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United States Nuclear Regulatory Commission
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NUREG-2187
Volume 2

Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Byron Unit 1

Appendices D to G

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Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Byron Unit 1

Appendices D to G

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Prepared by:
J. Corson,[1] D. Helton,[1] M. Tobin,[1] A. Bone[1]
M. Khatib-Rahbar,[2] A. Krall[2]
L. Kozak[3]
R. Buell[4]

[1]Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

[2]Energy Research Inc.
P.O. Box 2034
Rockville, MD 20847-2034

[3]Region III
U.S. Nuclear Regulatory Commission
2443 Warrenville Road, Suite 210
Lisle, IL 60532-4352

[4]Idaho National Laboratory
P.O. Box 1625
Idaho Falls, ID 83415

ABSTRACT

This report extends the work documented in NUREG-1953, “Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models–Surry and Peach Bottom” to the Byron Station, Unit 1. Its purpose is to produce an additional set of best-estimate thermal-hydraulic calculations that can be used to confirm or enhance specific success criteria (SC) for system performance and operator timing found in the agency’s probabilistic risk assessment (PRA) tools. Along with enhancing the technical basis for the Agency’s independent standardized plant analysis risk (SPAR) models, these calculations are expected to be a useful reference to model end-users for specific regulatory applications (e.g., the Significance Determination Process). The U.S. Nuclear Regulatory Commission selected Unit 1 of the Byron Station for this study because it is generally representative of a group of four-loop Westinghouse plants with large, dry containment designs.

This report first describes major assumptions used in this study, including the basis for using a core damage (CD) surrogate of 2,200 degrees Fahrenheit (1,204 degrees Celsius) peak cladding temperature (PCT). The justification for this PCT is documented in NUREG/CR-7177, “Compendium Of Analyses To Investigate Select Level 1 Probabilistic Risk Assessment End-State Definition And Success Criteria Modeling Issues.” The major plant characteristics for Byron Unit 1 are then described, in addition to the MELCOR model used to represent the plant. Finally, the report presents the results of MELCOR calculations for selected initiators and compares these results to SPAR SC, the licensee’s PRA sequence timing and SC, or other generic studies.

The study results provide additional timing information for several PRA sequences, confirm many of the existing SPAR model modeling assumptions, and provide a technical basis for a few specific SPAR modeling changes. Potential SPAR model changes supported by this study include:

- Small-Break Loss-of-Coolant Accident (SLOCA) Sequence Timing for Alignment of Sump Recirculation—For sequences where operator cooldown is credited as an alternative to high-pressure recirculation (HPR), the SPAR success criteria related to containment cooling could be enhanced by requiring one containment fan cooler to prevent containment spray actuation. Avoiding spray actuation extends the time available prior to refueling water storage tank depletion and allows the operators to successfully depressurize the plant using the post-LOCA procedures for cases when HPR is not available.

- SLOCA Success Criteria for Steam Generator (SG) Depressurization and Condensate Feed—Action to depressurize the SGs early and align condensate feed is a candidate for inclusion in the SPAR model. This would provide an additional success path for a loss of auxiliary feedwater event. If this is done, hotwell refill or alignment of alternate feedwater later in the scenario would also need to be modeled. Early depressurization to achieve condensate feed was not found to require primary-side depressurization actions (e.g., opening a power-operated relief valve (PORV)).

- SLOCA Success Criteria for Primary Side Bleed and Feed (B&F)—These calculations have demonstrated a potential conservatism that can be removed from the applicable SPAR models. It is proposed that the SC for SLOCA B&F be changed from (one safety

injection (SI) or centrifugal charging pump (CCP) and two PORVs) to (one SI pump and two PORVs) or (one CCP and one PORV). In other words, for SLOCAs the requirement for availability of a second PORV can be removed when a CCP is available.

- Loss of DC Bus-111 – Unavailable Diesel-Driven Auxiliary Feedwater, and Subsequent Primary Side B&F—These calculations are generally representative of non–loss-of-coolant accident (non-LOCA) B&F situations and have demonstrated a potential improvement that can be implemented in the Byron SPAR model. It is proposed that the SC for non-LOCA B&F be changed from (one SI or CCP and two PORVs) to (one CCP and one PORV). In other words, the same one CCP and one PORV enhancement as above is credited, but credit is eliminated for cases with no CCP available. This initiator was chosen because it was qualitatively felt to be more restrictive than those scenarios categorized as general transients in the PRA, and thus the conclusions are believed to be applicable to those initiators as well. Note that the applicability of the loss of DC bus SC may vary, (e.g., due to the unique reactor coolant pump trip situation that this initiator creates) and should be evaluated on a case-by-case basis before implementation for other plant models.

- SGTR – Spontaneous Steam Generator Tube Rupture with No Operator Action—For sequences with successful high-pressure injection (HPI) and auxiliary feedwater, but with steam generator isolation having failed, an additional success path or additional recovery credit may be justifiable pending additional consideration of closely-related accident sequence and human reliability modeling assumptions.

- Medium-Break Loss-of-Coolant Accident (MLOCA) – Injection SC— For breaks in the lower half of the MLOCA range, it was found that an early operator-induced depressurization based on the Functional Restoration Procedure (FRP) for inadequate core cooling would be needed to avoid core damage if HPI fails. The time available to implement these actions following the FRP entry criterion being met could be short. The accident sequence modeling and human reliability analysis associated with secondary-side cooldown for these situations (MLOCA with HPI failed) should be reviewed.

FOREWORD

The U.S. Nuclear Regulatory Commission's (NRC's) standardized plant analysis risk (SPAR) models are used to support a number of risk-informed initiatives. The fidelity and realism of these models is ensured through a number of processes, including cross-comparison with industry models, review and use by a wide range of technical experts, and confirmatory analysis. The following report—prepared by staff in the Office of Nuclear Regulatory Research in consultation with staff from the Office of Nuclear Reactor Regulation, experts from Energy Research Incorporated and Idaho National Laboratory, and the agency's senior reactor analysts—represents a major confirmatory analysis activity.

Probabilistic risk assessment (PRA) models for nuclear power plants rely on underlying modeling assumptions known as success criteria (SC) and sequence timing assumptions. These criteria and assumptions determine what combination of system and component availabilities will lead to postulated core damage (CD), as well as the timeframes during which components must operate or operators must take particular actions. This report investigates certain thermal-hydraulic aspects of a particular SPAR model (which is generally representative of other models within the same class of plant design), with the goal of further strengthening the technical basis for decisionmaking that relies on the SPAR models. This report augments the existing collection of contemporary Level 1 PRA SC analyses, and as such, supports (1) maintaining and enhancing the SPAR models that the NRC develops, (2) supporting the NRC's risk analysts when addressing specific issues in the accident sequence precursor program and the significance determination process, and (3) informing other ongoing and planned initiatives. This analysis employs the MELCOR computer code and uses a plant model developed for this project.

The analyses summarized in this report provide the basis for confirming or changing SC in the SPAR model for the Byron Station Unit 1. Further evaluation of these results will be performed to extend the results to similar plants. In addition, future work is planned to perform similar analysis for other design classes, and past work has already considered other design classes (see NUREG-1953, "Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models – Surry and Peach Bottom"). In addition, work has been recently completed to scope other aspects of this topical area, including the degree of variation typical in common PRA sequences and the quantification of conservatisms associated with CD surrogates (see NUREG/CR-7177, "Compendium of Analyses to Investigate Select Level 1 Probabilistic Risk Assessment End-State Definition and Success Criteria Modeling Issues"). Where applicable, insights from that work are referenced in this report. The confirmation of SC and other aspects of PRA modeling using the agency's state-of-the-art tools (e.g., the MELCOR computer code) is expected to receive continued focus as the agency continues to develop and improve its risk tools.

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Main Report

ABBREVIATIONS AND ACRONYMS

°C	degree(s) Celsius
°C/hr	degree(s) Celsius per hour
°F	degree(s) Fahrenheit
°F/hr	degree(s) Fahrenheit per hour
ΔT	temperature difference
ACC	accumulator
ADAMS	Agencywide Documents Access and Management System
AFW	auxiliary feedwater
ANS	American Nuclear Society
ASME	American Society of Mechanical Engineers
ASP	accident sequence precursor
B&F	bleed and feed
BAF	bottom of active fuel
BEP	Byron Emergency Procedure
BWR	boiling-water reactor
CCP	centrifugal charging pump
CCW	component cooling water
CD	core damage
CDF	core damage frequency
CET	core exit temperature
CFR	*Code of Federal Regulations*
cm	centimeter(s)
CNMT	containment
COR	MELCOR core package
CS	containment spray
CST	condensate storage tank
CVH	control volume hydrodynamics (MELCOR package)
CVTR	Carolinas Virginia Tube Reactor
DC	direct current
DD-AFW	diesel-driven auxiliary feedwater
ECA	emergency contingency action
ECCS	emergency core cooling system
EOP	emergency operating procedure
EPRI	Electric Power Research Institute
ESF	Engineered Safety Features
FCL	fan cooler
FRP	functaionl restoration procedure
FSAR	Final Safety Analysis Report
ft	foot/feet
ft^3	cubic foot/feet
FW	feedwater
gal	gallon(s)
gpm	gallon(s) per minute
HEM	homogeneous equilibrium model
HEP	human error probability
HFM	homogeneous frozen model
HPI	high-pressure [ECCS] injection

HPR	high-pressure [ECCS] recirculation
hr	hour(s)
HS	heat structure
in.	inch(es)
iPWR	integral pressurized-water reactor
K	Kelvin
kg	kilogram(s)
kg/s	kilogram(s) per second
kPa	kilopascal(s)
lb/s	pound(s) per second
LBLOCA	large-break loss-of-coolant accident
lbm/hr	pound(s) mass per hour
LOCA	loss-of-coolant accident
LoDCB-111	loss of DC bus 111
LOFT	loss-of-fluid test
LPI	low pressure [ECCS] injection
LPR	low pressure [ECCS] recirculation
LTOP	low temperature overpressure protection
m	meter(s)
m^3	cubic meter(s)
m^3/min	cubic meter(s) per minute
m^3/s	cubic meter(s) per second
MAAP4	Modular Accident Analysis Program version 4
MD-AFW	motor-driven auxiliary feedwater
MELCOR	Not an acronym
MFW	main feedwater
min	minute(s)
MLOCA	medium-break loss-of-coolant accident
MPa	megapascal(s)
MPa abs	megapascal(s) absolute
MSIV	main steam isolation valve
MUR	measurement uncertainty recapture
MW	megawatt(s)
MWt	megawatt(s) thermal
NPSH	net positive suction head
NR	narrow range [water level]
NRC	U.S. Nuclear Regulatory Commission
PCT	peak cladding temperature
PORV	power- (or pilot-) operated relief valve
PRA	probabilistic risk assessment
PRT	pressurizer relief tank
PSA	Probabilistic Safety Assessment
psi	pound(s) per square inch
psia	pound(s) per square inch absolute
psid	pound(s) per square inch differential
psig	pound(s) per square inch gage
PWR	pressurized-water reactor
PZR	pressurizer
RCFC	reactor containment fan cooler
RCP	reactor coolant pump
RCS	reactor coolant system

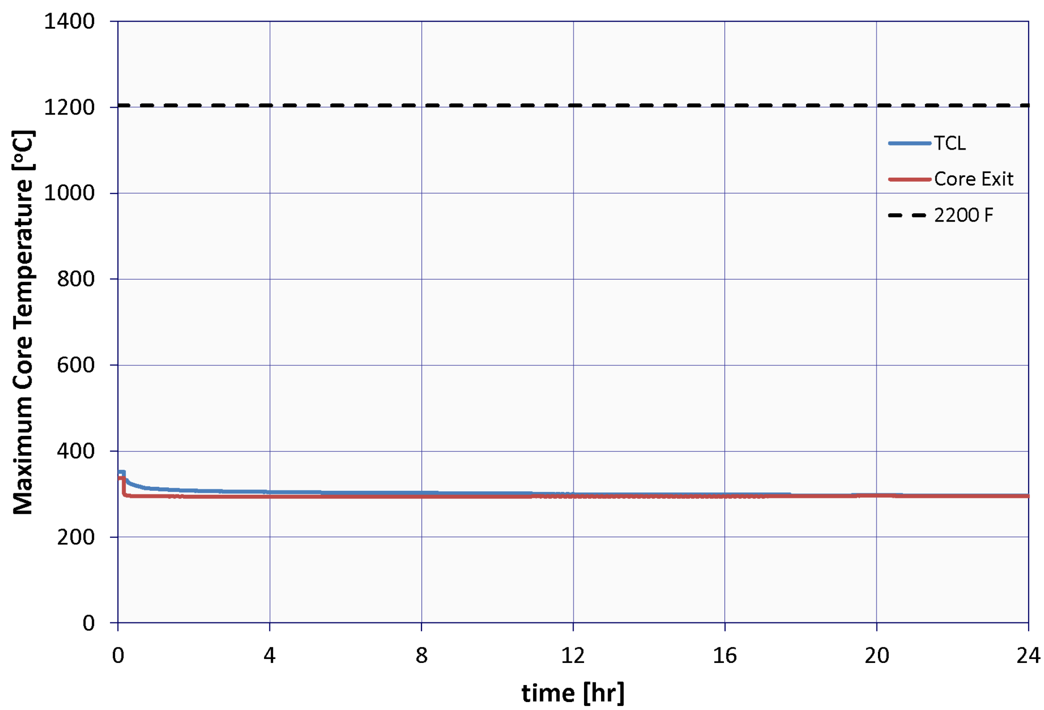
recirc	recirculation
RHR	residual heat removal
RHR HX	residual heat removal heat exchanger
RPS	reactor protection system
RPV	reactor pressure vessel
RWST	refueling water storage tank
s	second(s)
SC	success criterion/criteria
SDP	significance determination process
scfm	standard cubic foot/feet per minute
SG	steam generator
SG-x	steam generator in loop x
SGTR	steam generator tube rupture
SI	safety injection
SLOCA	small-break loss-of-coolant accident
SOARCA	State-of-the-Art Reactor Consequence Analyses
SPAR	standardized plant analysis risk
SRV	safety relief valve
TAF	top of active fuel
T_{avg}	loop average temperature
TBV	turbine bypass valve
TCL	cladding temperature
TRACE	TRAC/RELAP5 Advanced Computational Engine
VCT	volume control tank
WR	wide range [water level]

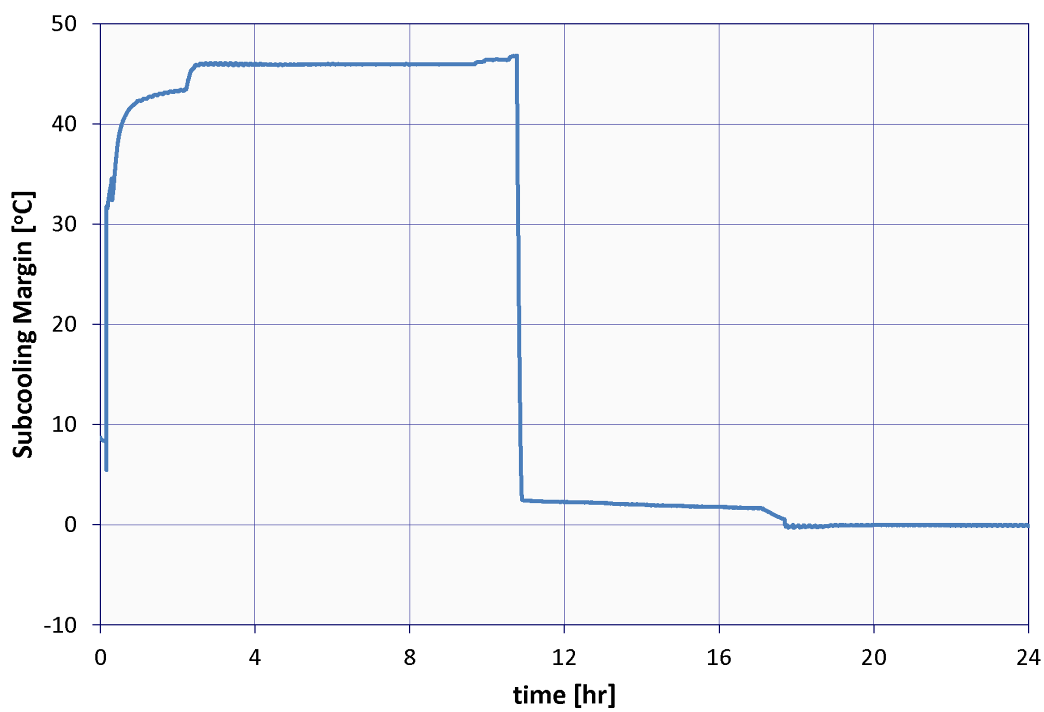
APPENDIX D

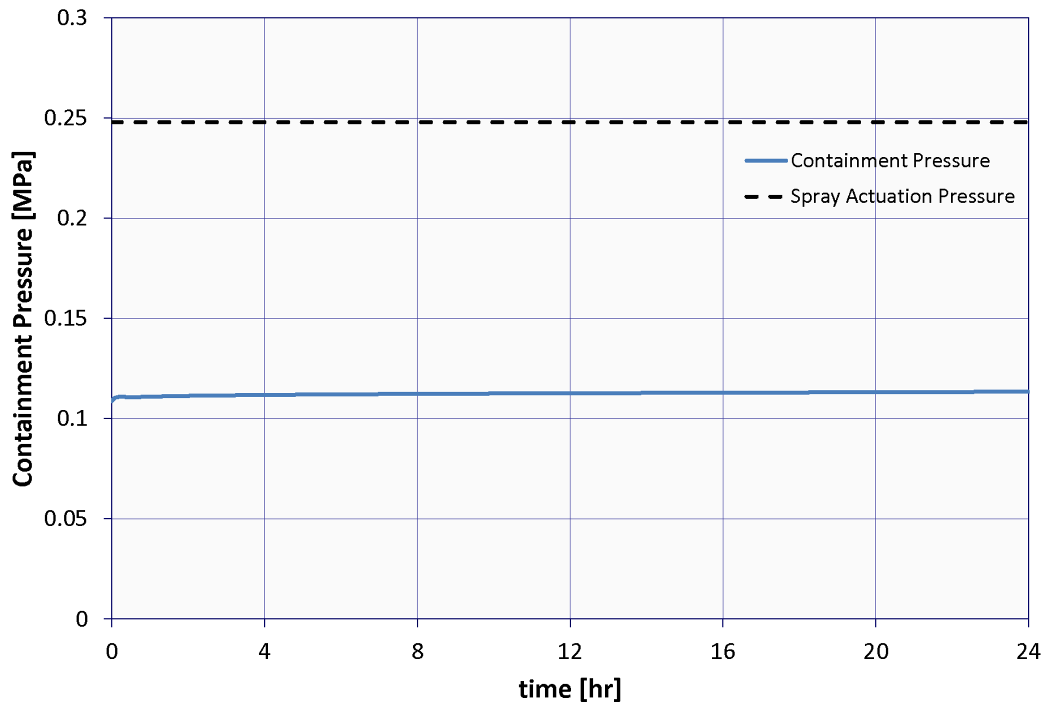
DETAILED STEAM GENERATOR TUBE RUPTURE ANALYSIS RESULTS

D.1 Spontaneous SG Tube Rupture with No Operator Action

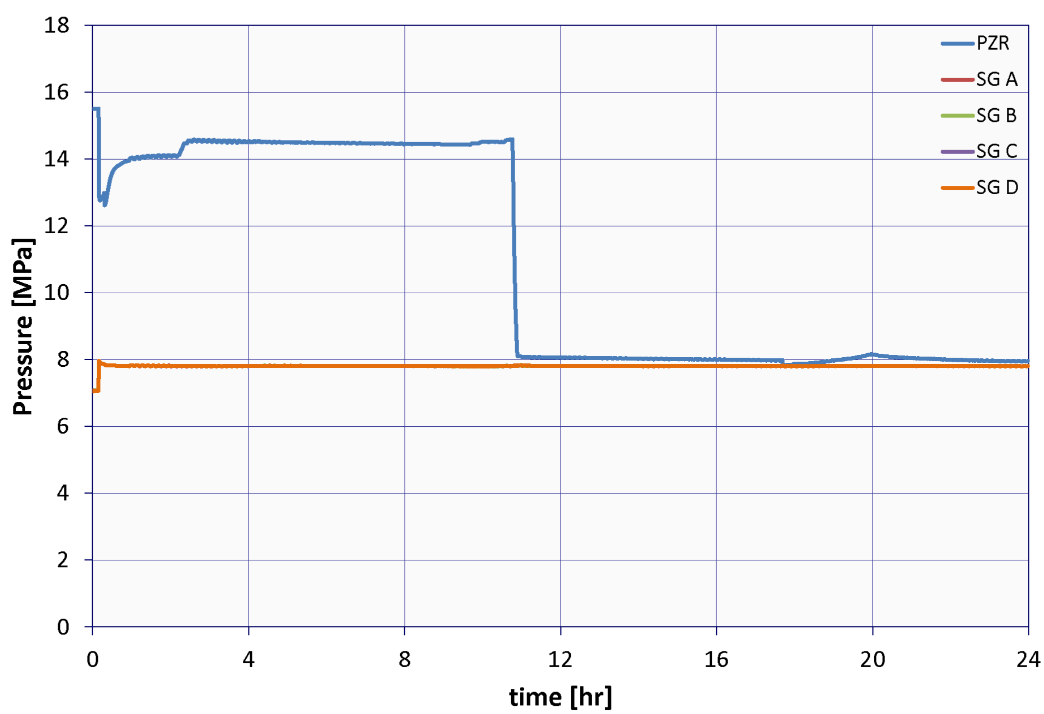
D.1.1 Case 1: 0.5 Tube, Min ECCS, No Steam Dumps



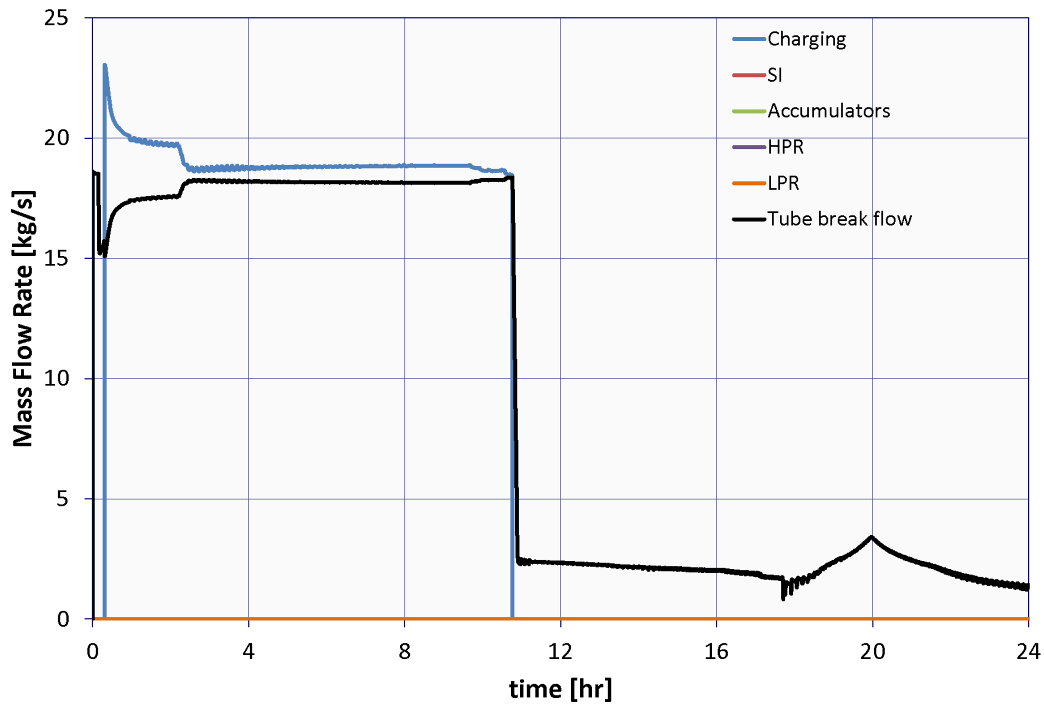




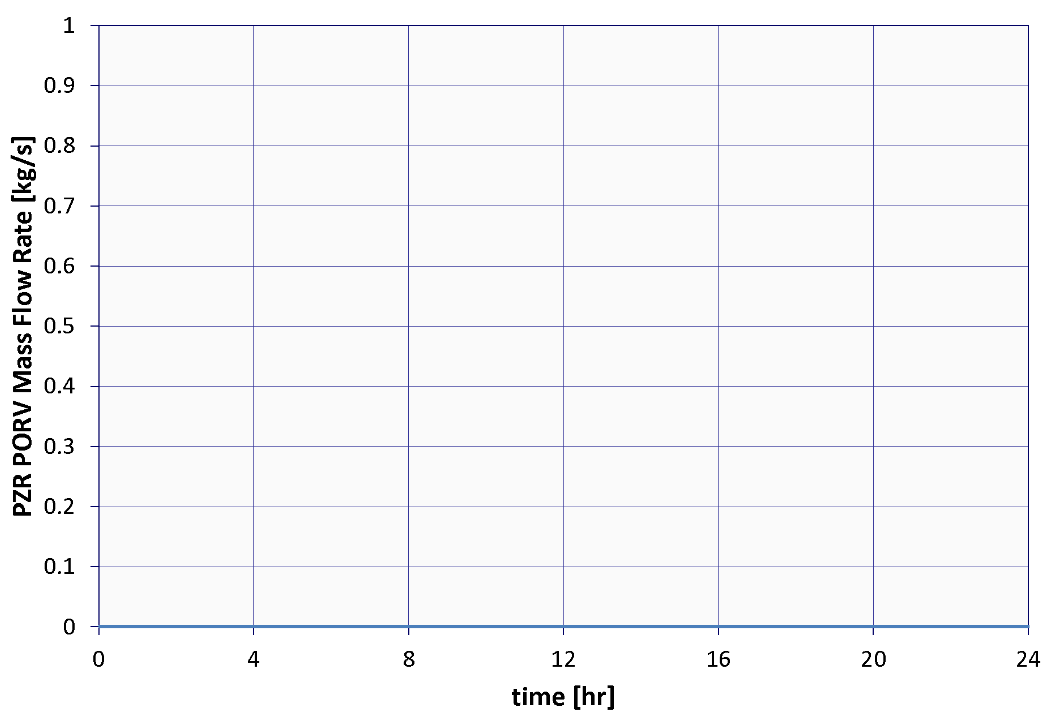
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure



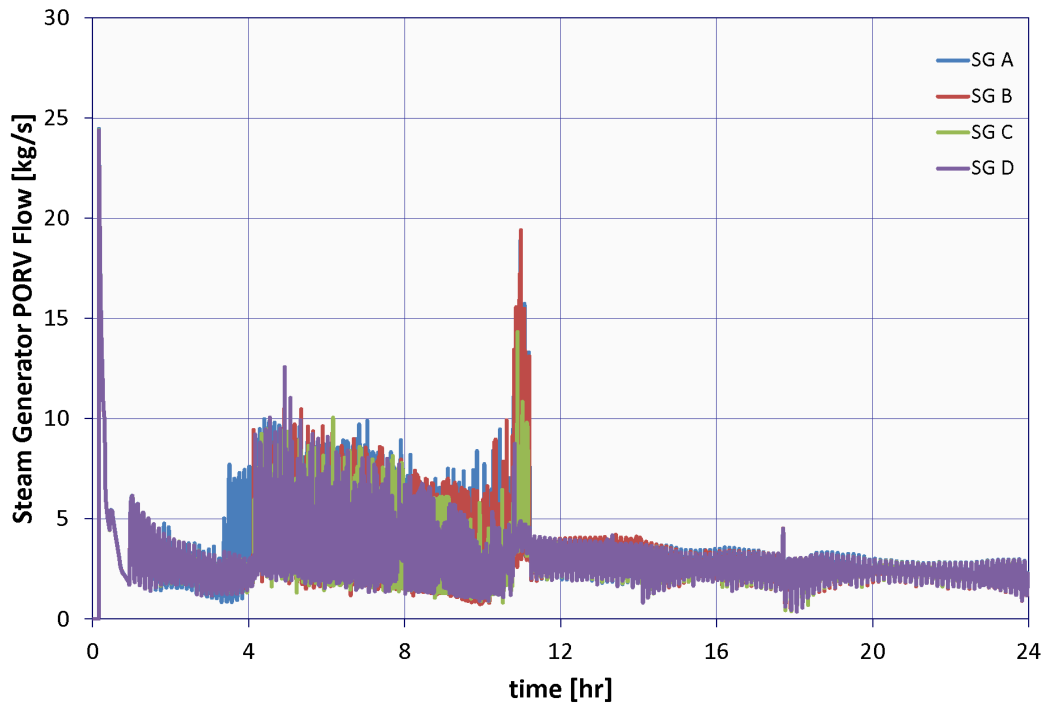
18
16
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



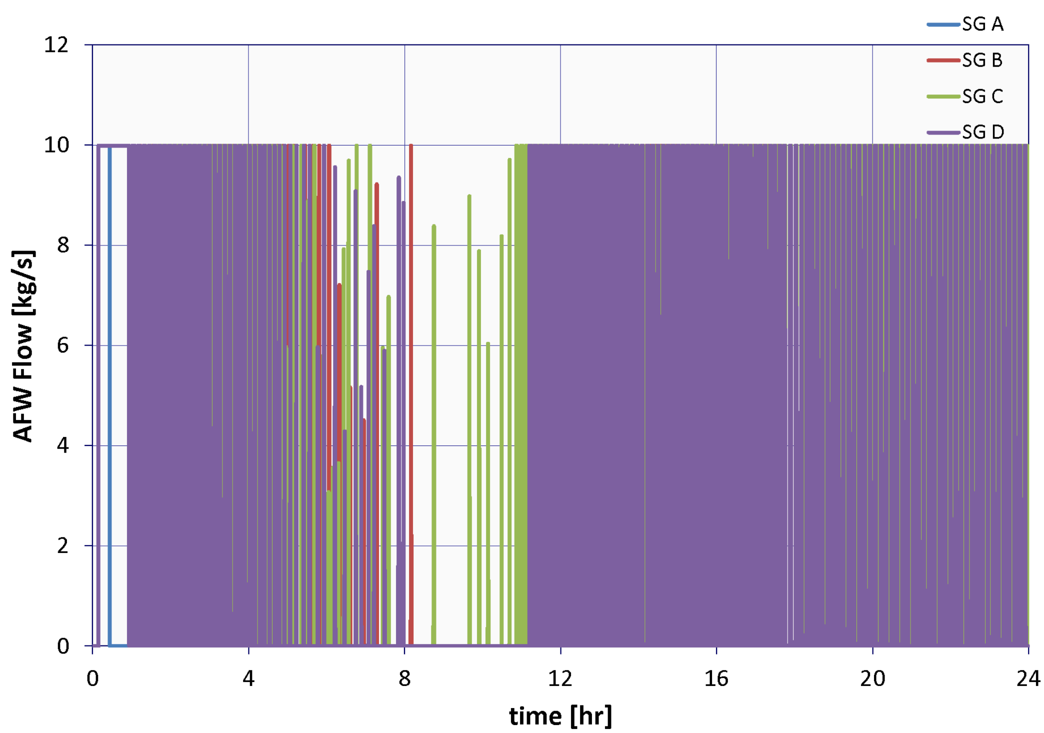
Charging
SI
Accumulators
HPR
LPR
Tube break flow
Mass Flow Rate [kg/s]
time [hr]



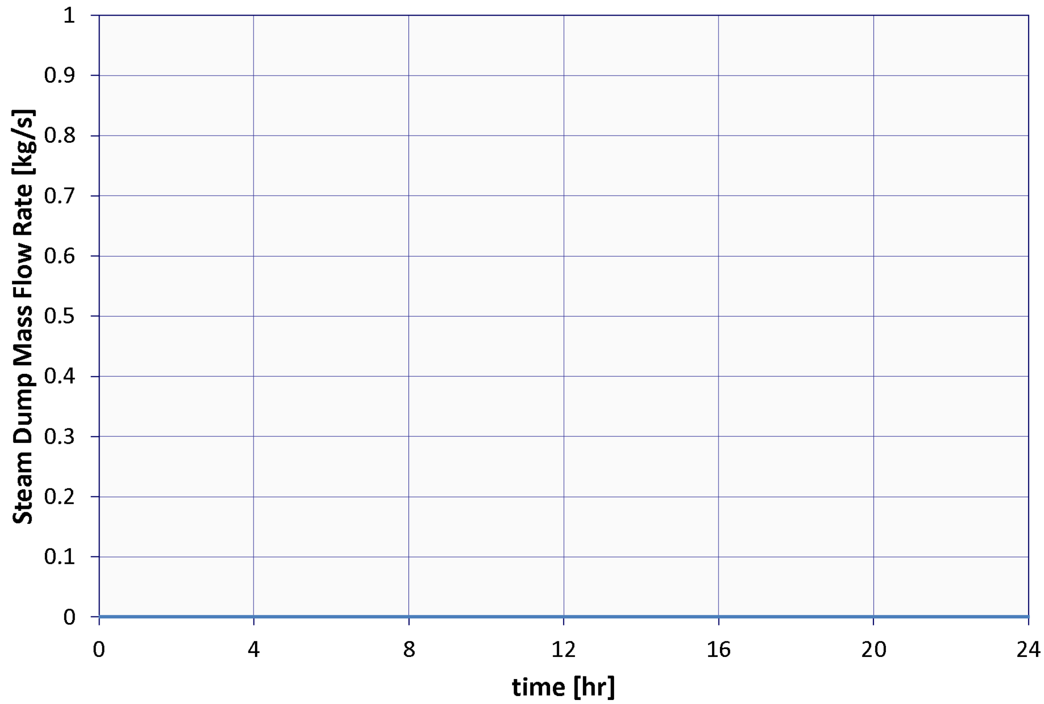
PZR PORV Mass Flow Rate [kg/s]
time [hr]

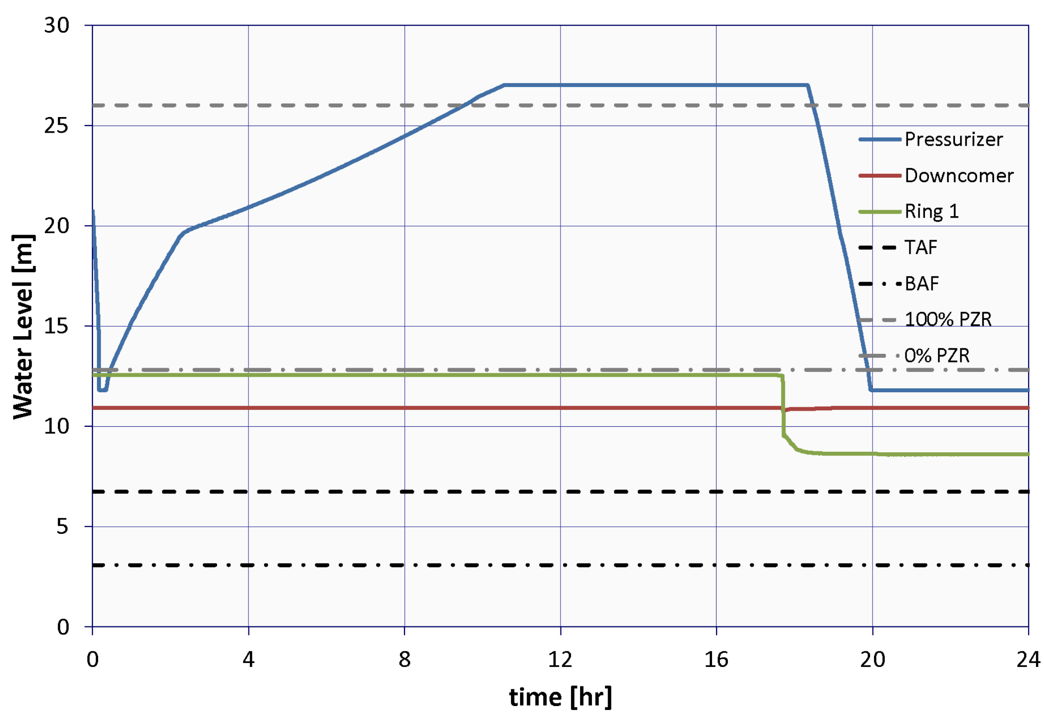


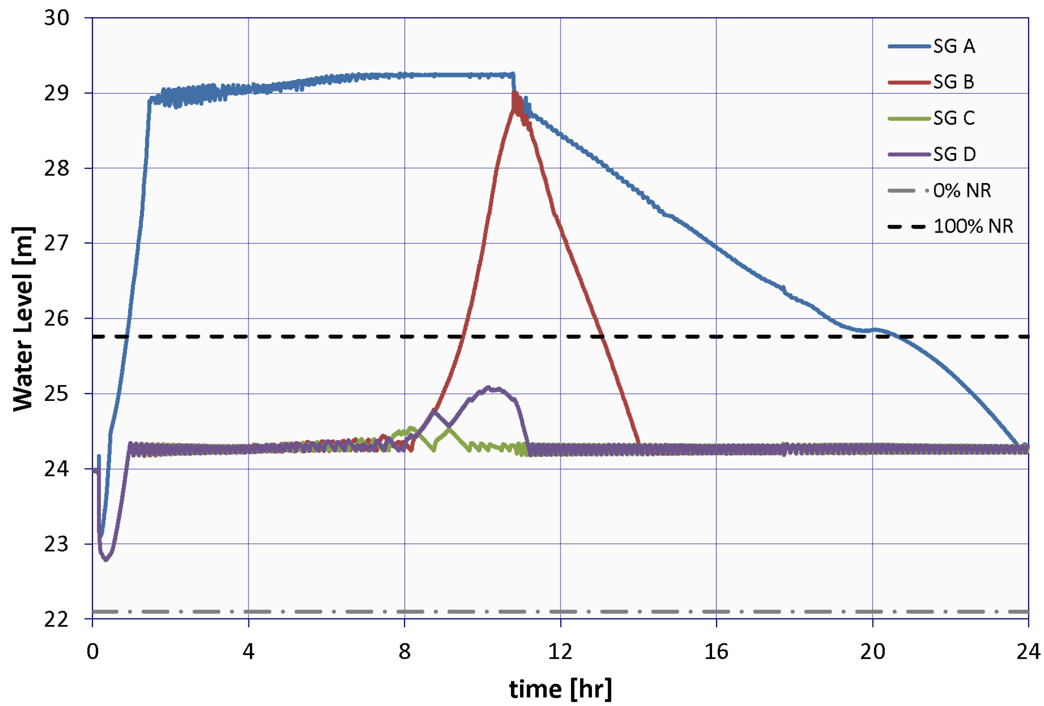
Steam Generator PORV Flow [kg/s]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



AFW Flow [kg/s]
12
10
8
6
4
2
0
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D


Steam Dump Mass Flow Rate [kg/s]
time [hr]


Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR



Water Level [m]
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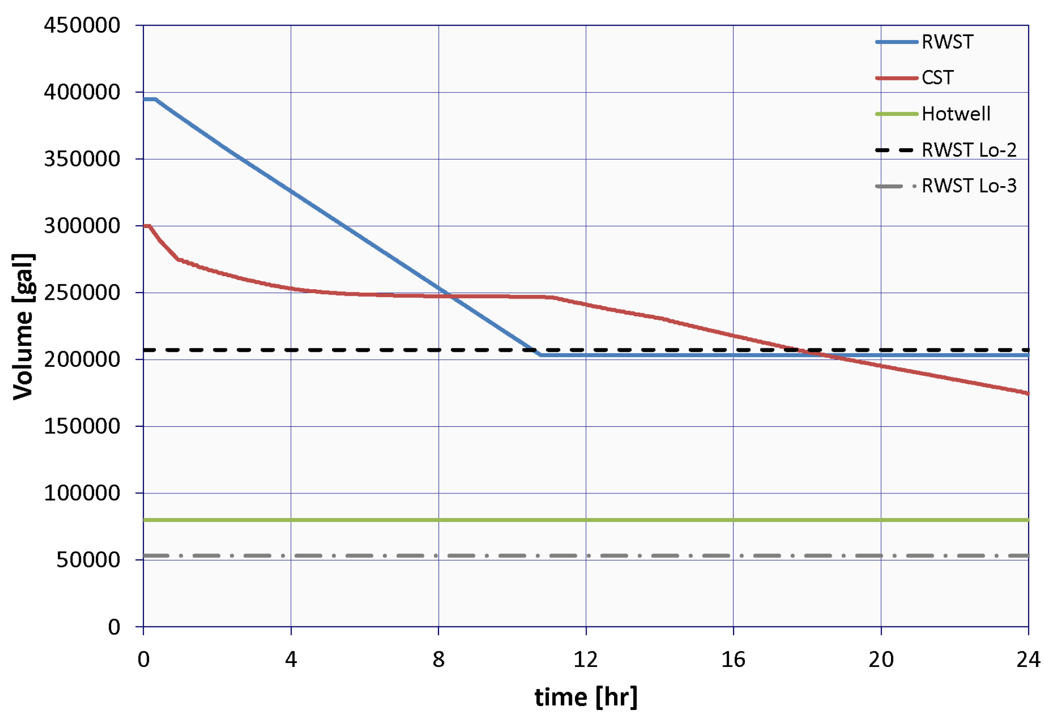
29
28
27
26
25
24
23
22
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR



Volume [gal]
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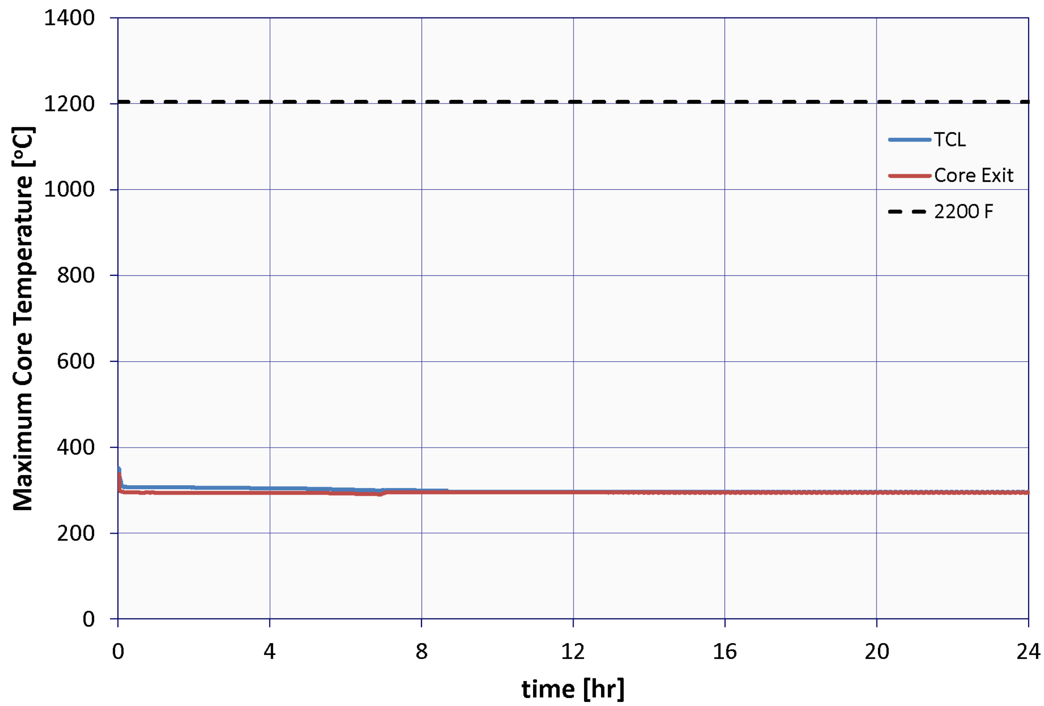
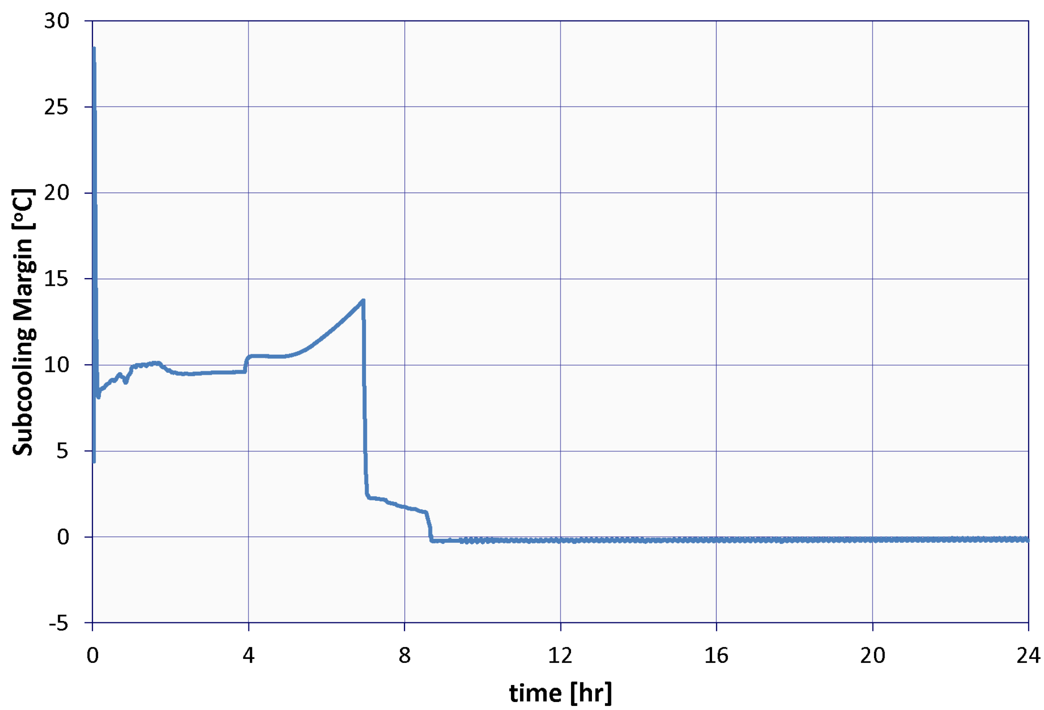
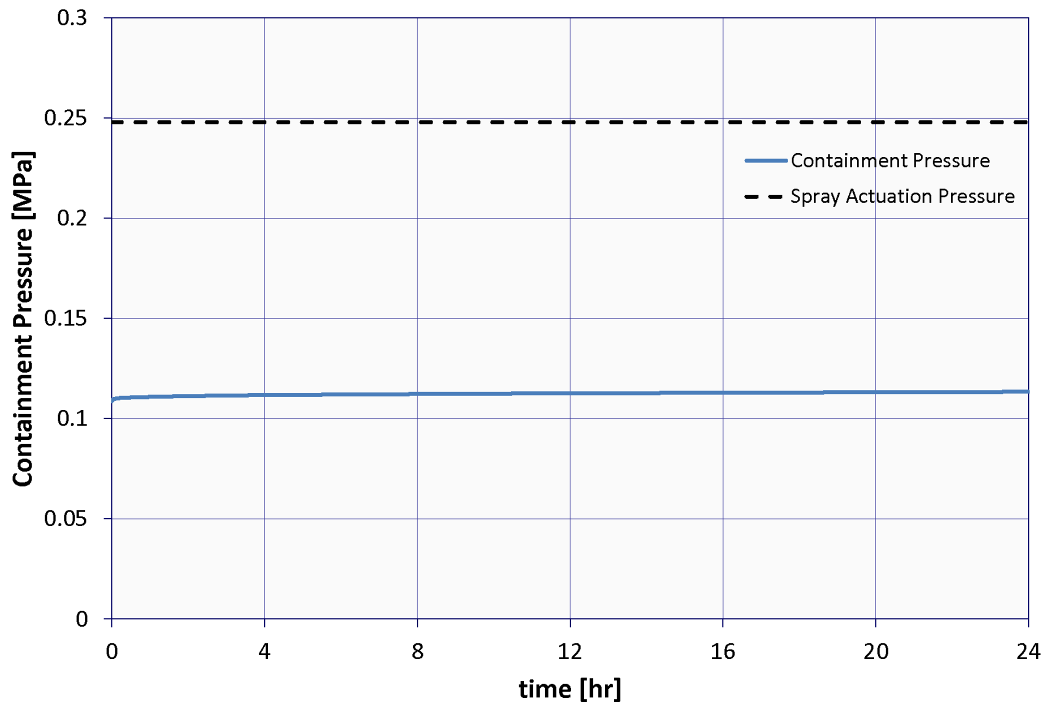
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

D.1.2 Case 2: 2 Tubes, Max ECCS, No Steam Dumps







0.3
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0.2
0.15
0.1
0.05
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Containment Pressure [MPa]
Containment Pressure
Spray Actuation Pressure
0
4
8
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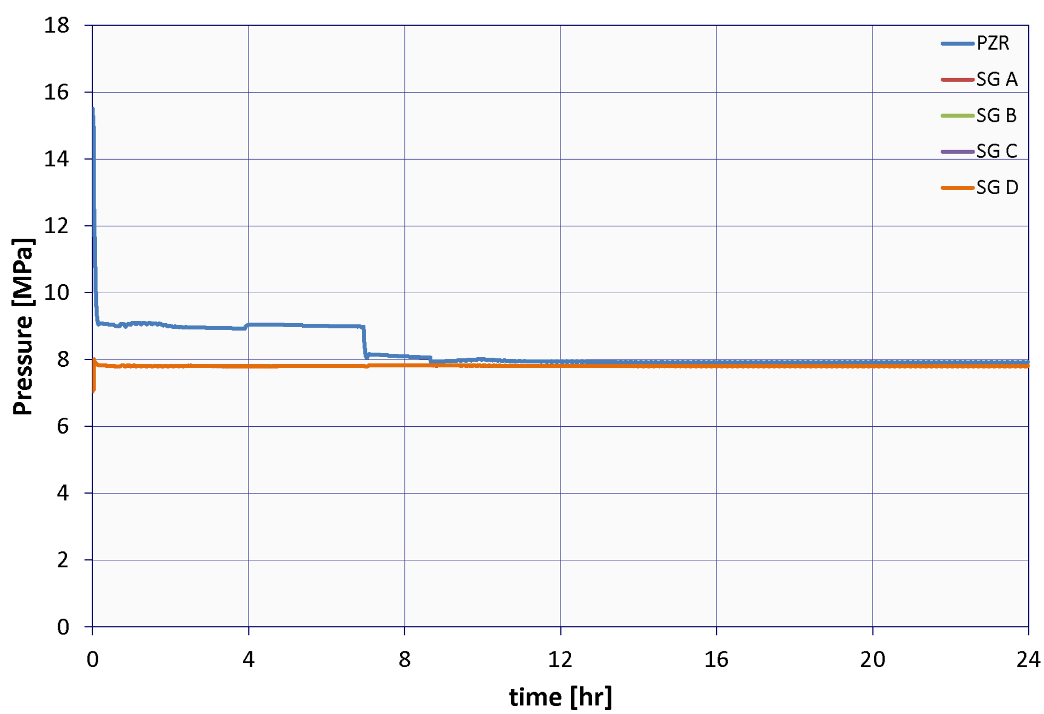
16
20
24
time [hr]



18
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14
12
10
8
6
4
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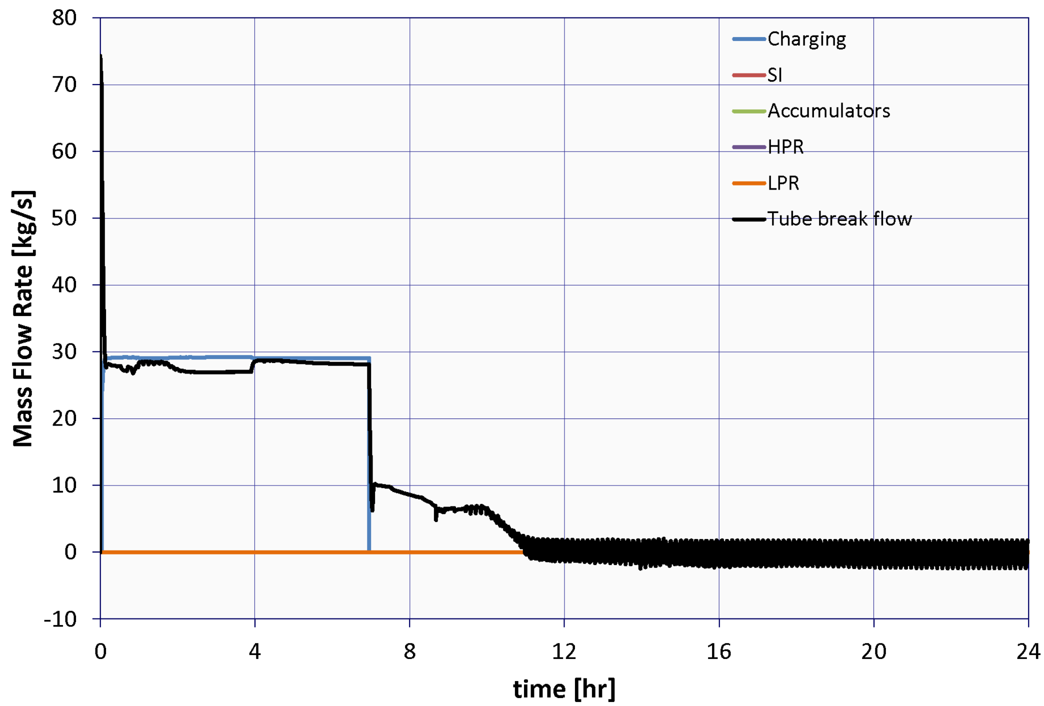
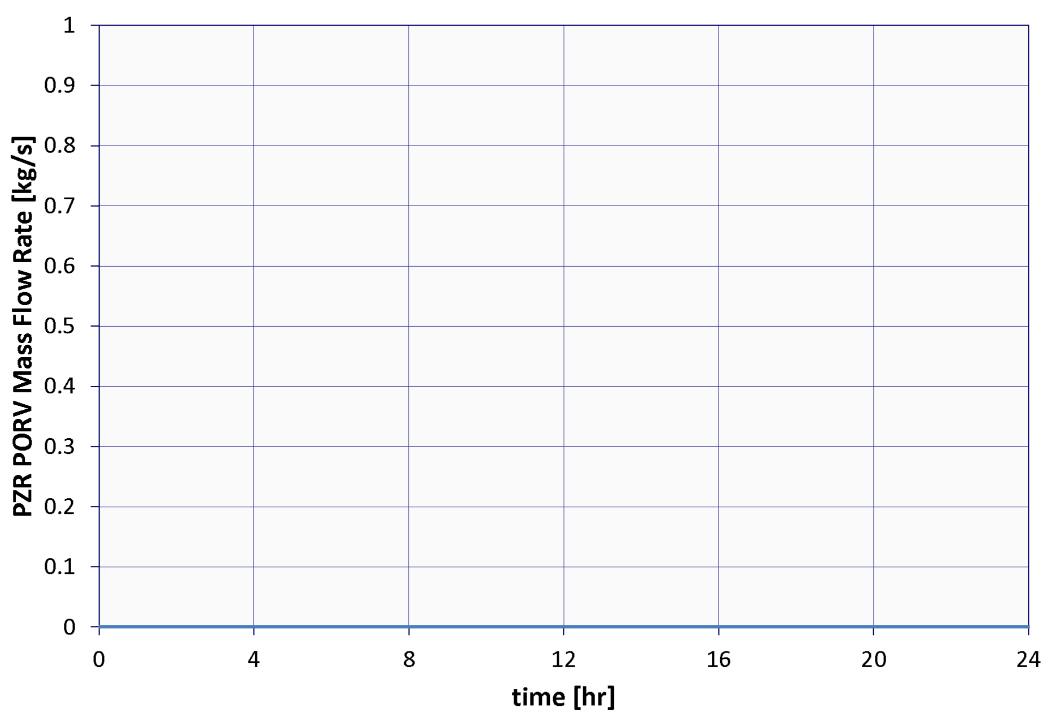
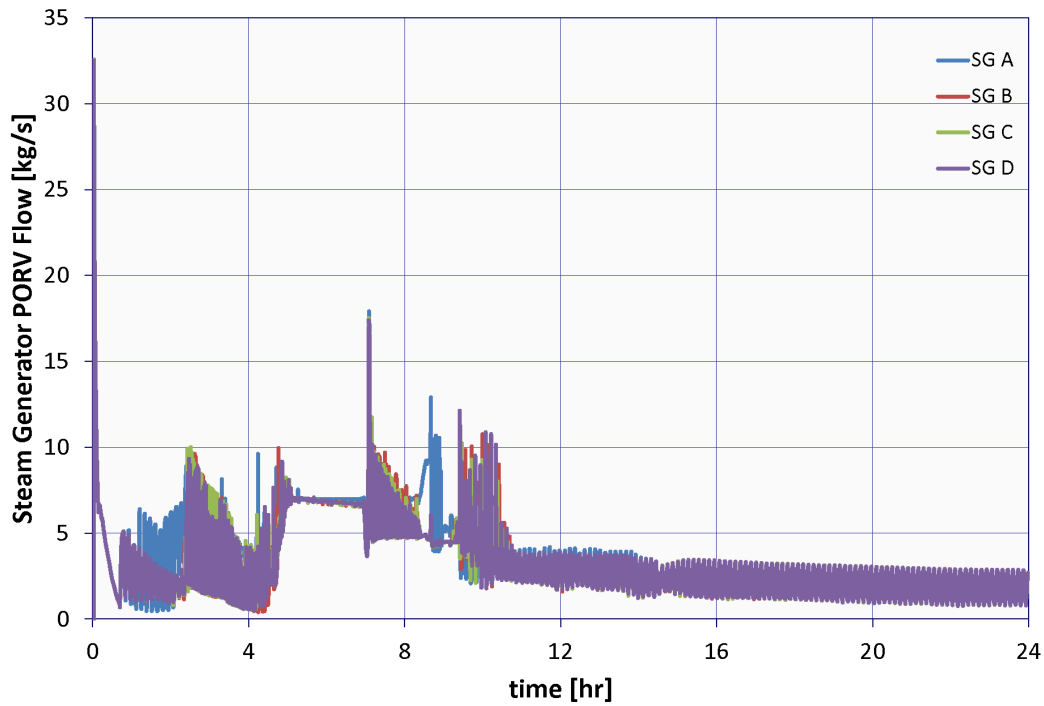
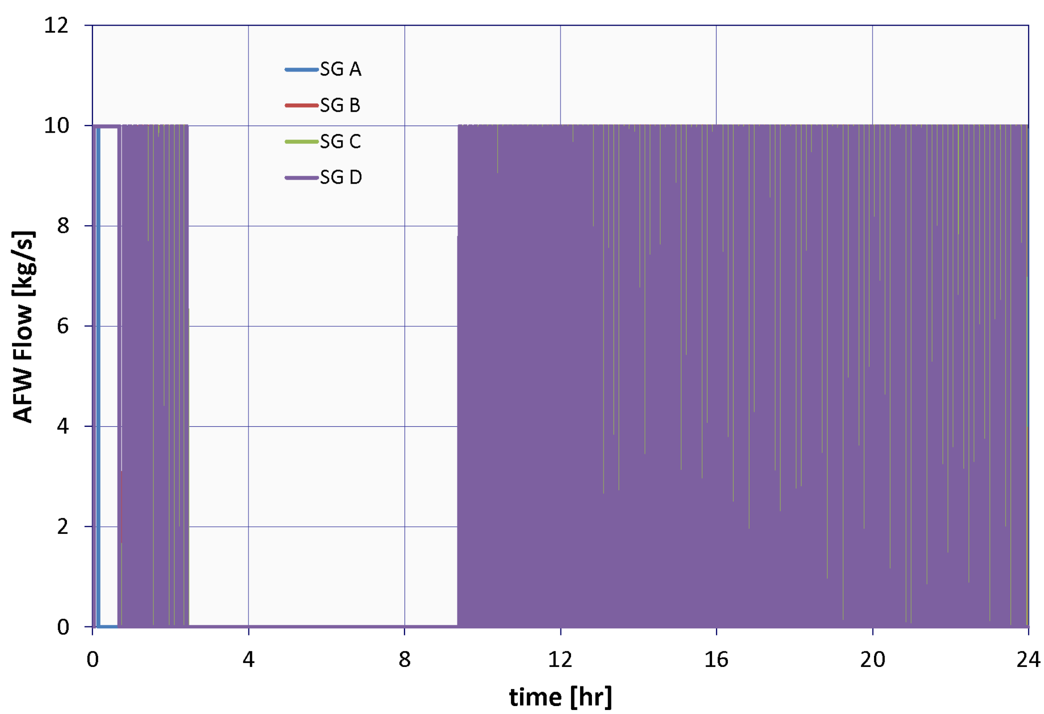
0
Pressure [MPa]
PZR
SG A
SG B
SG C
SG D
0
4
8
12
16
20
24
time [hr]


Mass Flow Rate [kg/s]
80
70
60
50
40
30
20
10
0
-10
0
4
8
12
16
20
24
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow


PZR PORV Mass Flow Rate [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
0
4
8
12
16
20
24


AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
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10
12
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4
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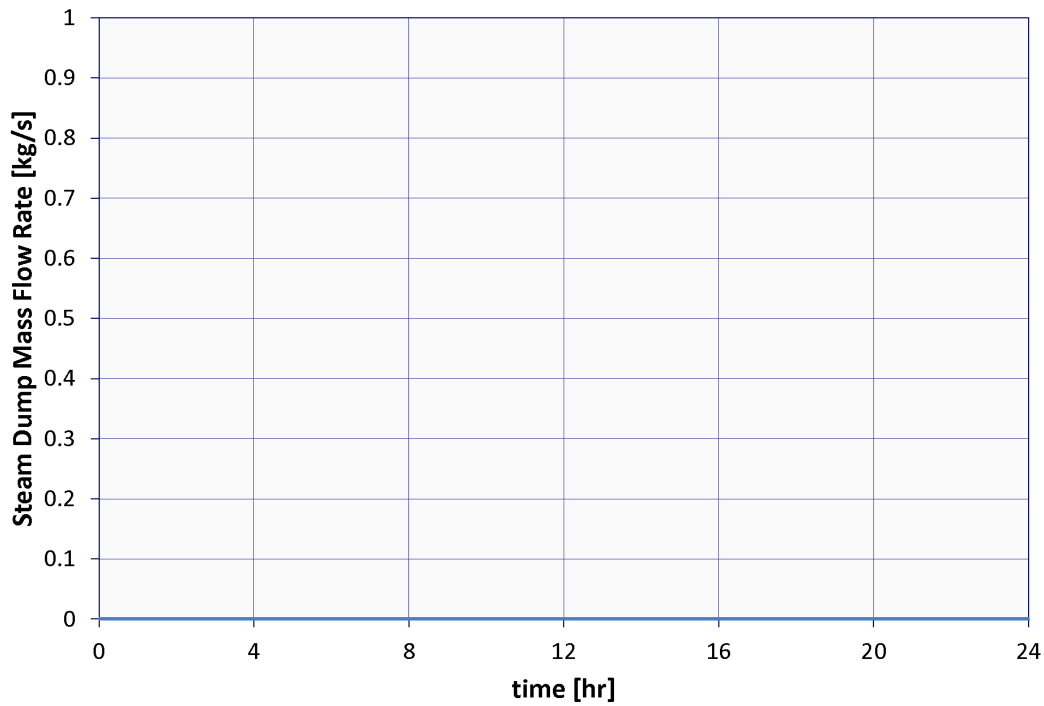
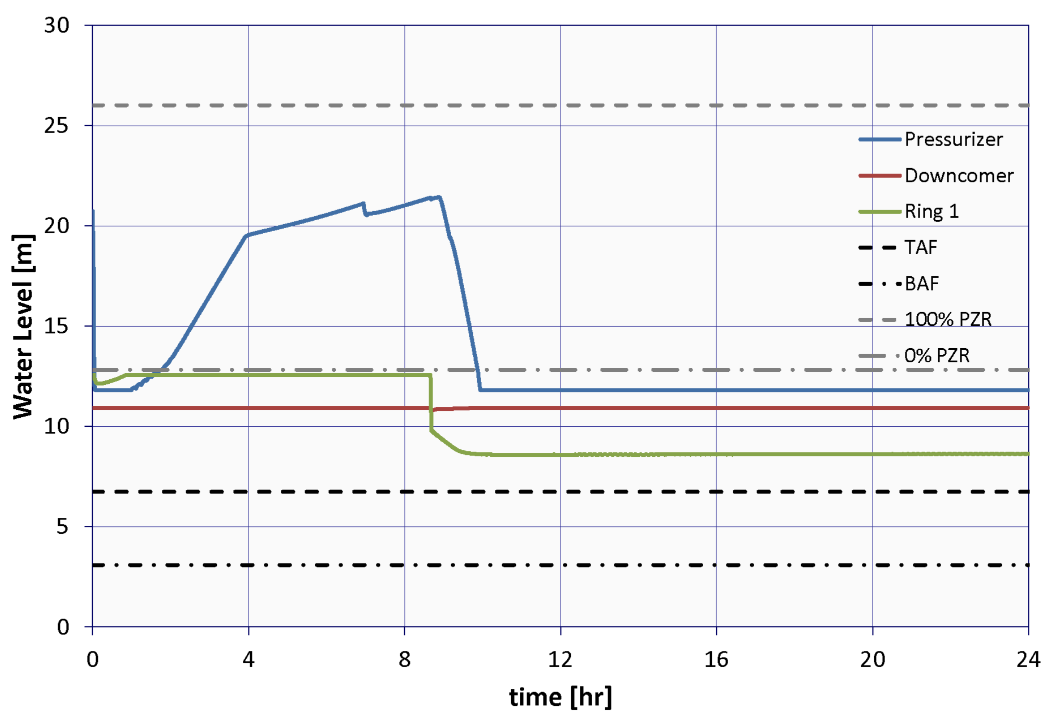
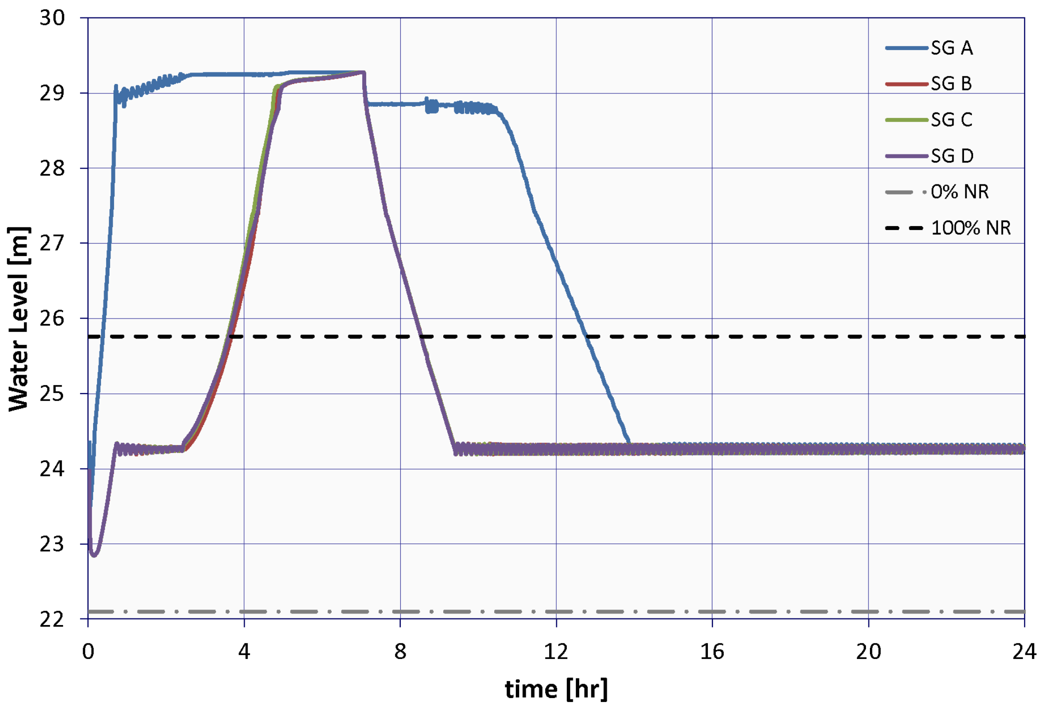
16
20
24

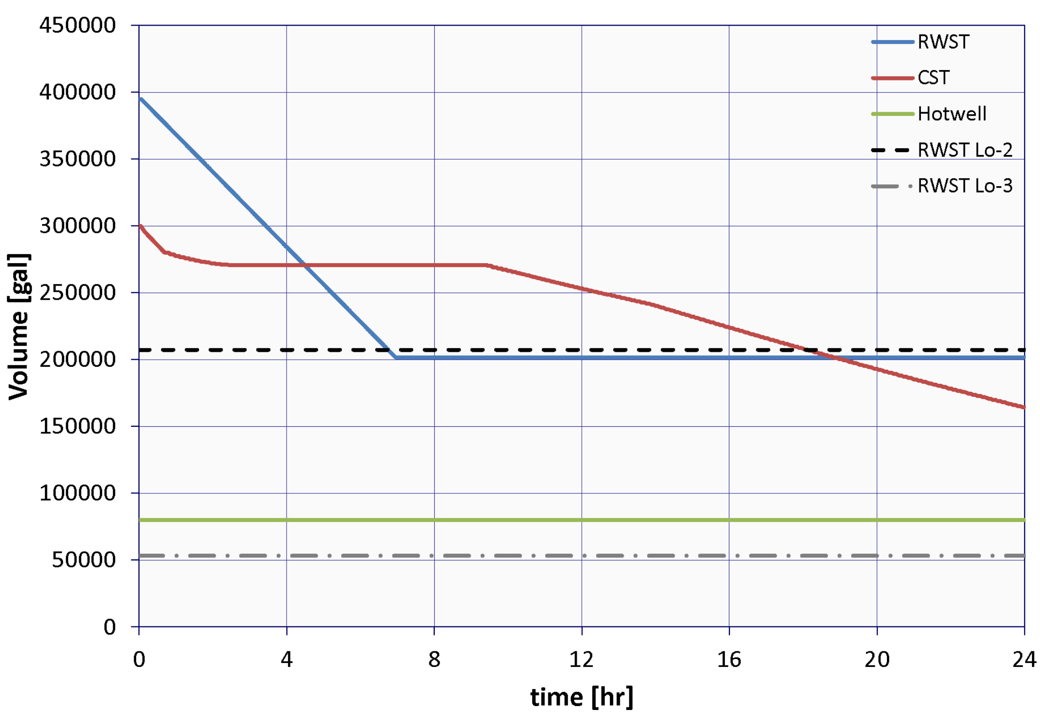


Steam Dump Mass Flow Rate [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]

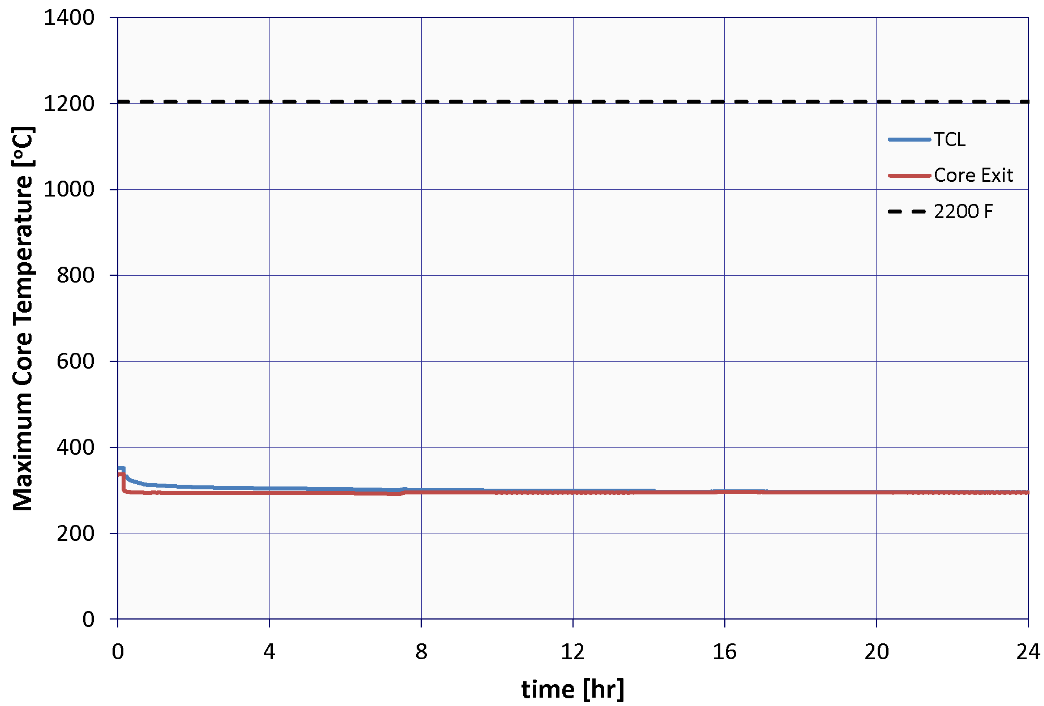


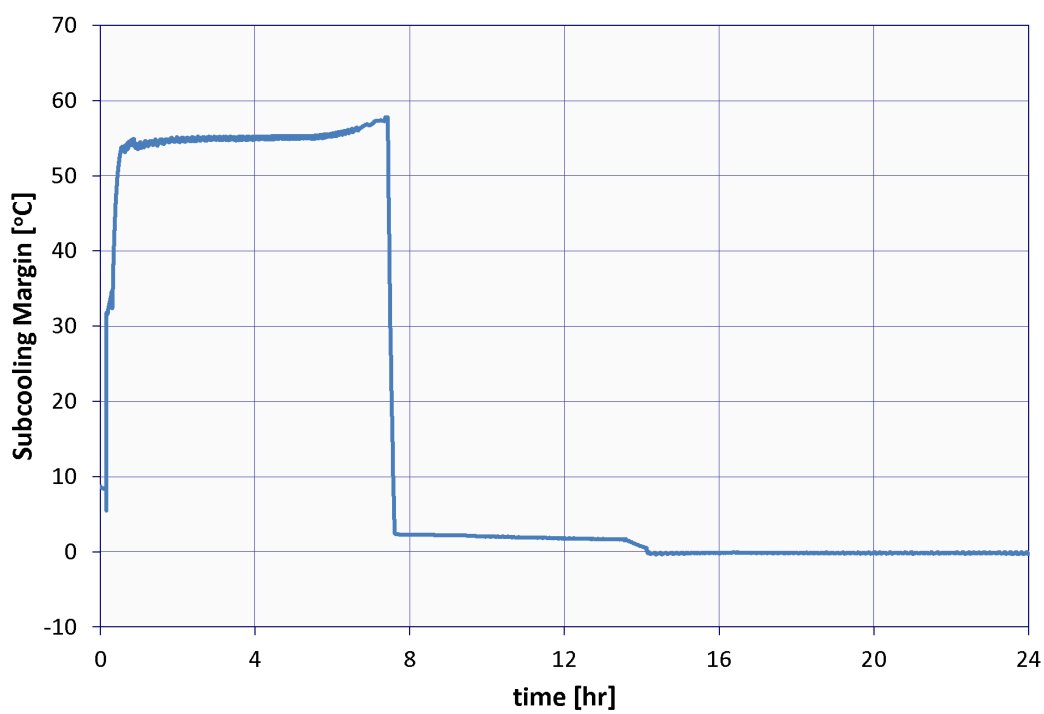
Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

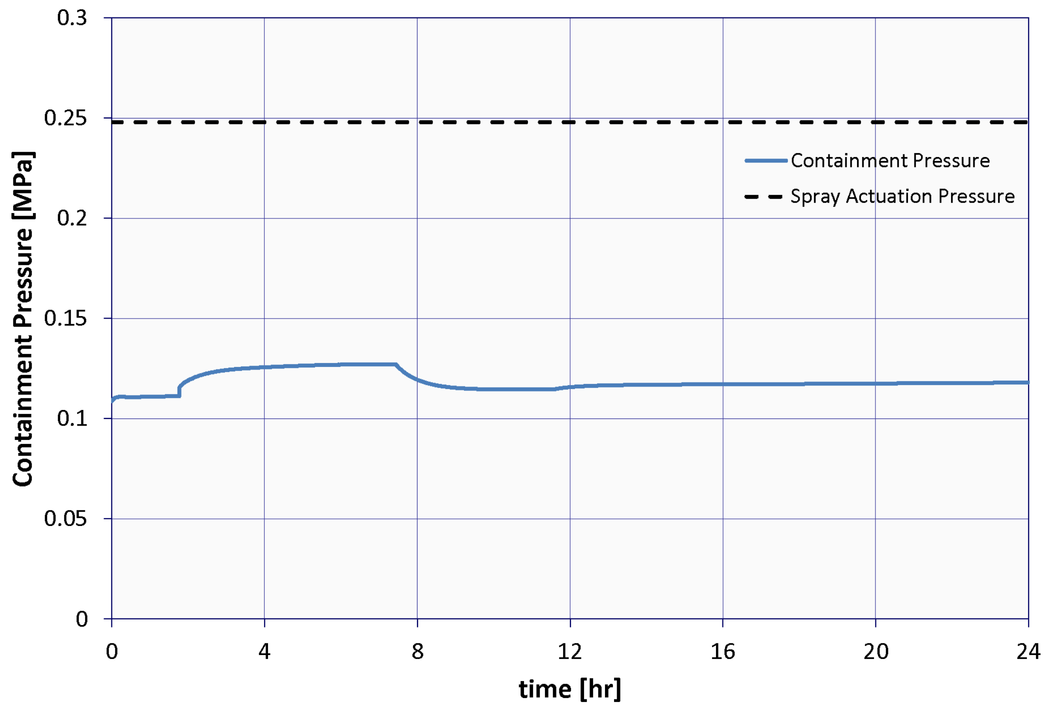

SG A
SG B
SG C
SG D
0% NR
100% NR
Water Level [m]
time [hr]
30
29
28
27
26
25
24
23
22
0
4
8
12
16
20
24

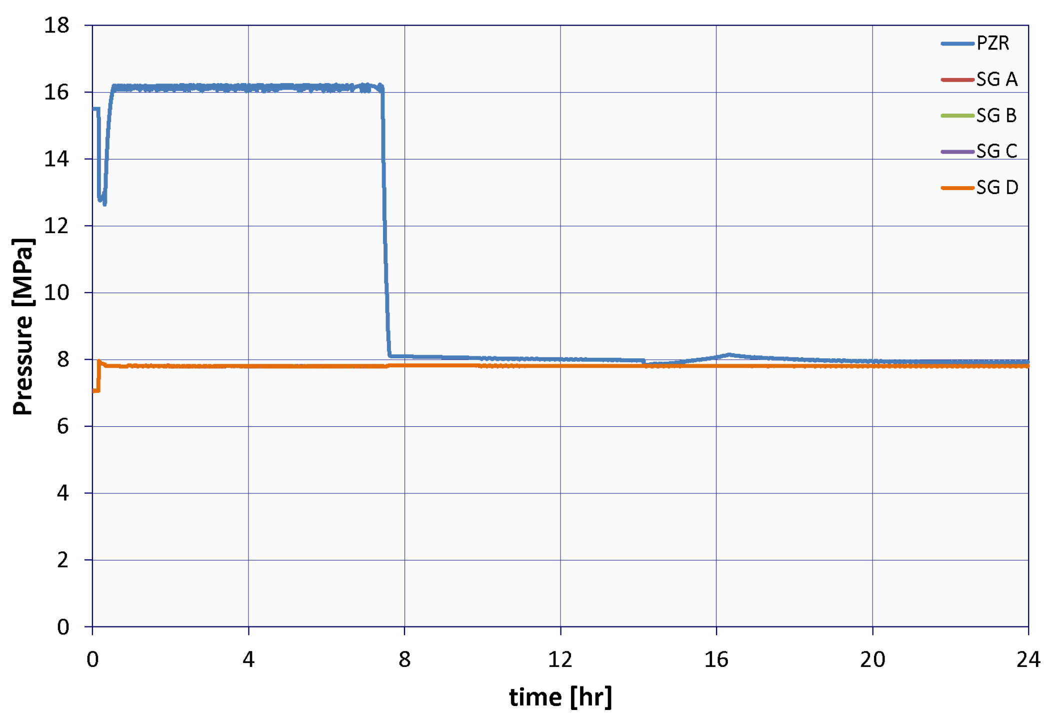

RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
Volume [gal]
time [hr]
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24

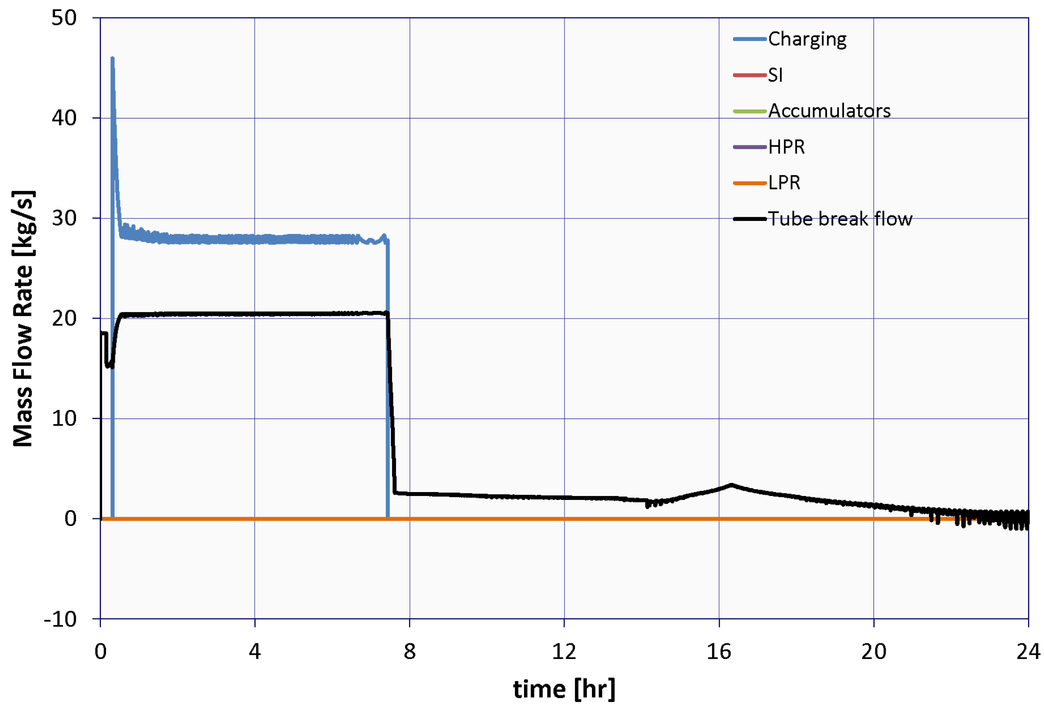
D.1.3 Case 3: 0.5 Tube, Min ECCS, No Steam Dumps



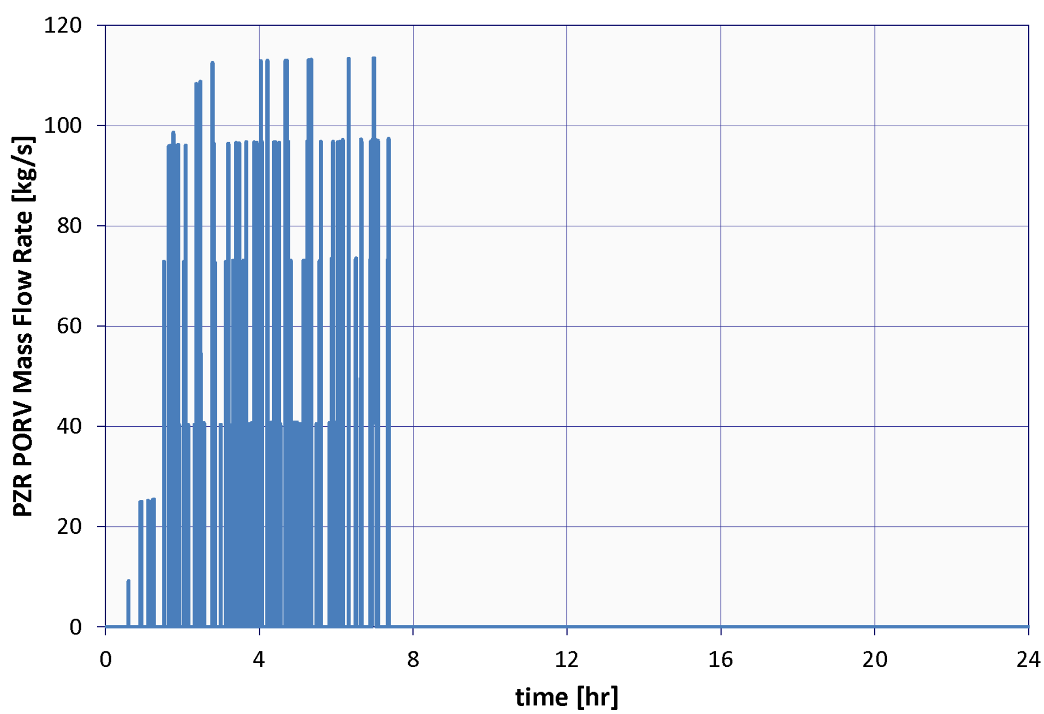



Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

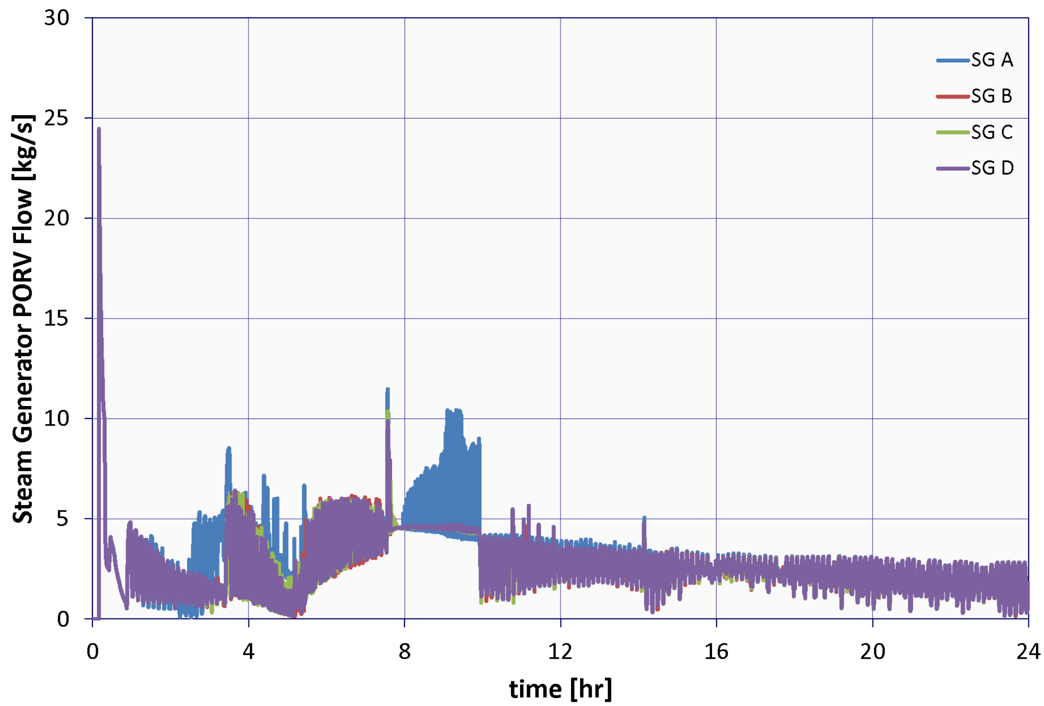

Pressure [MPa]
18
16
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



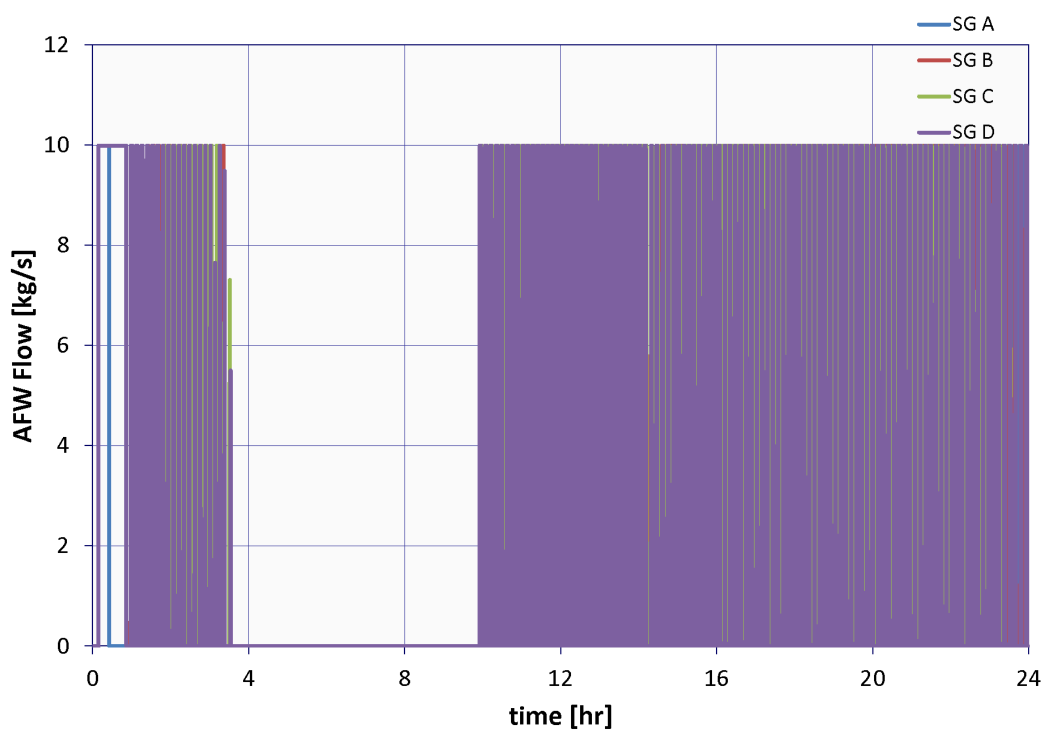
Charging
SI
Accumulators
HPR
LPR
Tube break flow
Mass Flow Rate [kg/s]
time [hr]



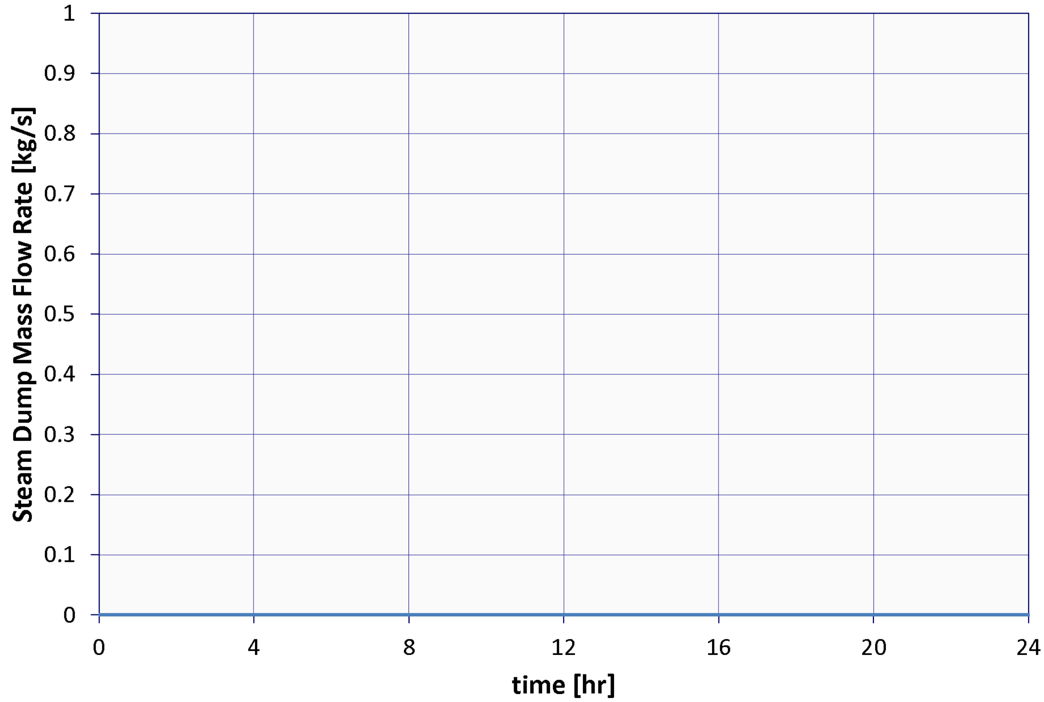
PZR PORV Mass Flow Rate [kg/s]
time [hr]

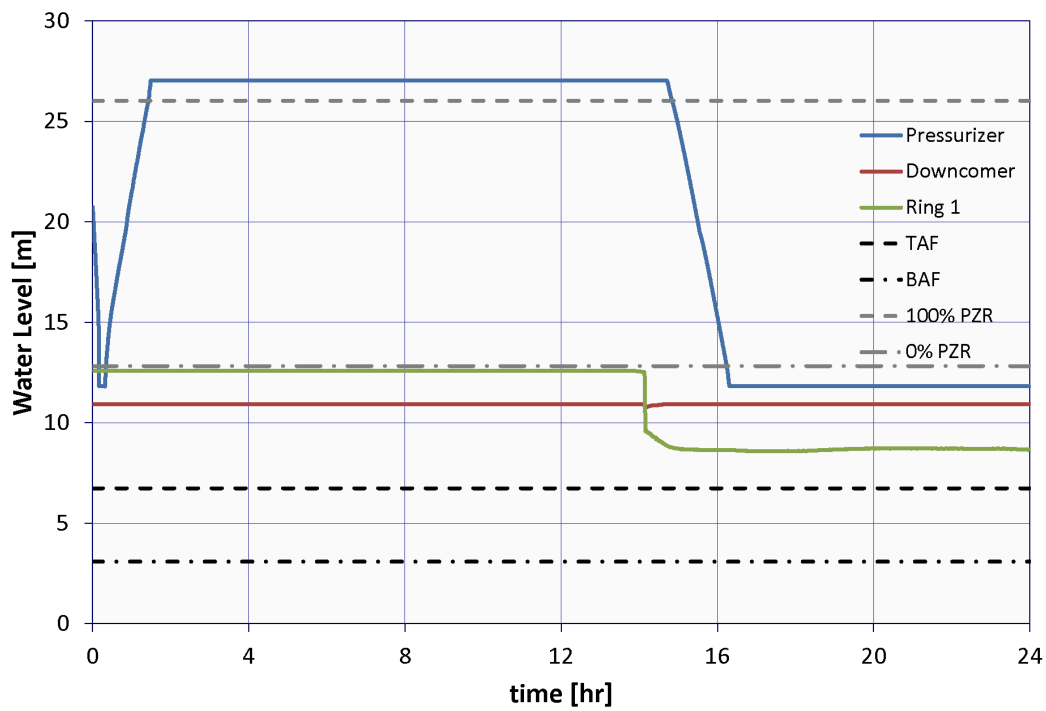


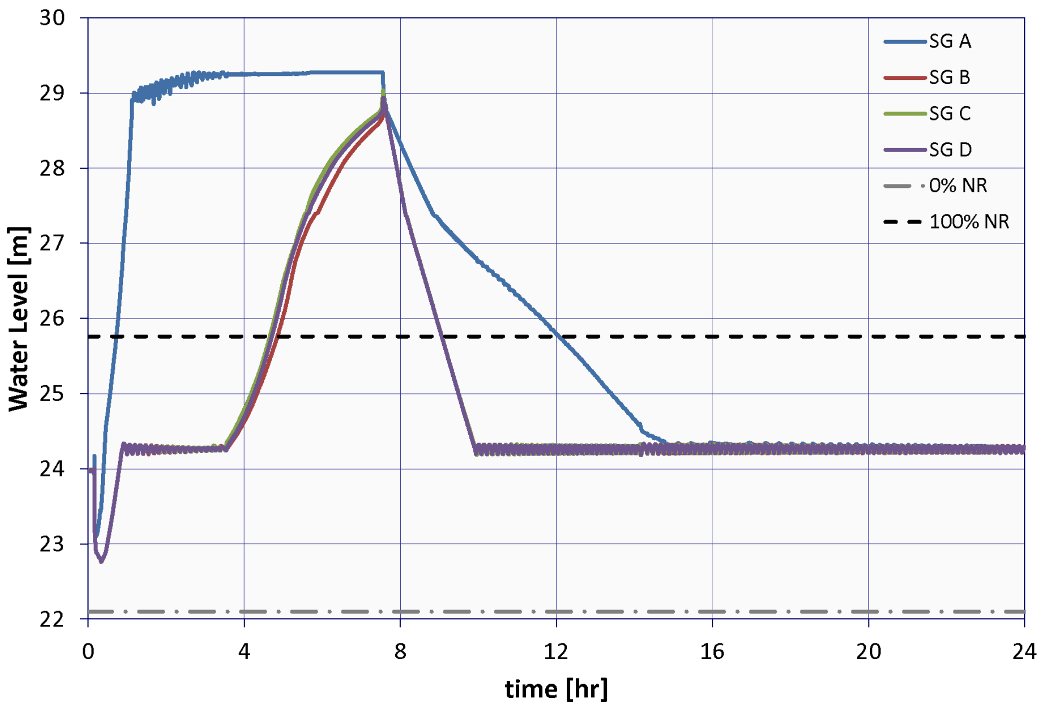
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
0
4
8
12
16
20
24

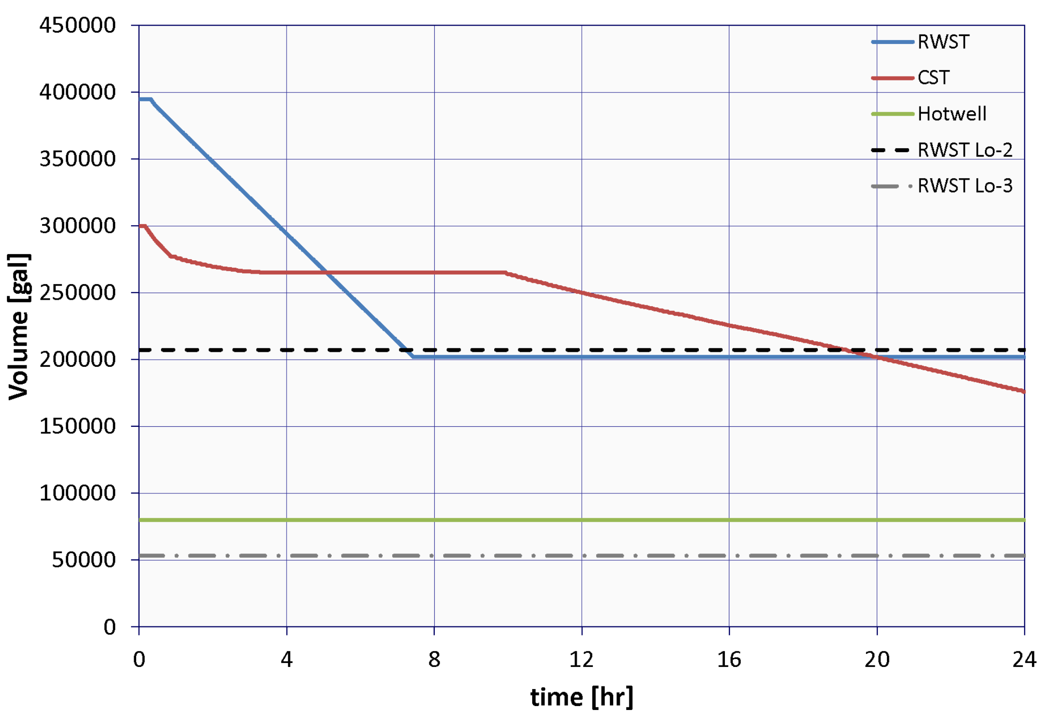


AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

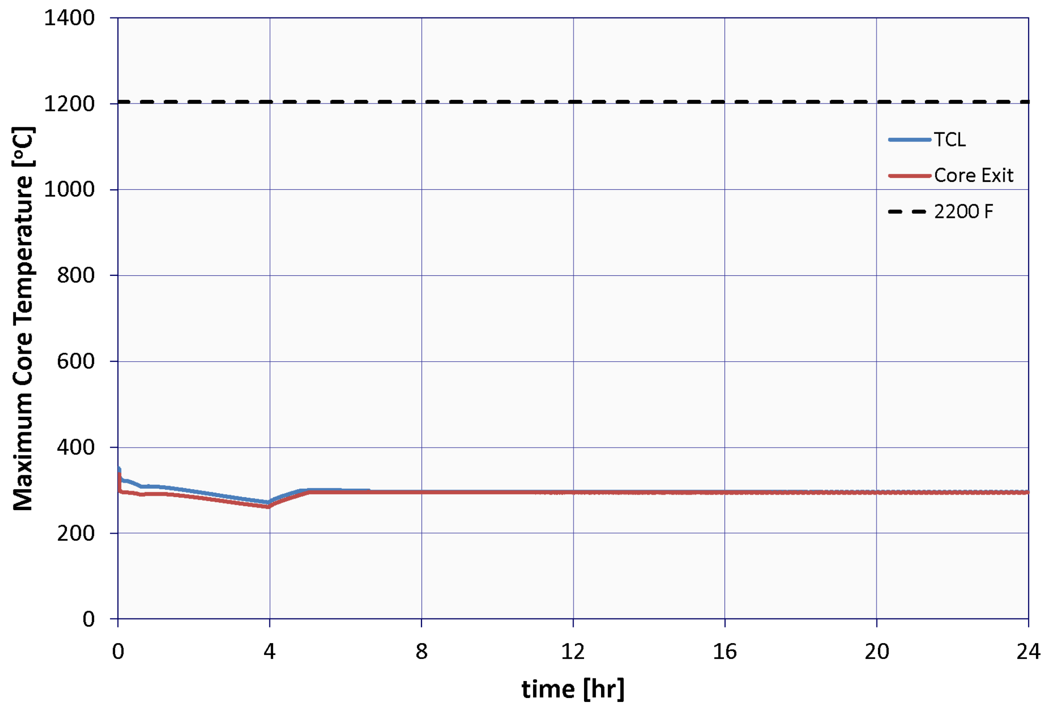

Steam Dump Mass Flow Rate [kg/s]
time [hr]

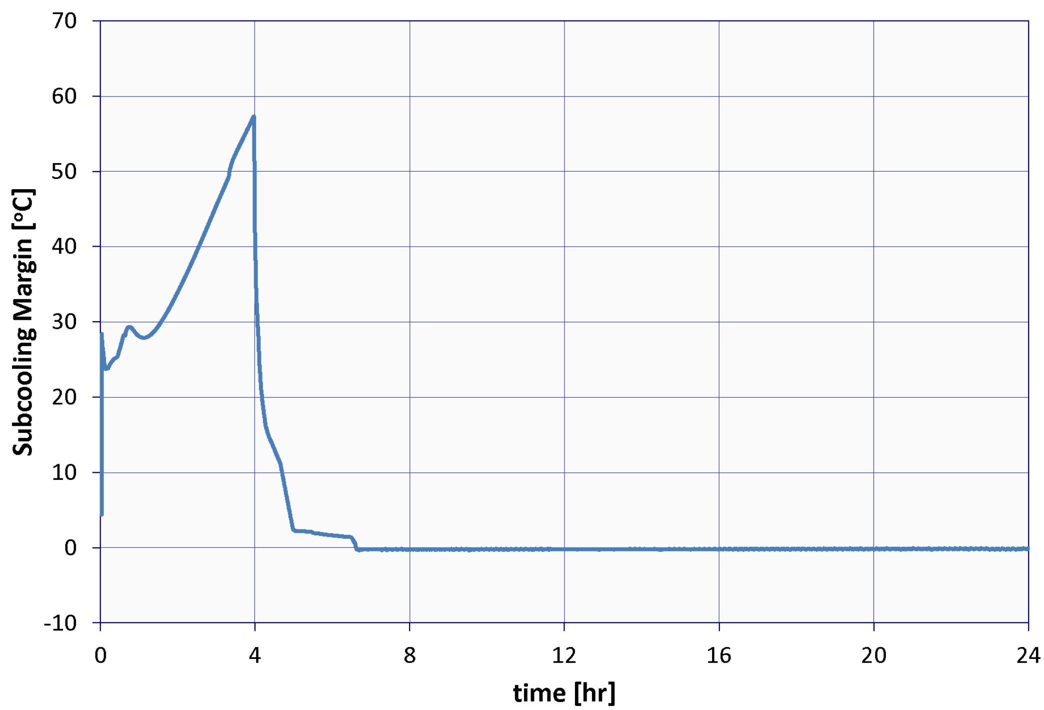

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

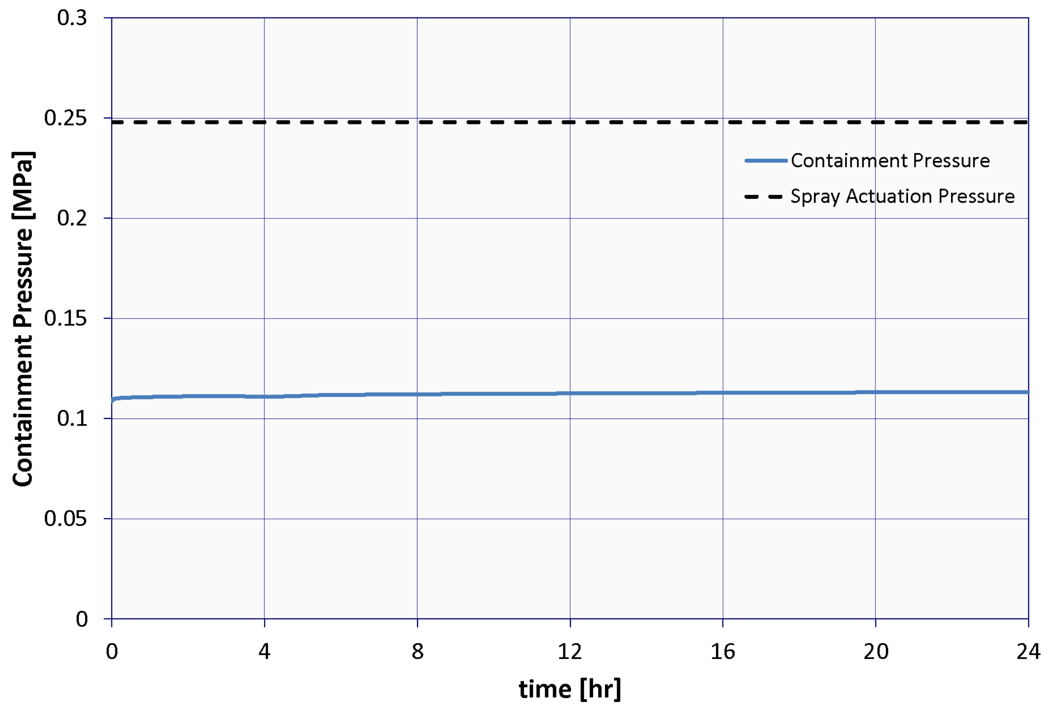

30
29
28
27
26
25
24
23
22
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

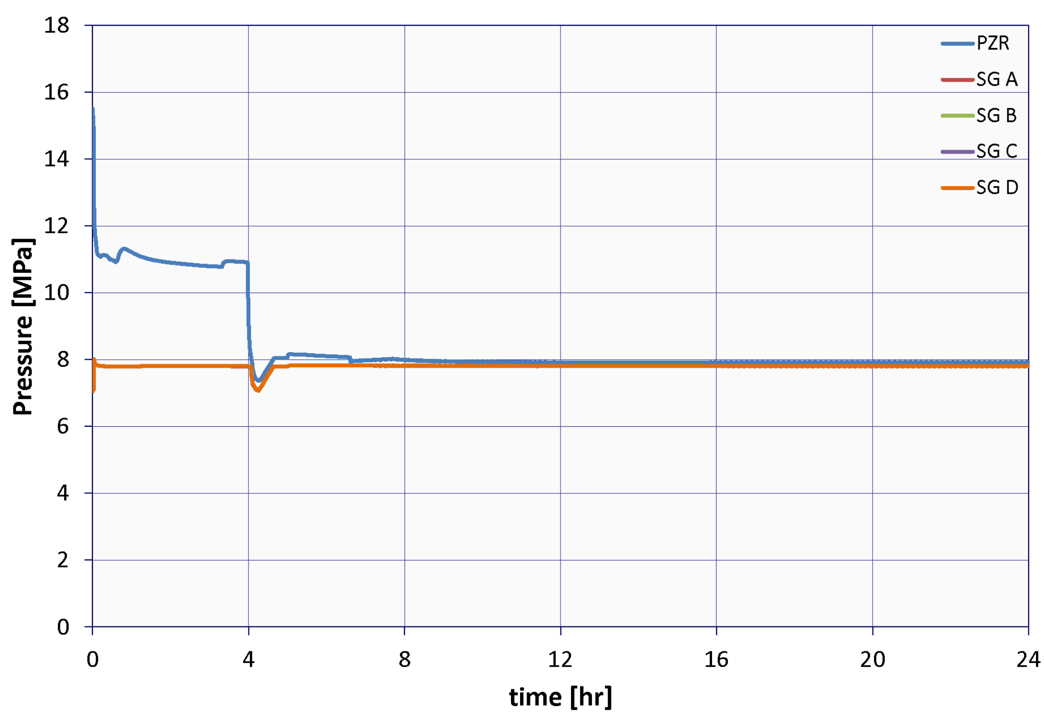

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

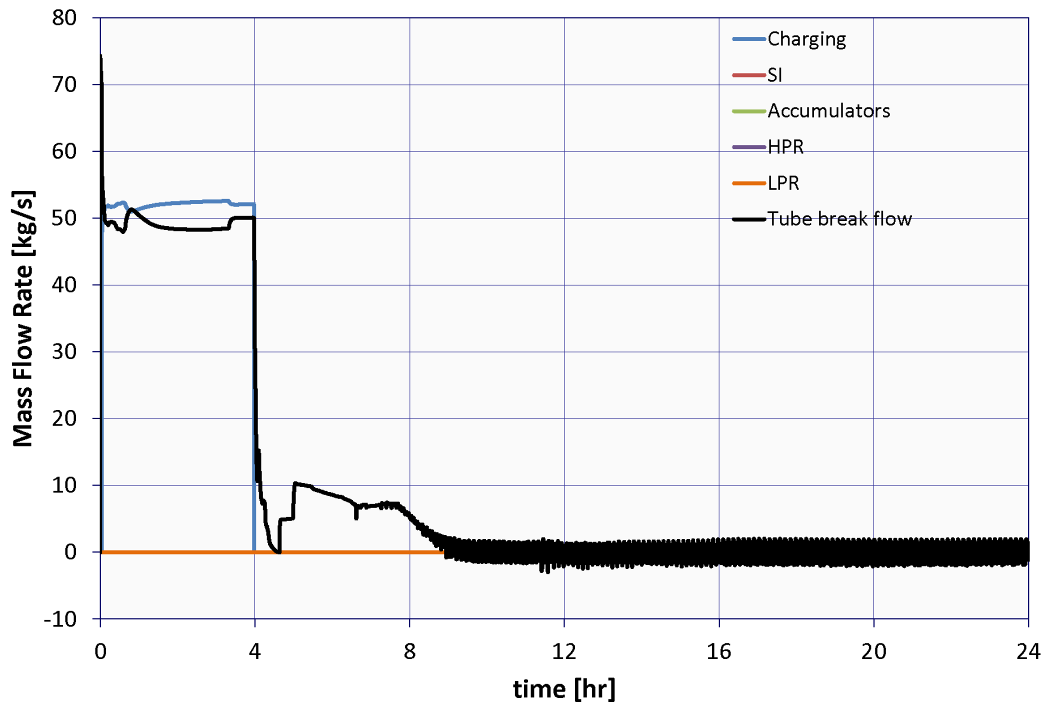
D.1.4 Case 4: 2 Tubes, Max ECCS, No Steam Dumps



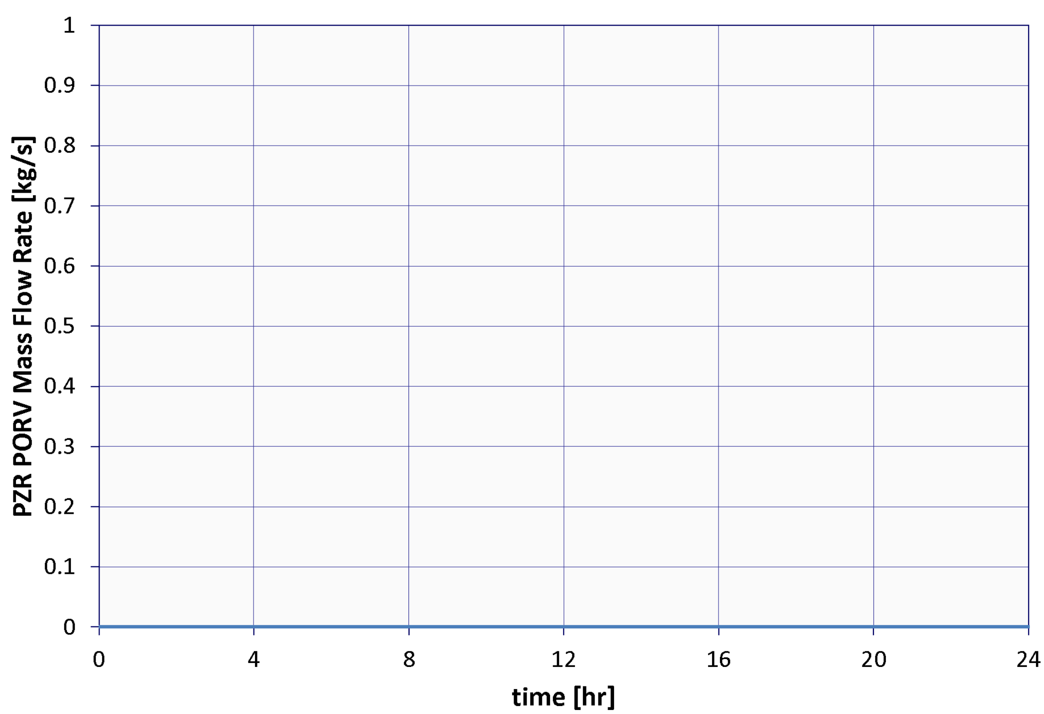



Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

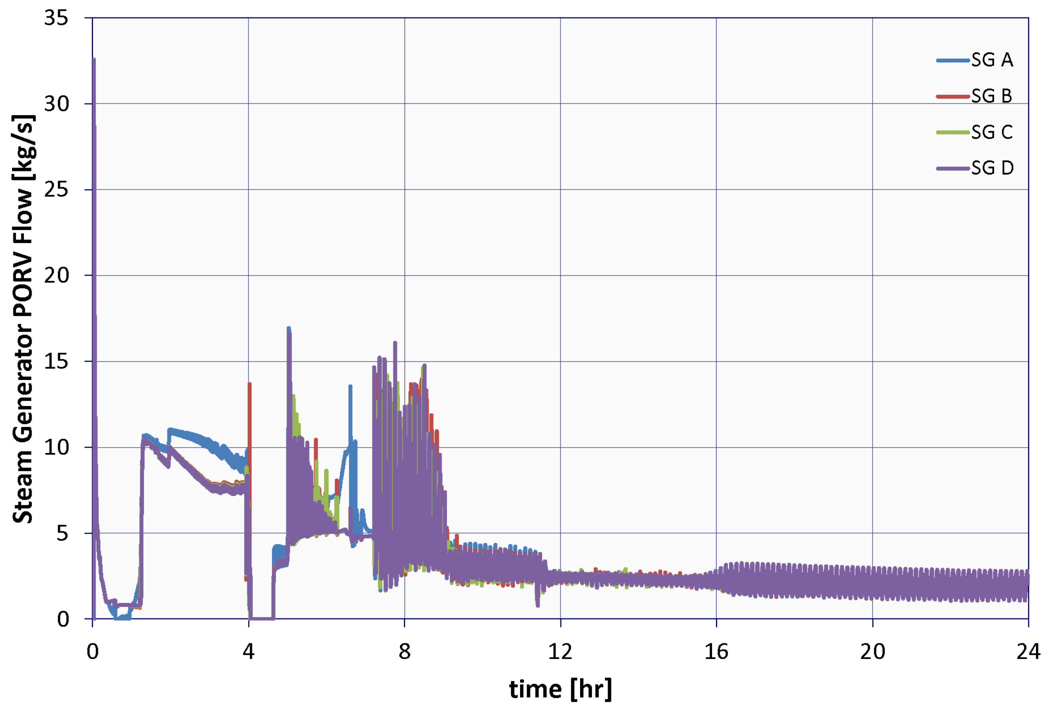

Pressure [MPa]
18
16
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



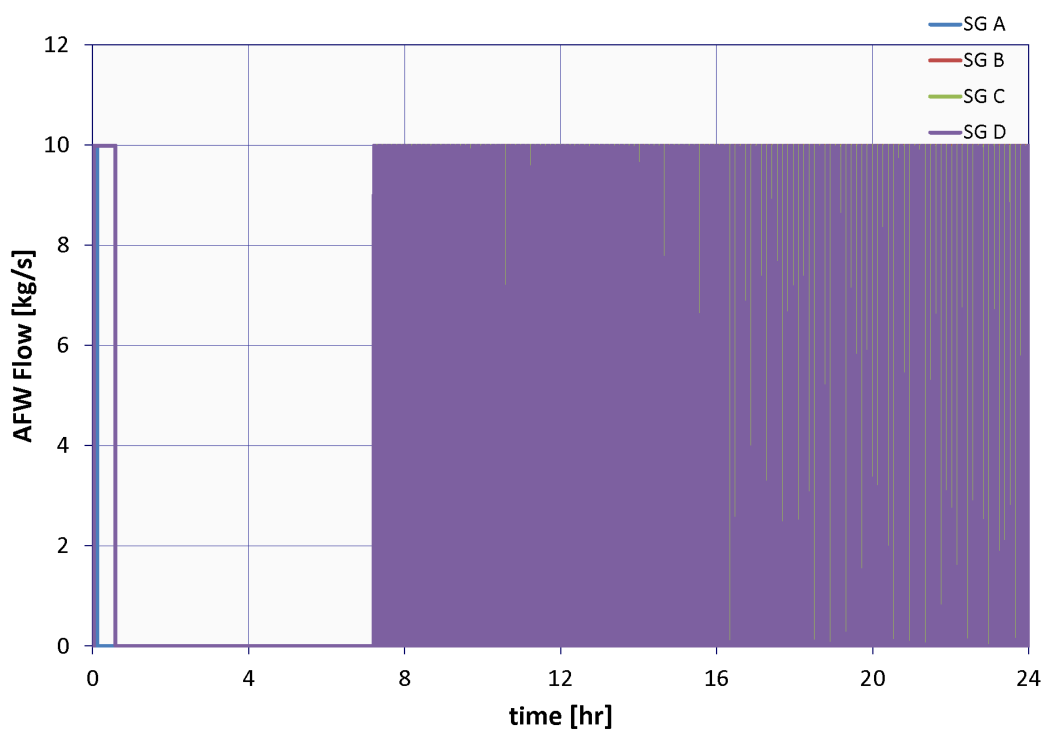
Mass Flow Rate [kg/s]
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow



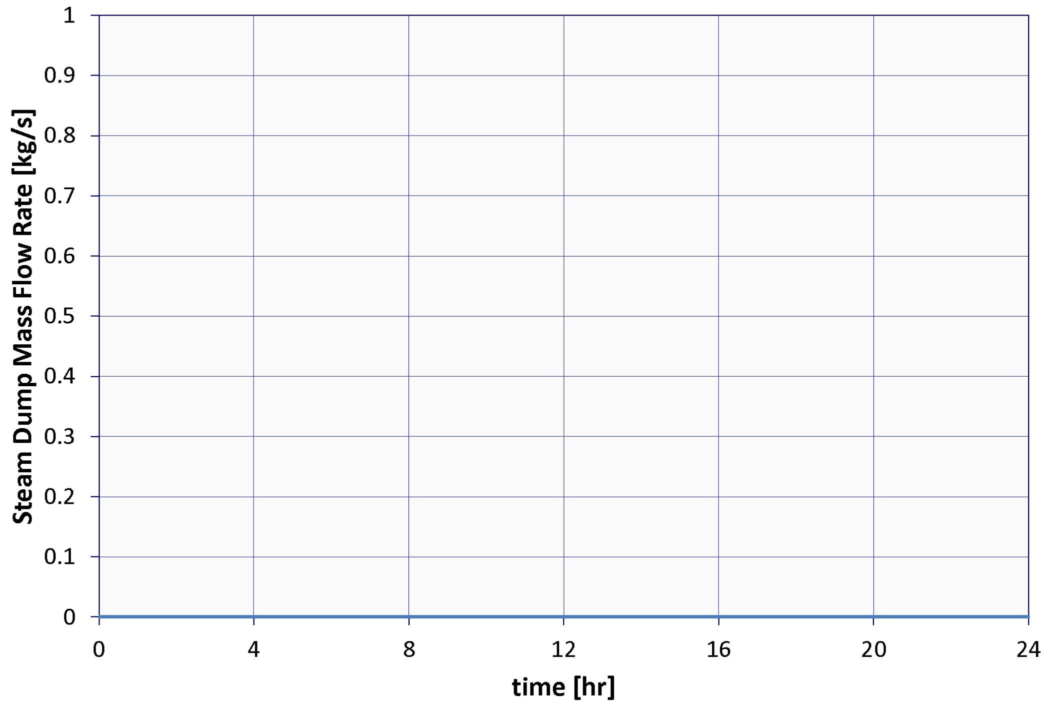
PZR PORV Mass Flow Rate [kg/s]
time [hr]

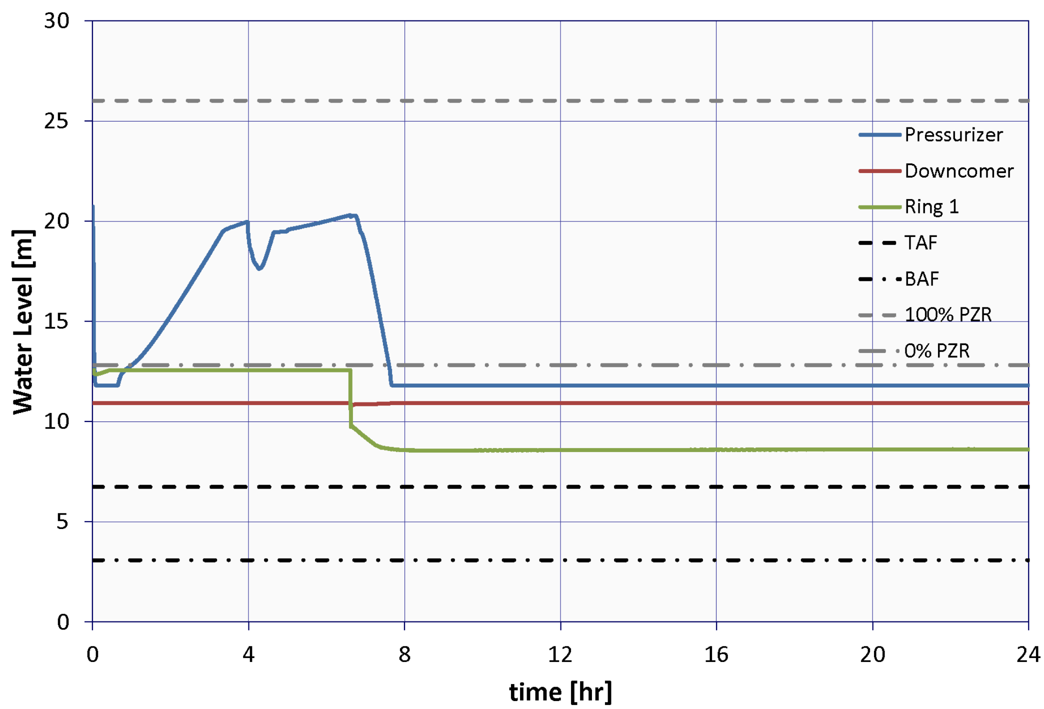


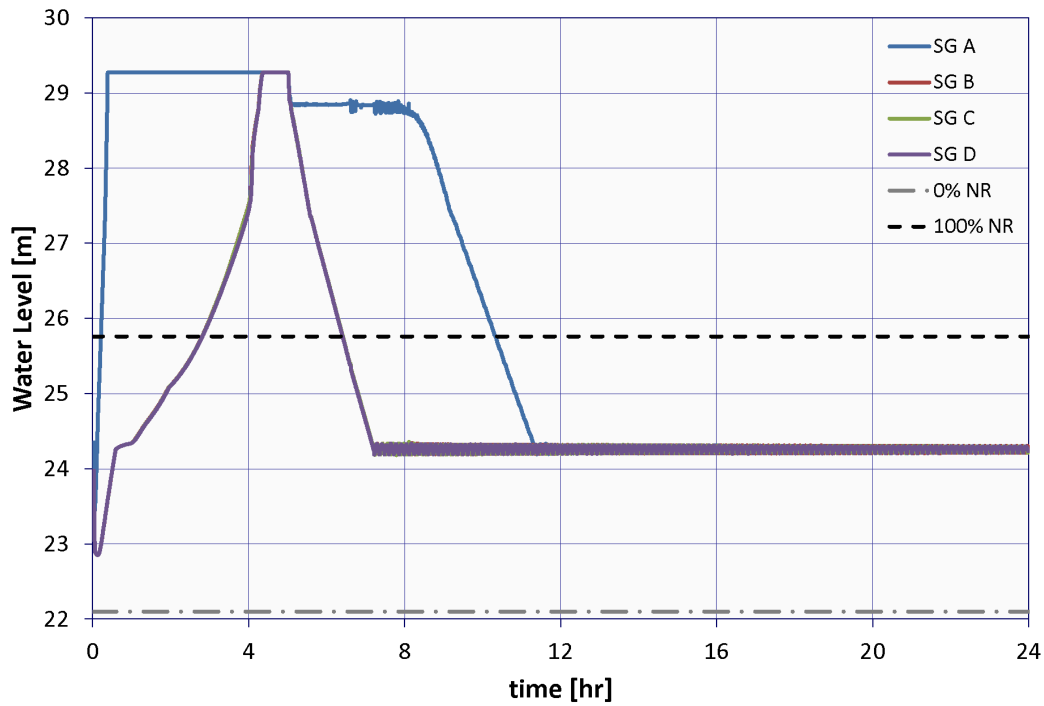
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
0
4
8
12
16
20
24



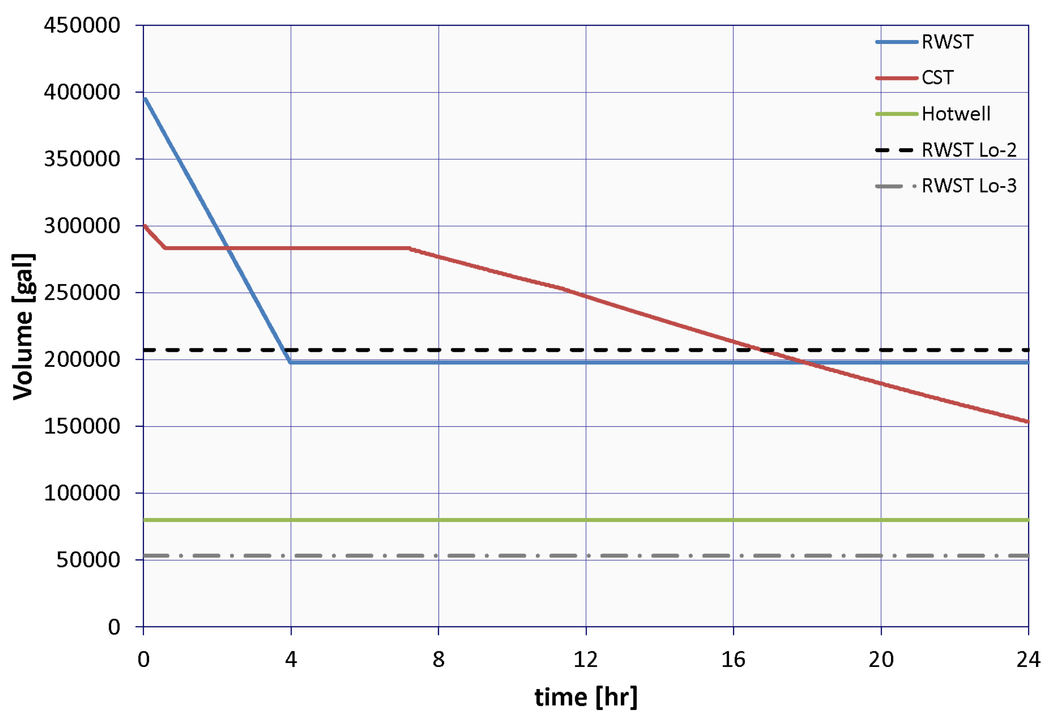
AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24


Steam Dump Mass Flow Rate [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]


Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

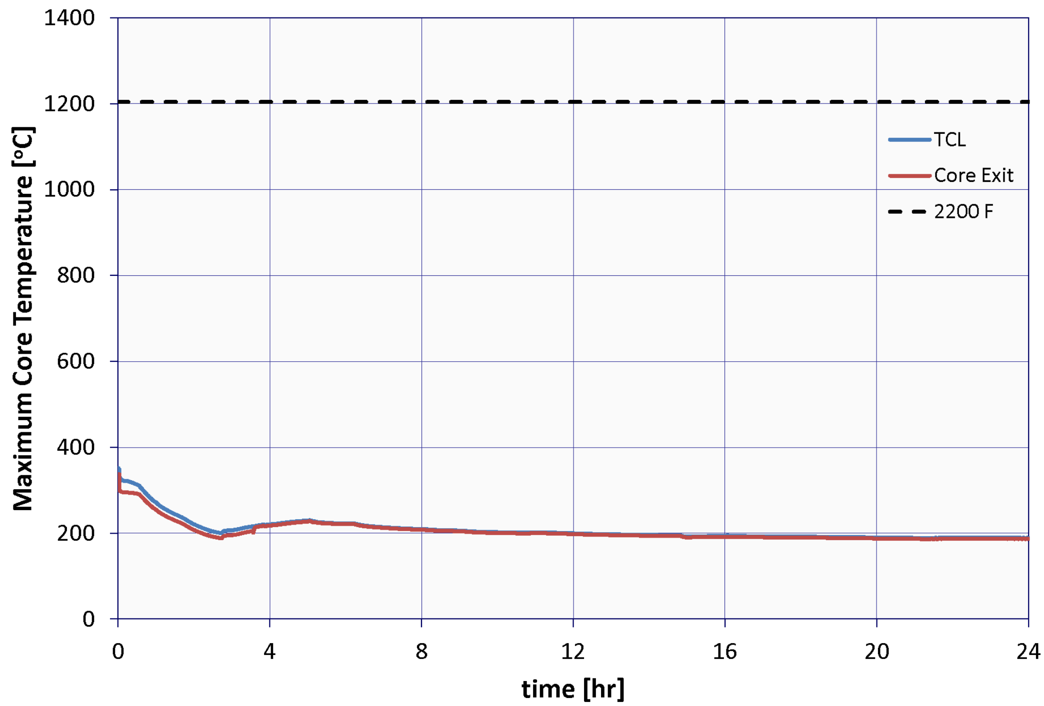


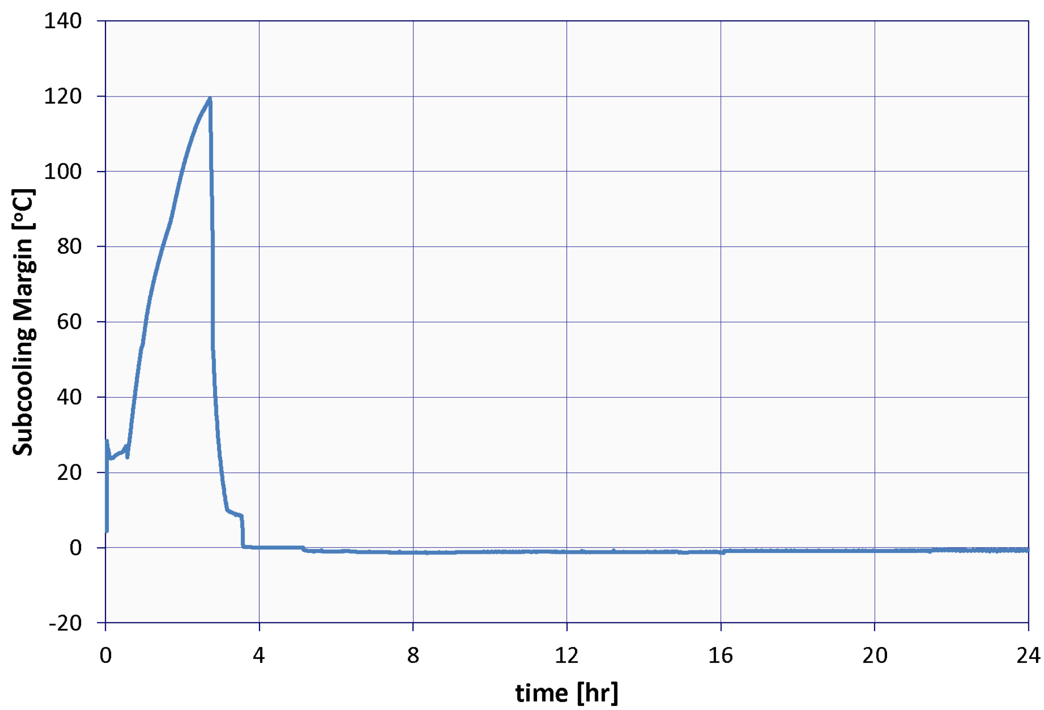
30
29
28
27
26
25
24
23
22
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

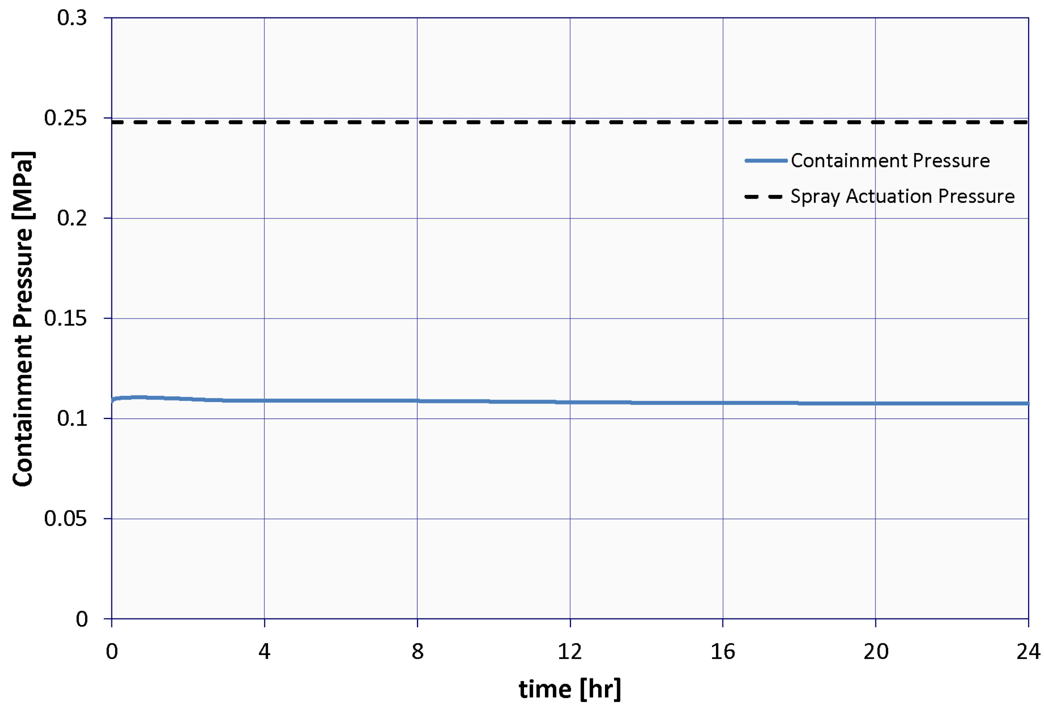


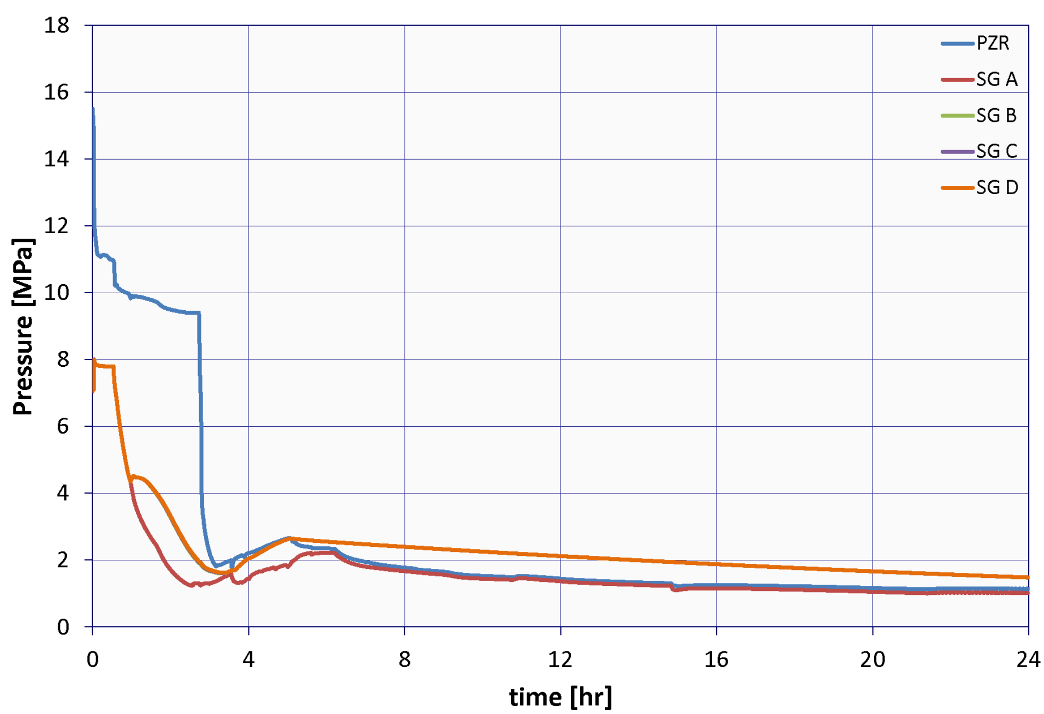
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

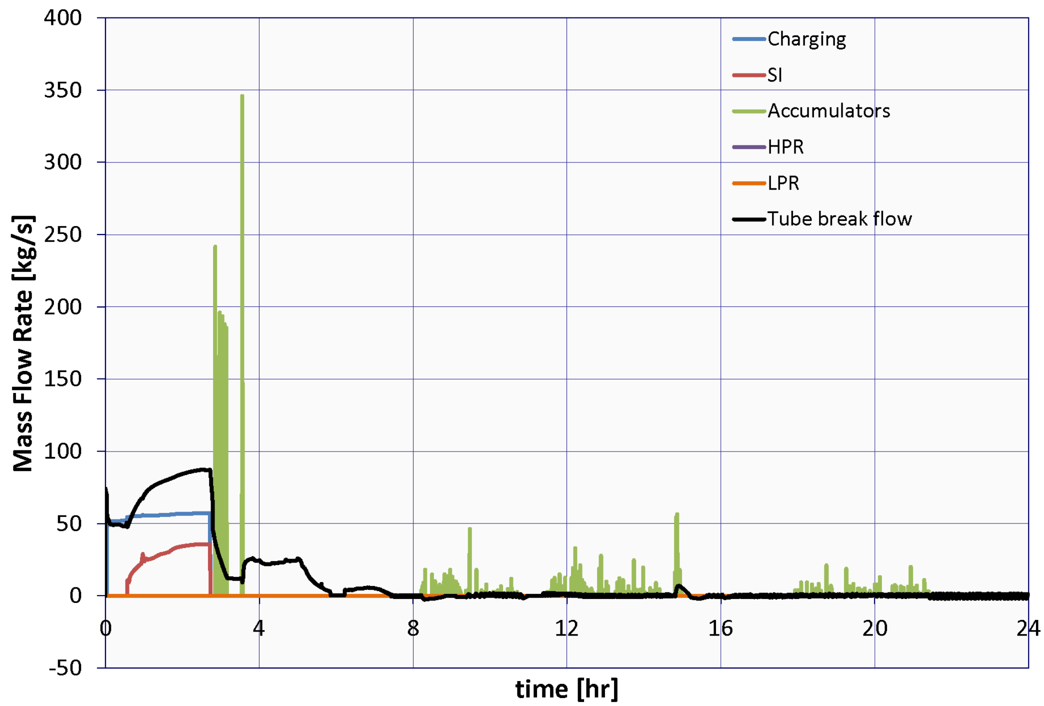
D.1.4.1 *Case 4a: 2 Tubes, Max ECCS, SG PORV Sticks Open*



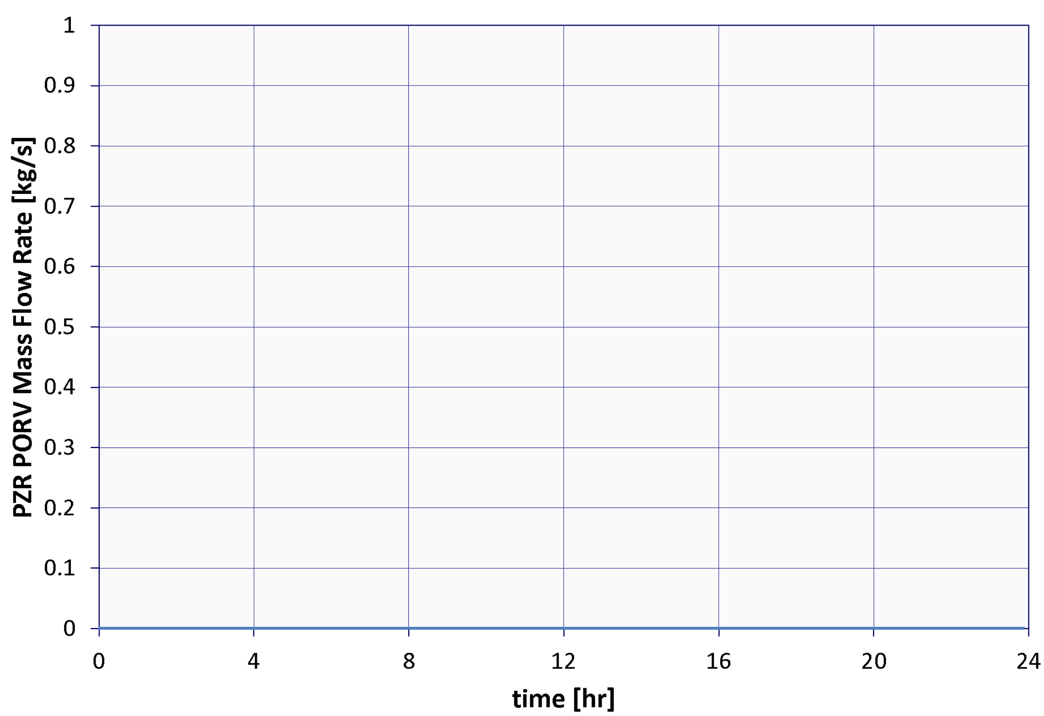



Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure

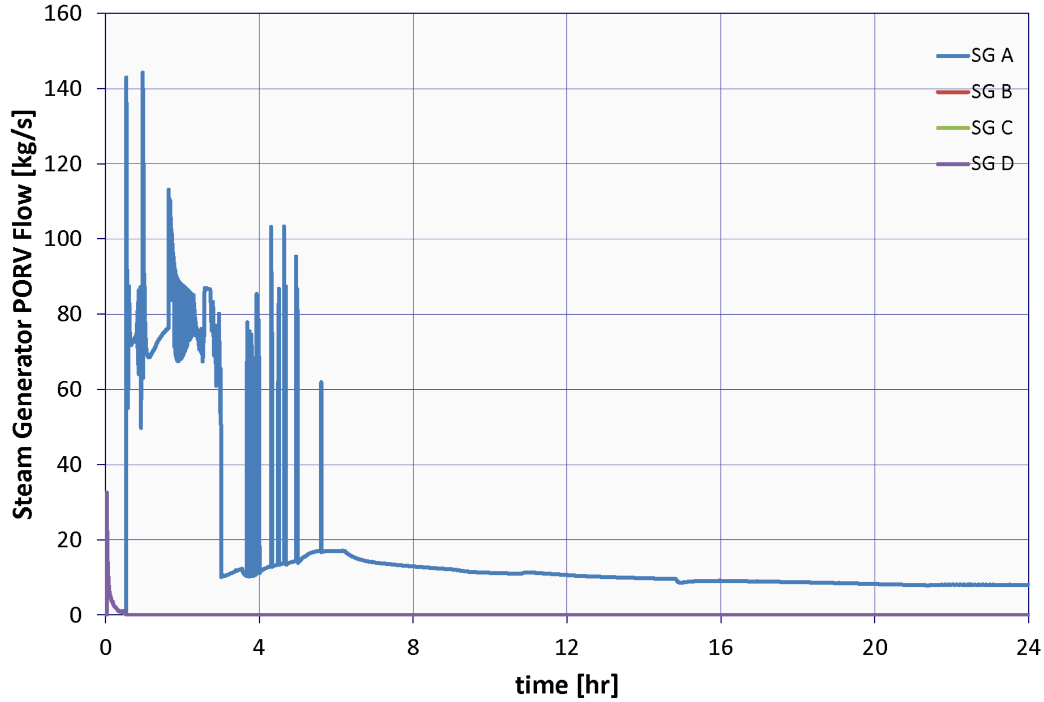

Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D

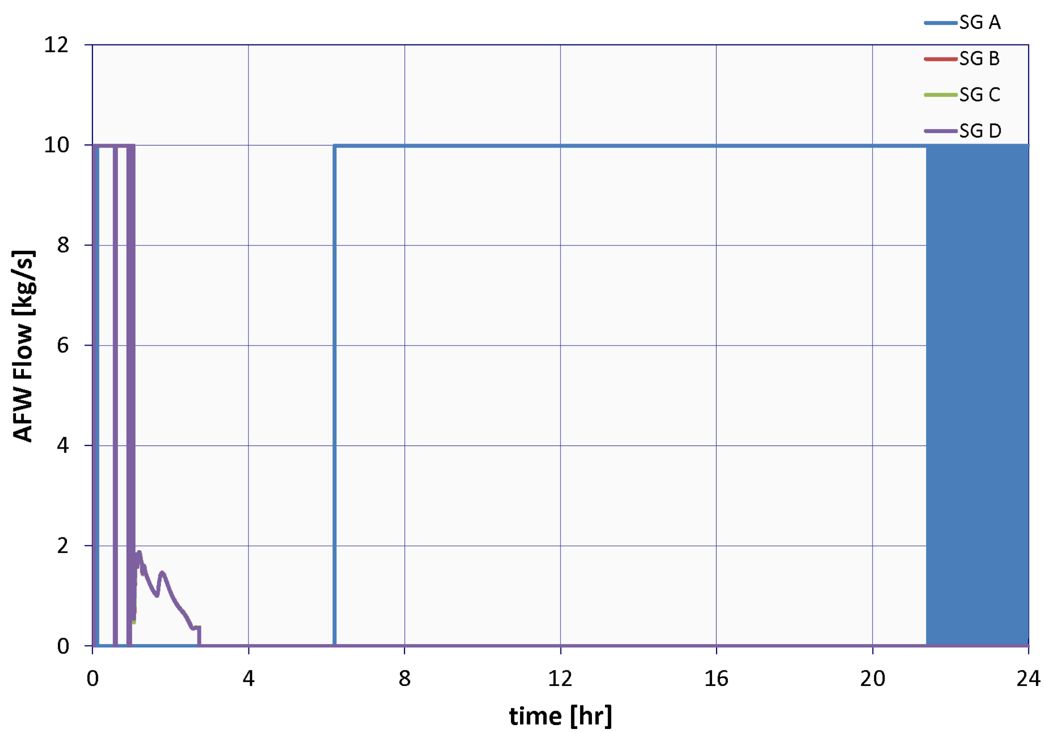


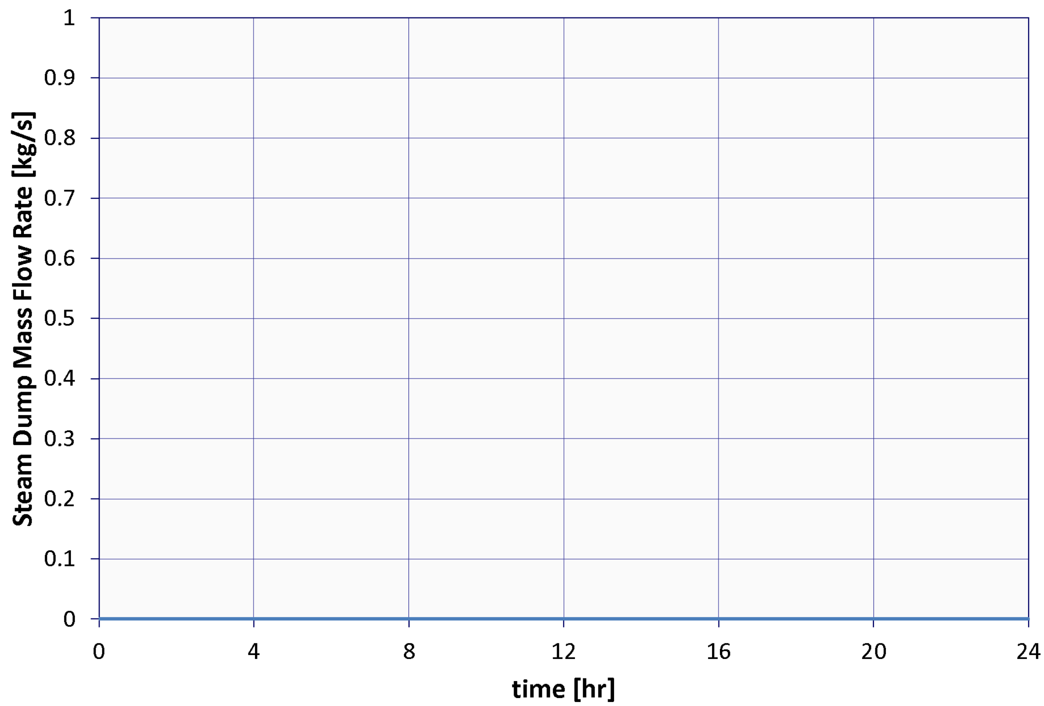
Charging
SI
Accumulators
HPR
LPR
Tube break flow
Mass Flow Rate [kg/s]
time [hr]

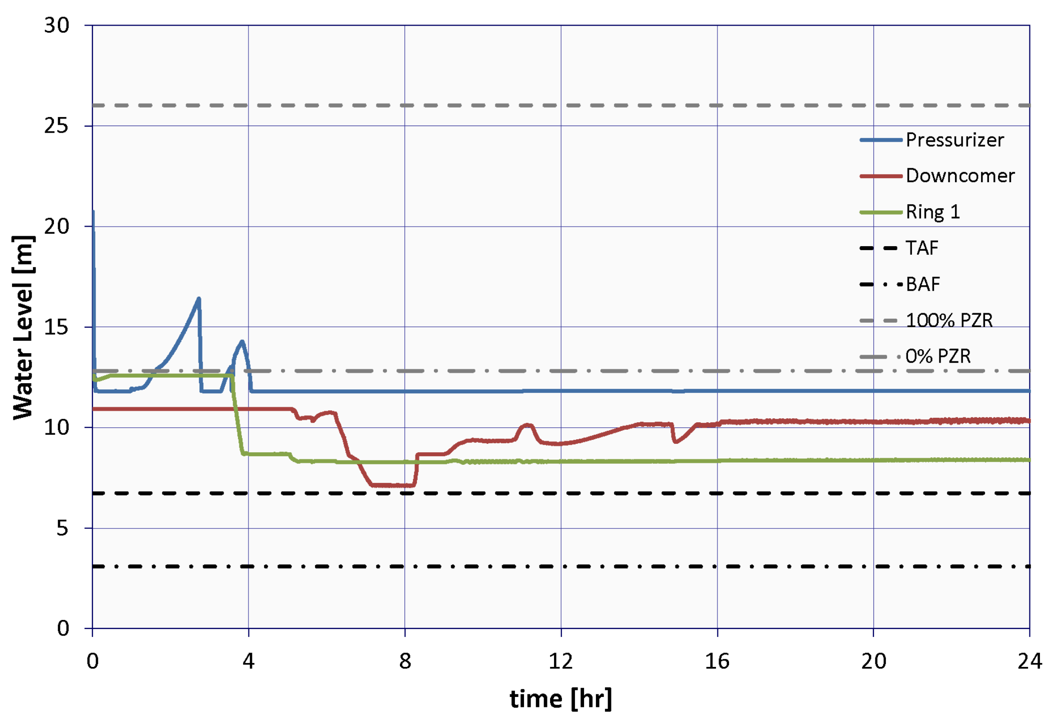


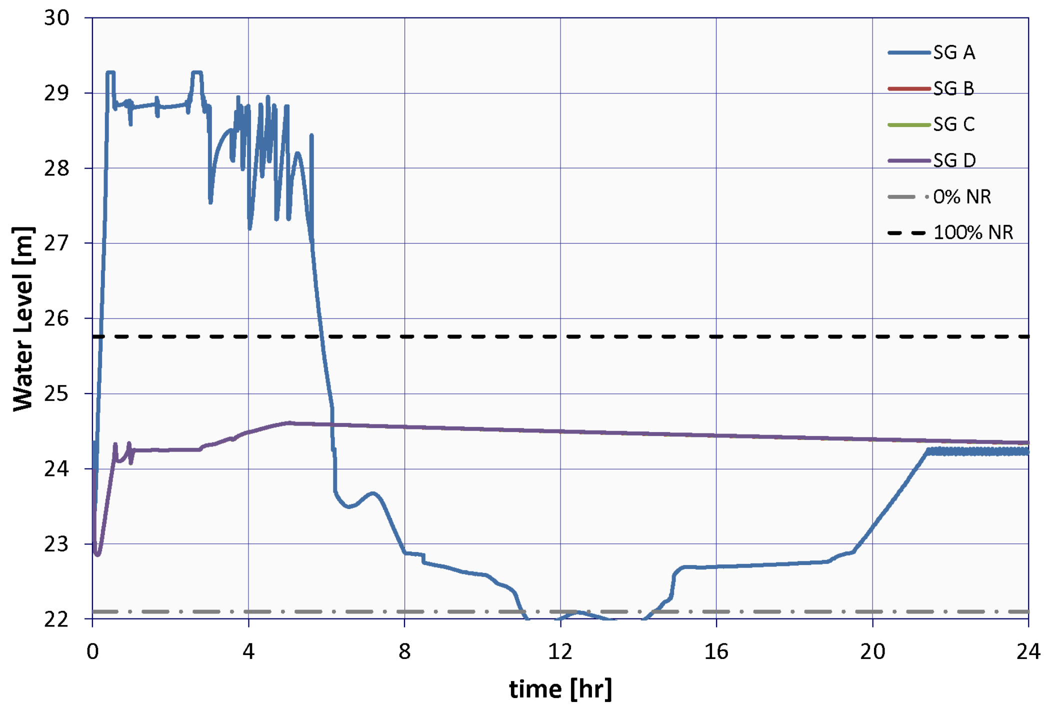
PZR PORV Mass Flow Rate [kg/s]
time [hr]


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
20
40
60
80
100
120
140
160
0
4
8
12
16
20
24

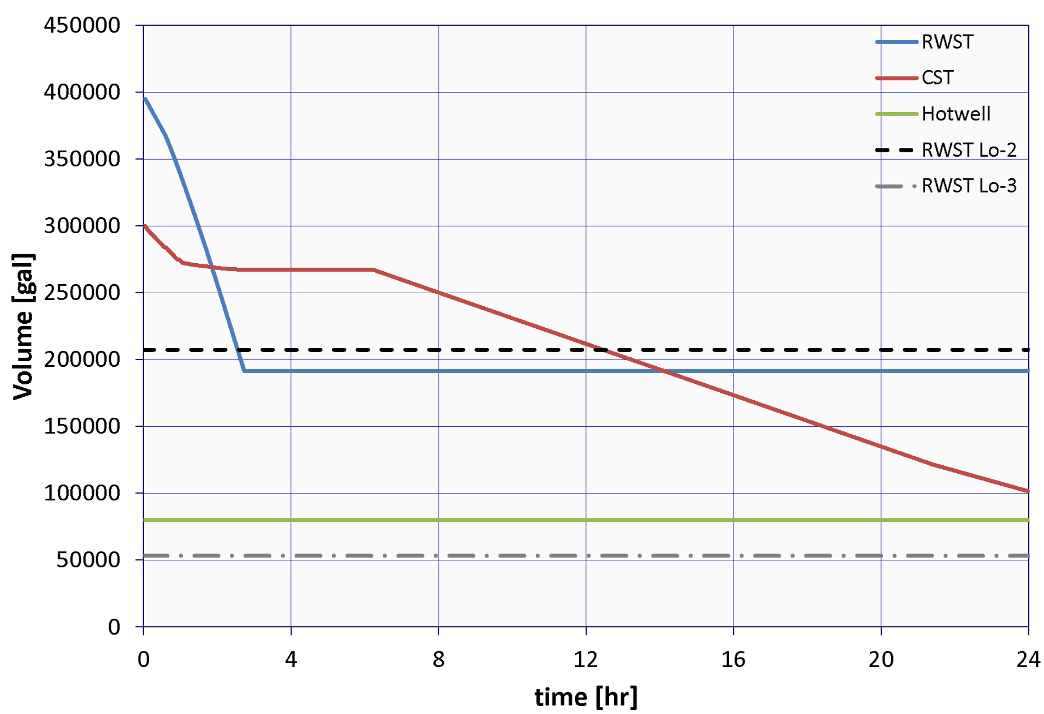

AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24


Steam Dump Mass Flow Rate [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]


Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

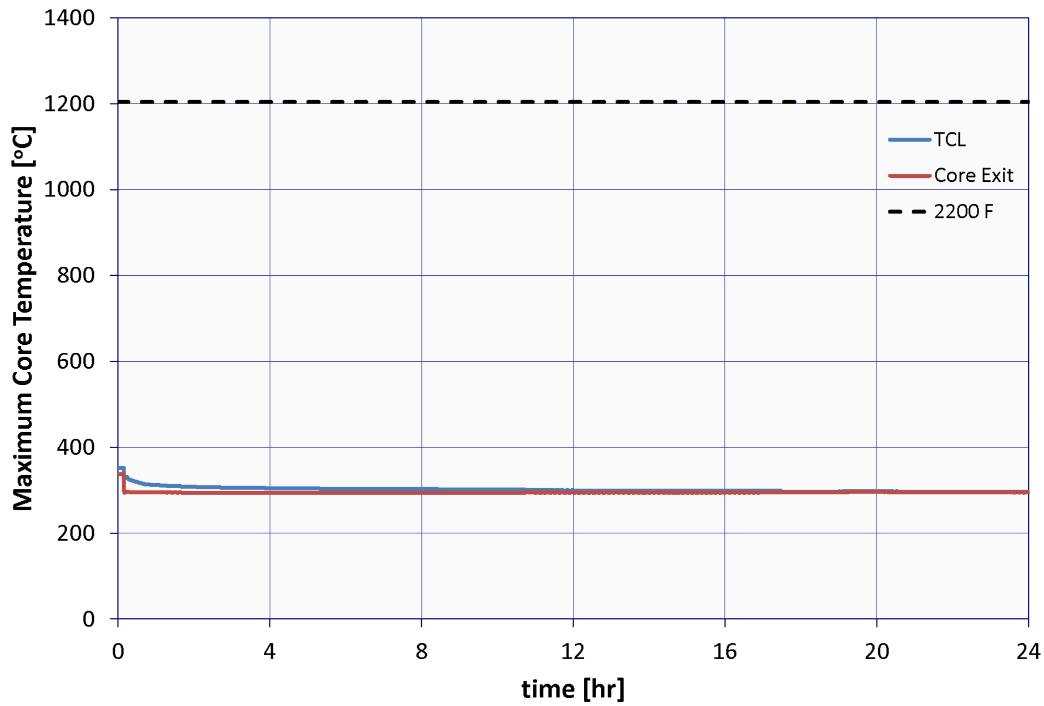


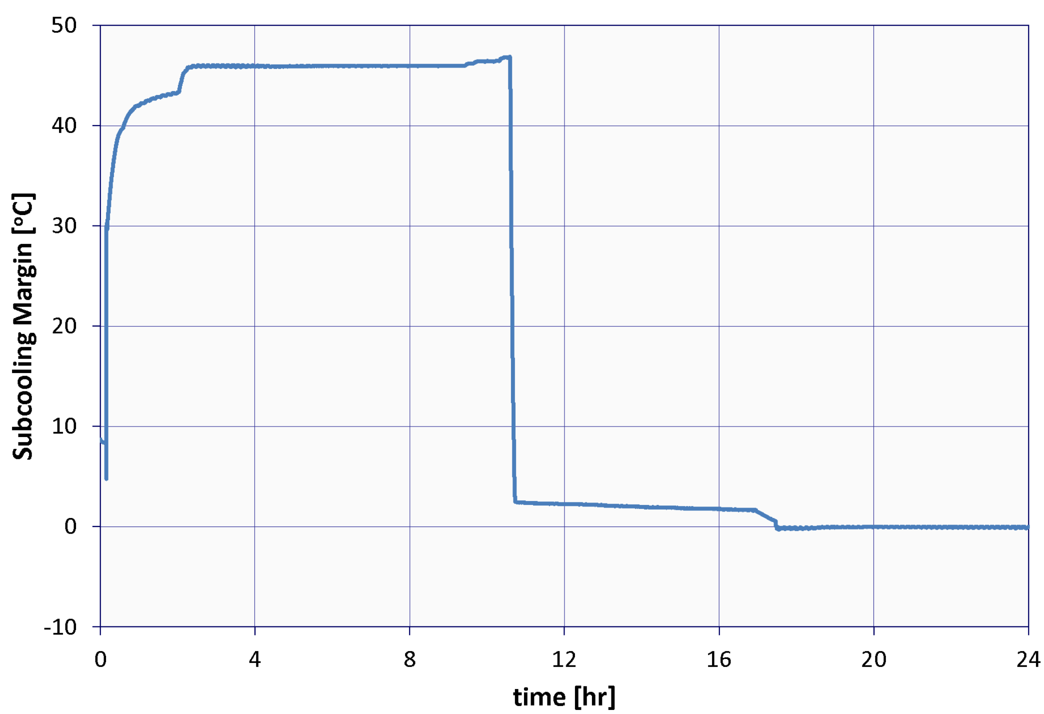
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

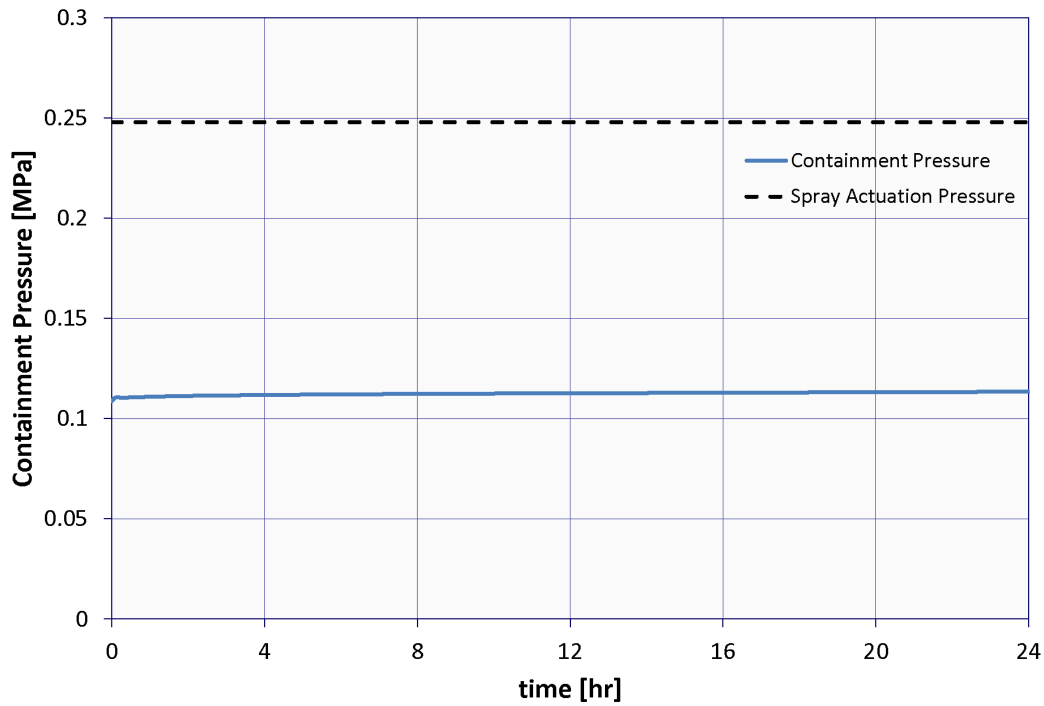


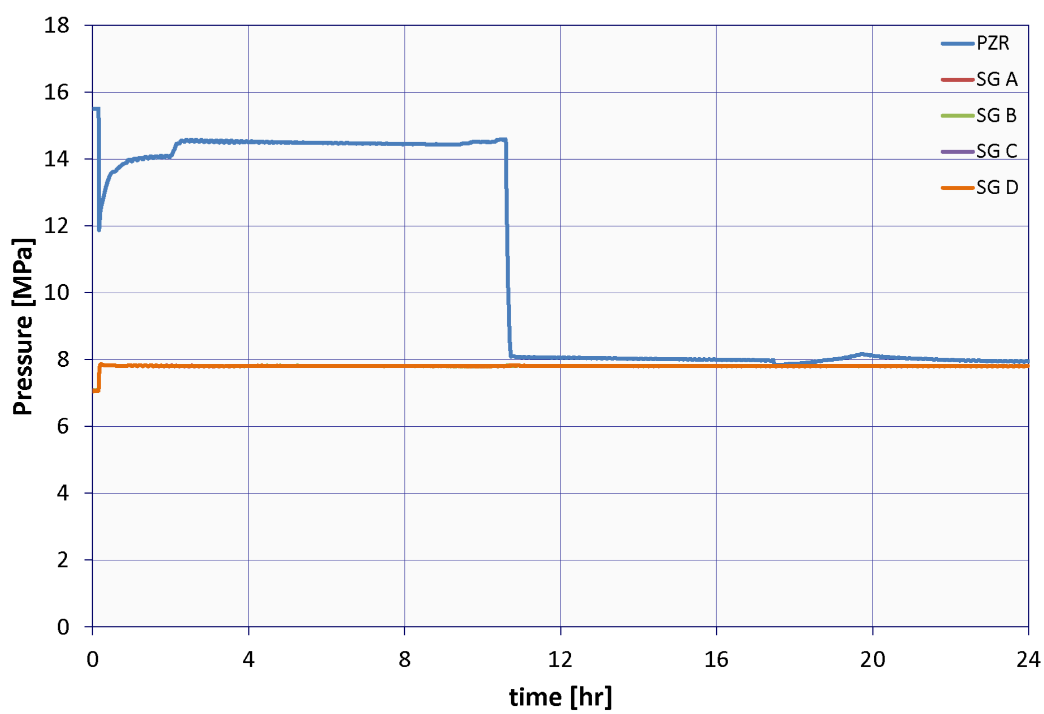
Volume [gal]
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

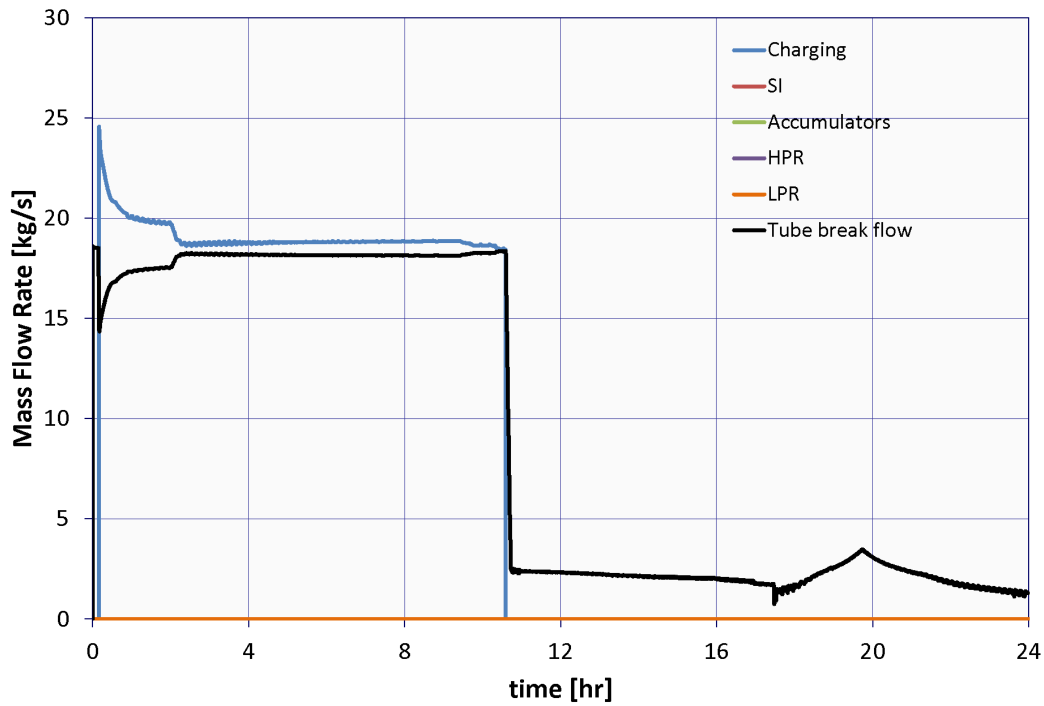
D.1.5 Case 5: 0.5 Tube, Min ECCS, Steam Dumps Available

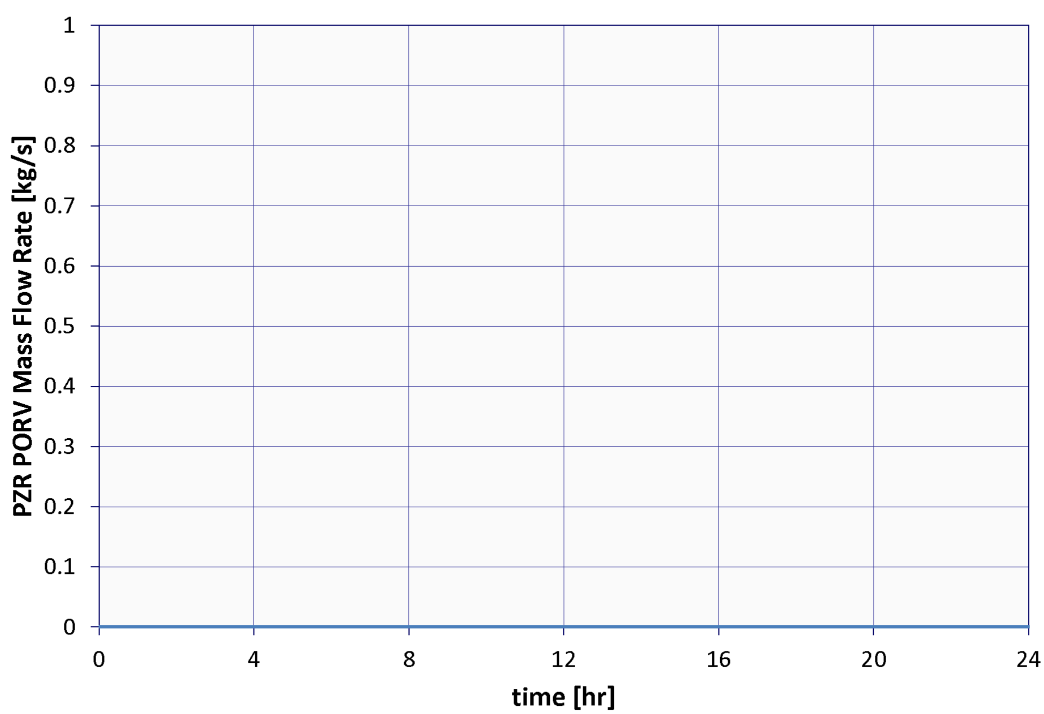


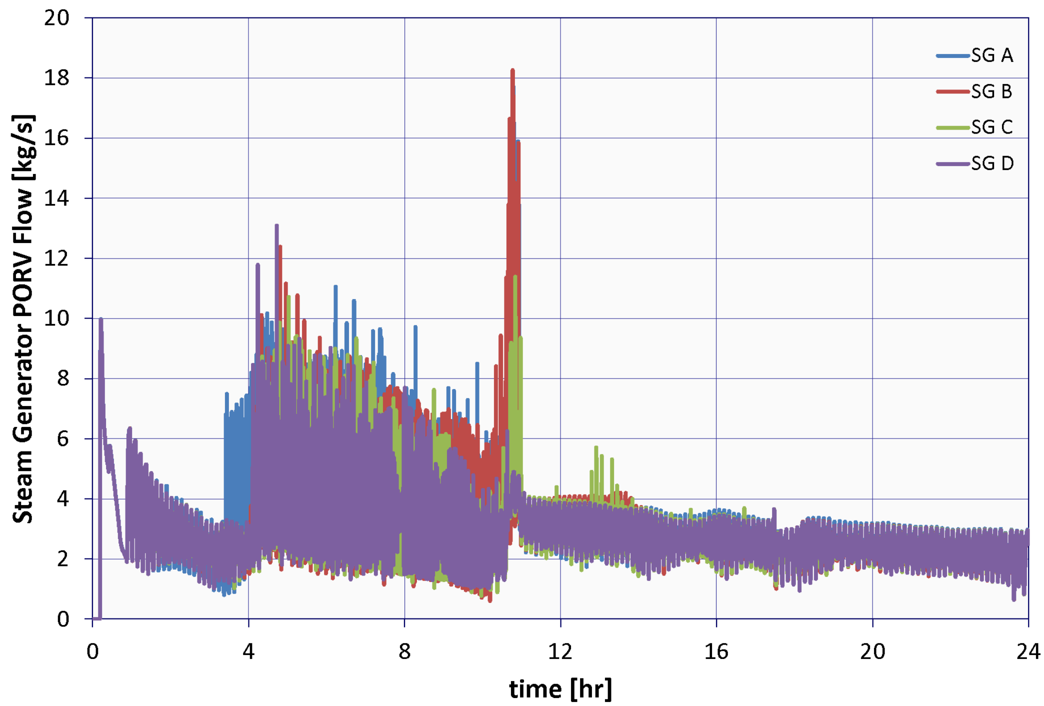


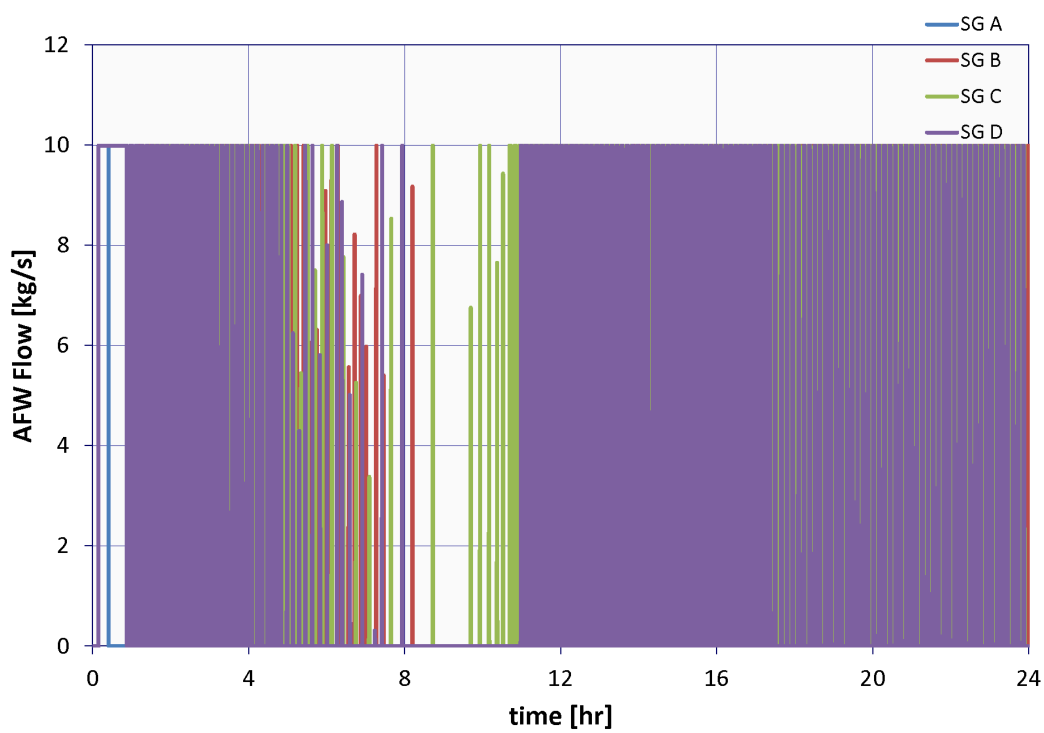

Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24

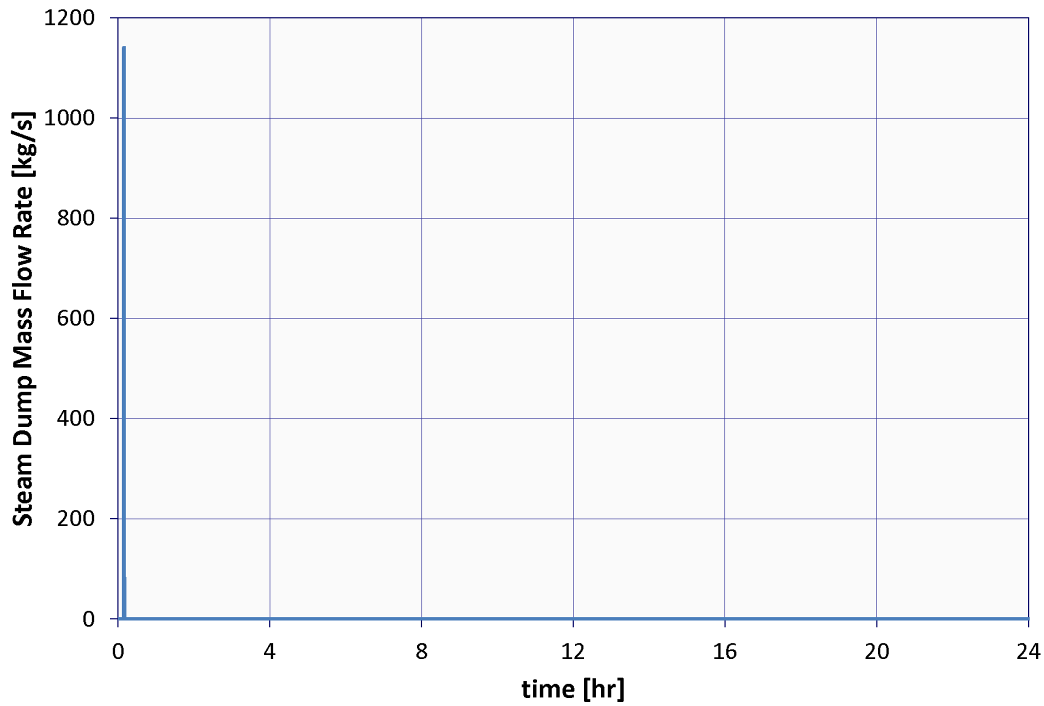

Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24


30
25
20
15
10
5
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow

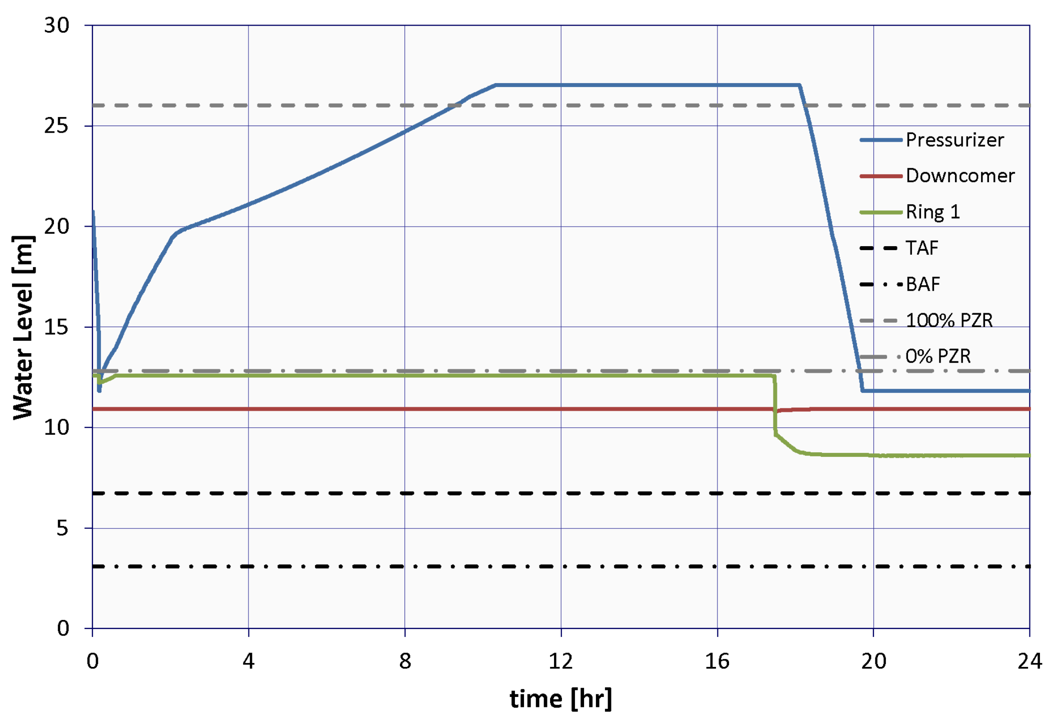

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PZR PORV Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
20
0
4
8
12
16
20
24

