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PUBLIC SERVICE COMPANY OF OKLAHOMA
A CENTRAL AND SOUTH WEST COMPANY

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Public Service Company of Oklahoma
Black Fox Station
LPCI Diversion Effects On
ECCS Performance
Docket STN 50-556 and STN 50-557

November 7, 1978
File: 6212.125.0500.210

Office of Nuclear Reactor Regulation
Division of Project Management
Light Water Reactors Branch No. 4
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attn: Steven A. Varga, Chief

Gentlemen:

In response to your request of October 11, 1978, Public Service Company of Oklahoma is submitting the results of an analysis performed to investigate the effects of LPCI diversion on ECCS performance for Black Fox Station Units 1 and 2.

The attached analysis will be submitted in Amendment 13 to the BFS PSAR, to be filed prior to Construction Permit issuance.

Very truly yours,

T. N. Ewing

T. N. Ewing
Manager, BFS Project

TNE:so

cc: See attached service list

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ANALYSIS OF LPCI DIVERSION EFFECTS ON ECCS PERFORMANCE

FOR

BLACK FOX STATION UNITS 1 AND 2

November 2, 1978

DOCKET NOS: STN 50-556
STN 50-557

PURPOSE

This analysis was performed to investigate the effect on the ECCS analysis for the Black Fox Nuclear Power Station of diverting low pressure coolant injection (LPCI) pumps to the containment spray mode ten minutes after a loss-of-coolant accident (LOCA) initiation.

Automatic diversion of LPCI flow to containment spray has been provided in response to an NRC requirement to assure containment integrity for postulated high steam flow bypassing the suppression pool. Such flow diversion would occur only if a high containment pressure (>9 psig) signal is present after ten minutes. The assumption of sufficient bypassing to cause such a pressure has been shown by GE to be extremely conservative and unrealistic[1].

CONCLUSION

The results show that the worst single failure/break type combination is the high pressure core spray (HPCS) line break (approximately .02 ft^2) assuming the failure of the low pressure core spray (LPCS) diesel generator (D/G) which powers one LPCS pump and one LPCI pump. This single failure/break type combination yields the highest peak cladding temperature (approximately 1985°F) of all the cases affected by LPCI diversion at ten minutes. The peak cladding temperatures experienced by the cases affected by LPCI diversion are below the limits established in 10 CFR 50.46 (2200°F). This temperature is also below the peak clad temperature (PCT) calculated for the break of a recirculation line (2038°F) which is not adversely affected by LPCI diversion at ten minutes.

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[1]NEDO-10977 Drywell Integrity Study: Investigation of Potential Cracking in BWR/6 Mark III Containment

ASSUMPTIONS

1) A maximum of two LPCI pumps (specifically LPCI "A" and LPCI "B") can be fully diverted at ten minutes to the containment spray mode. (NOTE: LPCI "A" shares an emergency diesel generator with the LPCS; LPCI "B" and "C" share an emergency diesel generator. The pump associated with LPCI "C" cannot be diverted to containment sprays.)

2) The standard FSAR assumption of one automatic depressurization system (ADS) valve failure combined with the worst additional single failure was retained because this assumption is built into the present model. This bounding assumption yields conservatively higher calculated peak cladding temperatures (PCTs) by approximately 100°F. The PCT reported on Page 1 does not include this assumption.

3) Approved Appendix K analysis models were used, except that some LPCI flow to the reactor vessel was stopped ten minutes after the accident.

GENERAL OBSERVATIONS FROM THE ANALYSES

Only those accident cases which are not reflooded to the hot node before ten minutes are affected by the assumed LPCI diversion. Once the core has been reflooded, only one ECCS pump is necessary to keep the core covered. Thus, the breaks affected include small breaks less than approximately 0.2 ft^2 (depending on the break location) and outside steam line breaks (OSLB). The effect of the assumed LPCI diversion on the OSLB is small and is discussed in a later section of this report.

After reviewing the effect of diversion on the rest of the small breaks, general statements can be made to describe the results in the area of interest:

1. The calculated PCTs (no LPCI diversion) in the small break regions affected by LPCI diversion generally decrease with decreasing break size. This follows from the fact that the core is uncovered for shorter periods and that the decay heat is lower at the time of uncovery as the break size increases.

