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RESULTS OF SEMISCALE PUMPS ON/OFF EXPERIMENTS

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Six experiments were conducted in the Semiscale Mod-3 system to investigate the effect of primary coolant pump operation on thermal-hydraulic behavior during a small break loss-of-coolant accident (LOCA). The impetus for these experiments stemmed from licensing concerns based on analyses conducted as a result of the accident at the Three Mile Island nuclear power plant. PWR vendor computer code analyses predicted that continued pump operation might cause more severe coolant depletion, thereby jeopardizing core coolability if the pumps had to be shut down at some intermediate point during the LOCA.

The Semiscale experiments were designed to evaluate the effect of pump operation on primary coolant mass inventory and distribution. Three cold leg break and three hot leg break experiments were conducted. The break size simulated was 2.5% (of cold leg pipe flow area), representing a circular opening in the side of a PWR pipe of approximately 11 cm. For each of the experiments, emergency core coolant (ECC) was injected into the cold legs at scaled flowrates corresponding to the availability of a single high pressure injection system train. The accumulators and low pressure injection system were not used in these experiments so as to improve the experimental determination of coolant inventory. A condenser and weigh tank arrangement was connected downstream of the break to provide an accurate measurement of break discharge. Three different pump operation scenarios were imposed for both the cold and hot leg break cases; pump trip at scram, delayed trip, and continuous pump operation.

For the cold leg break, early pump trip caused greater primary coolant system mass depletion than observed in either the continuous pump operation or delayed trip cases. The difference in minimum transient coolant inventory was small, however, amounting to a difference of only 8% between the early trip and continuous pump operation cases. It was found that early pump trip caused highly subcooled ECC liquid to pool in the vicinity of the break, resulting in a greater break discharge rate early in the transient. Pump operation tended to homogenize primary coolant, thereby resulting in less cold leg fluid subcooling. Approximately 350 s into the transients, break flow was higher with the pumps running, but not to the extent that the difference which developed early in the transient was reversed.

The system hydraulic behavior for the hot leg break experiments was similar. When the coolant pumps were left running, higher density fluid was delivered to the hot portions of the system (hot legs, core, and upper vessel regions). However, because the break was located in the hot leg, more mass was lost out the break when the pumps were left running than when the pumps were tripped early. This led to greater system mass depletion when the pumps were left on. The minimum coolant inventory was approximately 27% lower in the pumps-running case than in the early pump trip case.

Continuous pump operation in both the cold leg and hot leg break cases caused a greater percentage of system coolant to reside in the vessel, since the pumps continued to deliver liquid. Moreover, in the delayed pump trip experiments, liquid stored in the hot legs drained into the vessel when the pumps were tripped, thus augmenting vessel inventory. Consequently, delayed pump trip actually proved beneficial in Semiscale.

RELAP4/MOD7 computer code calculations correctly predicted the differential effect the pump operation had in the hot and cold leg break cases. However, the computer code failed to adequately predict several hydraulic aspects of these transients, notably fluid density in the hot legs where the existence of countercurrent flow was evident.

In summary, these experiments have provided useful data that will contribute toward an ultimate resolution of the pump operation issue. Effects of scale preclude a direct extrapolation of these results to expec. behavior in a full-size PWR. Nevertheless, the results have uncovered effects heretofore not considered in previous analyses and furthermore suggest that the differential system response caused by pump operation may be situational dependent. In addition, the data are providing a basis for refining computer code models so that more accurate predictions of PWR response under various scenarios are possible.

REFERENCES

1. B. Sheron, Generic Assessment of Delayed Reactor Coolant Pump Trip during Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors, Nuclear Regulatory Commission, NUREG 0623, November 1979.

2. J. M. Cozzuol, Experimental Operating Specification (EOS) for Tests S-SB-P1 and S-SB-P2, G. W. Johnsen letter to R. E. Tiller (GWJ-8-80), EG&G Idaho, Inc., February 13, 1980.

3. L. P. Leach, Experimental Operating Specification (EOS) for Small Break Test S-SB-P7, L. P. Leach letter to R. E. Tiller (LPL-33-80), EG&G Idaho, Inc., March 13, 1980.

4. L. P. Leach, Experimental Operating Specification (EOS) for Small Break Tests S-SB-P3, S-SB-P4, and S-SB-P6, L. P. Leach letter to R. E. Tiller (LPL-46-80), EG&G Idaho, Inc., April 3, 1980.

5. G. W. Johnsen, Test Prediction for Semiscale Mod-3 Small Break Test S-SB-P2, G. W. Johnsen letter to R. E. Tiller (GWJ-10-80), EG&G Idaho, Inc., February 13, 1980.

6. C. P. Fineman, Test Prediction for Semiscale Small Break Tests S-SB-P3 and S-SB-P4, EG&G Idaho, Inc., EGG-SEMI-5139 (April 1980).

7. S. E. Dingman, T. J. Fauble, J. R. Hewitt, Quick Look Report for Semiscale Mod-3 Small Break Tests S-SB-P1, S-SB-P2, and S-SB-P7, EG&G Idaho, Inc., EGG-SEMI-5137 (April 1980).

8. J. M. Cozzuol, Quick Look Report for Semiscale Mod-3 Small Break Tests S-SB-P3 and S-SB-P4, EG&G Idaho, Inc., EGG-SEMI-5158 (May 1980).

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by
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TEST OBJECTIVES

ASSIST IN THE RESOLUTION OF

NUREG-0623 ISSUES:

