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DCP/NRC0991
NSD-NRC-97-5275
Docket No.: 52-003

August 15, 1997

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

ATTENTION: T. R. QUAY

SUBJECT: RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION ON CHAPTER 15.6.5 OF THE AP600 STANDARD SAFETY ANALYSIS REPORT (RAI 440.660 AND RAI 440.662)

Dear Mr. Quay:

Attached are responses to requests for additional information on Chapter 15.6.5 of the AP600 Standard Safety Analysis Report. These responses close, from a Westinghouse perspective, RAI 440.660 (OITS-5533) and RAI 440.662 (OITS-5535). In addition, the response to RAI 440.660 addresses OITS-4515, OITS-4516, and OITS-4520 and the response to RAI 440.662 addresses OITS-4517. The Westinghouse status column in the OITS will be changed to "Action N" for all of the above items. The NRC should inform Westinghouse of the status to be designated in the "NRC Status" column of the OITS.

Please contact Ms. Susan V. Fanto (412)374-4028, if you have any questions concerning this material.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

E004 1/1

jml

Attachment

cc: W. C. Huffman, NRC (w/Attachment)
N. J. Liparulo, Westinghouse (w/o Attachment)

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RAI 440.660:

SSAR 15.6.5 describes the results of the LOCA break spectrum study for AP600. The NOTRUMP code is used to perform small-break LOCA analyses for the range of breaks from 0.5-inch to 10-inch diameter (about 0.55 sq.ft. cross sectional area), while the WCOBRA/TRAC code is used to analyze large-break LOCAs for breaks ranging from a DECLG break to a break of 14-inch diameter (approximately 1.0 sq.ft. cross sectional area). Westinghouse should justify the use of the NOTRUMP and WCOBRA/TRAC for LOCA analyses in the ranges of break sizes as proposed in SSAR 15.6.5. In addition, the LOCAs with breaks from 0.55 sq.ft. to 1.0 sq.ft. cross sectional area should be analyzed and the results should be provided for the staff to review. The analysis should use methods acceptable to the staff and identify the limiting LOCA case to satisfy the requirements of item (a)(1)(i) of 10CFR50.46.

Response:

The NOTRUMP code is used to analyze small break LOCAs up to and including 10 inches in equivalent diameter as reported in AP600 SSAR subsection 15.6.5. The NOTRUMP code version validated against the AP600-related tests (Reference 440.660-1) is used in these analyses. The validation against SPES and OSU integral tests which is documented in the reference justifies use of the code for break sizes up to the 7-inch equivalent diameter size of a postulated double-ended cold leg balance line rupture. Furthermore, the use of NOTRUMP for sizes up to and including the 92 sq.in. present when all ADS Stage 1 through 3 valves have opened is justified by the inadvertent ADS transient test simulations. Therefore, NOTRUMP may also be used to analyze the 10-inch equivalent diameter break size in AP600.

The WCOBRA/TRAC best estimate computer code (Reference 440.660-2) is used to analyze large break LOCAs in AP600 SSAR subsection 15.6.5. In Reference 440.660-2, Section 16.4, simulations of critical flow tests at nozzle diameters of 11.8 inches and greater produced good agreement between code and data. On this basis, WCOBRA/TRAC is used to analyze AP600 guillotine breaks and splits at the 0.6 split discharge coefficient (CD) size and larger in SSAR subsection 15.6.5.

The range of break sizes for which WCOBRA/TRAC was validated in Reference 440.660-2 supports its use for breaks as small as 11.8 inches in equivalent diameter. To augment the SSAR LOCA break spectrum, the CD=0.4 cold leg split break (area equals 1.056 sq.ft.) and a 12.0 inch diameter cold leg split break (area equals 0.785 sq.ft.) are analyzed as reported below. These two cases fill in the break size spectrum between the 10-inch diameter cold leg break (area equals 0.545 sq.ft.) analyzed with the NOTRUMP code and the larger size breaks which are analyzed with WCOBRA/TRAC as presented in SSAR Section 15.6.5.4A. The same WCOBRA/TRAC input and code version as used for the AP600 SSAR analysis are used for the two cases reported in this RAI response.

A review of the predicted pertinent phenomena among the WCOBRA/TRAC cases as break size decreases indicates that applying WCOBRA/TRAC to these smaller sizes is reasonable. The CD=0.4 split break case PCT transient does not exhibit blowdown and reflood peaks as do the DECLG breaks and the larger splits of SSAR Table 15.6.5-8; its hot rod PCT transient is shown in Figure 440.660-1, and PCT transients of the hot assembly, open hole, guide tube and peripheral assembly fuel rods are shown in Figure 440.660-2. The CD=0.4 split break is large enough to exhibit a downward (negative) liquid flow at the bottom of the core, but small enough that the liquid flow at the top of the core is positive (Figure 440.660-3). AP600 DECLG and large split break cases exhibit strong liquid downflow at the top of the core, as in SSAR Figure 15.6.5A-3, 6, 9, etc., during the latter part of the blowdown transient. The PCT excursion to thehot rod peak value of 892F occurs because the CD= 0.4 split break is large enough to deplete the vessel core and downcomer of its liquid inventory before the accumulator provides adequate water flow to replenish the vessel. As shown in Figures 440.660-4, 5, and 6, the core hot assembly becomes void of liquid during the rod heatup, and the lower plenum and downcomer also are depleted of mass. Once the accumulators are available, the core hot assembly quickly recovers, as shown in Figure 440.660-7. The reduced break flow through the smaller size split break delayed CHF and subsequent rod heatup such that the blowdown heatup phase observed in the large break LOCA cases did not occur until the reactor vessel was refilling. The pressure in the upper plenum is shown in Figure 440.660-8. Later in the transient, once the accumulator delivery rate slows because the nitrogen gas pressure approaches the vessel pressure of 80 psia, the core makeup tanks inject the flow necessary to maintain the core and downcomer liquid levels. Eventually, the CMTs drain to the ADS actuation setpoint, and the ADS depressurizes the RCS to the containment pressure.

The 12-inch break case continues the trend identified in the CD=0.4 split break. The depressurization due to the break is initially slower, as expected for a smaller break (Figure 440.660-16). The PCT transient for this break exhibits a single excursion similar to that of the CD=0.4 split, but the PCT time occurs later, and the PCT value is lower (817F), as shown in Figures 440.660-9 and 10. In this case, the bottom core flow again exhibits an interval of negative flow, but the magnitude of the negative flow absolute maximum value is only 50% of the CD=0.4 split break value (Figure 440.660-11). Figure 440.660-12 shows that the core hot assembly does not become completely void of liquid during the rod heatup period for the 12 inch equivalent diameter break. The collapsed liquid levels in the downcomer and lower plenum are significantly higher than in the CD=0.4 split break case, as shown in Figures 440.660-13 and 14. As in the CD=0.4 split break case, accumulator flow recovers the hot assembly with two-phase mixture (Figure 440.660-15).

The progression of phenomena as break size is decreased in these two WCOBRA/TRAC runs is reasonable. As the break size decreases from 1.056 sq.ft. to 0.785 sq.ft., the calculated PCT decreases from 892F to 817F. Consistent with this trend, the NOTRUMP result for the 0.545 sq.ft. break predicts no cladding heatup to occur during the transient; the PCT for this break is predicted to occur at the steady-state initial operating condition (PCT equals 706F). Moreover, the negative core flow period associated with large break LOCAs also diminishes in these runs, consistent with its relative unimportance for the 10-inch (and smaller) break sizes analyzed with NOTRUMP in the AP600 SSAR.

The LOCA break spectrum in SSAR Chapter 15.6.5 as augmented with the WCOBRA/TRAC cases reported herein is adequate to satisfy the requirement to analyze a range of break sizes for AP600. Figure 440.660-17 is attached to show the dependence of calculated PCT on break size. It illustrates that the large break LOCA DECLG case is the most limiting break size in the AP600 LOCA spectrum, and that the intermediate break sizes analyzed in response to this RAI are non-limiting.

SSAR Revision: None

References:

440.660-1 Fittante, R. L., et.al.," NOTRUMP Final Validation Report for AP600," WCAP-14807, Revision 1, (Proprietary), January 1997.

440.660-2 Bajorek, S. M., et.al., "Code Qualification Document for Best Estimate LOCA Analysis", WCAP-12945-P, Volumes 1 through 5.

