APPENDIX A

SURRY MELCOR ANALYSES

TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS III
LIST OF TABLES V
ABBREVIATIONS AND ACRONYMS VI
A.1 SUMMARY OF SURRY MODEL CHANGES A-1
A.1.1 Surry Model A-1
A.2 SMALL-BREAK LOSS-OF-COOLANT ACCIDENT DEPENDENCY ON SUMP RECIRCULATION A-5
A.2.1 Case 1: 1-Inch Break LOCA without Sprays A-7
A.2.2 Case 2: 1-Inch Break LOCA with Sprays A-11
A.2.2.1 Case 2a: 1-Inch Break LOCA with Sprays and Secure Two HHSI Pumps A-15
A.2.2.2 Case 2b: 1-Inch Break LOCA with Sprays, Secure HHSI Pumps, and Secondary Cooldown A-20
A.2.3 Case 3: 2-Inch Break LOCA without Sprays A-25
A.2.4 Case 4: 2-Inch Break LOCA with Sprays A-29
A.2.5 Case 5: 0.5-Inch Break LOCA without Sprays A-33
A.2.6 Case 6: 0.5-Inch Break LOCA with Sprays A-37
A.2.6.1 Case 6a: 0.5-Inch Break LOCA with Sprays and Secure HHSI Pumps A-41
A.2.6.2 Case 6b: 0.5-Inch Break LOCA with Sprays, Secure HHSI Pumps, and Secondary Cooldown A-46
A.2.7 Case 7: 0.5-Inch Break LOCA without Sprays and PRZ PORV Not Stuck Open A-51
A.2.8 Case 8: 0.5-Inch Break LOCA with Sprays and PRZ PORV Not Stuck Open A-55
A.3 FEED-AND-BLEED PORV SUCCESS CRITERIA A-59
A.3.1 Case 1: Nominal Power, Reactor Trip at Time Equals Zero A-60
A.3.2 Case 2: Nominal Power, Anticipatory Reactor Trip A-65
A.3.3 Case 3: 113.9 Percent Power Level, Reactor Trip on Low-Low SG Level . A-70
A.4 STEAM GENERATOR TUBE RUPTURE EVENT TREE TIMING A-75
A.4.1 Case 1: One Tube (Unmitigated) and Secure One HHSI Pumps A-76
A.4.2 Case 2: Five Tubes (Unmitigated) and Secure One HHSI Pumps A-79
A.4.3 Case 3: One Tube (Unmitigated) and Secure Two HHSI Pumps A-82
A.5 PRESSURIZED-WATER REACTOR STATION BLACKOUT A-85
A.5.1 Case 1: Station Blackout without Turbine-Driven Auxiliary Feedwater (500 gpm) A-87
A.5.1.1 Case 1a: Three HHSI Pumps at 2.14 Hours A-90
A.5.1.2 Case 1b: Three HHSI Pumps at 1.64 Hour A-92
A.5.2 Case 2: Station Blackout with Turbine-Driven Auxiliary Feedwater (500 gpm) A-94
A.5.3 Case 3: Station Blackout without Turbine-Driven Auxiliary Feedwater (21 gpm) A-97
A.5.4 Case 4: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm) A-101
A.5.5 Case 5: Station Blackout without Turbine-Driven Auxiliary Feedwater (21 gpm); Stuck-Open Relief Valve A-105
A.5.6 Case 6: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm); Stuck-Open Relief Valve A-109
A.5.7 Case 7: Station Blackout without Turbine-Driven Auxiliary Feedwater (182 gpm) A-114

TABLE OF CONTENTS (continued)

Section Page

A.5.8 Case 8: Station Blackout with Turbine-Driven Auxiliary Feedwater (182 gpm) A-117
A.5.9 Case 9: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm) and 4-Hour Direct Current A-120
A.5.10 Case 10: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm) and 4-Hour Direct Current; Stuck-Open Relief Valve A-124
A.6 PRESSURIZED-WATER REACTOR MEDIUM AND LARGE-BREAK LOCA INITIAL RESPONSE A-129
A.6.1 Case 1: 4-Inch Break LOCA, One HHSI, One LHSI, and No ACC A-133
A.6.2 Case 2: 6-Inch Break LOCA, One HHSI, One LHSI, and No ACC A-137
A.6.3 Case 3: 8-Inch Break LOCA, One HHSI, One LHSI, and No ACC A-141
A.6.4 Case 4: 10-Inch Break LOCA, One HHSI, One LHSI, and No ACC A-145
A.6.5 Case 5: 6-Inch Break LOCA, No HHSI, One LHSI, and No ACC A-149
A.6.6 Case 6: 6-Inch Break LOCA, No HHSI, One LHSI, and One ACC A-153
A.6.7 Case 7: 6-Inch Break LOCA, One HHSI, No LHSI, and No ACC A-157
A.6.8 Case 8: 6-Inch Break LOCA, One HHSI, No LHSI, and One ACC A-161
A.6.9 Case 9: 2-Inch Break LOCA, One HHSI, No LHSI, and No ACC A-165
A.6.10 Case 10: Double-Ended Cold Leg Break LOCA, No HHSI, One LHSI, and No ACC A-169
A.6.11 Case 11: 4-Inch Break LOCA, One HHSI, No LHSI, and No ACC A-173
A.6.12 Case 12: 4-Inch Break LOCA, No HHSI, One LHSI, and No ACC A-177
A.6.13 Case 13: 4-Inch Break LOCA, No HHSI, One LHSI, and One ACC A-180
A.6.14 Case 14: 4-Inch Break LOCA, No HHSI, One LHSI, and Two ACC A-184
A.6.15 Case 15: 2-Inch Break LOCA, No HHSI, One LHSI, and Two ACC A-188
A.6.16 Case 16: 6-Inch Break LOCA, One HHSI, One LHSI, and No ACC, without Auxiliary Feedwater A-192
A.6.17 Case 17: 6-Inch Break LOCA, One HHSI, No LHSI, and One ACC, without Auxiliary Feedwater A-196
A.6.18 Case 18: 8-Inch Break LOCA, One HHSI, No LHSI, and One ACC A-200
A.6.19 Case 19: 10-Inch Break LOCA, One HHSI, No LHSI, and One ACC A-204
A.6.20 Case 20: 2-Inch Break LOCA, One HHSI, No LHSI, and One ACC A-208
A.6.21 Case 21: 2-Inch Break LOCA, One HHSI, One LHSI, and No ACC A-212
A.6.22 Case 22: 4-Inch Break LOCA, One HHSI, No LHSI, and One ACC A-216
A.6.23 Case 23: 8-Inch Break LOCA, No HHSI, One LHSI, and One ACC A-220
A.6.24 Case 24: 10-Inch Break LOCA, No HHSI, One LHSI, and One ACC A-224
A.6.25 Case 25: 4-Inch Break LOCA, One HHSI, One LHSI, No ACC, without Auxiliary Feedwater A-228
A.6.26 Case 26: 6-Inch Break LOCA, No HHSI, One LHSI, and One ACC, without Auxiliary Feedwater A-232
A.6.27 Case 27: 2-Inch Break LOCA, One HHSI, No LHSI, and One ACC, without Auxiliary Feedwater A-236
A.6.28 Case 28: 4-Inch Break LOCA, One HHSI, No LHSI, and One ACC, without Auxiliary Feedwater A-240
A.6.29 Case 29: 2-Inch Break LOCA, One HHSI, One LHSI, and No ACC, without Auxiliary Feedwater A-244
A.7 REFERENCES A-249

LIST OF TABLES

Table 1 Conditions for Reactor Trip A-1
Table 2 High Head Safety Injection Flow per Pump A-2
Table 3 Low Head Safety Injection Flow per Pump A-3
Table 4 Opening and Closing Pressures for PORV and SRV A-4
Table 5 Surry SBLOCA Sump Recirculation Results A-5
Table 6 Surry SBLOCA Sump Recirculation Key Timings (Cases 1–4) A-5
Table 7 Surry SBLOCA Sump Recirculation Key Timings (Cases 5–8) A-6
Table 8 Surry Feed-and-Bleed PORV Success Criteria Results A-59
Table 9 Surry Feed-and-Bleed PORV Success Criteria Key Timings A-59
Table 10 Surry SGTR Results A-75
Table 11 Surry SGTR Key Timings A-75
Table 12 Surry Station Blackout Results A-85
Table 13 Surry Station Blackout Key Timings (Cases 1–2) A-86
Table 14 Surry Station Blackout Key Timings (Cases 3–6) A-86
Table 15 Surry Station Blackout Key Timings (Cases 7–10) A-86
Table 16 Surry MBLOCA and LBLOCA Results A-130
Table 17 Surry MBLOCA and LBLOCA Key Timings (2-inch Breaks) A-131
Table 18 Surry MBLOCA and LBLOCA Key Timings (4-inch Breaks Group 1) A-131
Table 19 Surry MBLOCA and LBLOCA Key Timings (4-inch Breaks Group 2) A-131
Table 20 Surry MBLOCA and LBLOCA Key Timings (6-inch Breaks Group 1) A-132
Table 21 Surry MBLOCA and LBLOCA Key Timings (6-inch Breaks Group 2) A-132
Table 22 Surry MBLOCA and LBLOCA Key Timings (8-inch Breaks) A-132
Table 23 Surry MBLOCA and LBLOCA Key Timings (≥ 10-inch Breaks) A-132

ABBREVIATIONS AND ACRONYMS

ac	alternating current
ACC	accumulator
BAF	bottom of active fuel
BRK	break
BTU/hr	British thermal units per hour
C	Celsius
CET	core exit thermocouple
CL-A	cold-leg of loop A
cm	centimeter
dc	direct current
DC	downcomer
Dt	delta temperature
ECCS	emergency core cooling system
eCST	emergency condensate storage tank
F	Fahrenheit
F/hr	degrees Fahrenheit per hour
ft	feet
ft^3	cubic feet
gal	gallons
gpm	gallons per minute
HHSI	high-head safety injection
HL-x	hot leg of loop x
hr	hour
in	inches
inj or Inj	injection
K	Kelvin
kg/s	kilograms per second
LHSI	low-head safety injection
LOCA	loss-of-coolant accident
m	meters
m^3/s	cubic meters per second
MCP	main coolant pump
MD-AFW	motor-driven auxiliary feedwater
MFW	main feedwater
min	minute
mm	millimeter
MPa	megapascals
MW	megawatt
MWt	megawatt thermal
PORV	power-(or pilot-) operated relief valve
PRT	pressurizer relief tank
PRZ	pressurizer
psia	pounds per square inch absolute
psid	pounds per square inch differential
psig	pounds per square inch gage
PWR	pressurized-water reactor
RCP	reactor coolant pump
RCS	reactor coolant system
Rec	recirculation
Recir	recirculation
RHR	residual heat removal
RWST	refueling water storage tank
SBLOCA	small-break loss-of-coolant accident
scfm	standard cubic feet per minute
sec	seconds
SG-x	steam generator for loop x
SG	steam generator
SI	safety injection
SOARCA	State-of-the-Art-Reactor Consequence Analyses
SRV	safety relief valve
TAF	top of active fuel
Tavg	average temperature
TCL	cladding temperature
TCV	turbine control valve
TD-AFW	turbine-driven auxiliary feedwater
TFU	fuel temperature

A.1 Summary of Surry Model Changes

A.1.1 Surry Model

The Surry input deck is consistent with the model used in the State-of-the-Art Reactor Consequence Analyses (SOARCA) project. For the present application, however, a number of modifications are made to control the reactor trip and the engineered safety features, including the emergency core cooling system (ECCS) and containment sprays. In addition, the treatment of reactor coolant pump (RCP) seal leakage is also different. The general setpoints and operation of the systems are described below.

Reactor Trip

The conditions for reactor trip are given in Table 1 below (i.e., if any condition becomes true, then the reactor is tripped).

Table 1 Conditions for Reactor Trip

	Condition	Comments
1	Loss of power	
2	ECCS actuation	See ECCS signals
3	MFW trip[1]	Scram or loss of power or manual
4	TCV closure	
5	MCP trip	Loss of power or loop void > 10%
6	HHSI activation	ECCS signal + power available
7	LHSI activation	ECCS signal + power available
8	High RCS pressure	> 2,400 psia (16.55 MPa)
9	Low RCS pressure	< 1,815 psia (12.51 MPa)
10	High PRZ level	> 44.97 ft (26.26 m in MELCOR model)
11	Low PRZ level	< 12.51 ft (16.36 m in MELCOR model)
12	High loop Dt	> 75 °F (41.67 °C)
13	Manual	Time based

[1] Several different configurations were found just among the three-loop high-head Westinghouse plants in terms of whether a main feedwater trip would result in a turbine trip and subsequent reactor trip. The trip in the Surry MELCOR model is potentially dated. For these reason, additional calculations were run in the loss of all feedwater section of this report to address the (perhaps more common) situation where a reactor trip would not occur until the reactor protection system trip signal(s) related to steam generator water level.

Emergency Core Cooling System

The high-head safety injection (HHSI), as well as the low-head safety injection (LHSI) and containment sprays in the injection mode, draw water from the refueling water storage tank (RWST). Once the RWST is depleted, the LHSI suction is switched over to the containment sump.

The ECCS actuation signals for HHSI and LHSI are given below (i.e., if any of the conditions are satisfied, then both systems are activated). In addition, power must be available.

- pressurizer (PRZ) pressure (less than 1,775 pounds per square inch gage (psig) (12.2 MPa))

- high steamline differential pressure (greater than 120 pounds per square inch differential (psid) (0.83 MPa))
- high containment pressure (greater than 17.7 pounds per square inch absolute (psia) (0.122 MPa))
- manual operator action

The condition for high steam flow and either low steam line pressure (less than 525 psig (3.62 MPa)) or low average temperature (Tavg) (543 degrees Fahrenheit (F) (284 degrees Celsius)) is not modeled.

High-Head Safety Injection

HHSI flows are delivered to the cold legs of the Surry model (CVs 240/340/440). All three HHSI pumps at Surry are assumed to start on HHSI activation.[1] Total HHSI flow is portioned equally between the three cold legs. HHSI pump performance is given in Table 2 below as HHSI flow per pump (gallons per minute (gpm)) [Byron Jackson Test T-30705-3, 5-13-69].

Table 2 High Head Safety Injection Flow per Pump

Feet (Meters)	gpm (m^3/min)	Comment
0 (0)	615 (2.33)	Runout
1,600 (488)	550 (2.08)	
2,500 (762)	500 (1.89)	
3,275 (998)	450 (1.70)	
3,950 (1,204)	400 (1.51)	
4,500 (1,372)	350 (1.32)	
4,950 (1,509)	300 (1.14)	
5,300 (1,615)	250 (0.946)	
5,600 (1,707)	200 (0.757)	
5,800 (1,768)	150 (0.568)	Rated
5,900 (1,798)	100 (0.379)	
5,905 (1,800)	0 (0)	Shutoff

Low-Head Safety Injection

LHSI flows are delivered to the cold legs of the Surry model (control volumes 240/340/440). The two LHSI pumps at Surry are assumed to start on LHSI activation. Total LHSI flow is portioned equally between the three cold legs. LHSI pump performance is given in Table 3 below as LHSI flow per pump (gpm) [Byron Jackson Test T-31192-1, 11-10-69].

[1] The present MELCOR model assumes that all three HHSI pumps inject upon receiving a safety injection (SI) signal (one pump on the H bus and two pumps on the J bus). This (perhaps atypical) capability is based on interactions with the licensee and is corroborated by particular references (e.g., the emergency operating procedures). The model does not account for the potential reduction in overall flow injection created by three pumps injecting through two trains. However, this modeling assumption is actually conservative in the present analysis because the three-pump alignment is only used for the small- break loss-of-coolant accident (LOCA) and steam generator tube rupture scenarios, in which the effect of RWST depletion and lack of system depressurization are more relevant than the core cooling (because adequate core cooling would be provided by fewer pumps).

Table 3 Low Head Safety Injection Flow per Pump

Feet (Meters)	gpm (m^3/min)	Comment
0 (0)	4,000 (15.1)	Runout
188 (57.3)	4,000 (15.1)	
213 (64.9)	3,500 (13.2)	
240 (73.2)	3,000 (11.4)	
269 (82.0)	2,500 (9.46)	
296 (90.2)	2,000 (7.57)	
321 (97.8)	1,500 (5.68)	
342 (104)	1,000 (3.79)	
356 (109)	500 (1.89)	
365 (111)	0 (0)	Shutoff

The RWST level must also be above 13.5 percent (RWST-to-sump switchover starts at 13.5 percent and takes 2.5 minutes). After LHSI from the RWST is terminated, a model is activated for LHSI from the reactor sump using the same pump curve. Sump water availability and water temperature are checked.

Accumulators

Accumulators are also modeled as mass and enthalpy injected into cold leg component control volumes 240, 340, and 440. The initial water volume per accumulator is 975 cubic feet (ft^3) (27.6 meters cubed) with an initial nitrogen cover gas volume of 475 ft^3 (13.5 meters cubed). The minimum operating pressure is given as 600 psig (4.137 megapascals (MPa)). All three accumulators are assumed to behave identically in that they are all modeled by a single set of control functions.

Containment Sprays

The injection sprays use two pumps that can operate at 2,900 gpm each (a rated flow of 3,200 gpm per pump minus bleed-off flow of 300 gpm per pump) (11 m^3/min). The droplet size released by the spray headers is 1 millimeter (mm). The pumps deliver water from the RWST at 45 degrees F (280.4 Kelvin (K), the maximum temperature allowed by the technical specifications) until the RWST water reaches 13.5 percent. There are three headers in the dome:

(1) the first at 95.50 feet (29.1 m) elevation with 88 nozzles
(2) the second at 142.40 feet (43.4 m) elevation with 73 nozzles
(3) the third at 143.75 feet (43.82) elevation with 73 nozzles

The delay from spray signal to full operation is less than 15 seconds. The recirculation sprays are modeled by two pumps identical to the injection mode. The cooler duty is 55,534,520 BTU per hour (BTU/hr) each (two per pump, four total), which translates to 16.276 megawatts (MW) per cooler (65.1 MW total). Headers are common with those of the injection system. The containment sprays are initiated at a pressure of 25 psia (0.17 MPa) and stop when the pressure is less than 12 psia (0.0827 MPa).

Containment Fan Coolers

The recirculation system has three 75,000-standard cubic feet per minute (scfm) recirculation fans (35.4 cubic meters per second (m^3/s). The total volumetric flow rate is 225,000 scfm (106.2 cubic meters per second (m^3/s)). It is supplied with 2,000 gpm at 70 degrees F (135.91 kilograms per second (kg/s), 294 K)) component cooling water until containment temperature and pressure are high enough or until pumps become submerged, at which point the systems goes to chilled cooling water. MELCOR monitors the liquid level, vapor temperature, and pressure in the lower dome (control volume 50) and initiates the fans when the correct parameters are met. The fan inlet and discharge is within the "basement" (control volume 5). The MELCOR input model contains a "low capacity" fan and a "high capacity" fan. Both recognize the same parameters, with the difference being that the high-capacity fan is turned on at a higher temperature. The low-capacity fans have a secondary coolant mass flow rate of 300 pounds per second (lb/s) (135.9 kg/s) and the high-capacity fan has a secondary coolant mass flow rate of 831 pounds per second (377.1 kg/s).

Main Coolant Pumps

The pumps operate at a rated head of 280 feet of water at 650 degrees F (85.3 m at 343 degrees C), 2,235 psig, which is 6.80×10^5 pascals. The pumps are tripped on either loss of power or high void (assumed to be 10 percent in the MELCOR model).

Power-Operated Relief Valve and Safety Relief Valve Setpoints

The opening and closing pressures for the group of pressurizer power-operated relief valves (PORVs) and safety relief valves (SRVs) modeled in the MELCOR input are given in Table 4 below.

Table 4 Opening and Closing Pressures for PORV and SRV

	Opening Pressure in MPa (psi)	Closing Pressure in MPa (psi)
PORV-1	16.2 (2350)	15.55 (2255)
PORV-2	16.3 (2364)	15.65 (2270)
SRV-1	17.23 (2499)	16.54 (2399)
SRV-2	17.33 (2514)	16.64 (2413)
SRV-3	17.43 (2528)	16.74 (2428)

A.2 Small-Break Loss-of-Coolant Accident Dependency on Sump Recirculation

Analysis Summary

Table 5 through Table 7 below provide results for this portion of the analysis.

Table 5 Surry SBLOCA Sump Recirculation Results

Case	Size (inch)[5]	HHSI Pumps	PORV Treatment	Sprays	Secondary-Side Cooldown	Core Uncovery (hr)	Core Damage (hr)
1	1	3	N/A	0	No	9.2[1]	11.9[1]
2				2		7.3[1]	9.9[1]
2a[2]		3/1				7.9[1]	10.0[1]
2b[3]		3/1/0			Yes	No[4]	No[4]
3	2	3		0	No	No	No
4				2		No	No
5	0.5		Sticks open after 247 lifts	0		No	No
6				2		No	No
6a[2]		3/1				8.8[1]	9.6[1]
6b[3]		3/1/0	N/A		Yes	No[4]	No[4]
7		3	Does not stick open	0	No	17.8[1]	25.1[1]
8				2		14.4[1]	21.4[1]

1 Core damage is an artifact of the assumed unavailability of HHSI recirculation.
2 It is assumed that two HHSI pumps are secured at 15 minutes.
3 It is assumed that two HHSI pumps are secured at 15 minutes, and the third pump is secured at 30 minutes, followed by secondary-side cooldown at 100 degrees F per hour (55.6 degrees C per hour).
4 These cases reach RHR entry conditions (both temperature and pressure) before heatup.
5 1 inch = 2.54 cm; 2 inch = 5.1 cm; 0.5 inch = 1.3 cm.

Table 6 Surry SBLOCA Sump Recirculation Key Timings (Cases 1–4)

Event	Case 1 (hr)	Case 2 (hr)	Case 2a (hr)	Case 2b (hr)	Case 3 (hr)	Case 4 (hr)
Reactor trip	0.03	0.03	0.03	0.03	0.01	0.01
HSSI injection	0.03	0.03	0.03	0.03	0.01	0.01
LHSI injection	-	-	-	2.02	-	-
First actuation of contain. sprays	-	2.65	3.29	-	-	1.76
RWST depletion (< 13.5%)	5.83	4.30	5.80	-	3.12	2.63
Spray recirculation	-	4.30	5.80	-	-	2.63
LHSI recirculation	-	-	-	-	3.38	2.86
Accumulator starts to inject	6.38	4.92	5.83	0.82	0.23	0.23
RCP trip (10% void)	7.38	5.76	6.73	1.41	-	-
Core uncovery	9.23	7.32	7.9	-	-	-
Core damage (max temp > 2,200 °F)[1]	11.9	9.93	10.0	-	-	-

1 2,200 °F = 1204 °C.

Table 7 Surry SBLOCA Sump Recirculation Key Timings (Cases 5–8)

Event	Case 5 (hr)	Case 6 (hr)	Case 6a (hr)	Case 6b (hr)	Case 7 (hr)	Case 8 (hr)
Reactor trip	0.01	0.01	0.01	0.01	0.01	0.01
HSSI injection	0.01	0.01	0.01	0.01	0.01	0.01
LHSI injection	-	-	-	3.49	-	-
PORV stuck open	0.83	0.83	4.65	-	-	-
First actuation of contain. sprays	-	2.20	5.30	-	-	3.23
RWST depletion (<13.5%)	4.14	3.43	7.45	-	8.17	5.52
Spray recirculation	-	3.43	7.45	-	-	5.53
LHSI recirculation	4.72	3.97	-	-	26.6	-
Accumulator starts to inject	4.15	3.44	7.18	1.10	8.28	5.65
RCP trip (10% void)	-	4.68	5.00	13.8	11.7	10.3
Core uncovery	-	-	8.77	-	17.8	14.4
Core damage (max temp > 2,200 °F)[1]	-	-	9.61	-	25.1	21.4

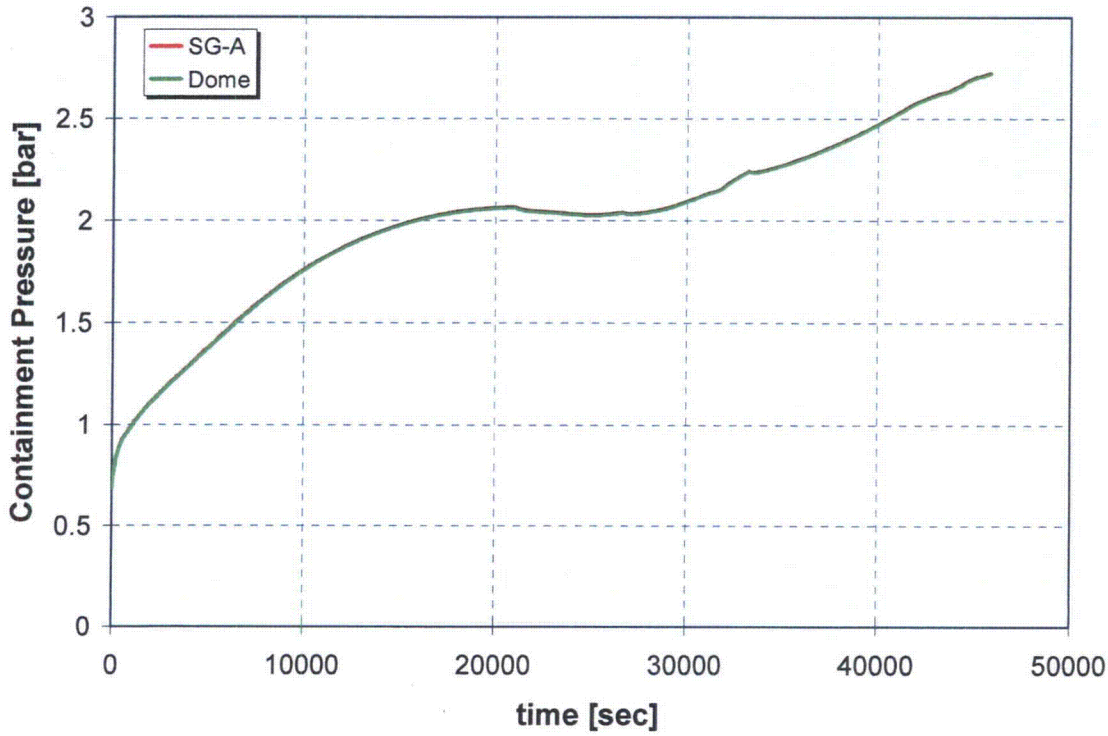
[1] 2,200 °F = 1204 °C.

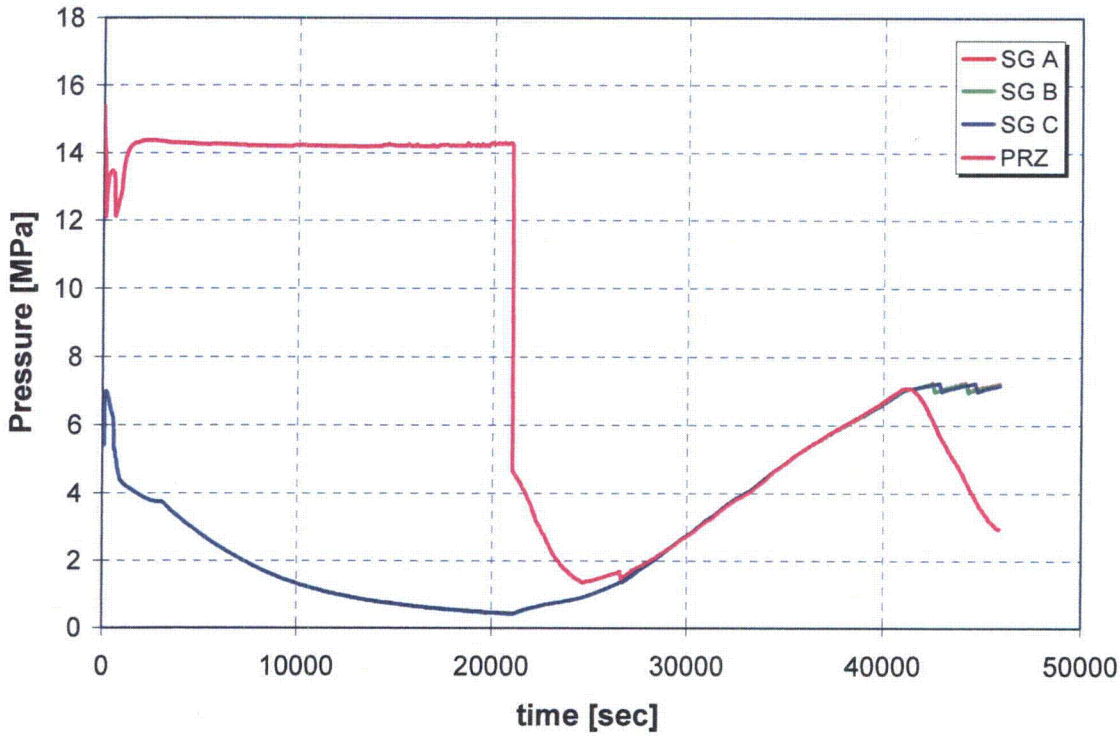
Notes

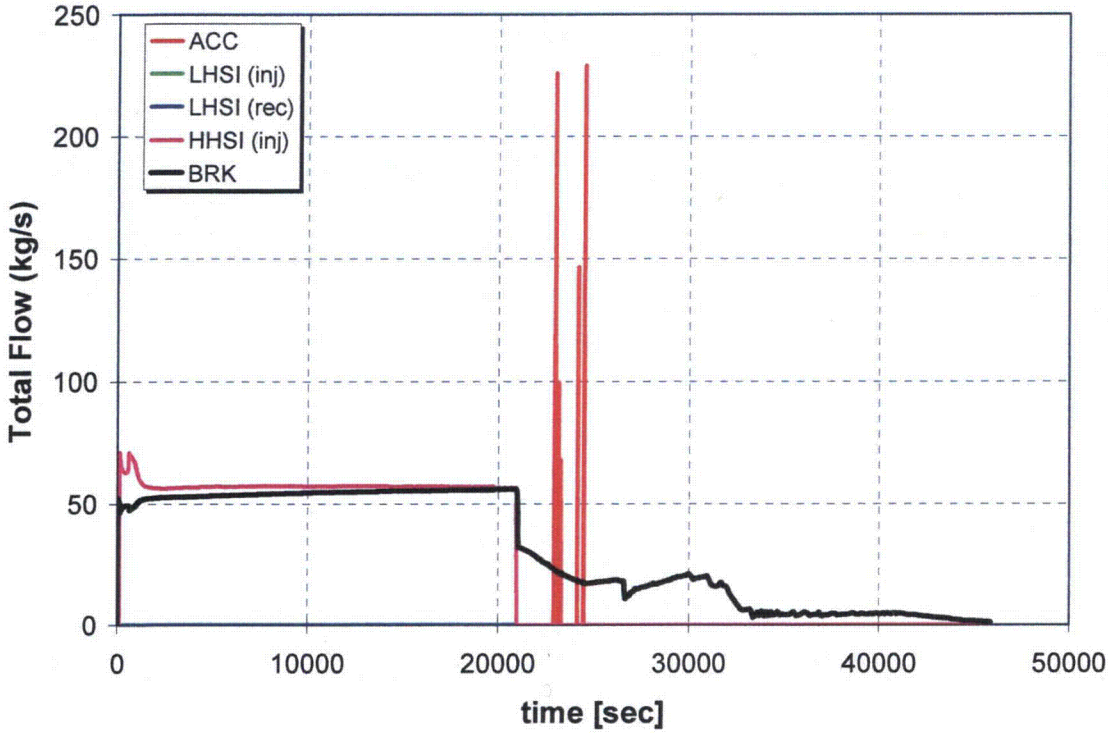
For Cases 5 and 6, PORV1 cycles initially and then gets stuck open because of the number of cycles (247 cycles). The equivalent diameter for the PORV is 1.387 inches, so it depressurizes and goes to LHSI recirculation mode.

Cases 2a, 2b, 6a, and 6b are sensitivity calculations to demonstrate the impact of HHSI injection and secondary cooldown on reactor coolant system (RCS) pressure, and to determine the residual heat removal (RHR) entry conditions. They may not represent actual plant operating procedures.

A.2.1 Case 1: 1-Inch Break LOCA without Sprays



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LHSI (rec)
HHSI (inj)
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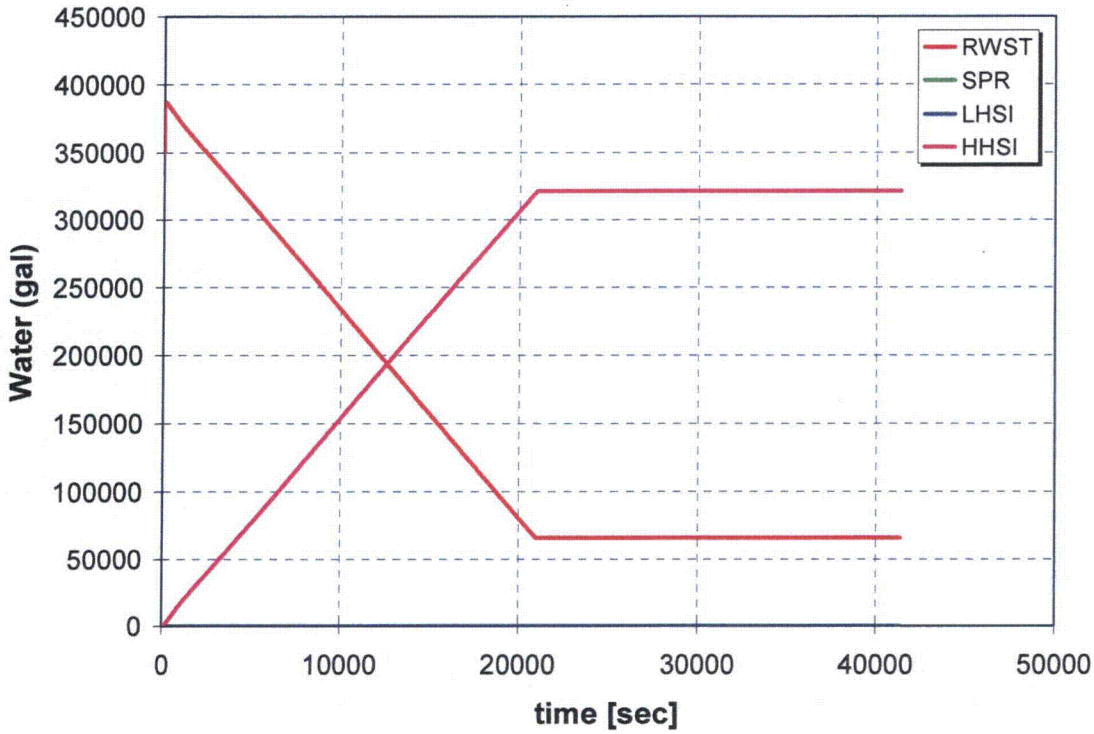
30000
40000
50000
time [sec]


RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
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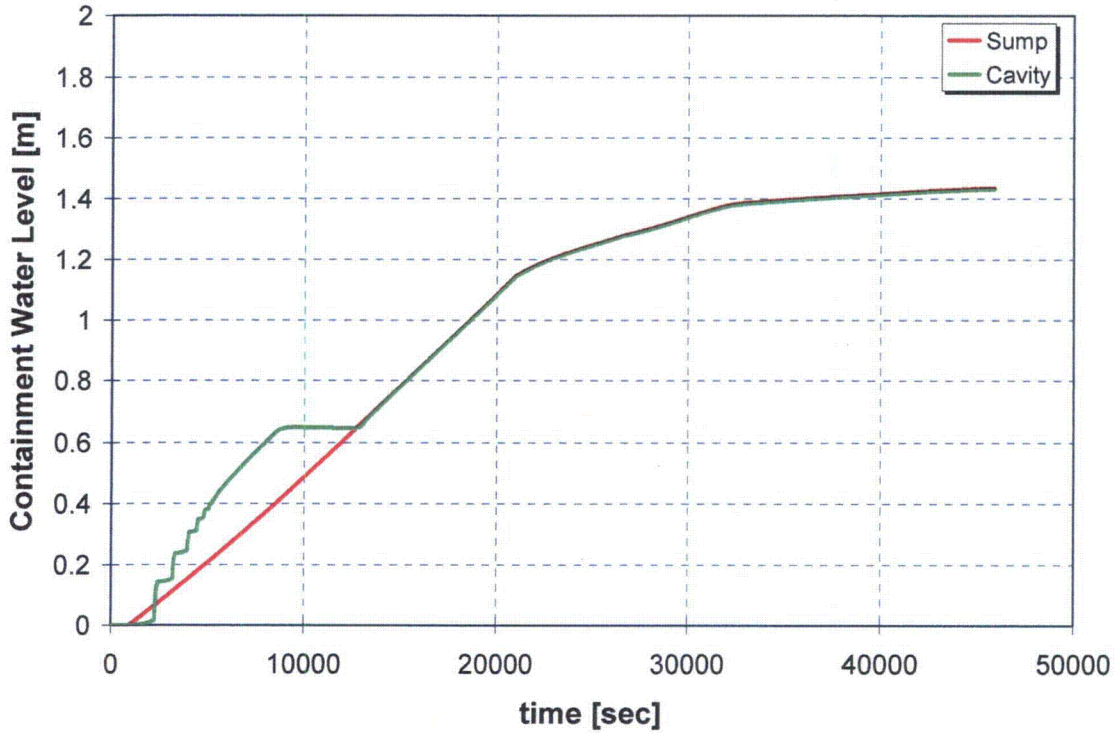
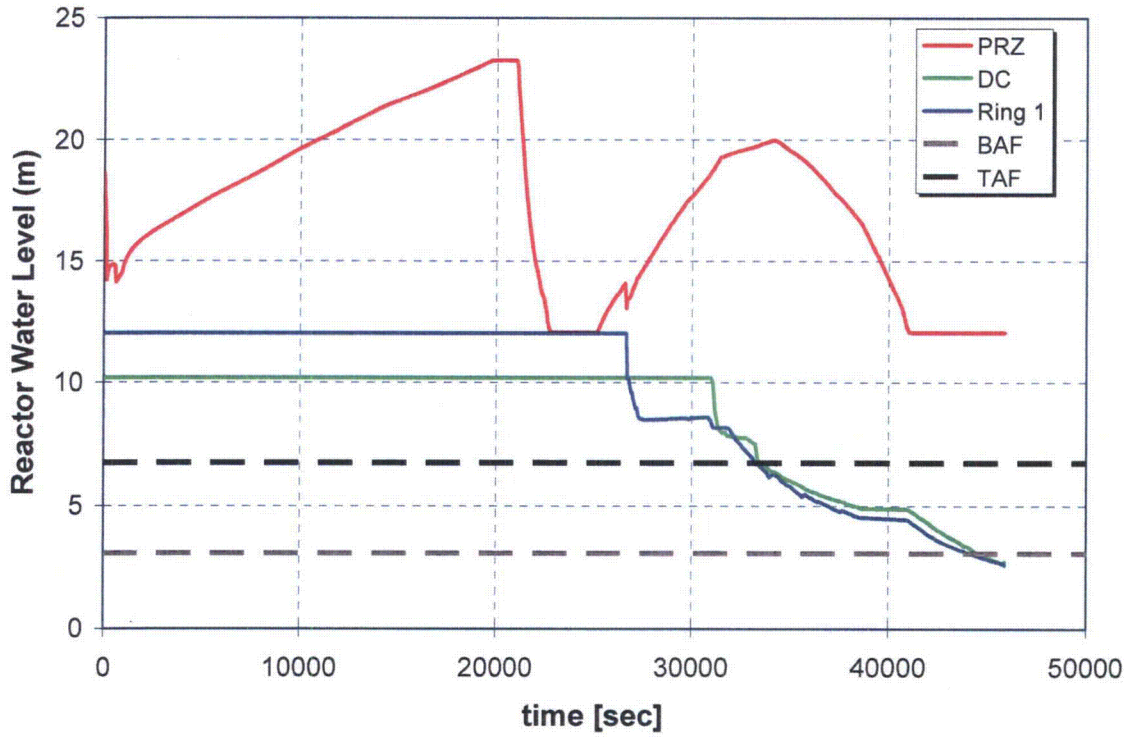
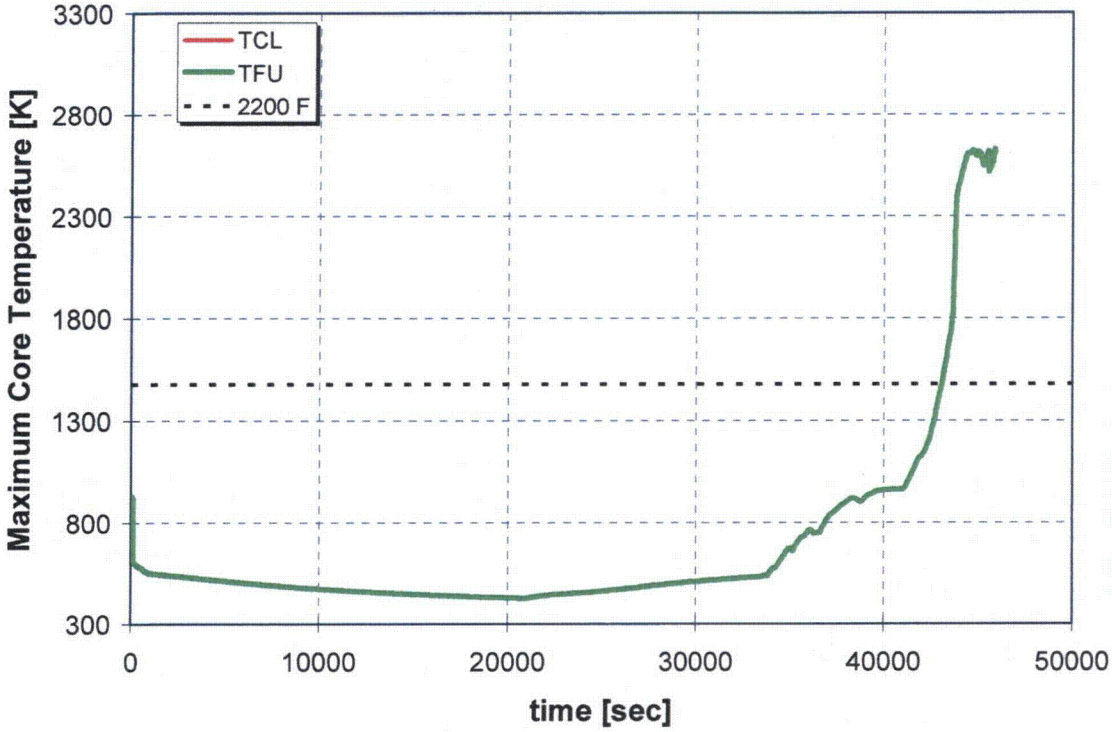
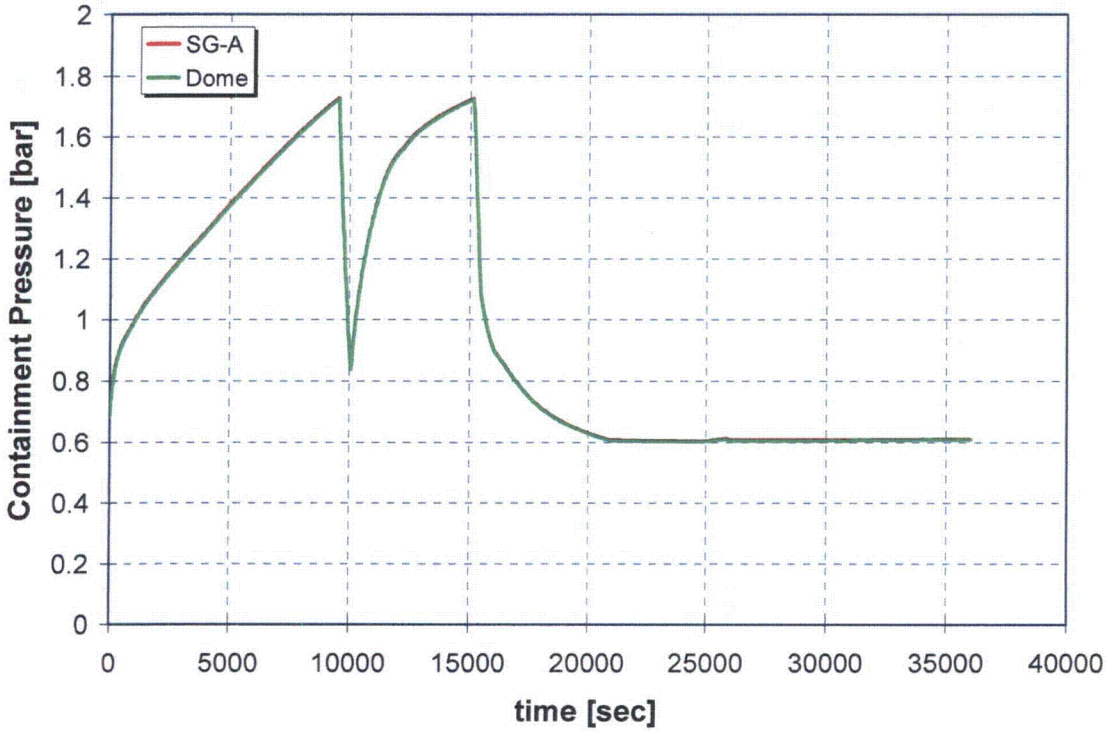
10000
20000
30000
40000
50000
time [sec]

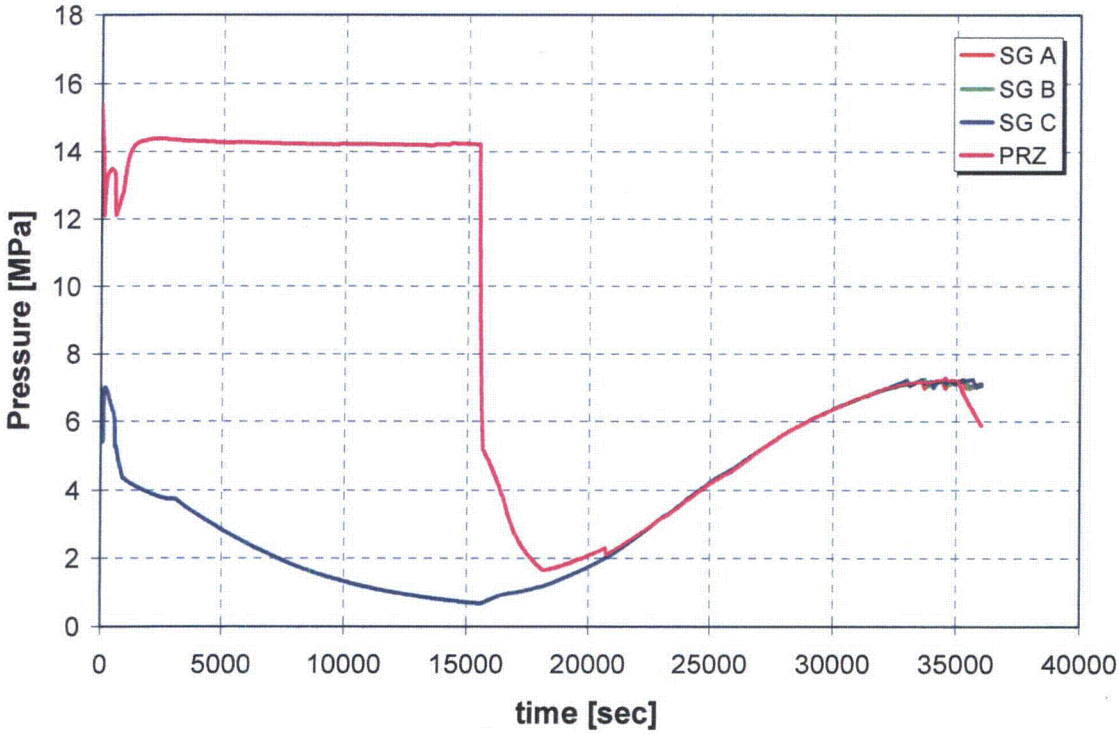

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10000
20000
30000
40000
50000

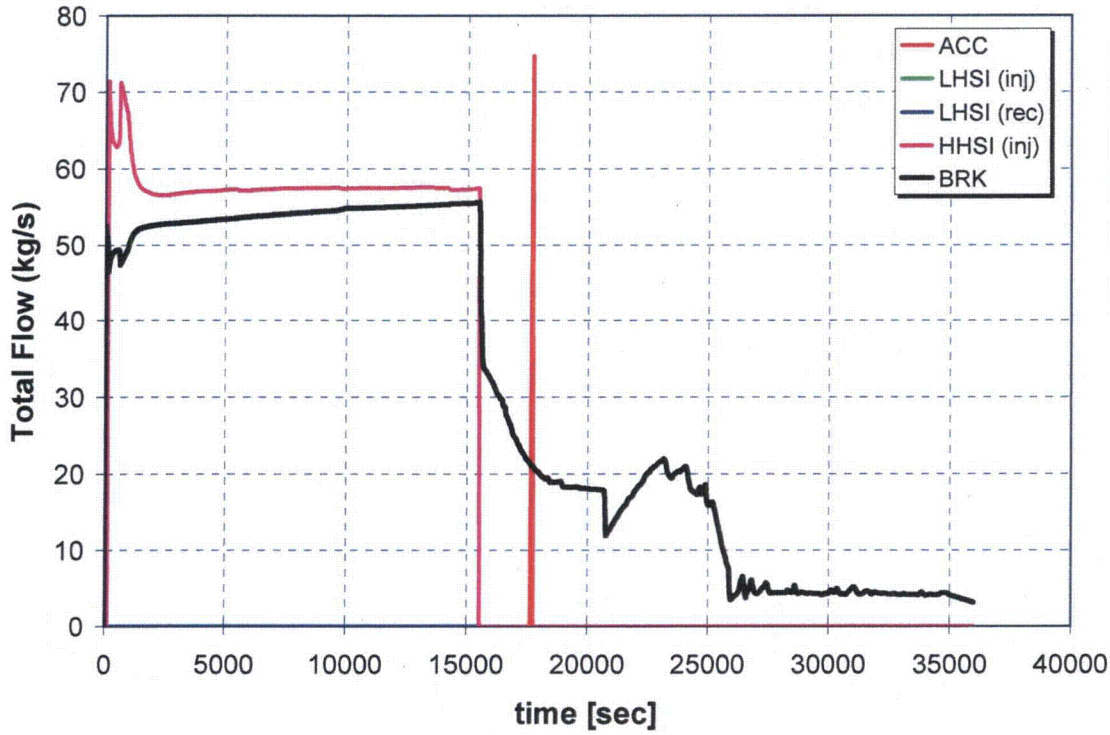

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
5
10
15
20
25
0
10000
20000
30000
40000
50000

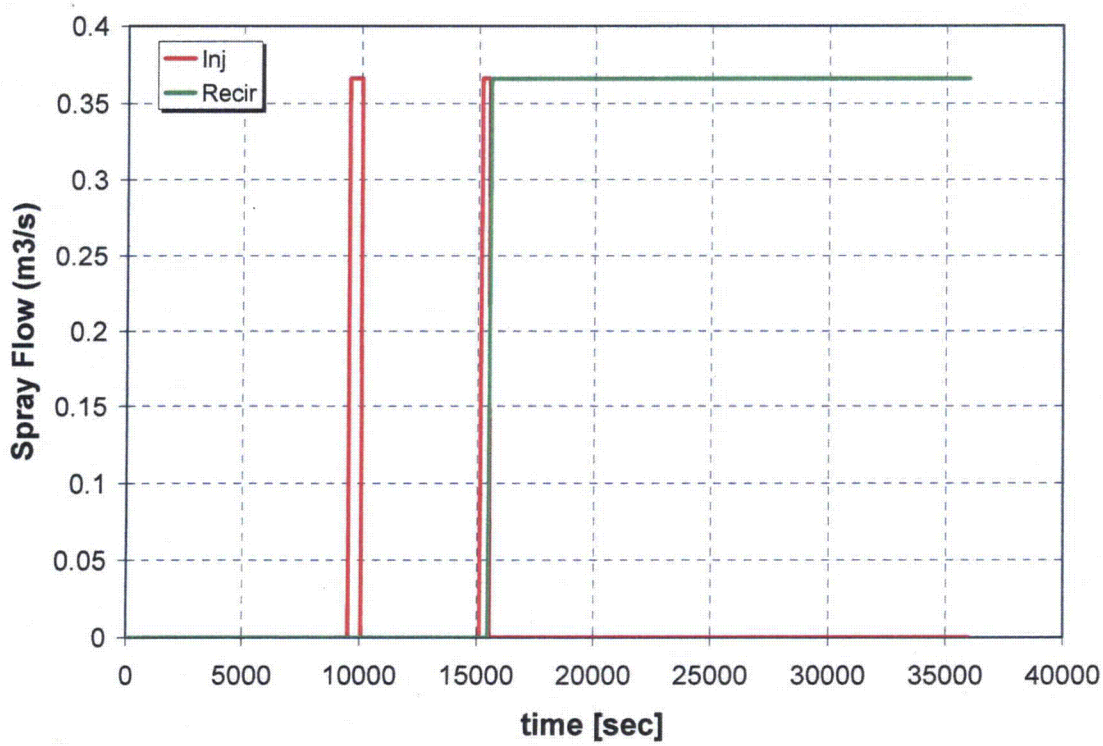

TCL
TFU
2200 F
Maximum Core Temperature [K]
3300
2800
2300
1800
1300
800
300
0
10000
20000
30000
40000
50000
time [sec]

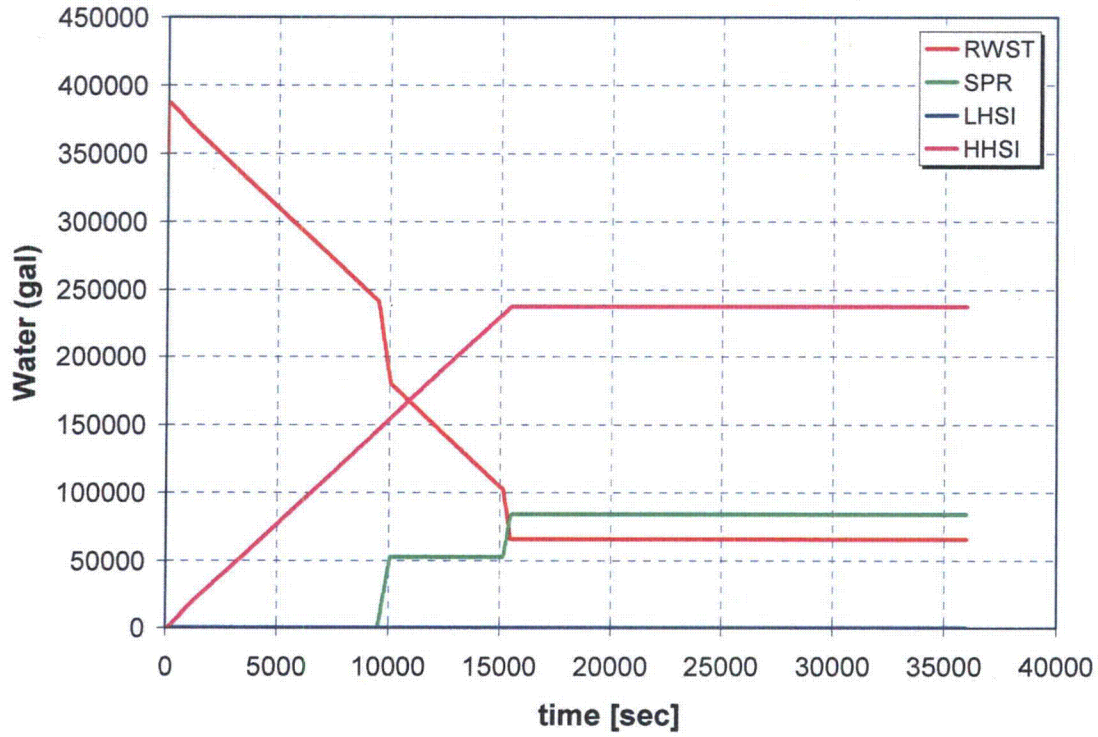
A.2.2 Case 2: 1-Inch Break LOCA with Sprays

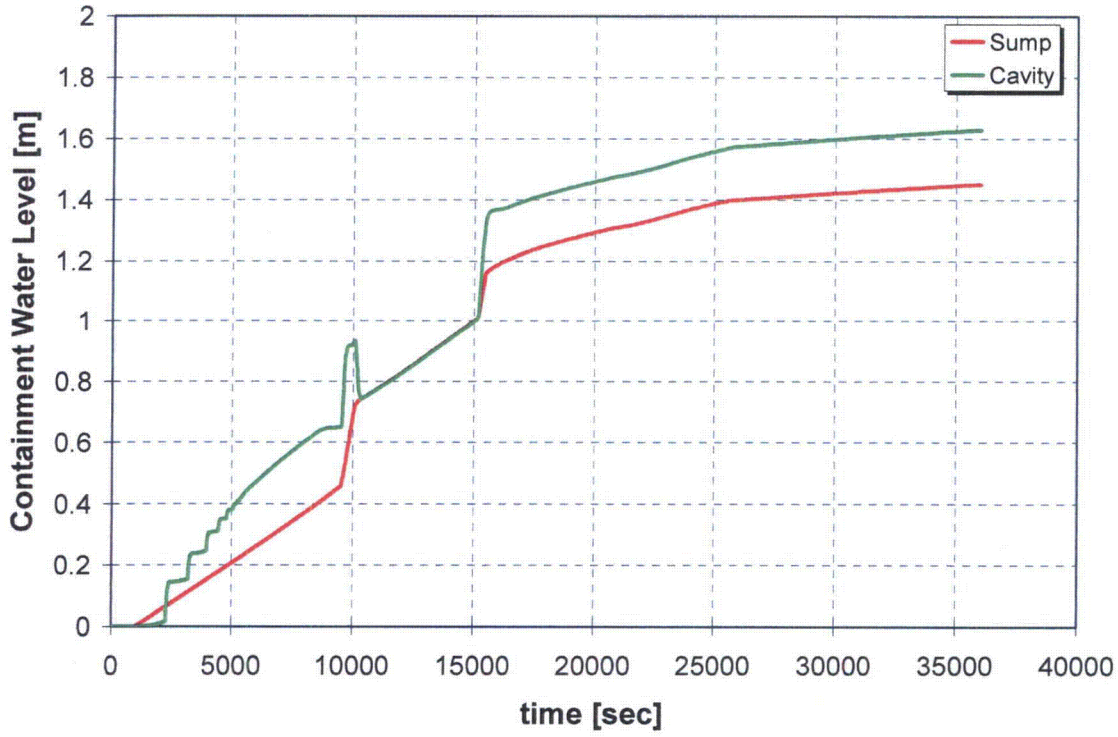


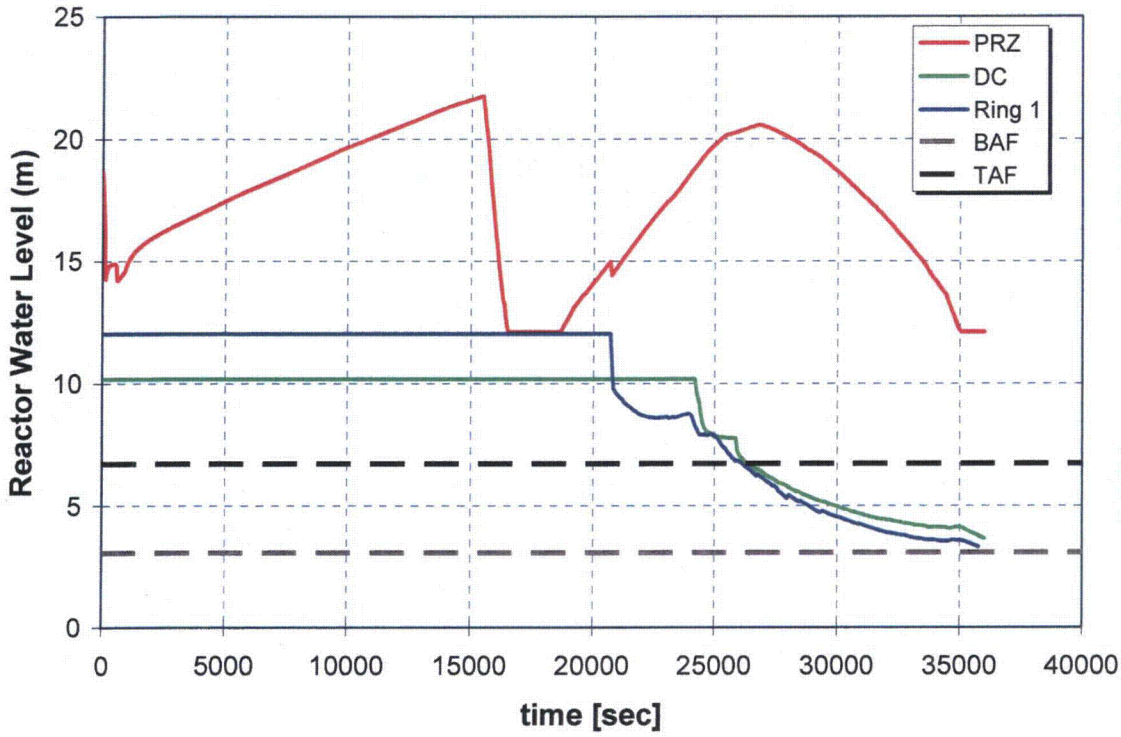


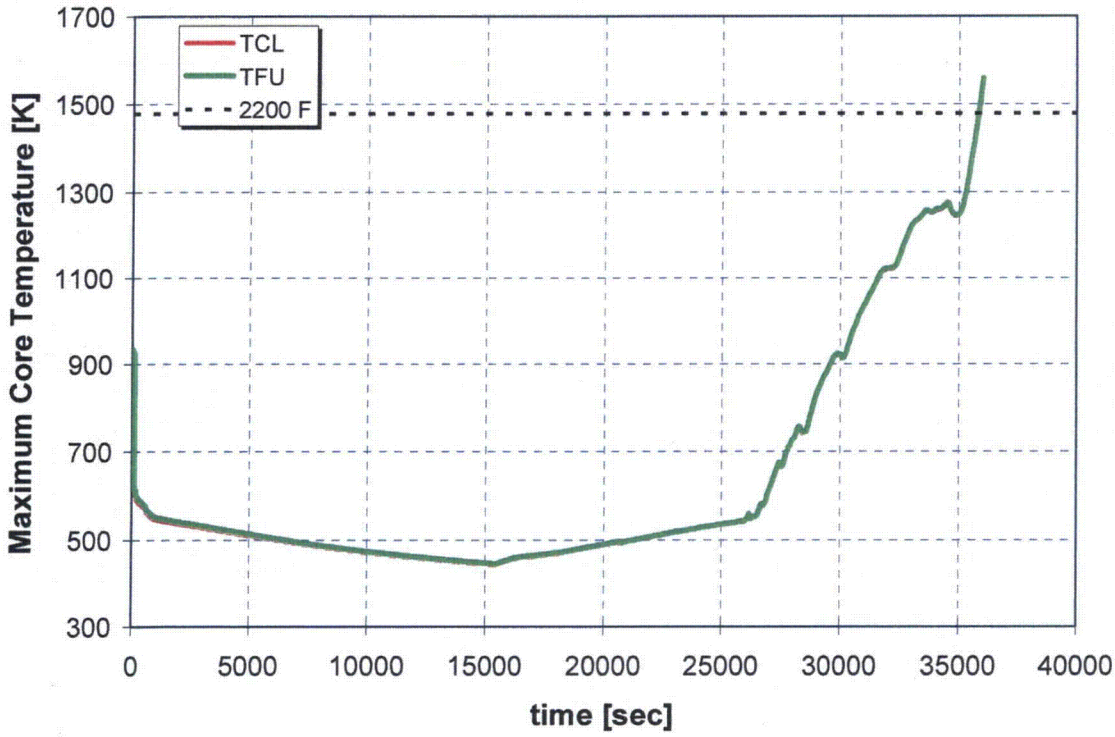

Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
10
20
30
40
50
60
70
80
0
5000
10000
15000
20000
25000
30000
35000
40000


Spray Flow (m3/s)
time [sec]
Inj
Recir
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
5000
10000
15000
20000
25000
30000
35000
40000

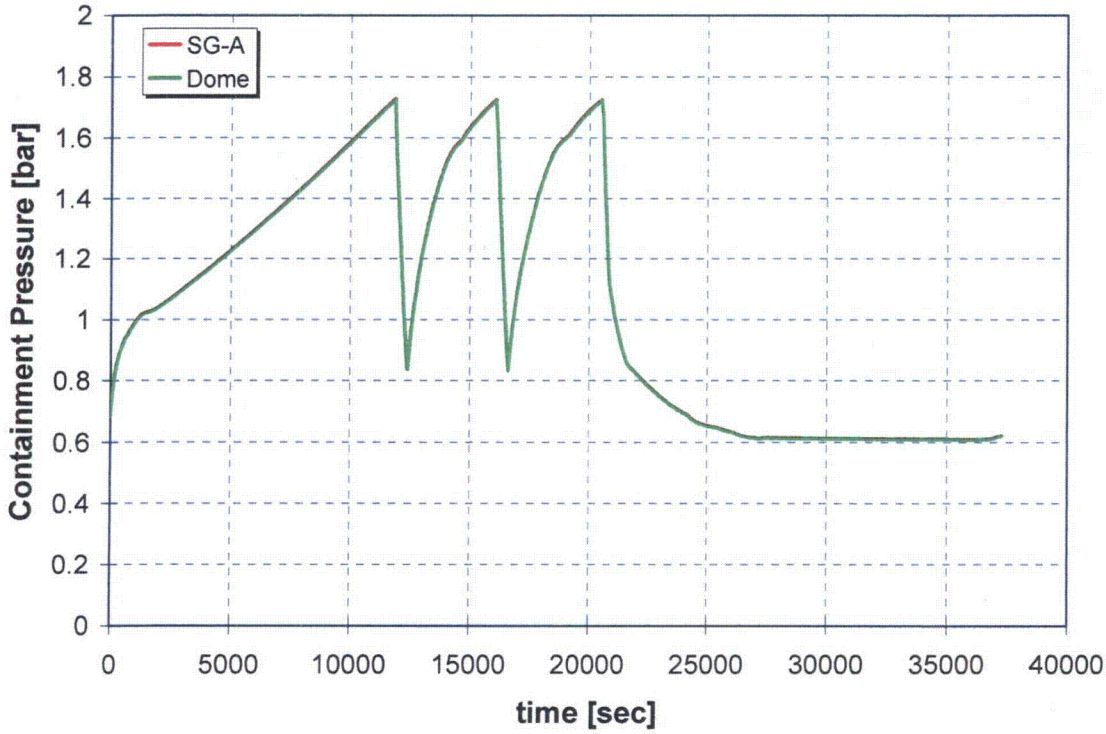

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
RWST
SPR
LHSI
HHSI

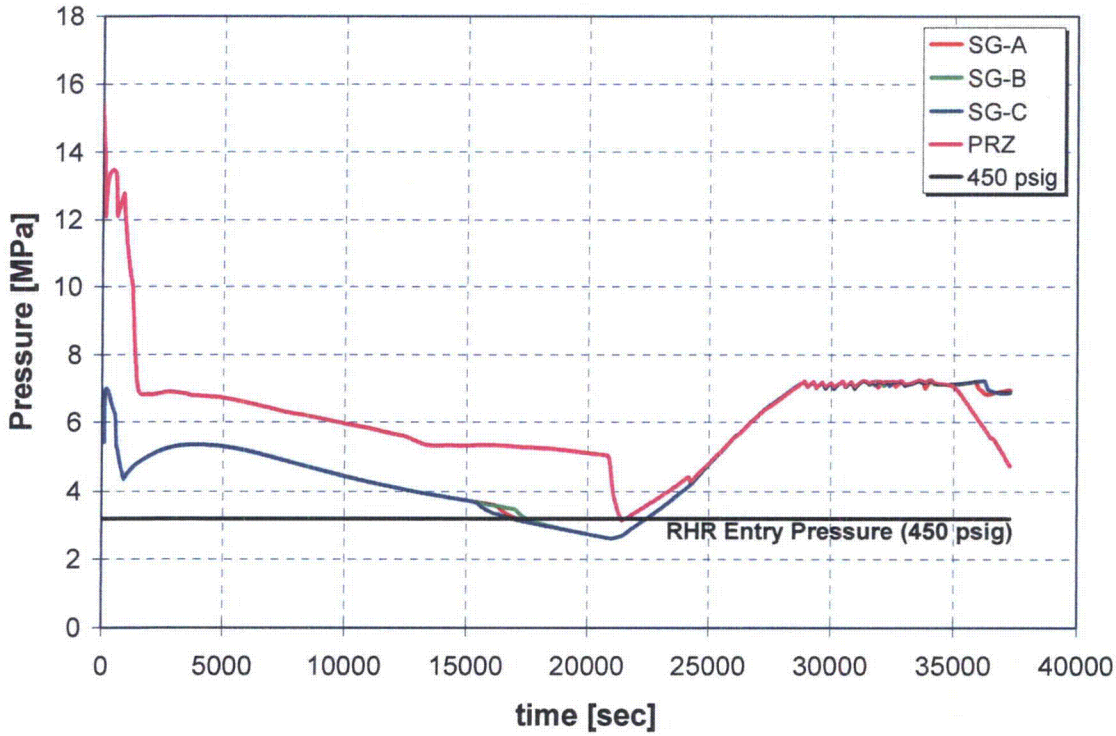

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
Sump
Cavity

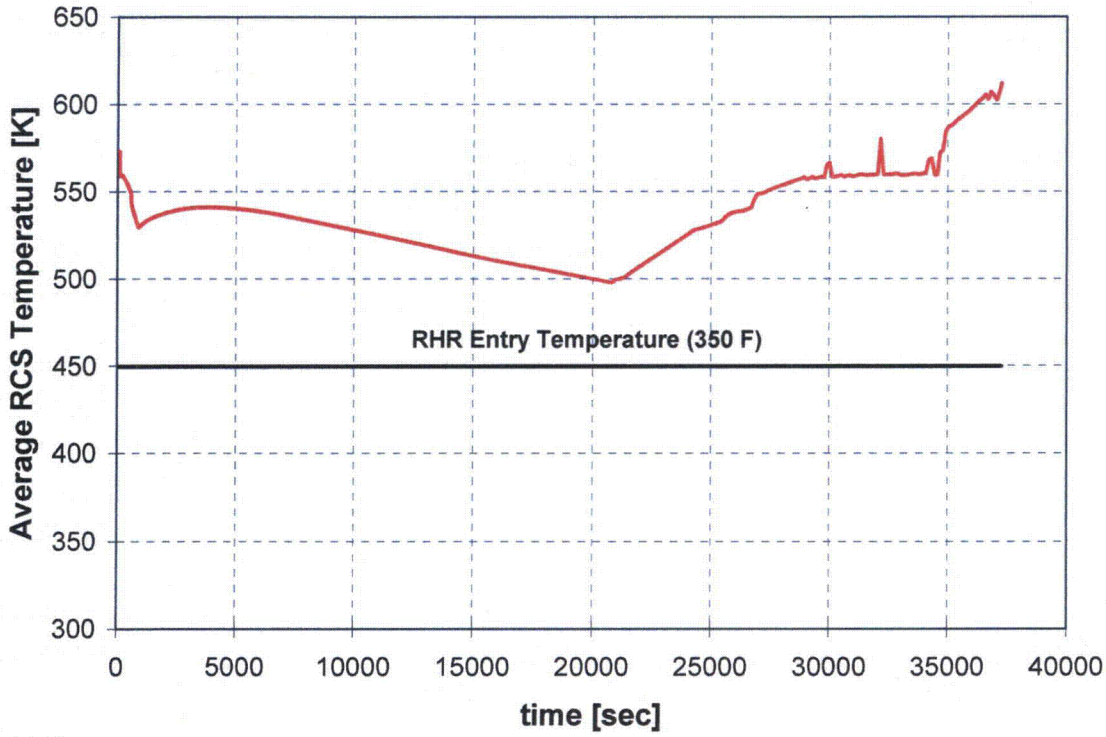

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
30000
35000
40000

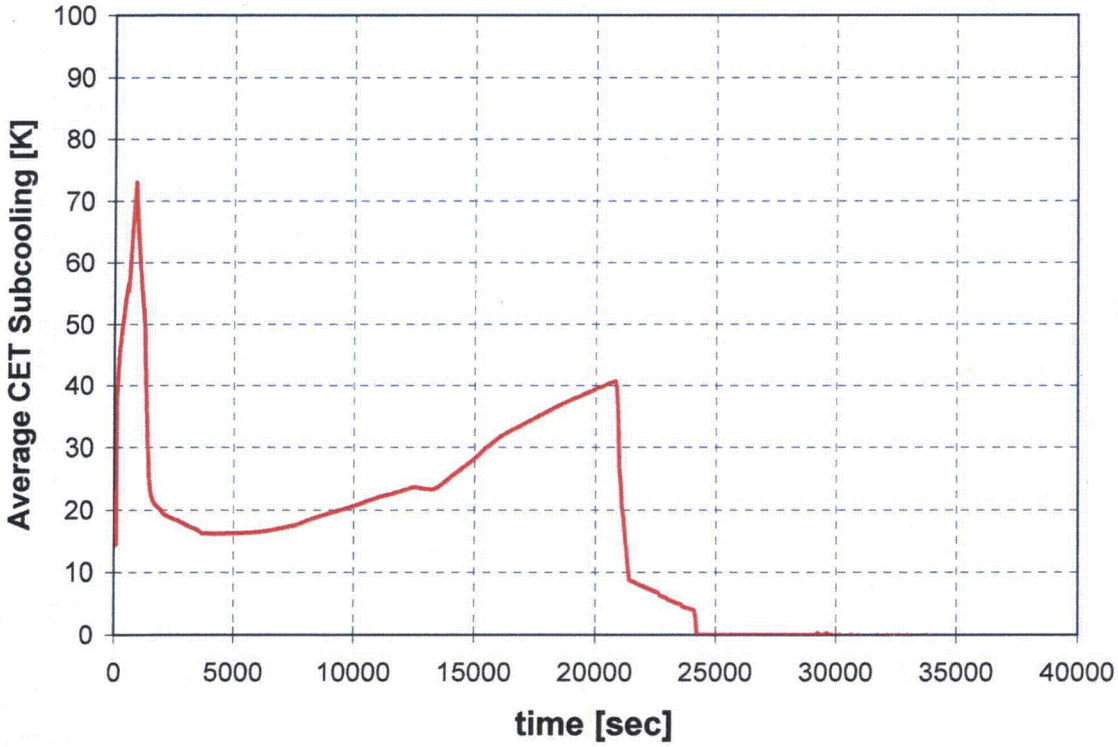

TCL
TFU
2200 F
Maximum Core Temperature [K]
time [sec]
300
500
700
900
1100
1300
1500
1700
0
5000
10000
15000
20000
25000
30000
35000
40000

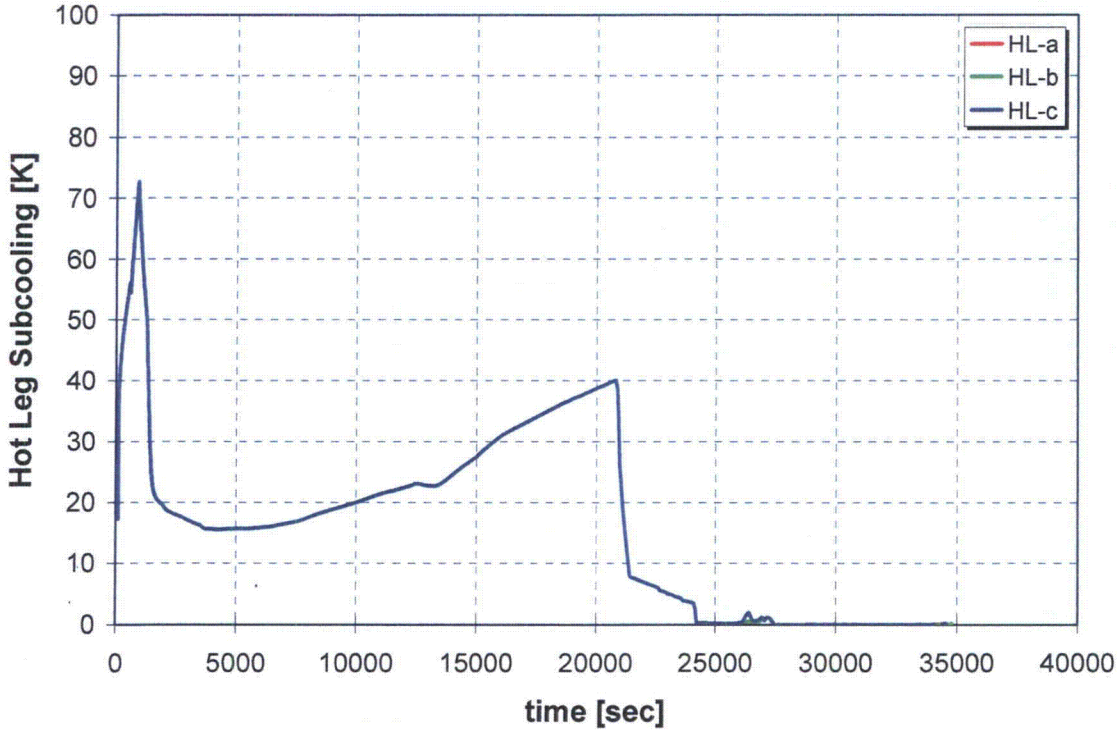
A.2.2.1 Case 2a: 1-Inch Break LOCA with Sprays and Secure Two HHSI Pumps

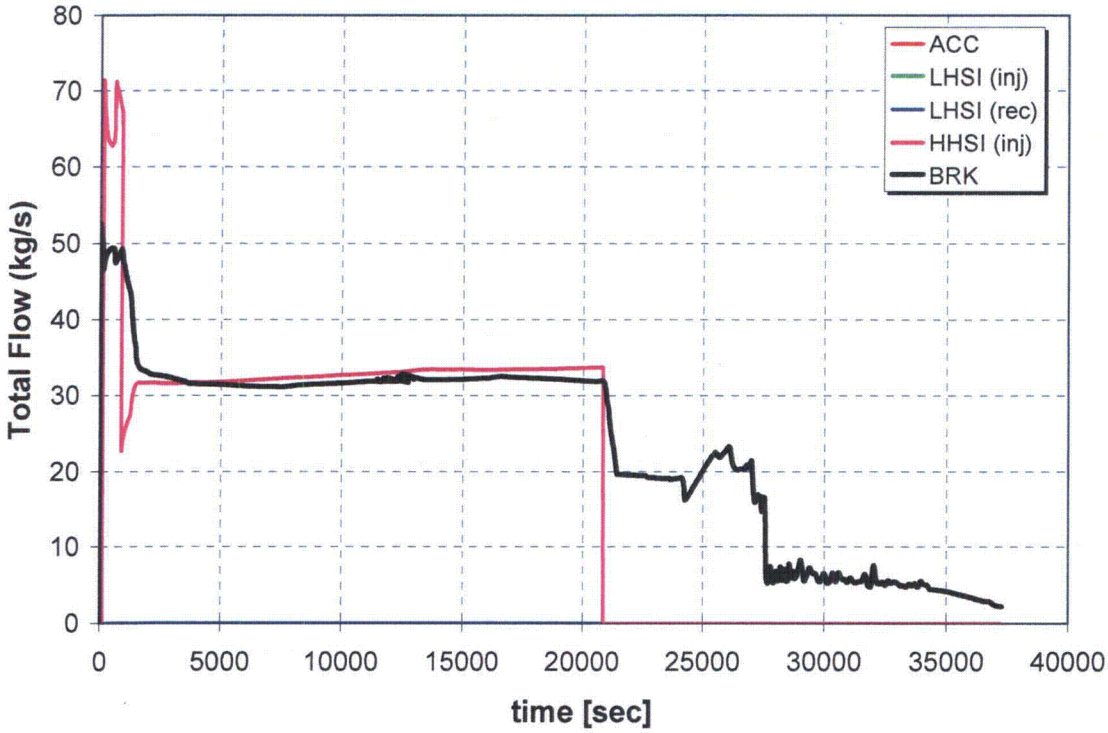


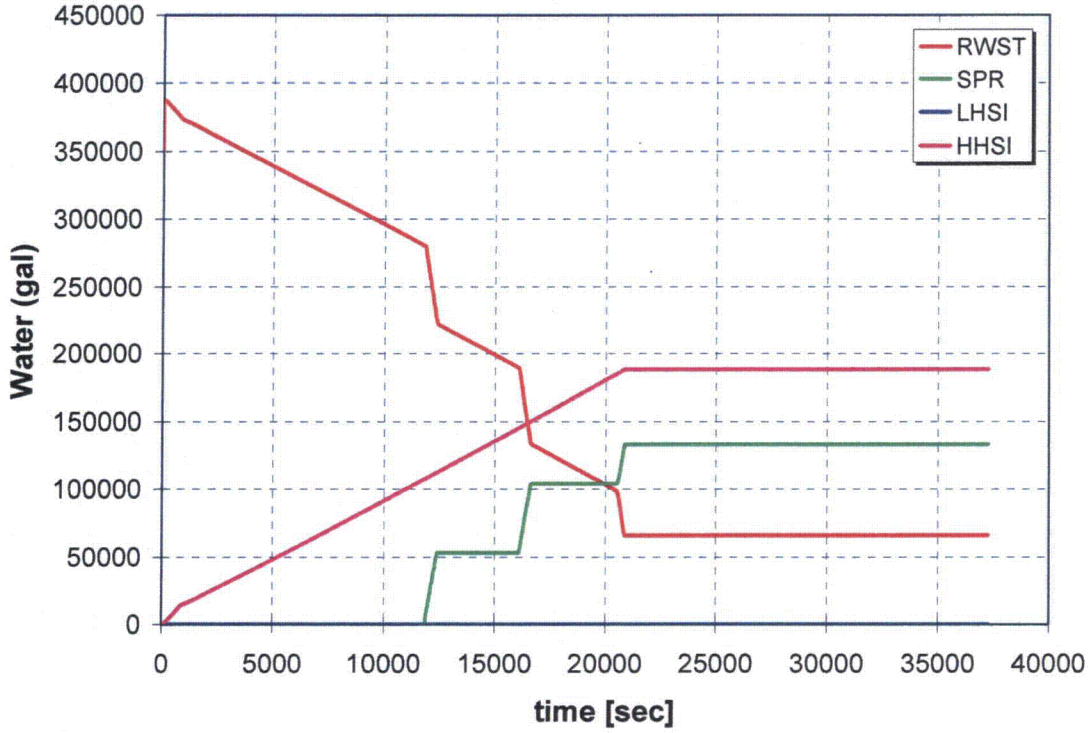


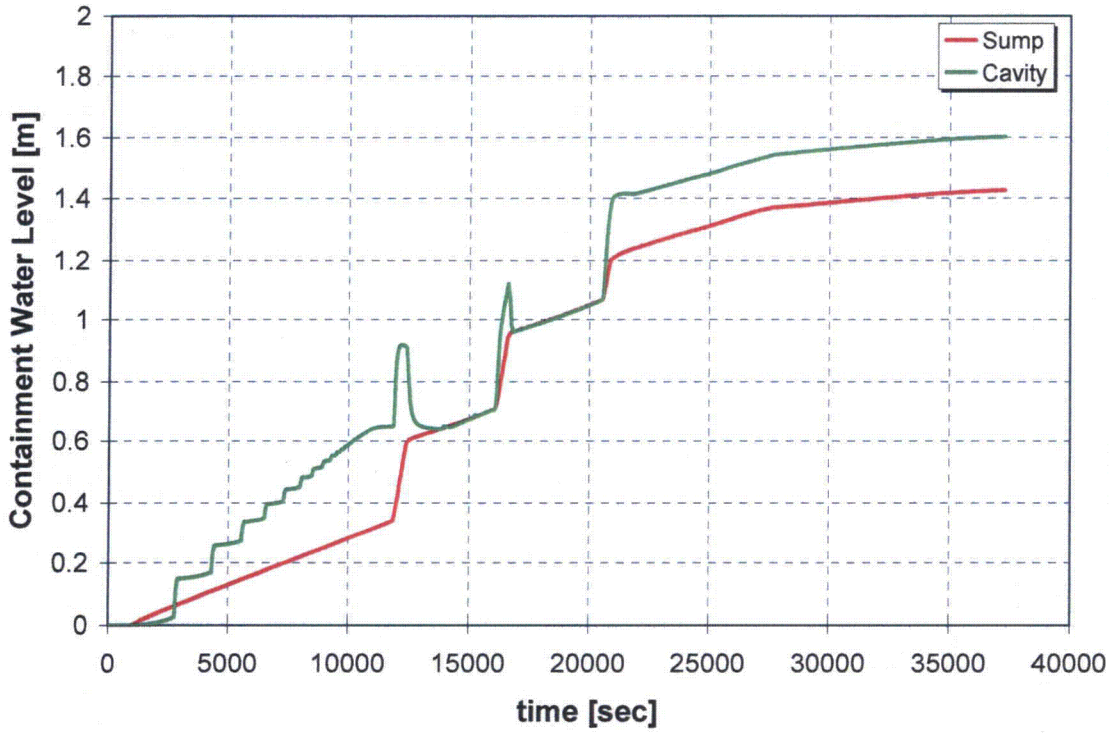

650
600
550
500
450
400
350
300
Average RCS Temperature [K]
RHR Entry Temperature (350 F)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

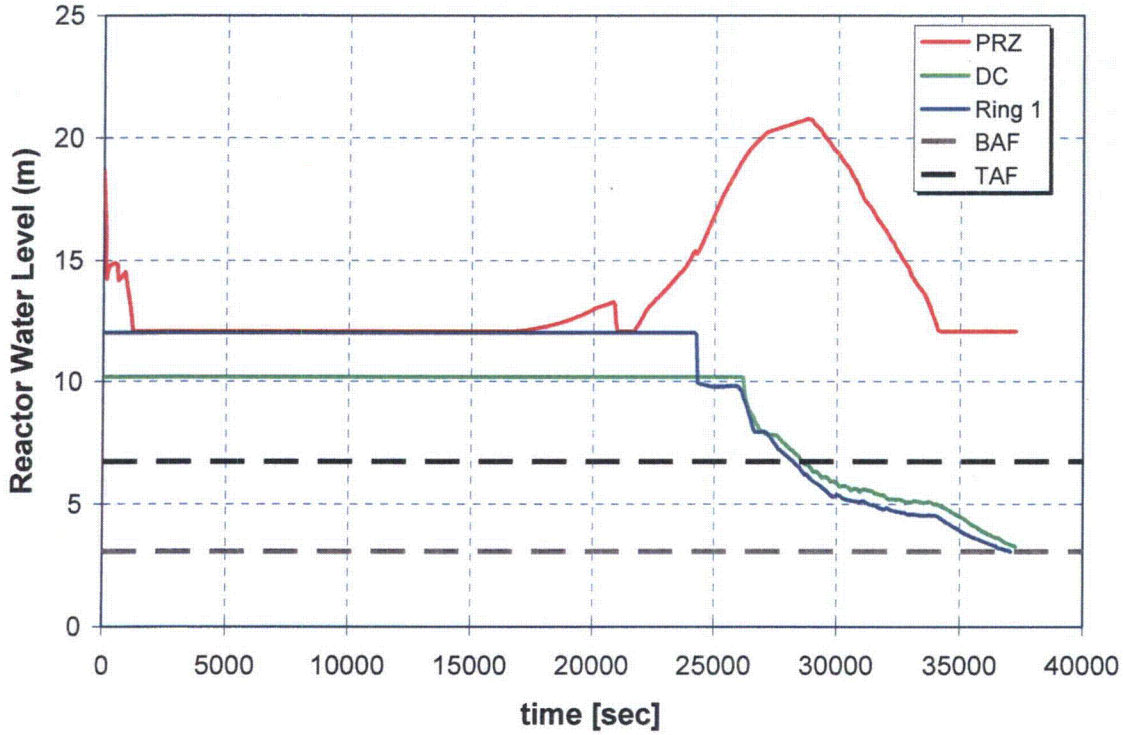

100
90
80
70
60
50
40
30
20
10
0
Average CET Subcooling [K]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

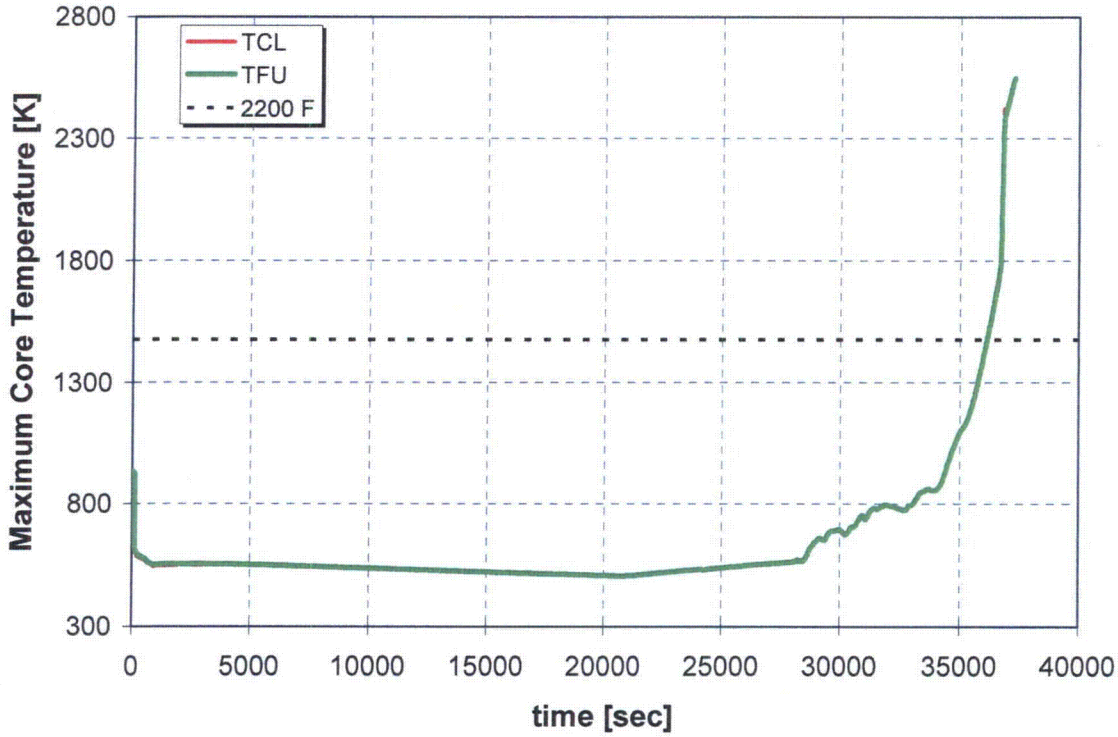

Hot Leg Subcooling [K]
time [sec]
HL-a
HL-b
HL-c
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000
35000
40000


Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
10
20
30
40
50
60
70
80
0
5000
10000
15000
20000
25000
30000
35000
40000

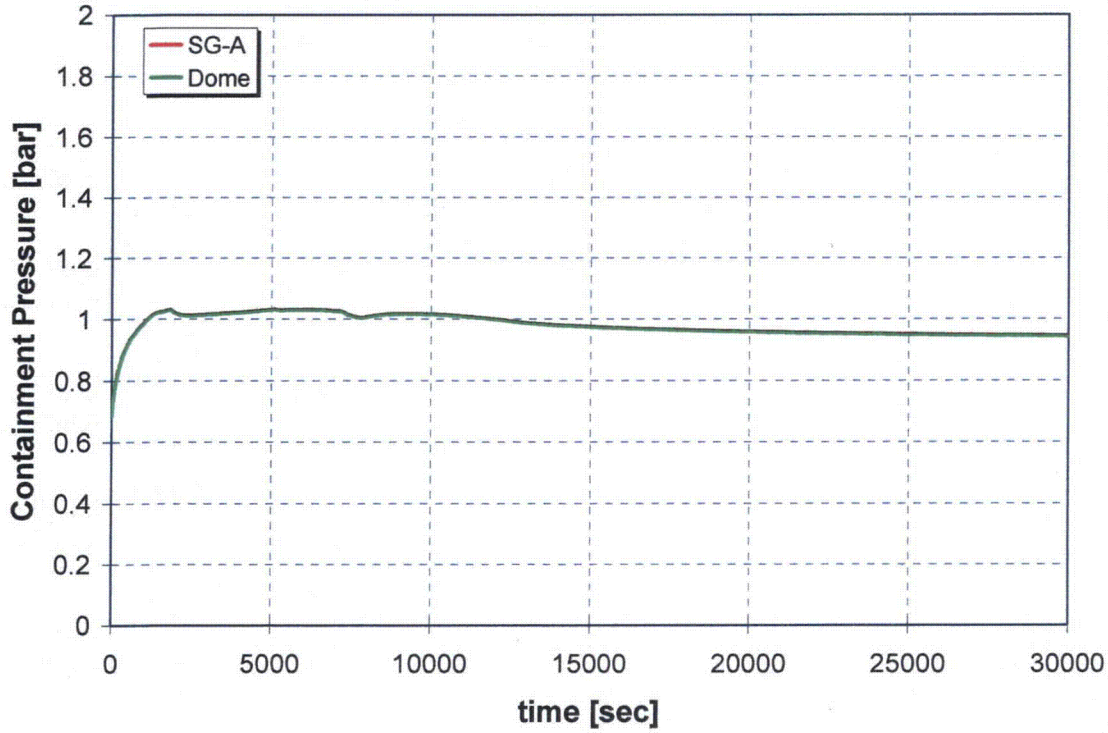

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
RWST
SPR
LHSI
HHSI

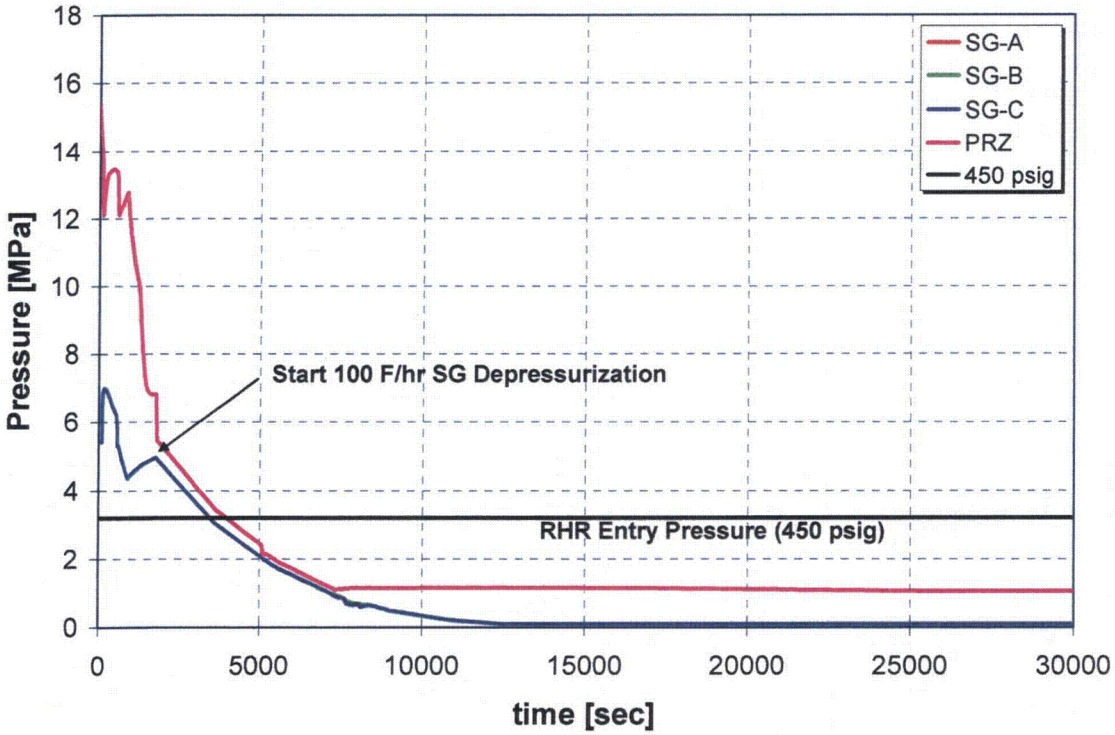

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
Sump
Cavity

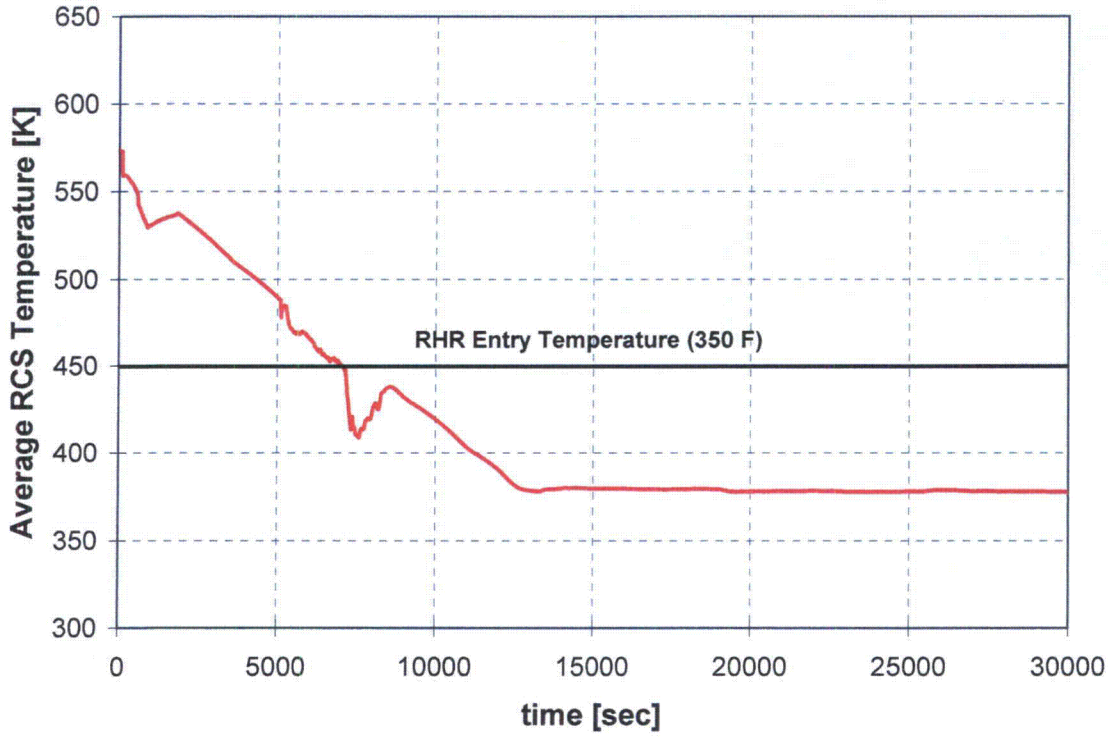

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

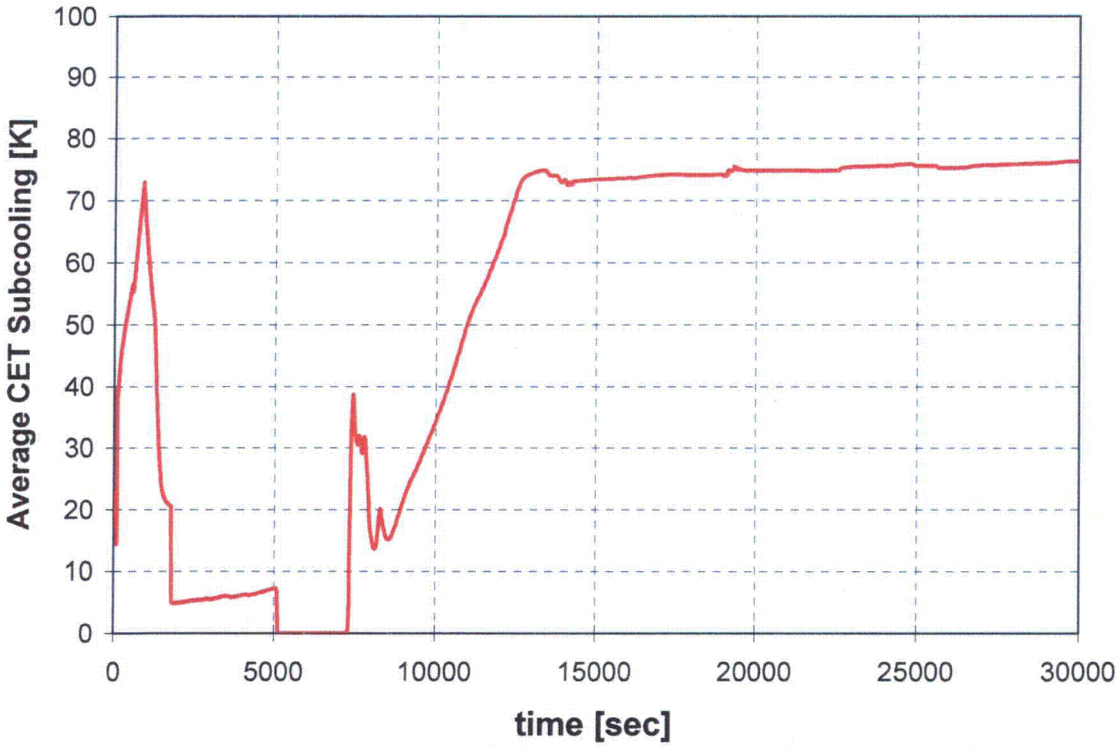

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

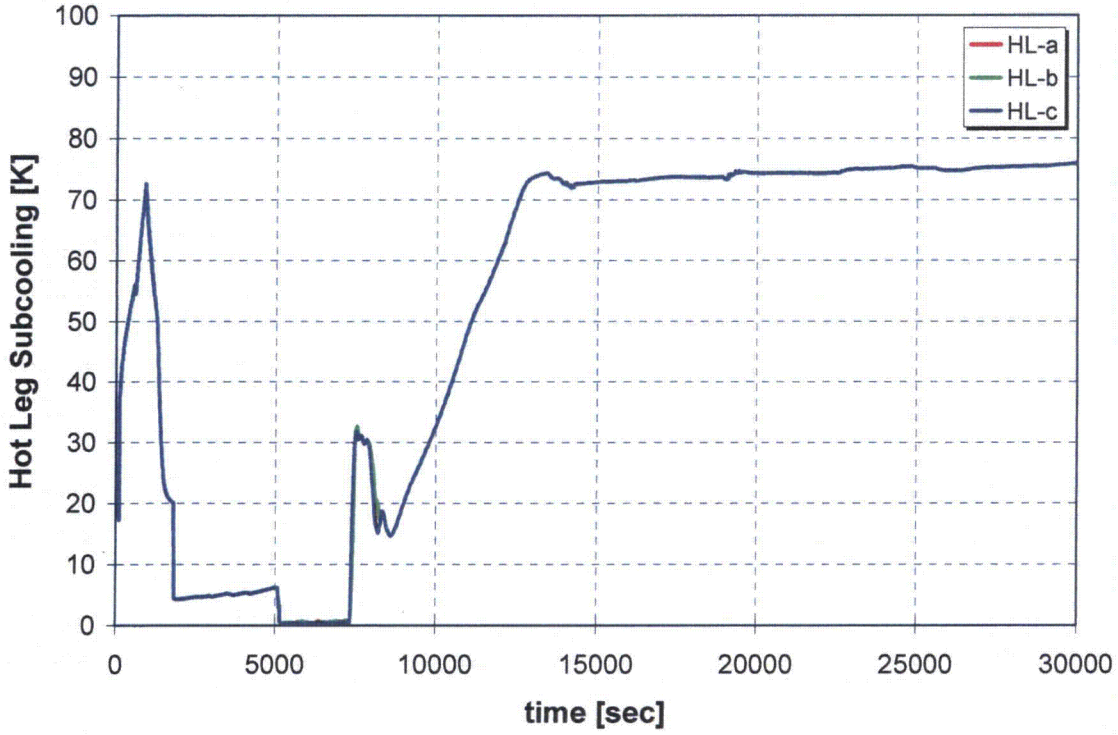
A.2.2.2 *Case 2b: 1-Inch Break LOCA with Sprays, Secure HHSI Pumps, and Secondary Cooldown*