2. The maximum temperature for the assumed LPCI diversion case for any given break location occurs at approximately that break size where the LPCI system would normally inject flow into the vessel starting at 600 seconds (i.e. the assumed LPCI diversion time). Bigger breaks get some reflooding benefit from the LPCI pumps before diversion. Smaller breaks have the same ECC systems available as this maximum break, but the smaller break area has a lower calculated PCT, as discussed previously. As an example, this worst break is indicated on Figure 1. A longer LPCI diversion time would have correspondingly smaller breaks where the maximum temperature would occur and hence lower calculated PCT.

3. Diverting LPCI from its ECCS flooding function does not always result in higher PCTs. When compared to no LPCI diversion, a reduction in PCT can be observed as a result of diverting LPCI if the LPCS is available. The reduction of subcooled LPCI water results in a reflooding mixture (due largely to LPCS flow) of steam and water which has higher voids. Thus, in the case where little LPCI flow is available for reflooding, even though less ECCS flow is entering the vessel, the swollen level inside the lower plenum is higher and reflooding can occur sooner. In such cases the calculated PCTs are extremely low and changes in PCT in either direction are insignificant.

4. Because this investigation is primarily concerned with small breaks, the failure of the HPCS, for non-core spray line breaks, is the worst single failure for this study. If the HPCS were operable, the break sizes being analyzed would reflood earlier than ten minutes with the very small break sizes never uncovering.

The following break locations were considered: A) core spray line, B) recirculation line, C) feedwater line, D) the steam line, and E) LPCI line. A brief summary of each analysis is provided below.

A. Core Spray Line Break (HPCS Line) - It is conservatively assumed that no flow enters the vessel through the broken line independent of the break size. For this case, the failure of the diesel generator associated with LPCS and LPCI "A" is the worst single failure since all credit for core spray cooling is eliminated. The ECC systems remaining before diversions are 2 LPCI + ADS and 1 LPCI + ADS after diversion at ten minutes. Becuase in both cases the reflooding time is based on only cooled LPCI flow reflooding the vessel, there is a longer reflooding time associated with the diverted case with reduced ECCS flow. The results of this investigation are shown in Figure 1. Because the temperature increase from the non-diverted case is a result of a loss of reflooding flow from 1 LPCI pump, intermediate cases (loss of part of the flow) will experience intermediate (lower) temperature increases.

   This particular failure/break type combination was the most adversely affected by the assumed LPCI diversion. However, the peak cladding temperatures are still below the limit of 2200°F.

B. Recirculation Line Break - For this break, the worst single failure is the HPCS failure, as described previously. The ECCS remaining before diversion are 3 LPCI + LPCS + ADS and, after diversion, 1 LPCI + LPCS + ADS. Since in the diverted case the remaining LPCI flow is not enough to significantly quench the voids in the lower plenum, the mixture in the lower plenum will reflood with a higher voided mixture. This higher void fraction for the diverted case more than offsets the reduction in ECCS flow entering the vessel due to this diversion of LPCI. Hence, there is a net reduction in PCT due to a shorter reflooding time and the recirculation line break without diversion which has already been reported is bounding relative to a line break with diversion. A representative break (.01 ft^2) was analyzed which confirmed these results. The results of this investigation are shown in Table 1. Intermediate cases (diversion of less than the full flow from two pumps) should result in smaller temperature decreases.

C. & D. Feedwater and Steam Line Breaks - For these breaks, the worst single failure is the HPCS failure, as described previously. The ECCS remaining before diversion are 3 LPCI + LPCS + ADS and after diversion 1 LPCI + LPCS + ADS. For the diverted case, there will be a reduction in calculated PCT for the same reasons discussed for the recirculation line break. A representative break (i.e. 01 ft^2) was again analyzed which confirmed the anticipated results. The results of this investigation are shown in Table 1. For both cases, insignificant decreases in calculated PCT result from LPCI diversion. The outside (isolated) steam line break was also considered with similar results.

E. LPCI Line Break - As in the case of the core spray line break, it is conservatively assumed that no flow enters the vessel through the broken line independent of the size. For this break, the worst single failure is the HPCS failure, as described previously. The ECCS remaining before diversion are 2 LPCI + LPCS + ADS and, after diversion, LPCS + ADS (if the break is in line "C") or LPCS + LPCI + ADS (if the break is in line "A"/or "B"). In either case there is insufficient LPCI flow to significantly quench the voids in the lower plenum. Therefore, the core will reflood with a voided mixture. This higher void fraction more than offsets the reduction in ECCS flow entering the vessel due to diversion of LPCI. Hence, there is a net reduction in PCT due to a shorter reflooding time.