- DETERMINE THE DIFFERENTIAL RESPONSE CAUSED BY CONTINUOUS PUMP OPERATION VERSUS EARLY PUMP TRIP DURING A SMALL BREAK

- PROVIDE RELEVANT INTEGRAL SYSTEM DATA TO ENABLE ASSESSMENT OF COMPUTER CODES

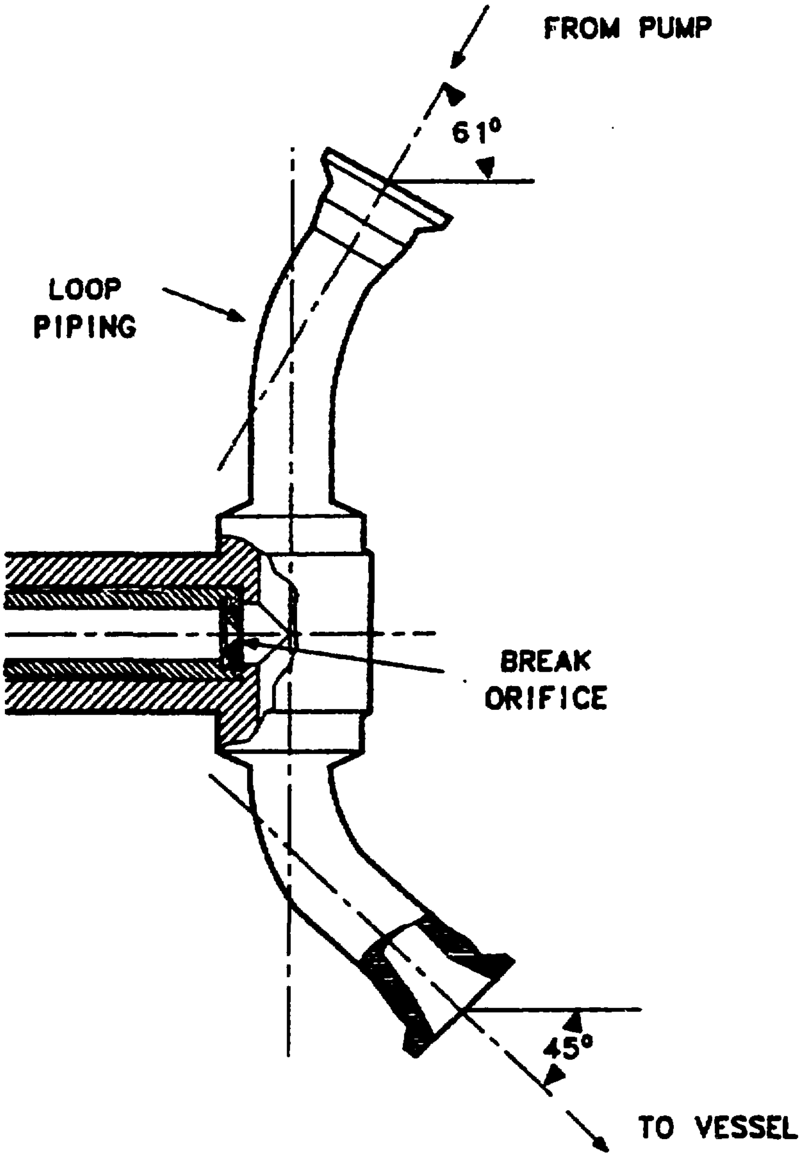
GHJ-2

TEST MATRIX

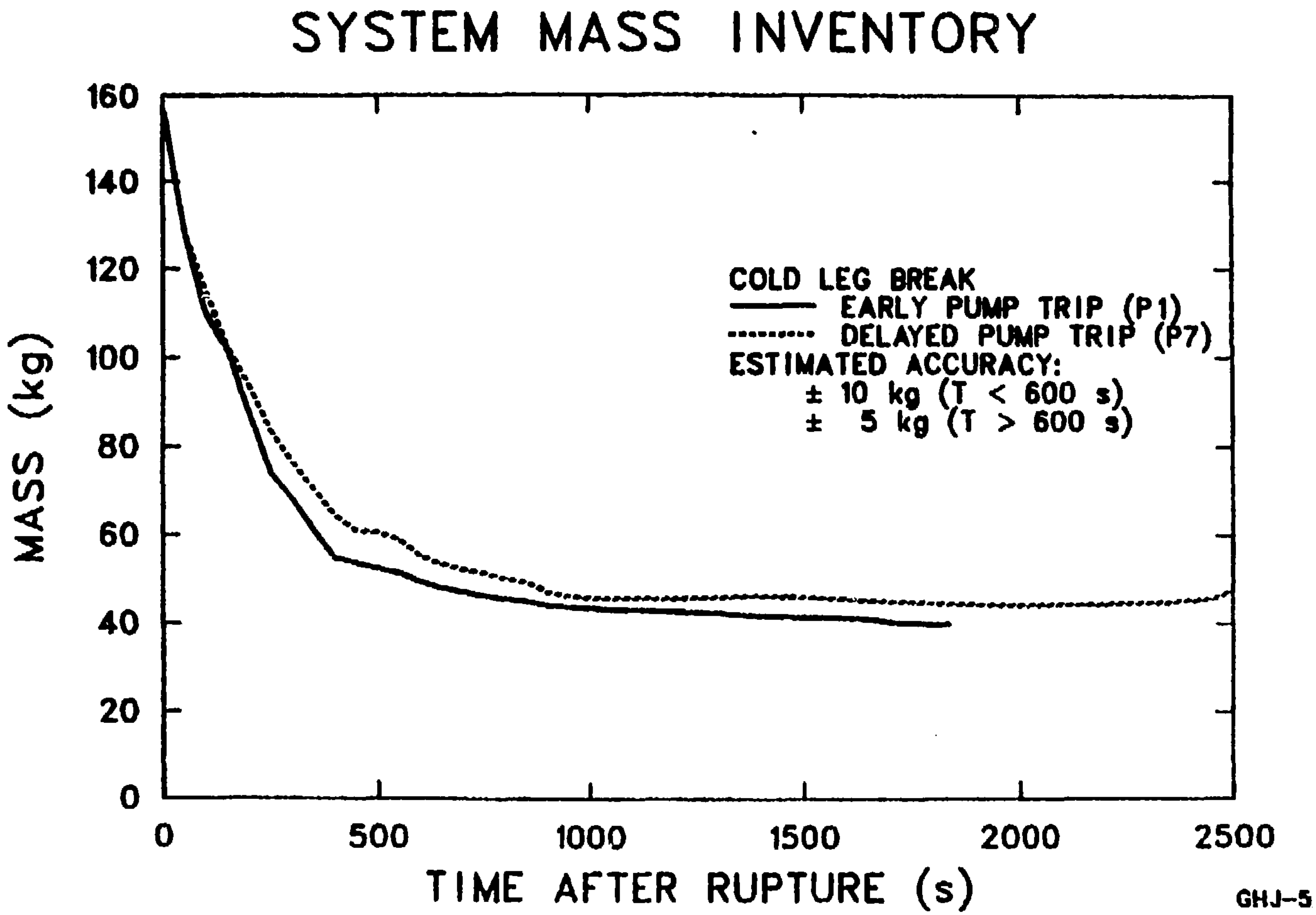
TEST	BREAK/LOCATION	PUMP OPERATION
S-SB-P1	2.5% COLD LEG	TRIP AT SCRAM
S-SB-P2	2.5% COLD LEG	CONTINUOUS
S-SB-P7	2.5% COLD LEG	TRIP AT 3.3 MPa
S-SB-P3	2.5% HOT LEG	TRIP AT SCRAM
S-SB-P4	2.5% HOT LEG	CONTINUOUS
S-SB-P6	2.5% HOT LEG	TRIP AT 3.3 MPa

