15.5 INCREASE IN REACTOR COOLANT SYSTEM INVENTORY

15.5.1 MODERATE FREQUENCY INCIDENTS

15.5.1.1 Chemical and Volume Control System Malfunction

→(DRN 05-543, R14)

The Chemical and Volume Control System Malfunction presented below was not revised for power uprate. Although the timing of event will be slightly different for power uprate, the underlying conclusions of acceptability are not affected.

→(DRN 06-1062, R15; EC-8458, R307)

The UFSAR presentation for this event assumes that the core is initially at full power. The analysis accounts for a reduction in charging flow temperature due to the imbalance of charging and letdown. Power increases minimally due to the resulting cooldown. The results of the AOR would be insensitive to the MTC used (-3.5 x 10-4 $\Delta\rho$/°F value was used as compared to the power uprate limit of -4.2 x 10-4 $\Delta\rho$/°F). The transient result would not be significantly affected by the 3716 MWth power uprate. The results should be insensitive to the high pressurizer pressure trip setpoint because trip occurs shortly after the system goes water solid. The sequence of events and results will remain applicable for the power uprate so long as the 44 gpm per pump charging flow and 29 gpm letdown flow used are preserved. The event timing documented in the UFSAR was based on a maximum pressurizer spray flow of 375 gpm and would be insignificantly affected by an increase in pressurizer spray flow because full flow was not achieved. The results presented in this section are based on the original steam generators and bound the replacement steam generators with up to 10% steam generator tube plugging.

←(DRN 05-543, R14; 06-1062, R15; EC-8458, R307)

15.5.1.1.1 Identification of Causes and Frequency Classification

The estimated frequency of a malfunction in the Pressurizer Level Control System or in the Chemical and Volume Control System (CVCS) classifies it as a moderate frequency incident as defined in Reference 1 of Section 15.0. A malfunction that produces an unplanned increase in reactor coolant inventory may be caused by an equipment or electrical malfunction or by an operator error, starting one or more charging pumps and interrupting letdown flow. The CVCS malfunction is assumed to occur without changing boron concentration. The case of a CVCS malfunction that produces a boron dilution is discussed in Subsection 15.4.1.5.

15.5.1.1.2 Sequence of Events and System Operation

Under normal operating conditions, the pressurizer Level Control System responds to an increase in pressurizer level and increases letdown flow to maintain the programmed level. Several faults or errors can be suggested which will lead to a mismatch between charging and letdown flow and in turn result in an increasing pressurizer level and pressure. For example, with the letdown control valve in MANUAL, the valve may be closed, reducing letdown flow to a minimum, while charging flow remains constant. In the same mode, a standby charging pump could start as the result of a single equipment fault or operator error; in this event, with constant letdown flow, pressurizer level would increase.

The limiting moderate frequency incident, i.e., the event which would lead to the most rapid increase in pressurizer level, is one which causes the letdown valve to close to its minimum opening and at the same time, starts all three charging pumps. With the systems in AUTOMATIC, a failure in the pressurizer level instrument serving the selected level control channel could transmit a false low level signal to the controller. In response, the controller would start both non-operating pumps (assuming that both are in STANDBY) and close the letdown control valve to its minimum opening.

A low level alarm will be annunciated immediately by the defective level instrument channel; a high level and then a high-high level alarm will be annunciated by the second control channel. (In this discussion, the second channel refers to that level control channel which has not been selected for control.)

The operator is expected to respond to the numerous alarms and indications, either selecting the second level control channel or stopping the charging pumps manually. Should he fail to respond, a reactor trip will be initiated on high pressurizer pressure before the pressurizer fills.

The secondary pressure is limited by the turbine bypass valves or by the steam generator safety valves.

The consequences of a single component or system malfunction following this event are discussed in Subsection 15.5.2.1.

15.5.1.1.3 Core and System Performance

a) Mathematical Model

The NSSS response to the CVCS malfunction was simulated using the CESEC-ATWS computer program described in Section 15.0.

b) Input Parameters and Initial Conditions

→(EC-13881, R304)

The input parameters and initial conditions used to analyze the NSSS response to the CVCS malfunction are discussed in Section 15.0. In particular, those parameters unique to this analysis are listed in Table 15.5-1.

Since the pressure transient is due to an increase in primary coolant inventory and not to thermal expansion, no power, coolant temperature, or DNB transient is produced prior to reactor trip. Therefore, the initial conditions for the principal process variables monitored by the COLSS, with the exception of RCS pressure, have no effect on the consequences of this transient. Minimizing the initial RCS pressure results in the longest possible delay in reactor trip on high pressurizer pressure and the maximum increase in RCS inventory. The initial pressurizer pressure was chosen at the lower limit of the operating region given in Table 15.0-4.

