FRAMATOME
TECHNOLOGIES

December 10, 1998
FTI-98-3797

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: A Request to Rescind FTI's Commitment to Analyze Top and Side SBLOCAs for T_{hot} Recirculating Steam Generator Plants – BAW-10168P-A, Revision 3, Volume II, December 1996.

Reference: Letter (JHT/96-56) to NRC Document Control Desk from J. H. Taylor (FTI), dated August 22, 1996, Subject: SBLOCA/Break Orientation.

Gentlemen:

The purpose of this letter is to provide the results of the FTI commitment to perform SBLOCA break orientation analysis as discussed in the referenced letter. In a letter from NRC to FTI dated August 22, 1996, NRC approved the small loss-of-coolant accident (SBLOCA) evaluation model (EM) in Volume II of BAW-10168-P, Revision 2, for applications to recirculating steam generator plants with a restriction on plants with small upper head spray nozzles (upper head T_{hot} plant, less than 0.022 ft^2 total flow area). The restriction is related to a concern with respect to the break orientation. For the T_{hot} plant with smaller breaks (less than 2-inch diameter) at the top of the cold leg pump discharge pipe, the ECC water injected into the broken cold leg pipe can flow backward into the pump suction pipe after initial loop seal clearing. As the core steam production decreases with time, the ECCS backflow may cause loop seal reformation and block steam venting through the loop, thereby, resulting in system repressurization that could lead to an extended period of core uncovering.

In order to address this concern and to rescind the restriction imposed on the FTI's SBLOCA EM for licensing application to the T_{hot} plant, FTI performed break spectrum analyses for breaks at the top and the side of the cold leg pump discharge pipe using the four-loop Sequoyah plant model with small upper head spray nozzle (Trojan plant spray nozzle). The results of the analyses provided in the attachment show that the downcomer water level (near the nozzle belt elevation) is sufficient to prevent an extended core uncovering during the initial loop seal clearing period and subsequent loop seal reformation and clearing cycles. Furthermore, the primary system repressurization associated with the loop seal reformation is not significant to cause substantial inventory loss. Thus, the primary system inventory loss is limited, and the long-term cooling is established. In addition, no plant-specific emergency operating procedures (EOP) for

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plant recovery following a SBLOCA in the T_{hot} plant are required. The results of the analyses demonstrate that the bottom break is limiting, and that the restriction requiring top break analyses for T_{hot} plants is not needed. We request NRC's concurrence in this conclusion and seek the removal of the need to analyze top and side breaks for T_{hot} plants.

If you have any questions, please feel free to call me at 804/832-2964 or John Biller at 804/832-2600.

Very truly yours,

J. J. Kelly, Manager
B&W Owners Group Services

JJK/bcc

Attachment

c: F. R. Orr/NRC - Nuclear Regulatory Commission
J. R. Biller - Framatome Technoplogies/OF53
R. N. Edwards - Framatome Technologies/MD82
M. A. Schoppman - Framatome Technologies/MD82

Attachment:

SBLOCA EVALUATION FOR TOP AND SIDE BREAKS

Introduction:

A small break LOCA is assumed to occur from 102 percent of full power operation. The transient can be generally characterized as developing in the following distinct phases: (1) subcooled depressurization, (2) loop saturation and loop flow coastdown, (3) loss of loop circulation and reflux mode cooling, (4) loop seal clearing and core boiloff, and (5) long-term cooling provided by high head safety pump and accumulator injections. Following the initial loop seal clearing in the fourth phase of the transient, the core undergoes boildown because the high head safety injection flow is not sufficient to makeup for inventory loss. The primary system depressurization after the loop seal clearing is relatively slow for break sizes less than 3.5-inch diameter. Thus, core uncovering may occur prior to the accumulator injection.

A small LOCA at the bottom of the pump discharge piping downstream of the ECC injection nozzles will cause most of ECC water injected into this location to flow out the break, and result in less ECC water for core cooling. Thus, the bottom break orientation is considered conservative in the SBLOCA analysis, and was used in all the SBLOCA analyses for licensing application. As discussed in Section 4.3.2.2 in Volume II of BAW-10168P, Revision 2, the SBLOCA EM uses a fictitious leak node directly below the cold leg pipe to achieve the ECCS bypass. The broken loop ECC injections are directed to the fictitious leak node after the loop seal clearing to ensure complete ECC bypass. However, for a break in the horizontal or the top of the cold leg pipe, the ECC water injected into the broken cold leg pipe may remain in the pipe below the break, and flow towards the reactor vessel. The ECC water may also flow backward into the pump suction piping after the loop seal clearing. The backflow of ECC water may reseal the pump suction piping and prevent steam venting, thereby resulting in an extended core level depression. The extent of the core level depression may depend on the upper head spray nozzle design that provides an alternate steam venting path from the core through the spray nozzle and downcomer to the break. In the Westinghouse T_{hot} plant, the upper head spray nozzle flow area is significantly smaller than that of the T_{cold} plant. Thus, steam venting through the upper head spray nozzle is relatively ineffective in reducing core level depression for the T_{hot} plant. Therefore, the SBLOCA analyses for the top and side break orientations using the T_{hot} spray nozzle area (0.0218 ft^2 based on the 4-loop Trojan plant) were performed to ensure that the bottom break in the pump discharge pipe remains the limiting break configuration.

SBLOCA Evaluation Model:

The RELAP5/MOD2-B&W (R5/2) code is used to predict the reactor coolant system thermal-hydraulic responses to a small break LOCA. The code has been approved by the NRC for licensing application, and is documented in detail in BAW 10164P, Revision 3. The noding description of the reactor coolant system used in the RELAP5/MOD2-B&W (R5/2) computer model is shown in Figures 1 and 2. For breaks at the top or side of the pump discharge pipe, the fictitious leak volume (volume 276) is placed directly above or beside the piping respectively as discussed in Section 4.3.2.2 in Volume II of BAW 10168P, Revision 2. The ECCS injection to the broken loop is directed to volume 270 (upstream of the leak) in the pump discharge pipe.

Summary of Results:

The evaluation model is based on the Sequoyah plant SBLOCA model. This model is selected because it has no weir plate in the pump discharge pipe to prevent ECC water backflow. This will maximize the ECC water backflow into the pump suction piping. The spray nozzle total flow area is revised with the Trojan plant data (0.0218 ft^2). A total peaking factor of 2.5 at the 10.3-ft elevation is used for the hot assembly power distribution. Figures 1 and 2 present the system nodalization. The reformation of loop seal is more likely to occur for (1) smaller leak areas that reduce ECC water bypass, and (2) lower core decay heat that produces less steam to entrain water droplets out the break. Thus, a typical core power profile shown in Figure 3 is used for breaks equivalent to 2-inch diameter and smaller. The accelerated core power reduction is initiated at 3600 seconds R5/2 transient time. The core power reduction is based on a ratio of LOCA time to R5/2 transient time. This ratio is approximately 10, and a plot of the LOCA time used in the core power vs. R5/2 transient time is presented in Figure 22.

The break spectrum results in Appendix A of Volume II, BAW 10168, Revision 2, show that the limiting break size generally falls in a range between 2.5- and 3.5-inch diameters. Thus, the 2.5- and 3.0-inch break sizes with side and top break orientations, and the 3-inch break size with bottom break orientation were analyzed with no decay heat reduction to demonstrate that the bottom break orientation yields the highest cladding temperature. Since the results show no significant differences in transient behaviors between the top and side breaks, the results from the 2.5- and 3.0-inch top breaks and the 3.0-inch bottom break are presented in Figures 4 through 6. Figure 4 shows hot rod cladding temperature at an upper elevation (10.9 ft) for the 2.5- and 3-inch breaks. The cladding temperature excursion observed in the 3-inch bottom break case confirms that the bottom break orientation is conservative for the SBLOCA analysis. No cladding heatup is predicted for both the top and side breaks. Figures 5 and 6 present water level in the downflow and riser sections of pump suction piping in the broken loop. The break sizes in this range and smaller generally clear only the broken loop seal as a result of extending pump suction U-bend (loop seal) in the intact loop 1.0 foot lower than that of the broken loop. With broken loop ECC water spilled out the break in the bottom break orientation, the mixture level falls below the top of the core after loop seal clearing. Break sizes in this range depressurize rapidly after the loop seal clearing, and provide sufficient ECC flow to makeup for inventory loss and to establish the long-term cooling.

Analyses for smaller breaks in a range between 1.0- to 2.0-inch diameters were performed for the top and side breaks orientation with the reduced decay heat shown in Figure 3. Since the primary system depressurizes at a relatively slower rate, the core decay heat reduction is initiated at 3600 seconds to simulate core steam generation at a lower power level to evaluate its impact on loop seal reformation. Again, no significant differences in transient behavior between the top and side breaks are observed. Thus, the transient results from the top break orientation are summarized below. Table 1 provides time sequence of events based on the R5/2 transient time for a spectrum of breaks. The results show that the cladding at the 10.9-ft elevation in Figures 7 experience a brief heatup during the loop seal clearing for the 1.5- and 1.25-inch breaks. The cladding temperatures increase approximately 150 F above the fluid temperature. Figures 8 and 9 present the primary and secondary side pressures respectively. For breaks greater than 1.0-inch diameter, the primary system depressurizes below the secondary side pressure, and will reach the actuation pressure of the accumulator (accumulators actuated for the 2-inch diameter break). The accumulator injection provides additional core cooling. However, the 1.5- and 1.25-inch breaks have relatively slow depressurization, and therefore mainly depend on the high head pump injection for core cooling. Figures 10 and 11 show timing of the loop seal clearing. The broken loop seal clearing is predicted for all break sizes except for the 1.0-inch break.

As the break size becomes smaller (less than 2.0-inch diameter), more ECC water accumulates in the pump discharge piping, and ECC water backflow into the pump suction piping increases. In order to enhance the backflow and to evaluate the effect of the loop seal reformation on the core level, a noding change was made to the pump discharge piping volume (volume 265) immediately downstream of the pump for the 1.5- and 1.25-inch top break cases just before the initial loop seal clearing. Volume 265 is split at the centerline of the pump discharge piping into two equal volumes each with a volume elevation equal to one half of the pipe diameter. The volume below the centerline is connected to volume 257 in the pump suction to enhance liquid draining to the pump suction piping, while the volume above the centerline permits steam venting. Figure 11 shows that the loop seal clearing and reformation cycle repeats several times for the 1.5- and 1.25-inch break cases. The loop seal reformation causes only a brief core uncovering followed quickly by core recovering. This prevents an extended core heatup. Break sizes equivalent to 1-inch diameter and smaller rely on reflux mode cooling and natural circulation to remove the core energy, and therefore, the primary system pressure remained slightly above the secondary side pressure to provide primary-to-secondary heat transfer. Figure 12 shows the downcomer water level. The top and side break configurations permit ECC water injected into the broken cold leg pipe to flow into the reactor vessel. This increases the downcomer water level, and maintains it near the centerline of the cold leg nozzle (elevation 0.0 ft) to prevent severe core level depression when the loop venting is interrupted. Figures 13 and 14 show the core collapsed and mixture levels respectively. The level remains above the top of the core except that the core uncovering occurs briefly during the loop seal clearing cycle. Figures 15 and 16 show fluid temperatures in the riser section of the pump suction piping for both the intact and broken loops for the 1.25- and 1.5-inch breaks respectively. The fluid temperature decreases significantly below the saturation temperature due to the ECC water backflow during the loop seal reformation cycle, thereby, preventing steam flow through the loop during subsequent loop seal clearing cycles, and resulting in primary system repressurization. The pressure oscillation continues, and the system pressure decreases as the core decay heat decreases. Figure 17 presents leak flows, and Figures 18 through 21 provide ECC flows for individual break size. The ECC injection increases as the primary system pressure decreases. A comparison of the leak flow with the ECC flow shows that the ECC injection approaches the leak flow to prevent further inventory loss. This will lead to a core boil-off suppression, and therefore, the long-term cooling will be established.