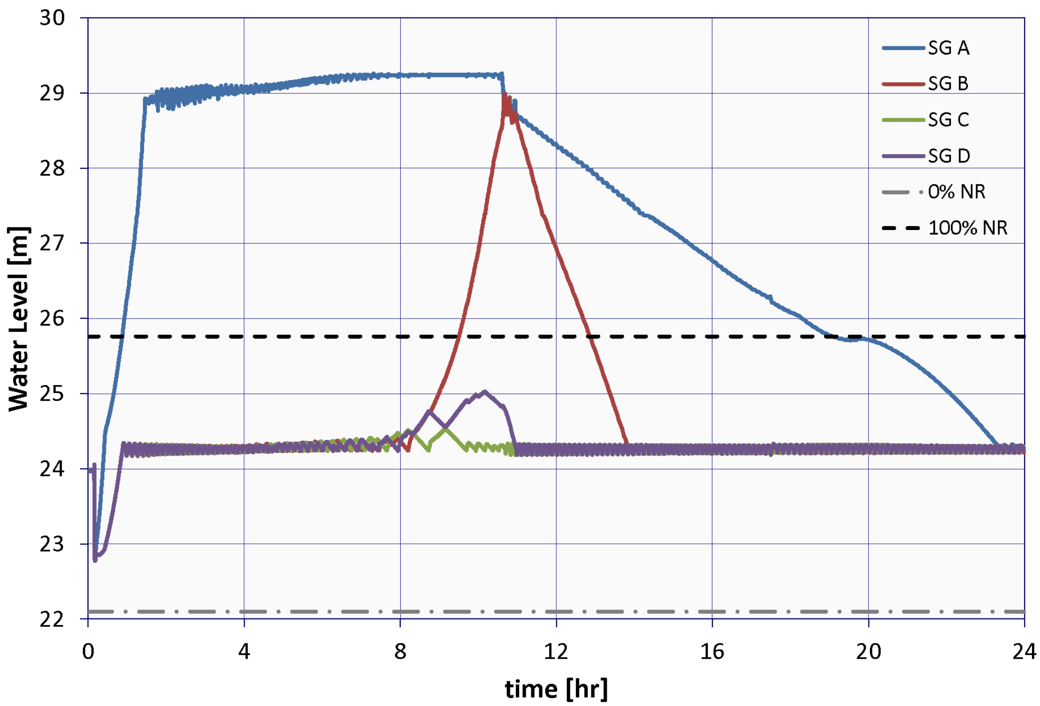

AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

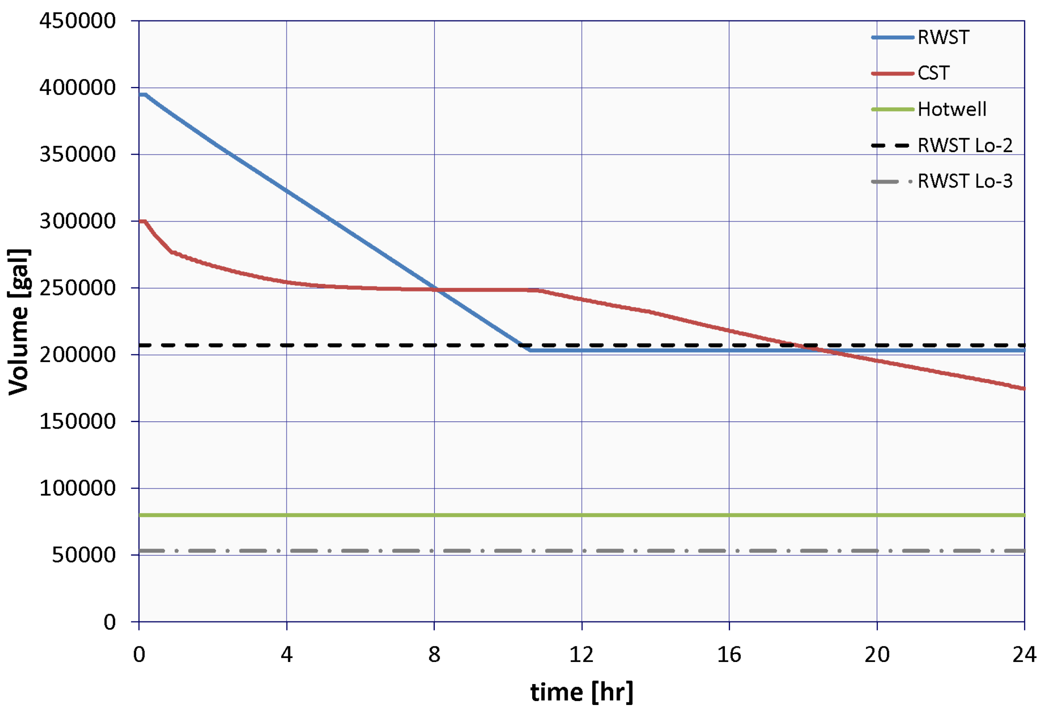


1200
1000
800
600
400
200
0
0
4
8
12
16
20
24
Steam Dump Mass Flow Rate [kg/s]
time [hr]

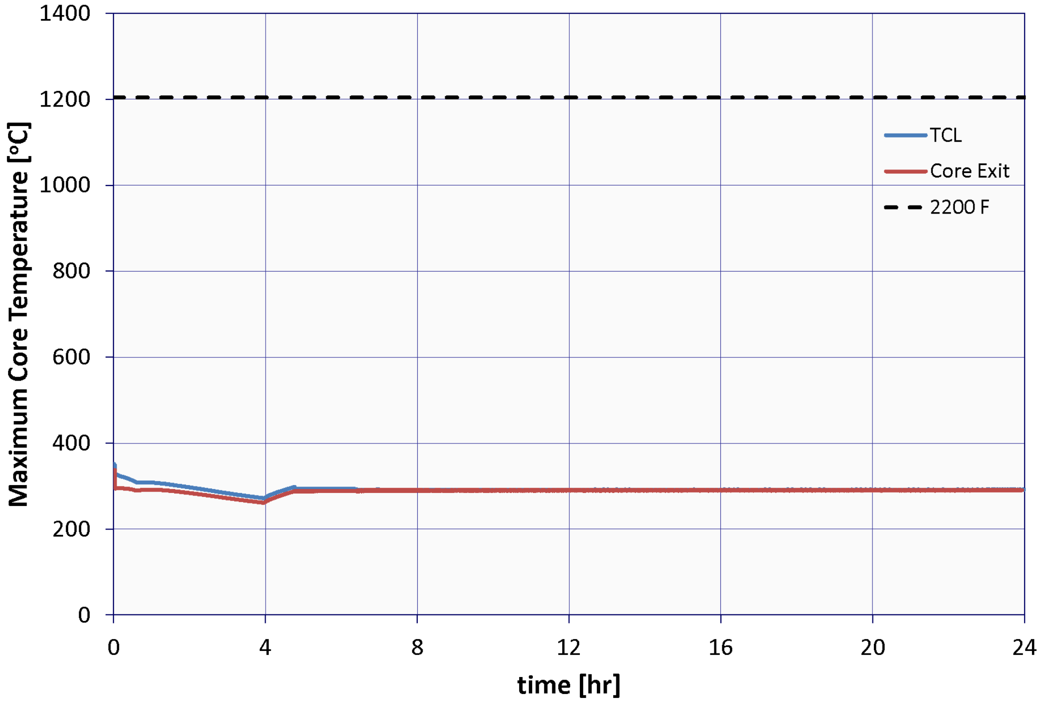


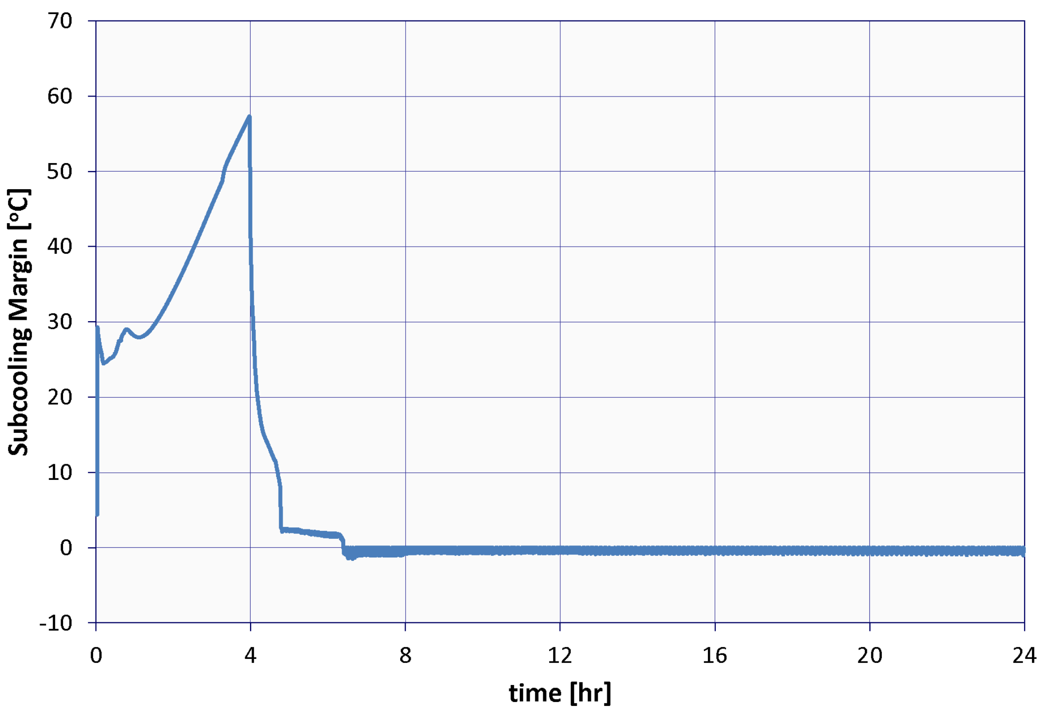
30
25
20
15
10
5
0
0
4
8
12
16
20
24
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

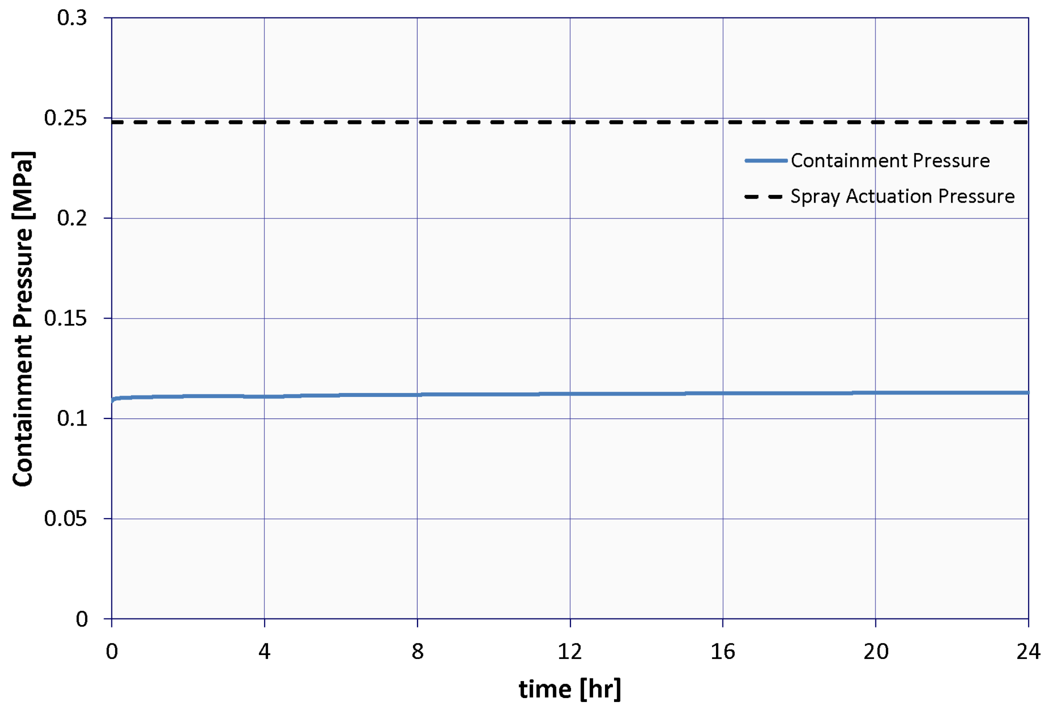

Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
30
29
28
27
26
25
24
23
22
0
4
8
12
16
20
24

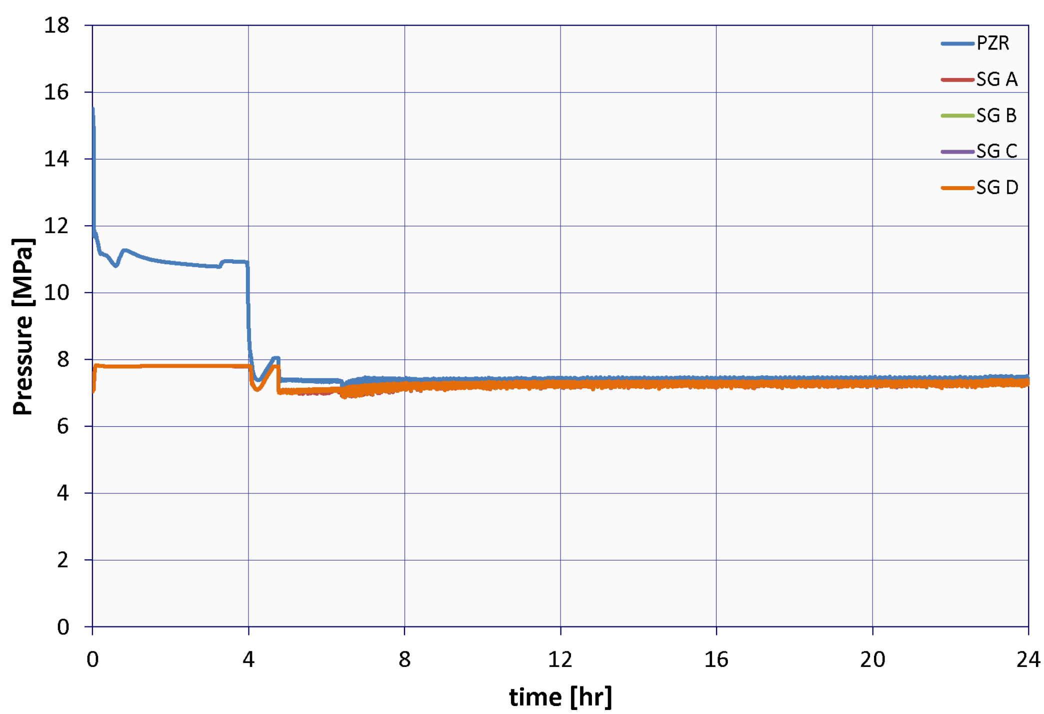

Volume [gal]
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24

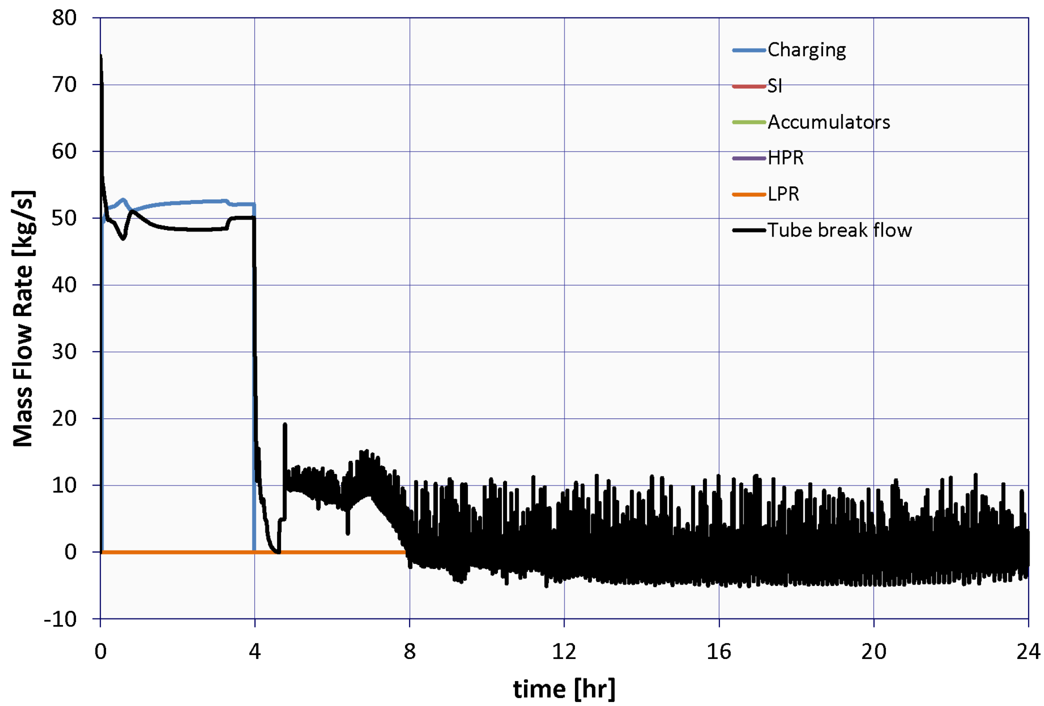
D.1.6 Case 6: 2 Tubes, Max ECCS, Steam Dumps Available

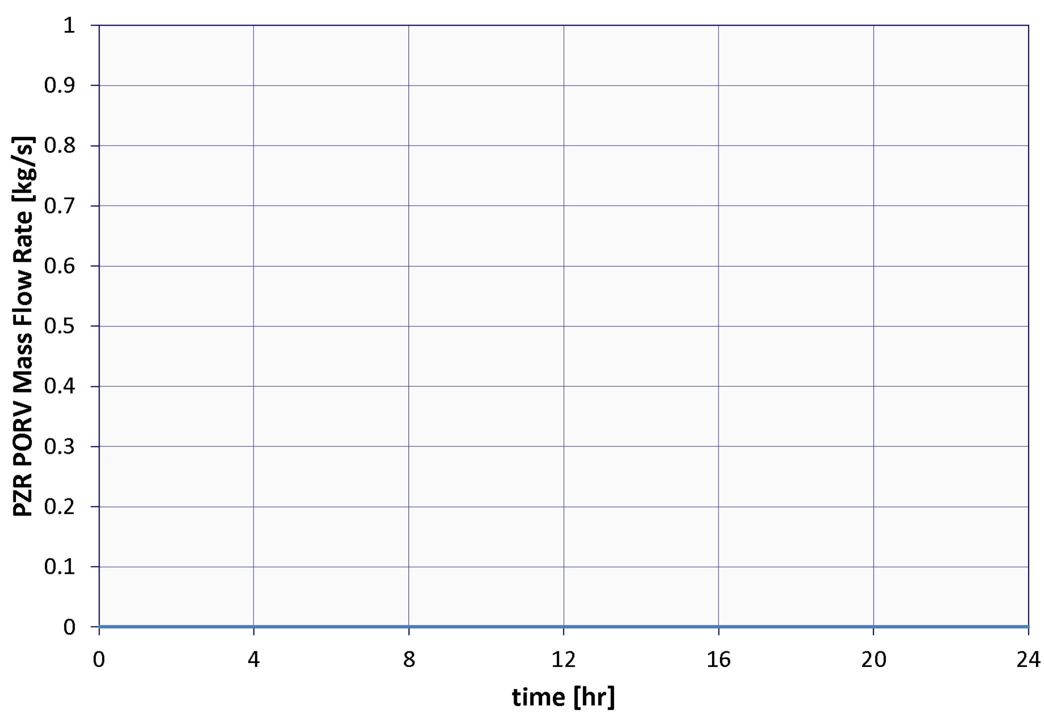


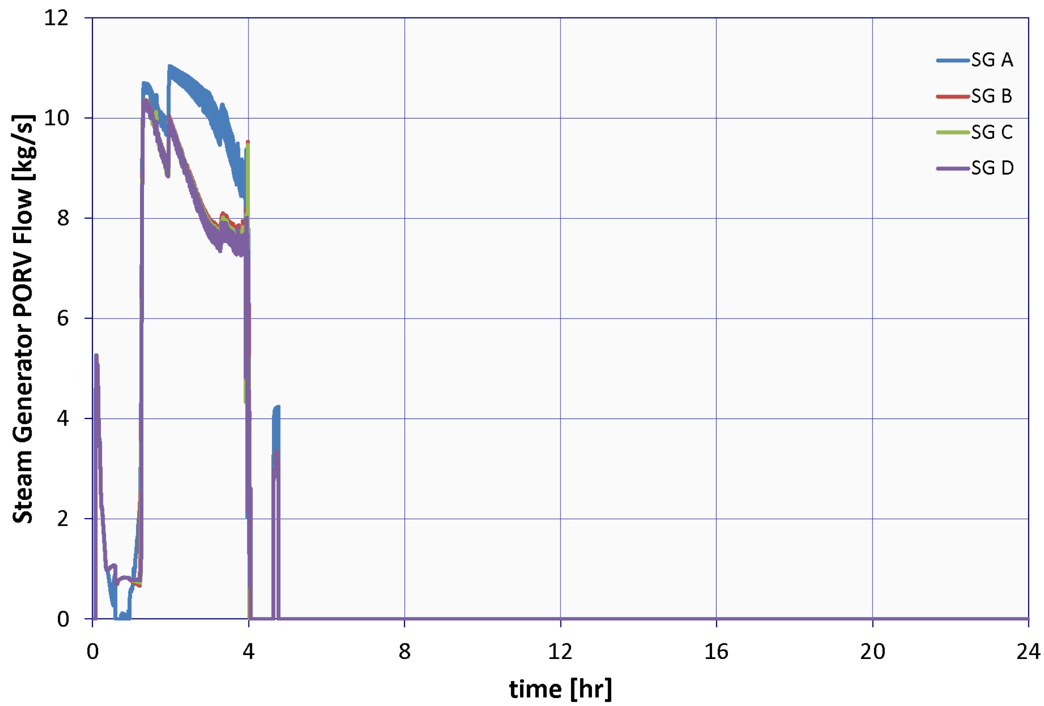



0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
Containment Pressure
Spray Actuation Pressure
0
4
8
12
16
20
24
time [hr]

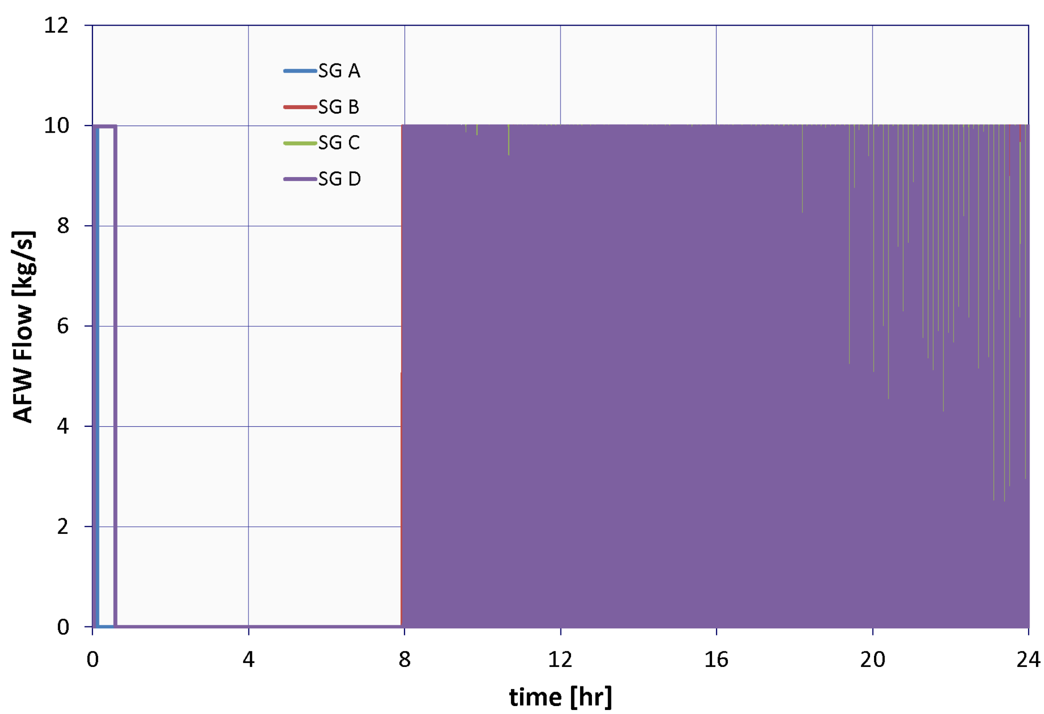

18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
PZR
SG A
SG B
SG C
SG D
0
4
8
12
16
20
24
time [hr]


Mass Flow Rate [kg/s]
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow

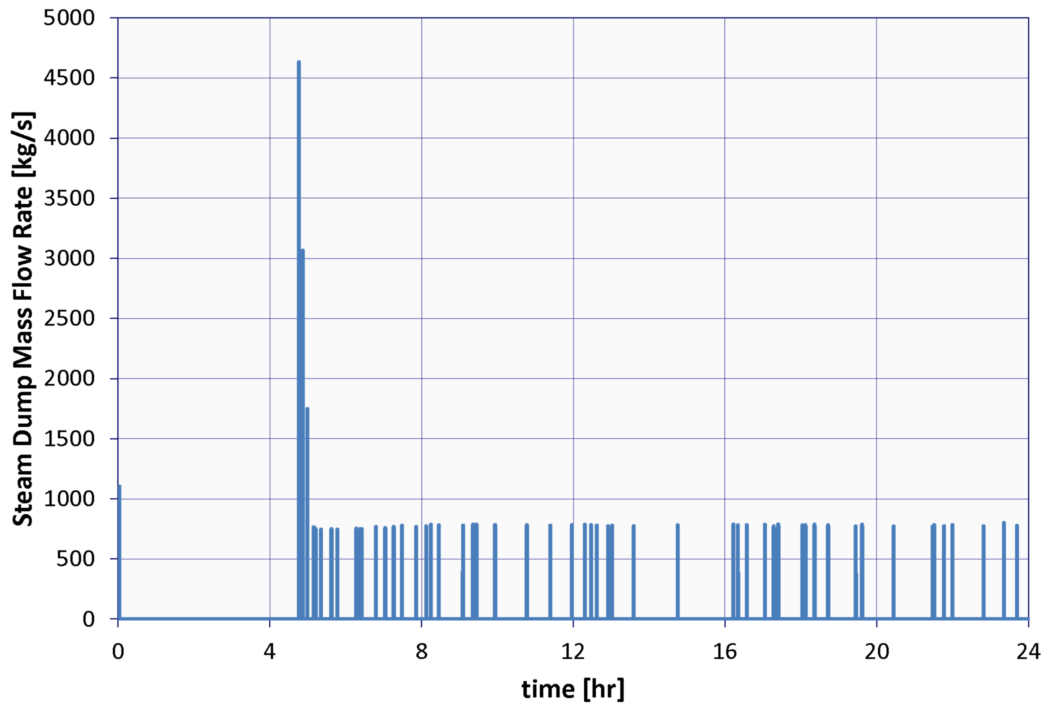

PZR PORV Mass Flow Rate [kg/s]
time [hr]



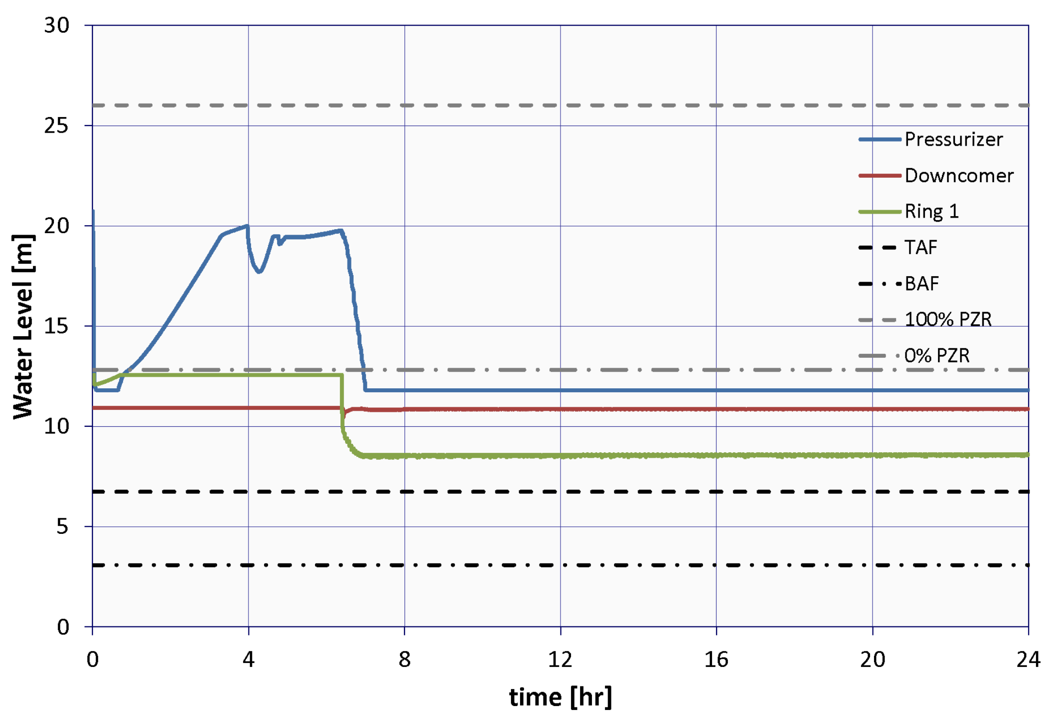
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



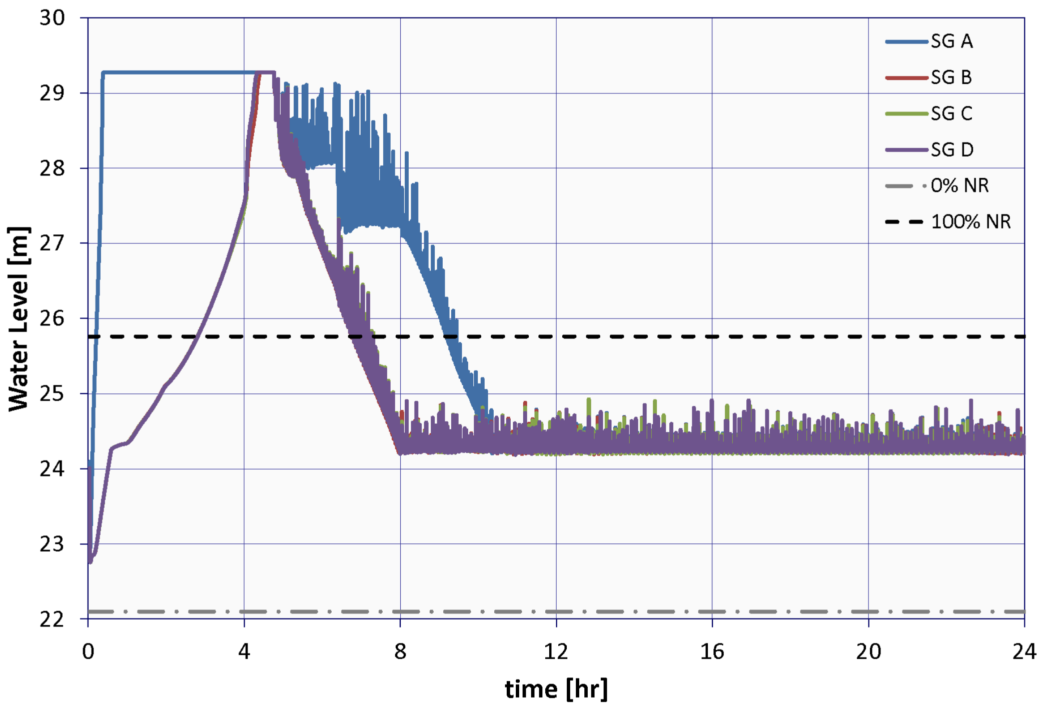
AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

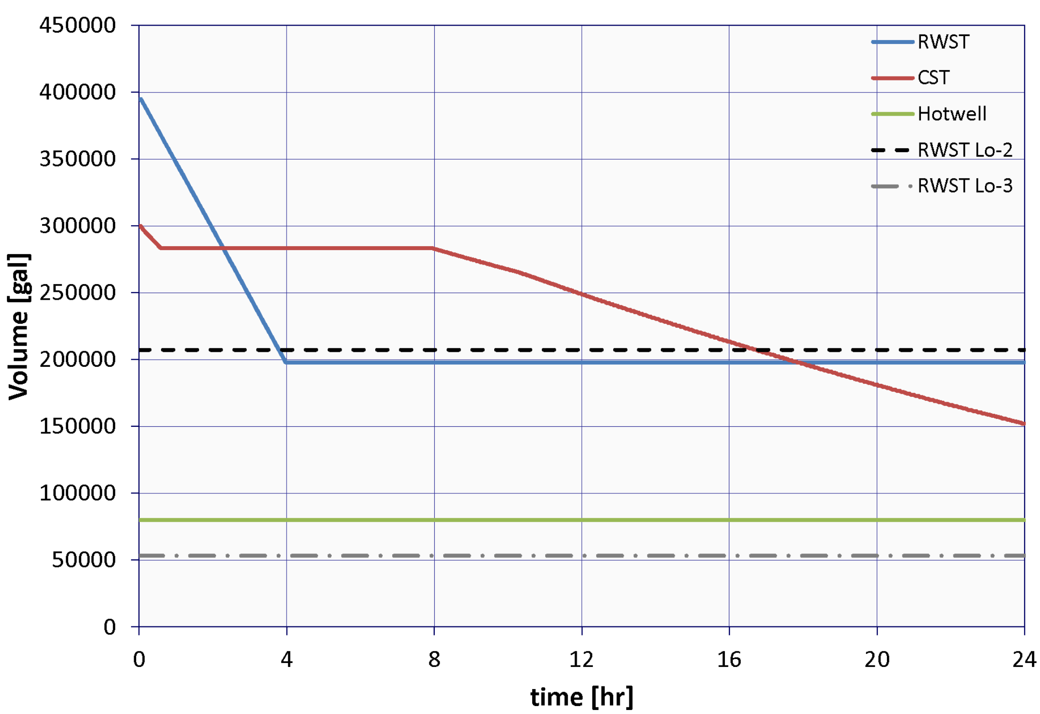


Steam Dump Mass Flow Rate [kg/s]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
4
8
12
16
20
24
time [hr]

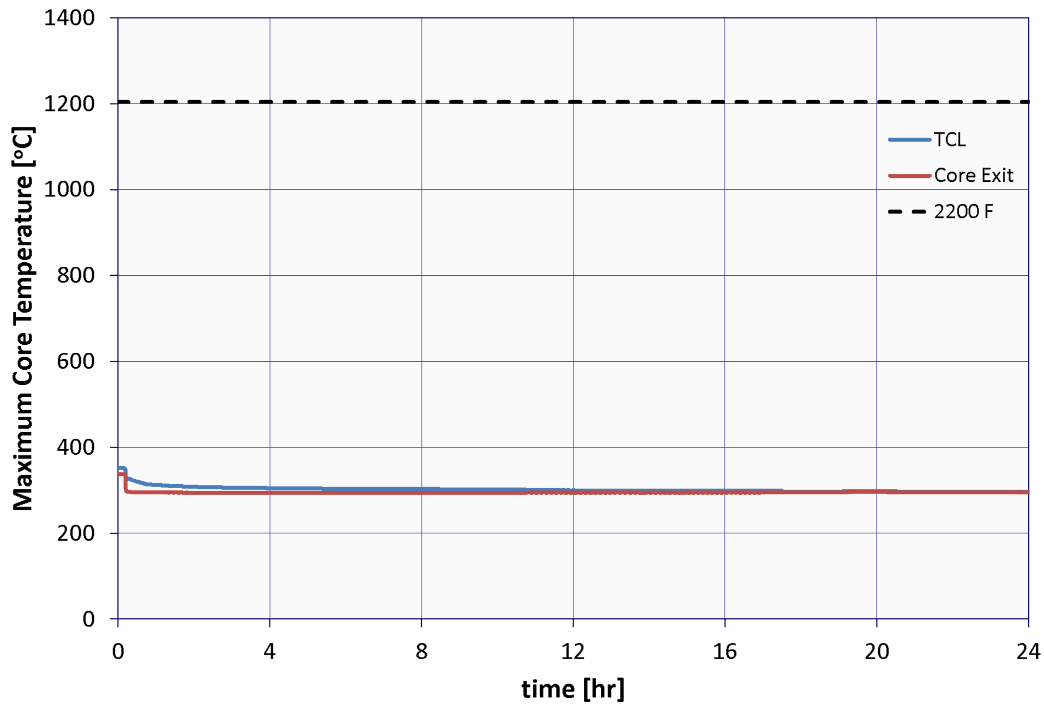


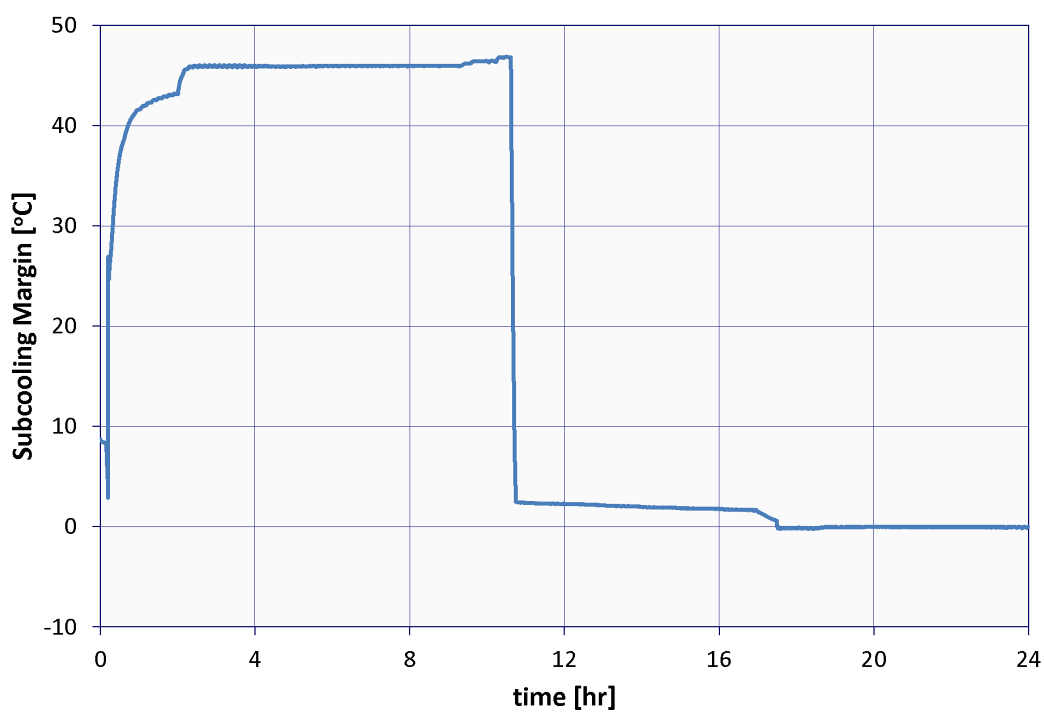
Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

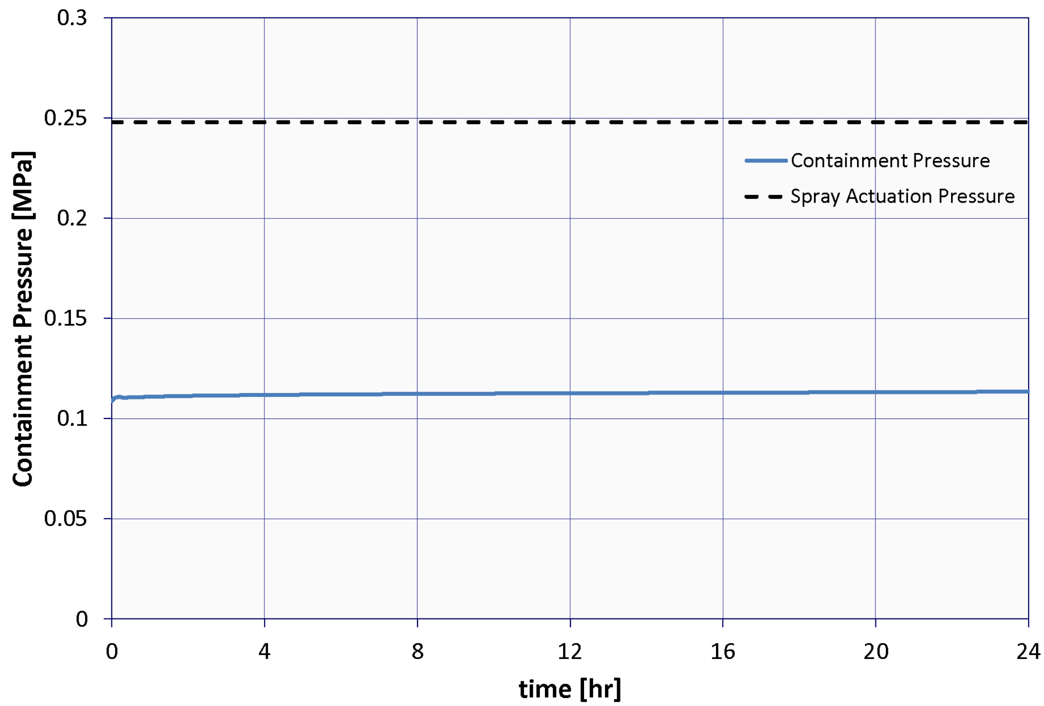

30
29
28
27
26
25
24
23
22
0
4
8
12
16
20
24
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24
Volume [gal]
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

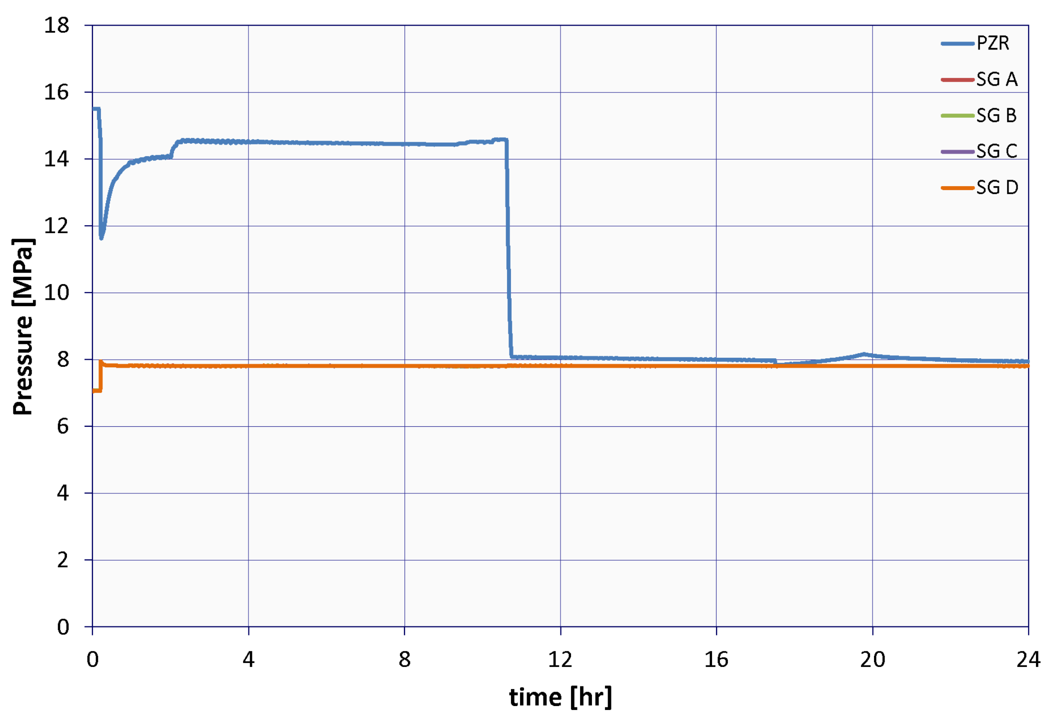
D.1.7 Case 7: 0.5 Tube, Min ECCS, Automatic Scram, No Steam Dumps



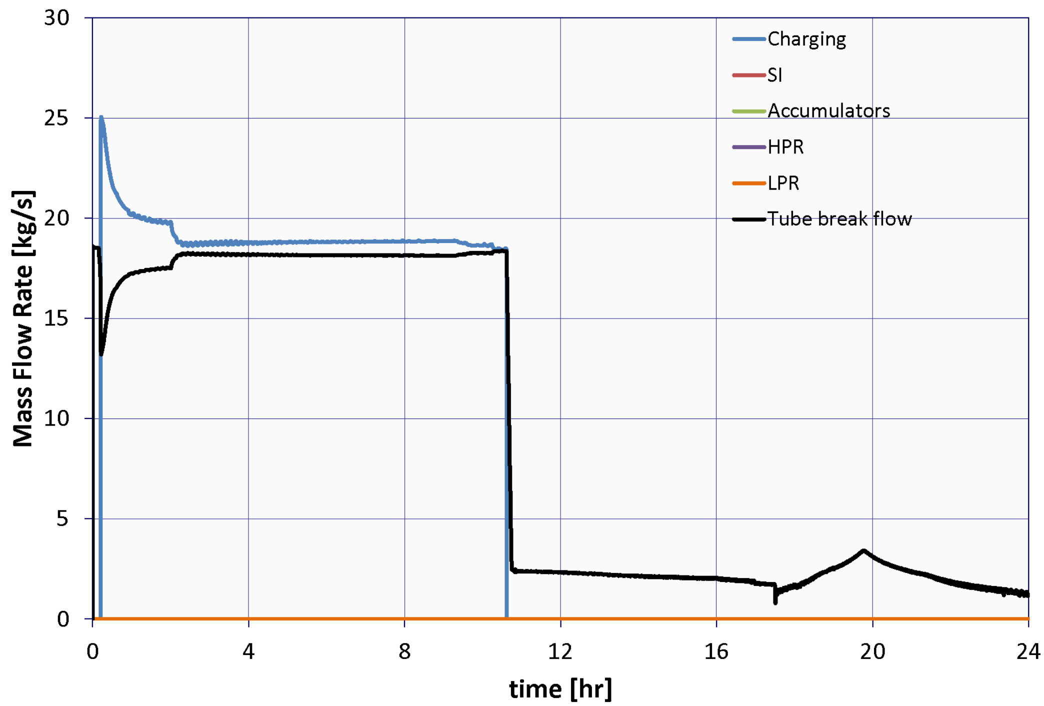




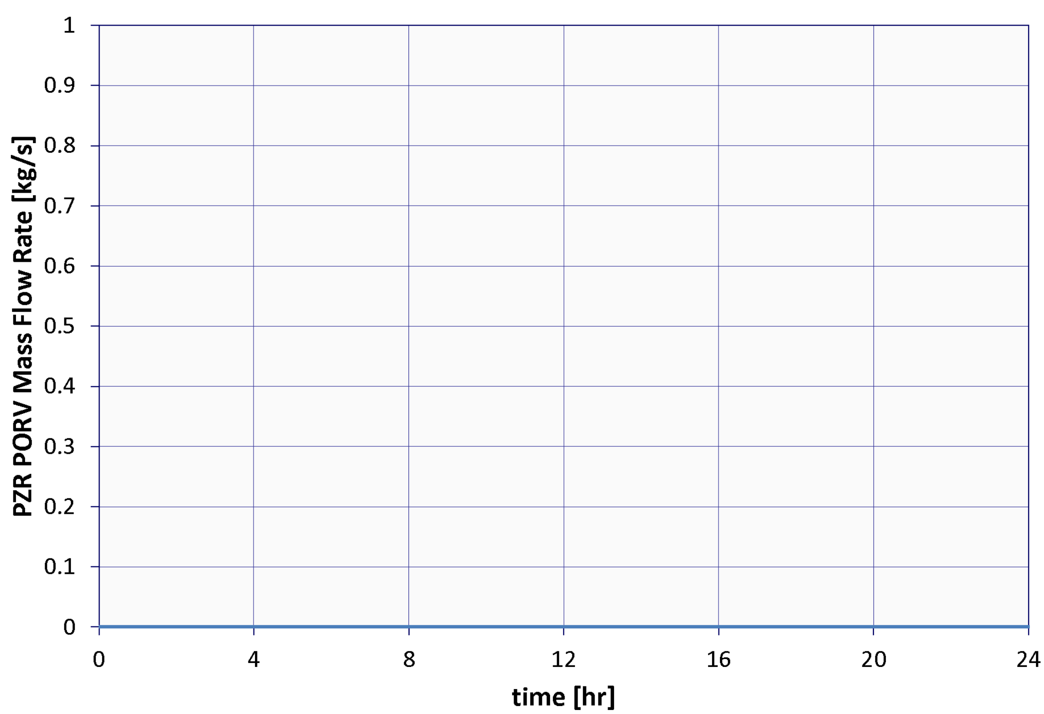
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure



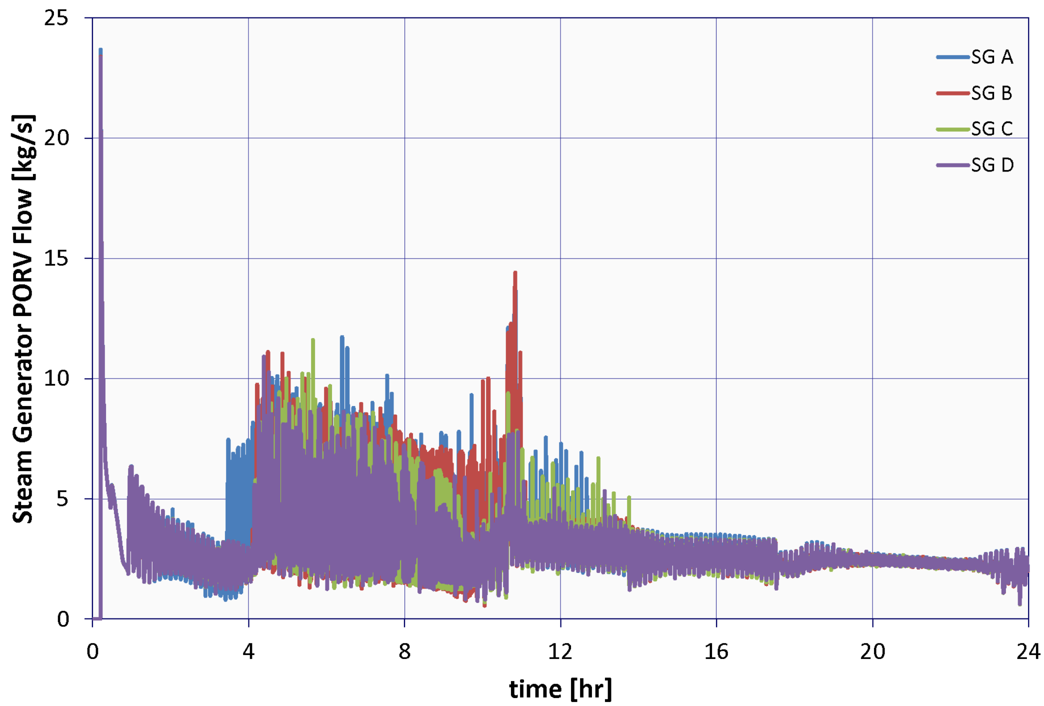
18
16
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



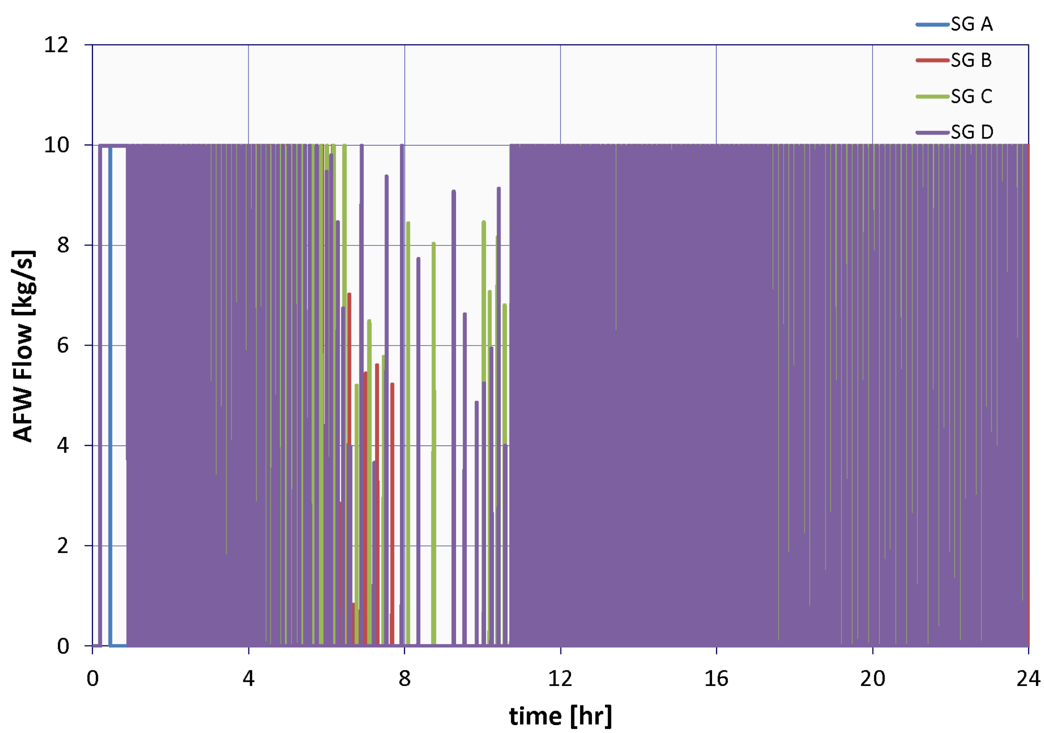
30
25
20
15
10
5
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow



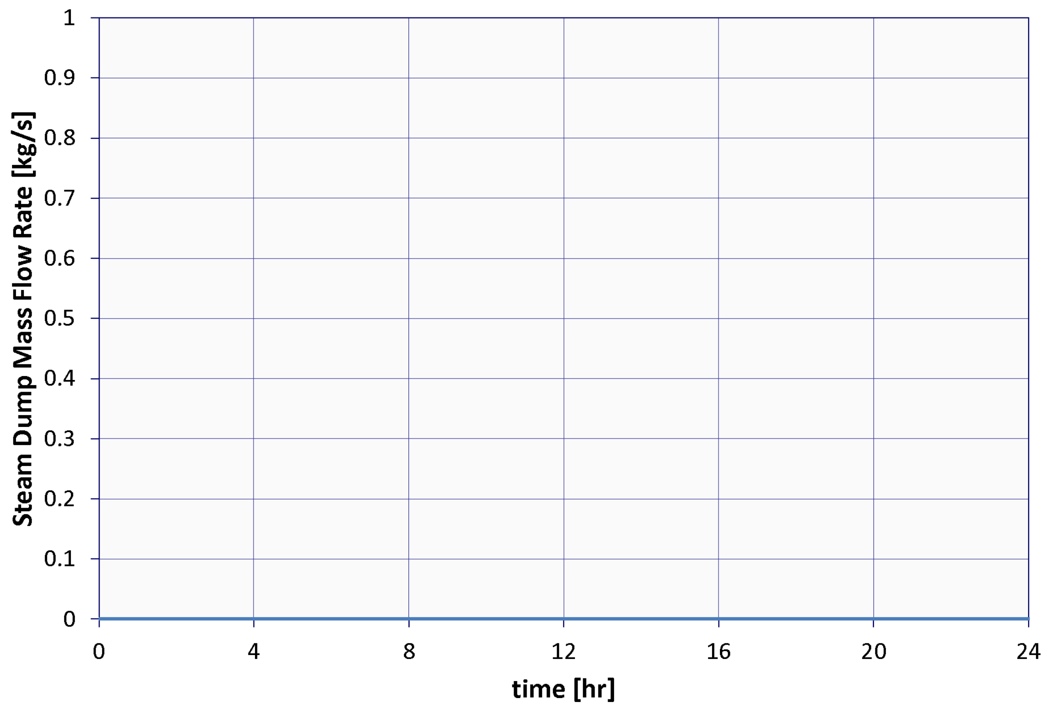
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PZR PORV Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]



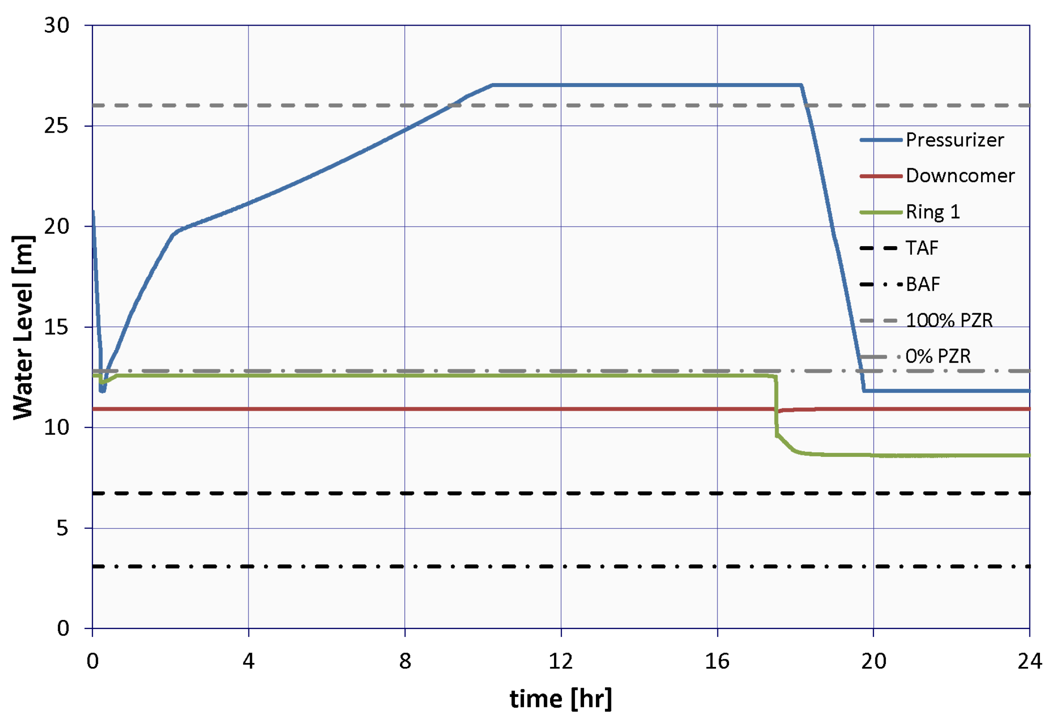
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



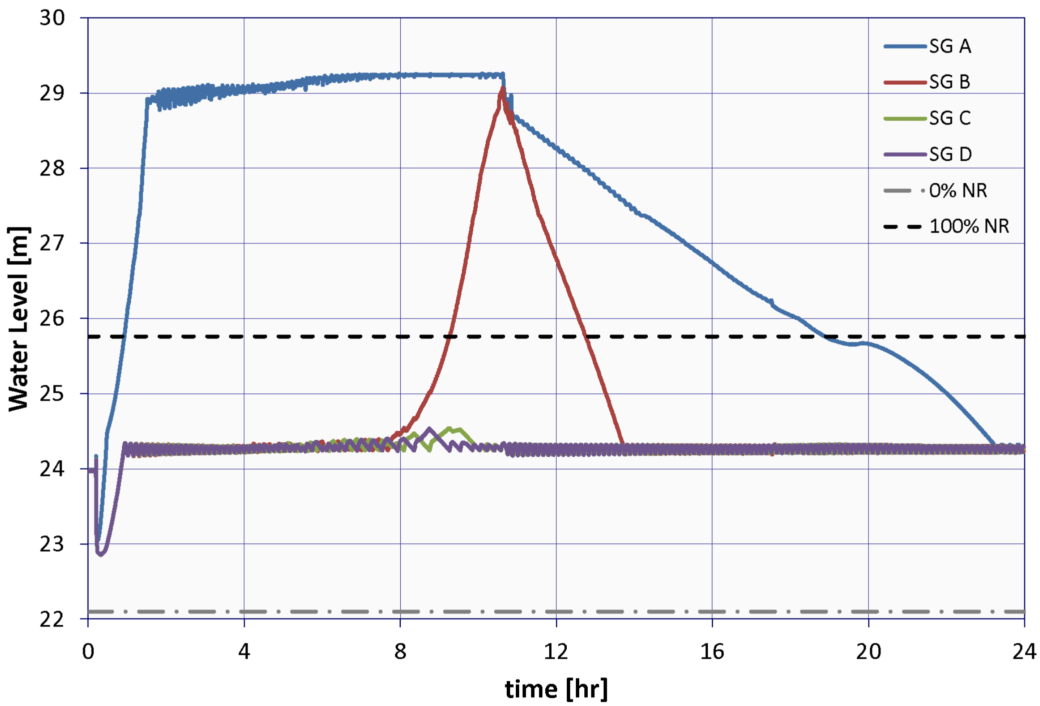
AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



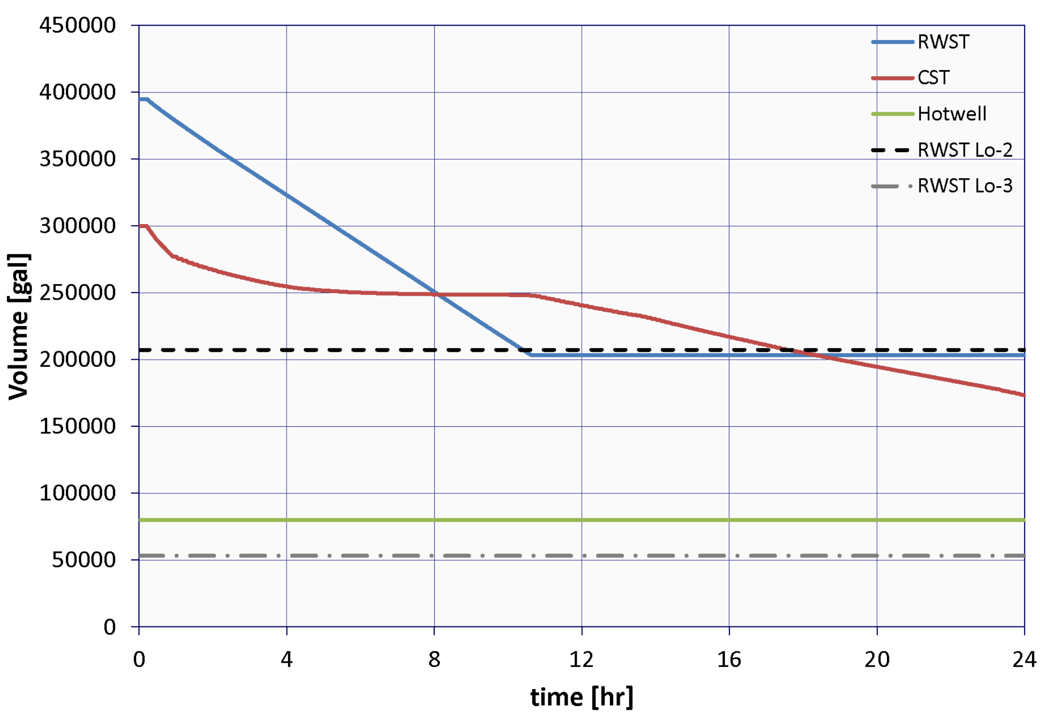
Steam Dump Mass Flow Rate [kg/s]
time [hr]



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

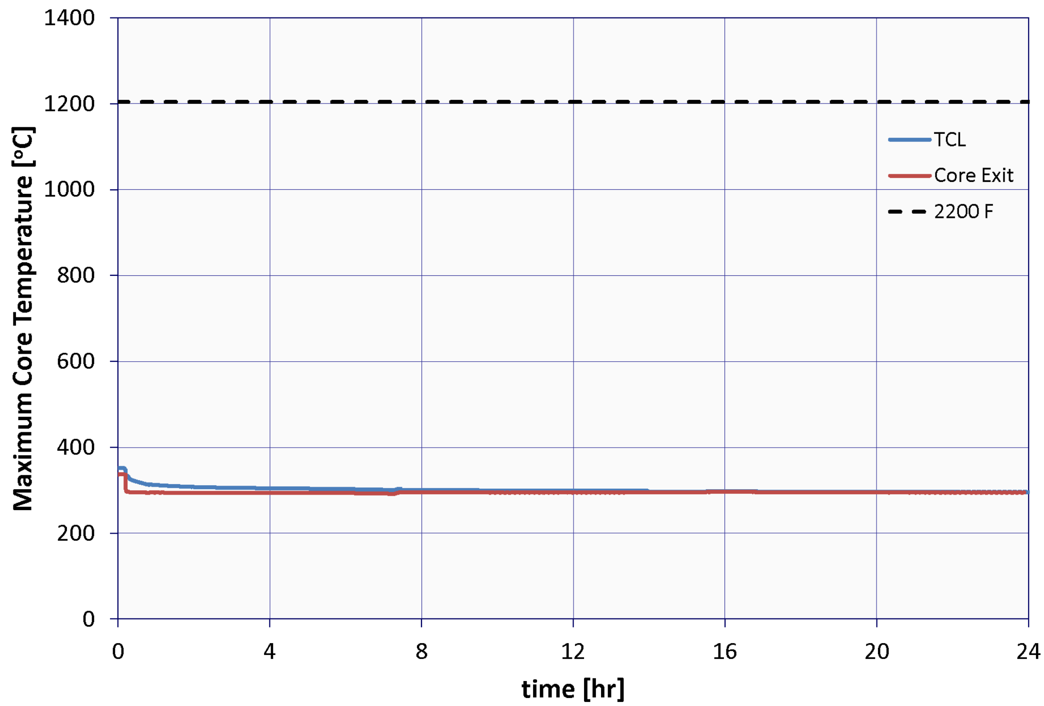


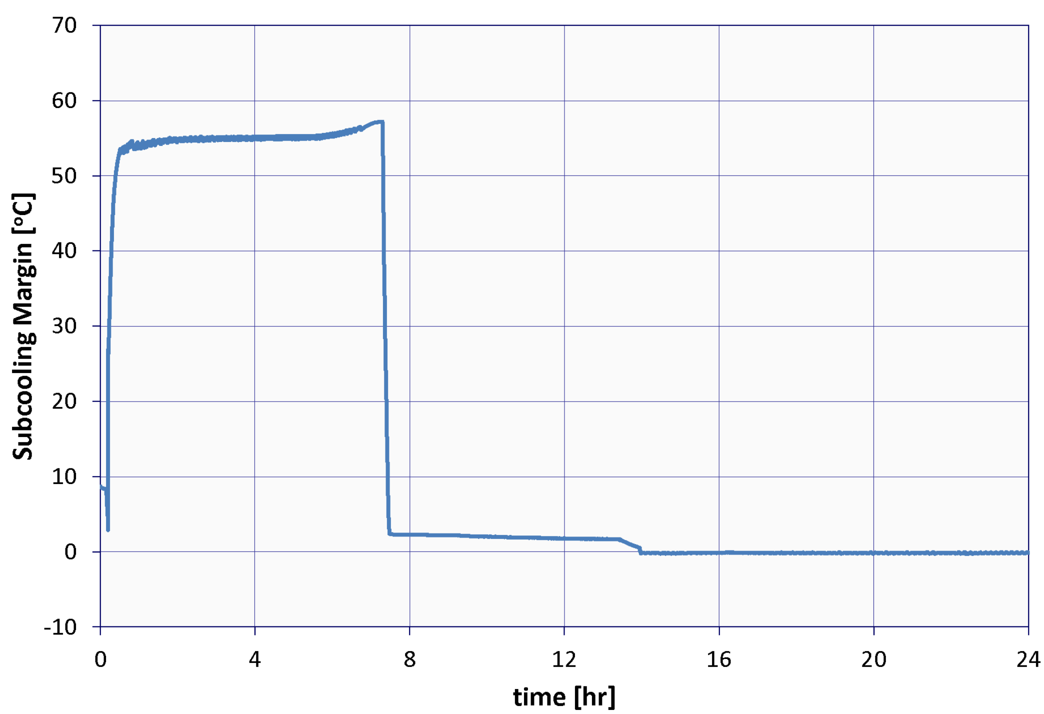
30
29
28
27
26
25
24
23
22
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

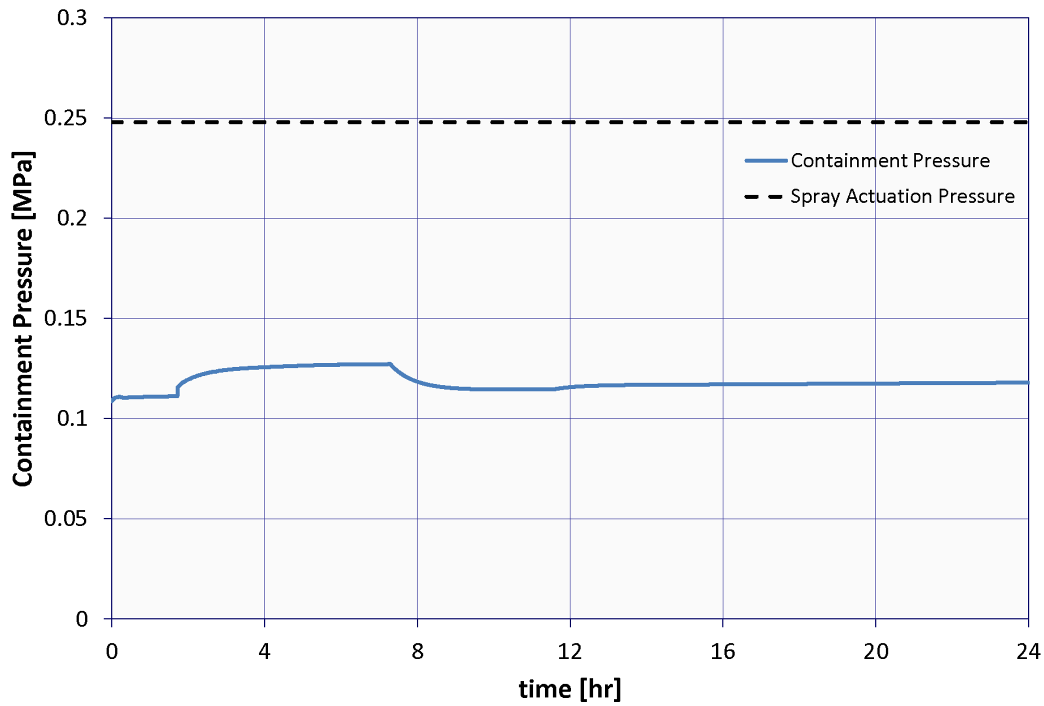


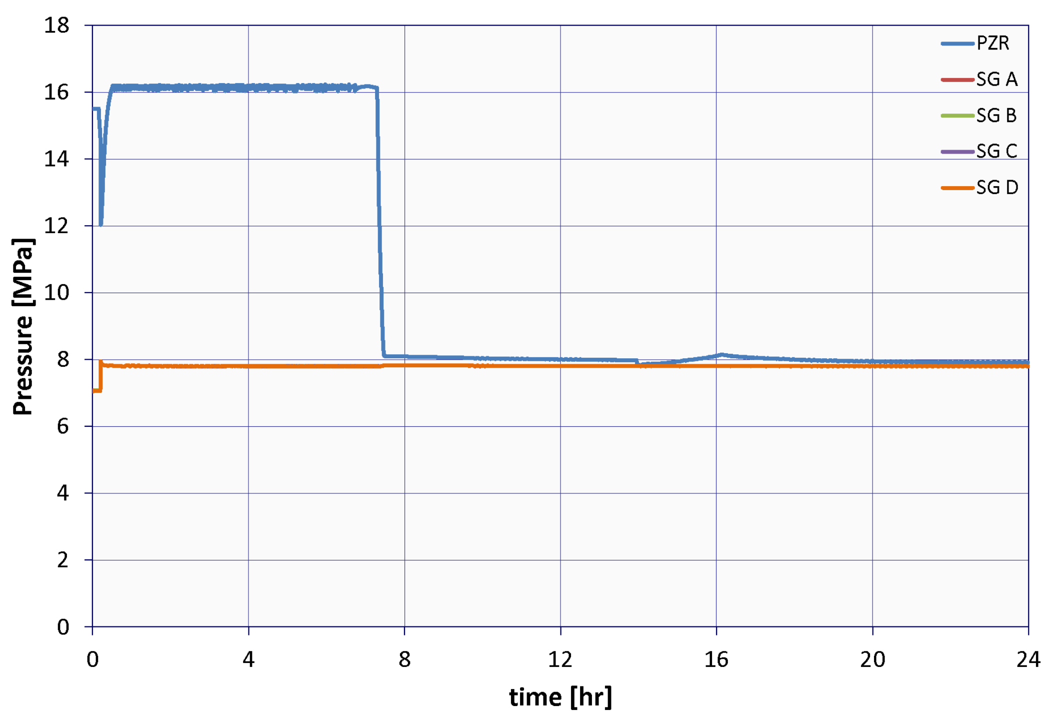
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

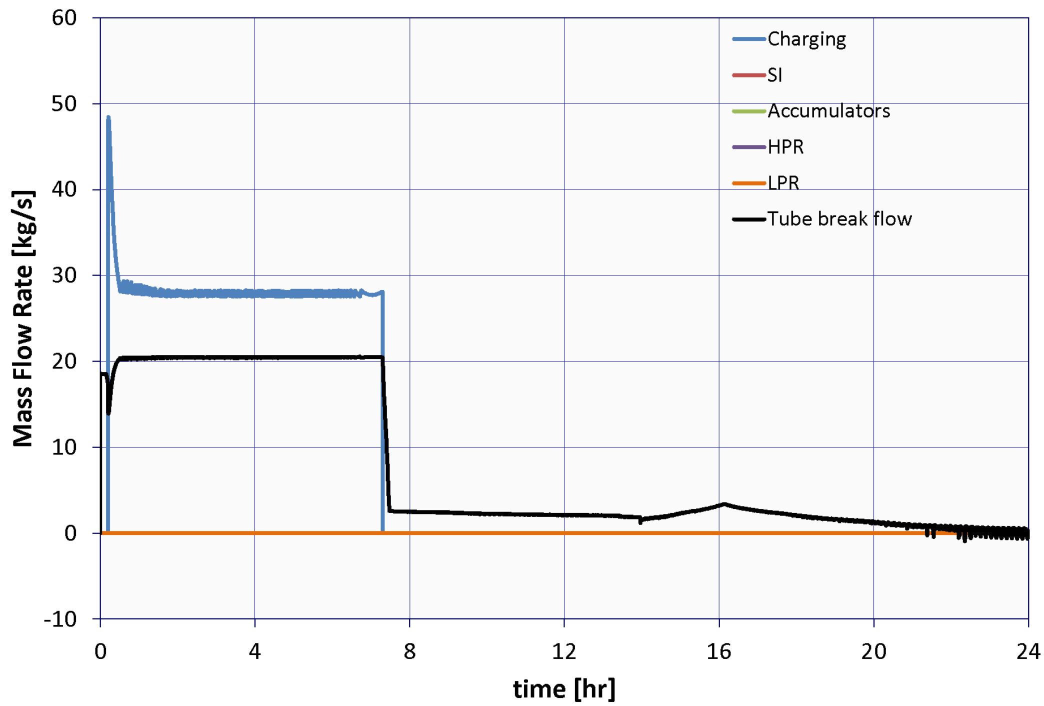
D.1.8 Case 8: 0.5 Tube, Max ECCS, Automatic Scram, No Steam Dumps



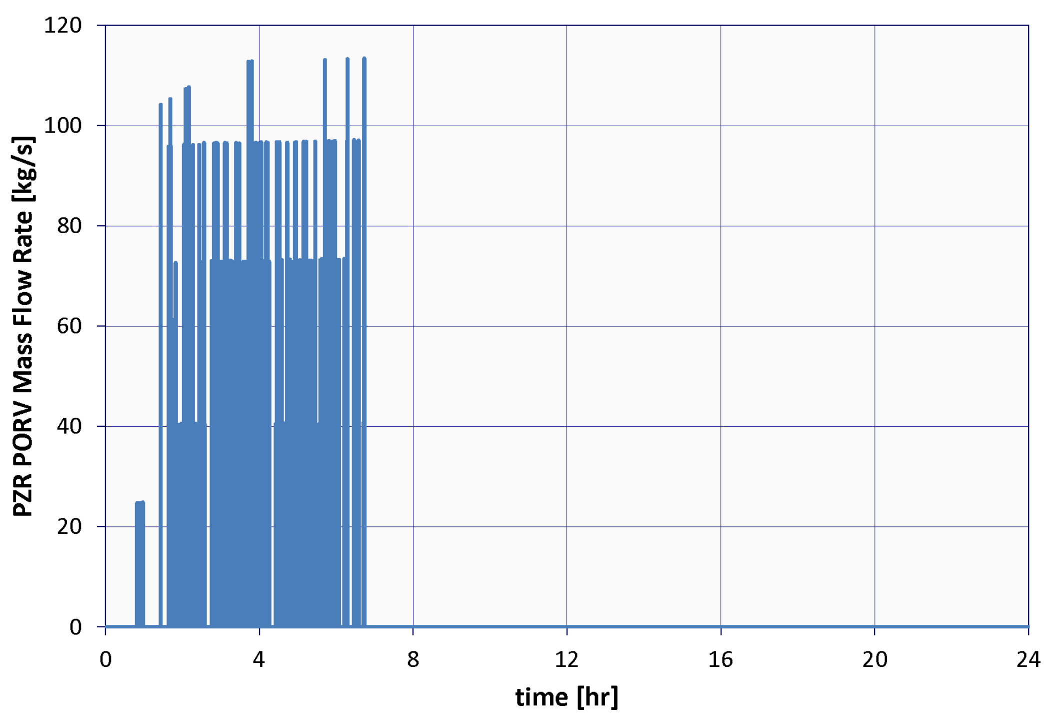



Containment Pressure
Spray Actuation Pressure
Containment Pressure [MPa]
time [hr]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24

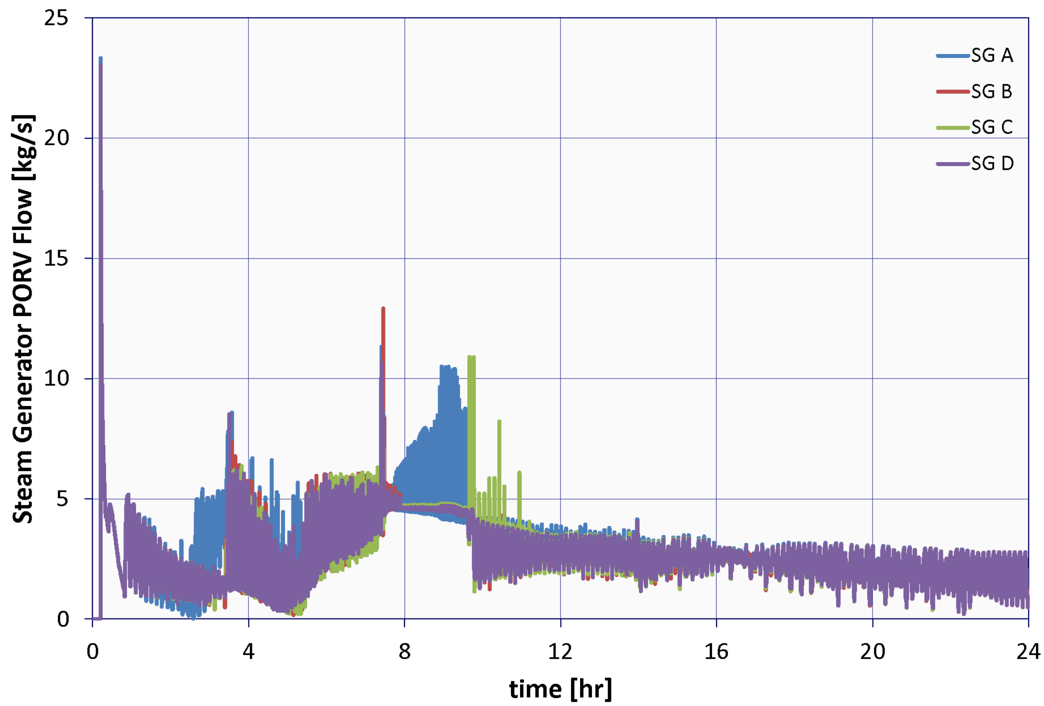

PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]
18
16
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24



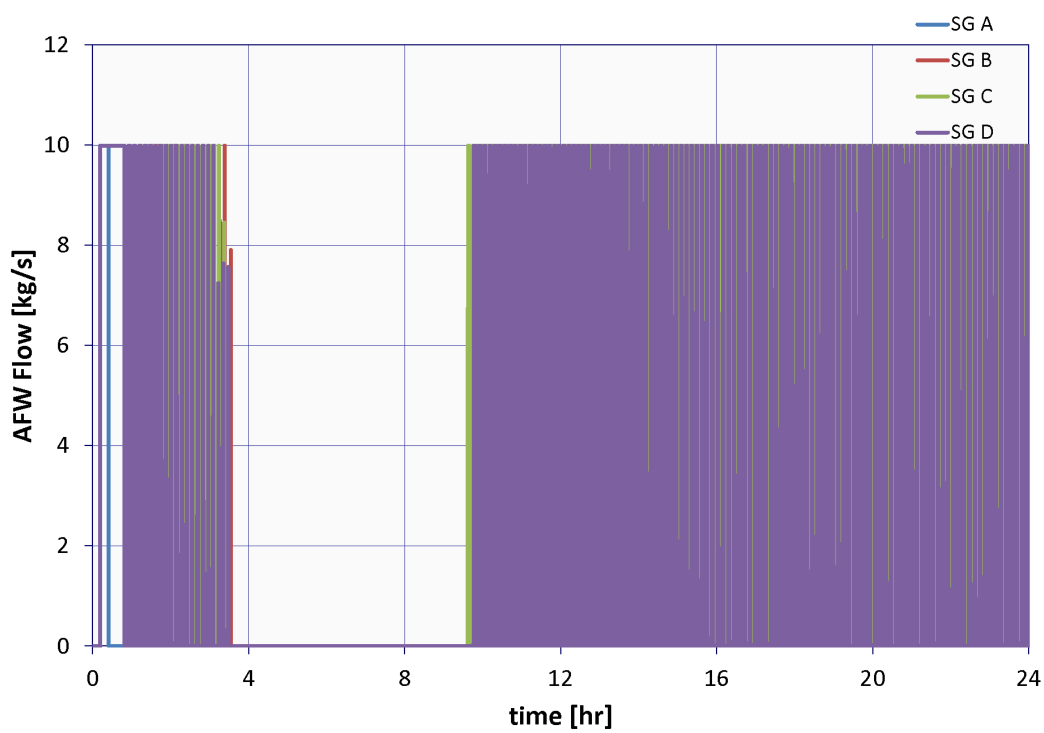
Mass Flow Rate [kg/s]
60
50
40
30
20
10
0
-10
0
4
8
12
16
20
24
time [hr]
Charging
SI
Accumulators
HPR
LPR
Tube break flow



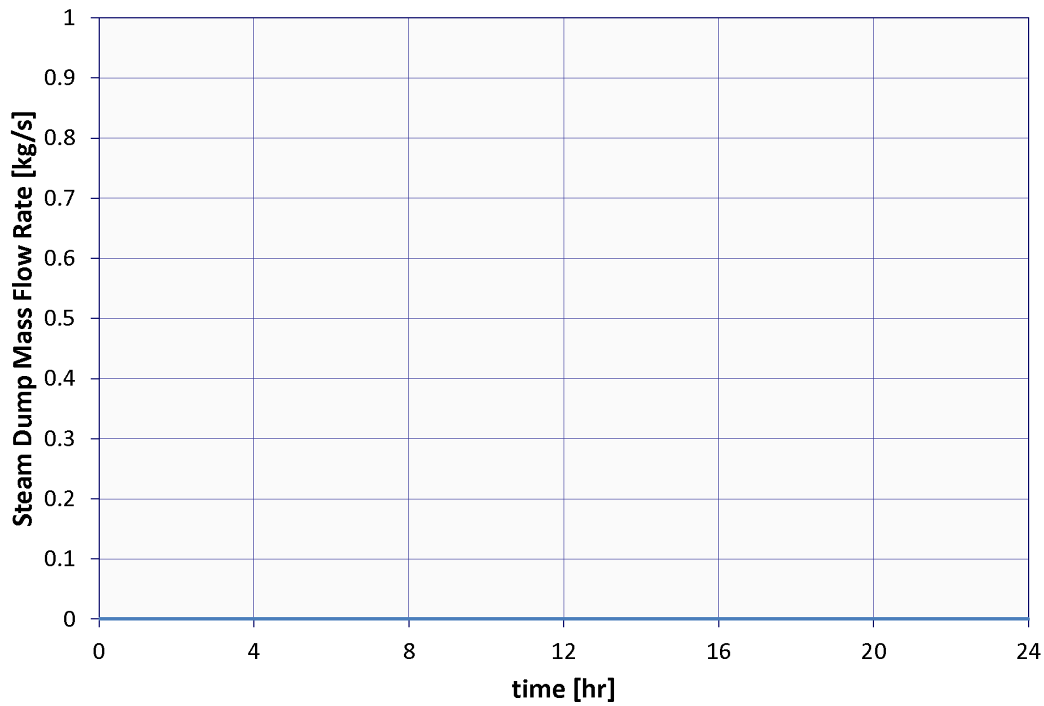
PZR PORV Mass Flow Rate [kg/s]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]

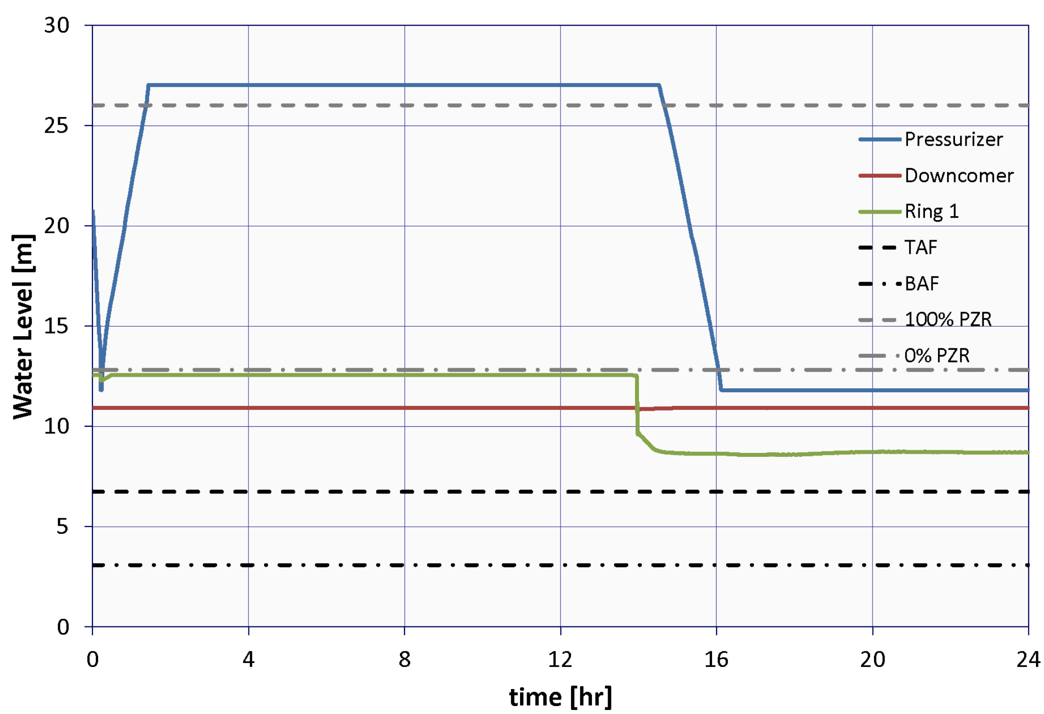


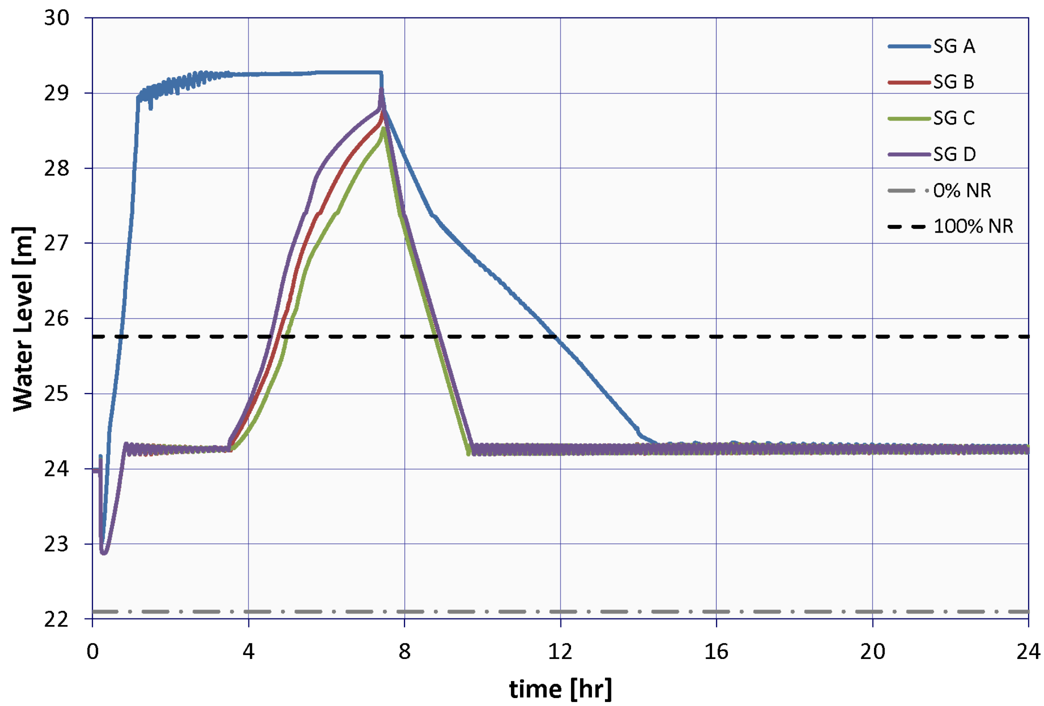
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

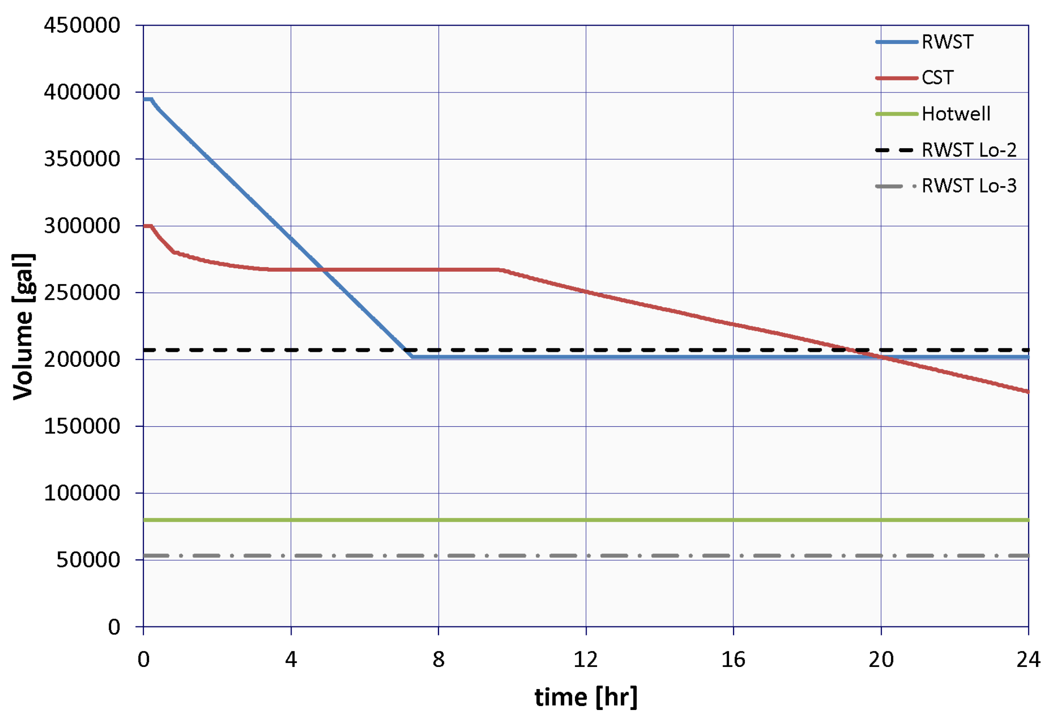


AFW Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D


Steam Dump Mass Flow Rate [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]


Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR


Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
30
29
28
27
26
25
24
23
22
0
4
8
12
16
20
24

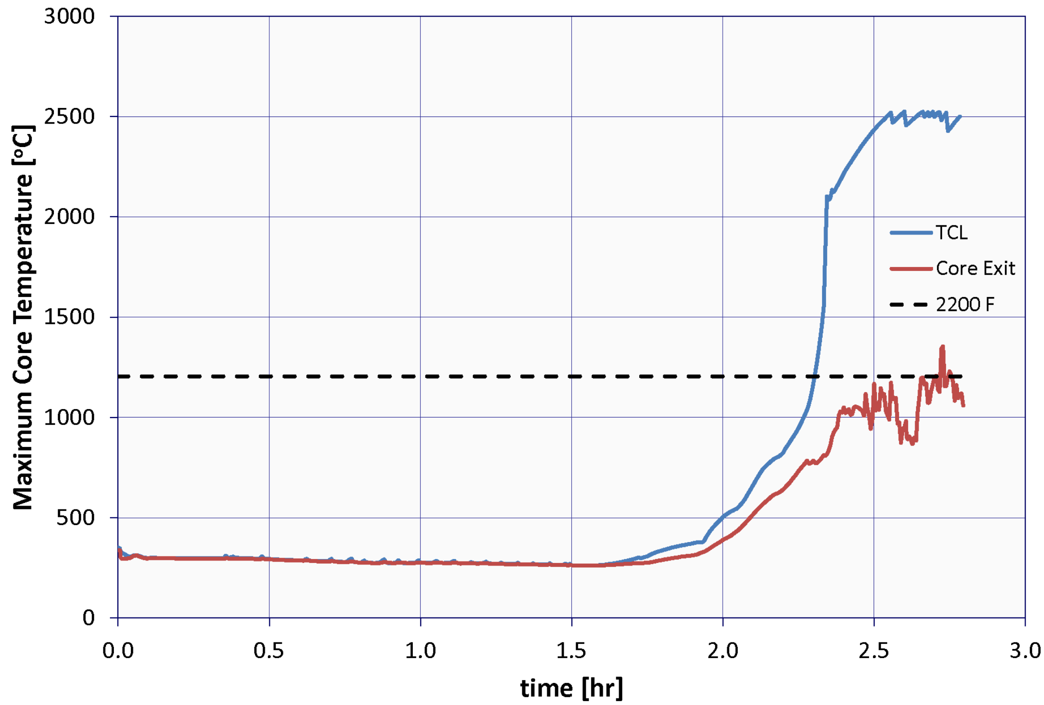

Volume [gal]
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24

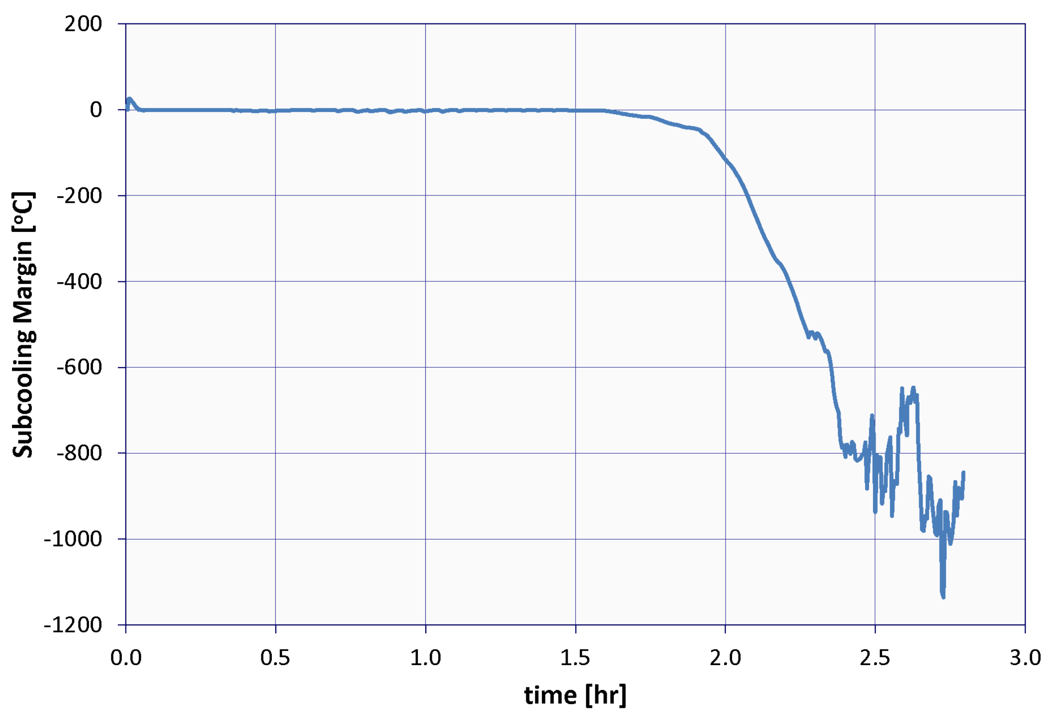
APPENDIX E

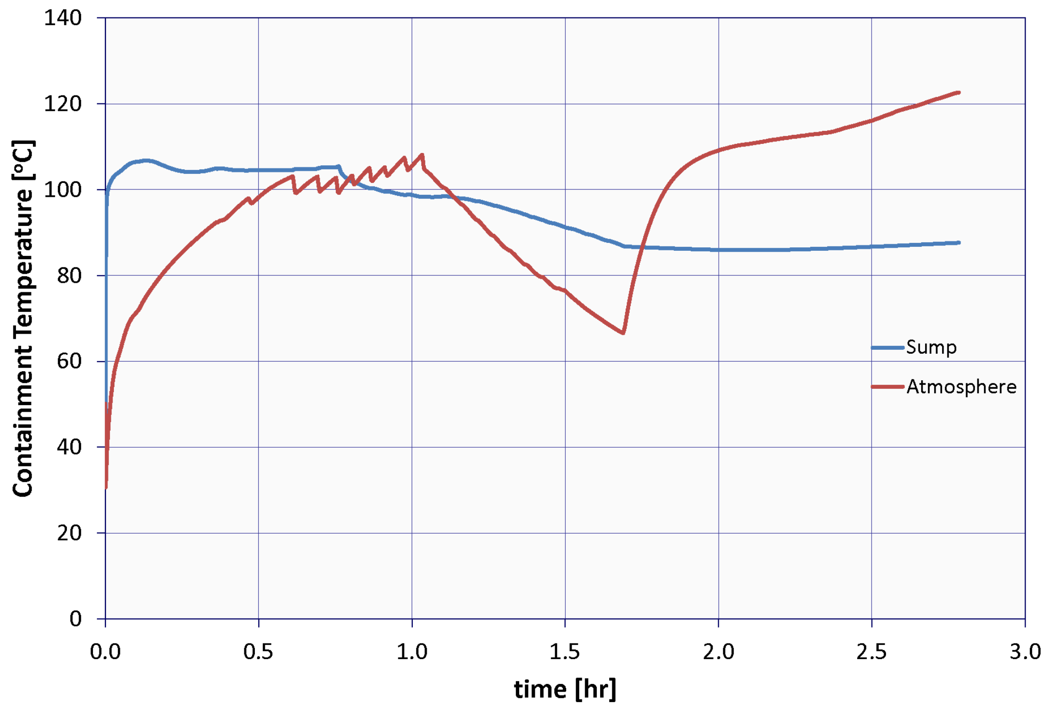
DETAILED MEDIUM-BREAK LOSS-OF-COOLANT ACCIDENT ANALYSIS RESULTS

E.1 Medium-Break Loss-of-Coolant Accident Injection Success Criteria

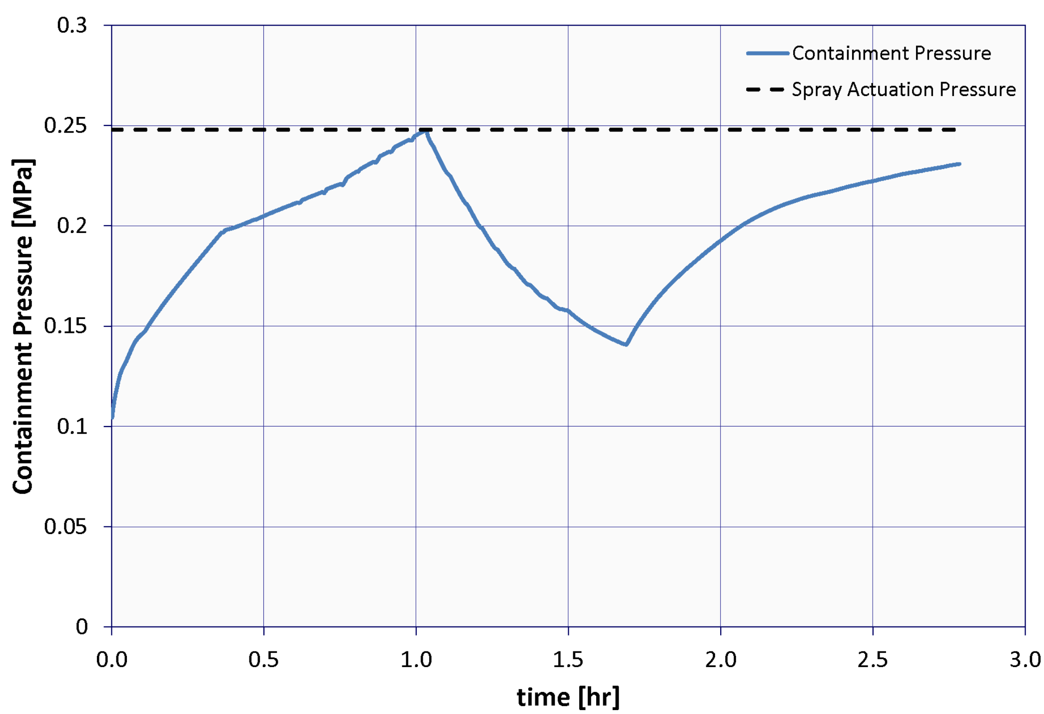
E.1.1 Case 1: 2-in. Break with 1/2 SI, 1/2 RHR, 2/2 CS Pumps



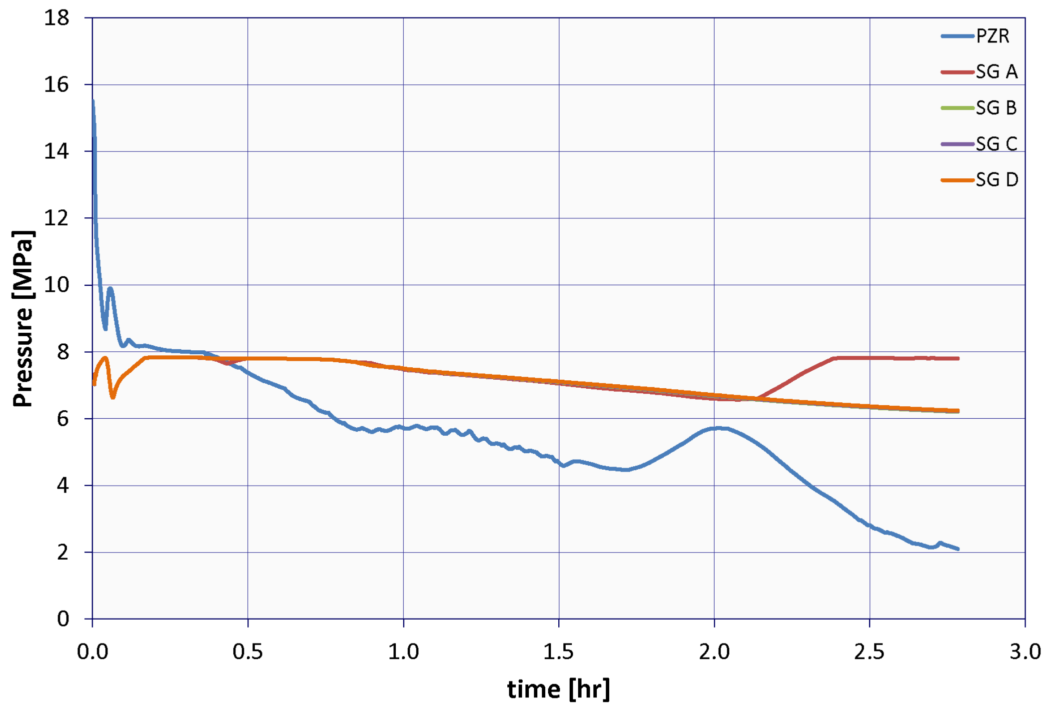




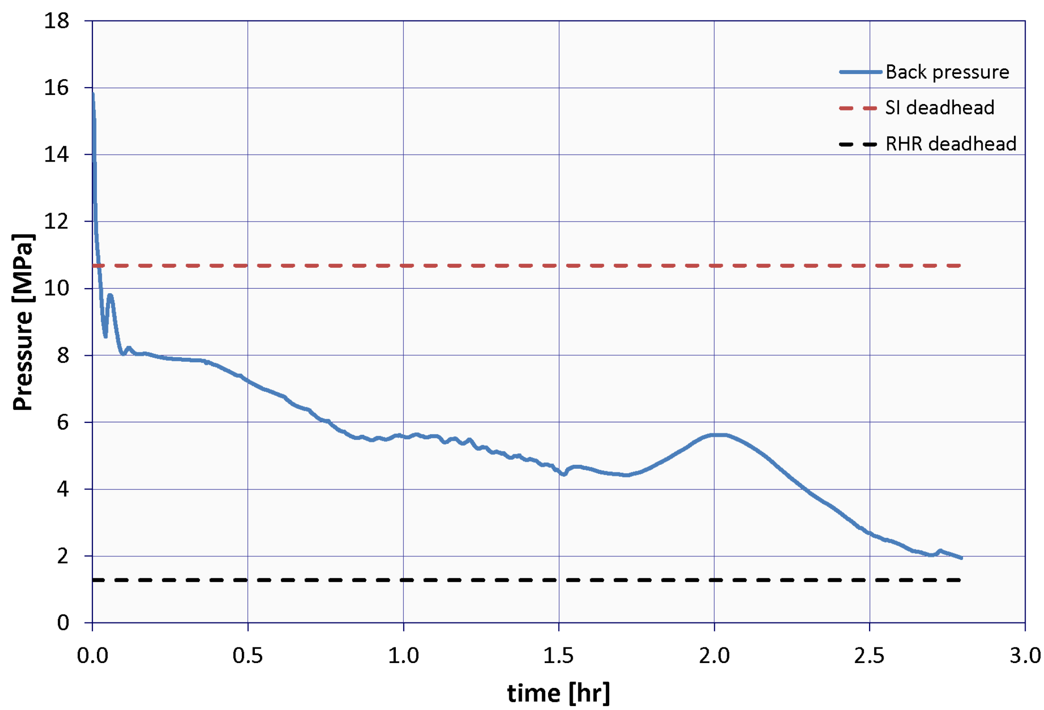
140
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Containment Temperature [ºC]
time [hr]
Sump
Atmosphere



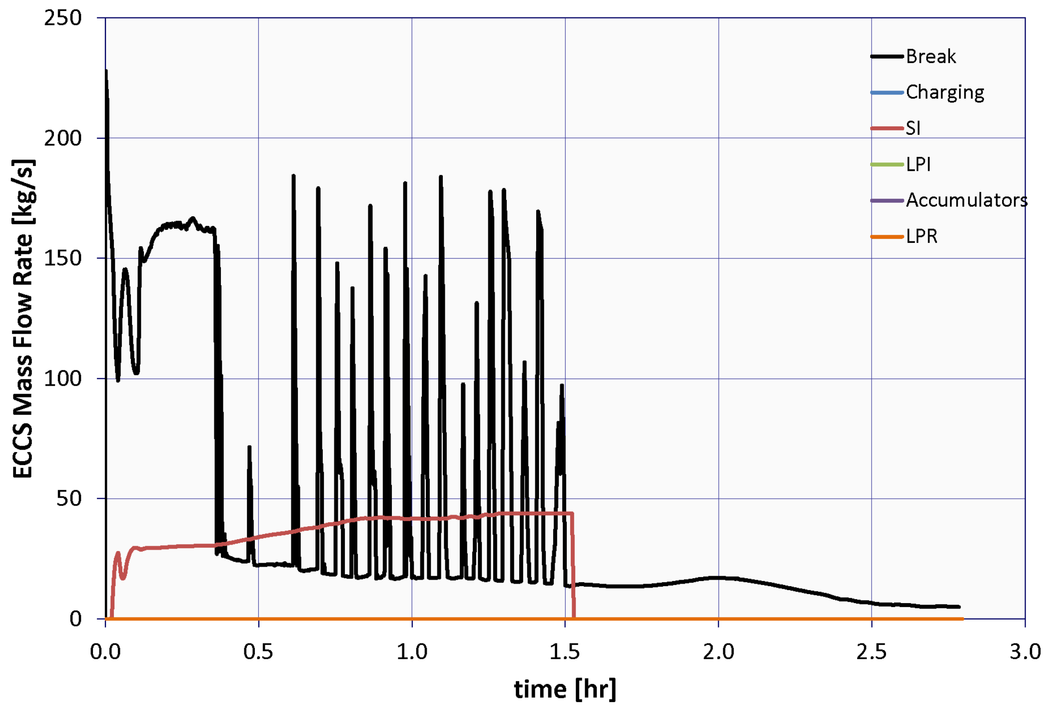
0.3
0.25
0.2
0.15
0.1
0.05
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure

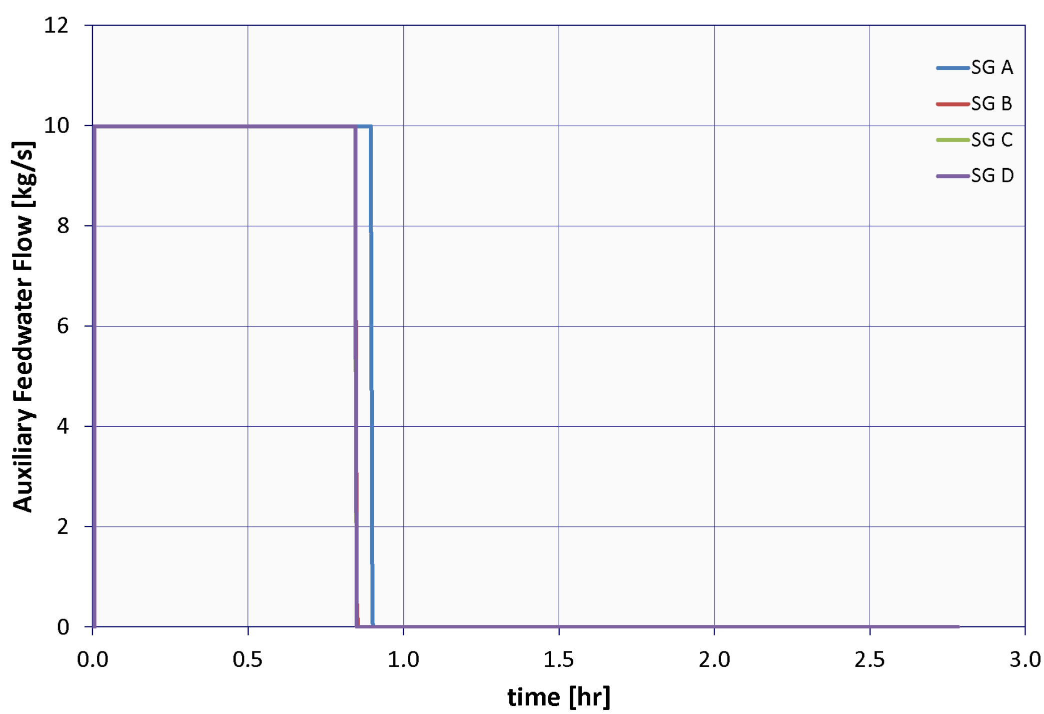


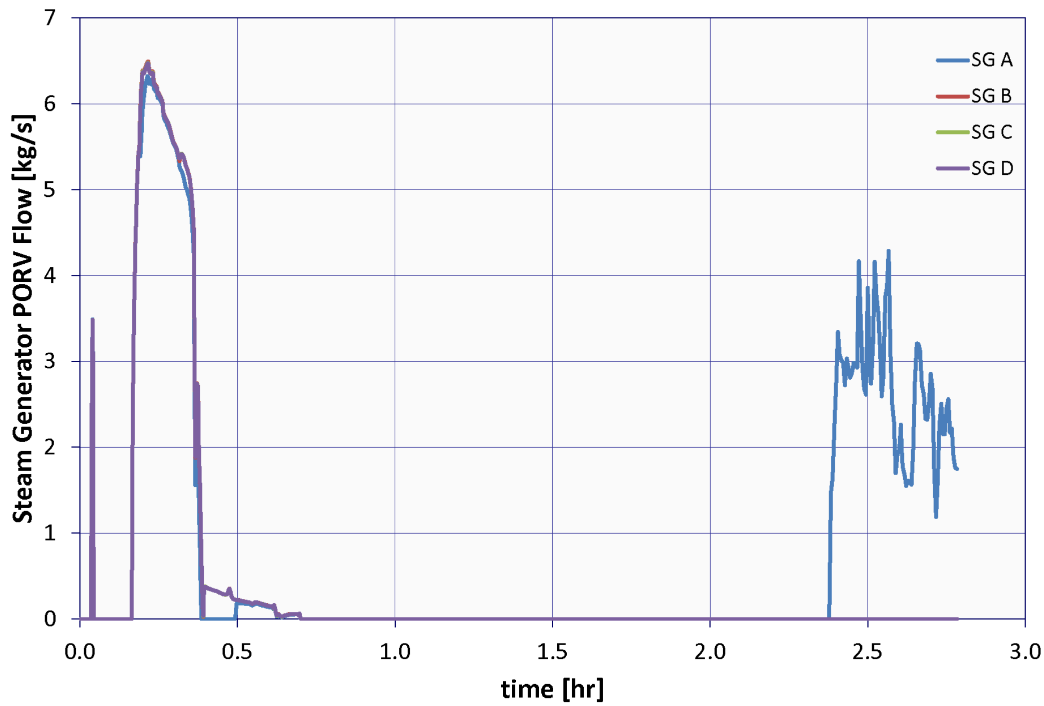
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D

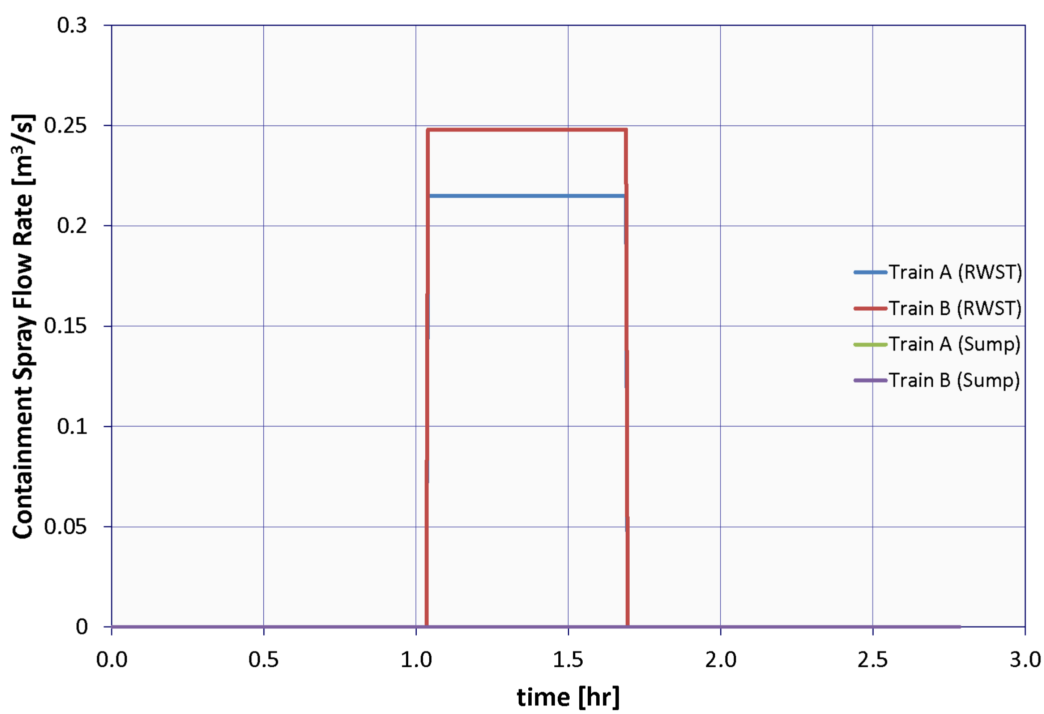


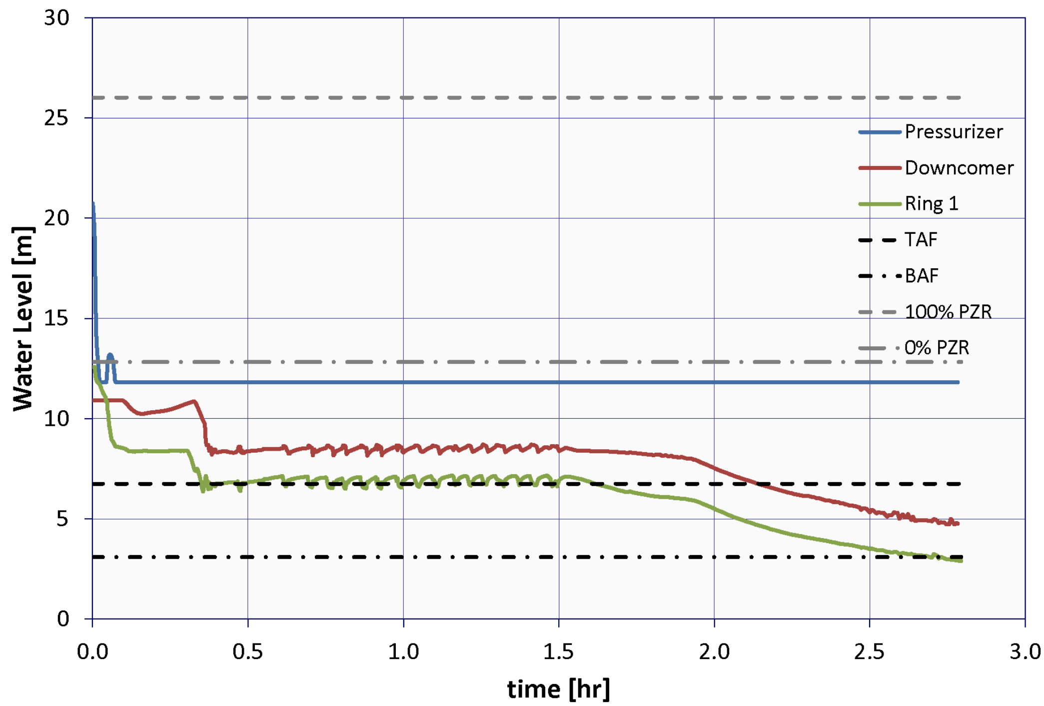
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead


ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
0
50
100
150
200
250
0.0
0.5
1.0
1.5
2.0
2.5
3.0

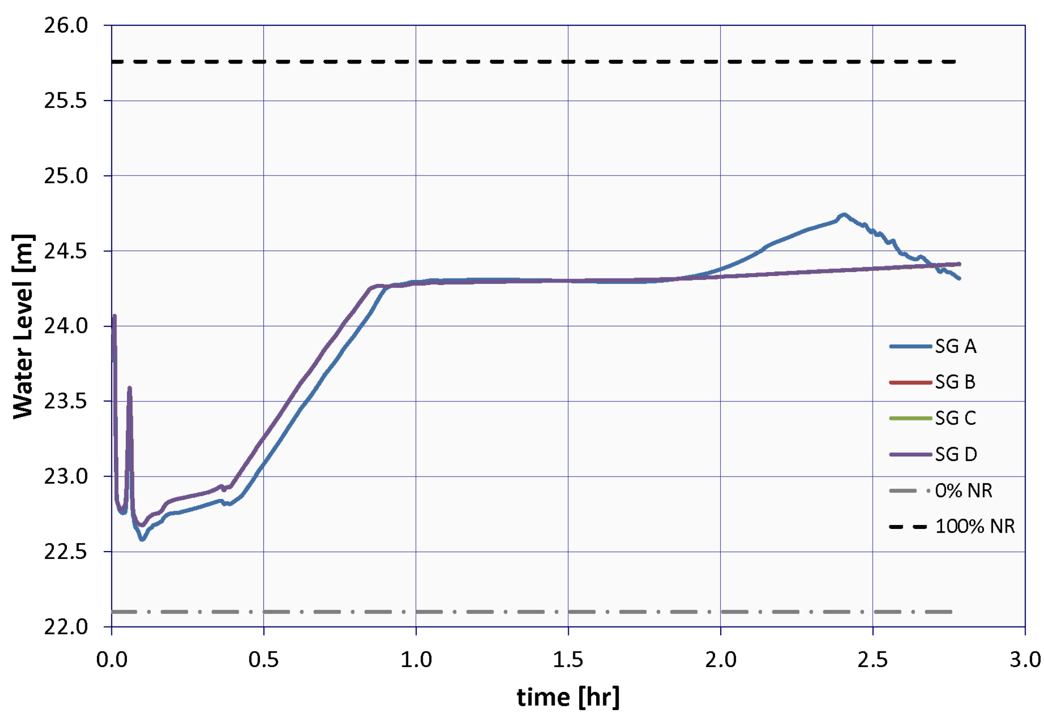

Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0.0
0.5
1.0
1.5
2.0
2.5
3.0


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
1
2
3
4
5
6
7
0.0
0.5
1.0
1.5
2.0
2.5
3.0

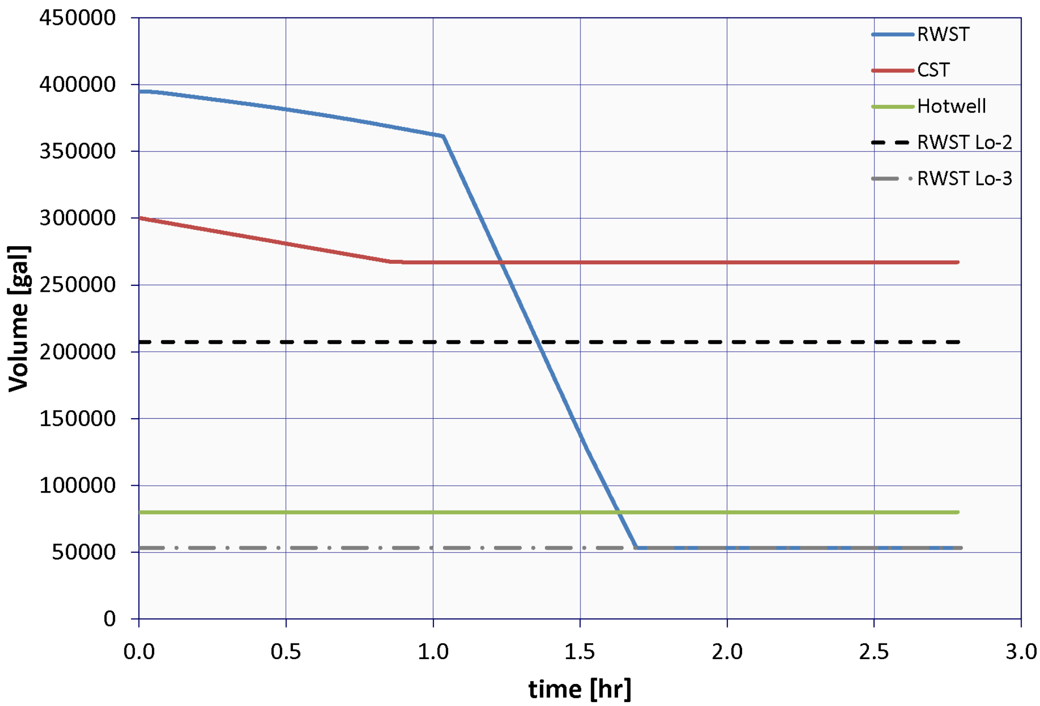

Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.0
0.5
1.0
1.5
2.0
2.5
3.0



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

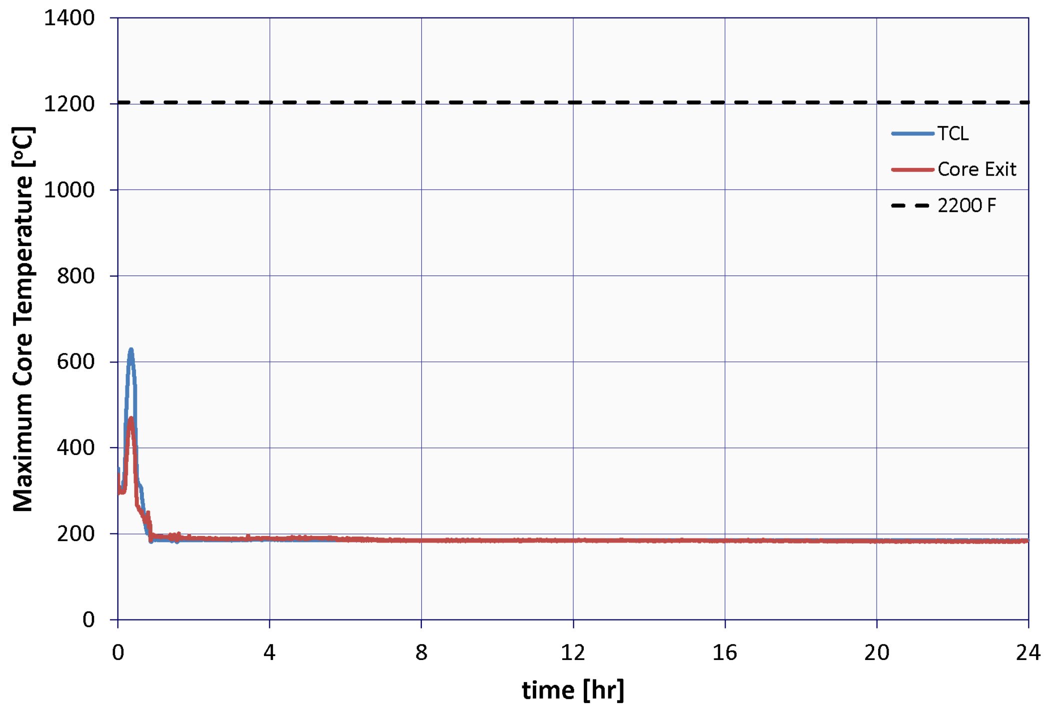


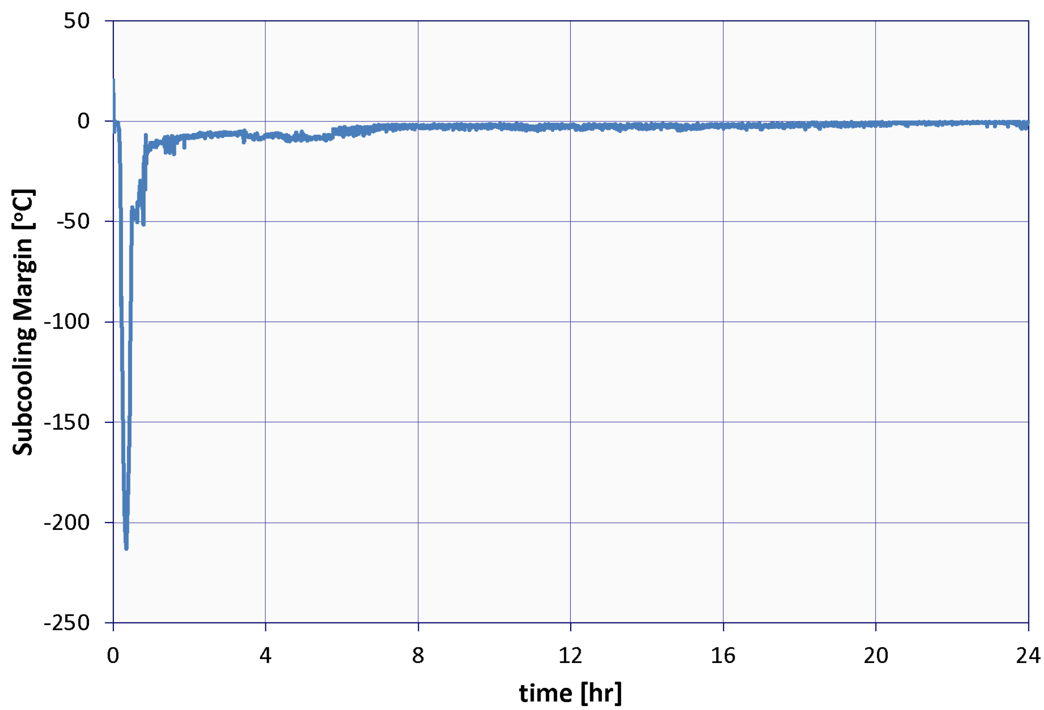
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

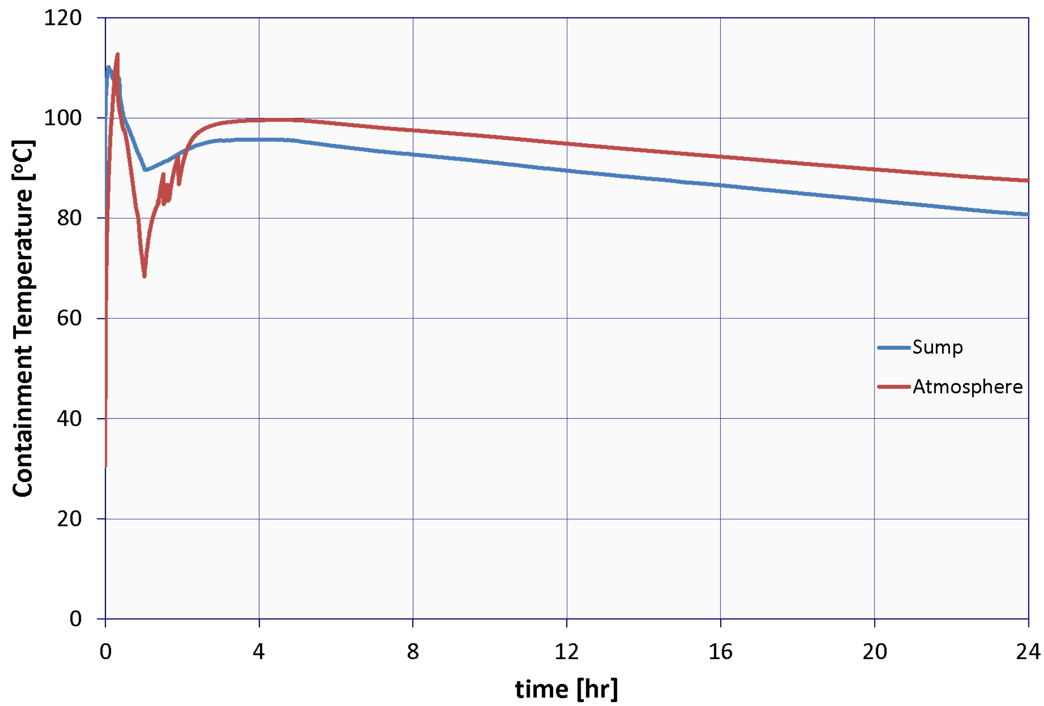


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

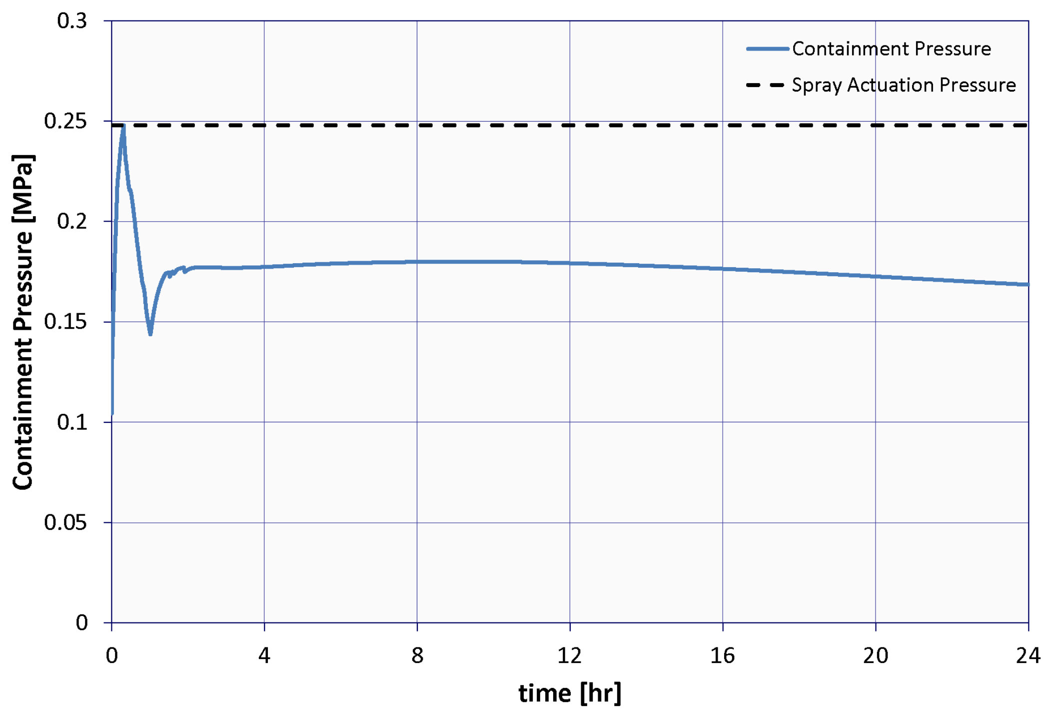
E.1.2 Case 2: 3.33-in. Break with 1/2 SI, 1/2 RHR, 2/2 CS Pumps



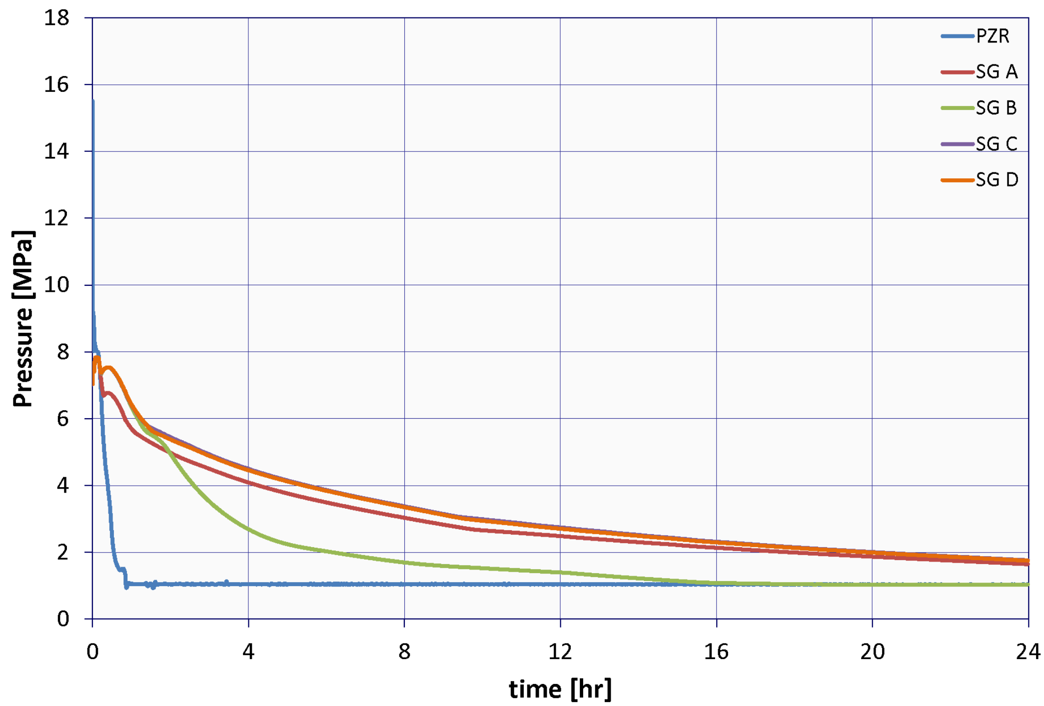




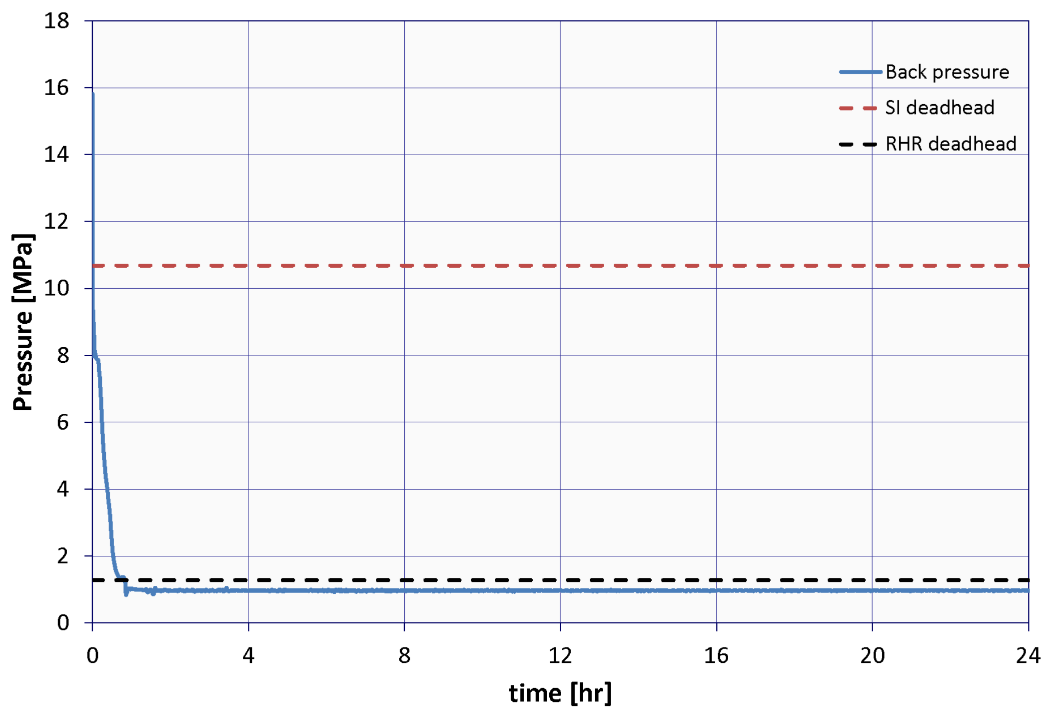
Containment Temperature [°C]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



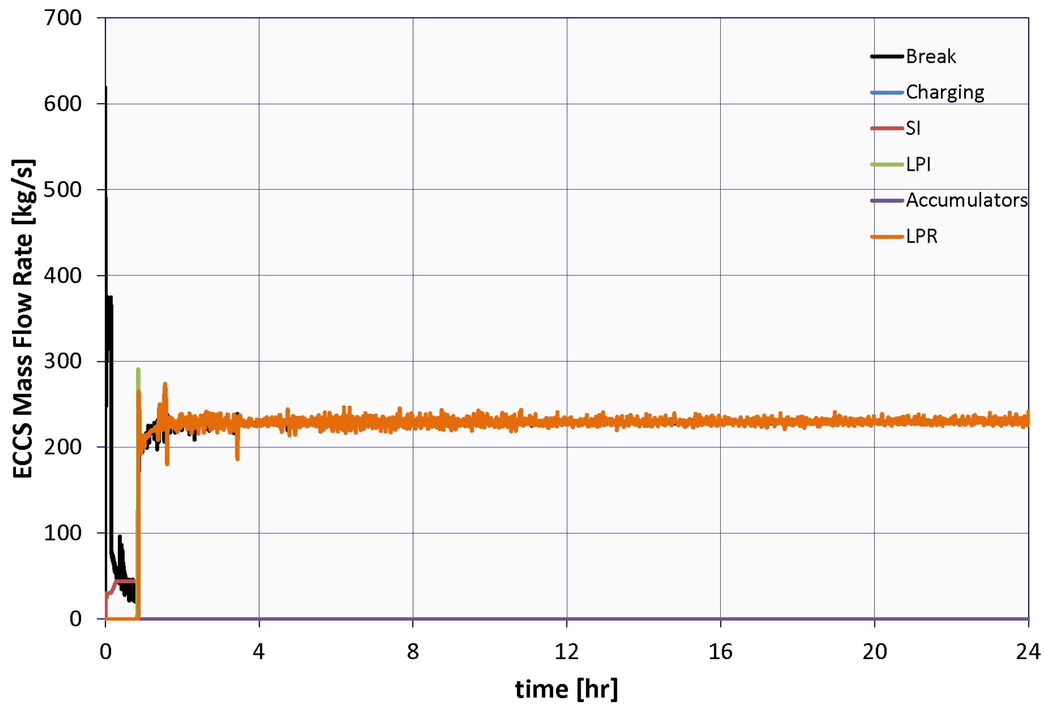
Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure



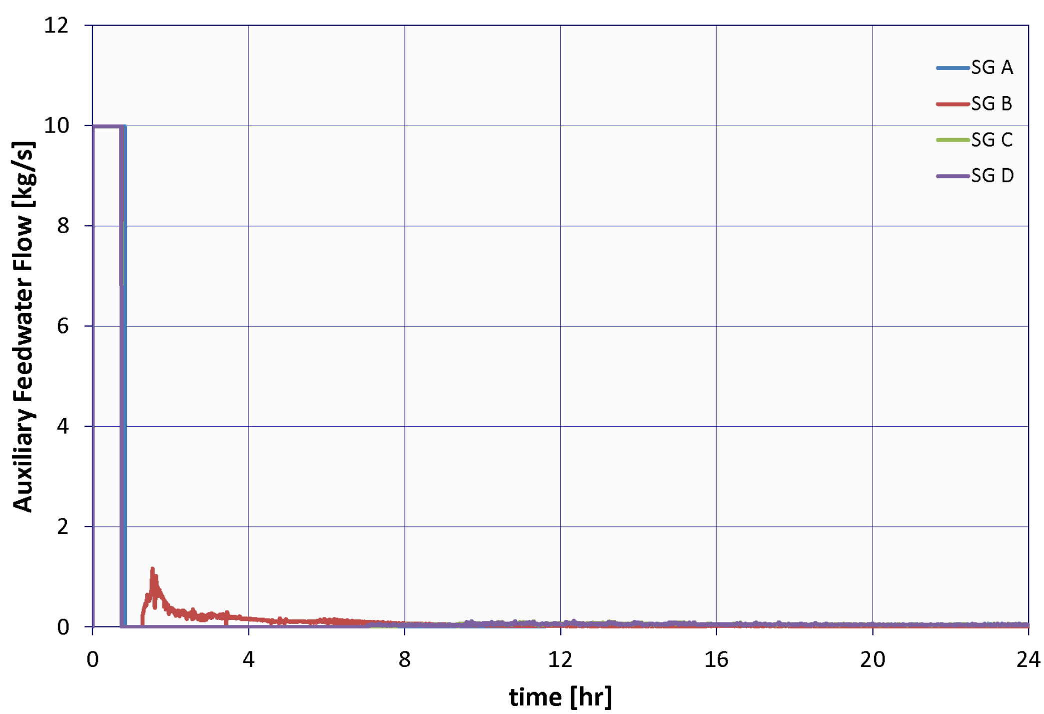
PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]



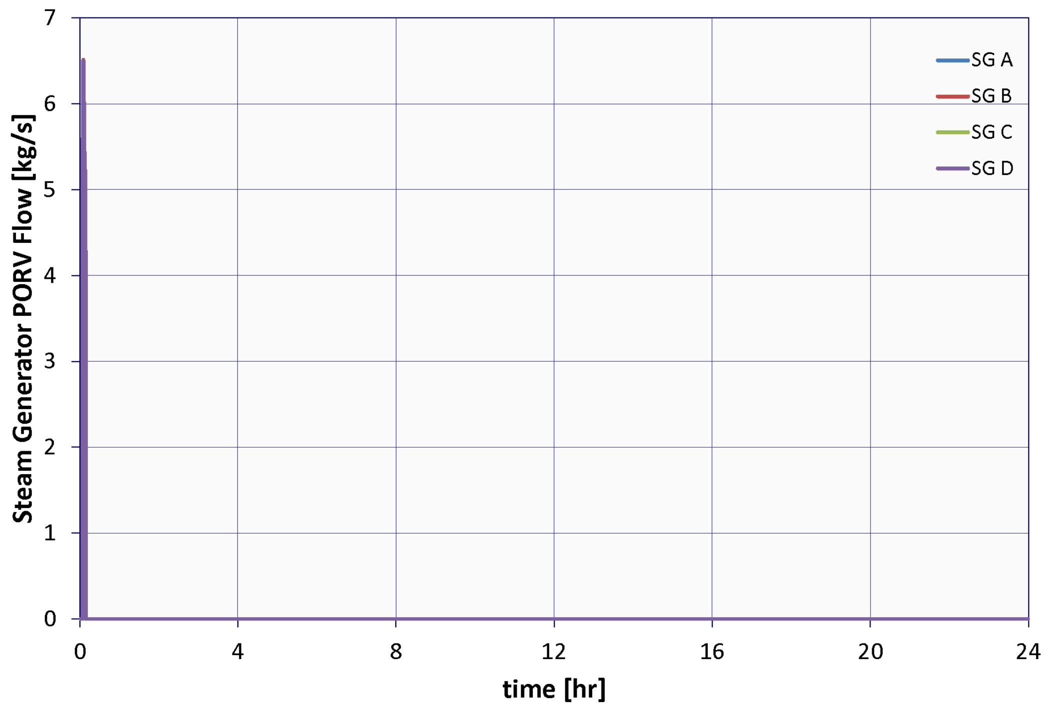
Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]



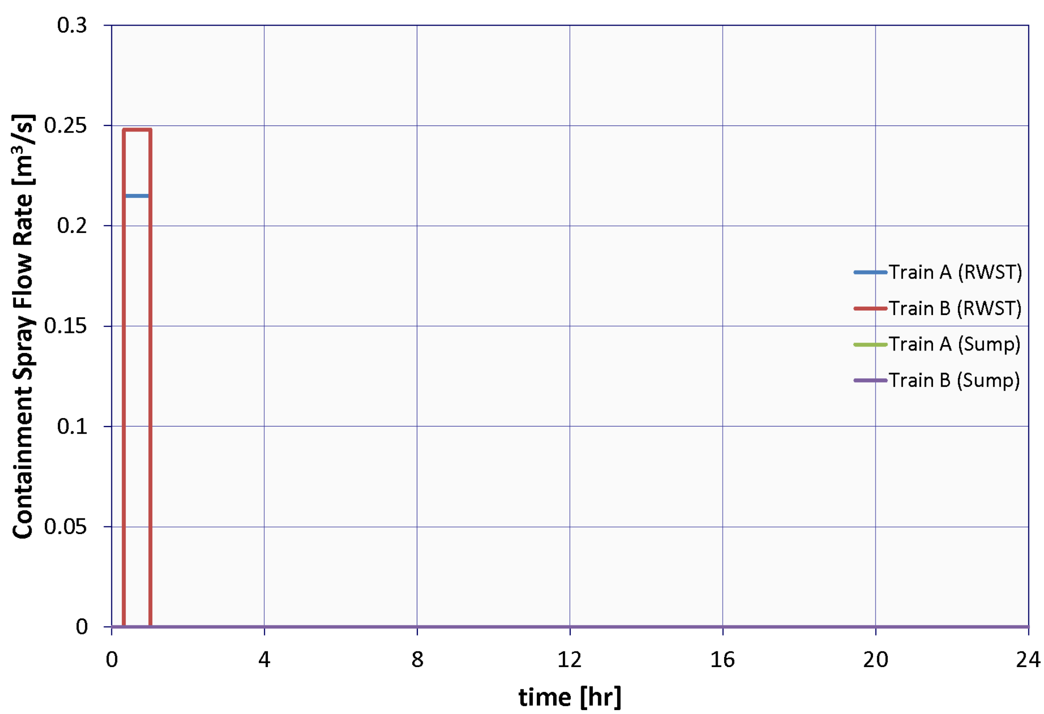
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



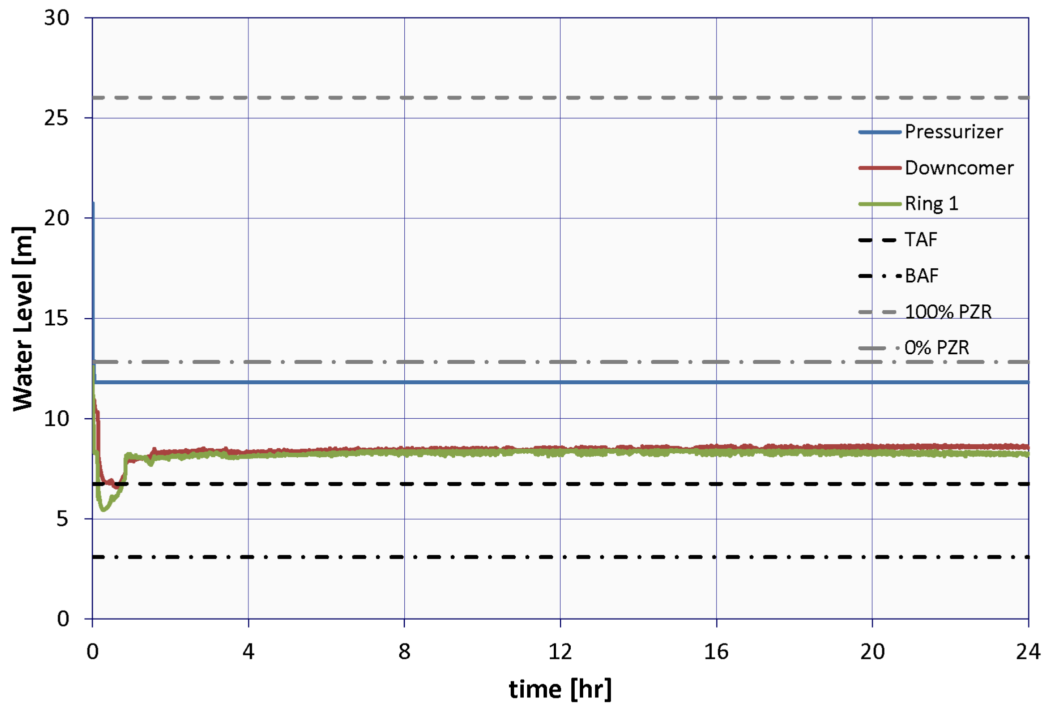
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



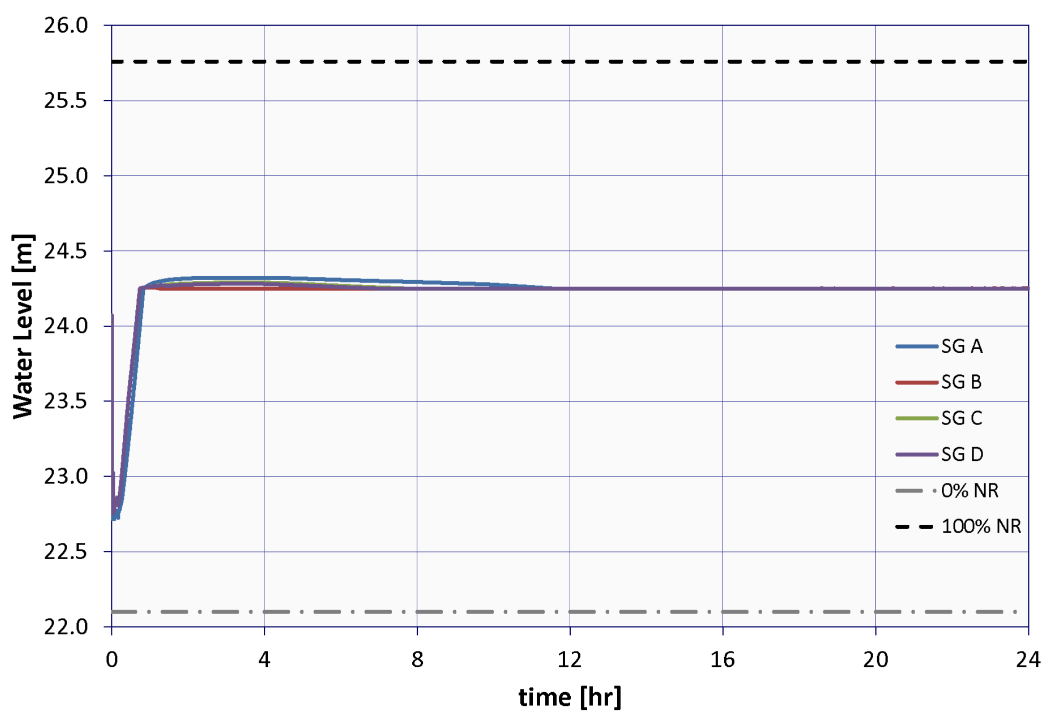
Steam Generator PORV Flow [kg/s]
7
6
5
4
3
2
1
0
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



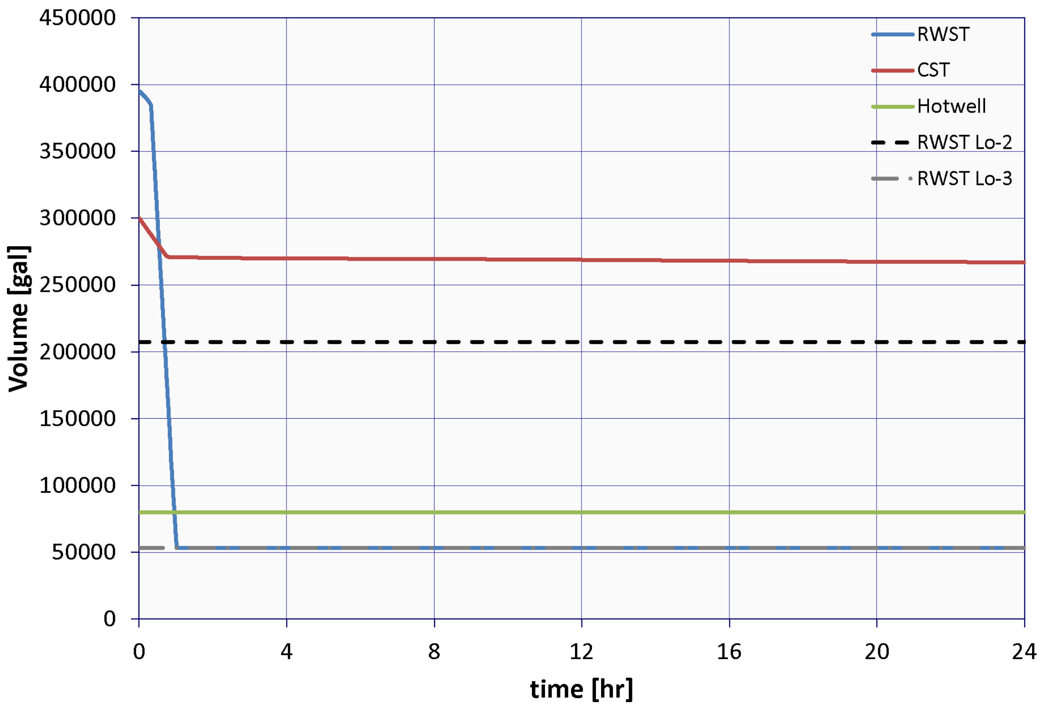
Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



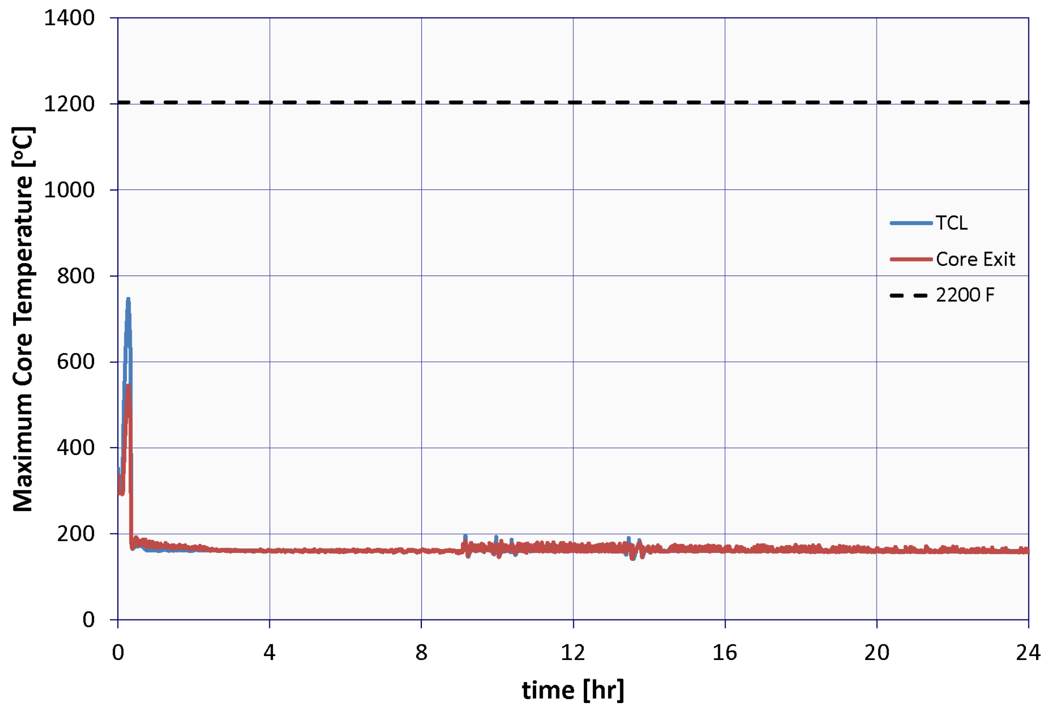
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

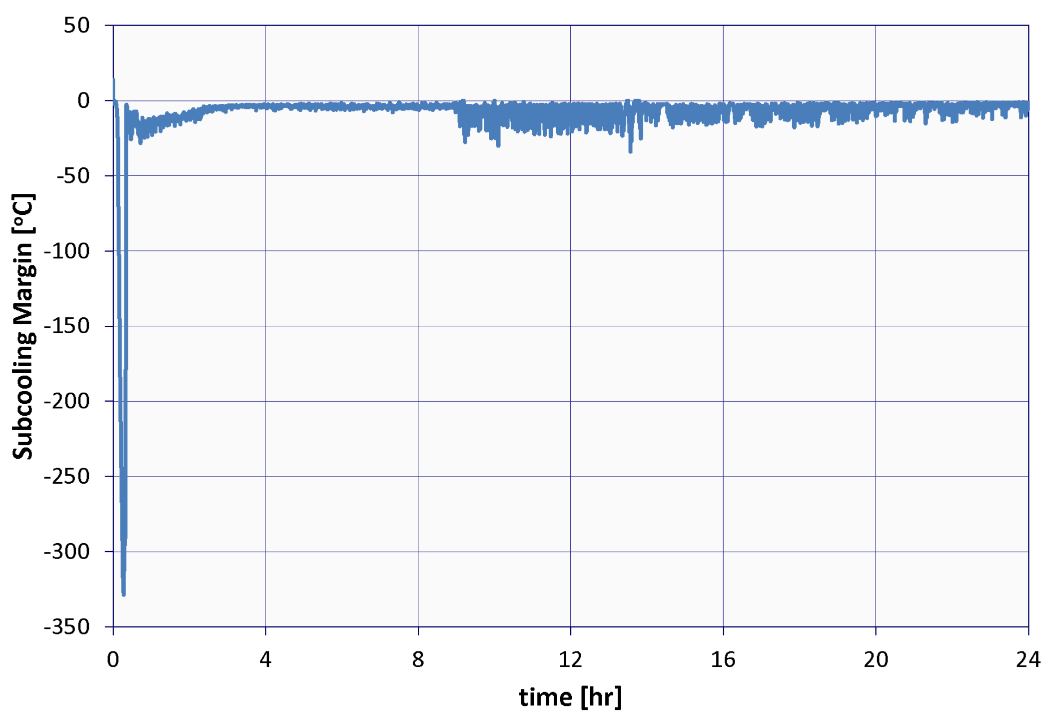


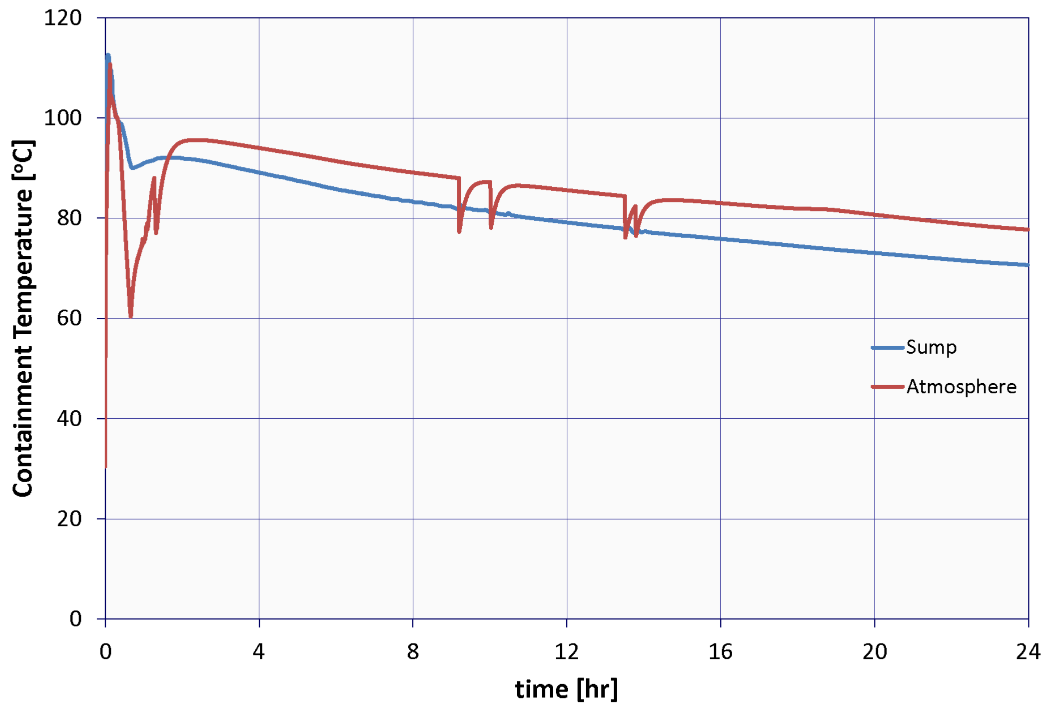
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

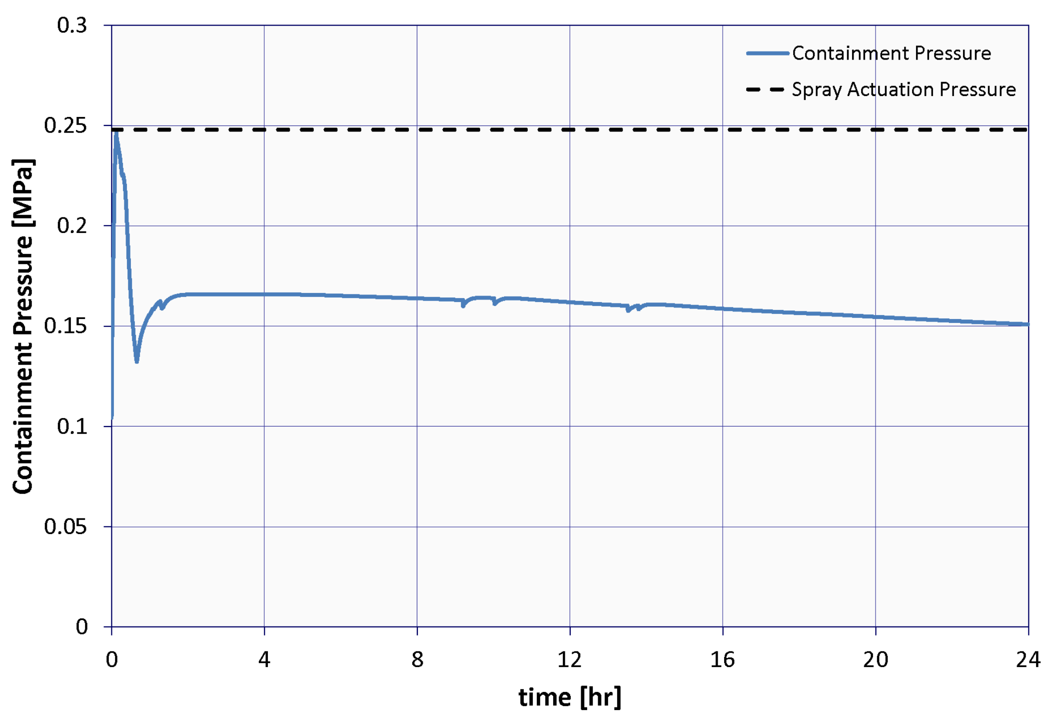

450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

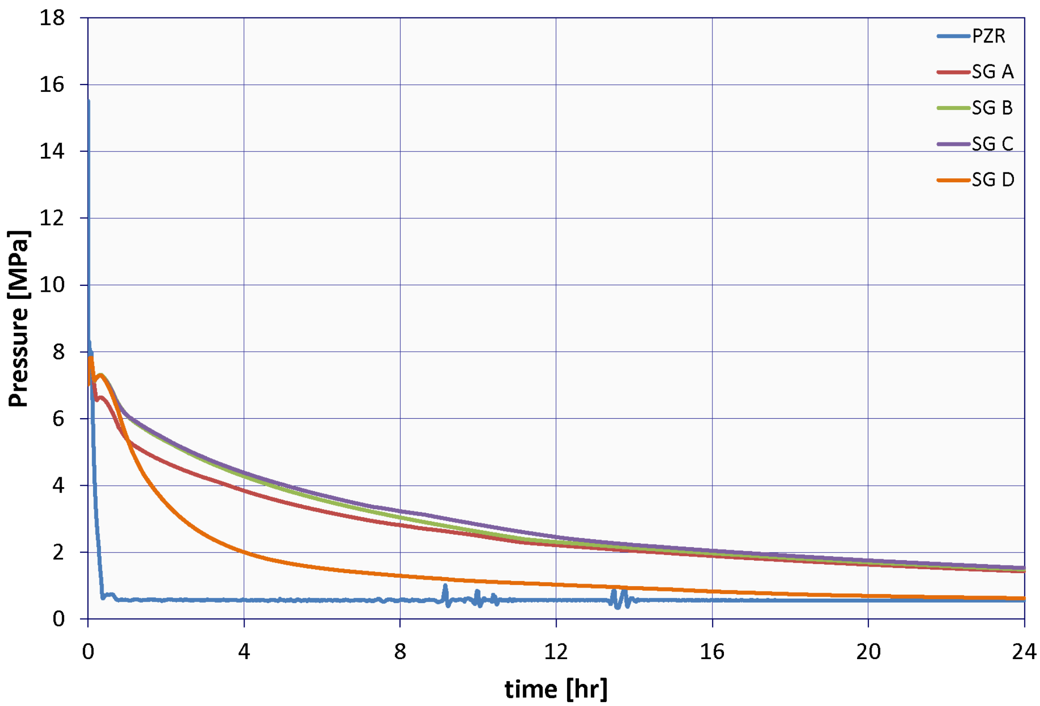
E.1.3 Case 3: 4.67-in. Break with 1/2 SI, 1/2 RHR, 2/2 CS Pumps



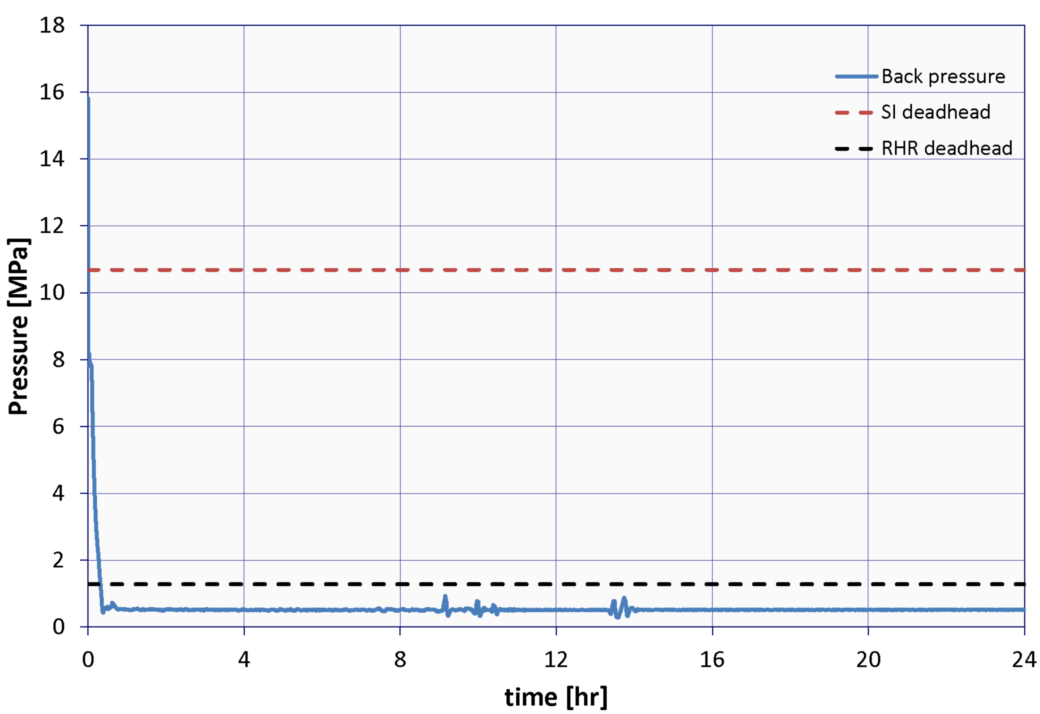



Containment Temperature [ºC]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

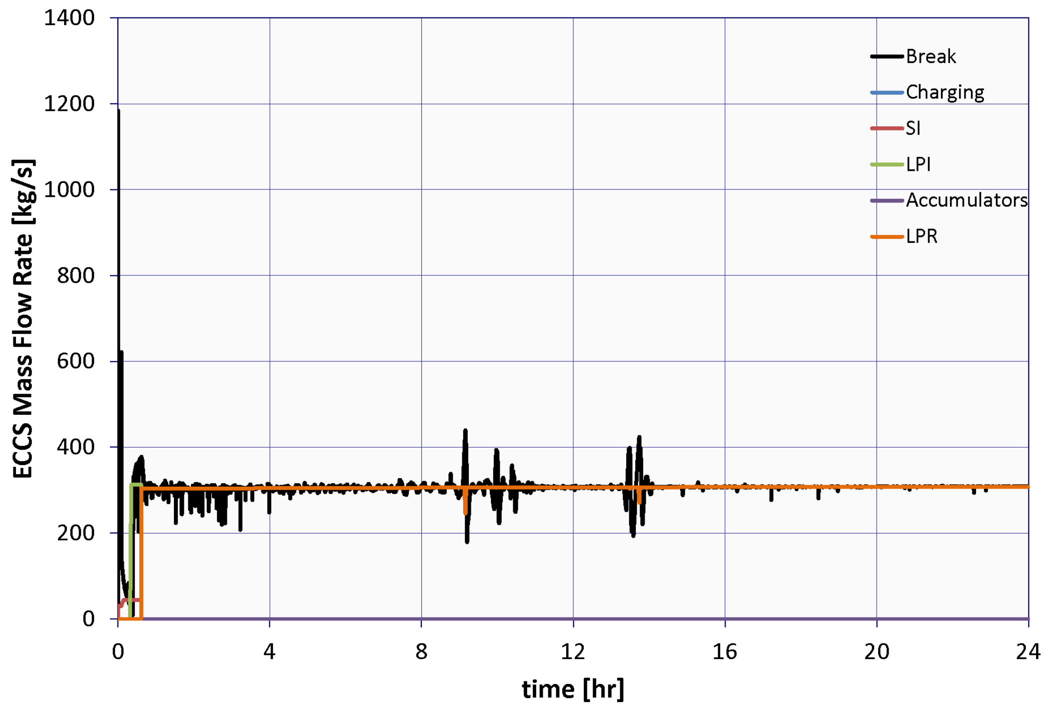

Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

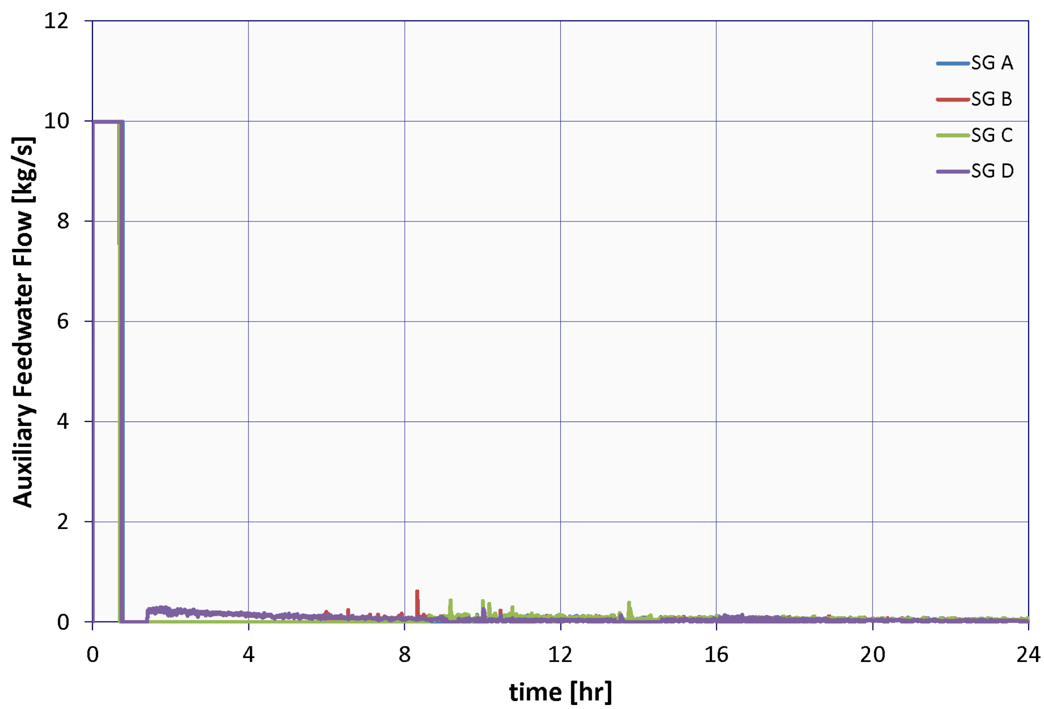


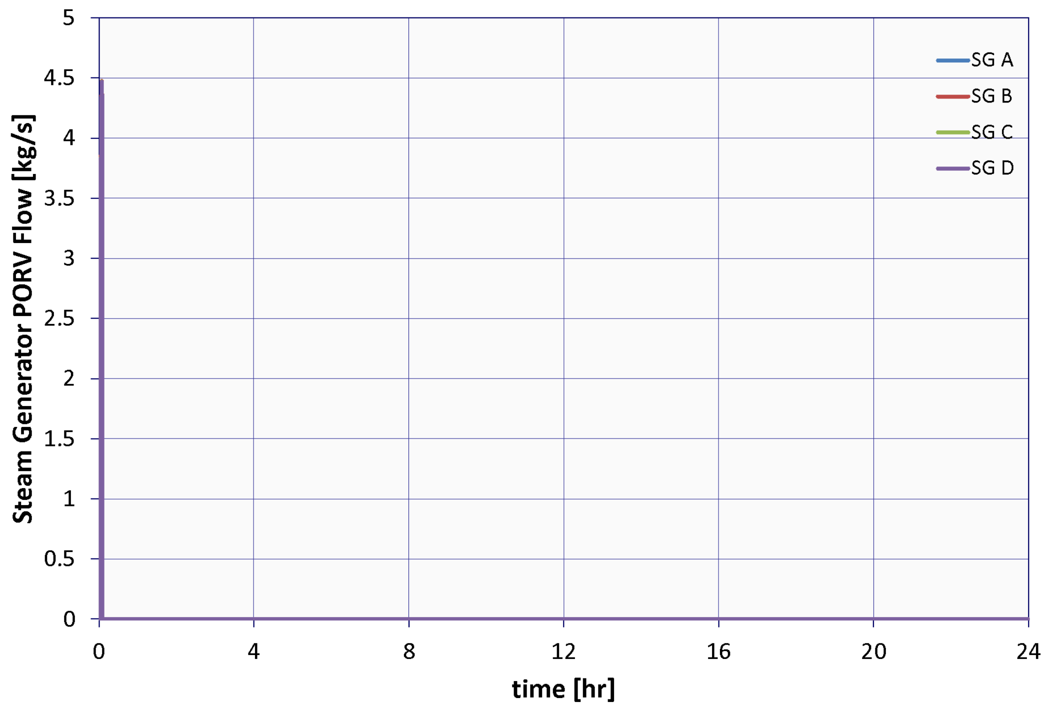
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



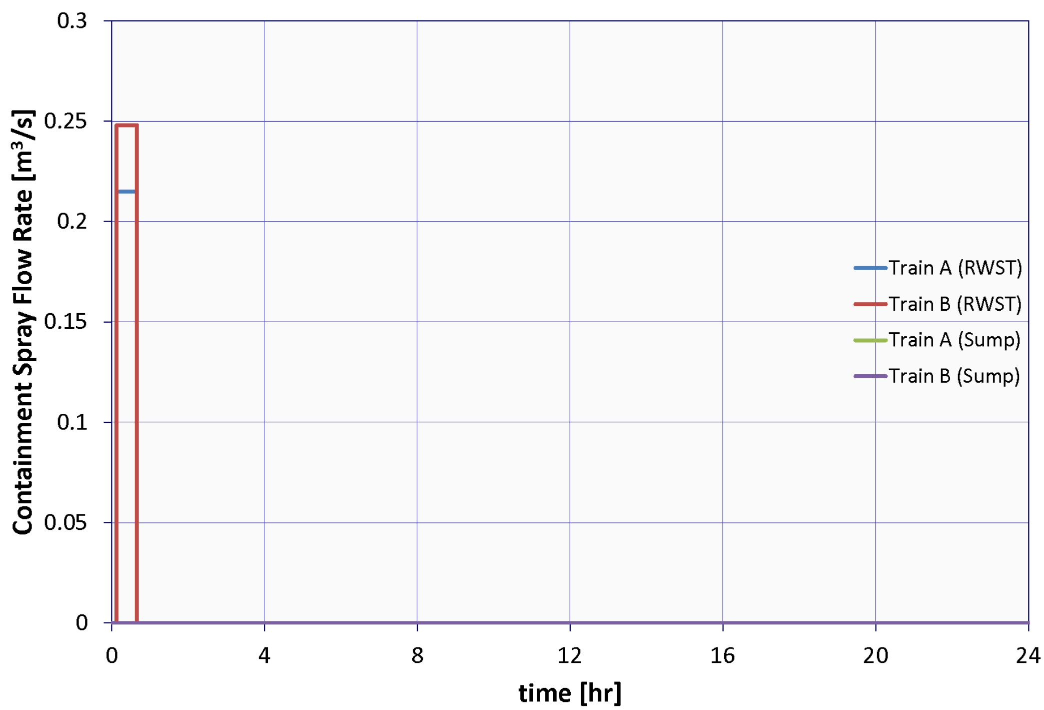
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead


ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
1400
1200
1000
800
600
400
200
0
0
4
8
12
16
20
24

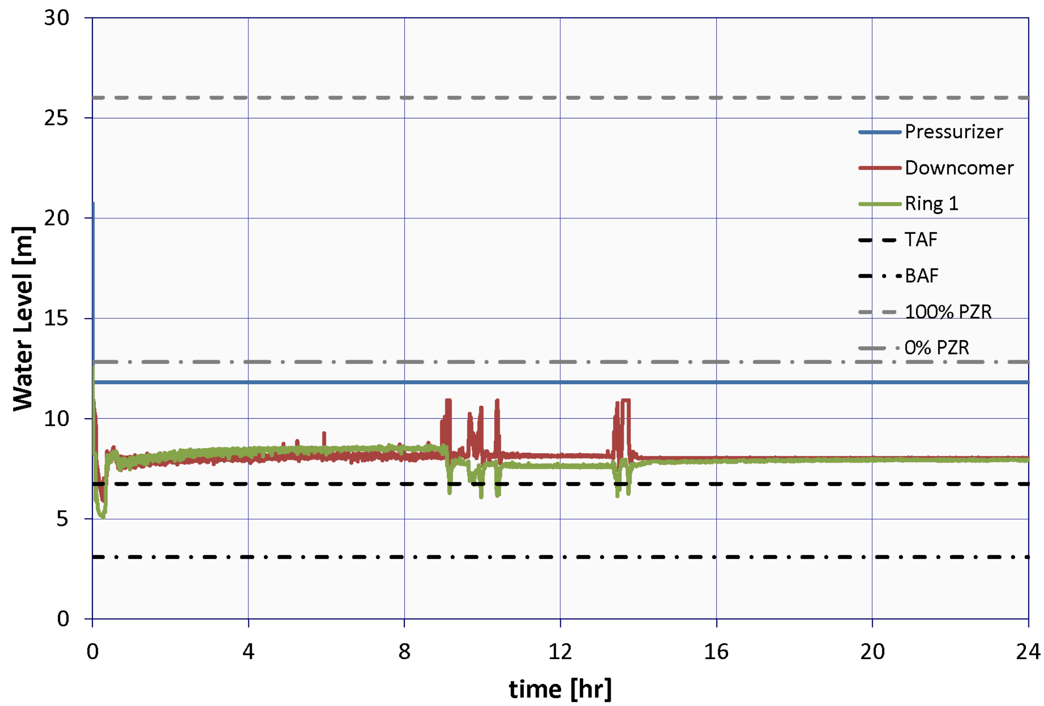

Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
12
10
8
6
4
2
0
0
4
8
12
16
20
24



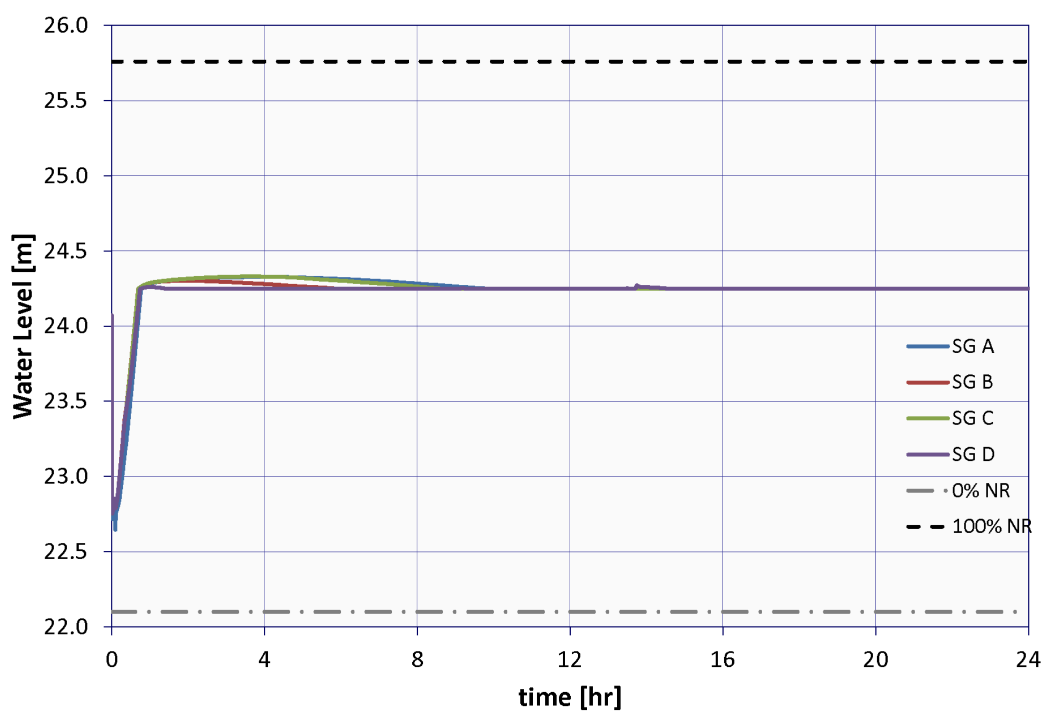
Steam Generator PORV Flow [kg/s]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



