15.5 Increase in Reactor Coolant Inventory

This section presents a discussion and analysis of the following events:

- Inadvertent operation of the core makeup tanks during power operation
- Chemical and volume control system malfunction that increases reactor coolant inventory

These Condition II events cause an increase in reactor coolant inventory.

15.5.1 Inadvertent Operation of the Core Makeup Tanks During Power Operation

15.5.1.1 Identification of the Causes and Accident Description

Spurious core makeup tank operation at power could be caused by an operator error, a false electrical actuation signal, or a valve malfunction. A spurious signal may originate from any of the safeguards (“S”) actuation channels as described in Section 7.3. The AP1000 protection logic is such that a single failure cannot actuate both core makeup tanks without also actuating the passive residual heat removal (PRHR) heat exchanger. A scenario such as this is the spurious “S” signal event. However, if one core makeup tank is inadvertently actuated by a single failure, the event may progress with the plant at power until a reactor trip is reached. For the plant under automatic rod control, a reactor trip on high-3 pressurizer water level reactor trip is expected to occur followed by the PRHR actuation and eventually by an “S” signal, which would then actuate the second core makeup tank. When a consequential loss of offsite power is assumed, this event is more conservative than the spurious “S” signal event.

The inadvertent opening of the core makeup tank discharge valves, due to operator error or valve failure, results in significant core makeup tank injection flow leading to a boration similar to that resulting from a chemical and volume control system malfunction event. If the automatic rod control system is operable, it will begin to withdraw rods from the core to counteract the reactivity effects of the boration. As a result, the core makeup tank will continue injection and slowly raise the pressurizer level until the high-3 pressurizer level trip setpoint is reached. In meeting the requirements of GDC 17 of 10 CFR Part 50, Appendix A, a loss of offsite power is assumed to occur as a consequence of reactor trip. The primary effect of this assumption is the coastdown of the reactor coolant pumps. The core makeup tank injection will increase as the steam generator outlet temperature increases resulting in a lower density in the CMT balance line. This event will then proceed similarly to a spurious “S” signal or chemical and volume control system malfunction event. However, this event is more limiting primarily due to the higher pressurizer level at the time of reactor trip and to the significant heat up of the injected fluid during the pre-trip phase of the accident. Thus, the inadvertent core makeup tank actuation event with a consequential loss of offsite power is analyzed here.

Upon receipt of the high-3 pressurizer level reactor trip signal, the reactor is tripped; then the turbine is immediately tripped, and after a 3-second delay, a consequential loss of offsite power is assumed. The basis for the 3-second delay is described in subsection 15.0.14. The high-3 pressurizer level signal also actuates the PRHR heat exchanger and blocks the pressurizer heaters, but a 15-second delay is built in to prevent unnecessary actuation of the PRHR heat exchanger if offsite power is maintained.

Following reactor trip, the reactor power drops and the average reactor coolant system temperature decreases with subsequent coolant shrinkage. However, due to the assumed loss of offsite power, the reactor coolant cold leg temperature, in the loop without PRHR, increases and the core makeup tank starts injecting cold water into the reactor coolant system at a much higher rate. The primary coolant system shrinkage is counteracted by the core makeup tank injection, and the pressurizer water volume starts to increase because of the heatup of the cold injected fluid by the decay heat. The high-3 pressurizer level setpoint is once again reached, and after a 15-second delay, the signal is sent to actuate the PRHR heat exchanger and block the pressurizer heaters.

Eventually, the core makeup tank heats up and the gravity-driven recirculation is significantly reduced. The PRHR heat exchanger continues to extract heat from the reactor coolant system, and the pressurizer water volume starts to decrease. Ultimately, the core makeup tank stops recirculating, the PRHR heat removal matches decay heat and the reactor coolant system cooldown begins eventually leading to a “S” signal on a Low T_{cold} setpoint.

The cold injection flow from the second CMT initially results in a fast decrease in temperature and shrinkage of the reactor coolant. However, as the temperature decreases, the PRHR heat removal capability diminishes and a moderate heat up occurs followed by the increase of pressurizer water level. The second CMT injection rate is much lower than that experienced during the first part of the transient from the first CMT. Due to the colder cold leg temperatures, the density in balance line is much higher than during the first part of the transient, resulting in a reduction of the total buoyancy driving head. Ultimately, the PRHR heat removal once again matches the decay heat and the final reactor coolant system cooldown begins.

This event is a Condition II incident (a fault of moderate frequency) as defined in subsection 15.0.1.

15.5.1.2 Analysis of Effects and Consequences

The plant response to an inadvertent core makeup tank actuation is analyzed by using a modified version of the computer program LOFTRAN described in subsection 15.0.11.2. The code simulates the neutron kinetics, reactor coolant system, pressurizer, pressurizer safety valves, pressurizer spray, steam generator, steam generator safety valves, PRHR heat exchanger, and core makeup tank. The program computes pertinent plant variables, including temperatures, pressures, and power level.

Reactor power and average temperature drop immediately following the trip, and the operating conditions never approach the core limits. The PRHR heat exchanger removes the long-term decay heat and prevents possible reactor coolant system overpressurization or loss of reactor coolant system water.

Core makeup tank and PRHR system performance is conservatively simulated. Core makeup tank enthalpies have been maximized. This is conservative because it minimizes the cooling provided by the core makeup tanks as flow recirculates and thereby increases the peak pressurizer water volume during the transient. Core makeup tank injection and balance lines pressure drop is minimized. This maximizes the core makeup tank flow injected in the primary system. During this event, the core makeup tanks remain filled with water. The volume of injection flow leaving the core makeup tanks is offset by an equal volume of recirculation flow that enters the core makeup tanks via the balance lines. PRHR heat transfer capability has been minimized.

Plant characteristics and initial conditions are further discussed in subsection 15.0.3.

The limiting case presented here bounds cases that model explicit operator action 60 minutes after reactor trip. The assumptions for this case are as follows:

- Initial operating conditions

  The initial reactor power is assumed to be 102 percent of nominal. The main feedwater flow measurement supports a 1-percent power uncertainty; use of a 2-percent power uncertainty is conservative. The initial pressurizer pressure is assumed to be 50 psi below nominal. The initial reactor coolant system average temperature is assumed to be 7°F below nominal.

- Control systems

  The pressurizer spray system and automatic rod control system are conservatively assumed to operate. The pressurizer heaters are automatically blocked on a high-3 pressurizer level signal, so they cannot add heat to the system during the period of thermal expansion that produces the peak pressurizer water volume. Thus, the pressurizer heaters are assumed to be inoperable during this event. Other control systems are conservatively not assumed to function during the transient. Cases with the turbine bypass (steam dump) and feedwater control systems working result in lower secondary and primary temperatures and in greater margin to overfilling.

- Moderator and Doppler coefficients of reactivity

  A least-negative moderator temperature coefficient, a Low (absolute value) Doppler power coefficient, and a maximum boron worth are assumed. With these minimum feedback parameters and the operability of the pressurizer spray system and automatic rod control system assumed, the reactivity effects of the boron injection from the core makeup tanks is counteracted. As a result, the high-3 pressurizer signal is the first reactor trip signal generated during the transient.

- Boron injection

  The transient is initiated by an inadvertent opening of the discharge valves of one of the two core makeup tanks. The core makeup tank injects 3400 ppm borated water.

- Protection and safety monitoring system actuations

  Reactor trip is initiated by the high-3 pressurizer level signal.

  The core decay heat is removed by the PRHR heat exchanger. The worst single failure is assumed to occur in the outlet line of the PRHR heat exchanger. One of the two parallel isolation valves is assumed to fail to open.

Plant systems and equipment available to mitigate the effect of the accident are discussed in subsection 15.0.8 and listed in Table 15.0-6.

15.5.1.3 Results

Figures 15.5.1-1 through 15.5.1-11 show the transient response to the inadvertent operation of one of the two core makeup tanks during power operation. The inadvertent opening of the core makeup tank discharge valves occurs at 10 seconds. As the core makeup tank continues to add inventory to the primary system, the pressurizer level begins to increase until the high-3 pressurizer level reactor trip setpoint is reached at about 520.7 seconds. After a 2-second delay, the neutron flux starts decreasing due to the reactor trip, which is immediately followed by the turbine trip. Following reactor trip, the reactor power drops and the average reactor coolant system temperature decreases with subsequent coolant shrinkage. However, due to the assumed loss of offsite power, the reactor coolant pumps trip at about 525.4 seconds. The cold leg temperature increases and the core makeup tank starts injecting cold water into the reactor coolant system at a much higher rate due to the increased driving head resulting from the density decreases in balance line. The primary coolant system shrinkage is counteracted by the core makeup tank injection, and the pressurizer water volume starts to increase because of the heatup of the cold injected fluid by the decay heat. The high-3 pressurizer level setpoint is once again reached at about 541.9 seconds, and after a 15-second delay, the signal is sent to actuate the PRHR heat exchanger and block the pressurizer heaters. Following a conservative 17-second delay, the valves are assumed to open to actuate the PRHR heat exchanger at about 573.9 seconds.

After reactor trip, the pressure in the primary and secondary systems increases initially due to the assumed unavailability of the non-safety-related control systems. The primary and secondary system pressures eventually decrease as the PRHR system removes decay heat. The core makeup tank works in recirculation mode, meaning it is always filled with water because cold borated water injected through the injection line is replaced by hot water coming from the cold leg (balance lines). At approximately 5,000 seconds, the PRHR heat flux matches the core decay heat. However, the pressurizer level continues to slowly increase until the core makeup tank recirculation is decreased sufficiently to significantly limit the mass addition to the RCS.

At 5,880 seconds, the pressurizer safety valves close. At about 6,600 seconds, the pressurizer water volume stops increasing. At about 12,354 seconds, the Low T_{cold} “S” setpoint is reached and the second CMT is actuated. The pressurizer level initially shrinks due to the addition of cold borated water. As the core makeup tank continues to add inventory to the primary system, the pressurizer level begins to increase. At approximately 13,300 seconds, the first core makeup tank essentially stops recirculating. The PRHR heat flux decreases below decay heat and a moderate heat up is experienced by the plant. Finally, at 21,800 seconds, the PRHR heat transfer matches the decay heat and the final cooldown commences.

Figure 15.5.1-6 shows the departure from nucleate boiling ratio (DNBR) until the time of reactor coolant trip and subsequent flow coastdown due to the loss of offsite power. At this time, core power and heat flux have diminished sufficiently, due to the reactor trip, that DNBR is well above the design limit value defined in Section 4.4.