FTI also performed an evaluation to further validate the above results. A non-EM SBLOCA R5/2 model was developed based on the approved EM model. The model contains four independent loops; the fictitious leak volume and the lowering of the intact loop pump suction pipes one foot below that of the broken loop were not used. The broken and three intact loop pump discharge pipe volumes were modified just before the initial loop seal clearing similar to that described on the previous page. All other model features are the same as the EM.

A 1.25-inch diameter top break was run with the non-EM model. The leak originated directly from the top of the pump discharge pipe. The clad temperature, system pressure, broken loop seal levels, and core liquid level are shown in Figures 23, 24, 25 and 26 respectively. These plots show that clad temperature, core performance, and loop seal clearing and replugging cycles are comparable in magnitudes and trends to the EM predictions. The non-EM case shows consistent loop seal clearing behavior, and there is no switching between the broken loop and the three intact loops. The broken loop is the loop that always clears. This evaluation further supports FTI's SBLOCA methods, confirming bottom breaks as limiting.

Conclusion:

The results of the SBLOCA break spectrum analysis demonstrate that loop seal clearing and reformation cycle is predicted for breaks between 1.0- and 2.0-inch diameter. The loop seal clearing does not cause an extended core heatup because it is a rapid transient followed by core refill. Furthermore, the downcomer level remains essentially full (near nozzle belt elevation) throughout the transient except a short period just before the loop seal clearing. The fluid in the pump suction piping becomes subcooled due to the ECC water backflow following the loop seal clearing, and prevents steam flow through the intact loop. The primary system repressurizes slightly during the loop seal reformation cycle, but the system pressure continues a downward trend. Thus, the ECC injection continues to increase and to prevent core uncovering. The results also confirm that the upper head spray nozzle flow area has no significant impact on the core level depression except that the transition break size for loop seal clearing is decreased from 1.9-inch diameter for the T_{cold} plant to 1.0-inch diameter for T_{hot} plant. The analyses demonstrate that, with the top and side break configurations, the ECCS injection approaches the leak flow as the core decay power decreases to less than 1 percent (approximately 6 hours after reactor scram). Thus, the long-term cooling will be established as the ECC injection continues to increase (enhanced by accumulator actuation). It is concluded that the bottom break orientation is limiting, and may be used for the SBLOCA analysis for the T_{hot} plant.

Table 1. Time Sequence Of Events for Top Breaks (R5/2 Transient Time)

Events, Sec	3-Inch	2.5-Inch	2.0-Inch	1.5-Inch	1.25-Inch	1.0-Inch
Break Initiation	0.0	0.0	0.0	0.0	0.0	0.0
Reactor Scram	23.4	33.4	51.6	91.5	131.9	207.7
R C Pump Coastdown	23.4	33.4	51.6	91.5	131.9	207.7
MSIV Closed	23.4	33.4	51.6	91.5	131.9	207.7
MFW Isolation	33.4	43.4	61.7	101.5	141.9	217.7
ECCS Injection	65.6	77.7	98.3	141.5	184.3	263.9
Loop Seal Clearing	596.0	858.1	1442.5	3253.9	5845.3	NA
Peak Cladding Temperature	NA	NA	NA	723	712	NA
Accumulator Injection	2230	NA	5910	NA	NA	NA

