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Dominion®

March 29, 2016

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Serial No.	16-011B
NLOS/WDC	R0
Docket No.	50-423
License No.	NPF-49

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING LICENSE AMENDMENT REQUEST TO ADOPT DOMINION CORE DESIGN AND SAFETY ANALYSIS METHODS AND TO ADDRESS THE ISSUES IDENTIFIED IN WESTINGHOUSE DOCUMENTS NSAL-09-5, REV. 1, NSAL-15-1, AND 06-IC-03 (CAC NO. MF6251)

By letter dated May 8, 2015, Dominion Nuclear Connecticut, Inc. (DNC) submitted a license amendment request (LAR) for Millstone Power Station Unit 3 (MPS3). The proposed amendment would revise the Technical Specifications (TS) to enable use of the Dominion nuclear safety analysis and reload core design methods for MPS3 and address the issues identified in three Westinghouse communication documents. In a letter dated January 8, 2016, the Nuclear Regulatory Commission (NRC) transmitted a request for additional information (RAI) to DNC related to the LAR. The RAI contained 18 questions. In a letter dated January 28, 2016, DNC responded to RAI Questions RAI-1 through RAI-8, RAI-13, and RAI-18. In a letter dated February 25, 2016, DNC responded to RAI Questions RAI-9 through RAI-12 and RAI-14 through RAI-16. Attachment 1 provides the DNC response to the final RAI Question, RAI-17. As part of the response to RAI-17, an update to the RETRAN benchmarking information, which was originally provided as Attachment 5 in the May 8, 2015 LAR and updated and provided as Attachment 2 in the February 25, 2016 RAI response, is provided in Attachment 2.

If you have any questions regarding this submittal, please contact Wanda Craft at (804) 273-4687.

Sincerely,

Dan Stoddard

Daniel G. Stoddard
Senior Vice President – Nuclear Operations

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Daniel G. Stoddard, who is Senior Vice President – Nuclear Operations of Dominion Nuclear Connecticut, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 29th day of March, 2016.

My Commission Expires: 12/31/16.

CRAIG D SLY
Notary Public
Commonwealth of Virginia
Reg. # 7518653
My Commission Expires December 31, 2016

Notary Public

A001
NRR

Commitments made in this letter: None

Attachments:

1. Response to Request for Additional Information Regarding License Amendment Request to Adopt Dominion Core Design and Safety Analysis Methods and to Address the Issues Identified in Westinghouse Documents NSAL-09-5, Rev. 1, NSAL-15-1, and 06-IC-03 (CAC No. MF6251) – RAI Question RAI-17
2. RETRAN Benchmarking Information – Updated

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ATTACHMENT 1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING LICENSE AMENDMENT REQUEST TO ADOPT DOMINION CORE DESIGN AND SAFETY ANALYSIS METHODS AND TO ADDRESS THE ISSUES IDENTIFIED IN WESTINGHOUSE DOCUMENTS NSAL-09-5, REV. 1, NSAL-15-1, AND 06-IC-03 (CAC NO. MF6251)

RAI QUESTION RAI-17

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

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RAI – 17 (SRXB): Steam Generator Tube Rupture (SGTR) Analysis

MPS3 FSAR 15.6-3 discussed the SGTR analysis for two cases: (1) the SG overfill margin analysis that is used to validate the assumptions of no water leaked from the affected SG to atmosphere; and (2) the mass release analysis that is used as input to a computer code for calculating the dose releases. This analysis involved simulation of the mitigating strategies directing operators to identify and isolate the ruptured SG, cooldown the RCS to establish subcooling margin, depressurize to restore RCS inventory, and terminate safety injection to stop primary-to-secondary leakage.

Perform the RETRAN benchmarking analysis for the SGTR event for both SG overfill and mass releases cases. The information to be provided should show that RETRAN is capable of simulating the operator actions specified in FSAR and discussed above and the results of the SG overfill and mass releases analyses are compatible with to the AOR.

DNC Response

The additional benchmarking analysis has been performed for the SGTR event, for both SG overfill and mass release cases. The discussion of the event analysis, including inputs and assumptions and results, as compared with the FSAR analysis are included in Section 4.7 of the update to the RETRAN benchmarking information enclosed in Attachment 2. The update to Attachment 2 is provided with the changes noted by a change bar in the right hand margin of the affected pages.

In a March 24, 2016 clarification call, the NRC requested that DNC address the applicability of Limitations 16 and 38 in the safety evaluation report for EPRI Topical Report NP-7450(P), Revision 4, dated January 25, 2001. Limitation 16 identifies concerns associated with application of the algebraic slip option, which is not used in

the Dominion model and is not applicable for this analysis. Limitation 38 addresses potential two-phase conditions. The RCS flow remains single-phase and subcooled throughout the RCS for the entire SGTR benchmark event and, therefore, Limitation 38 is not applicable for this analysis.

ATTACHMENT 2

RETRAN BENCHMARKING INFORMATION - UPDATED

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

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1.0 Introduction and Summary

1.1 Introduction

Topical report VEP-FRD-41-P-A, "VEPCO Reactor System Transient Analyses Using the RETRAN Computer Code," (Reference 1) details the Dominion methodology for Nuclear Steam Supply System (NSSS) non-LOCA transient analyses. This methodology encompasses the non-LOCA licensing analyses required for the Condition I, II, III, and IV transients and accidents addressed in the Final Safety Analysis Report (FSAR). The VEP-FRD-41-P-A methods are also used in support of reload core analysis. In addition, this capability is used to perform best-estimate analyses for plant operational support applications. The material herein supports the applicability assessment of the VEP-FRD-41-P-A methods to Millstone Power Station Unit 3 (MPS3) for the stated applications.

1.2 Summary

This attachment provides a description of the RETRAN base model for MPS3 and results of benchmarking analyses using this model. The MPS3 model was developed in accordance with the methods in VEP-FRD-41-P-A, with certain noding changes noted below. This assessment confirms the conclusion that the Dominion RETRAN methods, as documented in topical report VEP-FRD-41-P-A, are applicable to MPS3 and can be applied to MPS3 licensing analysis for reload core design and safety analysis. Dominion analyses of MPS3 will employ the modeling in VEP-FRD-41-P-A, as augmented with the noding changes listed below. Thus, VEP-FRD-41-P-A, as augmented, is the Dominion methodology for analyses of non-LOCA NSSS transients for MPS3.

The MPS3 RETRAN base model contains the following alterations in noding with respect to the modeling that is documented in VEP-FRD-41-P-A.

a) The MPS3 model explicitly models the safety injection (SI) accumulators.
b) The MPS3 model has separate volumes for the steam generator inlet and outlet plenums.
c) The MPS3 model includes cooling paths between downcomer and upper head.

2.0 MPS3 RETRAN Model

The MPS3 RETRAN-3D Base Model and associated model overlays are developed using Dominion analysis methods described in the Dominion RETRAN topical report (Reference 1). The Dominion analysis methods are applied consistent with the conditions and limitations described in the Dominion topical report and in the applicable NRC Safety Evaluation Reports (SERs).

The MPS3 Base Model noding diagram for a representative loop is shown on Figure 2-1. Volume numbers are circled, junctions are represented by arrows, and the heat conductors are shaded. This model simulates all four reactor coolant system (RCS) loops and has a single-node steam generator (SG) secondary side, consistent with Dominion methodology. The SG primary nodalization includes 10 steam generator tube volumes and conductors. There is a multi-node SG secondary overlay that can be added to the Base Model for sensitivity studies although none of the analysis results presented herein utilize this overlay.

In addition to the base MPS3 model, an overlay deck is used to create a split reactor vessel model to use when analyzing Main Steam Line Break (MSLB) events, consistent with Dominion methodology. This overlay adds volumes to create a second, parallel flow path through the active core from the lower plenum to the upper plenum such that RCS loop temperature asymmetries can be represented. This noding is consistent with the method described in VEP-FRD-41-P-A. A noding diagram of the split reactor vessel is shown on Figure 2-2.

The base MPS3 model noding is virtually identical to the Surry (SPS) and North Anna (NAPS) models with the exception of some minor noding differences listed as follows.

a) The MPS3 model explicitly models the SI accumulators.
b) The MPS3 model has separate volumes for the SG inlet and outlet plenums.
c) The MPS3 model includes cooling paths between downcomer and upper head.

The SI accumulators are part of the MPS3 model because injection from the accumulators occurs in the current FSAR analysis for MSLB. The use of separate volumes for the inlet and outlet should have little effect on transient response since the fluid temperature in these volumes is generally the same as the connecting RCS piping. The cooling paths are included to appropriately model upper head T-cold conditions.

The Dominion models, including the MPS3 model, have some differences compared to the vendor RETRAN model that was used to perform the current FSAR analyses. Table 2-1 and the subsequent text discussion provide an overview of these differences. Additional details

concerning differences between the Dominion MPS3 and FSAR RETRAN models are discussed in the benchmarking analyses in Section 4.

A description of the Dominion RETRAN methodology is provided in Reference 1, where specific model details are discussed in Sections 4 and 5 of that reference.

Table 2-1 RETRAN Model Comparison of Key Characteristics

Parameter	**Dominion**	**FSAR**
Code Version:	RETRAN-3D in "02 mode"	RETRAN-02
Noding:		
Reactor Vessel	Single flow path (special split core overlay for MSLB only)	Multiple parallel flow paths
Steam Generator	Single node secondary. Five axial levels (10 nodes) for SG tubes primary side. Local Conditions Heat Transfer model available for loss of heat sink events.	Multi-node secondary.
Reactivity Model		
Doppler Feedback	Doppler temperature coefficient that is a function of T_{FUEL}.	Doppler-only power coefficient and a Doppler temperature coefficient effect driven by moderator temperature.
Moderator Feedback	Moderator temperature coefficient	Moderator density coefficient
Decay Heat	ANS 1979 Standard U-235 with 1500 day burn. Q = 190 MeV/fission. 1.0 Decay Heat Multiplier Bounds additional 2σ uncertainty	ANS 1979 Standard Bounds additional 2σ uncertainty

Figure 2-1 MPS3 Base Model Nodalization Diagram

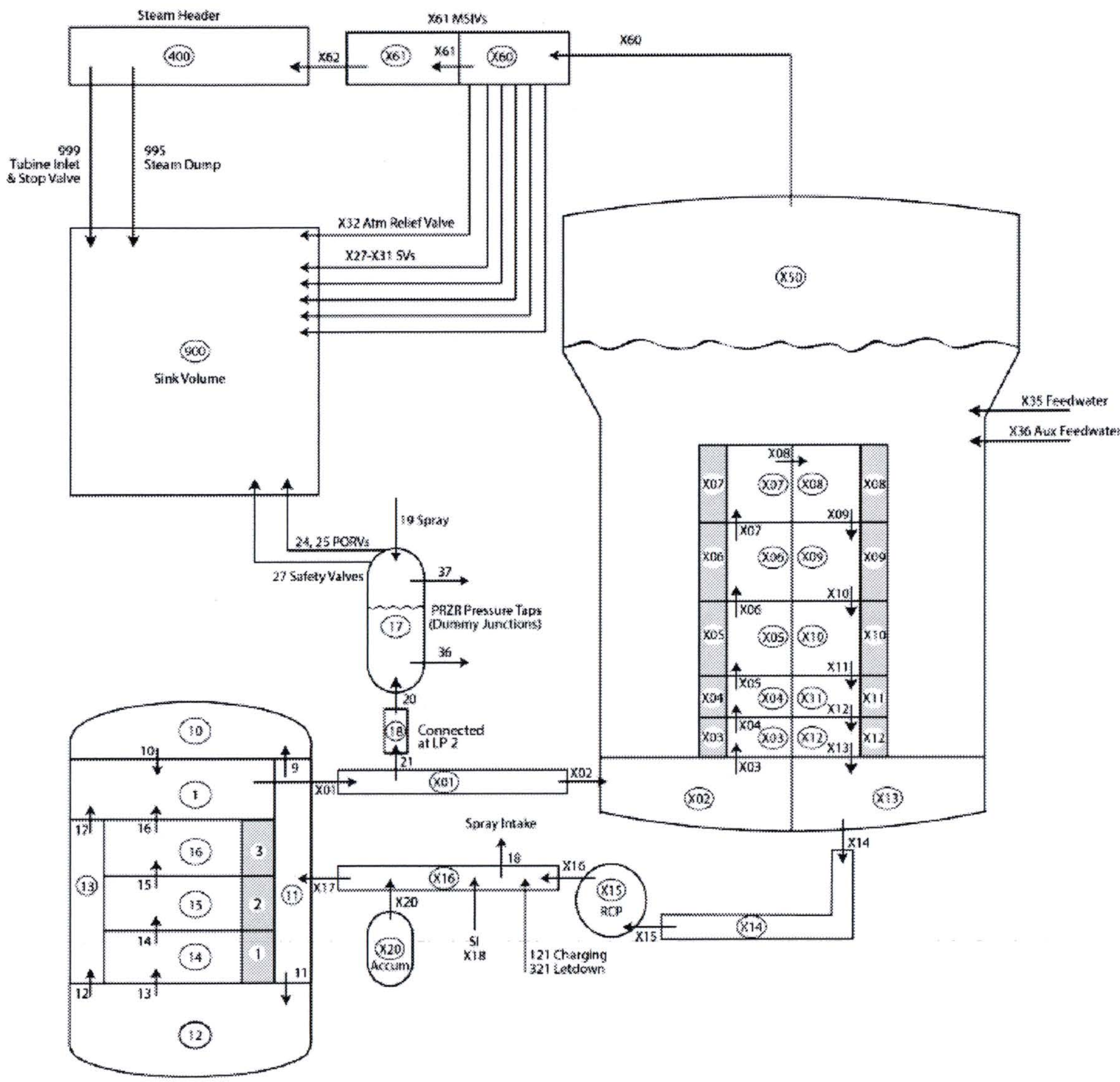
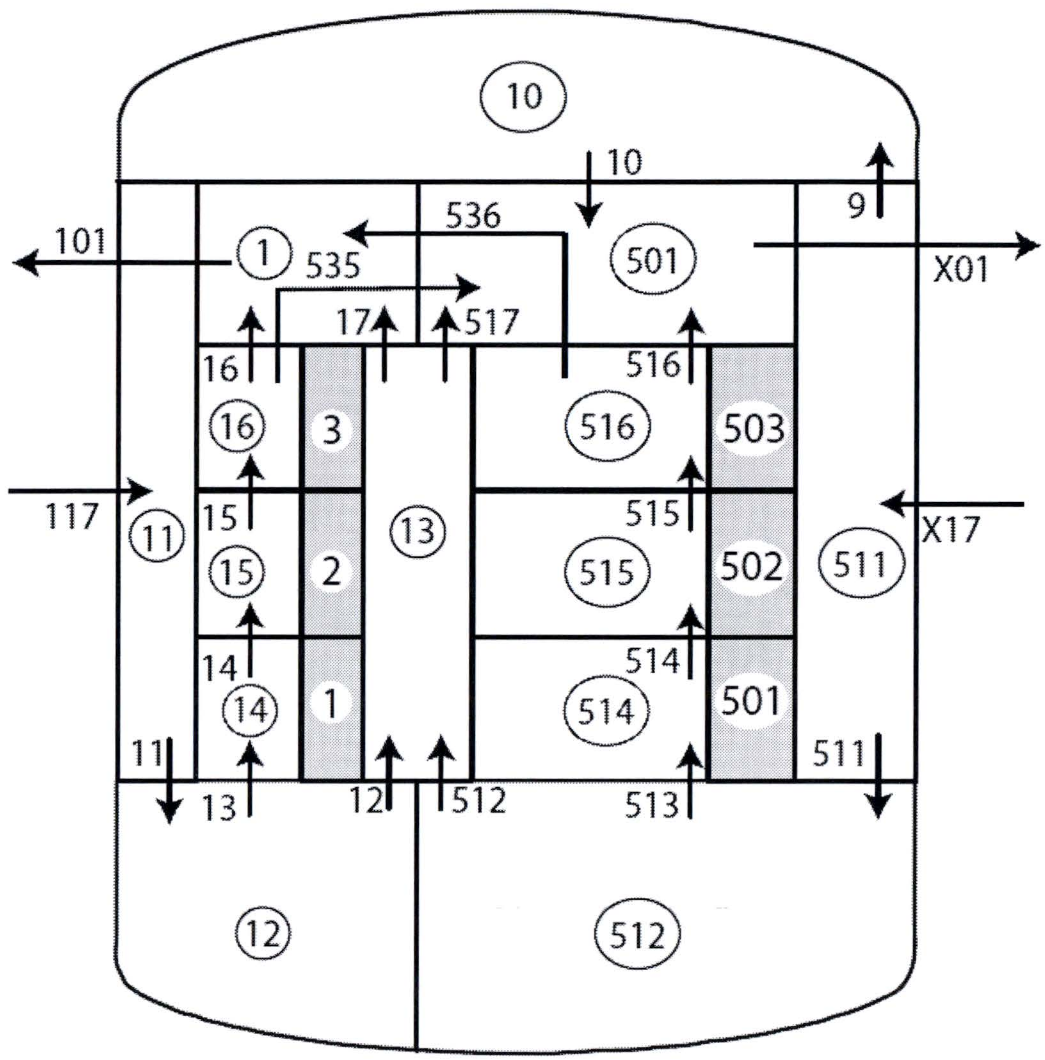


Figure 2-2 MPS3 Split Vessel Nodalization



3.0 Method of Analysis

Validation of the Dominion MPS3 RETRAN method involves comparison of RETRAN analyses to the MPS3 FSAR analysis of record (AOR) for select events. The Dominion analyses presented herein are not replacements for the existing AORs. These events represent a broad variation in behavior (e.g. RCS heatup, RCS cooldown/depressurization, reactivity excursion, loss of heat sink, etc.), and demonstrate the ability to appropriately model key phenomena for a range of transient responses. The transients selected for comparison with their corresponding MPS3 FSAR section are provided in Table 3-1. For each transient, an analysis is performed using the Dominion MPS3 RETRAN model and compared with the current FSAR analysis. Initial conditions and inputs are established for each benchmark to provide an adequate comparison of specific transient behavior.

Table 3-1 Transients Analyzed for FSAR Comparison

Transient	MPS3 FSAR Section
Main Steam Line Break	15.1.5
Loss of Load/Turbine Trip	15.2.3
Loss of Normal Feedwater	15.2.7
Locked Rotor	15.3.3
Control Rod Withdrawal at Power	15.4.2
Main Feedwater Line Break	15.2.8

4.0 Benchmarking Analysis Results

A summary for each transient comparison is presented in the following sections. Included in each section is an input summary identifying key inputs and assumptions along with differences from FSAR assumptions. A comparison of the results for key parameters is provided with an explanation of key differences between the Dominion and FSAR cases.

4.1 Loss of Load/Turbine Trip

The Loss of Load/Turbine Trip (LOL) event is defined as a complete loss-of-steam load and turbine trip from full power without a direct reactor trip, resulting in a primary fluid temperature rise and a corresponding pressure increase in the primary system. This transient results in degraded steam generator heat transfer, reactor coolant heatup and pressure increase following a manual turbine trip.

The LOL transient scenario presented here was developed to analyze primary RCS overpressurization. It is initiated by decreasing both the steam flow and feedwater flow to zero immediately after a manual turbine trip. The input summary is provided in Table 4.1-1.

Table 4.1-1 LOL Input Summary

Parameter	Value	Notes
Initial Conditions		
Core Power (MW)	3723	Includes 2% uncertainty
RCS Flow (gpm)	363,200	Thermal Design
Vessel T_{AVG} (F)	576.5	Low Tavg plus uncertainty
Pressurizer Pressure (psia)	2200	Includes -50 psia uncertainty
Pressurizer Level (%)	52.5	Low Tavg Target plus uncertainty
SG Level (%)	50.0	Nominal
SG tube plugging (%)	10	Maximum
Pump Power (MW/Pump)	5.0	Maximum
Assumptions/Configuration		
Reactor trip	-	only Hi Pzr Pressure is active
Automatic rod control	-	Not credited
Pressurizer sprays, PORVs	-	Not credited
Main steam dumps, SG PORV	-	Not credited
AFW flow	-	Not credited
Reactivity Parameters		
Doppler Reactivity Feedback	Least Negative	
Moderator Feedback	Most Positive	

Results - LOL

Pressure in the RCS increases during a LOL due to degraded heat transfer in the steam generator and is alleviated only when the pressurizer safety valves (PSV) open as well as the main steam safety valves (MSSV). The pressurizer pressure response is shown on Figure 4.1-1, RCP outlet pressure in Figure 4.1-2, and the peak RCS pressure values are listed in Table 4.1-2. The Dominion case predicts a pressurizer pressure and RCP outlet pressure response that agrees very well with the FSAR results past the point of peak RCS pressure.

Following the initial decrease in primary system pressure, the FSAR pressure levels out where the Dominion case results continue to decrease. The difference is due to differing secondary safety valve modeling in the vendor model, specifically in that the Dominion model includes the modeling of blowdown in the main steam safety valves and the vendor model does not. Hence, more energy is removed through the secondary system in the Dominion case once the main steam safety valves actuate than is removed from the secondary system in the vendor model.

Figure 4.1-3 shows the power response is nearly identical both before and after the reactor trip on high pressurizer pressure and control rod insertion. The Dominion case trips slightly earlier than the FSAR data because of the higher RCS pressurization rate.

The Dominion model vessel inlet temperature, Figure 4.1-4, and coolant average temperature, Figure 4.1-5, agrees in trend and rate of increase although the response lags the FSAR response before the inlet temperature peaks at a slightly lower value. This indicates that the FSAR steam generator heat transfer degrades sooner than what is predicted by Dominion model and is attributed to the difference expected between the use of a multi-node steam generator (MNSG) in the FSAR model and the single-node steam generator (SNSG) model employed in the Dominion model. Overall, both the Dominion model and FSAR models exhibit similar trends in the temperature responses and the differences have no effect on peak RCS pressure.

Table 4.1-2 LOL RCS Overpressure Results

Parameter	Dominion	FSAR
Sequence of Events:		
High Pressurizer Pressure Setpoint Reached (sec)	5.6	6.2
Peak RCS Pressure (sec)	9.2	9.9
Peak RCS Pressure (psia)	2705	2725

Figure 4.1-1 LOL - Pressurizer Pressure

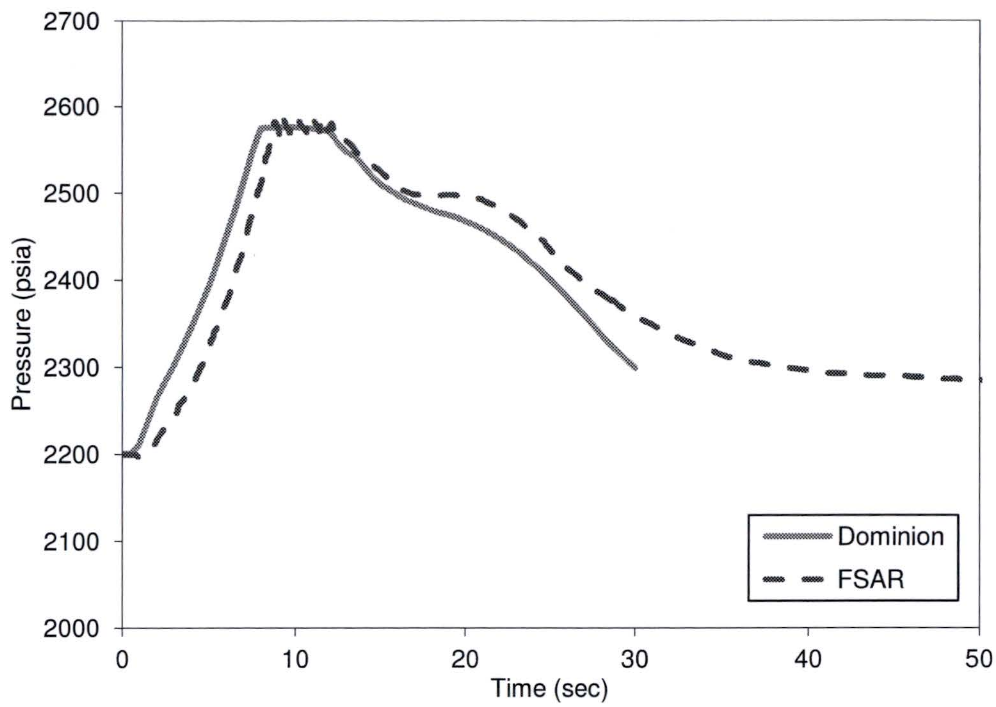


Figure 4.1-2 LOL – RCP Outlet Pressure

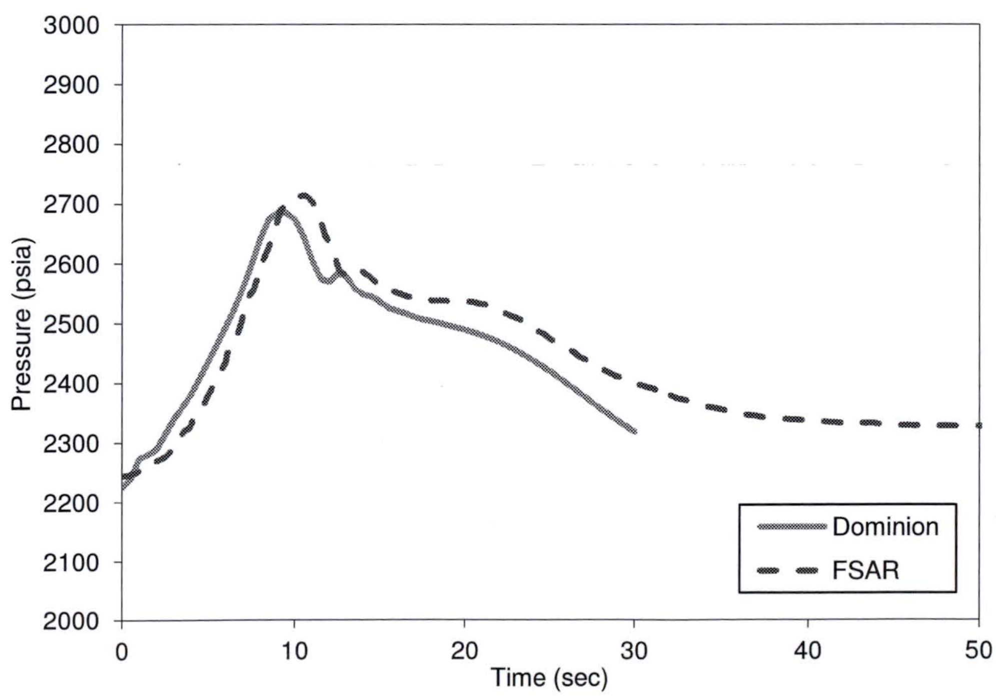


Figure 4.1-3 LOL – Nuclear Power

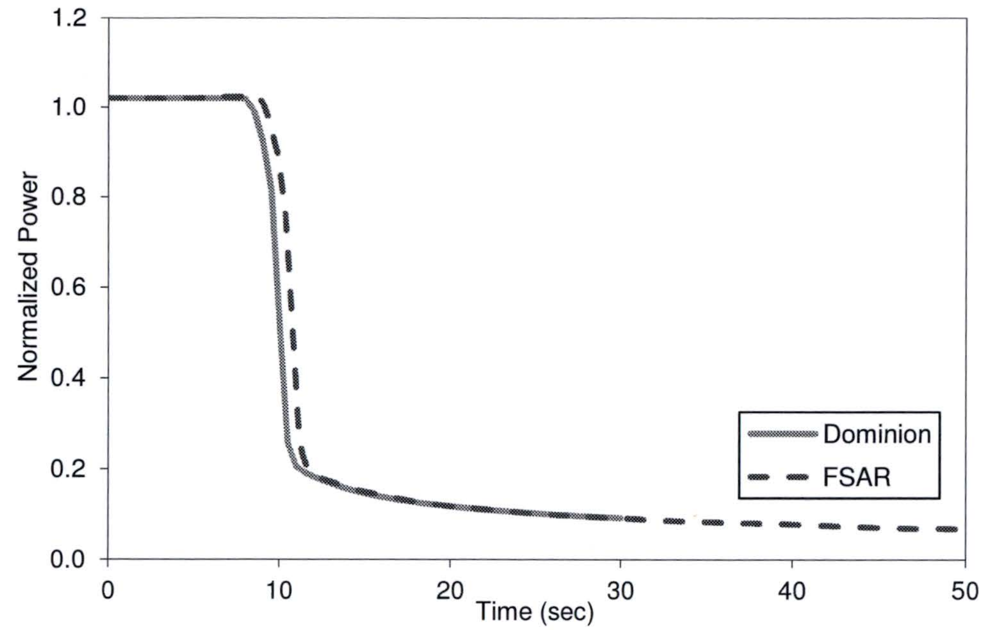


Figure 4.1-4 LOL– Vessel Inlet Temperature

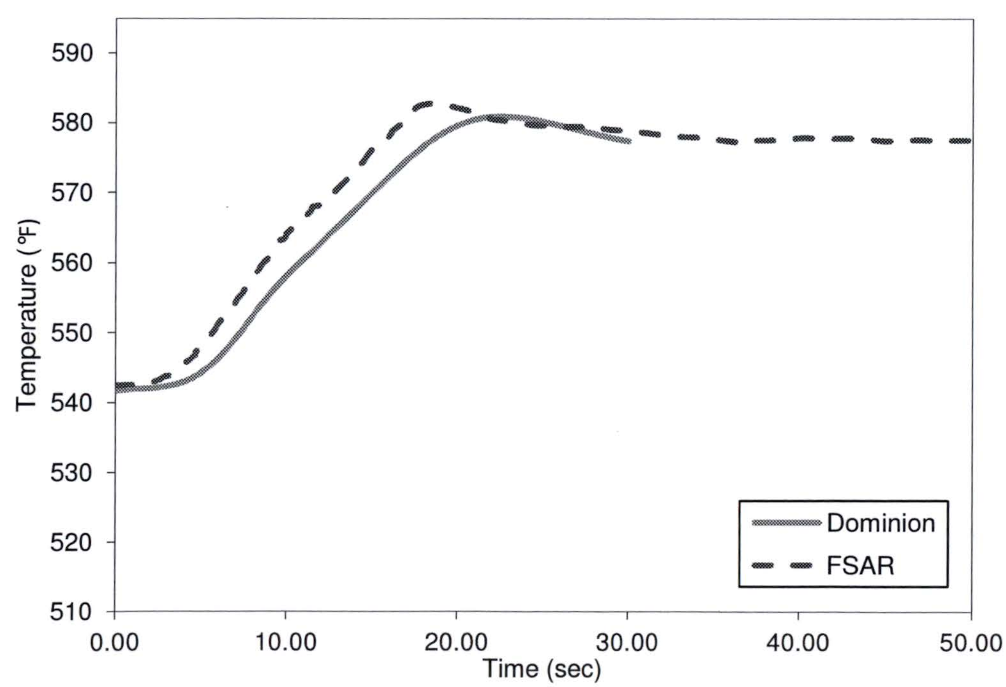
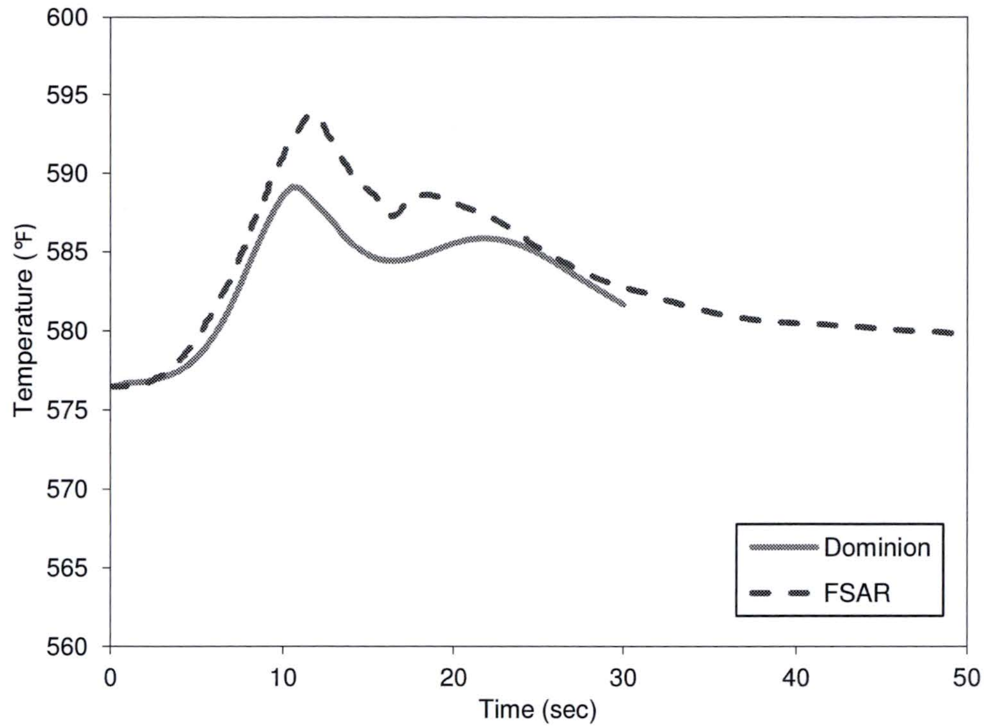


Figure 4.1-5 LOL – Vessel Average Temperature



Summary - LOL

The Dominion MPS3 analysis provides results that are similar to the FSAR analysis for the LOL event. The RCS peak pressures are essentially the same although the pressure diverge somewhat later in the event after pressure relief begins due to differences in MSSV modeling. There are small differences in the RCS temperature response due to differences in the SG models, however, this has no effect on the RCS peak pressure. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR.