As above, the .01 ft^2 break was analyzed which confirmed the anticipated results. The results of both diverted cases are shown in Table 1.

RESPONSE TO QUESTION (1)

The system provided for diversion of LPCI flow is a safety grade system. Consequently, it has a high reliability in performing its intended function. Postulation of a failure of this system to perform its function in combination with another single failure is not required under GDC 35 or 10 CFR 50.46.

RESPONSE TO QUESTION ON OPERATOR ACTION

The operation of the ECC systems including diversion of LPCI to containment sprays requires no operator action for at least 10 minutes following accident initiation. Ten minutes is the present licensing basis for operator manual action time following automatic actuation of the ECC system. There is no requirement either in 10CFR50.46 or GDC 35 for assuming no operator action 20 minutes after the initiation of the accident. Ten minutes continues to be the licensing basis used and supported by General Electric. It is also the basis for the containment performance evaluation as it has been for other BWR plants.

TABLE 1

THE EFFECT ON THE PCT OF DIVERTING LPCI FLOW AT 10 MINUTES FOR VARIOUS .01 FT^2 BREAK TYPES

BREAK TYPE	PCT NO DIVERSION	PCT WITH DIVERSION
Recirculation Line	948°F	877°F
Feedwater Line	917°F	836°F
Inside Steam Line	920°F	831°F
LPCI Line	834°F	804°F (1) 964°F (2)

NOTE: (1) PCT if break occurs in LPCI line "A" or "B"
(2) PCT if break occurs in LPCI line "C"