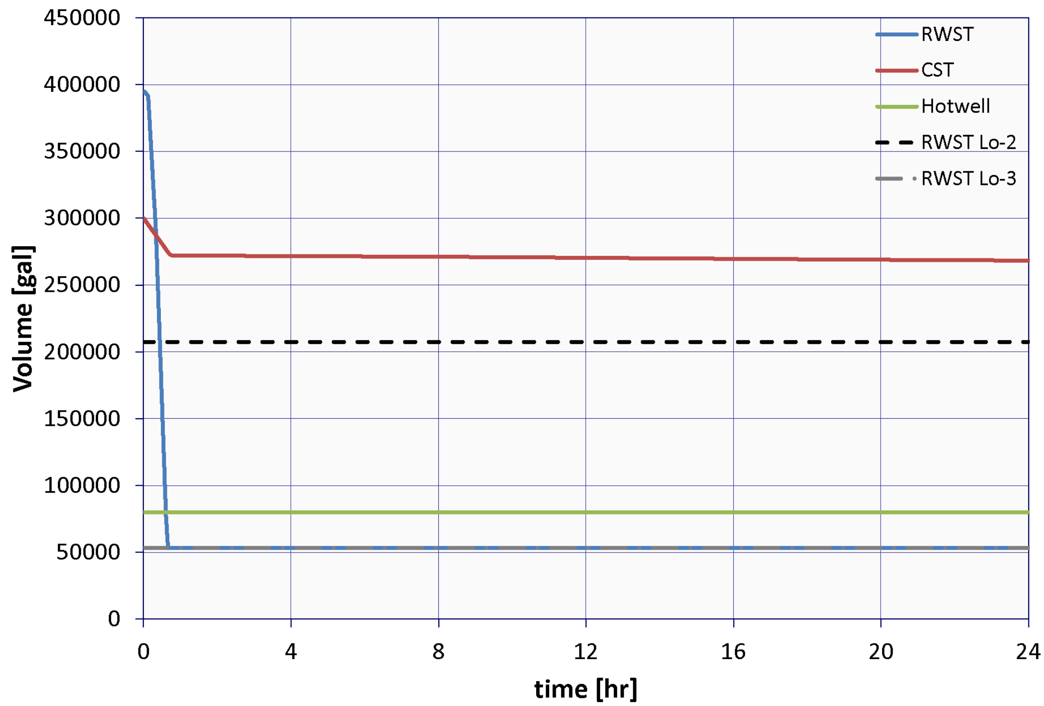
Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

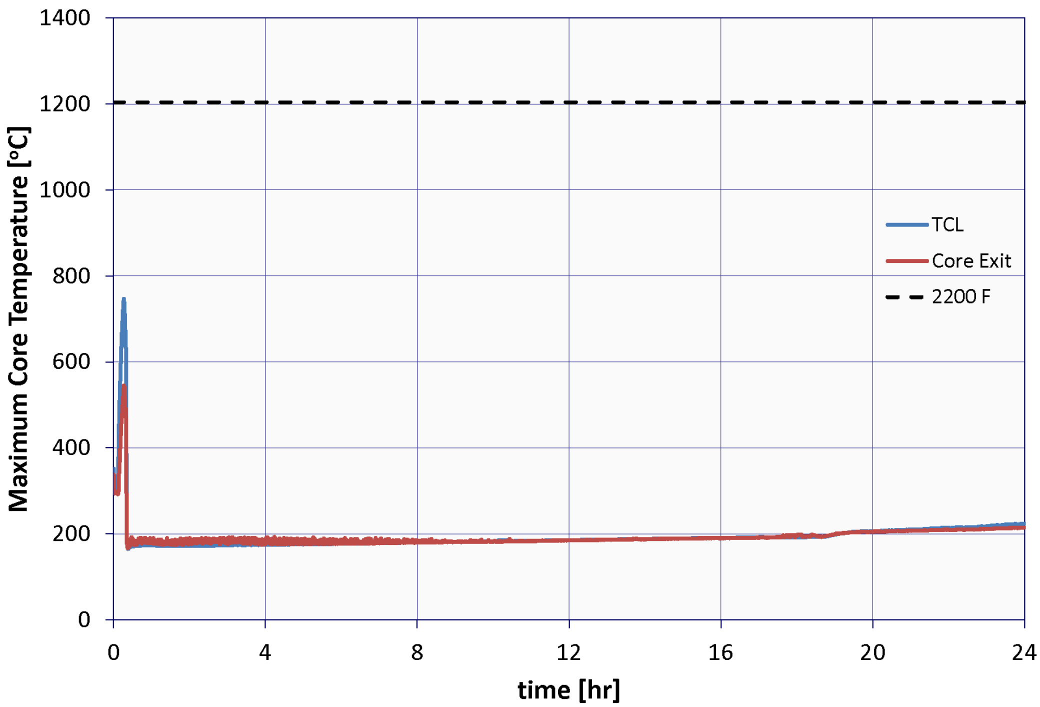


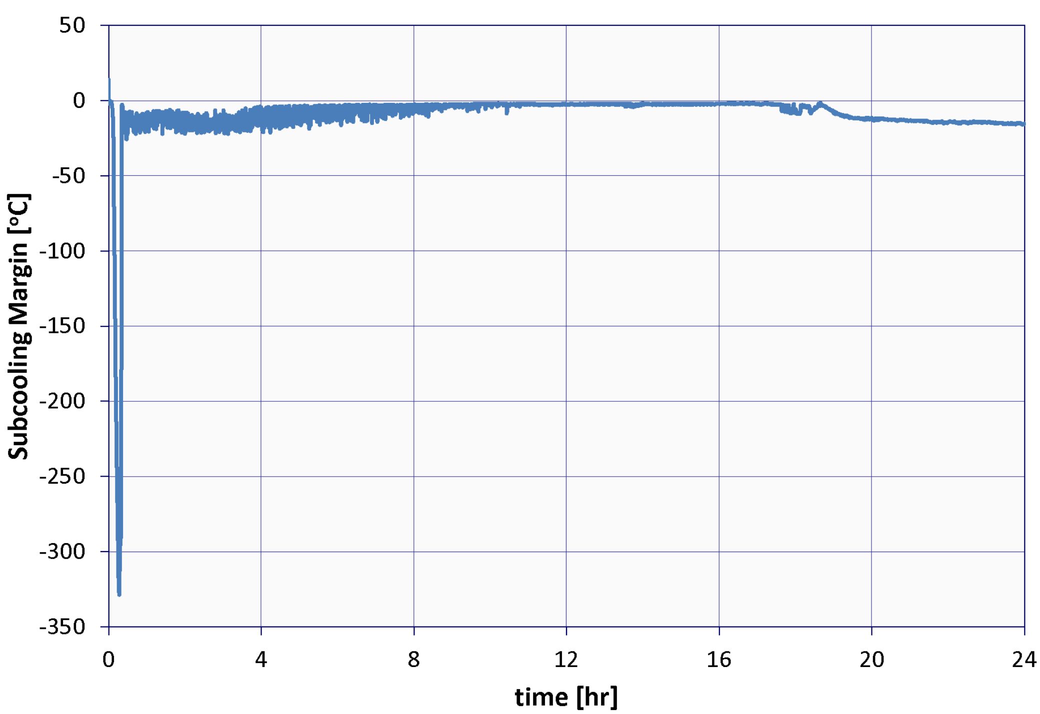
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

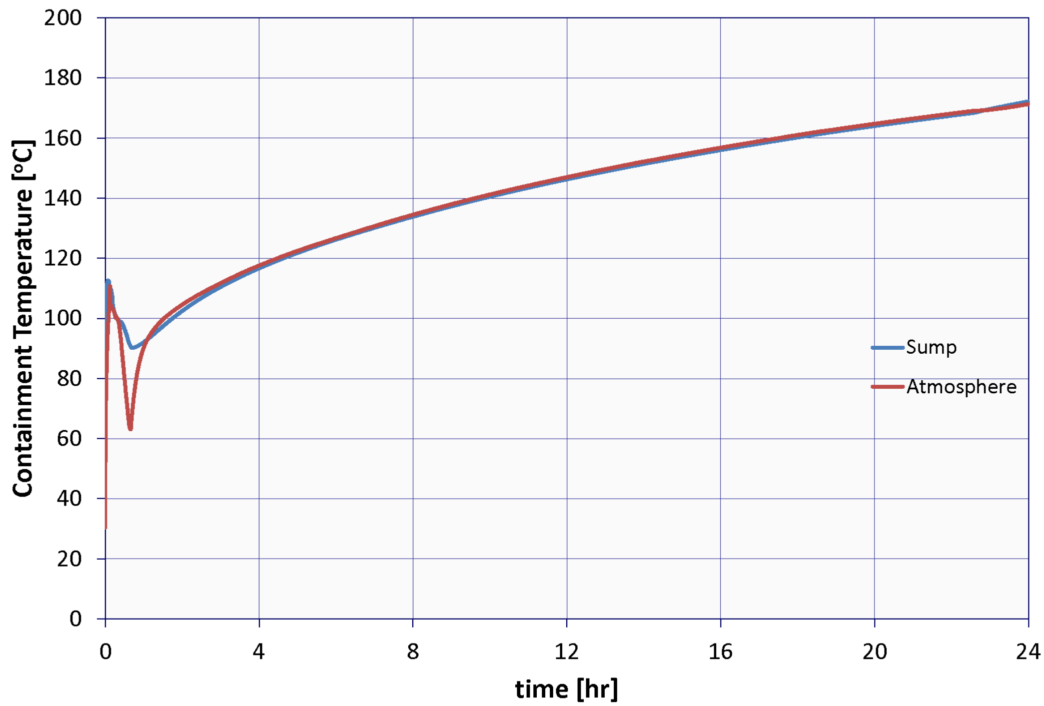


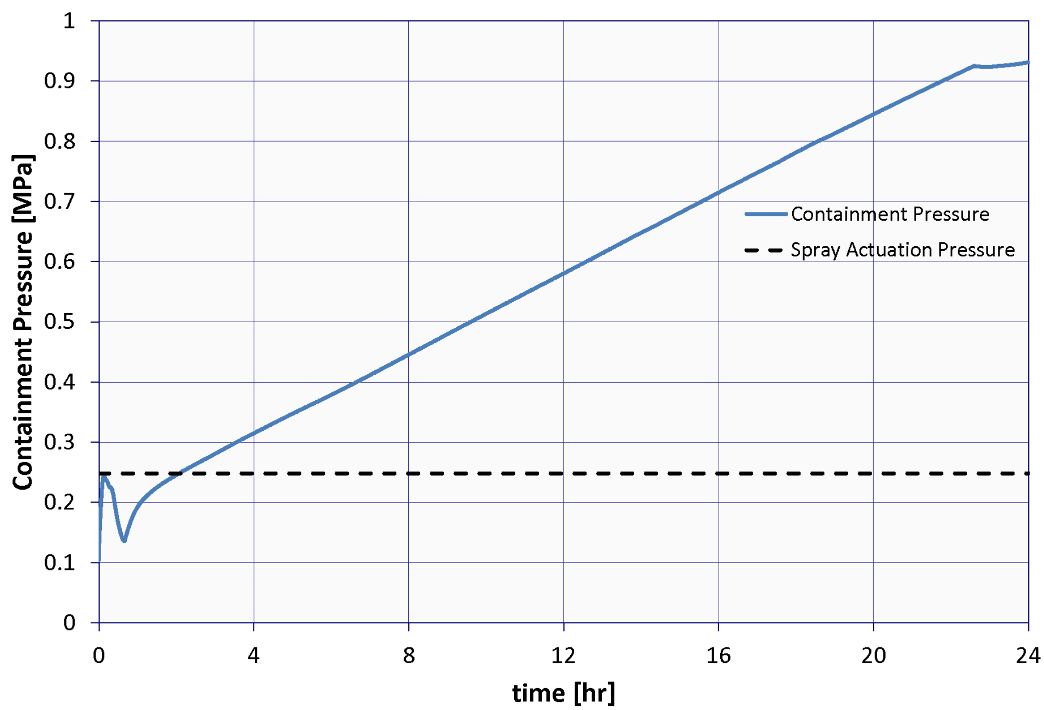
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

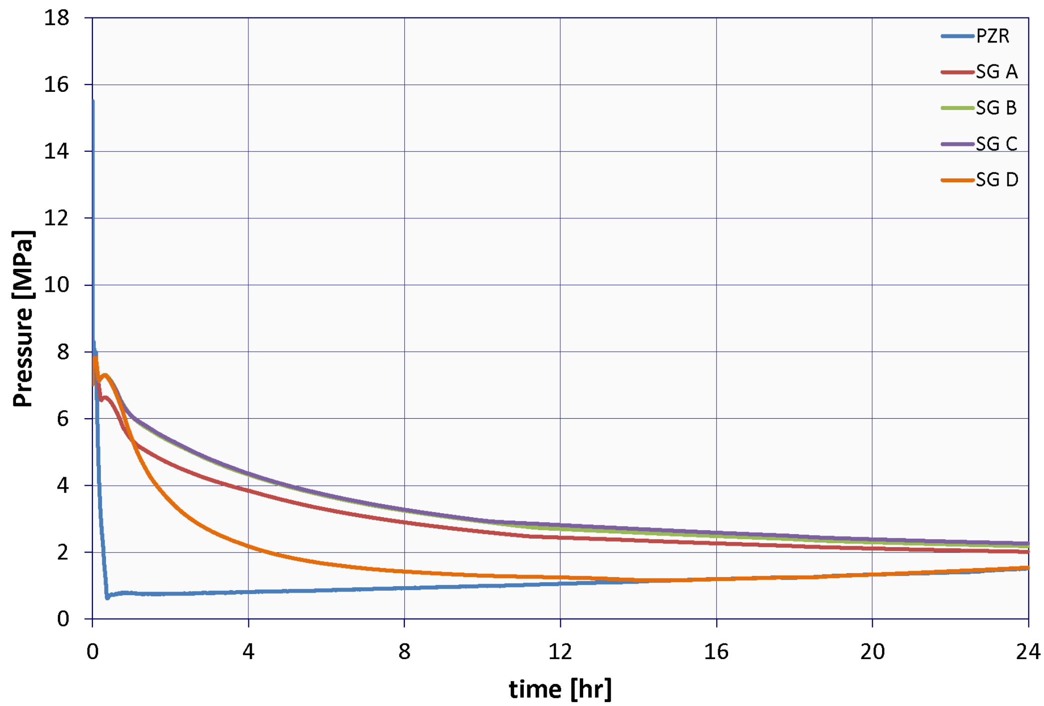
E.1.3.1 *Case 3a: 4.67-in. Break with 1/2 SI, 1/2 RHR, 2/2 CS Pumps, No RHRHX*

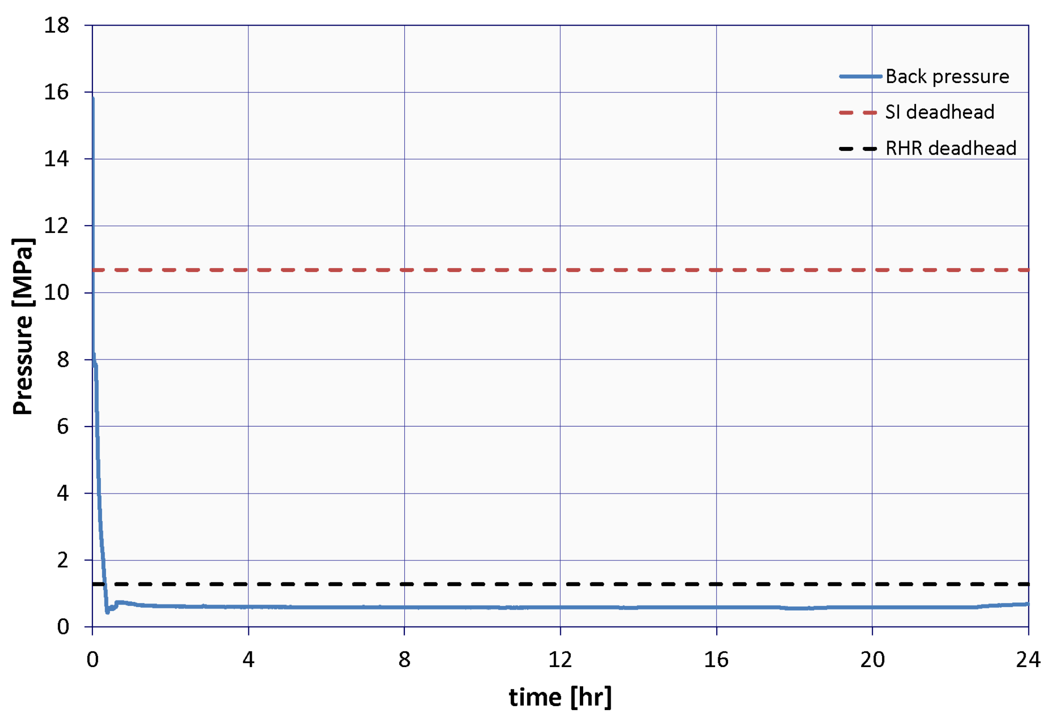


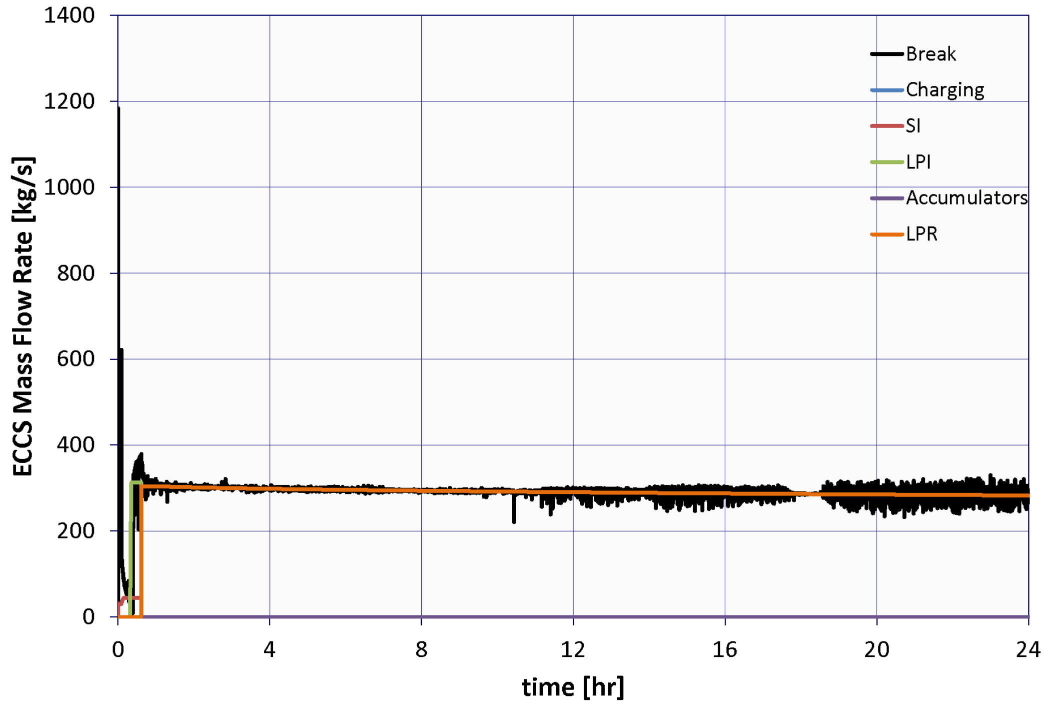


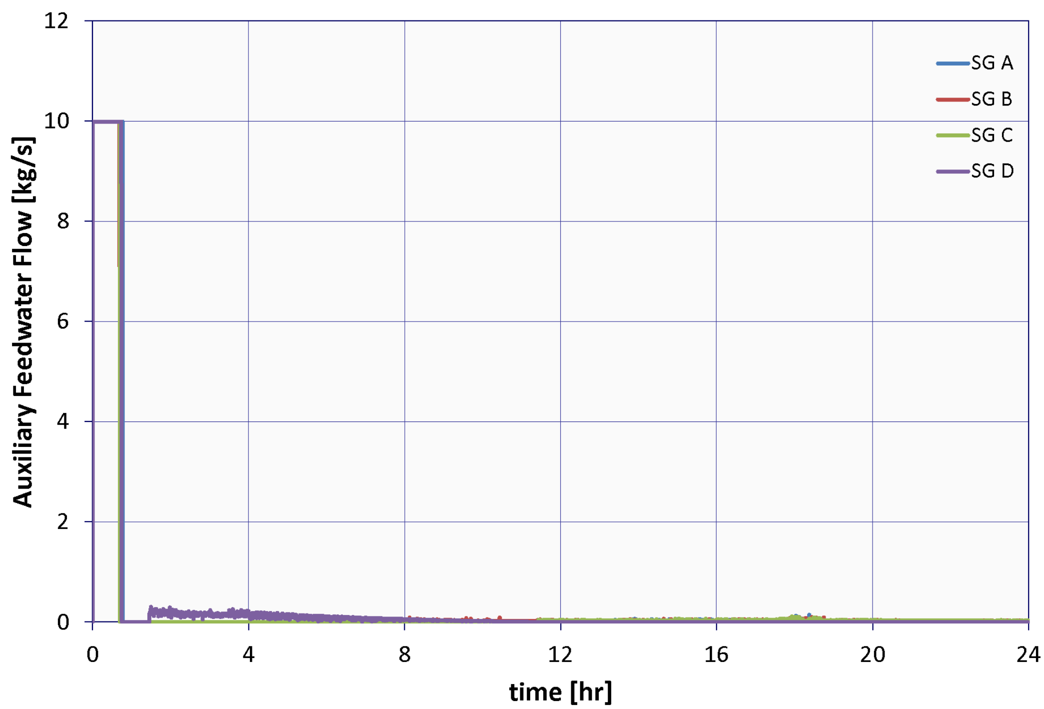

Containment Temperature [°C]
200
180
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

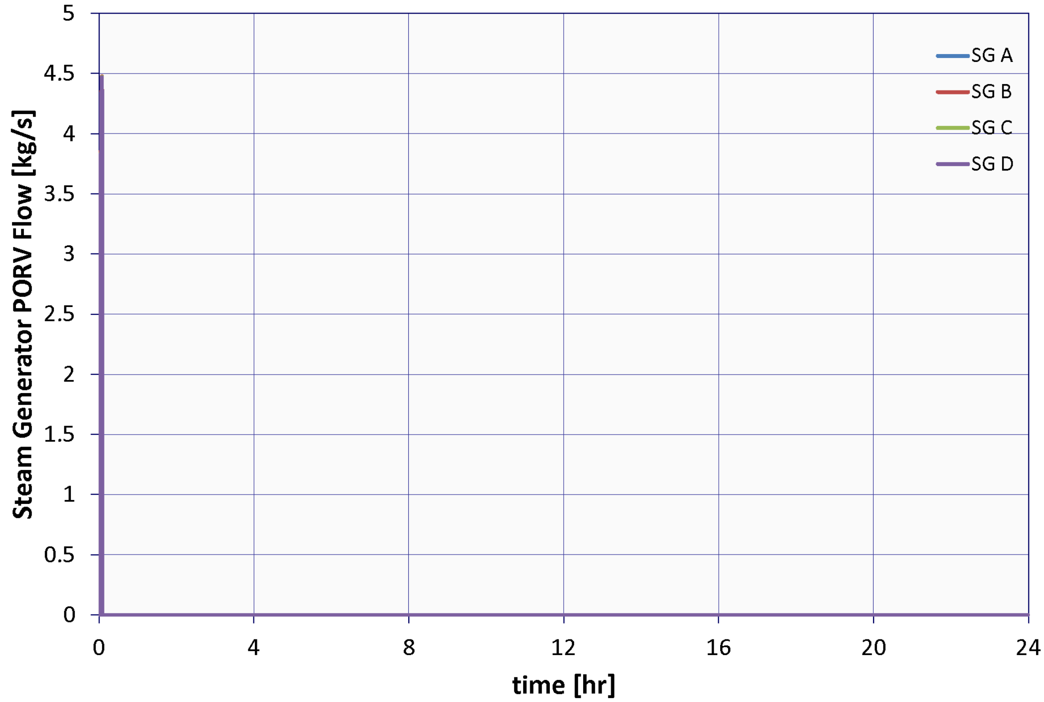

Containment Pressure [MPa]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

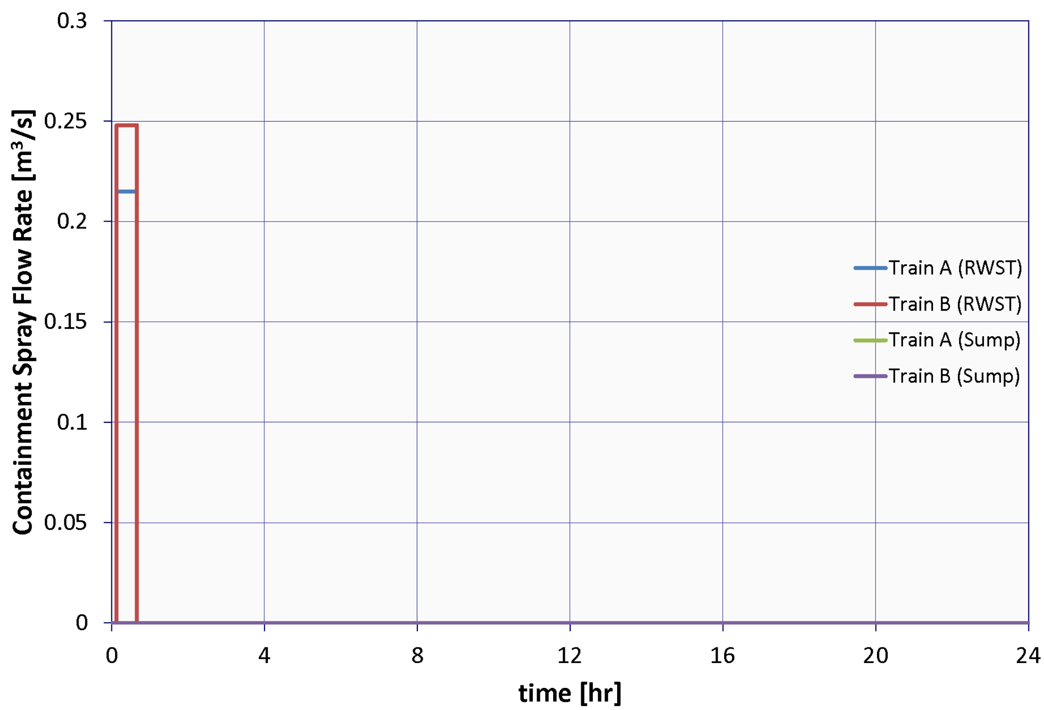

Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24

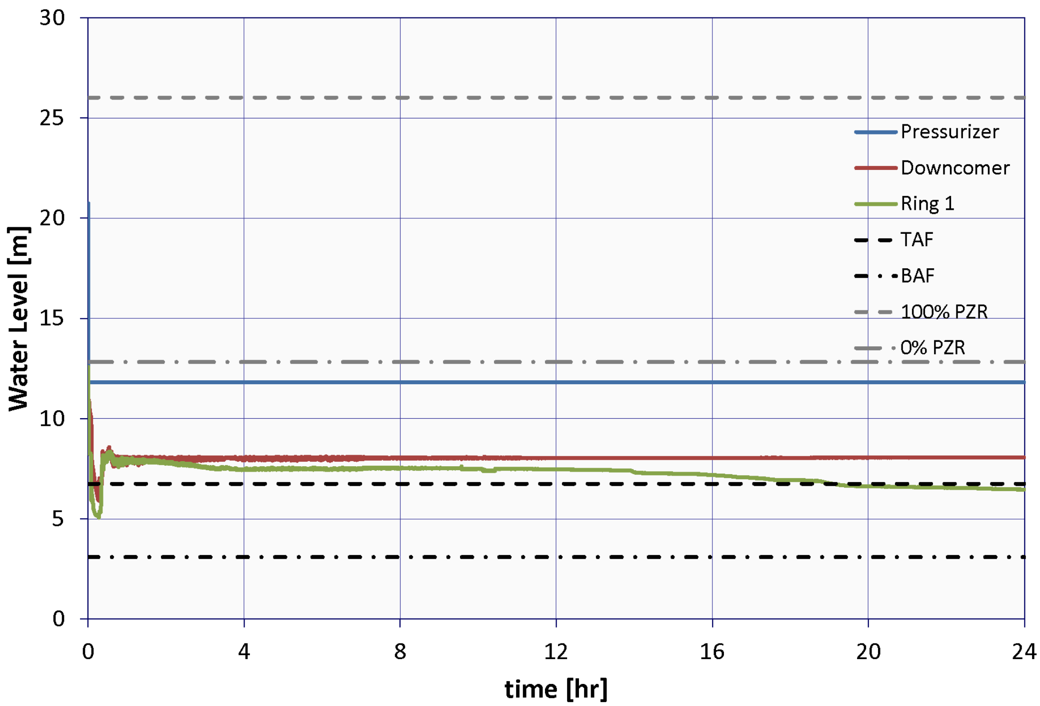

Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24


ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
0
200
400
600
800
1000
1200
1400
0
4
8
12
16
20
24

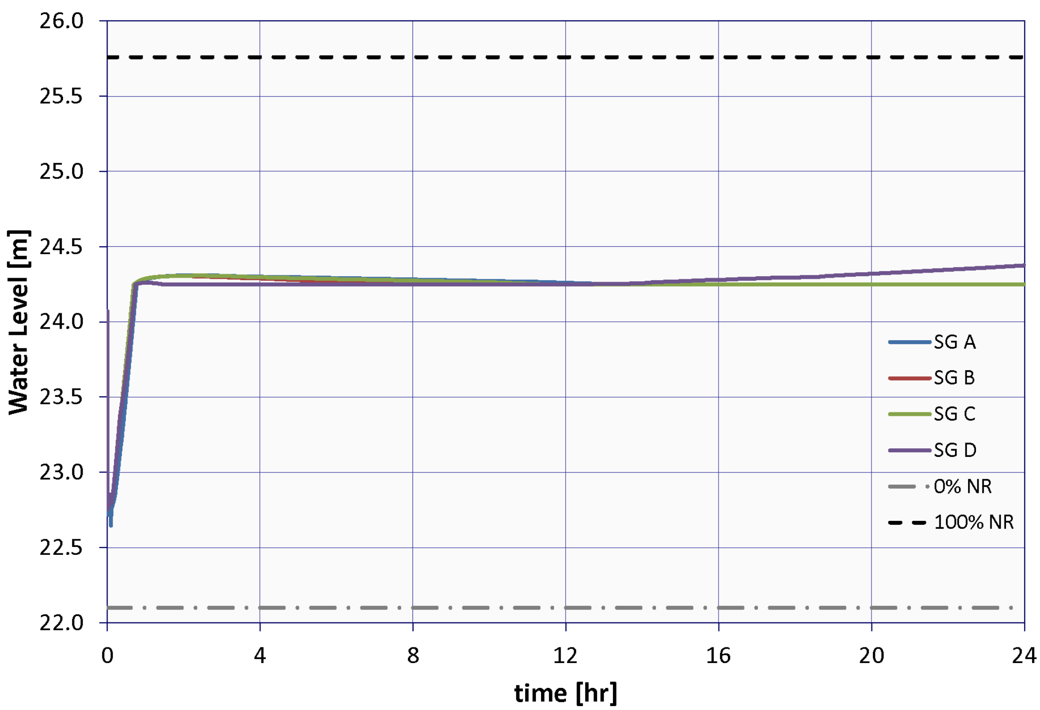

Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
4
8
12
16
20
24

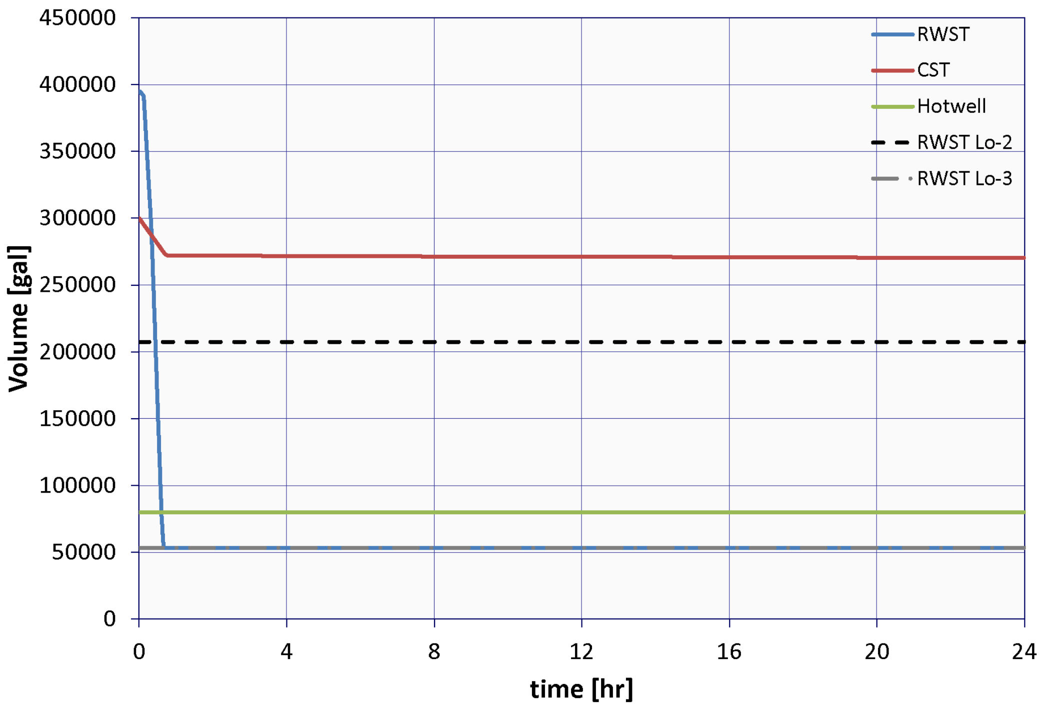

Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

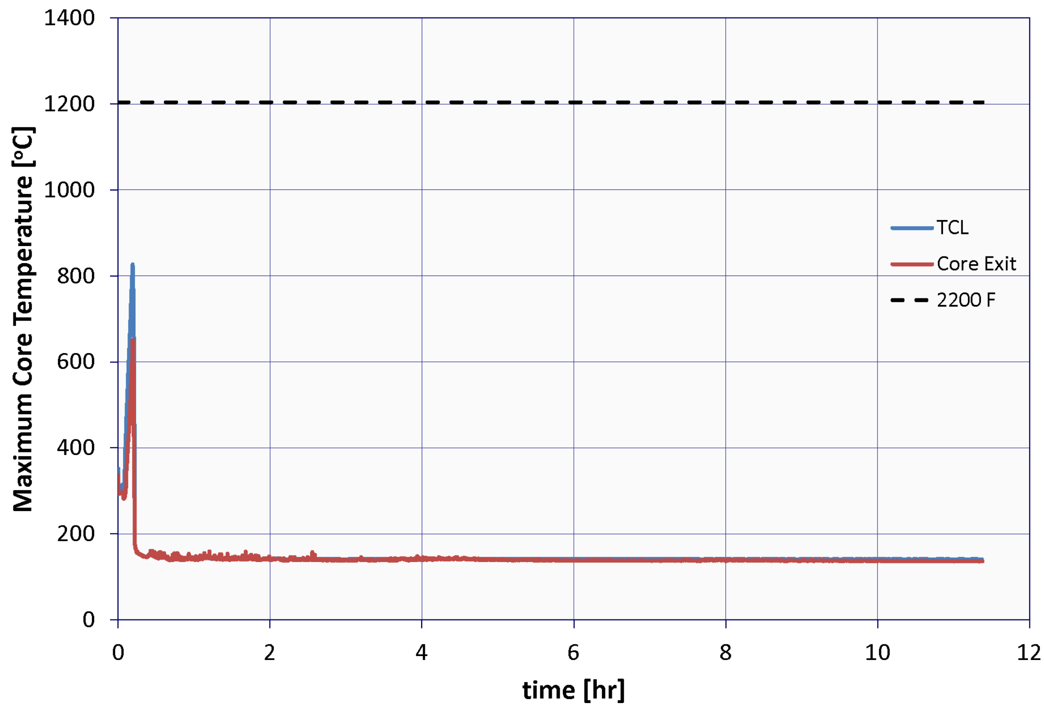


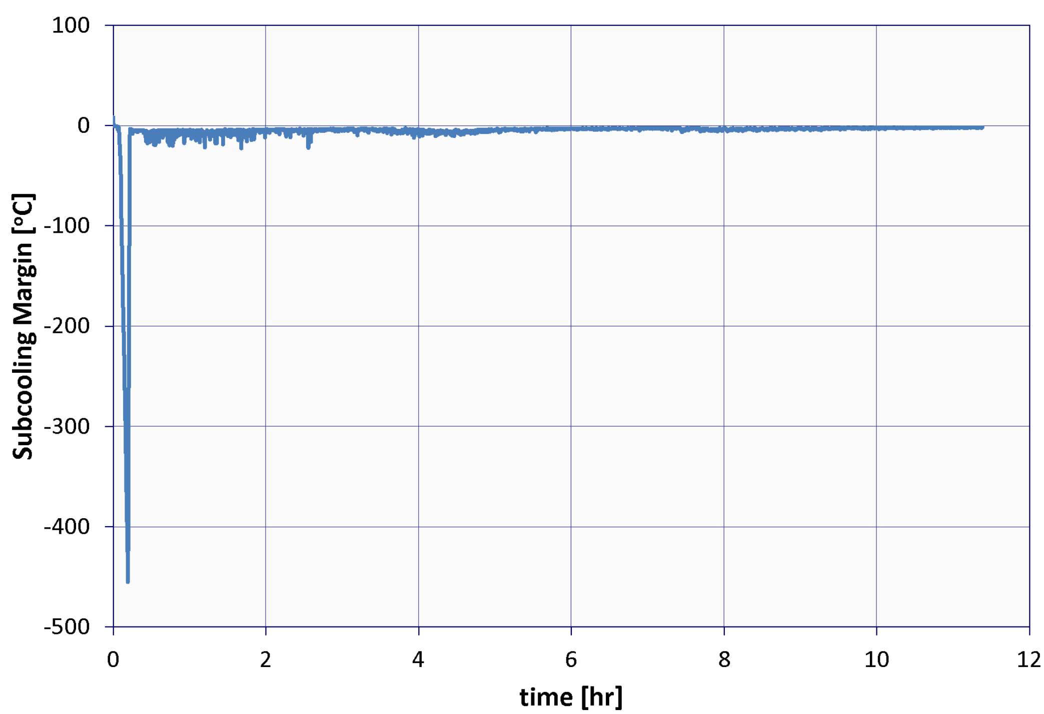
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

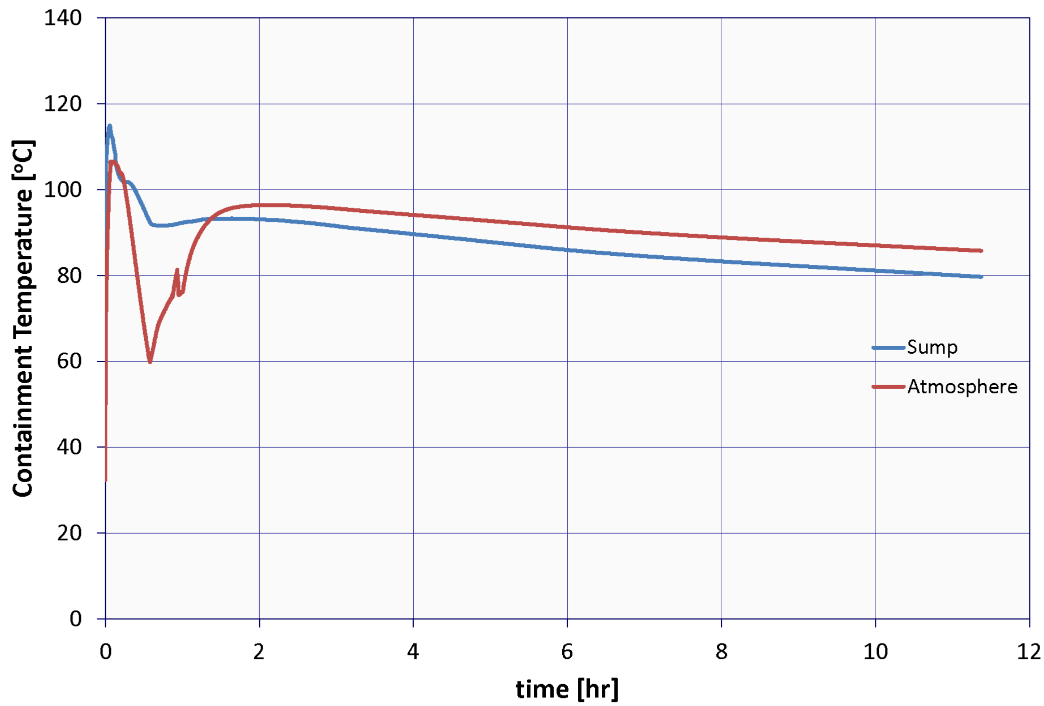


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

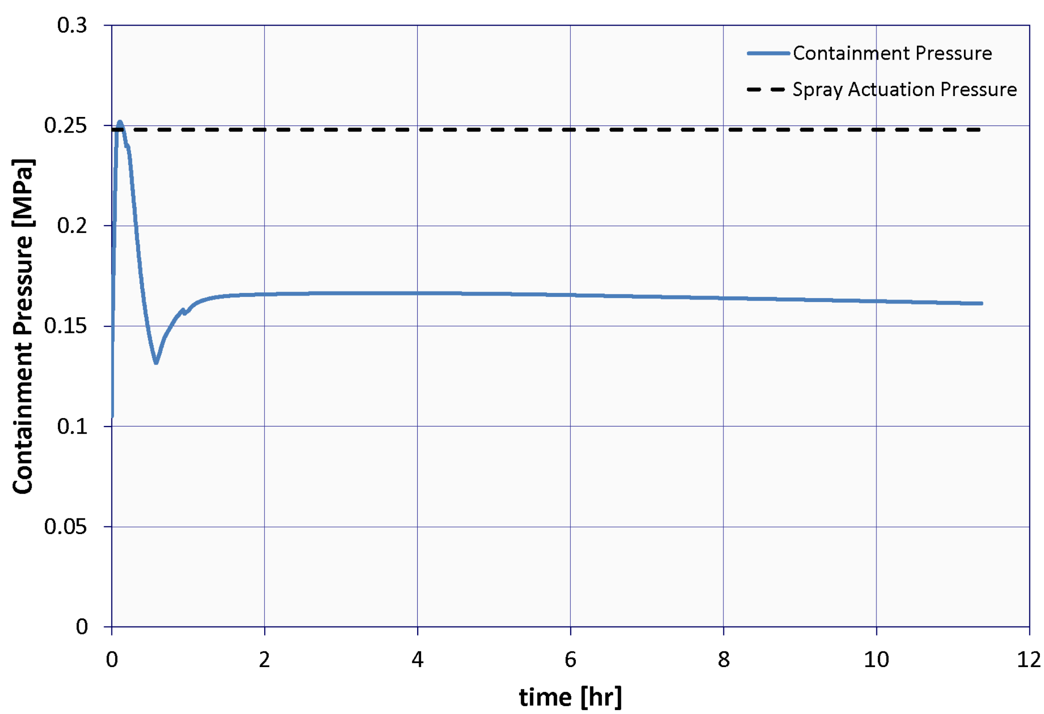
E.1.4 Case 4: 6-in. Break with 1/2 SI, 1/2 RHR, 2/2 CS Pumps



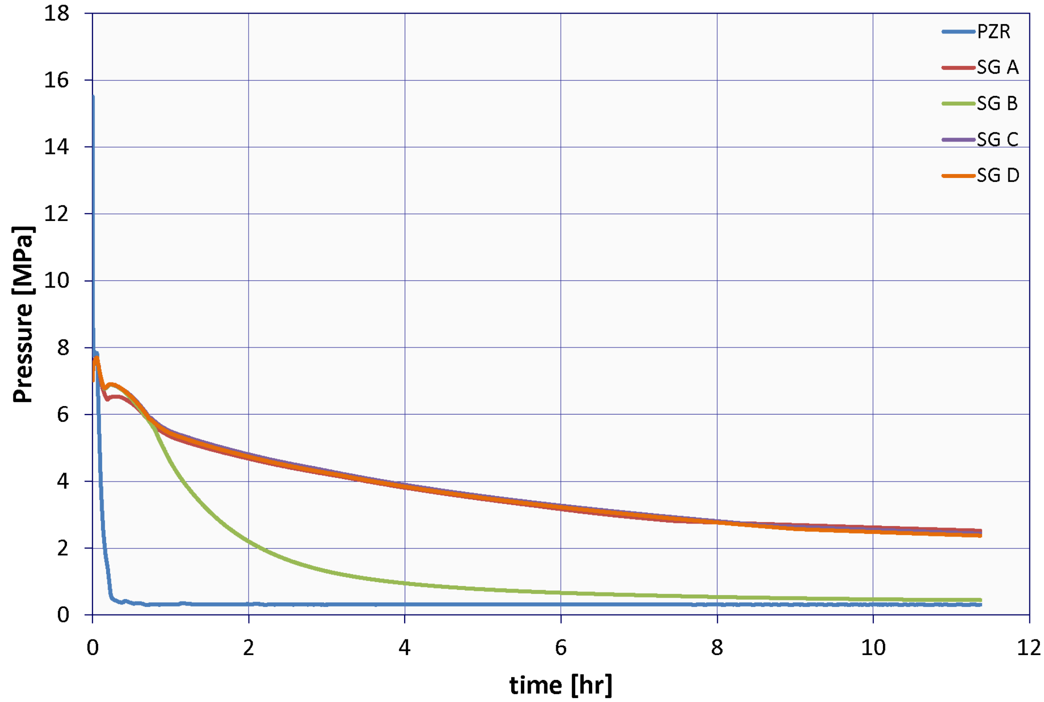




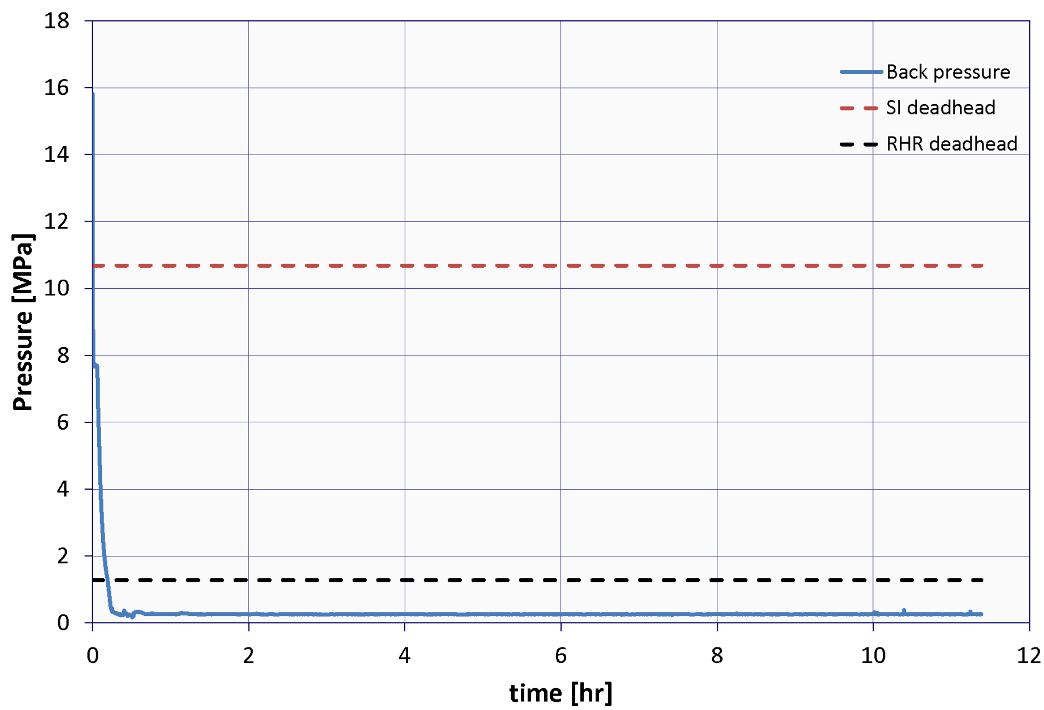
140
120
100
80
60
40
20
0
Containment Temperature [ºC]
0
2
4
6
8
10
12
time [hr]
Sump
Atmosphere



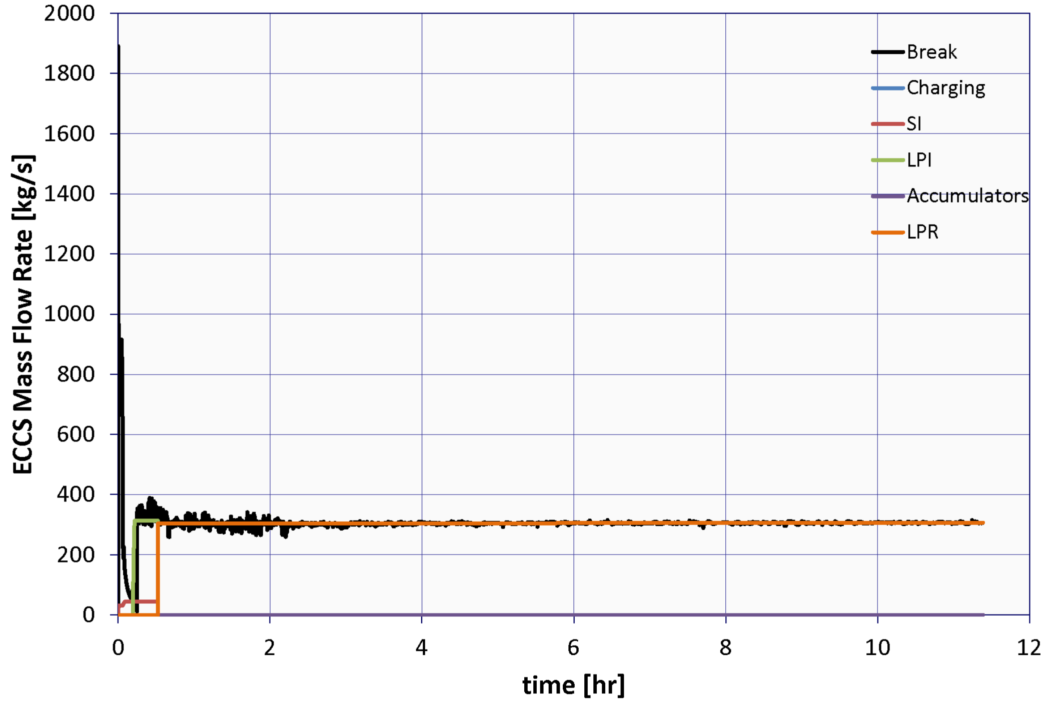
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
2
4
6
8
10
12
time [hr]
Containment Pressure
Spray Actuation Pressure



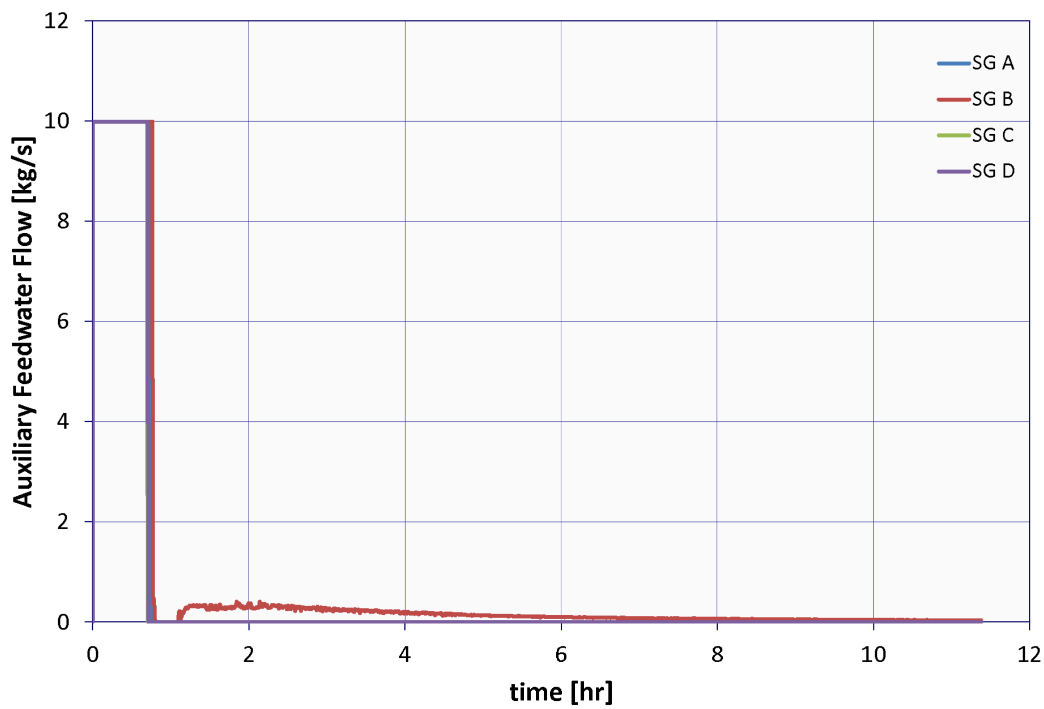
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
2
4
6
8
10
12
time [hr]
PZR
SG A
SG B
SG C
SG D



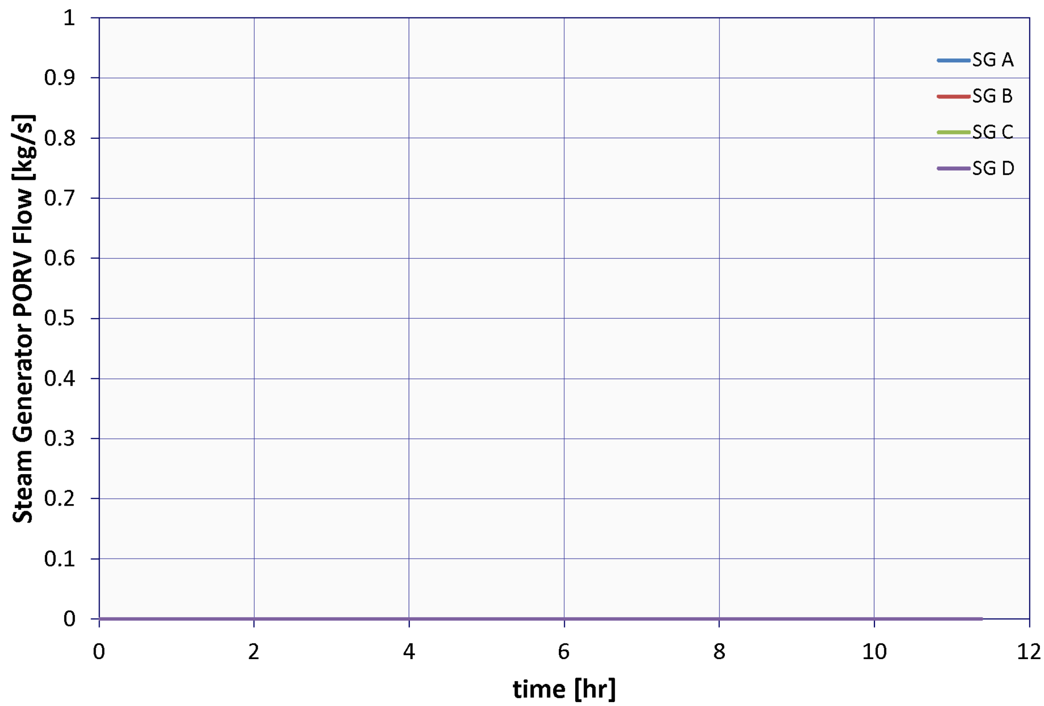
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
2
4
6
8
10
12
time [hr]
Back pressure
SI deadhead
RHR deadhead

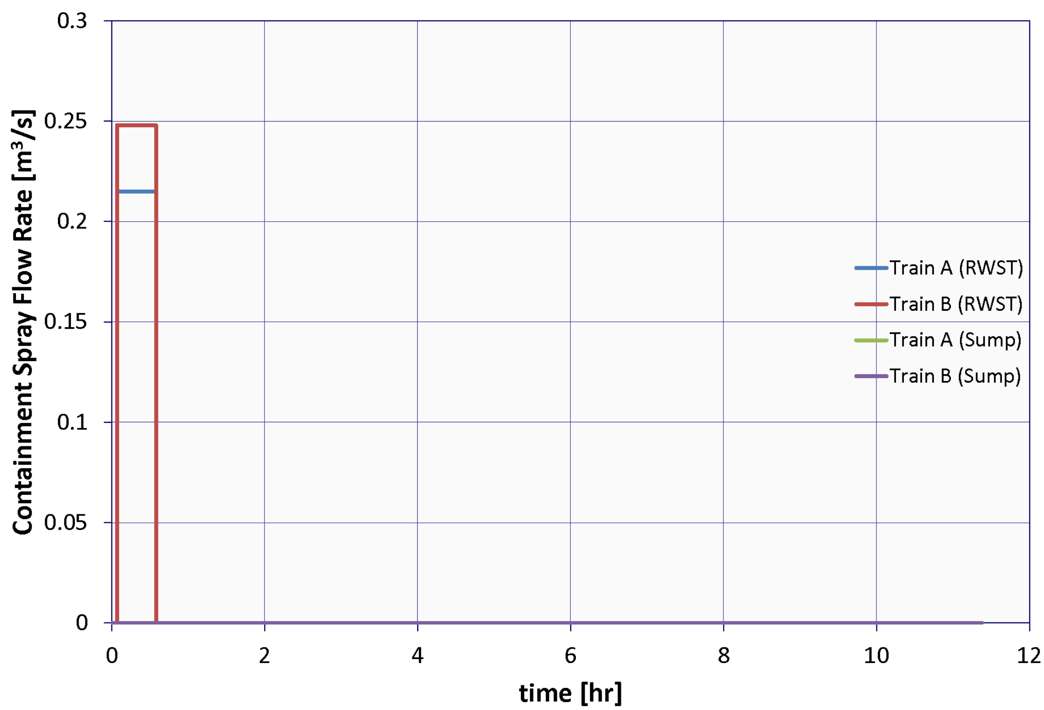


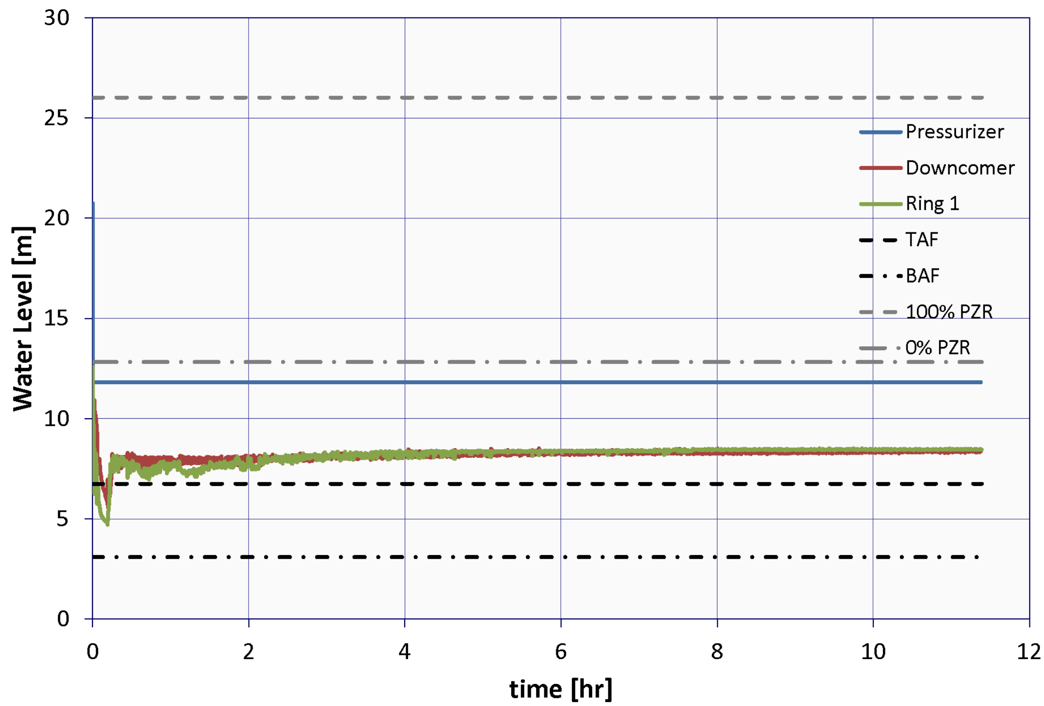
ECCS Mass Flow Rate [kg/s]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



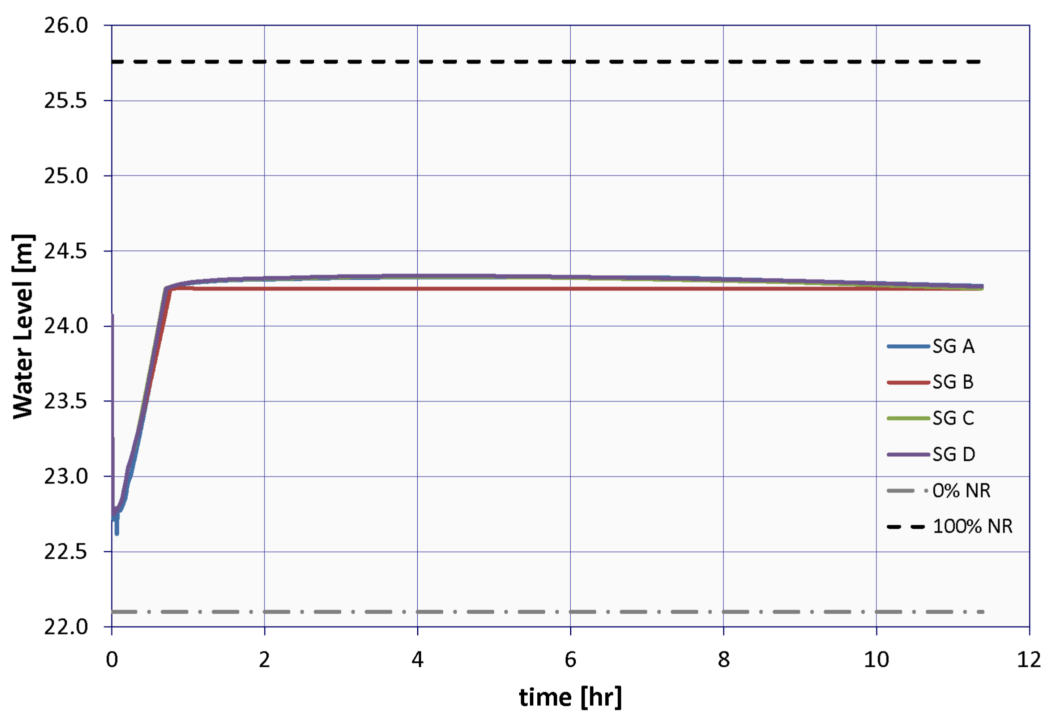
Auxiliary Feedwater Flow [kg/s]
12
10
8
6
4
2
0
0
2
4
6
8
10
12
time [hr]
SG A
SG B
SG C
SG D


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12

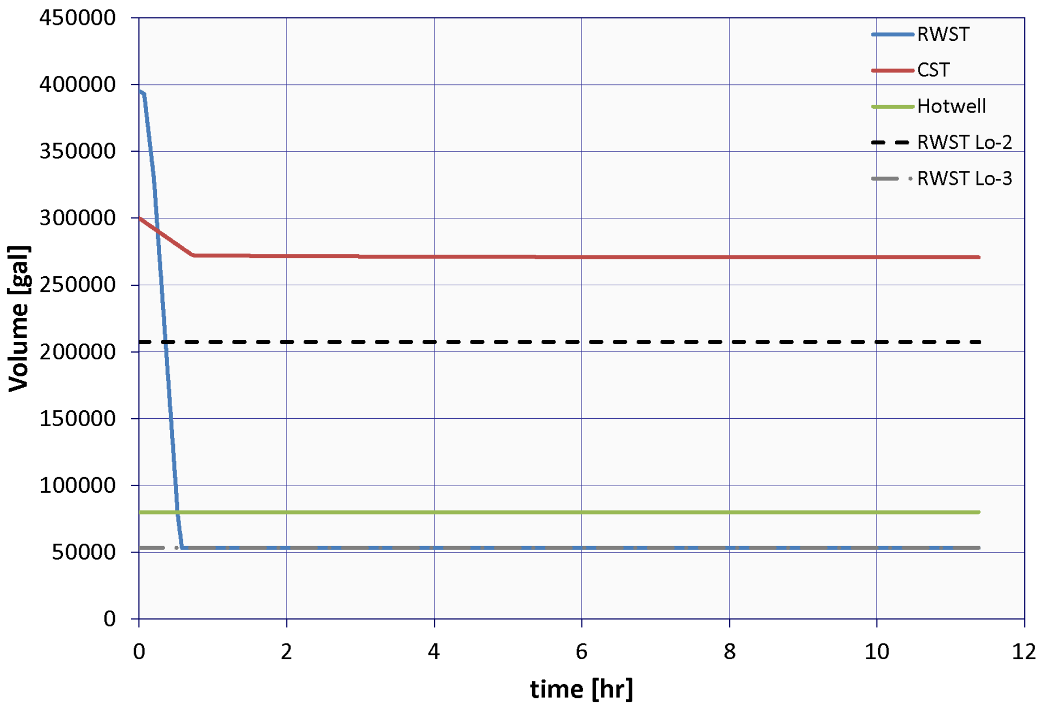

Containment Spray Flow Rate [m3/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12



30
25
20
15
10
5
0
Water Level [m]
0
2
4
6
8
10
12
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

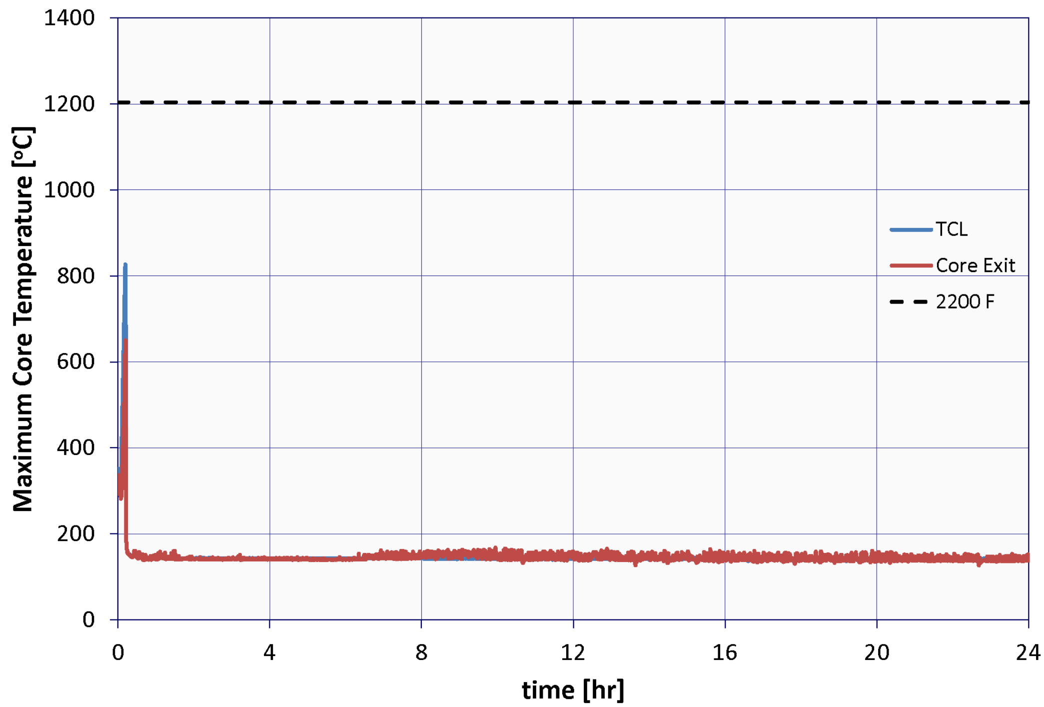


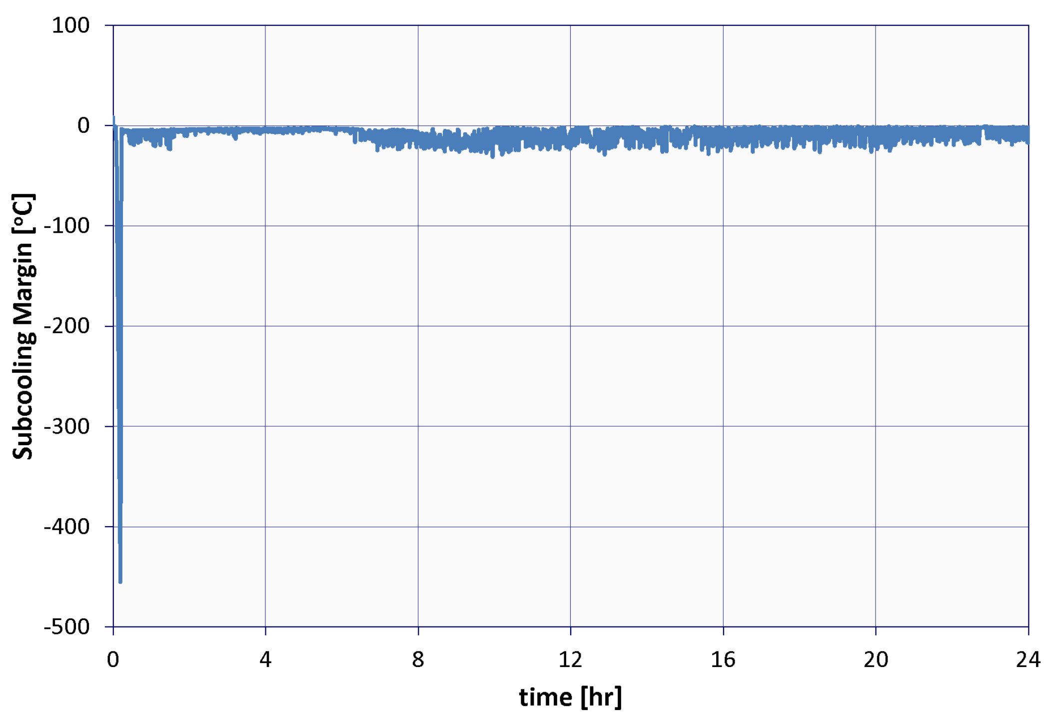
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
2
4
6
8
10
12
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

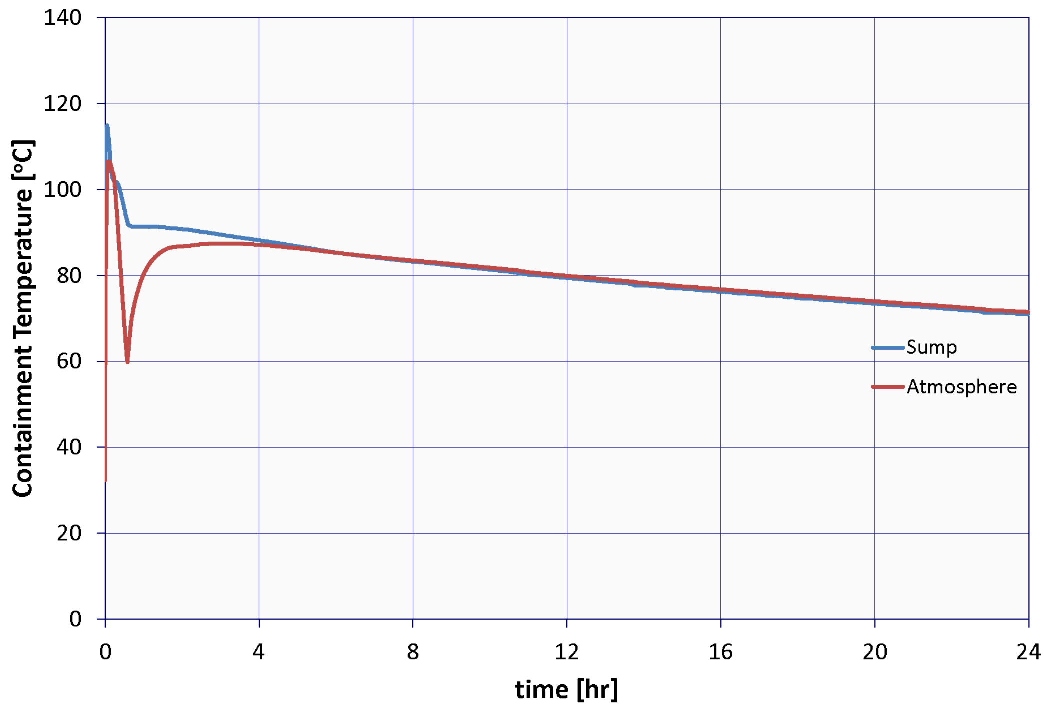


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
2
4
6
8
10
12
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

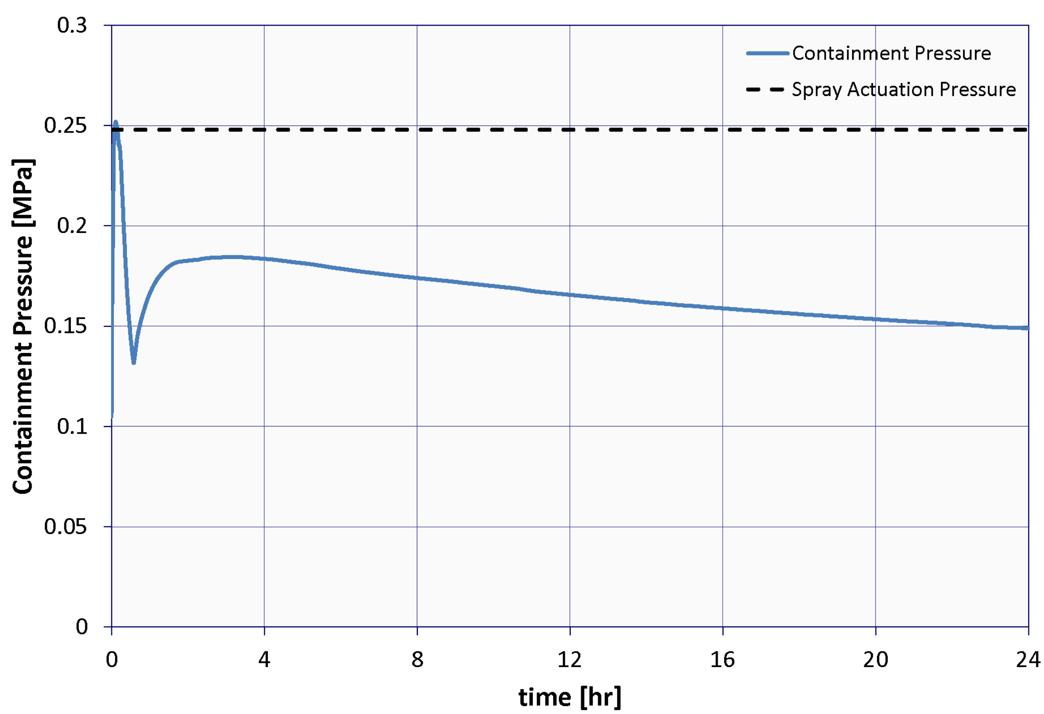
E.1.4.1 *Case 4a: 6-in. Break with 1/2 SI Pumps, 1/2 RHR Pump, 2/2 CS Pumps, CS Recirc*



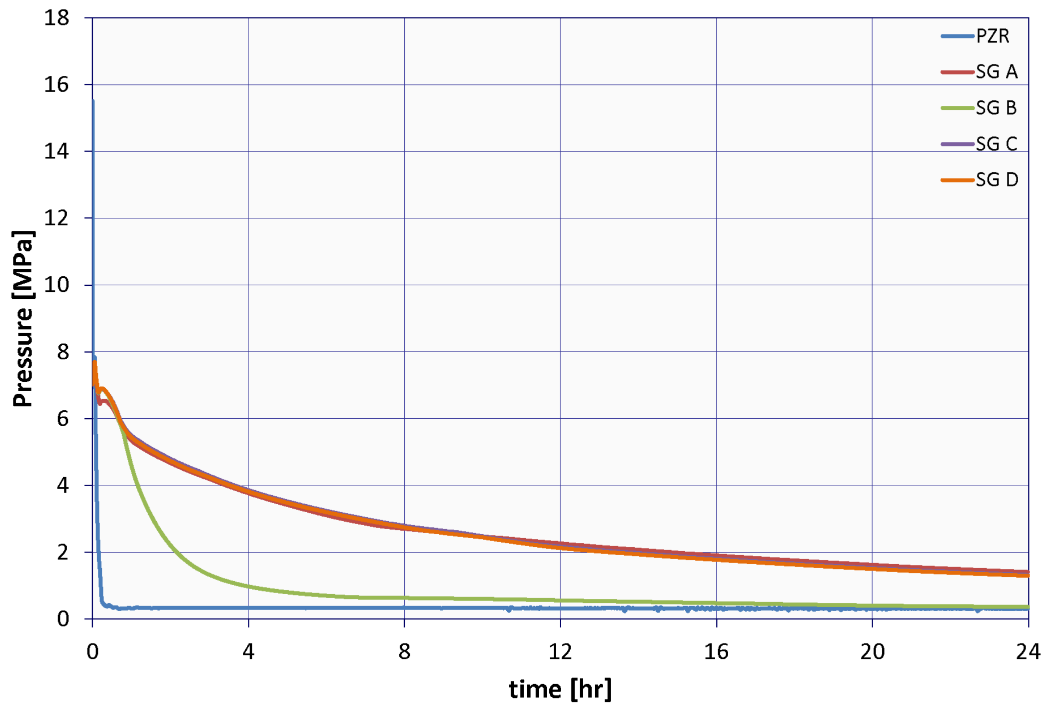




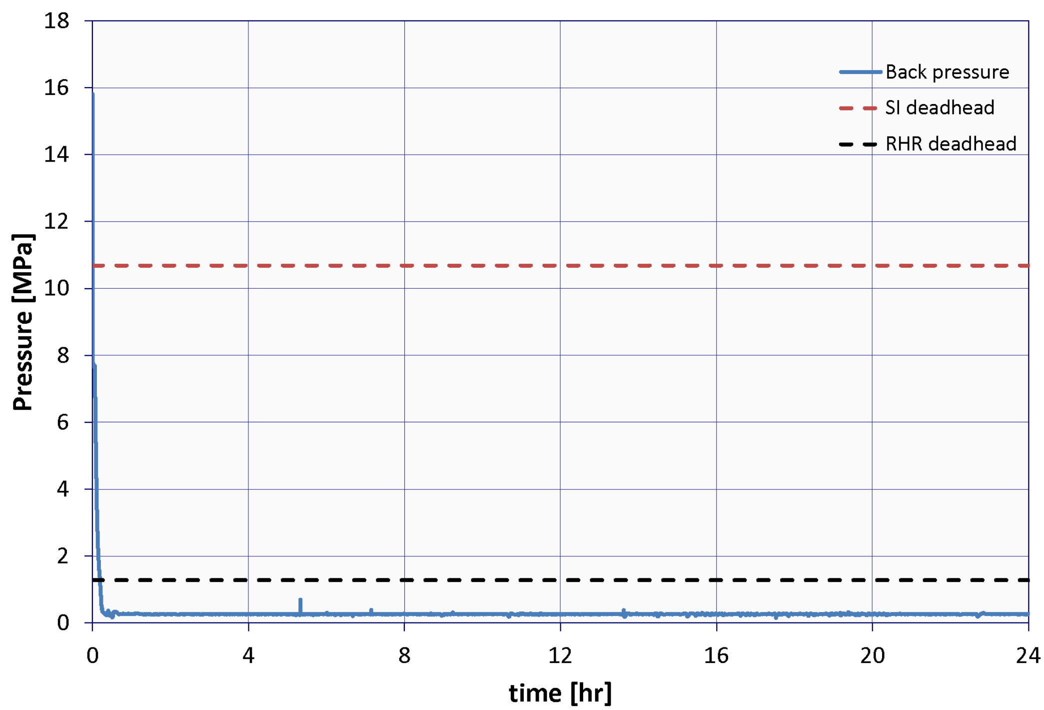
140
120
100
80
60
40
20
0
Containment Temperature [°C]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



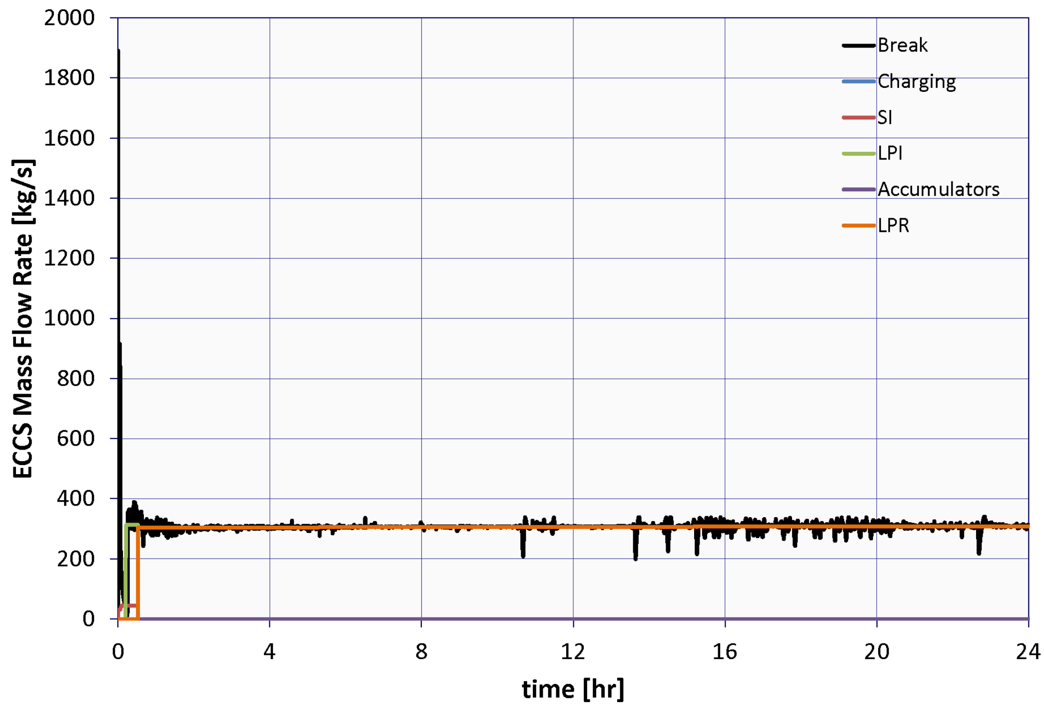
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

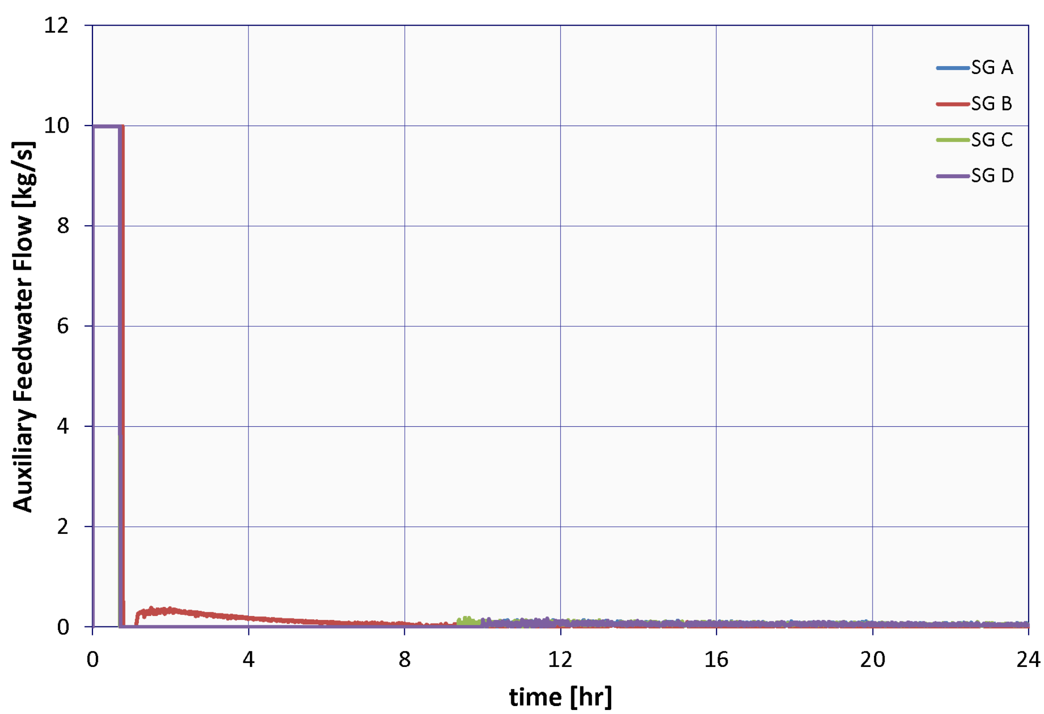


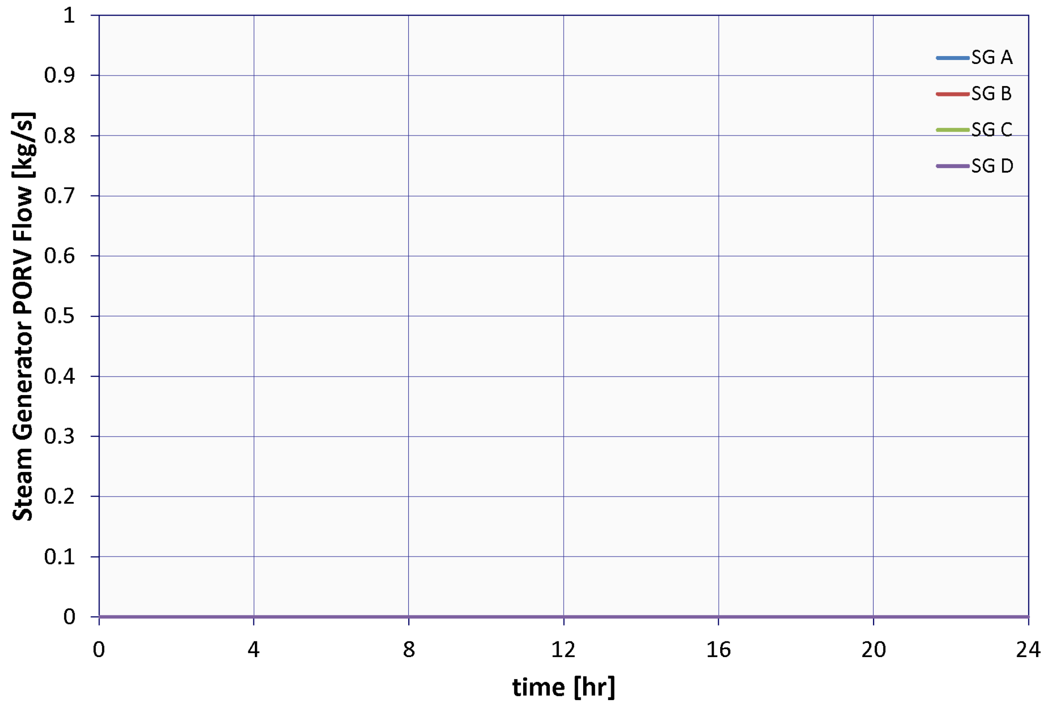
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



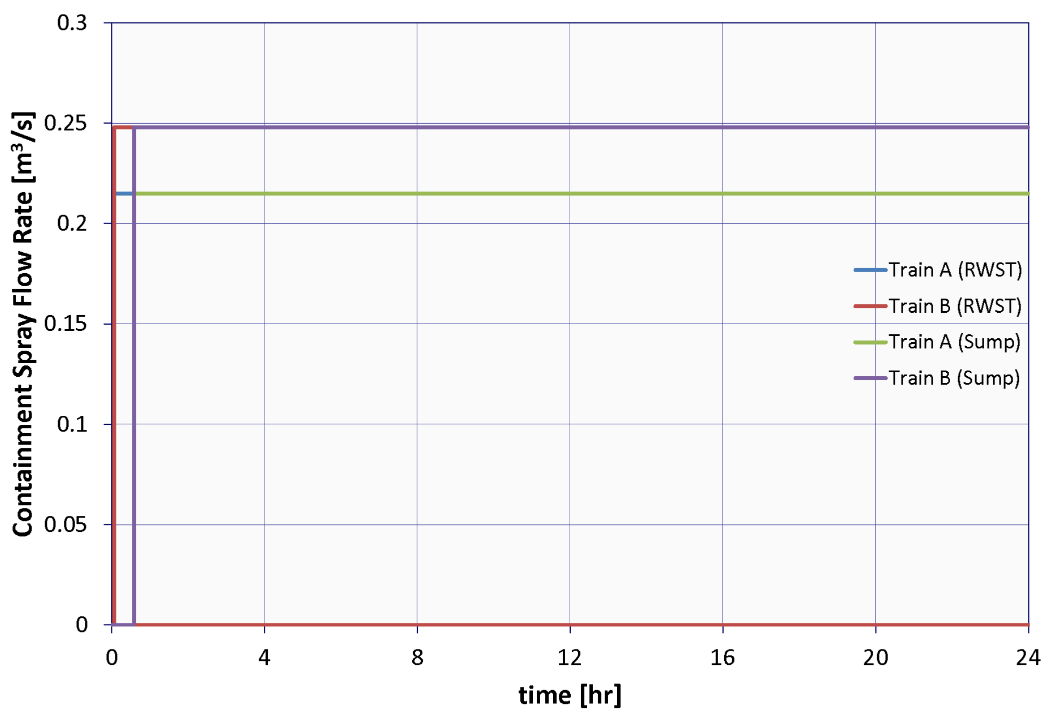
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead


2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

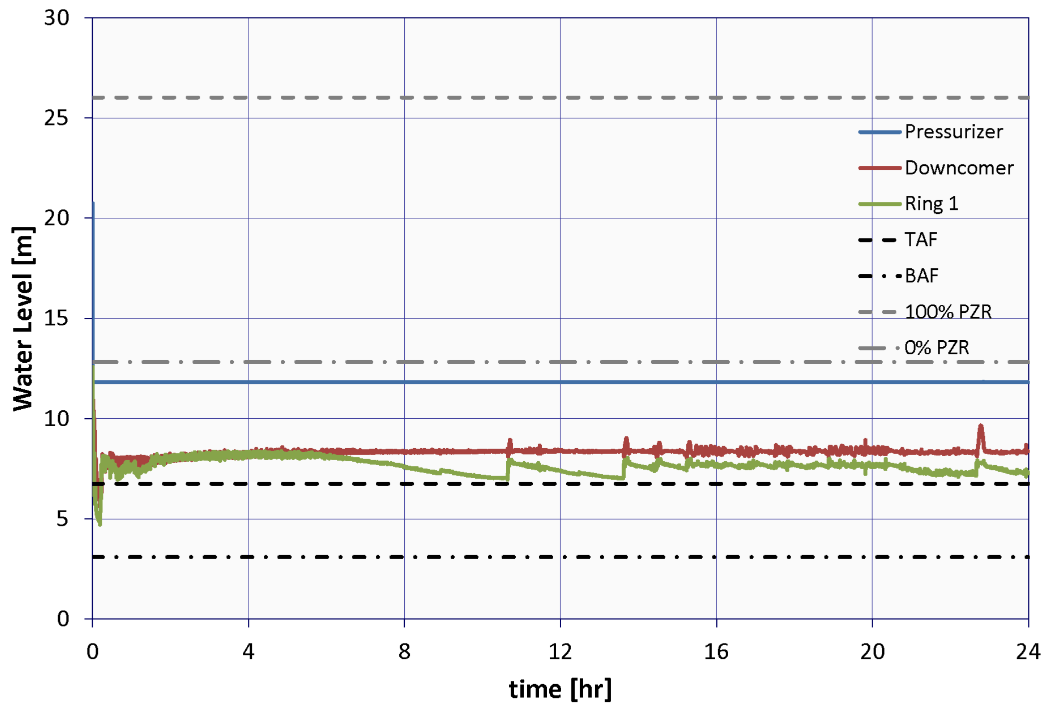

12
10
8
6
4
2
0
Auxiliary Feedwater Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



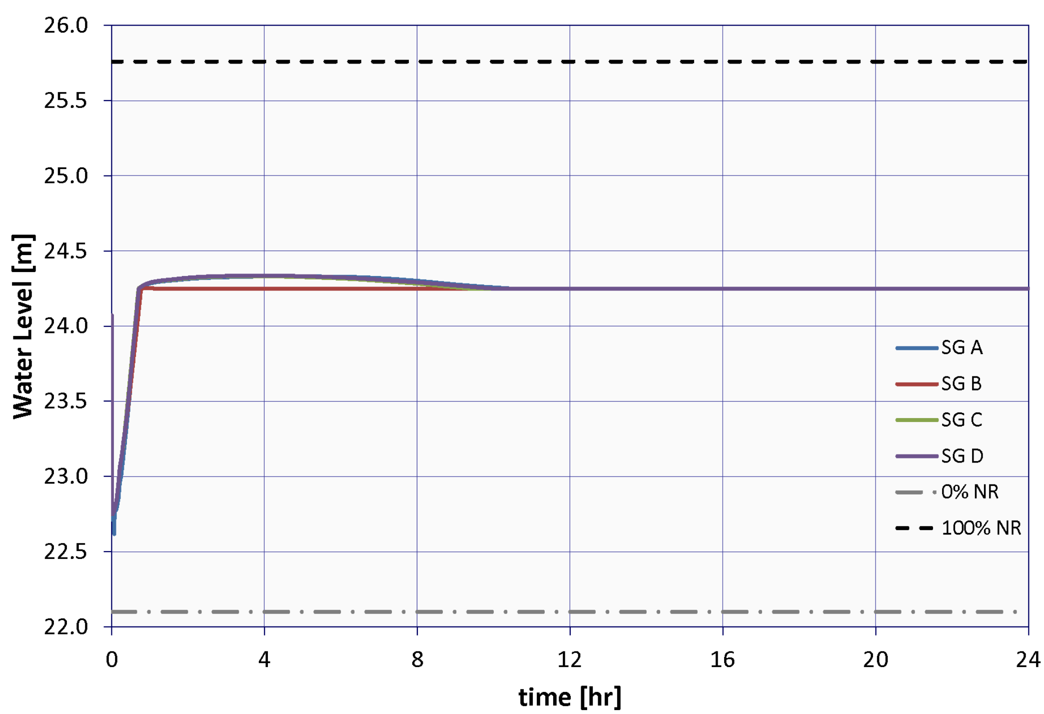
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



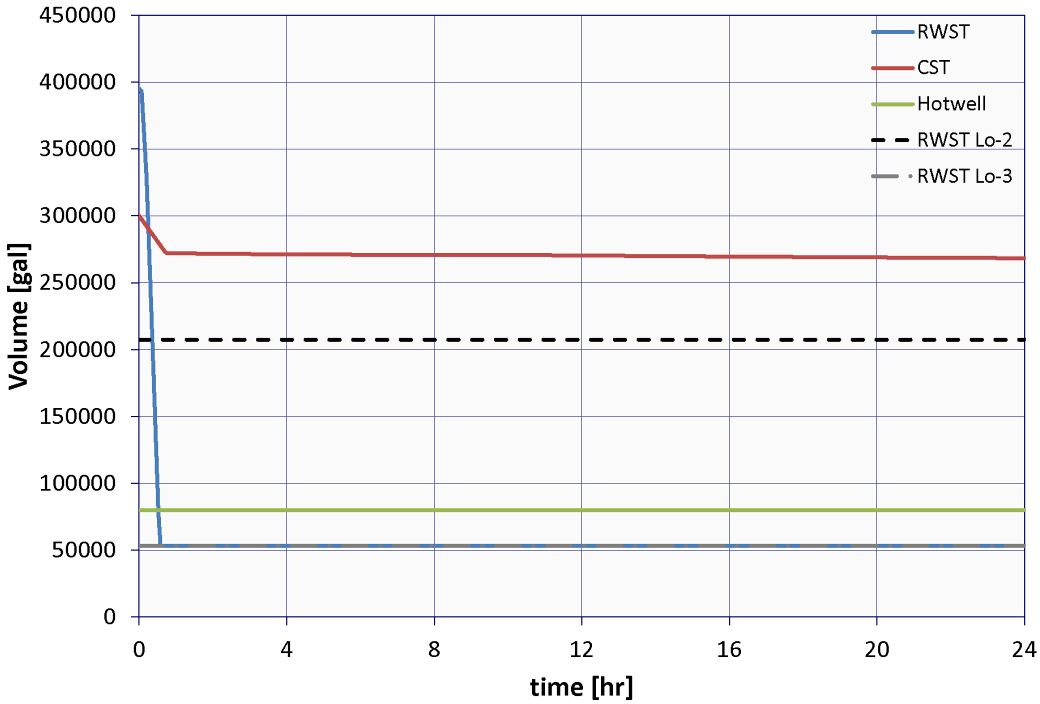
Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

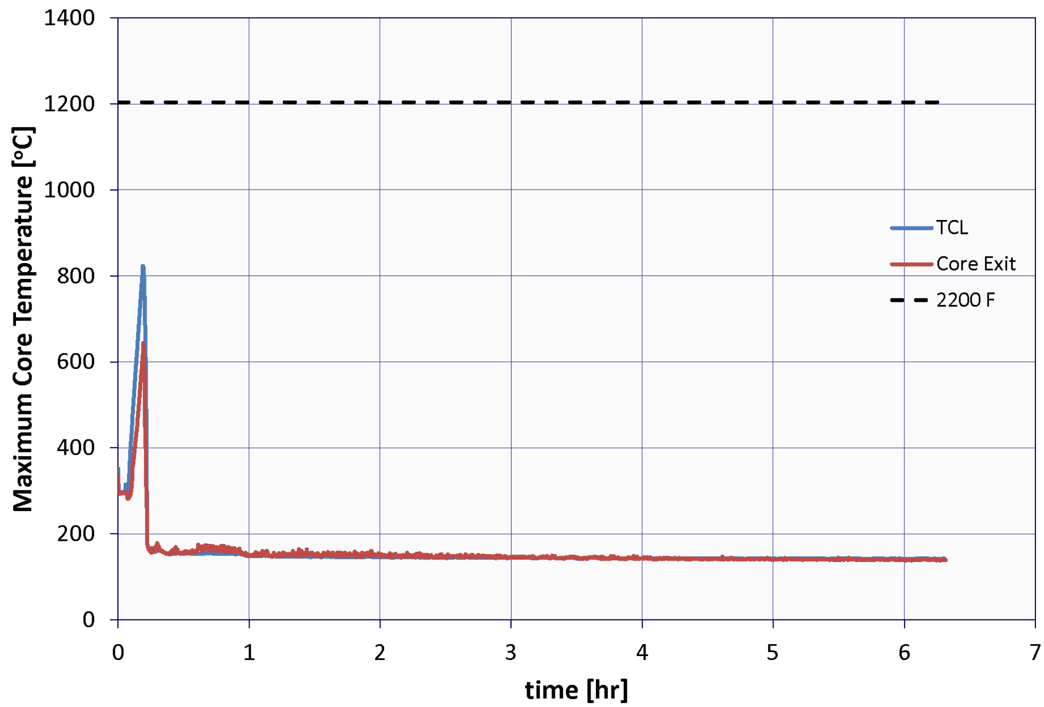


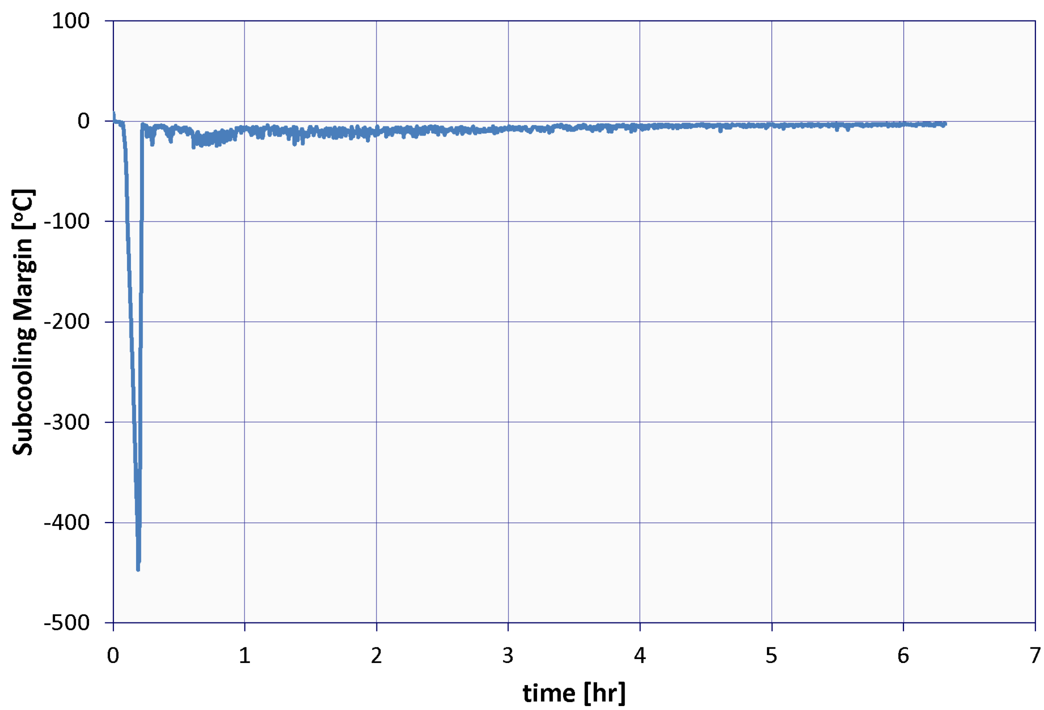
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

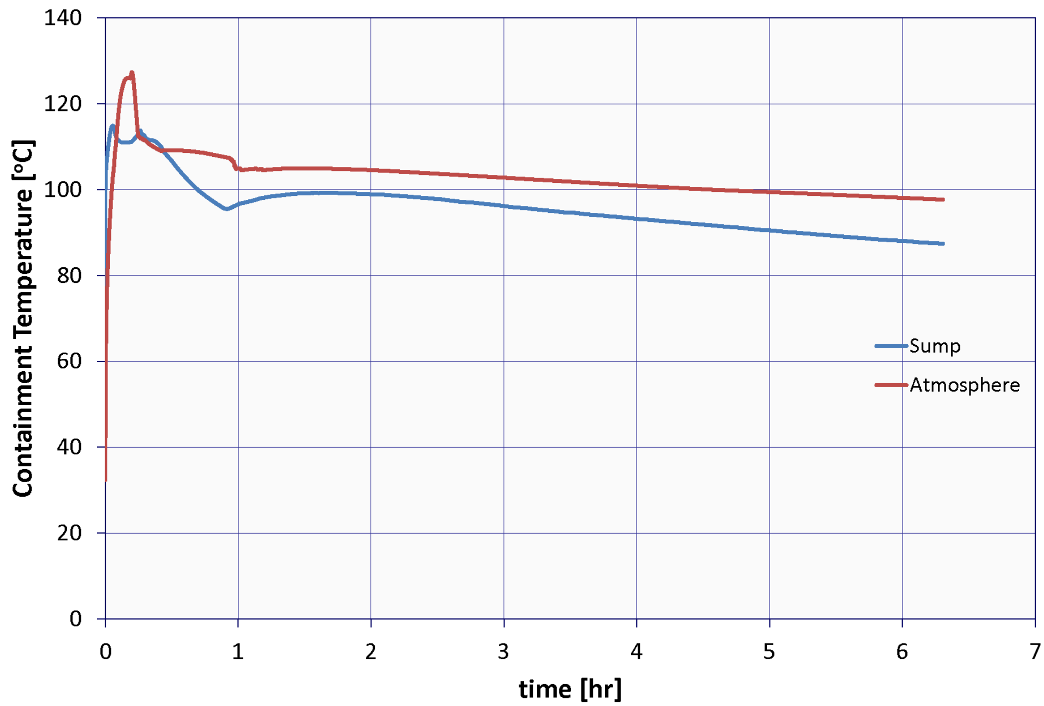


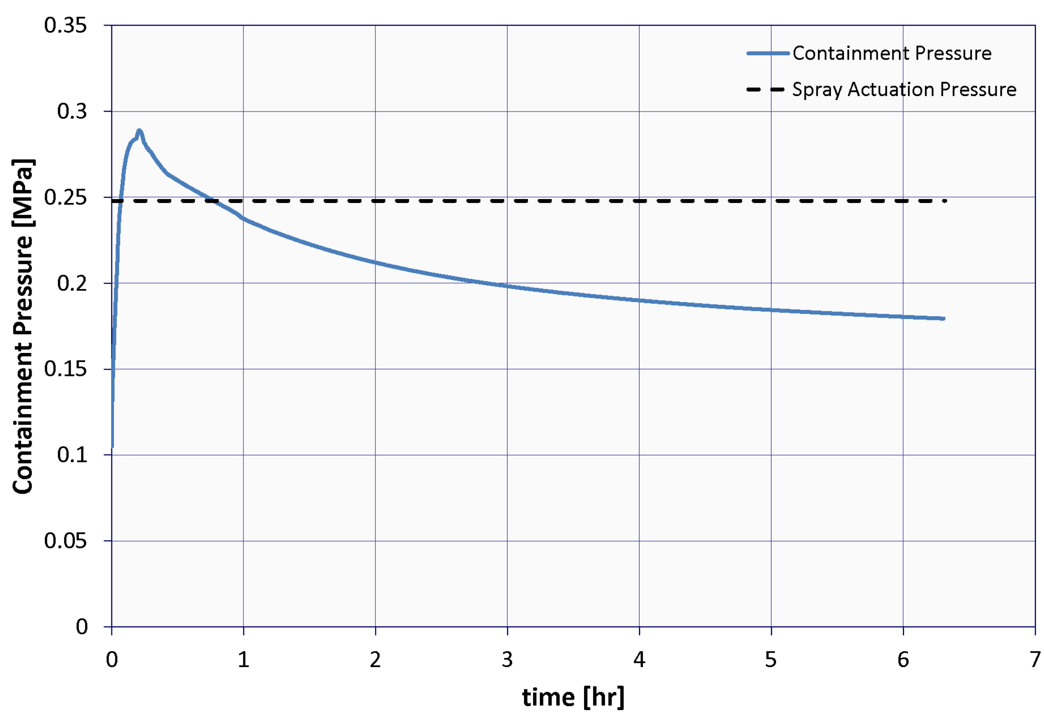
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

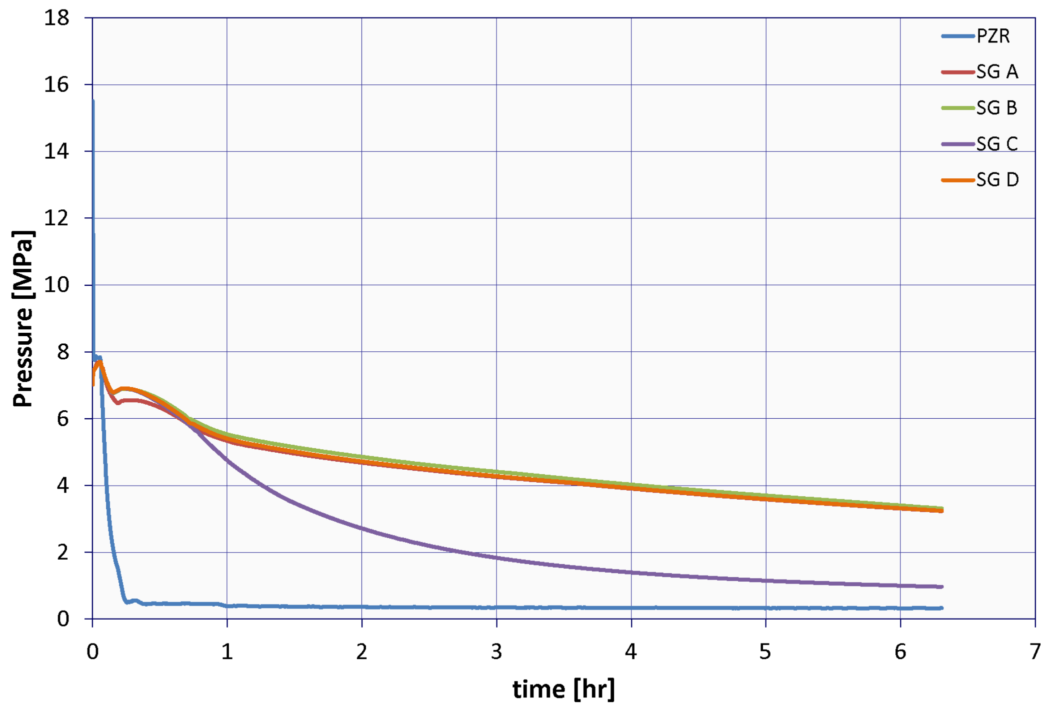
E.1.4.2 *Case 4b: 6-in. Break with 1/2 SI Pumps, 1/2 RHR Pump, 0/2 CS Pumps*



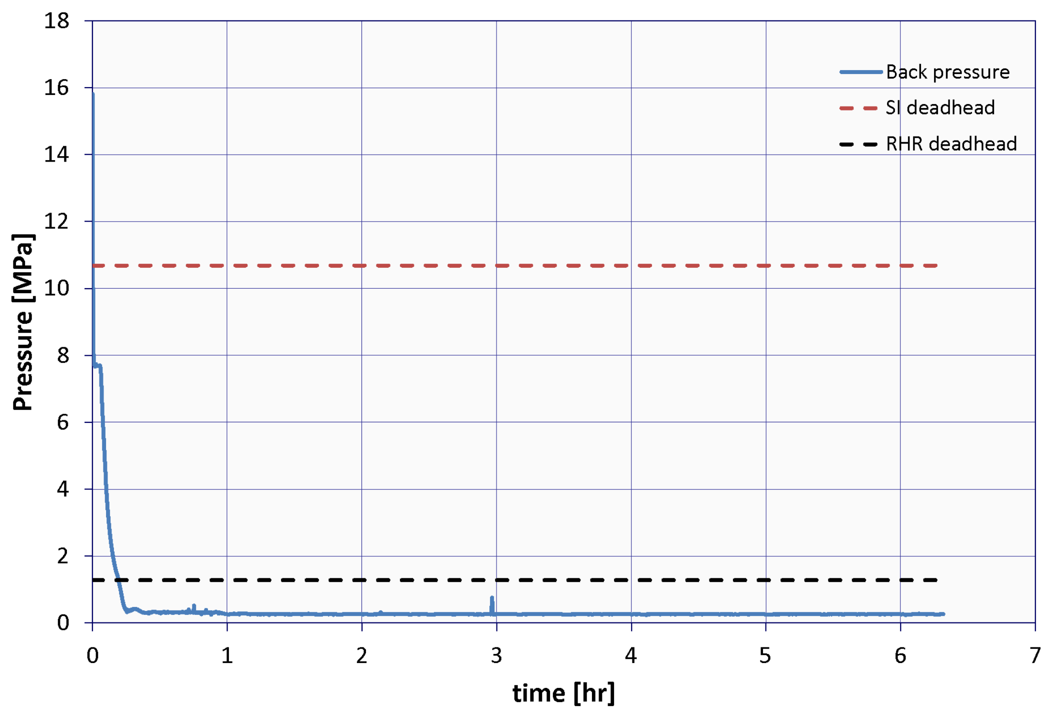



140
120
100
80
60
40
20
0
Containment Temperature [°C]
0
1
2
3
4
5
6
7
time [hr]
Sump
Atmosphere

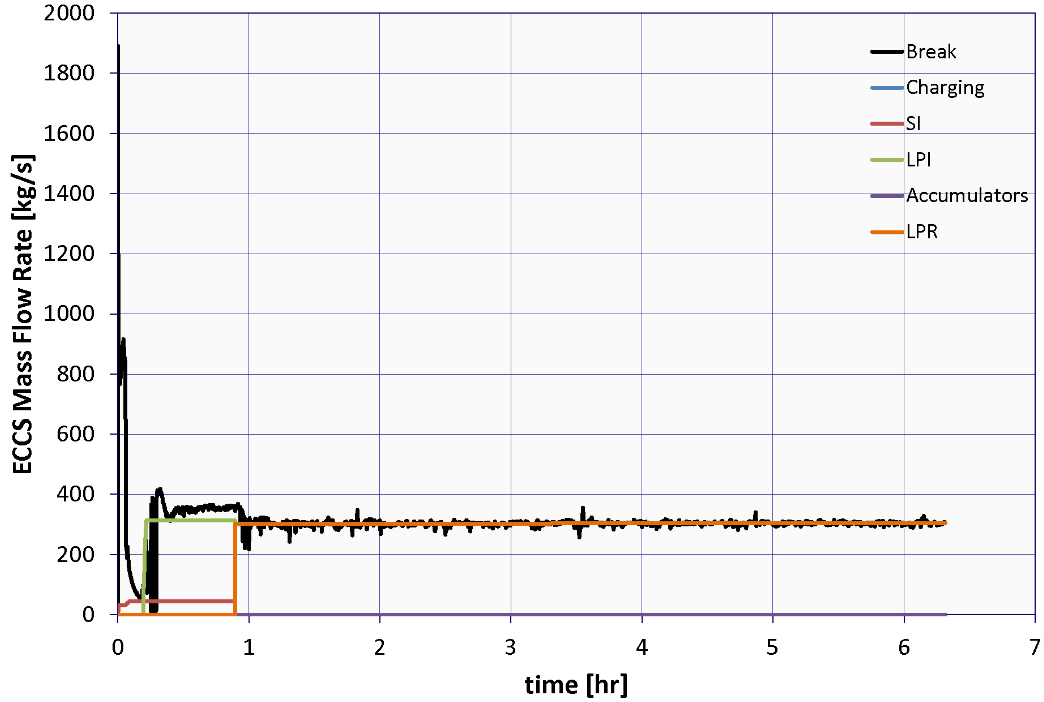

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
1
2
3
4
5
6
7
time [hr]
Containment Pressure
Spray Actuation Pressure



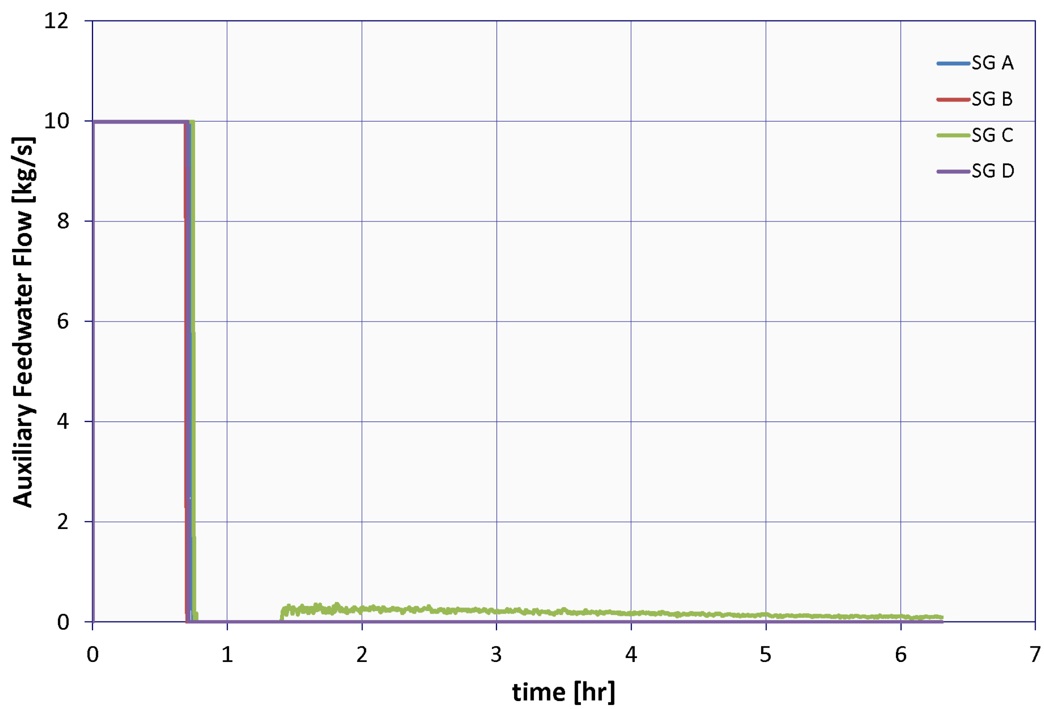
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
1
2
3
4
5
6
7
time [hr]
PZR
SG A
SG B
SG C
SG D



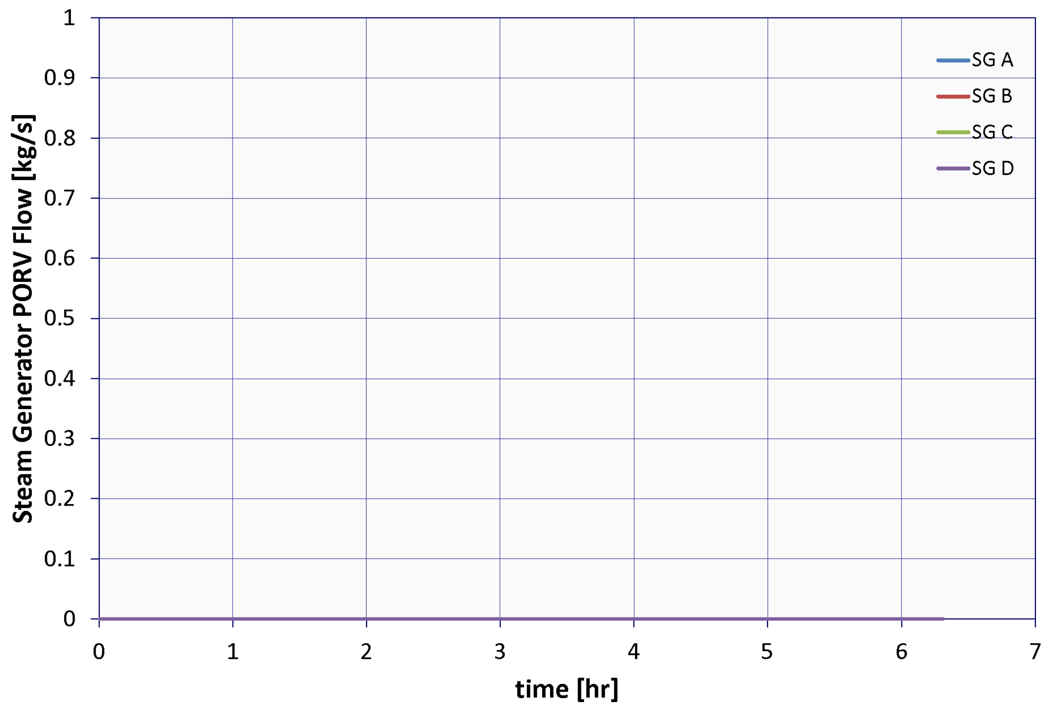
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
1
2
3
4
5
6
7
time [hr]
Back pressure
SI deadhead
RHR deadhead

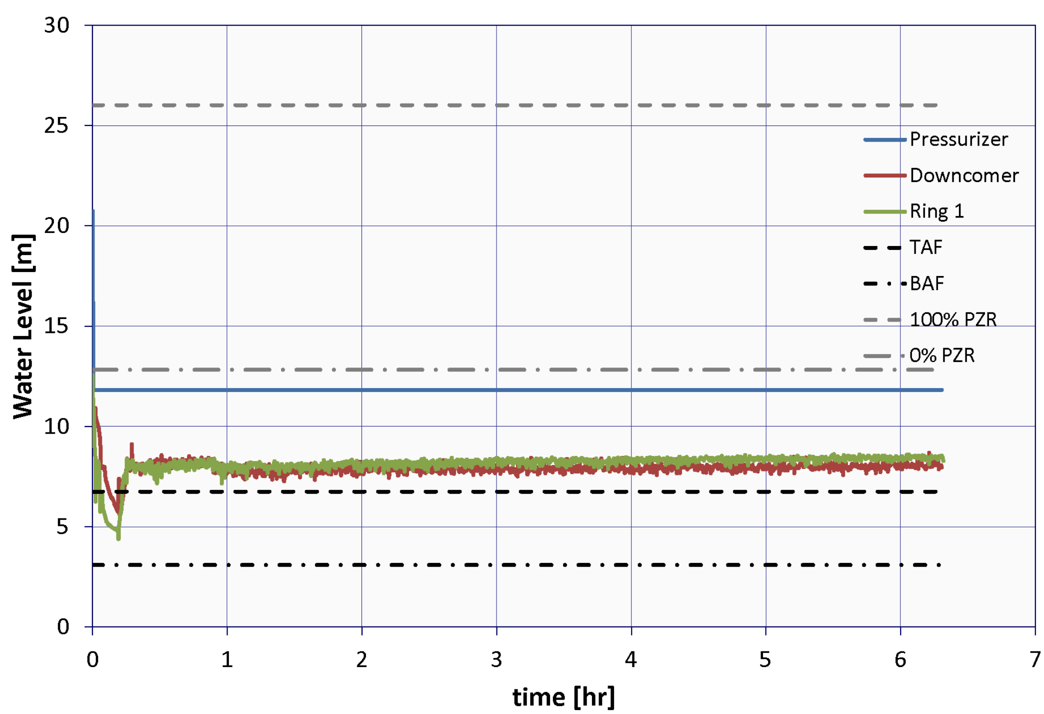


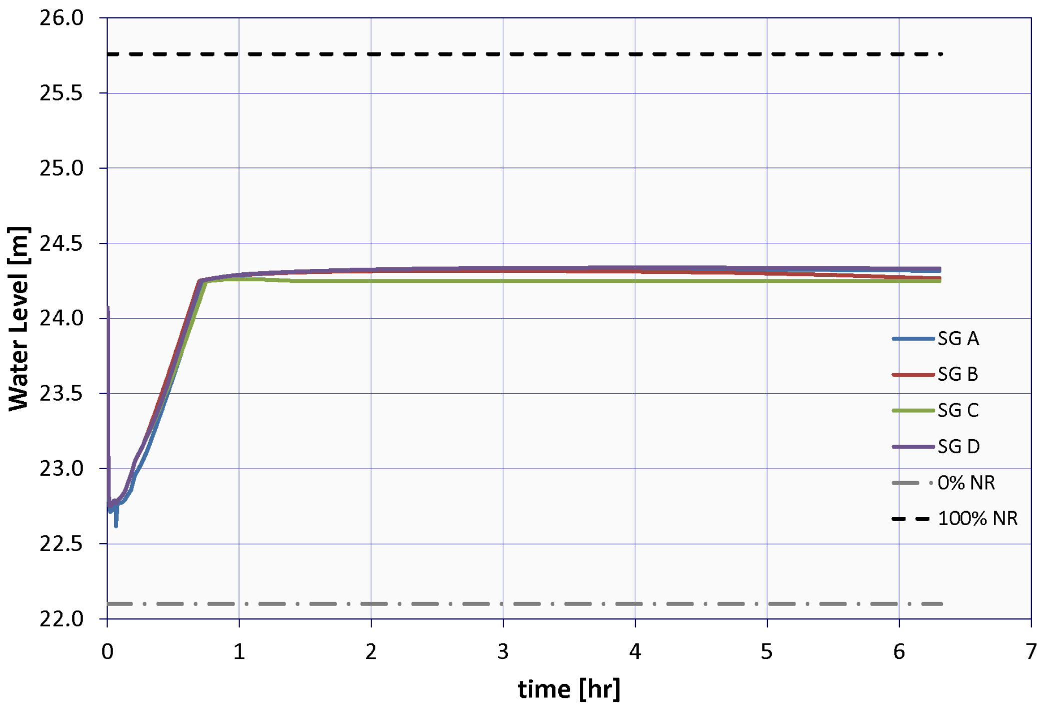
ECCS Mass Flow Rate [kg/s]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

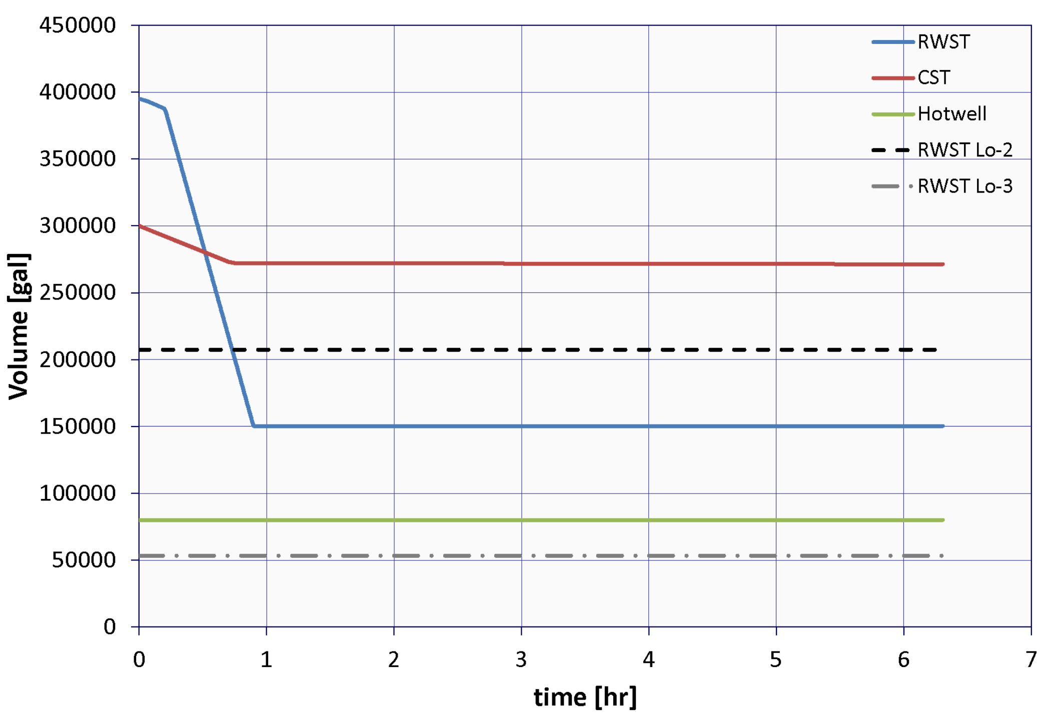


Auxiliary Feedwater Flow [kg/s]
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
time [hr]
SG A
SG B
SG C
SG D

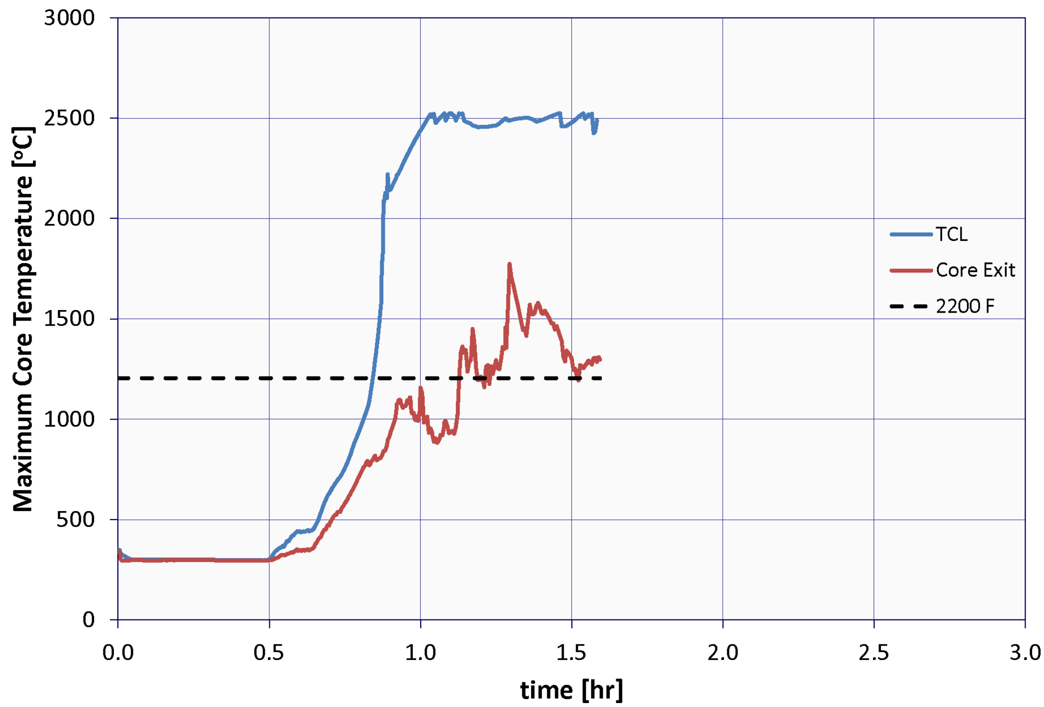

Steam Generator PORV Flow [kg/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
time [hr]
SG A
SG B
SG C
SG D

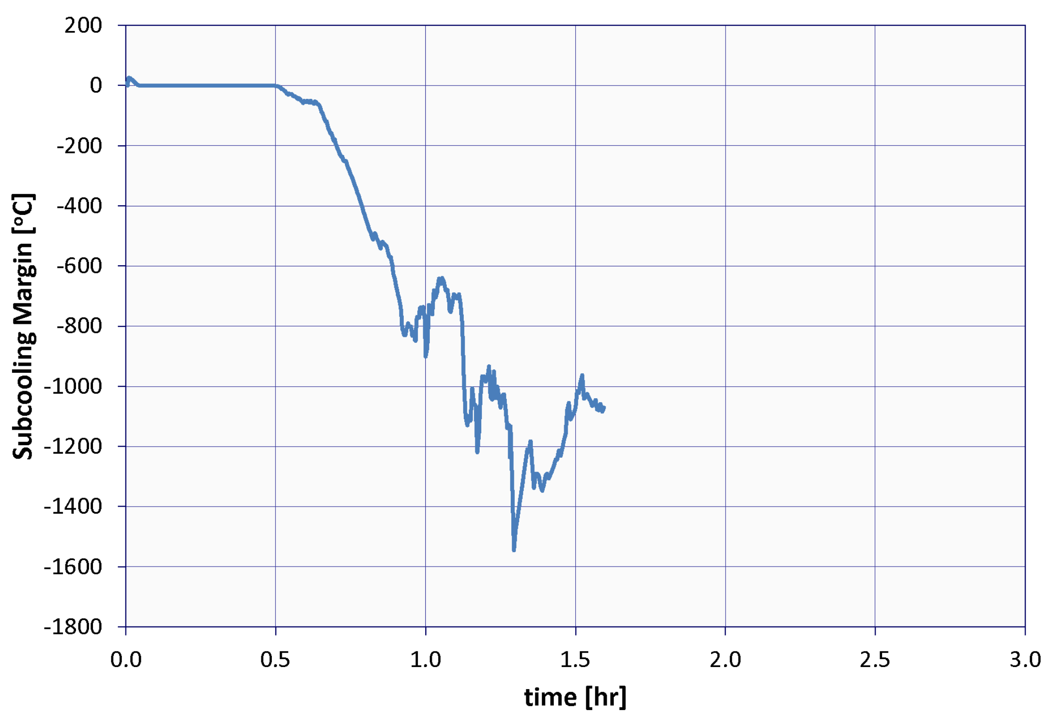

Water Level [m]
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

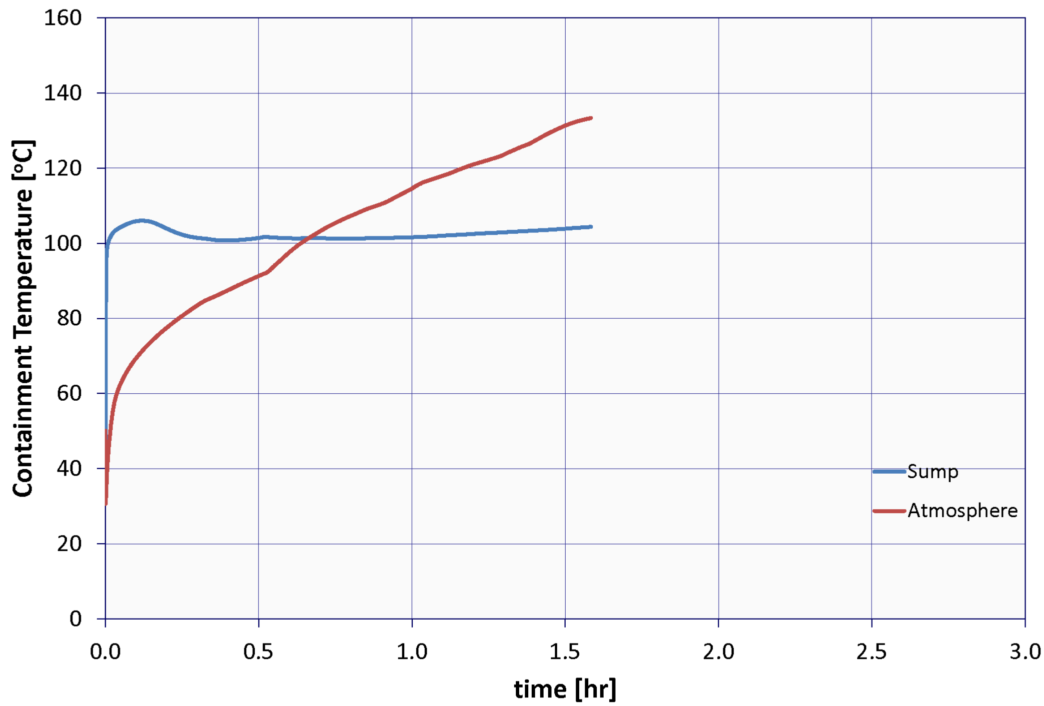

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
1
2
3
4
5
6
7
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
1
2
3
4
5
6
7
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

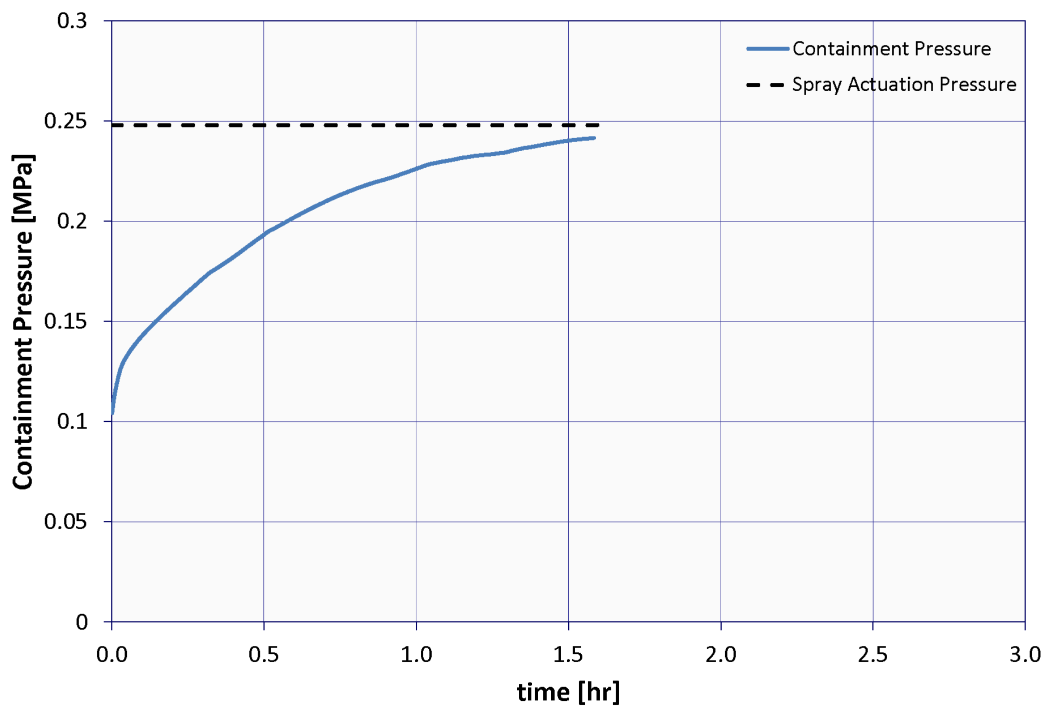
E.1.5 Case 5: 2-in. Break with 2 Accumulators, 1 RHR, 2/2 CS Pumps



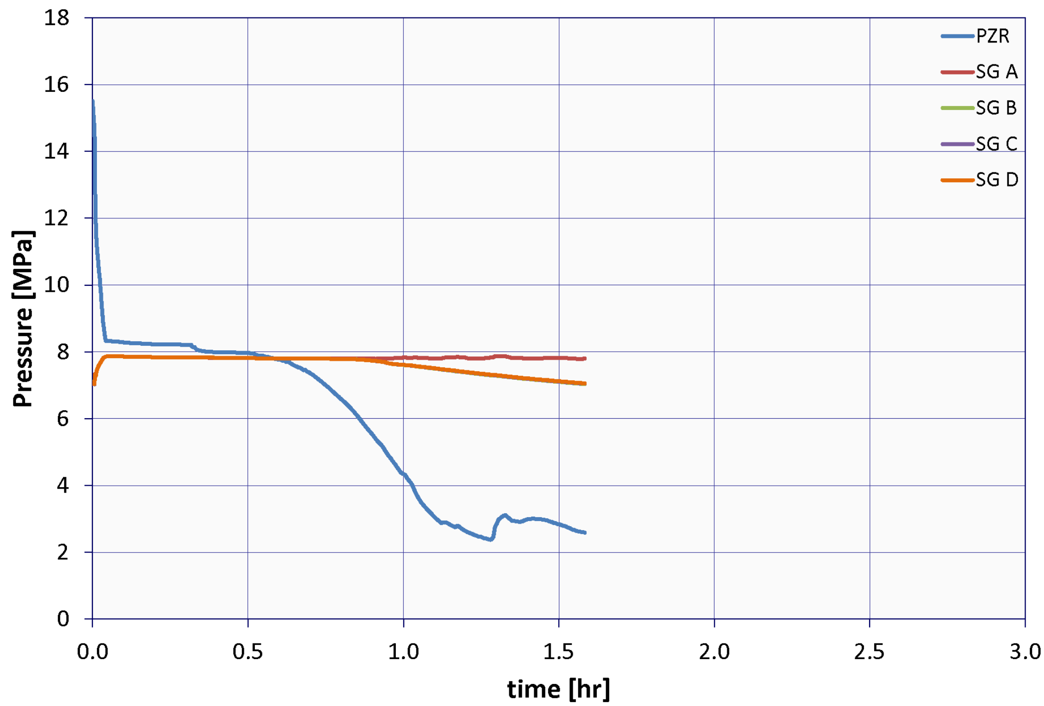


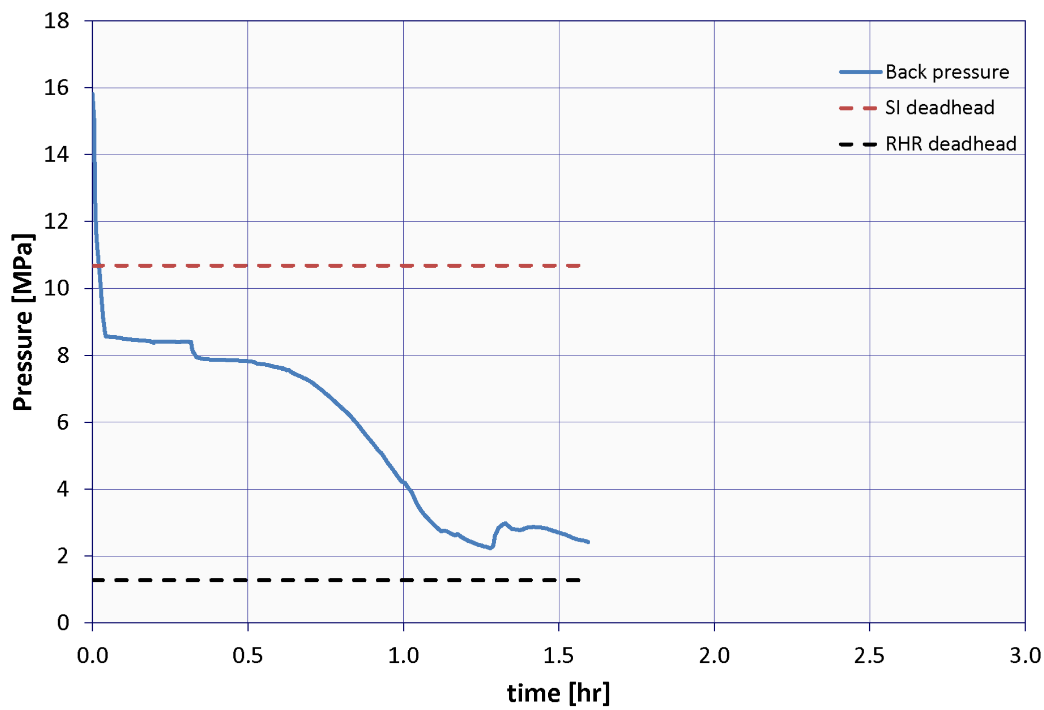


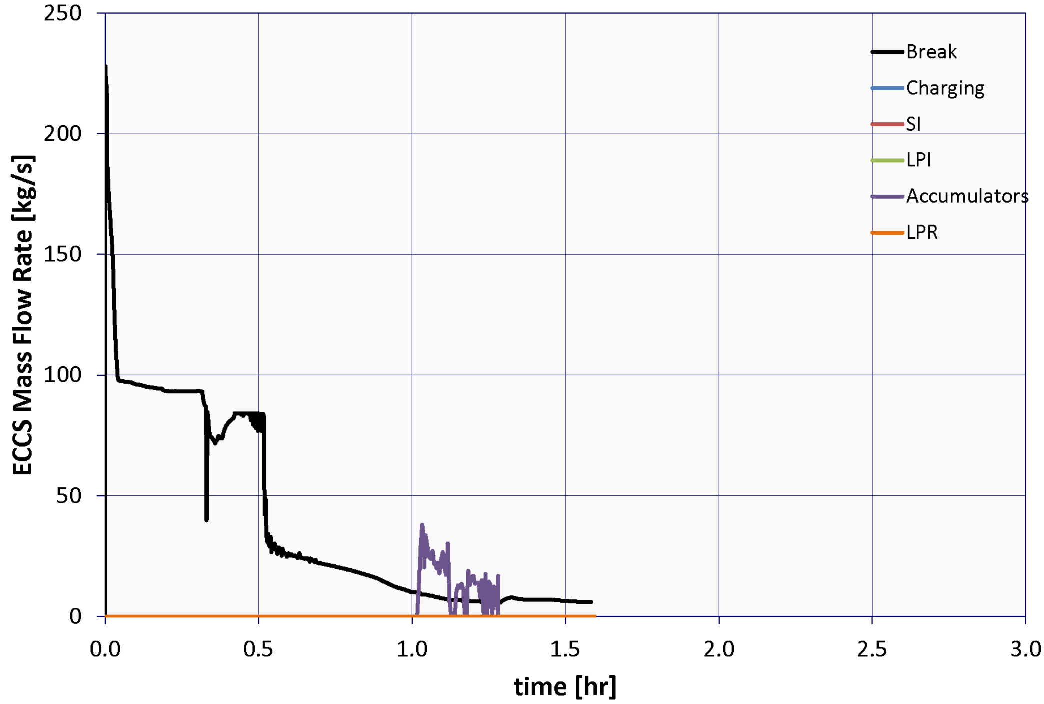
160
140
120
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Containment Temperature [ºC]
time [hr]
Sump
Atmosphere

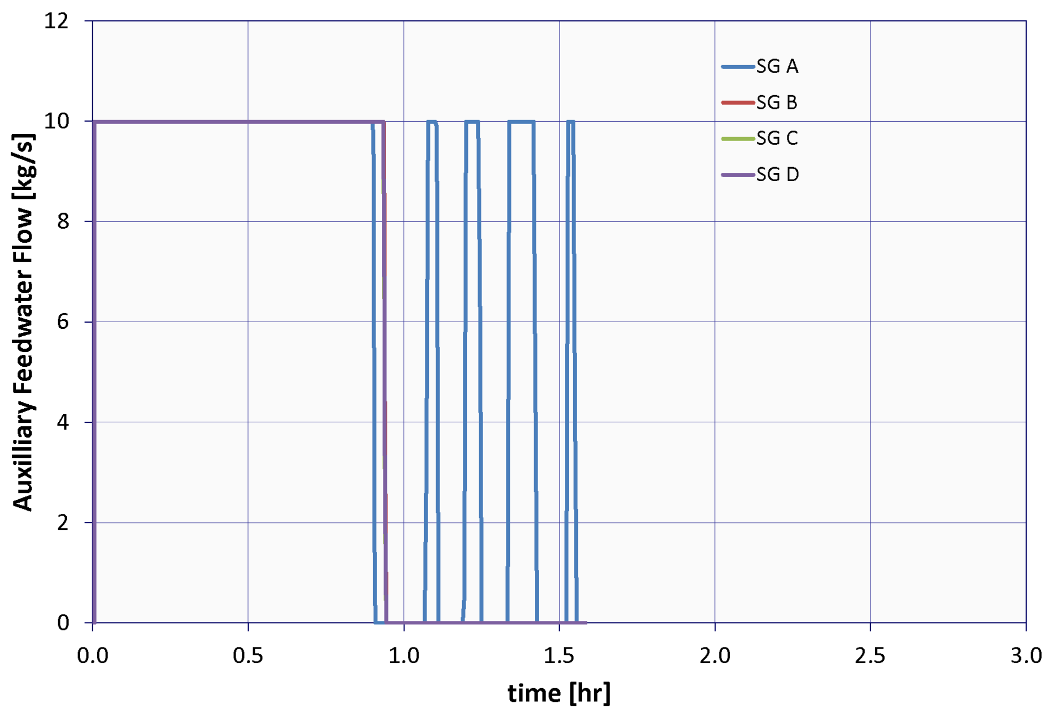


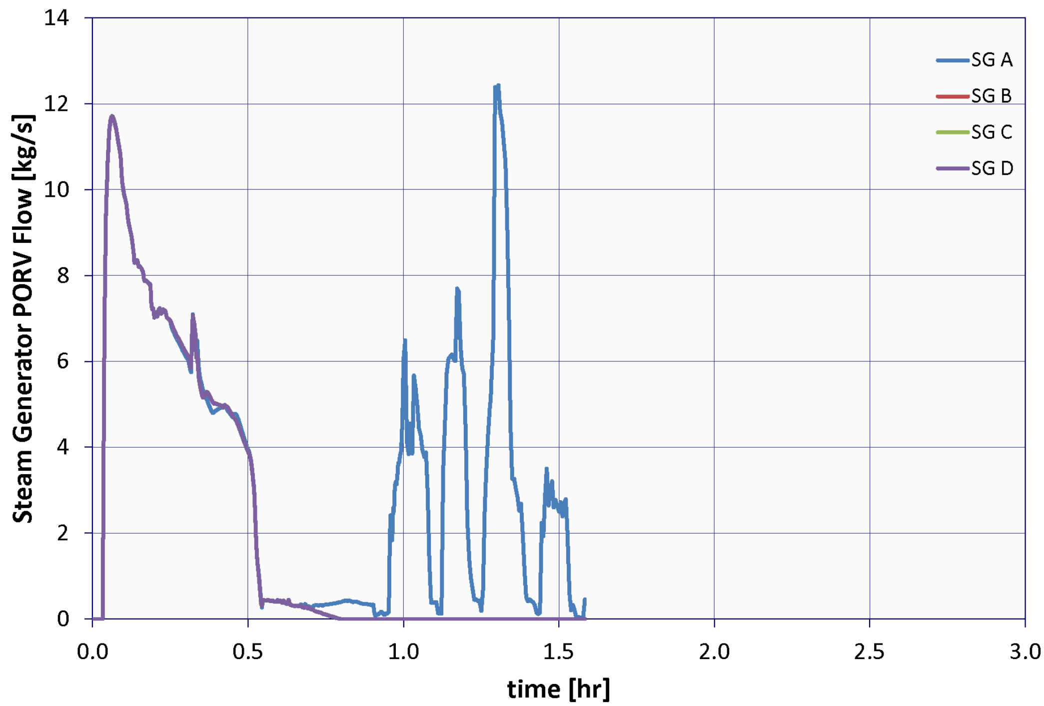
0.3
0.25
0.2
0.15
0.1
0.05
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure

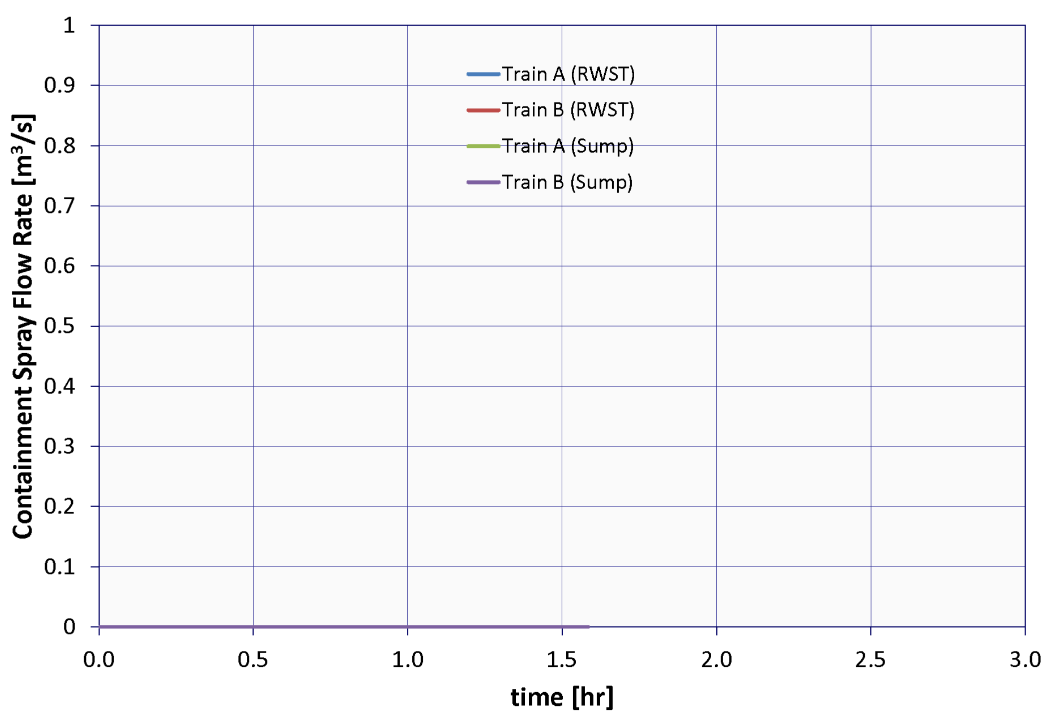

PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
0.0
0.5
1.0
1.5
2.0
2.5
3.0

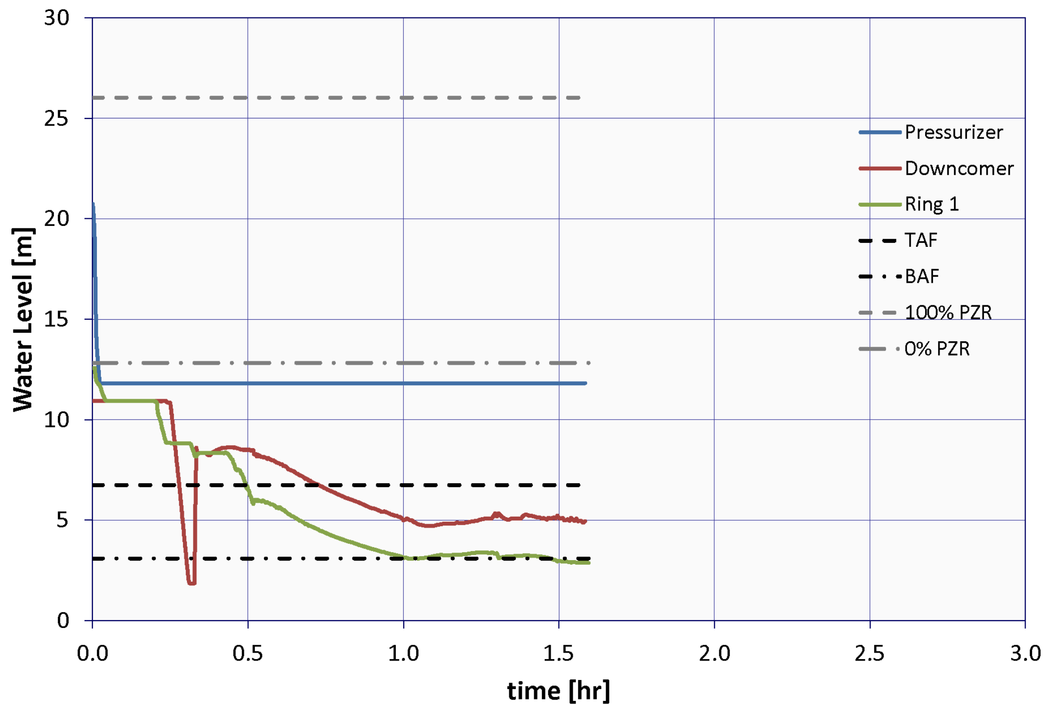

Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
0.0
0.5
1.0
1.5
2.0
2.5
3.0

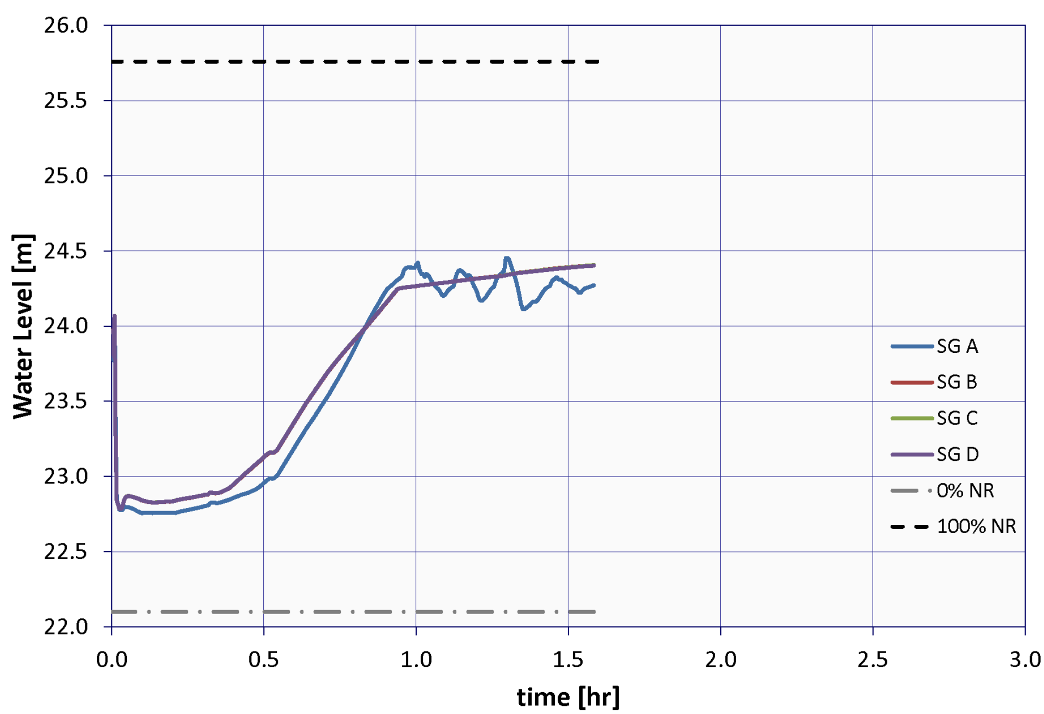

250
200
150
100
50
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

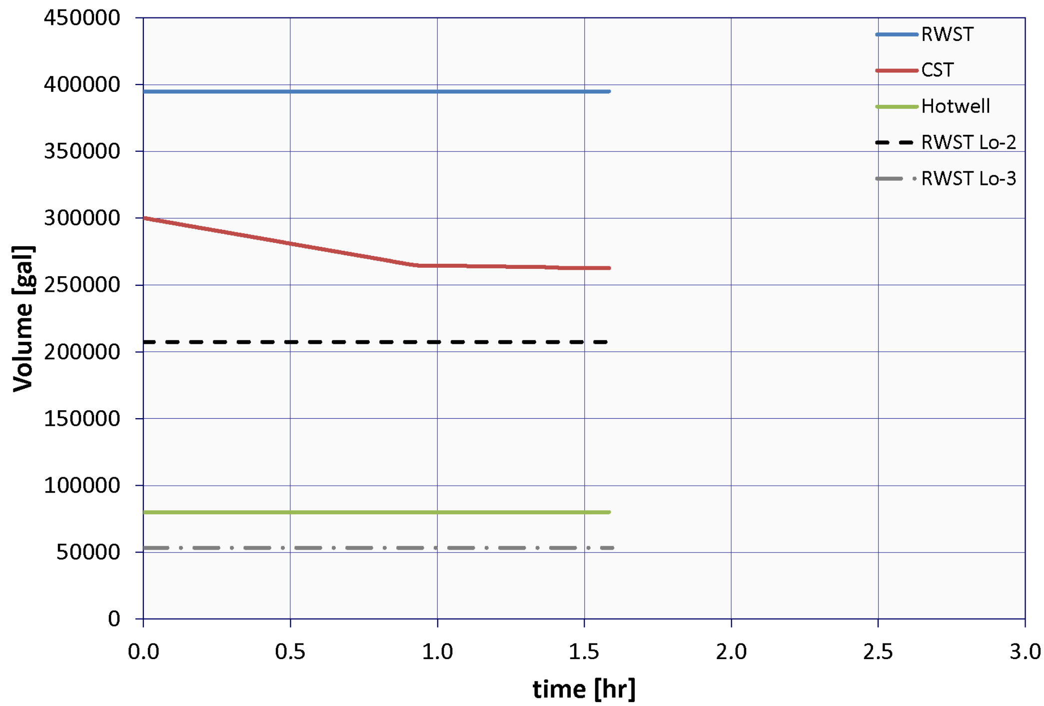

12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Auxilliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
0.0
0.5
1.0
1.5
2.0
2.5
3.0

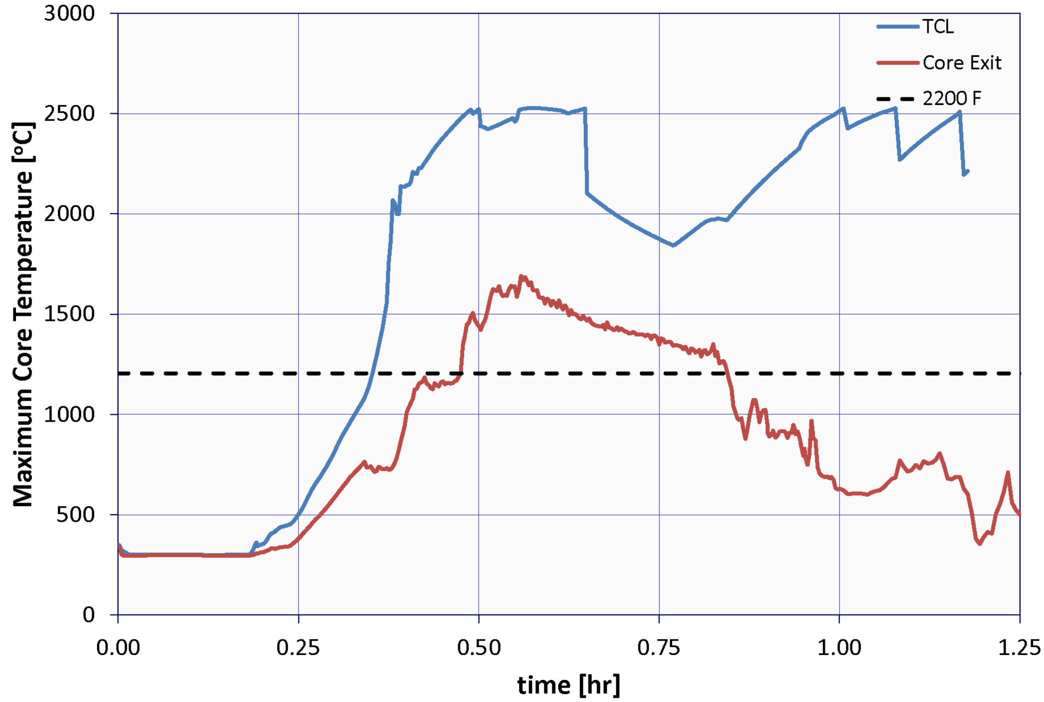

Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0
0.5
1.0
1.5
2.0
2.5
3.0

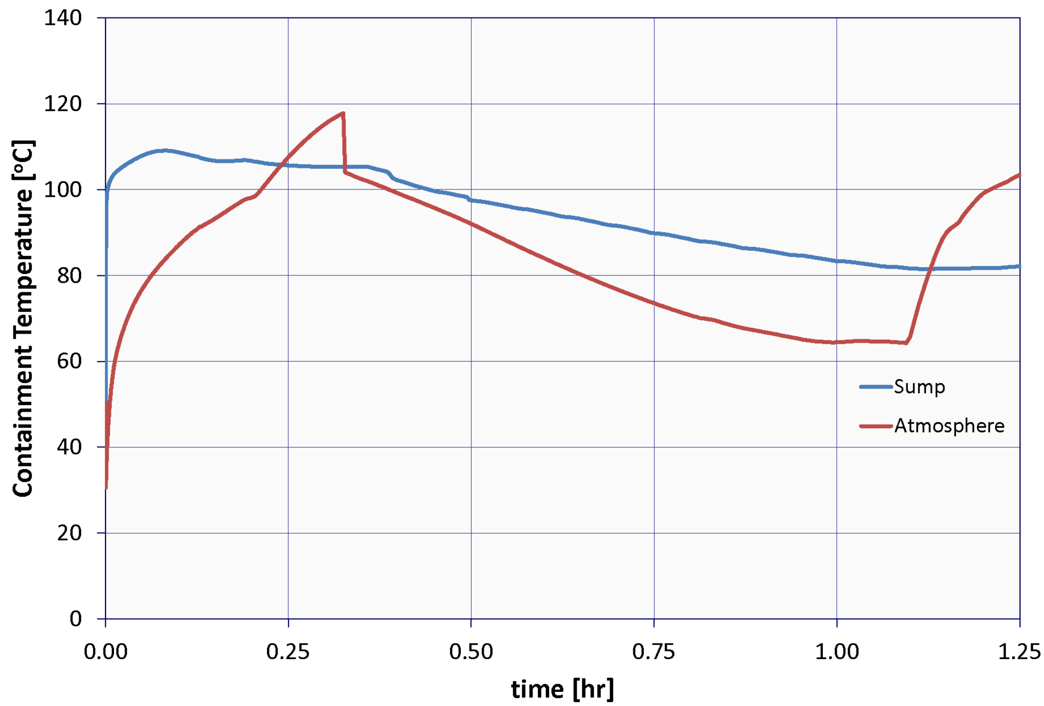

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR


Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

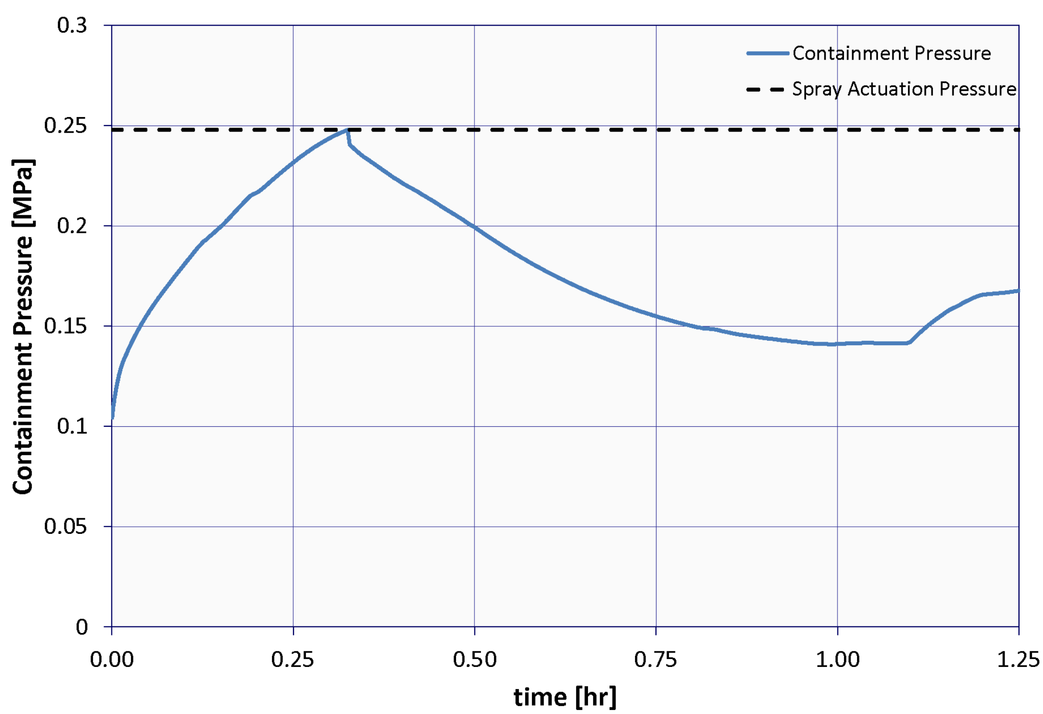

RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
Volume [gal]
time [hr]
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0

E.1.6 Case 6: 3.33-in. Break with 2 Accumulators, 1 RHR, 2/2 CS Pumps

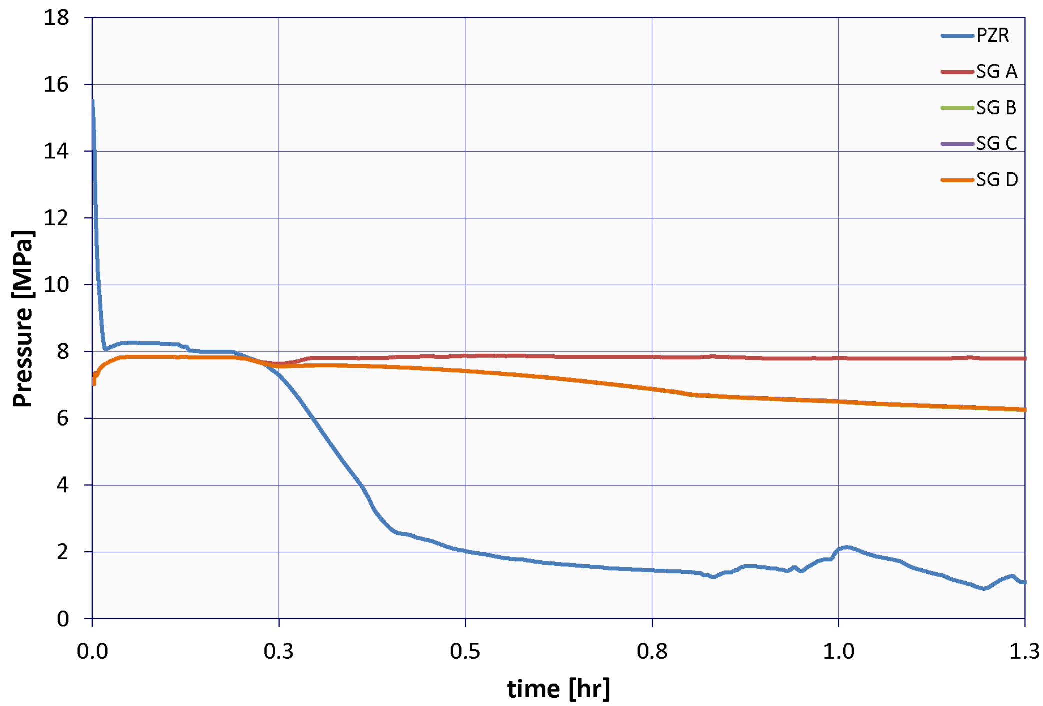


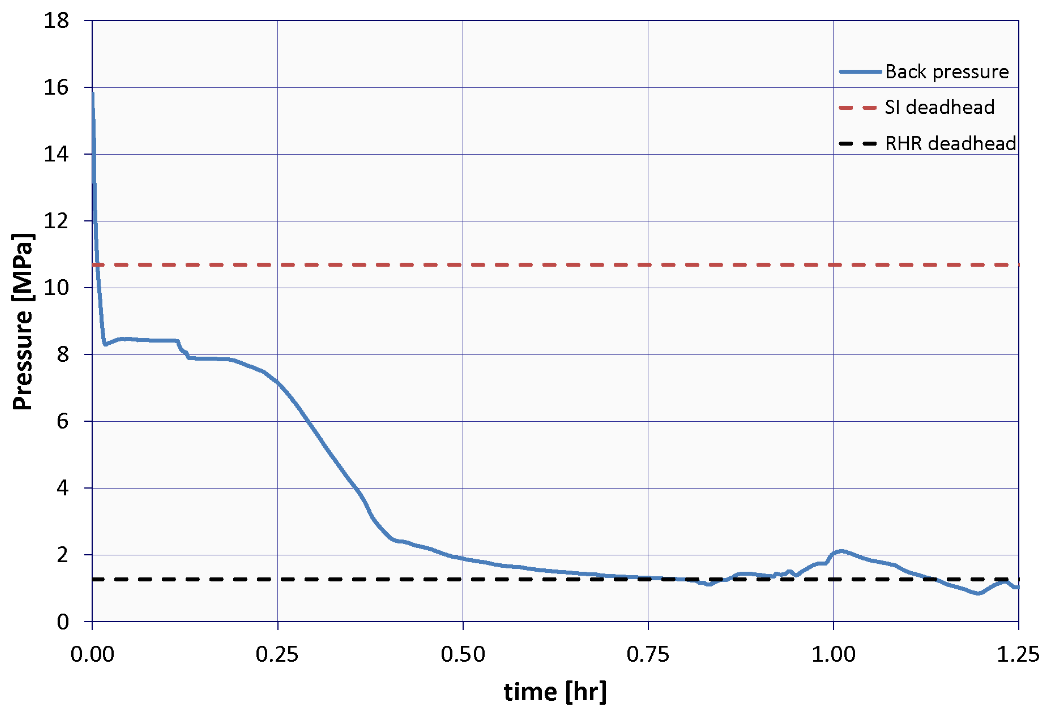


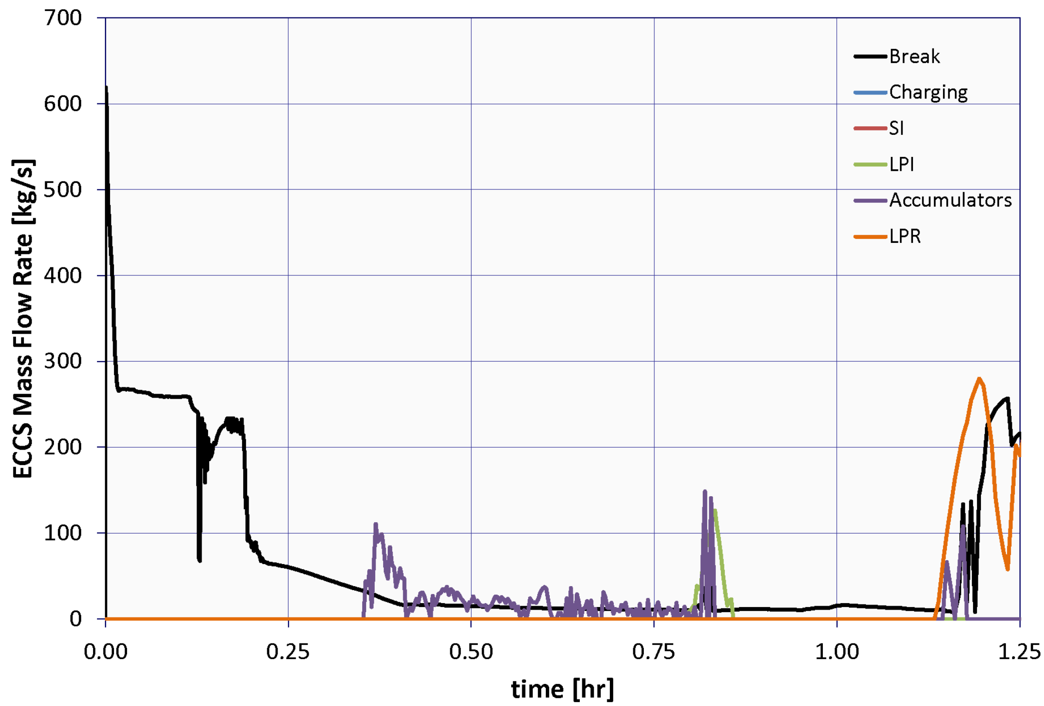
Containment Temperature [°C]
140
120
100
80
60
40
20
0
0.00
0.25
0.50
0.75
1.00
1.25
time [hr]
Sump
Atmosphere



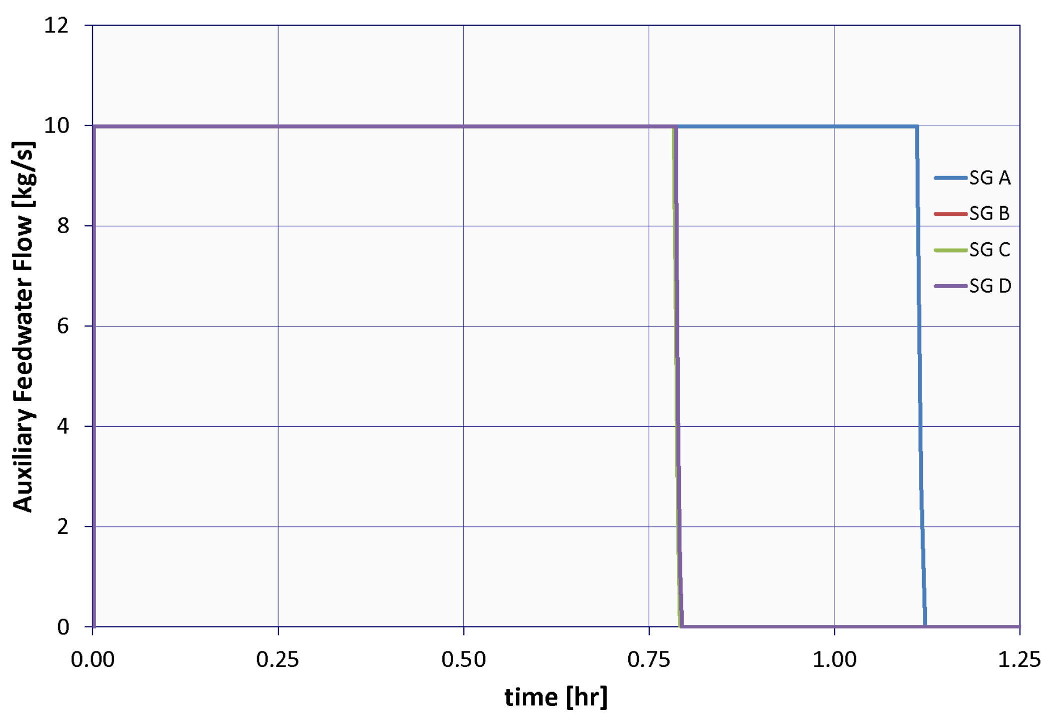
Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.25
0.50
0.75
1.00
1.25
time [hr]
Containment Pressure
Spray Actuation Pressure


Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
0.0
0.3
0.5
0.8
1.0
1.3

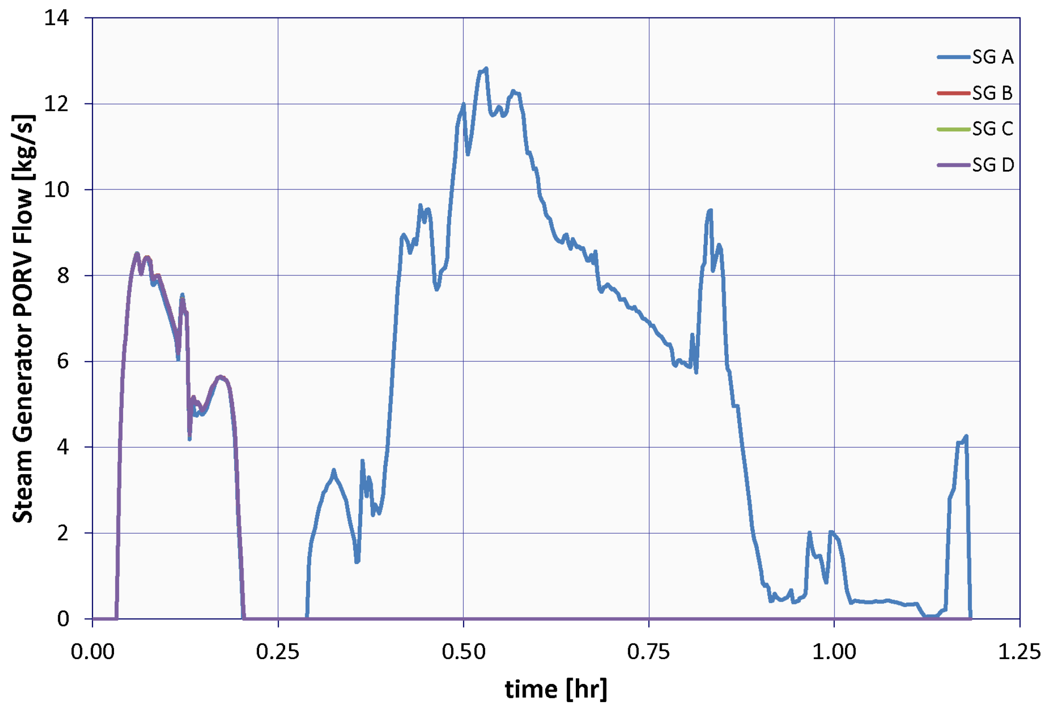

Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead
0
2
4
6
8
10
12
14
16
18
0.00
0.25
0.50
0.75
1.00
1.25

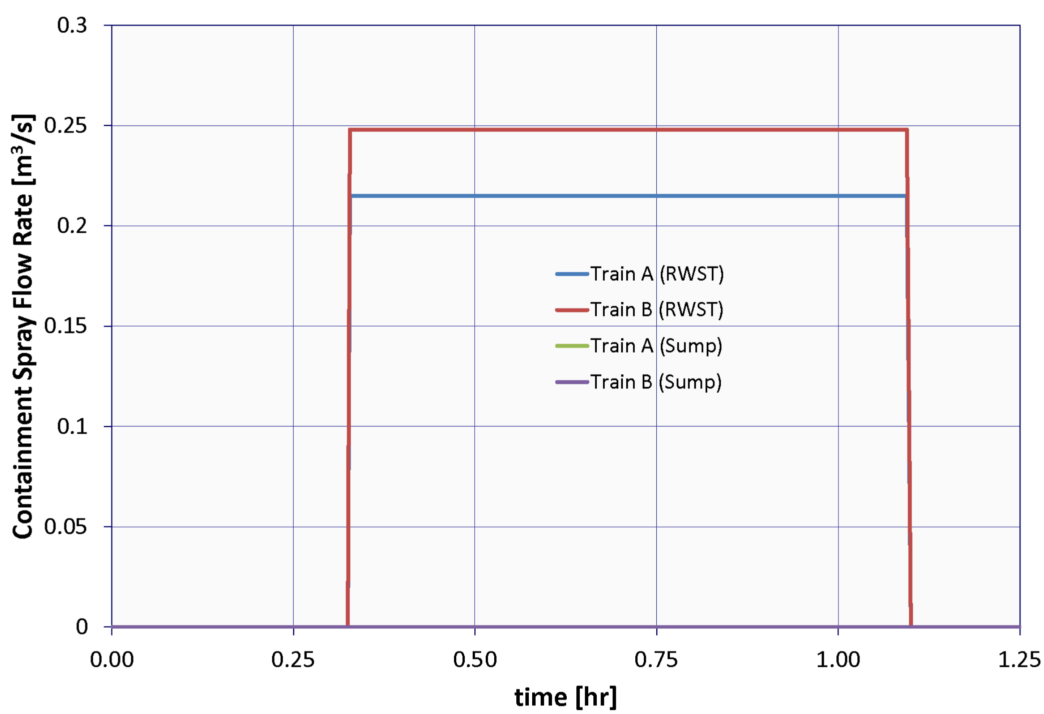


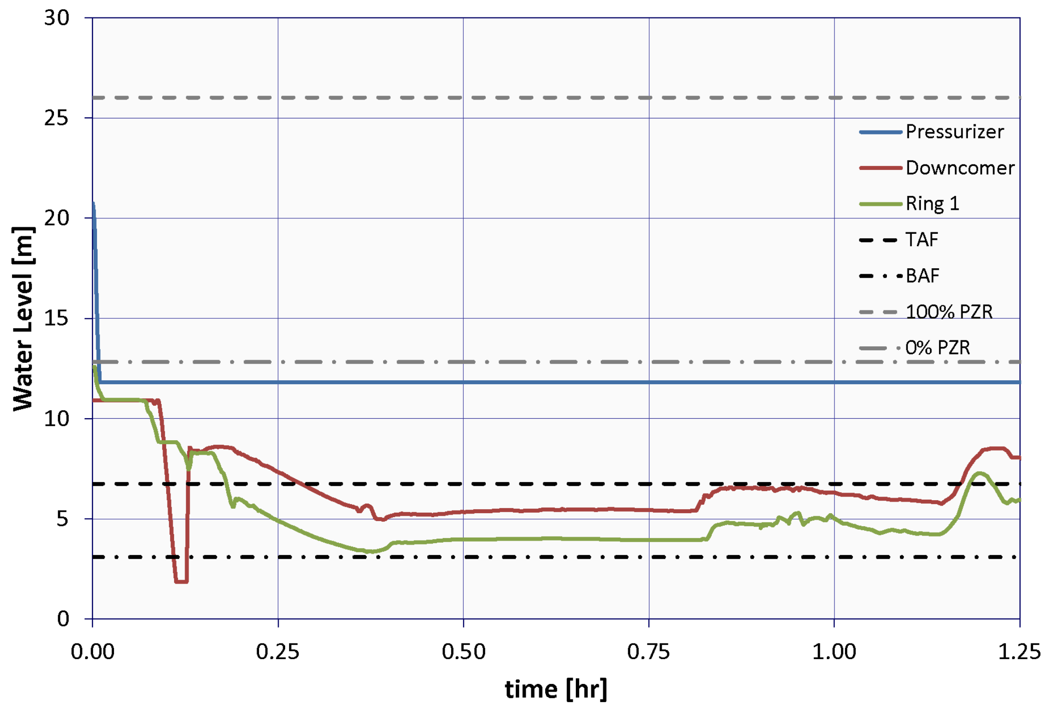
700
600
500
400
300
200
100
0
0.00
0.25
0.50
0.75
1.00
1.25
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