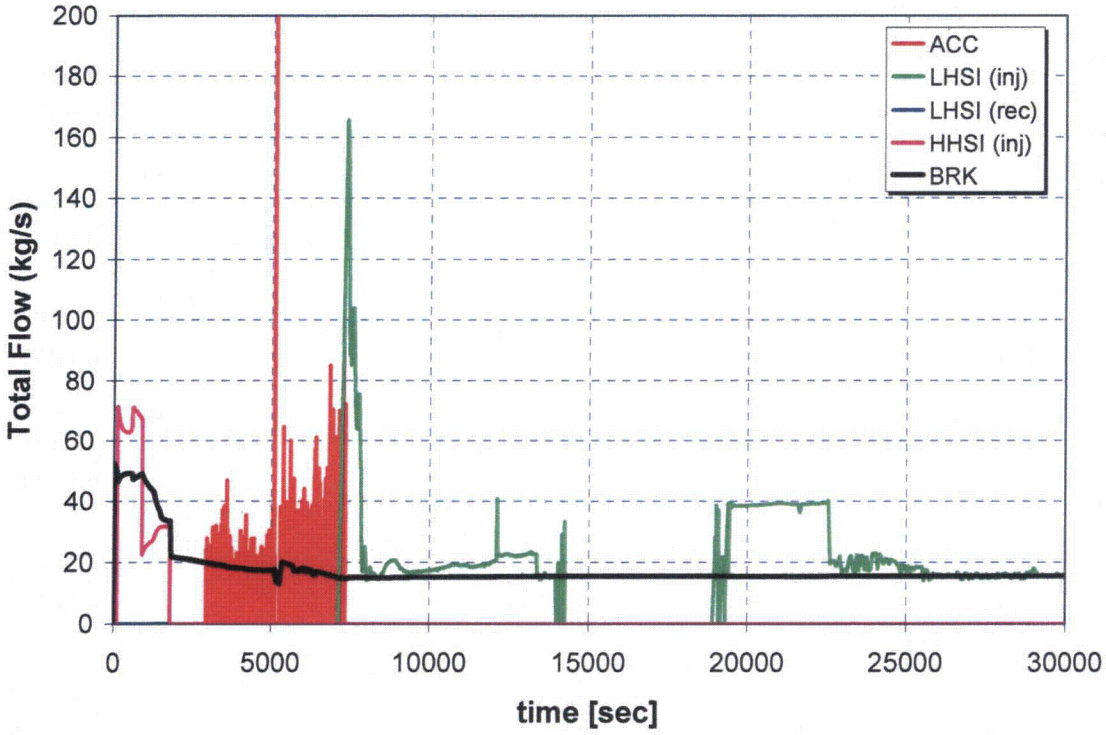


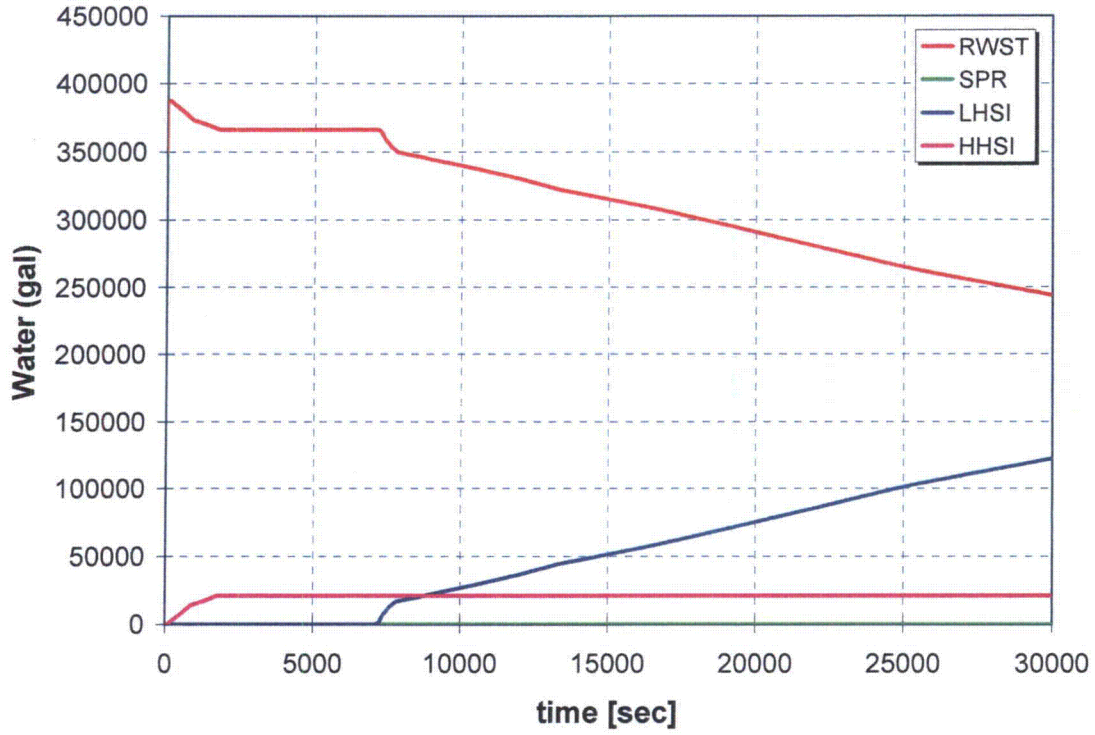


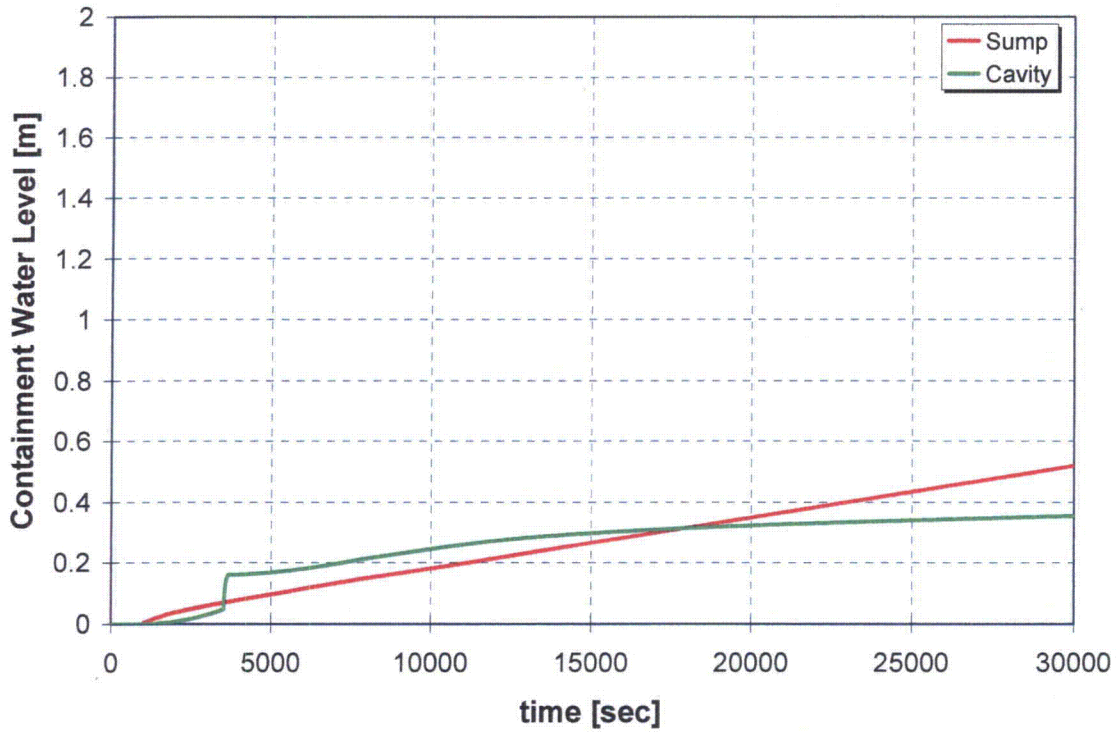

650
600
550
500
450
400
350
300
Average RCS Temperature [K]
RHR Entry Temperature (350 F)
0
5000
10000
15000
20000
25000
30000
time [sec]

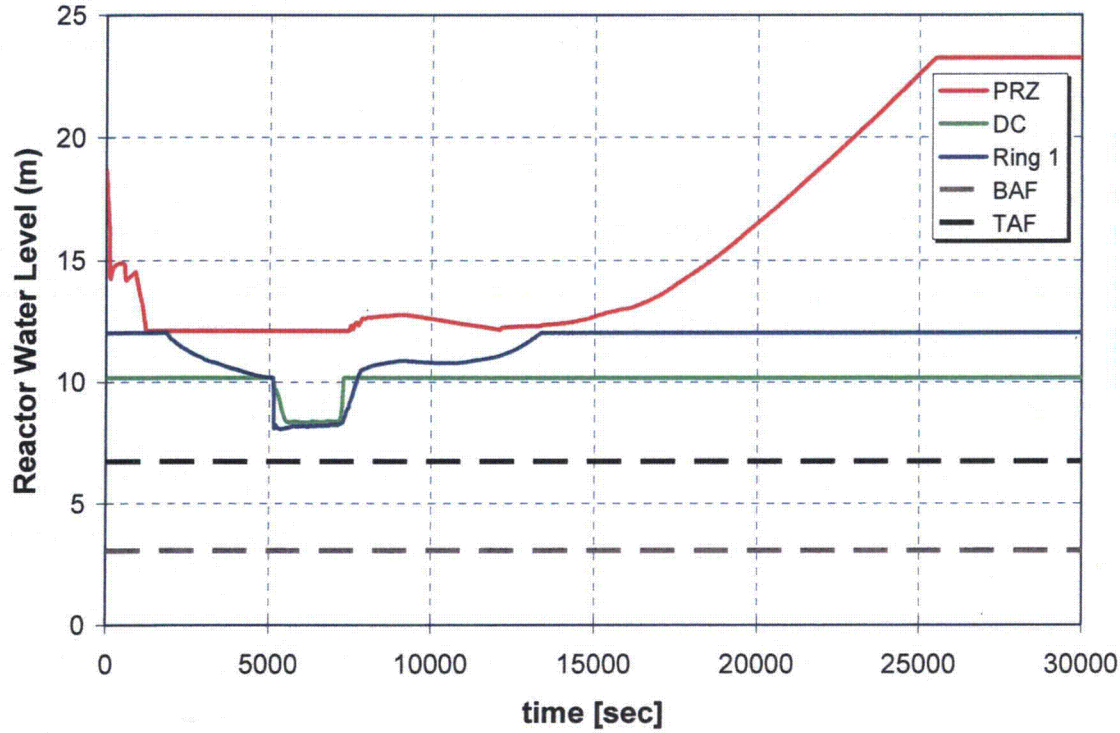

100
90
80
70
60
50
40
30
20
10
0
Average CET Subcooling [K]
0
5000
10000
15000
20000
25000
30000
time [sec]

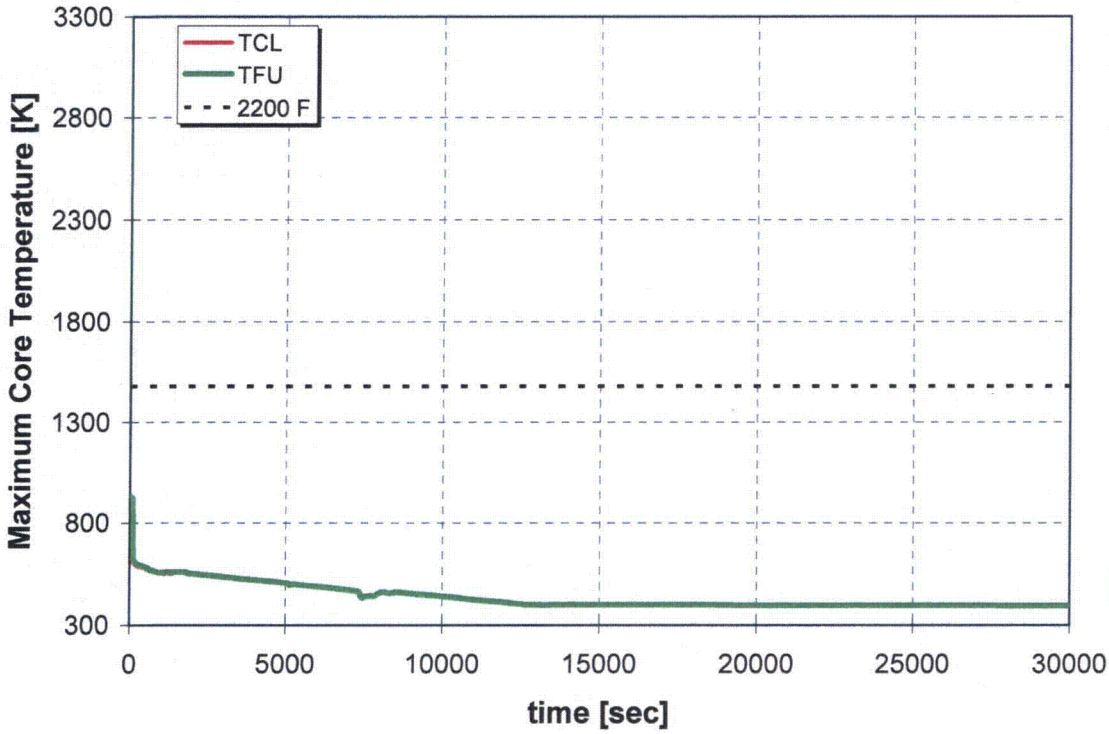

Hot Leg Subcooling [K]
time [sec]
HL-a
HL-b
HL-c
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000


Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
20
40
60
80
100
120
140
160
180
200
0
5000
10000
15000
20000
25000
30000

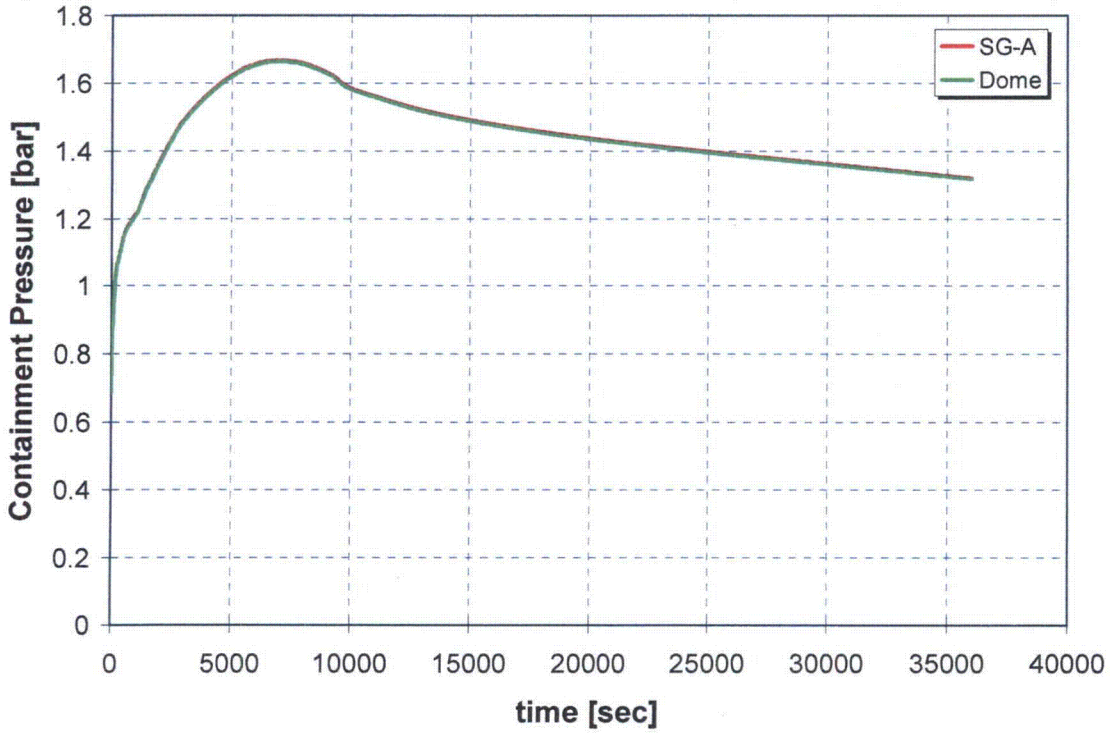

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
time [sec]
RWST
SPR
LHSI
HHSI

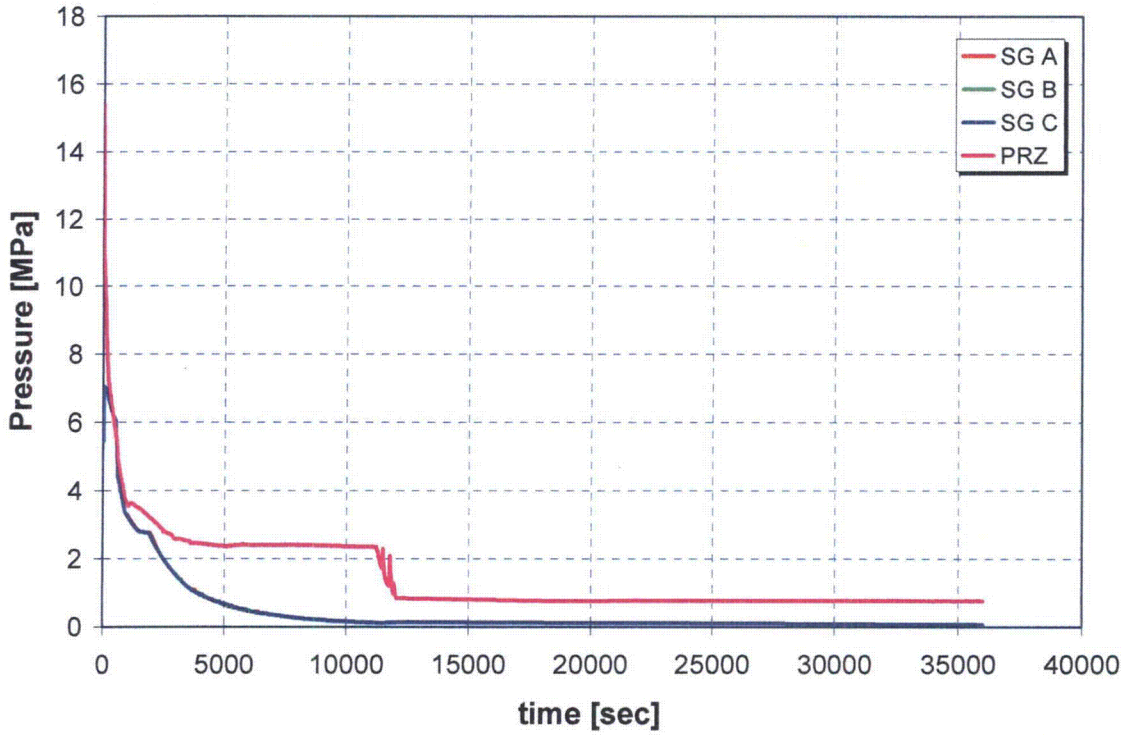

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
25000
30000
time [sec]
Sump
Cavity

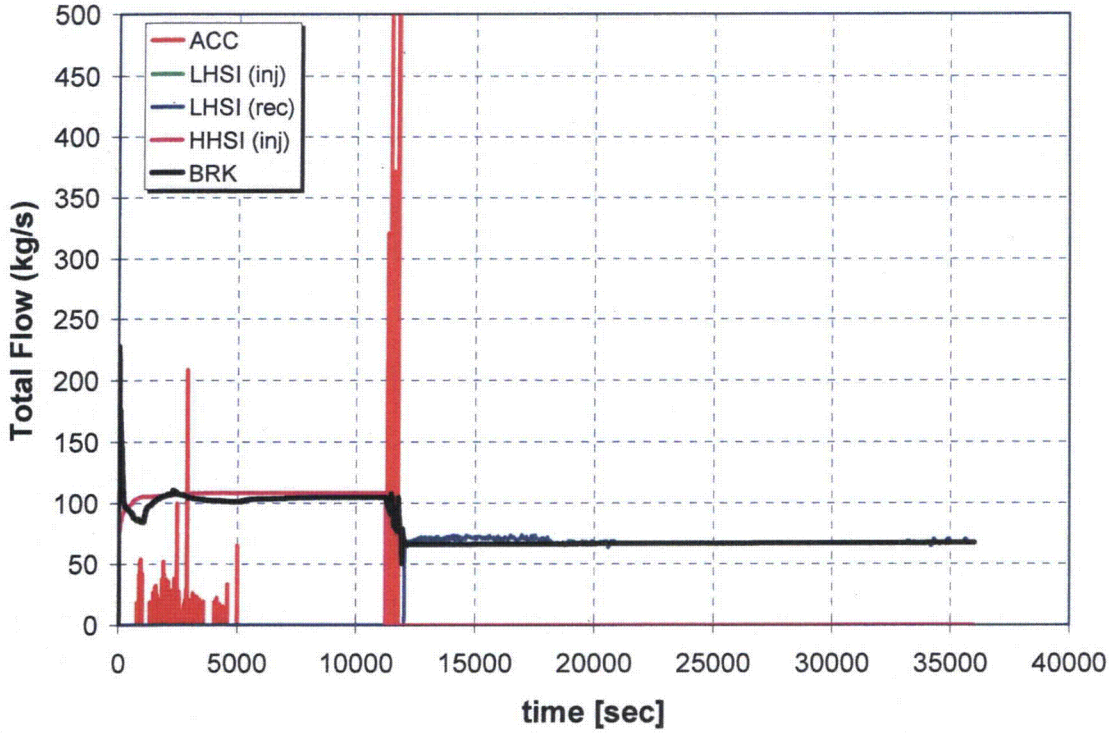

25
20
15
10
5
0
Reactor Water Level (m)
0
5000
10000
15000
20000
25000
30000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

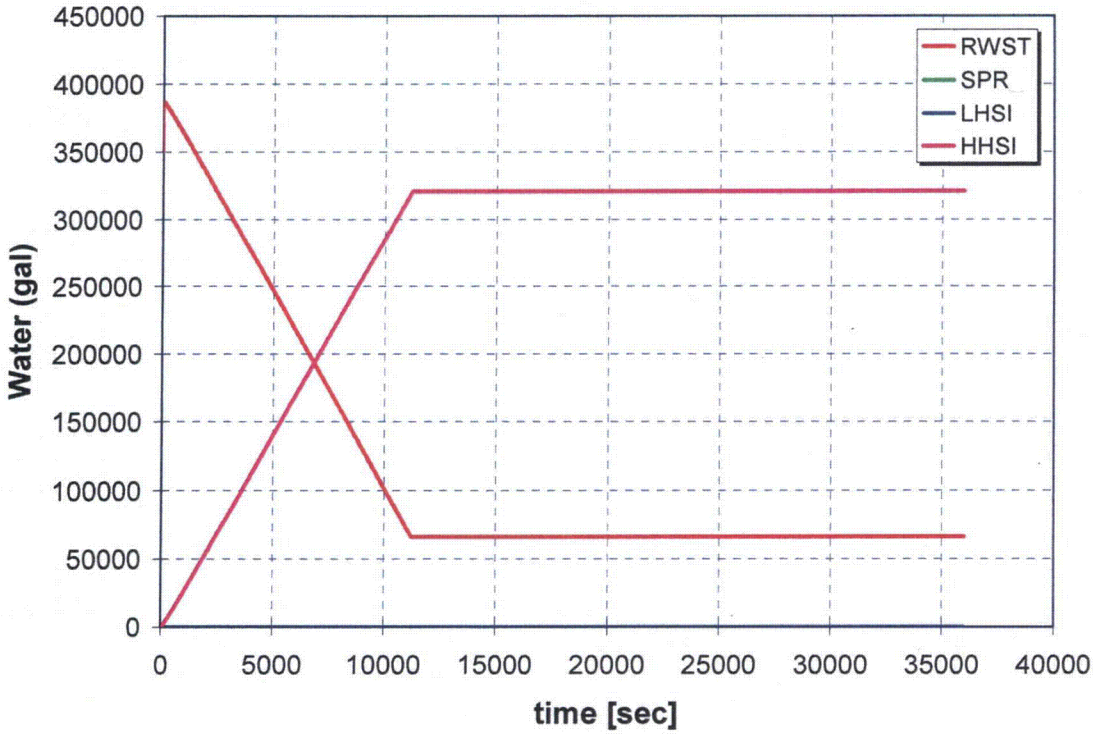

3300
2800
2300
1800
1300
800
300
Maximum Core Temperature [K]
0
5000
10000
15000
20000
25000
30000
time [sec]
TCL
TFU
2200 F

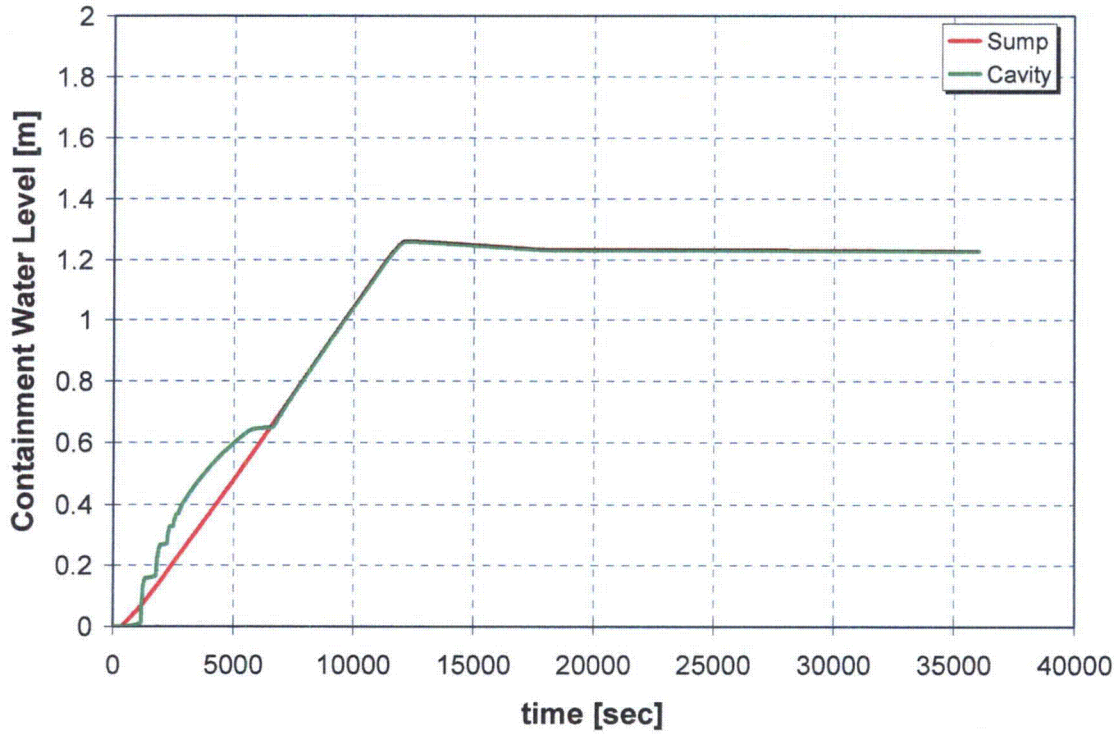
A.2.3 Case 3: 2-Inch Break LOCA without Sprays

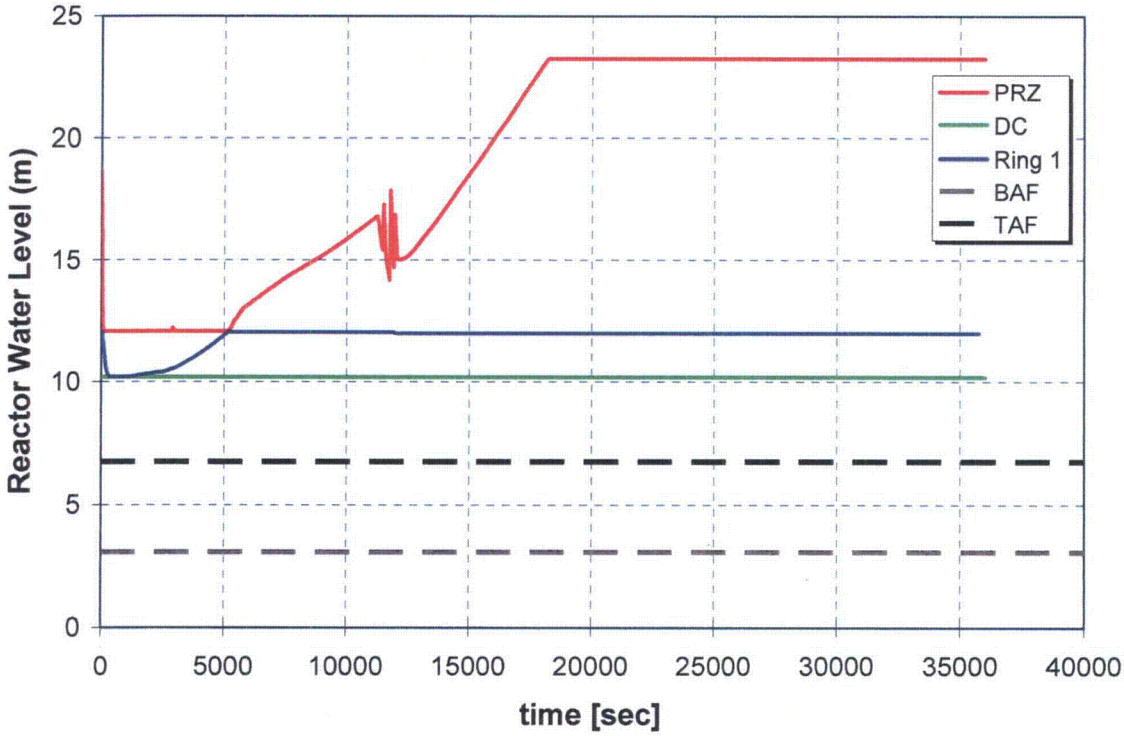


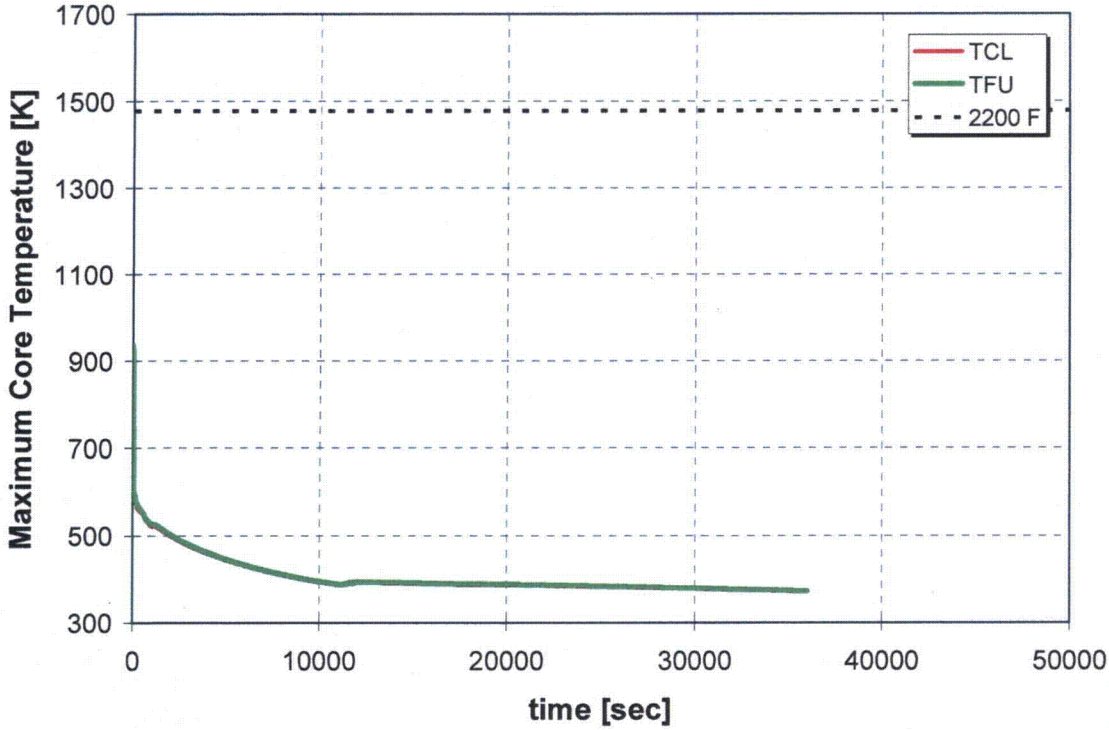



ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
500
450
400
350
300
250
200
150
100
50
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

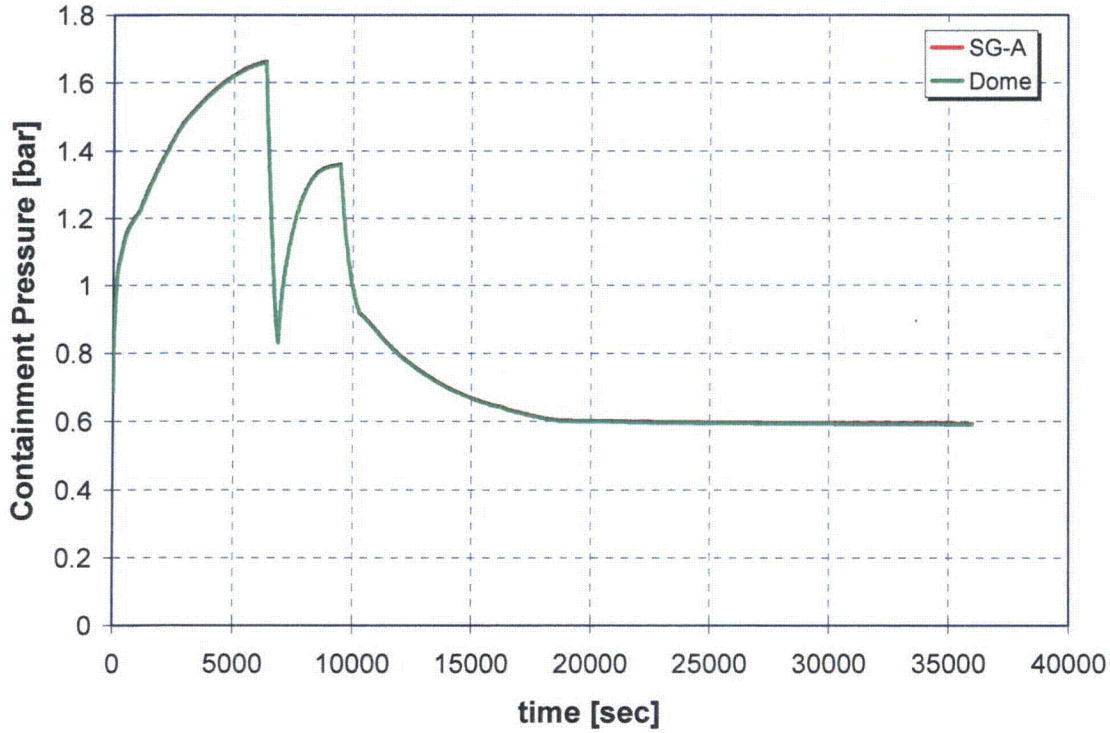

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

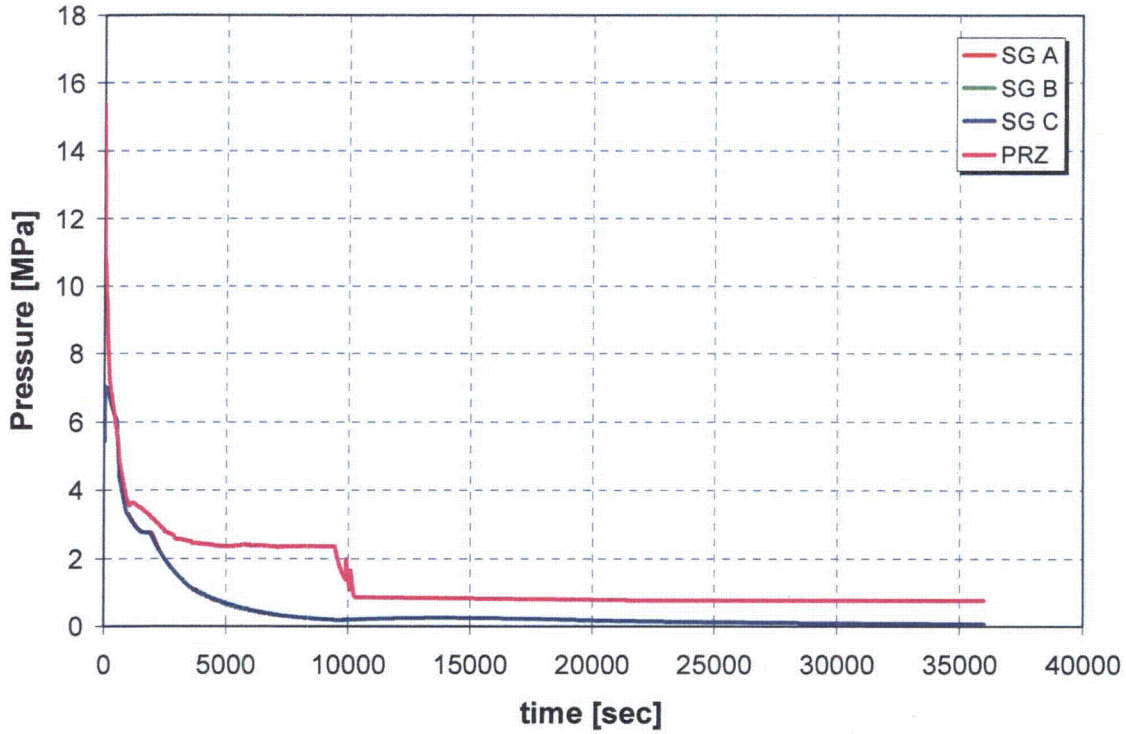

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000

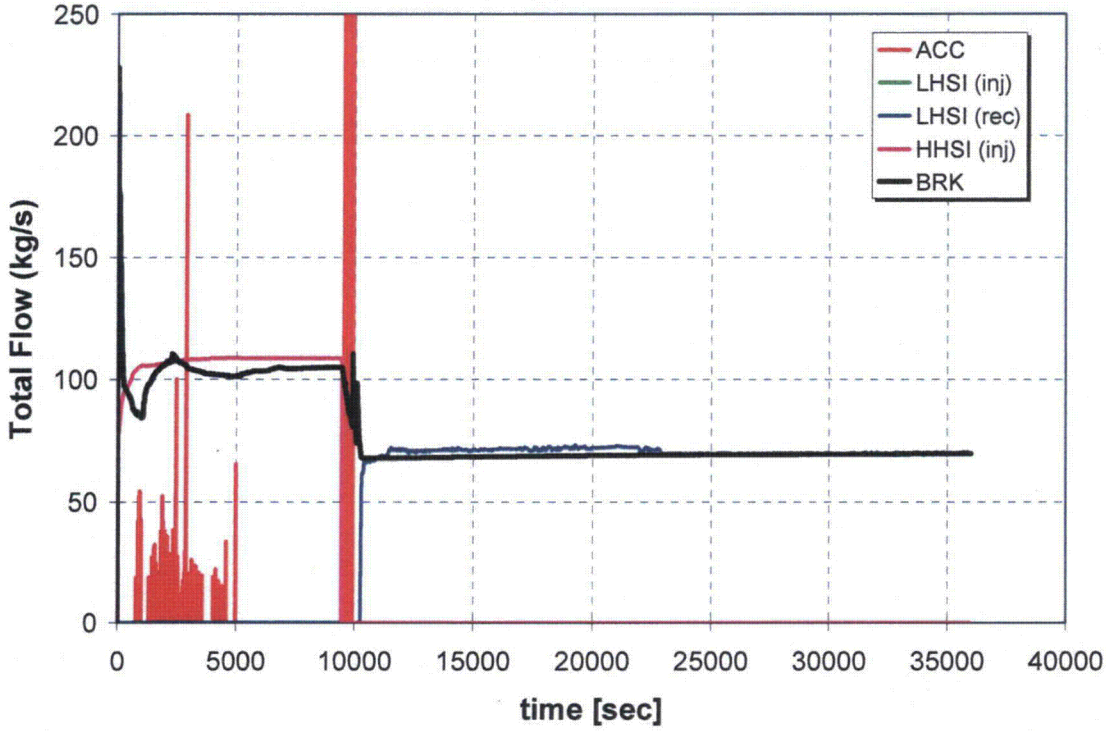

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
5
10
15
20
25
0
5000
10000
15000
20000
25000
30000
35000
40000

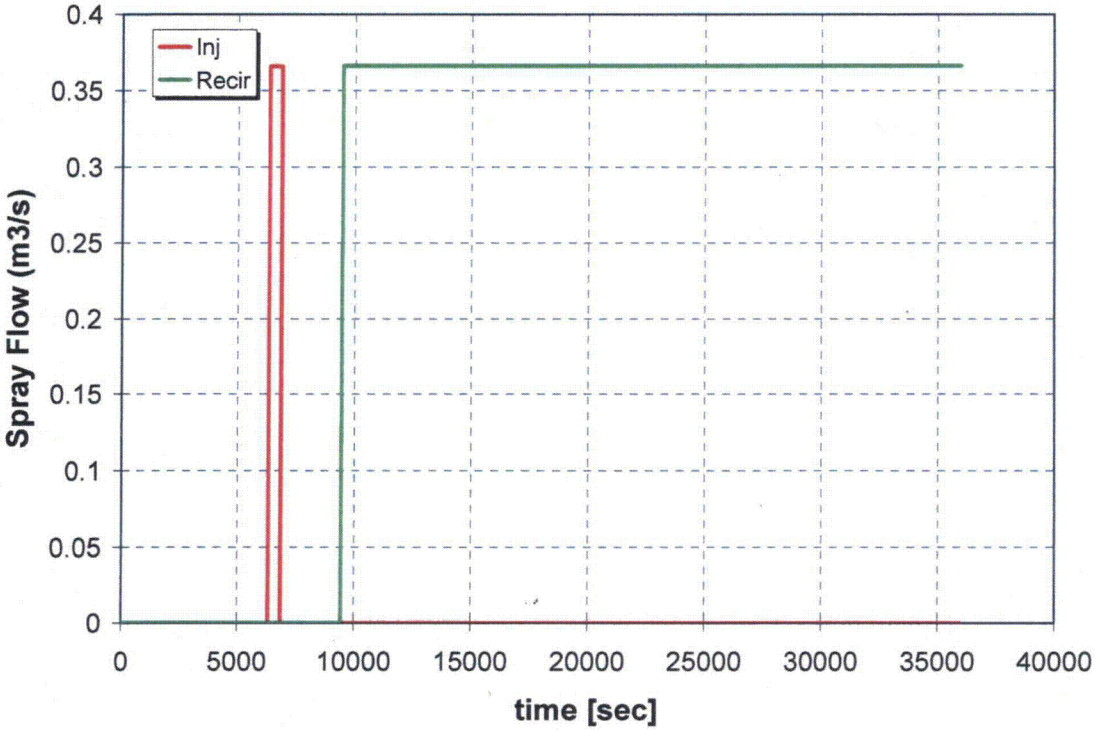

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
10000
20000
30000
40000
50000
time [sec]
TCL
TFU
2200 F

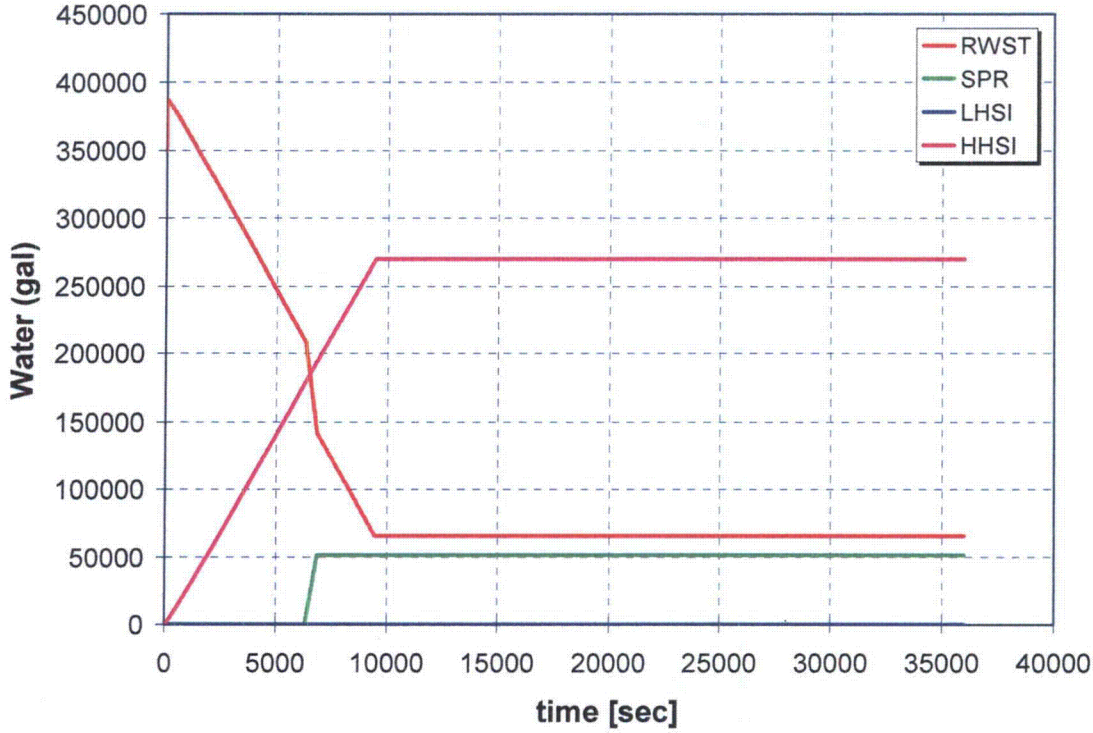
A.2.4 Case 4: 2-Inch Break LOCA with Sprays

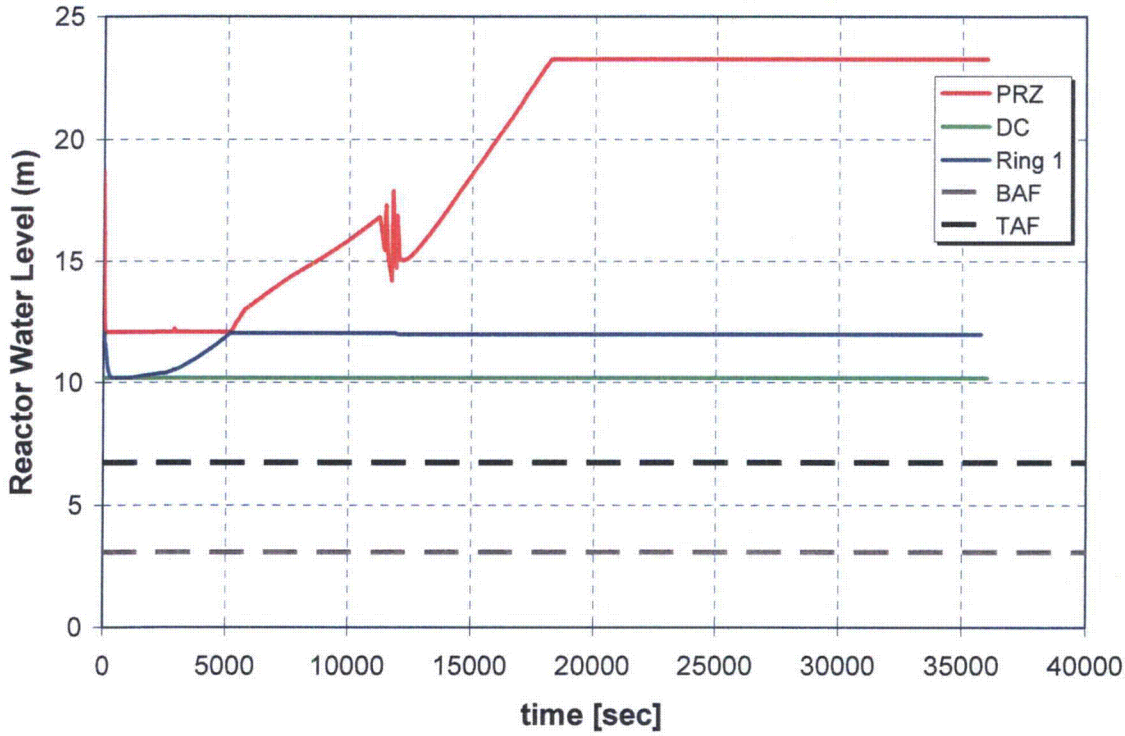


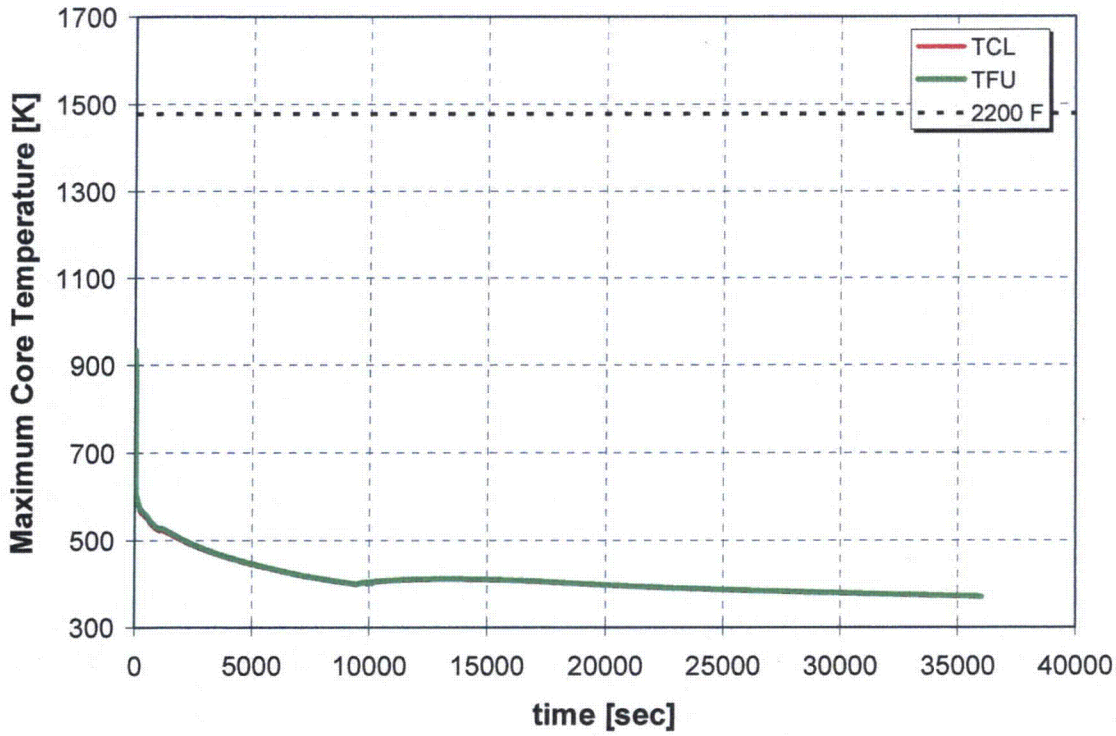



250
200
150
100
50
0
Total Flow (kg/s)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK

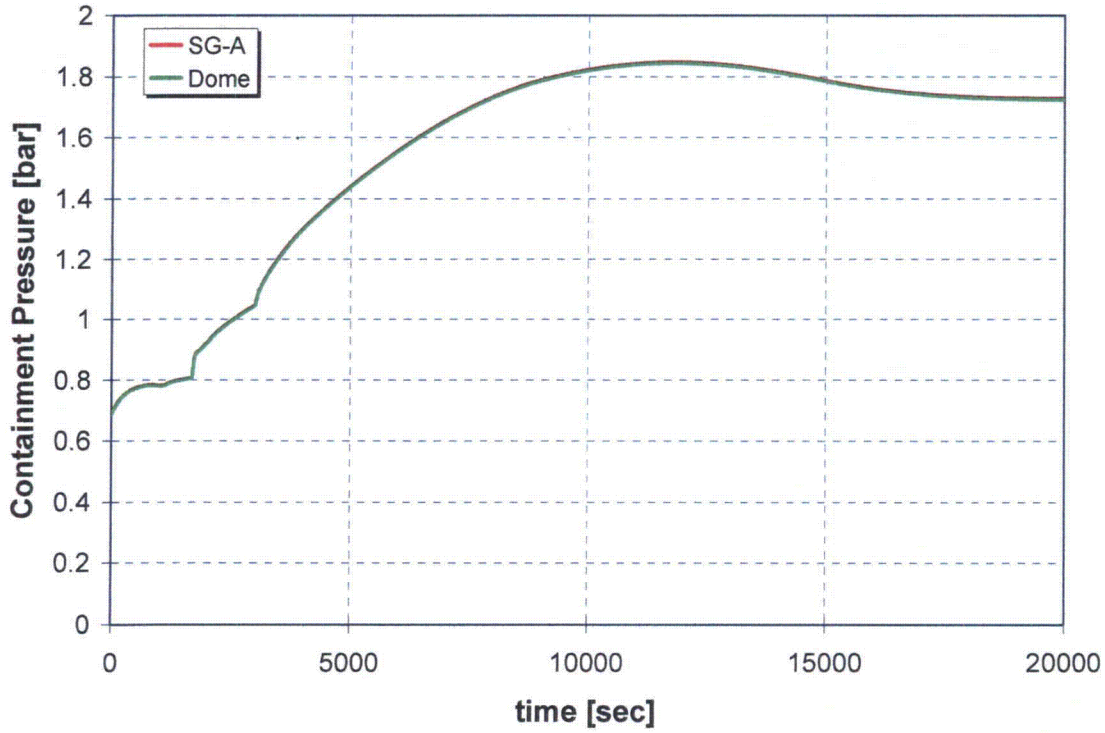

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Spray Flow (m3/s)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
Inj
Recir

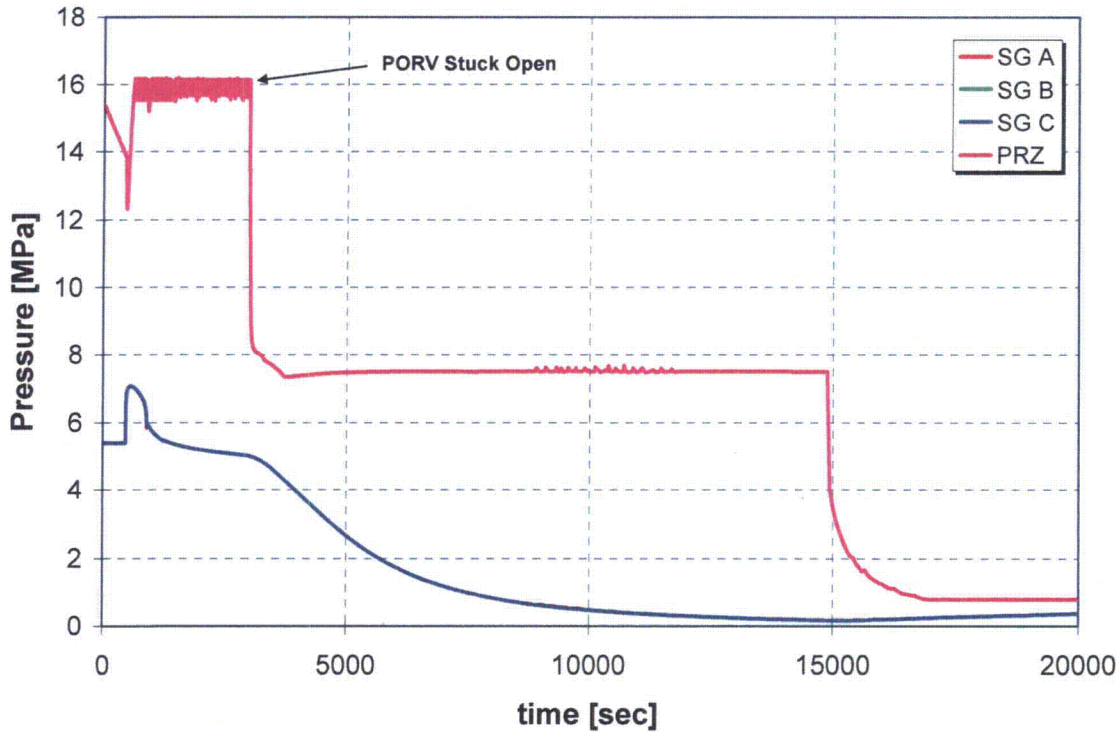

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
RWST
SPR
LHSI
HHSI

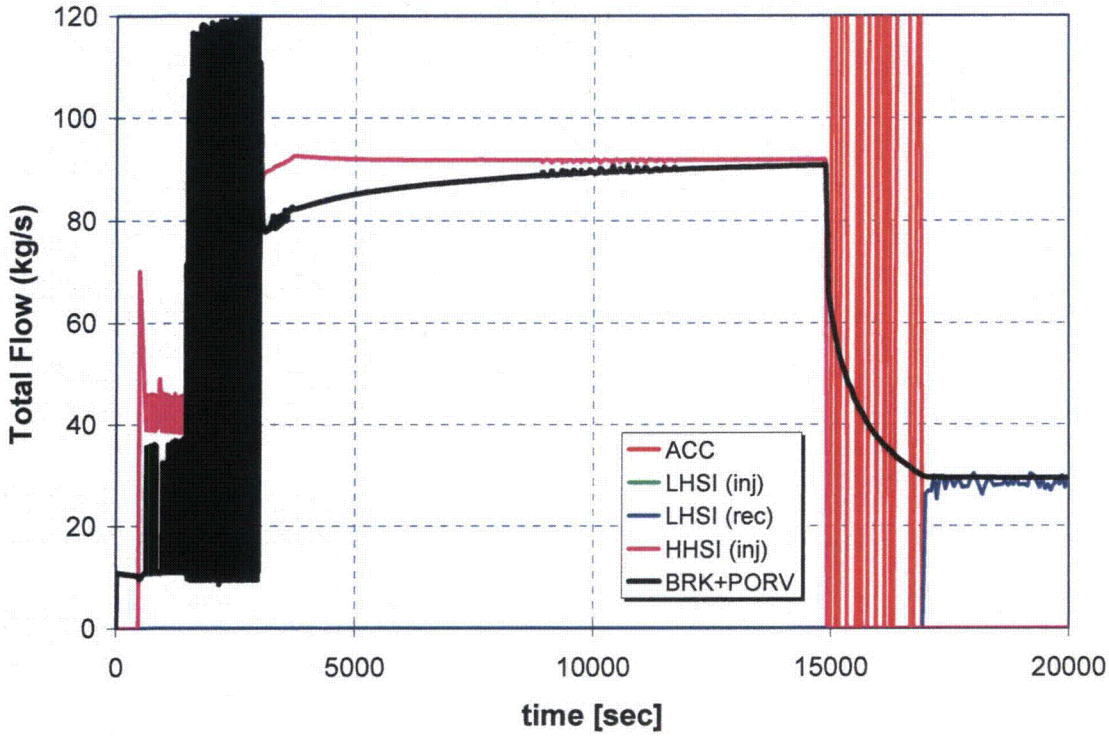

25
20
15
10
5
0
Reactor Water Level (m)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

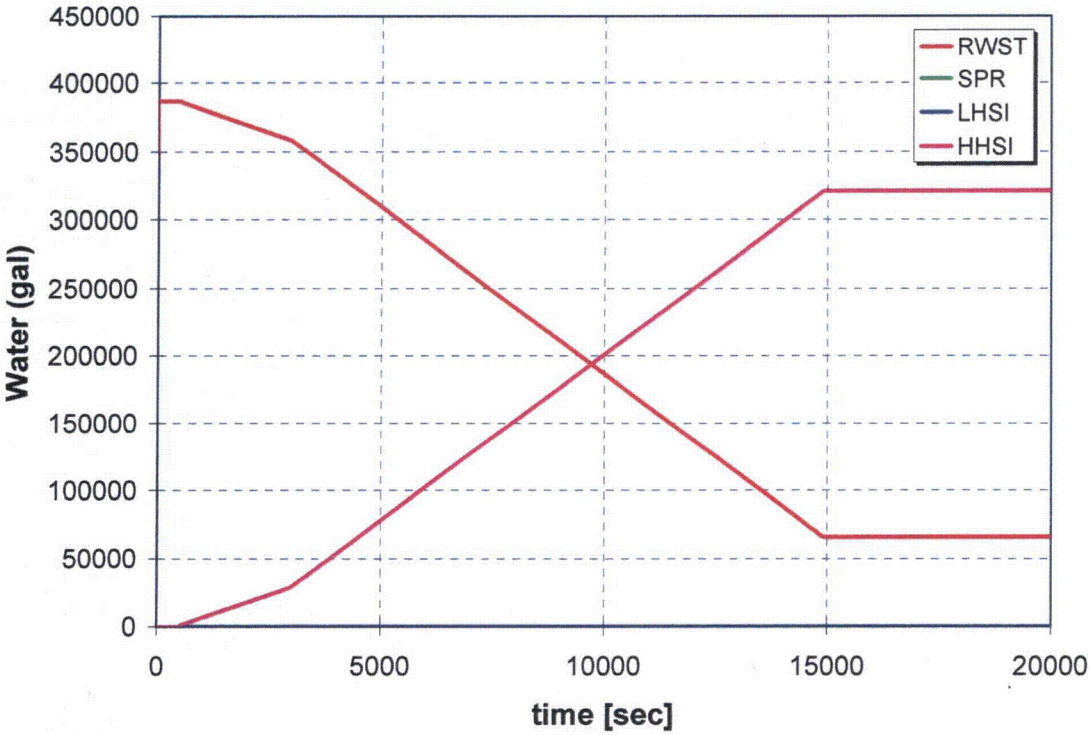

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
TCL
TFU
2200 F

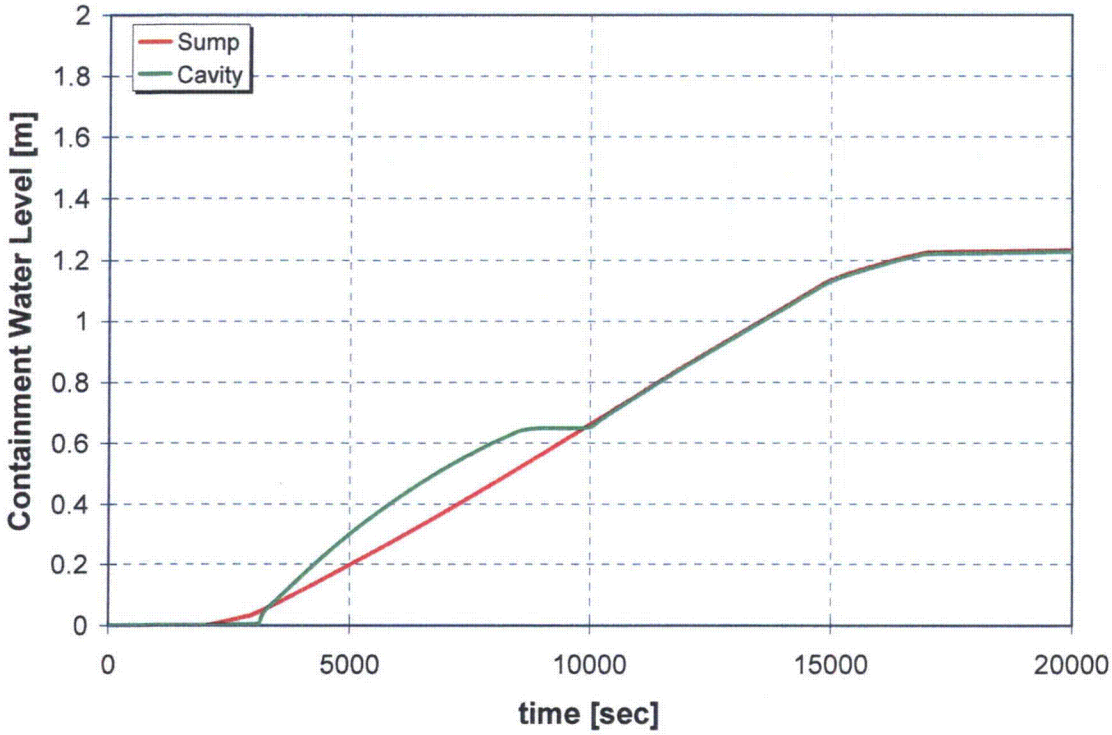
A.2.5 Case 5: 0.5-Inch Break LOCA without Sprays

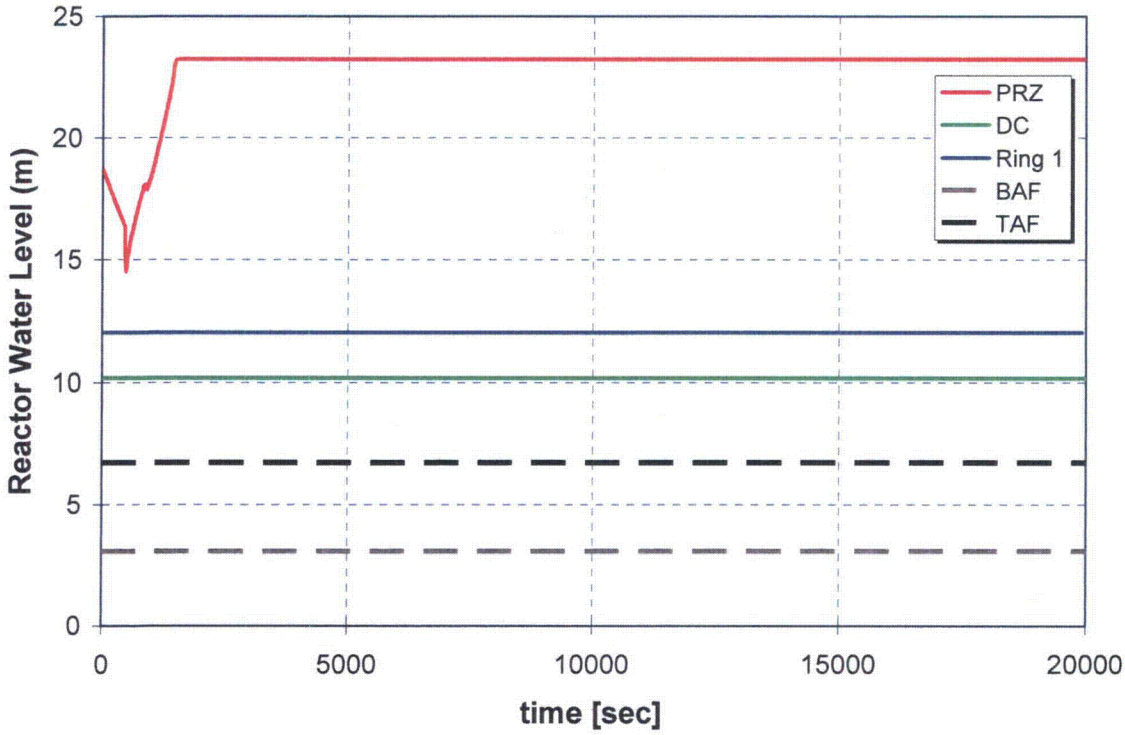


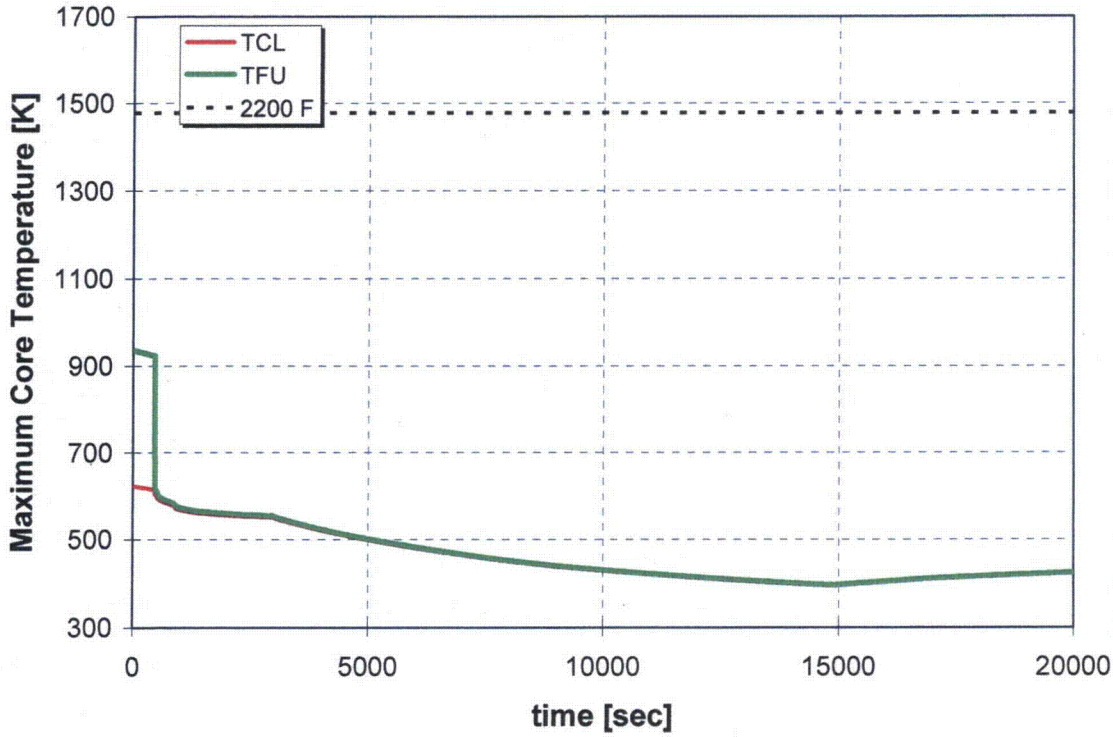



Total Flow (kg/s)
120
100
80
60
40
20
0
0
5000
10000
15000
20000
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK+PORV

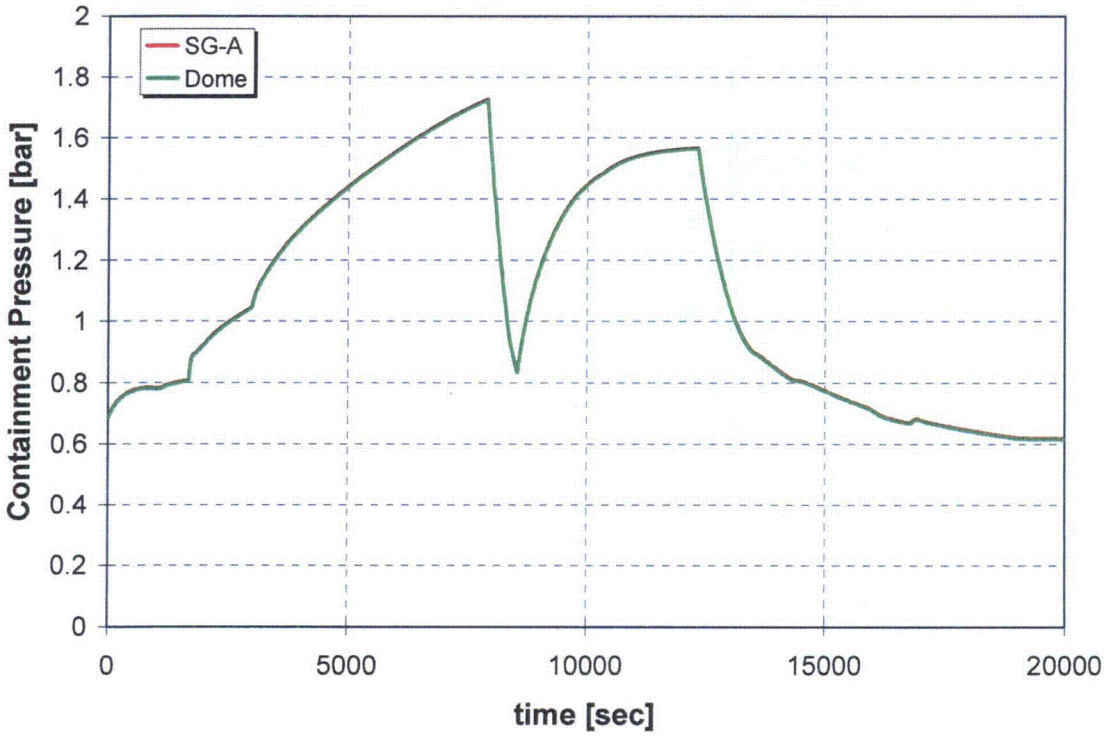

Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
5000
10000
15000
20000
time [sec]
RWST
SPR
LHSI
HHSI

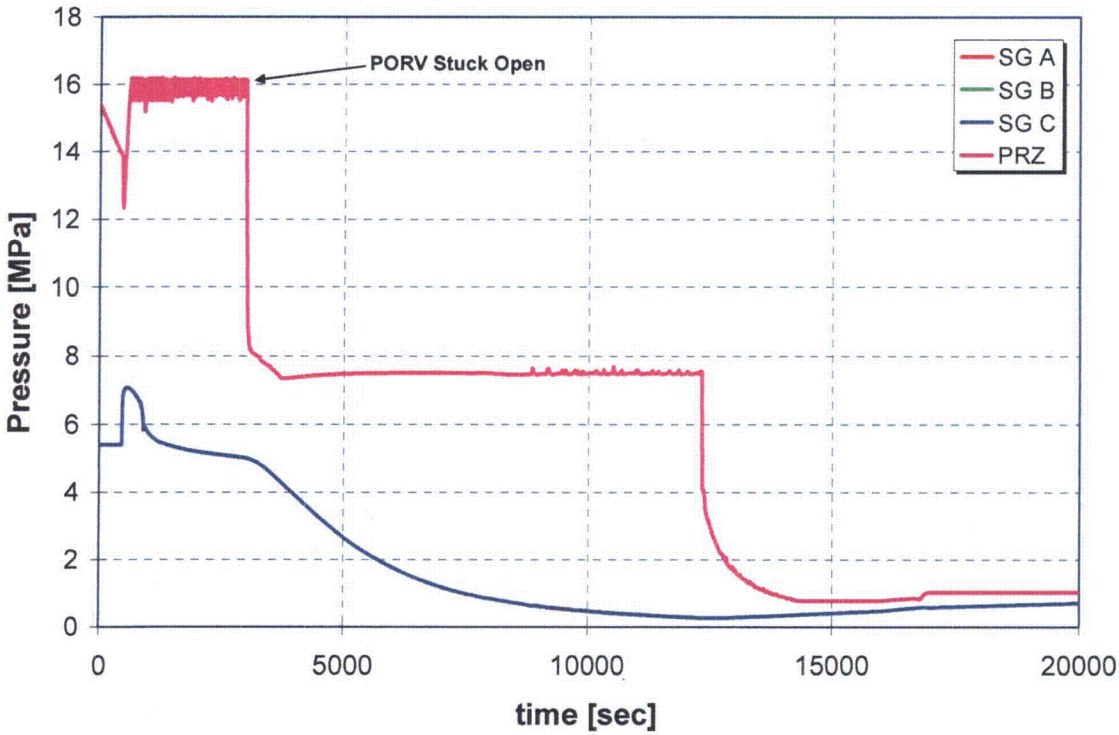

Sump
Cavity
Containment Water Level [m]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5000
10000
15000
20000
time [sec]

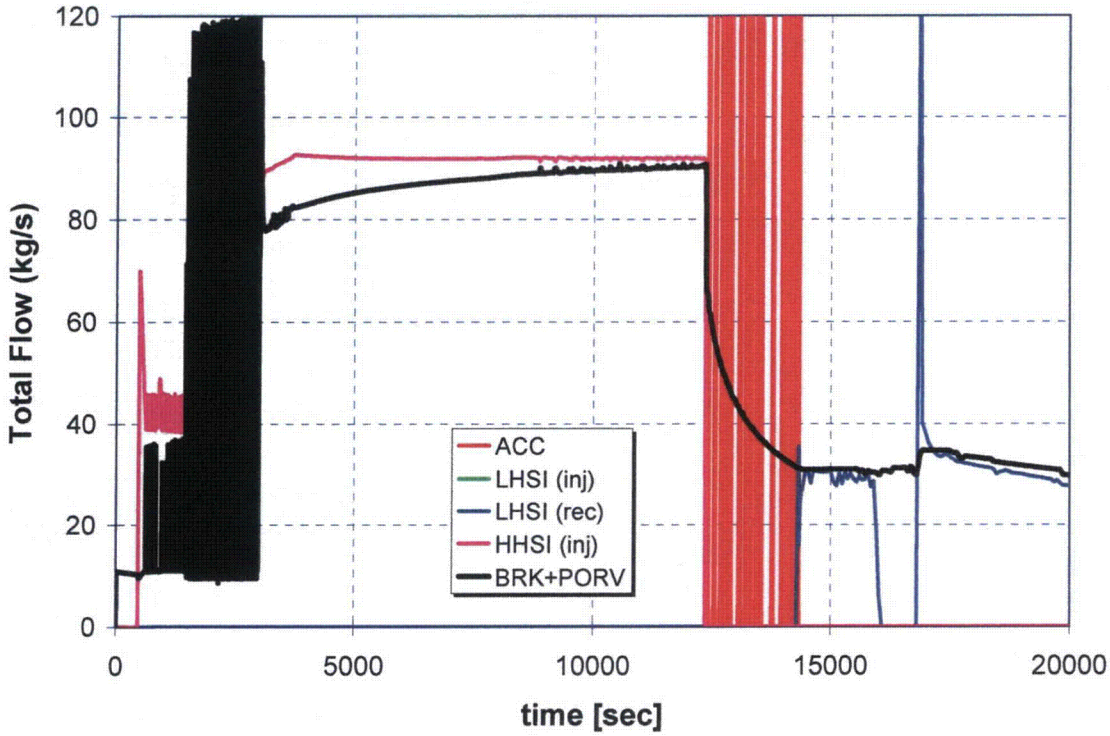

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
time [sec]

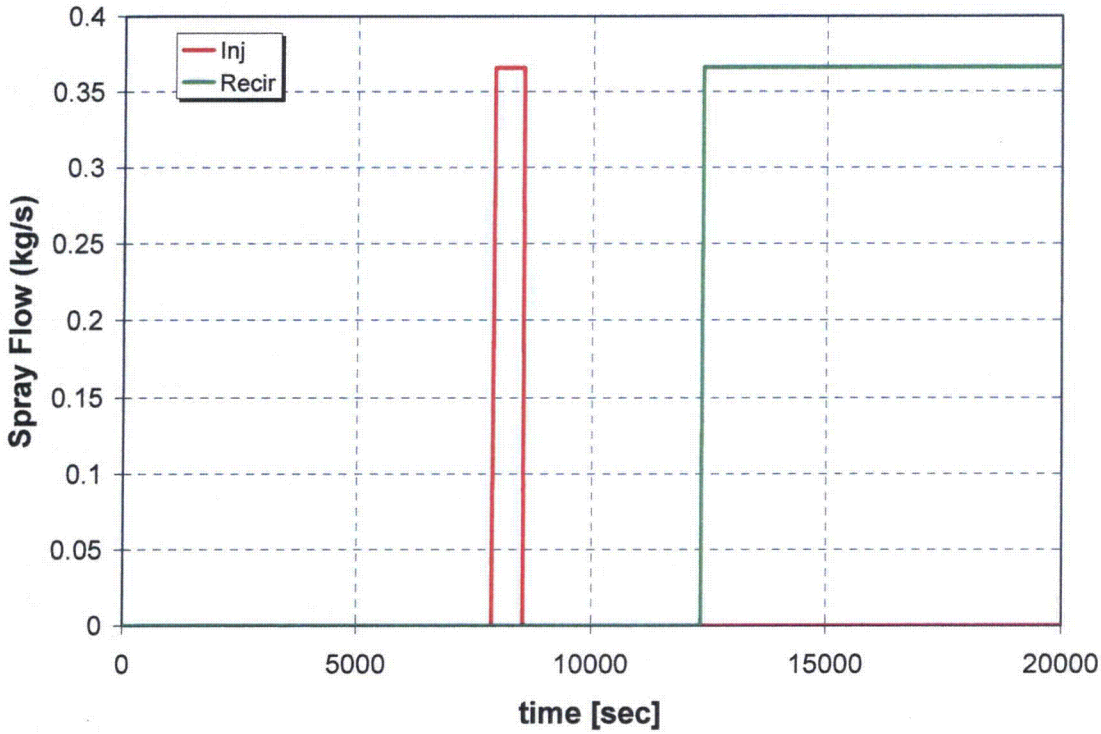

TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
5000
10000
15000
20000
time [sec]

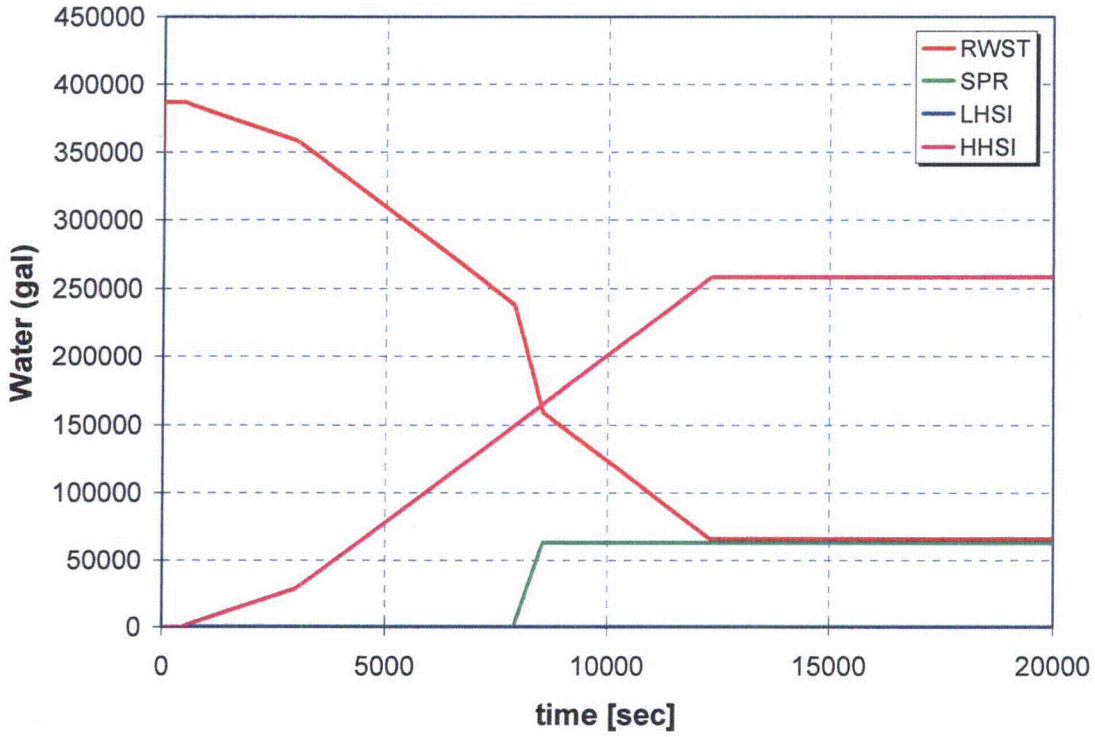
A.2.6 Case 6: 0.5-Inch Break LOCA with Sprays

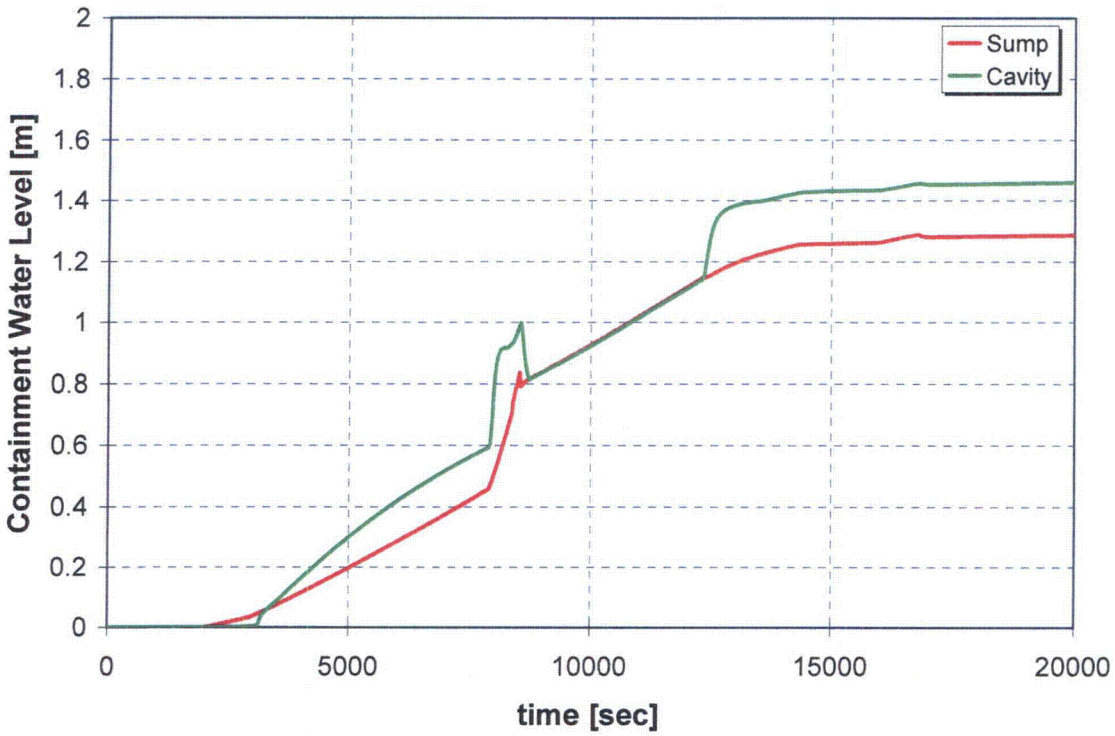


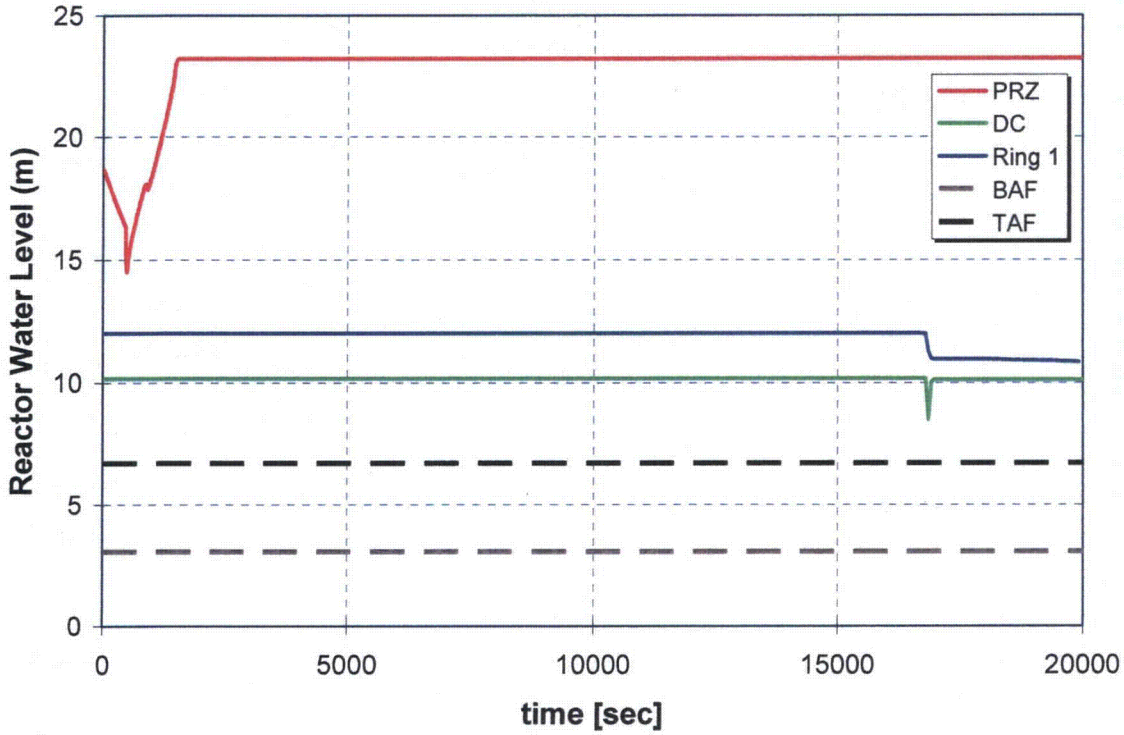


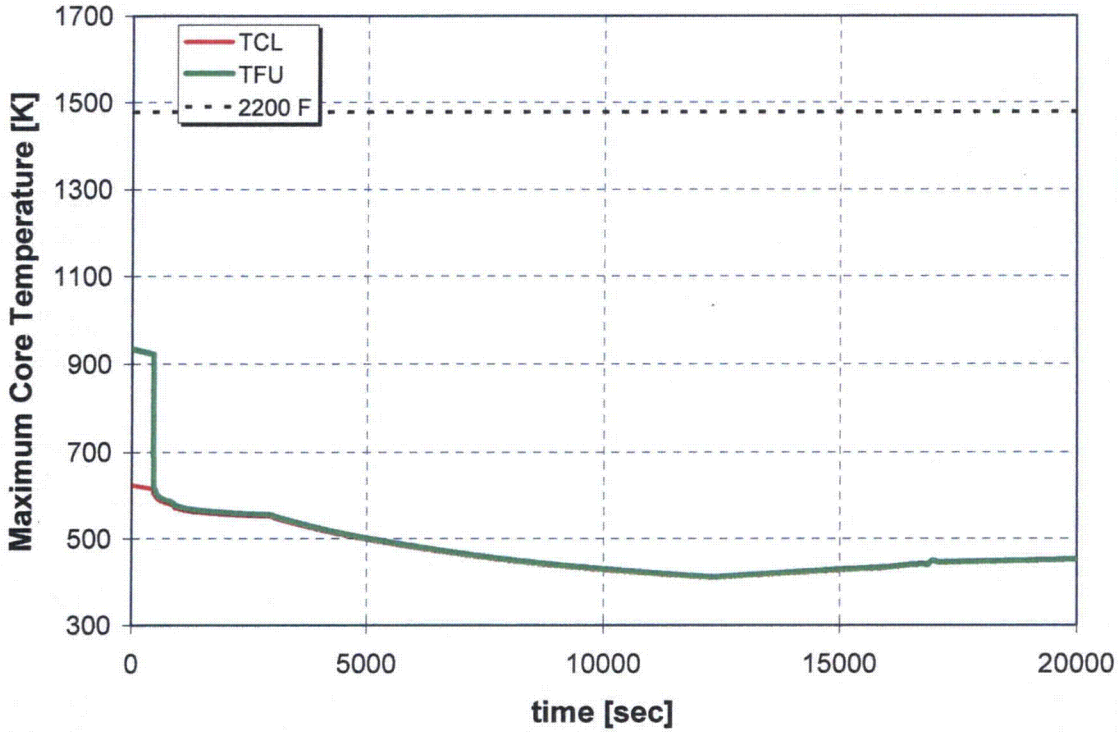

Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK+PORV
0
20
40
60
80
100
120
0
5000
10000
15000
20000


Spray Flow (kg/s)
time [sec]
Inj
Recir
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
5000
10000
15000
20000

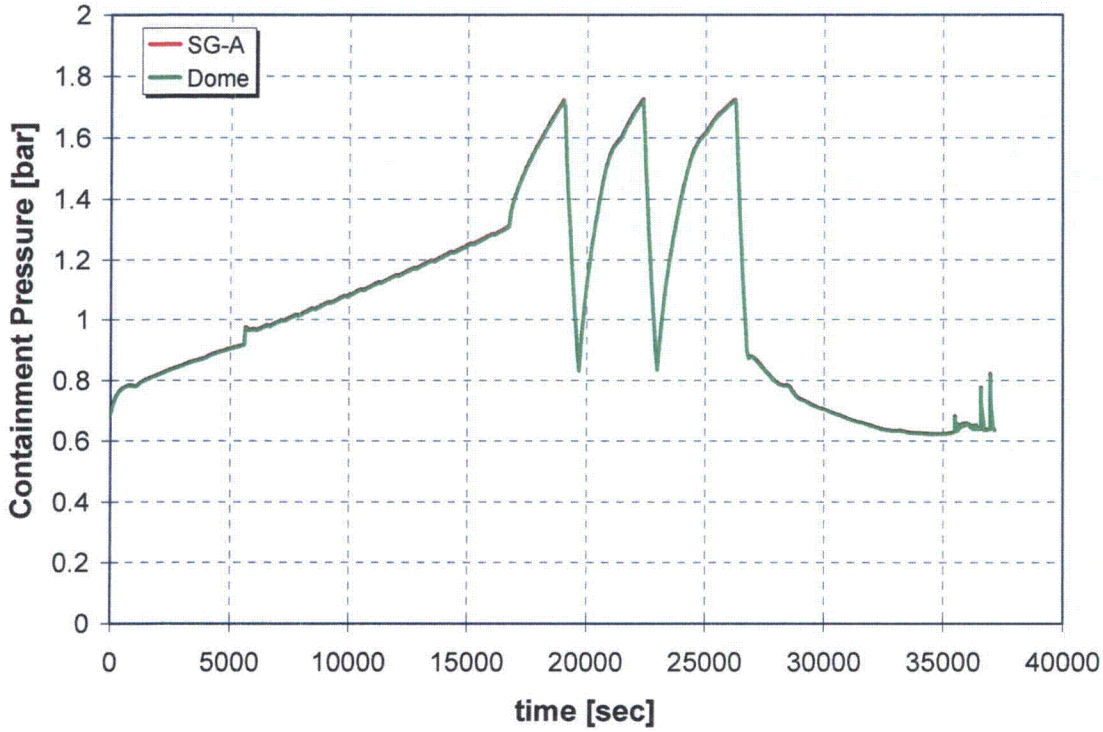

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
time [sec]
RWST
SPR
LHSI
HHSI

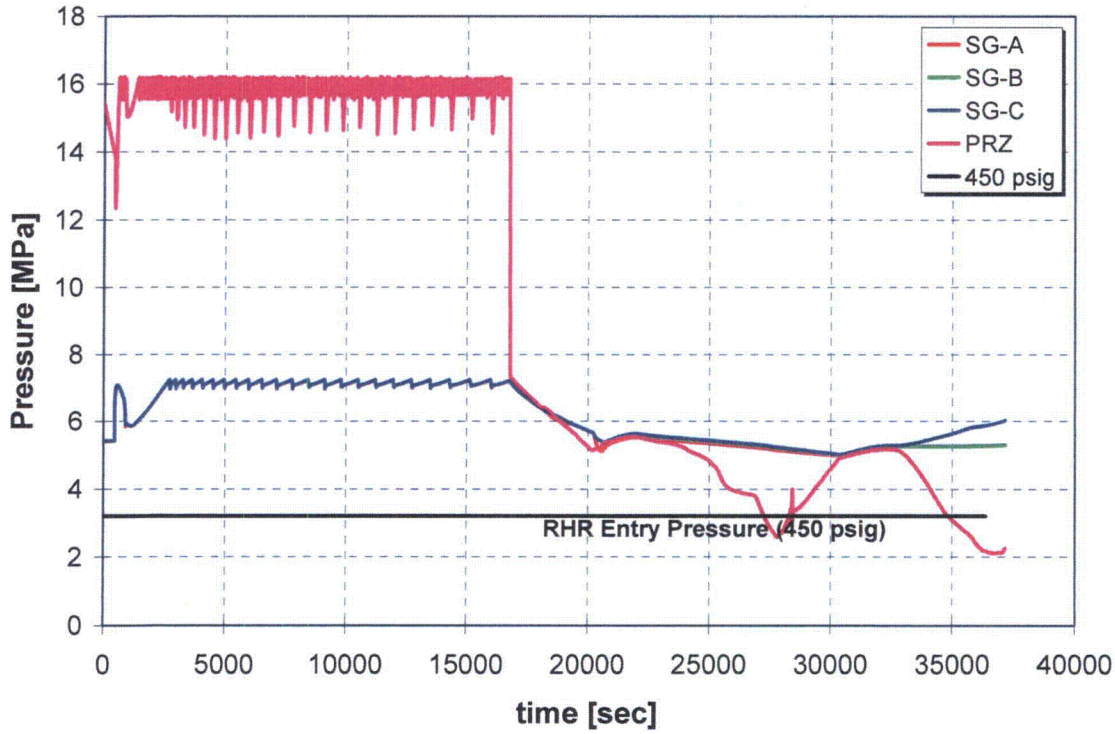

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
time [sec]
Sump
Cavity

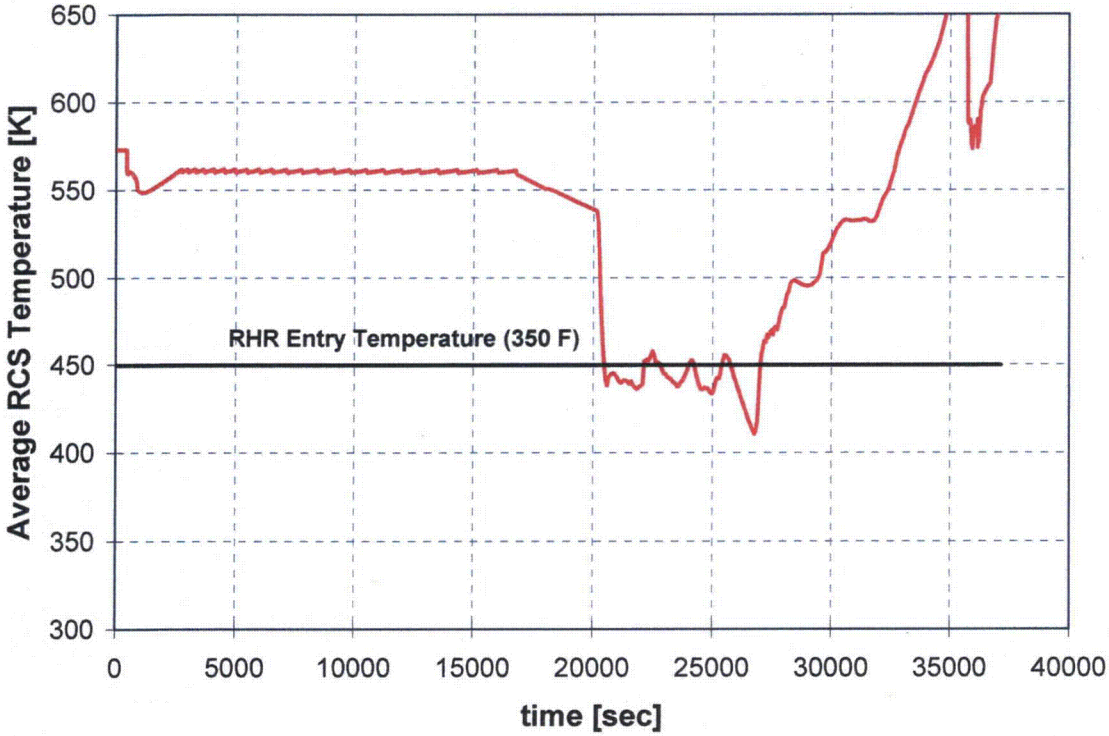

25
20
15
10
5
0
Reactor Water Level (m)
0
5000
10000
15000
20000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