4.2 Locked Rotor

The Locked Rotor / Shaft Break (LR) event is defined as an instantaneous seizure of a Reactor Coolant Pump (RCP) rotor, rapidly reducing flow in the affected reactor coolant loop leading to a reactor trip on a low-flow signal from the Reactor Protection System. The event creates a rapid expansion of the reactor coolant and reduced heat transfer in the steam generators, causing an insurge to the pressurizer and pressure increase throughout the reactor coolant system (RCS).

The LR transient scenario presented here was developed to analyze primary RCS overpressurization. It is initiated by setting one RCP speed to zero as the system is operating at full power. The reactor coolant low loop flow reactor trip is credited, with a setpoint of 85% of the initial flow. The input summary is provided in Table 4.2-1. Most of the input parameters are the same as those used in the FSAR Chapter 15 analyses.

Table 4.2-1 LR Input Summary

Parameter	Value	Notes
Initial Conditions		
Core Power (MW)	3723	Includes 2% uncertainty
RCS Flow (gpm)	363,200	Thermal Design Flow
Vessel T_{AVG} (F)	594.5	Nominal + 5°F
Pressurizer Pressure (psia)	2300	Includes +50 psia uncertainty
Pressurizer Level (%)	64	Nominal
SG Level (%)	50	Nominal
Assumptions/Configuration		
Reactor trip	-	Only Low RCS Loop Flow is credited
Automatic rod control	-	Not credited
Pressurizer sprays, PORVs	-	Not credited
Main steam dumps, SG PORV	-	Not credited
AFW flow	-	Not credited
SG tube plugging (%)	10[1]	Max value
Reactivity Parameters		
Doppler Reactivity Feedback	Most Negative	Dominion model adjusted to use FSAR Doppler Power Coeffcient
Moderator Feedback	Most Positive	

[1] Original benchmark case inadvertently assumed 0% SG tube plugging

Results – LR RCS Overpressure Case

Pressure in the RCS increases during a LR event due to degraded heat transfer in the steam generator and is alleviated only when the pressurizer safety valves (PSV) open. The magnitude of the Dominion model pressure response both in the reactor vessel lower plenum, Figure 4.2-1, and at the RCP exit, Figure 4.2-2, is greater than the FSAR model response, while following the same trends as the FSAR data. At the limiting point in the

transient response, the Dominion model conservatively predicts a pressure approximately 63 psi greater than the FSAR model in the reactor vessel lower plenum. The difference between the Dominion model and FSAR model's peak responses is the same at the RCP exit as in the lower plenum.

The Dominion faulted loop flow response (Figure 4.2-3) and unfaulted loop flow response (Figure 4.2-4) are in good agreement with the FSAR model response up to or just beyond the point of rod insertion . Following reactor trip there is some divergence in the unfaulted loop flow trends, which are consistent with the core heat flux predictions and assumed minor differences in the loop friction losses between the Dominion and FSAR models. With respect to the faulted loop flow response, the maximum reverse flow seen in the FSAR model is slightly greater than seen in the Dominion model, which is also attributed to small differences in the loop friction losses between the Dominion and FSAR models.

For the total core inlet flow response (Figure 4.2-5), the Dominion model predicts a lower flow than the FSAR model for approximately the first 4 seconds of the transient. After 4 seconds the FSAR and Dominion model core flow responses cross and the Dominion model predicts a slightly higher core flow rate. The limiting point in the transient occurs prior to 4 seconds such that RETRAN-3D produces a more limiting response than the FSAR model for the Locked Rotor/Shaft Break event.

The nuclear power response, Figure 4.2-6, predicted by the Dominion model agrees well with the FSAR data, with the Dominion model response slightly over predicting power during rod insertion following the reactor trip on low RCS flow. Similarly, the Dominion model core heat flux response, Figure 4.2-7, also slightly over predicts the FSAR model's response in the same time frame during control rod insertion. Additionally, the Dominion model heat flux response shows a slightly larger decrease at the initiation of the event over the decrease seen in the FSAR data. Both the initial under prediction of the heat flux response, followed by an over prediction during the rod insertion is indicative of the fuel rod heat transfer being modeled differently in the FSAR methods than in the Dominion model. However, the over prediction of both nuclear power and heat flux will lead to conservative results at the limiting point in the transient for both RCS overpressurization and DNB during rod insertion. Overall the nuclear power and heat flux predictions are very similar.

A summary of the LR transient analysis comparison is provided in Table 4.2-2.

Table 4.2-2 LR RCS Overpressure Results

Parameter	Dominion	FSAR
Sequence of Events:		
Low RCS Flow Setpoint Reached (sec)	0.1	0.1
Rods Begin to Drop (sec)	1.1	1.1
Peak RCS Pressure (sec)	3.8	4.1
Peak RCS Pressure (psia)	2680	2617

Summary - LR RCS Overpressure Case

The Dominion Millstone analysis provides responses that are similar to the FSAR analysis for the LR event, with the Dominion model predicting higher peak RCS pressures. Differences are attributed to loop friction losses and fuel rod modeling differences. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR.

Figure 4.2-1 LR – Reactor Vessel Lower Plenum Pressure

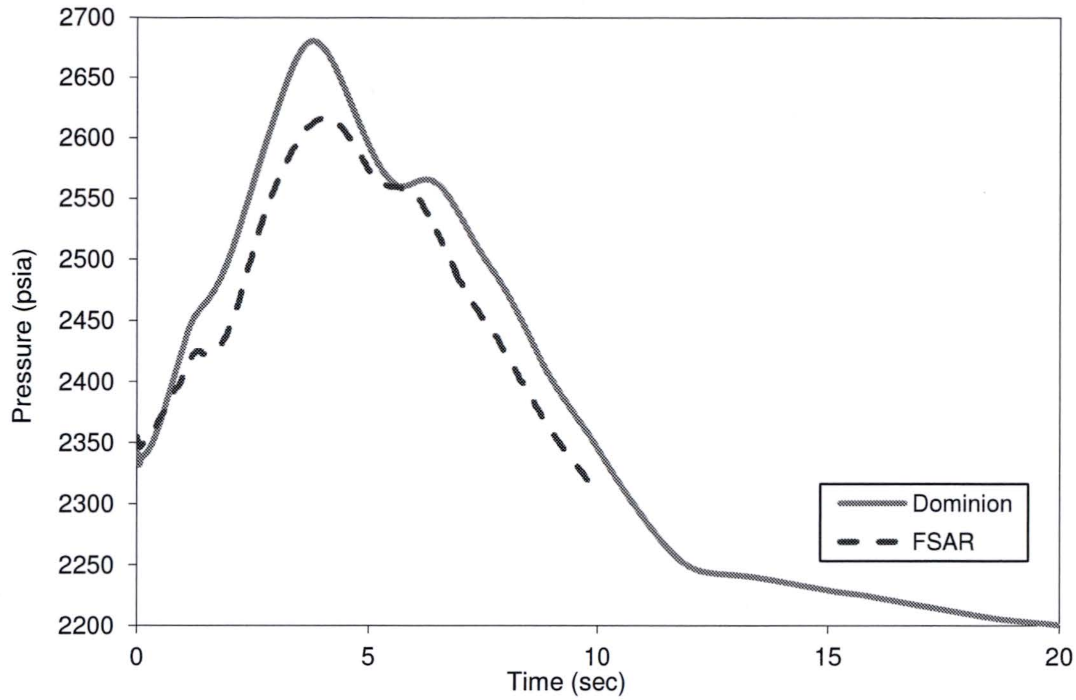


Figure 4.2-2 LR – RCP Outlet Plenum Pressure

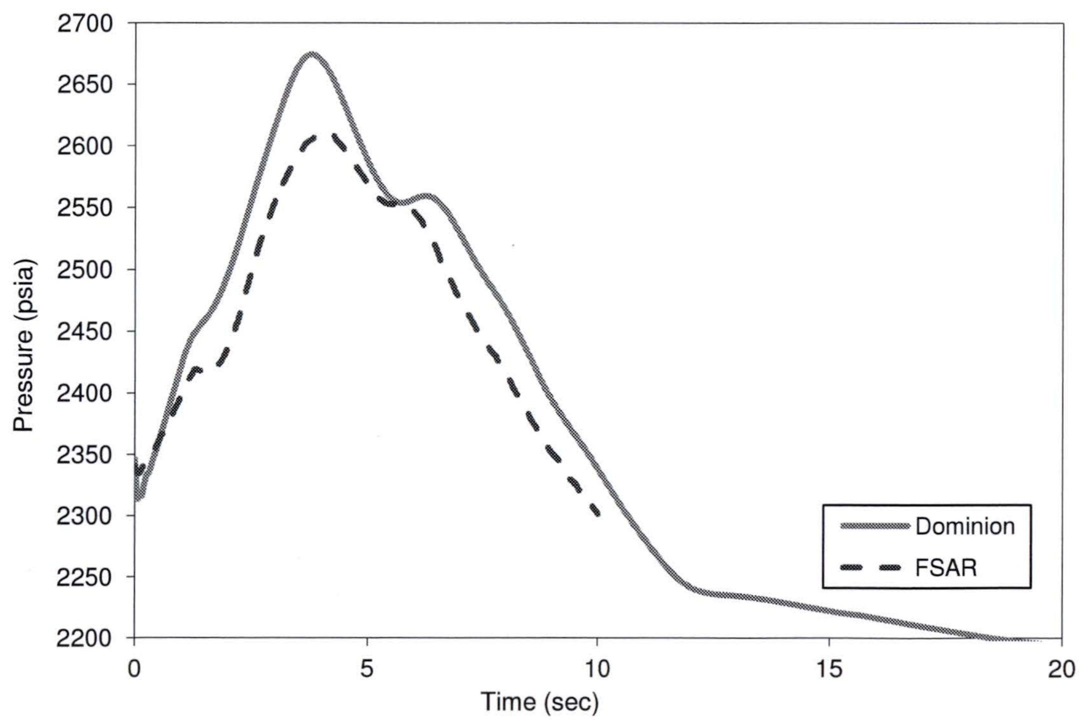


Figure 4.2-3 LR – Faulted Loop Normalized Flow

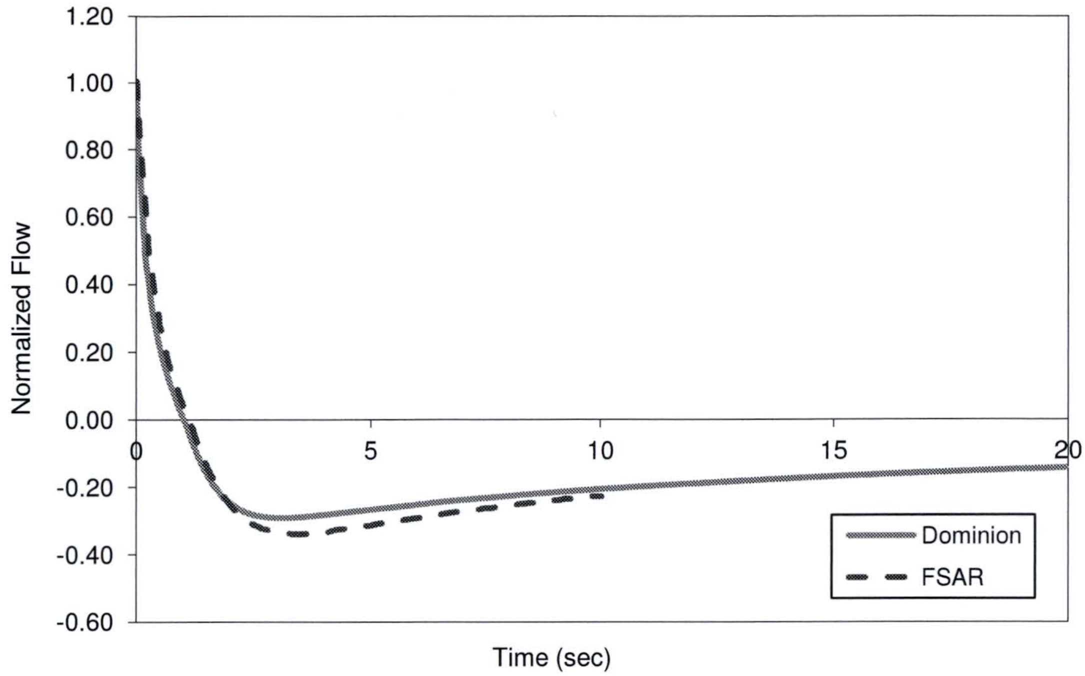


Figure 4.2-4 LR – Unfaulted Loop Normalized Flow

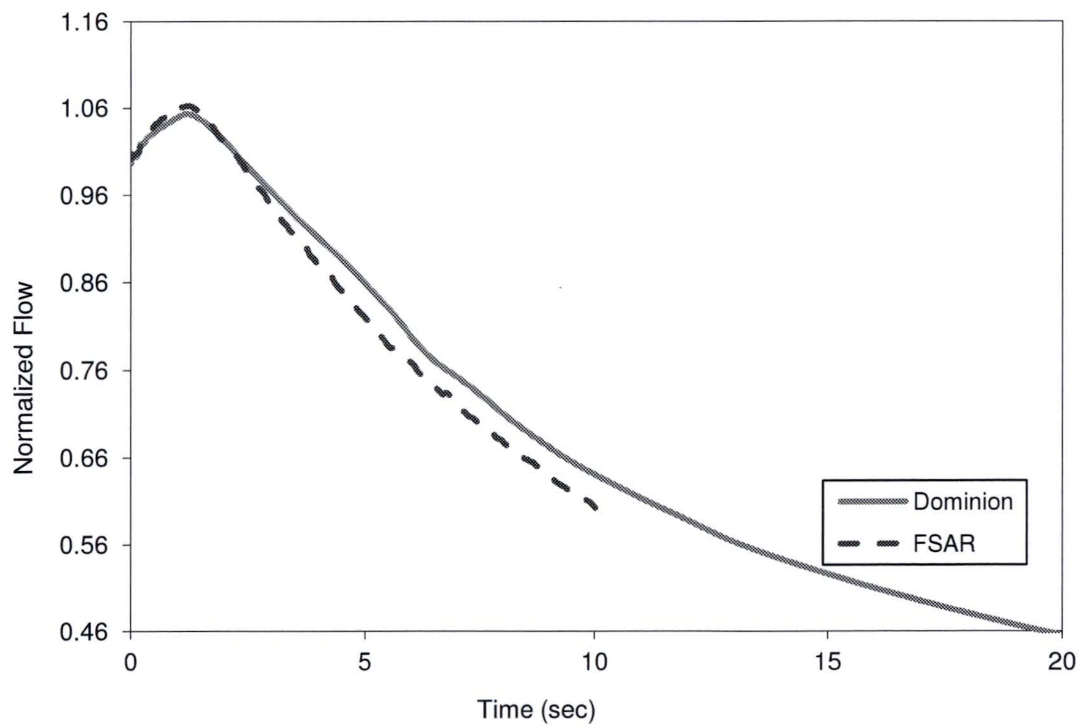


Figure 4.2-5 LR – Core Inlet Normalized Flow

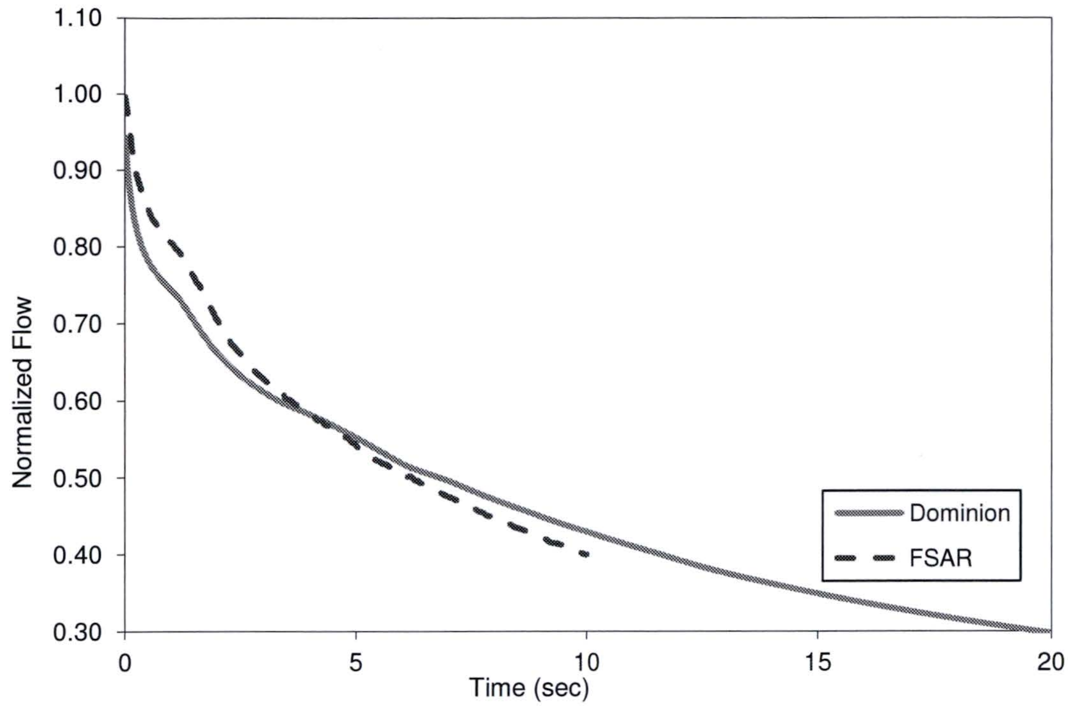


Figure 4.2-6 LR – Nuclear Power

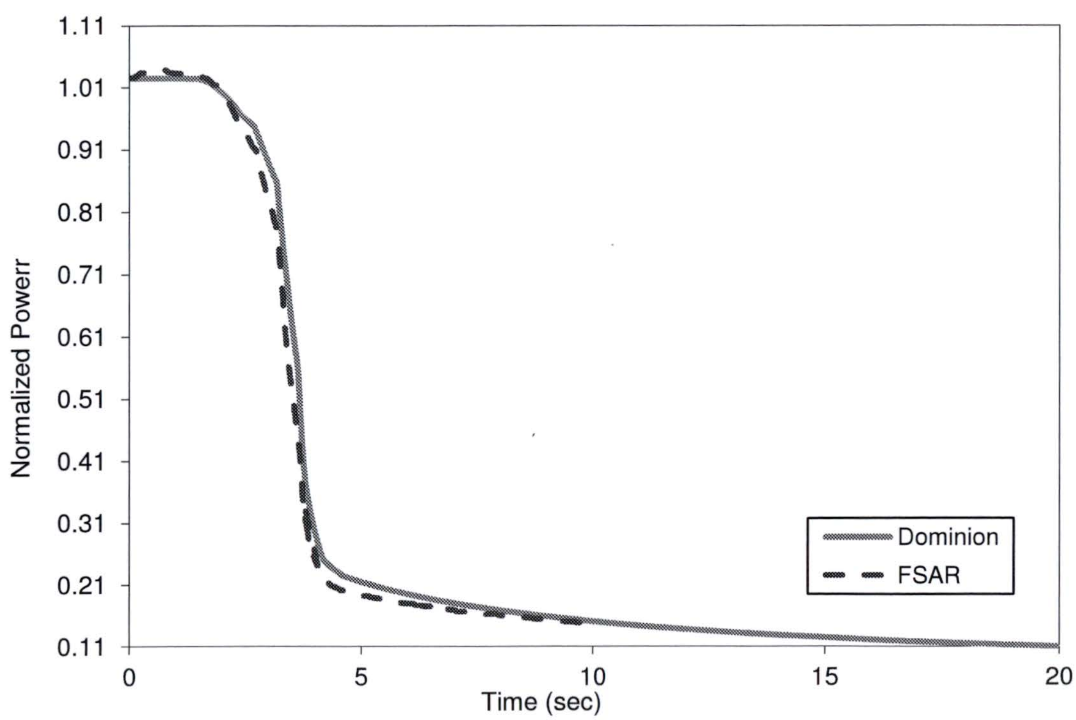
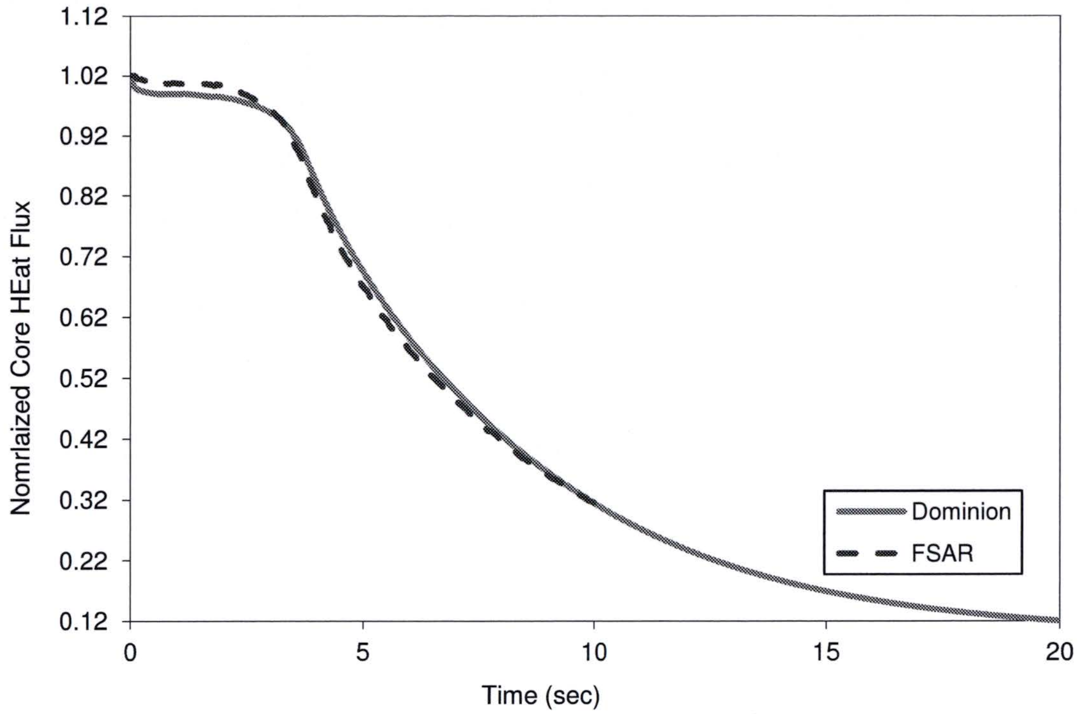


Figure 4.2-7 LR – Core Heat Flux



LR Peak Cladding Temperature

The Locked Rotor event is also analyzed to demonstrate that a coolable core geometry is maintained. A hot spot evaluation is performed to calculate the peak cladding temperature and oxidation level. The Dominion Hot Spot model is described in Topical Report VEP-NFE-2-A, "VEPCO Evaluation of the Control Rod Ejection Transient." (Reference 2). The Dominion Hot Spot model was used to evaluate the MPS3 PCT and oxidation level for the LR event.

The Dominion hot spot model is used to predict the thermal-hydraulic response of the fuel for a hypothetical core hot spot during a transient. The hot spot model describes a one-foot segment of a single fuel rod assumed to be at the location of the peak core power location during a transient. The hot spot model uses boundary conditions from the LR system transient analysis to define inlet flow and core average power conditions. The hot spot model uses MPS3-specific values for fuel dimensions, fuel material properties, fluid volume, and junction flow areas.

The hot spot model is run to 0.1 seconds and a restart file is saved. Upon restart, the fuel/cladding gap conductance (thermal conductivity) is modified to simulate gap closure by setting the gap heat transfer coefficient to 10,000 Btu/ft^2-hr-°F for a gap conductance of 2.708 Btu/ft-hr-°F. The hot spot model input summary is provided in Table 4.2-3. Most of the input parameters are the same as those used in the FSAR Chapter 15 analyses. Where differences from the FSAR inputs exist, they are indicated in the Notes column.

Table 4.2-3 Hot Spot Model Input Summary

Parameter	Value	Notes
Computer Code Used	RETRAN-3D	FSAR uses VIPRE
Initial Conditions		
Ratio of Initial to Nominal Power	1.02	
RCS Flow (gpm)	363,200	
Hot Spot Peaking Factor	2.60	
Assumptions/Configuration		
Pre-DNB Film Heat Transfer Coefficient	Thom	
Time of DNB (sec)	0.1	
Post DNB Film Boiling Heat Transfer Coefficient	Bishop-Sandberg-Tong	
Fuel Pin Model		
Post DNB Gap Heat Transfer Coefficient (Btu/hr-ft2-°F)	10,000	
Gap Thermal Expansion Model activated?	Yes	
Zircaloy-Water Reaction activated?	Yes	

LR Peak Cladding Temperature Results

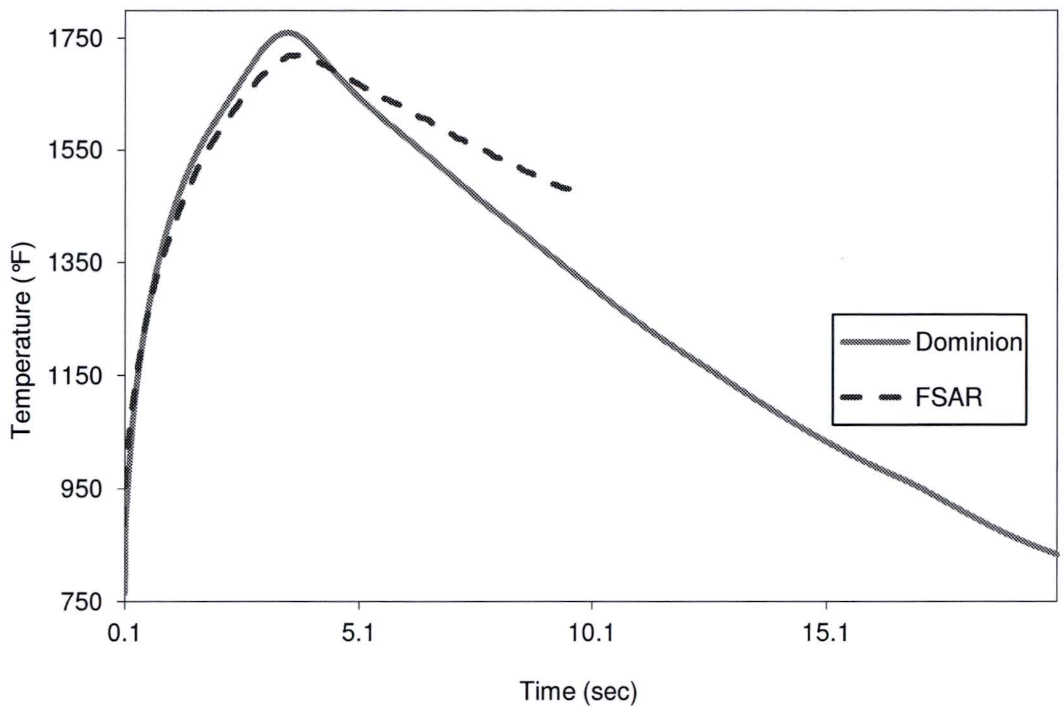
The peak cladding temperature obtained from Dominion's MPS3 hot spot model for the locked rotor event is 1760 °F. The maximum zircaloy-water reaction depth is 3.60875E-06 feet, which corresponds to approximately 0.19% by weight based on the nominal cladding thickness of 1.875E-03 feet. A summary of the LR Peak Cladding Temperature Hot Spot analysis comparison is provided in Table 4.2-4. The cladding inner surface temperature is shown in Figure 4.2-8.

Table 4.2-4 LR Hot Spot Results

Parameter	Dominion	FSAR
Peak Cladding Temperature	1760 °F	1718 °F
Maximum Zr-water reaction (w/o)	0.19	0.22

The Dominion peak cladding temperature and maximum oxidation values are comparable to the FSAR values. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR.

Figure 4.2-8 LR Hot Spot – Cladding Inner Surface Temperature



4.3 Loss of Normal Feedwater

The Loss of Normal Feedwater (LONF) event causes a reduction in heat removal from the primary side to the secondary system. Following a reactor trip, heat transfer to the steam generators continues to degrade resulting in an increase in RCS fluid temperature and a corresponding insurge of fluid into the pressurizer. There is the possibility of RCS pressure exceeding allowable values or the pressurizer becoming filled and discharging water through the relief valves. The event is mitigated when Auxiliary Feedwater (AFW) flow is initiated and adequate primary to secondary side heat removal is restored. This analysis shows that the AFW system is able to remove core decay heat, pump heat and stored energy such that there is no loss of water from the RCS and pressure limits are not exceeded. The LONF input summary is provided in Table 4.3-1.

Table 4.3-1 LONF Input Summary

Parameter	Value	Notes
Initial Conditions		
Core Power (MW)	3723	Includes 2% uncertainty
RCS Flow (gpm)	363,200	Thermal Design Flow
Vessel T_{AVG} (F)	583	FSAR value
RCS Pressure (psia)	2300	Nominal + 50 psi
Pressurizer Level (%)	71.6	Nominal + 7.6%
SG Mass	~ 89000	Dominion model adjusted to be consistent with FSAR analysis
Assumptions/Configuration		
Low-Low Level Reactor Trip Setpoint	0%	Percent of narrow range span
Pressurizer: sprays, heaters, PORVs	-	Assumed operable
AFW Temperature (F)	120	Max value
AFW Pump configuration	-	2 motor-driven pumps feed 4 SGs
Auxiliary feedwater flow rate (gpm)	-	Variable as function of SG press.
Local Conditions Heat Transfer model	active	SG secondary side FSAR= multi-node SG
Decay Heat	-	FSAR decay heat constants are applied for this case
Reactivity Parameters		
Doppler Reactivity Feedback	Most negative	Dominion model adjusted to use FSAR Doppler Power Coeffcient
Moderator Feedback	Most Positive	

Results - LONF

The results for the LONF comparison analysis are presented in Table 4.3-2 and Figures 4.3-1 through 4.3-7. The loss of feedwater flow to the steam generators (SG) results in a reduction in SG level until a reactor trip occurs on Low-Low SG level. Normalized power is shown on Figure 4.3-1 and normalized core heat flux in Figure 4.3-2. The nuclear power response and heat flux response predicted by the Dominion model are in excellent agreement with the FSAR data, indicating that the scram on low-low steam generator level occurred at essentially the same time shown for the FSAR data. The results continue to demonstrate good agreement through the end of the event.