The calculated sequence of events is shown in Table 15.5-1.

The limiting case presented here bounds all cases that model explicit operator action 60 minutes after reactor trip. For such events, the operator would take action to reduce the increase in coolant inventory. As the pressurizer water level would increase above the high pressurizer water level that normally isolates chemical and volume control system makeup, the normal letdown line could be placed into service to reduce the increase in coolant inventory. If letdown could not be placed into service, the operator could use the safety related reactor vessel head vent valves to reduce the increase in coolant inventory. For these events, following the procedures outlined in the Emergency Response Guidelines AFR-I.1, there is sufficient time for the operator to mitigate the consequences of this event, and the results of such an event have a greater margin to pressurizer overfill than that presented in this analysis.

15.5.1.4 Conclusions

The results of this analysis show that inadvertent operation of the core makeup tanks during power operation does not adversely affect the core, the reactor coolant system, or the steam system. The PRHR heat removal capacity is such that reactor coolant water is not relieved from the pressurizer safety valves. DNBR always remains above the design limit values, and reactor coolant system and steam generator pressures remain below 110 percent of their design values.

15.5.2 Chemical and Volume Control System Malfunction That Increases Reactor Coolant Inventory

15.5.2.1 Identification of Causes and Accident Description

An increase of reactor coolant inventory, which results from addition of cold unborated water to the reactor coolant system, is analyzed in subsection 15.4.6.

In this subsection 15.5.2, the increase of reactor coolant system inventory due to the addition of borated water is analyzed.

The increase of reactor coolant system coolant inventory may be due to the spurious operation of one or both of the chemical and volume control system pumps or by the closure of the letdown path. If the chemical and volume control system is injecting highly borated water into the reactor coolant system, the reactor experiences a negative reactivity excursion due to the injected boron, causing a decrease in reactor power and subsequent coolant shrinkage. The load decreases due to the effect of reduced steam pressure after the turbine control valve fully opens.

At high chemical and volume control system boron concentration, low reactivity feedback conditions, and reactor in manual rod control, an “S” signal will be generated by either the low T_{cold} or low steam line pressure setpoints before the chemical and volume control system can inject a significant amount of water into the reactor coolant system. In this case, the chemical and volume control system malfunction event proceeds similarly to, and is only slightly more limiting than, a spurious “S” signal event. If the automatic rod control is modeled and the pressurizer spray functions properly to prevent a high pressure reactor trip signal, no “S” signals are generated and this specific event is terminated by automatic isolation of the chemical and volume control system on the safety-related high-2 pressurizer level setpoint.

Under typical operating conditions for the AP1000, the boron concentration of the injected chemical and volume control system water is equal to that of the reactor coolant system. If the chemical and volume control system is functioning in this manner and the pressurizer spray system functions properly to prevent a high pressure reactor trip signal, no "S" signals are generated and this specific event is also terminated by automatic isolation of the chemical and volume control system on the safety-related high-2 pressurizer level setpoint.

While these scenarios are the most probable outcomes of a chemical and volume control system malfunction, several combinations of boron concentration, feedback conditions, and plant system interactions have been identified which can result in more limiting scenarios with respect to pressurizer overfill. The key factors that make this event more limiting than a spurious "S" signal event are that the reactor coolant system is at a lower average temperature, higher pressure, and a higher pressurizer level at the time an "S" signal is generated. These factors produce a greater volume of higher density water and, thus, a larger reactor coolant system mass at the time of the "S" signal. In addition, at lower reactor coolant system average temperature, the PRHR is less effective in removing decay heat, which results in greater expansion of the cold water injected by the core makeup tanks.

The limiting analysis scenario minimizes reactor coolant system average temperature, maximizes reactor coolant system mass, and maximizes pressurizer water volume at the time of an "S" signal. This scenario is as follows:

- Both of the chemical and volume control system pumps spuriously begin delivering flow at a boron concentration slightly higher than that of the reactor coolant system. (Assuming that a chemical and volume control system malfunction results in both chemical and volume control system pumps delivering flow is a conservative assumption. One chemical and volume control system pump is automatically controlled and one is manually controlled.)

- The non-safety-related pressurizer spray is assumed to be available, so that a high pressurizer pressure reactor trip is prevented.

Due to the boron addition in the core, the plant cools down until an "S" signal is generated on low cold leg temperature. On the "S" signal, the reactor is tripped, the reactor coolant pumps are tripped, the pressurizer heaters are blocked, and the main feedwater lines, steam lines, and chemical and volume control system are isolated. After a conservative 17-second delay, the PRHR heat exchanger is actuated and the core makeup tank discharge valves are opened.

Normally, the reactor coolant pumps would be tripped 15 seconds after the receipt of the "S" signal. However, to meet the requirements of GDC 17 of 10 CFR Part 50, Appendix A, a loss of offsite power is assumed to occur as a consequence of reactor trip. The primary effect of this assumption is the coastdown of the reactor coolant pumps. Immediately following reactor trip, the turbine is tripped, and after a 3-second delay, a consequential loss of offsite power is assumed. The basis for the 3-second delay is described in subsection 15.0.14. As a result, the reactor coolant pumps are conservatively assumed to trip about 10 seconds before they would otherwise trip due to the "S" signal.

This event is a Condition II incident (a fault of moderate frequency) as defined in subsection 15.0.1.

15.5.2.2 Analysis of Effects and Consequences

The malfunction of the chemical and volume control system is analyzed by using a modified version of the computer program LOFTRAN (Reference 1). The code simulates the neutron kinetics, reactor coolant system, pressurizer, pressurizer safety valves, pressurizer spray, steam generator, steam generator safety valves, PRHR heat exchanger, and core makeup tank. The program computes pertinent plant variables including temperatures, pressures, and power level.

Because of the power and temperature reduction during the transient, operating conditions do not approach the core limits. The PRHR heat exchanger removes the long-term decay heat to prevent possible reactor coolant system overpressurization or loss of reactor coolant system water.

Using an iterative analysis process, the boron concentration is chosen such that this limiting case bounds the cases that model explicit operator action 30 minutes after the reactor trip.

The assumptions are as follows:

- Initial operating conditions

  The initial reactor power is assumed to be 102 percent of nominal. The main feedwater flow measurement supports a 1-percent power uncertainty; use of a 2-percent power uncertainty is conservative. The initial pressurizer pressure is assumed to be 50 psi above nominal. The initial reactor coolant system average temperature is assumed to be 6.5°F above nominal.

- Moderator and Doppler coefficients of reactivity

  A least-negative moderator temperature coefficient, a low (absolute value) Doppler power coefficient, and a maximum boron worth are assumed. For a different set of reactivity feedback parameters, a different chemical and volume control system boron concentration can result in an identical transient.

- Reactor control

  Rod control is not modeled.

- Pressurizer heaters

  The pressurizer heaters are automatically blocked on an “S” signal, and do not add heat to the system during the period of fluid thermal expansion that produces the peak pressurizer water volume. Thus, the pressurizer heaters are assumed to be inoperable during this event.

- Pressurizer spray

  The spray system controls the pressurizer pressure so that a high pressurizer pressure reactor trip is prevented.

- Boron injection

  After 10 seconds at steady state, the chemical and volume control system pumps start injecting borated water, which is slightly above the reactor coolant system boron concentration. Upon receipt of an “S” signal, the chemical and volume control system pumps are isolated and the core makeup tanks begin injecting 3400 ppm borated water.

- Turbine load

  The turbine load is assumed constant until the turbine D-EHC drives the control valve wide open. Then the turbine load drops as steam pressure drops.

- Protection and safety monitoring system actuations

  If the automatic rod control system is modeled and the pressurizer spray system functions properly, no reactor trip signal is expected to occur. Instead, the event is terminated by automatic isolation of the chemical and volume control system on the safety grade high-2 pressurizer level setpoint. If the automatic rod control system is not active and the pressurizer spray system is assumed to be available, reactor trip may be initiated on either low T_{cold} “S” or a low steam line pressure “S” signal.

  The core decay heat is removed by the PRHR heat exchanger. The worst single failure is assumed to occur in the outlet line of the PRHR heat exchanger. One of the two parallel isolation valves is assumed to fail to open.

  Plant systems and equipment available to mitigate the effect of the accident are discussed in subsection 15.0.8 and listed in Table 15.0-6.

15.5.2.3 Results

Figures 15.5.2-1 through 15.5.2-11 show the transient response to a chemical and volume control system malfunction that results in an increase of reactor coolant system inventory. Neutron flux slowly decreases due to boron injection, but steam flow does not decrease until later in the transient when the turbine control valves are wide open.

As the chemical and volume control system injection flow increases reactor coolant system inventory, pressurizer water volume begins increasing while the primary system is cooling down. At about 1,090 seconds, the low T_{cold} setpoint is reached, the reactor trips, and the control rods start moving into the core.

Immediately following reactor trip, the turbine is tripped and after a 3-second delay, a consequential loss of offsite power is assumed and the reactor coolant pumps trip. The basis for the 3-second delay is described in subsection 15.0.14. Soon after reactor trip, the pressurizer heaters are blocked and the main feedwater lines, steam lines, and chemical and volume control system are isolated. After a conservative 17-second delay, the PRHR heat exchanger is actuated and the core makeup tank discharge valves are opened. The core makeup tanks work in recirculation mode, meaning they are always filled with water because cold borated water injected through the injection lines is replaced by hot water coming from the cold leg balance lines.

The operation of the PRHR heat exchanger and the core makeup tanks cools down the plant. Due to the swelling of the core makeup tank water, the pressurizer level is still increasing. As the reactor coolant system average temperature goes below 490°F, the cooling effect due to the core makeup tanks is decreasing. In this condition, the PRHR heat exchanger cannot remove the entire decay heat. Reactor coolant system temperature tends to increase until an equilibrium between decay heat power and heat absorbed by the PRHR heat exchanger is reached.

When the PRHR heat flux matches the core decay heat, the pressurizer water volume stops increasing, and the pressurizer safety valves close. Then the core makeup tanks essentially stop injecting.

Figure 15.5.2-6 shows the DNBR until the time of reactor coolant pump trip and subsequent flow coastdown due to the loss of offsite power. At this time, core power and heat flux have diminished sufficiently, due to the reactor trip, that DNBR is well above the design limit value defined in Section 4.4.

The calculated sequence of events is shown in Table 15.5-1.