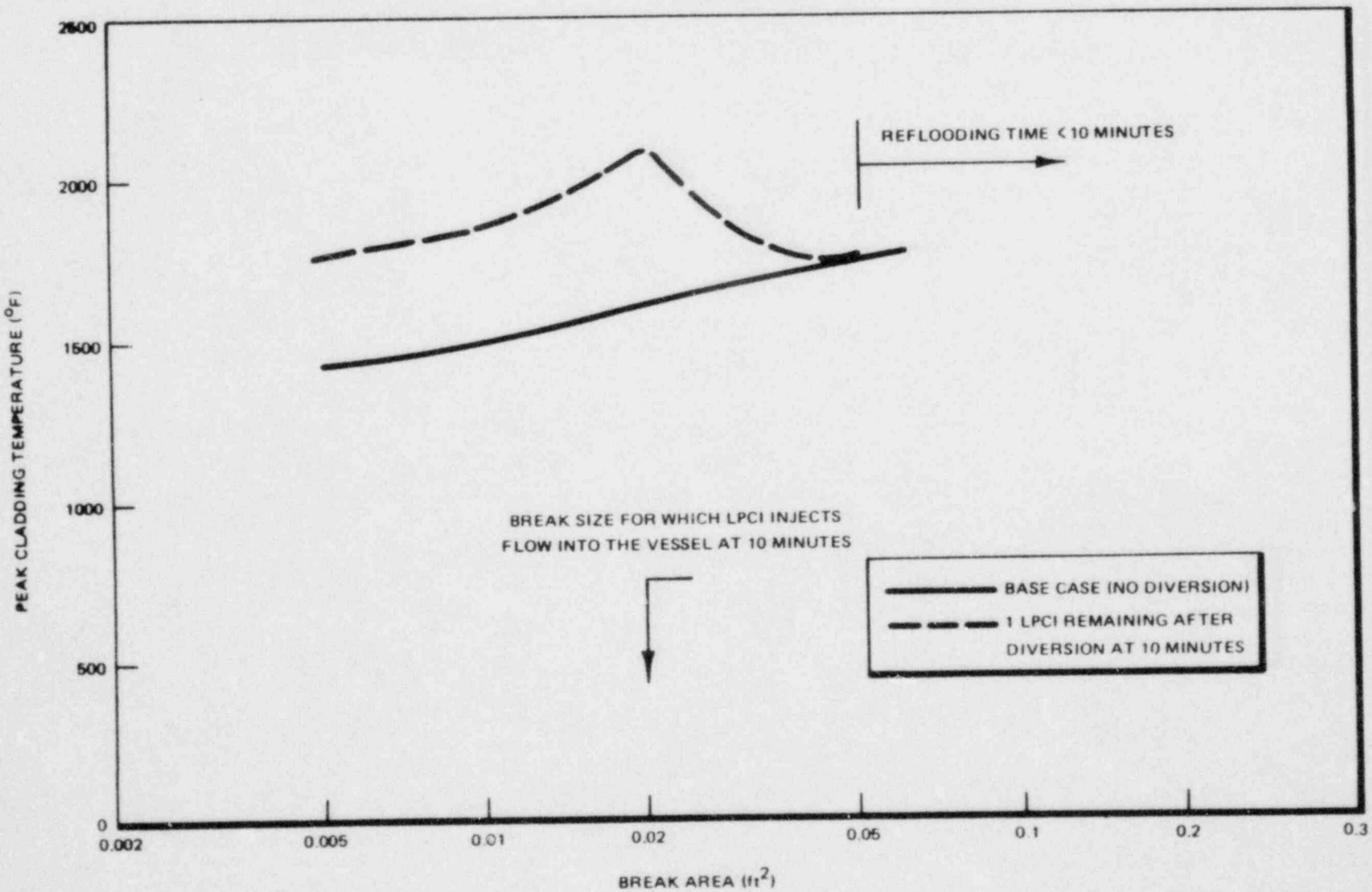

Figure 1. Peak Cladding Temperature versus Break Area for an HPCS Line Break Assuming an LPCS Diesel-Generator Failure. Systems Remaining: 2 LPCI + ADS