FIGURE 1. RELAP5/2 SBLOCA NODING DIAGRAM FOR RC LOOPS

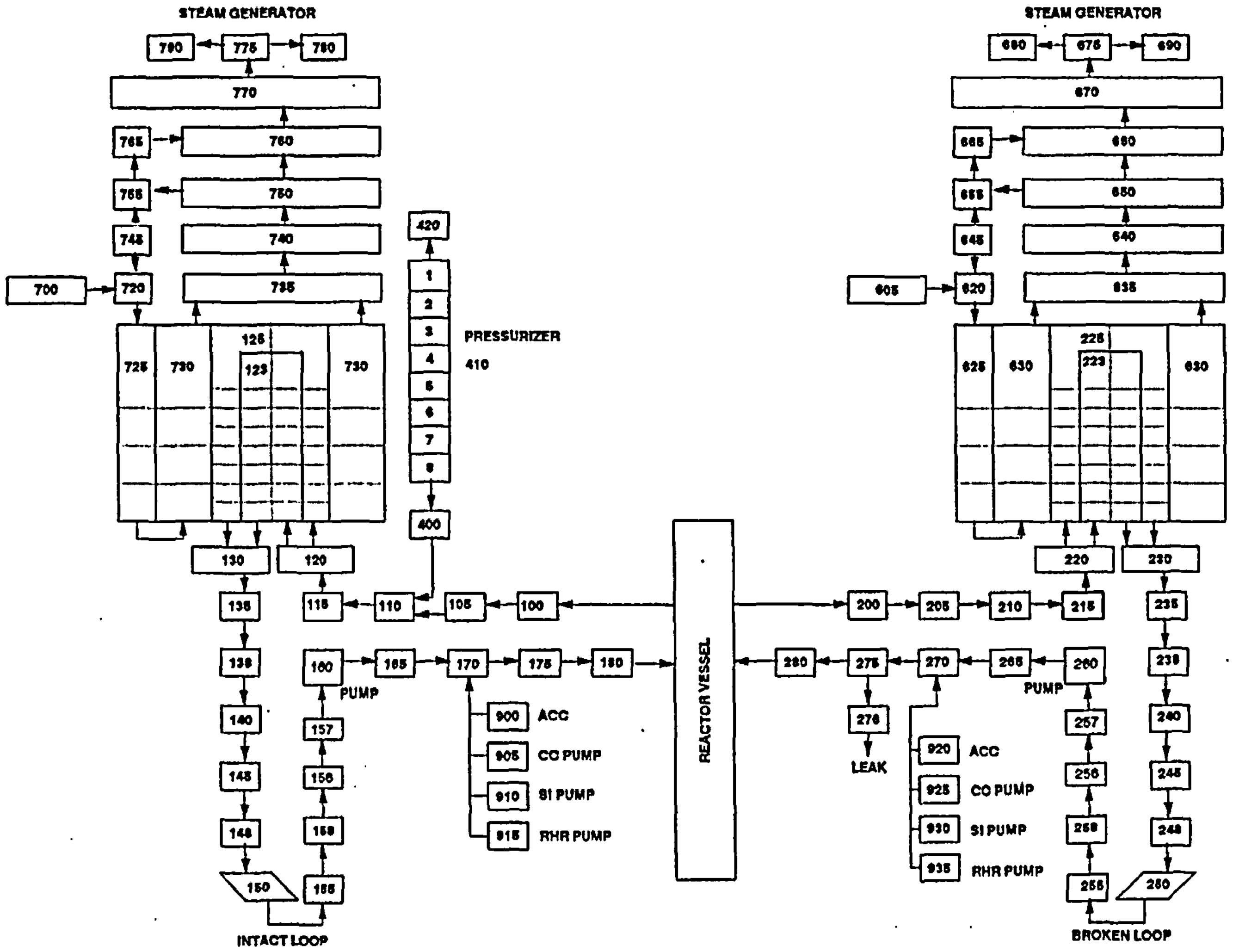


FIGURE 2. RELAP5/2 SBLOCA NODING FOR REACTOR VESSEL

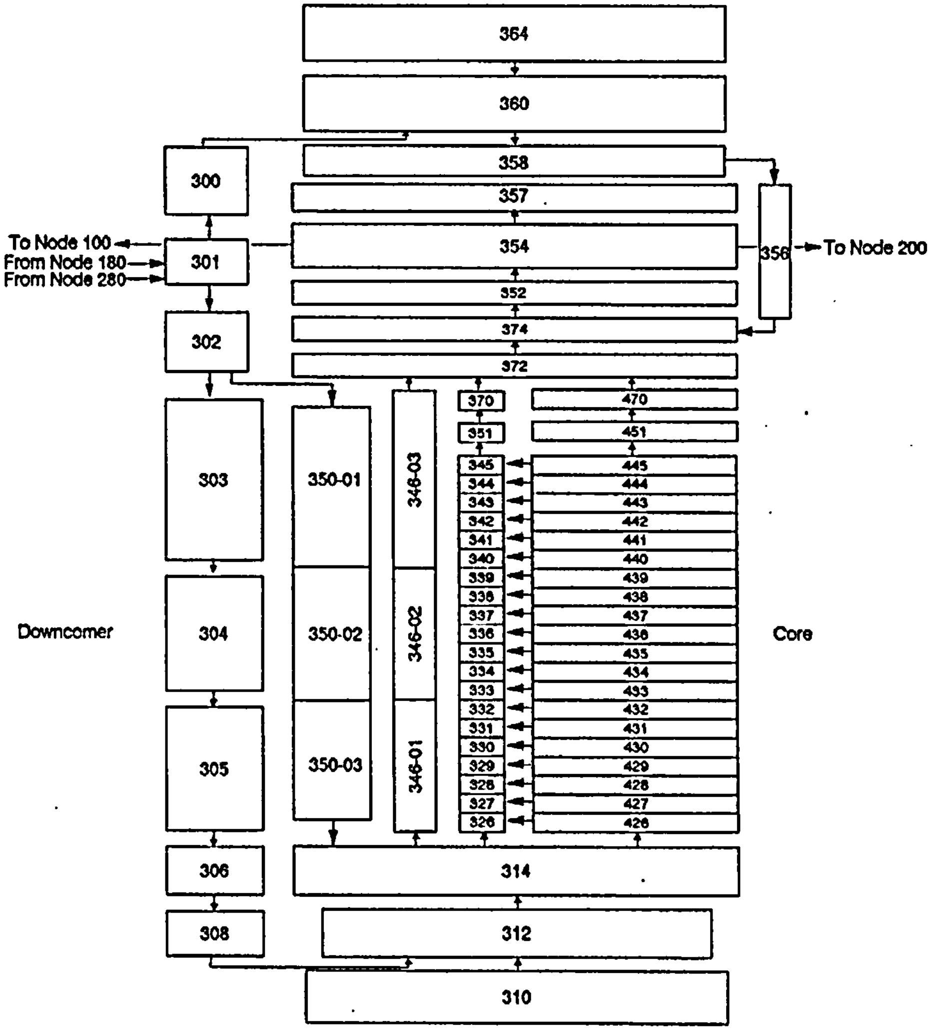


FIGURE 3. Core Decay Power
1.25-Inch Diameter Break

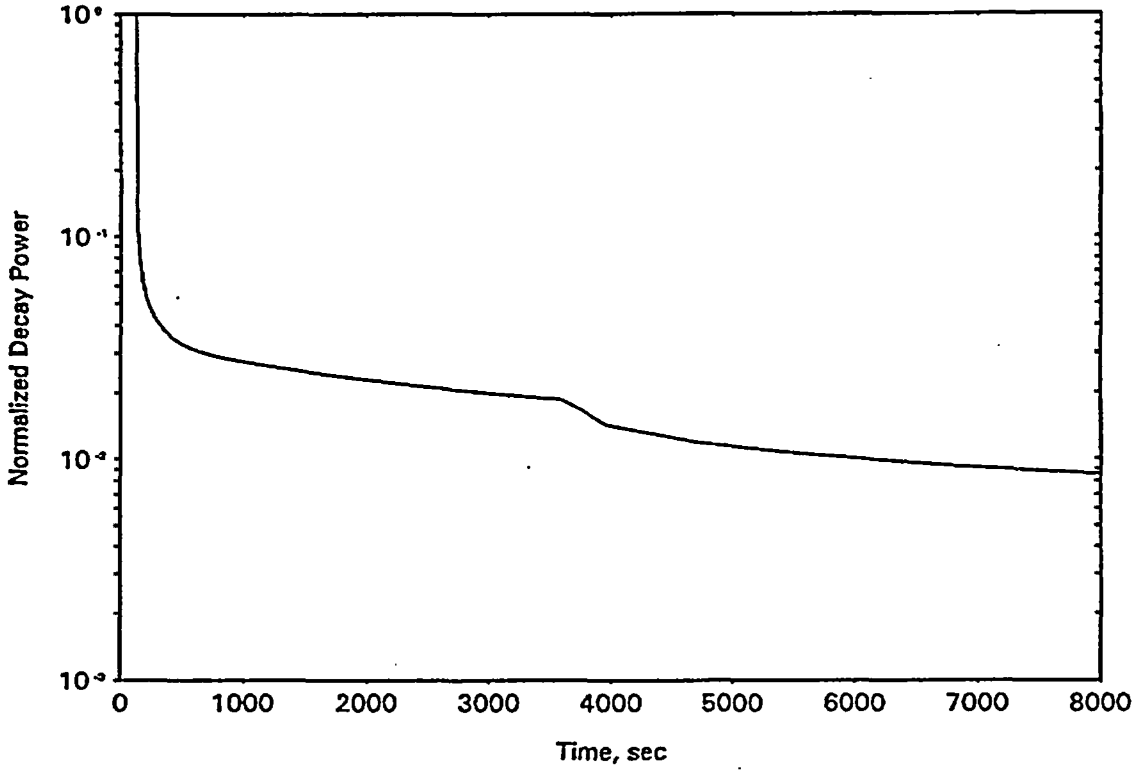


FIGURE 4. Hot Rod Cladding Temperature At 10.9 ft
2.5- and 3.0-Inch Diameter Break