Figure 4.3-3 shows the steam generator pressure response. The Dominion steam generator pressure is initialized at a slightly different pressure than the FSAR model because the Dominion model initial condition is adjusted to minimize the steam generator area adjustment. Between 10 and 34 seconds the FSAR pressure increases more rapidly to a pressure ~43 psi greater than the Dominion model prediction when the steam line is isolated. This difference is attributed to differing heat transfer degradation in the MNSG model used in the FSAR analysis versus the SNSG model used in the RETRAN-3D model. Steam line isolation occurs at nearly the same time, causing pressure to increase rapidly. The peak pressure is limited by the main steam safety valves (MSSVs), resulting in an almost identical peak pressure in both the Dominion and FSAR responses. However, the Dominion model pressure decreases following the peak value, where the FSAR model response remains at a constant value near the peak value, due to differences in MSSV modeling. Figure 3.1-4 shows the steam generator liquid mass. The steam generator liquid mass depletes faster in the Dominion cases than in the FSAR cases. This is consistent with the increased relief flow as shown in the steam generator pressure response.

The response in the pressurizer is shown in Figures 4.3-5 and 4.3-6. Between the FSAR and Dominion model, the pressure responses are in good agreement until around 45 – 50 seconds where the Dominion pressure is lower than the FSAR, reflecting less heat transfer degradation during this period. This is followed by a second pressure peak that is higher for Dominion than the FSAR. Based on the sharpness of the Dominion peak compared with the FSAR data, this difference is most likely driven by differences in the pressurizer spray models and primary to secondary heat transfer.

For the pressurizer water volume, shown in Figure 4.3-6, the Dominion model results follow the same trends as the FSAR data, but drops lower in the period from 63 to 900 seconds, then demonstrates a strong insurge during the second heat-up period in the transient while peaking at a somewhat lower value than the FSAR. The difference seen in the pressurizer

volume results is primarily due to the previously discussed MSSV modeling differences and the resultant increased steam release from the Dominion model compared to the FSAR model as well as possible differences in the pressurizer spray models.

Table 4.3-2 LONF Results

Parameter	Dominion	FSAR
Peak PZR Liquid Volume (ft3)	1610	1730

Figure 4.3-1 LONF - Nuclear Power

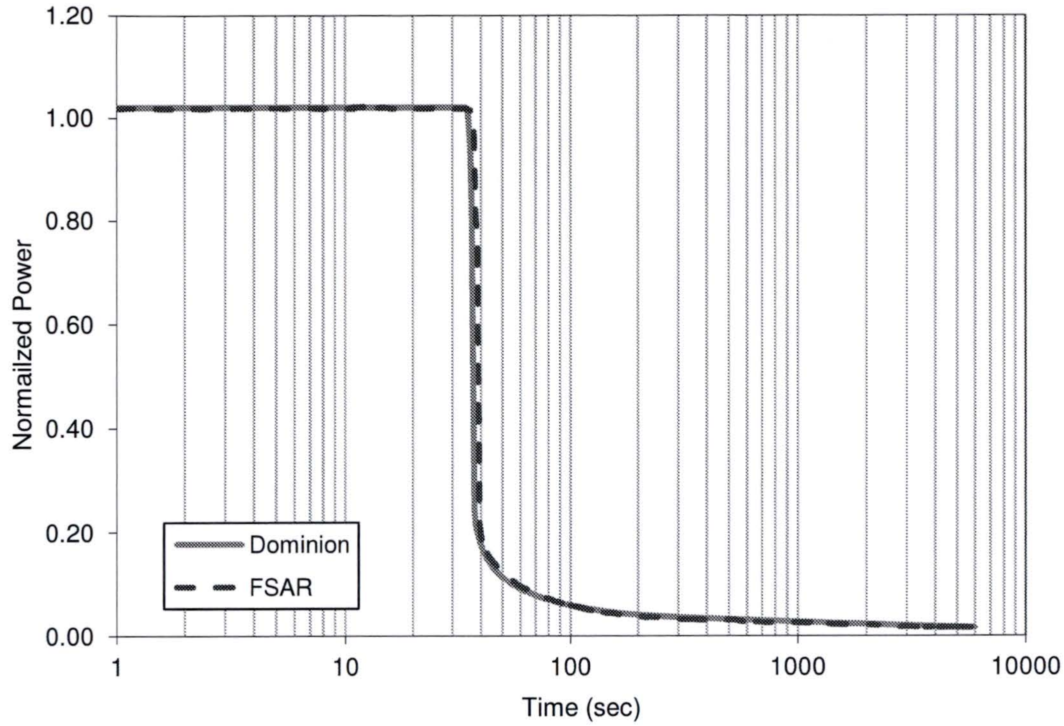


Figure 4.3-2 LONF - Normalized Core Heat Flux

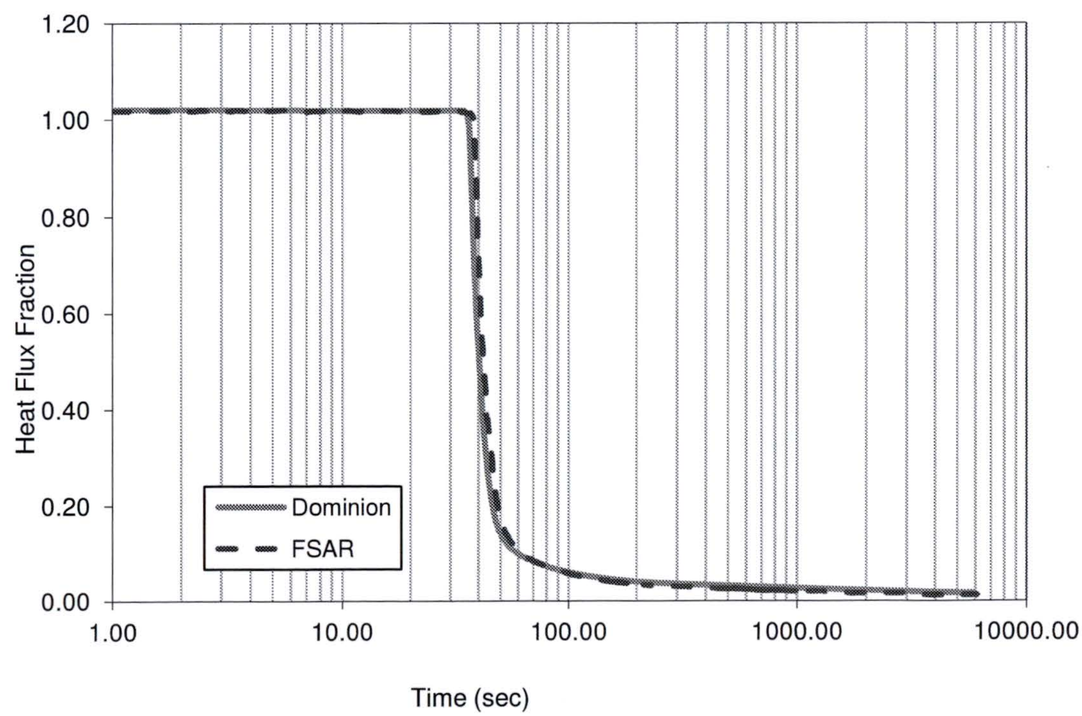


Figure 4.3-3 LONF – Steam Generator Pressure

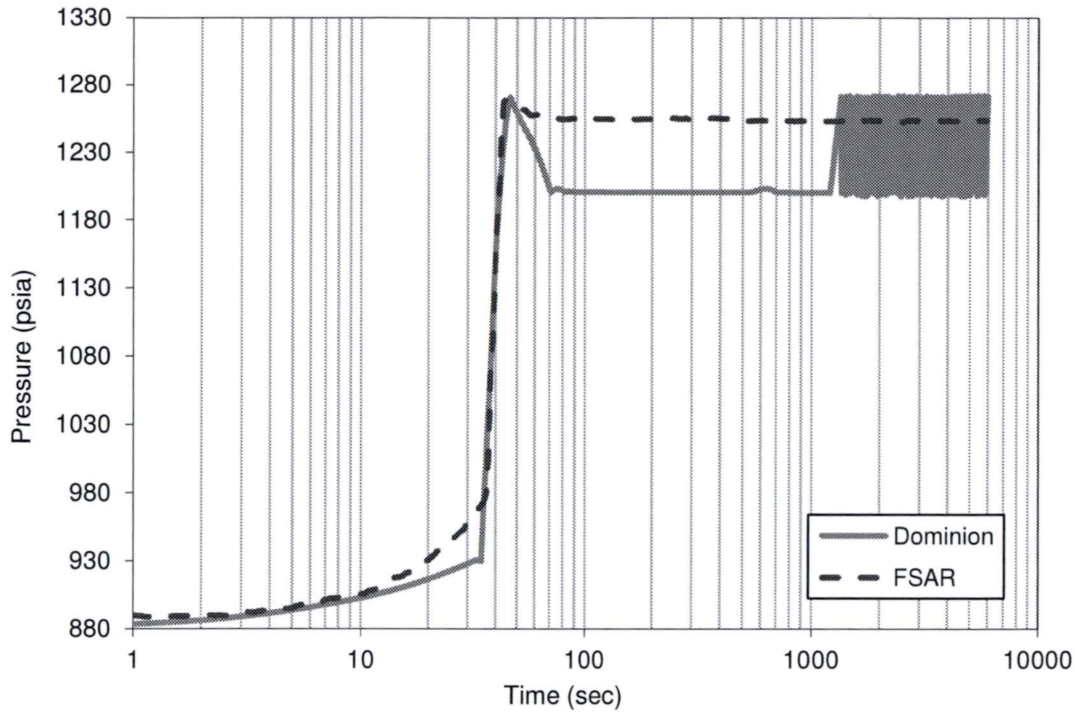


Figure 4.3-4 LONF – Steam Generator Liquid Mass

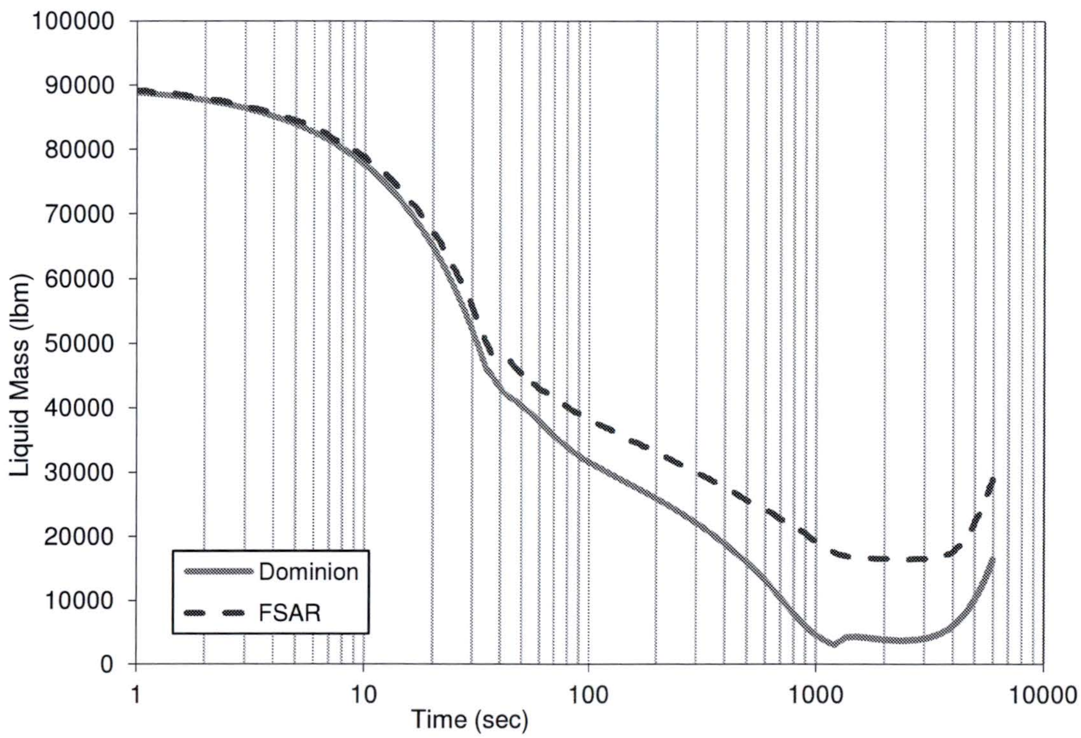


Figure 4.3-5 LONF – Pressurizer Pressure

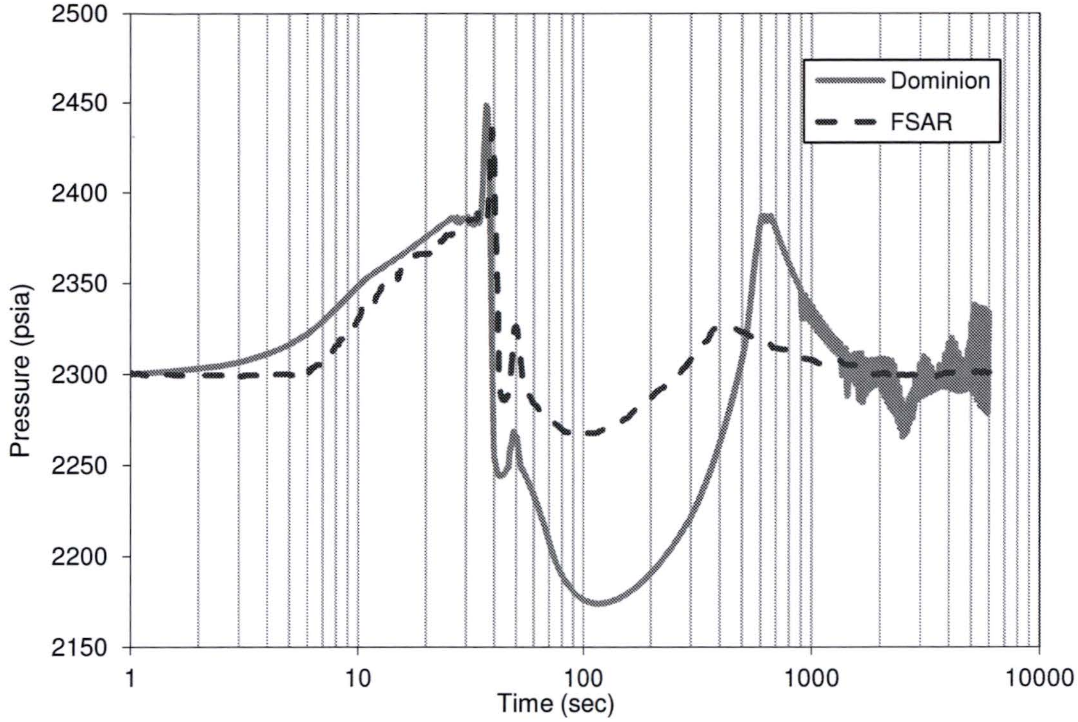


Figure 4.3-6 LONF – Pressurizer Water Volume

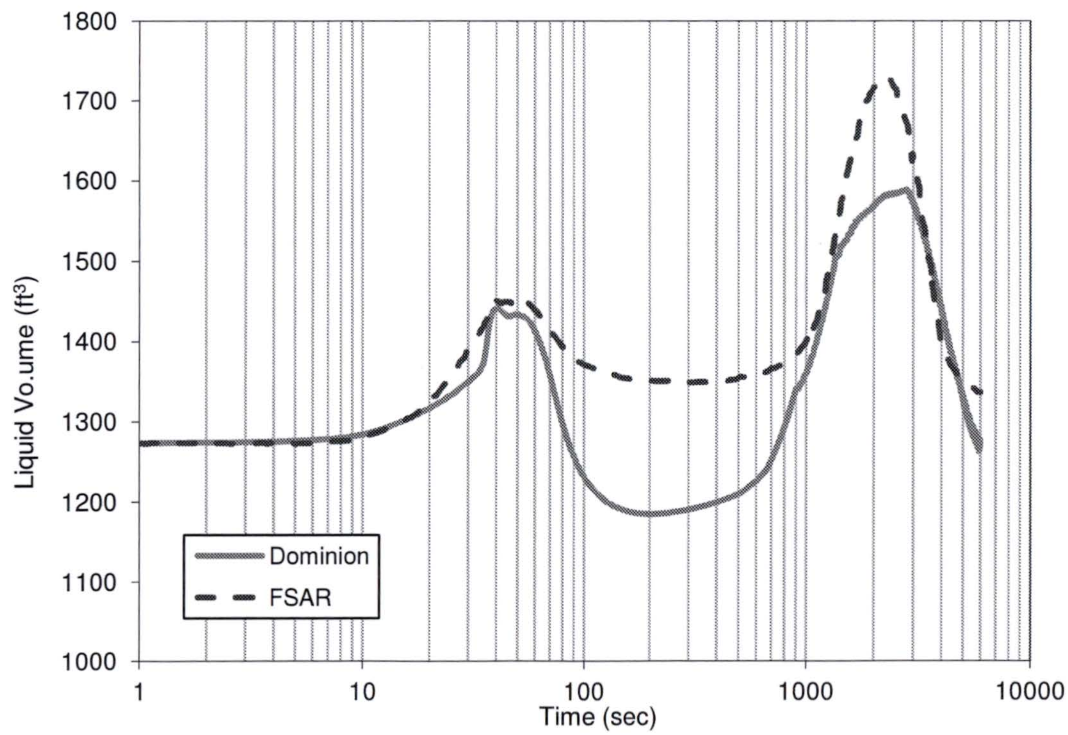
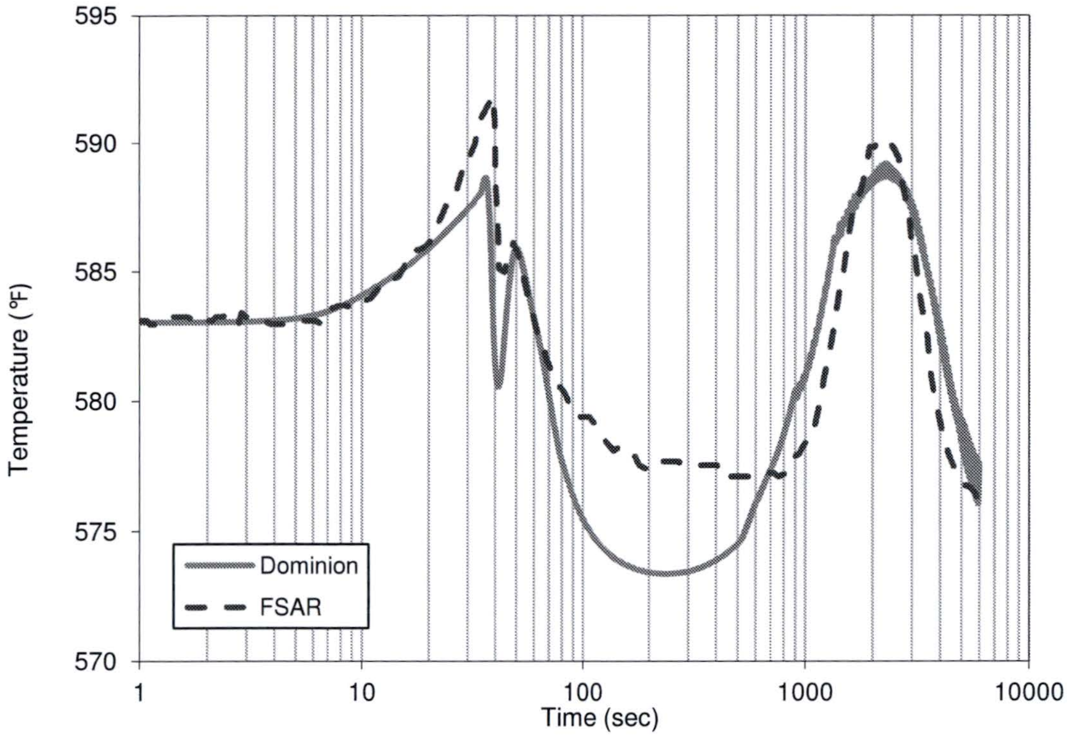


Figure 4.3-7 LONF – Loop Average Temperature



Summary - LONF

The Dominion analysis provides results that are similar to the FSAR analysis for the LONF event. The major differences result from the main steam safety relief valve modeling, which results in higher steam releases and a subsequent increase in heat transfer following the reactor trip. In addition, the steam generator nodalization and related heat transfer along with other modeling differences such as pressurizer spray also affect the transient response. These effects are cumulative resulting in a somewhat smaller long-term pressurizer insurge and higher pressurizer pressure peak compared to the FSAR results. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR.

4.4 Main Steam Line Break

The Main Steam Line Break (MSLB) event is a rupture in the main steam piping resulting in a rapid depressurization of the SG secondary and corresponding cooldown of the primary. The temperature reduction results in an insertion of positive reactivity with the potential for core power increase and DNBR violation.

The MSLB transient scenario presented here is modeled as an instantaneous, double-ended break at the nozzle of one steam generator from hot shutdown conditions with offsite power available. The input summary is provided in Table 4.4-1.

Table 4.4-1 MSLB Input Summary

Parameter	Value	Notes
Initial Conditions		
Core power (MW)	~1%	HZP
Pump power (MW)	0.0	
RCS Flow (gpm)	363,200	Thermal Design Flow
Vessel T_{AVG} (F)	557	HZP nominal
RCS Pressure (psia)	2250	Nominal
Pressurizer Level (%)	28	HZP nominal
SG Level (%)	50	Nominal
Assumptions/Configuration		
Heat transfer option	Forced HT Map (note 1)	FSAR uses a proprietary heat transfer formulation
Main feedwater flow (% HFP value)	100	initiated at time 0 sec
Auxiliary feedwater flow rate (gpm)	Max	initiated at time 0 sec
SG tube plugging (%)	0	Minimum value
Reactivity Parameters		
RWST Boron	Credited	FSAR does not credit boron from the SI system
Accumulator Boron	Not Credited	
Doppler Reactivity Feedback	Doppler Only Power defect, DTC model disabled	FSAR - Doppler power defect plus DTC included in moderator density feedback
Moderator Feedback	Moderator density feedback	Moderator density feedback

1 - Dominion method maximizes heat transfer coefficients for the faulted SG secondary side.

Results – MSLB with Offsite Power Available

The faulted loop steam flow and steam generator pressure responses shown in Figure 4.4-1 and Figure 4.4-3 match the FSAR data reasonably well with the steam flow and pressure in the Dominion model remaining somewhat higher than the FSAR data. This is partly caused by the slightly larger break junction area and the higher initial steam pressure for the Dominion model. In addition, the Dominion model uses conservatively high heat transfer coefficients in the faulted steam generator, which allow the faulted steam generator to pull heat faster from the primary side.

The Intact loop steam flow (Figure 4.4-2) shows a different response due to differences in the MSIV closure. In the Dominion model, the MSIVs close linearly over 10 seconds, while the FSAR model uses a delay of 10 seconds to conservatively increase RCS overcooling. The initial steam flow is higher for the Dominion case, decreasing below the FSAR value as the MSIVs close. The steam generator mass and pressure responses, shown in Figure 4.4-8 and Figure 4.4-4, reveals the differences in MSIV modeling with the Dominion model releasing somewhat less liquid inventory prior to valve closure.

For both the faulted and intact loops the main feedwater and auxiliary feedwater responses (Figure 4.4-5) give an excellent match to the FSAR data. The steam generator inventory (Figure 4.4-7) for the faulted loop depletes faster in the Dominion model than in the FSAR case due to the higher steaming rate from the faulted steam generator and the quicker and more conservative return to power.

The nuclear power and core heat flux responses (Figure 4.4-9 and Figure 4.4-10) calculated by the Dominion model peak higher and more quickly than the FSAR data. This response is contributed to by the greater cooling effects of the faulted steam generator on the RCS due to its higher steam production. The quicker return to power is also a result of differences in the nodalization and mixing at the core inlet and outlet between the Dominion model and the FSAR model. The return to power also drops off approximately 50 seconds sooner in the Dominion model. This is also caused by the higher steam rate in the Dominion model which causes the faulted steam generator to dry out sooner. The power response for both models is not affected by the delivery of boron to the RCS. This is because the FSAR model does not credit boron and in the Dominion model boron does not reach the RCS from the SI system until after the termination of the transient. Overall, the Dominion model results in a more conservative response for core heat flux and power.

The pressurizer pressure response (Figure 4.4-12) agrees very well with the pressure predicted by the FSAR model for the first 50 seconds of the transient, after which the FSAR data falls approximately 100 psi lower than the pressure calculated by the Dominion model. This difference is a result of using only a single upper head leakage path in the Dominion model. The upper head leakage is taken from the three intact loops and does not credit any flow from the lower temperature, faulted loop. This causes the upper head temperature to remain slightly higher than would actually be the case, which allows a vapor bubble in the upper head to form sooner and become larger. This in turn prevents the RCS pressure from falling lower.

The pressurizer drains at approximately the same rate for the Dominion model and FSAR models (Figure 4.4-13). However, for the Dominion model the pressurizer begins to refill approximately 100 seconds sooner. The quicker refilling is a result of the higher and quicker return to power which causes the RCS temperature to rise sooner in the Dominion model. This causes the RCS fluid inventory to expand which results in the pressurizer refilling sooner in the Dominion model than is seen from the FSAR model.

Table 4.4-2 MSLB with Offsite Power Results

Event	Time (sec) From Start of Transient	
	Dominion	**FSAR**
Steam Line Ruptures	0	0
Manual Reactor Trip	0	0
Increase MFW to 100% of Nominal HFP Value	0	0
Initiate Maximum AFW to Faulted Steam Generator	0	0
Main Feedwater Isolation	7.5	8.2
MSIVs Closed	12.5	13.5
Pressurizer Empty	15.5	20.5
Criticality Attained	33.5	28.0
Safety Injection Flow Initiation	47.9	72.8
Faulted Steam Generator Dries Out	298	~350