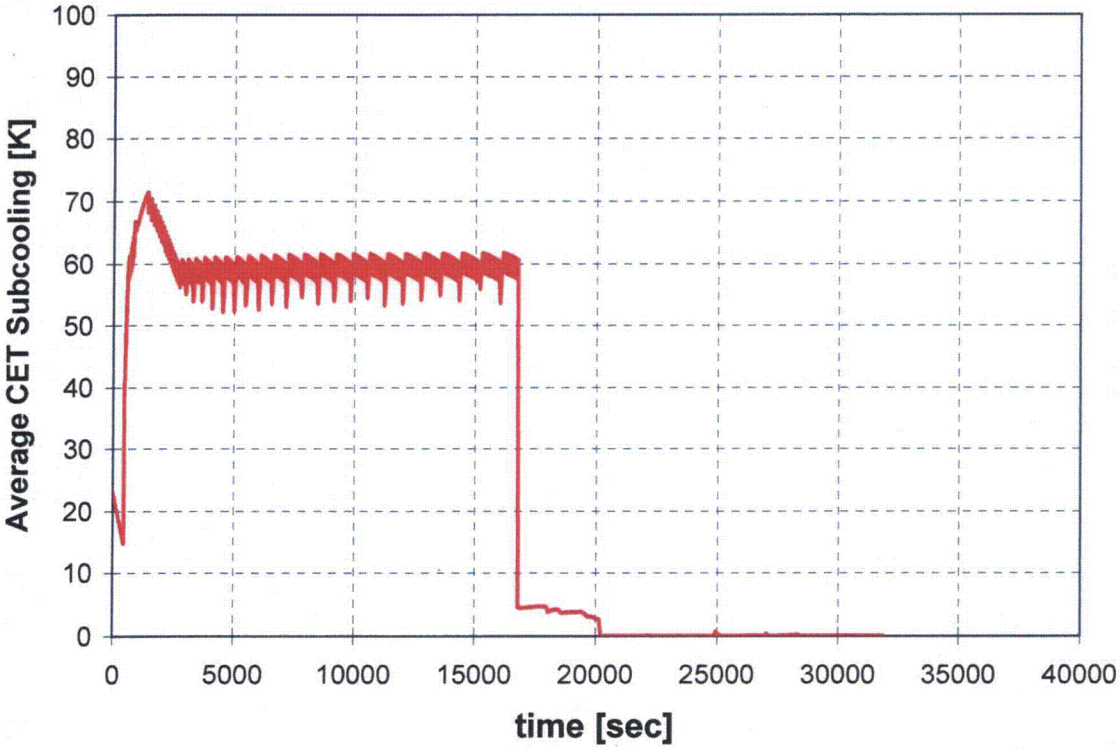

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
5000
10000
15000
20000
time [sec]
TCL
TFU
2200 F

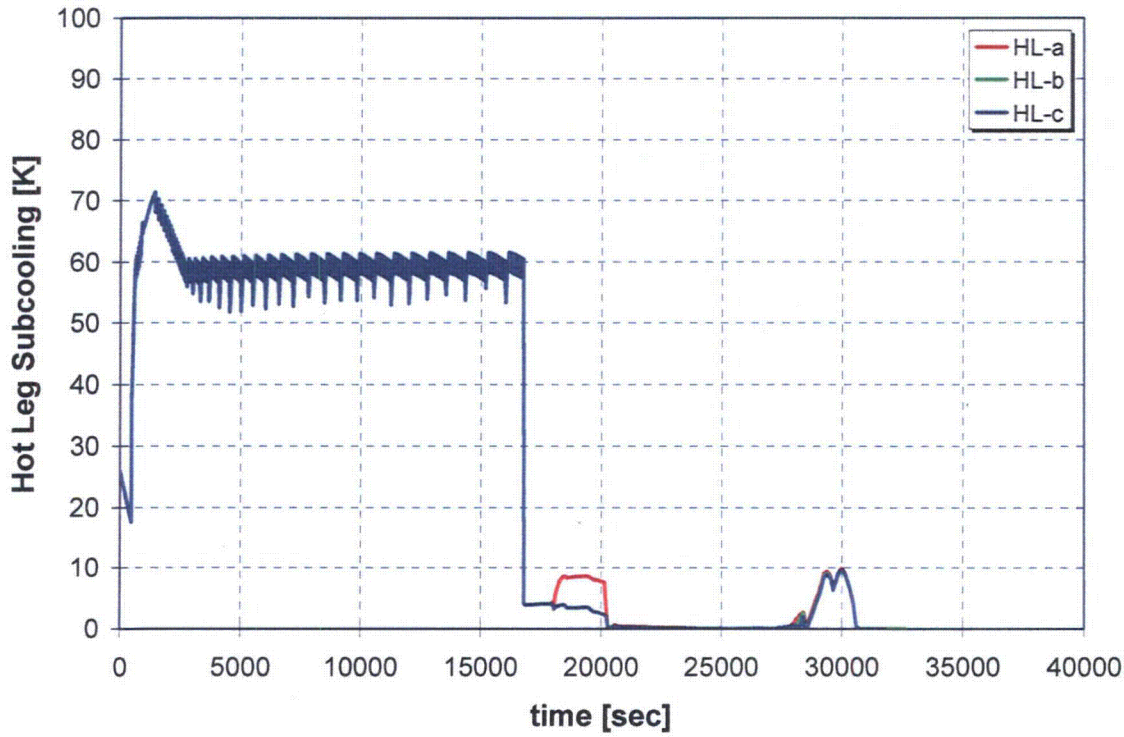
A.2.6.1 Case 6a: 0.5-Inch Break LOCA with Sprays and Secure HHSI Pumps

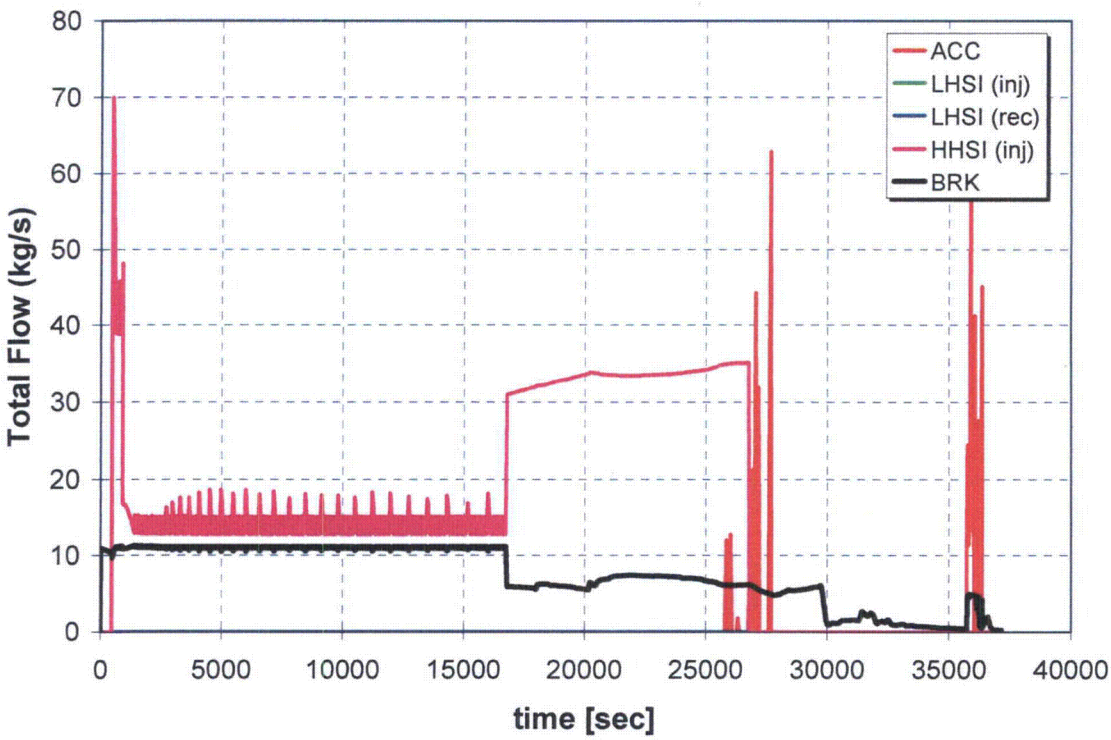


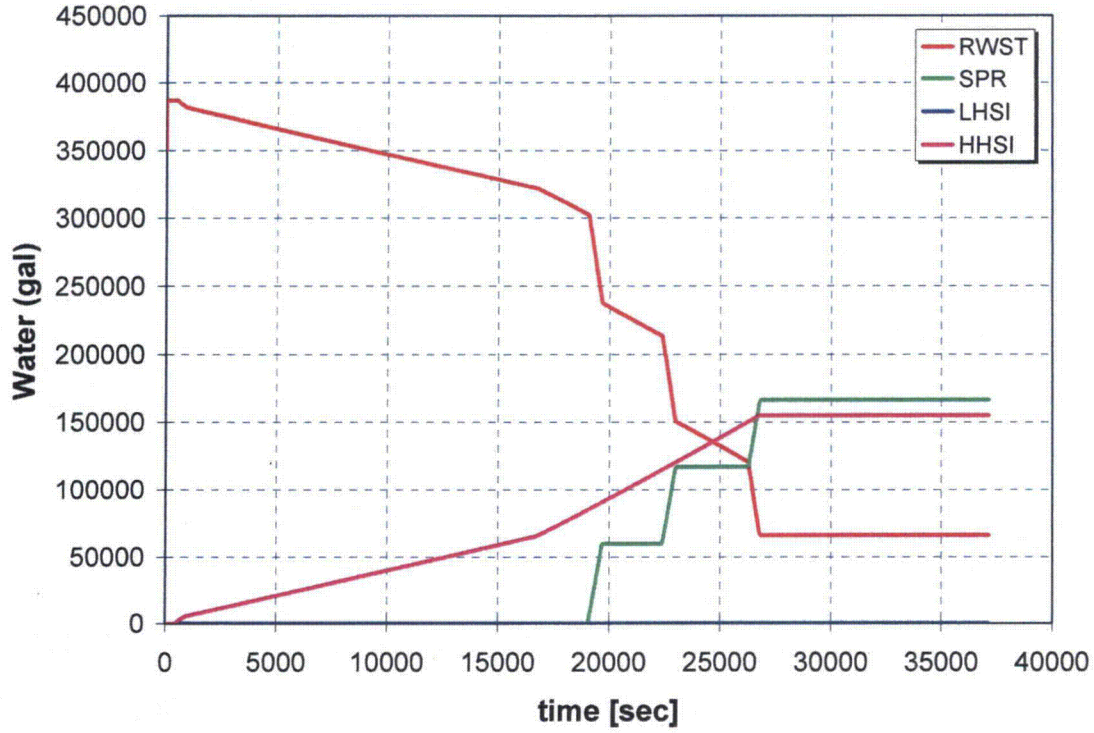


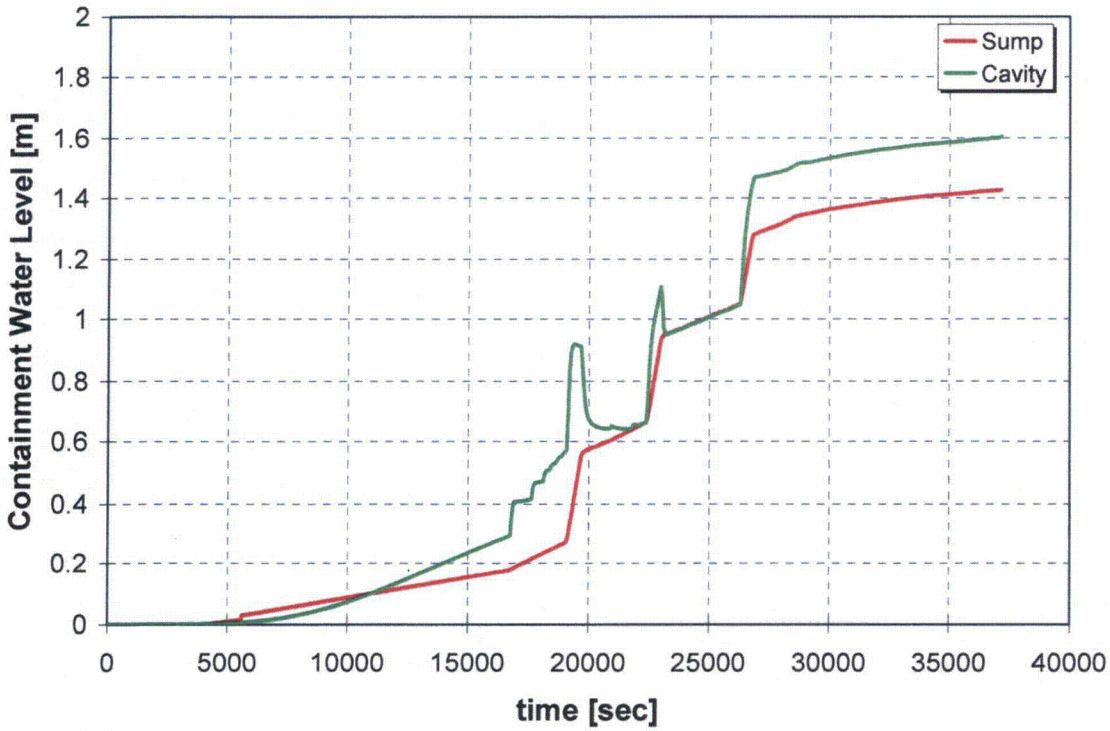

650
600
550
500
450
400
350
300
Average RCS Temperature [K]
RHR Entry Temperature (350 F)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

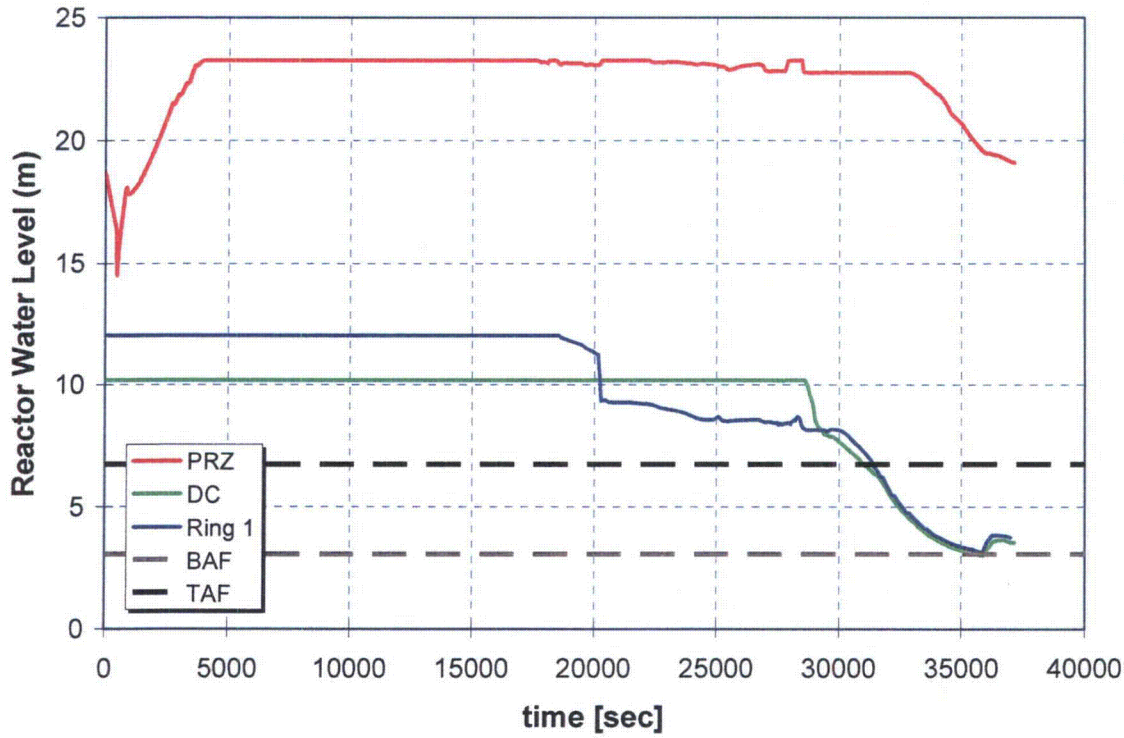

100
90
80
70
60
50
40
30
20
10
0
Average CET Subcooling [K]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

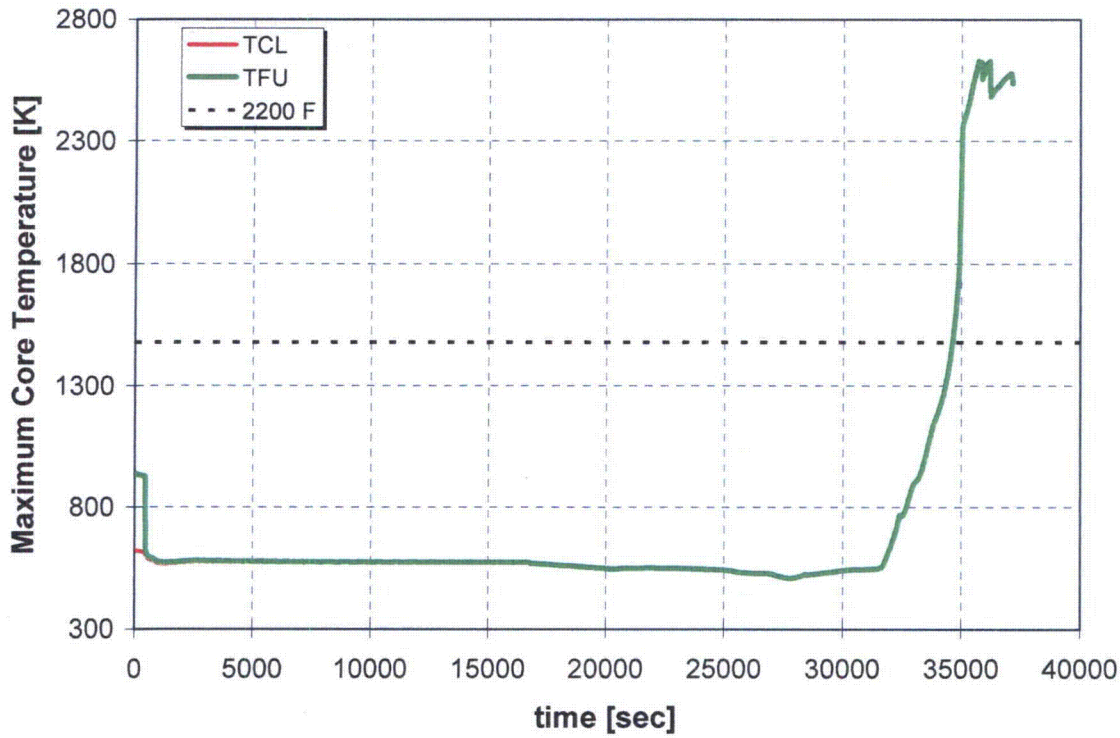

Hot Leg Subcooling [K]
time [sec]
HL-a
HL-b
HL-c
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000
35000
40000


Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
10
20
30
40
50
60
70
80
0
5000
10000
15000
20000
25000
30000
35000
40000

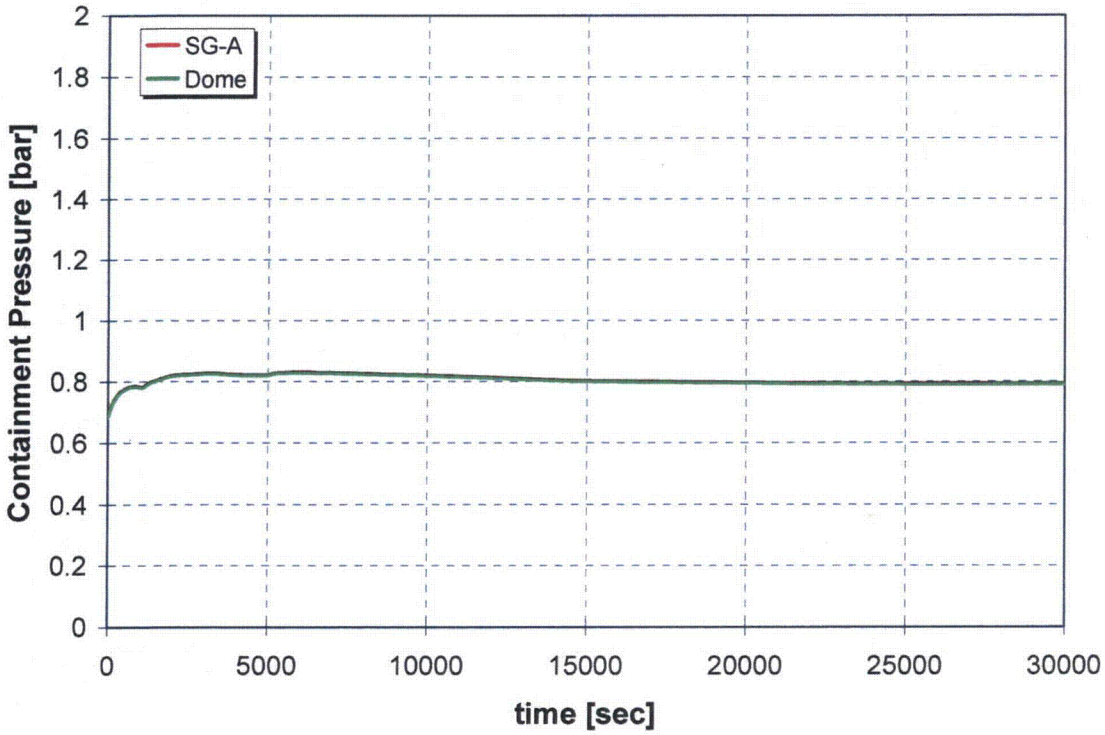

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
RWST
SPR
LHSI
HHSI

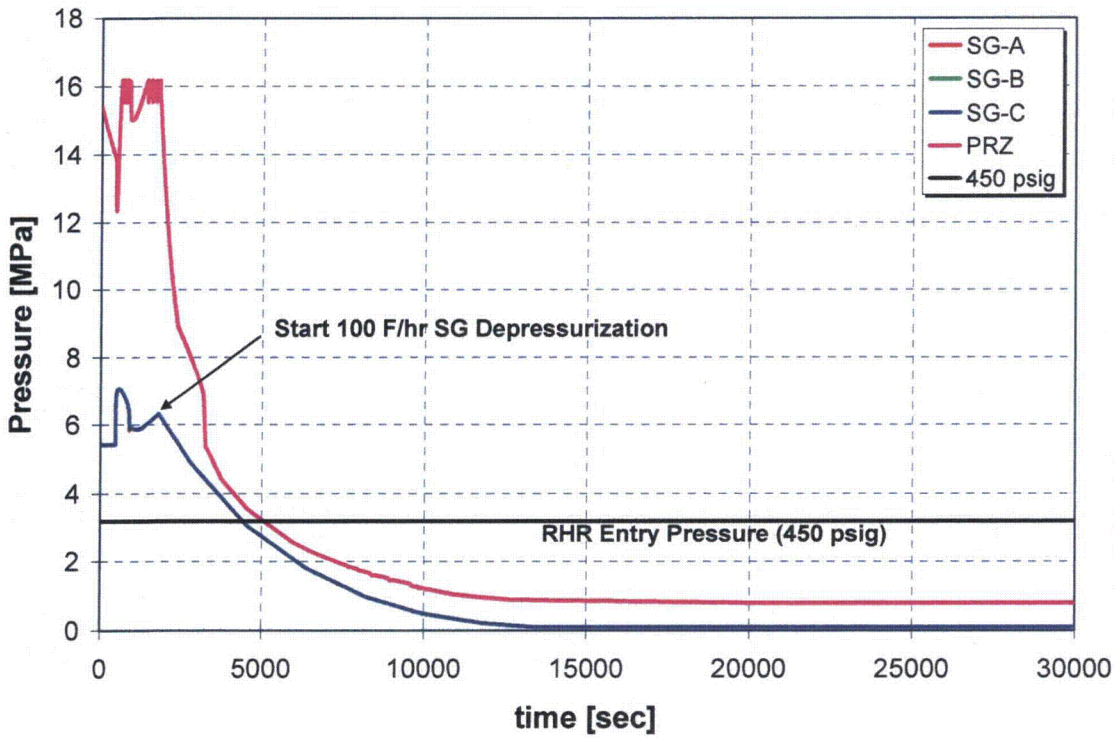

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
Sump
Cavity

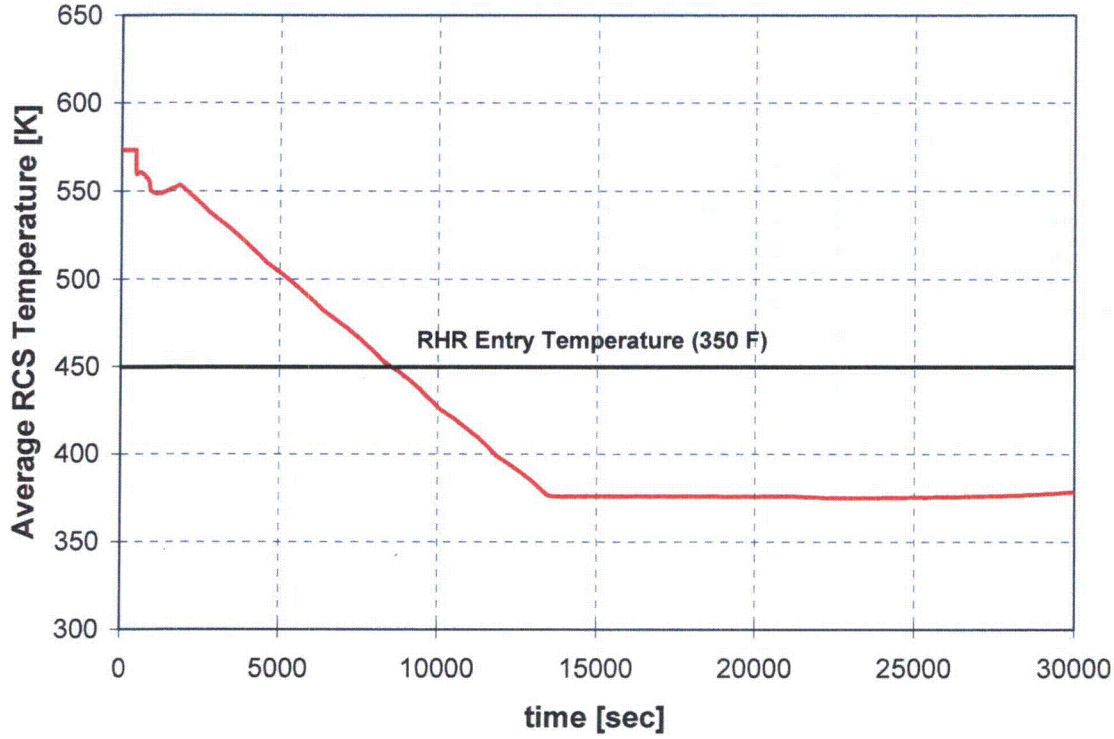

Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

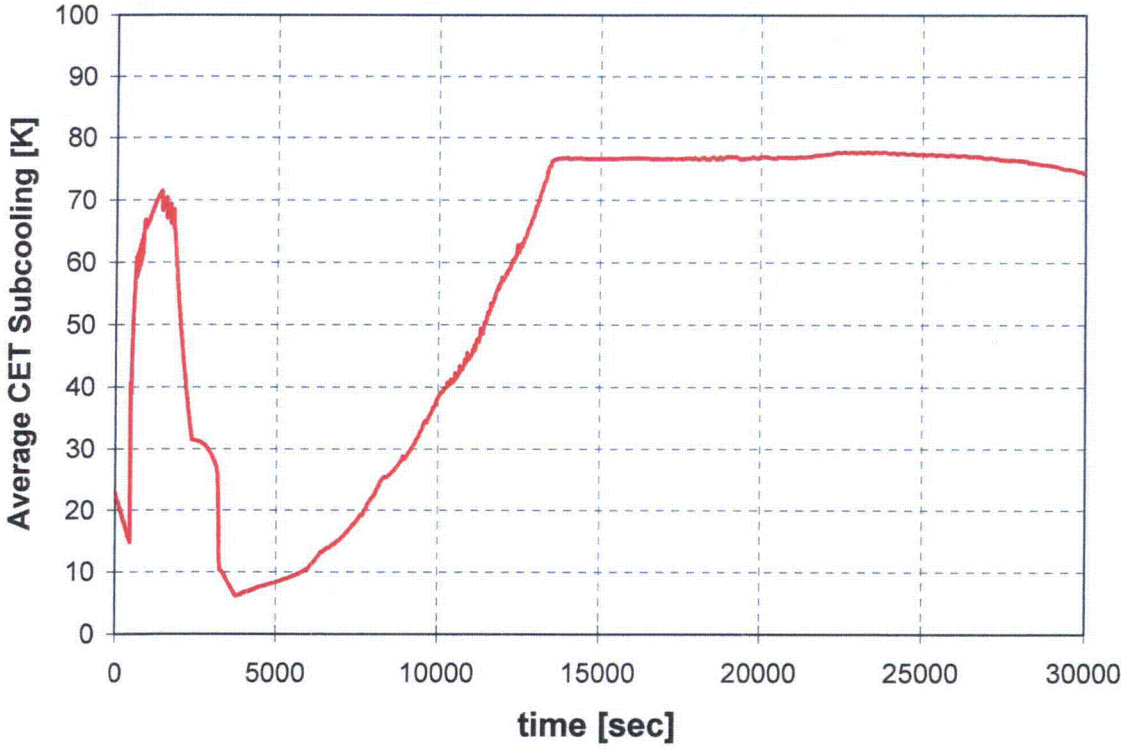

Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]
TCL
TFU
2200 F

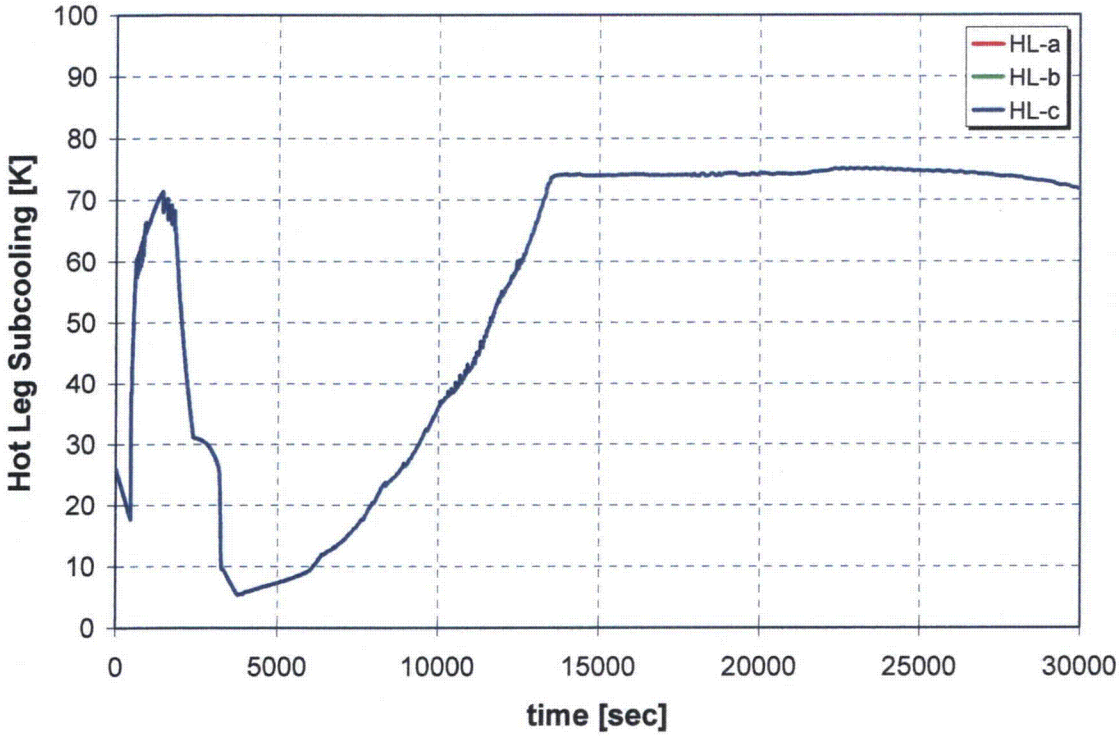
A.2.6.2 Case 6b: 0.5-Inch Break LOCA with Sprays, Secure HHSI Pumps, and Secondary Cooldown

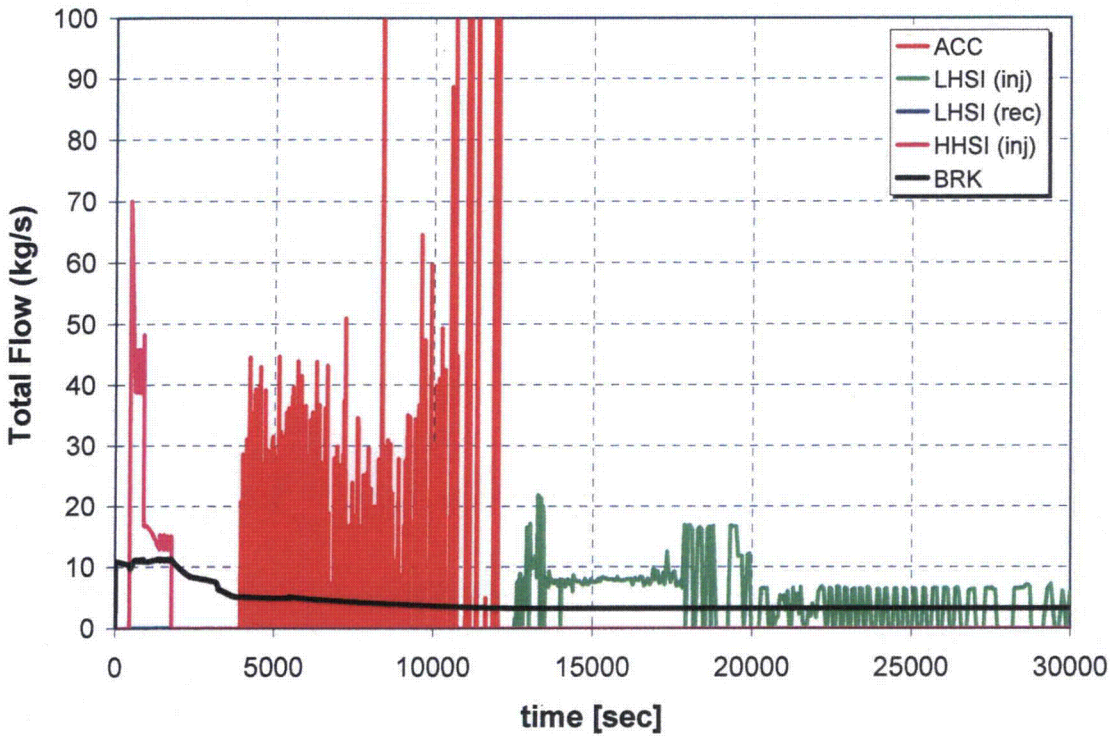


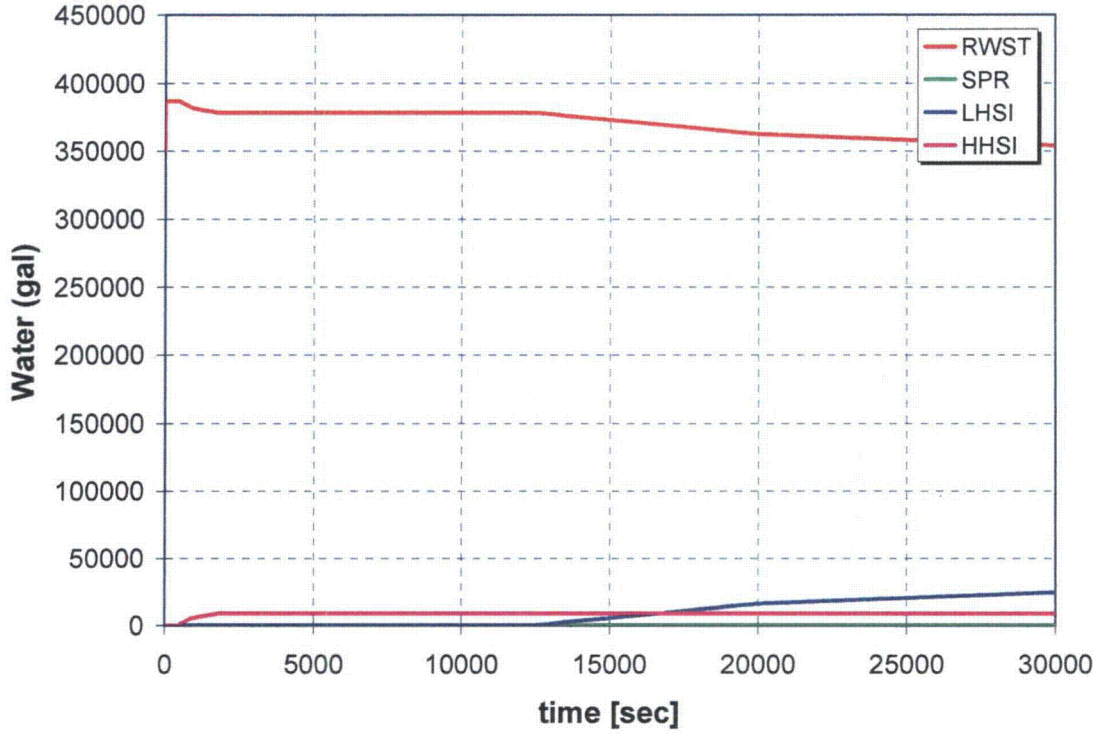


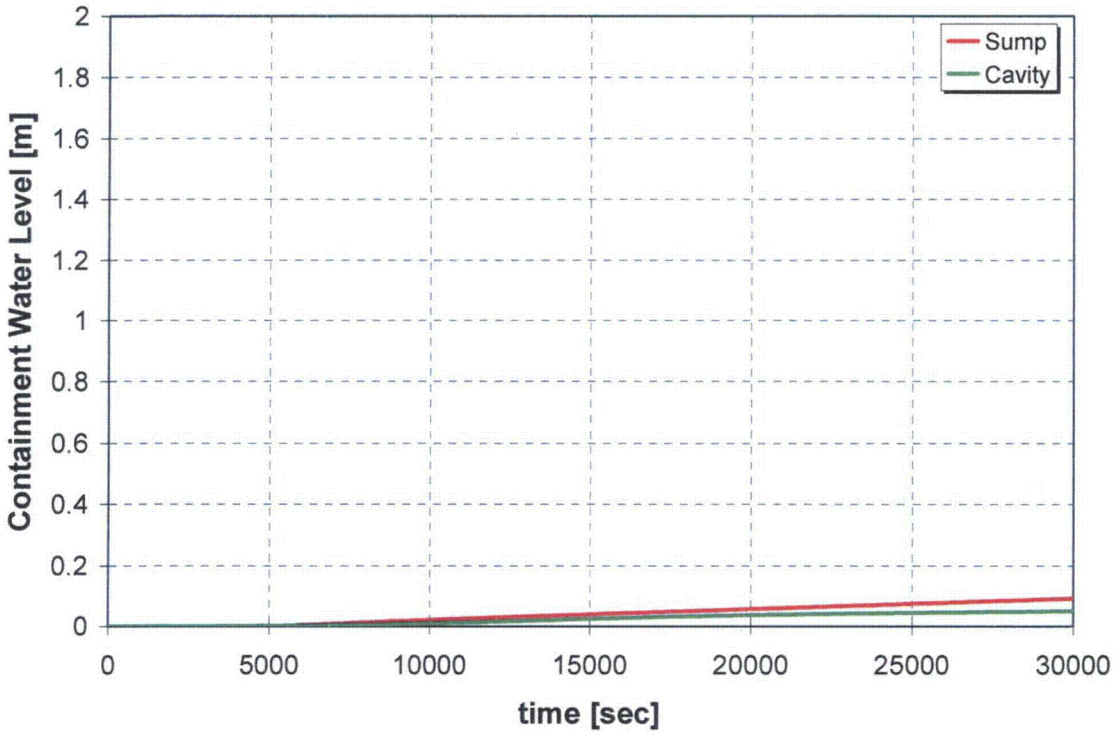

650
600
550
500
450
400
350
300
Average RCS Temperature [K]
RHR Entry Temperature (350 F)
0
5000
10000
15000
20000
25000
30000
time [sec]

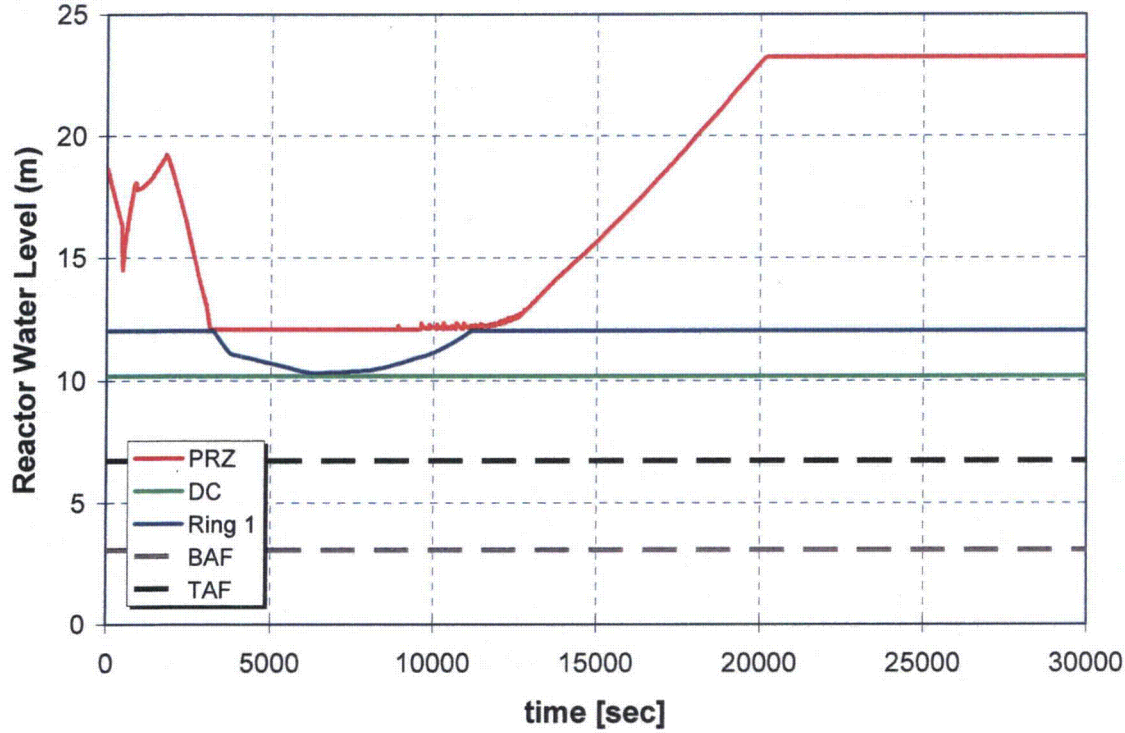

100
90
80
70
60
50
40
30
20
10
0
Average CET Subcooling [K]
0
5000
10000
15000
20000
25000
30000
time [sec]

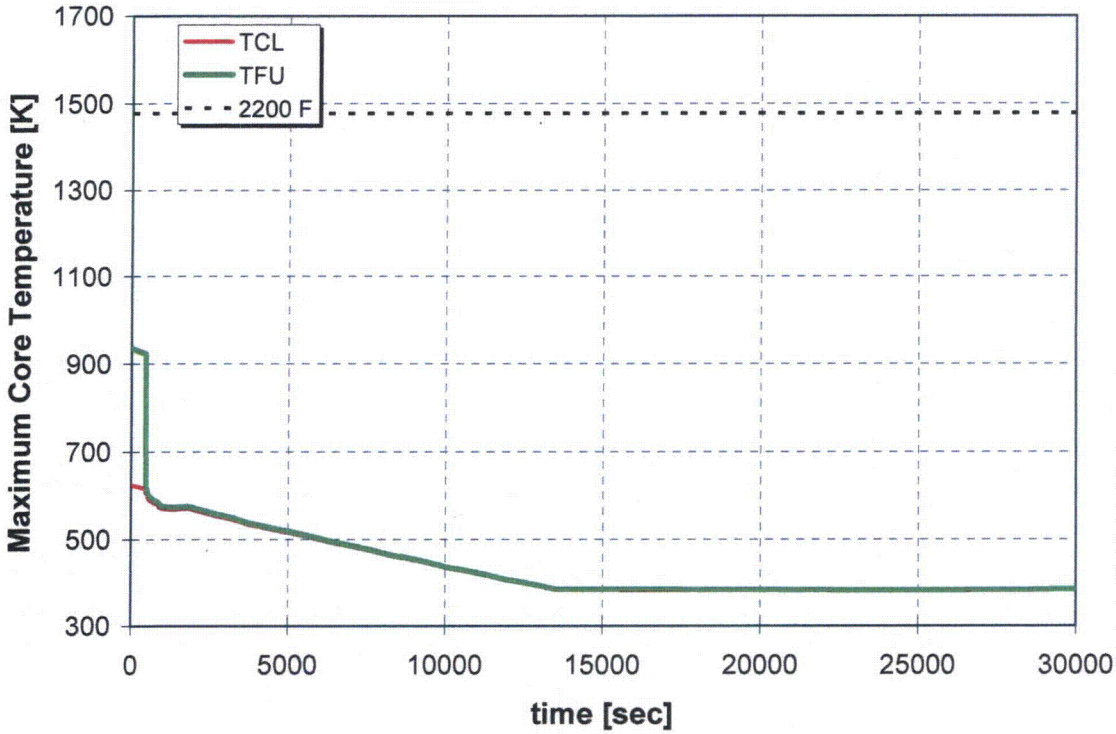

Hot Leg Subcooling [K]
time [sec]
HL-a
HL-b
HL-c
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000


Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000

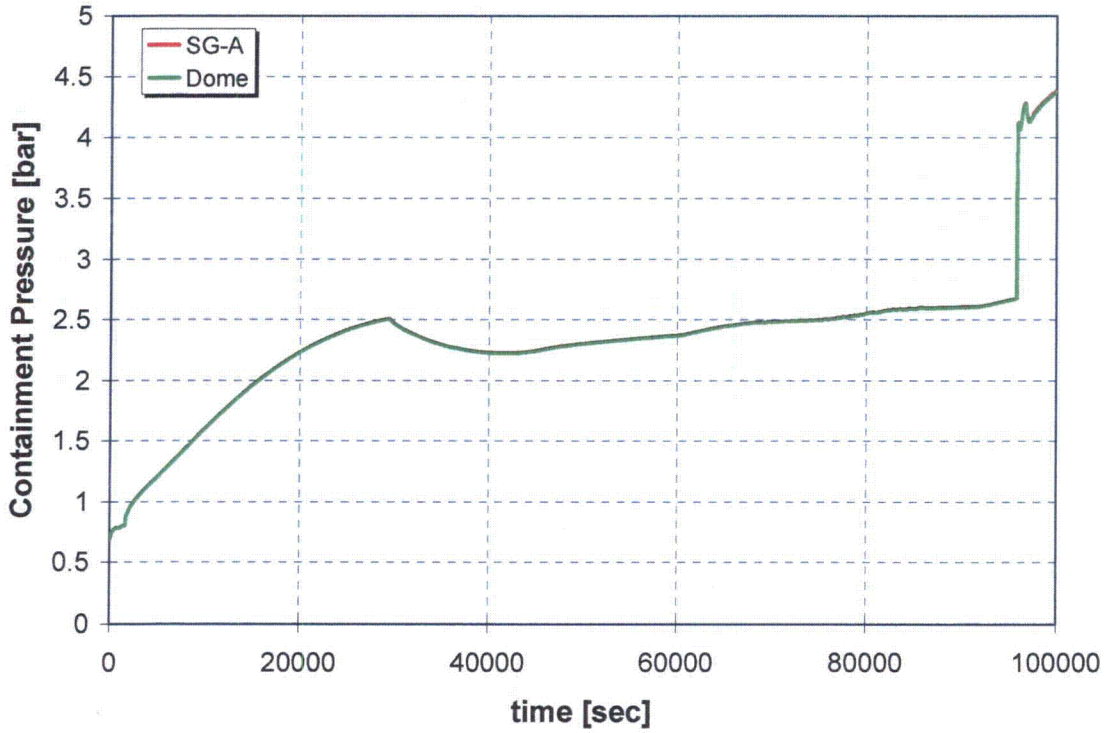

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
5000
10000
15000
20000
25000
30000
time [sec]
RWST
SPR
LHSI
HHSI

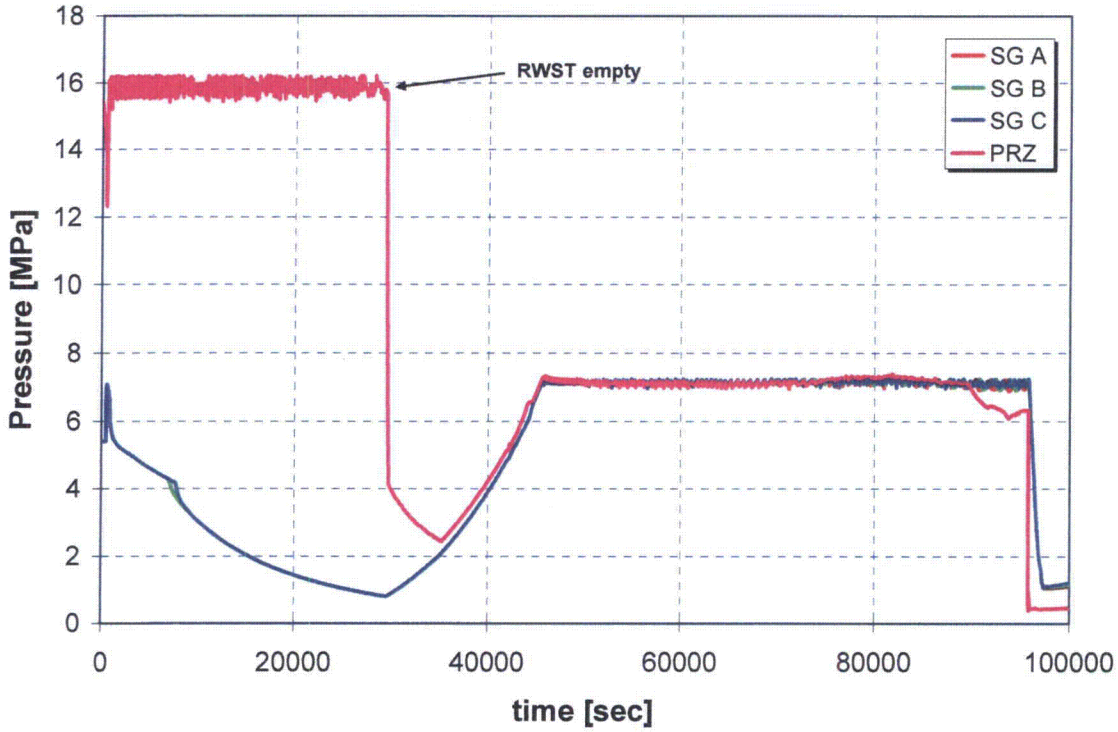

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
5000
10000
15000
20000
25000
30000
time [sec]
Sump
Cavity

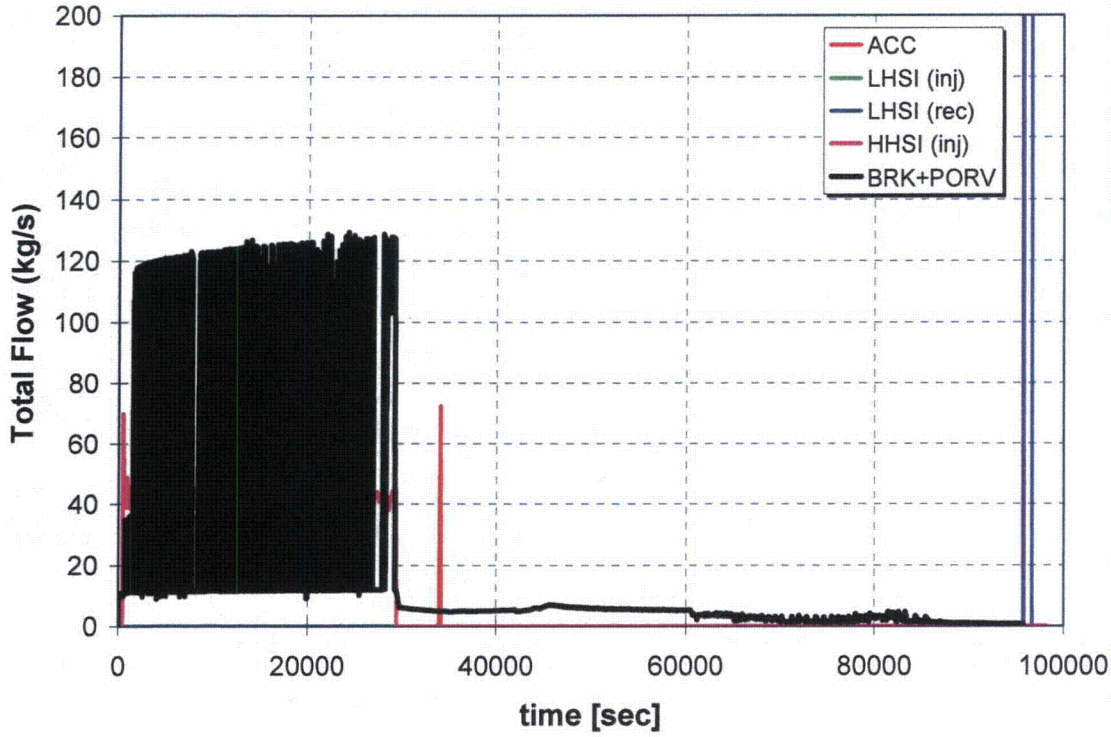

Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

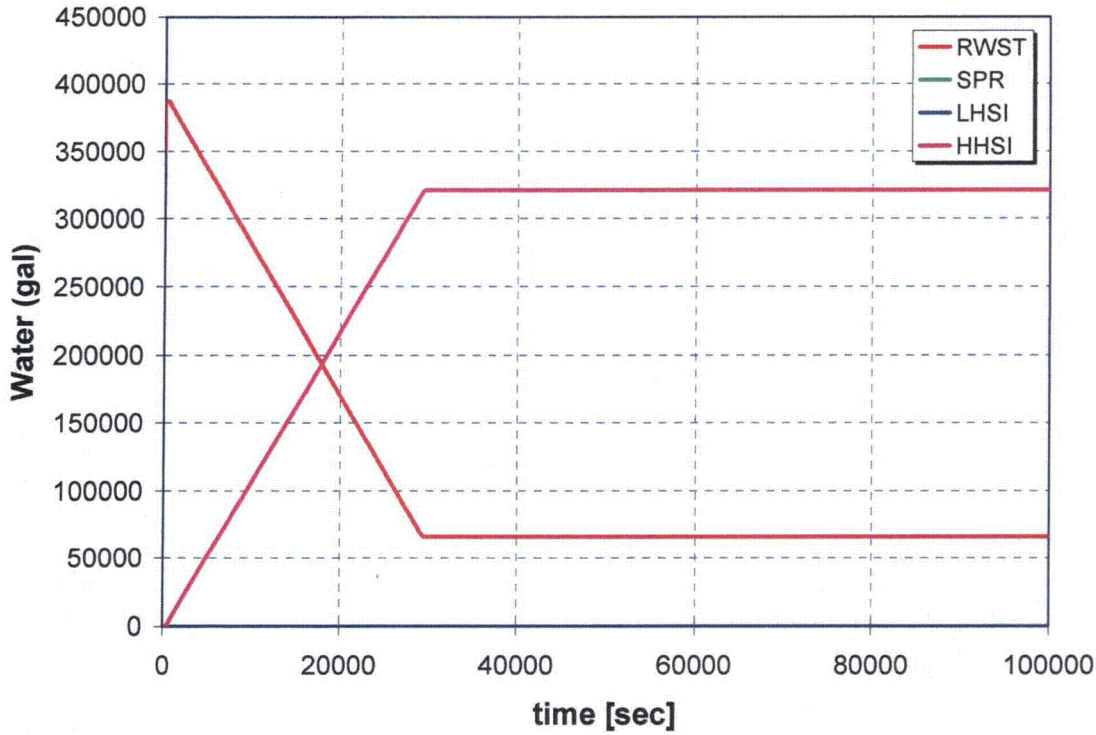

Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
5000
10000
15000
20000
25000
30000
time [sec]
TCL
TFU
2200 F

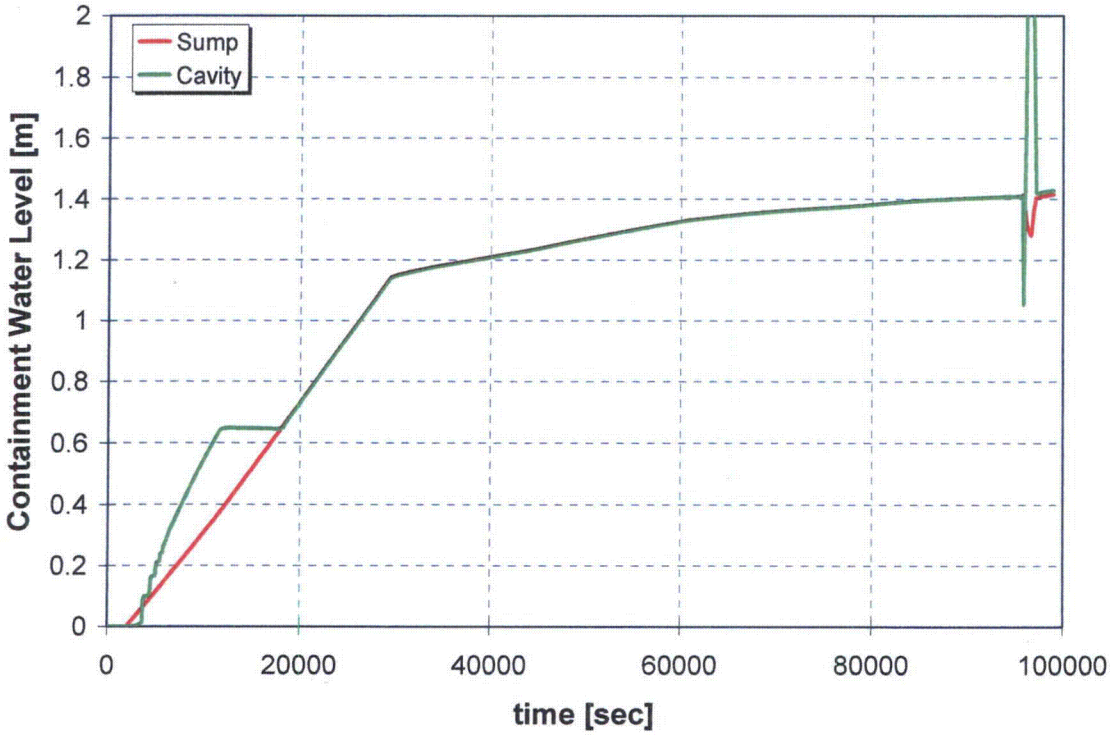
A.2.7 Case 7: 0.5-Inch Break LOCA without Sprays and PRZ PORV Not Stuck Open

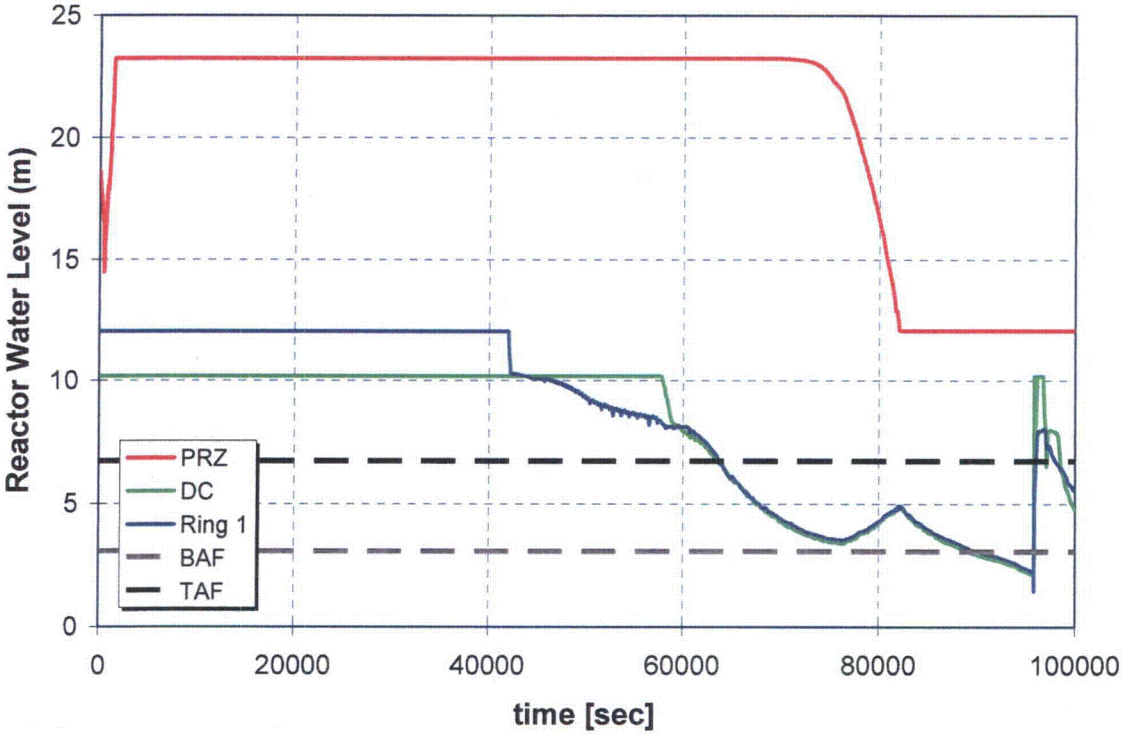


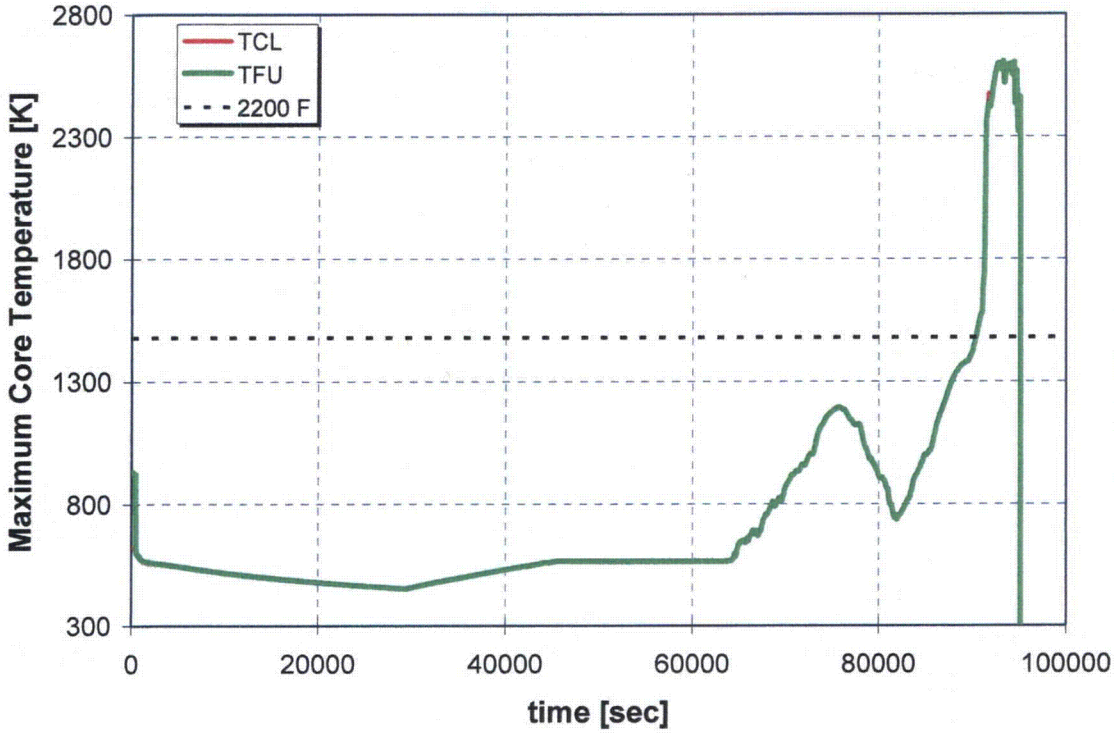



Total Flow (kg/s)
200
180
160
140
120
100
80
60
40
20
0
0
20000
40000
60000
80000
100000
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK+PORV

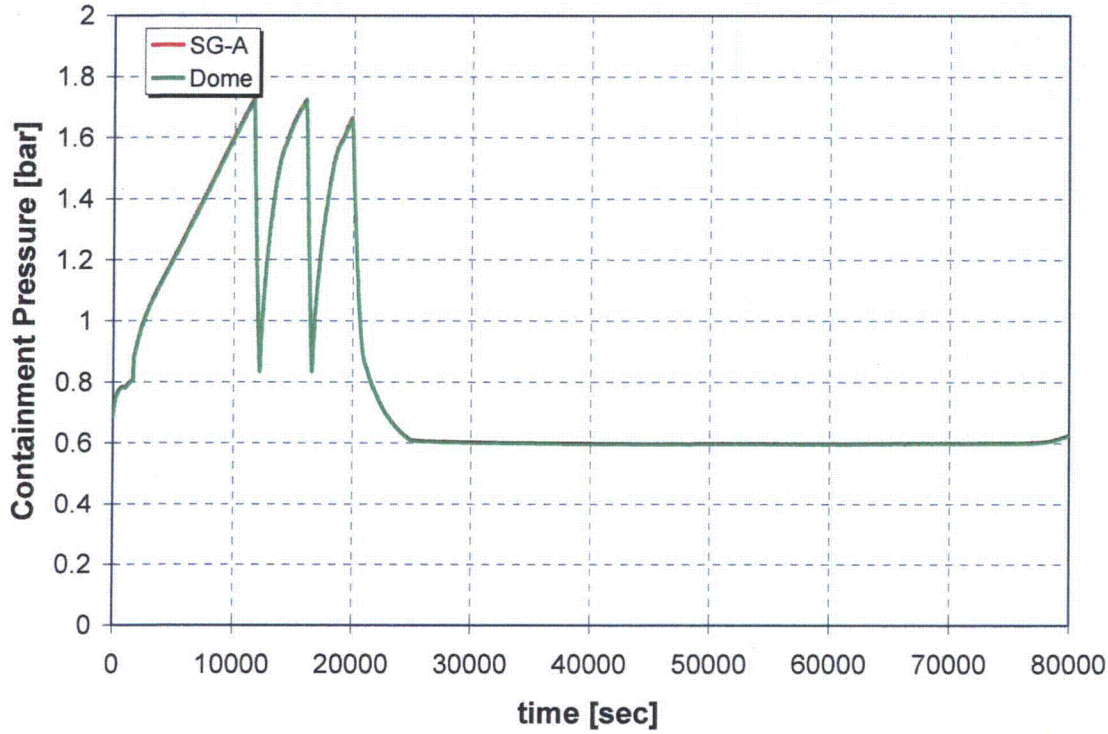

Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
20000
40000
60000
80000
100000
time [sec]
RWST
SPR
LHSI
HHSI

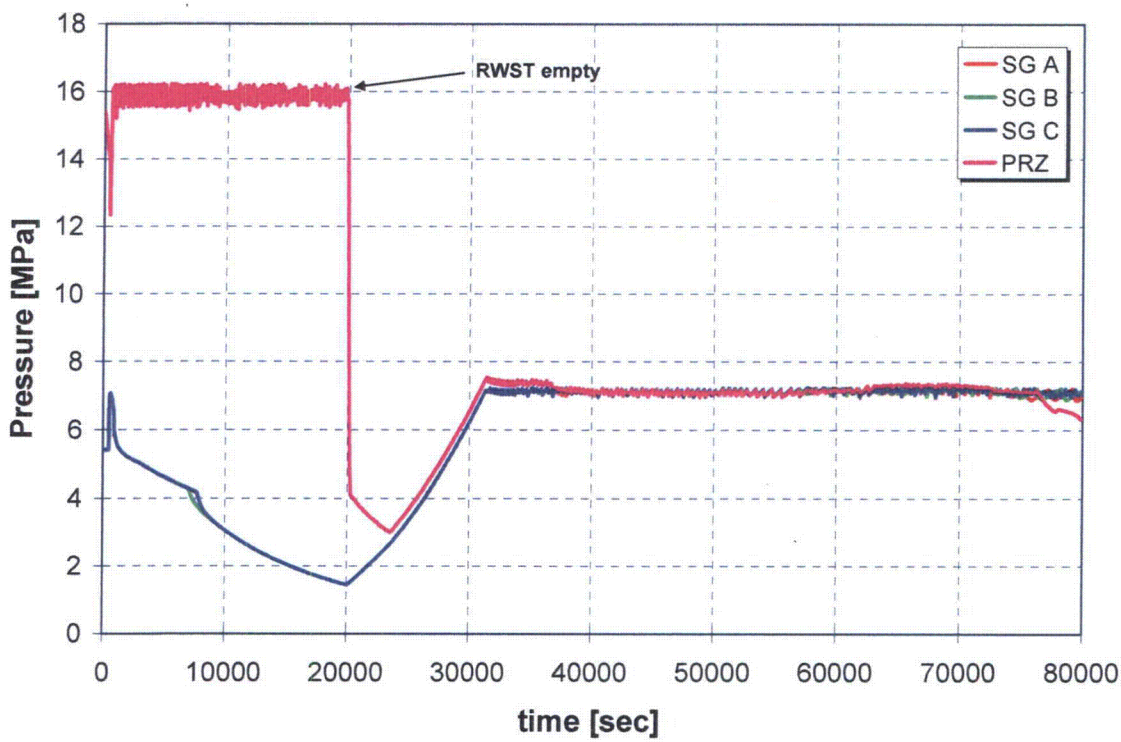

Sump
Cavity
Containment Water Level [m]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
20000
40000
60000
80000
100000
time [sec]

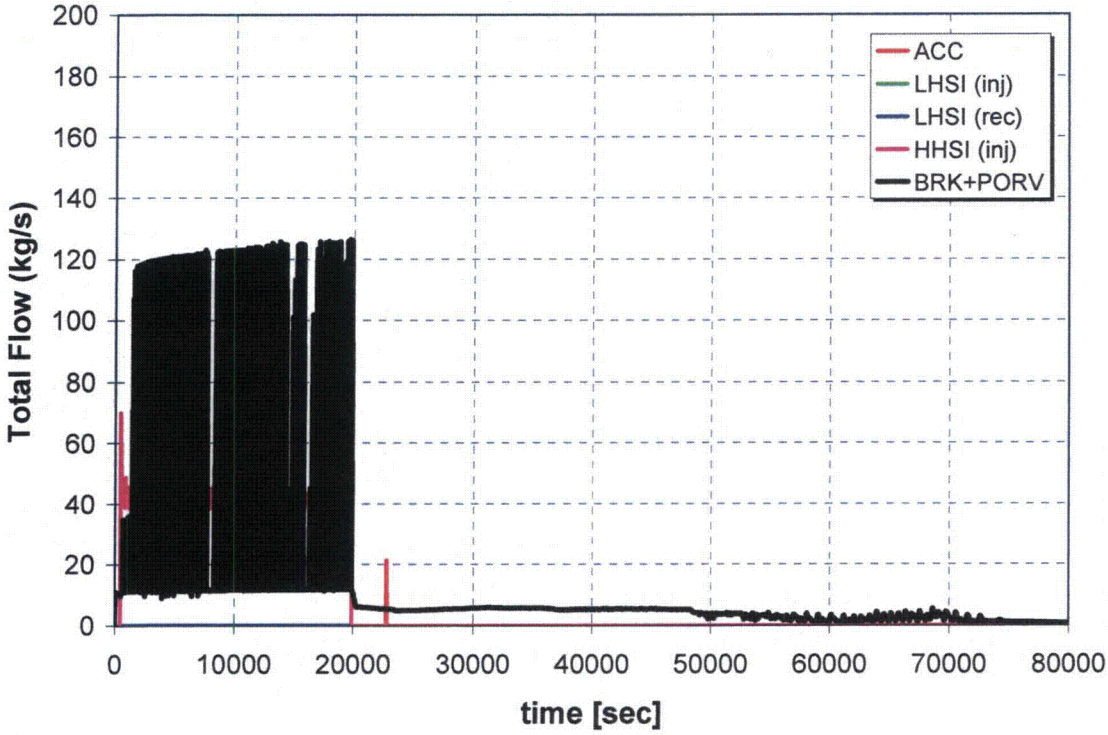

Reactor Water Level (m)
25
20
15
10
5
0
PRZ
DC
Ring 1
BAF
TAF
0
20000
40000
60000
80000
100000
time [sec]

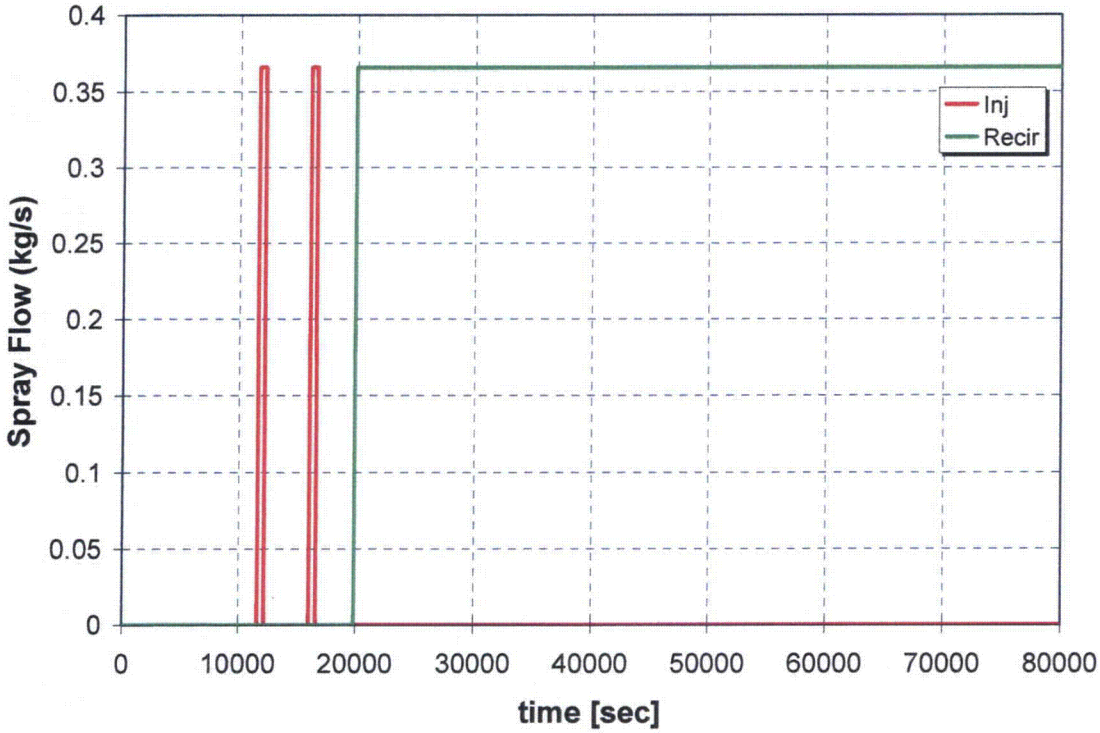

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
20000
40000
60000
80000
100000
time [sec]

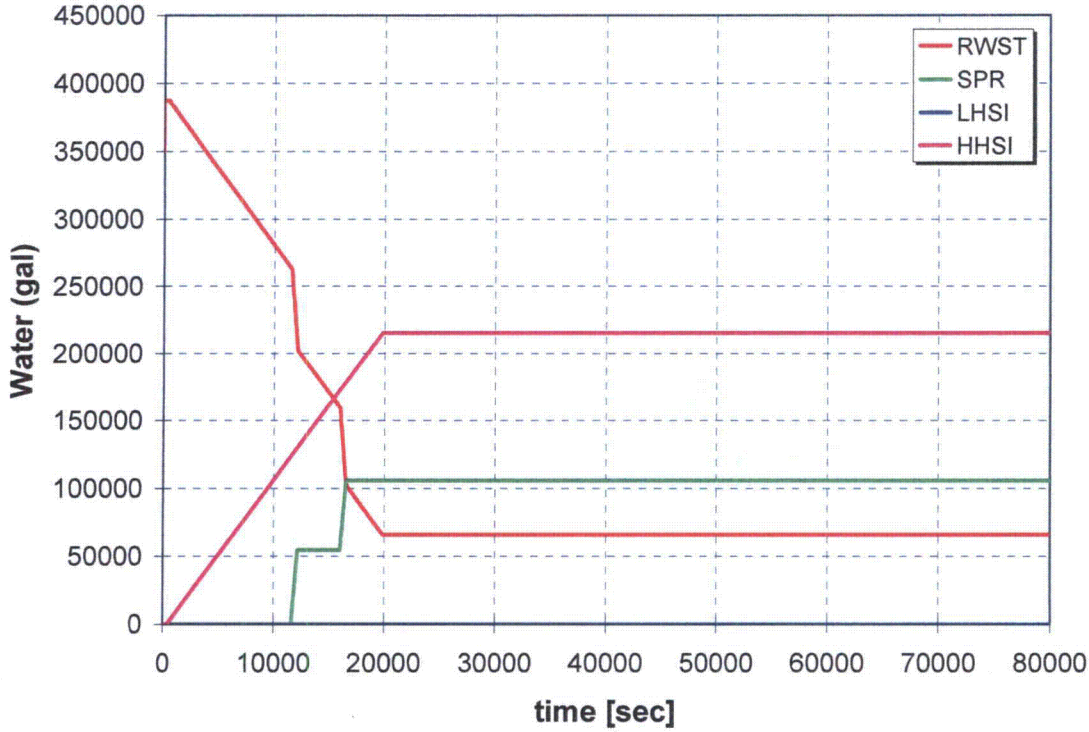
A.2.8 Case 8: 0.5-Inch Break LOCA with Sprays and PRZ PORV Not Stuck Open

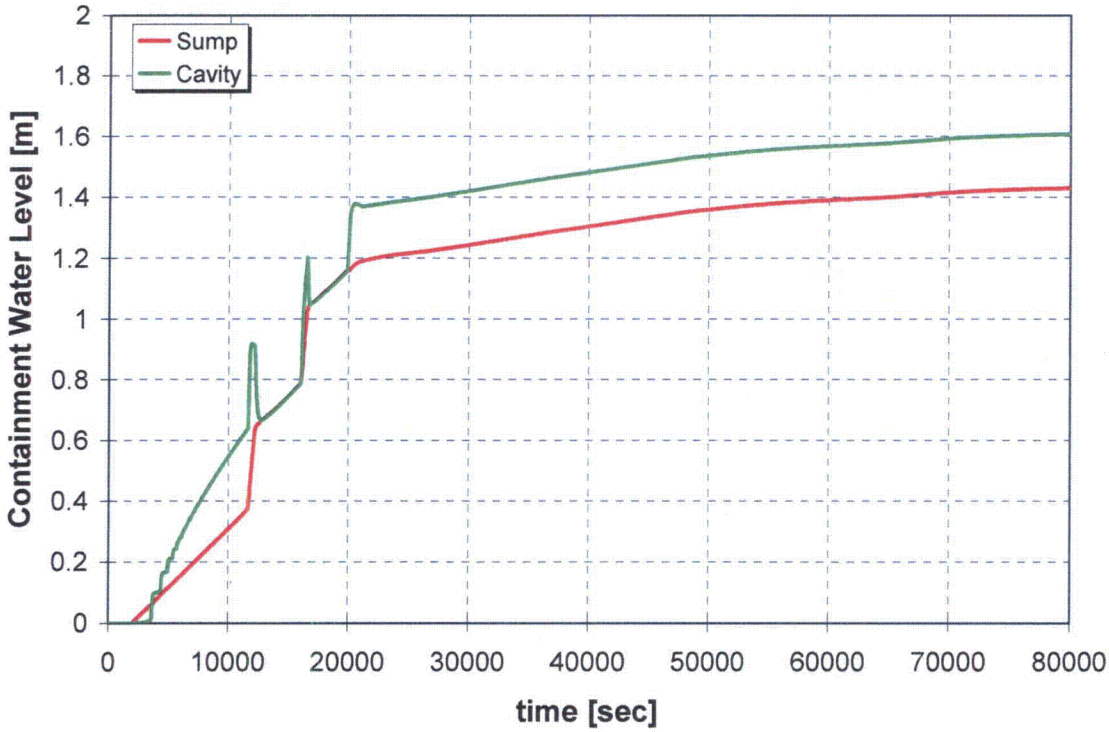


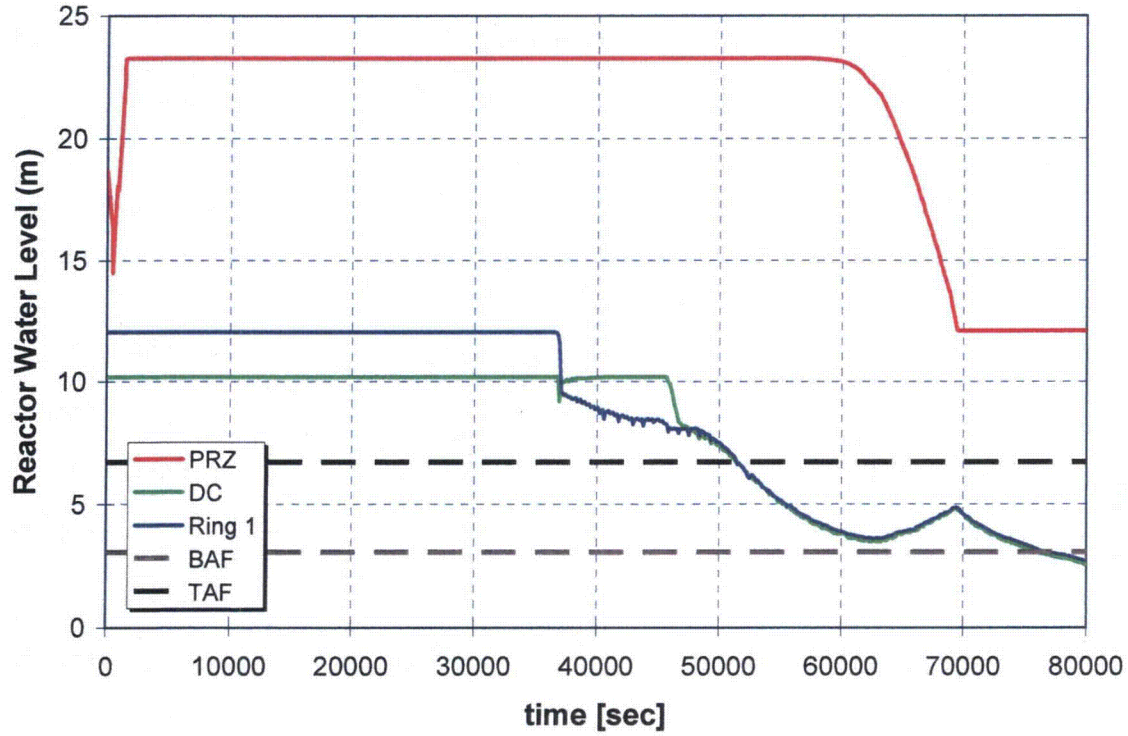


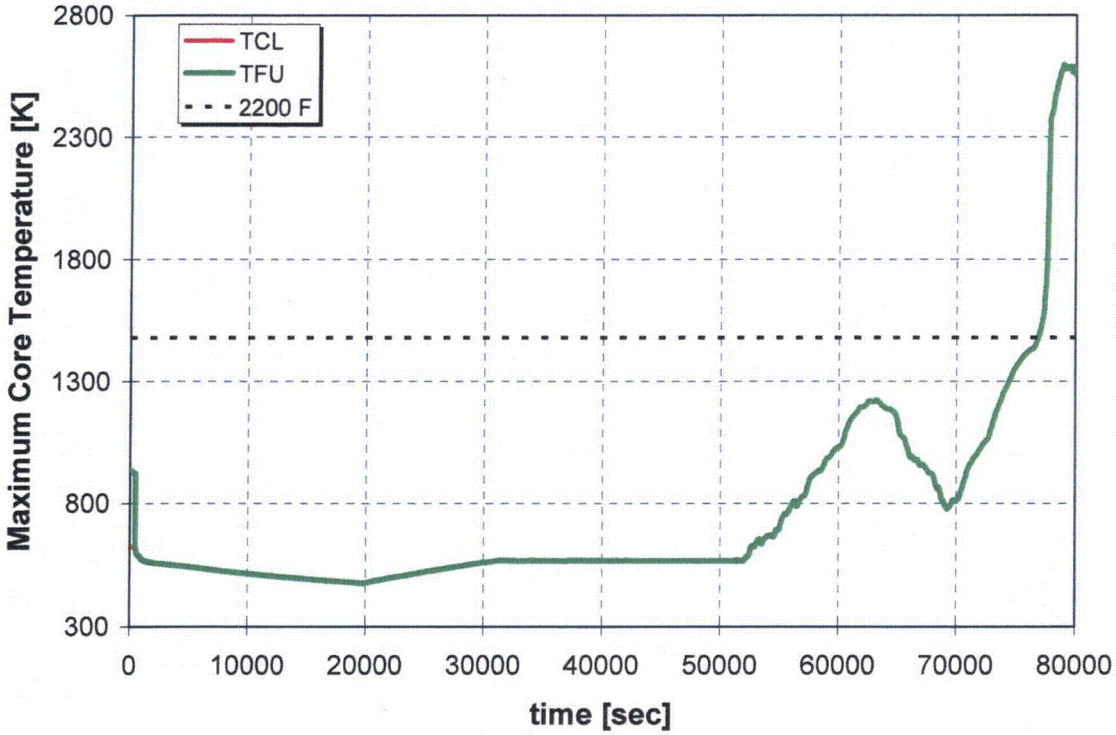

Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK+PORV
0
20
40
60
80
100
120
140
160
180
200
0
10000
20000
30000
40000
50000
60000
70000
80000


Spray Flow (kg/s)
time [sec]
Inj
Recir
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
10000
20000
30000
40000
50000
60000
70000
80000


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
10000
20000
30000
40000
50000
60000
70000
80000
time [sec]
RWST
SPR
LHSI
HHSI


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Containment Water Level [m]
0
10000
20000
30000
40000
50000
60000
70000
80000
time [sec]
Sump
Cavity


Reactor Water Level (m)
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
70000
80000
time [sec]
PRZ
DC
Ring 1
BAF
TAF


Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
10000
20000
30000
40000
50000
60000
70000
80000
time [sec]
TCL
TFU
2200 F

A.3 Feed-and-Bleed PORV Success Criteria

Analysis Summary

Table 8 and Table 9 below provide results for this portion of the analysis.

Table 8 Surry Feed-and-Bleed PORV Success Criteria Results

Case	Power Level[1]	Cause of Reactor Trip[2]	Cause of SI	# HHSI Pumps	# of Pressurizer PORVs	Core Uncovery	Core Damage
1	Nominal	MFW trip	High Cont. Press.	1	1	No[3]	No[3]
2		Low SG level + feed/steam mismatch				No[3]	No[3]
3	113.9%	Low-low SG level				No[3]	No[3]

1 Nominal equals 2,546 MWt (Surry) and 113.9% equals 2,900 MWt (Beaver Valley, Harris, and Summer); 2,900 MWt is the highest present power level of the three-loop Westinghouse plants.

2 Low SG level is < 19% of narrow-range span, while low-low SG level is < 16% of narrow-range span, based on Technical Specification 2.3-3 [NRC, 2003].

3 Core uncovery and damage late in the simulation are artifacts of the assumed unavailability of HHSI recirculation.

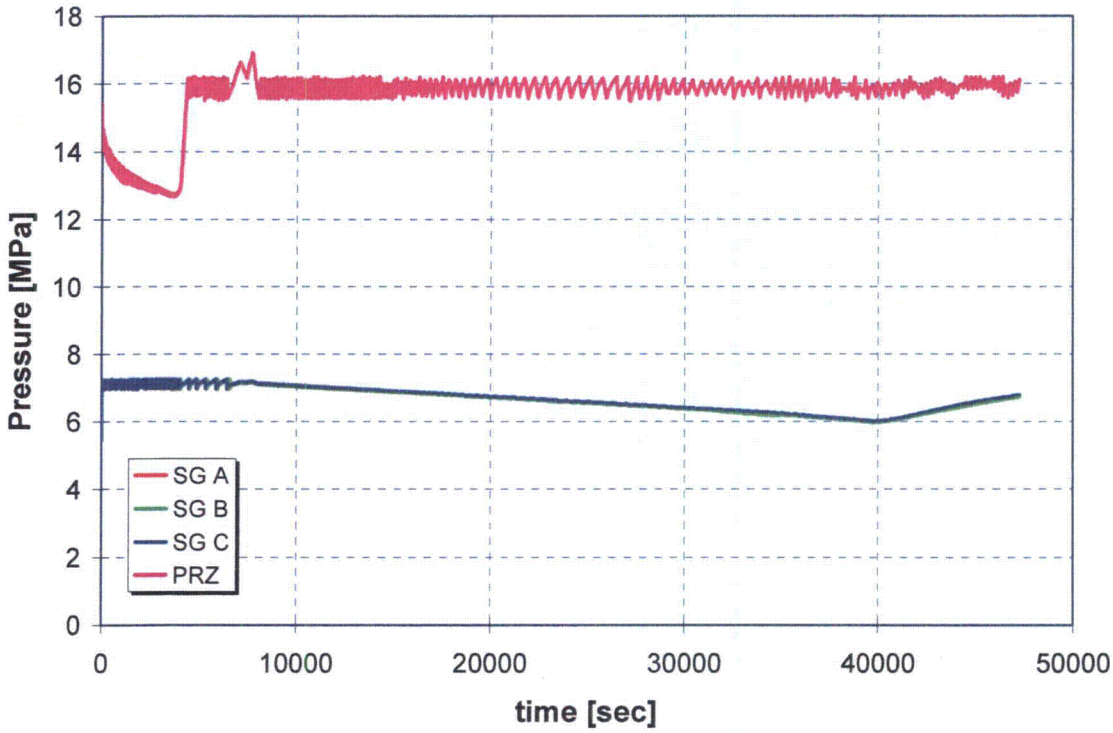
Table 9 Surry Feed-and-Bleed PORV Success Criteria Key Timings

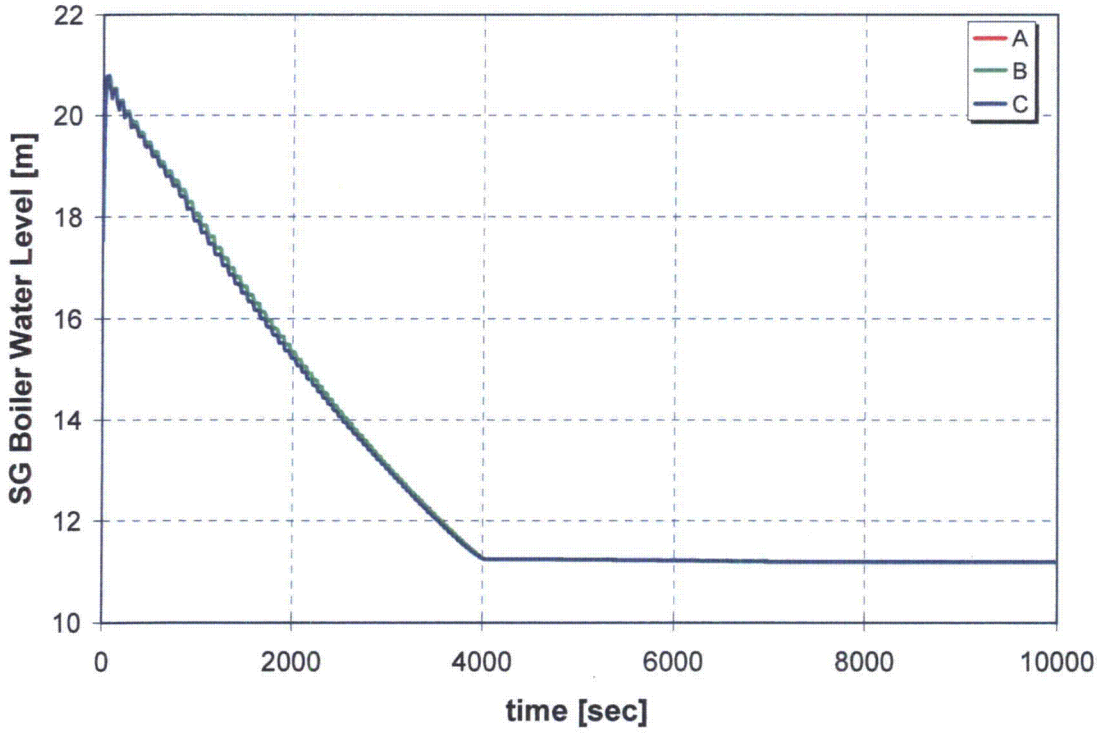
Event[1]	Case 1 (hr)	Case 2 (hr)	Case 3 (hr)
MFW, MD-AFW, TD-AFW unavailable	0	0	0
Reactor trip	0	0.008 (29 s)	0.008 (27 s)
Steam generator dryout	1.11	0.63	0.58
PRT rupture disk open	1.56	0.97	0.93
SI signal (containment pressure > 1.22 bars)	1.96	1.36	1.29
MCP trip (10% void)	2.05	1.43	1.35
First actuation of containment sprays (containment pressure > 1.72 bars)	3.84	3.24	3.17
RWST depletion (< 13.5%)	9.43	8.35	8.24
Core uncovery	10.90[2]	1.65 / 9.54[2]	1.60 / 9.42[2]
Core damage (max temp > 2,200 °F)	13.53	11.80	11.68

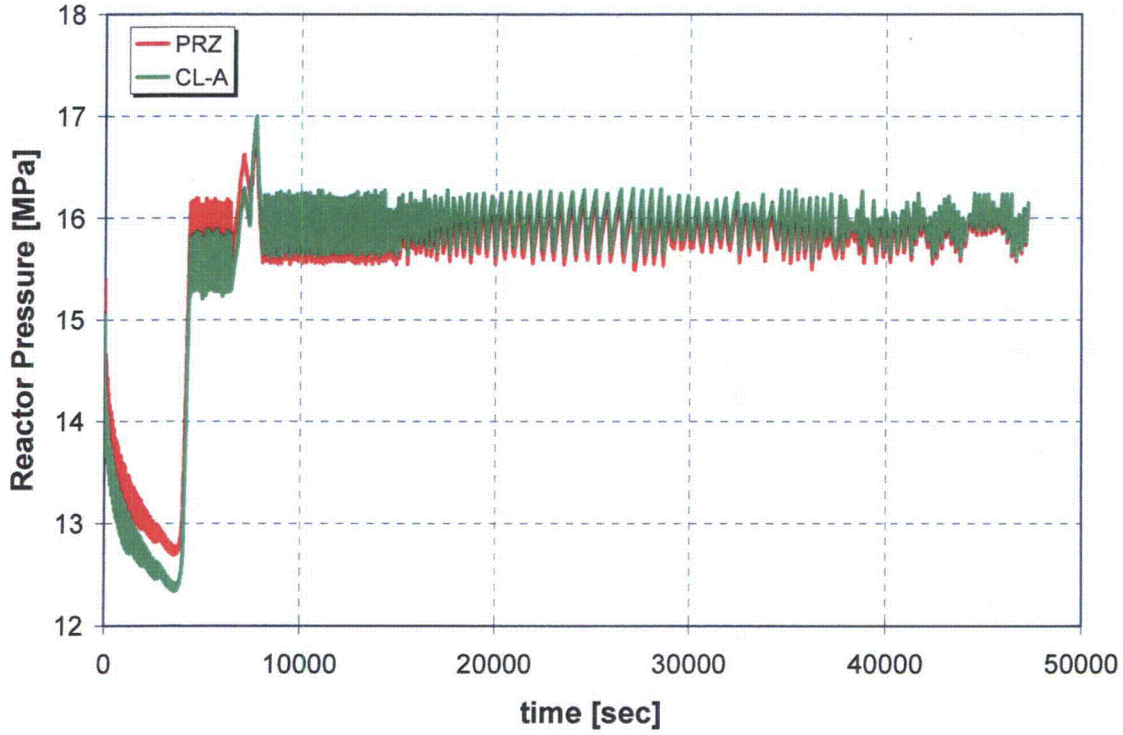
1 1.22 bars = 0.122 MPa; 1.72 bars = 0.172 MPa; 2,200 °F = 1,204 °C.

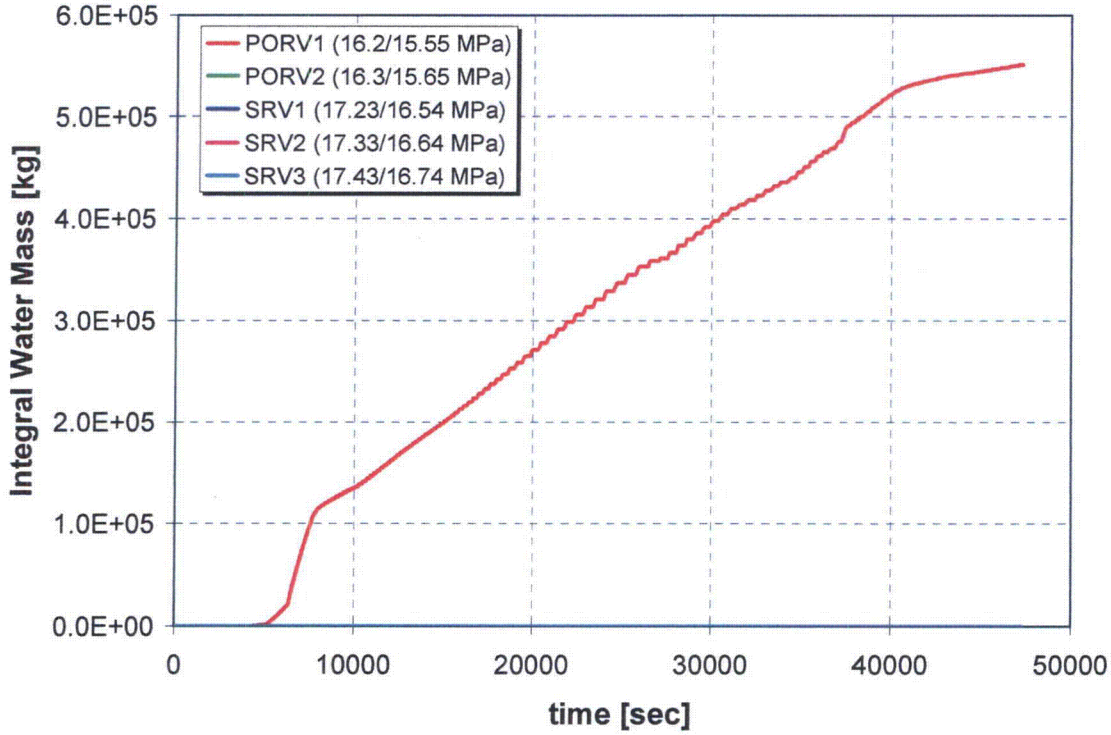
2 For Case 1, the core comes close to uncovering around the time of SI actuation, and then later does uncover after the loss of HHSI. For Cases 2 and 3, the core uncovers early in the accident, recovers prior to significant heatup, and later uncovers again (due to the loss of HHSI).

