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Mail stop: 556

November 7, 1980

Mr. R. W. Houston, Branch Chief
Accident Evaluation Branch
Division of Systems Integration
Office of Nuclear Reactor Regulation
US Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Houston:

SUBJECT: TRAC CALCULATIONS OF STEAM GENERATOR TUBE RUPTURE/MAIN STEAM LINE BREAK FOR ZION STATION

This is to report the results of simulations of steam generator tube ruptures (SGTR) induced by main steam line break (MSLB). Three TRAC-PD2 calculations were performed representing double-ended breaks in one, two and five tubes of Zion's B steam generator (SG). This loop contains the reactor's pressurizer. Tube rupture at the SG outlet side of the tube sheet was assumed to occur simultaneously with a double-ended MSLB adjacent to and upstream of the main steam isolation valve (MSIV), in the steam tunnel outside the containment. This is a worst-case scenario for SGTR occurring within seconds after MSLB. The calculations were performed in LASL's Multifault Accident Analysis Section by Dean Dobranich at a total effort of 2 man weeks and $8000.

The following assumptions were used in the analyses:

(1) At time zero, the 4-loop Westinghouse reactor experienced a MSLB which immediately induced SGTR in loop B.

(2) Reactor scram logic included trip after 18 per cent overpower or 60 per cent excess steam flow in steam line B. A 3 1/2 per cent shutdown margin was assumed with a 1.0 second rod insertion time. Moderator and Doppler feedback reactivity were as specified in the Zion FSAR. Switch to auxiliary feedwater (AFW) was concurrent with reactor trip; flow was throttled to 50 per cent.

(3) Emergency core cooling system (ECCS) actuation was set to activate upon primary system pressure decrease to 1685 psig. Concurrent with ECCS actuation would be tripping of the RCPs in all loops.

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(4) Operators identified the damaged SG after 15 min. and closed the loop isolation valves on both hot and cold legs of affected loop, as specified in Zion's operating procedures. They also tripped the AFW to the affected SG.

Summaries of the sequence of events for the SGTRs are listed below:

ONE TUBE RUPTURE

Time(s)	Description	Comment
0.0	Double-ended steam line break; one tube ruptures.	A worst-case scenario. SGTR would normally be expected to occur seconds after the MSLB.
1.8	Reactor scrammed upon high steam flow. AFW auto-starts; throttled to 50 per cent.	Includes 1.5 s delay between time of trip signal generation (0.3 s) and scram initiation (1.8 s).
25.0	All RCP's tripped, ECC initiated (flow equals 57 kg/s)	Rapid depressurization due to SG blowdown. Pressurizer level very low due to rapid primary system contraction, but starts to refill at a rate determined by the difference between SGTR leak rate and ECCS injection rate.
110.0	SG-B blowndown to 2 bars; steaming of AFW and primary water in SG at 36 kg/s.	Primary/secondary equilibration reached. Primary leakage rate equals 22 kg/s (400 gpm). AFW rate is 14 kg/s.
900.0	Throttle AFW to SG-B to zero; close loop B isolation valves.	Complete isolation of damaged SG. Pressure drops to one bar, leakage drops to zero. Pressurizer level returns to normal.

TWO TUBE RUPTURE

Time(s)	Description	Comment
0.0	Doubled-ended steam line break; two tubes rupture.	
1.8	Reactor scram, AFW auto-starts.	

24.0	All RCPs tripped, ECC initiated (flow equals 67 kg/s).	ECCS delivery rate pressure-dependence taken from Zion FSAR.
115.0	SG-B blown down to 2 bars; steaming rate equals 75 kg/s.	Primary leakage rate equals 47 kg/s (900 gpm).
900.0	AFW set to zero on SG-B, close loop B isolation valves.	

FIVE TUBE RUPTURE

Time(s)	Description	Comment
0.0	Double-ended steam line break; 5 tubes rupture.	
1.8	Reactor scram, AFW auto-starts.	
22.5	All RCPs tripped, ECC initiated (flow equals 80 kg/s).	System pressure drops lower than one tube rupture case.
160.0	SG-B blown down to 4 bars; steaming rate equal to 150 kg/s.	Primary leakage rate equals 98 kg/s (2000 gpm).
900.0	AFW set to zero on SG-B; close loop B isolation valves.	

Conclusions of analyses:

The amount of primary liquid lost is approximately a linear function of the number of tubes ruptured and the length of time before the damaged SG is isolated (taken to be 15 minutes for these analyses). For a one tube rupture, the leakage remains essentially constant because the primary pressure is held up by the ECC flow. A five tube rupture leak rate is about five times that for the one tube rupture initially but decreases with time because the ECC flow rate is less than the leakage rate and is not able to maintain a constant primary pressure. The SG blows down faster for the one tube rupture because the primary leakage is lower. The greater leakage for the five tube rupture holds the SG pressure at a higher level. Once the damaged loop has been isolated, the leakage is essentially ended (except for 9000 kg of primary water between the top of the U-tubes and the break location in the tube sheet) so the amount of primary liquid lost can be approximated by the formula:

$$M_{Lost} \cong \dot{m}_{oT} \cdot N \cdot T$$

where

$\dot{m}_{OT}$ → 22 kg/s (leakage rate for one tube)

N → number of tubes ruptured

T → time in seconds until loop is isolated.

This formula is good for less than 5 tubes when the ECC flow rate is equal to or greater than the leakage rate and is conservative because the SGTR was assumed to be double ended. For more than five tubes, the primary pressure decreases and the leakage rate is less than $\dot{m}_{OT} \cdot N$.

Accompanying plots include time histories of:

(1) SG-B pressure,
(2) steam line break flow rate,
(3) primary to secondary leakage rate,
(4) primary pressure,
(5) core average temperature,
(6) core saturation temperature,
(7) reactor power,
(8) SG vapor fraction,
(9) SG vapor temperature,
(10) pressurizer level, and
(11) clad temperature.

I hope these results will be useful to you in your work. Please contact me at (FTS) 843-7322 if I can provide further details from these calculations.