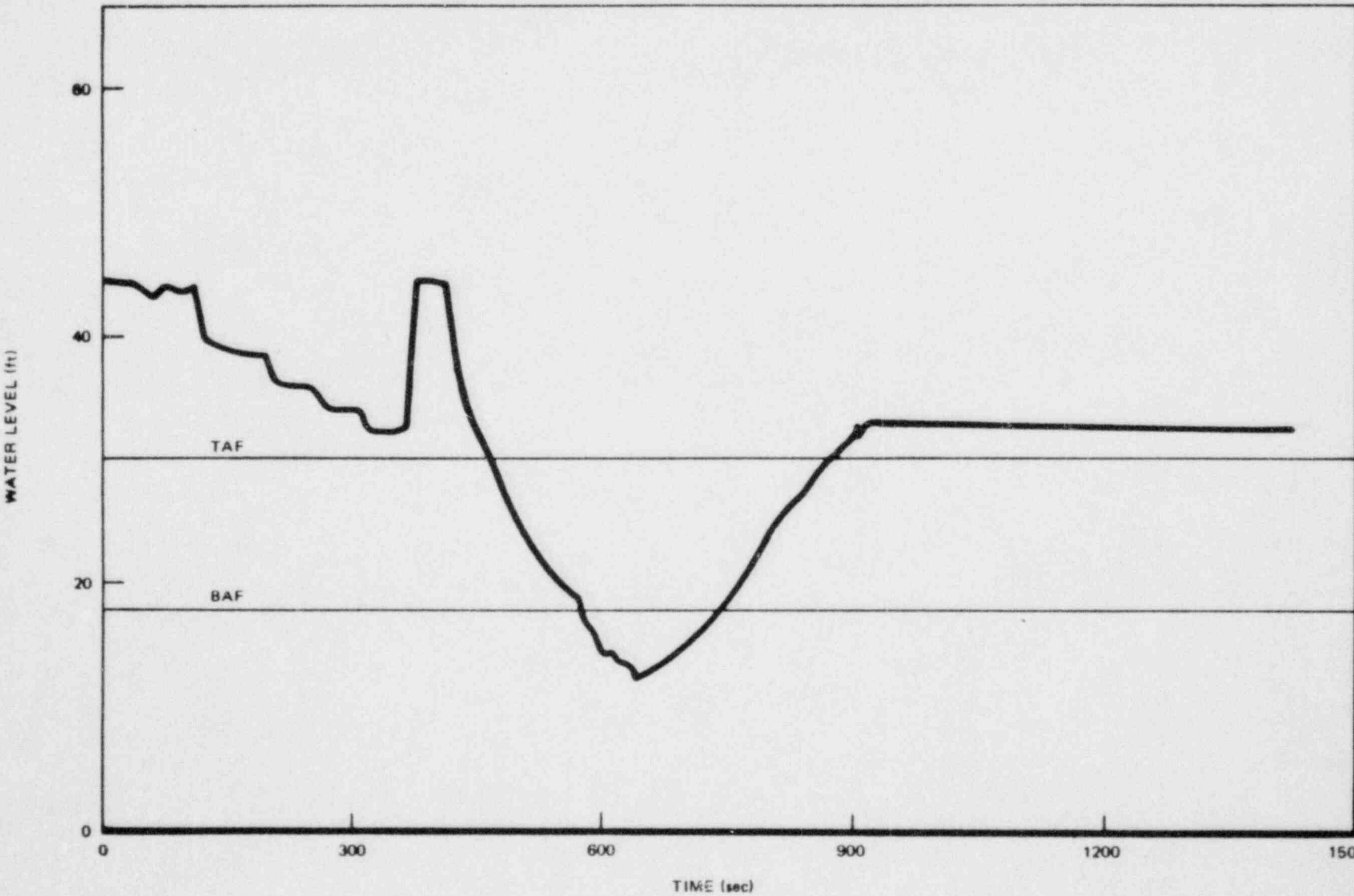

Figure 4a. Water Level Inside the Shroud Following a HIGH PRES URE Core Spray Line Break, LPCS DG Failure, Break Area = 0.0[illegible] ft^2 (SBM).