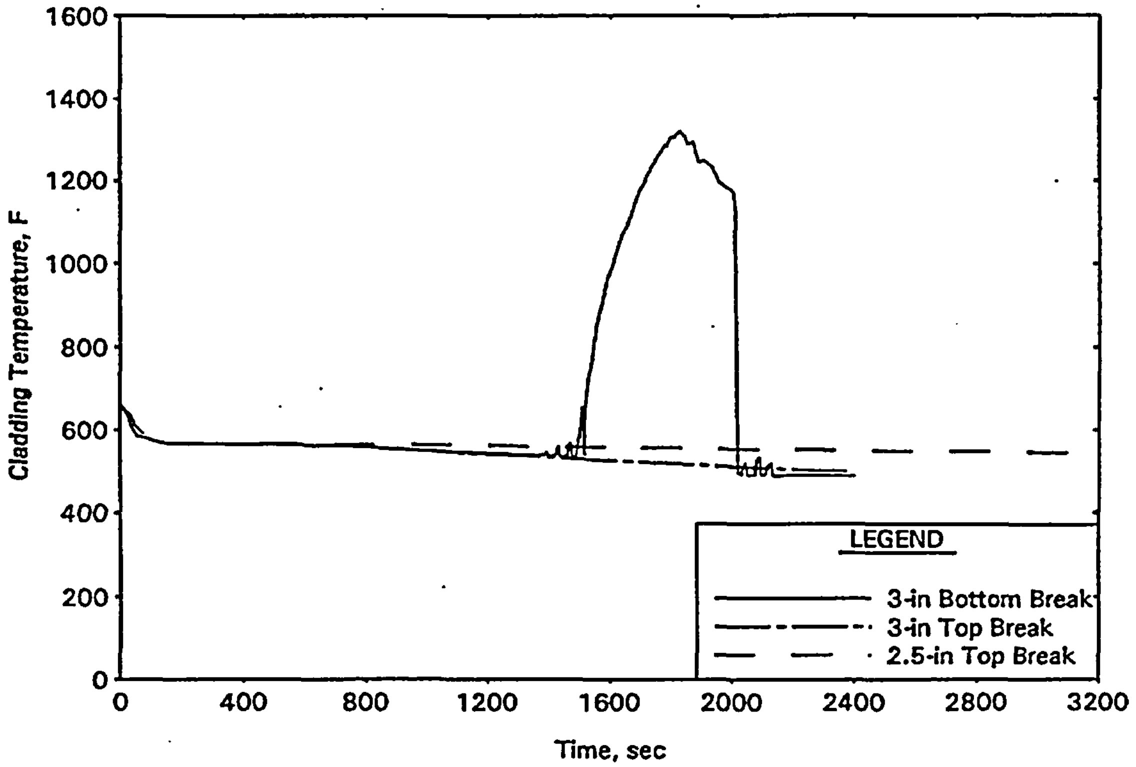


FIGURE 5. Broken Loop Seal Downflow Leg 2.5- and 3.0-Inch Diameter Break

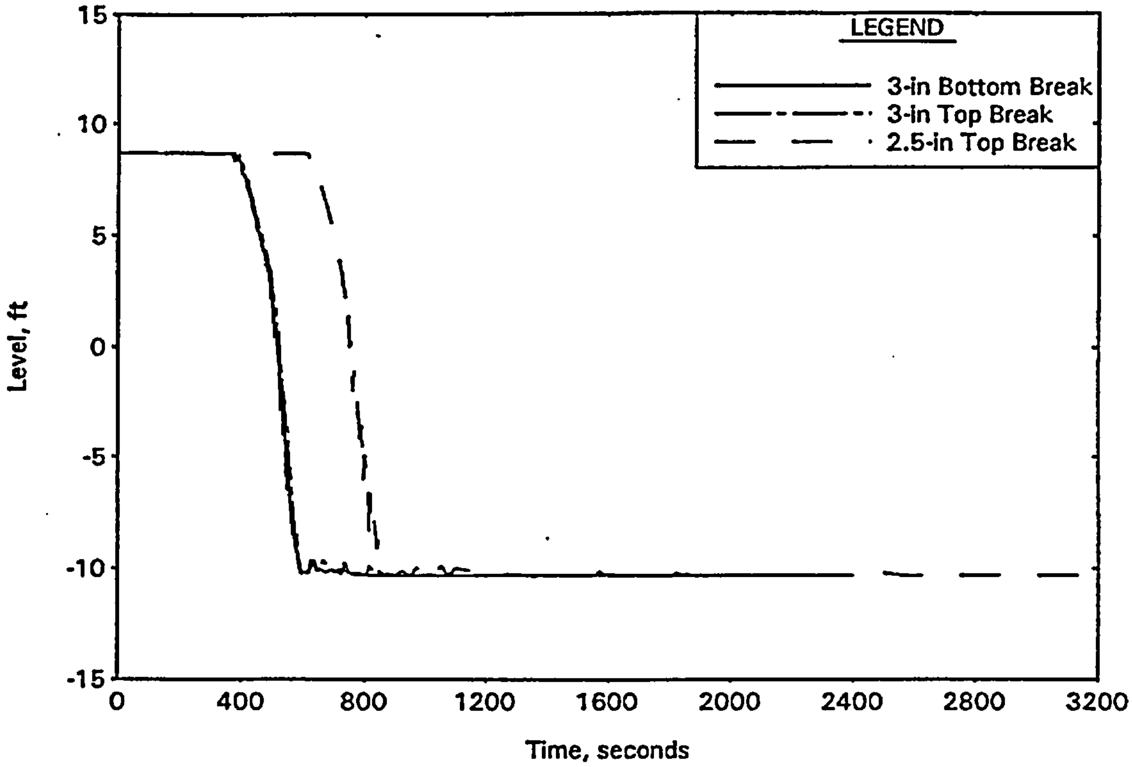


FIGURE 6. Broken Loop Seal Upflow Leg 2.5 and 3.0-Inch Diameter Break

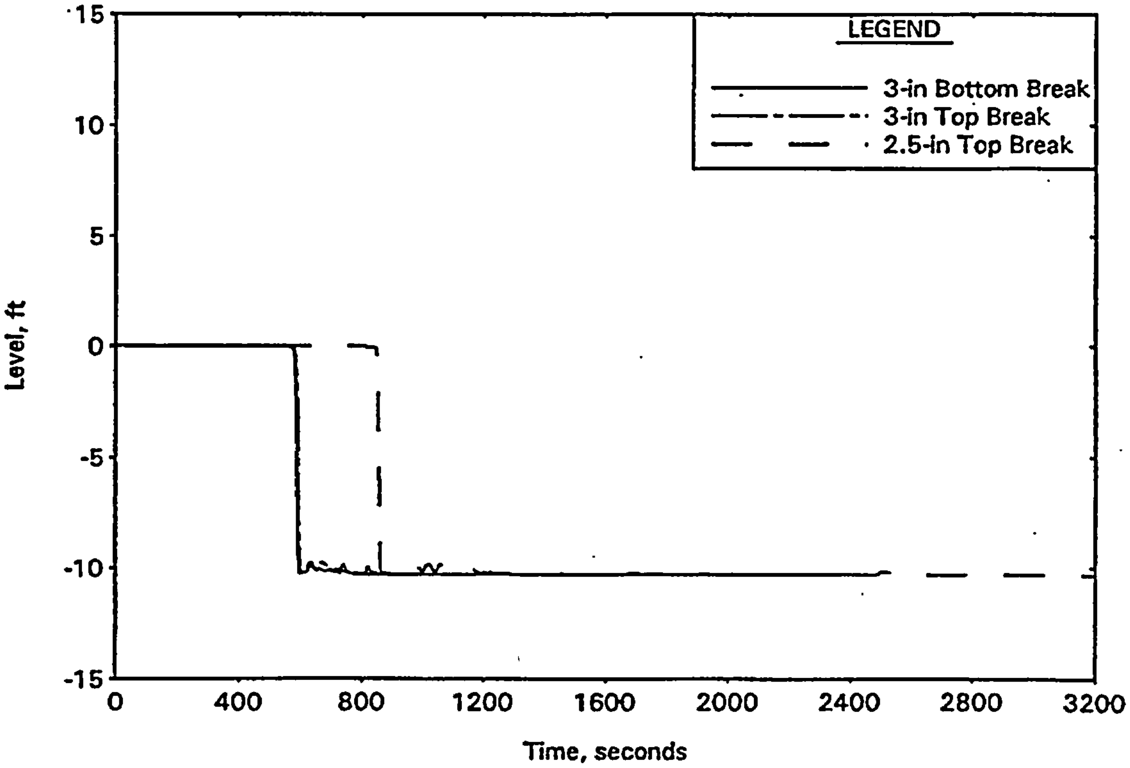


FIGURE 7. Hot Rod Cladding Temperature at 10.9 ft SBLOCA Top Break

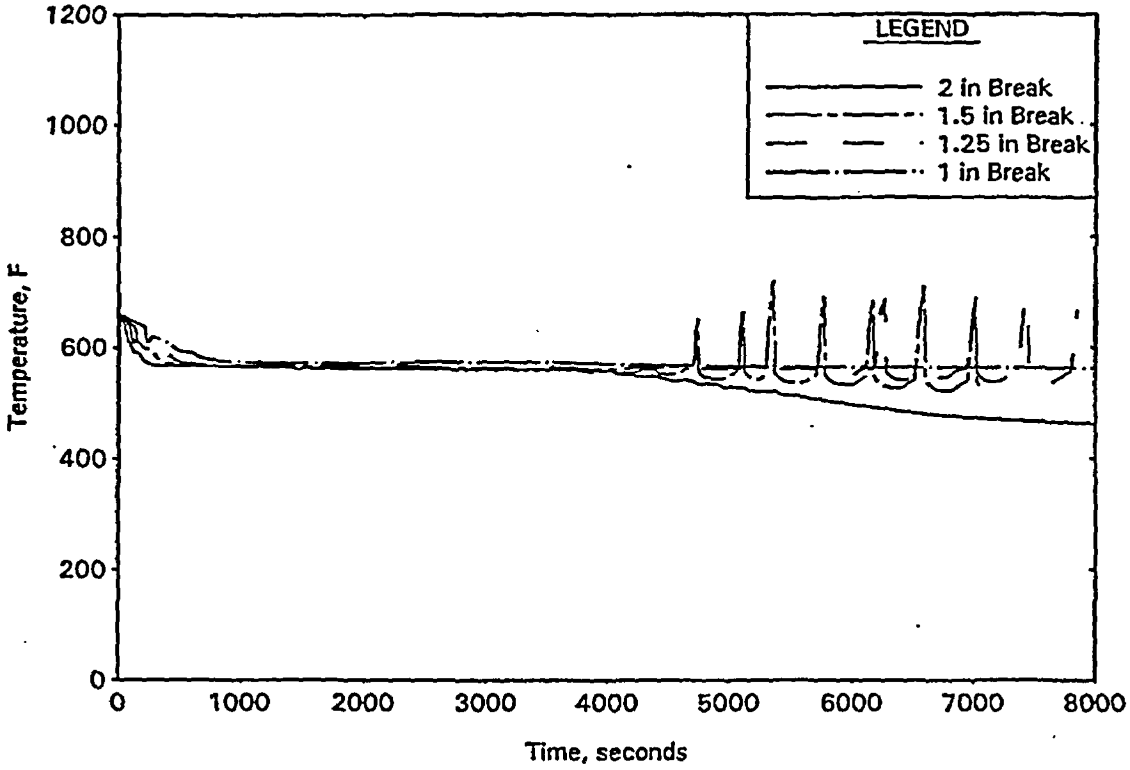


FIGURE 8. Primary System Pressure SBLOCA Top Break

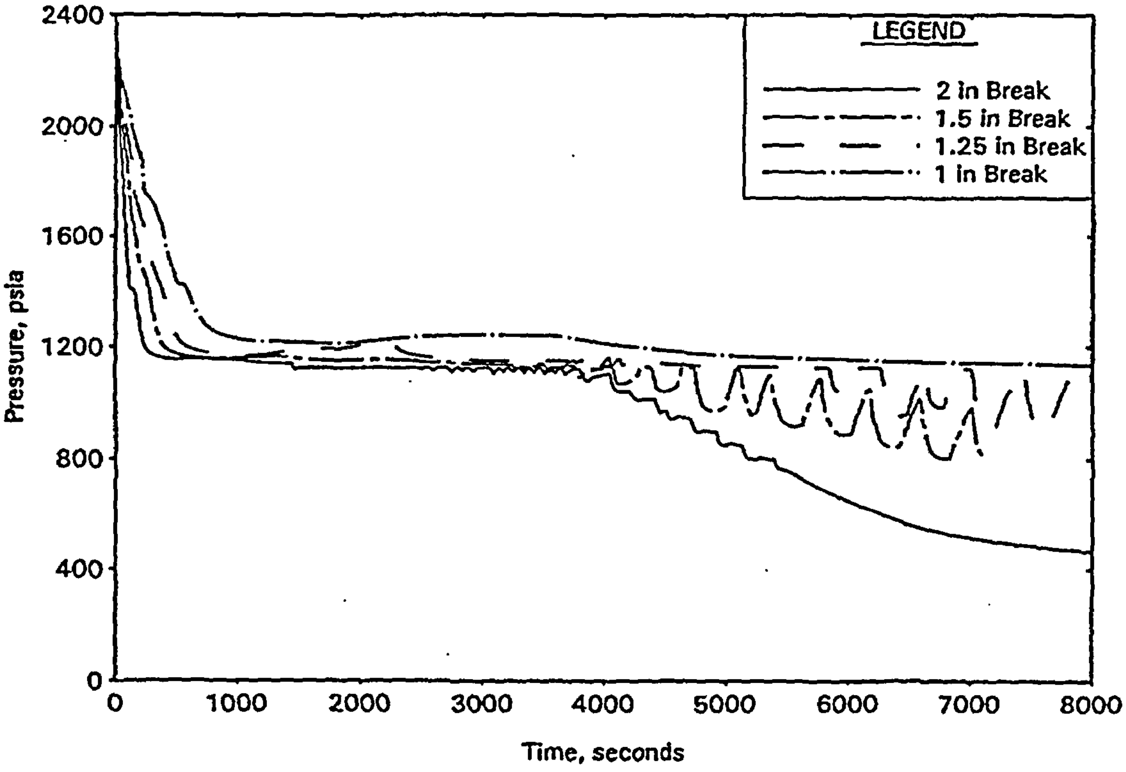