Sincerely,

Robert D. Burns III, Section Leader
Multifault Accident Analysis

RDB:ym/R660

Enc. as stated

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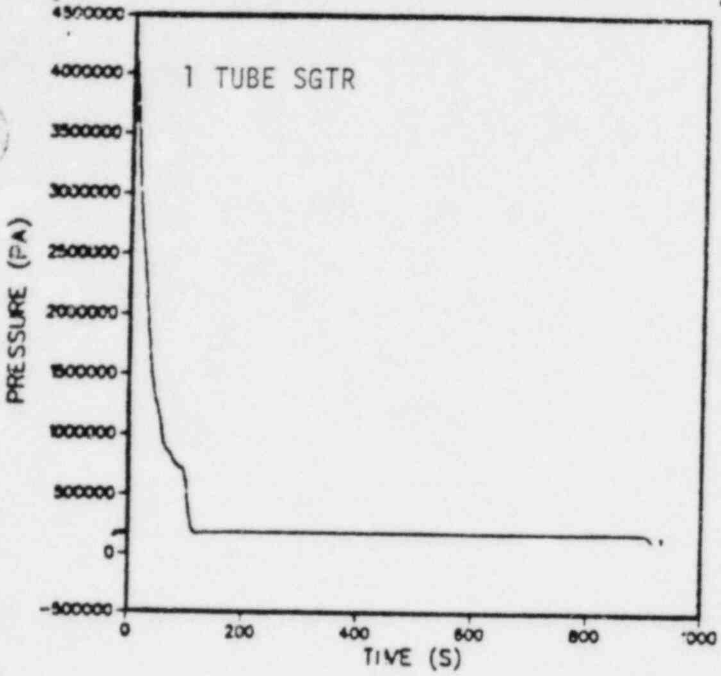
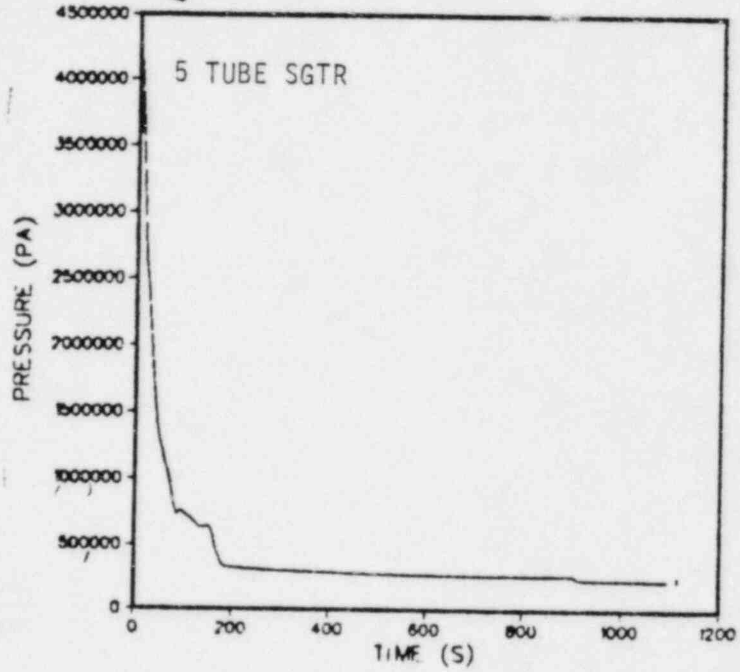
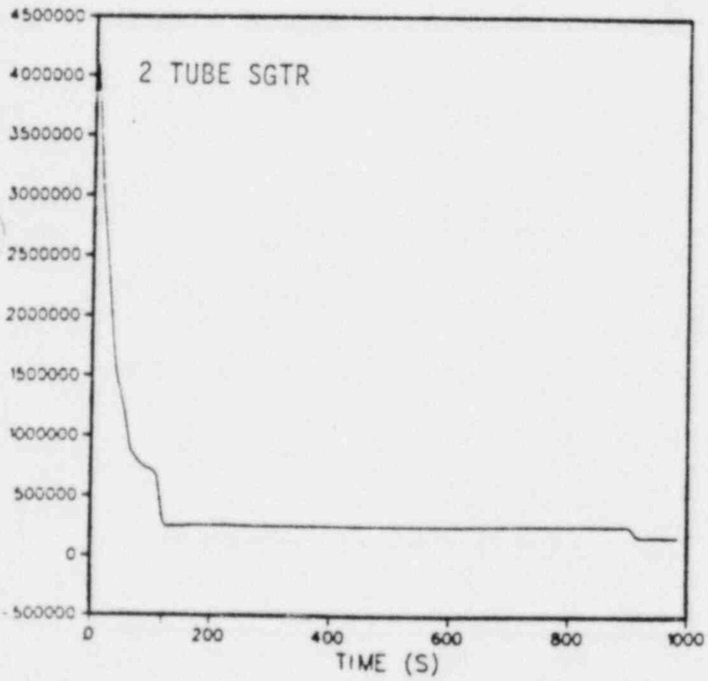
R. Burns, Q-7, MS-556
D. Dobranich, Q-7, MS-556
CRMO (2), MS-150
File (RDB, RF, R682)