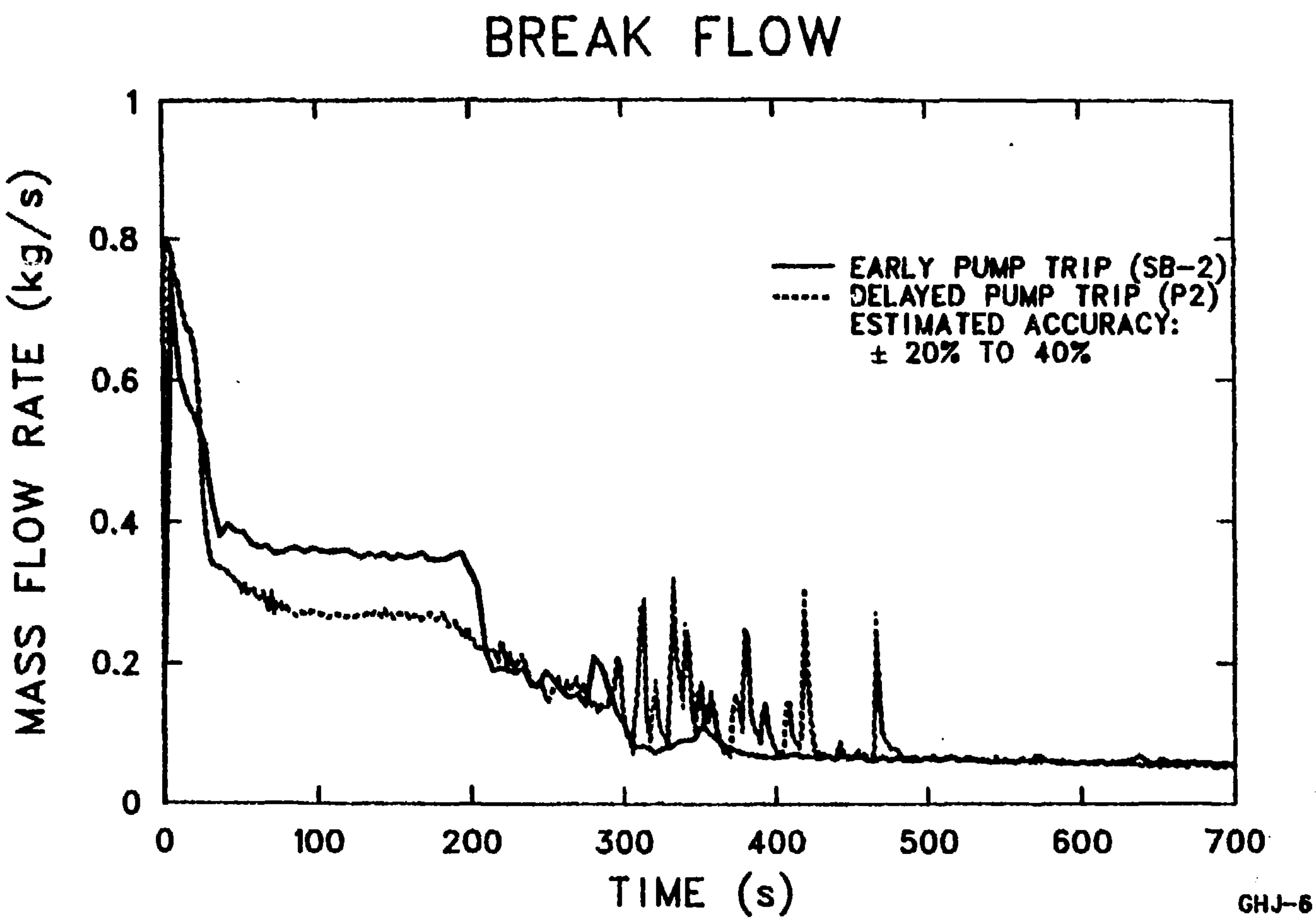
GHJ-3

COLD LEG BREAK
CONFIGURATION - PLAN VIEW



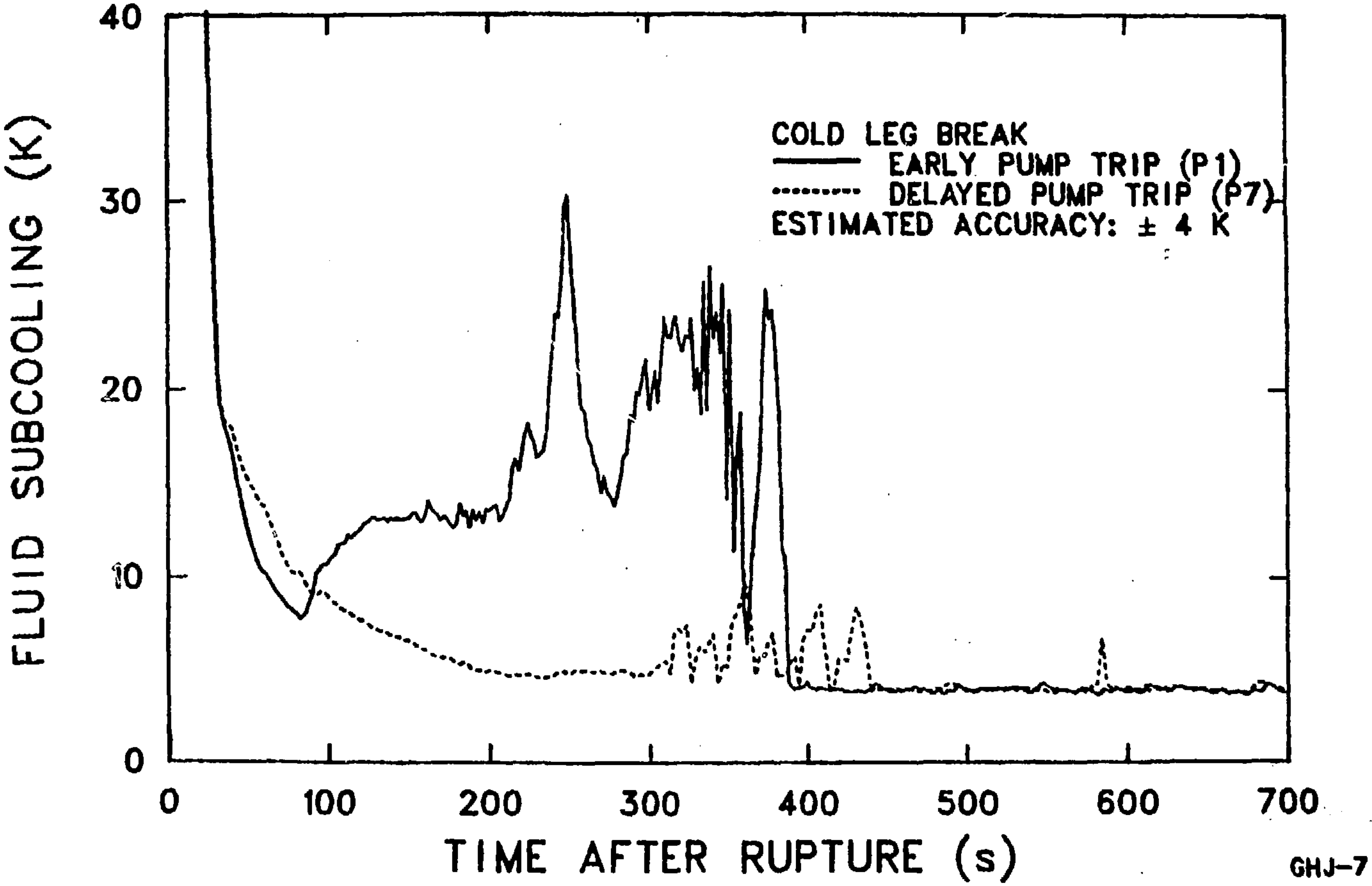
GHJ-4

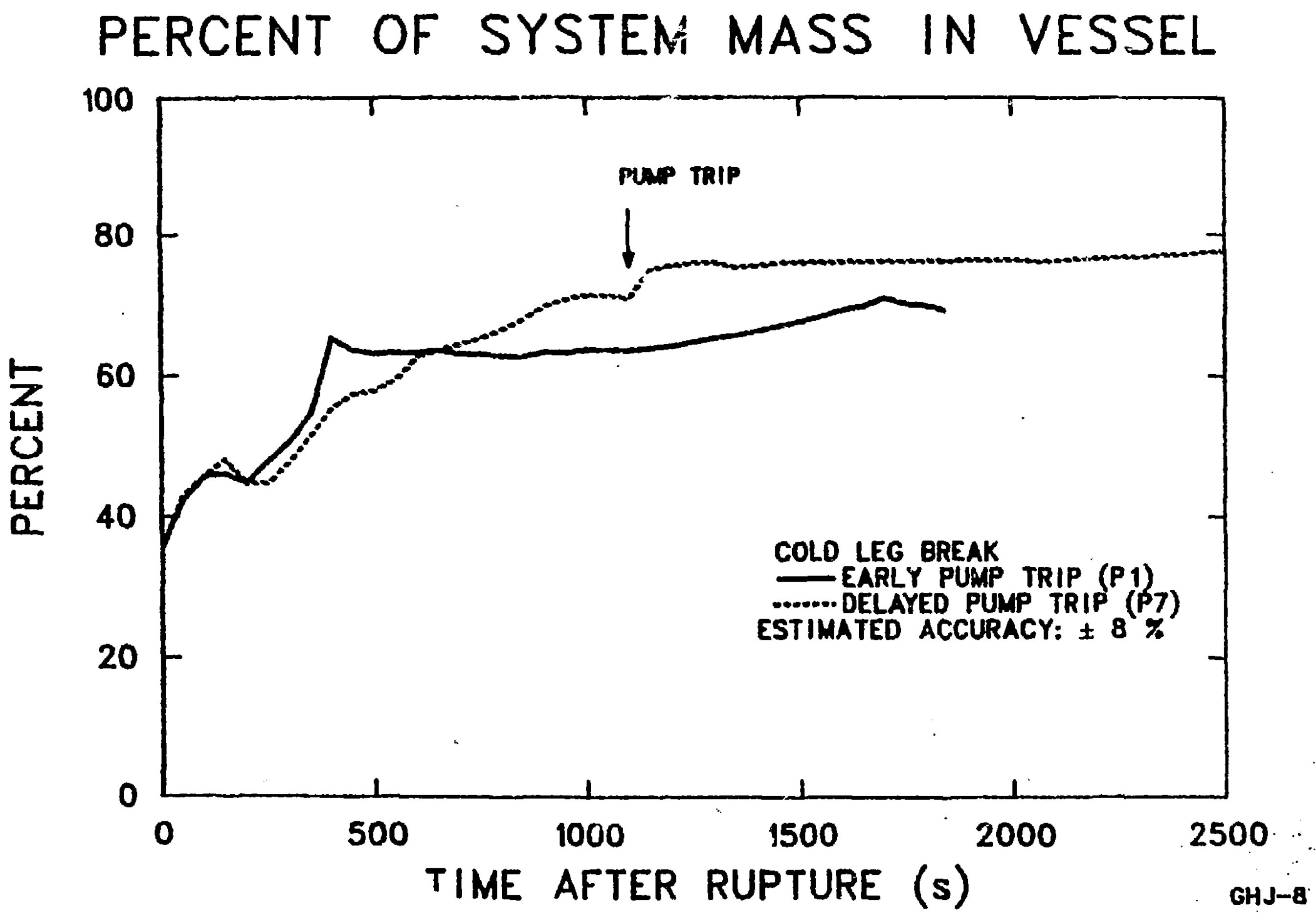

SYSTEM MASS INVENTORY
160
140
120
100
80
60
40
20
0
MASS (kg)
0
500
1000
1500
2000
2500
TIME AFTER RUPTURE (s)
COLD LEG BREAK
EARLY PUMP TRIP (P1)
DELAYED PUMP TRIP (P7)
ESTIMATED ACCURACY:
± 10 kg (T < 600 s)
± 5 kg (T > 600 s)
GHJ-5