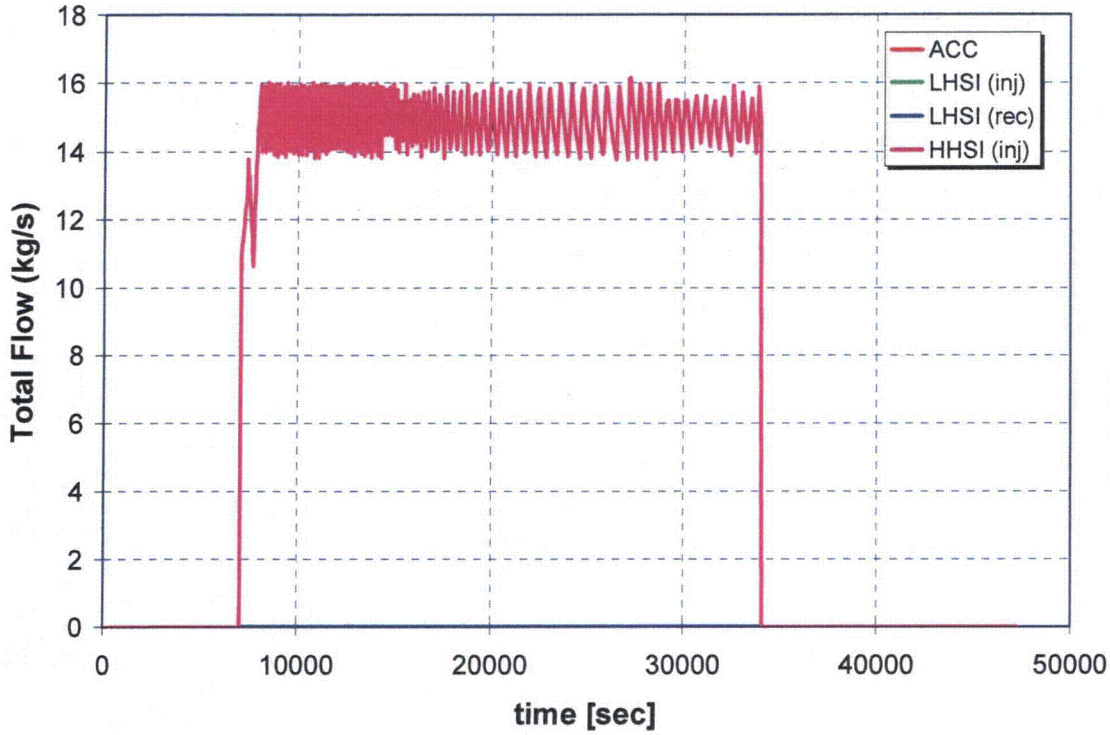
A.3.1 Case 1: Nominal Power, Reactor Trip at Time Equals Zero

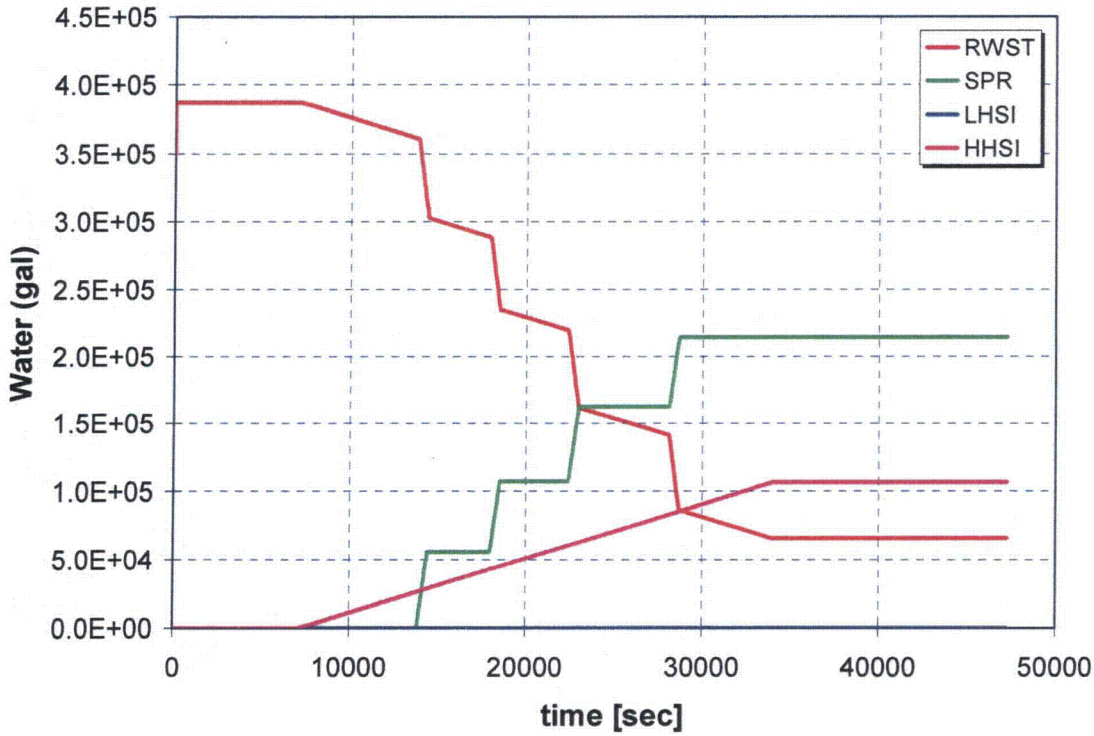


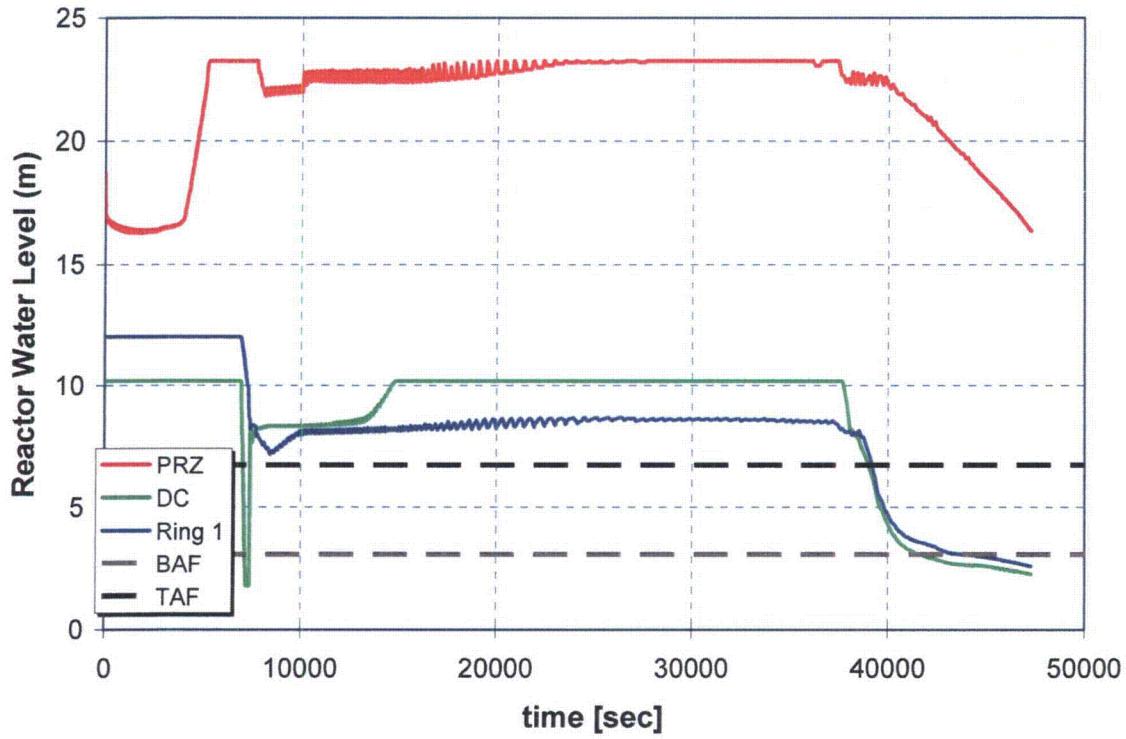


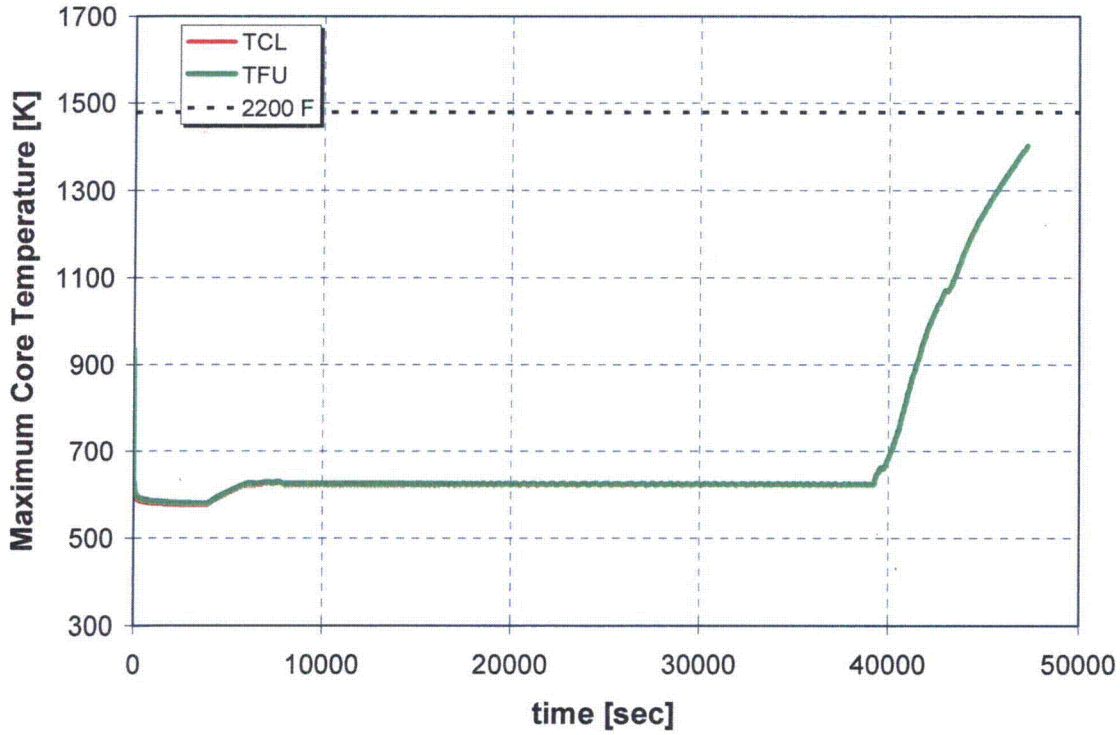

PRZ
CL-A
Reactor Pressure [MPa]
18
17
16
15
14
13
12
0
10000
20000
30000
40000
50000
time [sec]

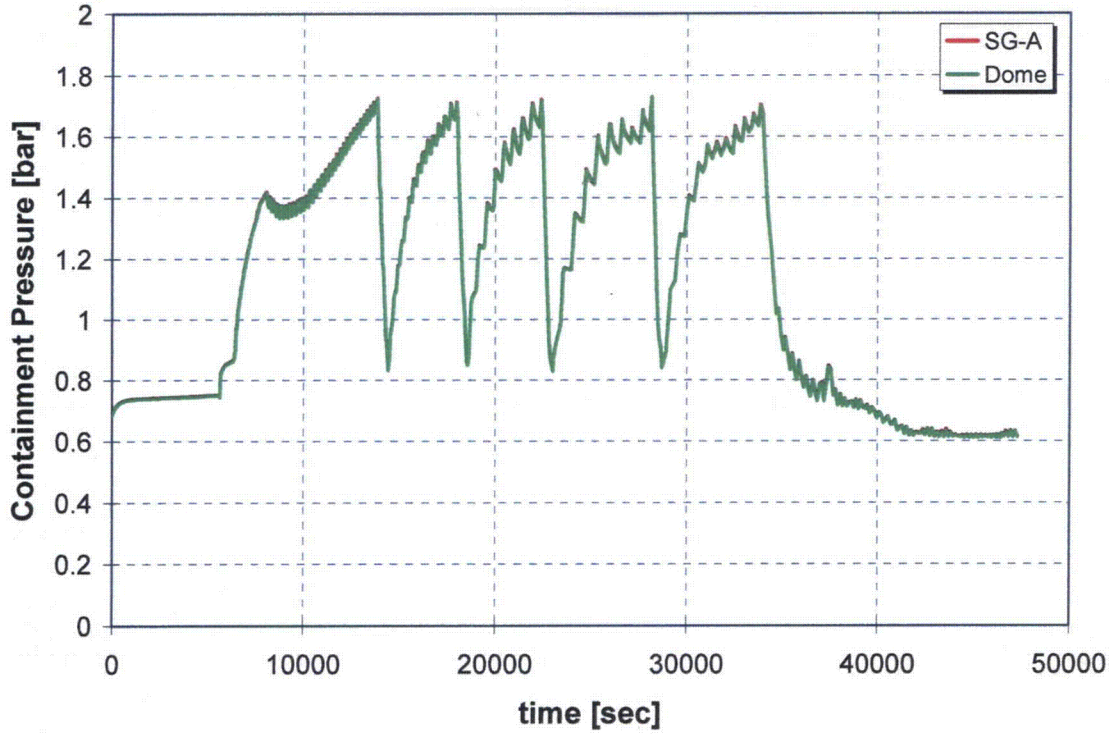

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
6.0E+05
5.0E+05
4.0E+05
3.0E+05
2.0E+05
1.0E+05
0.0E+00
0
10000
20000
30000
40000
50000
time [sec]

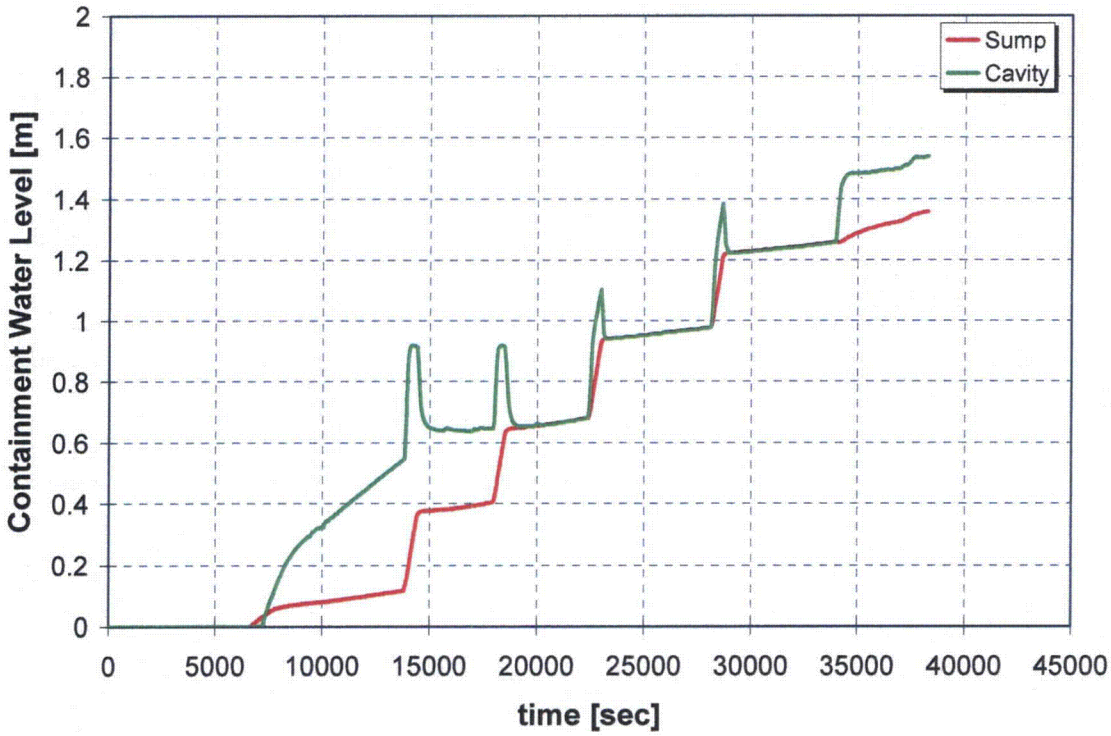

Total Flow (kg/s)
18
16
14
12
10
8
6
4
2
0
0
10000
20000
30000
40000
50000
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)


Water (gal)
4.5E+05
4.0E+05
3.5E+05
3.0E+05
2.5E+05
2.0E+05
1.5E+05
1.0E+05
5.0E+04
0.0E+00
0
10000
20000
30000
40000
50000
time [sec]
RWST
SPR
LHSI
HHSI

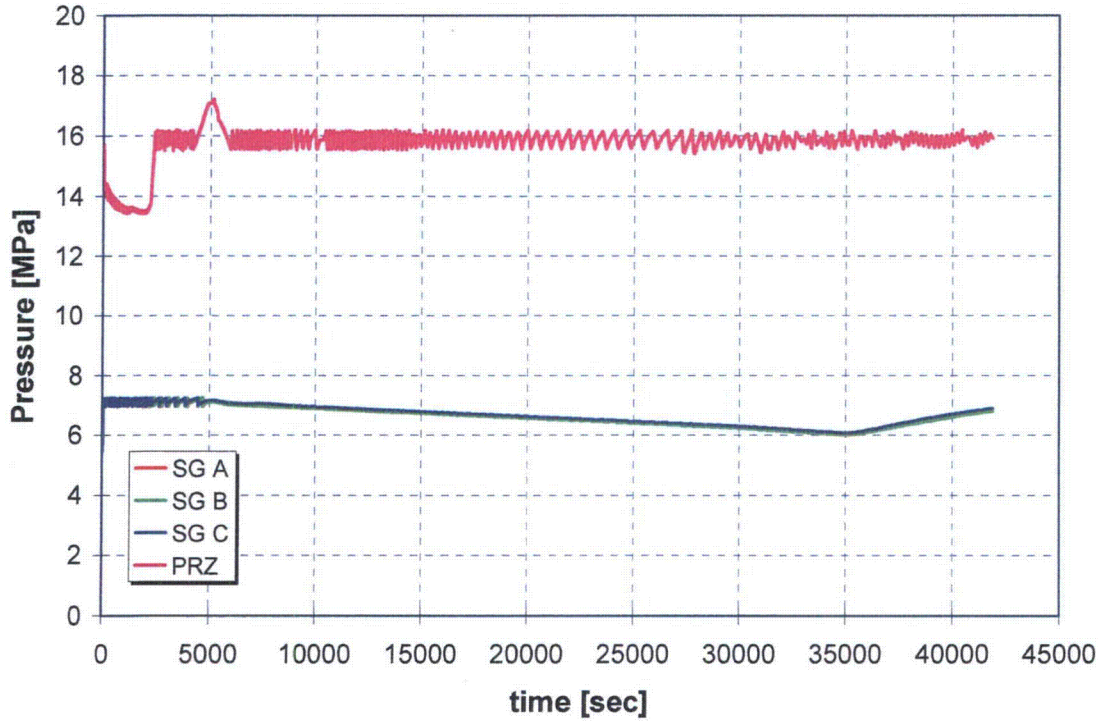

Reactor Water Level (m)
25
20
15
10
5
0
PRZ
DC
Ring 1
BAF
TAF
0
10000
20000
30000
40000
50000
time [sec]

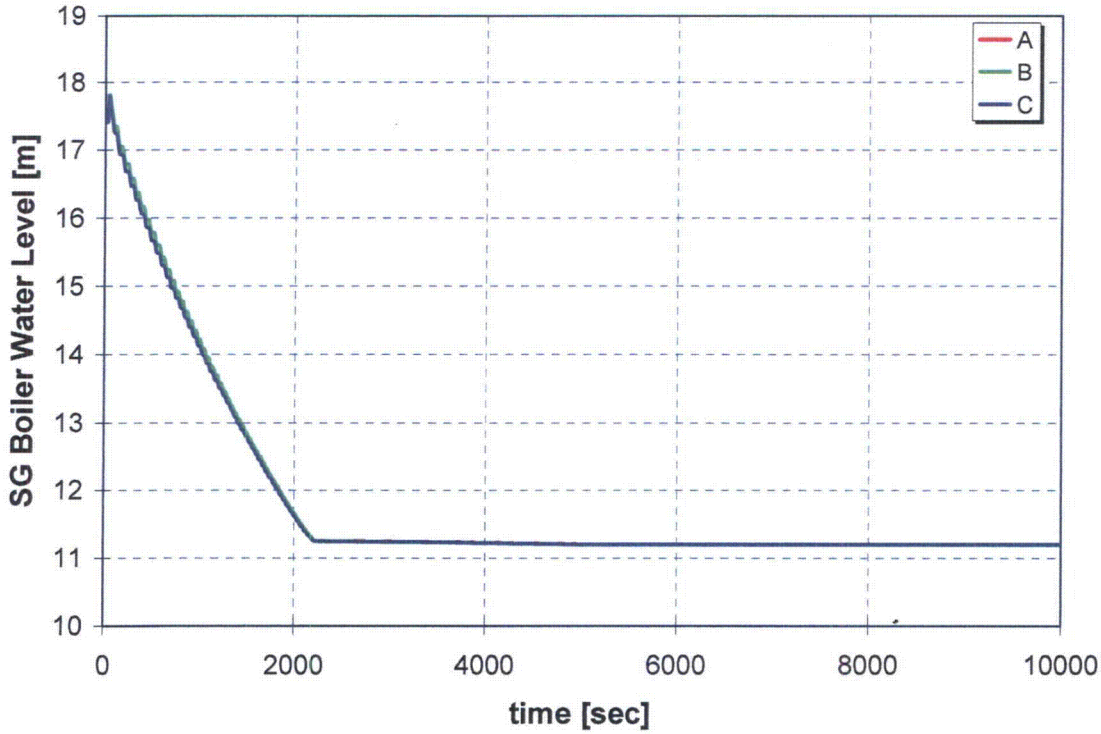

Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
TCL
TFU
2200 F
0
10000
20000
30000
40000
50000
time [sec]

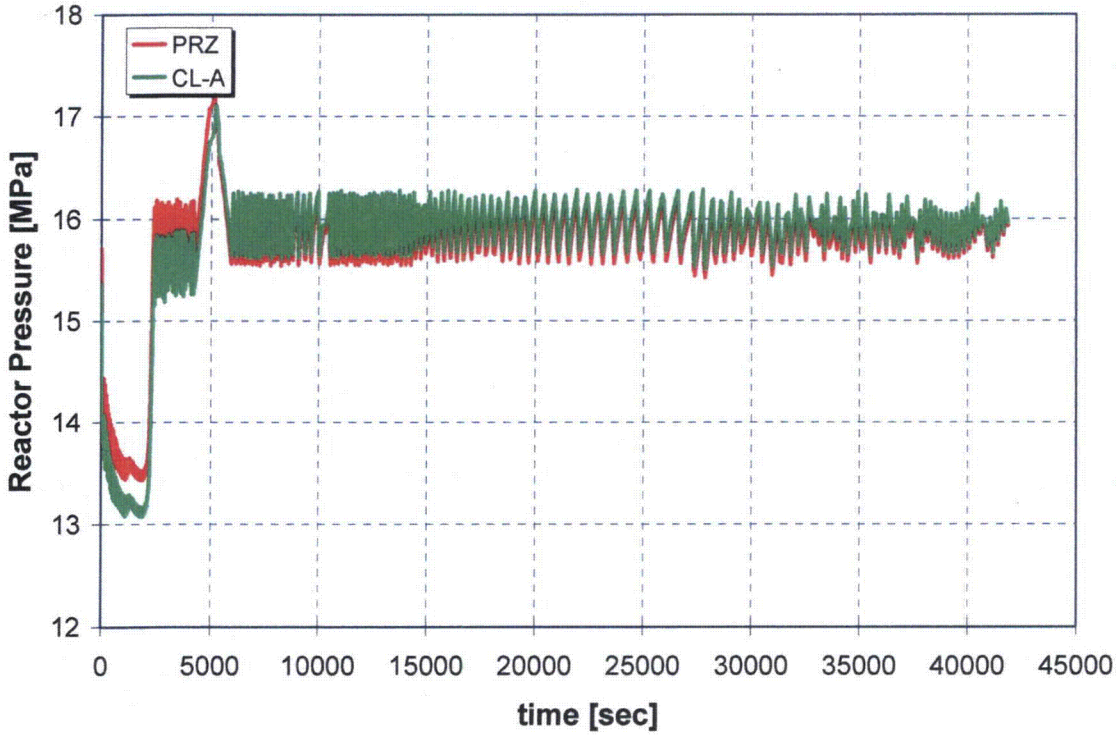

SG-A
Dome
Containment Pressure [bar]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10000
20000
30000
40000
50000

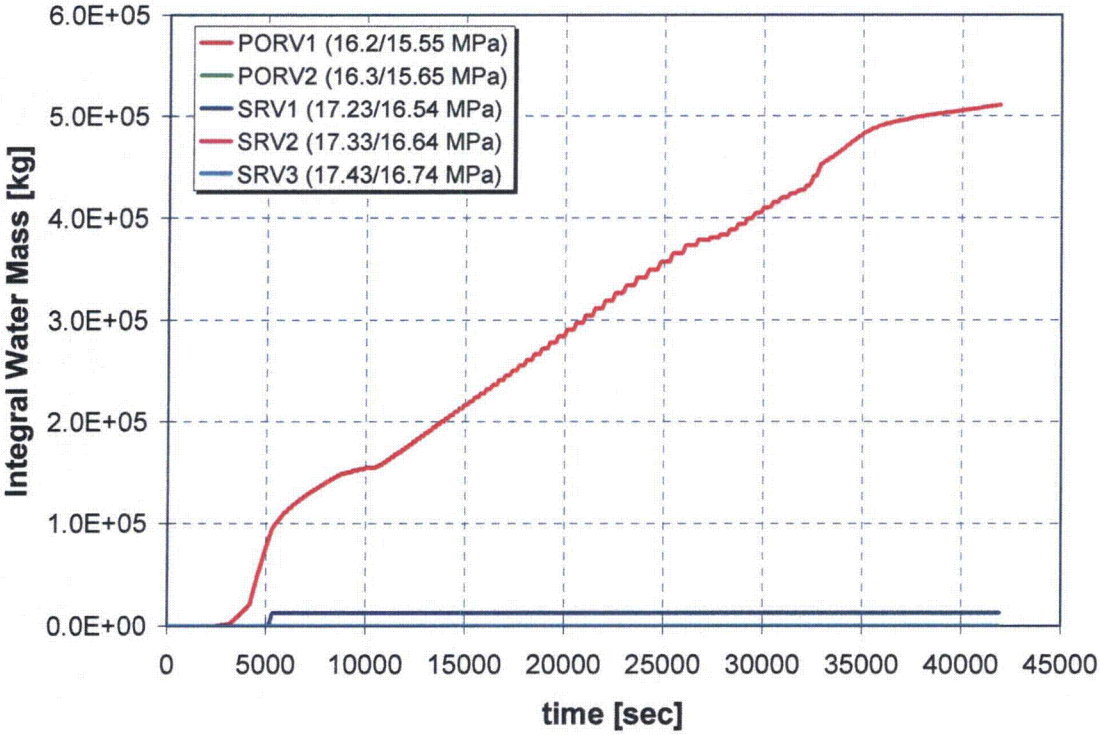

Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

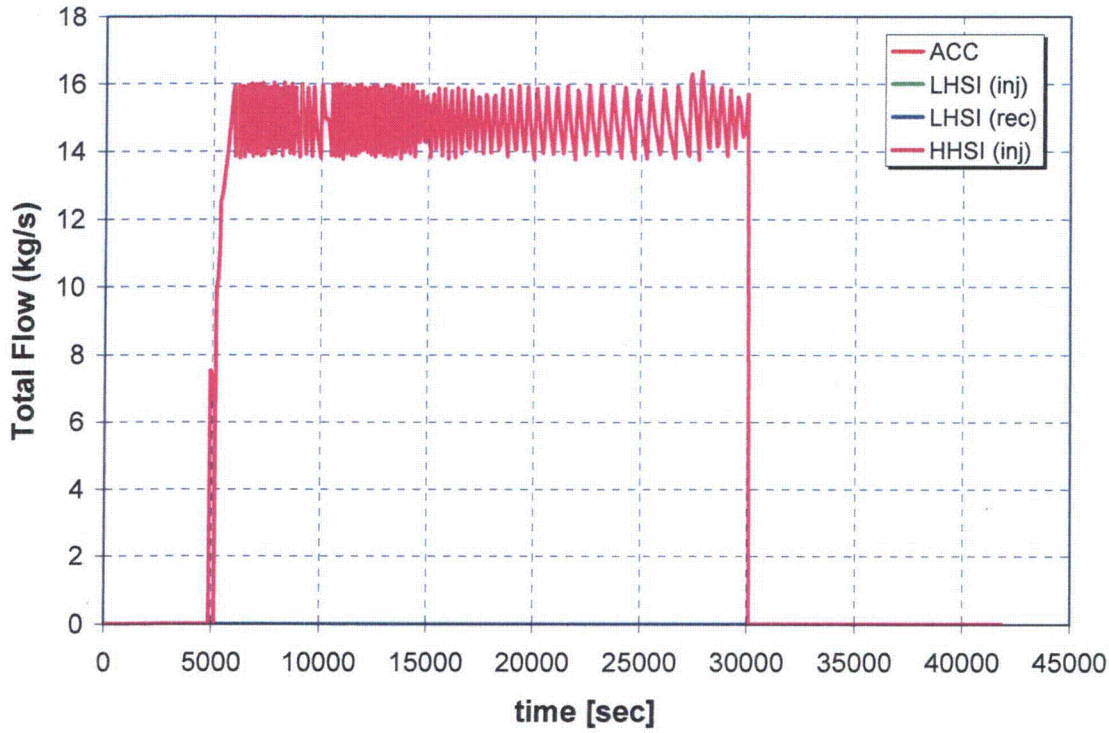
A.3.2 Case 2: Nominal Power, Anticipatory Reactor Trip

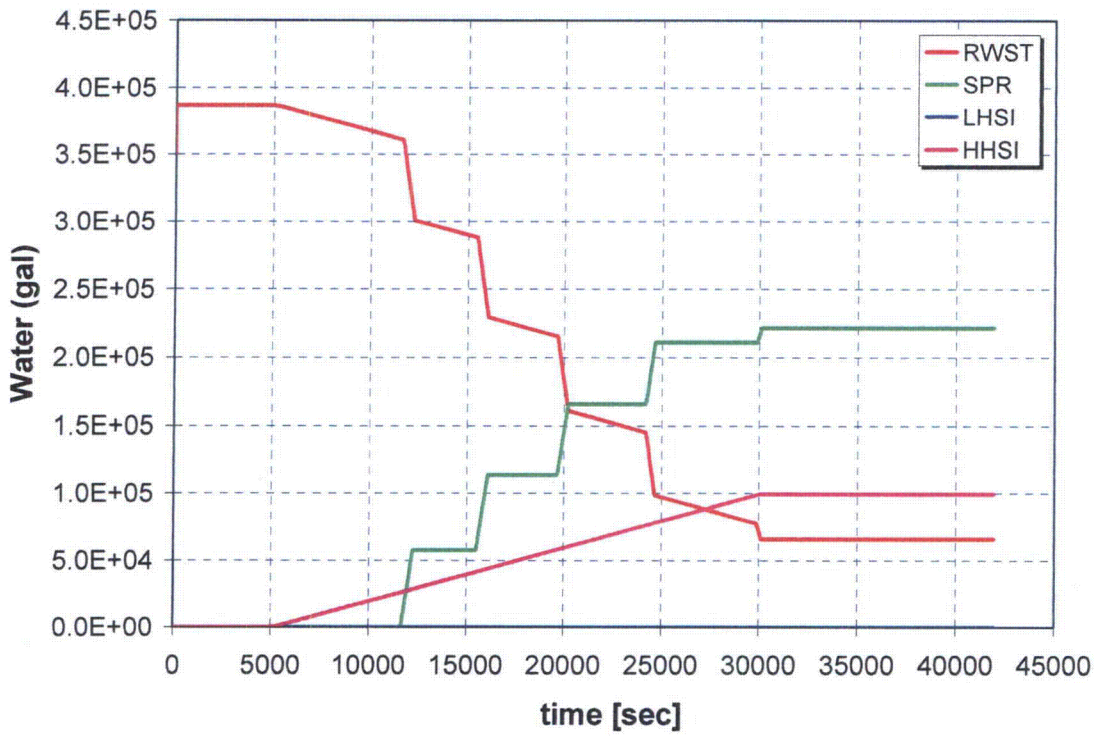


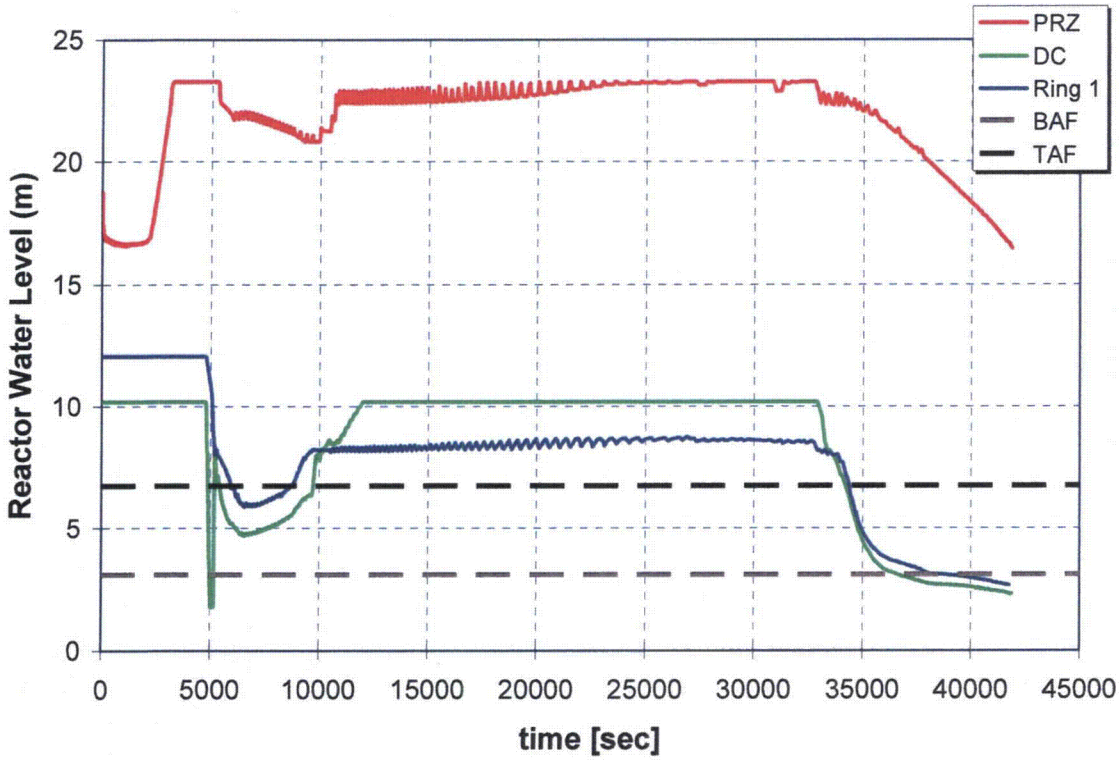


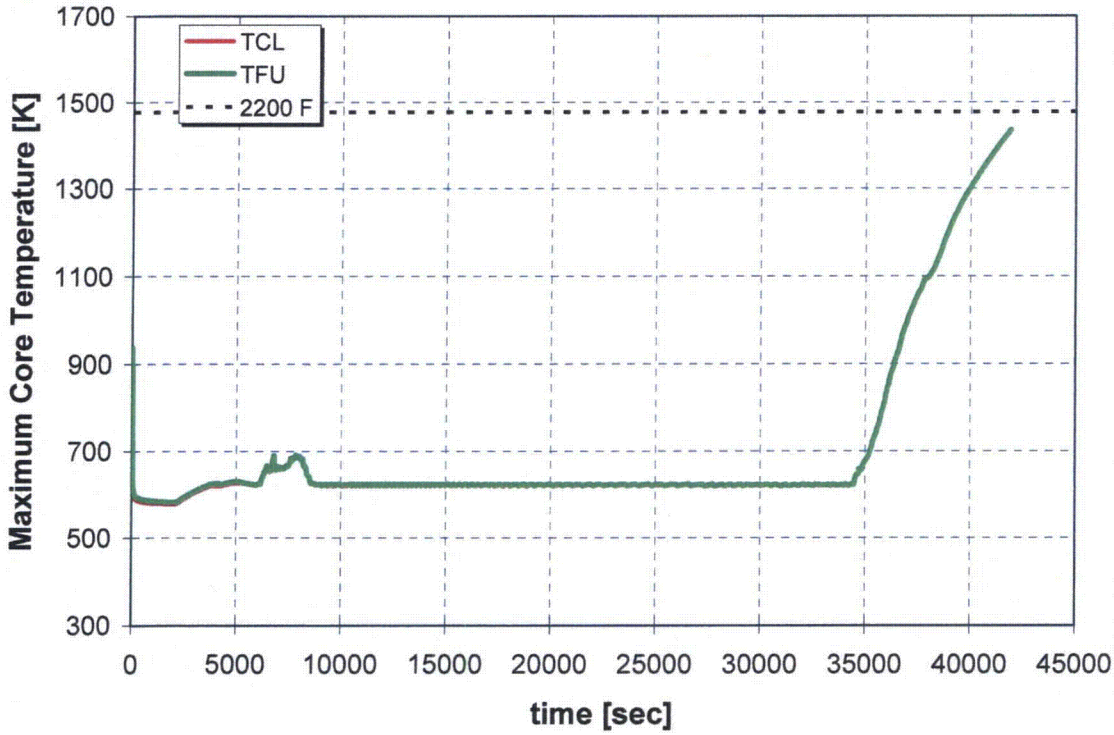

PRZ
CL-A
Reactor Pressure [MPa]
18
17
16
15
14
13
12
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

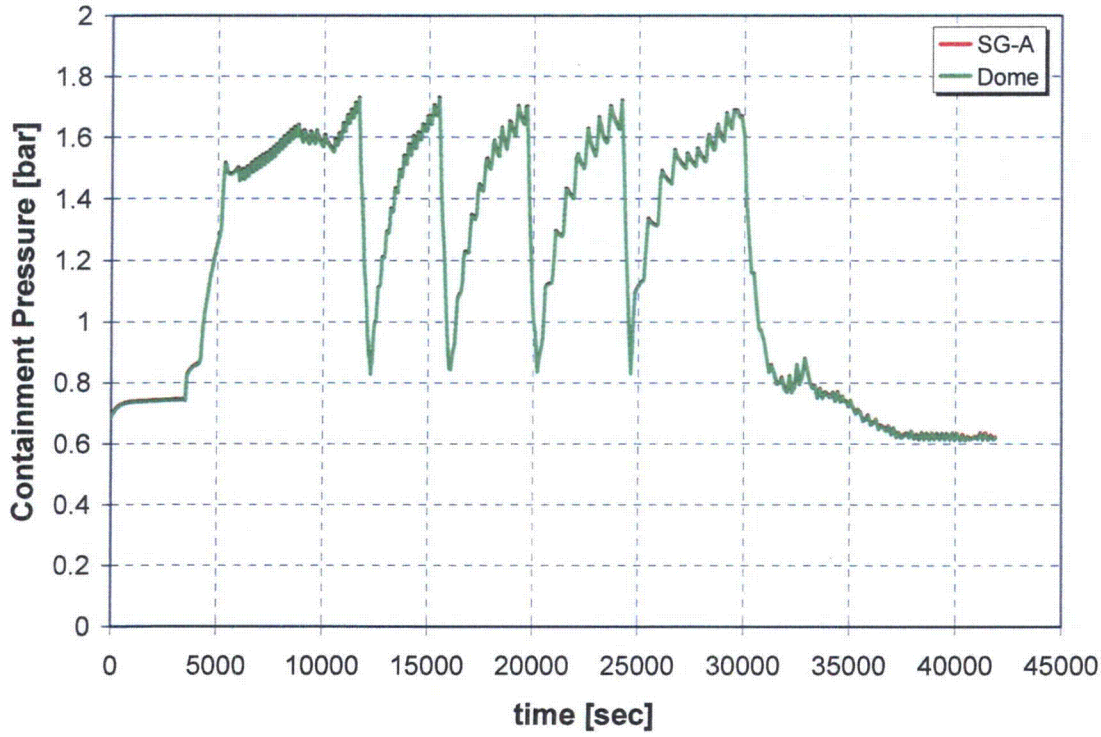

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
6.0E+05
5.0E+05
4.0E+05
3.0E+05
2.0E+05
1.0E+05
0.0E+00
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

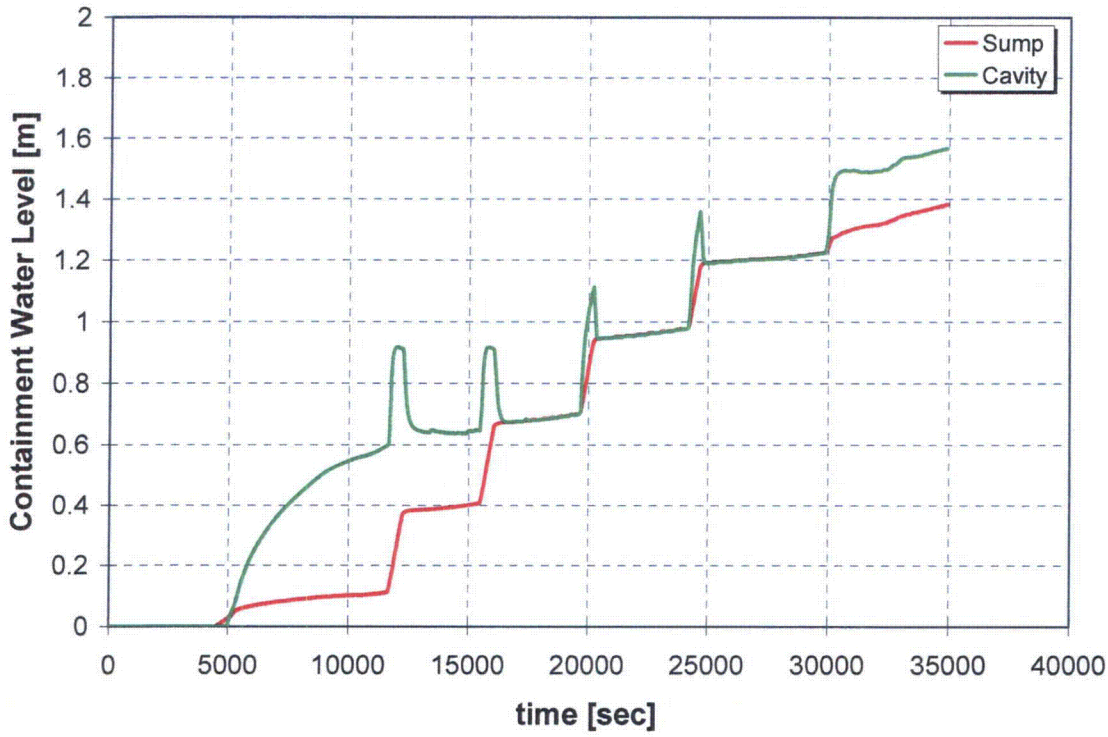

Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
0
2
4
6
8
10
12
14
16
18
0
5000
10000
15000
20000
25000
30000
35000
40000
45000


Water (gal)
time [sec]
RWST
SPR
LHSI
HHSI
0.0E+00
5.0E+04
1.0E+05
1.5E+05
2.0E+05
2.5E+05
3.0E+05
3.5E+05
4.0E+05
4.5E+05
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

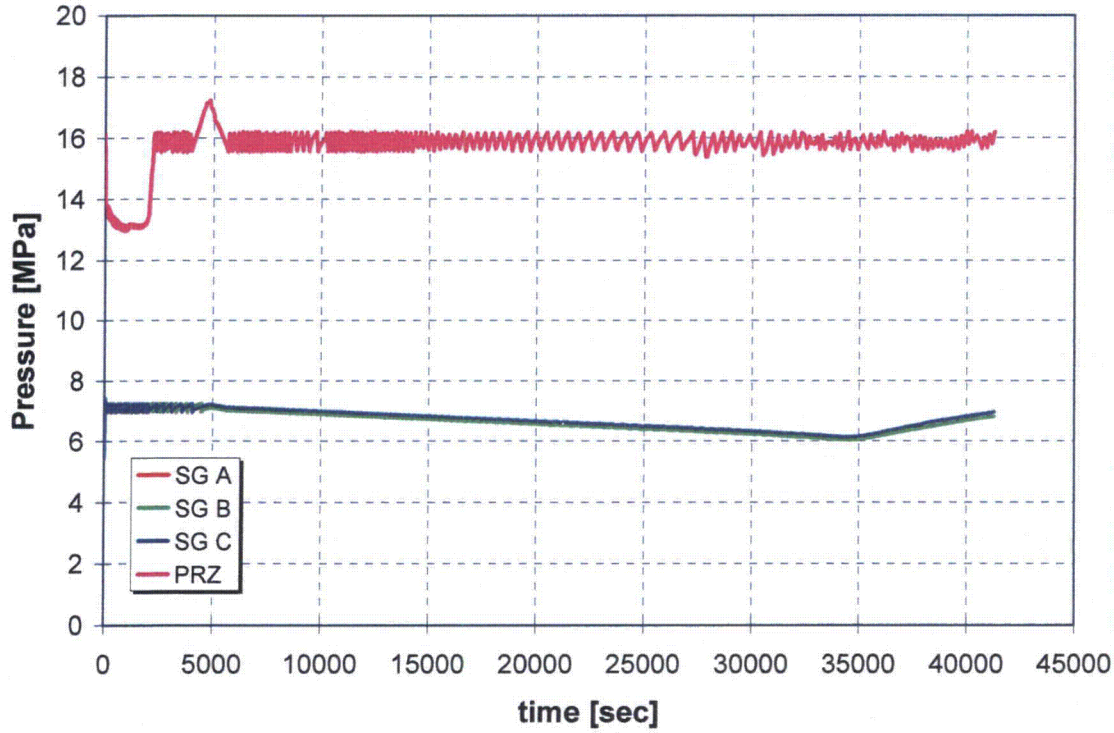

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

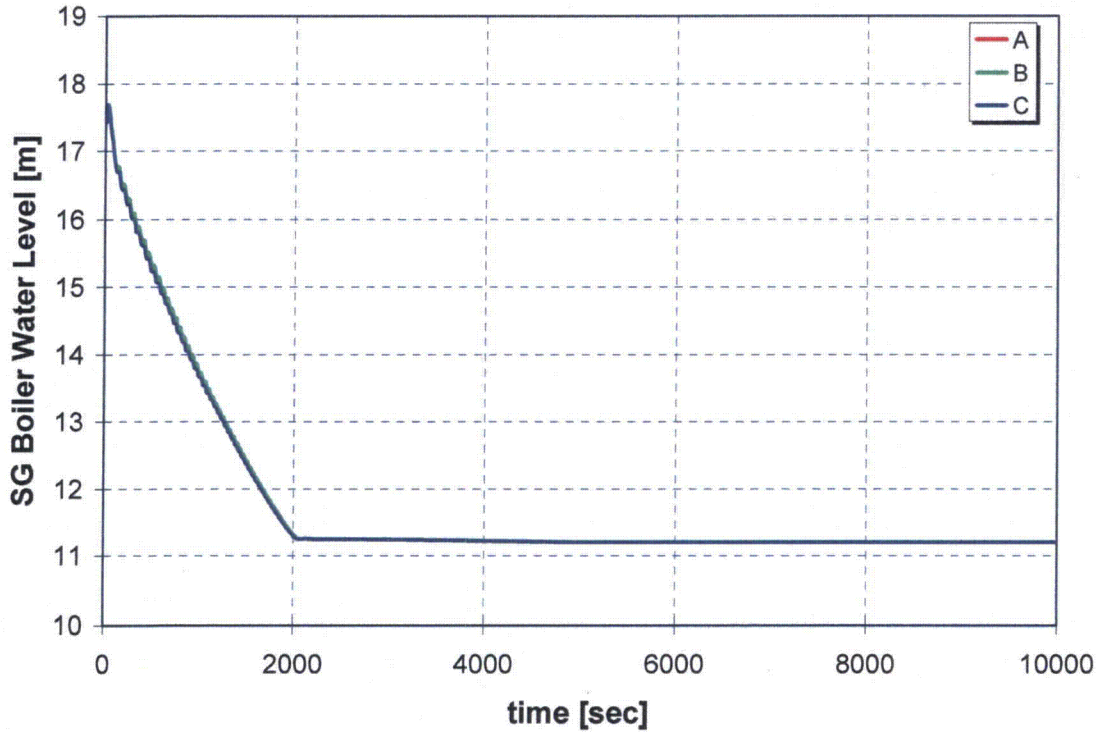

TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

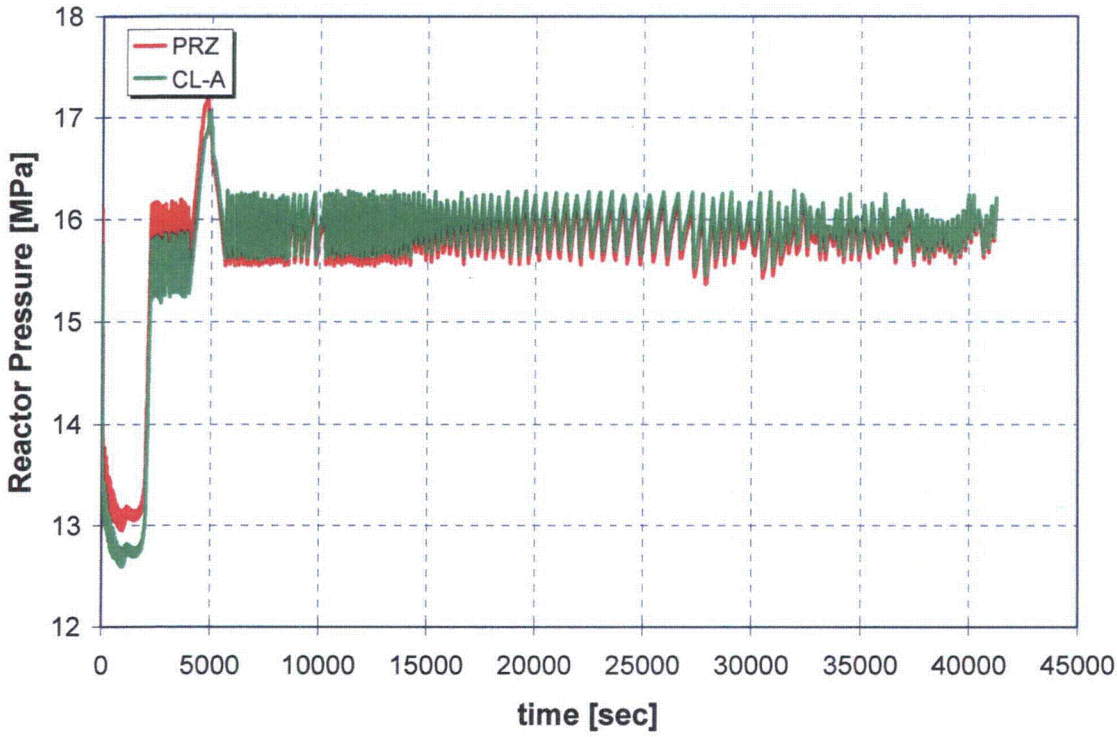

SG-A
Dome
Containment Pressure [bar]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

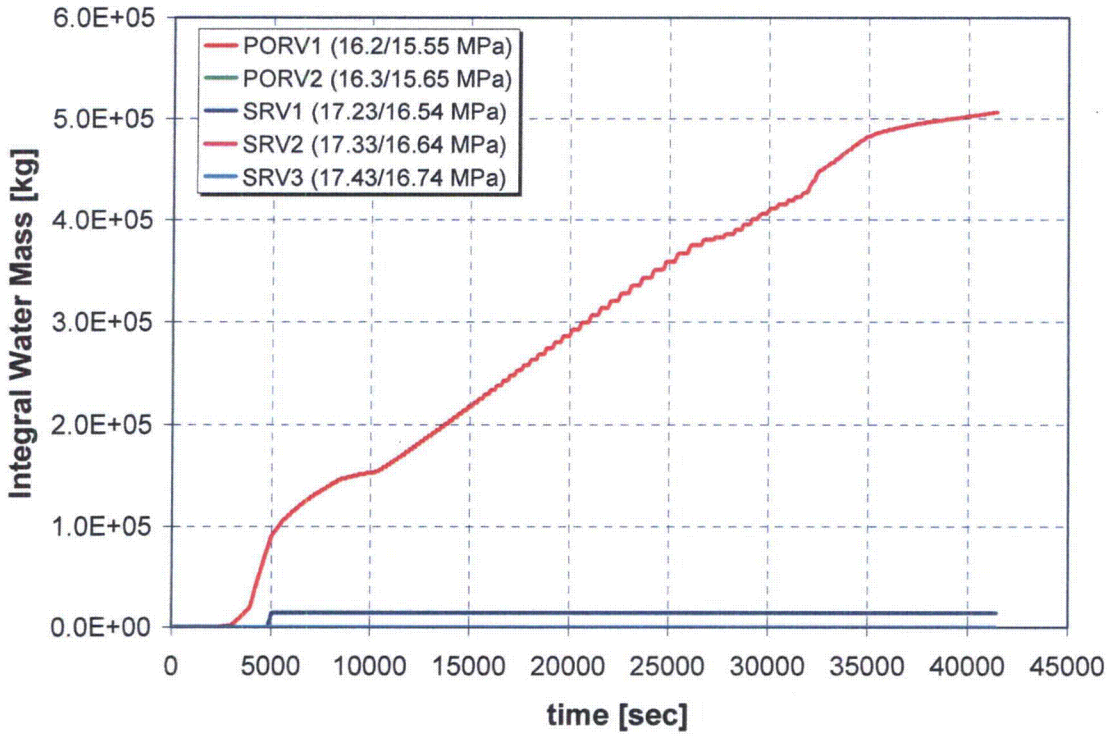

Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000

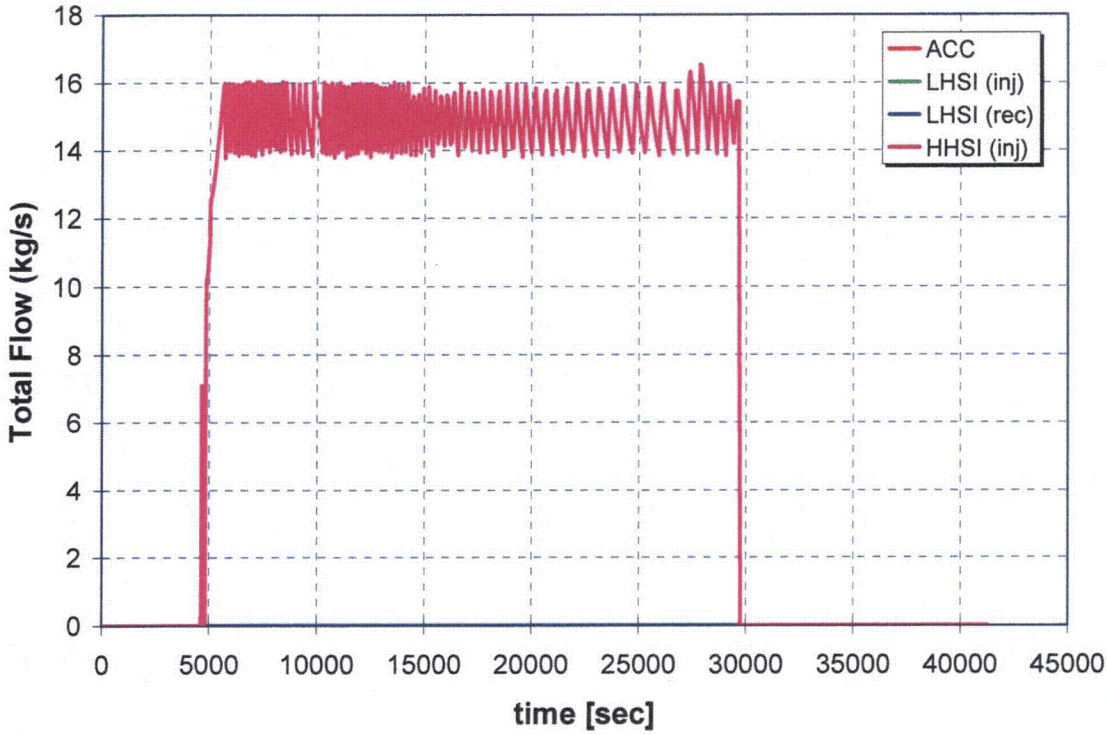
A.3.3 Case 3: 113.9 Percent Power Level, Reactor Trip on Low-Low SG Level

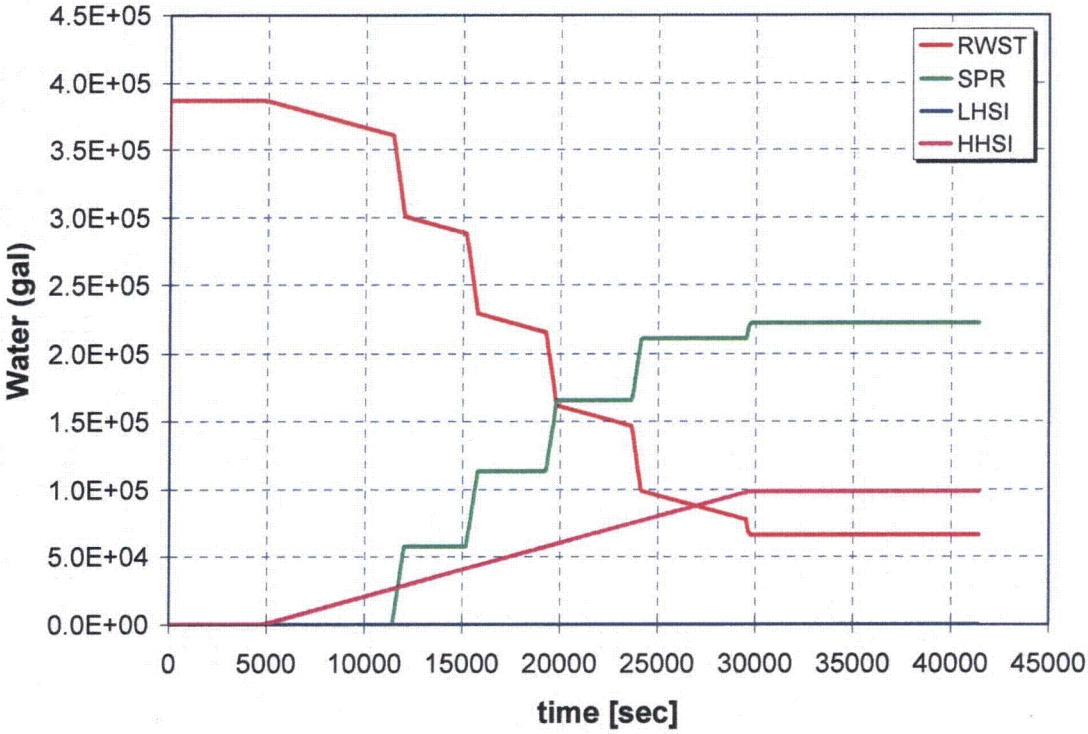


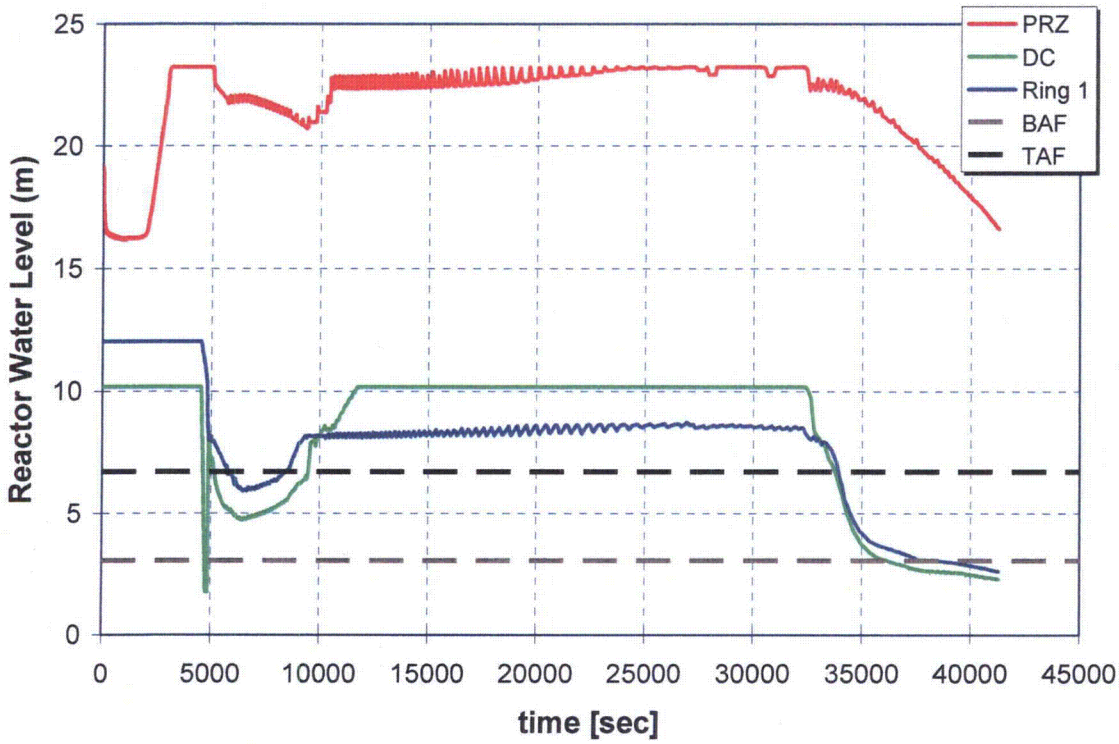


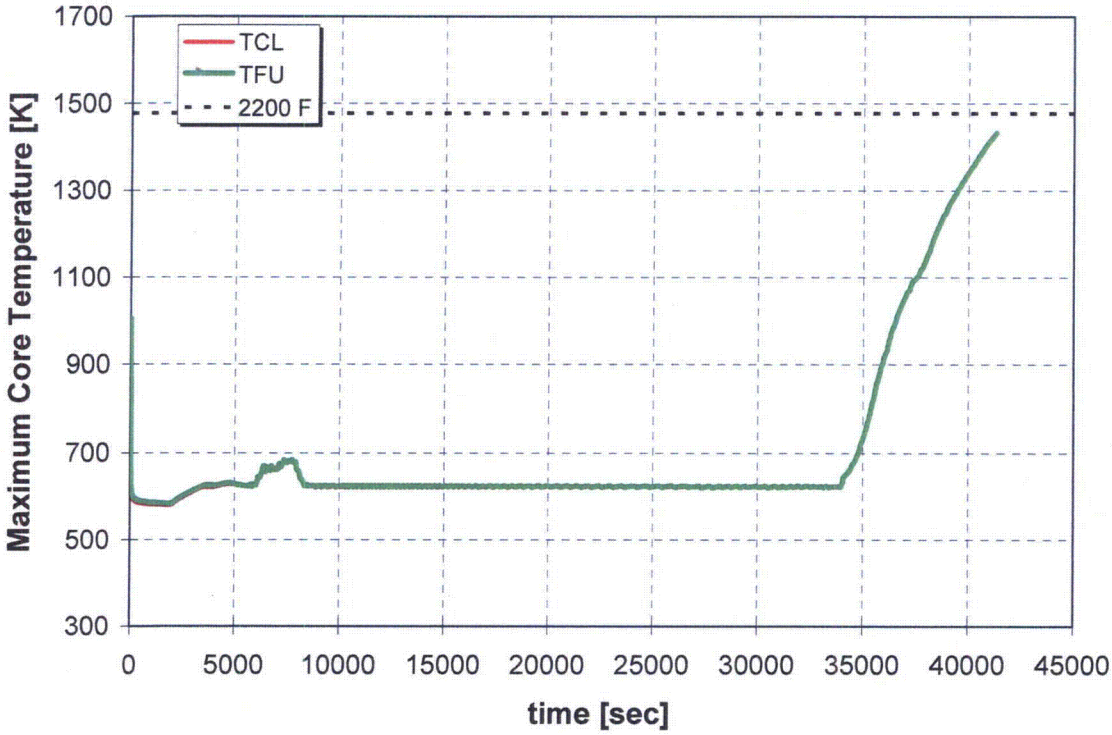

PRZ
CL-A
Reactor Pressure [MPa]
18
17
16
15
14
13
12
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

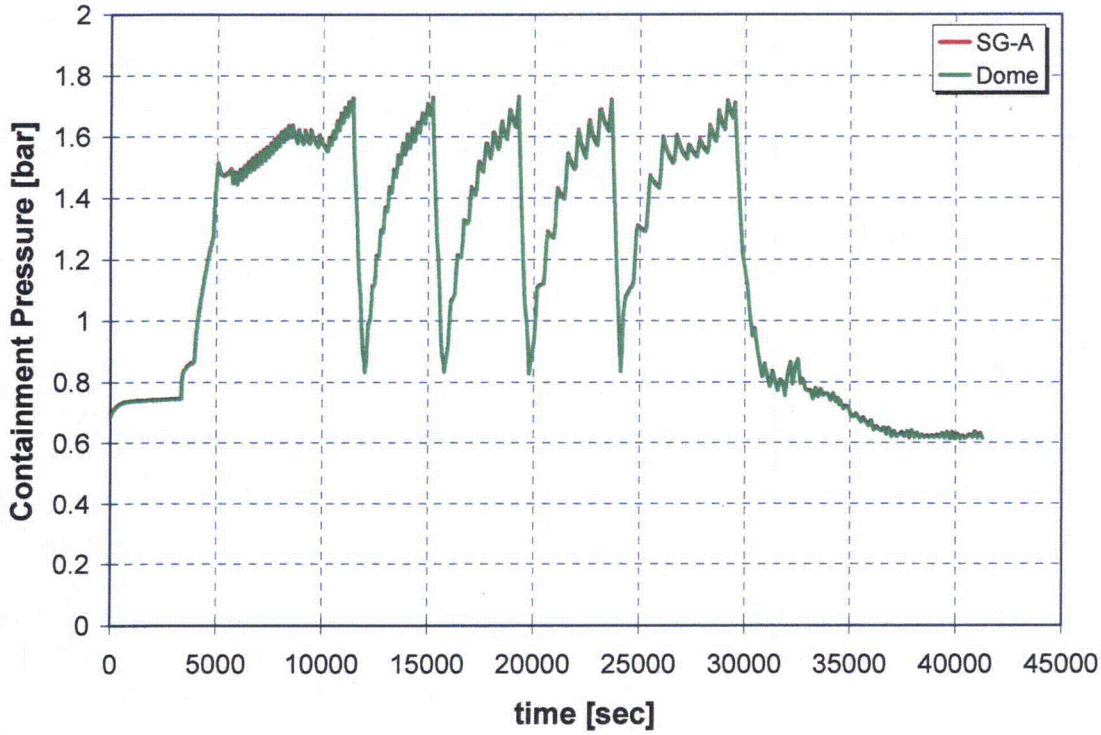

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
6.0E+05
5.0E+05
4.0E+05
3.0E+05
2.0E+05
1.0E+05
0.0E+00
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]

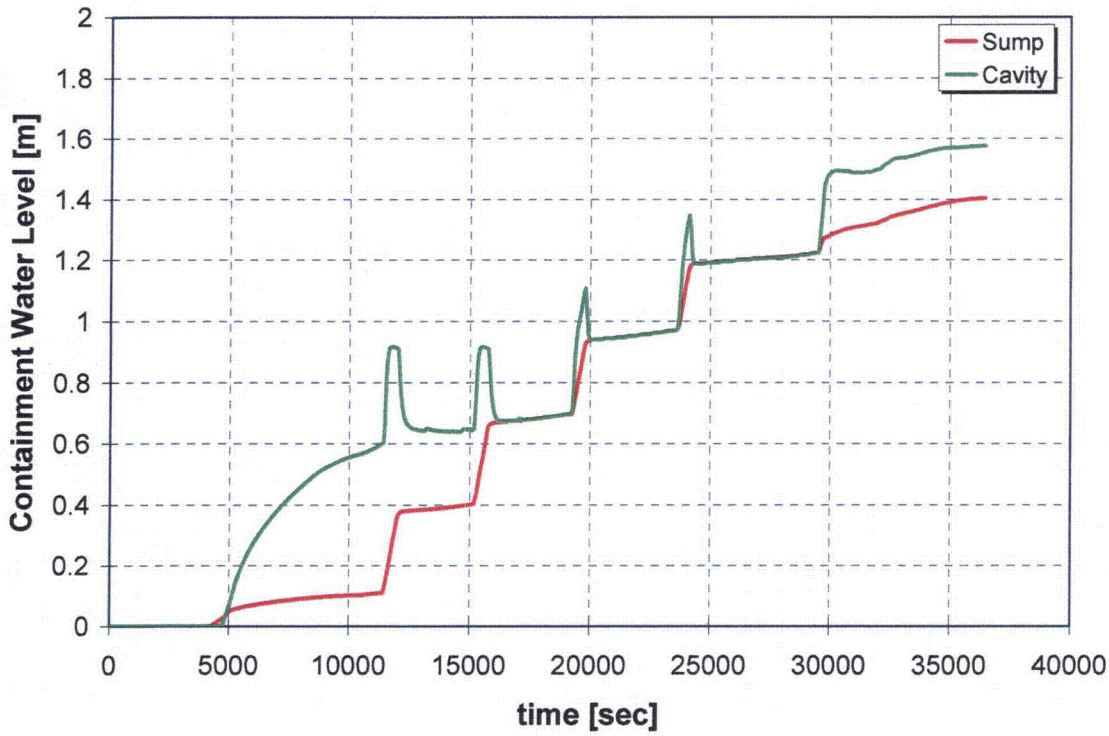

Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
0
2
4
6
8
10
12
14
16
18
0
5000
10000
15000
20000
25000
30000
35000
40000
45000


Water (gal)
time [sec]
RWST
SPR
LHSI
HHSI
0.0E+00
5.0E+04
1.0E+05
1.5E+05
2.0E+05
2.5E+05
3.0E+05
3.5E+05
4.0E+05
4.5E+05
0
5000
10000
15000
20000
25000
30000
35000
40000
45000


PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]


TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
time [sec]


SG-A
Dome
Containment Pressure [bar]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000
45000


Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000
35000
40000

A.4 Steam Generator Tube Rupture Event Tree Timing

Analysis Summary

For Section A.4.1 through Section A.4.3, operators fail to (1) isolate faulted steam generator (SG), (2) depressurize and cool RCS, and (3) extend ECCS duration by refilling RWST or cross connection to other unit's RWST. Loop A has the faulted SG. Table 10 and Table 11 below provide results for this portion of the analysis.

Table 10 Surry SGTR Results

Case	No. Tubes	HHSI Pumps	TD-AFW	MD-AFW	Core Uncovery	Core Damage
1	1	3/2	Yes		No[1]	No[1]
2	5				No[1]	No[1]
3	1	3/1			No[1]	No[1]

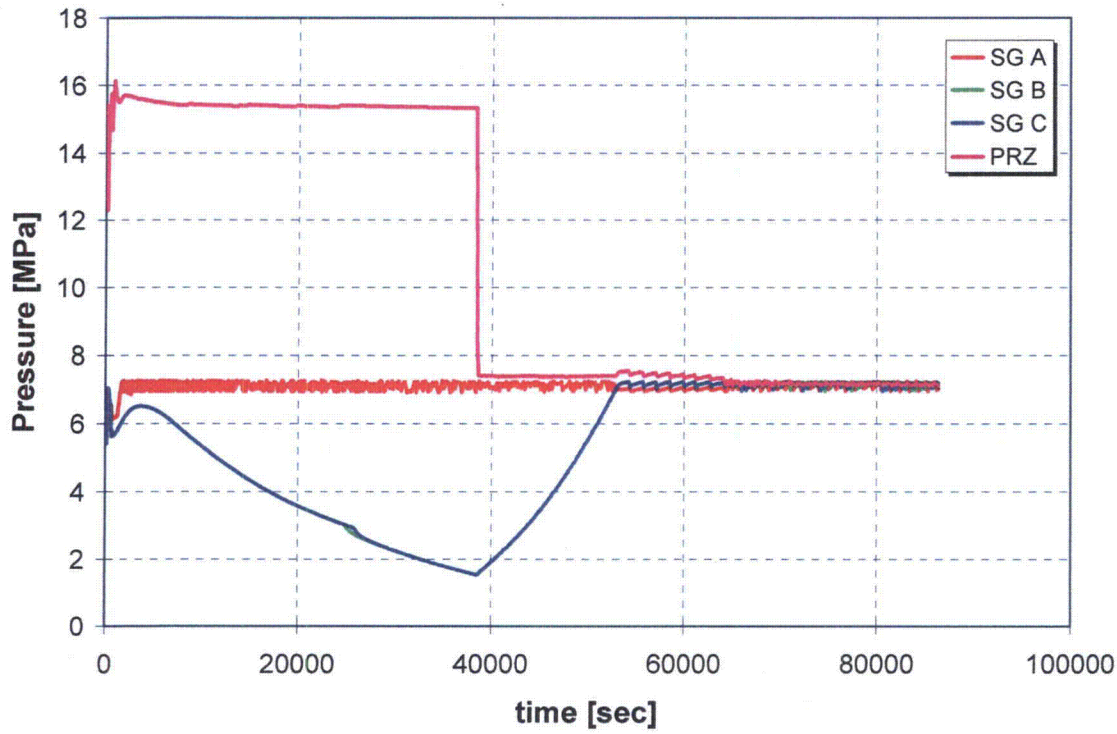
[1] Based on a 24-hour mission time.

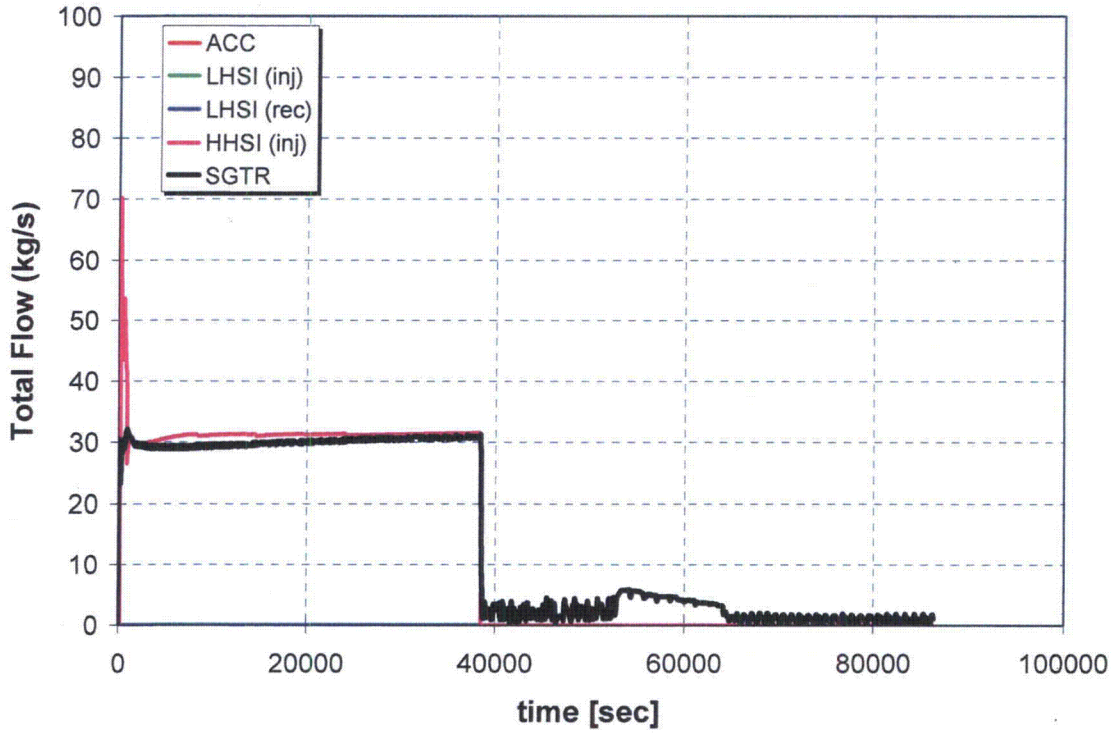
Table 11 Surry SGTR Key Timings

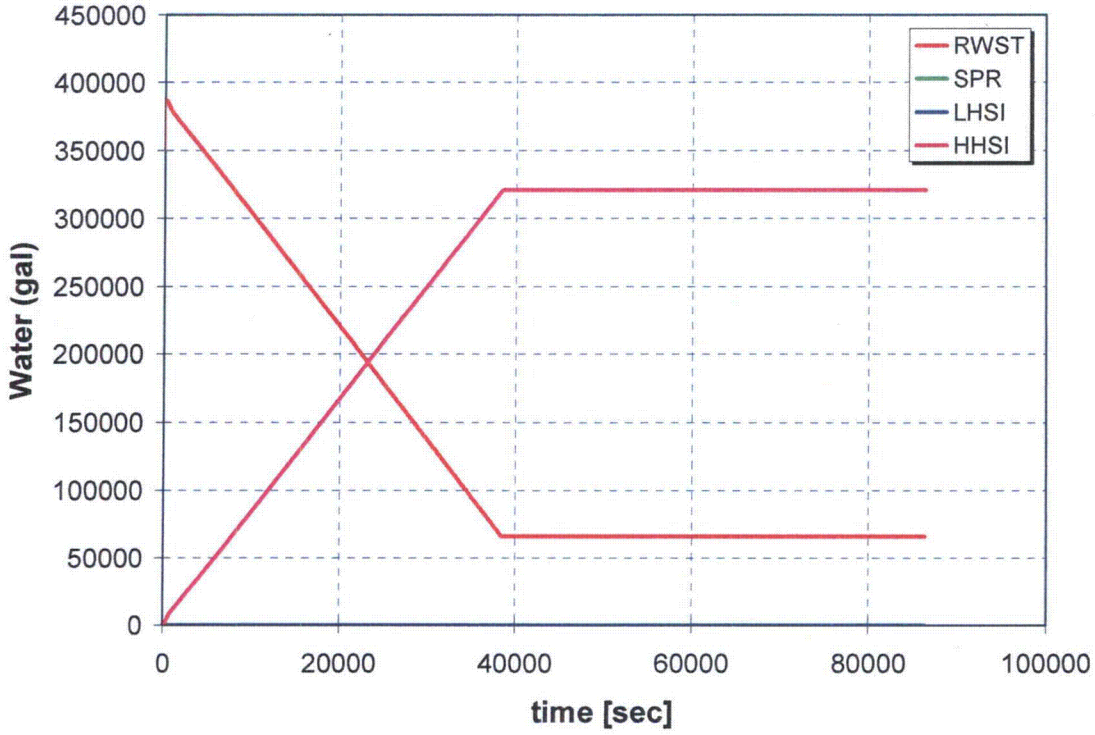
Event	Case 1 (hr)	Case 2 (hr)	Case 3 (hr)
Reactor trip	0.048	0.012	0.048
HHSI initiates (3 pumps)	0.051	0.013	0.051
1 of 3 HHSI pumps secured	0.25	0.25	N/A
2 of 3 HHSI pumps secured	N/A	N/A	0.25
RWST depletion (< 13.5%)[1]	10.68	5.58	14.06
MCP trip (10% void)	17.81	11.71	20.20
Core damage	> 24 hours		

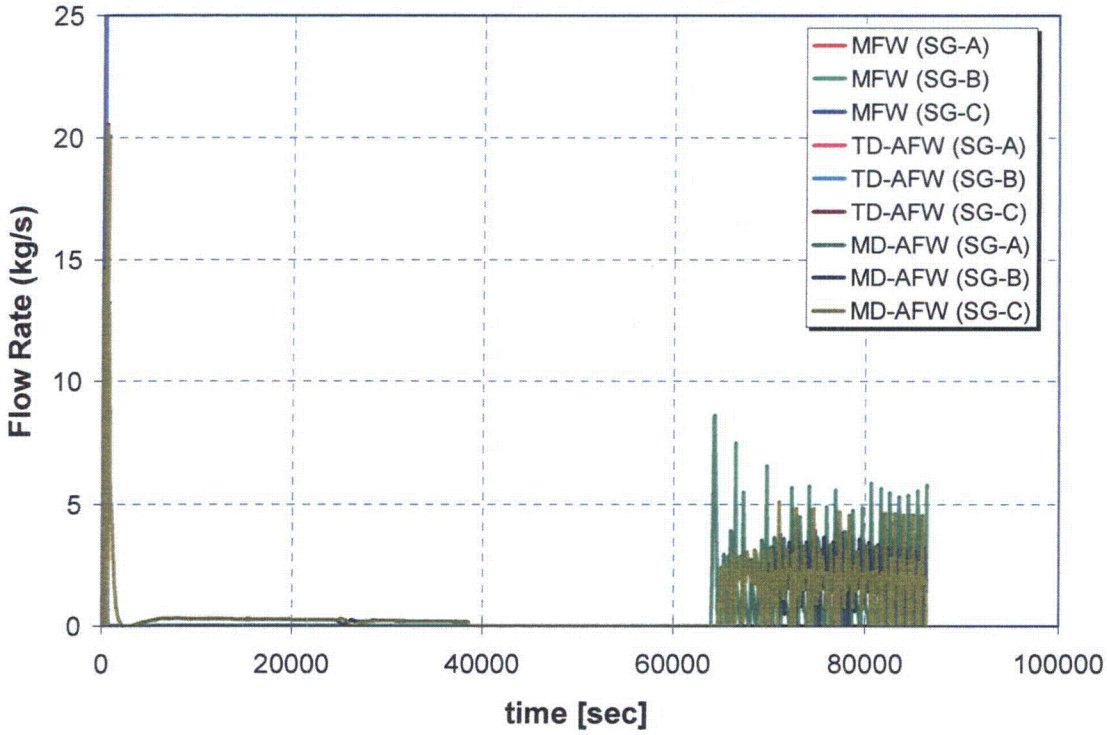
[1] Recall that, because the RCS leak location is the ruptured SG tubes, a substantial amount of water is expelled from the system via the SG relief valves (rather than into containment).

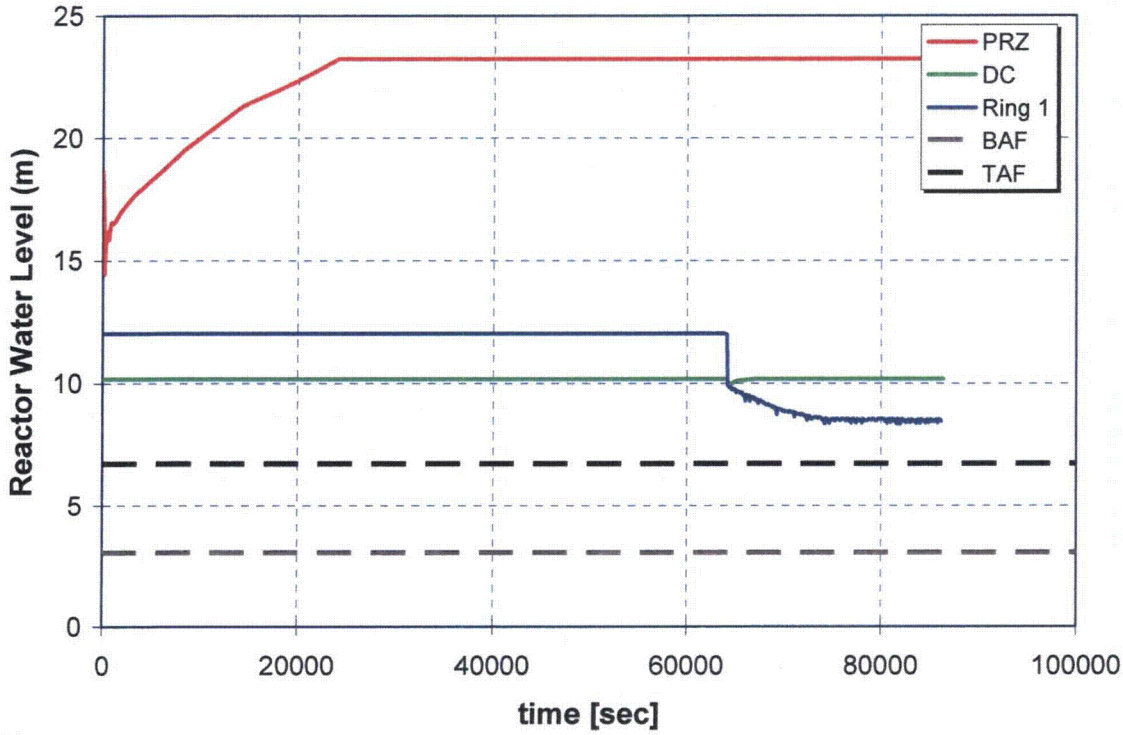
A.4.1 Case 1: One Tube (Unmitigated) and Secure One HHSI Pumps

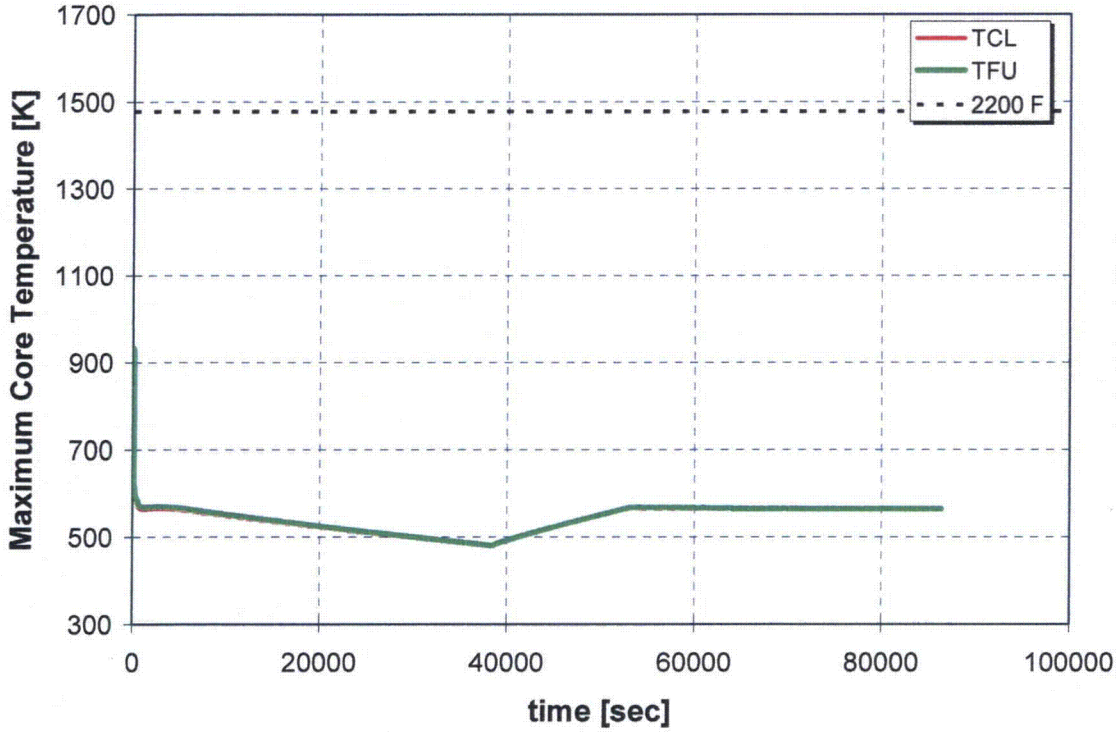




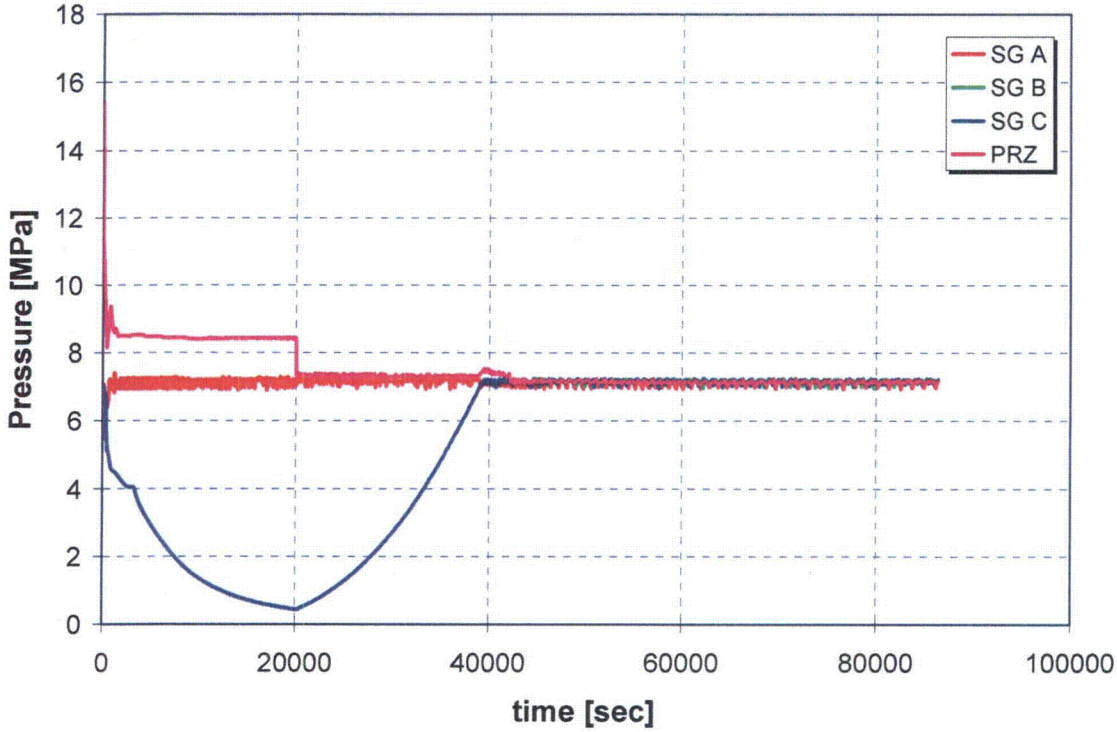

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
20000
40000
60000
80000
100000
time [sec]
RWST
SPR
LHSI
HHSI

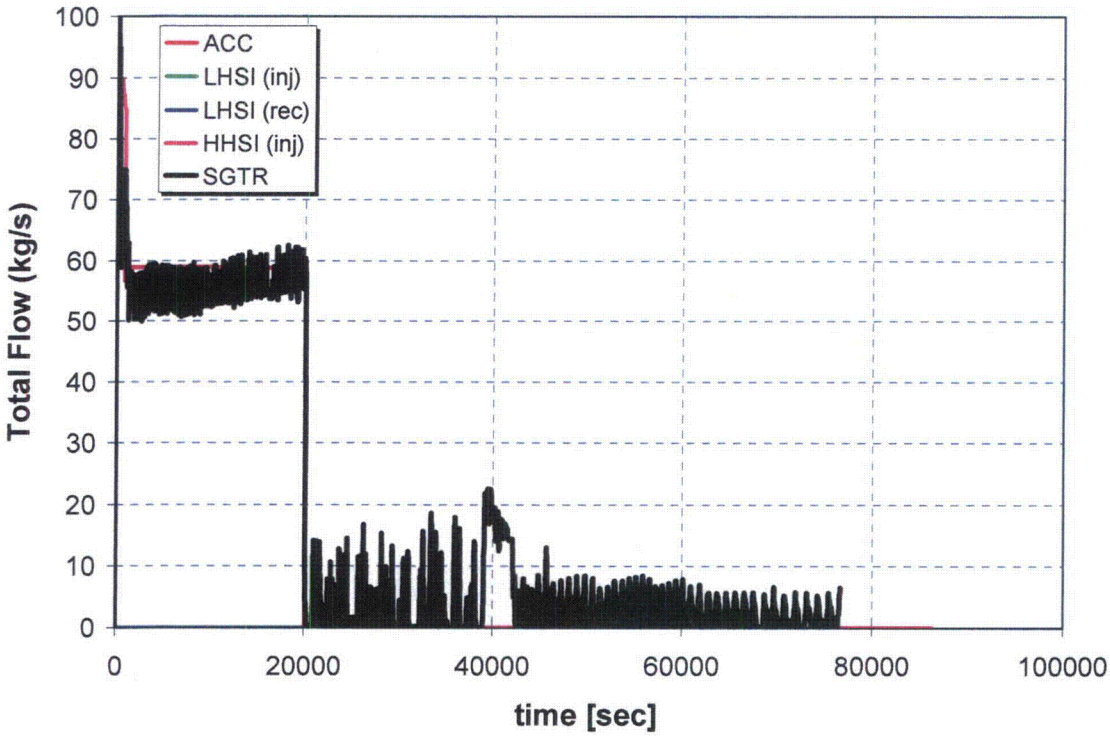

25
20
15
10
5
0
Flow Rate (kg/s)
0
20000
40000
60000
80000
100000
time [sec]
MFW (SG-A)
MFW (SG-B)
MFW (SG-C)
TD-AFW (SG-A)
TD-AFW (SG-B)
TD-AFW (SG-C)
MD-AFW (SG-A)
MD-AFW (SG-B)
MD-AFW (SG-C)

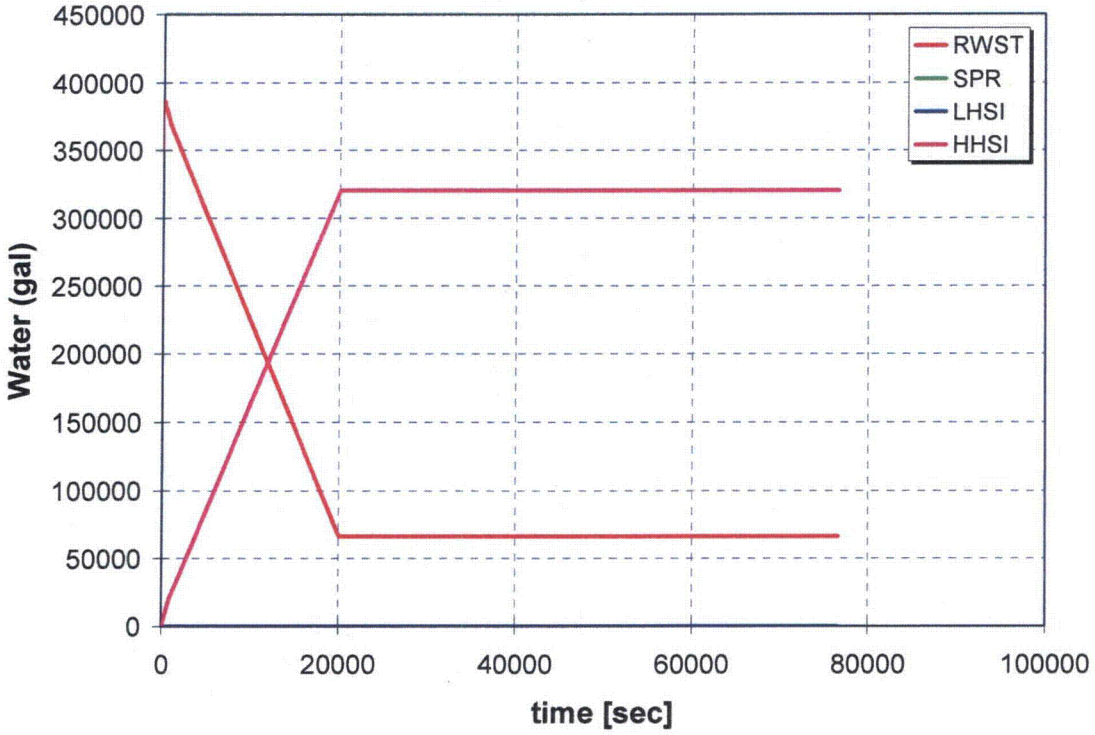

Reactor Water Level (m)
25
20
15
10
5
0
0
20000
40000
60000
80000
100000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

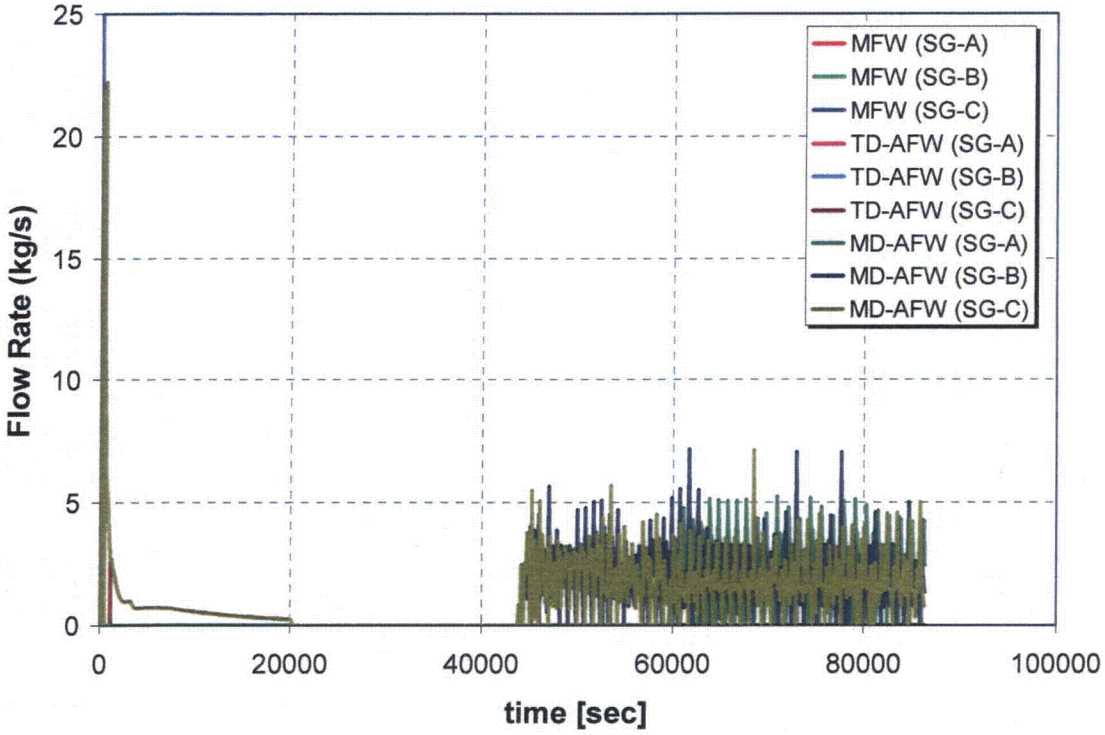

Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
20000
40000
60000
80000
100000
time [sec]
TCL
TFU
2200 F

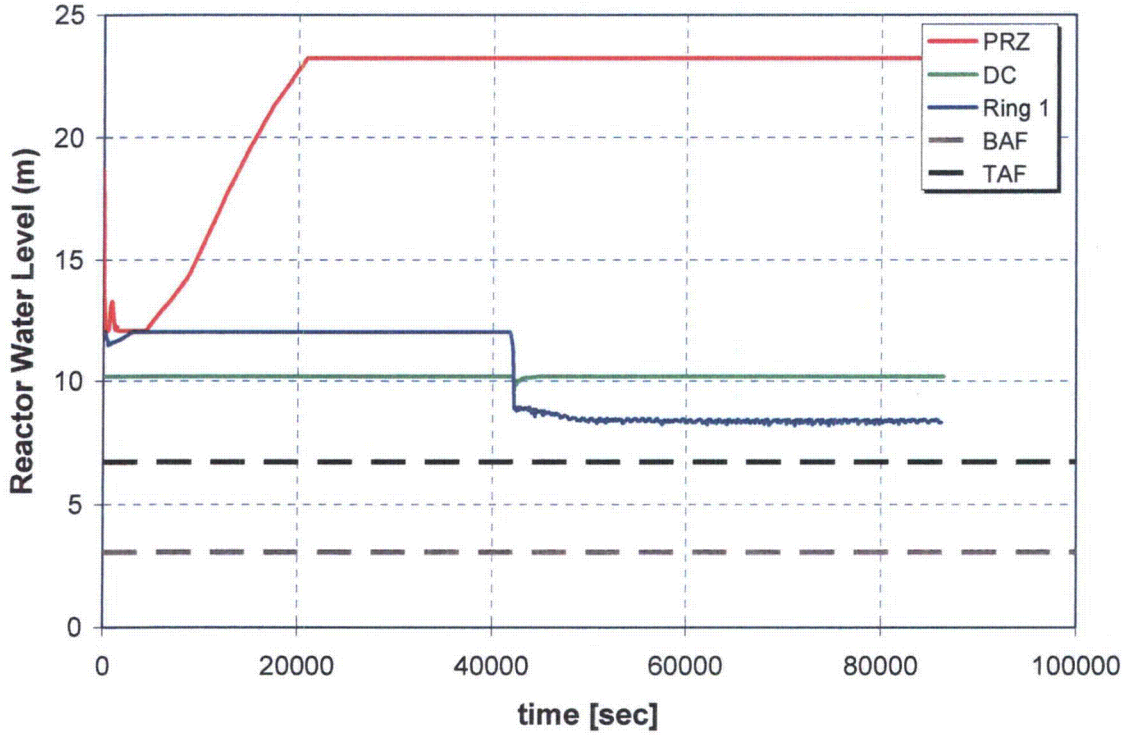
A.4.2 Case 2: Five Tubes (Unmitigated) and Secure One HHSI Pumps