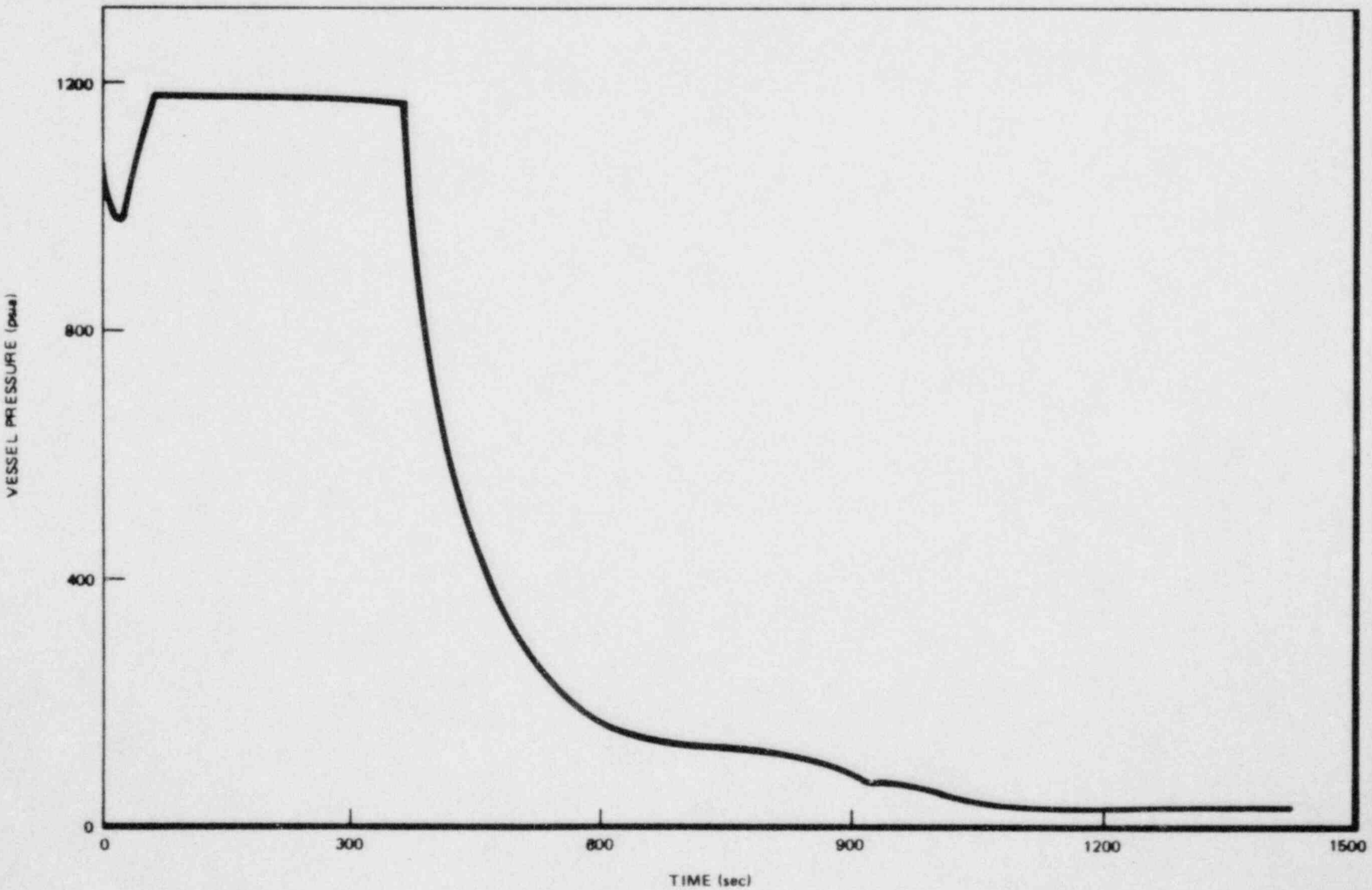

Figure 4b. Reactor Vessel Pressure Following a HIGH PRESSURE Core Spray Line Break, LPCS DG Failure; Break Area = 0.02 ft^2 (SBM).

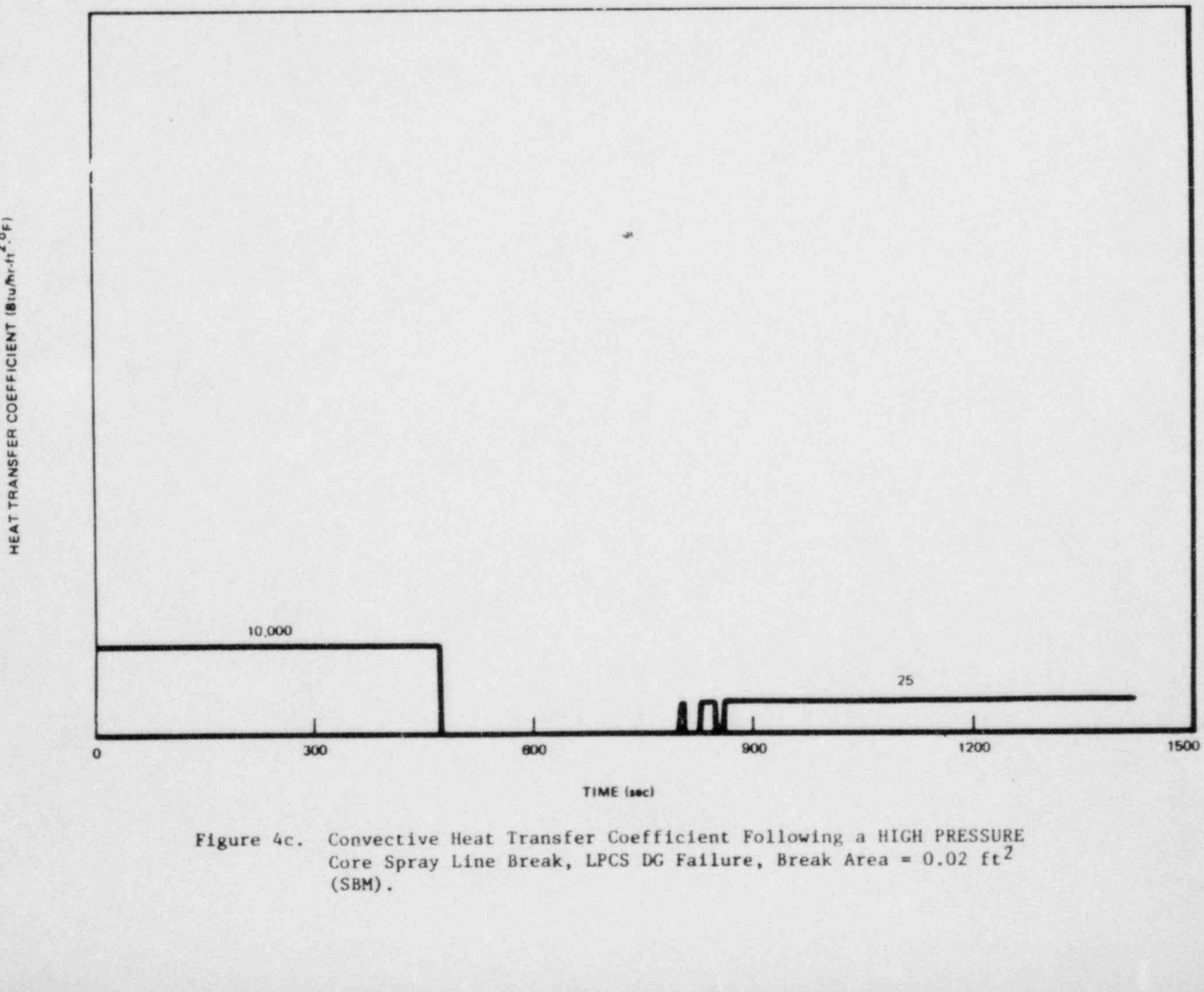

Figure 4c. Convective Heat Transfer Coefficient Following a HIGH PRESSURE Core Spray Line Break, LPCS DG Failure, Break Area = 0.02 ft^2 (SBM).

