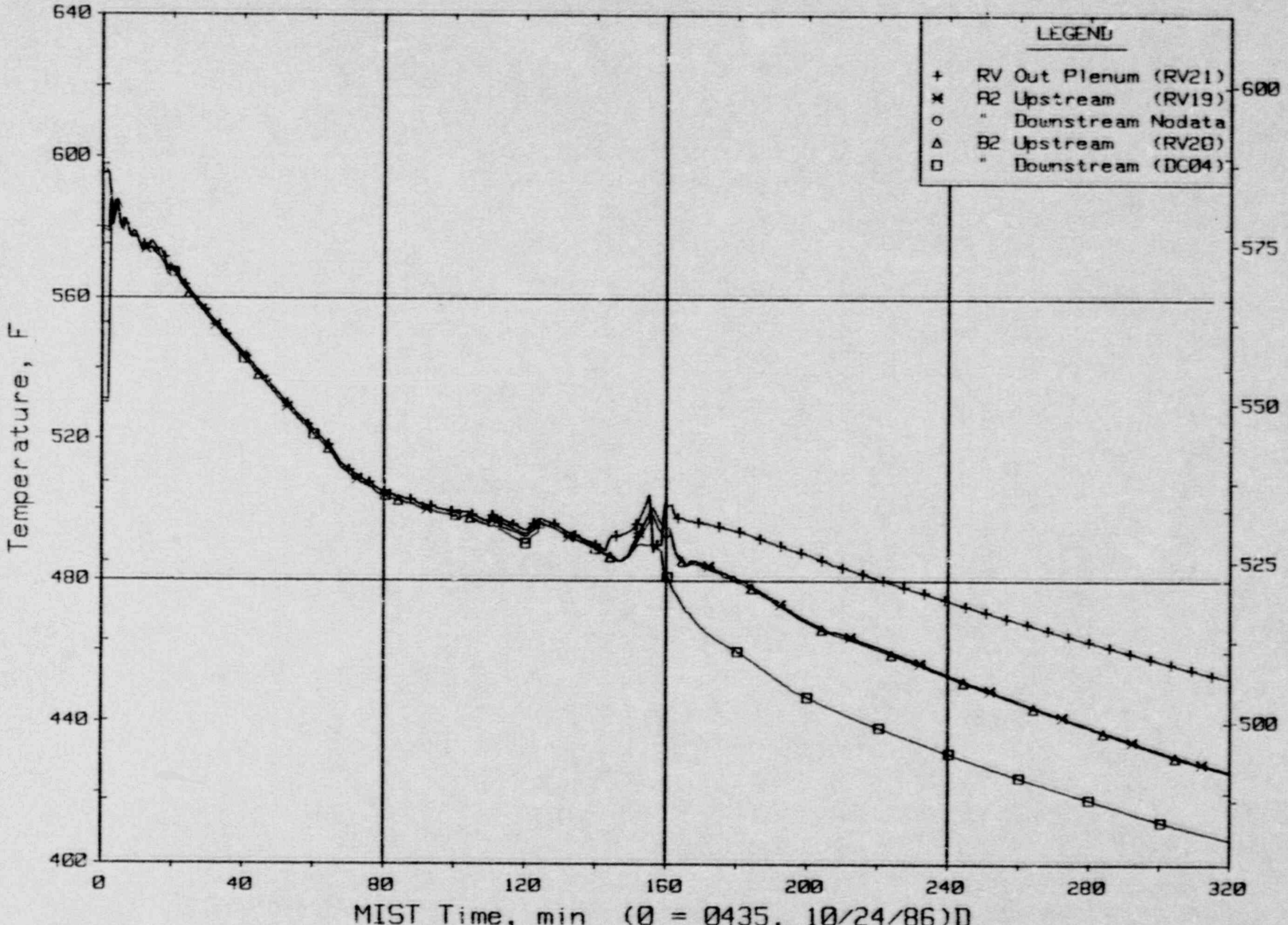
RVVVs A1 and B1 Bracketing Fluid Temperatures (TCs).

Mon Jan 16 12:04:35 1989

VVTC1

FINAL DATA

T350800: Group 35 Test 8, Nitrogen and Suction Leak.



RVVVs A2 and B2 Bracketing Fluid Temperatures (TCs).

Mon Jan 16 12:07:28 1989

VVTC2