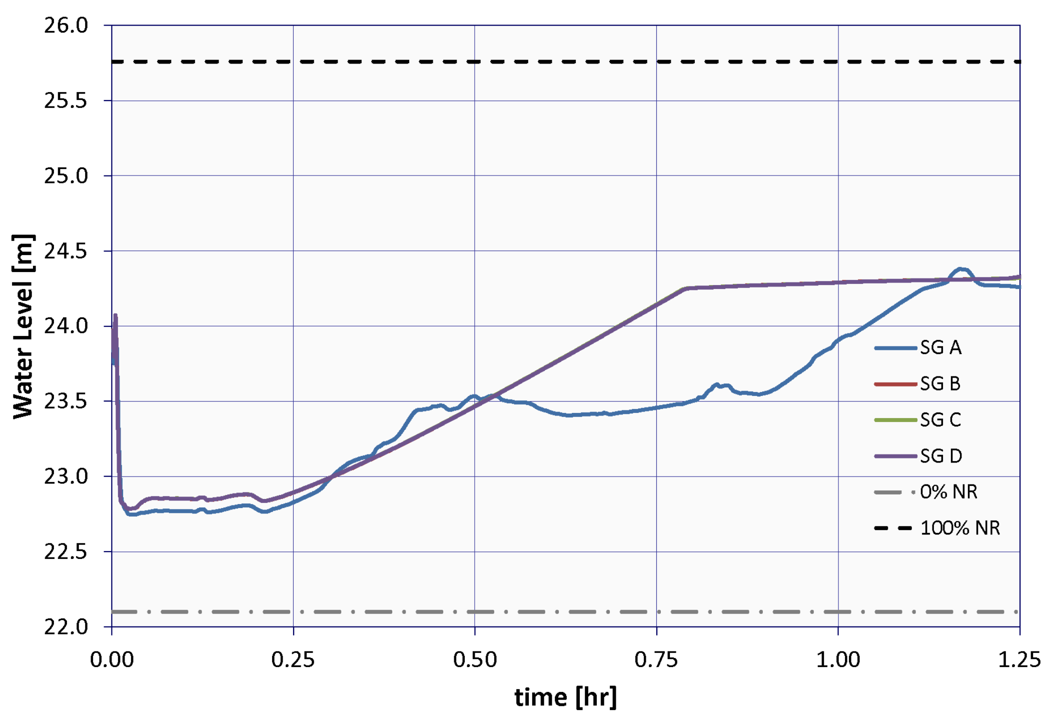
12
10
8
6
4
2
0
0.00
0.25
0.50
0.75
1.00
1.25
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
0.00
0.25
0.50
0.75
1.00
1.25

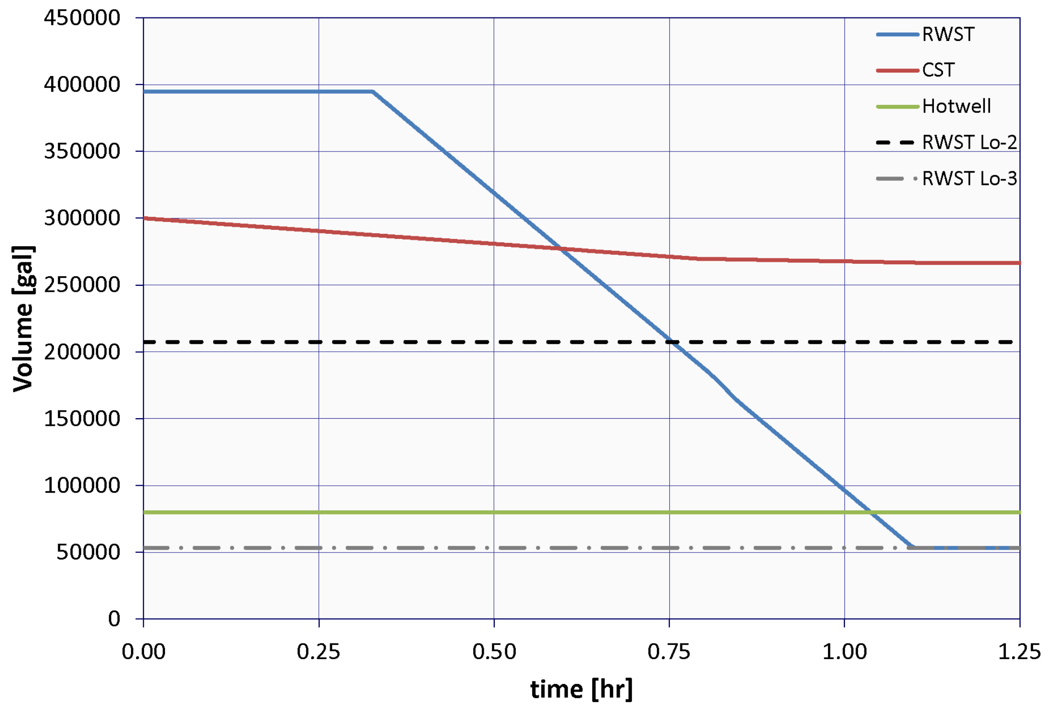

Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.00
0.25
0.50
0.75
1.00
1.25



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

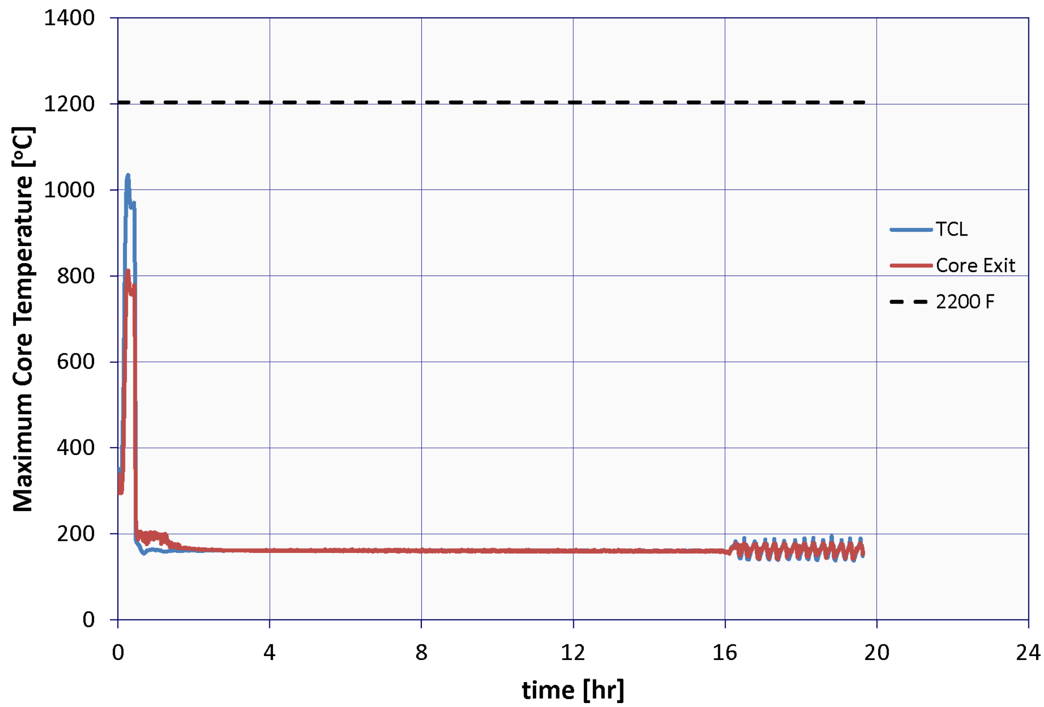


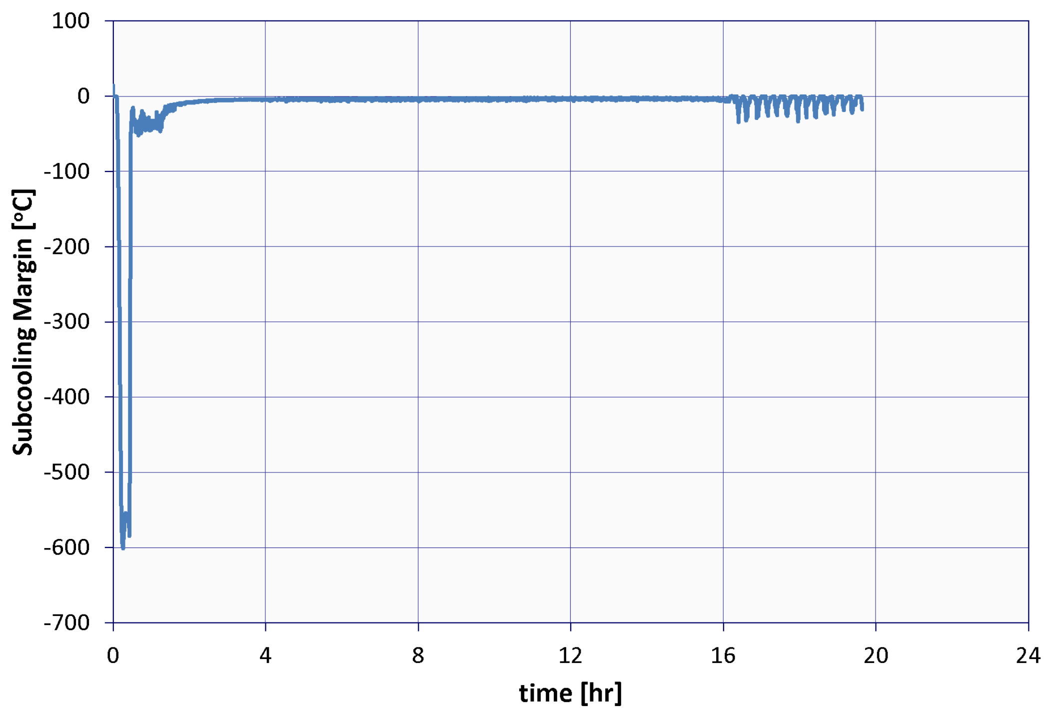
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

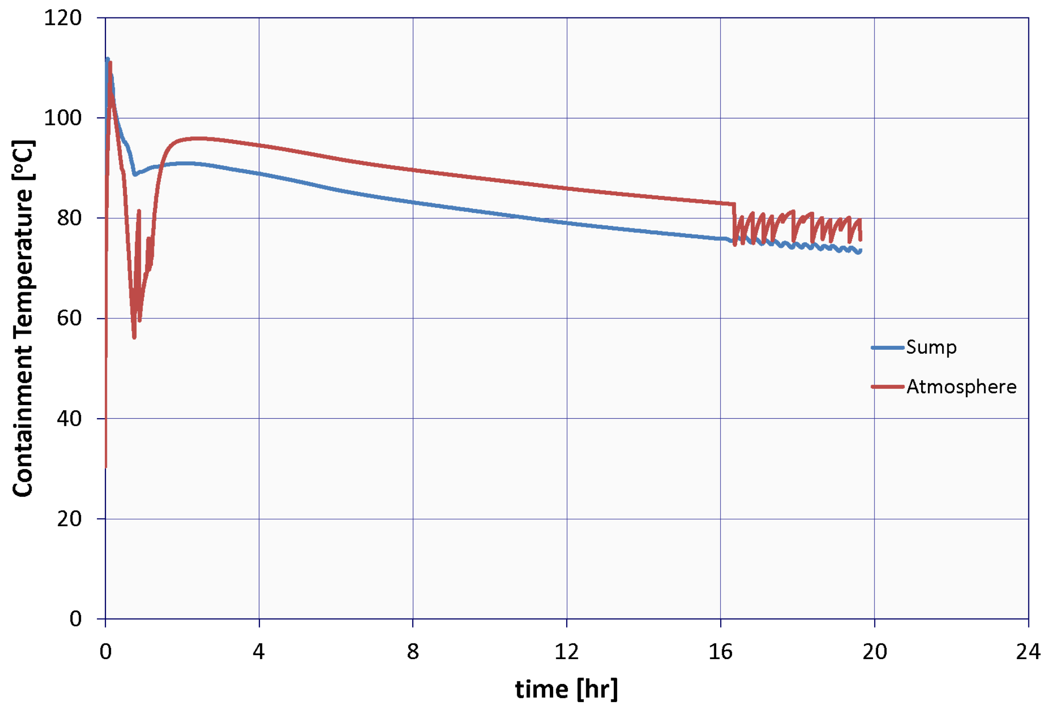


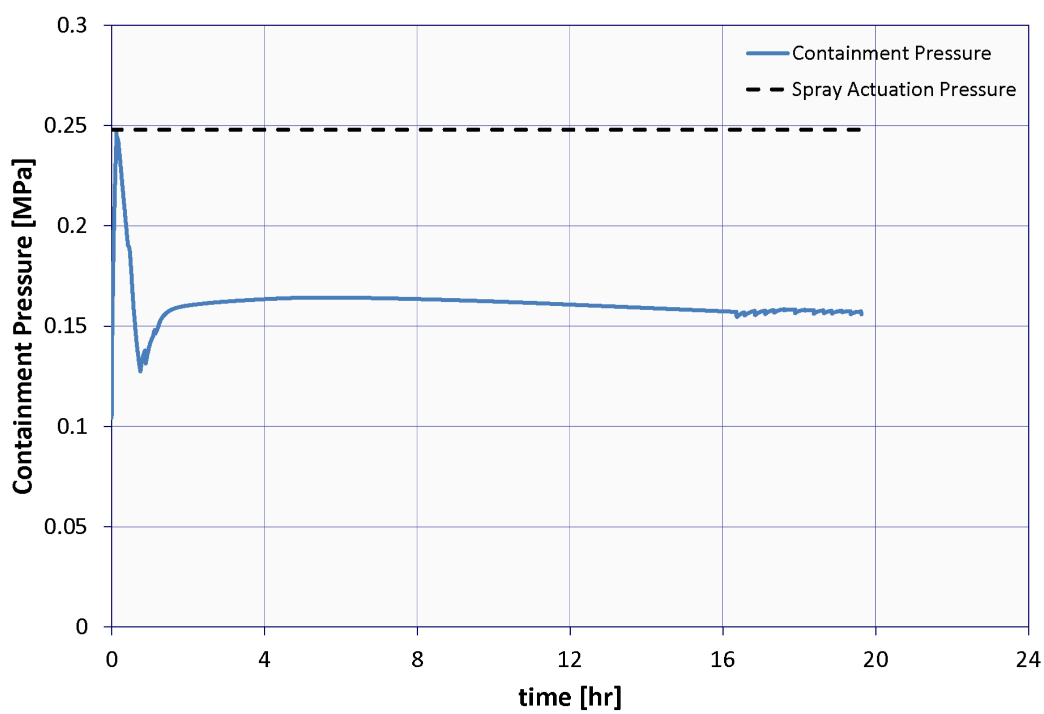
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
Volume [gal]
time [hr]
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0.00
0.25
0.50
0.75
1.00
1.25

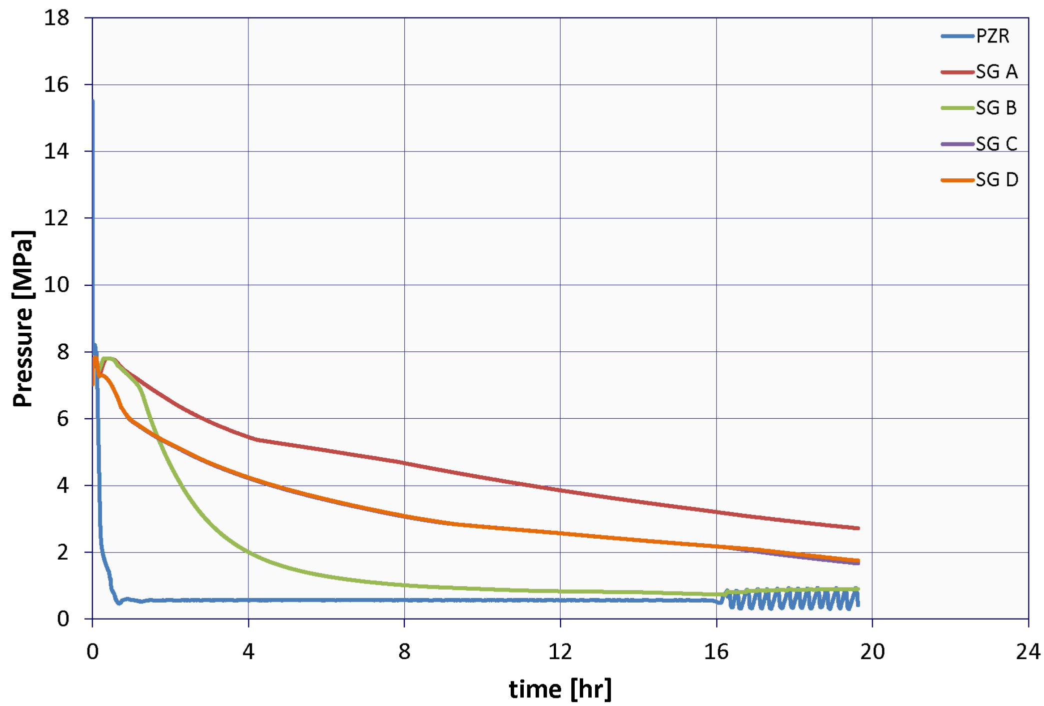
E.1.7 Case 7: 4.67-in. Break with 2 Accumulators, 1 RHR, 2/2 CS Pumps



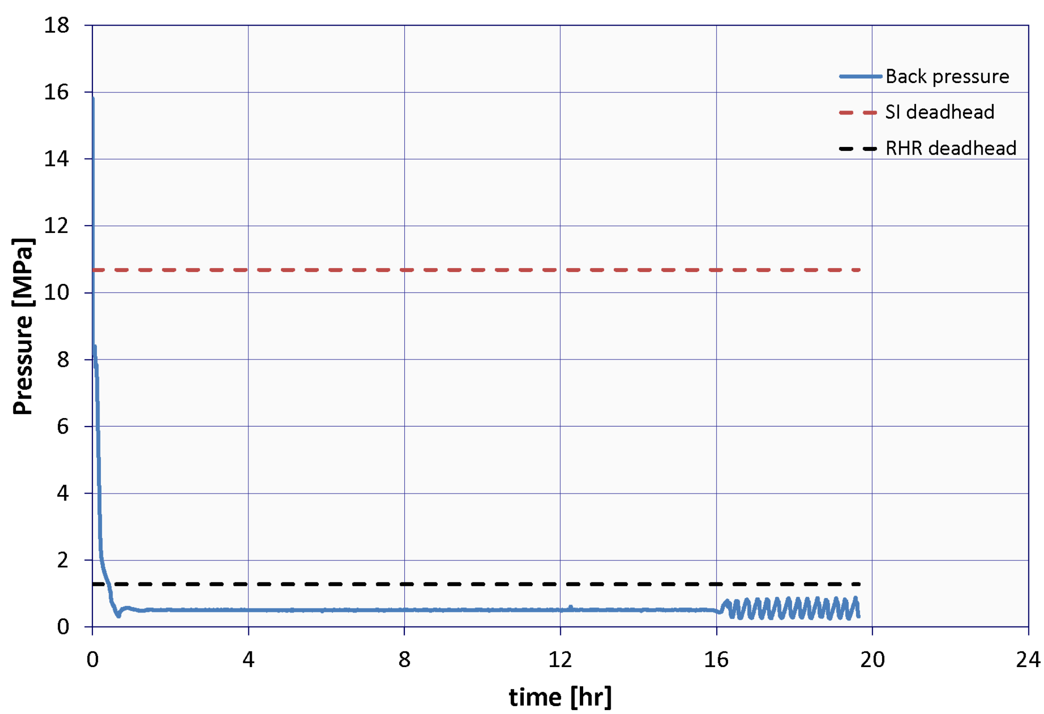



Containment Temperature [°C]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

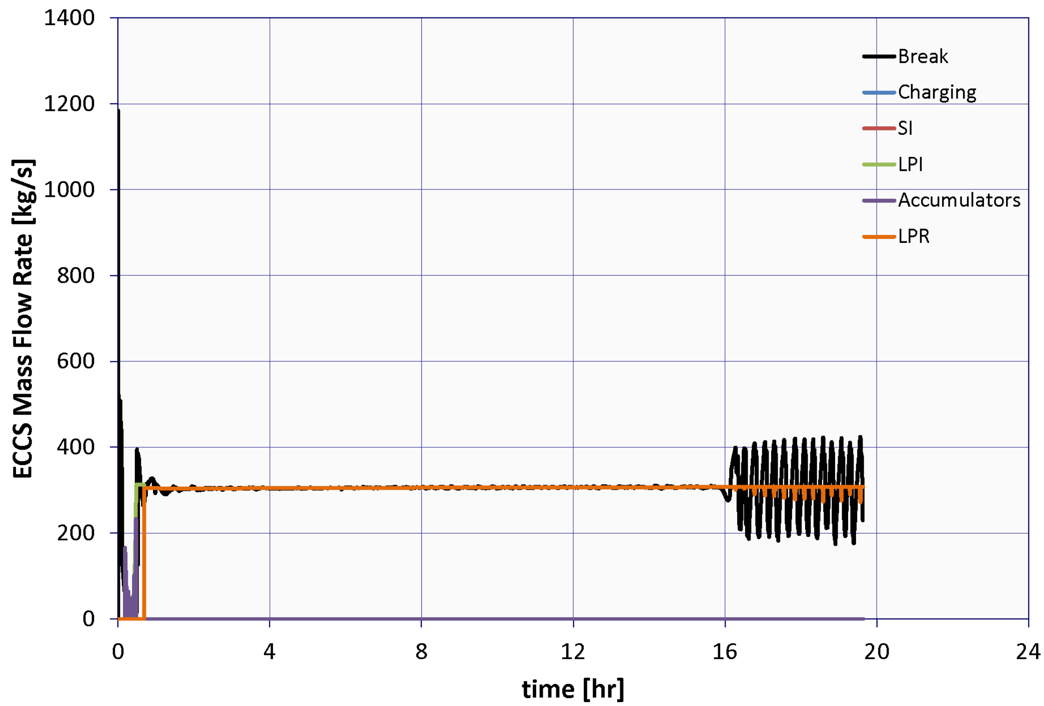

Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure



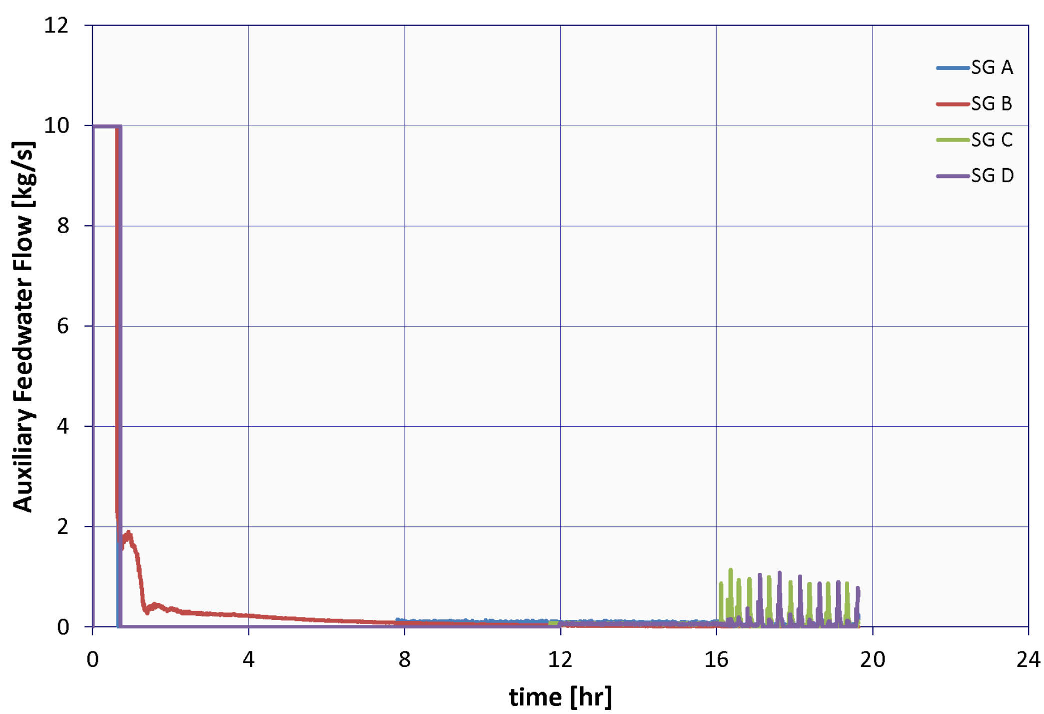
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



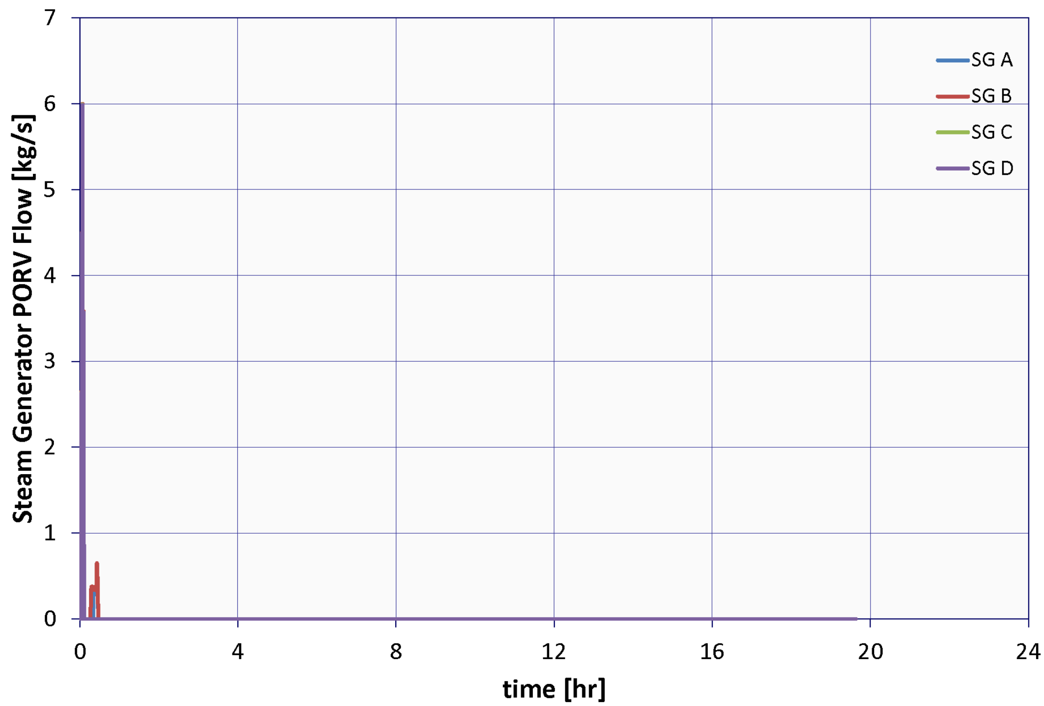
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead

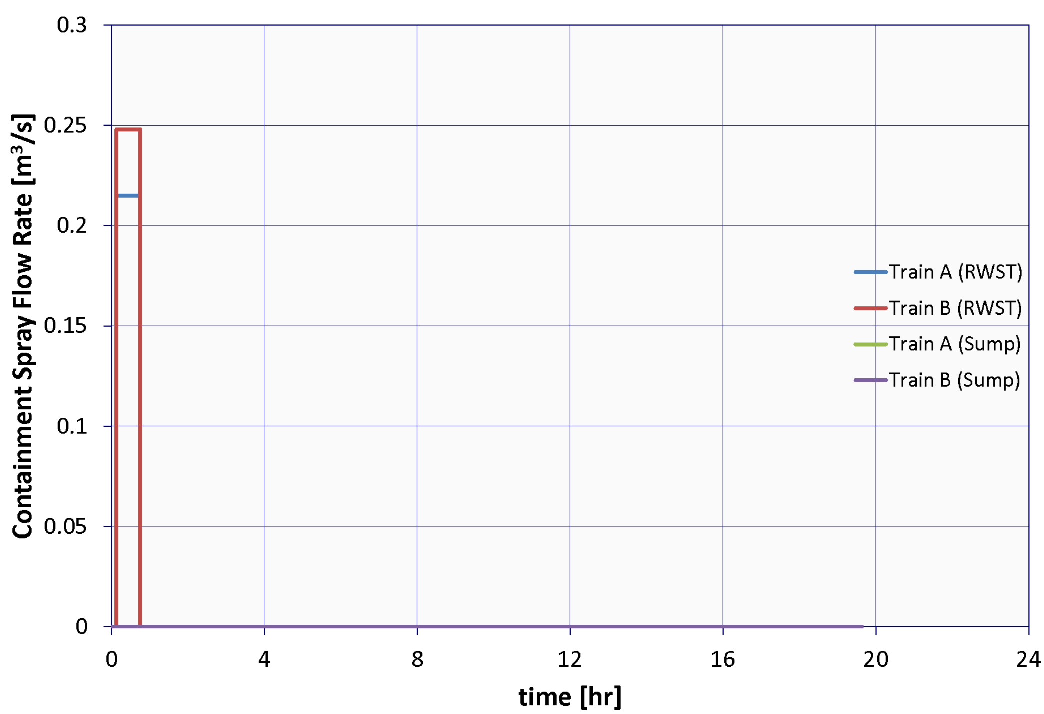


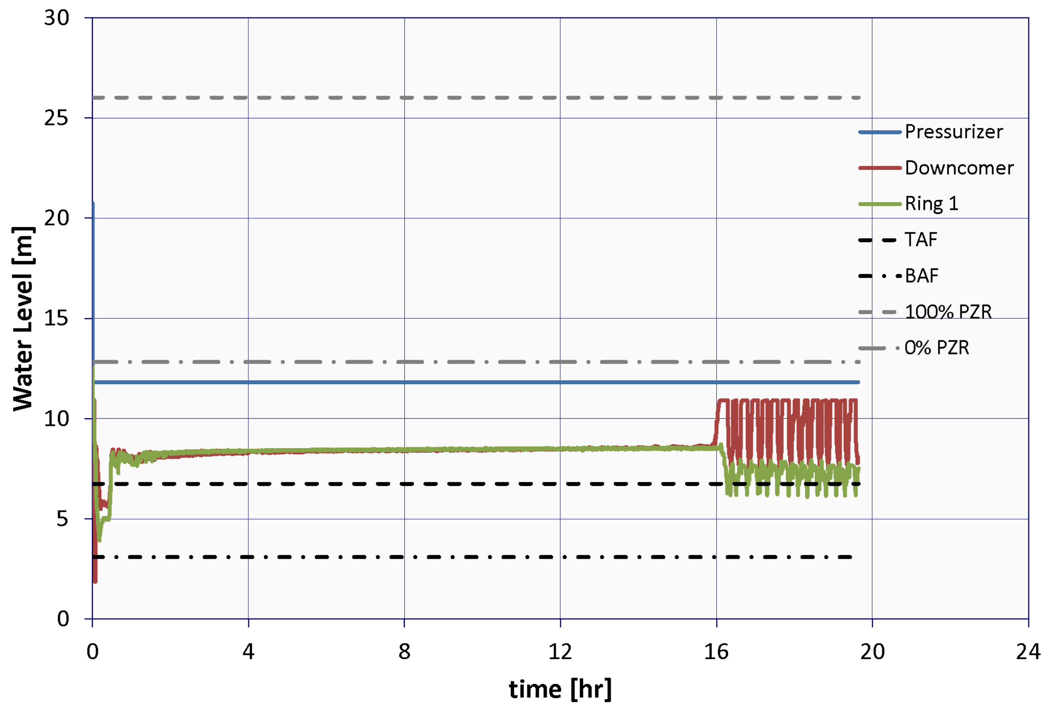
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
0
200
400
600
800
1000
1200
1400
0
4
8
12
16
20
24

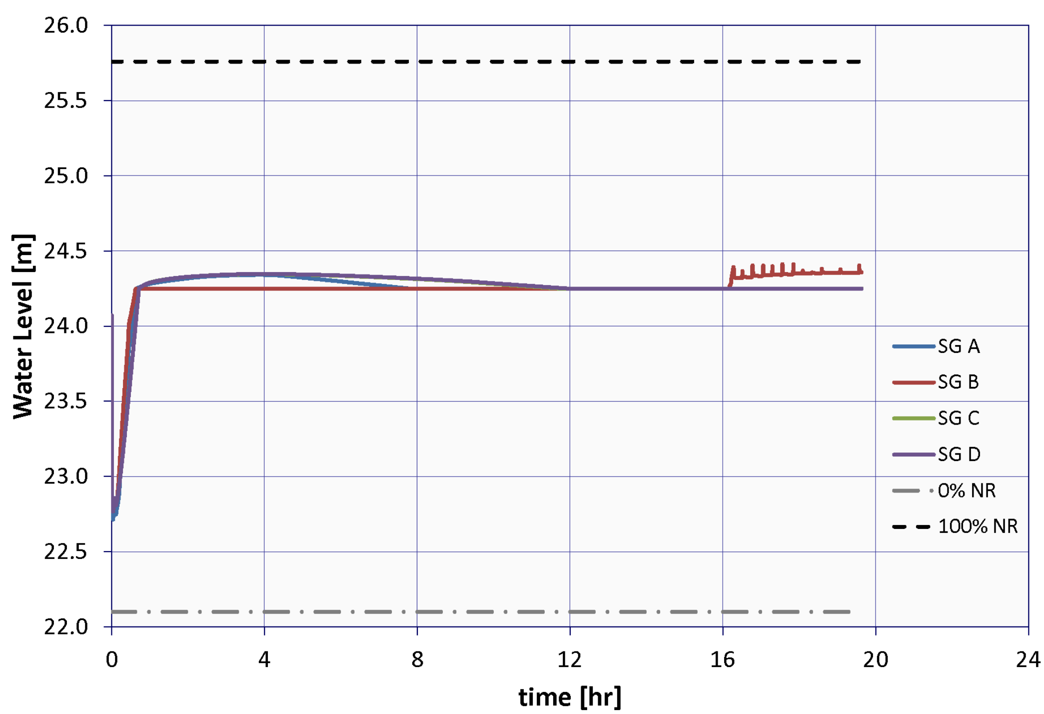


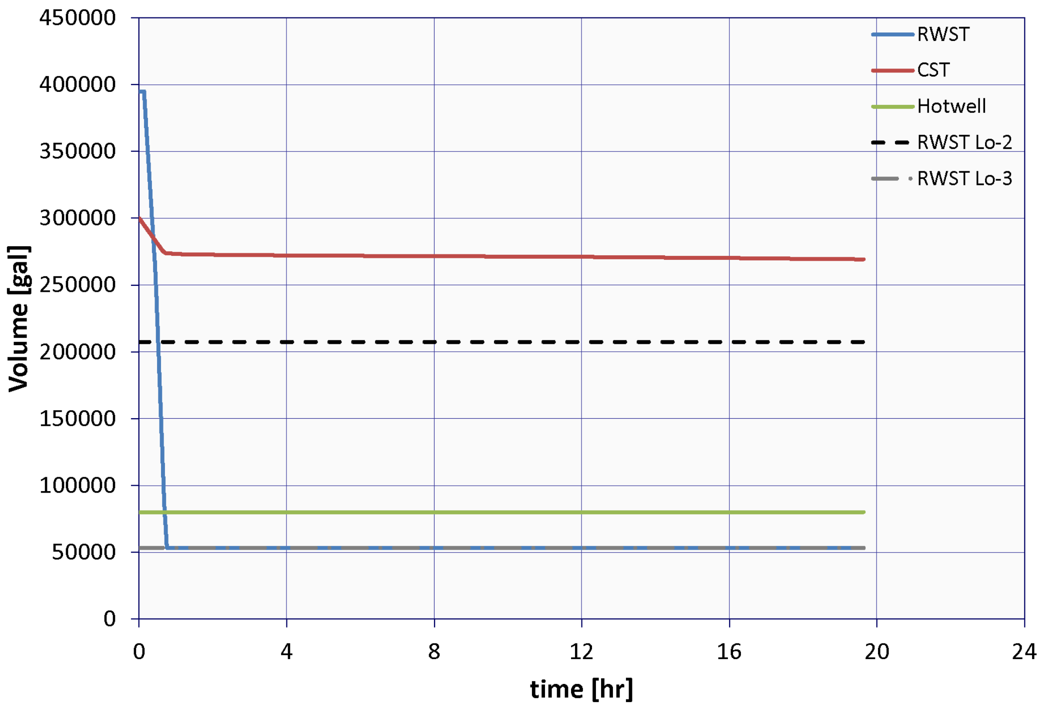
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24


Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24

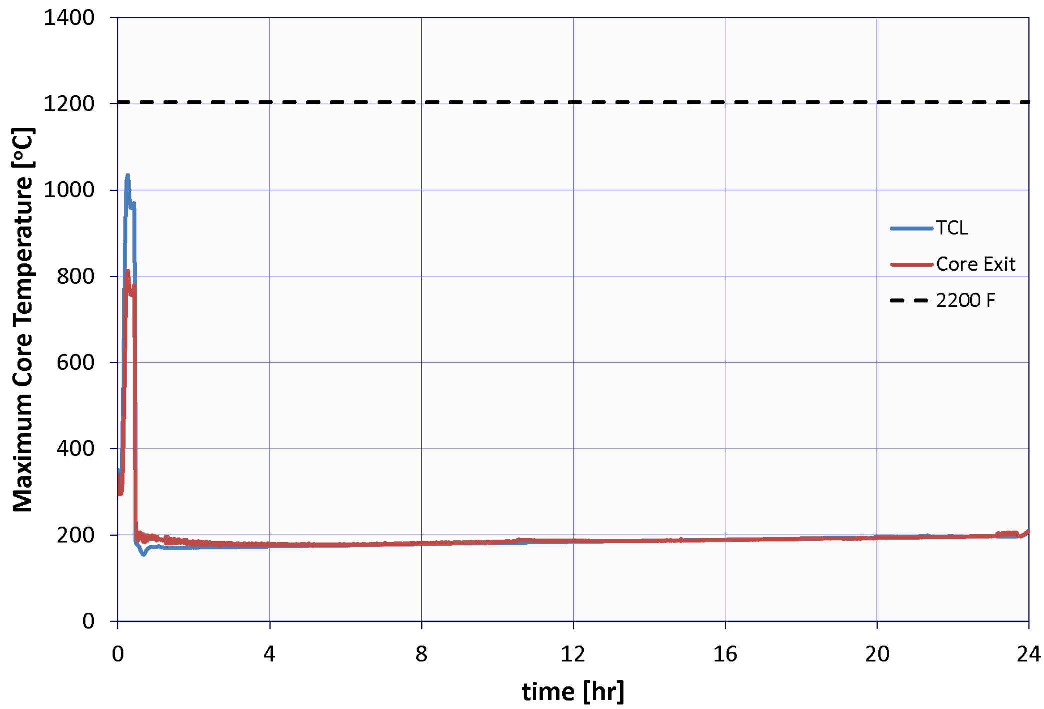

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
30
25
20
15
10
5
0
0
4
8
12
16
20
24

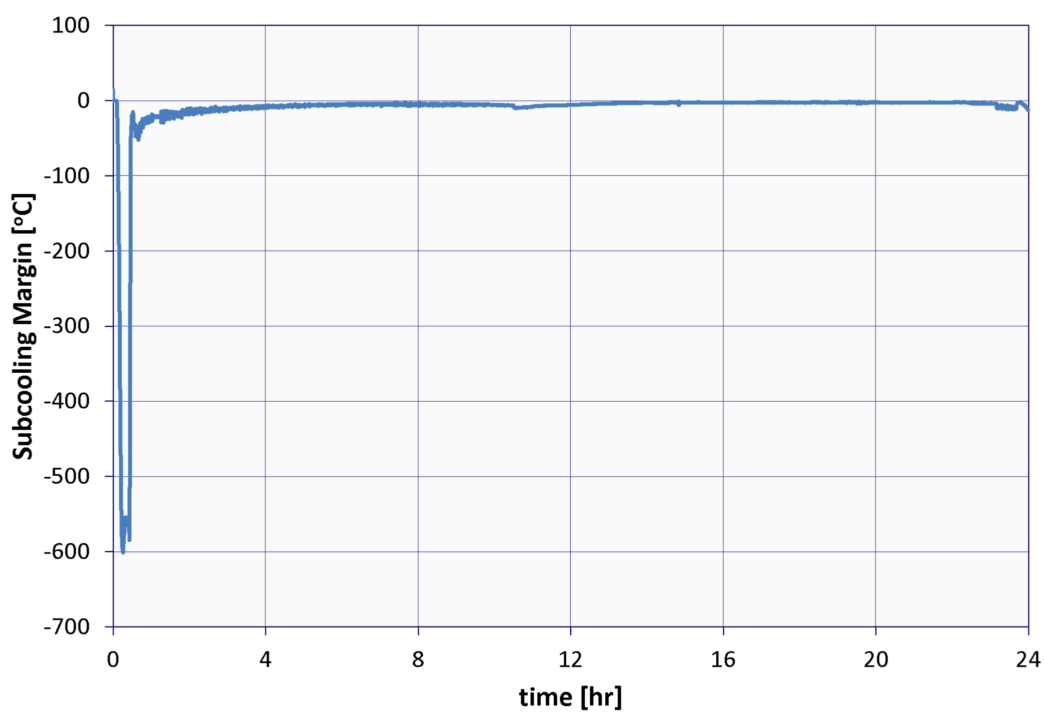

Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
0
4
8
12
16
20
24

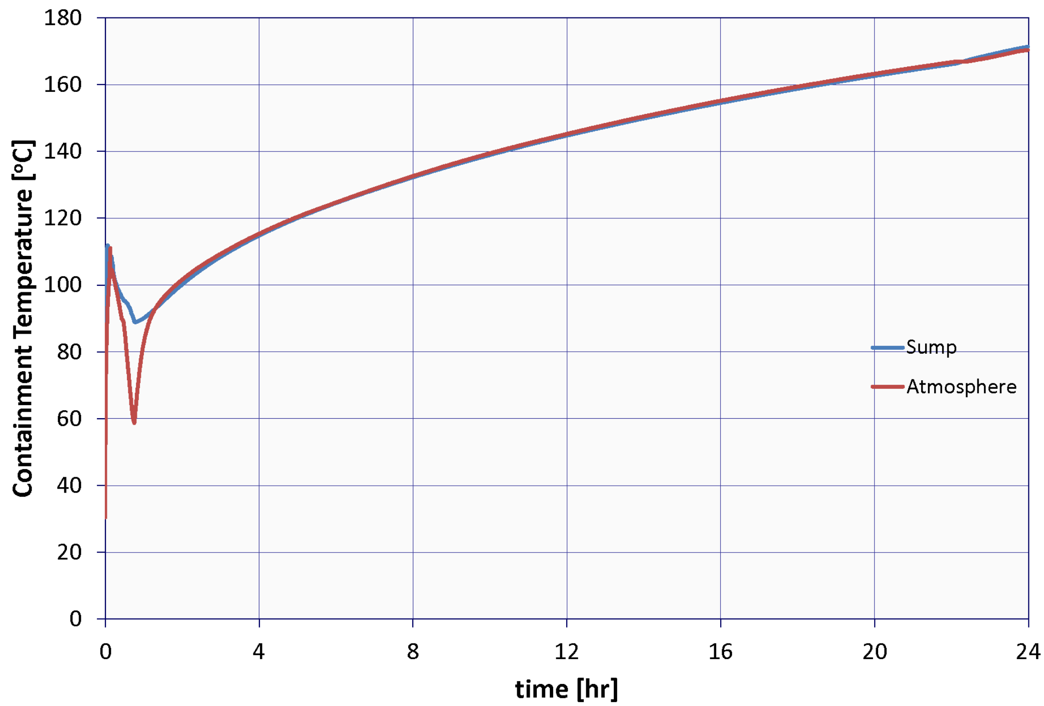


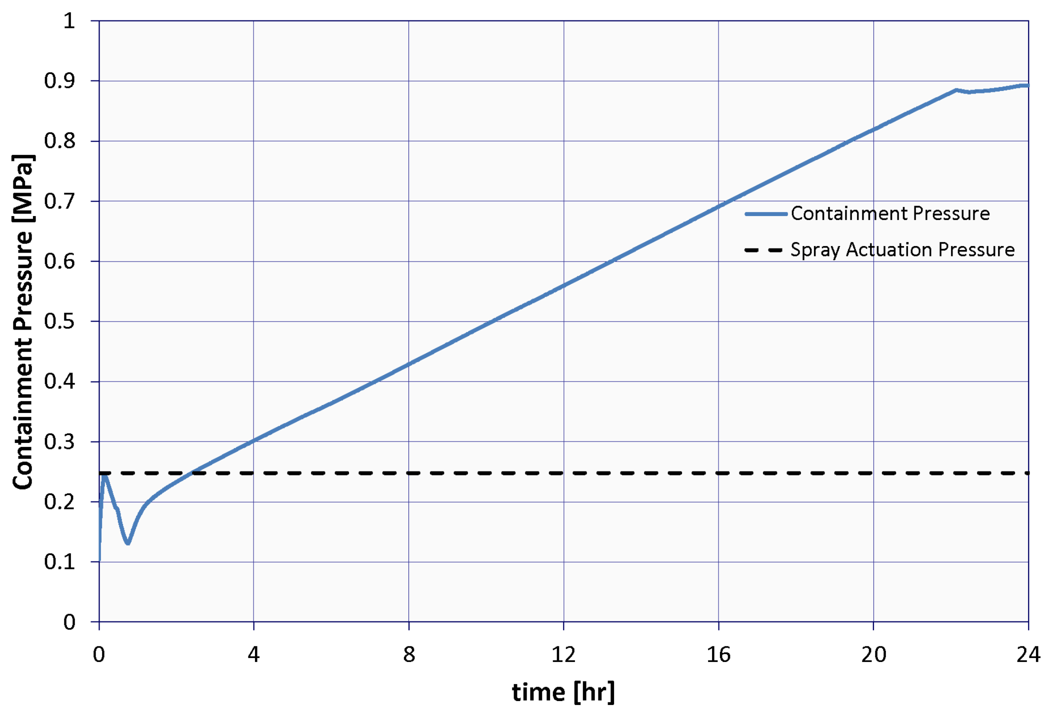
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

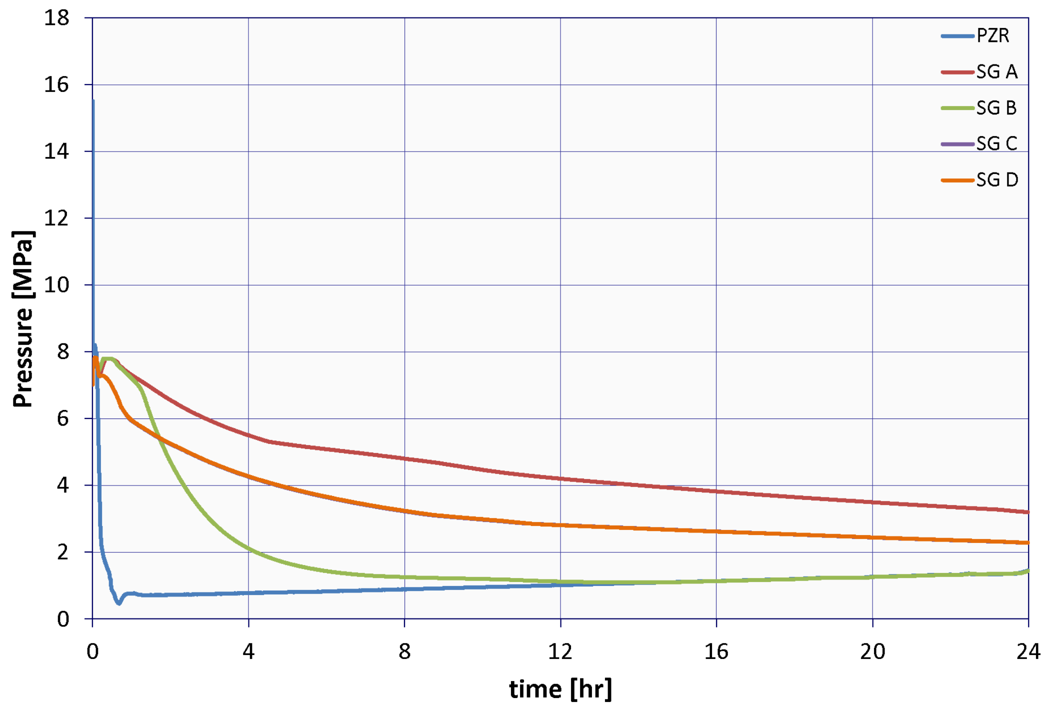
E.1.7.1 *Case 7a: 4.67-in. Break with 2 Accumulators, 1 RHR, 2/2 CS Pumps, No RHRHX*



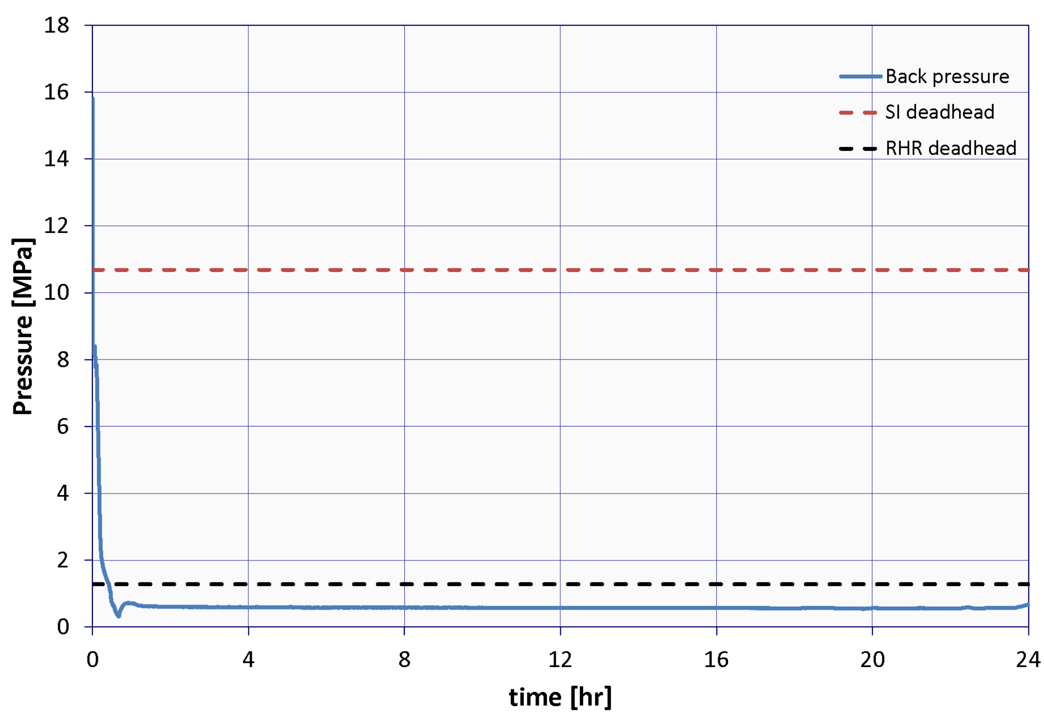



180
160
140
120
100
80
60
40
20
0
Containment Temperature [ºC]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

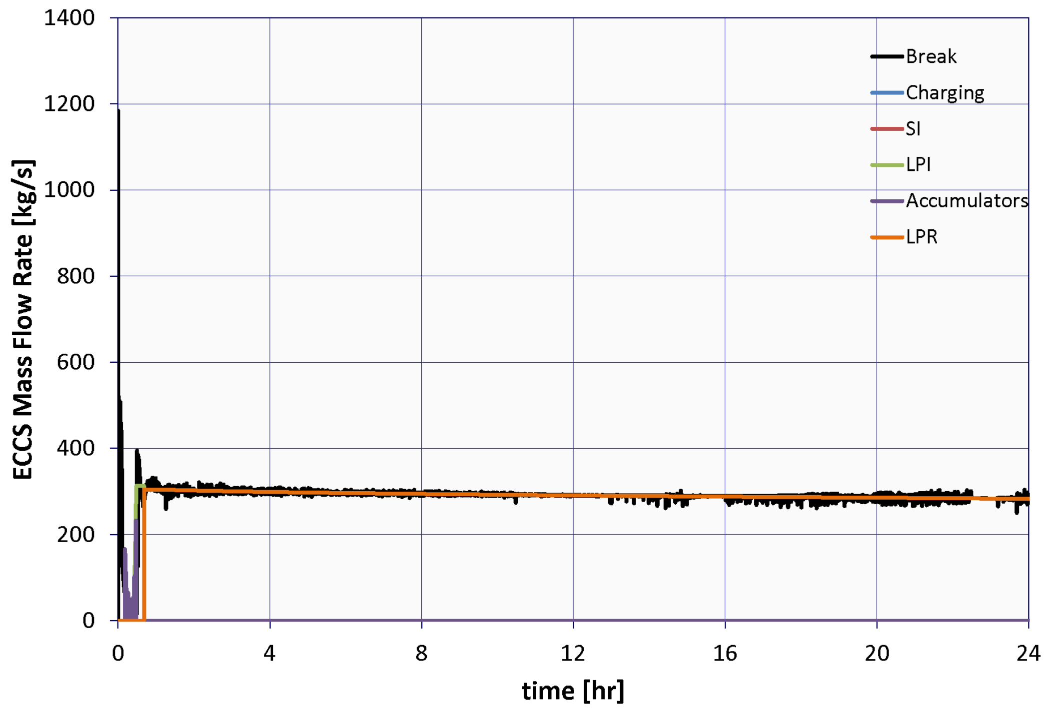

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

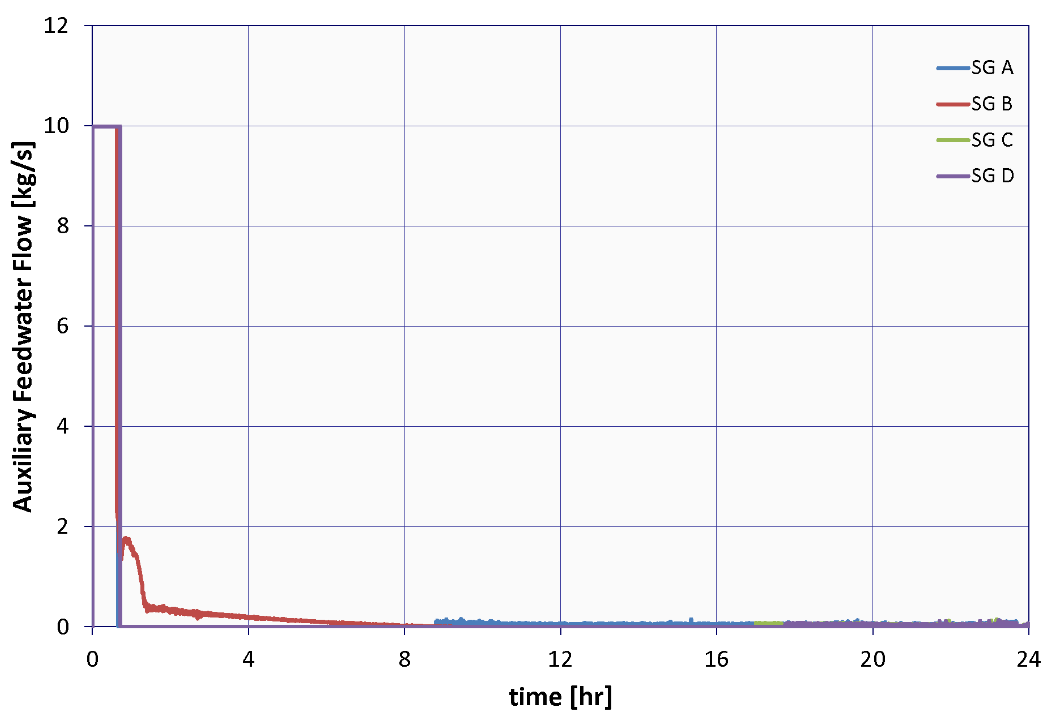


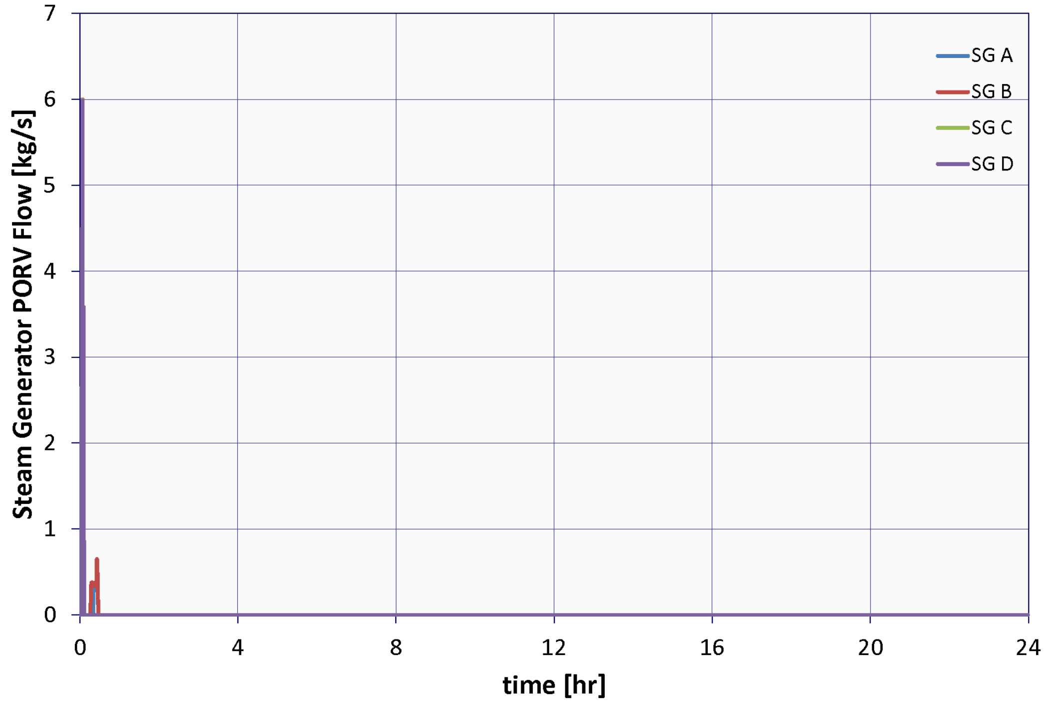
PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]

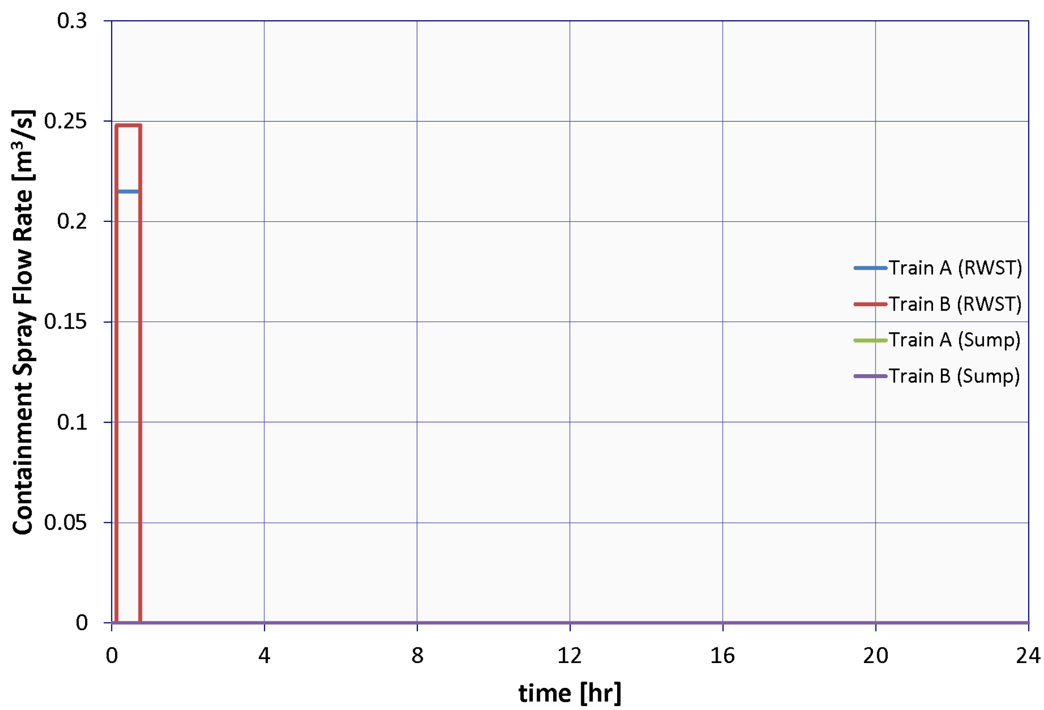


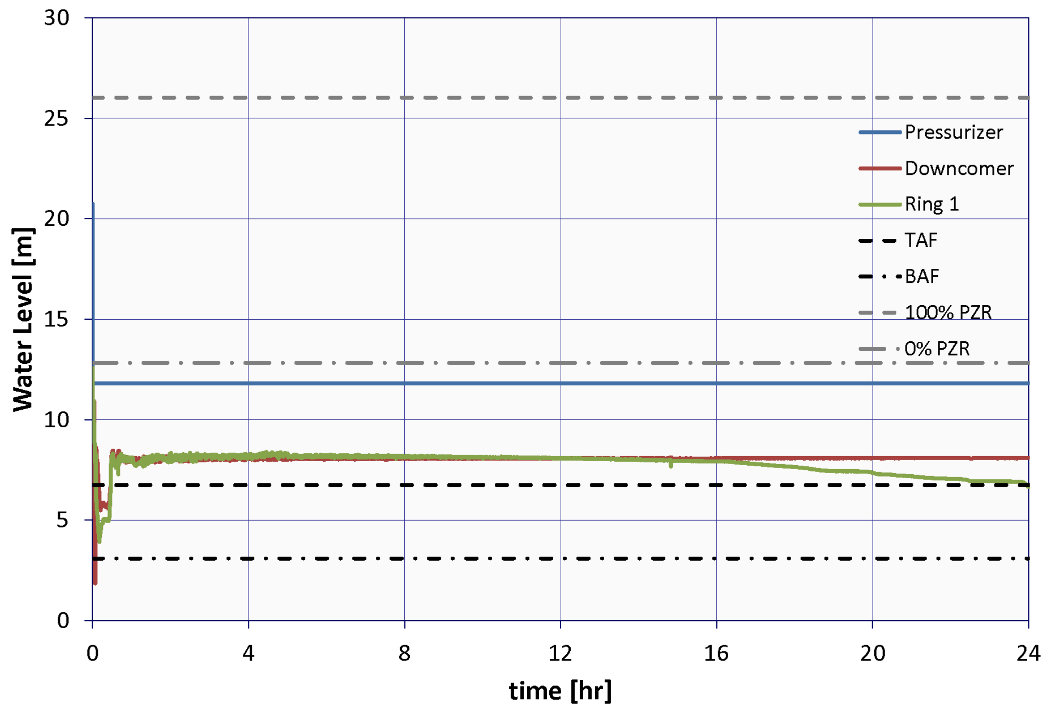
Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]

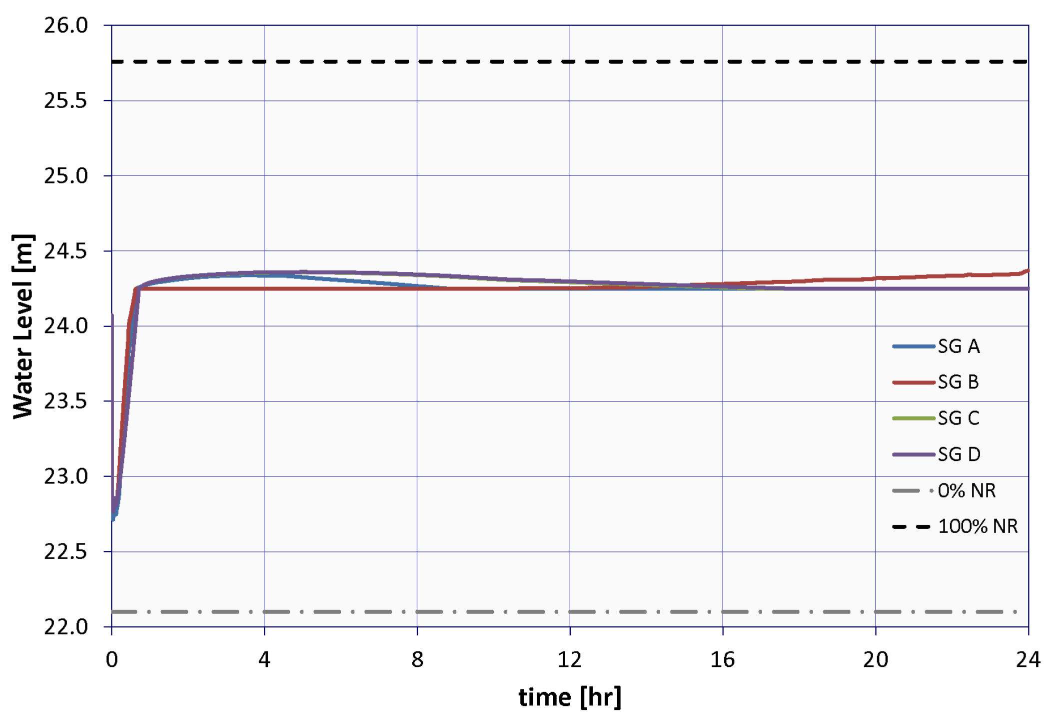

1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

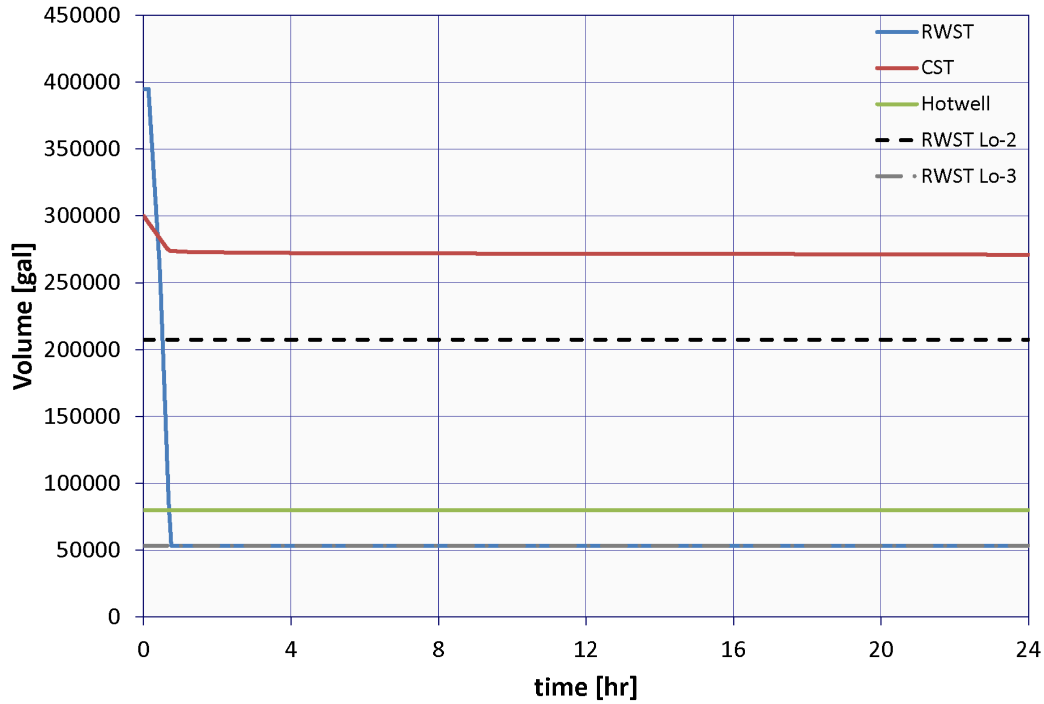

12
10
8
6
4
2
0
Auxiliary Feedwater Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
1
2
3
4
5
6
7
0
4
8
12
16
20
24


Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24

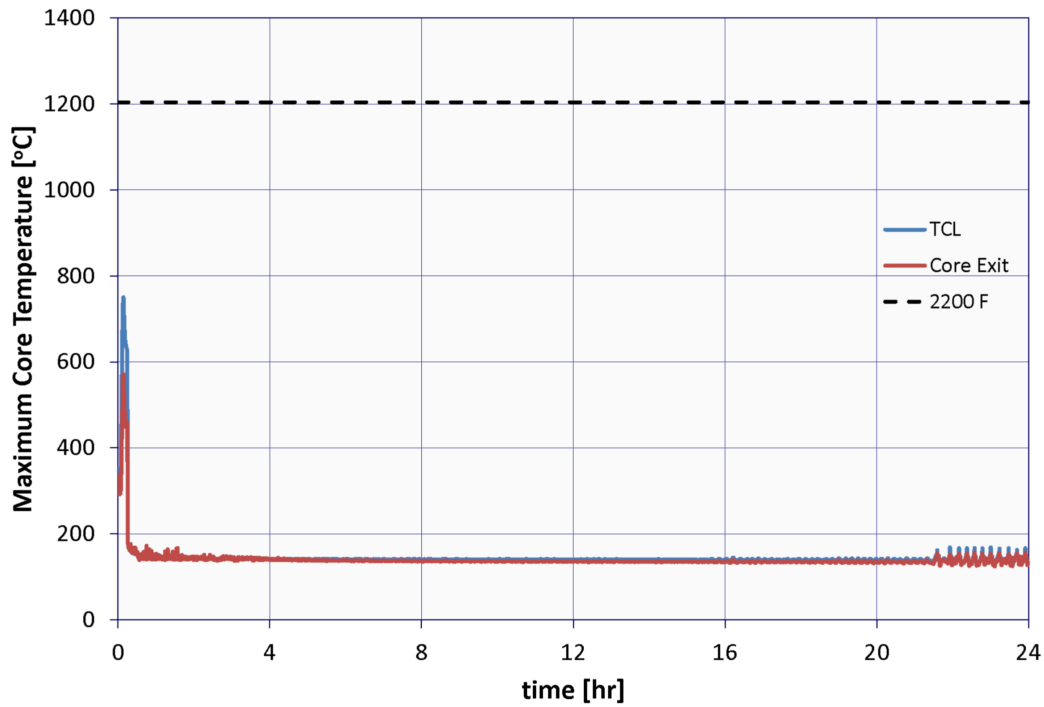

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

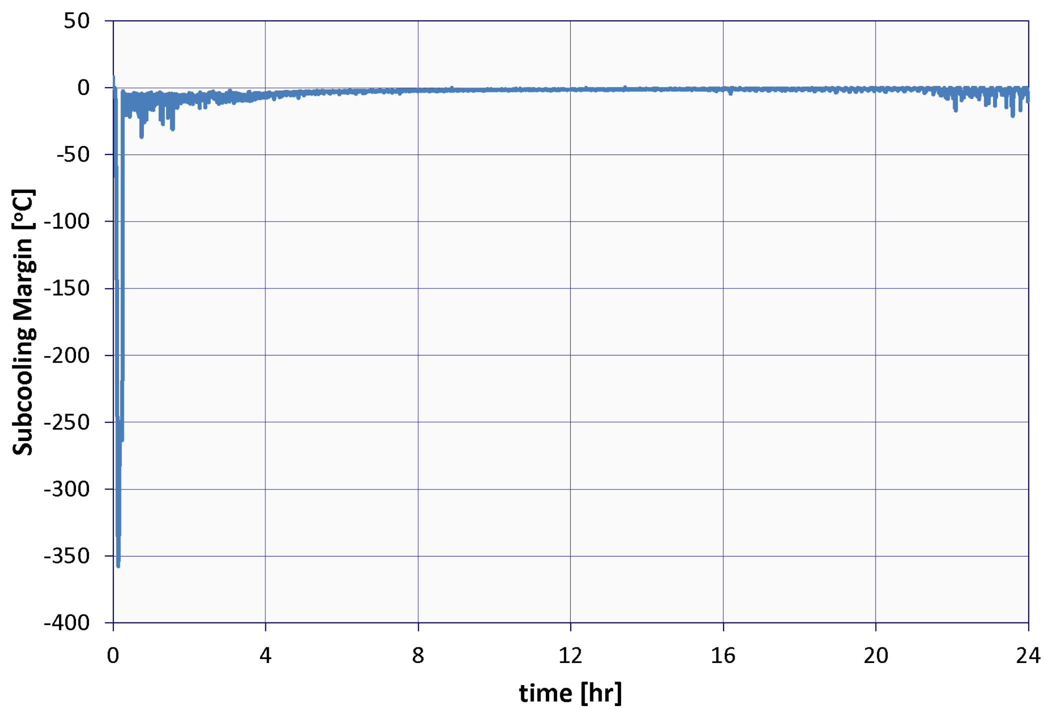

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

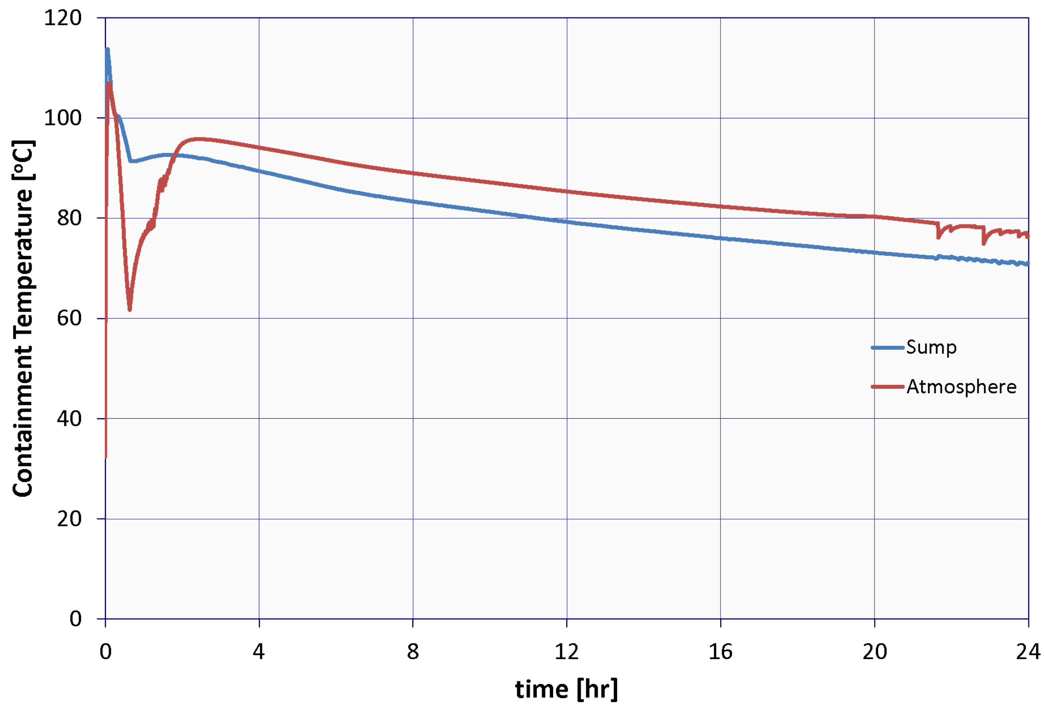


Volume [gal]
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

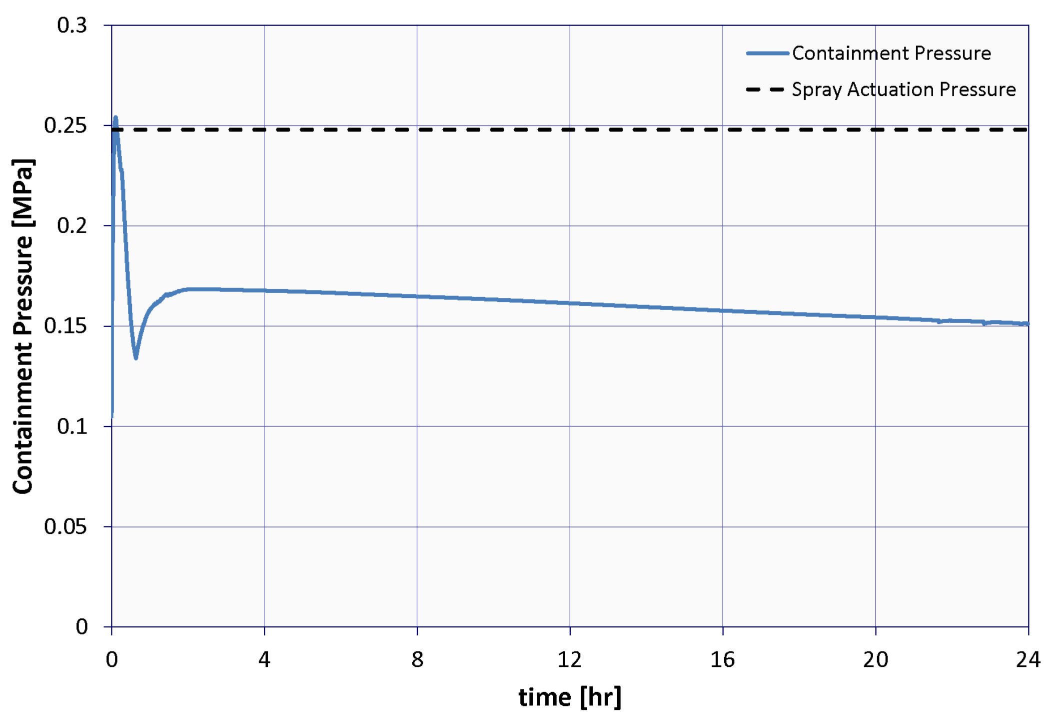
E.1.8 Case 8: 6-in. Break with 2 Accumulators, 1 RHR, 2/2 CS Pumps



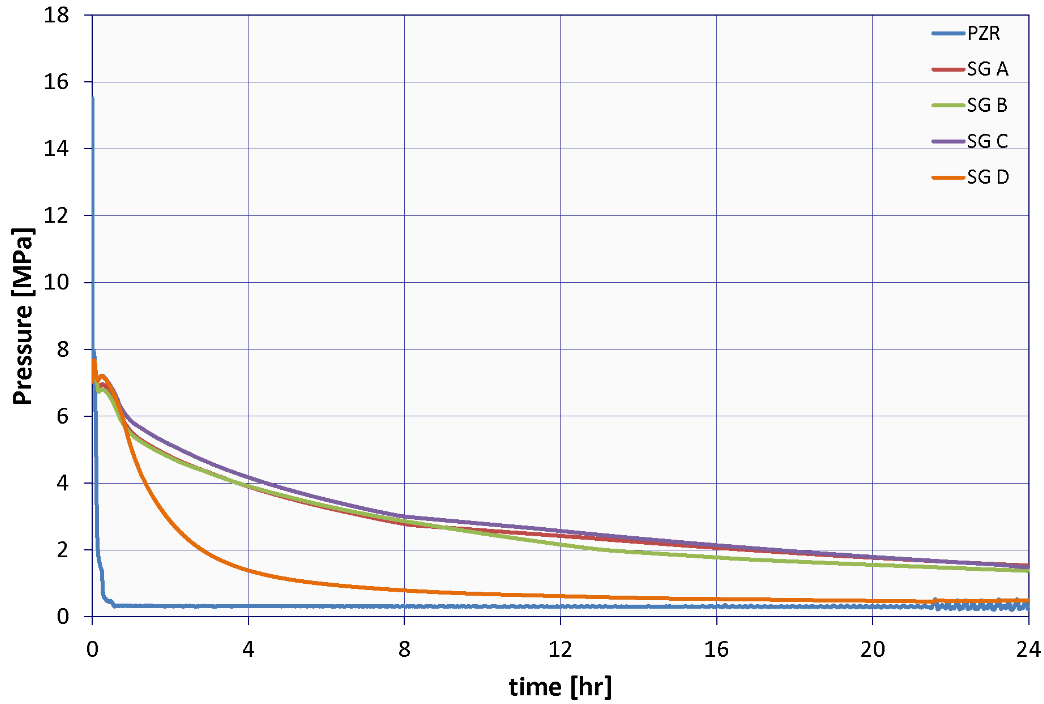


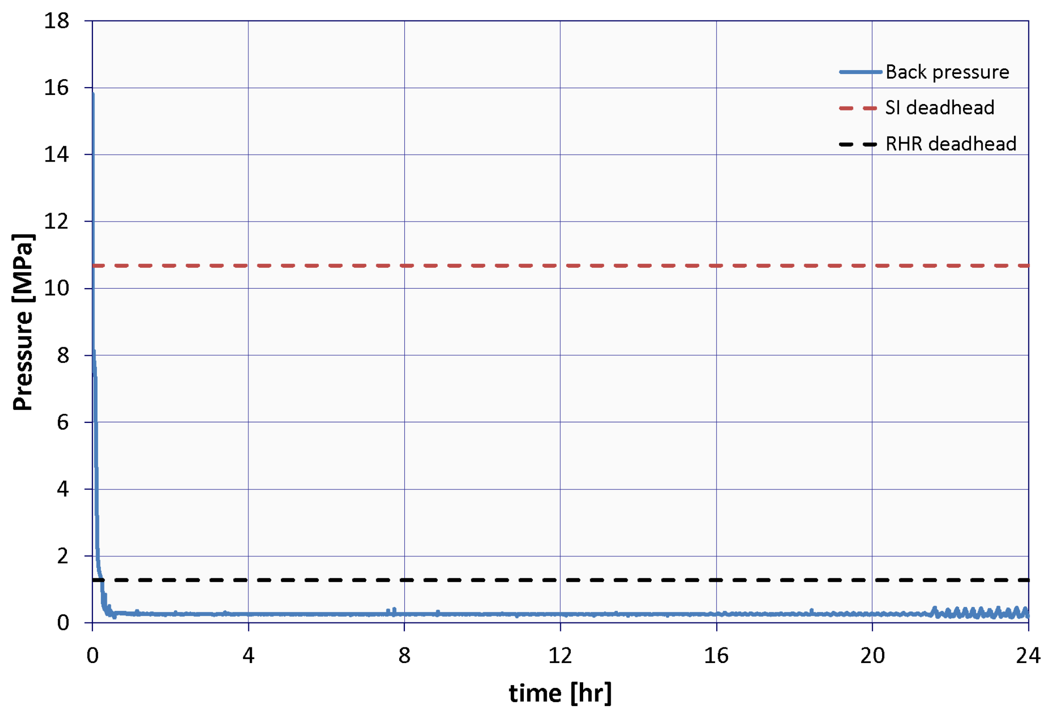


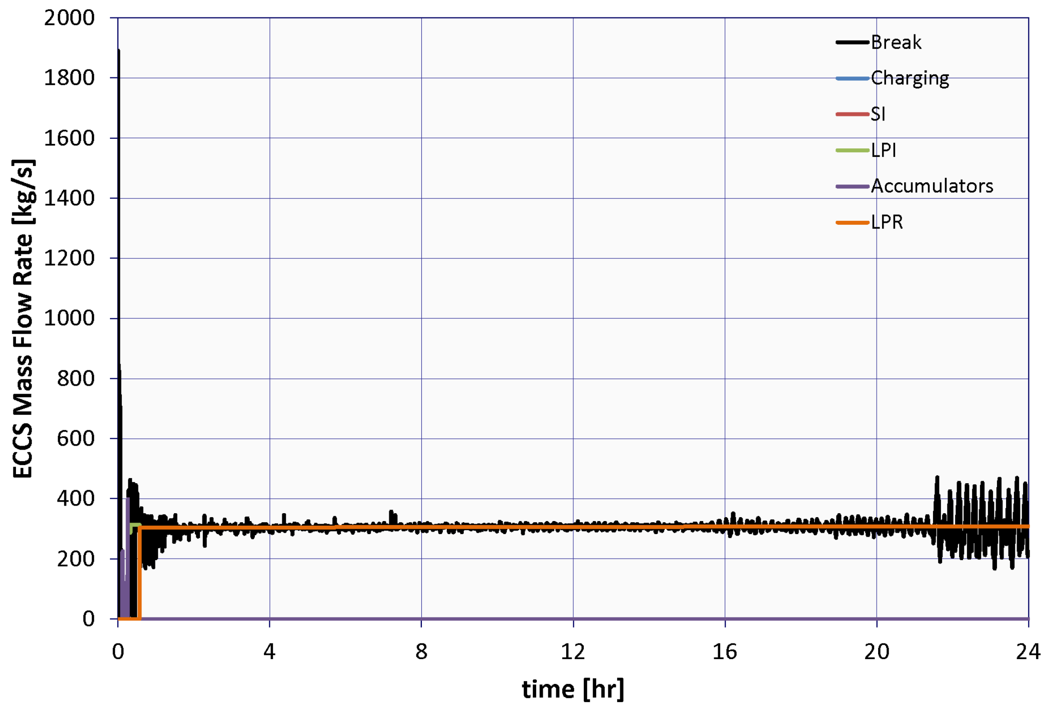
120
100
80
60
40
20
0
Containment Temperature [°C]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



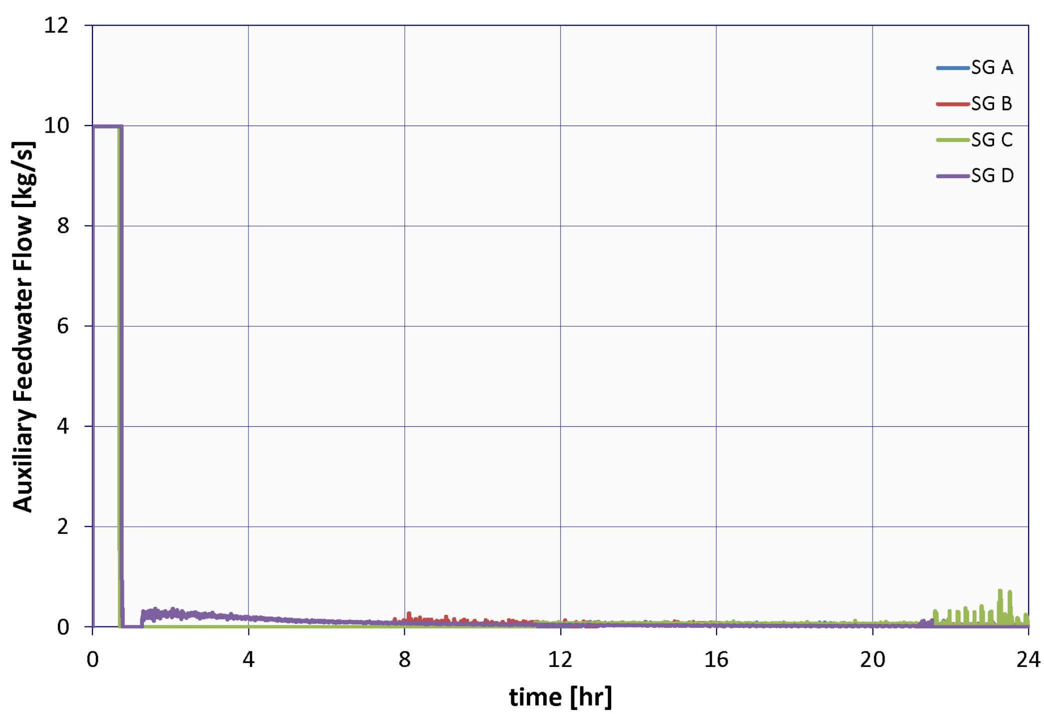
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure


18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D

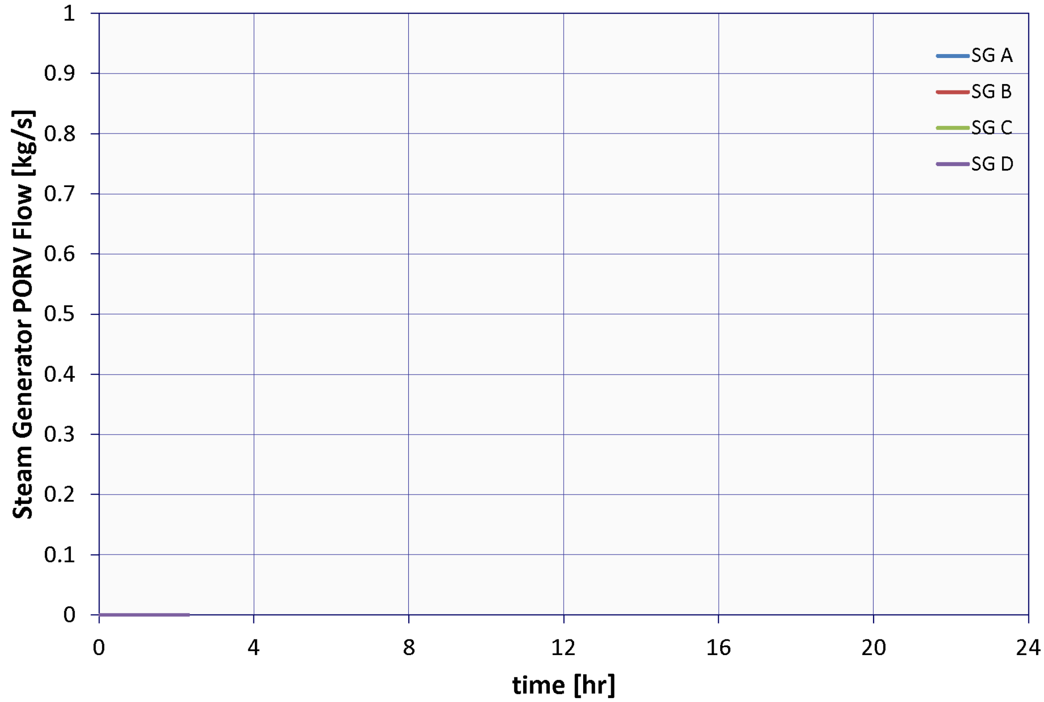

18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead

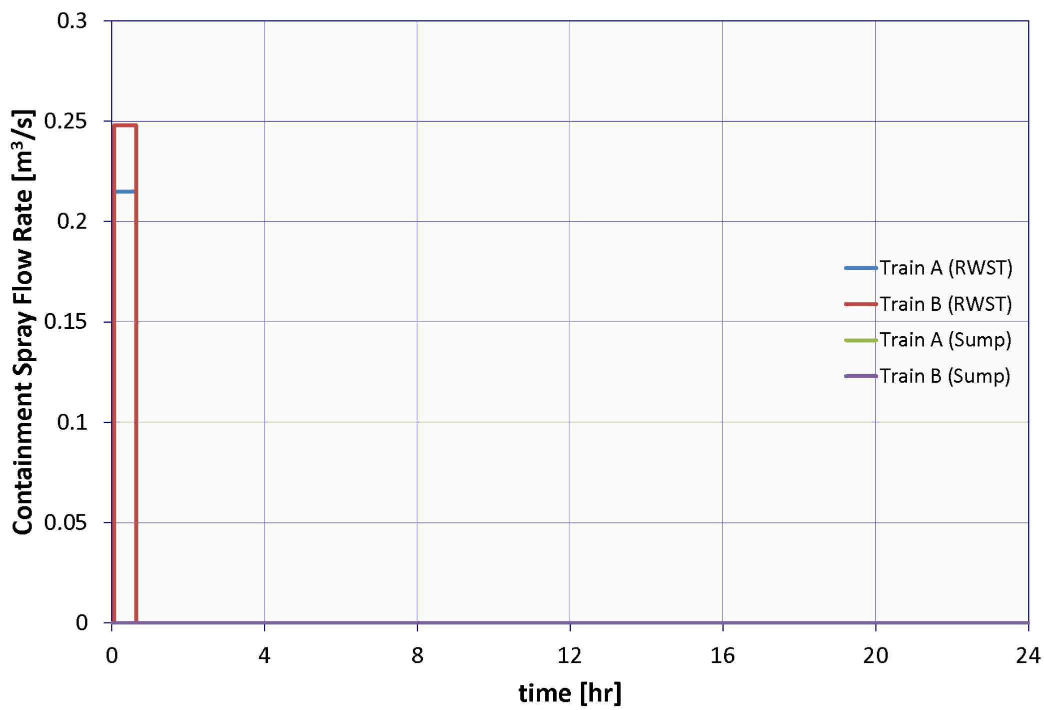


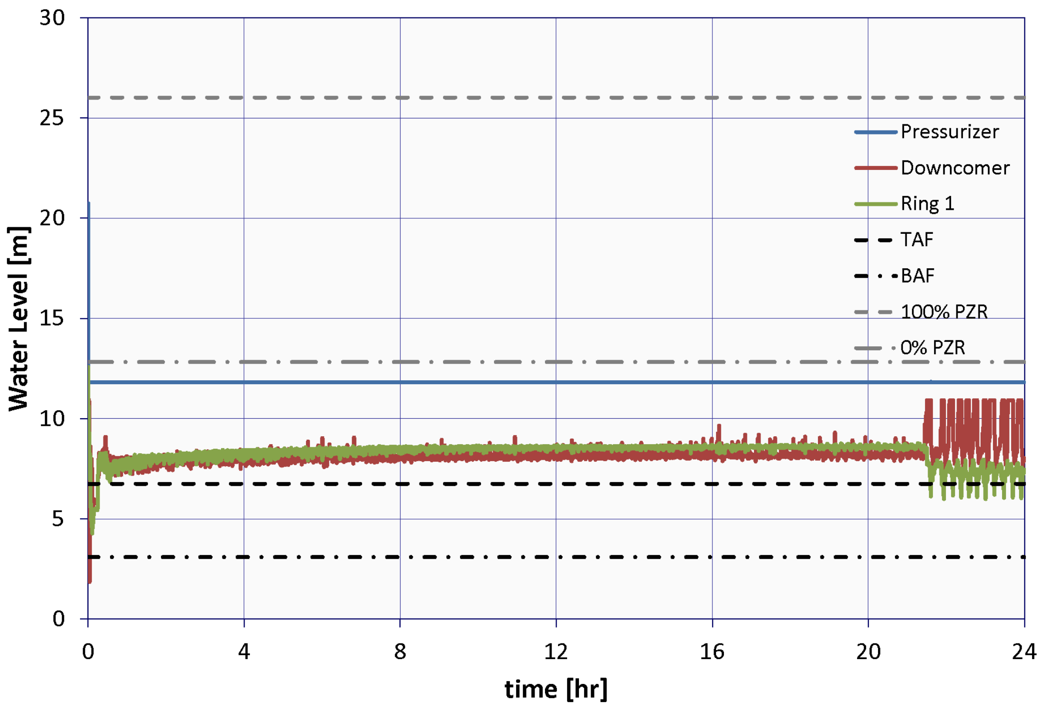
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

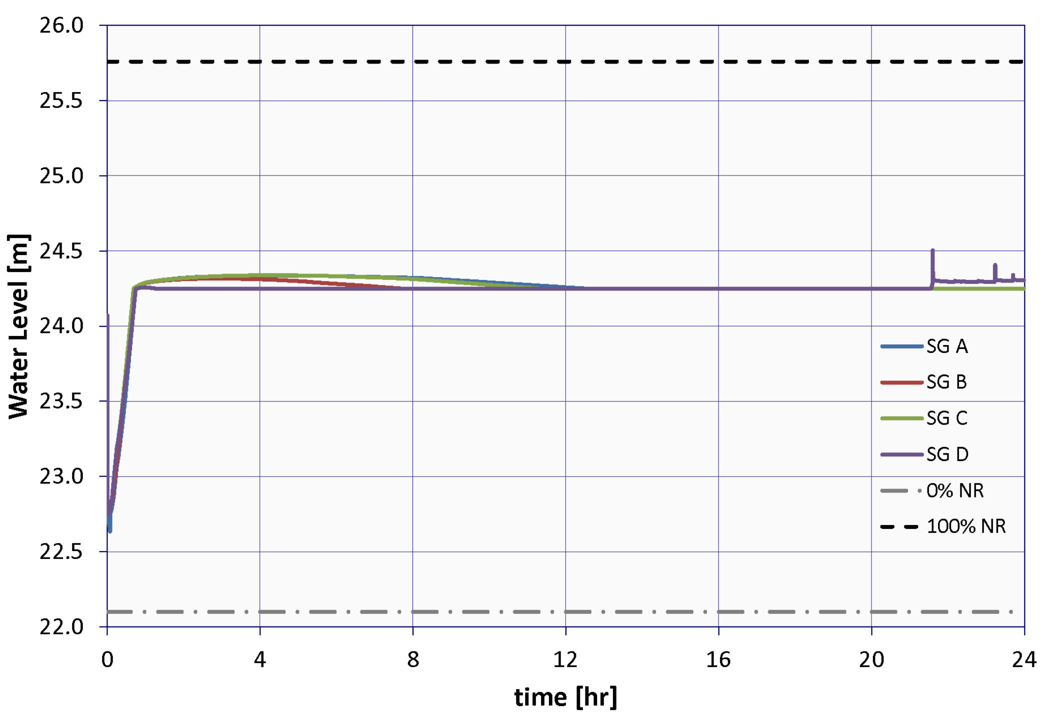


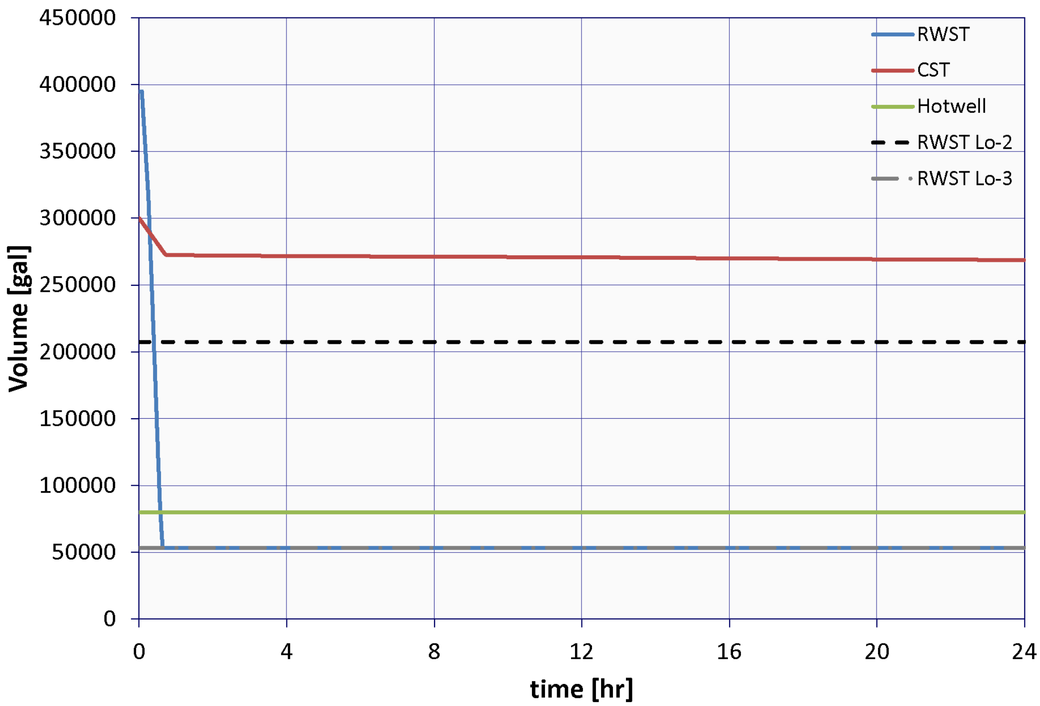
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
4
8
12
16
20
24


Containment Spray Flow Rate [m3/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24

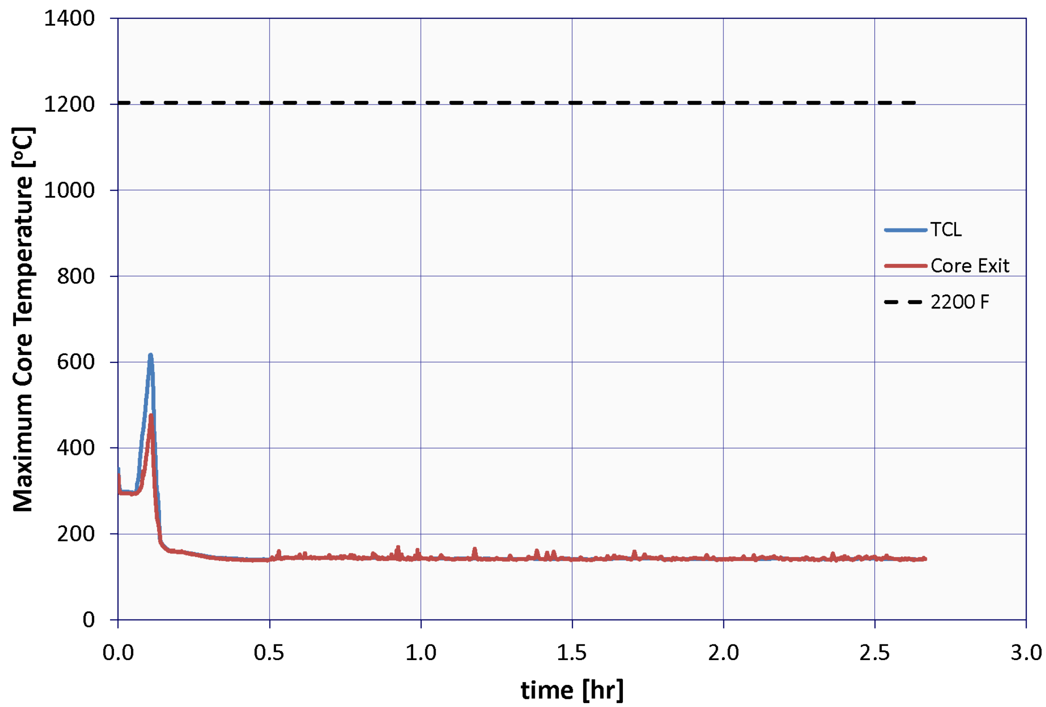

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

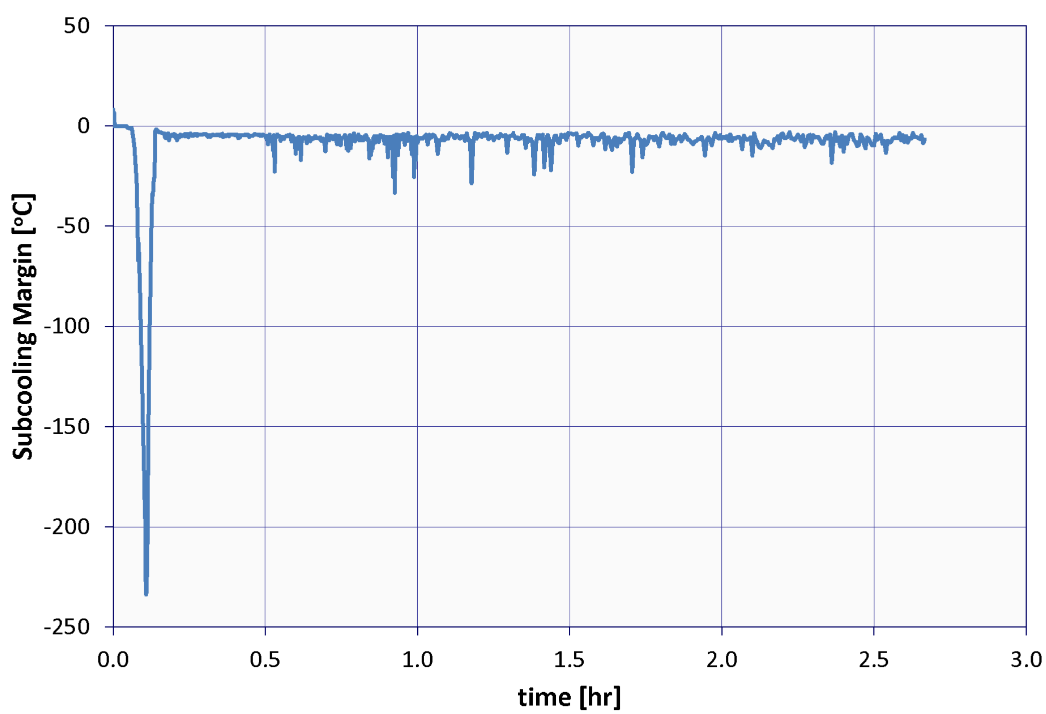

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

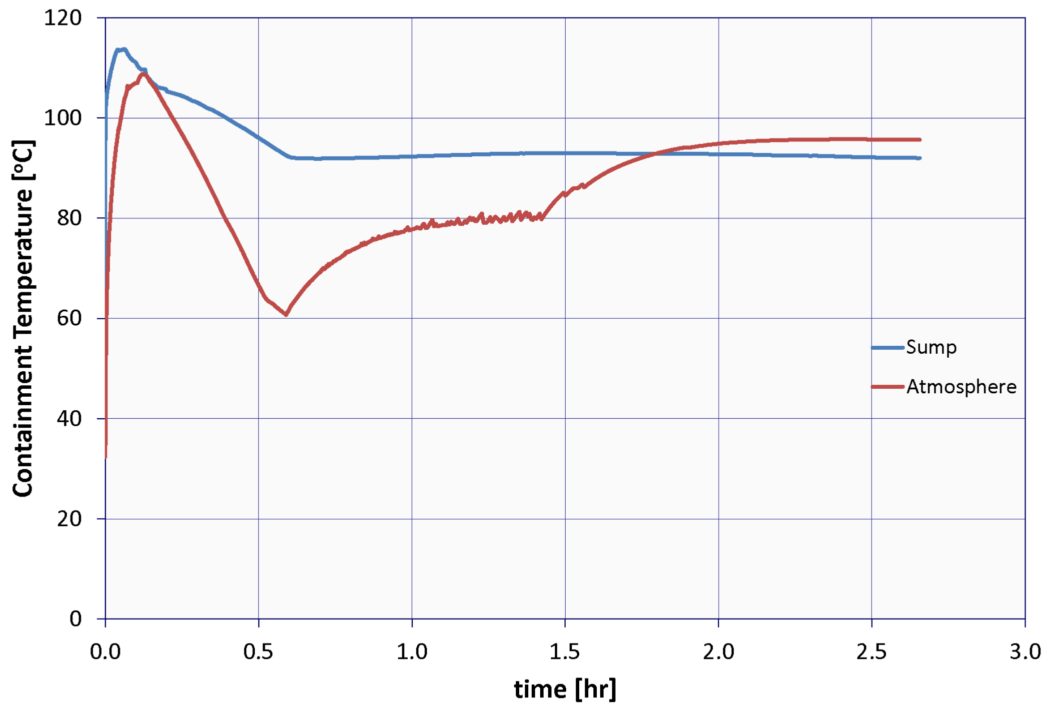


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

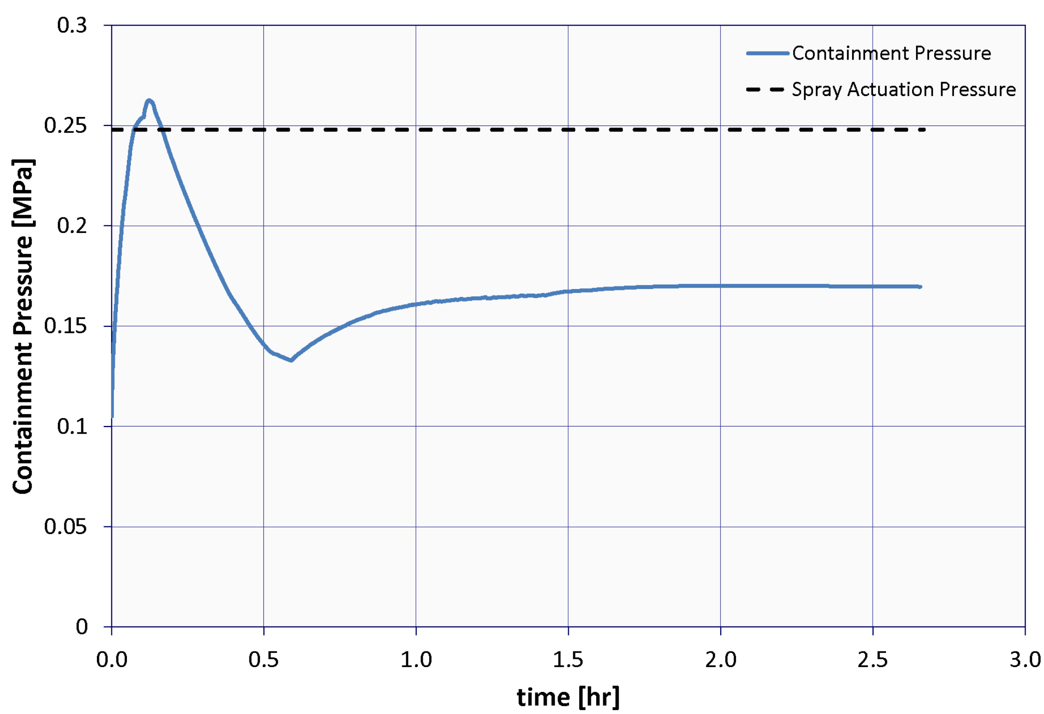
E.1.8.1 *Case 8a: 6-in. Break with 2 Accumulators (1 in Broken Loop), 1 RHR, 2/2 CS Pumps*



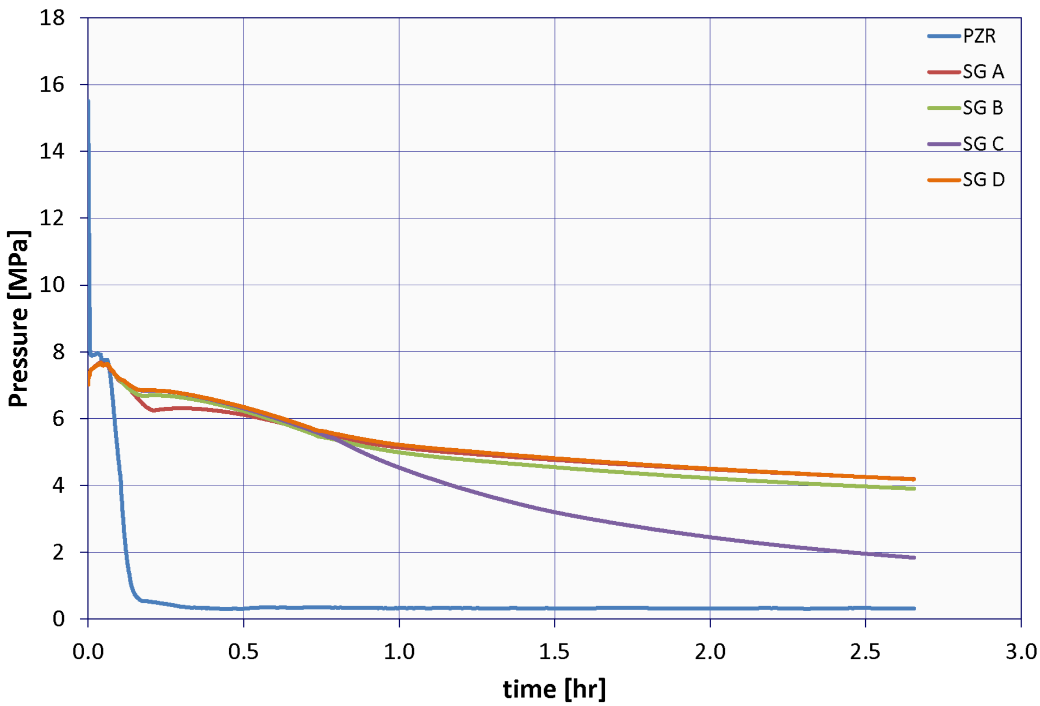




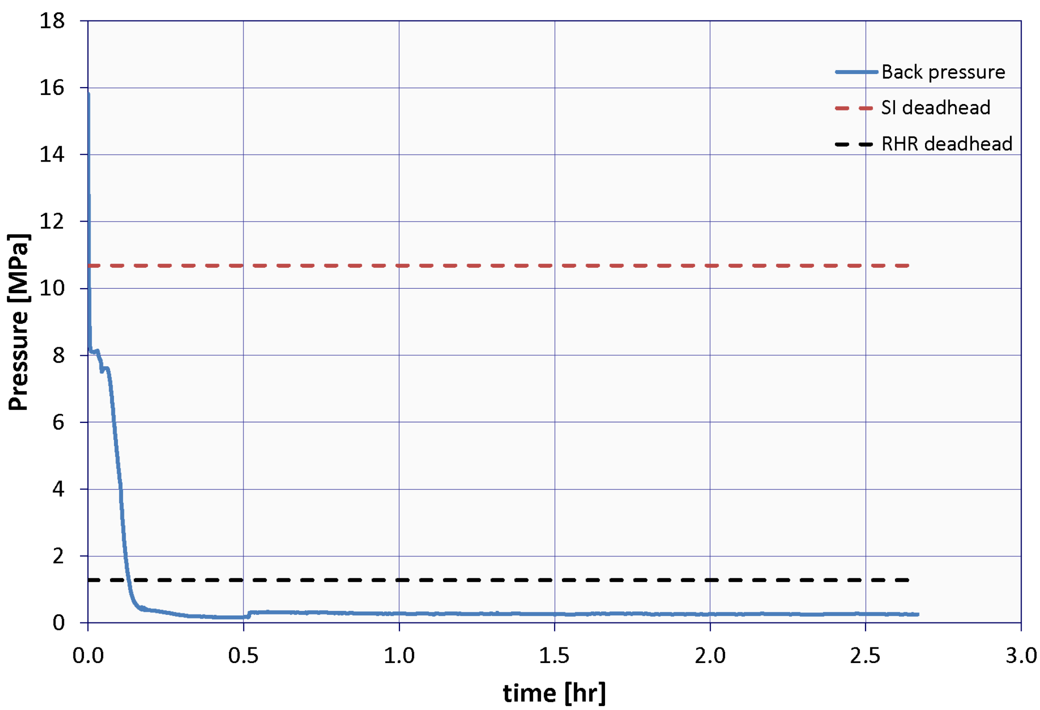
Containment Temperature [°C]
time [hr]
Sump
Atmosphere



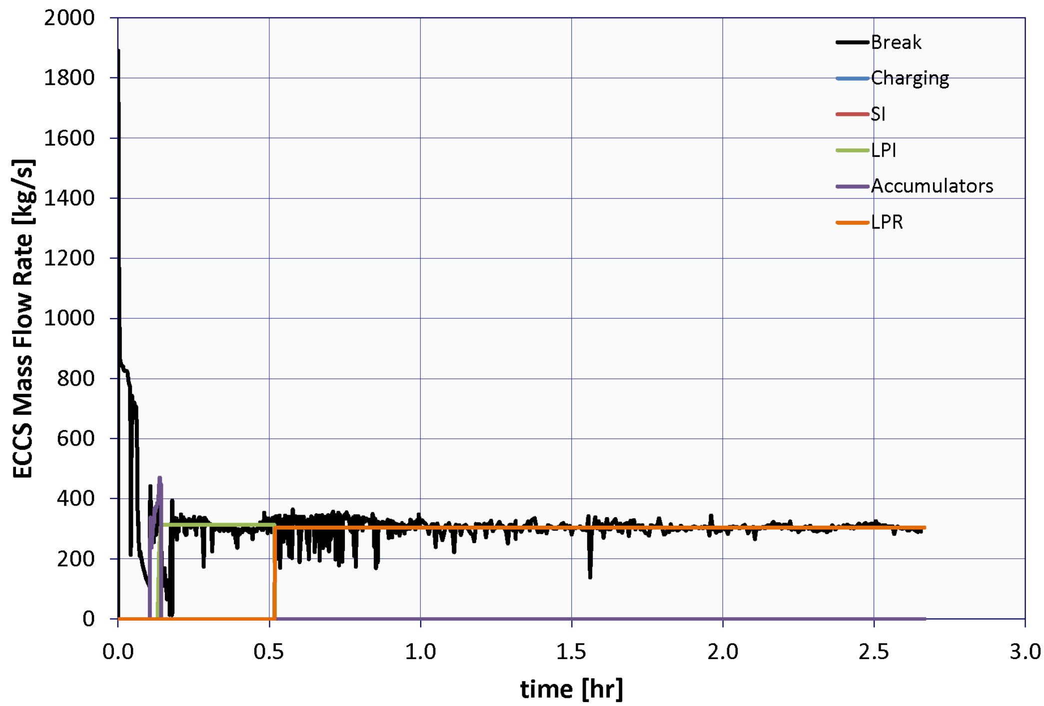
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure

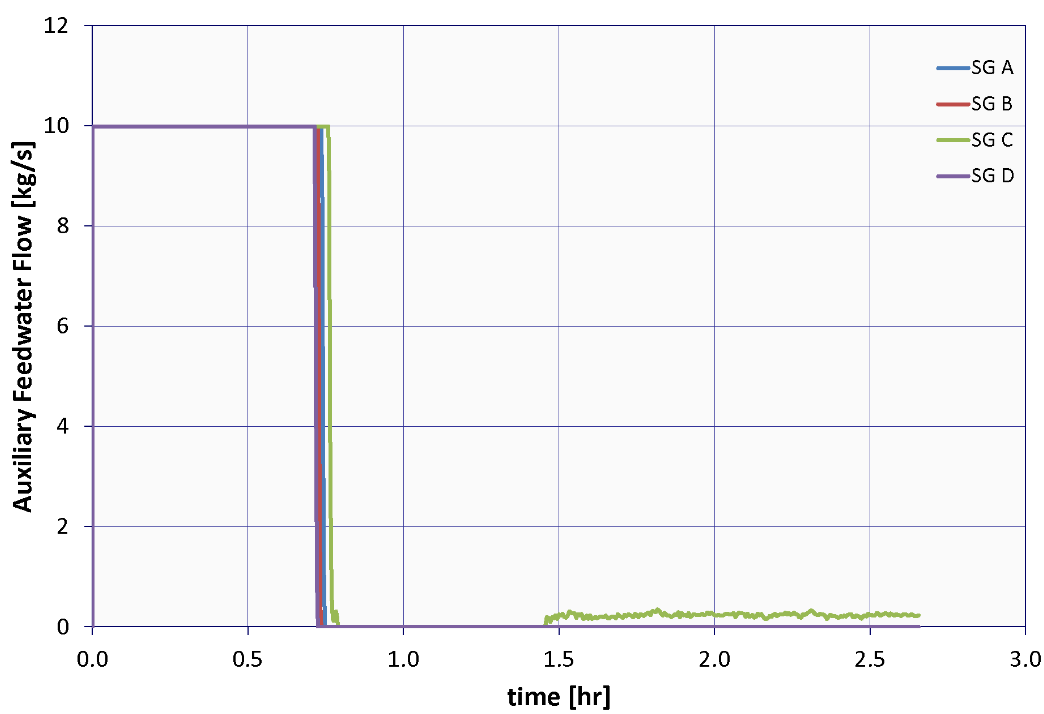


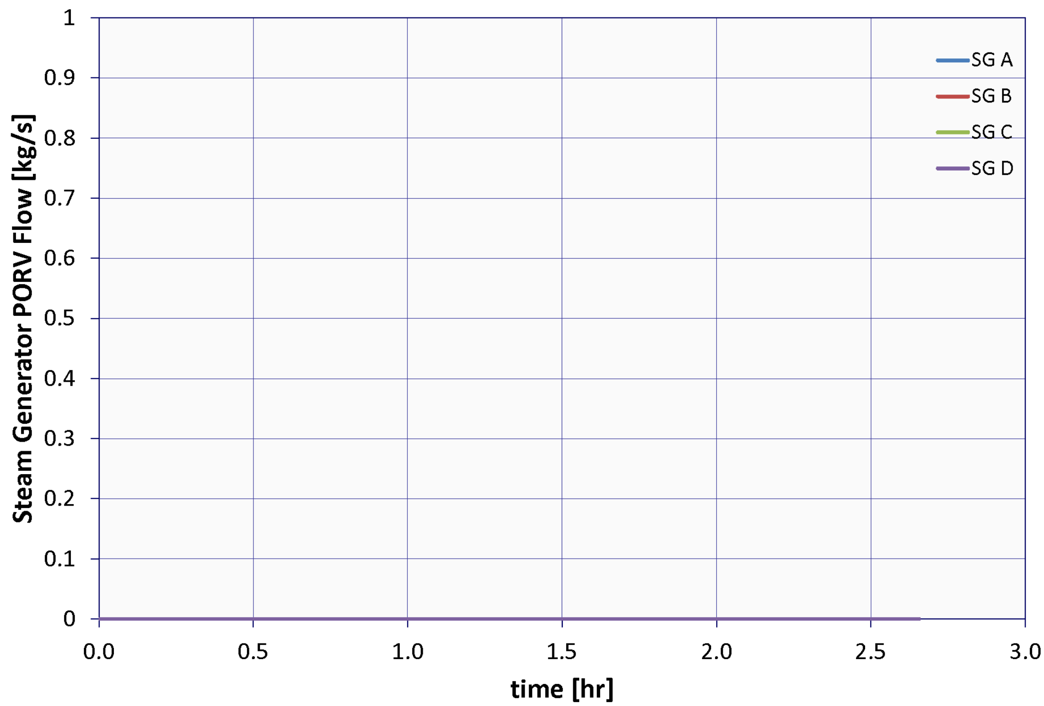
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
time [hr]
PZR
SG A
SG B
SG C
SG D



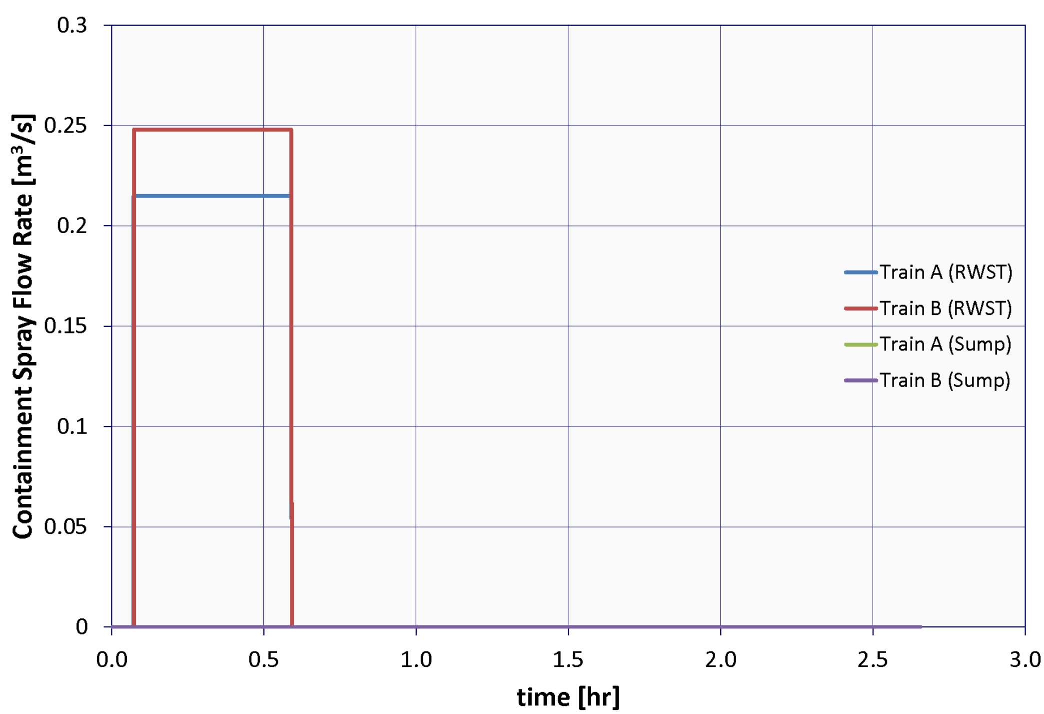
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
time [hr]
Back pressure
SI deadhead
RHR deadhead


ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0.0
0.5
1.0
1.5
2.0
2.5
3.0

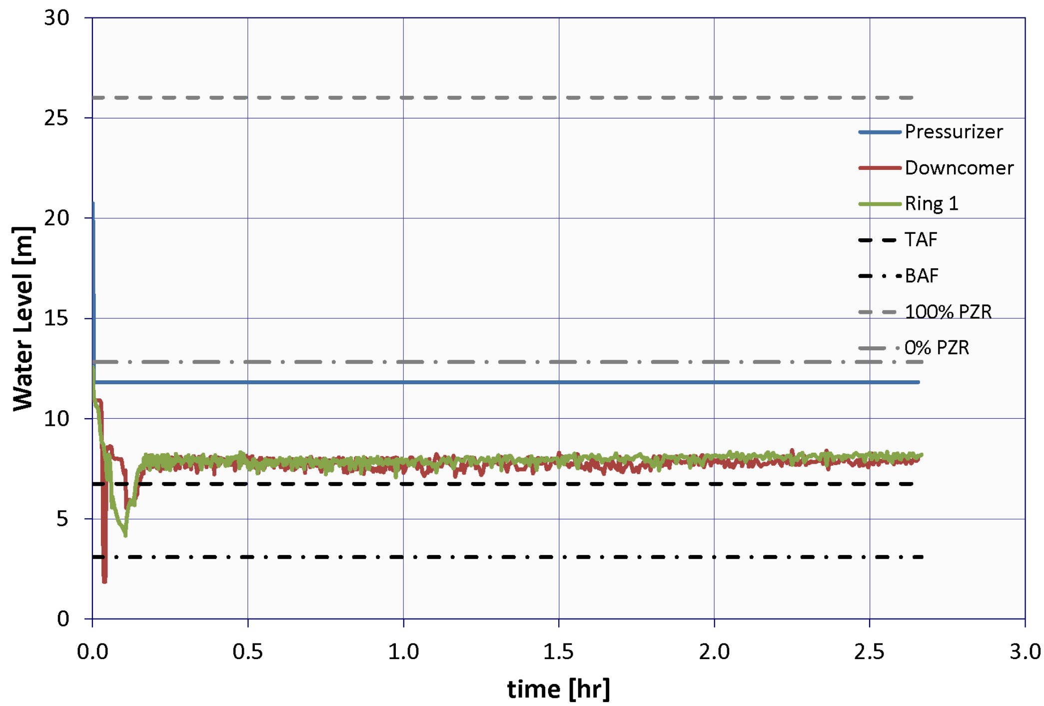

Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0.0
0.5
1.0
1.5
2.0
2.5
3.0



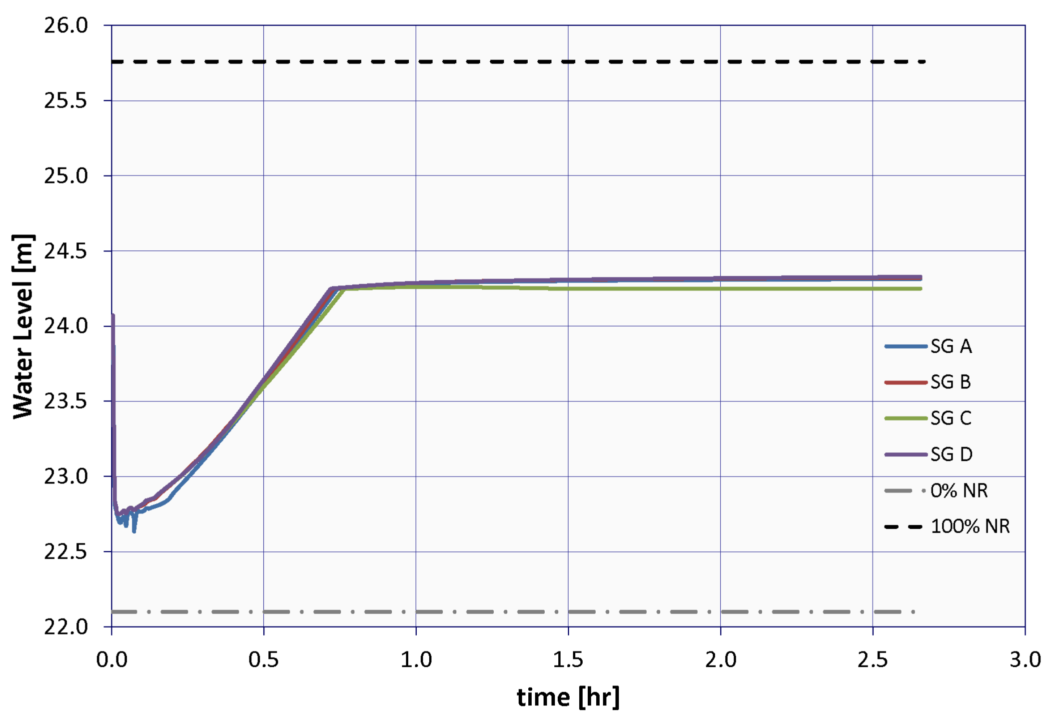
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0



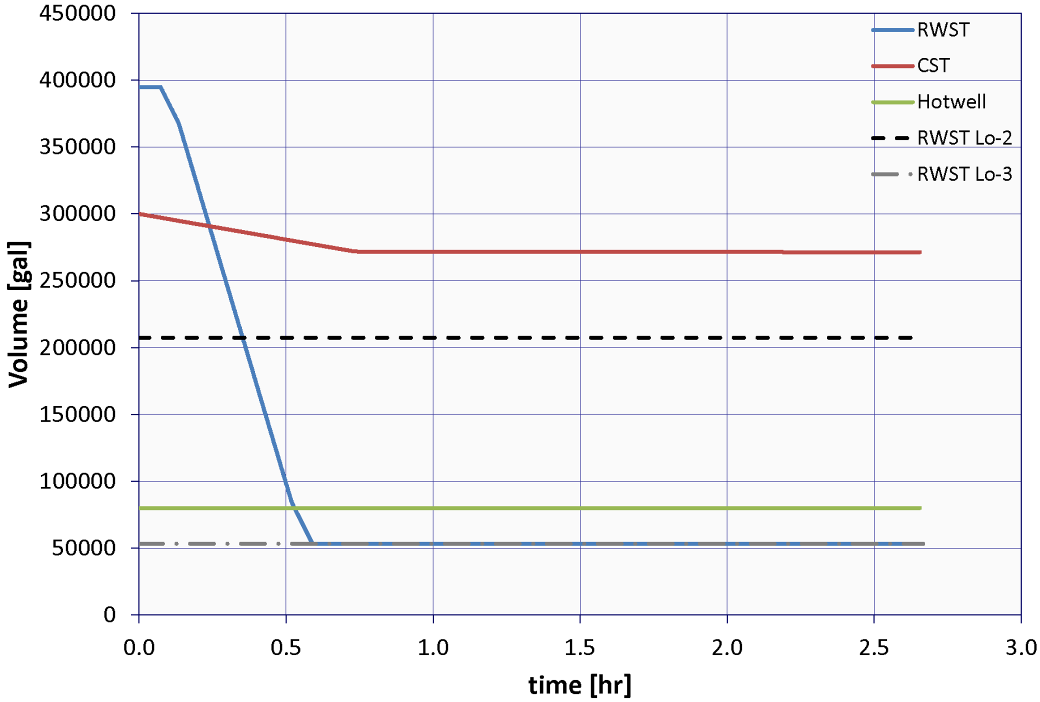
Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
0.3
0.25
0.2
0.15
0.1
0.05
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0



30
25
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR



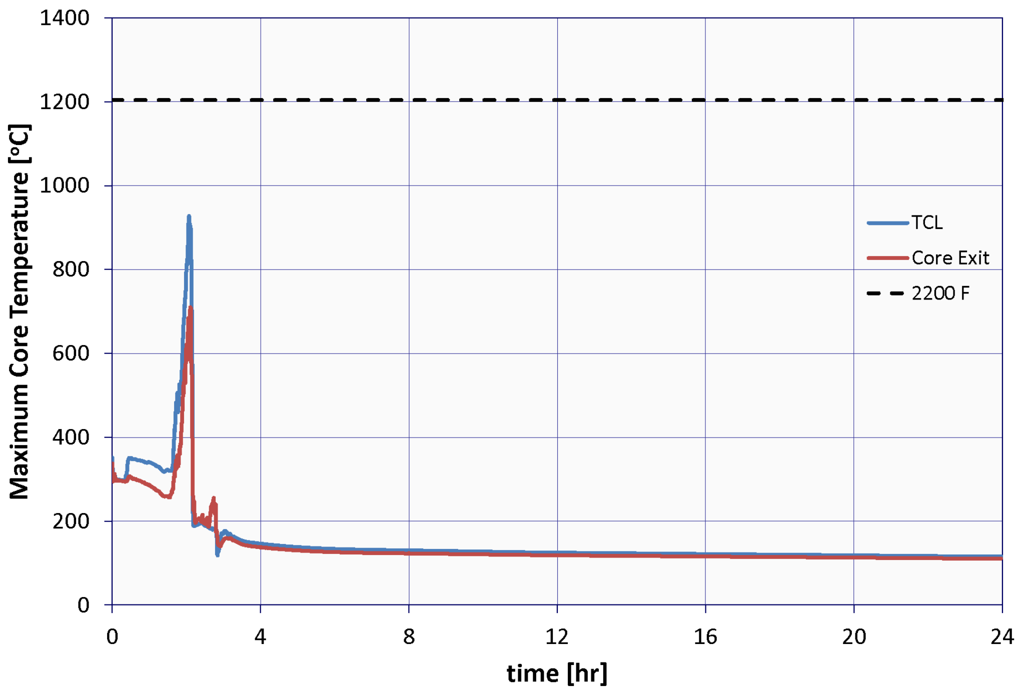
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

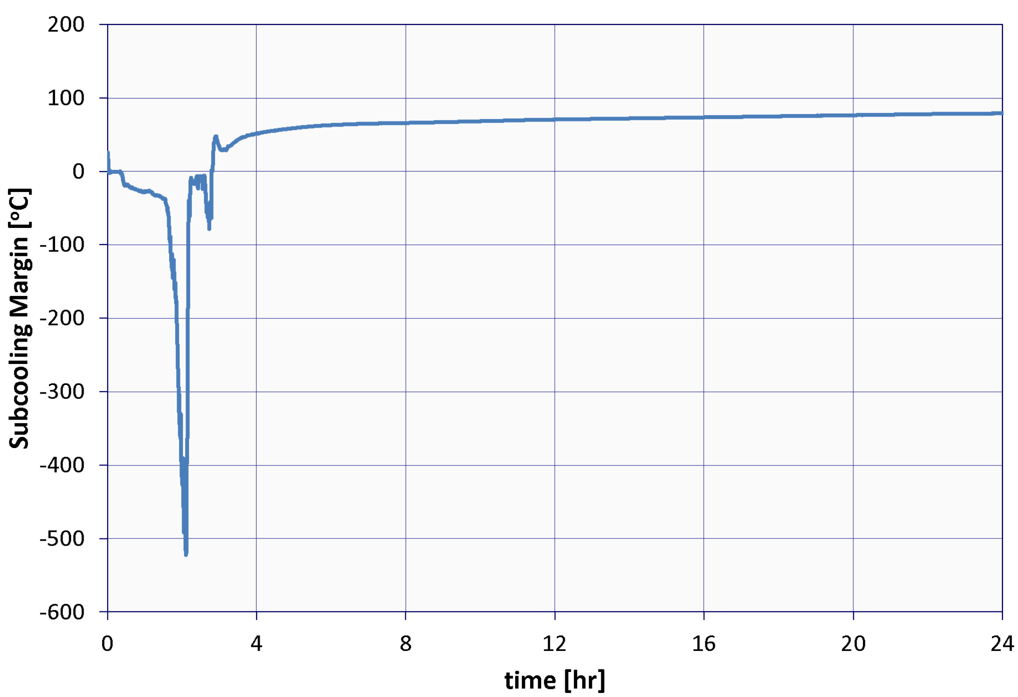


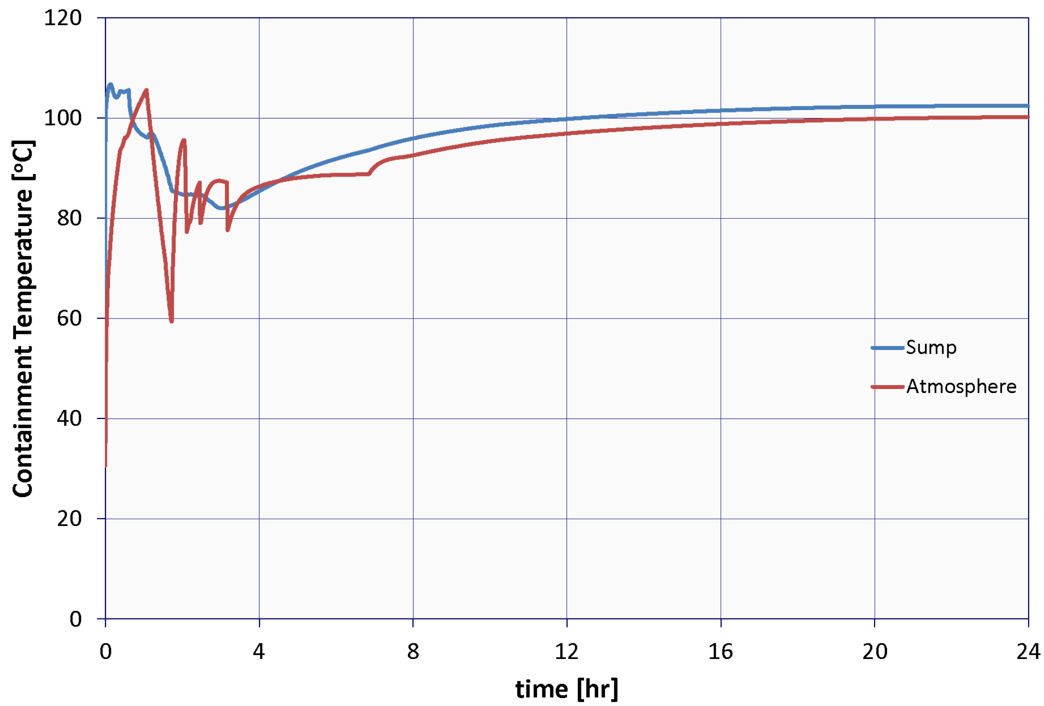
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

E.2 Medium-Break Loss-of-Coolant Accident Cooldown Timing for Low-Pressure Recirculation

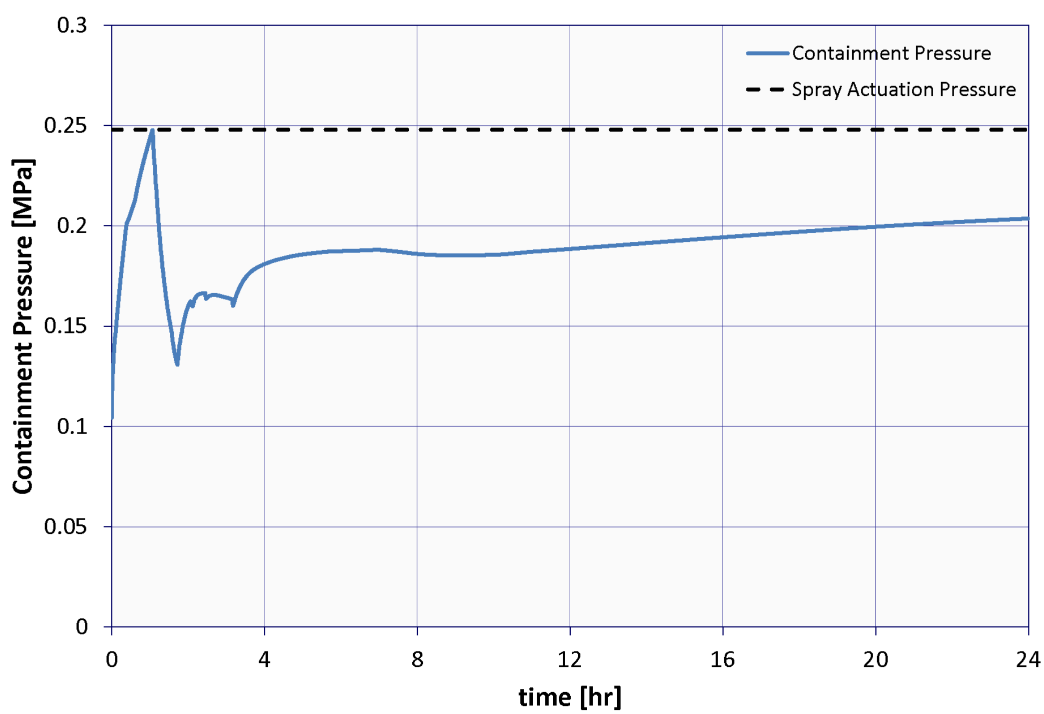
E.2.1 Case 1: 2-in. Break, 100 °F/hr Cooldown at 20 min, 2/2 CS Pumps, 0/4 RCFC



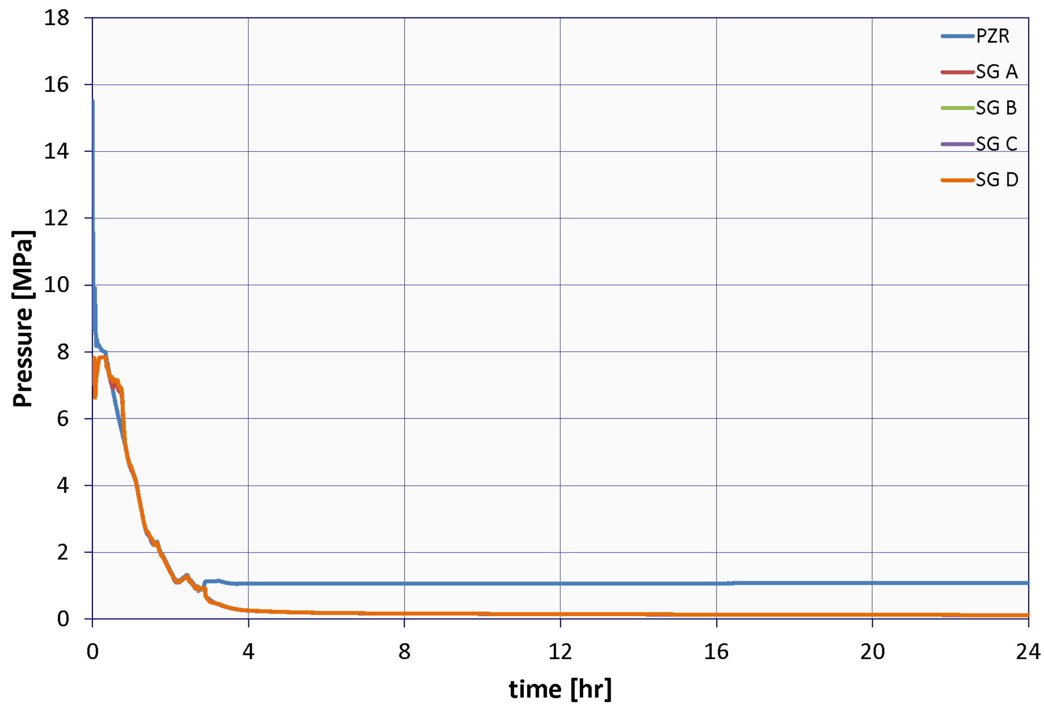


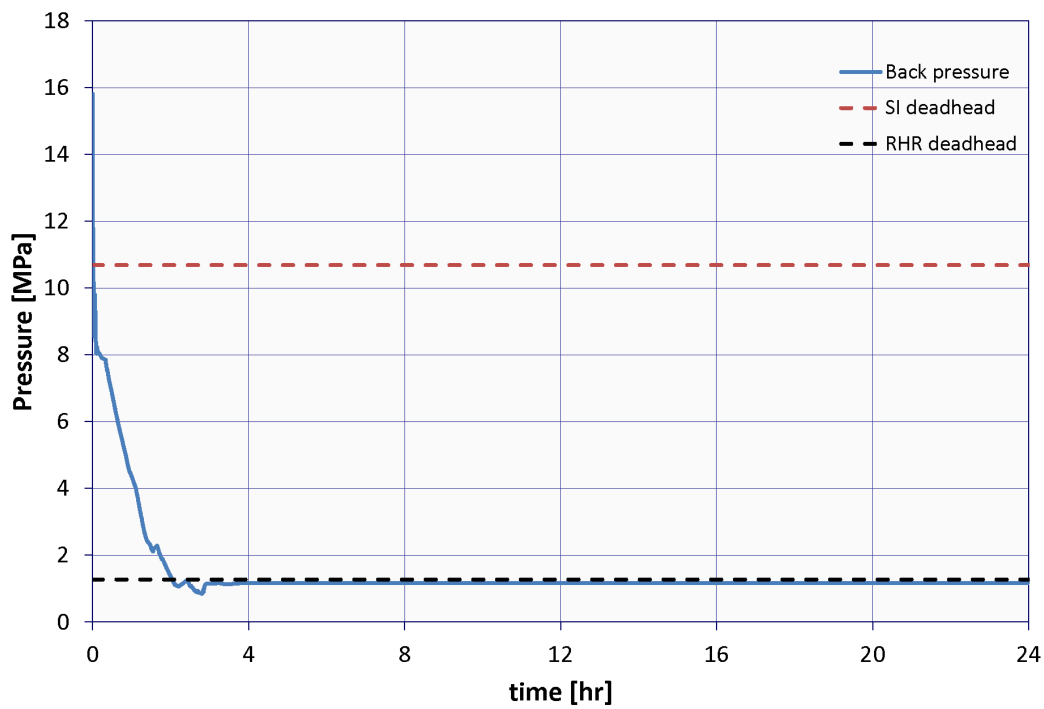


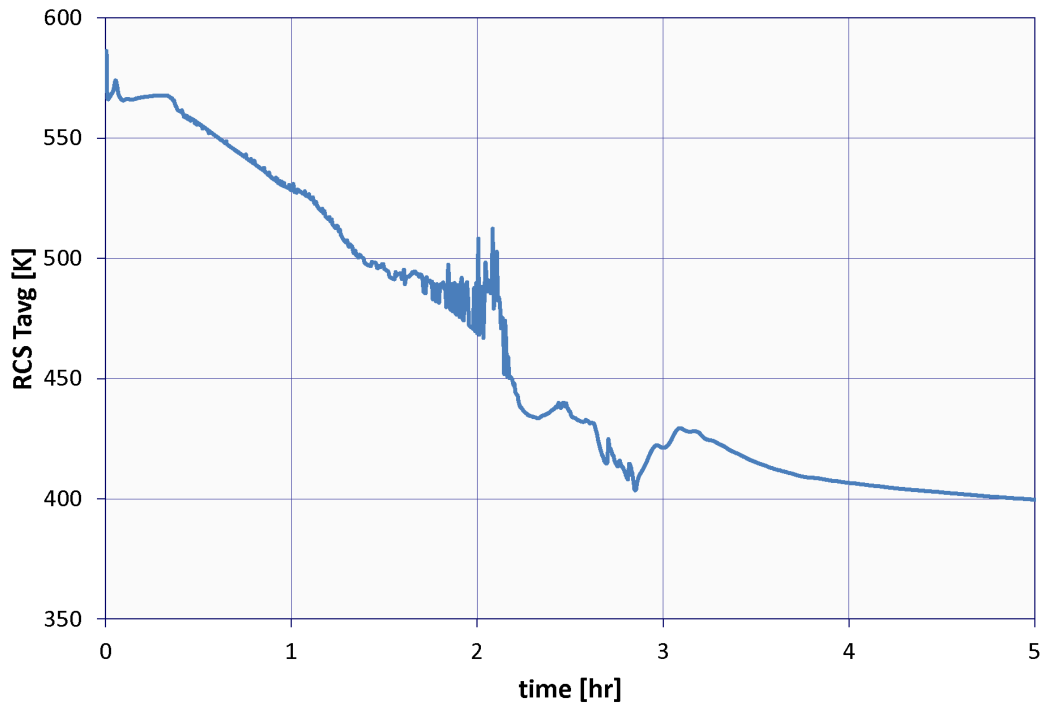
Containment Temperature [°C]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

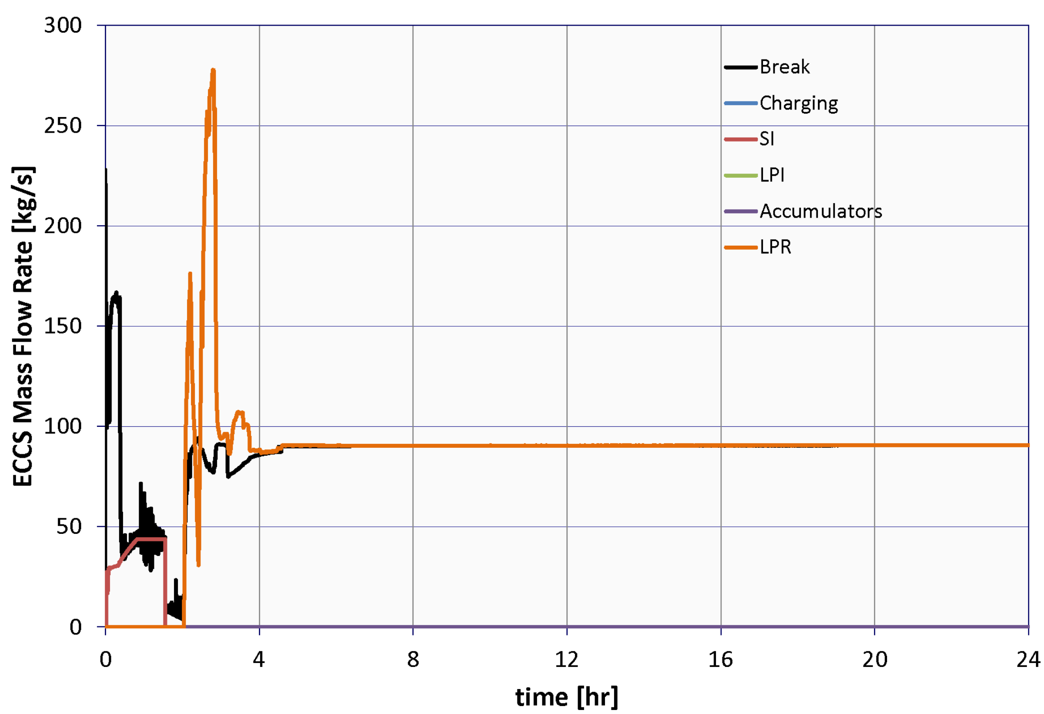


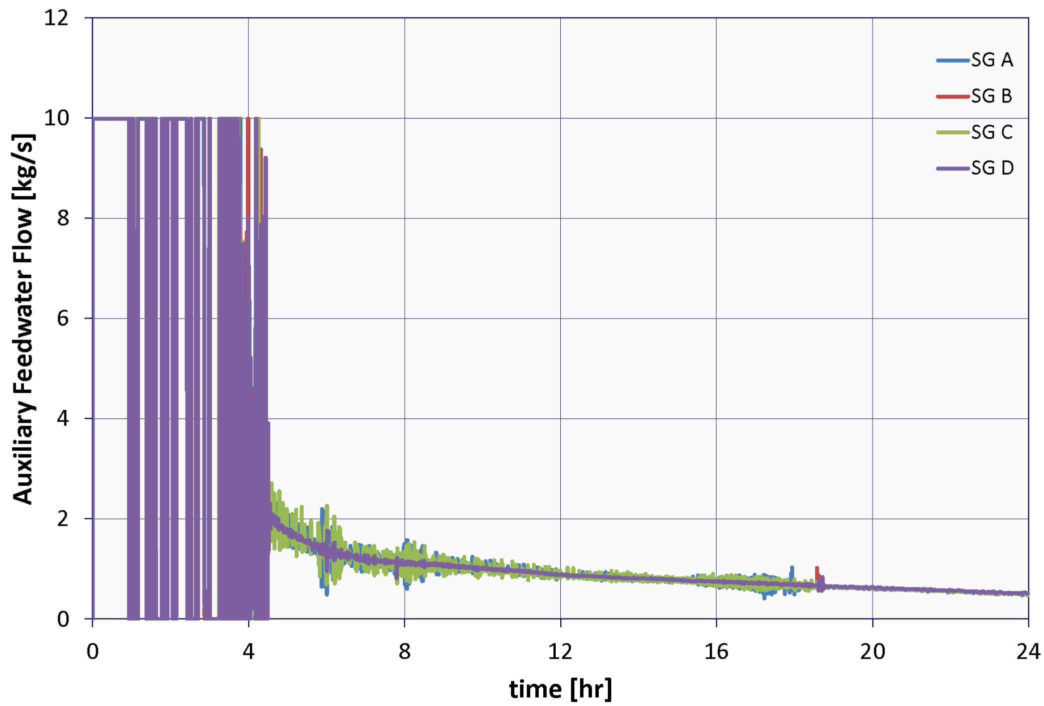
Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure


PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]

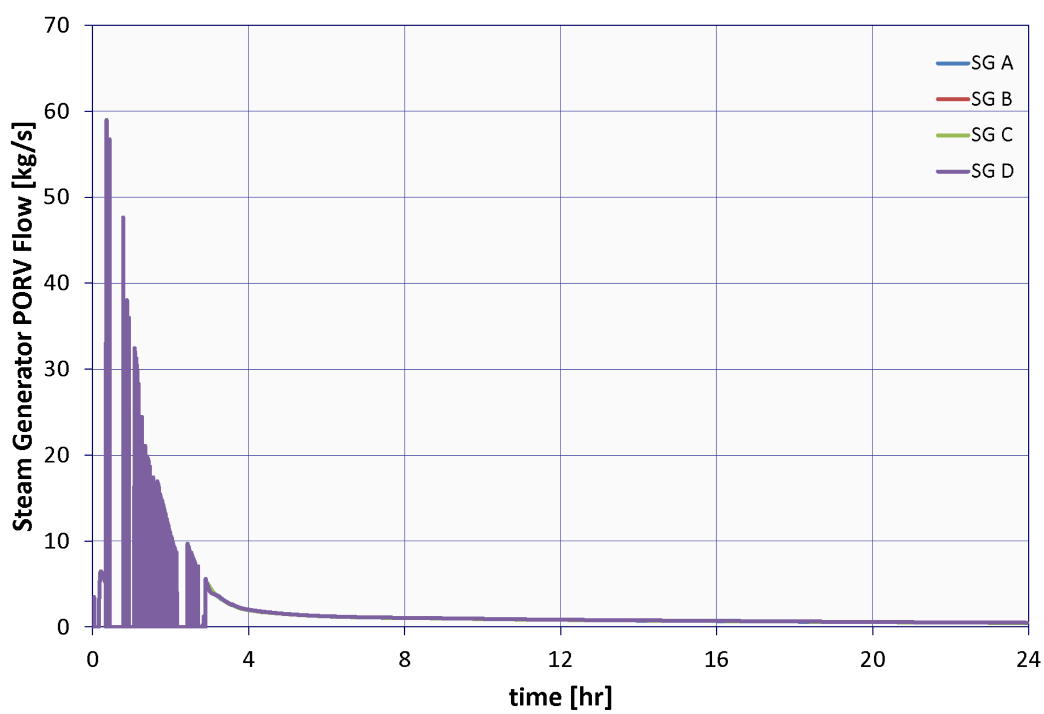

Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]


600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]

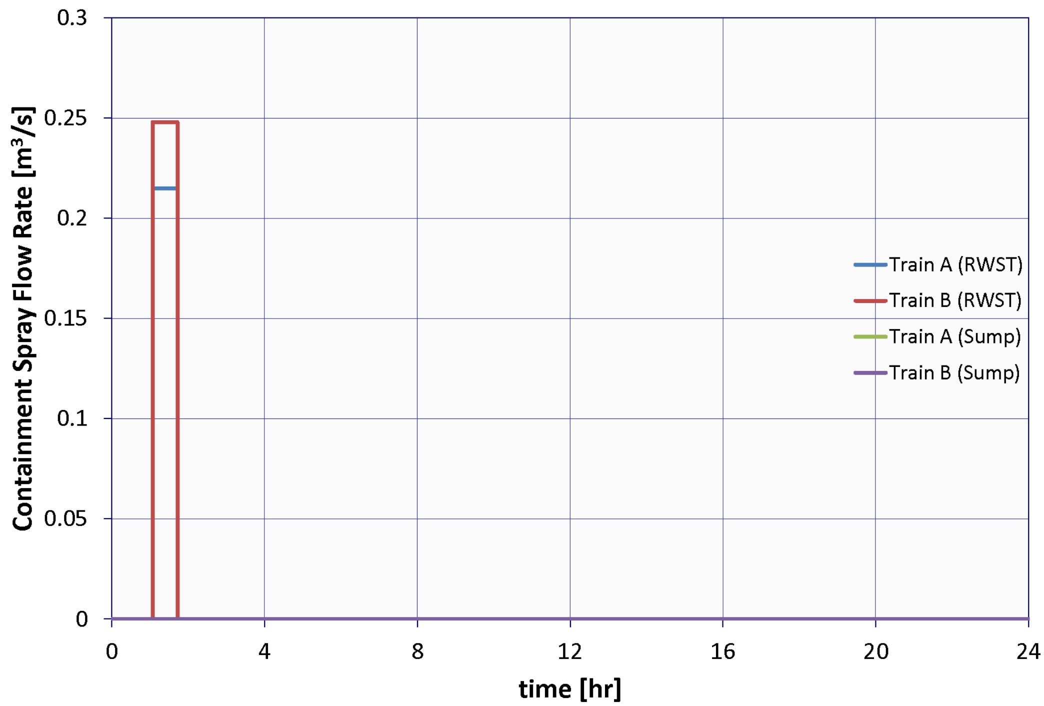

300
250
200
150
100
50
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



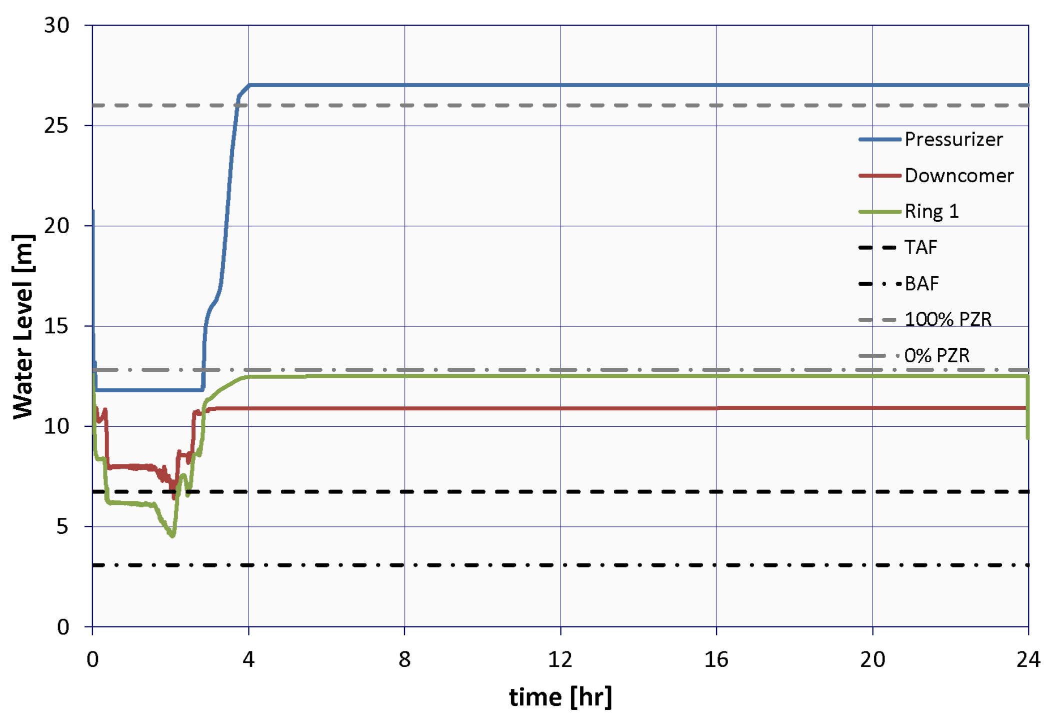
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



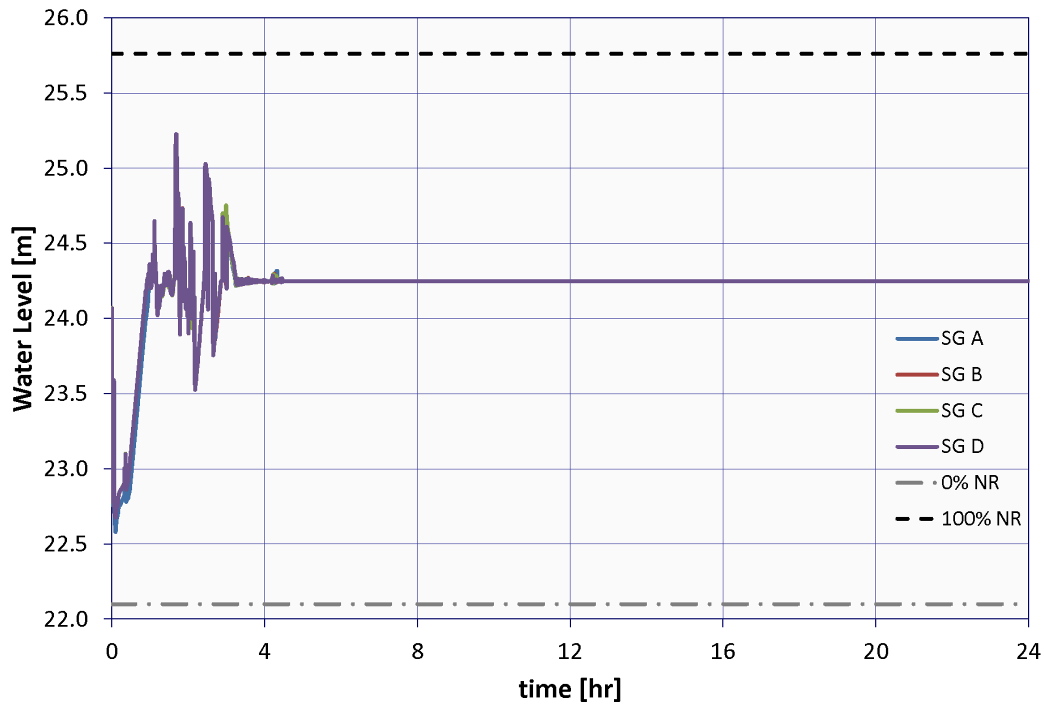
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



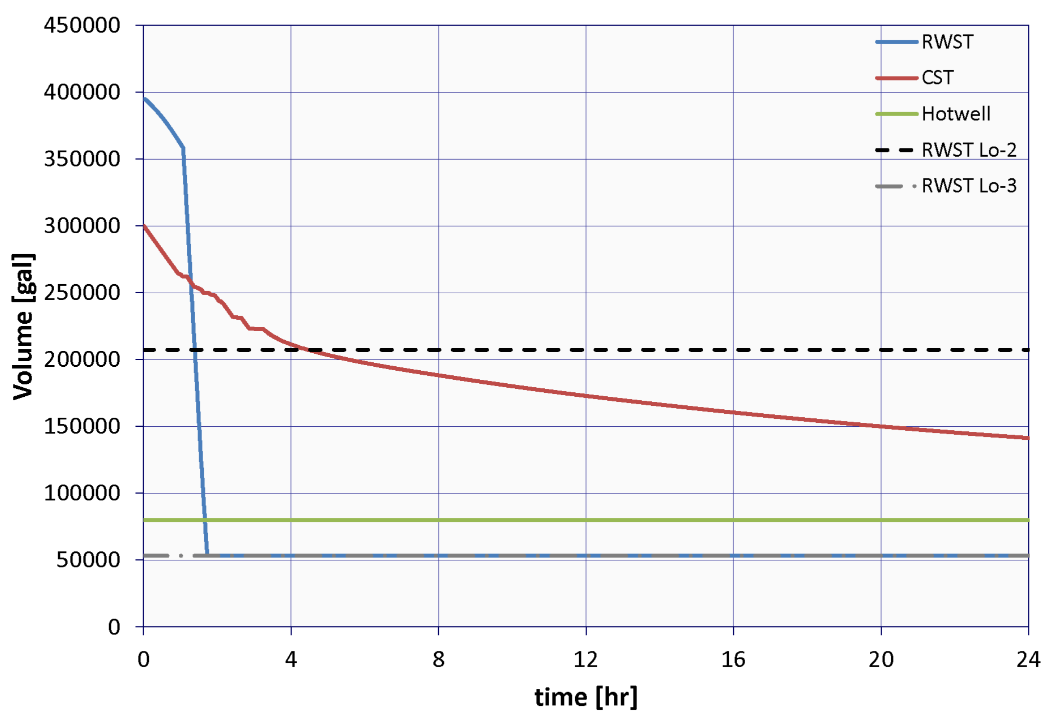
Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

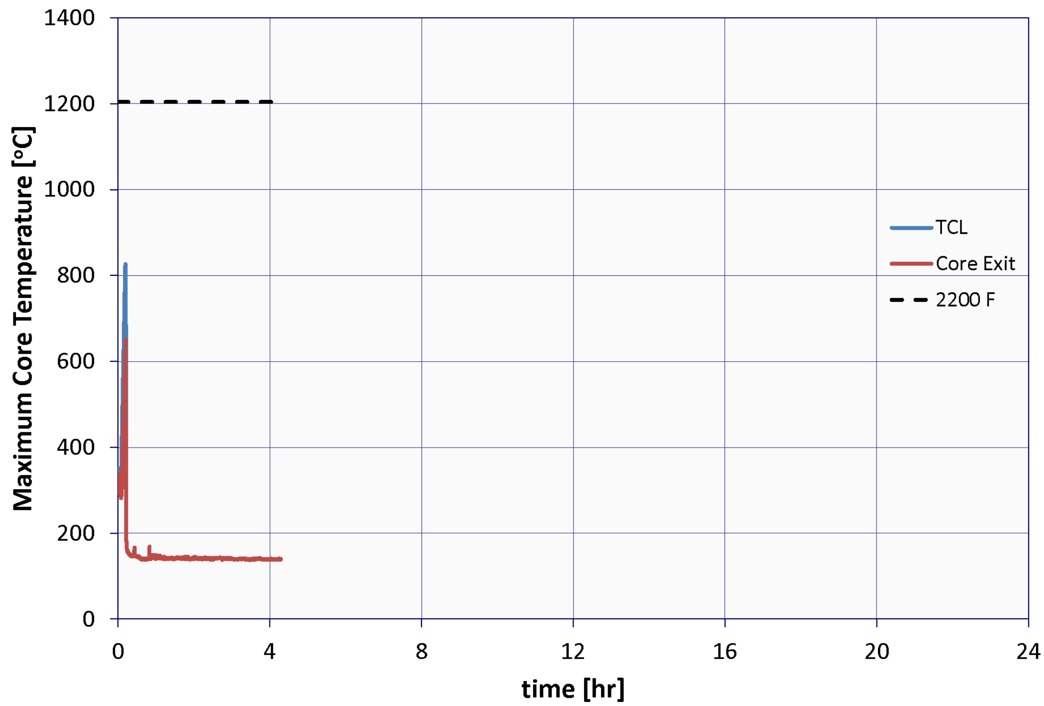


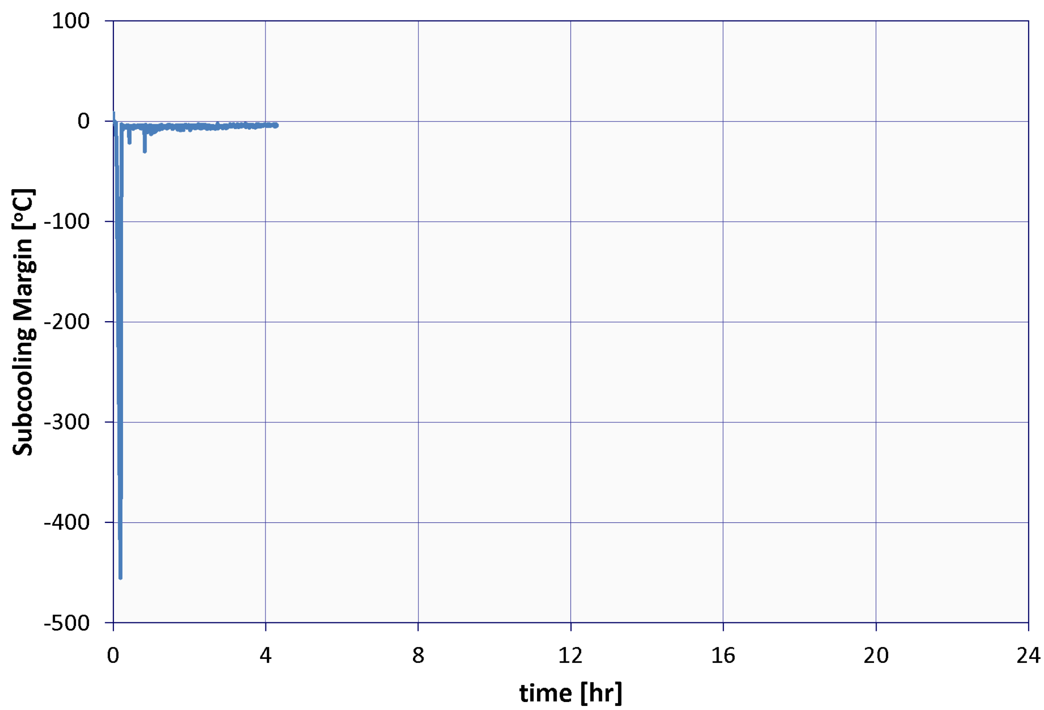
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

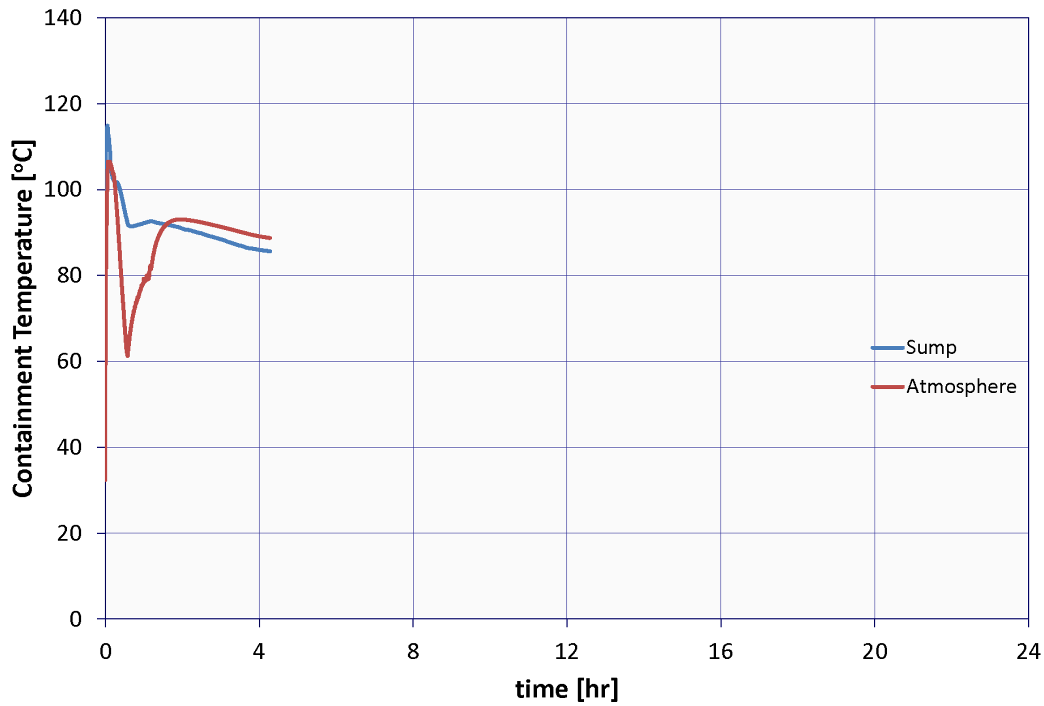


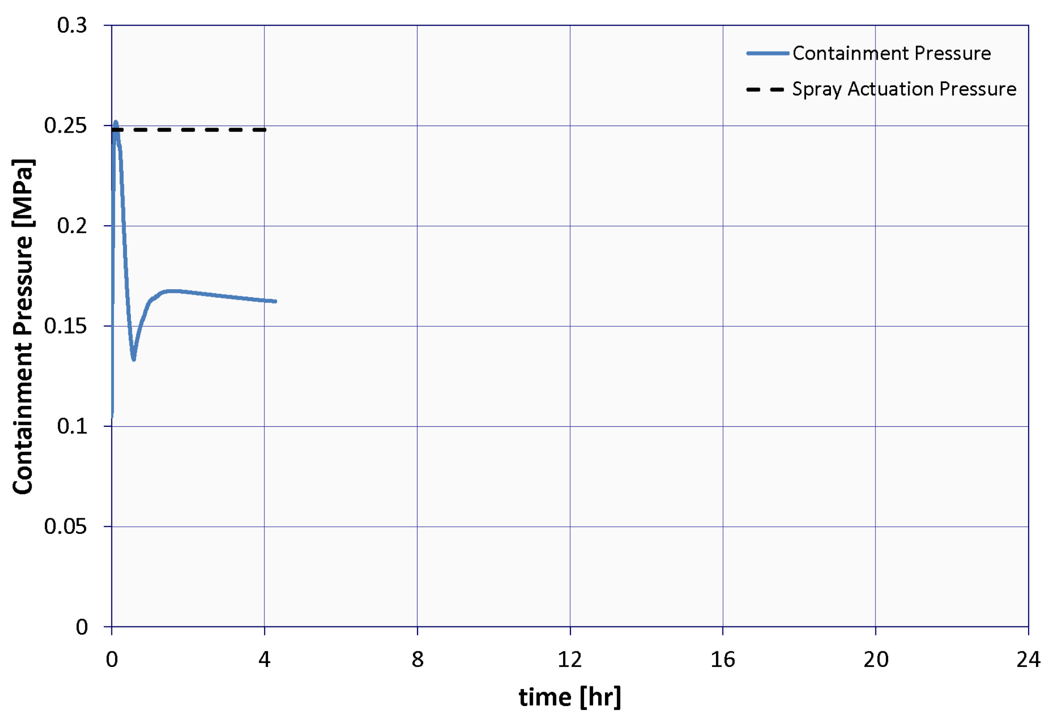
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

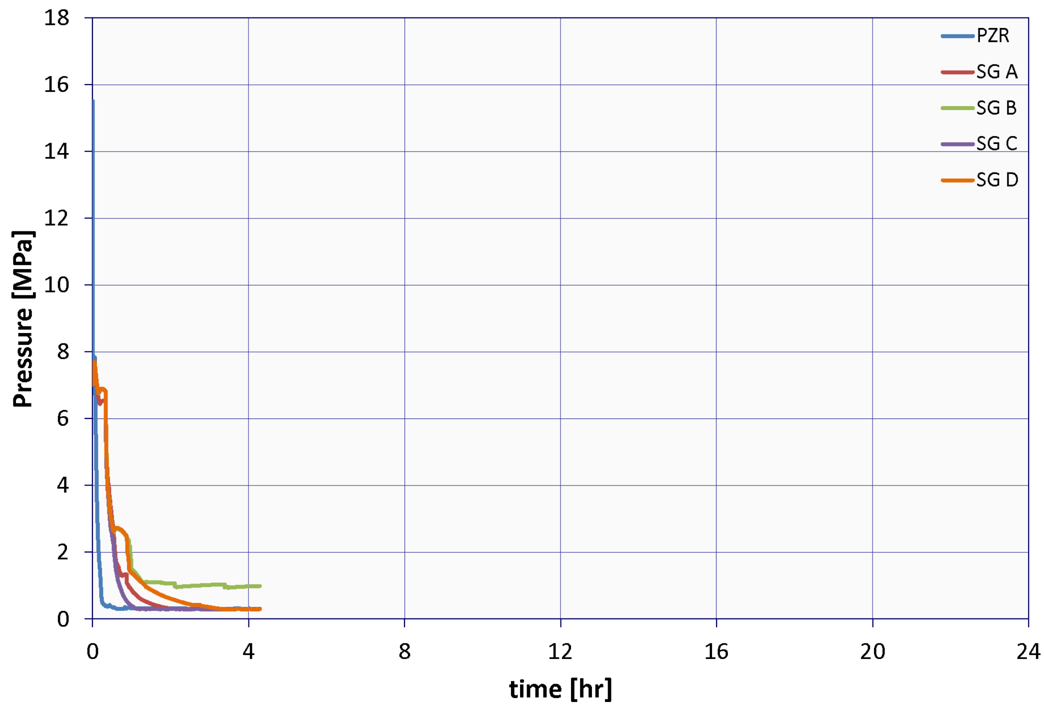
E.2.2 Case 2: 6-in. Break, 100 °F/hr Cooldown at 20 min, 2/2 CS Pumps, 0/4 RCFC



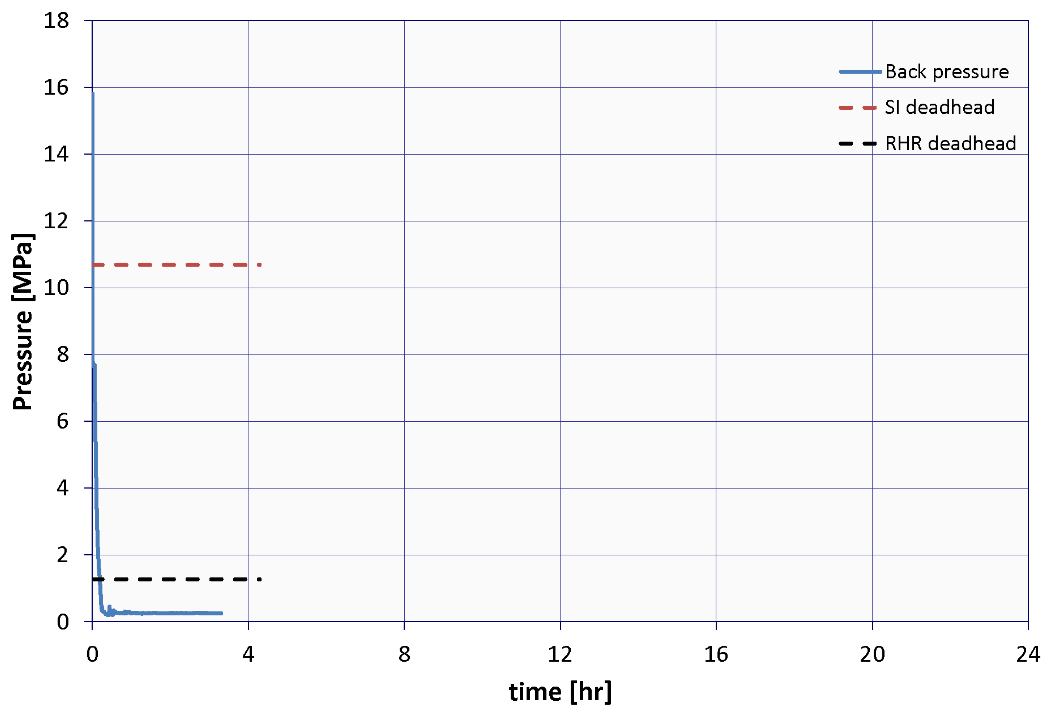



140
120
100
80
60
40
20
0
Containment Temperature [°C]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

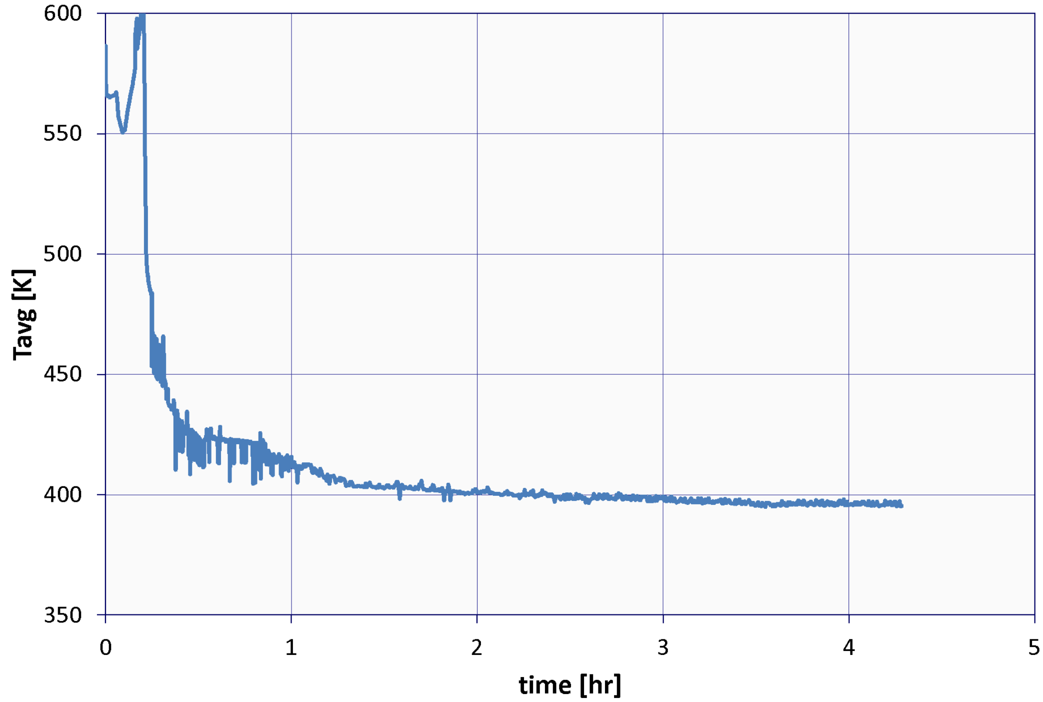

0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure



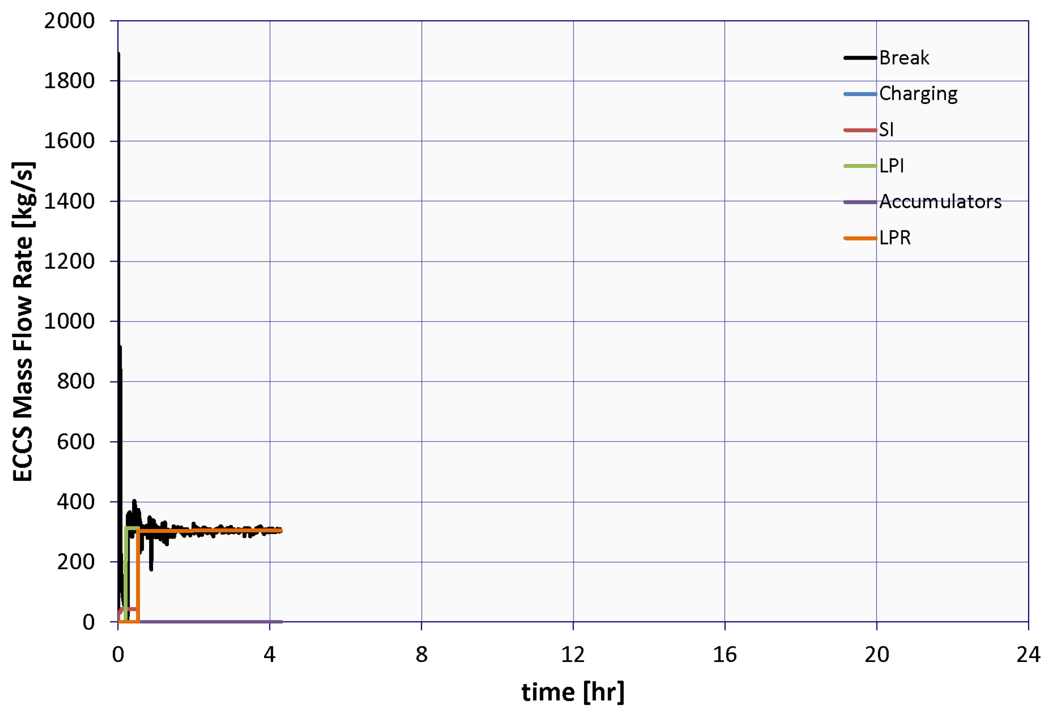
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