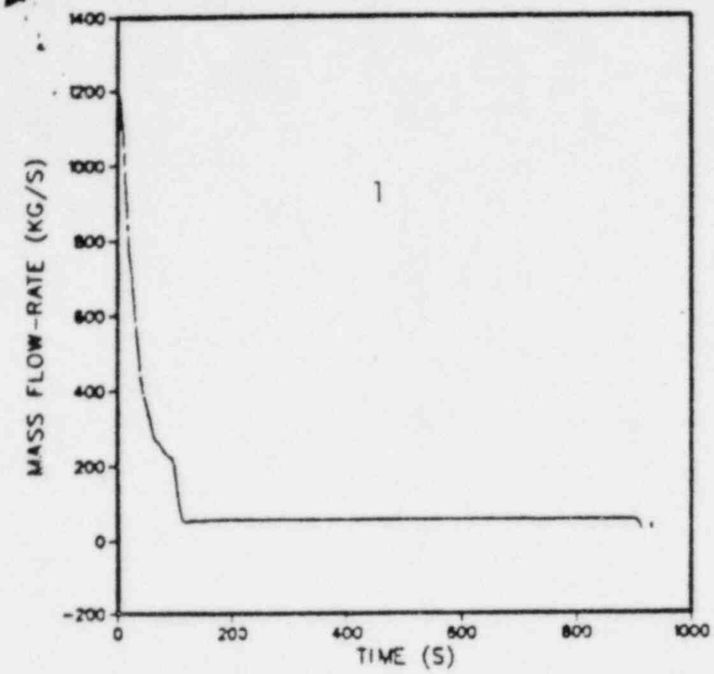


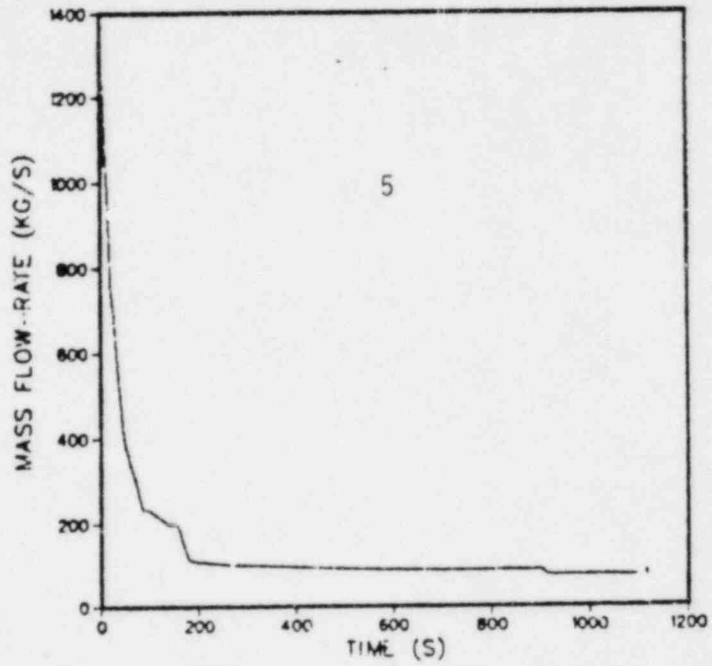


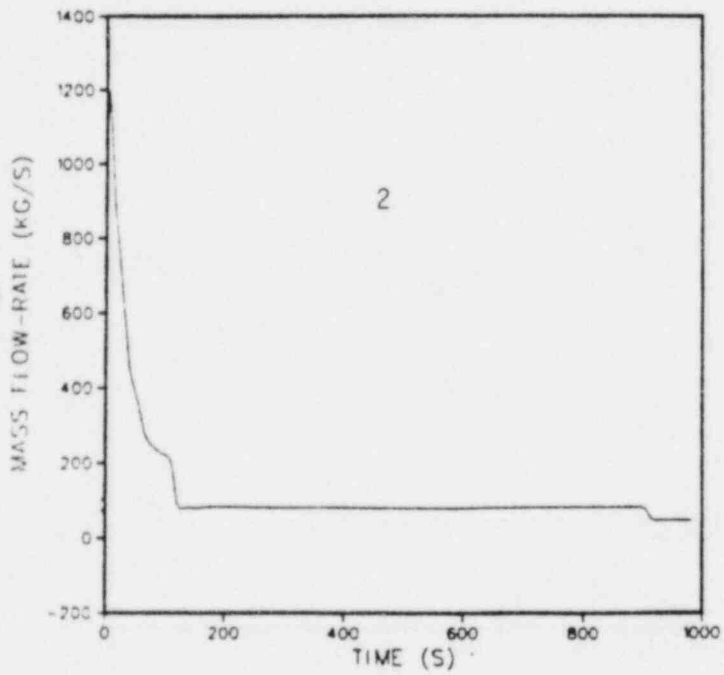


B SG PRESSURE

(1) Initial SG pressure was 5 MPa.

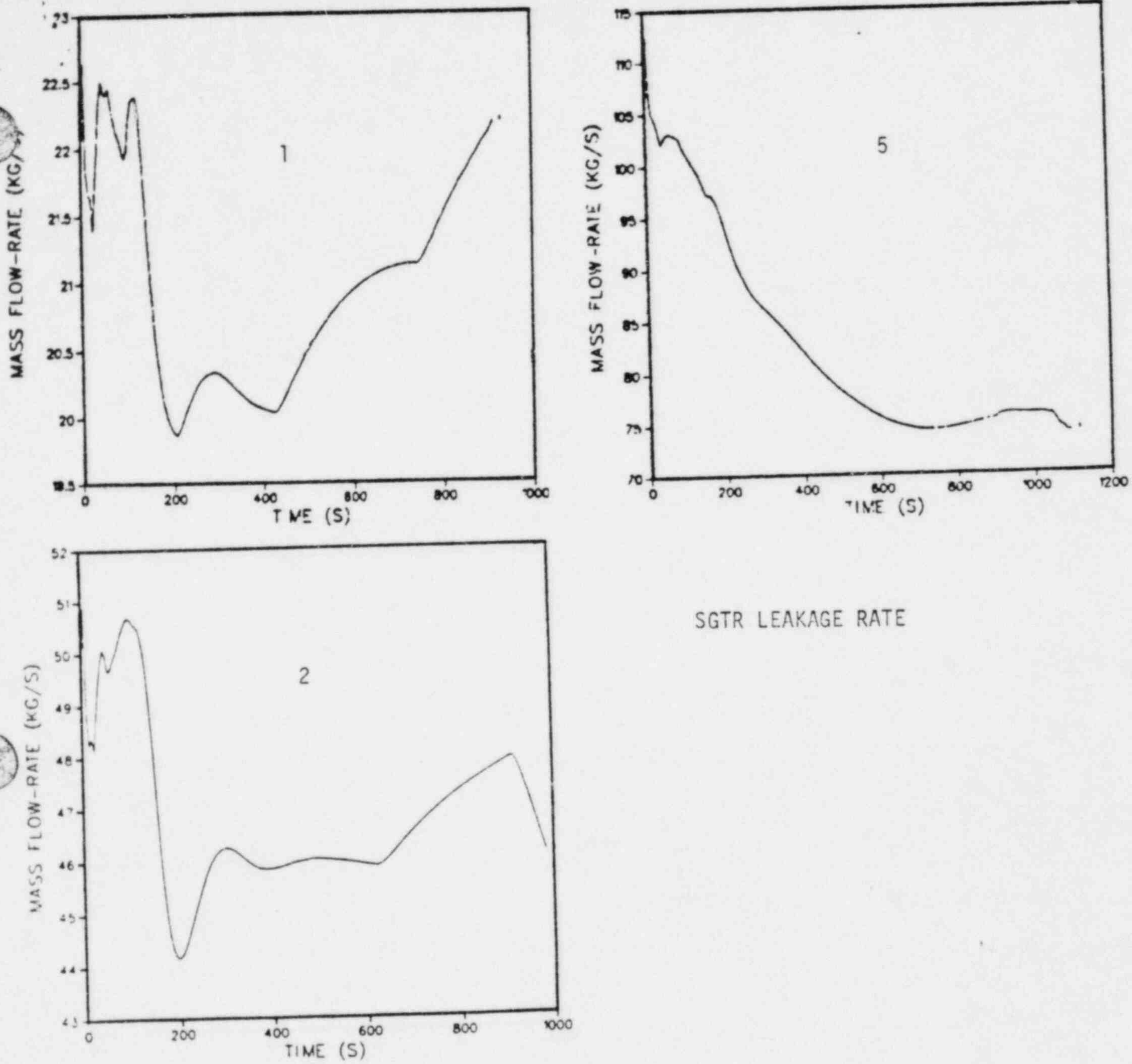






Steam Line Break Mass Flow Rate

(1) SG isolated at 15 min (900 s) by closing of B loop isolation values. Mass flow does not go to zero because 9000 kg of primary water remains between the top of the u-tubes and the SGTR in the tube sheet. That water drains through the SGTR over the next 30 min.