Figure 4.4-1 MSLB – Faulted Loop Steam Flow

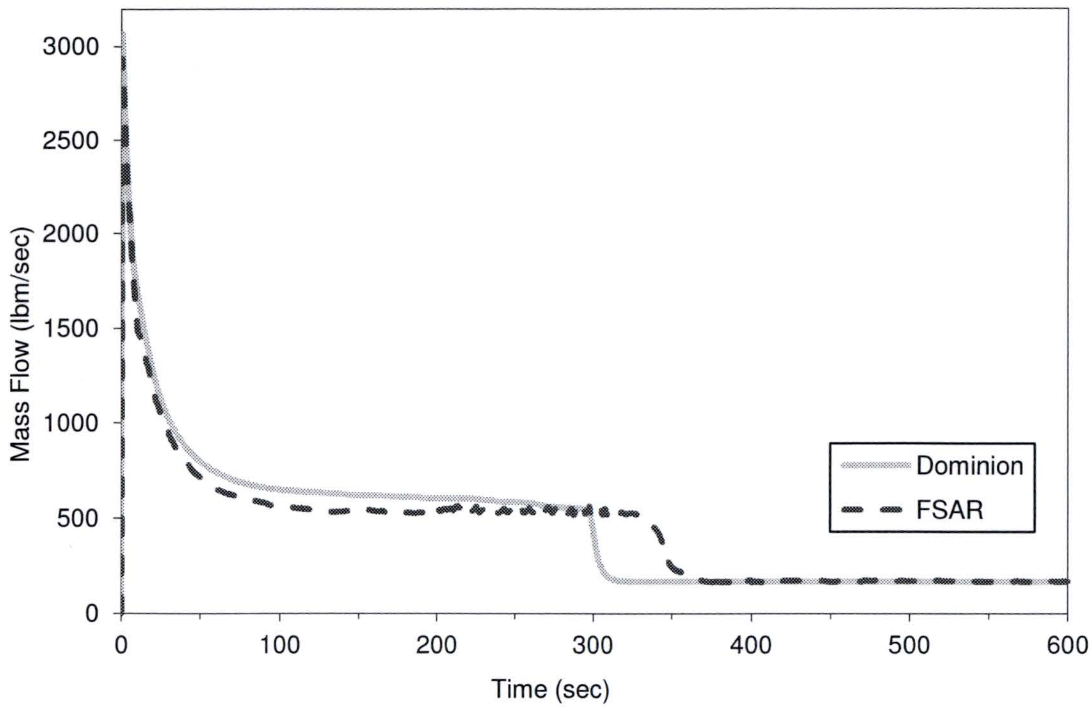


Figure 4.4-2 MSLB – Intact Loop Steam Flow

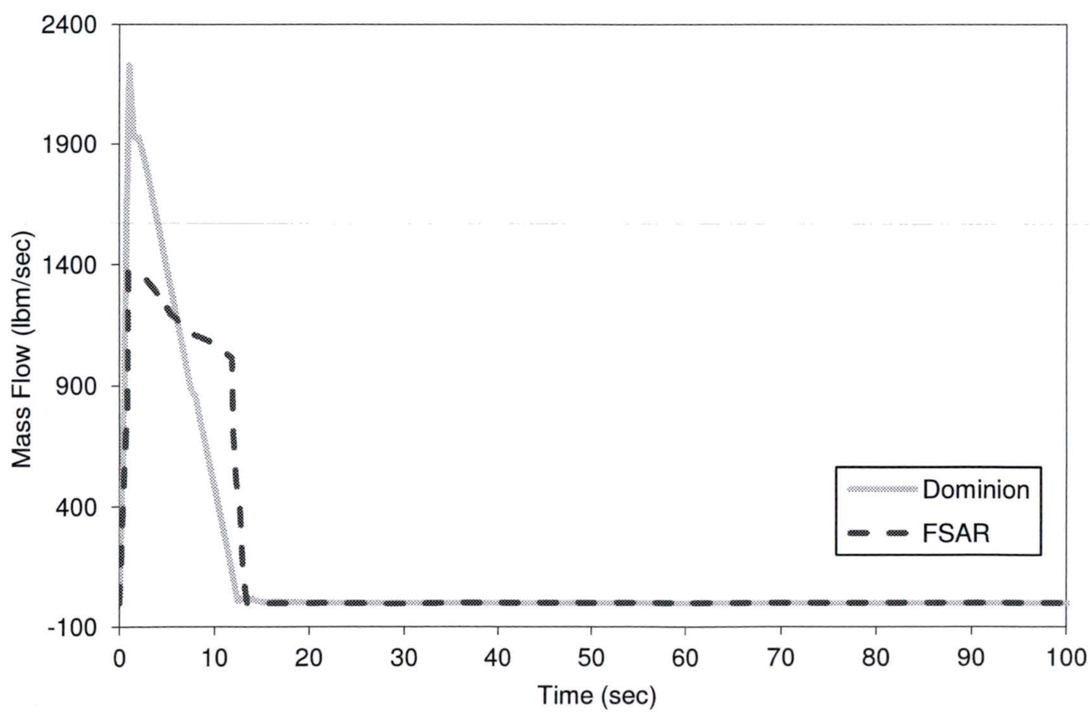


Figure 4.4-3 MSLB – Faulted Loop Steam Generator Pressure

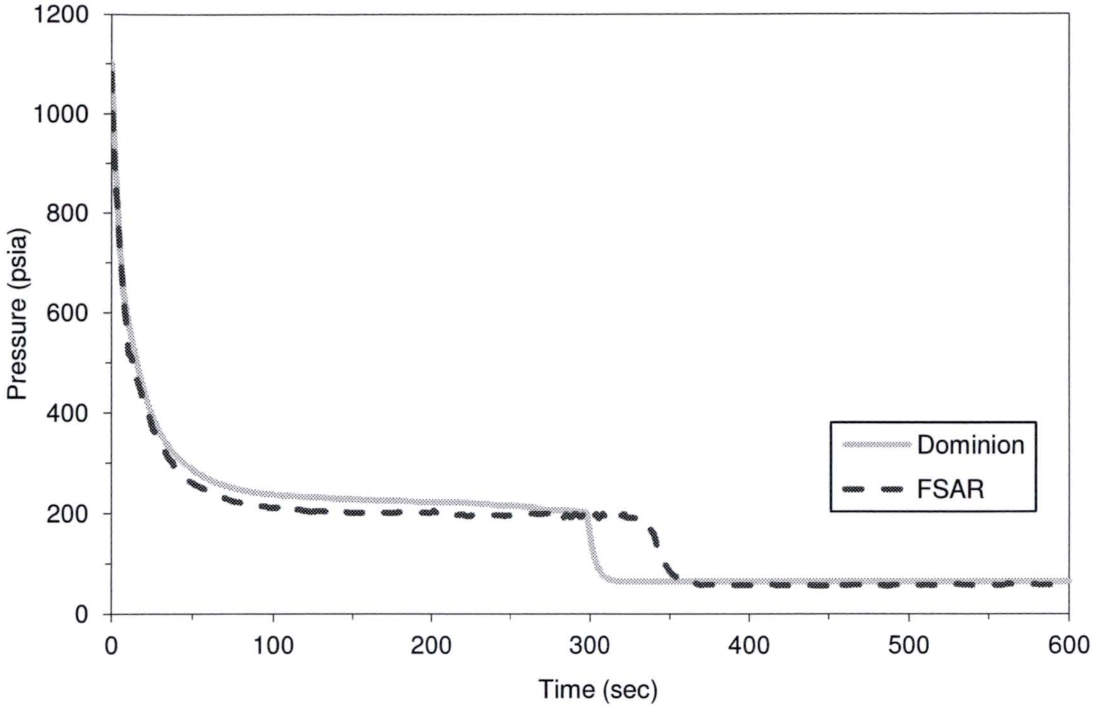


Figure 4.4-4 MSLB –Intact Loop Steam Generator Pressure

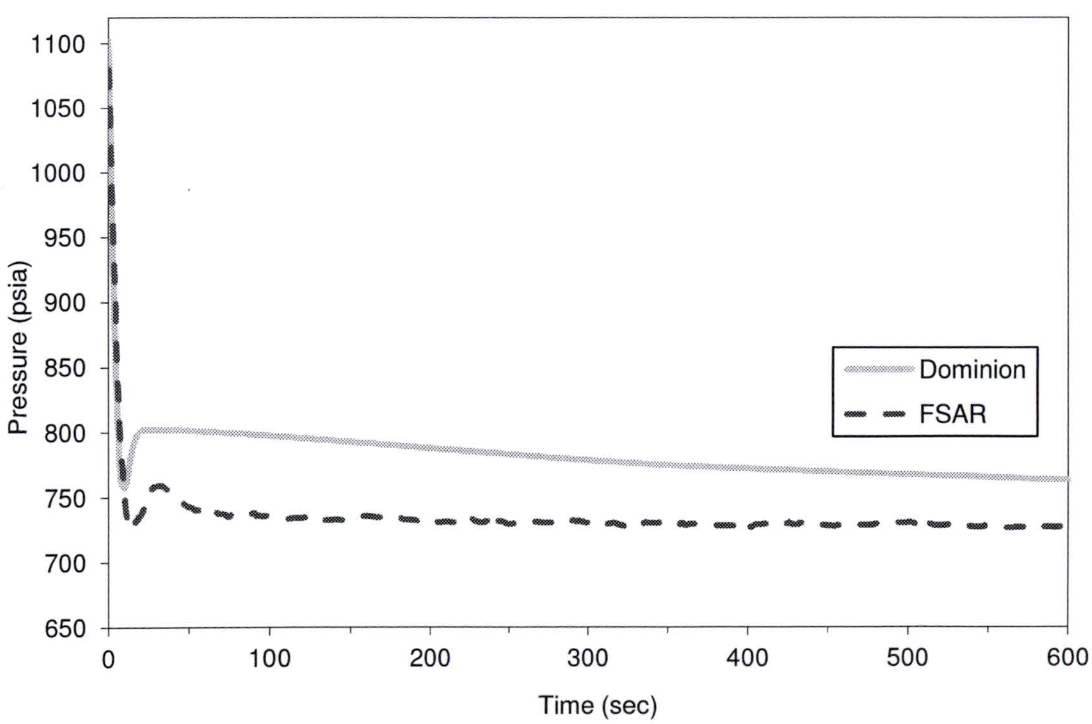


Figure 4.4-5 MSLB – Faulted Loop Total Feedwater Flow

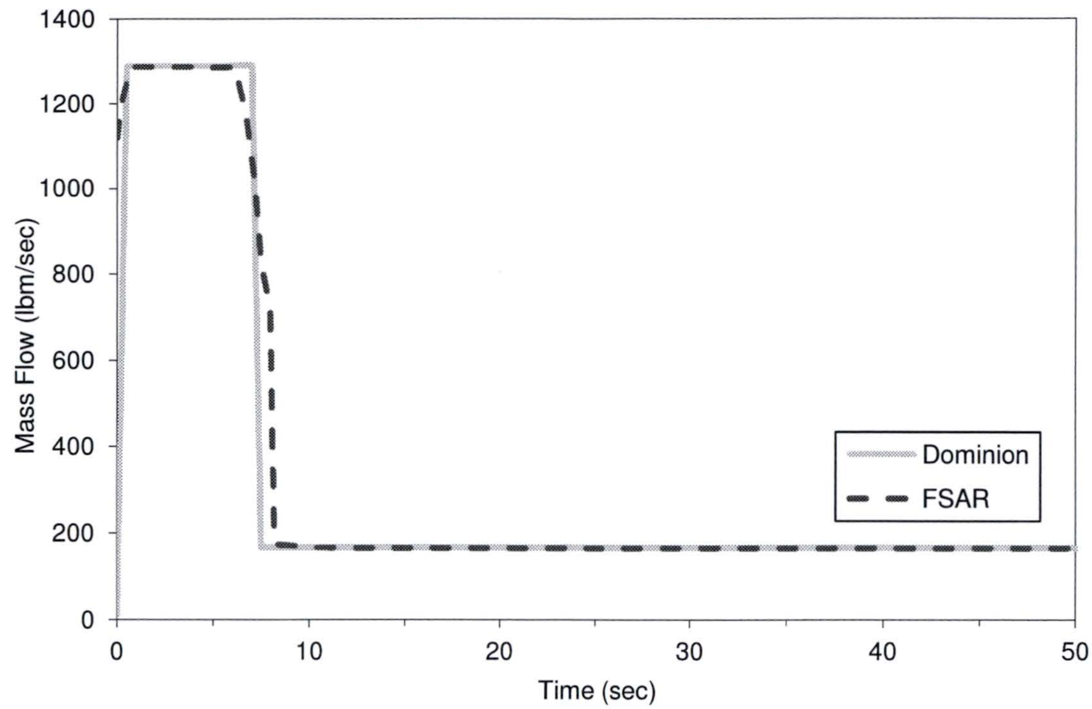


Figure 4.4-6 MSLB – Intact Loop Total Feedwater Flow

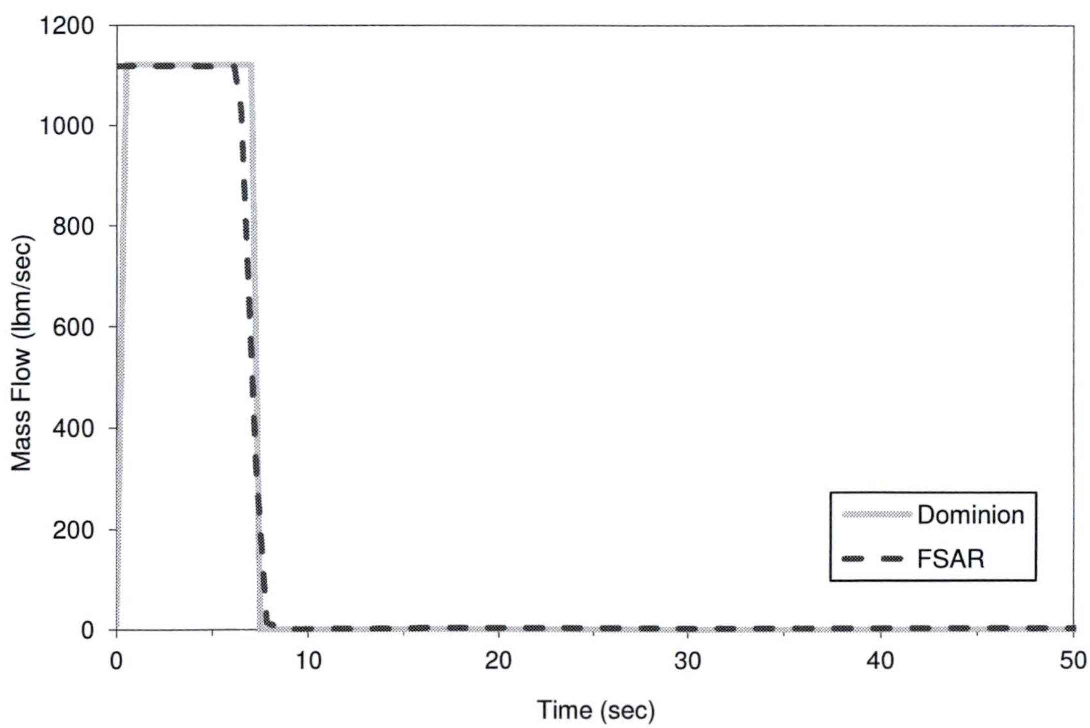


Figure 4.4-7 MSLB – Faulted Loop SG Liquid Mass

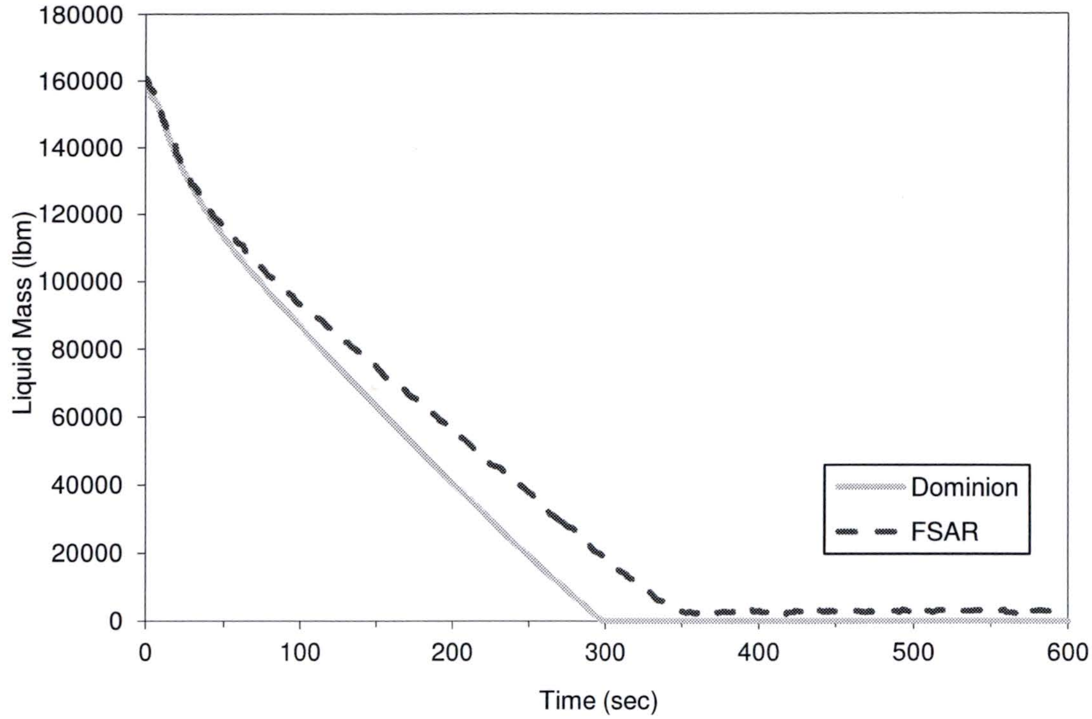


Figure 4.4-8 MSLB – Intact Loop SG Liquid Mass

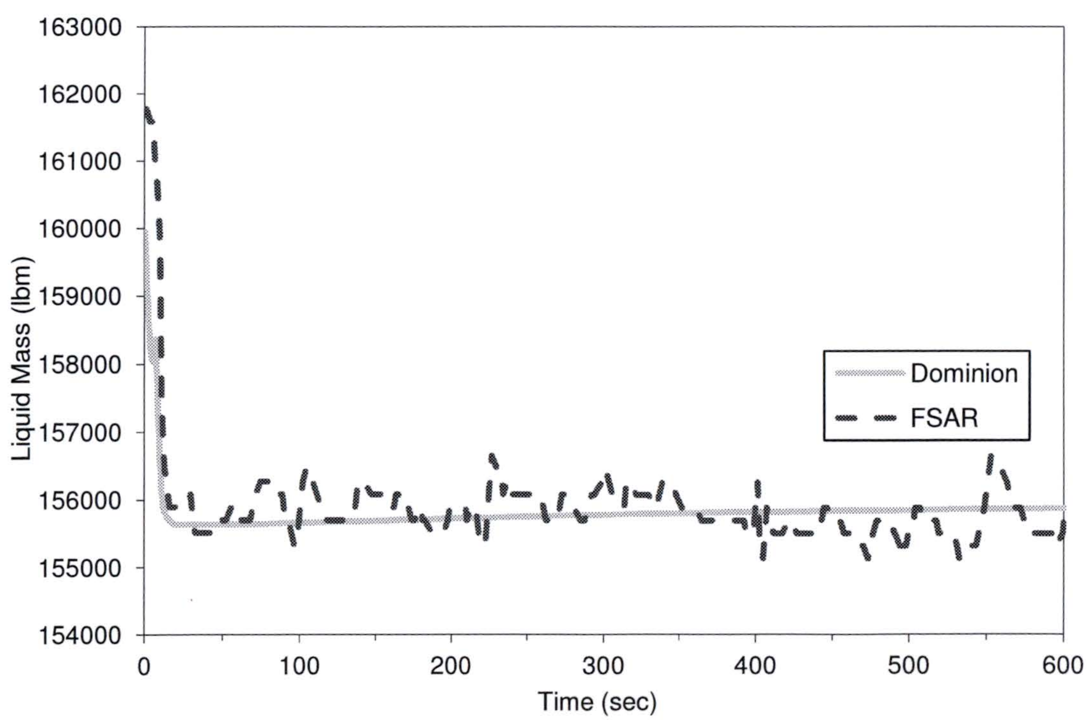


Figure 4.4-9 MSLB – Normalized Core Power

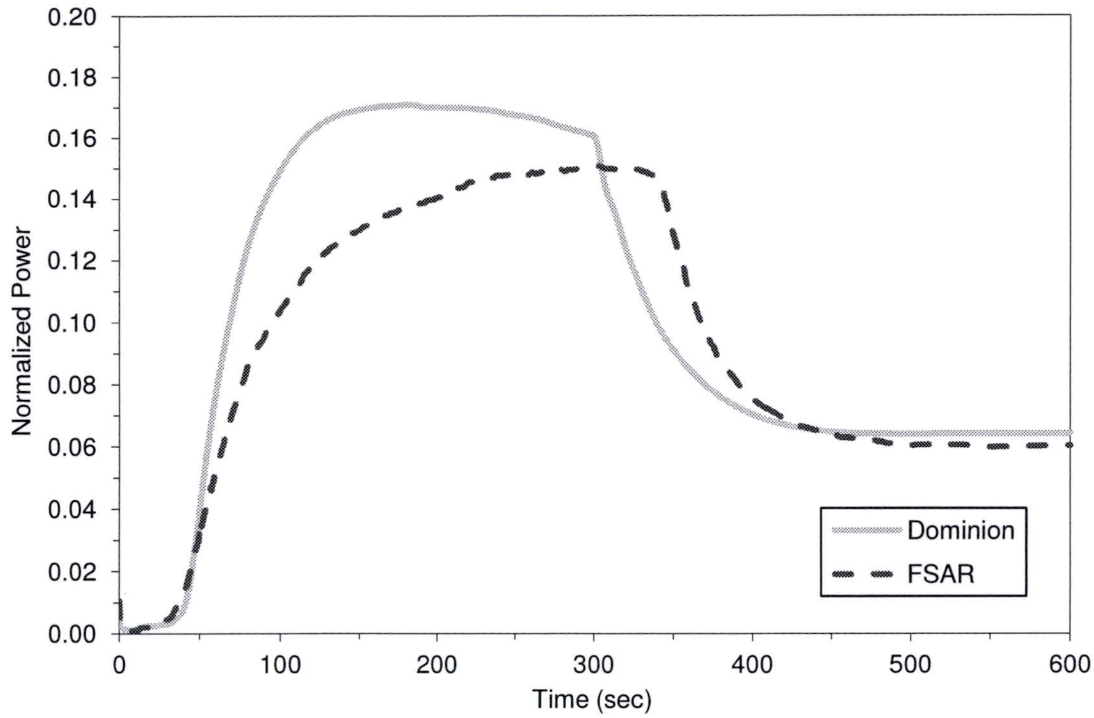


Figure 4.4-10 MSLB – Normalized Core Heat Flux

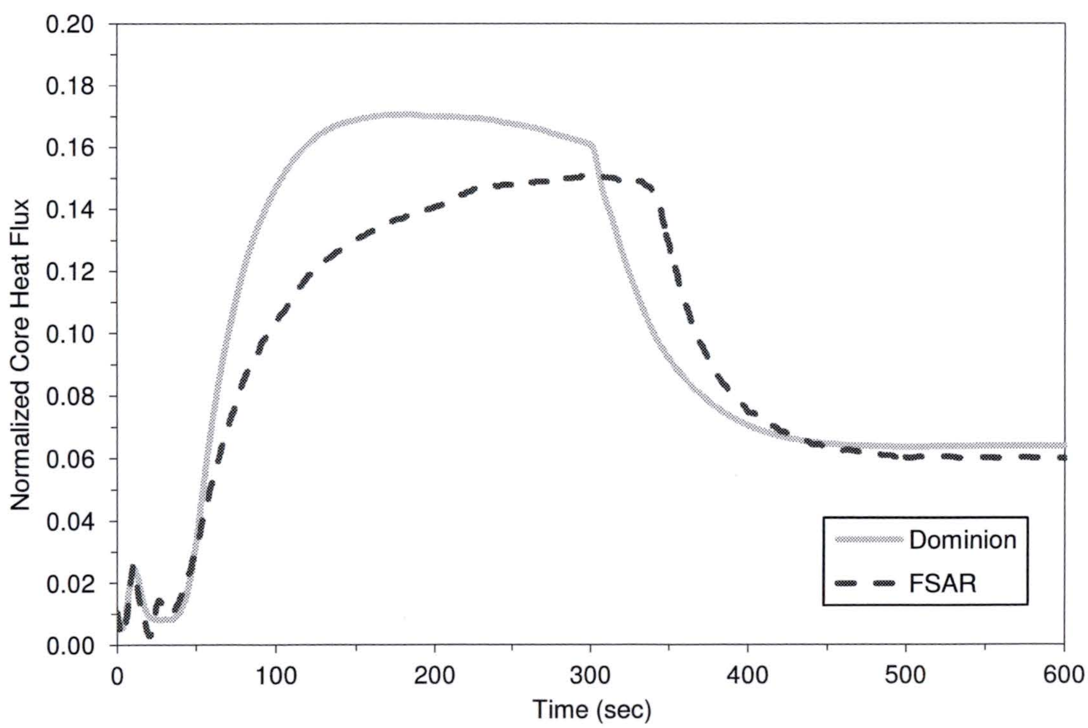


Figure 4.4-11 MSLB – Reactivity Feedback

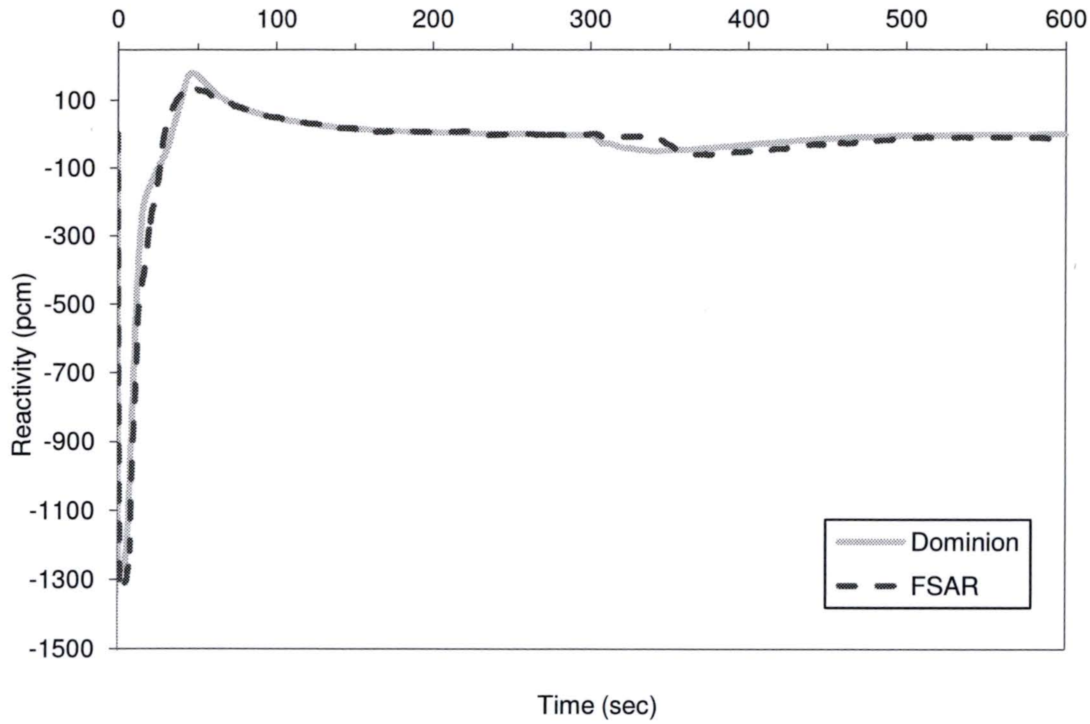


Figure 4.4-12 MSLB – Pressurizer Pressure

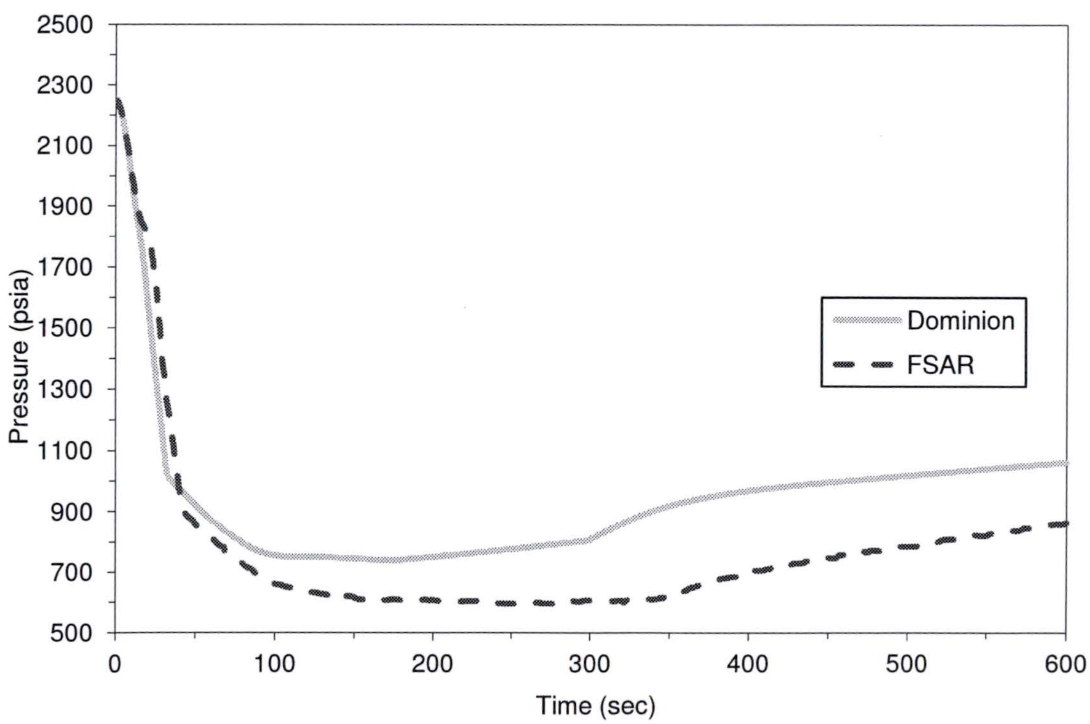


Figure 4.4-13 MSLB – Pressurizer Liquid Volume

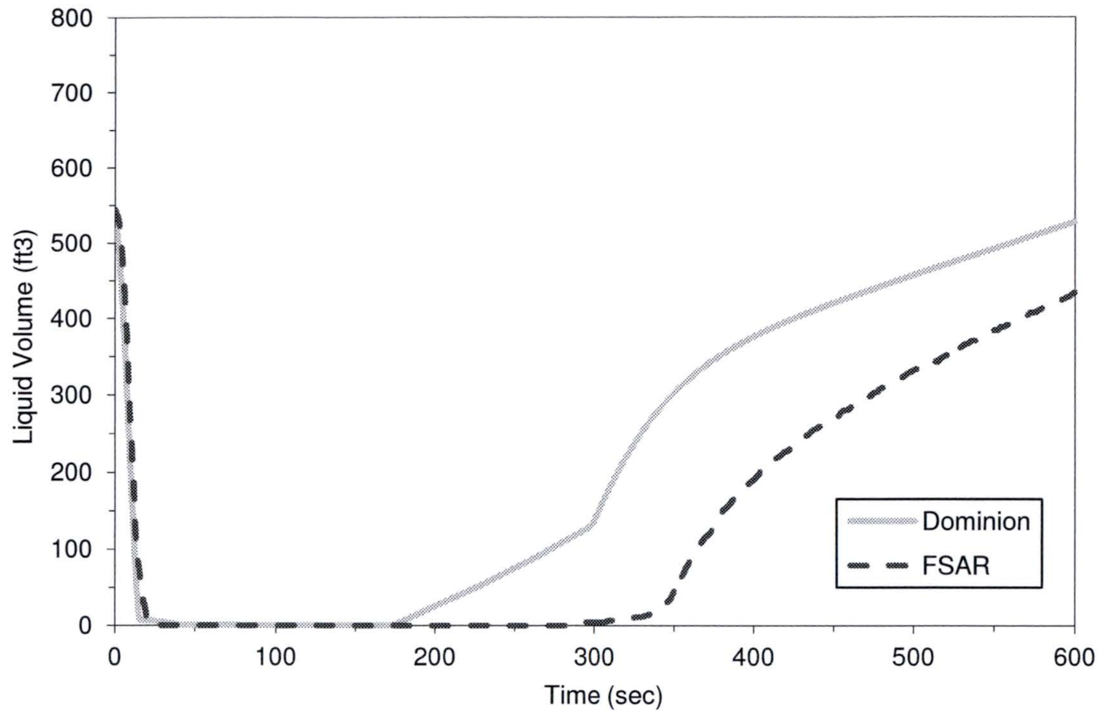


Figure 4.4-14 MSLB – Faulted Loop Vessel Inlet Temperature

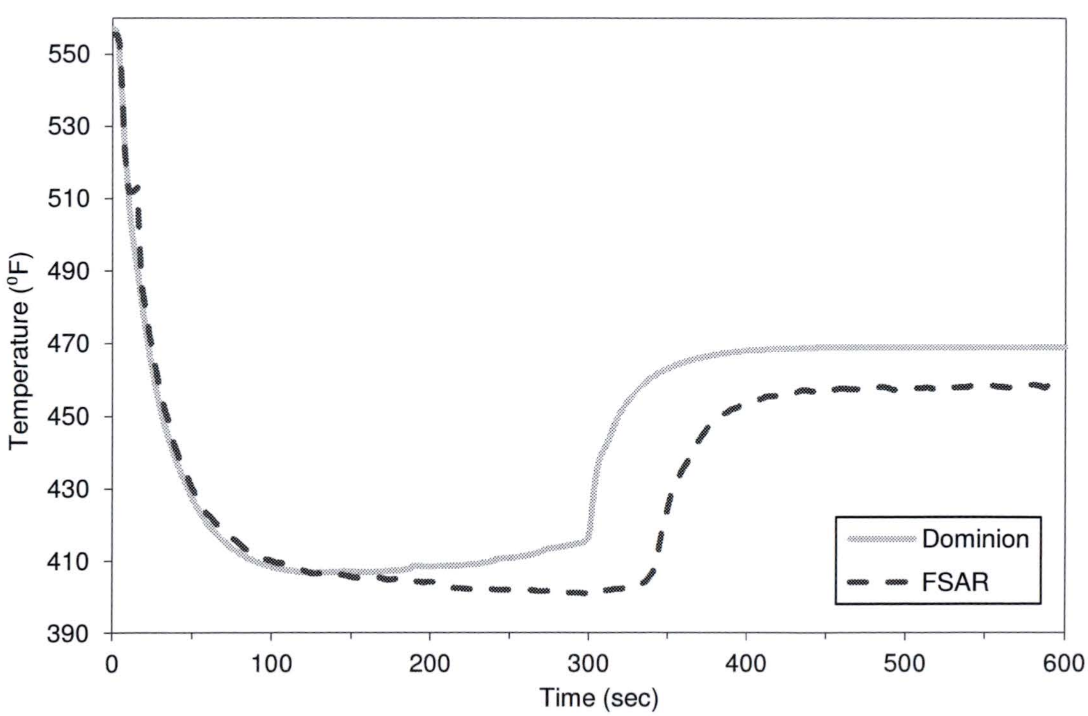
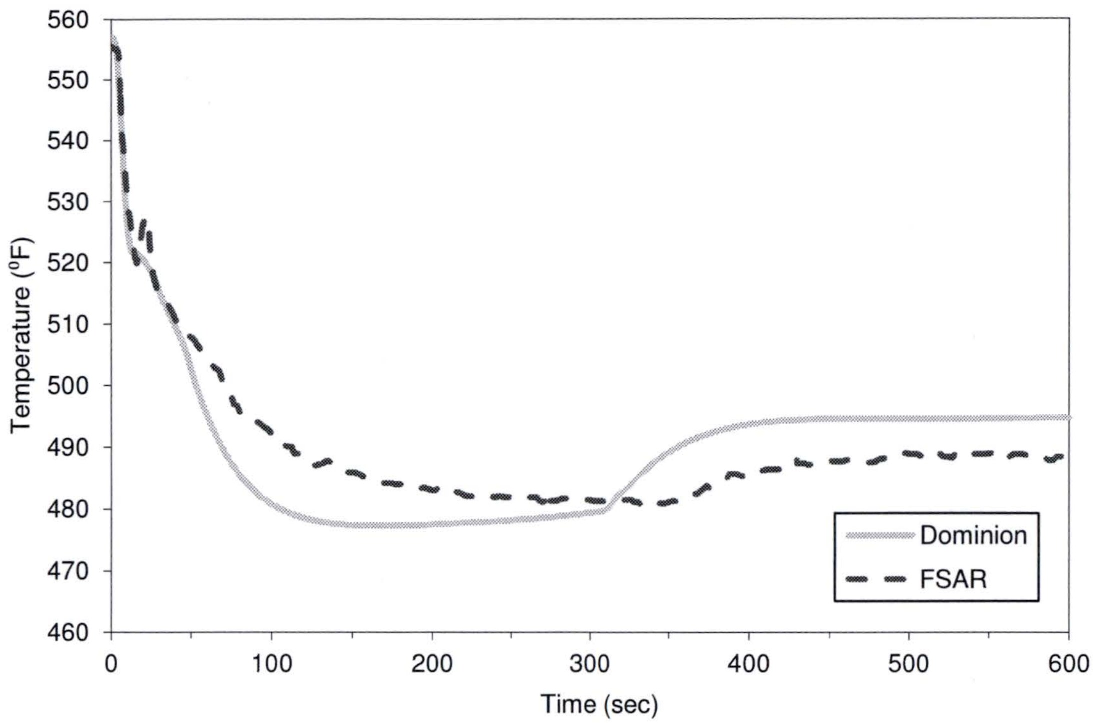


Figure 4.4-15 MSLB – Intact Loop Vessel Inlet Temperature



Summary - MSLB

This section presents a comparison of a RETRAN-3D Main Steam Line Break transient calculation with the Millstone model using the Dominion RETRAN transient analysis methods (Reference 1) compared to the FSAR results. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR. The key observations from these comparisons are that:

1) The peak power and heat flux reached with the Dominion methods is higher than the FSAR result.

