RELAP5 Thermal Hydraulic Analysis to Support PTS Evaluations for the Calvert Cliffs Nuclear Power Plant

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ADV	Atmospheric Dump Valve
DC	Downcomer
HPI	High Pressure Injection
HFP	Hot Full Power
HZP	Hot Zero Power
LOCA	Loss of Coolant Accident
LPI	Low Pressure Injection
PTS	Pressurized Thermal Shock
MSLB	Main Steam Line Break
MFW	Main Feedwater System
PORV	Power Operated Relief Valve
PTS	Pressurized Thermal Shock
RCS	Reactor Coolant System
SG	Steam Generator
SIRWST	Safety Injection Refueling Water Storage Tank
SIT	Safety Injection Tank
SRV	Safety Relief Valve
TBV	Turbine Bypass Valve

1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission undertook a study, referred to as the PTS Rebaselining Study, to determine whether brittle fracture of the reactor vessel is credible for all classes of cooldown transients and accidents. Part of the reason for undertaking this study is to utilize improved analytical capability to evaluate PTS events. This capability includes improved embrittlement correlations, greatly improved knowledge to estimate original flaw density, size, orientation, and distribution, refinement of the probabilistic fracture mechanics code, and improved understanding of flow interruption, flow stagnation, and fluid mixing behavior. Also, improvements in computing capabilities since earlier studies conducted in the 1980's means that more variations of PTS events can be considered, resulting in a better understanding of the types of transients that are significant contributors to risk.

This report documents the results of the Calvert Cliffs thermal hydraulic analyses performed as part of the PTS Rebaselining study and summarizes the downcomer boundary conditions for the FAVOR fracture mechanics analysis. The boundary conditions of interest are the time dependent primary system pressure, fluid temperature in the downcomer, and the convective heat transfer coefficient between the downcomer fluid and the vessel wall.

In NUREG/CR-6858, the results of the Oconee-1, Beaver Valley-1, and Palisades nuclear power plants analyses are discussed. These plants were analyzed using of the RELAP5/MOD3.2.2 gamma computer program. Originally, the PTS study was to include the Calvert Cliffs plant, but it was anticipated that the Calvert Cliffs PTS risk results would be sufficiently similar to the results from the Oconee, Beaver Valley and Palisades plants so that further analysis was not needed. However, a number of thermal hydraulic RELAP5 analyses were performed in FY 2003 timeframe when Calvert Cliffs was to be included in the study that is discussed in this report. These results, which were not revised to include items that were learned since that time, are presented in this report.

2.0 RELAP5 MODELS FOR THE CALVERT CLIFFS NUCLEAR POWER PLANT

The Calvert Cliffs Nuclear Power Plant is a pressurized water reactor of Combustion Engineering design with a rated thermal power of 2700 MW. The Calvert Cliffs reactor coolant system consists of a reactor vessel and two coolant loops connected in parallel and designated as Loops 1 and 2. Each coolant loop includes hot leg piping, an inverted U-tube type steam generator, and two sets of reactor coolant pumps and cold leg piping. The cold legs and reactor coolant pumps on each loop are designated as A and B. The normal coolant flow on each loop is from the reactor vessel outlet nozzle, through the hot leg, steam generator, reactor coolant pumps and cold legs to the reactor vessel inlet nozzle. A pressurizer is connected via a surge line to the hot leg on Loop 1. The electrically-heated pressurizer provides pressure control for the reactor coolant system. Pressurizer spray lines are routed from one of the pump-discharge cold legs on each loop through control valves to a spray nozzle in the pressurizer upper dome. Reactor coolant system overpressure protection is provided by power operated relief valves and safety relief valves mounted on top the pressurizer. Emergency core cooling functions are provided by high and low pressure injection systems and safety injection tanks, which are connected to each of the four pump-discharge cold legs. A charging/letdown system performs the functions of reactor coolant system water chemistry control and pressurizer level control.

Decay heat removal capability is provided by motor-driven and turbine-driven auxiliary feedwater systems that discharge into the steam generator downcomers. Steam generator secondary system overpressure protection is provided by safety relief valves, atmospheric dump valves and turbine bypass valves located on the main steam lines. Main steam isolation valves are located in each of the two steam lines, limiting the influence that a break in one of the steam generator secondary systems would have on the other.

The Calvert Cliffs RELAP5 model is a detailed thermal-hydraulic representation of the Calvert Cliffs Nuclear Power Plant that includes all major components of the primary and secondary coolant systems and the plant control systems pertinent for simulating the PTS transient event sequences. The thermal-hydraulic analysis methodology used for Calvert Cliffs is similar to the approach used in NUREG/CR-6857 for the Oconee, Beaver Valley, and Palisades plants. The Calvert Cliffs RELAP5 input model developed by the Idaho National Laboratory (INL) was used as the starting point to expedite the model development process. Nodalization diagrams for the Calvert Cliffs RELAP5 model are illustrated in Figures 2-1 through 2-8.

The reactor vessel model nodalization is shown in Figure 2-1. Because of the need for detailed information on reactor vessel downcomer temperature for evaluating PTS, a two-dimensional nodalization scheme with six azimuthal nodes is used in the downcomer region. The downcomer nodalization is shown in Figure 2-2. The reactor core region is modeled using six axial nodes. Other nodes are used to represent the lower plenum, upper plenum, core bypass, control rod guide tube and upper head regions of the reactor vessel.

The reactor coolant loop region nodalization is shown in Figures 2-3 and 2-4 for Loop 1 and Figures 2-5 and 2-6 for Loop 2. The speed of the reactor coolant pump models is held constant to deliver the normal-operation flow rate unless the pumps are tripped by operator action (based on indications of low reactor coolant system pressure or low subcooling). Once tripped, the reactor coolant pump speed coasts down based on rotational inertia effects. Charging flow is injected into the Loop 1A and 2B pump-discharge cold leg piping and letdown flow is withdrawn from the Loop 2A pump-suction cold leg piping. The charging flow is controlled so as to maintain a desired pressurizer setpoint level, which is specified as a function of average reactor coolant system temperature. The letdown flow is isolated upon receipt of a safety injection actuation signal, which results from a low pressurizer pressure condition. The operation of the pressurizer heater power and spray valve flow area are specified so as to maintain the pressurizer pressure within the desired range.

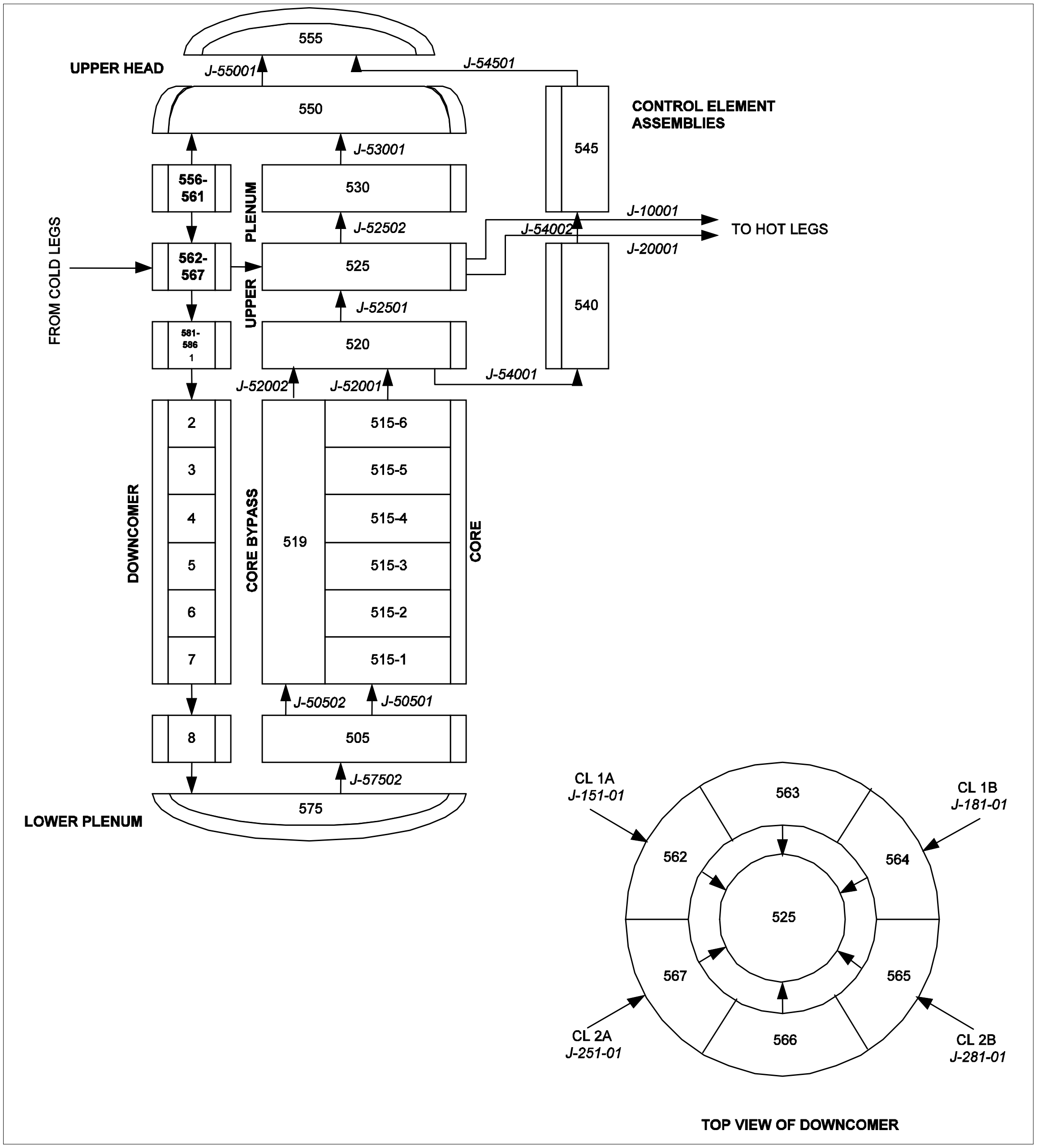


Figure 2-1 Reactor Vessel RELAP5 Nodalization Diagram

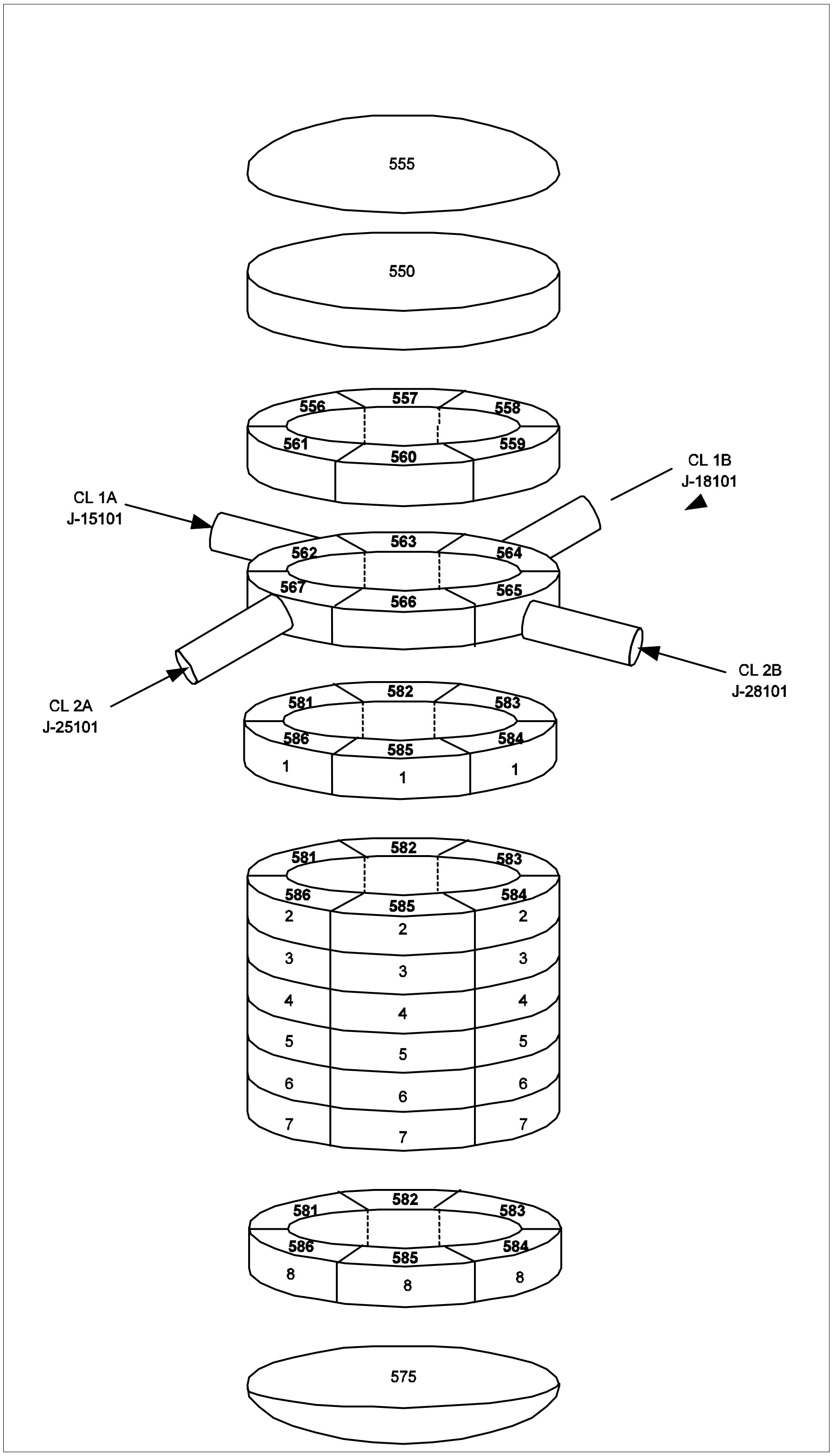


Figure 2-2   2-D Downcomer Nodalization Diagram

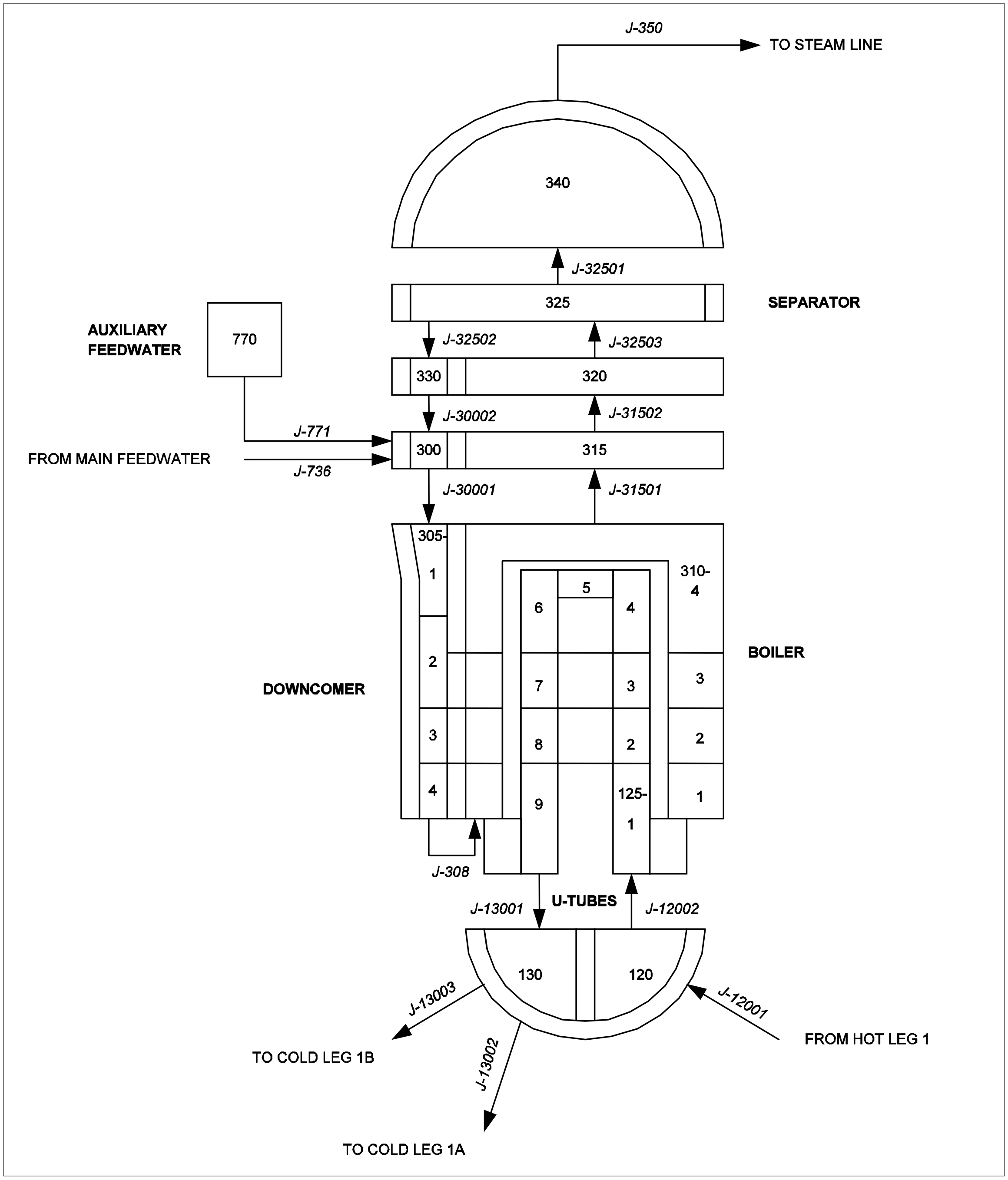


Figure 2-3 Steam Generator Loop 1 Nodalization Diagram

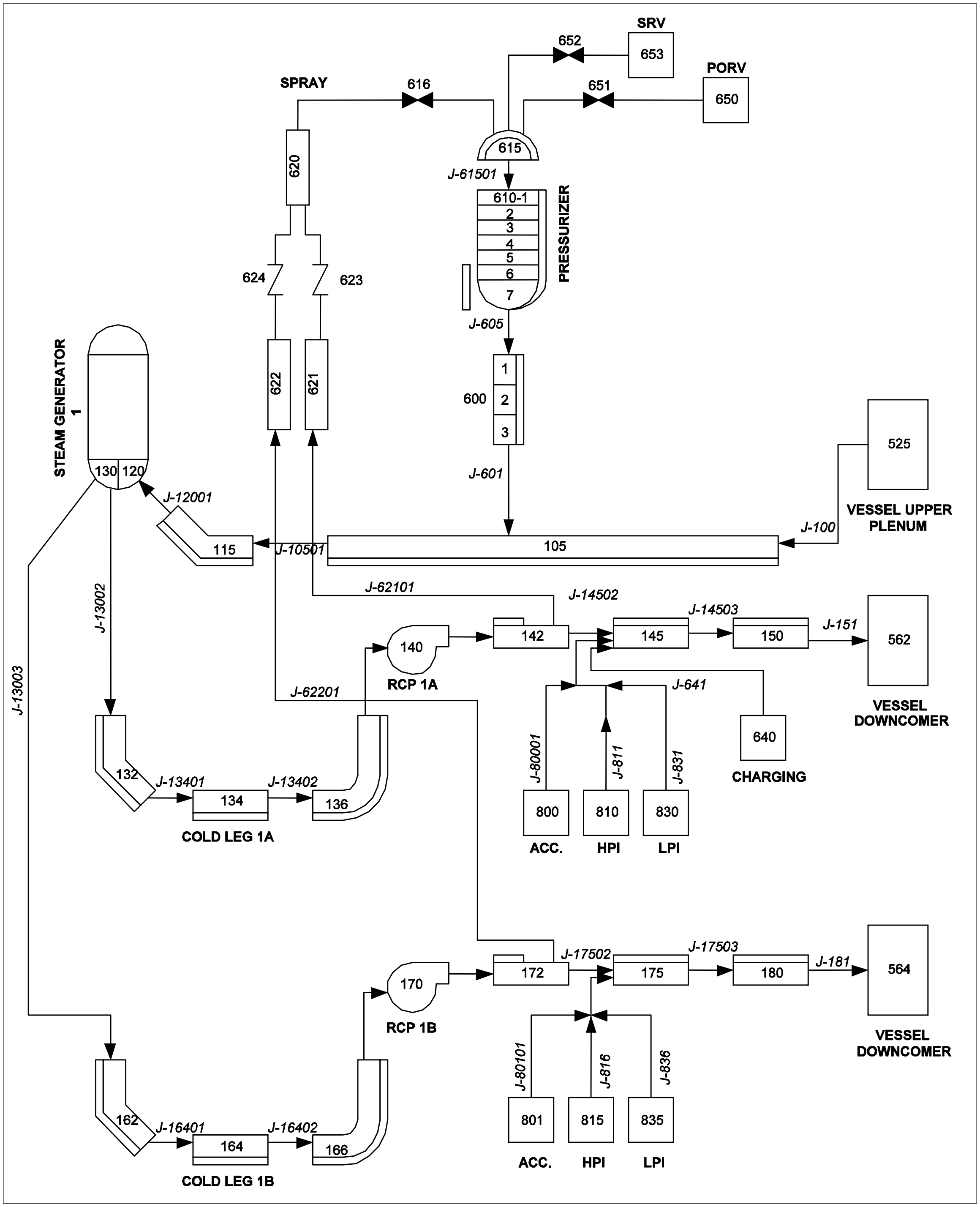


Figure 2-4 Reactor Coolant System Loop 1 Nodalization Diagram

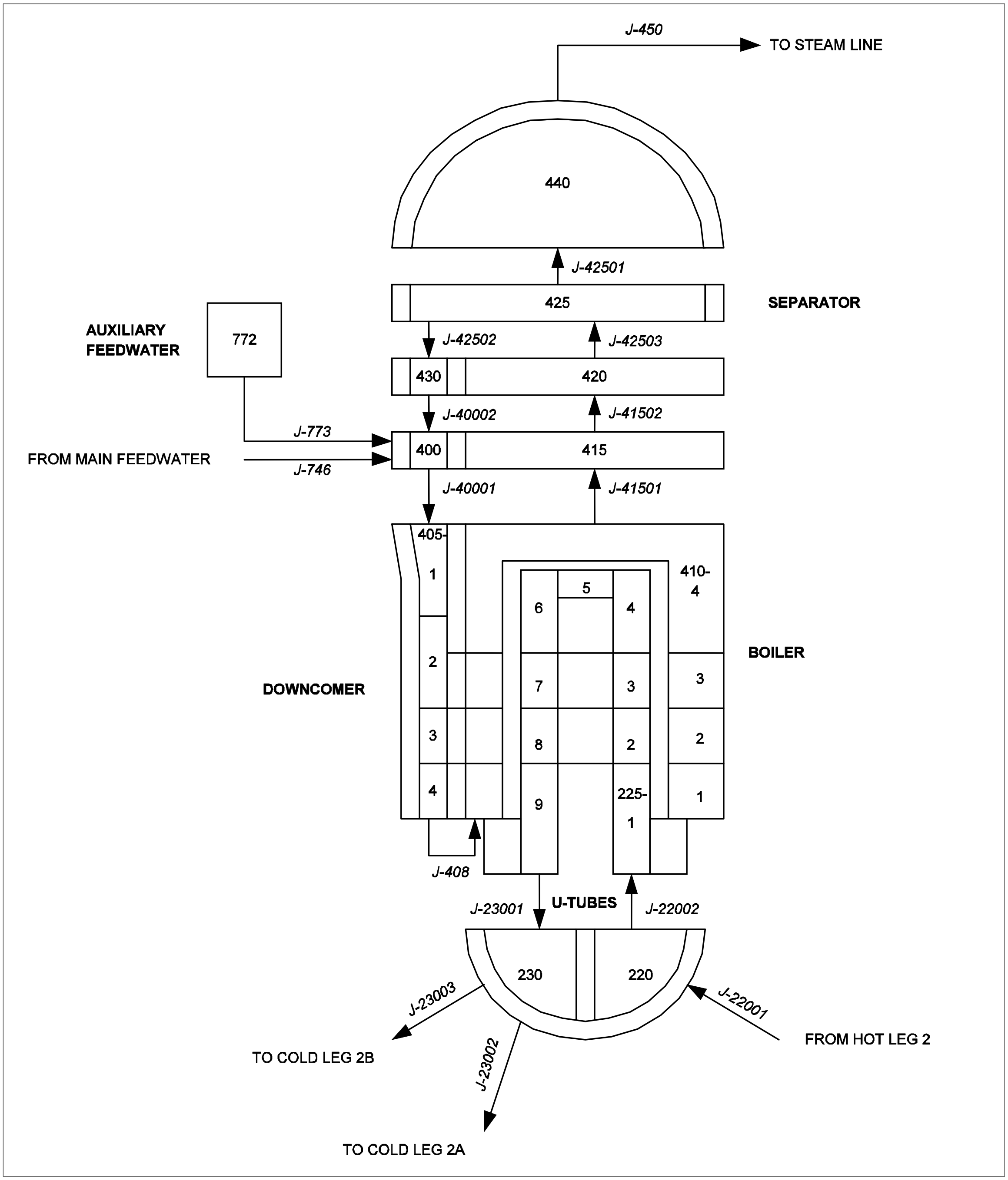


Figure 2-5 Steam Generator Loop 2 Nodalization Diagram

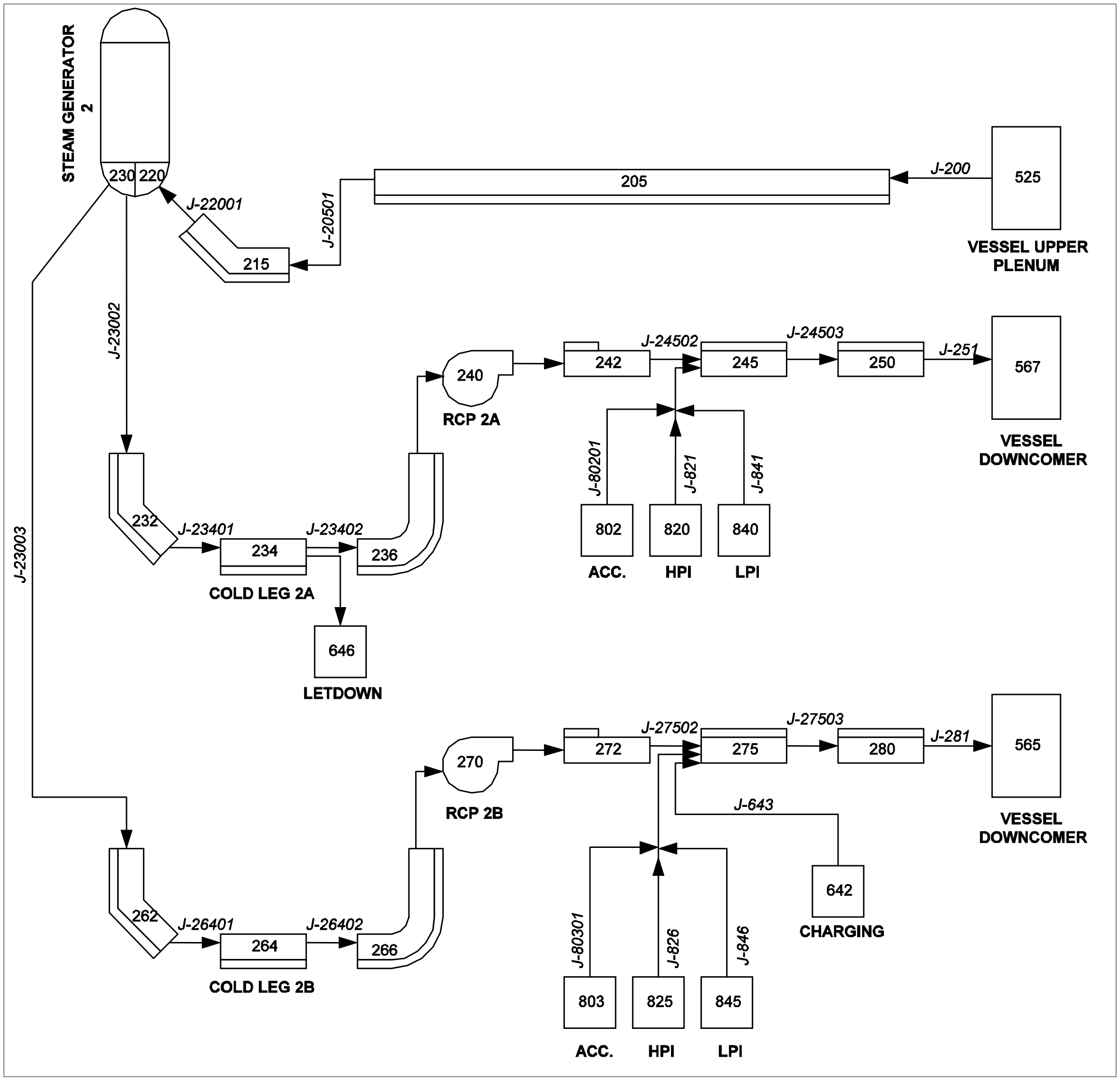


Figure 2-6 Reactor Coolant System Loop 2 Nodalization Diagram

The safety injection tanks are modeled on each of the four pump-discharge cold legs using RELAP5 accumulator components. Accumulator flow occurs whenever the cold leg pressure is below the tank pressure. The tank pressure is 1.48 MPa (214.7 psia). The high and low pressure injection systems are represented using RELAP5 time dependent volume and junction component pairs on each of the four pump discharge cold legs. The injection characteristics of these centrifugal pump systems are modeled with the flow delivered specified as a function of the cold leg pressure; flow is initiated after a time delay following the occurrence of a safety injection actuation signal.

Various ECCS injection temperatures were considered during the course of the analysis. Most cases utilized the nominal temperature conditions. In some cases, winter and summer conditions were considered in the analysis to support the uncertainty/sensitivity evaluation performed by the University of Maryland.

System	Nominal	Winter	Summer
Safety Injection Tanks	300 K (80°F)	292 K (65°F)	308 K (95°F)
High Pressure Injection	289 K (60°F)	278 K (40°F)	300 K (80°F)
Low Pressure Injection	289 K (60°F)	278 K (40°F)	300 K (80°F)

Control logic is included such that operator throttling of high pressure injection (based on pressurizer level and subcooling criteria) can be represented for event sequences specified to include that operator function. Control logic is also included to estimate the time that ECCS suction switches from the safety injection refueling water storage tank (SIRWST) to the containment sump. The SIRWST supplies water for the charging, high pressure injection, low pressure injection and containment spray systems. When the inventory of the tank has been expended, the model includes features that represent the actions taken in the plant (termination of the charging and low pressure injections and switching the suction of the high pressure injection system to the containment sump). Following this switch, the high pressure injection system flow characteristics are changed and the injected water temperature increases.

The main feedwater flow is adjusted so as to control the steam generator levels at the setpoint level and to match the feedwater and steam flow rates in each steam generator. After turbine trip, the main feedwater flow stops and the auxiliary feedwater flow is delivered to control steam generator levels within a specified range.

The main steam and main feedwater system nodalizations are shown in Figure 2-7 and 2-8. The model represents the steam line from each steam generator to the common turbine inlet header. A valve component is used to represent the turbine stop valves, which close upon receipt of a turbine trip signal. Overpressure protection is modeled by the main steam safety relief valve components on each steam line. Steam pressure control for post-turbine trip operating conditions is provided by a turbine bypass valve component located on the turbine inlet header. Primary coolant system average temperature control is provided by an atmospheric dump valve component on each of the steam lines. Main steam isolation valves connect each steam line to the turbine inlet header. These valves close if a low pressure condition is sensed in either steam generator or if a containment high pressure condition is sensed.

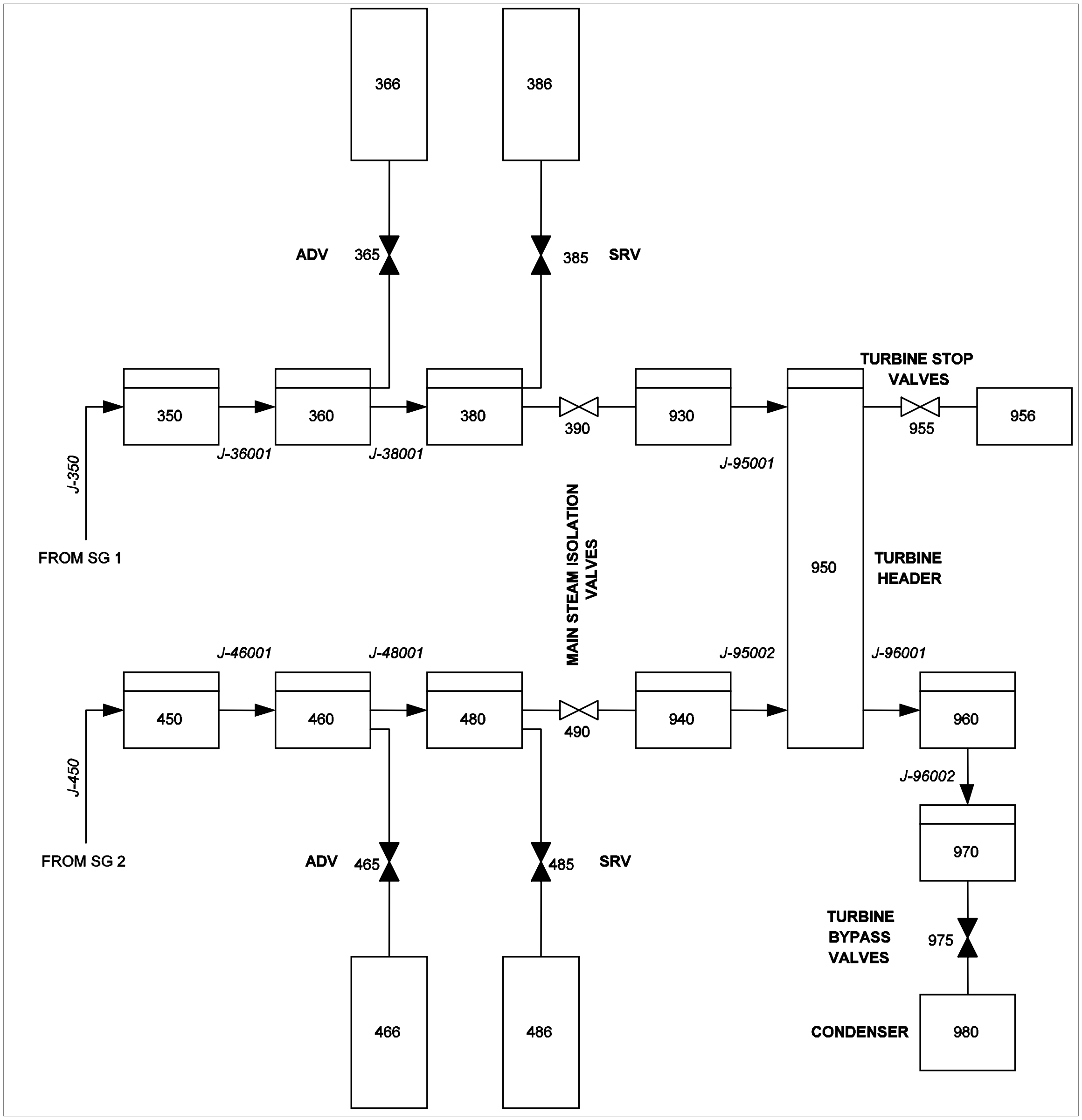


Figure 2-7 Main Steamline Nodalization Diagram

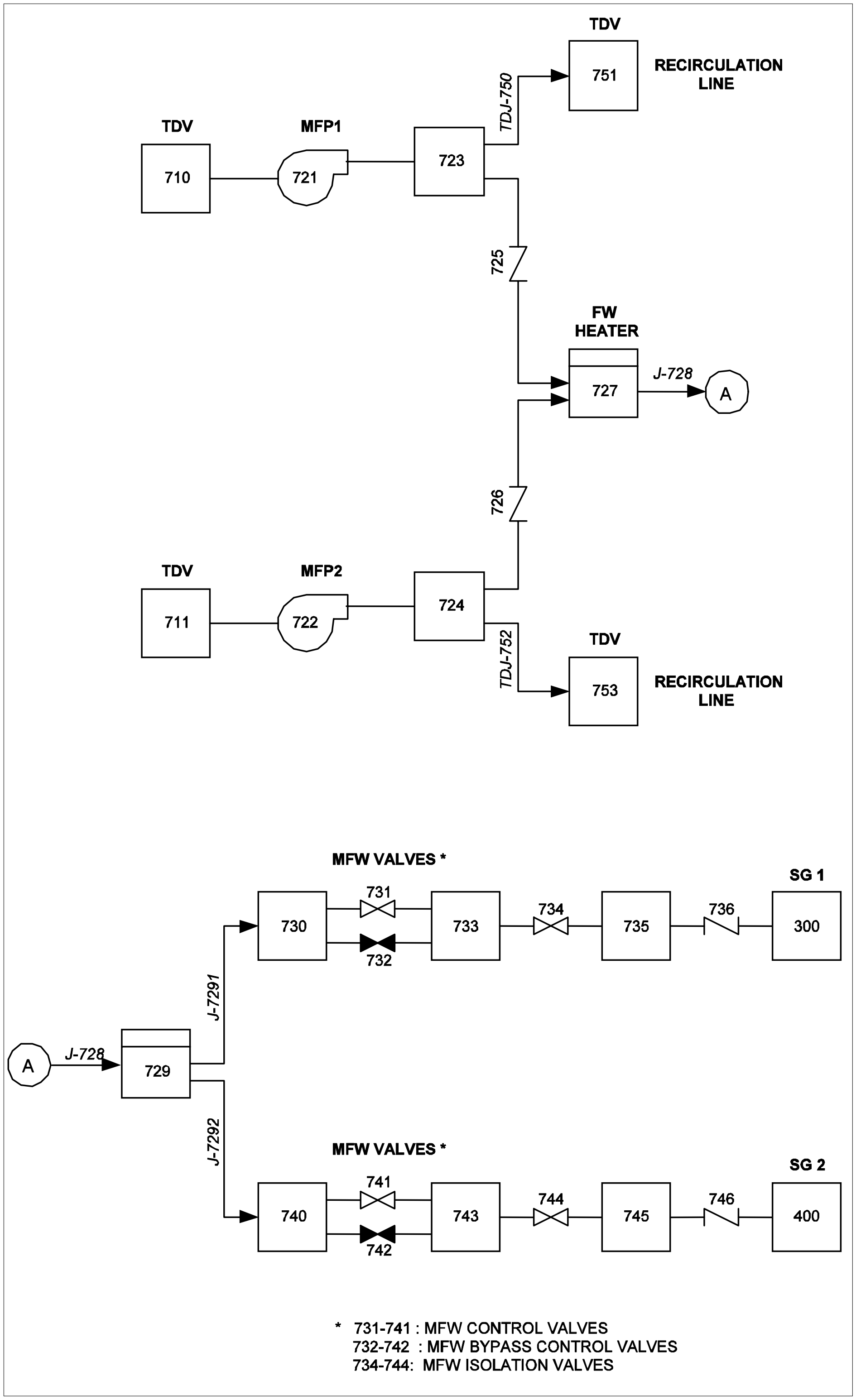


Figure 2-8 Calvert Cliffs RELAP5 Nodalization Diagram – Main Feedwater System

During the course of the analysis of Oconee, Beaver Valley and Palisades plants, certain analytical assumptions were used to inhibit flow circulations in the same-loop cold legs in the LOCA cases or in the downcomer itself. To inhibit flow recirculation in the same-loop cold legs in the Palisades and Oconee models, artificial high reverse loss coefficients were used in the reactor coolant pump regions of the cold legs. The veracity of the cold leg circulations could not be proved. So, for conservatism, the artificial loss coefficients were used in the Oconee and Palisades analysis. However, the decision to categorically apply the artificial high loss coefficients to all LOCA cases was not made at the time the Calvert Cliffs cases were run (2003 time frame). As a result, the high reverse loss coefficients were not included in the Calvert Cliffs analysis.

The effect of not including the high reverse loss coefficients depends on the diameter of the LOCA being analyzed. For large break LOCAs, omission of the high reverse loss coefficients will likely have little impact considering that vessel failures are predicted to occur very early in the transient by Favor (typically within 10-20 minutes). For the smaller breaks, omission of the high reverse loss coefficients will generally result in the prediction of warmer downcomer temperatures.

Unphysical numerically-driven flow recirculation in the downcomer was inhibited by deactivating the use of momentum flux in all junctions internal to the downcomer region. Checks of the results of the Calvert Cliffs RELAP5 runs did not uncover any indication of unreasonably high flow circulation velocities in the downcomer. Axial and circumferential circulation velocities of less than approximately 0.61 m/s (2 ft/s) are typically observed.

Another issue that was evolving in the FY 2003 timeframe was the impact of ECCS switchover to the containment sump. While the ECCS water source is the SIRWST, the temperature is lower than when pump suction switches to the containment sump. Some of the large break LOCA cases were reanalyzed with ECCS suction switchover included in the model in FY 2003, which are identified in the case list in Appendix A.

Steady-state calculations simulating hot full power and hot zero power plant operation were performed with the Calvert Cliffs RELAP5 model in order to establish model initial conditions from which to begin transient accident calculations. Hot zero power is defined as a constant 0.2% of full power for this analysis. Long (8,000 s) steady state runs were made to assure that steady conditions had been achieved in the fluids and heat structures represented by the Calvert Cliffs RELAP5 model. Figures 2-9 and 2-10, respectively, show the cold leg pressure and fluid temperature responses from the hot full power and hot zero power RELAP5 calculations. The figures demonstrate that the RELAP5 solutions are steady at the ends of the calculations. Tables 2-1 and 2-2, respectively, compare the RELAP5-calculated steady-state results for key parameters (at the 8,000 s end points of the calculations) with the desired Calvert Cliffs plant values for hot full power and hot zero power plant operation. The tables indicate that the RELAP5-calculated steady-state solutions are in excellent agreement with the desired steady plant conditions for both cases.

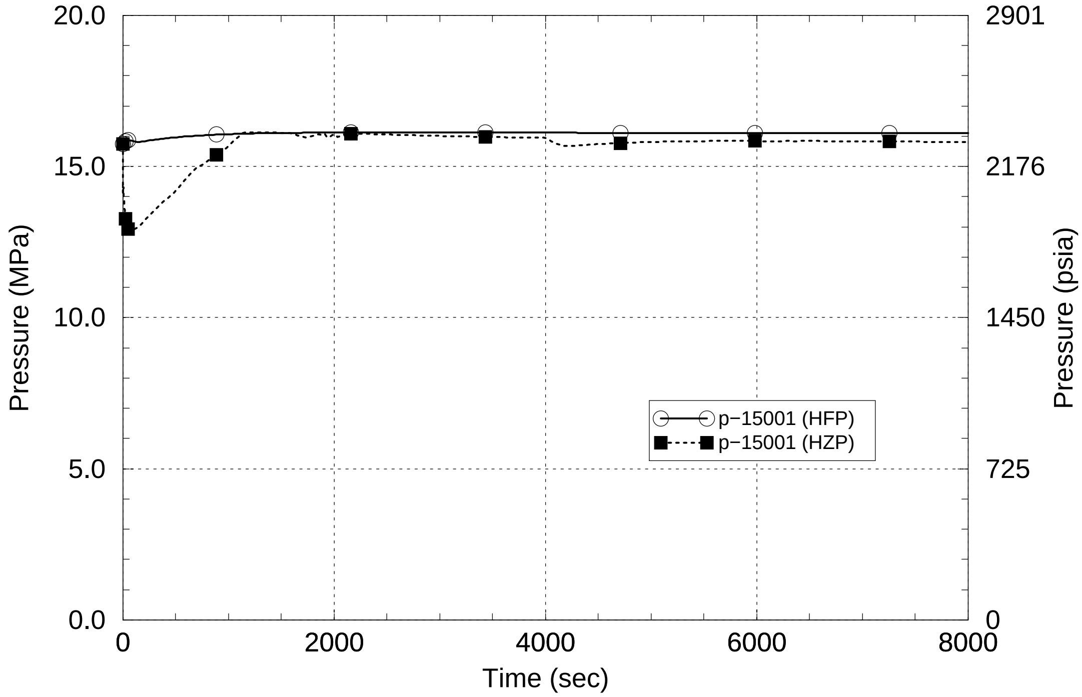


Figure 2-9 Calvert Cliffs Cold Leg Pressure Response – Steady State

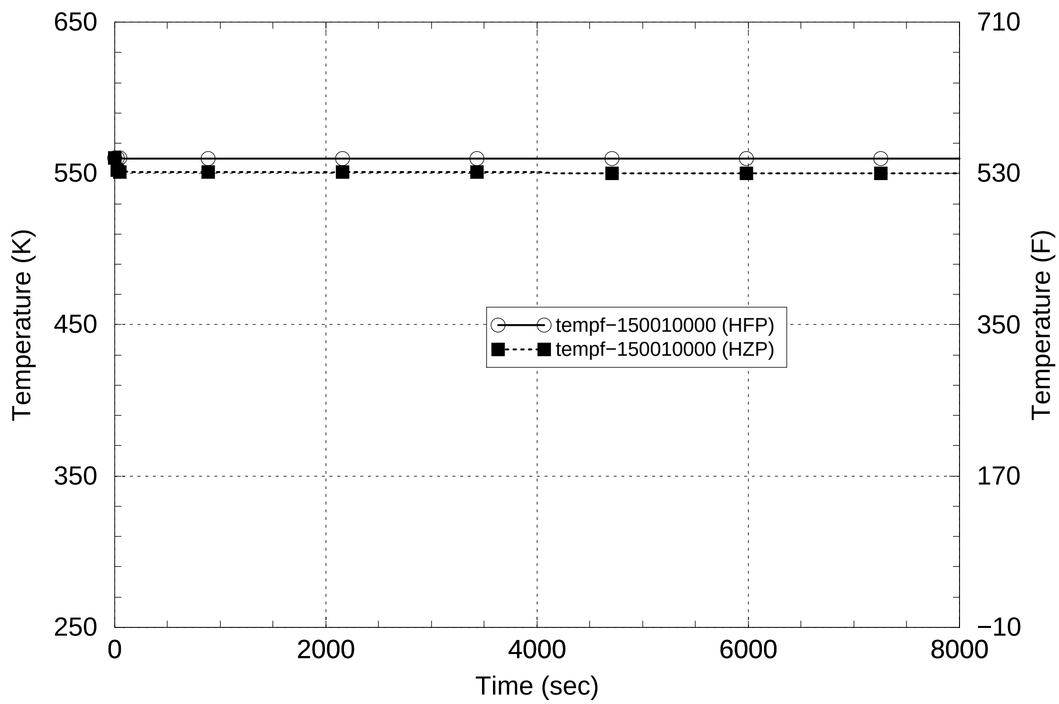


Figure 2-10 Calvert Cliffs Cold Leg Temperature Response – Steady State

Table 2-1 Comparison of RELAP5-Calculated and Calvert Cliffs Desired Plant Conditions for Steady, Hot Full Power Operation

Parameter (units)	RELAP5 Calculated Value	Desired Plant Value
Core Thermal Power (MW)	2,700	2,700 [a]
Pressurizer Pressure (psia)	2,296	2,200 to 2,300 [b]
Hot Leg Temperature (°F)	595.0	601.0 [c]
Cold Leg Temperature (°F)	548.0	548.0
RCS Average Temperature (°F)	571.5	574.5 [c]
Primary Coolant Flow Rate, Total (lbm/s)	41,528	39,944
Pressurizer Level (inches)	222.6	216.0
SG Secondary Pressure (psia)	874.3	850.0
SG Narrow Range Level (inches)	0.0	0.0
Secondary Mass per SG (lbm)	130,568	~130,500
Feedwater Temperature (°F)	434.1	431.5
Feedwater/Steam Flow Rate per SG (lbm/s)	1,639	1,666

a. The value is 100% of the plant rated thermal power.
b. The RCS pressure is controlled within this range by operation of the pressurizer heaters and spray.
c. These plant values are considered "maximums".

Table 2-2 Comparison of RELAP5-Calculated and Calvert Cliffs Desired Plant Conditions for Steady, Hot Zero Power Operation

Parameter (units)	RELAP5 Calculated Value	Desired Plant Value
Core Thermal Power (MW)	5.400 [a]	---
Pressurizer Pressure (psia)	2,253	2,200 to 2,300 [b]
RCS Average Temperature (°F)	530.6	532.0
Primary Coolant Flow Rate, Total (lbm/s)	42,690	---
Pressurizer Level (inches)	164.6	158.4
SG Secondary Pressure (psia)	874.8	900.0
SG Narrow Range Level (inches)	-1.9	-18.0 to +24.0 [c]
Secondary Mass per SG (lbm)	223,736	230,897
Feedwater Temperature (°F)	281.2	210.0

a. The calculated value corresponds to 0.2% of the plant rated thermal power and represents the core decay heat 30 days after a reactor trip.
b. The RCS pressure is controlled within this range by operation of the pressurizer heaters and spray.
c. The level is maintained within this range by operator manual control.

3.0 RELAP5/MOD3 ANALYSIS OF TRANSIENTS FOR PTS EVALUATION

The thermal-hydraulic responses for various PTS transient event sequences are calculated with the RELAP5 code and the plant model described in Section 2. The event sequences analyzed were defined based on risk analysis performed by the Sandia National Laboratories to identify sequences that may be important for risk due to PTS. The sequences analyzed were initiated by LOCAs in the pressurizer surge line, hot and cold leg piping, stuck-open pressurizer relief valves, reactor and turbine trips with stuck-open steam line valves, main steam line breaks and feedwater overfill events. A total of 100 cases were run for Calvert Cliffs.

3.1 Key Thermal Hydraulic Results

From the PTS perspective, the principal thermal-hydraulic results of interest are the system pressure and downcomer temperature in the reactor vessel downcomer along with the heat transfer coefficient on the inside surface of the reactor vessel wall at elevations corresponding to the span of the reactor core. These thermal-hydraulic results are used as boundary conditions for vessel wall probabilistic fracture mechanics analyses. Figures showing the time-history response of these and other parameters for representative PTS event scenarios are provided in this section, along with descriptions of the event sequences, the modeling changes implemented and brief analyses of the RELAP5-calculated plant transient responses. The system pressure and temperature in the reactor vessel downcomer along with the heat transfer coefficient on the inside surface of the reactor vessel wall for all cases analyzed are presented in Appendix A. Transients selected for discussion in this section are those that were either risk significant in the Palisades analysis or are of general interest.

All RELAP5 transient case calculations were restarted from the end points of the steady state runs representing hot full power and hot zero power operation of the Calvert Cliffs plant, as described in Section 2. All RELAP5 base case calculations were run for 15,000 s following the occurrence of the sequence initiating event. On the accompanying plots, the data shown prior to time zero represents the calculated steady-state condition prior to the transient initiation.

3.1.1 Double-Ended Guillotine Main Steam Line Break from Hot Full Power Conditions with AFW Not Isolated – Calvert Cliffs Case 46

This event starts with a double-ended rupture of the main steam line on SG 1 when the plant is in hot full power operation. The rupture is assumed to be downstream of the steam line flow restrictor and inside the containment. A low SG pressure condition causes the MSIVs to close, resulting in a continuing blowdown only of SG 1. The operator is assumed to not isolate the AFW flow to either SG; normal control of the AFW flow continues, based on the SG levels.

The following modeling changes were made to simulate this event sequence. The steam line rupture is implemented in the SG 1 steam line between the flow restrictor and the connecting lines for the atmospheric dump valve and main steam safety valves. Breaks with a flow area of 0.522 m^2 [5.62 ft^2], representing the full steam line area, were modeled from the SG and steam-line sides to constant atmospheric-pressure boundary conditions. The flow area of the steam line flow restrictor, located between SG 1 and the break location is 0.224 m^2 [2.42 ft^2]. The critical flow model was activated at the break and flow restrictor junctions. A containment high pressure signal was assumed to occur at the time when the break opens, causing the operators to trip all four reactor coolant pumps. The trip and control logic was modified to prevent AFW system isolation.

The RELAP5-calculated sequence of events for Case 46 is shown in Table 3-1. The RELAP5-calculated responses for the RCS pressure, average reactor vessel downcomer fluid temperature and average reactor vessel wall inside surface heat transfer coefficient are shown in Figures 3-1, 3-2 and 3-3, respectively. The cooling afforded to the RCS fluid from heat transfer to depressurized SG 1 resulted in a rapid RCS cooldown. This cooling also caused the RCS fluid volume to shrink, which rapidly depressurized the RCS as well.

The SG 1 pressure rapidly declined when the break opened, as shown in Figure 3-4. The SG 2 pressure also declined, but much less rapidly because of the closure of the MSIVs. The slower SG 2 pressure decline is caused by reverse heat transfer from SG 2 to the RCS.

Figure 3-5 shows the AFW flows and Figure 3-6 shows the secondary-side inventories for the two SGs. AFW flow to both SGs began early during the event sequence as a result of low SG level indications. AFW flow to unaffected SG 2 was automatically throttled at 2,365 s, when the normal level had been reestablished. The delivery of AFW flow to affected SG 1 was instrumental in cooling the RCS over an extended period. The heat removed from the RCS to SG 1 boiled the AFW flow, and the steam produced flowed out the break in the steam line. By about 5,000 s, the RCS fluid had been cooled to near the saturation temperature at atmospheric pressure, the boiling rate slowed and AFW began refilling SG 1. AFW flow to SG 1 was throttled at 10,385 s, when the normal water level had been reestablished in the depressurized SG.

The RCS depressurization led to a safety injection actuation signal, which resulted in starting the HPI and LPI pumps. The calculated HPI flow rate for Cold Leg A1 is shown in Figure 3-7; the total HPI flow rate is four times the flow shown in the figure. The flow delivered from the centrifugal pumps of the HPI system is a function of the cold leg pressure, with lower pressures resulting in higher HPI flow and with no HPI flow delivered whenever the RCS pressure exceeds the shutoff head of the HPI system (8.791 MPa [1,275 psia]). In the calculation, HPI coolant was injected at a low rate and only for brief periods because the RCS pressure declined only slightly and momentarily below the HPI shutoff head. The RCS pressure did not decline below the initial pressure of the SITs or below the shutoff head of the LPI system and therefore no SIT or LPI flows were delivered.

The containment high pressure signal at the time the break opens resulted in the operators tripping all four reactor coolant pumps. Figure 3-8 shows the flow rates through the two Loop-1 cold legs at their connections with the reactor vessel. The reactor coolant pumps coasted down following trip, but a strong coolant loop natural circulation flow continued in Loop 1 as a result of continual heat removal to SG 1. No significant natural circulation flow was observed in Loop 2 because of the reverse heat transfer in SG 2. The effects of the reactor coolant pump trips on the reactor vessel inside-wall heat transfer coefficient are evident in Figure 3-3.