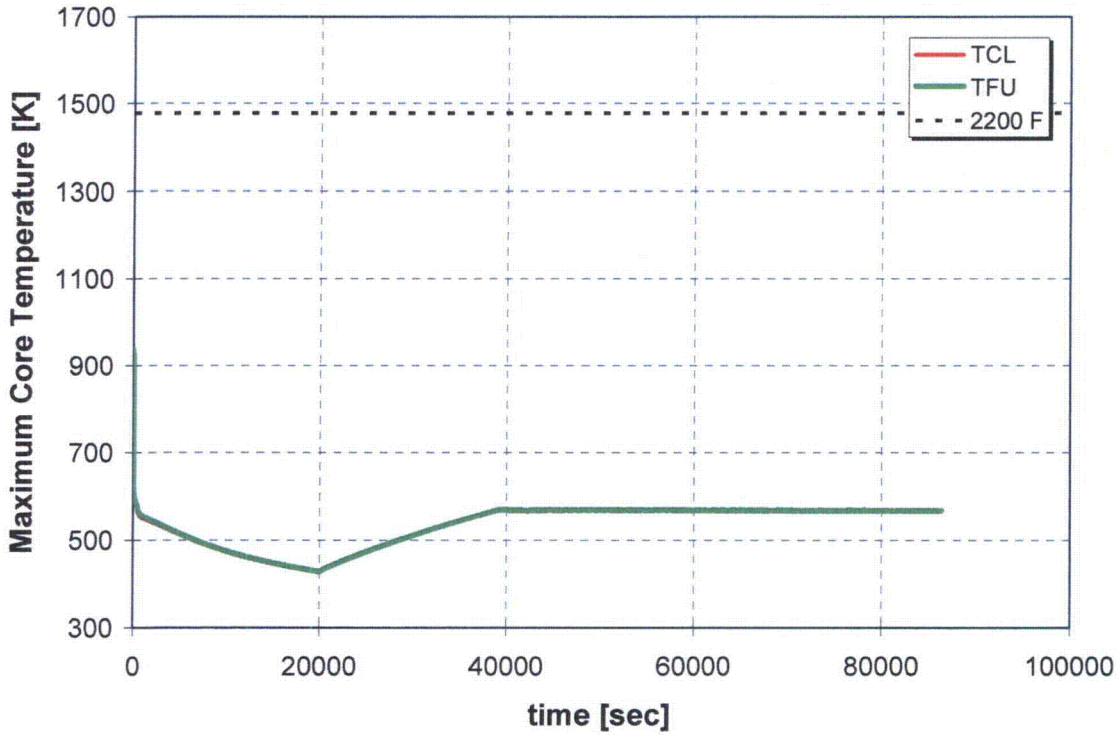




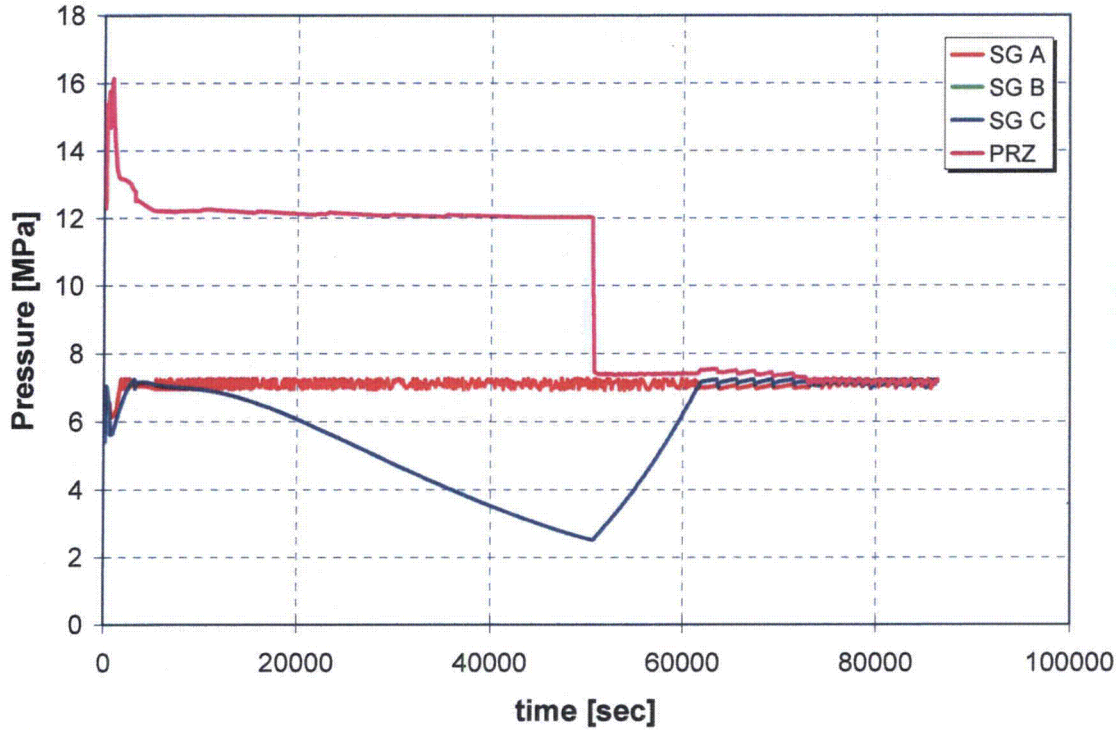

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
20000
40000
60000
80000
100000
time [sec]
RWST
SPR
LHSI
HHSI

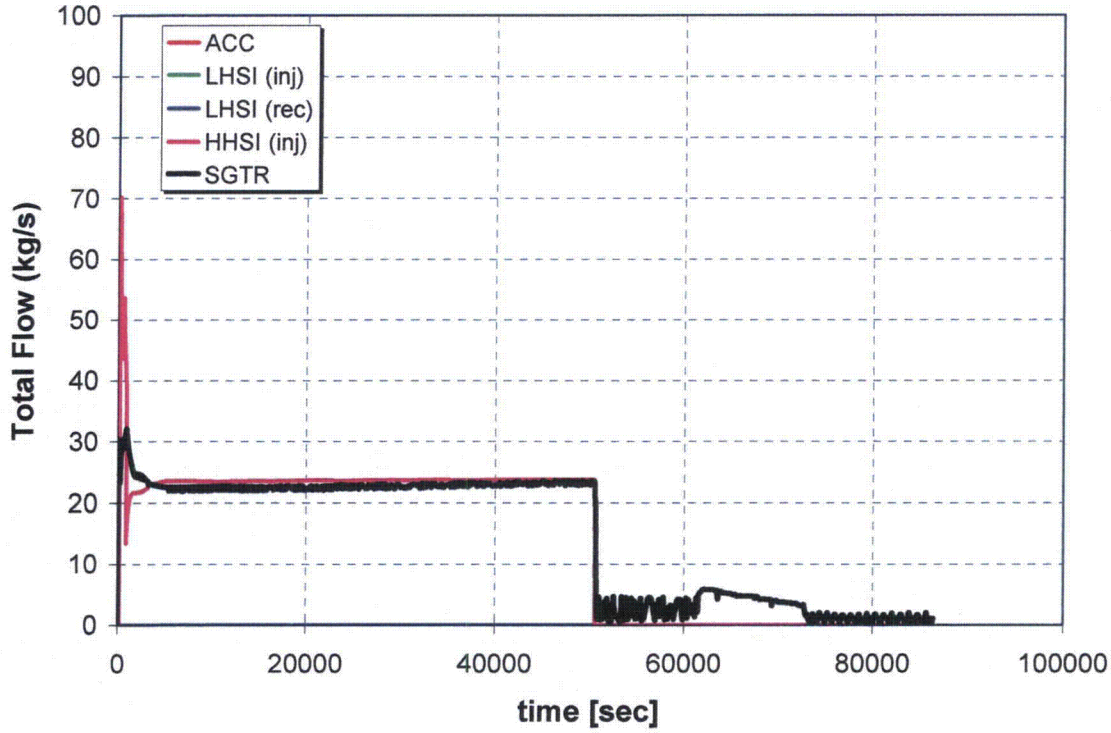

25
20
15
10
5
0
Flow Rate (kg/s)
0
20000
40000
60000
80000
100000
time [sec]
MFW (SG-A)
MFW (SG-B)
MFW (SG-C)
TD-AFW (SG-A)
TD-AFW (SG-B)
TD-AFW (SG-C)
MD-AFW (SG-A)
MD-AFW (SG-B)
MD-AFW (SG-C)

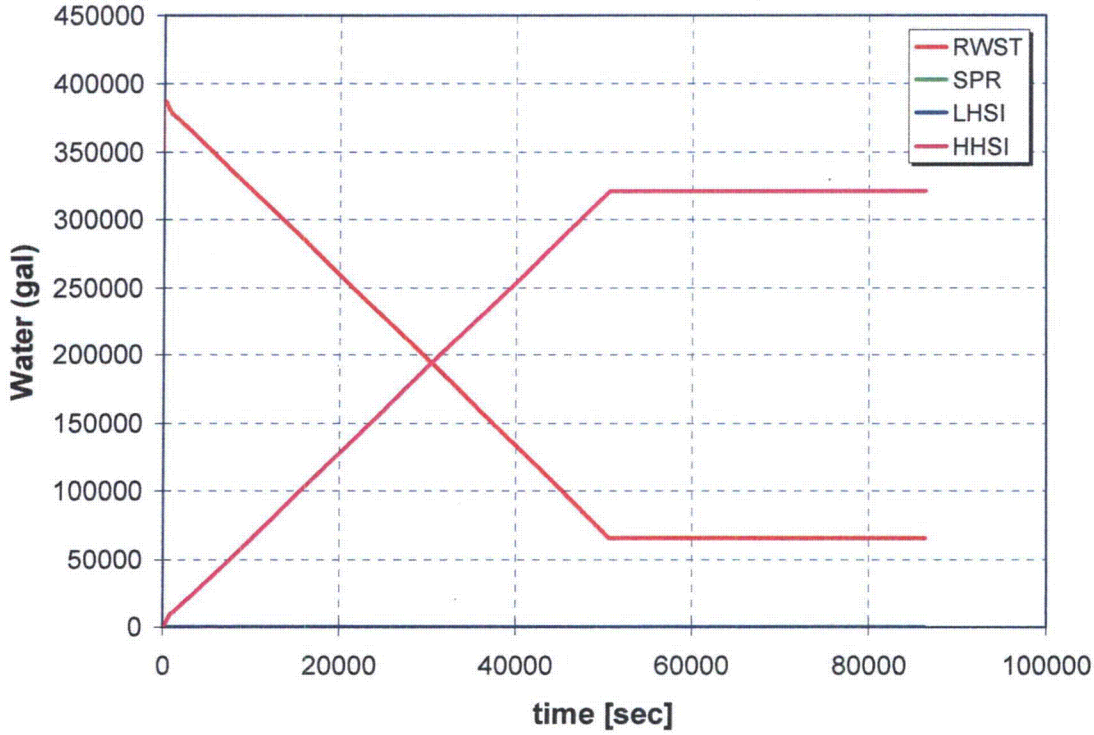

Reactor Water Level (m)
25
20
15
10
5
0
0
20000
40000
60000
80000
100000
time [sec]
PRZ
DC
Ring 1
BAF
TAF

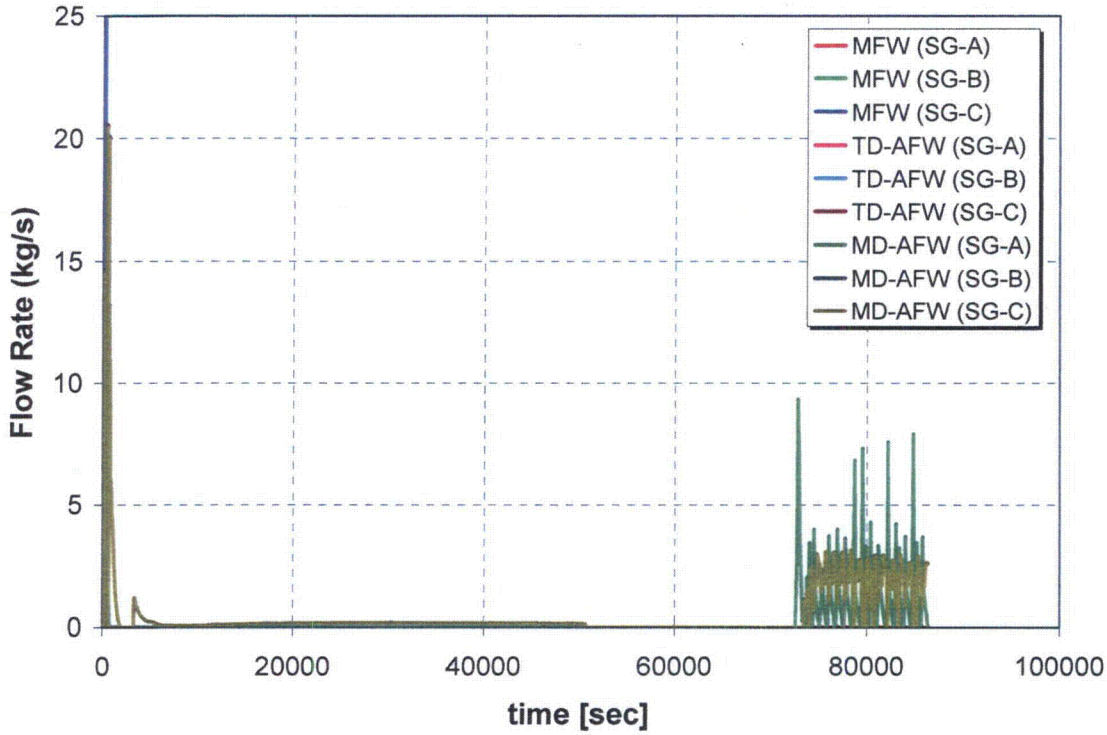

Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
20000
40000
60000
80000
100000
time [sec]
TCL
TFU
2200 F

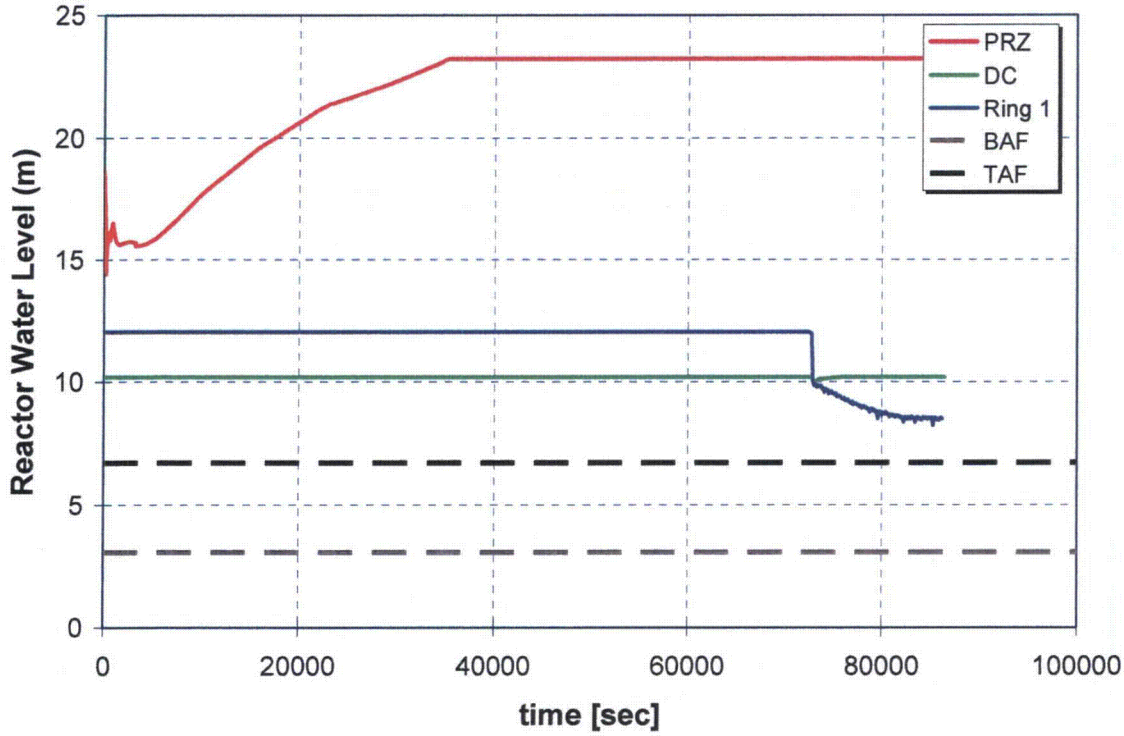
A.4.3 Case 3: One Tube (Unmitigated) and Secure Two HHSI Pumps

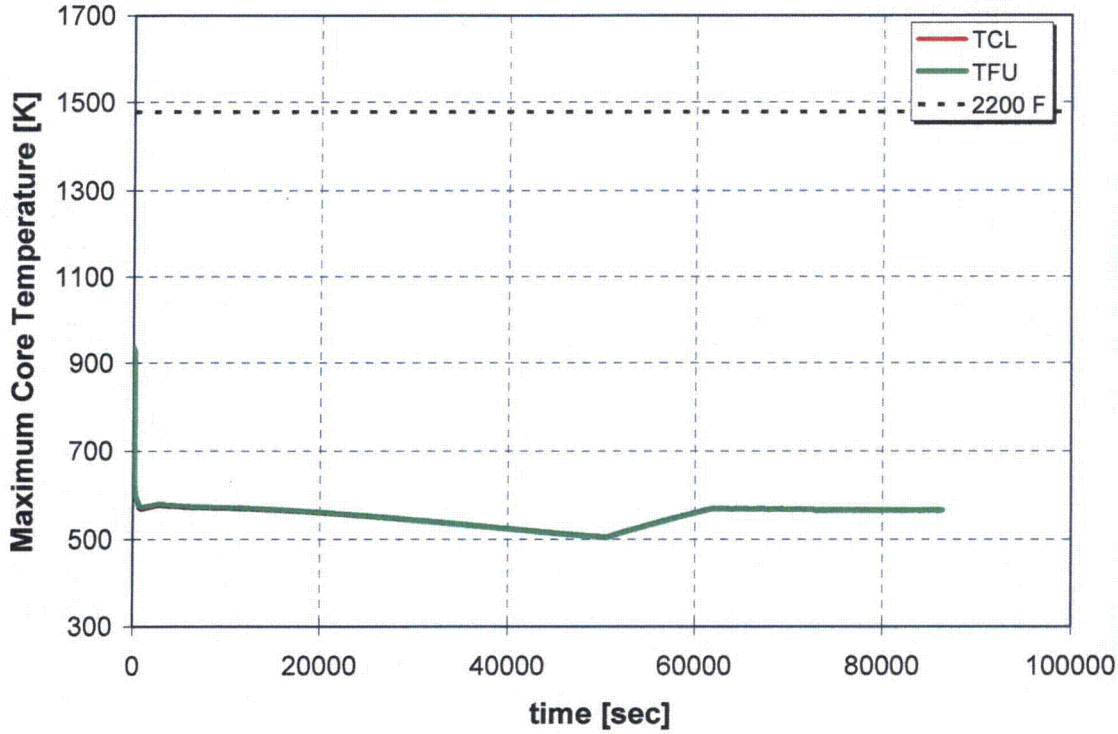





450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water (gal)
0
20000
40000
60000
80000
100000
time [sec]
RWST
SPR
LHSI
HHSI


25
20
15
10
5
0
Flow Rate (kg/s)
0
20000
40000
60000
80000
100000
time [sec]
MFW (SG-A)
MFW (SG-B)
MFW (SG-C)
TD-AFW (SG-A)
TD-AFW (SG-B)
TD-AFW (SG-C)
MD-AFW (SG-A)
MD-AFW (SG-B)
MD-AFW (SG-C)


Reactor Water Level (m)
25
20
15
10
5
0
0
20000
40000
60000
80000
100000
time [sec]
PRZ
DC
Ring 1
BAF
TAF


Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
20000
40000
60000
80000
100000
time [sec]
TCL
TFU
2200 F

A.5 Pressurized-Water Reactor Station Blackout

Analysis Summary

The station blackout sequence is similar to the SOARCA analysis. In all cases, there is 21 gpm existing leakage, but in some cases seal failure at 13 minutes leads to either 182 gpm or 500 gpm leakage. Note that this is different from how RCP seal failure is modeled in the SOARCA project. For the modeling of stuck-open pressurizer SRV, there are two choices: (1) SRV sticks open based on number of cycles, or (2) the valve does not recluse after the first lift-off. Note that none of the cases reach the 256-lift criterion before core damage.

Two sensitivity calculations are performed in Section A.5.1: (1) initiation of three HHSI pumps at 2.14 hours (when core damage occurs), and (2) initiation of three HHSI pumps at 1.64 hours (half an hour earlier). Section A.5.1.1 shows that core damage would continue for the former case, while Section A.5.1.2 shows that there is sufficient time and injection flow rate to avert fuel melting and arrest core heatup in the latter case. Table 12 through Table 15 below provide results for this portion of the analysis.

Table 12 Surry Station Blackout Results

Case	Seal Leakage Rate[1] after Failure (gpm[3] per pump)	Seal Failure Time (min)	SRV Stuck Open	TD-AFW	ac/dc	Core Uncovery (hr)	Core Damage (hr)
1	500	13	N/A[2]	Fails to start	-	1.4	2.1
1a					ac recovery at 2.1 hours	1.4	2.1
1b					ac recovery at 1.6 hours	1.4	-
2				Available	-	1.6	2.3
3	21	-		Fails to start		2.3	3.4
4				Available; successful blind feeding		13.3	16.3
5			1st lift	Fails to start		2.1	2.6
6				Available; successful blind feeding		13.0	13.8
7	182	13	N/A[2]	Fails to start		2.0	3.1
8				Available		3.9	4.8
9	21	-		Available; lost at 4 hours	dc lost at 4 hours	8.4	10.9
10			1st lift			8.1	8.8

1 The leakage rate provided here is the leakage rate at full system pressure. As the system depressurizes, the leak rate decreases.

2 The model is set to stick the valve open after 256 lifts, but the valve does not lift that many times for these calculations.

3 500 gpm = 1.89 m^3/min;182 gpm = 0.689 m^3/min; 21 gpm = 0.076 m^3/min.

Table 13 Surry Station Blackout Key Timings (Cases 1–2)

Event[1]	Case 1 (hr)	Case 1a (hr)	Case 1b (hr)	Case 2 (hr)
Reactor trip, RCP trip, MFW/TD-AFW/MD-AFW	0	0	0	0
Seal leakage (21 gpm/pump)	0	0	0	0
Seal failure (500 gpm/pump)	0.22	0.22	0.22	0.22
Primary side SG tubes water level starts to decrease	0.52	0.52	0.52	0.52
Primary side SG tubes dry	0.96	0.96	0.96	0.98
SG dryout	1.16	1.16	1.16	-
Core uncovery	1.40	1.40	1.40	1.63
Gap release	1.92	1.92	-	2.15
Core damage (max temp > 2,200 °F)	2.14	2.14	-	2.25

[1] 500 gpm = 1.89 m^3/min; 21 gpm = 0.076 m^3/min; 2,200 °F = 1,204 °C.

Table 14 Surry Station Blackout Key Timings (Cases 3–6)

Event[1]	Case 3 (hr)	Case 4 (hr)	Case 5 (hr)	Case 6 (hr)
Reactor trip, RCP trip, MFW/TD-AFW/MD-AFW	0	0	0	0
Seal leakage (21 gpm/pump)	0	0	0	0
Primary side SG tubes water level starts to decrease	1.92	5.38	1.52	5.42
Emergency CST depleted	-	7.97	-	7.97
Primary side SG tubes dry	2.03	11.30	1.66	11.30
SG dryout	1.19	11.77	1.19	11.80
SRV sticks open	N/A	N/A	1.45	12.71
Core uncovery	2.28	13.31	2.06	13.03
Gap release	2.96	14.83	2.42	13.60
Core damage (max temp > 2,200 °F)	3.40	16.33	2.57	13.80

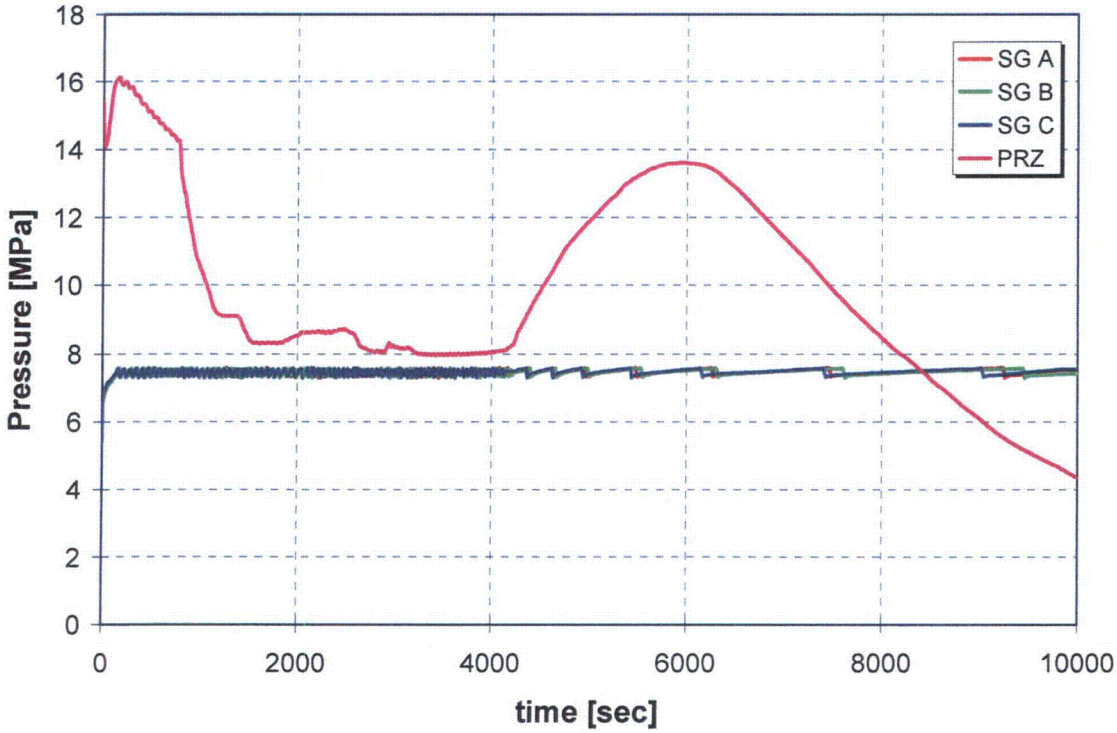
[1] 21 gpm = 0.076 m^3/min; 2,200 °F = 1,204 °C.

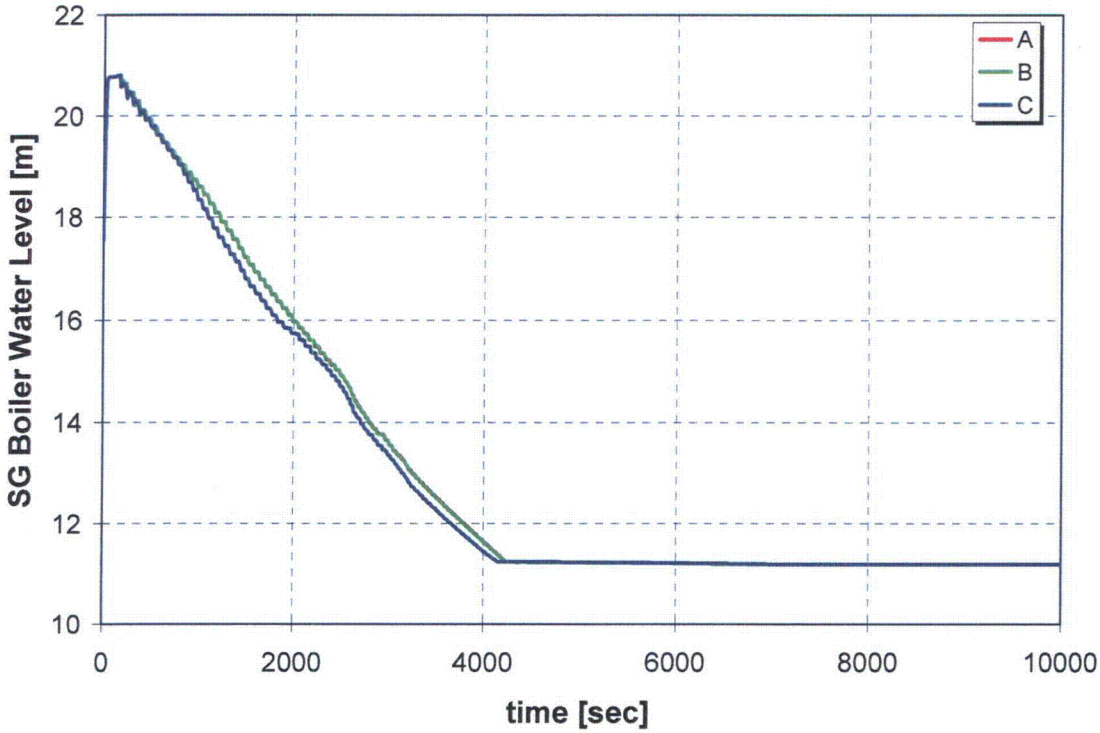
Table 15 Surry Station Blackout Key Timings (Cases 7–10)

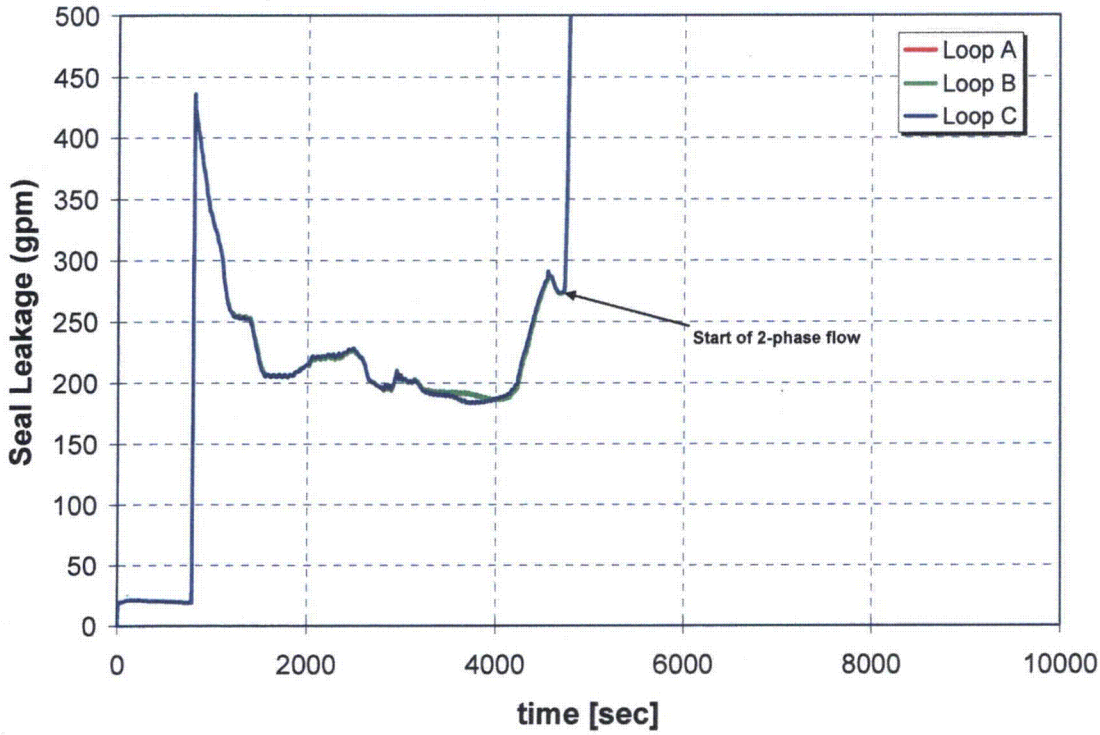
Event[1]	Case 7 (hr)	Case 8 (hr)	Case 9 (hr)	Case 10 (hr)
Reactor trip, RCP trip, MFW/TD-AFW/MD-AFW	0	0	0	0
Seal leakage (21 gpm/pump)	0	0	0	0
Seal failure (182 gpm/pump)	0.22	0.22	-	-
TD-AFW assumed lost at battery depletion	-	-	4	4
Primary side SG tubes water level starts to decrease	1.04	1.01	5.62	5.63
Primary side SG tubes dry	1.52	2.22	6.58	6.58
SG dryout	1.22	-	7.13	7.12
SRV sticks open	N/A	N/A	N/A	7.67
Core uncovery	1.98	3.88	8.37	8.10
Gap release	2.63	4.00	9.48	8.59
Core damage (max temp > 2, 200 °F)	3.09	4.77	10.85	8.77

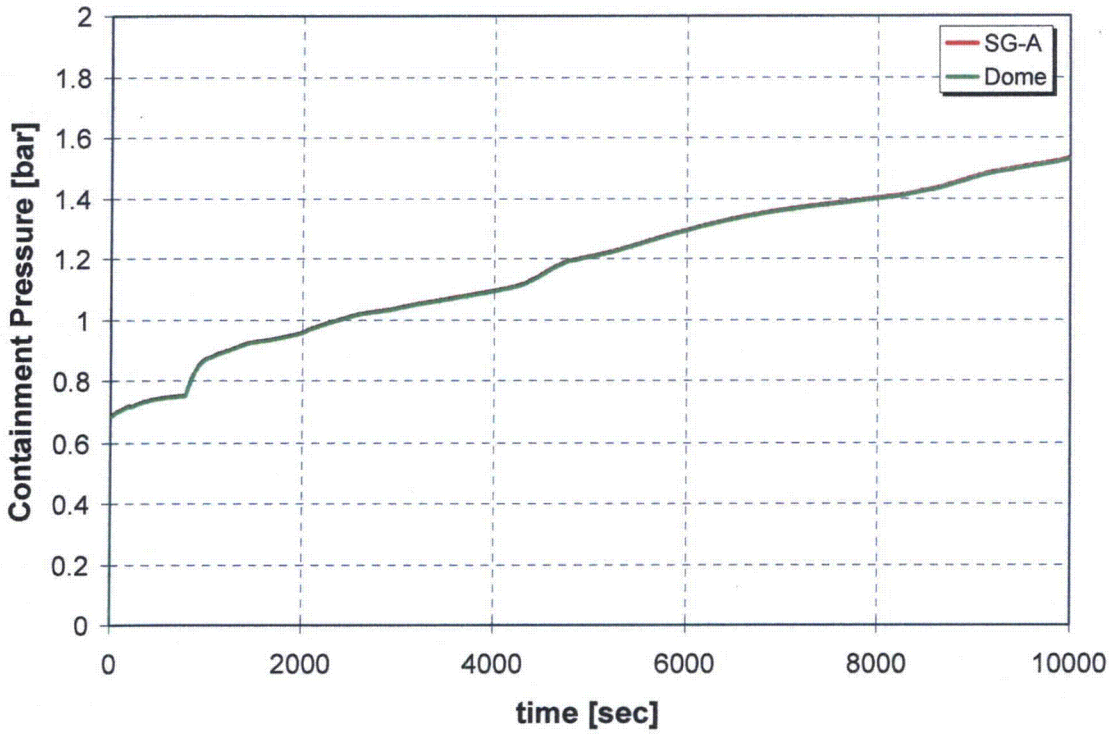
[1] 182 gpm = 0.689 m^3/min; 21 gpm = 0.076 m^3/min; 2,200 °F = 1,204 °C.

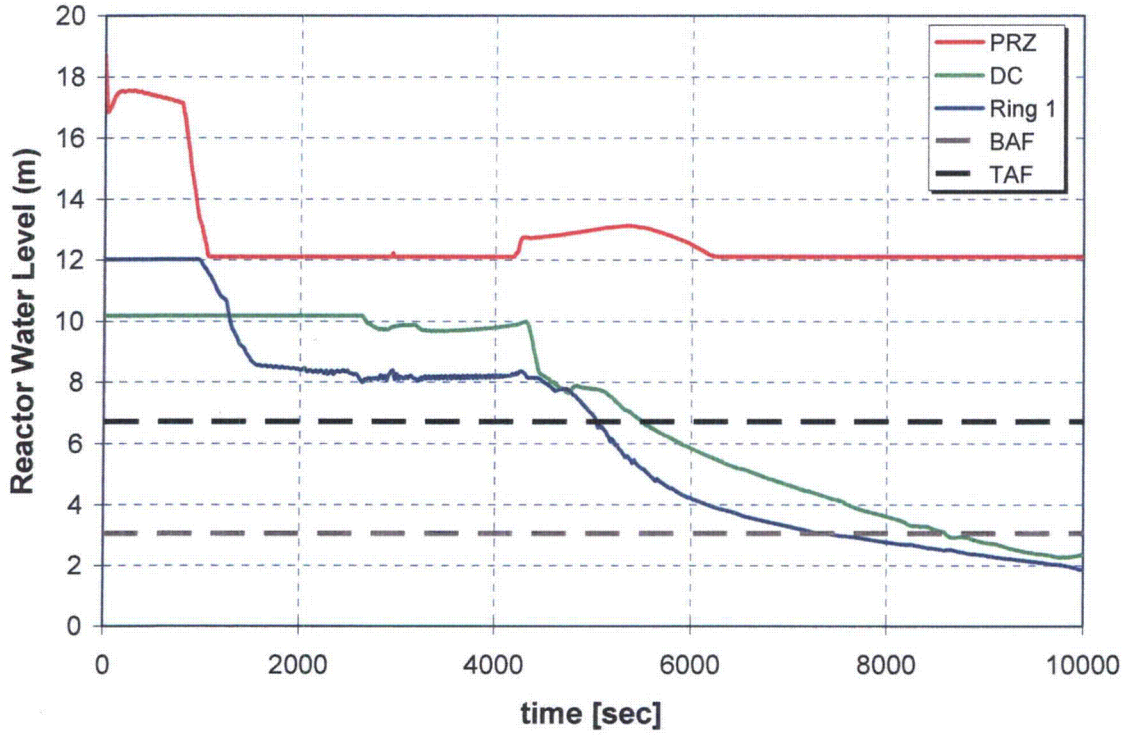
A.5.1 Case 1: Station Blackout without Turbine-Driven Auxiliary Feedwater (500 gpm)

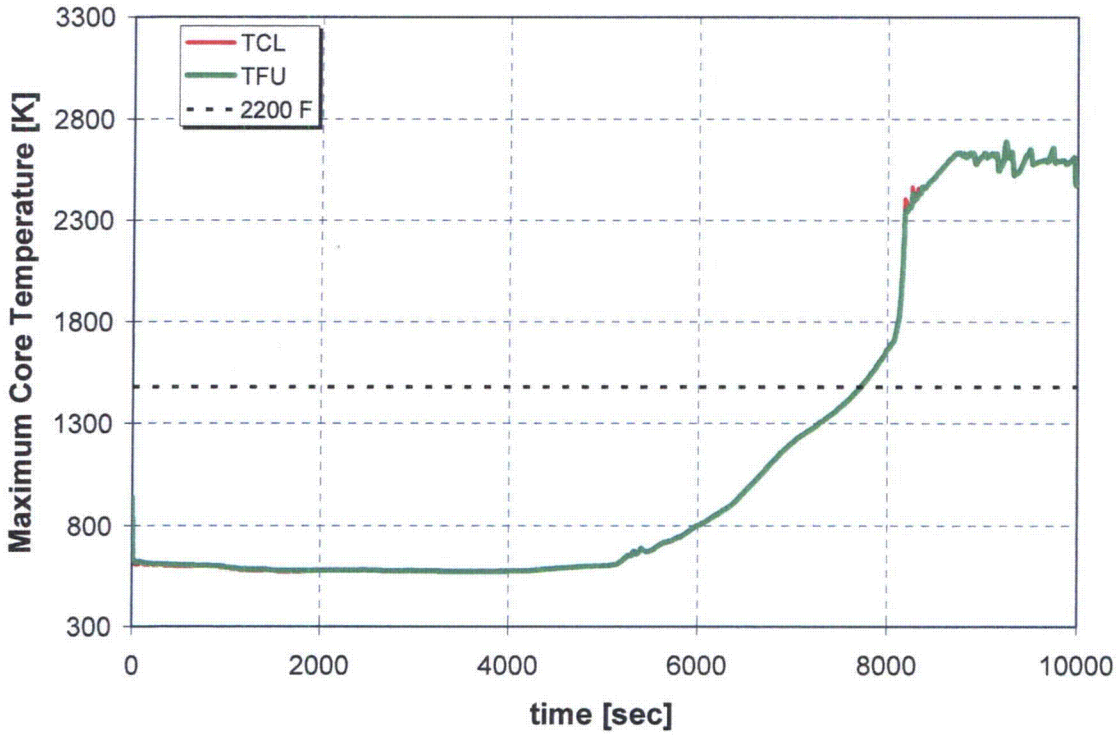




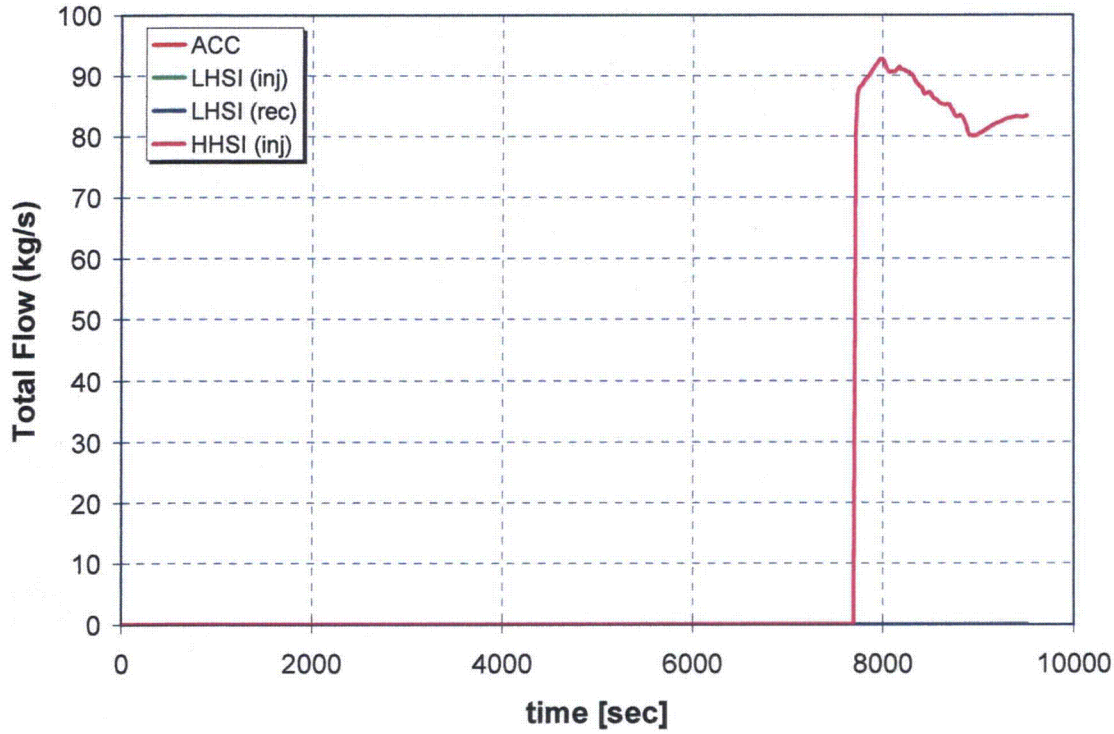

Seal Leakage (gpm)
500
450
400
350
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
time [sec]
Loop A
Loop B
Loop C
Start of 2-phase flow

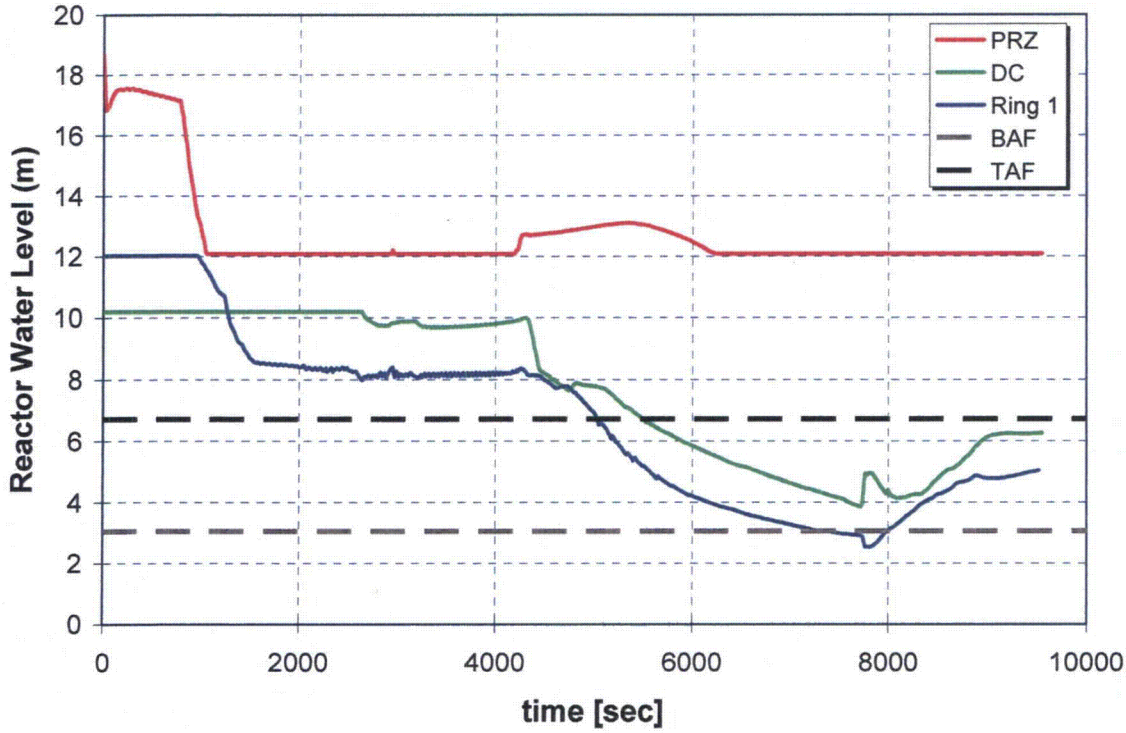

Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
time [sec]
SG-A
Dome

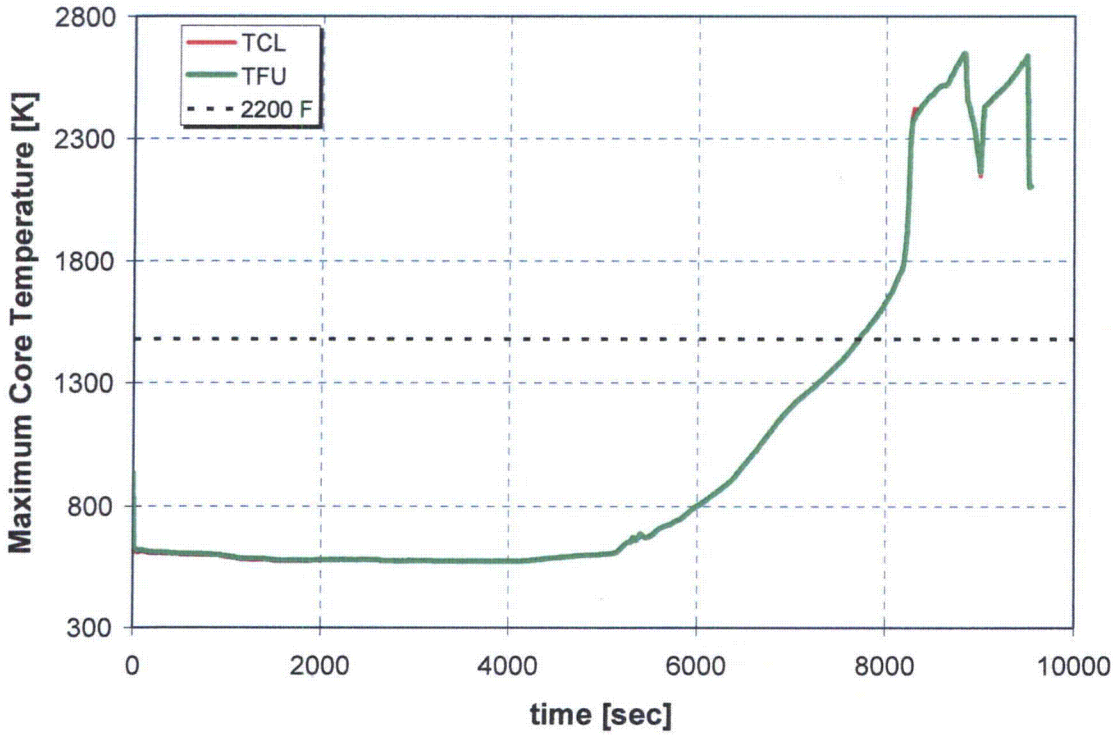

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
2000
4000
6000
8000
10000


Maximum Core Temperature [K]
time [sec]
TCL
TFU
2200 F
300
800
1300
1800
2300
2800
3300
0
2000
4000
6000
8000
10000

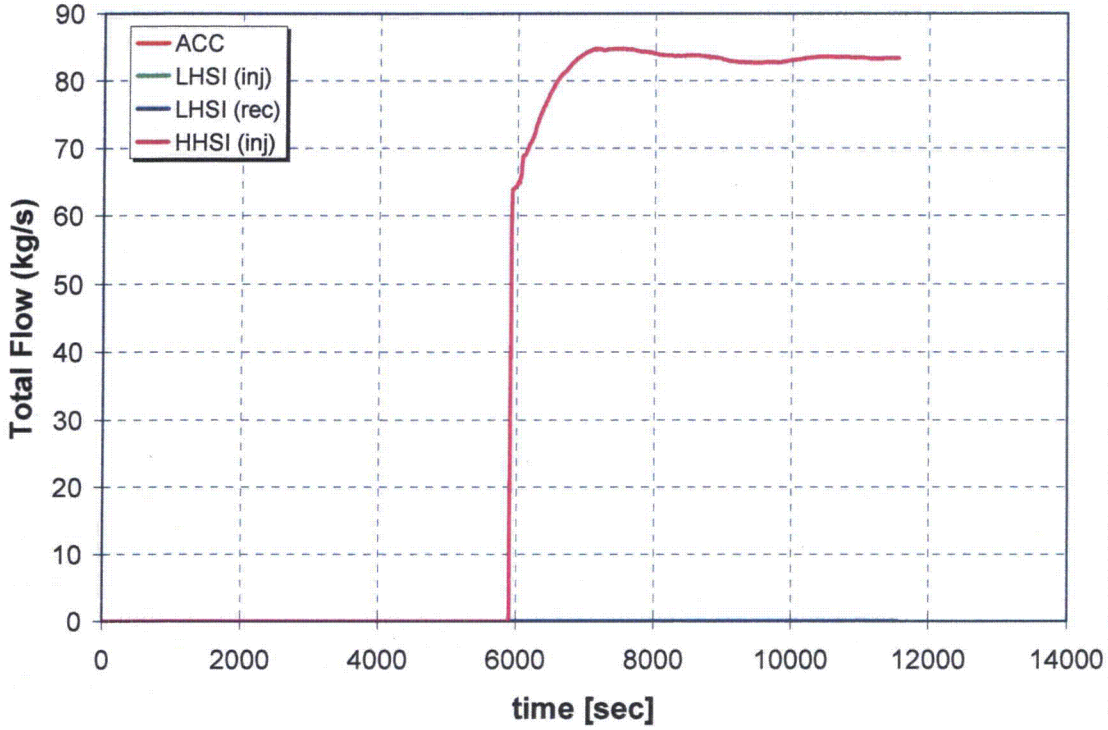
A.5.1.1 Case 1a: Three HHSI Pumps at 2.14 Hours

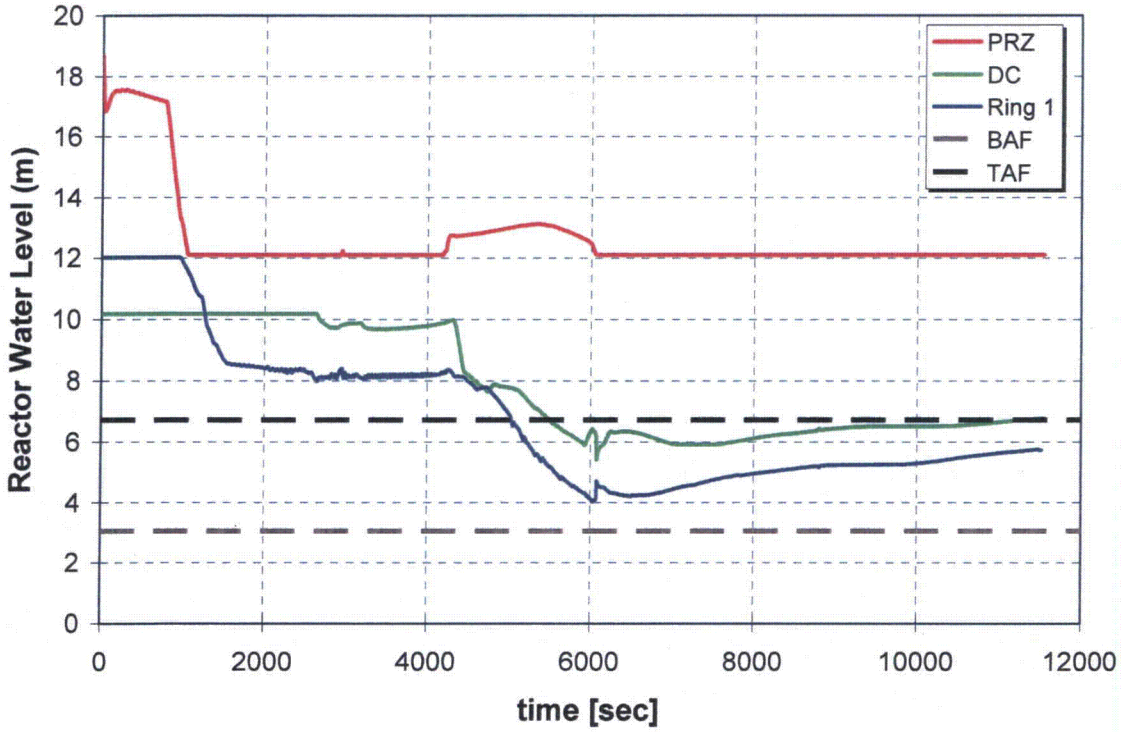


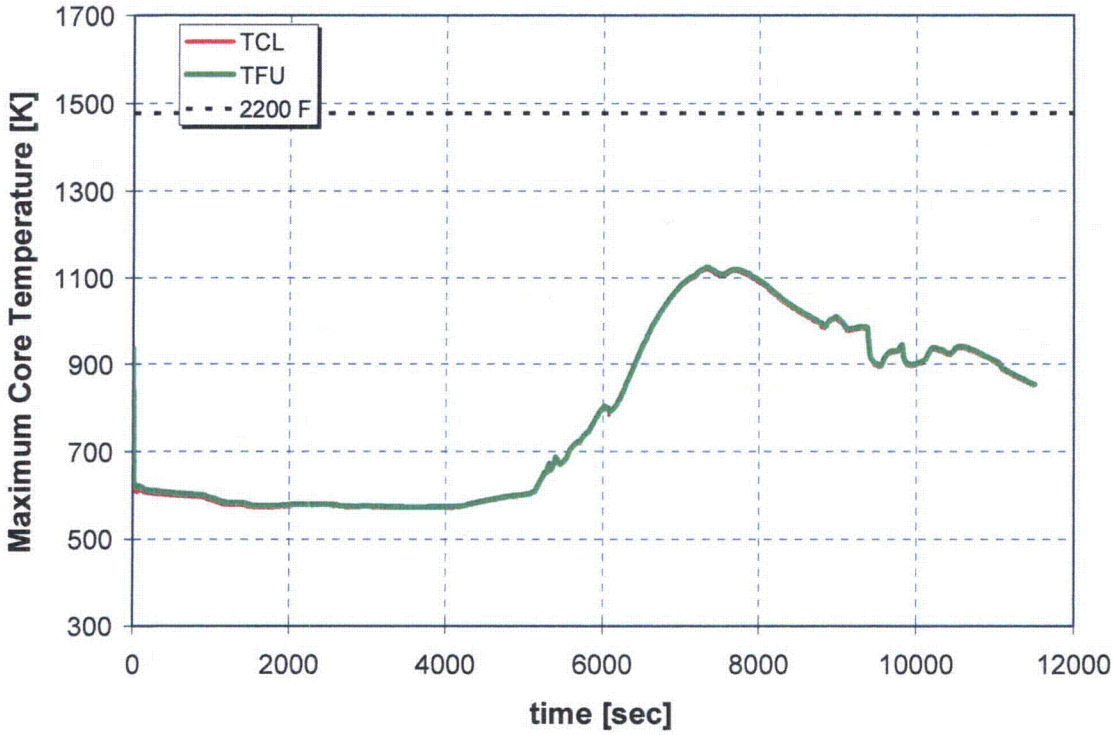



TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
2000
4000
6000
8000
10000
time [sec]

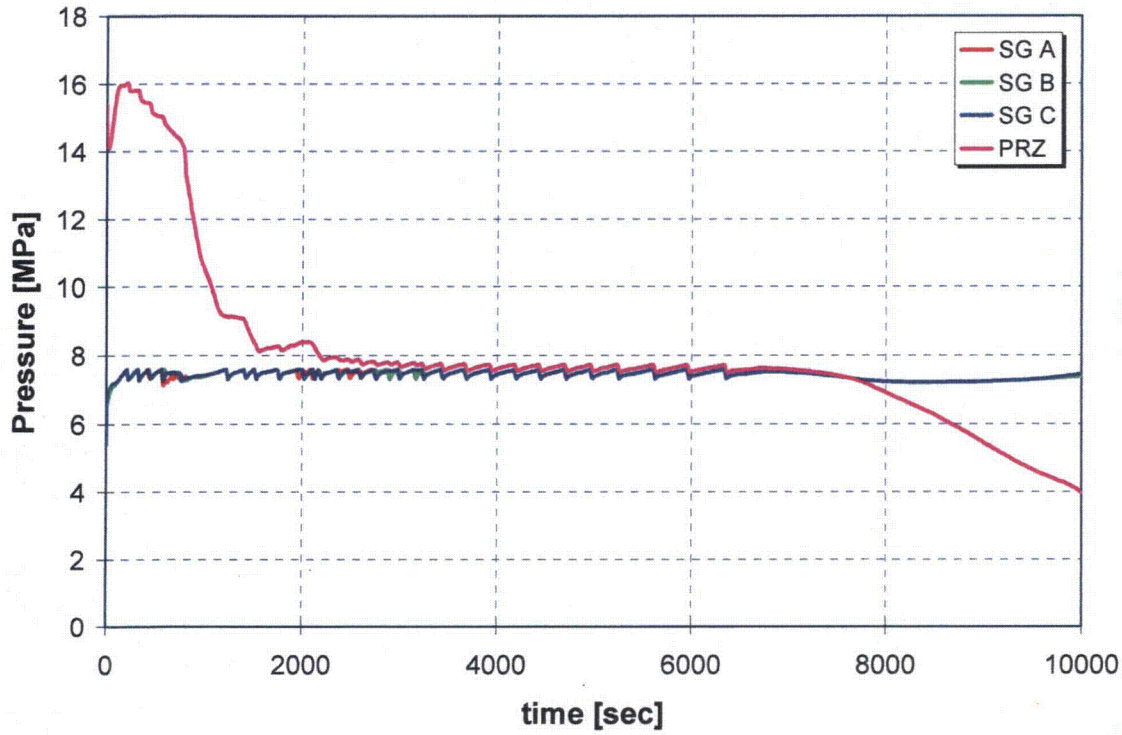
A.5.1.2 Case 1b: Three HHSI Pumps at 1.64 Hour

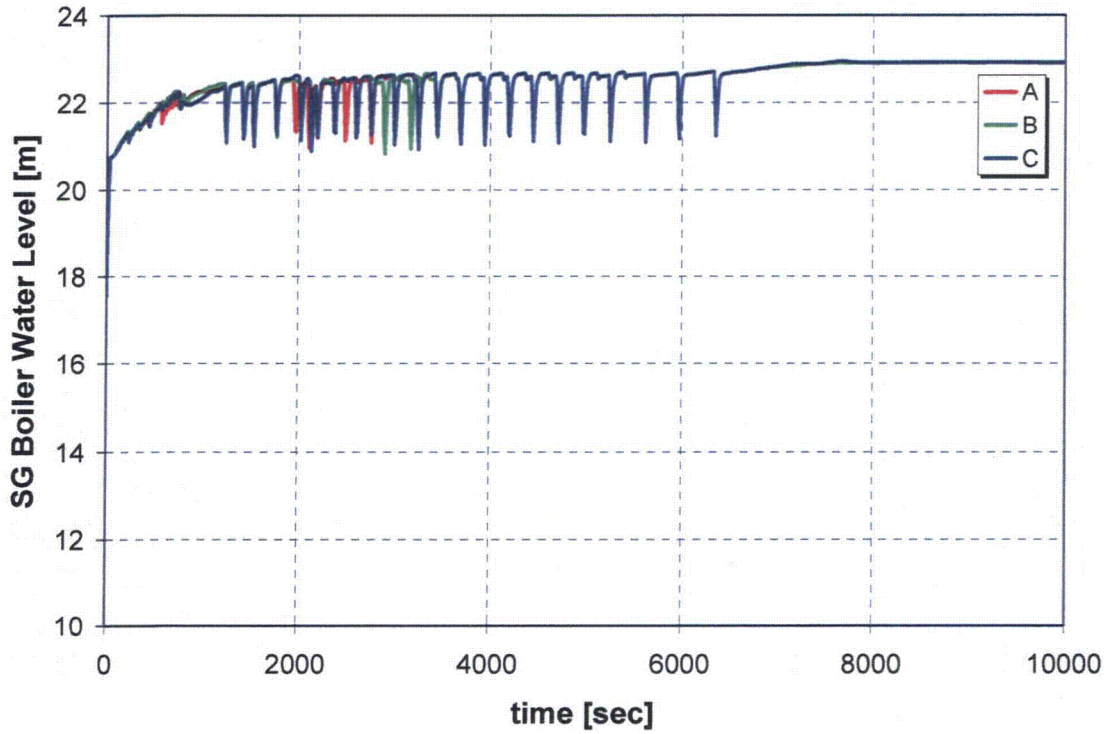


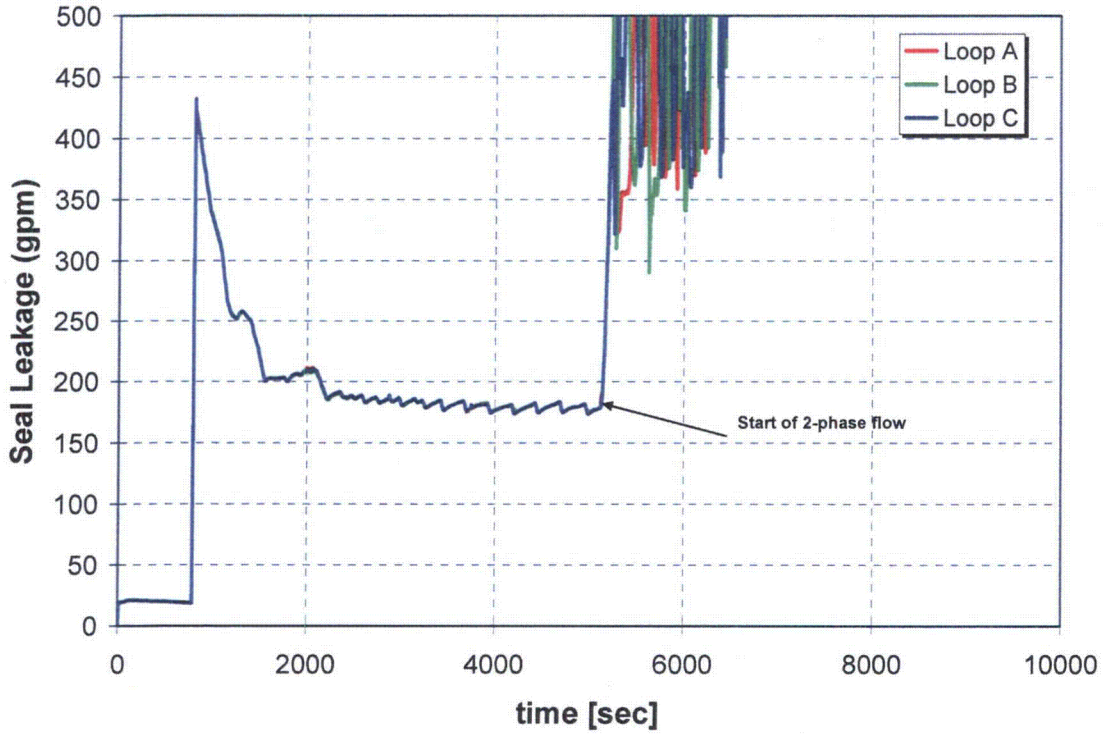


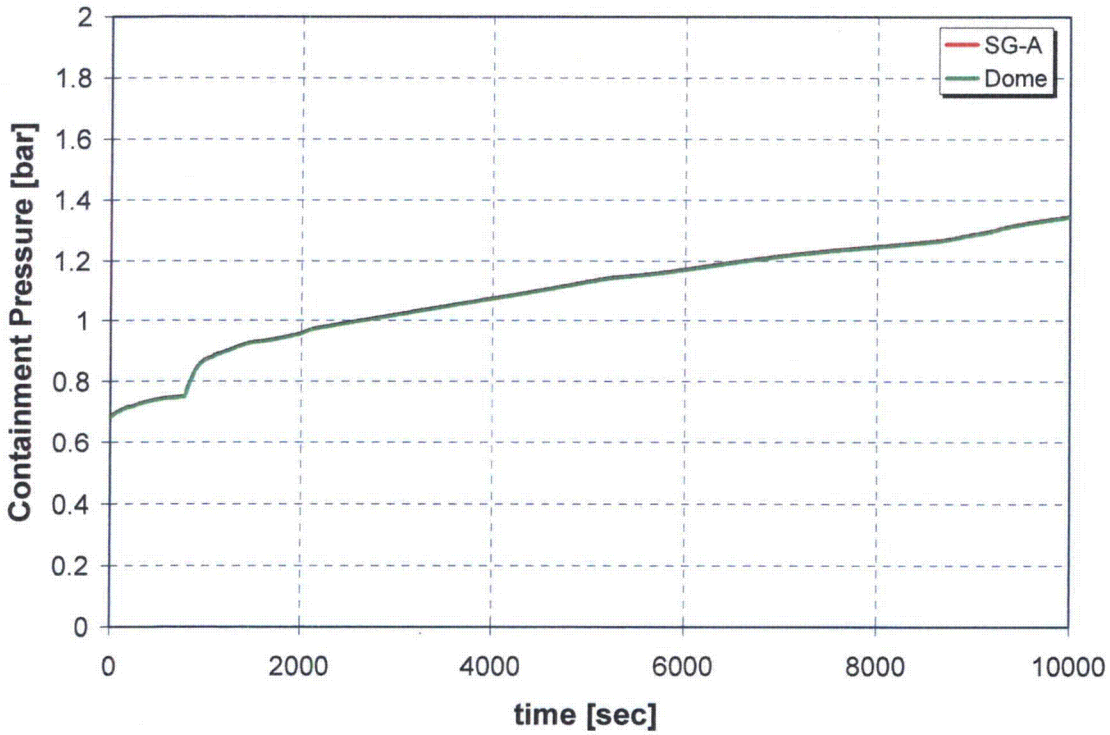

TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
2000
4000
6000
8000
10000
12000
time [sec]

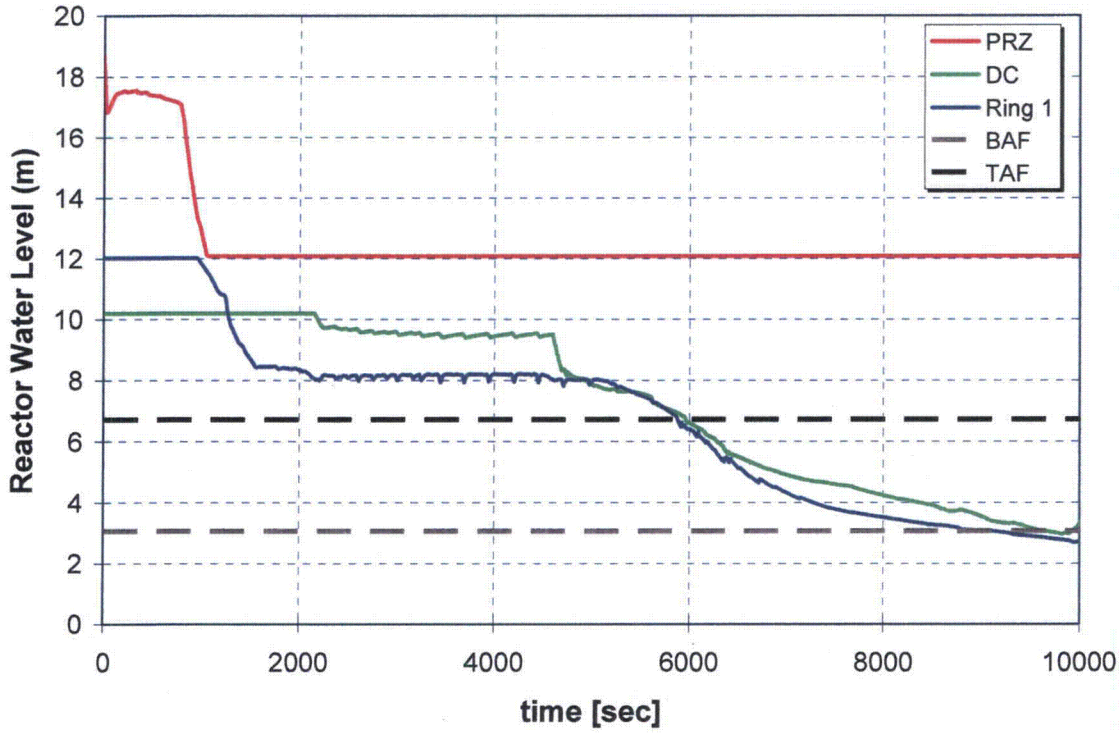
A.5.2 Case 2: Station Blackout with Turbine-Driven Auxiliary Feedwater (500 gpm)

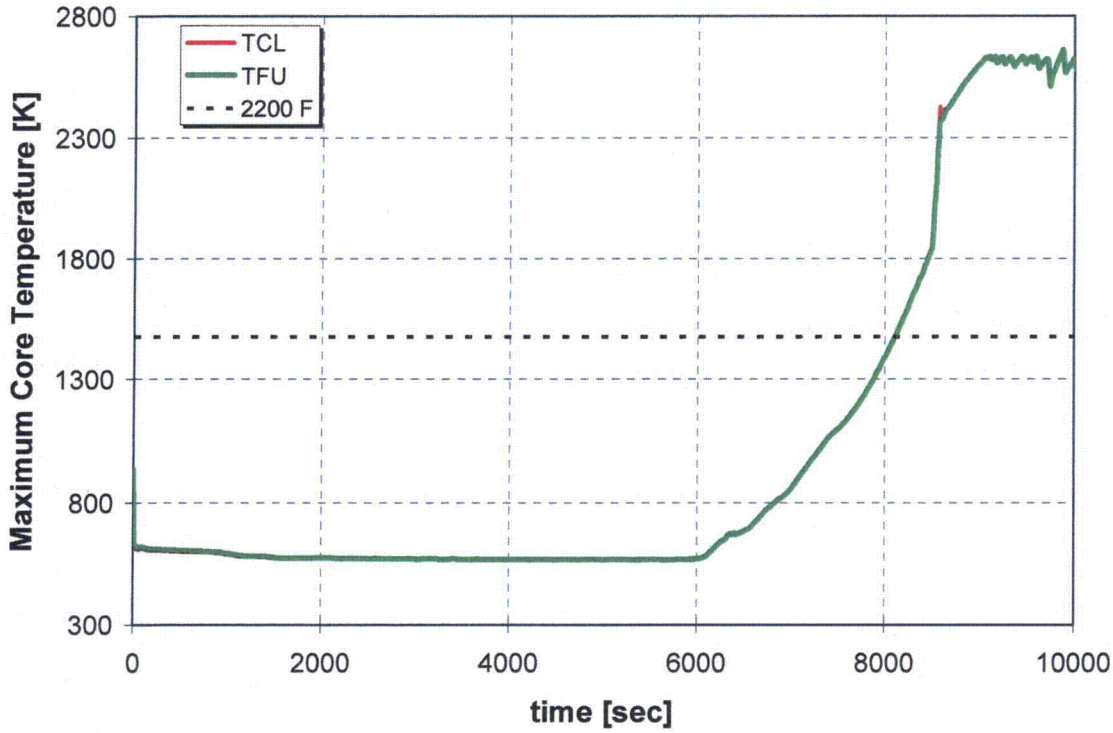




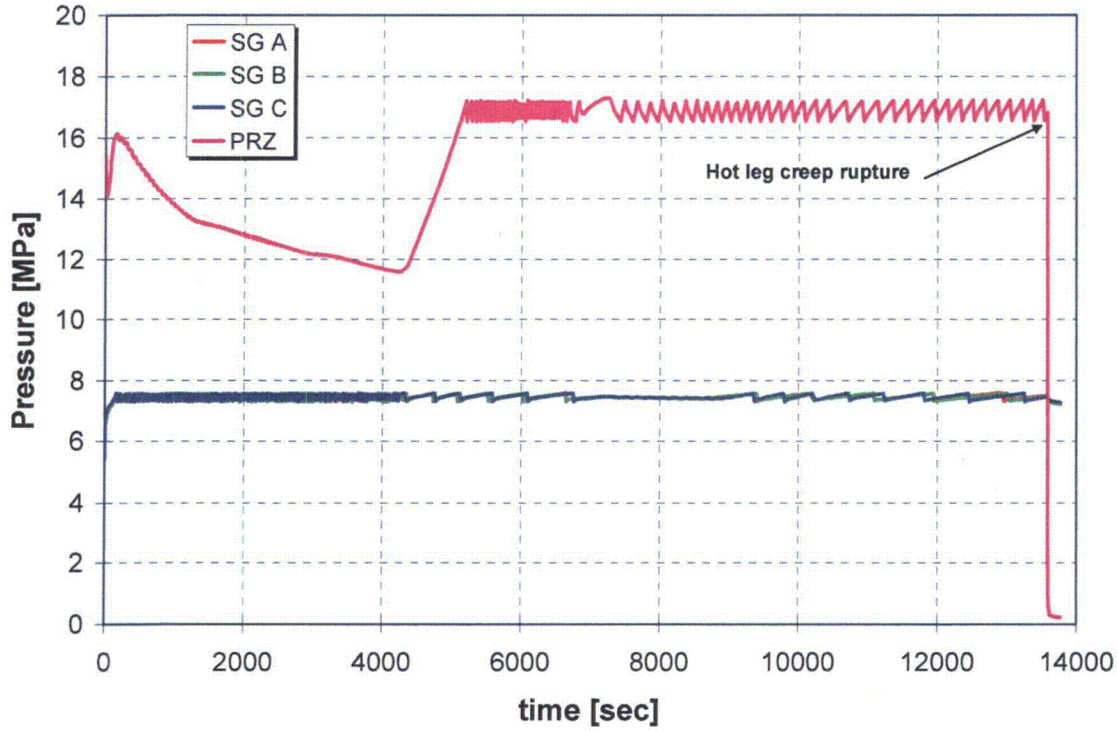

Seal Leakage (gpm)
500
450
400
350
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
time [sec]
Loop A
Loop B
Loop C
Start of 2-phase flow

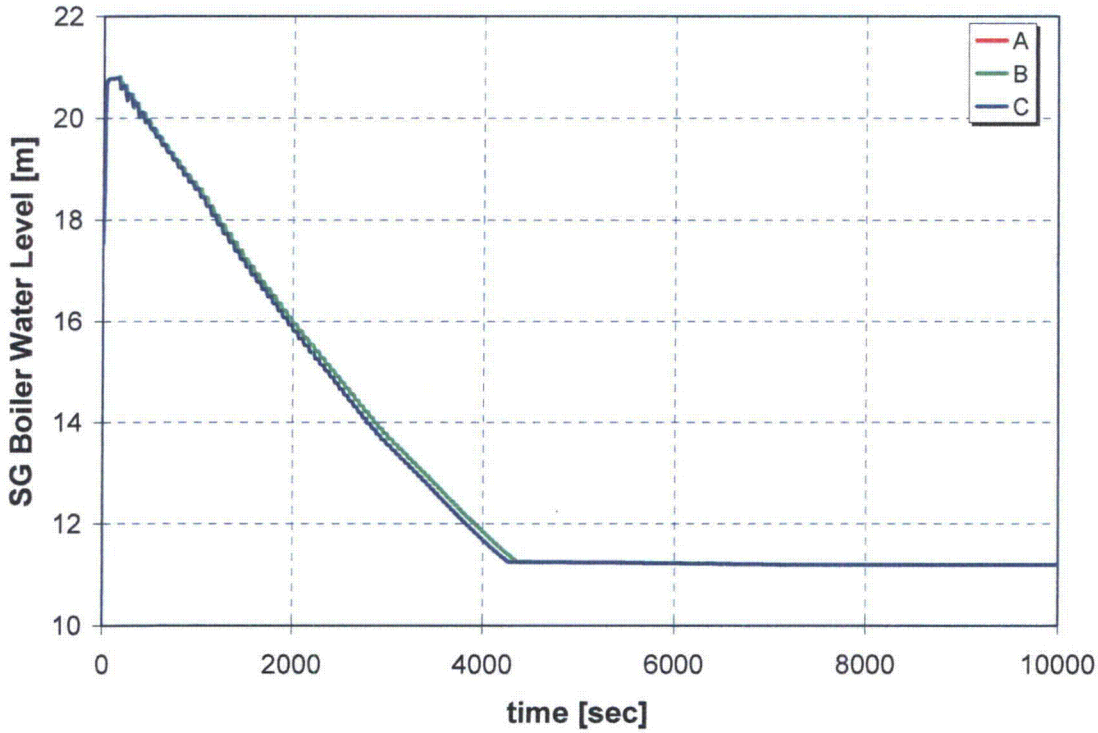

Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
time [sec]
SG-A
Dome

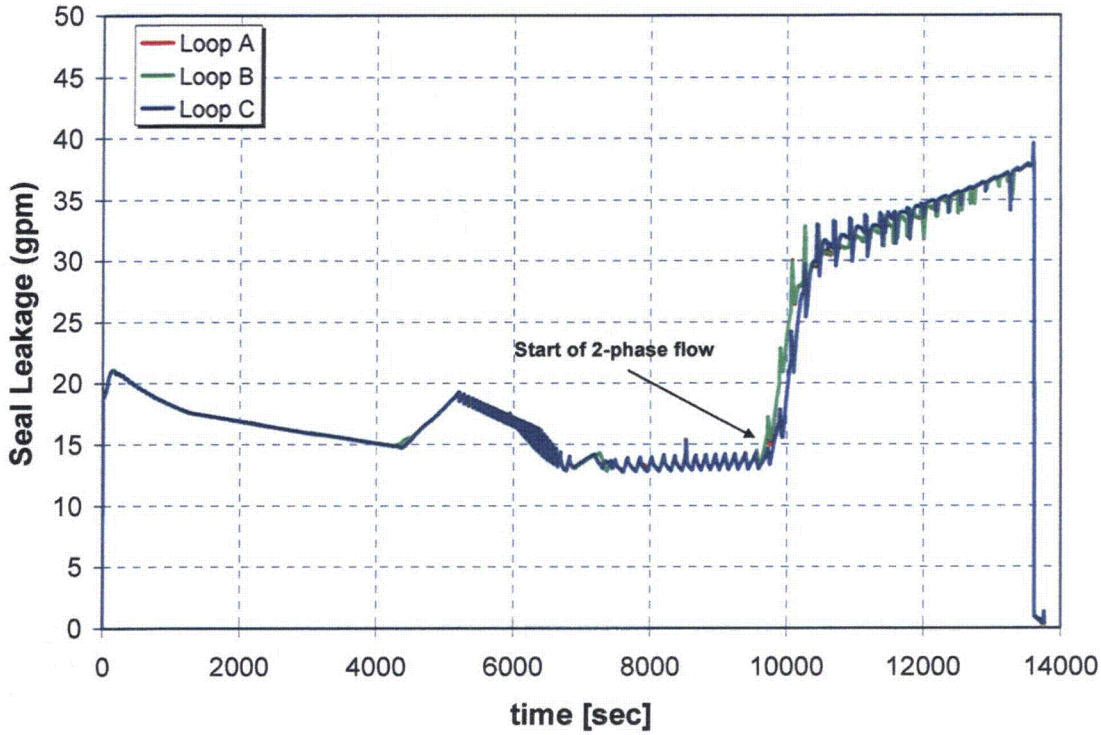

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
2
4
6
8
10
12
14
16
18
20
0
2000
4000
6000
8000
10000

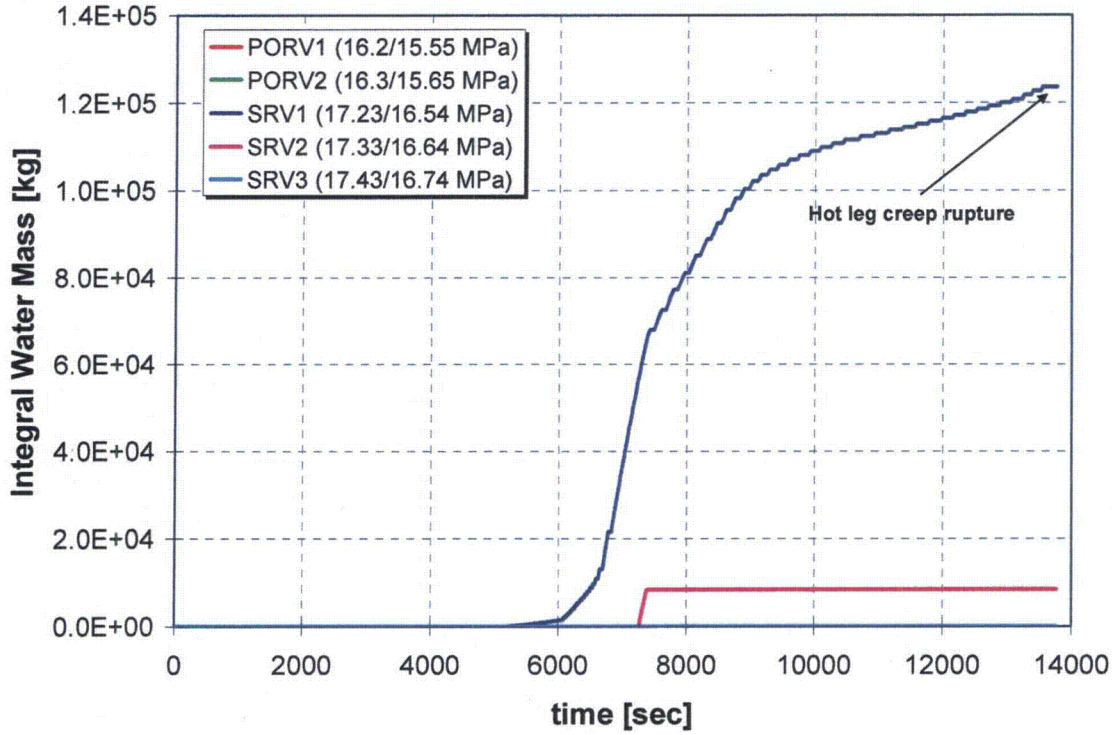

TCL
TFU
2200 F
Maximum Core Temperature [K]
time [sec]
300
800
1300
1800
2300
2800
0
2000
4000
6000
8000
10000

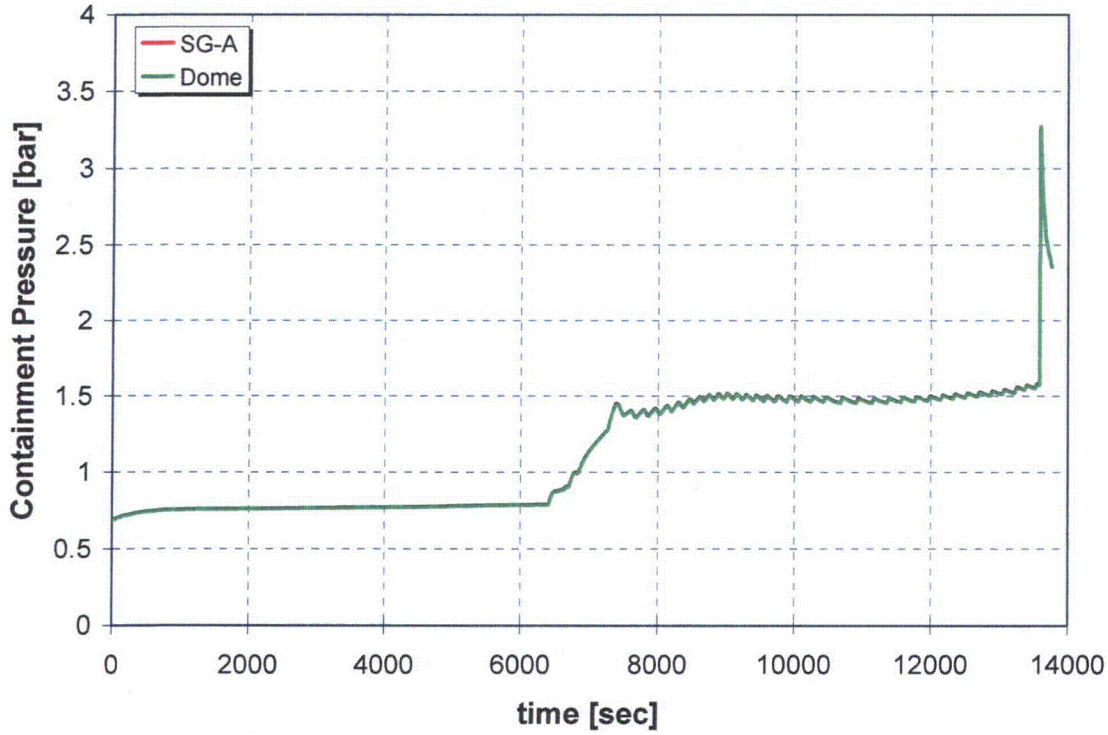
A.5.3 Case 3: Station Blackout without Turbine-Driven Auxiliary Feedwater (21 gpm)

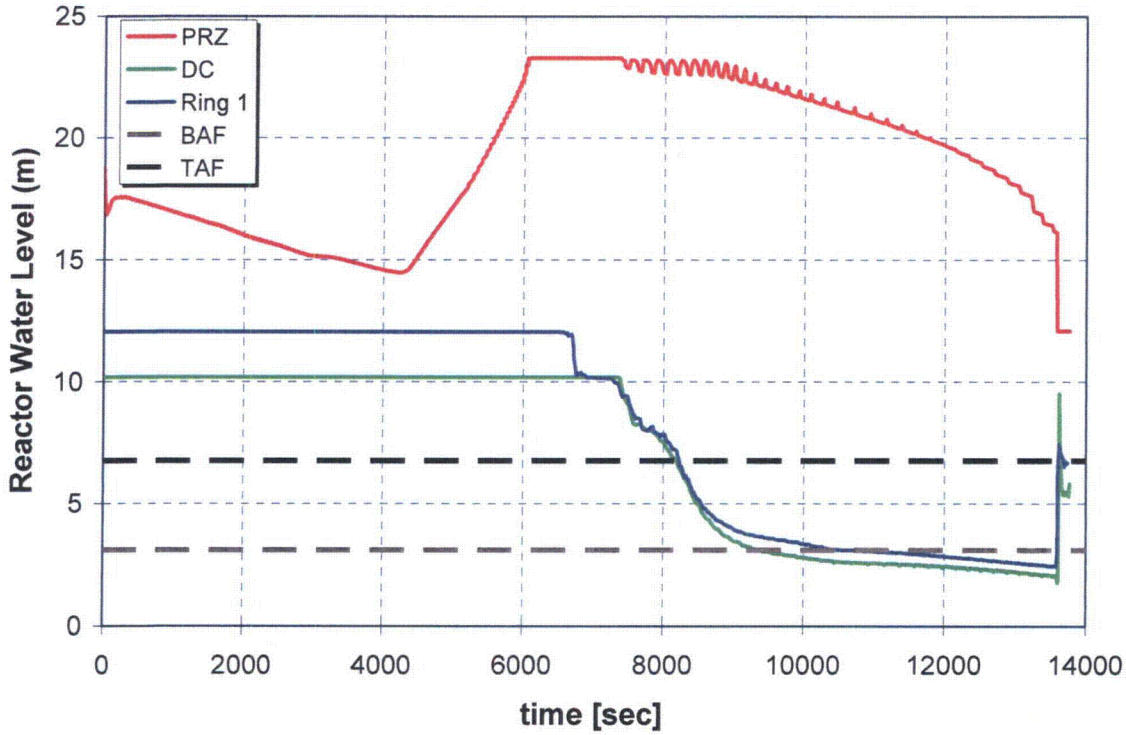


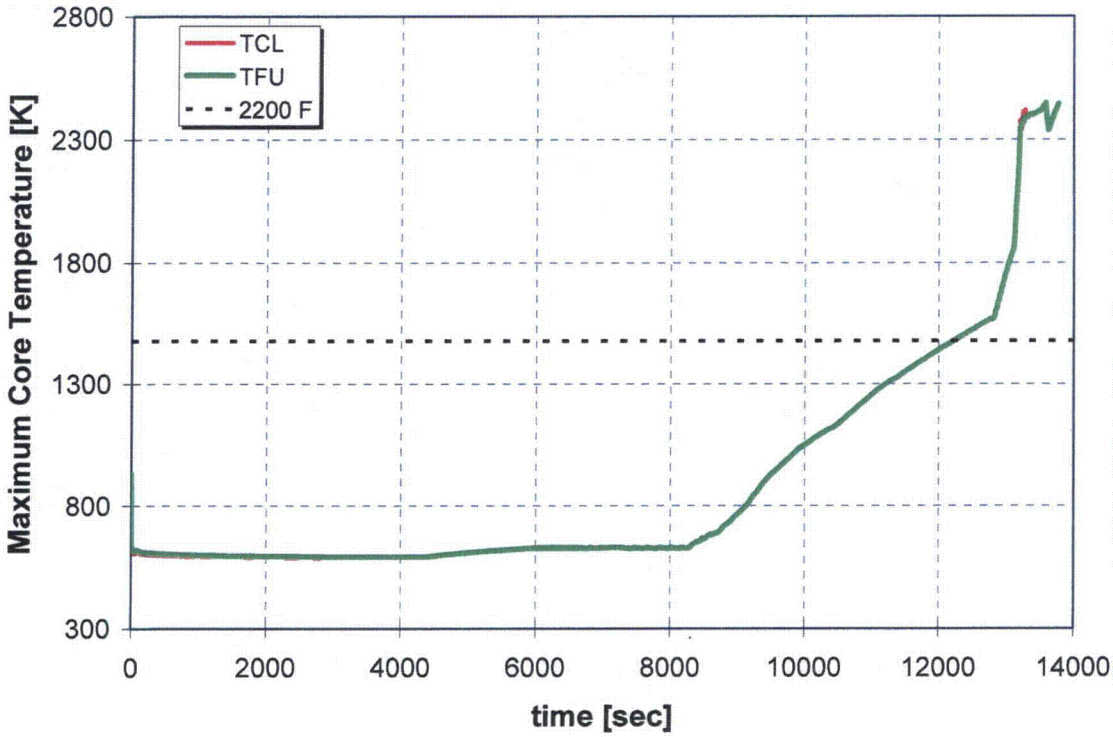



Loop A
Loop B
Loop C
Seal Leakage (gpm)
Start of 2-phase flow
time [sec]
0
5
10
15
20
25
30
35
40
45
50
0
2000
4000
6000
8000
10000
12000
14000

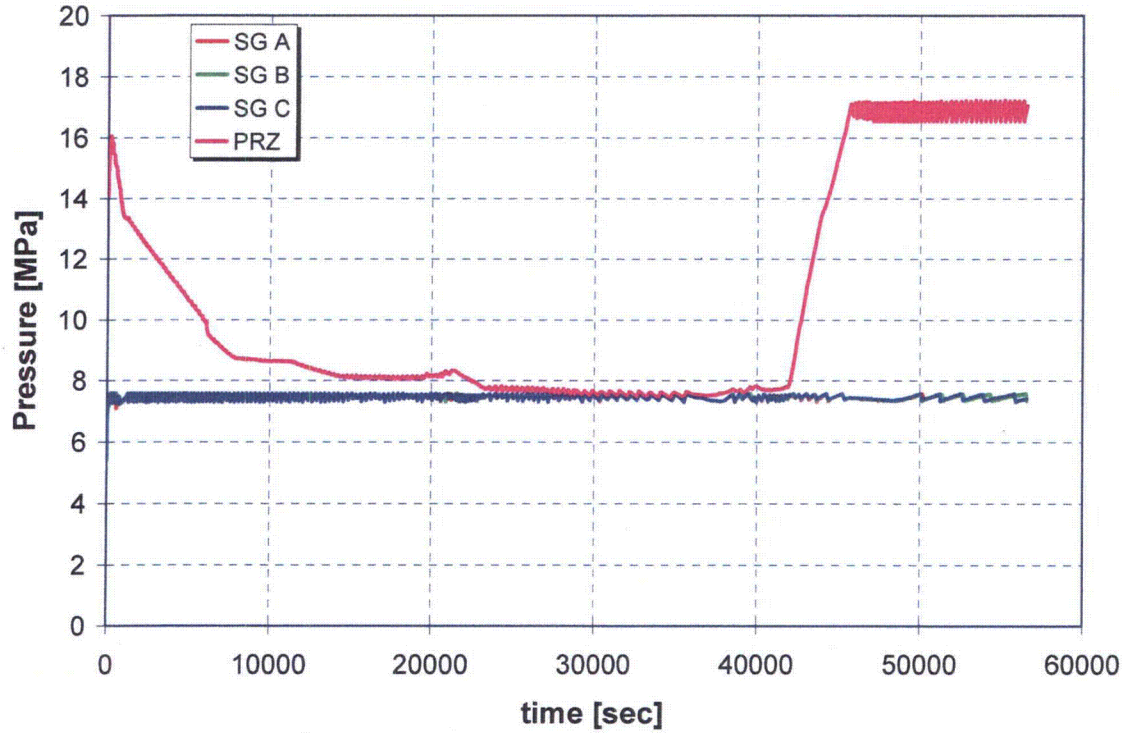

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Hot leg creep rupture
Integral Water Mass [kg]
time [sec]
0.0E+00
2.0E+04
4.0E+04
6.0E+04
8.0E+04
1.0E+05
1.2E+05
1.4E+05
0
2000
4000
6000
8000
10000
12000
14000

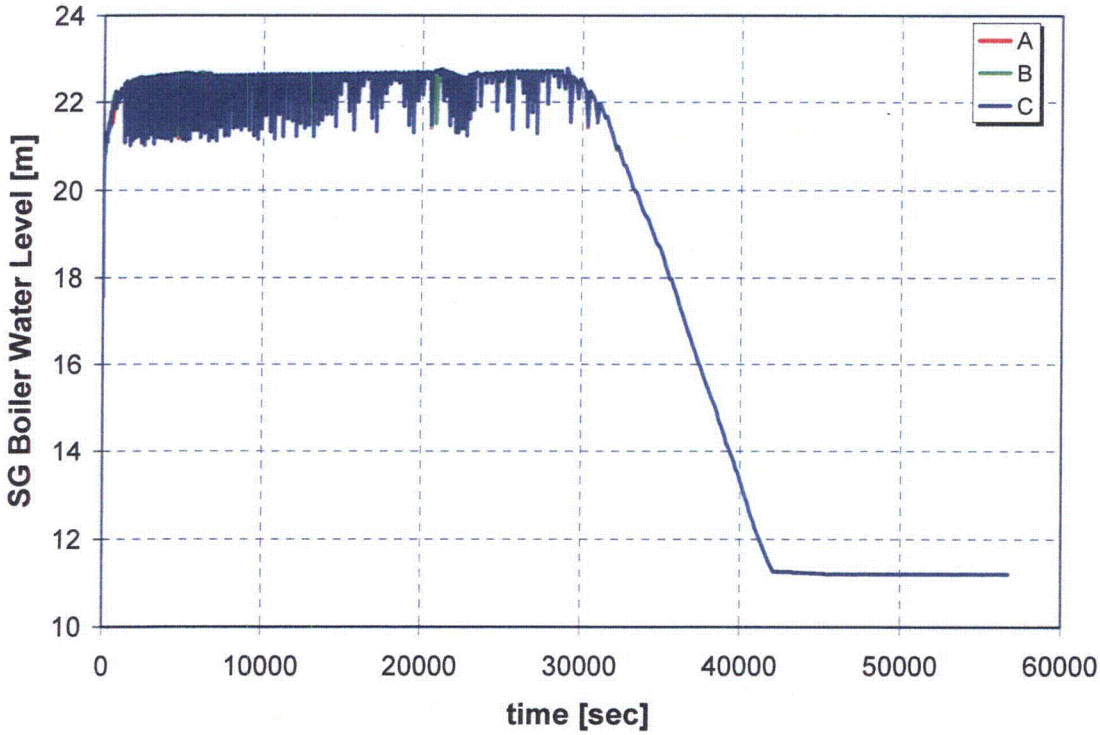

SG-A
Dome
Containment Pressure [bar]
time [sec]
0
0.5
1
1.5
2
2.5
3
3.5
4
0
2000
4000
6000
8000
10000
12000
14000

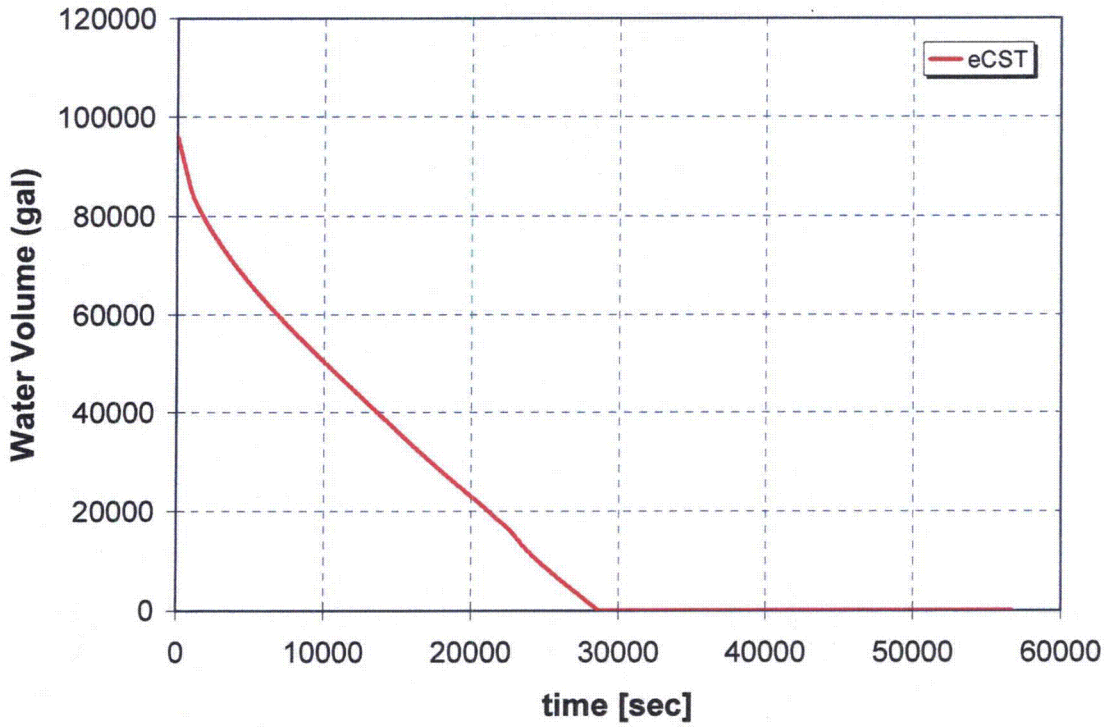

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
5
10
15
20
25
0
2000
4000
6000
8000
10000
12000
14000

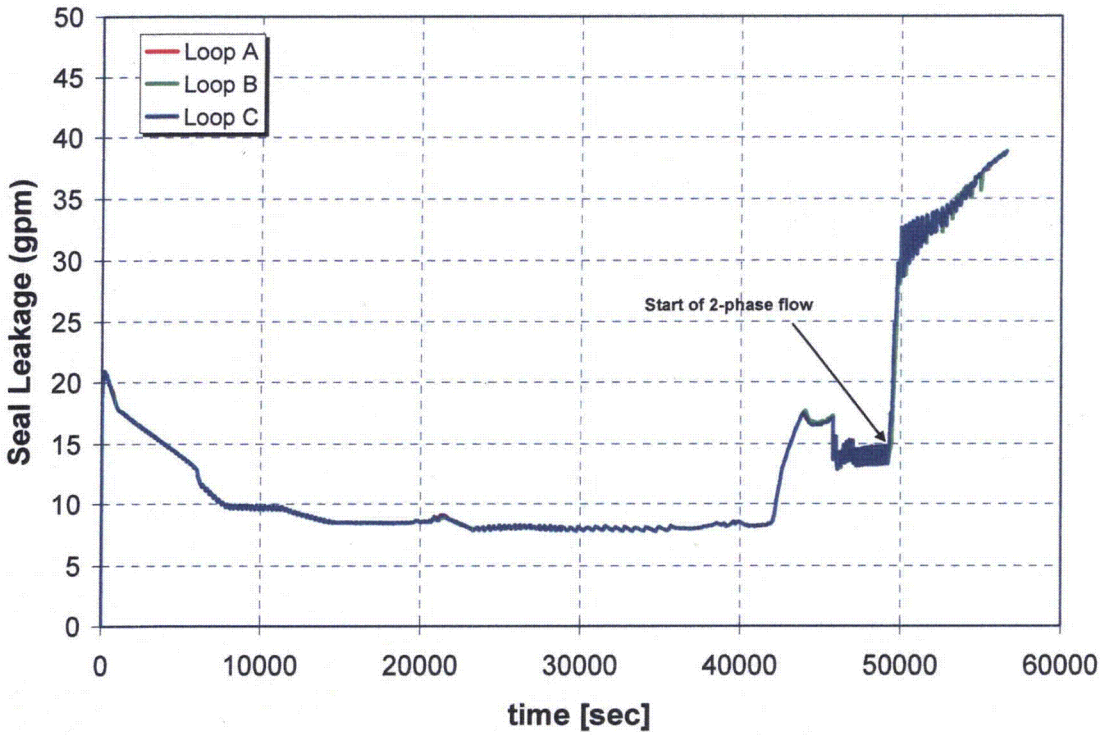

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
2000
4000
6000
8000
10000
12000
14000
time [sec]