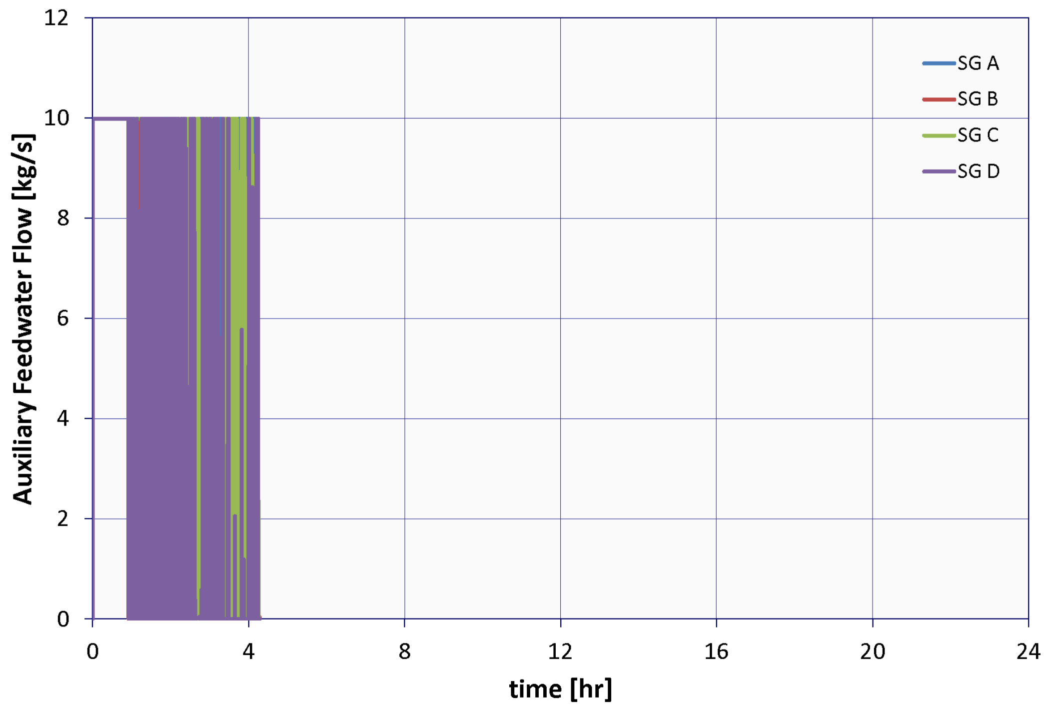
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead



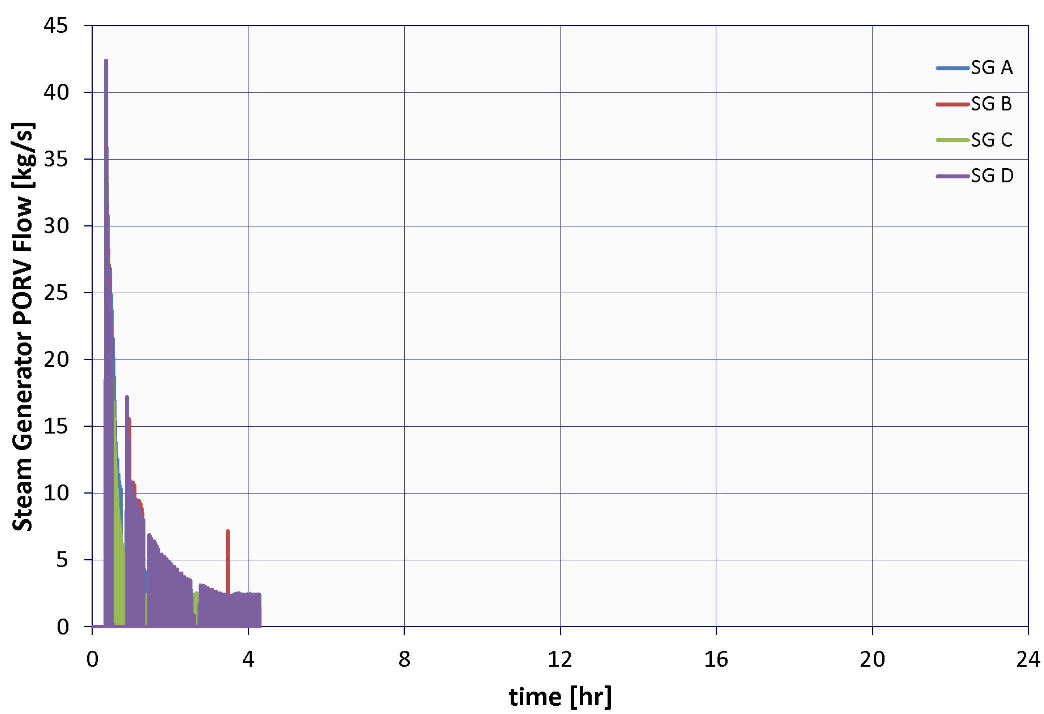
600
550
500
450
400
350
Tavg [K]
0
1
2
3
4
5
time [hr]



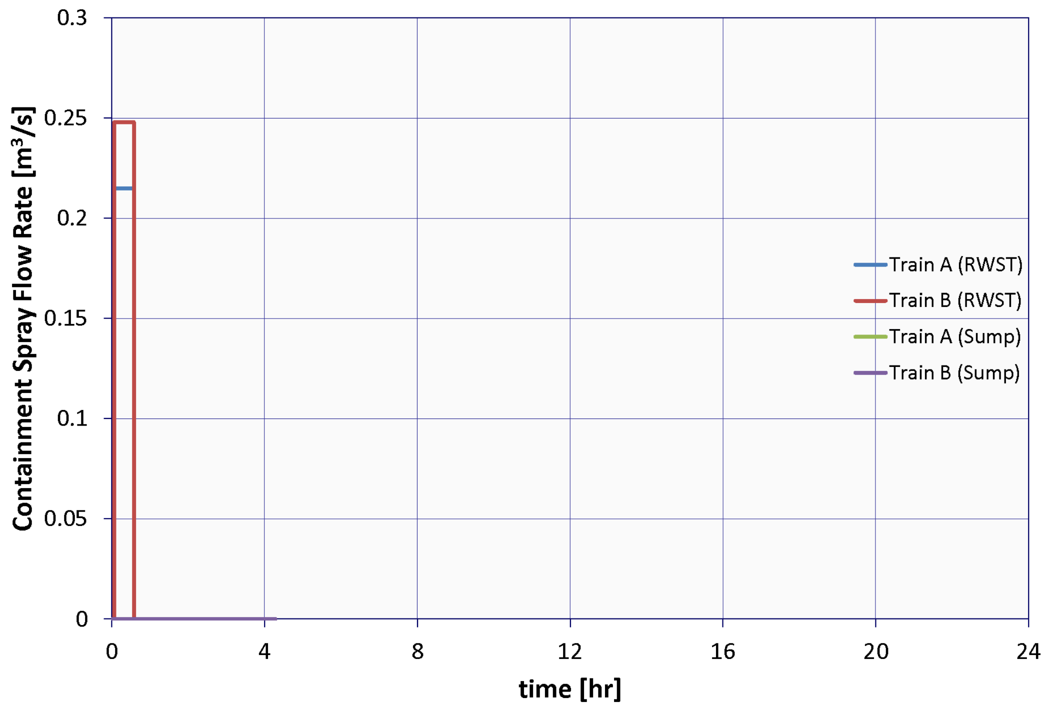
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



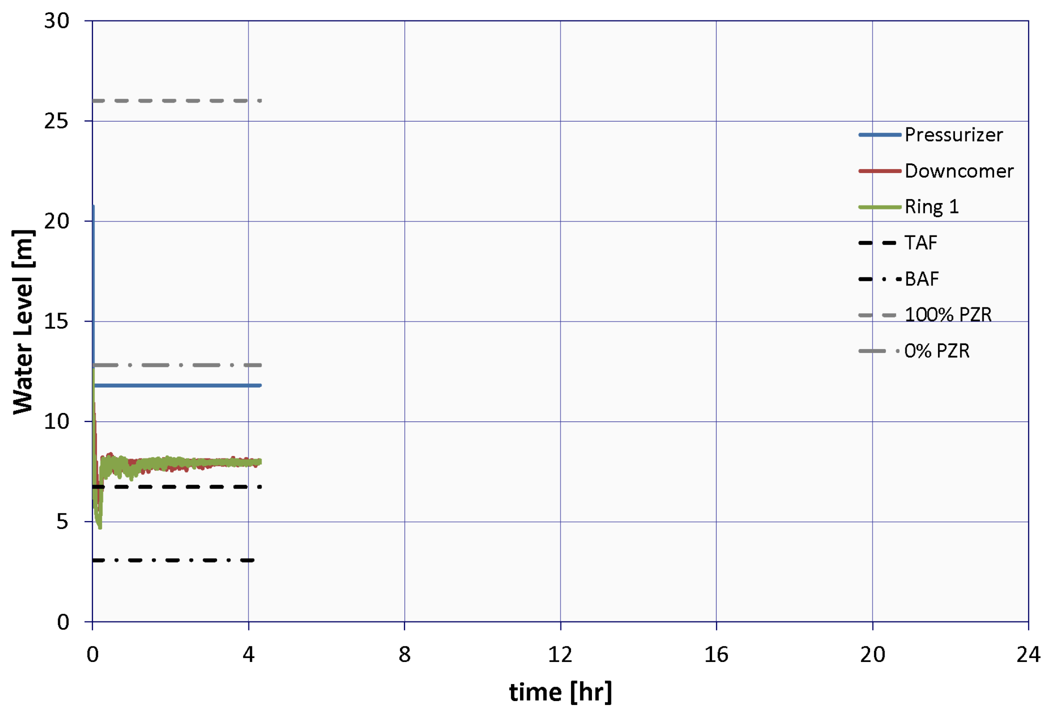
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24



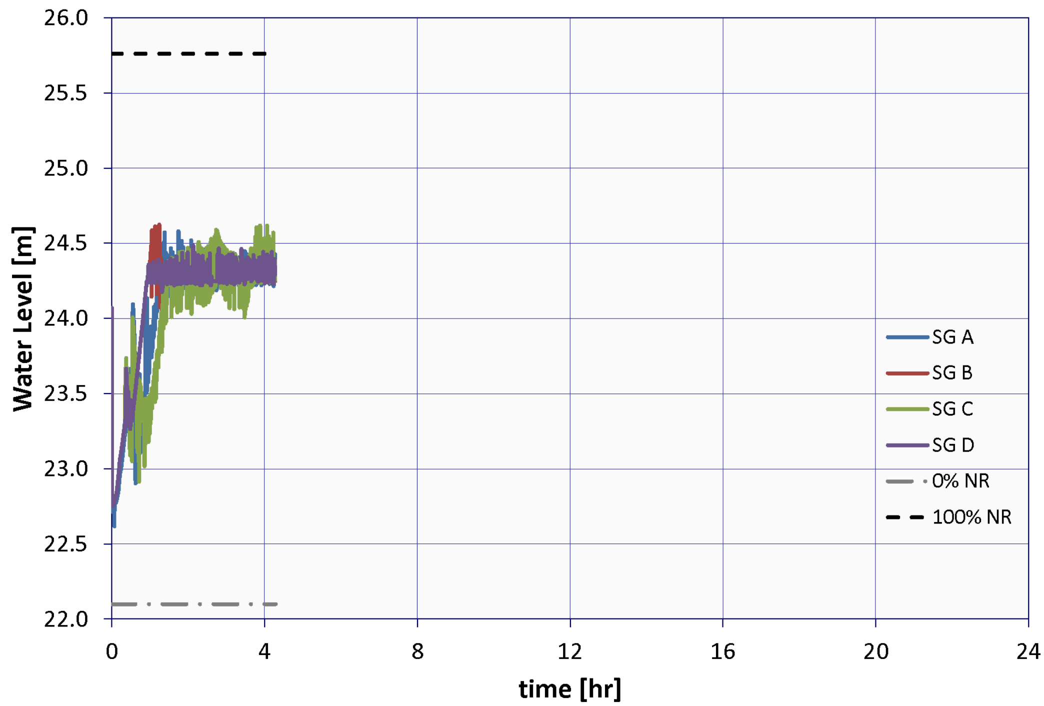
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
40
45
0
4
8
12
16
20
24

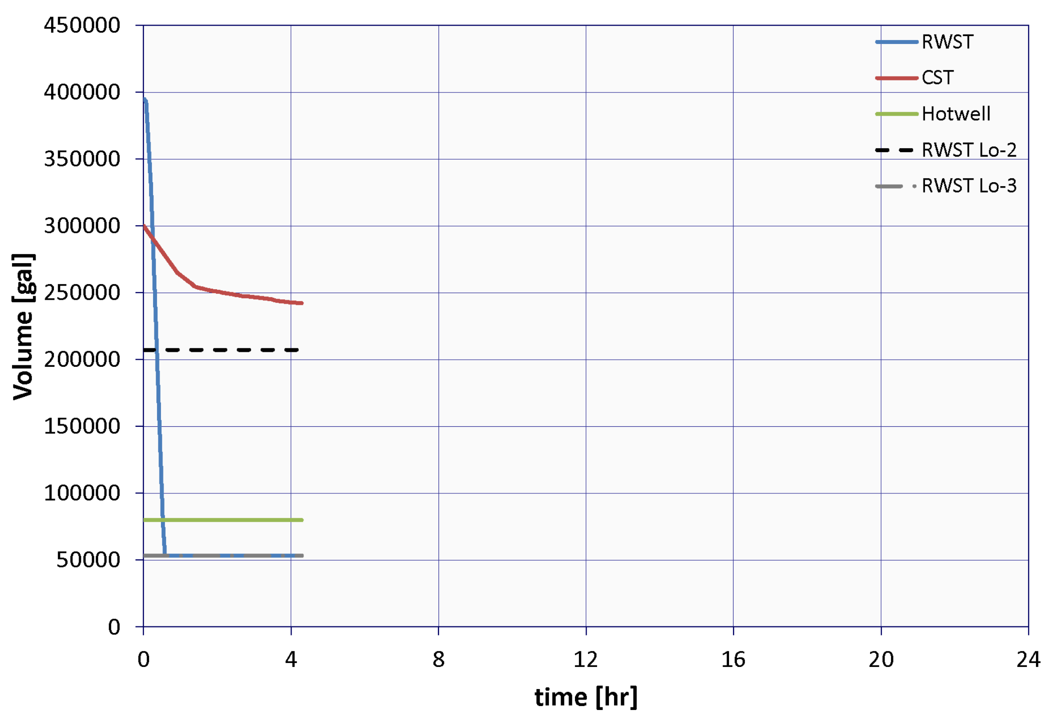


Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

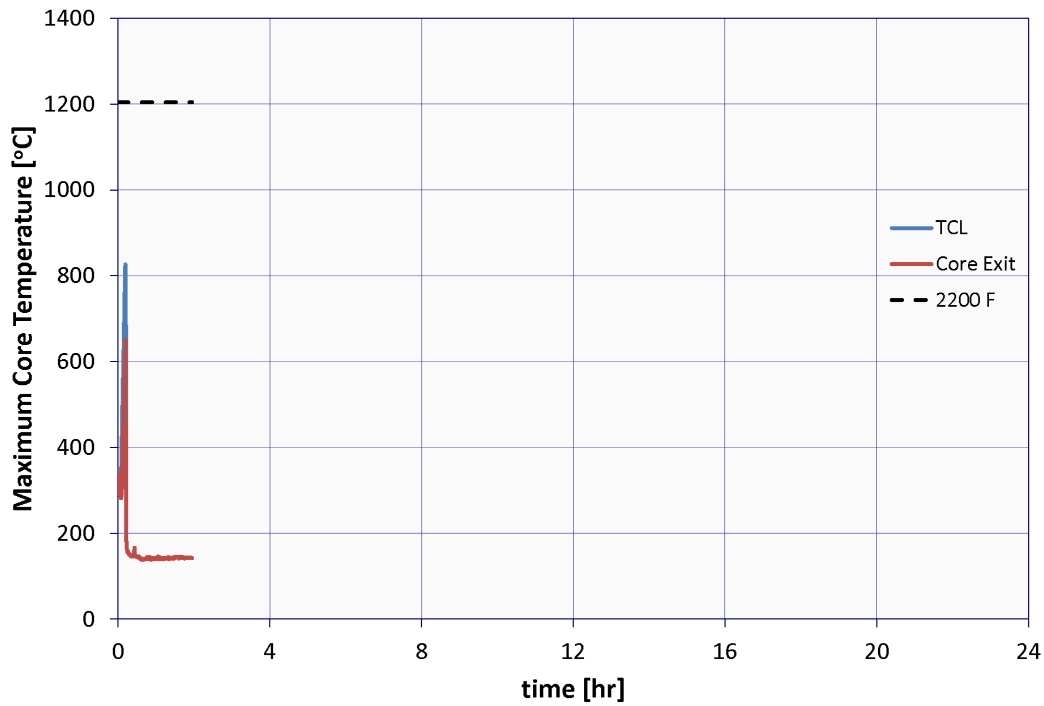


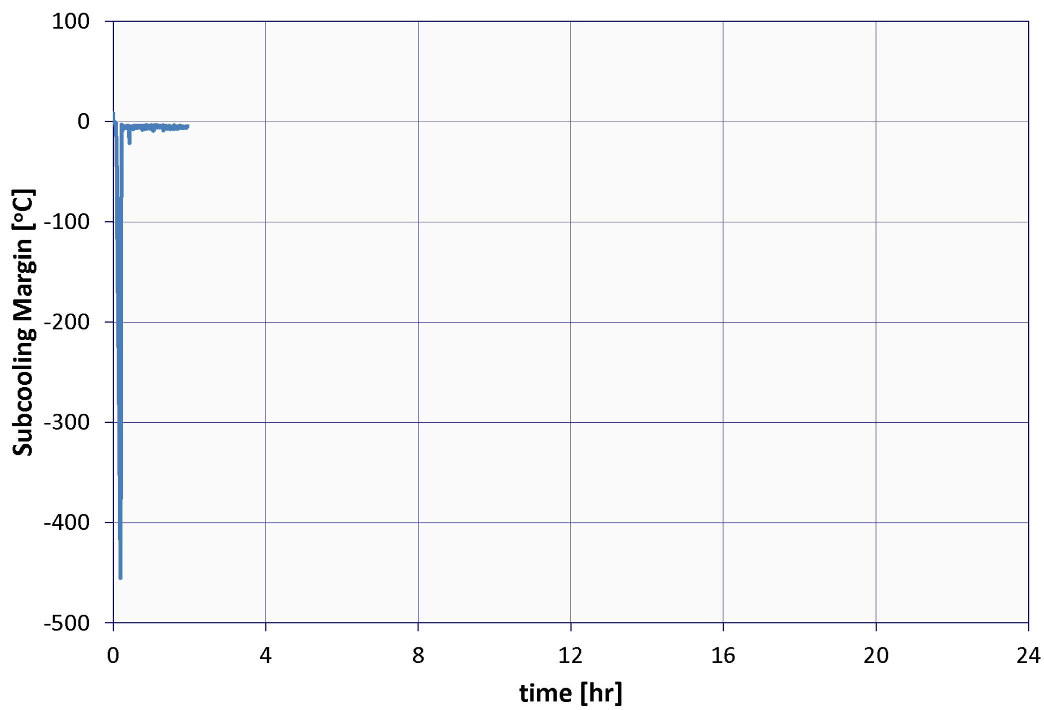
Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

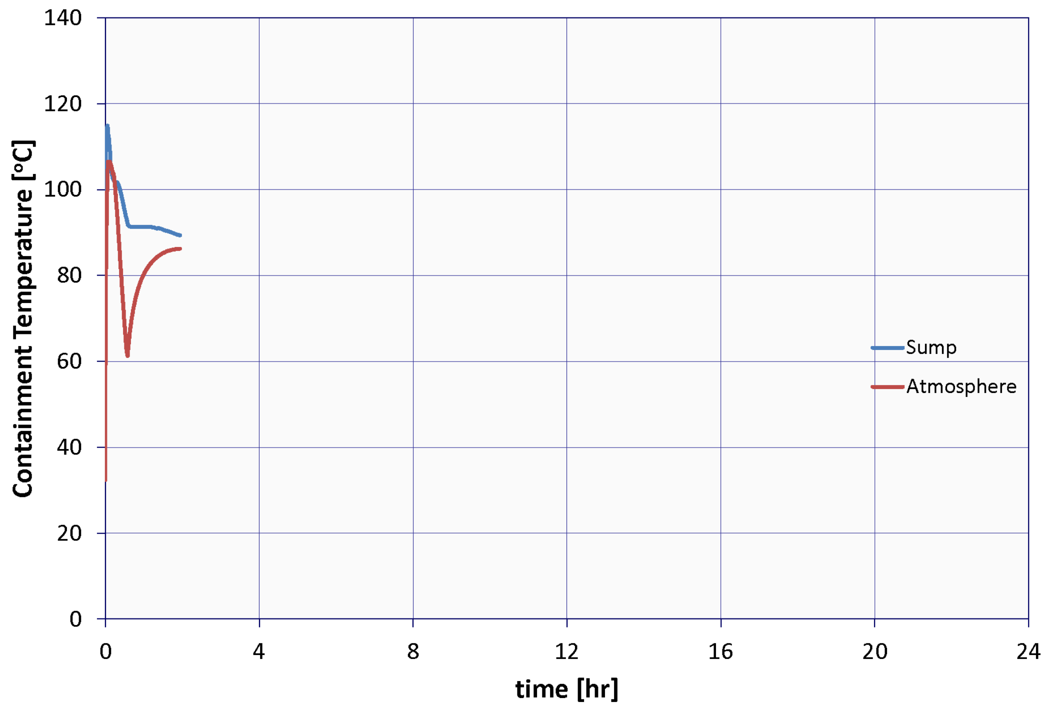

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

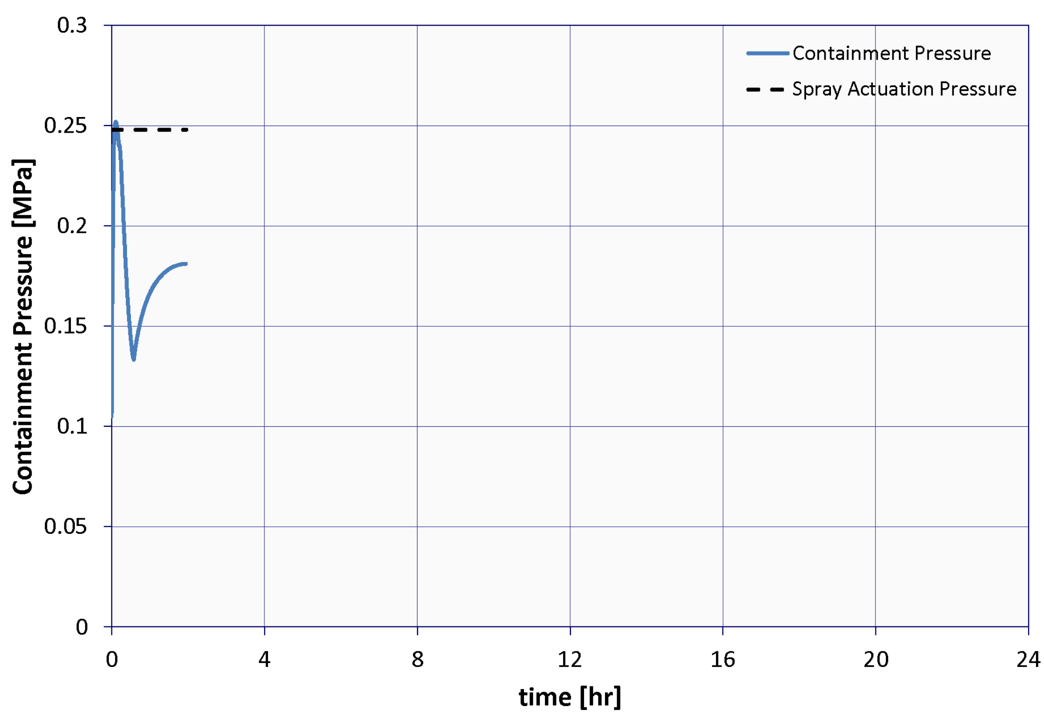
E.2.2.1 *Case 2a: 6-in. Break, 100 °F/hr Cooldown at 20 min, 2/2 CS Pumps, 0/4 RCFC, CS Recirc*



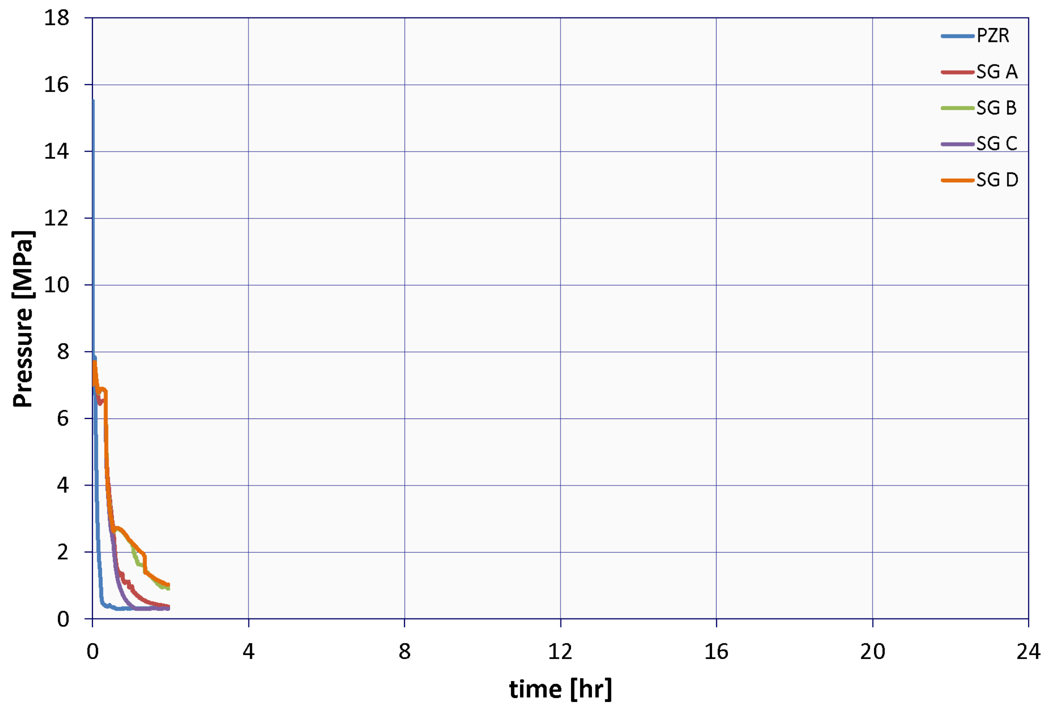




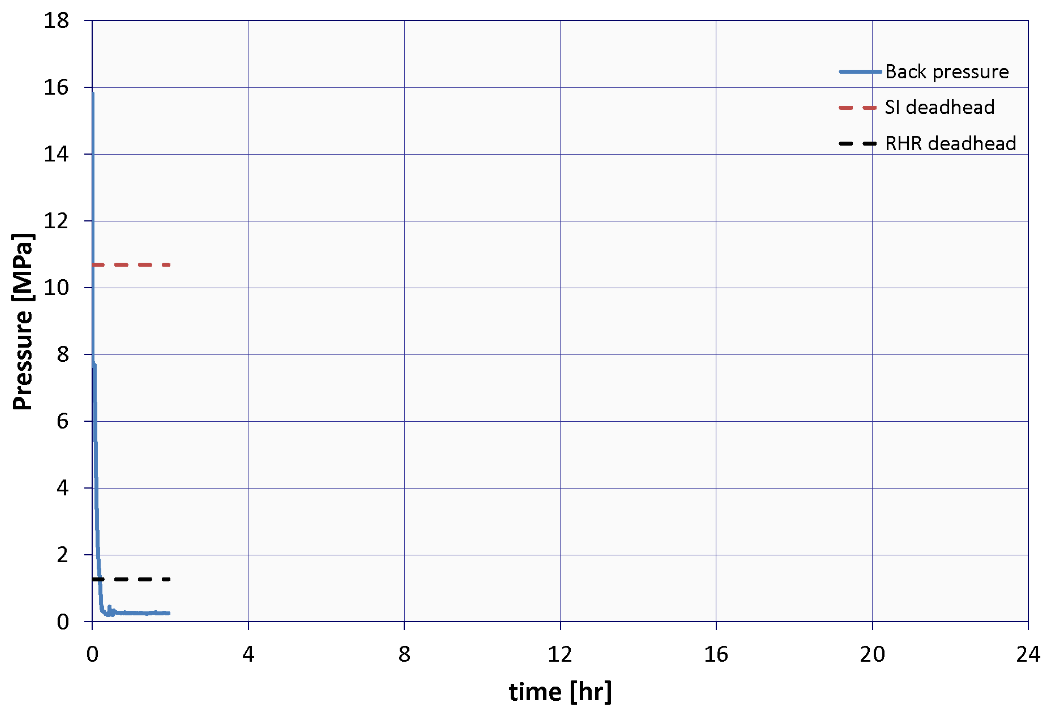
Containment Temperature [°C]
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



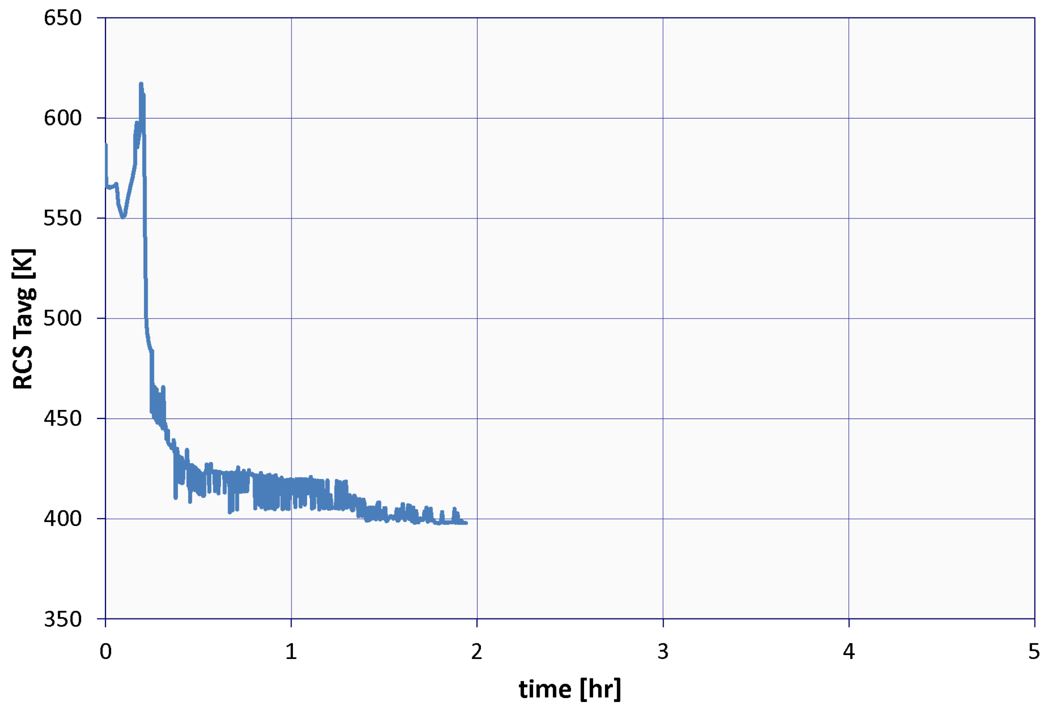
Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

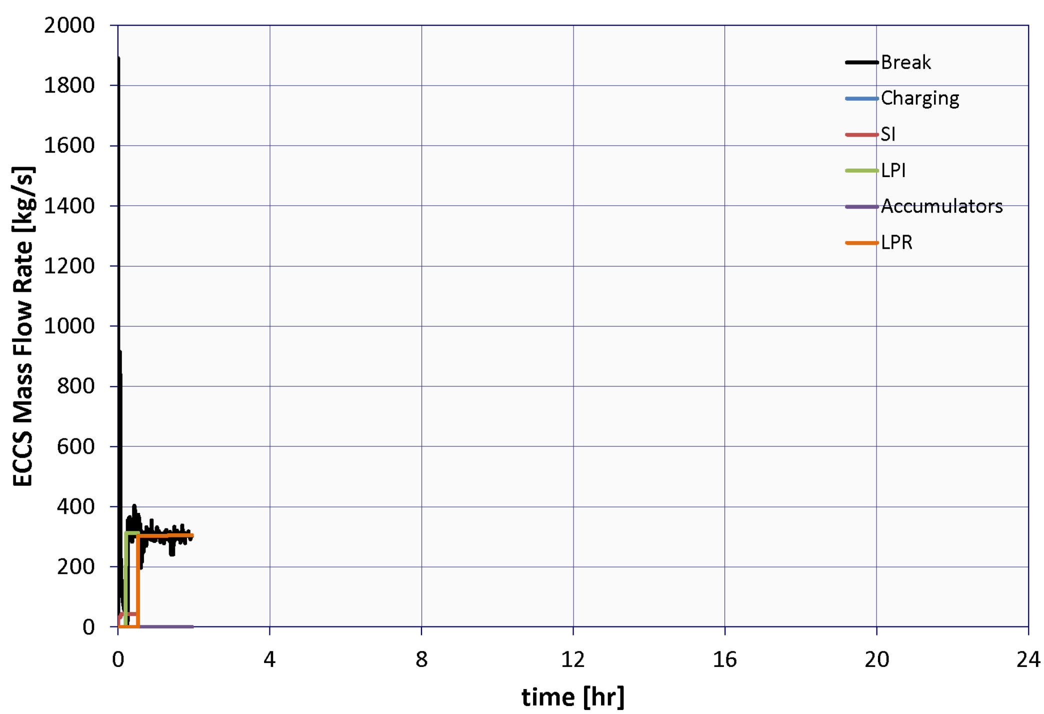


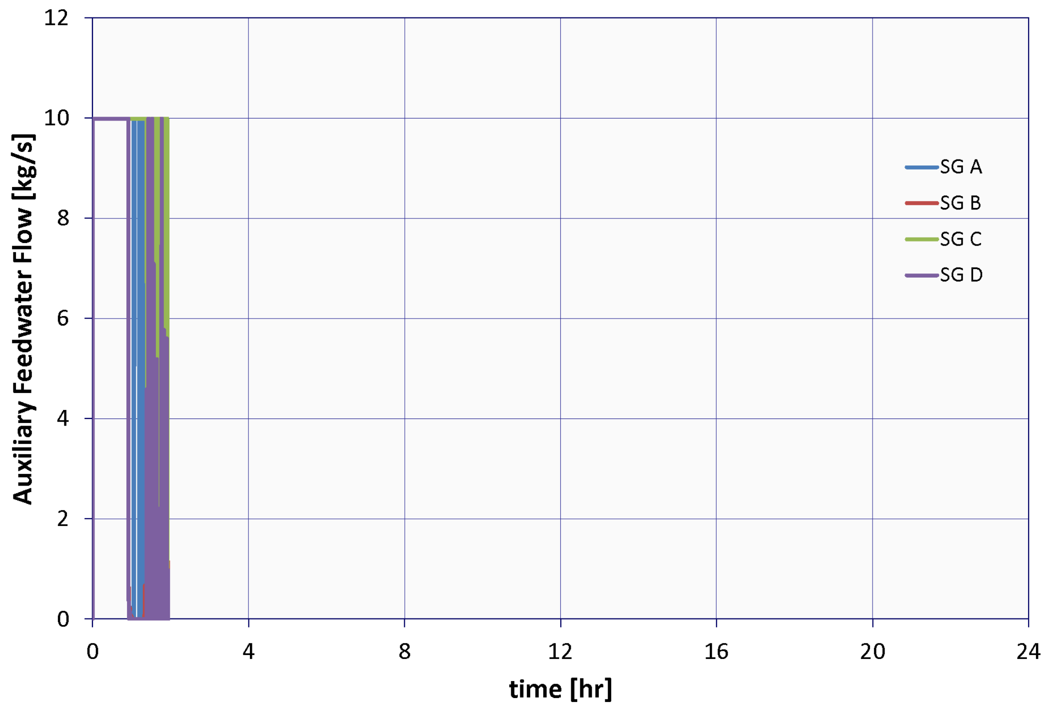
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24

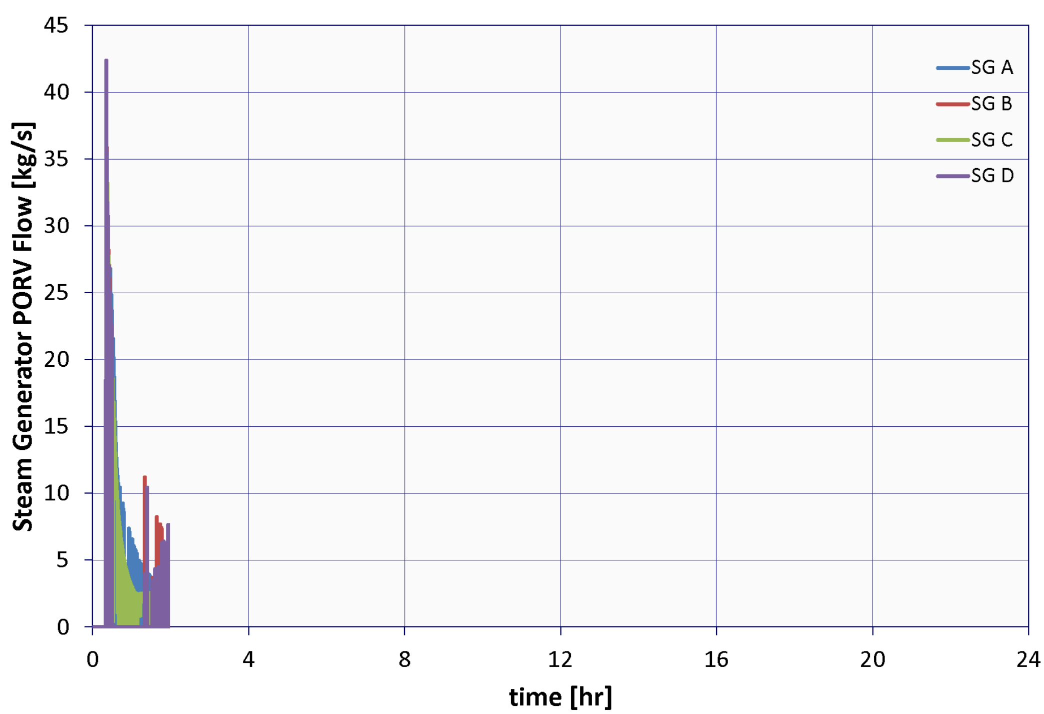


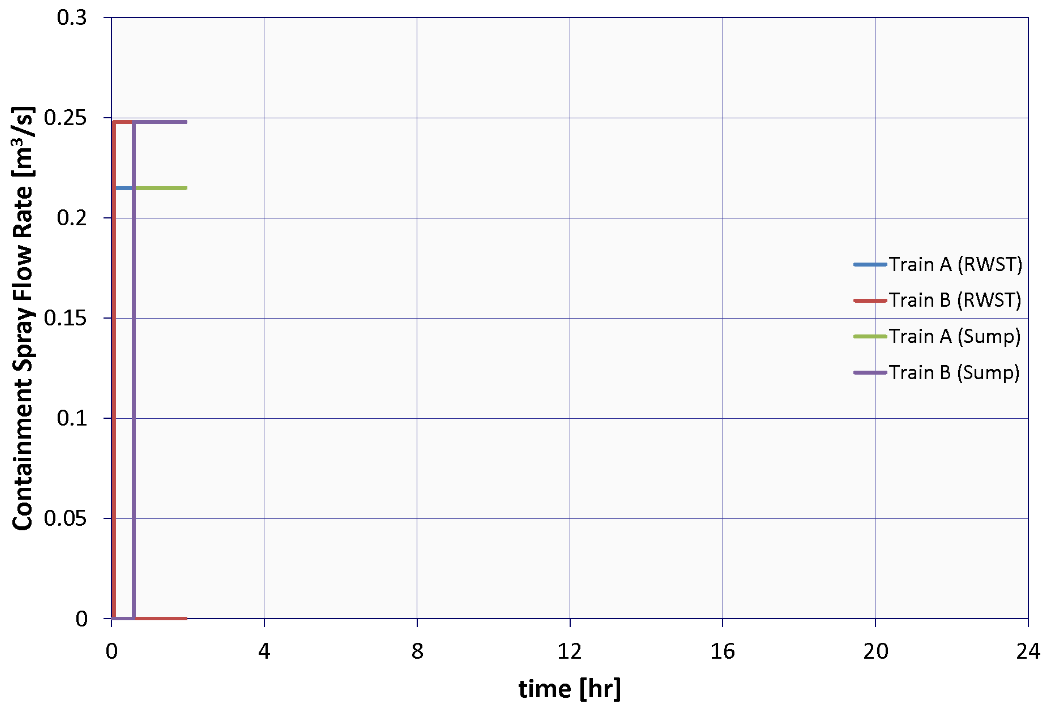
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24


650
600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]

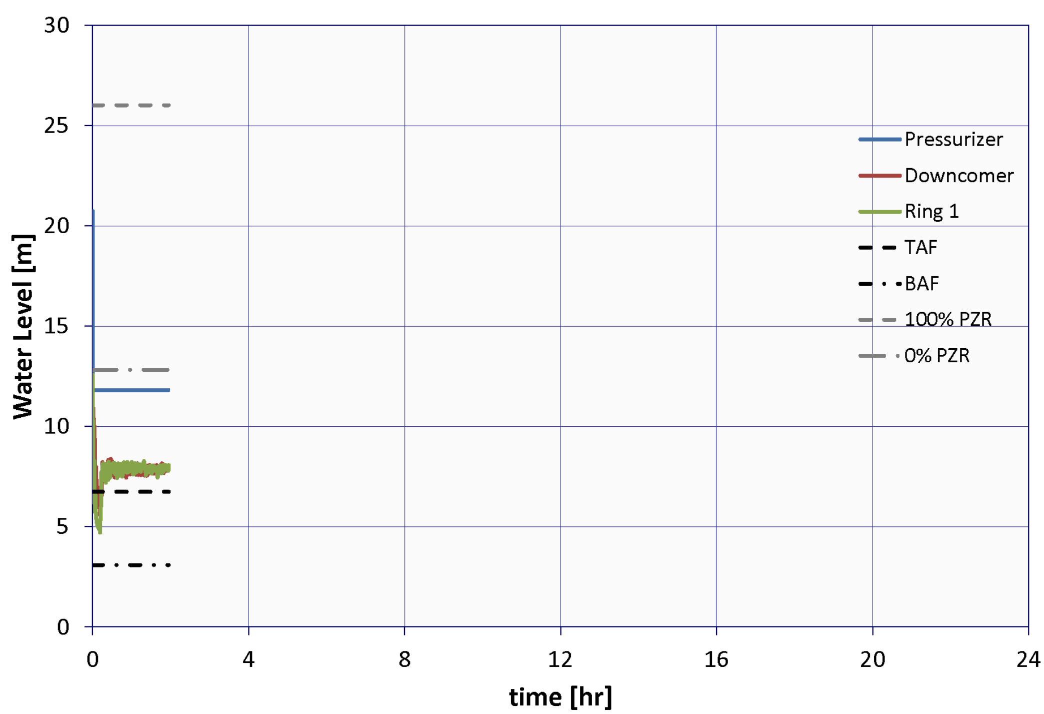

2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR


Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

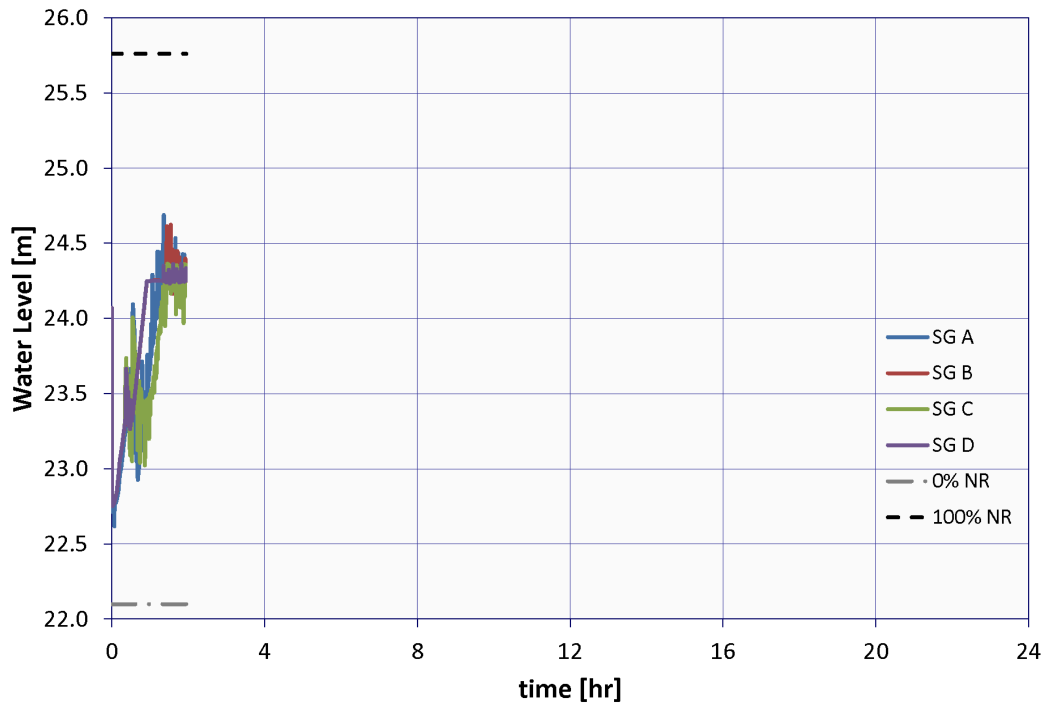

Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



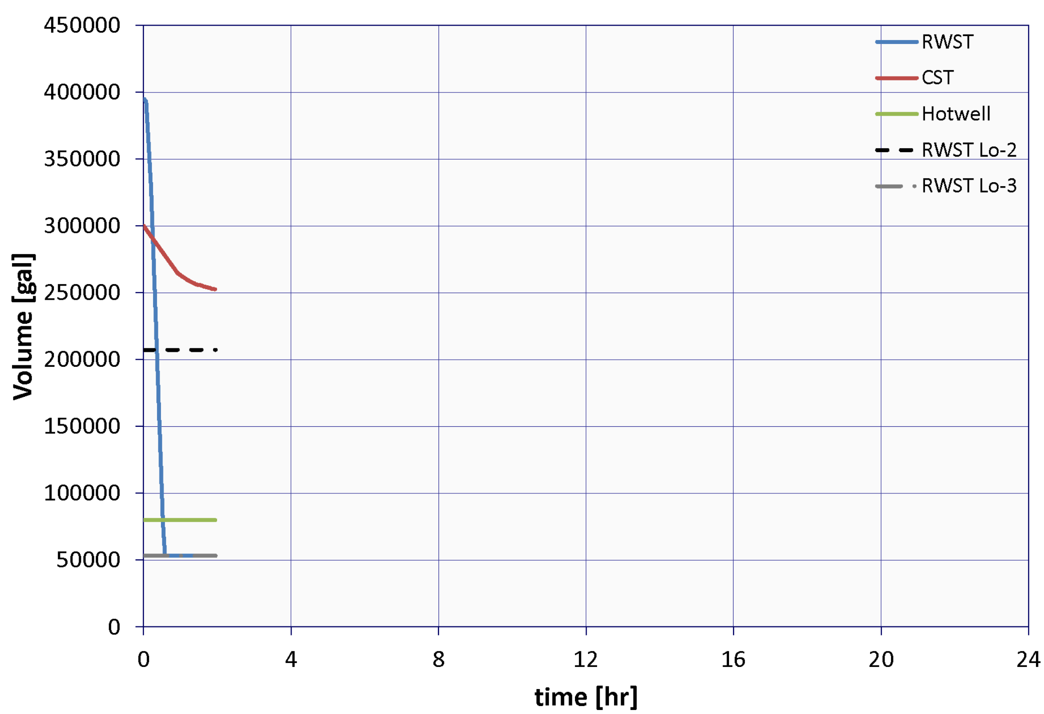
Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

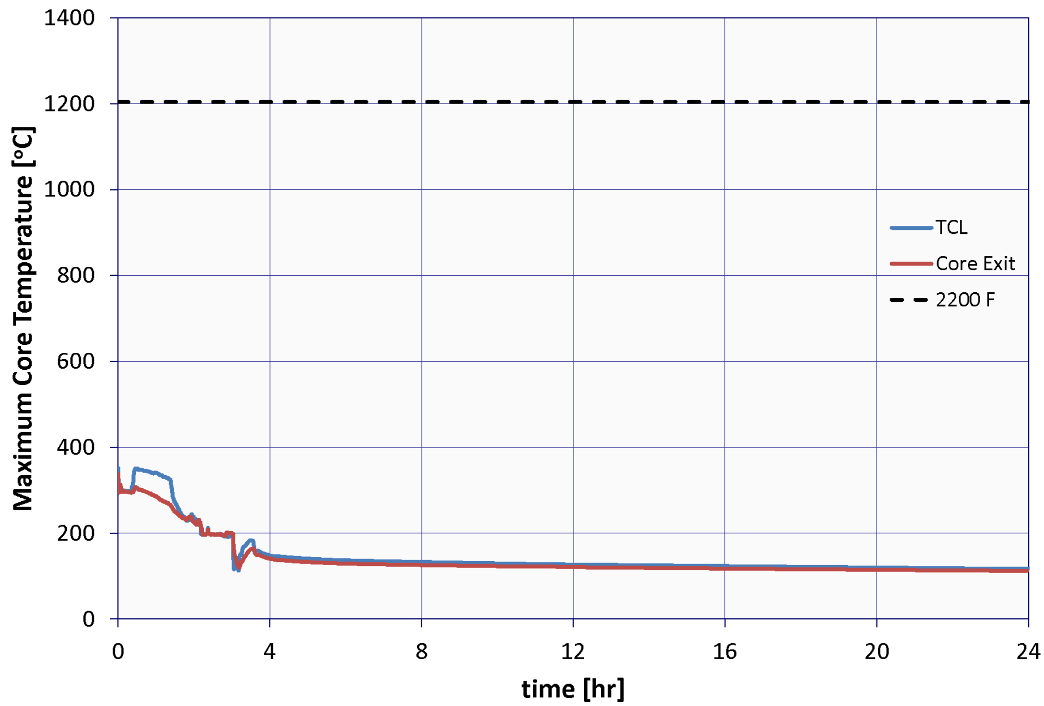


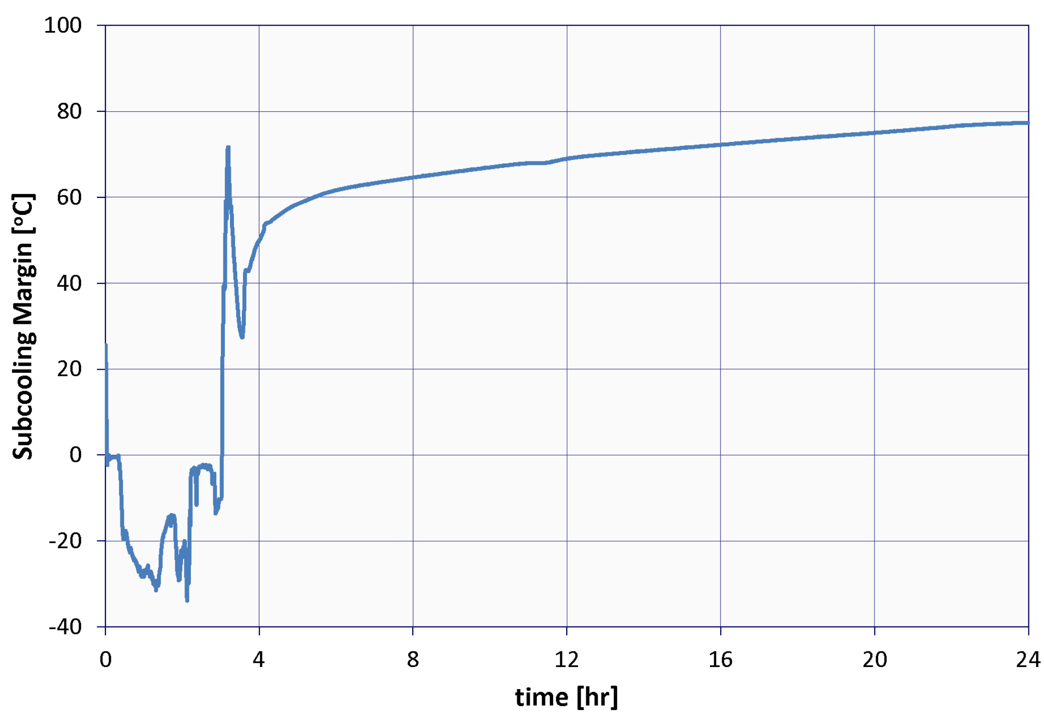
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

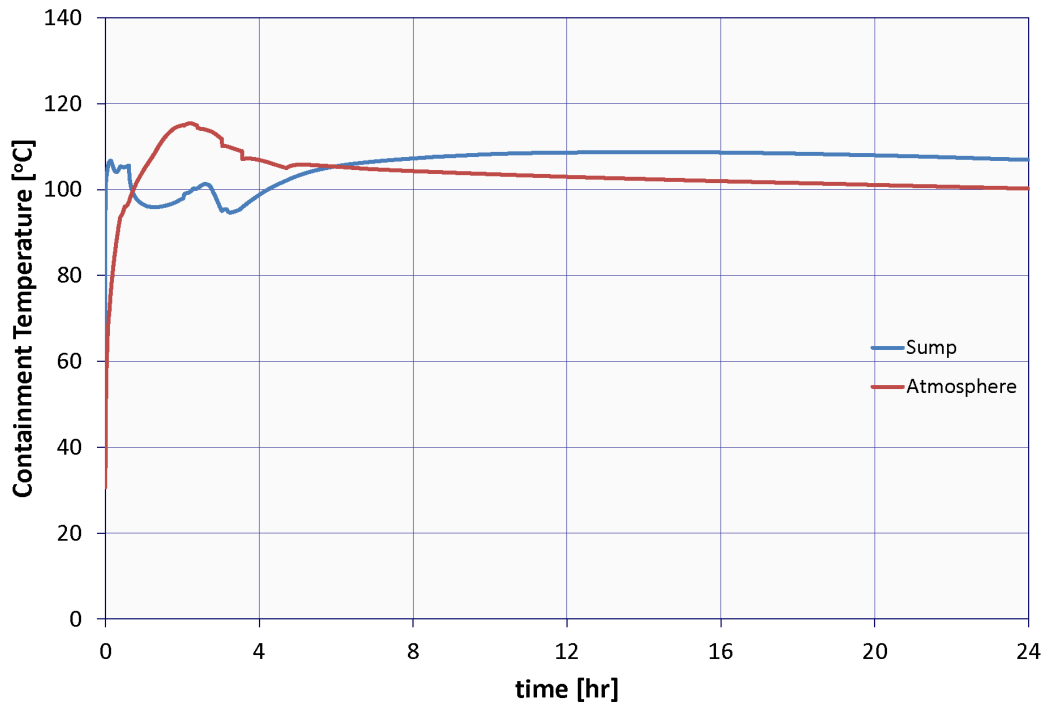


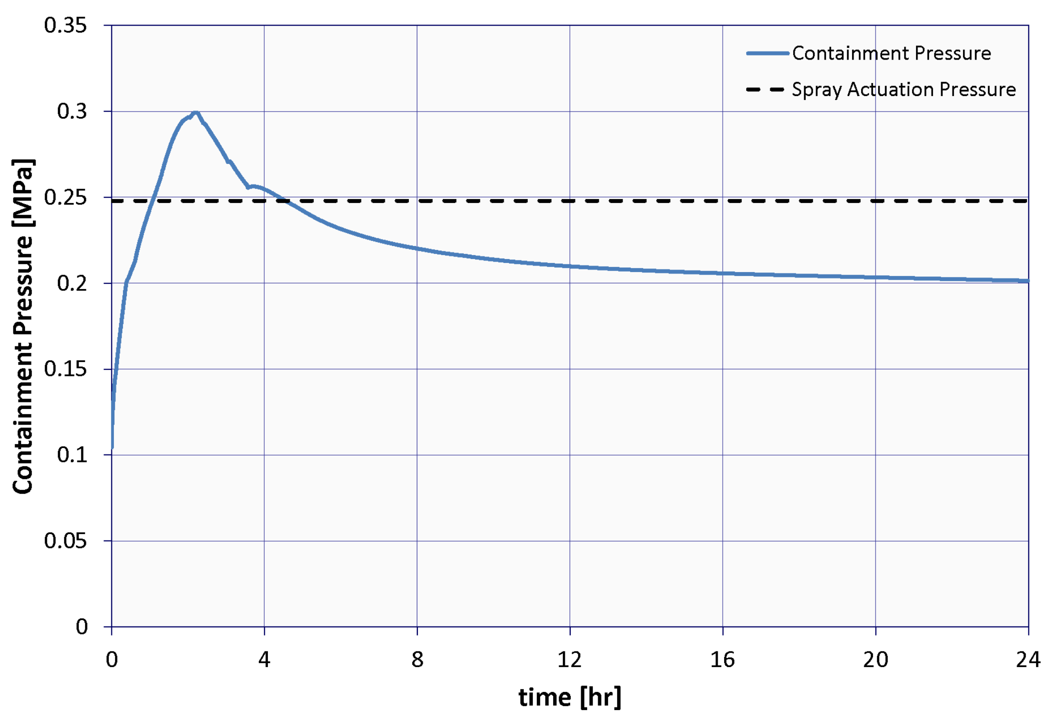
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

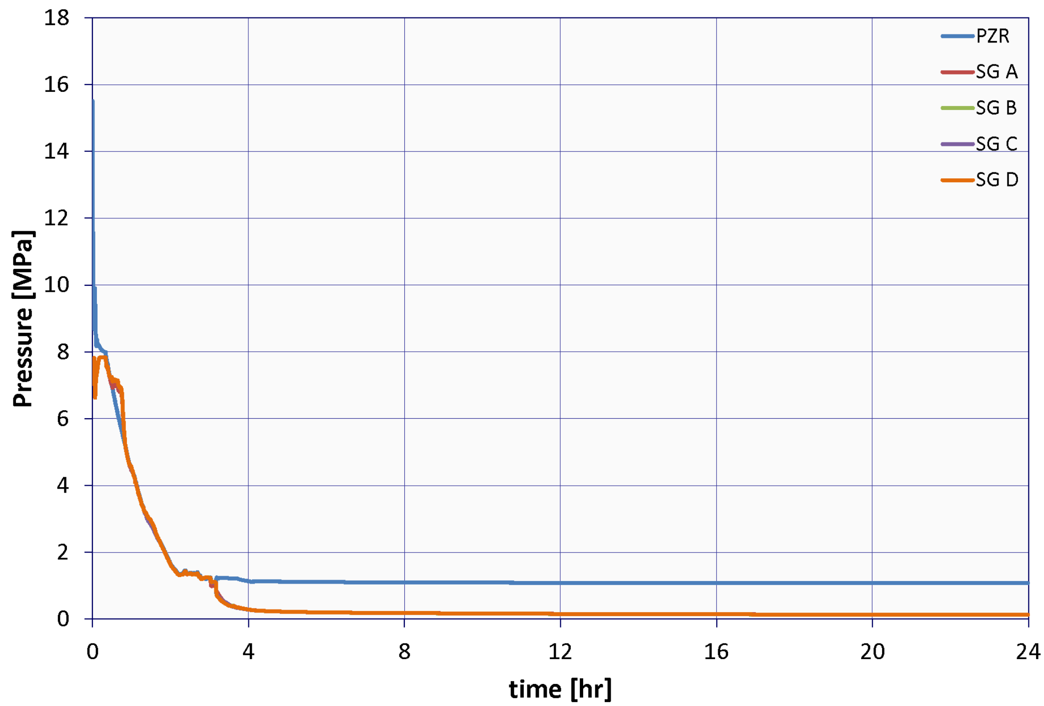
E.2.3 Case 3: 2-in. Break, 100 °F/hr Cooldown at 20 min, 0/2 CS Pumps, 0/4 RCFC



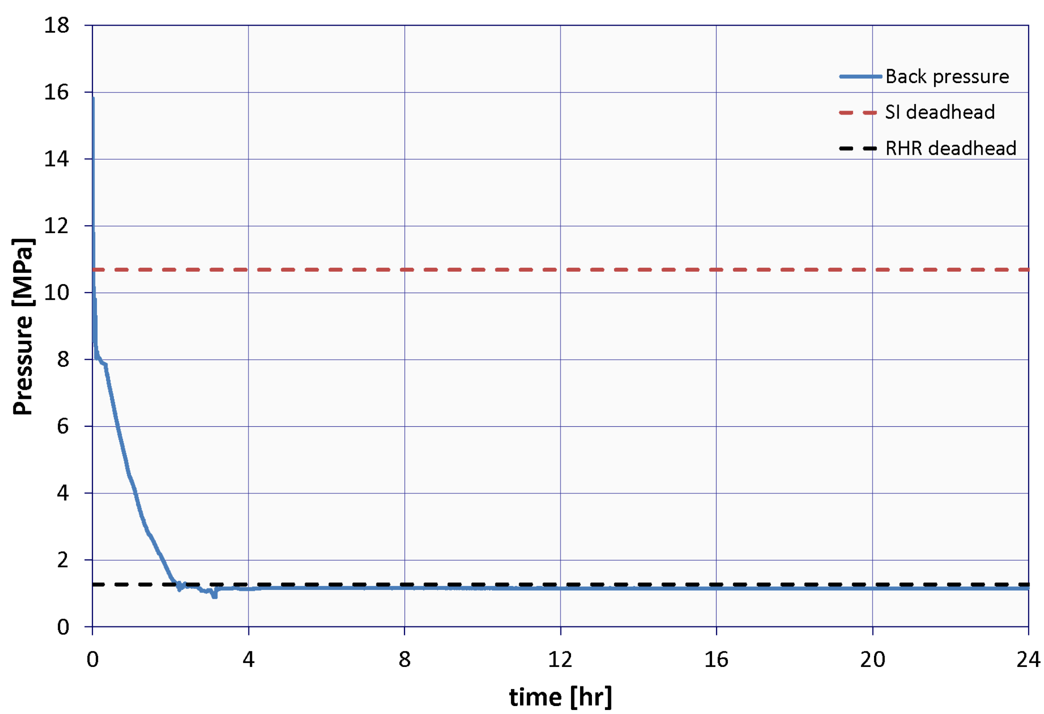



Containment Temperature [°C]
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

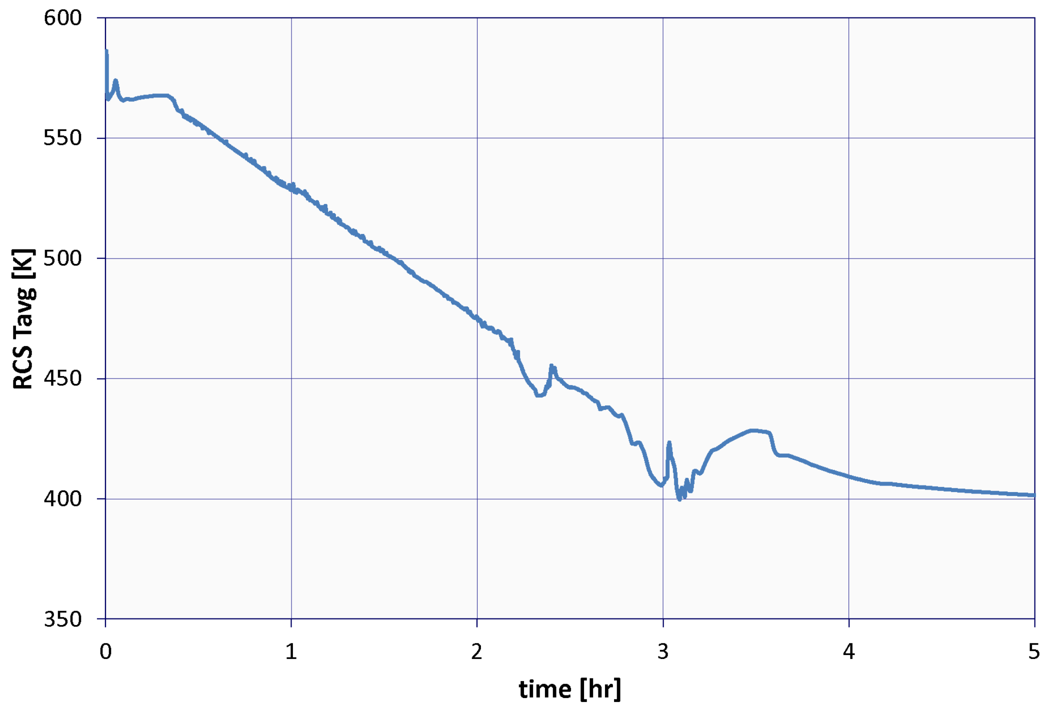

Containment Pressure [MPa]
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

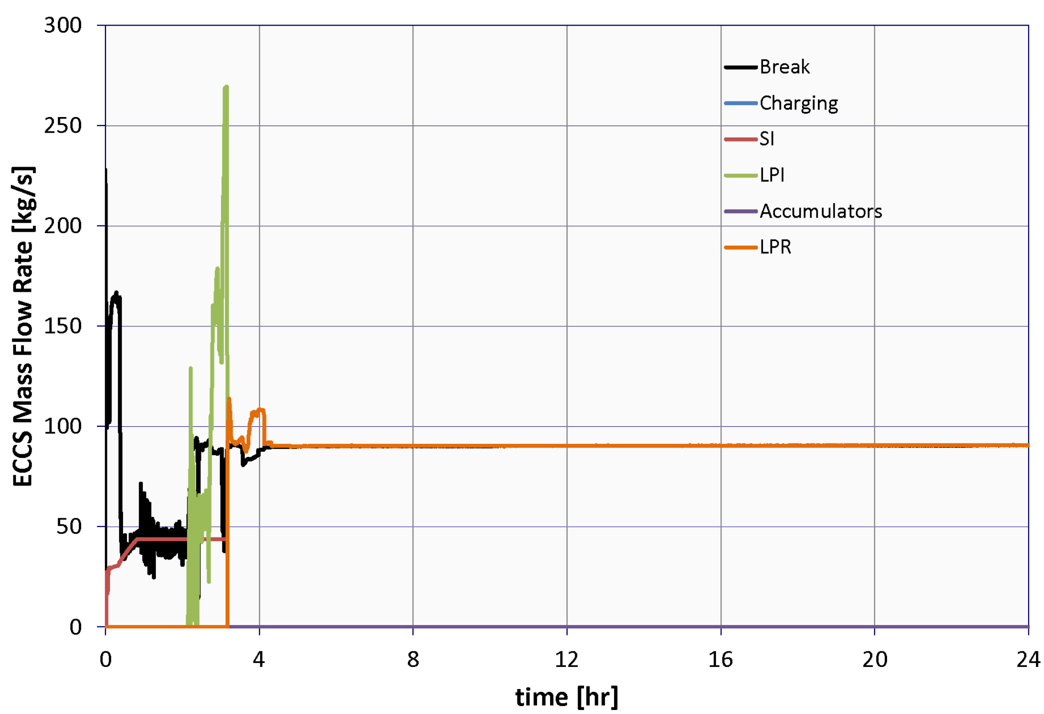


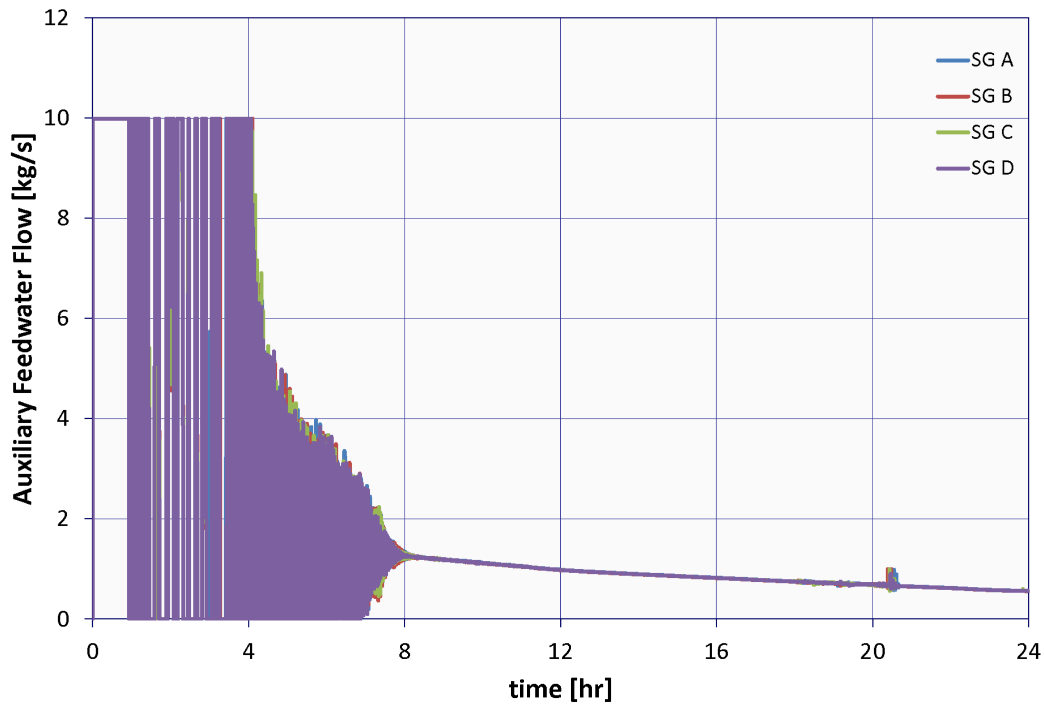
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D

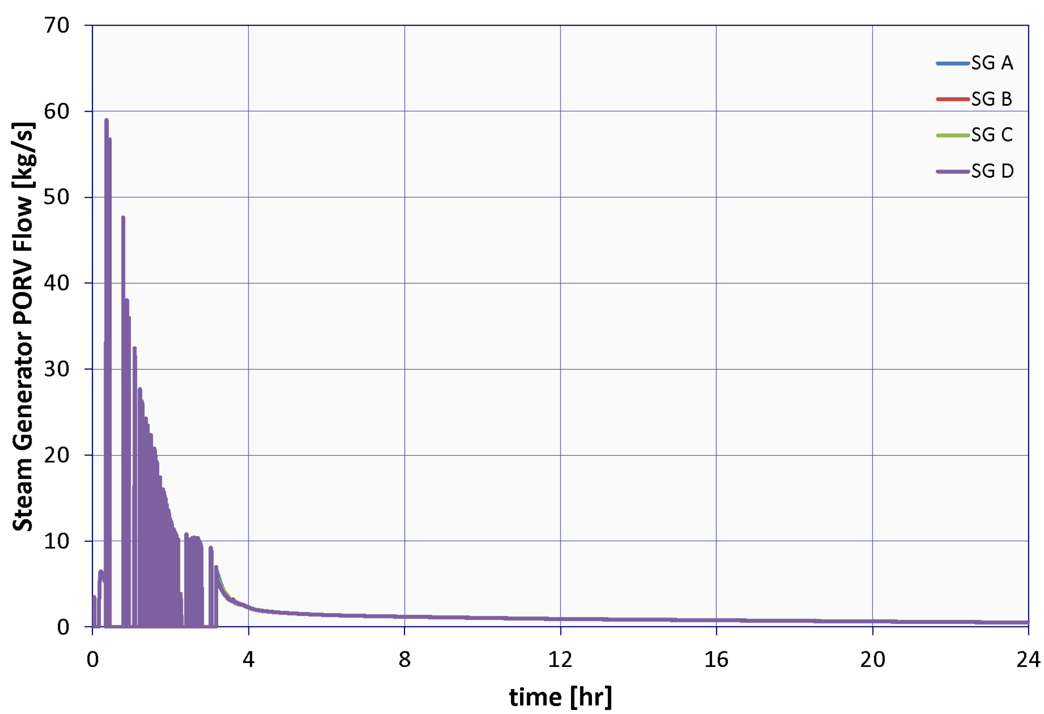


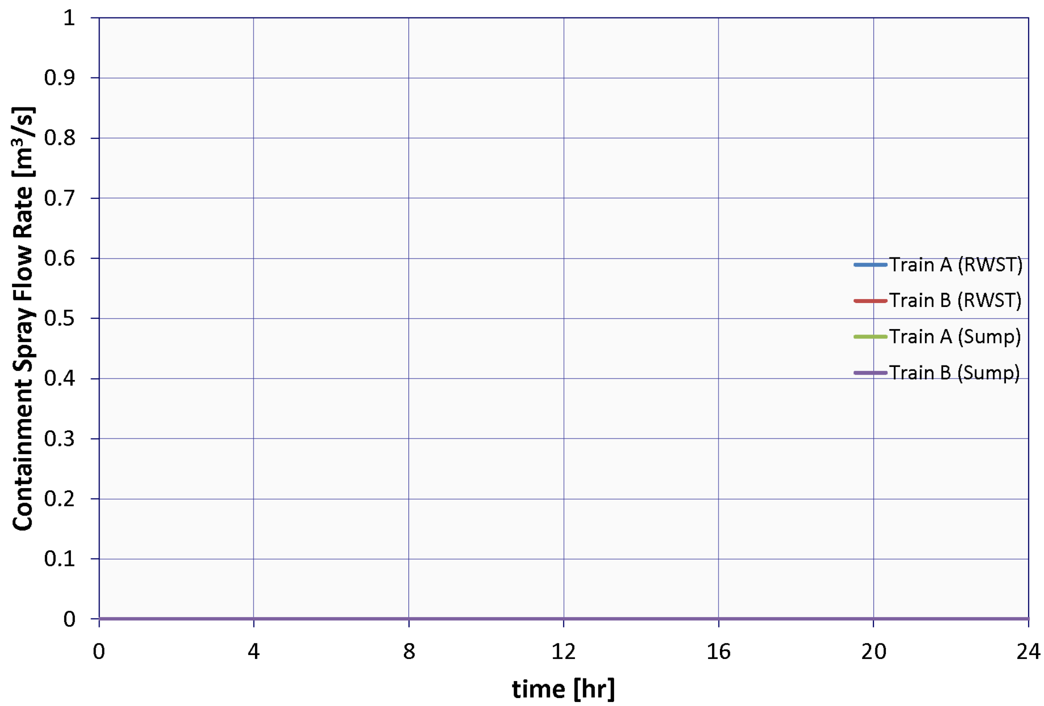
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead


600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]

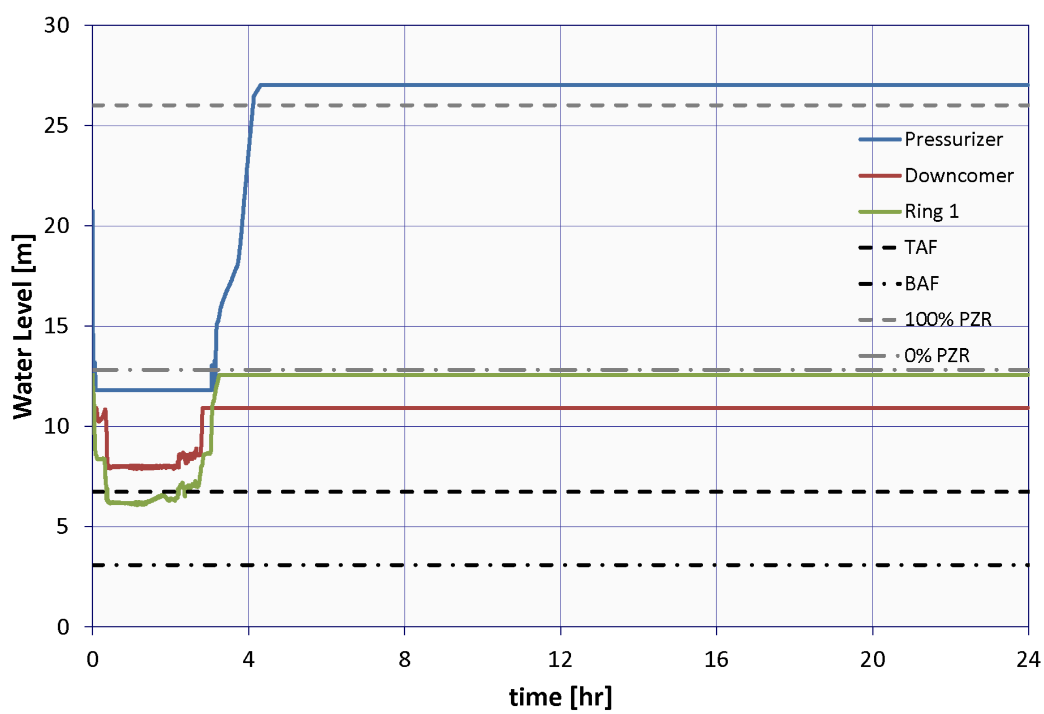

300
250
200
150
100
50
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR


12
10
8
6
4
2
0
Auxiliary Feedwater Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D

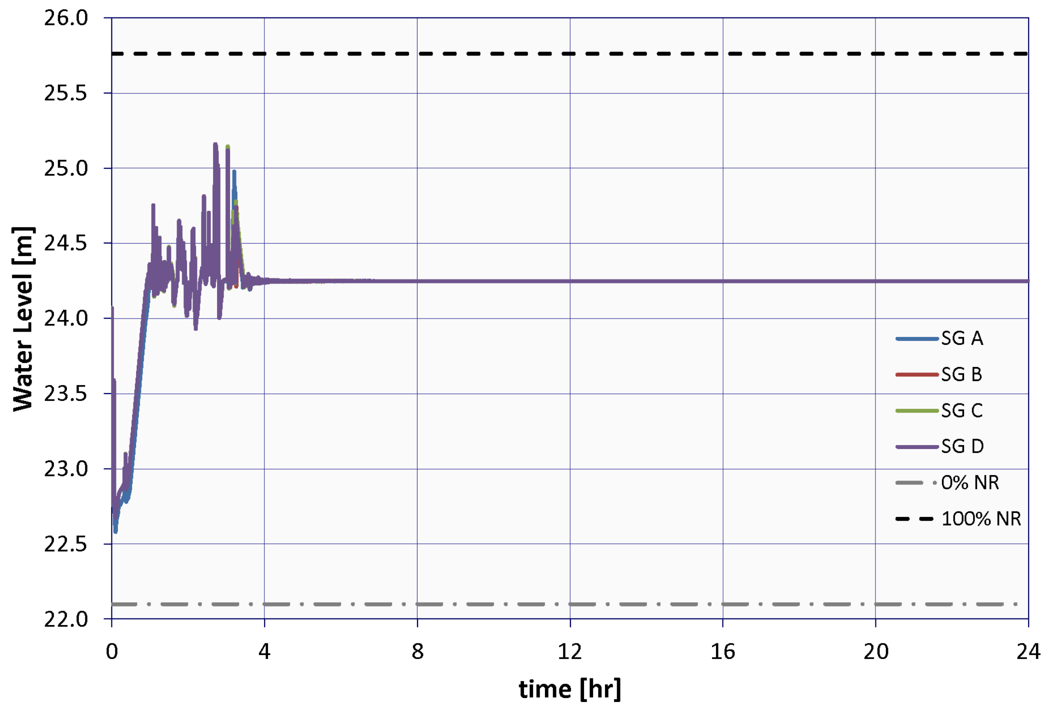

70
60
50
40
30
20
10
0
Steam Generator PORV Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D

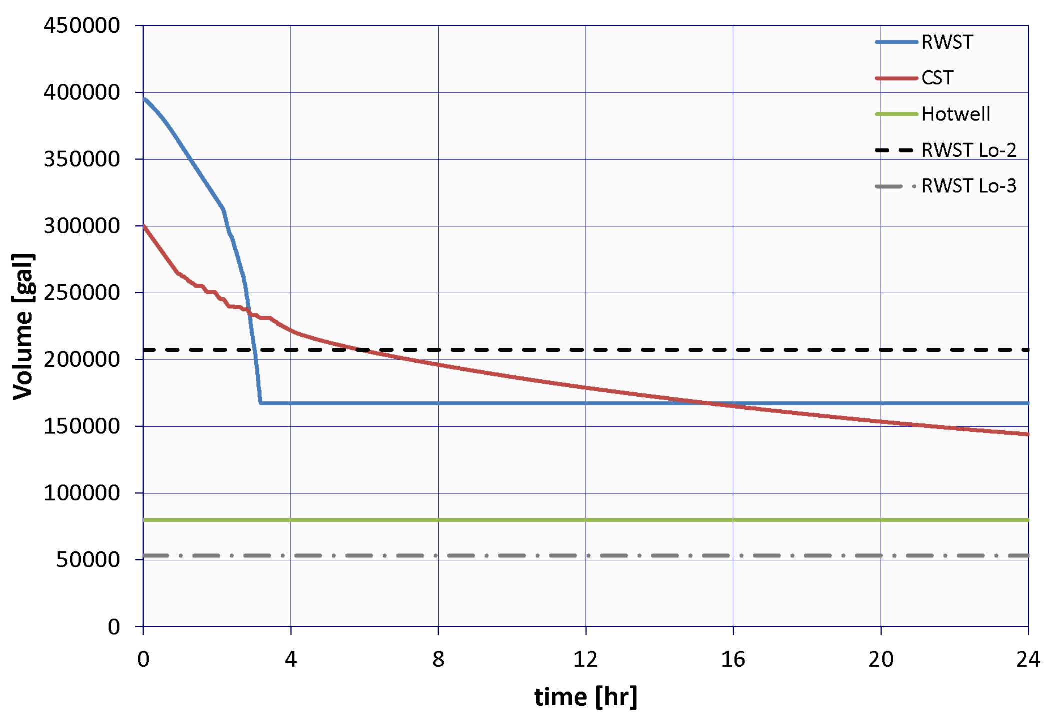


Containment Spray Flow Rate [m3/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

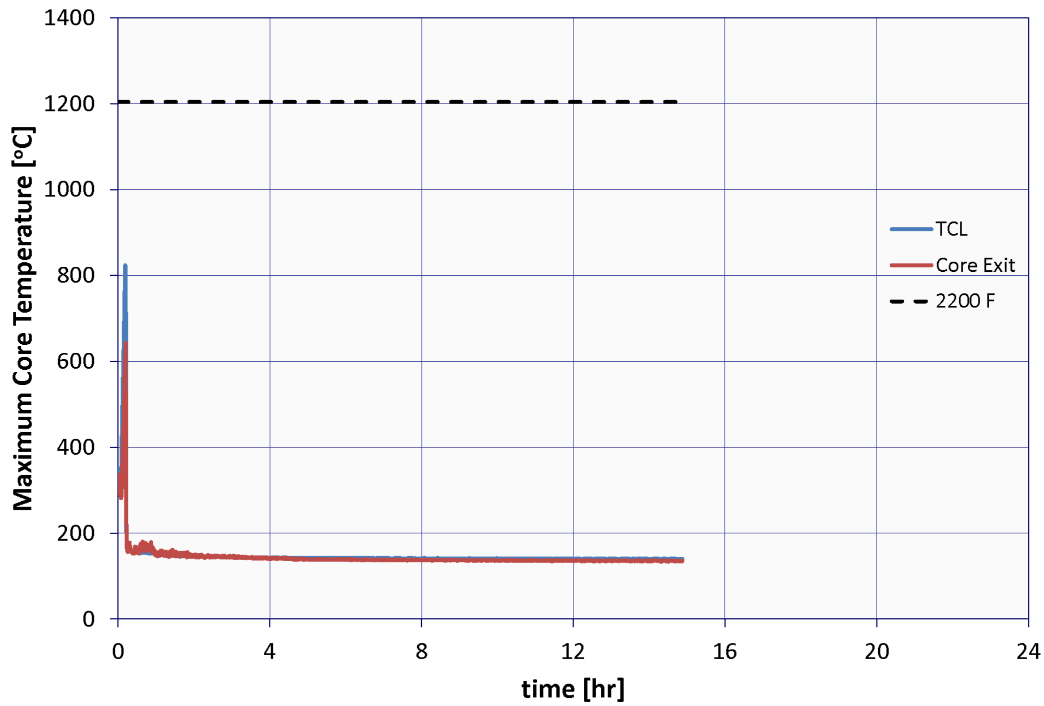


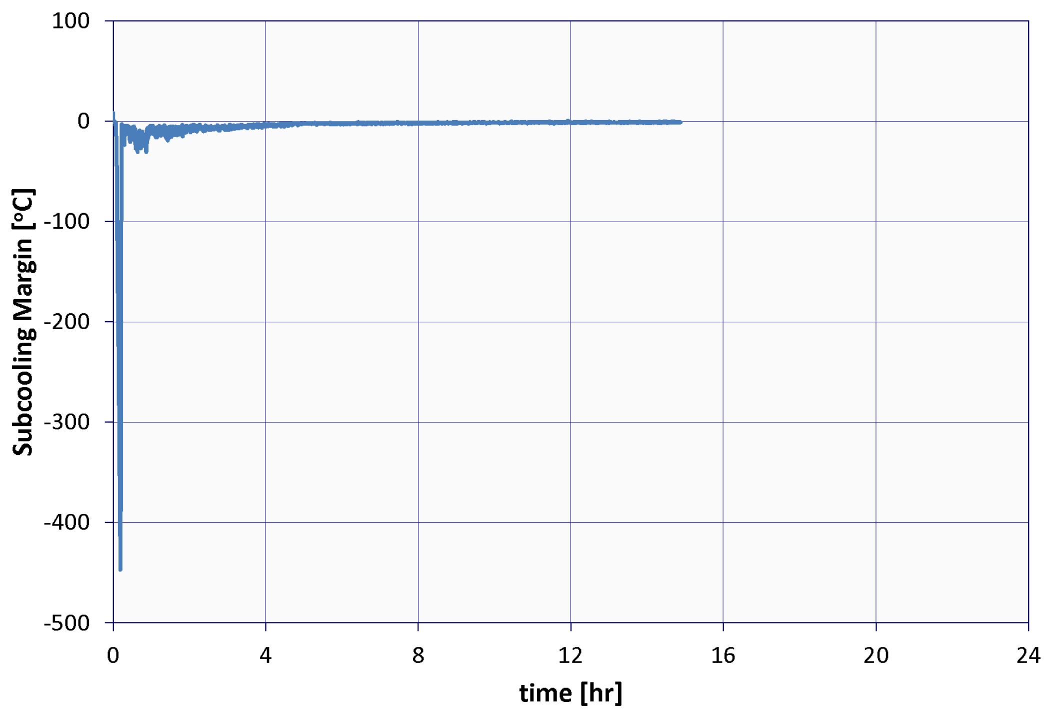
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

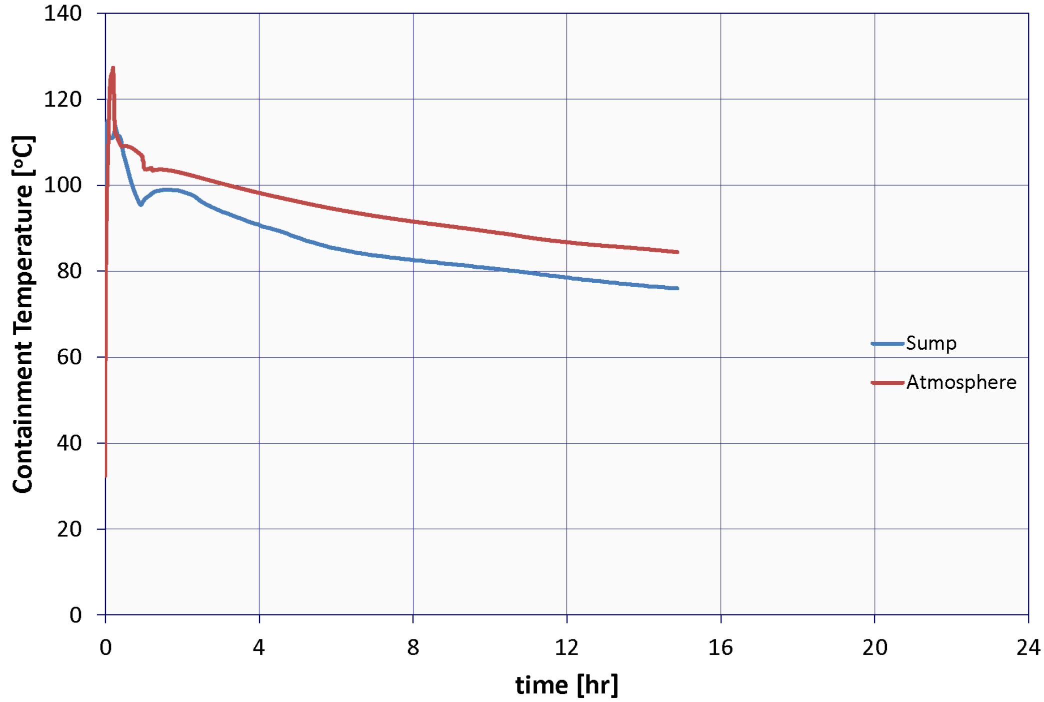

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

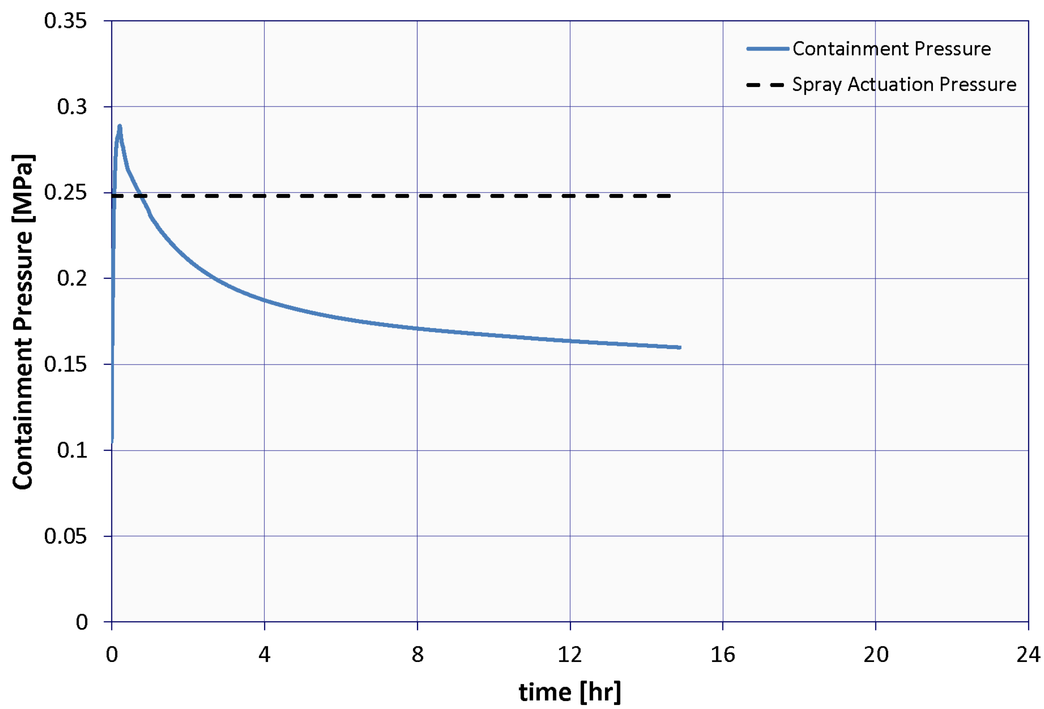
E.2.4 Case 4: 6-in. Break, 100 °F/hr Cooldown at 20 min, 0/2 CS Pumps, 0/4 RCFC



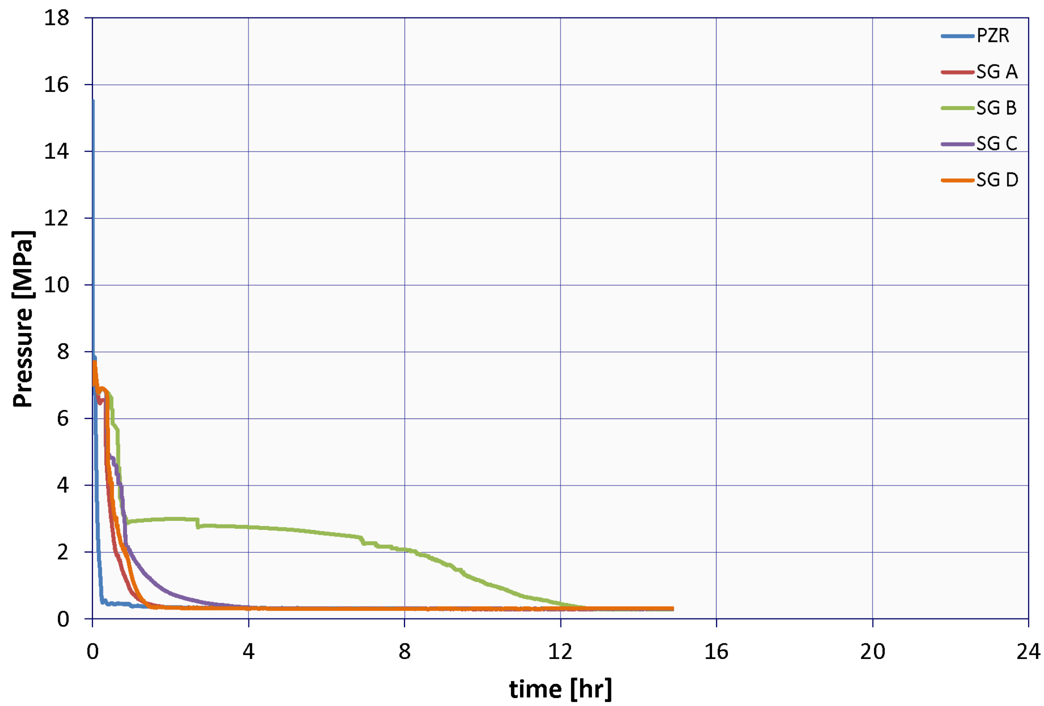




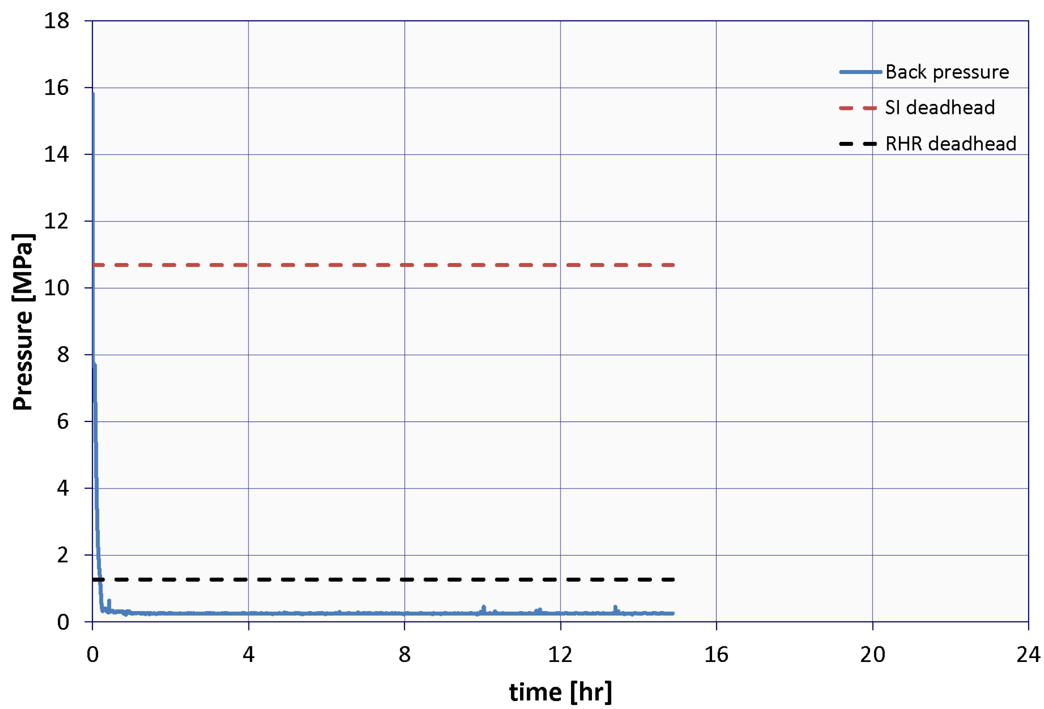
Containment Temperature [°C]
time [hr]
Sump
Atmosphere
0
20
40
60
80
100
120
140
0
4
8
12
16
20
24



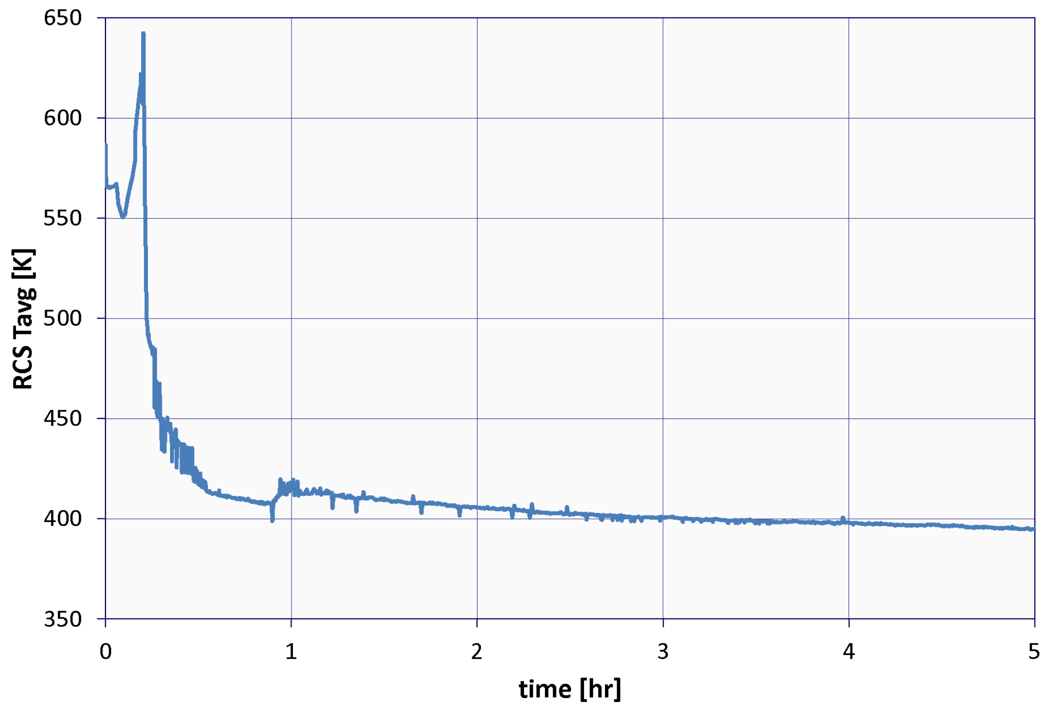
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
4
8
12
16
20
24



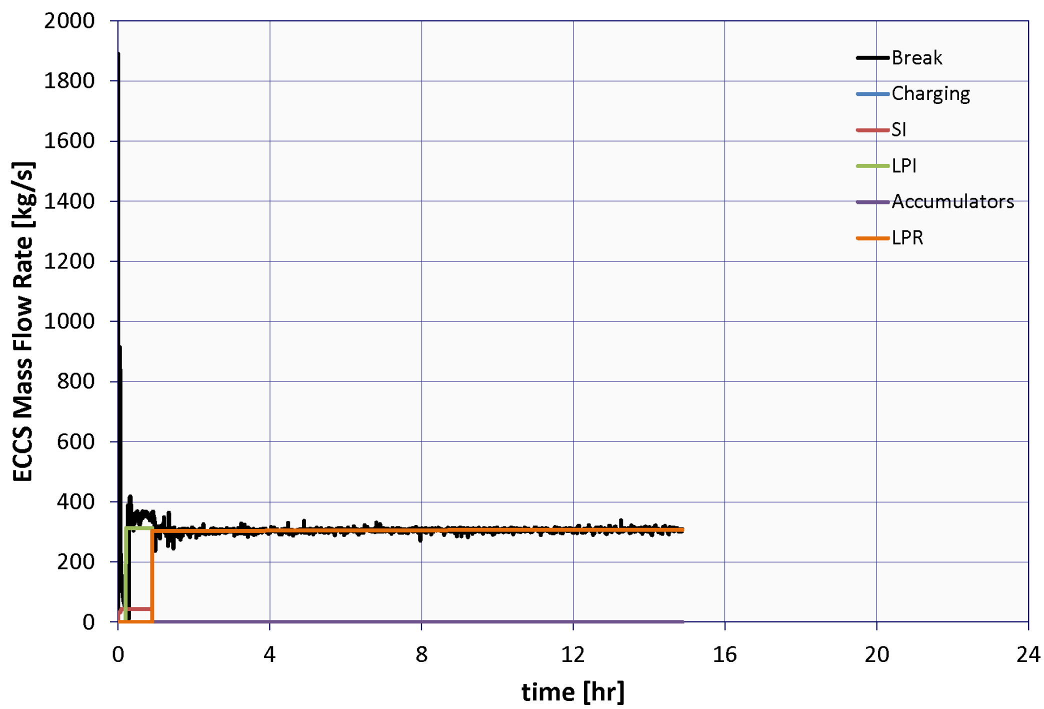
PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
20
24



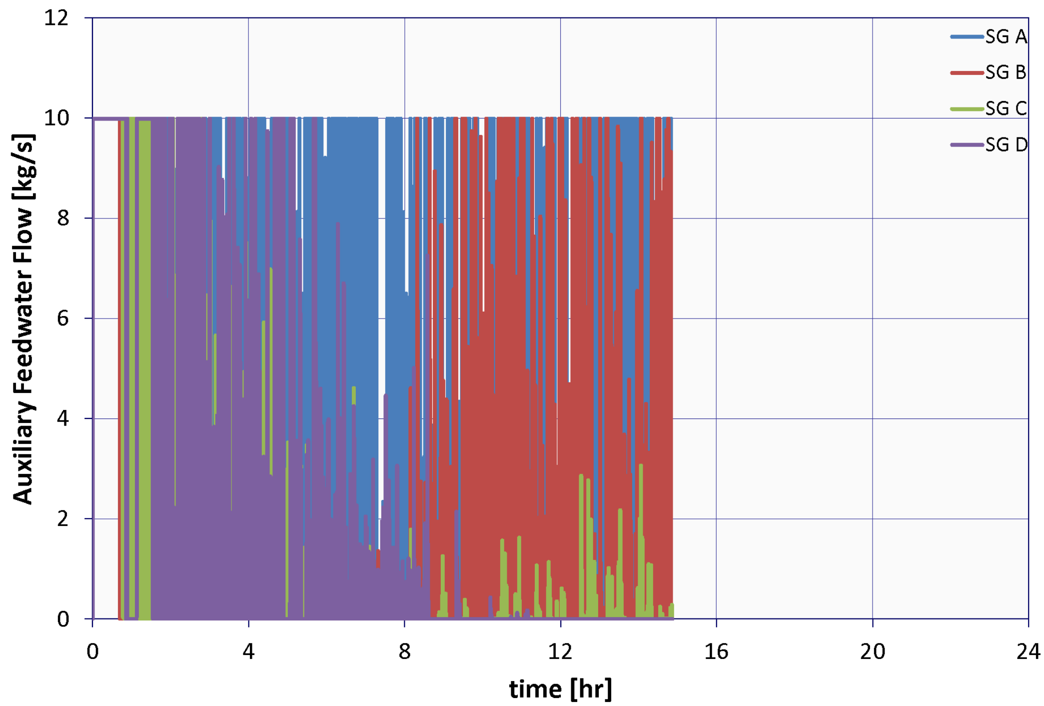
Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
20
24



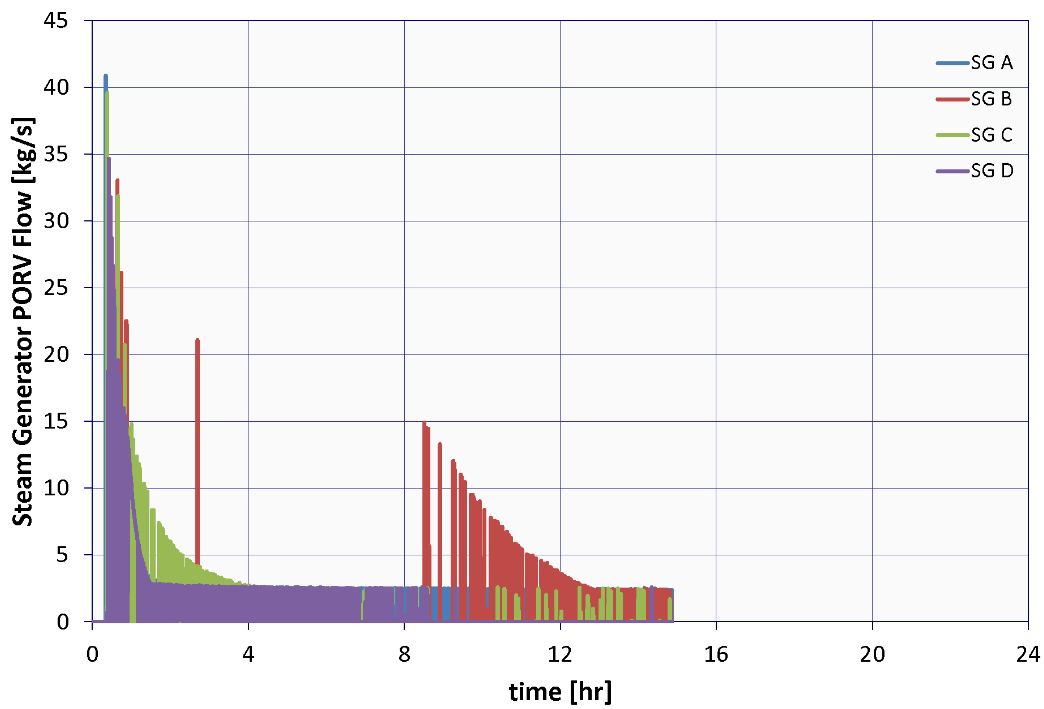
650
600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]



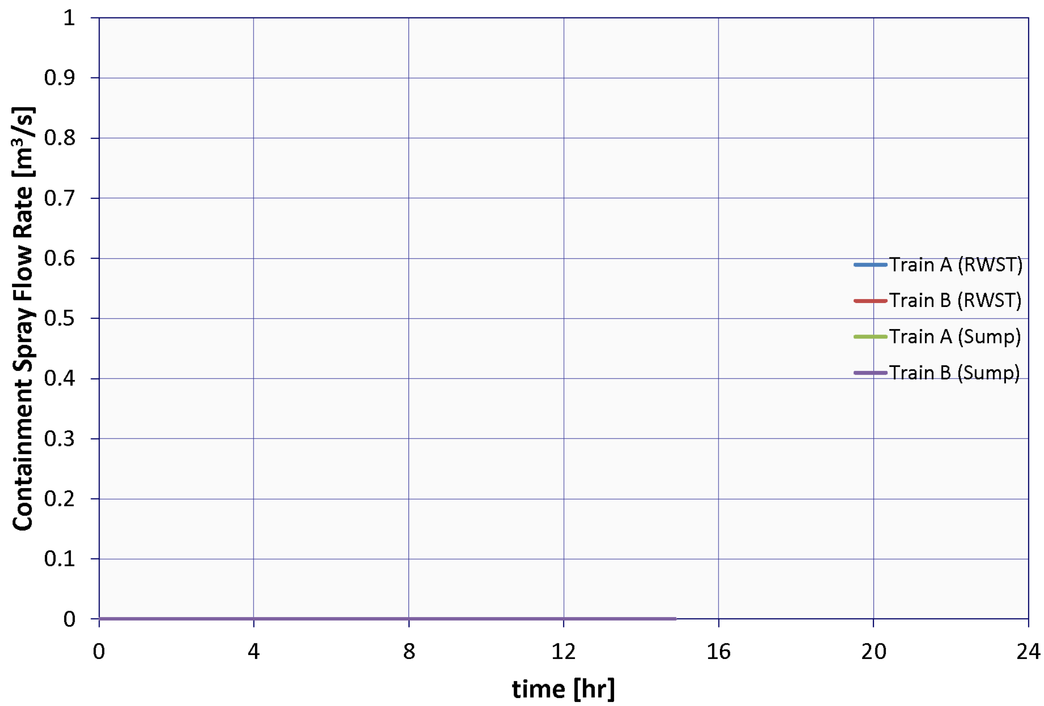
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

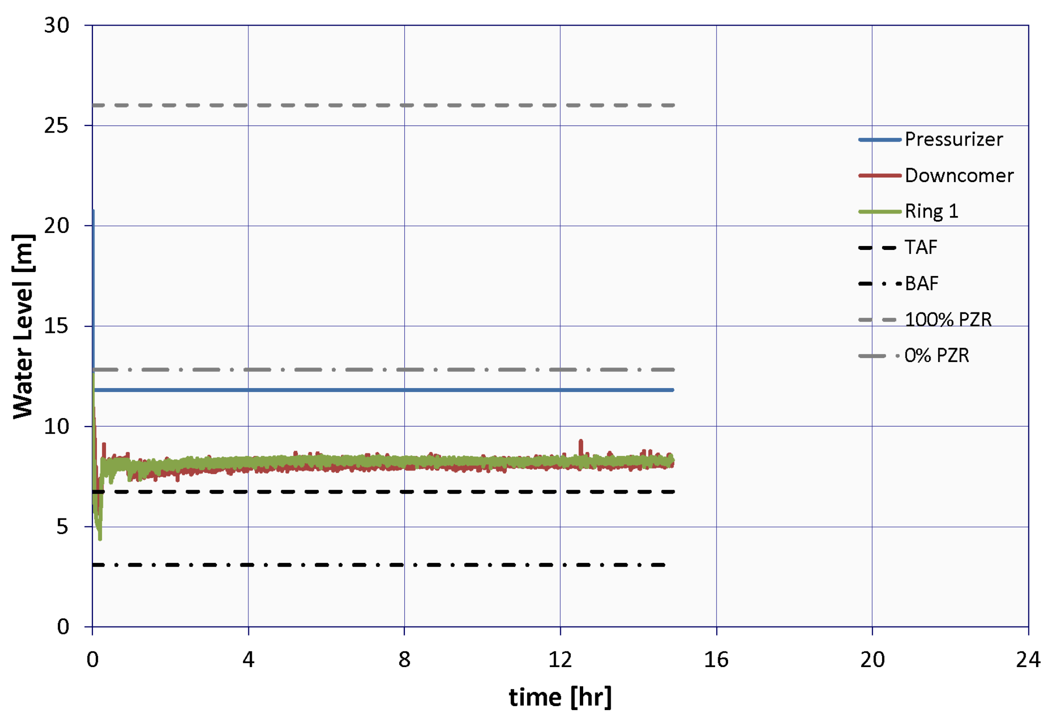


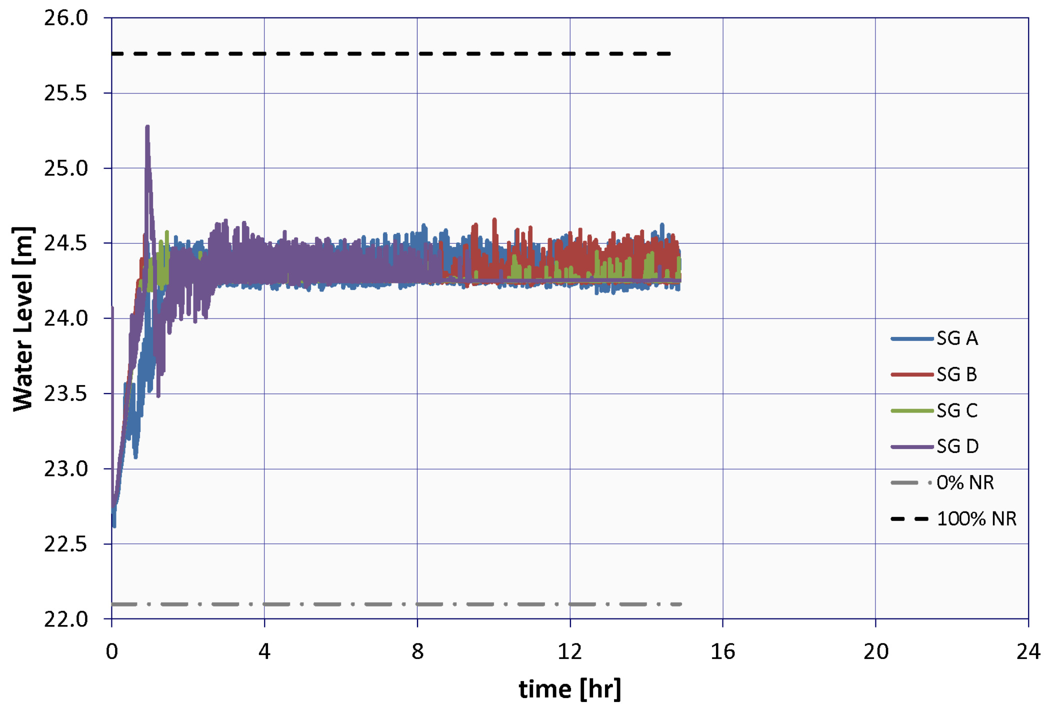
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

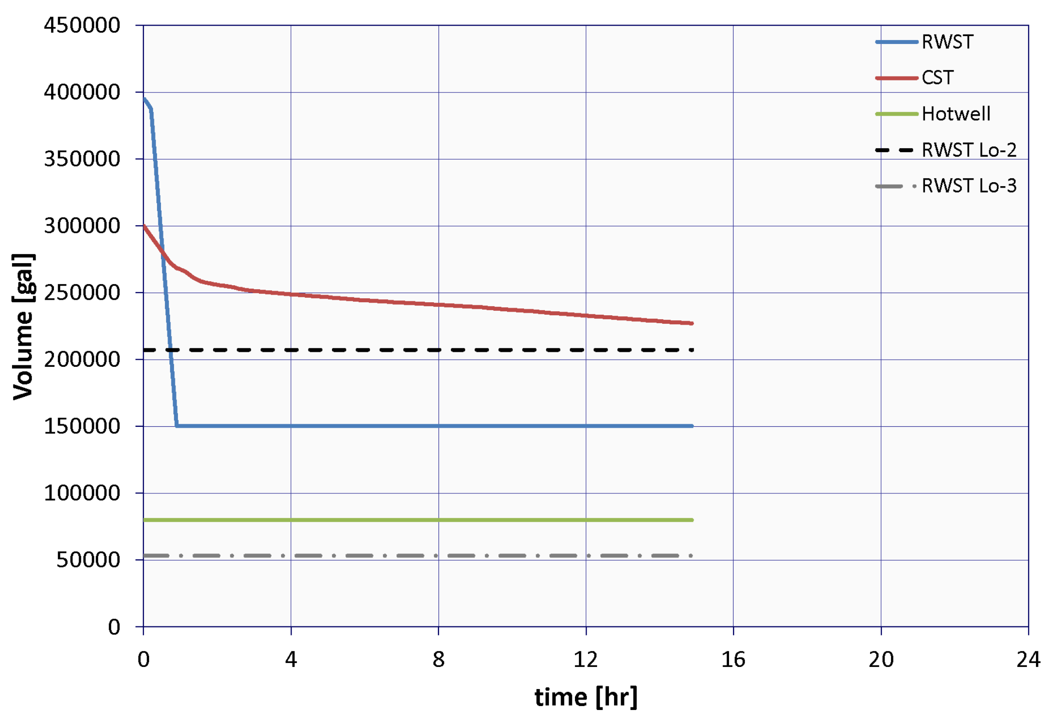


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

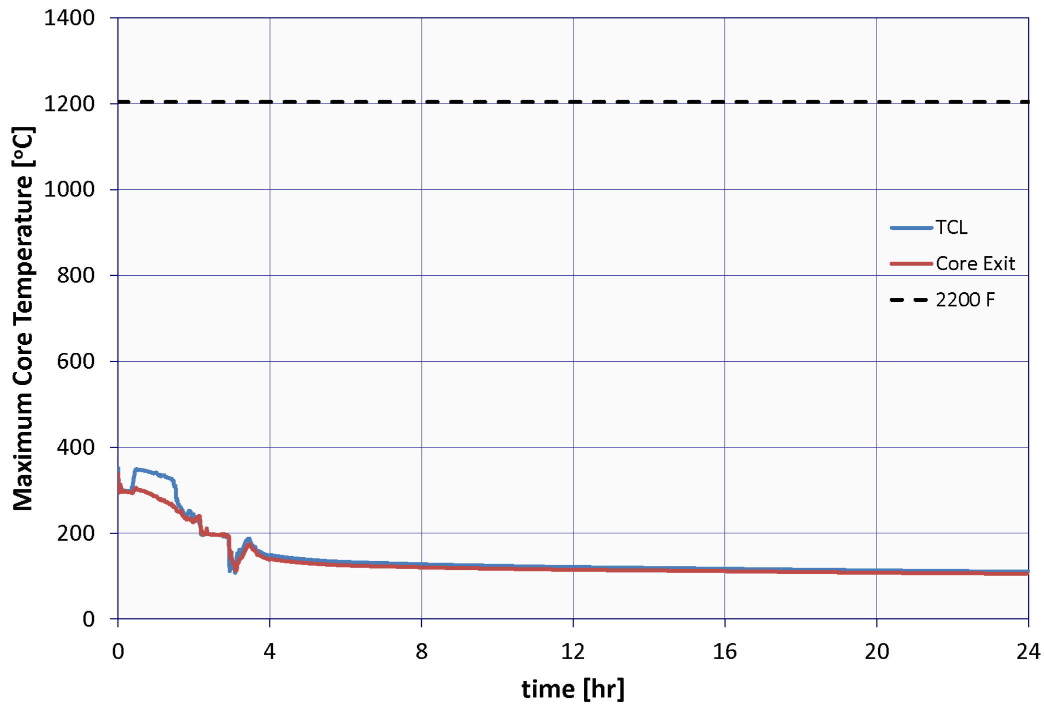

Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

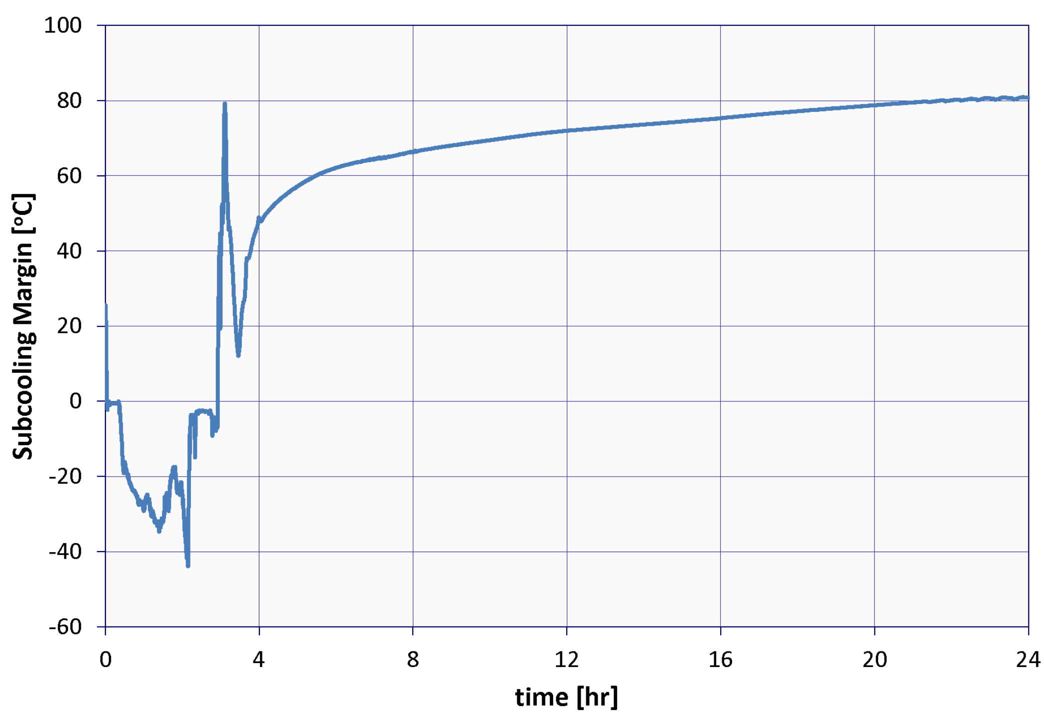

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

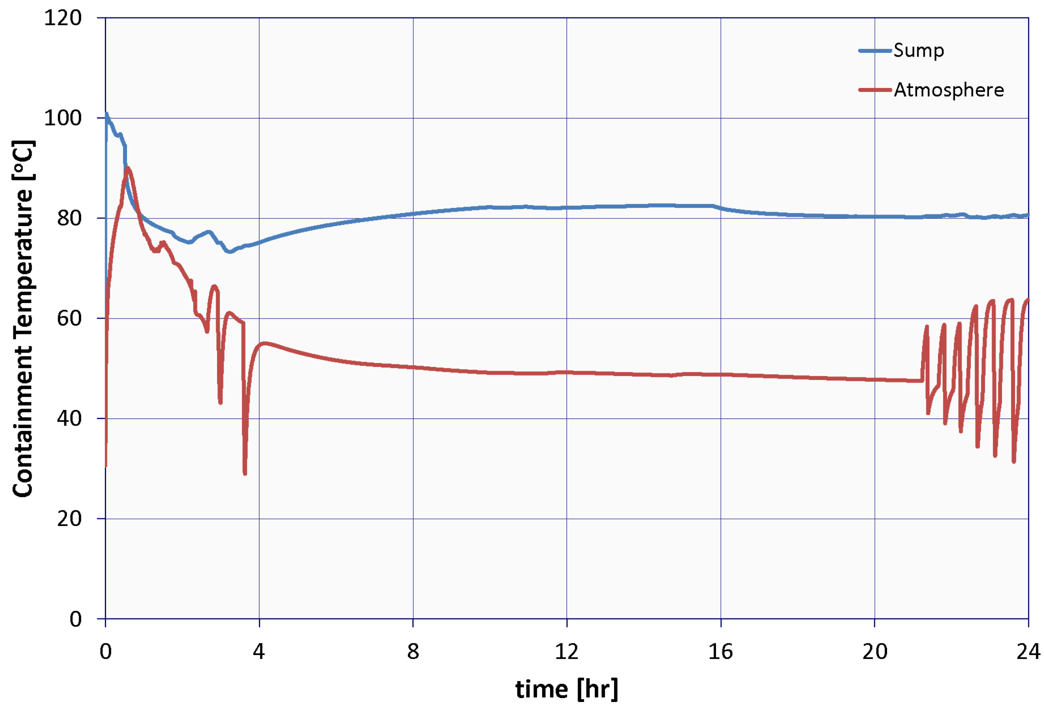

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

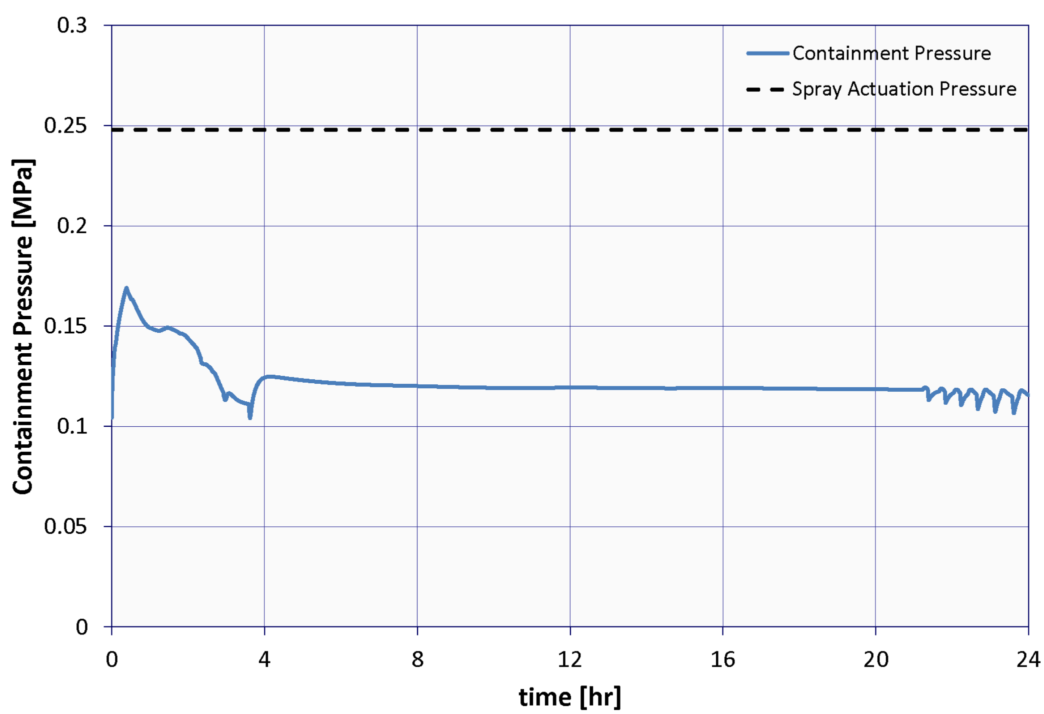
E.2.5 Case 5: 2-in. Break, 100 °F/hr Cooldown at 20 min, 0/2 CS Pumps, 4/4 RCFC



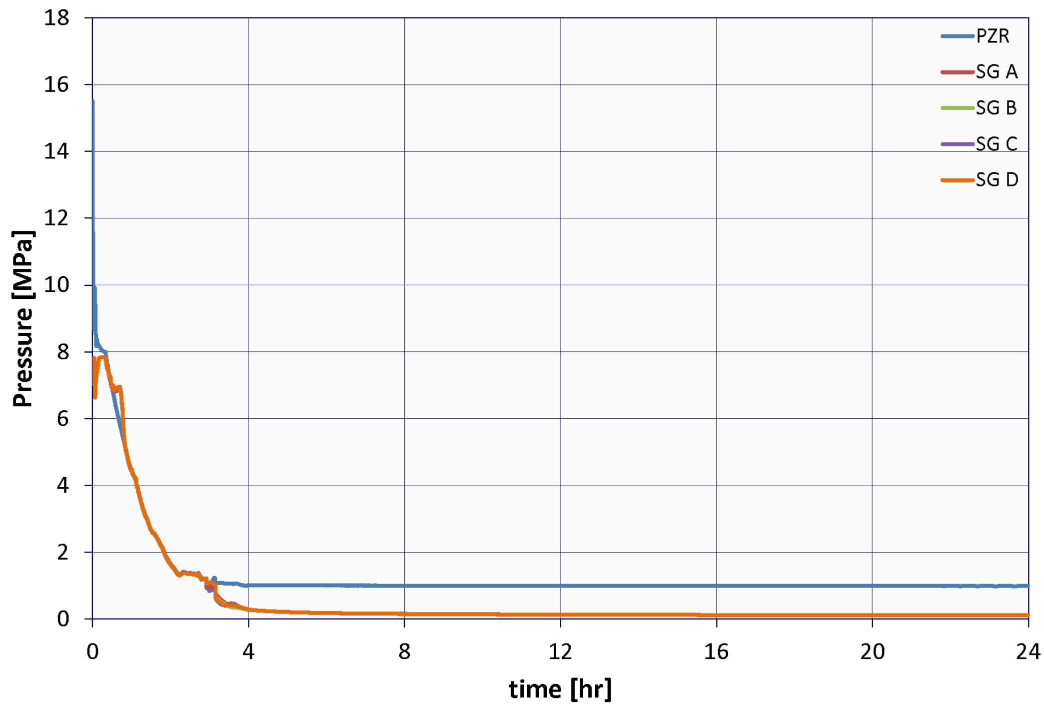




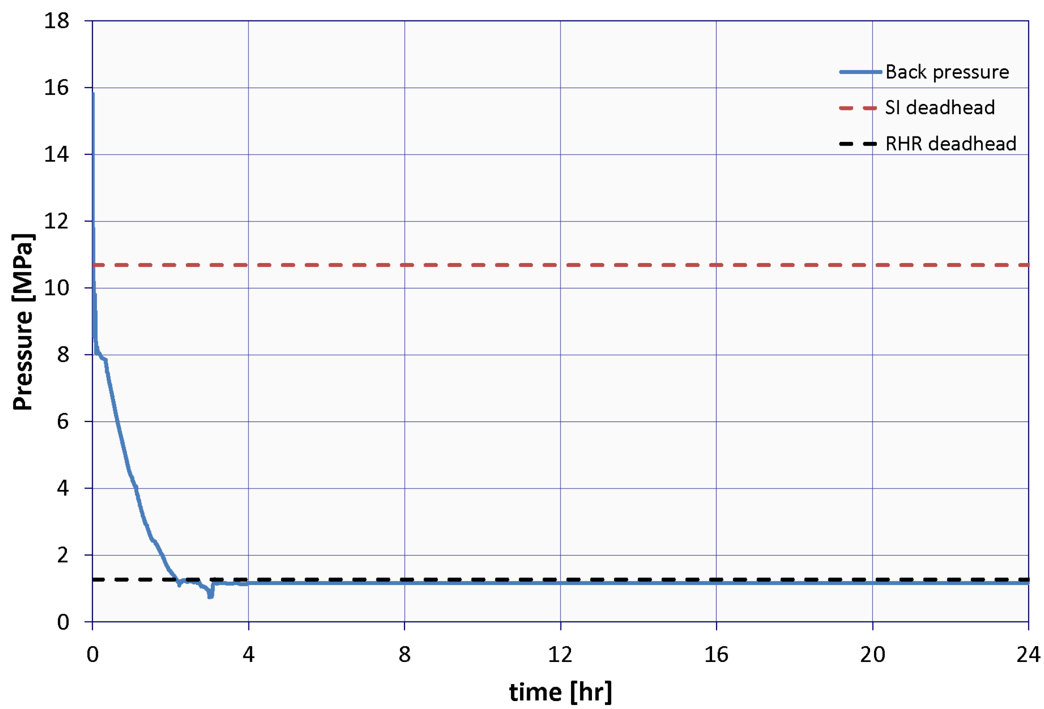
Containment Temperature [°C]
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



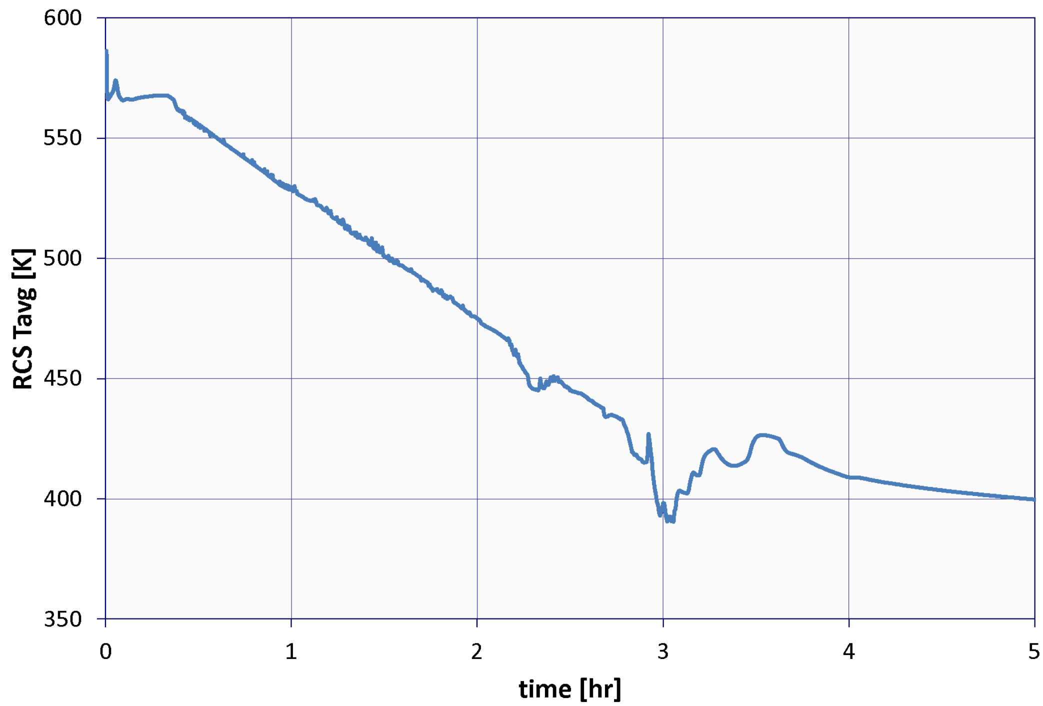
Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure

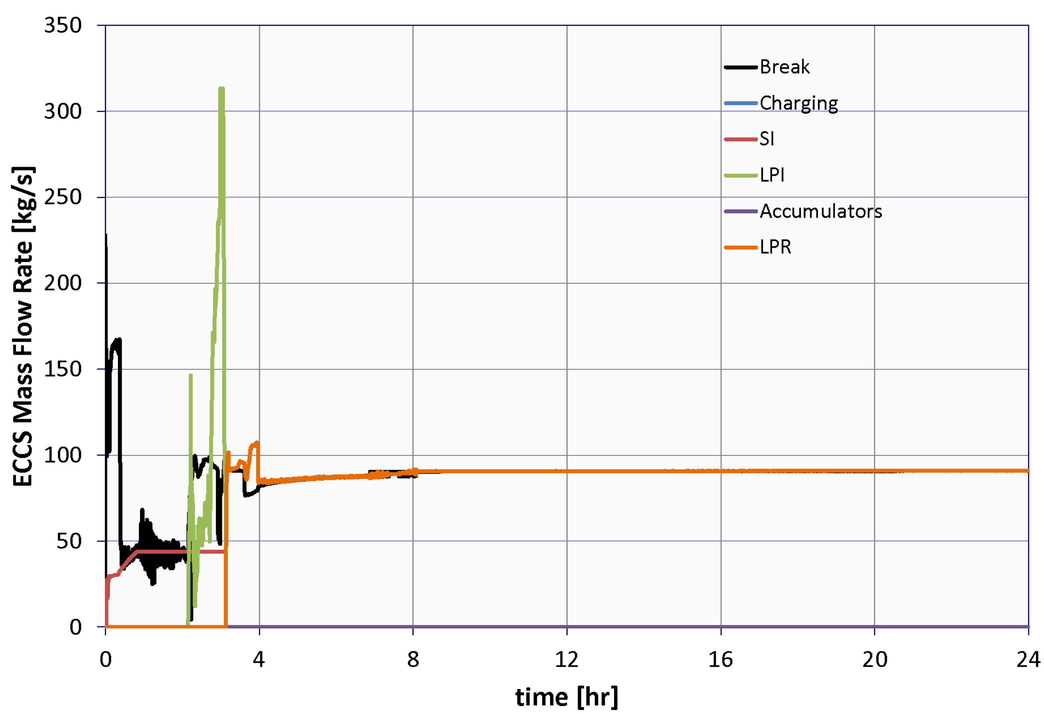


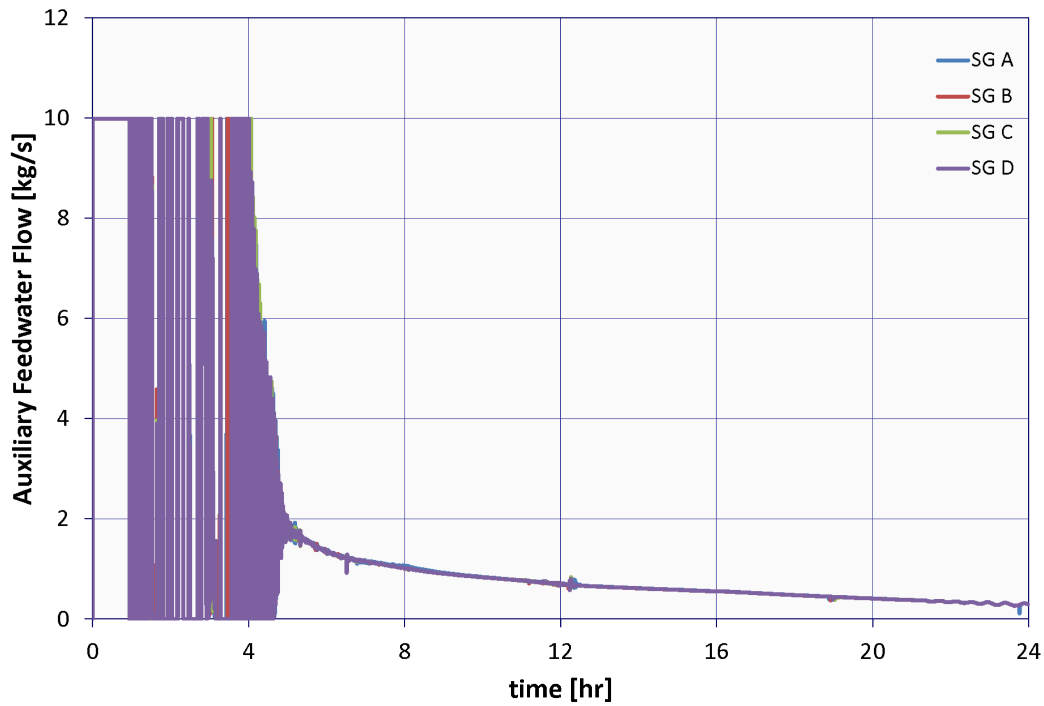
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D

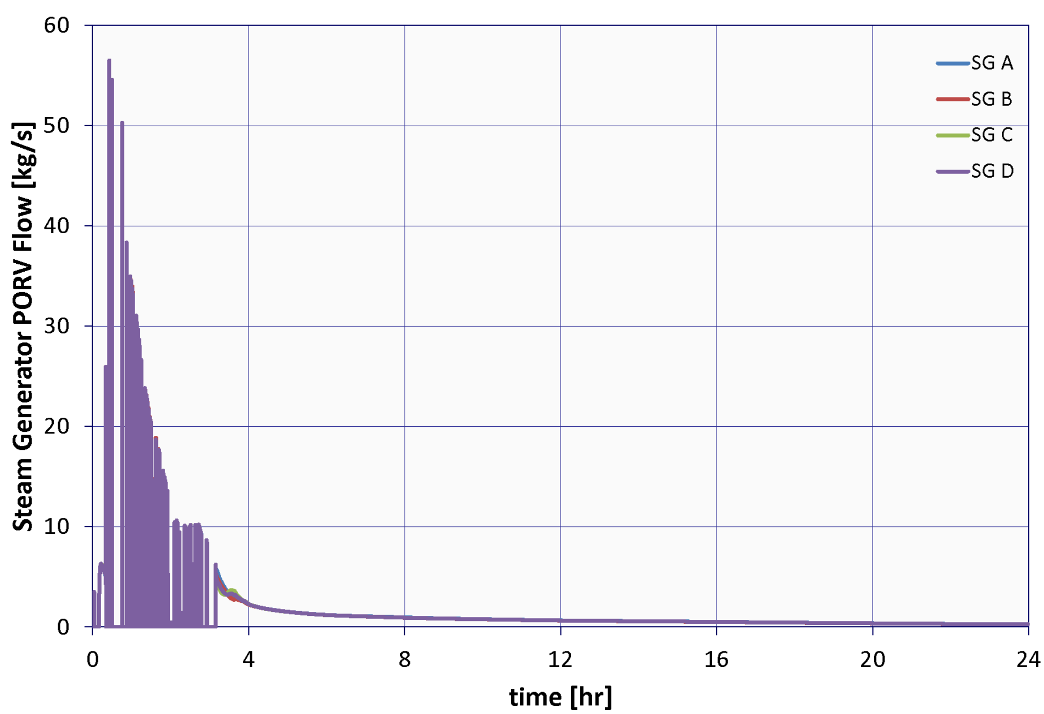


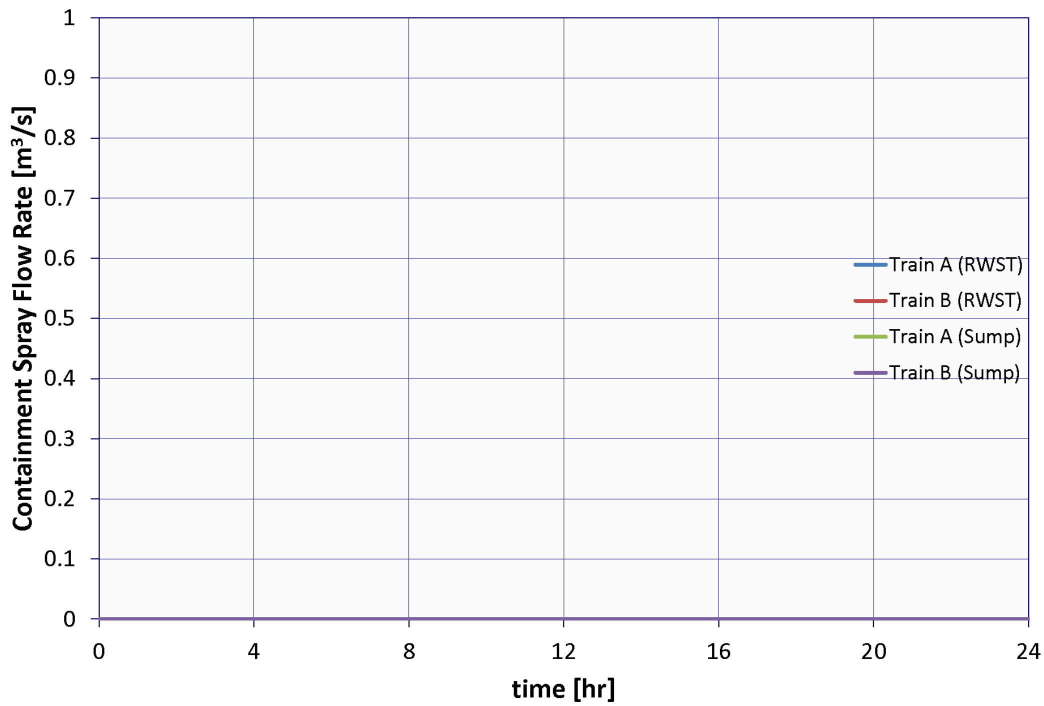
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead

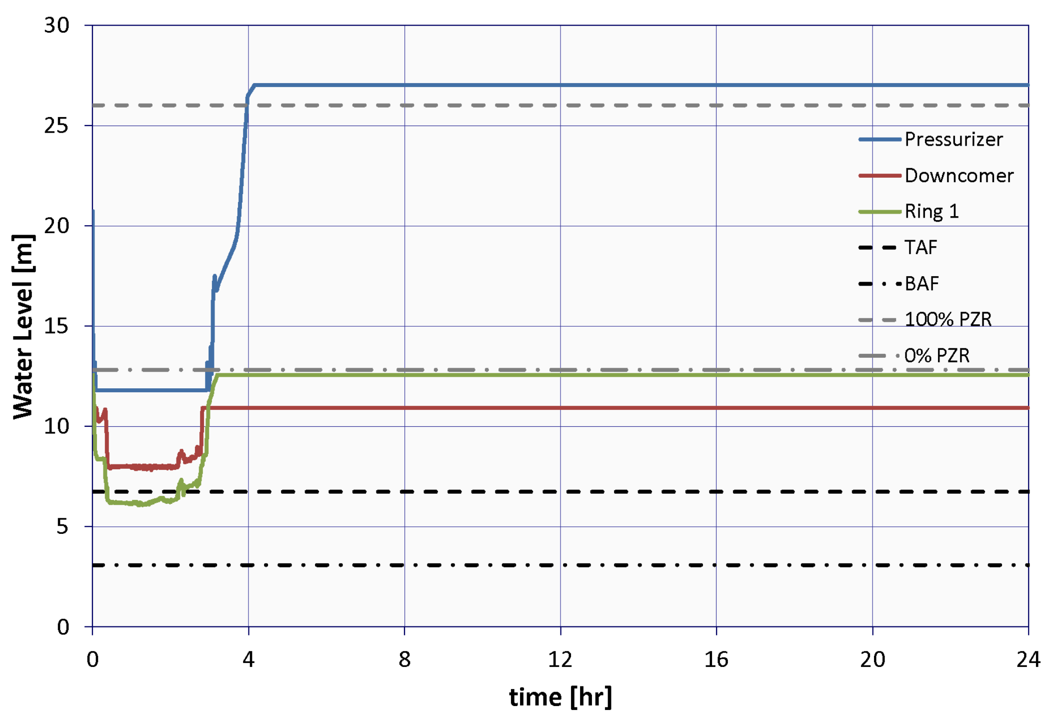

600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]

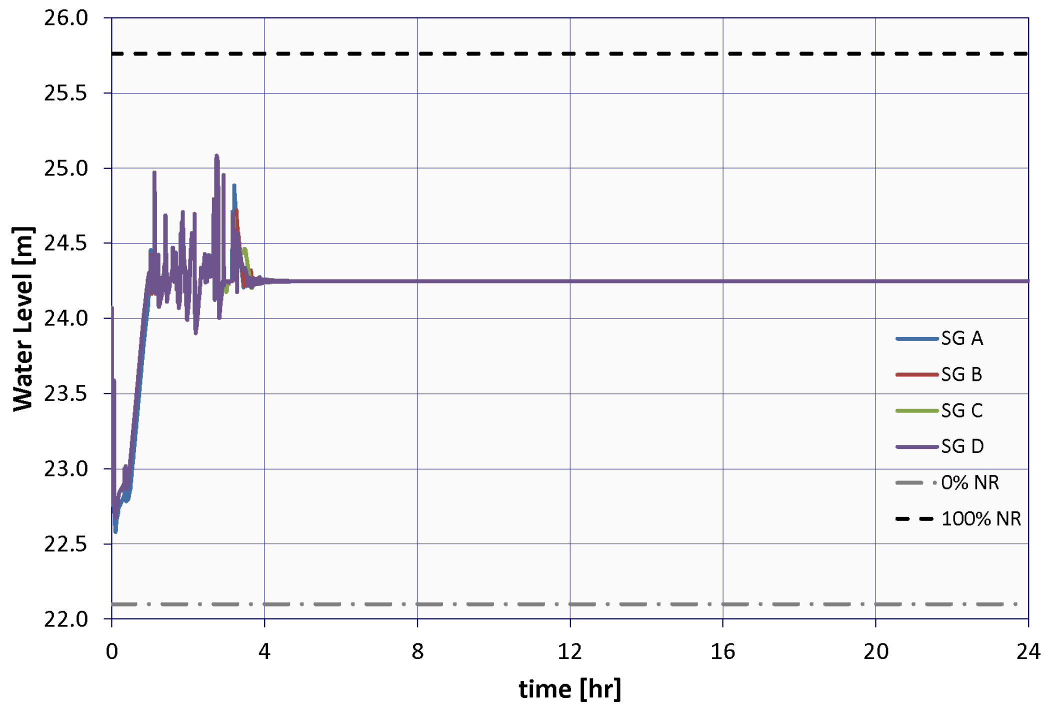

350
300
250
200
150
100
50
0
ECCS Mass Flow Rate [kg/s]
Break
Charging
SI
LPI
Accumulators
LPR
0
4
8
12
16
20
24
time [hr]


Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

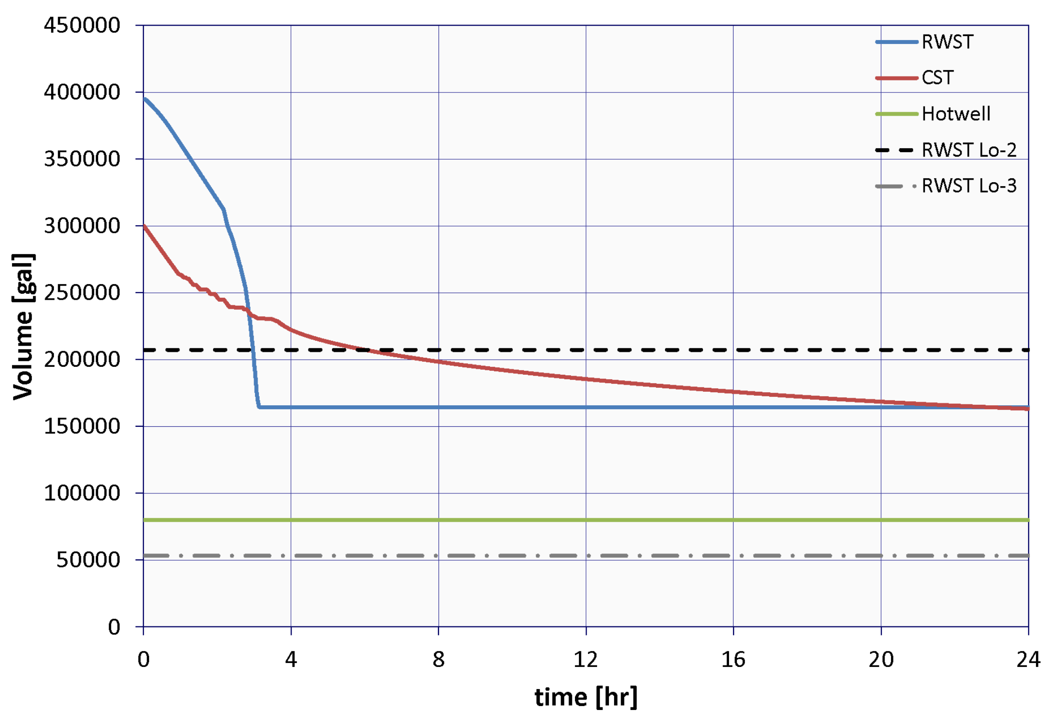

Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
10
20
30
40
50
60
0
4
8
12
16
20
24


Containment Spray Flow Rate [m3/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)


Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

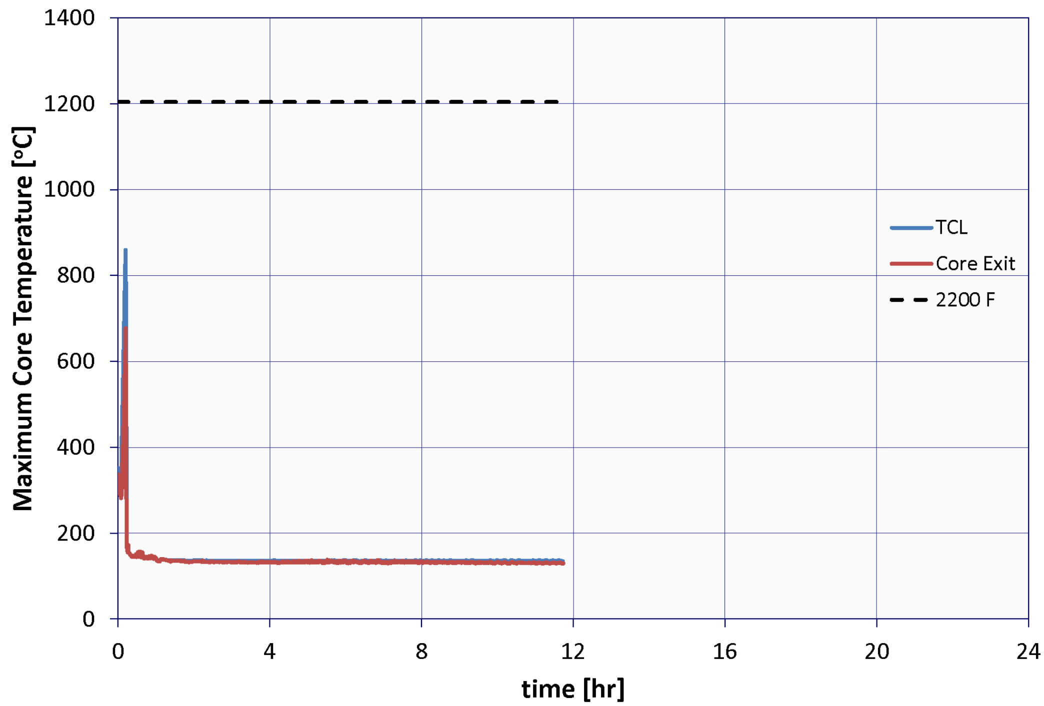


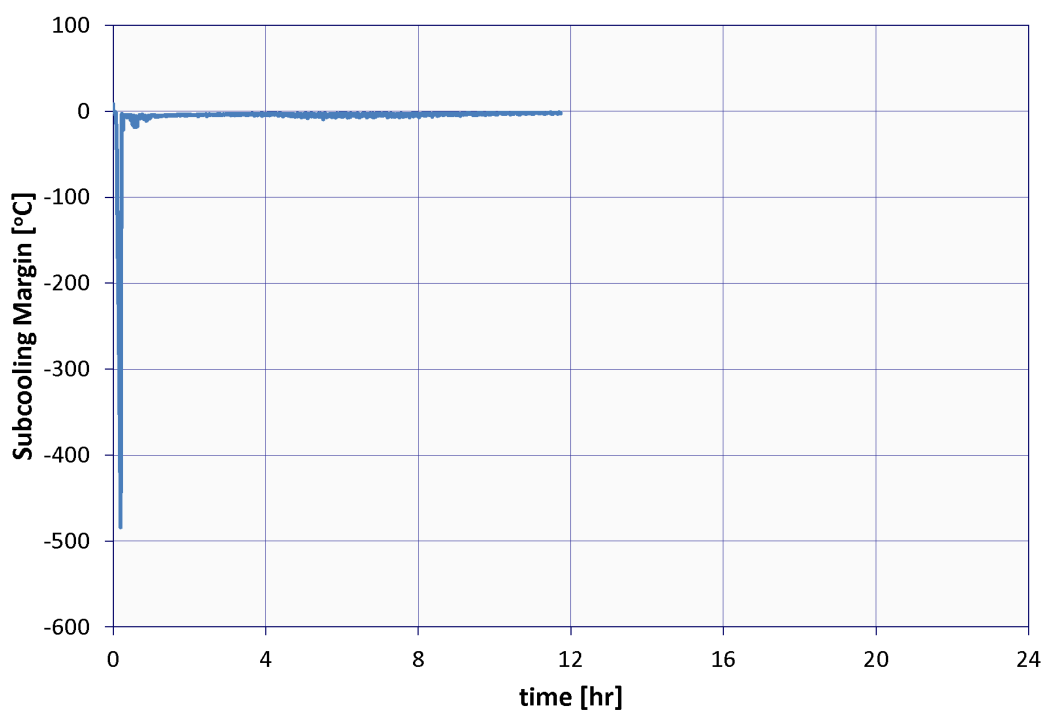
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

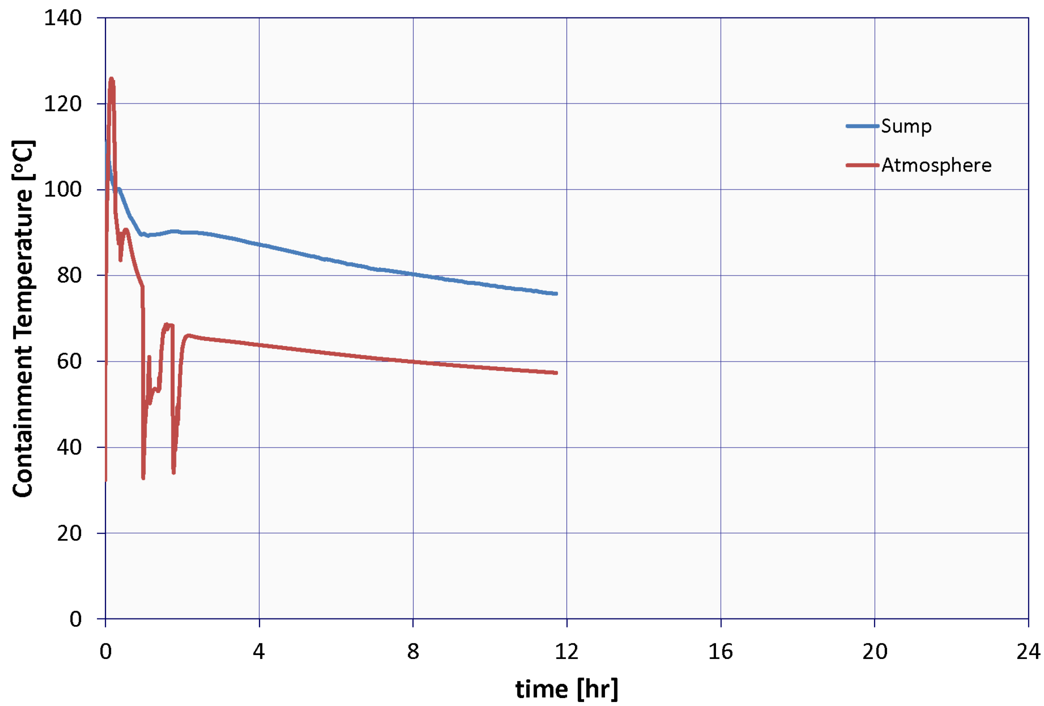


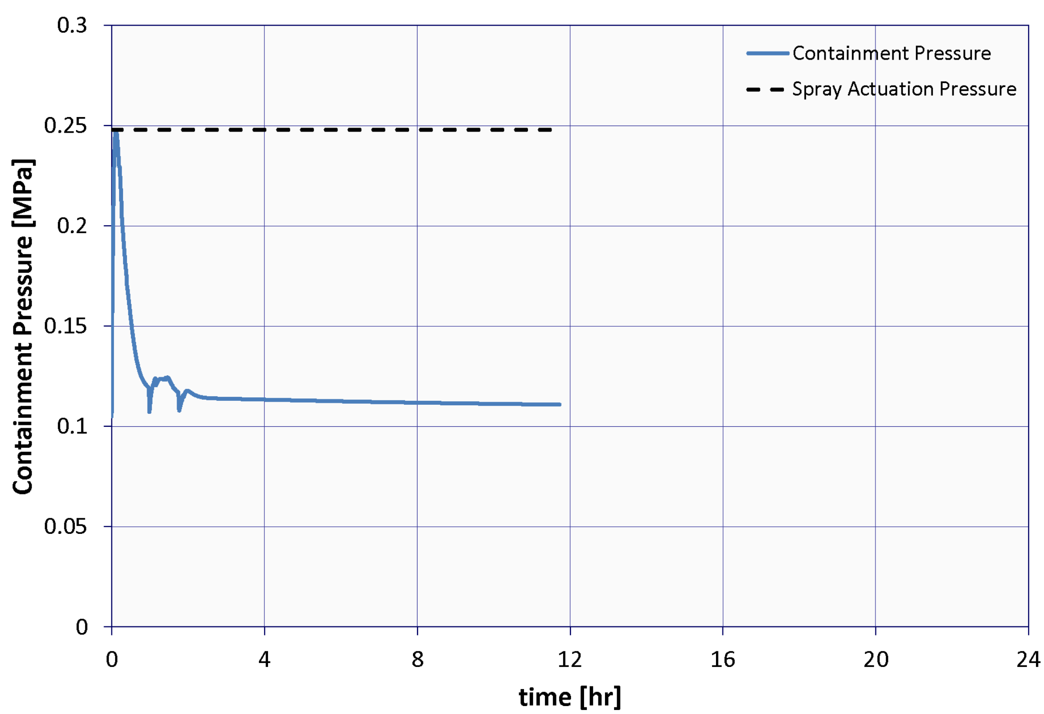
Volume [gal]
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

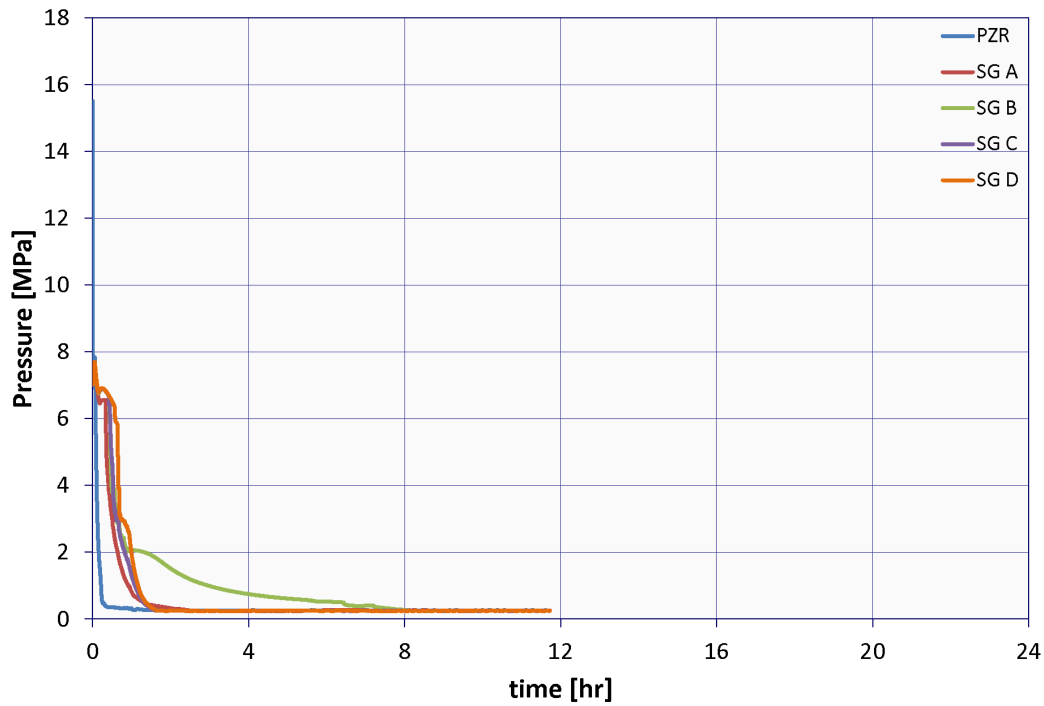
E.2.6 Case 6: 6-in. Break, 100 °F/hr Cooldown at 20 min, 0/2 CS Pumps, 4/4 RCFC



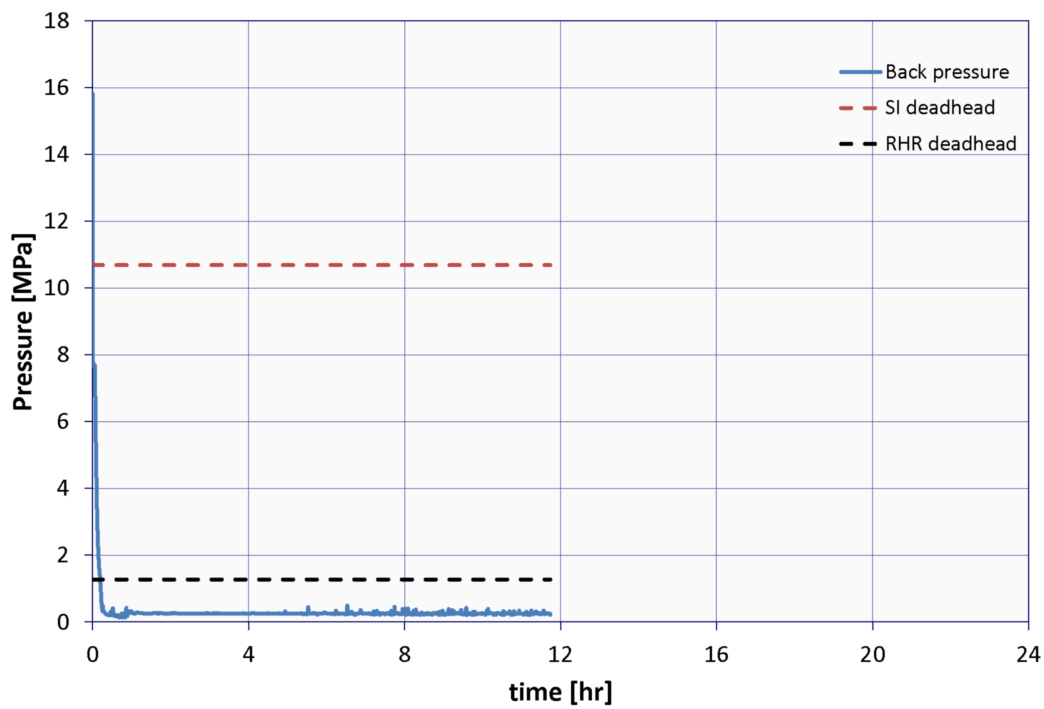



Containment Temperature [°C]
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

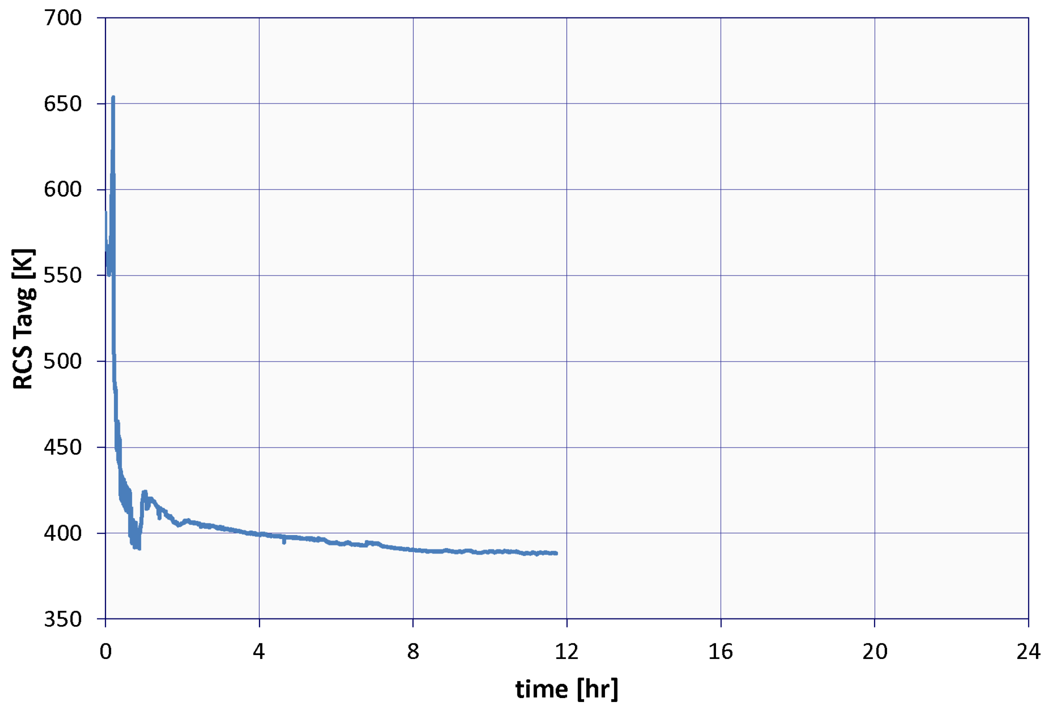

Containment Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure



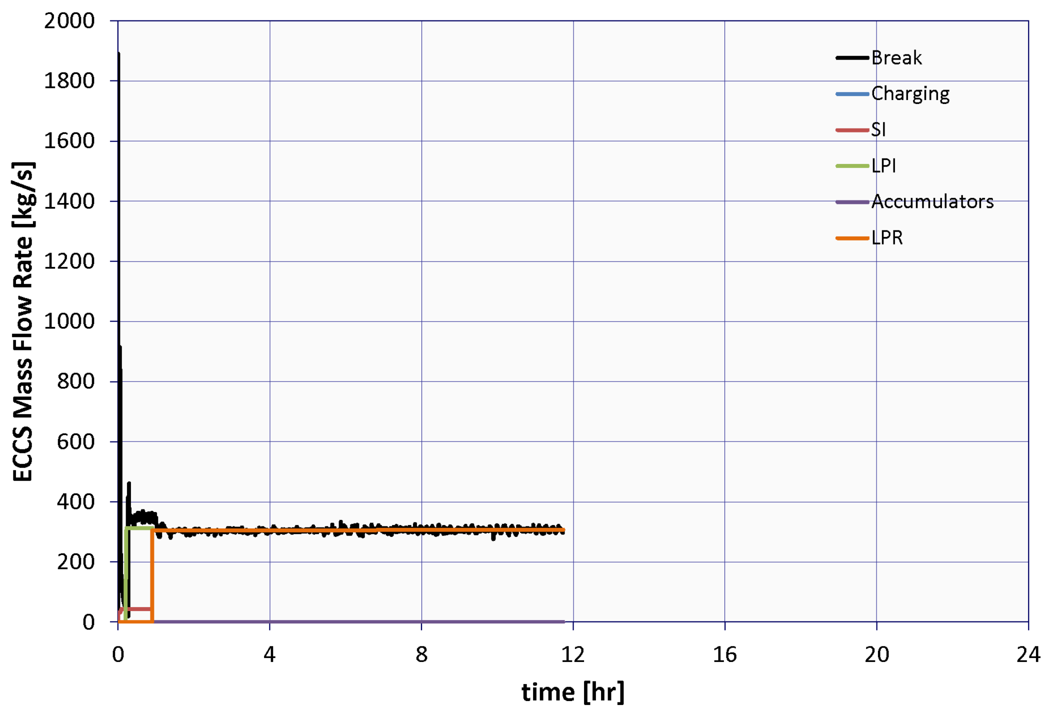
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



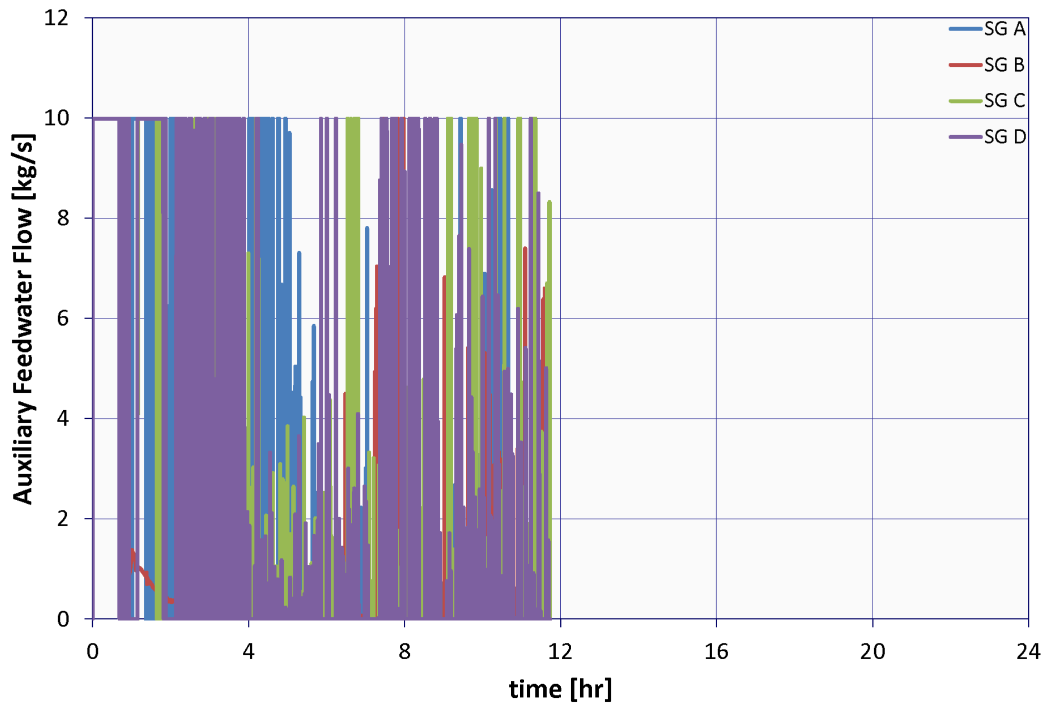
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Back pressure
SI deadhead
RHR deadhead

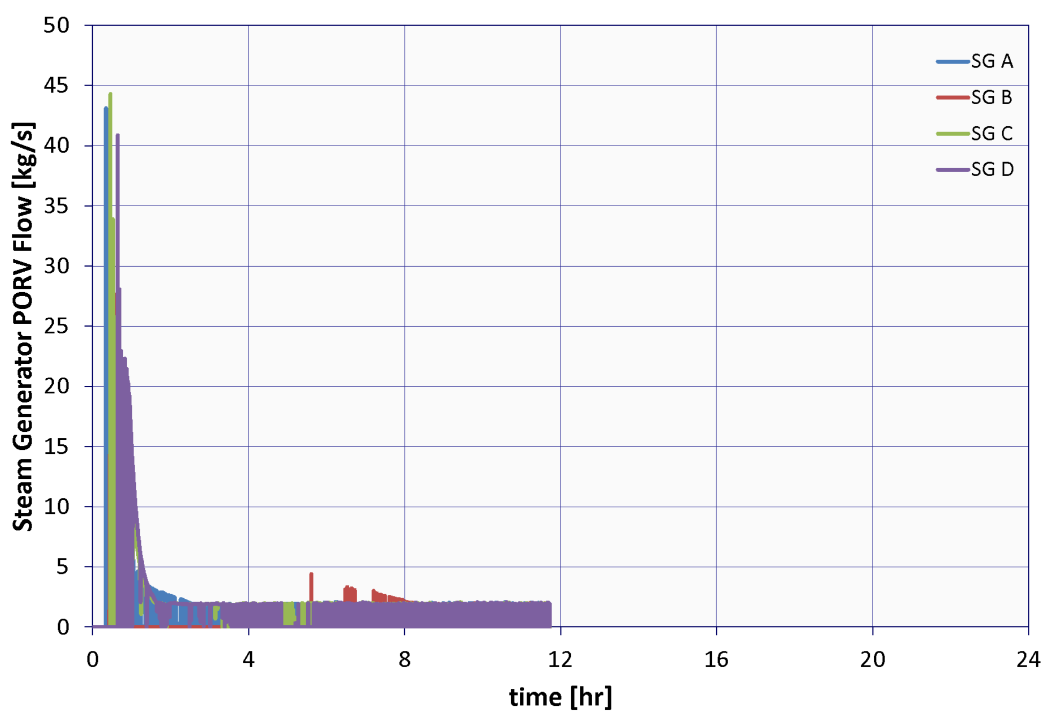


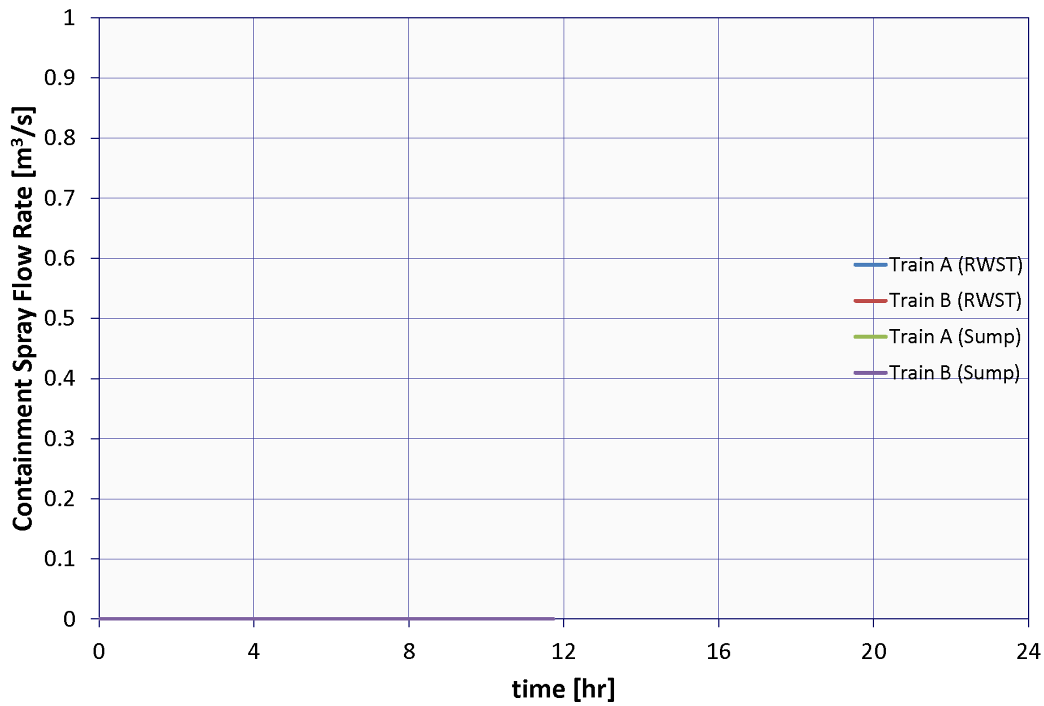
RCS Tavg [K]
700
650
600
550
500
450
400
350
0
4
8
12
16
20
24
time [hr]

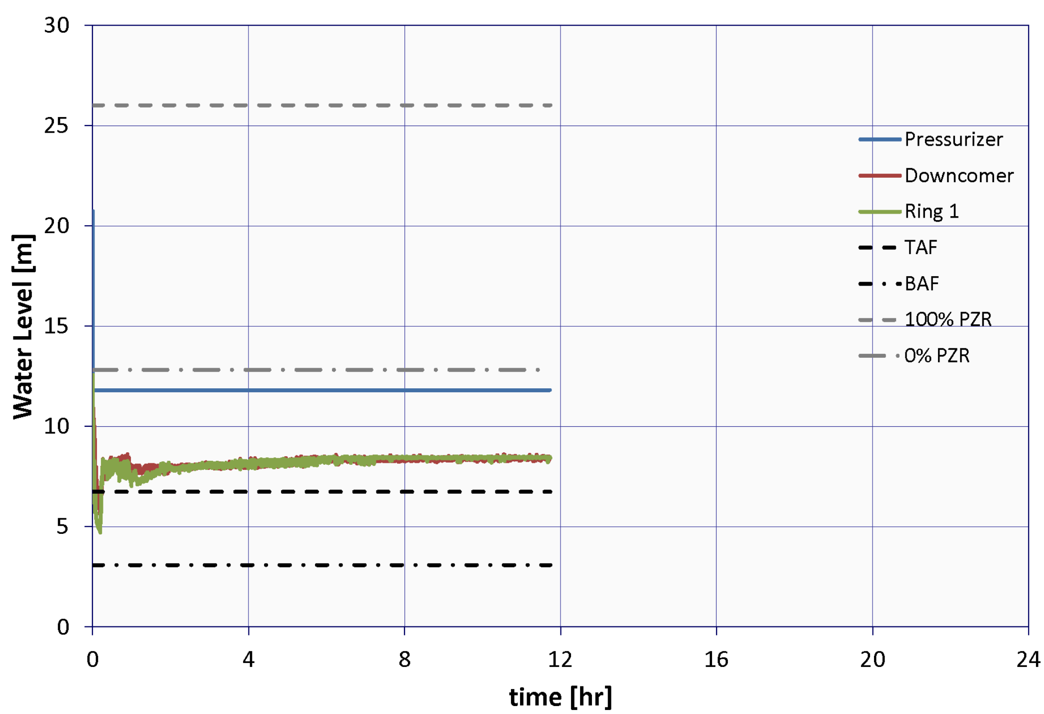


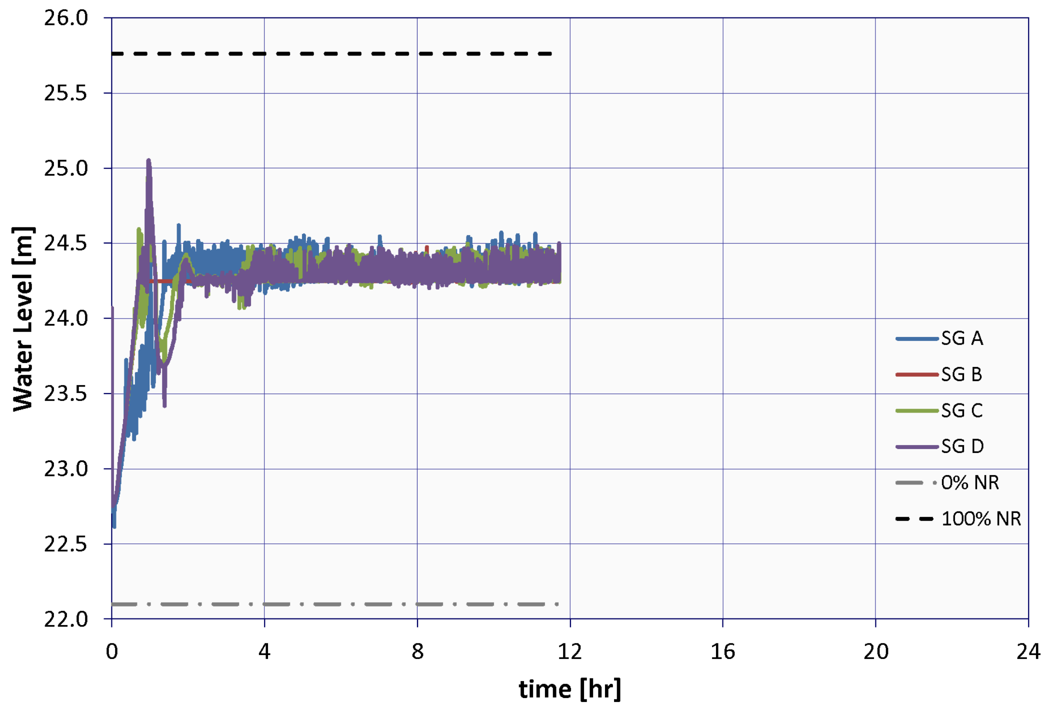
ECCS Mass Flow Rate [kg/s]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR


Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

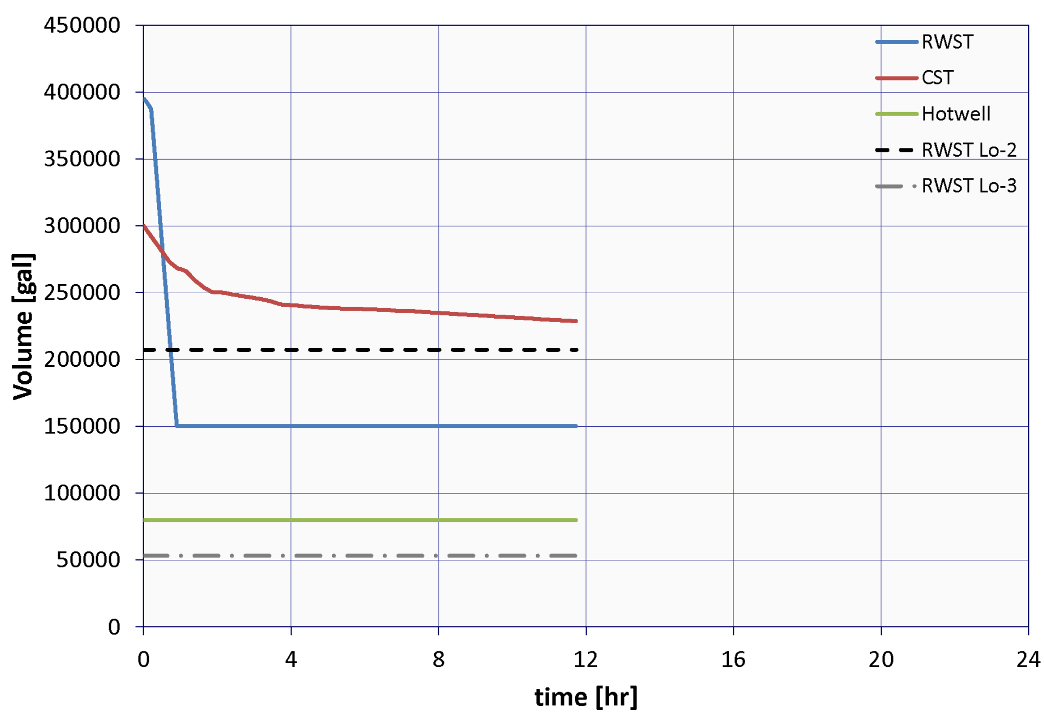

Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
40
45
50
0
4
8
12
16
20
24


Containment Spray Flow Rate [m³/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)


Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

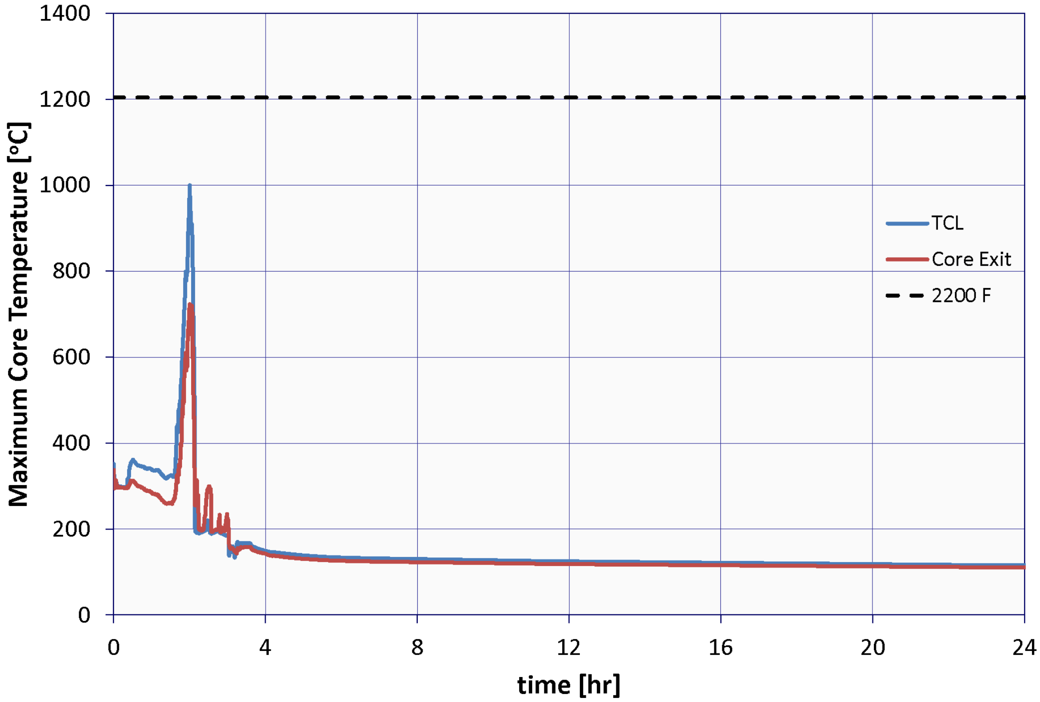


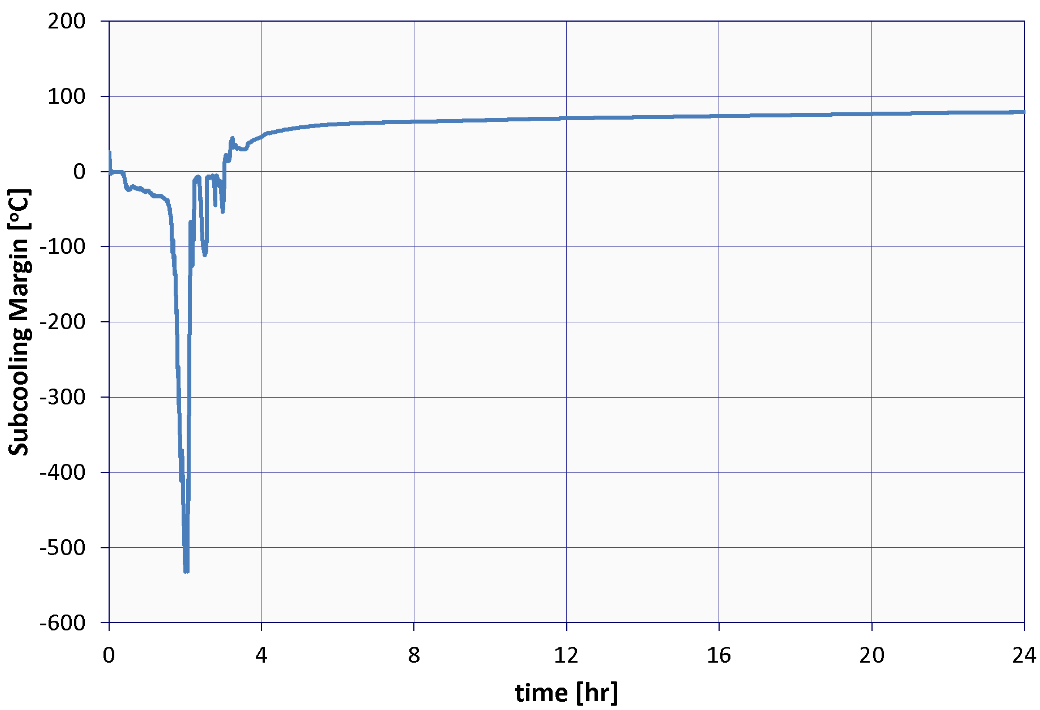
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

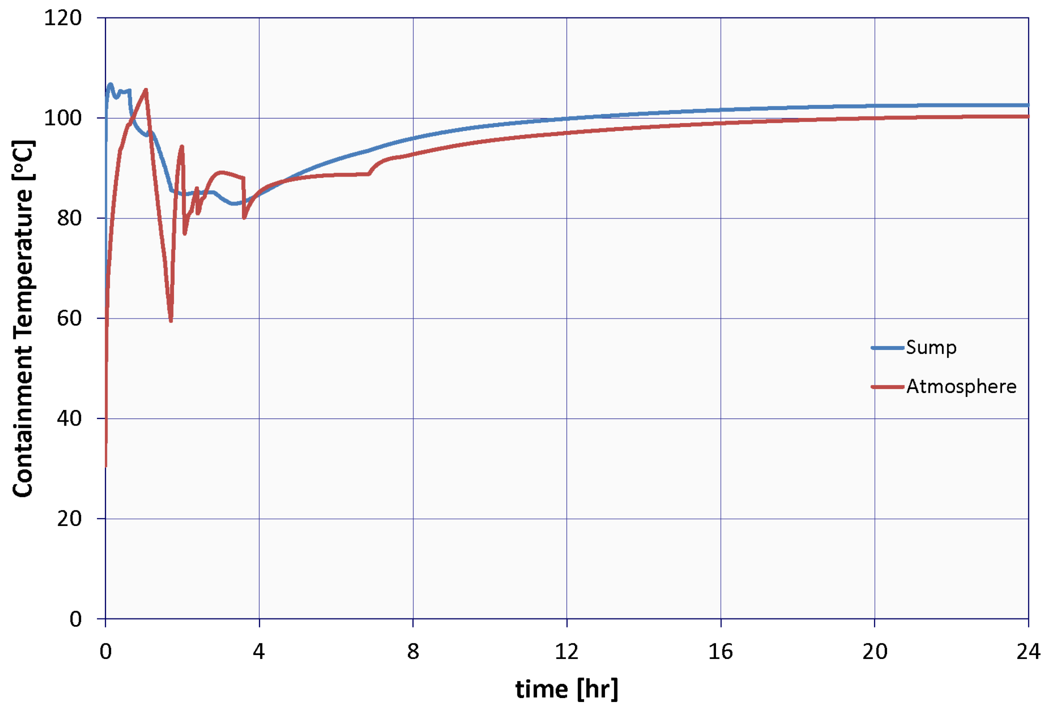


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

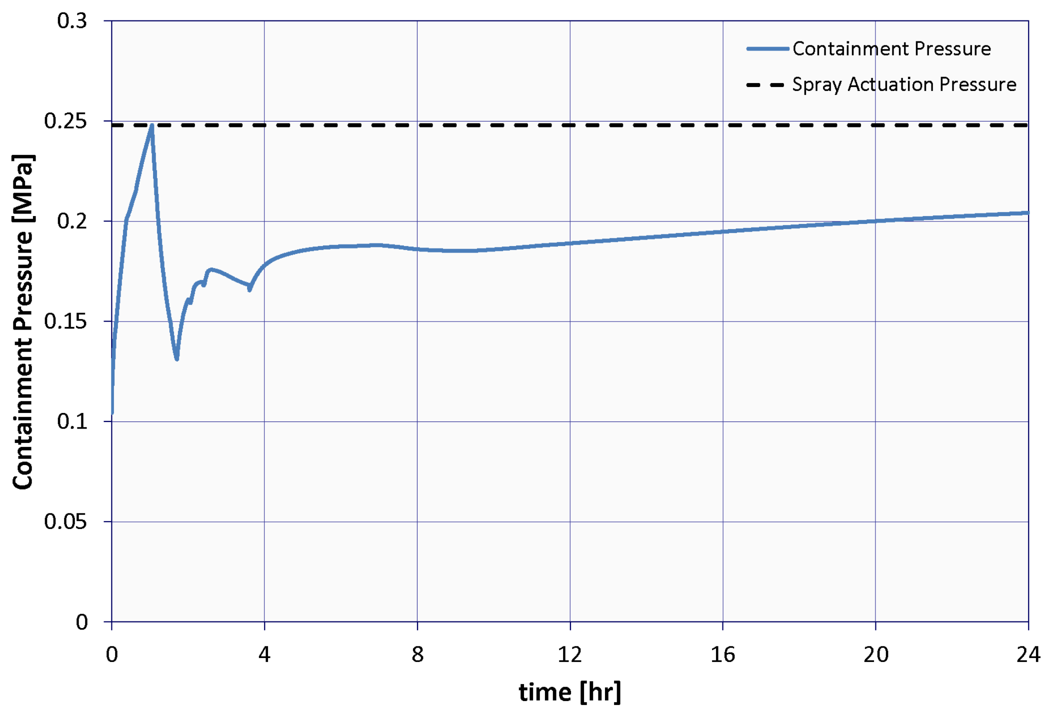
E.2.7 Case 7: 2-in. Break, 100 °F/hr Cooldown at 40 min, 2/2 CS Pumps, 0/4 RCFC



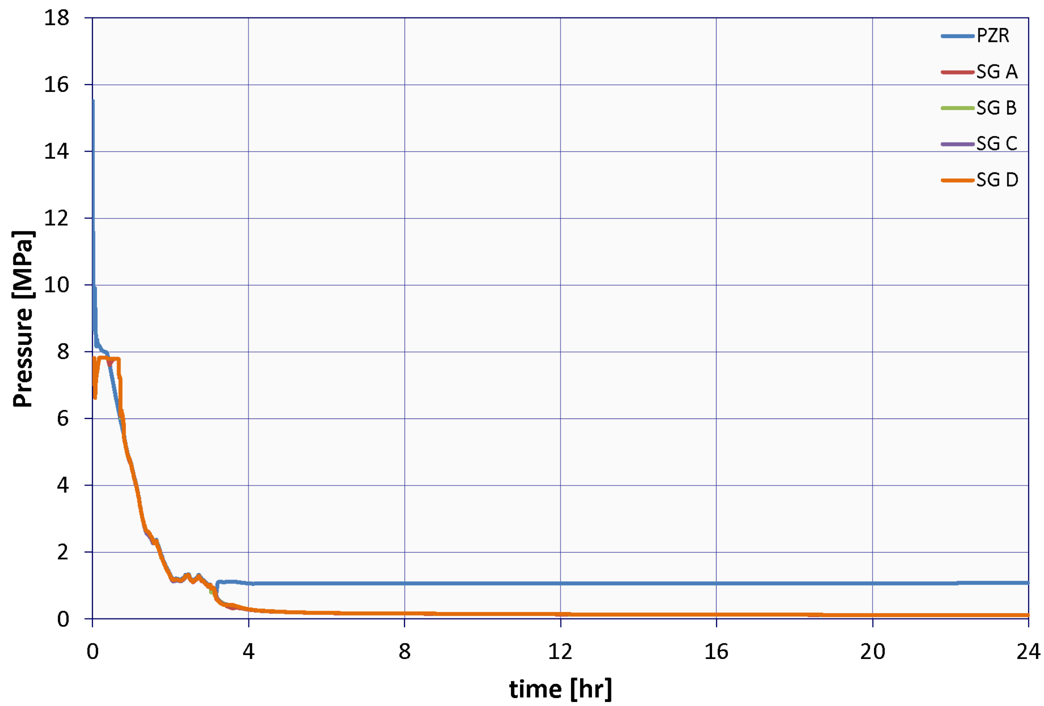


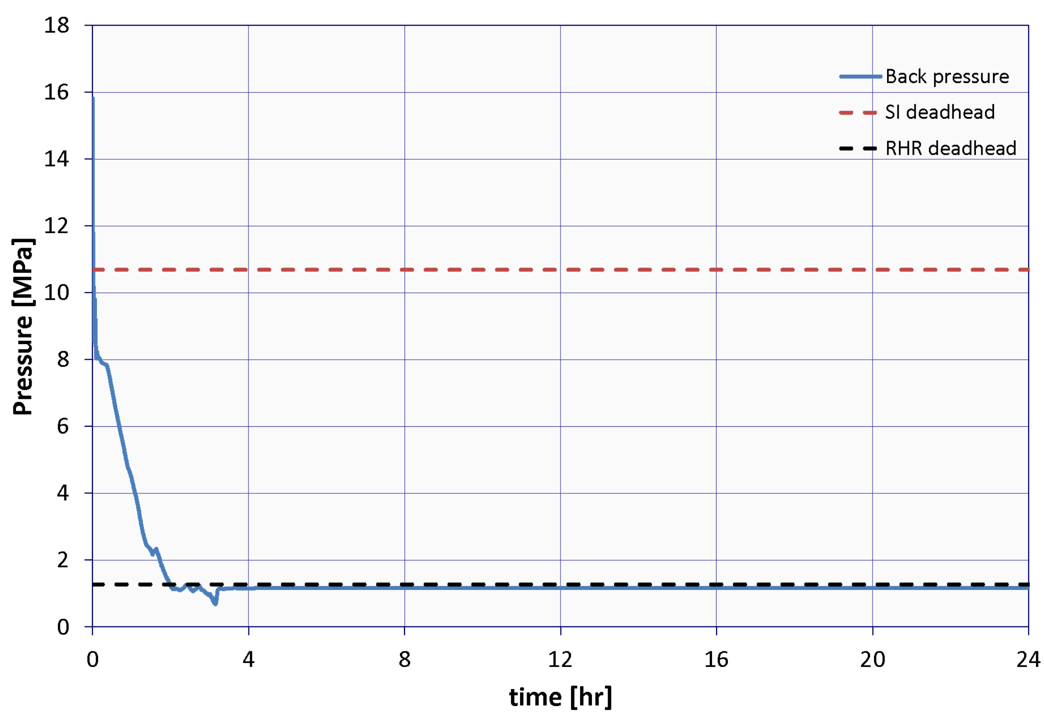


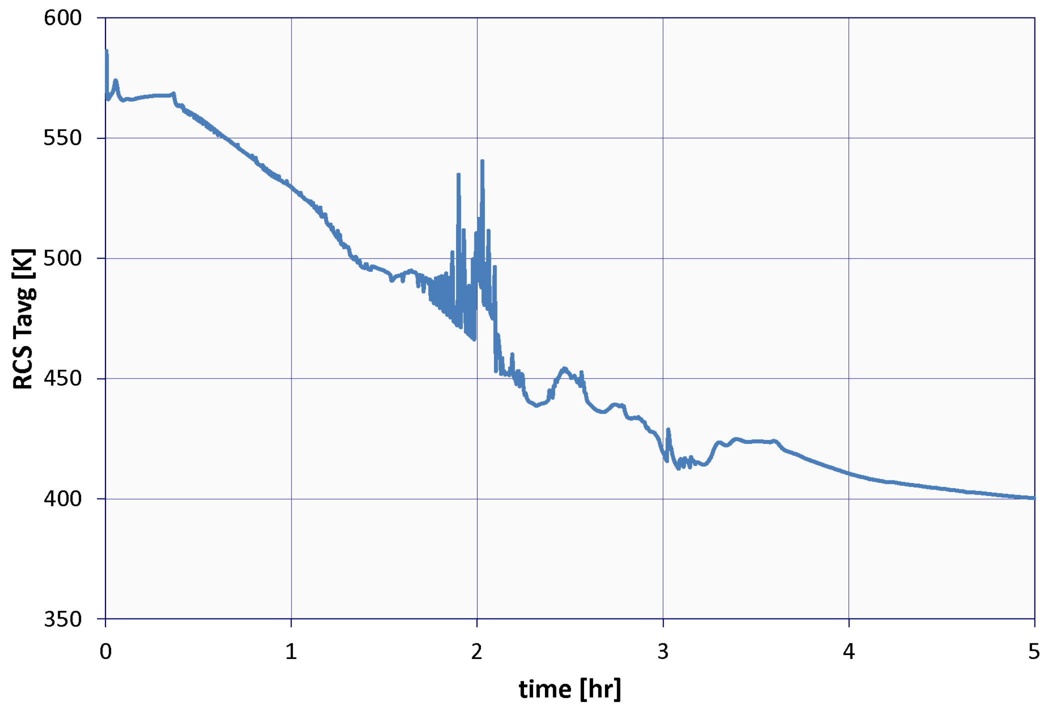
120
100
80
60
40
20
0
Containment Temperature [°C]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere

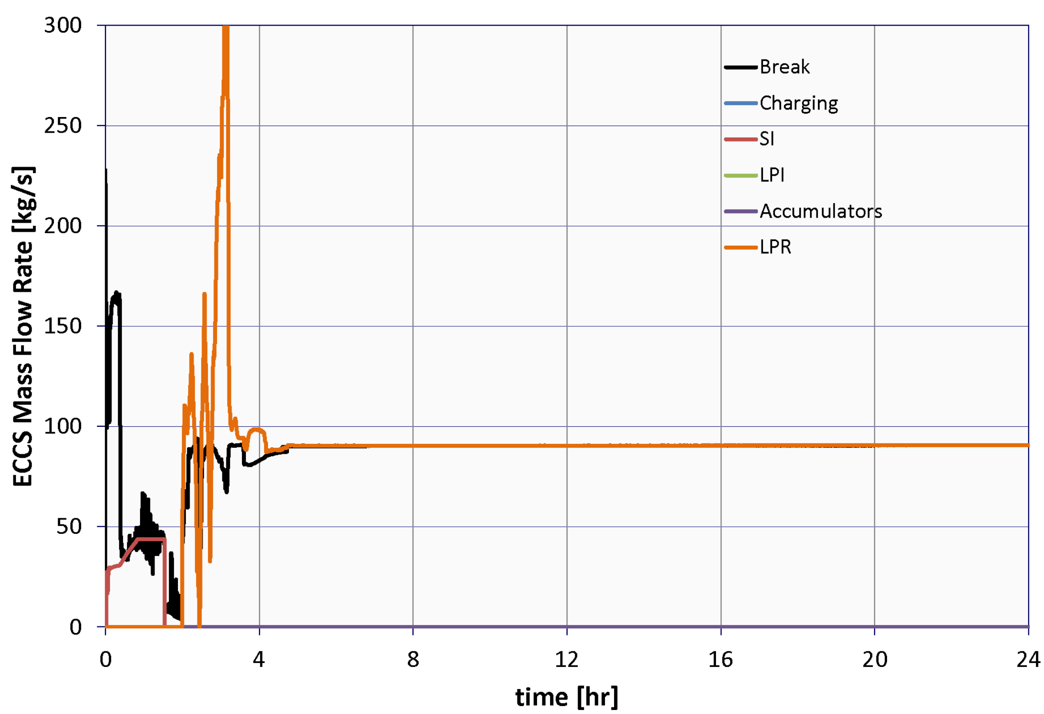


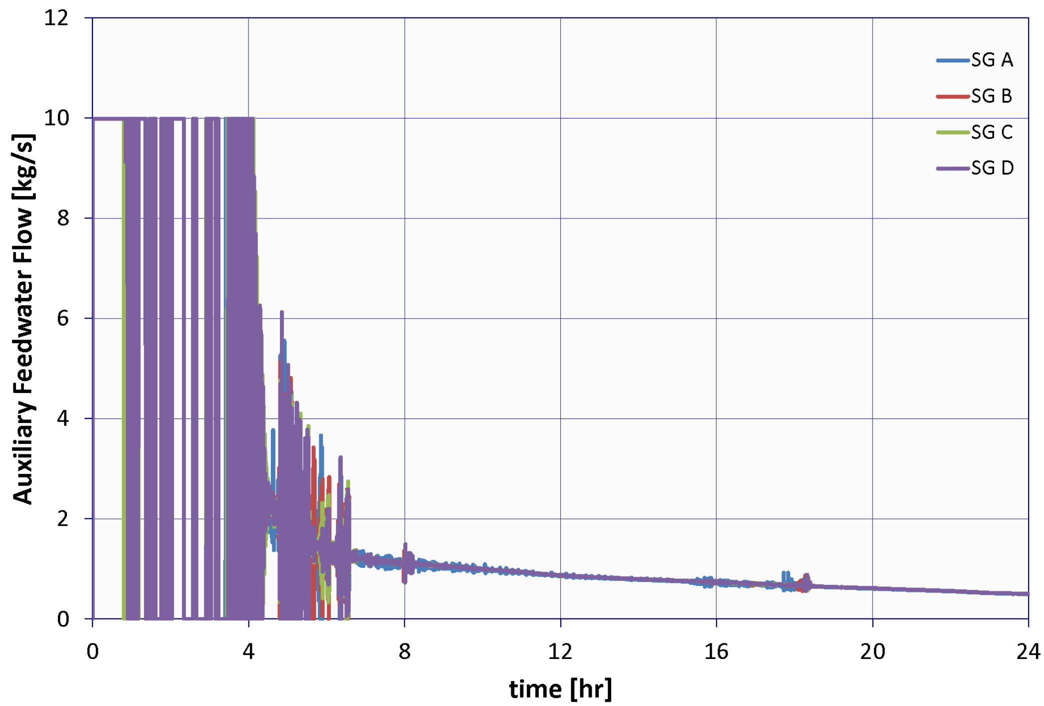
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure


Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D

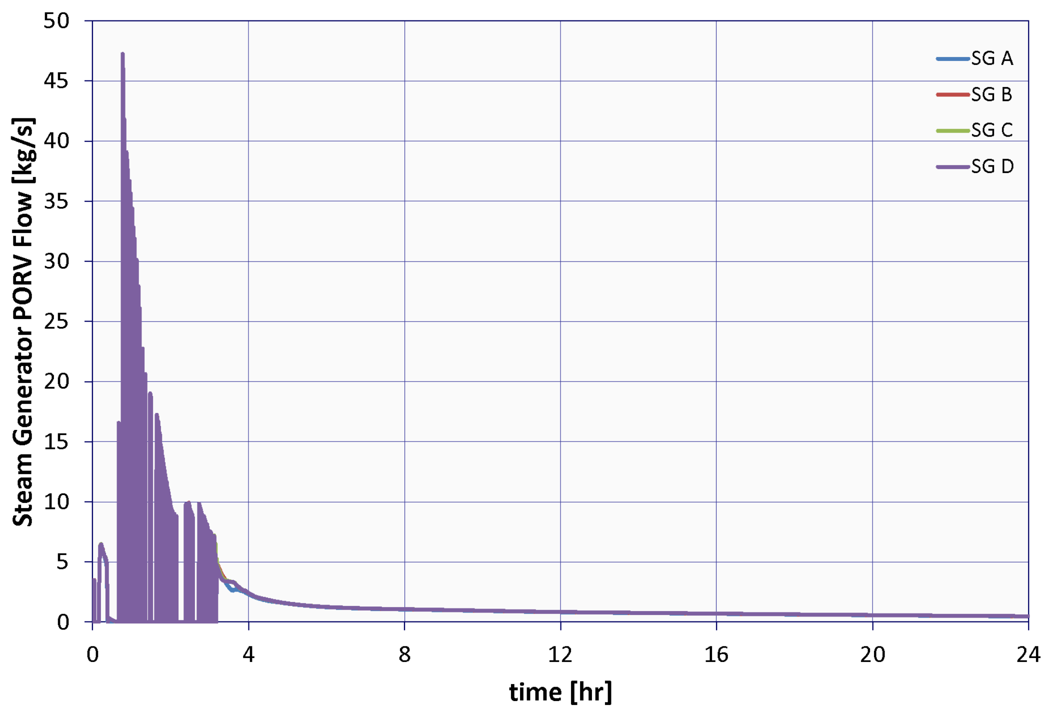

Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead


RCS Tavg [K]
600
550
500
450
400
350
0
1
2
3
4
5
time [hr]

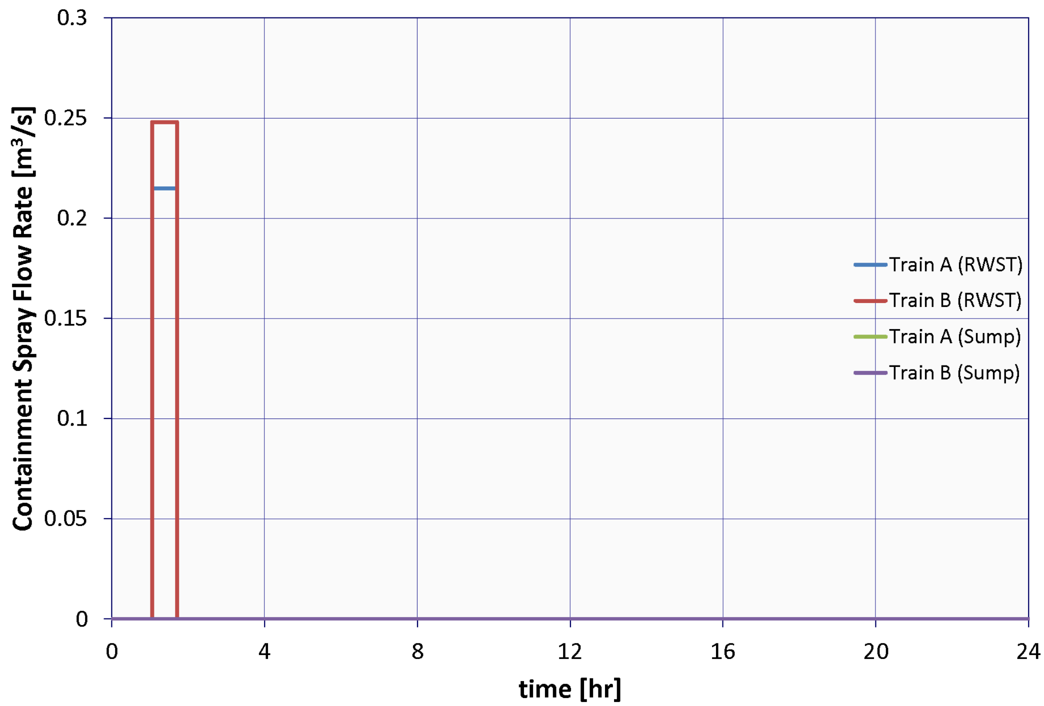

ECCS Mass Flow Rate [kg/s]
300
250
200
150
100
50
0
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

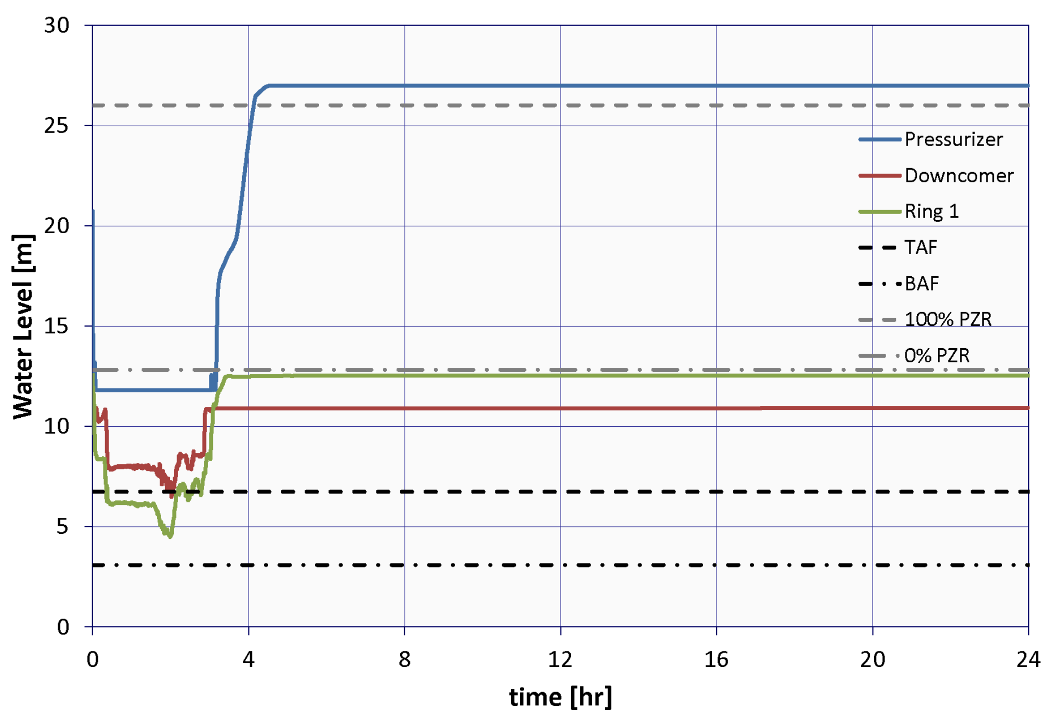


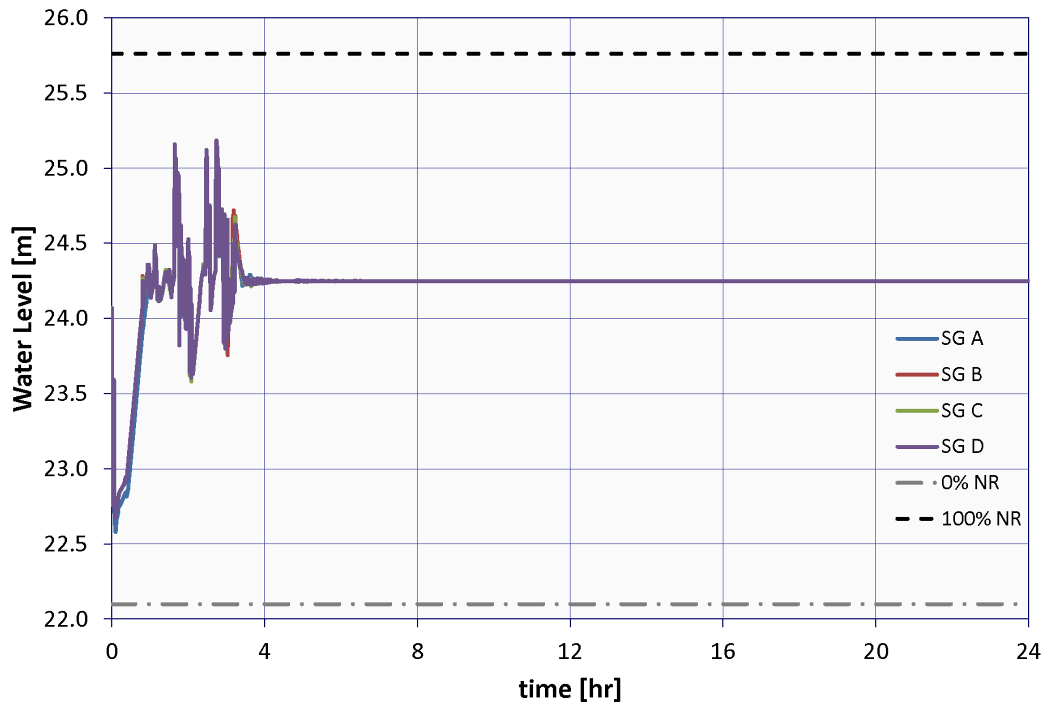
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24



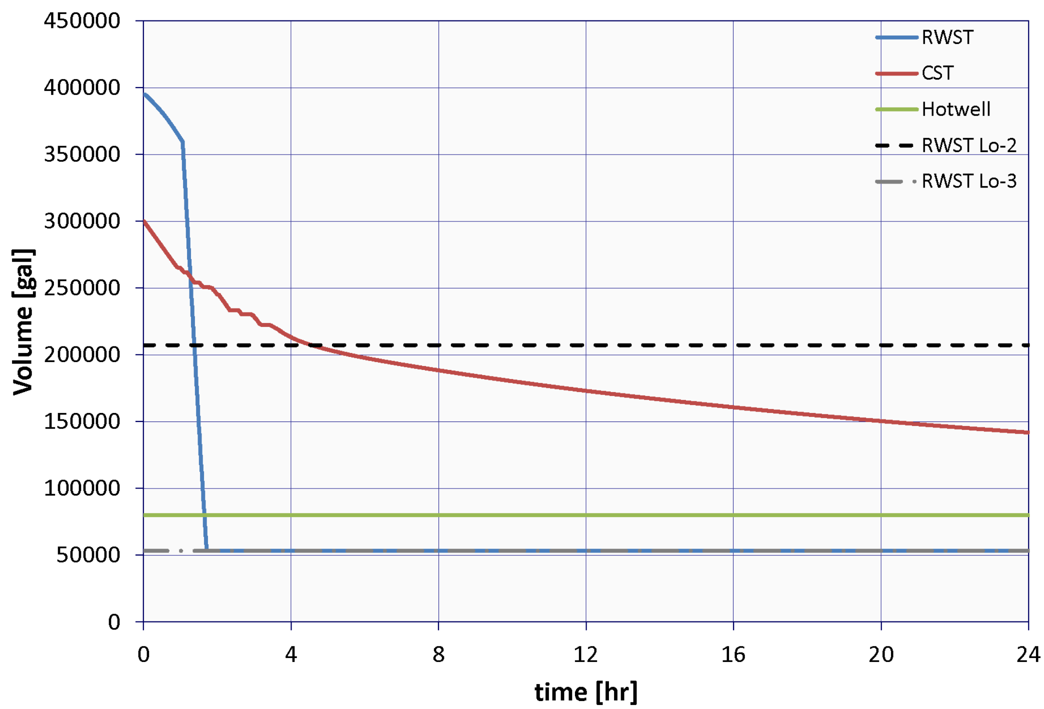
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
40
45
50
0
4
8
12
16
20
24


Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)


Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

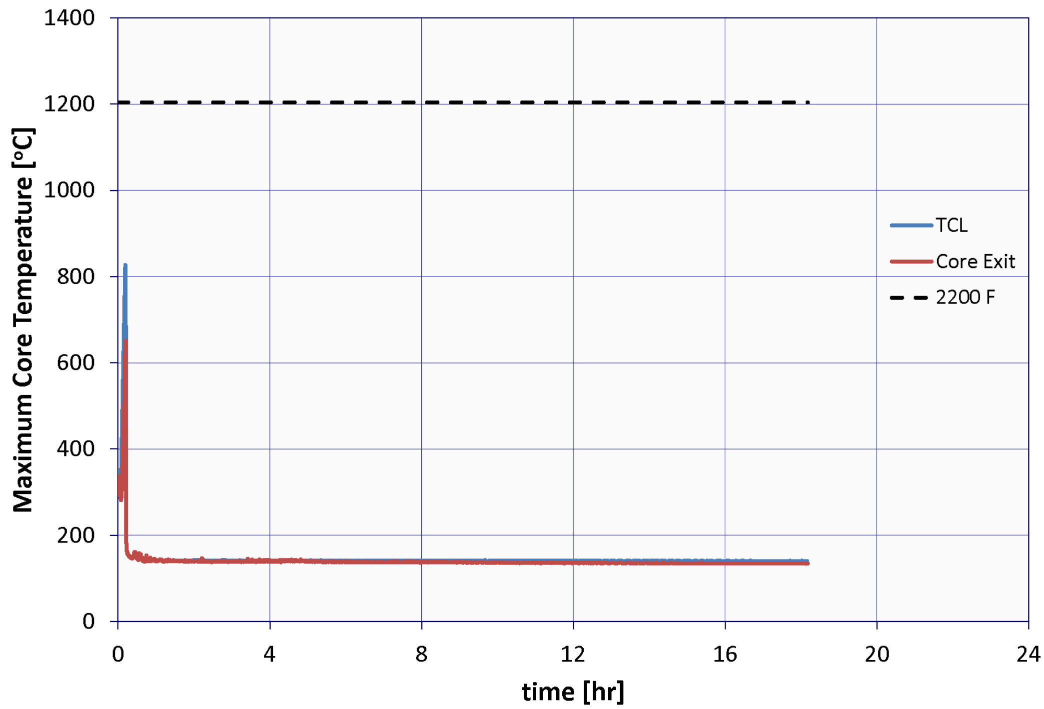


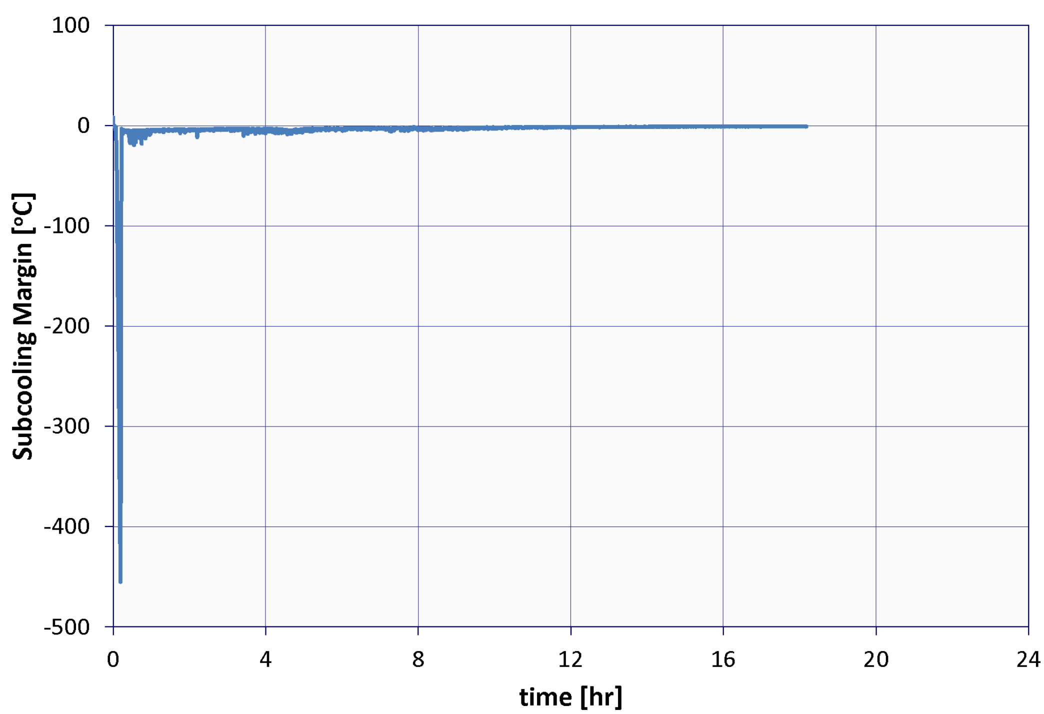
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

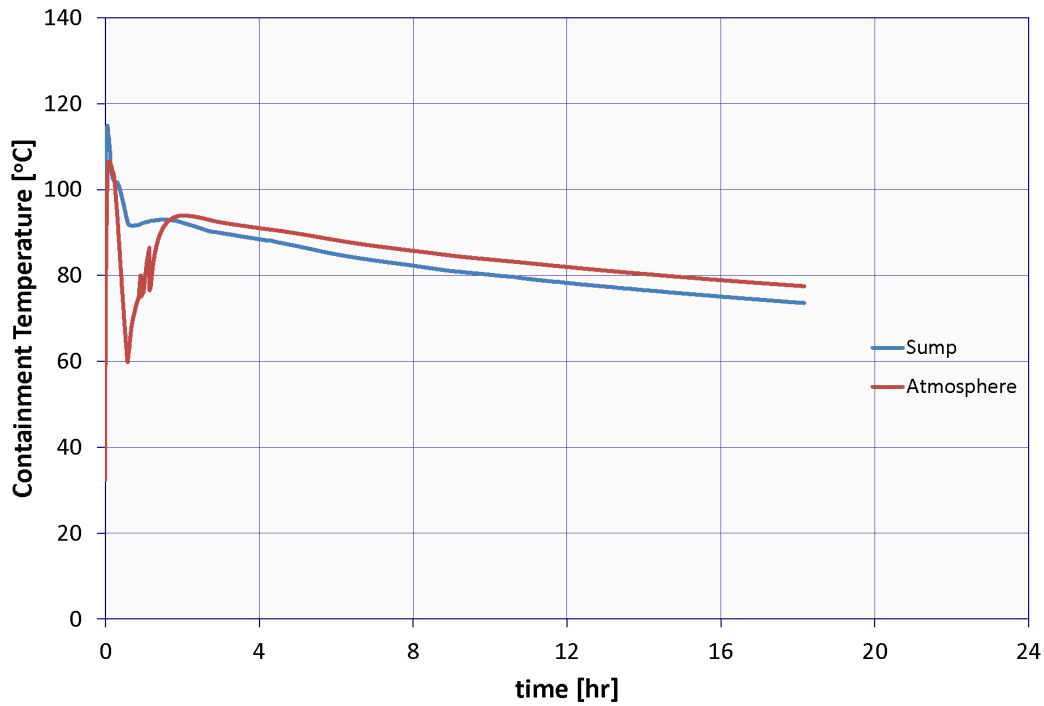


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

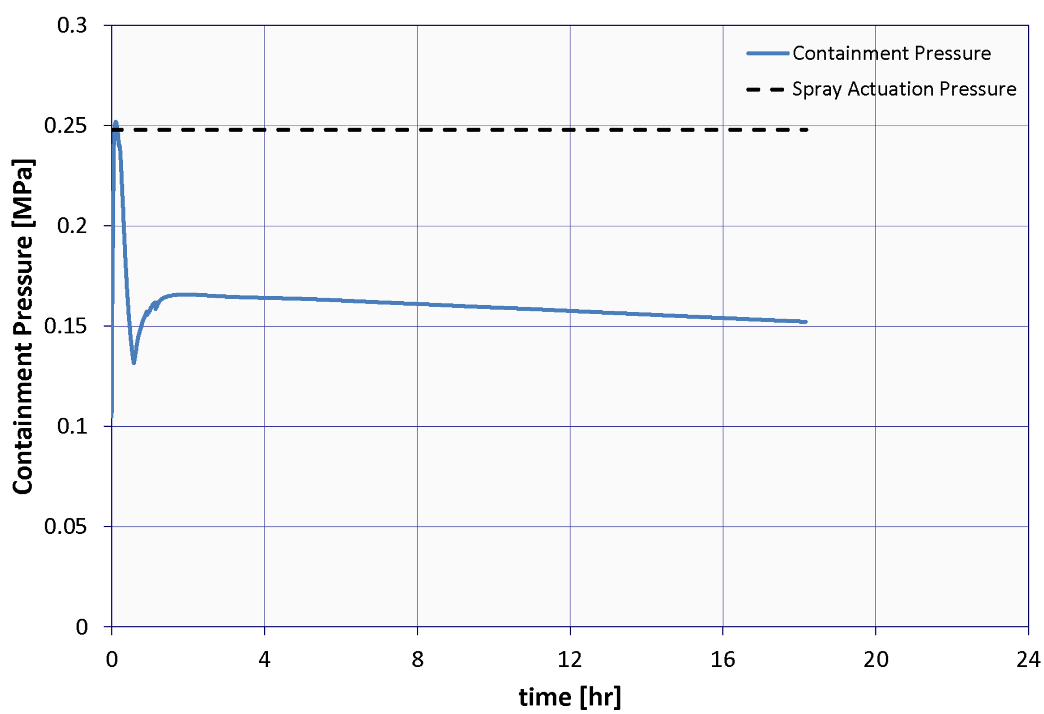
E.2.8 Case 8: 6-in. Break, 100 °F/hr Cooldown at 40 min, 2/2 CS Pumps, 0/4 RCFC



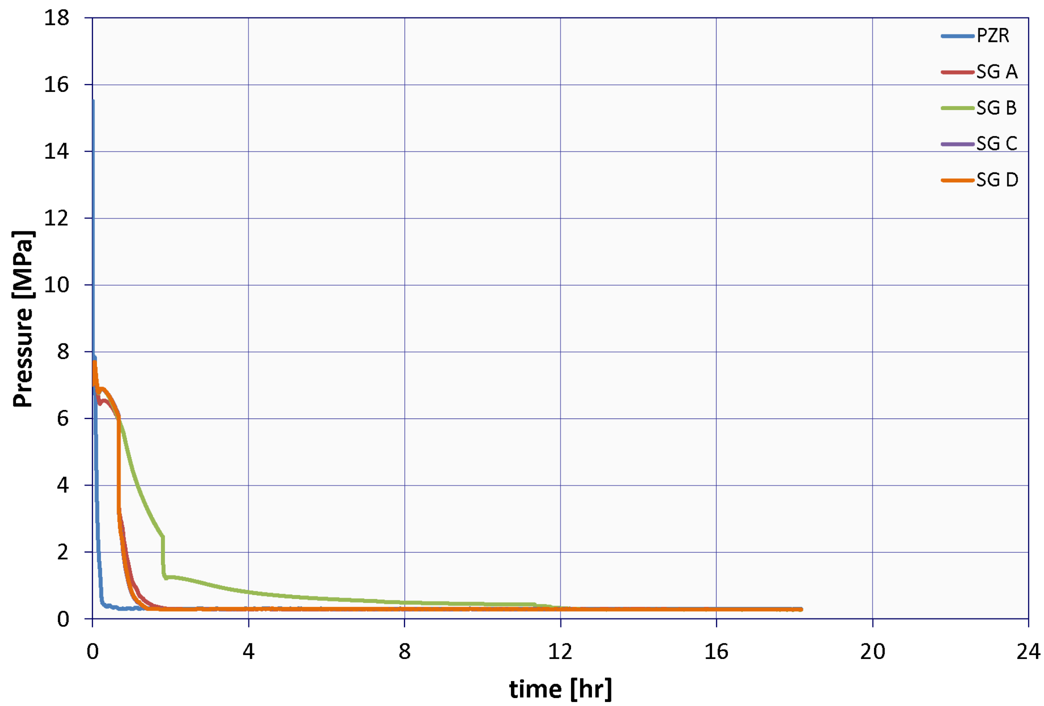




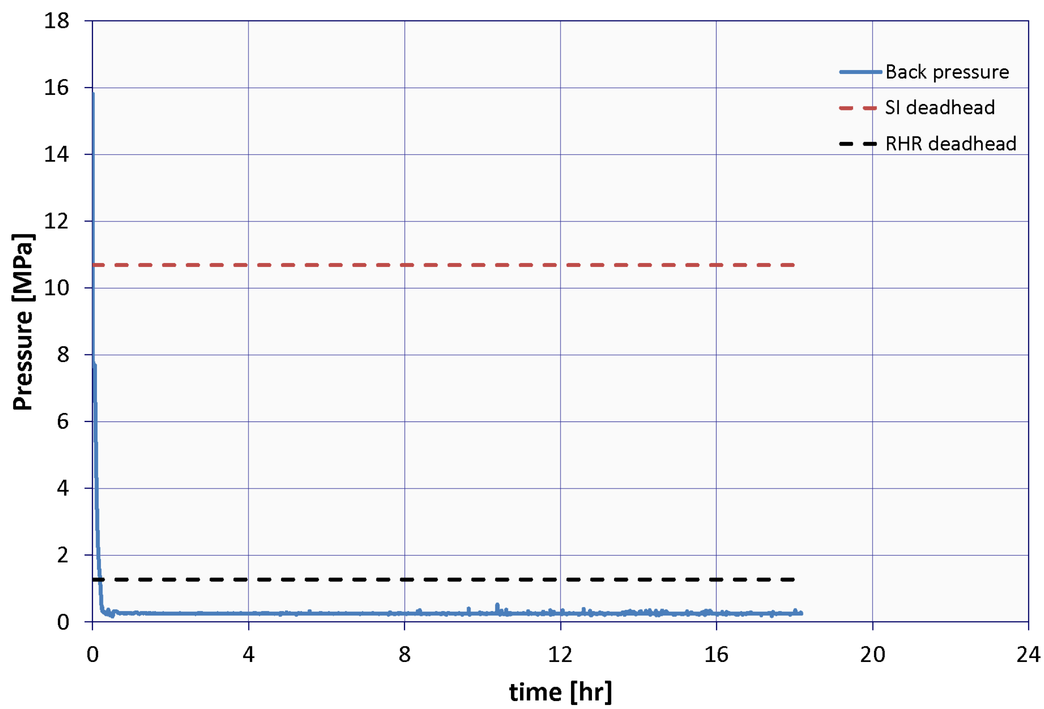
Containment Temperature [°C]
time [hr]
Sump
Atmosphere
0
20
40
60
80
100
120
140
0
4
8
12
16
20
24



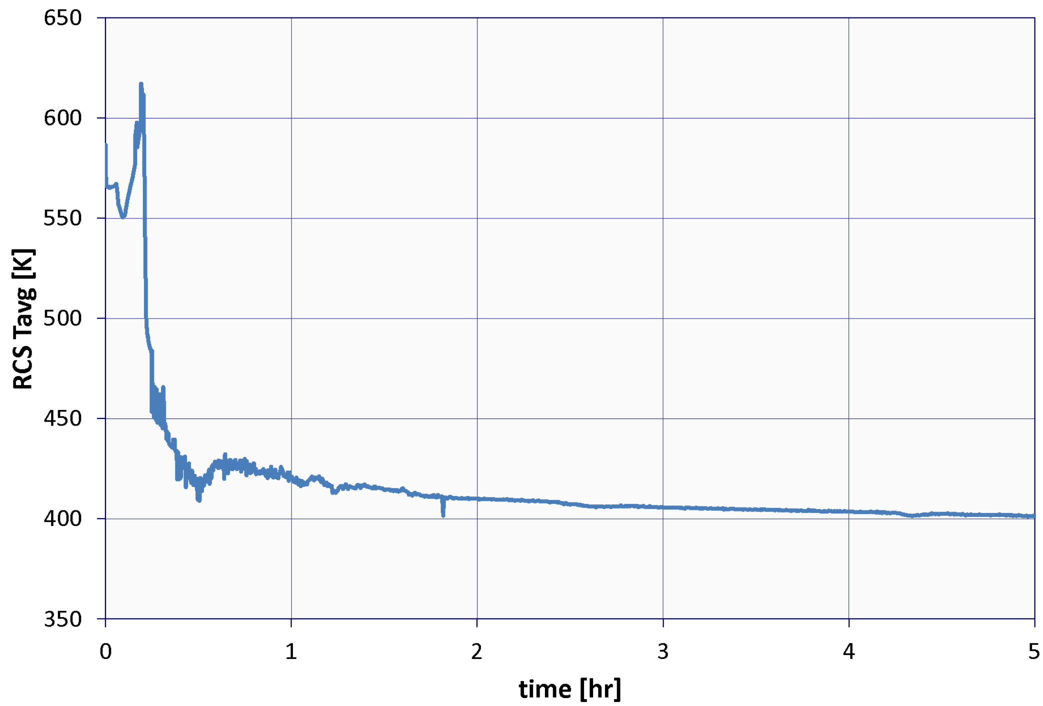
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24



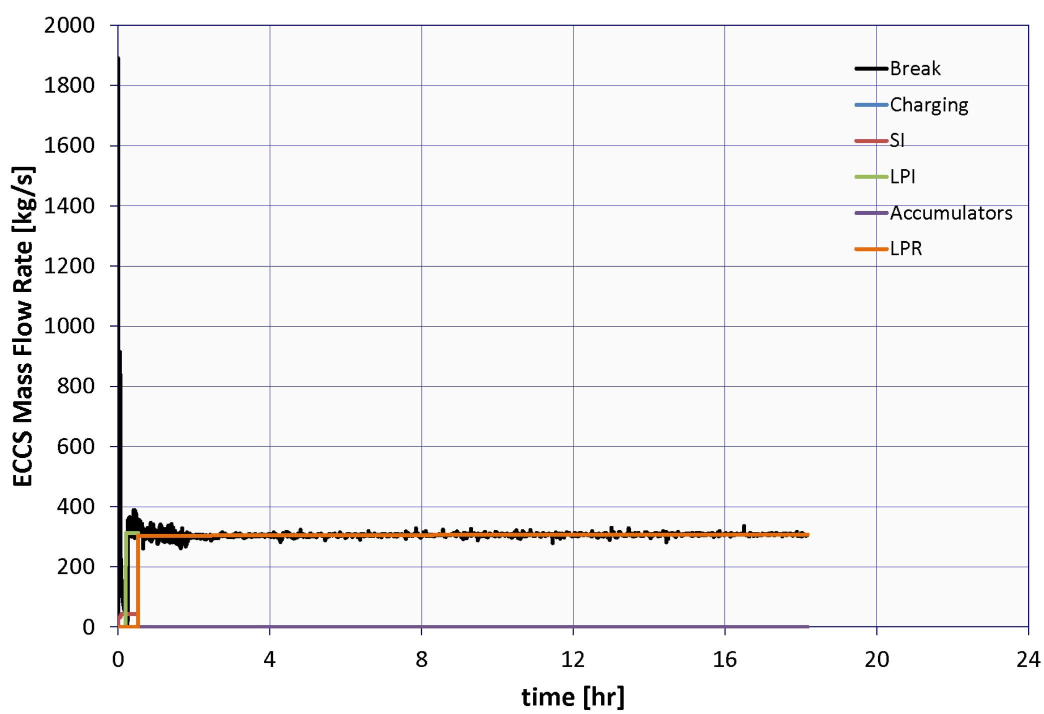
PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]



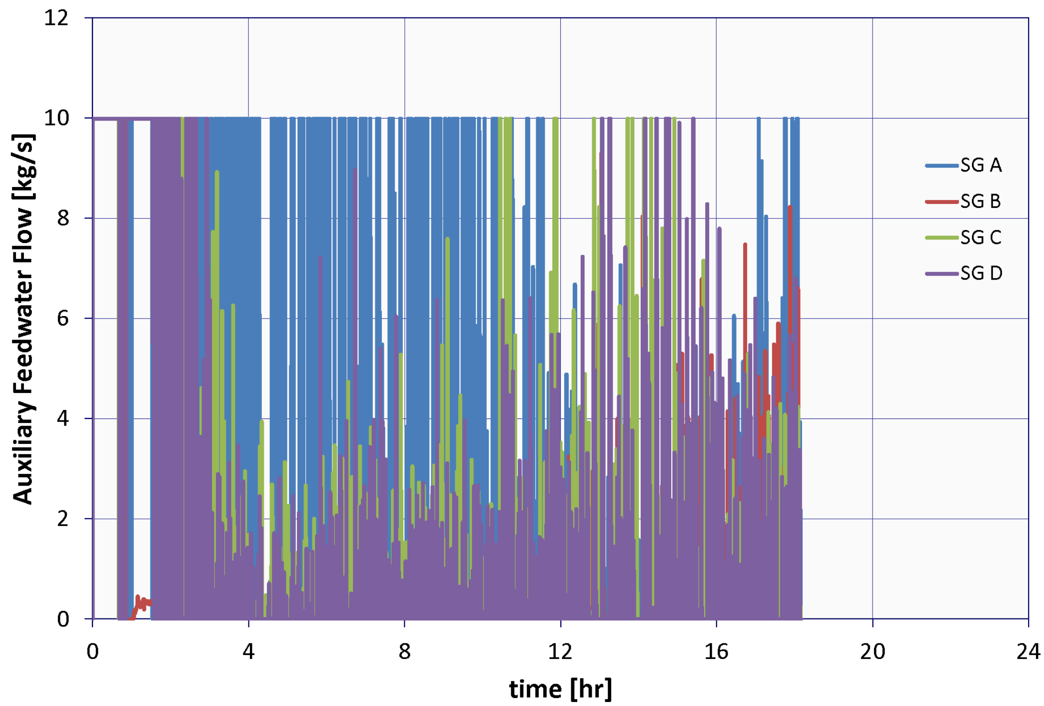
Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]



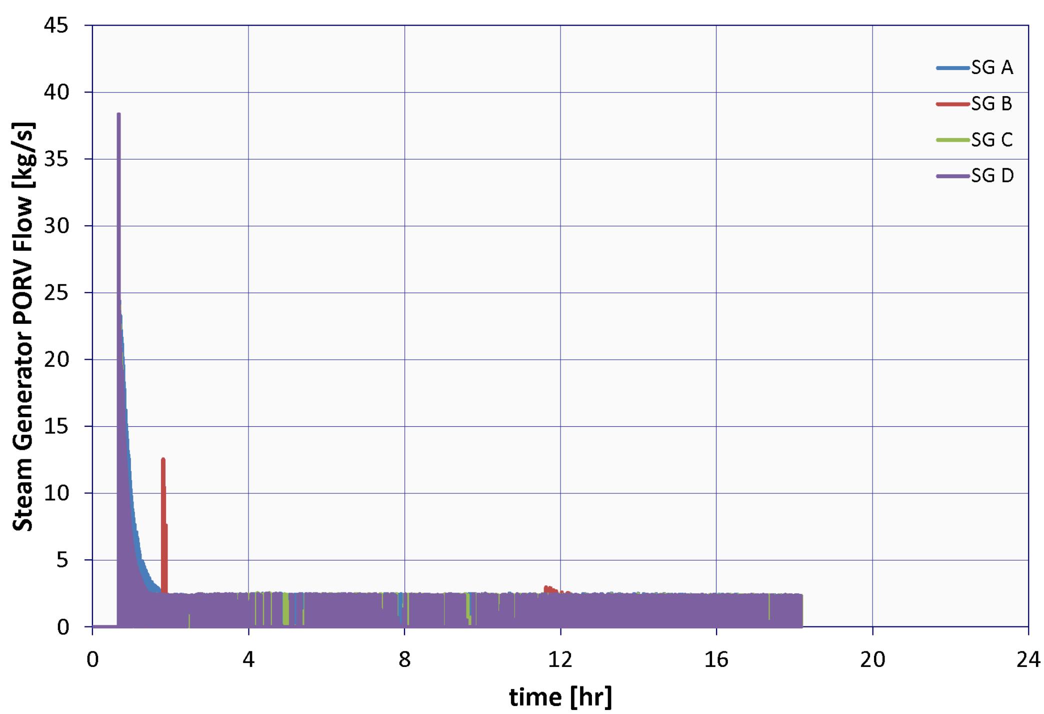
650
600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]



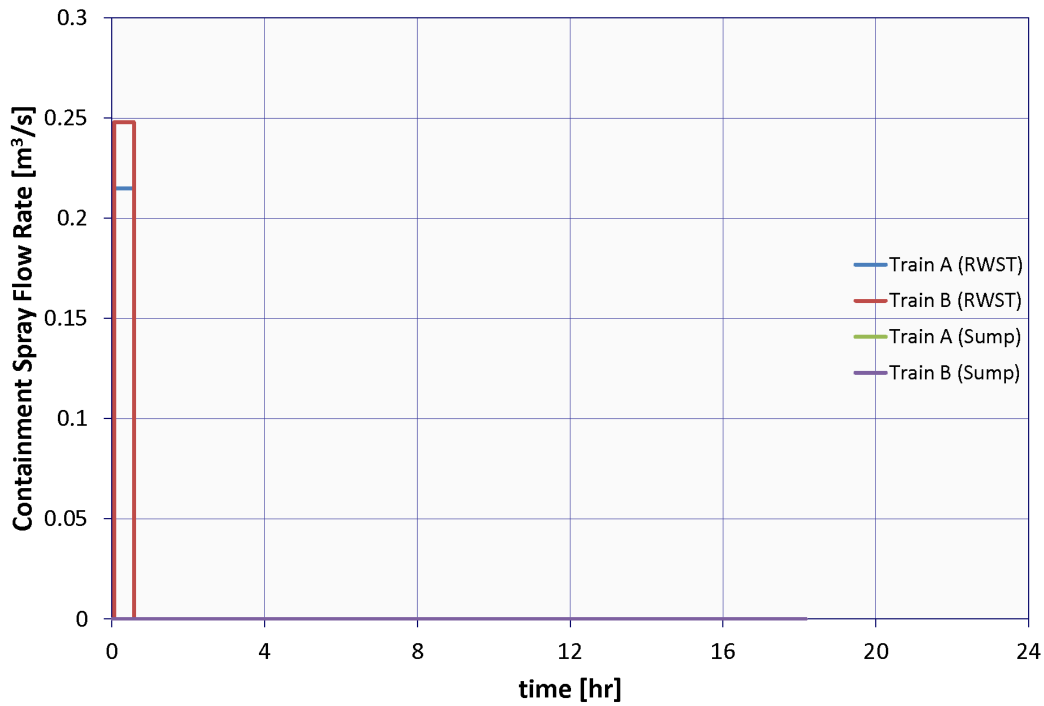
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
Break
Charging
SI
LPI
Accumulators
LPR
0
4
8
12
16
20
24
time [hr]



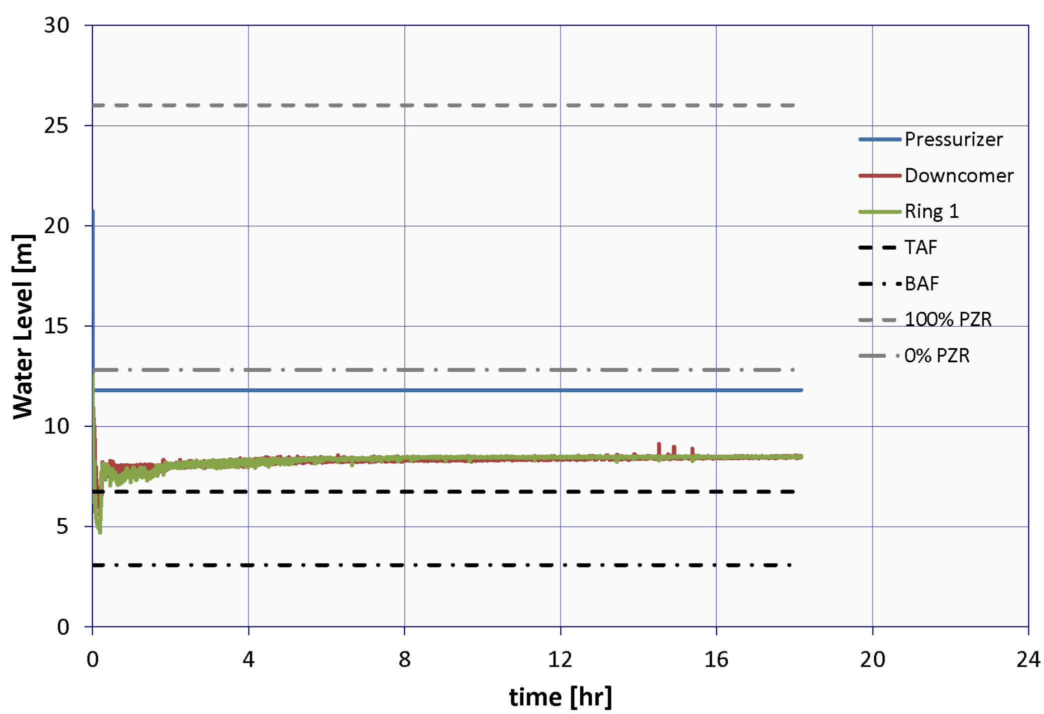
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D



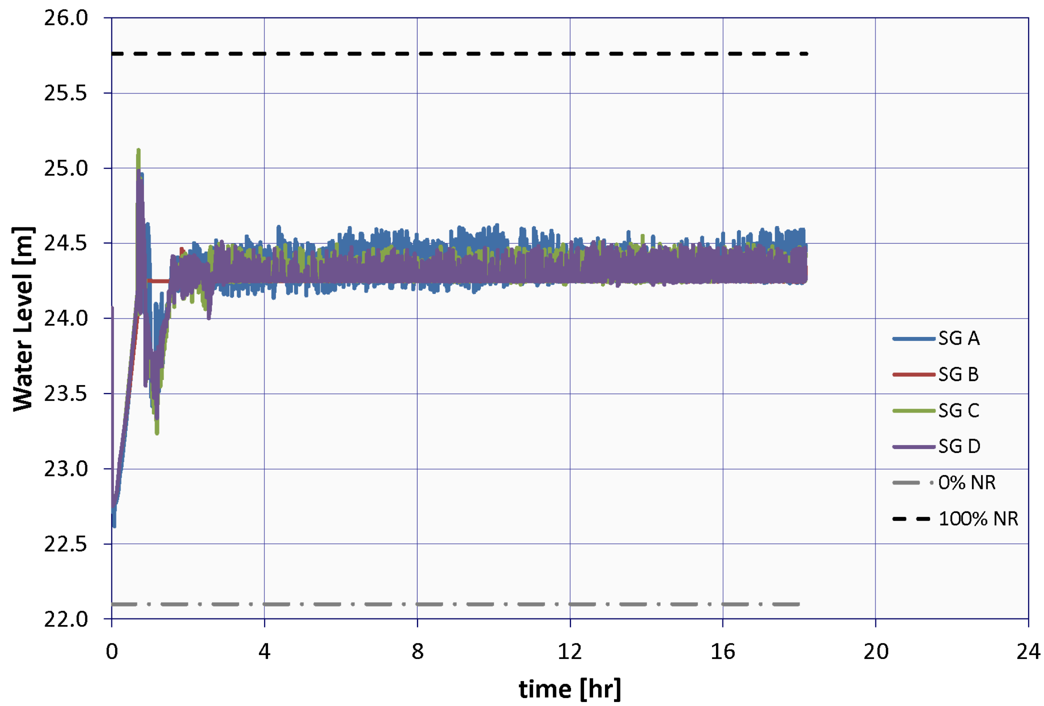
Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D

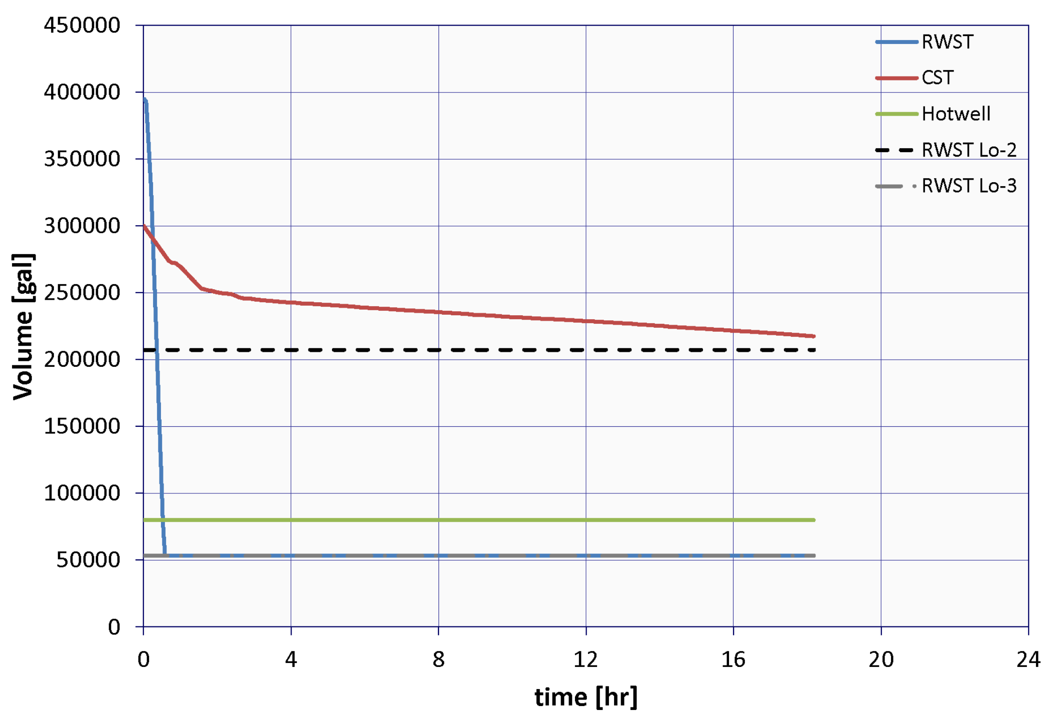


Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

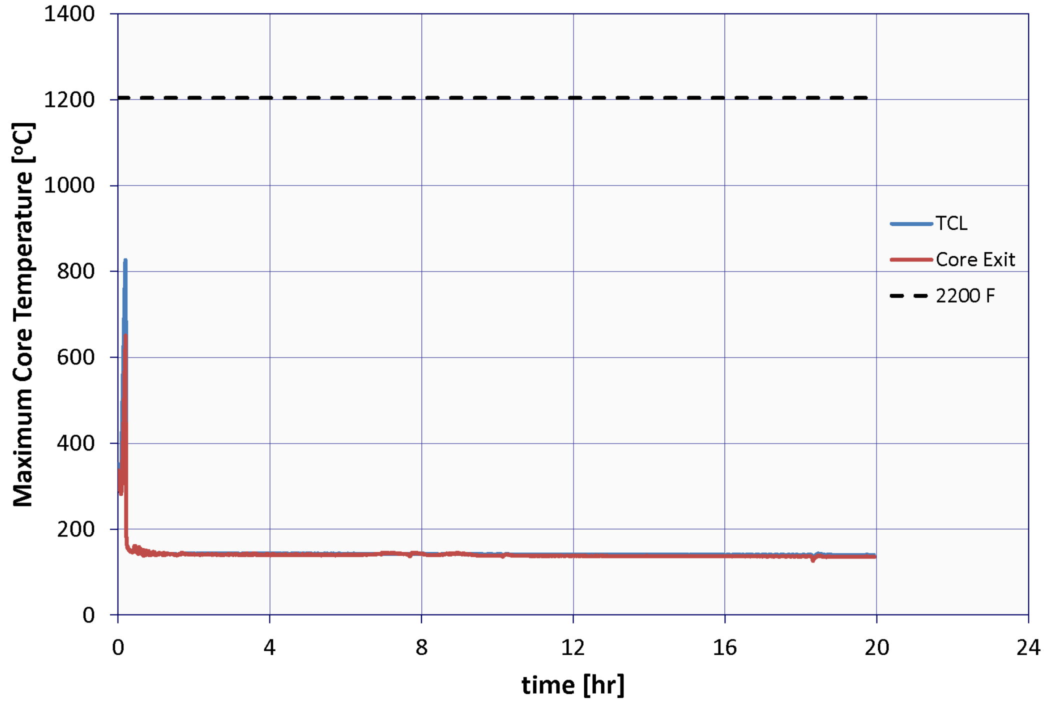


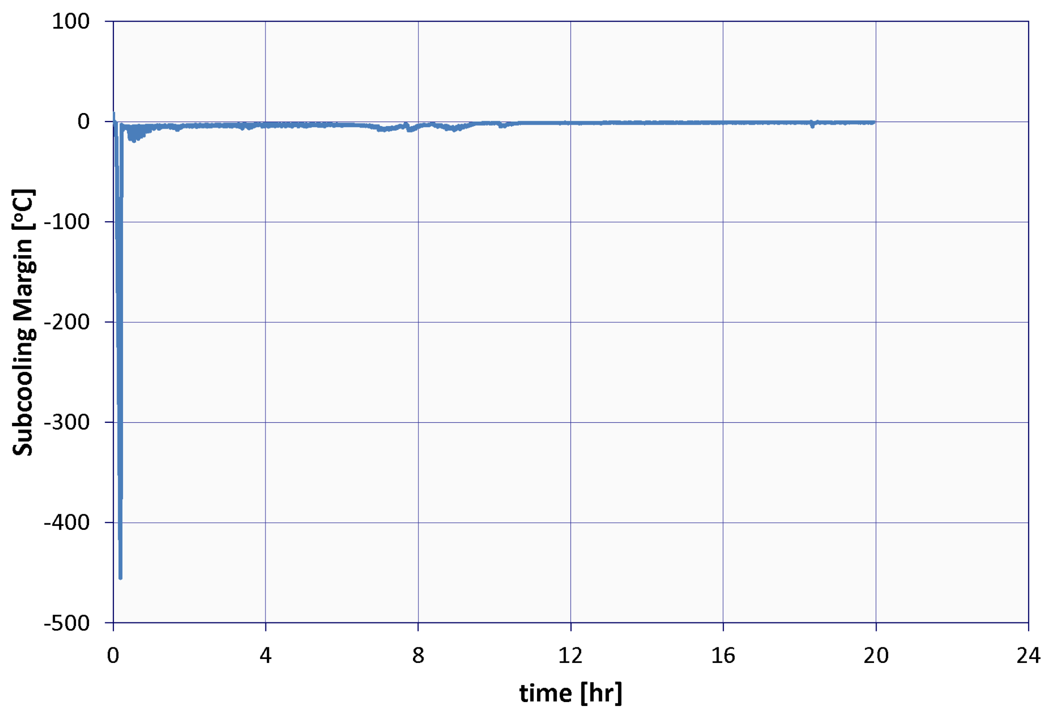
Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

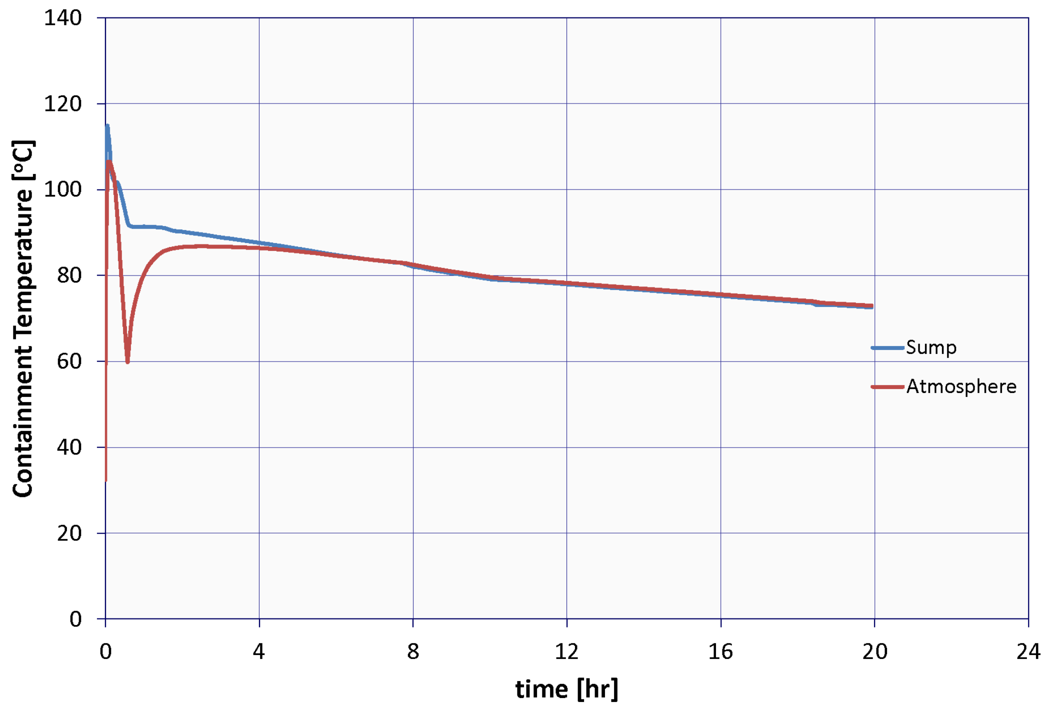

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

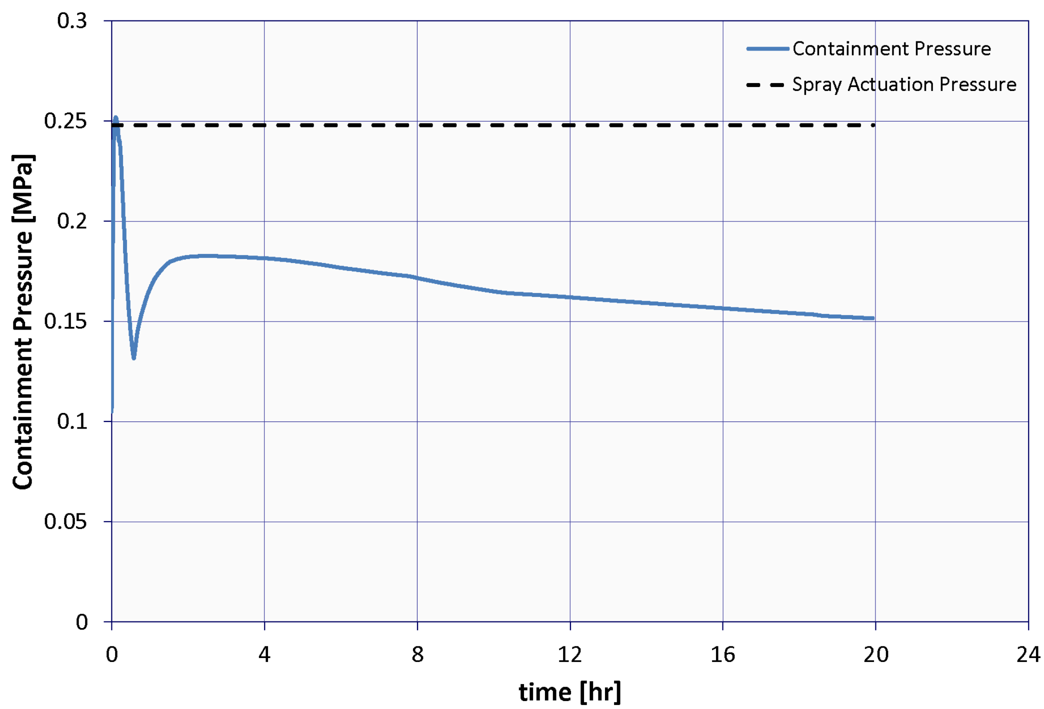
E.2.8.1 *Case 8a: 6-in. Break, 100 °F/hr Cooldown at 40 min, 2/2 CS Pumps, 0/4 RCFC, CS Recirc*



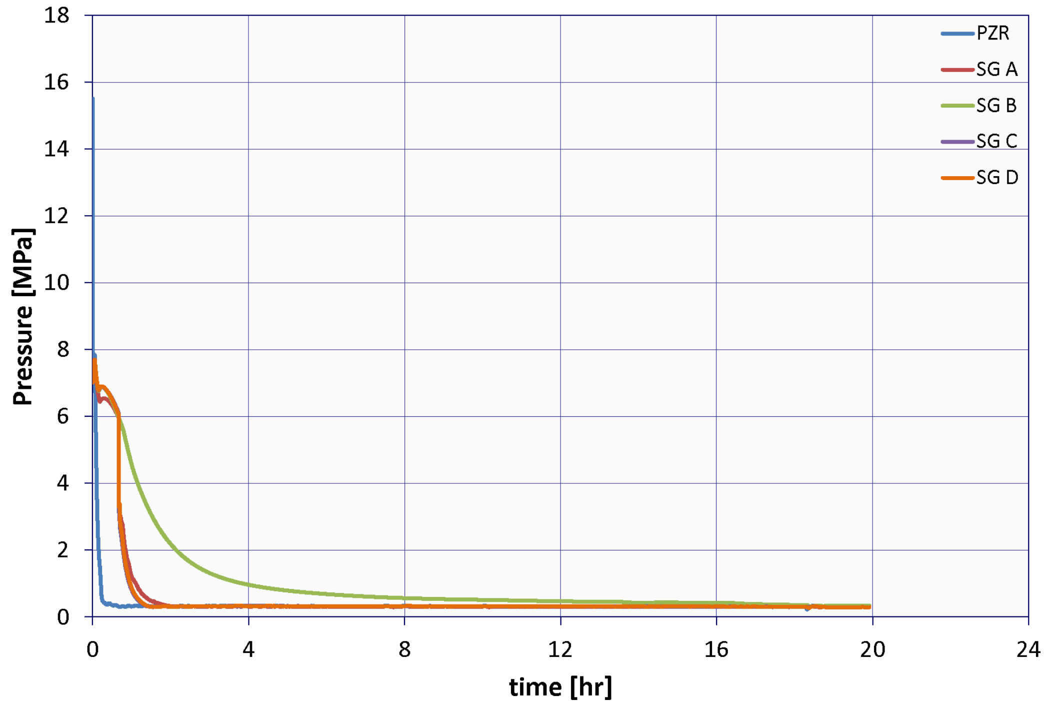


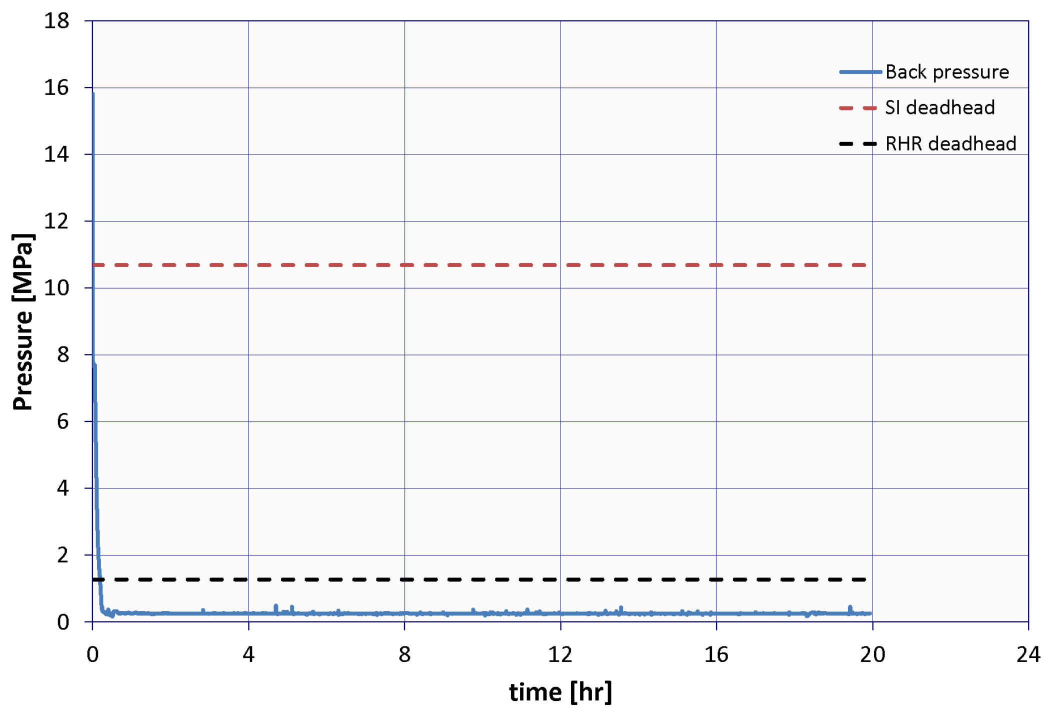


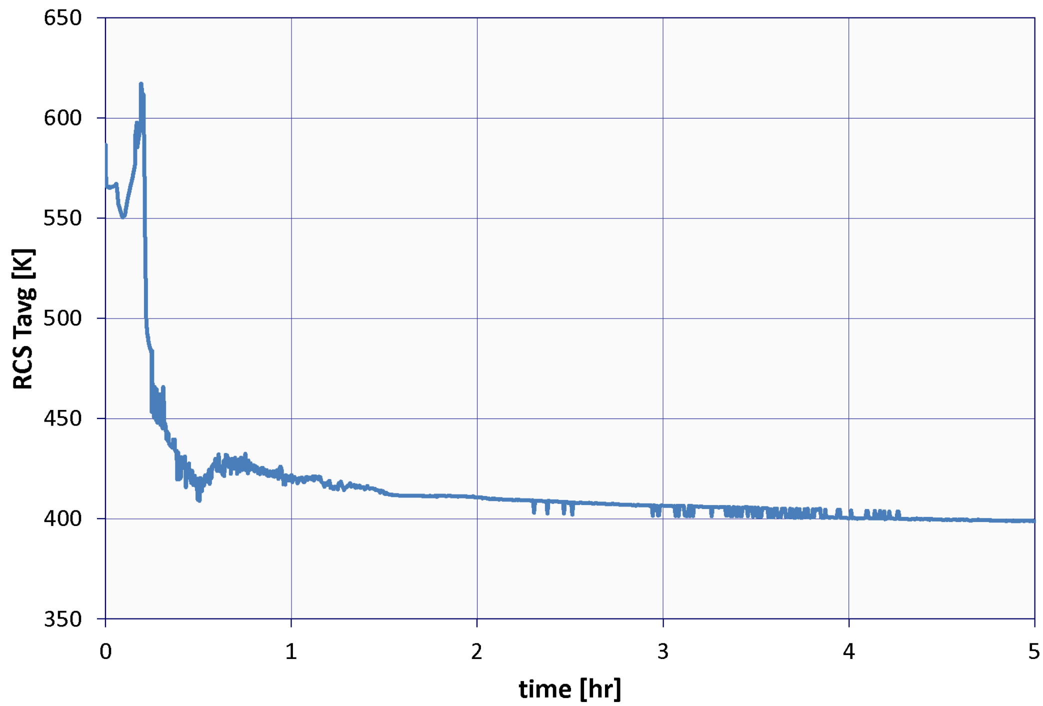
140
120
100
80
60
40
20
0
Containment Temperature [°C]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



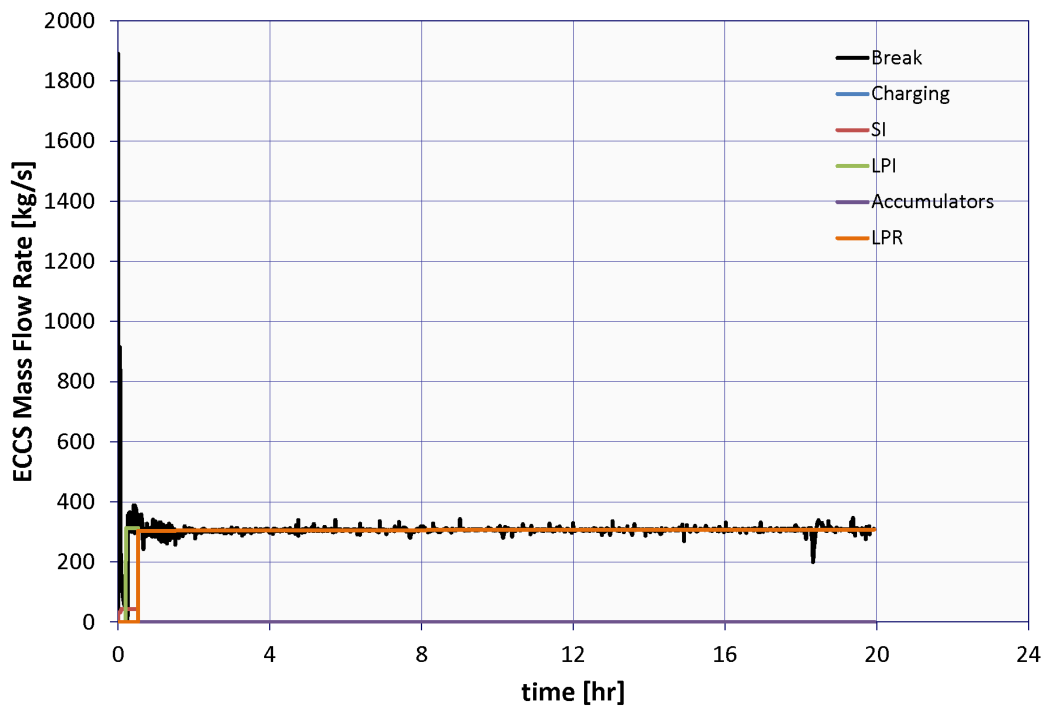
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure


PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
20
24

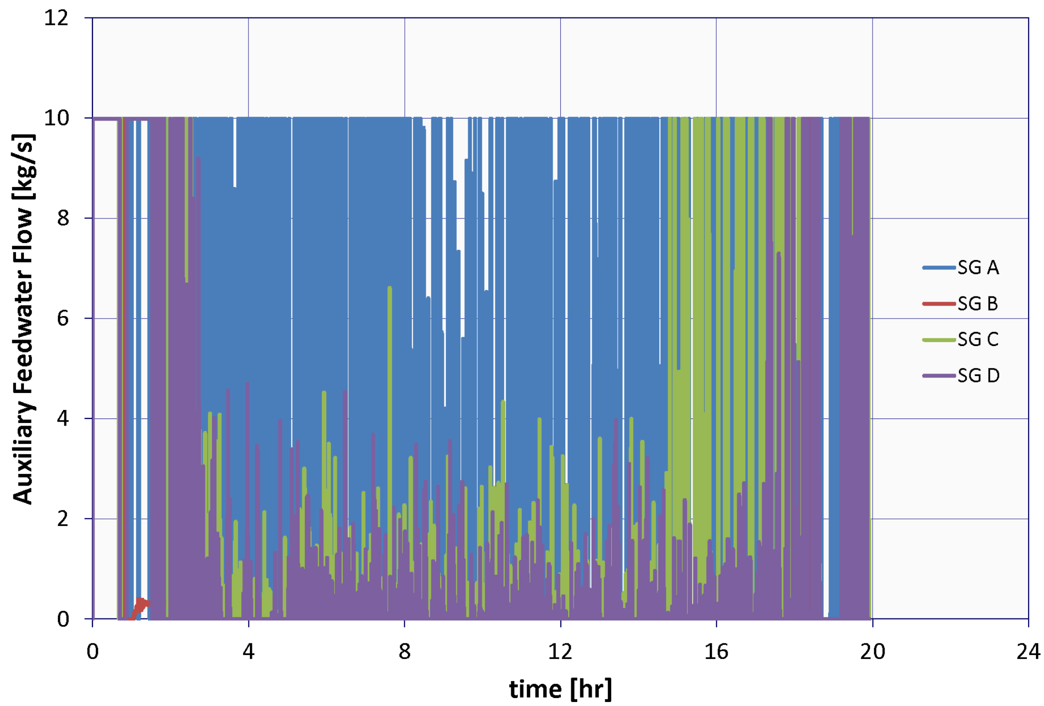

Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
20
24

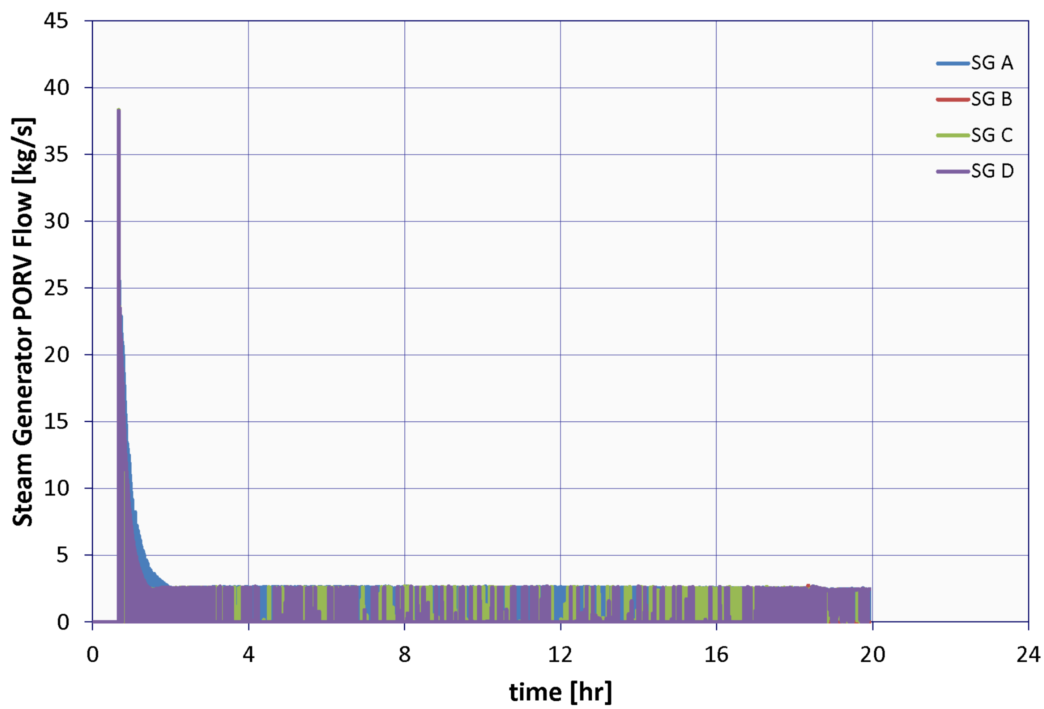


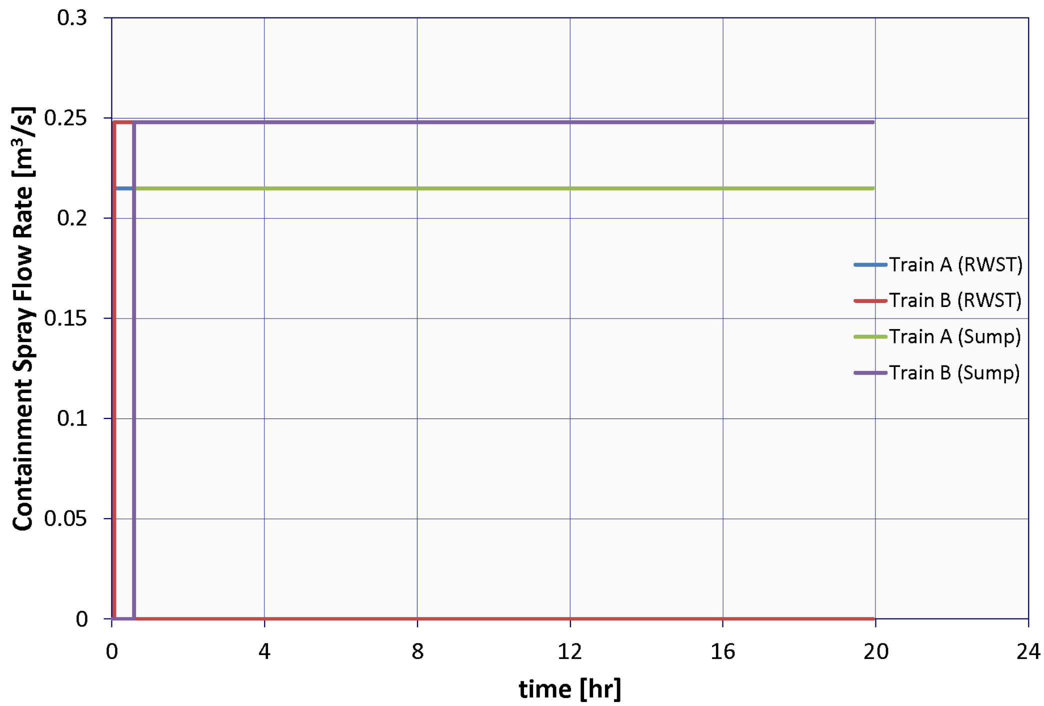
650
600
550
500
450
400
350
RCS Tavg [K]
0
1
2
3
4
5
time [hr]



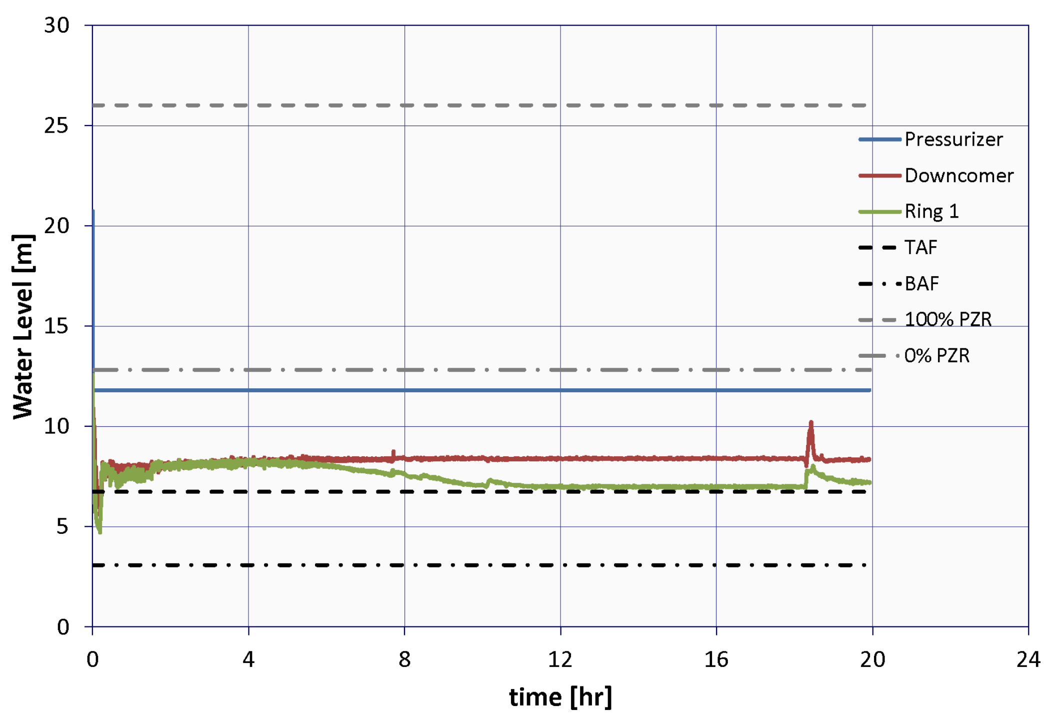
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ECCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR


Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

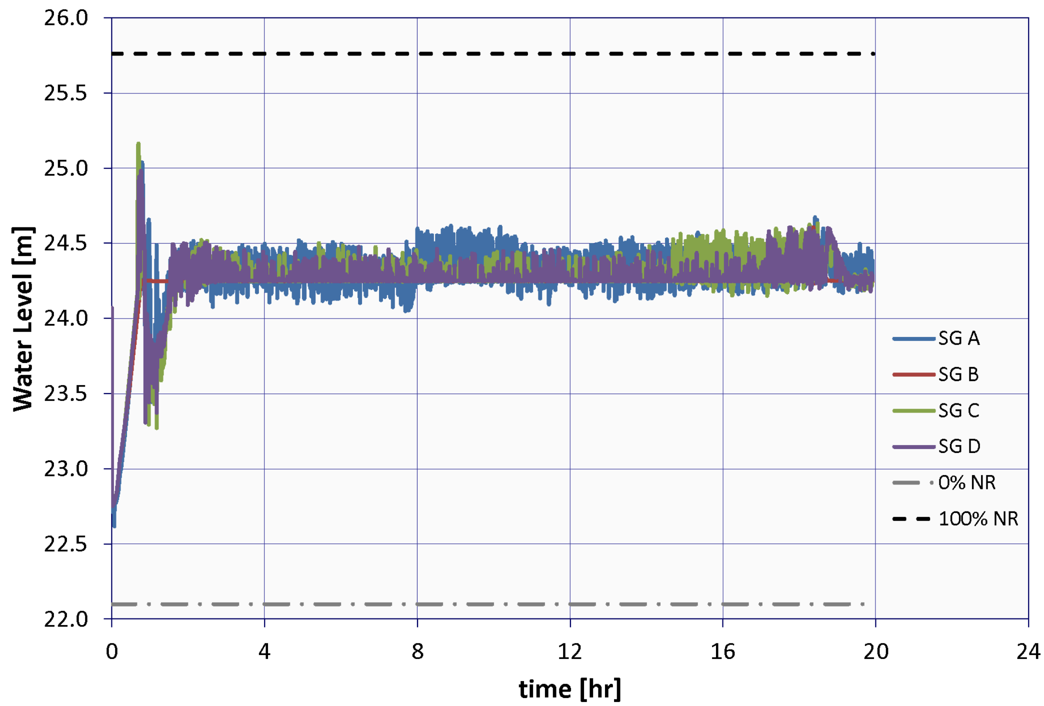

Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
40
45
0
4
8
12
16
20
24

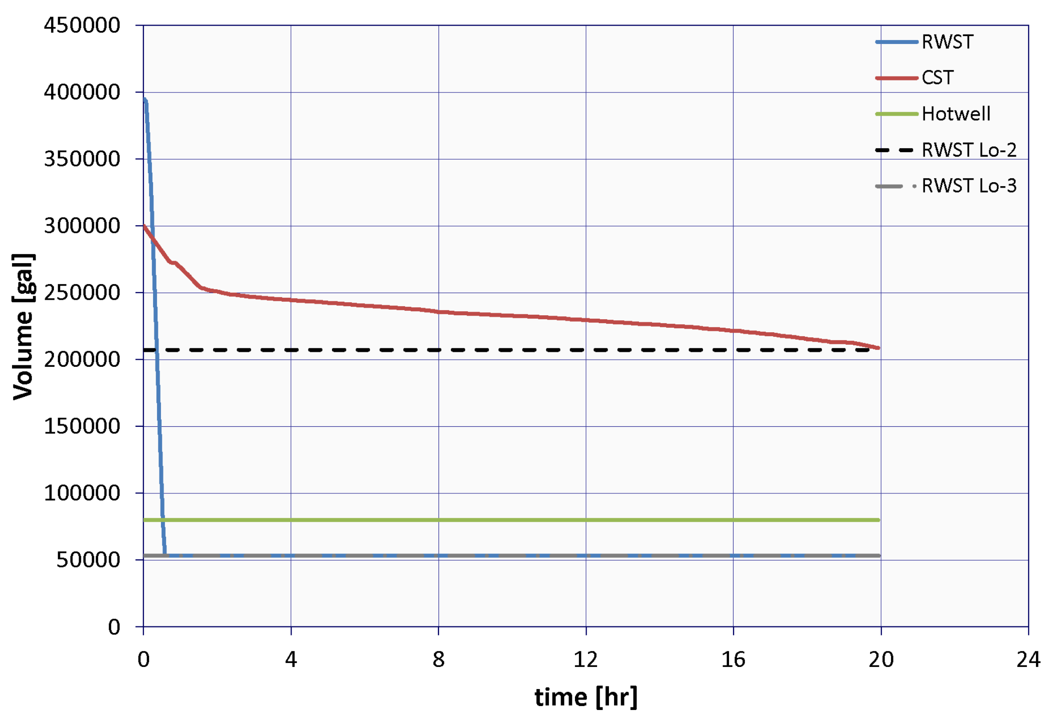


Containment Spray Flow Rate [m³/s]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

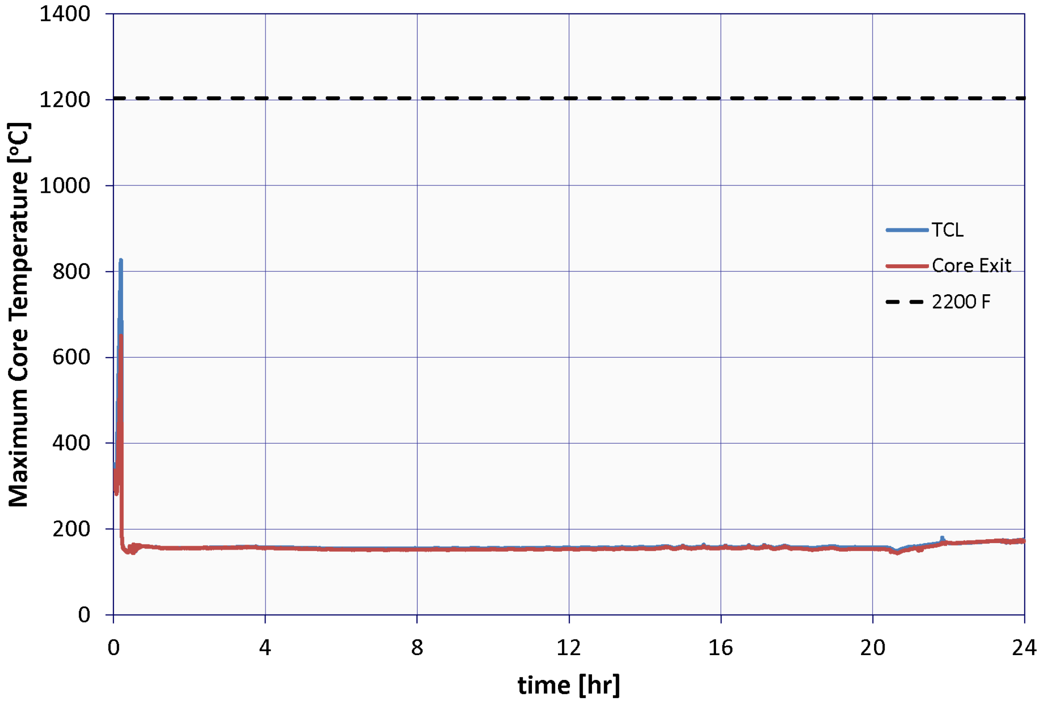


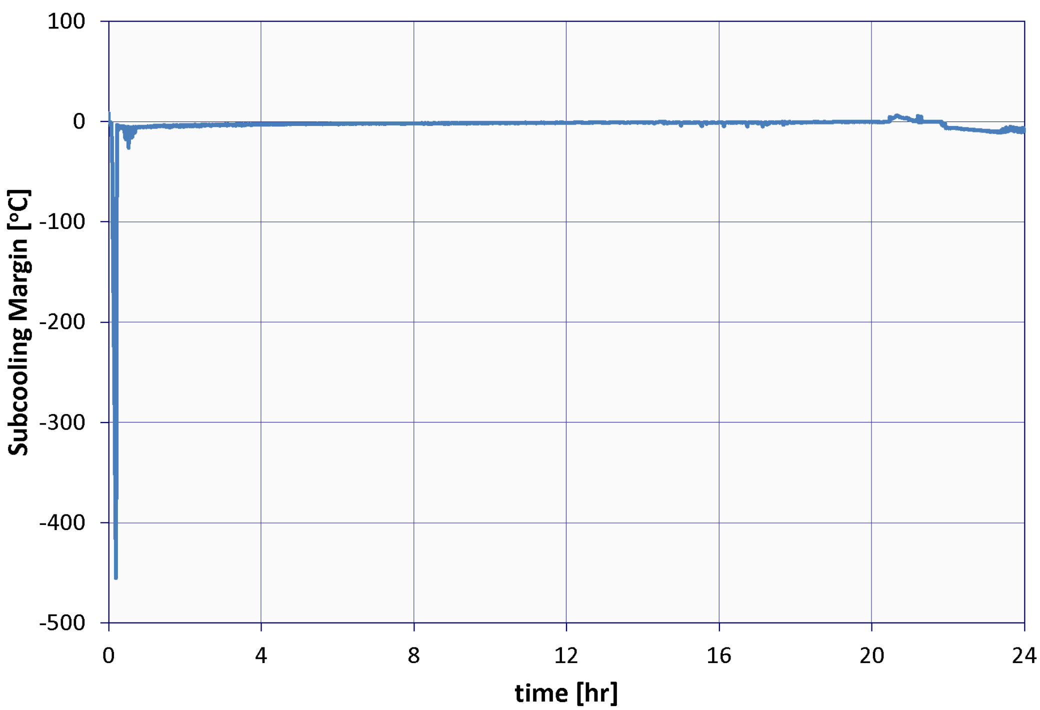
Water Level [m]
30
25
20
15
10
5
0
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

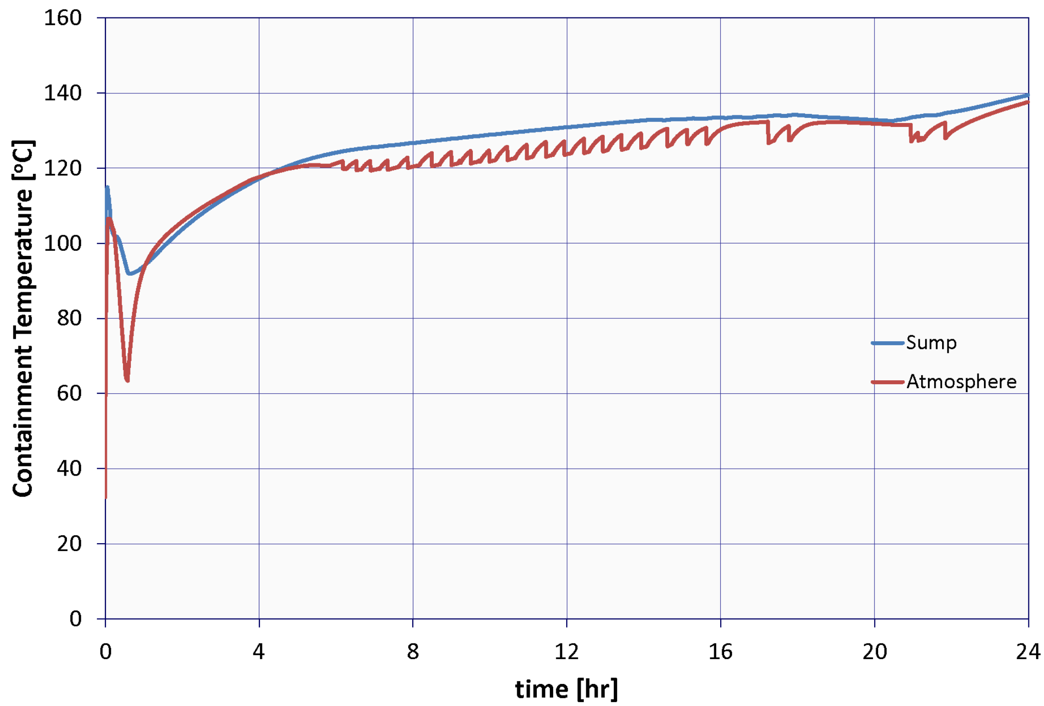

26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

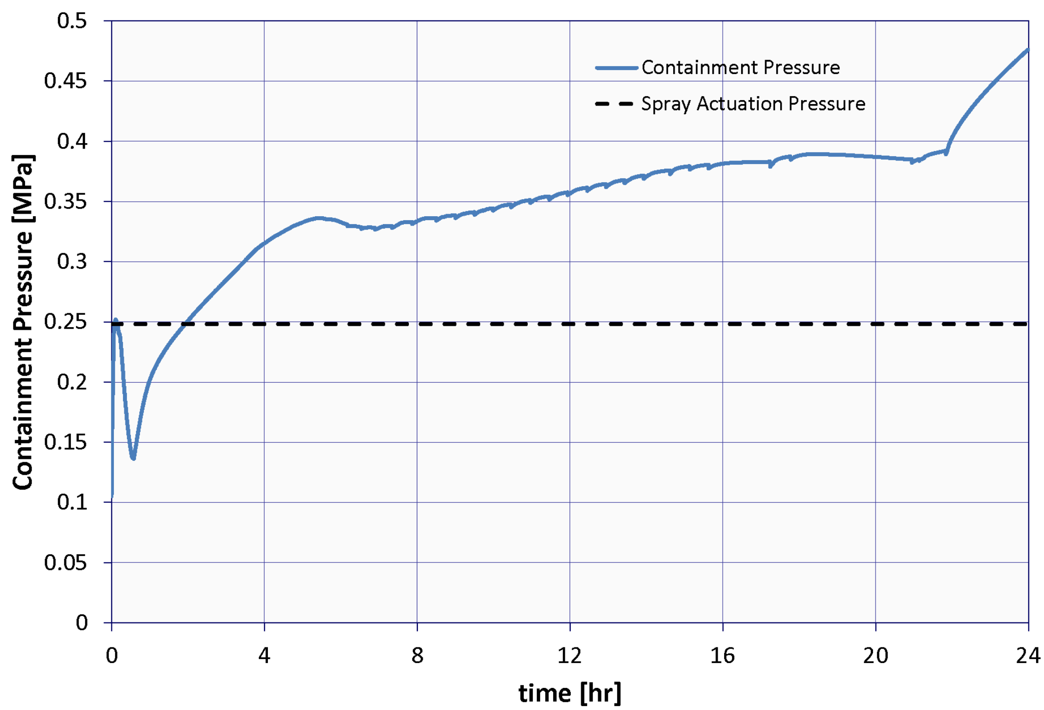
E.2.8.2 *Case 8b: 6-in. Break, 100 °F/hr Cooldown at 40 min, 2/2 CS Pumps, 0/4 RCFC, No RHRHX*



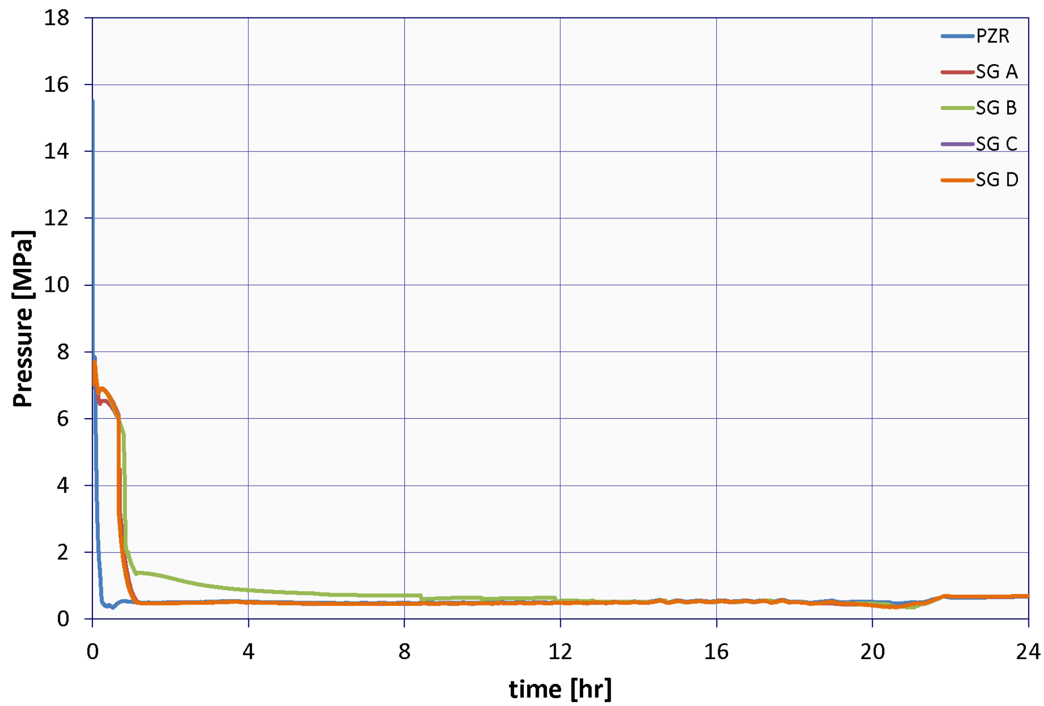




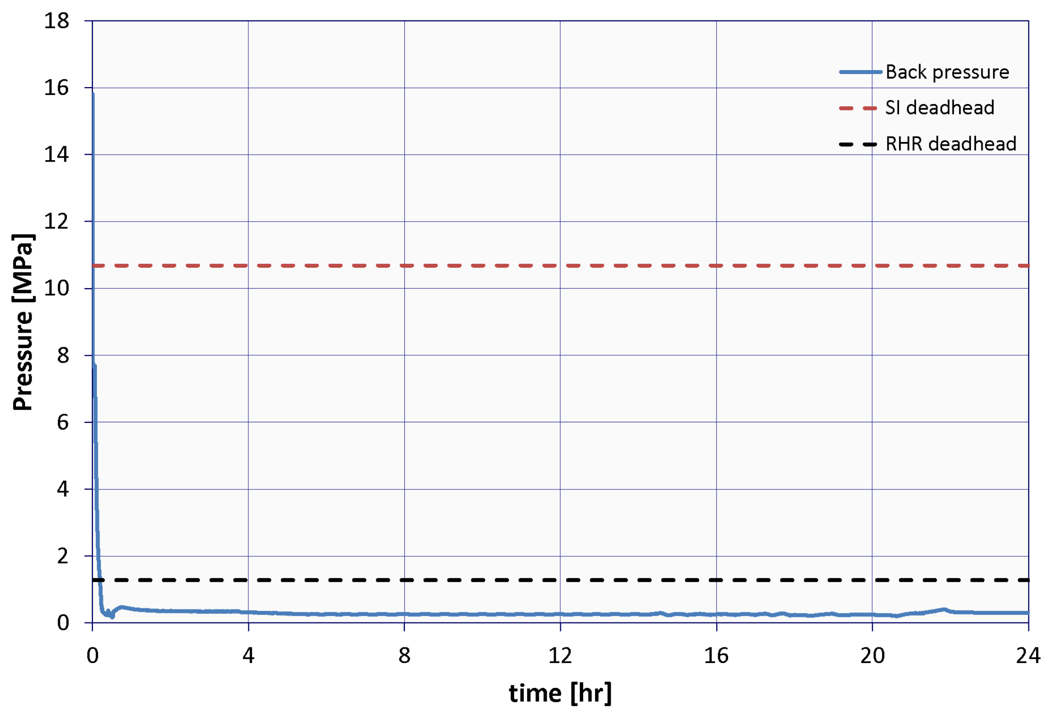
160
140
120
100
80
60
40
20
0
Containment Temperature [ºC]
0
4
8
12
16
20
24
time [hr]
Sump
Atmosphere



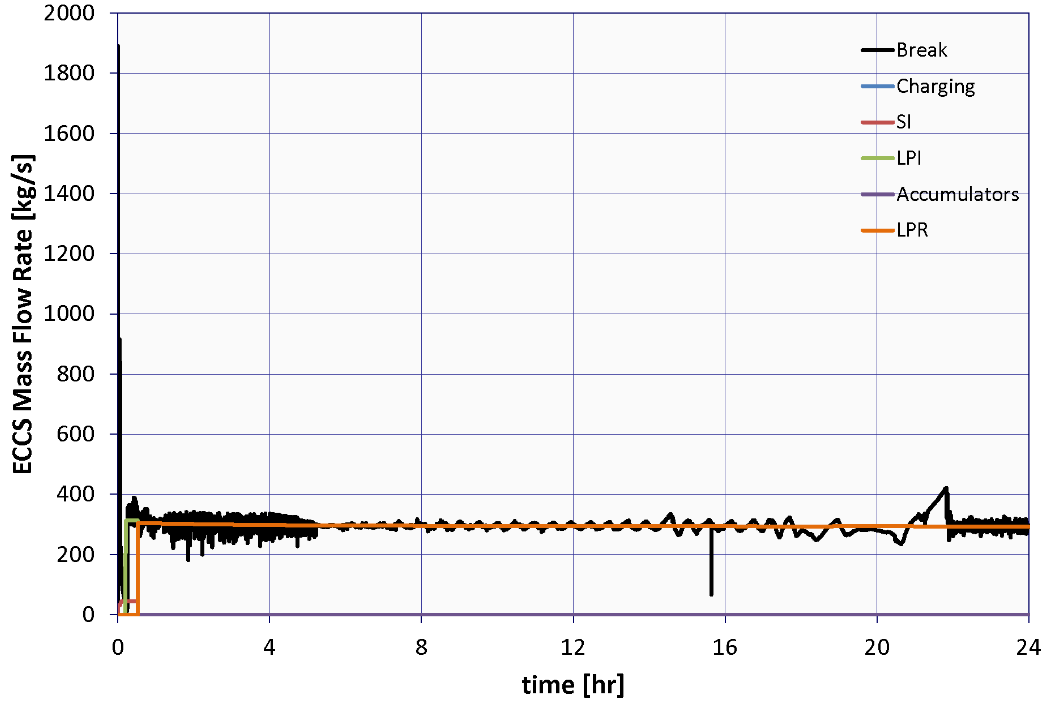
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
Containment Pressure
Spray Actuation Pressure



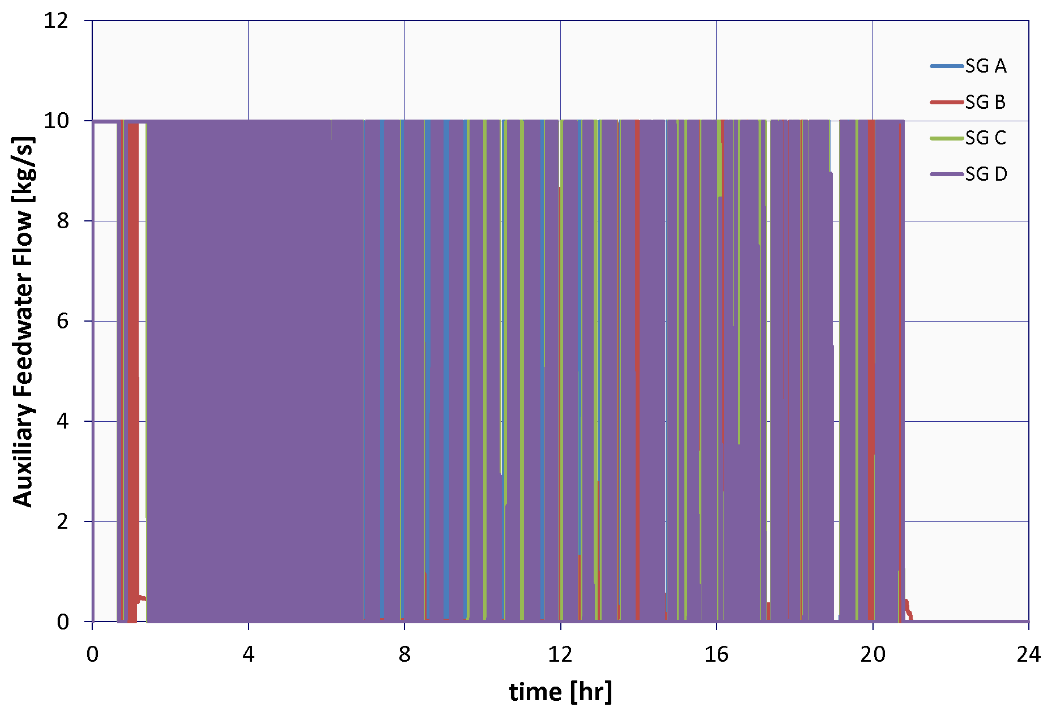
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



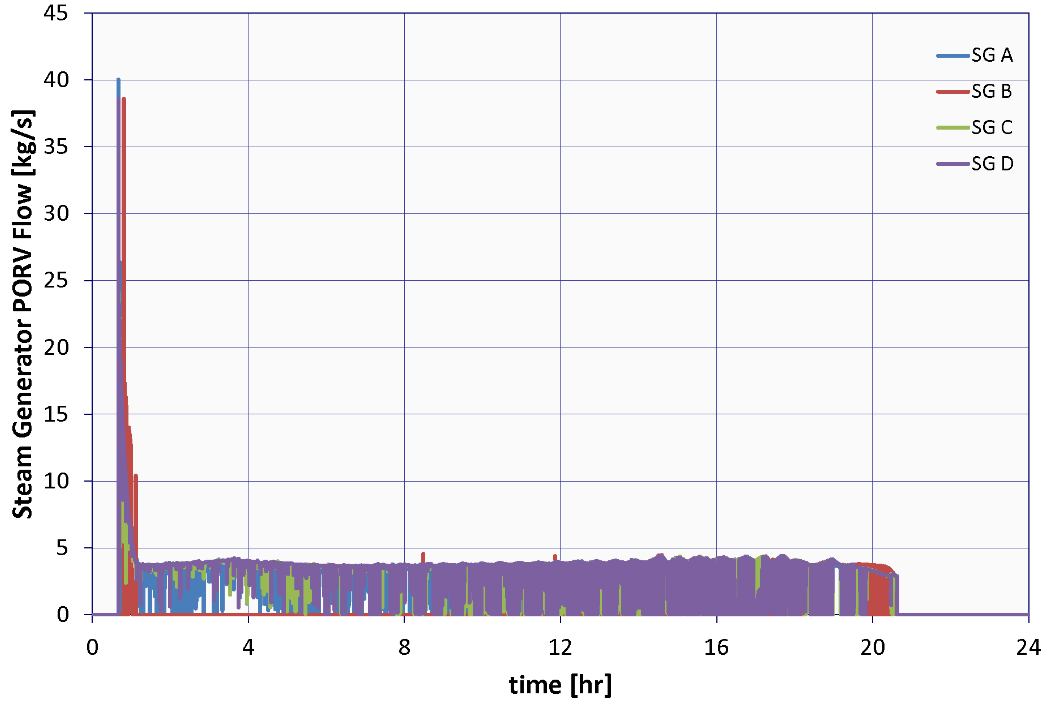
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead



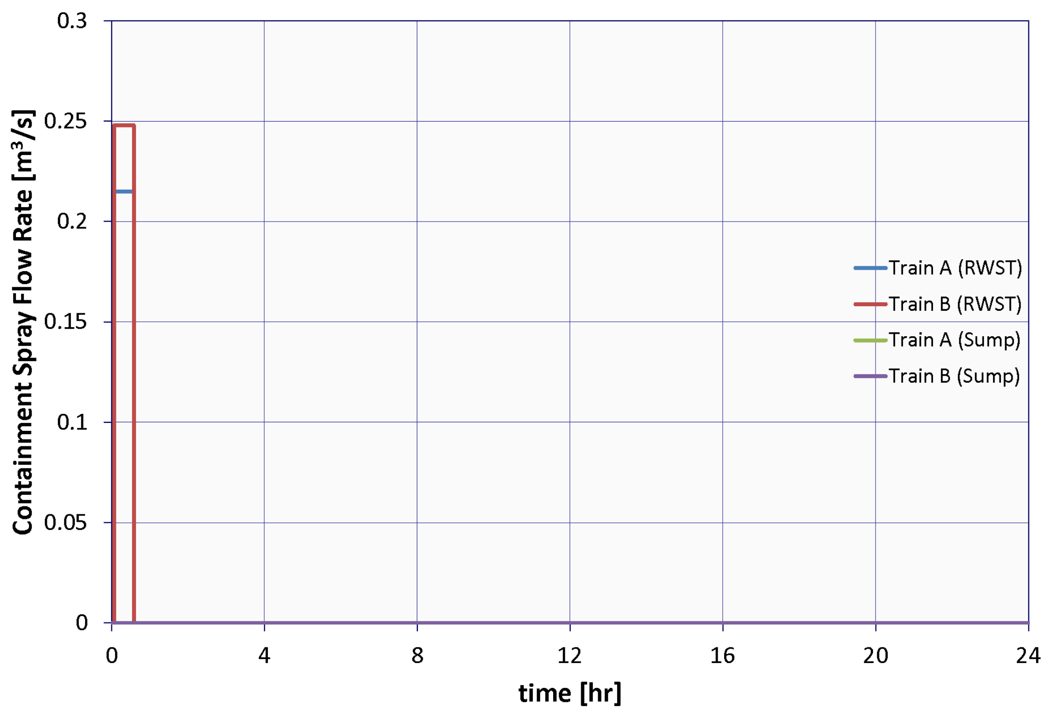
ECCS Mass Flow Rate [kg/s]
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
4
8
12
16
20
24



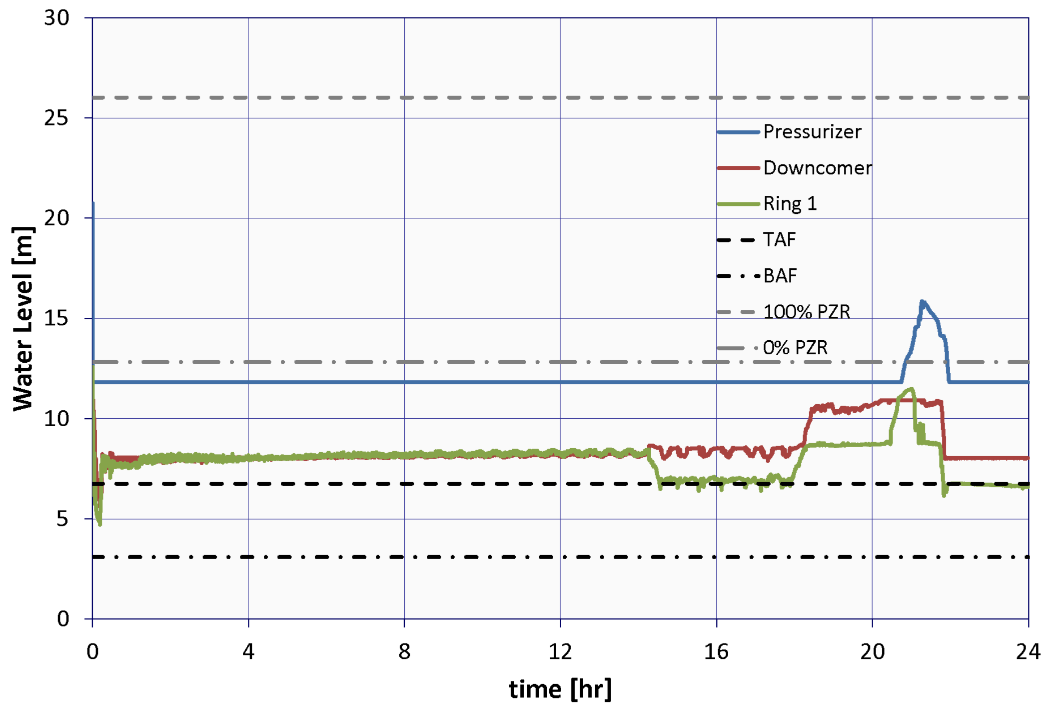
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24



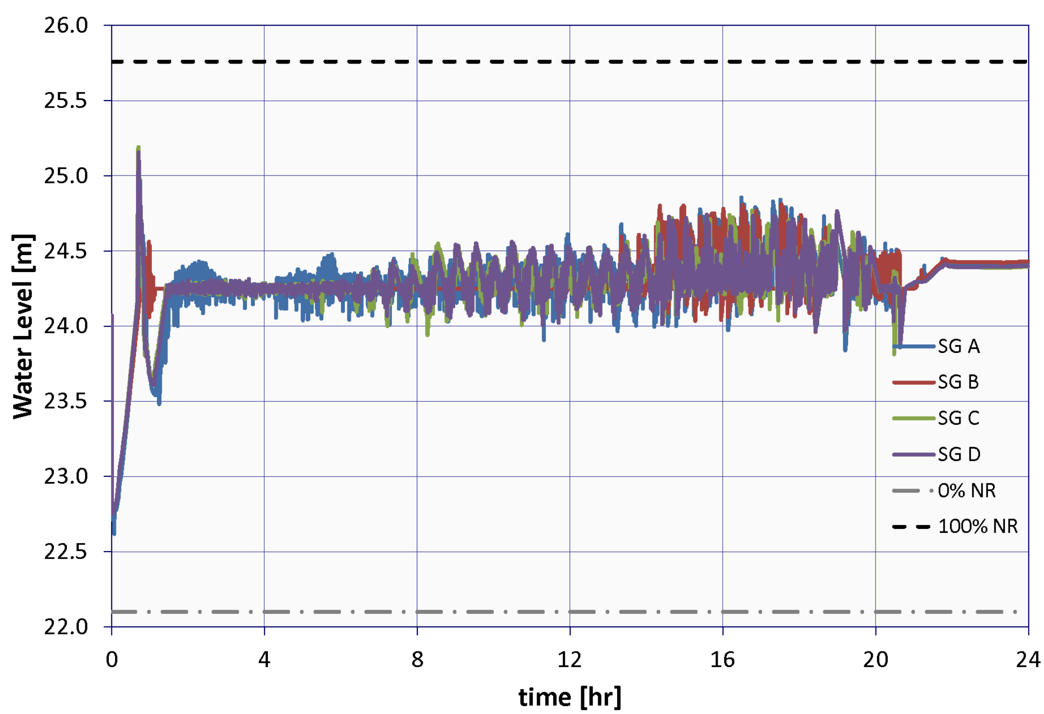
45
40
35
30
25
20
15
10
5
0
Steam Generator PORV Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



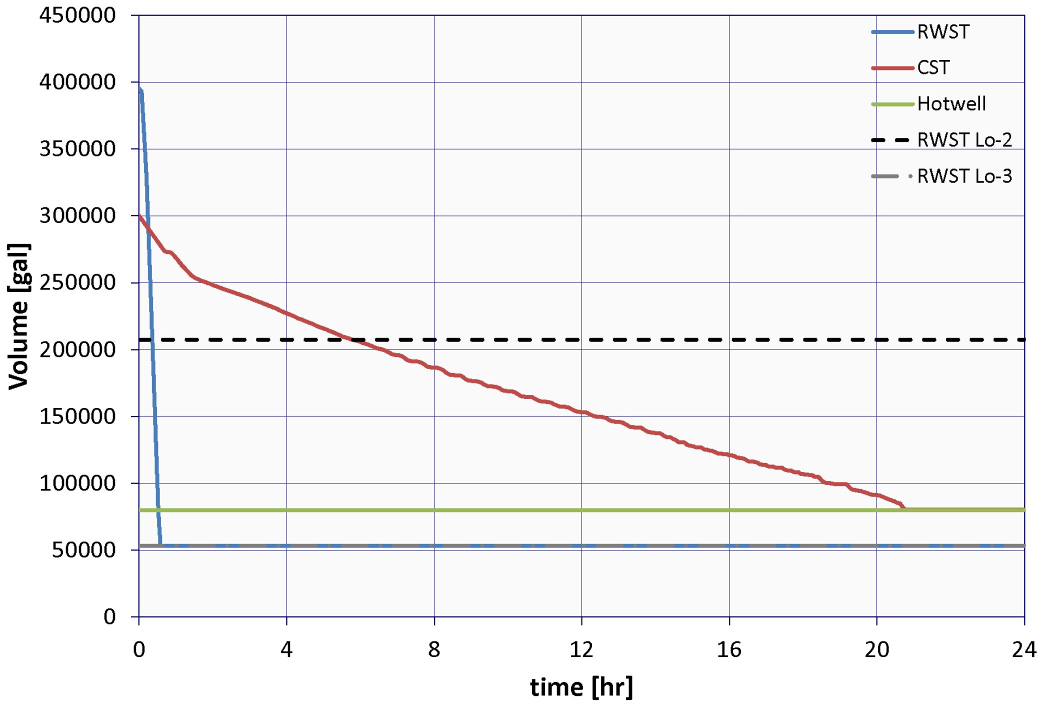
0.3
0.25
0.2
0.15
0.1
0.05
0
Containment Spray Flow Rate [m³/s]
0
4
8
12
16
20
24
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

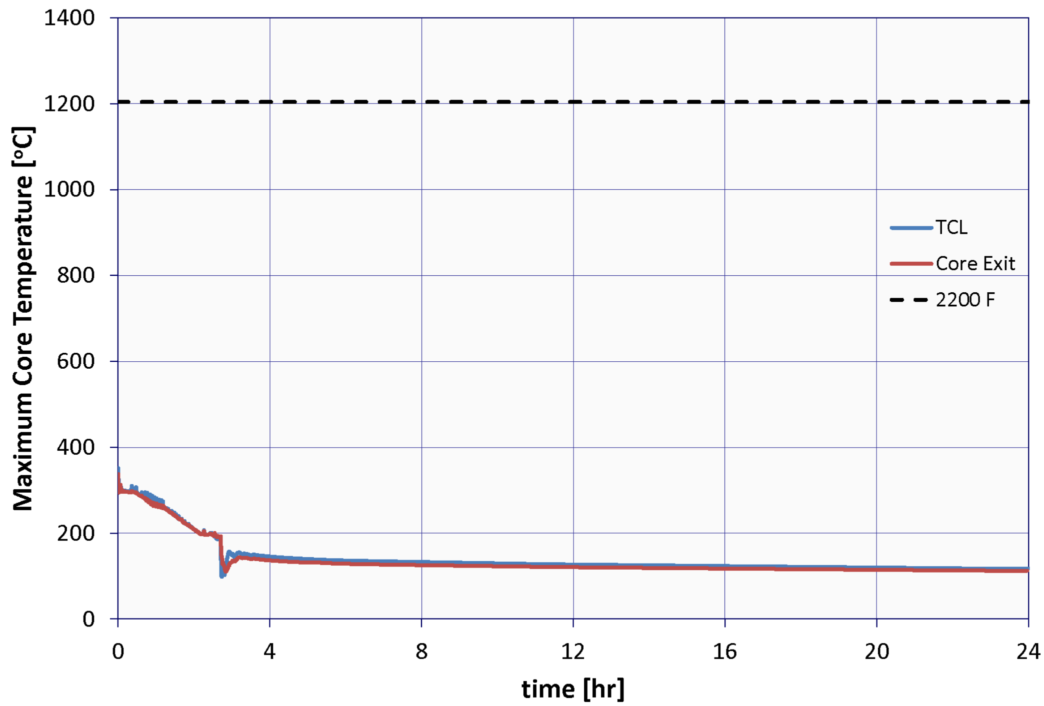


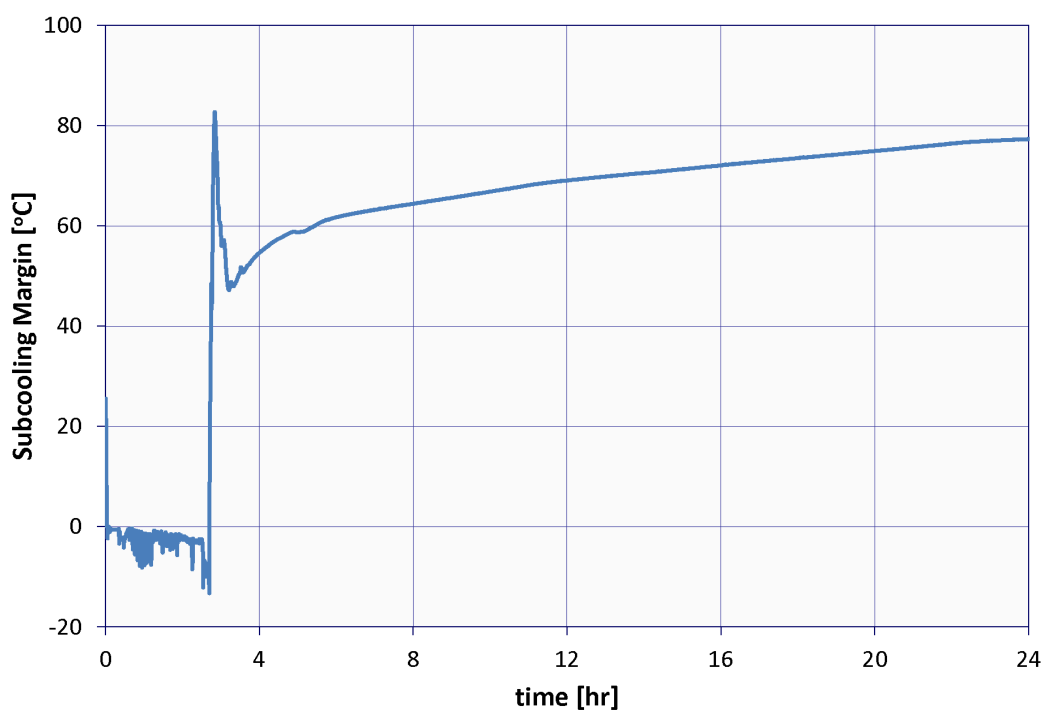
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

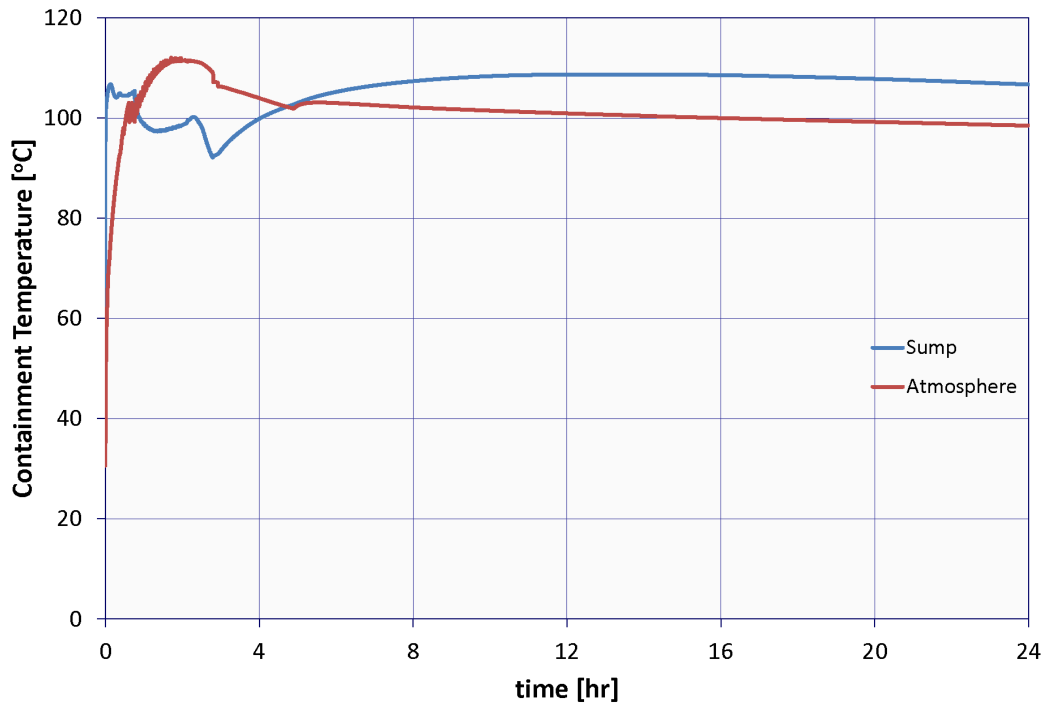


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

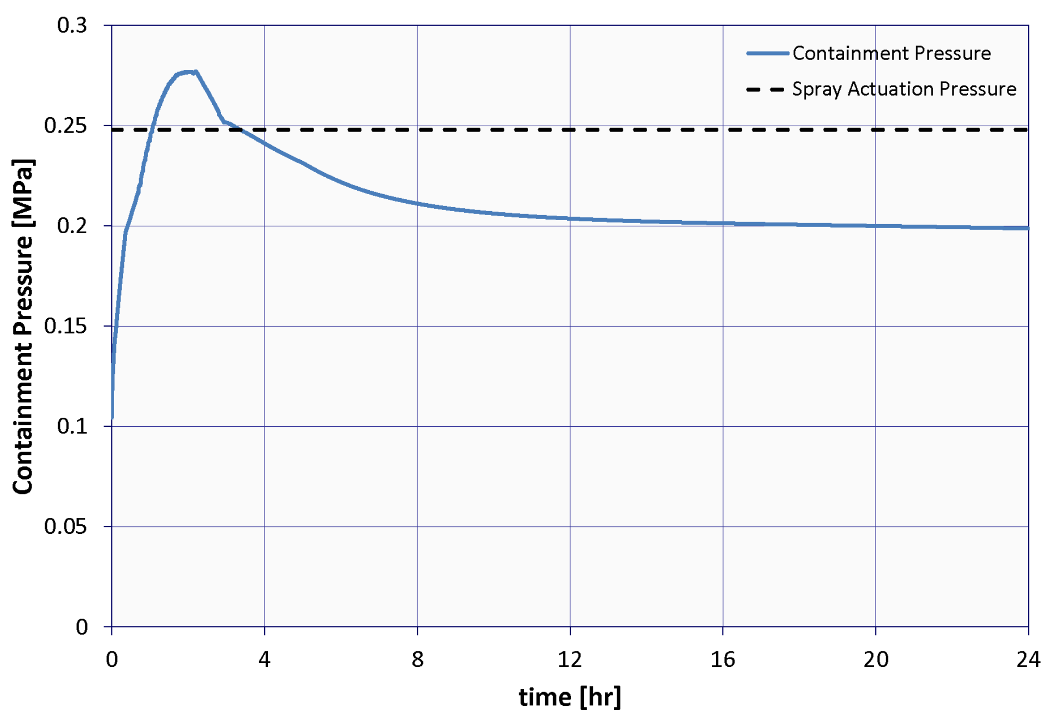
E.2.9 Case 9: 2-in. Break, 100 °F/hr Cooldown at 40 min, 0/2 CS Pumps, 0/4 RCFC



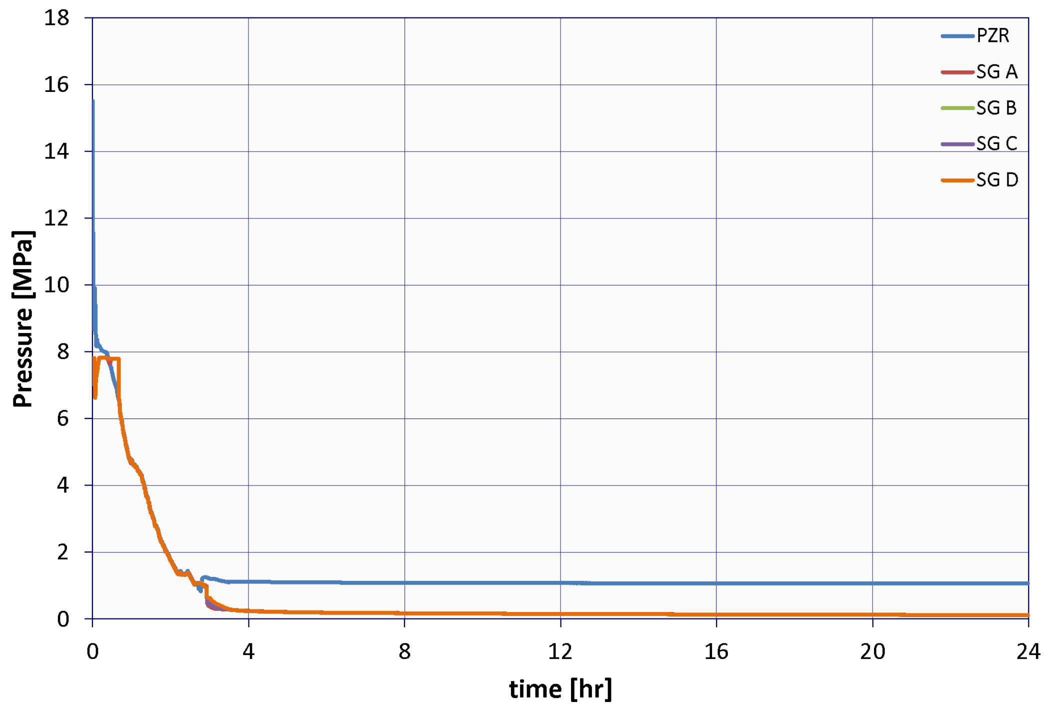




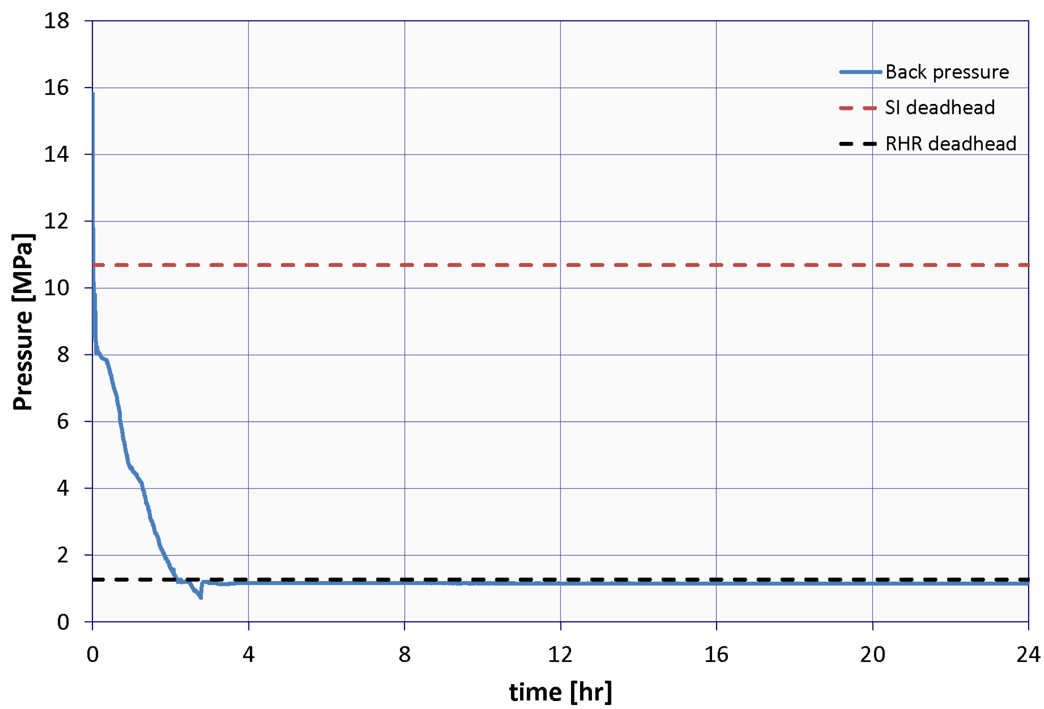
Containment Temperature [ºC]
time [hr]
Sump
Atmosphere
0
20
40
60
80
100
120
0
4
8
12
16
20
24



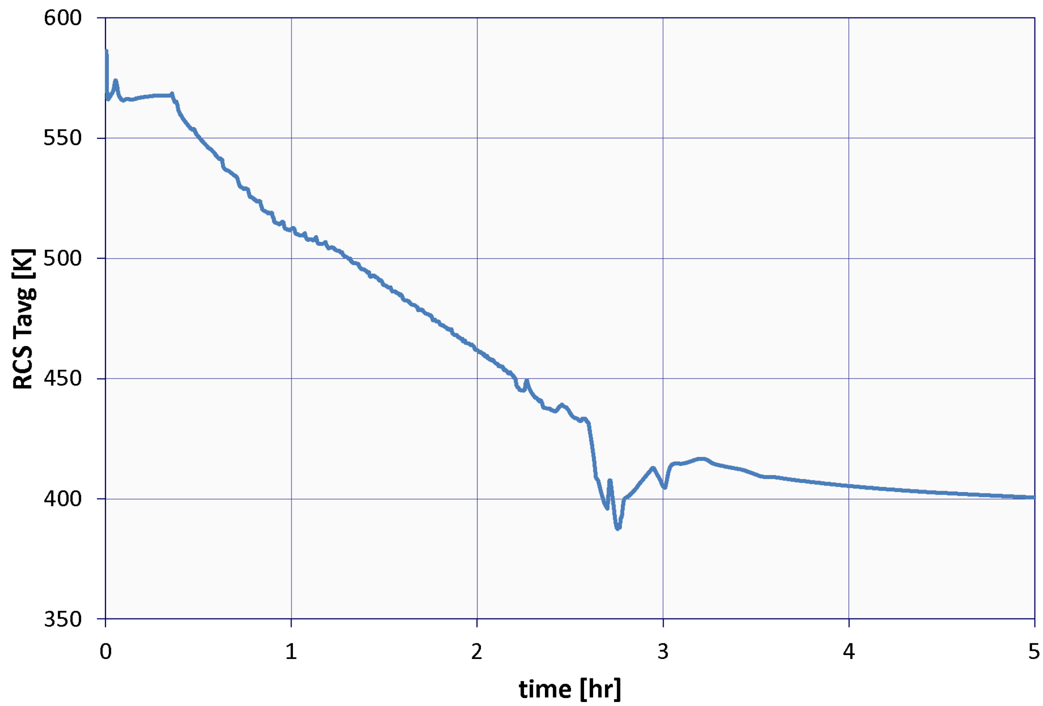
Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure
0
0.05
0.1
0.15
0.2
0.25
0.3
0
4
8
12
16
20
24



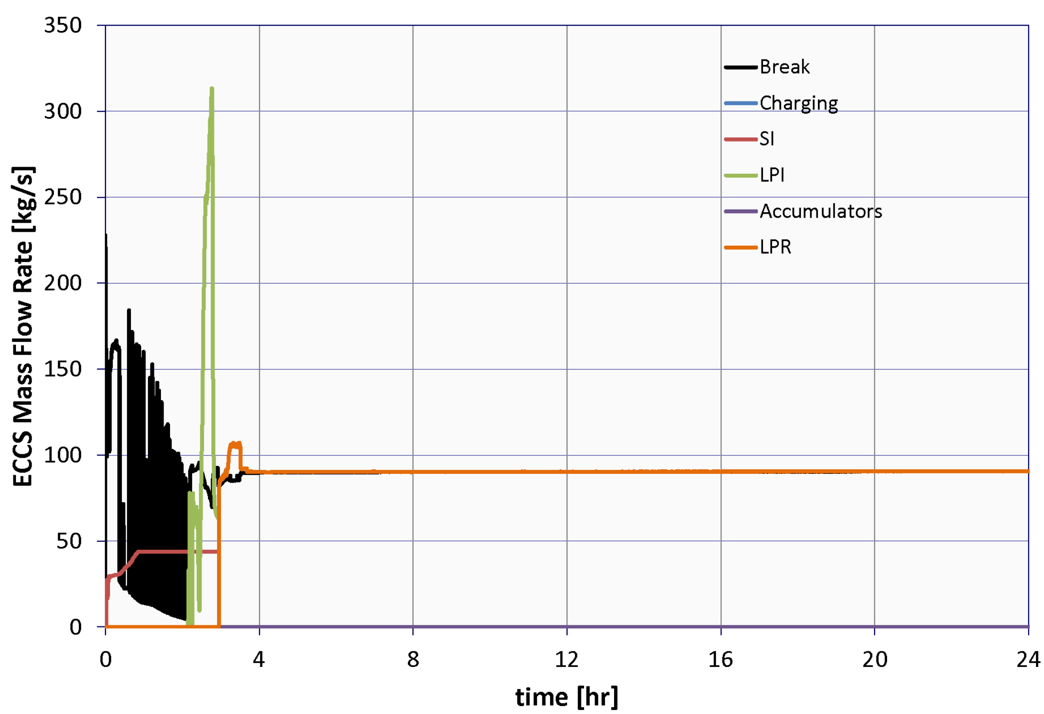
PZR
SG A
SG B
SG C
SG D
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24



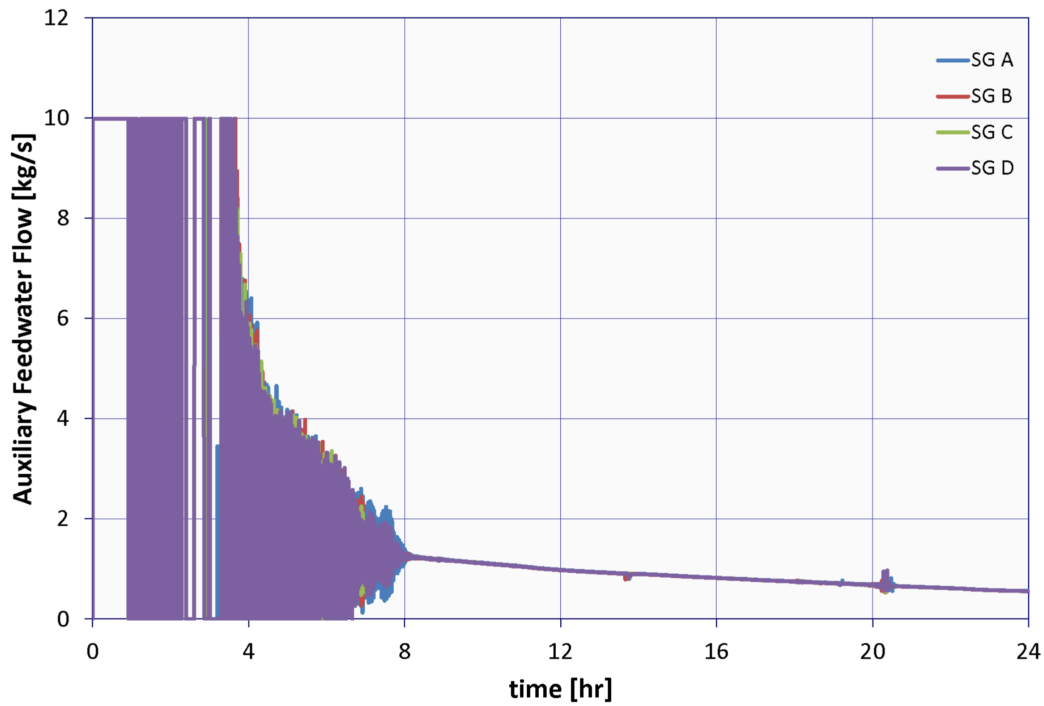
Back pressure
SI deadhead
RHR deadhead
Pressure [MPa]
time [hr]
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24



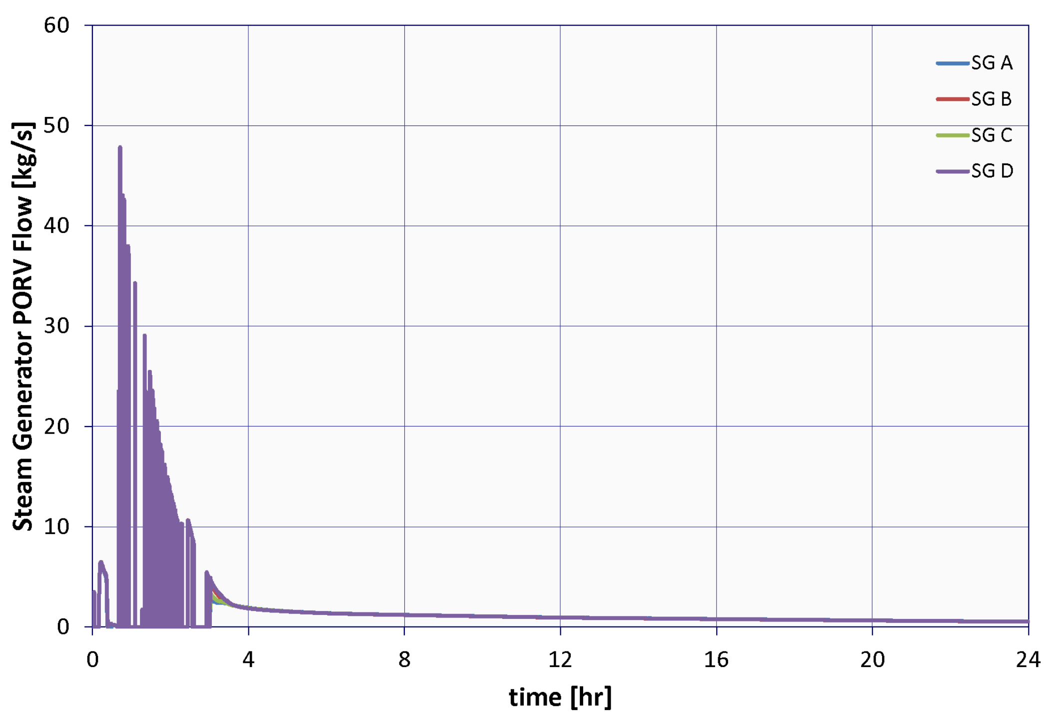
RCS Tavg [K]
600
550
500
450
400
350
0
1
2
3
4
5
time [hr]



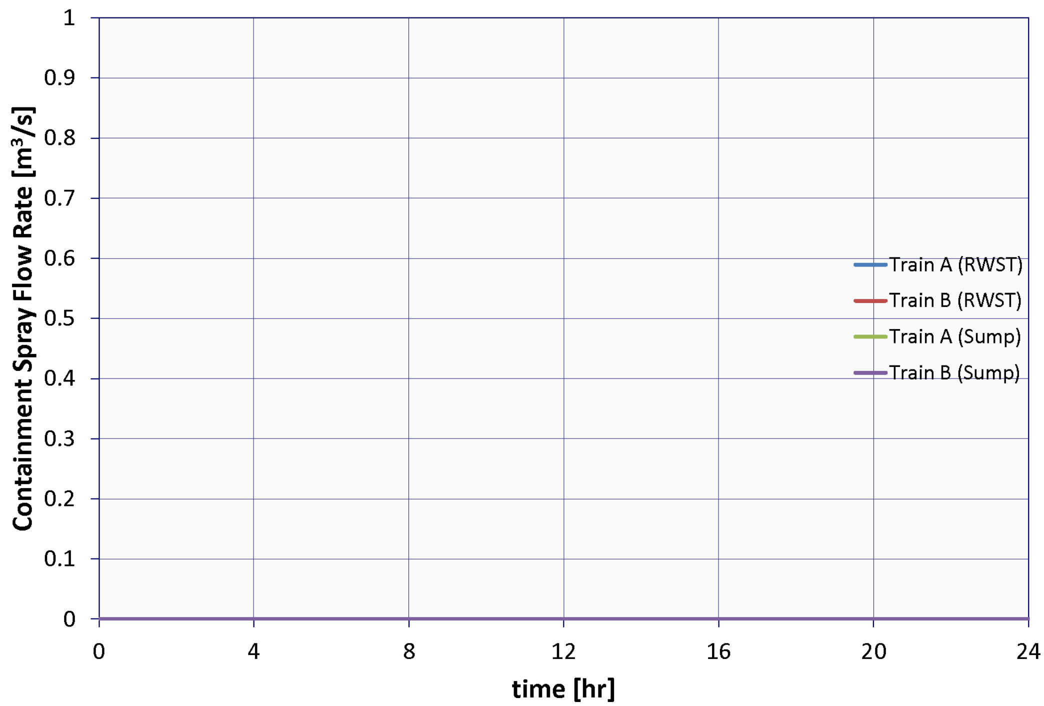
ECCS Mass Flow Rate [kg/s]
350
300
250
200
150
100
50
0
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR



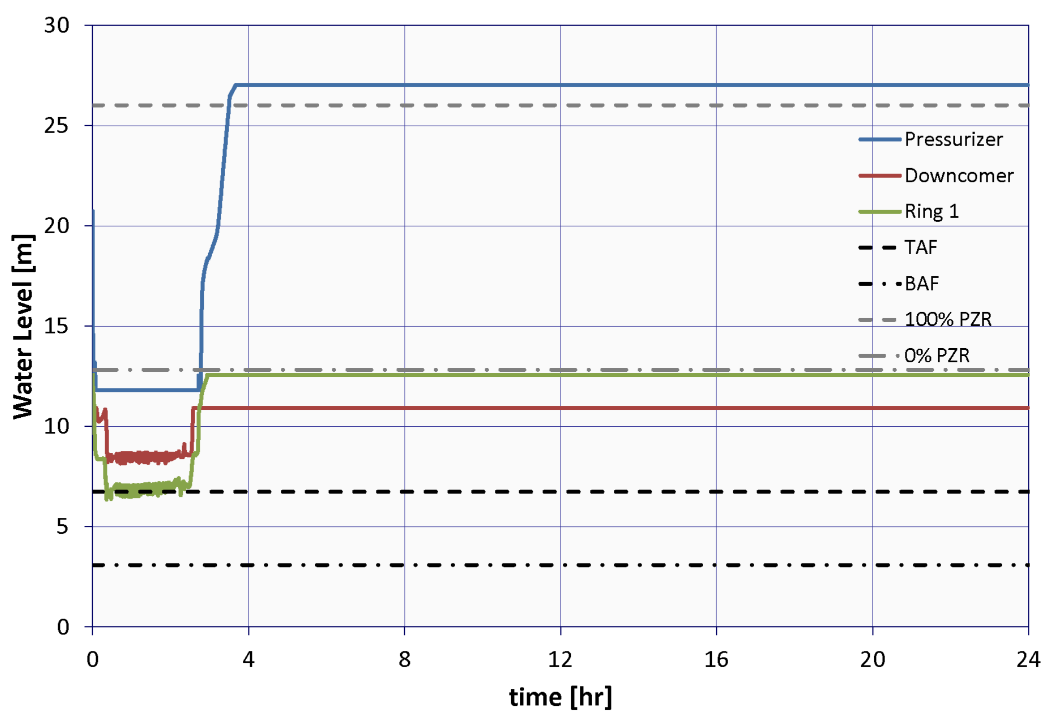
12
10
8
6
4
2
0
Auxiliary Feedwater Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D



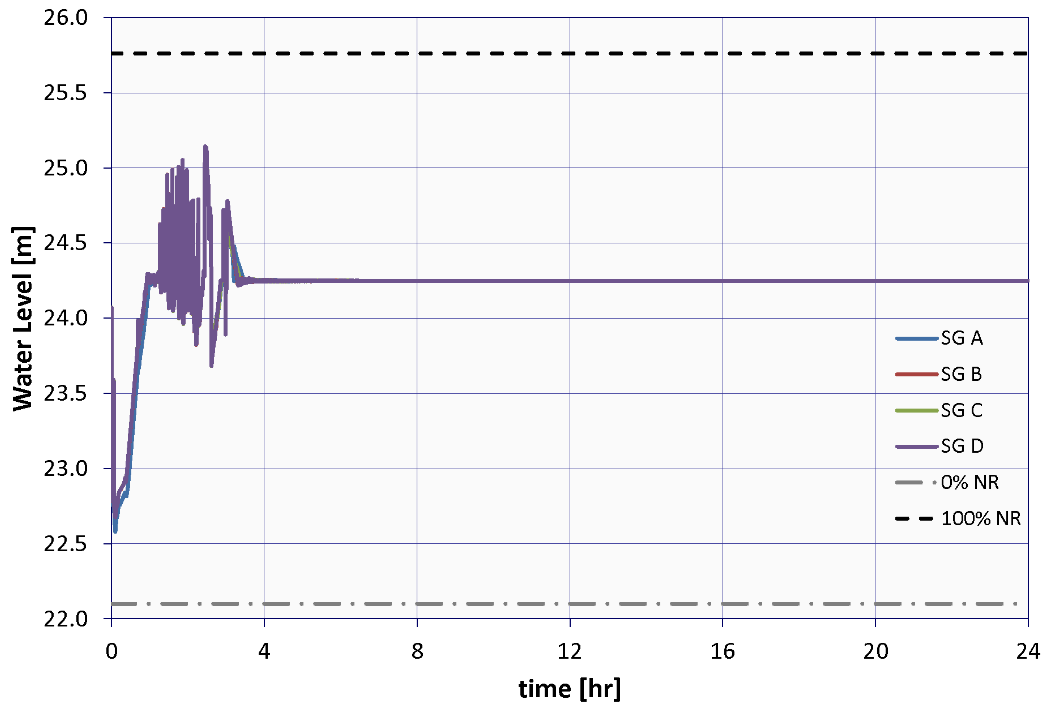
60
50
40
30
20
10
0
Steam Generator PORV Flow [kg/s]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D

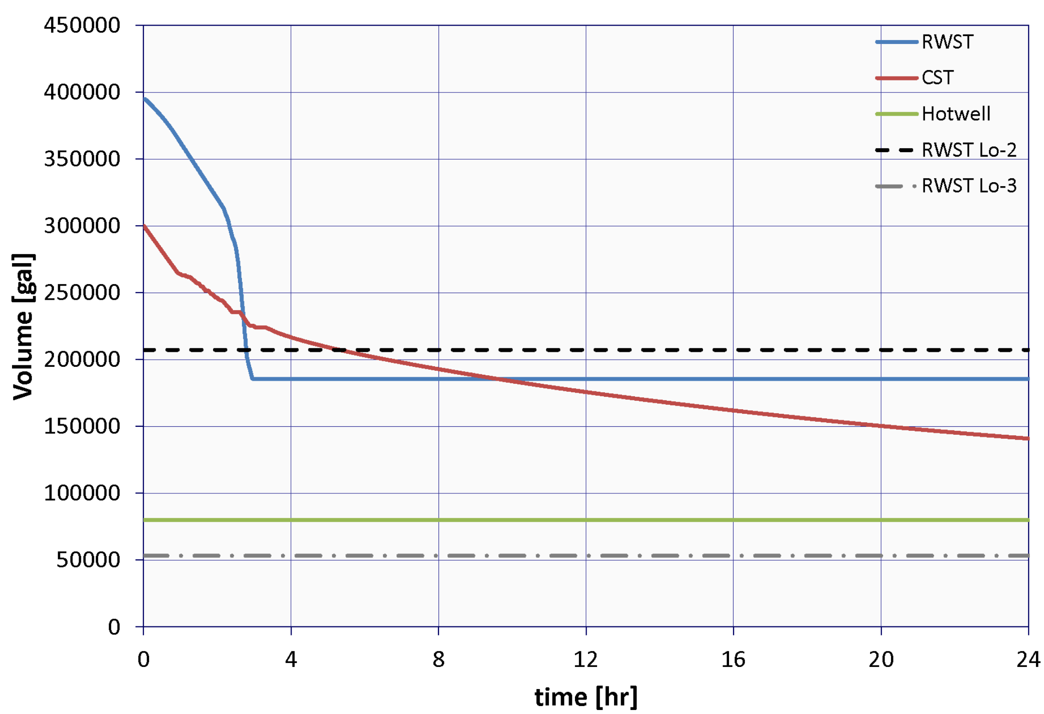


Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)

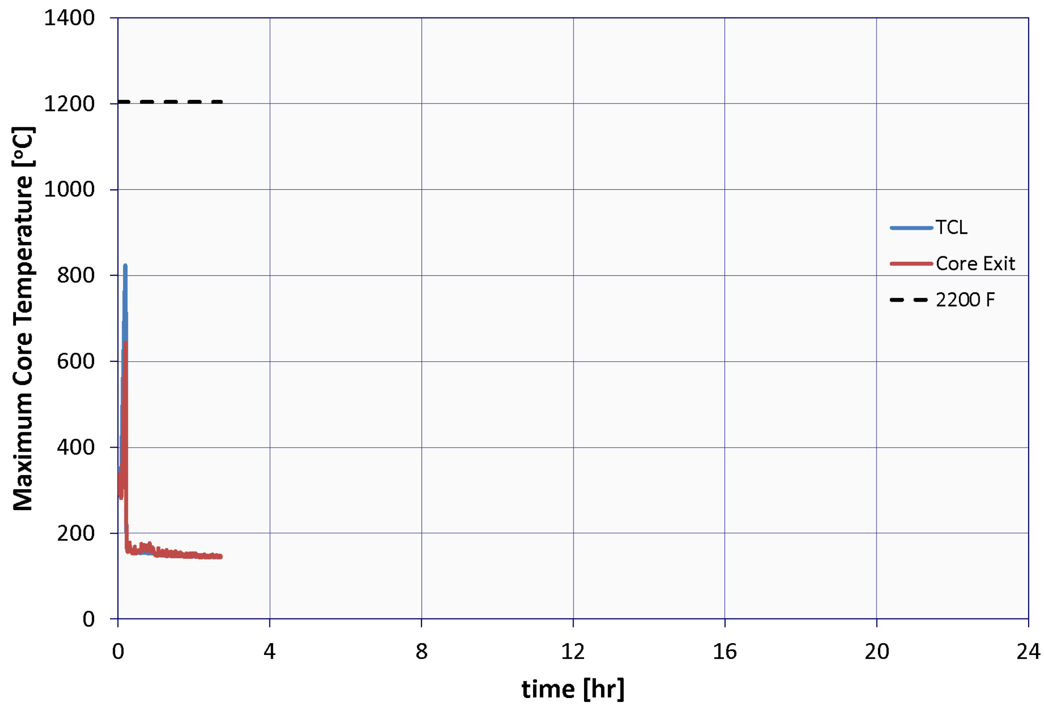


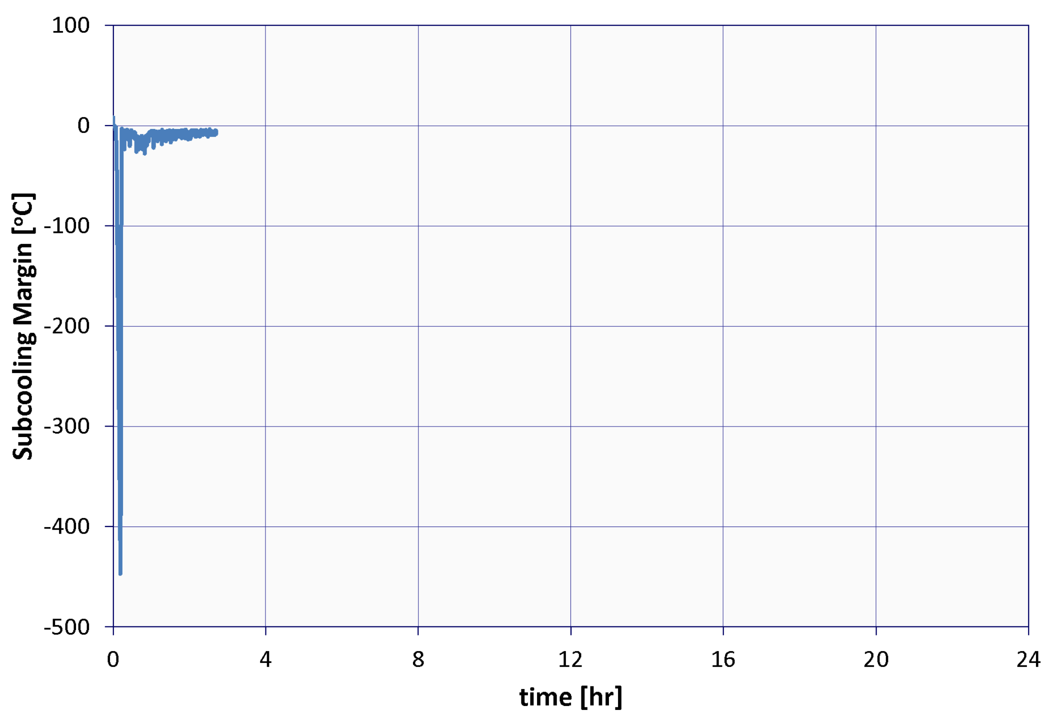
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

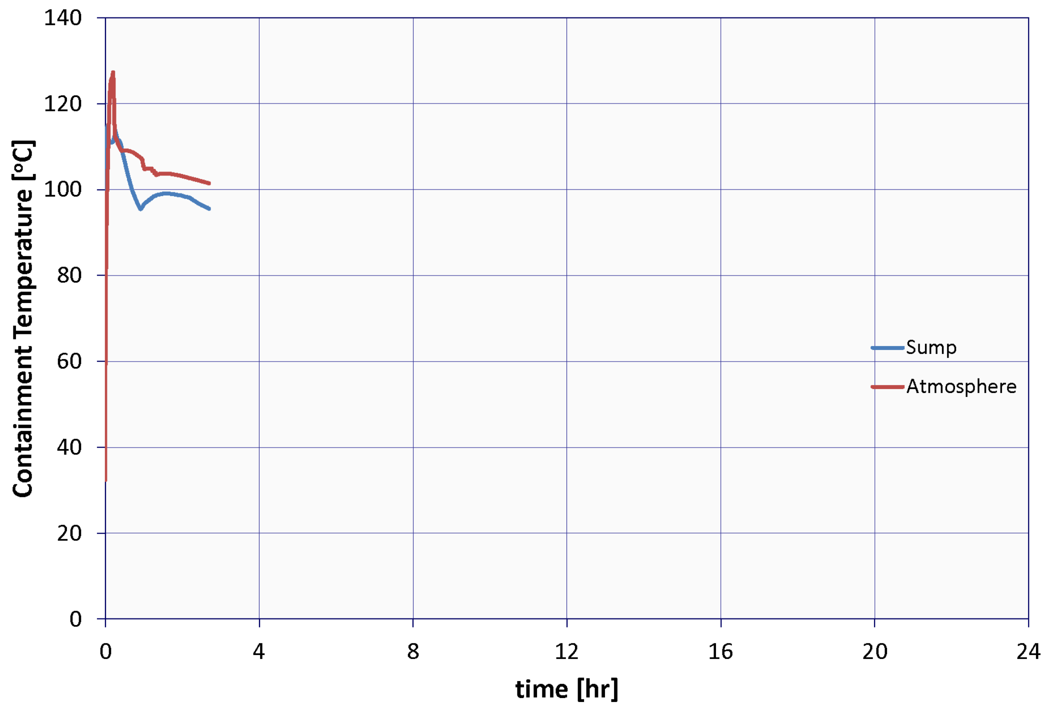

Water Level [m]
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

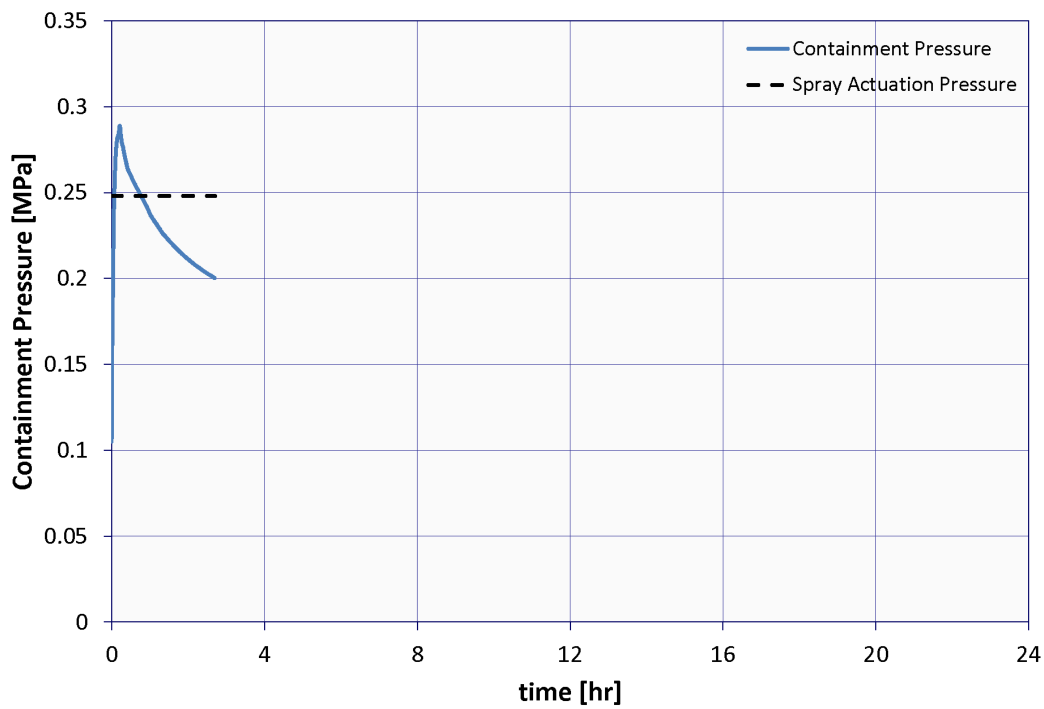

Volume [gal]
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

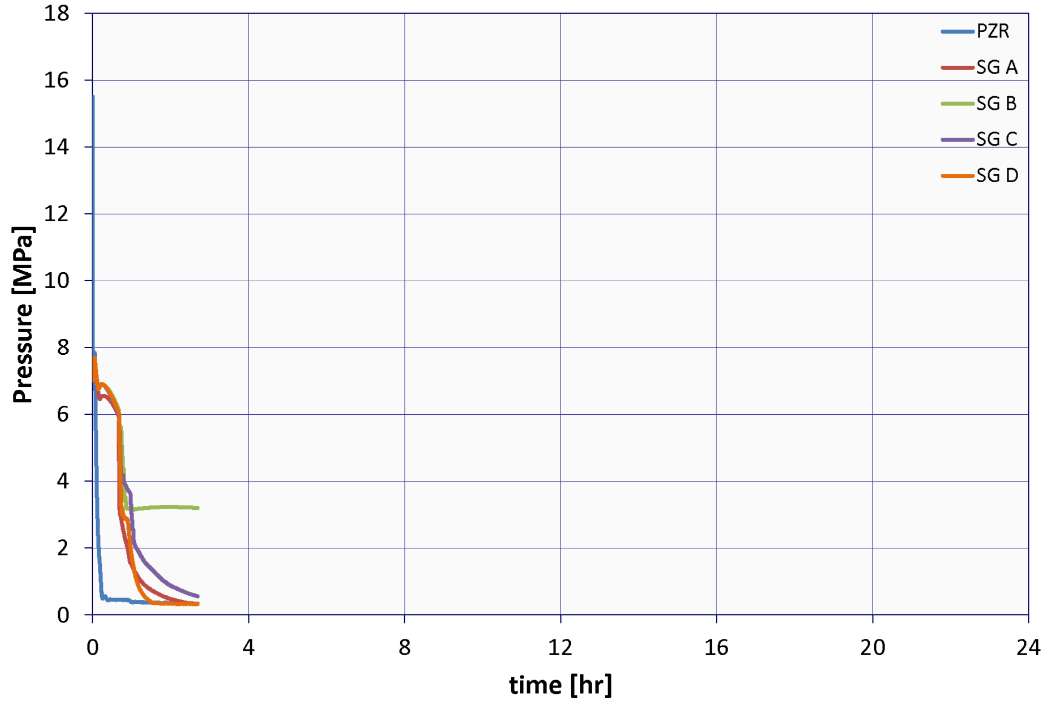
E.2.10 Case 10: 6-in. Break, 100 °F/hr Cooldown at 40 min, 0/2 CS Pumps, 0/4 RCFC



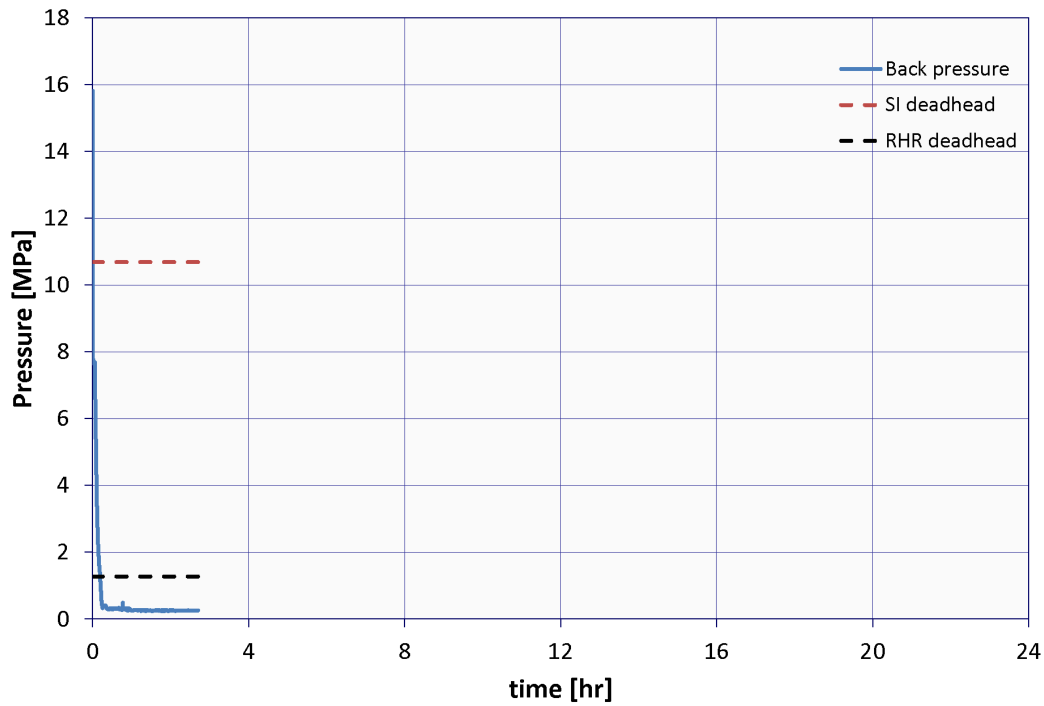



Containment Temperature [°C]
time [hr]
Sump
Atmosphere
0
20
40
60
80
100
120
140
0
4
8
12
16
20
24

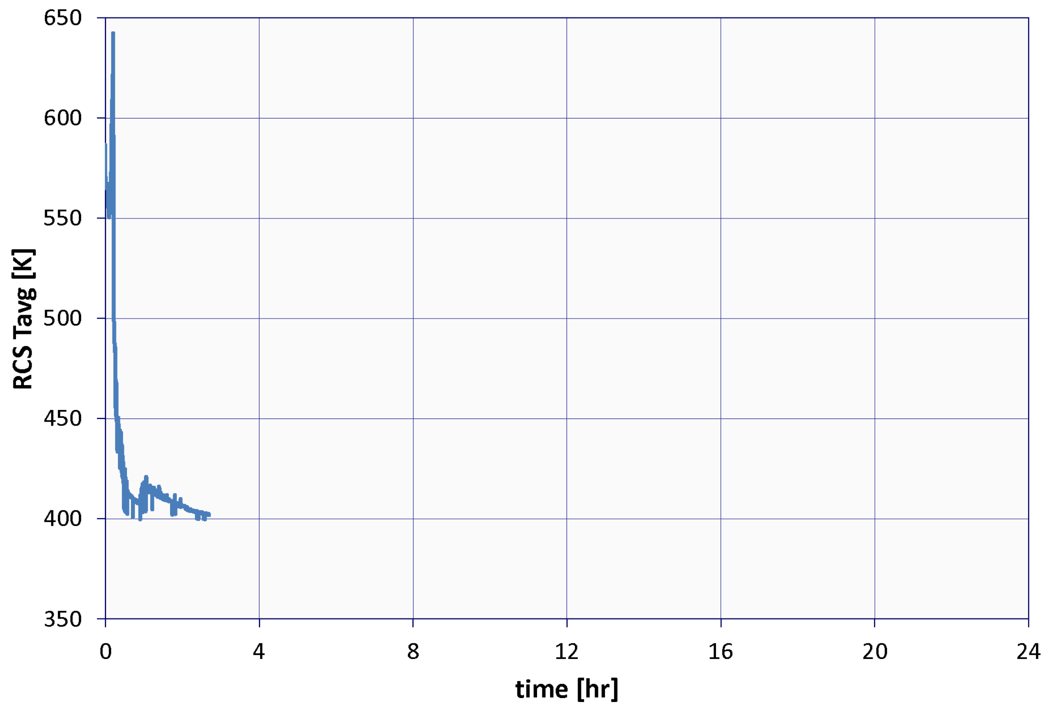

Containment Pressure [MPa]
time [hr]
Containment Pressure
Spray Actuation Pressure
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
4
8
12
16
20
24

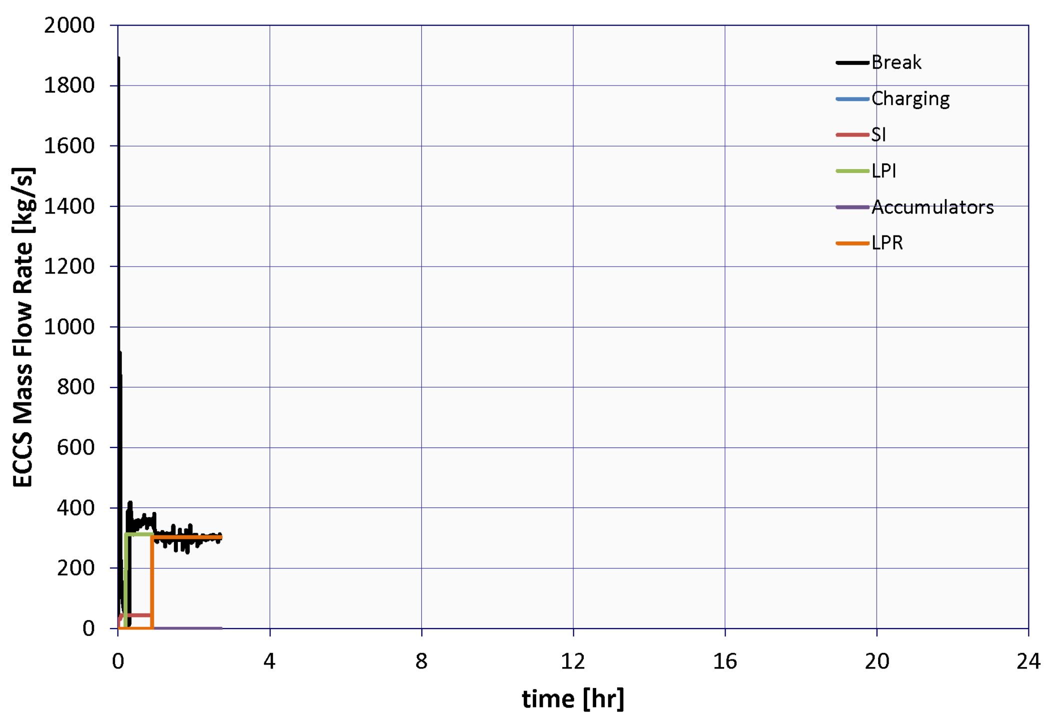


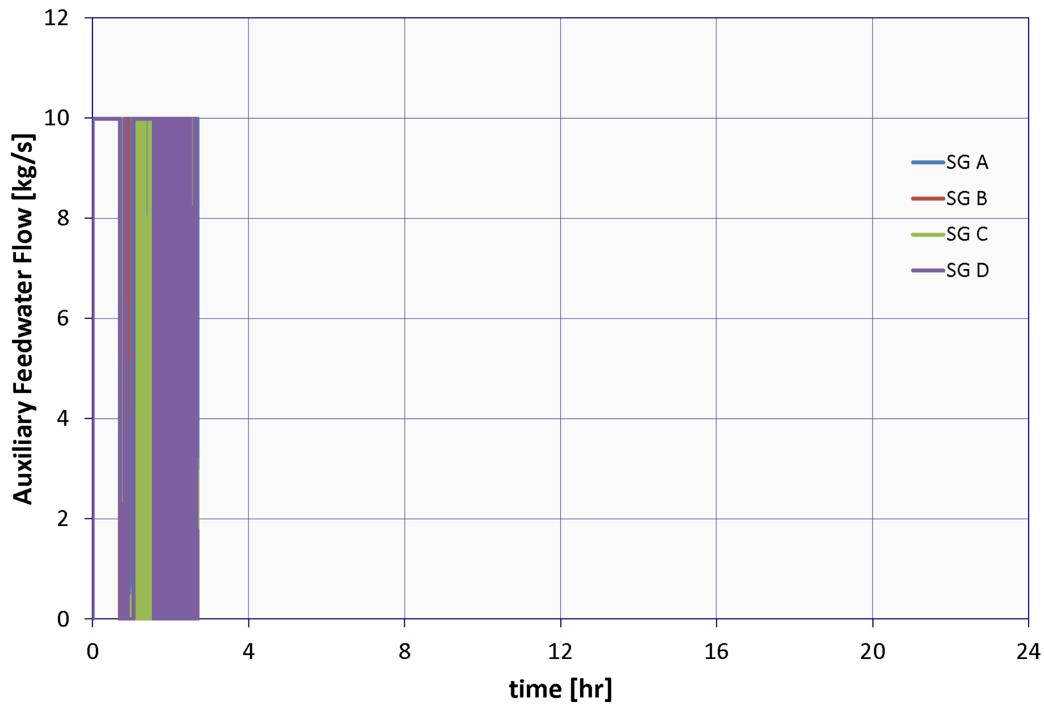
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D



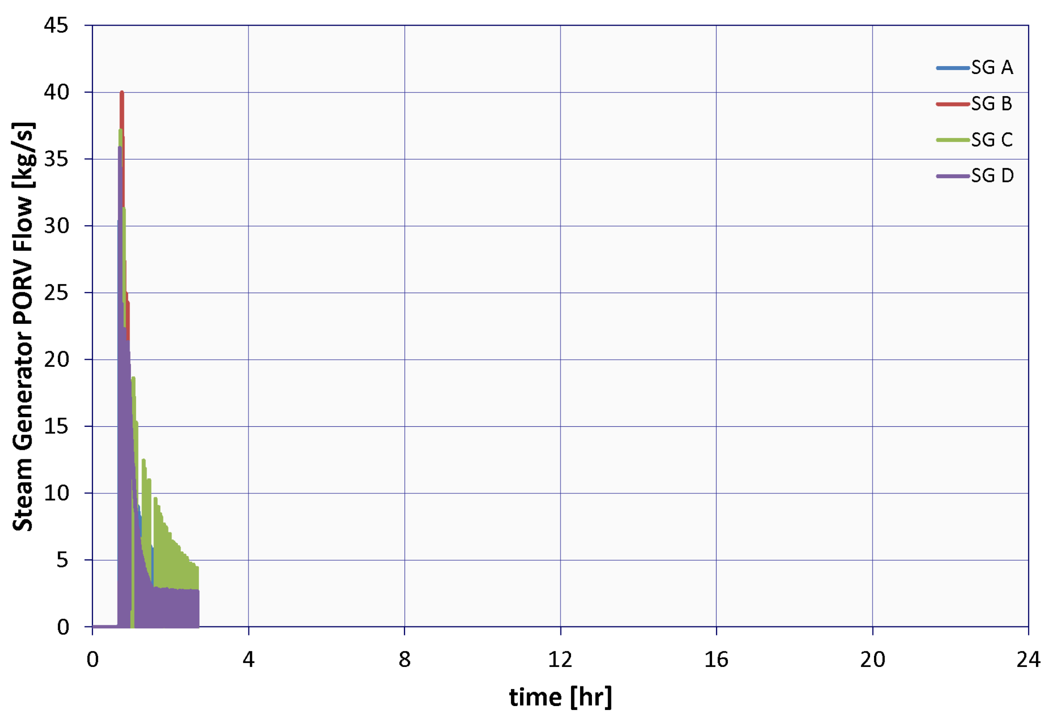
Pressure [MPa]
time [hr]
Back pressure
SI deadhead
RHR deadhead


RCS Tavg [K]
650
600
550
500
450
400
350
0
4
8
12
16
20
24
time [hr]

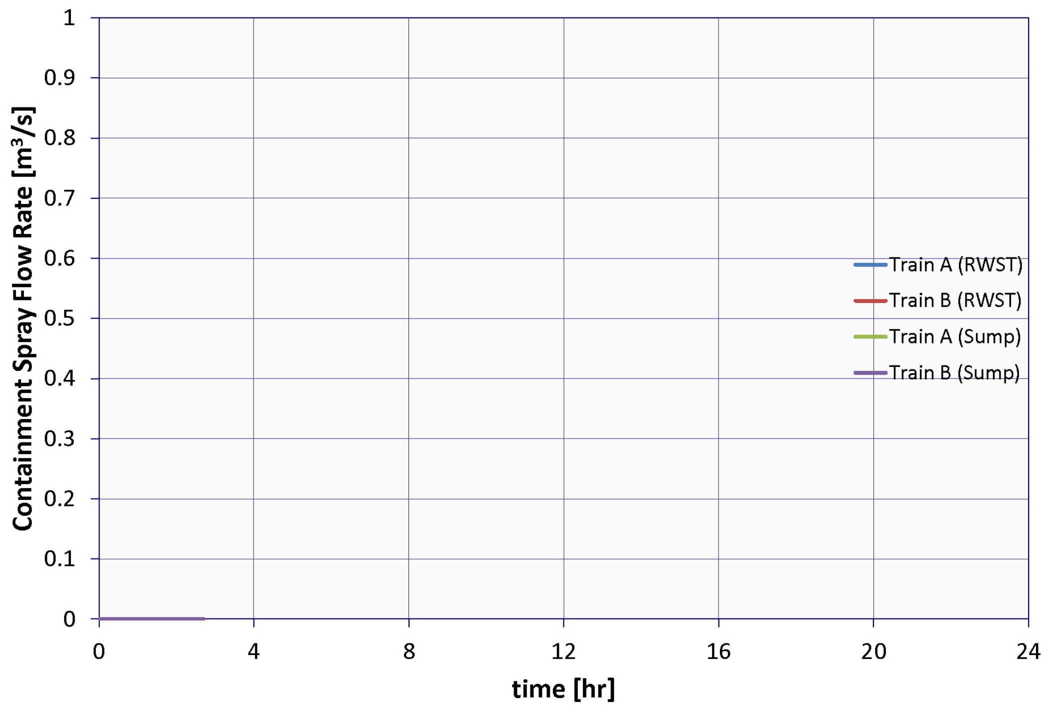

ECCS Mass Flow Rate [kg/s]
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
4
8
12
16
20
24
time [hr]
Break
Charging
SI
LPI
Accumulators
LPR

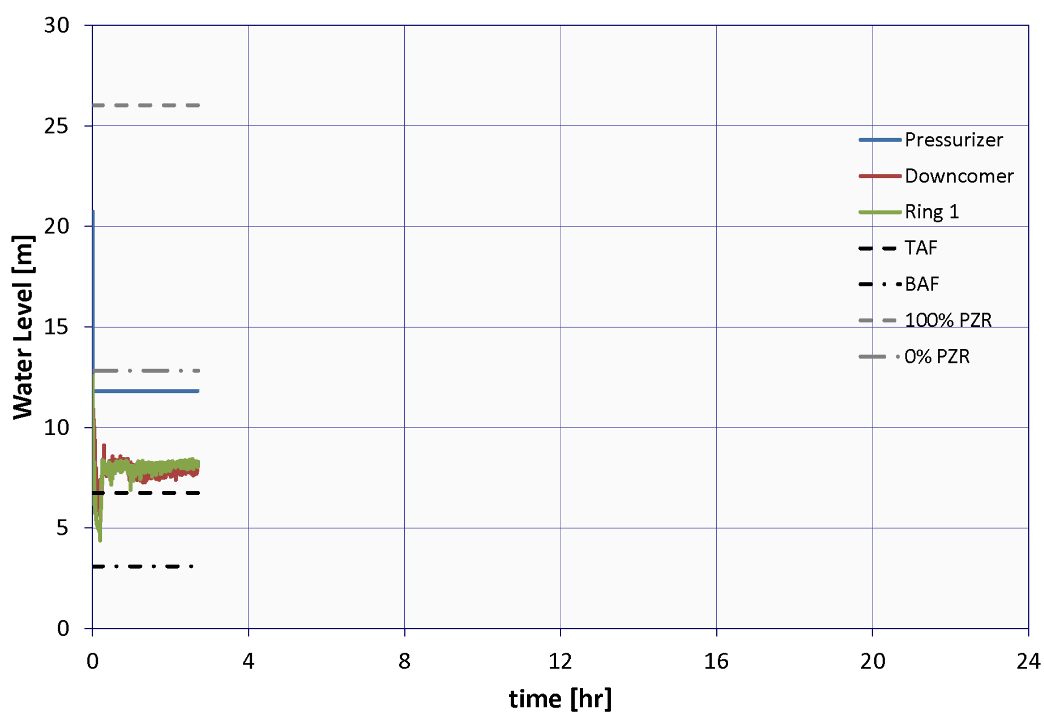


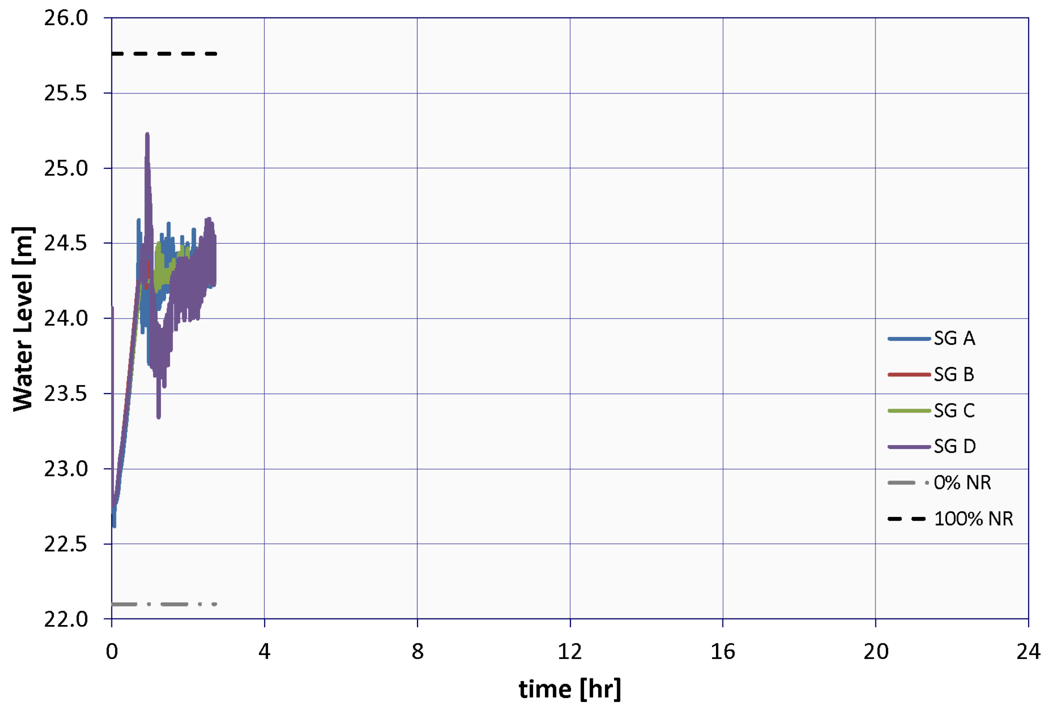
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

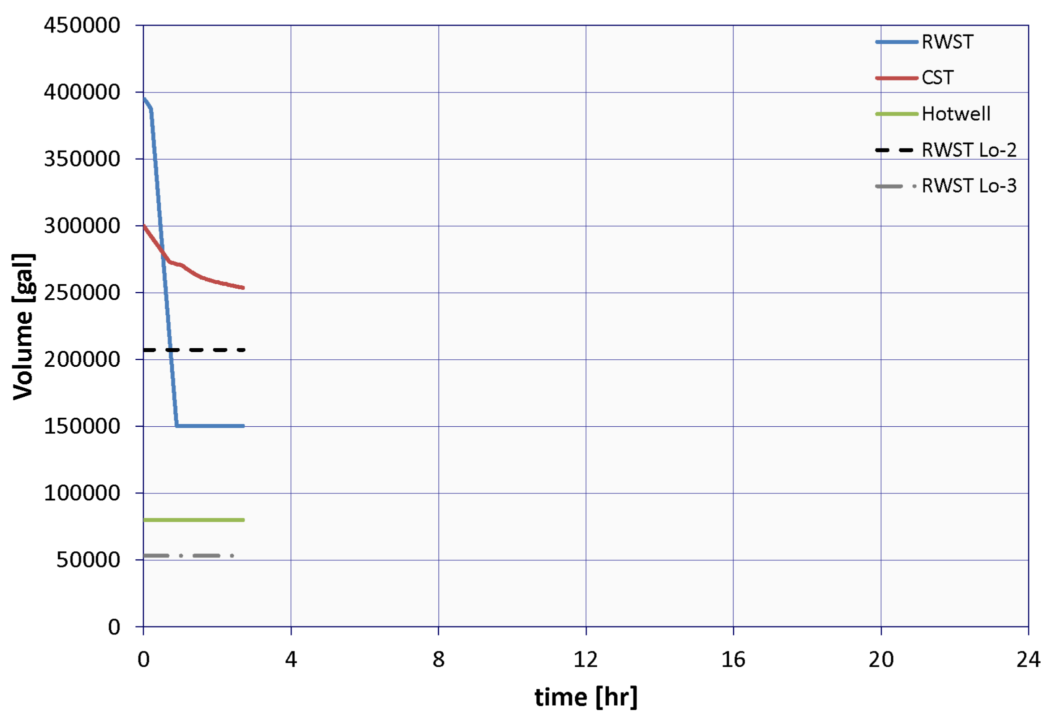


Steam Generator PORV Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
5
10
15
20
25
30
35
40
45
0
4
8
12
16
20
24


Containment Spray Flow Rate [m³/s]
time [hr]
Train A (RWST)
Train B (RWST)
Train A (Sump)
Train B (Sump)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24


Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
30
25
20
15
10
5
0
0
4
8
12
16
20
24


26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

APPENDIX F

DETAILED LOSS OF SHUTDOWN COOLING RESULTS

F.1 Mode 4 Calculations

Notes

The following list identifies the major changes that were made to the MELCOR input deck in order to perform Mode 4 shutdown calculations.