FIGURE 440.660-1

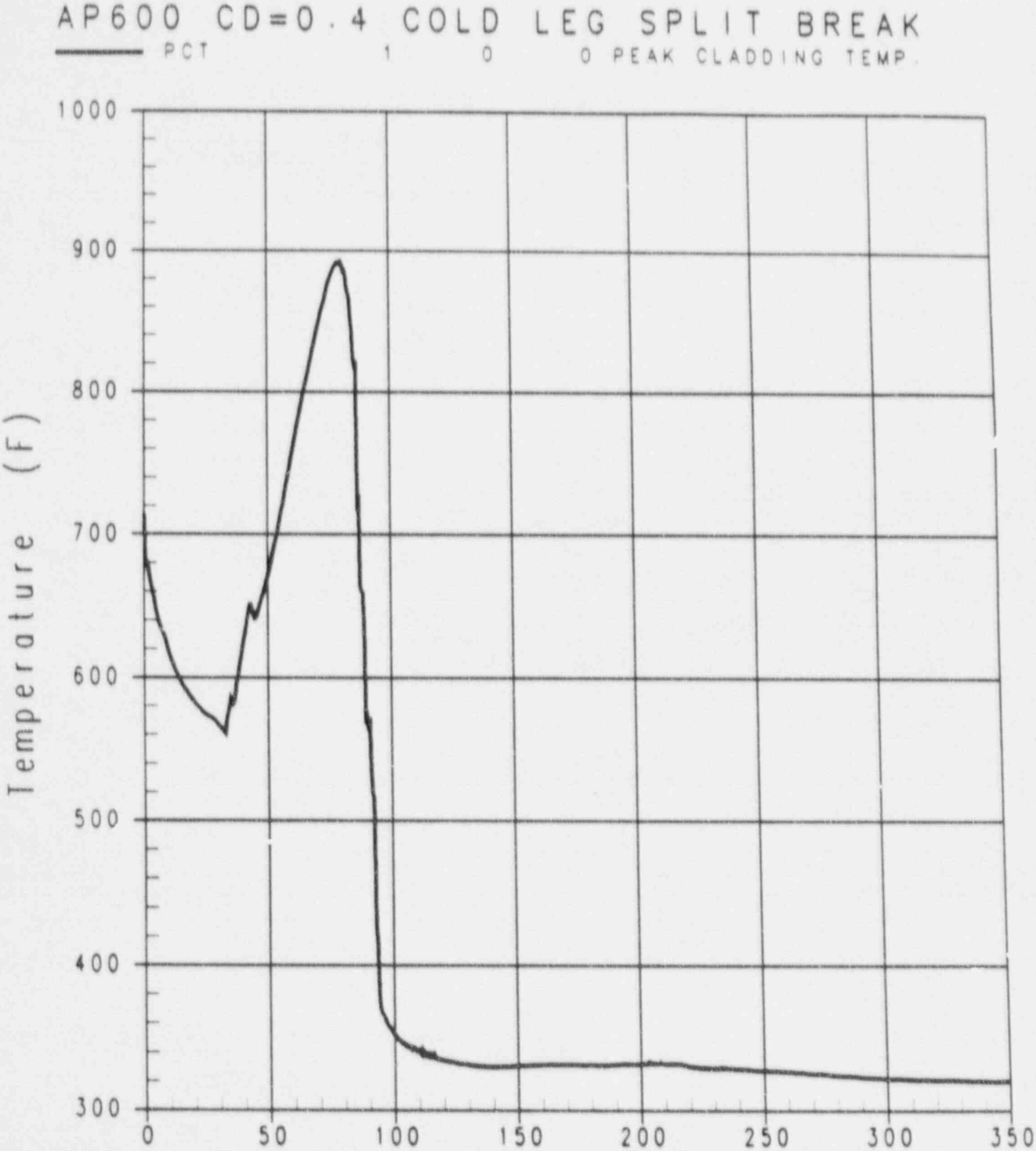


FIGURE 440.660-2

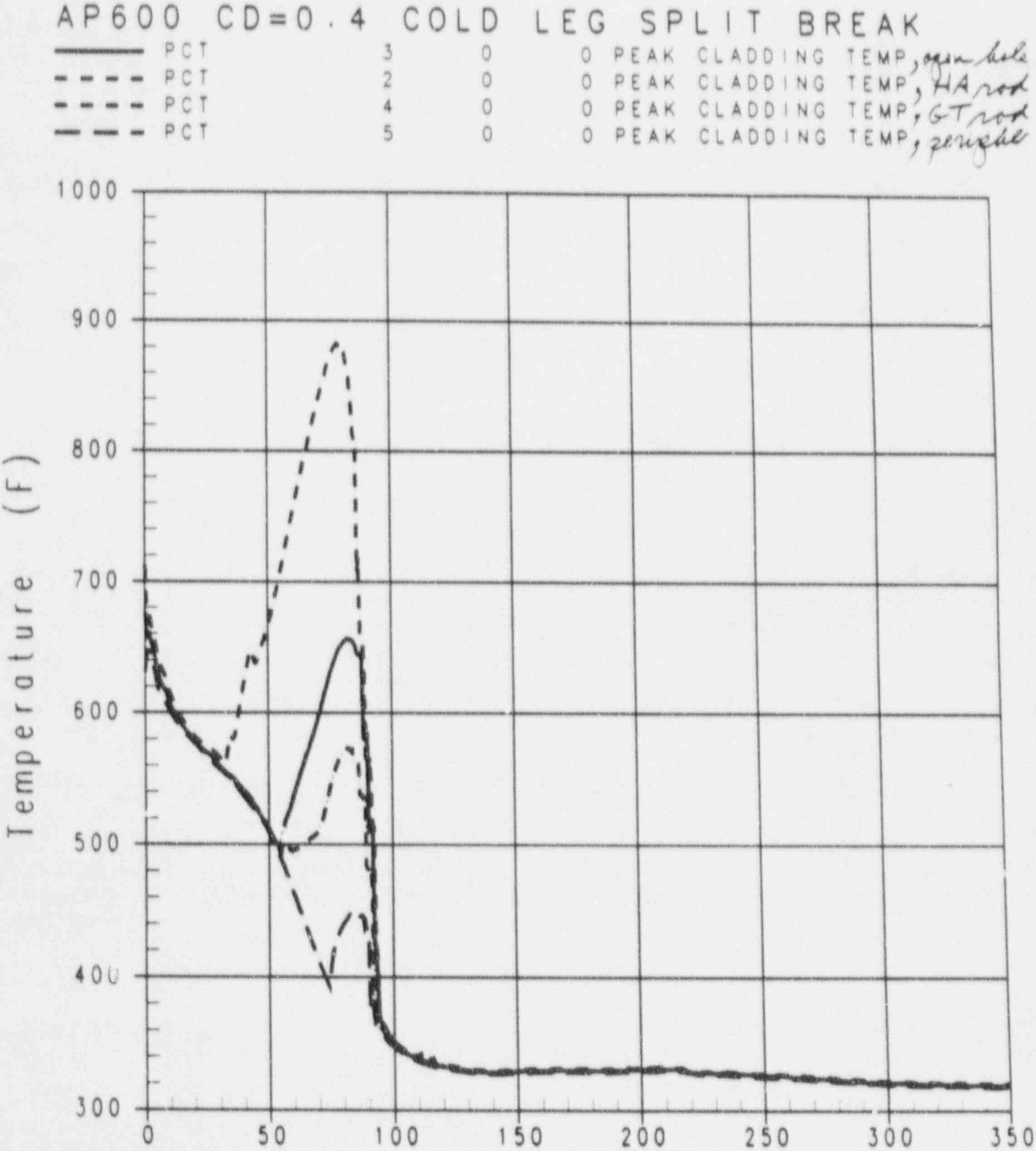


FIGURE 440.660-3

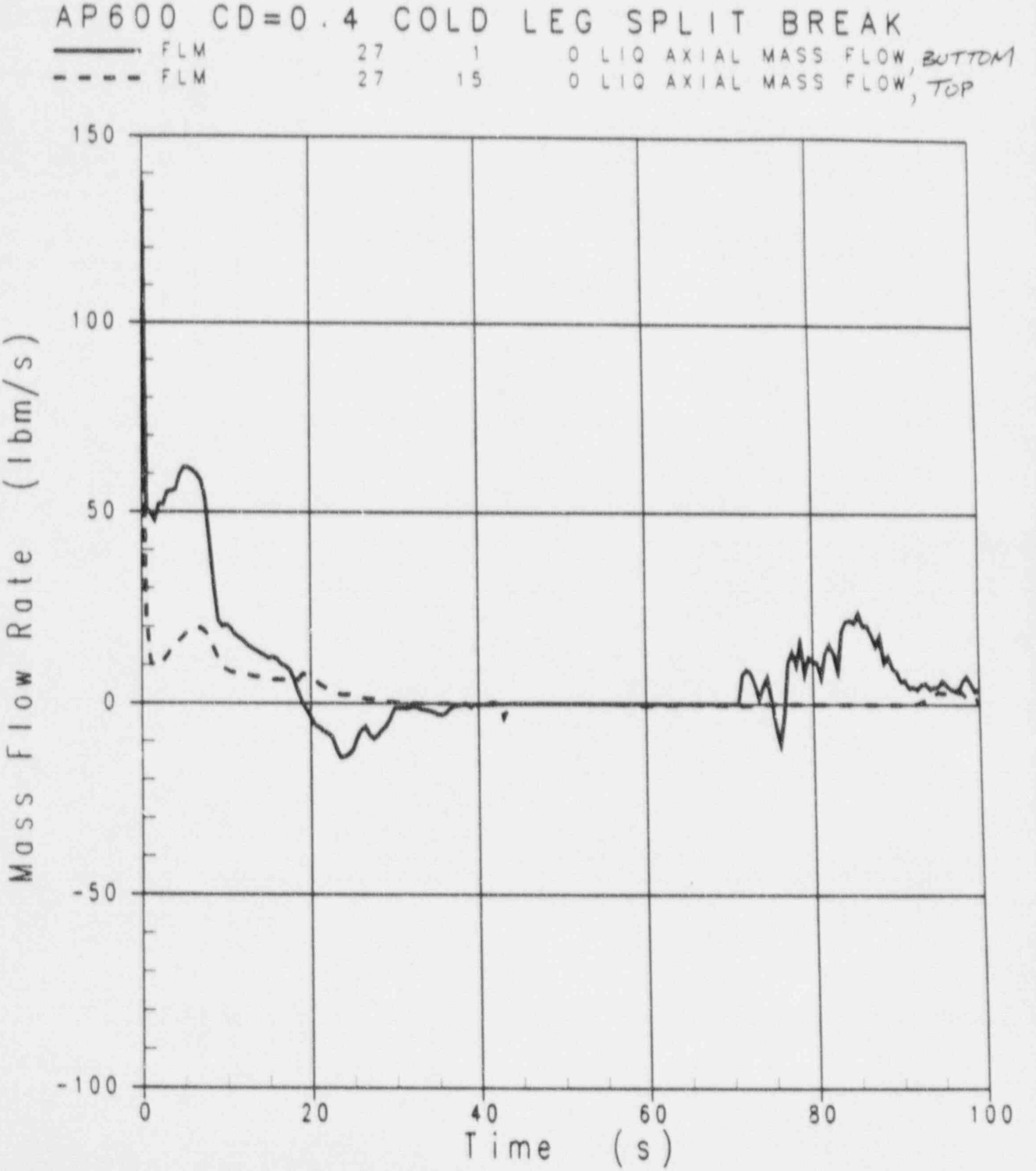


FIGURE 440.660-4

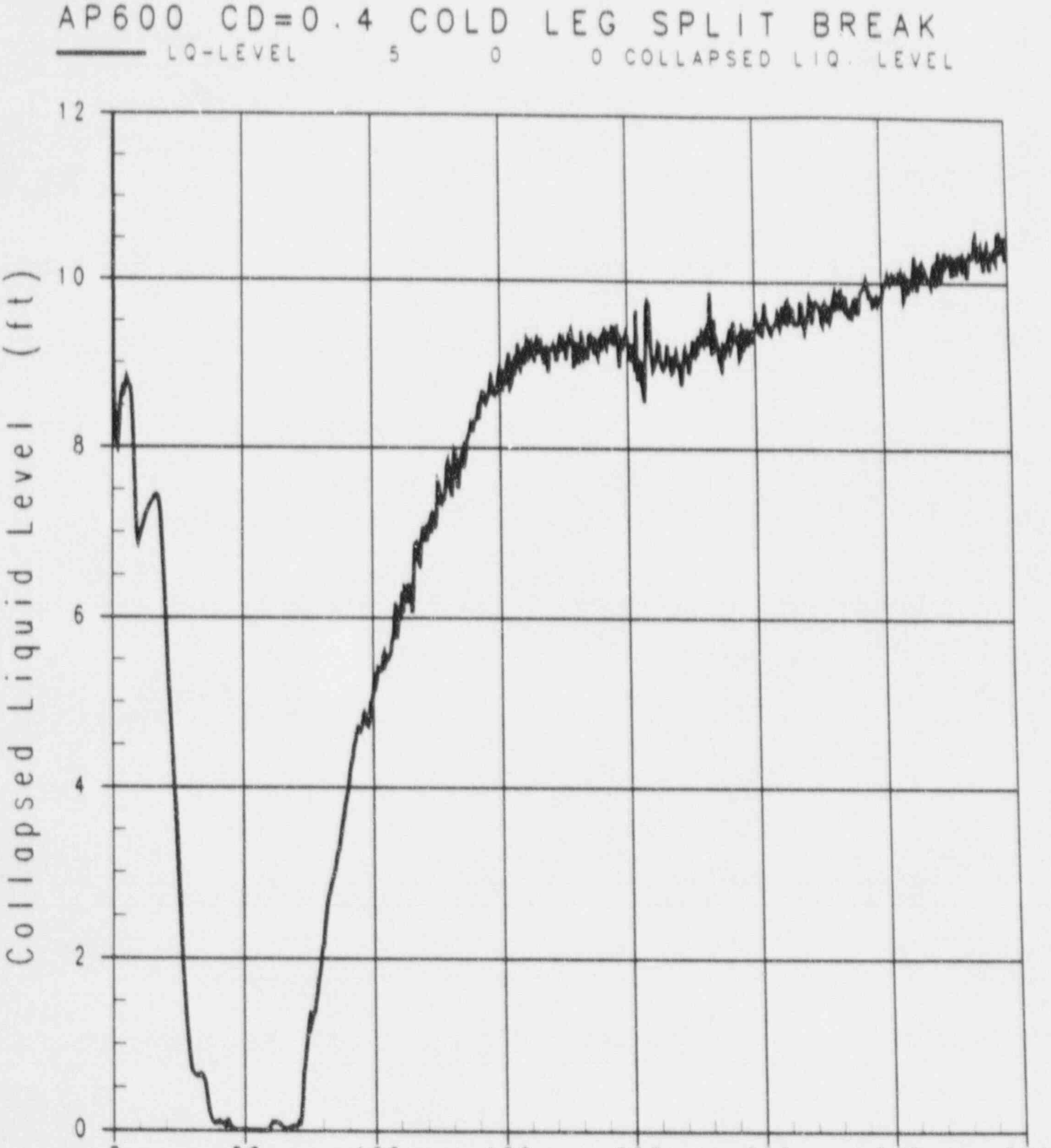


FIGURE 440.660-5

FIGURE 440.660-6

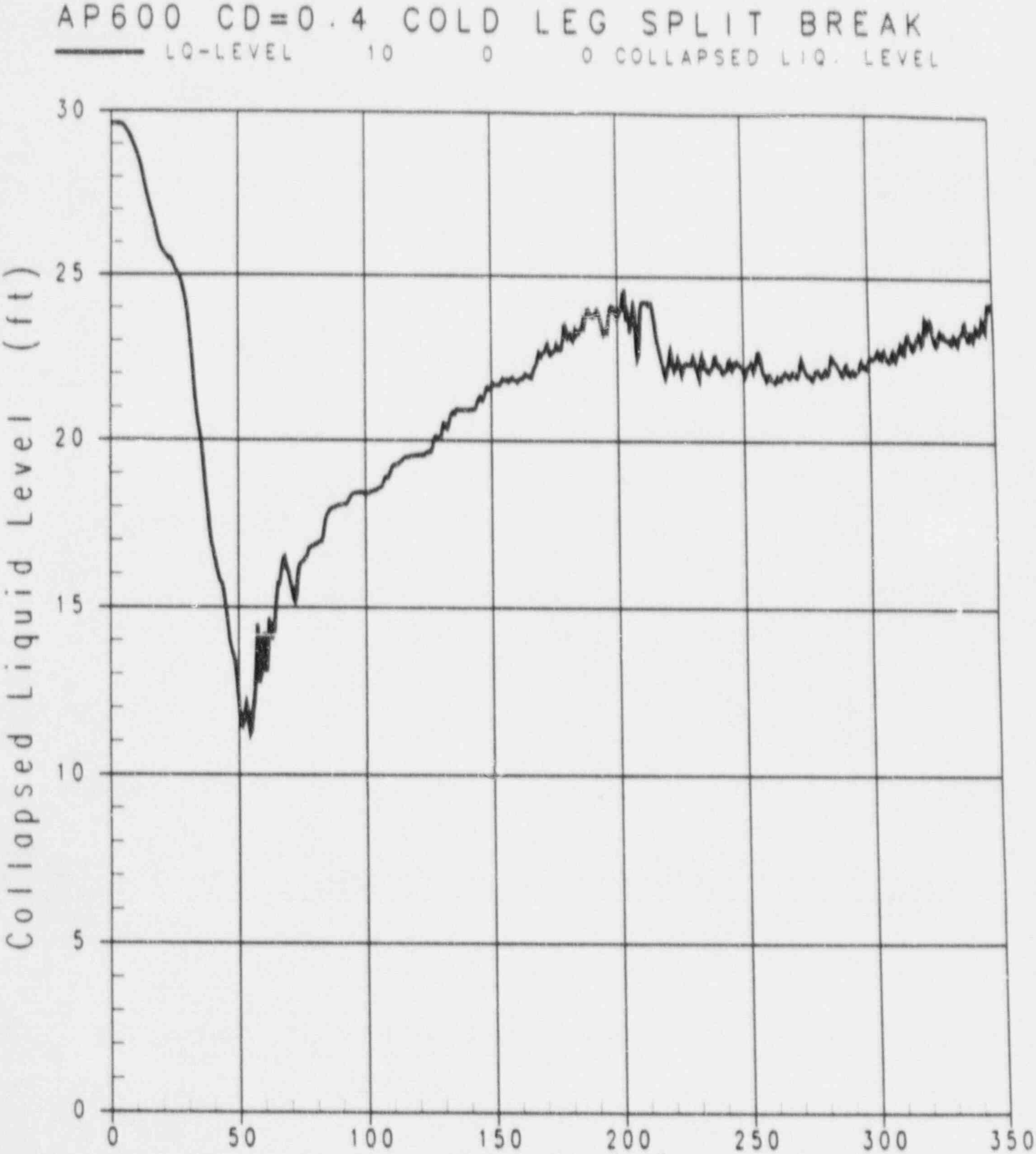


FIGURE 440.660-7

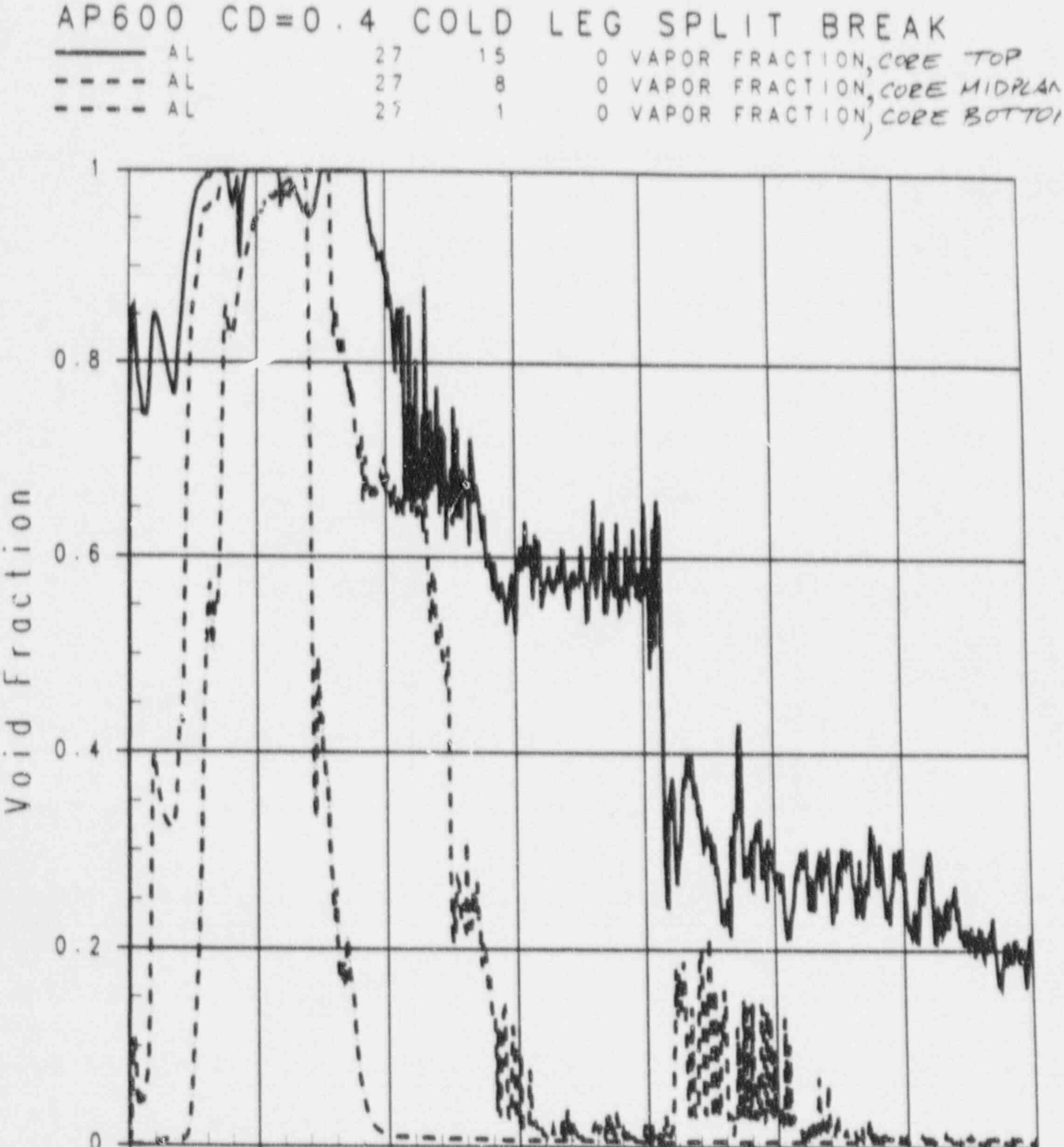