Table 3-1 RELAP5-Calculated Sequence of Events for Calvert Cliffs Case 46

Event(s)	Event Time (Seconds)
Break opens in the SG 1 steam line, containment high pressure signal, operators trip all reactor coolant pumps	0
Reactor trip signal, turbine trip, MSIV closure signal	3
MSIVs fully closed	9
Safety injection actuation signal	29
Reactor coolant pump coast-down is complete	114
HPI flow begins	344
AFW throttled at normal setpoint level in SG 2	2,365
RCS pressure reaches pressurizer PORV opening setpoint pressure, PORV cycling begins	7,370
Charging flow throttled at normal setpoint level in the pressurizer	8,210
AFW flow throttled at normal setpoint level in SG 1	10,385
Calculation terminated	15,000

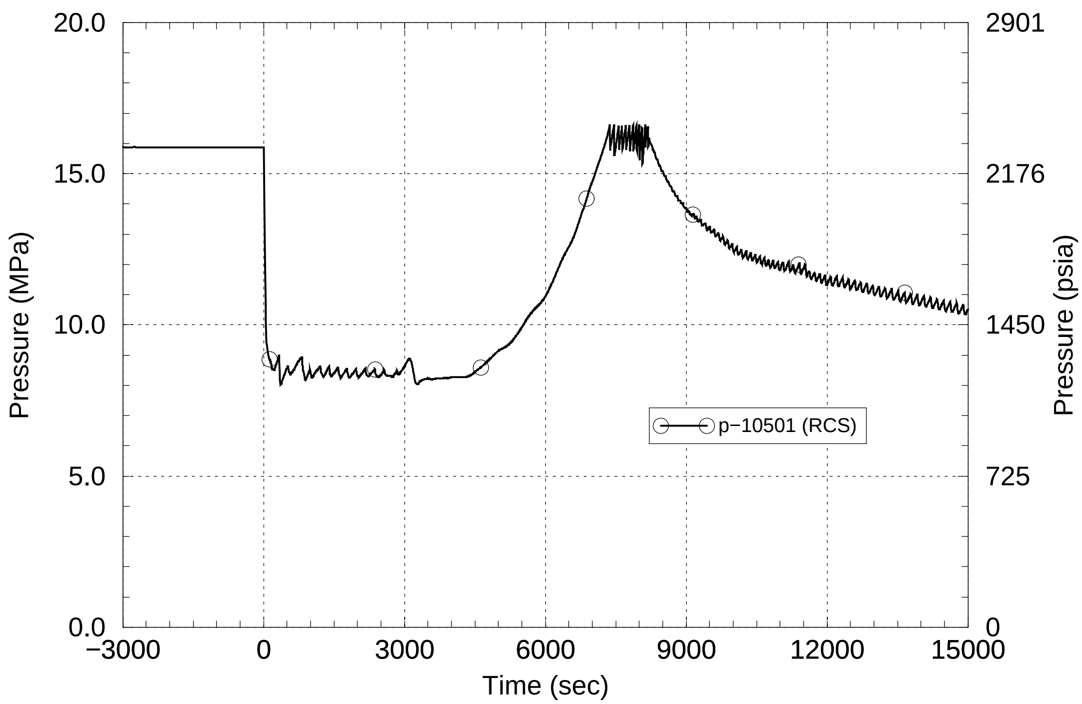


Figure 3-1 Reactor Coolant System Pressure – Calvert Cliffs Case 46

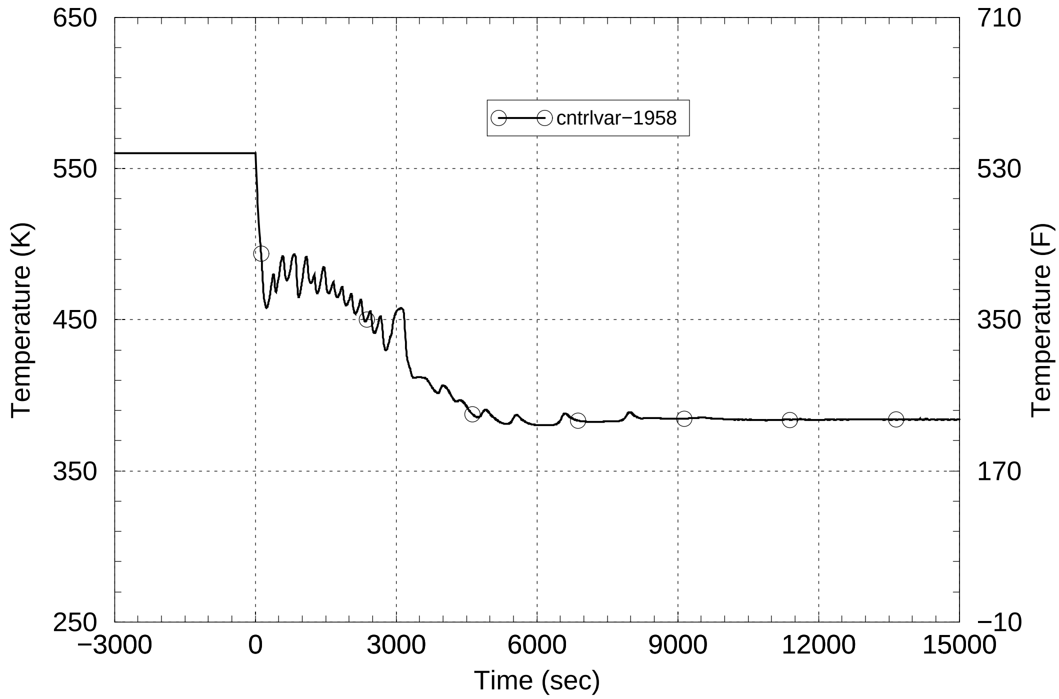


Figure 3-2 Average Reactor Vessel Downcomer Fluid Temperature – Calvert Cliffs Case 46

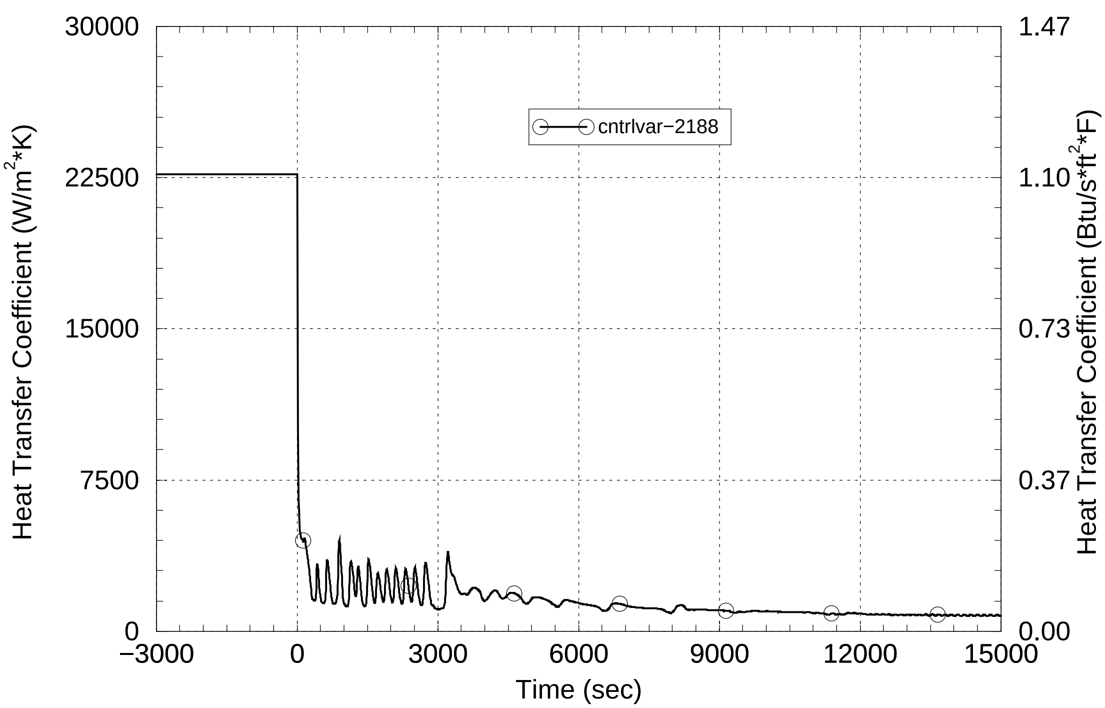


Figure 3-3 Average Reactor Vessel Inner-Wall Heat Transfer Coefficient – Calvert Cliffs Case 46

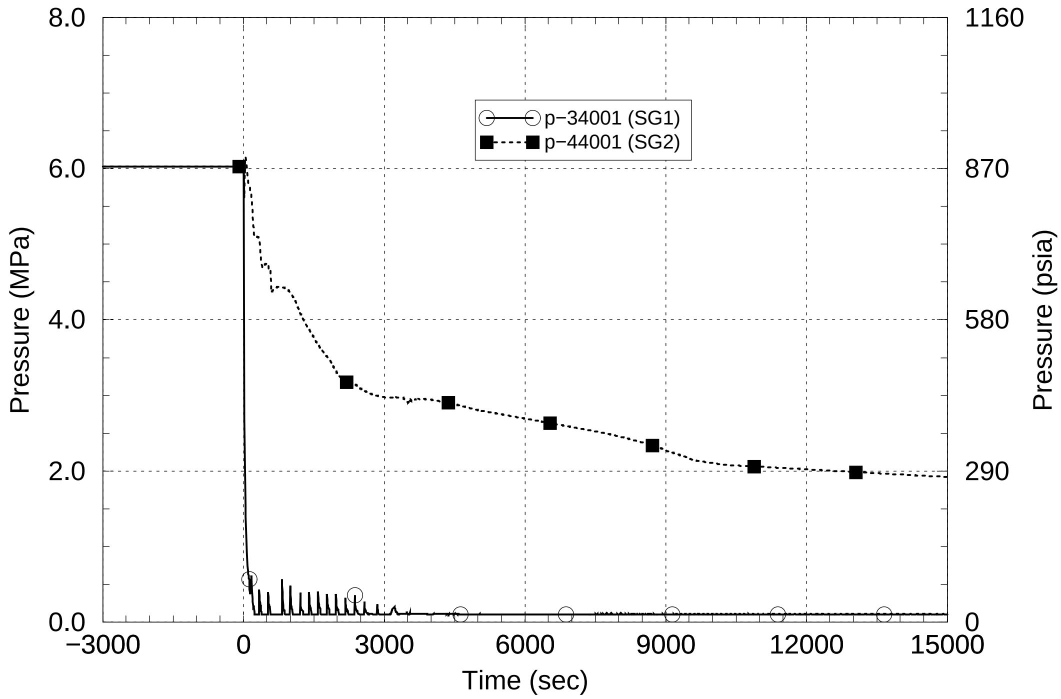


Figure 3-4 Steam Generator Pressures – Calvert Cliffs Case 46

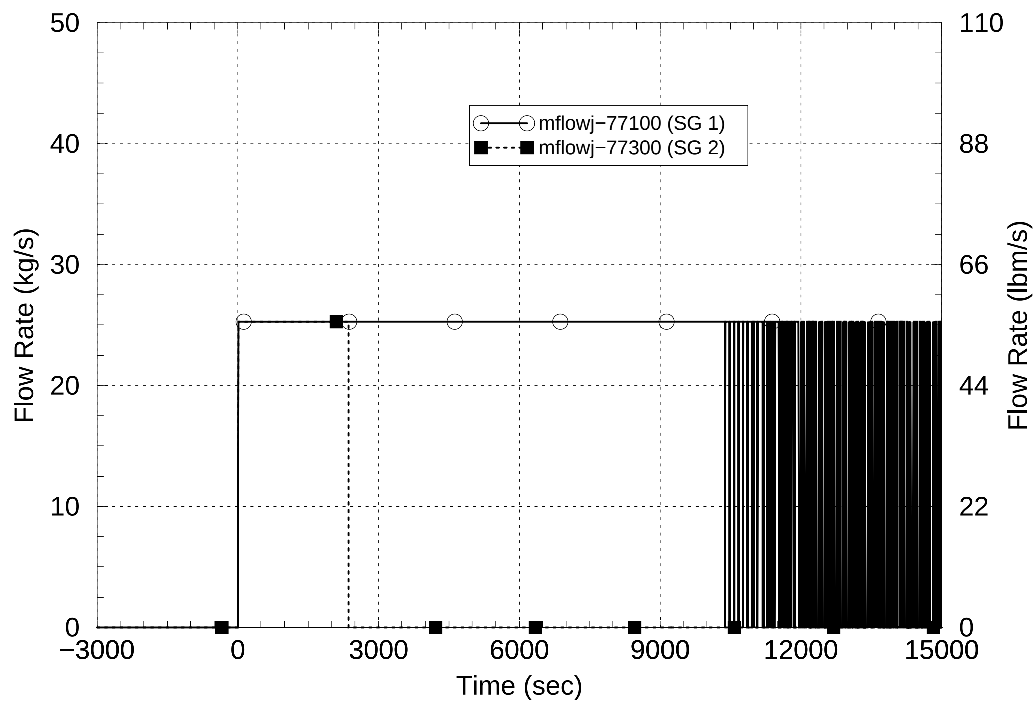


Figure 3-5 Auxiliary Feedwater Flows – Calvert Cliffs Case 46

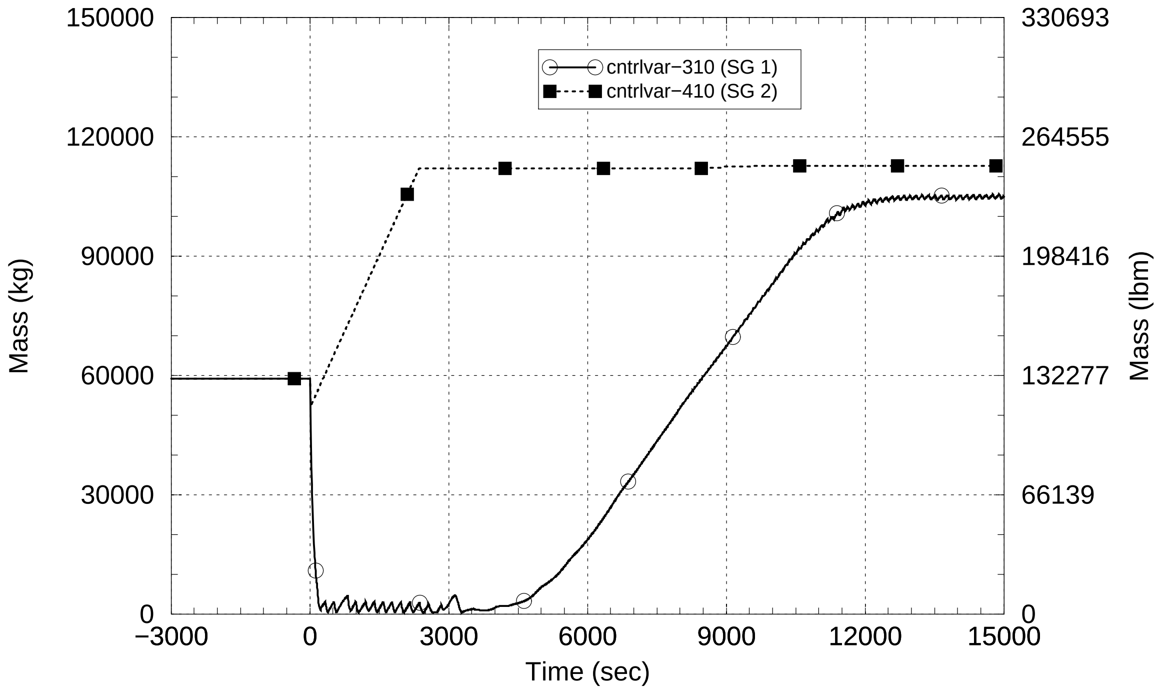


Figure 3-6 Steam Generator Secondary Fluid Masses – Calvert Cliffs Case 46

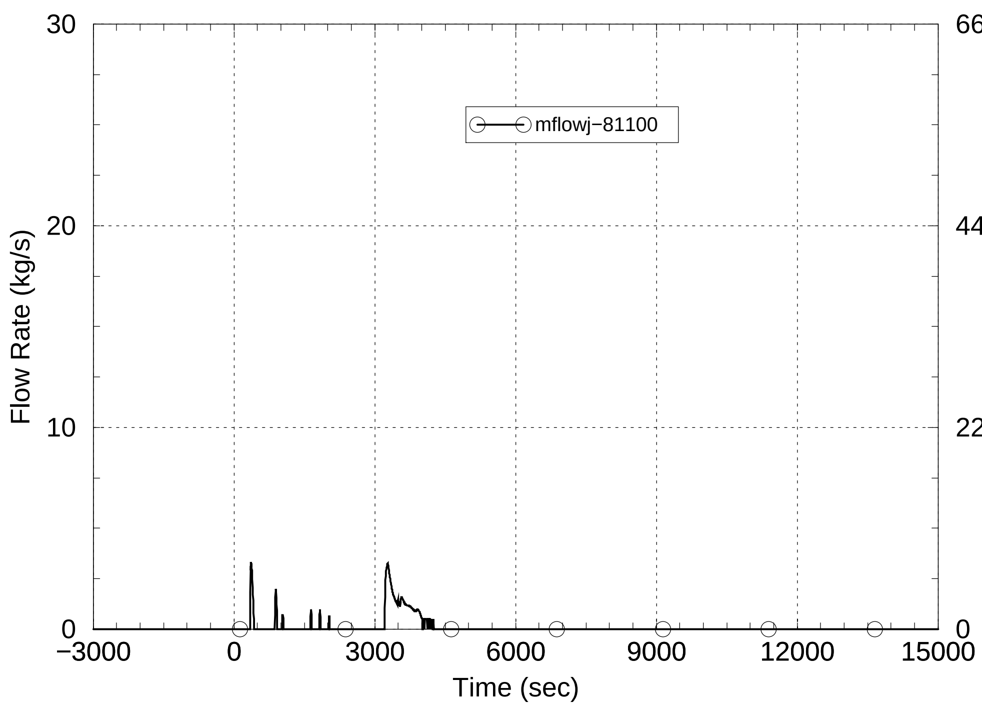


Figure 3-7 Loop A1 High Pressure Injection Flow – Calvert Cliffs Case 46

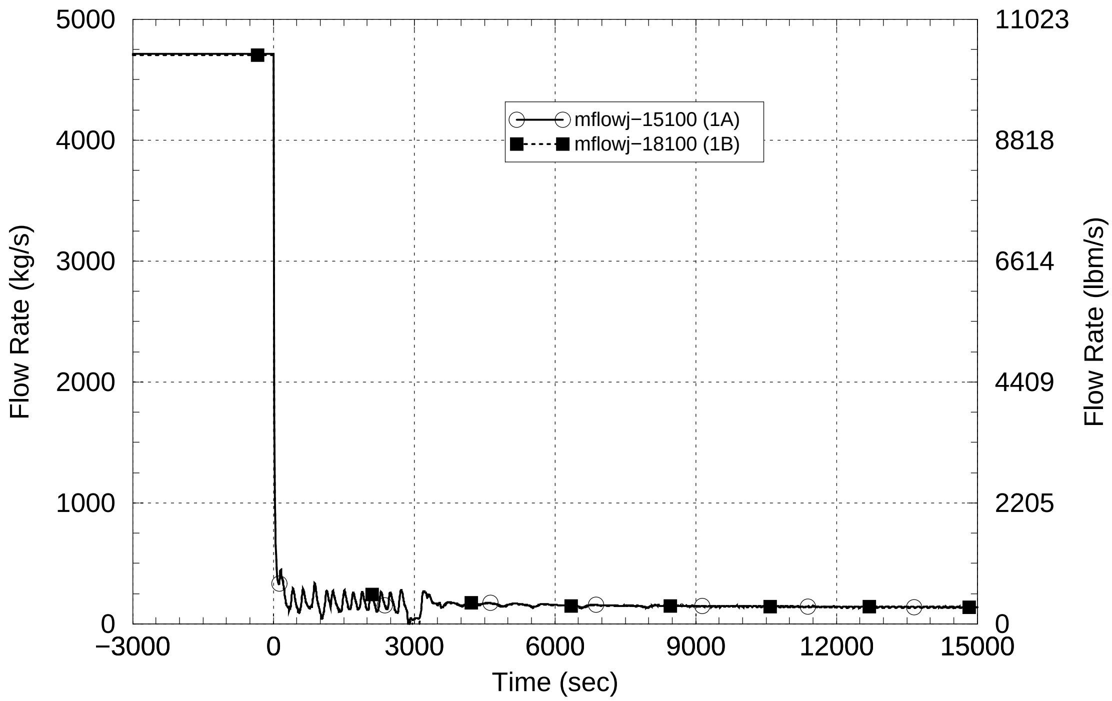


Figure 3-8   Loop 1 Cold Leg Flows – Calvert Cliffs Case 46

The pressurizer level response is shown in Figure 3-9. The RCS fluid volume shrinkage caused by the cooldown was almost sufficient to drain the pressurizer. The HPI and charging flows replenished the RCS fluid volume lost due to shrinkage, and this resulted in the pressurizer refilling. Since the RCS is a closed system during this event sequence, the pressurizer refill was accompanied by a RCS repressurization to above the HPI system shutoff head and this terminated the HPI flow.

Figure 3-10 shows the charging and letdown flow responses during the event sequence. Charging flow is injected equally into the Loop 1A and 2B cold legs whenever the pressurizer inventory is below the normal water level. By 7,370 s, the charging flow was sufficient to raise the RCS pressure to the opening setpoint pressure of the pressurizer PORVs, 16.55 MPa [2400 psia], and those valves began to cycle. The charging flow was throttled at 8,210 s, when it had succeeded in reestablishing the normal pressurizer level. The throttling of the charging flow caused the RCS pressure to decline and afterward the pressurizer PORVs remained closed. The letdown flow was isolated early in the event sequence as a result of the low pressurizer level and is not reactivated.

The minimum average reactor vessel downcomer fluid temperature, 380 K [225°F], was reached at 6,180 s. The RCS pressure was calculated to be 11.48 MPa [1666 psia] at that time.

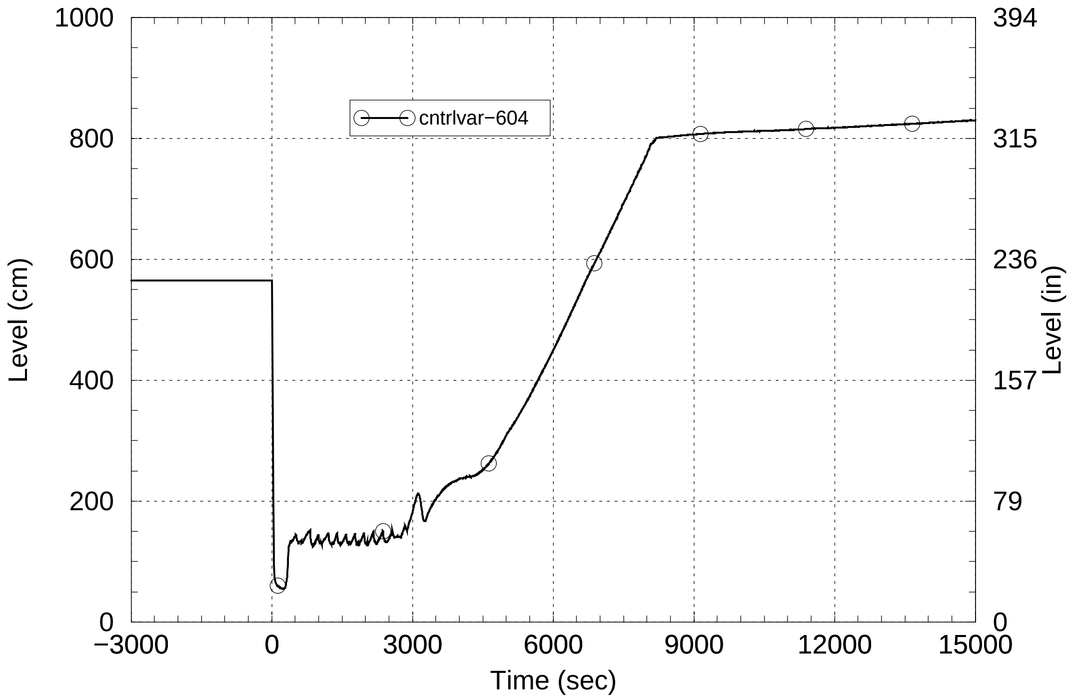


Figure 3-9 Pressurizer Level – Calvert Cliffs Case 46

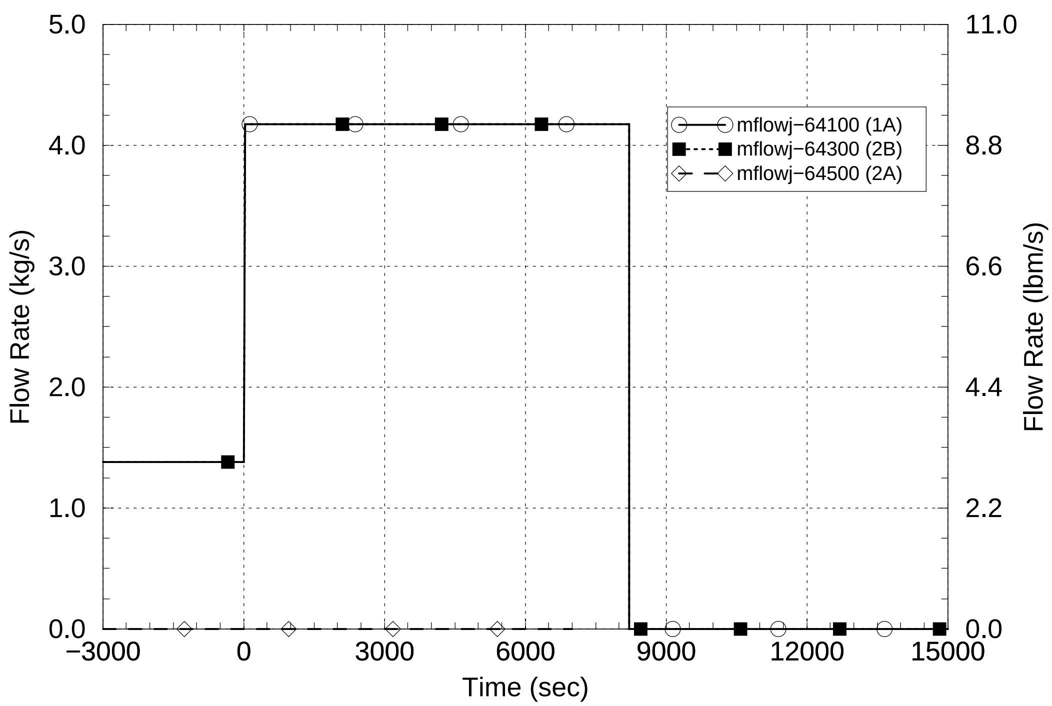


Figure 3-10 Charging and Letdown Flows – Calvert Cliffs Case 46

3.1.2 5.08-cm [2-in] Pressurizer Surge Line Break from Hot Full Power Conditions – Calvert Cliffs Case 3

This event starts with a 5.08-cm [2-in] diameter break in the pressurizer surge line when the reactor is operating at hot full power.

The following modeling changes were made to simulate this event sequence. The pressurizer surge line break to a constant atmospheric-pressure containment boundary condition was added to the model. The equivalent break flow area for a circular break with a diameter 5.08 cm [2 in] was specified. The break was connected on the top of a horizontal section of the surge line. The critical flow model was activated at the break junction and the flow loss coefficients specified were based on AP600-derived flow loss coefficients and scaled for the specific break size and location for this event sequence.

The RELAP5-calculated sequence of events for Case 3 is shown in Table 3-2. The RELAP5-calculated responses for the RCS pressure, average reactor vessel downcomer fluid temperature and average reactor vessel wall inside surface heat transfer coefficient for this case are shown in Figures 3-11, 3-12 and 3-13, respectively.

The calculated break flow response is shown in Figure 3-14. When the break opened, the RCS pressure fell rapidly at first, and then more slowly as flashing was encountered within the RCS. The RCS depressurization caused a reactor trip signal at 56 s. The reactor trip caused a turbine trip, isolating the steam generator systems.

Table 3-2 RELAP5-Calculated Sequence of Events for Calvert Cliffs Case 3

Event(s)	Event Time (Seconds)
Break opens in pressurizer surge line	0
Reactor trip signal, turbine trip	56
Safety injection actuation signal	64
Low RCS subcooling condition, operators trip one reactor coolant pump in each loop	84
Low RCS pressure condition, operators trip the remaining two reactor coolant pumps	95
HPI flow begins	135
Reactor coolant pump coast-down is completed	269
Pressurizer is empty	488
Normal pressurizer level reestablished, charging flow throttled	8,234
Calculation terminated	15,000

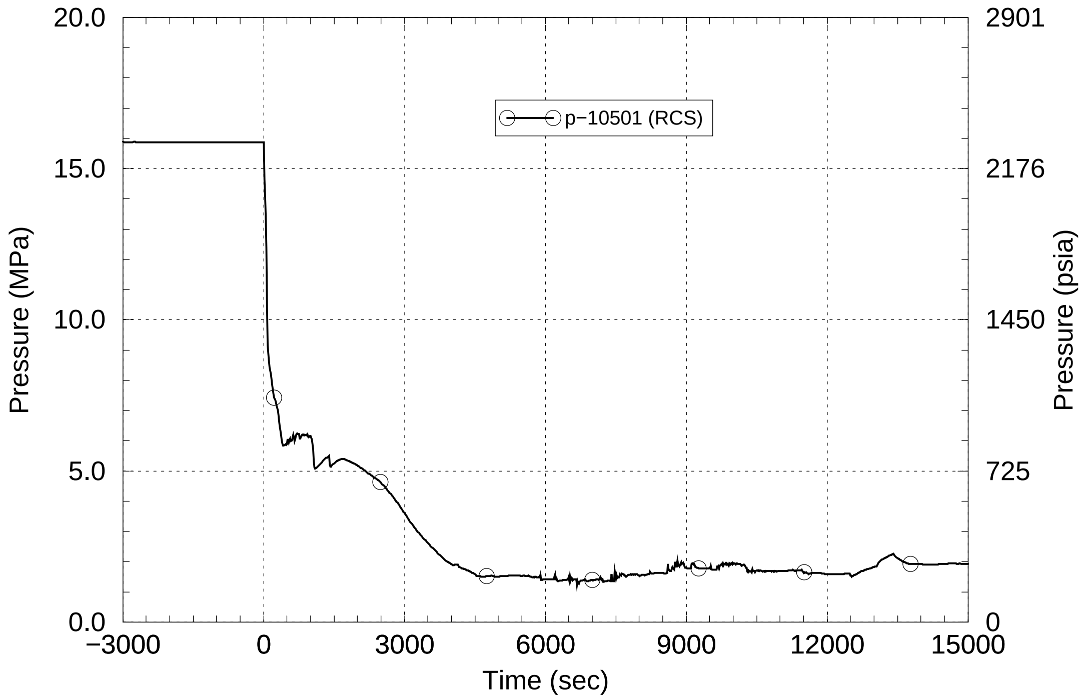


Figure 3-11 Reactor Coolant System Pressure – Calvert Cliffs Case 3

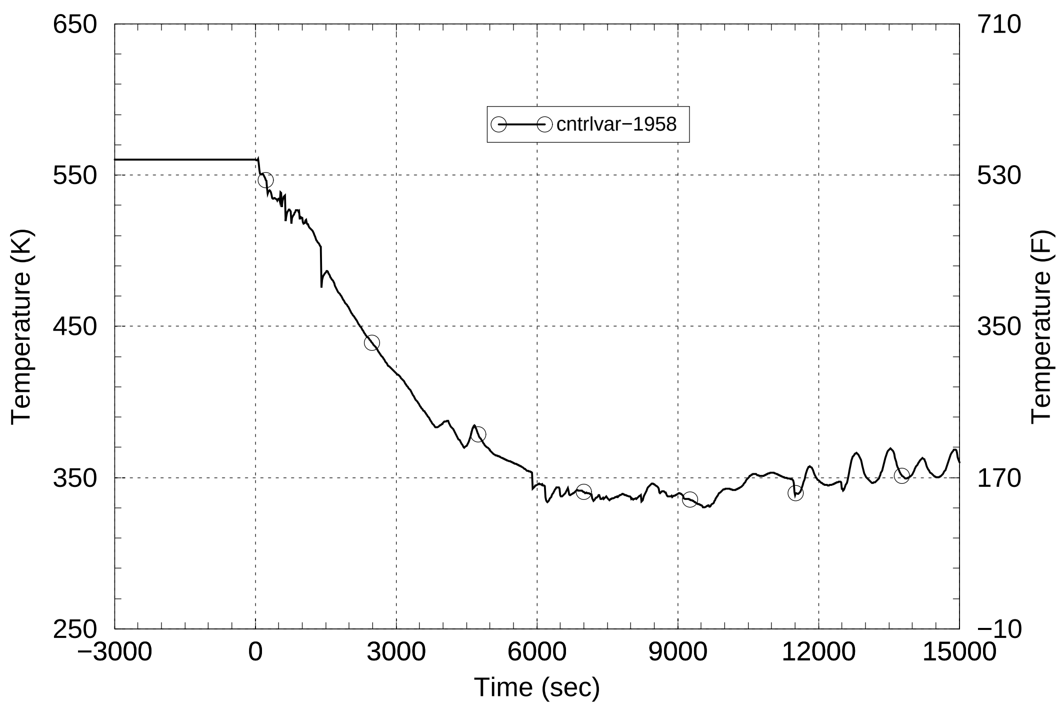


Figure 3-12 Average Reactor Vessel Downcomer Fluid Temperature – Calvert Cliffs Case 3

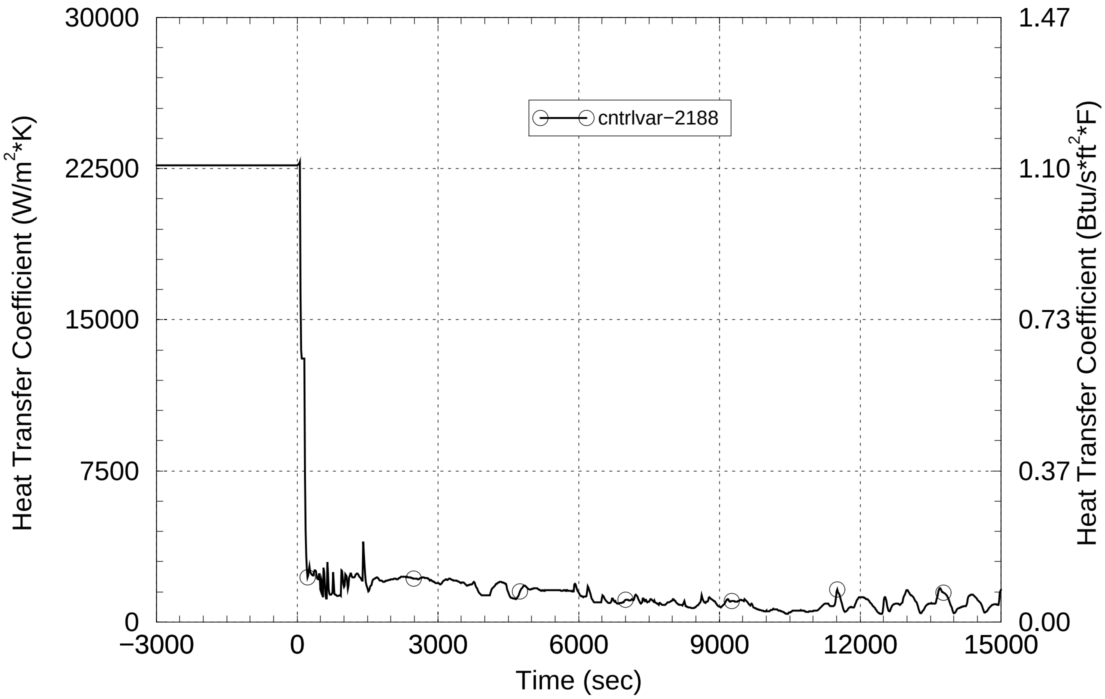


Figure 3-13 Average Reactor Vessel Inner-Wall Heat Transfer Coefficient – Calvert Cliffs Case 3

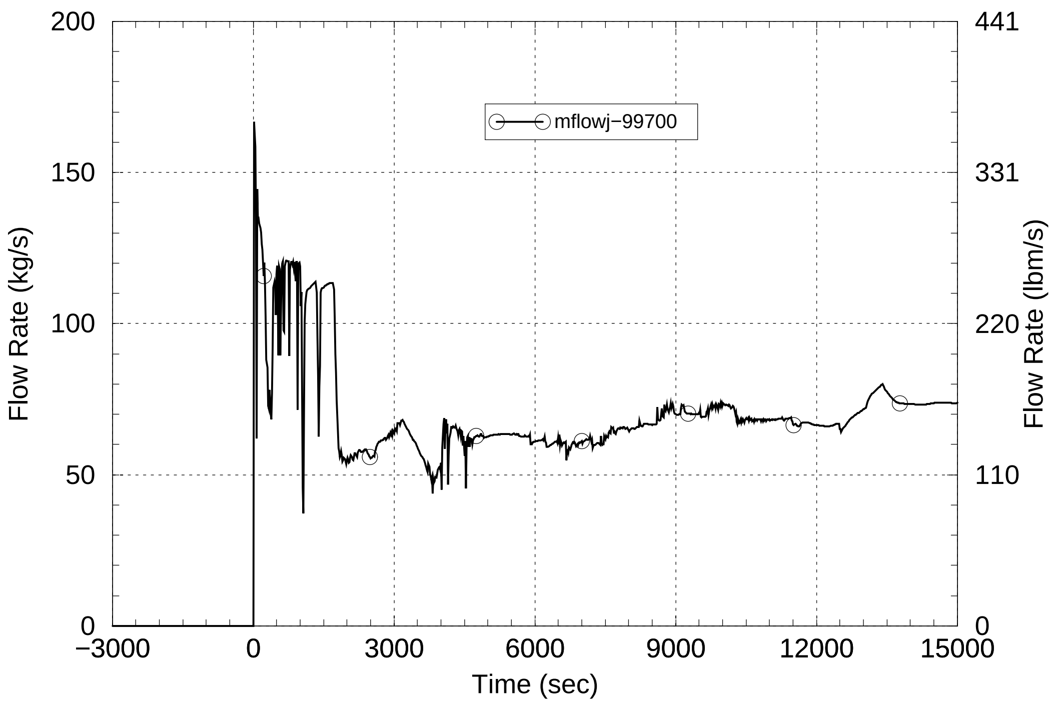


Figure 3-14 Break Flow – Calvert Cliffs Case 3

Figure 3-15 shows the calculated SG secondary system pressure responses. The turbine trip caused the secondary system pressures to rise; the pressure increase was limited by the opening of the turbine bypass and atmospheric dump valves. The steam pressures did not increase sufficiently to open the main steam safety relief valves. The declining SG pressures after about 5000 s are an indication of reverse (i.e., secondary system to primary system) SG heat transfer caused by the cooling down of the RCS. The SG secondary fluid mass inventories are shown in Figure 3-16. The turbine trip resulted in closure of the main feedwater regulation control valves. The SG inventory was increased and controlled to maintain SG levels within the normal range by flow through the main feedwater bypass control valves. The SG levels did not decline sufficiently to activate the auxiliary feedwater system.

The falling RCS pressure resulted in the operators tripping one reactor coolant pump in each loop. Shortly afterward the declining RCS subcooling resulted in the operators tripping the remaining two reactor coolant pumps. The decline in the coolant loop flows caused by the pump trip is indicated in Figure 3-17, which shows the two hot leg flows at the reactor vessel connections. The coolant loop flows transitioned from forced circulation behavior to natural circulation behavior after the pumps were tripped. The coolant loop natural circulation flows continued in both loops until about 750 s. Afterward, the loss of RCS fluid inventory was sufficient to drain fluid from inside the upper regions of the SG tubes, which stopped coolant loop natural circulation flow through both loops. The small Loop-1 hot leg flow shown after 750 s reflects fluid flowing toward the pressurizer surge line break.

The RCS depressurization also led to a safety injection actuation signal and starting of the HPI and LPI pumps. The calculated HPI and LPI flow rates for Cold Leg A1 are shown in Figure 3-18; the total HPI and LPI flow rates are four times the flows shown in the figure. The flows delivered from the centrifugal pumps of the HPI and LPI systems are a function of the cold leg pressure, with lower pressures resulting in higher injection rates and with no flow delivered whenever the RCS pressure exceeds the shutoff head of the systems (8.791 MPa [1,275 psia] for HPI and 1.241 MPa [180 psia] for LPI). During the calculation for this event sequence, the RCS pressure only briefly declined below the shutoff head of the LPI system so the period of LPI delivery was very short.

As shown in Figure 3-19, the pressurizer was drained over the early portion of the event sequence as a result of the loss of coolant out the break. The Loop A1 SIT liquid inventory response is shown in Figure 3-20 (this represents one-fourth of the total SIT liquid inventory in the plant). The RCS pressure briefly fell below the initial SIT pressure and SIT flow was delivered only over a short period. The pressurizer level recovered through the combination of charging, HPI, LPI and SIT injection flows. The charging flow was throttled at 8,234 s when the normal pressurizer level had been reestablished.

During the latter portion of the event sequence the calculated conditions reflect balances in the RCS mass and energy flows. The break mass flow rate is balanced by the HPI mass addition rate. The core heat addition rate is balanced by the cooling afforded to the RCS from adding cold HPI fluid and removing warm fluid at the break. These balanced conditions were reached at about 8,000 s.

The minimum average reactor vessel downcomer fluid temperature, 330 K [135°F], was reached at 9,540 s. The RCS pressure was calculated to be 1.751 MPa [254 psia] at that time.

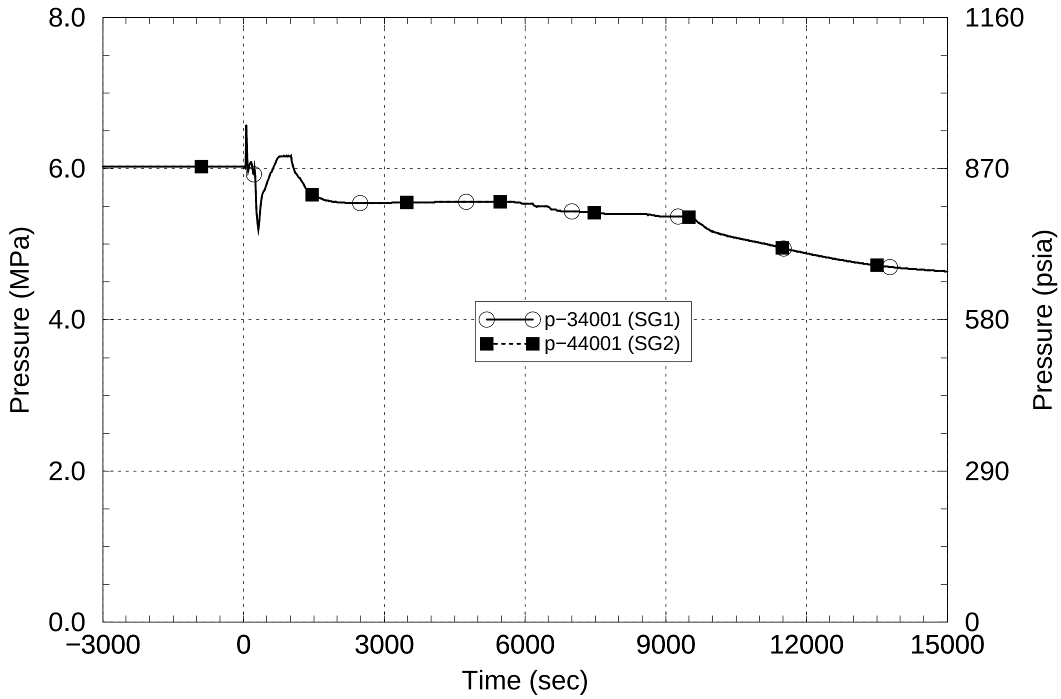


Figure 3-15 Steam Generator Pressures – Calvert Cliffs Case 3

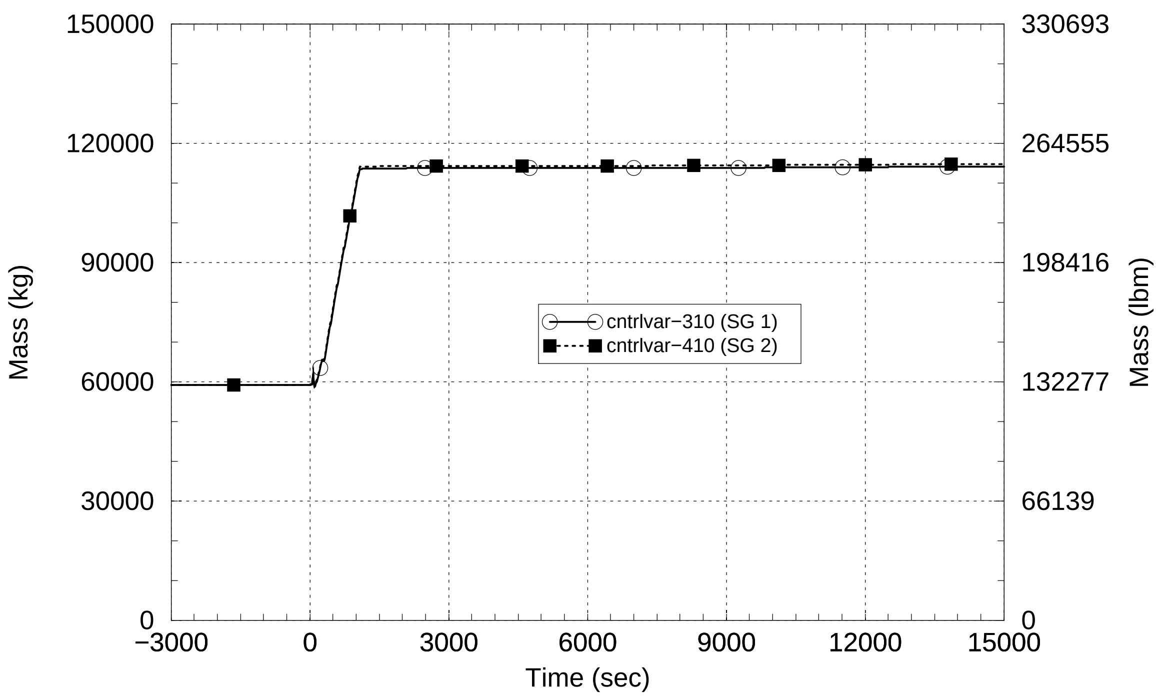


Figure 3-16 Steam Generator Secondary Fluid Masses – Calvert Cliffs Case 3

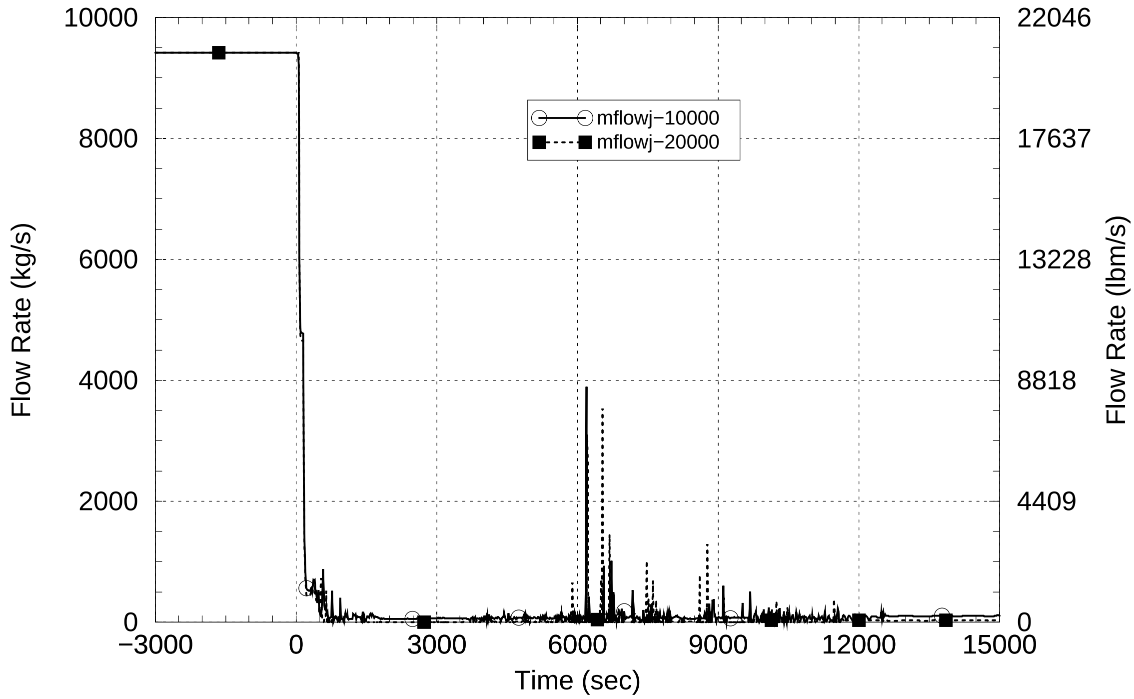


Figure 3-17 Hot Leg Flows – Calvert Cliffs Case 3

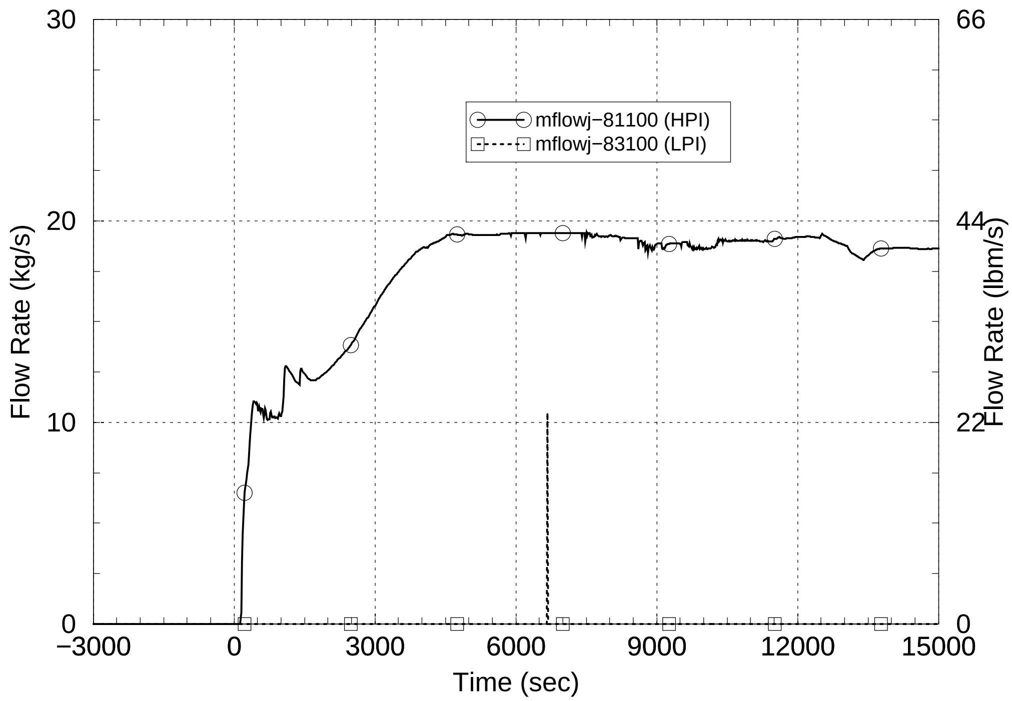


Figure 3-18 Loop A1 HPI and LPI Flows – Calvert Cliffs Case 3

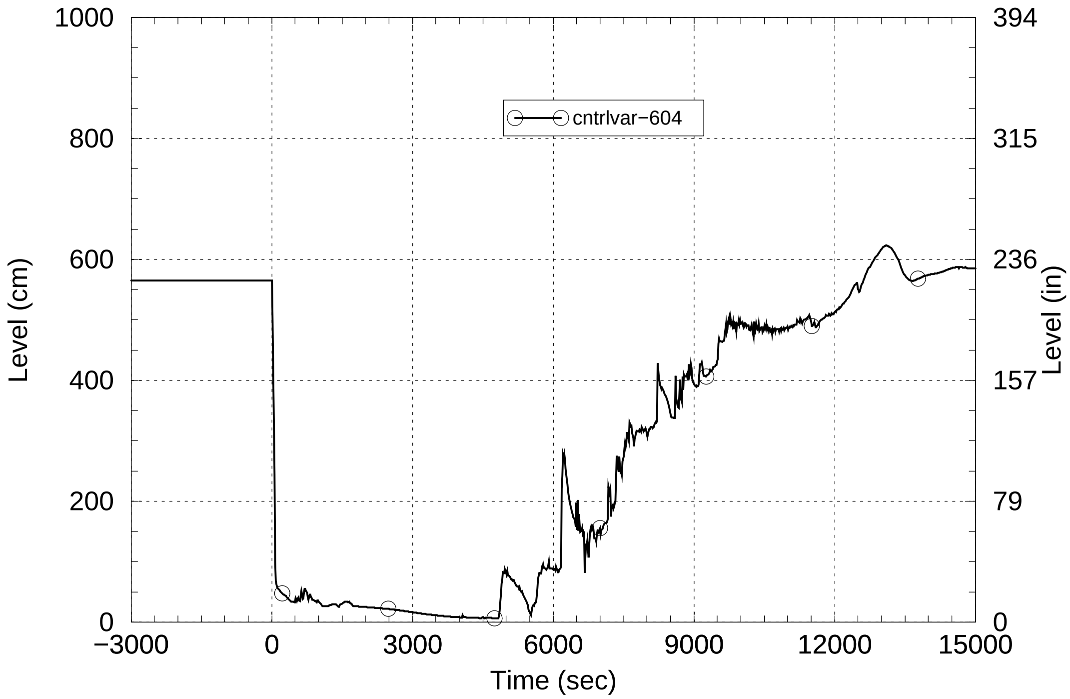


Figure 3-19   Pressurizer Level – Calvert Cliffs Case 3

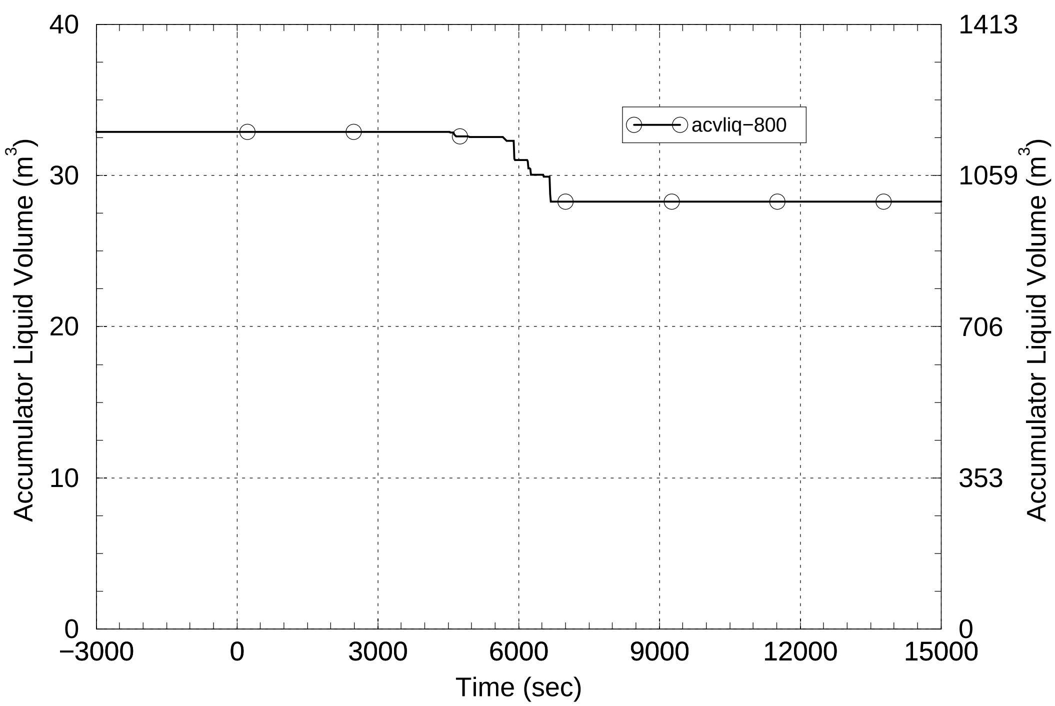


Figure 3-20   Loop 1A SIT Flow – Calvert Cliffs Case 3

3.1.3 Reactor Trip/Turbine Trip from Hot Zero Power Conditions with One Stuck-Open Pressurizer SRV which Re-Closes at 6,000 s – Calvert Cliffs Case 59

This event starts with a reactor trip and the failing-open of one of the two pressurizer safety relief valves (SRVs) with the plant in hot zero power operation. Since the pressurizer SRVs are not challenged following a reactor trip from HZP conditions, the failing open of an SRV represents a spurious failure. The failed-open SRV is assumed to close 6,000 s into the event sequence, after the RCS has depressurized and cooled.

The following modeling changes were made to simulate this event sequence. Model input was changed to trip the reactor and open the pressurizer SRV at the start of the transient calculation. Trip input also was changed to re-close the failed-open SRV at 6,000 s. The equivalent diameter for the failed-open SRV is 4.04 cm [1.59 in]. The model (which lumps together the two SRVs) assumes that one SRV is open from 0 to 6,000 s and that afterward both SRVs are inoperable. Therefore only the two pressurizer PORVs are available to limit the subsequent RCS repressurization.

The RELAP5-calculated sequence of events for Case 59 is shown in Table 3-3. The RELAP5-calculated responses for the RCS pressure, average reactor vessel downcomer fluid temperature and average reactor vessel wall inside surface heat transfer coefficient for this case are shown in Figures 3-21, 3-22 and 3-23, respectively.

The flow response through the failed-open pressurizer SRV is shown in Figure 3-24. The mass flow rate through the failed-open SRV increases over the first 2,500 s of the event sequence as water is drawn upward through the pressurizer toward it. When the SRV fails opens, the RCS pressure falls rapidly at first, then more slowly as flashing is encountered within the RCS.

Figure 3-25 shows the calculated SG secondary pressure responses. Because the core power is so low during HZP operation, the steam pressures do not increase at the beginning of the event sequence. The slowly-declining SG pressures shown in the figure are an indication of reverse (i.e., secondary system to primary system) SG heat transfer caused by the cooling down of the RCS. The SG secondary fluid mass inventories are shown in Figure 3-26. The SG heat loads during this transient are small, so no SG inventory is lost through the main steam SRVs and no AFW flow is needed to maintain SG levels within the normal range.

The falling RCS pressure resulted in the operators tripping one reactor coolant pump in each loop. Shortly afterward, the declining RCS subcooling resulted in the operators tripping the remaining two reactor coolant pumps. The decline in the coolant loop flows caused by the pump trip is indicated in Figure 3-27, which shows the two hot leg flows at the reactor vessel connections. Because the core power at HZP conditions is so low, the SGs are not needed to remove the RCS heat load and therefore no period of coolant loop natural circulation flow is seen. Instead, after the reactor coolant pumps were tripped both loops rapidly transitioned from forced circulation to stagnant conditions. The small Loop 1 hot leg flow shown after the time of the pump trip and before 6000 s reflects fluid flowing toward the failed-open pressurizer SRV.

Table 3-3 RELAP5-Calculated Sequence of Events for Calvert Cliffs Case 59

Event(s)	Event Time (Seconds)
Reactor trip, turbine trip, one pressurizer SRV sticks open	0
Safety injection actuation signal	26
Low RCS subcooling condition, operators trip one reactor coolant pump in each loop	45
Low RCS pressure condition, operators trip the remaining two reactor coolant pumps	57
HPI flow begins	90
Reactor coolant pump coast-down is completed	224
Stuck-open pressurizer SRV closes	6,000
RCS pressure above HPI shutoff head, HPI flow stops	6,390
RCS pressure reaches pressurizer PORV opening setpoint pressure, PORV cycling begins	6,751
Calculation terminated	15,000

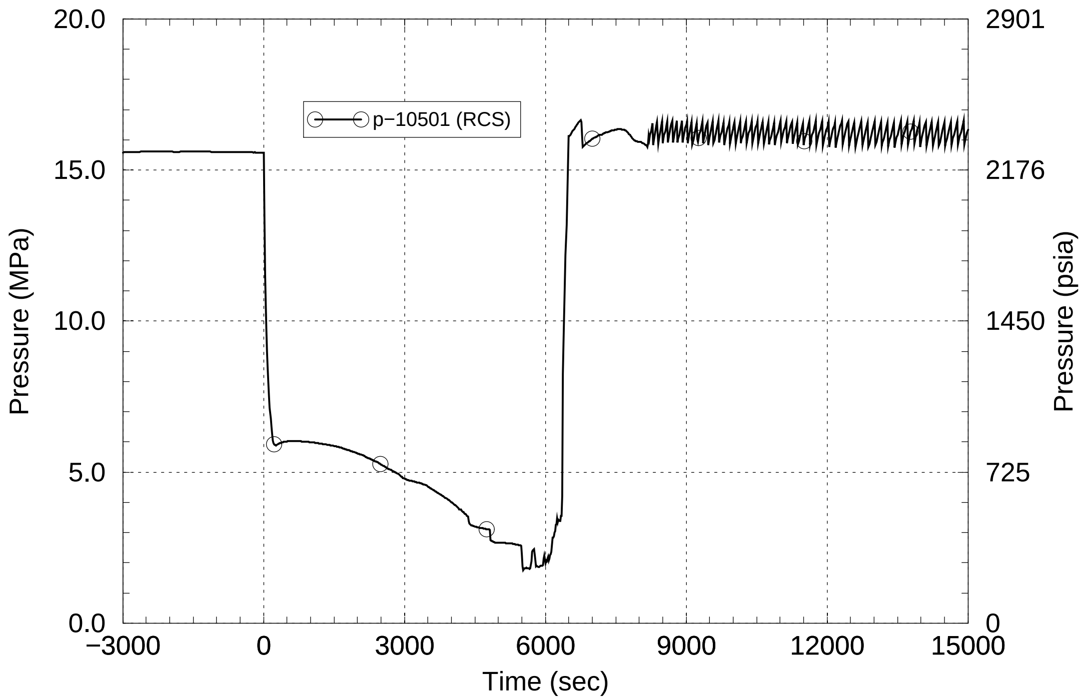


Figure 3-21 Reactor Coolant System Pressure – Calvert Cliffs Case 59

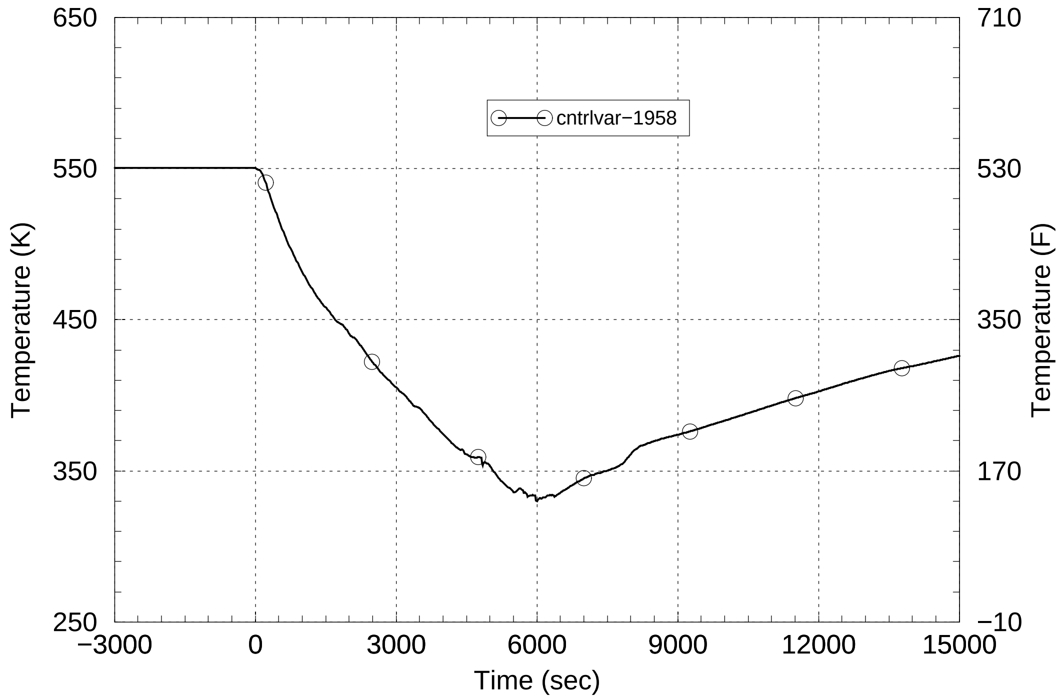


Figure 3-22 Average Reactor Vessel Downcomer Fluid Temperature – Calvert Cliffs Case 59

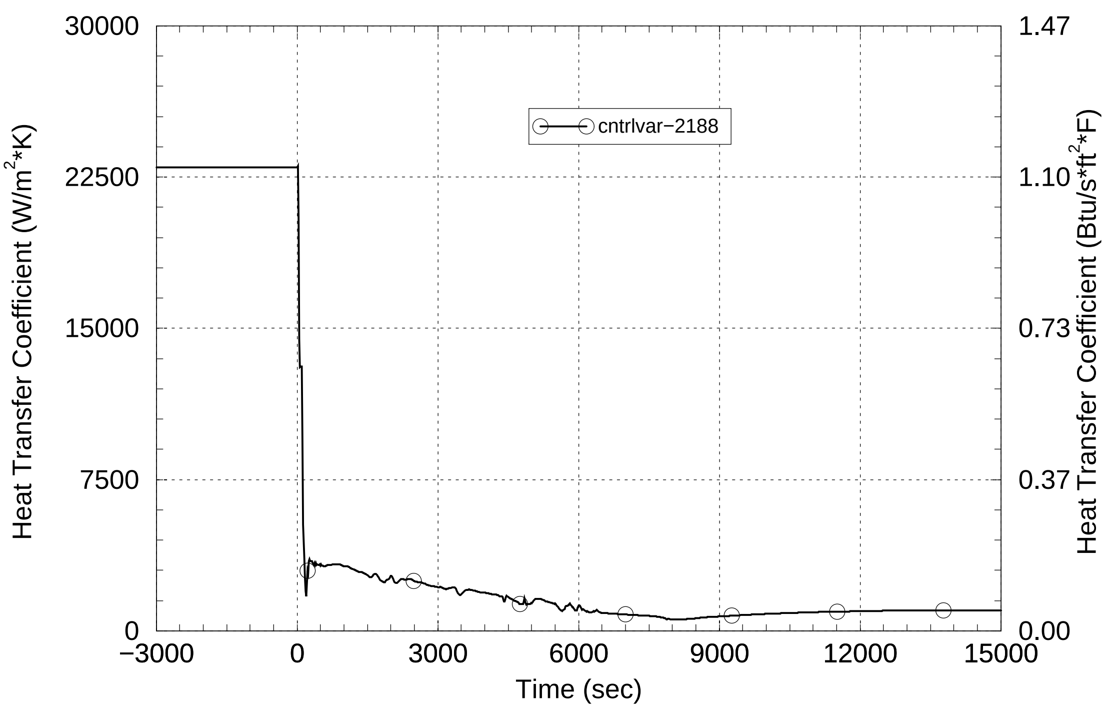


Figure 3-23 Average Reactor Vessel Inner-Wall Heat Transfer Coefficient – Calvert Cliffs Case 59