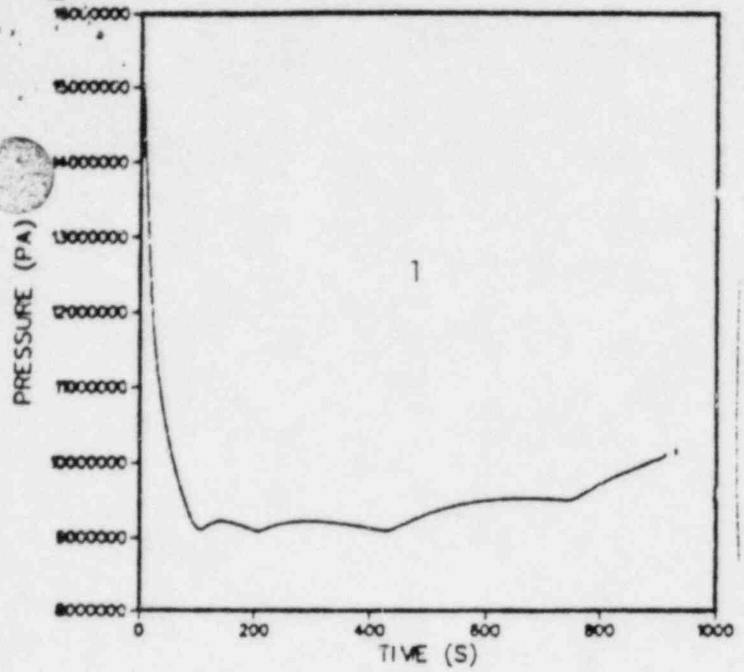


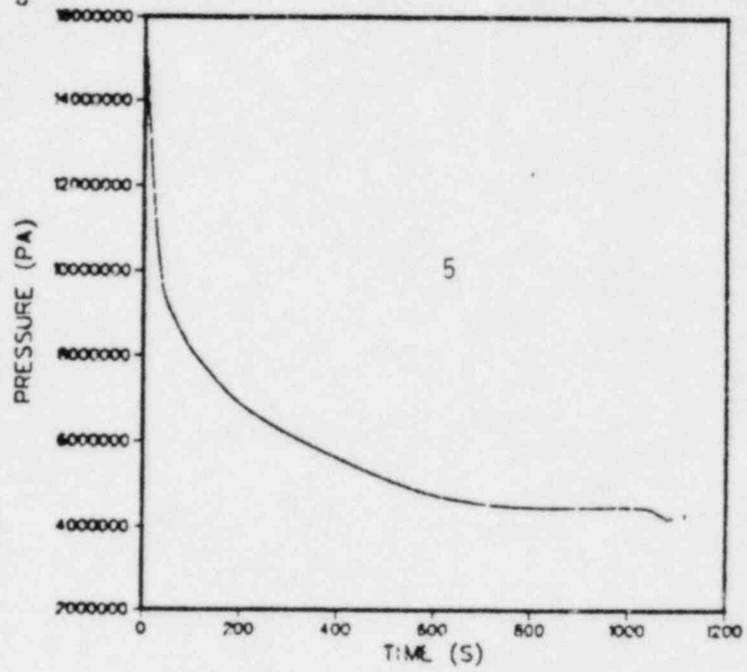
SGTR LEAKAGE RATE

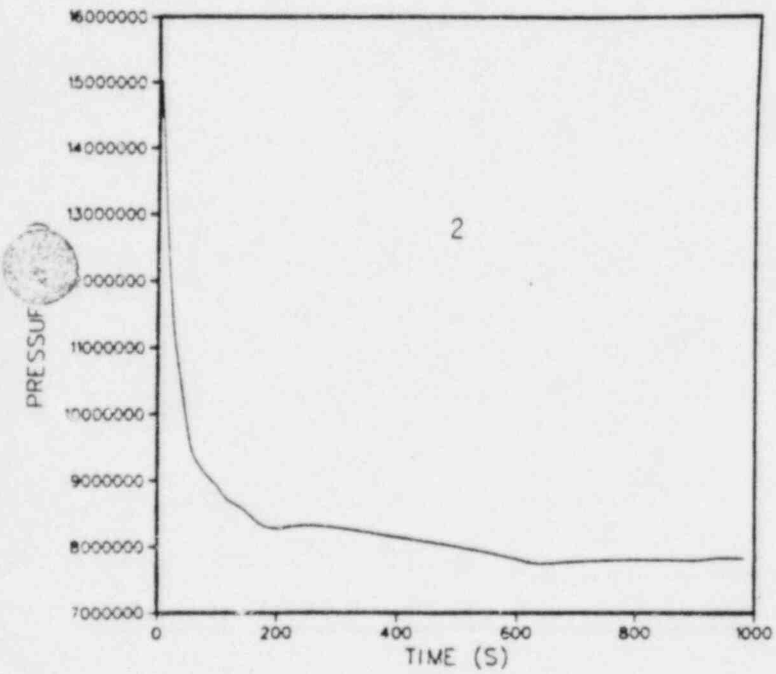
(1) Leakage continues past 900 s when SG is isolated because 9000 kg of primary water must drain through the SGTR. (see STEAM LINE BREAK MASS FLOW RATE footnote).

(2) Sudden drop in flow rate before 200 s (1 and 2 tube SGTR) occurred because the SG secondary boiled dry at about 2 min.

(3) Rise in flow rate at approximately 20 s due to RCP trip and ECCS initiation at that time.