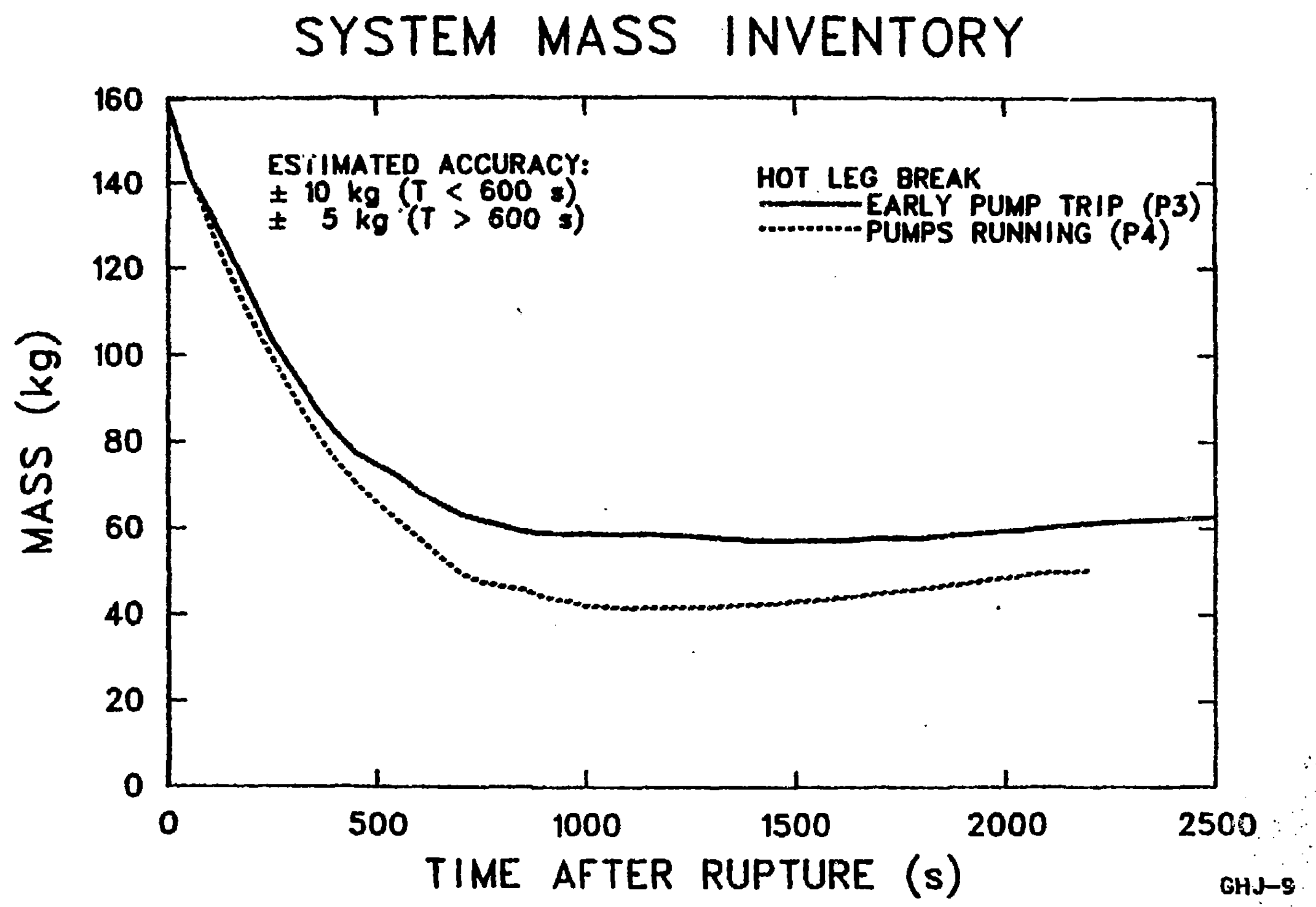


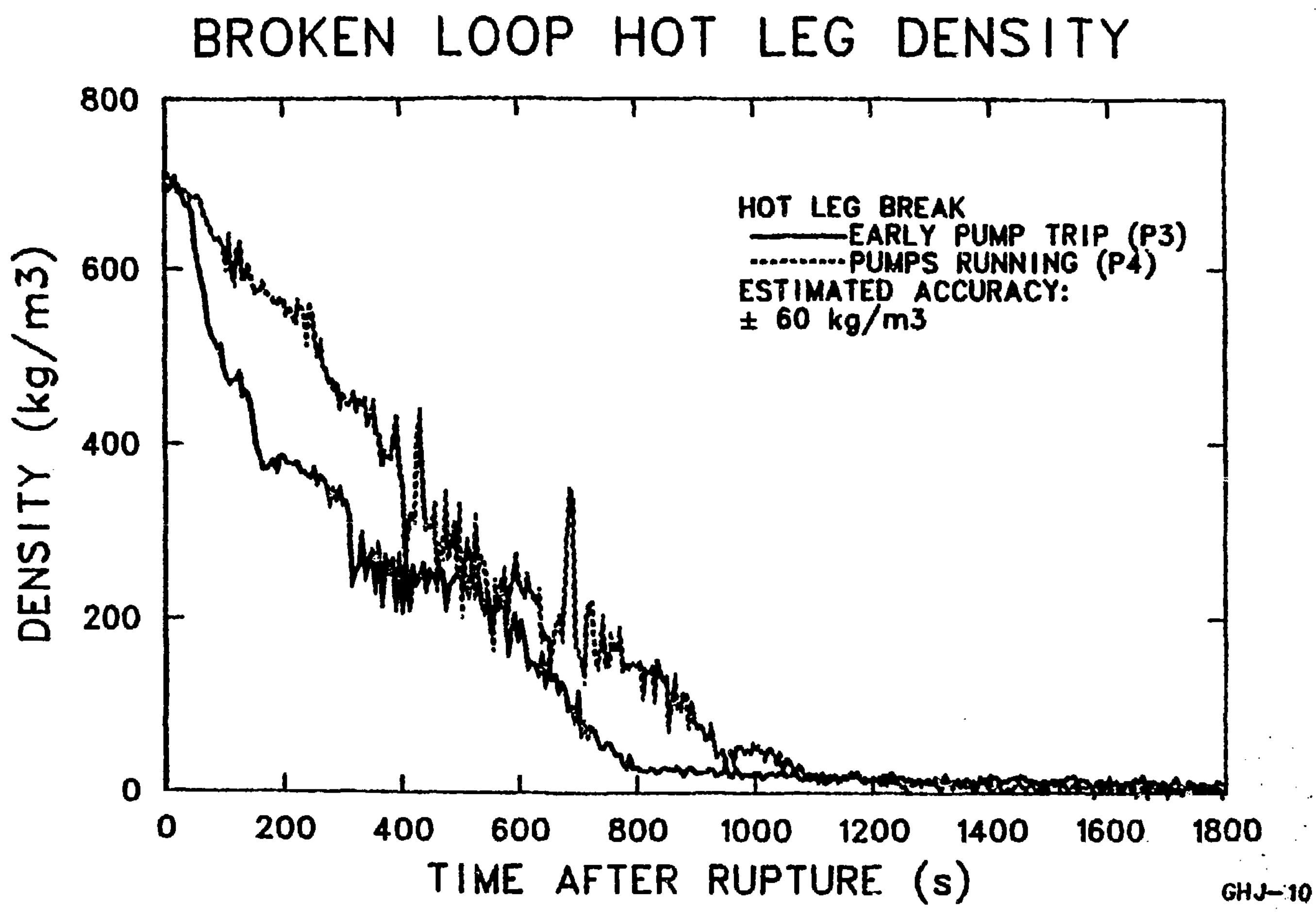
BREAK FLOW
MASS FLOW RATE (kg/s)
TIME (s)
EARLY PUMP TRIP (SB-2)
DELAYED PUMP TRIP (P2)
ESTIMATED ACCURACY:
± 20% TO 40%
0
0.2
0.4
0.6
0.8
1
0
100
200
300
400
500
600
700
GHJ-6