Since the charging flow through the regenerative heat exchanger exceeds the letdown flow, the temperature of the makeup water added to the RCS by the charging pumps is decreased significantly. Therefore, the most negative value of moderator temperature coefficient was selected to maximize the positive reactivity addition from injection of cold makeup water.

c) Results

It is assumed that no corrective action is taken by the operator for 30 minutes after the start of the transient.

←(EC-13881, R304)

The dynamic behavior of the significant NSSS parameters following a CVCS malfunction is shown in Figures 15.5-1 through 15.5-7, and the sequence of events is given in Table 15.5-2.

The increase in reactor coolant inventory resulting from the interruption of letdown flow coupled with starting of both standby charging pumps produces an increase in pressurizer level, compressing the steam volume and increasing pressurizer pressure. At 421.2 seconds the pressurizer spray is activated, the spray is sufficient to terminate the pressure transient until the rising water level covers the spray nozzles at 1555 seconds. Further compression of the steam results in reactor trip on high pressurizer pressure at 1641.5 seconds. At this point, the transient behavior resembles a loss of condenser vacuum. The primary (pressurizer) safety valves open briefly (for 2.5 seconds) and the steam generator safety valves open at 1648.0 seconds. These safety valves function to limit the primary and secondary pressure transients to 2539 and 1110 psia, respectively. Operator action to terminate charging and letdown flow at 1800 seconds is assumed, and the steam generator safety valves close at 1925 seconds.

→(EC-13881, R304)

After 1800 seconds, the operator can use the Steam Bypass System to cool the plant until the Shutdown Cooling System can be activated. The duration of this cooldown would be no longer than that for the loss of condenser vacuum, described in Subsection 15.2.1.3.4.3.

←(EC-13881, R304)

The maximum primary and secondary pressures are less than 110 percent of the design pressure following a CVCS malfunction, thus assuring that the integrity of the RCS and Main Steam System is maintained. All parameters affecting the DNBR are either unchanged during the transient or vary in a manner that increases the DNBR (i.e., RCS pressure increases), thus assuring that there is no violation of the fuel thermal design limits.

15.5.1.1.4 Barrier Performance

a) Mathematical Model

→(EC-13881, R304)

The model used for evaluation of barrier performance is identical to that described in Subsection 15.5.1.1.3.

b) Input Parameters and Initial Conditions

The input parameters and initial conditions used for evaluating barrier performance are identical to those described in Subsection 15.5.1.1.3.

c) Results

The 42 lbm of steam discharged by the primary (pressurizer) safety valves is completely condensed in the quench tank and not released to the atmosphere. The steam generator safety valves discharge 38,650 lbm of steam prior to closing at 1925 seconds. Steam releases required to cool the RCS to 350°F would be no greater than those for the loss of condenser vacuum, Subsection 15.2.1.3.4.3.

←(EC-13881, R304)

15.5.1.1.5 Radiological Consequences

→(DRN 04-704, R14)

The radiological consequences due to steam releases from the secondary system are less severe than those due to the feedwater line break, discussed in Subsection 15.2.3.1.3.1.5.

←(DRN 04-704, R14)

15.5.1.2 <u>Inadvertent Operation of the ECCS During Power Operation</u>

During power operation, the CPC low pressure trip ensures that the RCS pressure is greater than 1785 psia. This pressure exceeds the shutoff head of the safety injection pumps and the opening pressure of the safety injection tanks. Therefore, a spurious safety injection actuation signal (SIAS) will not cause injection of emergency cooling fluid into the RCS during power operation.

15.5.2 INFREQUENT INCIDENTS

15.5.2.1 Chemical and Volume Control System Malfunction with a Concurrent Single Failure of an Active Component

15.5.2.1.1 Identification of Causes and Frequency Classification

→(DRN 06-1062, R15; EC-8458, R307)

The estimated frequency of a malfunction in the Pressurizer Level Control System or in the CVCS with a concurrent single failure of an active component classifies it as an infrequent incident as defined in Reference 1 of Section 15.0. The causes of the event are discussed in Subsection 15.5.1.1. Various single active failures were considered to determine which failure has the most adverse effect. The results presented in this section are based on the original steam generators and bound the replacement steam generators with up to 10% steam generator tube plugging.