FIGURE 9. Broken Loop S G Pressure SBLOCA Top Break

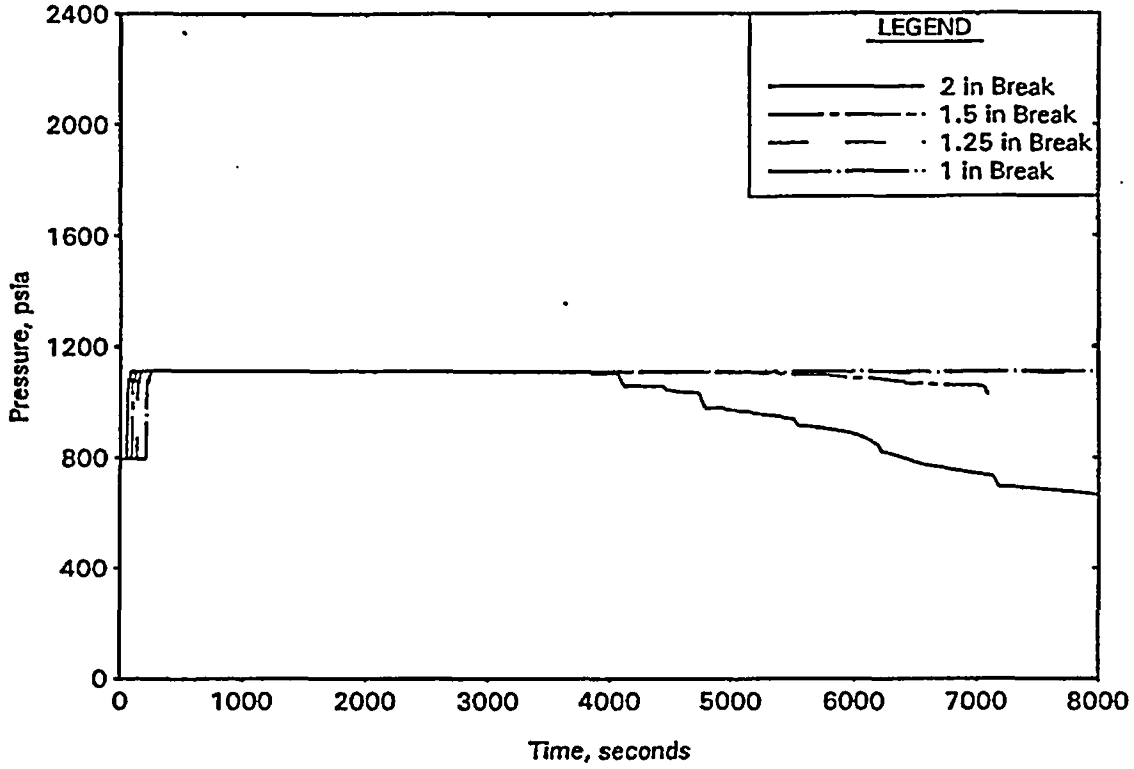


FIGURE 10. Broken Loop Seal Downflow Leg SBLOCA Top Break

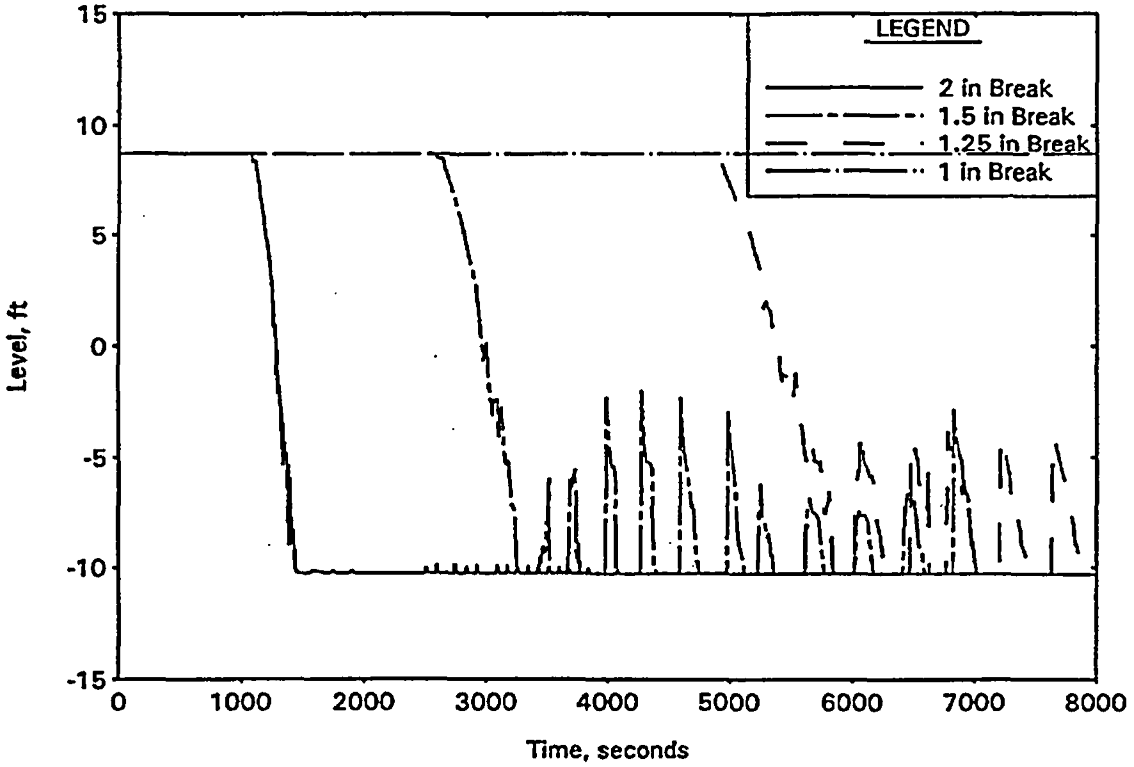


FIGURE 11. Broken Loop Seal Upflow Leg
SBLOCA Top Break

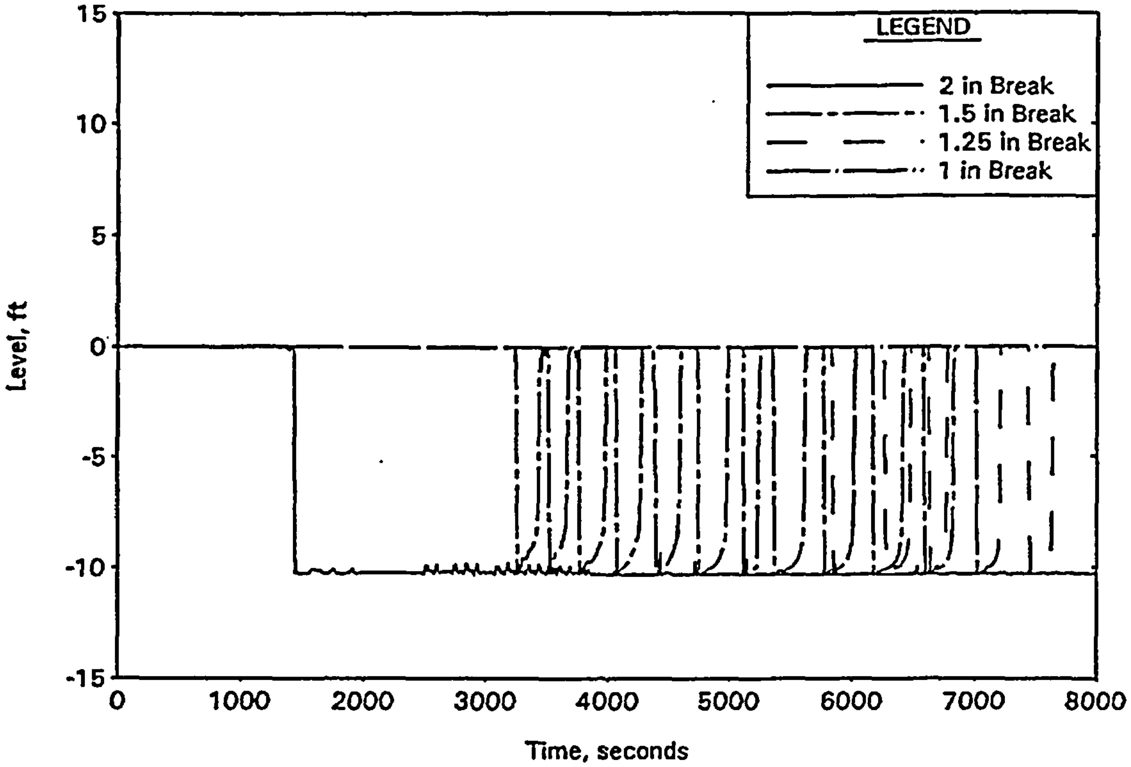


FIGURE 12. Downcomer Water Level
SBLOCA Top Break

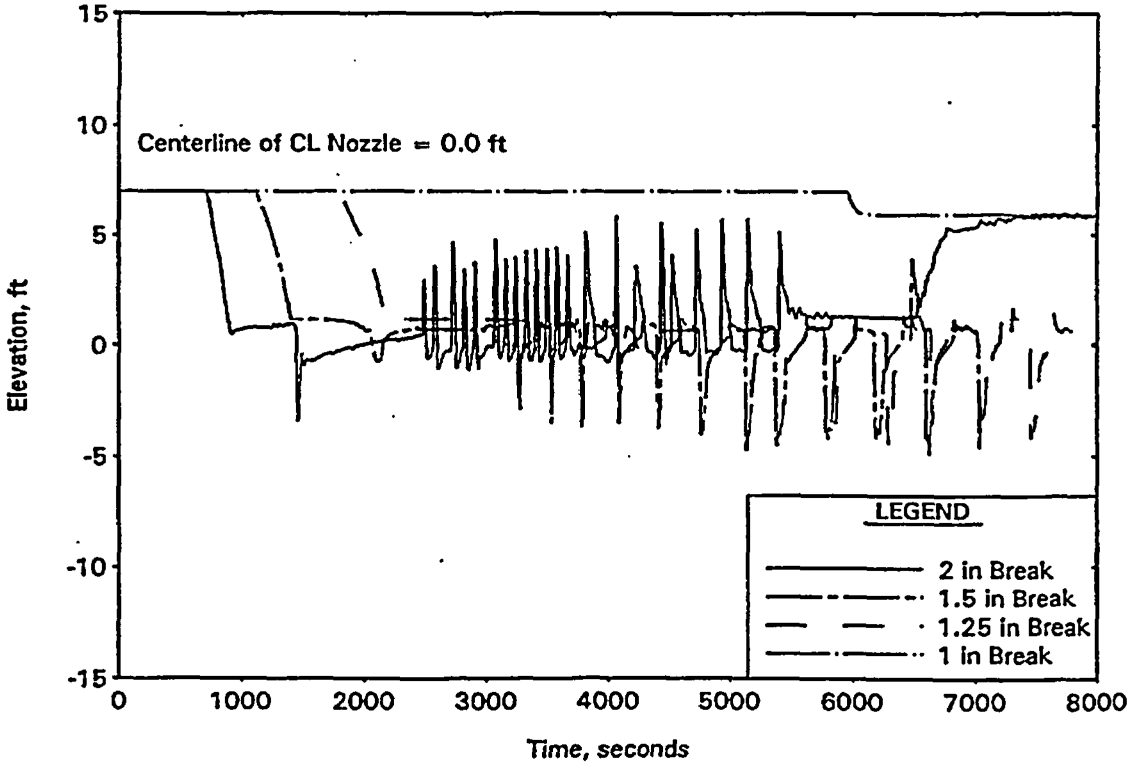


FIGURE 13. Core Collapsed Water Level
SBLOCA Top Break

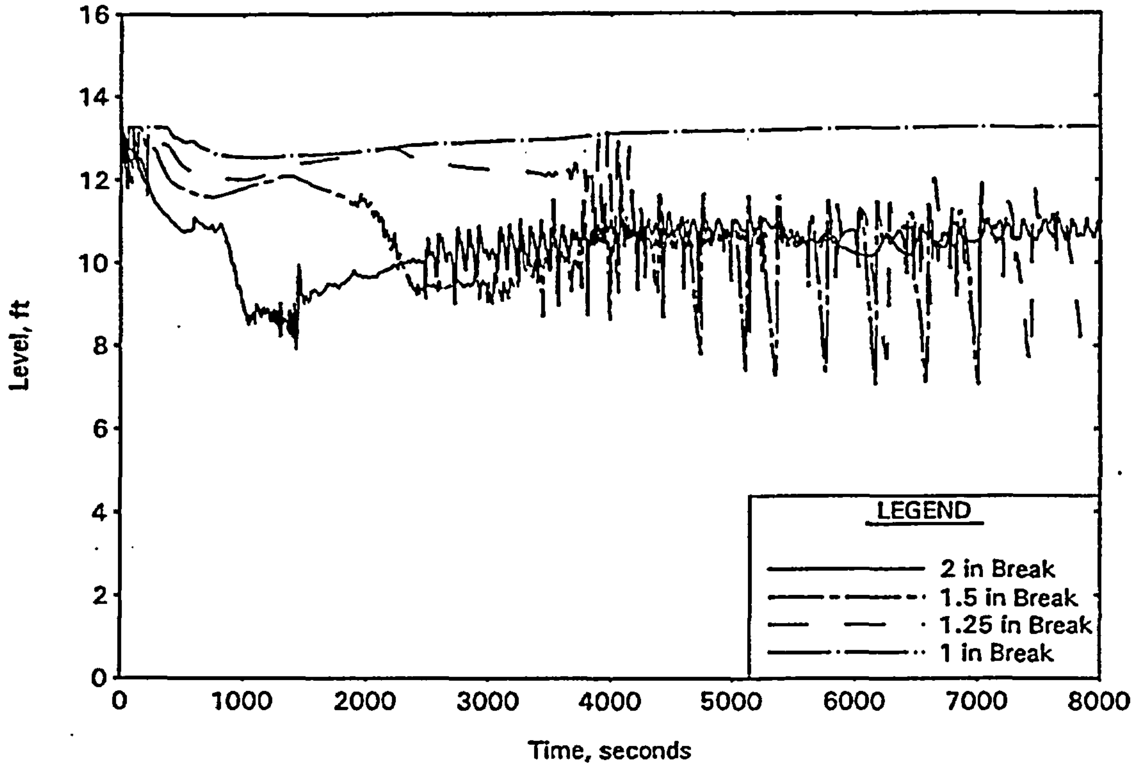


FIGURE 14. Hot Channel Mixture Level