The limiting case presented here bounds all cases that model explicit operator action 30 minutes after reactor trip. For such events, the operator could take action to reduce the increase in coolant inventory. As the pressurizer water level would increase above the high pressurizer water level that normally isolates chemical and volume control system makeup, the normal letdown line could be placed into service to reduce the increase in coolant inventory. If letdown could not be placed into service, the operator would use the safety-related reactor vessel head vent valves to reduce the increase in coolant inventory. For these events, following the procedures outlined in the AP1000 Emergency Response Guidelines AFR-I.1, there is sufficient time for the operator to mitigate the consequences of this event, and the results of such an event have a greater margin to pressurizer overfill than that presented in this analysis.

15.5.2.4 Conclusions

The results of this analysis show that a chemical and volume control system malfunction does not adversely affect the core, the reactor coolant system, or the steam system. The PRHR heat removal capacity is such that reactor coolant water is not relieved from the pressurizer safety valves. DNBR remains above the design limit values, and reactor coolant system and steam generator pressures remain below 110 percent of their design values.

If the automatic rod control system and the pressurizer spray systems are assumed to function, no reactor trip signal is expected to occur. Instead, the event is terminated by automatic isolation of the chemical and volume control system on the safety grade high pressurizer level setpoint. If manual rod control is assumed and the pressurizer spray system is assumed to be unavailable, reactor trip may be initiated on either a high pressurizer pressure, low T_{cold} “S”, or a low steam line pressure “S” signal.

15.5.3 Boiling Water Reactor Transients

This subsection is not applicable to the AP1000.

15.5.4 Combined License Information

This subsection has no requirement for additional information to be provided in support of the Combined License application.

15.5.5 References

1. Burnett, T. W. T., et al., "LOFTRAN Code Description," WCAP-7907-P-A (Proprietary) and WCAP-7907-A (Nonproprietary), April 1984.

Table 15.5-1 (Sheet 1 of 2)

TIME SEQUENCE OF EVENTS FOR INCIDENTS WHICH RESULT IN AN INCREASE IN REACTOR COOLANT INVENTORY

Accident	**Event**	**Time (seconds)**
Inadvertent operation of the core makeup tanks during power operation	Core makeup tank discharge valves open	10
	High-3 pressurizer level setpoint reached	520.7
	Rod motion begins	522.7
	Loss of offsite power	525.4
	Reactor coolant pumps trip	525.4
	High-3 pressurizer level setpoint reached	541.9
	PRHR heat exchanger actuated	573.9
	Pressurizer safety valves open	574.0
	Pressurizer safety valves close	594.0
	Pressurizer safety valves open	1,312
	Pressurizer safety valves close	5,880
	Low T_{cold} “S” setpoint is reached	12,354
	Second CMT starts recirculating	12,361
	First Core makeup tank stops recirculating	13,300
	Main steam and feed lines are isolated	12,366
	Pressurizer safety valves open	14,960
	Pressurizer safety valves close	20,140
	Peak pressurizer water volume occurs	20,480
	PRHR matches decay heat	21,800
	Second Core makeup tank stops recirculating	30,900

Table 15.5-1 (Sheet 2 of 2)

TIME SEQUENCE OF EVENTS FOR INCIDENTS WHICH RESULT IN AN INCREASE IN REACTOR COOLANT INVENTORY

Accident	**Event**	**Time (seconds)**
Chemical and volume control system malfunction that increases reactor coolant inventory	Chemical and volume control system charging pumps start	10
	Low T_{cold} "S" signal is reached	1,088
	Rod motion begins	1,090
	Loss of offsite power	1,093
	Reactor coolant pumps trip	1,093
	Main steam and feed lines are isolated	1,100
	Chemical and volume control system charging pumps are isolated	1,100
	Core makeup tank discharge valves open	1,100
	PRHR heat exchanger actuated	1,105
	Pressurizer safety valves open	1,424
	PRHR matches decay heat	14,720
	Pressurizer safety valves close	15,088
	Peak pressurizer water volume occurs	15,262
	Core makeup tanks stop recirculating	20,200

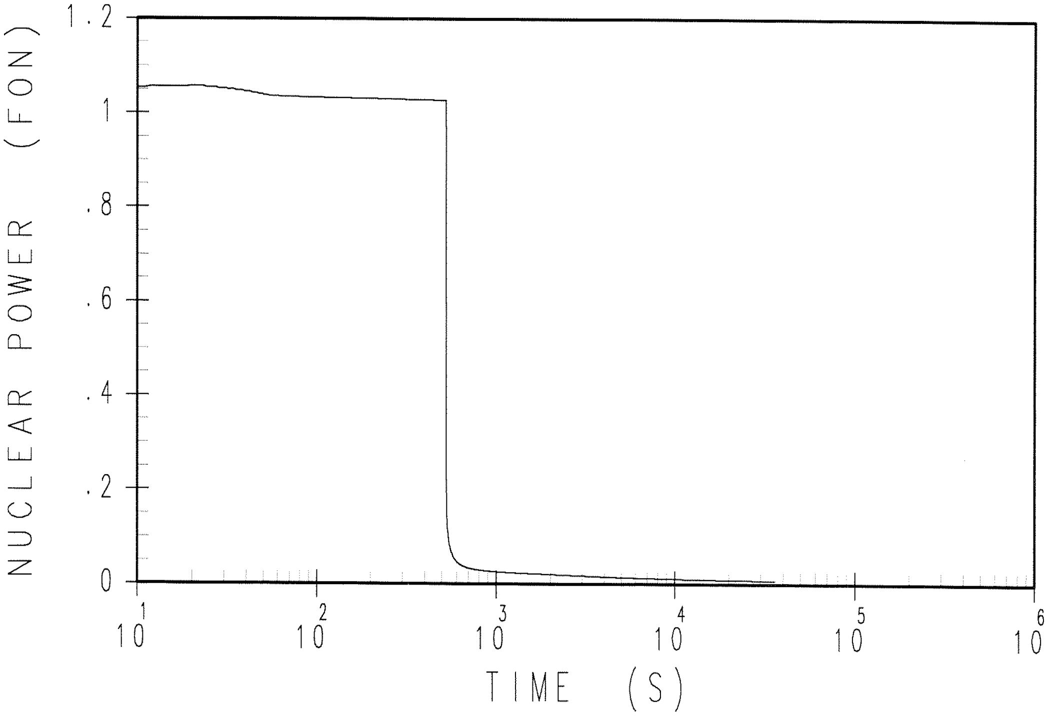

Figure 15.5.1-1

Core Nuclear Power Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

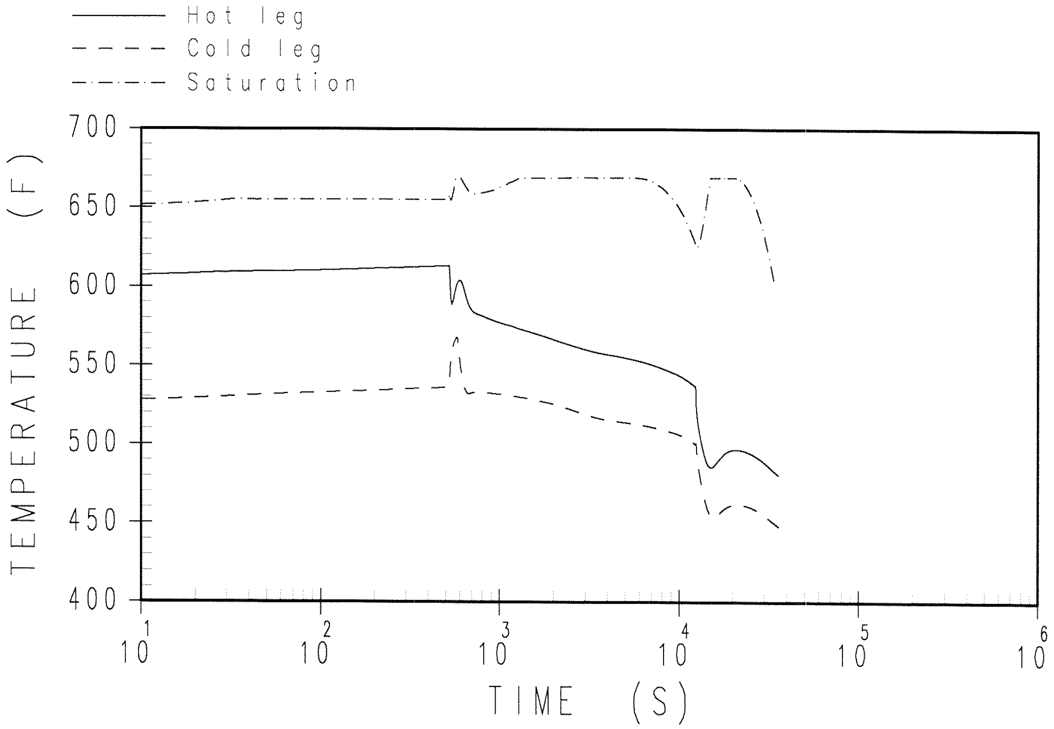

Figure 15.5.1-2

RCS Temperature Transient in Loop Containing the PRHR for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

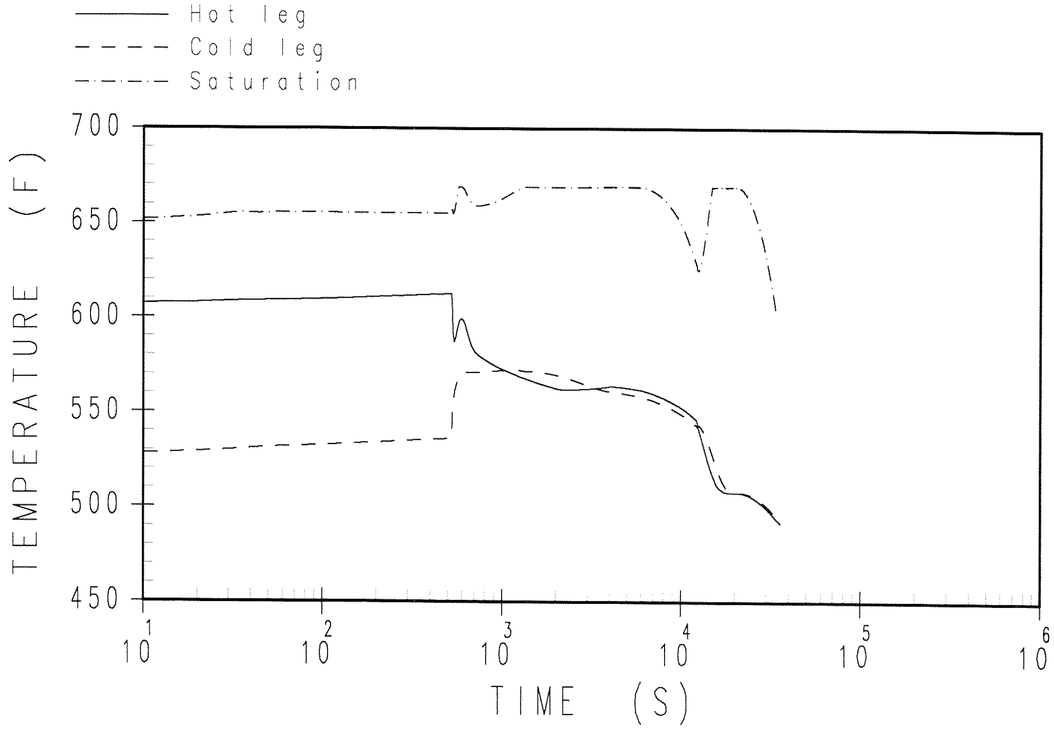

Figure 15.5.1-3

RCS Temperature Transient in Loop Not Containing the PRHR for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