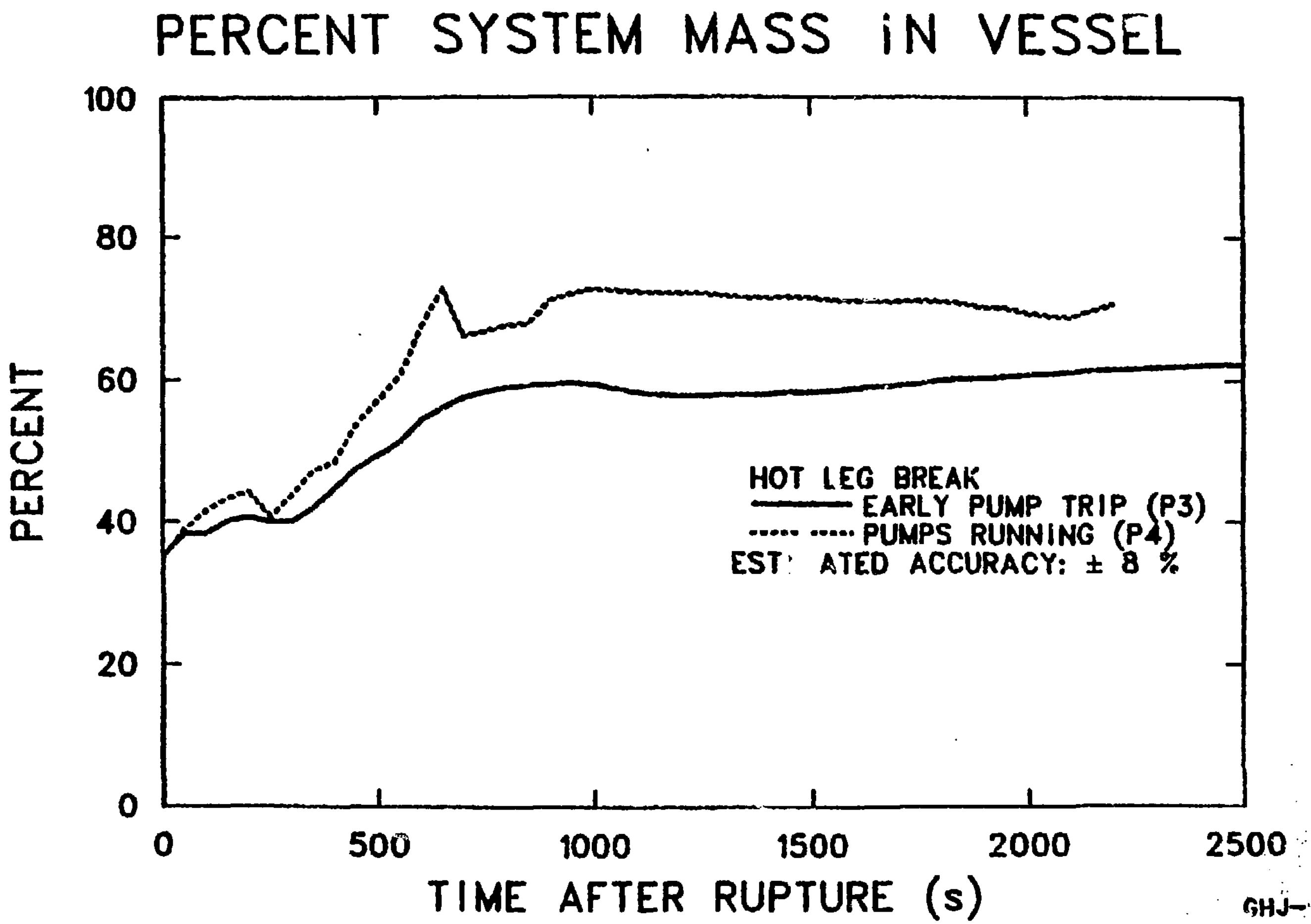
FLUID SUBCOOLING IN BROKEN COLD LEG



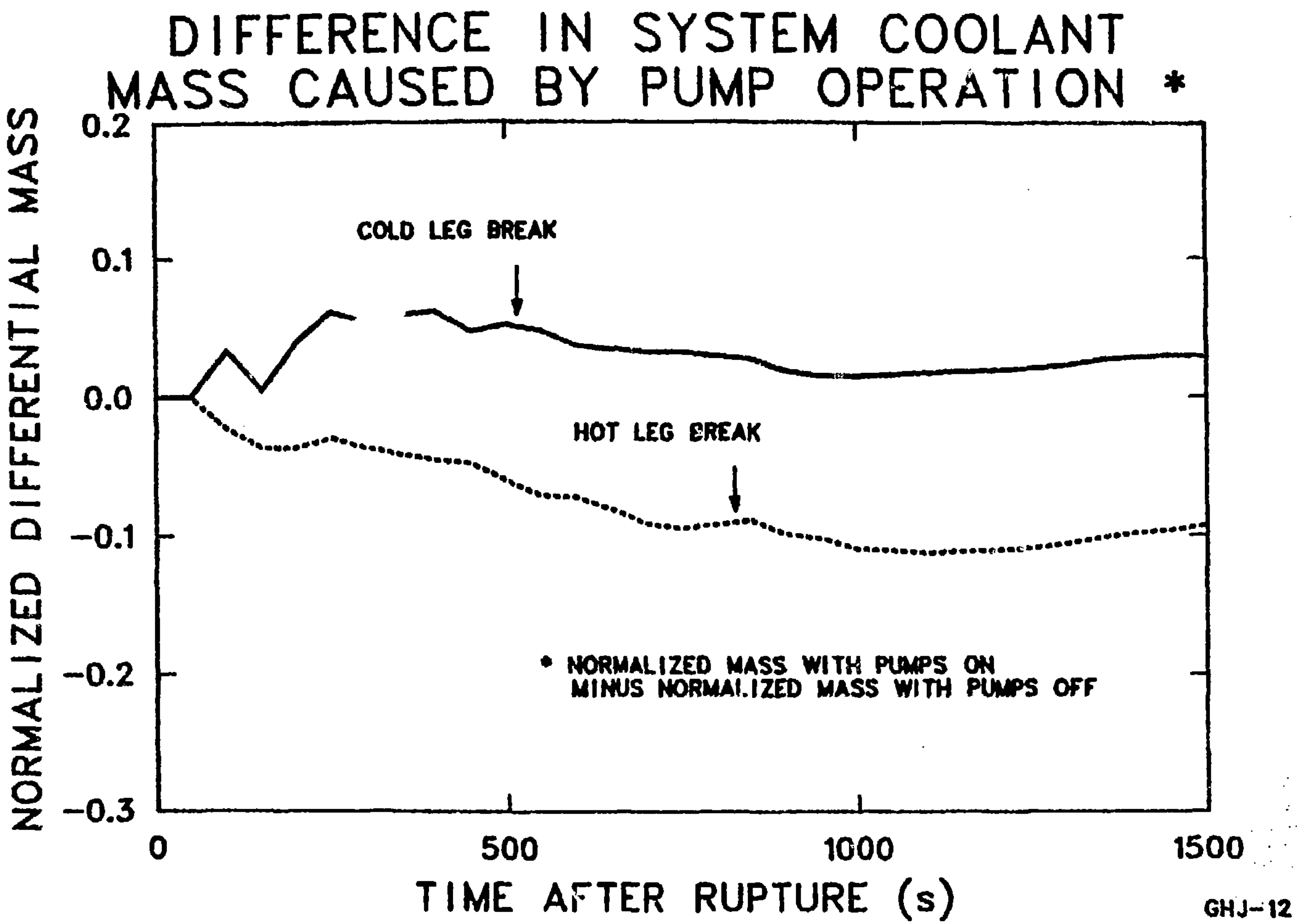

PERCENT OF SYSTEM MASS IN VESSEL
100
80
60
40
20
0
PERCENT
PUMP TRIP
COLD LEG BREAK
EARLY PUMP TRIP (P1)
DELAYED PUMP TRIP (P7)
ESTIMATED ACCURACY: ± 8 %
0
500
1000
1500
2000
2500
TIME AFTER RUPTURE (s)
GHJ-8


SYSTEM MASS INVENTORY
ESTIMATED ACCURACY:
± 10 kg (T < 600 s)
± 5 kg (T > 600 s)