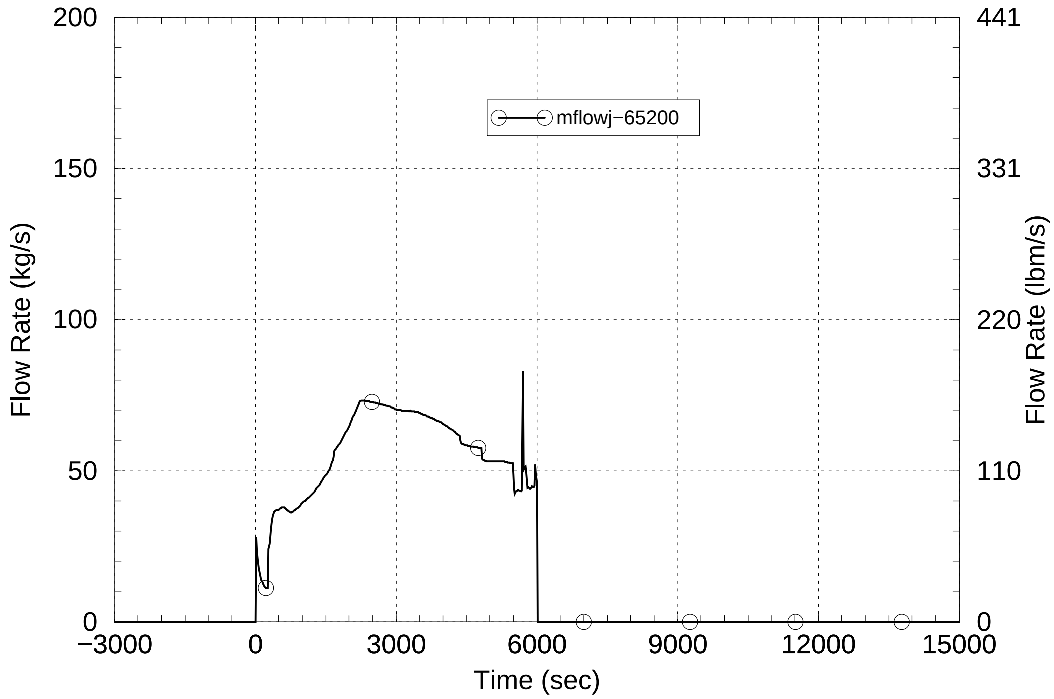


Figure 3-24 Break Flow – Calvert Cliffs Case 59

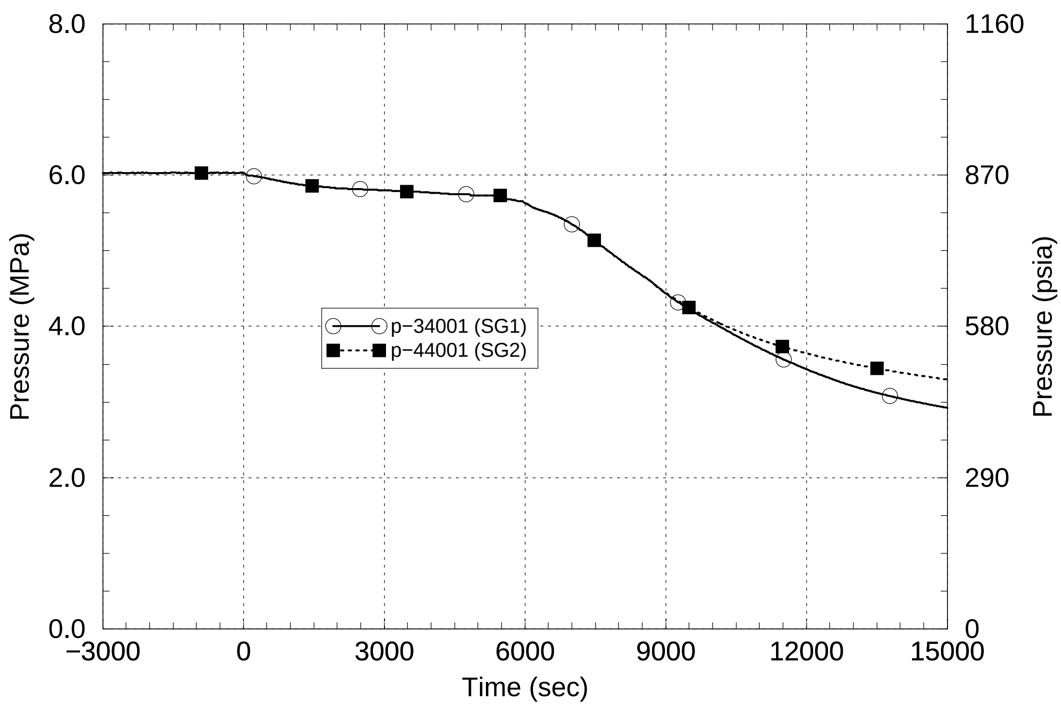


Figure 3-25 Steam Generator Pressures – Calvert Cliffs Case 59

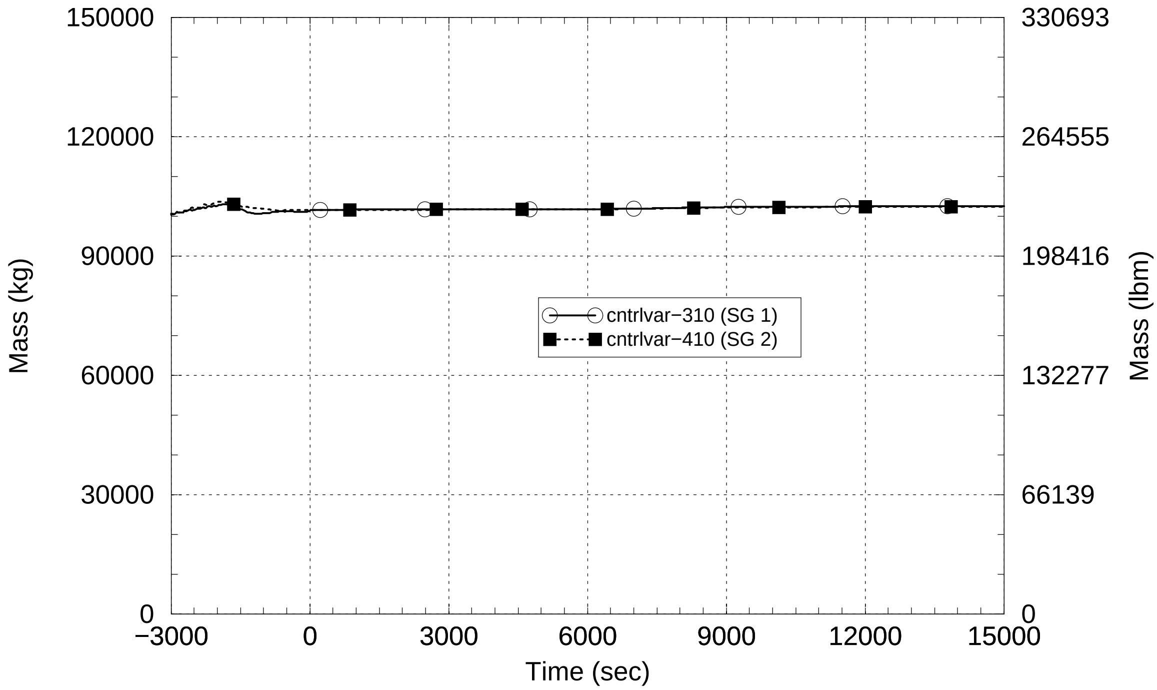


Figure 3-26 Steam Generator Secondary Fluid Masses – Calvert Cliffs Case 59

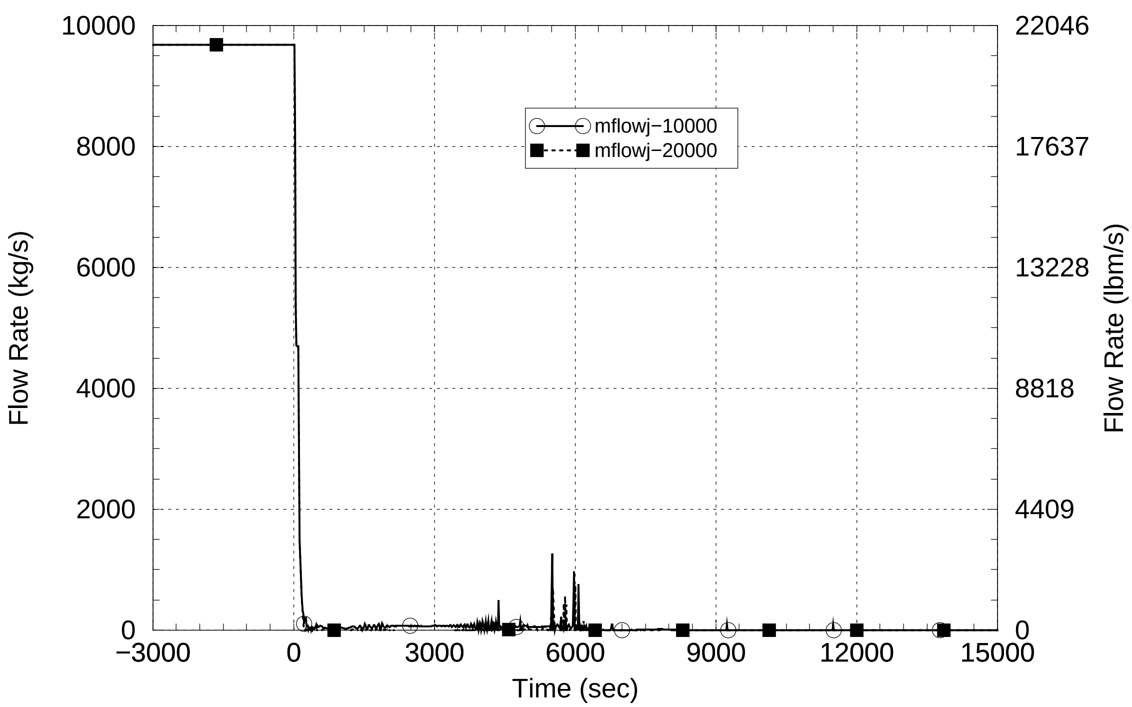


Figure 3-27 Hot Leg Flows – Calvert Cliffs Case 59

The RCS depressurization also led to a safety injection actuation signal at 26 s and starting of the HPI and LPI pumps. The calculated HPI flow rate for Cold Leg A1 is shown in Figure 3-28; the total HPI flow rate is four times the flow shown in the figure. The flow delivered from the centrifugal pumps of the HPI system is a function of the cold leg pressure, with lower pressures resulting in higher HPI flow and with no HPI flow delivered whenever the RCS pressure exceeds the shutoff head of the HPI system (8.791 MPa [1,275 psia]). During this event sequence calculation, the RCS pressure did not decline below the initial pressure of the SITs or below the shutoff head of the LPI system and therefore no SIT or LPI flows were delivered.

The pressurizer level response is shown in Figure 3-29 and the charging and letdown flow responses are shown in Figure 3-30. The failed-open SRV on the top of the pressurizer draws fluid upward inside the pressurizer and the pressurizer level remains high throughout the accident sequence. The letdown flow was isolated and the charging flow increased following the safety injection actuation signal. At 8,354 s, the charging system is isolated as a result of high RCS pressure.

At 6,000 s, the failed-open pressurizer SRV was assumed to close. This event resulted in a rapid RCS repressurization (Figure 3-21) to above the shutoff head of the HPI system, which stopped the HPI flow (Figure 3-28). The RCS cooling afforded by the flow of mass and energy flow out the pressurizer SRV stopped when the valve closed and this reversed the RCS cooldown as shown in Figure 3-22. The rising RCS temperature caused the RCS pressure to increase. The RCS repressurization was limited by the opening of the pressurizer PORVs.

The minimum average reactor vessel downcomer fluid temperature, 330 K [135°F], was reached at the time when the failed-open pressurizer SRV re-closed. Subsequently, the RCS pressure rapidly increased and was controlled between the opening and closing setpoint pressures of the pressurizer PORVs, 16.55-to-15.72 MPa [2,400-to-2,280 psia].

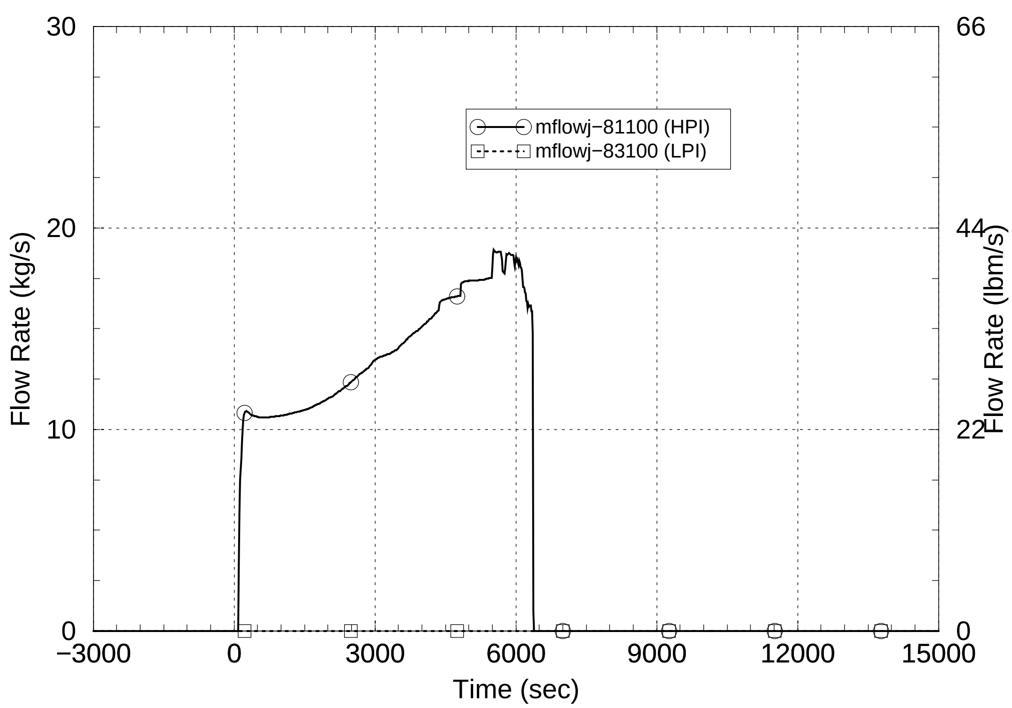


Figure 3-28 Loop A1 High Pressure Injection Flow – Calvert Cliffs Case 59

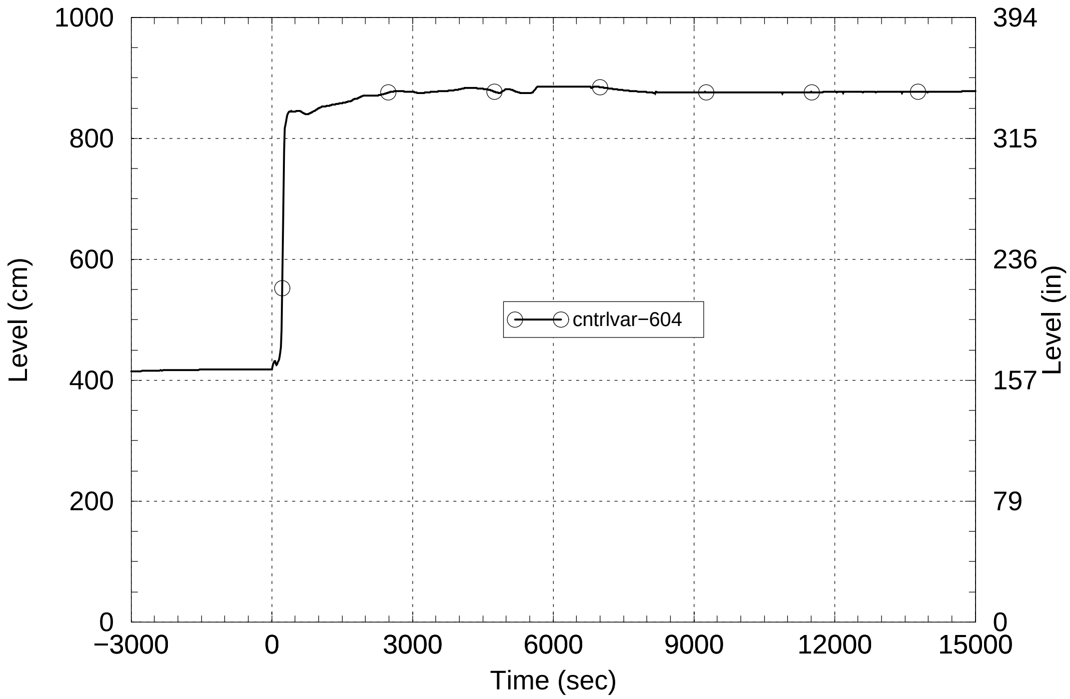


Figure 3-29 Pressurizer Level – Calvert Cliffs Case 59

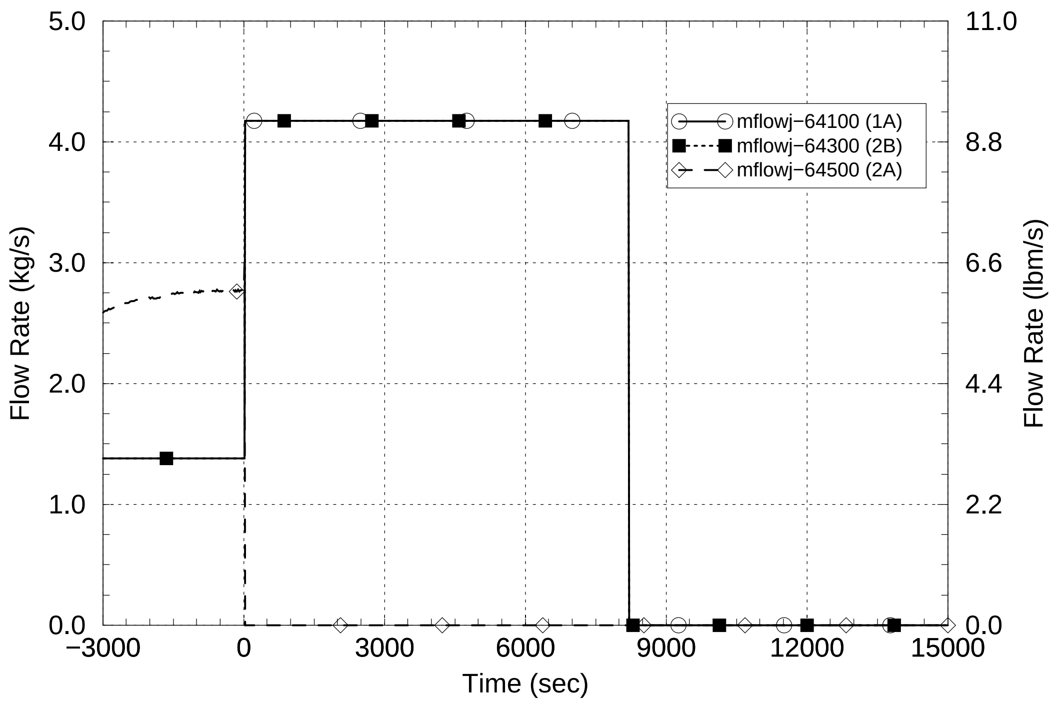


Figure 3-30 Charging and Letdown Flows – Calvert Cliffs Case 59

3.1.4 40.64-cm [16-in] Hot Leg Break from Hot Full Power Conditions with Sump Recirculation – Calvert Cliffs Case 9

This event starts with a 40.64-cm [16-in] diameter break in the hot leg when the plant is in hot full power operation.

The following modeling changes were made to simulate this event sequence. The hot leg break to a constant atmospheric-pressure containment boundary condition was added to the model in Loop 1. The equivalent break flow area for a circular break with a diameter of 40.64 cm [16 in] was specified. The break was connected on the side of the horizontal section of the hot leg. The critical flow model was activated at the break junction and the flow loss coefficients specified were based on AP600-derived flow loss coefficients and scaled for the specific break size and location for this event sequence. The containment high pressure signal, which results in containment spray actuation, was assumed to occur at the time when the break opens. The modeling for the HPI fluid temperature was modified so as to represent the constant nominal SIRWST temperature, 288.7 K [60°F], prior to the draining of that tank at 2,460 s, then switch to a representation of a variable containment sump temperature (specified as a function of the time after the switch). The HPI fluid temperature immediately increases to 349.8 K [170.0°F] following the switch and then falls to 338.7 K [150.0°F] at the end of the calculation (15,000 s after the break opens).

The RELAP5-calculated sequence of events for Case 9 is shown in Table 3-4. The RELAP5-calculated responses for the RCS pressure, average reactor vessel downcomer fluid temperature and average reactor vessel wall inside surface heat transfer coefficient for this case are shown in Figures 3-31, 3-32 and 3-33, respectively.

The calculated break flow response is shown in Figure 3-34. When the break opened, the RCS pressure fell very rapidly to near atmospheric pressure (it required only 414 s for the hot leg pressure to reach 0.2 MPa [30 psia]). The depressurization caused a reactor trip signal at 3 s. The reactor trip caused a turbine trip, isolating the steam generator systems.

Figure 3-35 shows the calculated SG secondary system pressure responses. The turbine trip caused the secondary system pressures to rise. The pressure increases were limited by the opening of the atmospheric dump and turbine bypass valves. Steam pressures did not increase sufficiently to open the main steam safety relief valves. Afterward, the declining SG pressures are an indication of reverse (i.e., secondary system to primary system) SG heat transfer caused by the cooling down of the RCS. The SG secondary fluid mass responses are shown in Figure 3-36. The turbine trip resulted in closure of the main feedwater regulation control valves. The SG inventory was increased and controlled to maintain SG levels within the normal range by flow through the main feedwater bypass control valves. The SG levels did not decline sufficiently to activate the auxiliary feedwater system.

Shortly after the break opened, RCS subcooling and pressure fell below their setpoint conditions that result in the operators tripping all four reactor coolant pumps. The decline in the coolant loop flow caused by the pump trips is indicated in Figure 3-37, which shows the two hot leg flows at the reactor vessel connections. The decline in the coolant loop flow was rapid and total, with no period of natural circulation prior to complete stagnation of the loop flows. The Loop 1 hot leg flow response reflects the fluid flowing toward the hot leg break in that loop. The effects of loop flow stagnation on the reactor vessel downcomer fluid temperature are evident in Figure 3-32. Under the stagnant coolant loop conditions, the effects of injecting cold HPI, LPI and SIT fluid into the cold legs are directly felt in the vessel downcomer and the fluid temperatures there decline rapidly.

Table 3-4 RELAP5-Calculated Sequence of Events for Calvert Cliffs Case 9

Event(s)	Event Time (Seconds)
Break opens in Hot Leg 1	0
Reactor trip signal, turbine trip	3
Safety injection actuation signal, HPI flow begins	5
Operators trip all reactor coolant pumps due to low RCS subcooling and low RCS pressure conditions	5
Pressurizer is empty	20
SIT flow begins	75
LPI flow begins	75
SITs are empty	160
Reactor coolant pump coast-down is completed	203
Recirculation actuation signal, suction for HPI system switched to containment sump, LPI pumps tripped	2,460
Calculation terminated	15,000

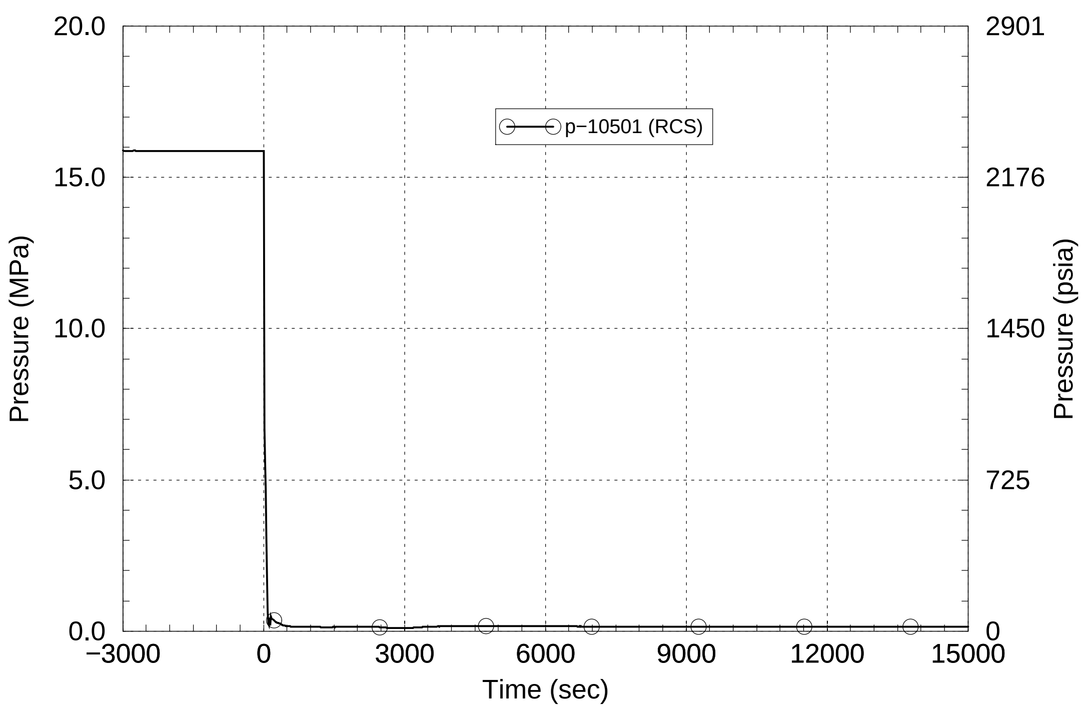


Figure 3-31 Reactor Coolant System Pressure – Calvert Cliffs Case 9

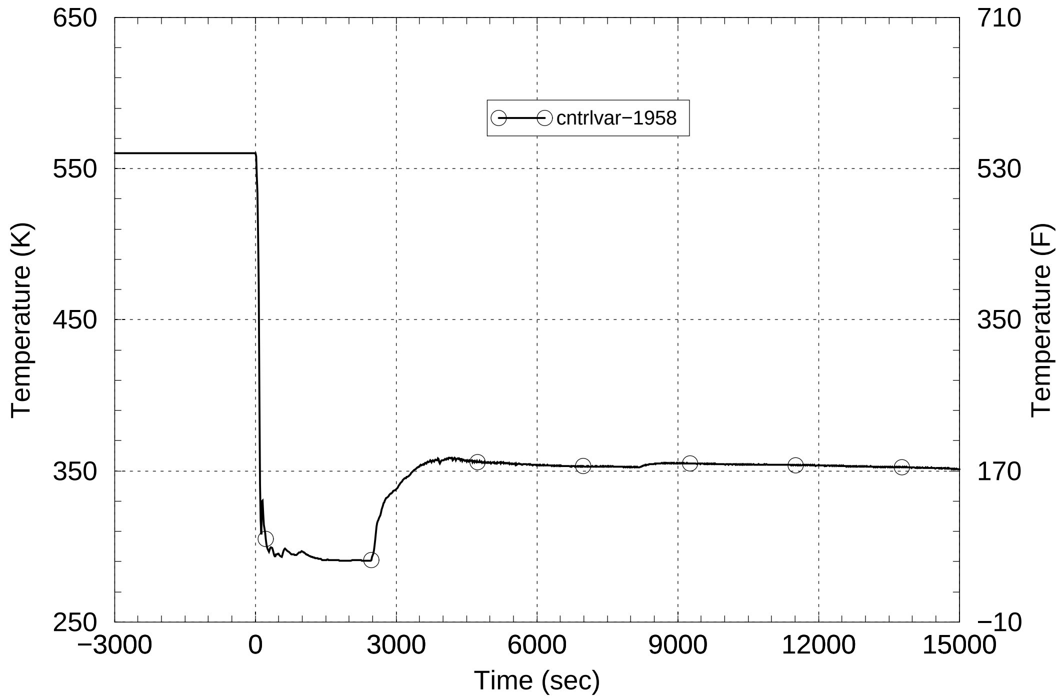


Figure 3-32 Average Reactor Vessel Downcomer Fluid Temperature – Calvert Cliffs Case 9

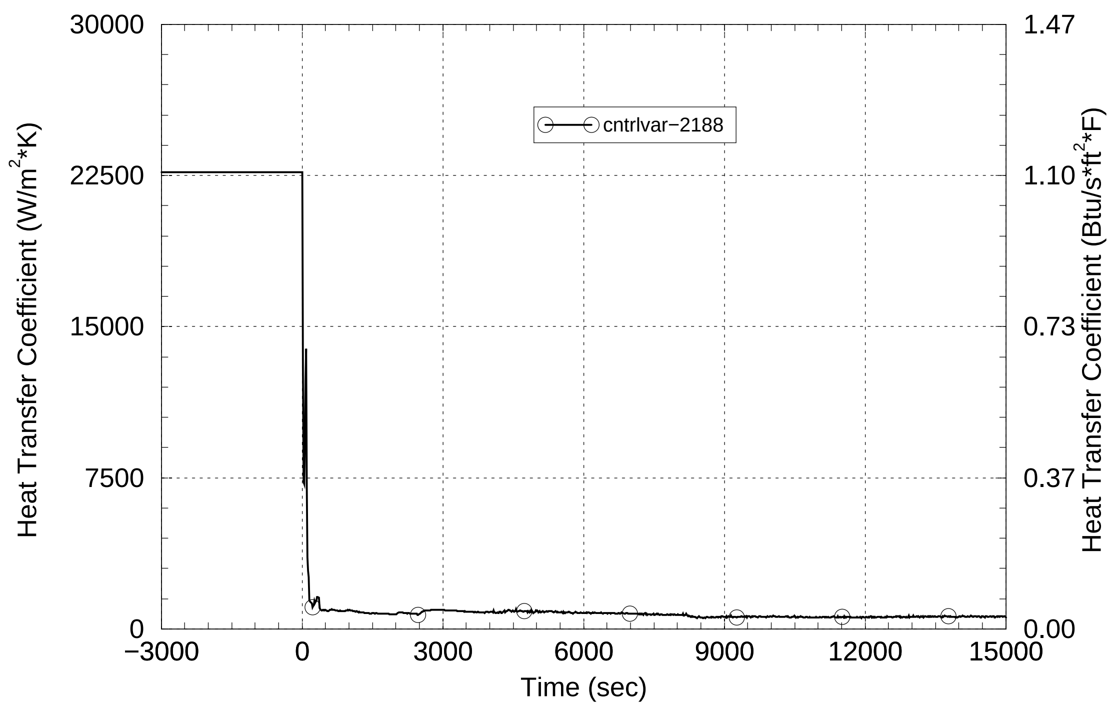


Figure 3-33 Average Reactor Vessel Inner Wall Heat Transfer Coefficient – Calvert Cliffs Case 9

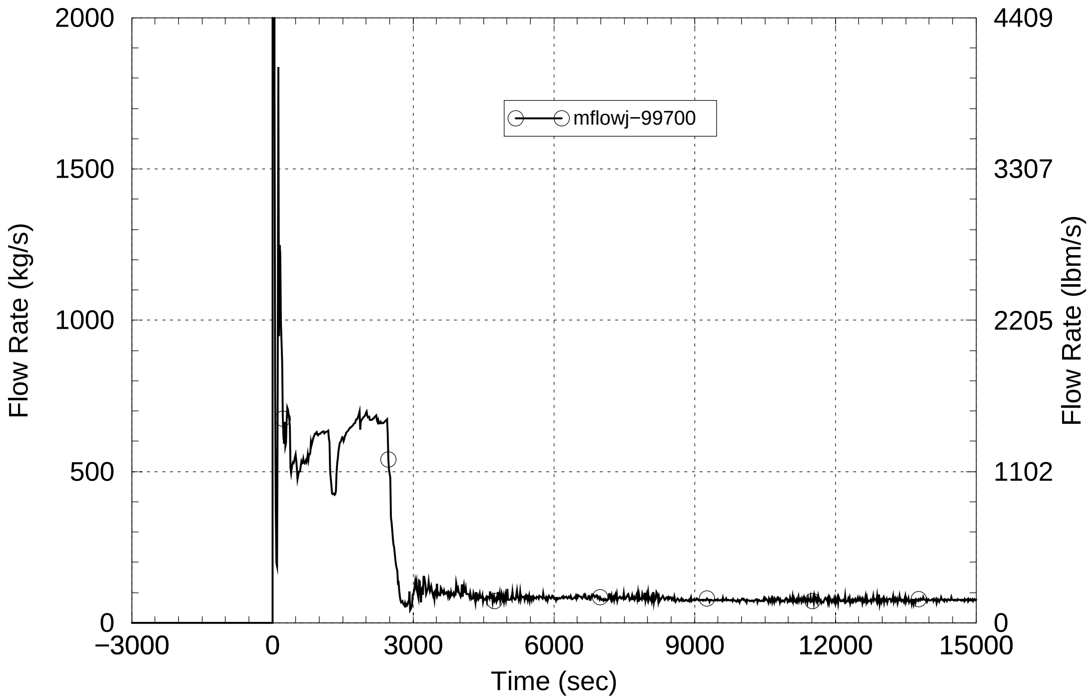


Figure 3-34 Break Flow – Calvert Cliffs Case 9

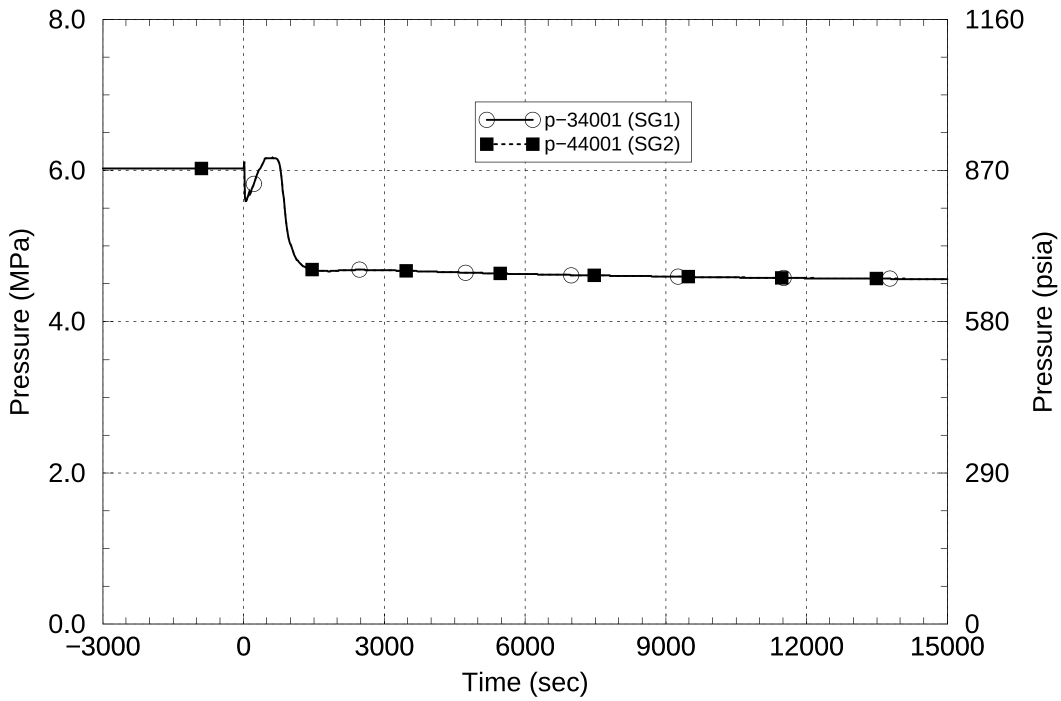


Figure 3-35 Steam Generator Pressures – Calvert Cliffs Case 9

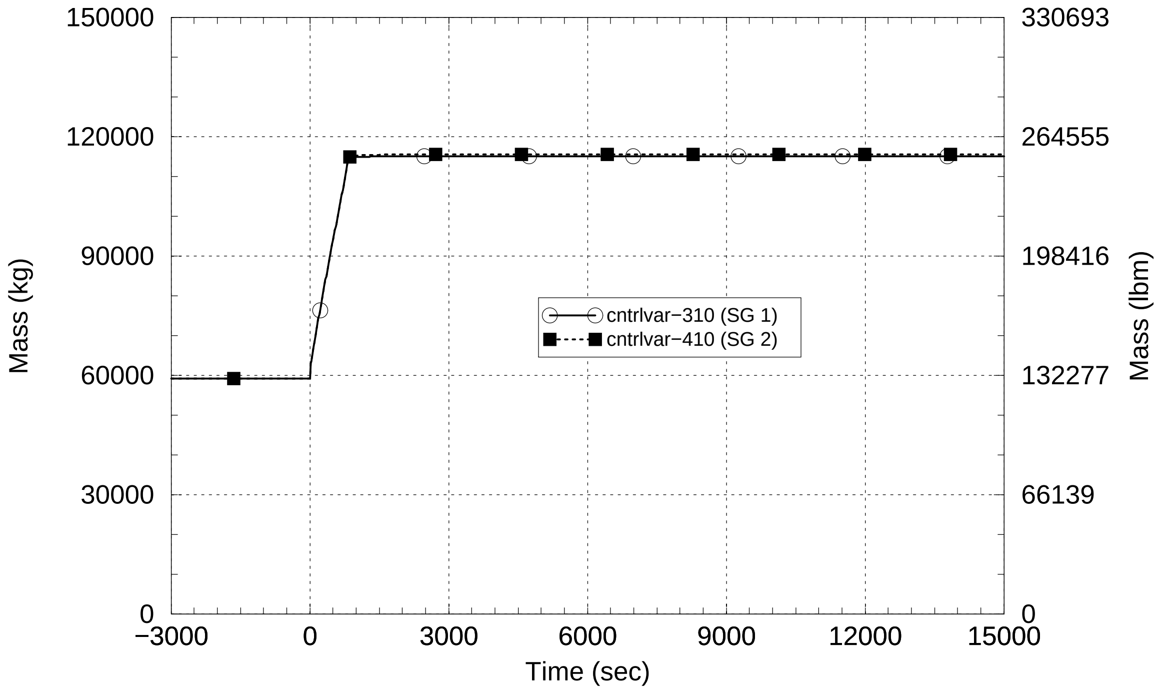


Figure 3-36   Steam Generator Secondary Fluid Masses – Calvert Cliffs Case 9

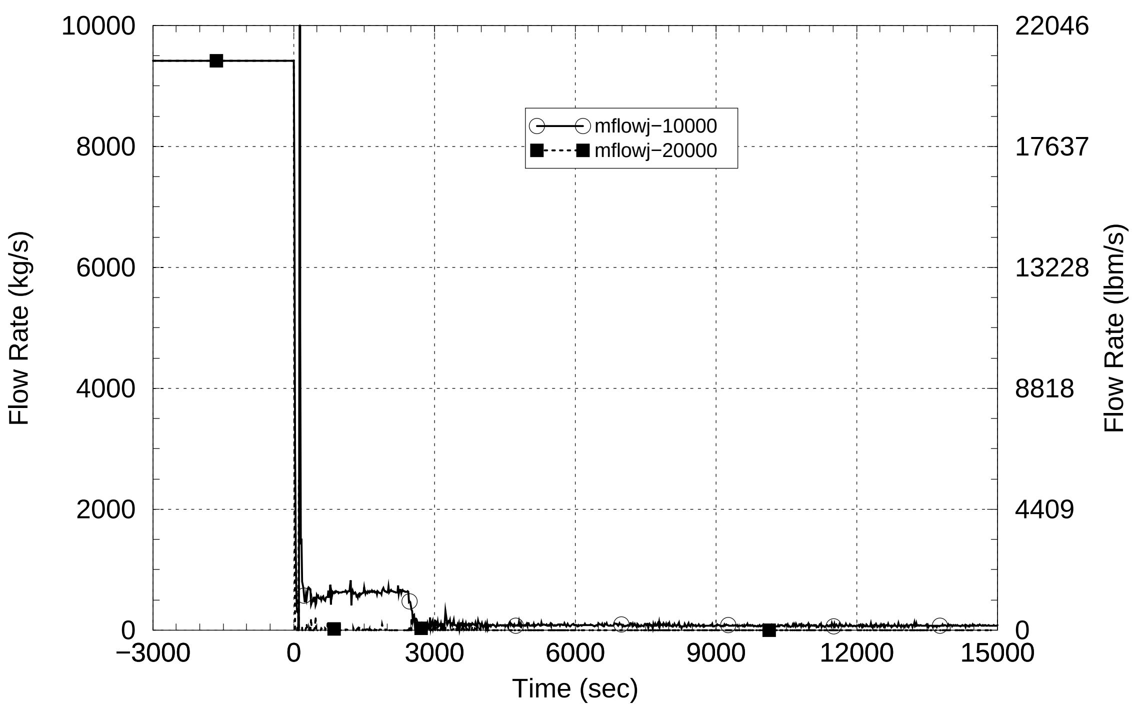


Figure 3-37   Hot Leg Flows – Calvert Cliffs Case 9

The RCS depressurization also led to a safety injection actuation signal and the starting of the HPI and LPI pumps. The calculated HPI and LPI flow rates for Cold Leg A1 are shown in Figure 3-38; the total HPI and LPI flow rates are four times the flows shown in the figure. The flows delivered from the centrifugal pumps of the HPI and LPI systems are functions of the cold leg pressure, with lower pressures resulting in higher injection flows. At 2,460 s, a recirculation actuation signal was calculated as a result of a low SIRWST level condition. At that time the suction for the HPI system is switched from the SIRWST to the containment sump (with the resulting increase in HPI fluid temperature described above) and the LPI pumps are automatically tripped.

The effects of RCS coolant inventory loss through the break are evident in the pressurizer level response shown in Figure 3-39. The break flow caused the pressurizer to completely drain over the first 20 s of the event sequence. The pressurizer subsequently refilled as a result of the rapid influx of LPI and SIT water into the RCS, then drained again. LPI injection into the four cold legs in conjunction with the assumed break location (discharge of component 105) near the surge line connection caused the pressurizer to refill temporarily. The pressurizer drained when LPI was terminated due to ECCS suction switchover to the containment sump. The letdown flow was isolated early in the event sequence at the time of the safety injection actuation signal. The charging system flow increased in response to the low pressurizer level condition. Charging flow was terminated after the time of the recirculation actuation signal. Because the break size for this event sequence is large, the charging system flow is of relatively small importance in relation to the HPI, LPI and SIT ECCS flows.

The Loop 1A SIT liquid inventory response is shown in Figure 3-40; the total SIT inventory is four times the liquid volume shown in the figure. Intermittent SIT flow began at 75 s, when the RCS pressure fell below the initial SIT pressure, 1.480 MPa [214.7 psia]. The SITs discharge whenever the RCS pressure is below the tank pressure (which declines as the liquid inventory flows out of the SITs). The SIT discharge period ended at 160 s when the liquid inventories of the SITs had been completely discharged.

During the latter portion of the event sequence the calculated conditions reflect balances in the RCS mass and energy flows. The break mass flow rate is balanced by the HPI mass addition rate. The core heat addition rate is balanced by the cooling afforded to the RCS from adding cold HPI fluid and removing warm fluid at the break.

The minimum average reactor vessel downcomer fluid temperature, 290 K [63.2°F], was reached at 1950 s, shortly before the time when the suction for the HPI system was switched to the containment sump and the LPI pumps were tripped. The RCS pressure, which was calculated to be 0.16 MPa [23.0 psia] at that time, remained low until the end of the event sequence.

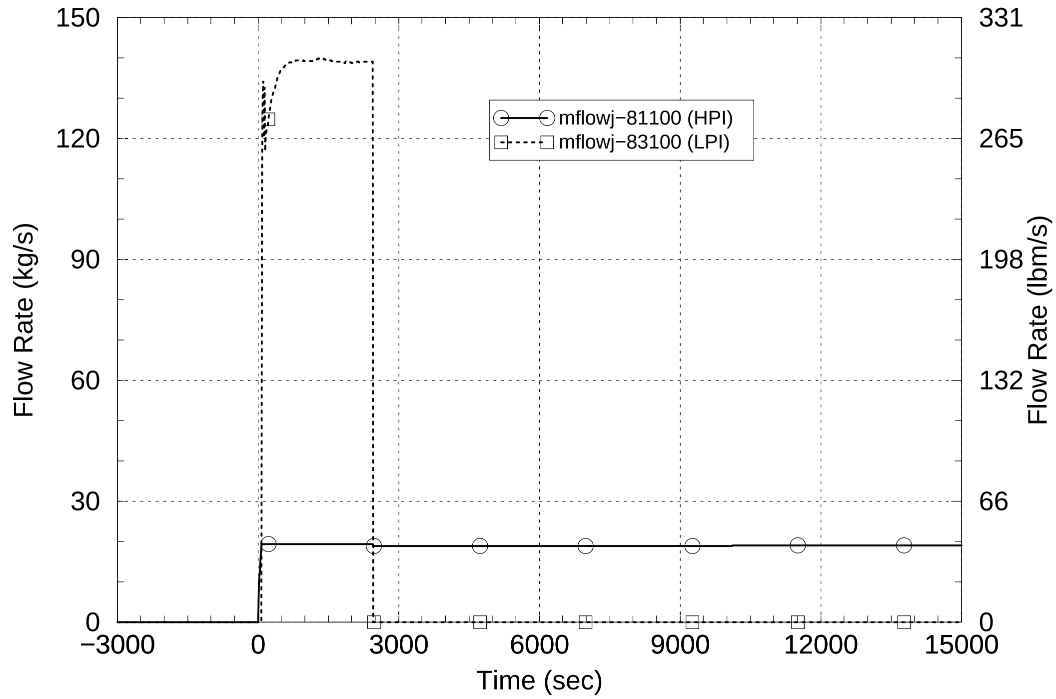


Figure 3-38 Loop A1 HPI and LPI Flows – Calvert Cliffs Case 9

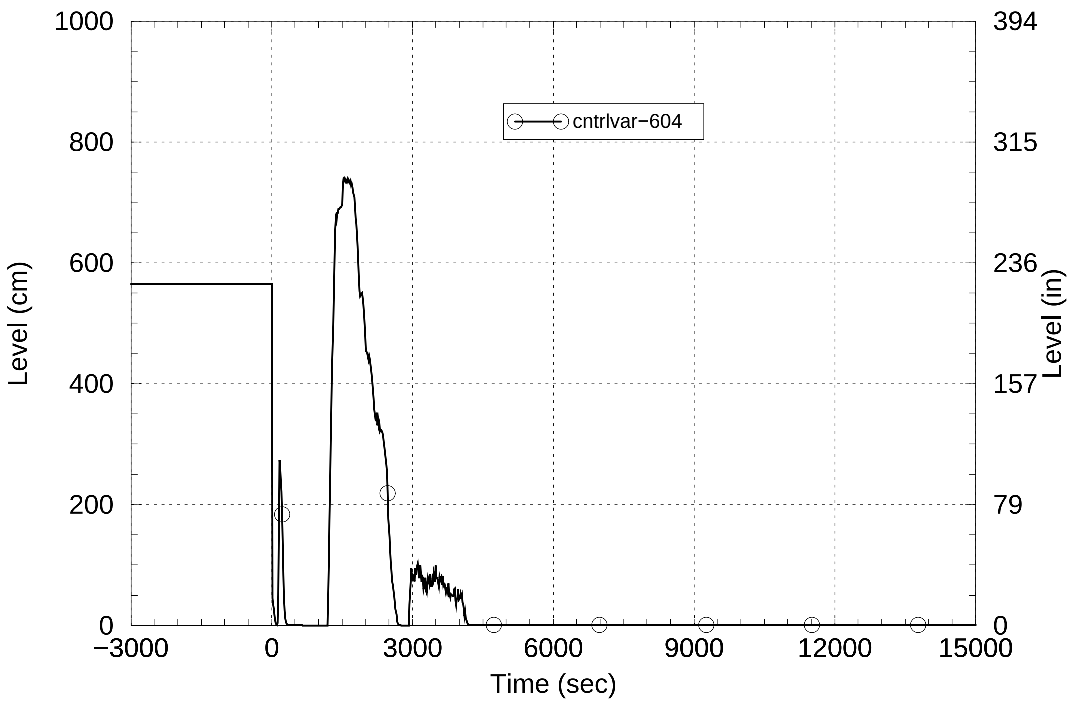


Figure 3-39 Pressurizer Level – Calvert Cliffs Case 9

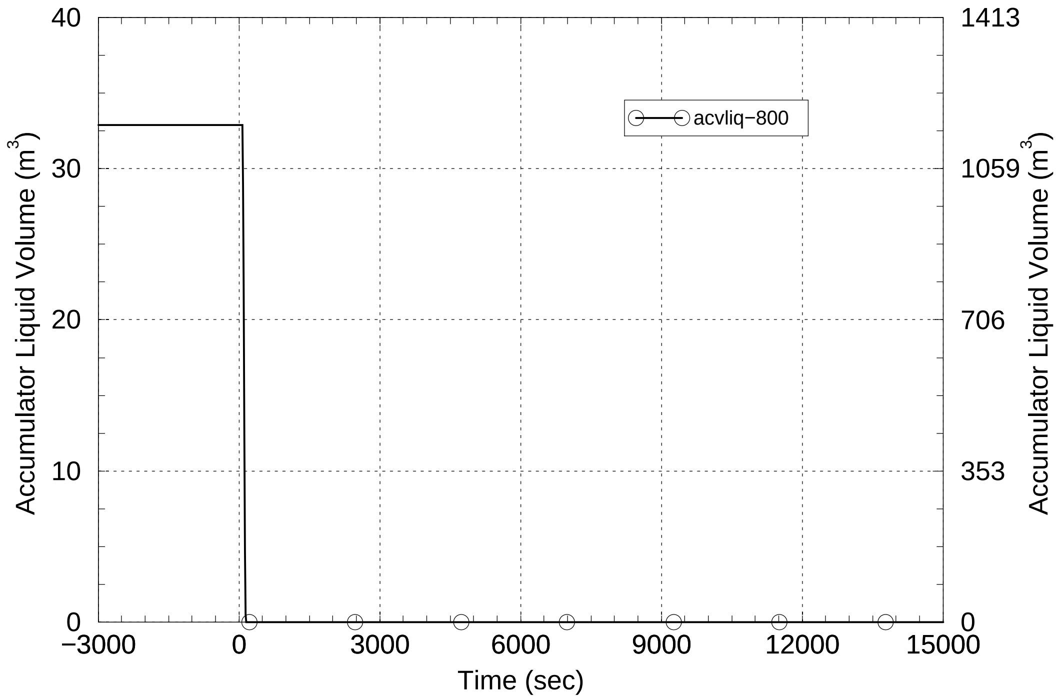


Figure 3-40   Loop 1A SIT Flow – Calvert Cliffs Case 9

4.0 SUMMARY AND COMPARISON TO THE NUREG/CR-6858 ANALYSIS

This section provides a brief summary of the observations made on the Calvert Cliffs minimum downcomer temperature results for key transients compared to the NUREG/CR-6858 results for Oconee, Beaver Valley and Palisades. Note that the Calvert Cliffs plant is a Combustion Engineering design similar in many aspects to Palisades. It is recognized that comparisons of many parameters among the four plants can be made. Generic conclusions regarding classes of sequences similar to those evaluated for Calvert Cliffs analysis are presented in Chapter 4 of NUREG/CR-6858. These conclusions are applicable to the Calvert Cliffs results. However, the thermal hydraulic analysis discussed in this report as in NUREG/CR-6858 is a part of an overall risk analysis where the risk of vessel failure due to a PTS event is determined by sequence probabilities that define the sequences analyzed and the fracture mechanics analysis that combined with the sequence probabilities and thermal hydraulic results determine the risk.

The LOCA analyses for the Calvert Cliffs plants are comparable to the Oconee, Beaver Valley and Palisades plants. For the 40.64 cm [16 in] break from HFP, the minimum temperature is 290 K [63°F] at 1,955 s for Calvert Cliffs (Case 009). The Oconee minimum temperature is 298 K [76°F] at 1,721 s (Case 156) while the Beaver Valley and Palisades temperature results (Cases 009 and 40, respectively) are 291 K [64°F] at 960 s and 308 K [94°F] at 1,260 s, respectively. The difference in the temperature is principally driven by the ECCS injection temperature used. The ECCS injection temperature for Calvert Cliffs is 289 K [60°F]. In comparison, the ECCS injection temperature for Beaver Valley is the lowest at 283 K [50°F] while the Oconee and Palisades injection temperatures are 300 K [80°F] and 304 K [88°F], respectively.

Plant design differences may account for some of the variation in the time that the minimum temperature is predicted during a large break LOCA. These differences do not have much of an impact of the minimum temperature results for a LOCA of this size. For smaller breaks, the minimum temperature is also generally dependent on the assumed ECCS injection temperature, although the time that the minimum temperature is reached is later since the blowdown time and time that the various ECCS systems start is longer. In addition, plant differences in ECCS flow capability and shutoff head can lead to differences in results. In general, the downcomer temperature decreases to near the injection temperature because the ECCS systems continue to inject cold water into the reactor coolant system with the time that the minimum is reached dependent on the break size.

Other scenarios involving stuck open pressurizer safety valves may not be as comparable among the plants as for the LOCA transients. Reasons for this difference are due to differences in valve sizes and boundary conditions that are part of the sequence definitions particularly injection temperature. For example, the downcomer temperature for Calvert Cliffs Case 59 where a stuck open pressurizer safety valve occurs during HZP operation and recloses at 6,000 s at nominal temperature conditions (injection temperature is 289 K [60°F]) was 330 K [134°F]. For Palisades Case 65, the minimum downcomer fluid temperature is 366 K [199°F] at summer operating conditions (injection temperature is 311 K [100°F]). This difference illustrates the impact of injection temperature, which is part of the sequence definition.

For main steam line breaks, the downcomer temperature results for the three plants are similar despite differences in assumptions for operator actions for HPI throttling, break location inside and outside containment, and timing of AFW isolation to the affected steam generator. The minimum downcomer temperature for Calvert Cliffs Case 46, a MSLB without AFW isolation from HFP conditions is 380 K [225°F] at 6,175 s. In comparison, Beaver Valley Case 102, a MSLB from HFP conditions where AFW continues to feed the affected steam generator for 30 minutes and where the operator controls HHSI 30 minutes after allowed is 373 K [212°F] at 3,990 s. Palisades Case 54, a MSLB that occurs inside containment and where the AFW continues to feed the affected steam generator and the operator does not throttle HPI flow results in a minimum downcomer temperature of 377 K [219°F] at 4,110 s. The results are not that different (12 K [22°F]) even given the modeling differences.

One reason for the relative uniformity of the MSLB downcomer temperature results is that the RCS generally remains full during MSLBs with loop natural circulation (and forced circulation in some cases) continuing throughout the event sequences. This circulation tends to keep the RCS fluid well mixed, so that the downcomer temperature does not drop to the ECCS injection temperature. Instead, the downcomer temperature tends to approach 373 K [212°F], which is the saturation temperature at the atmospheric pressure present in the affected steam generator secondary side. In contrast to the LOCA where the temperature of ECCS injection drives the downcomer temperature, MSLBs remove heat from the reactor coolant system uniformly, so that minimum downcomer temperatures tend to be higher.

5.0 REFERENCES

Arcieri, W.C., Beaton, R.M., and Fletcher, C.D., *RELAP5 Thermal Hydraulic Analysis to Support PTS Evaluations for the Oconee-1, Beaver Valley-1, and Palisades Nuclear Power Plants*, NUREG/CR-6858, September 2004.

Appendix A – Summary of Calvert Cliffs RELAP5 Results

This appendix presents an overview of the RELAP5 modeling details and the results of the 100 cases evaluated for the Calvert Cliffs plant. Table A-1 presents a list of the cases analyzed. These cases include a mix of LOCAs, stuck open pressurizer safety valves, main steam line breaks, and secondary side failures from both hot full power and hot zero power conditions.

Results for each of the base cases are presented below as Figures A-1 to A-102. The following information is given in tabular format for each case:

Case Category	LOCA, RT/TT, MSLB, etc.
Primary Failures	Description of the primary side failure.
Secondary Failures	Description of the secondary side failure.
Operator Action	Description of any operator actions.
Min DC Temp	The minimum average downcomer fluid temperature and the associated time that the minimum occurred.
Comments	Any comments specific to the event.

In addition to the information described above, plots of average downcomer fluid temperature, primary system pressure, and downcomer wall heat transfer coefficient are presented. Any analytical assumptions used in each case are also presented. To facilitate comparisons among cases, each figure presents summary information for the minimum downcomer average temperature in the reactor vessel and the time during the event sequence when that minimum is reached.

All cases are run from hot full power conditions except where noted in Table A-1. Note that cases 86, 90, 92, and 95 were not completed, as they were not needed for any analyses at the time these RELAP5 runs were made. These cases are listed for completeness.

All analyses use nominal ECCS injection temperature conditions unless otherwise indicated in Table A-1. The ECCS injection temperatures used for the nominal, summer, and winter conditions are presented in Section 2.

Table A-1 List of Calvert Cliffs RELAP5 Cases

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
001	LOCA	2.54 cm [1.0 in] surge line break.	None.	None.	None.
002	LOCA	3.59 cm [1.414 in] surge line break.	None.	None.	None.
003	LOCA	5.08 cm [2.0 in] surge line break.	None.	None.	None.
004	LOCA	7.18 cm [2.828 in] surge line break.	None.	None.	None.
005	LOCA	10.16 cm [4.0 in] surge line break.	None.	None.	None.
006	LOCA	14.37 cm [5.657 in] surge line break.	None.	None.	None.
007	LOCA	20.32 cm [8.0 in] surge line break.	None.	None.	None.
008	LOCA	28.74 cm [11.314 in] hot leg break.	None.	None.	Includes sump recirculation.
009	LOCA	40.64 cm [16.0 in] hot leg break.	None.	None.	Includes sump recirculation.
010	LOCA	57.47 cm [22.627 in] hot leg break.	None.	None.	Includes sump recirculation.
011	LOCA	5.08 cm [2.0 in] cold leg break.	None.	None.	None.
012	LOCA	40.64 cm [16.0 in] cold leg break.	None.	None.	Includes sump recirculation.
013	RT/TT	One stuck open pressurizer PORV.	None.	None.	None.
014	RT/TT	One stuck open pressurizer PORV.	None.	Operator isolates PORV after 20 minutes.	None.
015	RT/TT	One stuck open pressurizer SRV.	None.	None.	None.
016	RT/TT	None.	One stuck open TBV.	None.	None.
017	RT/TT	None.	Two stuck open TBVs.	None.	None.
018	RT/TT	None.	Three stuck open TBVs.	None.	None.
019	RT/TT	None.	One stuck open ADV.	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.	None.
020	RT/TT	None.	Two stuck open ADVs.	None.	None.
021	RT/TT	None.	One stuck open ADV in SG 1.	None.	None.
022	RT/TT	None.	None	None.	No concurrent failures.
023	RT/TT	One stuck open pressurizer PORV.	One stuck open ADV in SG 1.	None.	None.
024	RT/TT	One stuck open pressurizer SRV.	One stuck open ADV in SG 1.	None.	None.
025	RT/TT	None.	One stuck open main steam SRV.	None.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
026	RT/TT	None.	Two stuck open main steam SRVs (one in each steam generator).	None.	None.
027	RT/TT	None.	MFW overfills SG-1.	Operator trips main feedwater when water enters the steam line.	None.
028	RT/TT	None.	MFW overfills both SGs.	Operator trips main feedwater when water enters the steam line.	None.
029	MSLB	None.	Main Steam Line Break (double ended guillotine break).	None.	None.
030	RT/TT	Two stuck open pressurizer PORVs.	None.	None.	None.
031	RT/TT	Two stuck open pressurizer SRVs.	None.	None.	None.
032	RT/TT	One stuck open pressurizer SRV which recloses at 4,000 s.	None.	None.	None.
033	RT/TT	Two stuck open pressurizer SRVs that reclose when primary pressure decreases to 4.93 MPa (700 psig).	None.	None.	None.
034	SGTR	Steam generator tube rupture (single tube).	None.	None.	None.
035	SGTR	Steam generator tube rupture (single tube).	One stuck open TBV.	None.	None.
036	RT/TT	One stuck open pressurizer PORV.	One stuck open TBV.	None.	None.
037	RT/TT	One stuck open pressurizer SRV.	One stuck open TBV.	None.	None.
038	RT/TT	One stuck open pressurizer SRV.	One stuck open main steam SRV.	None.	None.
039	RT/TT	One stuck open pressurizer SRV which recloses at 6,000 s.	None.	None.	None.
040	RT/TT	Two stuck open pressurizer SRVs which reclose at 6,000 s.	None.	None.	None.
041	RT/TT	None.	One stuck open ADV in SG 1.	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.	None.
042	RT/TT	None.	One stuck open ADV in SG 1.	Operator fails to isolate AFW.	None.
043	RT/TT	One stuck open pressurizer PORV.	One stuck open ADV in SG 1.	None. Operator fails to isolate AFW.	None.
044	RT/TT	One stuck open pressurizer SRV.	One stuck open ADV in SG 1.	None. Operator fails to isolate AFW.	None.
045	RT/TT	None.	One stuck open main steam SRV.	None. Operator fails to isolate AFW.	None.
046	MSLB	None.	Main Steam Line Break (double ended guillotine break).	None. Operator fails to isolate AFW.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
047	RT/TT	One stuck open pressurizer SRV.	One stuck open main steam SRV.	None. Operator fails to isolate AFW.	None.
048	RT/TT	None.	One stuck open ADV in SG 1. AFW controls level in SG 1 at steam line elevation once AFW starts.	None. Operator fails to isolate AFW.	None.
049	RT/TT	One stuck open pressurizer SRV	One stuck open ADV in SG 1. AFW controls level in SG 1 at steam line elevation once AFW starts.	None. Operator fails to isolate AFW.	None.
050	LOCA, HZP	3.59 cm [1.414 in] surge line break from HZP.	None.	None. Operator fails to isolate AFW.	None.
051	LOCA, HZP	5.08 cm [2.0 in] surge line break from HZP.	None.	None. Operator fails to isolate AFW.	None.
052	LOCA, HZP	7.18 cm [2.828 in] surge line break from HZP.	None.	None. Operator fails to isolate AFW.	None.
053	LOCA, HZP	5.08 cm [2.0 in] cold leg break from HZP.	None.	None. Operator fails to isolate AFW.	None.
054	RT/TT, HZP	One stuck open pressurizer PORV from HZP.	None.	None. Operator fails to isolate AFW.	None.
055	RT/TT, HZP	One stuck open pressurizer SRV from HZP.	None.	None. Operator fails to isolate AFW.	None.
056	RT/TT, HZP	None.	Full MFW flow to SG 1 and 2 from HZP.	Operator trips MFW when water enters the steam line. Operator fails to isolate AFW.	None.
057	RT/TT, HZP	Two stuck open pressurizer PORVs from HZP.	None.	None. Operator fails to isolate AFW.	None.
058	RT/TT, HZP	Two stuck open pressurizer SRVs from HZP.	None.	None. Operator fails to isolate AFW.	None.
059	RT/TT, HZP	One stuck open pressurizer SRV which recloses at 6,000 s from HZP.	None.	None. Operator fails to isolate AFW.	None.
060	RT/TT, HZP	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.	None.	None. Operator fails to isolate AFW.	None.
061	RT/TT, HZP	None.	One stuck open ADV in SG 1 from HZP.	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.	None.
062	RT/TT, HZP	None.	One stuck open ADV in SG 1 from HZP.	None. Operator fails to isolate AFW.	None.
063	RT/TT, HZP	One stuck open pressurizer PORV from HZP.	One stuck open ADV in SG 1.	None. Operator fails to isolate AFW.	None.
064	RT/TT, HZP	One stuck open pressurizer SRV from HZP.	One stuck open ADV in SG 1.	None. Operator fails to isolate AFW.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
065	RT/TT, HZP	None.	One stuck open main steam SRV from HZP.	None. Operator fails to isolate AFW.	None.
066	MSLB, HZP	None.	Main Steam Line Break (double ended guillotine break) from HZP.	None. Operator fails to isolate AFW.	None.
067	RT/TT, HZP	One stuck open pressurizer SRV from HZP.	One stuck open main steam SRV.	None. Operator fails to isolate AFW.	None.
068	LOCA, HZP	10.16 cm [4.0 in] surge line break from HZP.	None.	None.	None.
069	LOCA, HZP	14.37 cm [5.657 in] surge line break from HZP.	None.	None.	None.
070	LOCA, HZP	57.47 cm [22.627 in] hot leg break from HZP.	None.	None.	Includes sump recirculation.
071	LOCA, HZP	3.59 cm [1.414 in] surge line break from HZP.	None.	None.	None.
072	LOCA, HZP	20.32 cm [8.0 in] surge line break from HZP.	None.	None.	None.
073	LOCA, HZP	28.74 cm [11.314 in] hot leg break from HZP.	None.	None.	Includes sump recirculation.
074	LOCA, HZP	40.64 cm [16.0 in] hot leg break from HZP.	None.	None.	Includes sump recirculation.
075	RT/TT	Two stuck open pressurizer SRVs that reclose at 6,000 s.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
076	RT/TT, HZP	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
077	RT/TT	Two stuck open pressurizer SRVs that reclose at 6,000 s.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
078	RT/TT, HZP	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
079	RT/TT	One stuck open pressurizer SRV that recloses at 6,000 s from HZP.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
080	RT/TT, HZP	One stuck open pressurizer SRV that recloses at 6,000 s from HZP.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
081	LOCA	7.18 cm [2.828 in] surge line break.	None.	None.	DC fluid to wall heat transfer coefficient decreased by 30%.
082	LOCA	7.18 cm [2.828 in] surge line break.	None.	None.	DC fluid to wall heat transfer coefficient increased by 30%.
083	LOCA	8.5 cm [3.347 in] surge line break.	None.	None.	DC fluid to wall heat transfer coefficient increased by 30%.
084	LOCA	6.01 cm [2.366 in] surge line break.	None.	None.	Winter conditions assumed.
085	LOCA	6.01 cm [2.366 in] cold leg break.	None.	None.	None.
087	LOCA, HZP	8.5 cm [3.347 in] surge line break from HZP.	None.	None.	Summer conditions assumed.
088	LOCA, HZP	6.01 cm [2.366 in] cold leg break from HZP.	None.	None.	HPI flow increased by 10%.
089	LOCA, HZP	6.01 cm [2.366 in] cold leg break from HZP.	None.	None.	Winter conditions assumed.
091	LOCA	20.32 cm [8.0 in] cold leg break.	None.	None.	Winter conditions assumed.
093	LOCA	8.5 cm [3.347 in] surge line break.	None.	None.	None.
094	LOCA, HZP	20.32 cm [8.0 in] cold leg break from HZP.	None.	None.	Winter conditions assumed.
096	LOCA, HZP	8.5 cm [3.347 in] surge line break from HZP.	None.	None.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
097	RT/TT	One stuck open pressurizer SRV that recloses at 3,000 s.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
098	RT/TT	One stuck open pressurizer SRV that recloses at 3,000 s.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
099	RT/TT	One stuck open pressurizer SRV that recloses at 3,000 s.	None.	None. Operator does not throttle HPI.	None.
100	RT/TT	One stuck open pressurizer SRV that recloses at 6,000 s.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
101	RT/TT	One stuck open pressurizer SRV that recloses at 6,000 s.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
102	RT/TT	Two stuck open pressurizer SRVs that reclose at 3,000 s.	None.	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.
103	RT/TT	Two stuck open pressurizer SRVs that reclose at 3,000 s.	None.	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.	None.