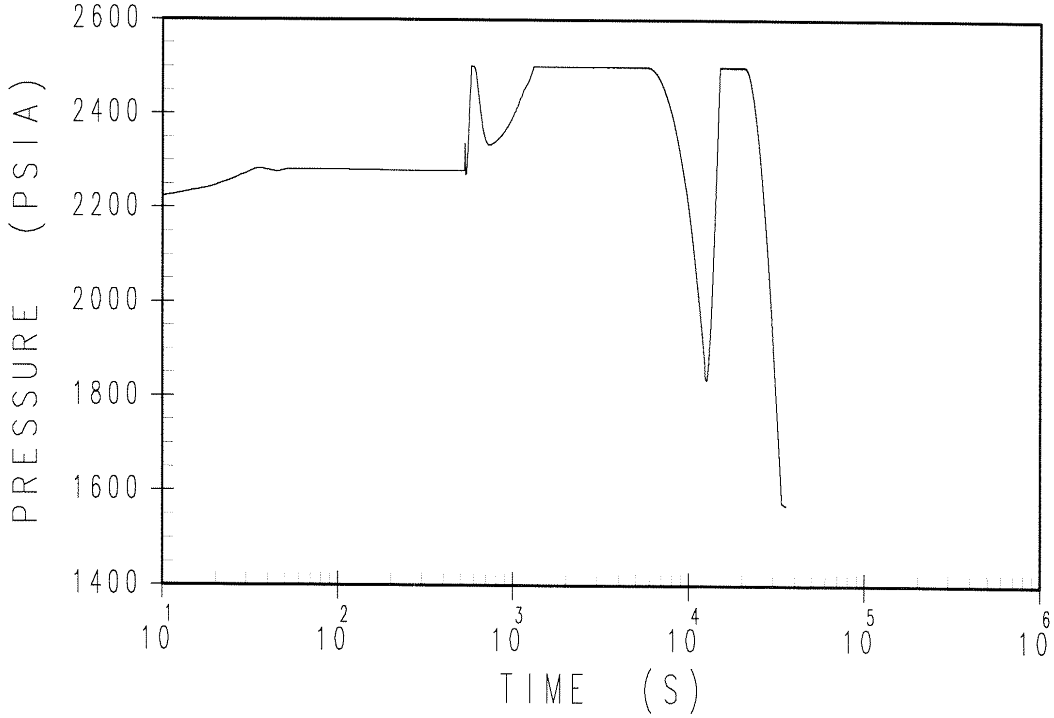

Figure 15.5.1-4

Pressurizer Pressure Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

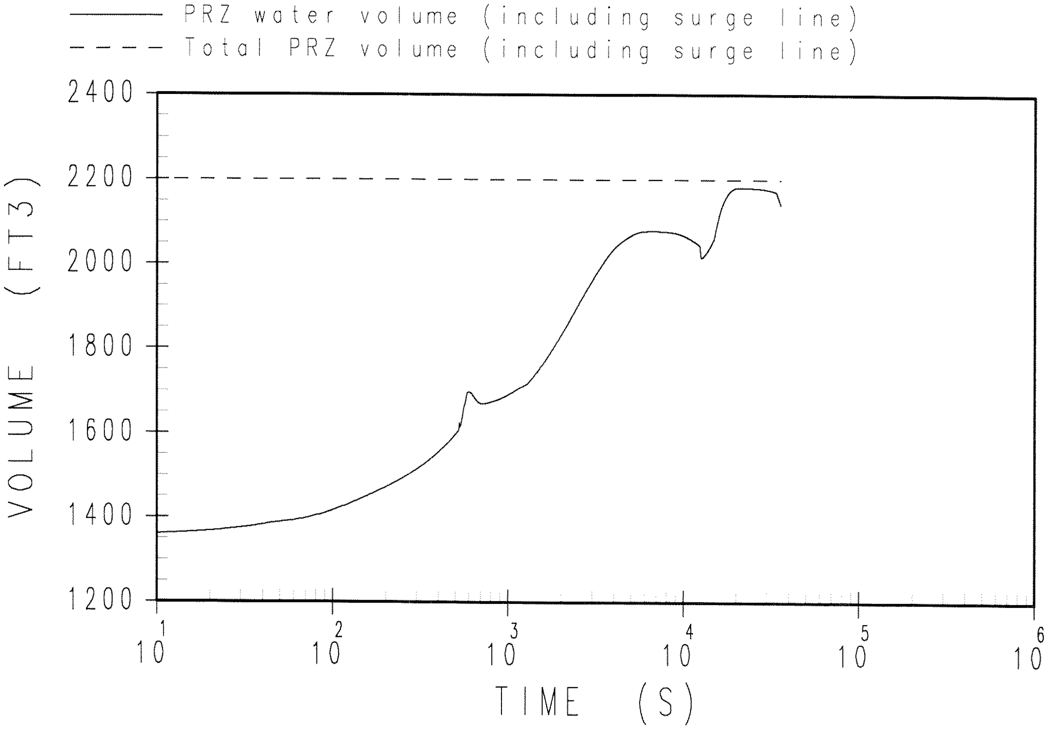

Figure 15.5.1-5

Pressurizer Water Volume Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

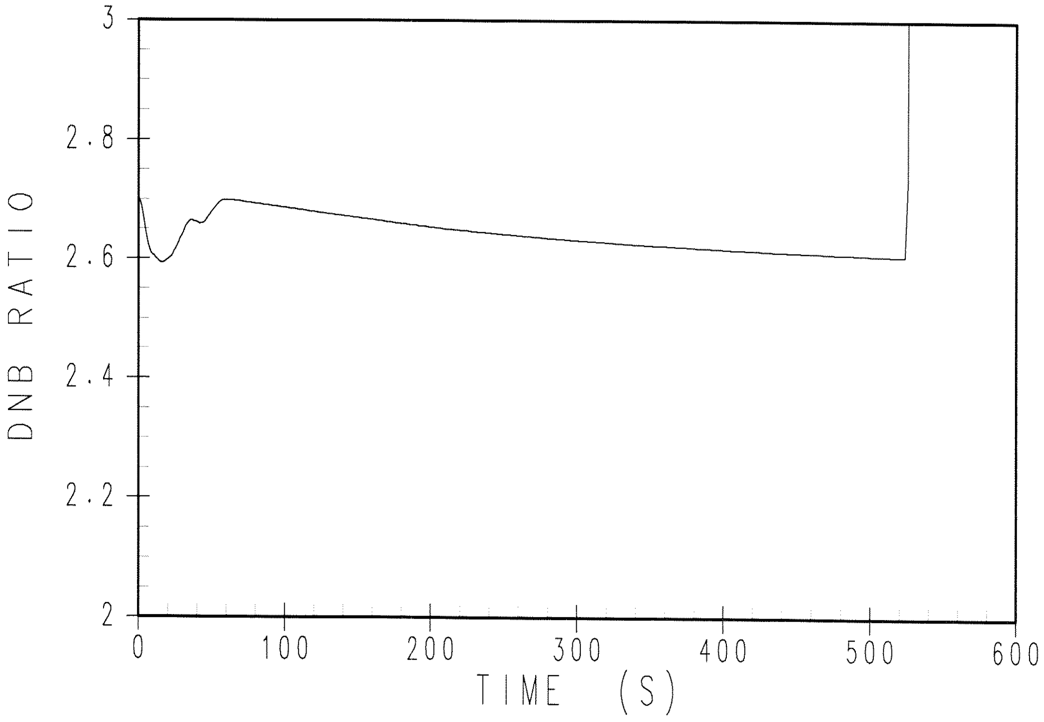

Figure 15.5.1-6

DNBR Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

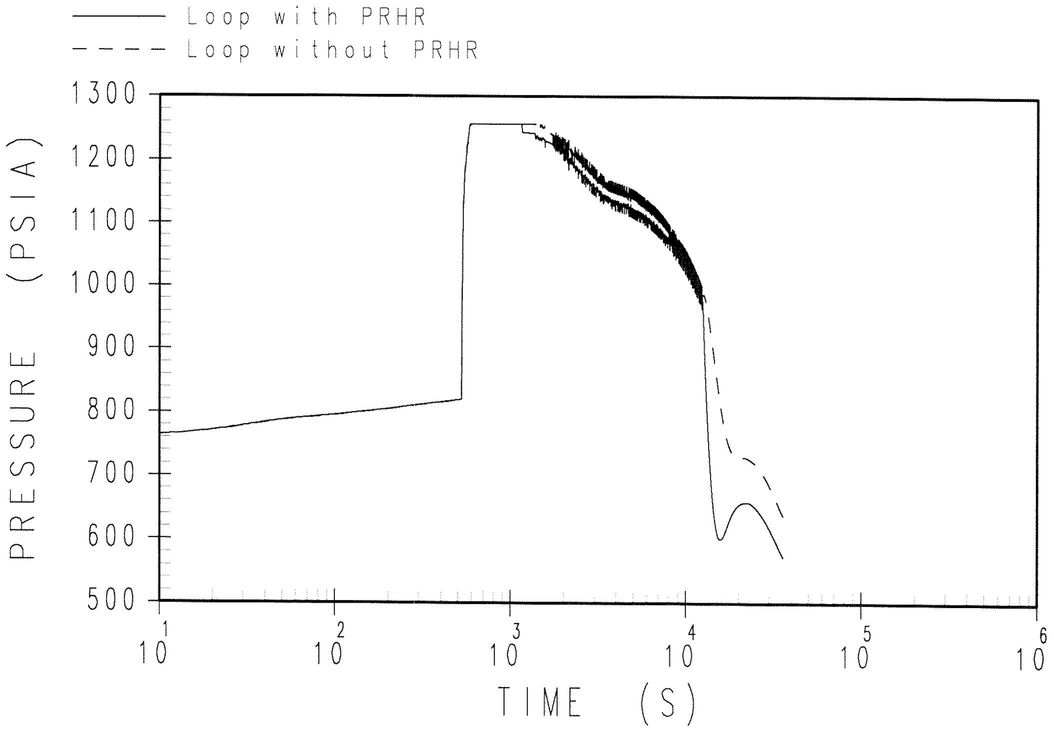

Figure 15.5.1-7

Steam Generator Pressure Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

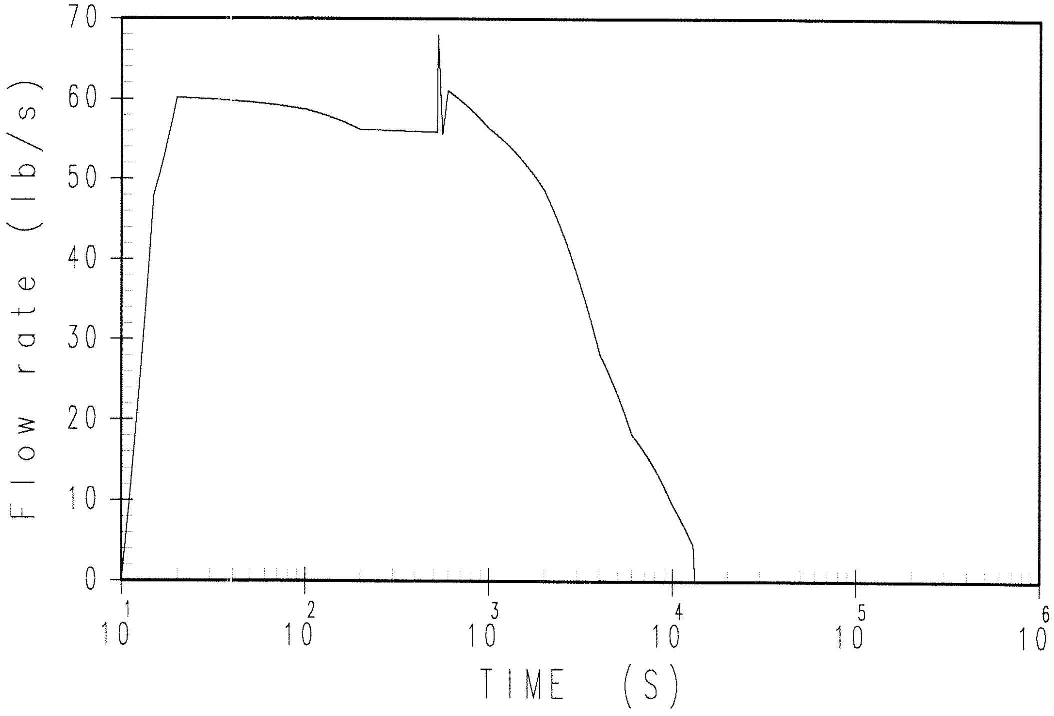

Figure 15.5.1-8

Inadvertent Actuated CMT Flow Rate Transient