HOT LEG BREAK
EARLY PUMP TRIP (P3)
PUMPS RUNNING (P4)
MASS (kg)
0
20
40
60
80
100
120
140
160
0
500
1000
1500
2000
2500
TIME AFTER RUPTURE (s)
GHJ-9

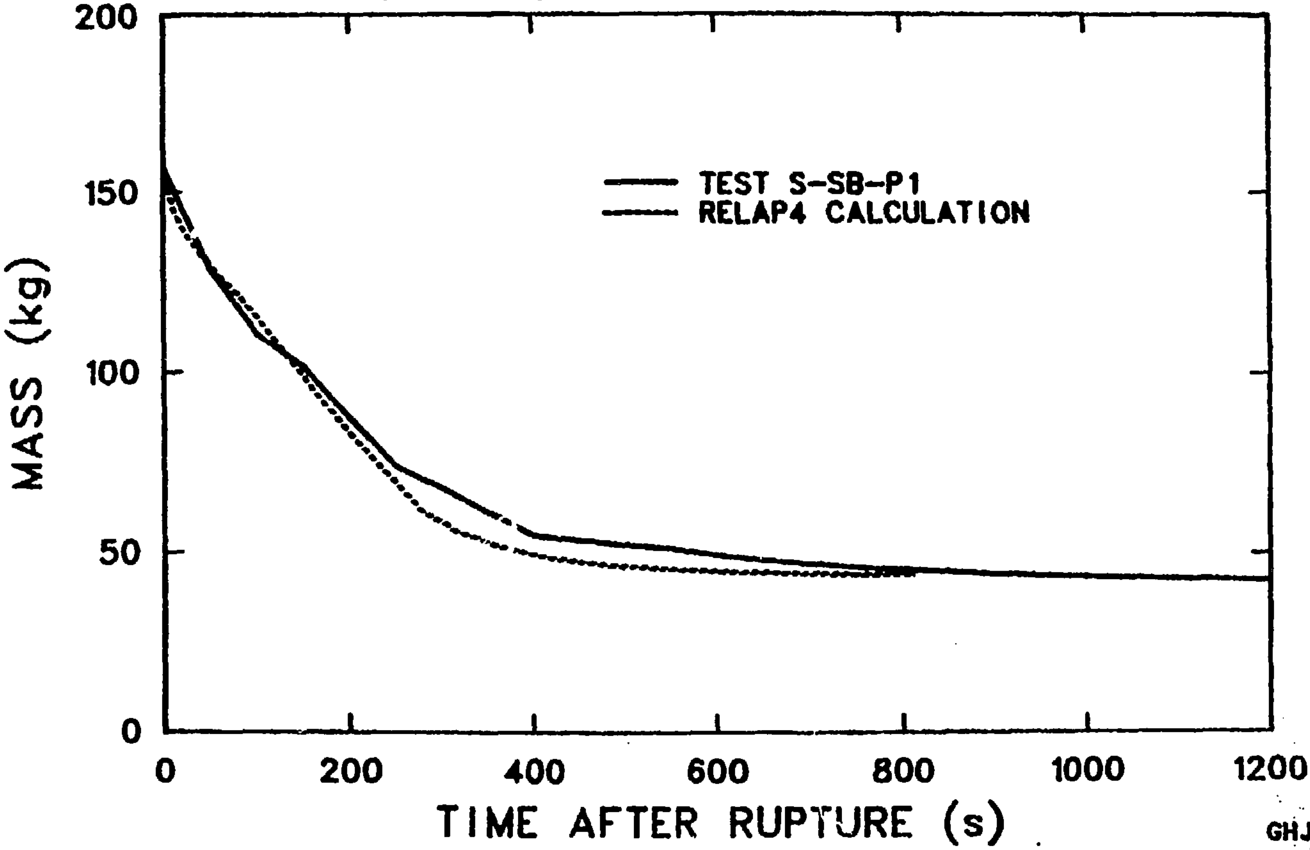

BROKEN LOOP HOT LEG DENSITY
800
600
400
200
0
DENSITY (kg/m3)
0
200
400
600
800
1000
1200
1400
1600
1800
TIME AFTER RUPTURE (s)
HOT LEG BREAK
EARLY PUMP TRIP (P3)
PUMPS RUNNING (P4)
ESTIMATED ACCURACY:
± 60 kg/m3
GHJ-10