←(DRN 06-1062, R15; EC-8458, R307)

The single failures considered were (1) failure of the pressurizer heaters, (2) failure of the pressurizer sprays, and (3) failure or complete closure of the letdown valve. Loss of the heaters would result in the liquid phase remaining subcooled at all times prior to reactor trip, thus removing the slight increase in RCS pressure shown in Figure 15.5-3 at 1193 seconds, but altering the time of reactor trip. Failure of the sprays would preclude suppression of the pressure transient as shown in Figure 15.5-3 at 476 seconds, thus allowing the pressure to increase at the rate shown prior to 476 seconds. This would result in a high pressurizer pressure reactor trip at 545 seconds, when a much larger steam volume existed in the pressurizer, with behavior similar to a loss of condenser vacuum described in Subsection 15.2.1.3. Failure of the letdown valve produces the most adverse effect, as it results in the most rapid increase in RCS inventory.

15.5.2.1.2 Sequence of Events and System Operation

→(EC-13881, R304)

The systems and reactor trip that function during this event are the same as those described in Subsection 15.5.1.1.2, except that the letdown line is completely isolated. This results in the most rapid increase in pressurizer level.

15.5.2.1.3 Core and System Performance

a) <u>Mathematical Model</u>

The model used for evaluating core and system performance is identical to that described in Subsection 15.5.1.1.3.

b) <u>Input Parameters and Initial Conditions</u>

The input parameters and initial conditions used for evaluation of core and systems performance are identical to those described in Subsection 15.5.1.1.3.

c) <u>Results</u>

The response of the NSSS following this event is essentially identical to that described in Subsection 15.5.1.1.3 except that all events other than operator action takes place somewhat earlier.

←(EC-13881, R304)

15.5.2.1.4 Barrier Performance

a) Mathematical Model

The model used for evaluating barrier performance is identical to that described in Subsection 15.5.1.1.3.

b) Input Parameters and Initial Conditions

The input parameters and initial conditions used for evaluating barrier performance are identical to those described in Subsection 15.5.1.1.3.

c) Results

The amount of steam release to atmosphere is not greater than the amount released in a loss of condenser vacuum with single failure, described in Subsection 15.2.2.3.

15.5.2.1.5 Radiological Consequences

→(DRN 04-704, R14)

The radiological consequences of this event are less severe than those of the feedwater line break, discussed in Subsection 15.2.3.1.3.1.5.

←(DRN 04-704, R14)

15.5.3 LIMITING FAULTS

There are no limiting faults resulting from an increase in RCS inventory.

TABLE 15.5-1 Revision 304 (06/10)

ASSUMPTIONS FOR THE CVCS MALFUNCTION ANALYSIS

→(EC-13881, R304)

Parameter	Assumption
→(DRN 02-526, R12) Initial core power level, MWt * ←(DRN 02-526, R12)	3,478
Core inlet coolant temperature, °F	553
Core mass flow, 10^6 lbm/hr	143.0
Reactor coolant system pressure, psia	2,000
Steam generator pressure, psia	900
One pin radial peaking factor, with uncertainty	1.55
Maximum axial peaking factor	1.26
Initial core minimum DNBR	1.27
Moderator temperature coefficient, 10^{-4} $\Delta\rho$/ °F	-3.3
Doppler coefficient multiplier	0.85
CEA worth on trip, 10^{-2} $\Delta\rho$	-8.15
Steam Bypass Control System, mode	Manual
Pressurizer level and Pressure Control Systems, mode	Automatic

←(EC-13881, R304)

→(DRN 02-526, R12)

* Rated thermal power, plus power measurement uncertainty, plus reactor coolant pump heat.

←(DRN 02-526, R12)

→(DRN 05-543, R14)

Note: Analysis was not revised for power uprate – Section 15.5.1.1

←(DRN 05-543, R14)

TABLE 15.5-2 Revision 304 (06/10)

SEQUENCE OF EVENTS FOR THE CVCS MALFUNCTION EVENT

→(EC-13881, R304)

Time (Sec.)	Event	Setpoint or Value
0	Charging flow (maximized) letdown flow (minimized) gpm	132 and 29, respectively
326.3	Backup Heaters Deenergized, psia	2225
421.2	Proportional Heaters Deenergized, Proportional Sprays activated, psia	2275
440.0	All heaters energized on high pressurizer water level, ft. above programmed level	1.67
1555.3	Spray nozzles covered, ft^3 steam remaining	30.2
1595.1	High pressurizer pressure alarm psia	2350
1641.5	High pressurizer pressure reactor trip, psia	2422
1643.9	Pressurizer safety valves open, psia	2525
1644.2	Maximum RCS pressure, psia	2539
1646.4	Pressurizer safety valves close, psia	2424
1648.0	Steam generator safety valves open, psia	1085
1653.0	Maximum steam generator pressure, psia	1110
1800.0	Operator terminates flow imbalance	----
1925.0	Steam Generator Safety Valves Close, psia	1042

←(EC-13881, R304)

→(DRN 05-543, R14)

Note: Analysis was not revised for power uprate – Section 15.5.1.1

←(DRN 05-543, R14)