for Inadvertent Operation of the Emergency Core Cooling System
Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

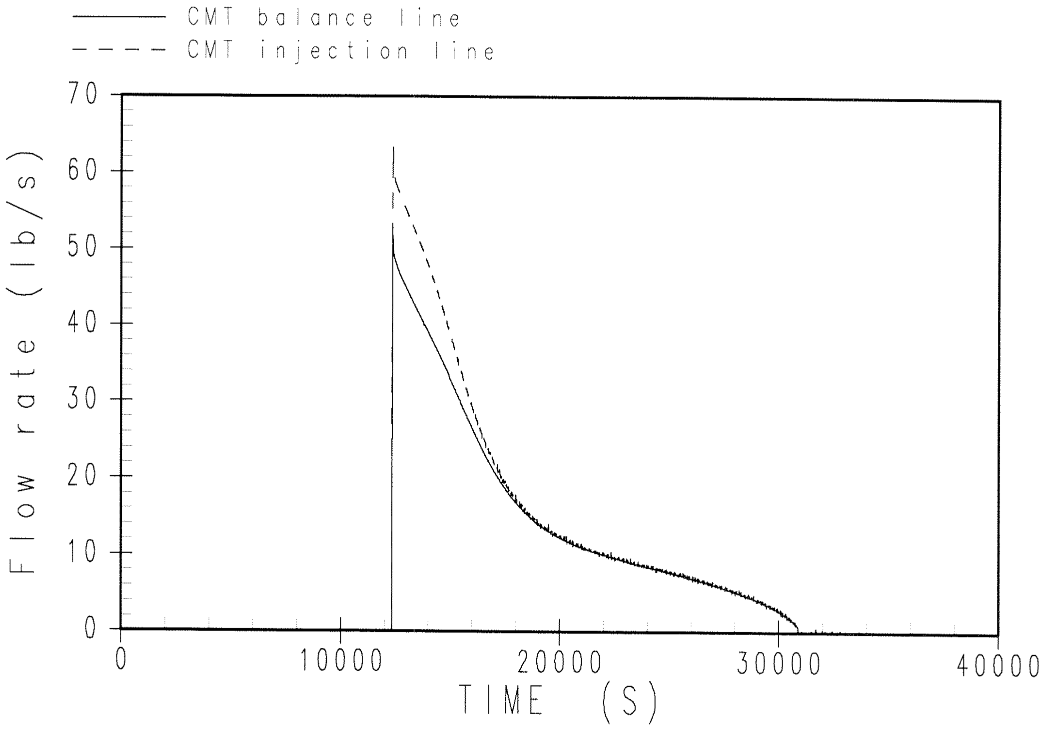

Figure 15.5.1-9

Intact CMT Flow Rate Transient
for Inadvertent Operation of the Emergency Core Cooling System
Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

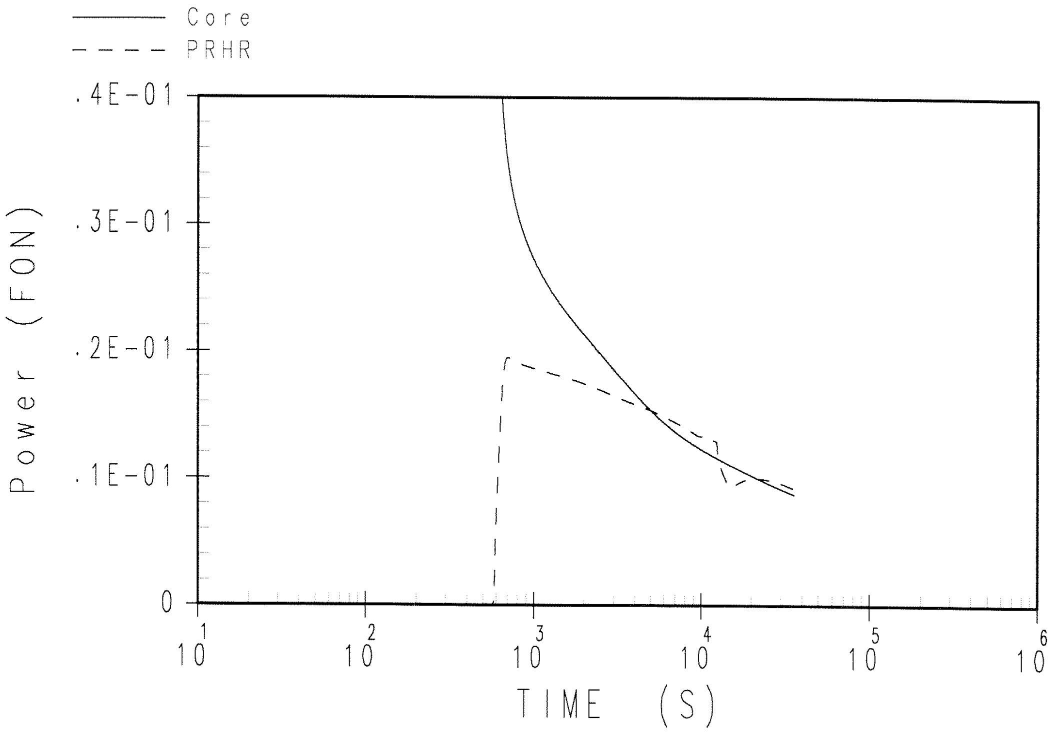

Figure 15.5.1-10

PRHR and Core Heat Flux Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

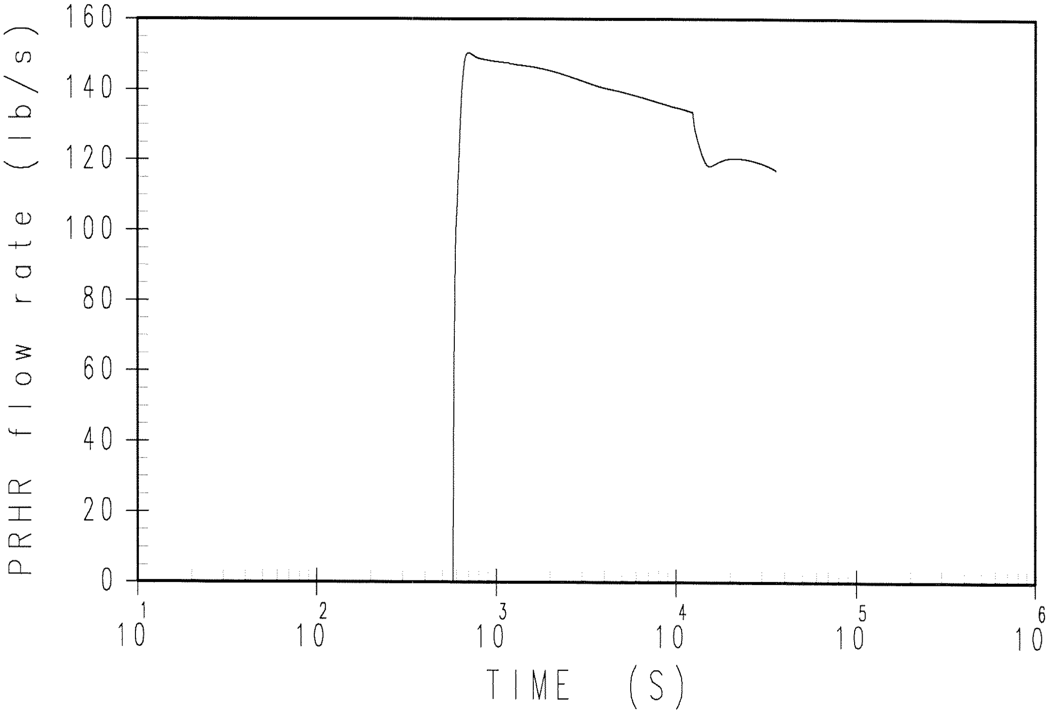

Figure 15.5.1-11

PRHR Flow Rate Transient for Inadvertent Operation of the Emergency Core Cooling System Due to a Spurious Opening of the Core Makeup Tank Discharge Valves