SBLOCA Top Break

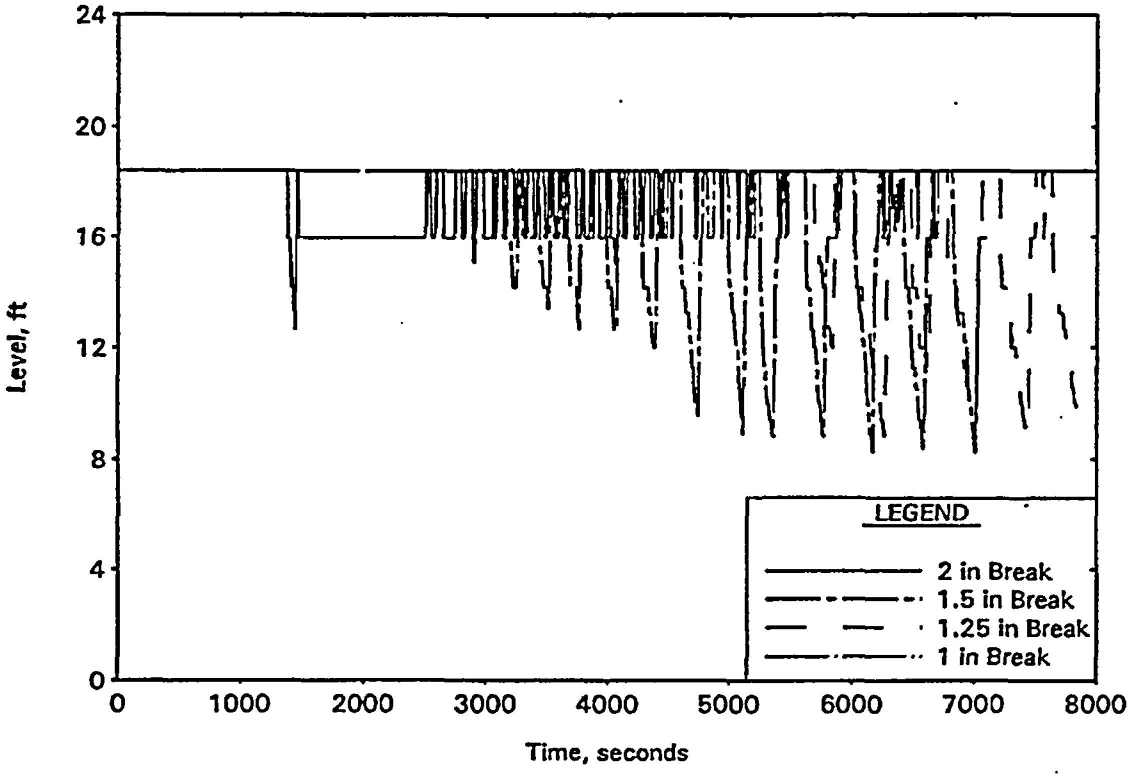


FIGURE 15. Pump Suction Pipe Fluid Temperature
1.25 Inch Top Break

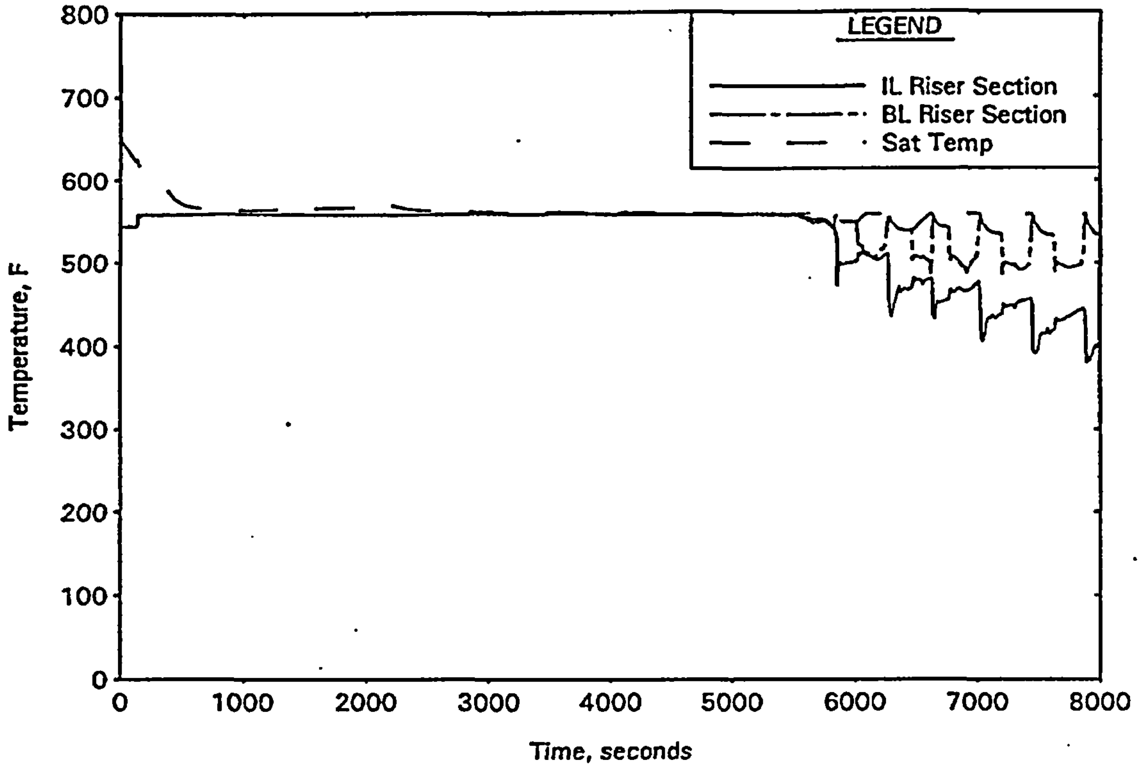


FIGURE 16. Pump Suction Pipe Fluid Temperature
1.5 Inch Top Break

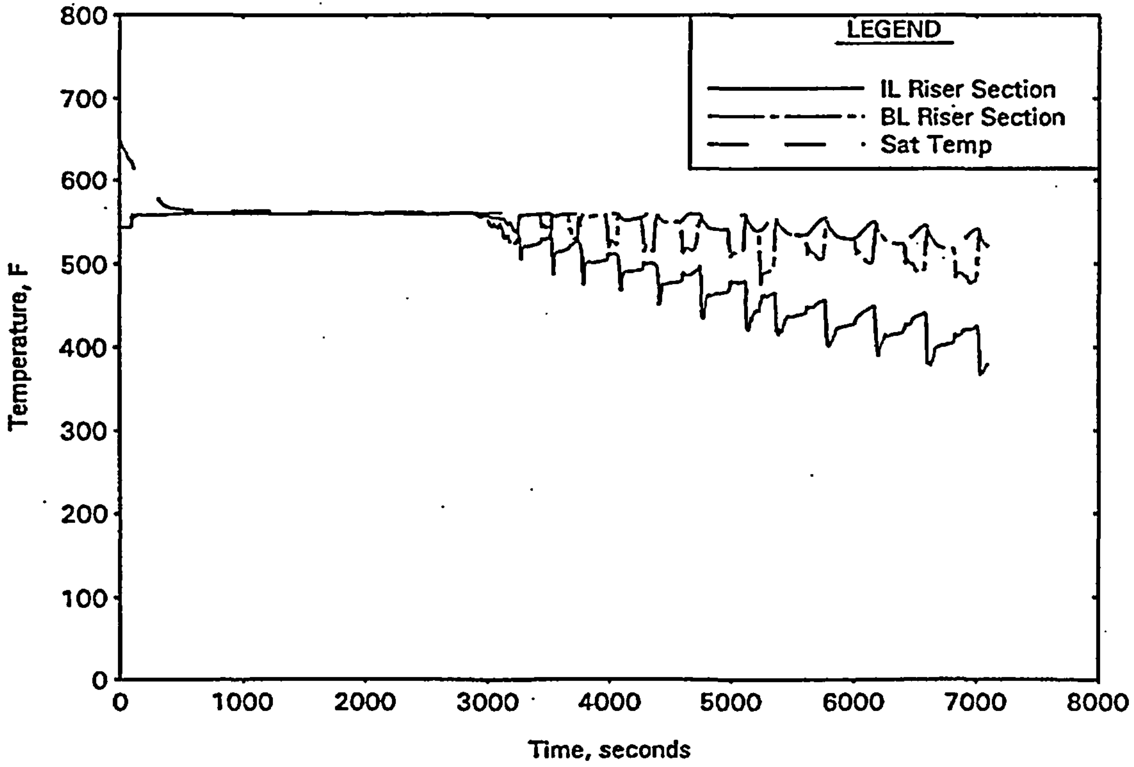


FIGURE 17. Leak Flow Rate
SBLOCA Top Break

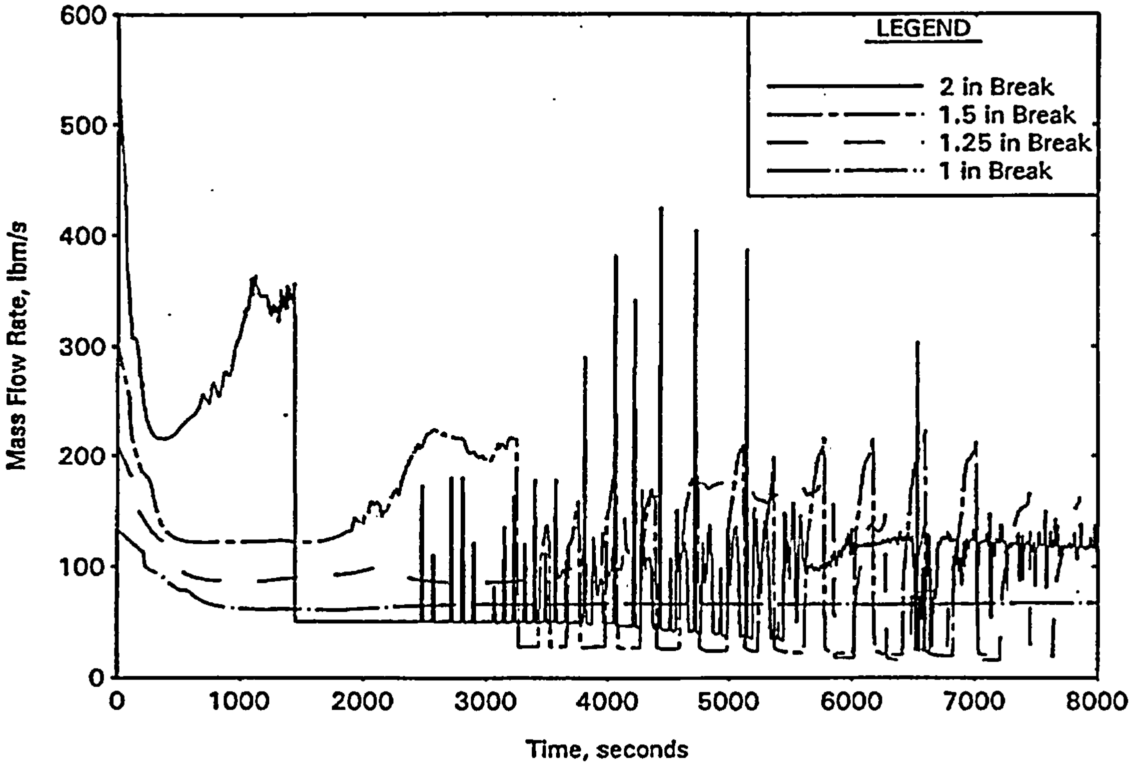


FIGURE 18. ECCS Flow Rate
2-Inch Diameter Break

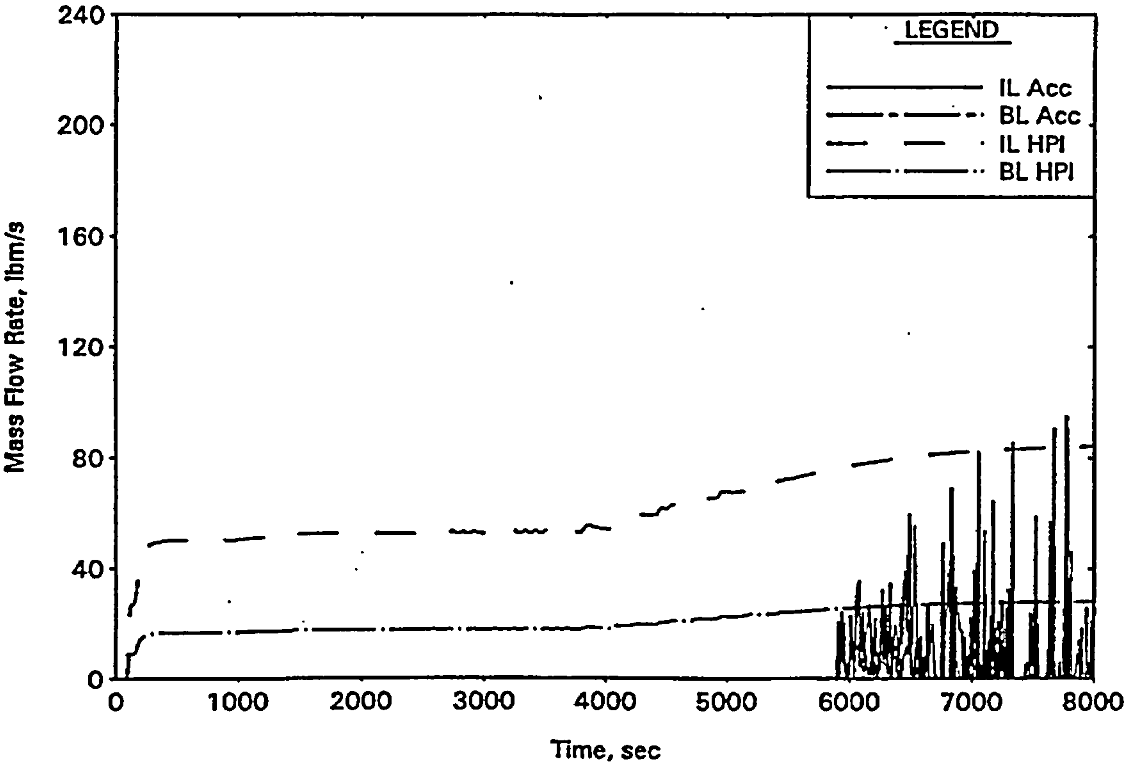


FIGURE 19. ECCS Flow Rate
1.5-Inch Diameter Break