FIGURE 440.660-8

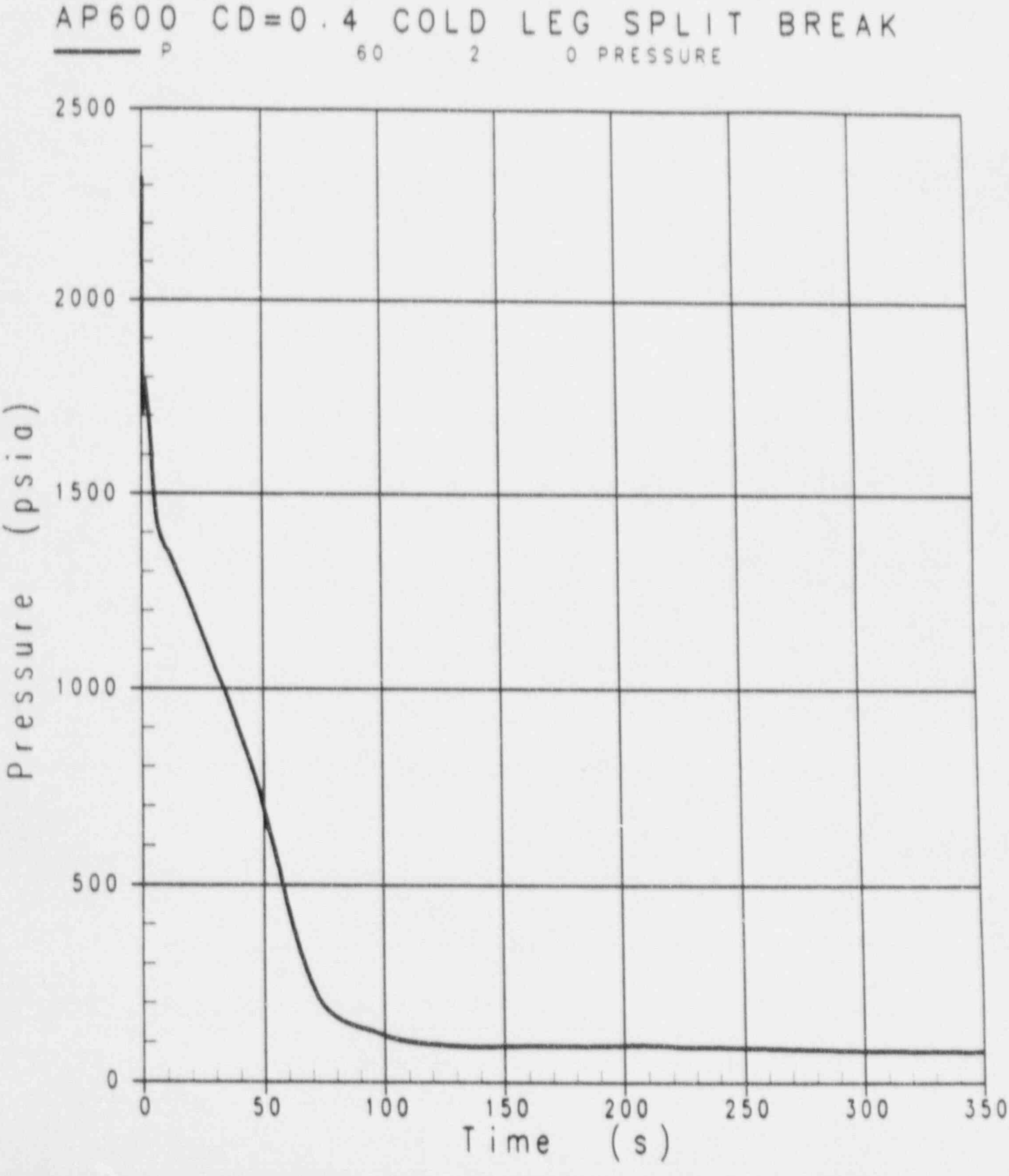


FIGURE 440.660-9

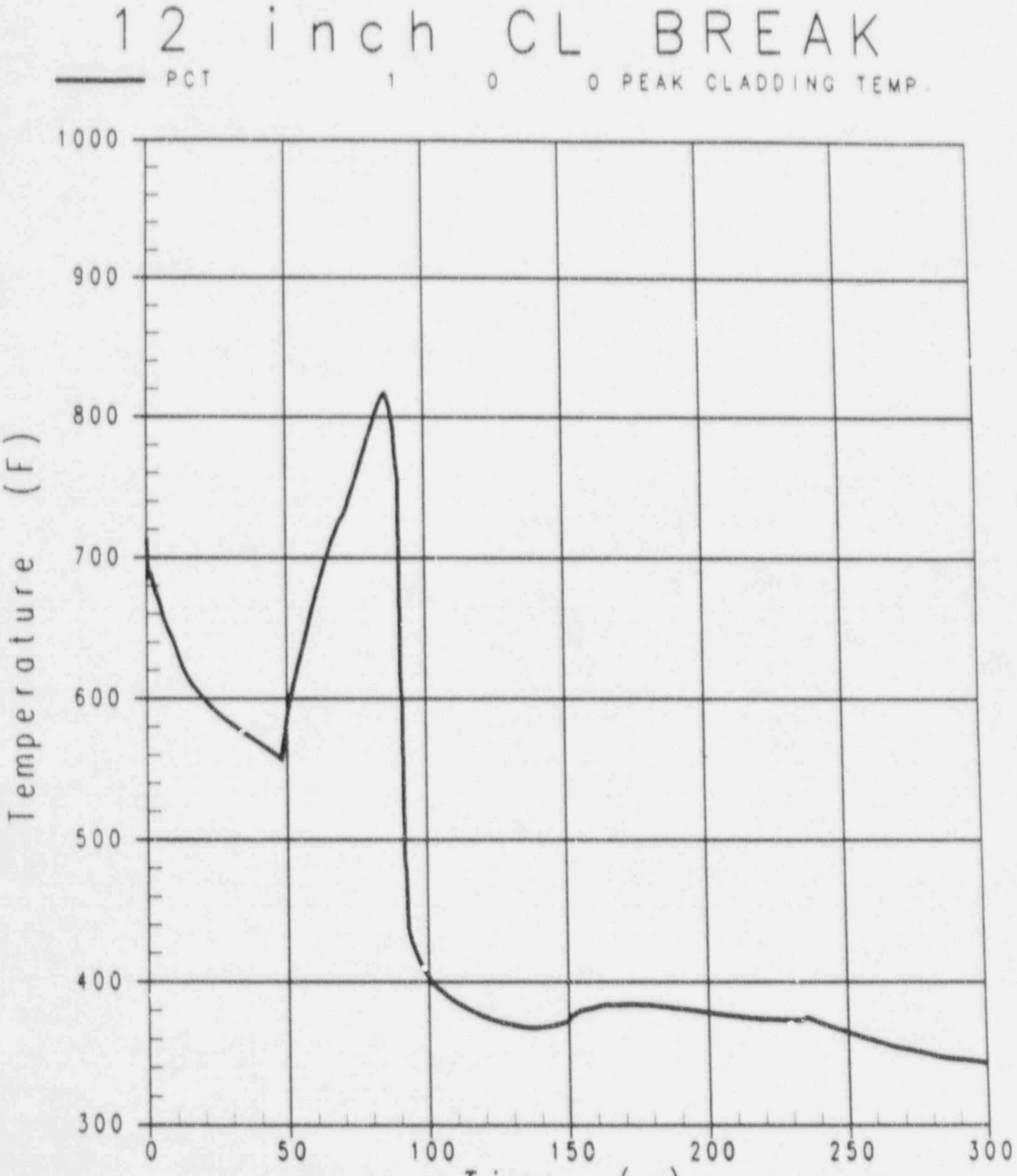


FIGURE 440.660-10

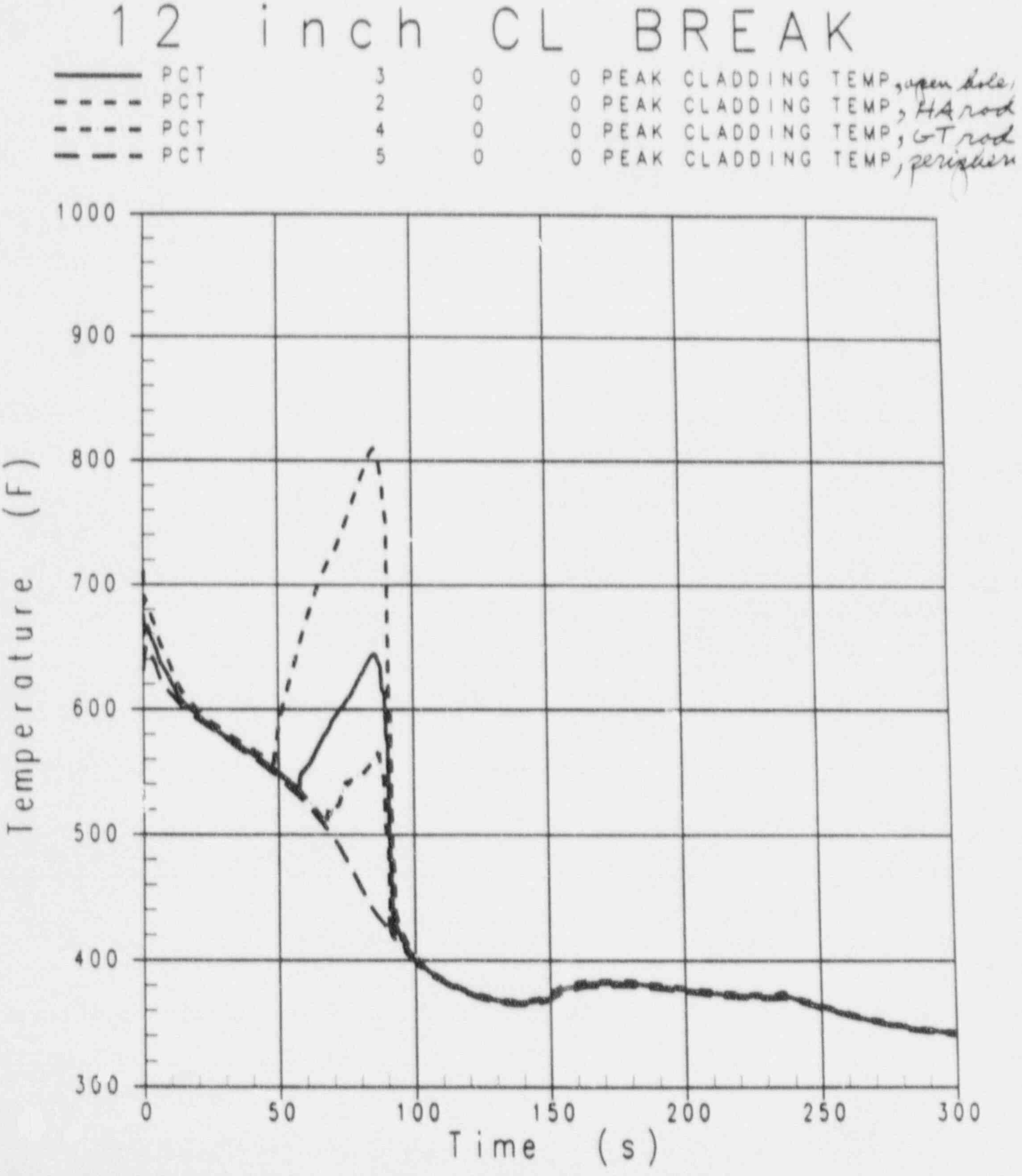


FIGURE 440.660-11

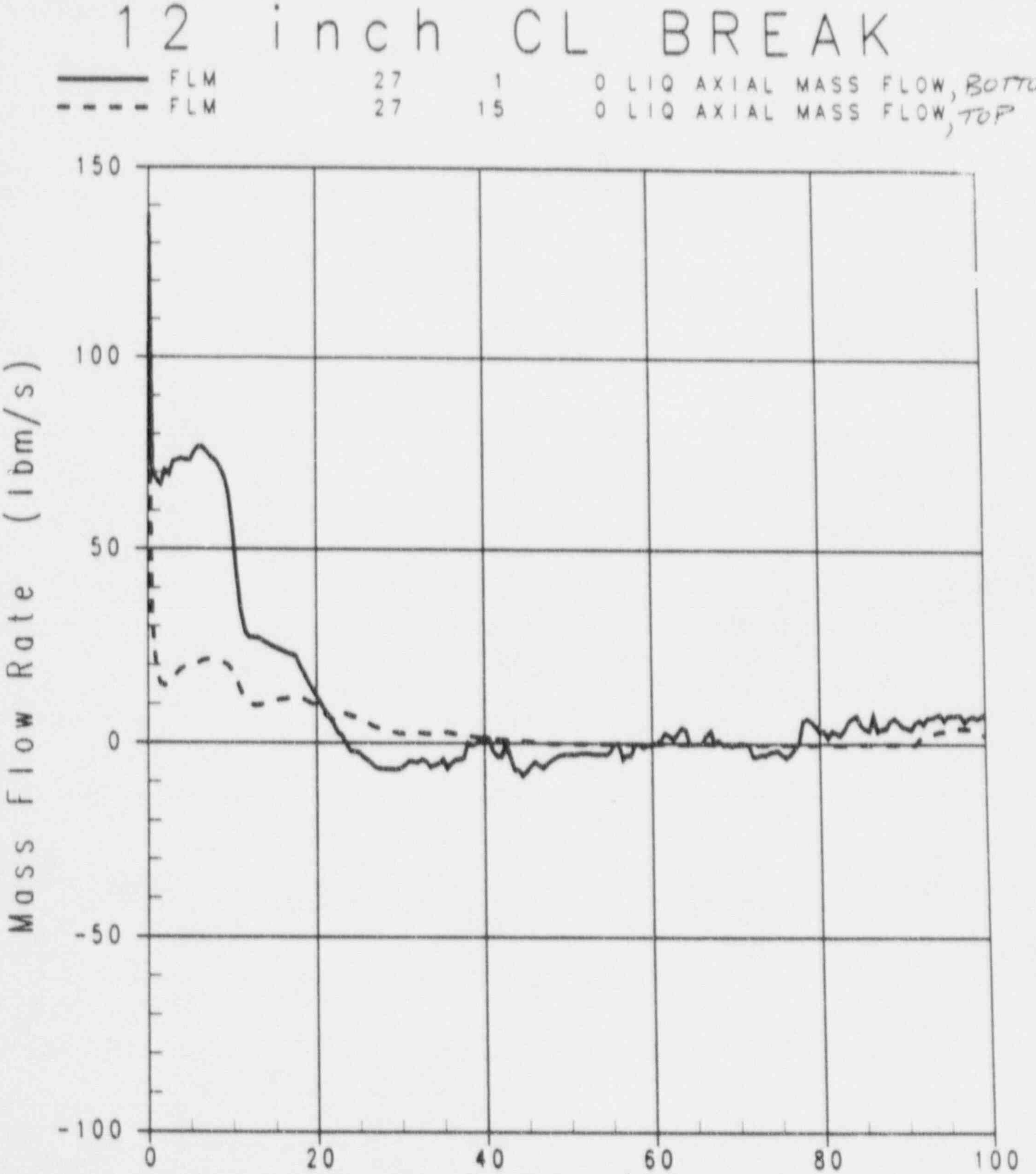


FIGURE 440.660-12

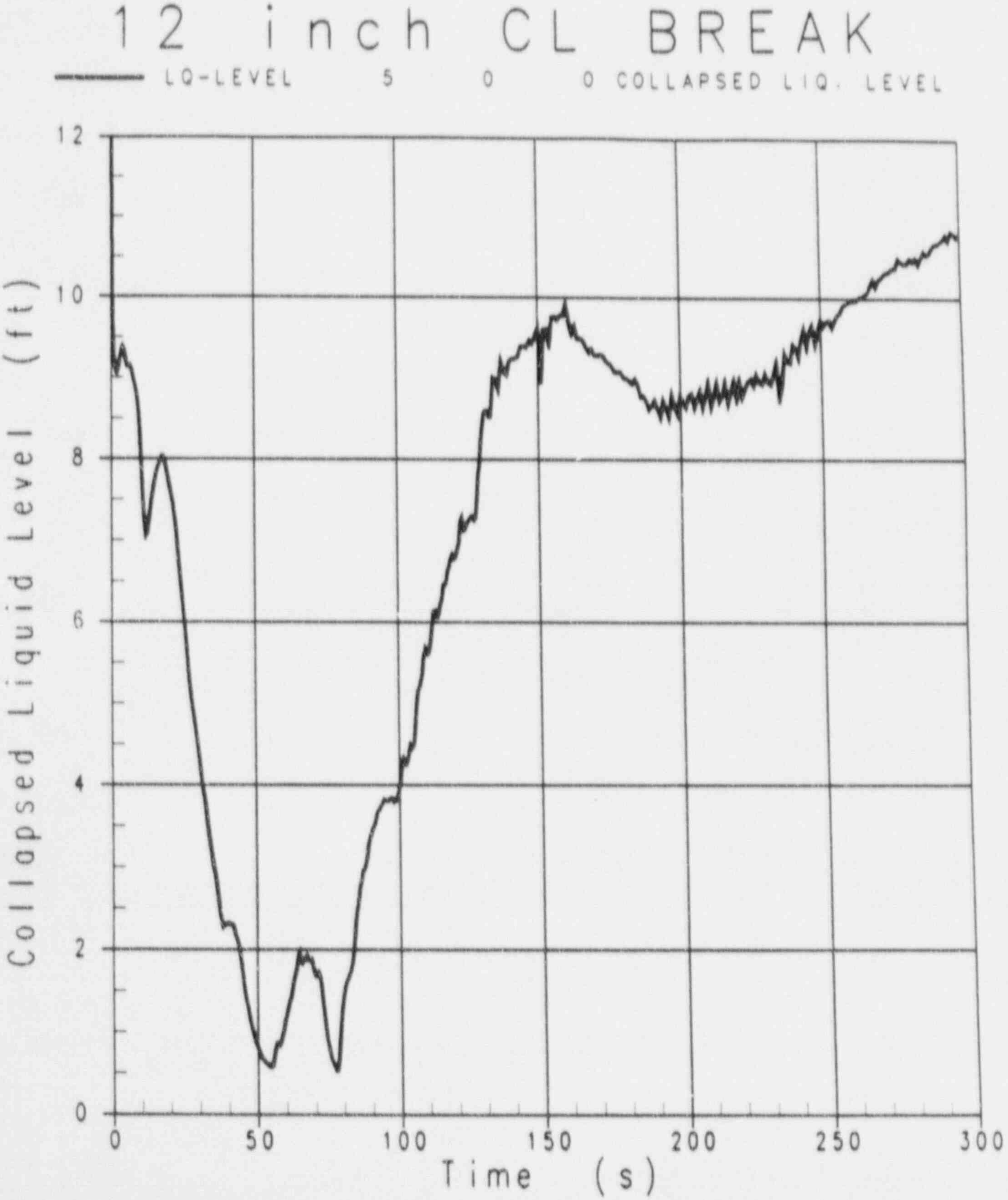


FIGURE 440.660-13

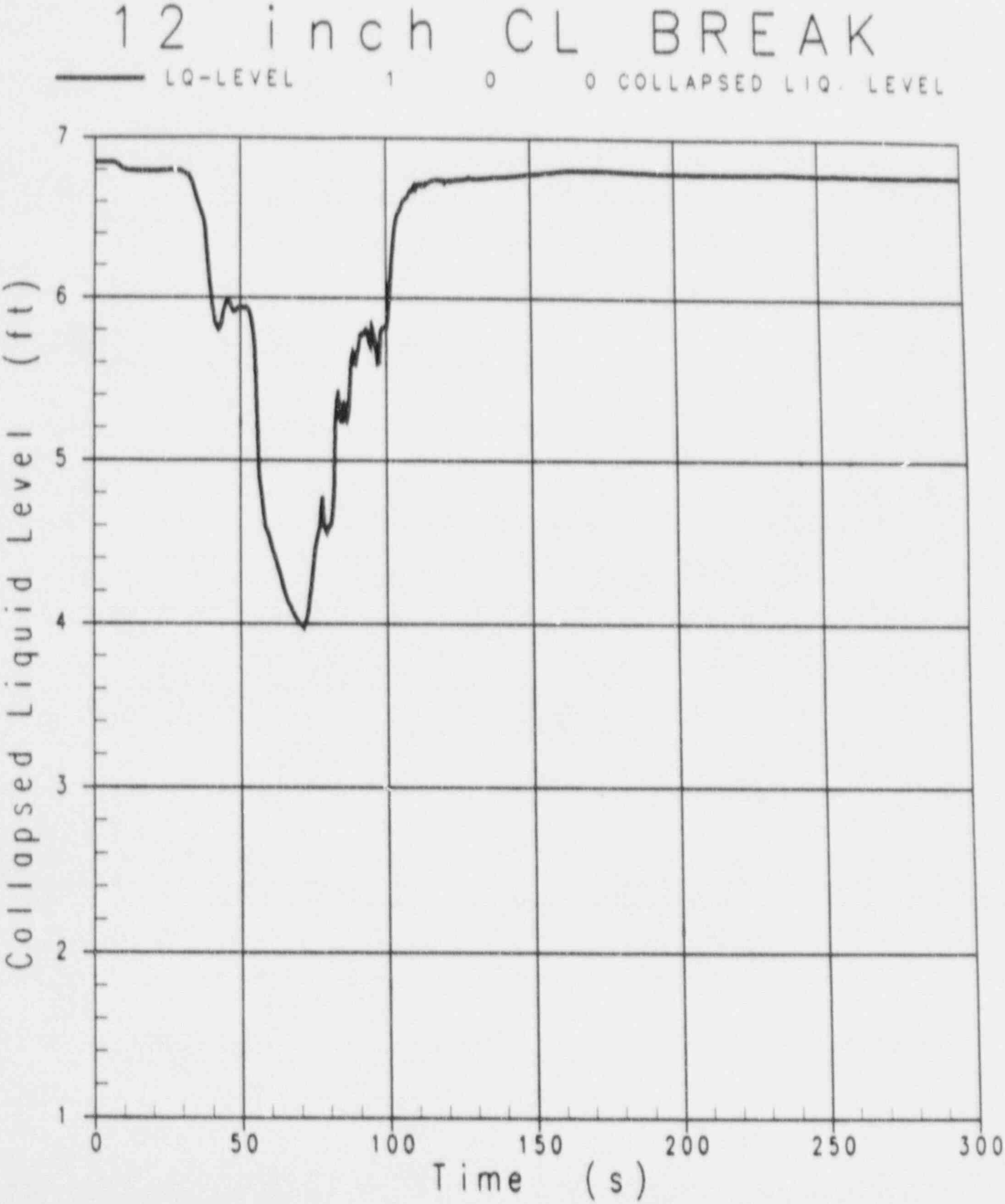


FIGURE 440.660-14