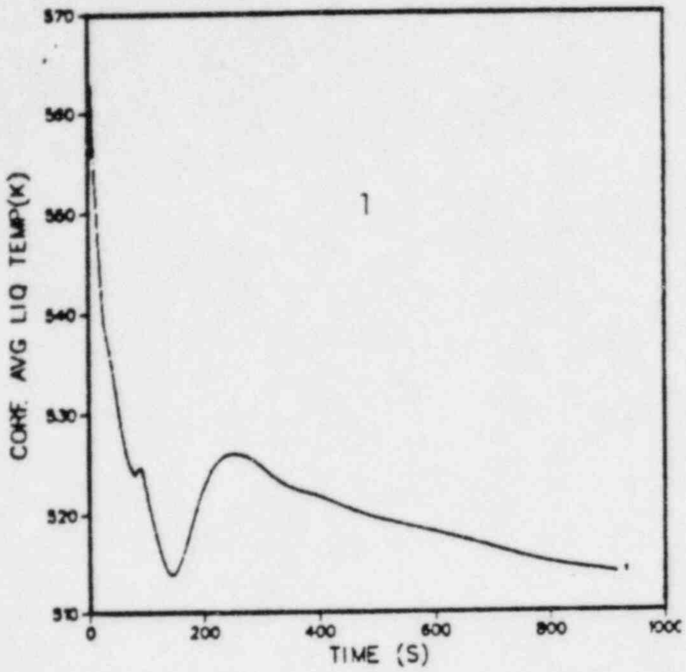


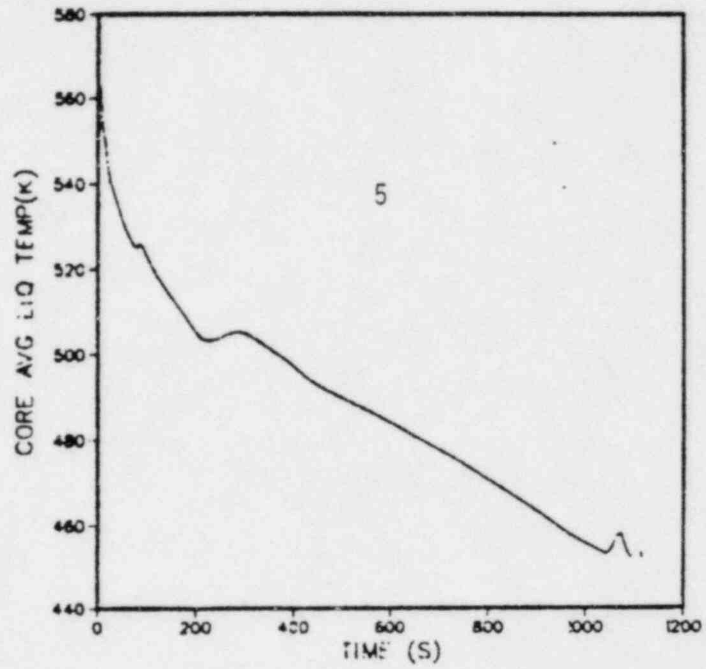


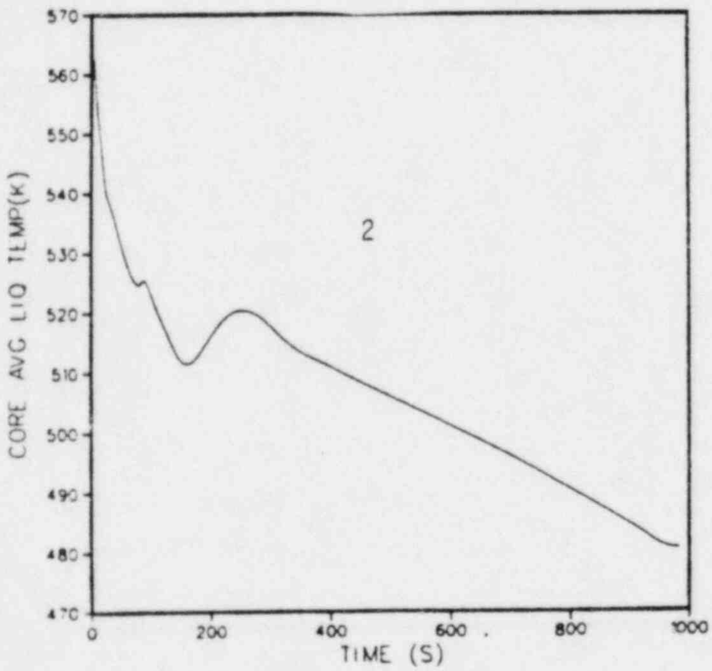
PRIMARY PRESSURIZER PRESSURE

(1) Initial pressure was 15.4 MPa (2235 psi).

(2) Pressure increases on one tube rupture case because ECC Flowrate exceeds leakage rate.



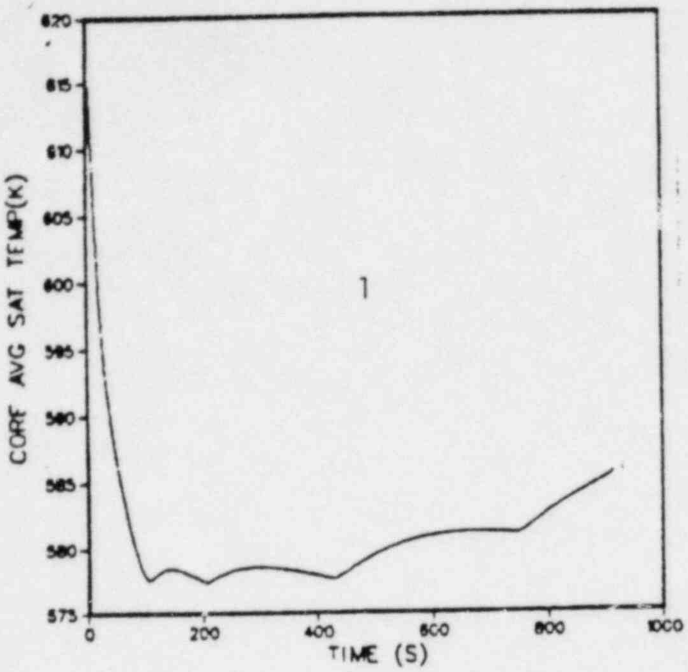


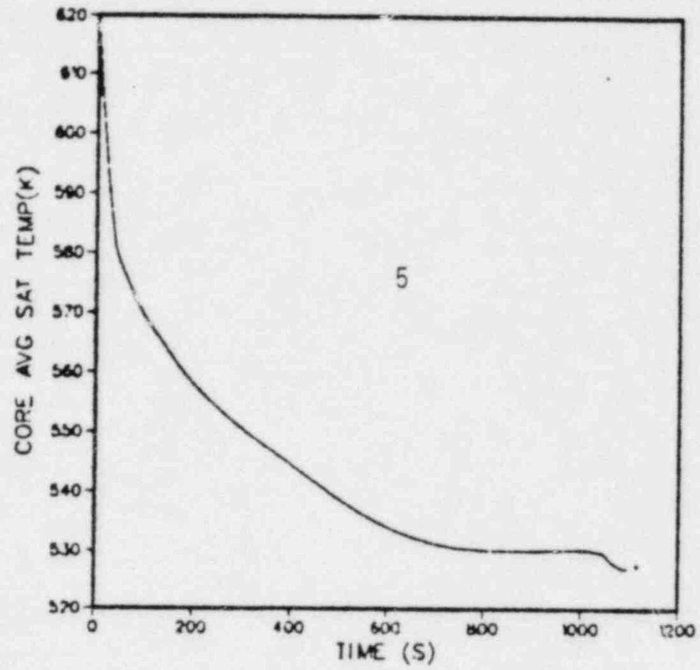


CORE WATER TEMPERATURE

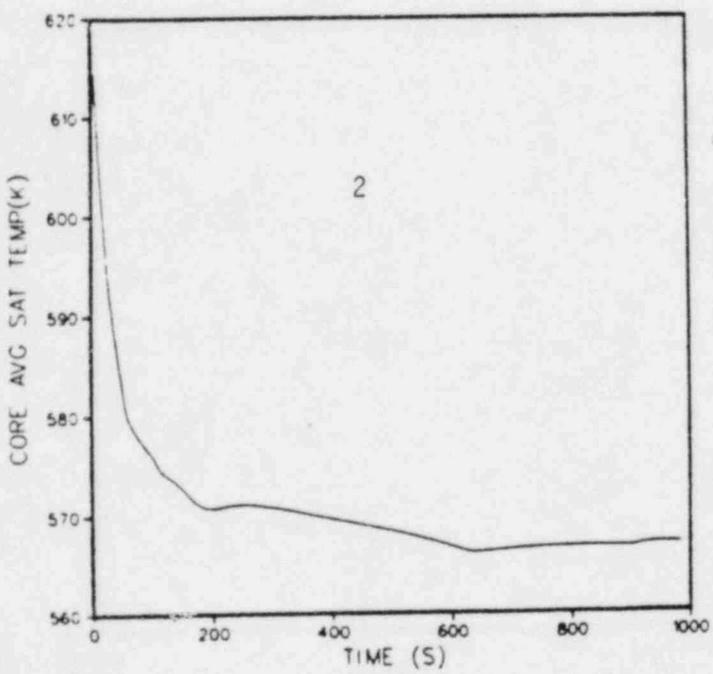
(1) ECCS delivery rate was greater for larger SGTR, causing earlier cooling of core.

(2) Temperature rise before 200 s due to dry-out of B SG.