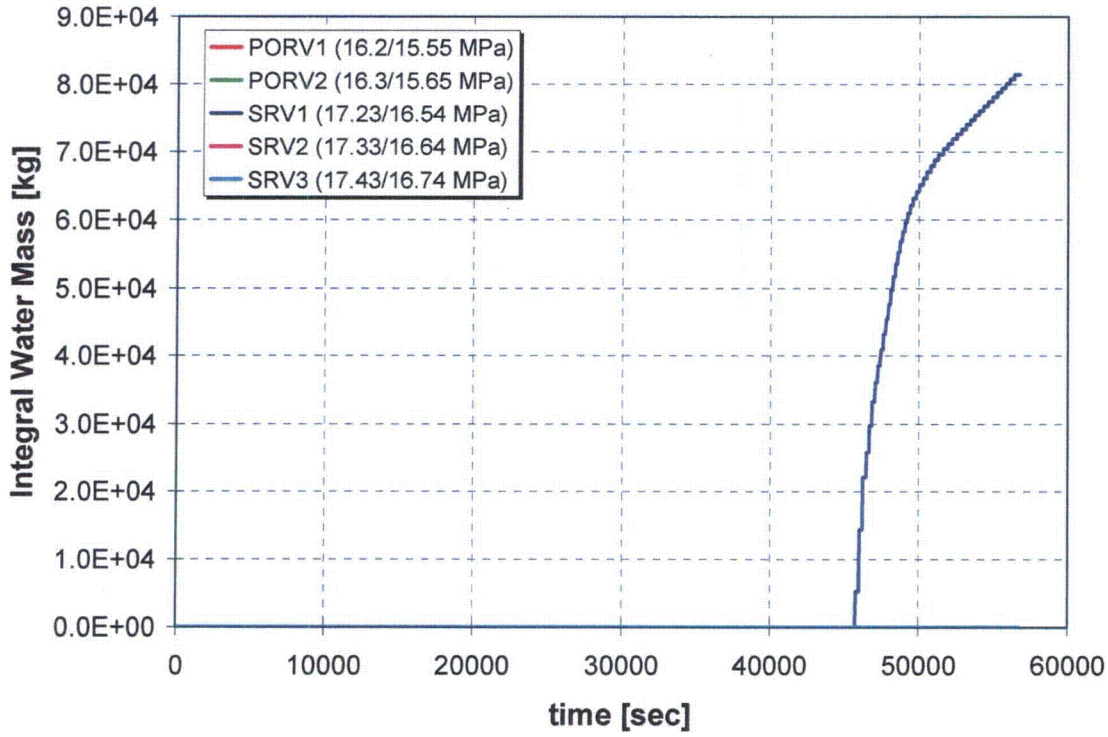
A.5.4 Case 4: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm)

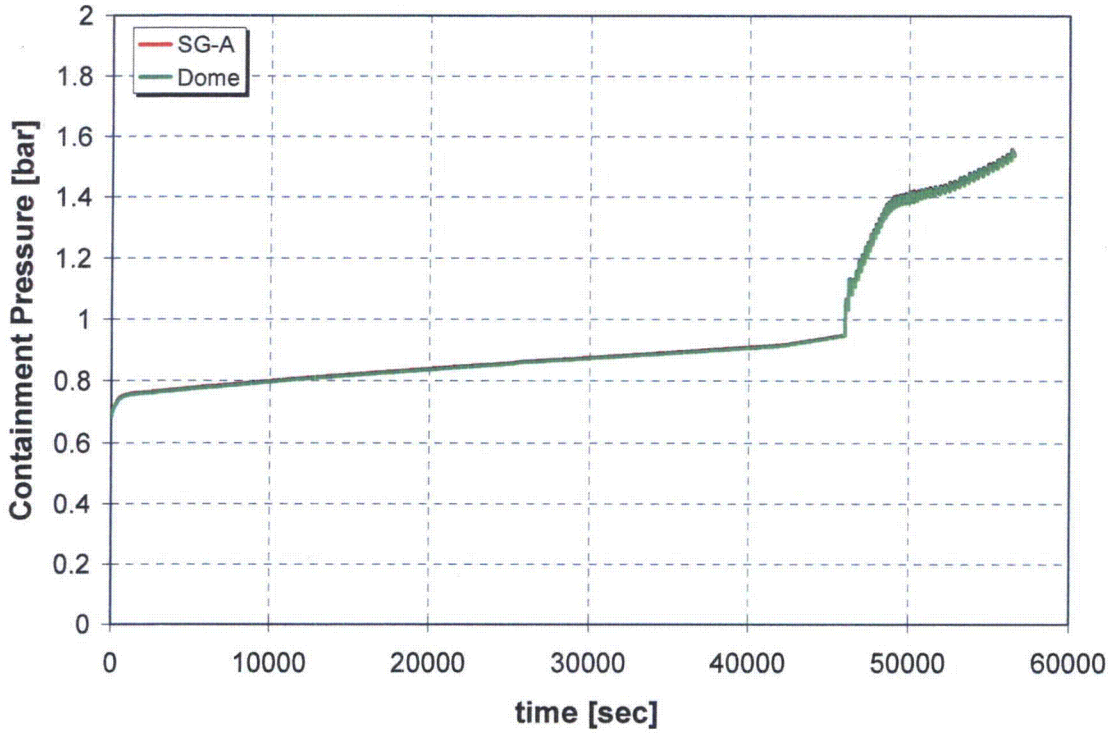


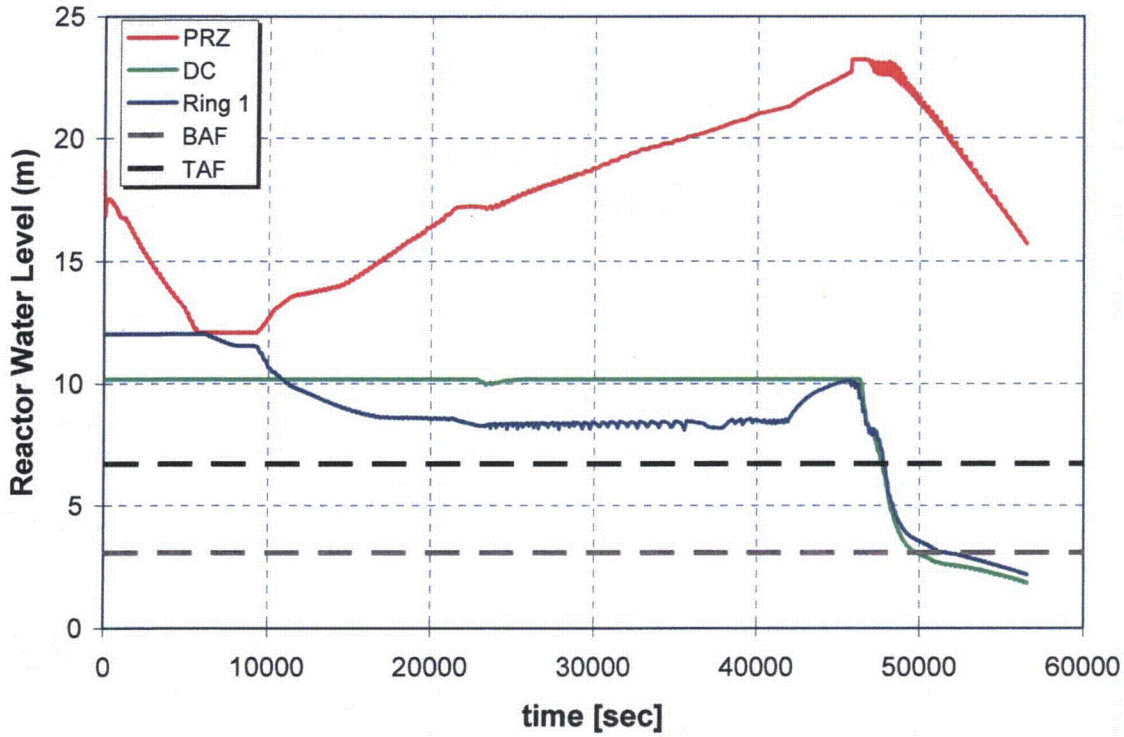


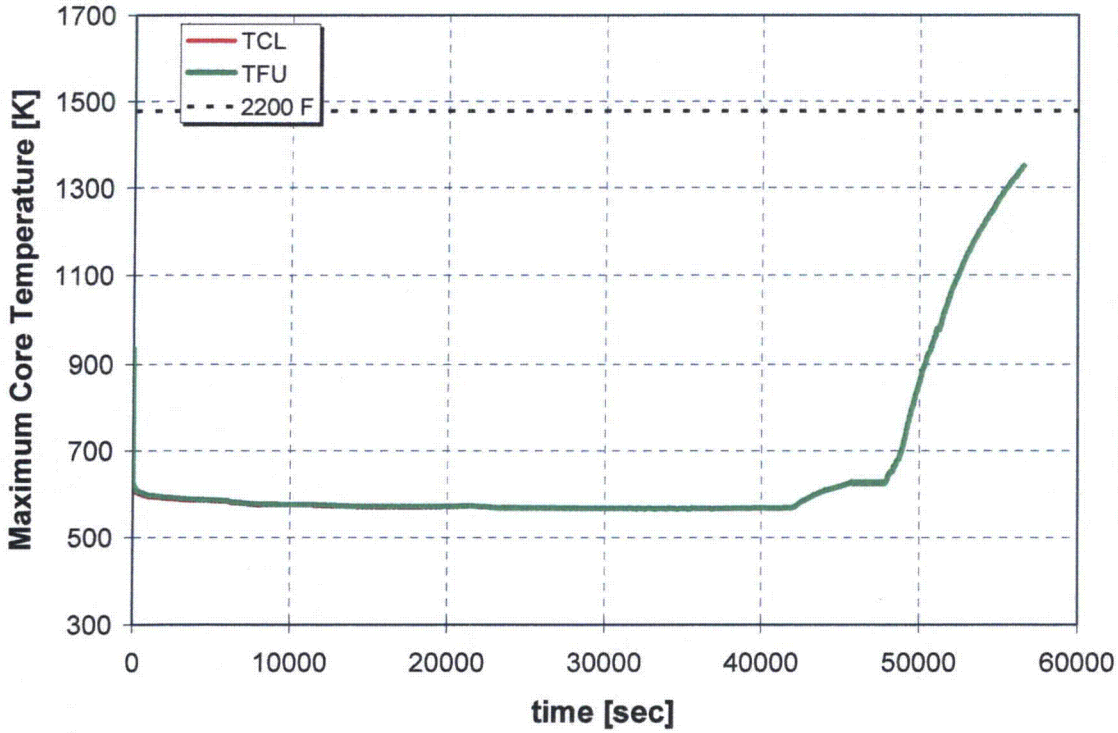

eCST
Water Volume (gal)
120000
100000
80000
60000
40000
20000
0
0
10000
20000
30000
40000
50000
60000
time [sec]


Loop A
Loop B
Loop C
Start of 2-phase flow
Seal Leakage (gpm)
50
45
40
35
30
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
time [sec]

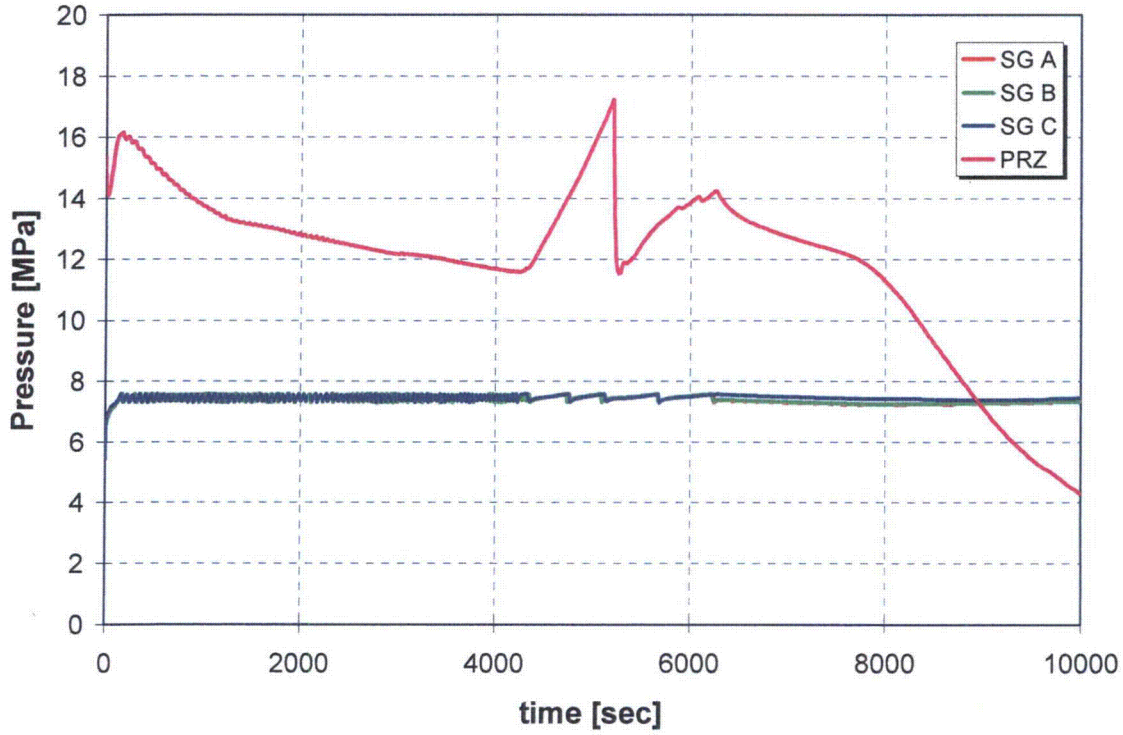

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
9.0E+04
8.0E+04
7.0E+04
6.0E+04
5.0E+04
4.0E+04
3.0E+04
2.0E+04
1.0E+04
0.0E+00
0
10000
20000
30000
40000
50000
60000
time [sec]

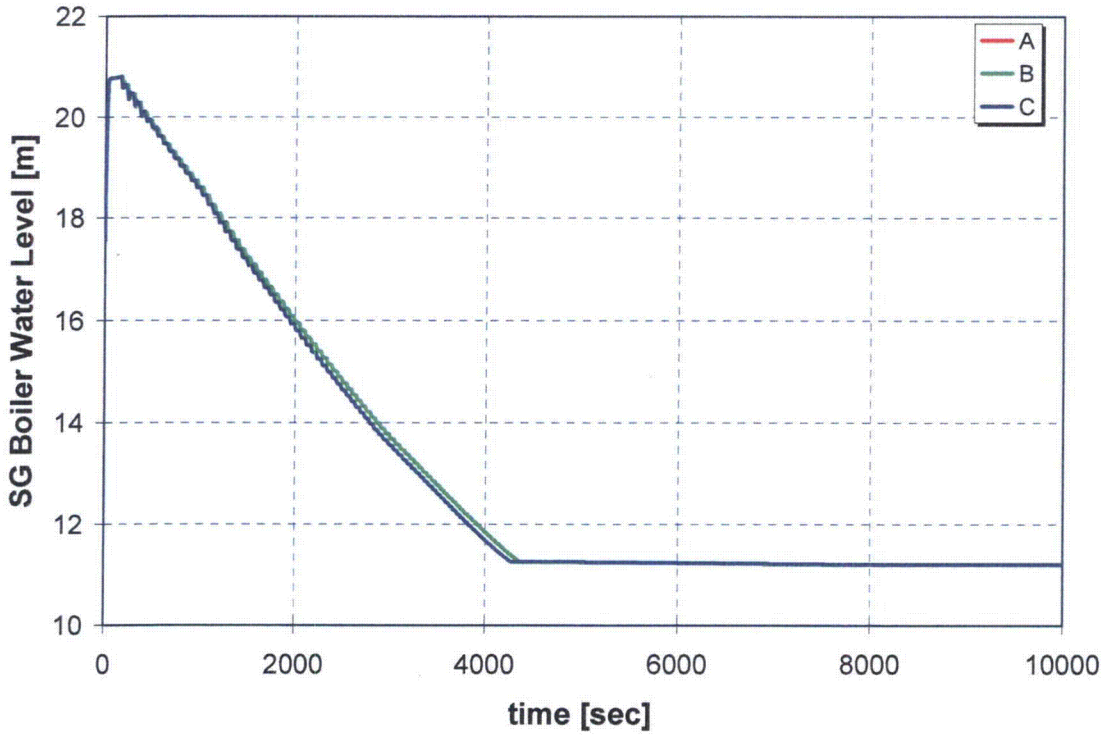

SG-A
Dome
Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10000
20000
30000
40000
50000
60000
time [sec]

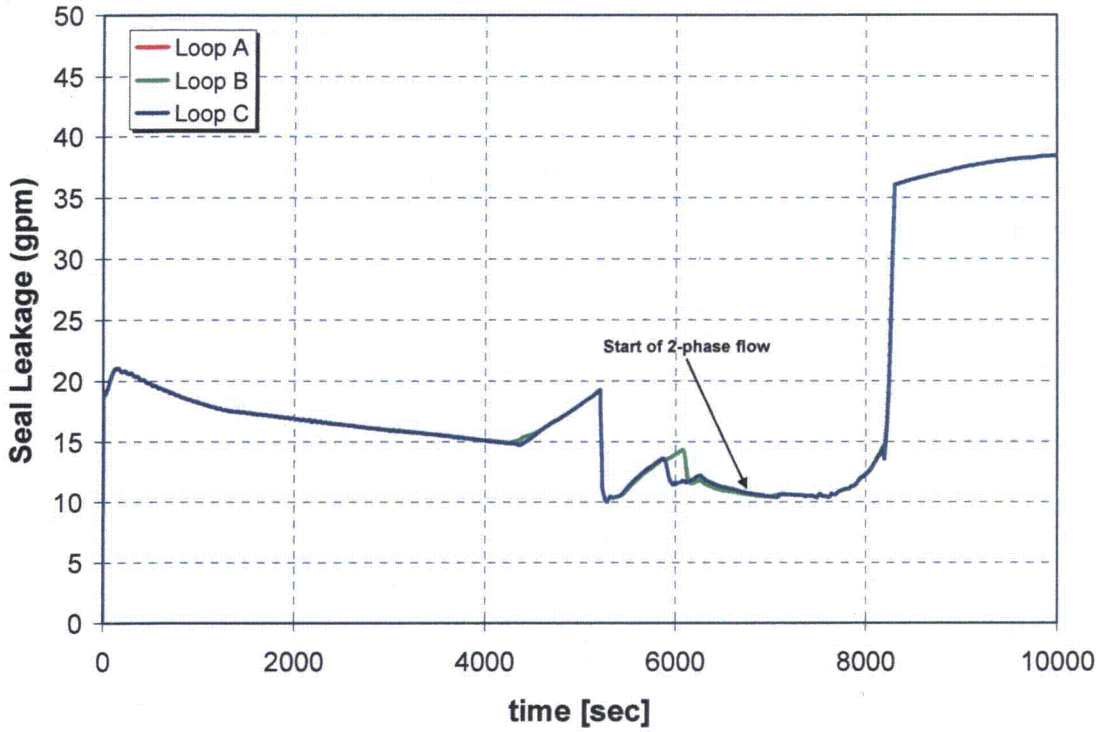

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
time [sec]

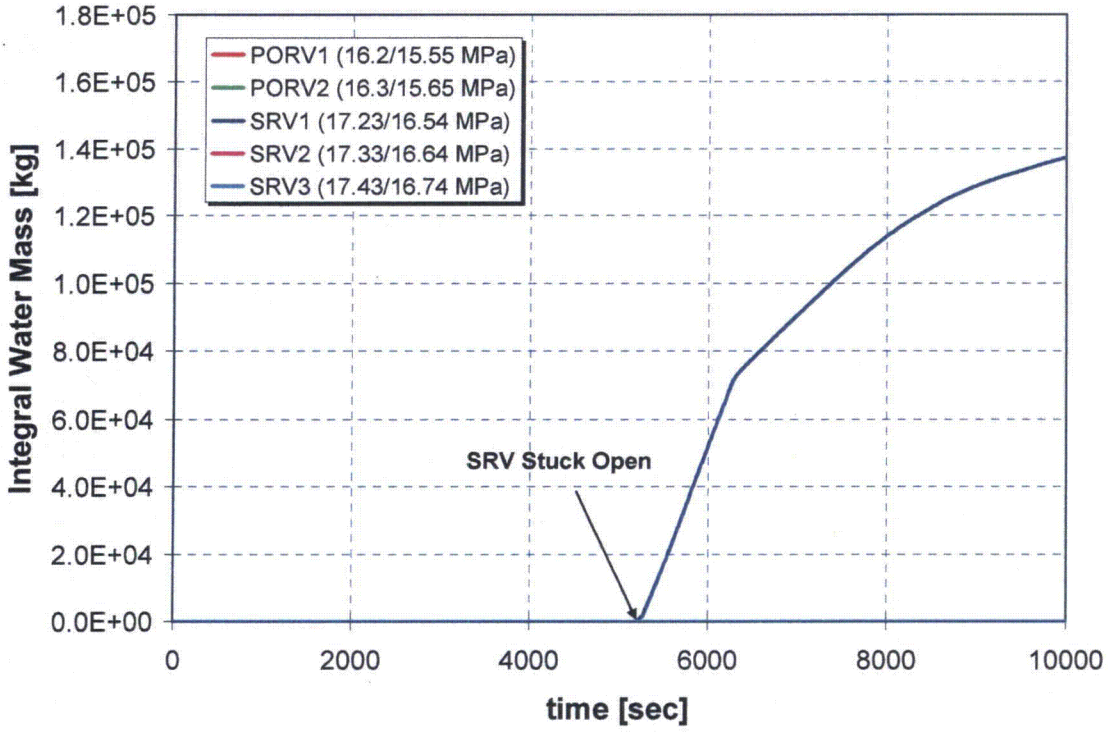

TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
10000
20000
30000
40000
50000
60000
time [sec]

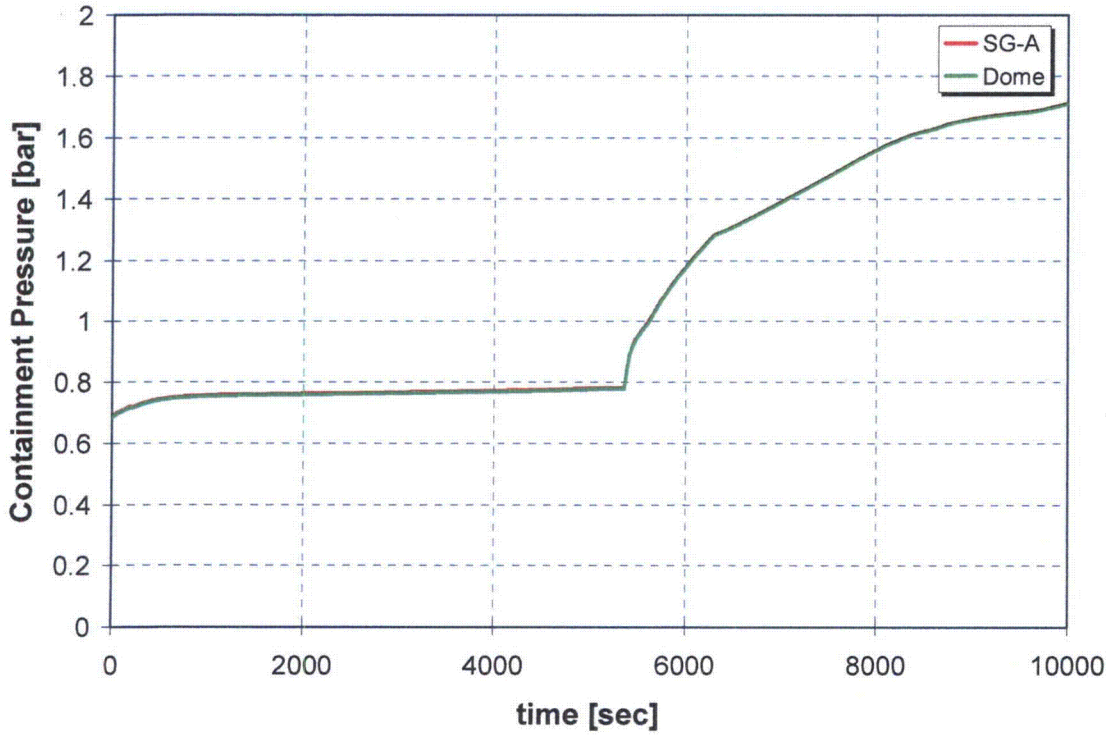
A.5.5 Case 5: Station Blackout without Turbine-Driven Auxiliary Feedwater (21 gpm); Stuck-Open Relief Valve

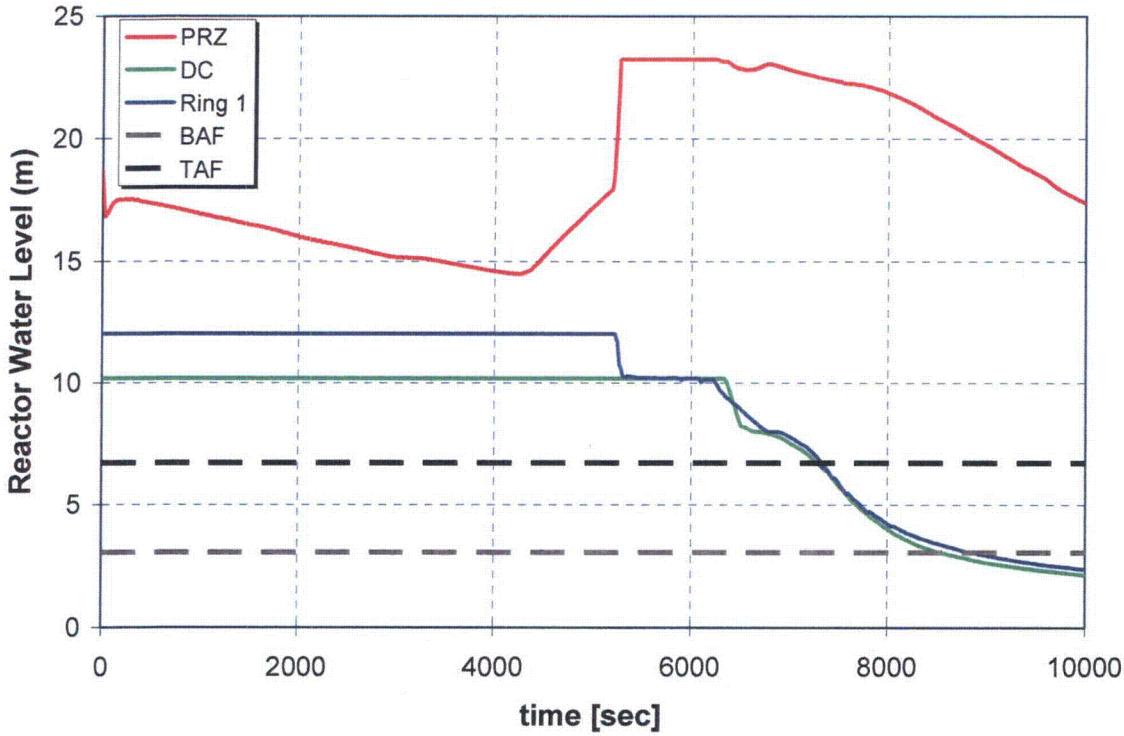


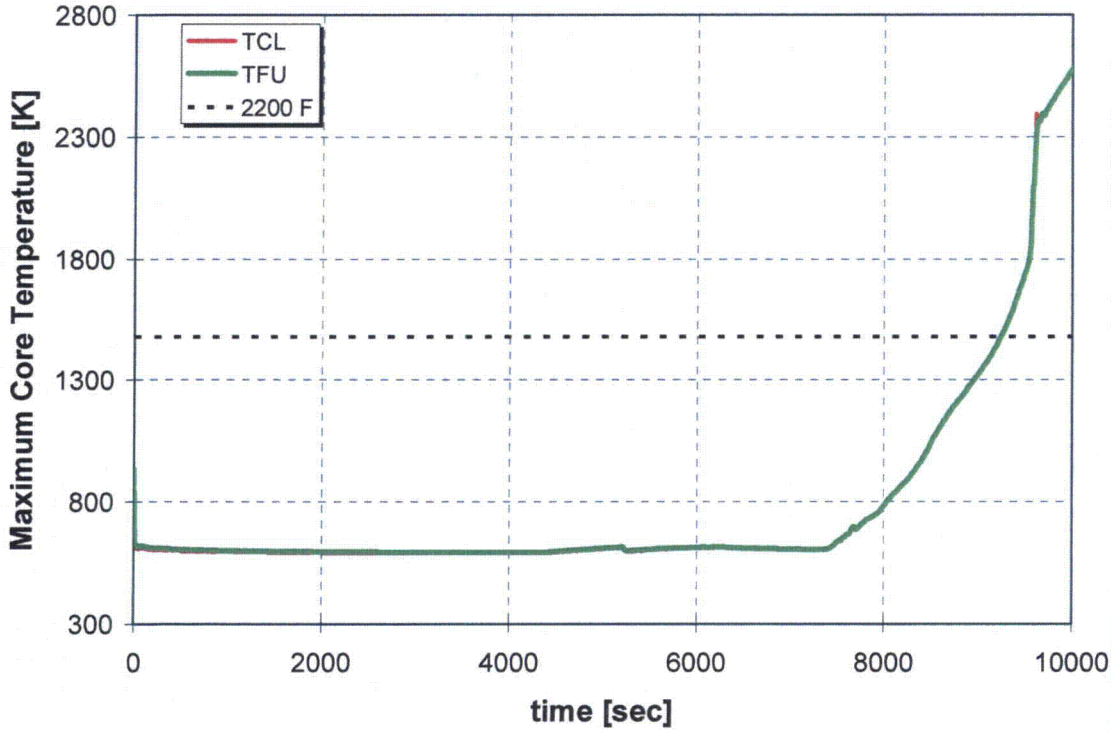



Loop A
Loop B
Loop C
Seal Leakage (gpm)
Start of 2-phase flow
time [sec]
0
5
10
15
20
25
30
35
40
45
50
0
2000
4000
6000
8000
10000

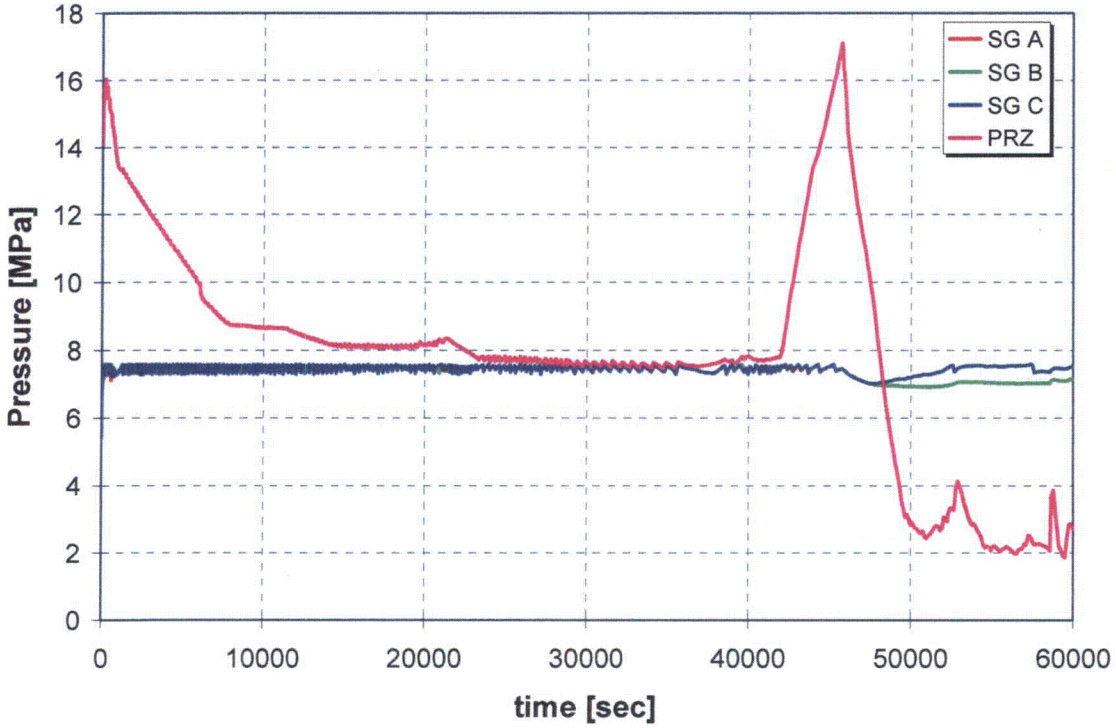

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
SRV Stuck Open
time [sec]
0.0E+00
2.0E+04
4.0E+04
6.0E+04
8.0E+04
1.0E+05
1.2E+05
1.4E+05
1.6E+05
1.8E+05
0
2000
4000
6000
8000
10000

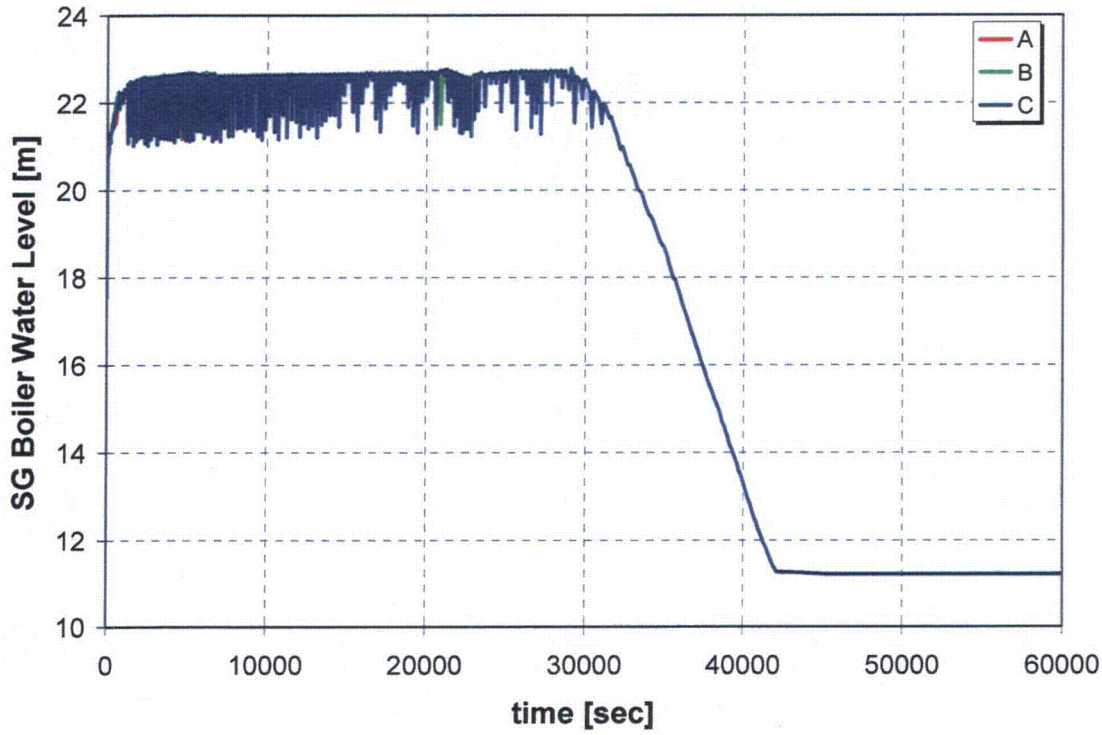

SG-A
Dome
Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
time [sec]

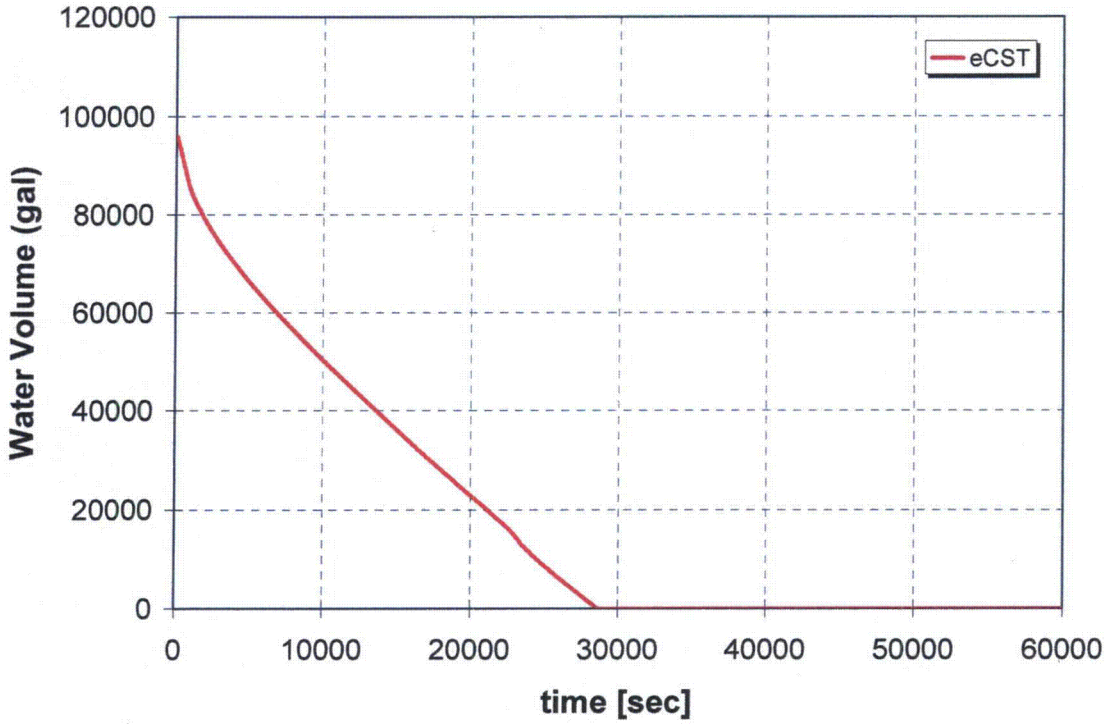

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
time [sec]

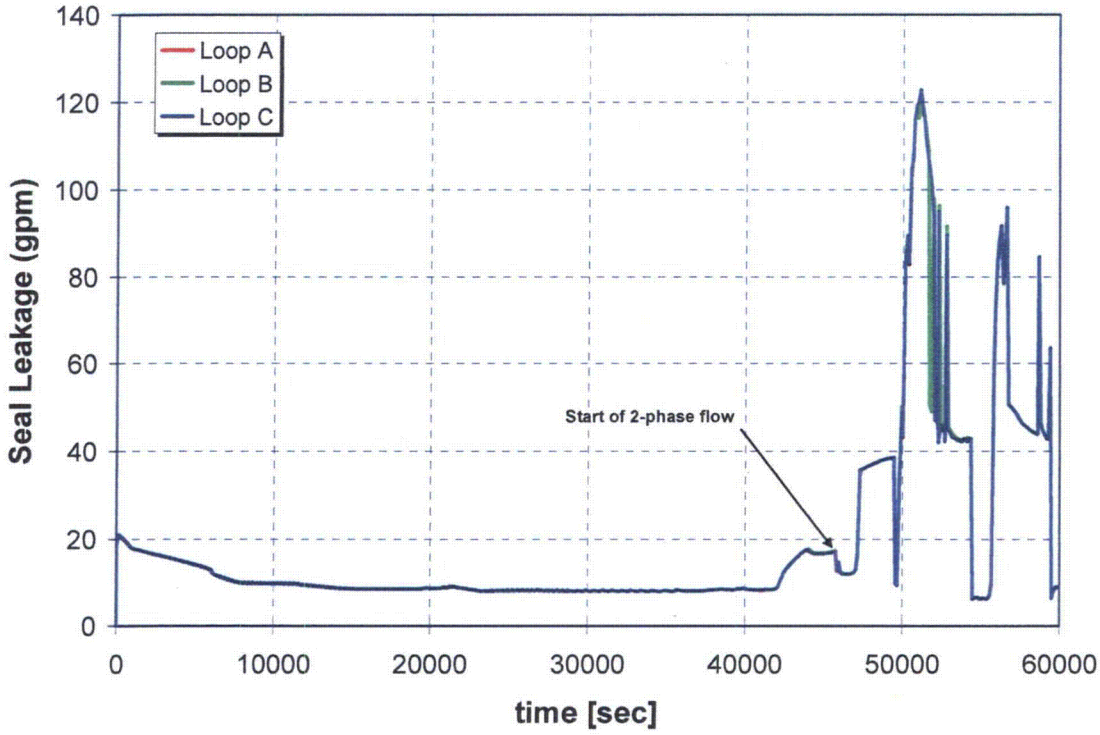

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
2000
4000
6000
8000
10000
time [sec]

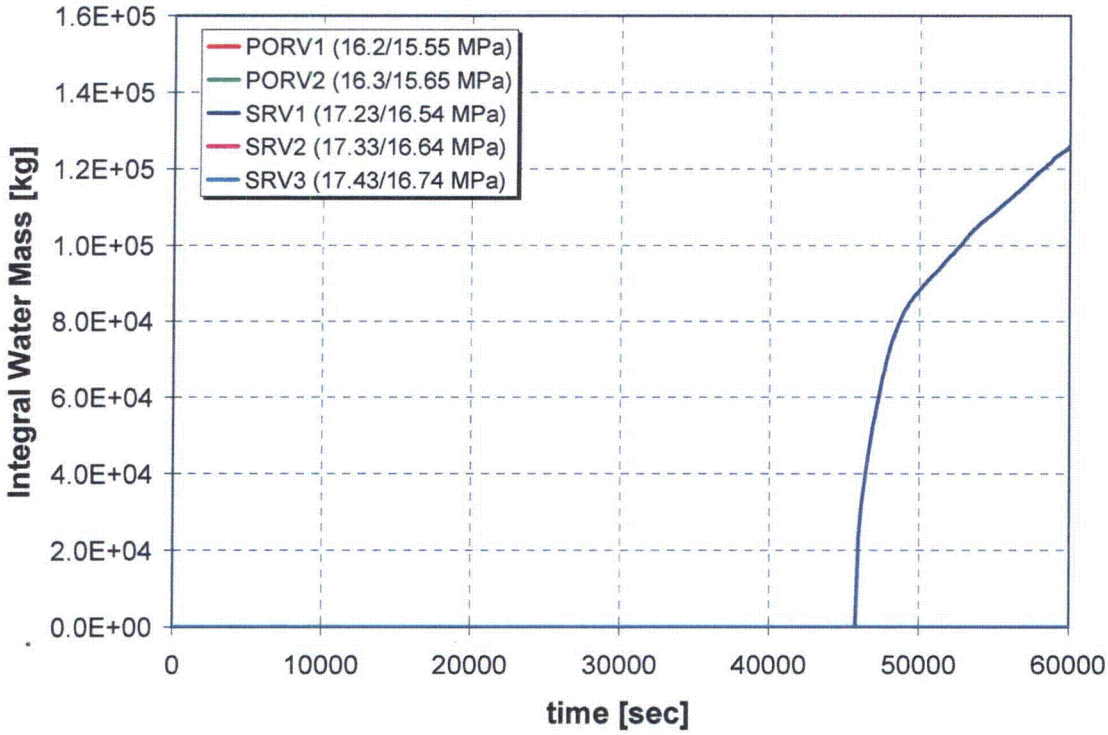
A.5.6 Case 6: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm); Stuck-Open Relief Valve

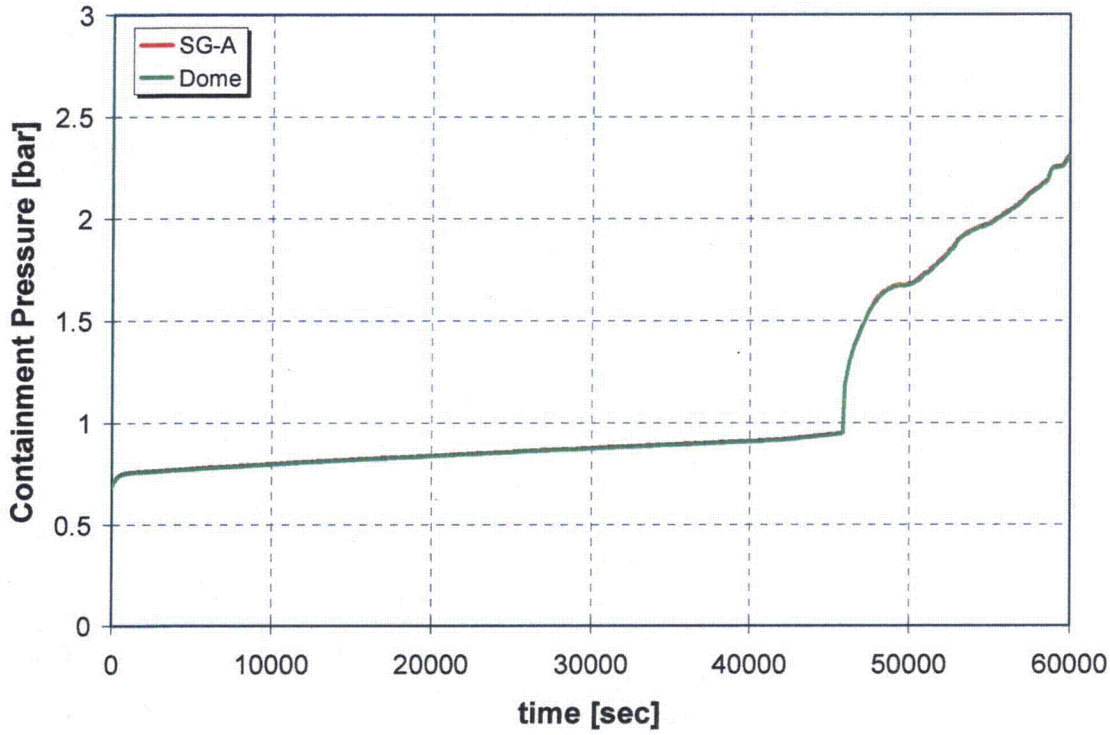


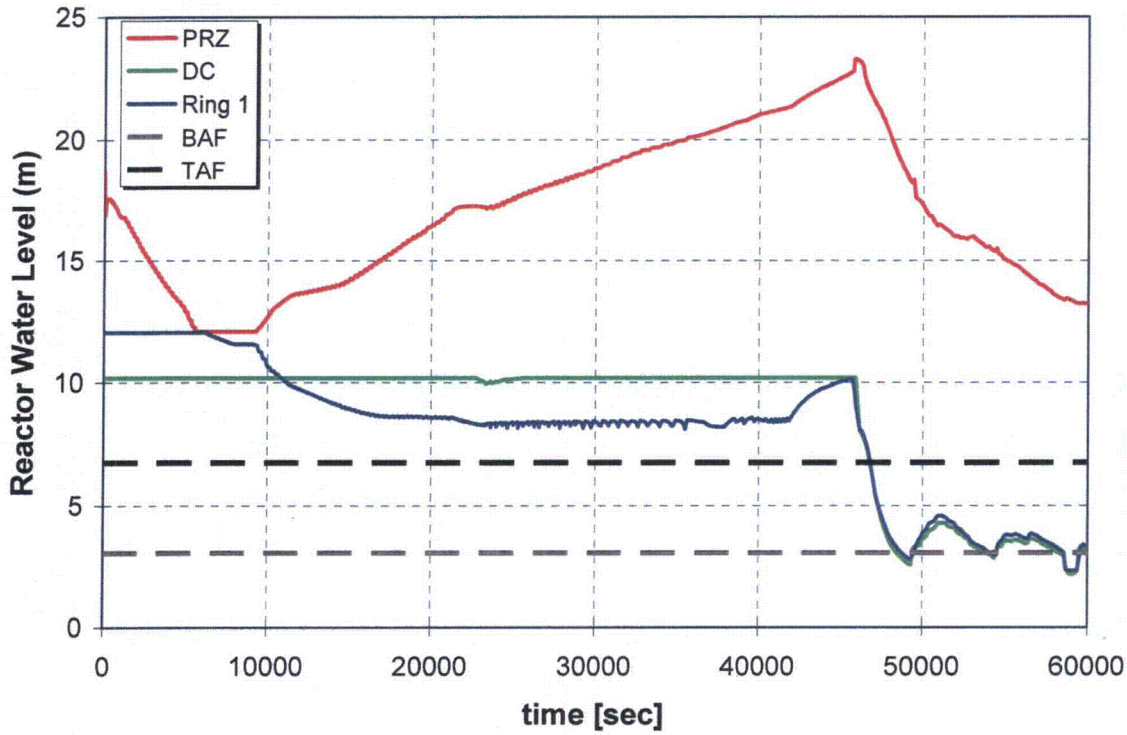

24
22
20
18
16
14
12
10
SG Boiler Water Level [m]
0
10000
20000
30000
40000
50000
60000
time [sec]
A
B
C

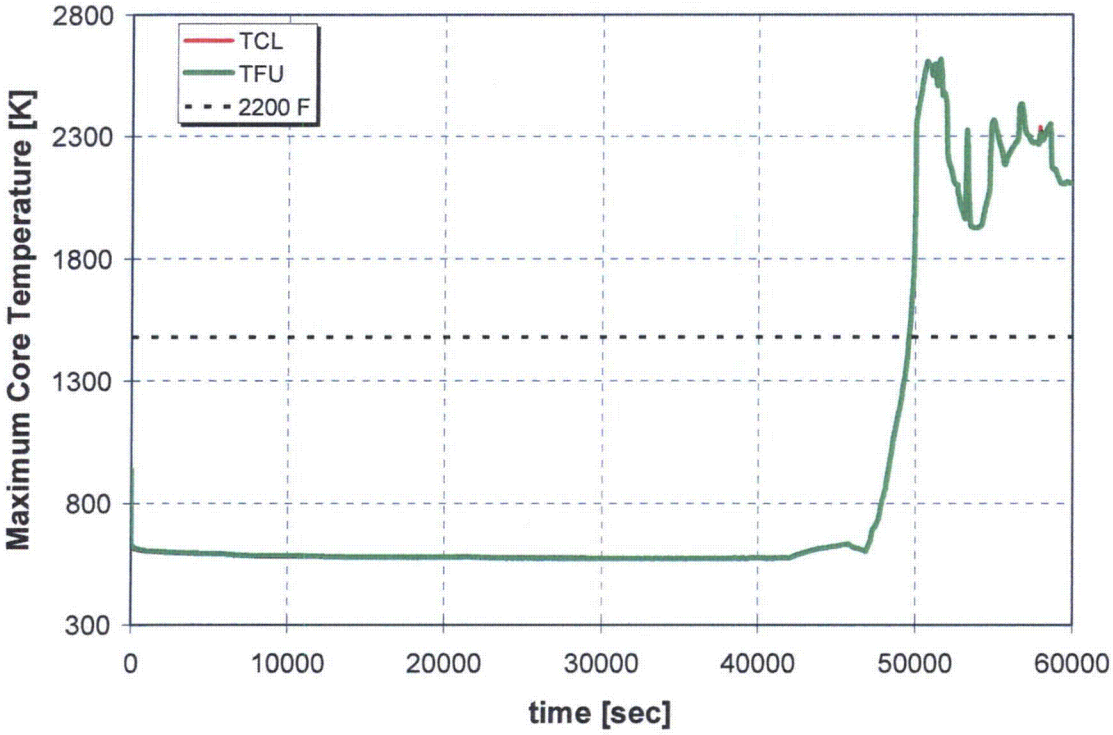

120000
100000
80000
60000
40000
20000
0
Water Volume (gal)
0
10000
20000
30000
40000
50000
60000
time [sec]
eCST


Loop A
Loop B
Loop C
Seal Leakage (gpm)
Start of 2-phase flow
time [sec]
0
20
40
60
80
100
120
140
0
10000
20000
30000
40000
50000
60000

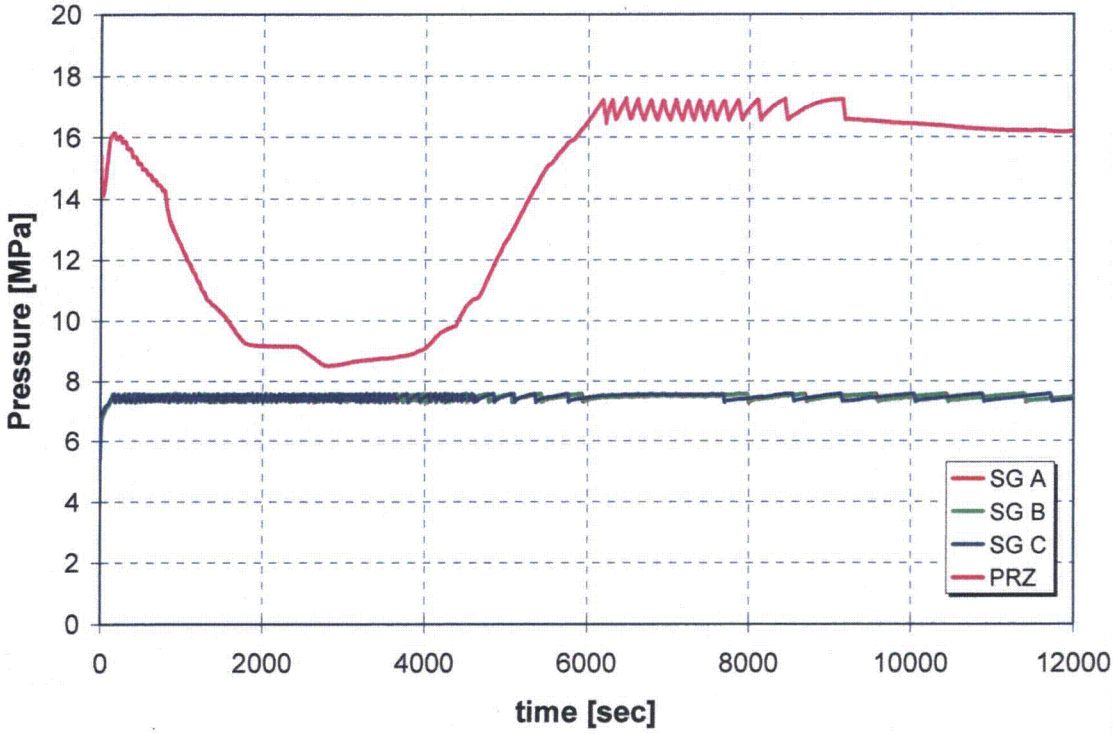

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
time [sec]
0.0E+00
2.0E+04
4.0E+04
6.0E+04
8.0E+04
1.0E+05
1.2E+05
1.4E+05
1.6E+05
0
10000
20000
30000
40000
50000
60000

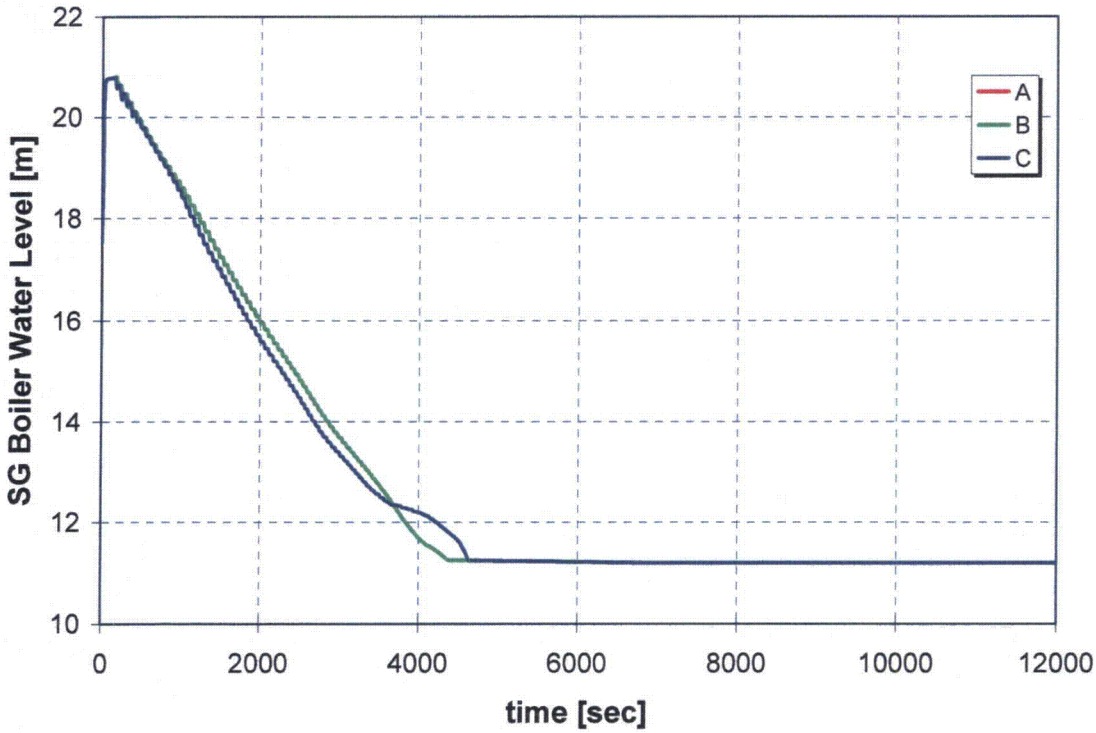

SG-A
Dome
Containment Pressure [bar]
3
2.5
2
1.5
1
0.5
0
0
10000
20000
30000
40000
50000
60000
time [sec]

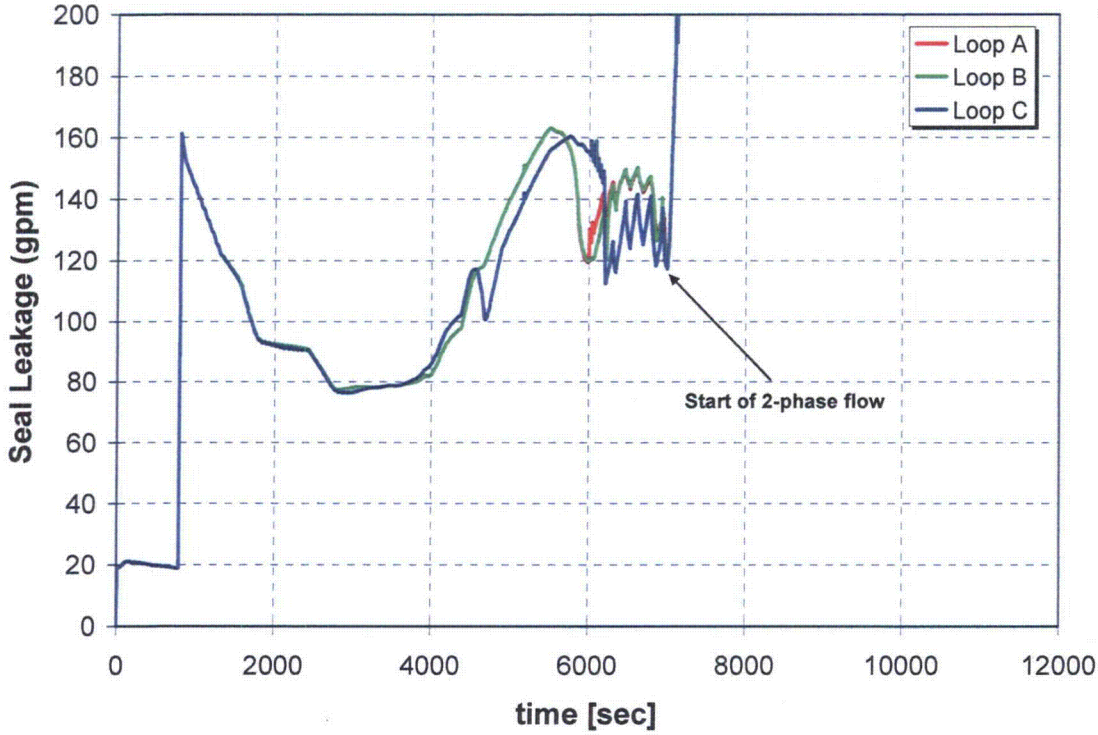

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
time [sec]

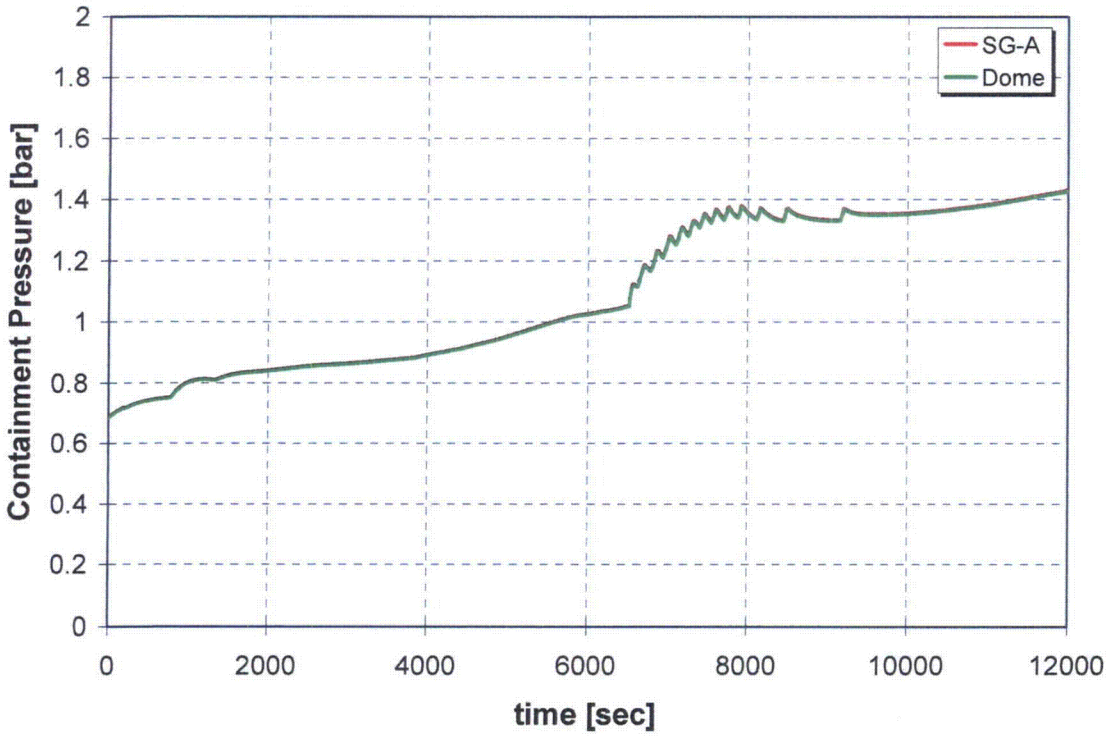

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
10000
20000
30000
40000
50000
60000
time [sec]

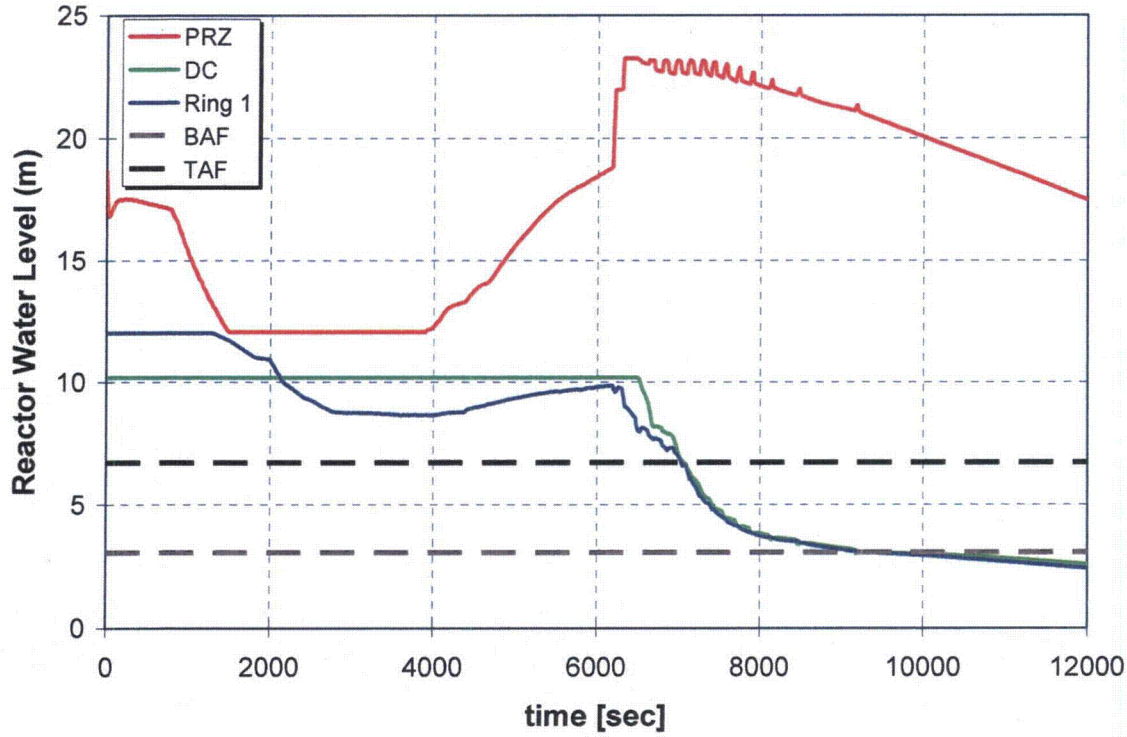
A.5.7 Case 7: Station Blackout without Turbine-Driven Auxiliary Feedwater (182 gpm)

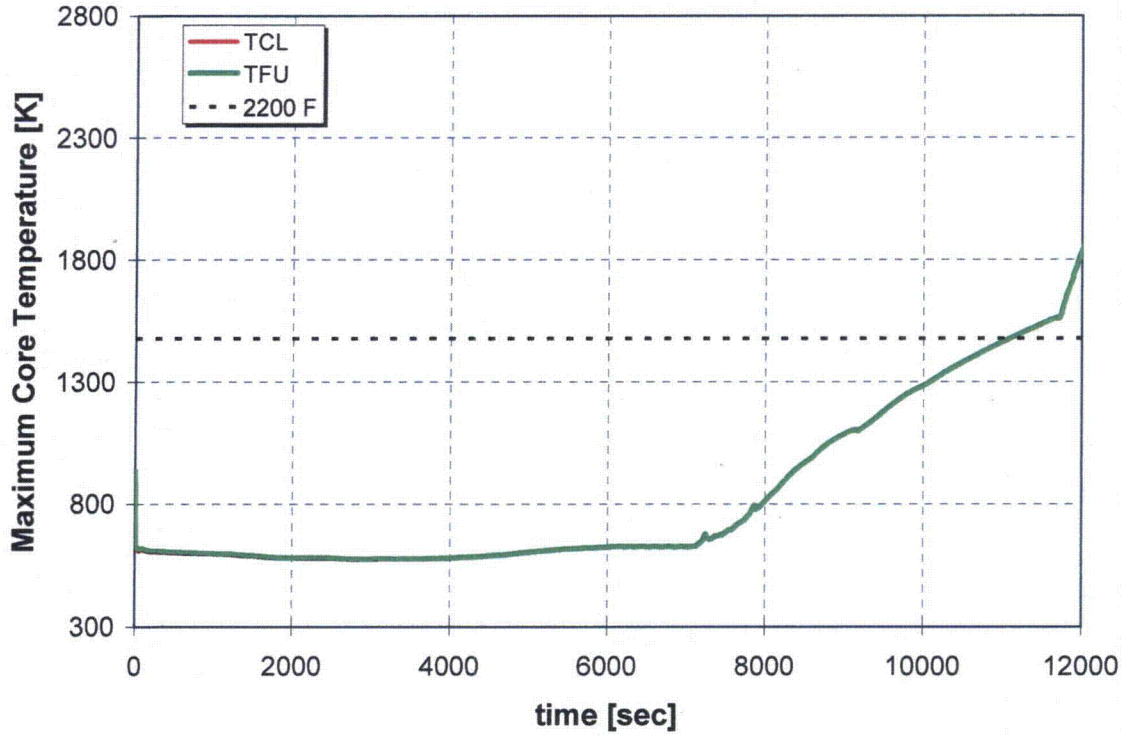




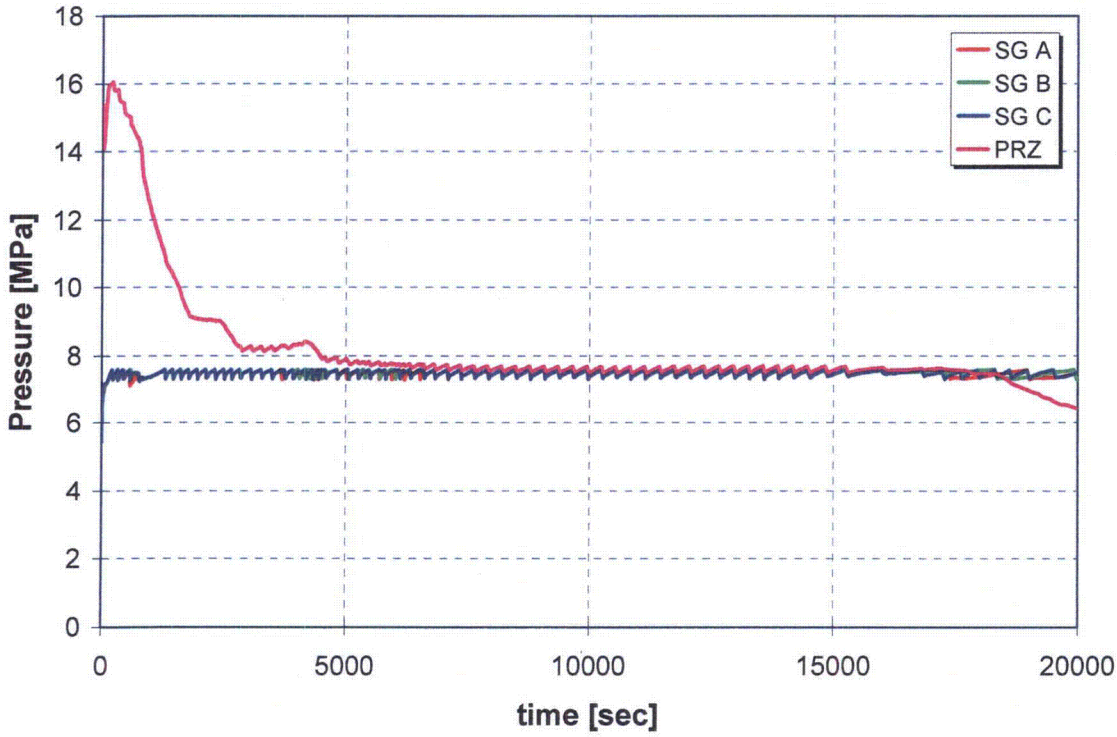

Seal Leakage (gpm)
time [sec]
Loop A
Loop B
Loop C
Start of 2-phase flow
0
20
40
60
80
100
120
140
160
180
200
0
2000
4000
6000
8000
10000
12000

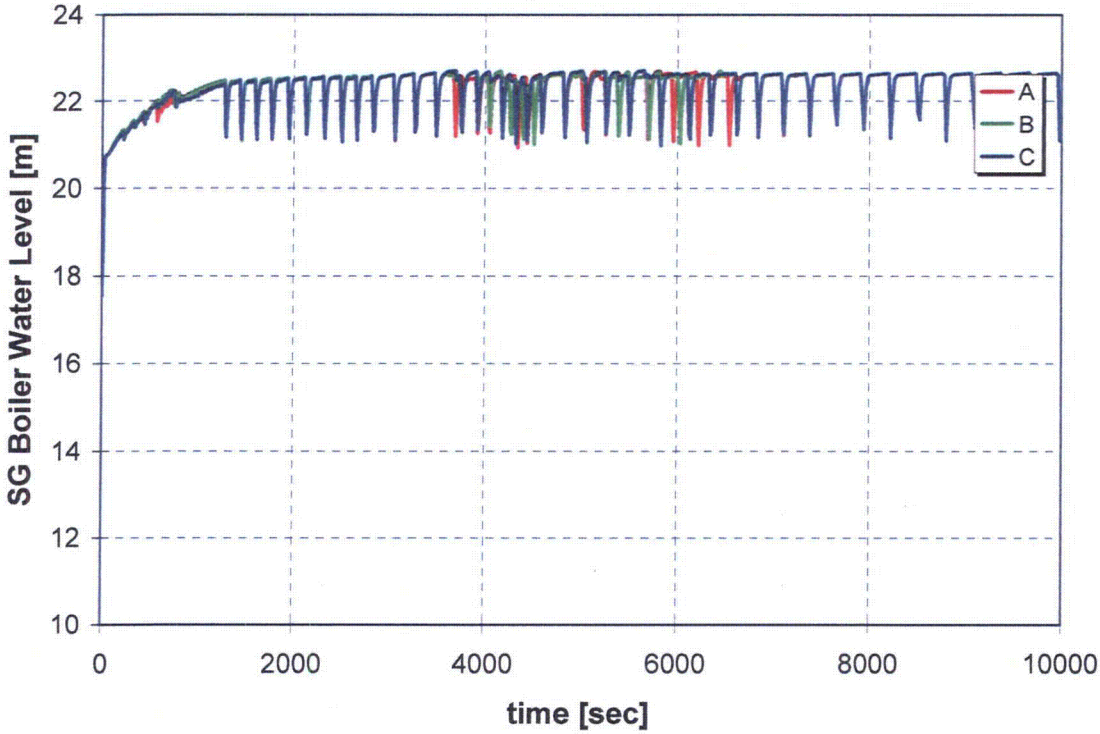

Containment Pressure [bar]
time [sec]
SG-A
Dome
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2000
4000
6000
8000
10000
12000

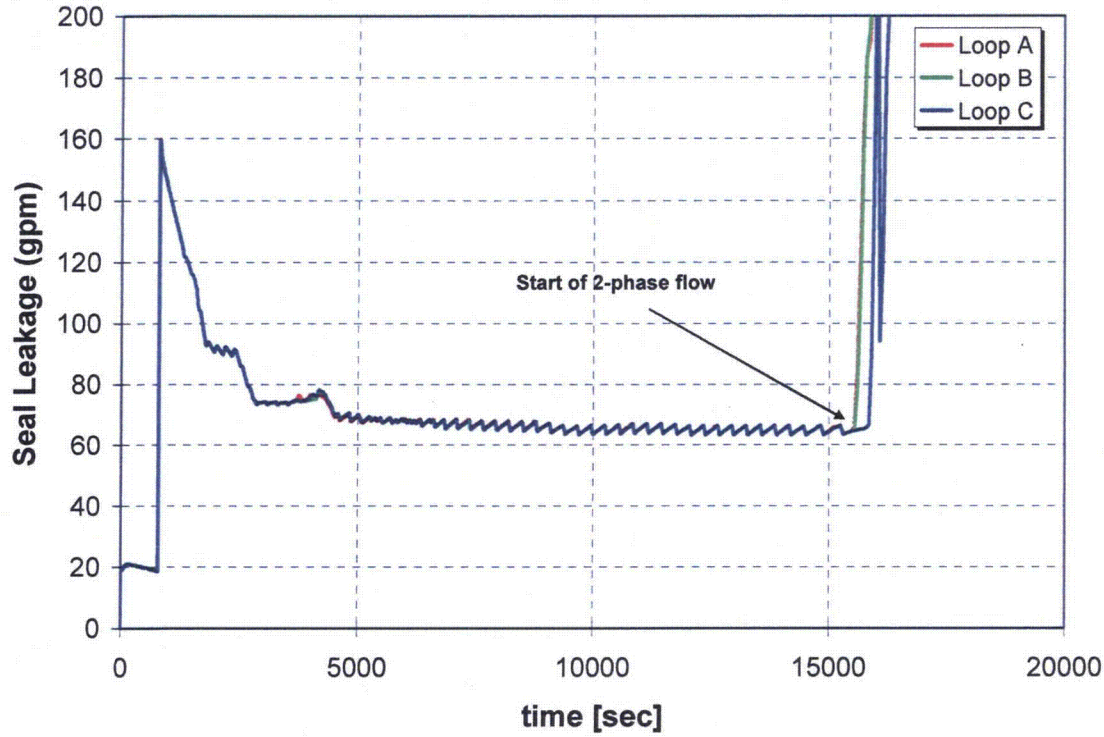

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
time [sec]

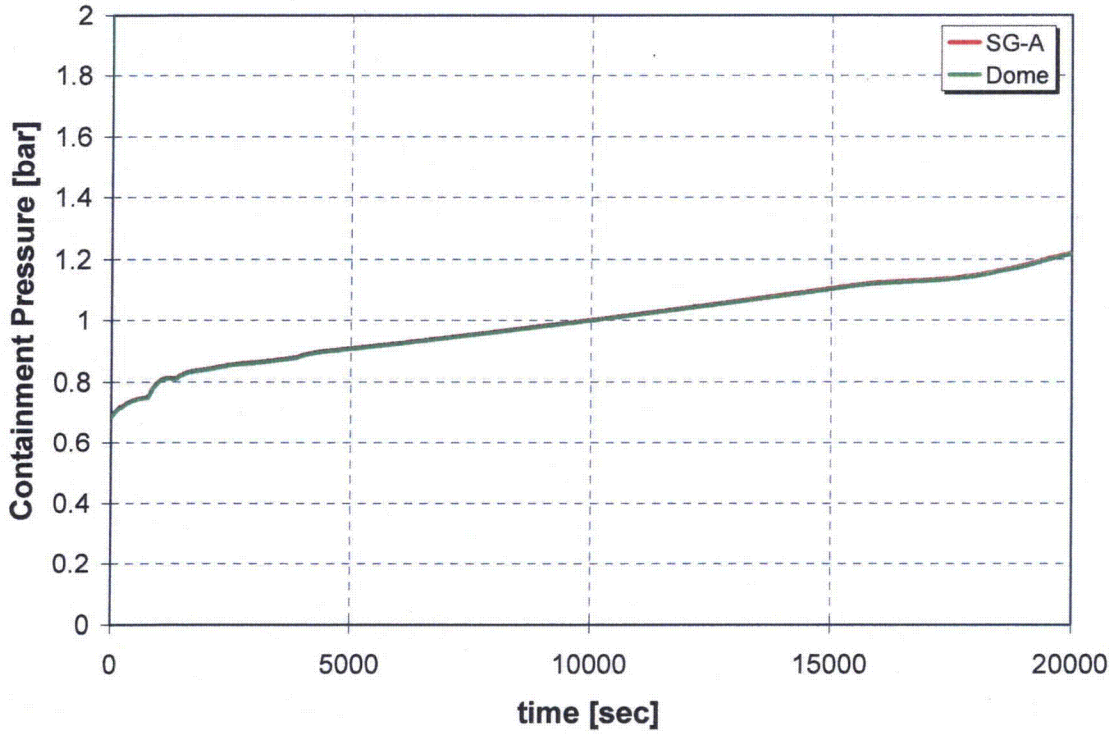

TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
2000
4000
6000
8000
10000
12000
time [sec]

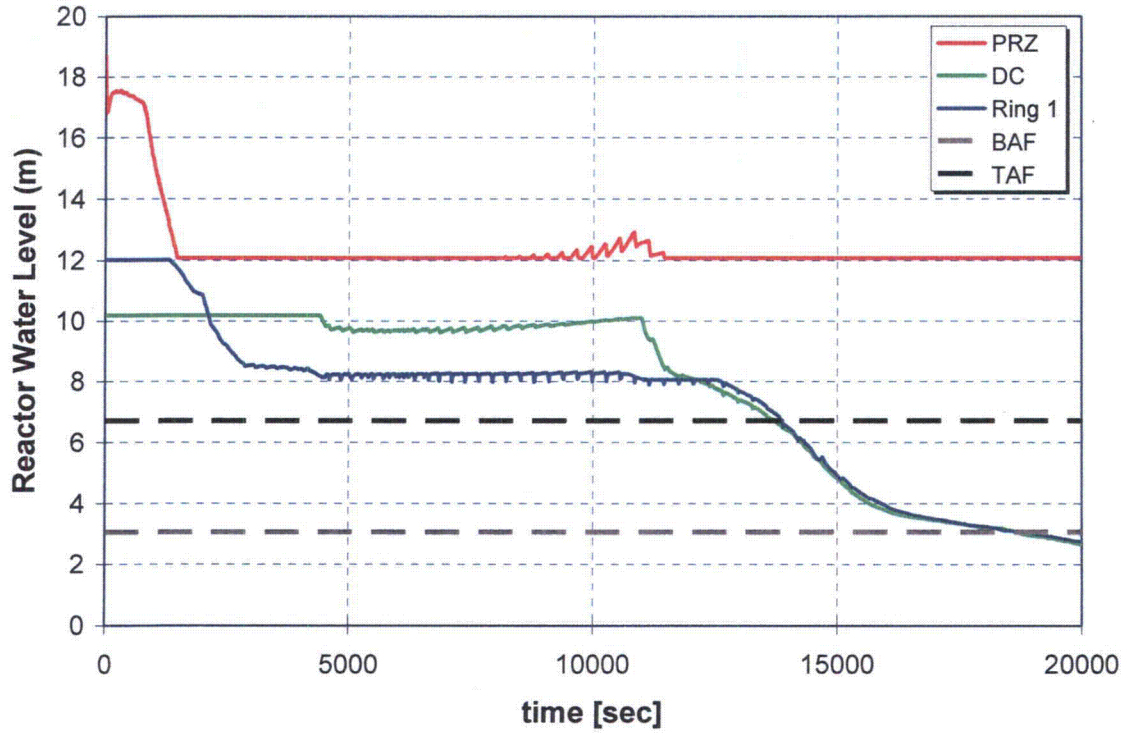
A.5.8 Case 8: Station Blackout with Turbine-Driven Auxiliary Feedwater (182 gpm)

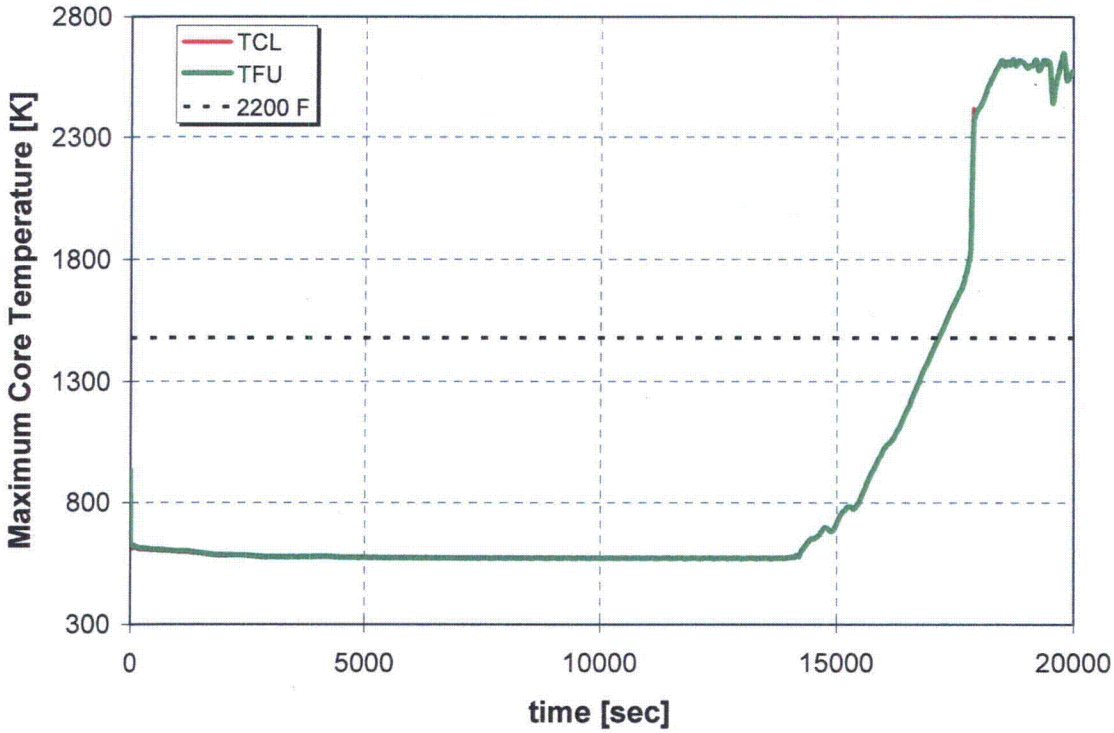




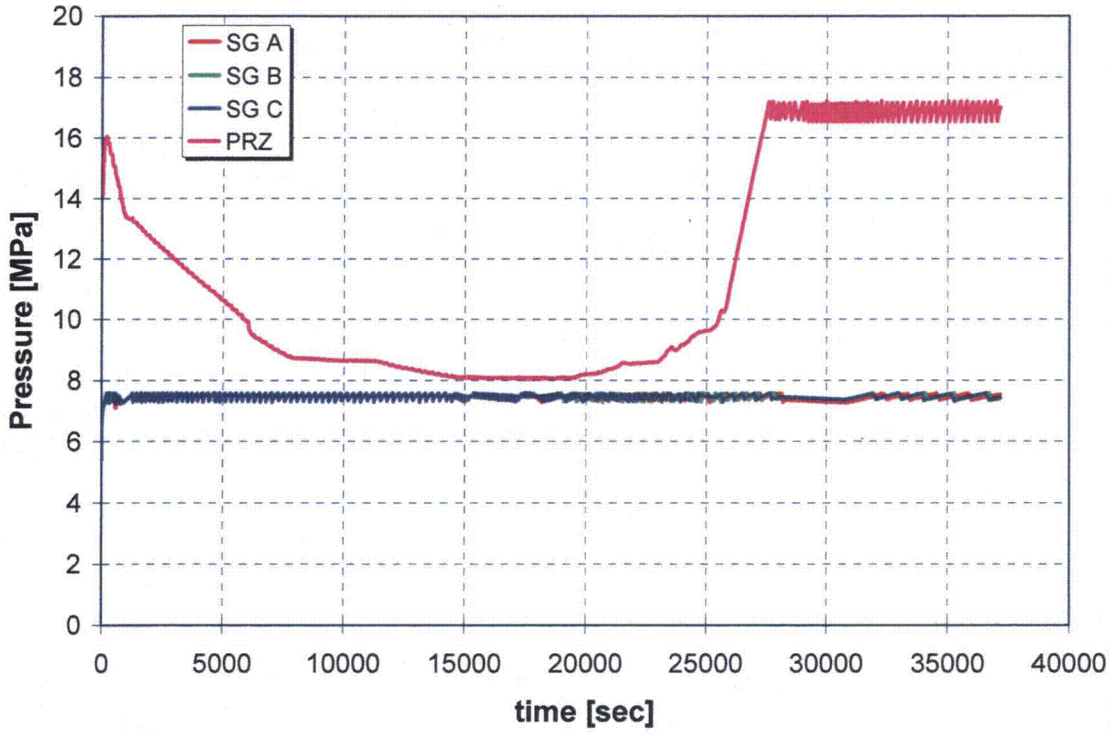

Seal Leakage (gpm)
200
180
160
140
120
100
80
60
40
20
0
0
5000
10000
15000
20000
time [sec]
Loop A
Loop B
Loop C
Start of 2-phase flow

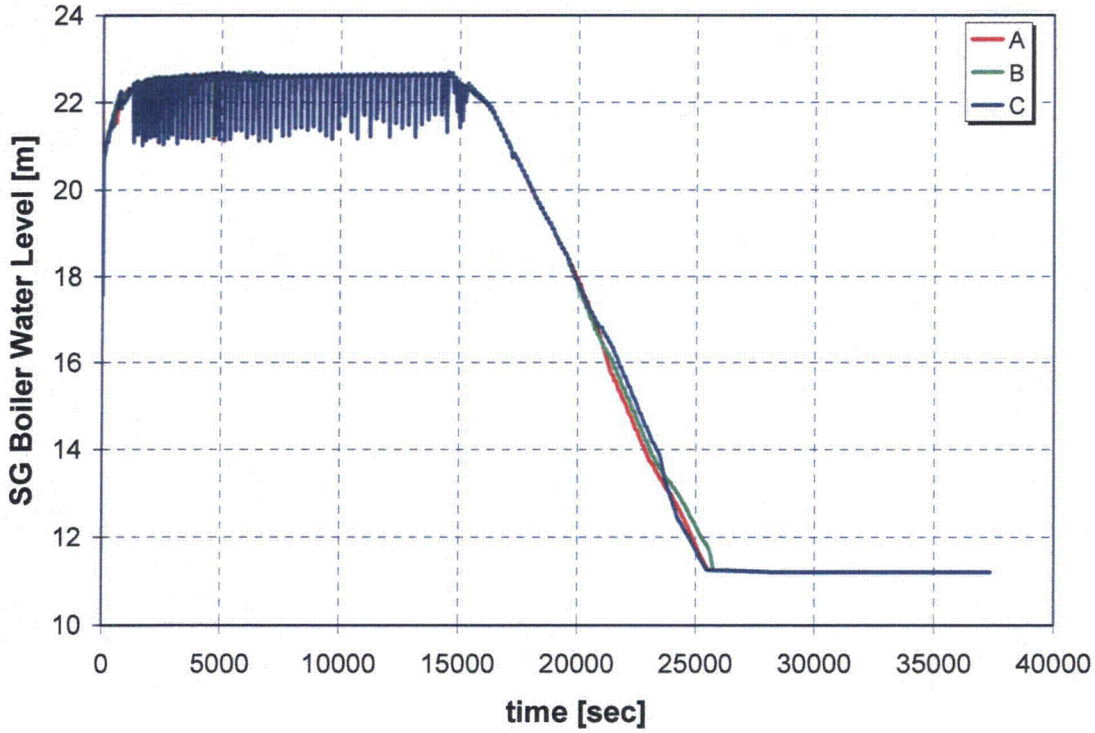

Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5000
10000
15000
20000
time [sec]
SG-A
Dome

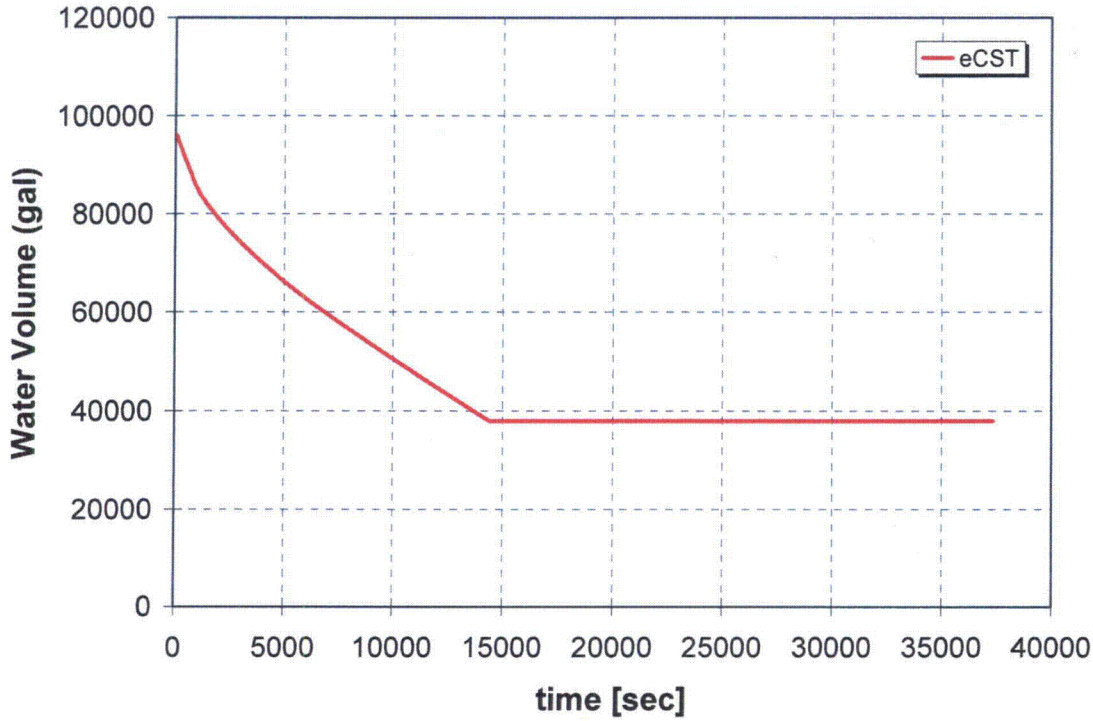

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
5000
10000
15000
20000

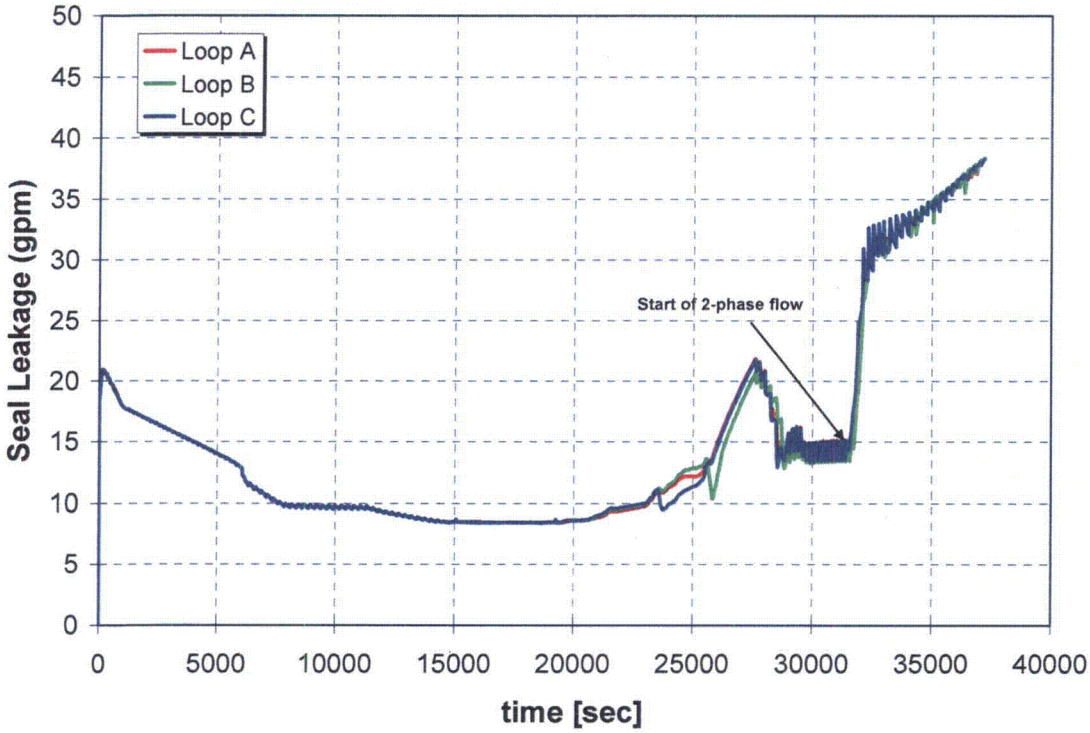

Maximum Core Temperature [K]
time [sec]
TCL
TFU
2200 F
300
800
1300
1800
2300
2800
0
5000
10000
15000
20000

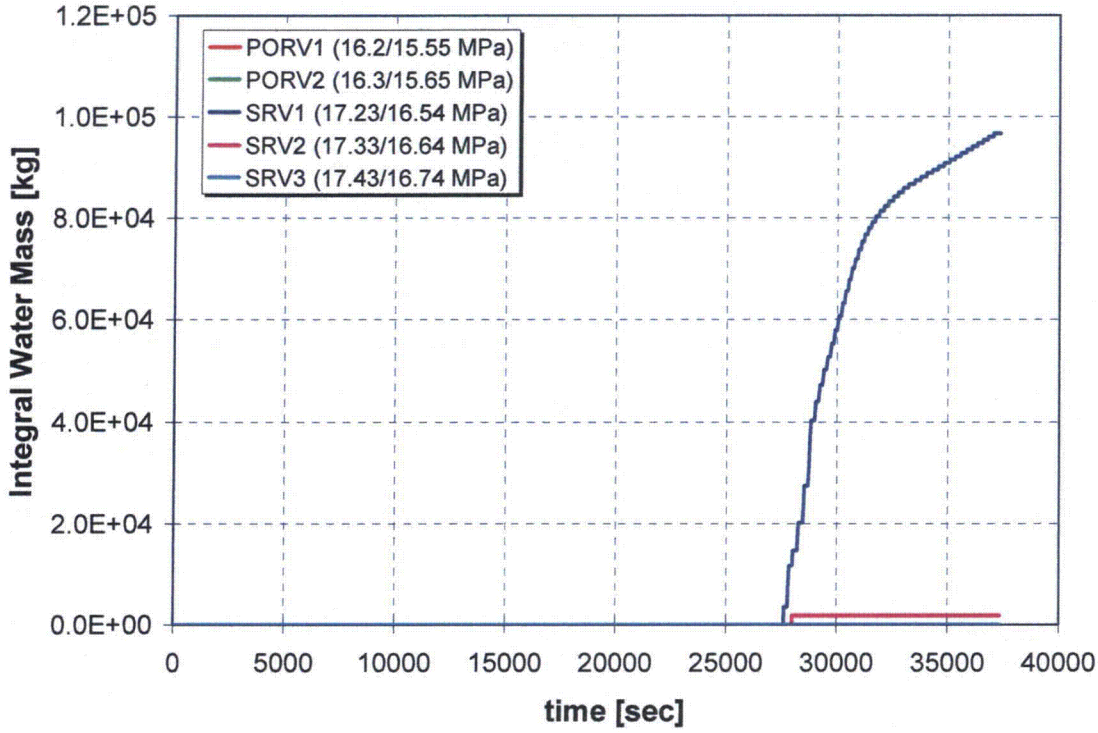
A.5.9 Case 9: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm) and 4-Hour Direct Current

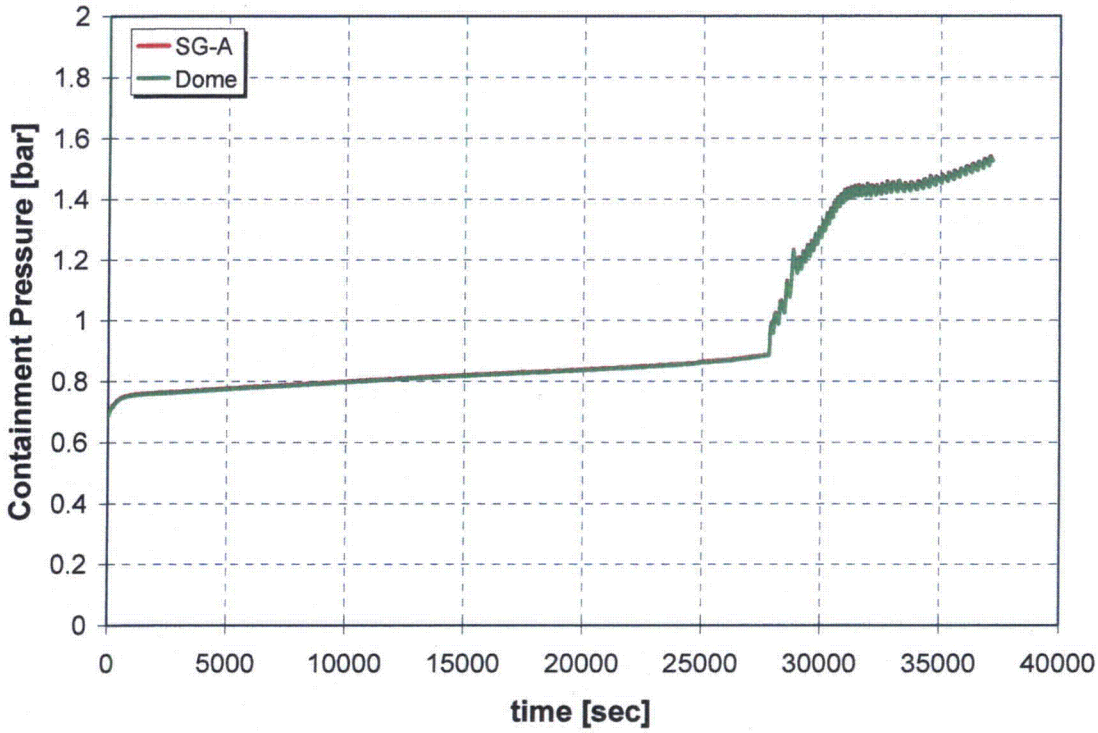


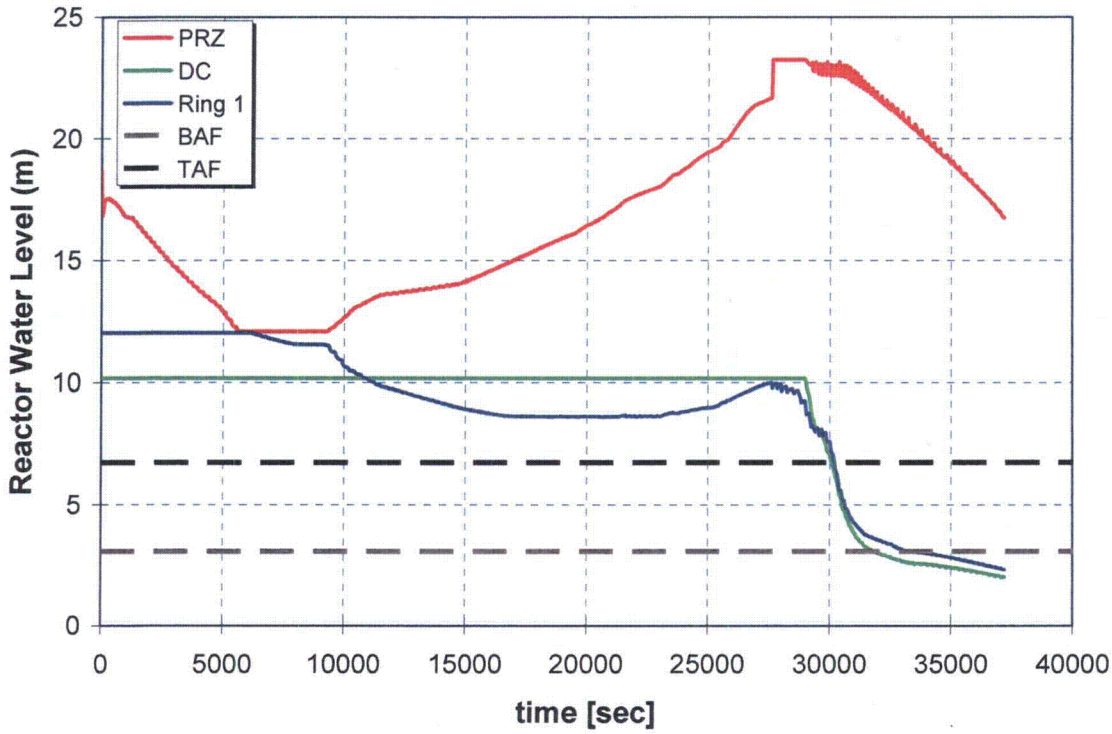


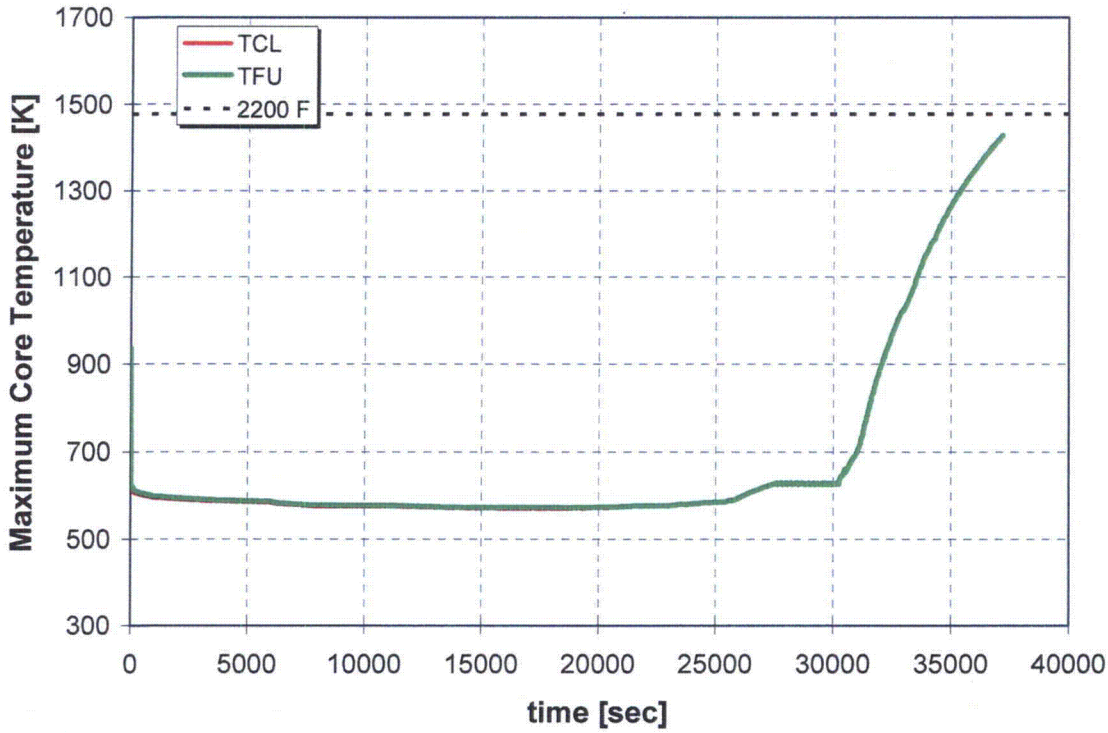

eCST
Water Volume (gal)
120000
100000
80000
60000
40000
20000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]