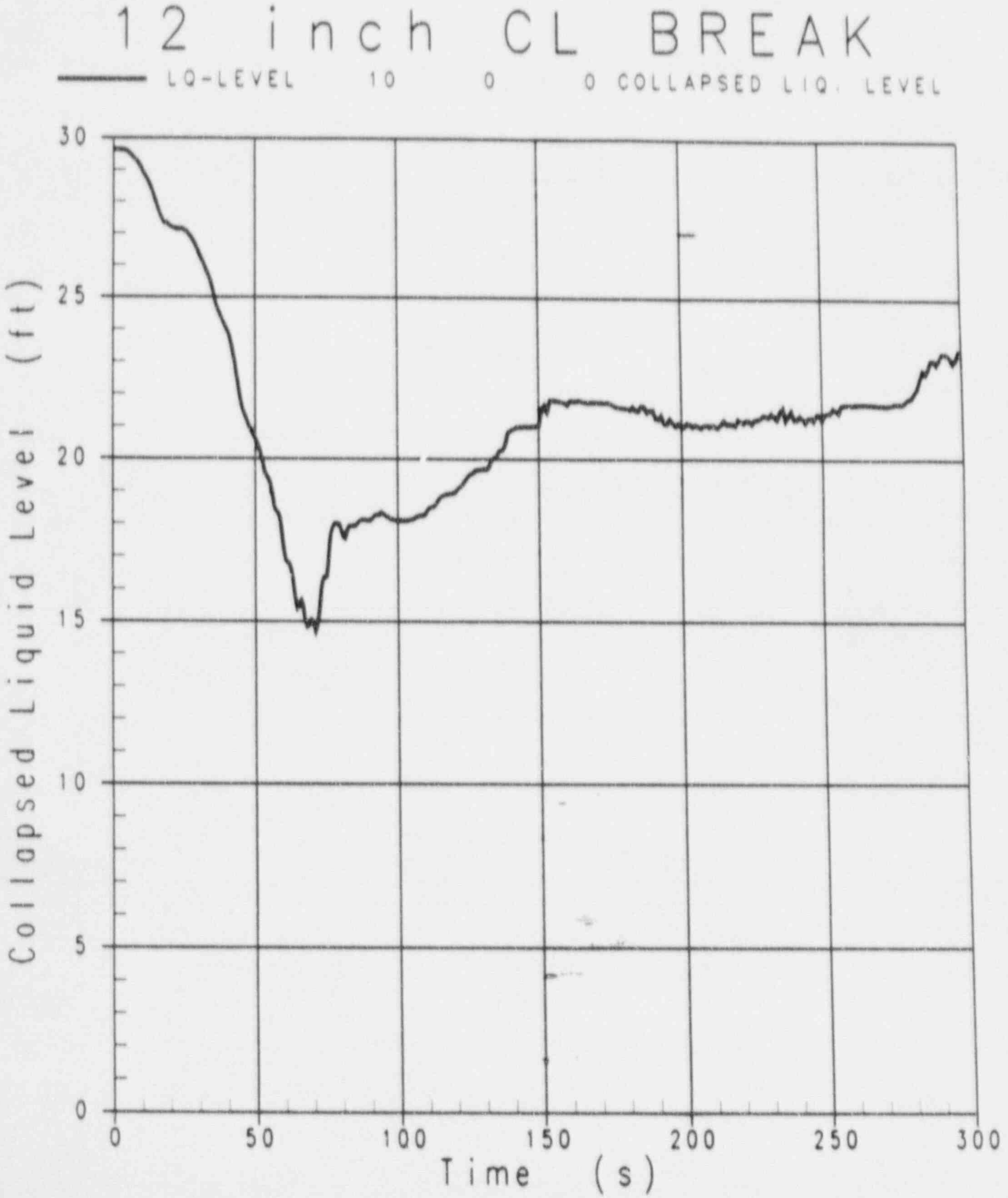


FIGURE 440.660-15

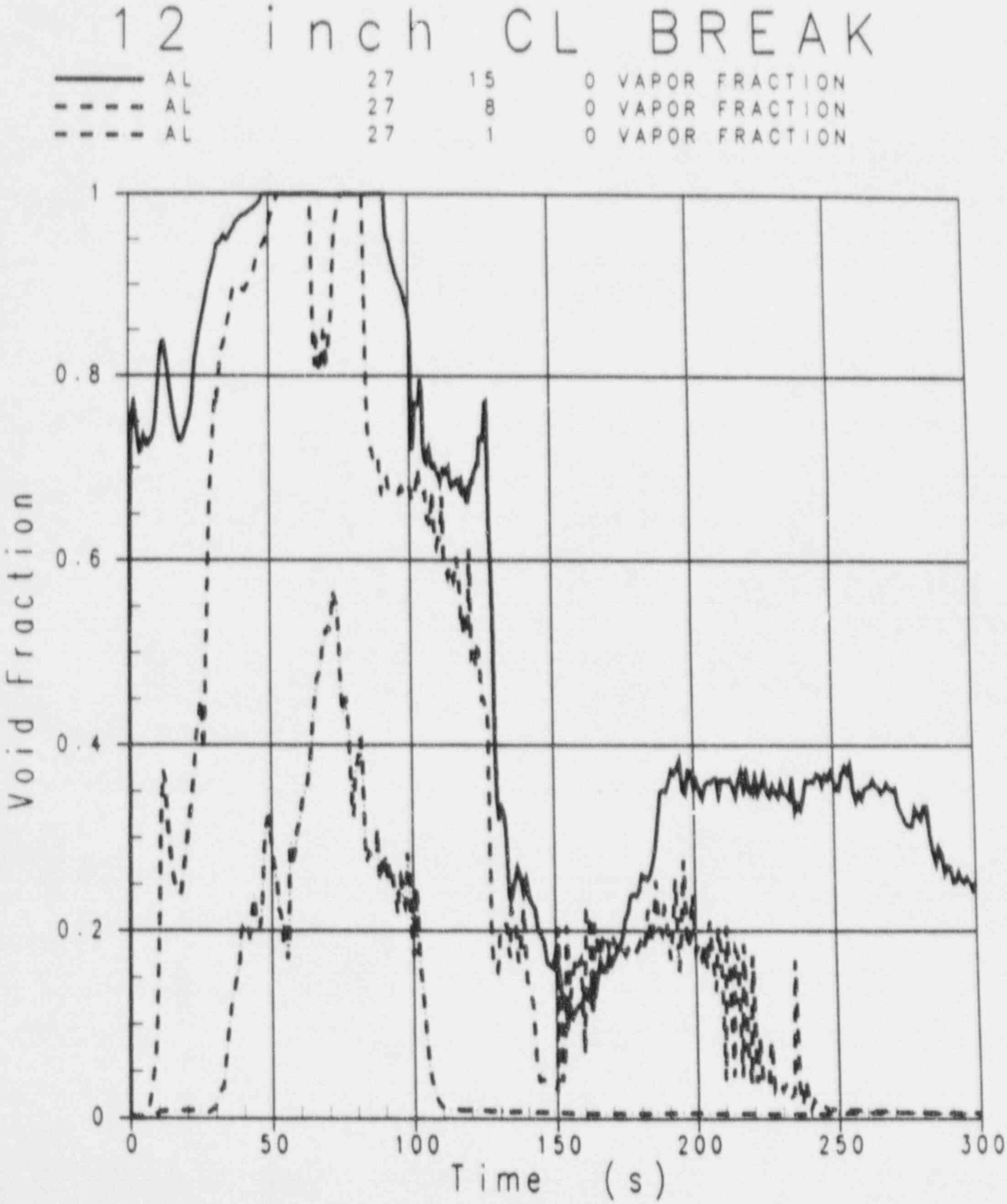
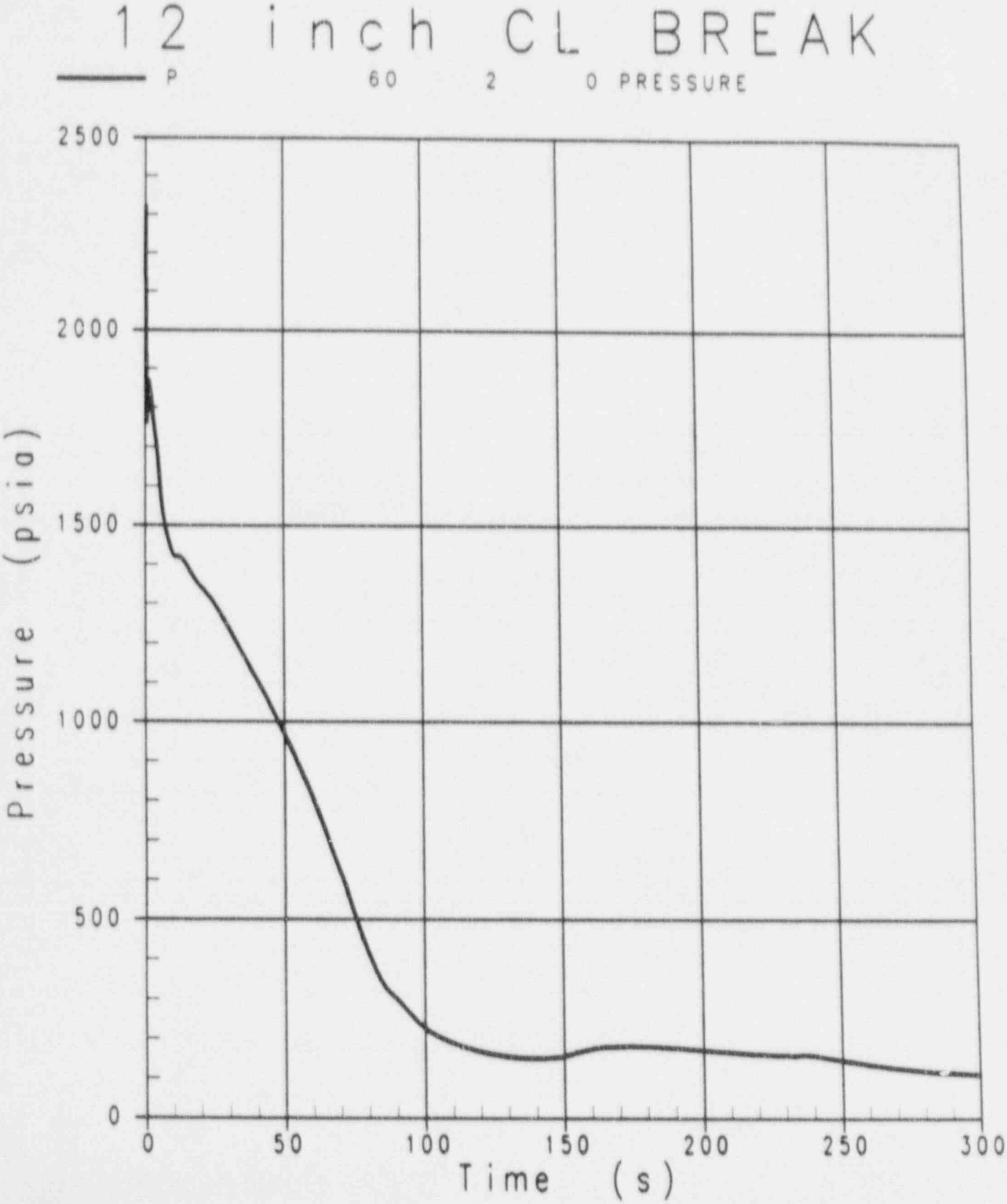
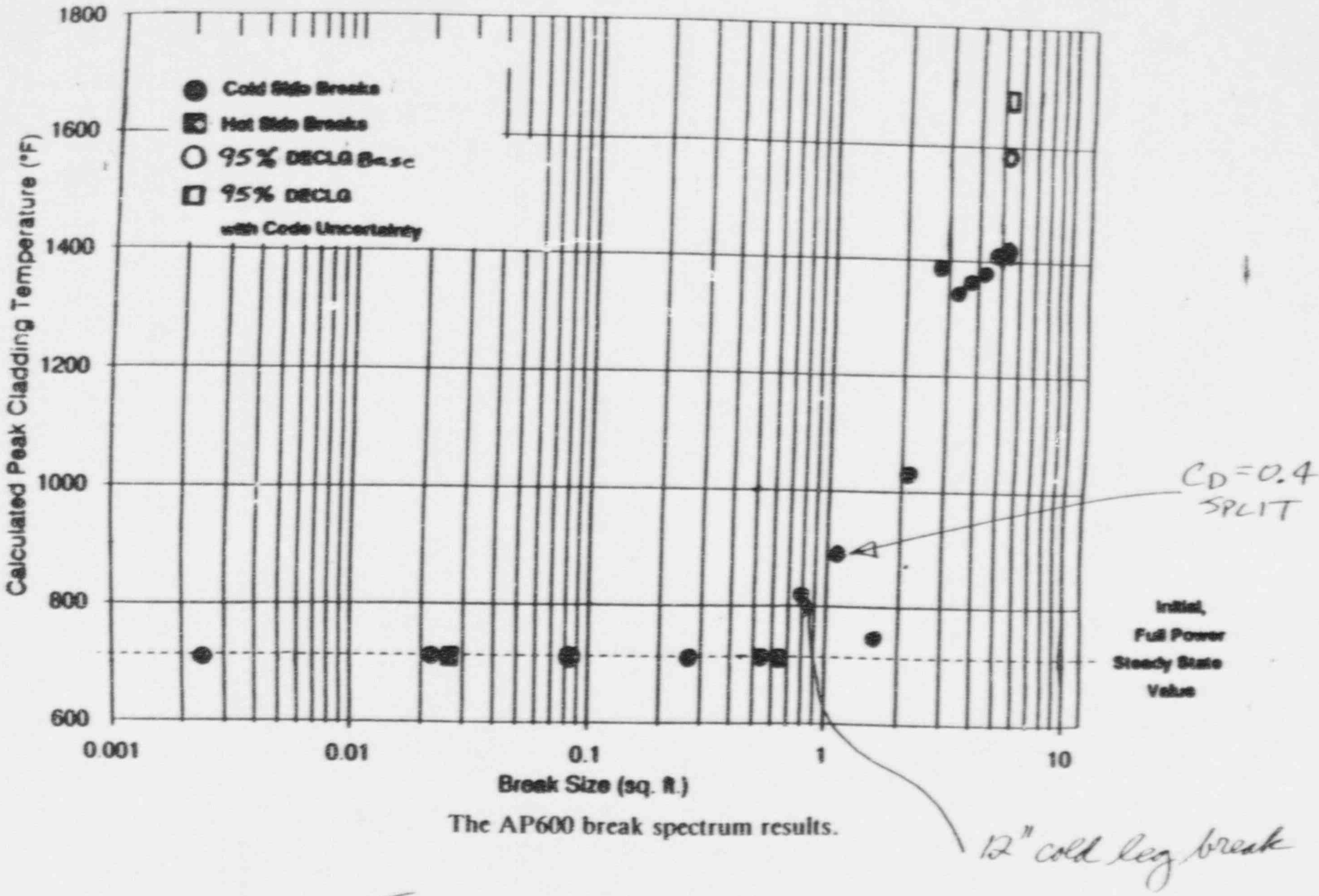


FIGURE 440.660-16





The AP600 break spectrum results.

FIGURE 440.660-17

RAI 440.662:

SSAR Section 15.6.5.4B.1.0 states that the failure of one ADS-4 valve to open is the limiting single failure (SF) during small-break LOCAs. The qualitative argument presented in the same SSAR section does not clearly demonstrate why the failure of one ADS-4 valve to open is more limiting than the failure of one ADS- 1 valve to open for the double-ended DVI (DEDVI) line break. Pro''de a quantitative analysis to confirm that the limiting SF is the failure of one ADS-4 valve during SBLOCAs.