2) Core and steam generator nodalization effects asymmetric transients such as a MSLB.

4.5 Control Rod Bank Withdrawal at Power

The Control Rod Bank Withdrawal at Power (RWAP) event is defined as the inadvertent addition of core reactivity caused by the withdrawal of rod control cluster assembly (RCCA) banks when the core is above no load conditions. The RCCA bank withdrawal results in positive reactivity insertion, a subsequent increase in core nuclear power, and a corresponding rise in the core heat flux. The RWAP event described here is terminated by the Reactor Protection System on a high neutron flux trip or the overtemperature ΔT trip (OTΔT), consistent with the FSAR analyses.

The RWAP event is simulated by modeling a constant rate of reactivity insertion starting at time zero and continuing until a reactor trip occurs. The Dominion analysis involves two different reactivity insertion rates, 1 pcm/sec and 100 pcm/sec that match the reactivity insertion rates presented plots in the FSAR. Most of the input parameters are the same as those used in the FSAR Chapter 15 analyses. Where differences from the FSAR inputs exist, they are indicated in the Notes column.

Table 4.5-1 RWAP Input Summary

Parameter	Value	Notes
Initial Conditions		
Core Power (MW)	3650	Nominal
RCS Flow (gpm)	379,200	Minimum Measured Flow
Vessel T_{AVG} (F)	589.5	Nominal
RCS Pressure (psia)	2250	Nominal
Pressurizer Level (%)	64	Nominal
SG Level (%)	50	Nominal
Initial Fuel Temperature	Minimum	Uses current FSAR analysis conductivity adjustments
Assumptions/Configuration		
Reactor trip	-	High neutron flux or OTΔT
Automatic rod control	-	Not credited
Pressurizer level control	-	Not credited
Pressurizer heaters	-	Not credited
Pressurizer sprays, PORVs	-	Active
SG tube plugging (%)	10	Max value
Reactivity Parameters		
Doppler Reactivity Feedback	Least Negative	
Moderator Feedback	Most Positive	Zero MTC for cases from full power

Results – RWAP 1 pcm/sec Case

Figure 4.5-1 shows the core power response. The core power rate of increase for the Dominion model is greater than the FSAR data. This leads to the Dominion modeling

tripping on high neutron flux at about 74 seconds. The FSAR case rises in power at a slower rate, which trips on an OTΔT signal at about 93 seconds. The difference in reactor trip mechanisms between the Dominion and FSAR cases is reasonable considering the breakpoint for switching between OTΔT and high flux as shown in FSAR Figure 15.4-10. The pressure response also affects the OTΔT setpoint such that the lower FSAR pressure (see below) will act to reduce the setpoint.

The pressurizer pressure response is shown in Figure 4.5-2. For the Dominion model, the pressure rises faster than the FSAR result. At about 42 seconds, the Dominion model reaches the pressurizer relief valve setpoint and begins to cycle. The FSAR more slowly increases in pressure and reaches the relief valve set point around 10 seconds prior to the reactor trip. The difference in pressure response can be attributed to the difference in core power response as each cases pressure response initially mimics the energy generated by the core as seen in Figure 4.5-1 and the higher spray flow assumed in the FSAR analysis, which acts to suppress pressure. The same can be seen in the vessel average temperature response where the FSAR case lags the Dominion response, yet reaches a temperature approximately 5 degrees higher than the Dominion case due to the FSAR case tripping later in the transient.

Table 4.5-2 RWAP 1 pcm/sec Time Sequence of Events

Event	Time (seconds)	
	Dominion	**FSAR**
Reactivity Insertion at 1 pcm/sec	0.0	0.0
Reactor Trip Signal Initiated	73.7*	93.6**

* *Trip on high neutron flux*

** *Trip on OTΔT*

Results – RWAP 100 pcm/sec Case

Figure 4.5-4 shows the core power response for the current FSAR analysis and the Dominion model. The Dominion model trips on a high neutron flux at about 1.17 seconds, compared to about 1.29 seconds for the current FSAR analysis. The 100 pcm/sec transient is a fast transient and the time period before the reactor trip is so brief that any differences in fuel pin heat transfer modeling assumptions have little impact on Doppler reactivity feedback. Overall, the Dominion model peaks at a higher, thus more conservative power level.

The pressurizer pressure response is shown in Figure 4.2-5. The Dominion model matches very well with the FSAR analysis. The main difference being that the Dominion model peaks at a higher pressure than the FSAR analysis. This correlates with the power response shown in Figure 4.2-4 where the Dominion model peaks at a higher overall nuclear power. Figure 4.2-6 shows the vessel average temperature. For the 100 pcm/sec case the Dominion model matchs very closely with the FSAR analysis

Table 4.5-3 RWAP 100 pcm/sec Time Sequence of Events

Event	Time (seconds)	
	Dominion	FSAR
Reactivity Insertion at 100 pcm/sec	0.0	0.0
Reactor Trip Signal Initiated	1.17*	1.29*

* *Trip on high neutron flux*

Figure 4.5-1 RWAP – 1 pcm/sec Nuclear Power

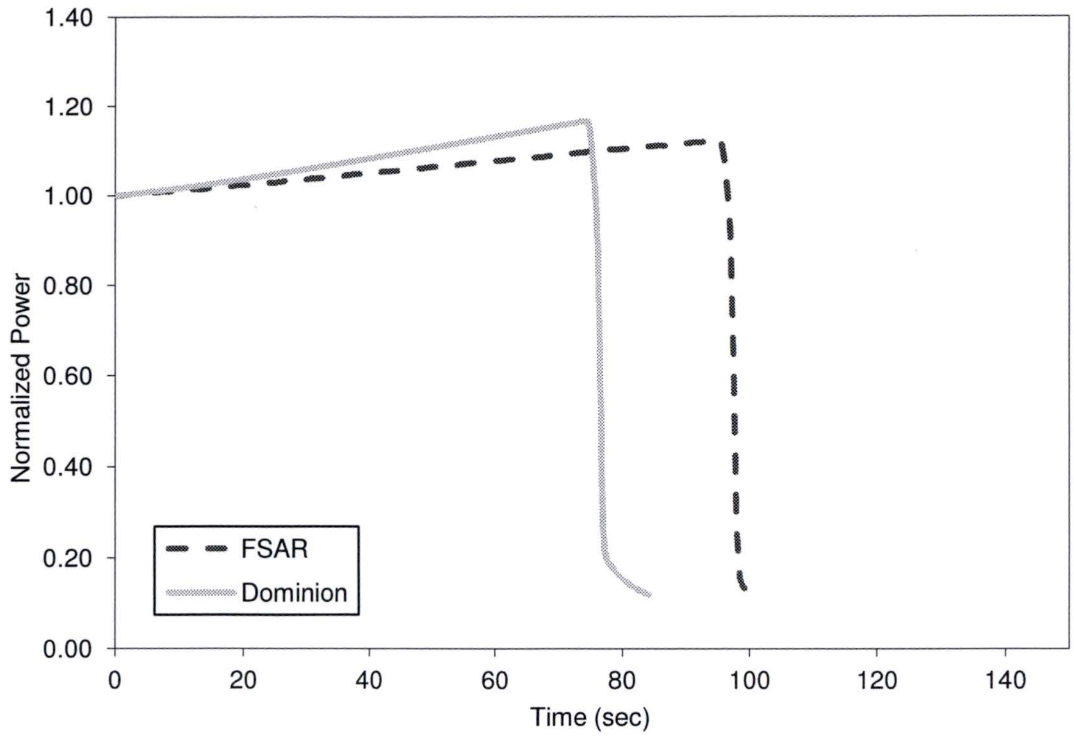


Figure 4.5-2 RWAP – 1 pcm/sec Pressurizer Pressure

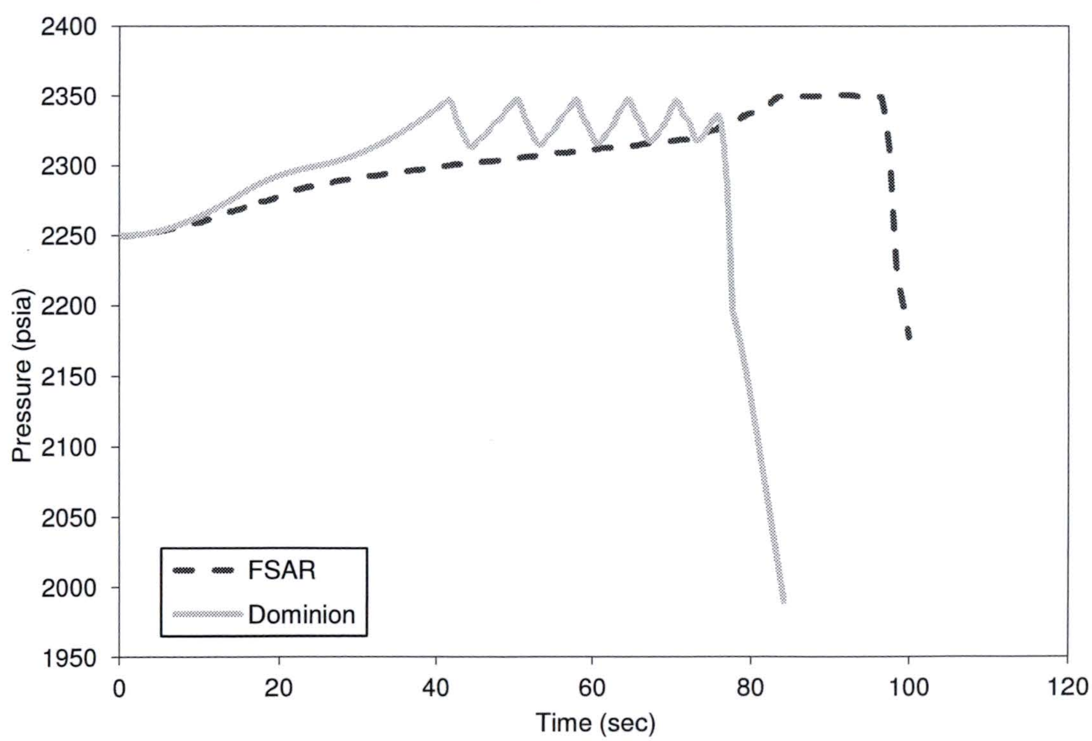


Figure 4.5-3 RWAP – 1 pcm/sec Vessel Average Temperature

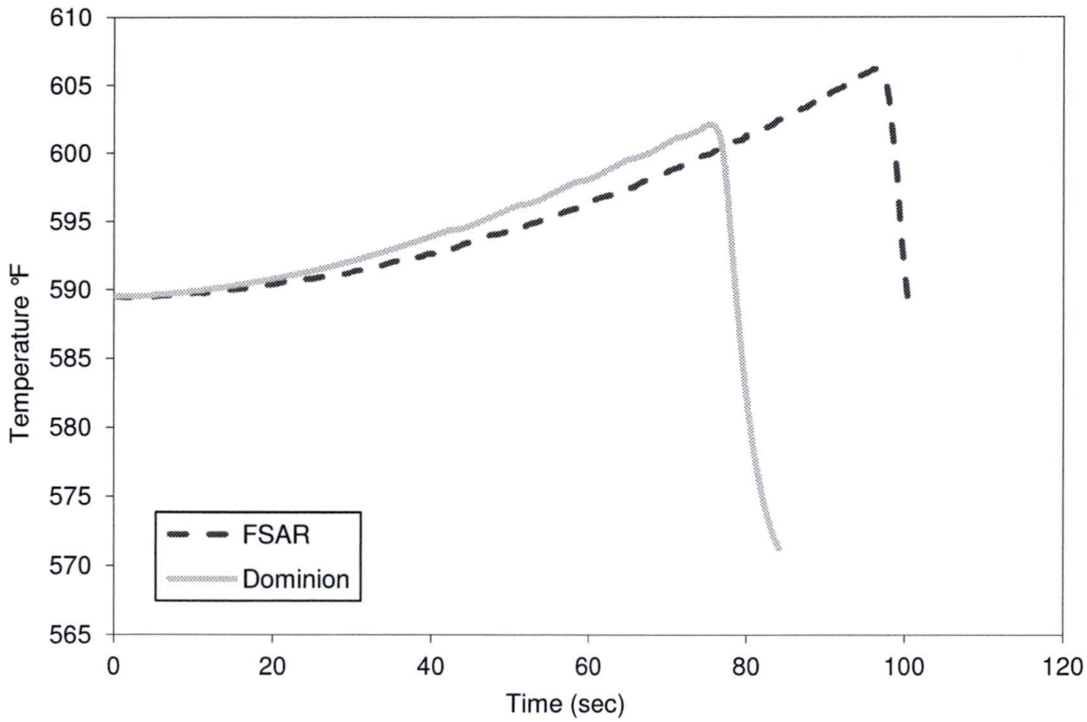


Figure 4.5-4 RWAP – 100 pcm/sec Nuclear Power

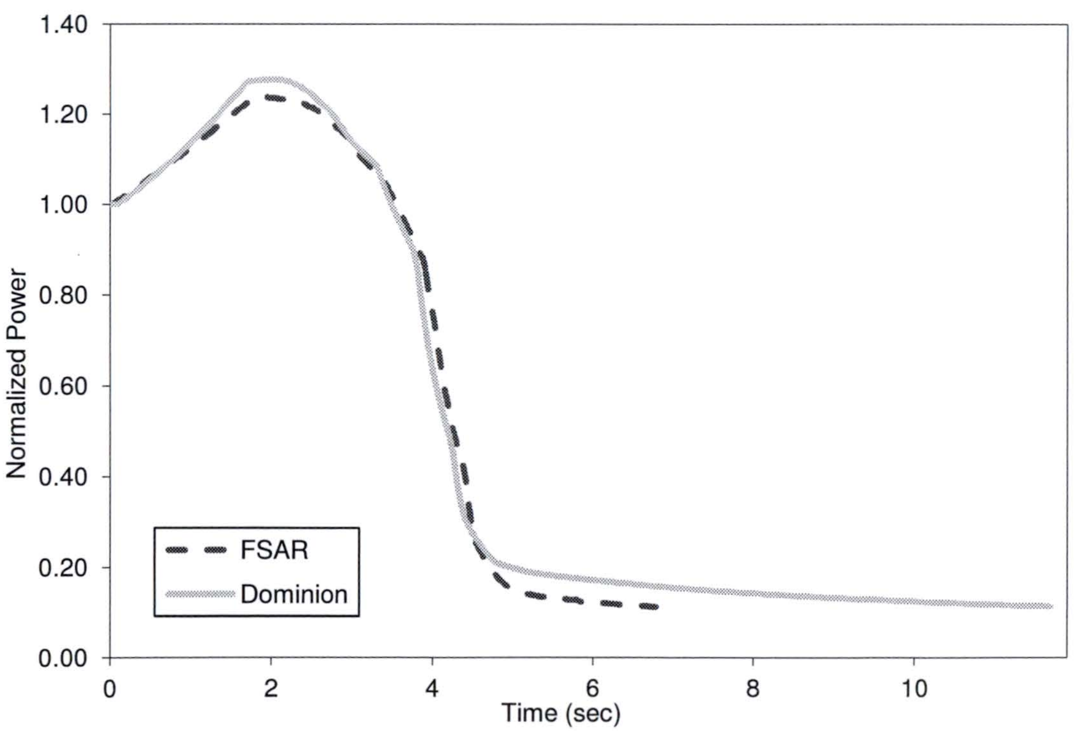


Figure 4.5-5 RWAP – 100 pcm/sec Pressurizer Pressure

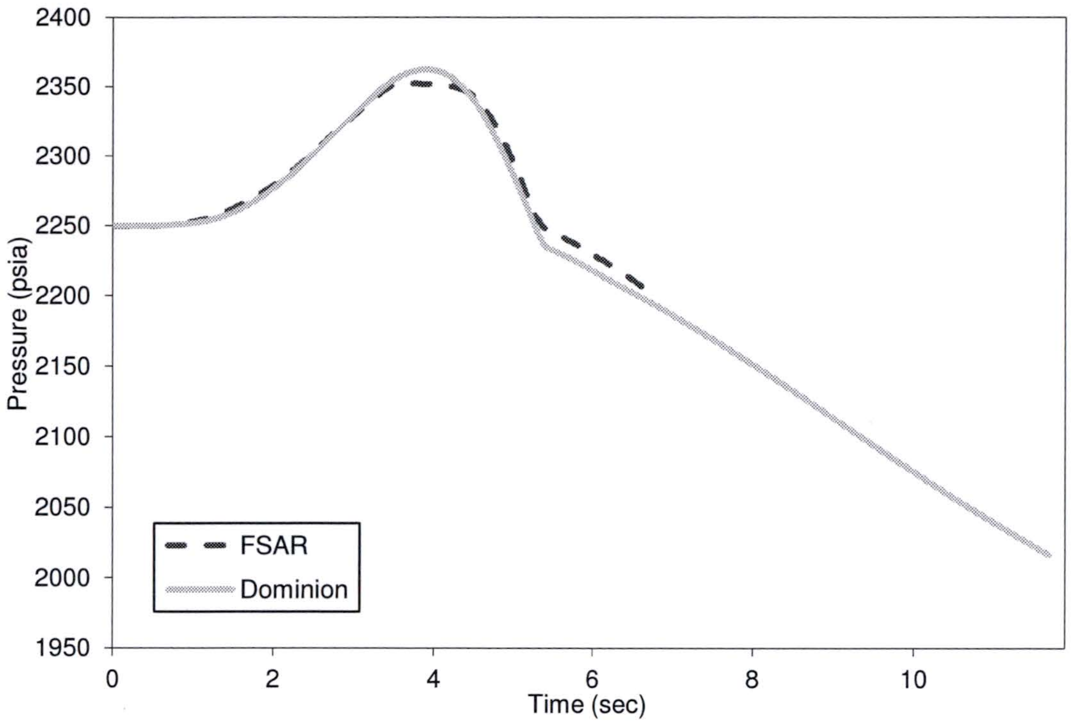
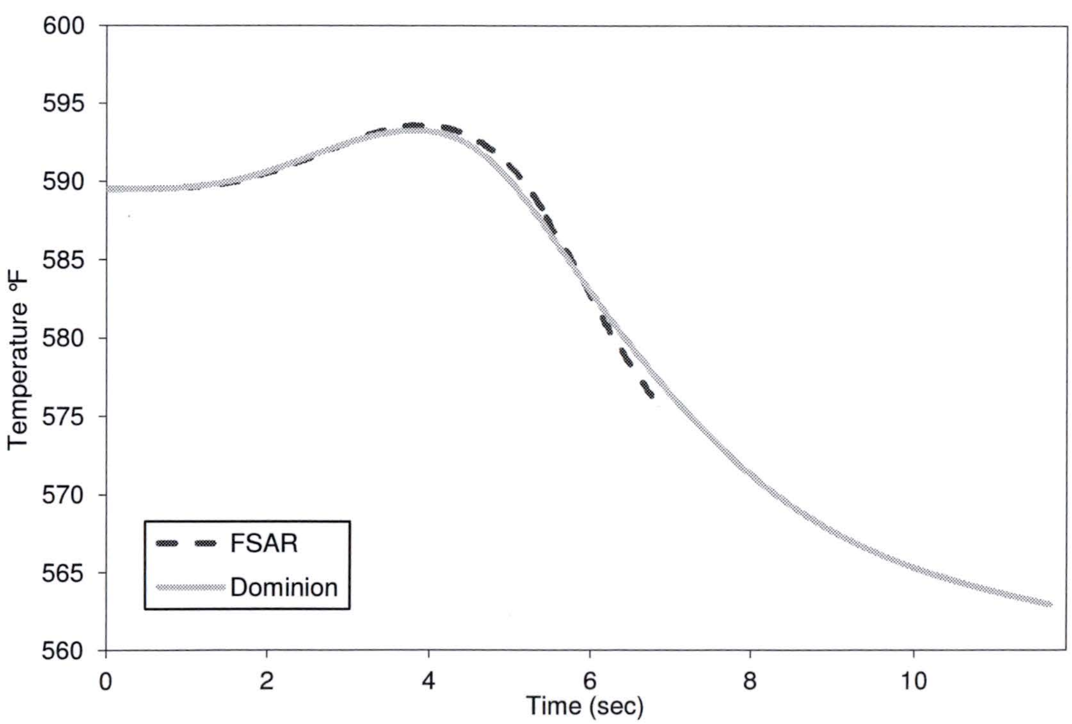


Figure 4.5-6 RWAP – 100 pcm/sec Vessel Average Temperature



Summary - RWAP

The Dominion Millstone model provides results that are similar to the FSAR analysis for the RWAP event. At higher insertion rates, the results match very well. At lower insertion rates, the power increases at a greater rate in the Dominion model than the FSAR model. However, the temperature increases to a higher peak in the FSAR analysis. The Dominion MPS3 analysis is presented for benchmark comparison, and does not replace the existing AOR.

4.6 Main Feedwater Line Break

The Main Feedwater Line Break (MFLB) event is defined as a break in a feedwater line large enough to prevent the addition of sufficient feedwater to the steam generators to maintain shell side fluid inventory in the steam generators. If the break is postulated in a feedline between the check valve and the steam generator, fluid from the steam generator may also be discharged through the break. Depending upon the size of the break and the plant operating conditions at the time of the break, the break could cause either a RCS cooldown (by excessive energy discharge through the break) or a RCS heatup. The FSAR analysis presents the RCS heatup scenario.

A major feedwater line rupture is classified as an ANS Condition IV event as discussed in FSAR Section 15.0.1. A main feedwater line rupture is the most limiting event in the decrease in secondary heat removal category. Based on a number of prior analyses, it is concluded in FSAR Section 15.2.8 that the most limiting feedwater line rupture is a double ended rupture of the largest feedwater line, occurring at full power with and without offsite power available. Cases both with and without offsite power available are simulated for the benchmark analysis herein.

The MFLB transient is initiated in the Dominion model by opening the break on steam generator 1 and stopping main feedwater to all four steam generators (SG) as the reactor is operating at full power. Upon transient initation, the break path opens and allows blowdown from the faulted SG secondary side inventory to the atmosphere. The input parameters are the same as those used in the FSAR Chapter 15 analyses as shown in Table 4.6-1 below.

The results for the MFLB transient need to demonstrate that the reactor core remains covered, the RCS does not overpressurize, and the AFW system is able to adequately remove decay heat.

Table 4.6-1 MFLB Input Summary

Parameter	Value	Notes
Initial Conditions		
Core Power (MW)	3723	Includes 2% uncertainty
RCS Flow (gpm)	363,200	Thermal Design Flow
Vessel T_{AVG} (F)	594.5	Nominal + 5 °F
RCS Pressure (psia)	2300	Nominal + 50 psi
Pressurizer Level (%)	71.6	Nominal + 7.6%
SG Level (%)	62 38	Nominal + 12% (Faulted Loop) Nominal – 12% (Intact Loops)
SG tube plugging (%)	10	Maximum
Pump Power (MW/pump)	5.0	Maximum
Assumptions/Configuration		
Low-Low Level Reactor Trip Setpoint	0%	% narrow range span in faulted SG
Pressurizer: sprays, heaters, PORVs	-	Not credited
AFW Temperature (F)	120	Max value
Auxiliary feedwater flow rate (gpm)	-	Variable as function of SG press.
Main Feedwater	0	All MFW assumed lost at time of break
Reactivity Parameters		
Doppler Reactivity Feedback Moderator Feedback	Most Negative	Conservative assumption

Results – MFLB Case With Offsite Power Available

The results for the MFLB case with offsite power available are presented on Figure 4.6-1 through Figure 4.6-8. The nuclear power response (Figure 4.6-1) predicted by the Dominion model is in good agreement with the FSAR data, with the reactor trip occurring on low-low steam generator level. There is a return to power between approximately 100-200 seconds due primarily to moderator reactivity feedback effects during the primary side cooldown prior to steam line isolation (SLI). After that time, the core remains subcritical for the duration of the transient.

The response for pressurizer pressure and pressurizer water volume are shown on Figure 4.6-2 and Figure 4.6-3. The Dominion results trend well with the FSAR results for pressurizer pressure and water volume. One difference is a brief increase in pressurizer pressure and associated insurge into the pressurizer around the point of reactor trip for the Dominion case. This increase occurs due to differences in the primary-to-secondary heat transfer following the reactor and turbine trips between the MNSG FSAR model and the Dominion SNSG. The SNSG responds more quickly to the decrease in secondary side level following the loss of main feedwater compared to the MNSG, which initially

experiences less reduction in SG level and associated heat transfer. This effect only occurs for a relatively brief duration. Eventually, steam line isolation (SLI) occurs on low steam line pressure resulting in a primary side heatup as the intact SGs repressurize. Pressurizer pressure increases until the pressurizer safety valve (PSV) setpoint is reached and remains essentially constant at the PSV relief pressure until a downturn in pressure occurs near the end of the transient. This indicates the termination of the event as sufficient cooling is being provided by auxiliary feedwater (AFW) for the removal of primary side energy.

The hot leg and cold leg temperature response is shown on Figure 4.6-4 for the faulted loop and on Figure 4.6-5 for the intact loops. There is good agreement between the Dominion and FSAR cases with temperatures exhibiting the same trends throughout the event and deviating only slightly prior to SLI, which has a negligible effect on the overall results for this comparison due to the long term nature of this event. As noted for the pressure response discussion above, the temperatures are decreasing at the end of the transient indicating adequate long term heat removal.

The Dominion RCS flow fraction results are shown on Figure 4.6-6. Since power to the reactor pumps is not lost for this case, flow is maintained throughout the transient and varies only with coolant conditions. The Dominion case is in good agreement with the FSAR data throughout the transient.

The secondary system pressure response is presented on Figure 4.6-7 where SG pressure increases briefly following the reactor trip then decreases due to the loss of fluid mass through the feed line break. After SLI occurs, the intact SG pressure increases to the MSSV setpoint while the faulted SG pressure continues to decrease to atmospheric pressure as the remaining fluid mass is depleted. The Dominion and FSAR cases show good agreement as both the magnitude and trends of faulted and intact loops are consistent following the point of reactor trip and subsequent SLI.

Figure 4.6-8 shows excellent agreement between the main feedwater break flow rate response in both the Dominion and FSAR case. One difference is seen around the point of reactor trip over a period of approximately 12 seconds that is related to the steam generator modeling differences. As discussed relative to the pressurizer pressure response, the Dominion SNSG model results in a faster reduction in liquid level and more rapid increase in break flow quality such that flow falls off more quickly as the break is uncovering. After this brief transition period the break flow rates continue to agree well and this difference has a negligible effect on the overall transient response.