PERCENT SYSTEM MASS IN VESSEL
100
80
60
40
20
0
PERCENT
0
500
1000
1500
2000
2500
TIME AFTER RUPTURE (s)
HOT LEG BREAK
EARLY PUMP TRIP (P3)
PUMPS RUNNING (P4)
EST ATED ACCURACY: ± 8 %

GHJ-11

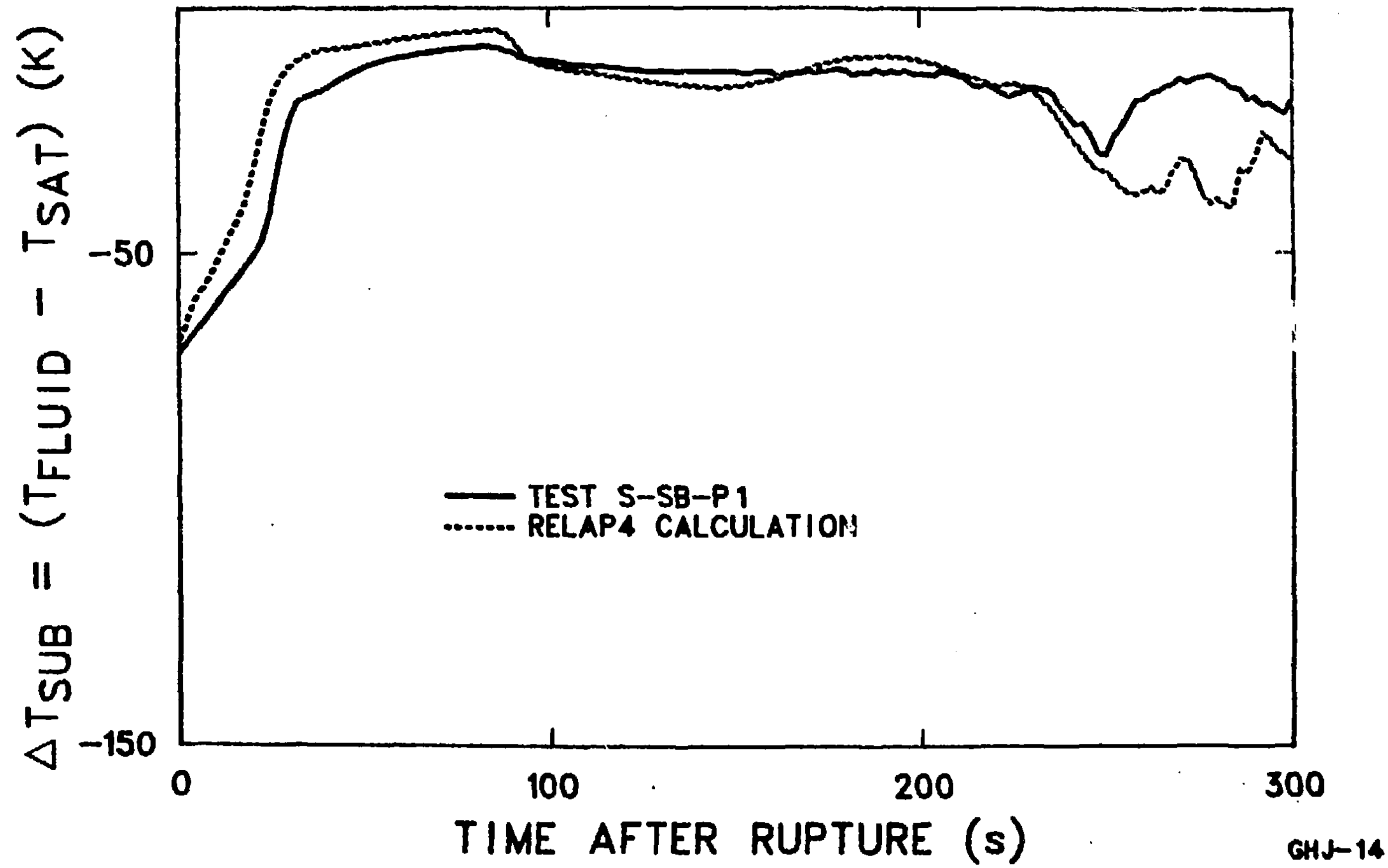

DIFFERENCE IN SYSTEM COOLANT
MASS CAUSED BY PUMP OPERATION *
NORMALIZED DIFFERENTIAL MASS
0.2
0.1
0.0
−0.1
−0.2
−0.3
COLD LEG BREAK
HOT LEG BREAK
* NORMALIZED MASS WITH PUMPS ON
MINUS NORMALIZED MASS WITH PUMPS OFF
0
500
1000
1500
TIME AFTER RUPTURE (s)
GHJ-12

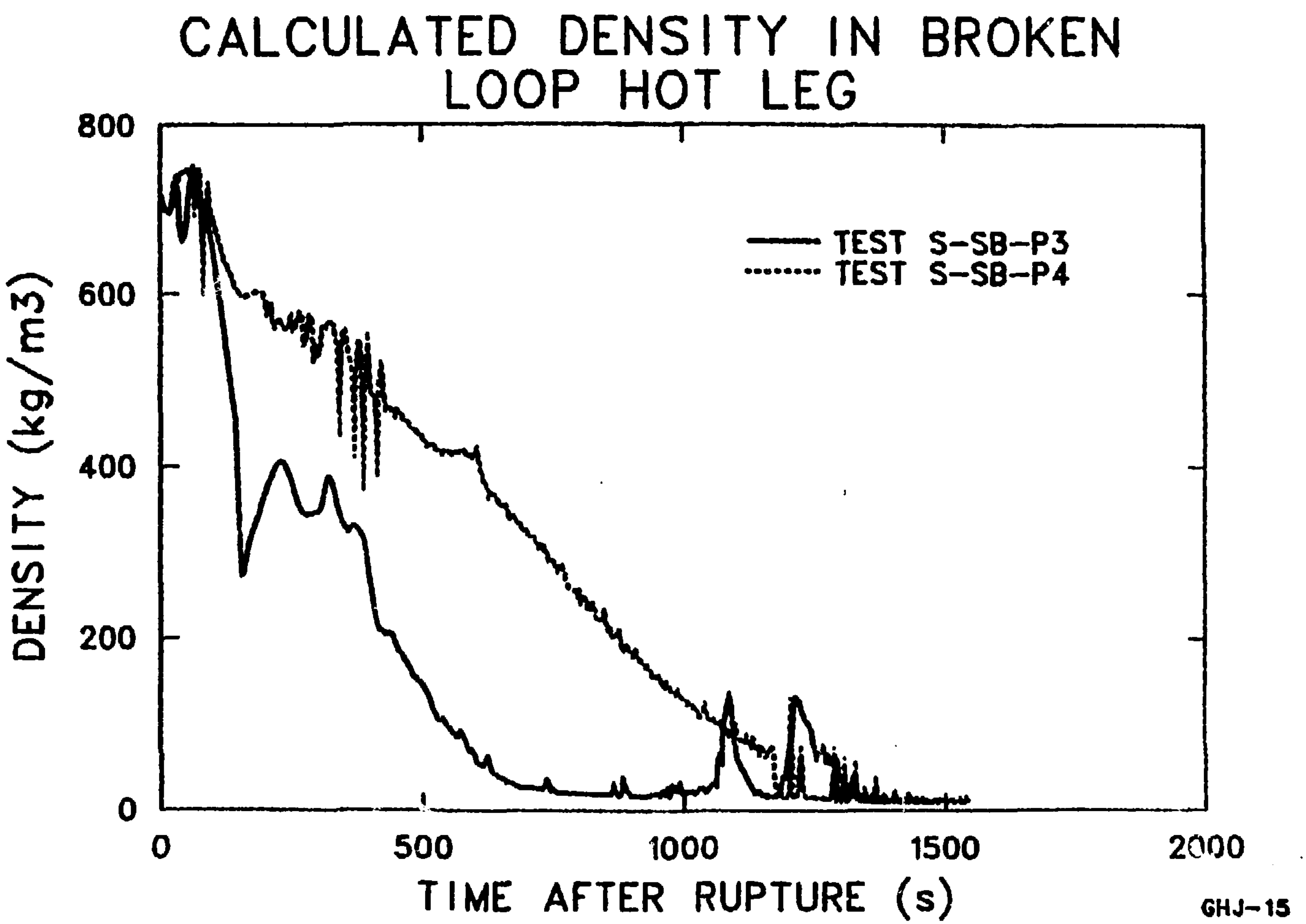
CALCULATED AND MEASURED TOTAL SYSTEM MASS