Response:

The double-ended DVI line break case in SSAR subsection 15.6.5.4B assumed as a single failure the loss of one ADS Stage 4 flow path. To verify that this is the limiting single failure for AP600 small break LOCA events, the double-ended DVI line break has been analyzed assuming the failure of one ADS Stage 1 and one ADS Stage 3 valve instead of the ADS Stage 4 valve. No other NOTRUMP input or modeling changes were made to the SSAR base case. The results of this sensitivity case are presented to show that there is little effect on the ECCS performance from the different single failure assumption.

The results of the double-ended DVI line break sensitivity case are presented in the attached sequence of events table and in Figures 440.662-1 through 11. Overall, the transient is changed little by the revised single failure assumption. Figures 440.662-1 through 11 may be compared with the corresponding figures from SSAR Figures 15.6.5B-12 through 29. Among items of particular note, downcomer pressure (Figure 440.662-1) decreases more slowly than in the SSAR DEDVI break until the ADS Stage 4 valves are activated, after which time the pressure quickly falls to approximately the SSAR case value. The core makeup tank and accumulator flows are little different from the SSAR values (Figures 440.662-2 an 3). With the entire ADS Stage 4 venting capability available, core and downcomer mixture levels in Figures 440.662-4 and 5 are sustained at higher levels than in the SSAR case, which shows variations in these levels. The top core node void fraction of Figure 440.662-6 is about the same as in the SSAR case.

Figure 440.662-7 does not show the variations in ADS stage 4 flow that appear in SSAR Figure 15.6.5.4B-24 during ADS stage 4 venting. Figure 440.662-8 shows that the integrated ADS Stage 4 flow through four open flow paths exceeds that which occurs in the SSAR DEDVI case, which has three ADS Stage 4 paths. The ADS Stage 1, 2 and 3 vapor flow rate is lower at the actuation of ADS Stage 1 (Figure 440.662-9) than in the SSAR case. The minimum mass inventory, which occurs at the time of ADS stage 1 actuation, is the same for both cases. In the time period after this initial mass inventory minimum, the sensitivity case exhibits a larger mass inventory during injection from the core makeup tanks (Figure 440.662-10). The downcomer and core mixture levels show less variation than the SSAR case because the sensitivity case, with its greater ADS Stage 4 venting capability, is able to vent liquid continuously rather than intermittently through the ADS Stage 4 paths. Both cases reach the same minimum mass inventory during the IRWST injection (115,000 lbm) phase, although this occurs earlier in Figure 440.662-10 than it does in the SSAR case. IRWST flow delivery in the ADS Stage 1/3 failure case is shown in Figure 440.662-11. It compares well with SSAR Figure 15.6.5.4B-27. Overall, conditions predicted for the primary system during the two DEDVI transients are similar.

The postulated single active failure among the ADS stages has no effect on the minimum mass inventories of the double-ended balance line and 10-inch diameter cold leg breaks presented in the SSAR. The minimum inventory of these cases occurs before ADS stage 1 actuation, and the depressurization due to break flow is adequate to replenish the RCS mass from its minimum inventory condition by continuous injection of accumulator water. Therefore, the minimum mass inventory is insensitive to the single failure assumption for both of these cases.

The DEDVI break sensitivity case shows that there is little impact on the calculated ECCS performance by changing the single failure assumption. The larger breaks in the small break LOCA matrix are the limiting cases in terms of RCS mass inventory (Reference SSAR subsection 15.6.5.5, and RAI 440.660). For breaks smaller than the DEDVI, the failure of an ADS Stage 4 valve penalizes the RCS depressurization to containment pressure and delays IRWST injection at the time in the transient when the RCS mass inventory is at its minimum (refer to SSAR subsection 15.6.5.4B). At the time of ADS stage 1 actuation, the RCS has a large mass inventory in each of the smaller breaks among the small break LOCAs. The insensitivity of the DEDVI break case to the postulated failure of an ADS stage 1 valve and an ADS Stage 3 valve supports the conclusion that an ADS Stage 4 valve failure represents the limiting single active failure for the AP600 small break LOCA ECCS performance analysis.