Case No.	Case Category	Primary Side Failures	Secondary Side Failures	Operator Actions	Comments
104	RT/TT	Two stuck open pressurizer SRVs that reclose at 3,000 s.	None.	None. Operator does not throttle HPI.	None.

Case Category	LOCA
Primary Failures	2.54 cm [1.0 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	487.7 K [418.1EF] at 15,000 s
Comments	None.

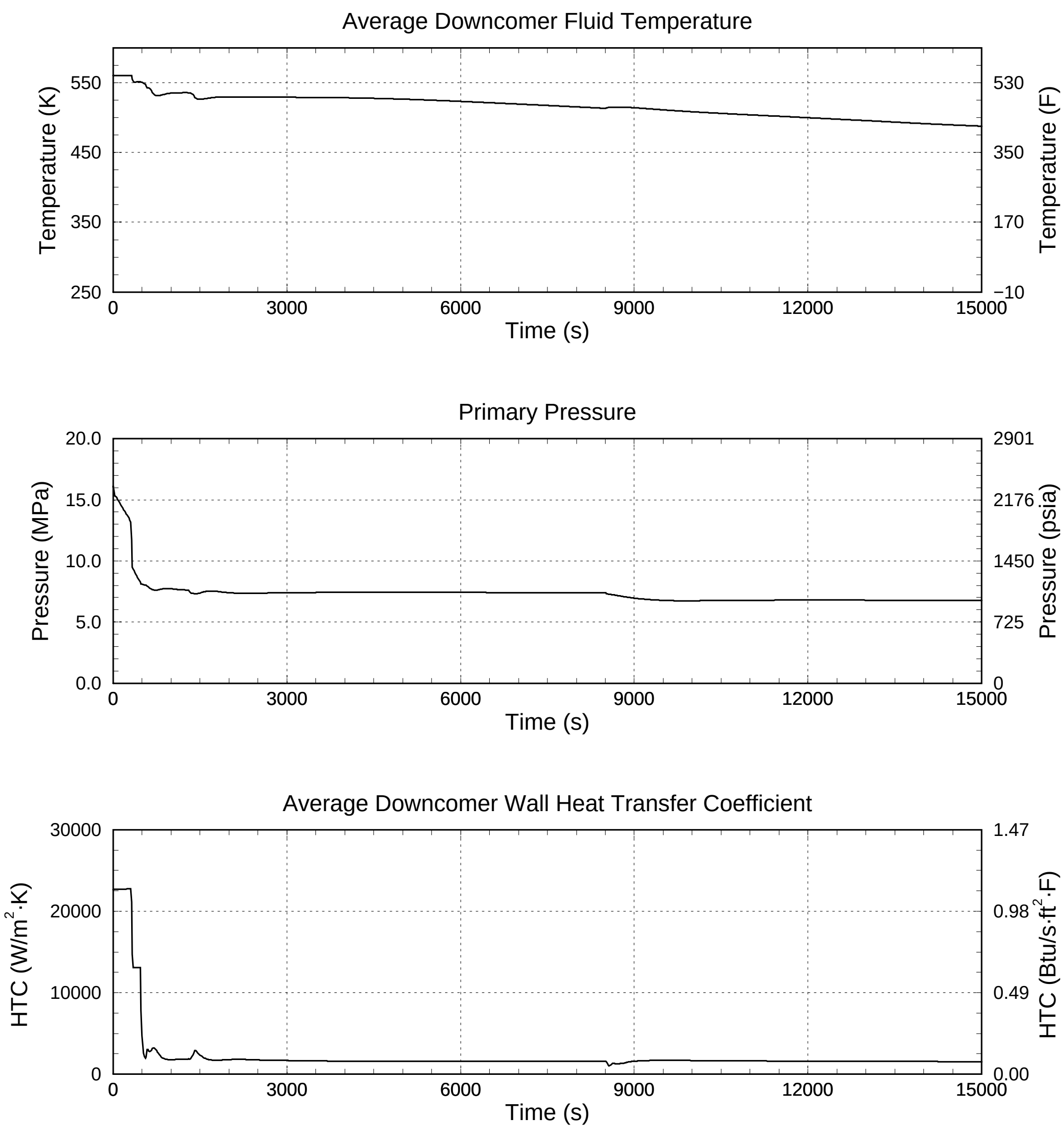


Figure A-1 Calvert Cliffs PTS Results for Case 001

Case Category	LOCA
Primary Failures	3.59 cm [1.414 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	411.8 K [281.6EF] at 15,000 s
Comments	None.

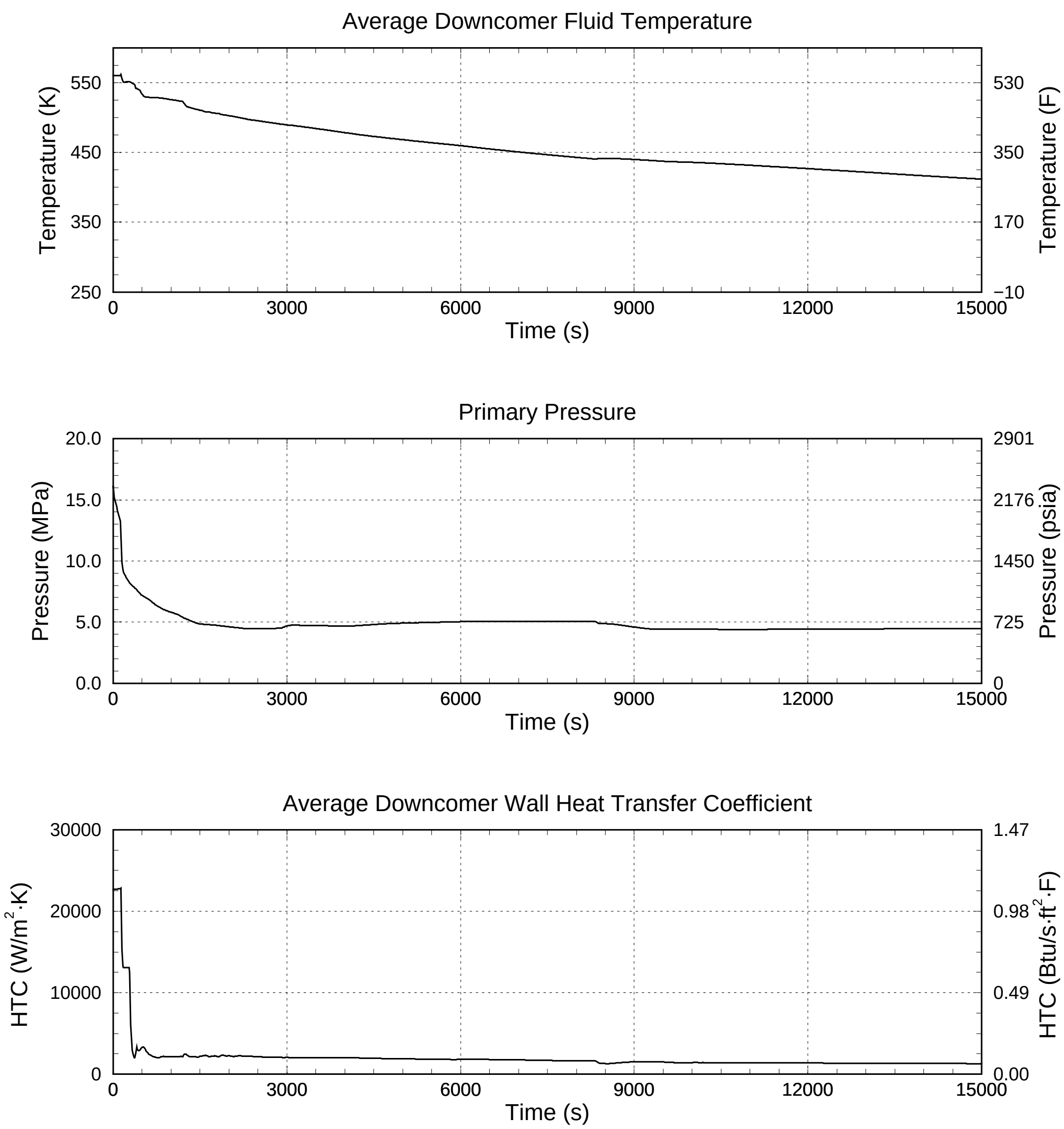


Figure A-2 Calvert Cliffs PTS Results for Case 002

Case Category	LOCA
Primary Failures	5.08 cm [2.0 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	330.3 K [134.8EF] at 9,540 s
Comments	None.

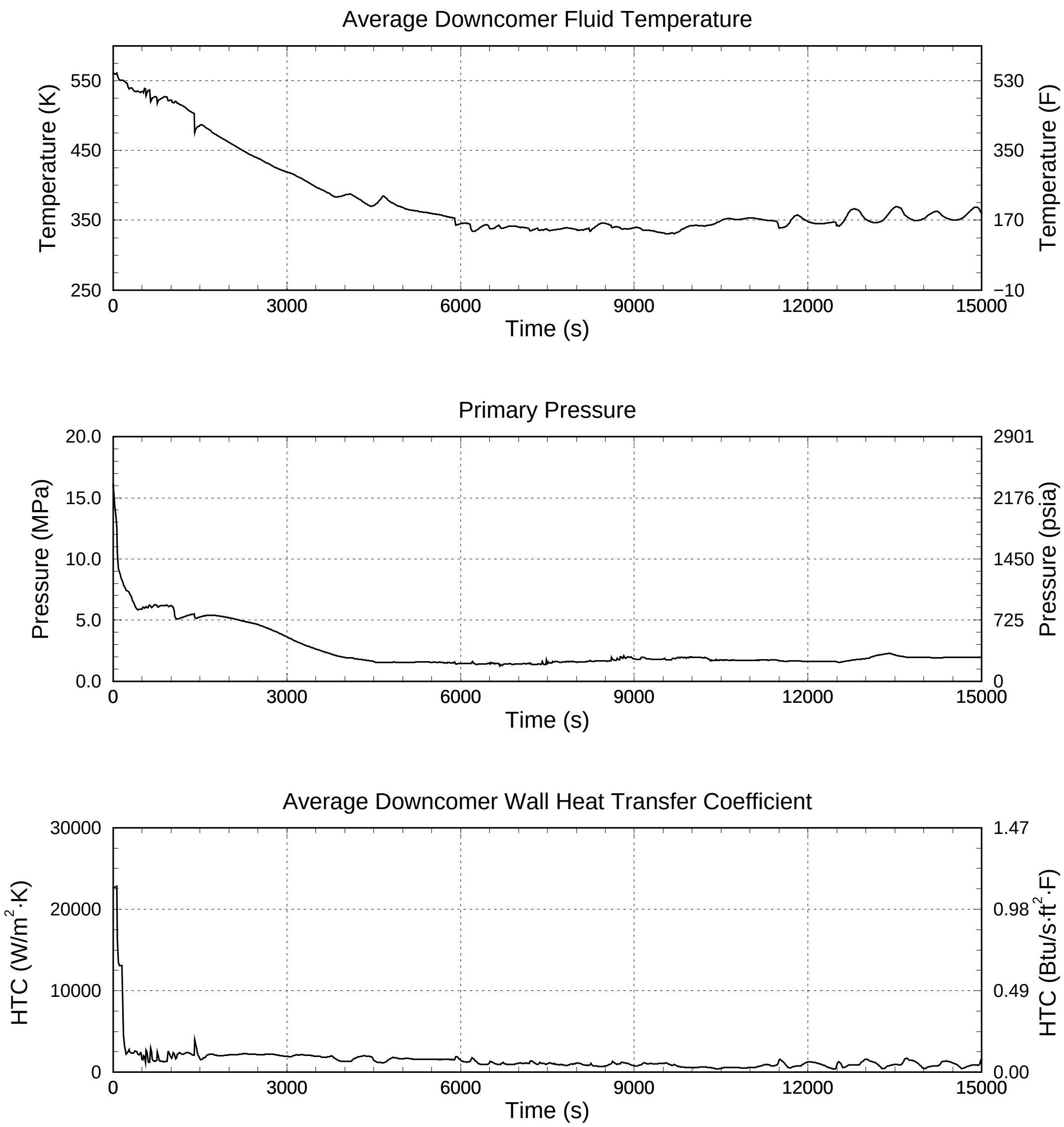


Figure A-3 Calvert Cliffs PTS Results for Case 003

Case Category	LOCA
Primary Failures	7.18 cm [2.828 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	307.8 K [94.4EF] at 4,095 s
Comments	None.

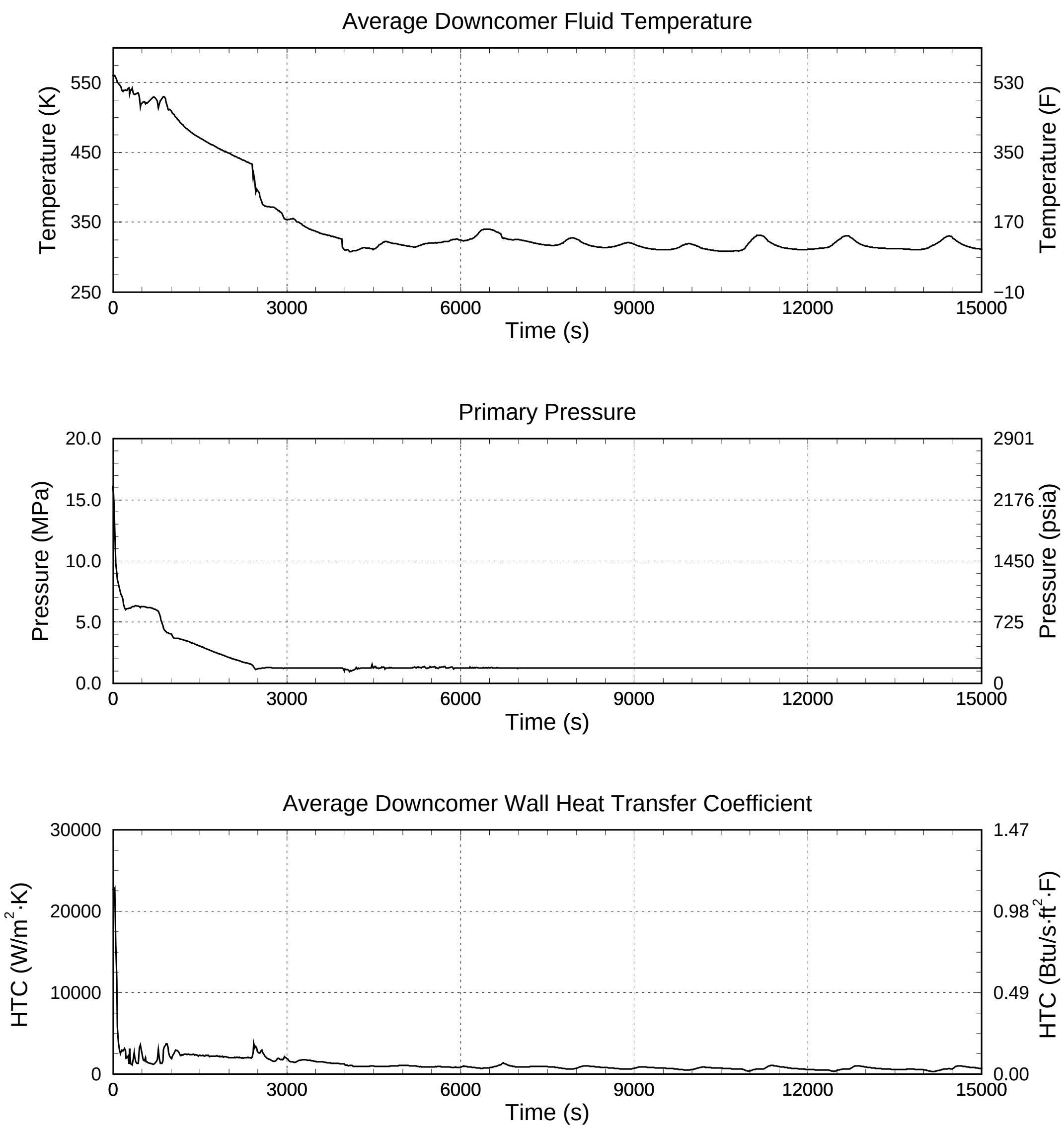


Figure A-4 Calvert Cliffs PTS Results for Case 004

Case Category	LOCA
Primary Failures	10.16 cm [4.0 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.8 K [63.8EF] at 10,575 s
Comments	None.

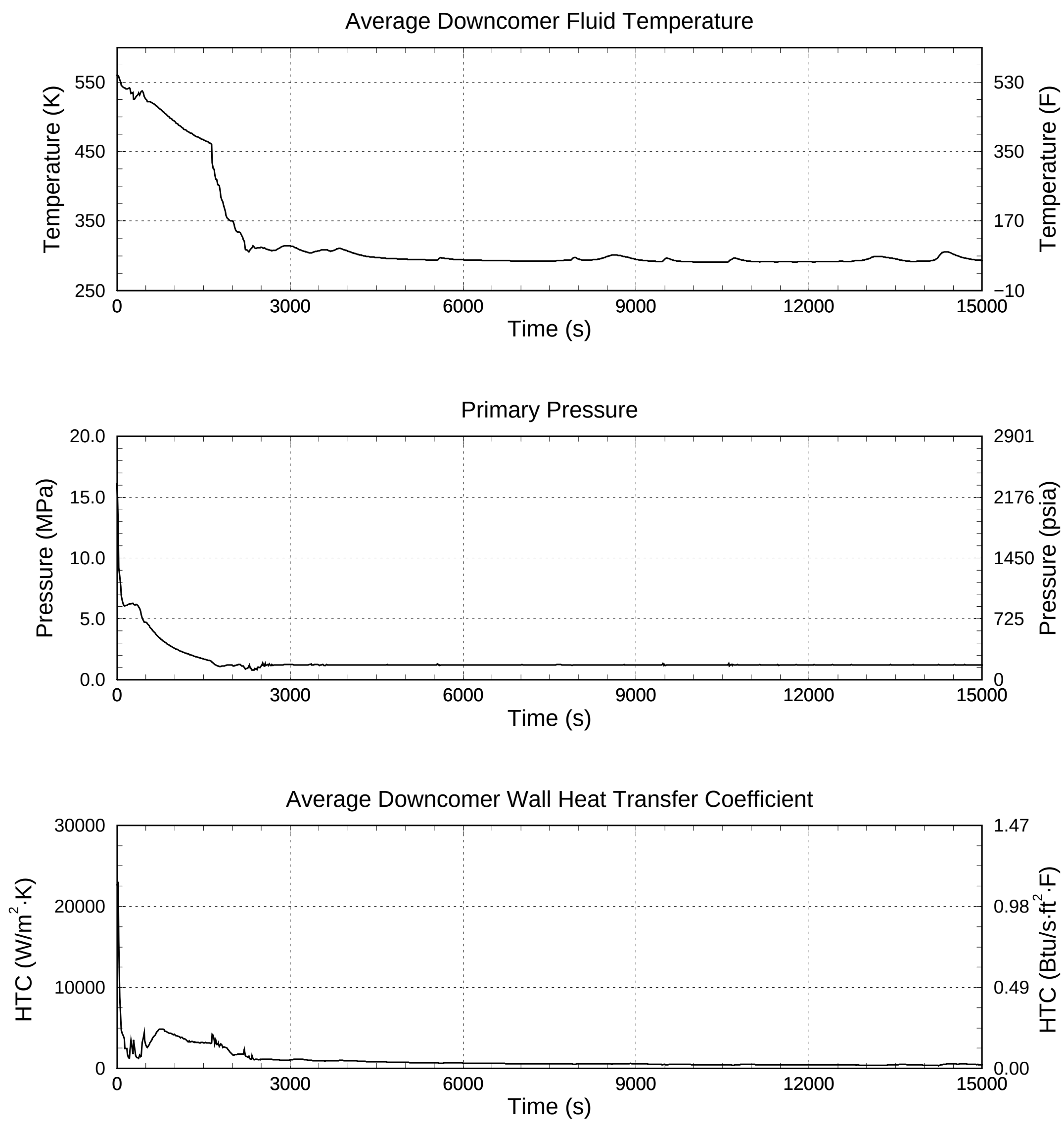


Figure A-5 Calvert Cliffs PTS Results for Case 005

Case Category	LOCA
Primary Failures	14.37 cm [5.657 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.1 K [60.7EF] at 14,475 s
Comments	None.

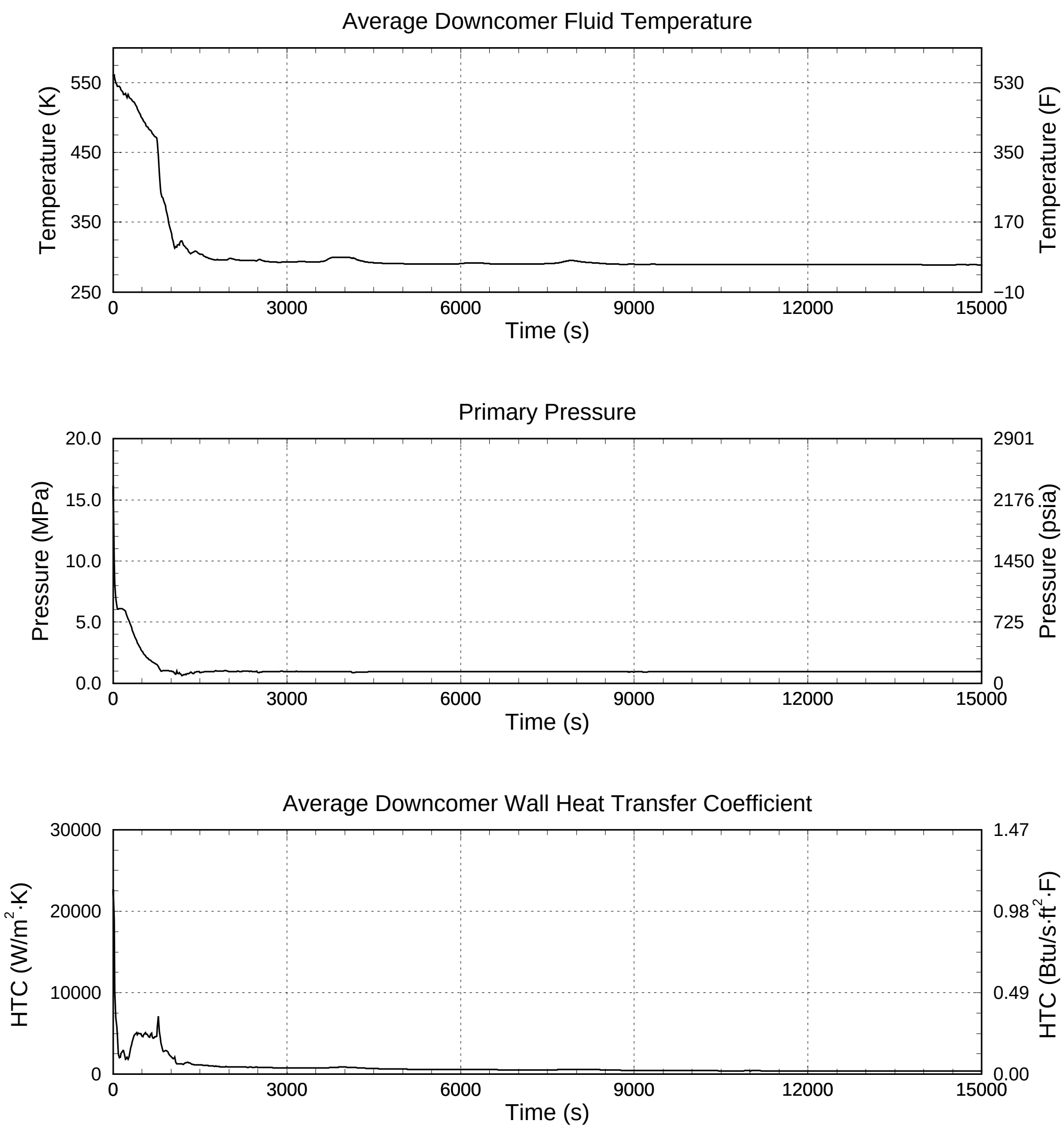


Figure A-6 Calvert Cliffs PTS Results for Case 006

Case Category	LOCA
Primary Failures	20.32 cm [8.0 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.0 K [60.5EF] at 13,170 s
Comments	None.

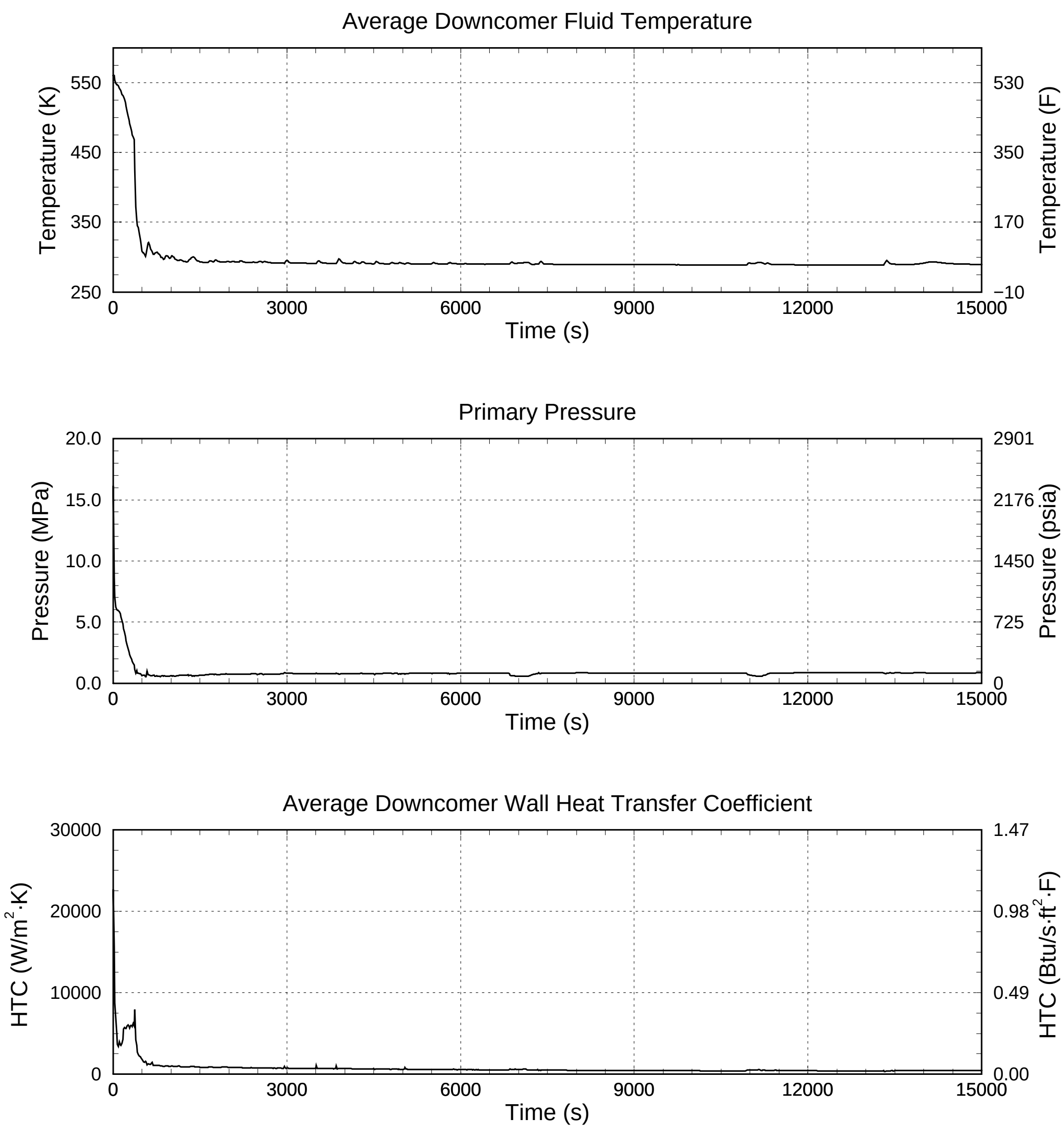


Figure A-7   Calvert Cliffs PTS Results for Case 007

Case Category	LOCA
Primary Failures	28.74 cm [11.314 in] hot leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.4 K [63.1EF] at 2,520 s
Comments	Includes sump recirculation.

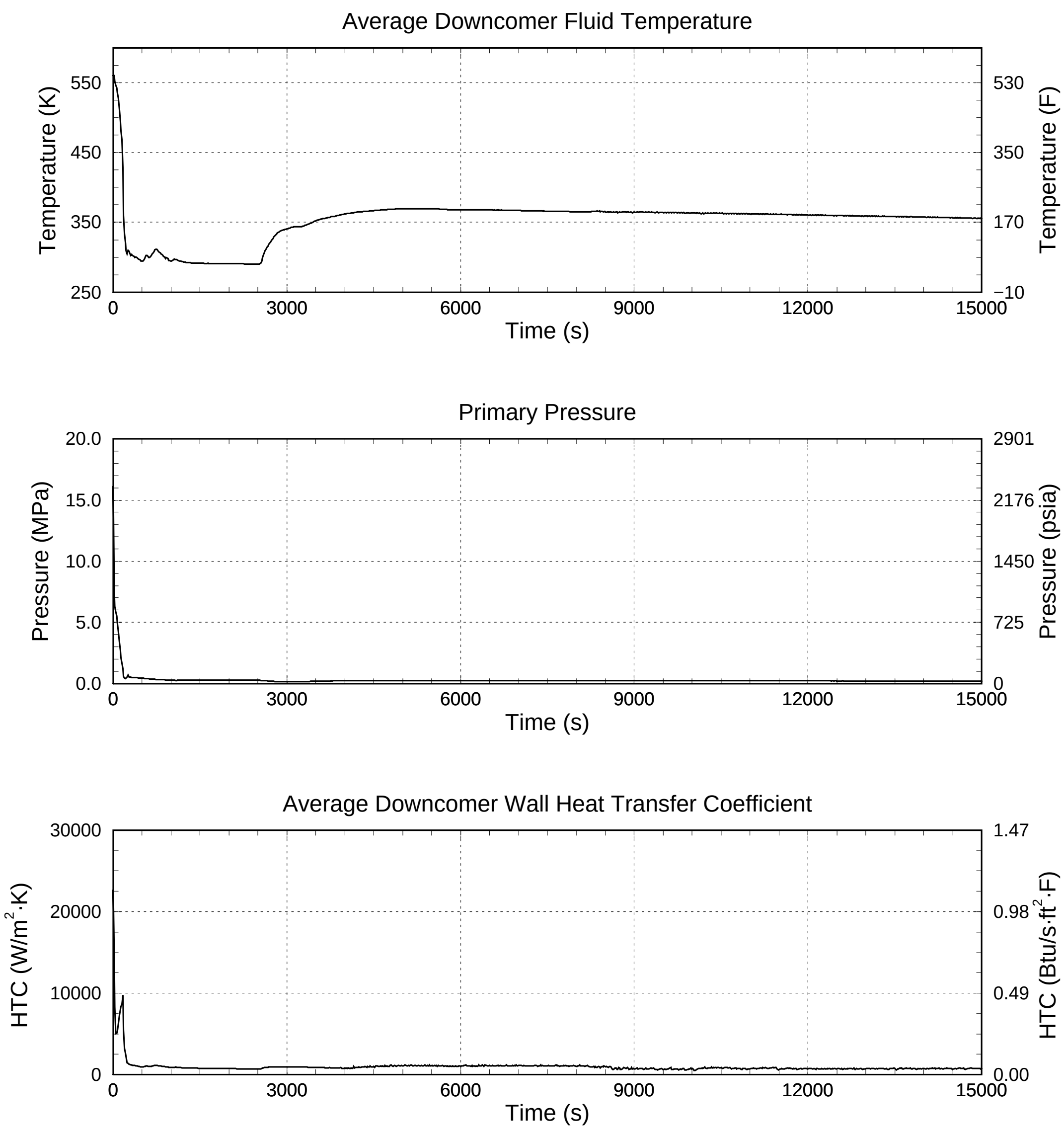


Figure A-8 Calvert Cliffs PTS Results for Case 008

Case Category	LOCA
Primary Failures	40.64 cm [16.0 in] hot leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.5 K [63.2EF] at 1,950 s
Comments	Includes sump recirculation.

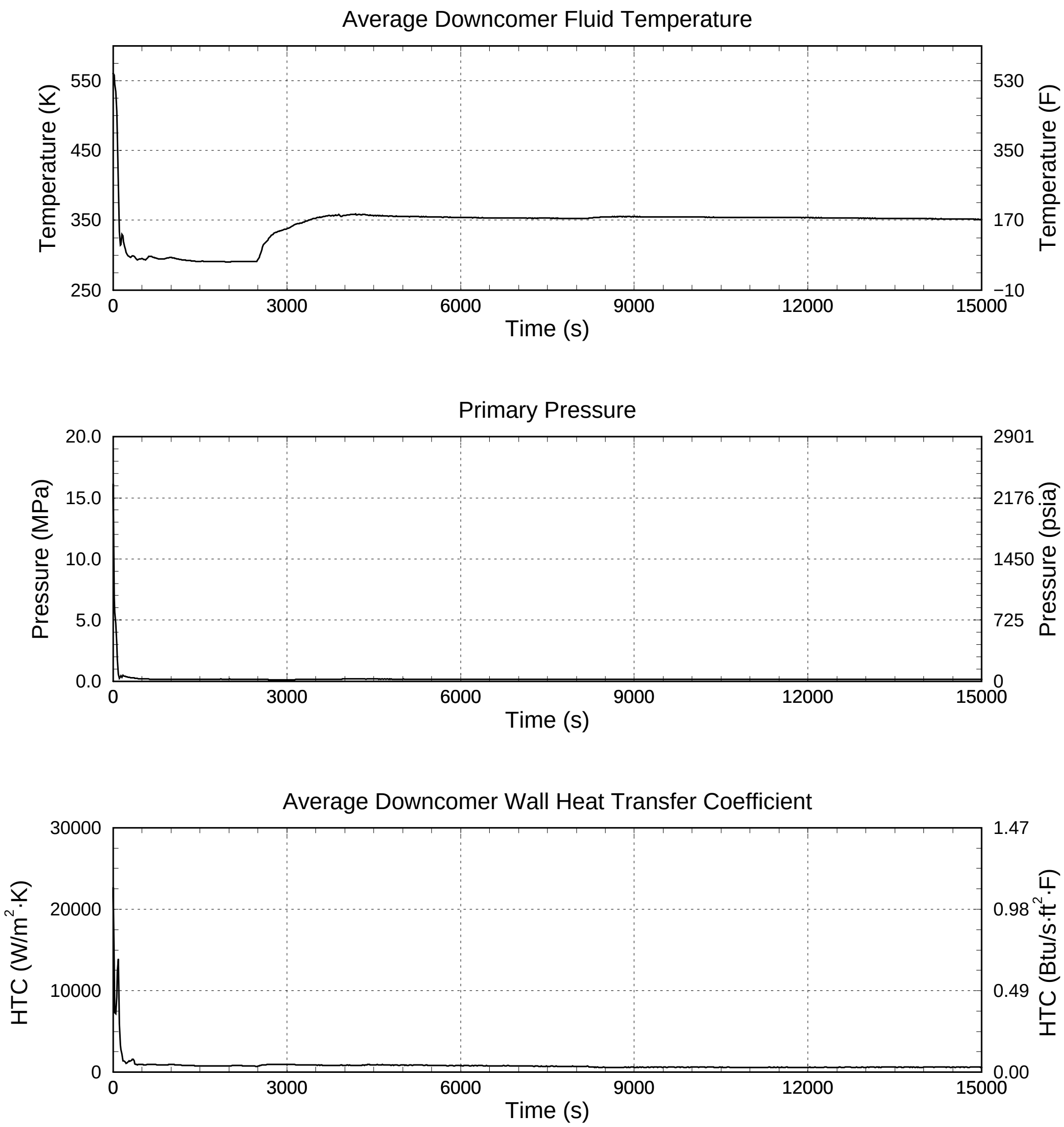


Figure A-9 Calvert Cliffs PTS Results for Case 009

Case Category	LOCA
Primary Failures	57.47 cm [22.627 in] hot leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.2 K [62.7EF] at 2,340 s
Comments	Includes sump recirculation.

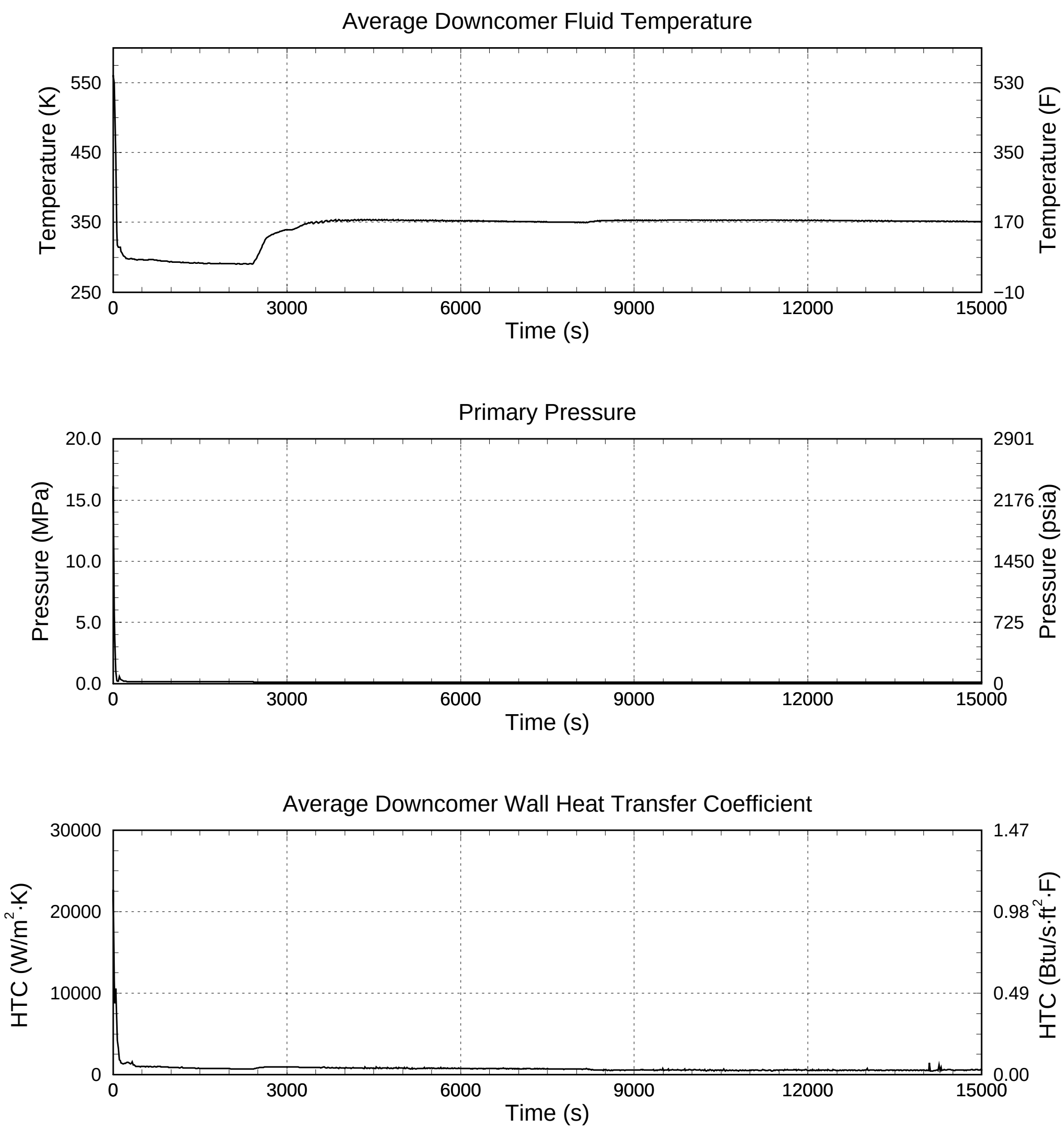
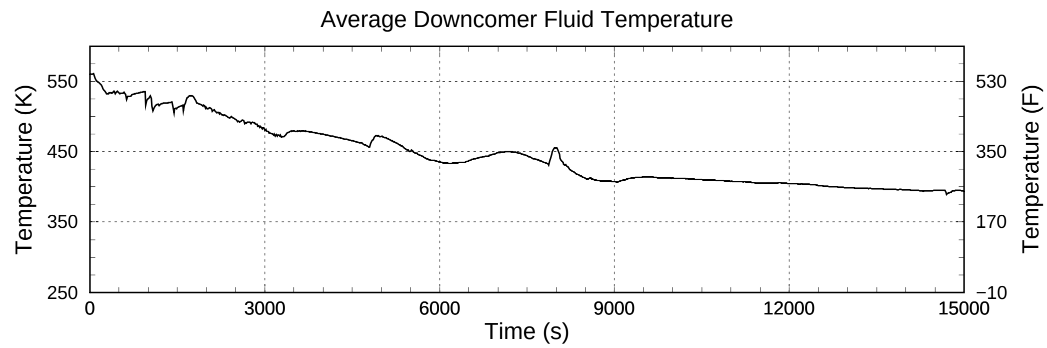
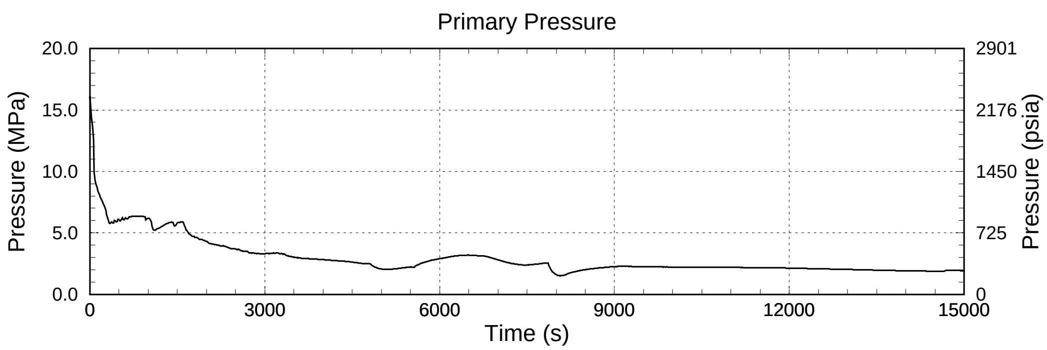


Figure A-10 Calvert Cliffs PTS Results for Case 010

Case Category	LOCA
Primary Failures	5.08 cm [2.0 in] cold leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	389.4 K [241.2EF] at 14,700 s
Comments	None.





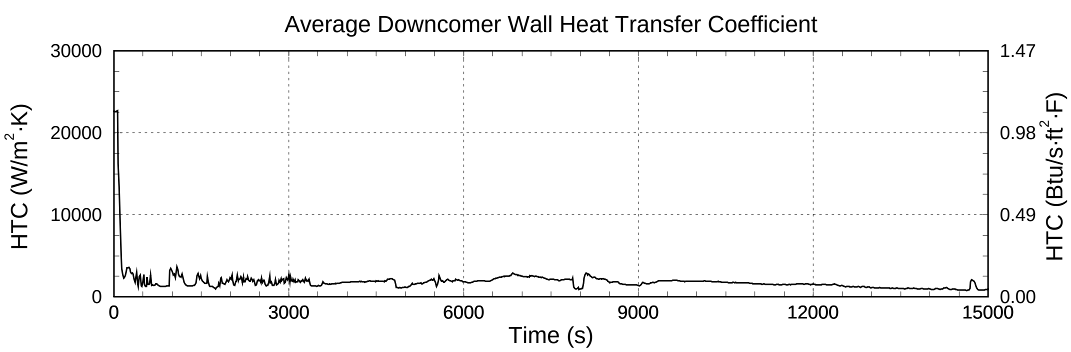


Figure A-11 Calvert Cliffs PTS Results for Case 011

Case Category	LOCA
Primary Failures	40.64 cm [16.0 in] cold leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	312.5 K [102.9EF] at 2,460 s
Comments	Includes sump recirculation.

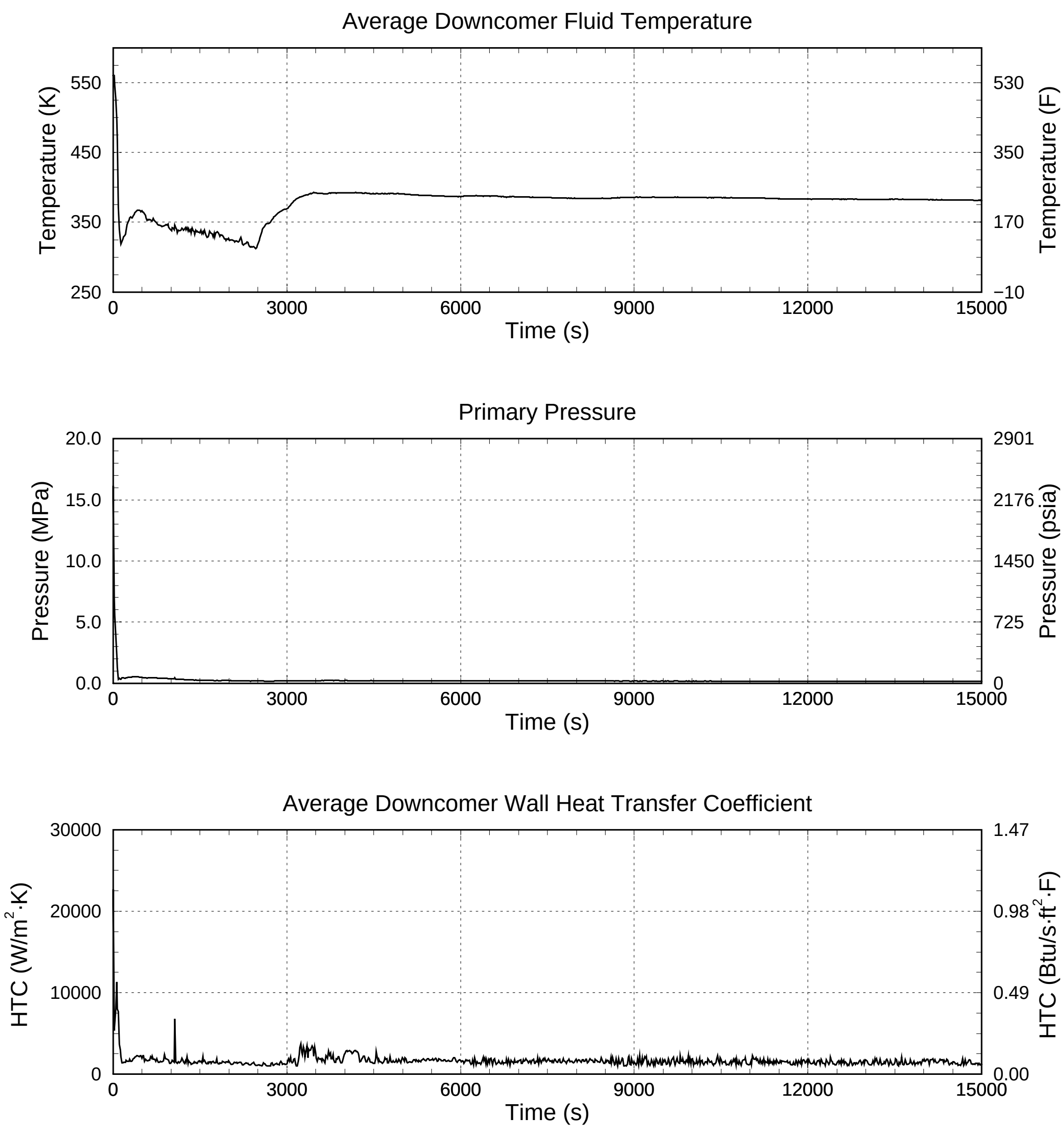


Figure A-12 Calvert Cliffs PTS Results for Case 012

Case Category	RT/TT
Primary Failures	One stuck open pressurizer PORV.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	453.0 K [355.7EF] at 15,000 s
Comments	None.

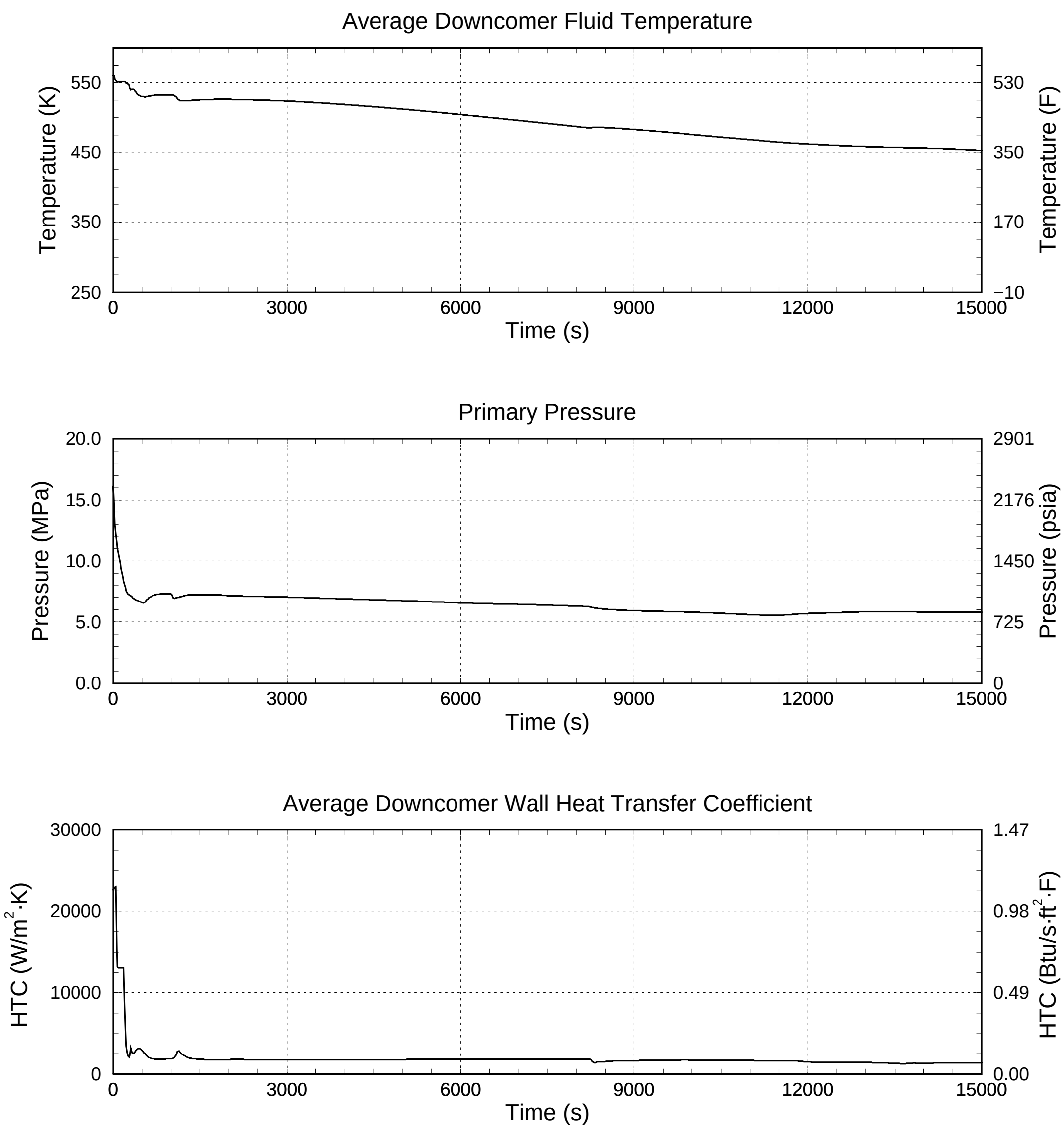


Figure A-13   Calvert Cliffs PTS Results for Case 013

Case Category	RT/TT
Primary Failures	One stuck open pressurizer PORV.
Secondary Failures	None.
Operator Actions	Operator isolates PORV after 20 minutes.
Min DC Temperature	523.9 K [483.4EF] at 1,200 s
Comments	None.

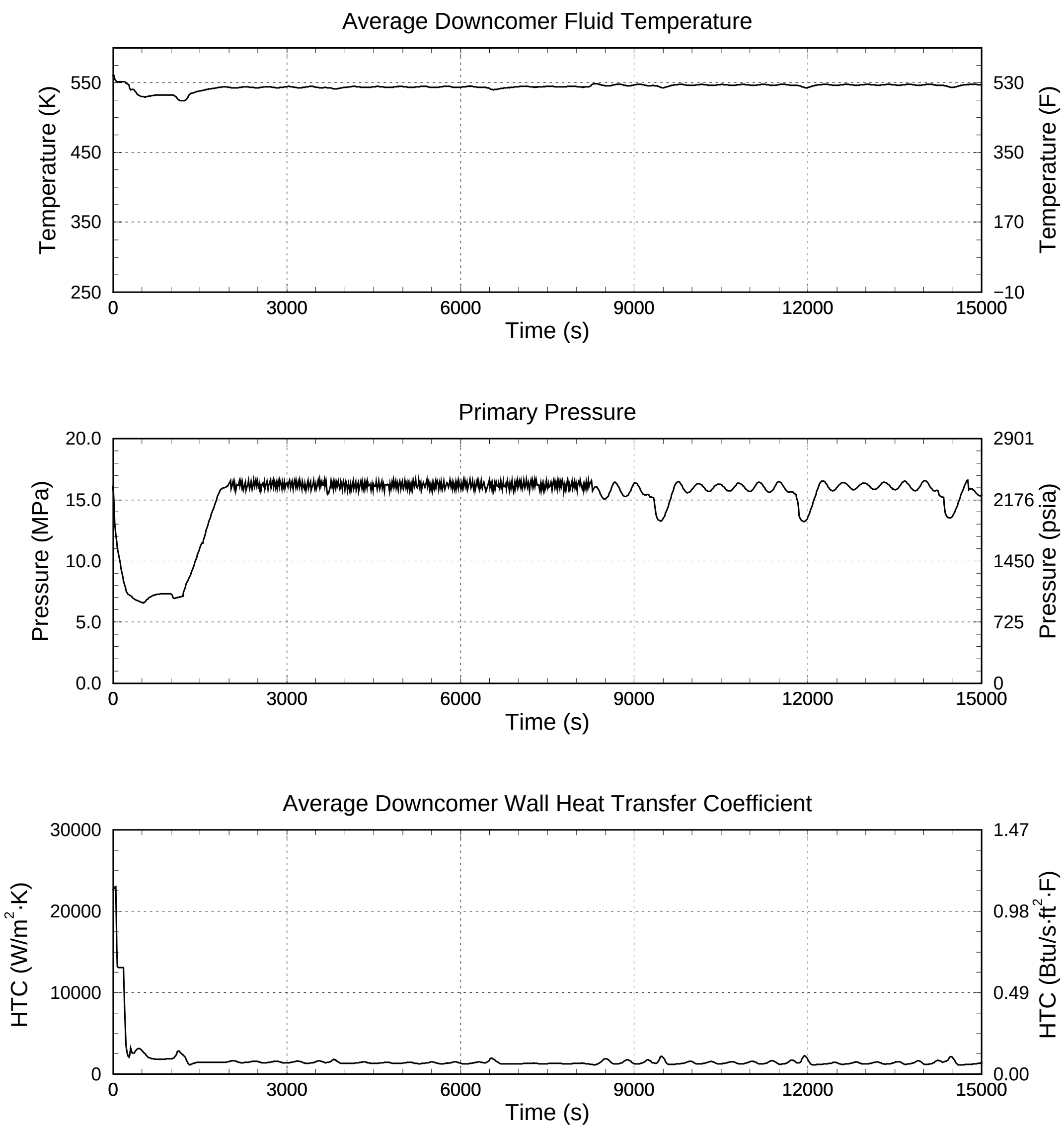


Figure A-14 Calvert Cliffs PTS Results for Case 014

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	395.5 K [252.2EF] at 15,000 s
Comments	None.