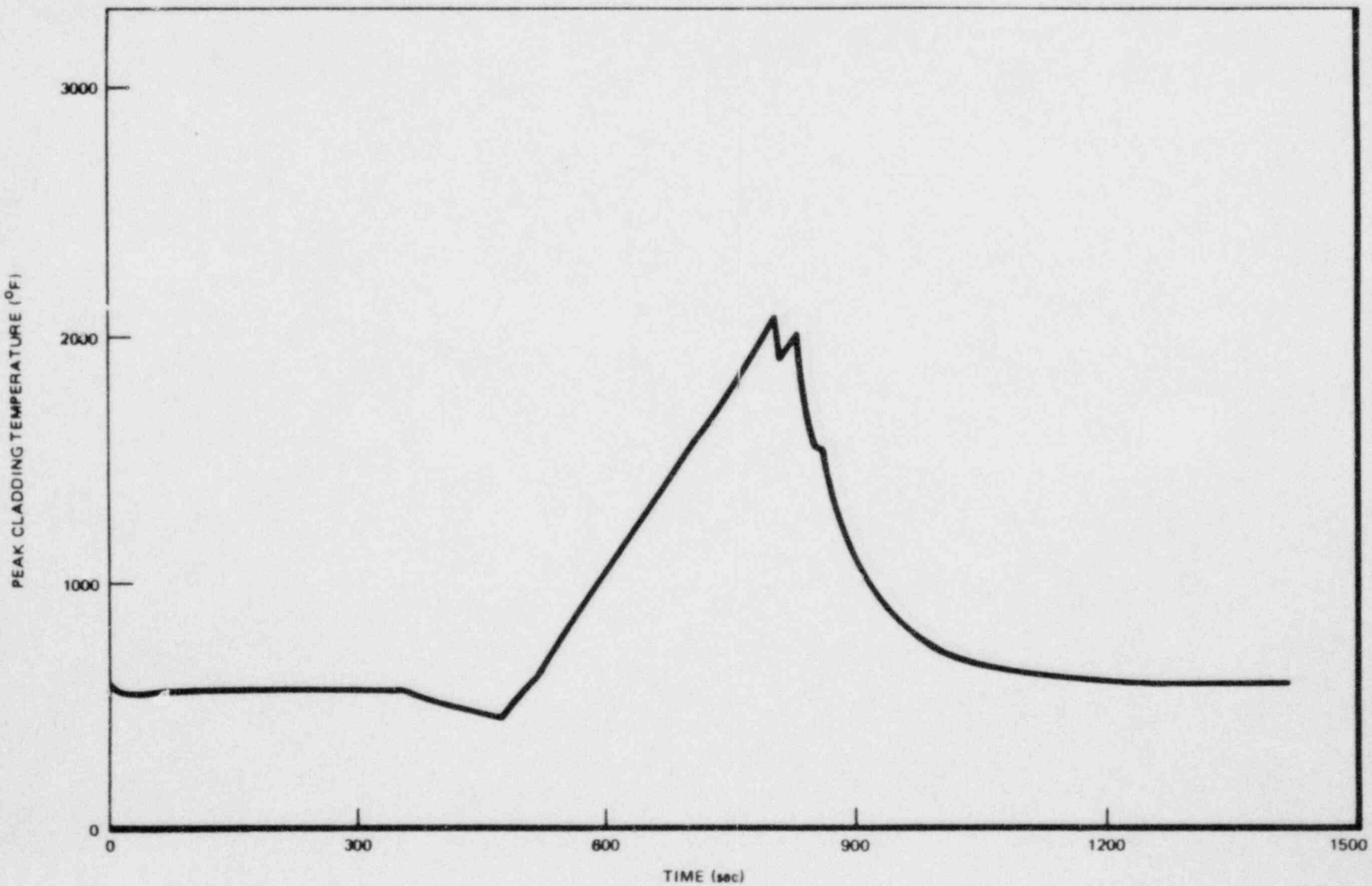

Figure 4d. Peak Cladding Temperature Following a HIGH PRESSURE Core Spray Line Break, LPCS DG Failure, Break Area = 0.02 ft^2 (SBM).