SSAR Revision: None

FIGURE 440.662-1

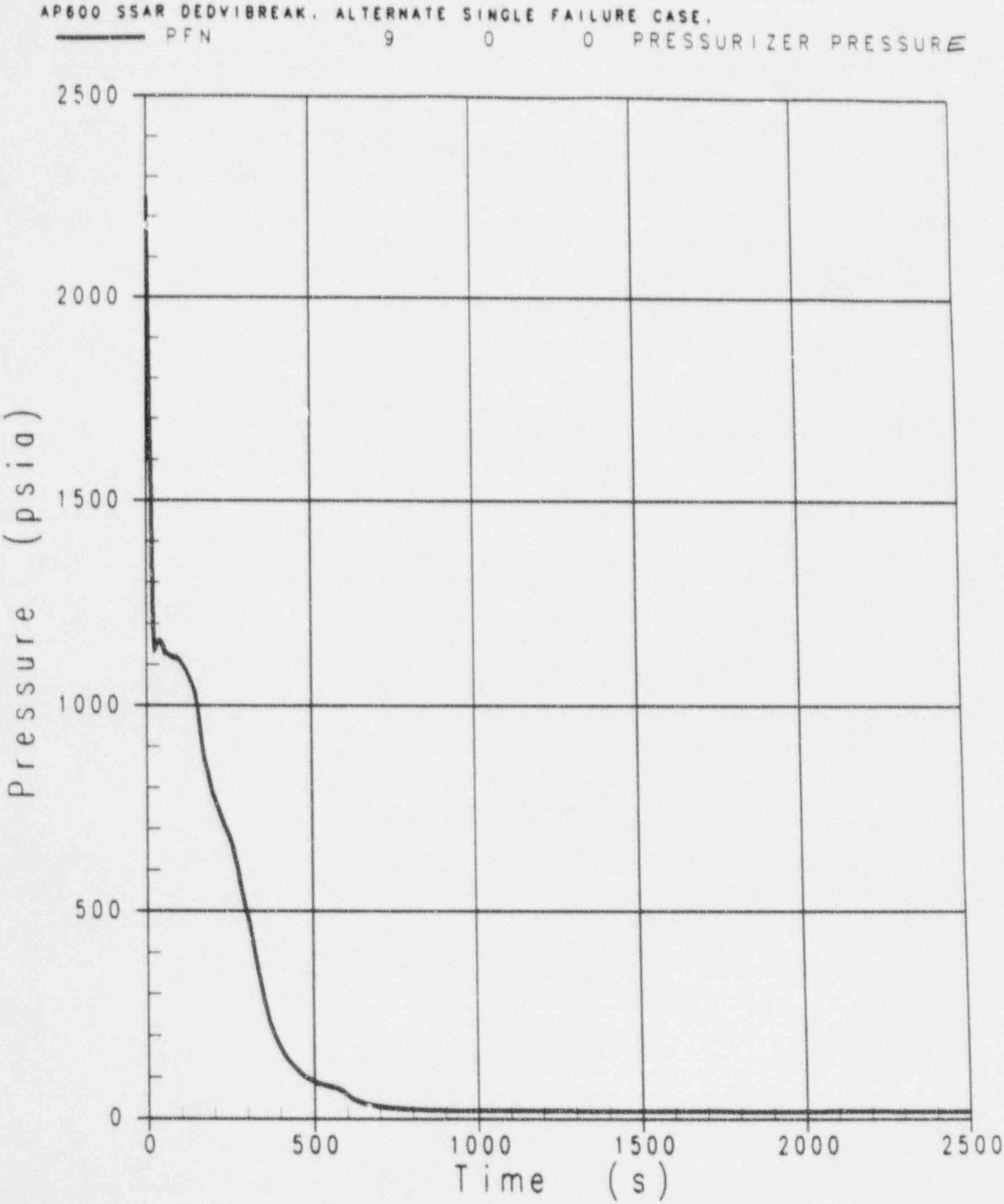


FIGURE 440.662-2

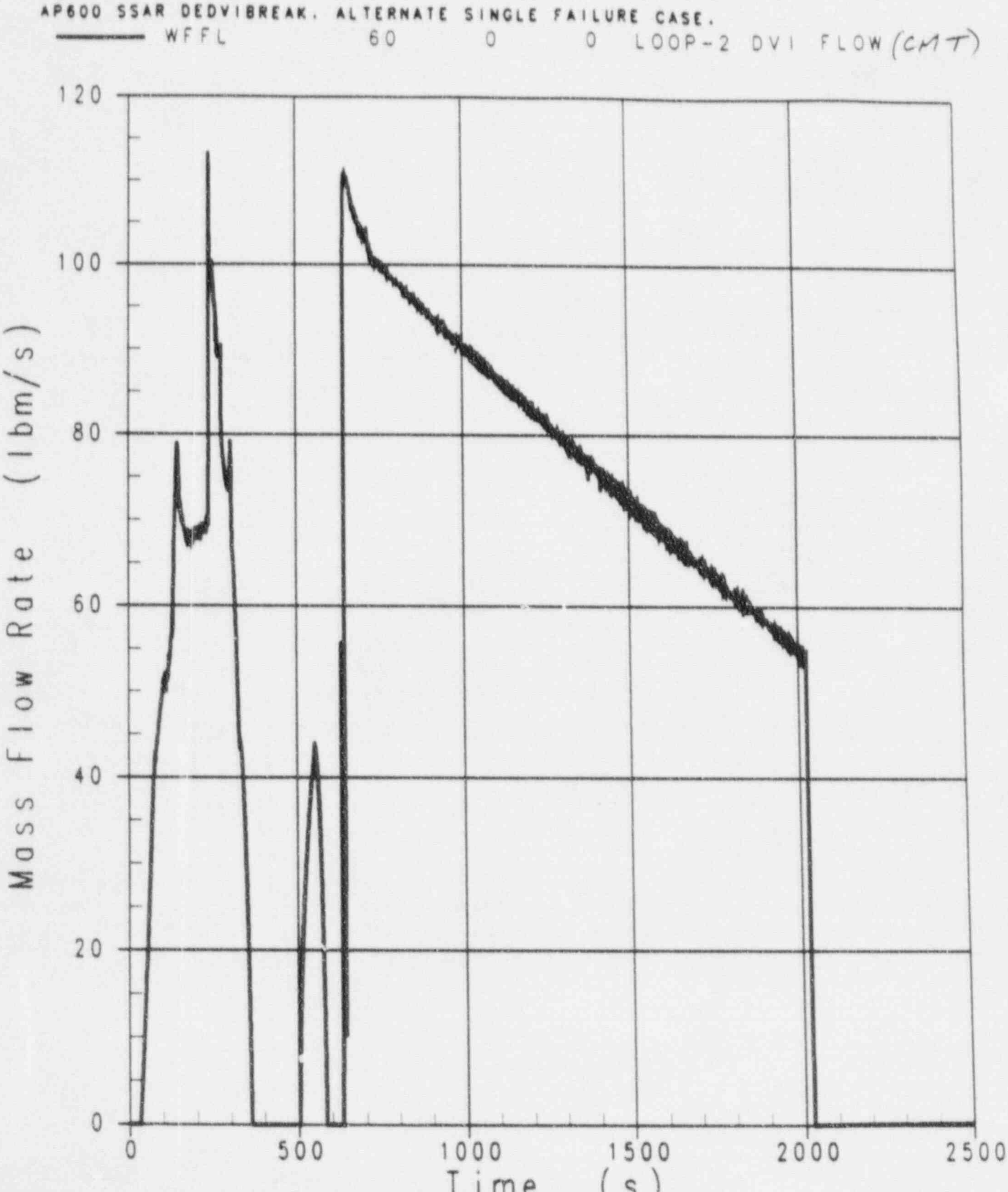


FIGURE 440.662-3

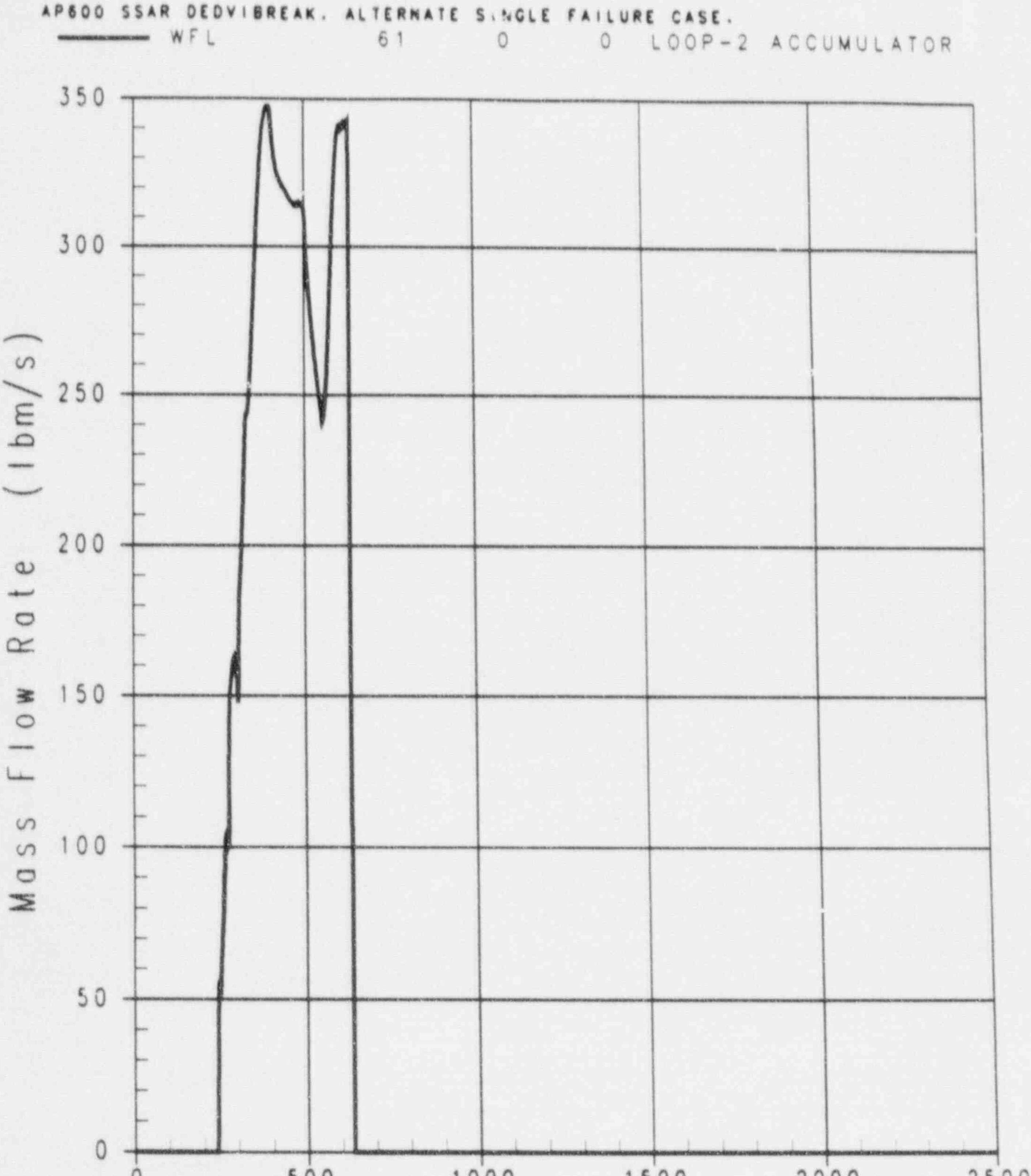


FIGURE 440.662-4

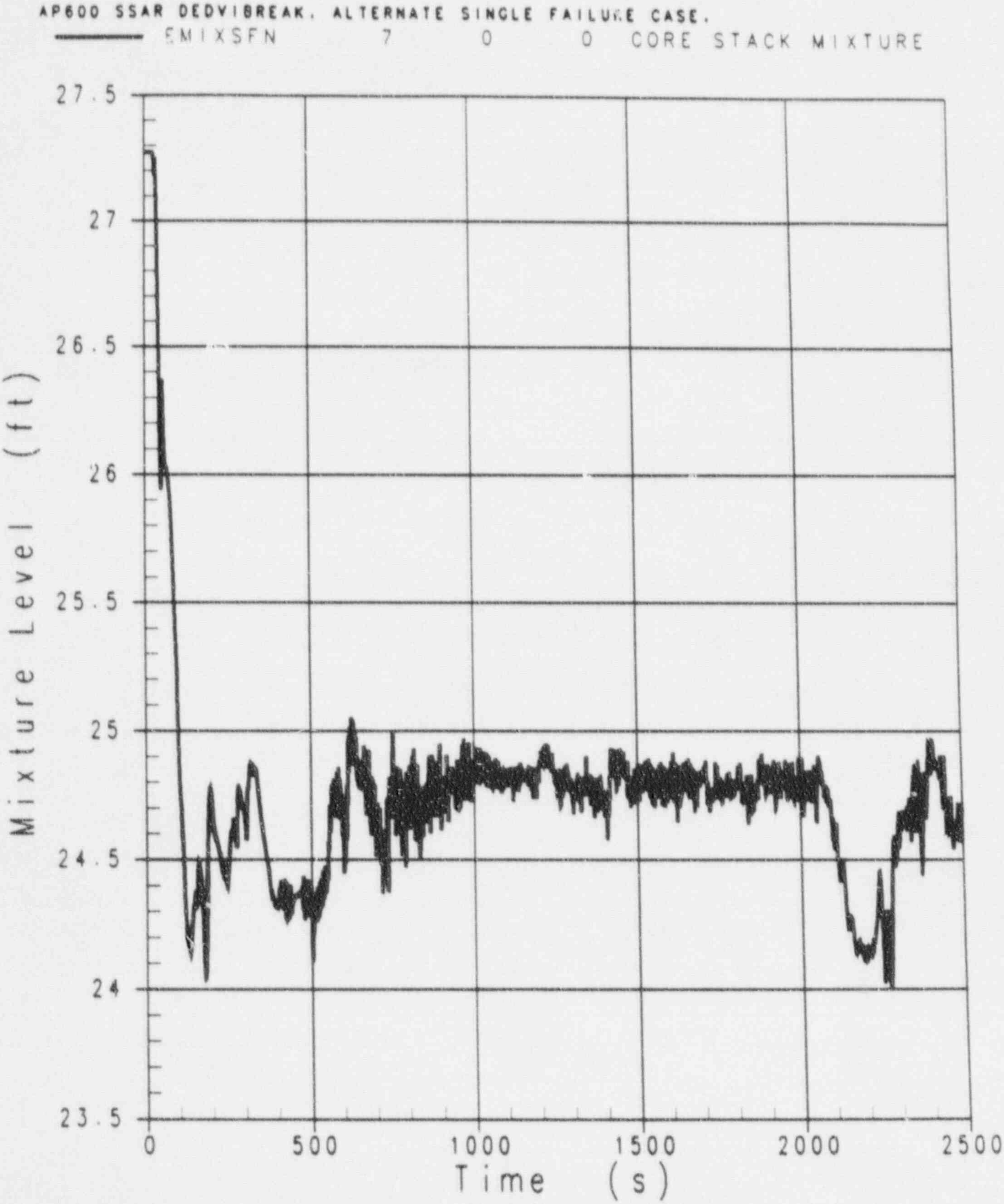


FIGURE 440.662-5

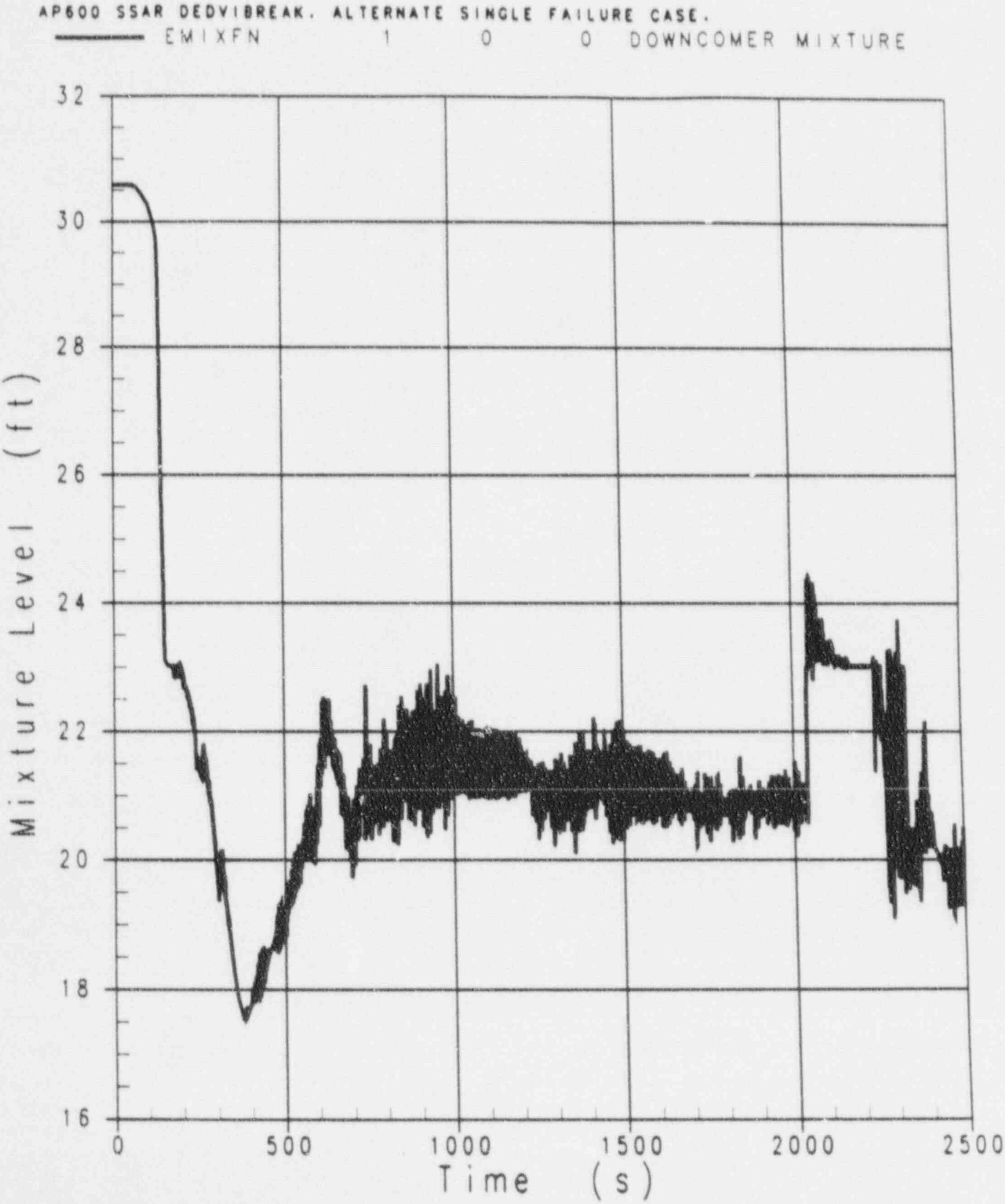


FIGURE 440.662-6