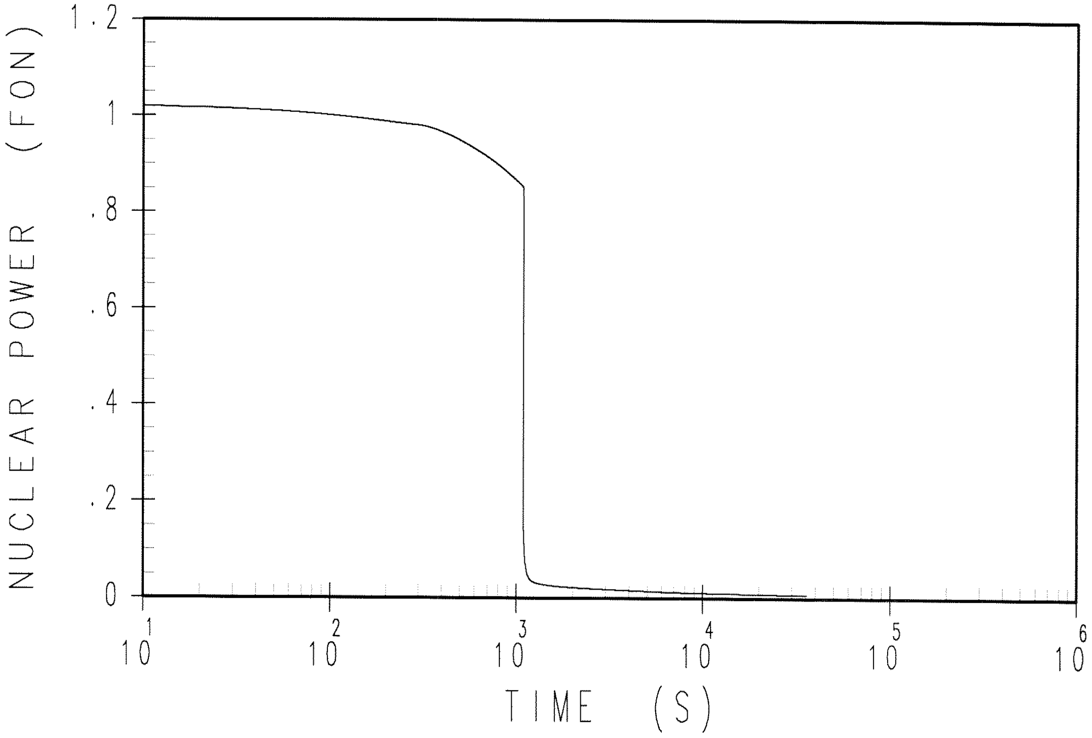

Figure 15.5.2-1

Core Nuclear Power Transient for Chemical and Volume Control System Malfunction

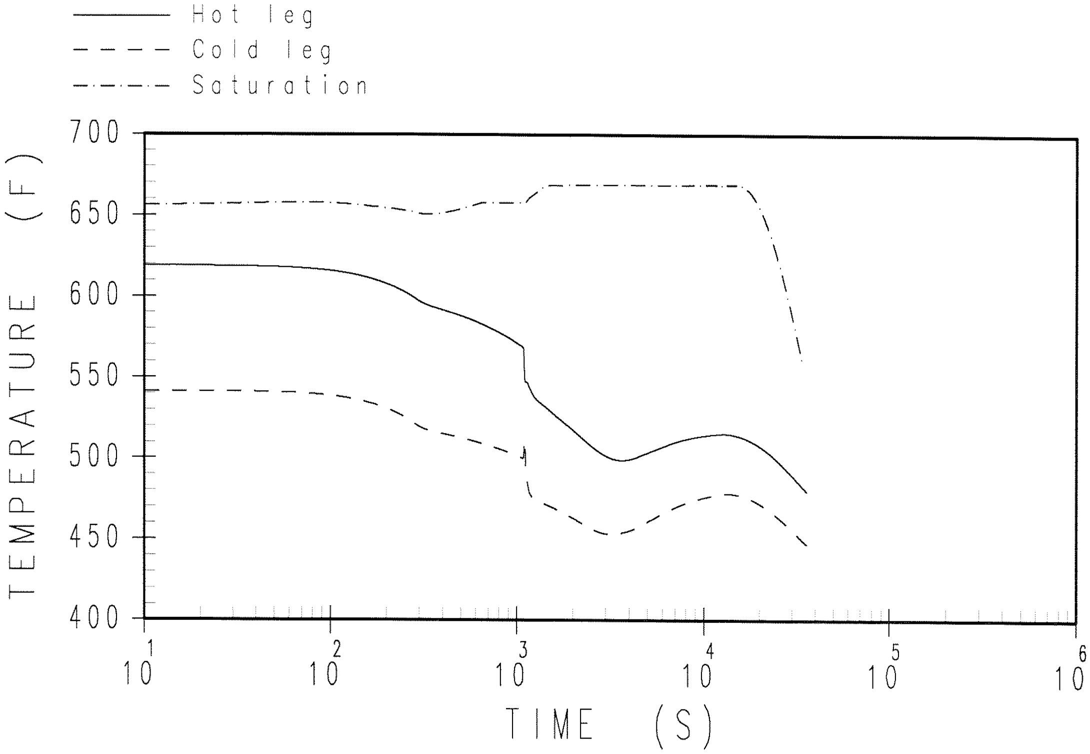

Figure 15.5.2-2

RCS Temperature Transient in Loop Containing the PRHR for Chemical and Volume Control System Malfunction

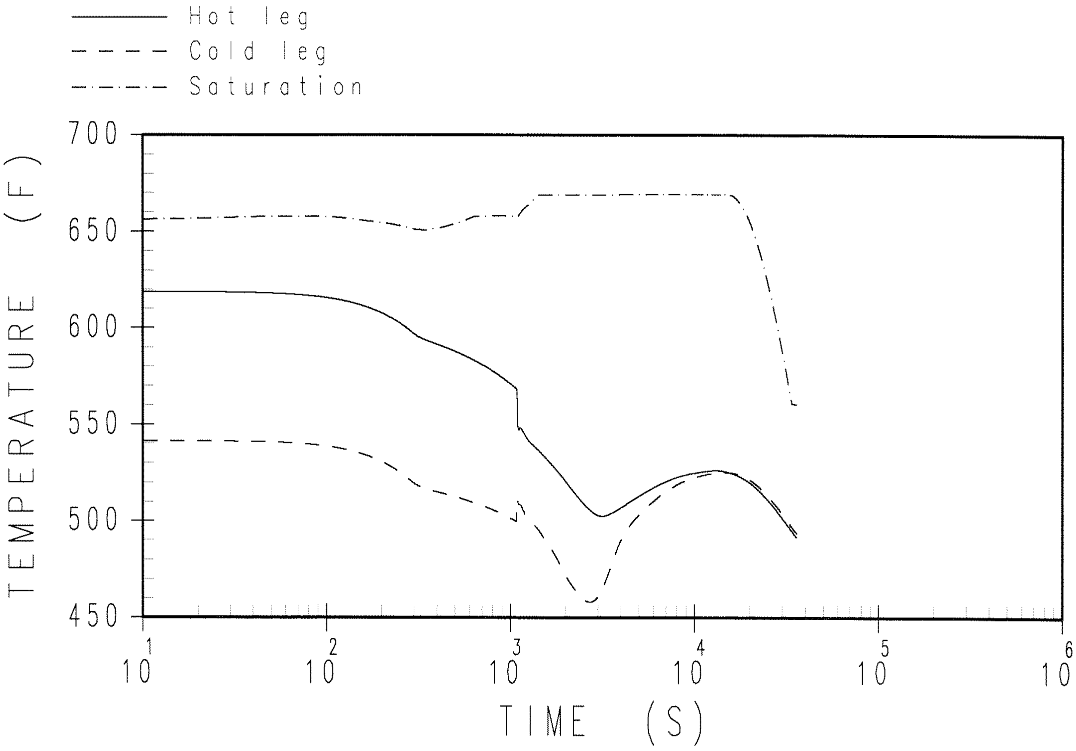

Figure 15.5.2-3

RCS Temperature Transient in Loop Not Containing the PRHR for Chemical and Volume Control System Malfunction