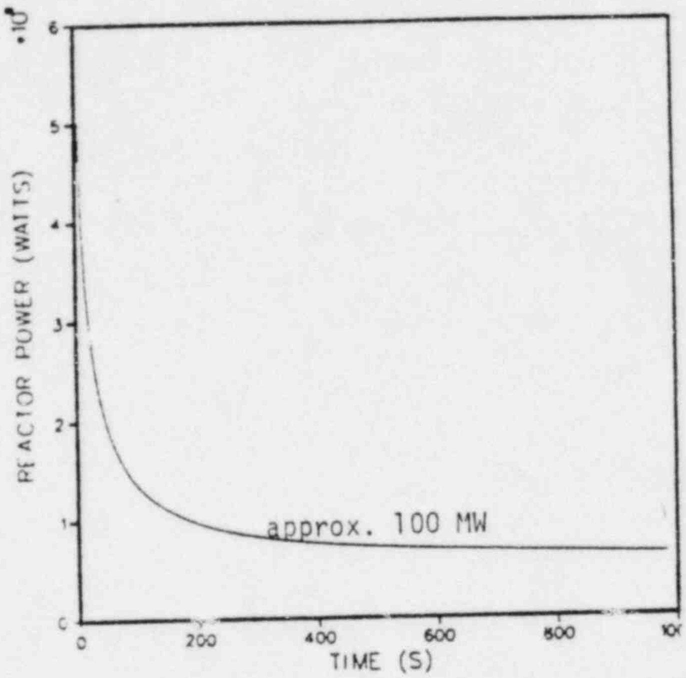




CORE SATURATION TEMPERATURE



(1) Saturation temperature was always at least 50 K above core temperature. Minimum difference occurred after 200 s in response to B SG dry-out.



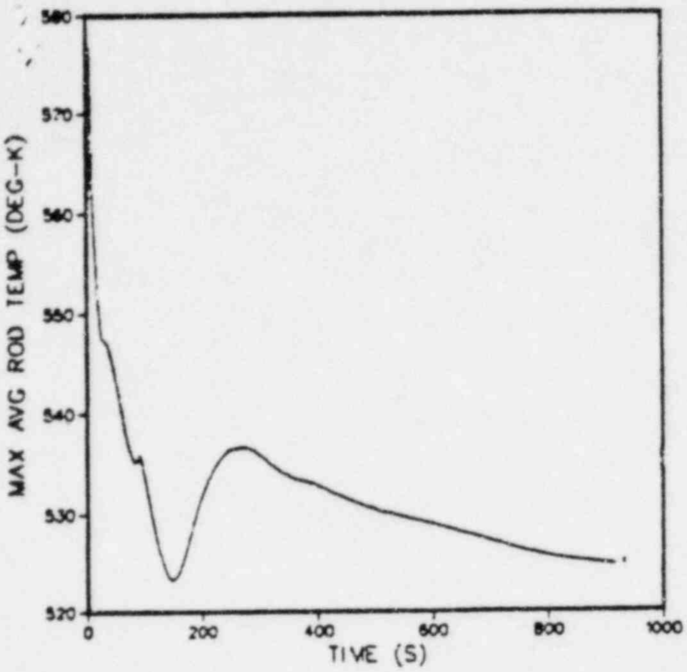
REACTOR POWER

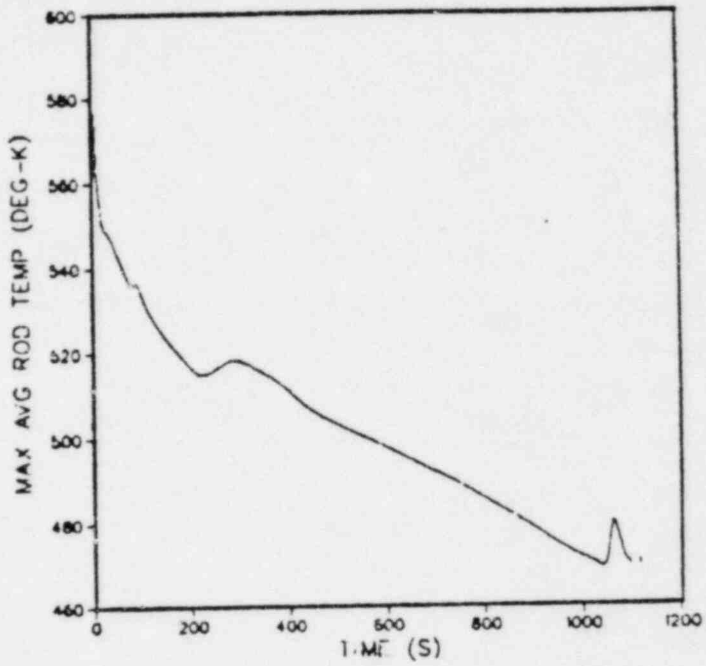
(1) Initial power was 3238 MW.

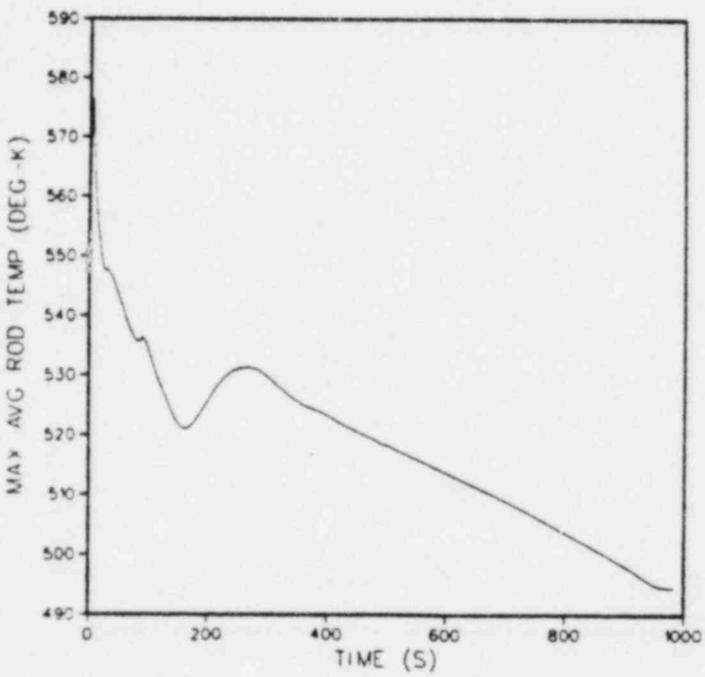
(2) 3-1/2 percent shut down margin assumed; moderator and Doppler feedback were modeled according to zion FSAR data.

(3) ANS decay curve parameters assumed.

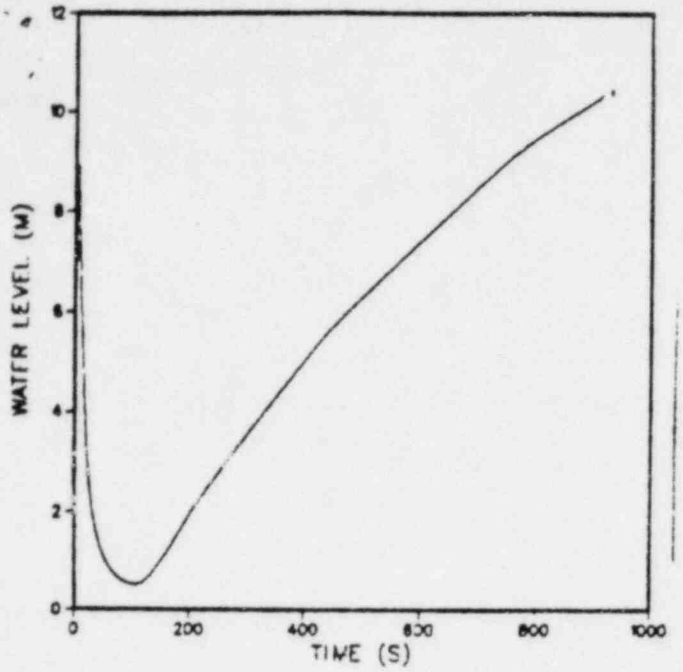
(4) Reactor power response was essentially identical for 1, 2, and 5 tube SGTR cases.