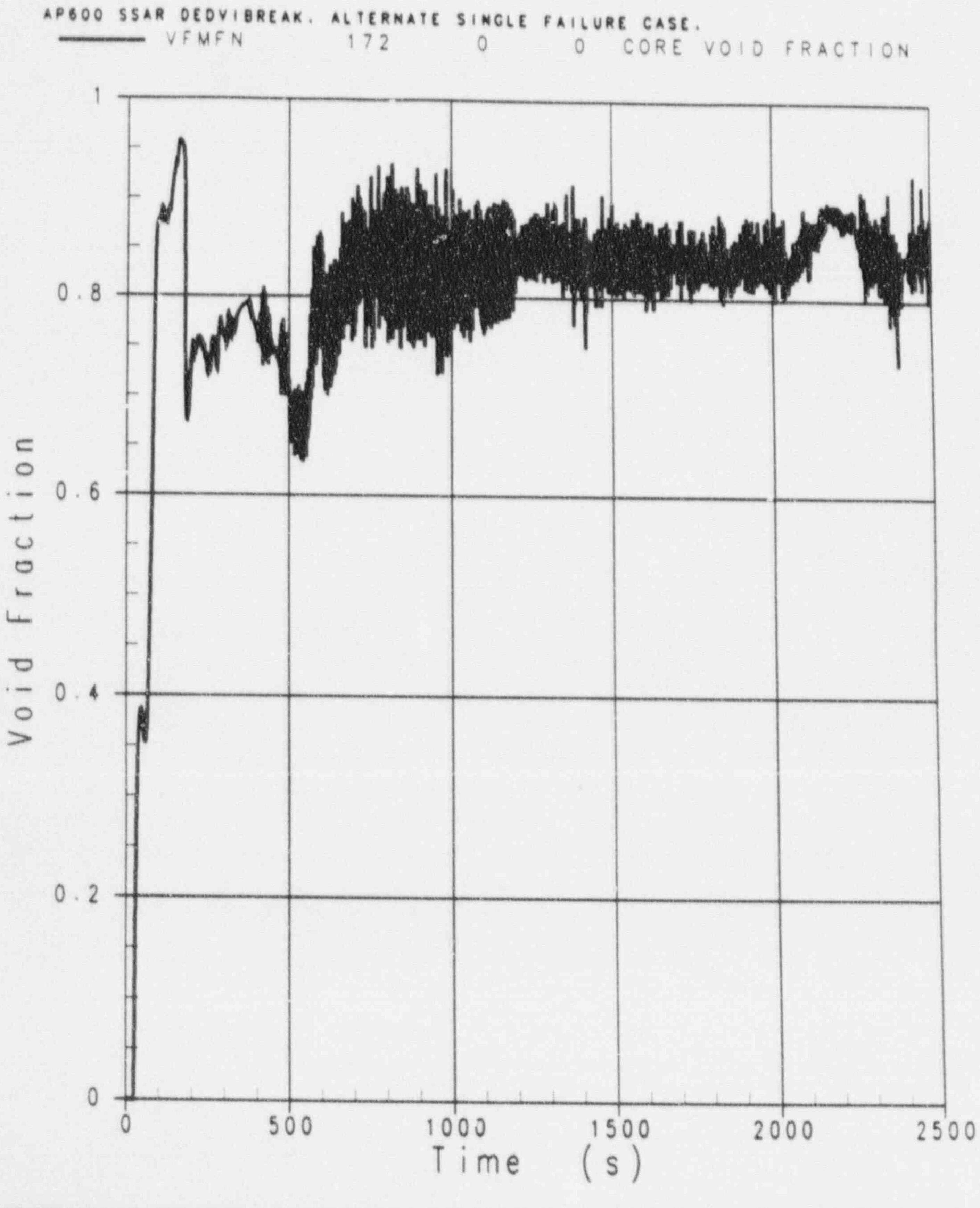


FIGURE 440.662-7

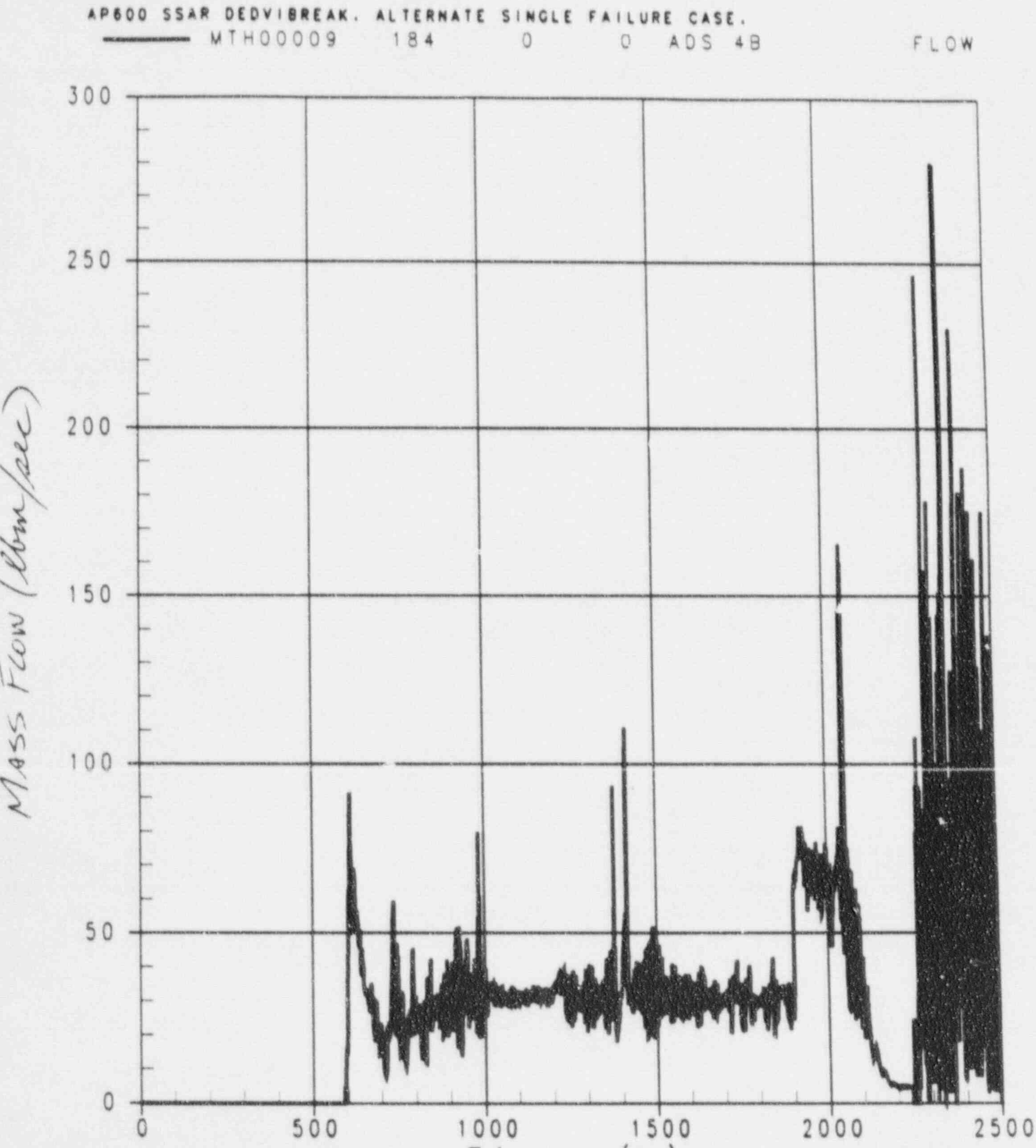


FIGURE 440.662-8

AP600 SSAR DEDVIBREAK. ALTERNATE SINGLE FAILURE CASE.

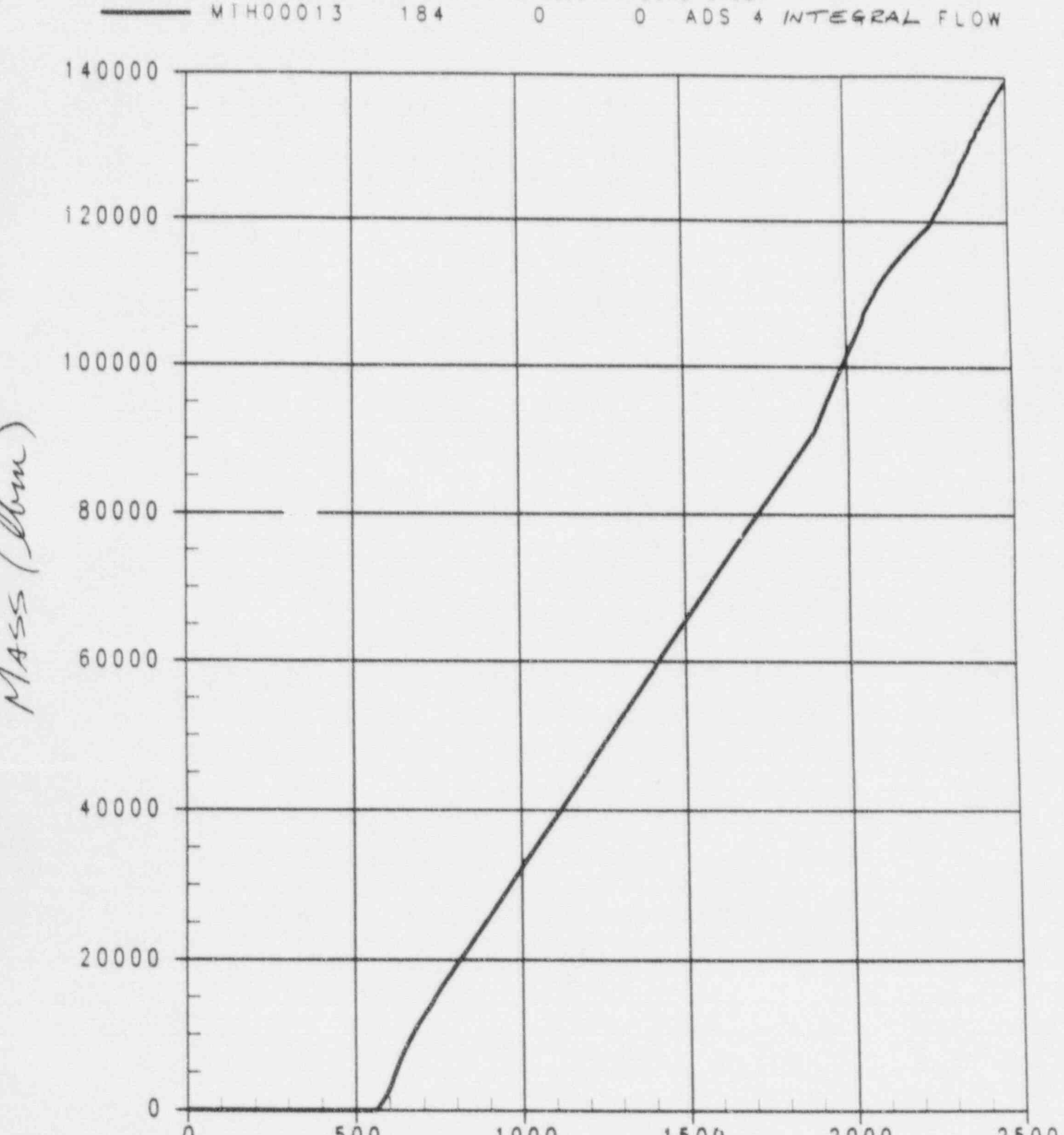


FIGURE 440.662-9

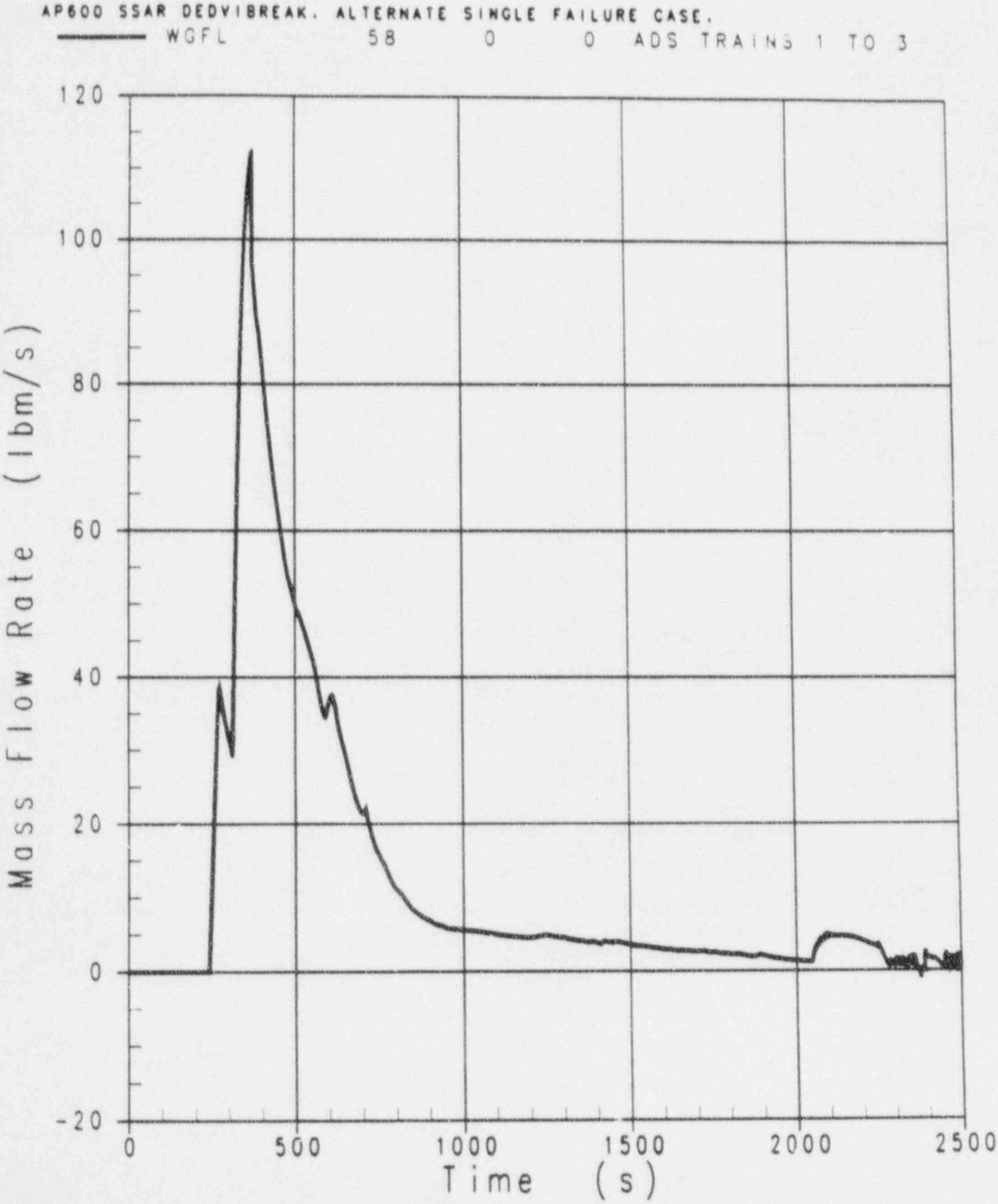


FIGURE 440.662-10

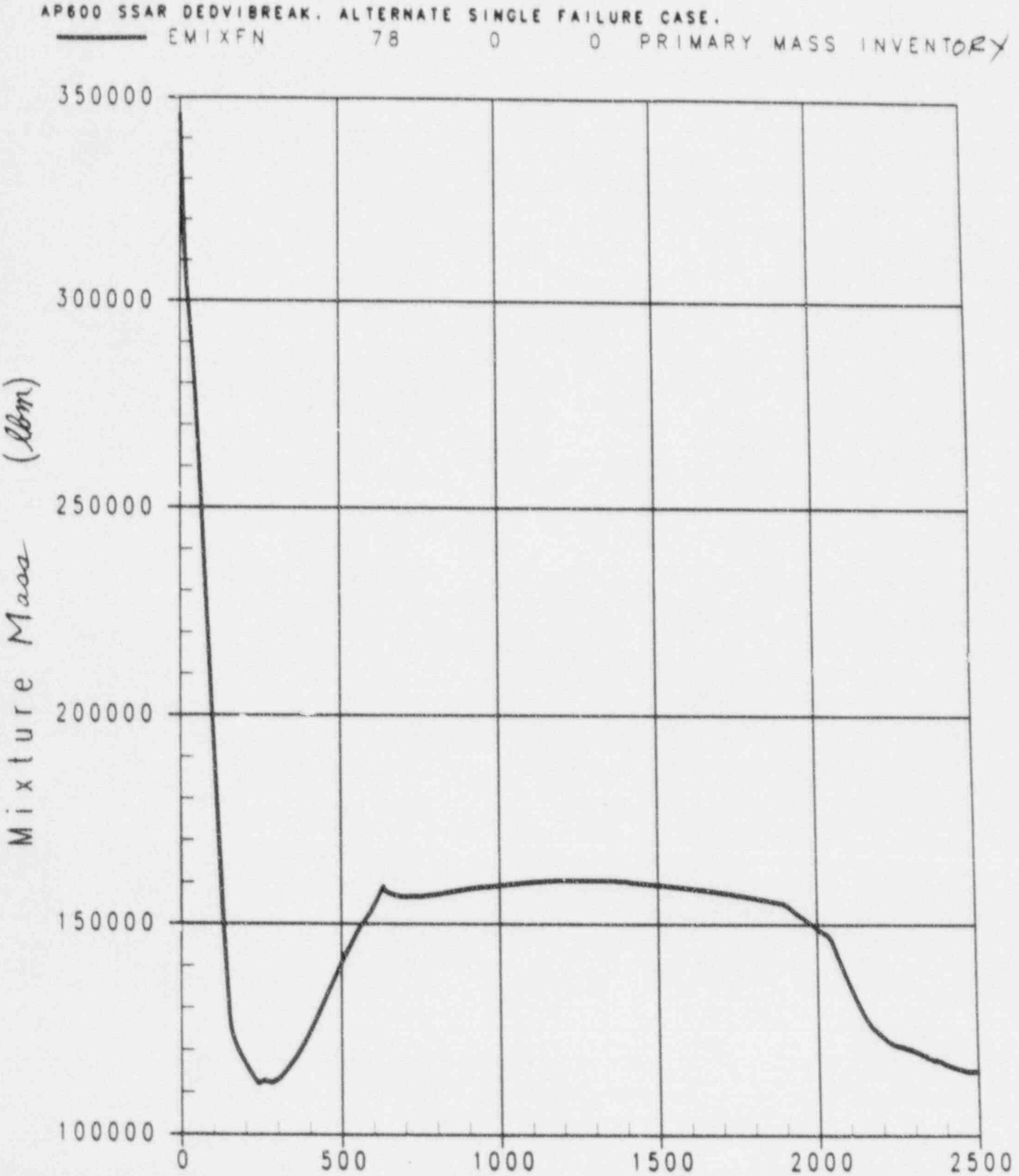


FIGURE 440.662-11