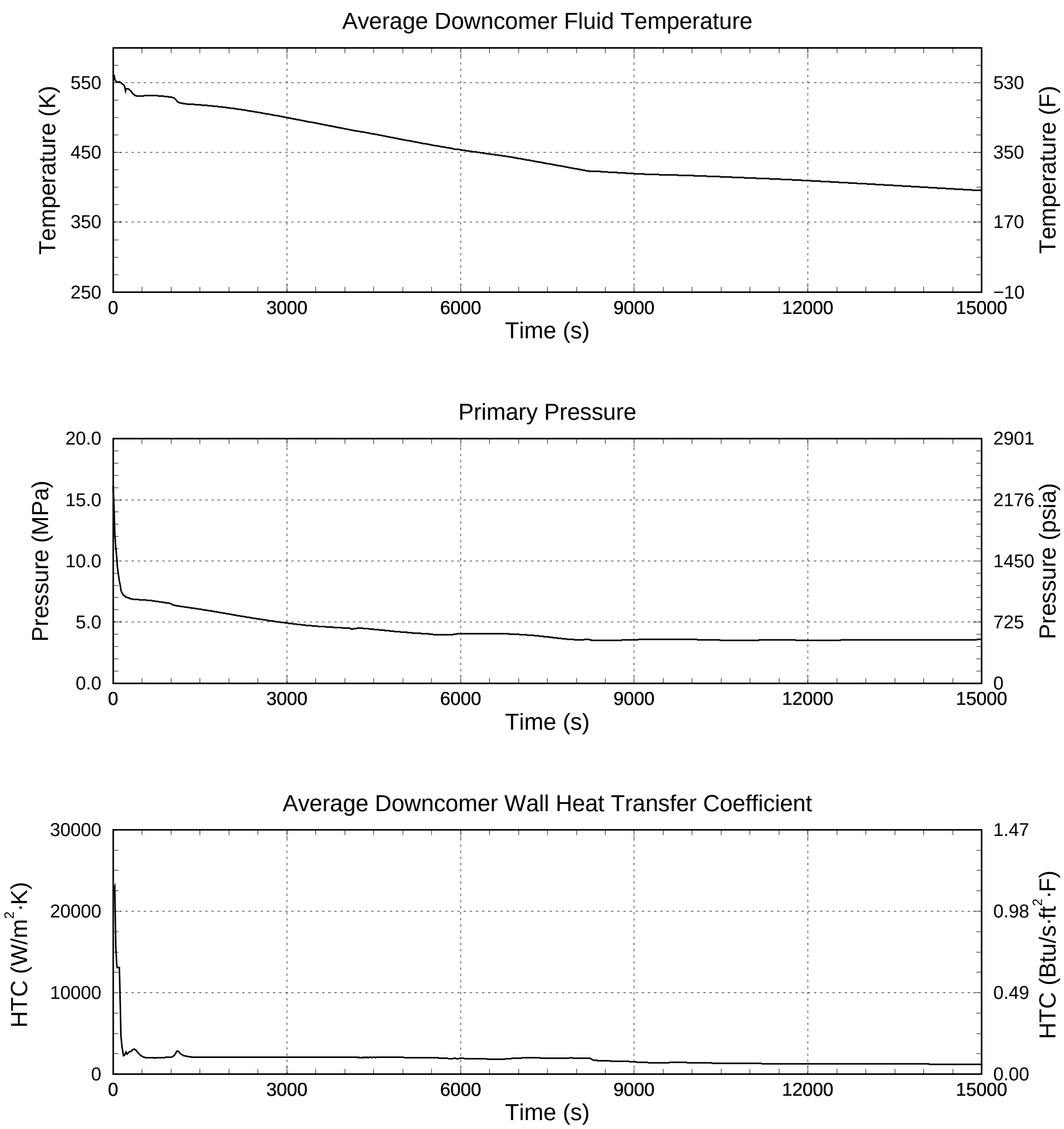


Figure A-15 Calvert Cliffs PTS Results for Case 015

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open TBV.
Operator Actions	None.
Min DC Temperature	534.2 K [501.9EF] at 345 s
Comments	None.

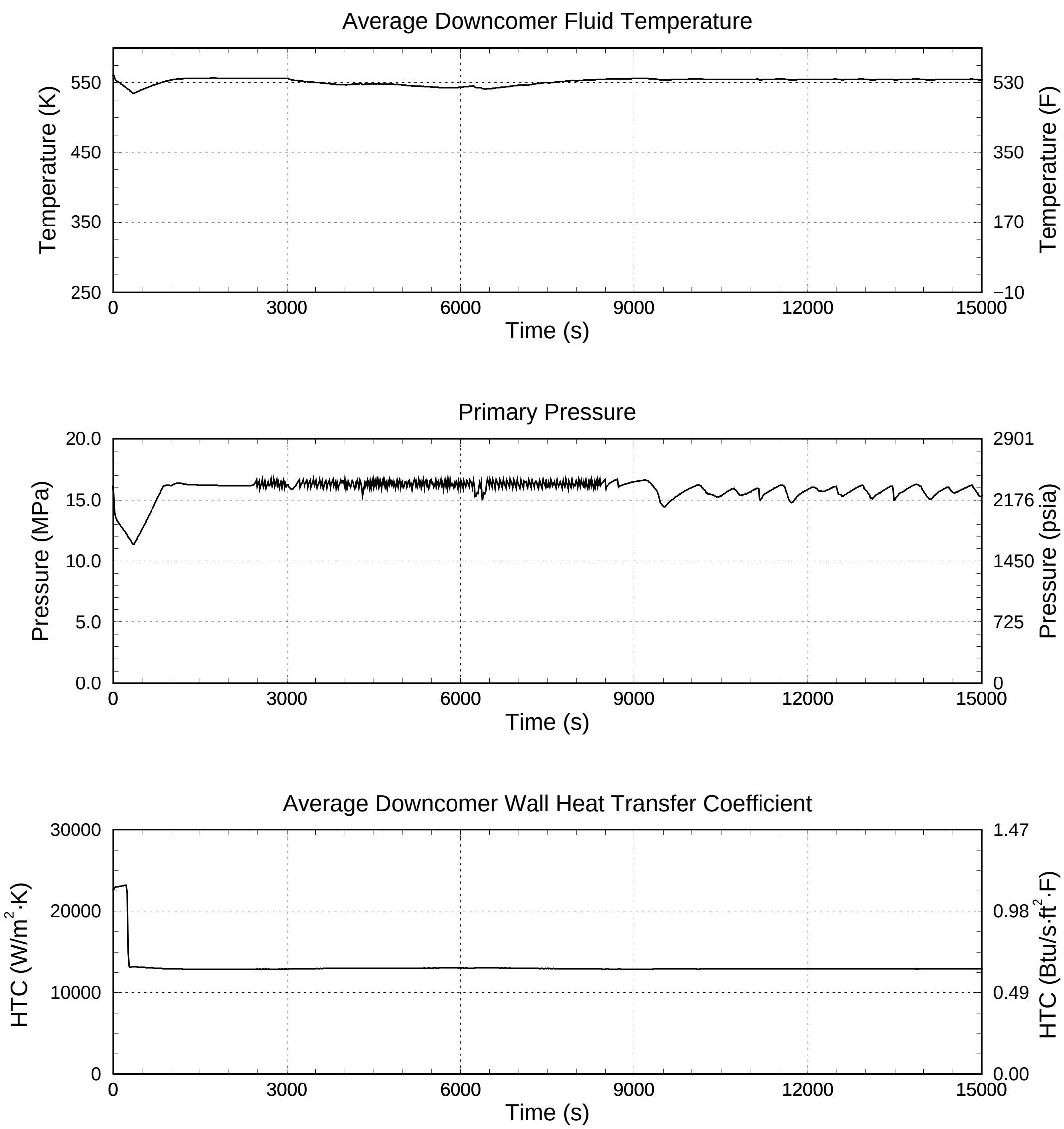


Figure A-16 Calvert Cliffs PTS Results for Case 016

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	Two stuck open TBVs.
Operator Actions	None.
Min DC Temperature	534.4 K [502.3EF] at 180 s
Comments	None.

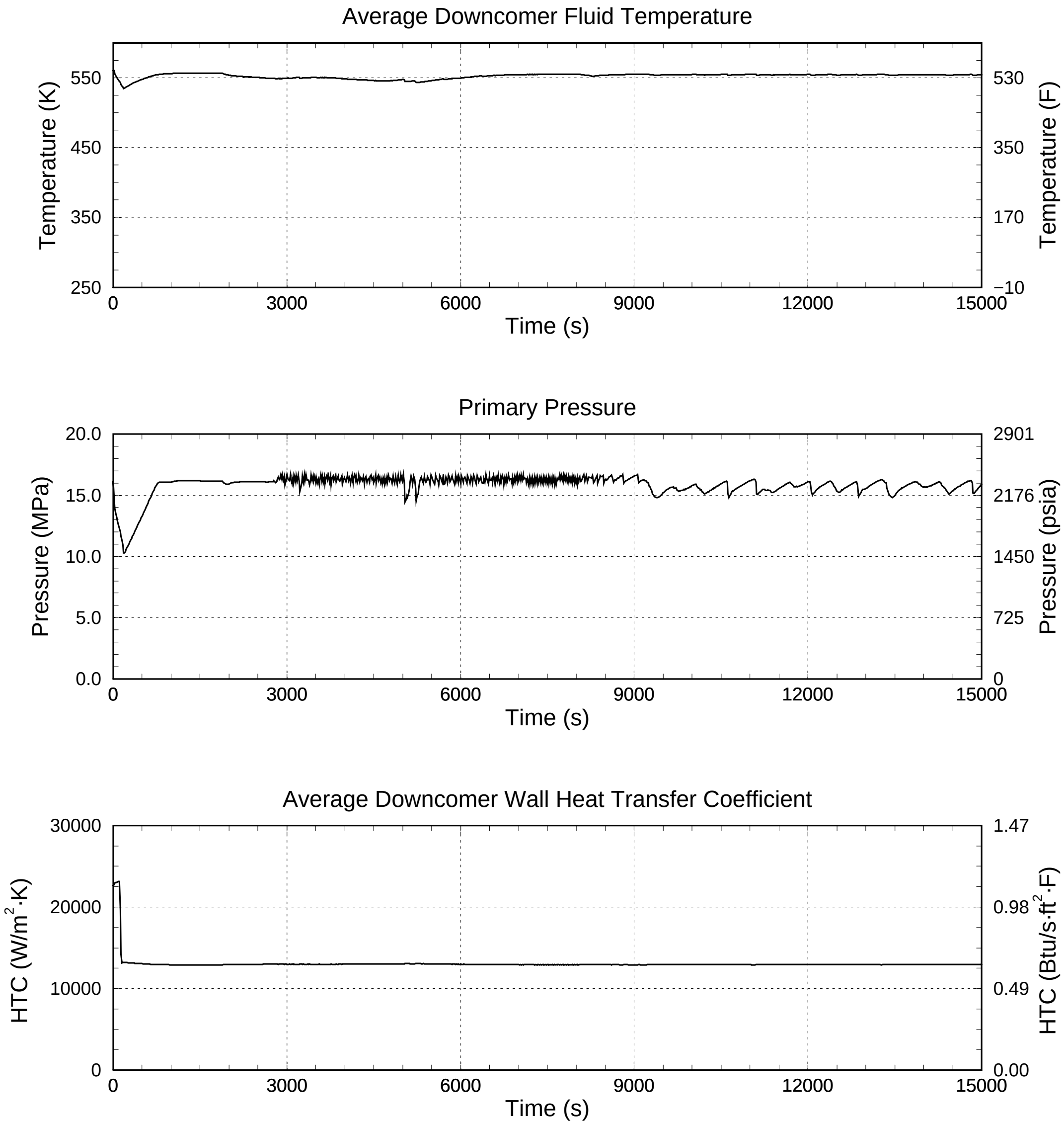


Figure A-17 Calvert Cliffs PTS Results for Case 017

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	Three stuck open TBVs.
Operator Actions	None.
Min DC Temperature	534.5 K [502.4EF] at 135 s
Comments	None.

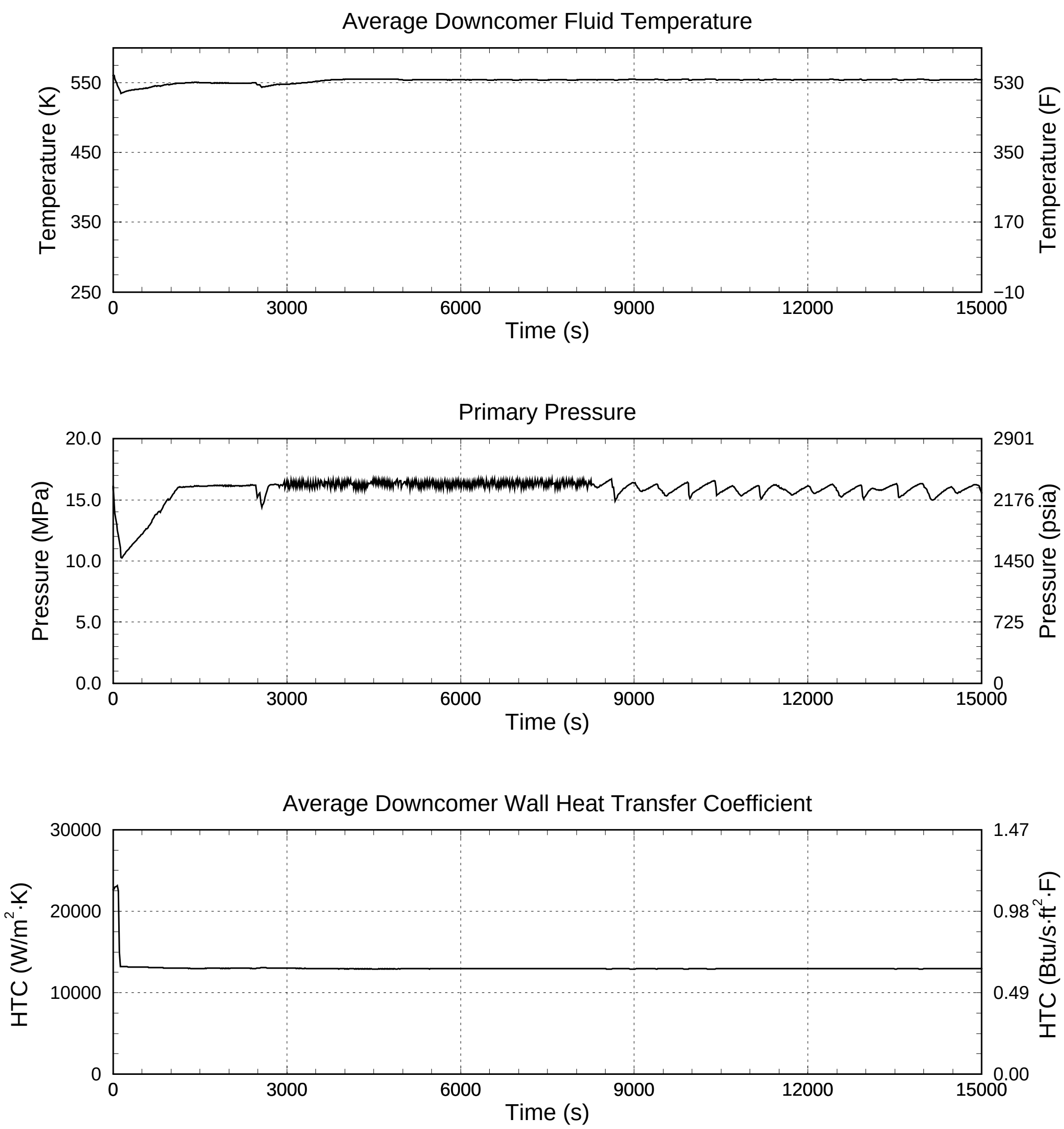


Figure A-18 Calvert Cliffs PTS Results for Case 018

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open ADV.
Operator Actions	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.
Min DC Temperature	530.8 K [495.7EF] at 7,680 s
Comments	None.

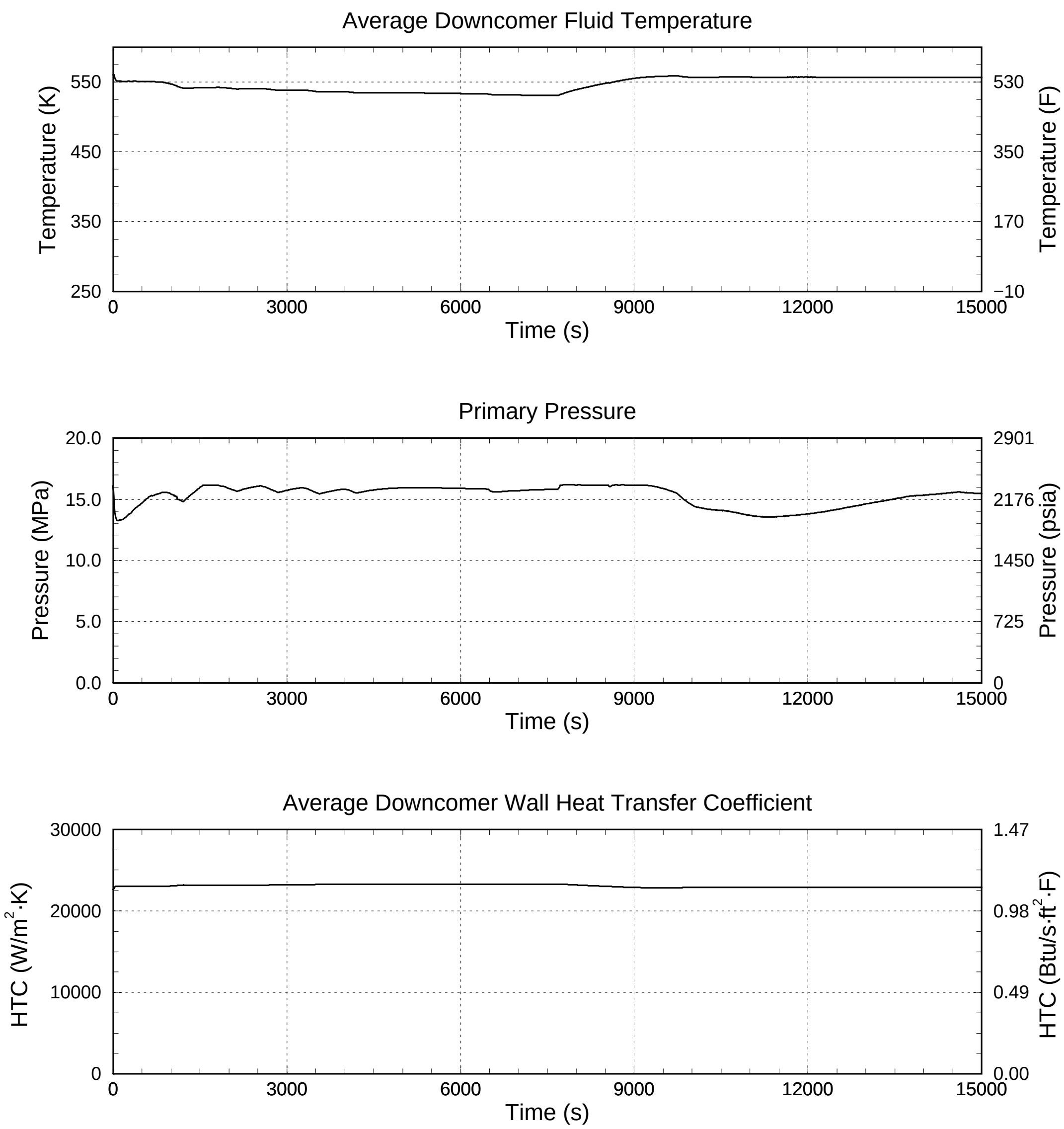
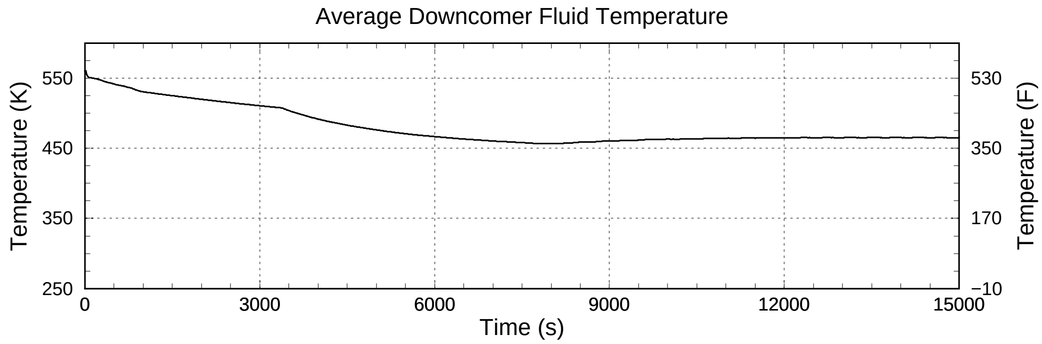
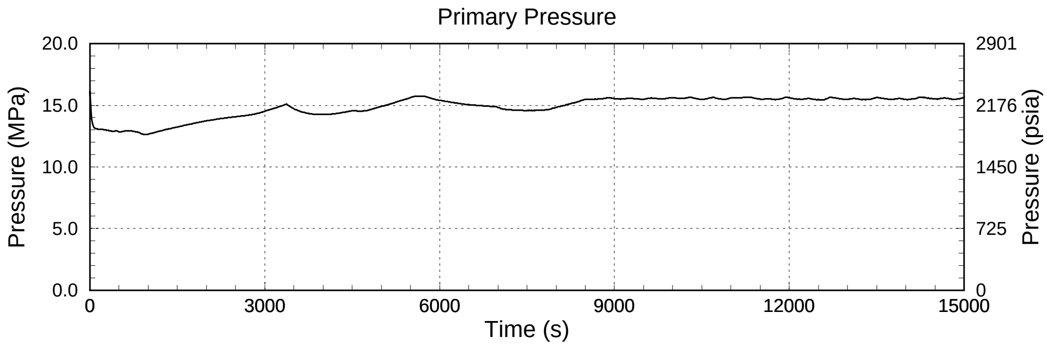


Figure A-19   Calvert Cliffs PTS Results for Case 019

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	Two stuck open ADVs.
Operator Actions	None.
Min DC Temperature	456.4 K [361.9EF] at 7,875 s
Comments	None.





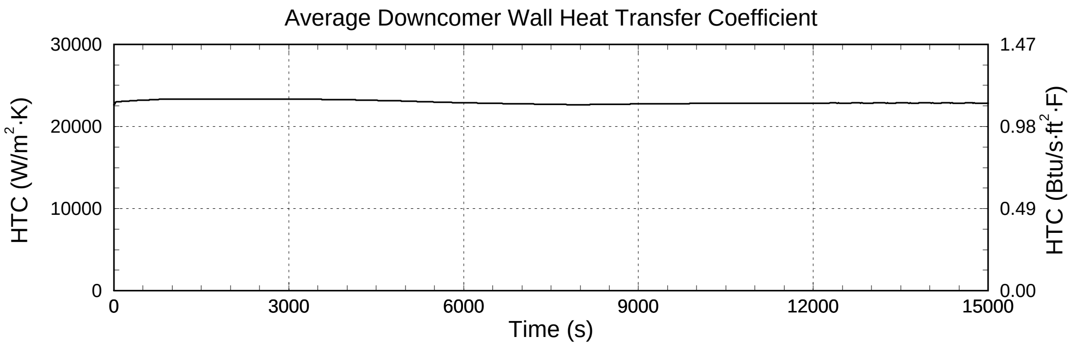


Figure A-20 Calvert Cliffs PTS Results for Case 020

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None.
Min DC Temperature	523.6 K [482.9EF] at 7,815 s
Comments	None.

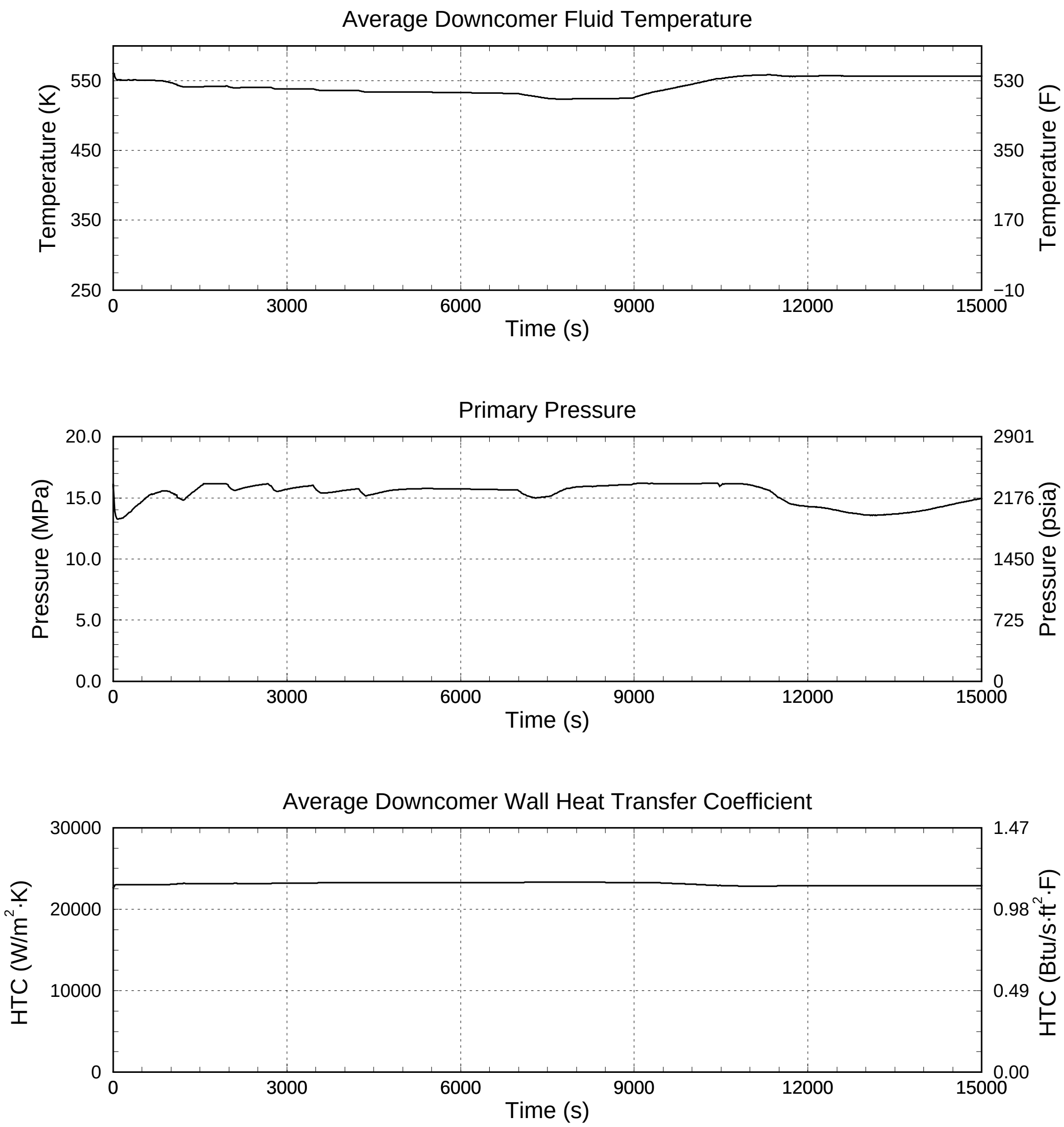
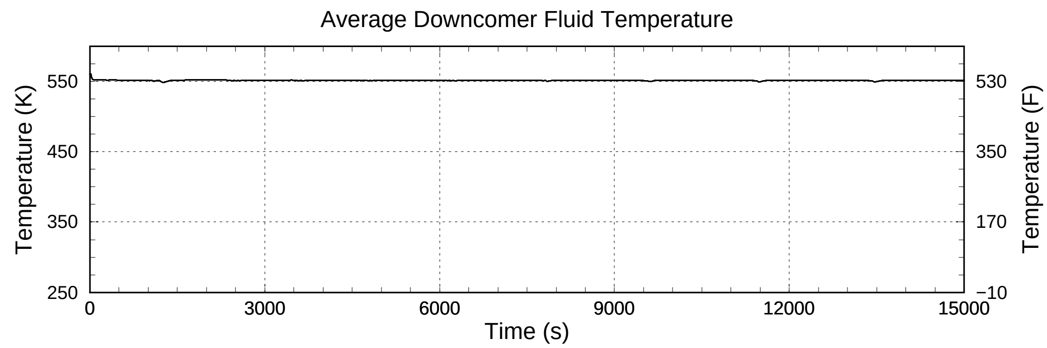
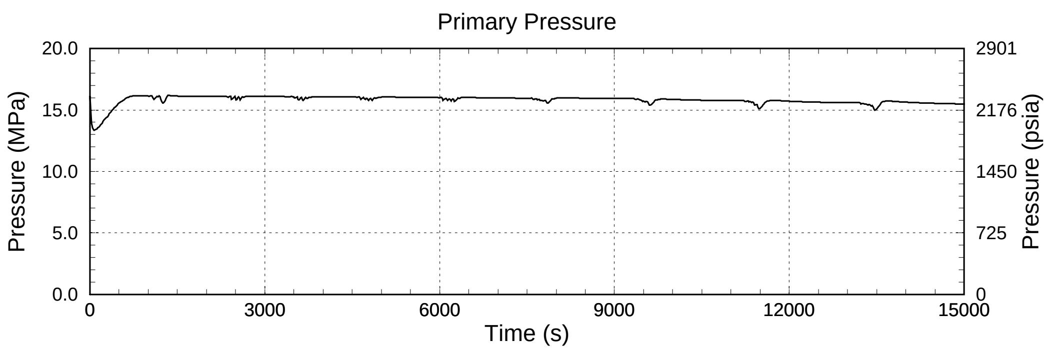


Figure A-21 Calvert Cliffs PTS Results for Case 021

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	None
Operator Actions	None.
Min DC Temperature	548.2 K [527.0EF] at 1,260 s
Comments	No concurrent failures.





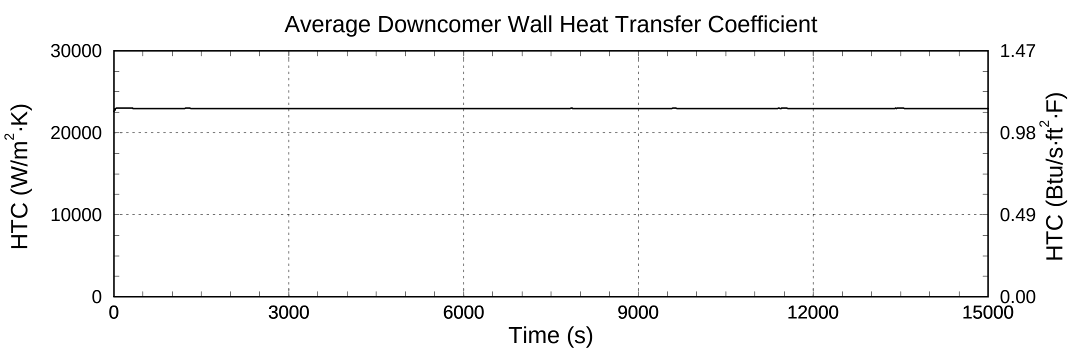


Figure A-22 Calvert Cliffs PTS Results for Case 022

Case Category	RT/TT
Primary Failures	One stuck open pressurizer PORV.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None.
Min DC Temperature	391.7 K [245.4EF] at 15,000 s
Comments	None.

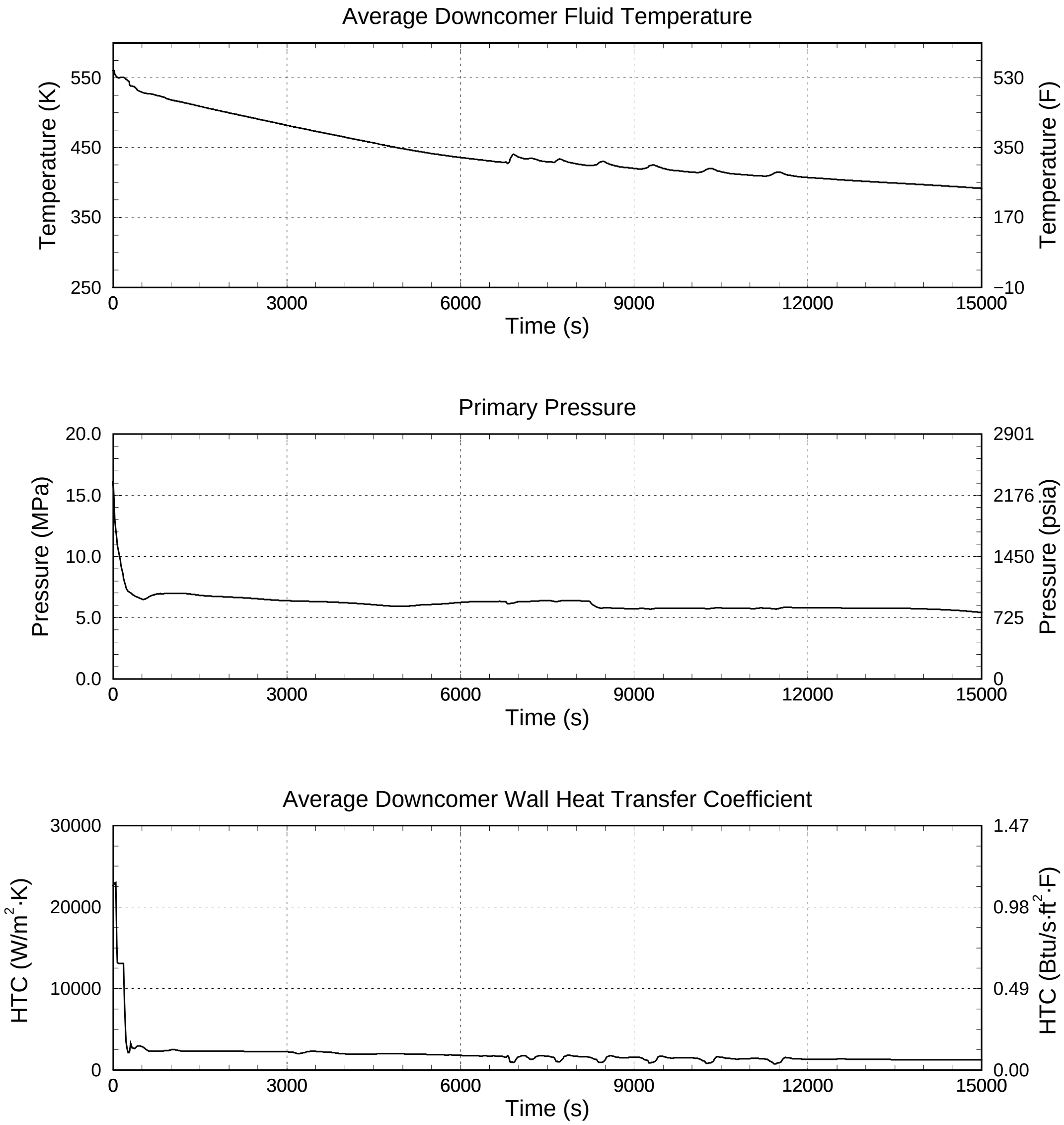
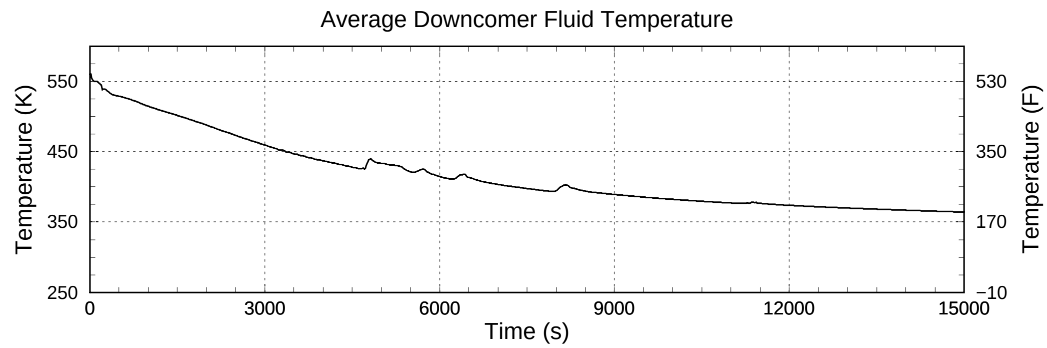
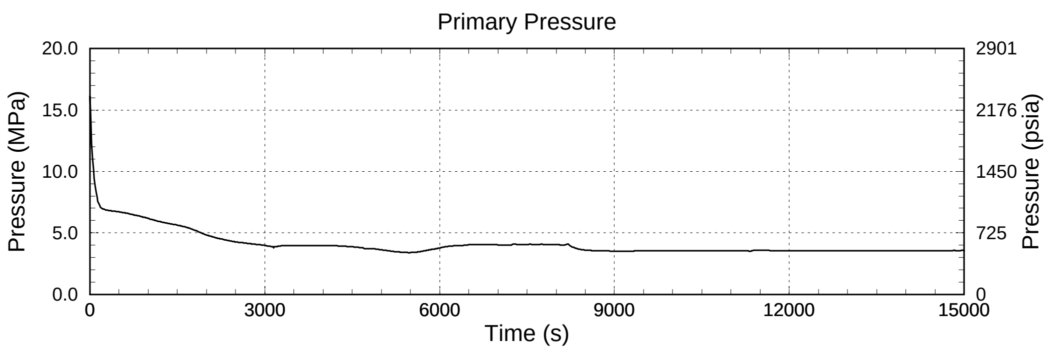


Figure A-23 Calvert Cliffs PTS Results for Case 023

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None.
Min DC Temperature	364.2 K [195.9EF] at 15,000 s
Comments	None.





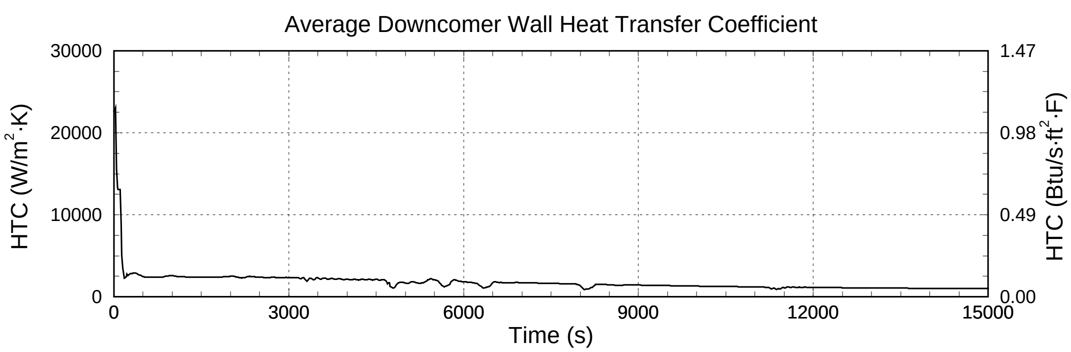


Figure A-24 Calvert Cliffs PTS Results for Case 024

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open main steam SRV.
Operator Actions	None.
Min DC Temperature	510.5 K [459.3EF] at 2,370 s
Comments	None.

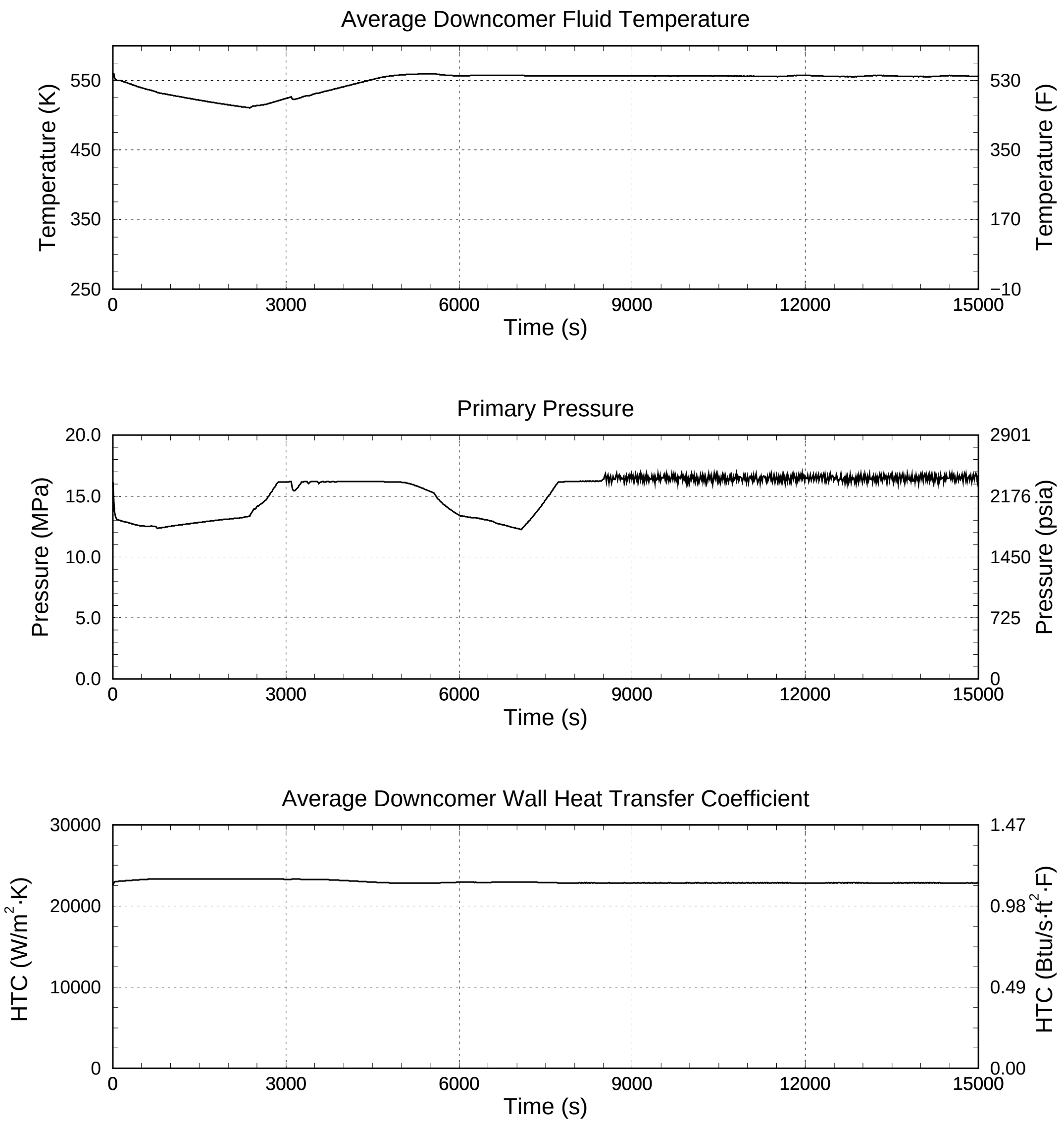


Figure A-25 Calvert Cliffs PTS Results for Case 025

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	Two stuck open main steam SRVs (one in each steam generator).
Operator Actions	None.
Min DC Temperature	421.3 K [298.7EF] at 6,090 s
Comments	None.

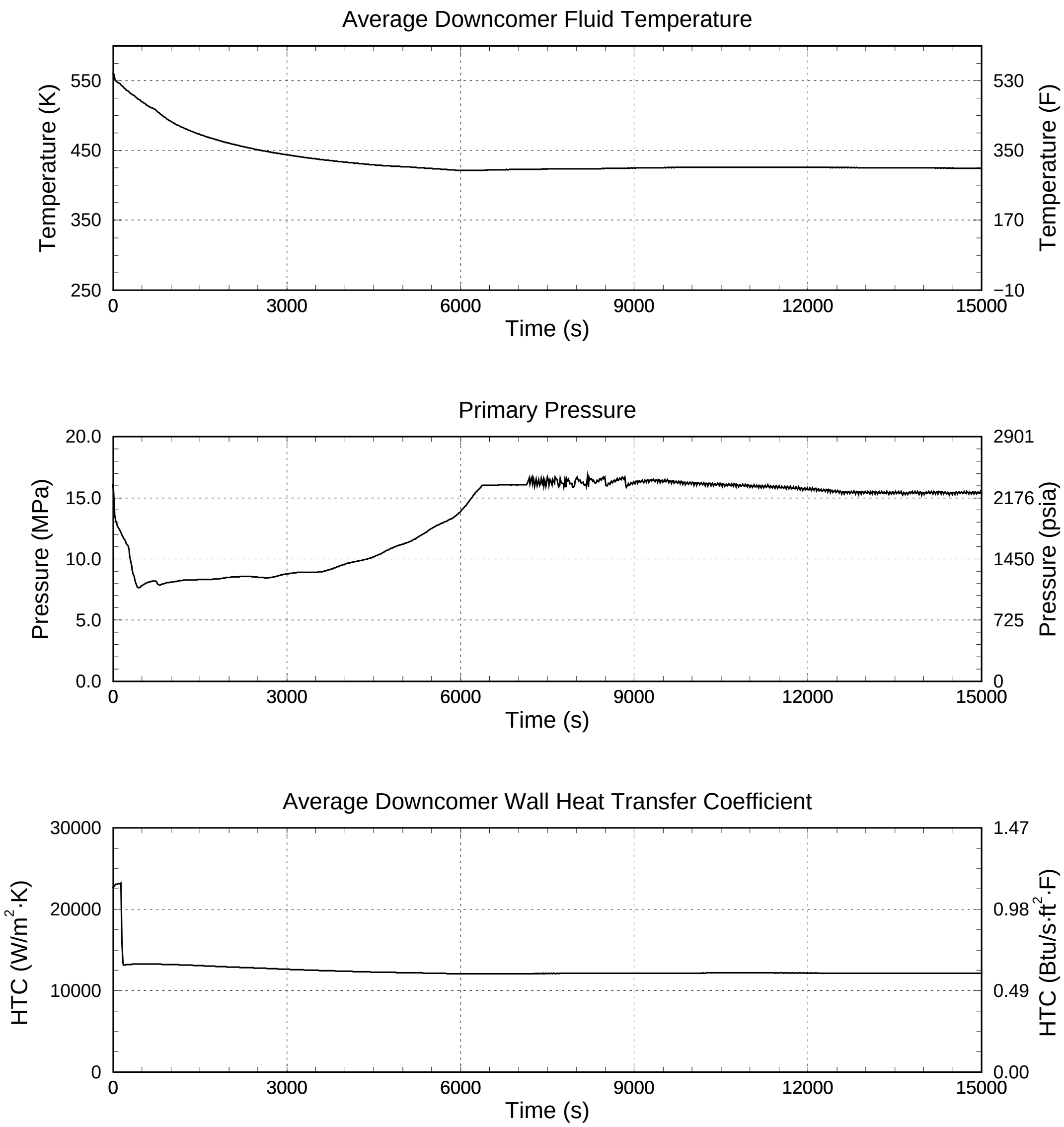


Figure A-26 Calvert Cliffs PTS Results for Case 026

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	MFW overfills SG-1.
Operator Actions	Operator trips main feedwater when water enters the steam line.
Min DC Temperature	543.6 K [518.8EF] at 150 s
Comments	None.

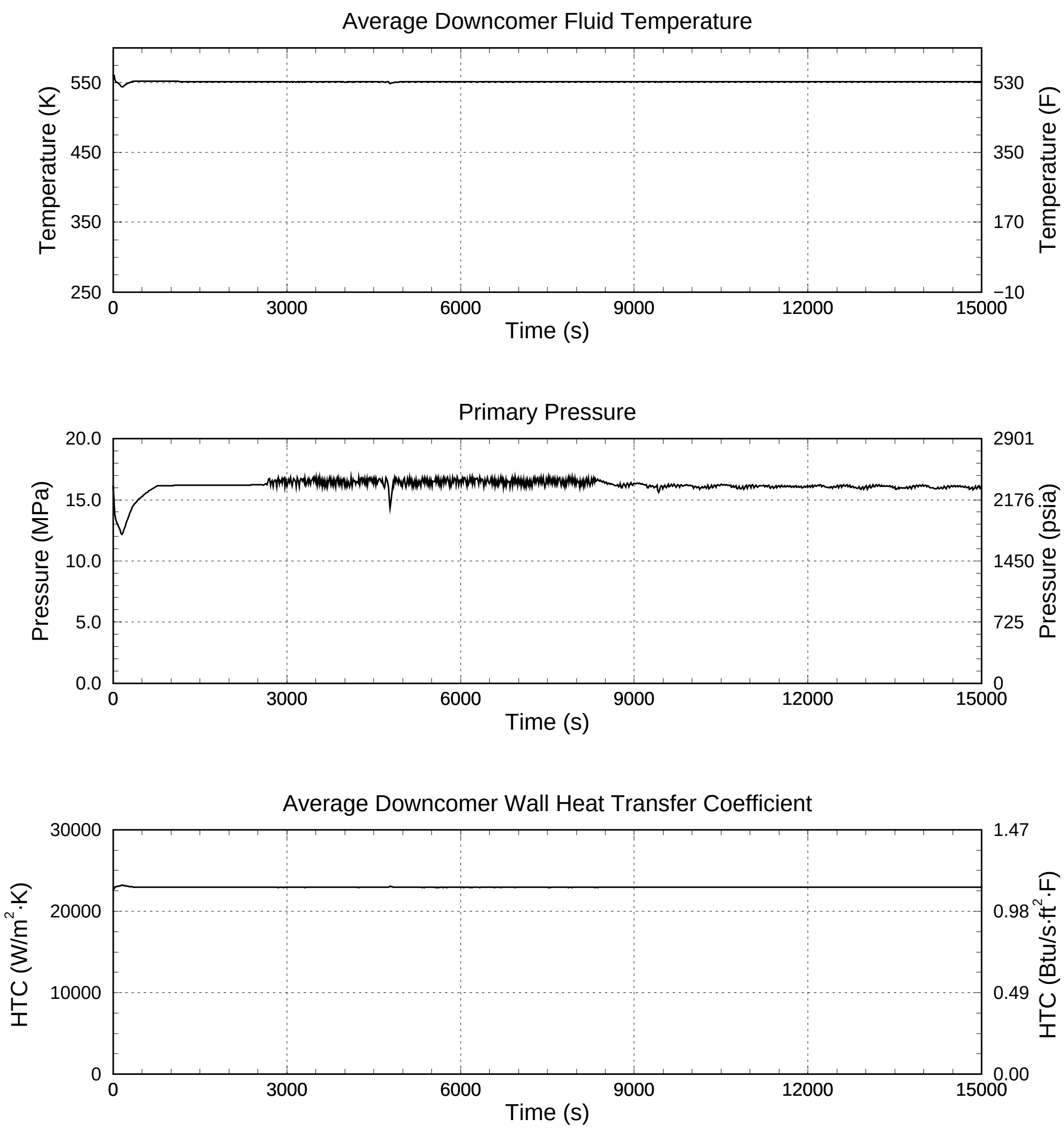
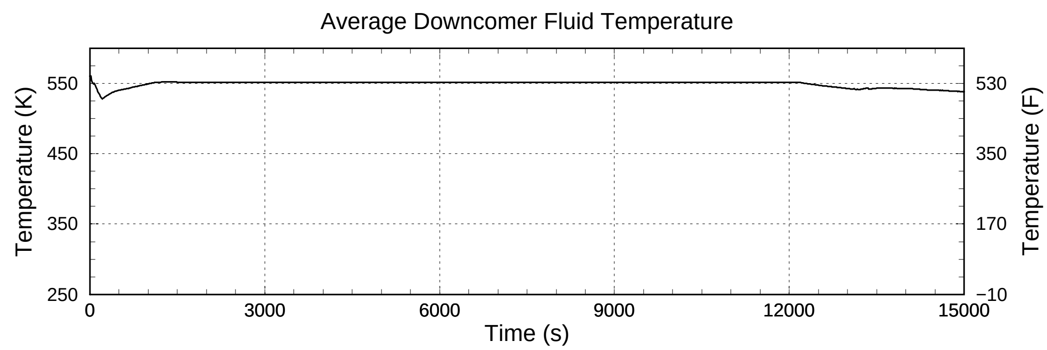
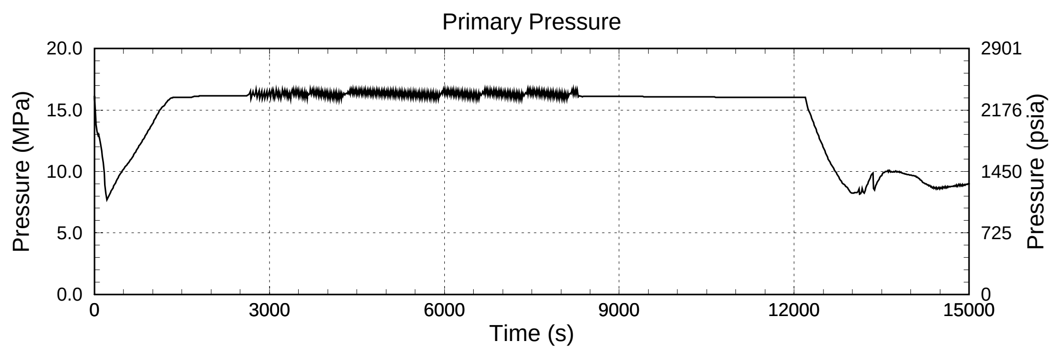


Figure A-27 Calvert Cliffs PTS Results for Case 027

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	MFW overfills both SGs.
Operator Actions	Operator trips main feedwater when water enters the steam line.
Min DC Temperature	528.2 K [491.0EF] at 210 s
Comments	None.





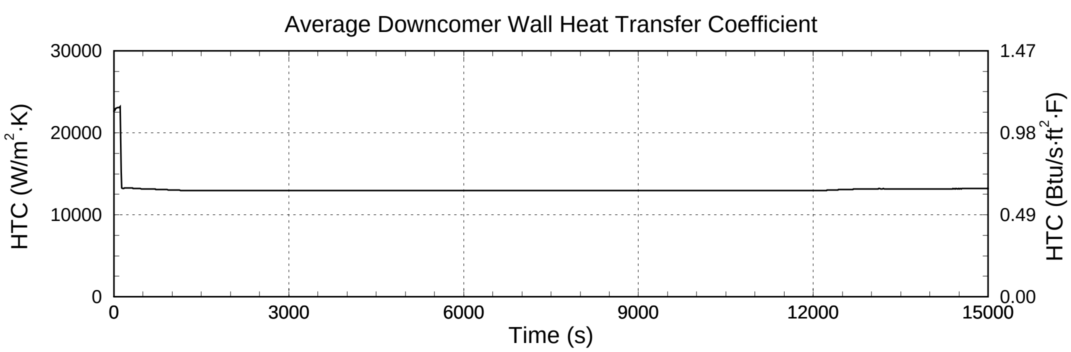
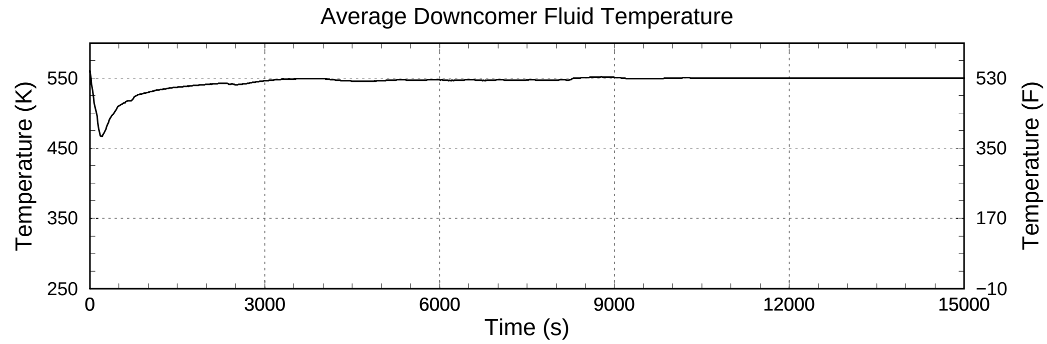
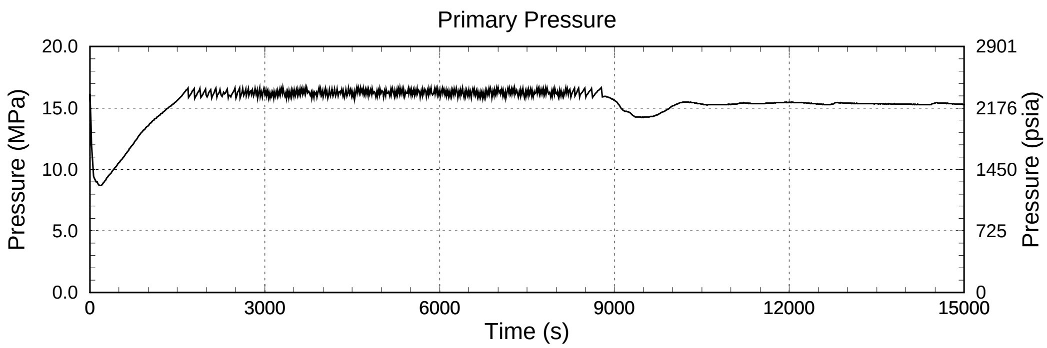


Figure A-28 Calvert Cliffs PTS Results for Case 028

Case Category	MSLB
Primary Failures	None.
Secondary Failures	Main Steam Line Break (double ended guillotine break).
Operator Actions	None.
Min DC Temperature	466.7 K [380.4EF] at 195 s
Comments	None.





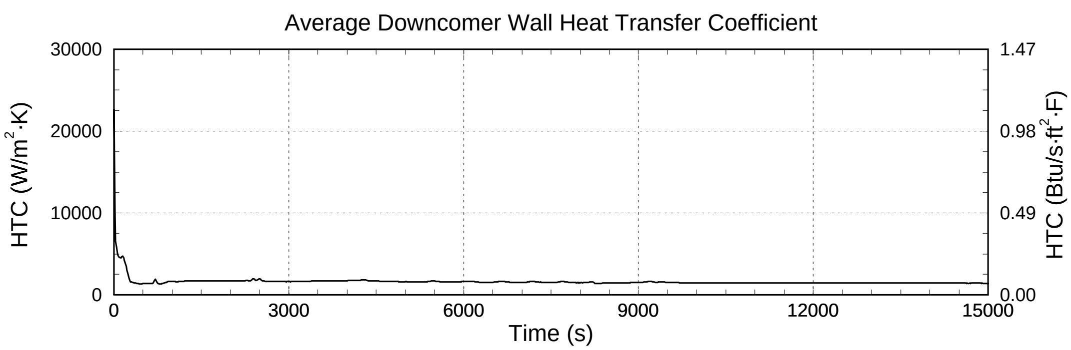
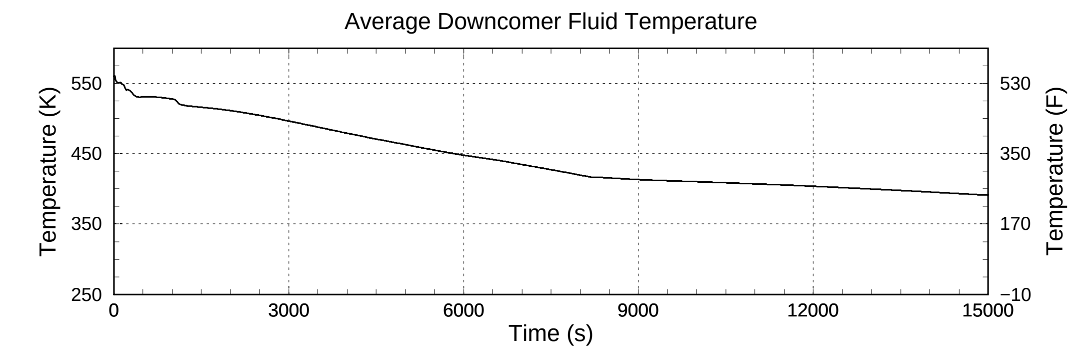
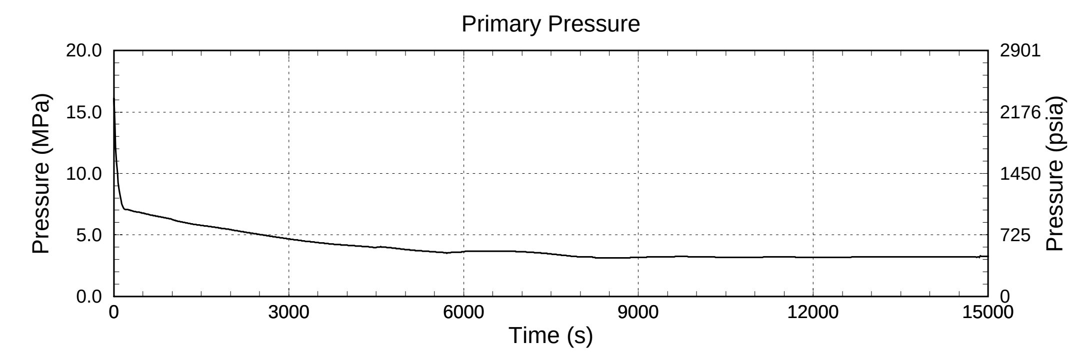


Figure A-29 Calvert Cliffs PTS Results for Case 029

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer PORVs.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	391.1 K [244.3EF] at 15,000 s
Comments	None.





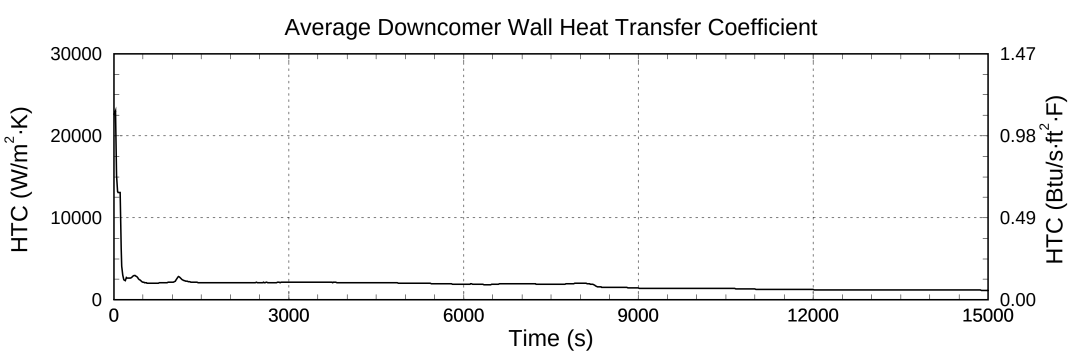


Figure A-30 Calvert Cliffs PTS Results for Case 030

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	314.8 K [106.9EF] at 12,000 s
Comments	None.