Figure 4.6-1 MFLB – Nuclear Power (case with power)

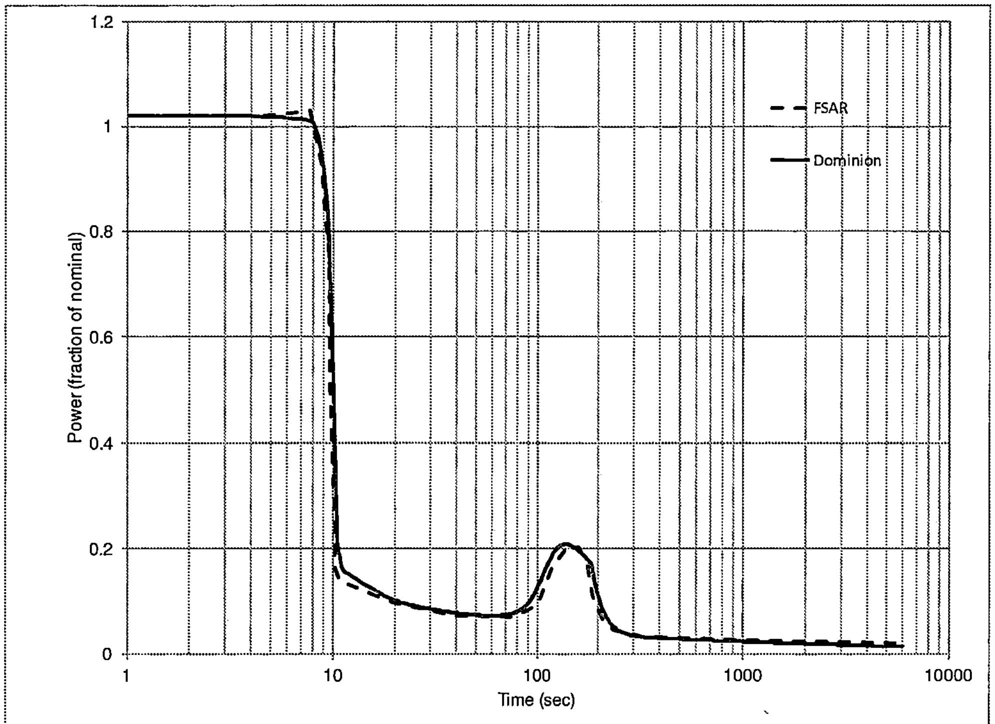


Figure 4.6-2 MFLB – Pressurizer Pressure (case with power)

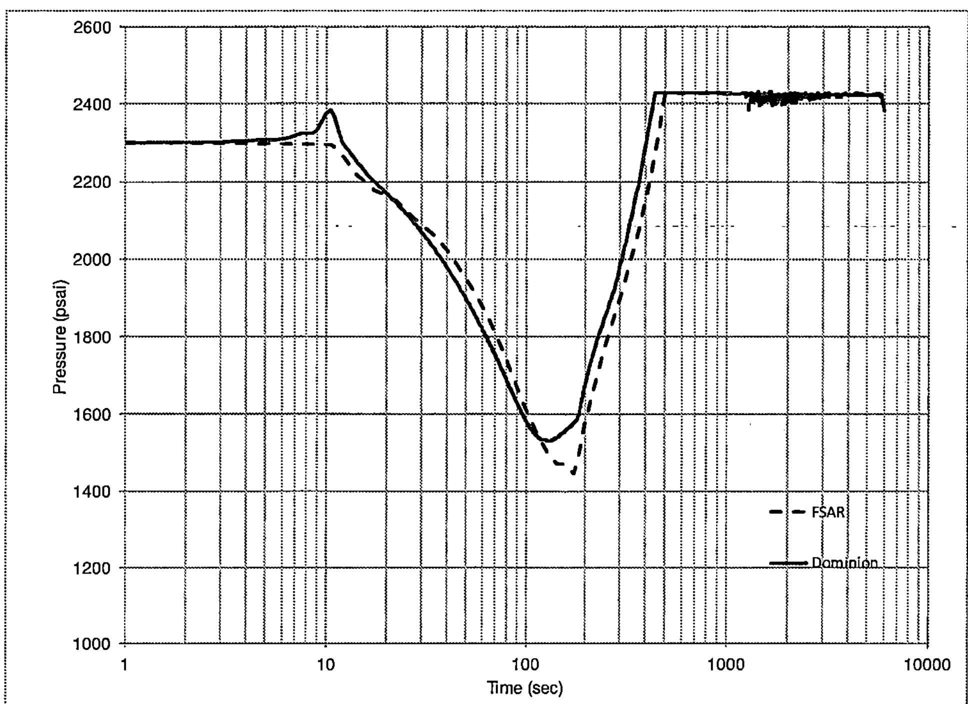


Figure 4.6-3 MFLB – Pressurizer Liquid Volume (case with power)

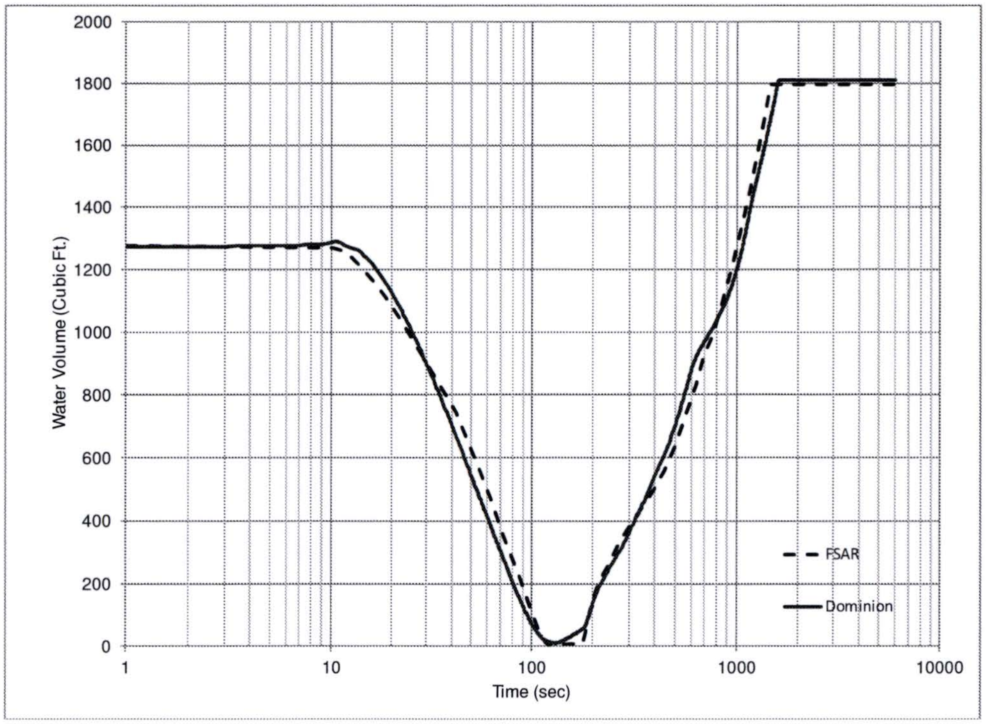


Figure 4.6-4 MFLB – RCS Temperatures – Faulted Loop (case with power)

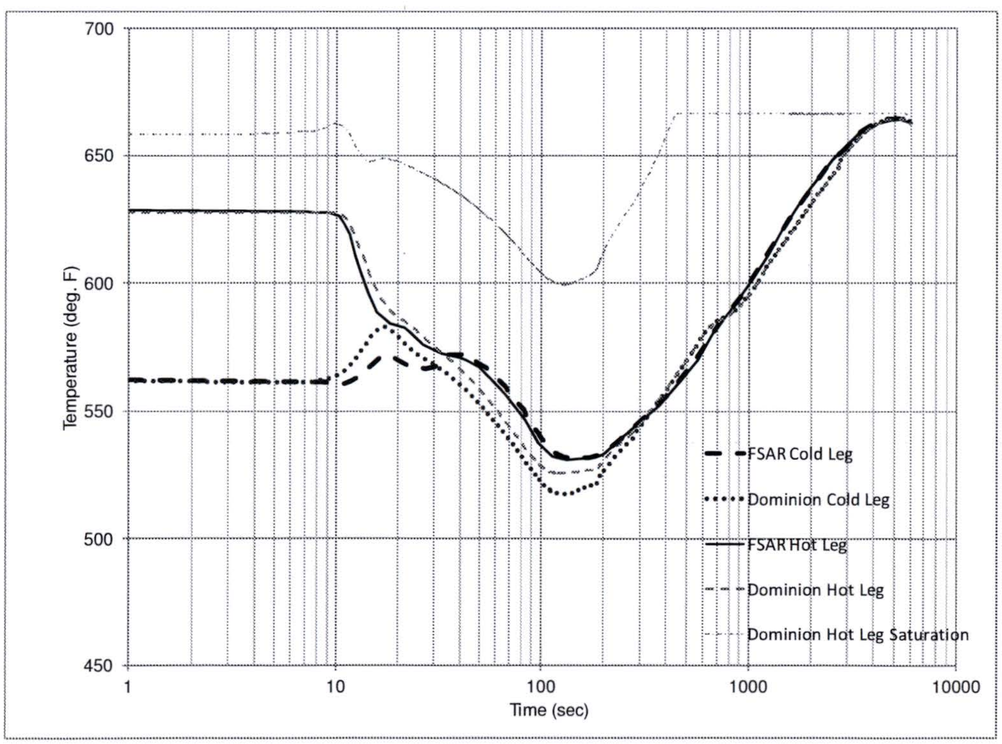


Figure 4.6-5 MFLB – RCS Temperatures – Intact Loops (case with power)

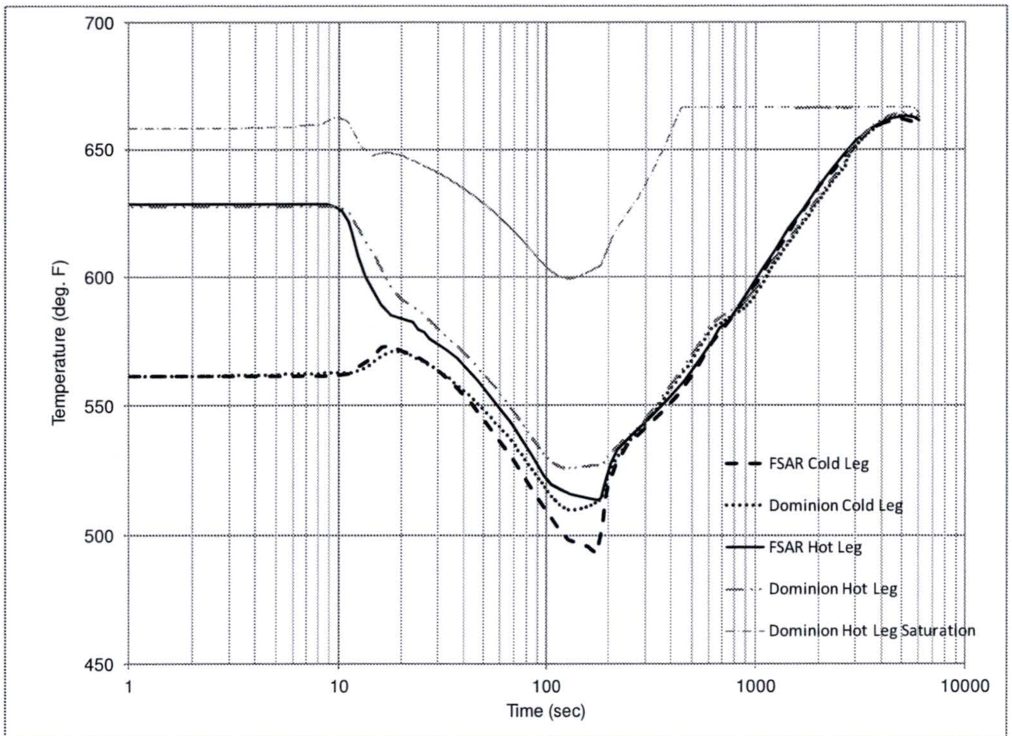


Figure 4.6-6 MFLB – Normalized RCS Flow (case with power)

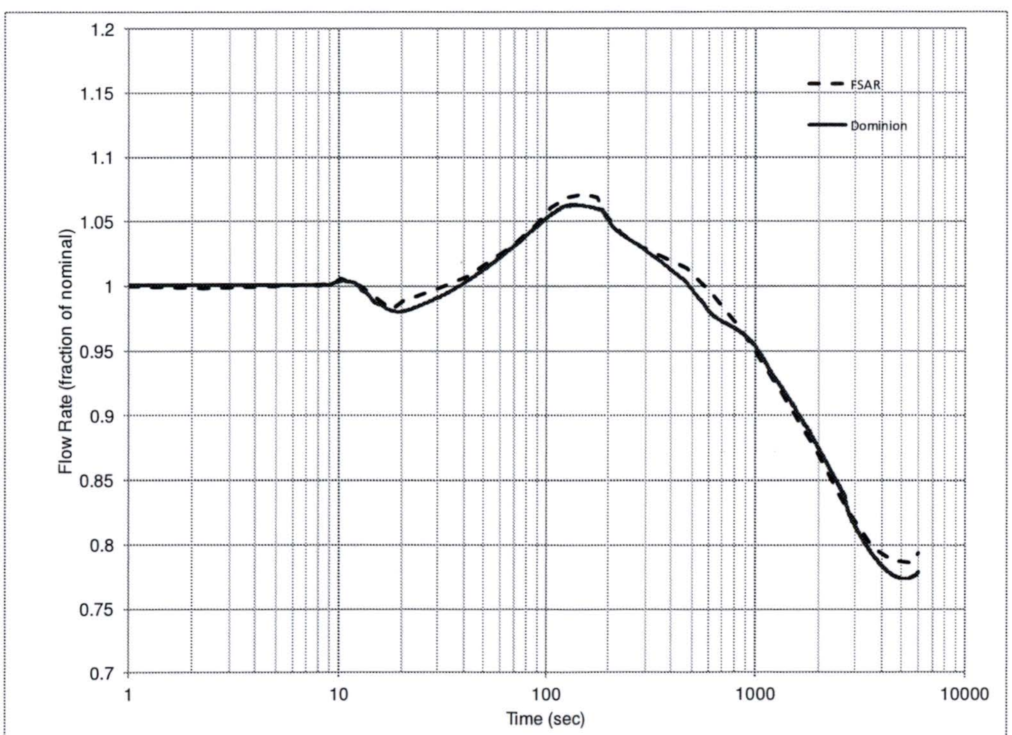


Figure 4.6-7 MFLB – Steam Generator Pressure (case with power)

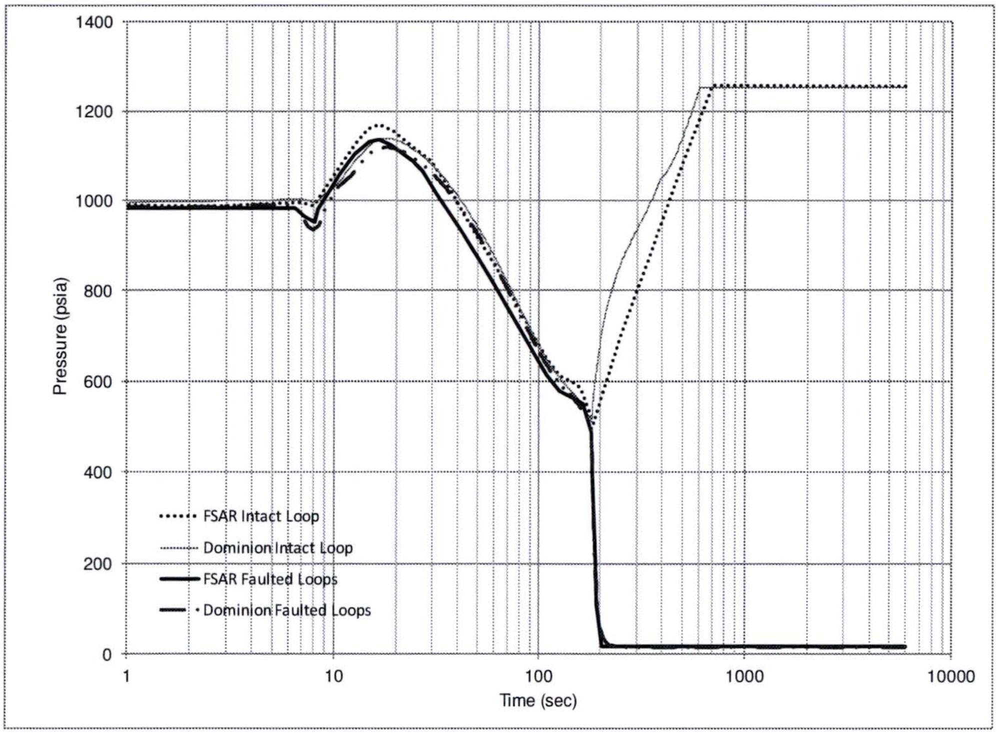
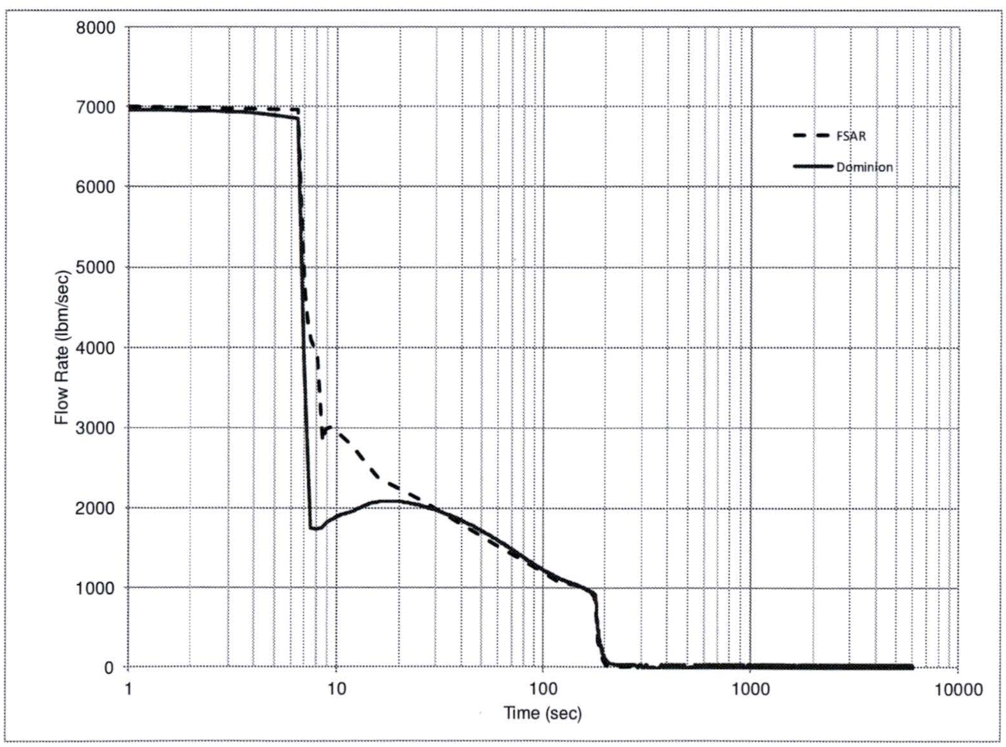


Figure 4.6-8 MFLB – Feed Line Break Flow (case with power)



Results – MFLB Case Without Offsite Power Available

The results for the MFLB case without offsite power are similar to the case with power available but are generally less limiting for long-term primary side heat removal since the RCPs are not running and adding heat to the primary side fluid.

The nuclear power response (Figure 4.6-9) predicted by the Dominion case is in good agreement with the FSAR data. As shown for this case, there is no return to power during the early portion of the cooldown due to less reactivity feedback and the reactor core remains subcritical for the duration of the transient.

The responses for pressurizer pressure and primary side temperatures are shown on Figures 4.6-10 through 4.6-12. As discussed above for the case with offsite power, the Dominion case exhibits a brief increase in pressure around the time of reactor trip but otherwise the response is similar to the FSAR case with long-term pressure maintained at the PSV setpoint. The hot leg and cold leg temperature response shown on Figure 4.6-11 and Figure 4.6-12 also demonstrate similar trends. One difference is that the cooldown that occurs prior to SLI is more pronounced for the Dominion case, which is primarily attributed to higher primary to secondary heat transfer. This is the result of a somewhat slower rate of flow decrease following the RCP trip for the Dominion case, resulting in maintaining better primary side heat removal during that phase. In addition, SLI occurs slightly later in the Dominion case, which also enhances heat removal prior to the time of isolation. Similarly, the delay in break isolation delays the point of steam generator dry-out, such that additional heat is extracted through the break. As shown, these differences have little effect on the long-term temperature response as the Dominion and FSAR temperatures agree very well through the end of the transient. This case results in lower long-term temperatures, as the RCPs trip due to the loss of offsite power and do not contribute any pump heat to the system.

The secondary system pressure response, presented in Figure 4.6-13, is similar to the response for the case with power. Since there is less primary side heat generation and heat removal for this case, the SG depressurizes more quickly and SLI occurs earlier in the transient, compared to the case with offsite power available. Long term trends are similar with heat removal via the MSSVs on the intact SGs. There is good agreement between the Dominion and FSAR cases with the FSAR case depressurizing slightly faster prior to SLI.

The Dominion RCS flow fraction results are in good agreement with the FSAR result as shown on Figure 4.6-14, where the loss of flow associated with the loss of power and associated RCP trip are seen. As noted above, the flow decreases somewhat more

quickly for the FSAR case, which appears to affect the intermediate temperatures but does not impact the long term temperature results.

Figure 4.6-15 shows good agreement between the main feedwater break flow rate response in both the Dominion and FSAR data. The small differences seen around the point of reactor trip are due to differences in the Dominion SNSG and the FSAR MNSG as discussed above for the case with power available. That is, the Dominion SNSG model results in a faster reduction in liquid level and more rapid increase in break flow quality such that flow falls off more quickly as the break is uncovering. After this brief transition period the break flow rates continue to agree well and this difference has a negligible effect on the overall transient response

Figure 4.6-9 MFLB – Nuclear Power (case without power)

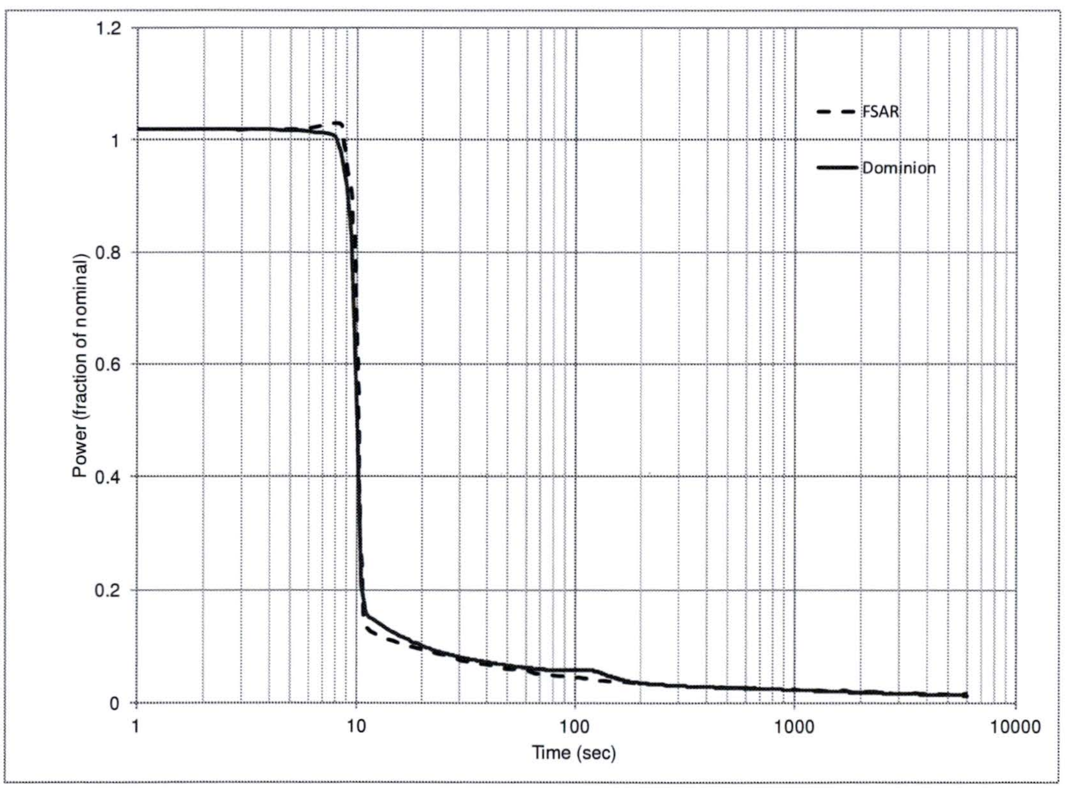


Figure 4.6-10 MFLB – Pressurizer Pressure (case without power)

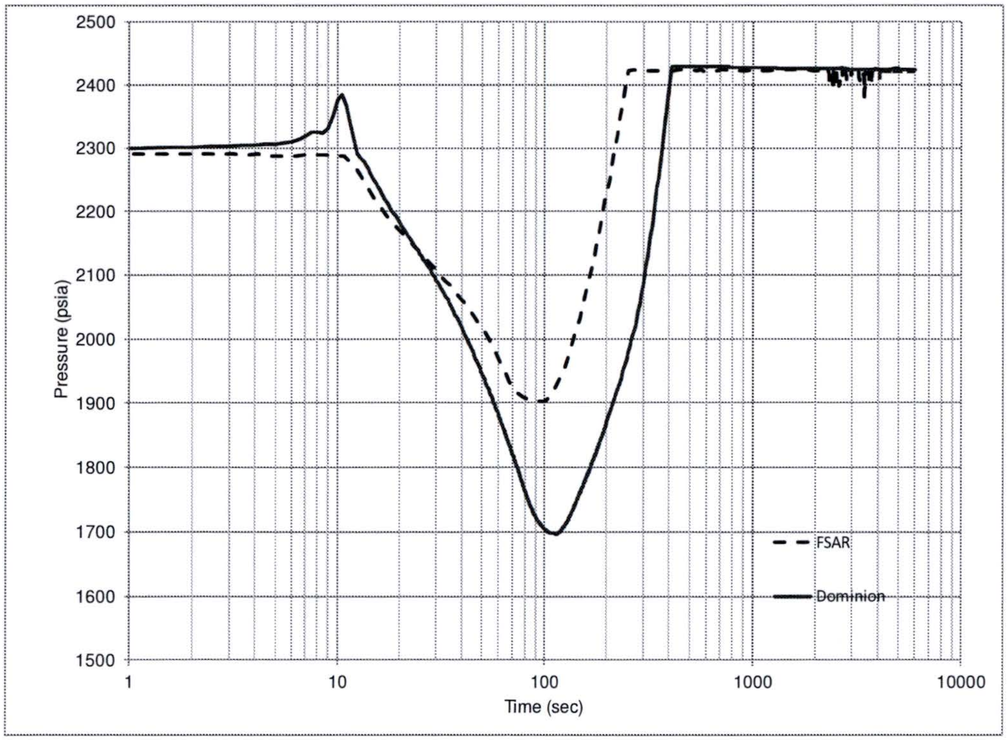


Figure 4.6-11 MFLB – RCS Temperatures – Faulted Loop (case without power)

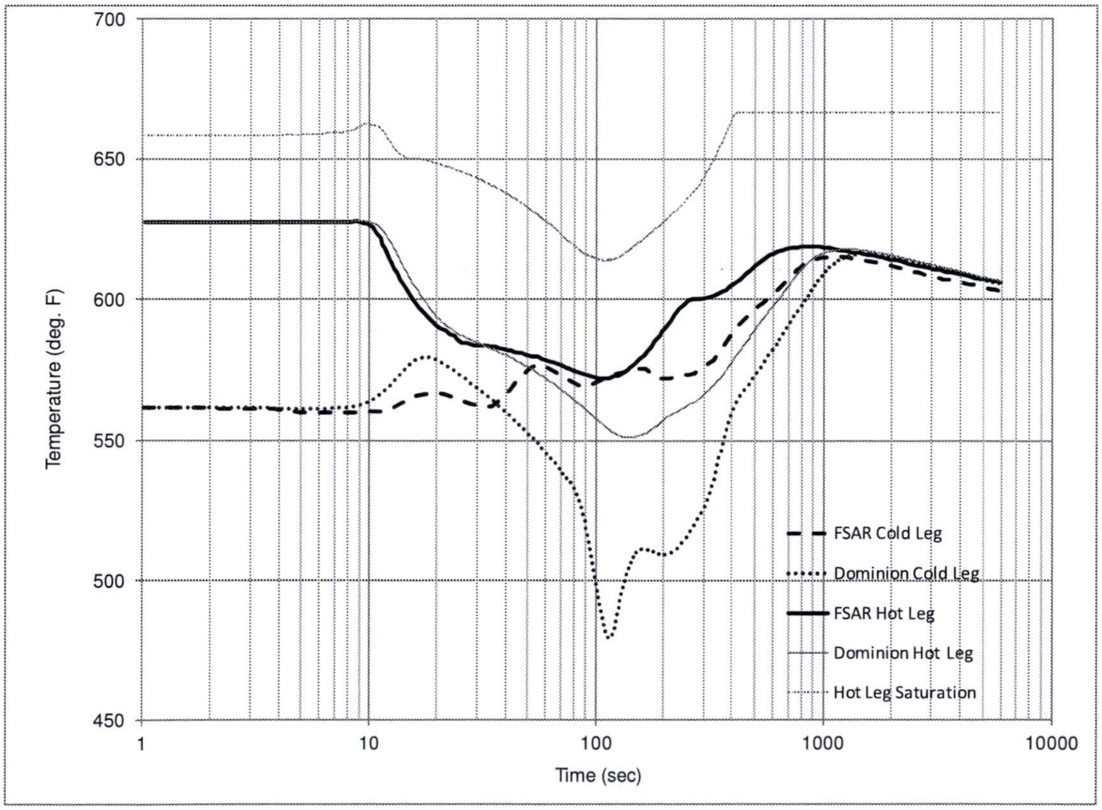


Figure 4.6-12 MFLB – RCS Temperatures – Intact Loops (case without power)

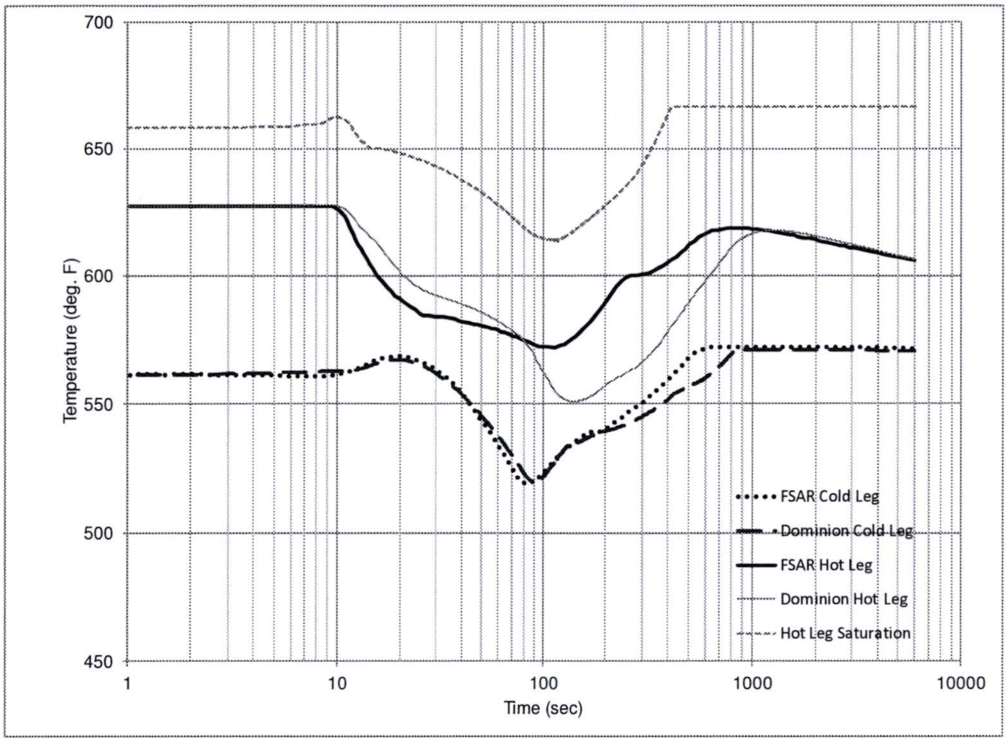


Figure 4.6-13 MFLB – Steam Generator Pressure (case without power)

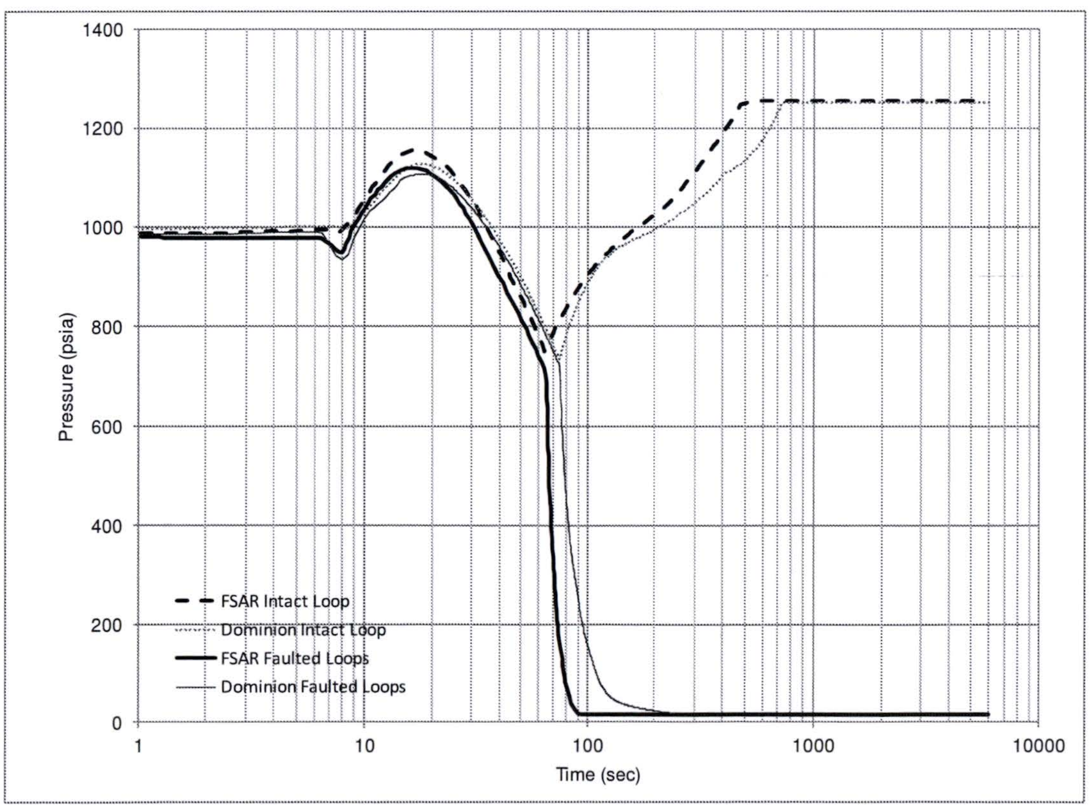


Figure 4.6-14 MFLB – Normalized RCS Flow (case without power)