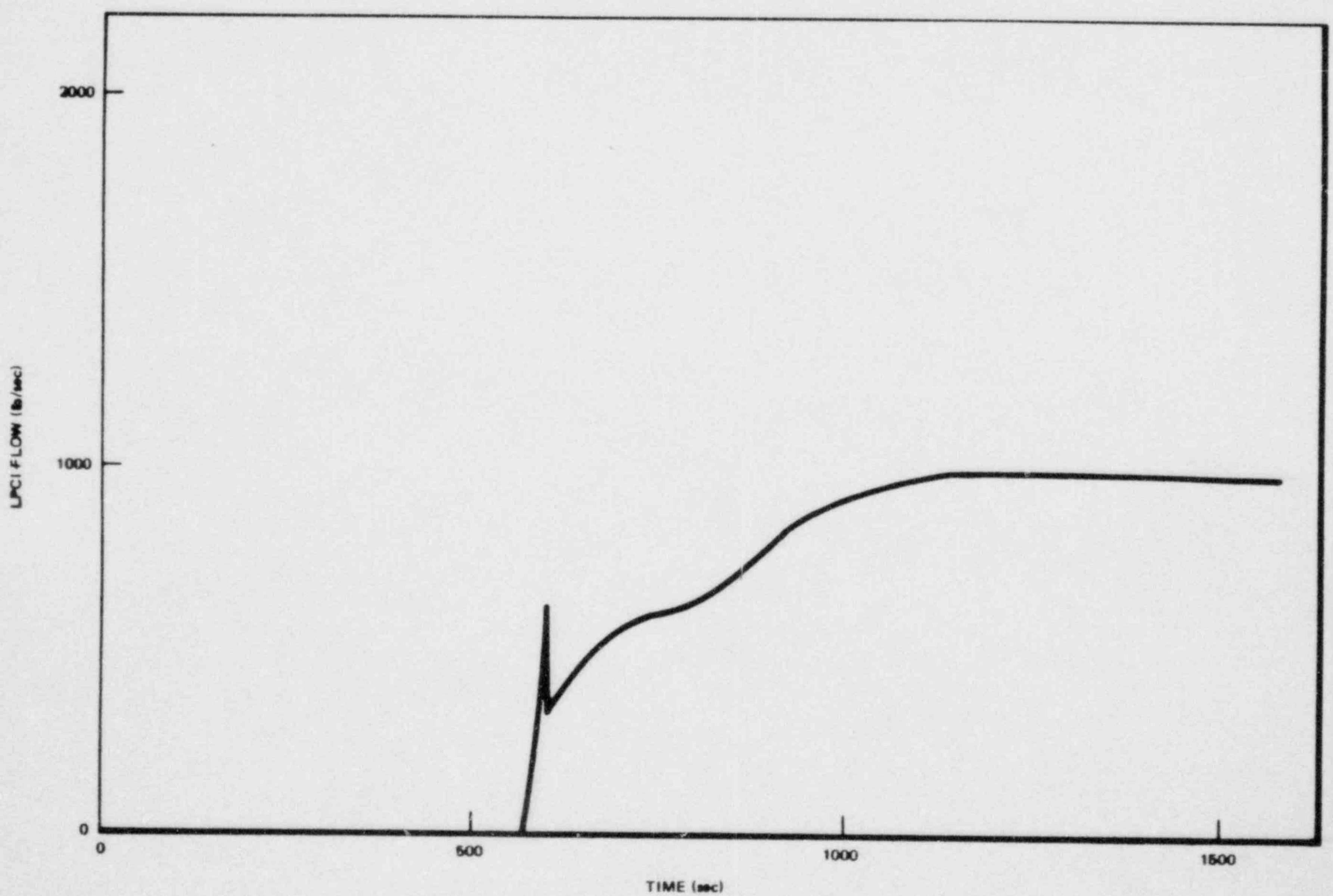

Figure 4e. LPCI Flow Rate Following a HIGH PRESSURE Core Spray Line Break, LPCS DG Failure, Break Area = 0.02 ft^2 (SBM).