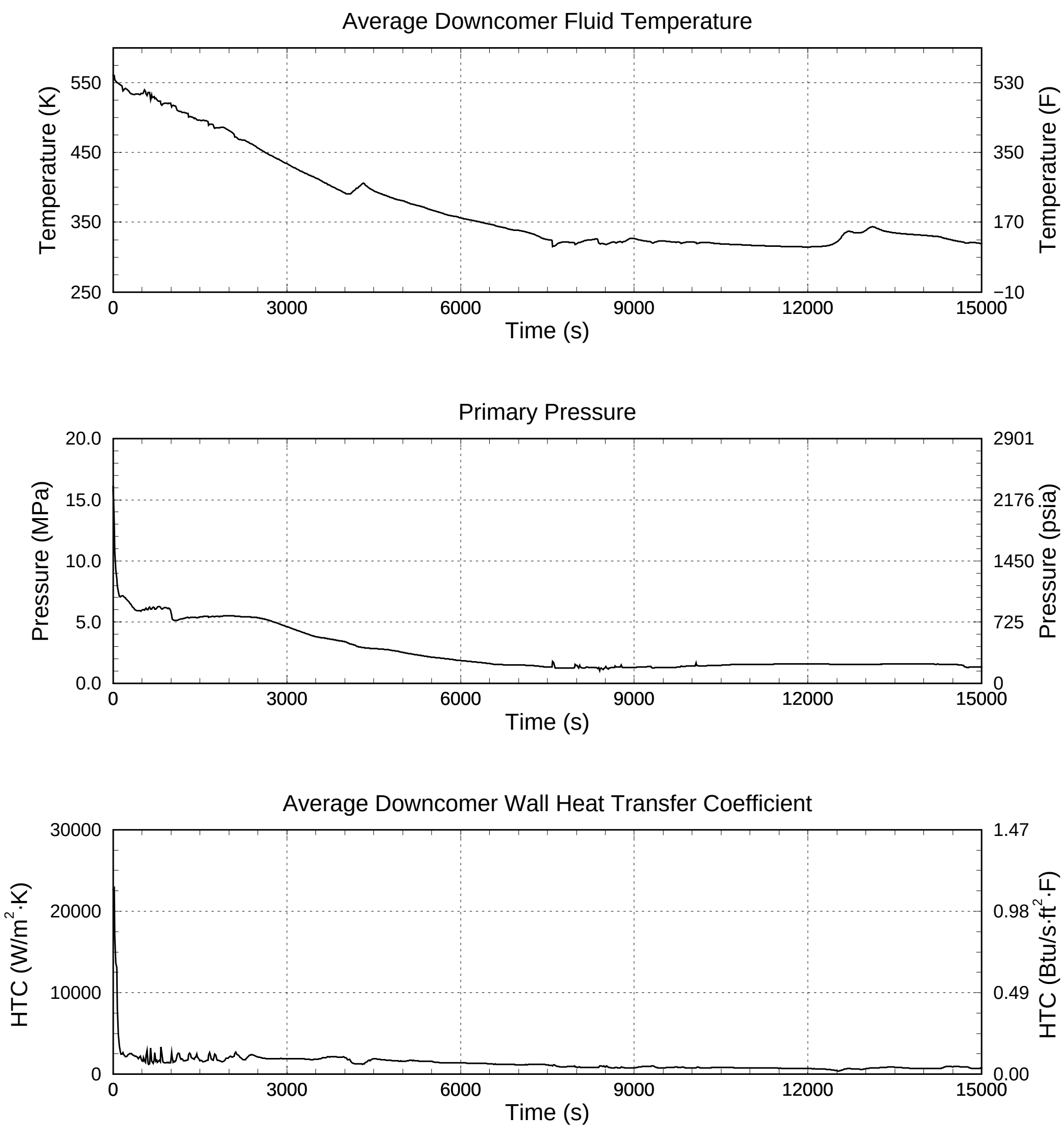
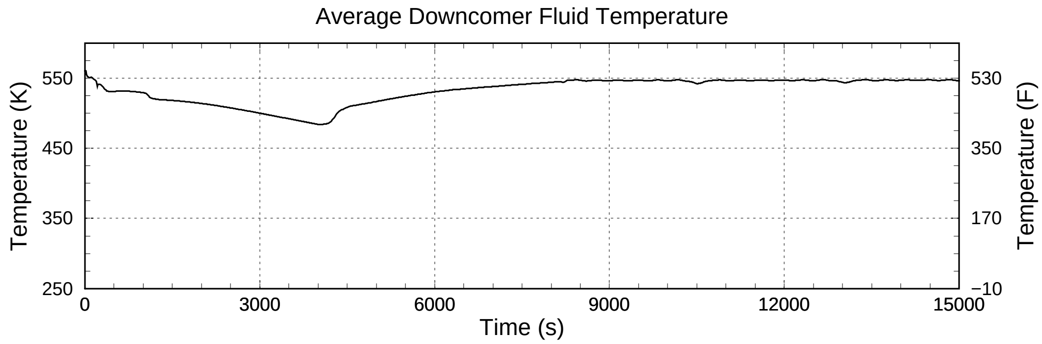
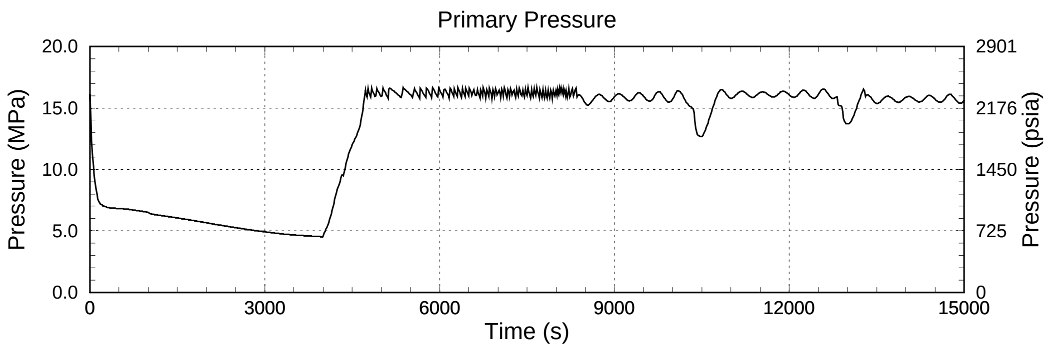


Figure A-31 Calvert Cliffs PTS Results for Case 031

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV which recloses at 4,000 s.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	483.5 K [410.7EF] at 4,050 s
Comments	None.





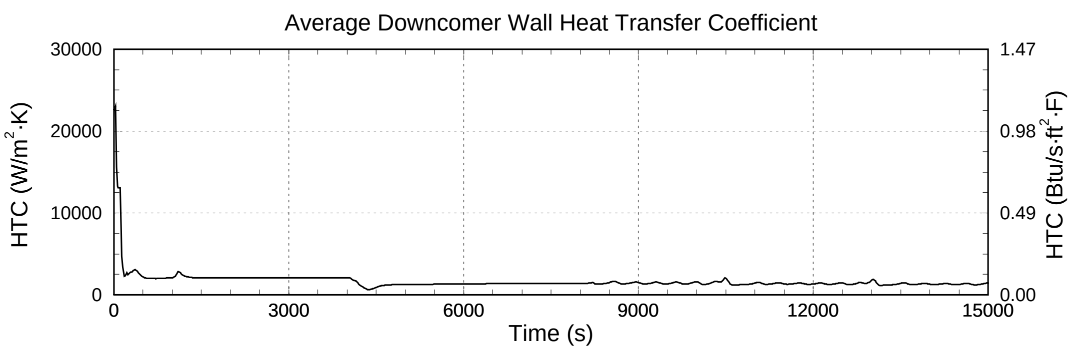
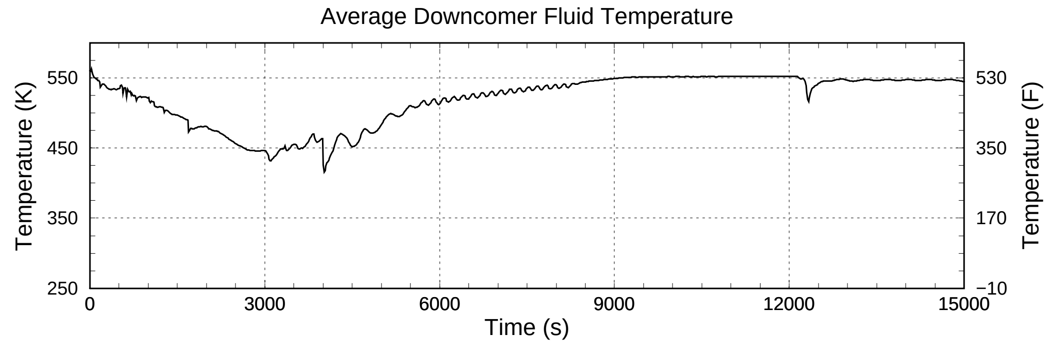
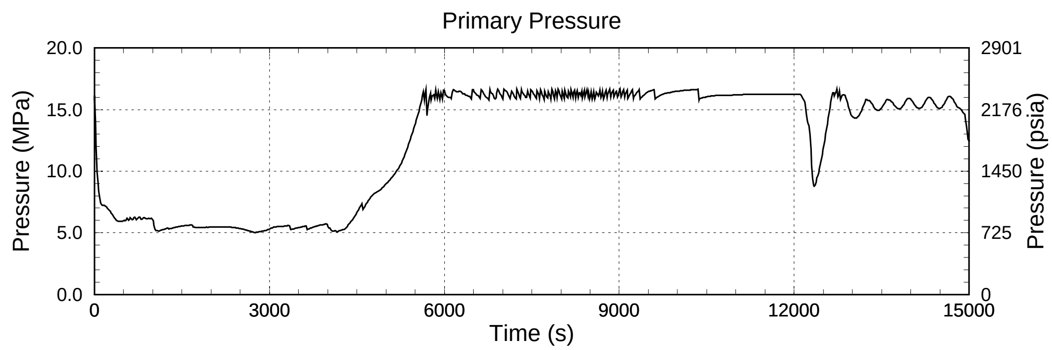


Figure A-32 Calvert Cliffs PTS Results for Case 032

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose when primary pressure decreases to 4.93 MPa (700 psig).
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	415.5 K [288.2EF] at 4,020 s
Comments	None.





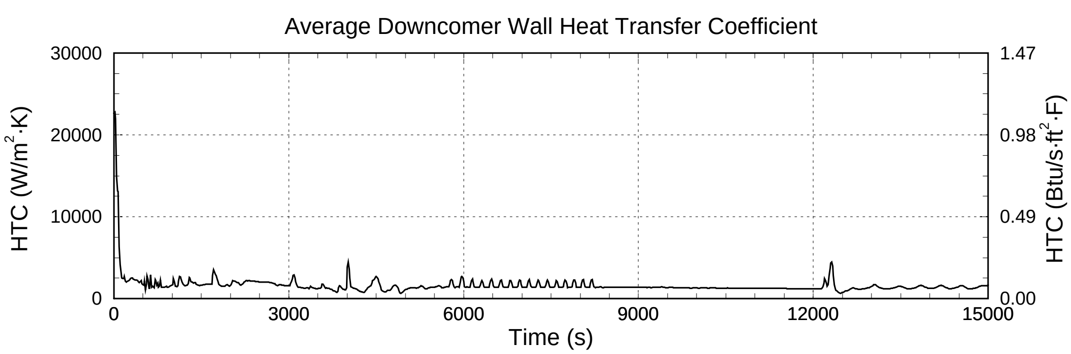


Figure A-33 Calvert Cliffs PTS Results for Case 033

Case Category	SGTR
Primary Failures	Steam generator tube rupture (single tube).
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	536.6 K [506.2EF] at 1,440 s
Comments	None.

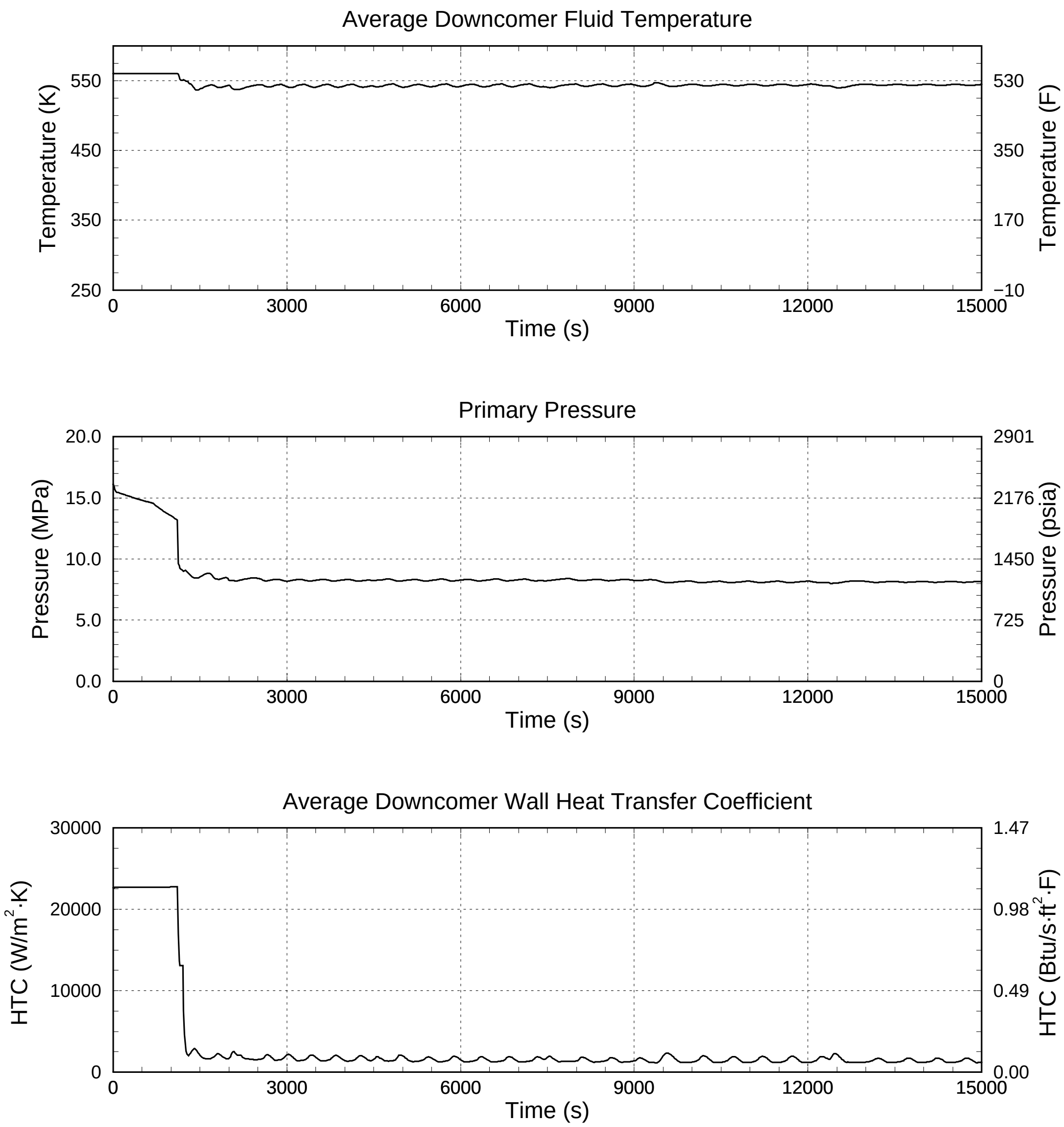
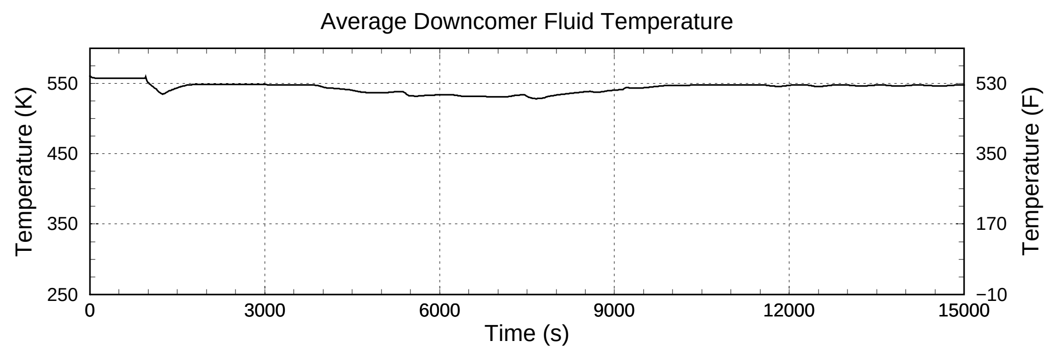
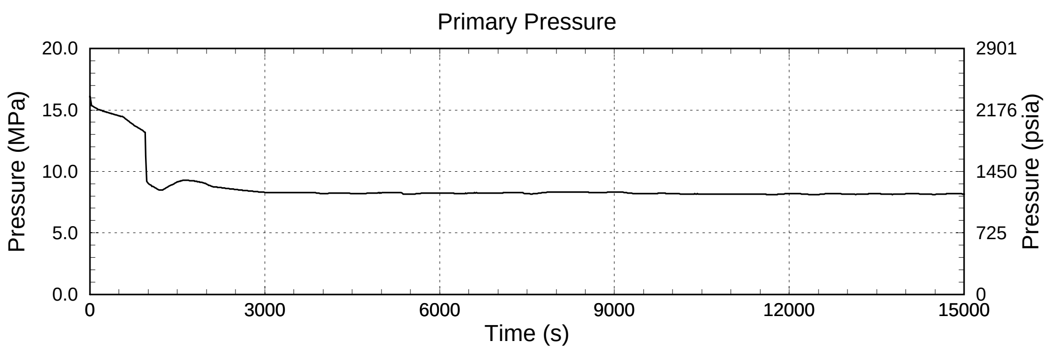


Figure A-34 Calvert Cliffs PTS Results for Case 034

Case Category	SGTR
Primary Failures	Steam generator tube rupture (single tube).
Secondary Failures	One stuck open TBV.
Operator Actions	None.
Min DC Temperature	528.2 K [491.1EF] at 7,650 s
Comments	None.





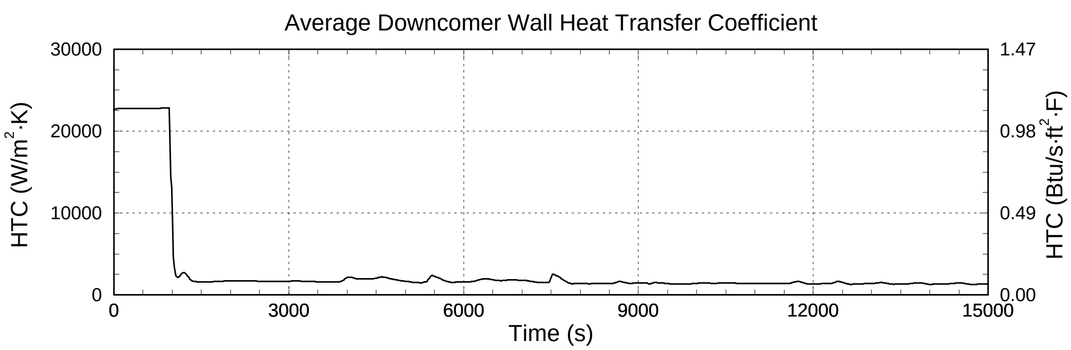


Figure A-35 Calvert Cliffs PTS Results for Case 035

Case Category	RT/TT
Primary Failures	One stuck open pressurizer PORV.
Secondary Failures	One stuck open TBV.
Operator Actions	None.
Min DC Temperature	454.0 K [357.5EF] at 15,000 s
Comments	None.

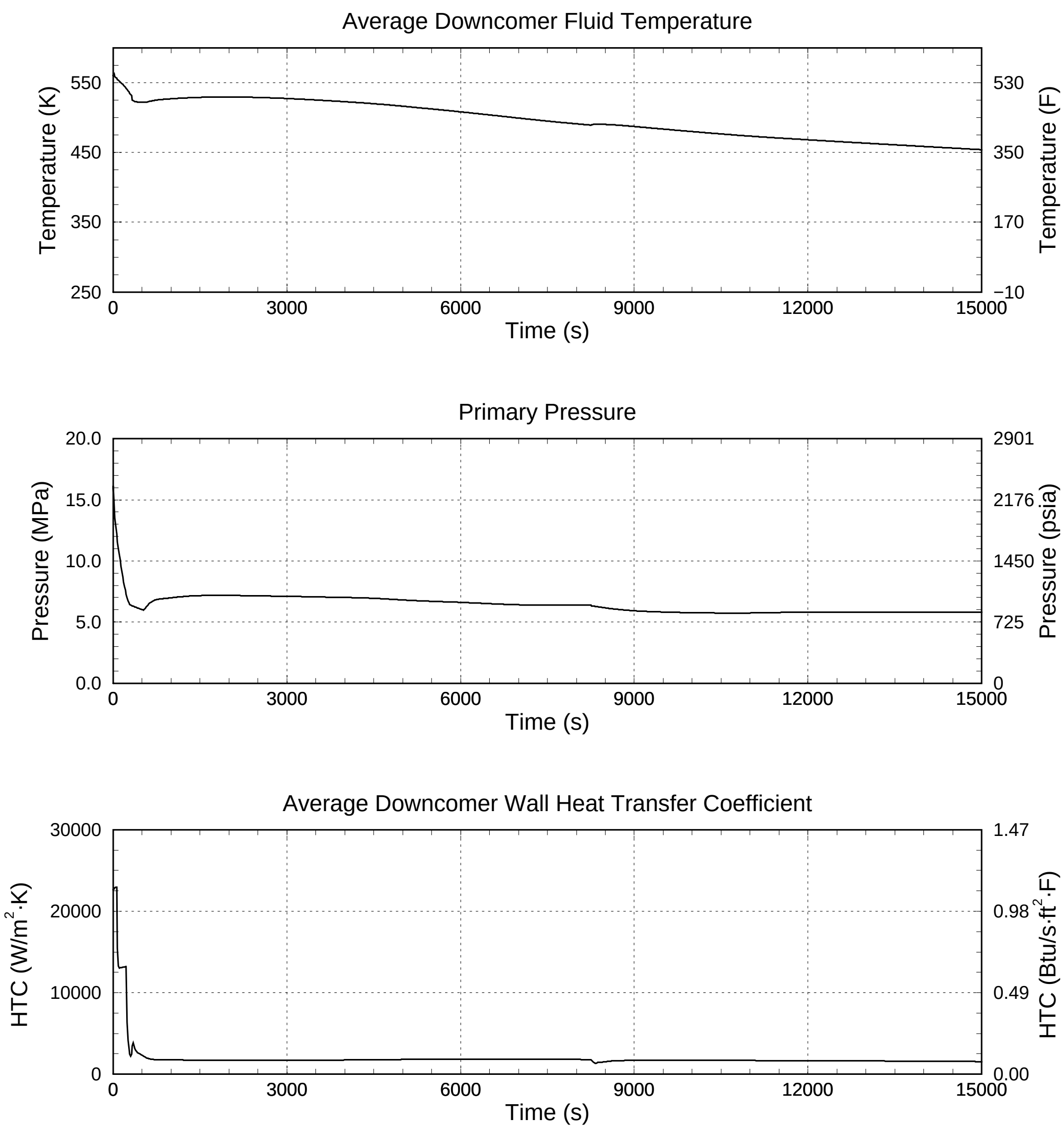


Figure A-36 Calvert Cliffs PTS Results for Case 036

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	One stuck open TBV.
Operator Actions	None.
Min DC Temperature	403.3 K [266.3EF] at 15,000 s
Comments	None.

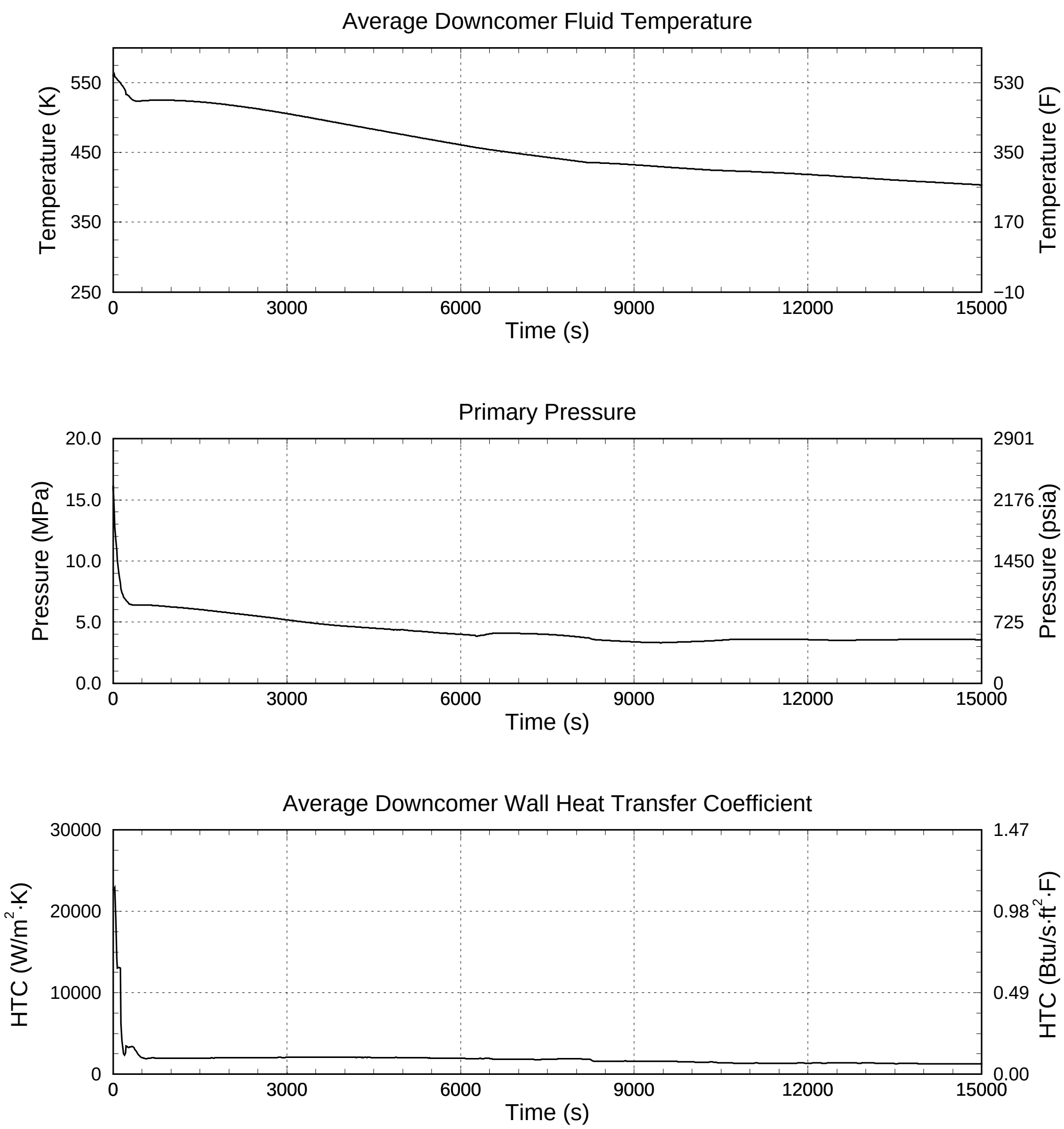


Figure A-37 Calvert Cliffs PTS Results for Case 037

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	One stuck open main steam SRV.
Operator Actions	None.
Min DC Temperature	376.4 K [217.8EF] at 14,685 s
Comments	None.

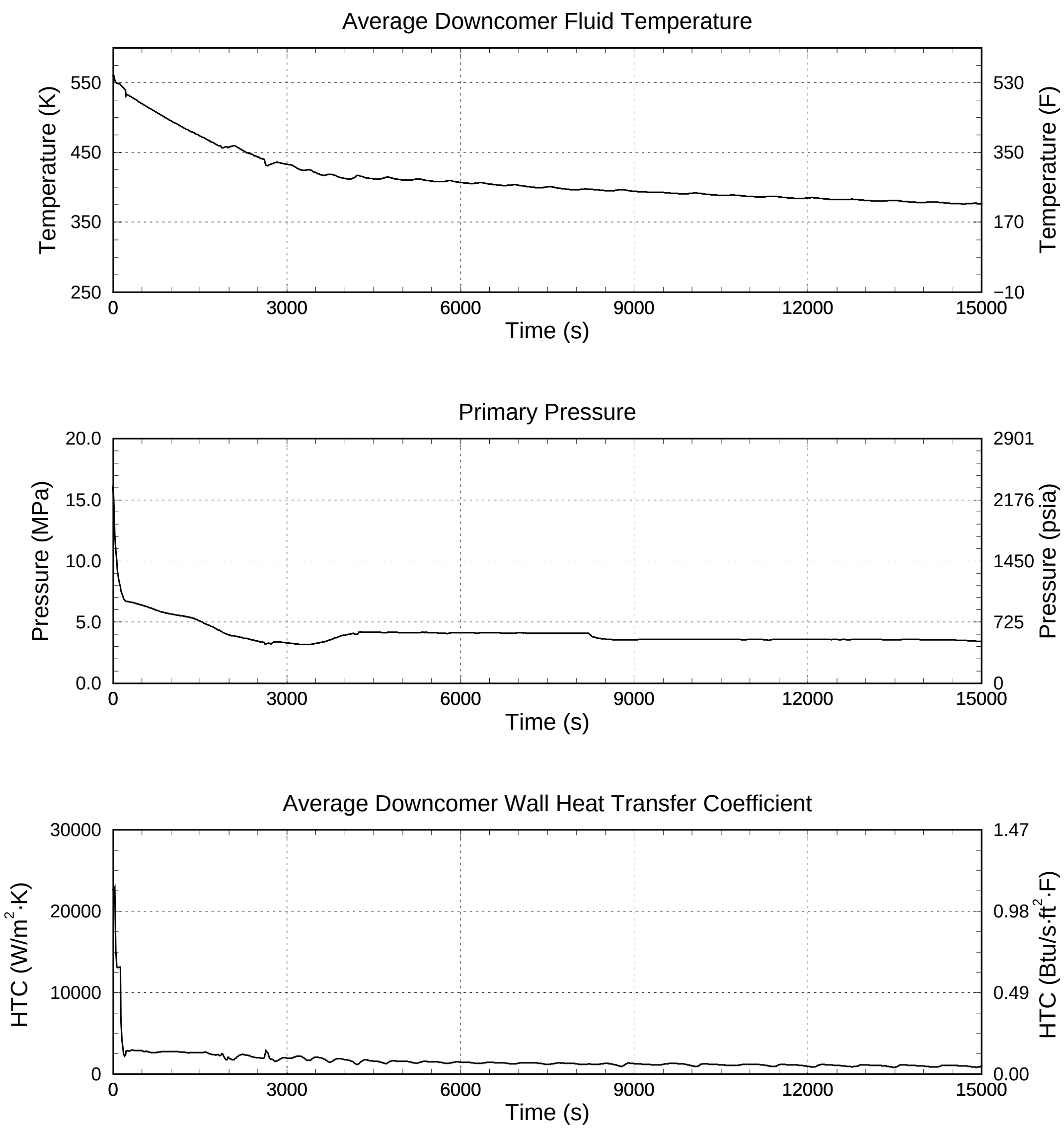


Figure A-38   Calvert Cliffs PTS Results for Case 038

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV which recloses at 6,000 s.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	453.5 K [356.6EF] at 6,045 s
Comments	None.

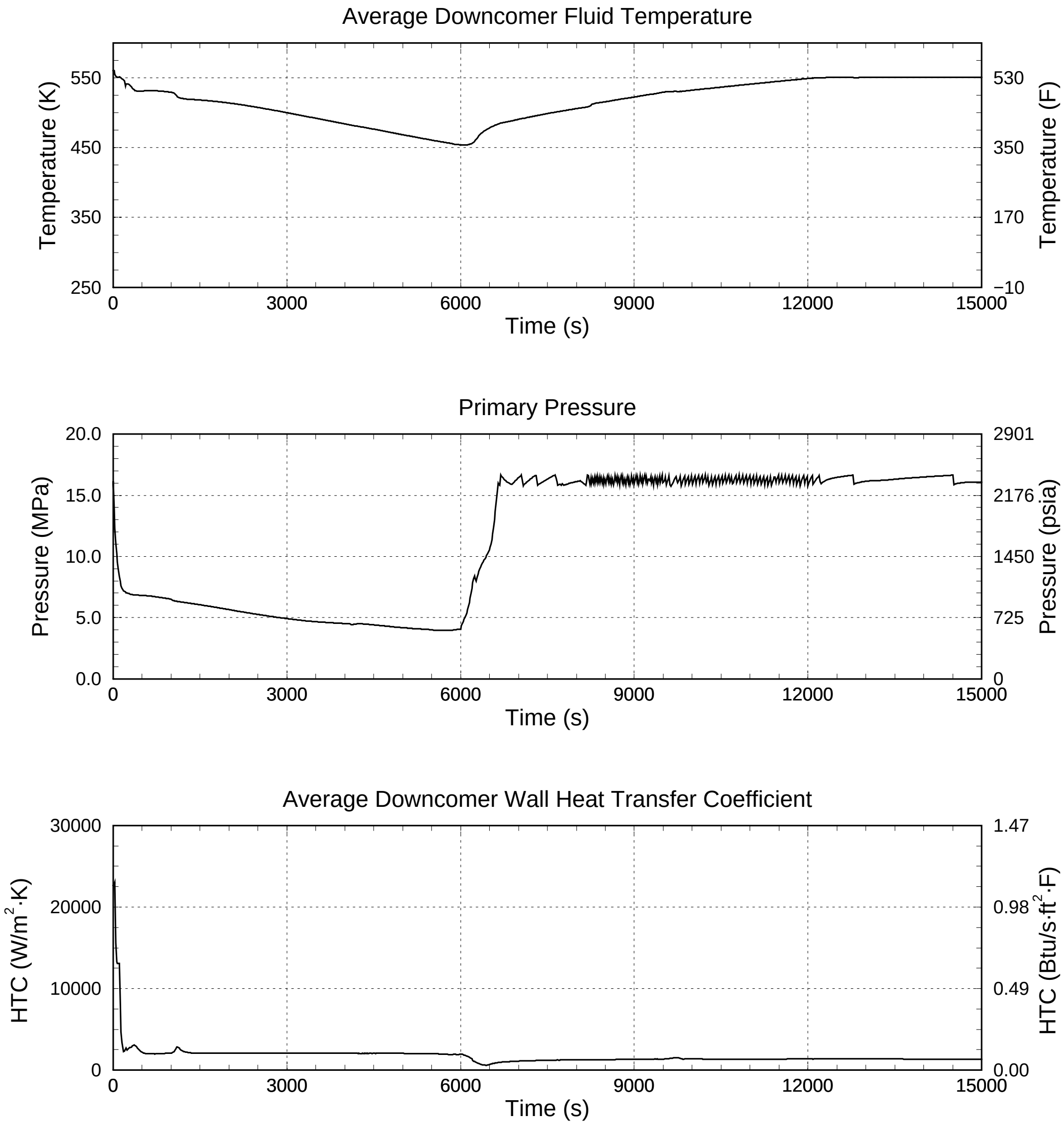


Figure A-39 Calvert Cliffs PTS Results for Case 039

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs which reclose at 6,000 s.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	346.8 K [164.6EF] at 6,435 s
Comments	None.

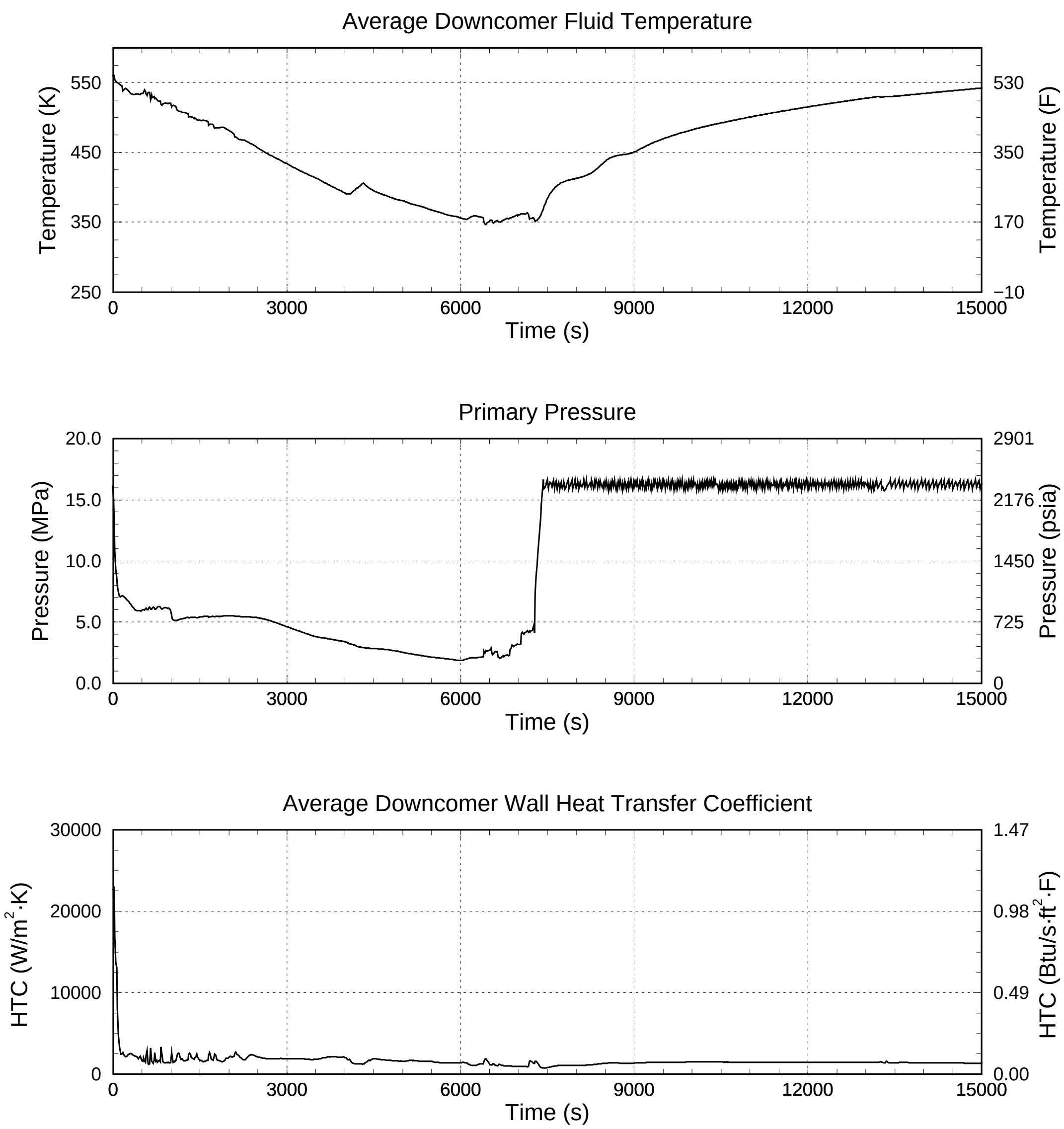


Figure A-40 Calvert Cliffs PTS Results for Case 040

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.
Min DC Temperature	489.8 K [421.9EF] at 15,000 s
Comments	None.

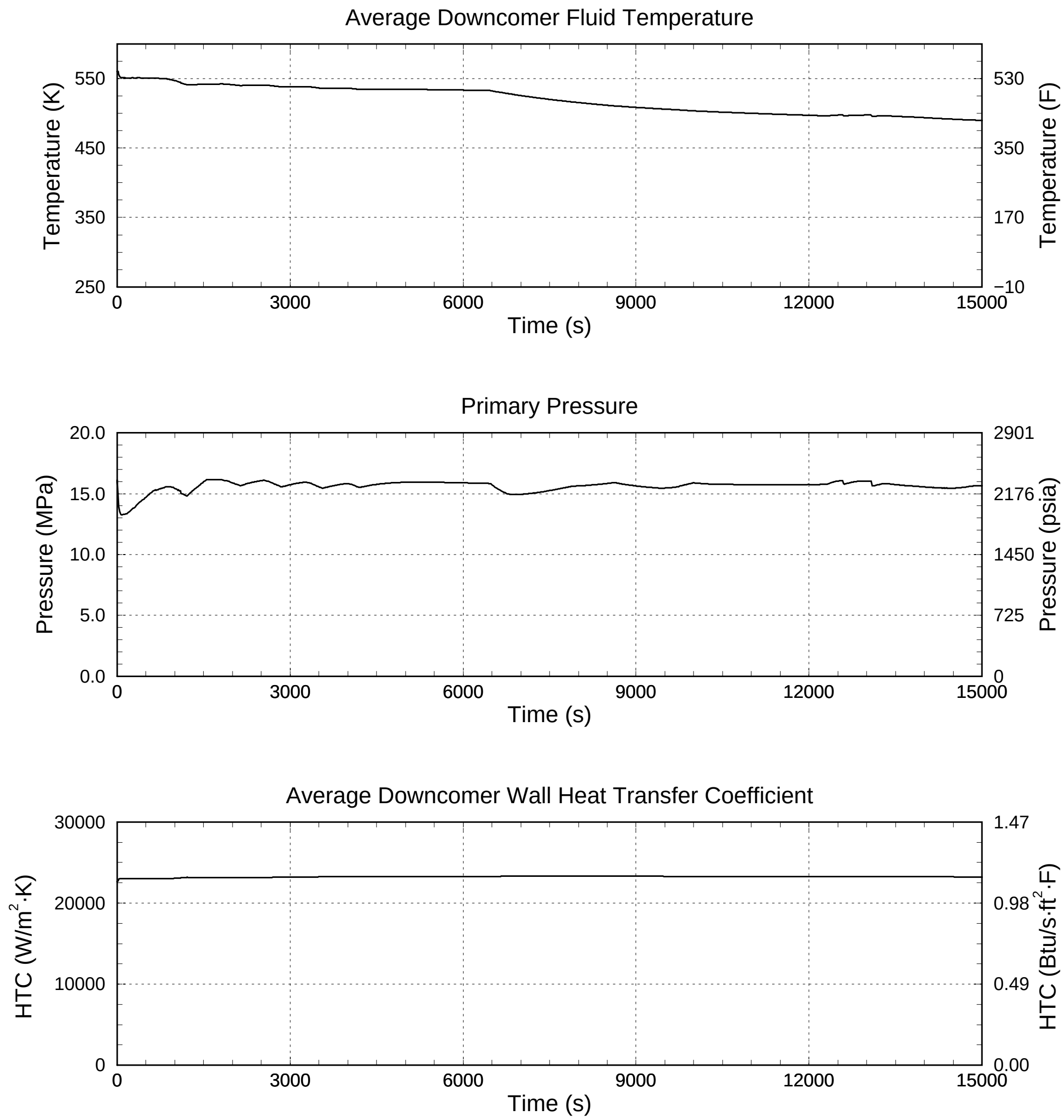


Figure A-41 Calvert Cliffs PTS Results for Case 041

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	Operator fails to isolate AFW.
Min DC Temperature	490.5 K [423.3EF] at 15,000 s
Comments	None.

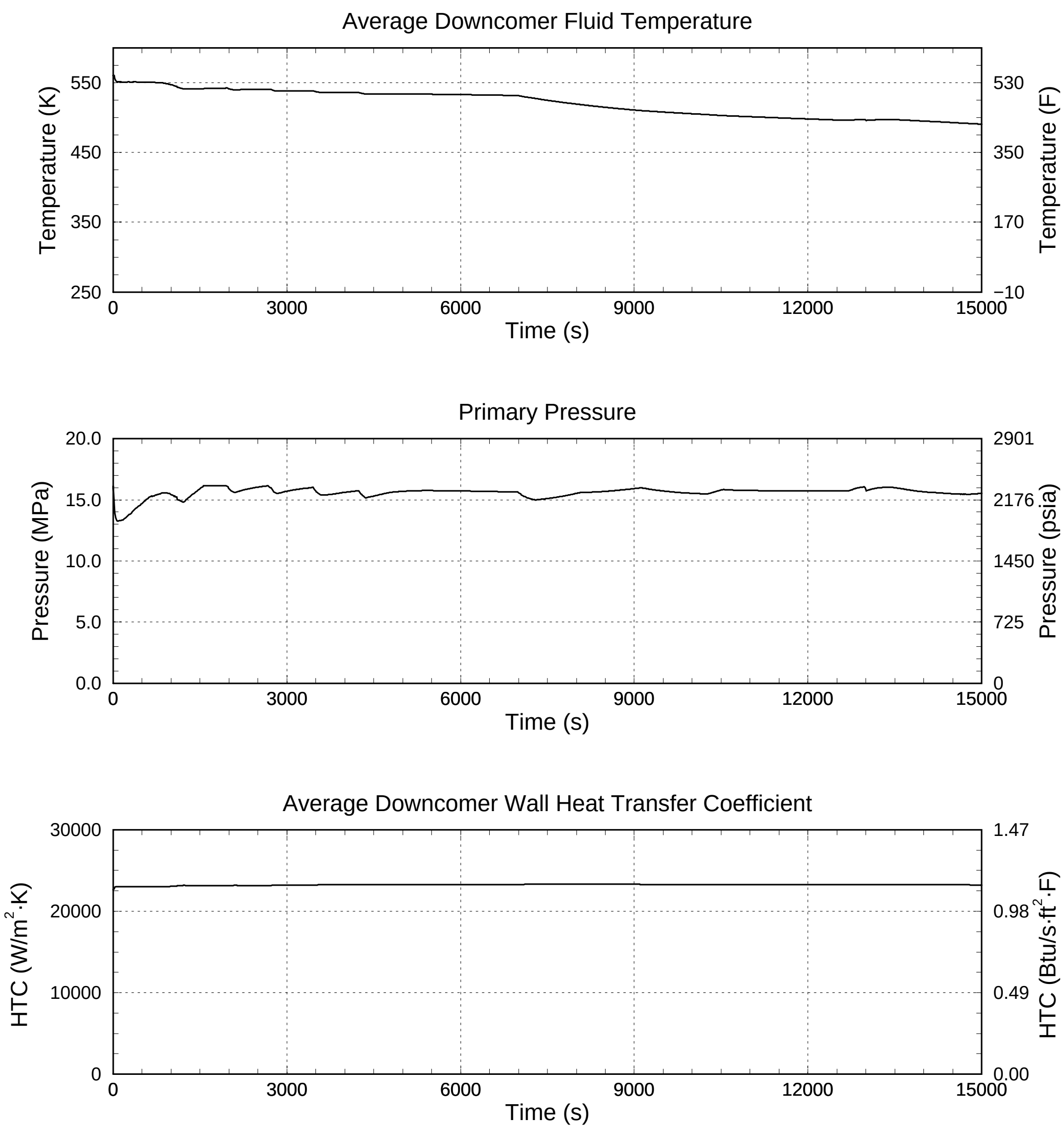


Figure A-42 Calvert Cliffs PTS Results for Case 042

Case Category	RT/TT
Primary Failures	One stuck open pressurizer PORV.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	392.6 K [247.1EF] at 15,000 s
Comments	None.

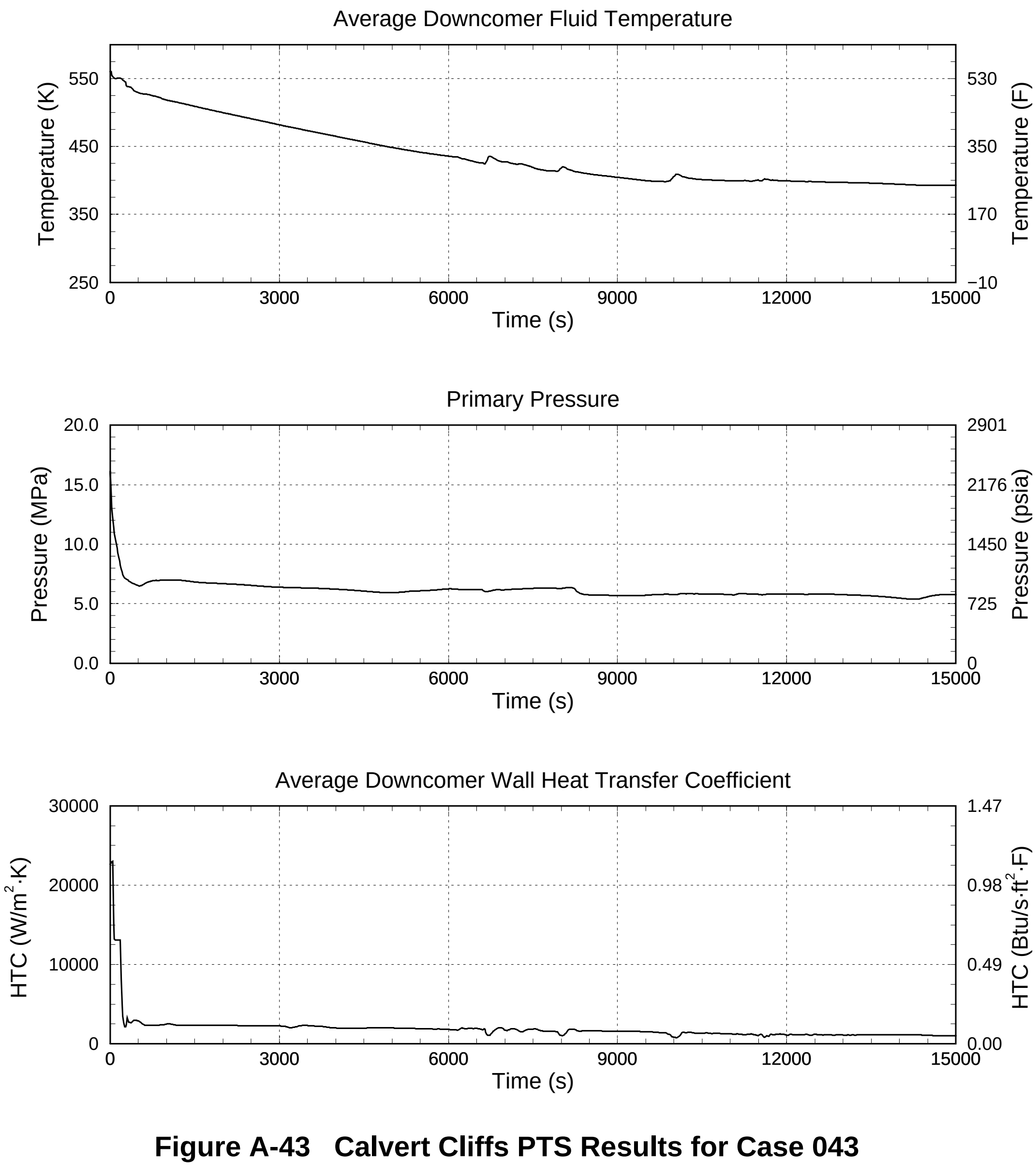


Figure A-43 Calvert Cliffs PTS Results for Case 043

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	360.1 K [188.6EF] at 15,000 s
Comments	None.

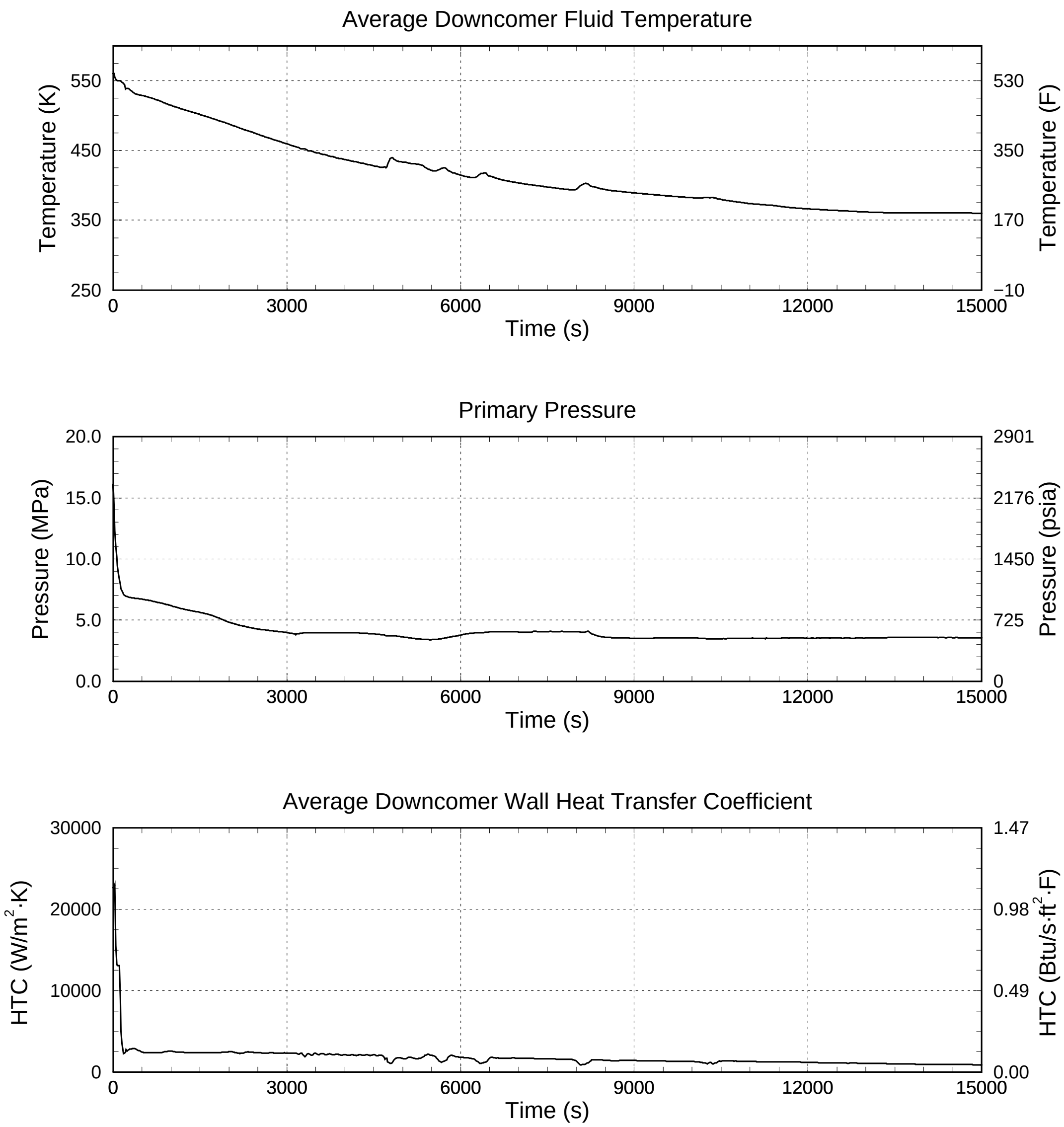


Figure A-44 Calvert Cliffs PTS Results for Case 044

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open main steam SRV.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	457.2 K [363.3EF] at 13,575 s
Comments	None.

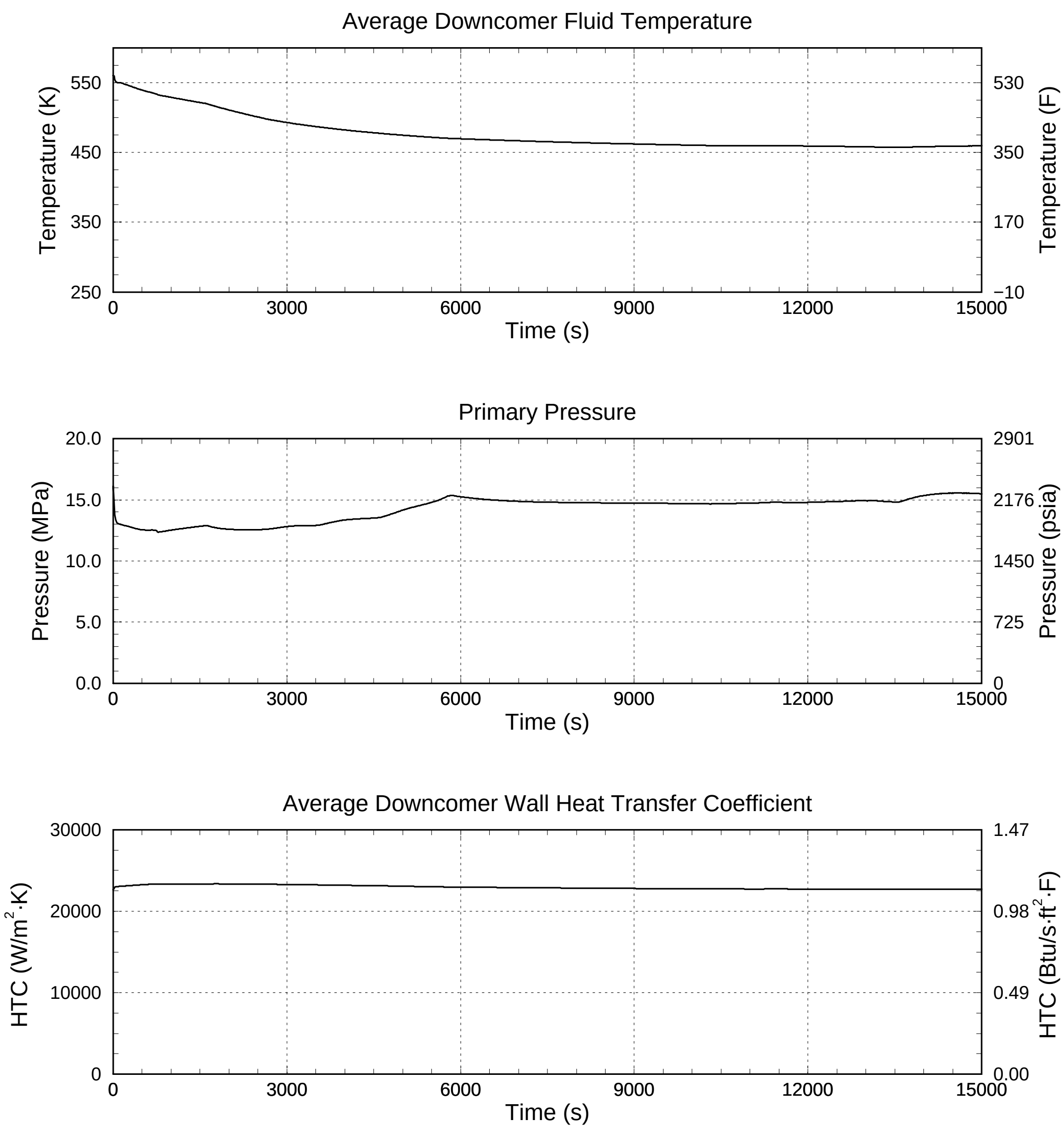


Figure A-45 Calvert Cliffs PTS Results for Case 045

Case Category	MSLB
Primary Failures	None.
Secondary Failures	Main Steam Line Break (double ended guillotine break).
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	380.2 K [224.7EF] at 6,180 s
Comments	None.

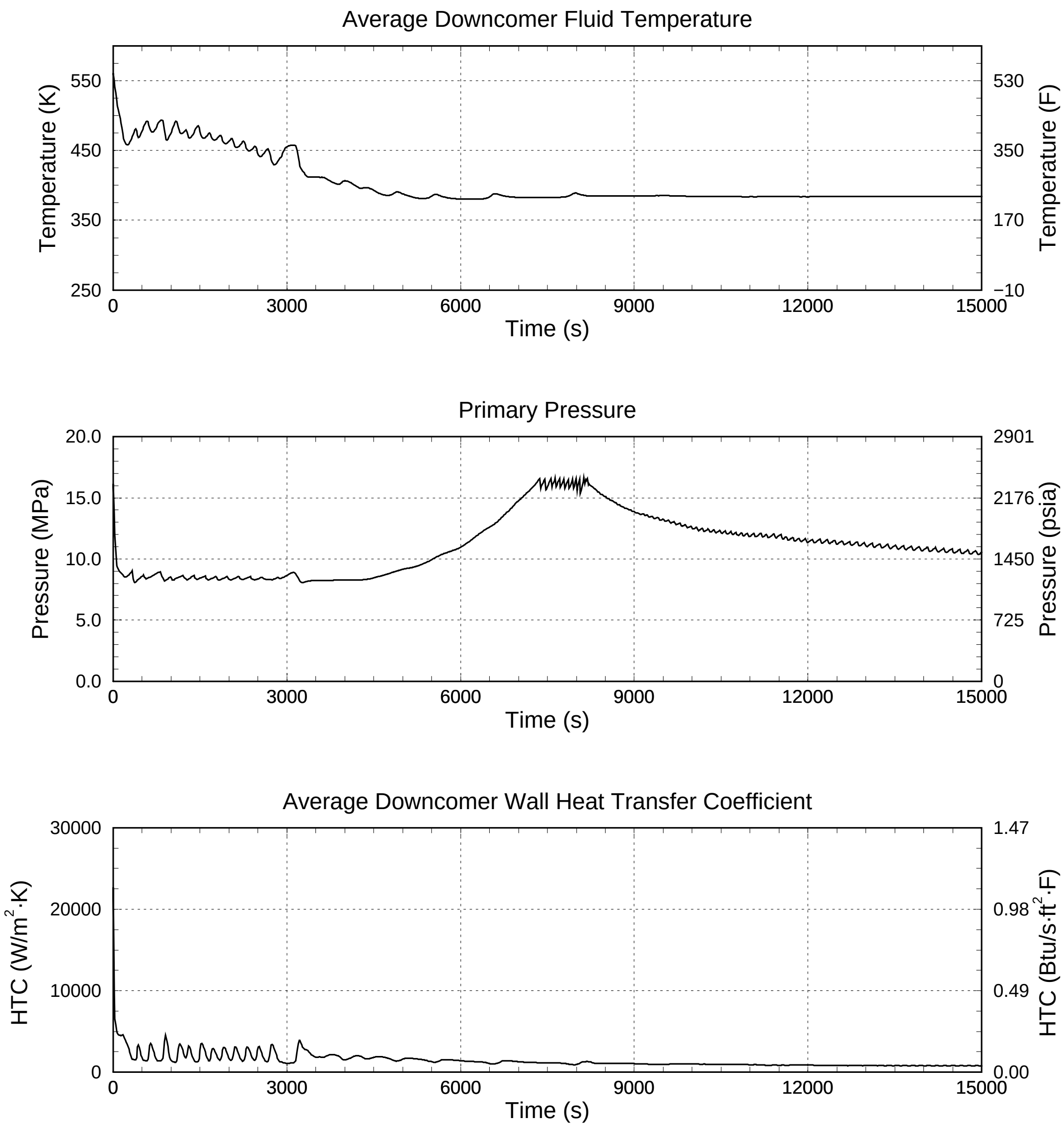


Figure A-46 Calvert Cliffs PTS Results for Case 046

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV.
Secondary Failures	One stuck open main steam SRV.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	365.8 K [198.8EF] at 15,000 s
Comments	None.