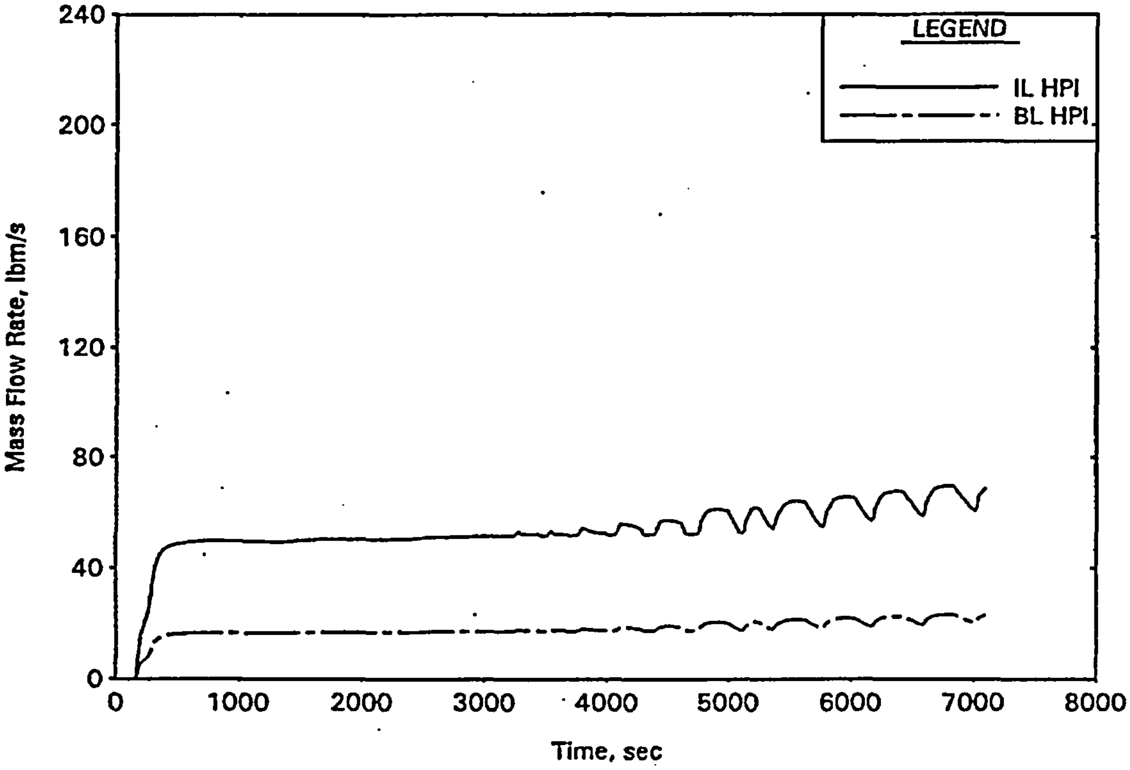


FIGURE 20. ECCS Flow Rate
1.25-Inch Diameter Break

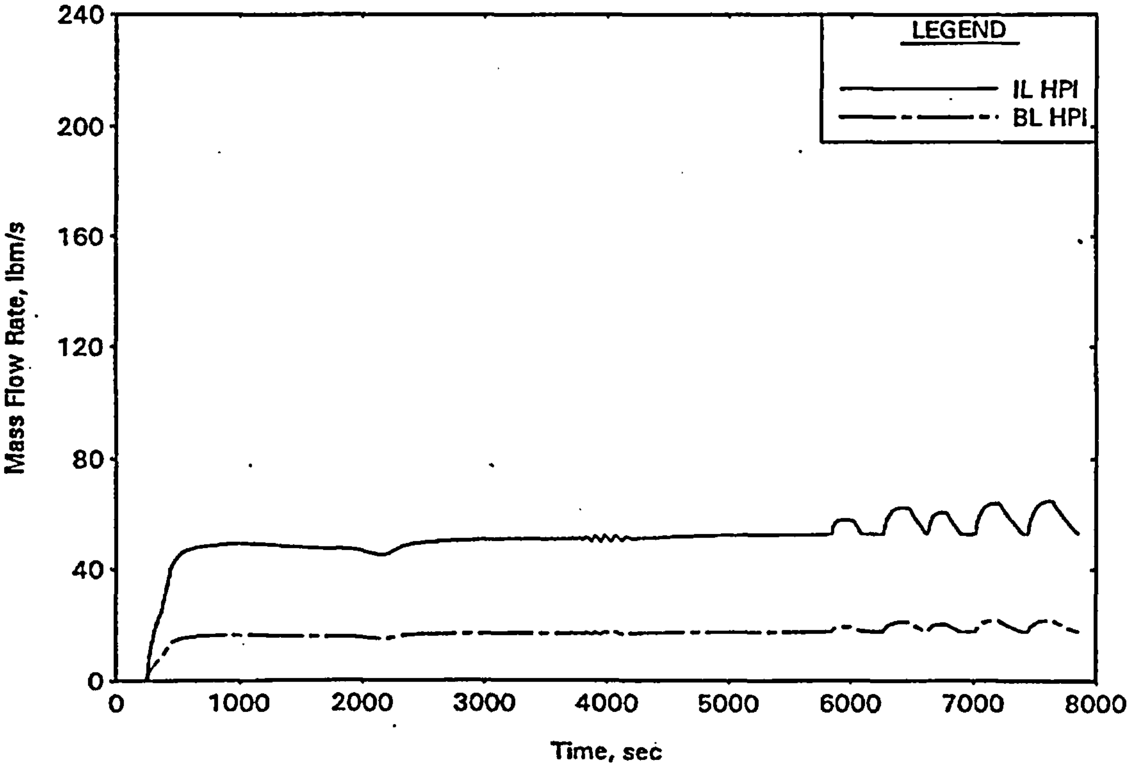


FIGURE 21. ECCS Flow Rate 1.0-Inch Diameter Break

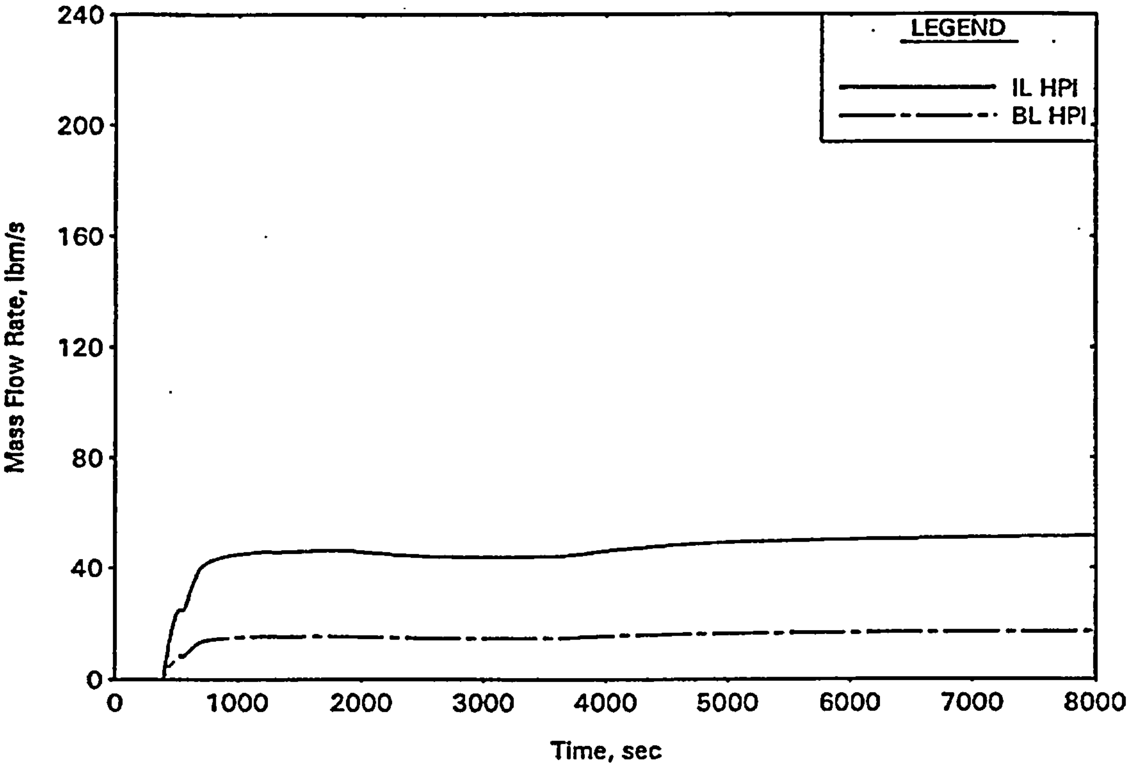


FIGURE 22. LOCA Vs. R5/2 Transient Time SBLOCA Top and Side Breaks

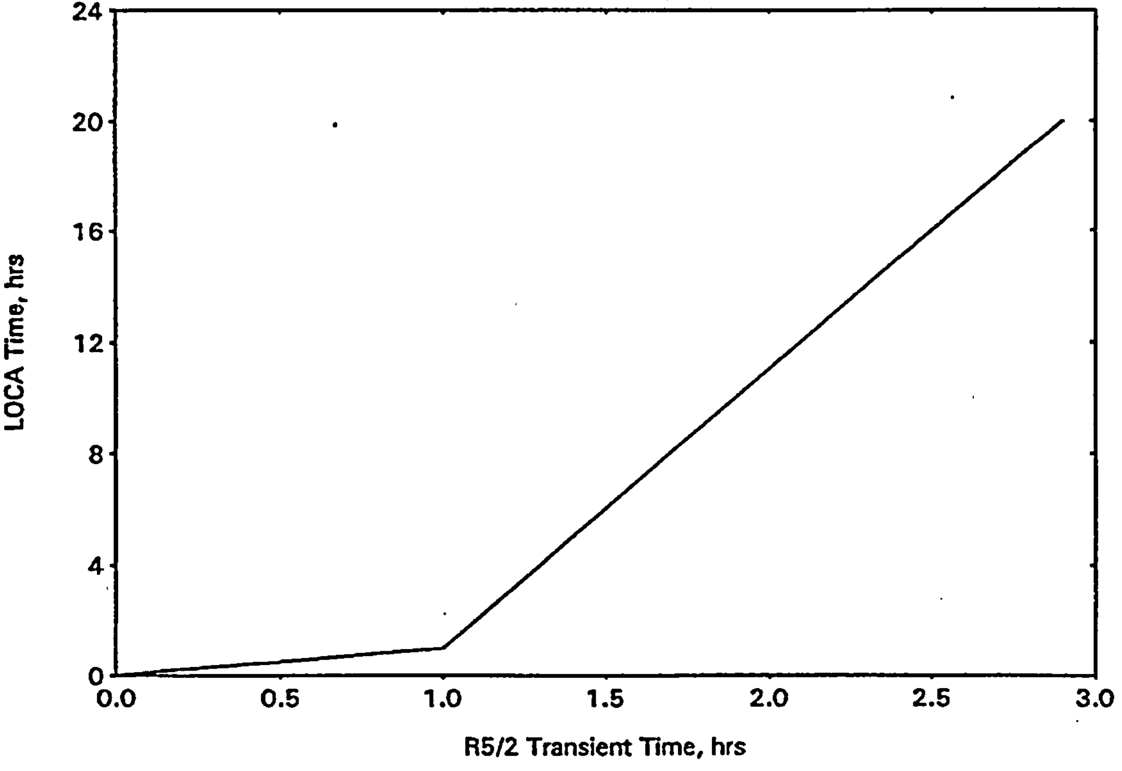


FIGURE 23. Hot Rod Cladding Temperature at 10.9 ft
1.25-Inch Diameter Top Break

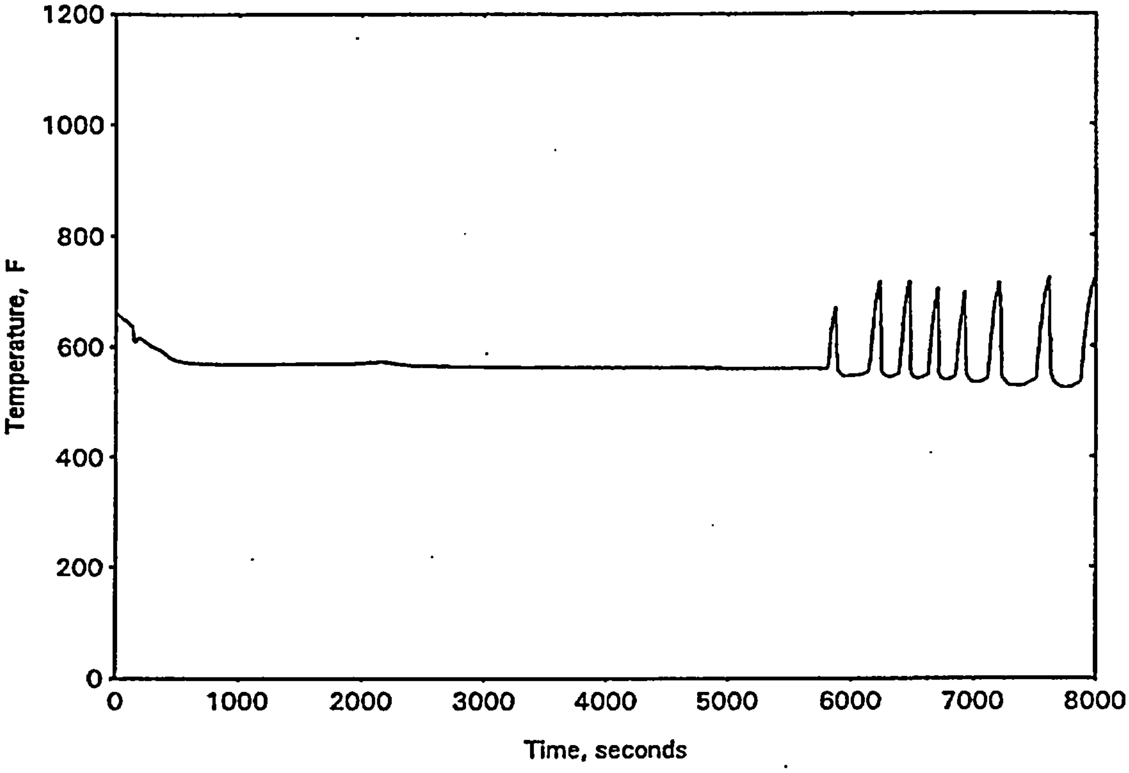


FIGURE 24. Primary System Pressure