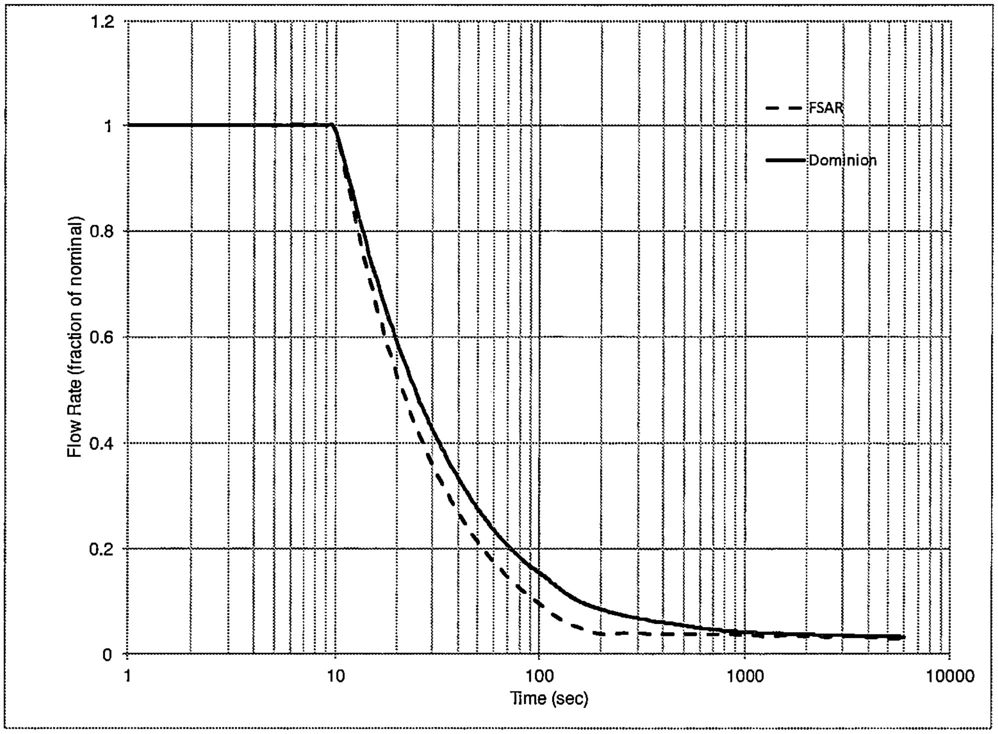
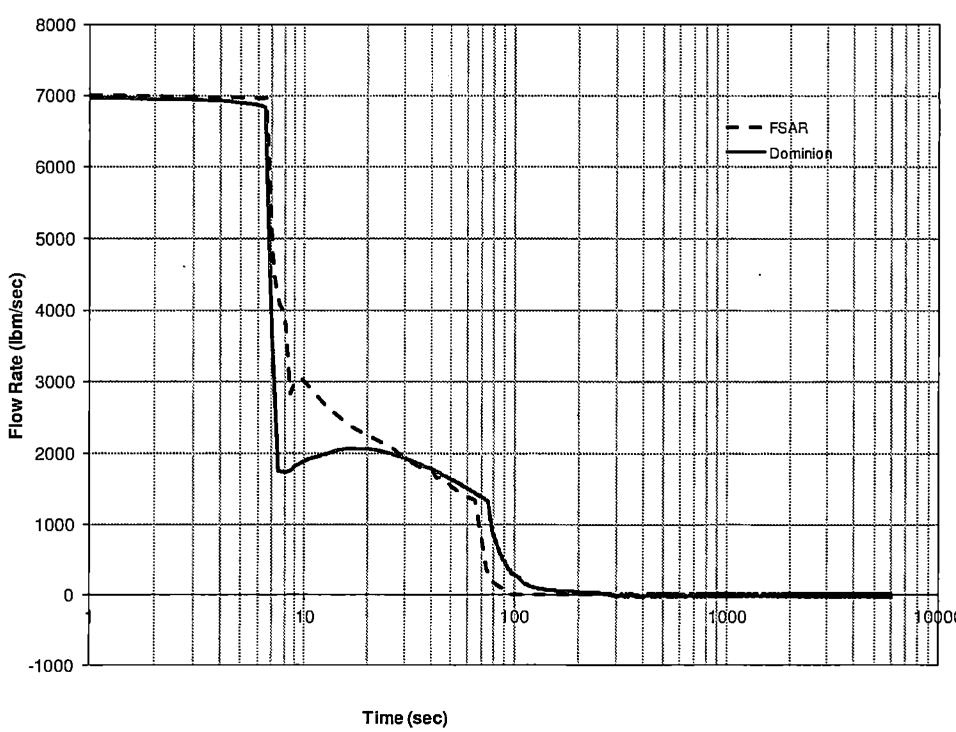


Figure 4.6-15 MFLB – Feed Line Break Flow (case without power)



Summary - MFLB

The Dominion Millstone model provides results that are similar to the FSAR analysis for the MFLB event. Two cases are analyzed, one with offsite power available and another without offsite power. Some small differences are observed early in the transient for RCS temperatures, which are attributable to differences in the Dominion SNSG model and the FSAR MNSG model; however, these differences have a negligible effect on the long-term primary side heat removal and associated temperature response. All acceptance criteria are satisfied for both cases.

4.7 Steam Generator Tube Rupture

The Steam Generator Tube Rupture (SGTR) event is a breach of the Reactor Coolant Pressure (RCP) Boundary via a steam generator (SG) tube. The accident examined is the complete severance of a single steam generator tube. Such a break results in a loss of Reactor Coolant System (RCS) fluid to the secondary side of the affected SG. Two different analyses were performed for the SGTR event including a thermal-hydraulic case to determine the mass releases to atmosphere for radiation dose, and a case for the margin to SG overfill. These analysis cases are described in FSAR Sections 15.6.3.2.2 and 15.6.3.2.1, respectively, where it is noted that the FSAR analyses are performed using the LOFTTR2 computer code. The SGTR is classified as an ANS Condition IV event as discussed in FSAR Section 15.0.1.

The SGTR transient is initiated from full power by modeling the complete severance of a SG tube. Upon transient initiation, the break path opens and allows fluid to flow from the RCS primary into the ruptured SG secondary. Several operator actions are credited in the analysis to mitigate the effect of the transient. These operator actions and other input parameters assumed for this analysis are shown in Table 4.7-1 below.

Table 4.7-1 SGTR Input Summary

Parameter	Value	Notes
NSSS Power (MW)	3739	Includes 2% core power uncertainty; 16 MW reactor coolant pump power
RCS Flow (gpm)	363,200	Thermal Design Flow
Vessel T_{AVG} (F)	571.5	Low Tavg with coastdown
RCS Pressure (psia)	2200	Nominal - 50 psi
Pressurizer Level (%)	45.4	Consistent with Low Tavg
SG tube plugging (%)	0	Mass release case. 10% assumed for overfill case
Auxiliary feedwater flow rate (gpm)	1200	Maximum total
Loss of Offsite Power (LOOP)	Assumed	Occurs at reactor trip
Single failure	Relief valve failure	Mass Release – ADV fails open on ruptured SG at time of steam line isolation. Overfill – ADV bypass valve fails to function on two intact SGs.
Key Operator Actions		
Isolate AFW flow to the ruptured SG	See notes	Based on achieving target SG level
Isolate ruptured steam generator	25 minutes	After initiation of break
Isolate failed opened ADV (mass release case only)	20 minutes	After ADV fails
Initiate RCS cooldown	8 minutes	After ruptured SG is isolated
Initiate RCS Depressurization	3 minutes	After RCS cooldown is complete
Initiate SI flow termination	6 minutes	After RCS depressurization complete (or based on termination criteria)

Results – SGTR Mass Release Case

The results for the Mass Release case are provided on Figure 4.7-1 through Figure 4.7-9 and the Sequence of Events is presented in Table 4.7-2. The pressurizer pressure response is shown on Figure 4.7-1. The Dominion pressurizer pressure tracks closely with the FSAR data through most of the event. After SI is isolated near the end of the event, the pressures diverge as the primary and secondary side pressures equilibrate, with the Dominion pressure decreasing more due to the lower secondary side pressure (Figure 4.7-3). This phase of the event is discussed in additional detail below. Similarly, the pressurizer level response shown on Figure 4.7-2 shows similar trends between the Dominion response and the FSAR data. During the RCS cooldown phase (approximately 3200-3700 seconds), the FSAR level decreases more than the Dominion level. This occurs as the primary to secondary heat transfer is reduced for the Dominion case due to the loss of natural circulation flow on the ruptured SG and during a period when the SI flow is increasing significantly due to the reduction in RCS pressure. These points are discussed in additional detail below. After SI is isolated, the longer duration in break flow for the FSAR case is reflected in lower pressurizer level at the end of the transient. It is noted that these divergences occur late in the transient well after the flow path to atmosphere through the failed ADV has been isolated and do not have a significant effect on the overall results.

The SG pressure response for the ruptured and intact SGs is shown on Figure 4.7-3. As shown, the Dominion and FSAR pressures for the intact SGs (dashed lines) are in good agreement. For the ruptured SGs, there is also good agreement although the pressures diverge near the end of the transient. This is an indication that the primary-to-secondary heat transfer for the Dominion case is significantly reduced, which is due primarily to the effect of the RCS cooldown on natural circulation RCS flows and the associated heat transfer to the ruptured SG. After the failed ADV is isolated (2702 seconds), the pressure in the ruptured SG increases toward the relief valve setpoint for both the Dominion and FSAR cases. During this time period, the RCS cooldown is initiated on the intact SGs (3182 seconds) as indicated by the decreasing intact SG pressures, which ultimately reduces the heat transfer to the ruptured SG and slows the rate of pressure increase. As shown, the FSAR pressure slowly increases toward the relief valve setpoint while the Dominion pressure turns over and slowly begins to decrease, indicating that there is insufficient heat transfer from the RCS primary to sustain secondary side pressure. A better understanding of this is obtained from Figure 4.7-9, where the Dominion RCS flow rate for the ruptured loop decreases to a negligible value at approximately 3600 seconds. This occurs when the RCS temperature difference in the ruptured loop (Figure 4.7-5) has been reduced to a value that is unable to sustain appreciable natural circulation flow and reverse heat transfer is occurring

from the SG secondary into the RCS. Even though more energy is being removed by the ruptured SG for the FSAR case, the mass release rates to the atmosphere are very small for the remainder of the transient as shown on Figure 4.7-7. Natural circulation continues to be maintained in the intact RCS loops following the RCS cooldown and most of the heat removal occurs through the intact SGs as indicated by the mass release rates to the atmosphere shown on Figure 4.7-8.

The primary side temperature response is shown on Figure 4.7-4 for the intact SGs and Figure 4.7-5 for the ruptured SGs. As shown on Figure 4.7-4, the Dominion and FSAR results for the intact SG temperatures are in very good agreement. For the ruptured SGs, there is good agreement between the Dominion and FSAR cases until about 3600 seconds, at which time the Dominion cold leg temperature trends below the FSAR results. This is due to the negligible natural circulation flow rate discussed above that occurs on the ruptured loop as a result of the RCS cooldown. With the small RCS loop flow rate, the SI flow has a more noticeable effect on cold leg fluid temperature. The FSAR cold leg temperature for the ruptured loop also decreases well below the saturation temperature for the SG secondary, but is likely mixing with a higher natural circulation flow since some heat transfer is being sustained. Nevertheless, this has very little effect on the overall results for the transient since most of the heat removal occurs through the intact SGs during this time as discussed above and the ruptured SG has been previously isolated.

The break flow rate through the ruptured SG tube is shown on Figure 4.7-6. There is very good agreement between the Dominion and FSAR cases until the period late in the transient after SI has been isolated and the break flow is trending towards zero. This difference occurs late in the transient and the effect on the overall results is small since the ruptured SG has been isolated by this time. Additional discussion relative to this response is provided with the Overfill case below.

Table 4.7-2 SGTR – Mass Release Case Sequence of Events

Event	Time (seconds)	
	Dominion	**FSAR**
SG Tube Ruptured	0.0	0
Reactor Trip (OTDT)	208	135
SI Actuated	216	143
AFW Flow Initiated	268	195
Ruptured SG Steamline Isolated	1500	1500
Ruptured SG ADV fails open	1502	1502
Ruptured SG ADV isolated	2702	2702
RCS Cooldown Initiated	3182	3182
RCS Cooldown Terminated	3740	3690
RCS Depressurization Initiated	3920	3872
RCS Depressurization Terminated	3991	3952
SI Terminated	4352	4312
Total Break Flow Terminated	5635	6412

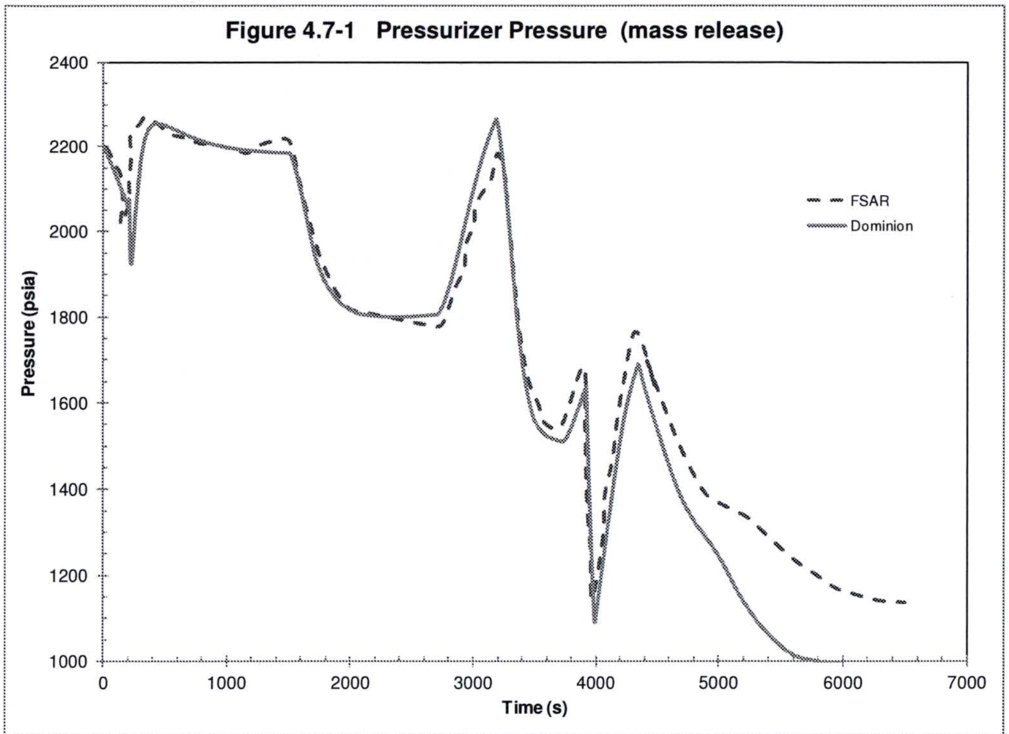


Figure 4.7-1 Pressurizer Pressure (mass release)
Pressure (psia)
2400
2200
2000
1800
1600
1400
1200
1000
0
1000
2000
3000
4000
5000
6000
7000
Time (s)
FSAR
Dominion

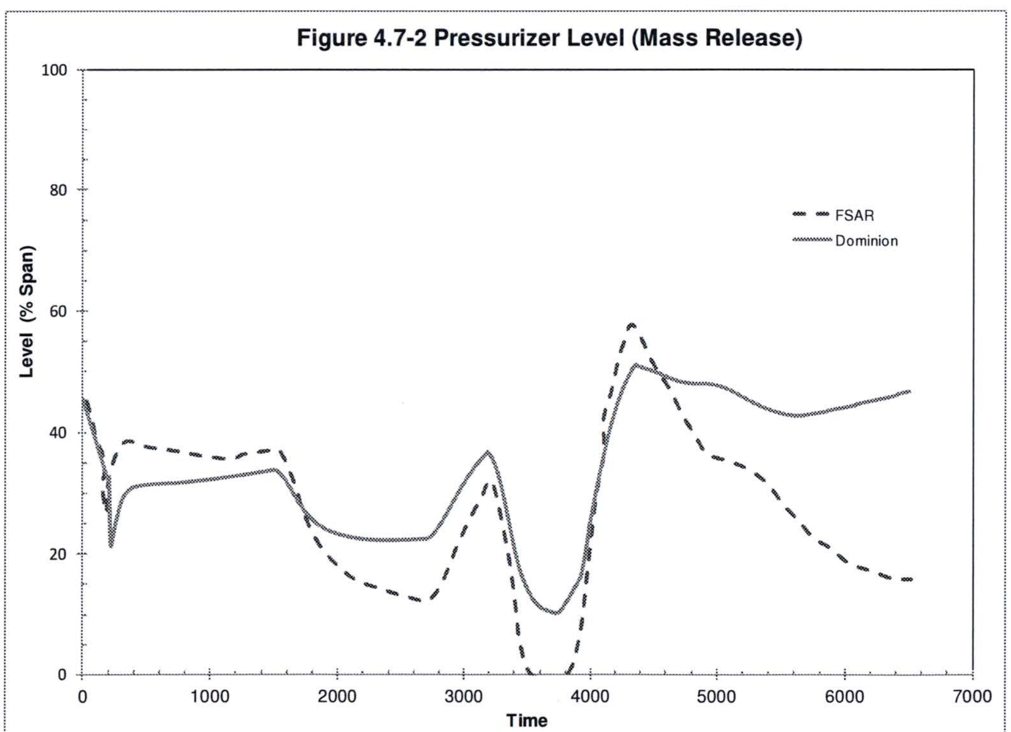


Figure 4.7-2 Pressurizer Level (Mass Release)
Level (% Span)
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
6000
7000
Time
FSAR
Dominion

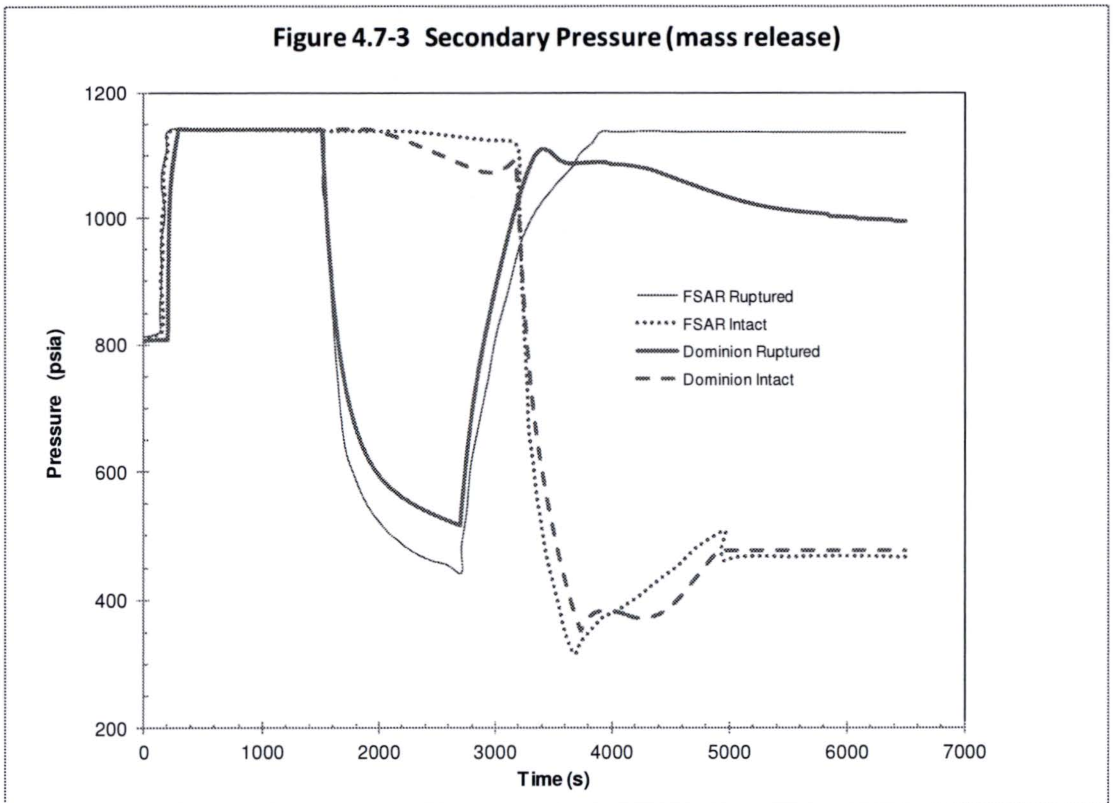


Figure 4.7-3 Secondary Pressure (mass release)
1200
1000
800
600
400
200
Pressure (psia)
0
1000
2000
3000
4000
5000
6000
7000
Time (s)
FSAR Ruptured
FSAR Intact
Dominion Ruptured
Dominion Intact

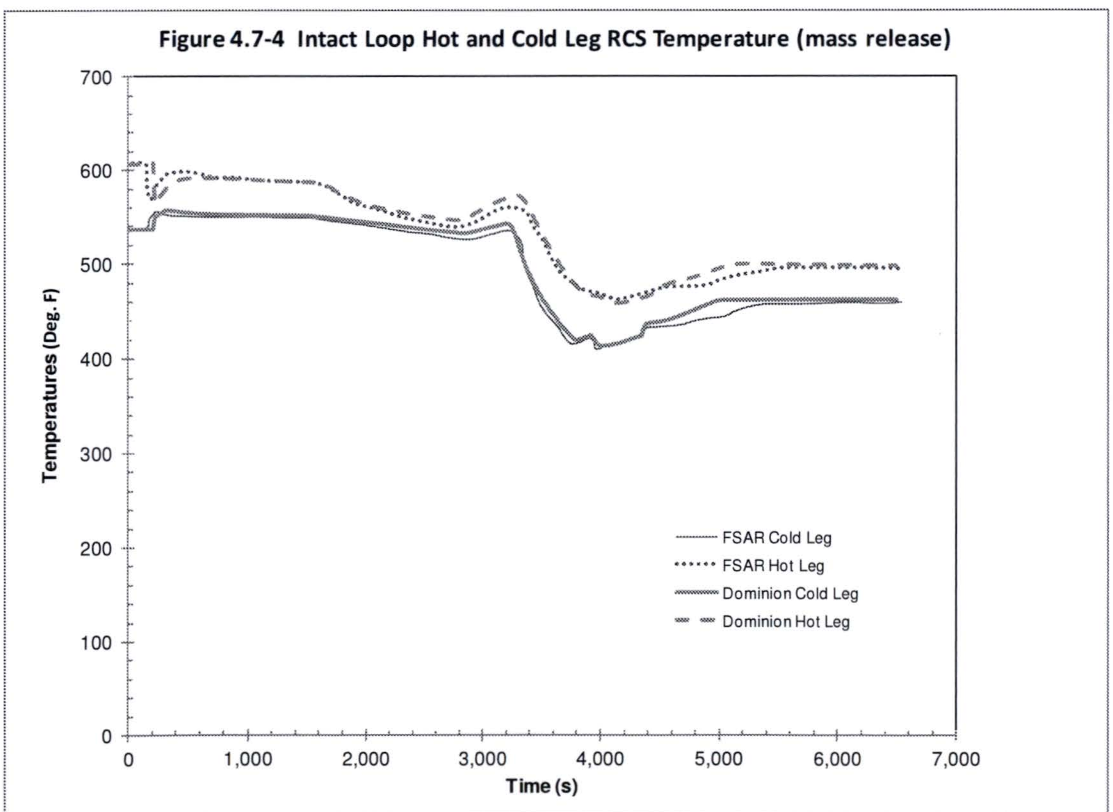


Figure 4.7-4 Intact Loop Hot and Cold Leg RCS Temperature (mass release)
700
600
500
400
300
200
100
0
Temperatures (Deg. F)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Time (s)
FSAR Cold Leg
FSAR Hot Leg
Dominion Cold Leg
Dominion Hot Leg

Figure 4.7-5 Ruptured Loop Hot and Cold Leg RCS Temperature (mass release)

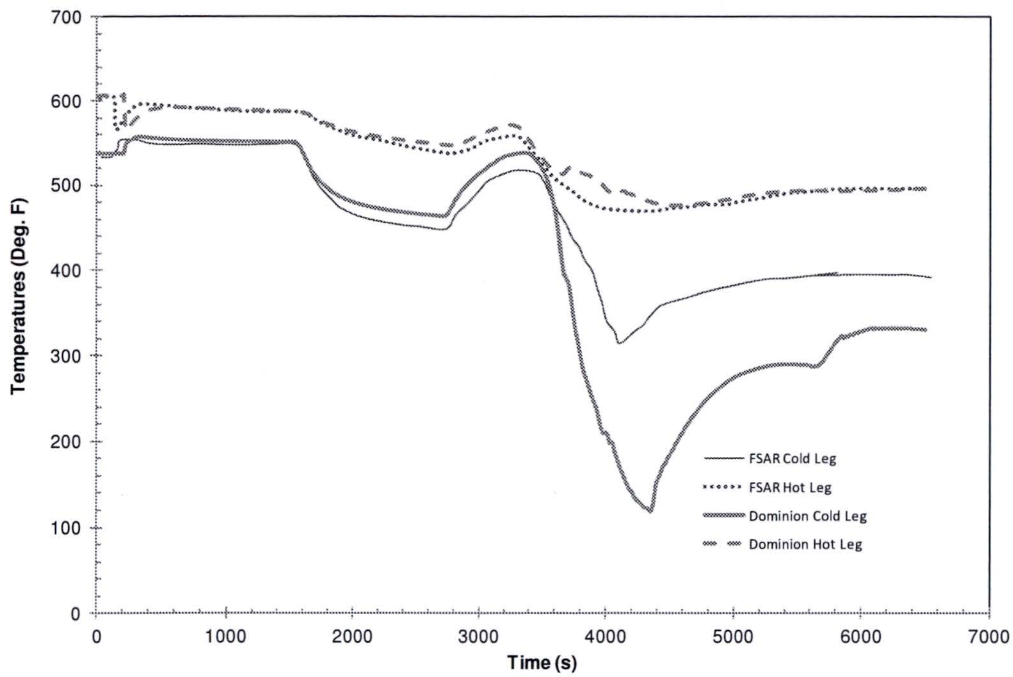


Figure 4.7-6 Primary to Secondary Break Flow Rate (mass release)

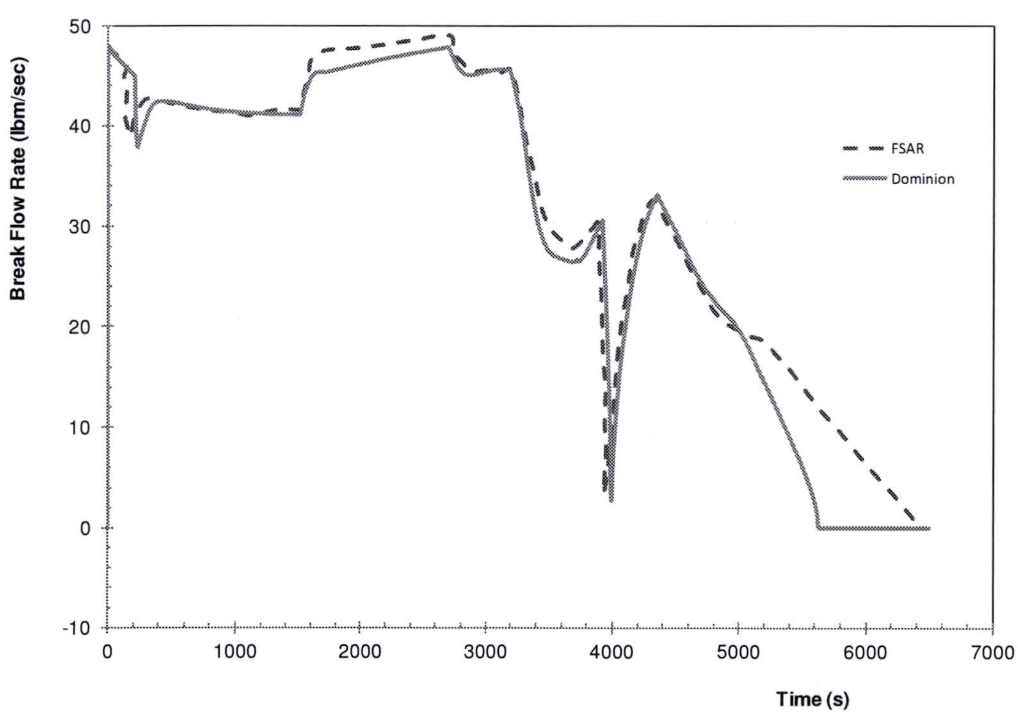


Figure 4.7-7 Ruptured SG Mass Release rate (mass release)