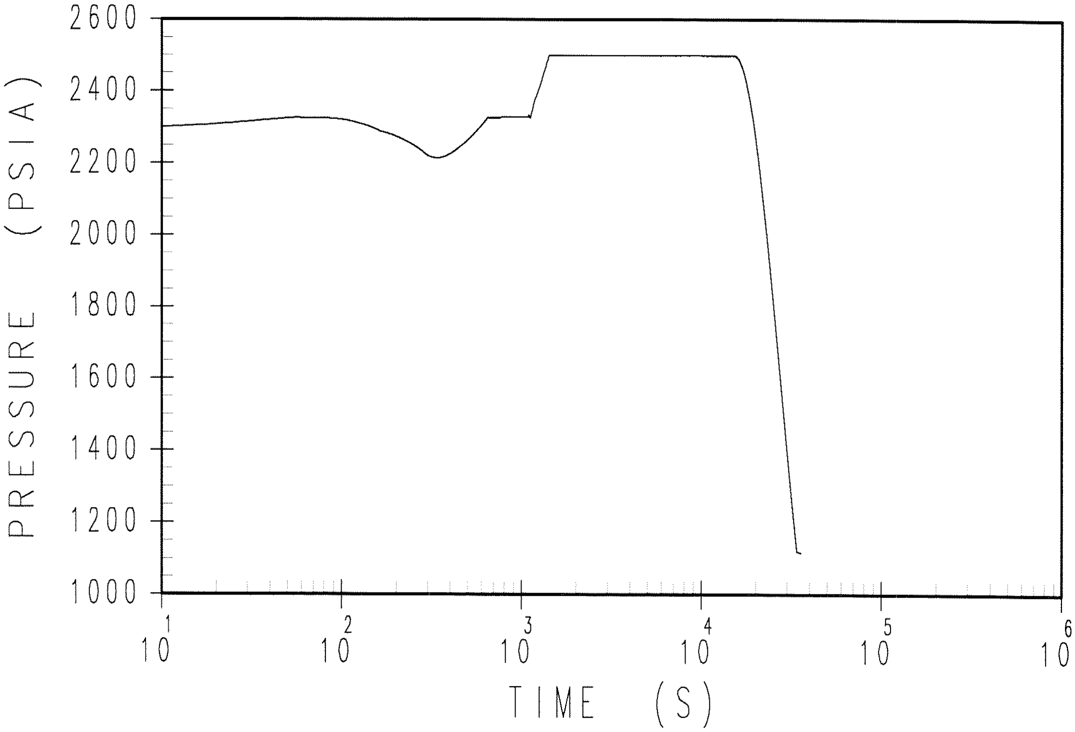

Figure 15.5.2-4

Pressurizer Pressure Transient for Chemical and Volume Control System Malfunction

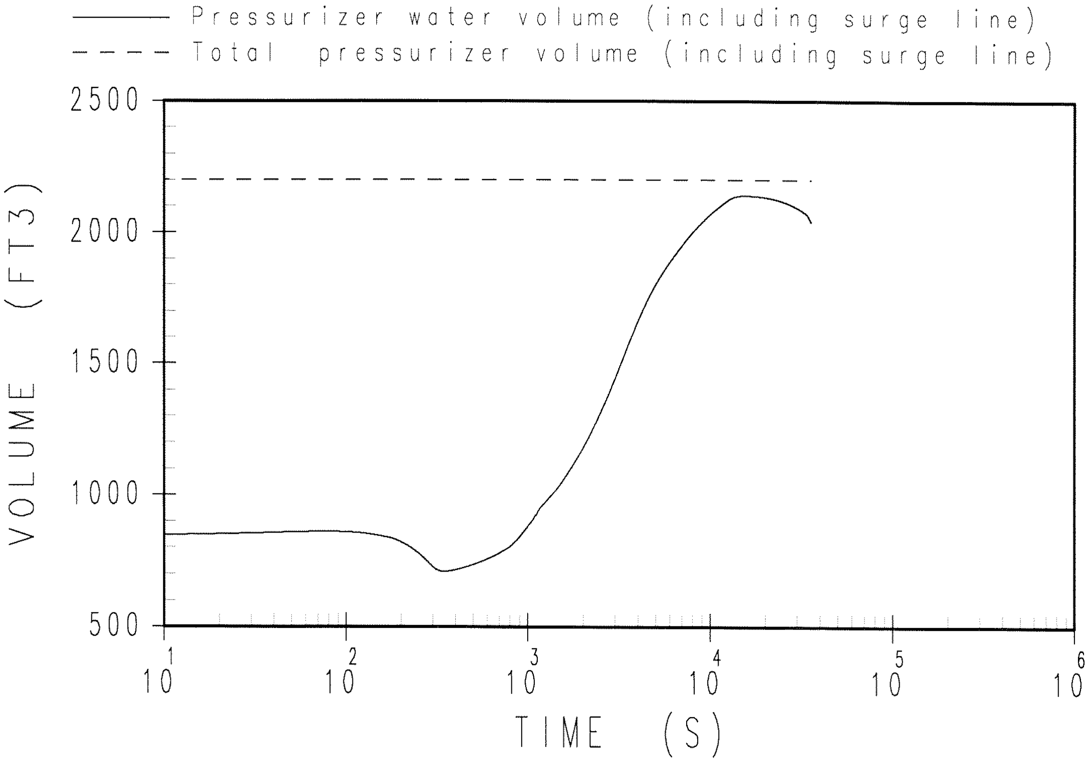

Figure 15.5.2-5

Pressurizer Water Volume Transient for Chemical and Volume Control System Malfunction