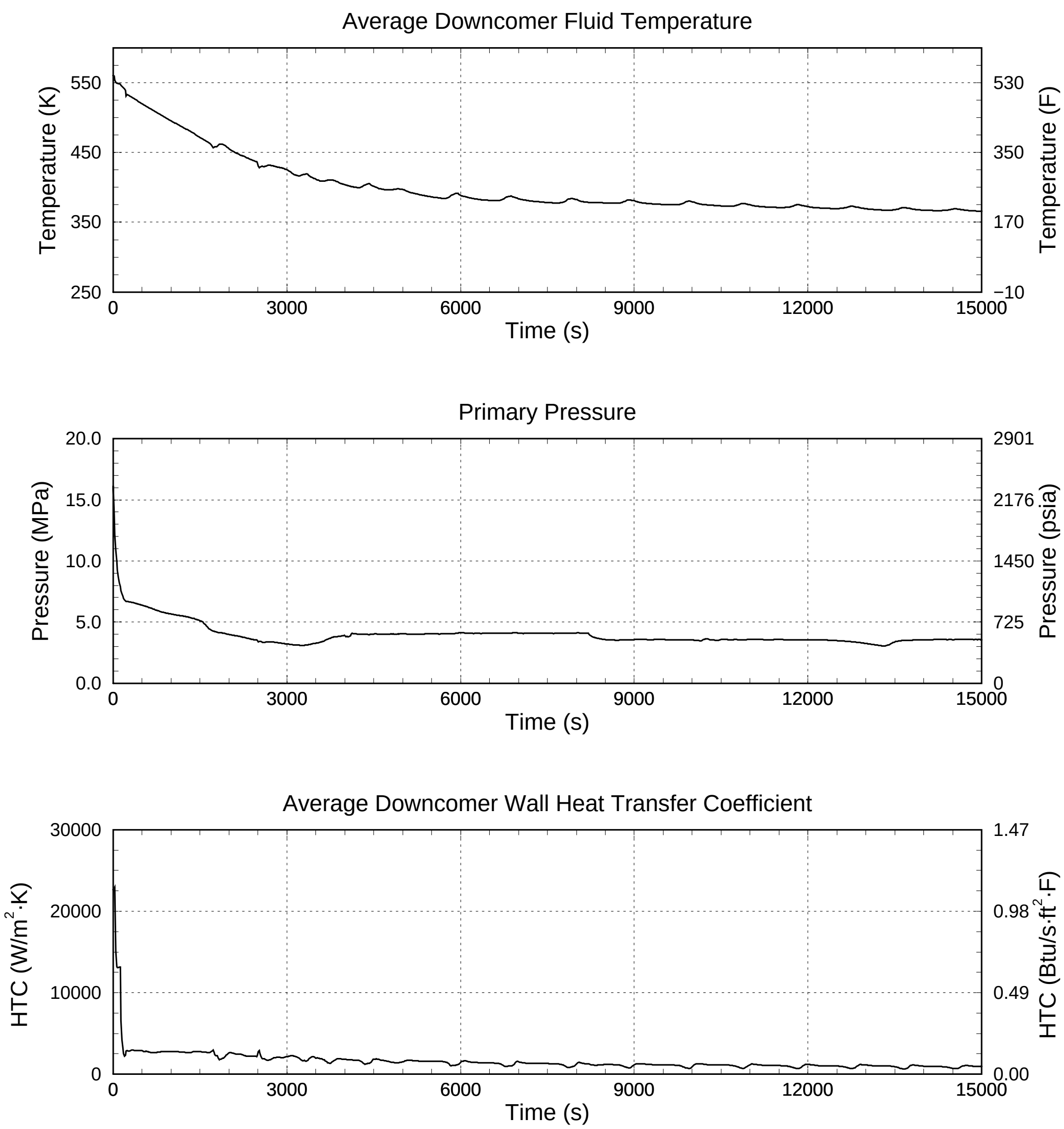
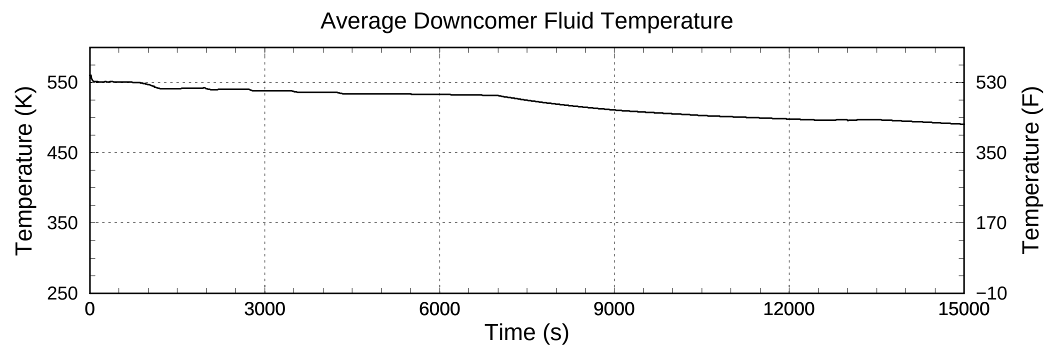
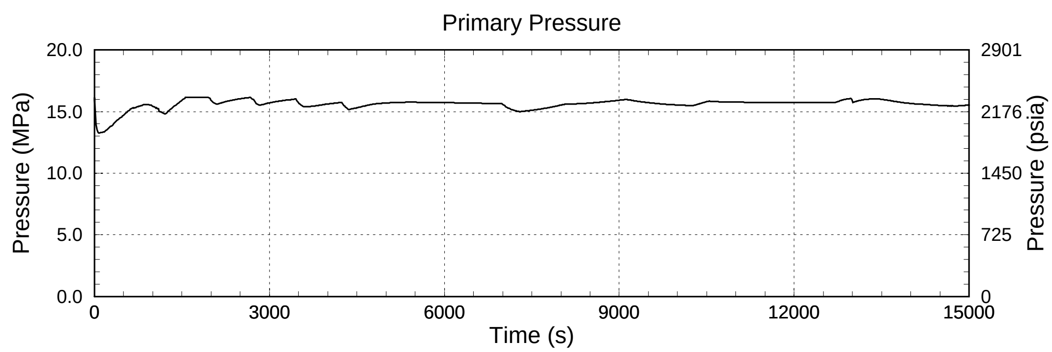


Figure A-47 Calvert Cliffs PTS Results for Case 047

Case Category	RT/TT
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1. AFW controls level in SG 1 at steam line elevation once AFW starts.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	490.5 K [423.3EF] at 15,000 s
Comments	None.





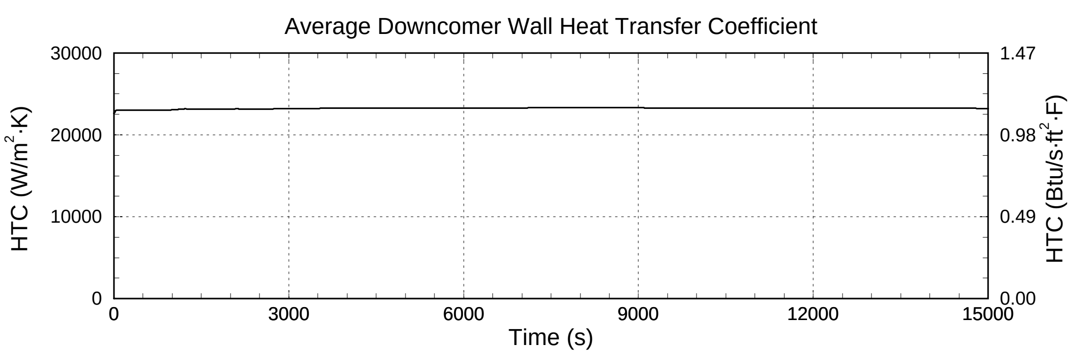


Figure A-48 Calvert Cliffs PTS Results for Case 048

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV
Secondary Failures	One stuck open ADV in SG 1. AFW controls level in SG 1 at steam line elevation once AFW starts.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	354.2 K [177.9EF] at 15,000 s
Comments	None.

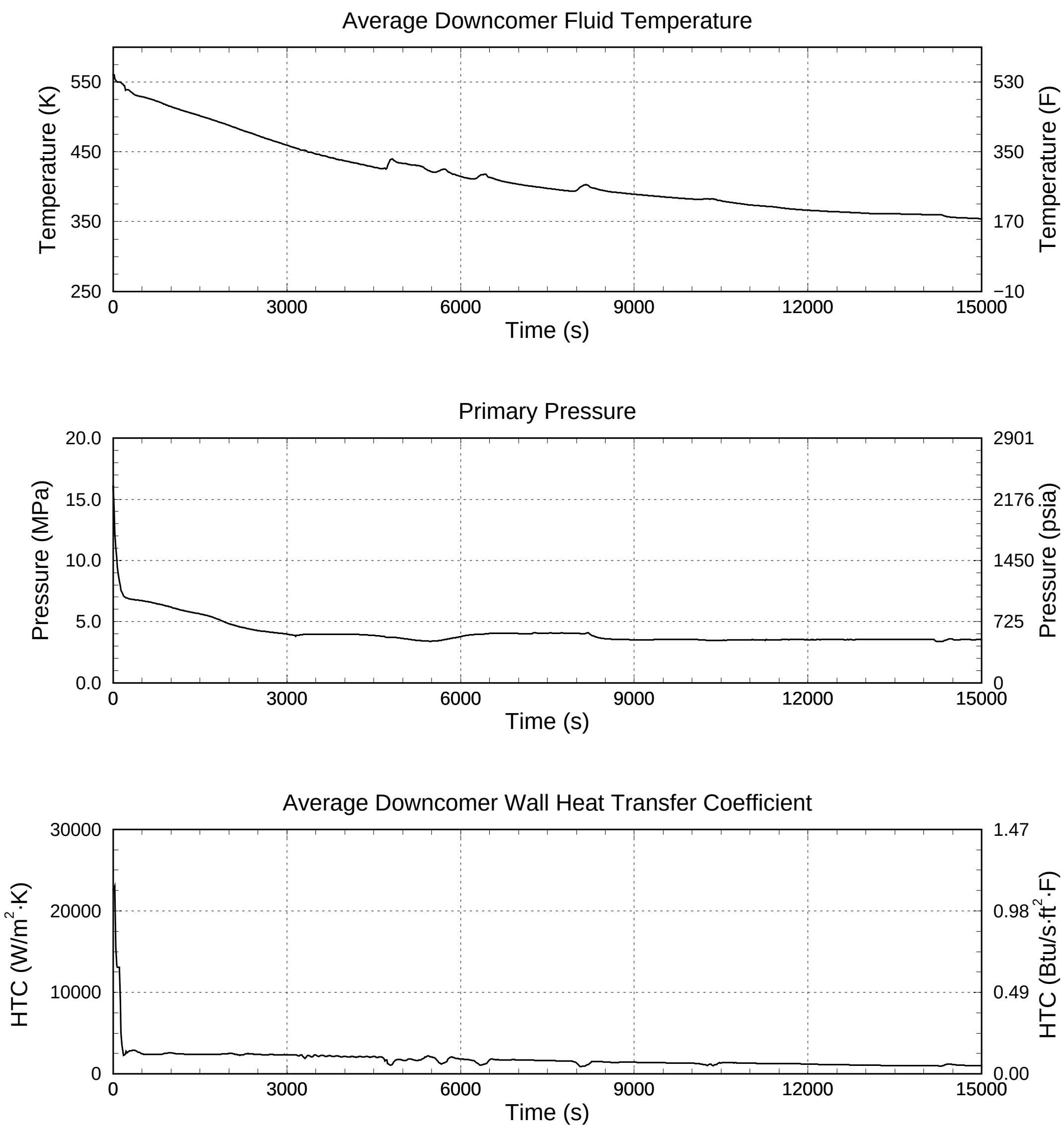


Figure A-49 Calvert Cliffs PTS Results for Case 049

Case Category	LOCA, HZP
Primary Failures	3.59 cm [1.414 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	294.3 K [70.1EF] at 15,000 s
Comments	None.

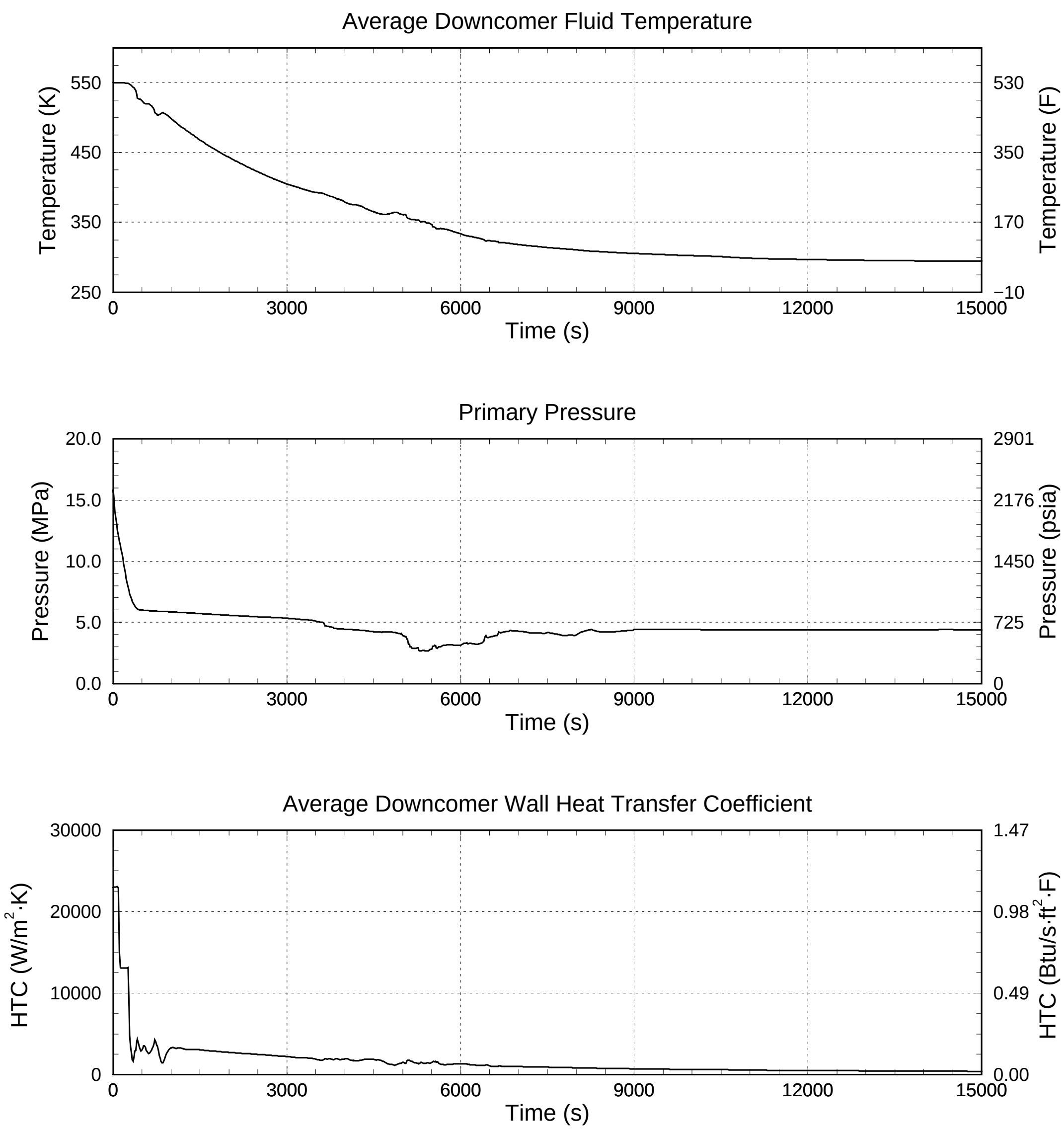


Figure A-50 Calvert Cliffs PTS Results for Case 050

Case Category	LOCA, HZP
Primary Failures	5.08 cm [2.0 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	291.6 K [65.3EF] at 15,000 s
Comments	None.

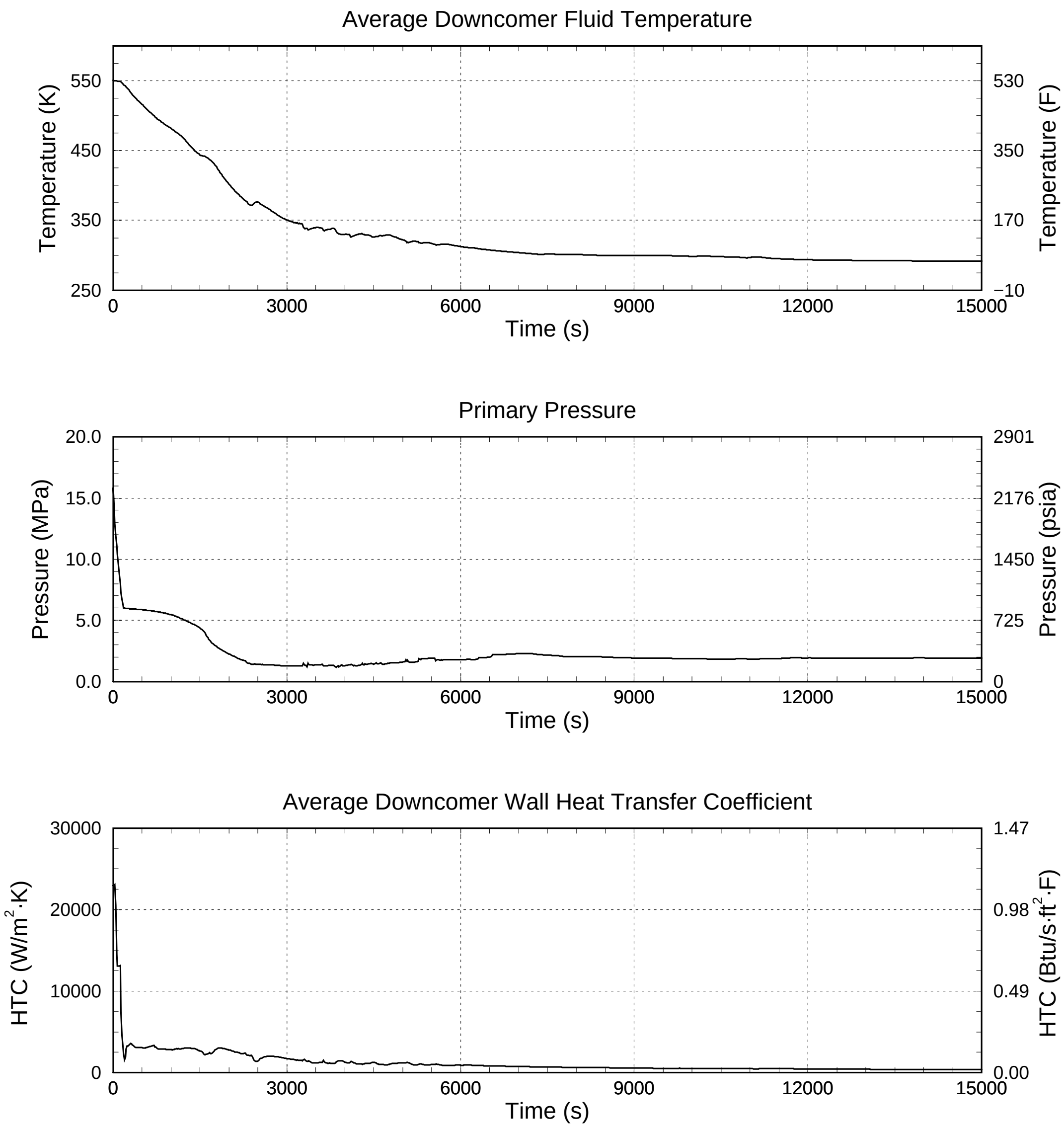


Figure A-51   Calvert Cliffs PTS Results for Case 051

Case Category	LOCA, HZP
Primary Failures	7.18 cm [2.828 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	289.9 K [62.2EF] at 15,000 s
Comments	None.

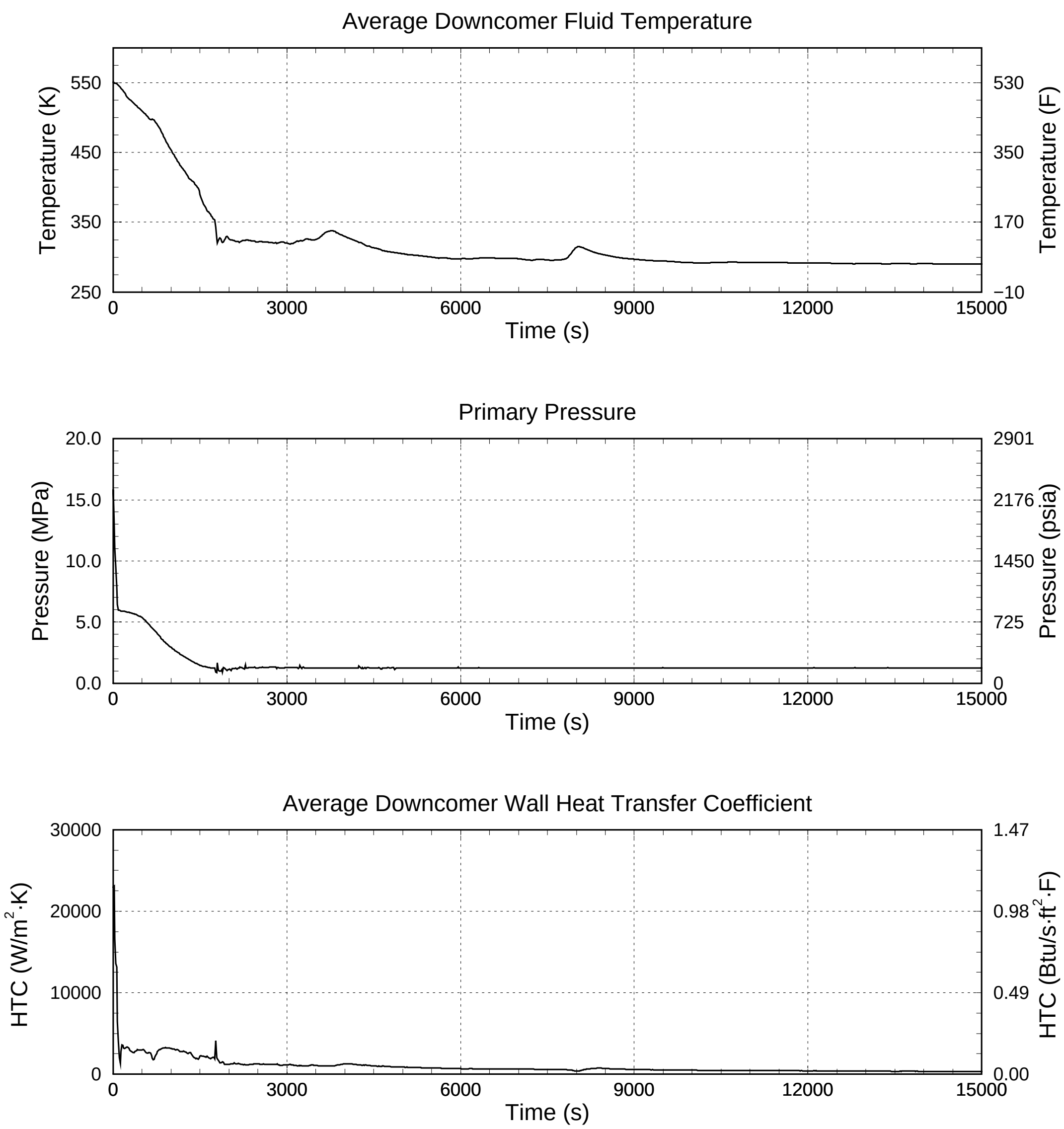
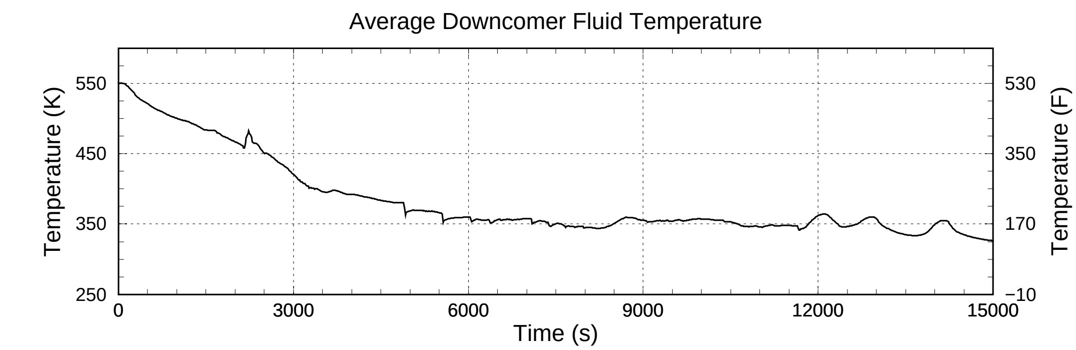
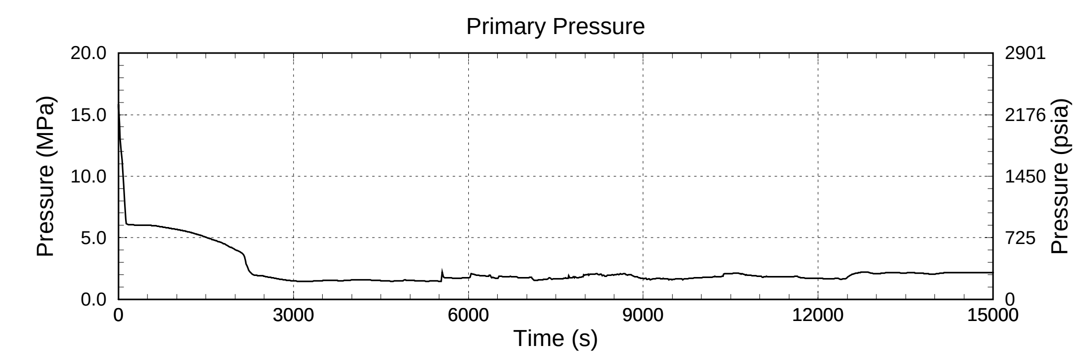


Figure A-52 Calvert Cliffs PTS Results for Case 052

Case Category	LOCA, HZP
Primary Failures	5.08 cm [2.0 in] cold leg break from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	326.4 K [127.8EF] at 15,000 s
Comments	None.





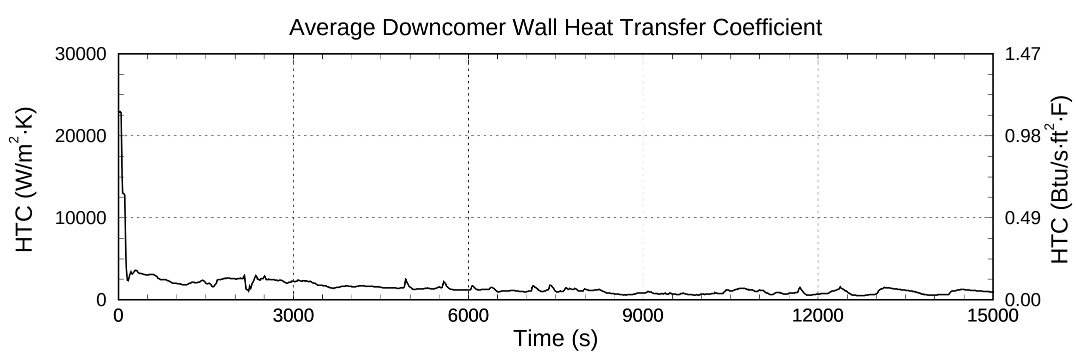


Figure A-53 Calvert Cliffs PTS Results for Case 053

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer PORV from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	309.6 K [97.6EF] at 15,000 s
Comments	None.

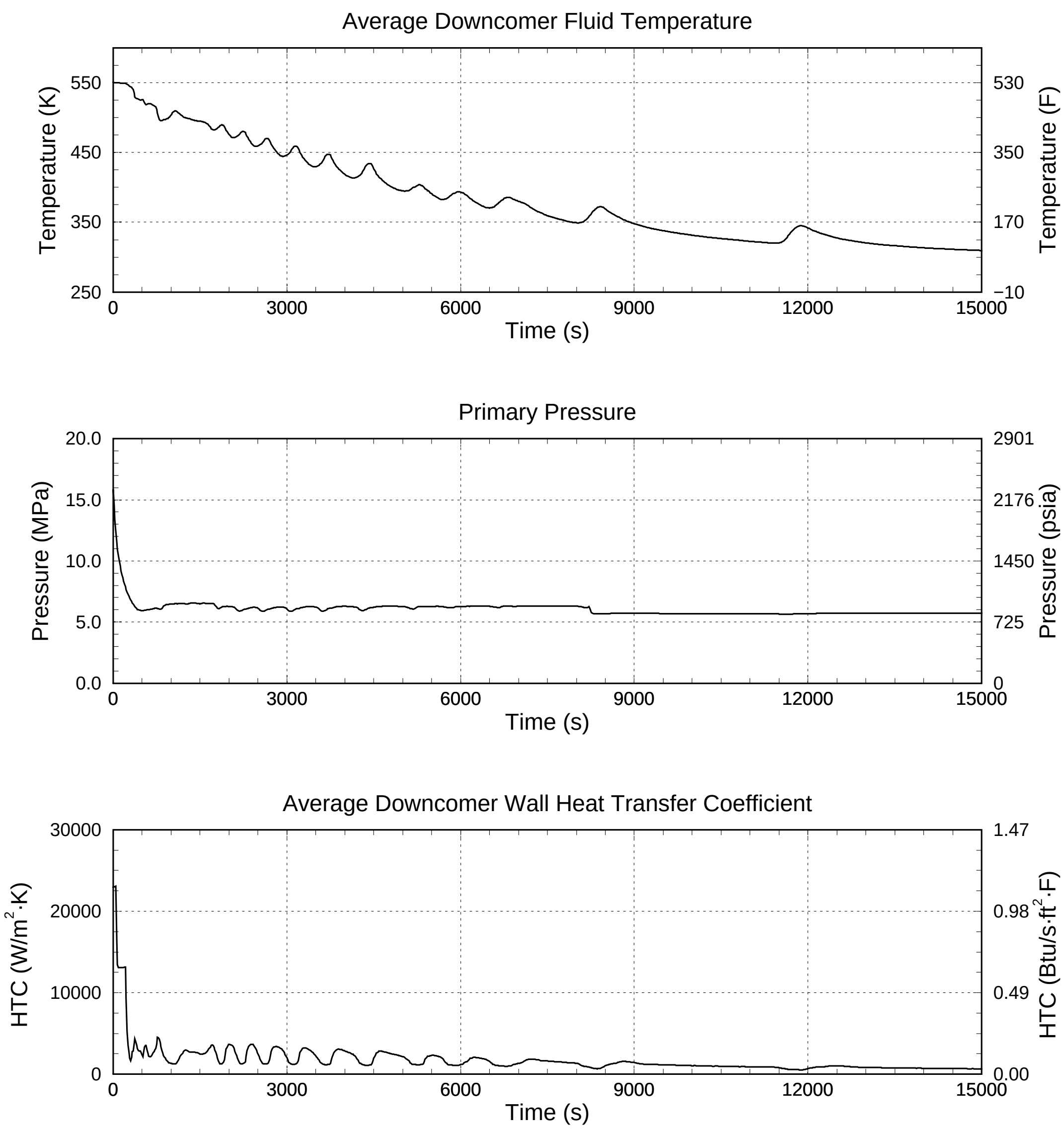


Figure A-54 Calvert Cliffs PTS Results for Case 054

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer SRV from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	293.1 K [67.9EF] at 15,000 s
Comments	None.

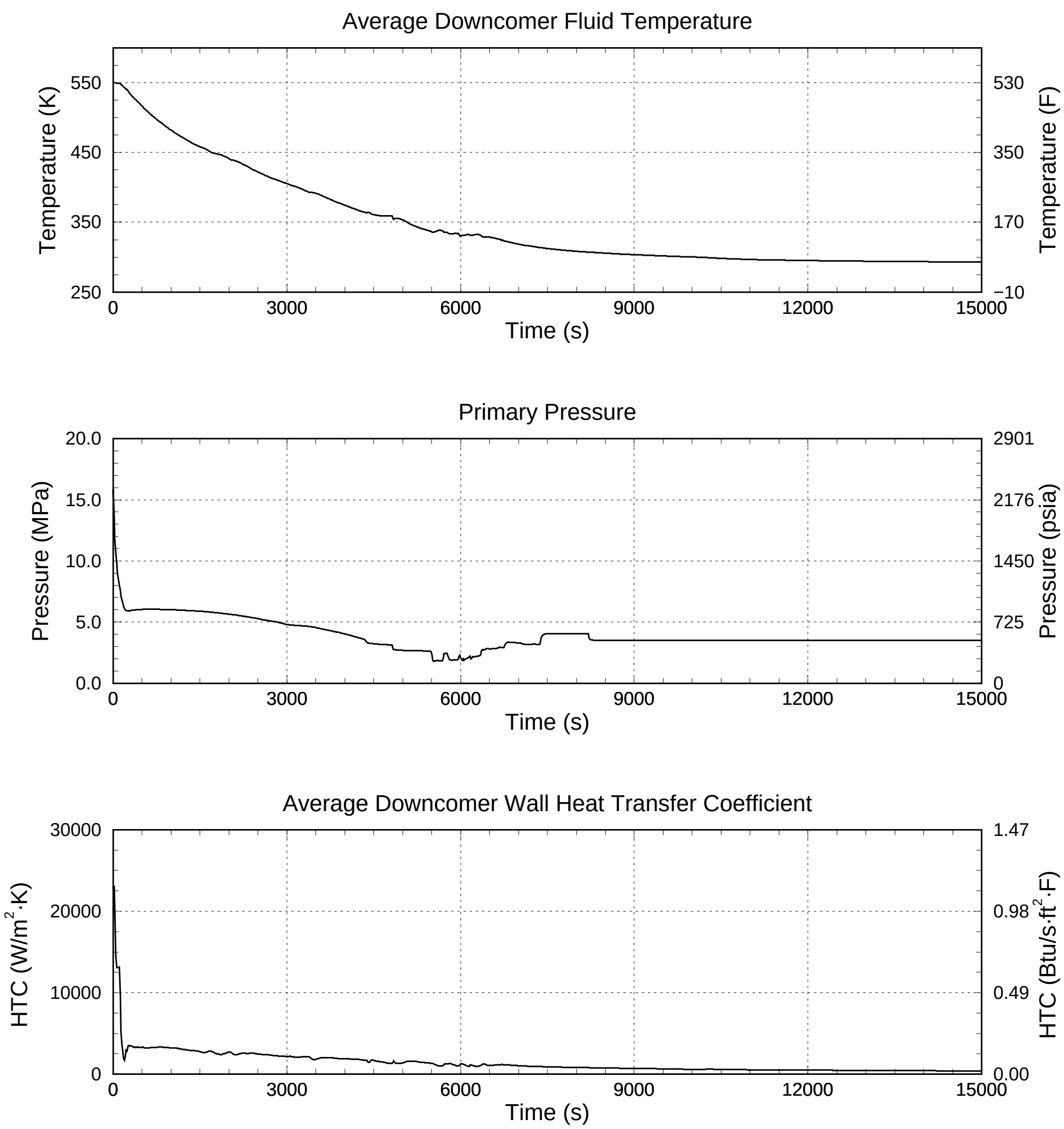


Figure A-55 Calvert Cliffs PTS Results for Case 055

Case Category	RT/TT, HZP
Primary Failures	None.
Secondary Failures	Full MFW flow to SG 1 and 2 from HZP.
Operator Actions	Operator trips MFW when water enters the steam line. Operator fails to isolate AFW.
Min DC Temperature	501.2 K [442.5EF] at 135 s
Comments	None.

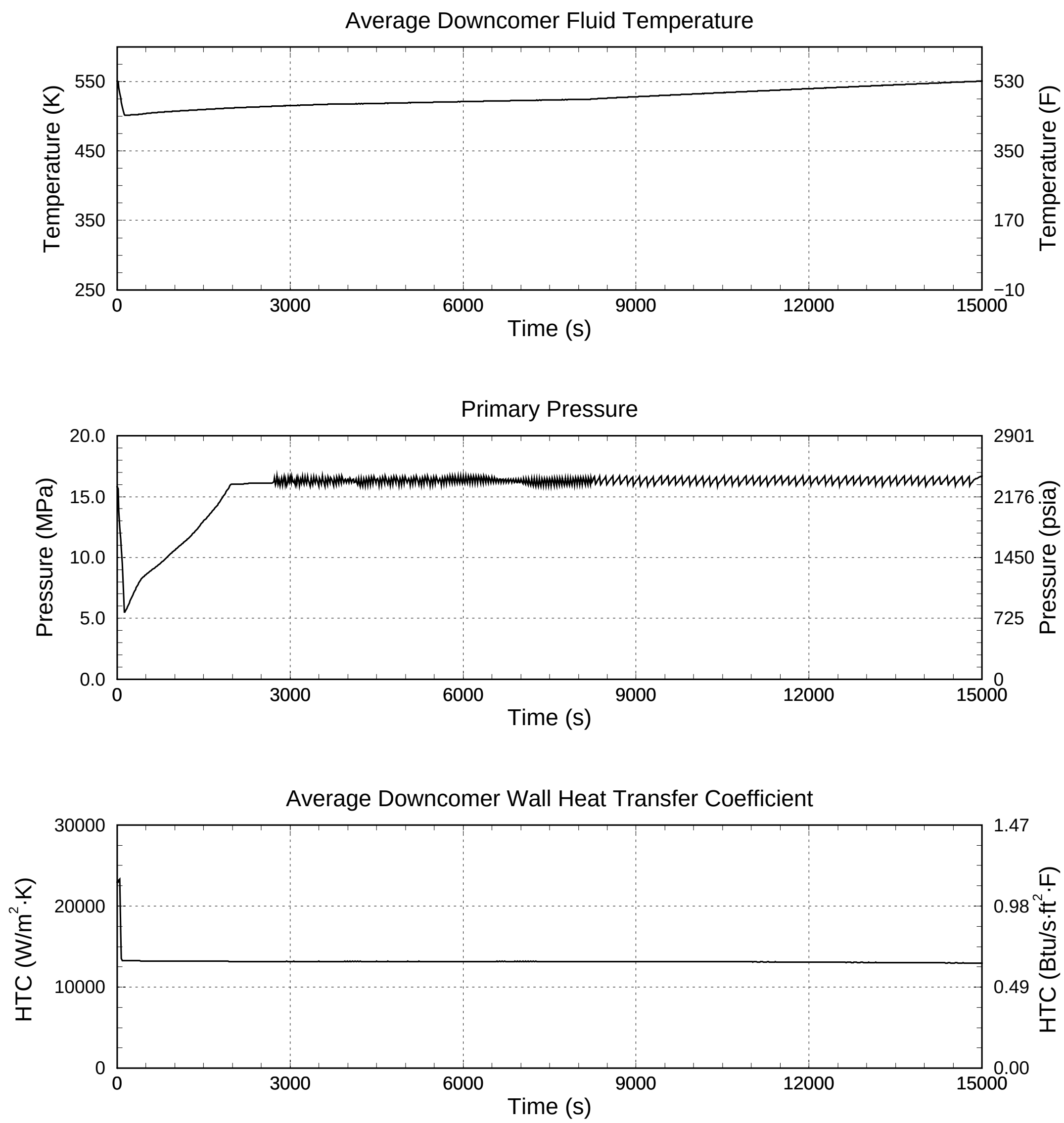


Figure A-56 Calvert Cliffs PTS Results for Case 056

Case Category	RT/TT, HZP
Primary Failures	Two stuck open pressurizer PORVs from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	292.8 K [67.4EF] at 15,000 s
Comments	None.

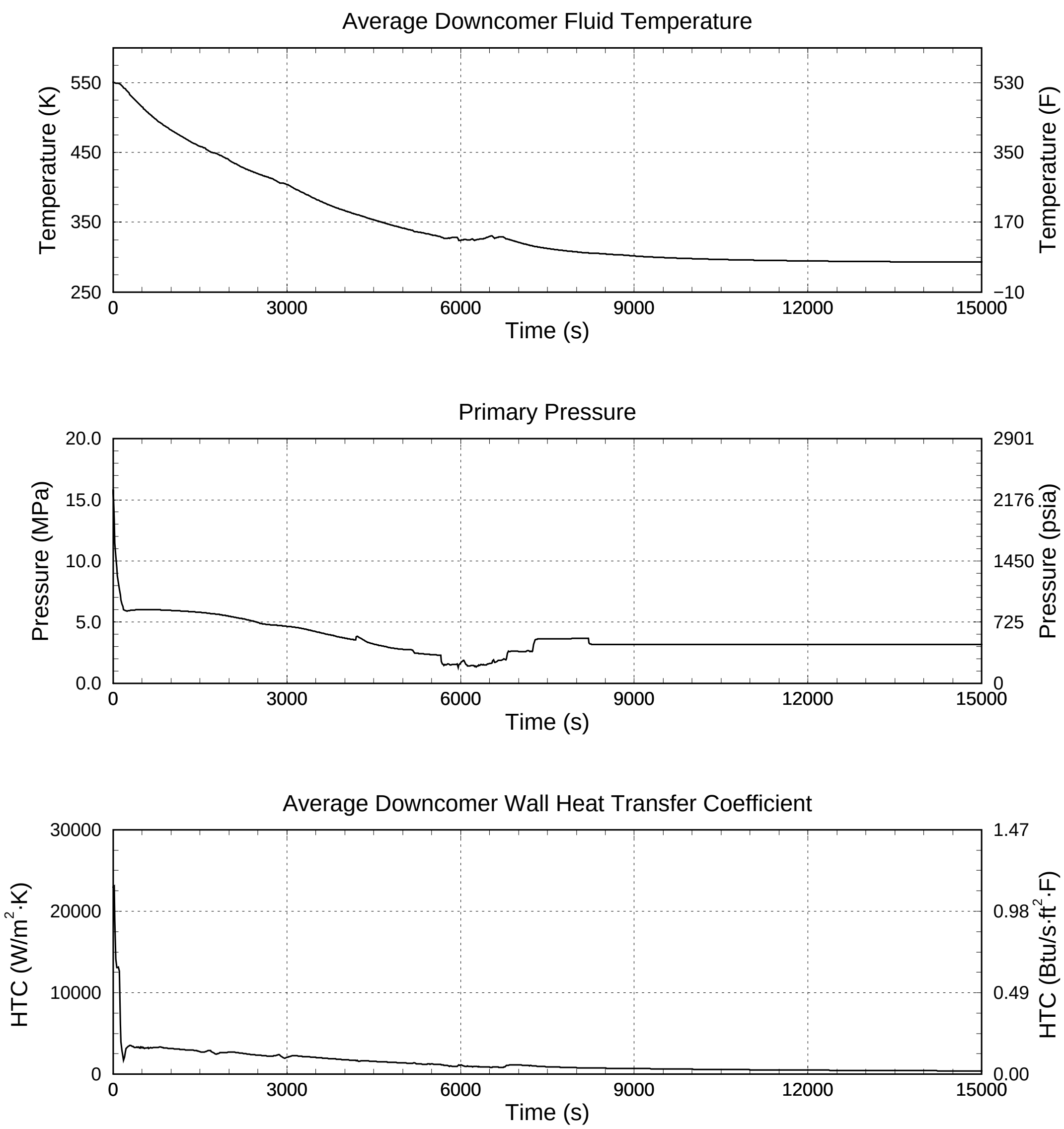


Figure A-57   Calvert Cliffs PTS Results for Case 057

Case Category	RT/TT, HZP
Primary Failures	Two stuck open pressurizer SRVs from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	292.2 K [66.4EF] at 15,000 s
Comments	None.

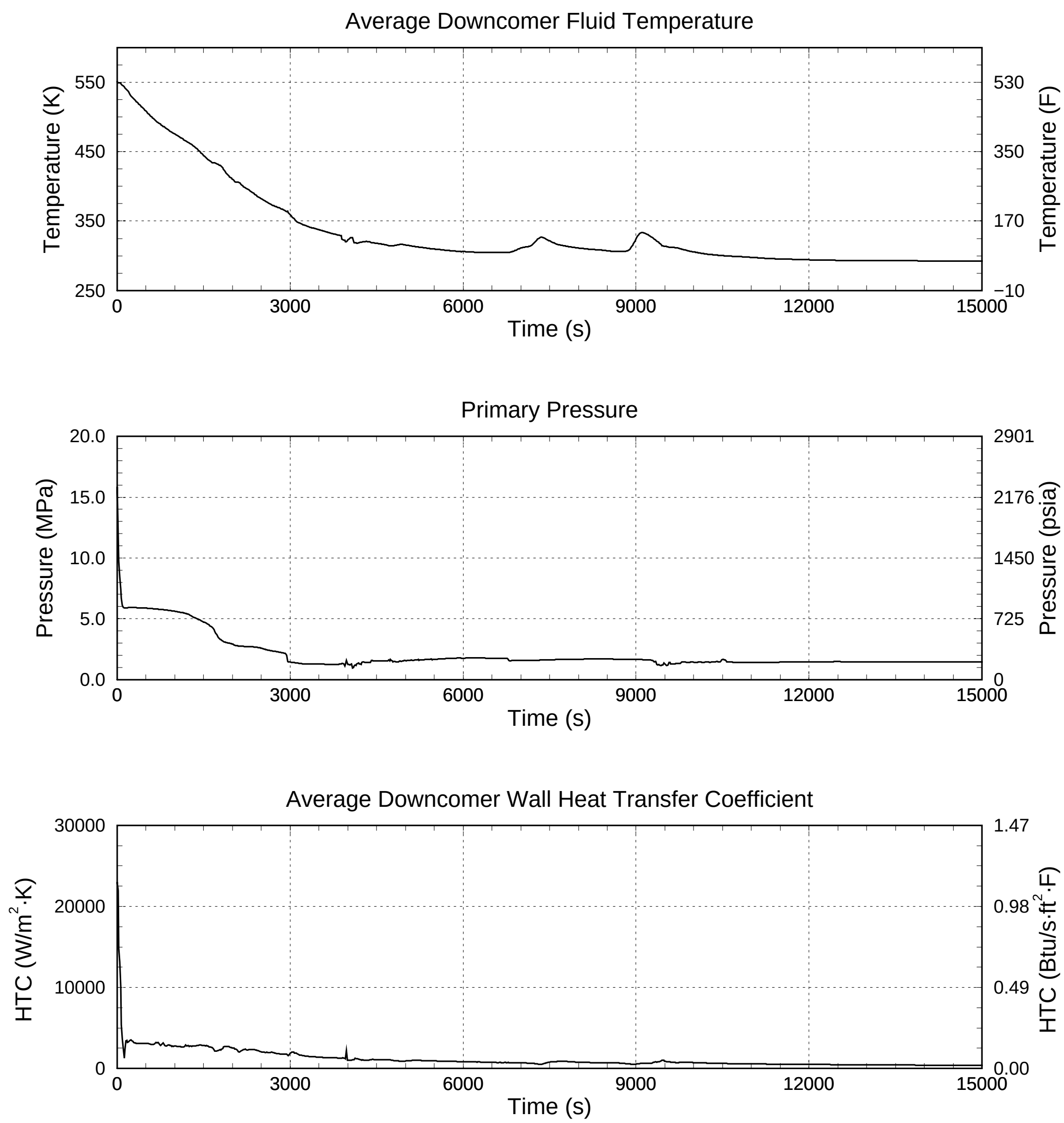
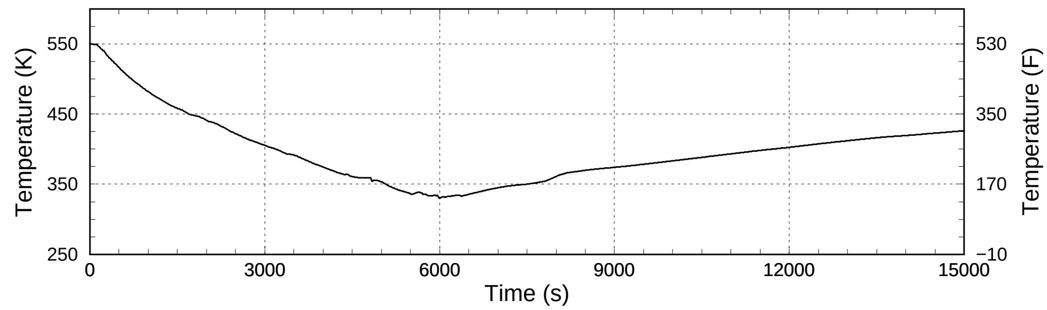


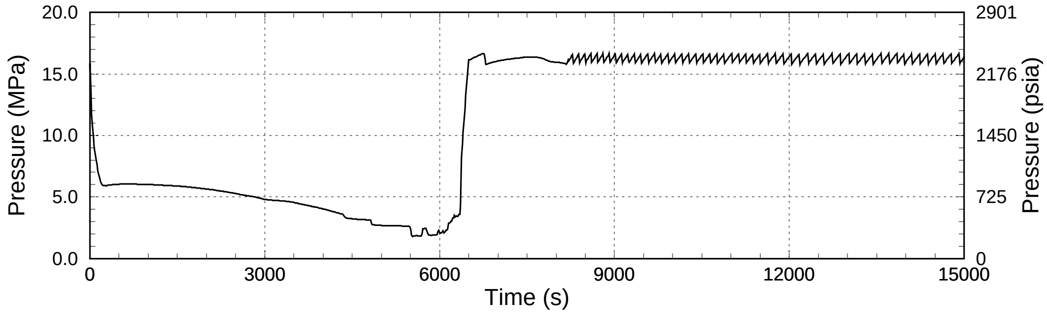
Figure A-58   Calvert Cliffs PTS Results for Case 058

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer SRV which recloses at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	330.2 K [134.7EF] at 6,000 s
Comments	None.

Average Downcomer Fluid Temperature



Primary Pressure



Average Downcomer Wall Heat Transfer Coefficient

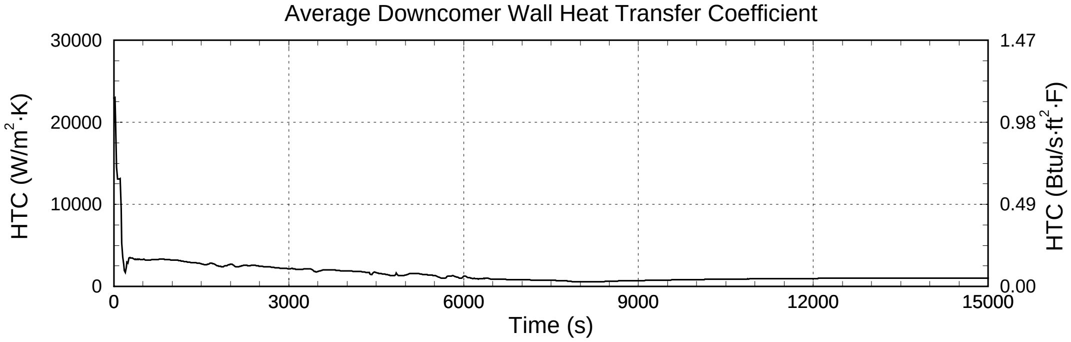
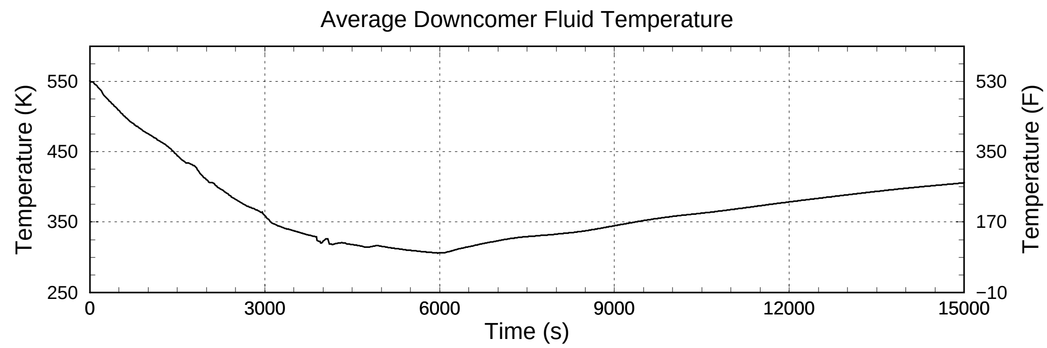
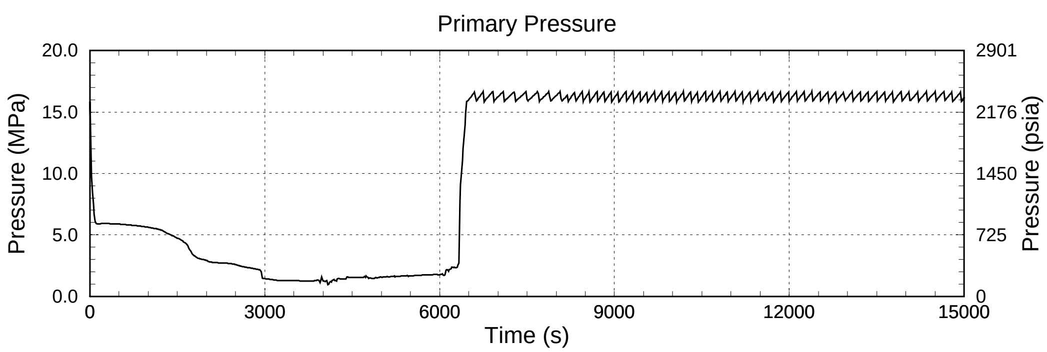


Figure A-59 Calvert Cliffs PTS Results for Case 059

Case Category	RT/TT, HZP
Primary Failures	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	306.0 K [91.1EF] at 5,970 s
Comments	None.





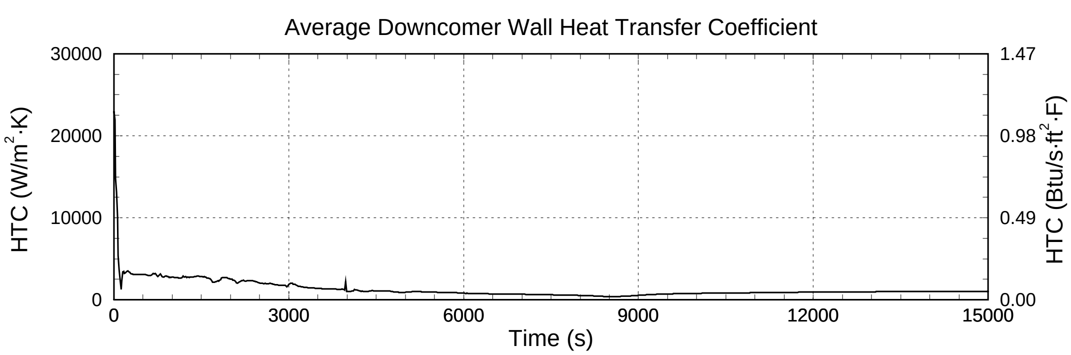


Figure A-60   Calvert Cliffs PTS Results for Case 060

Case Category	RT/TT, HZP
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1 from HZP.
Operator Actions	Operator closes MSIV after 20 minutes. Operator fails to isolate AFW.
Min DC Temperature	467.2 K [381.2EF] at 9,315 s
Comments	None.

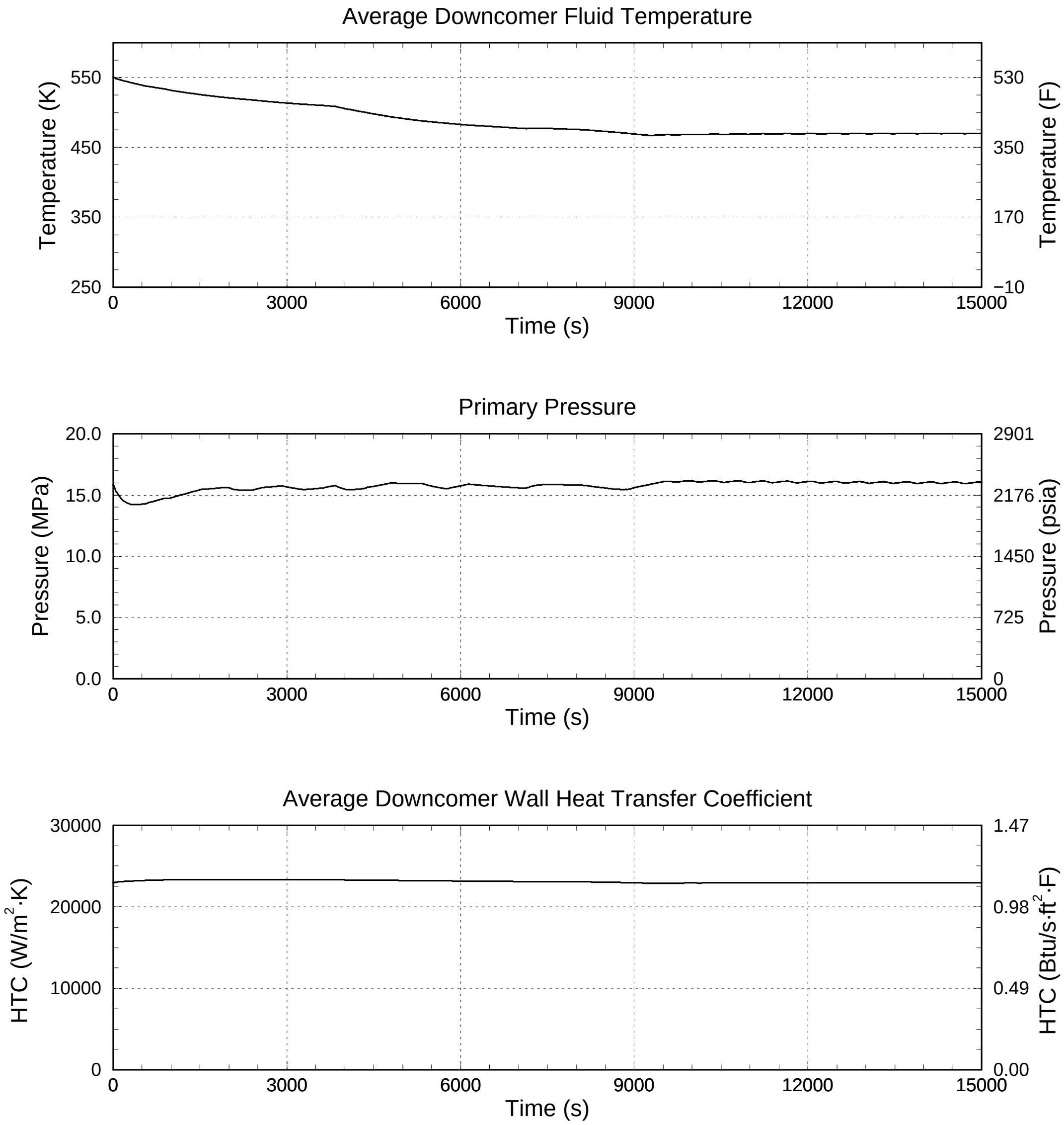


Figure A-61   Calvert Cliffs PTS Results for Case 061

Case Category	RT/TT, HZP
Primary Failures	None.
Secondary Failures	One stuck open ADV in SG 1 from HZP.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	467.2 K [381.2EF] at 9,315 s
Comments	None.