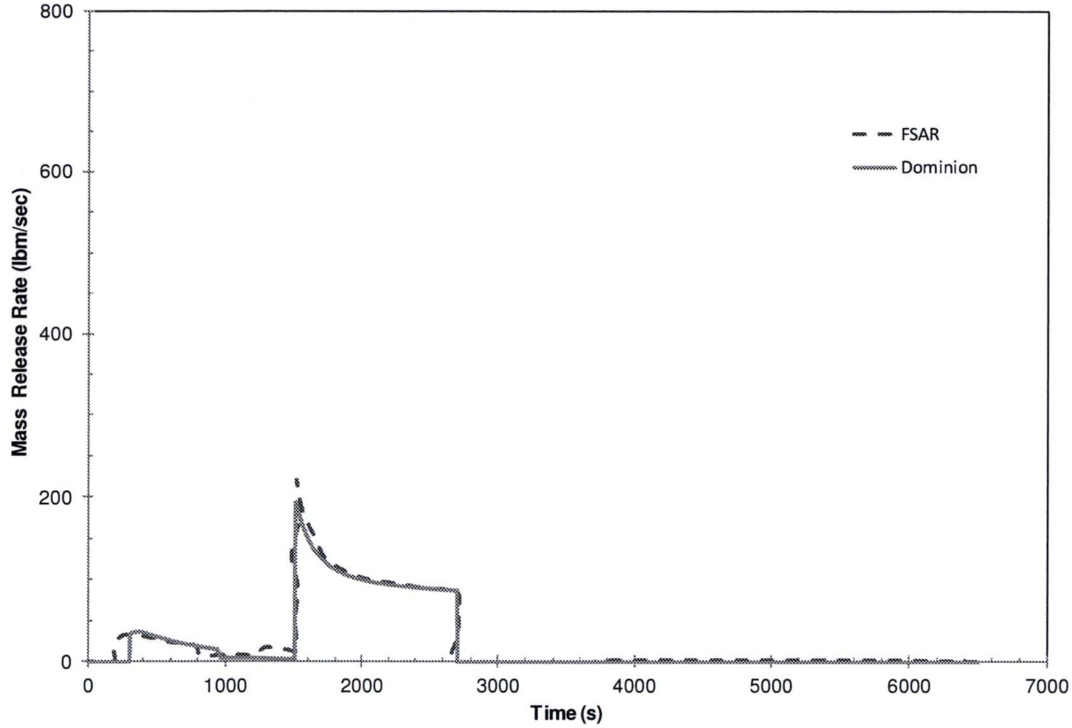
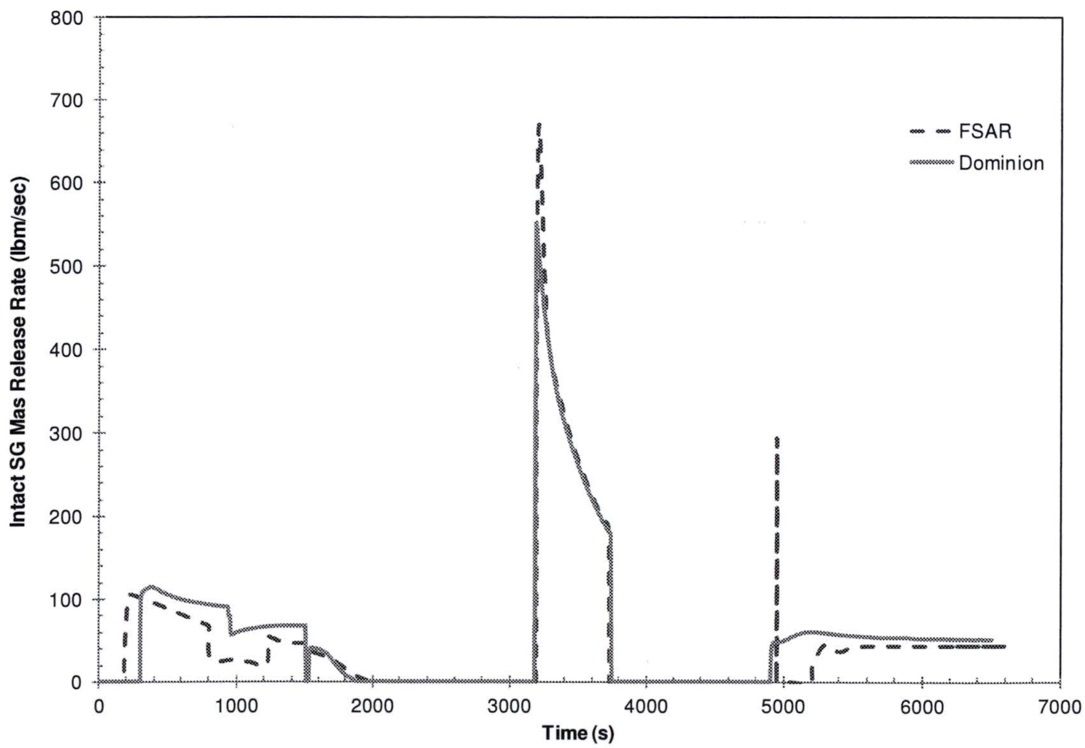


Figure 4.7-8 Intact SG Mass Release rate to Atmosphere (mass release)



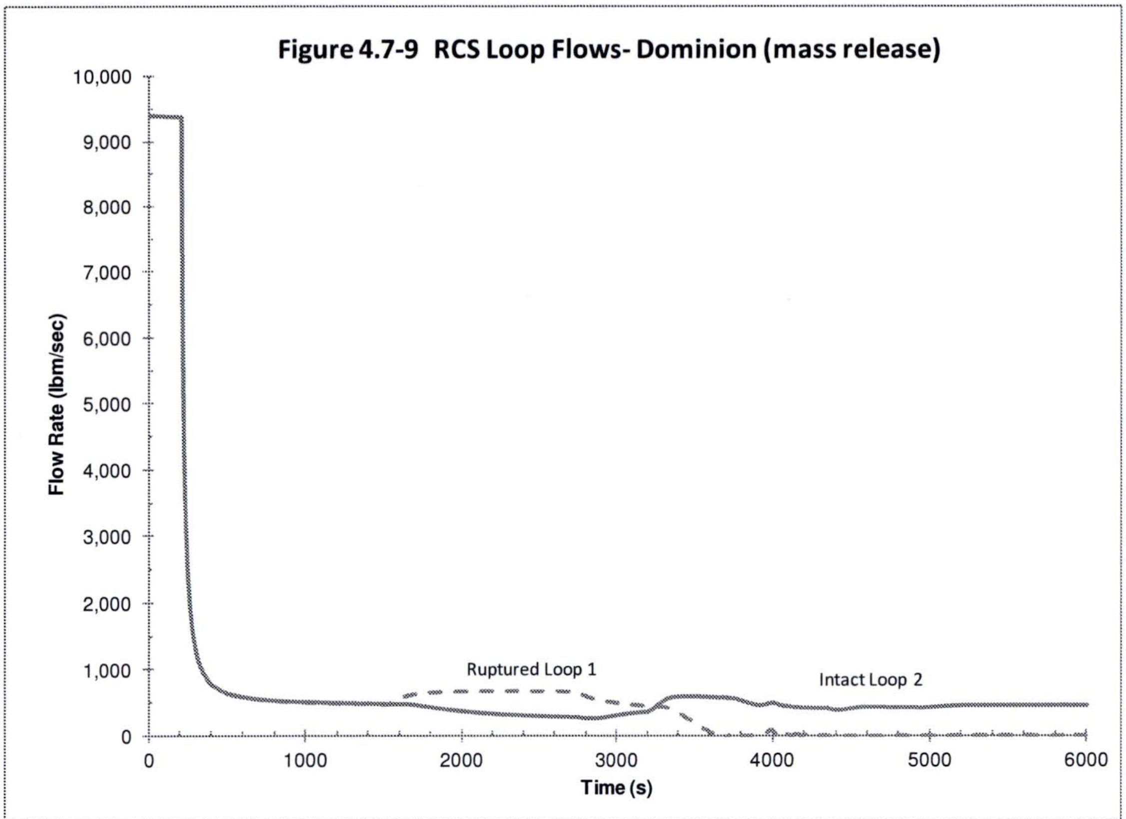


Figure 4.7-9 RCS Loop Flows- Dominion (mass release)
Flow Rate (lbm/sec)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
1000
2000
3000
4000
5000
6000
Time (s)
Ruptured Loop 1
Intact Loop 2

Results – SGTR Overfill Case

The response for the SG Overfill case is shown on Figure 4.7-10 through Figure 4.7-17 and the sequence of events is provided in Table 4.7-3. In general, the overfill case trends are similar to the Mass Release case except that the ADV on the ruptured SG is not assumed to fail open when the main steam lines are isolated. In addition, the RCS cooldown phase takes longer since only one valve is available to perform that function. The FSAR contains no plots for the SG Overfill case which could be used for comparison. Therefore, for this benchmark, comparisons are based on the SGTR analysis presented in the Stretch Power Uprate (SPU) licensing report (Attachment 5 of Reference 1).

The pressurizer pressure response is shown on Figure 4.7-10. The Dominion pressurizer pressure tracks closely with the SPU data through most of the event. After SI is isolated near the end of the event, the Dominion pressure is less than the SPU pressure and remains below for the duration of the event, which is consistent with lower SG pressure (Figure 4.7-12) and the pressurizer pressure results provided for the Mass Release case above. The higher SPU pressurizer pressure when SI is isolated is also consistent with the higher SPU pressurizer fluid insurge prior to that period shown on Figure 4.7-11 as discussed in more detail below.

The SG pressure response for the ruptured and intact SGs is shown on Figure 4.7-12. As shown, the Dominion and SPU trends (dashed lines) are in good agreement for the intact SGs. For the ruptured SGs, the Dominion and SPU pressures agree well until the heat transfer is reduced due to the loss of appreciable natural circulation flow around 2600 seconds as shown by the RCS flows on Figure 4.7-17. As discussed for the Mass Release case, this is the result of the reduced ruptured loop temperatures following the RCS cooldown that limit natural circulation flow and yield reverse heat transfer from the ruptured SG secondary into the RCS. After this time the Dominion pressure is no longer maintained at the ADV relief valve setpoint and begins to slowly decrease.

The primary side temperature response is shown on Figure 4.7-13 for the intact SGs and Figure 4.7-14 for the ruptured SGs. As shown on Figure 4.7-13, the Dominion and SPU results for the intact SG temperatures are in very good agreement. For the ruptured SGs, there is good agreement between the Dominion and SPU cases until about 2600 seconds when natural circulation flow is lost in the ruptured RCS loop and the cold leg temperatures are more strongly affected by the cooler SI flow as discussed above for the Mass Release case. After SI flow is terminated, the Dominion cold leg temperature trends toward the SPU value.

The break flow rate through the ruptured SG tube is shown on Figure 4.7-15. There is very good agreement between the Dominion and SPU cases until the period late in the transient after SI has been isolated and the break flow is trending towards zero. This is also seen for the ruptured SG liquid volume response shown on Figure 4.7-16 where the Dominion and SPU responses agree well although the Dominion value stabilizes at a somewhat lower value near the end of the transient. Although there is not enough information available to determine the exact cause of this difference, there are several factors that could influence the final SG fluid volume. First, any difference in the assumed decay heat profile results in a different amount of fluid boiled from the SG secondary and associated liquid volume. Second, any differences in the integrated SI fluid injection affect the RCS fluid inventory available for release to the ruptured SG. It is noted that during the RCS depressurization phase which occurs just prior to SI isolation, SI flow rates increase dramatically due to flow from the intermediate head SI pumps and the FSAR case shows a greater increase in pressurizer level during this time. On the secondary side, differences in the integrated AFW flow rates affect the fluid delivered to the ruptured SG fluid volume as well as the energy removed by the intact SGs. Similarly, differences in SG relief valve flow rates affect mass and energy removal from the system. Lastly, it should be noted that any differences in the Dominion and SPU model noding and related assumptions could affect the differential pressure between the respective fluid levels in the RCS and SG secondary, which would also affect the final equilibrium level and associated fluid volume. Nevertheless, there is good overall agreement between the Dominion and SPU results.

Table 4.7-3 SGTR – Overfill Case Sequence of Event

Event	Time (seconds)	
	Dominion	**SPU**
SG Tube Ruptured	0	0
Reactor Trip (OTDT)	206	135
SI Actuated	216	145
AFW Flow Initiated	236	165
Ruptured SG AFW Isolated	855	794
Ruptured SG Steamline Isolated	1500	1500
RCS Cooldown Initiated	1980	1980
RCS Cooldown Terminated	2830	2850
RCS Depressurization Initiated	3010	3030
RCS Depressurization Terminated	3094	3124
SI Terminated	3454	3484
Break Flow Terminated	4535	5082

Figure 4.7-10 Pressurizer Pressure (overfill)

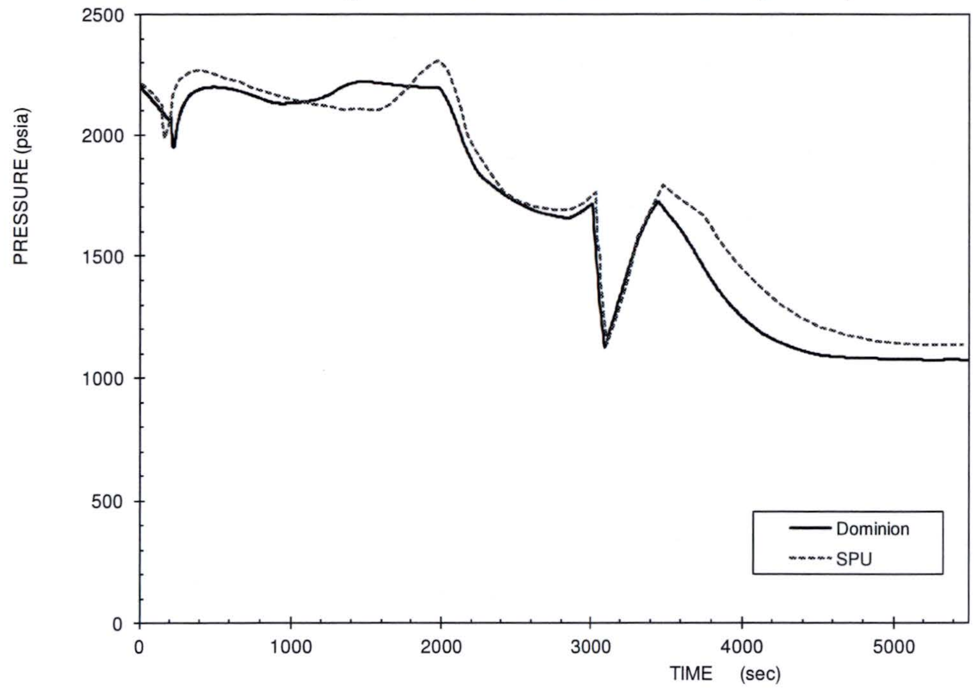


Figure 4.7-11 Pressurizer Level (overfill)

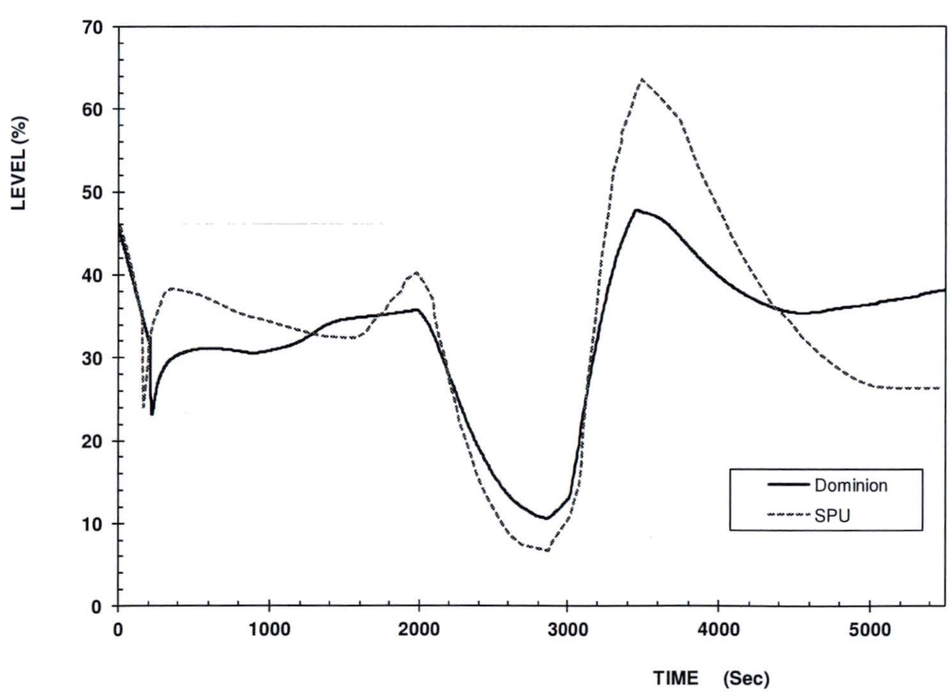


Figure 4.7-12 Secondary Pressure (overfill)

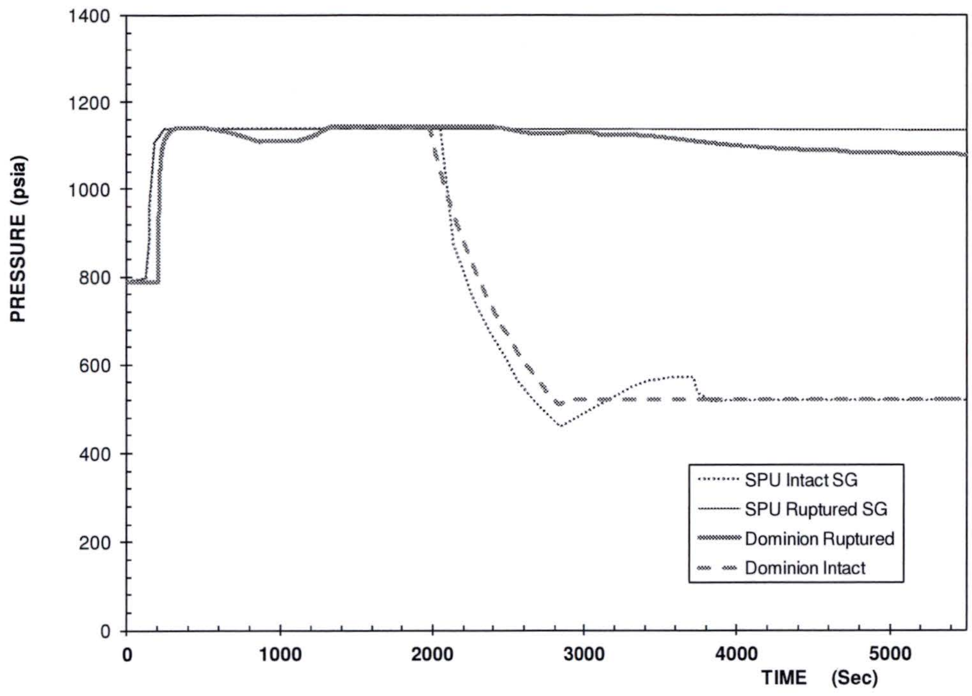
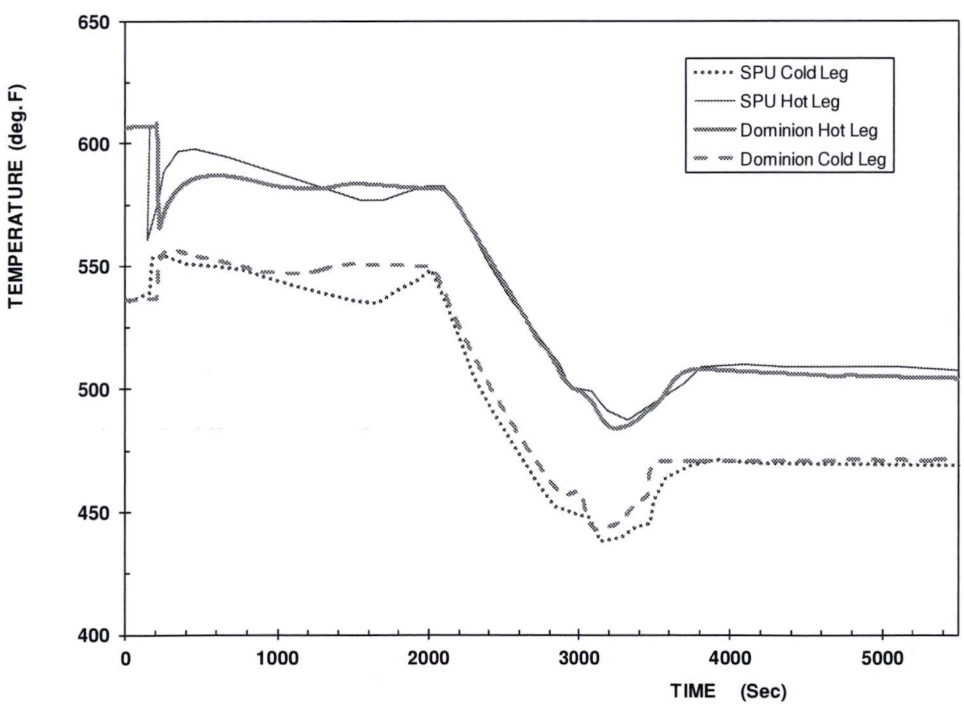


Figure 4.7-13 Intact Loop Hot and Cold Leg RCS Temperature (overfill)



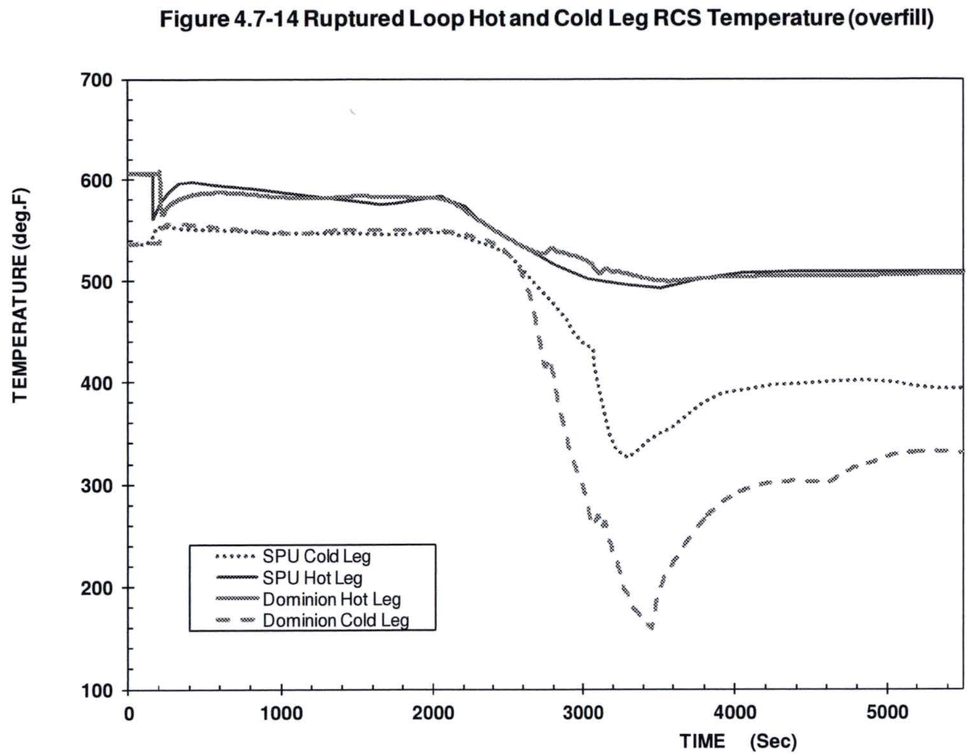


Figure 4.7-14 Ruptured Loop Hot and Cold Leg RCS Temperature (overfill)
TEMPERATURE (deg.F)
700
600
500
400
300
200
100
0
1000
2000
3000
4000
5000
TIME (Sec)
SPU Cold Leg
SPU Hot Leg
Dominion Hot Leg
Dominion Cold Leg

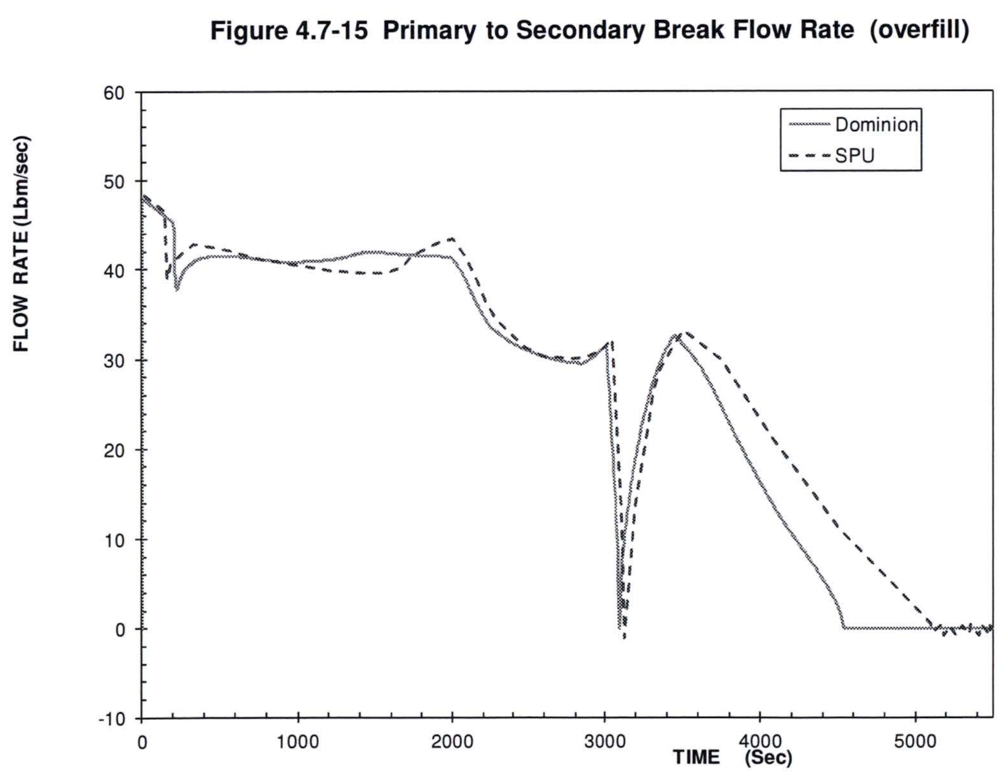


Figure 4.7-15 Primary to Secondary Break Flow Rate (overfill)
FLOW RATE (Lbm/sec)
60
50
40
30
20
10
0
-10
0
1000
2000
3000
4000
5000
TIME (Sec)
Dominion
SPU

Figure 4.7-16 Ruptured SG Liquid Volume (overfill)

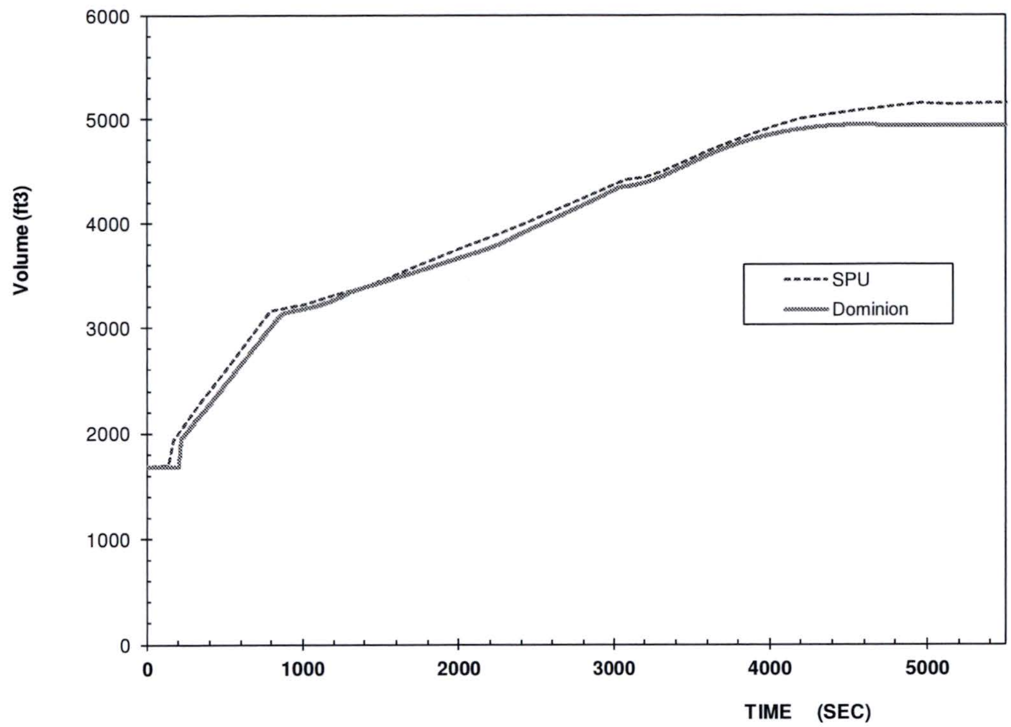
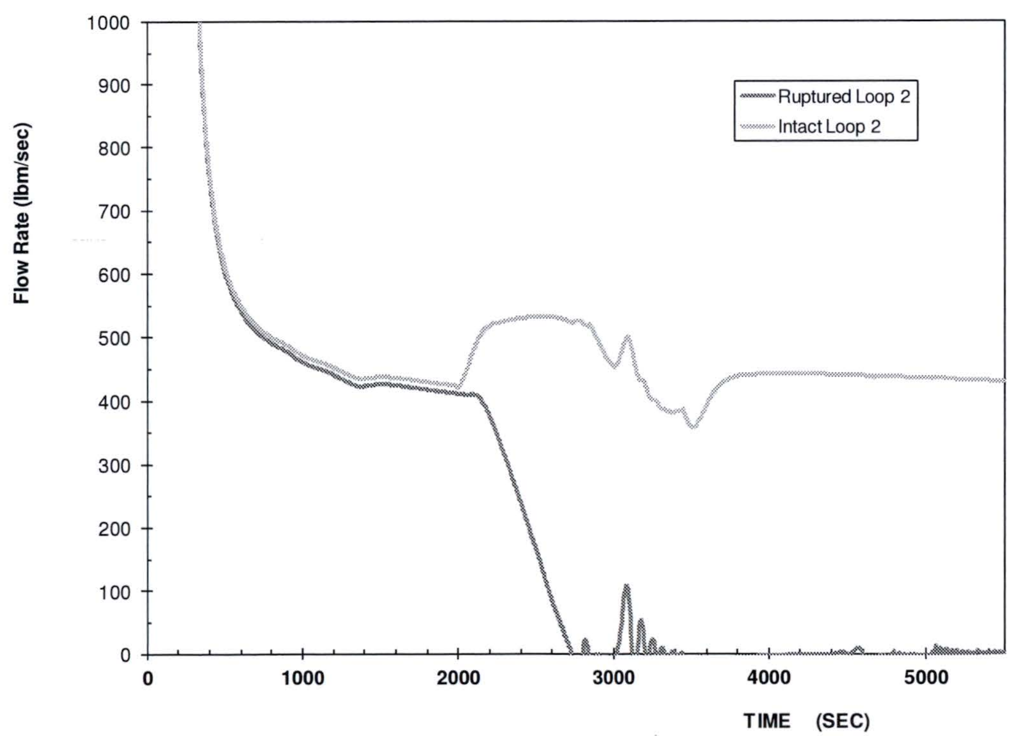


Figure 4.7-17 RCS Loop Flows - Dominion (overfill)



Summary - SGTR

The Dominion Millstone model provides results that are similar to the FSAR and SPU analyses for the SGTR event. Two cases are analyzed, a thermal-hydraulic case to determine mass releases to the atmosphere for radiological dose, and a second case to ensure that SG overfill does not occur. There is overall good agreement in the parameters for both cases although some differences occurring near the end of the events have been noted with an explanation provided.

References

1. DNC Letter 07-0450, "Dominion Nuclear Connecticut, Inc., Millstone Power Station Unit 3 License Amendment Request Stretch Power Uprate," July 13, 2007. (ADAMS Accession No. ML072000386)

5.0 Conclusions

This attachment presents benchmarking transient analyses performed with the MPS3 RETRAN model developed in accordance with VEP-FRD-41-P-A. These analysis results are compared with current Millstone FSAR results. The following conclusions are drawn based on these analyses.

1) It is demonstrated that the Dominion RETRAN-3D model and analysis methods can predict the response of transient events with results that compare well to FSAR results.

2) Where there are differences between the Dominion results and the FSAR results, they are understood based on differences in noding, inputs, or other modeling assumptions.

3) The Dominion Millstone RETRAN-3D model is consistent with current Dominion methods (Reference 1). These methods have been applied extensively for Surry and North Anna licensing, engineering and plant support analyses.

4) The RETRAN comparison analyses satisfy the applicability assessment criteria and provide further validation of the conclusion that Dominion's RETRAN analysis methods are applicable to Millstone and can be applied to Millstone licensing analysis for reload core design and safety analysis.

6.0 References

1) Topical Report, VEP-FRD-41-P-A, Rev. 0.2, "VEPCO Reactor System Transient Analyses Using the RETRAN Computer Code," March 2015.

2) Topical Report, VEP-NFE-2-A, "VEPCO Evaluation of the Control Rod Ejection Transient," December 1984.