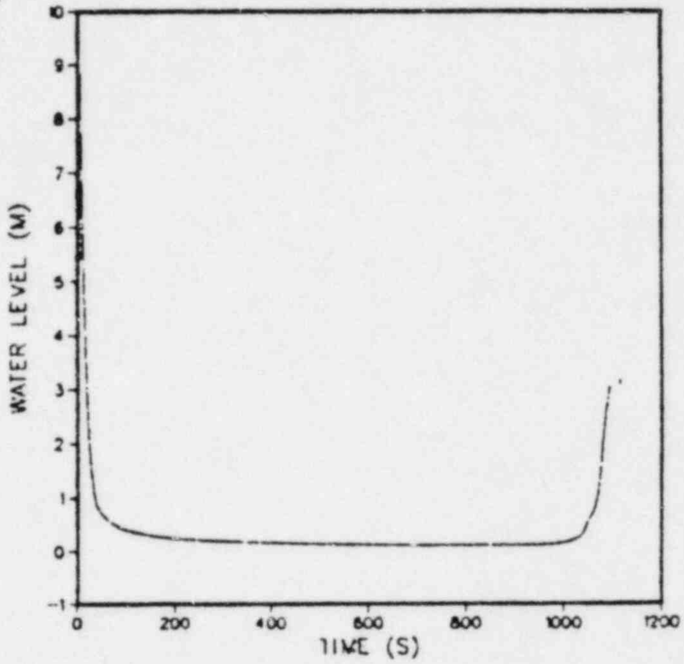


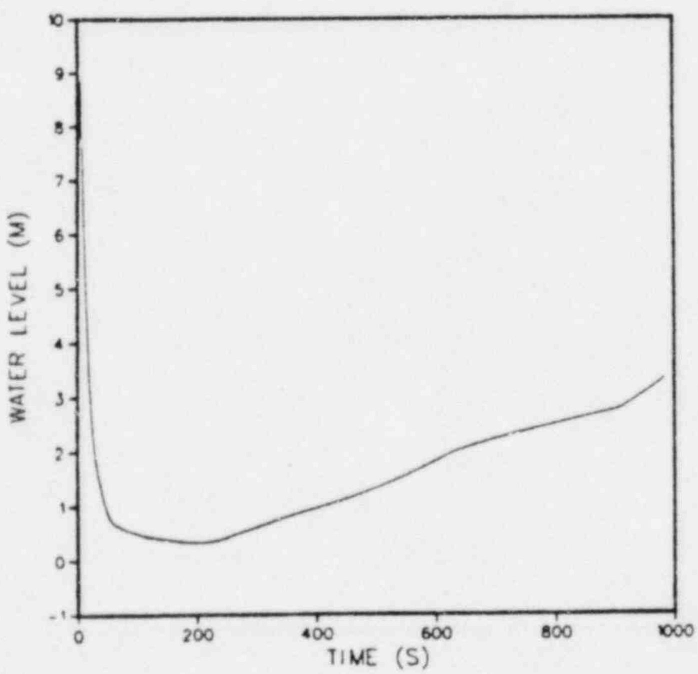




MAXIMUM (HOT ROD) AVERAGE (RADIALLY ACROSS CLAD) CLAD TEMPERATURE

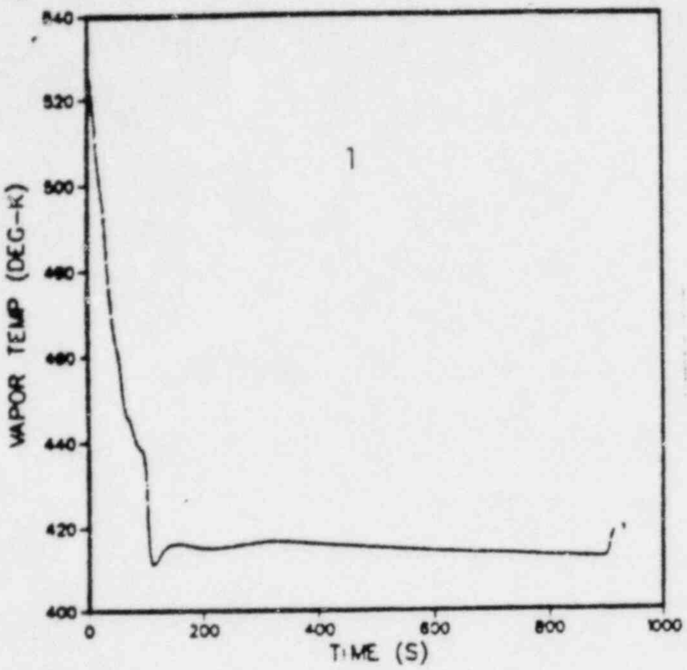


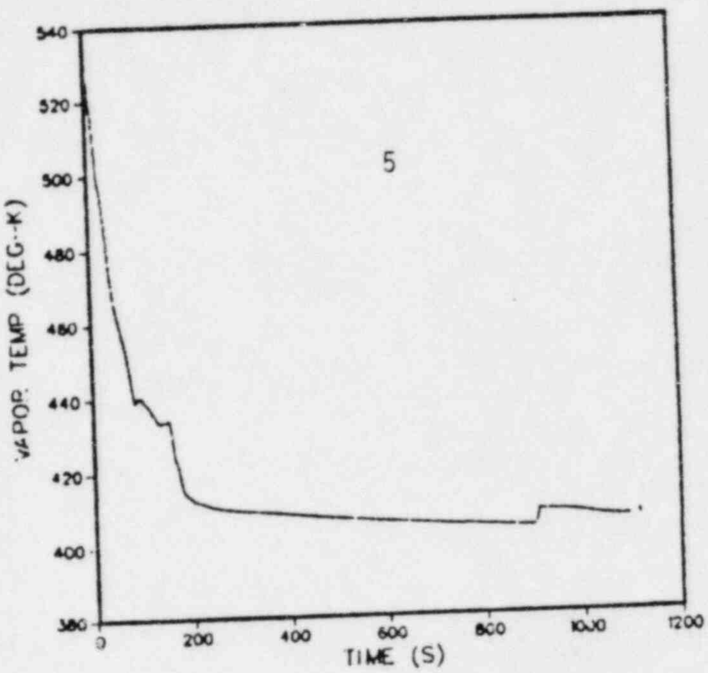


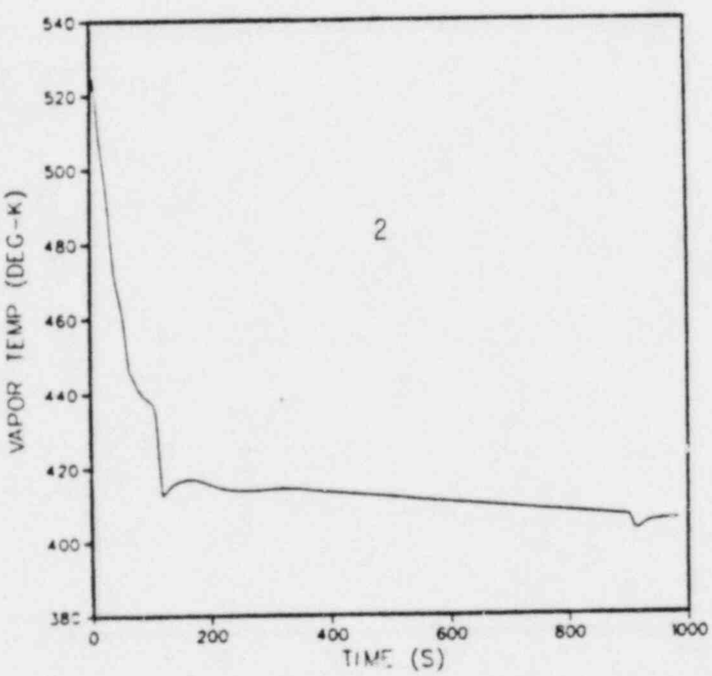


PRESSURIZER WATER LEVEL

(1) Initial level was 9.9 m.

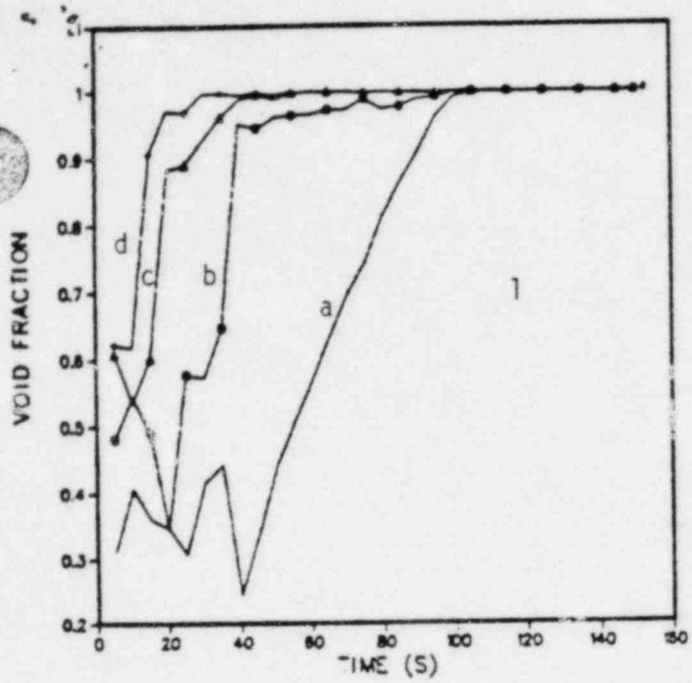


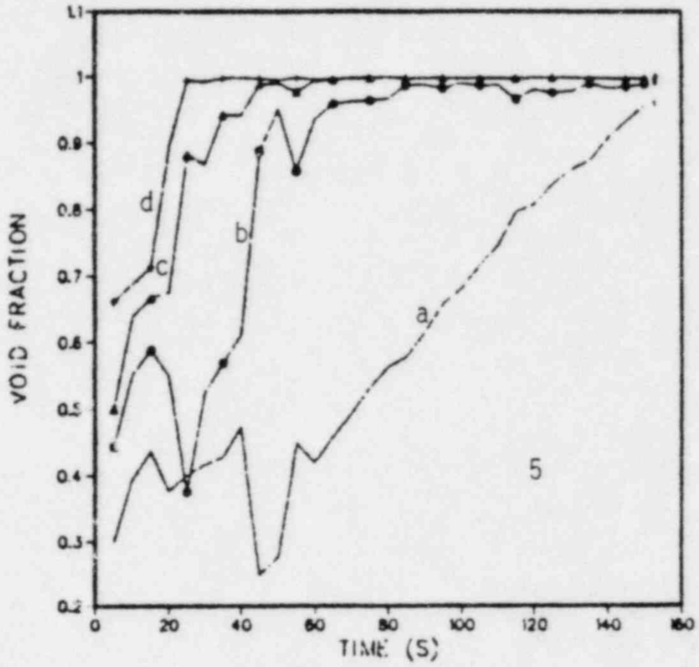


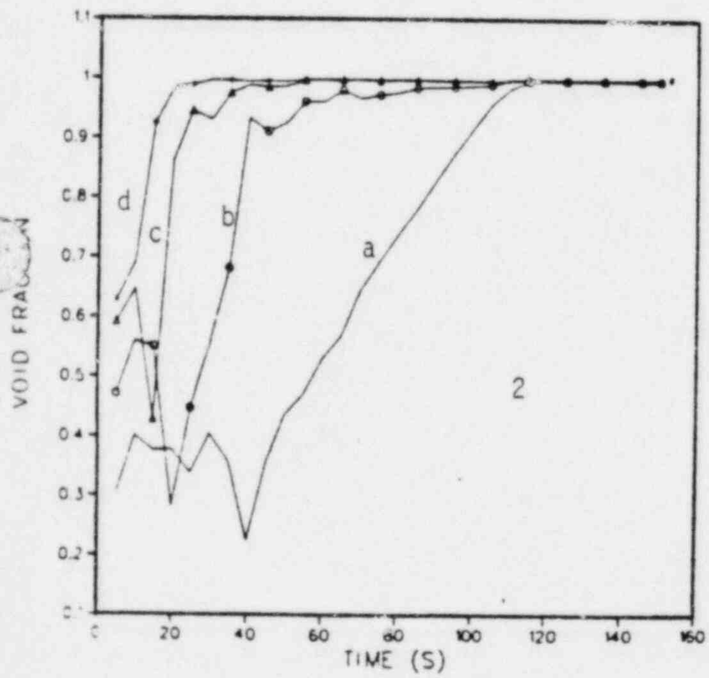


B SG VAPOR TEMPERATURE

(1) Initial temperature was 537 K.







B SG SECONDARY WATER INVENTORY

Plots a, b, c, and d are vapor fractions in four axial volume cells representing the SG secondary below the steam separators.

a. 16.7 m^3 cell from tube sheet to 3 m above tube sheet.
b. 16.7 m^3 cell from 3 m to 6 m above tube sheet.
c. 16.7 m^3 cell from 6 m to 9 m above tube sheet.
d. 16.7 m^3 cell from 9 m to 12 m above tube sheet.

(1) SG secondary was in saturation. Water and steam conditions can be found using steam tables and B SG pressure plot.

(2) SGTR leakage entered secondary at cell a (bottom axial cell).

(3) U-tube bend was located in cell d (top axial cell).