- Logic has been added to model the shutdown cooling function of the residual heat removal (RHR) system. This logic is set up such that RHR flow rate is adjusted in order to maintain a constant coolant temperature, up to the maximum flow rate of the system. The logic also includes provisions to achieve a target cooldown rate; however, this feature is not used in any of the shutdown calculations performed for this report.

- Pressurizer level control logic has been modified to control water level at the no-load setpoint (25 percent level) during the steady-state portion of the calculation.

- Similarly, pressurizer heater logic has been modified to achieve the desired pressure during the steady-state portion of the Mode 4 calculations.

- Logic that makes it possible to turn off emergency core cooling system (ECCS) flow to prevent overfilling the pressurizer has been modified in order to simulate recovery actions in which operators inject using a charging pump when reactor pressure vessel (RPV) level is low. This feature is exercised in Mode 4 Cases 2 and 5.

- The decay heat curves have been shifted in order to simulate the desired times after trip. For example, the decay heat curve is shifted by 12 hours for Mode 4 Cases 1–5. Note that during the steady-state portion of the calculation, the decay heat is assumed to be constant and to equal the decay power at 12 hours. The same is true for all other times since subcriticality that are analyzed in Section 5.8.2 of the report.

- Initial temperature and pressure of reactor coolant system (RCS) control volumes have been set to 275 degrees Fahrenheit (F) (408.15 Kelvin (K)) and 350 pounds per square inch absolute (psia) (2.413 megapascals (MPa)).

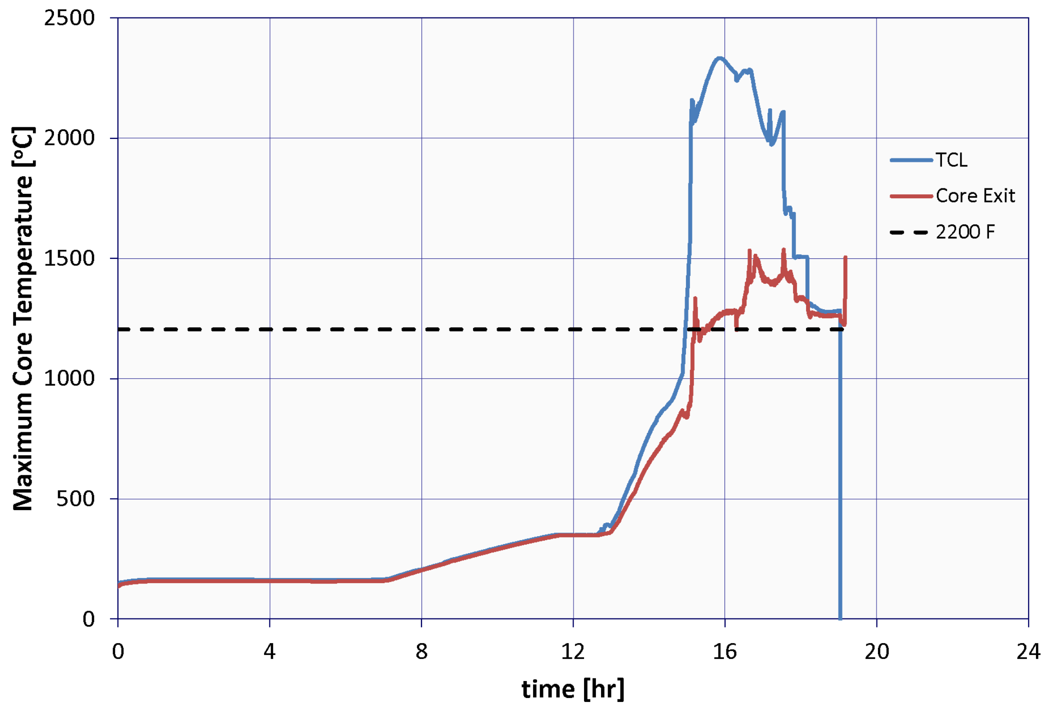
- Secondary-side temperatures (including feedwater temperature) have been set to 275 degrees F (408.15 K).

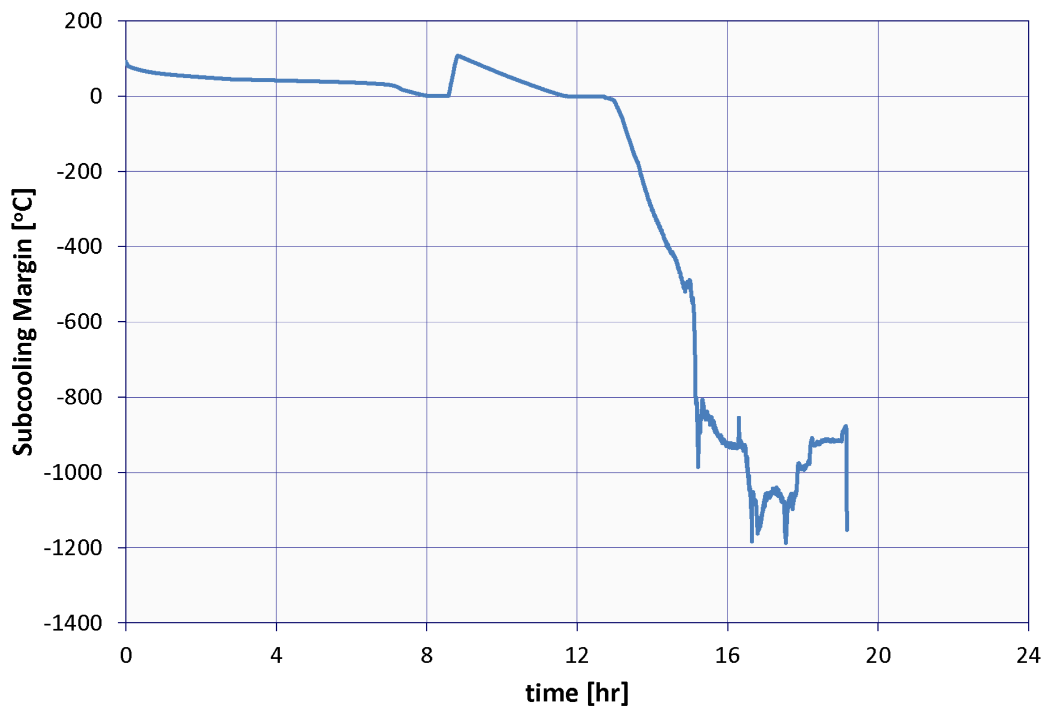
- Logic for the steam dump valves has been modified to maintain secondary-side pressure at 45 psia (0.313 MPa), which is the saturation pressure at 275 degrees F (408.15 K).

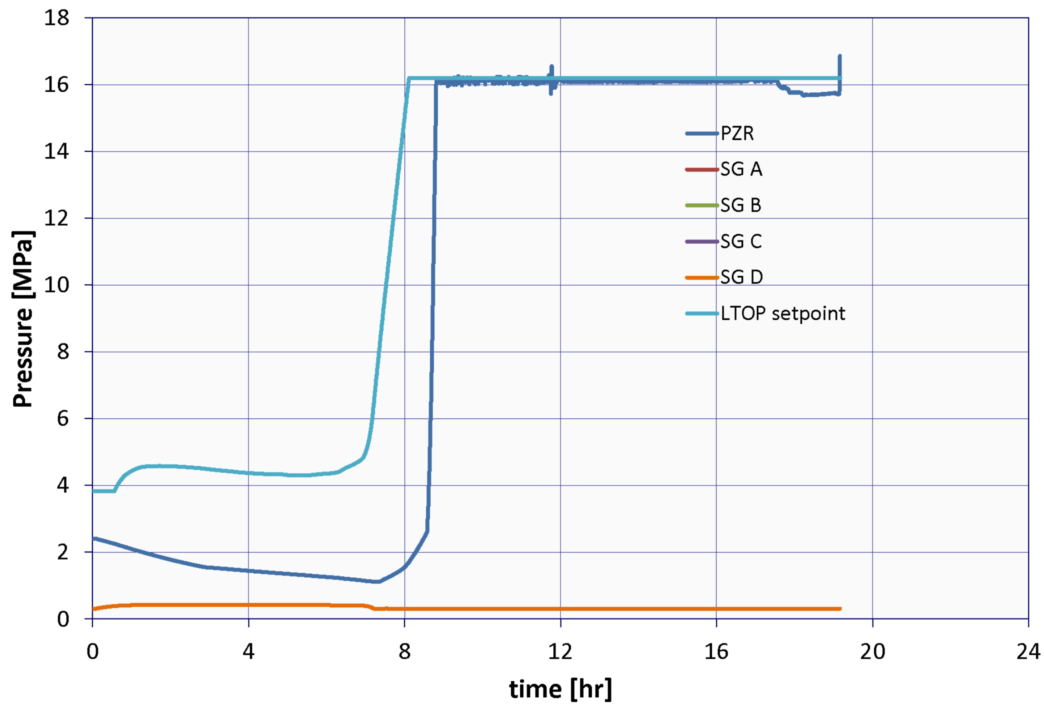
- Steam generator water level logic has been modified so that steady-state water level is controlled at 18 percent narrow range (NR) or 27 percent wide range (WR) level, depending on the case being analyzed.

- Cold volumes have been used in place of hot volumes for RCS control volumes. This decreases the RCS volume by approximately 1 percent.

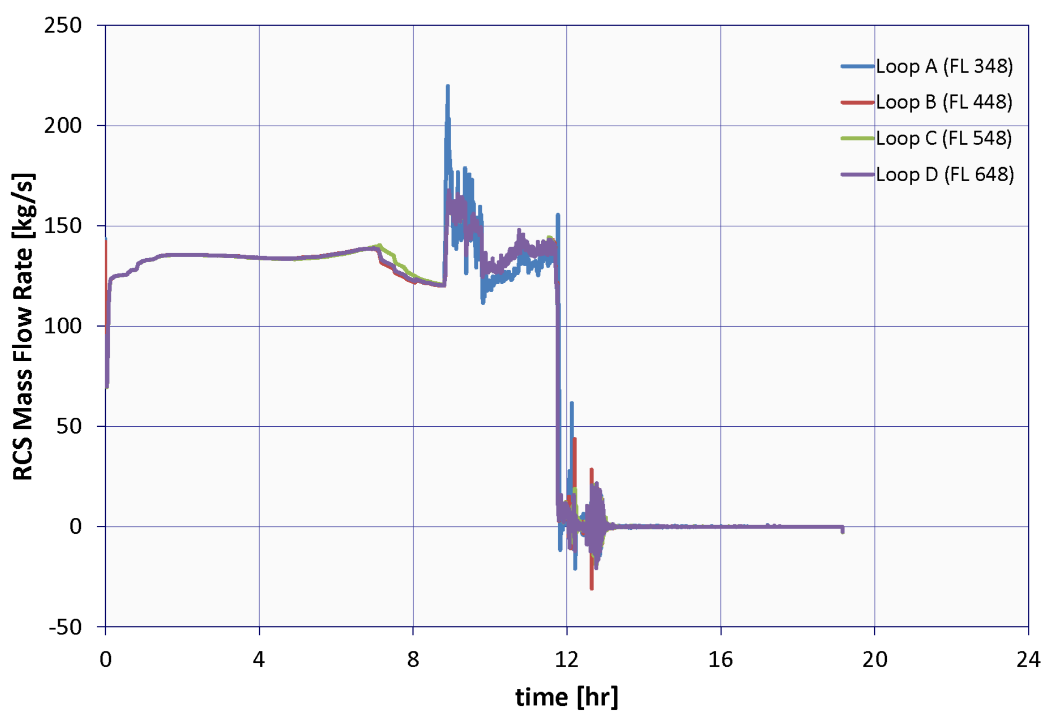
F.1.1 Case 1: SG at 18% NR Level, 12 hr after Shutdown, No Recovery Actions



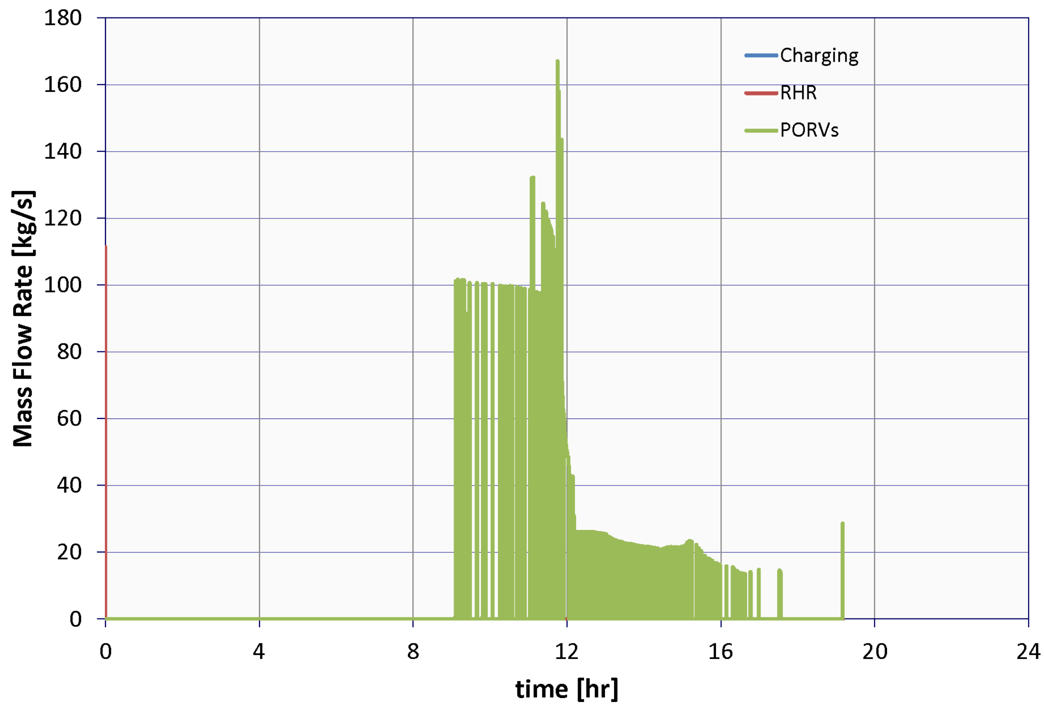




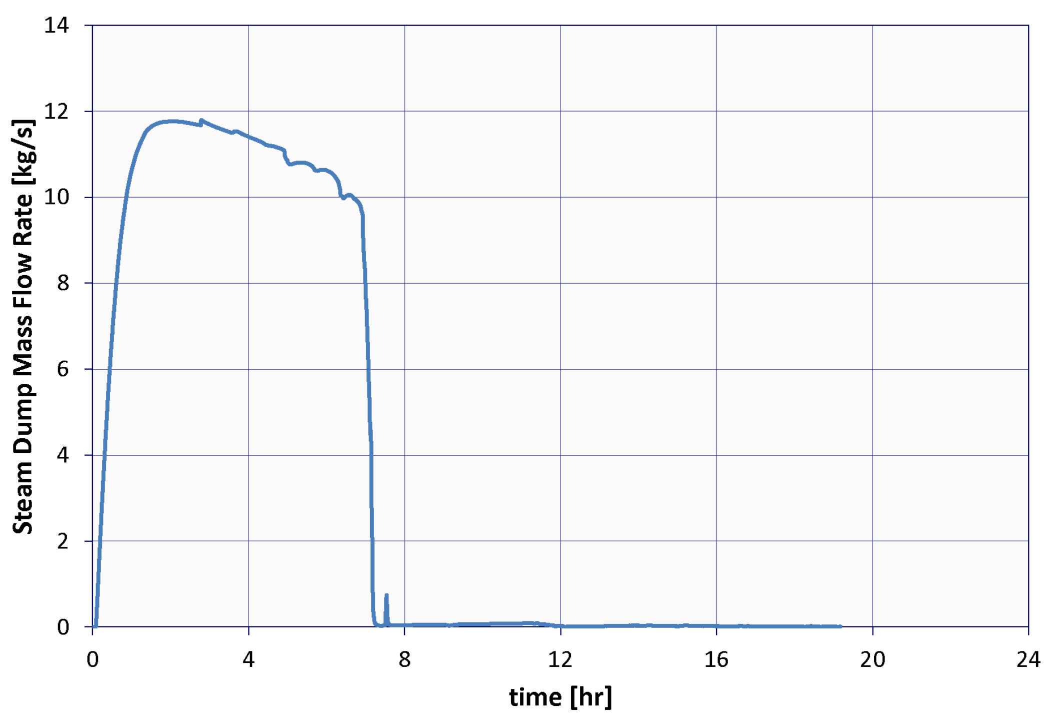
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D
LTOP setpoint



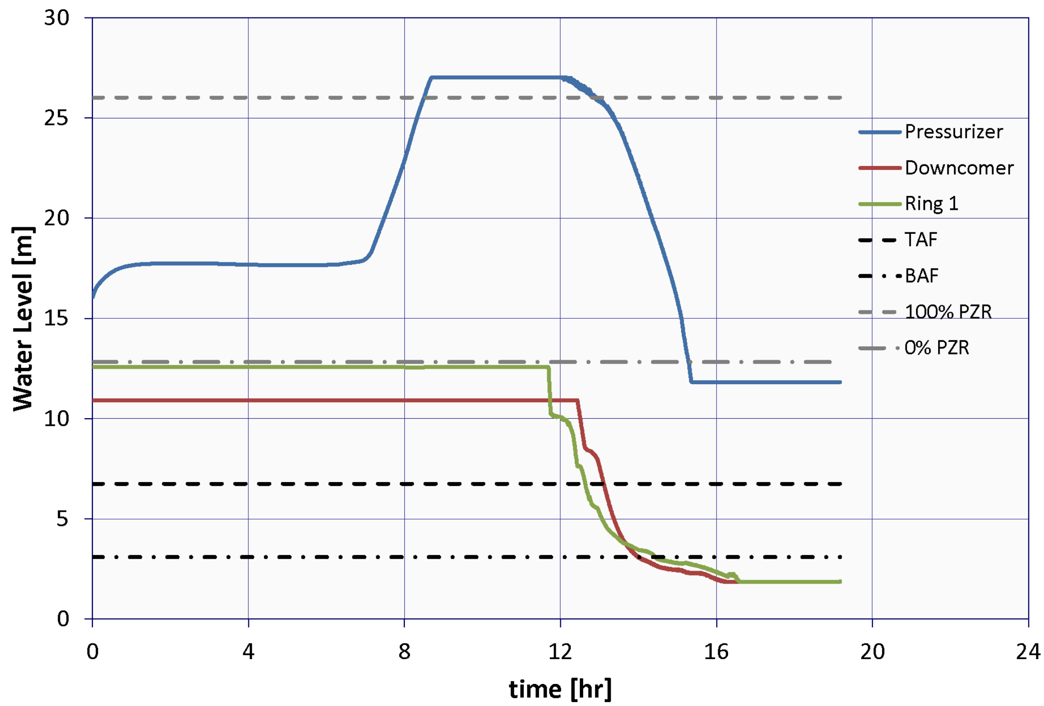
250
200
150
100
50
0
-50
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

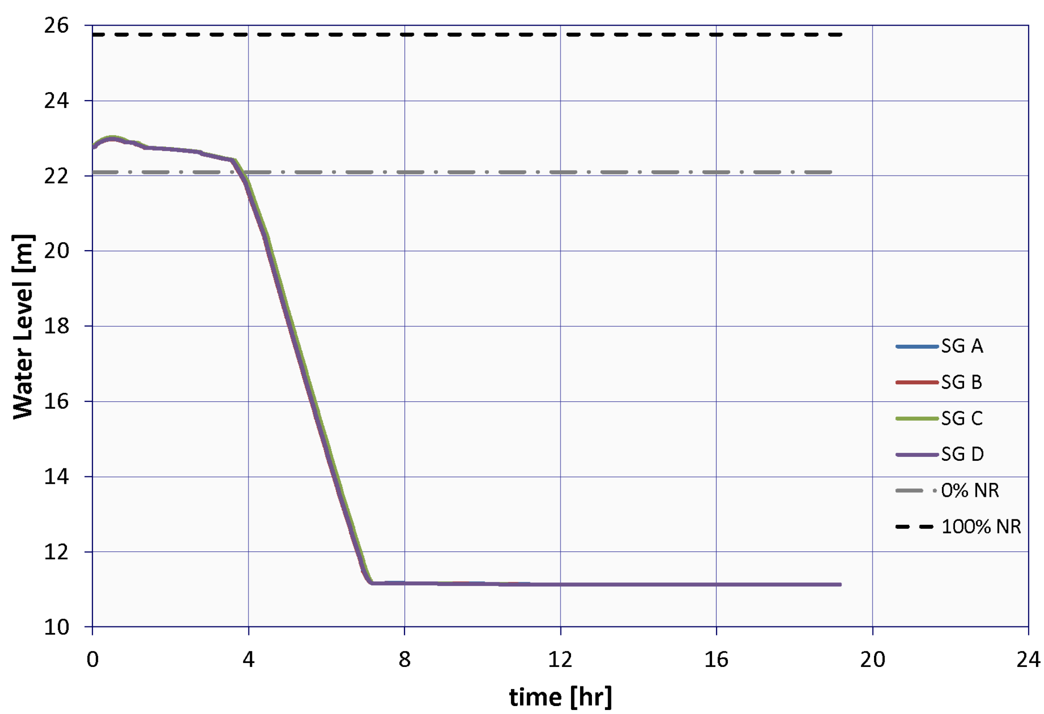


180
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
Mass Flow Rate [kg/s]
time [hr]
Charging
RHR
PORVs

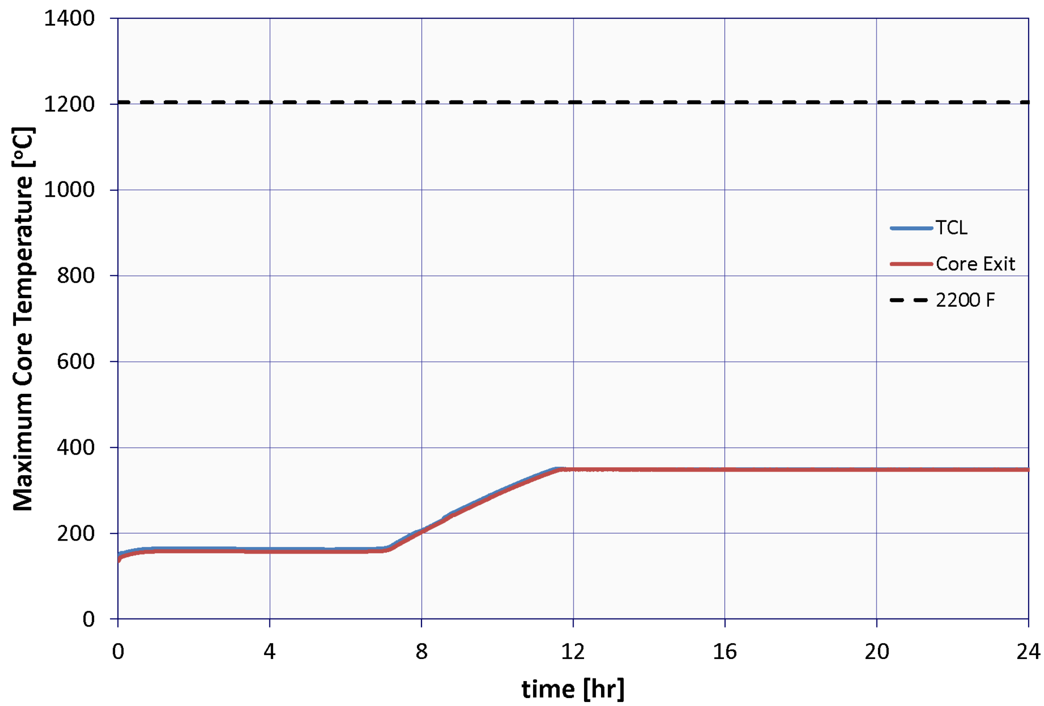


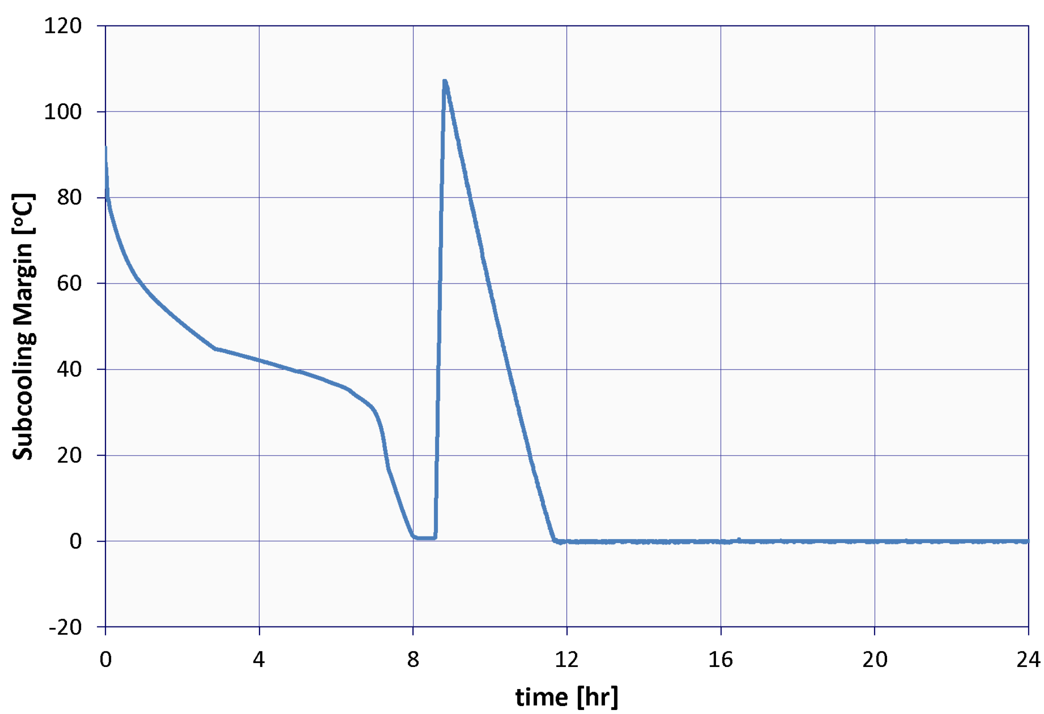
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24
Steam Dump Mass Flow Rate [kg/s]
time [hr]

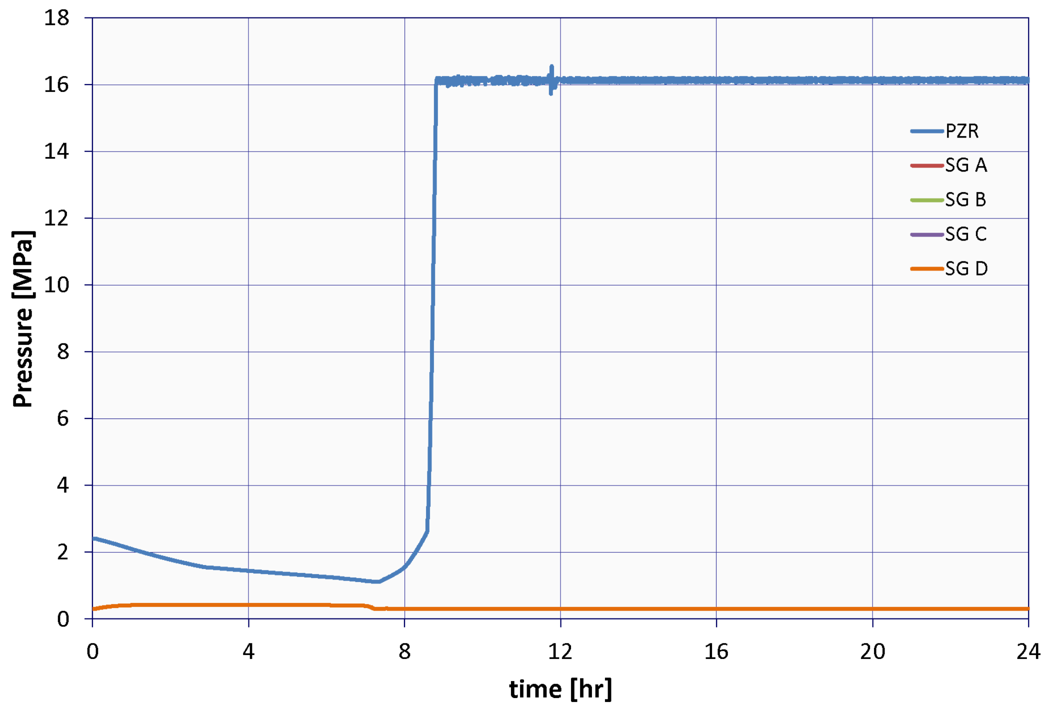

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR


26
24
22
20
18
16
14
12
10
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

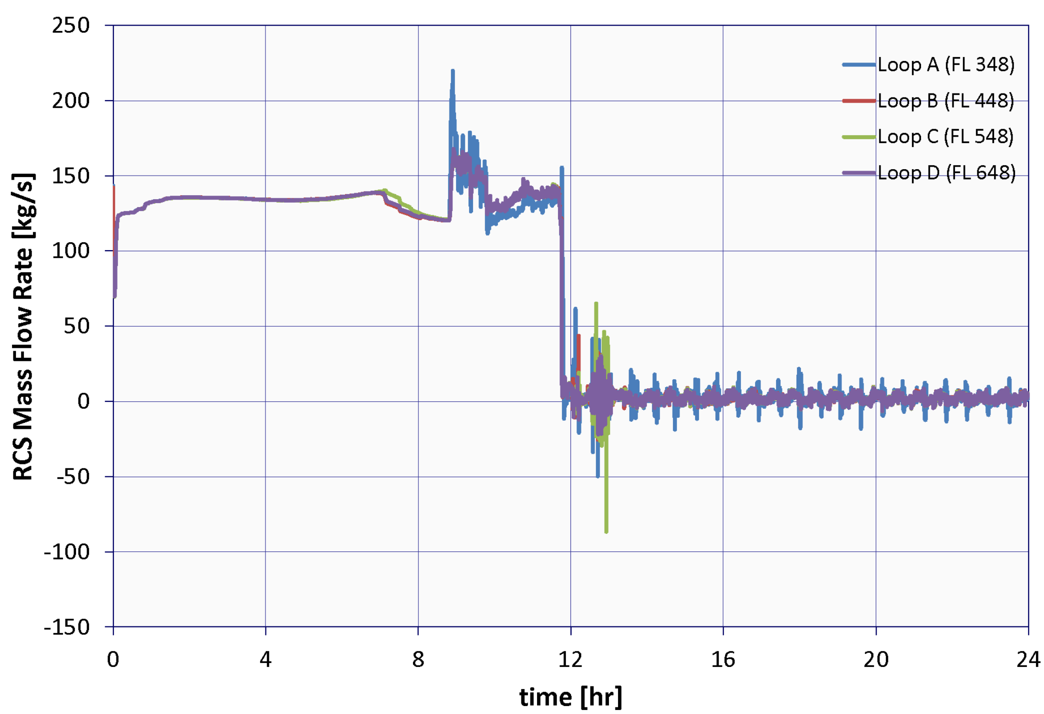
F.1.2 Case 2: SG at 18% NR Level, 12 hr after Shutdown, Start CCP on Low RPV Level



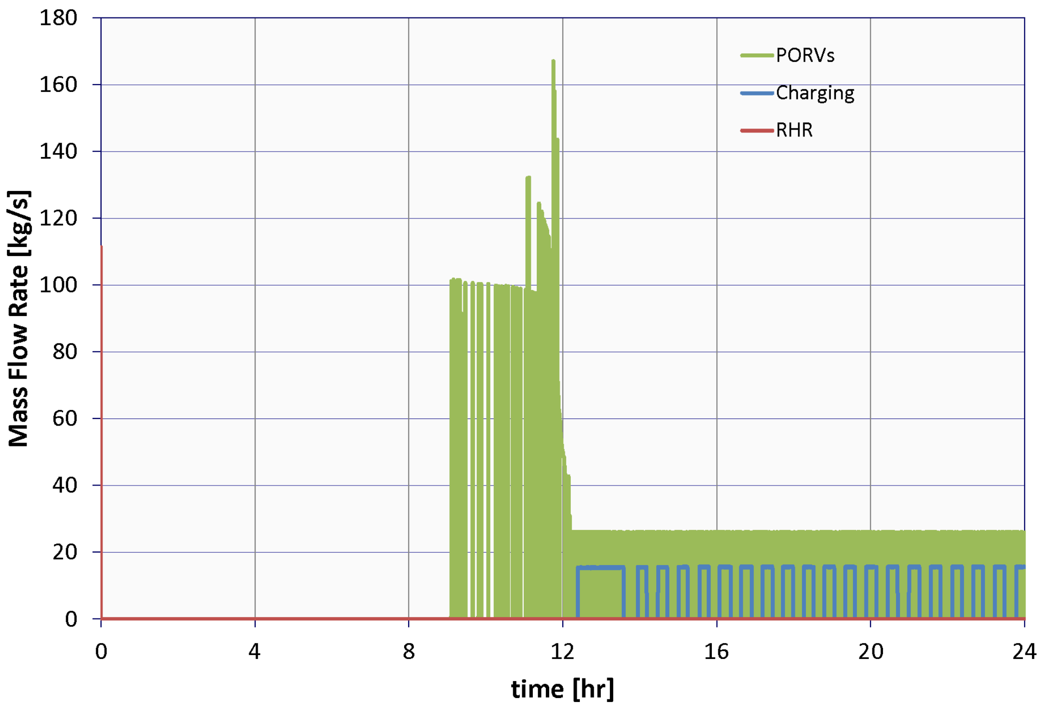




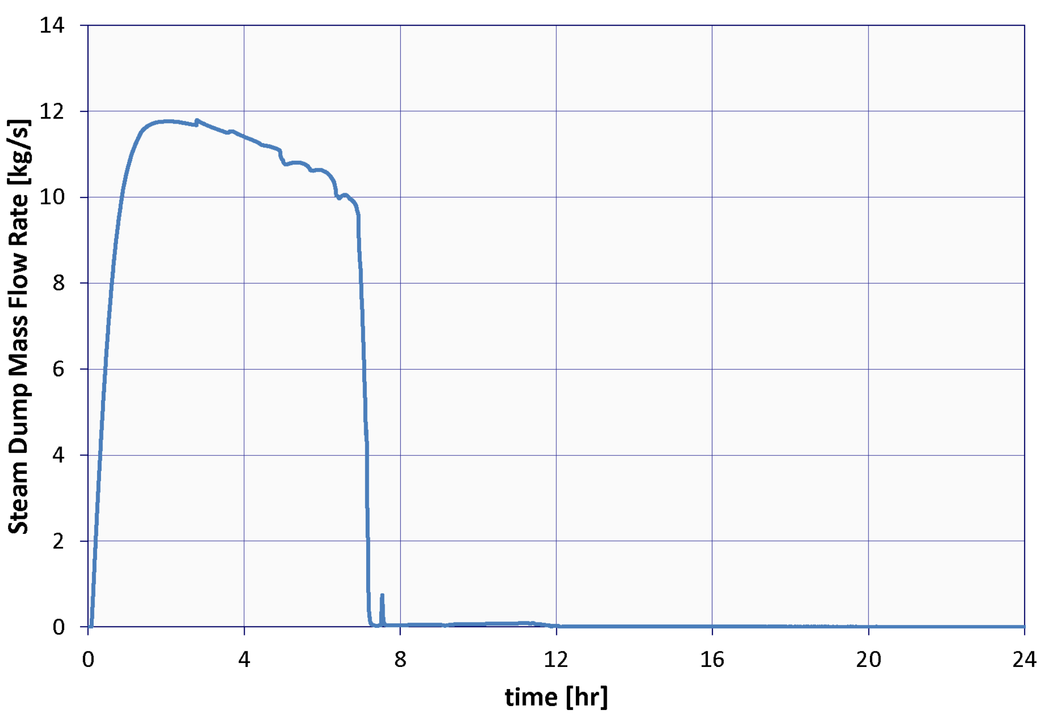
Pressure [MPa]
time [hr]
PZR
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
14
16
18
0
4
8
12
16
20
24



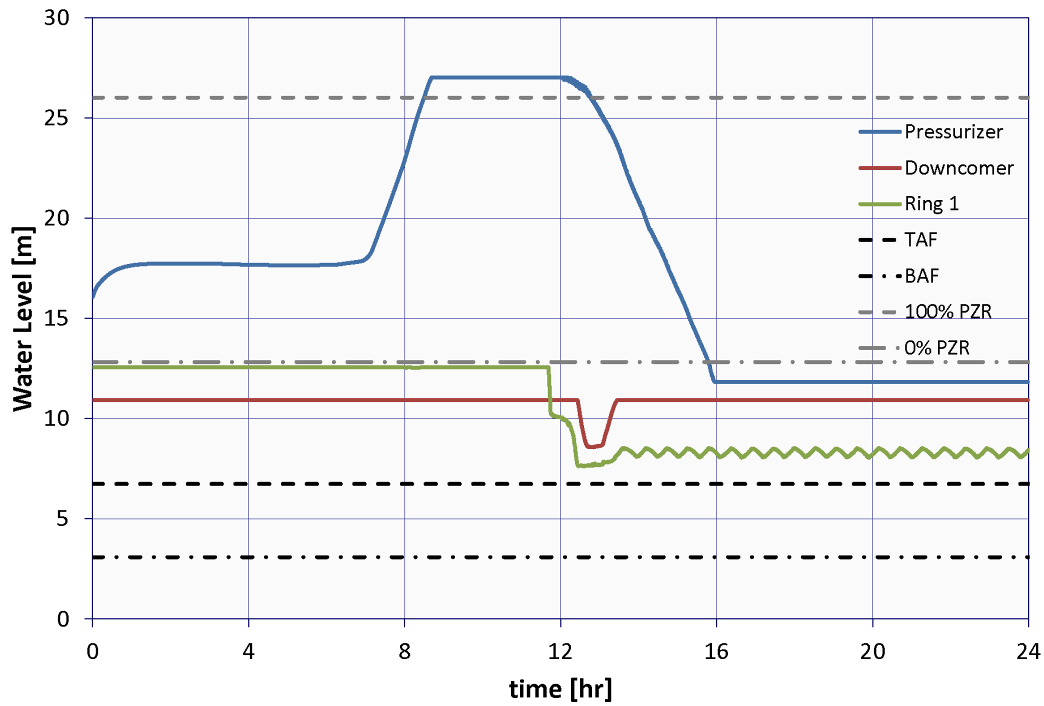
RCS Mass Flow Rate [kg/s]
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)
-150
-100
-50
0
50
100
150
200
250
0
4
8
12
16
20
24



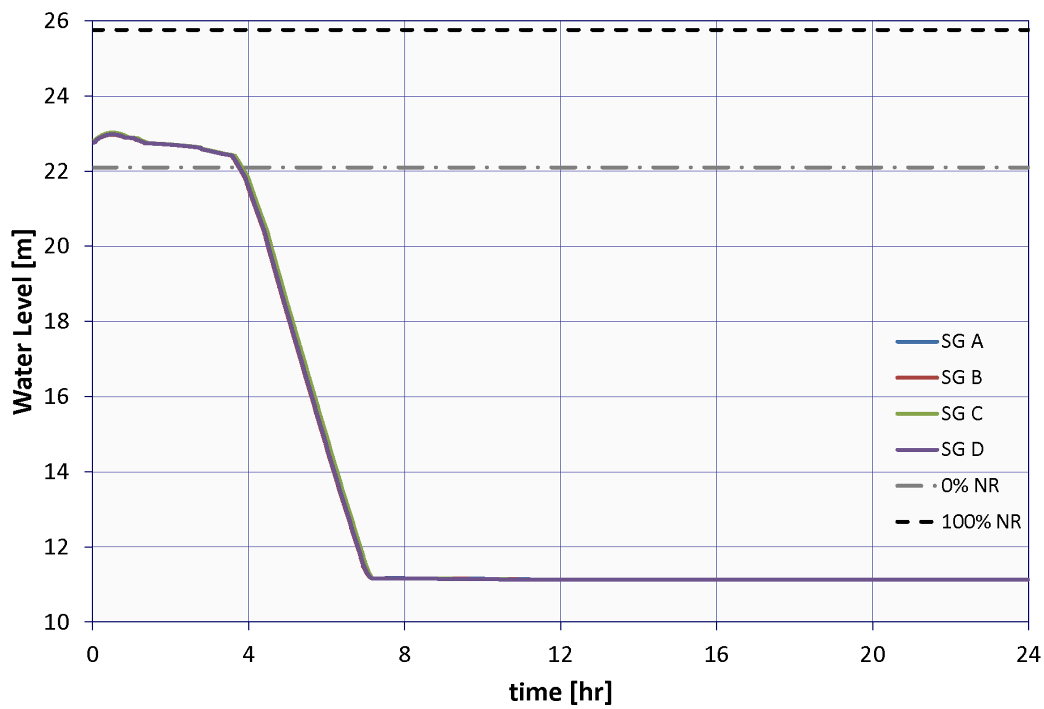
180
160
140
120
100
80
60
40
20
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
PORVs
Charging
RHR



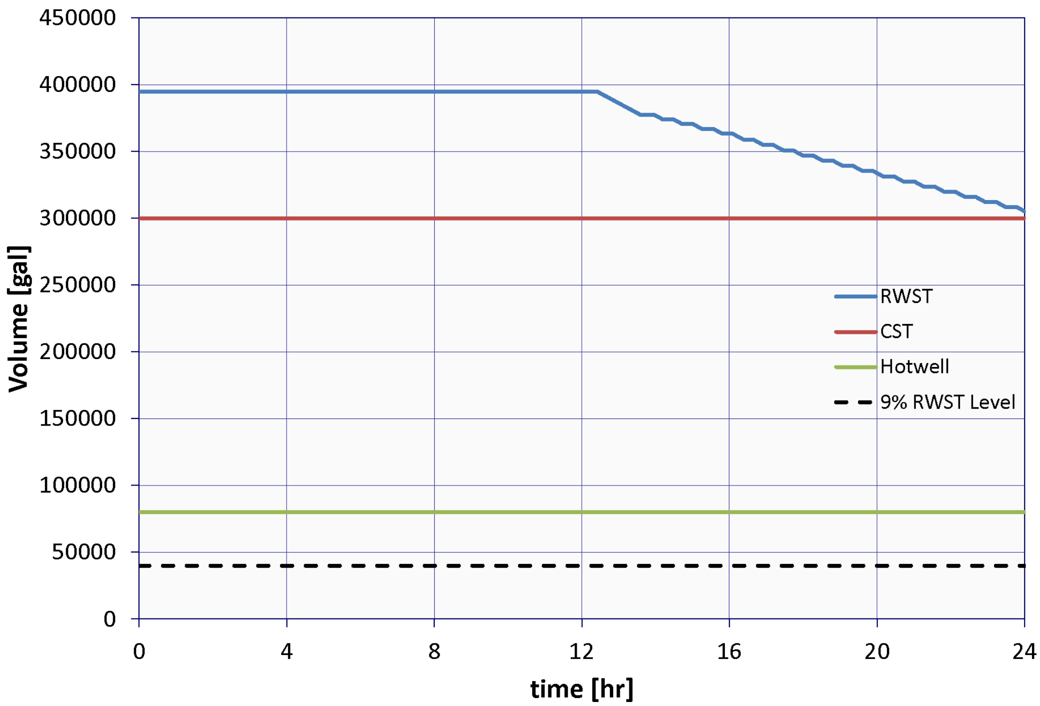
14
12
10
8
6
4
2
0
Steam Dump Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]



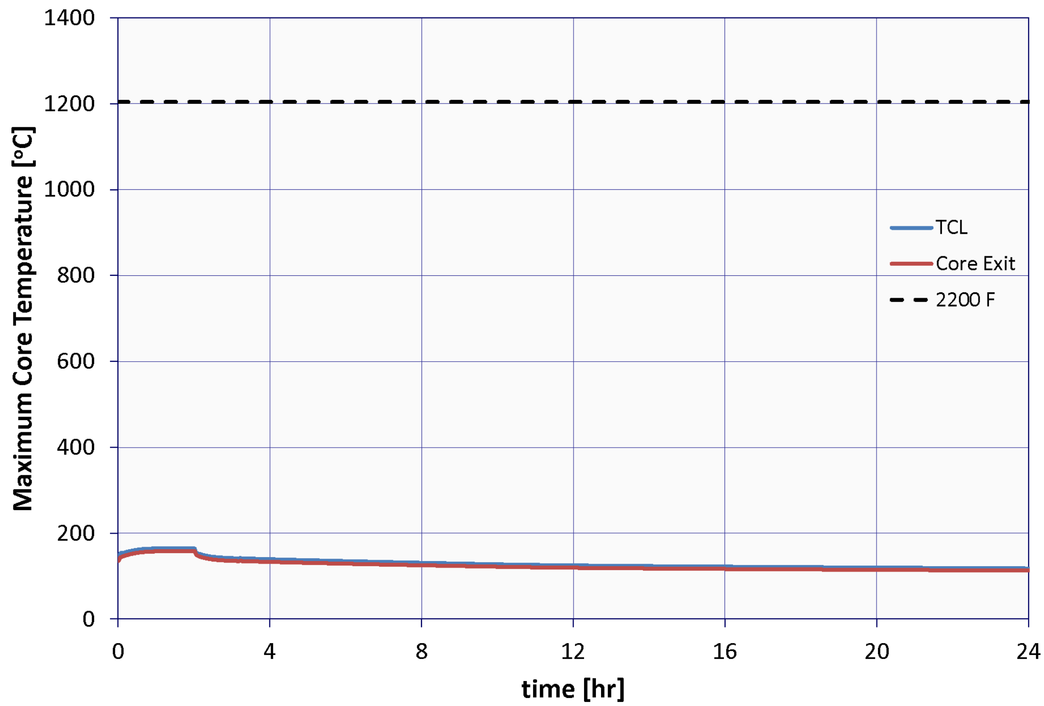
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

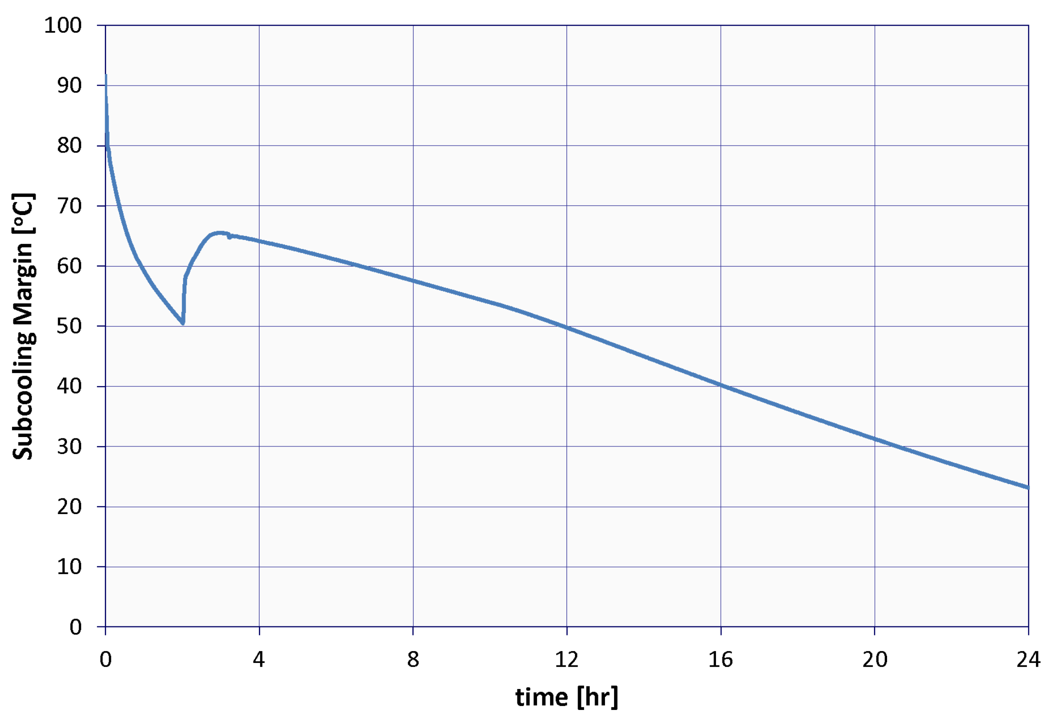


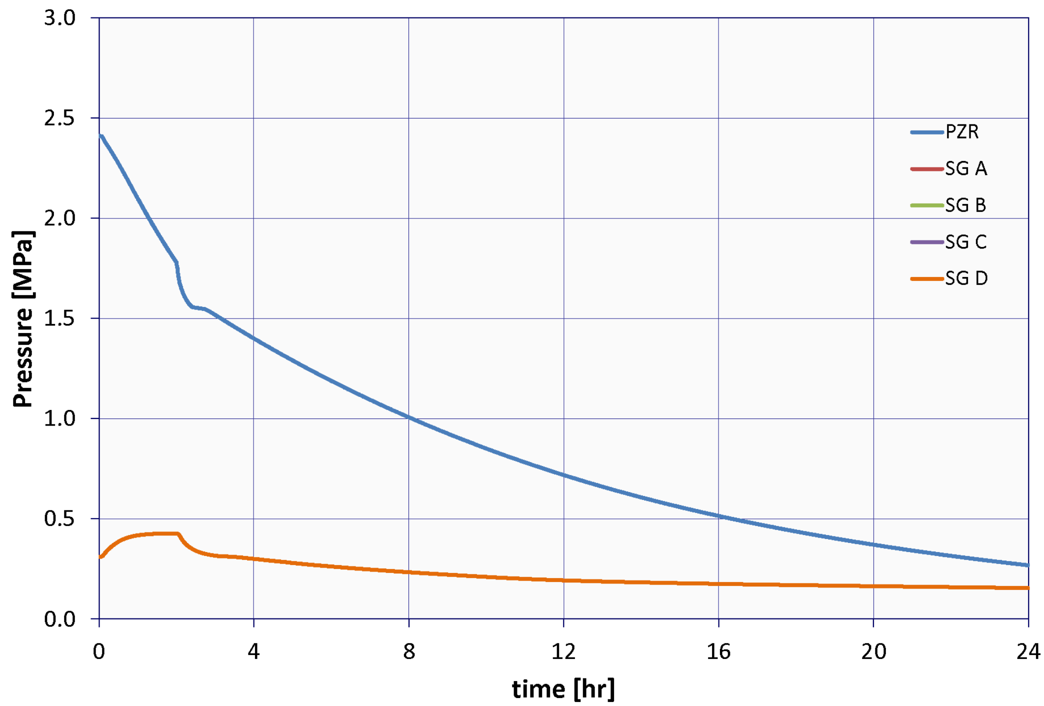
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
9% RWST Level

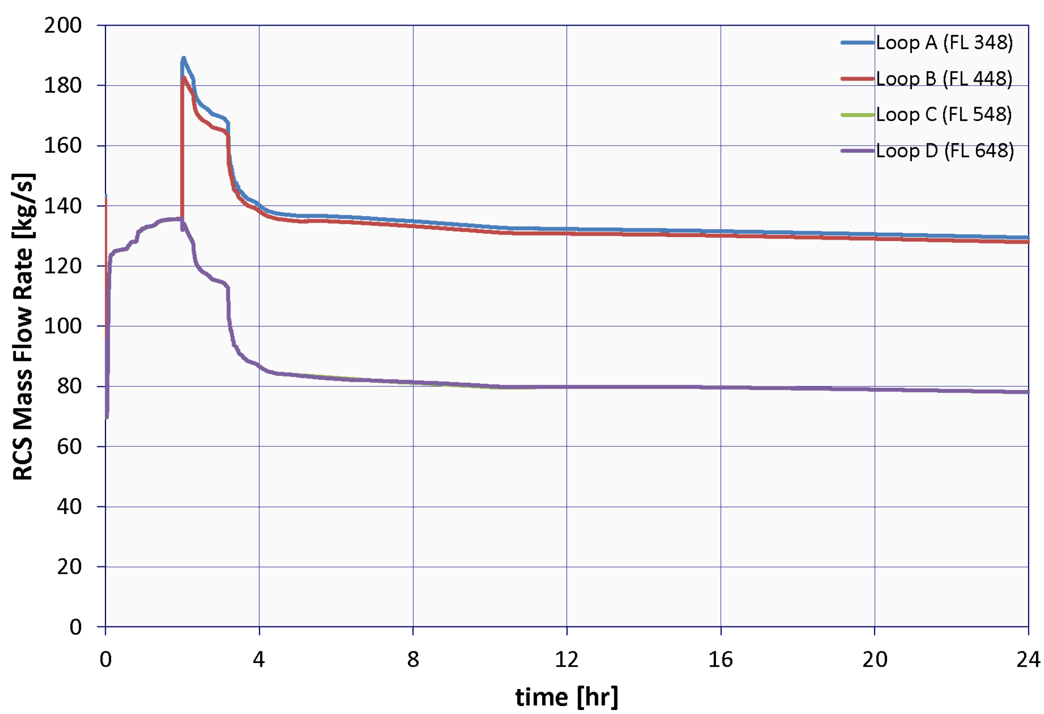
F.1.3 Case 3: SG at 18% NR Level, 12 hr after Shutdown, Recover RHR at 2 hr



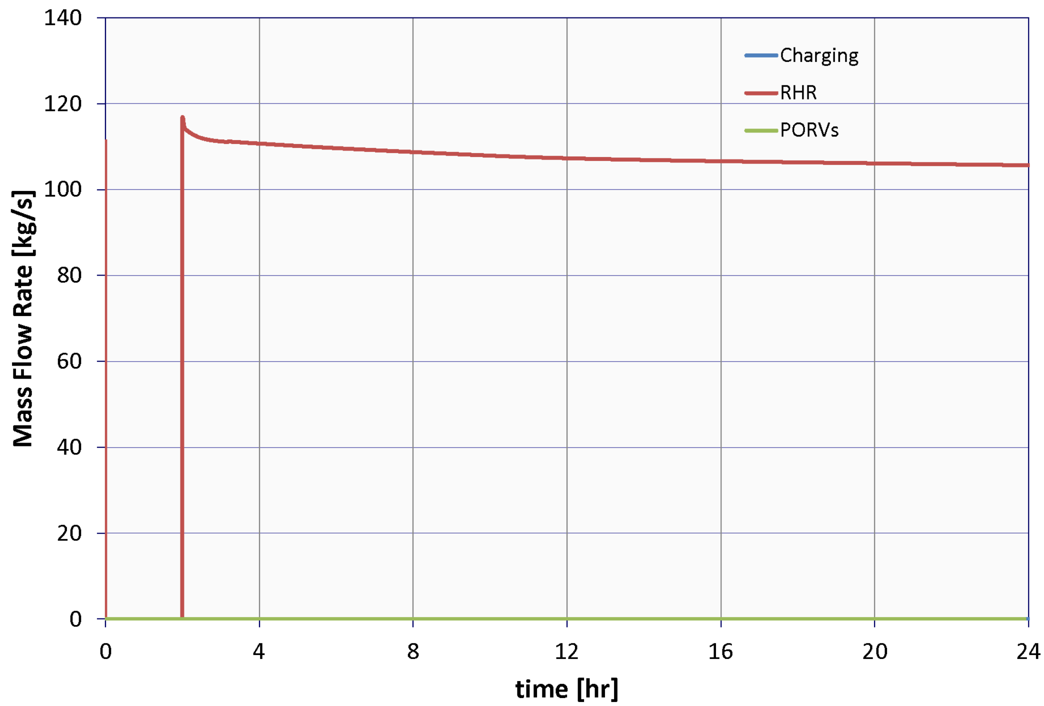




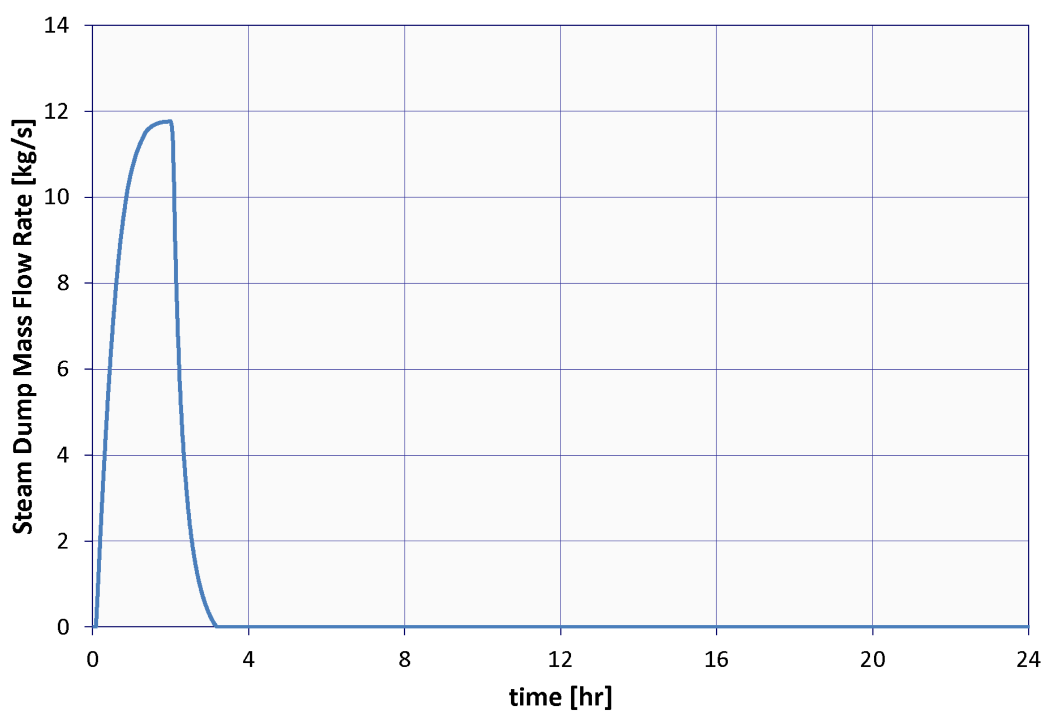
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



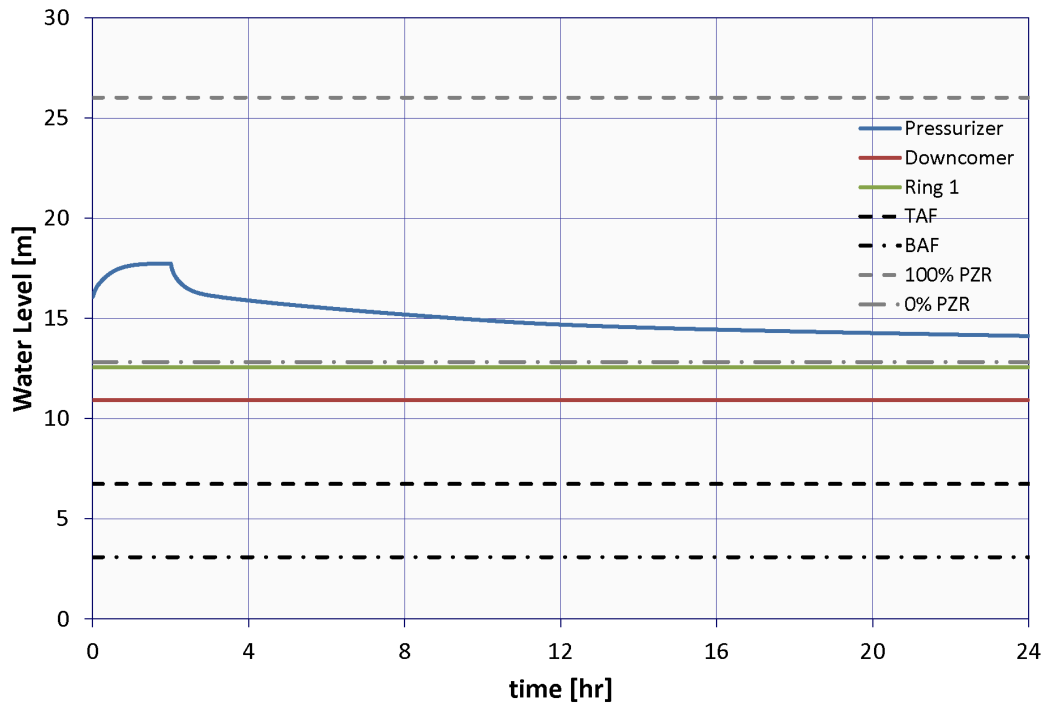
200
180
160
140
120
100
80
60
40
20
0
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

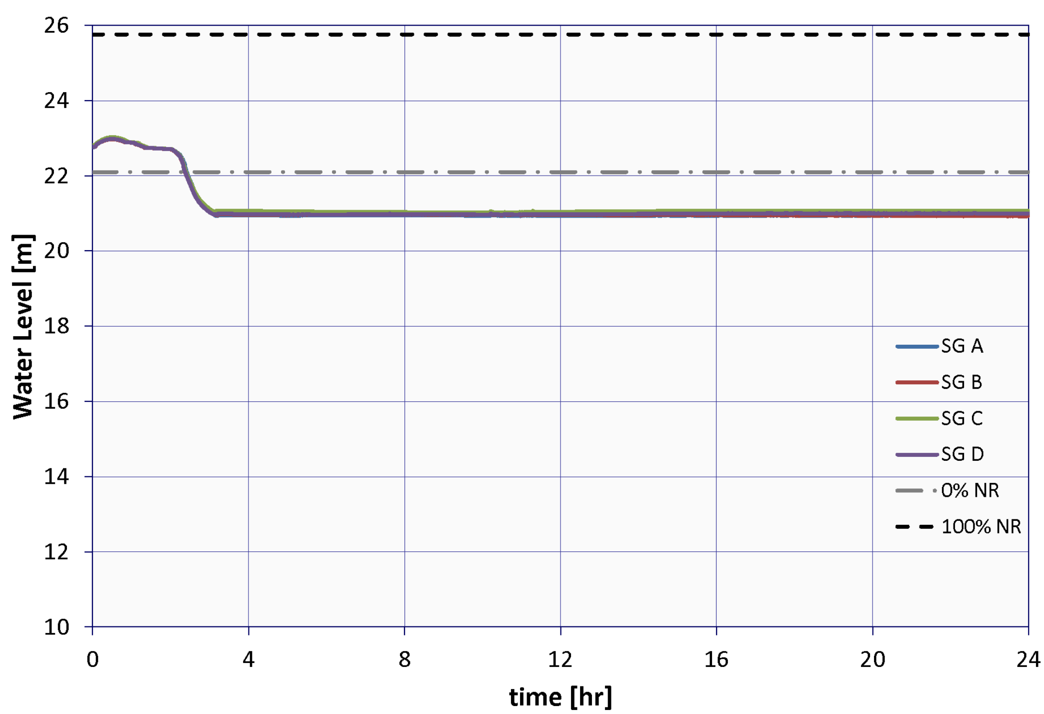


Mass Flow Rate [kg/s]
time [hr]
Charging
RHR
PORVs
0
20
40
60
80
100
120
140
0
4
8
12
16
20
24

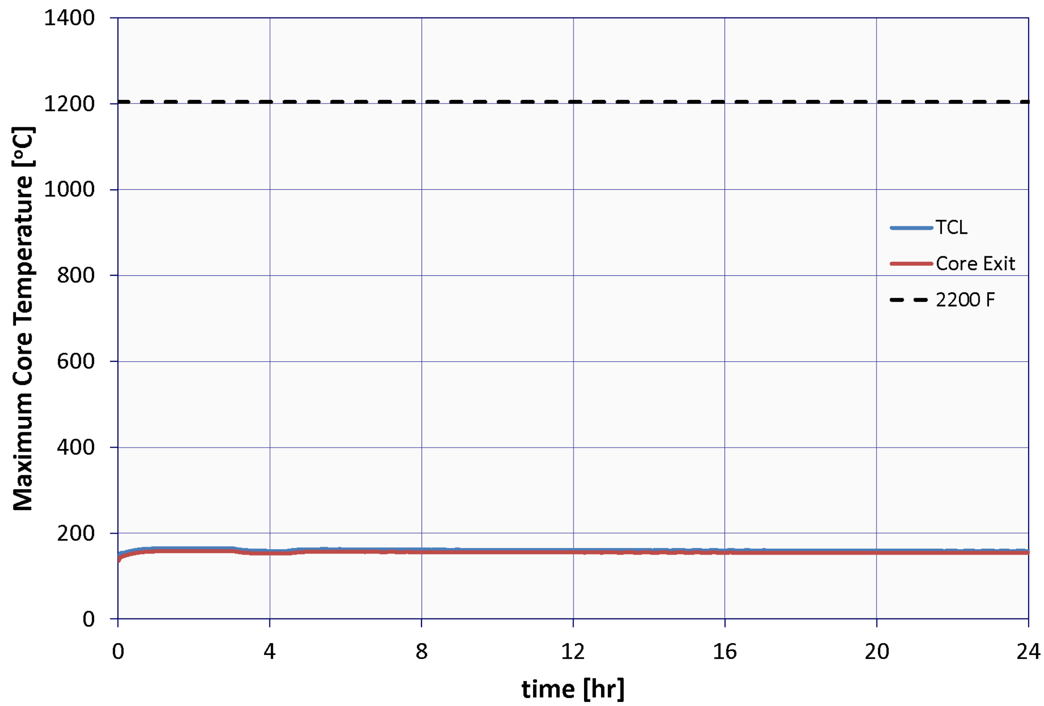


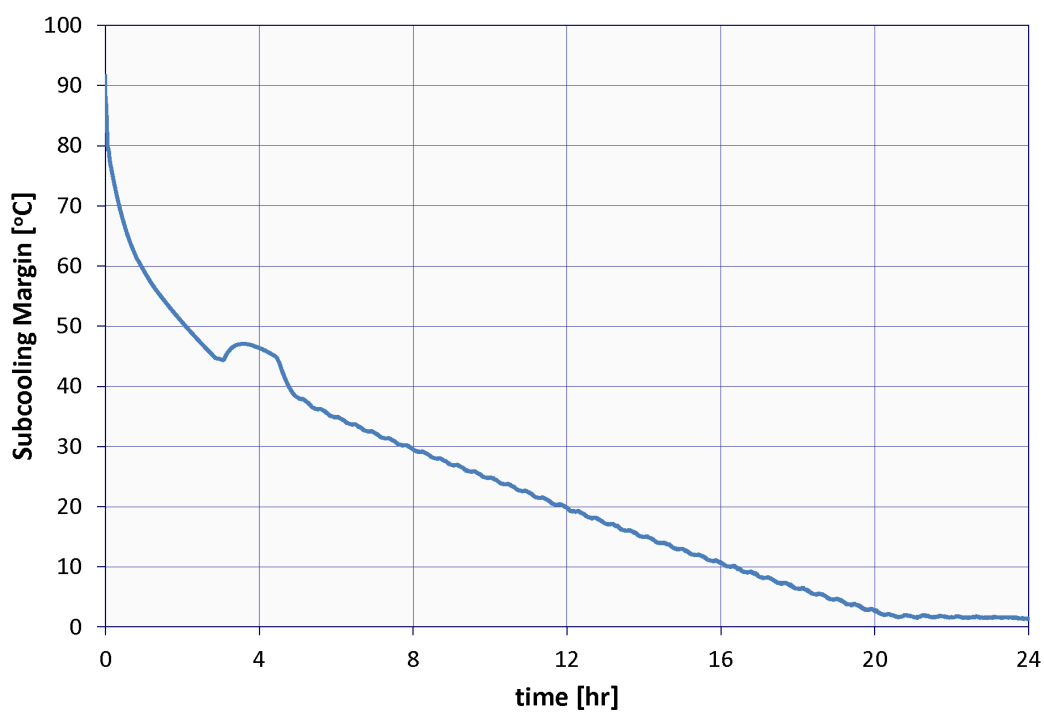
Steam Dump Mass Flow Rate [kg/s]
time [hr]
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24

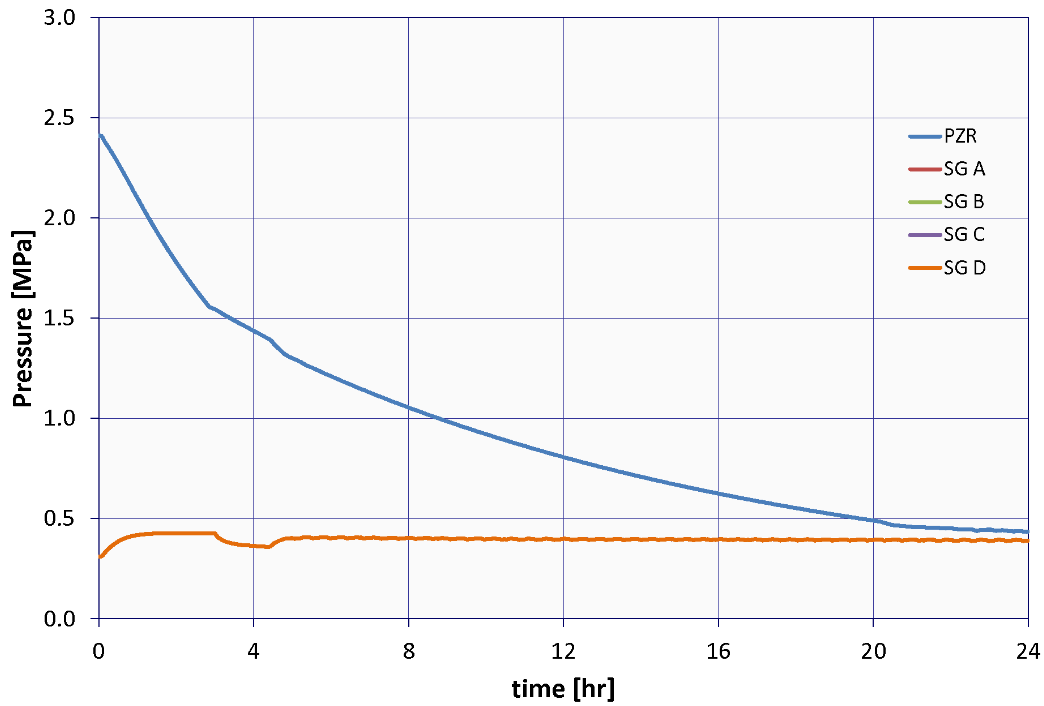

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR


26
24
22
20
18
16
14
12
10
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

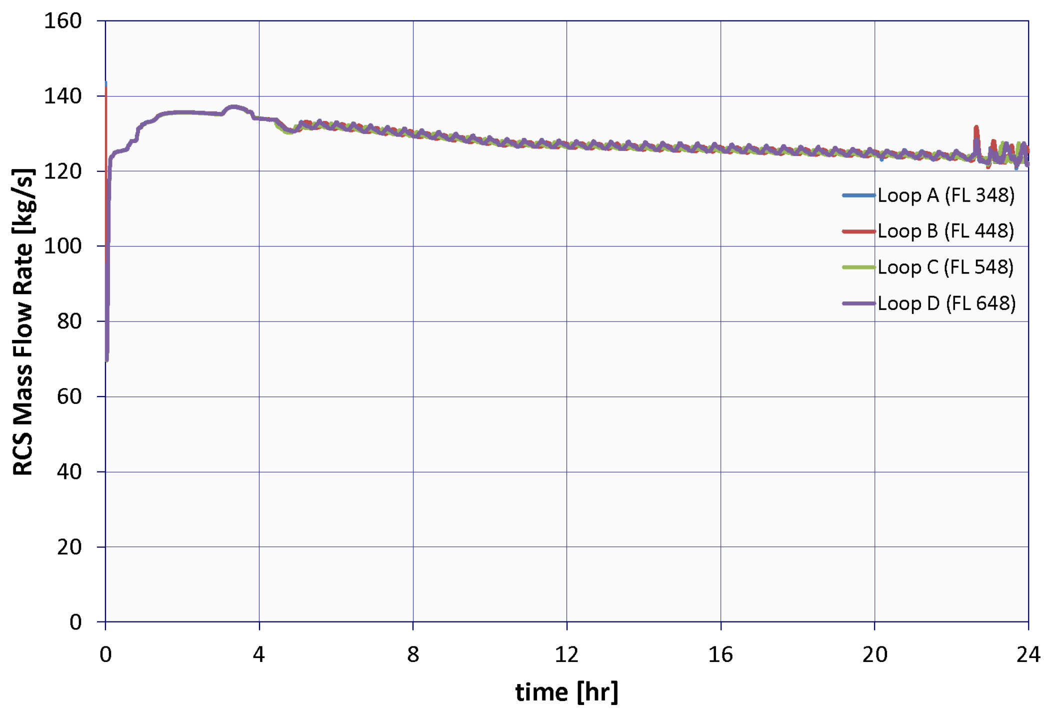
F.1.4 Case 4: SG at 18% NR Level, 12 hr after Shutdown, Initiate AFW at 3 hr



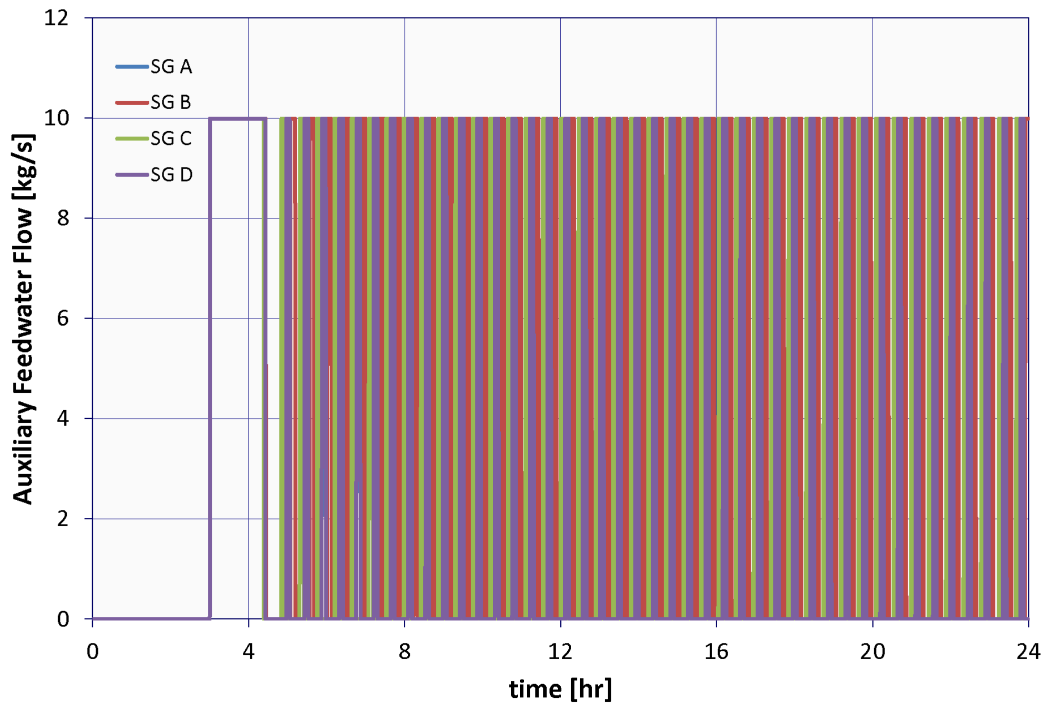


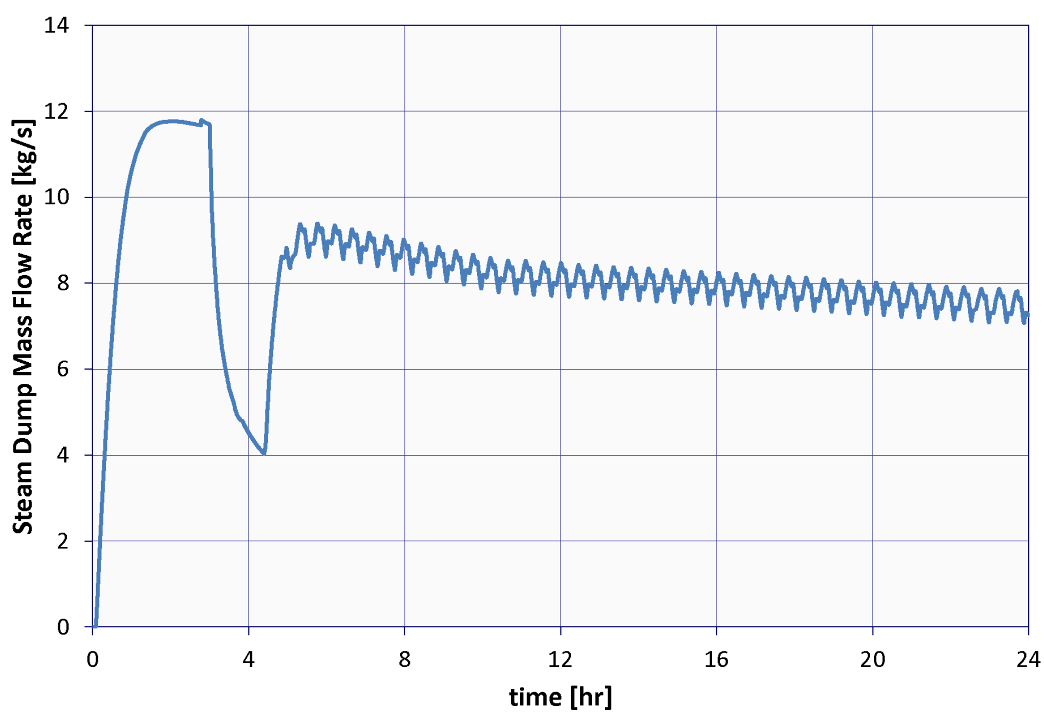


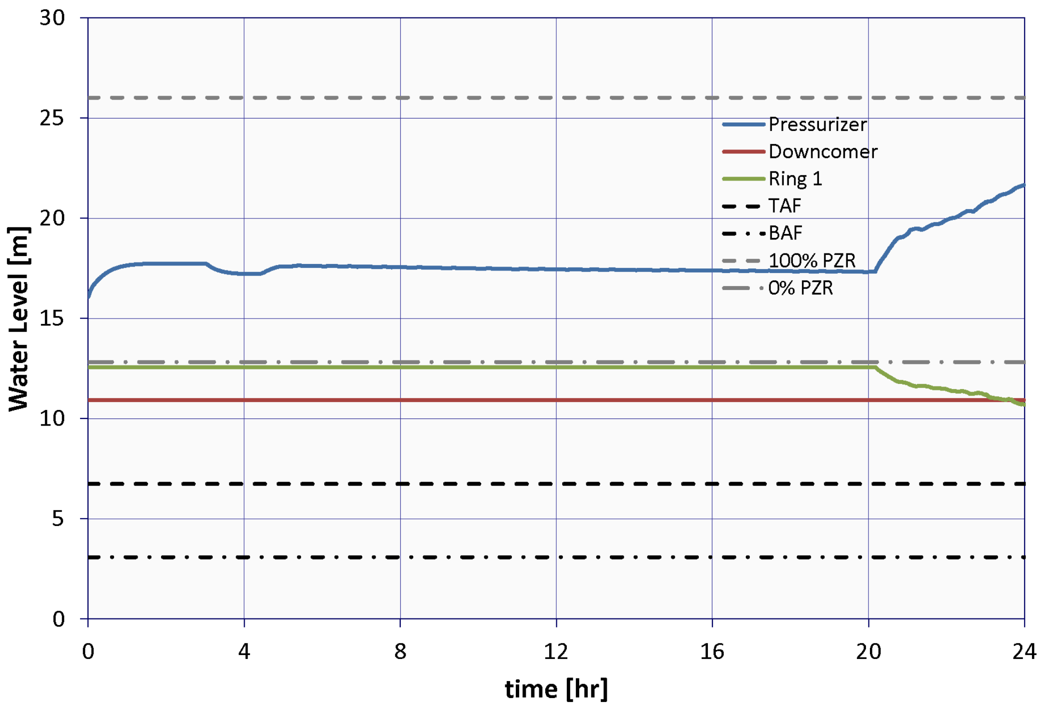
Pressure [MPa]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D

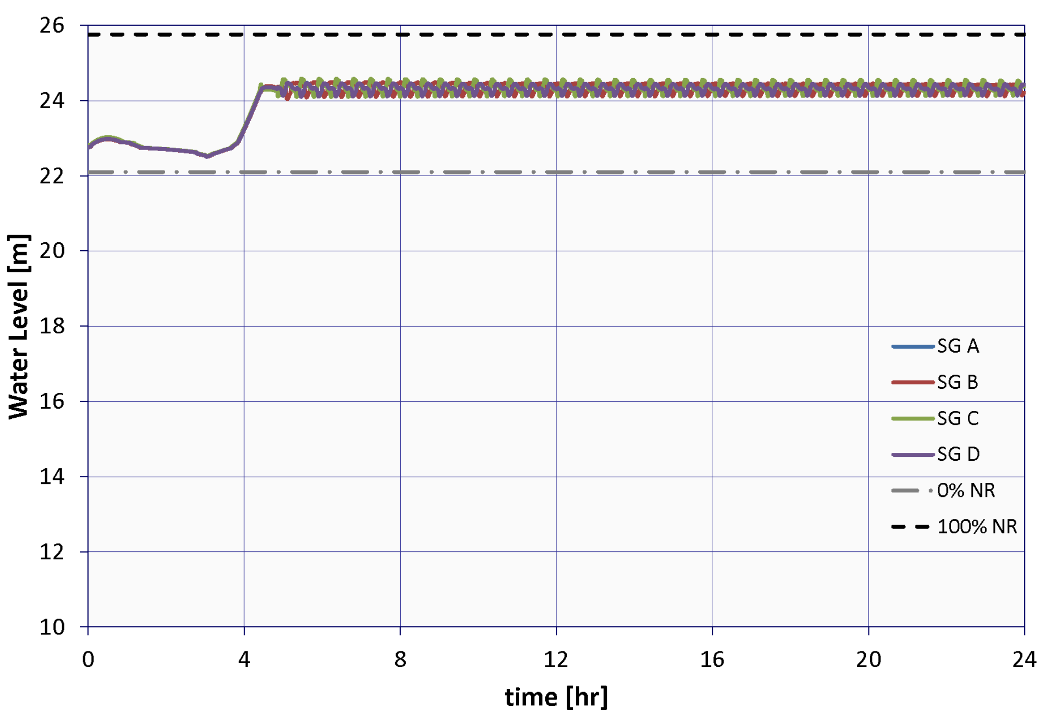


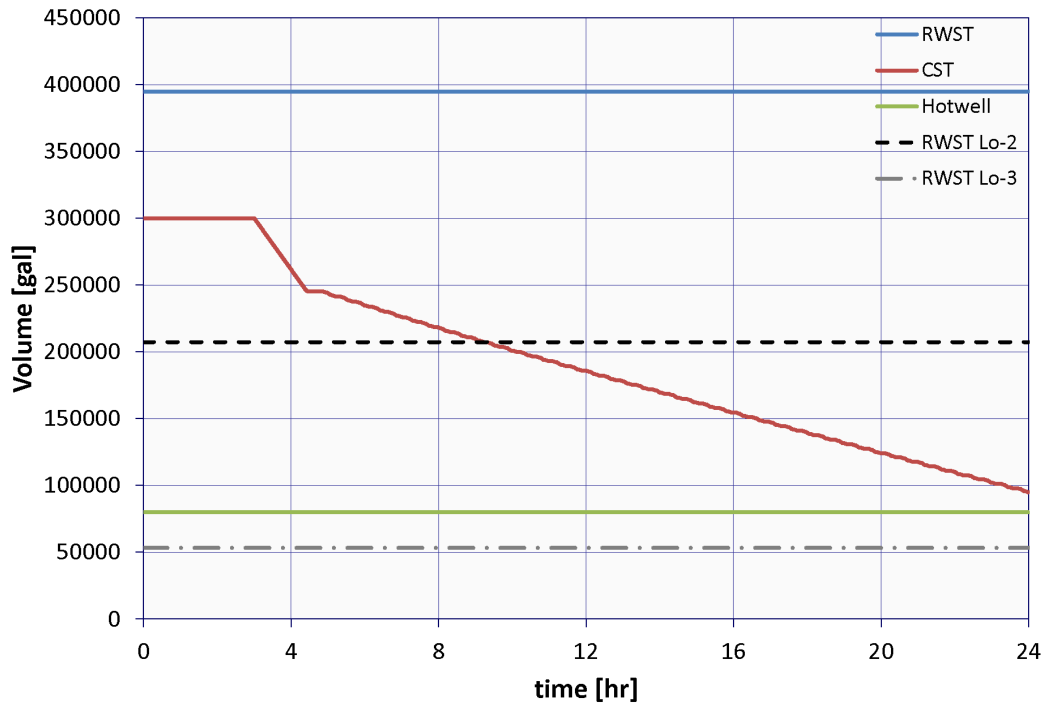
RCS Mass Flow Rate [kg/s]
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)


Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24

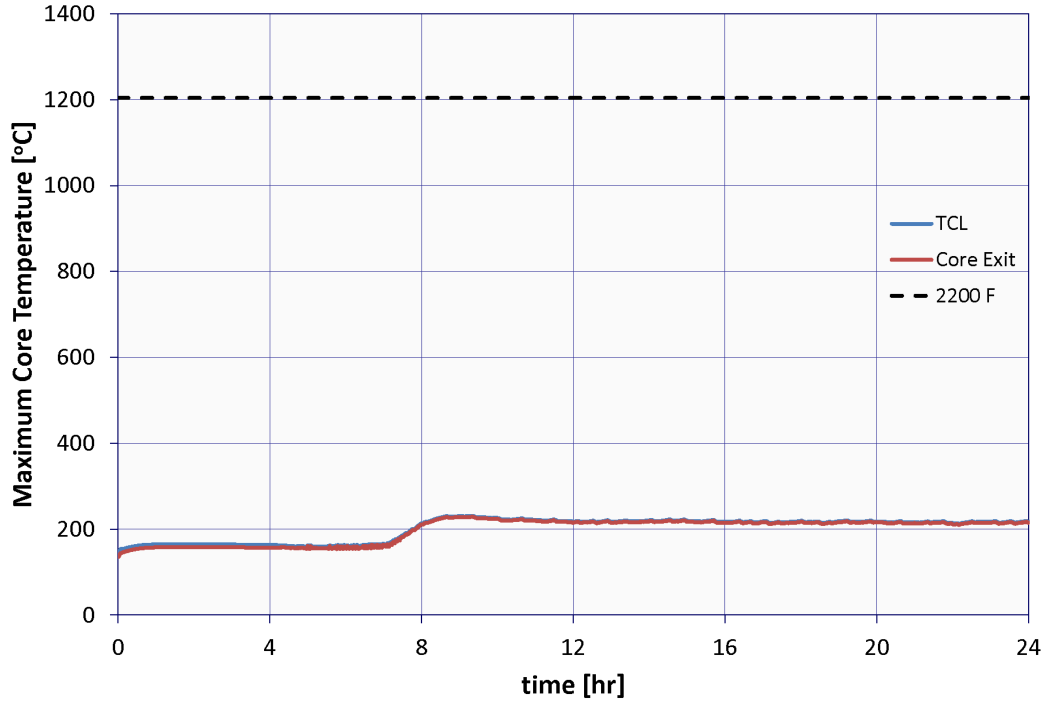

Steam Dump Mass Flow Rate [kg/s]
time [hr]
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24

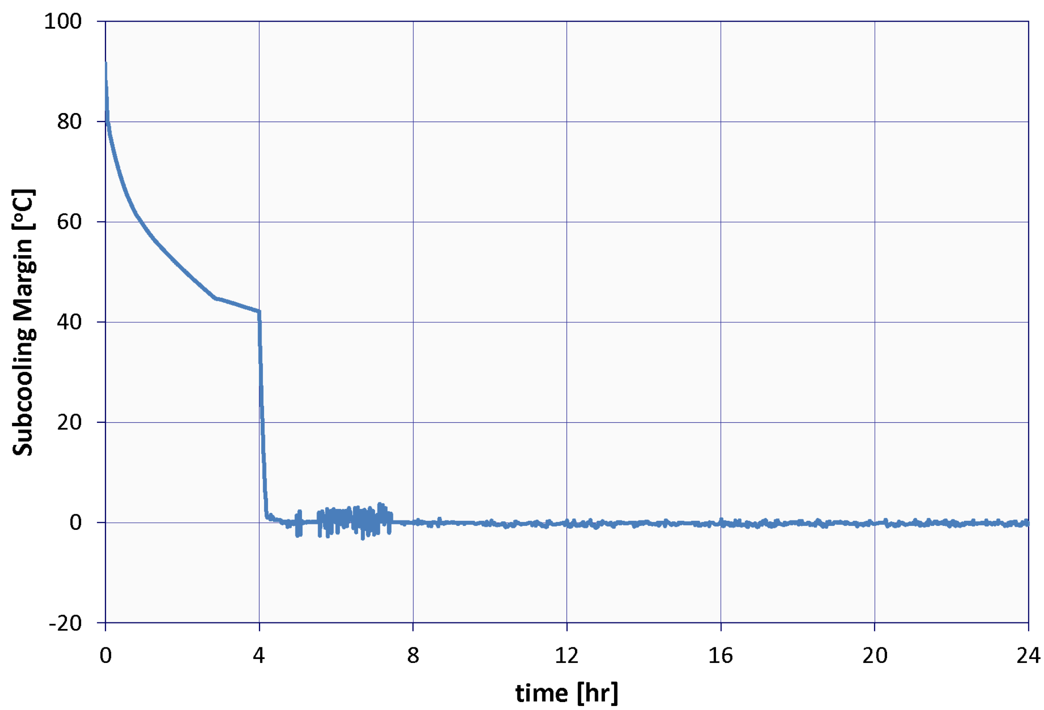

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
0
5
10
15
20
25
30
0
4
8
12
16
20
24

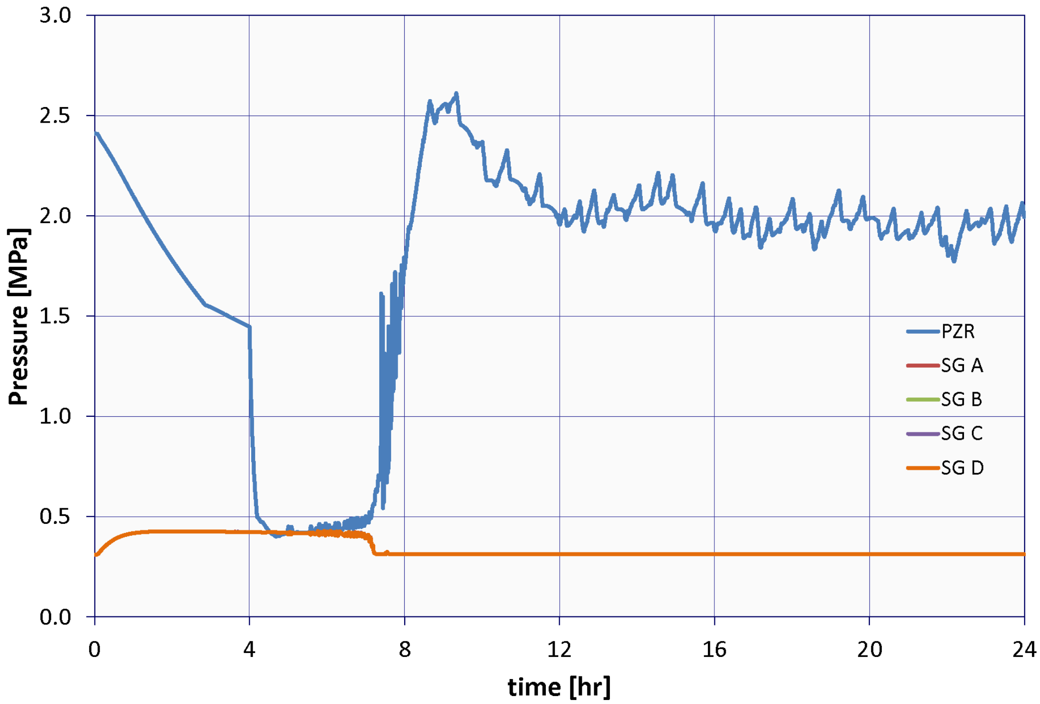

Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
10
12
14
16
18
20
22
24
26
0
4
8
12
16
20
24


RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3
Volume [gal]
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
4
8
12
16
20
24
time [hr]

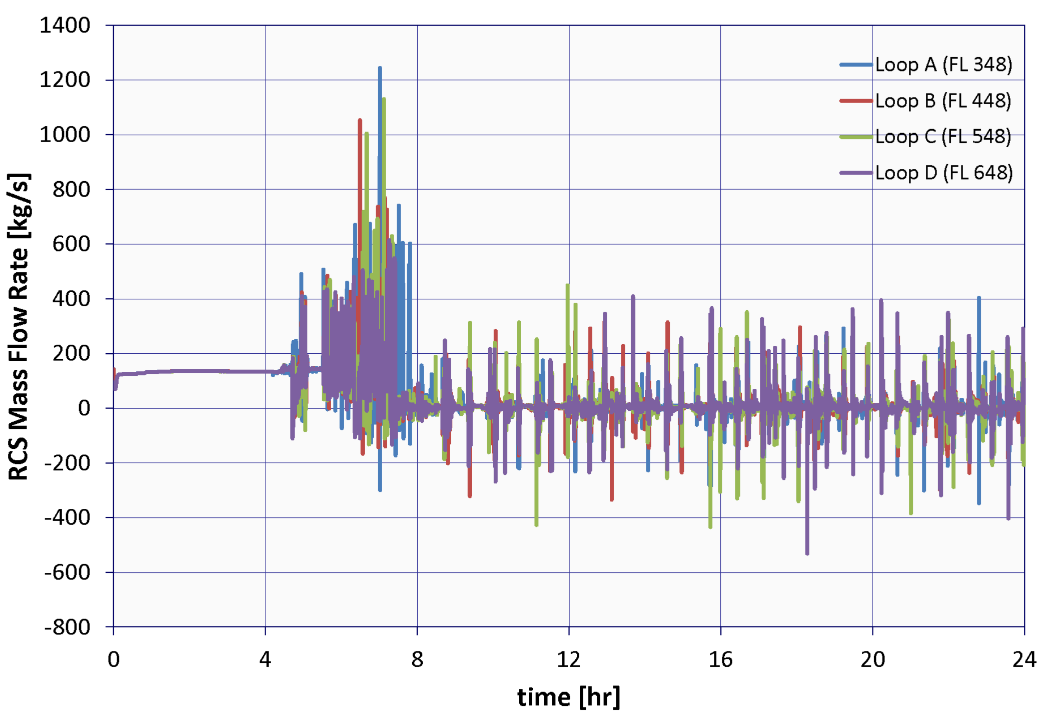
F.1.5 Case 5: SG at 18% NR Level, 12 hr after Shutdown, Initiate Bleed & Feed at 5 hr



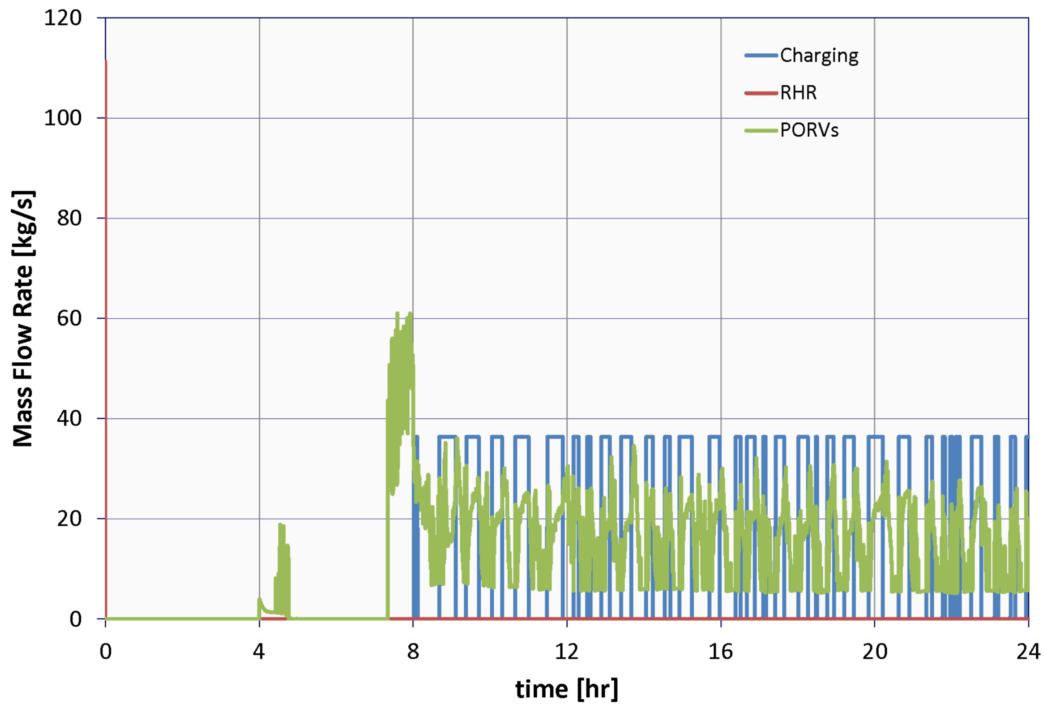




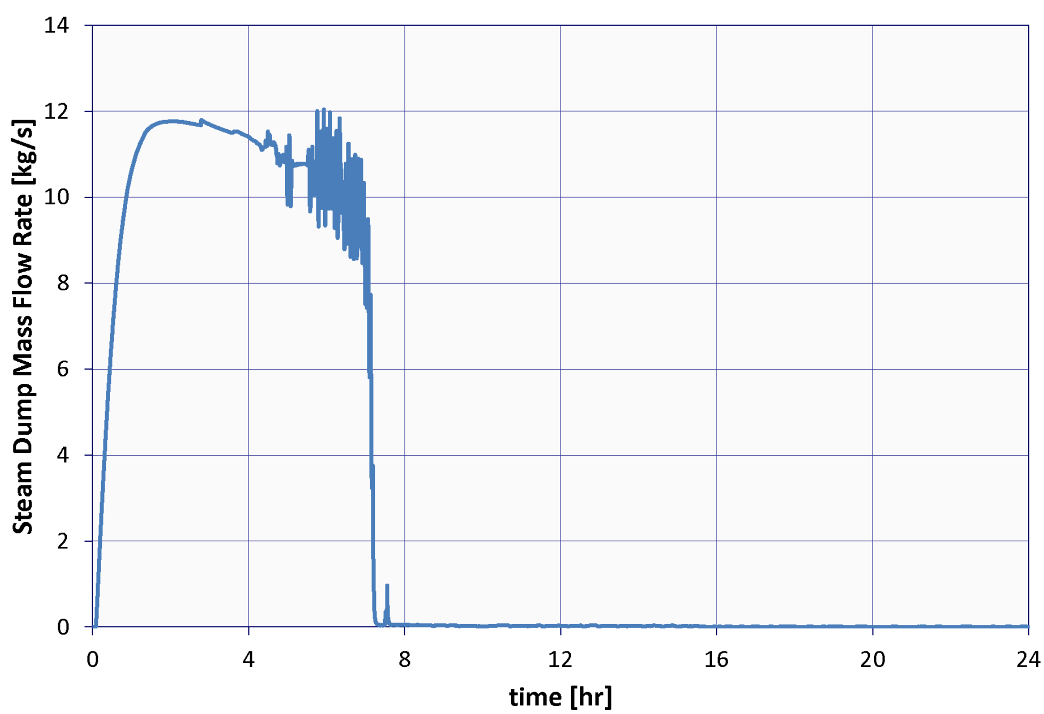
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



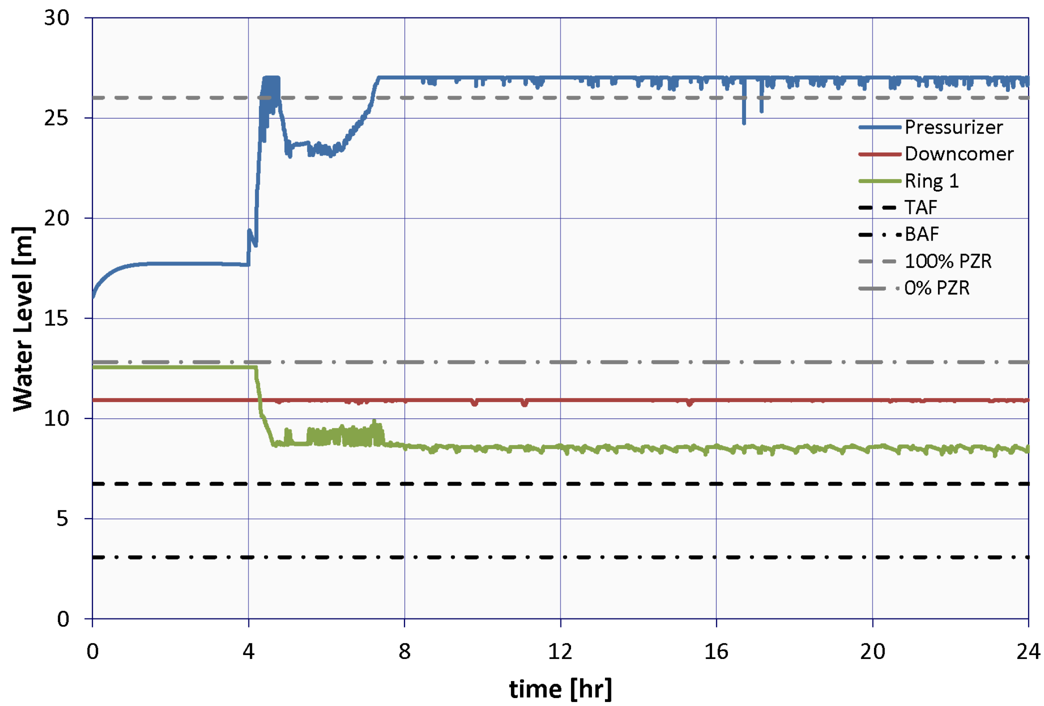
1400
1200
1000
800
600
400
200
0
-200
-400
-600
-800
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)



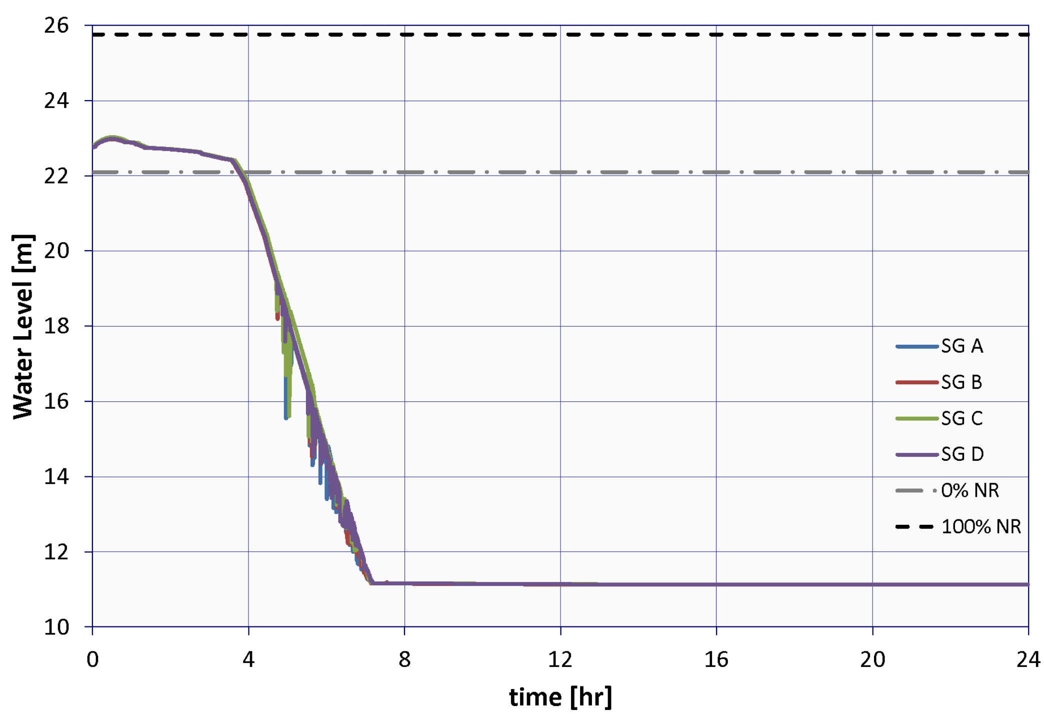
Charging
RHR
PORVs
Mass Flow Rate [kg/s]
time [hr]
120
100
80
60
40
20
0
0
4
8
12
16
20
24



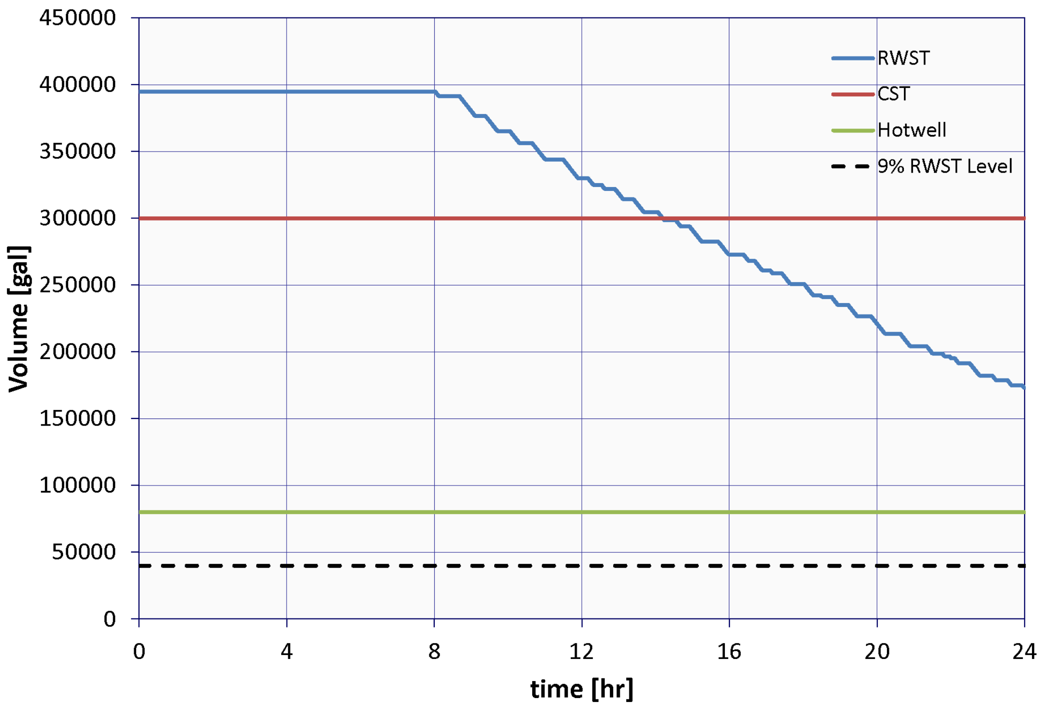
Steam Dump Mass Flow Rate [kg/s]
time [hr]
14
12
10
8
6
4
2
0
0
4
8
12
16
20
24



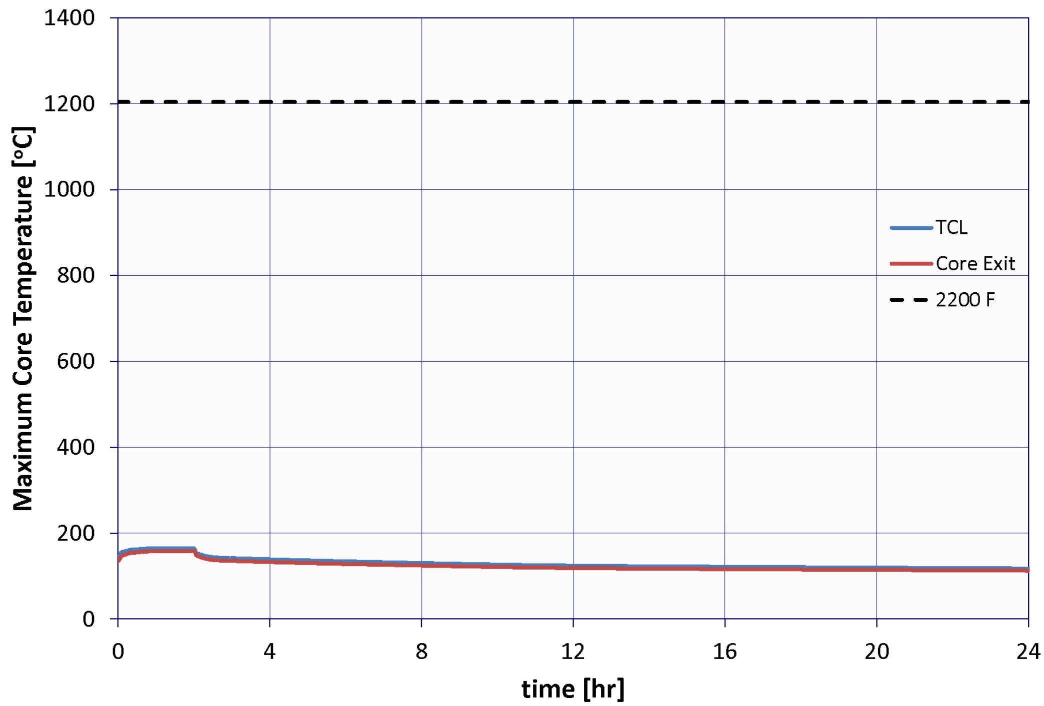
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

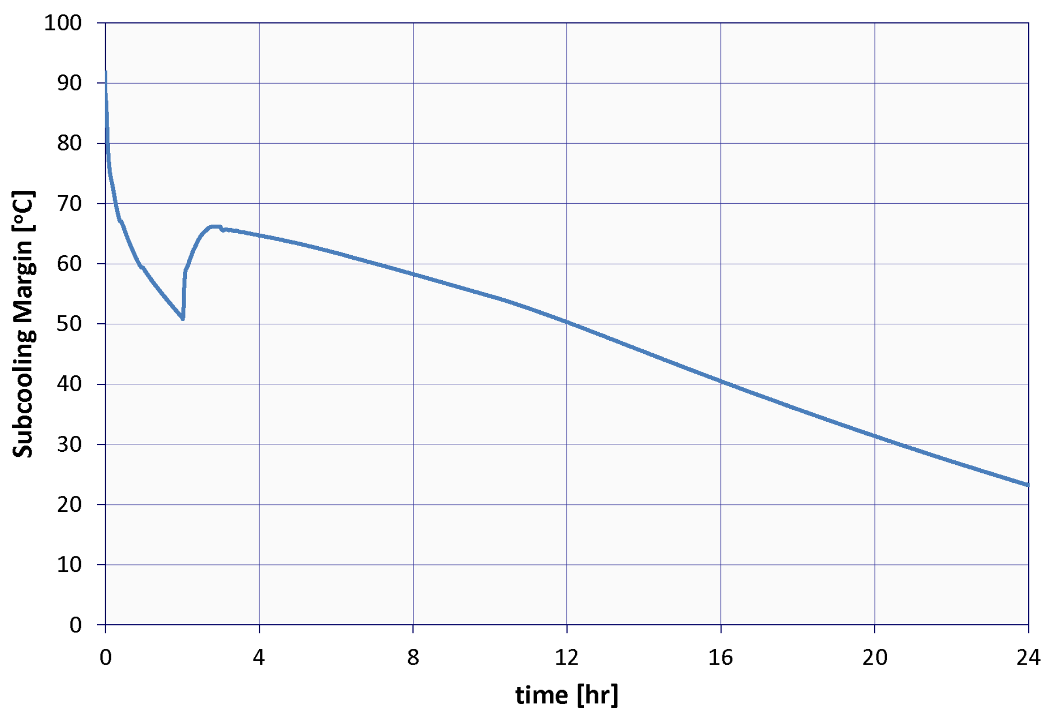


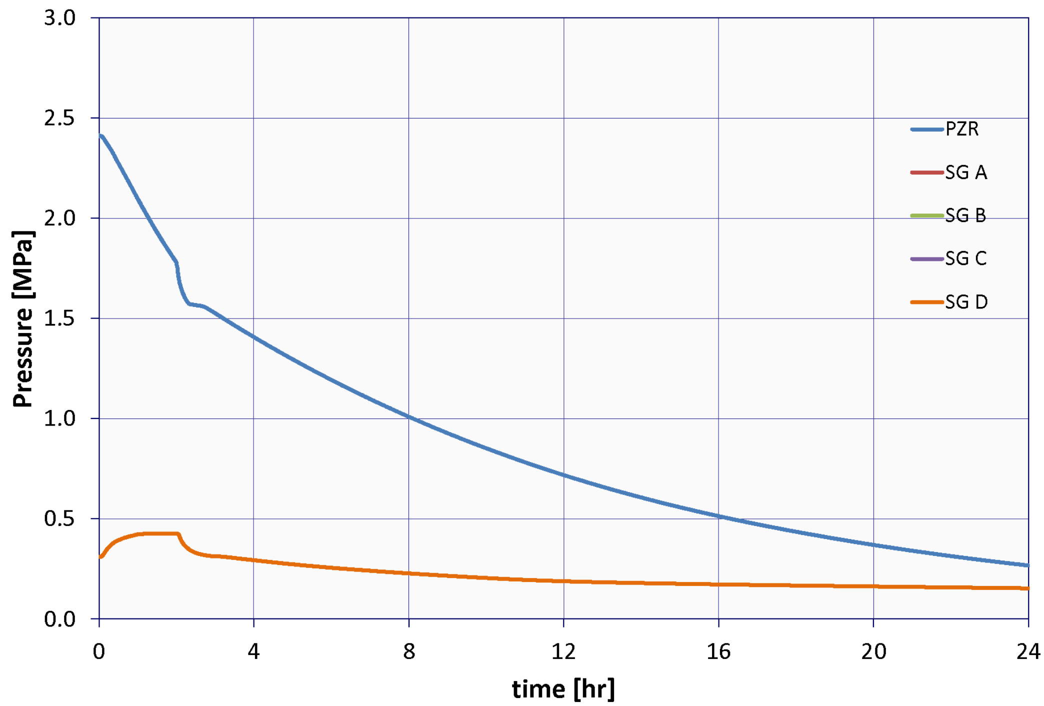
Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR


RWST
CST
Hotwell
9% RWST Level
Volume [gal]
time [hr]
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0
4
8
12
16
20
24

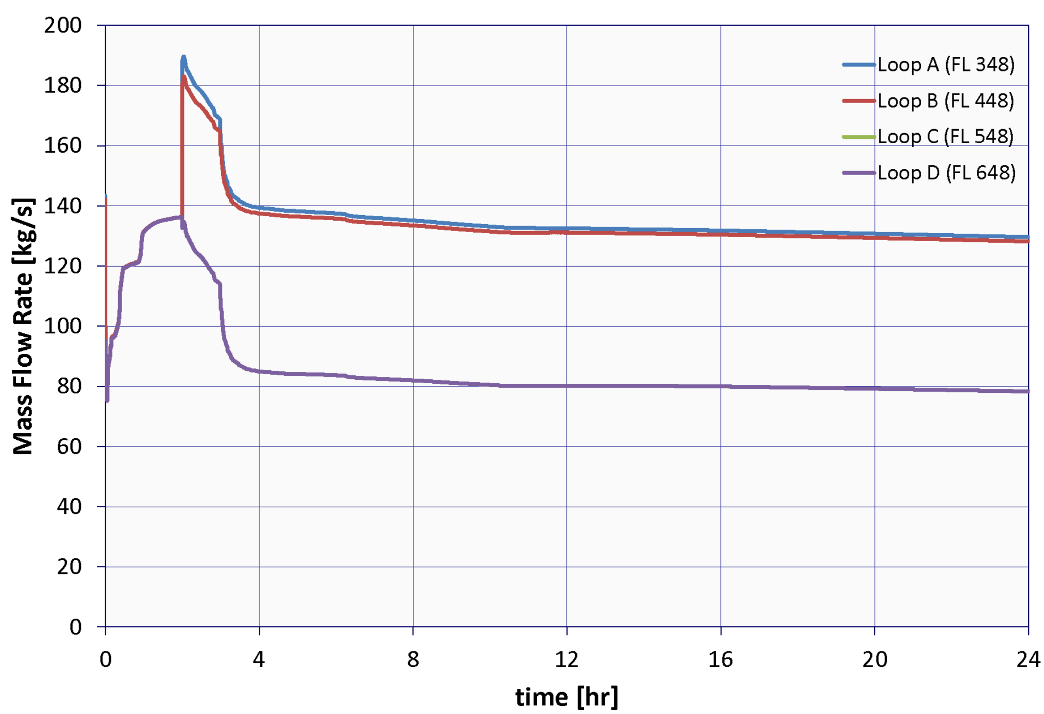
F.1.6 Case 6: SG at 27% WR Level, 12 hr after Shutdown, Recover RHR at 2 hr



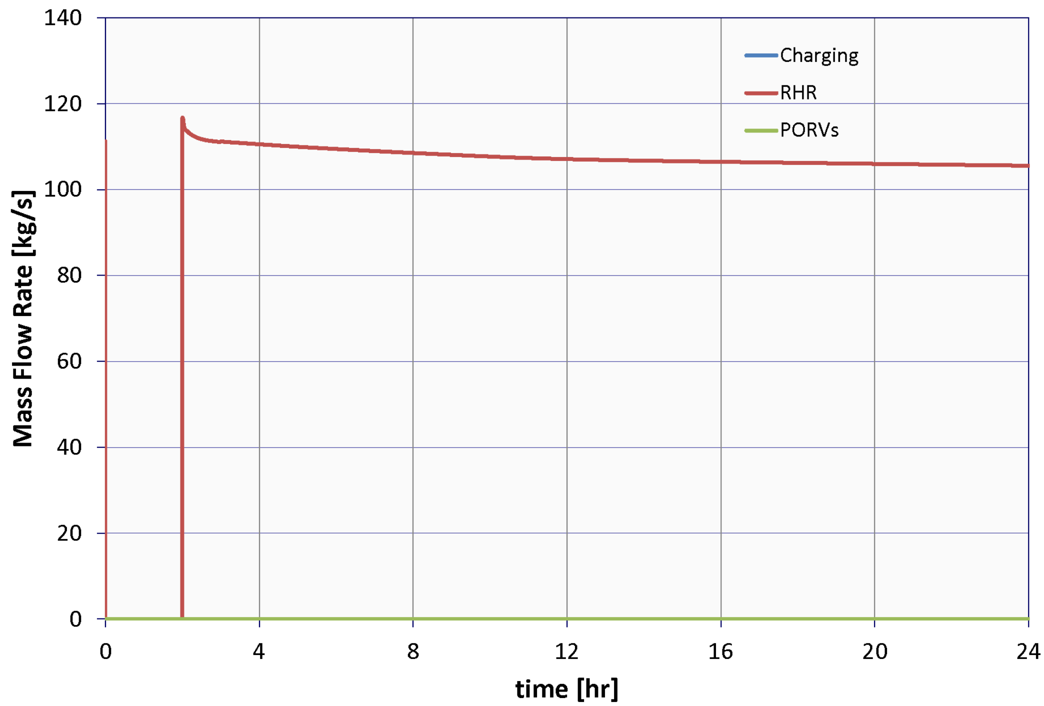




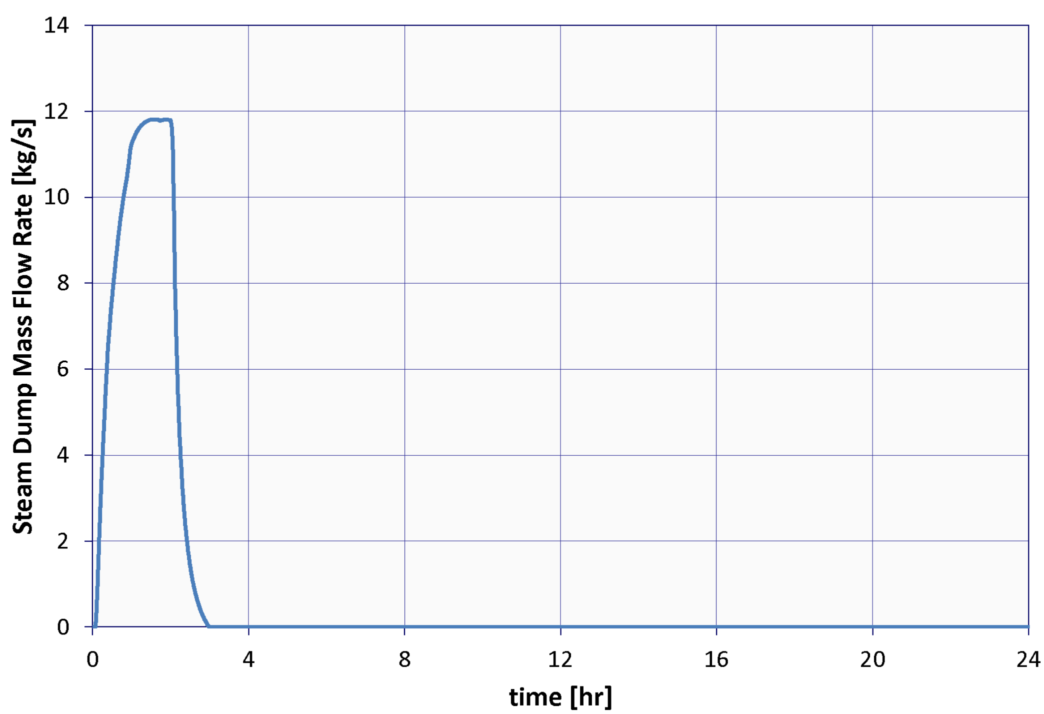
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



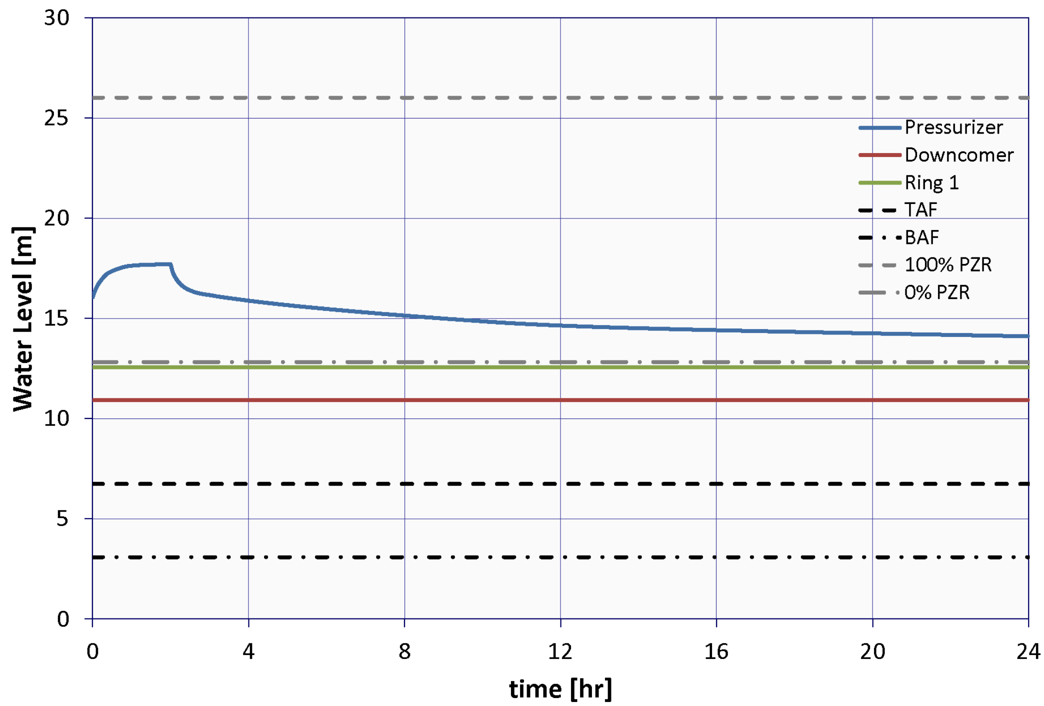
200
180
160
140
120
100
80
60
40
20
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

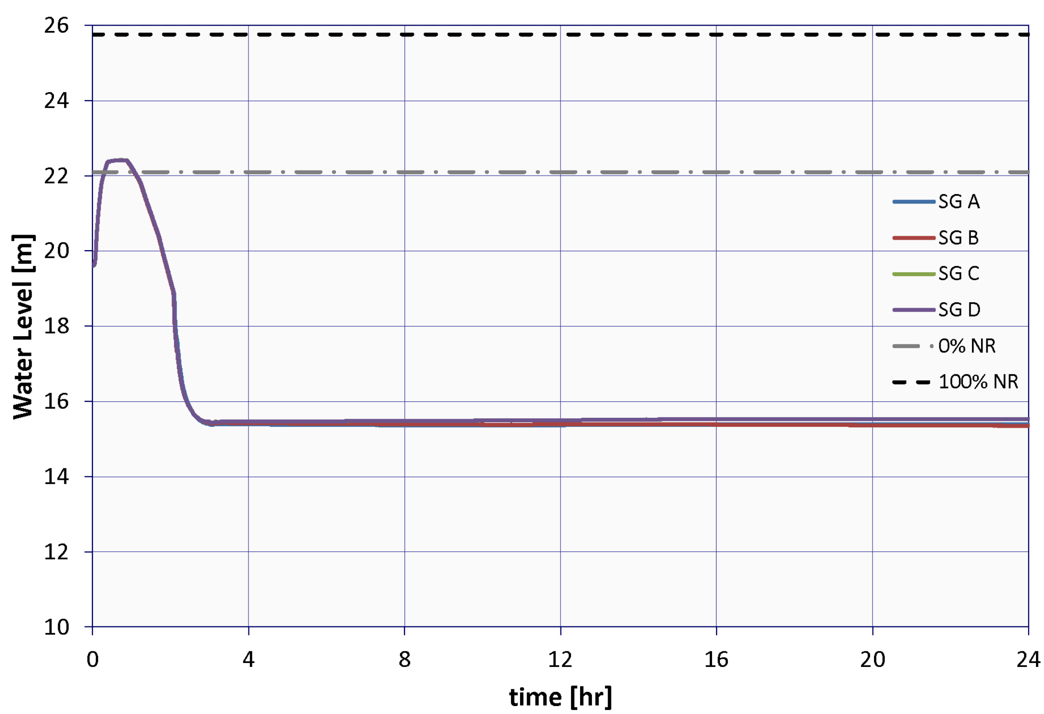


Charging
RHR
PORVs
Mass Flow Rate [kg/s]
time [hr]

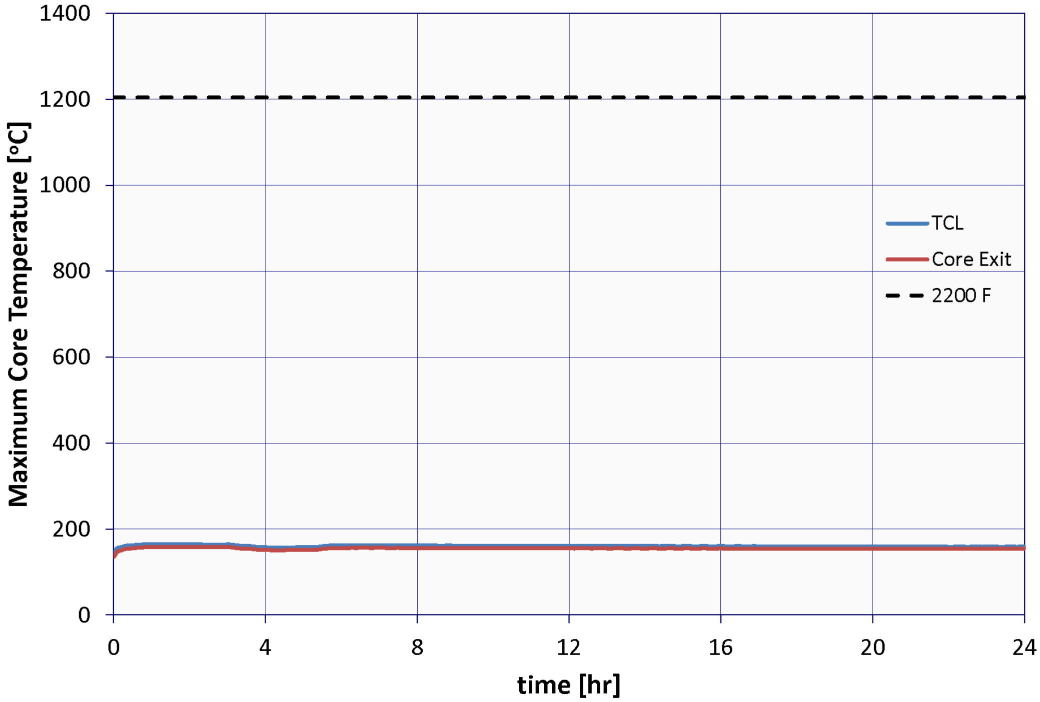


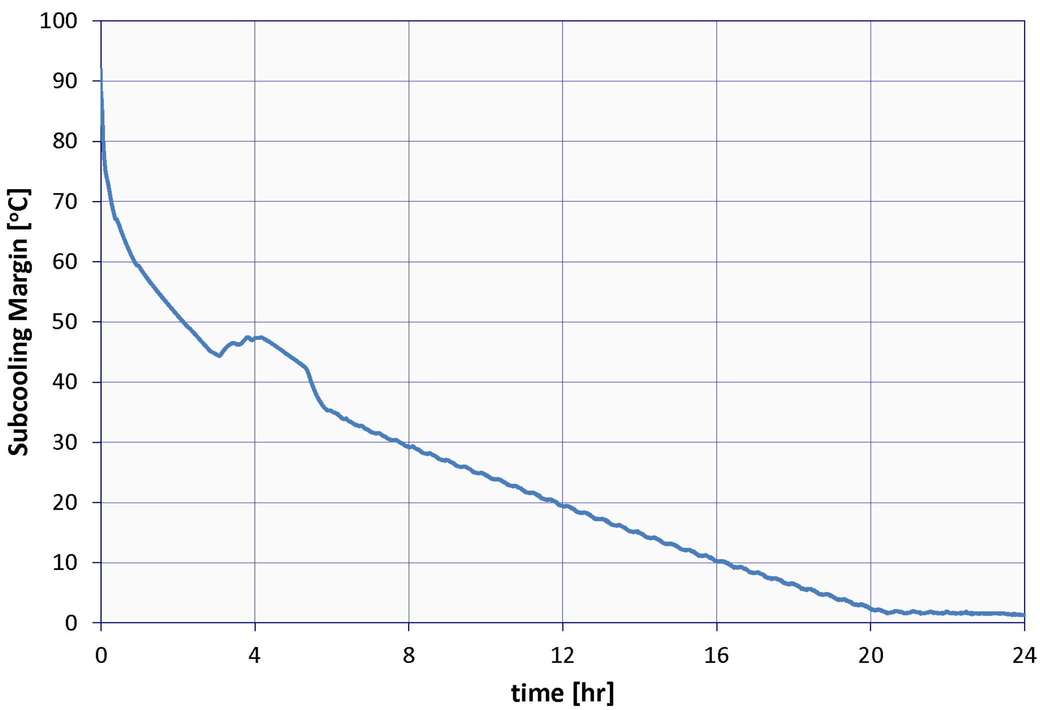
Steam Dump Mass Flow Rate [kg/s]
time [hr]

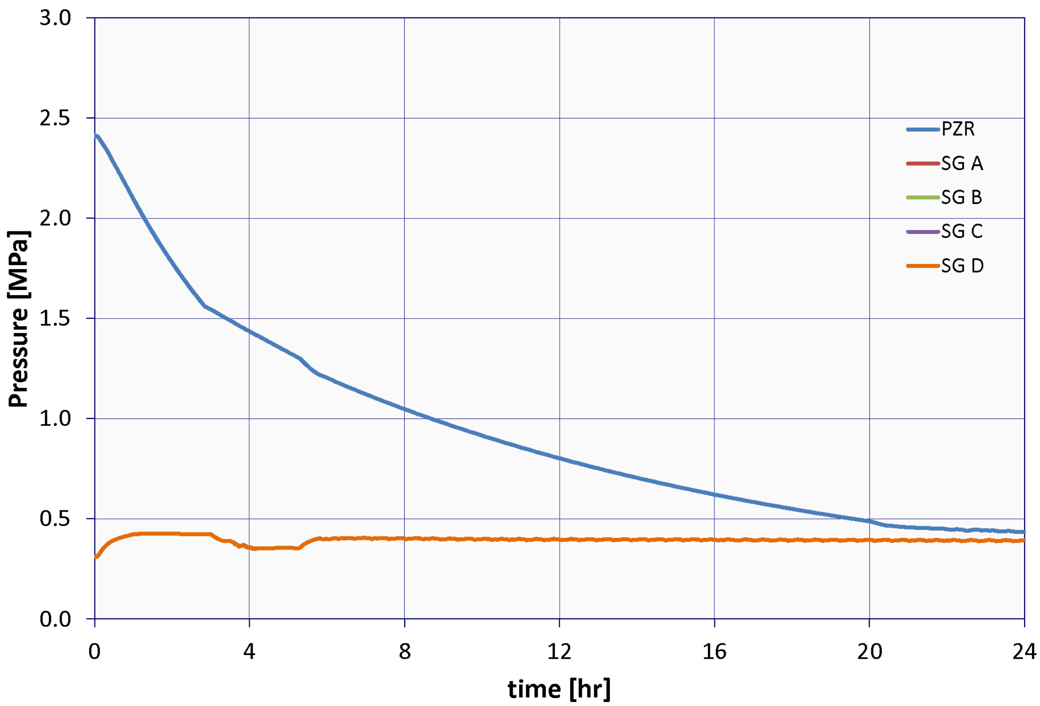

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

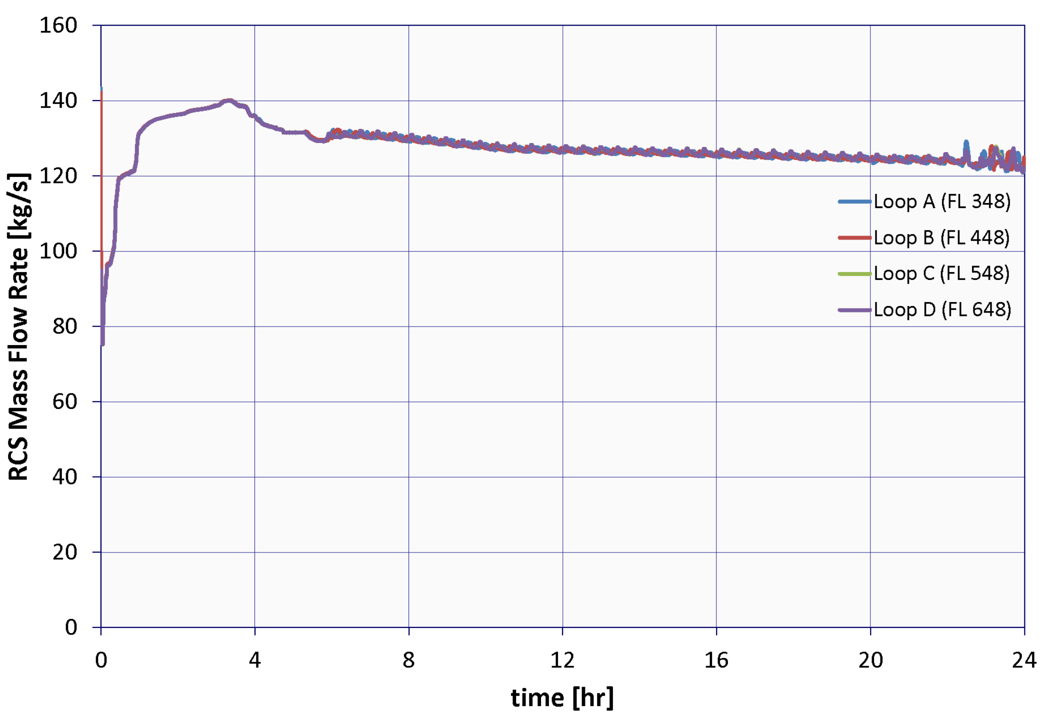

26
24
22
20
18
16
14
12
10
Water Level [m]
0
4
8
12
16
20
24
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

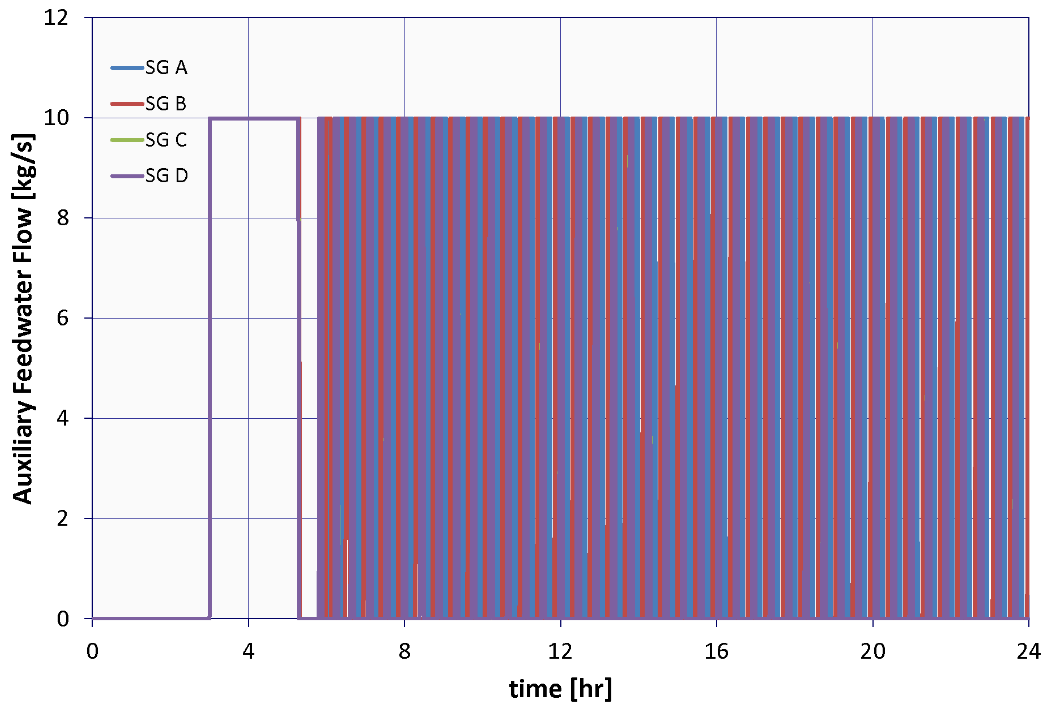
F.1.7 Case 7: SG at 27% WR Level, 12 hr after Shutdown, Initiate AFW at 3 hr



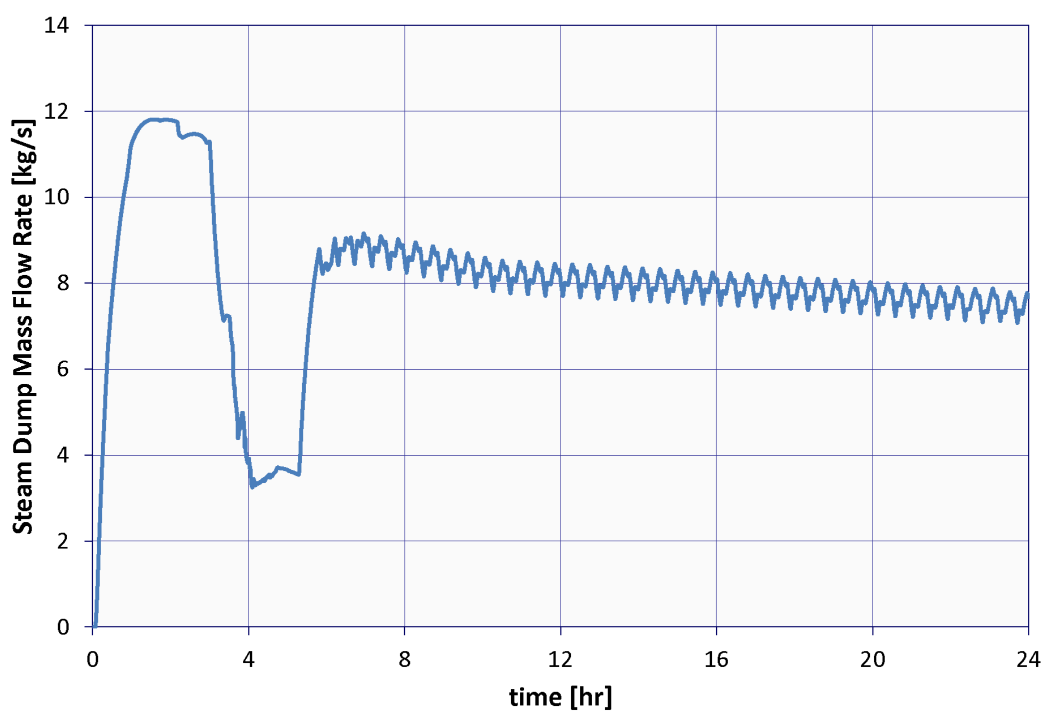



Pressure [MPa]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D

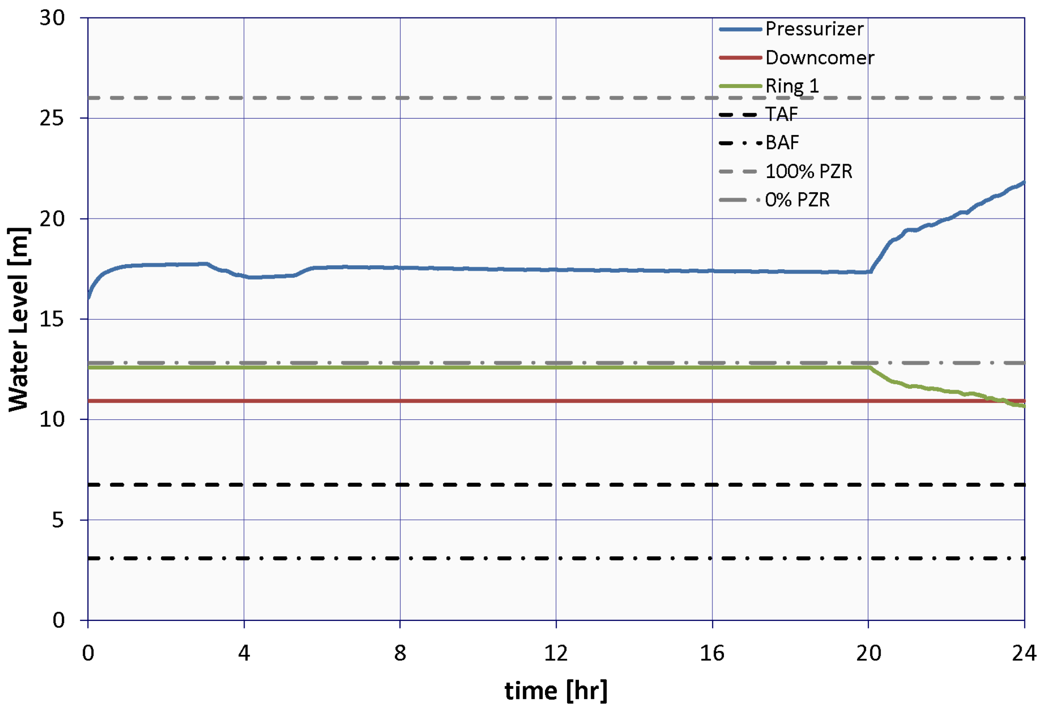

RCS Mass Flow Rate [kg/s]
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

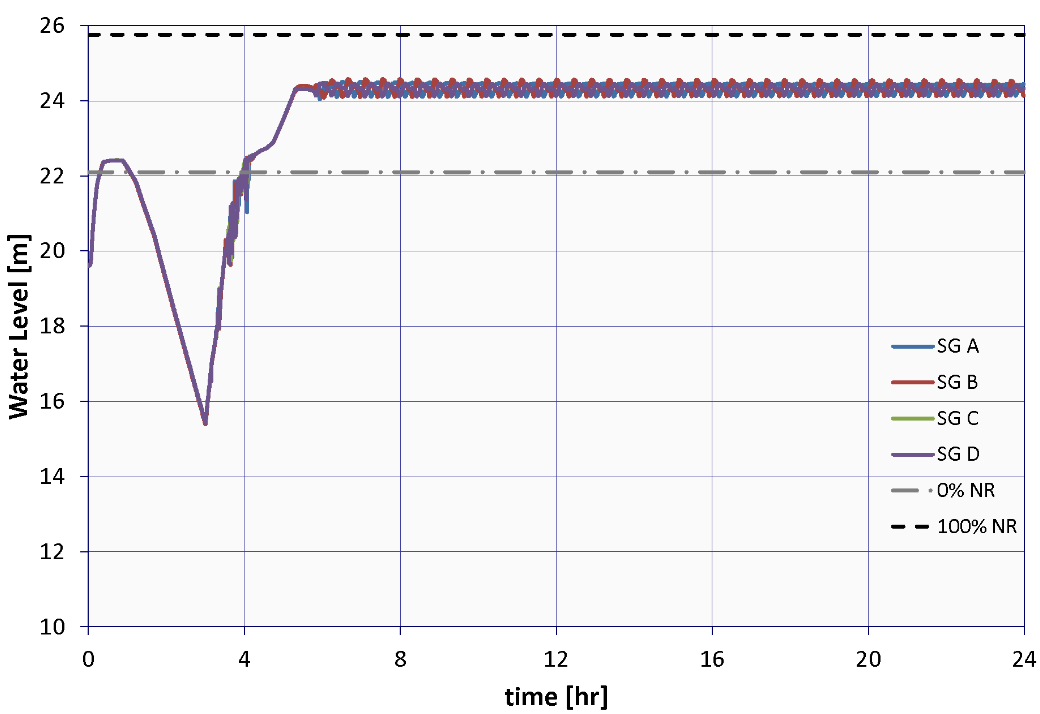


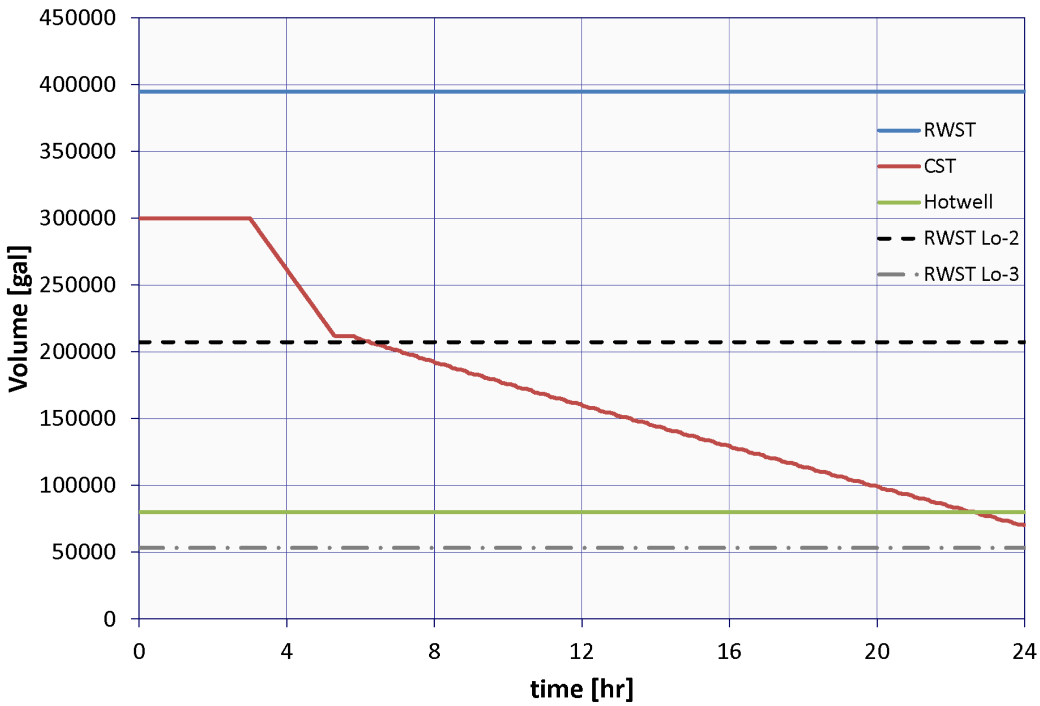
Auxiliary Feedwater Flow [kg/s]
time [hr]
SG A
SG B
SG C
SG D
0
2
4
6
8
10
12
0
4
8
12
16
20
24



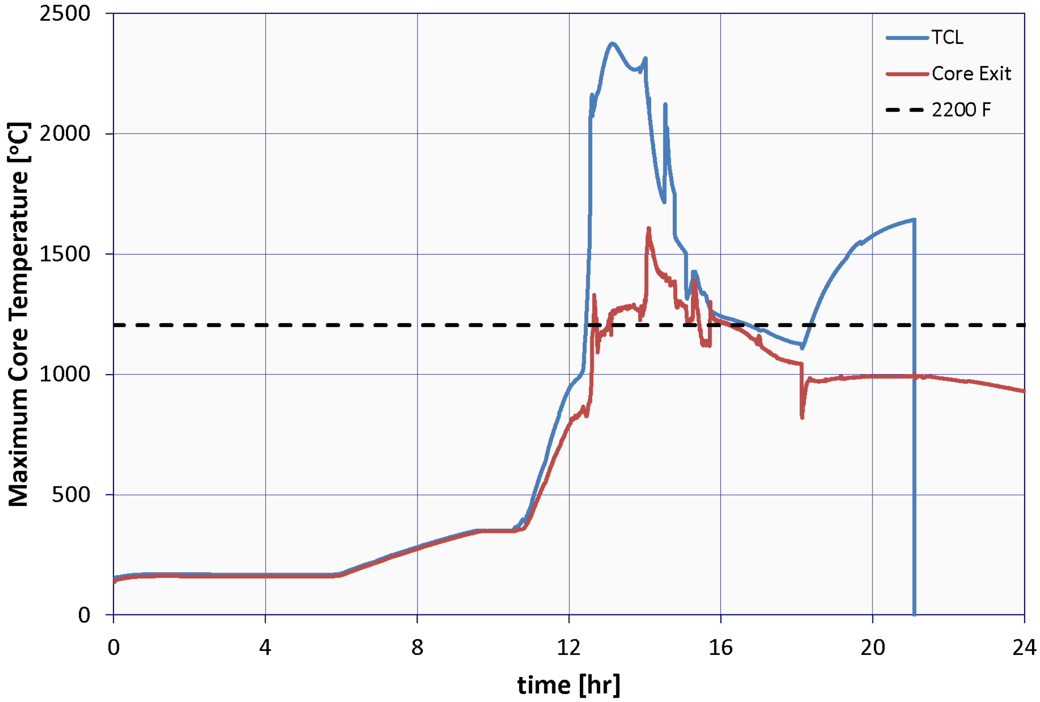
Steam Dump Mass Flow Rate [kg/s]
time [hr]
0
2
4
6
8
10
12
14
0
4
8
12
16
20
24

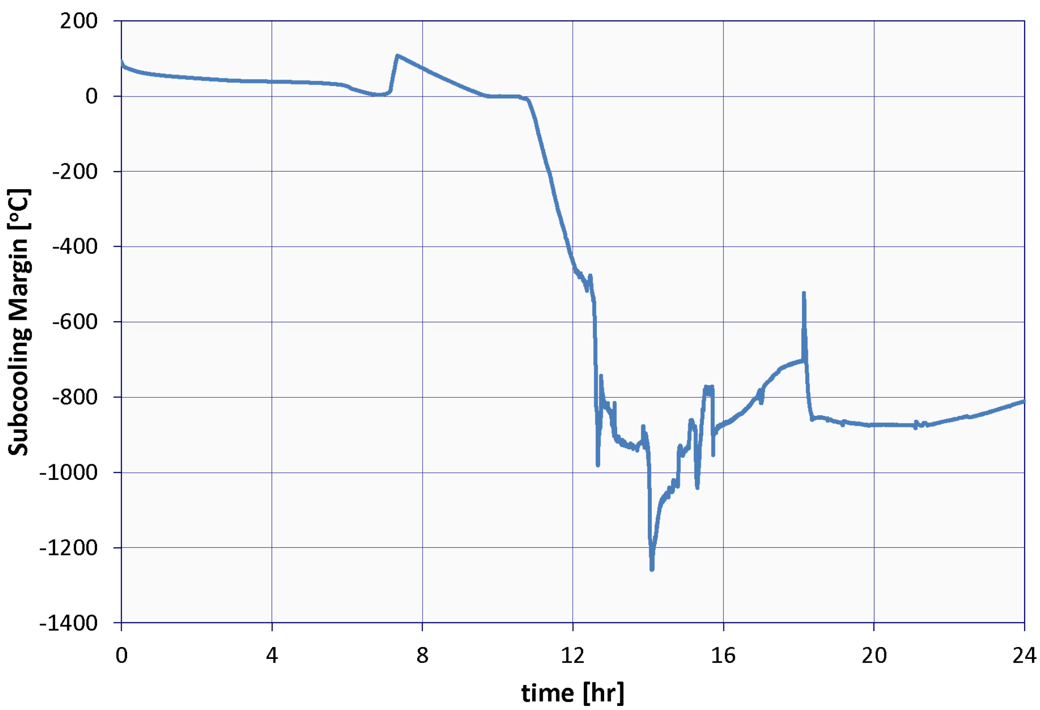

Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
Water Level [m]
time [hr]

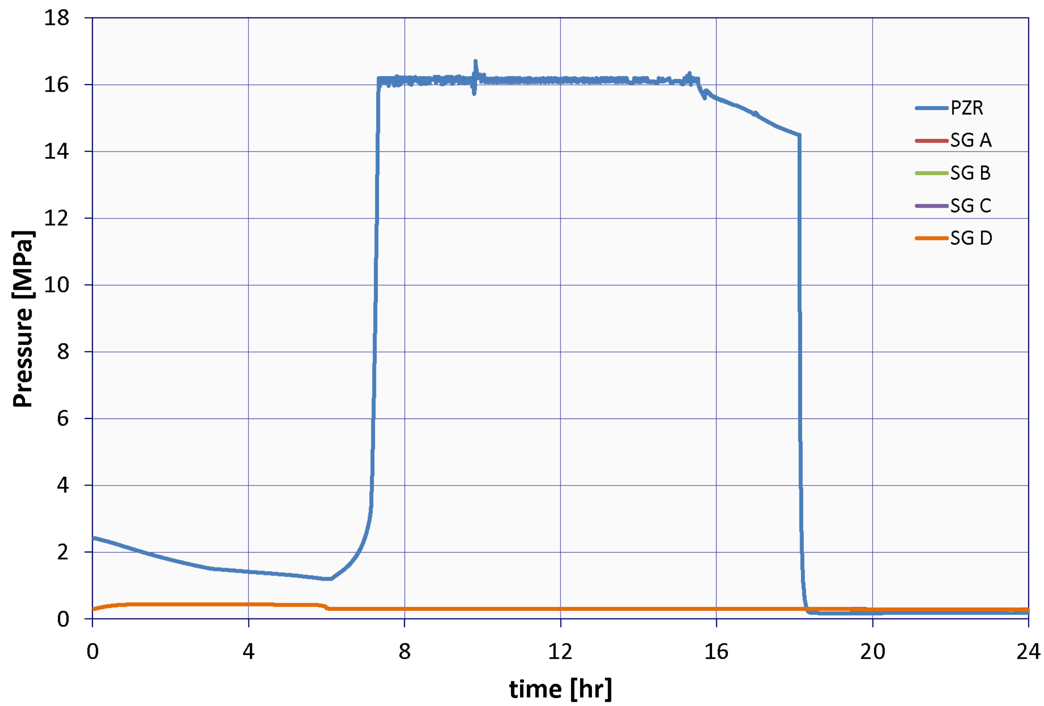

SG A
SG B
SG C
SG D
0% NR
100% NR
Water Level [m]
time [hr]


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

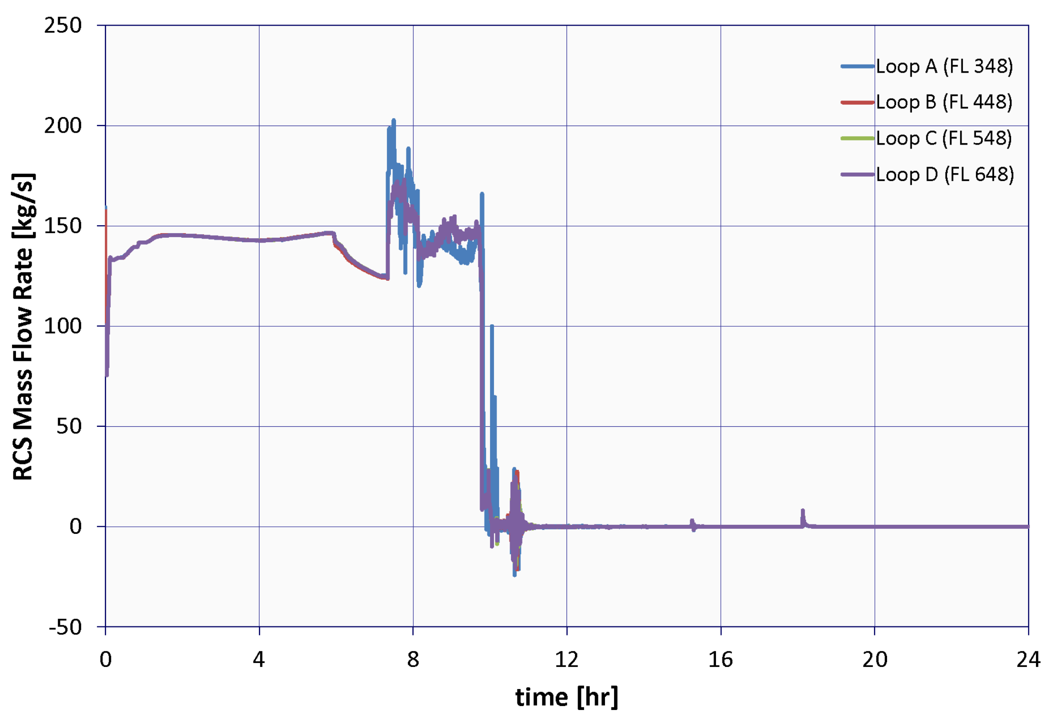
F.1.8 Case 8: SG at 18% NR Level, 6 hr after Shutdown, No Recovery Actions



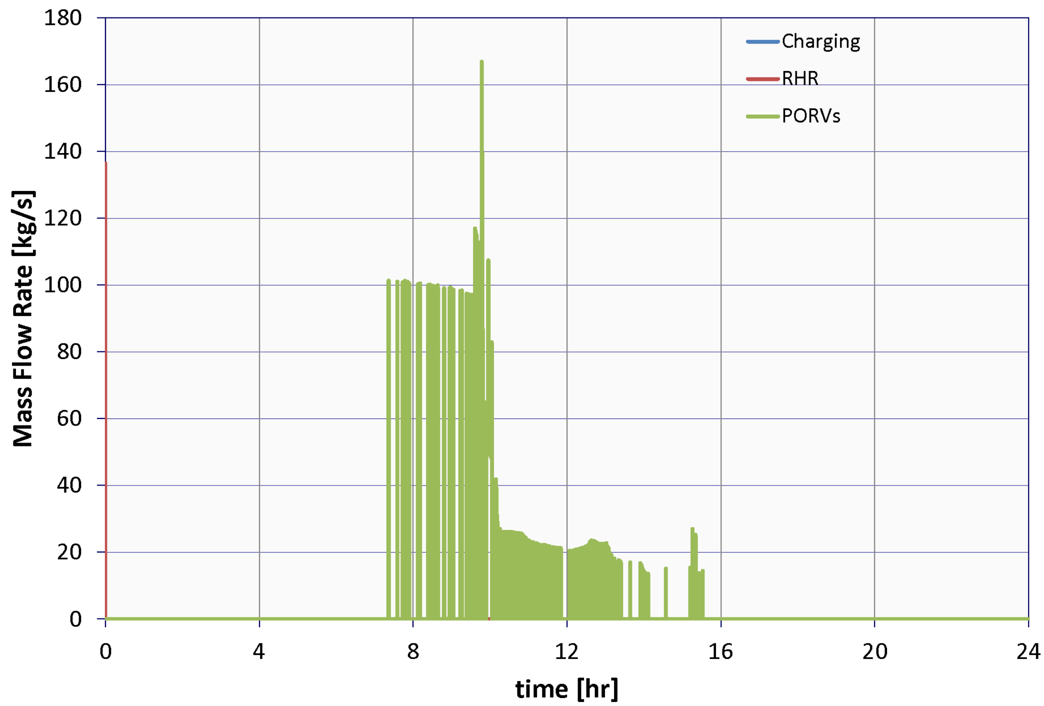




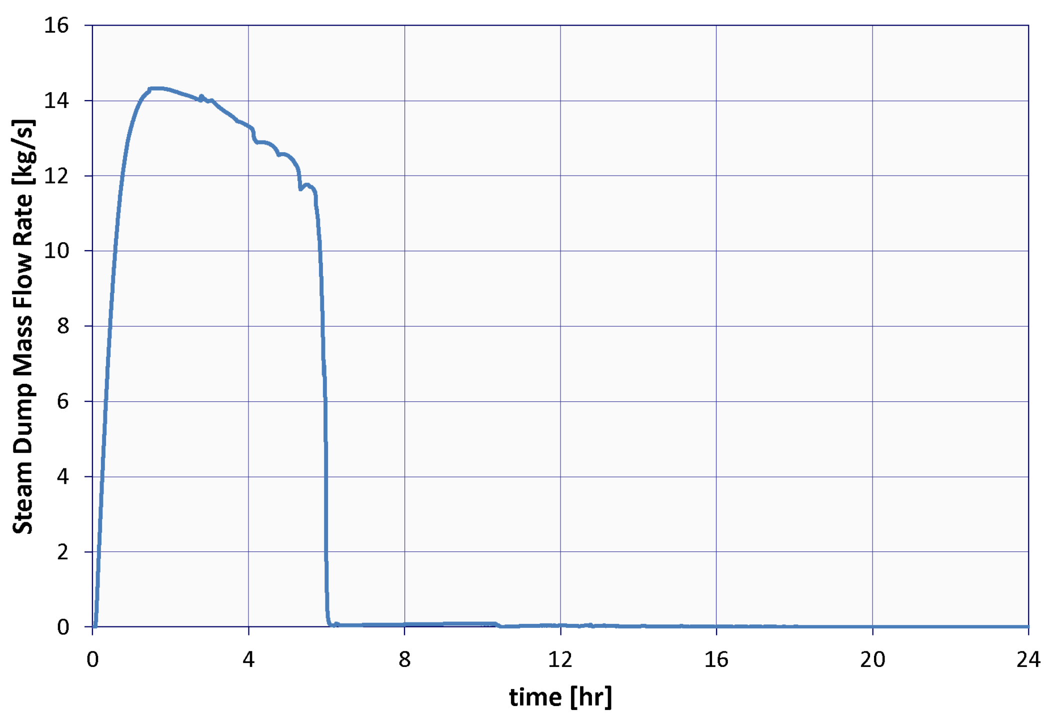
18
16
14
12
10
8
6
4
2
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