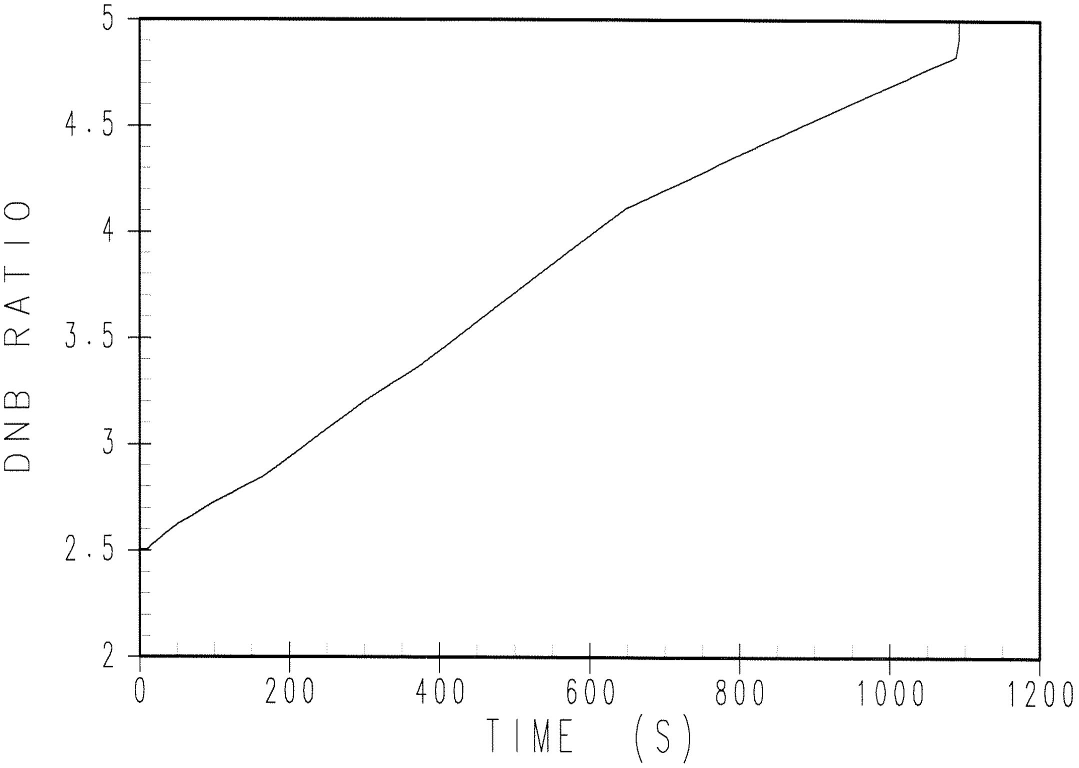

Figure 15.5.2-6

DNBR Transient for Chemical and Volume Control System Malfunction

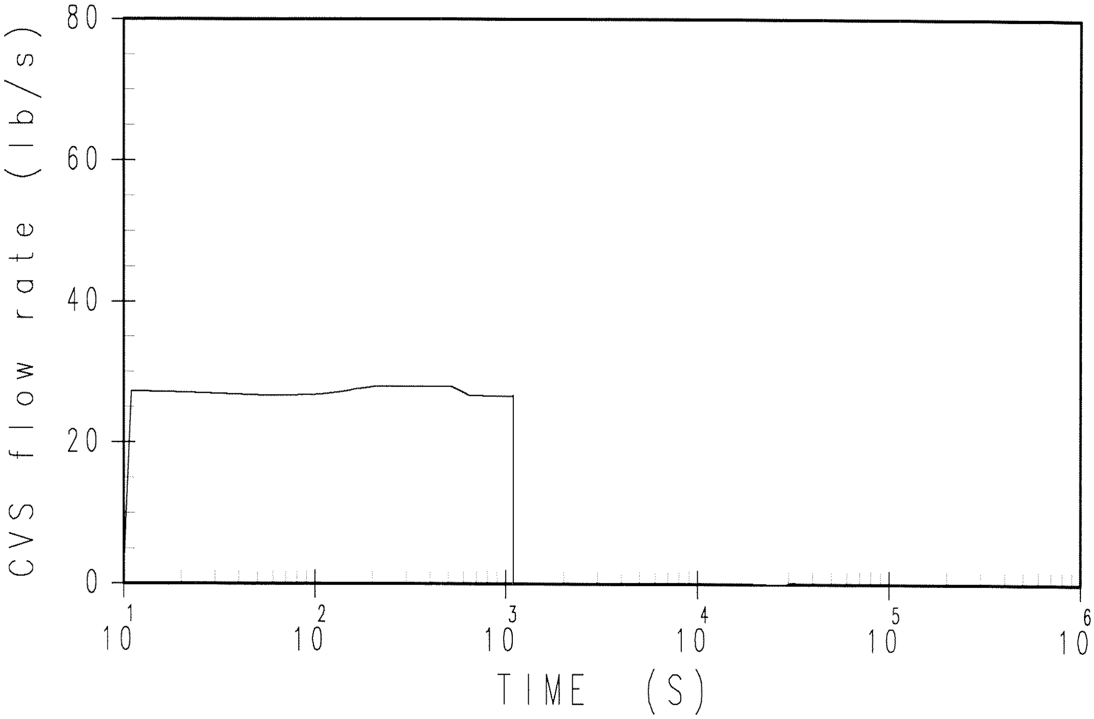

Figure 15.5.2-7

CVS Flow Rate Transient
for Chemical and Volume Control System Malfunction

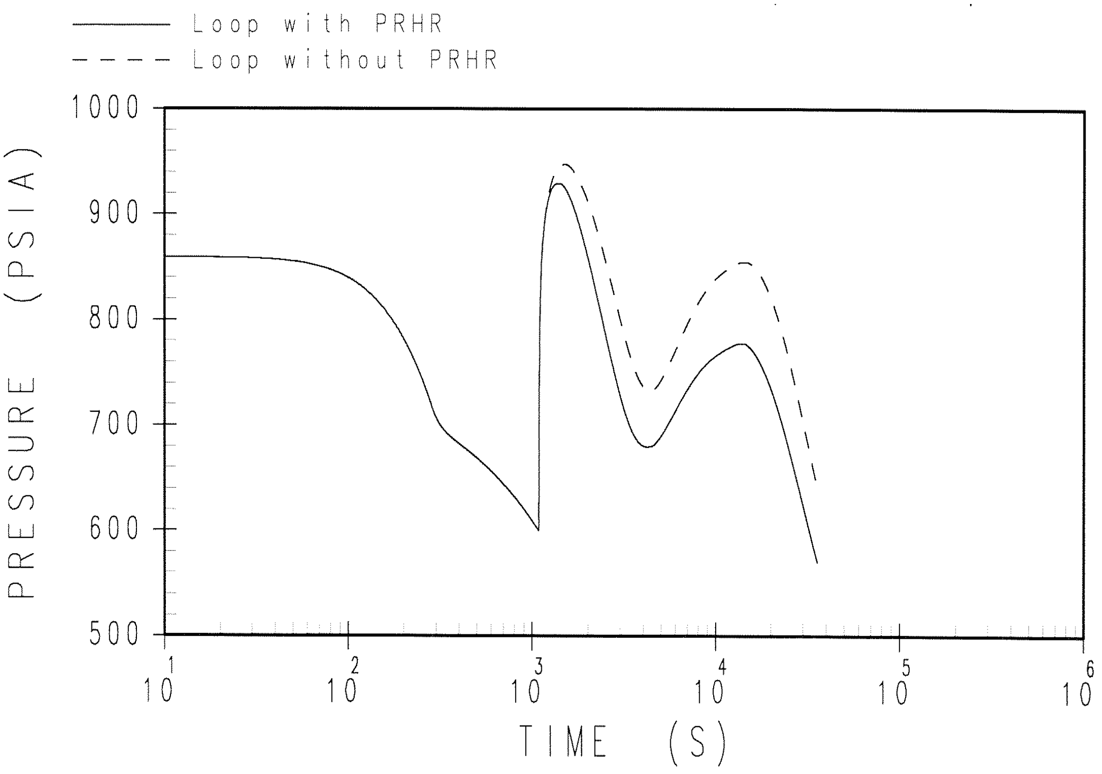

Figure 15.5.2-8

Steam Generator Pressure Transient for Chemical and Volume Control System Malfunction

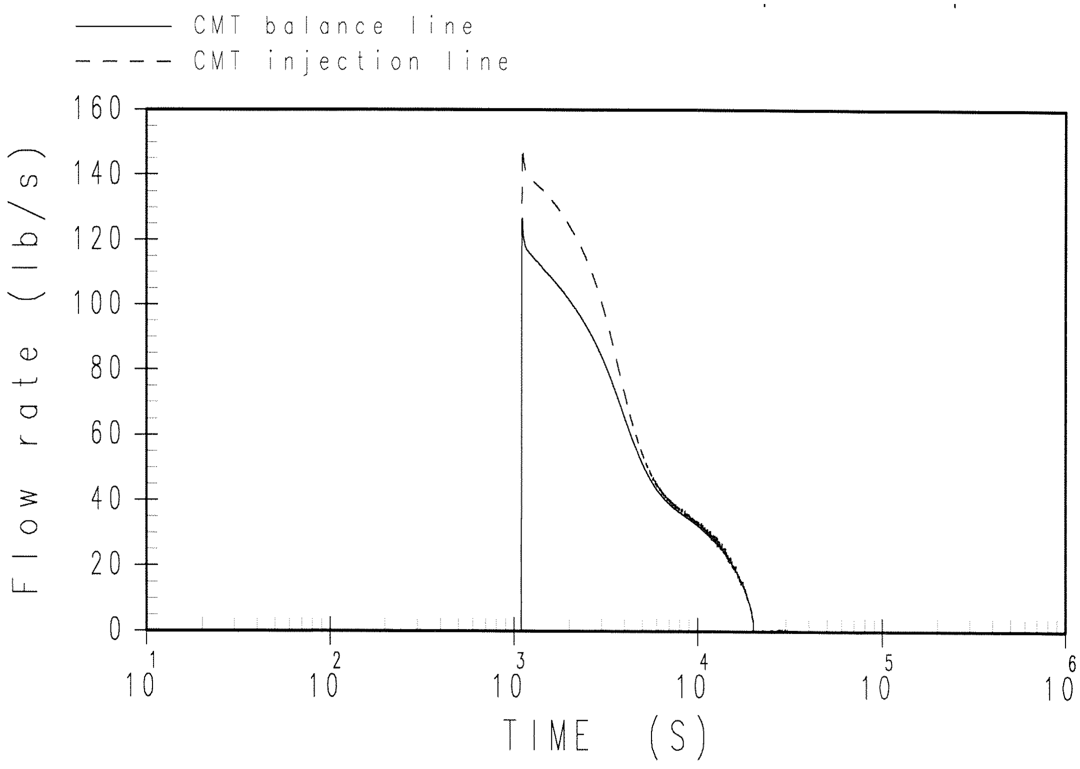

Figure 15.5.2-9

CMT Injection Line and Balance Line Flow Transient for Chemical and Volume Control System Malfunction

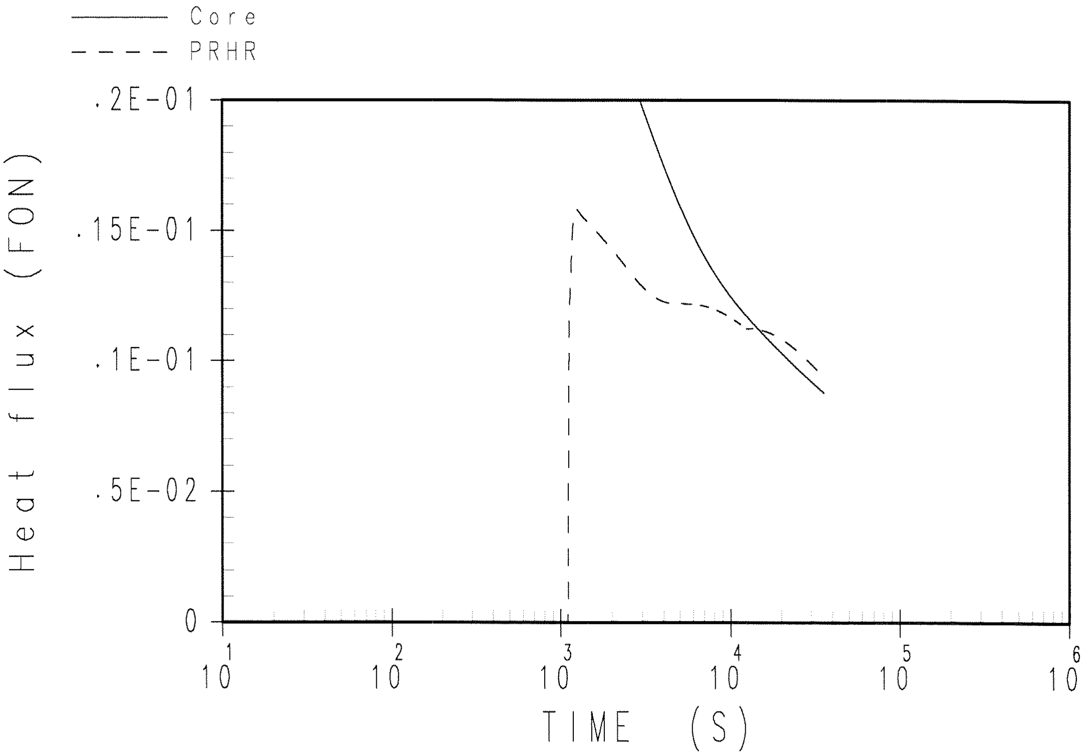

Figure 15.5.2-10

PRHR and Core Heat Flux Transient for Chemical and Volume Control System Malfunction

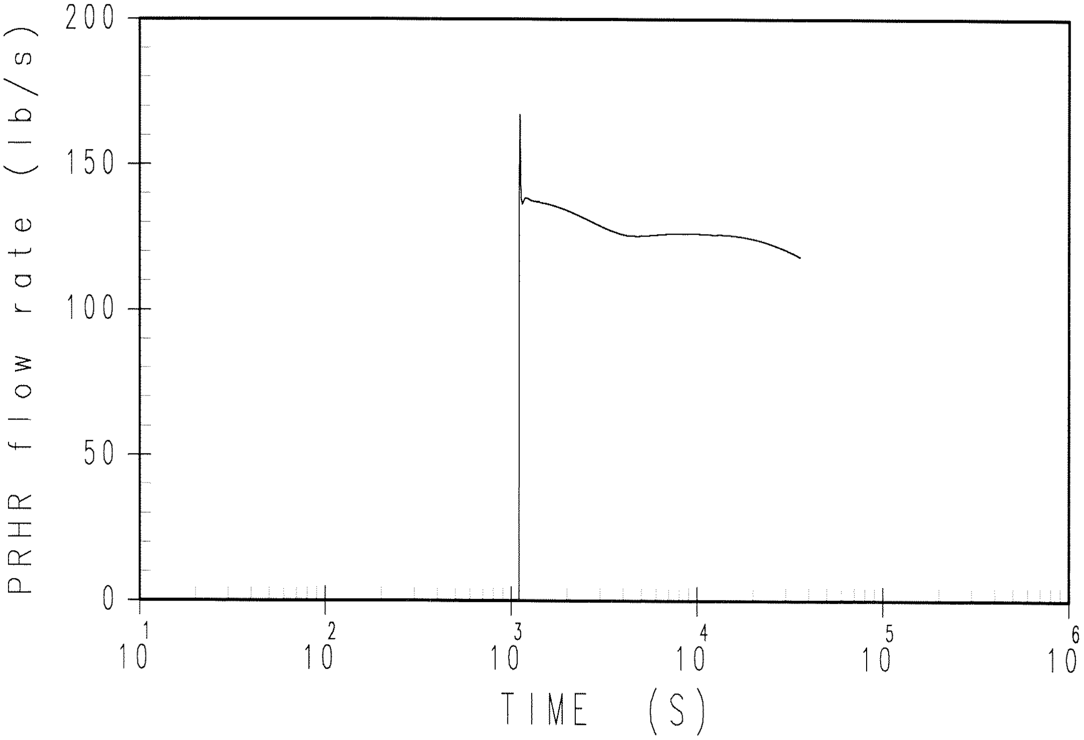

Figure 15.5.2-11

PRHR Flow Rate Transient
for Chemical and Volume Control System Malfunction