Loop A
Loop B
Loop C
Start of 2-phase flow
Seal Leakage (gpm)
50
45
40
35
30
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

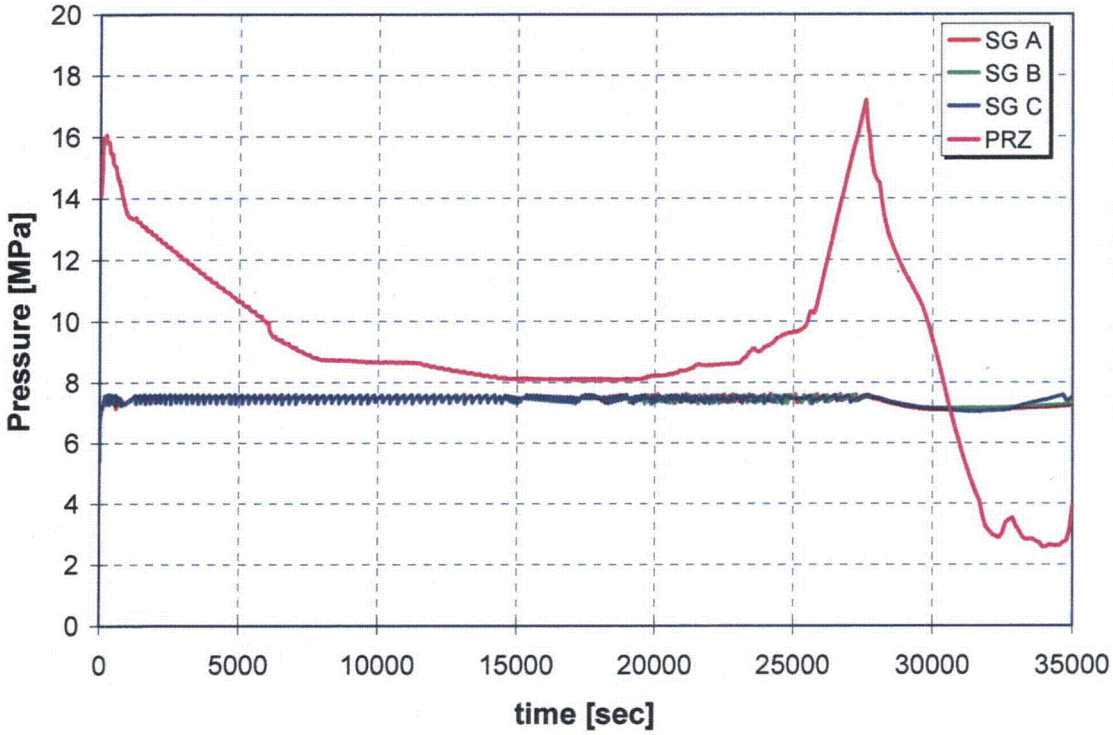

PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
1.2E+05
1.0E+05
8.0E+04
6.0E+04
4.0E+04
2.0E+04
0.0E+00
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

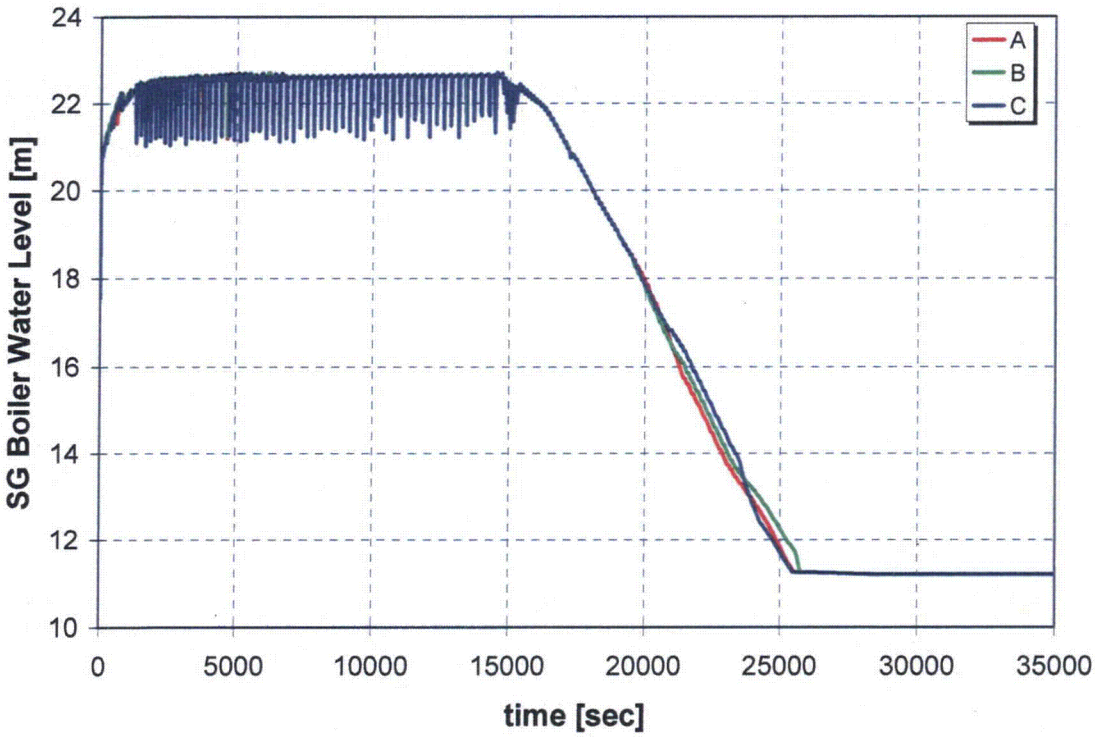

SG-A
Dome
Containment Pressure [bar]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

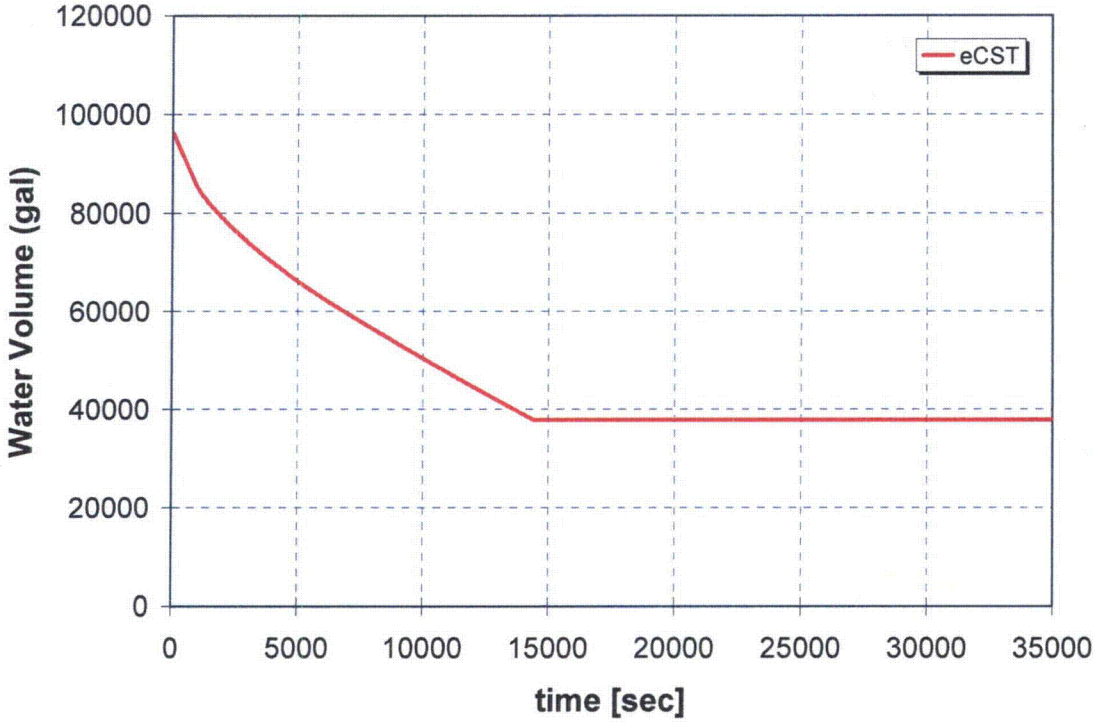

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

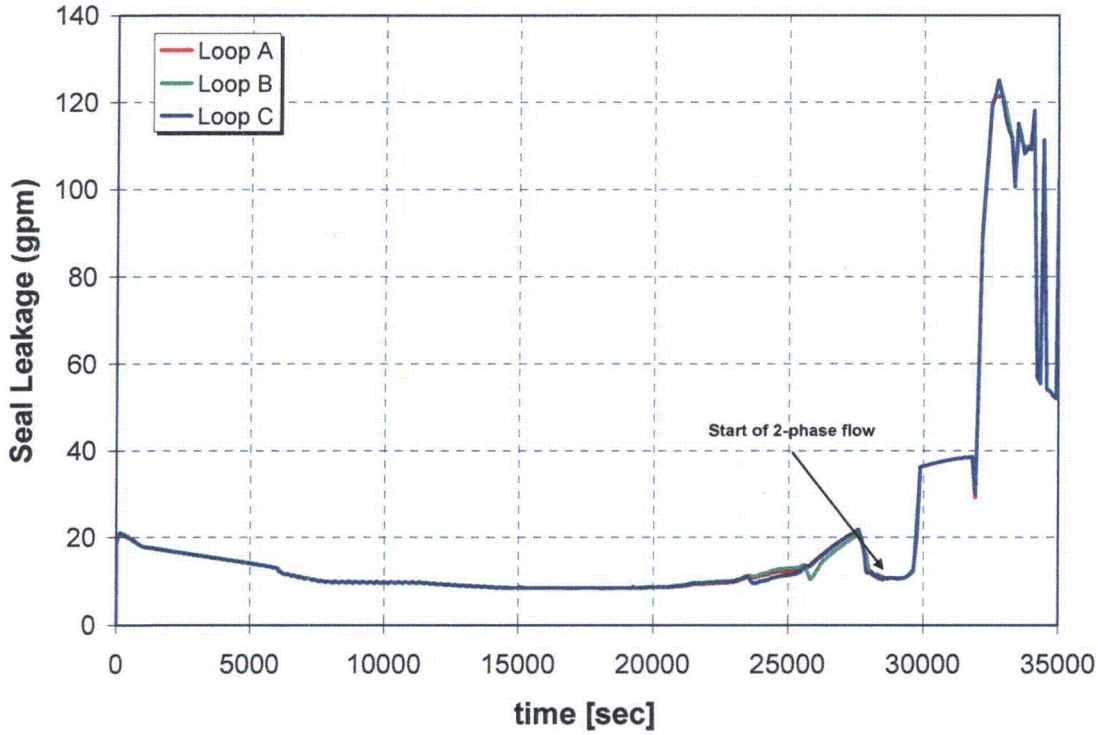

TCL
TFU
2200 F
Maximum Core Temperature [K]
1700
1500
1300
1100
900
700
500
300
0
5000
10000
15000
20000
25000
30000
35000
40000
time [sec]

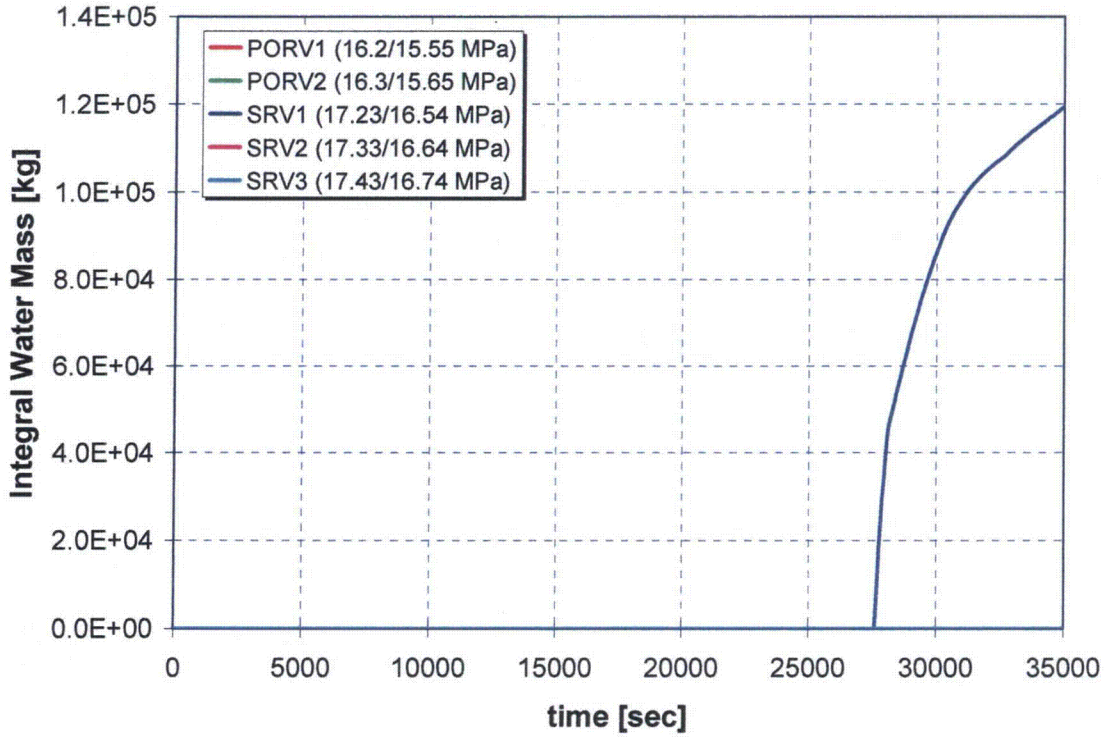
A.5.10 Case 10: Station Blackout with Turbine-Driven Auxiliary Feedwater (21 gpm) and 4-Hour Direct Current; Stuck-Open Relief Valve

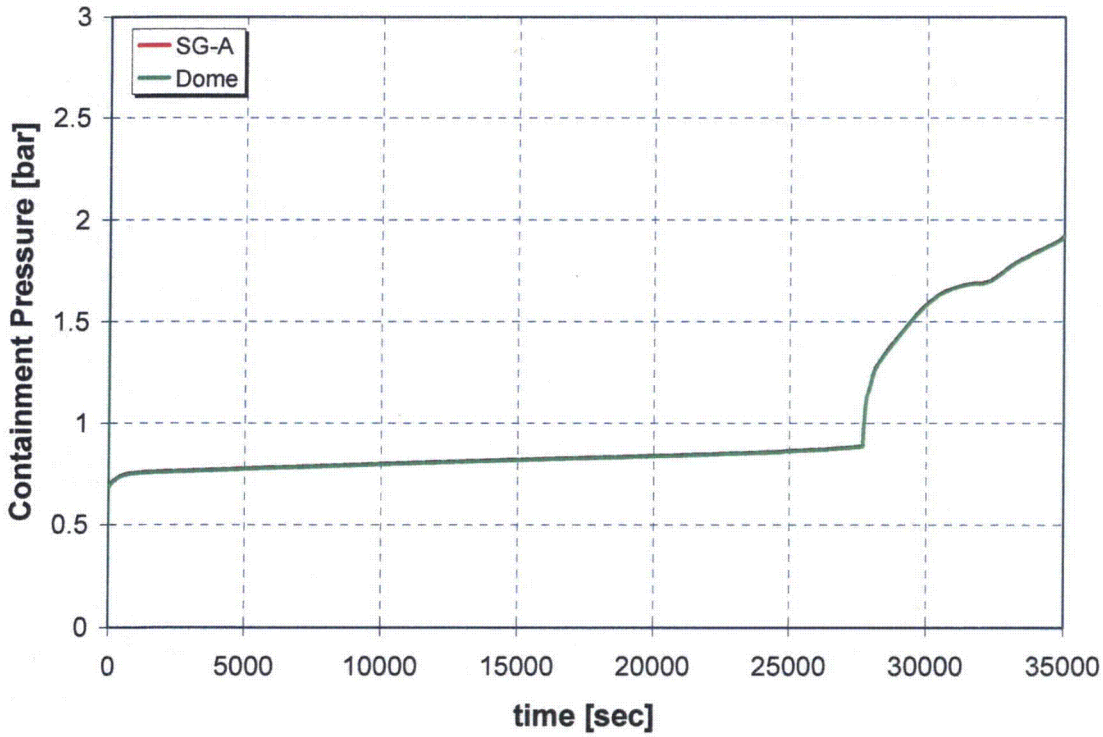


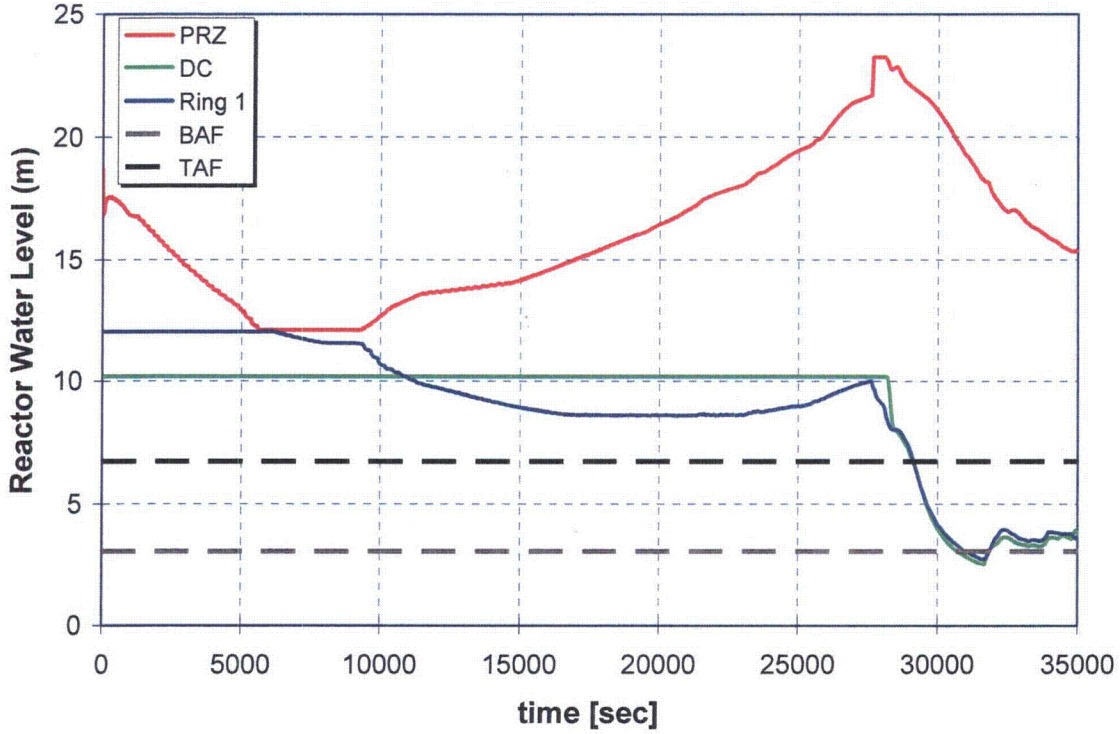


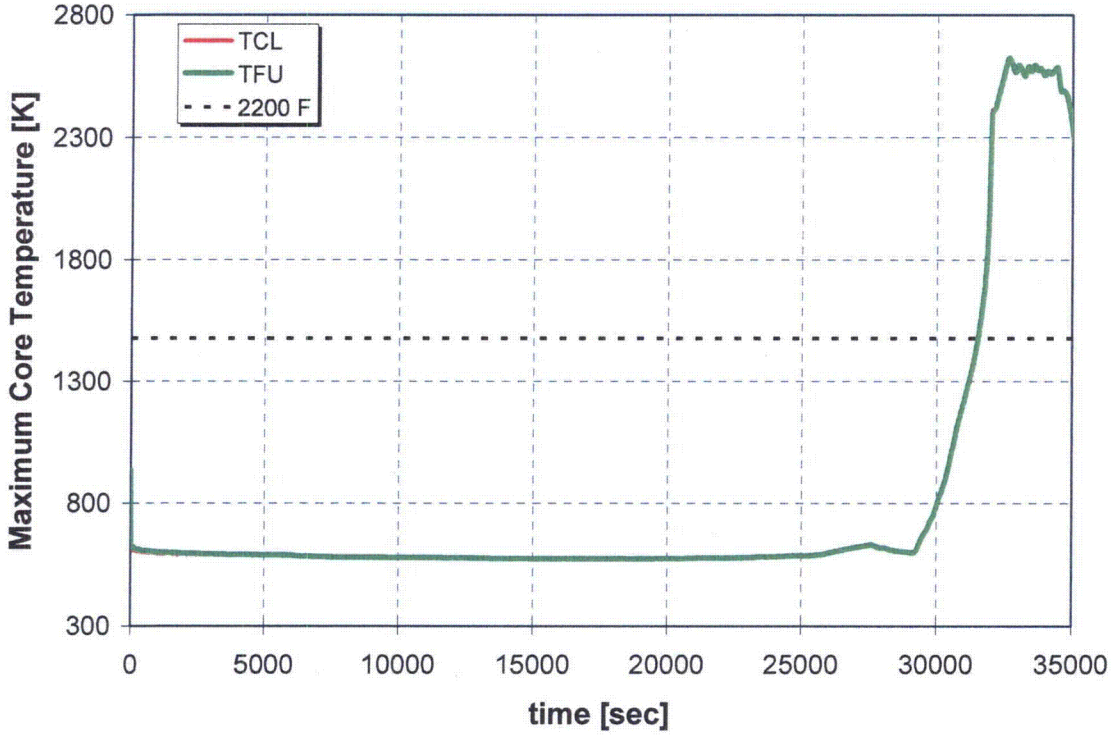

eCST
Water Volume (gal)
120000
100000
80000
60000
40000
20000
0
0
5000
10000
15000
20000
25000
30000
35000
time [sec]


Loop A
Loop B
Loop C
Seal Leakage (gpm)
140
120
100
80
60
40
20
0
Start of 2-phase flow
0
5000
10000
15000
20000
25000
30000
35000
time [sec]


PORV1 (16.2/15.55 MPa)
PORV2 (16.3/15.65 MPa)
SRV1 (17.23/16.54 MPa)
SRV2 (17.33/16.64 MPa)
SRV3 (17.43/16.74 MPa)
Integral Water Mass [kg]
1.4E+05
1.2E+05
1.0E+05
8.0E+04
6.0E+04
4.0E+04
2.0E+04
0.0E+00
0
5000
10000
15000
20000
25000
30000
35000
time [sec]


SG-A
Dome
Containment Pressure [bar]
3
2.5
2
1.5
1
0.5
0
0
5000
10000
15000
20000
25000
30000
35000
time [sec]


PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000
35000
time [sec]


TCL
TFU
2200 F
Maximum Core Temperature [K]
2800
2300
1800
1300
800
300
0
5000
10000
15000
20000
25000
30000
35000
time [sec]

A.6 Pressurized-Water Reactor Medium and Large-Break LOCA Initial Response

Analysis Summary

For all loss-of-coolant accident (LOCA) scenarios, containment fan coolers and containment sprays are available. The break is assumed to occur in the horizontal part of the cold leg in Loop A (pressurizer loop). Table 16 through Table 23 below provide results for this portion of the analysis.

Table 16 Surry MBLOCA and LBLOCA Results

Case	Break Size (inch)[4]	# HHSI Pumps	# Accum.	# LHSI Pumps	AFW?[1]	Time of Initial Core Uncovery (hr)	Core Damage During Injection Phase? (hr)
9	2	1	0	0	Yes	0.42	No[2]
15		0	2	1		0.41	0.73
20		1	1	0		0.42	No[2]
21		1	0	1		0.42	No[3]
27		1	1	0	No	0.38	No[2]
29		1	0	1		0.38	No[3]
1	4	1	0	1	Yes	0.09	No
11		1	0	0		0.09	No[2]
12		0	0	1		0.10	0.27
13		0	1	1		0.10	0.27
14		0	2	1		0.10	No
22		1	1	0		0.09	No[2]
25		1	0	1	No	0.09	No
28		1	1	0		0.09	No[2]
2	6	1	0	1	Yes	0.04	No
5		0	0	1		0.04	0.16
6		0	1	1		0.04	No
7		1	0	0		0.07	0.28
8		1	1	0		0.08	No[2]
16		1	0	1	No	0.04	No
17		1	1	0		0.06	No[2]
26		0	1	1		0.04	No
3	8	1	0	1	Yes	0.02	No
18		1	1	0		0.01	No[2]
23		0	1	1		0.03	No
4	10	1	0	1		0.01	No
19		1	1	0		0.01	No[2]
24		0	1	1		0.02	No
10	Double-ended	0	0	1		0.02	No

1 Conventionally, AFW is not needed for success for large break LOCA; the break size is large enough to remove decay heat and the system fully depressurizes.

2 Note that core damage eventually occurs (or would occur, in cases where the calculation was terminated early) because of the inability to go to HHSI recirculation (due to the unavailability of LHSI) or, more directly, from the lack of a low-pressure injection source. Recall that the present calculations are focused only on the injection phase success criteria.

3 For these cases, core damage eventually occurs because HHSI recirculation is not modeled, and the pressure is not sufficiently low prior to core damage to allow for LHSI recirculation.

4 2 inch = 5.1 cm; 4 inch = 10.2 cm; 6 inch = 15.2 cm; 8 inch = 20.3 cm; 10 inch = 25.4 cm.

Table 17 Surry MBLOCA and LBLOCA Key Timings (2-inch Breaks)

Event	Case 9 (hr)	Case 15 (hr)	Case 20 (hr)	Case 21 (hr)	Case 27 (hr)	Case 29 (hr)
Reactor trip	0.01	0.003	0.01	0.01	0.01	0.01
HHSI injection	0.01	-	0.01	0.01	0.01	0.01
RCP trip (10% void)	0.28	0.07	0.28	0.28	0.18	0.17
First actuation of containment sprays	1.14	-	1.21	1.14	0.94	0.94
Core uncovery (water < TAF)	0.42	0.41	0.42	0.42	0.38	0.38
LHSI injection	-	-	-	6.39	-	6.17
Maximum cladding temperature timing (max. temperature)	0.44 (592 K)	0.73 (1,477 K[1])	0.44 (592 K)	0.44 (592 K)	0.40 (592 K)	0.40 (592 K)
Core covered	0.87	N/A	0.8	0.87	0.75	0.75

[1] Actual peak temperature would be higher; this value corresponds to the surrogate used in this project for core damage, 2,200 °F (1,204 °C).

Table 18 Surry MBLOCA and LBLOCA Key Timings (4-inch Breaks Group 1)

Event	Case 1 (hr)	Case 11 (hr)	Case 12 (hr)	Case 13 (hr)
Reactor trip	0.003	0.003	0.003	0.003
HHSI injection	0.003	0.004	-	-
RCP trip (10% void)	0.04	0.04	0.04	0.04
First actuation of containment sprays	0.08	0.08	0.07	0.07
Core uncovery (water < TAF)	0.09	0.09	0.10	0.10
LHSI injection	0.29	-	0.33	0.45
Maximum cladding temperature timing (max. temperature)	0.34 (982 K)	0.53 (1,209 K)	0.27 (1,477 K[1])	0.27 (1,477 K[1])
Core covered	0.38	>0.83	N/A	N/A

[1] Actual peak temperature would be higher; this value corresponds to the surrogate used in this project for core damage, 2,200 °F (1,204 °C).

Table 19 Surry MBLOCA and LBLOCA Key Timings (4-inch Breaks Group 2)

Event	Case 14 (hr)	Case 22 (hr)	Case 25 (hr)	Case 28 (hr)
Reactor trip	0.003	0.003	0.003	0.003
HHSI injection	-	0.004	0.004	0.004
RCP trip (10% void)	0.04	0.04	0.04	0.03
First actuation of containment sprays	0.07	0.08	0.08	0.07
Core uncovery (water < TAF)	0.10	0.09	0.09	0.09
LHSI injection	0.73	-	0.30	-
Maximum cladding temperature timing (max. temperature)	0.73 (1183K)	0.21 (807K)	0.32 (1054K)	0.26 (721K)
Core covered	0.79	0.39	0.39	0.41

Table 20 Surry MBLOCA and LBLOCA Key Timings (6-inch Breaks Group 1)

Event	Case 2 (hr)	Case 5 (hr)	Case 6 (hr)	Case 7 (hr)
Reactor trip	0.002	0.002	0.002	0.002
HHSI injection	0.002	-	-	0.002
RCP trip (10% void)	0.02	0.02	0.02	0.02
First actuation of containment sprays	0.03	0.03	0.03	0.03
Core uncovery (water < TAF)	0.04	0.04	0.04	0.07
LHSI injection	0.13	0.14	0.18	-
Maximum cladding temperature timing (maximum temperature)	0.15 (774K)	0.16 (1477K[1])	0.16 (990K)	0.28 (1477K[1])
Core covered	0.19	N/A	0.20	N/A

[1] Actual peak temperature would be higher; this value corresponds to the surrogate used in this project for core damage (2200F [1204 C])

Table 21 Surry MBLOCA and LBLOCA Key Timings (6-inch Breaks Group 2)

Event	Case 8 (hr)	Case 16 (hr)	Case 17 (hr)	Case 26 (hr)
Reactor trip	0.002	0.002	0.002	0.002
HHSI injection	0.002	0.002	0.002	-
RCP trip (10% void)	0.02	0.02	0.02	0.02
First actuation of containment sprays	0.03	0.03	0.03	0.03
Core uncovery (water < TAF)	0.08	0.04	0.06	0.04
LHSI injection	-	0.13	-	0.18
Maximum cladding temperature timing (maximum temperature)	0.04 (592K)	0.152 (775K)	0.04 (575K)	0.13 (931K)
Core covered	0.10	0.19	0.12	0.22

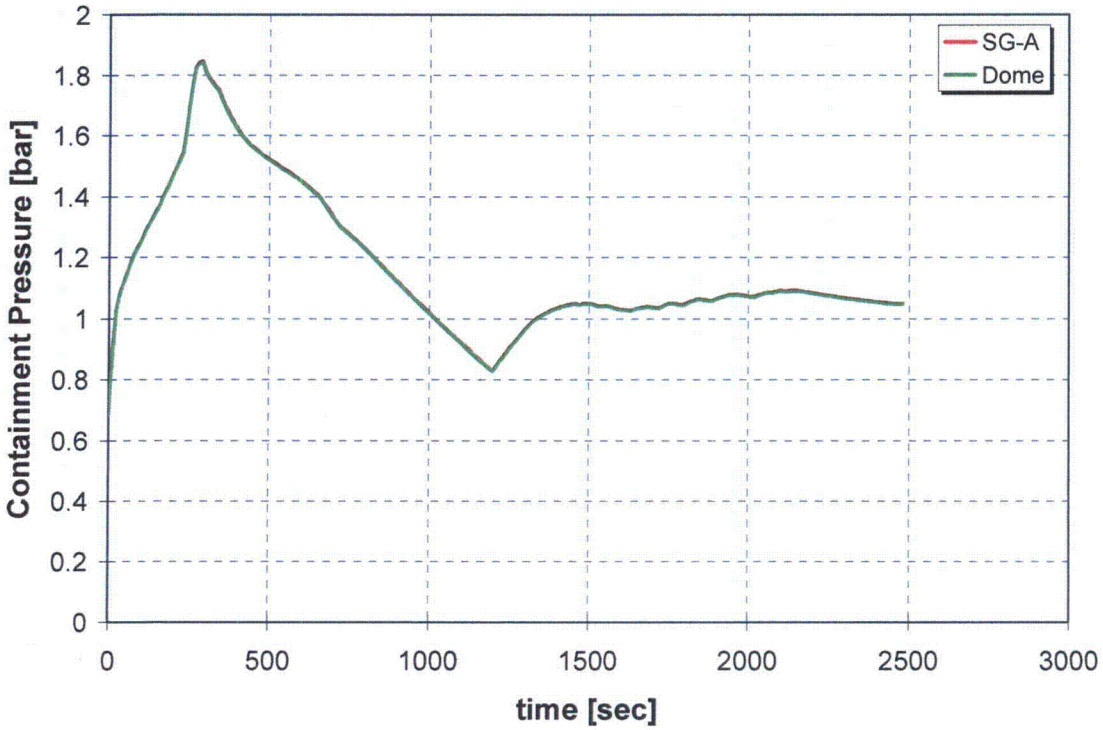
Table 22 Surry MBLOCA and LBLOCA Key Timings (8-inch Breaks)

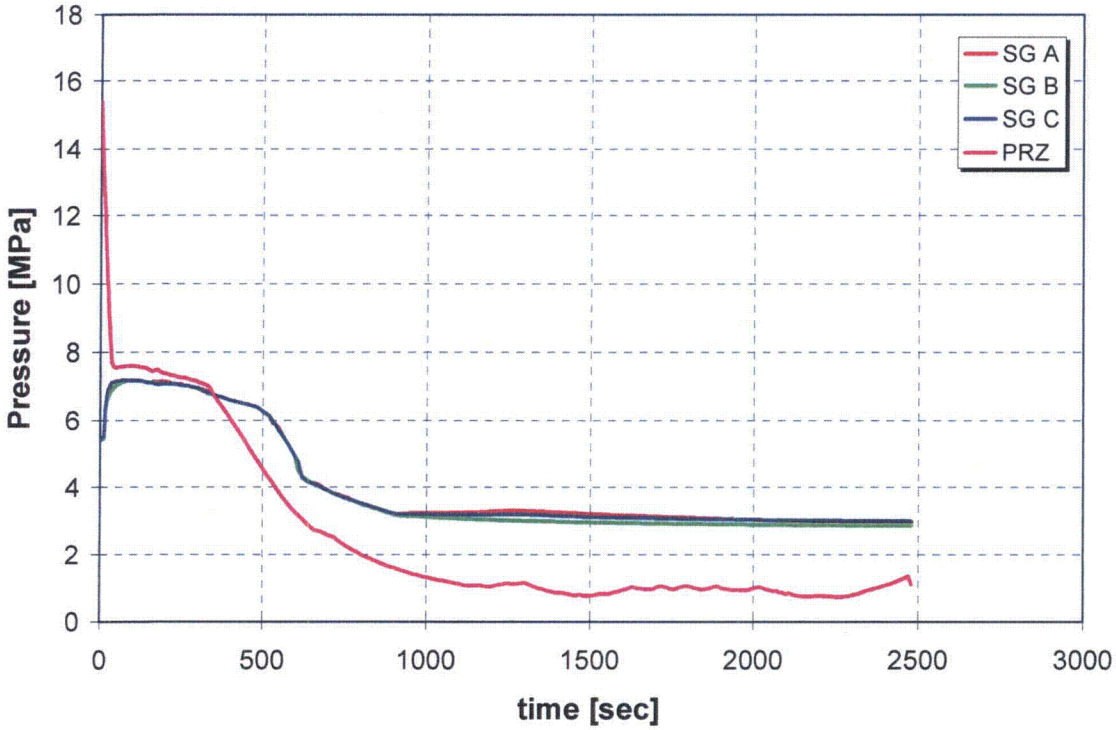
Event	Case 3 (hr)	Case 18 (hr)	Case 23 (hr)
Reactor trip	0.002	0.002	0.002
HHSI injection	0.002	0.002	-
RCP trip (10% void)	0.009	0.009	0.01
First actuation of containment sprays	0.01	0.01	0.01
Core uncovery (water < TAF)	0.02	0.01	0.03
LHSI injection	0.07	-	0.08
Maximum cladding temperature timing (maximum temperature)	0.10 (851 K)	0.40 (1,085 K)	0.07 (792 K)
Core covered	0.14	0.91	0.11

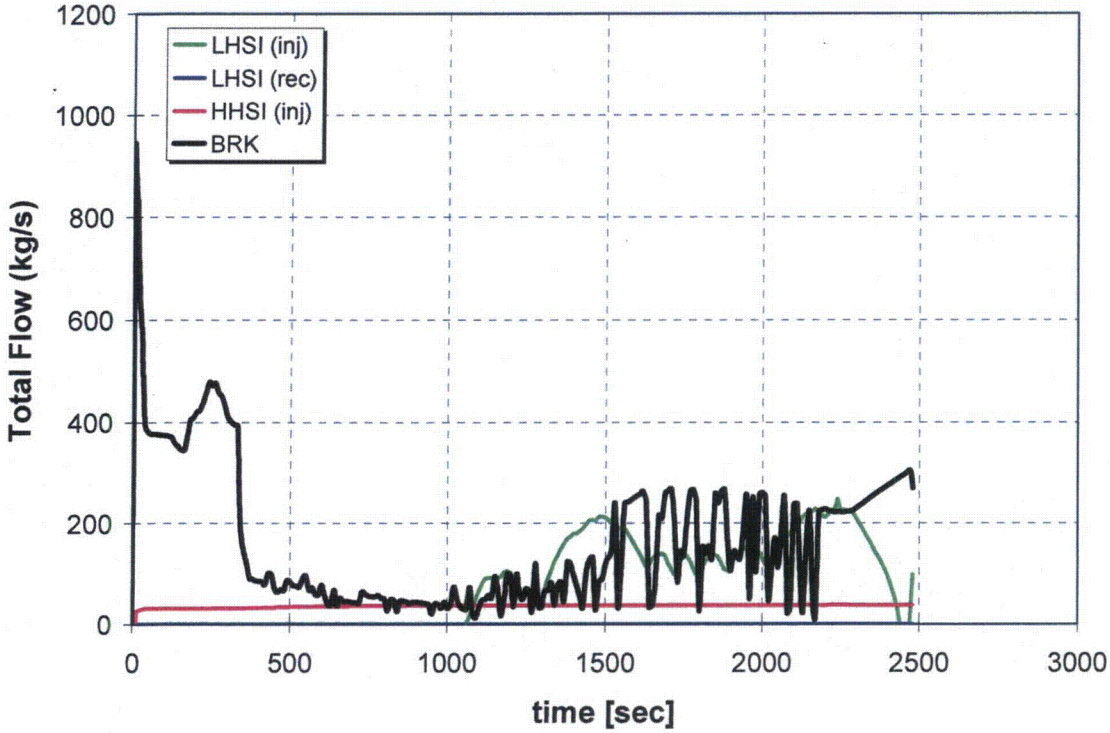
Table 23 Surry MBLOCA and LBLOCA Key Timings (≥ 10-inch Breaks)

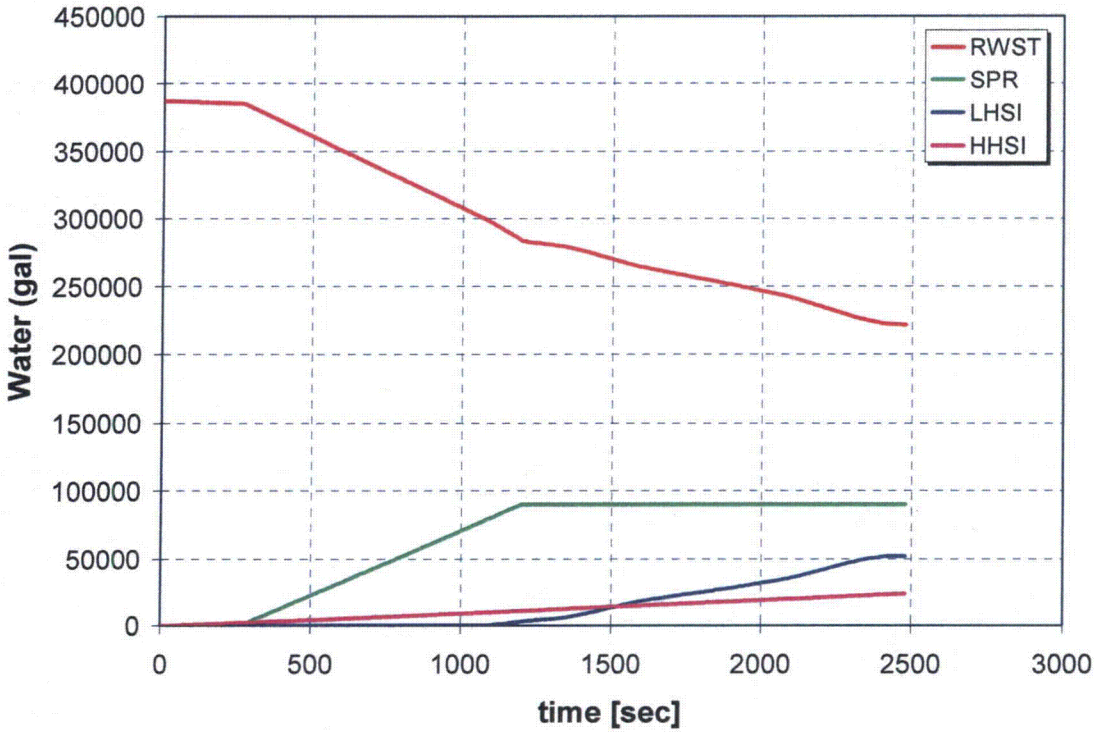
Event	Case 4 (hr)	Case 19 (hr)	Case 24 (hr)	Case 10 (hr)
Reactor trip	0.001	0.001	0.001	0.001
HHSI injection	0.001	0.001	-	-
RCP trip (10% void)	0.008	0.008	0.006	0.001
First actuation of containment sprays	0.008	0.008	0.008	0.005
Core uncovery (water < TAF)	0.01	0.008	0.02	0.022
LHSI injection	0.04	-	0.05	0.005
Maximum cladding temperature timing (maximum temperature)	0.08 (850 K)	0.30 (835 K)	0.04 (640 K)	0.036 (1043 K)
Core covered	0.12	0.87	0.06	0.053

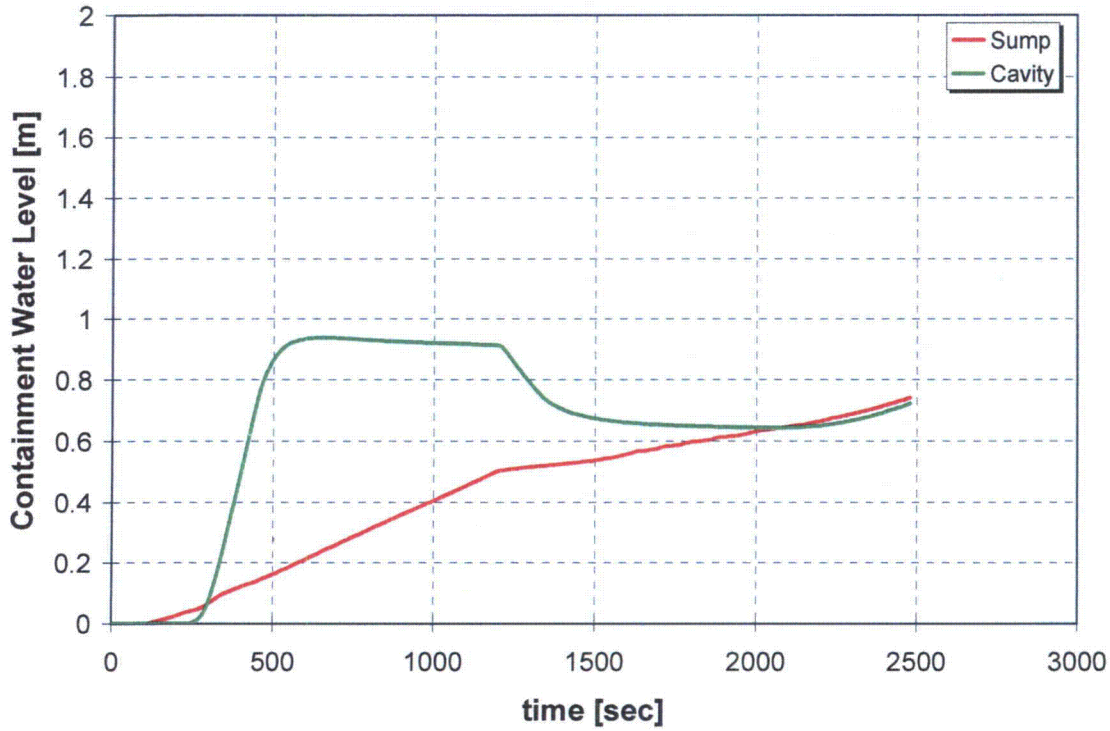
A.6.1 Case 1: 4-Inch Break LOCA, One HHSI, One LHSI, and No ACC

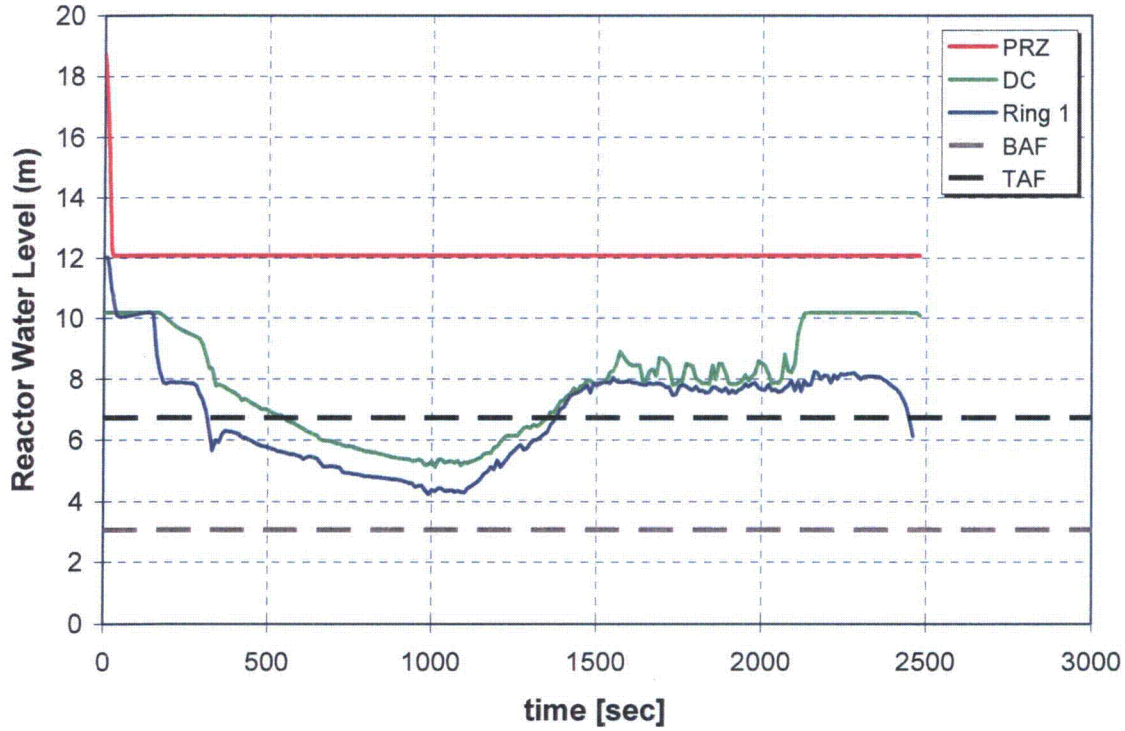


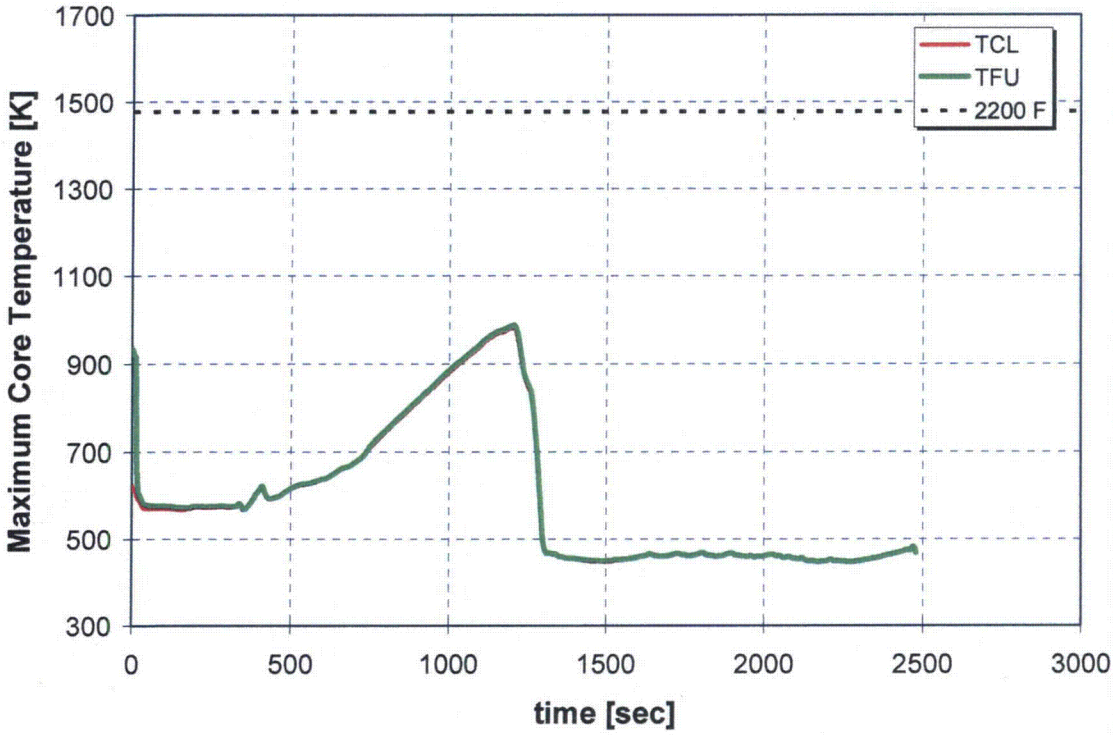



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
time [sec]

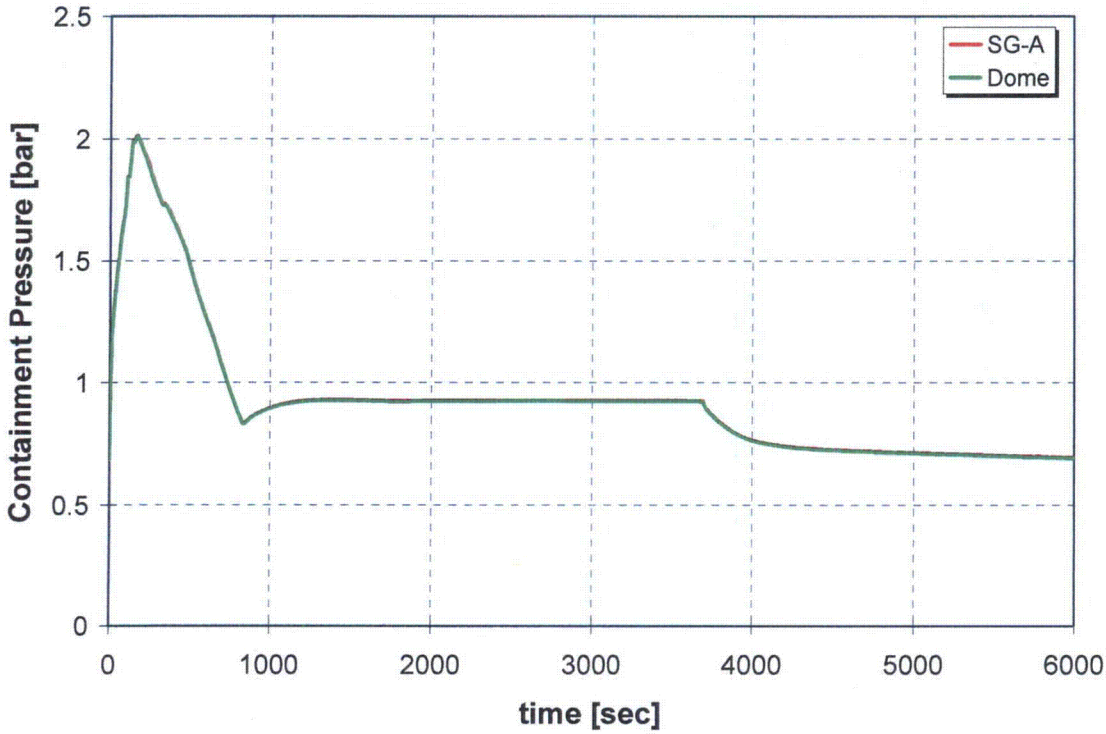

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
500
1000
1500
2000
2500
3000
time [sec]

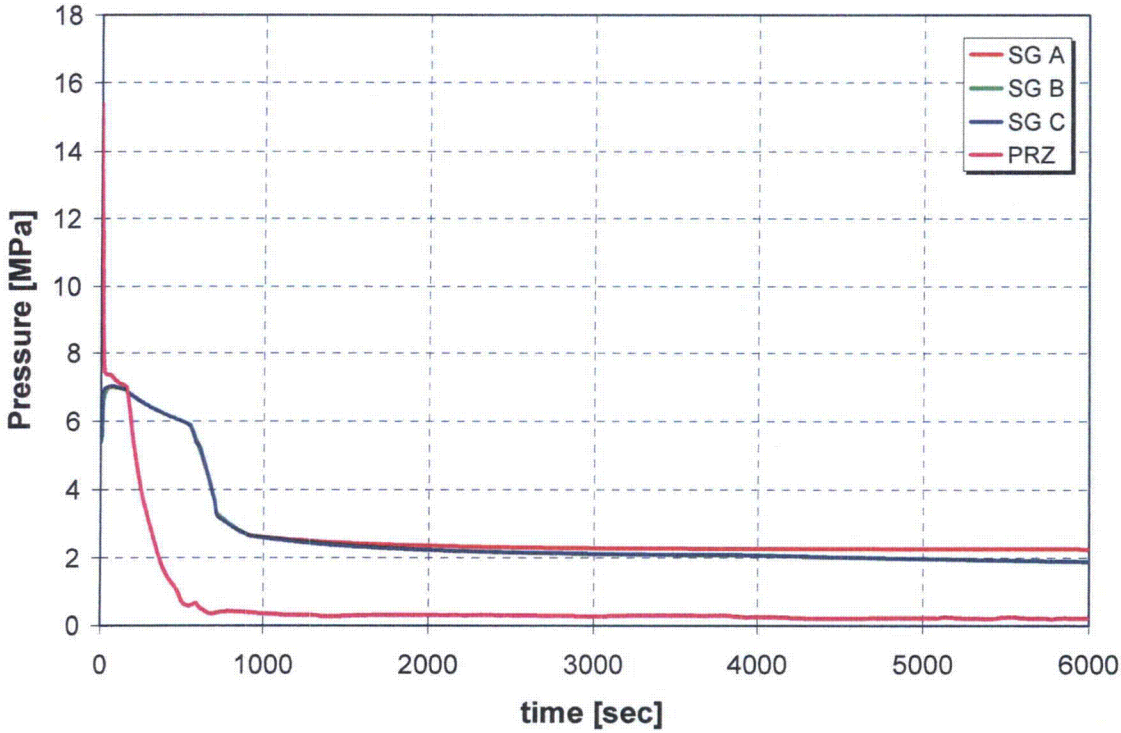

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
500
1000
1500
2000
2500
3000

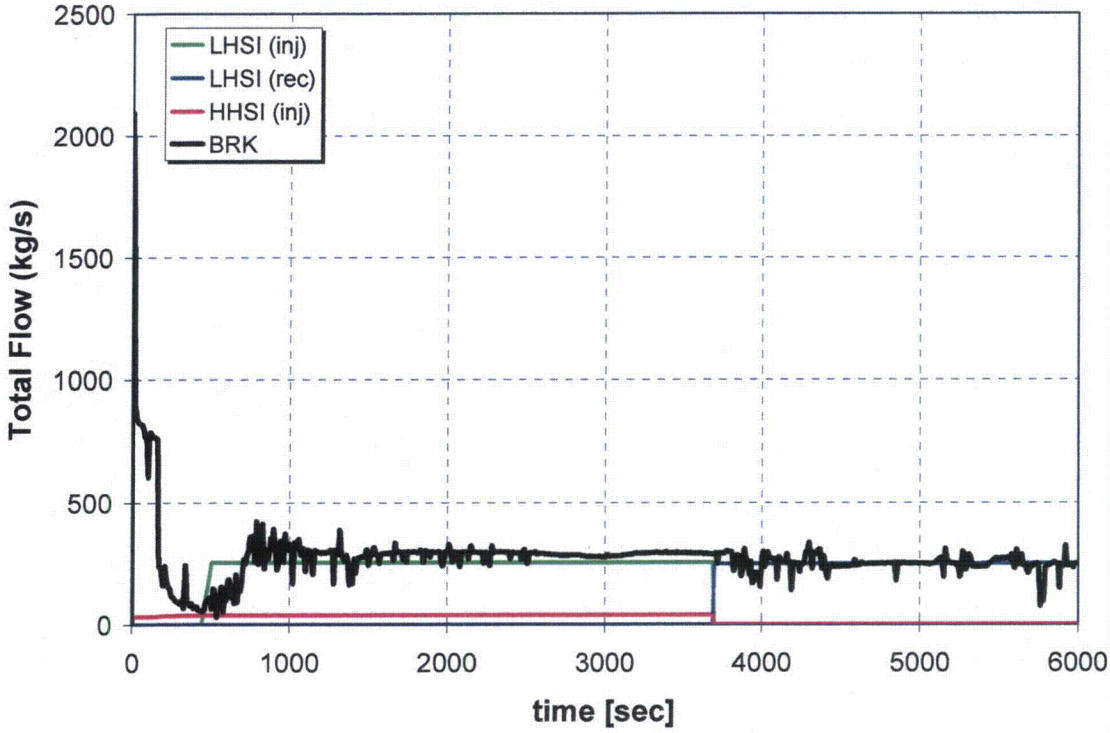

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000

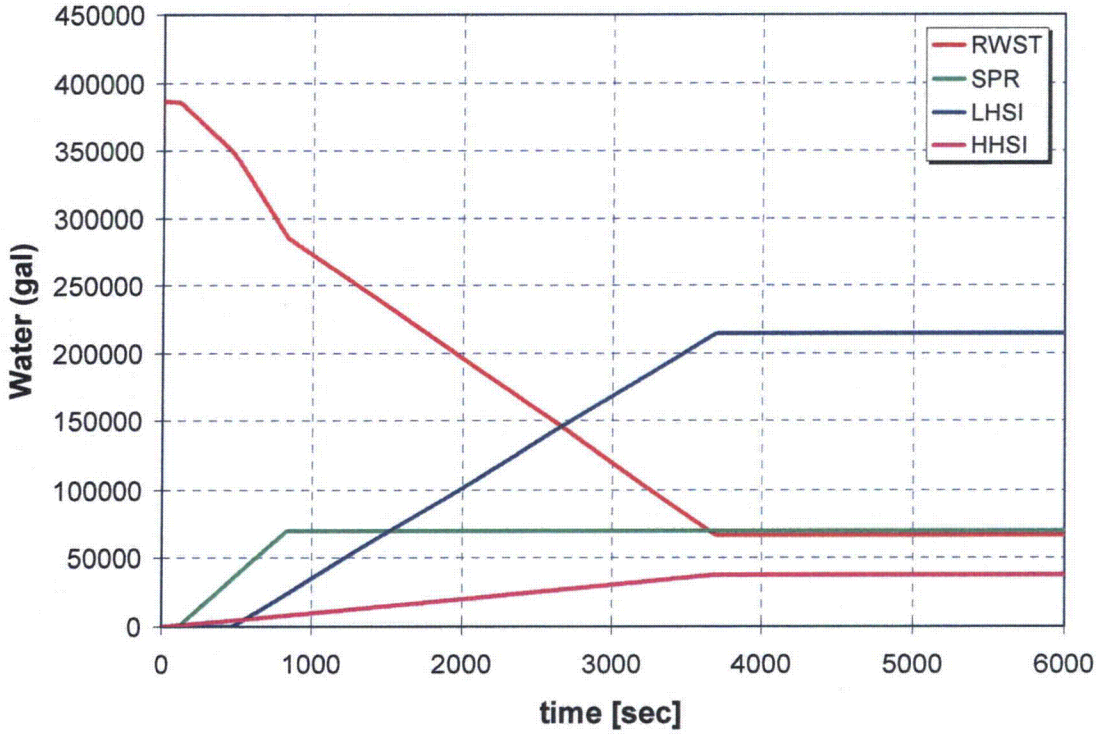

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
500
1000
1500
2000
2500
3000
time [sec]
TCL
TFU
2200 F

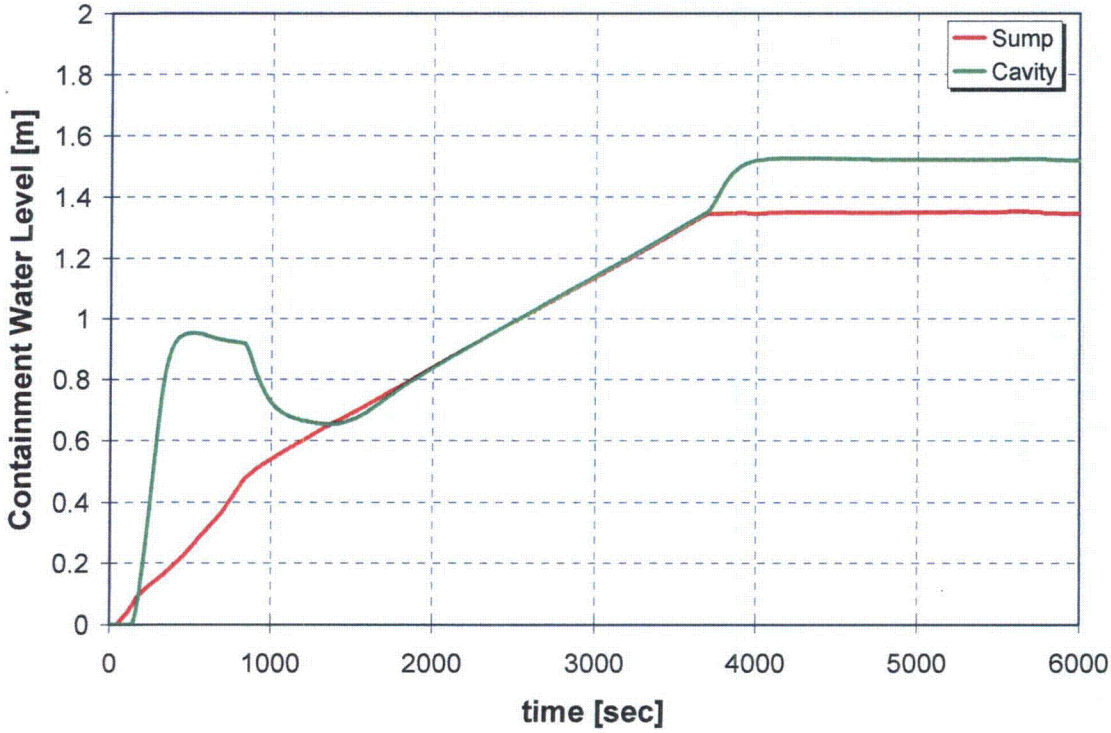
A.6.2 Case 2: 6-Inch Break LOCA, One HHSI, One LHSI, and No ACC

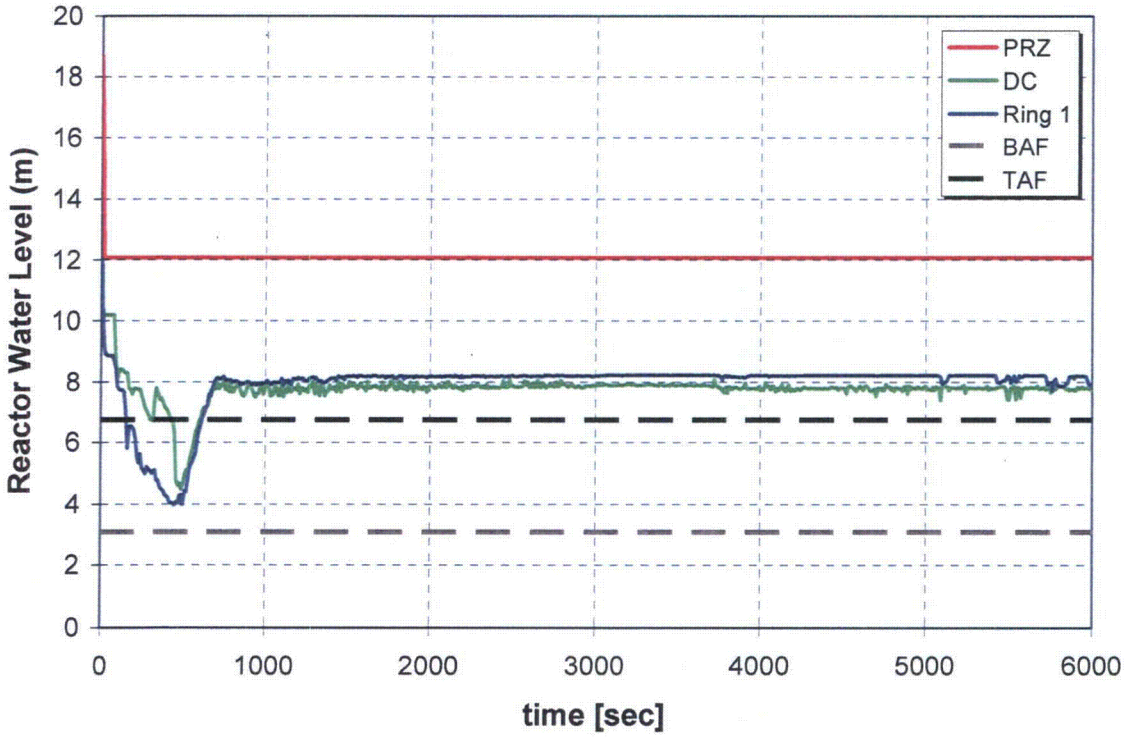


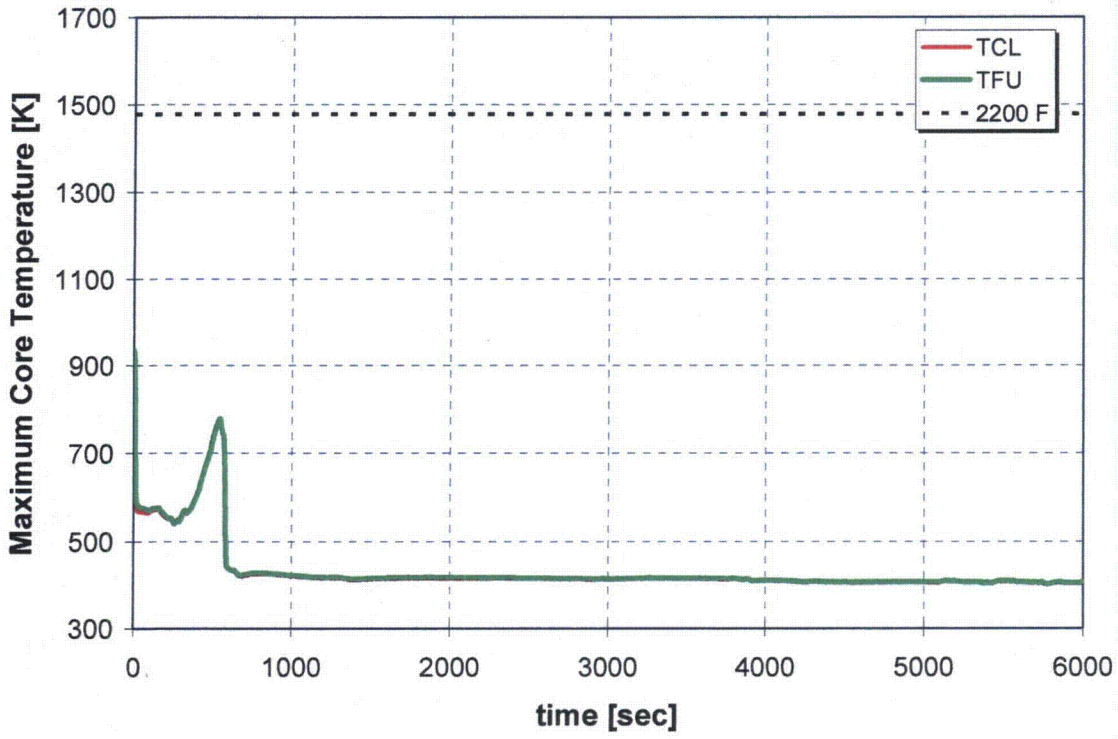



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
time [sec]

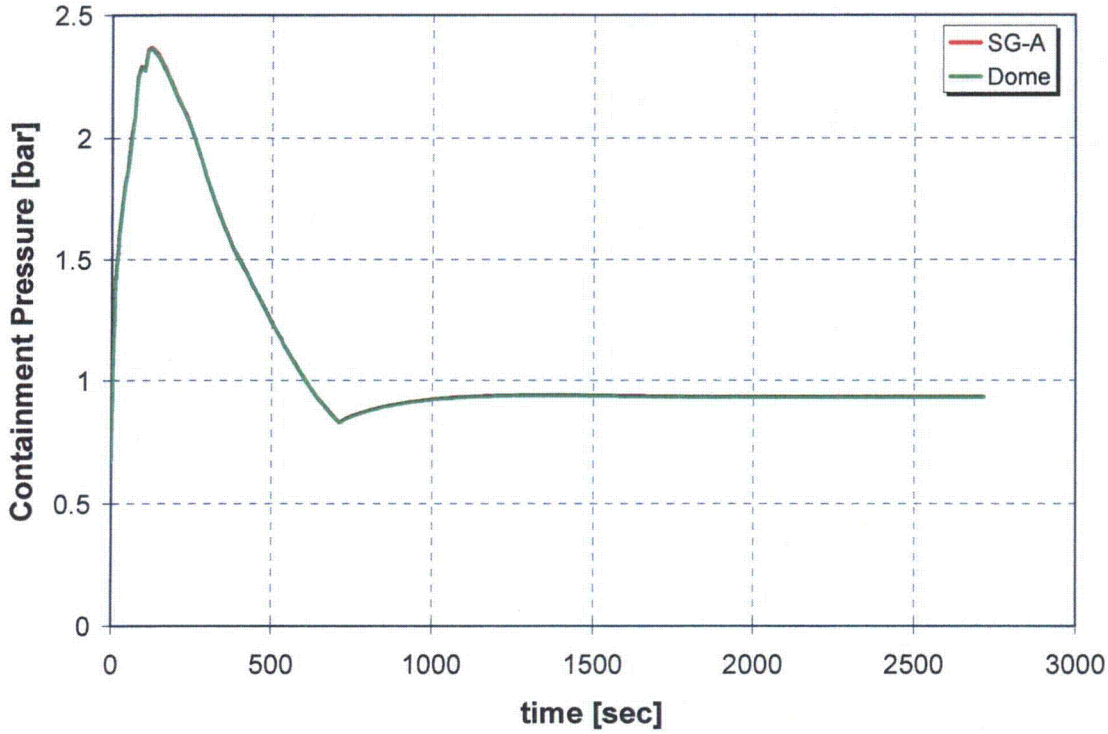

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
1000
2000
3000
4000
5000
6000
time [sec]

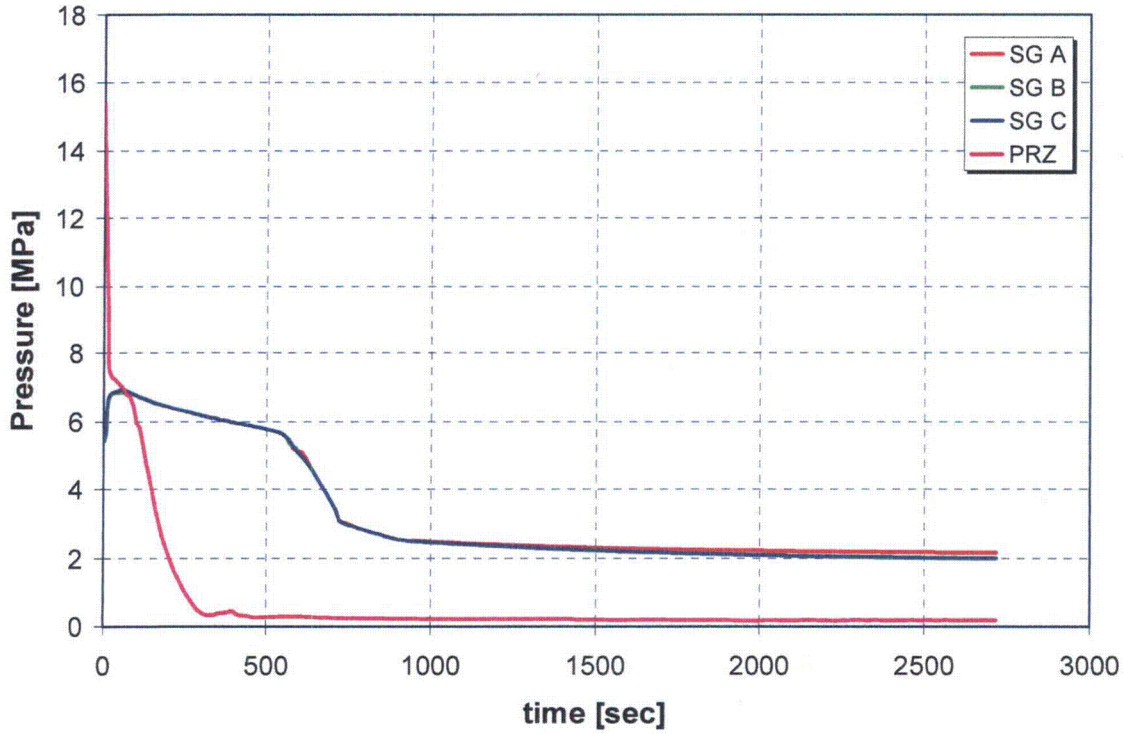

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1000
2000
3000
4000
5000
6000

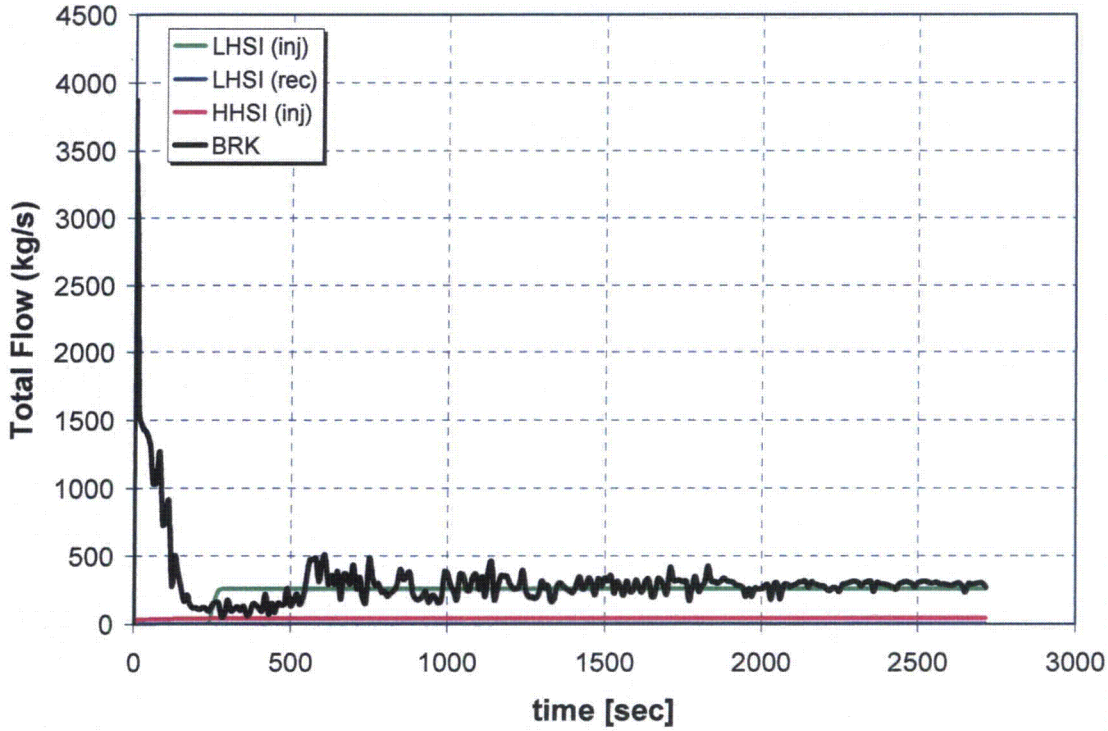

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000
6000

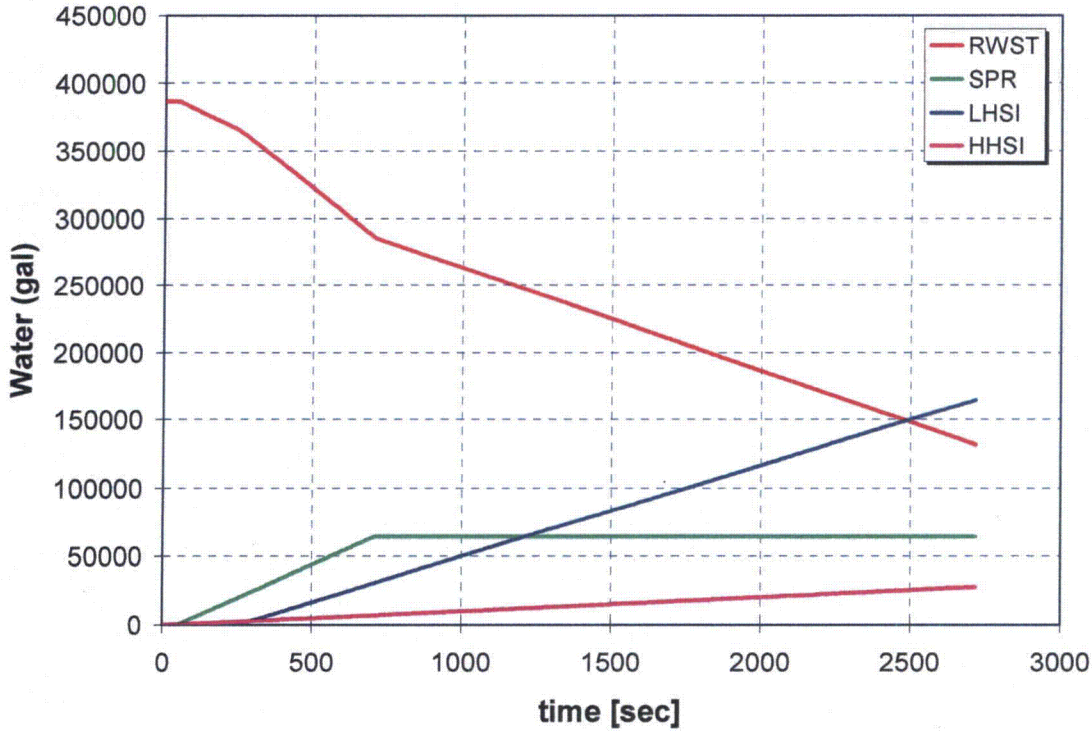

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
1000
2000
3000
4000
5000
6000
time [sec]
TCL
TFU
2200 F

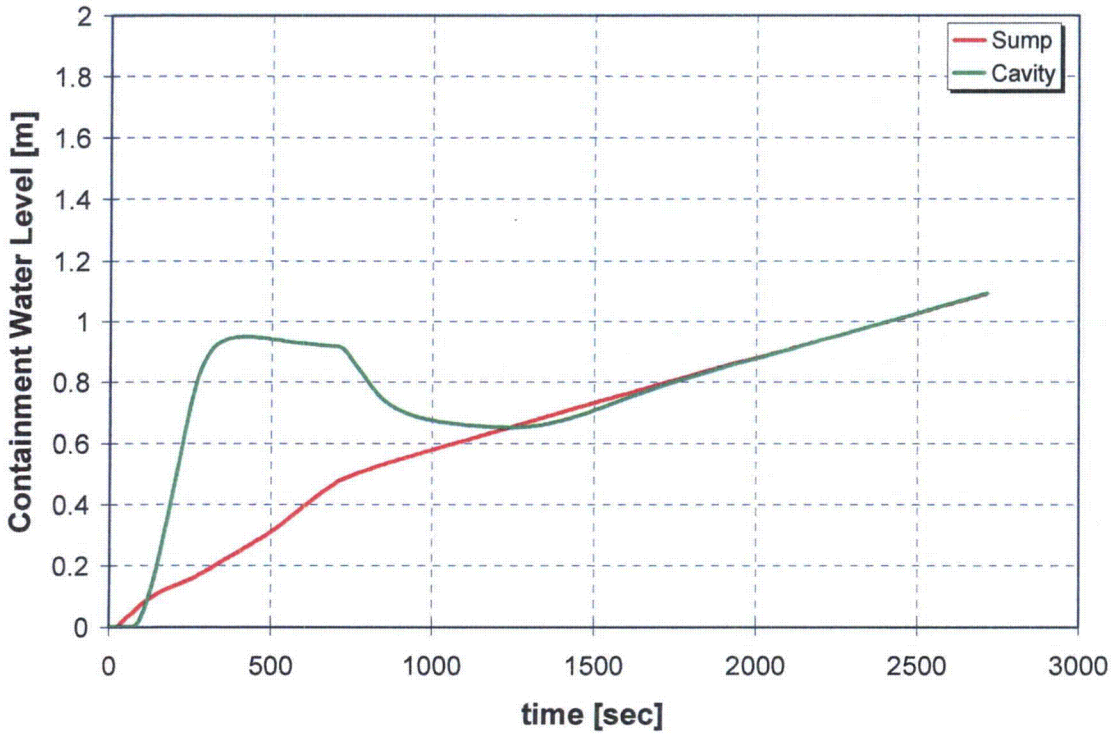
A.6.3 Case 3: 8-Inch Break LOCA, One HHSI, One LHSI, and No ACC

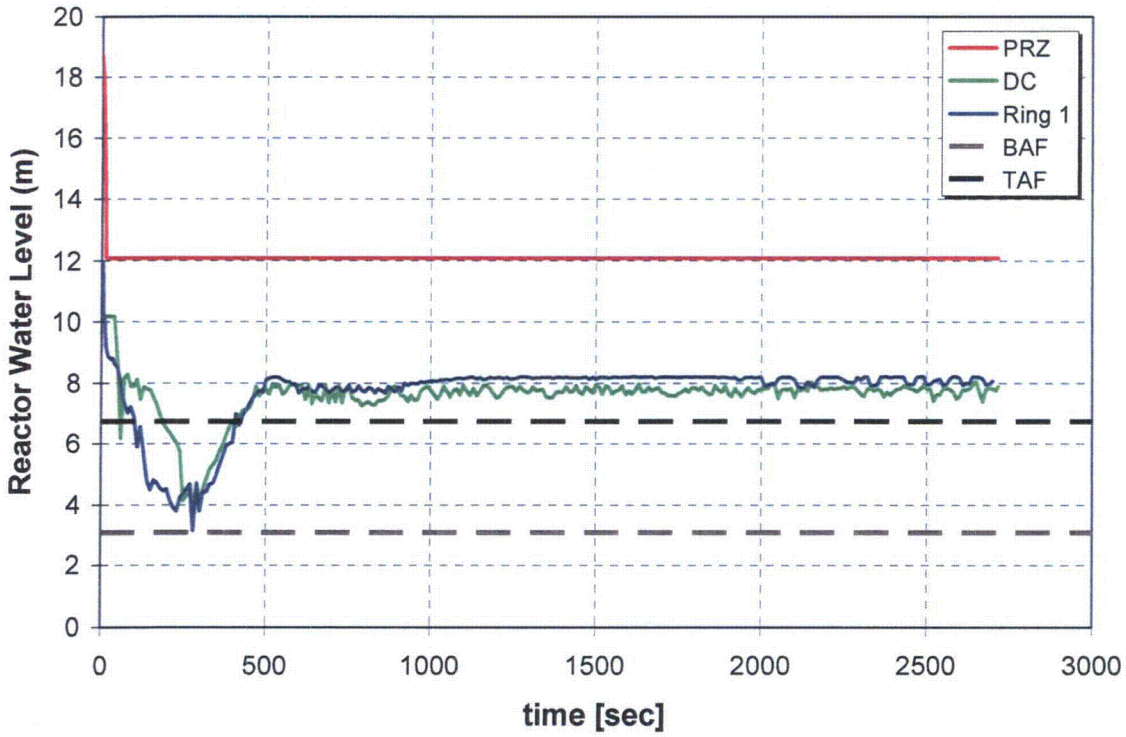


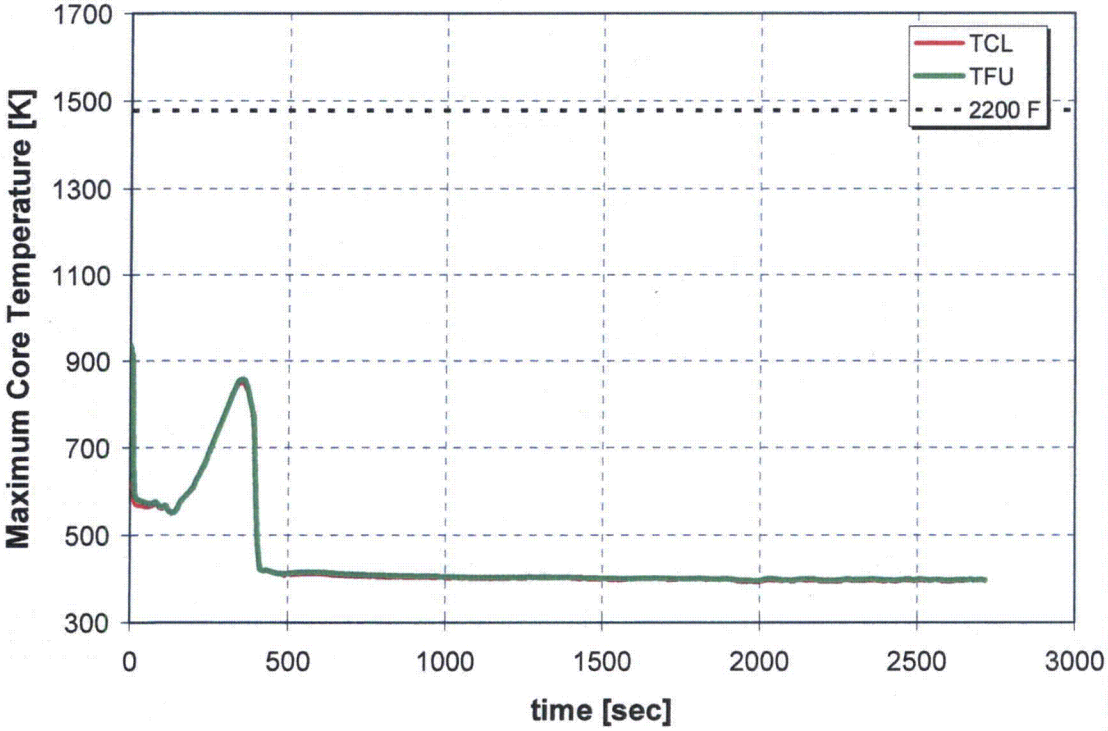



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
time [sec]

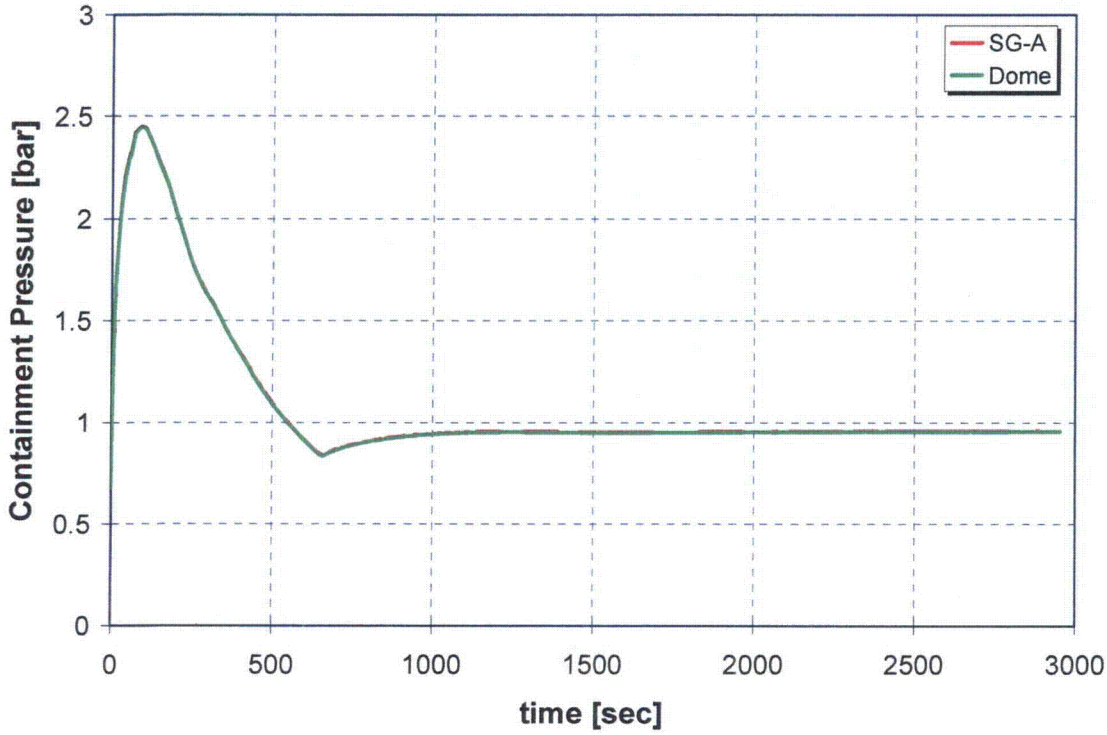

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
500
1000
1500
2000
2500
3000
time [sec]

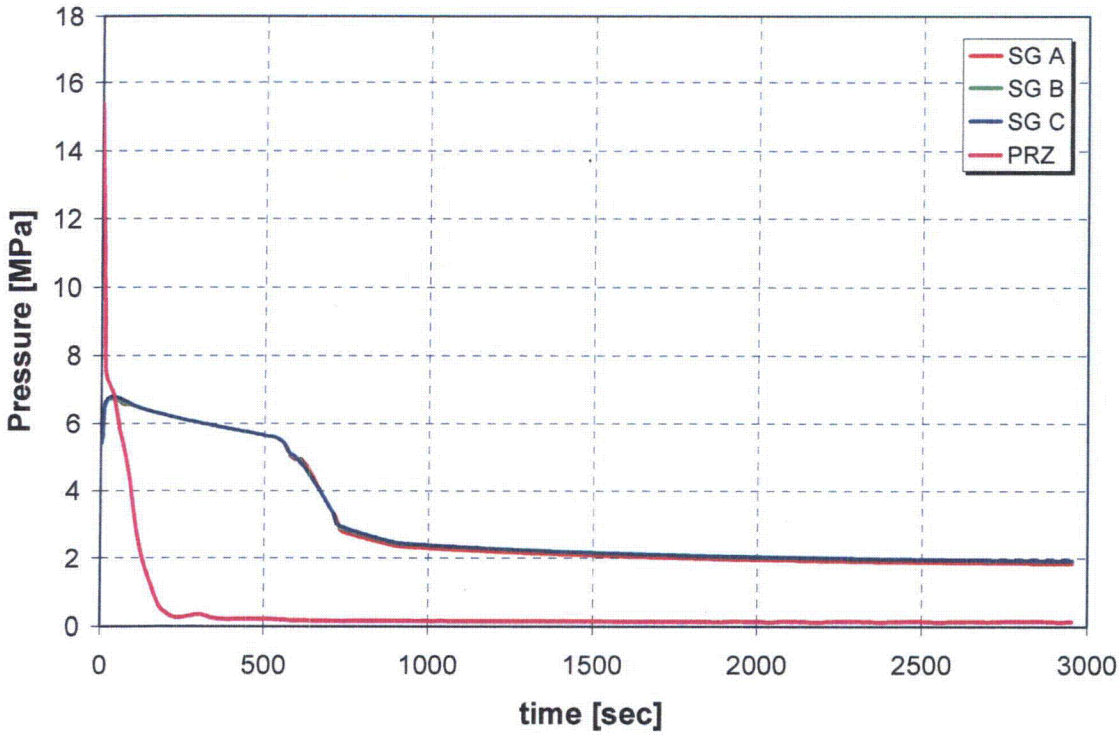

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
500
1000
1500
2000
2500
3000

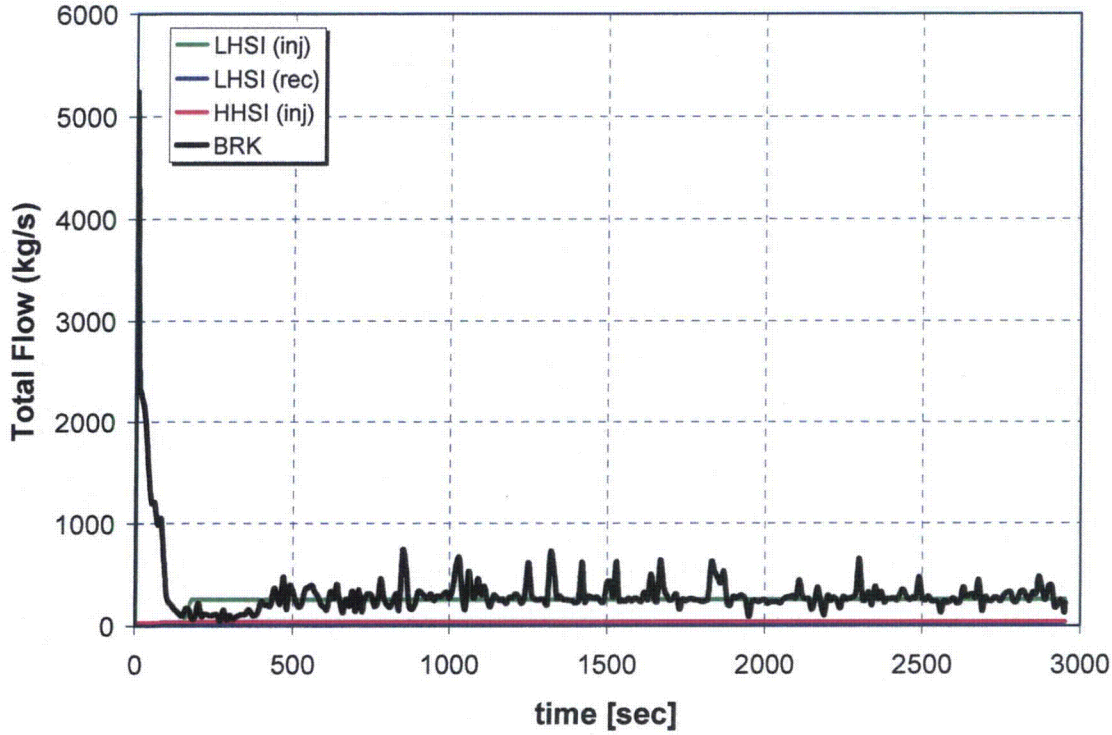

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000

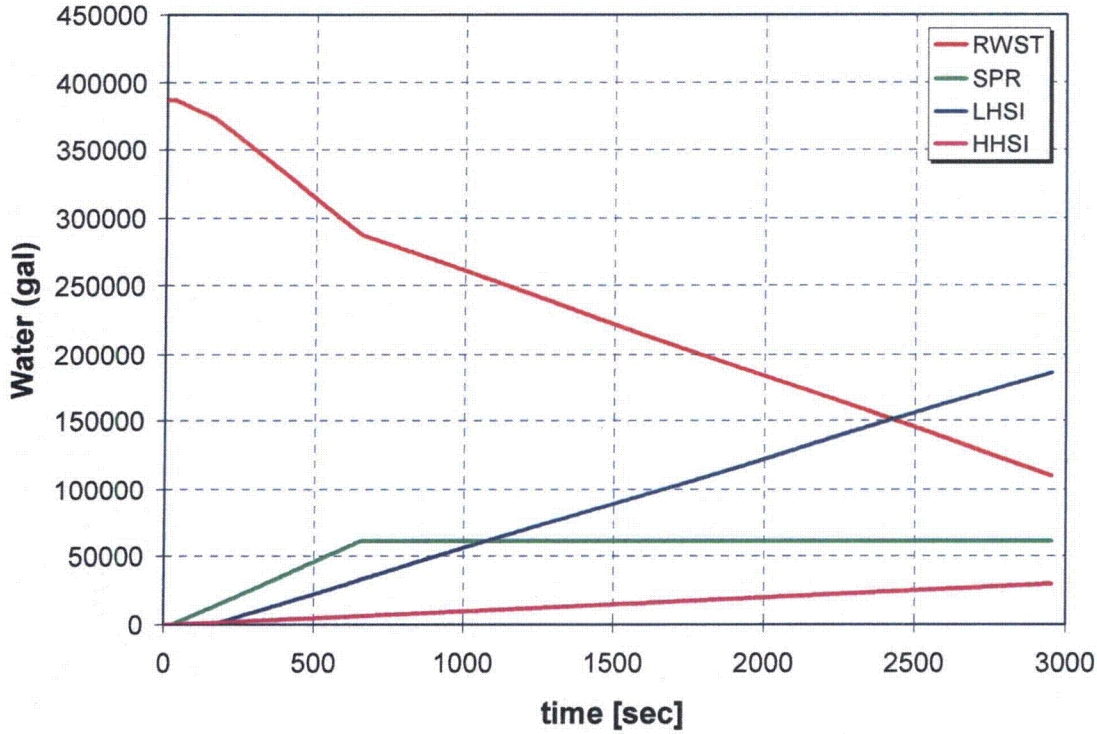

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
500
1000
1500
2000
2500
3000
time [sec]
TCL
TFU
2200 F