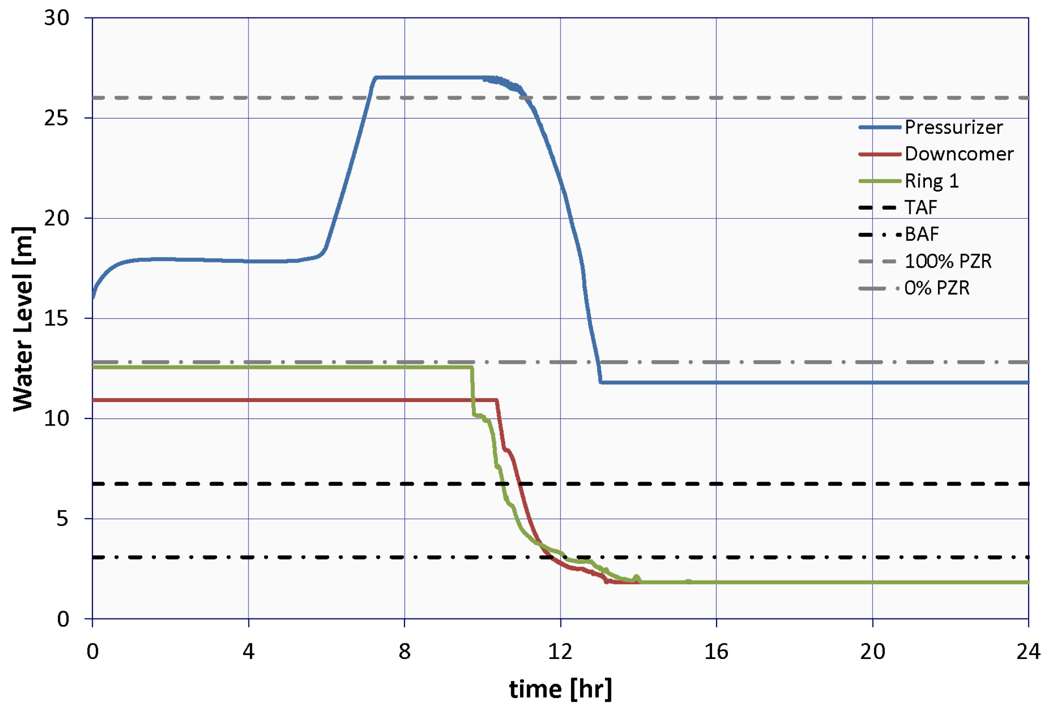
250
200
150
100
50
0
-50
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

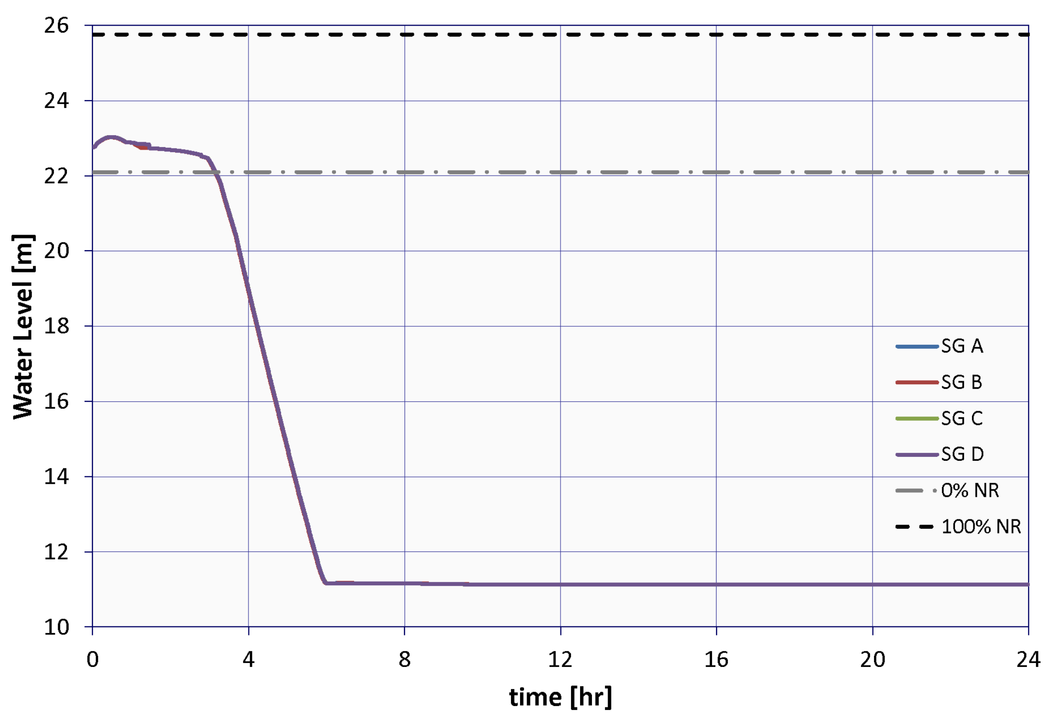


Charging
RHR
PORVs
Mass Flow Rate [kg/s]
time [hr]
0
20
40
60
80
100
120
140
160
180
0
4
8
12
16
20
24

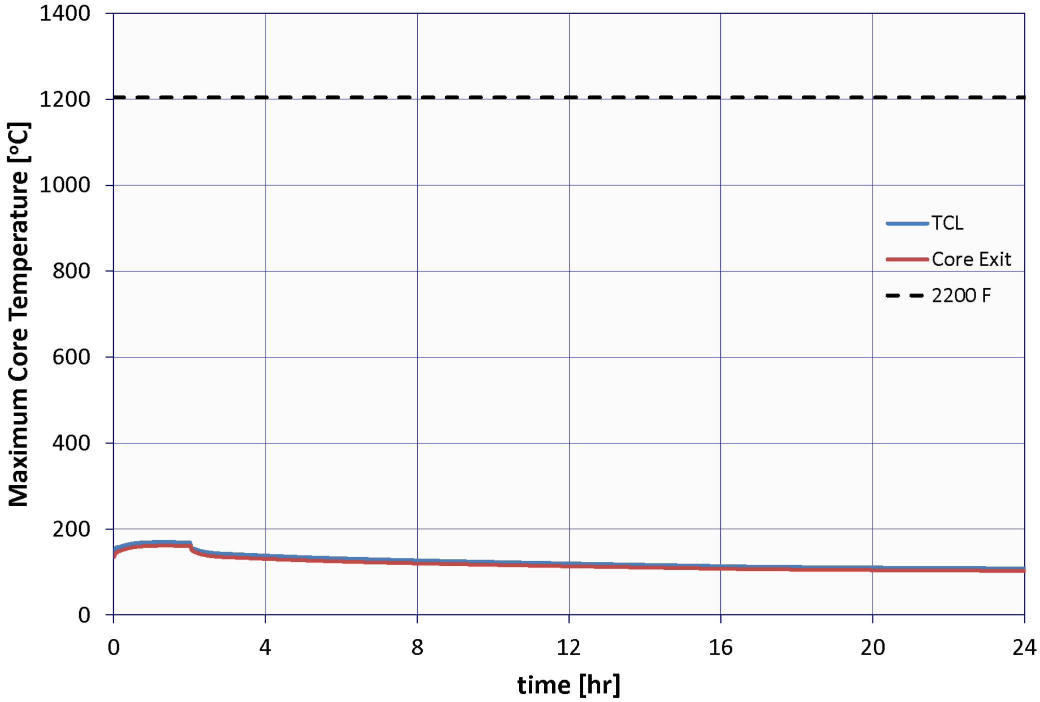


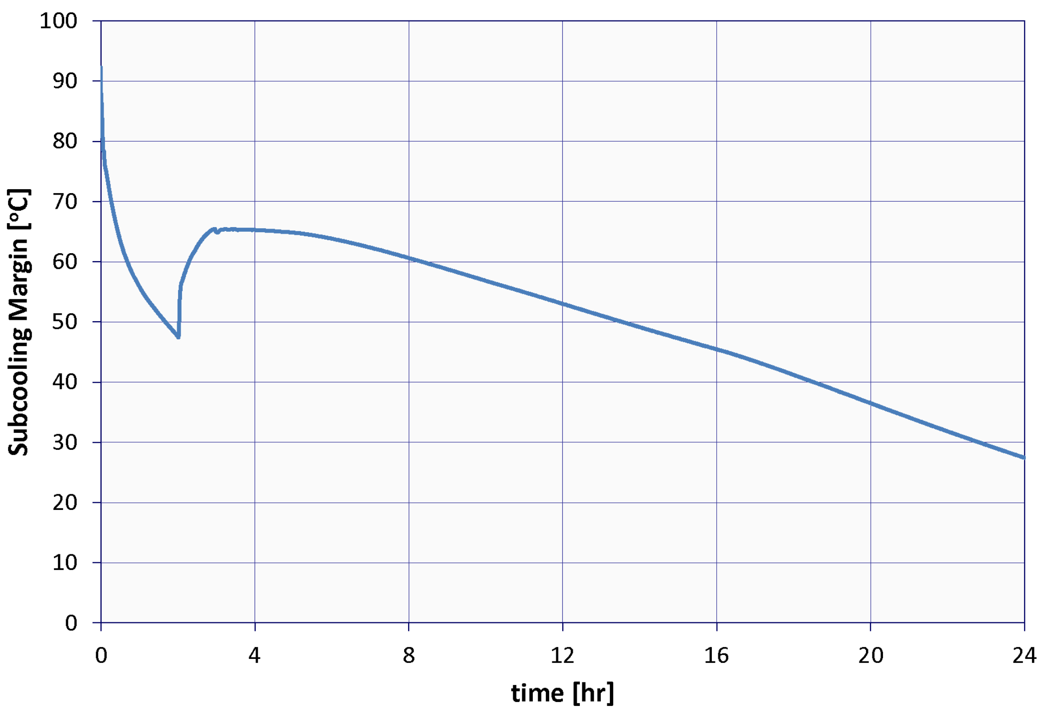
Steam Dump Mass Flow Rate [kg/s]
time [hr]
0
2
4
6
8
10
12
14
16
0
4
8
12
16
20
24

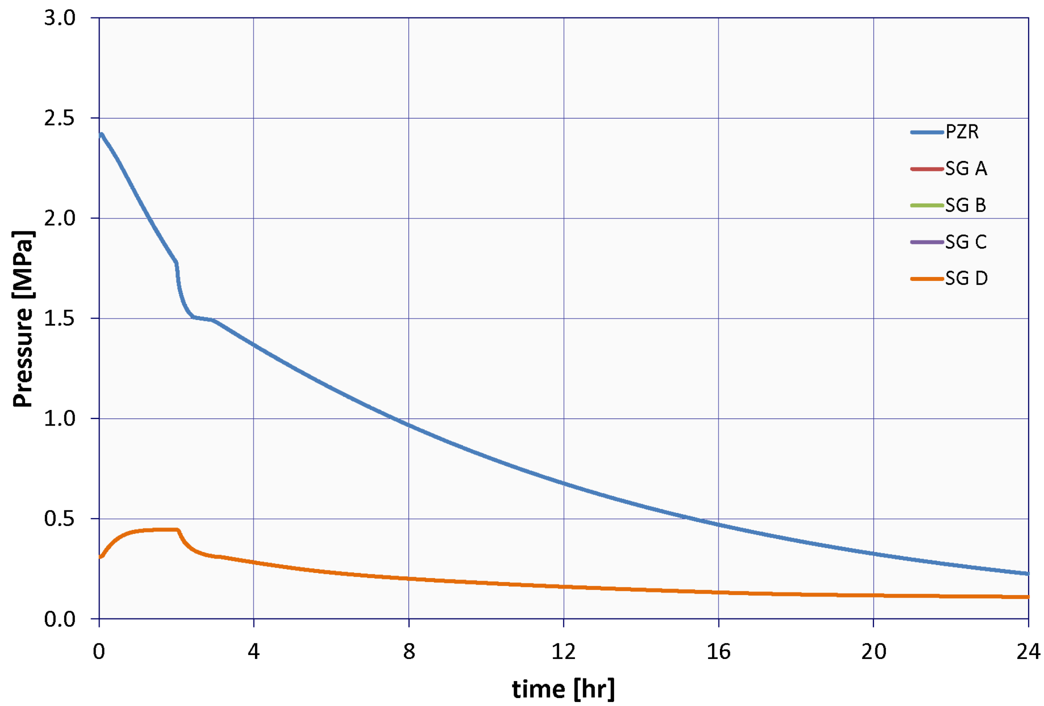

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR


Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR

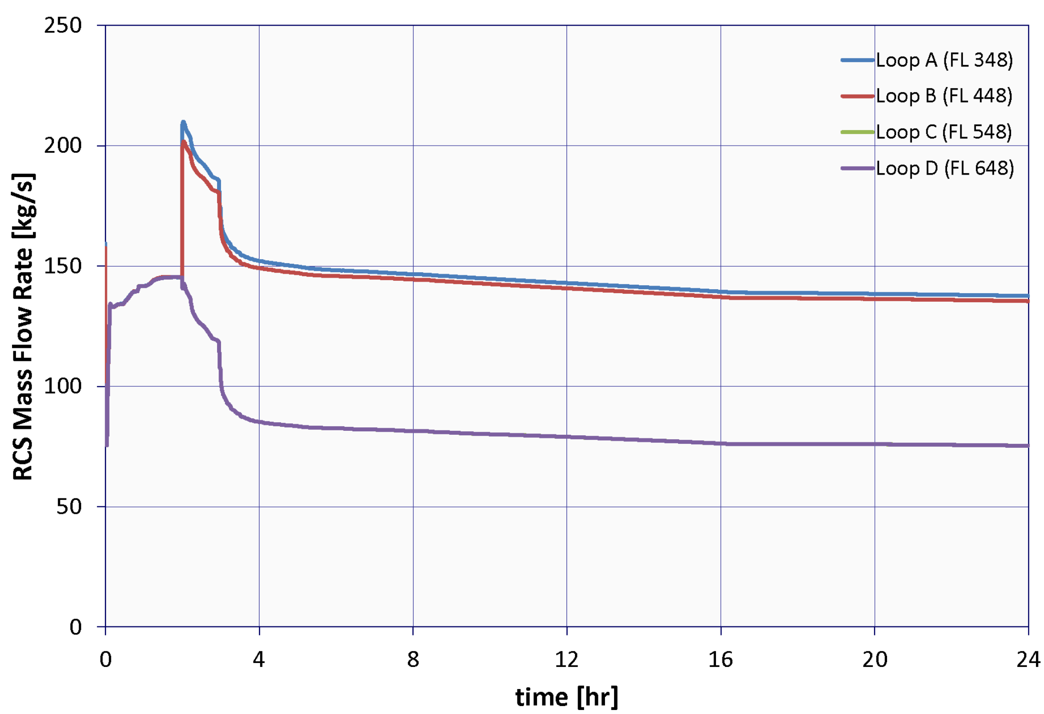
F.1.9 Case 9: SG at 18% NR Level, 6 hr after Shutdown, Recover RHR at 2 hr



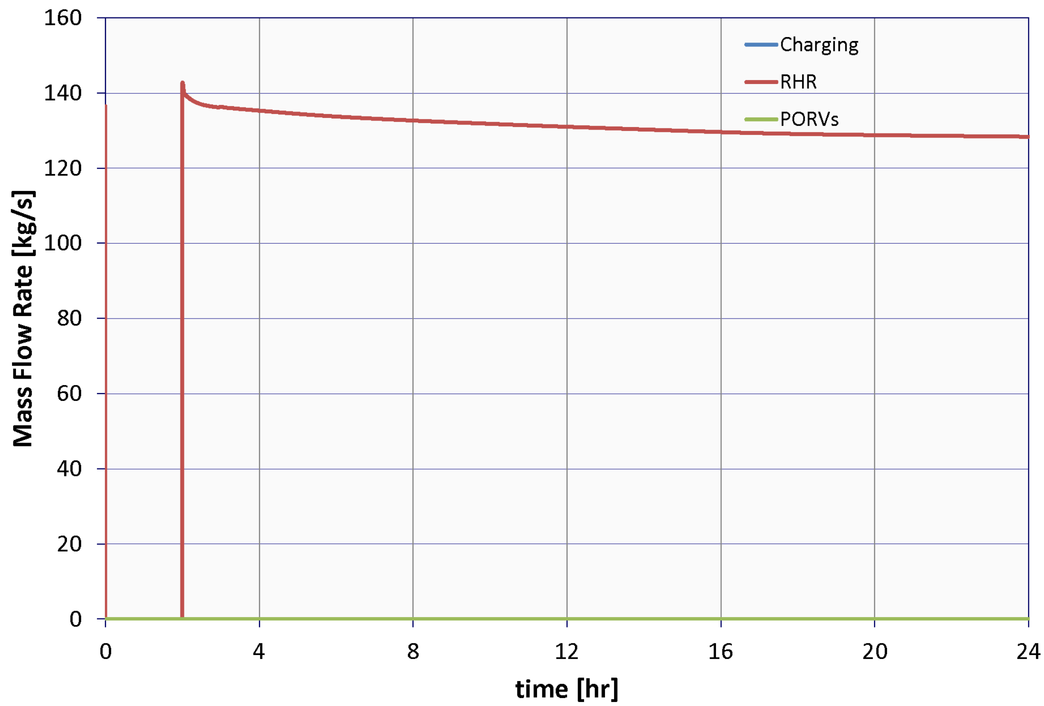




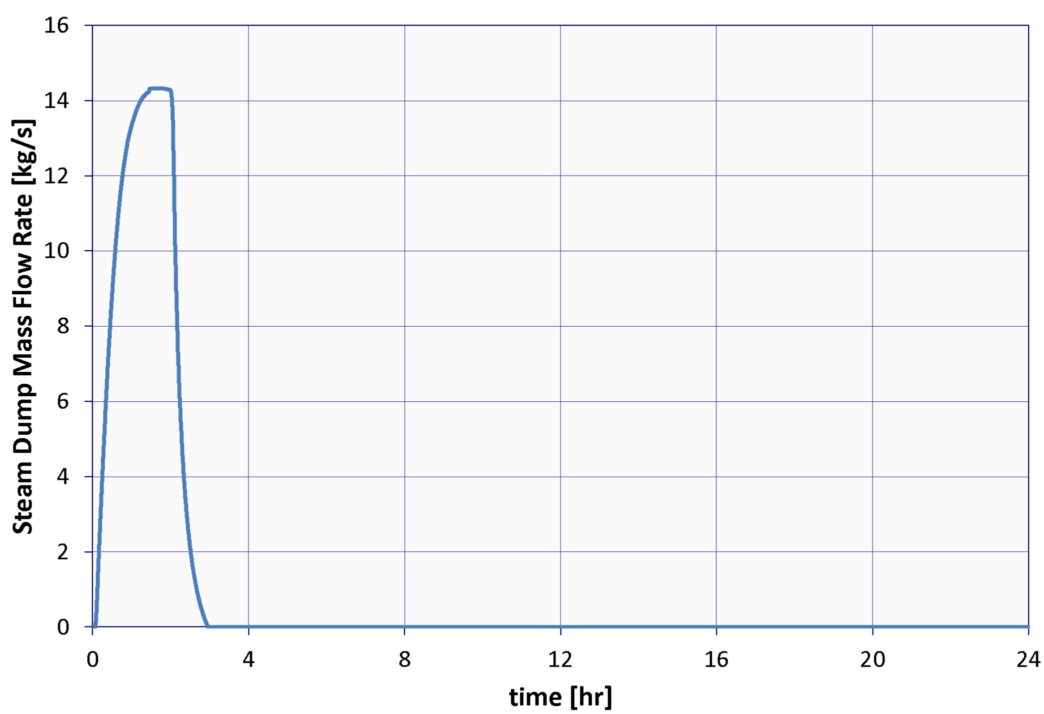
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



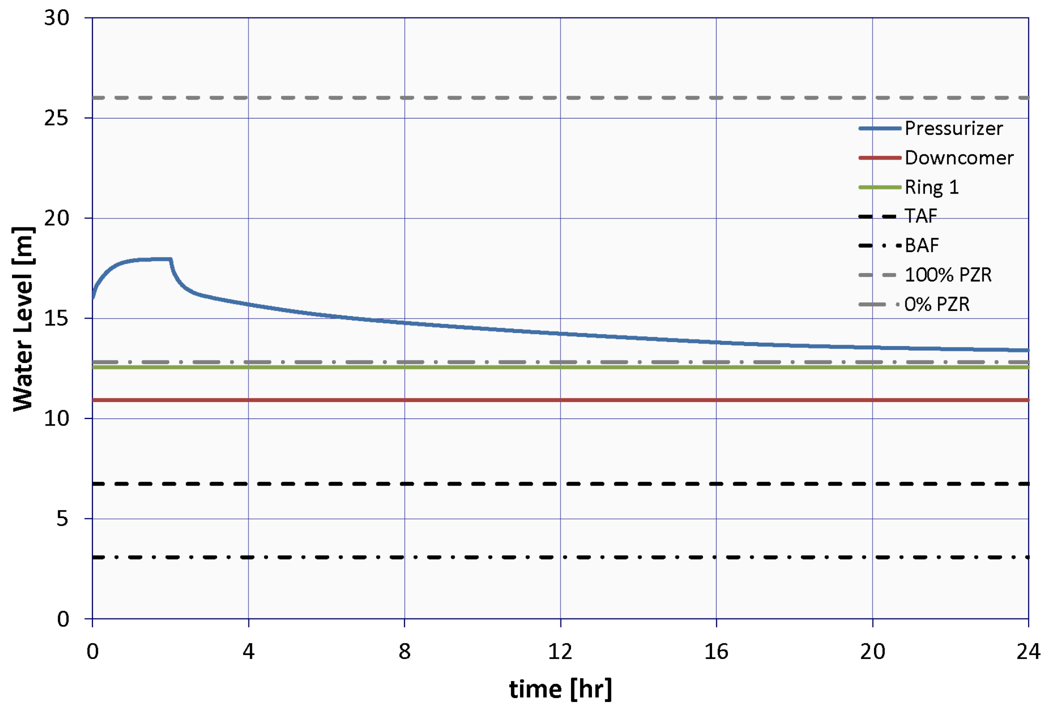
250
200
150
100
50
0
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

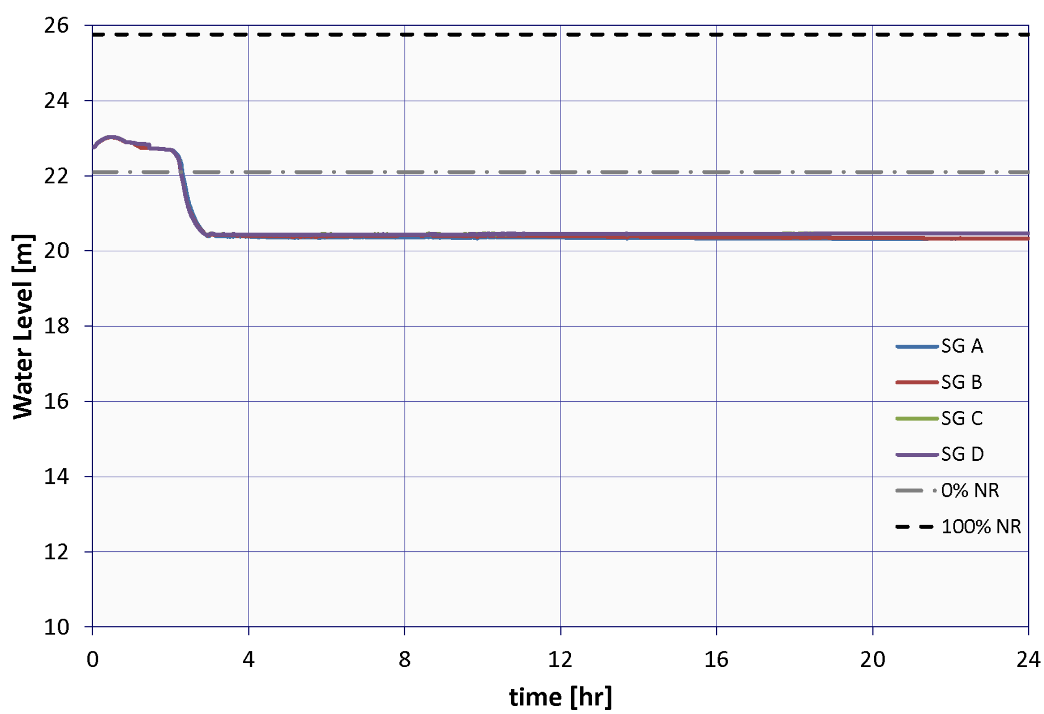


Charging
RHR
PORVs
Mass Flow Rate [kg/s]
time [hr]
0
20
40
60
80
100
120
140
160
0
4
8
12
16
20
24

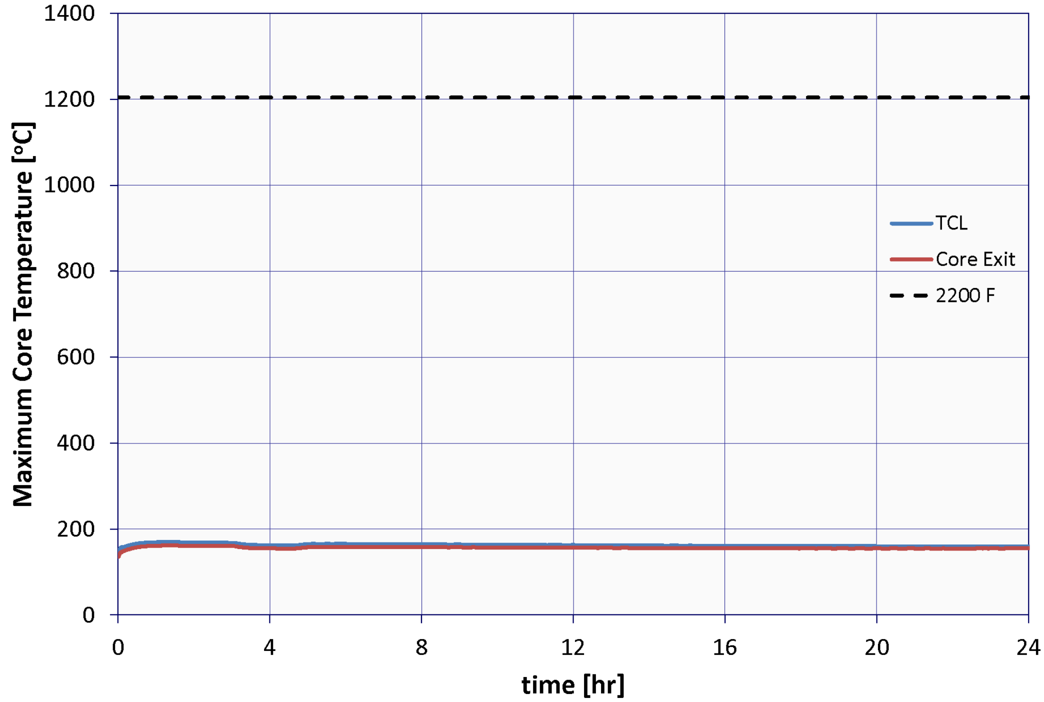


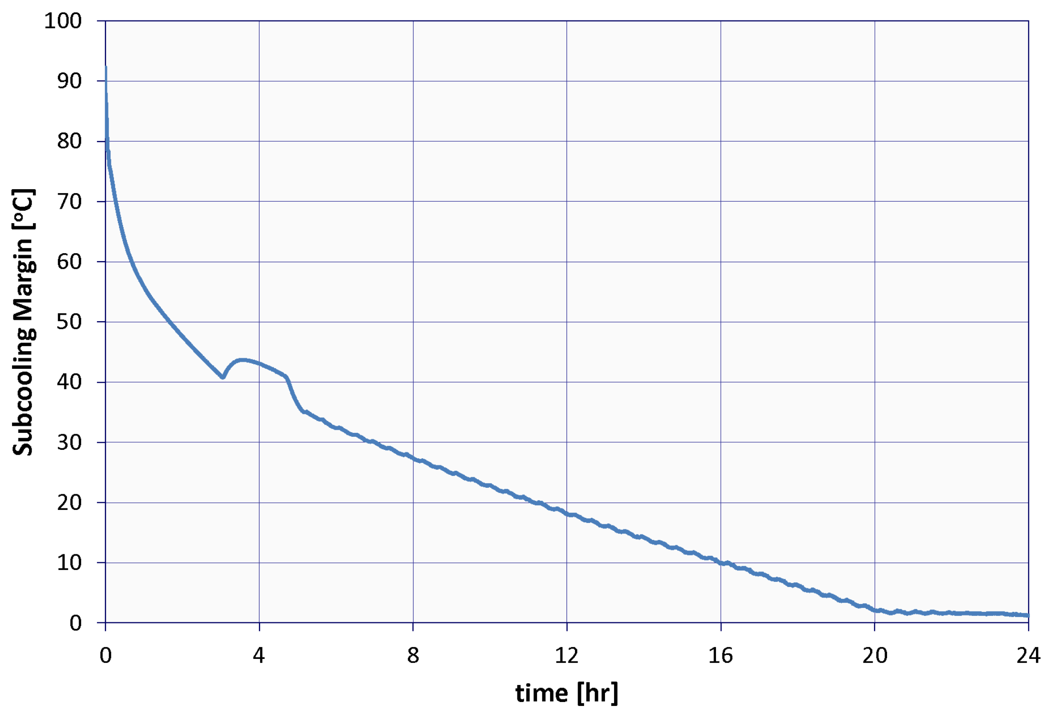
Steam Dump Mass Flow Rate [kg/s]
time [hr]
0
2
4
6
8
10
12
14
16
0
4
8
12
16
20
24

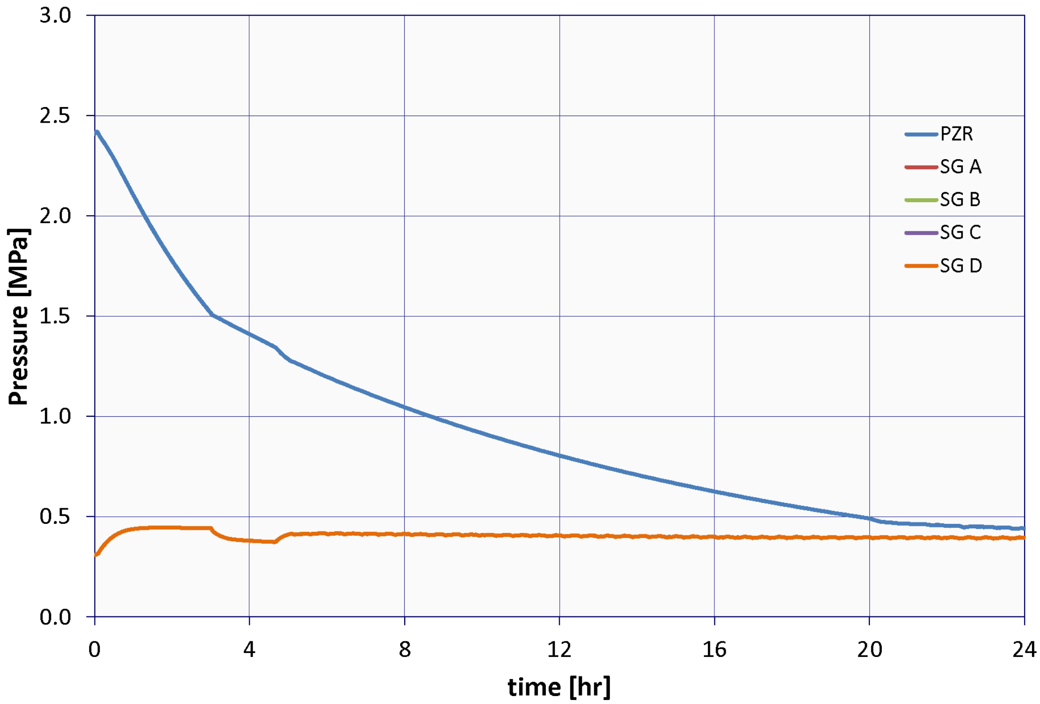

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
30
25
20
15
10
5
0
0
4
8
12
16
20
24


Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
26
24
22
20
18
16
14
12
10
0
4
8
12
16
20
24

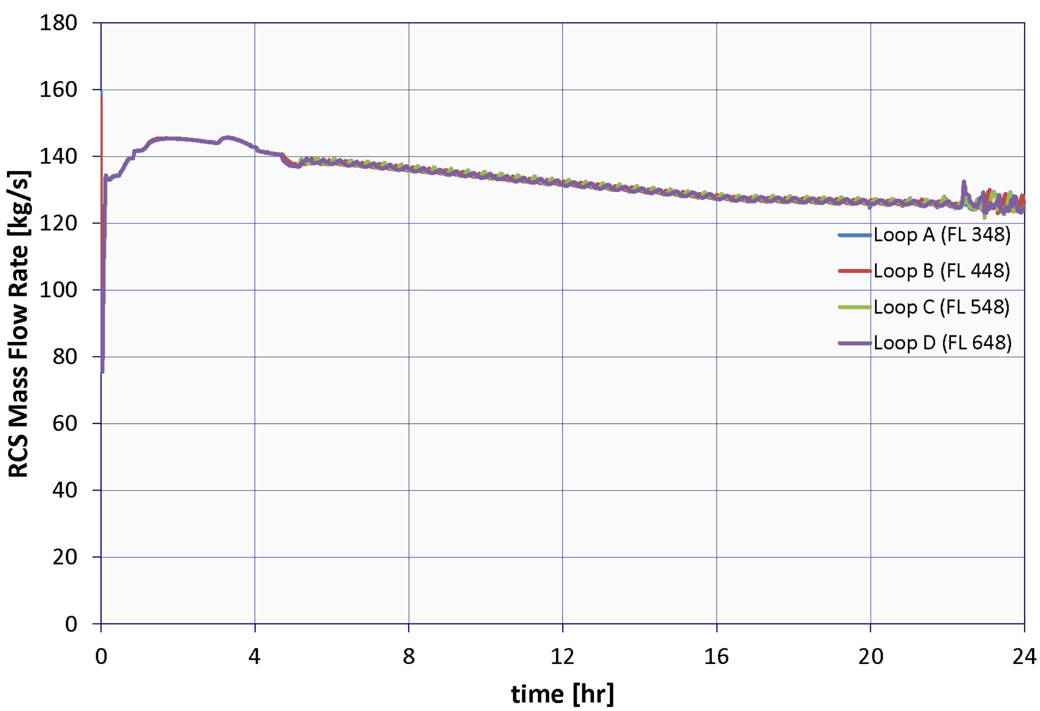
F.1.10 Case 10: SG at 18% NR Level, 6 hr after Shutdown, Initiate AFW at 3 hr



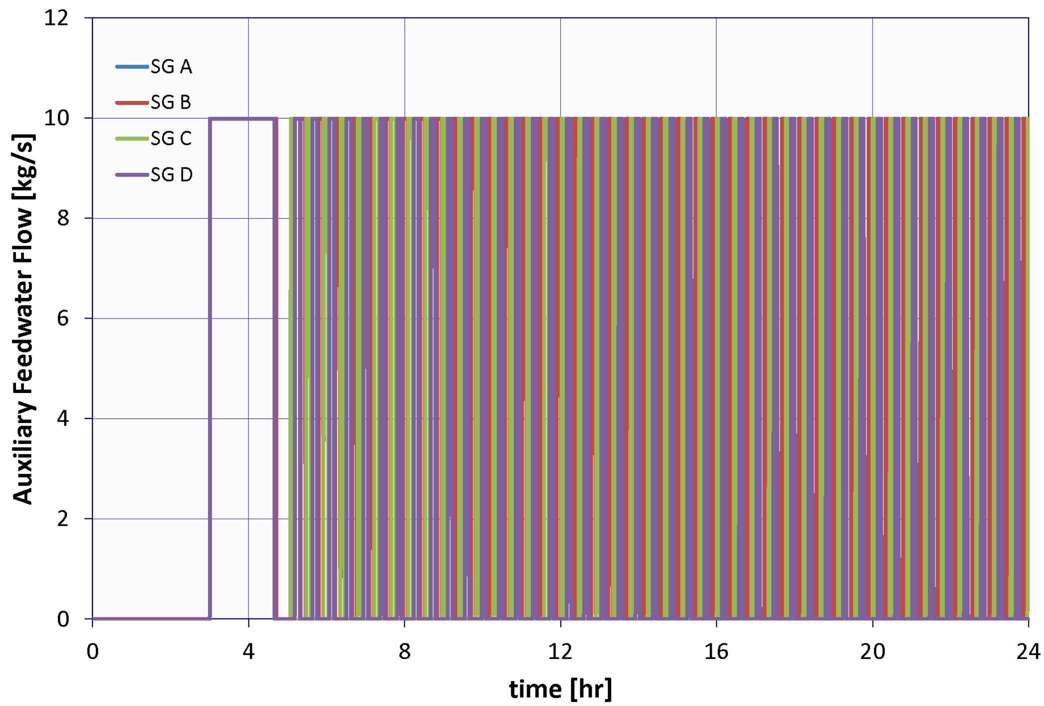




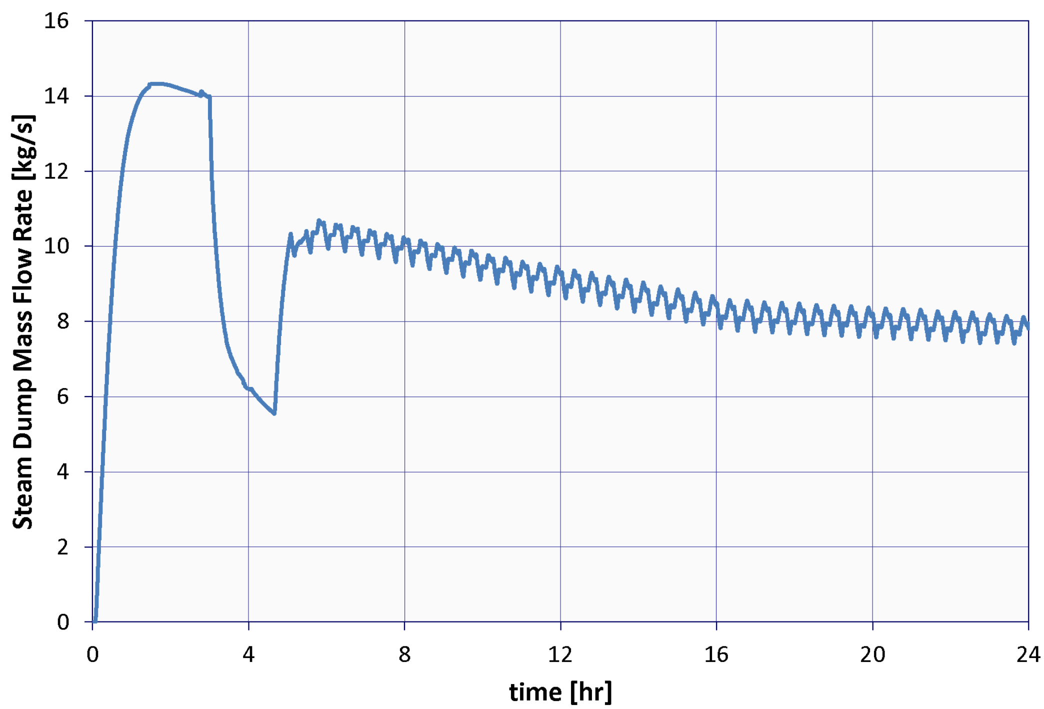
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR
SG A
SG B
SG C
SG D



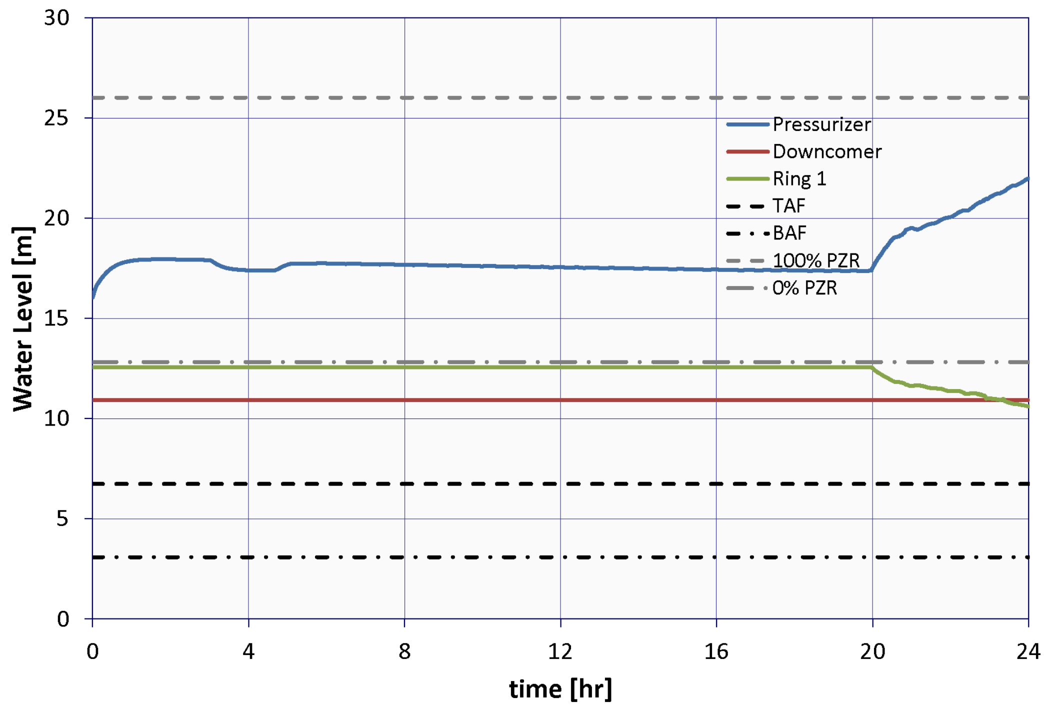
180
160
140
120
100
80
60
40
20
0
RCS Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Loop A (FL 348)
Loop B (FL 448)
Loop C (FL 548)
Loop D (FL 648)

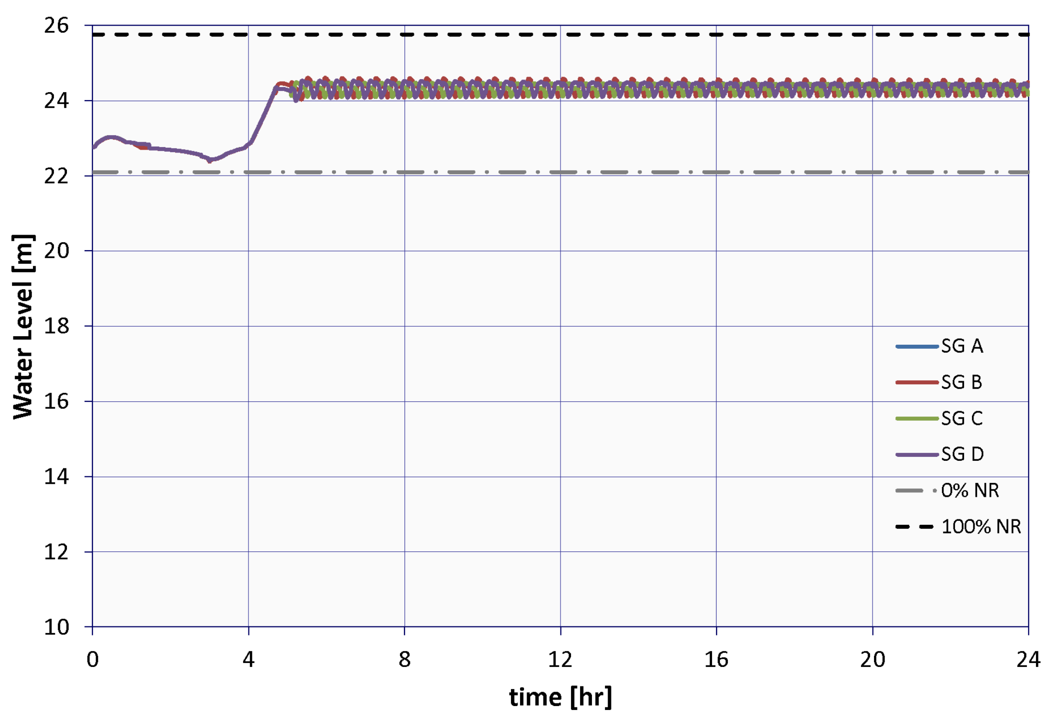


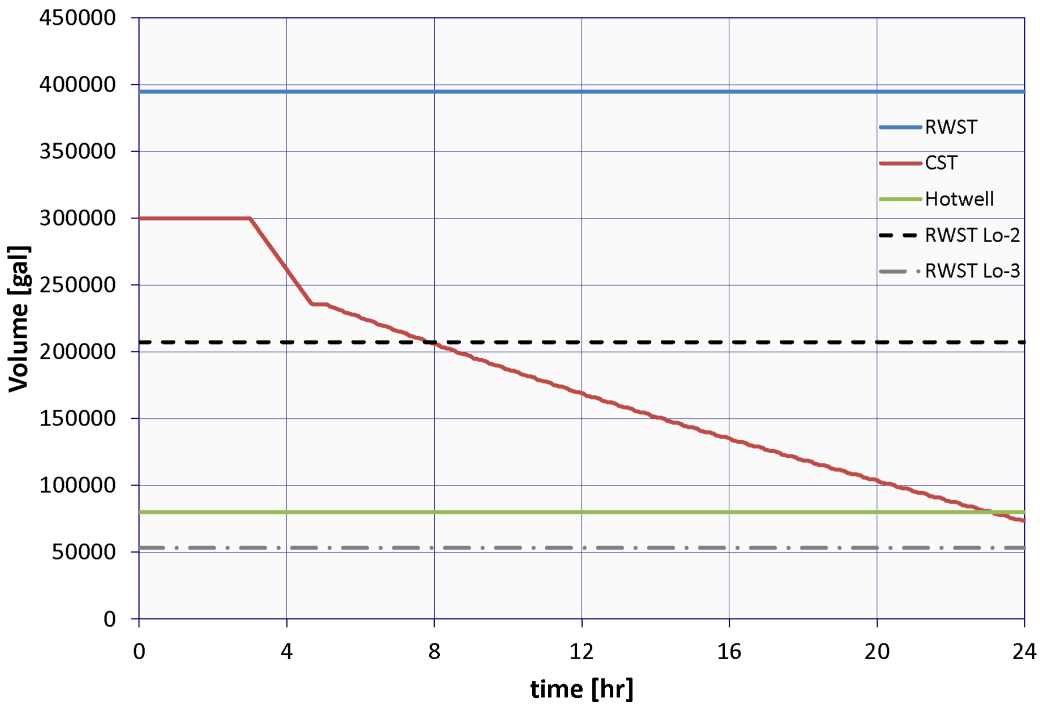
SG A
SG B
SG C
SG D
Auxiliary Feedwater Flow [kg/s]
0
2
4
6
8
10
12
0
4
8
12
16
20
24
time [hr]



Steam Dump Mass Flow Rate [kg/s]
0
2
4
6
8
10
12
14
16
0
4
8
12
16
20
24
time [hr]


Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
0
5
10
15
20
25
30
0
4
8
12
16
20
24


Water Level [m]
time [hr]
SG A
SG B
SG C
SG D
0% NR
100% NR
10
12
14
16
18
20
22
24
26
0
4
8
12
16
20
24


450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Volume [gal]
0
4
8
12
16
20
24
time [hr]
RWST
CST
Hotwell
RWST Lo-2
RWST Lo-3

F.2 Mode 5 Calculations

Notes

The following list identifies some of the changes that were made to the MELCOR input deck in order to perform Mode 5 shutdown calculations.

- Logic has been added to model the shutdown cooling function of the RHR system. This logic is set up such that RHR flow rate is adjusted in order to maintain a constant coolant temperature, up to the maximum flow rate of the system. The logic also includes provisions to achieve a target cooldown rate; however, this feature is not used in any of the shutdown calculations performed for this report.

- Pressurizer level control logic has been modified to control water level during the steady-state portion of the calculation. For the Mode 5 calculations, level control is based on RPV level because the level is assumed to be at the vessel flange, which is below the bottom of the pressurizer.

- Pressurizer heaters have been disabled because the pressurizer is empty.

- Logic that makes it possible to turn off ECCS flow to prevent overfilling the pressurizer has been modified in order to simulate recovery actions in which operators inject using a charging pump when RPV level is low. This feature is exercised in Mode 5 Cases 2, 5, and 8.

- The decay heat curves have been shifted in order to simulate the desired times after trip. For example, the decay heat curve is shifted by 40 hours for Mode 5 Cases 1–3. Note that during the steady-state portion of the calculation, the decay heat is assumed to be constant and to equal the decay power at 40 hours. The same is true for all other times since subcriticality that are analyzed in Section 5.8.3 of the report.

- Initial temperature and pressure of RCS control volumes have been set to 170 degrees F (349.8 K) and atmospheric pressure.

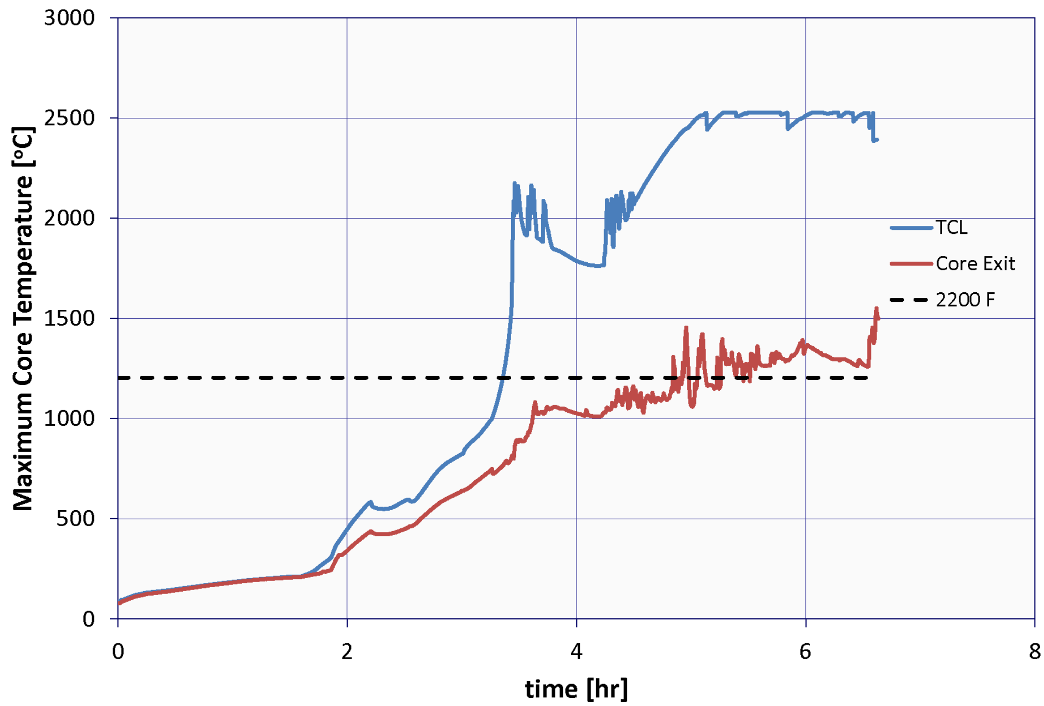
- Flow paths have been added to model the antisiphon hole in the line leading from the pressurizer power-operated relief valves to the pressurizer relief tank (PRT). It is necessary to include this flow path because, otherwise, the RCS will draw a vacuum when RHR is operating.

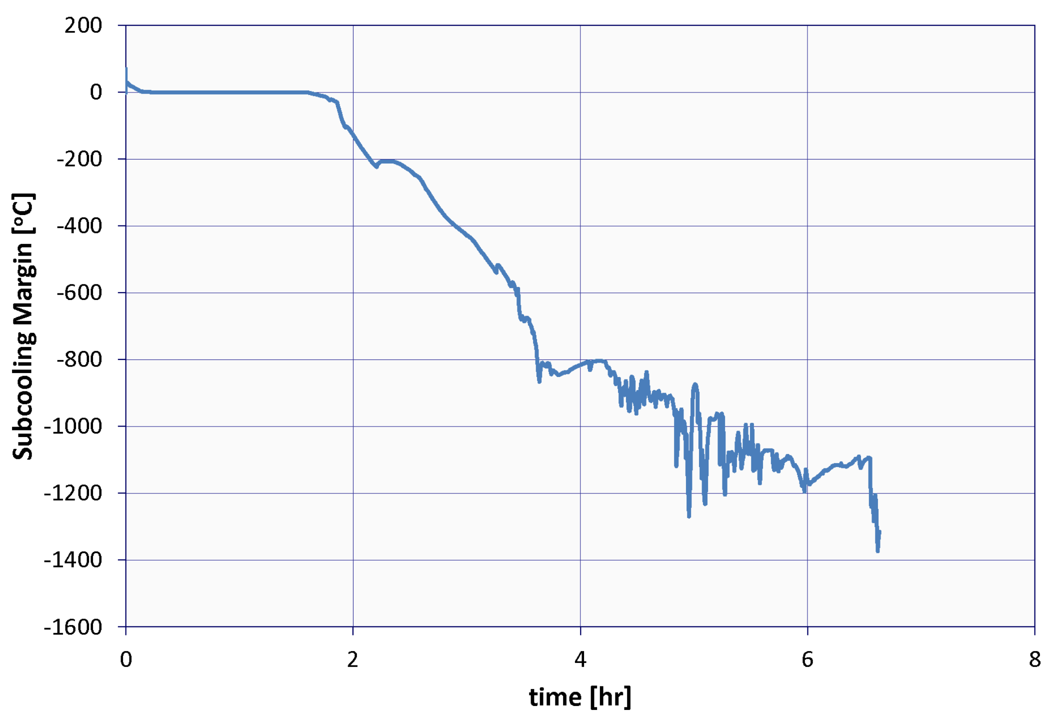
- The flow path representing the PRT rupture disk is held open throughout the Mode 5 calculations. It is expected that the PRT would be vented to containment during this operating stage; however, the characteristics of this vent path are unknown. In the absence of better information, the PRT rupture disk flow path is used as the vent path for this model.

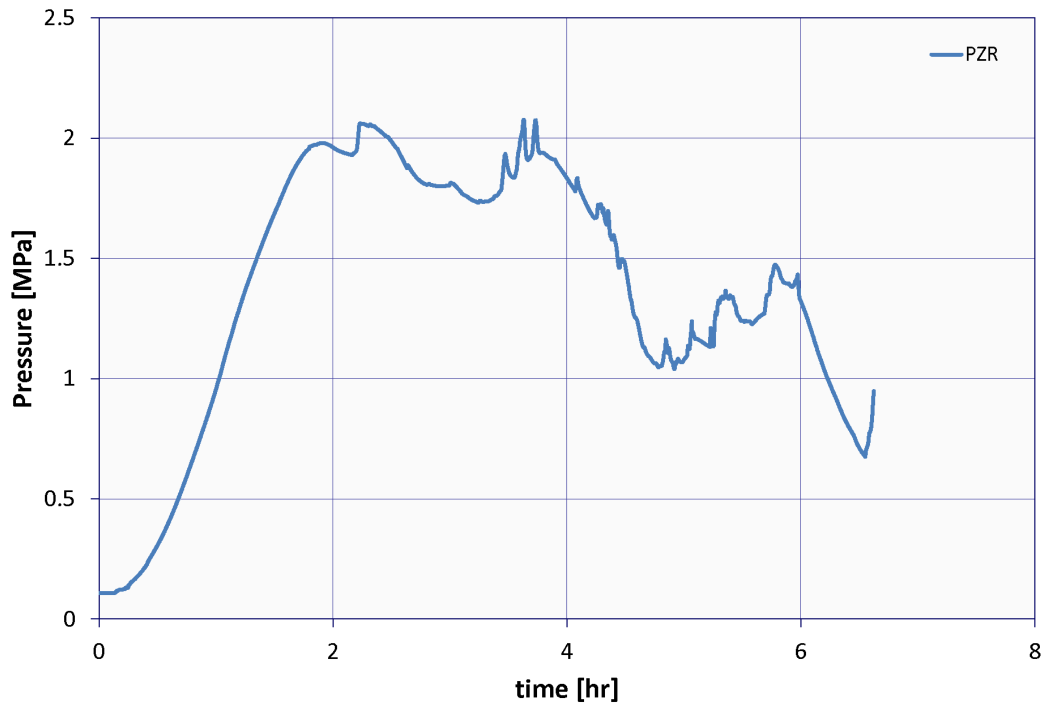
- Flow paths from CV 310 and 311 to 320 and 321 have been deleted, or the valves in the flow paths have been closed, to simulate loop stop valve closure. The same is true for flow paths between CV 346 and 348 in the cold leg and between analogous control volumes in the other loops.

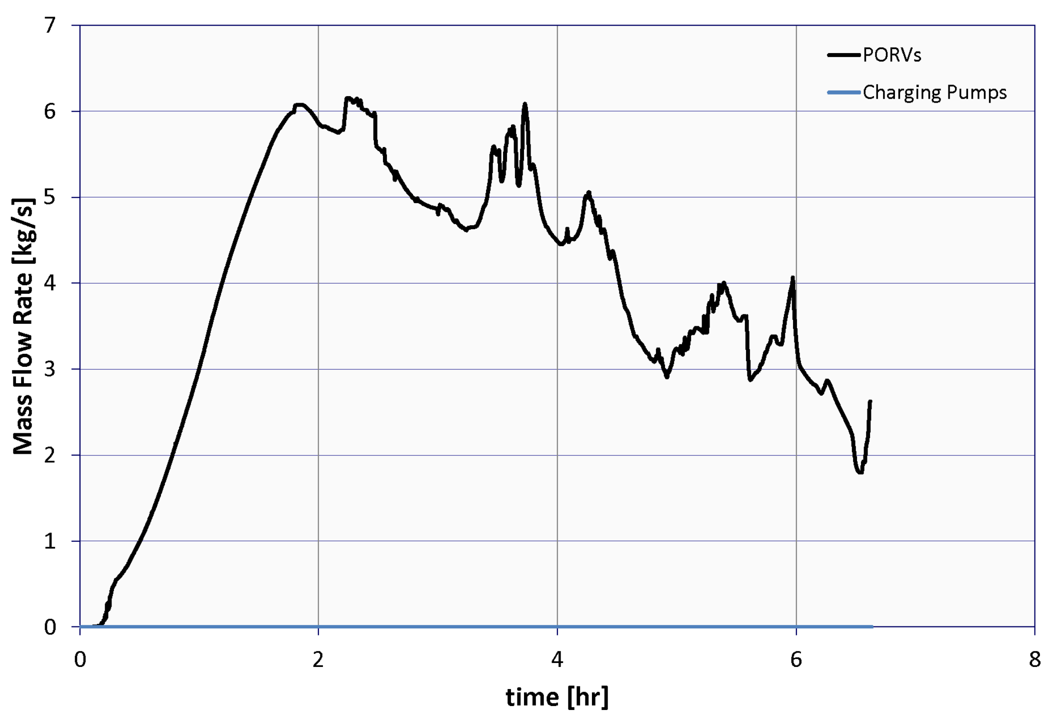
- Cold volumes have been used in place of hot volumes for RCS control volumes. This decreases the RCS volume by approximately 1 percent.

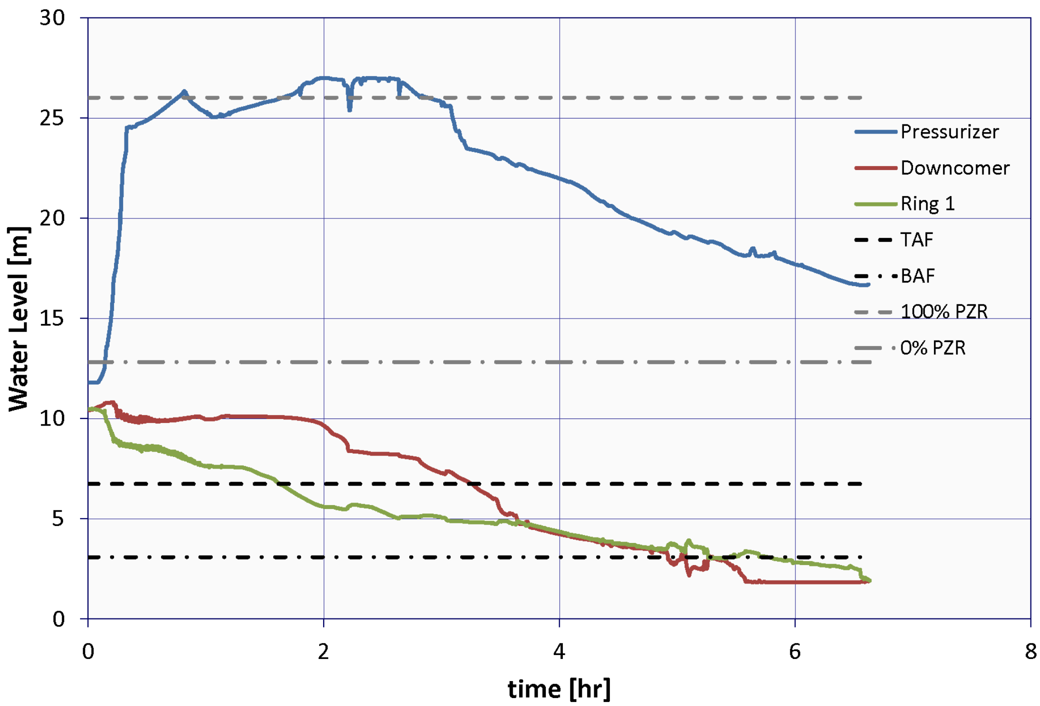
F.2.1 Case 1: 40 hr after Shutdown, No Recovery Actions





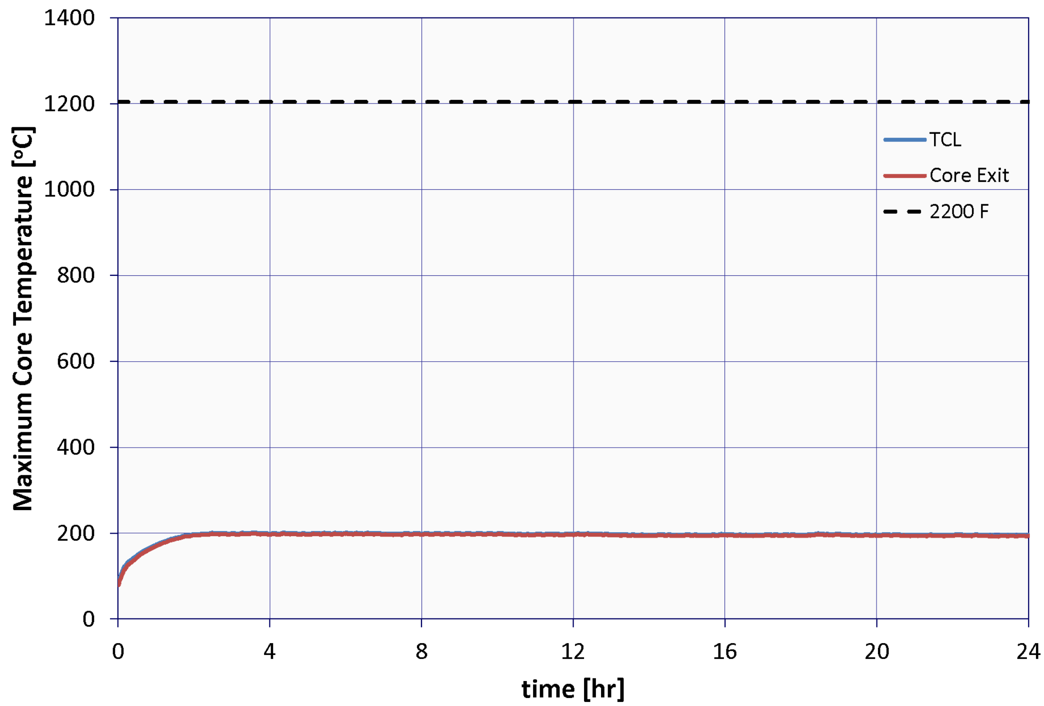

PZR
Pressure [MPa]
time [hr]
2.5
2
1.5
1
0.5
0
0
2
4
6
8

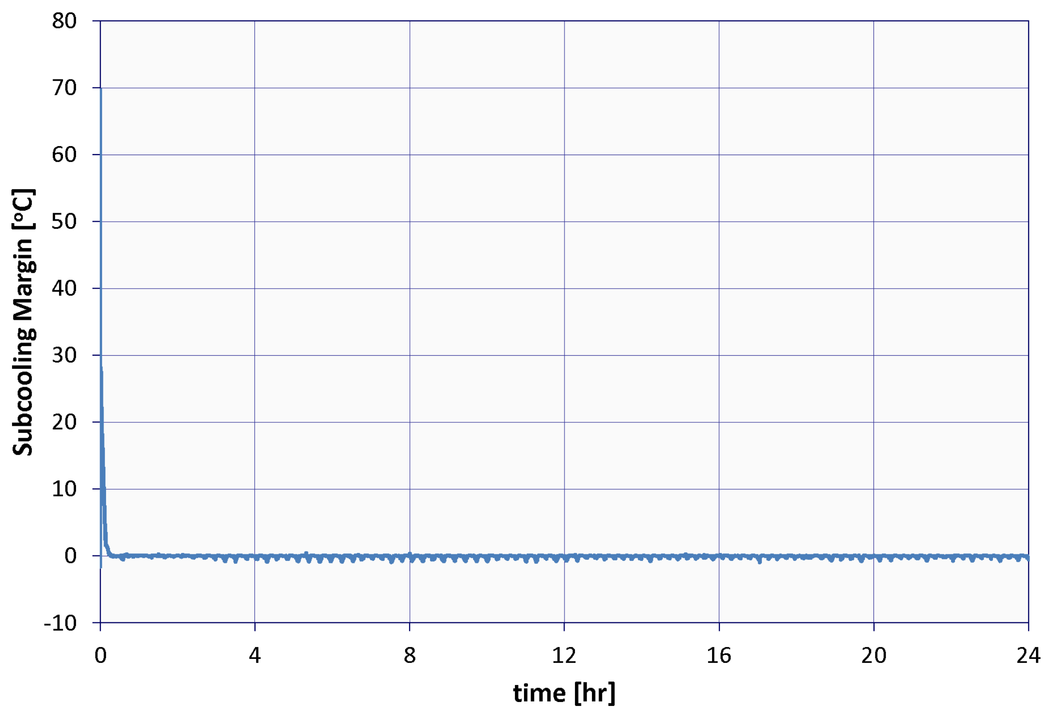

PORVs
Charging Pumps
Mass Flow Rate [kg/s]
time [hr]
7
6
5
4
3
2
1
0
0
2
4
6
8

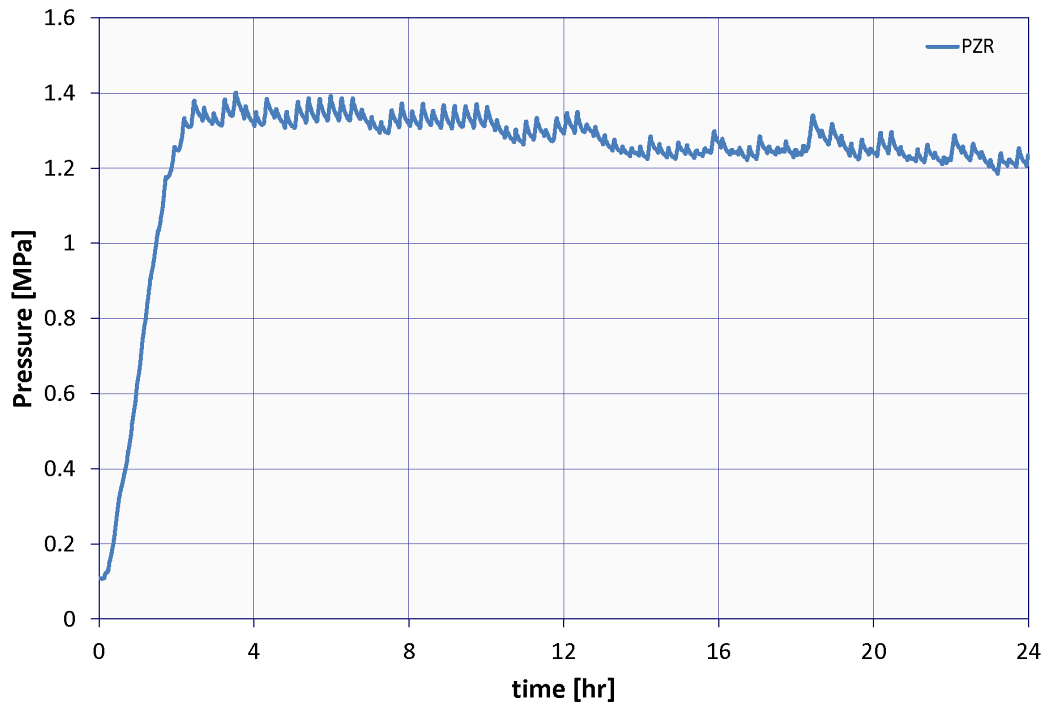


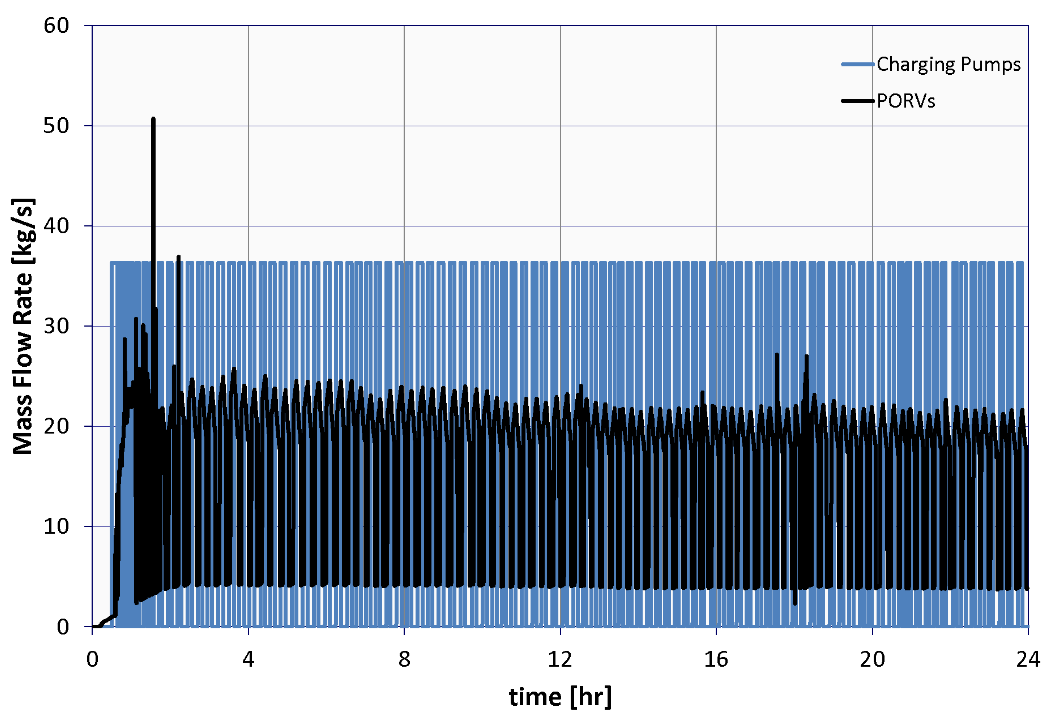
Water Level [m]
time [hr]
0
5
10
15
20
25
30
0
2
4
6
8
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

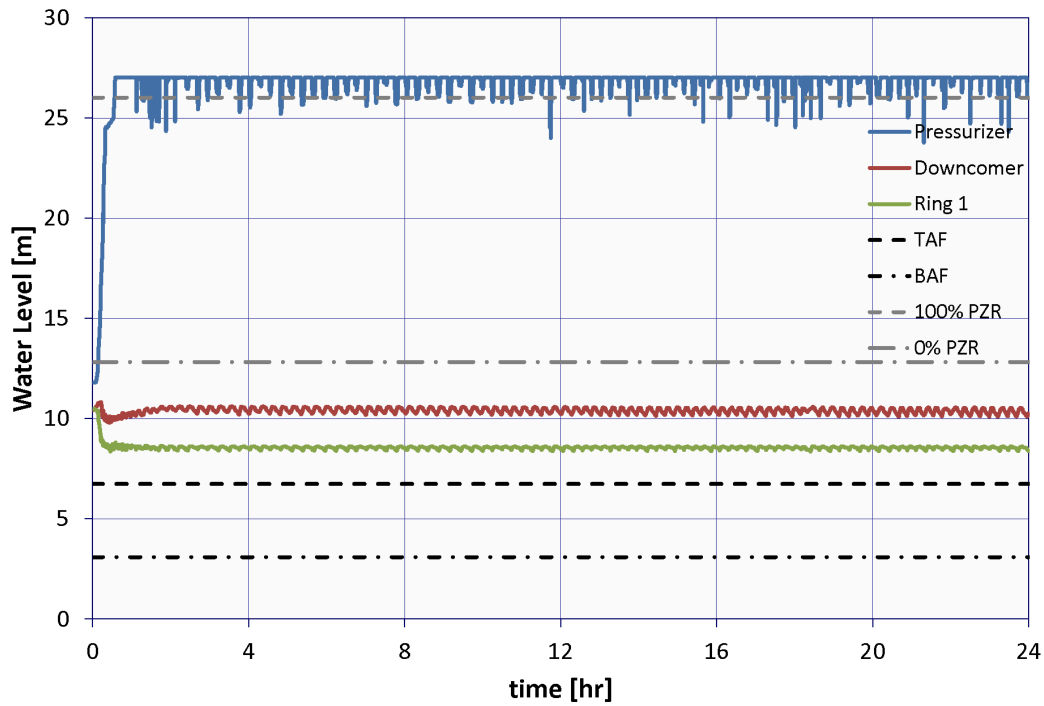
F.2.2 Case 2: 40 hr after Shutdown, Start CCP on Low RPV Level



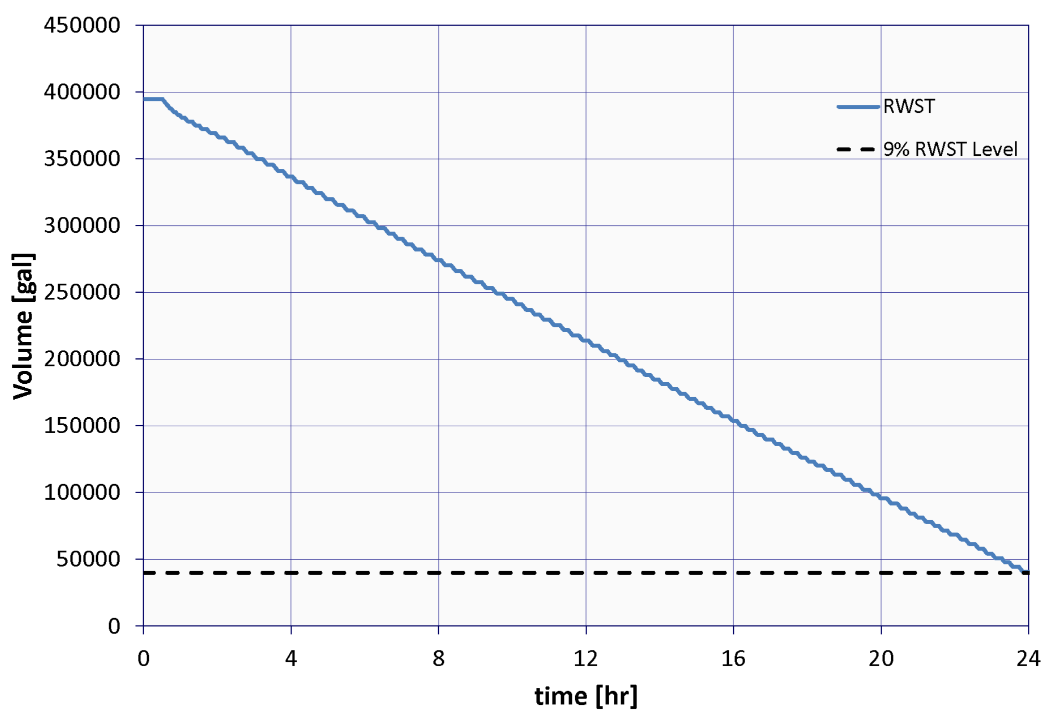



PZR
Pressure [MPa]
time [hr]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
4
8
12
16
20
24


Charging Pumps
PORVs
Mass Flow Rate [kg/s]
time [hr]
0
10
20
30
40
50
60
0
4
8
12
16
20
24

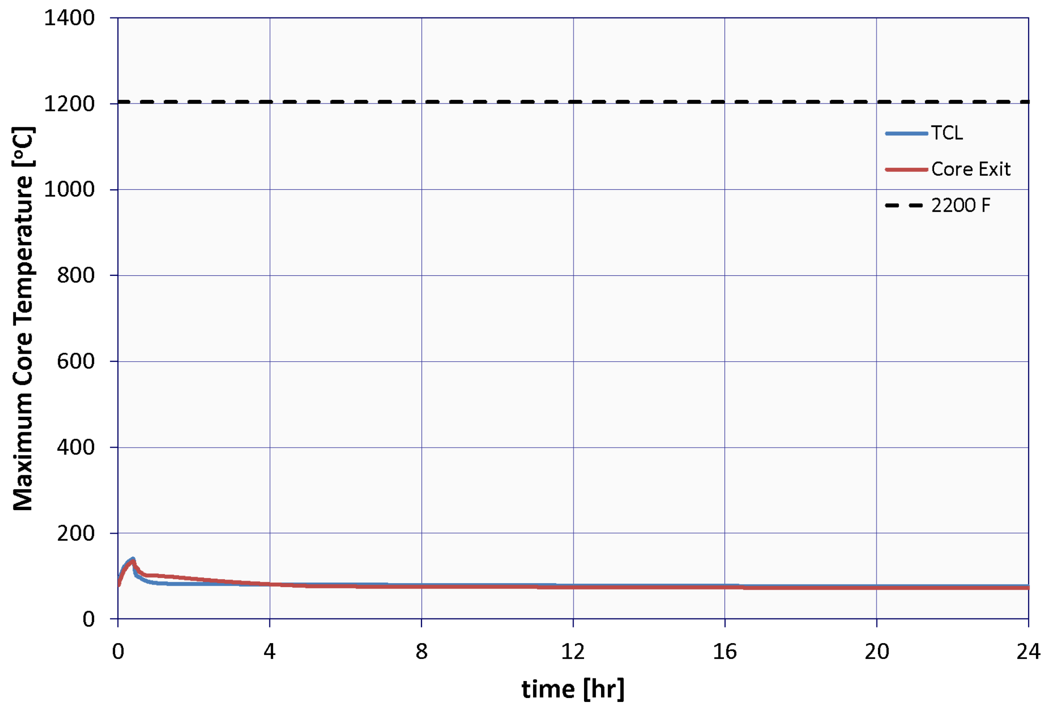


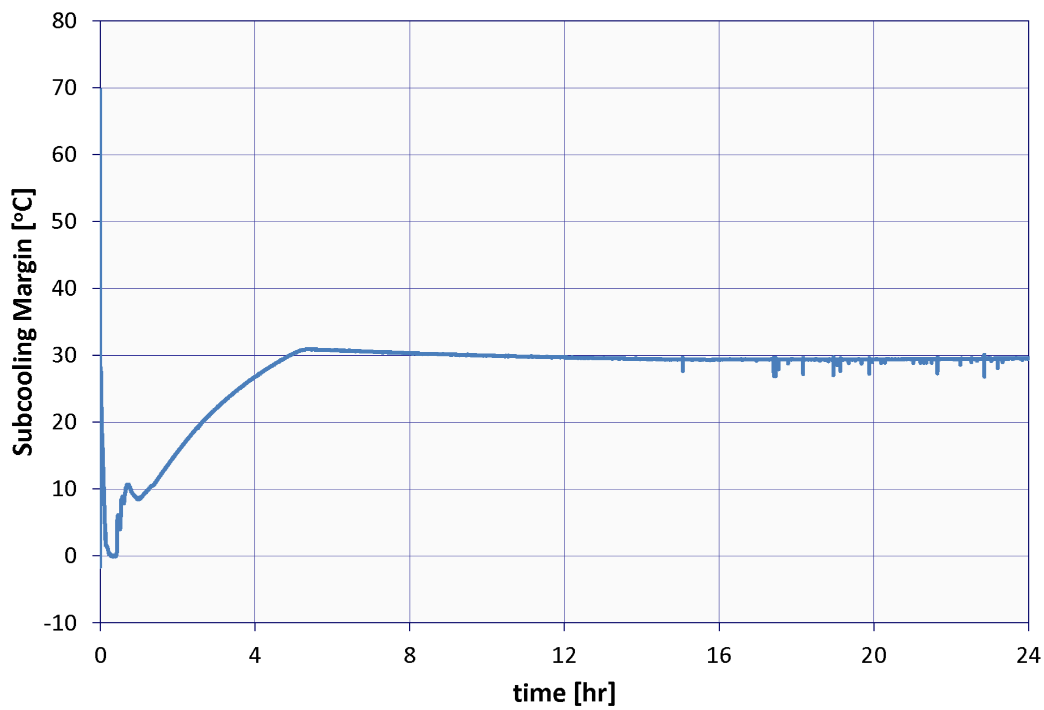
Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

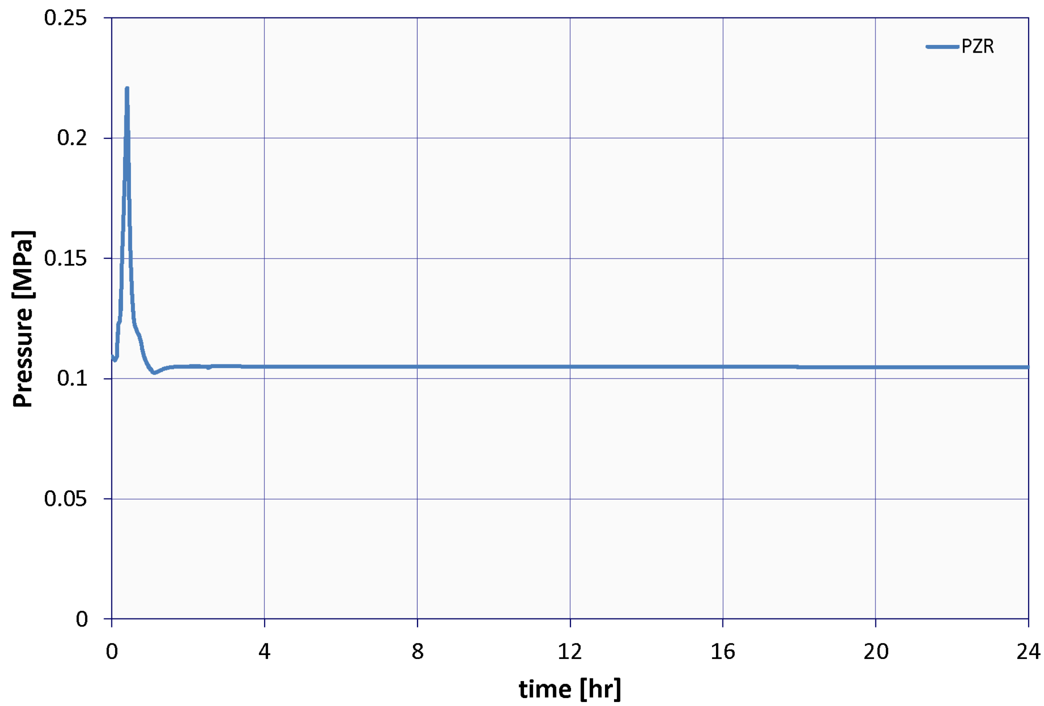


Volume [gal]
time [hr]
RWST
9% RWST Level

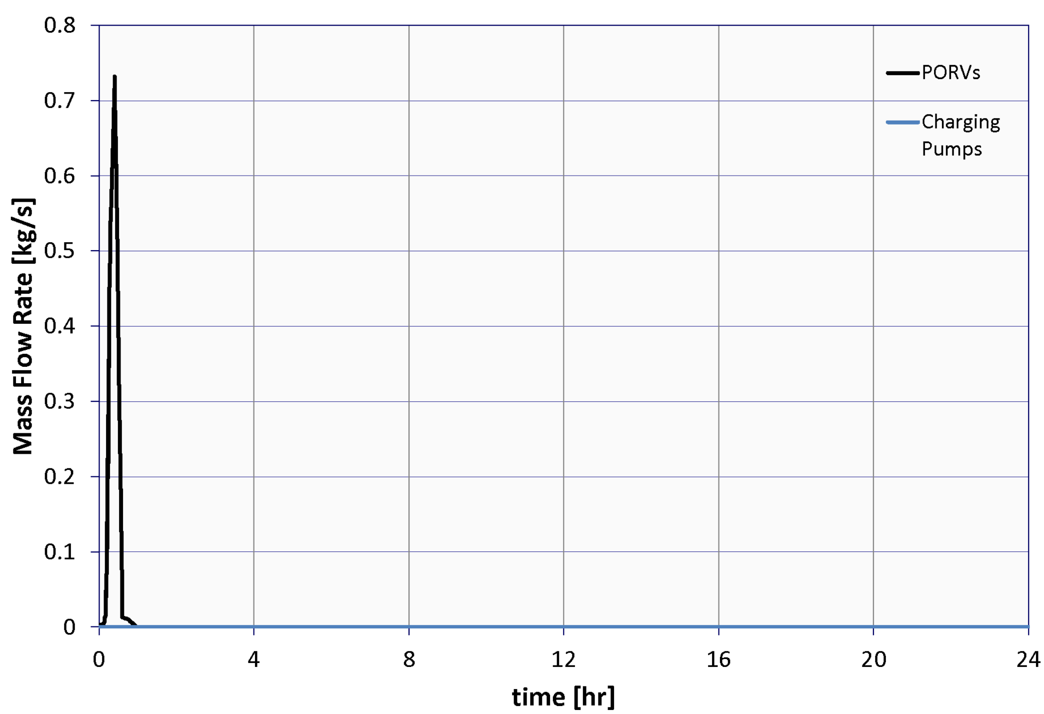
F.2.3 Case 3: 40 hr after Shutdown, Recover RHR at 23 Minutes



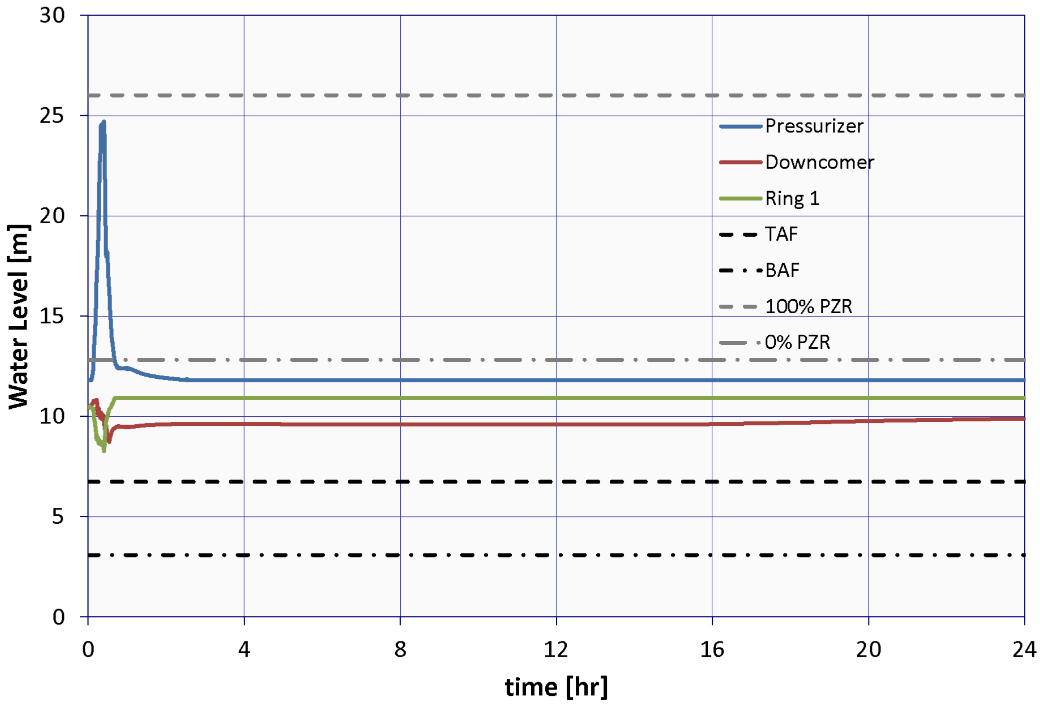




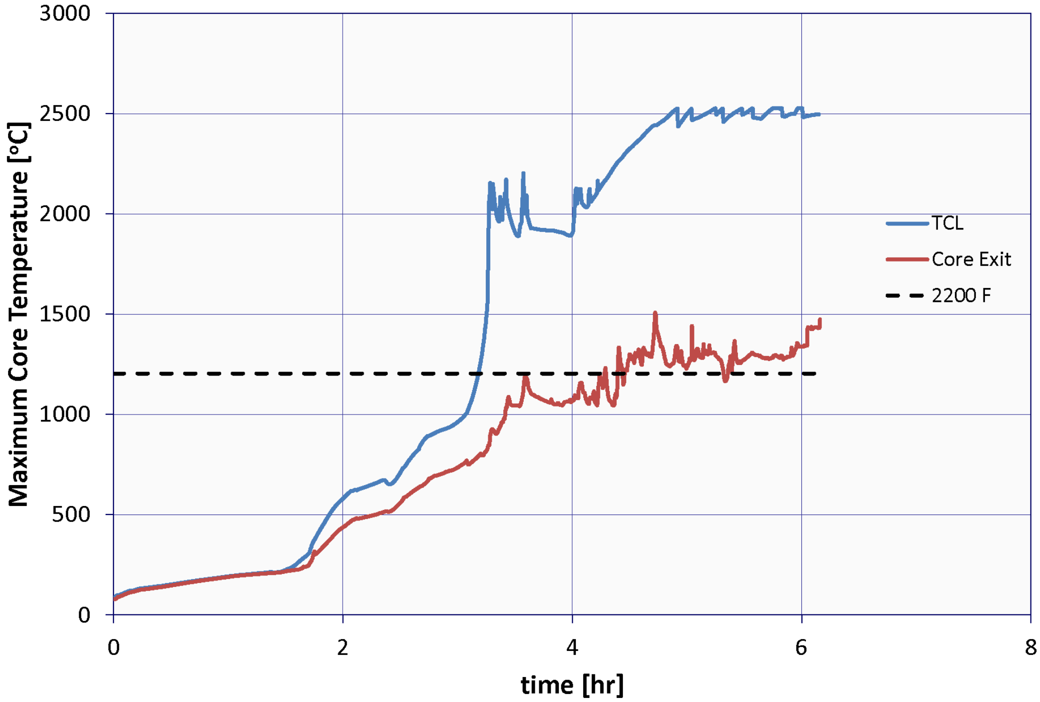
0.25
0.2
0.15
0.1
0.05
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR

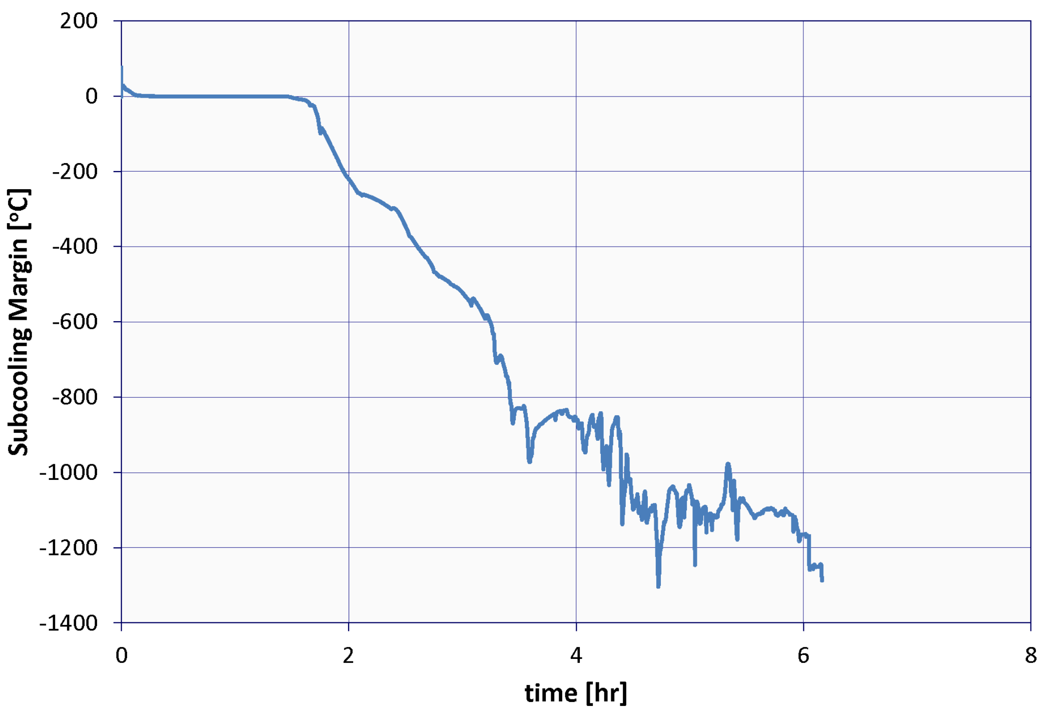


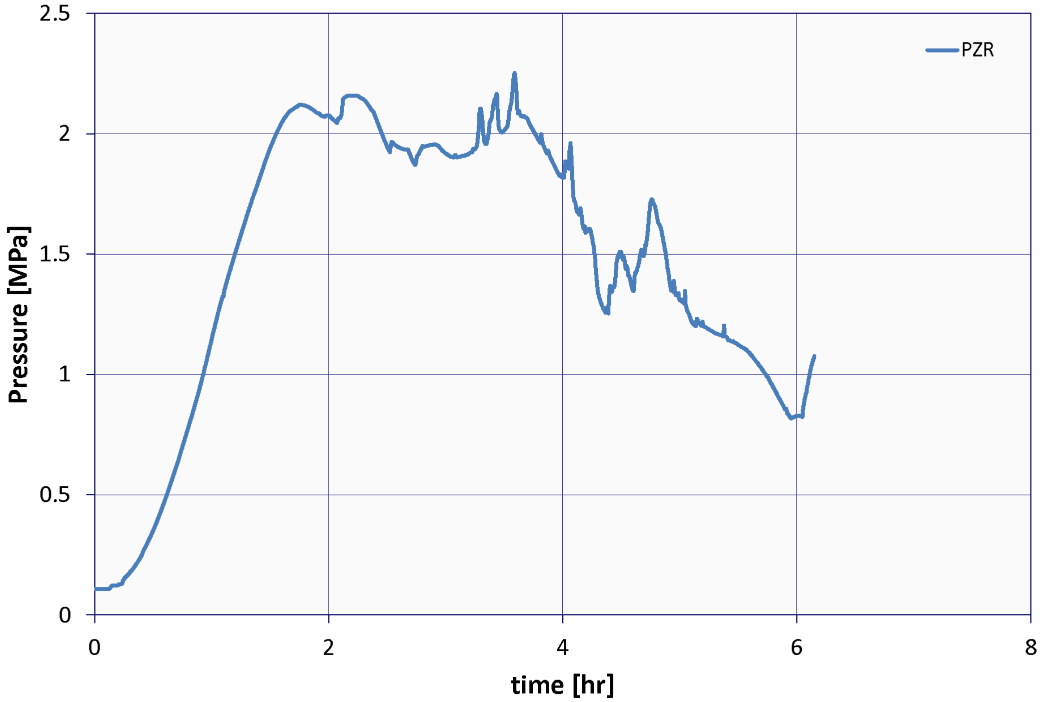
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
PORVs
Charging Pumps

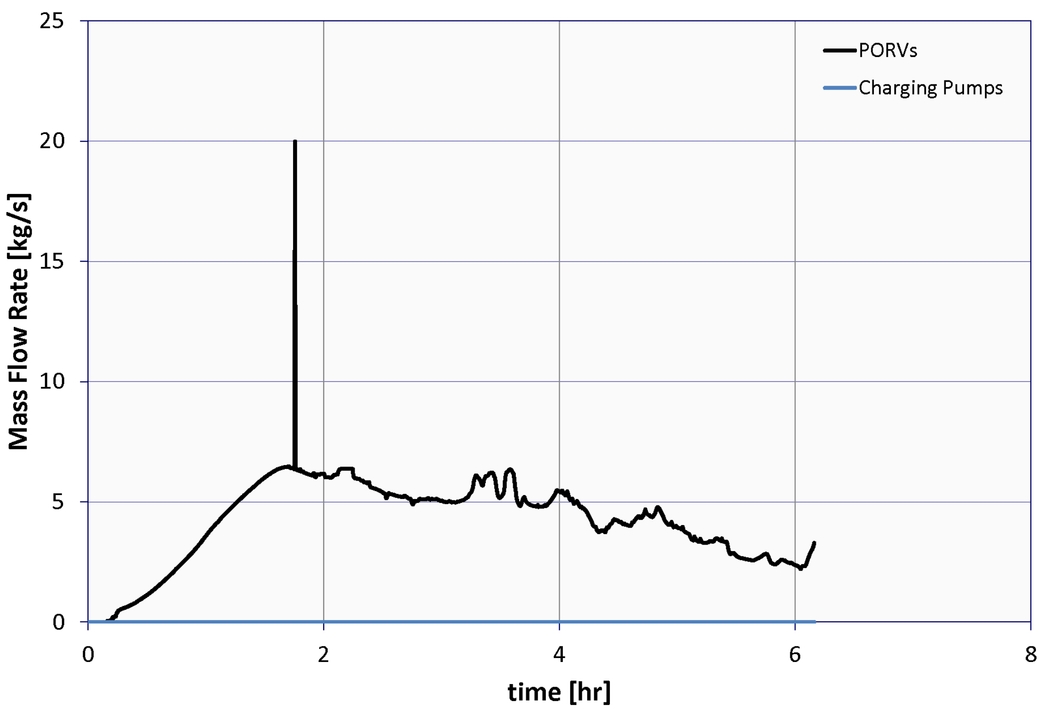

30
25
20
15
10
5
0
Water Level [m]
0
4
8
12
16
20
24
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

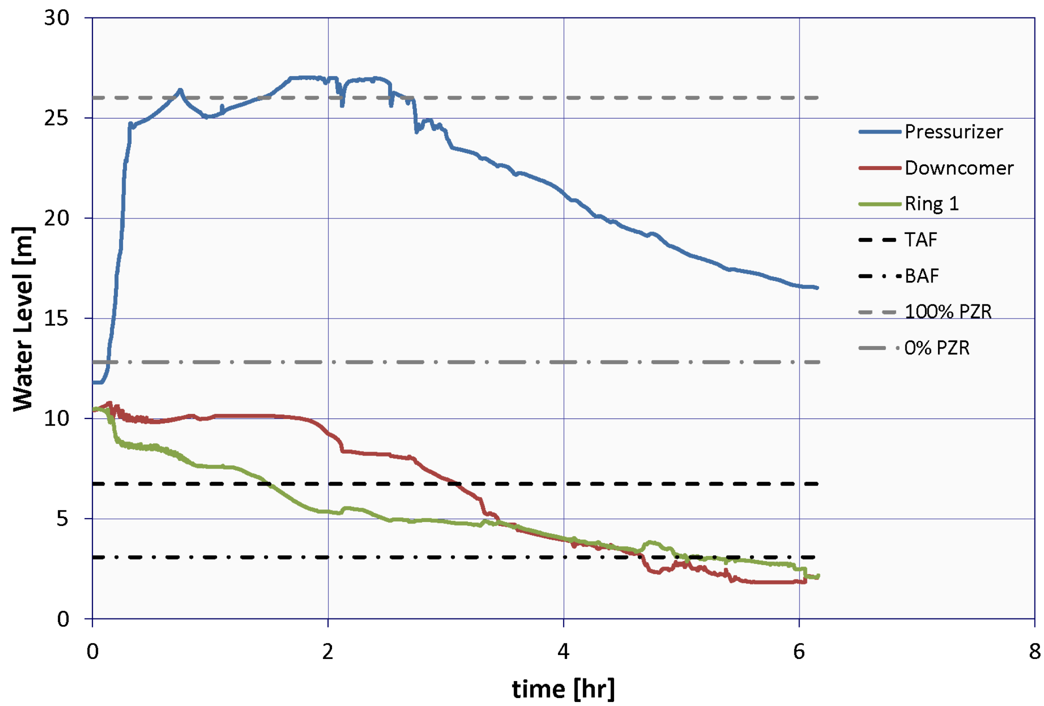
F.2.4 Case 4: 30 hr after Shutdown, No Recovery Actions



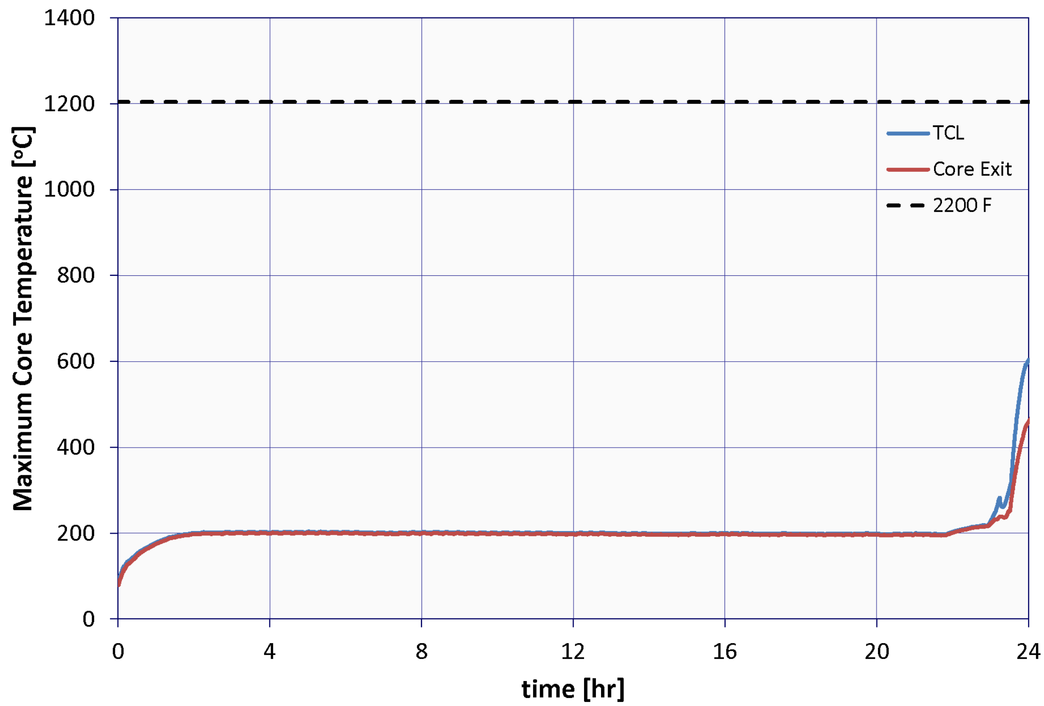


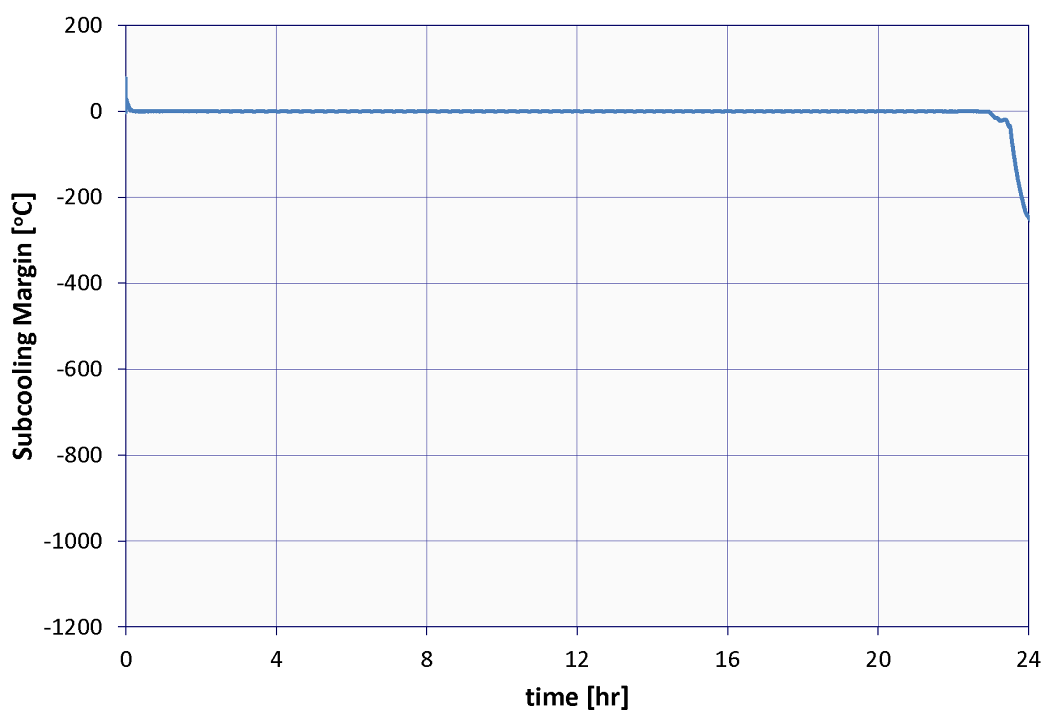

PZR
Pressure [MPa]
time [hr]
2.5
2
1.5
1
0.5
0
0
2
4
6
8

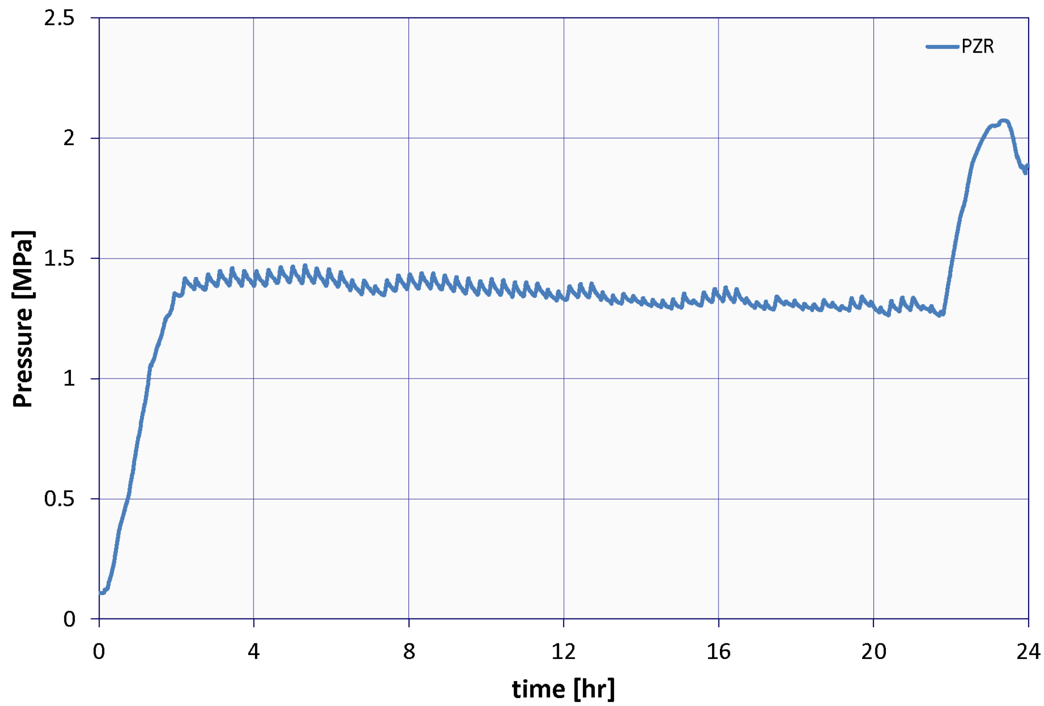

PORVs
Charging Pumps
Mass Flow Rate [kg/s]
time [hr]
25
20
15
10
5
0
0
2
4
6
8


30
25
20
15
10
5
0
Water Level [m]
0
2
4
6
8
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

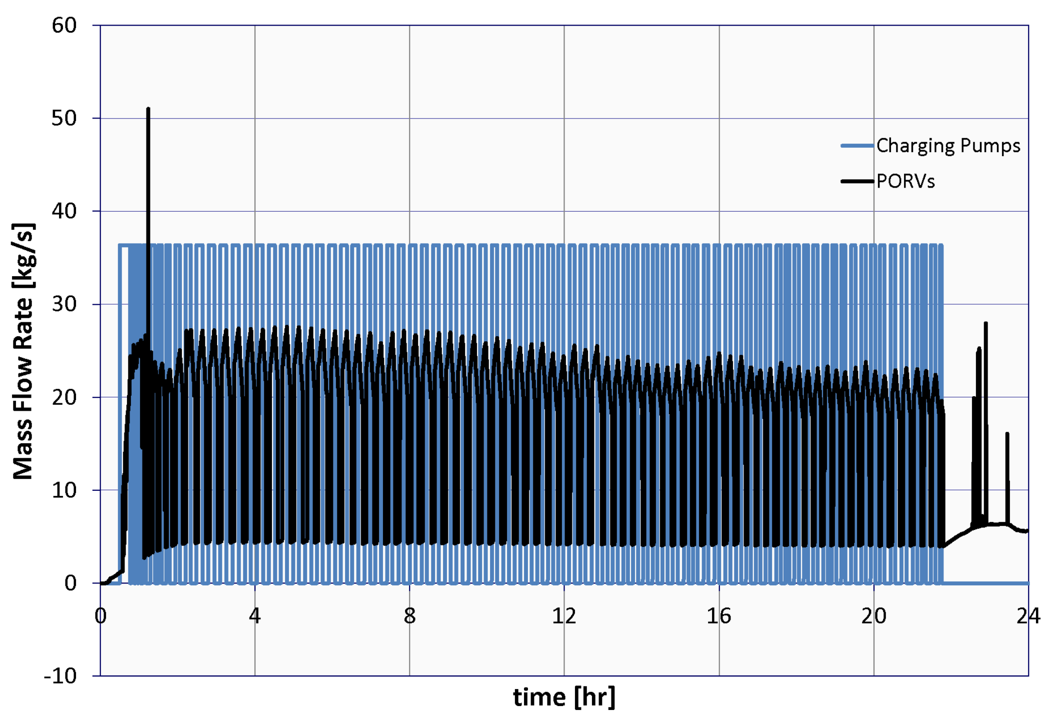
F.2.5 Case 5: 30 hr after Shutdown, Start CCP on Low RPV Level



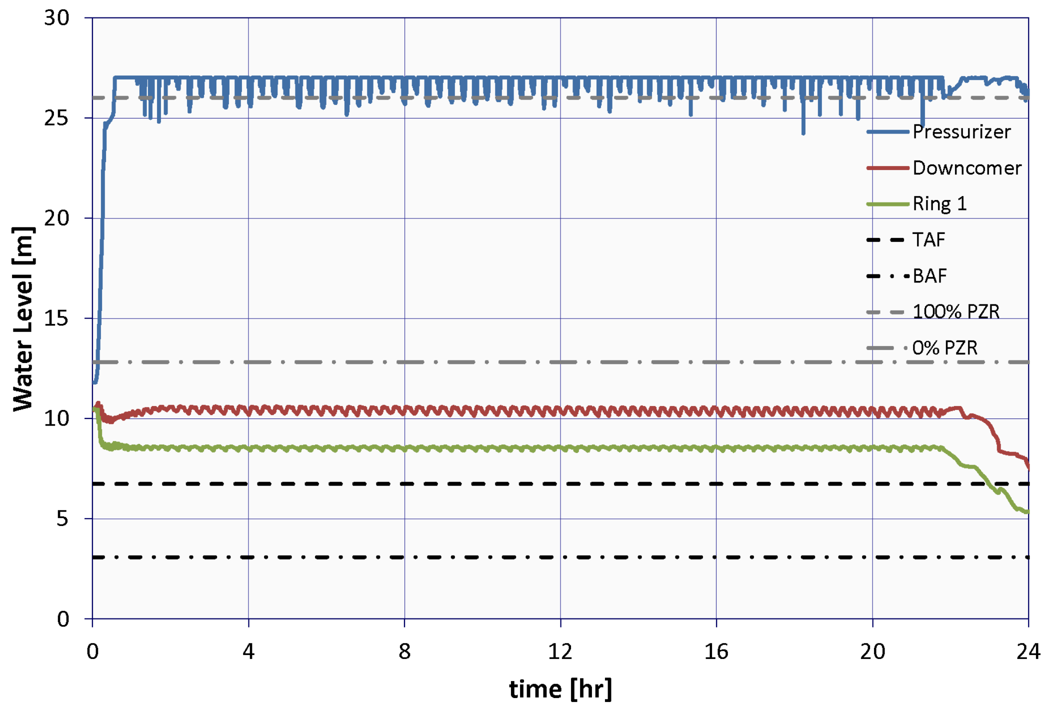


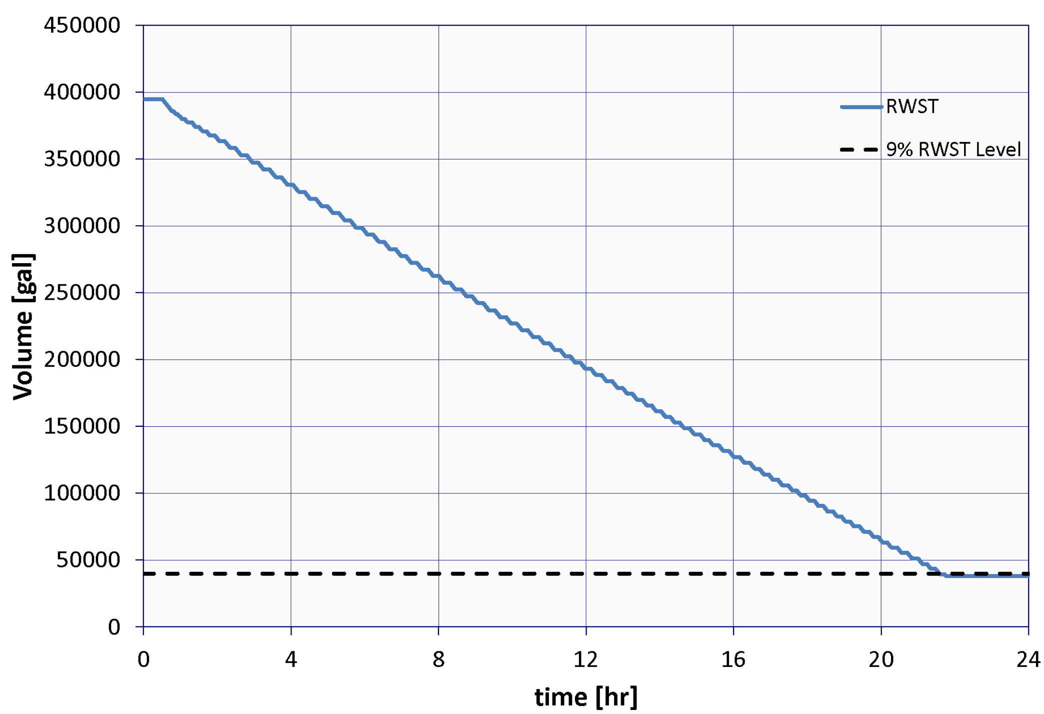


2.5
2
1.5
1
0.5
0
Pressure [MPa]
0
4
8
12
16
20
24
time [hr]
PZR

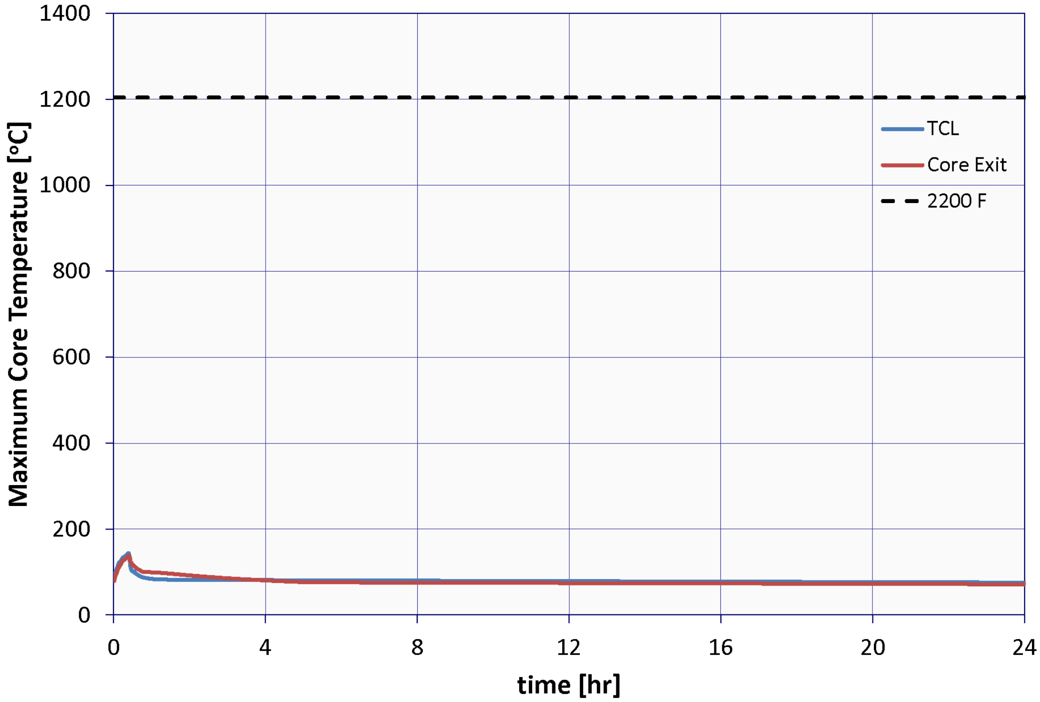


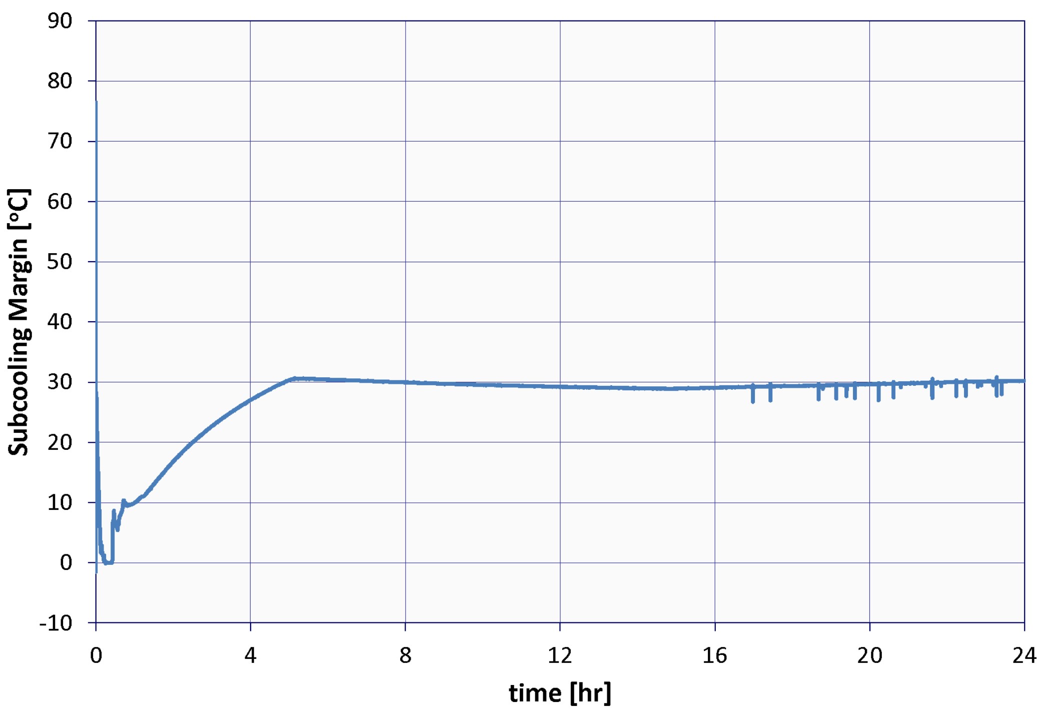
60
50
40
30
20
10
0
-10
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]
Charging Pumps
PORVs

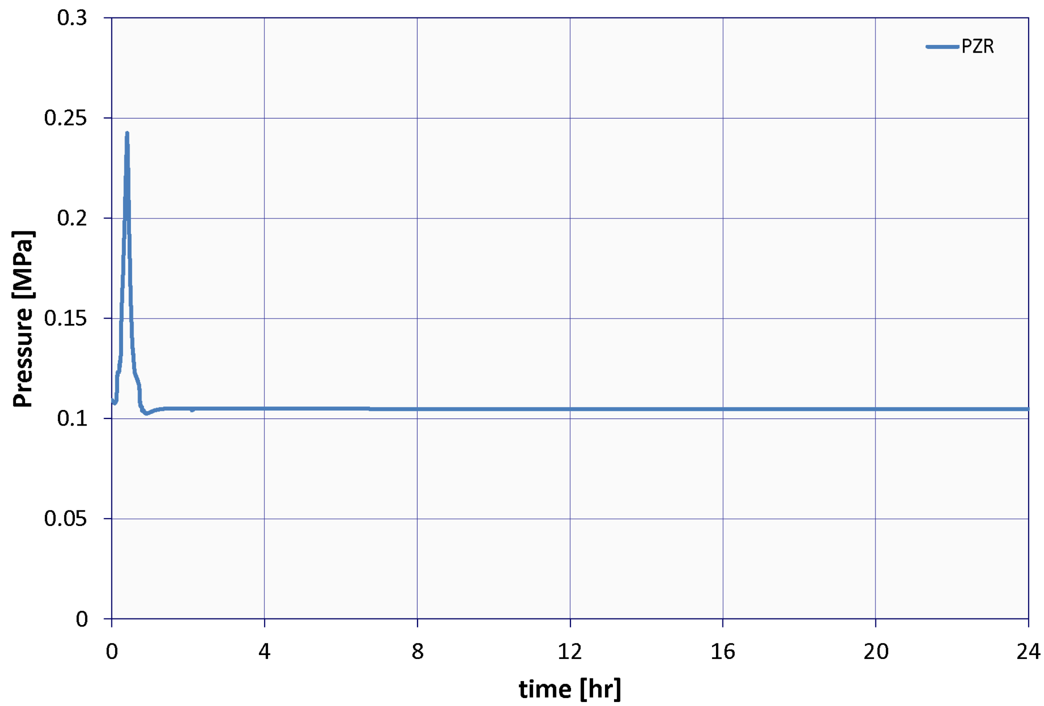

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
0
5
10
15
20
25
30
0
4
8
12
16
20
24

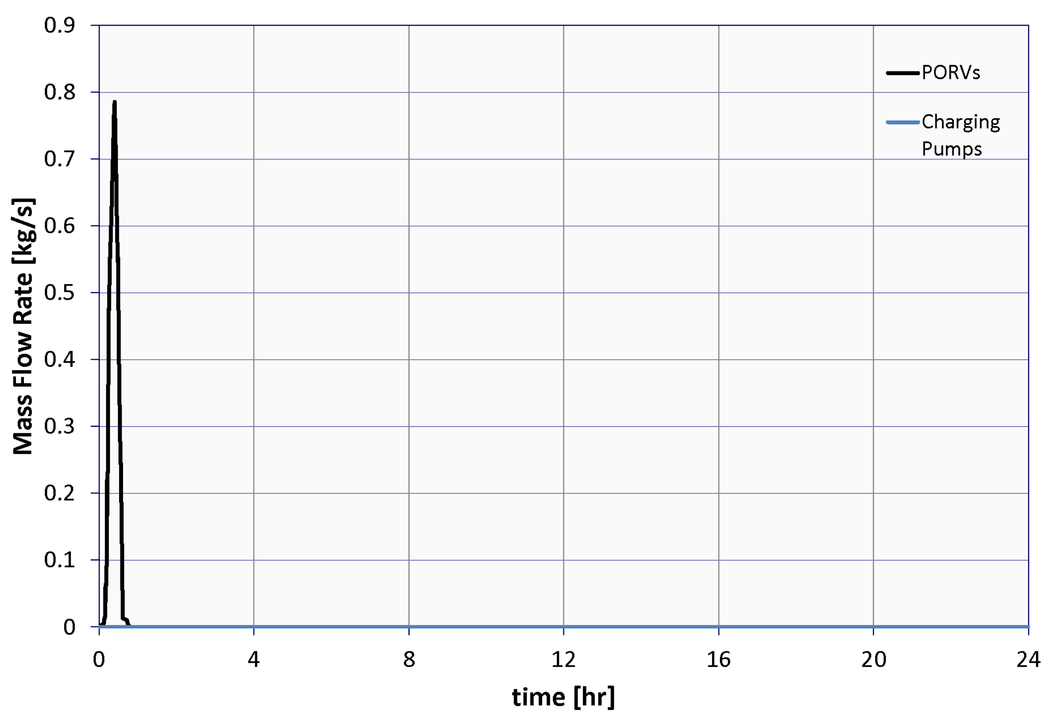

Volume [gal]
time [hr]
RWST
9% RWST Level
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
0
4
8
12
16
20
24

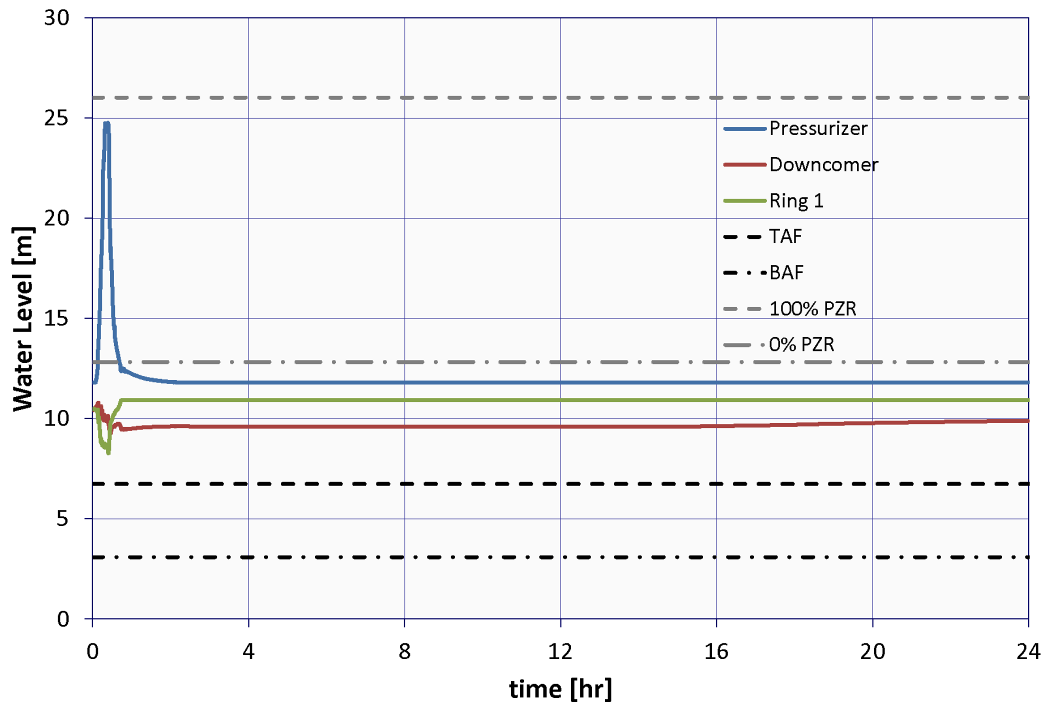
F.2.6 Case 6: 30 hr after Shutdown, Recover RHR at 23 Minutes



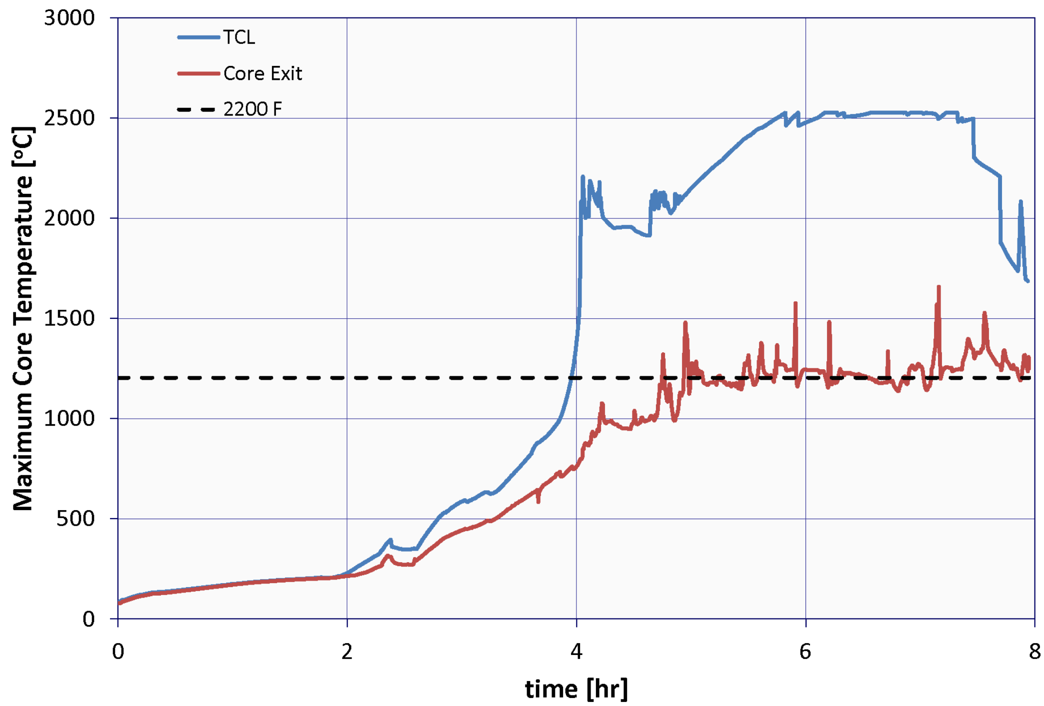


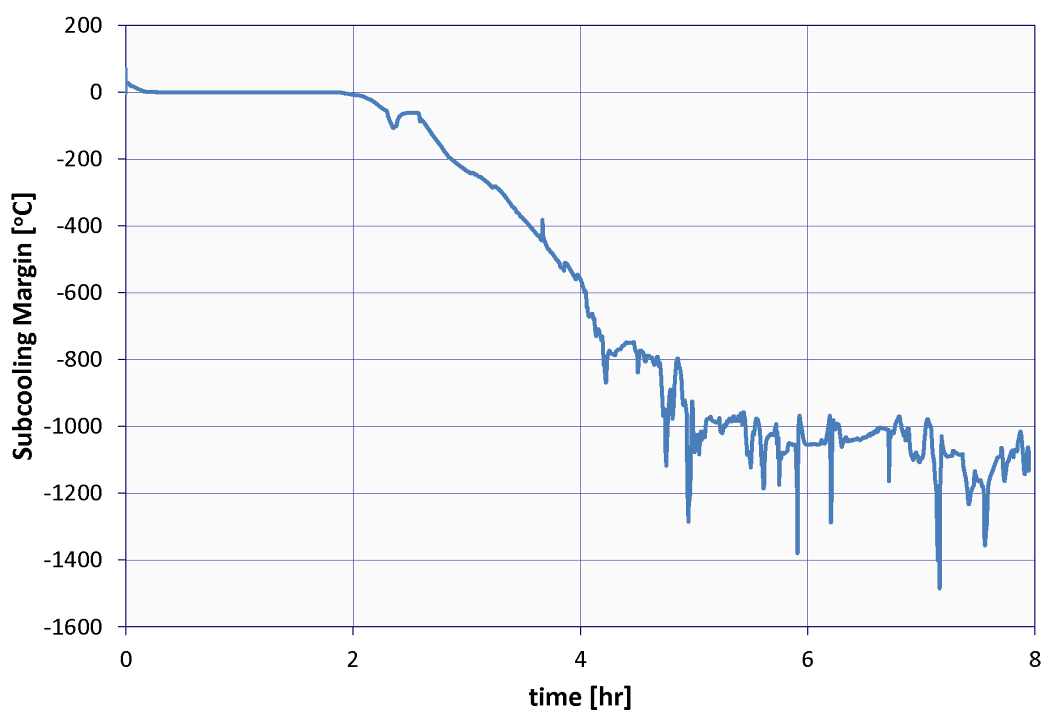

PZR
Pressure [MPa]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24
time [hr]

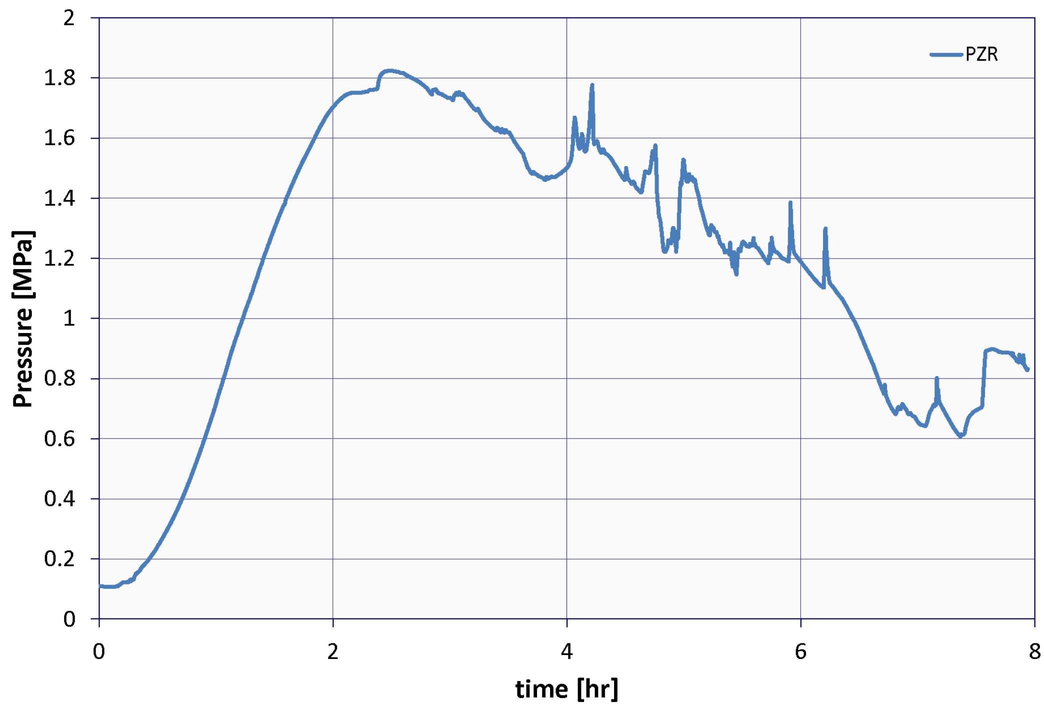

PORVs
Charging Pumps
Mass Flow Rate [kg/s]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24
time [hr]

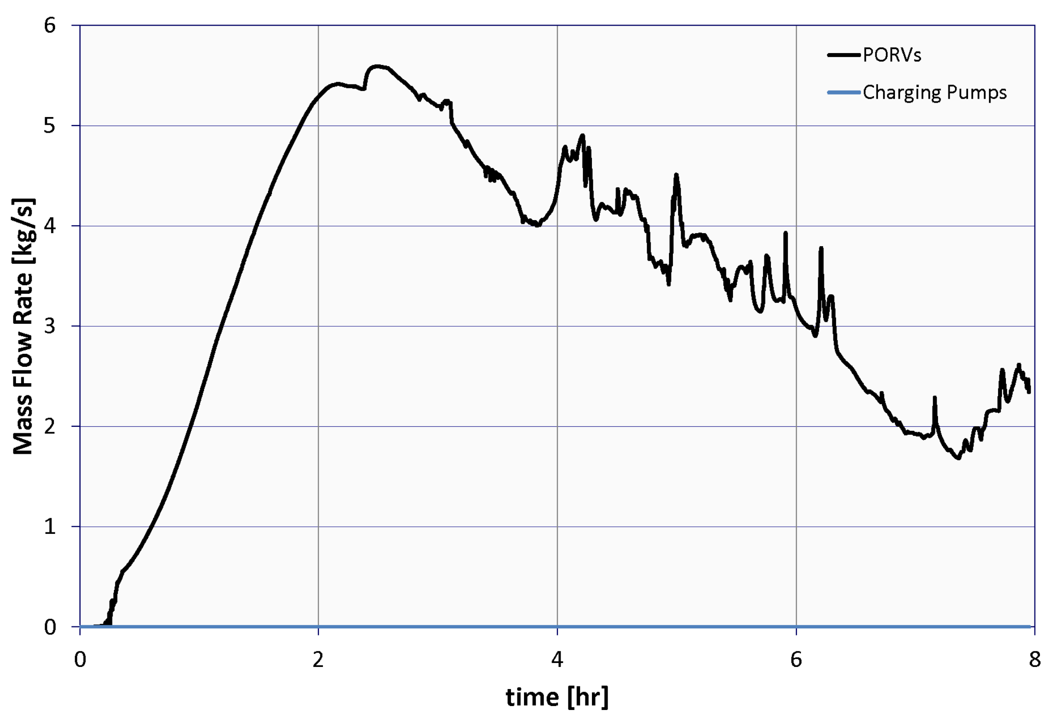

Water Level [m]
time [hr]
0
5
10
15
20
25
30
0
4
8
12
16
20
24
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

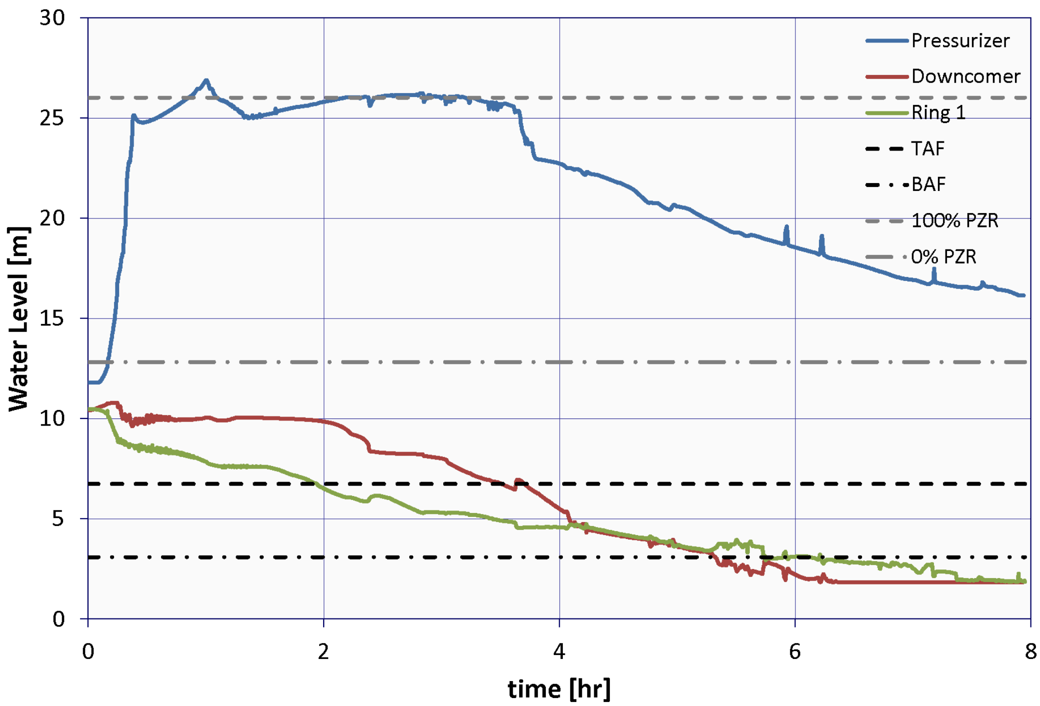
F.2.7 Case 7: 60 hr after Shutdown, No Recovery Actions





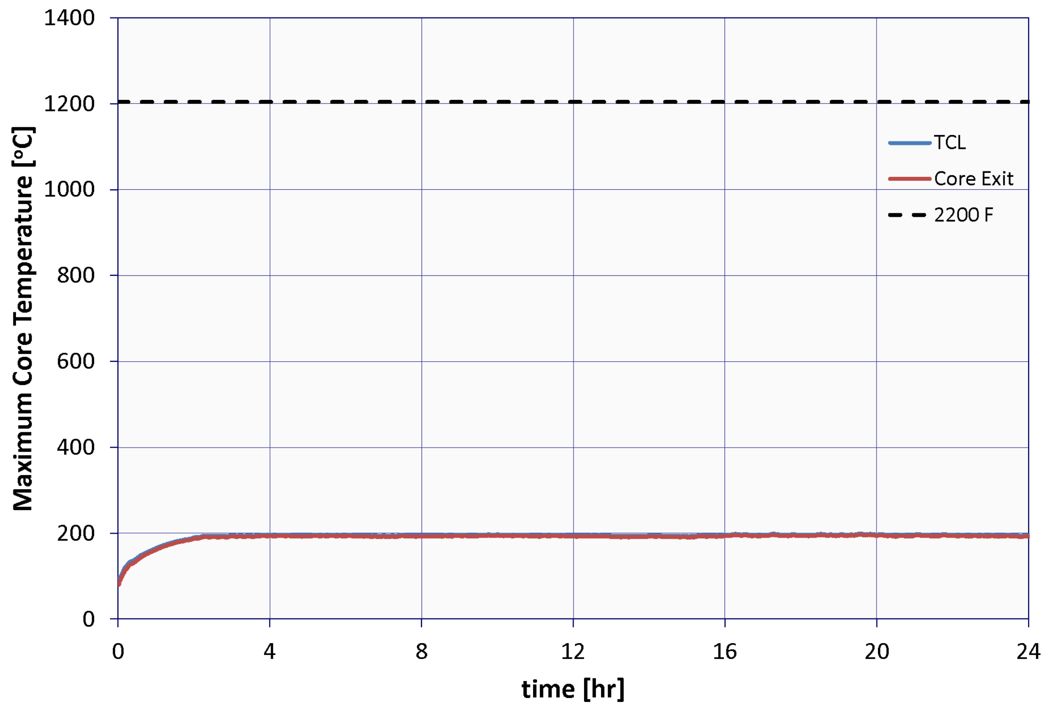

PZR
Pressure [MPa]
time [hr]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
2
4
6
8

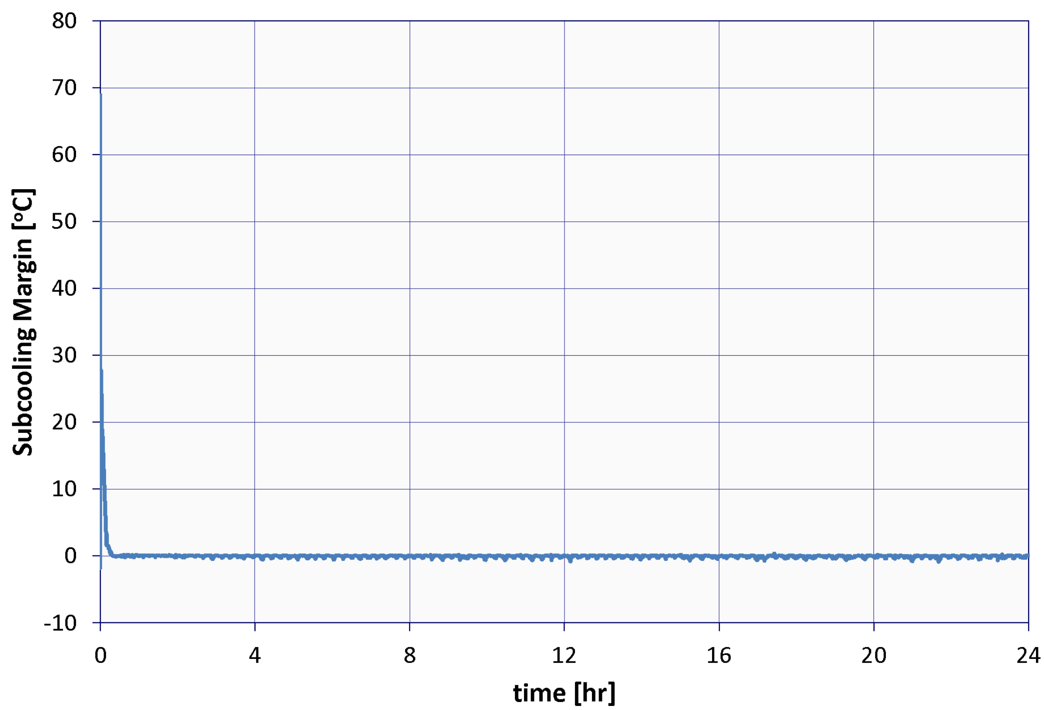

PORVs
Charging Pumps
Mass Flow Rate [kg/s]
time [hr]
0
1
2
3
4
5
6
0
2
4
6
8

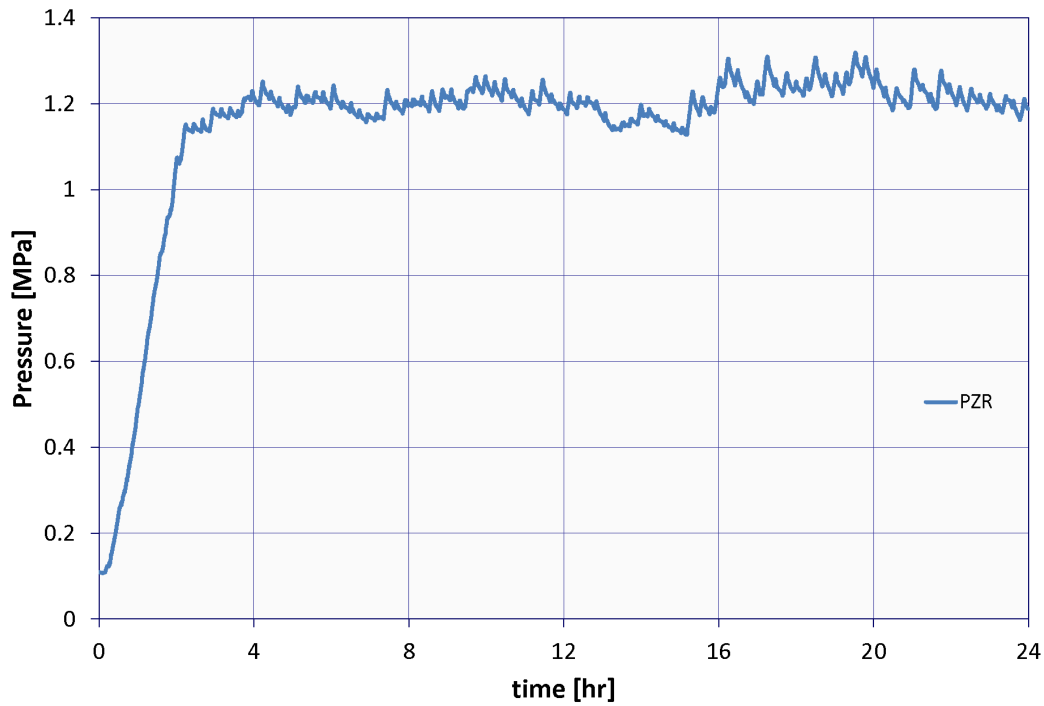


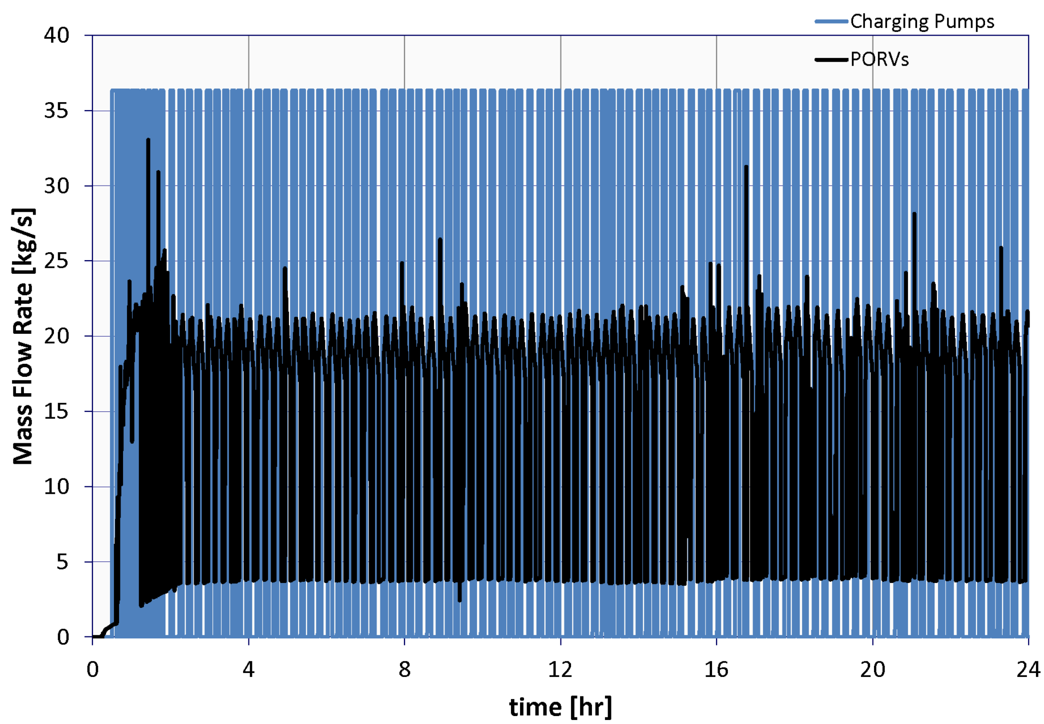
Water Level [m]
30
25
20
15
10
5
0
0
2
4
6
8
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

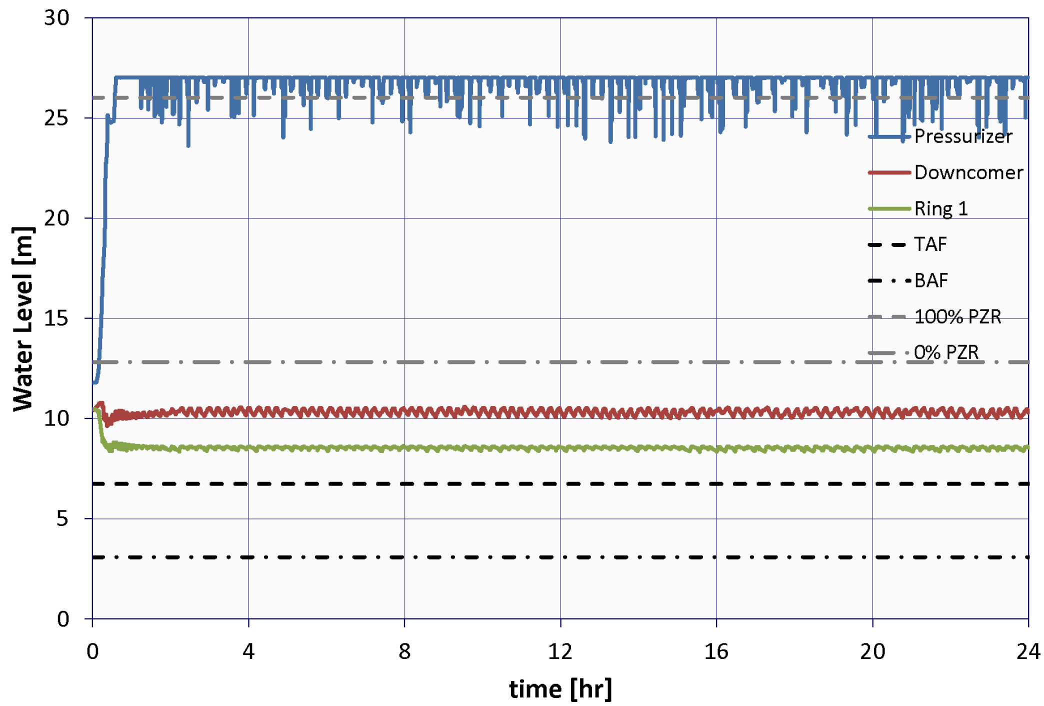
F.2.8 Case 8: 60 hr after Shutdown, Start CCP on Low RPV Level

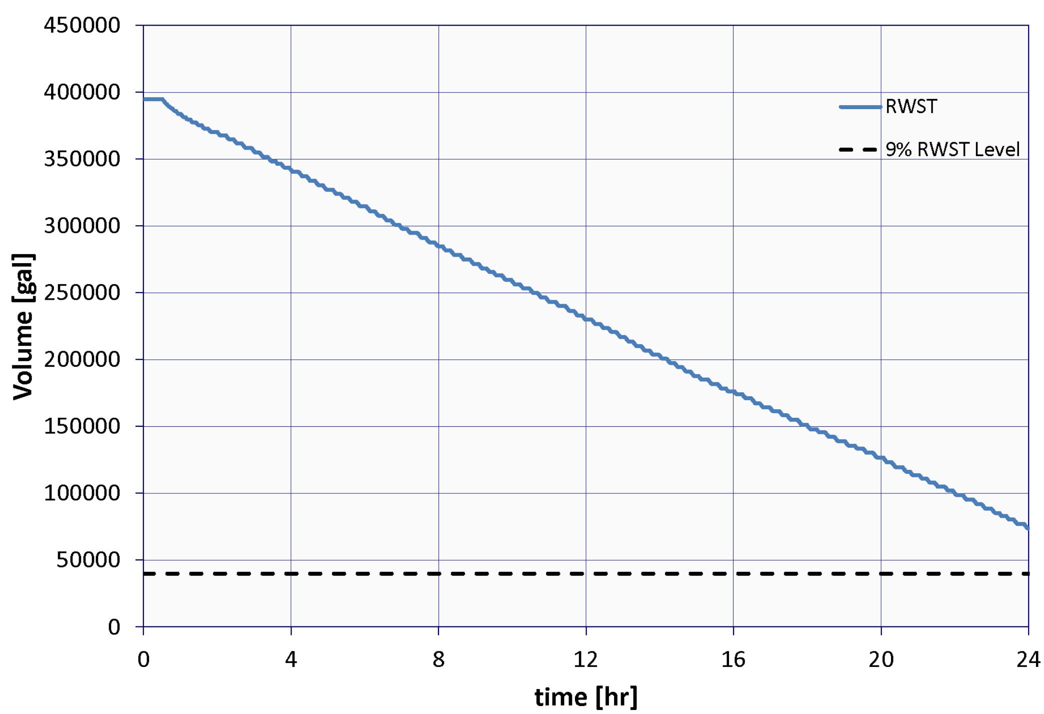




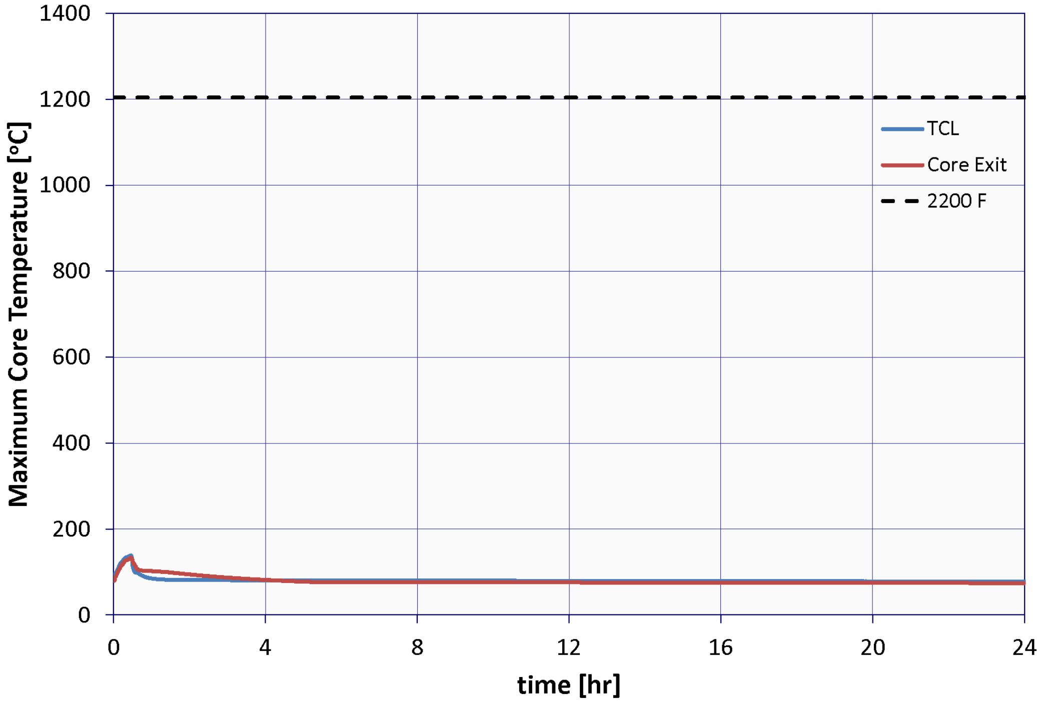

1.4
1.2
1
0.8
0.6
0.4
0.2
0
Pressure [MPa]
PZR
0
4
8
12
16
20
24
time [hr]

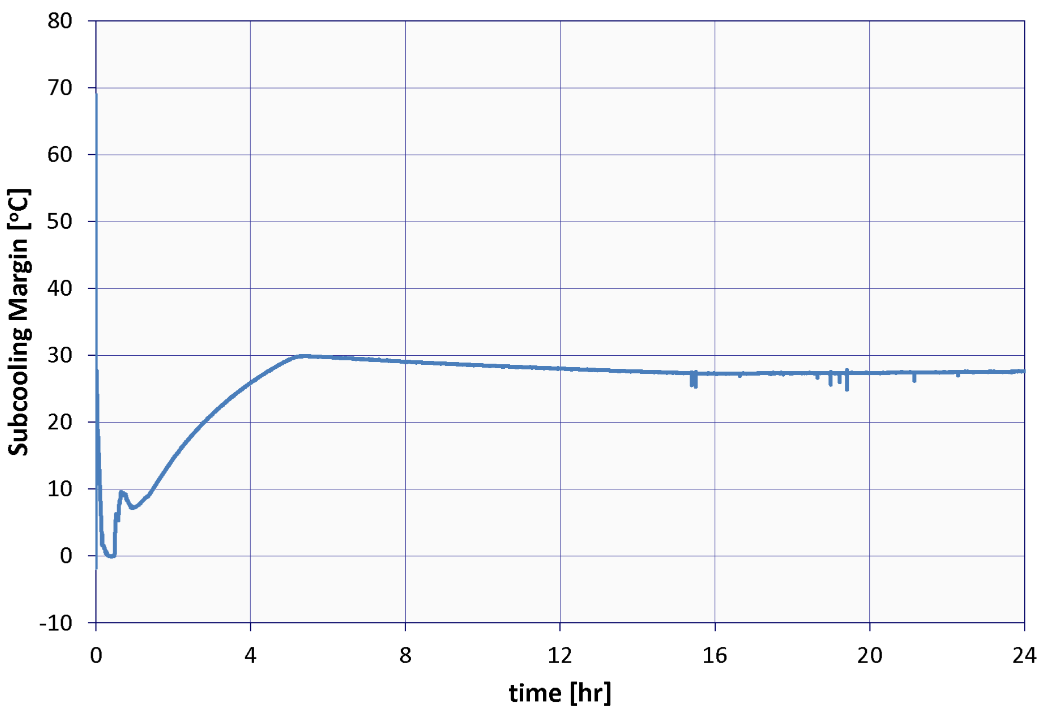

Charging Pumps
PORVs
40
35
30
25
20
15
10
5
0
Mass Flow Rate [kg/s]
0
4
8
12
16
20
24
time [hr]

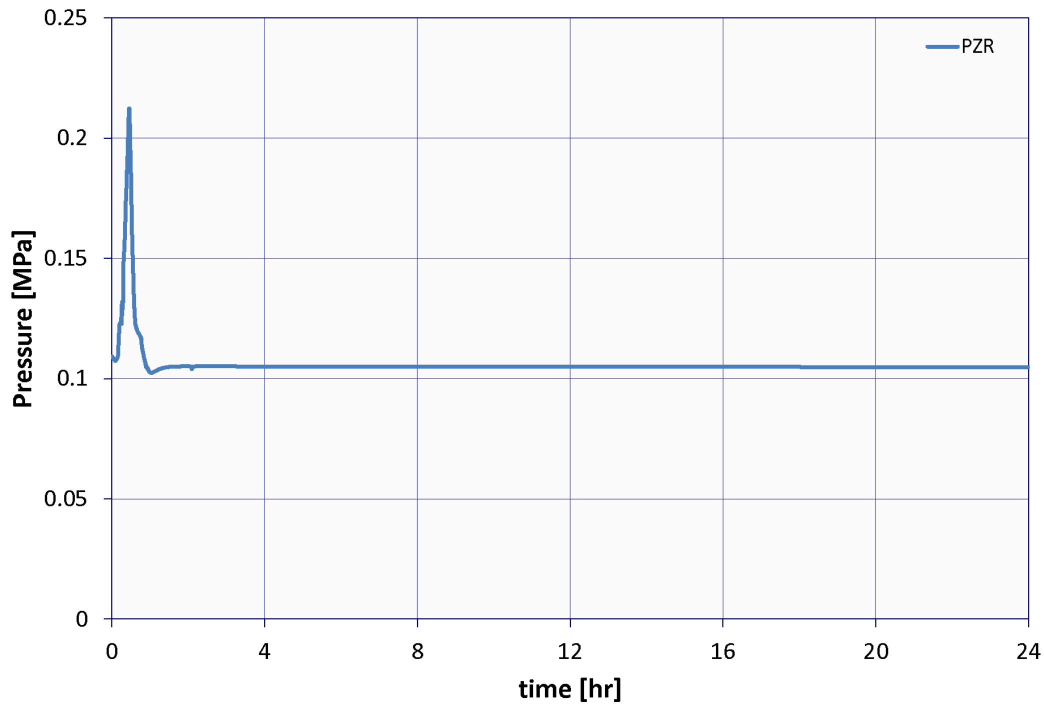

Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR

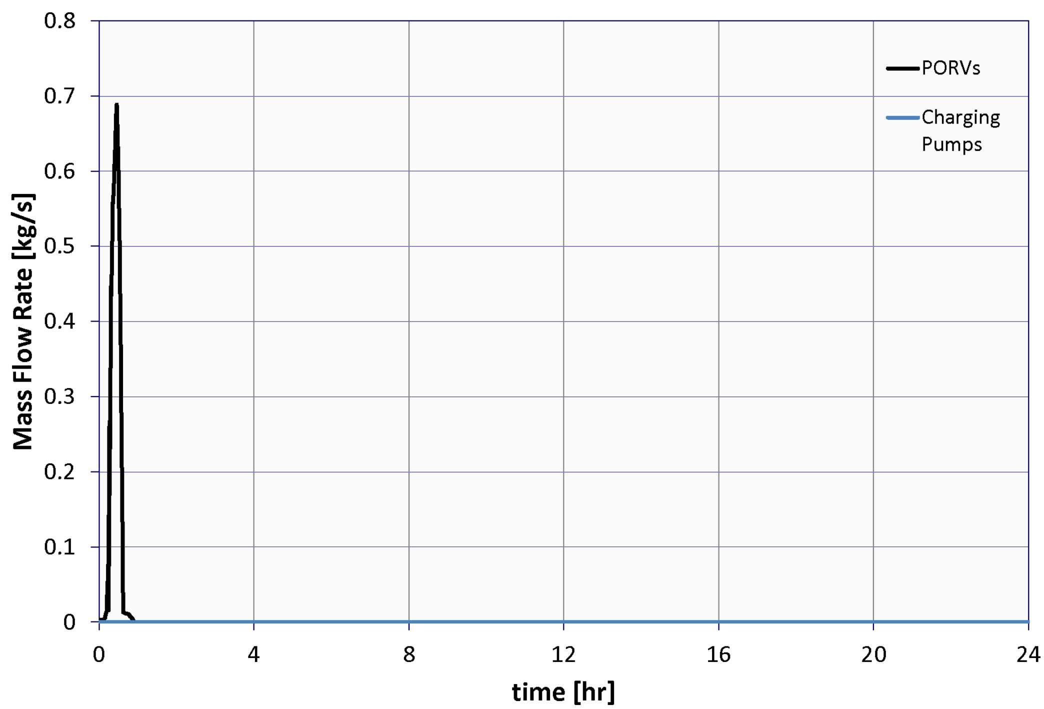

Volume [gal]
time [hr]
RWST
9% RWST Level

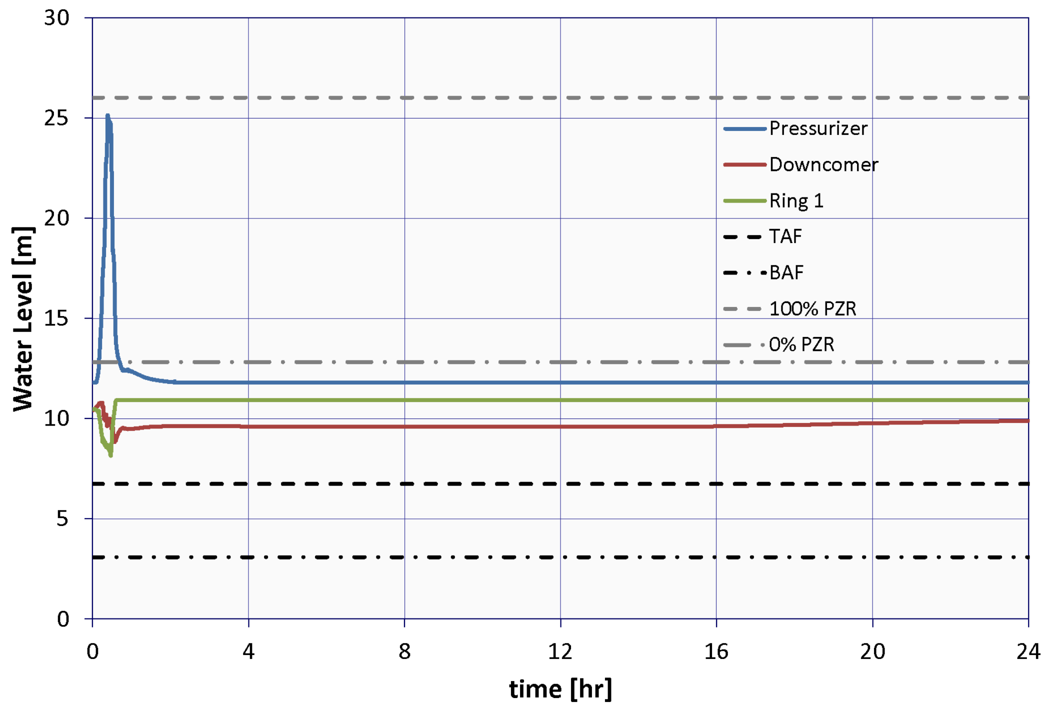
F.2.9 Case 9: 60 hr after Shutdown, Recover RHR at 27 Minutes






PZR
Pressure [MPa]
time [hr]
0.25
0.2
0.15
0.1
0.05
0
0
4
8
12
16
20
24


PORVs
Charging Pumps
Mass Flow Rate [kg/s]
time [hr]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
4
8
12
16
20
24



Water Level [m]
time [hr]
Pressurizer
Downcomer
Ring 1
TAF
BAF
100% PZR
0% PZR
0
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APPENDIX G

EVENT TREE MODELS FOR STUDIED INITIATORS

G.1 Byron SPAR Model Event Trees

This section provides the relevant event trees from the Byron (v8.27) Standardized Plant Analysis Risk model dated April 2014. These event trees show the sequences described in the main report.

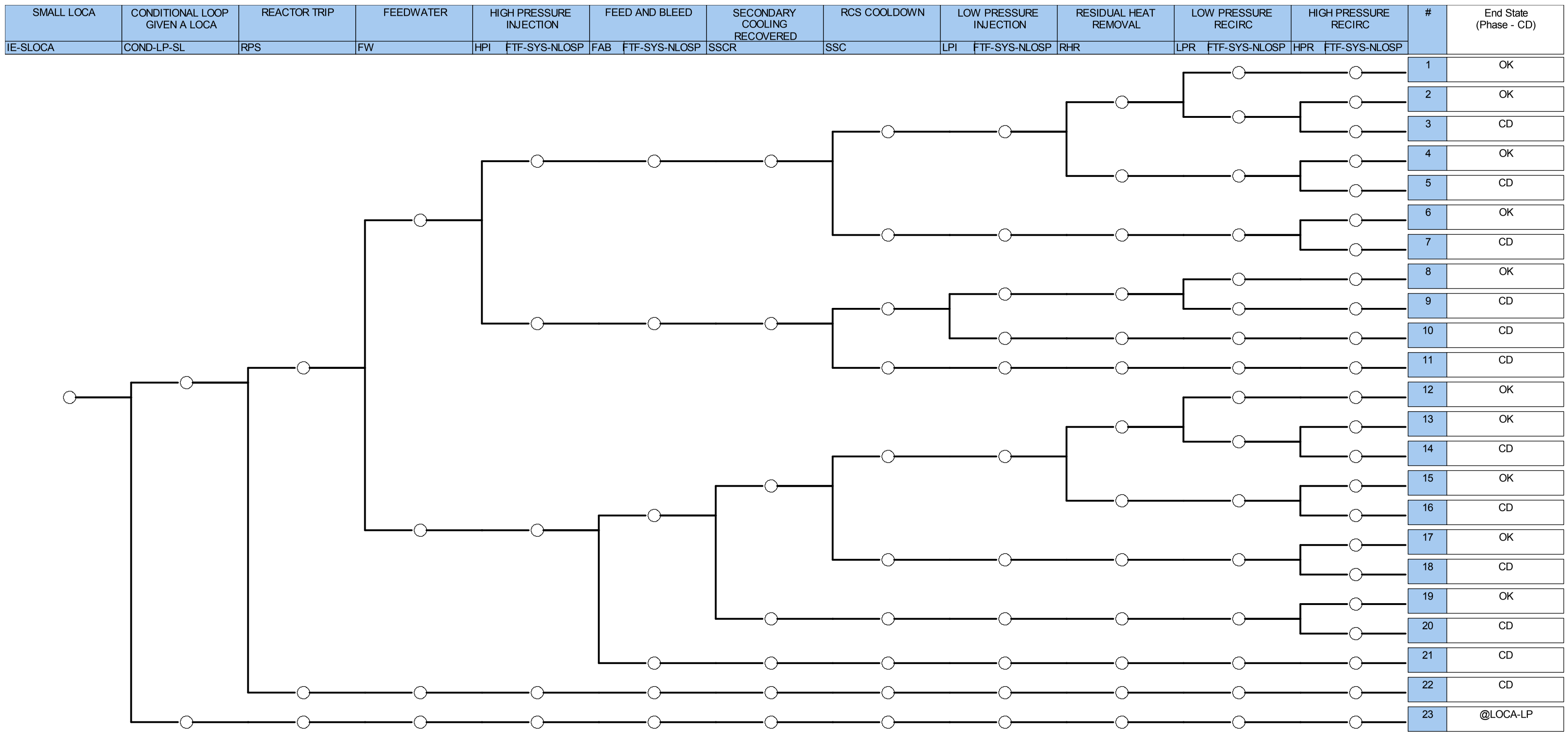

Figure G-1 Small-break loss-of-coolant accident (SLOCA) event tree

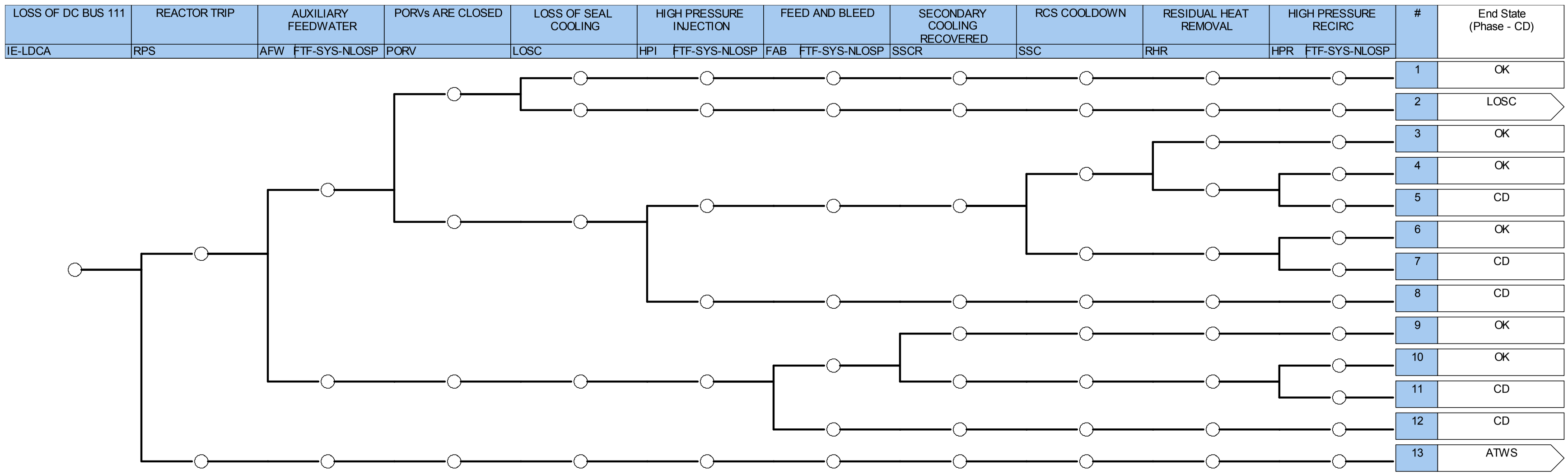

Figure G-2 Loss of 125V vital DC bus 111 event tree

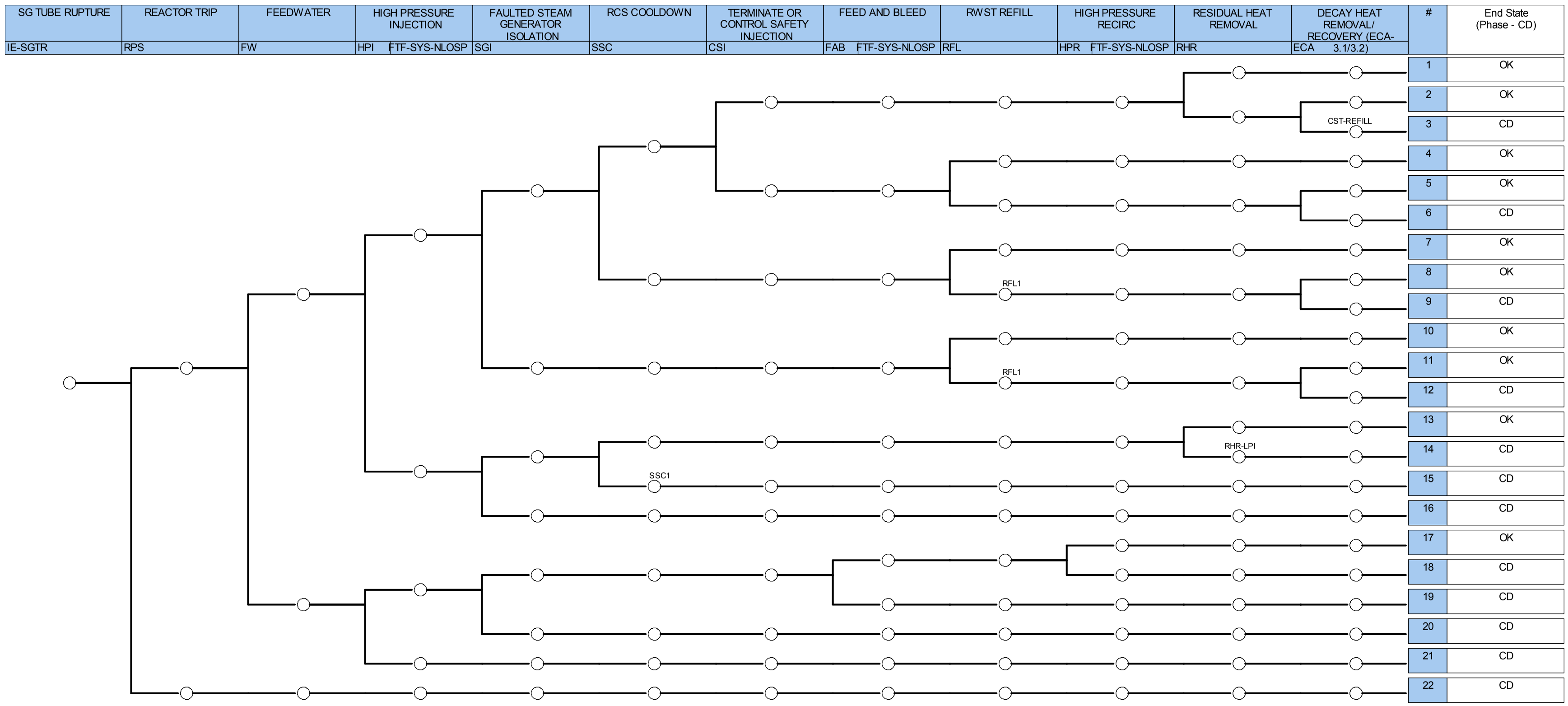

Figure G-3 Steam generator tube rupture (SGTR) event tree

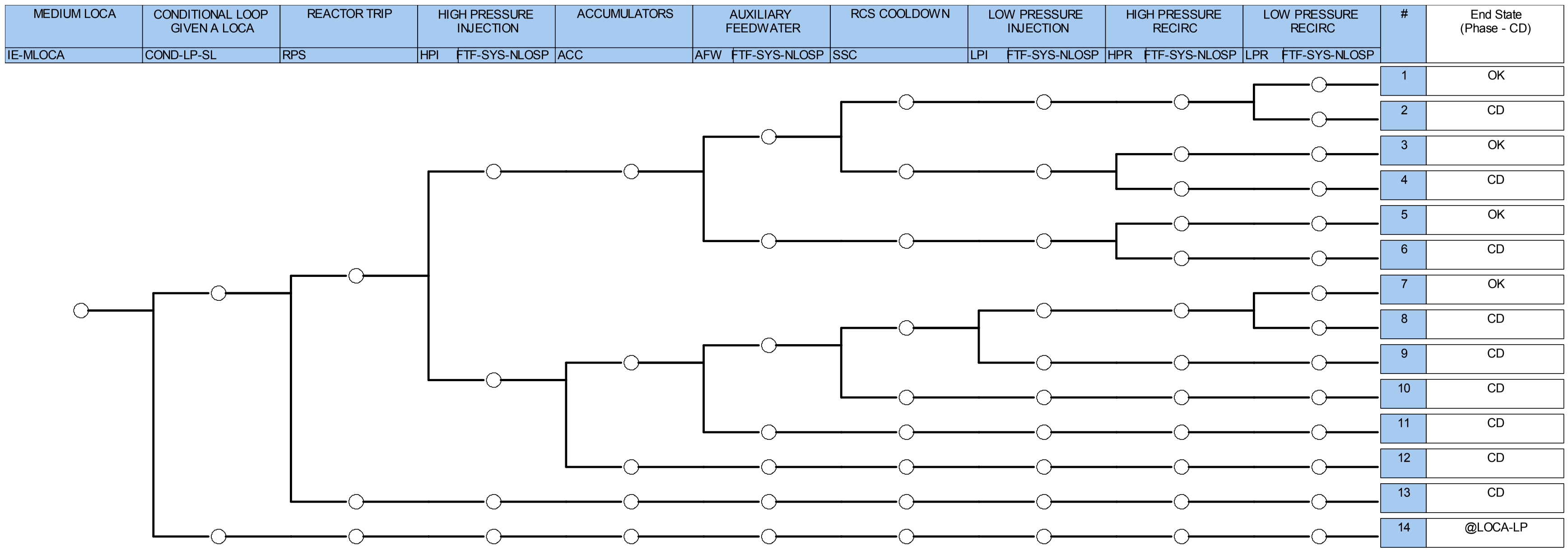

Figure G-4 Medium-break loss-of-coolant accident (MLOCA) event tree

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J. Corson, D. Helton, M. Tobin, A. Bone (US NRC HQ)
M. Khatib-Rahbar, A. Krall (Energy Research Inc.)
L. Kozak (US NRC Region 3)
R. Buell (Idaho National Laboratory)

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This report extends the work documented in NUREG 1953, "Confirmatory Thermal Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models–Surry and Peach Bottom" to the Byron Station, Unit 1. Its purpose is to produce an additional set of best estimate thermal hydraulic calculations that can be used to confirm or enhance specific success criteria (SC) found in the agency's probabilistic risk assessment (PRA) tools. Along with promoting realism in the standardized plant analysis risk (SPAR) models, these calculations are expected to be a useful reference to model end users for specific regulatory applications (e.g., the Significance Determination Process). The U.S. Nuclear Regulatory Commission selected Unit 1 of the Byron Station for this study because it is generally representative of a group of four loop Westinghouse plants with large, dry containment designs.

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