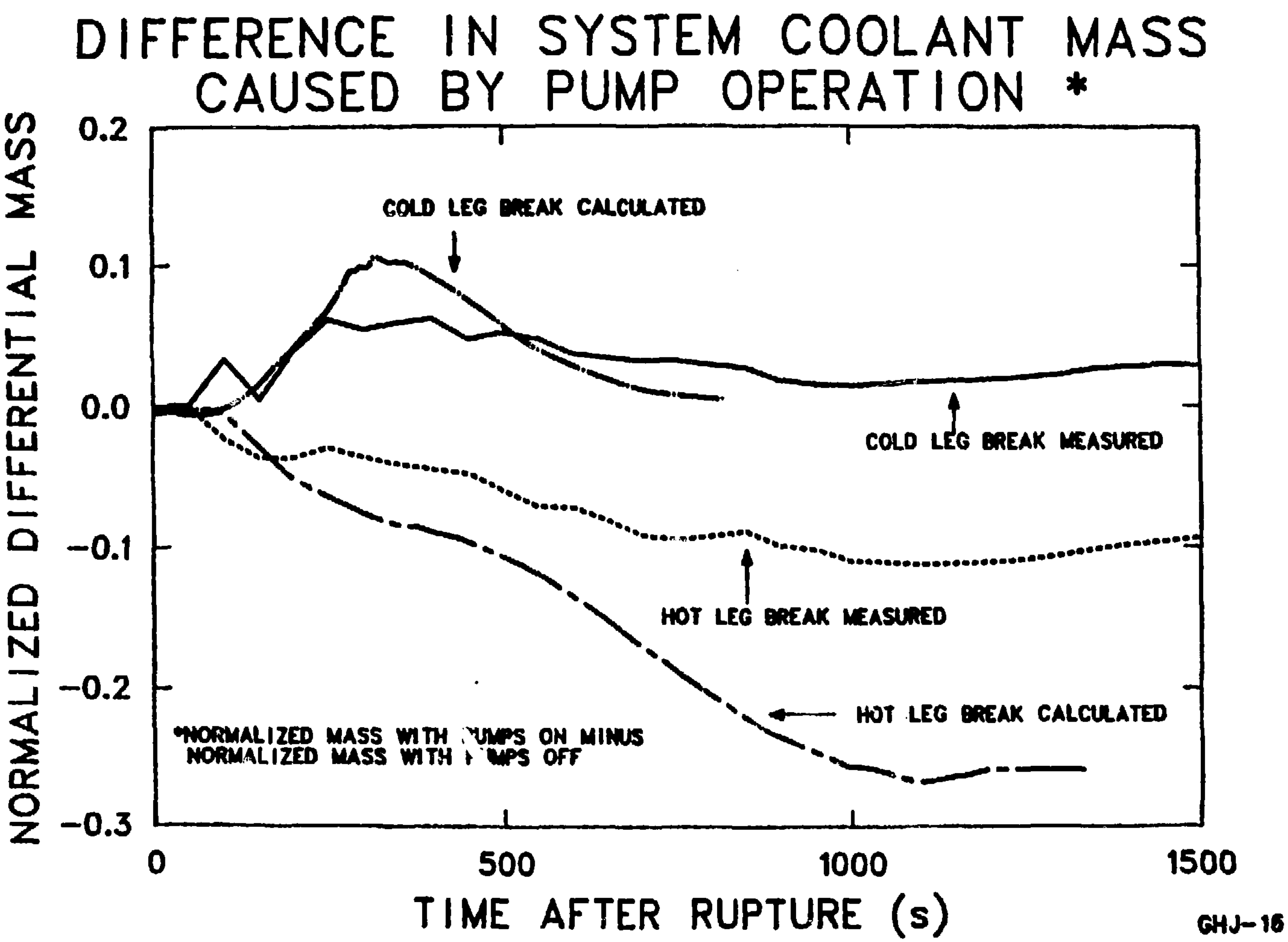


GHJ-13

SUBCOOLING IN THE BROKEN LOOP COLD LEG




CALCULATED DENSITY IN BROKEN
LOOP HOT LEG
TEST S-SB-P3
TEST S-SB-P4
DENSITY (kg/m3)
0
200
400
600
800
0
500
1000
1500
2000
TIME AFTER RUPTURE (s)
GHJ-15


DIFFERENCE IN SYSTEM COOLANT MASS
CAUSED BY PUMP OPERATION *
NORMALIZED DIFFERENTIAL MASS
0.2
0.1
0.0
−0.1
−0.2
−0.3
COLD LEG BREAK CALCULATED
COLD LEG BREAK MEASURED
HOT LEG BREAK MEASURED
HOT LEG BREAK CALCULATED
*NORMALIZED MASS WITH PUMPS ON MINUS
NORMALIZED MASS WITH PUMPS OFF
0
500
1000
1500
TIME AFTER RUPTURE (s)
GHJ-16

CONCLUSIONS

- CONTINUED PUMP OPERATION INFLUENCES BREAK DISCHARGE
  - LESS MASS DEPLETION FOR COLD LEG BREAK
  - GREATER MASS DEPLETION FOR HOT LEG BREAK
- PUMP OPERATION CAUSES COOLANT REDISTRIBUTION FROM COLD TO HOT PORTIONS OF SYSTEM

GHJ-17

CONCLUSIONS (CONT'D)

- HOT LEG BREAK LESS SEVERE THAN COLD LEG BREAK
- RELAP4 CODE CORRECTLY PREDICTS DIFFERENTIAL TRENDS CAUSED BY PUMP OPERATION
- OVERALL RESULTS SUGGEST SENSITIVITY TO ASSUMED BREAK CONFIGURATION AND SCENARIO