1.25-Inch Top Break

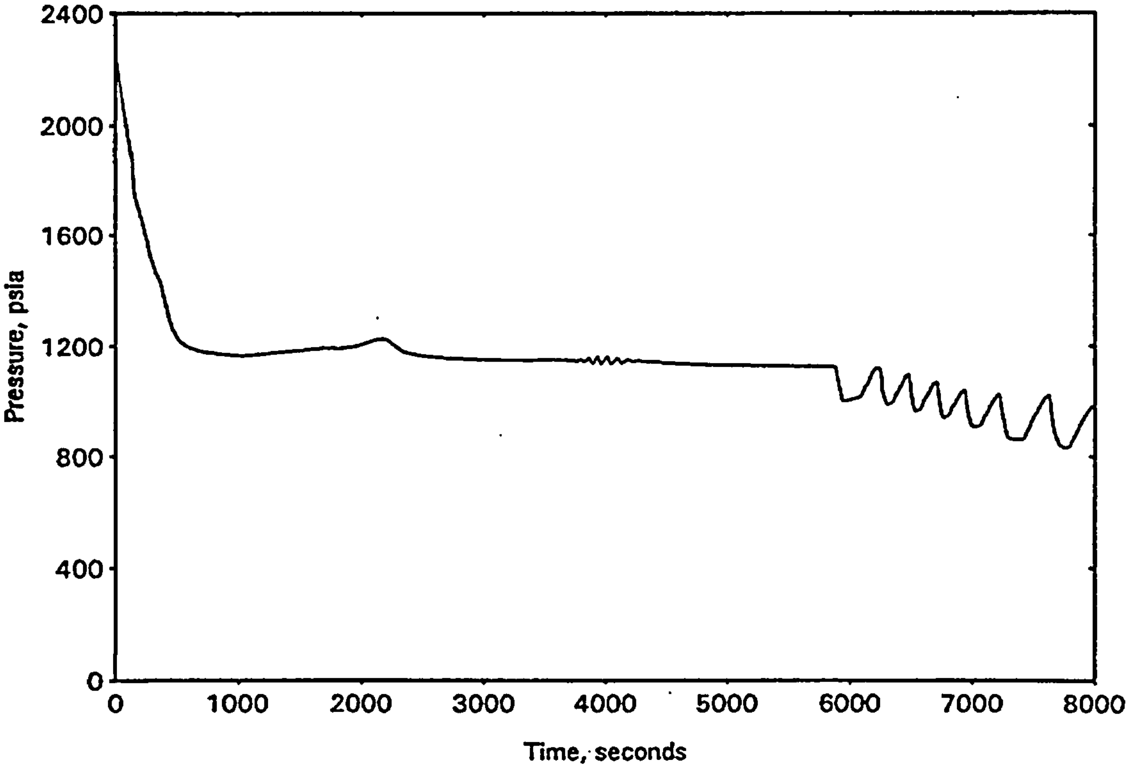


FIGURE 25. Broken Loop Seal Level
1.25-Inch Diameter Top Break

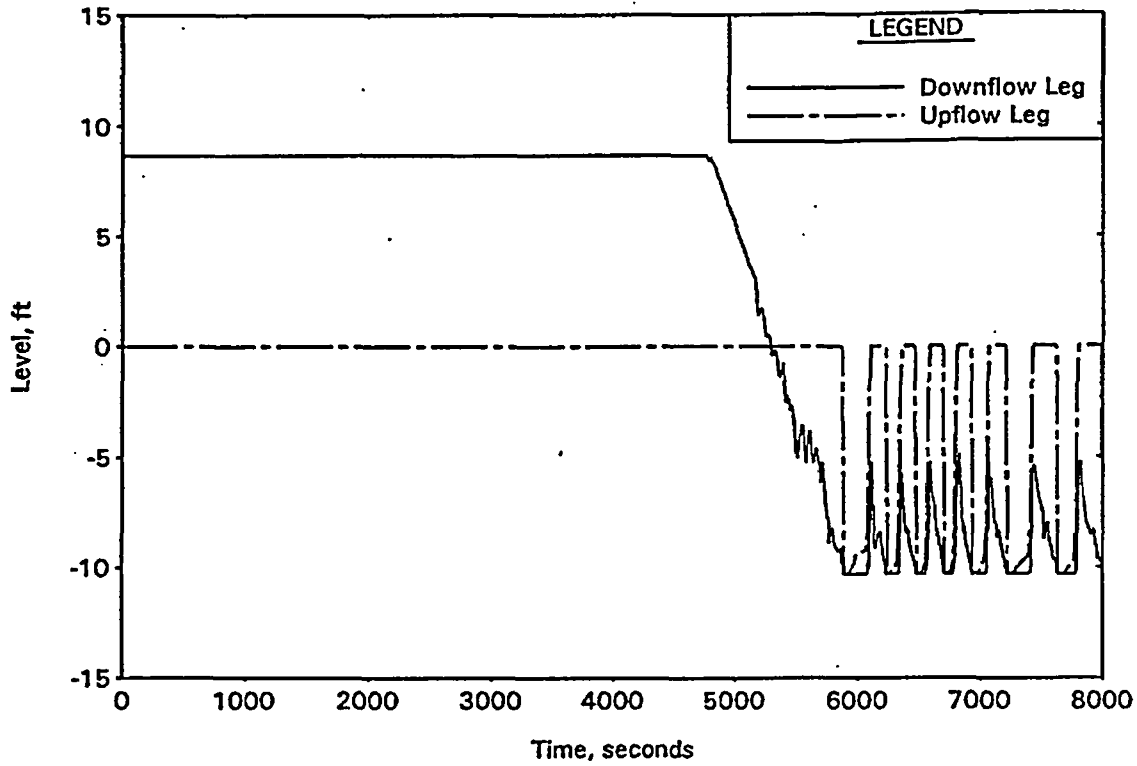
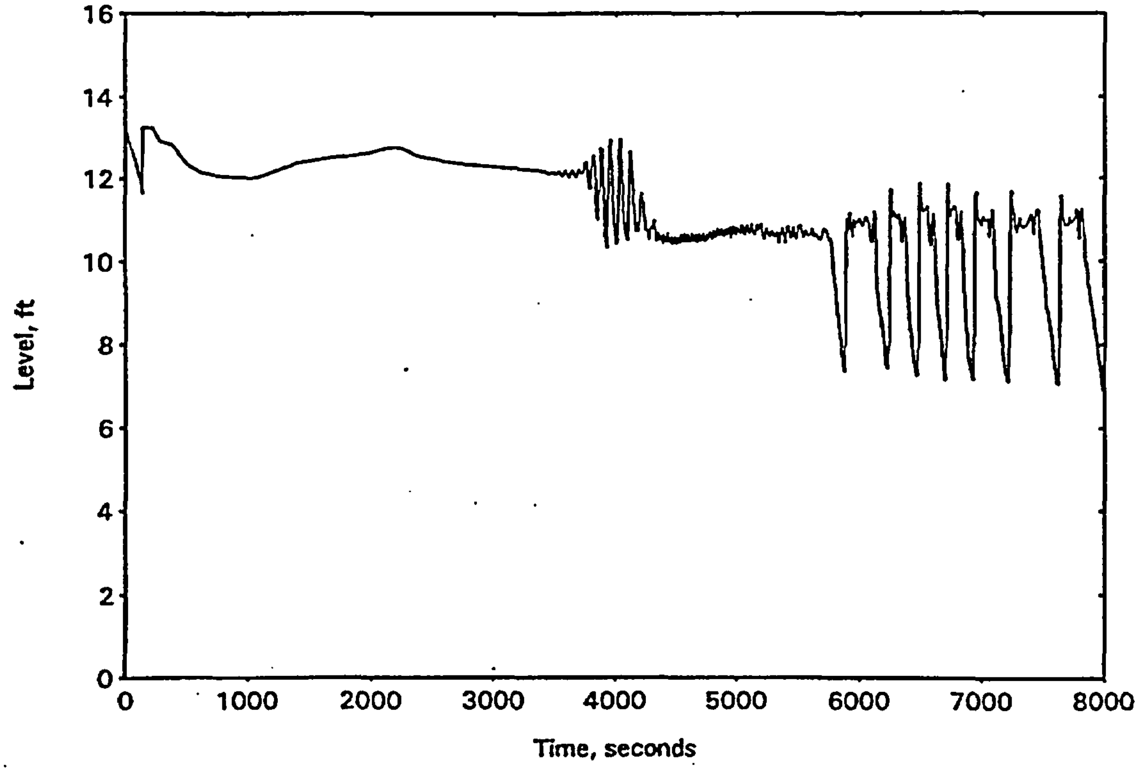


FIGURE 26. Core Collapsed Water Level
SBLOCA 1.25-inch Top Break



From: Thomas Kozak
To: Donald Norkin
Date: 3/23/04 12:10PM
Subject: Fwd: Contractors

Hi Don, please see attached for FY 2005 contractor requests from Region III. We are still working on a team leader for Point Beach this year.