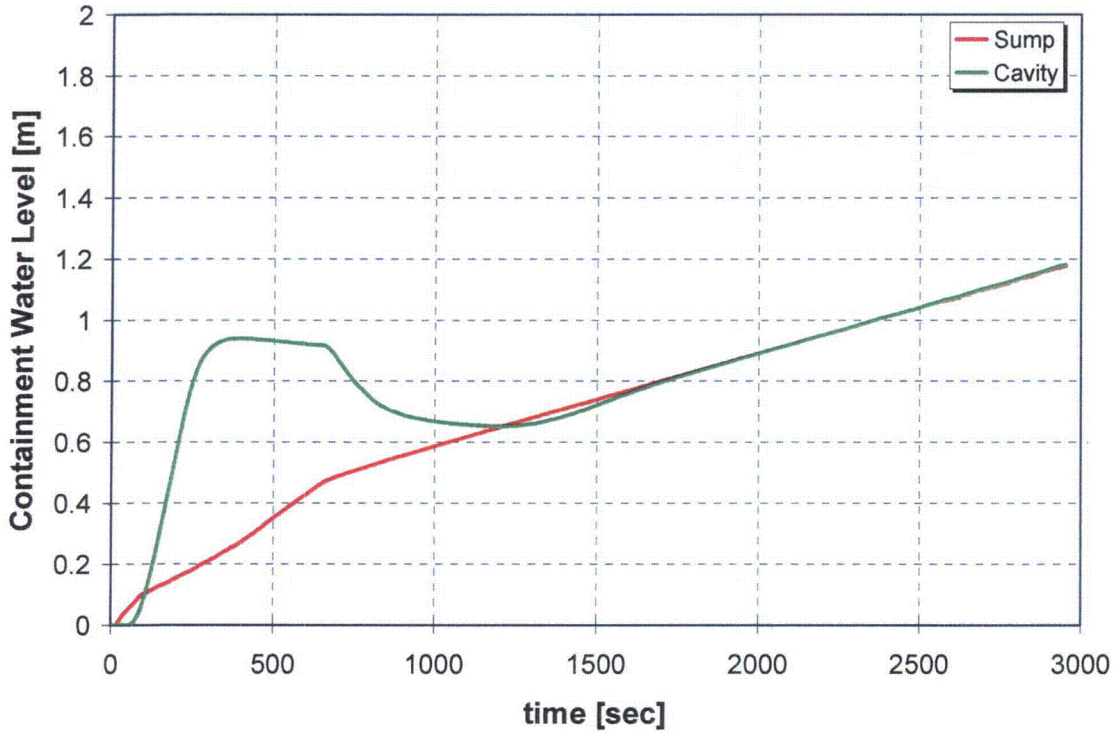
A.6.4 Case 4: 10-Inch Break LOCA, One HHSI, One LHSI, and No ACC

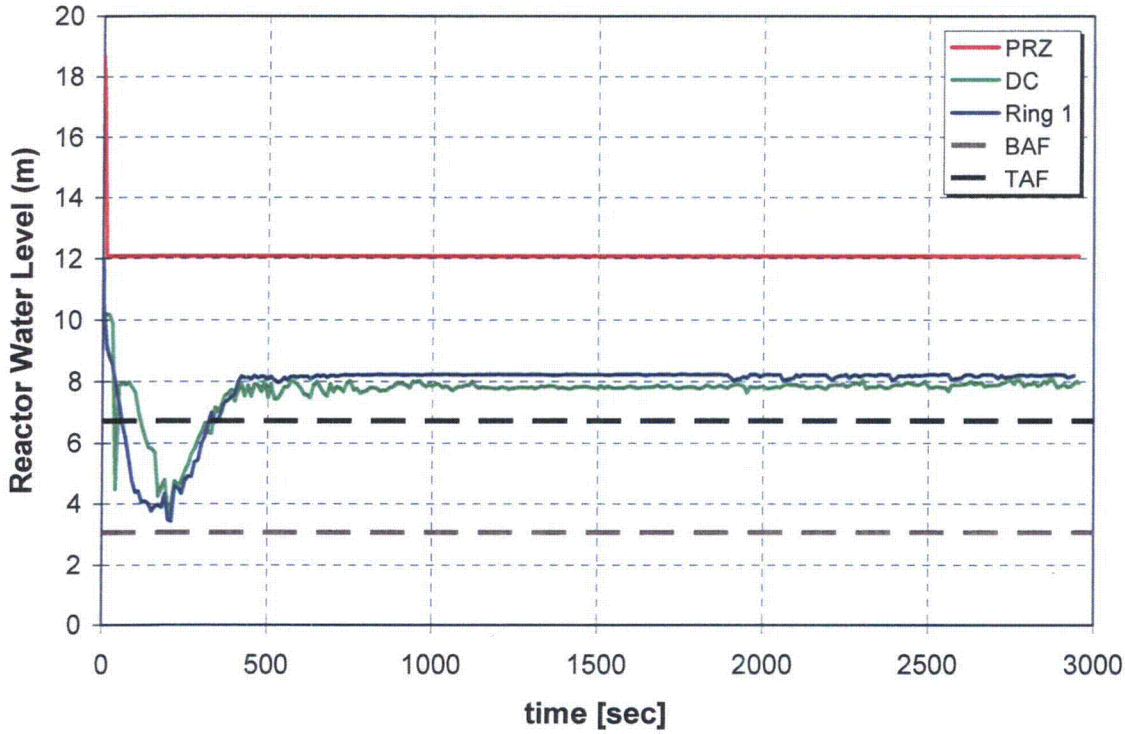


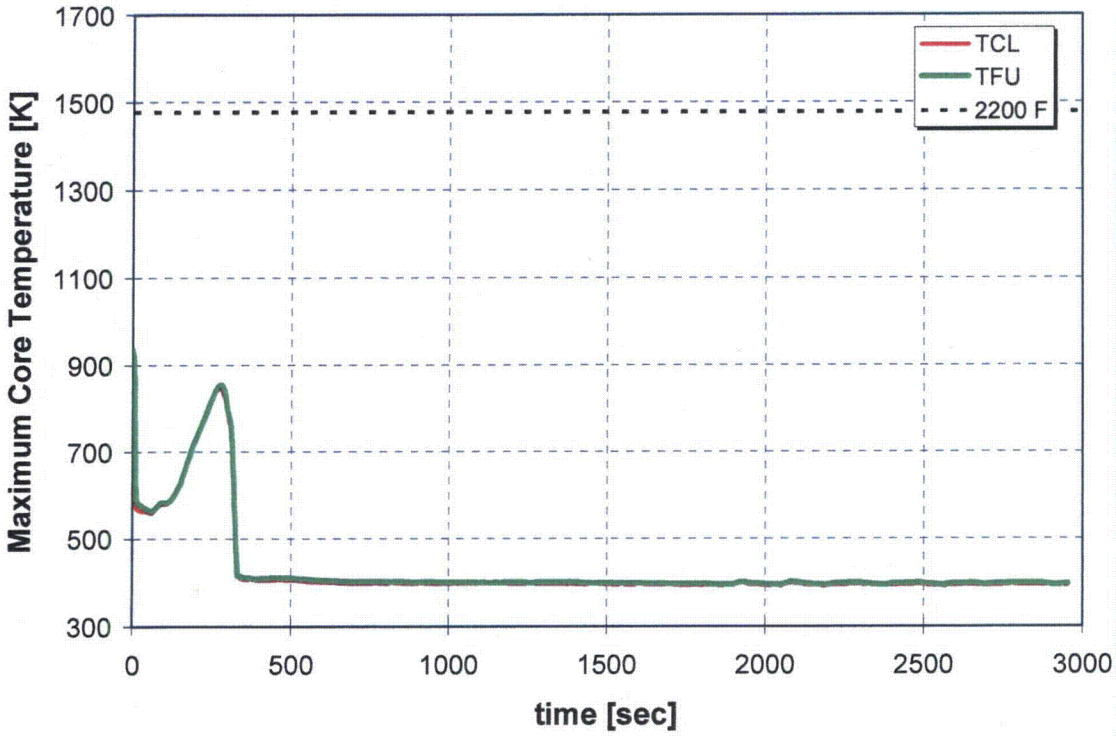



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
time [sec]

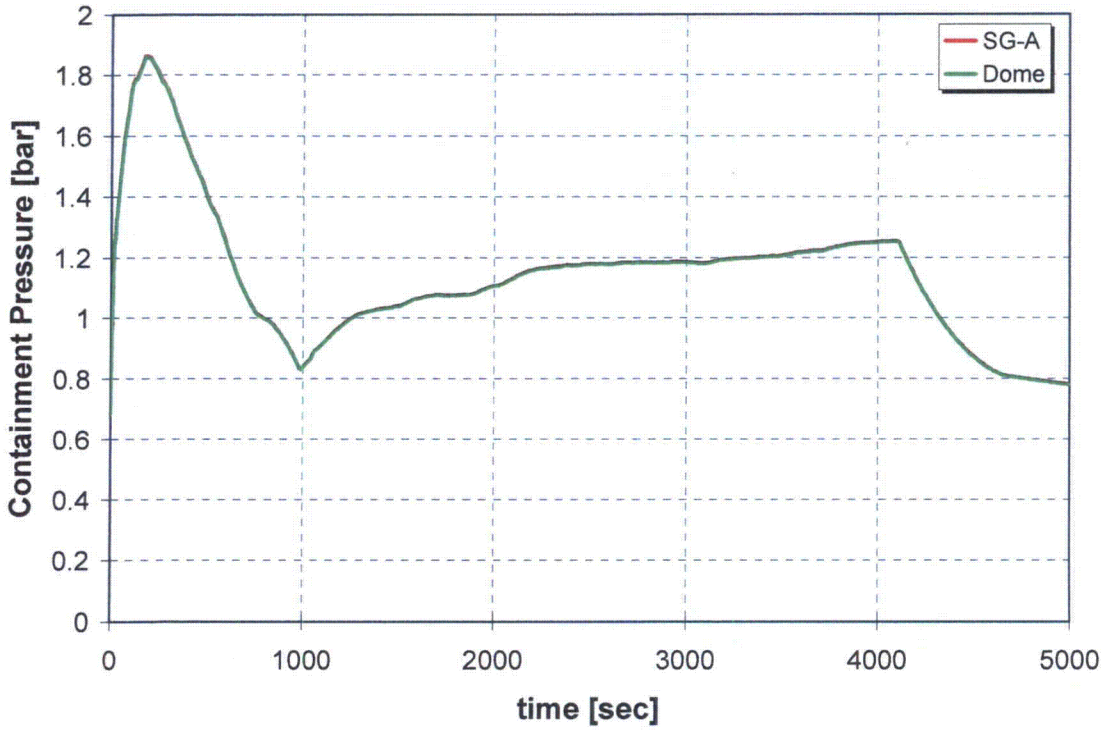

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
500
1000
1500
2000
2500
3000
time [sec]

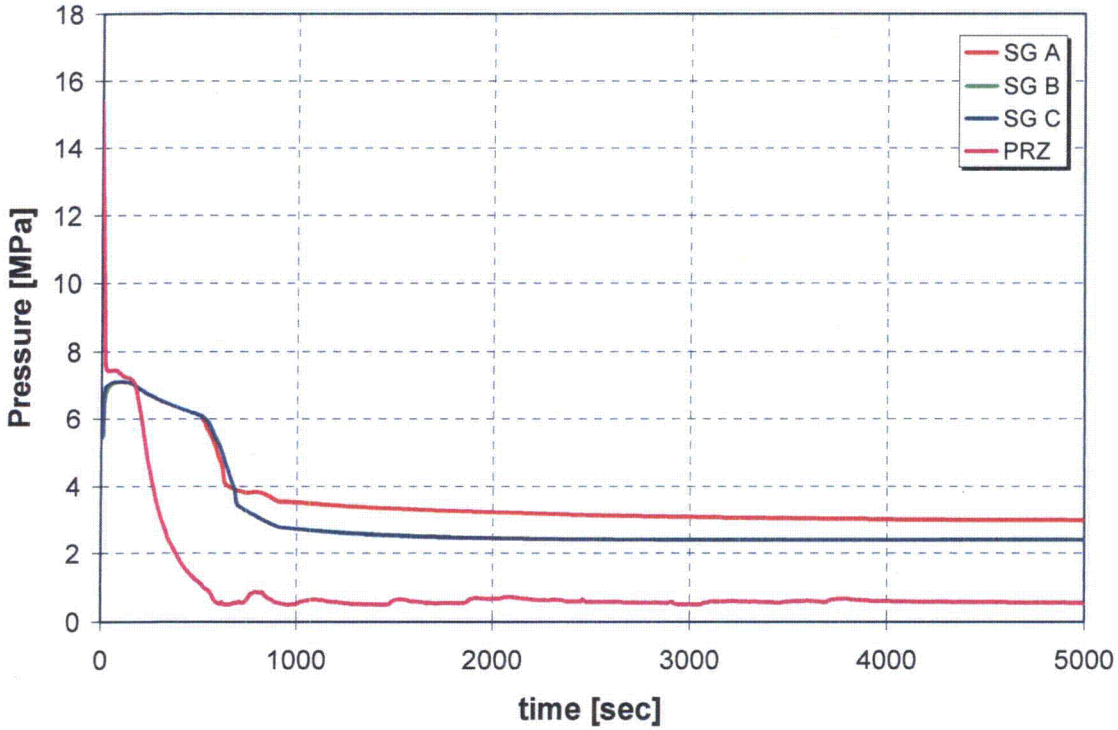

Containment Water Level [m]
time [sec]
Sump
Cavity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
500
1000
1500
2000
2500
3000

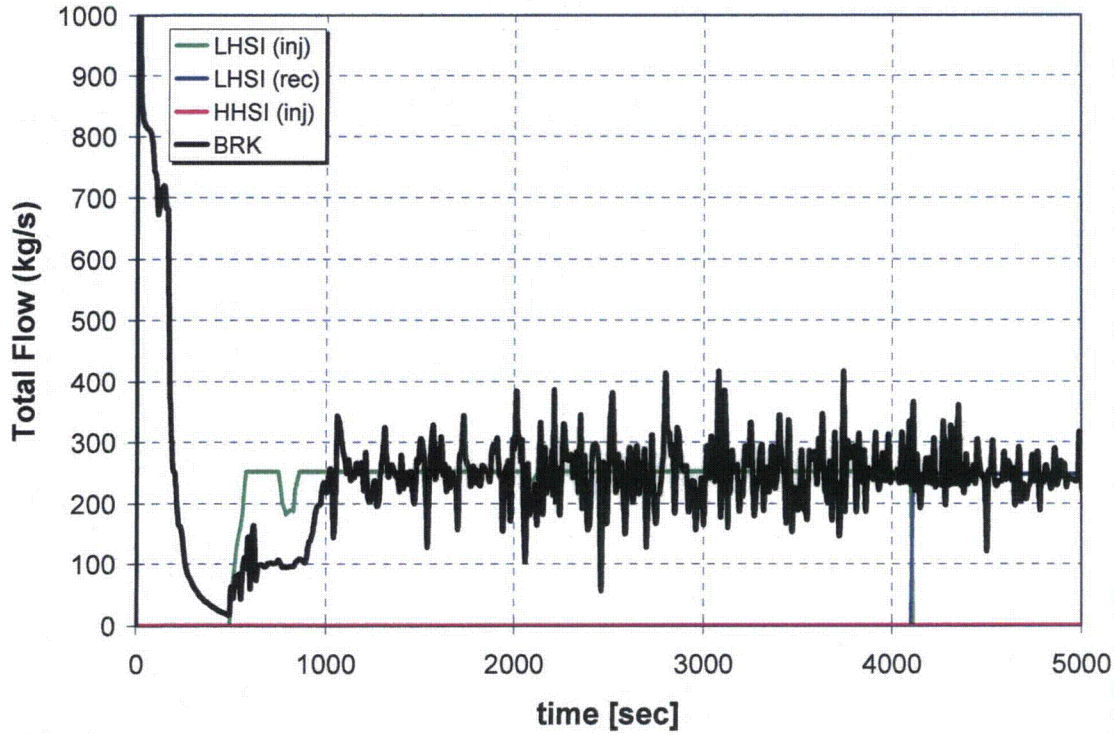

Reactor Water Level (m)
time [sec]
PRZ
DC
Ring 1
BAF
TAF
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000

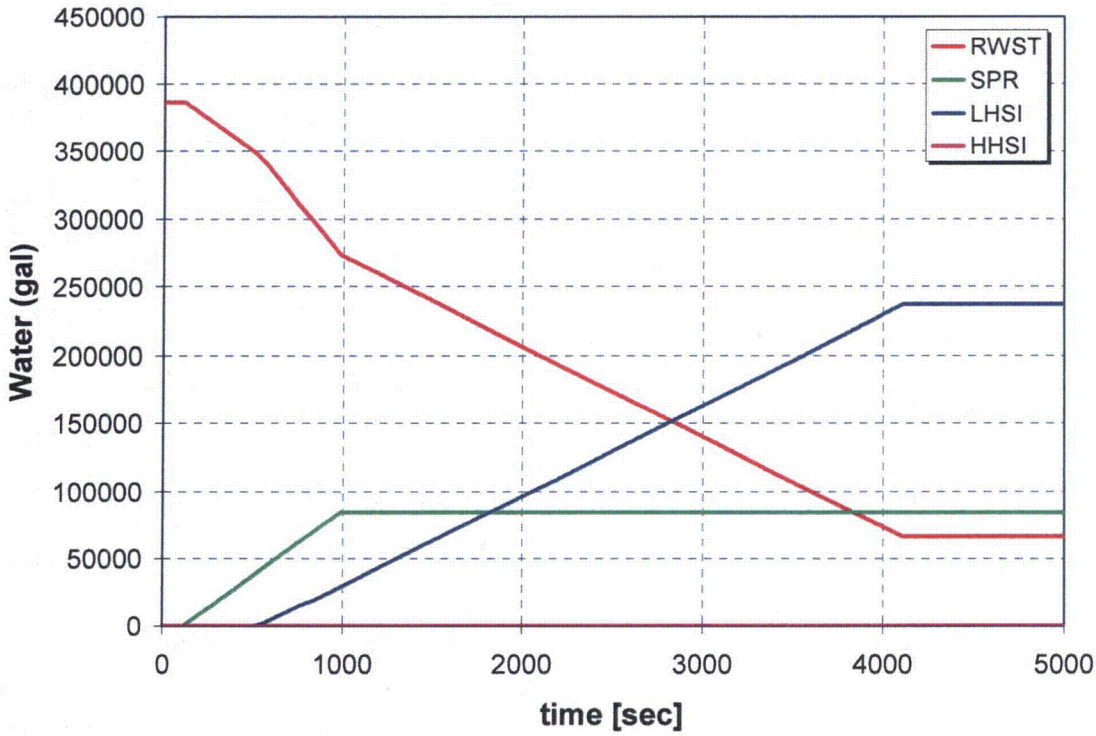

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
0
500
1000
1500
2000
2500
3000
time [sec]
TCL
TFU
2200 F

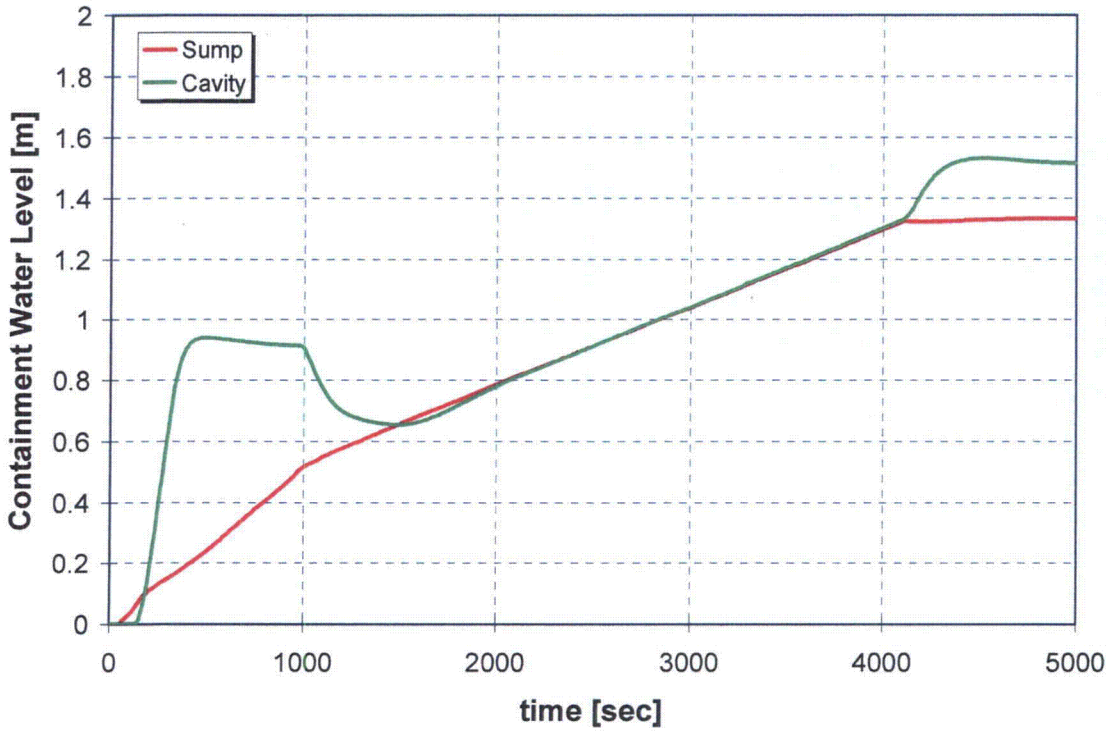
A.6.5 Case 5: 6-Inch Break LOCA, No HHSI, One LHSI, and No ACC

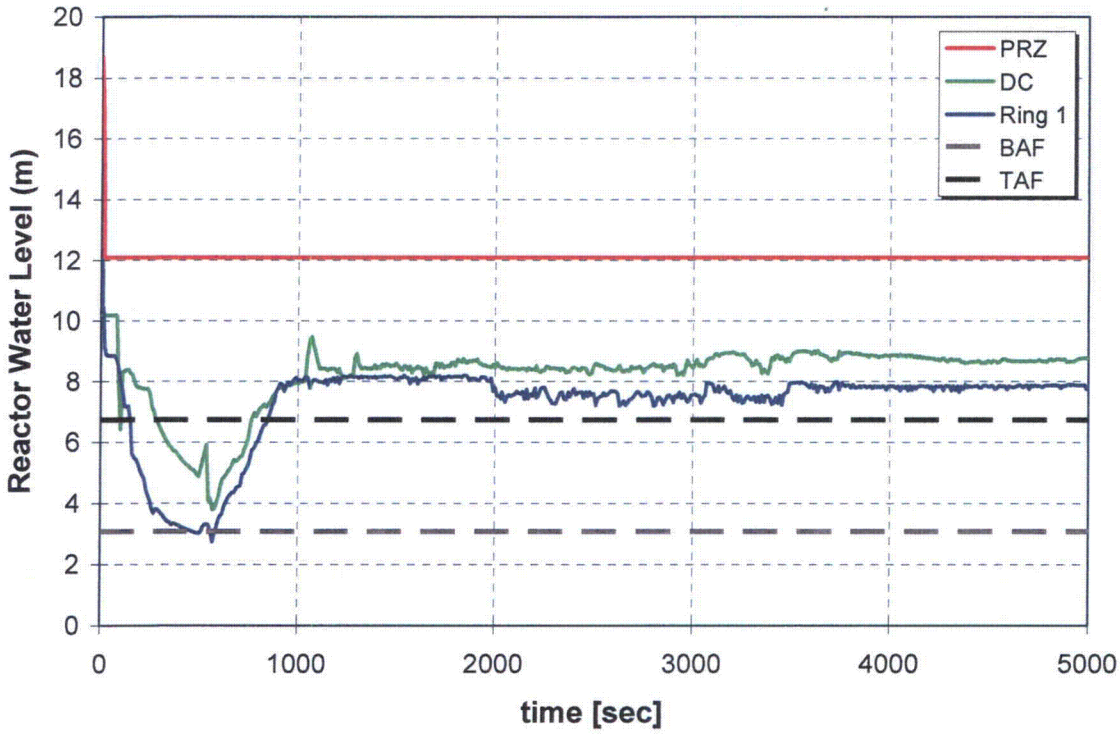


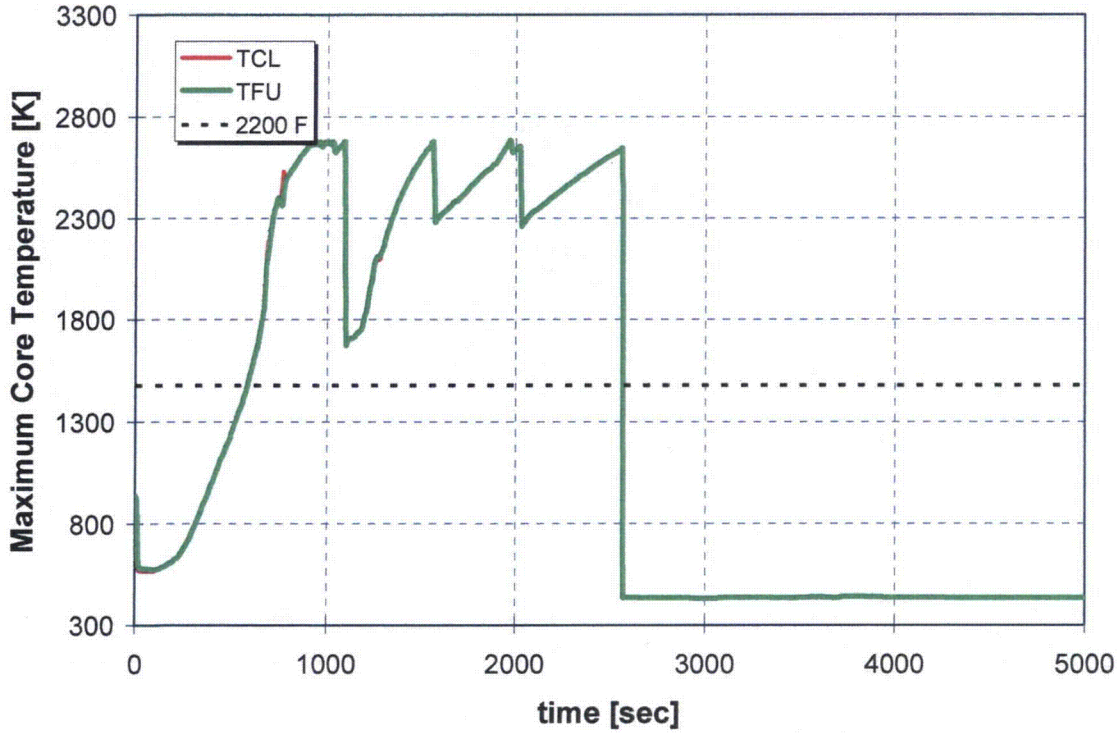



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
time [sec]
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000

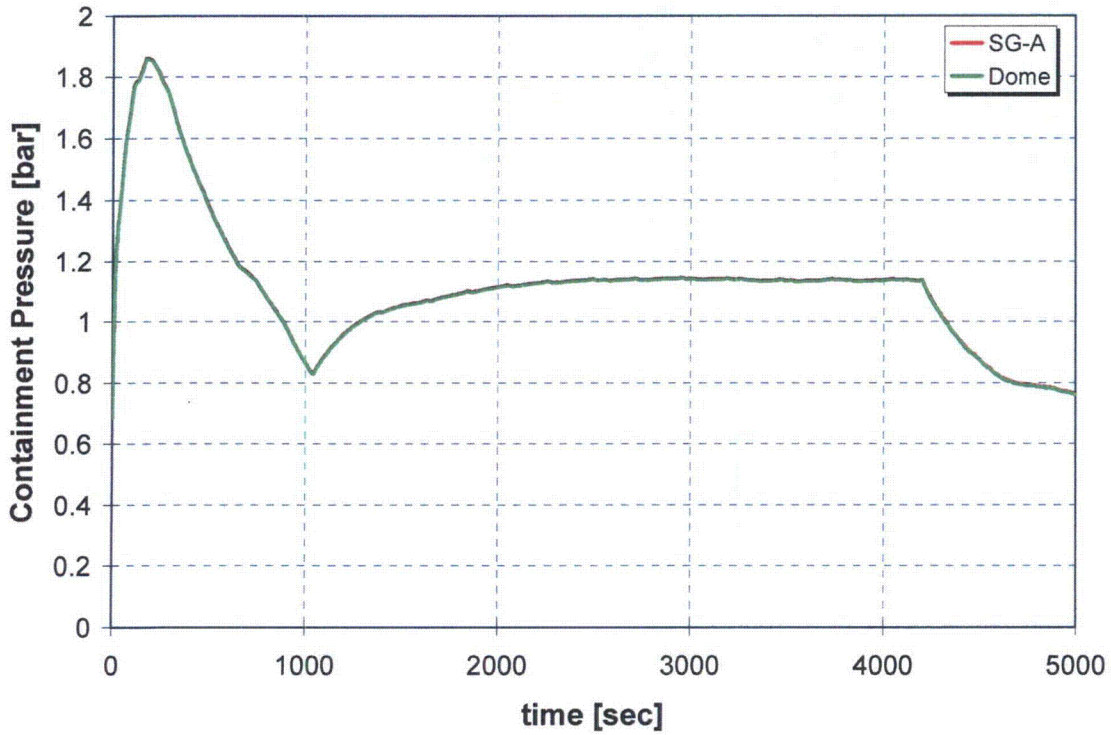

RWST
SPR
LHSI
HHSI
Water (gal)
time [sec]
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0
1000
2000
3000
4000
5000

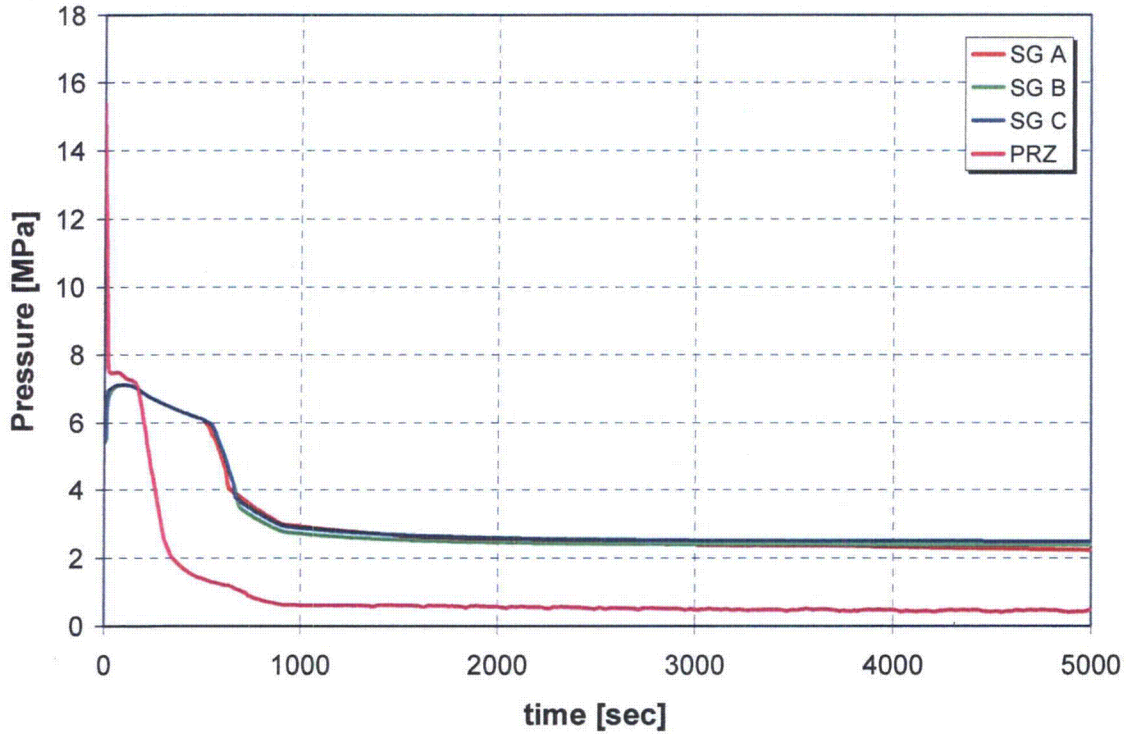

Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1000
2000
3000
4000
5000

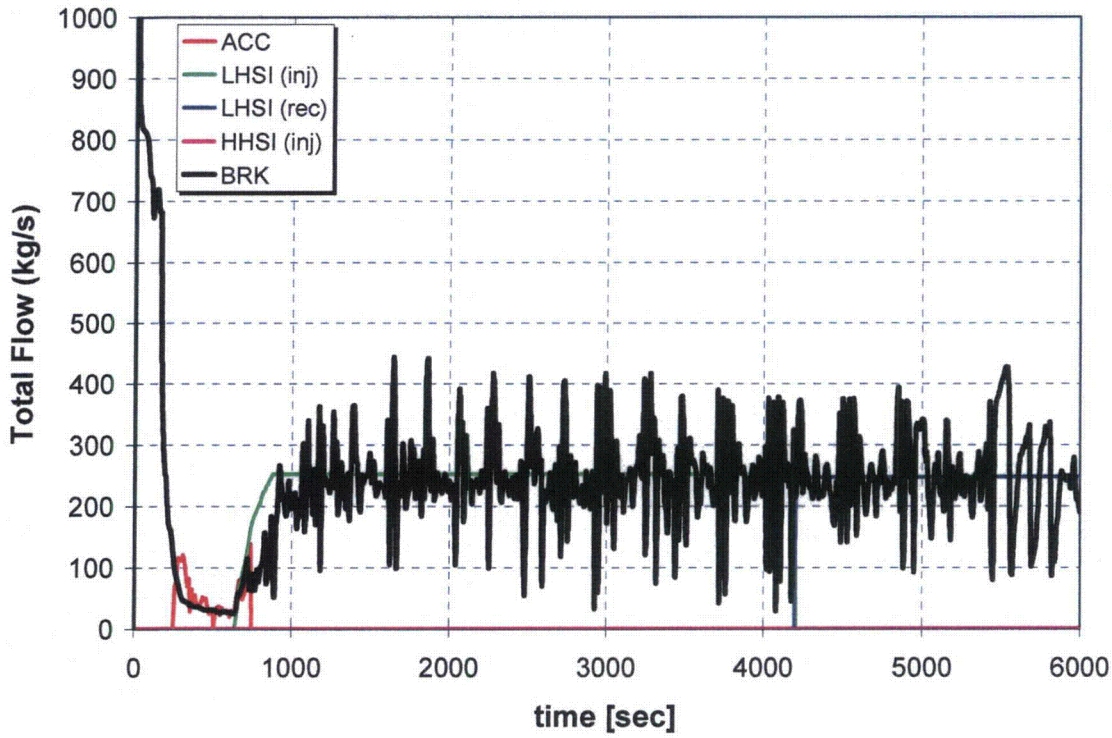

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000

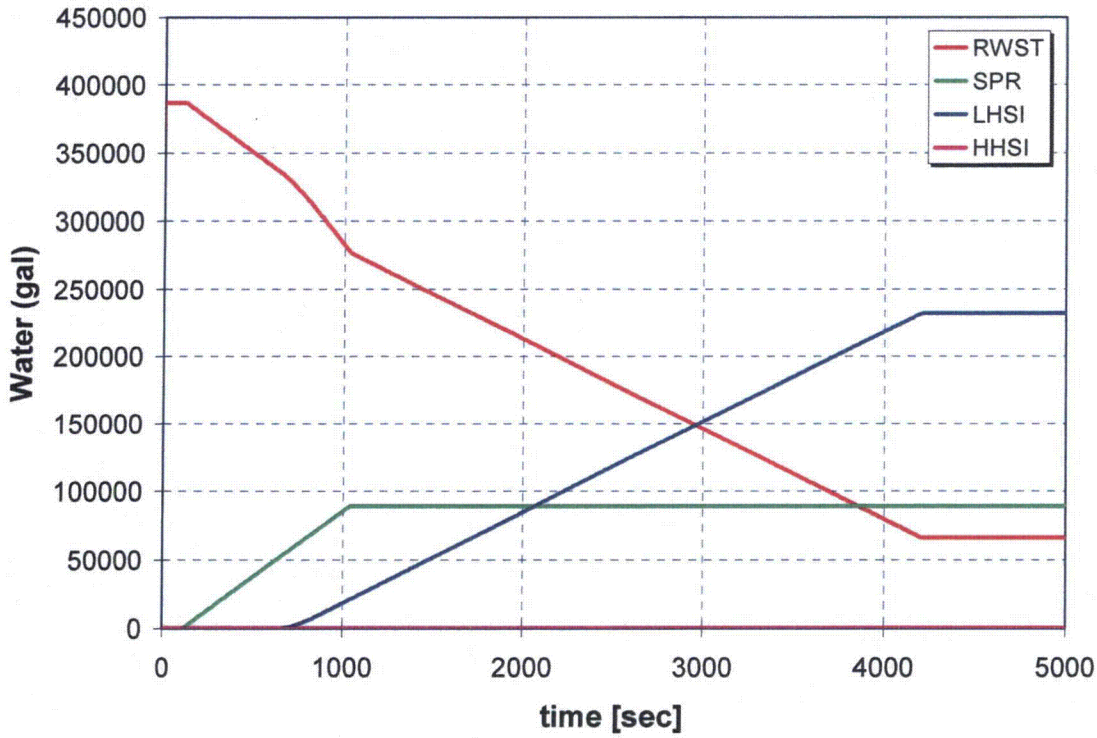

3300
2800
2300
1800
1300
800
300
Maximum Core Temperature [K]
TCL
TFU
2200 F
0
1000
2000
3000
4000
5000
time [sec]

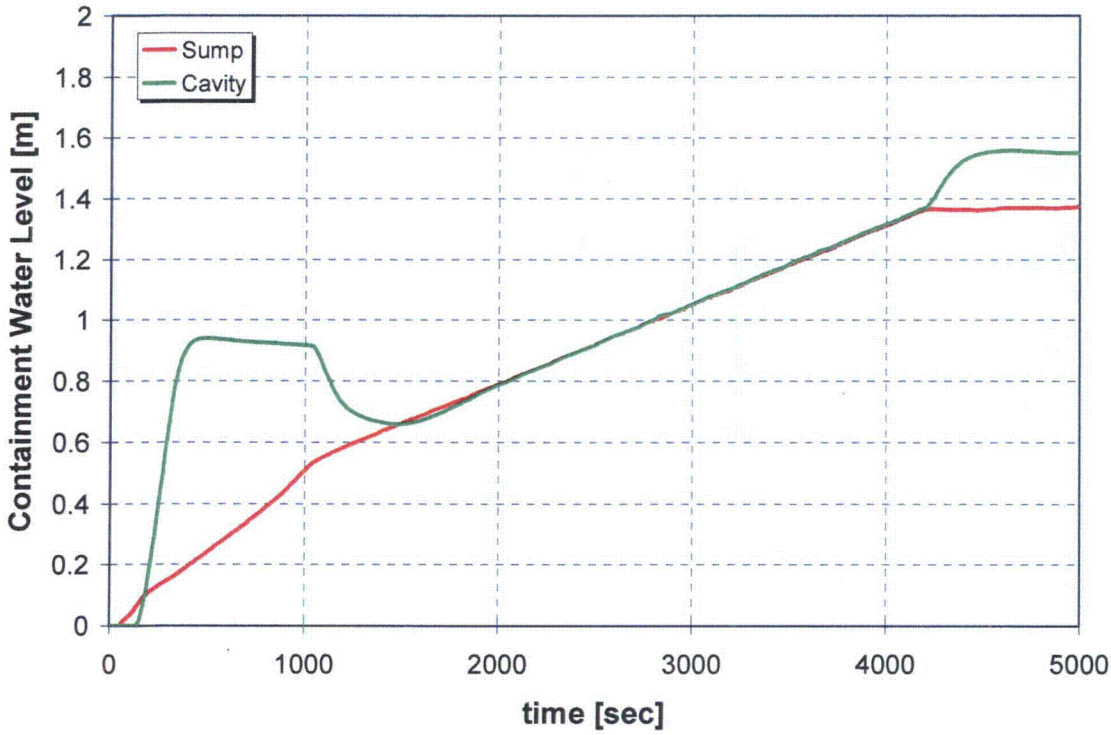
A.6.6 Case 6: 6-Inch Break LOCA, No HHSI, One LHSI, and One ACC

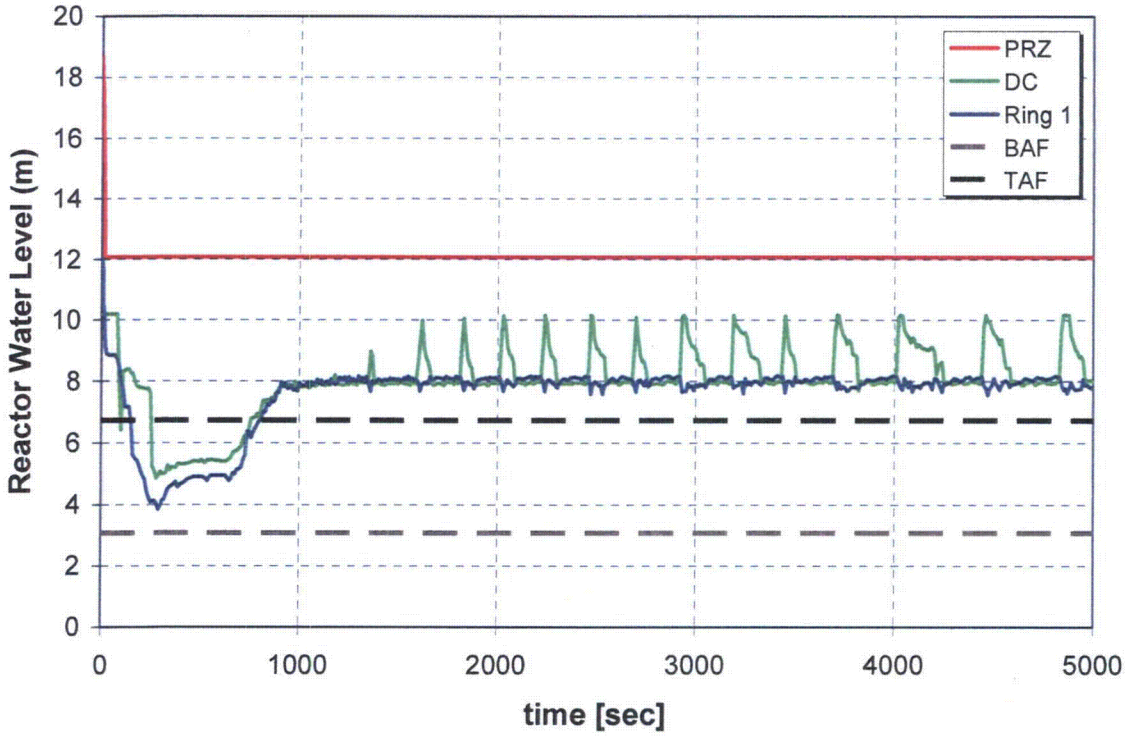


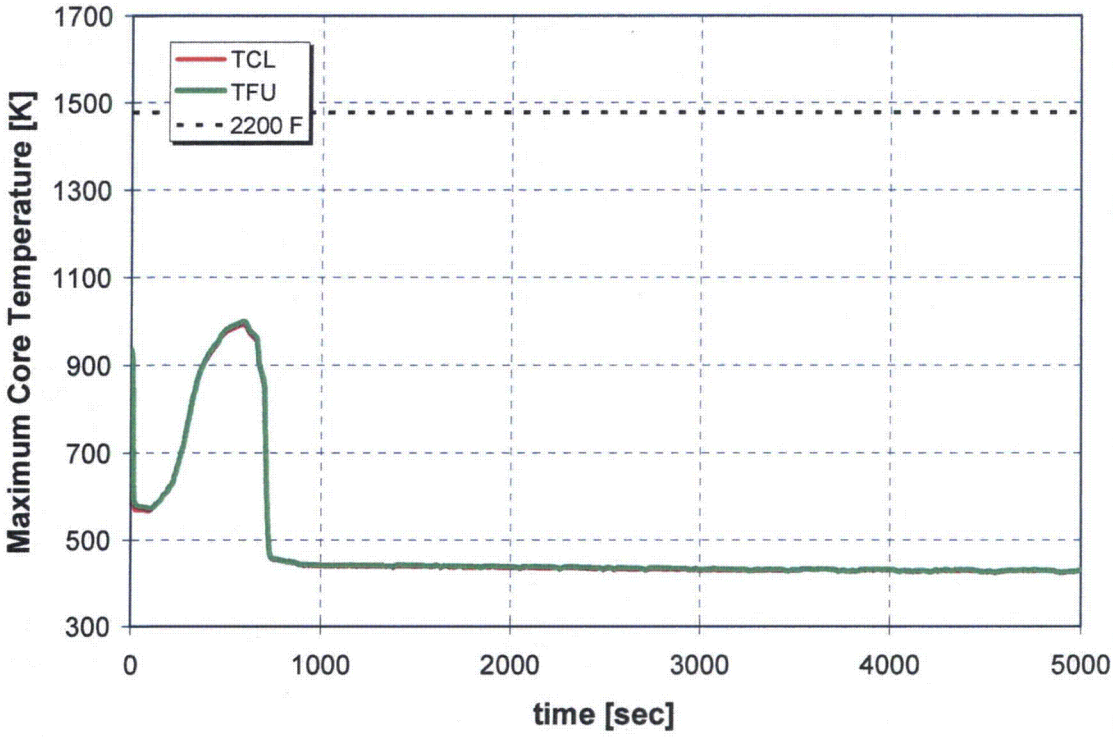



ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
time [sec]
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
6000

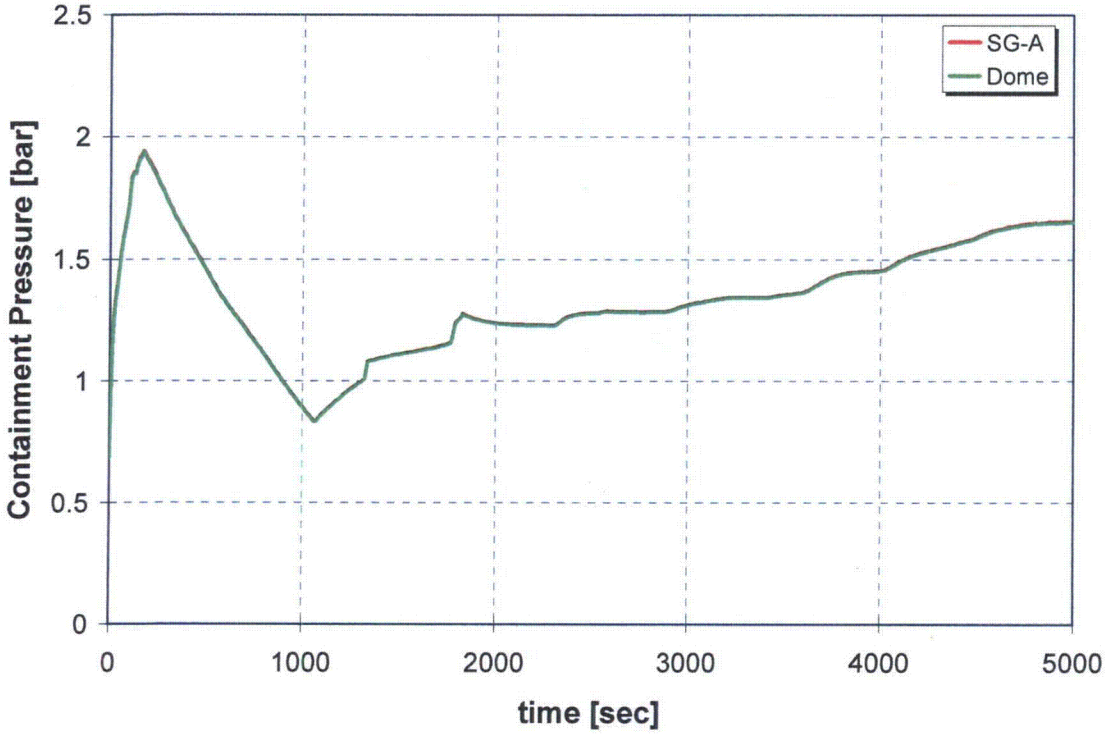

RWST
SPR
LHSI
HHSI
Water (gal)
time [sec]
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0
1000
2000
3000
4000
5000

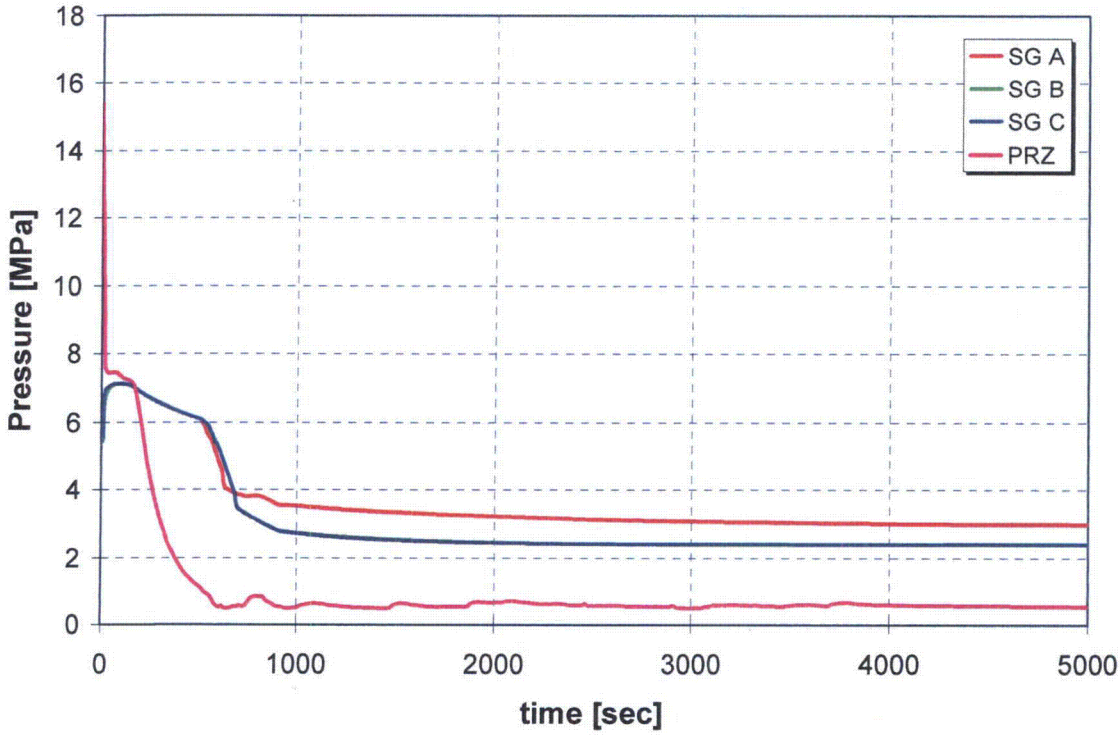

Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
1000
2000
3000
4000
5000

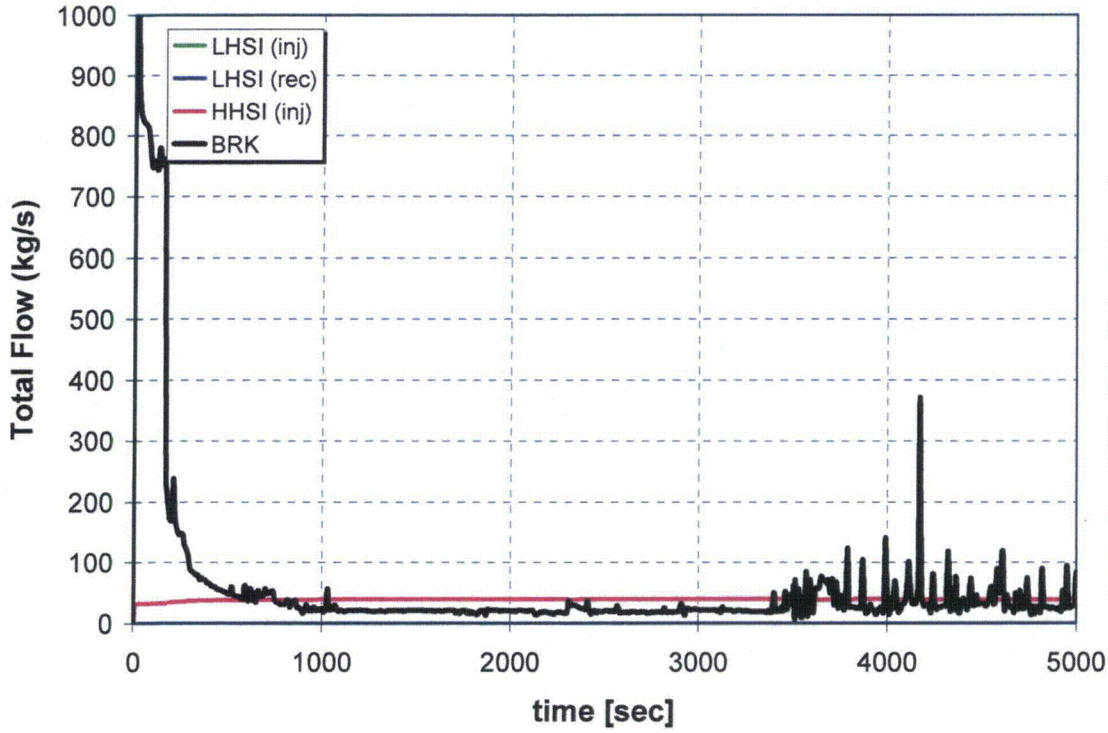

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000

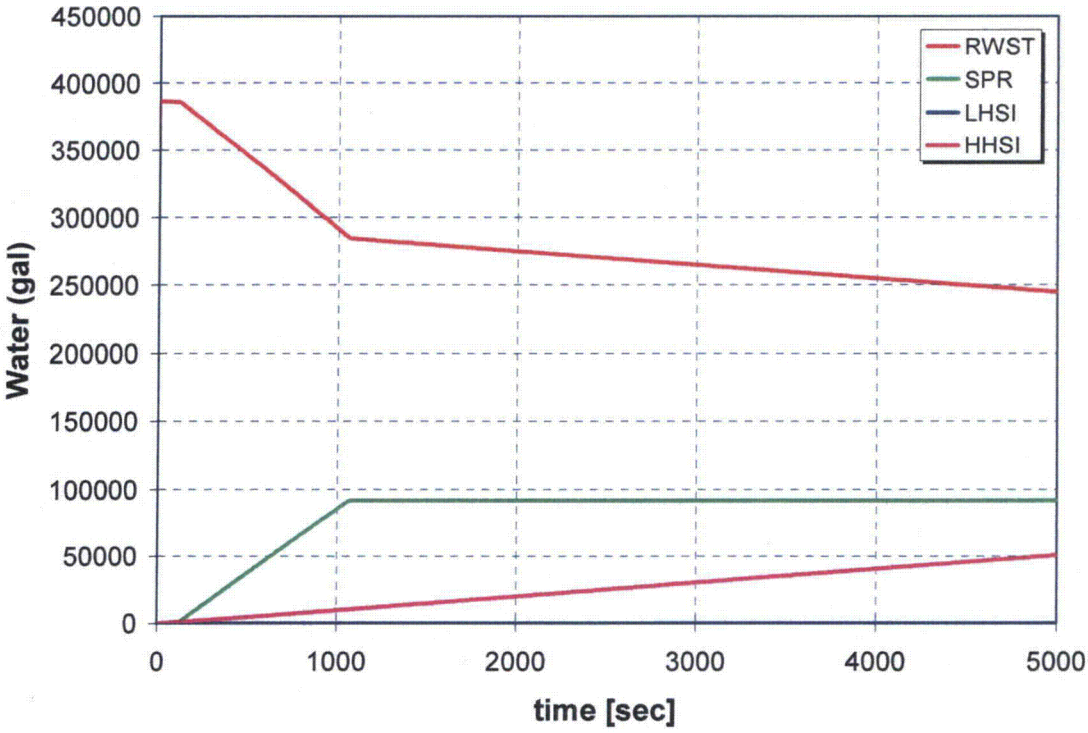

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
TCL
TFU
2200 F
0
1000
2000
3000
4000
5000
time [sec]

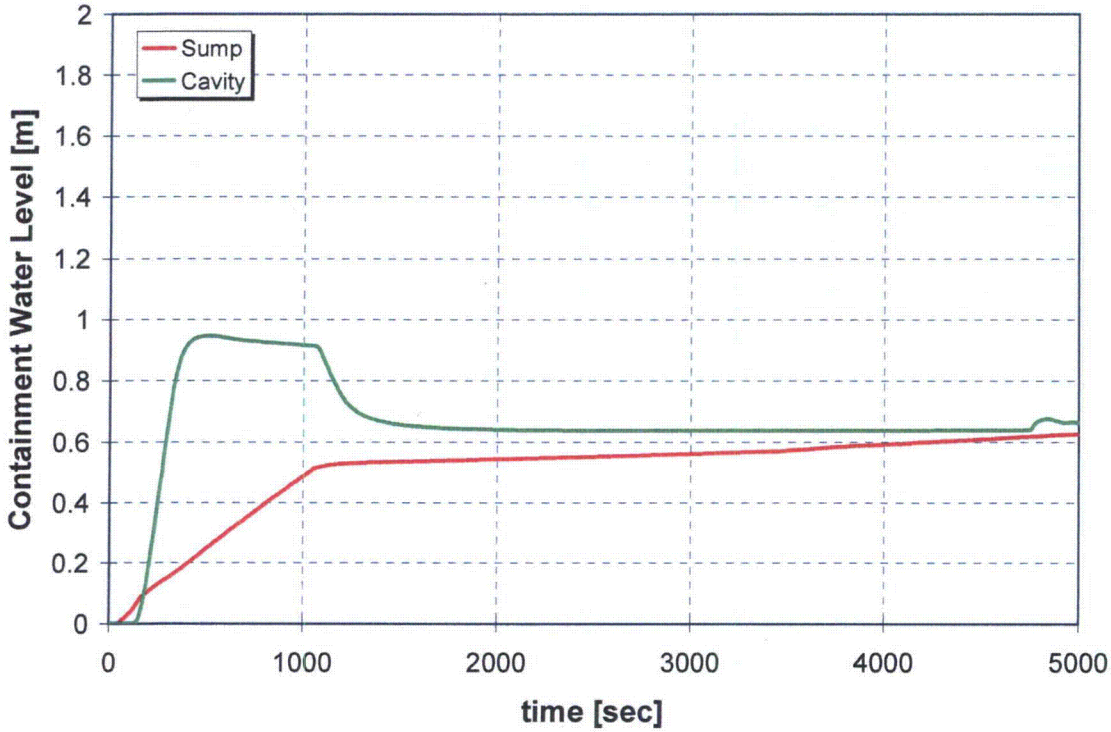
A.6.7 Case 7: 6-Inch Break LOCA, One HHSI, No LHSI, and No ACC

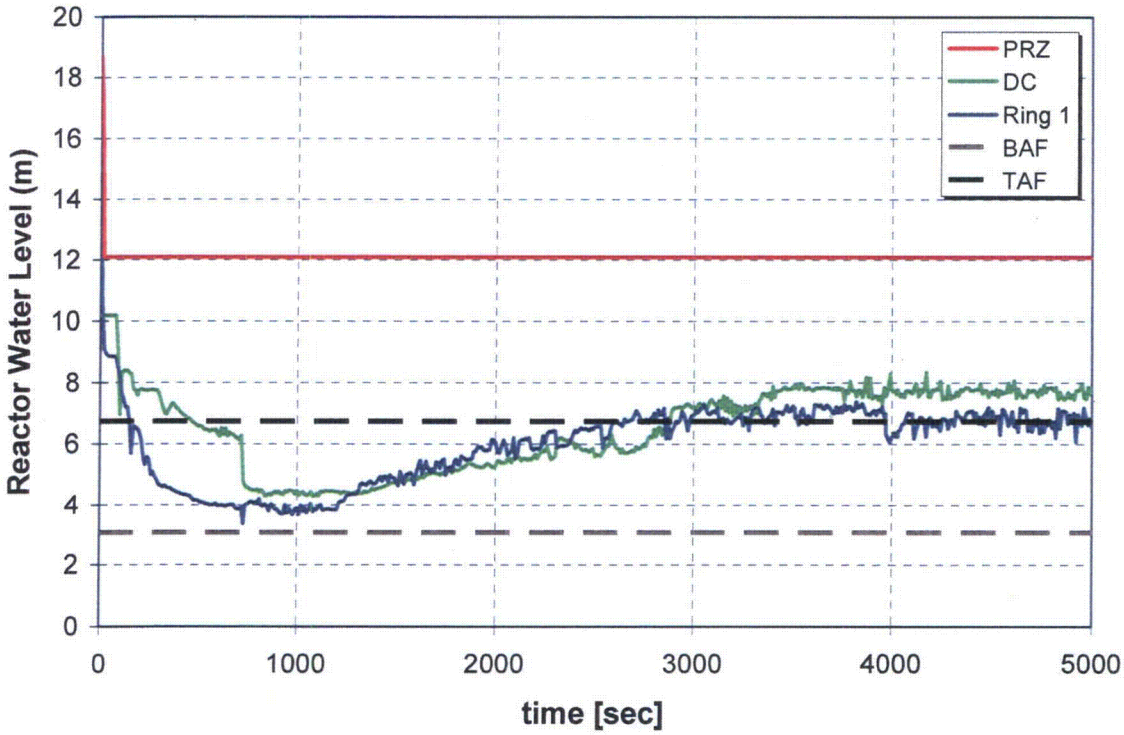


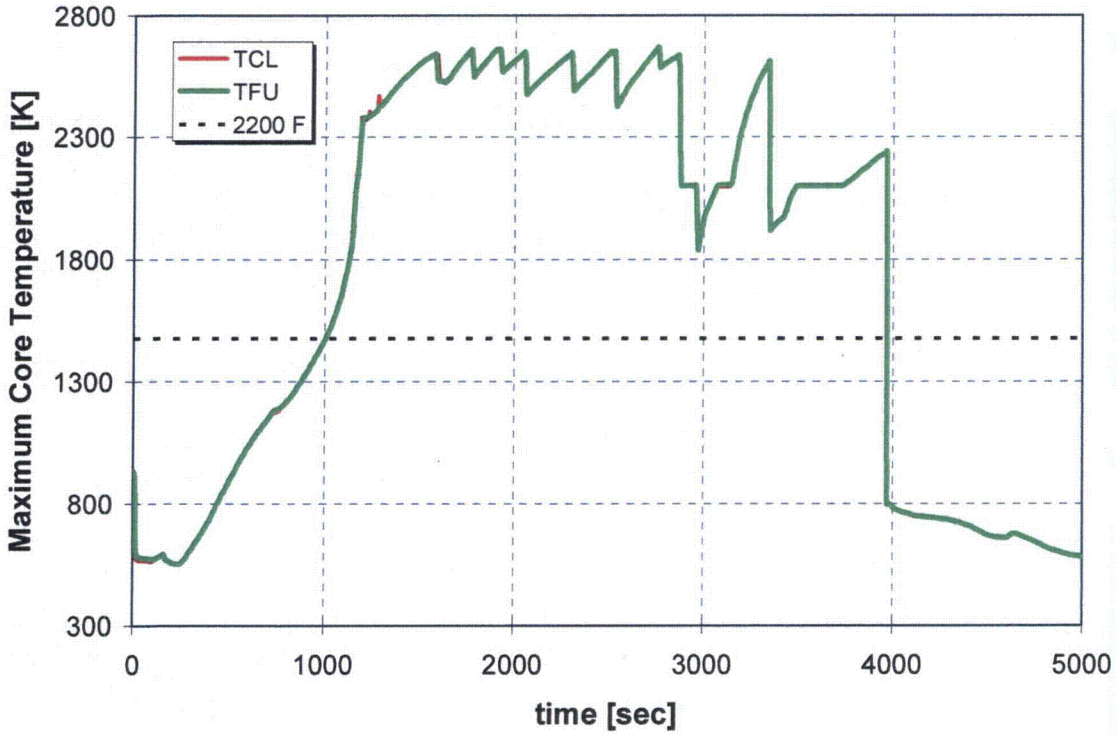



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
1000
900
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
time [sec]

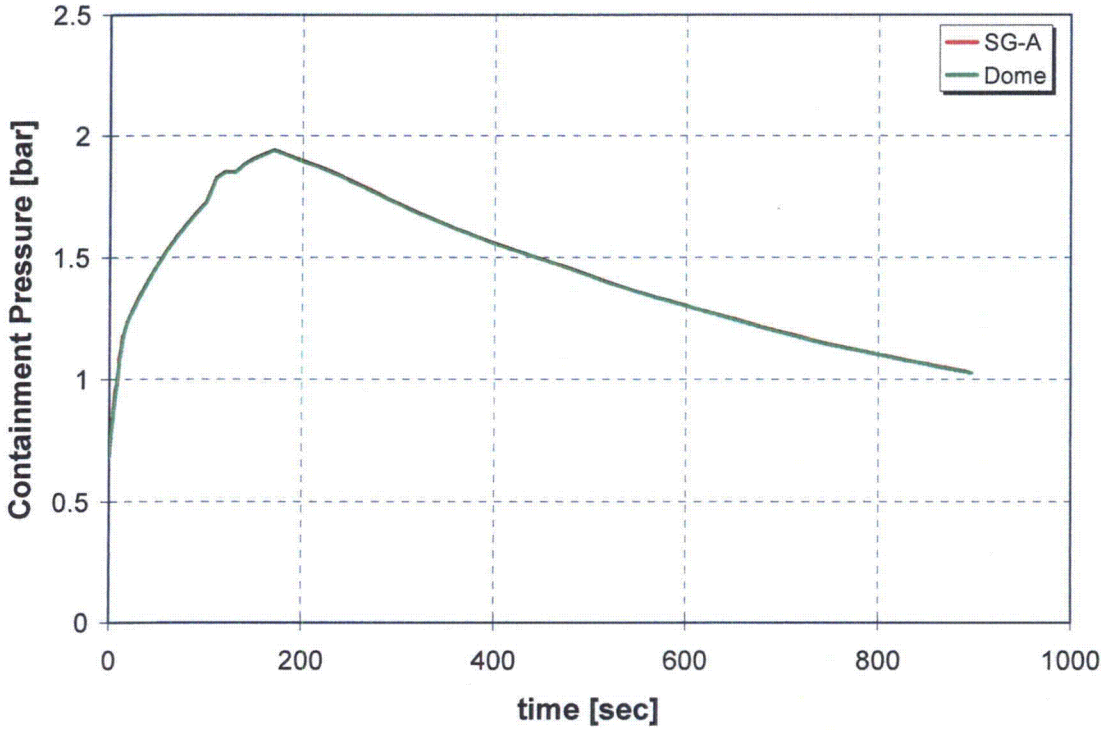

RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
1000
2000
3000
4000
5000
time [sec]

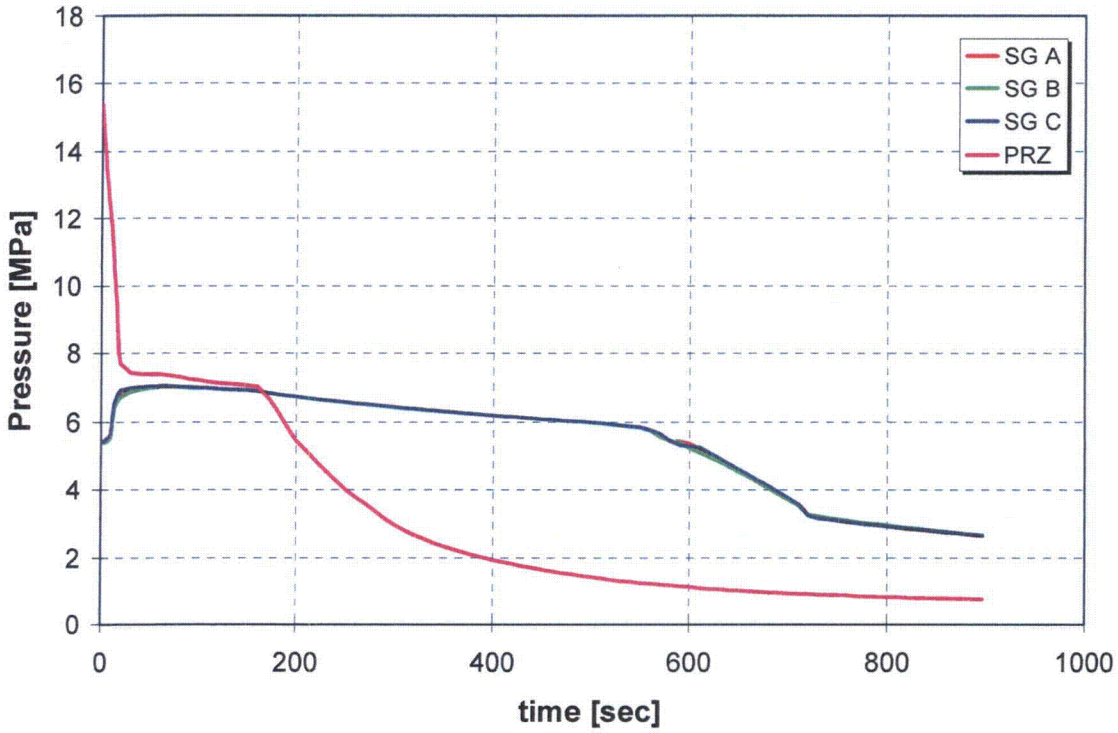

Sump
Cavity
Containment Water Level [m]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
5000
time [sec]

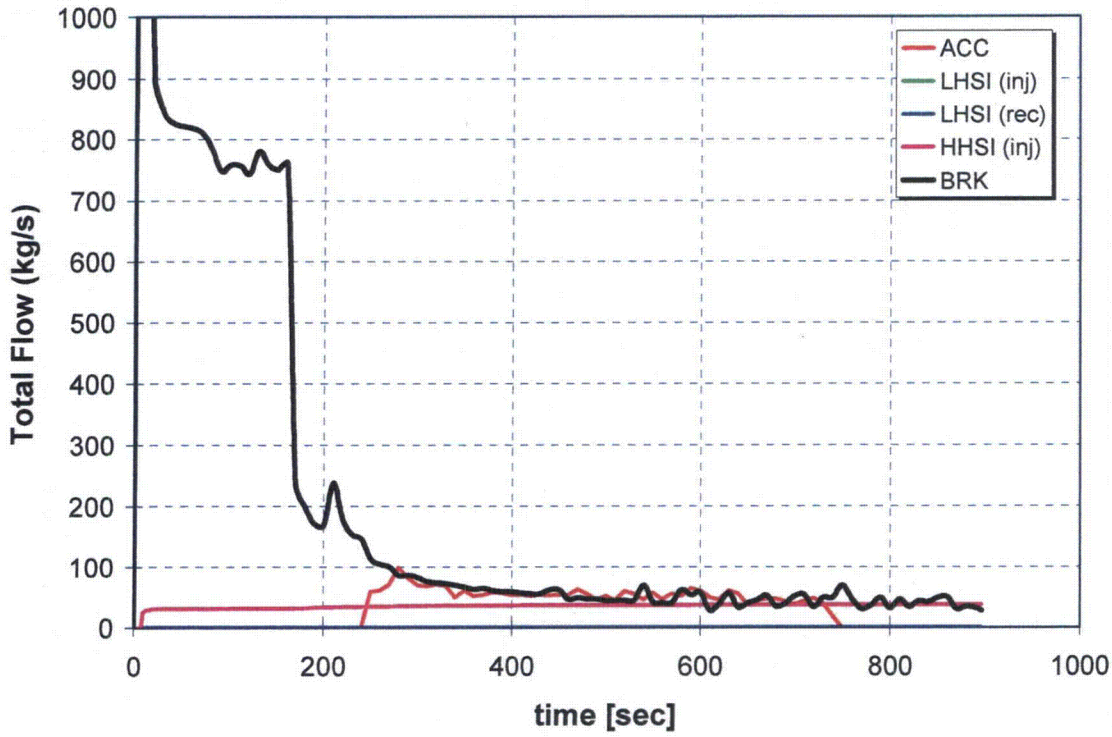

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
20
18
16
14
12
10
8
6
4
2
0
0
1000
2000
3000
4000
5000
time [sec]

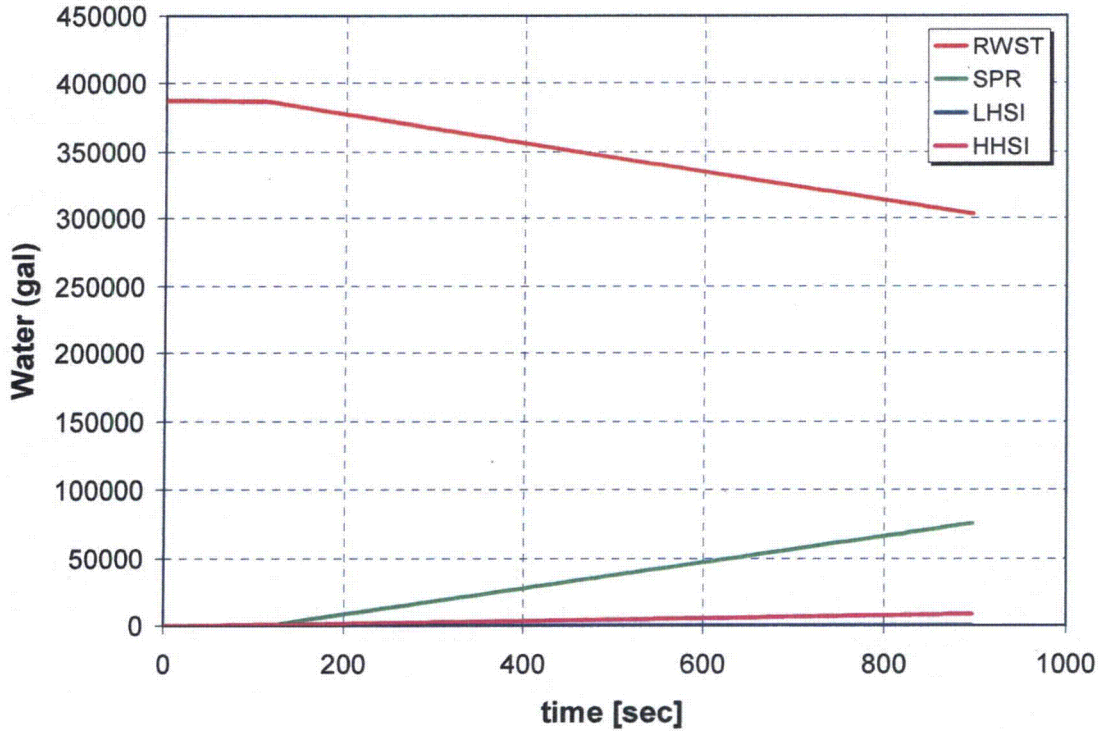

2800
2300
1800
1300
800
300
Maximum Core Temperature [K]
TCL
TFU
2200 F
0
1000
2000
3000
4000
5000
time [sec]

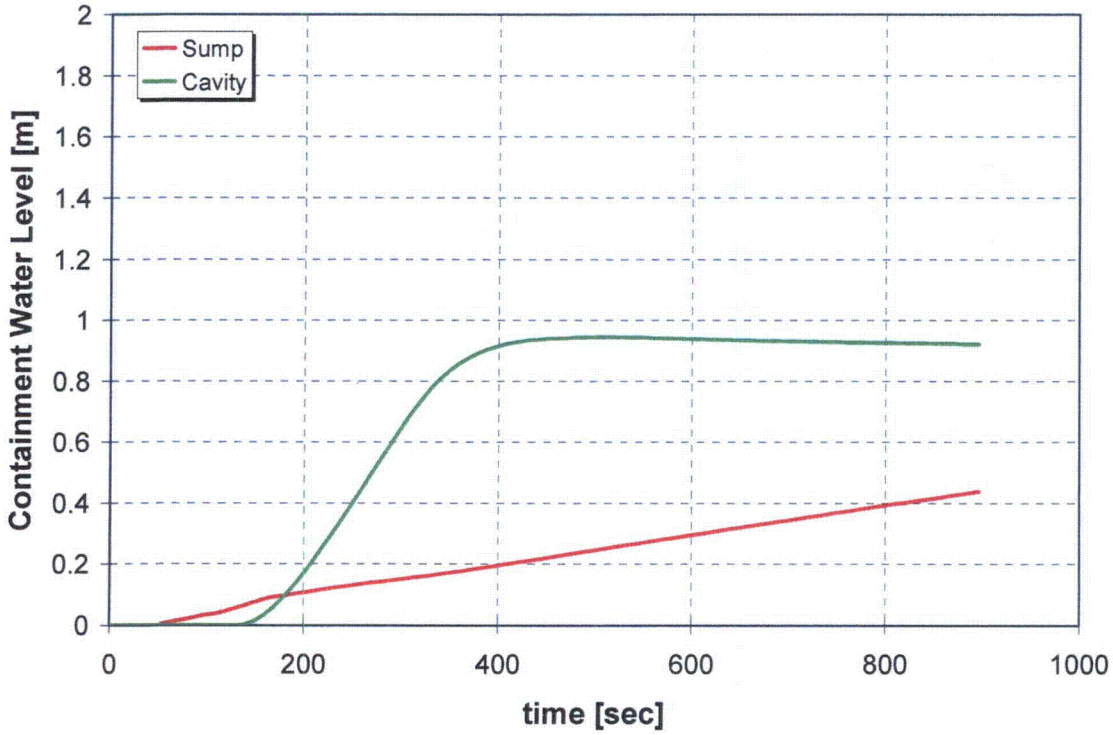
A.6.8 Case 8: 6-Inch Break LOCA, One HHSI, No LHSI, and One ACC

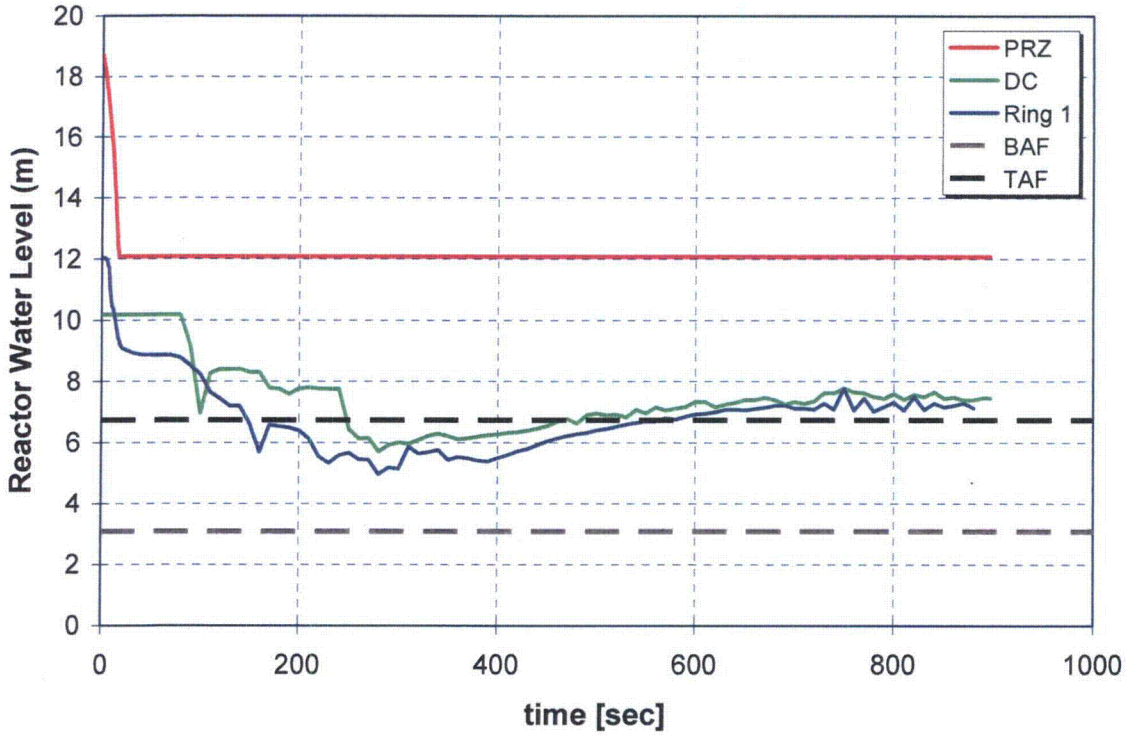


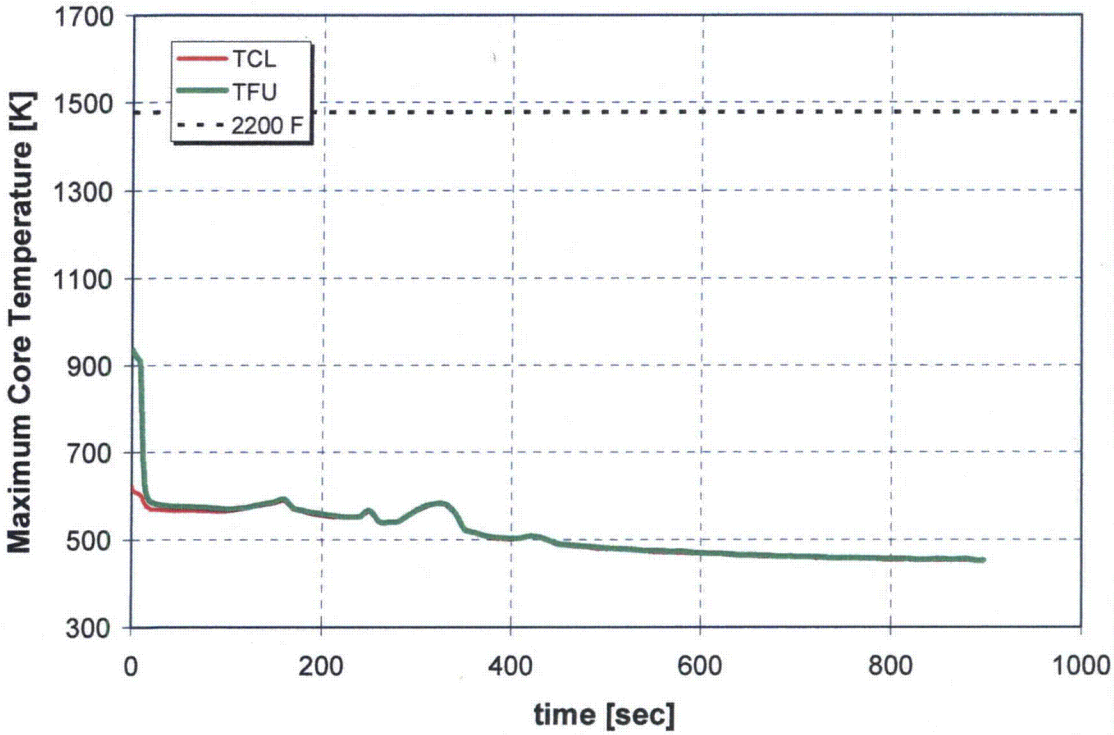



Total Flow (kg/s)
time [sec]
ACC
LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
0
100
200
300
400
500
600
700
800
900
1000
0
200
400
600
800
1000

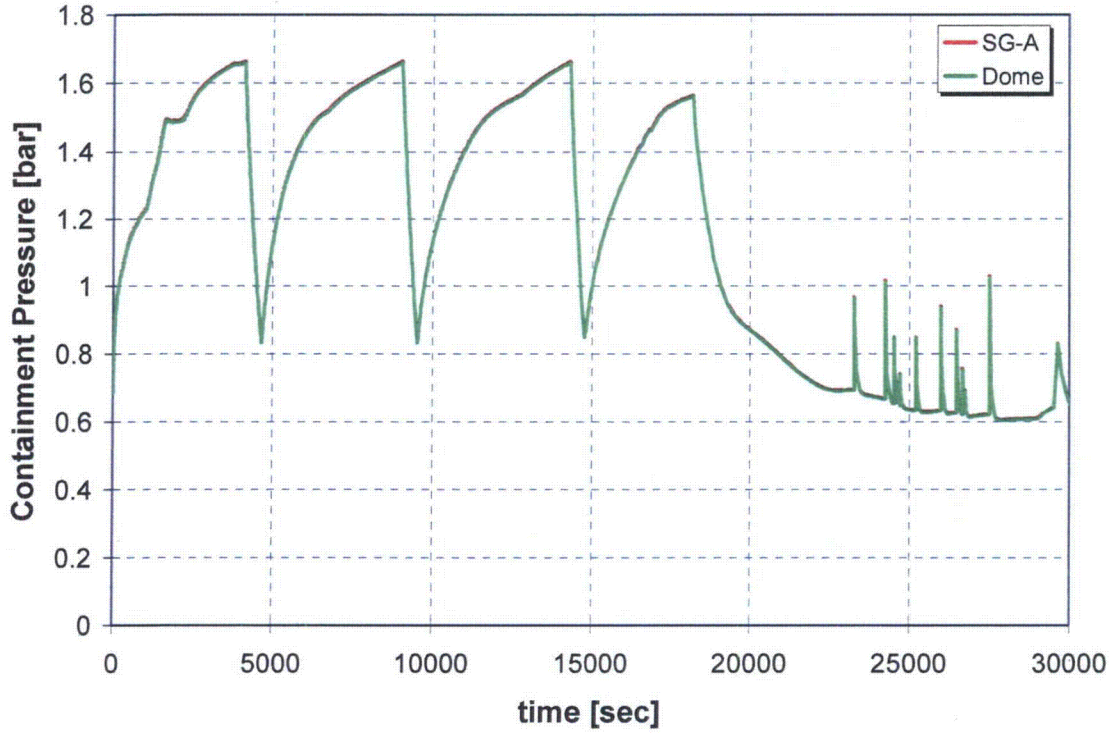

Water (gal)
time [sec]
RWST
SPR
LHSI
HHSI
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0
200
400
600
800
1000

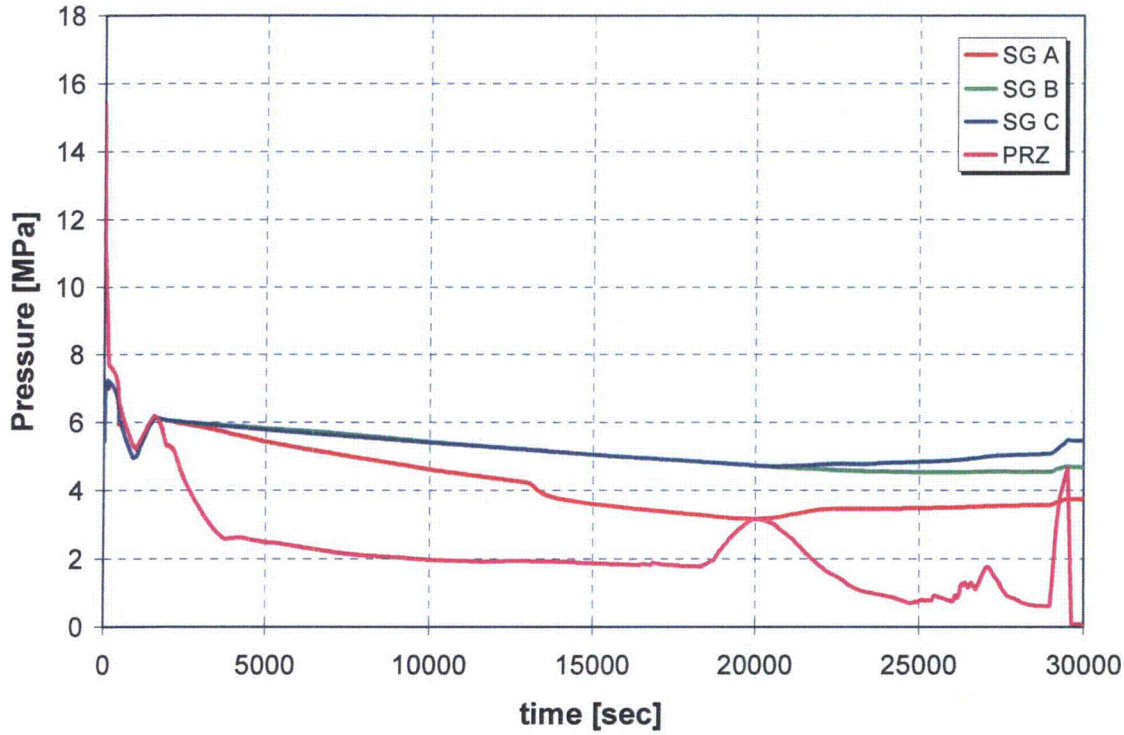

Sump
Cavity
Containment Water Level [m]
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
time [sec]

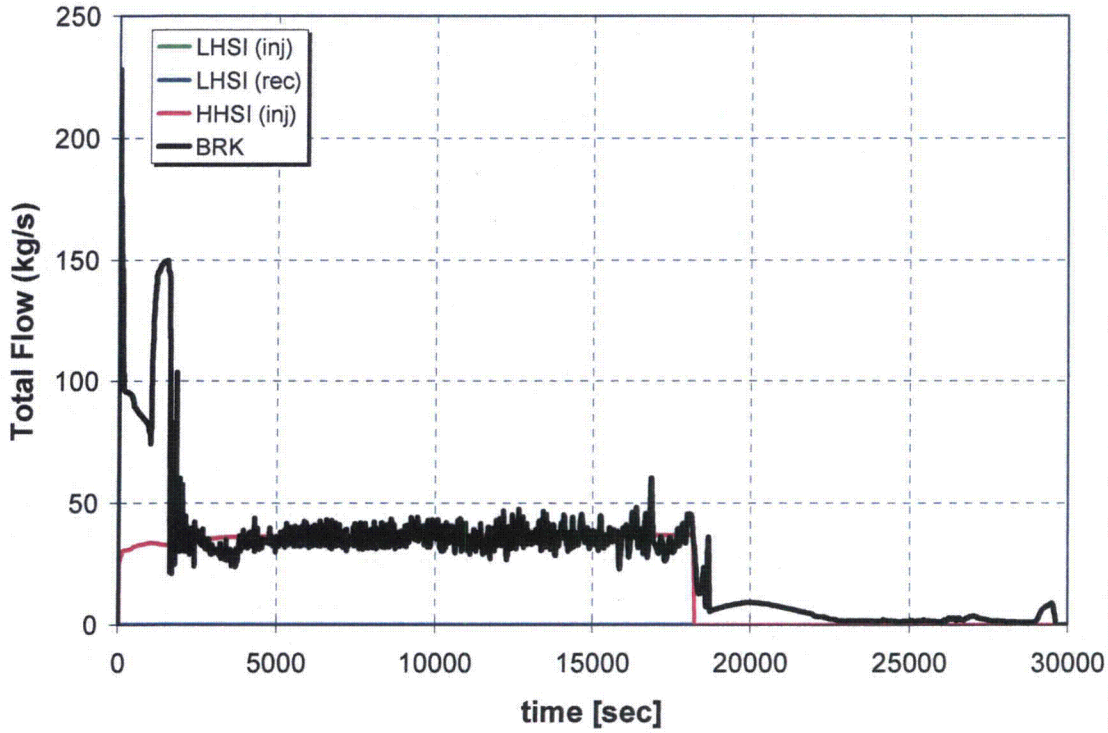

PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
20
18
16
14
12
10
8
6
4
2
0
0
200
400
600
800
1000
time [sec]

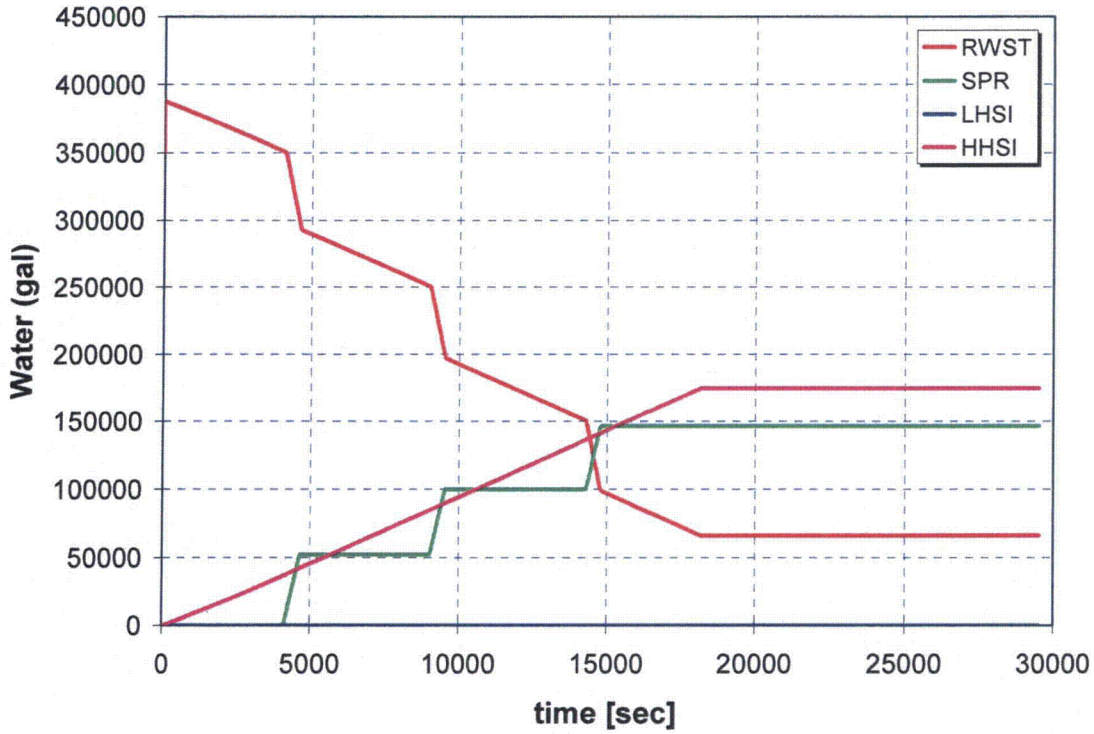

1700
1500
1300
1100
900
700
500
300
Maximum Core Temperature [K]
TCL
TFU
2200 F
0
200
400
600
800
1000
time [sec]

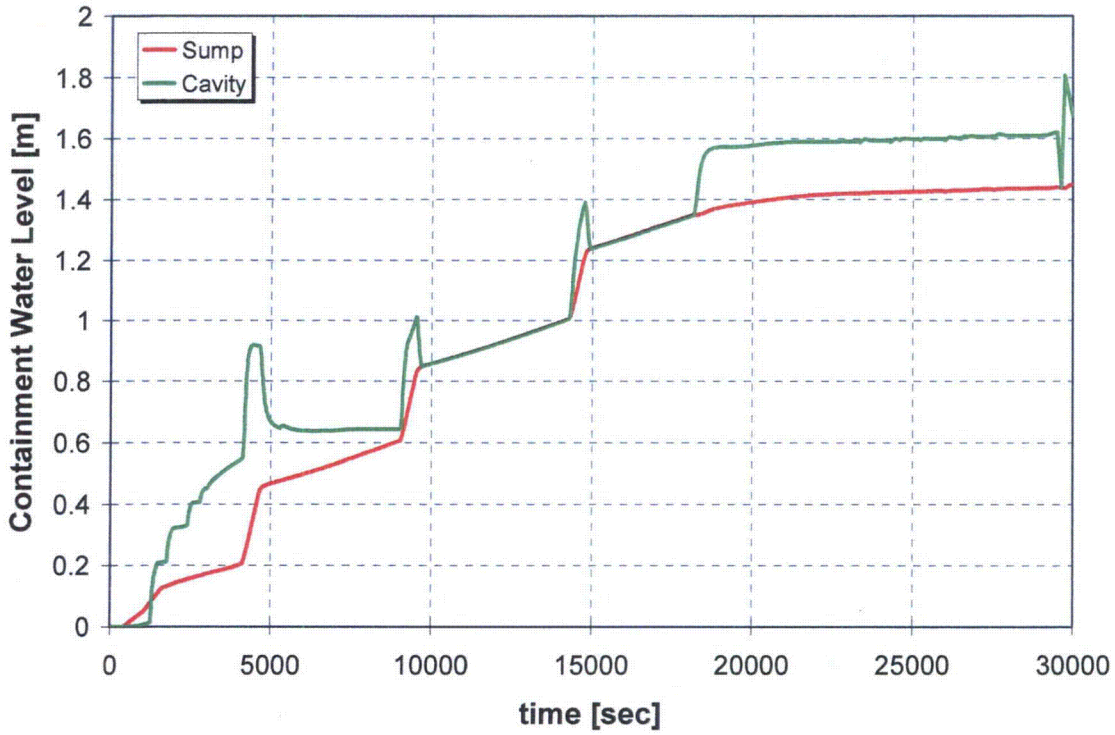
A.6.9 Case 9: 2-Inch Break LOCA, One HHSI, No LHSI, and No ACC

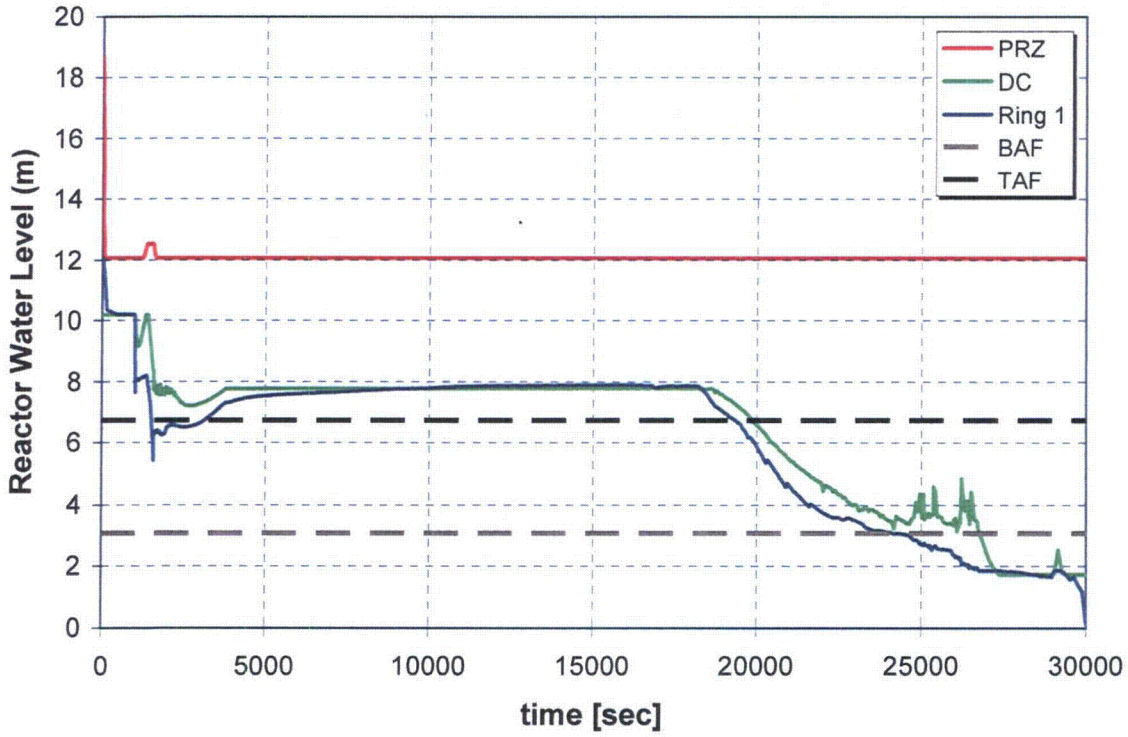


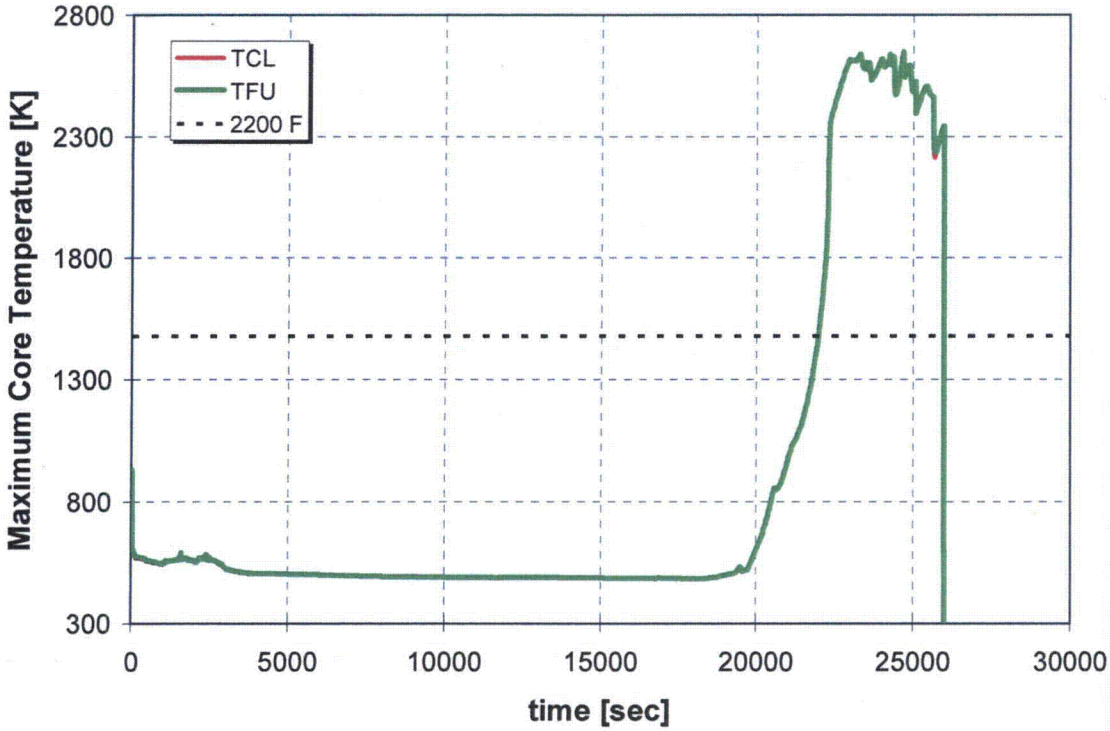



LHSI (inj)
LHSI (rec)
HHSI (inj)
BRK
Total Flow (kg/s)
250
200
150
100
50
0
0
5000
10000
15000
20000
25000
30000
time [sec]


RWST
SPR
LHSI
HHSI
Water (gal)
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
5000
10000
15000
20000
25000
30000
time [sec]


Sump
Cavity
Containment Water Level [m]
time [sec]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
5000
10000
15000
20000
25000
30000


PRZ
DC
Ring 1
BAF
TAF
Reactor Water Level (m)
time [sec]
0
2
4
6
8
10
12
14
16
18
20
0
5000
10000
15000
20000
25000
30000


2800
2300
1800
1300
800
300
Maximum Core Temperature [K]
TCL
TFU
2200 F
0
5000
10000
15000
20000
25000
30000
time [sec]