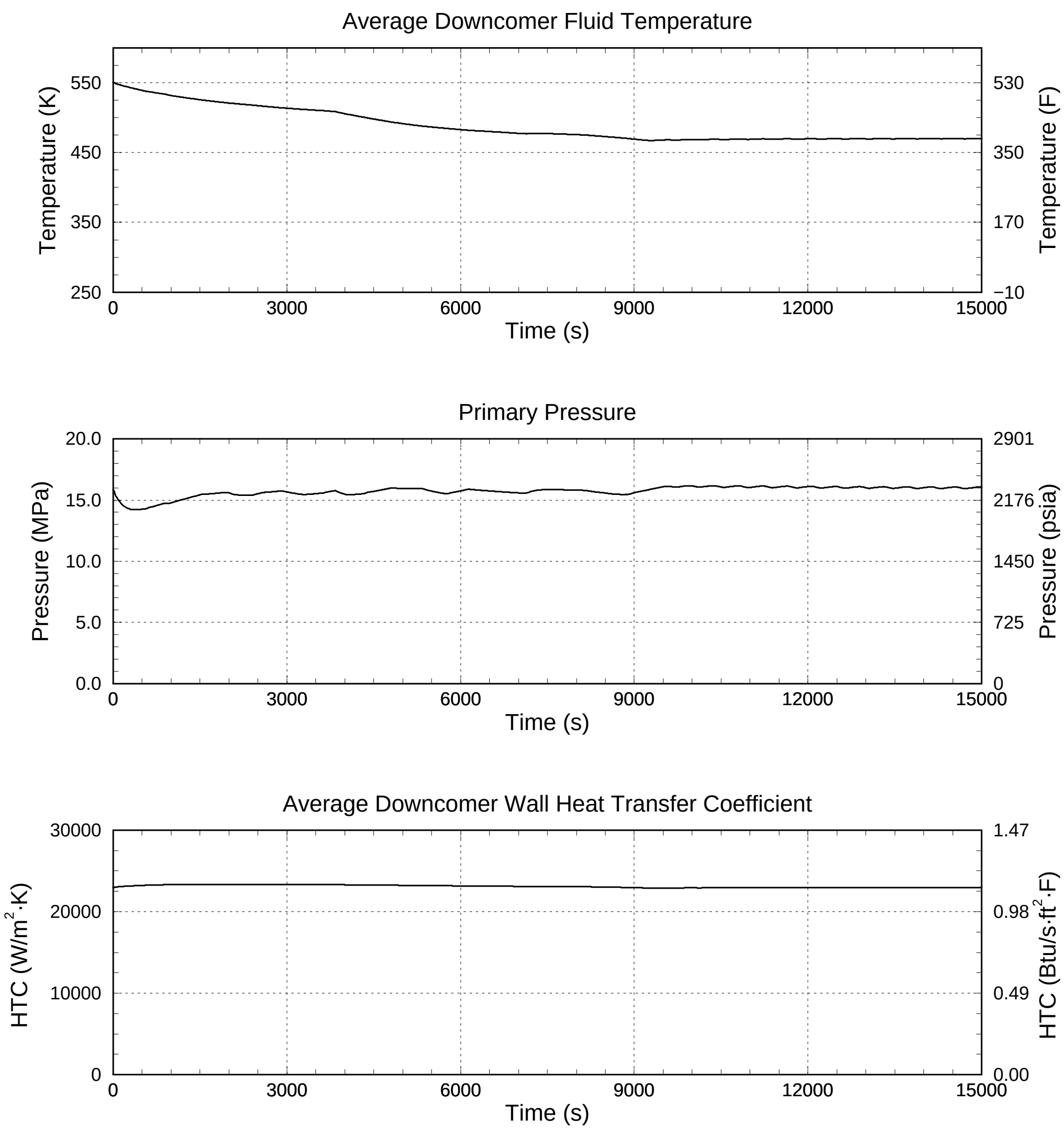


Figure A-62 Calvert Cliffs PTS Results for Case 062

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer PORV from HZP.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	330.2 K [134.6EF] at 15,000 s
Comments	None.

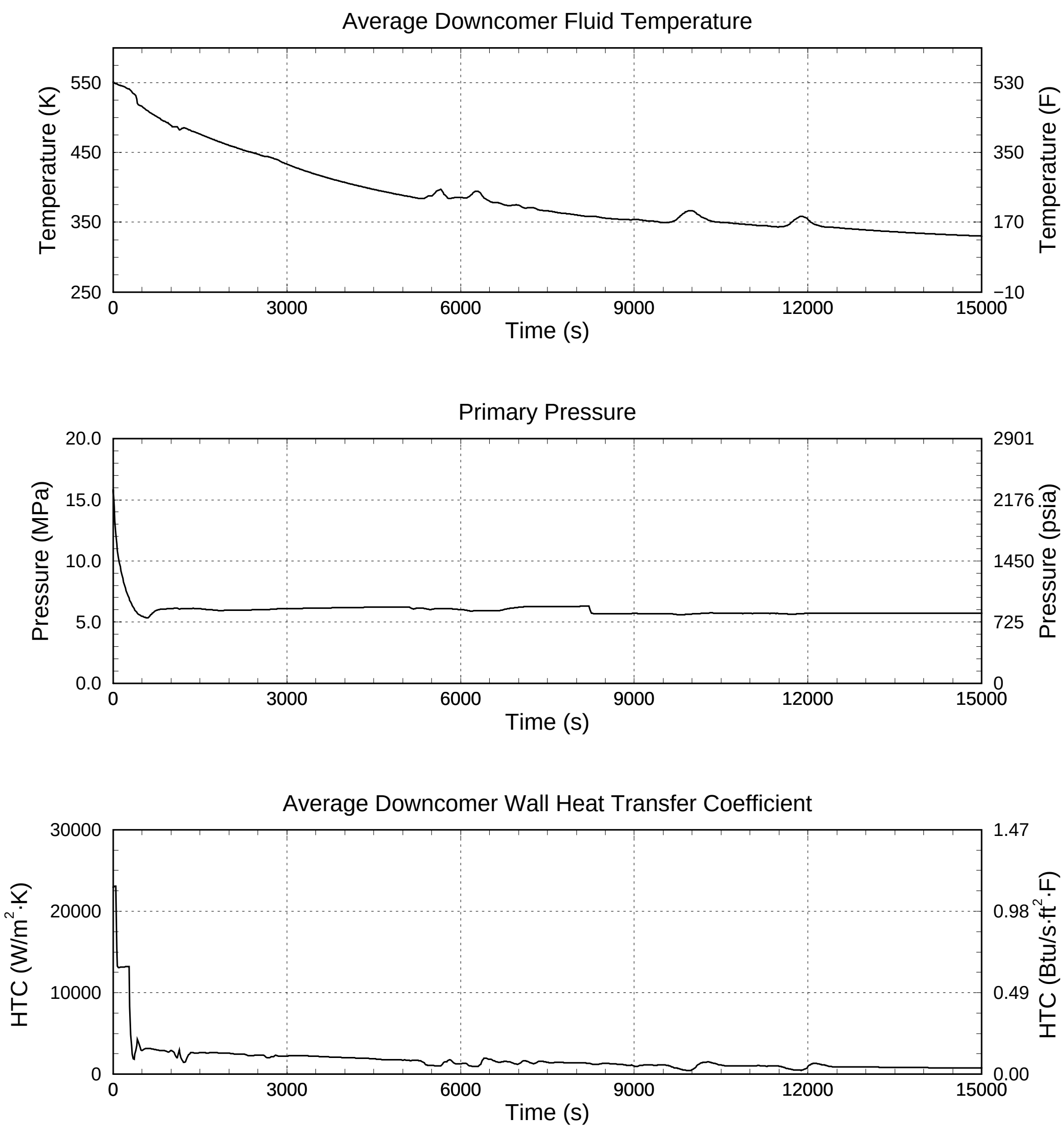


Figure A-63 Calvert Cliffs PTS Results for Case 063

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer SRV from HZP.
Secondary Failures	One stuck open ADV in SG 1.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	293.7 K [69.1EF] at 15,000 s
Comments	None.

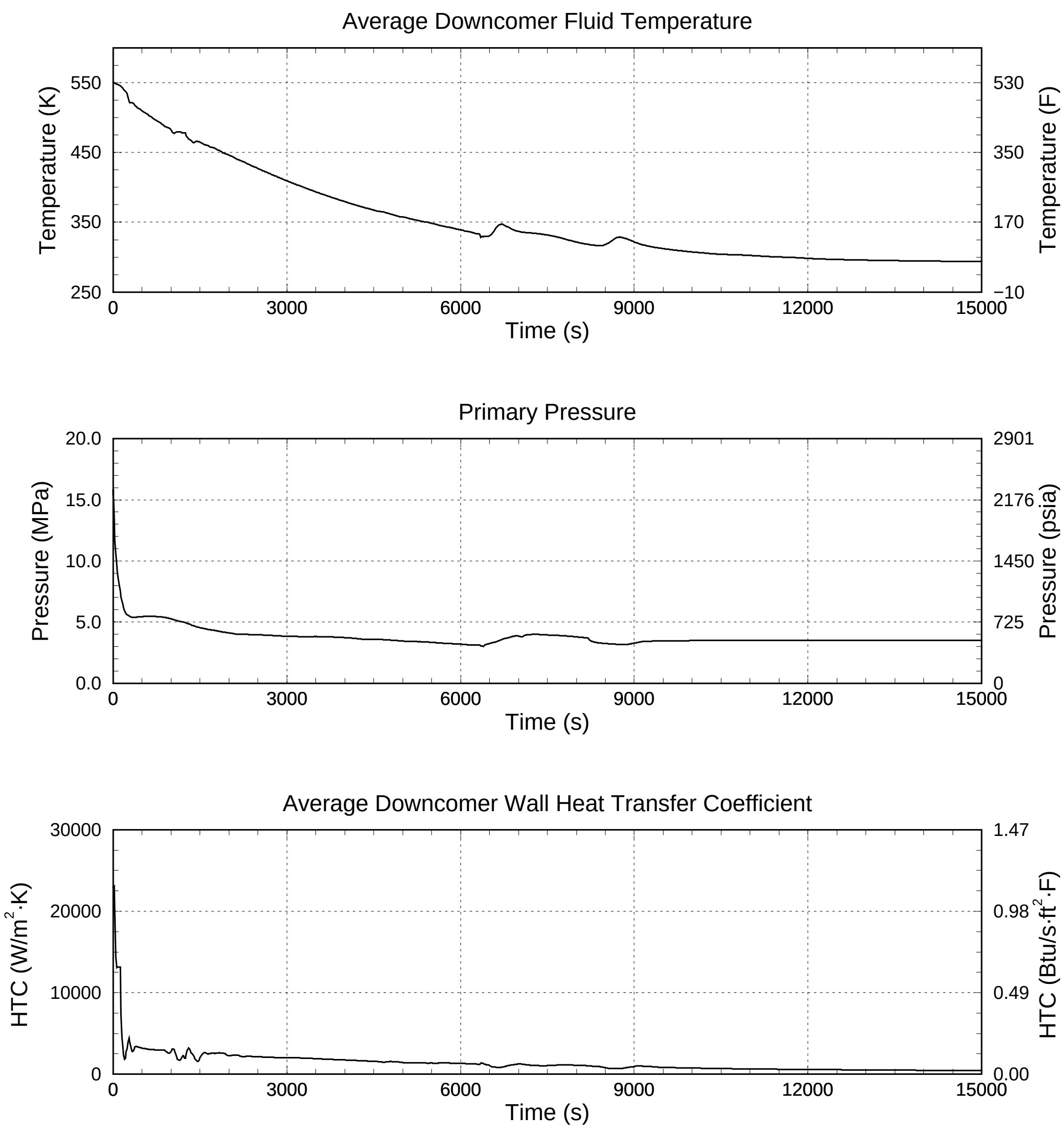
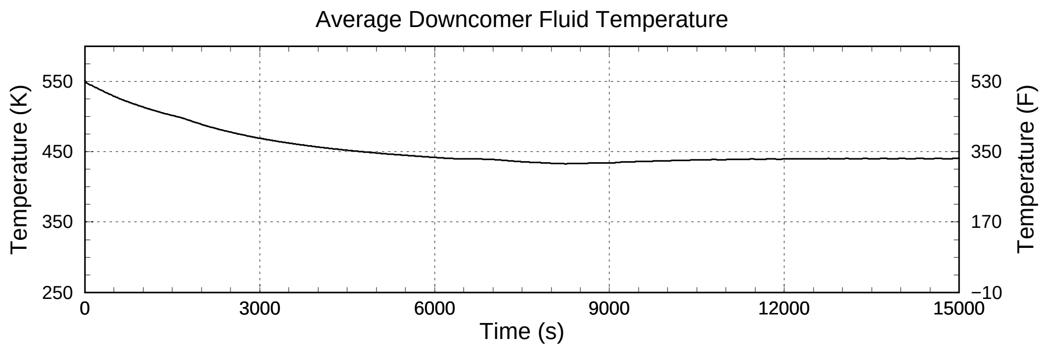
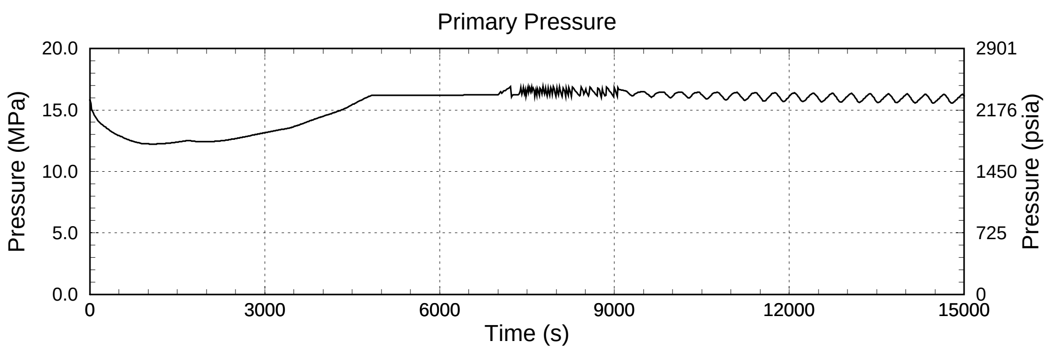


Figure A-64 Calvert Cliffs PTS Results for Case 064

Case Category	RT/TT, HZP
Primary Failures	None.
Secondary Failures	One stuck open main steam SRV from HZP.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	432.8 K [319.3EF] at 8,265 s
Comments	None.





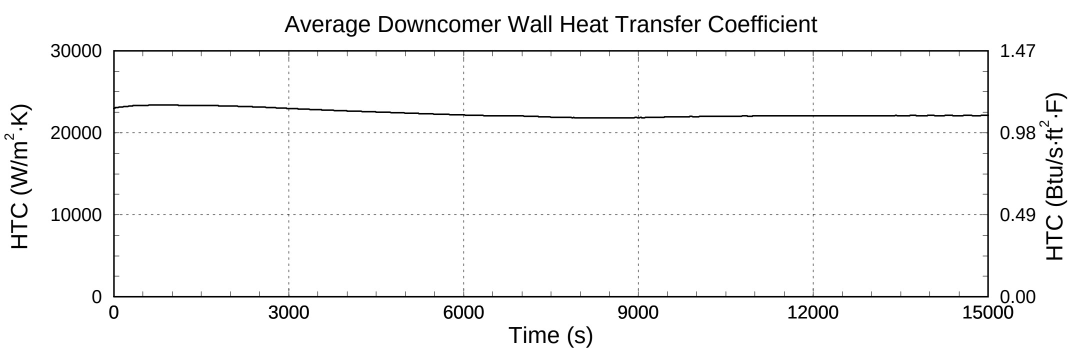


Figure A-65 Calvert Cliffs PTS Results for Case 065

Case Category	MSLB, HZP
Primary Failures	None.
Secondary Failures	Main Steam Line Break (double ended guillotine break) from HZP.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	380.0 K [224.4EF] at 7,125 s
Comments	None.

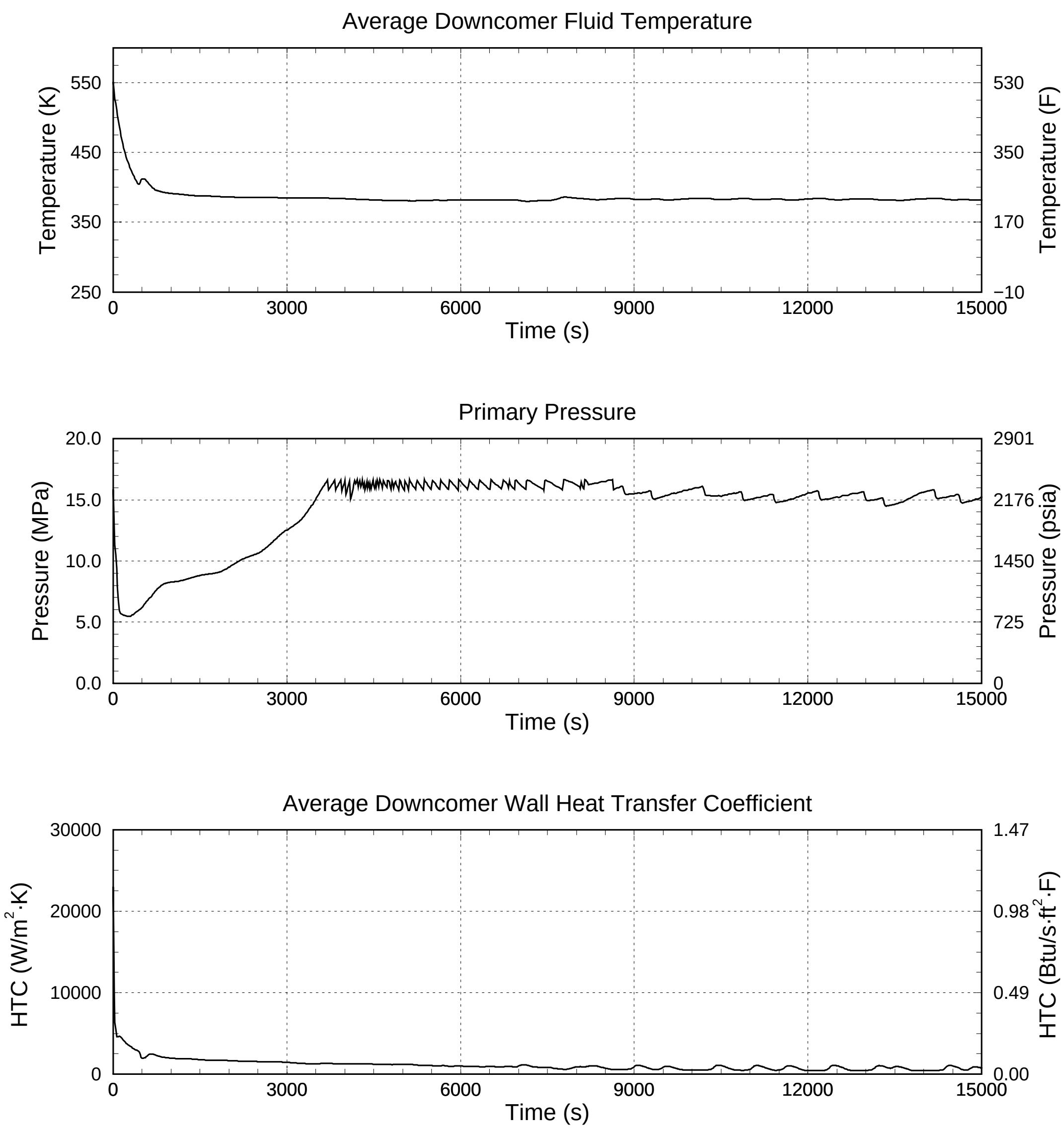


Figure A-66 Calvert Cliffs PTS Results for Case 066

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer SRV from HZP.
Secondary Failures	One stuck open main steam SRV.
Operator Actions	None. Operator fails to isolate AFW.
Min DC Temperature	300.5 K [81.2EF] at 15,000 s
Comments	None.

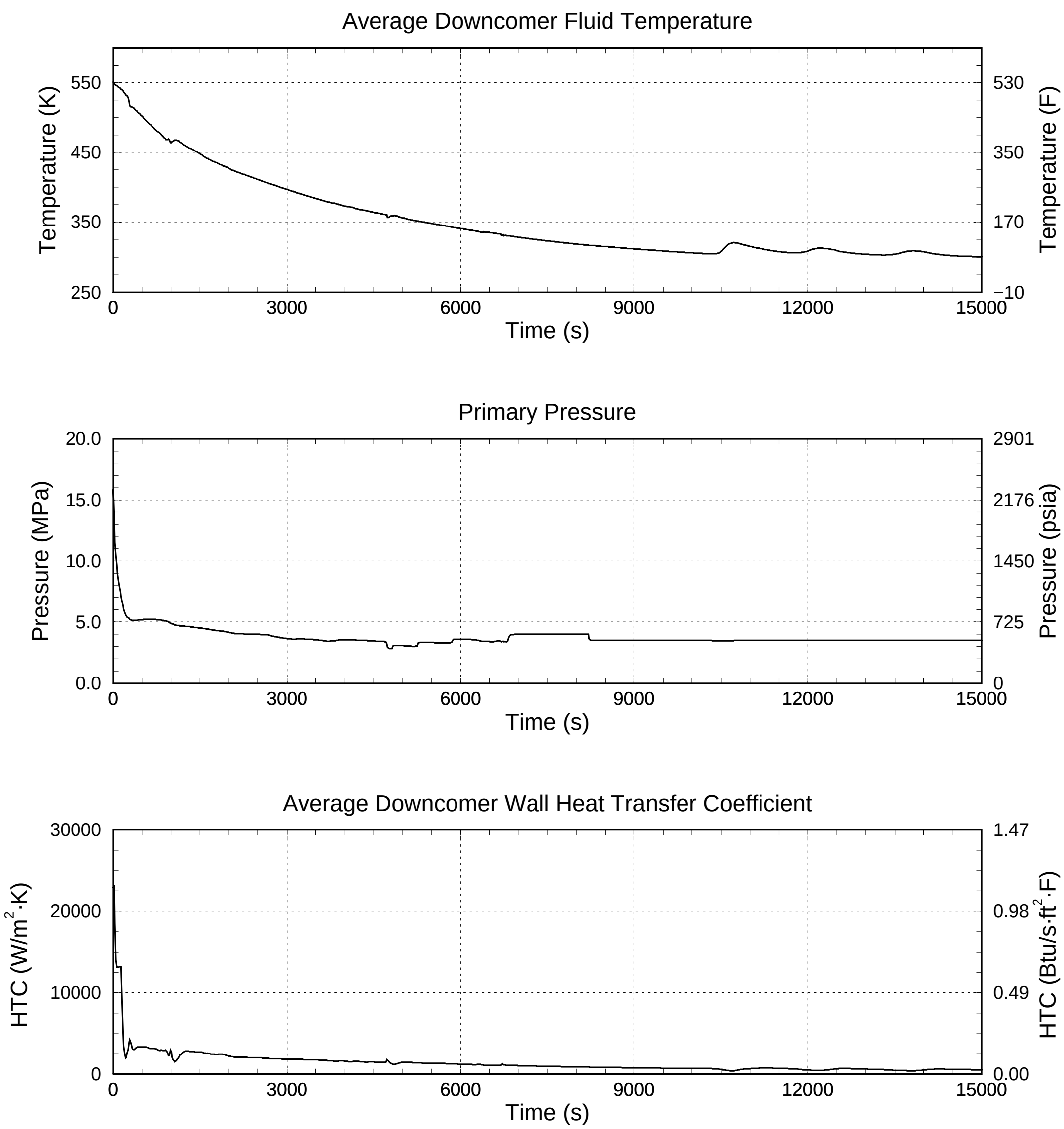


Figure A-67   Calvert Cliffs PTS Results for Case 067

Case Category	LOCA, HZP
Primary Failures	10.16 cm [4.0 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.0 K [60.5EF] at 14,610 s
Comments	None.

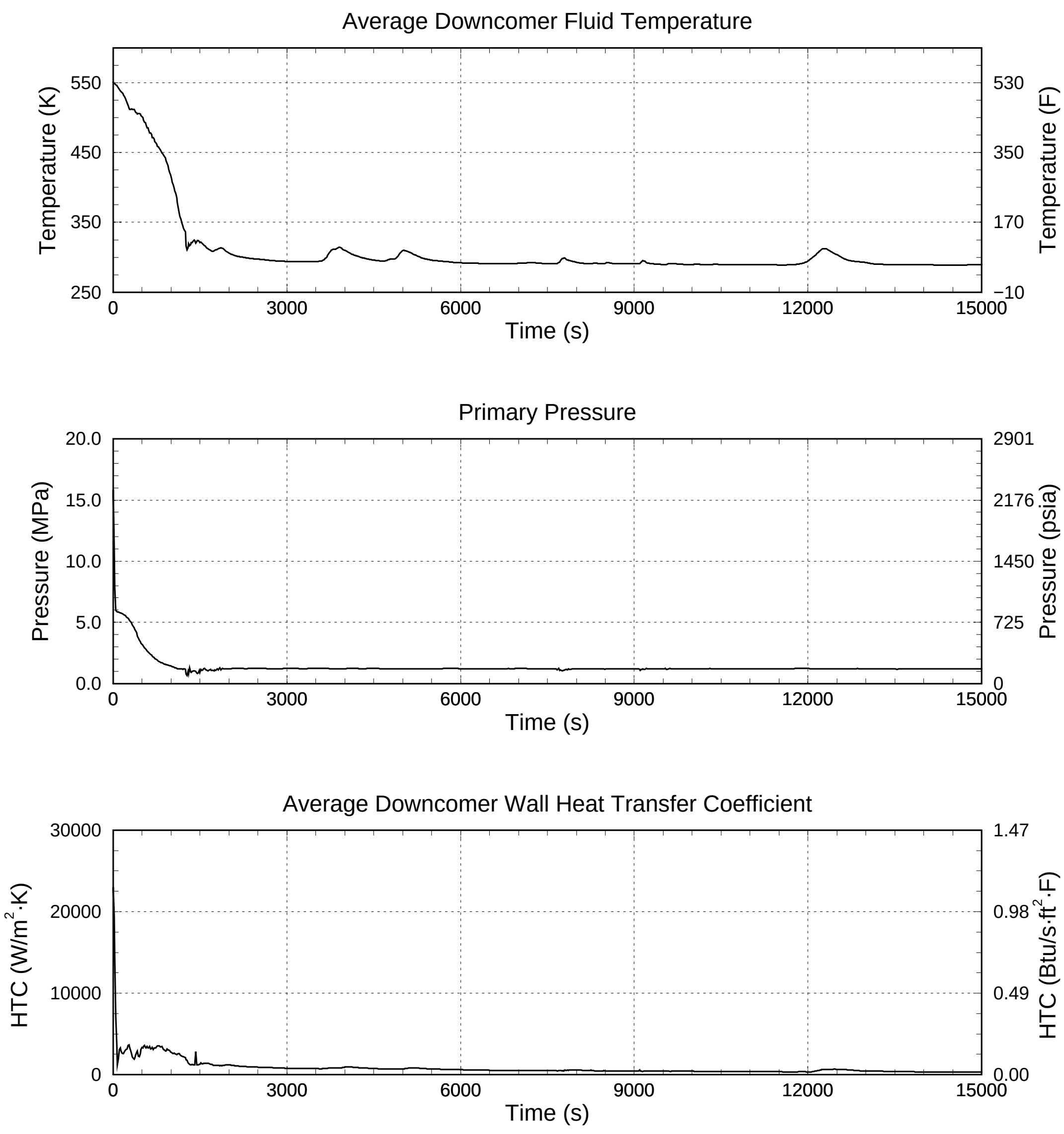


Figure A-68   Calvert Cliffs PTS Results for Case 068

Case Category	LOCA, HZP
Primary Failures	14.37 cm [5.657 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	288.9 K [60.3EF] at 14,430 s
Comments	None.

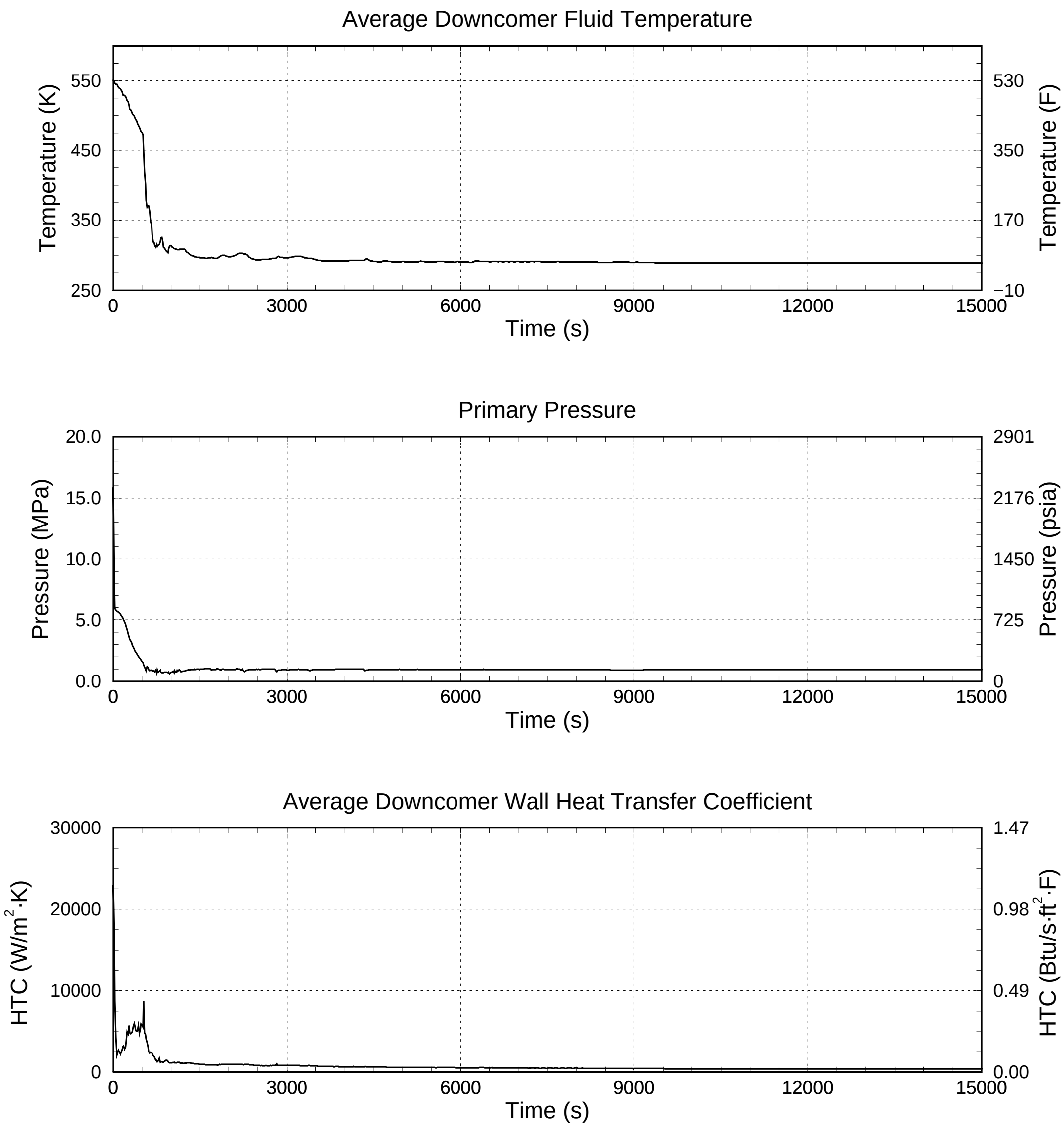


Figure A-69 Calvert Cliffs PTS Results for Case 069

Case Category	LOCA, HZP
Primary Failures	57.47 cm [22.627 in] hot leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.3 K [62.9EF] at 1,515 s
Comments	Includes sump recirculation.

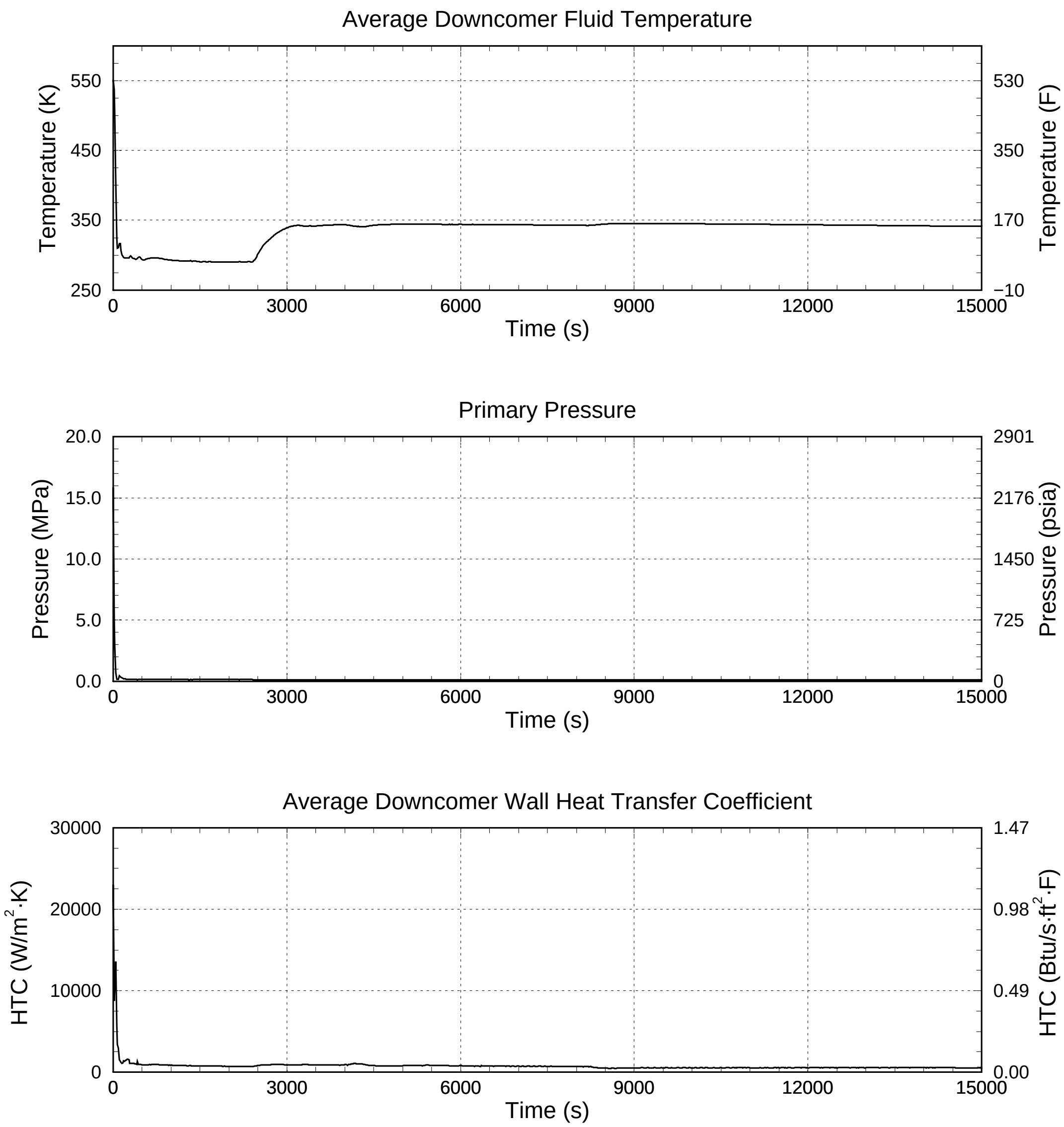


Figure A-70 Calvert Cliffs PTS Results for Case 070

Case Category	LOCA, HZP
Primary Failures	3.59 cm [1.414 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	294.3 K [70.1EF] at 15,000 s
Comments	None.

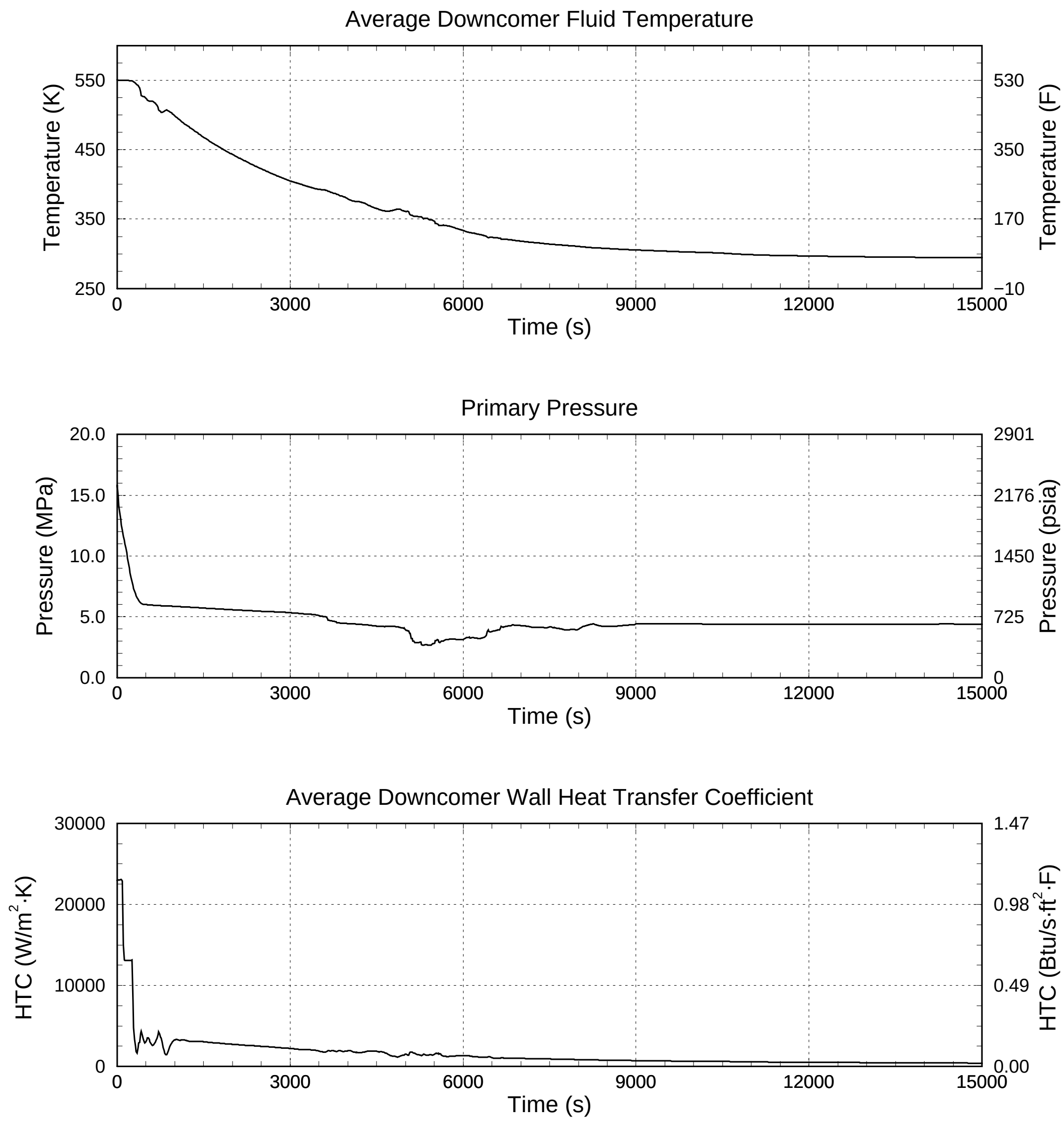


Figure A-71 Calvert Cliffs PTS Results for Case 071

Case Category	LOCA, HZP
Primary Failures	20.32 cm [8.0 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.3 K [61.0EF] at 10,545 s
Comments	None.

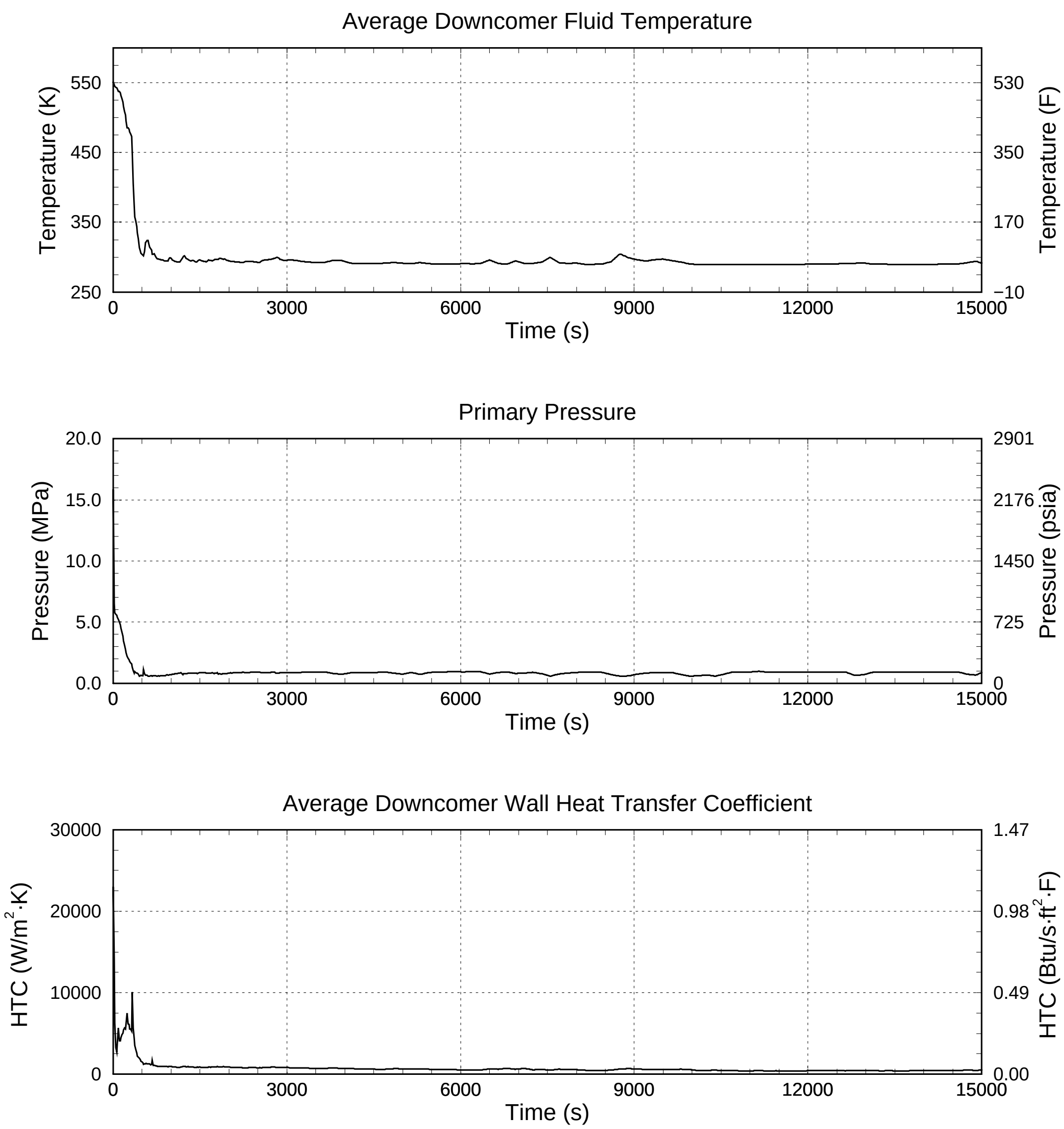


Figure A-72 Calvert Cliffs PTS Results for Case 072

Case Category	LOCA, HZP
Primary Failures	28.74 cm [11.314 in] hot leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.4 K [63.0EF] at 2,520 s
Comments	Includes sump recirculation.

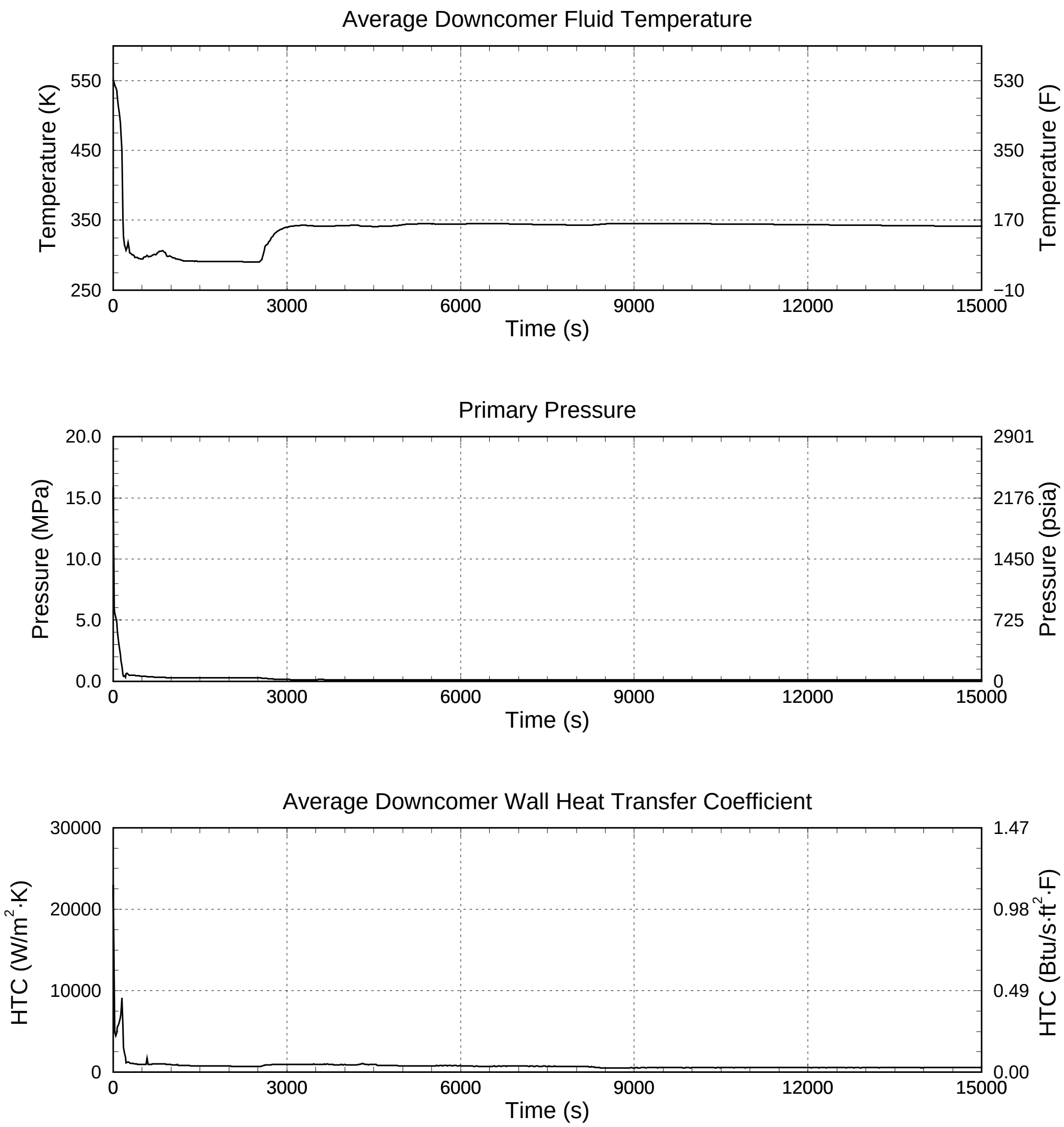


Figure A-73 Calvert Cliffs PTS Results for Case 073

Case Category	LOCA, HZP
Primary Failures	40.64 cm [16.0 in] hot leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	290.7 K [63.5EF] at 2,460 s
Comments	Includes sump recirculation.

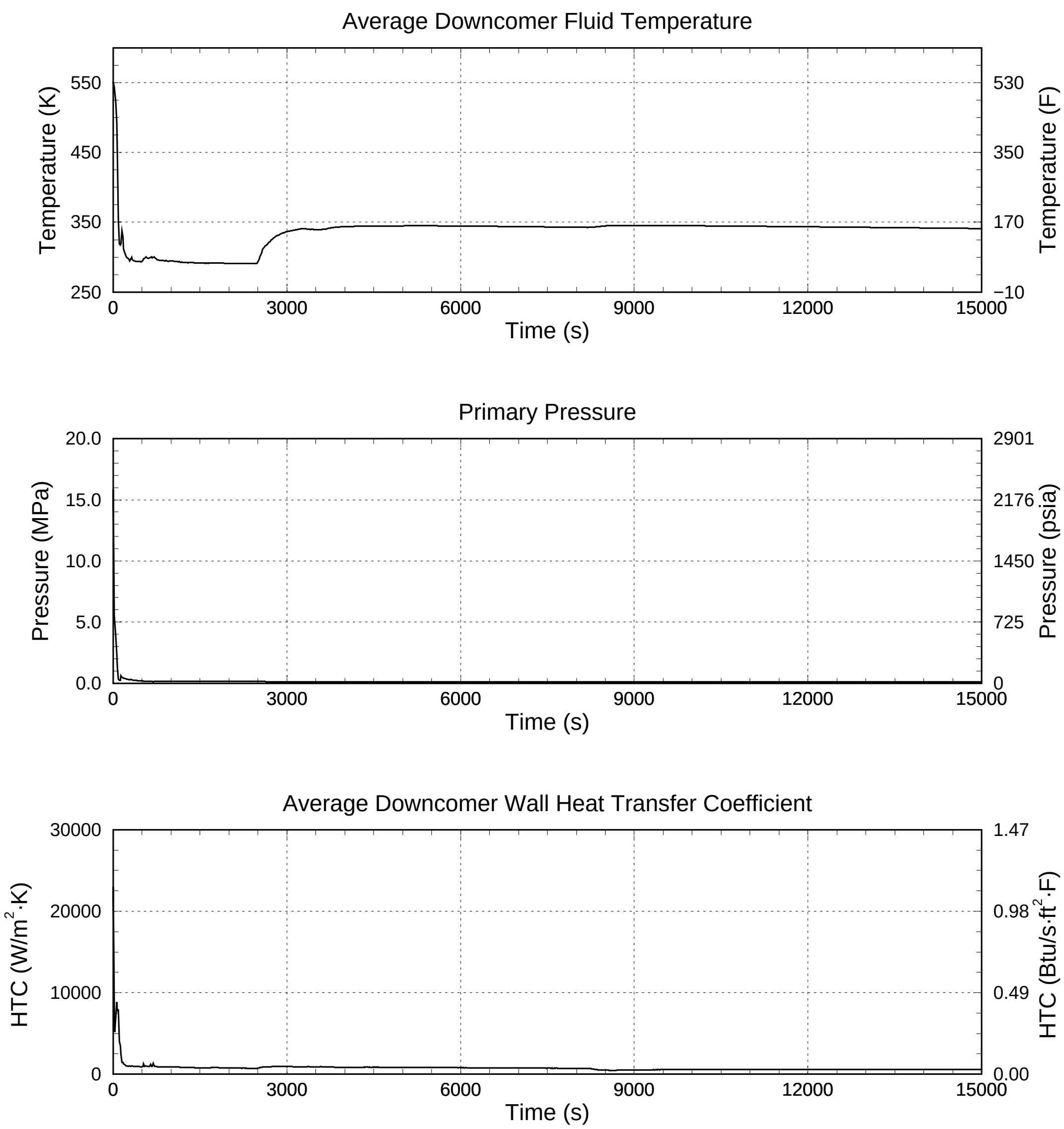
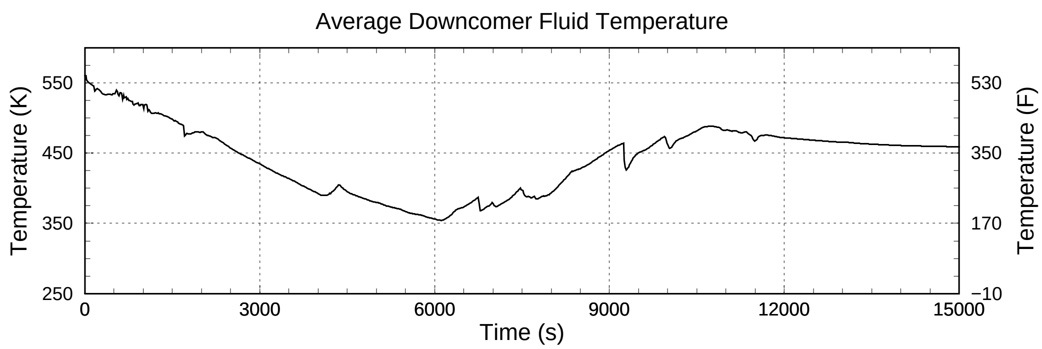
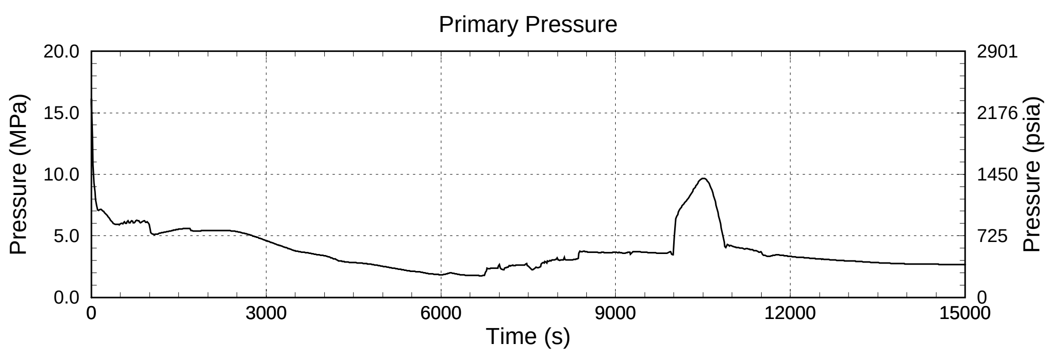


Figure A-74 Calvert Cliffs PTS Results for Case 074

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose at 6,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	354.0 K [177.5EF] at 6,105 s
Comments	None.





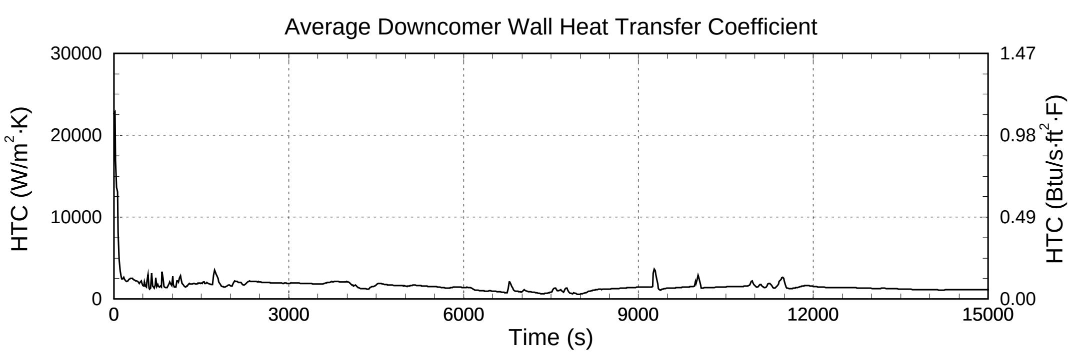


Figure A-75 Calvert Cliffs PTS Results for Case 075

Case Category	RT/TT, HZP
Primary Failures	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	308.4 K [95.5EF] at 6,030 s
Comments	None.

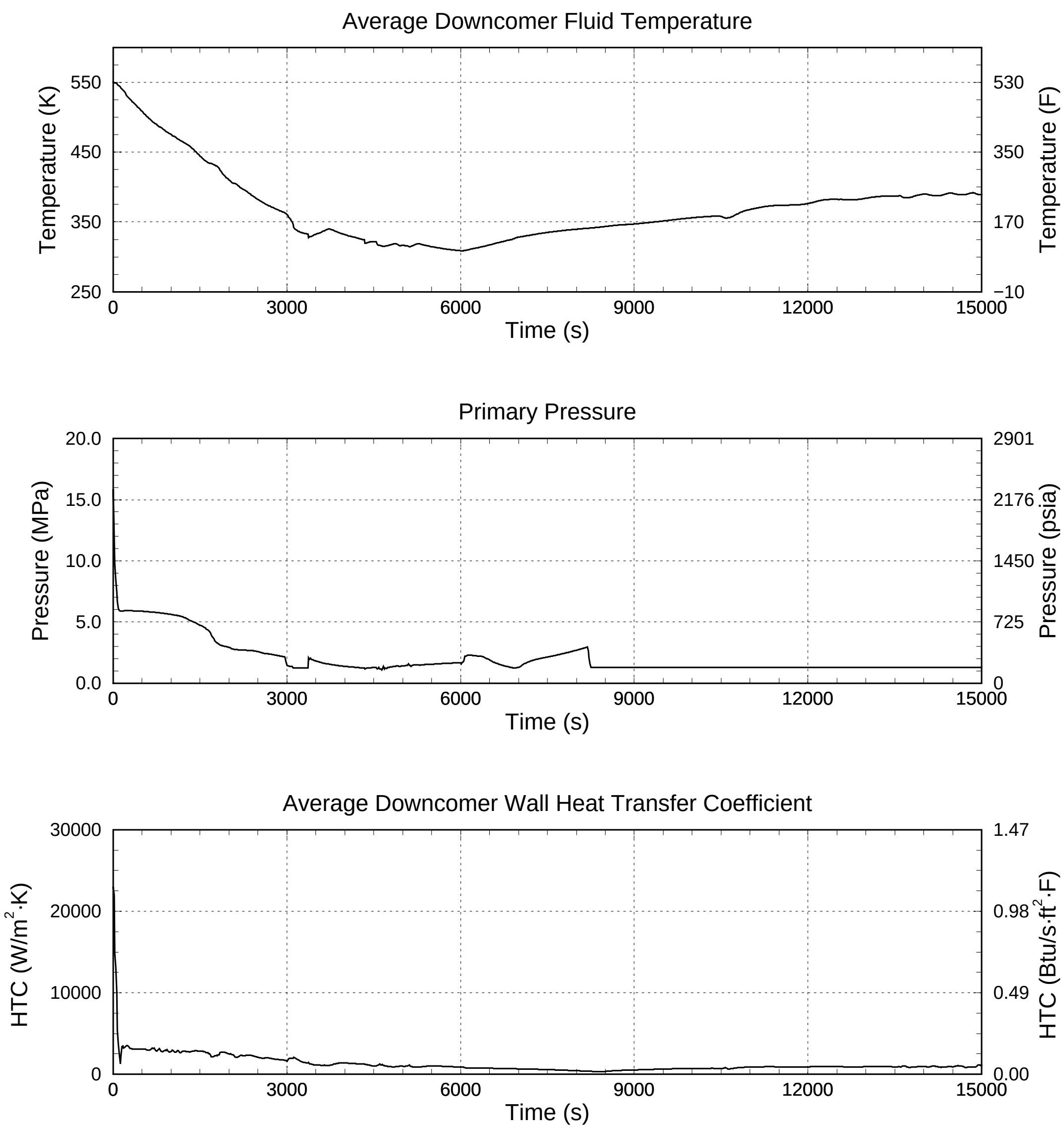


Figure A-76 Calvert Cliffs PTS Results for Case 076

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose at 6,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	348.6 K [167.8EF] at 6,570 s
Comments	None.

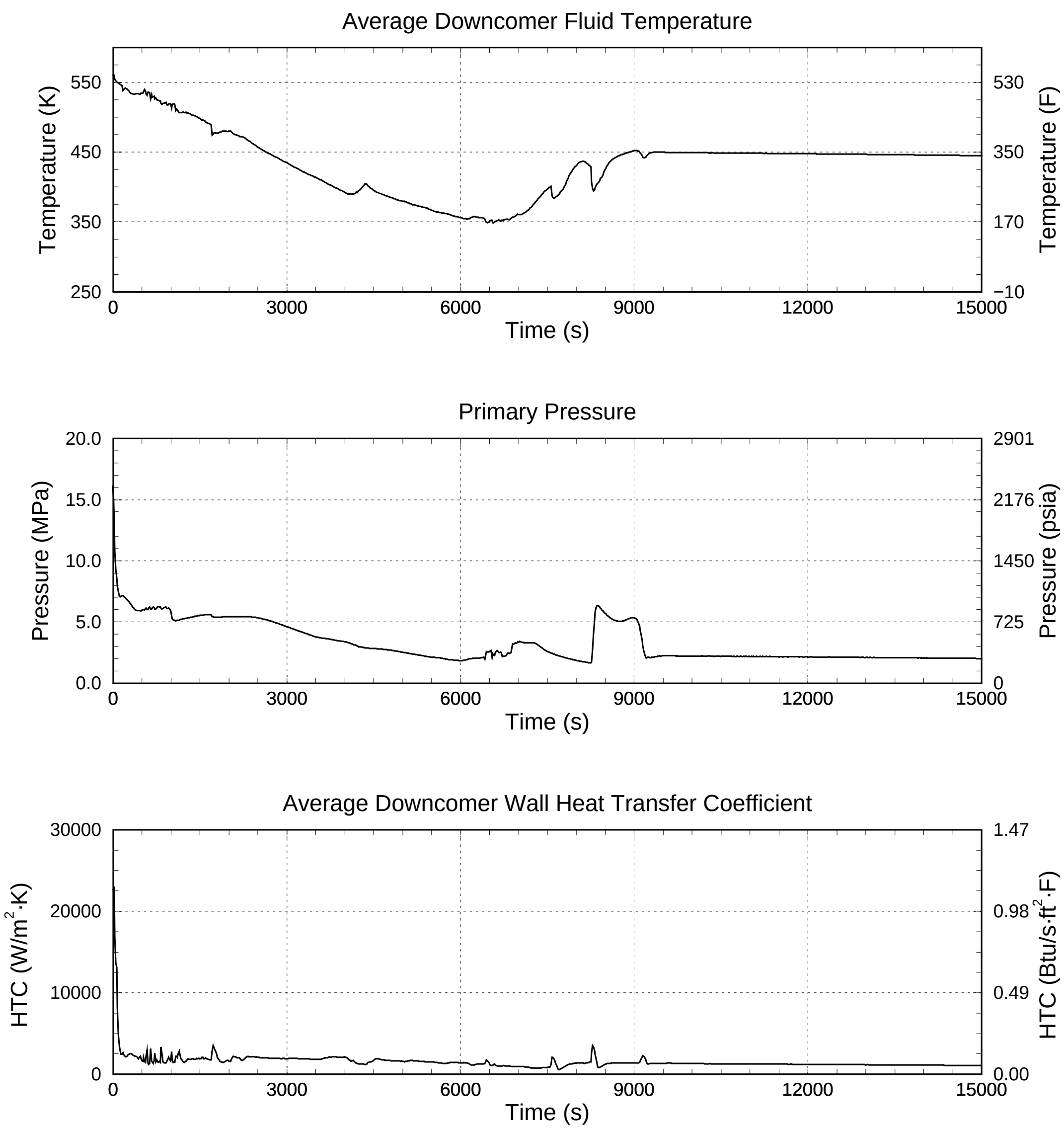


Figure A-77 Calvert Cliffs PTS Results for Case 077

Case Category	RT/TT, HZP
Primary Failures	Two stuck open pressurizer SRVs that reclose at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	308.4 K [95.5EF] at 6,030 s
Comments	None.

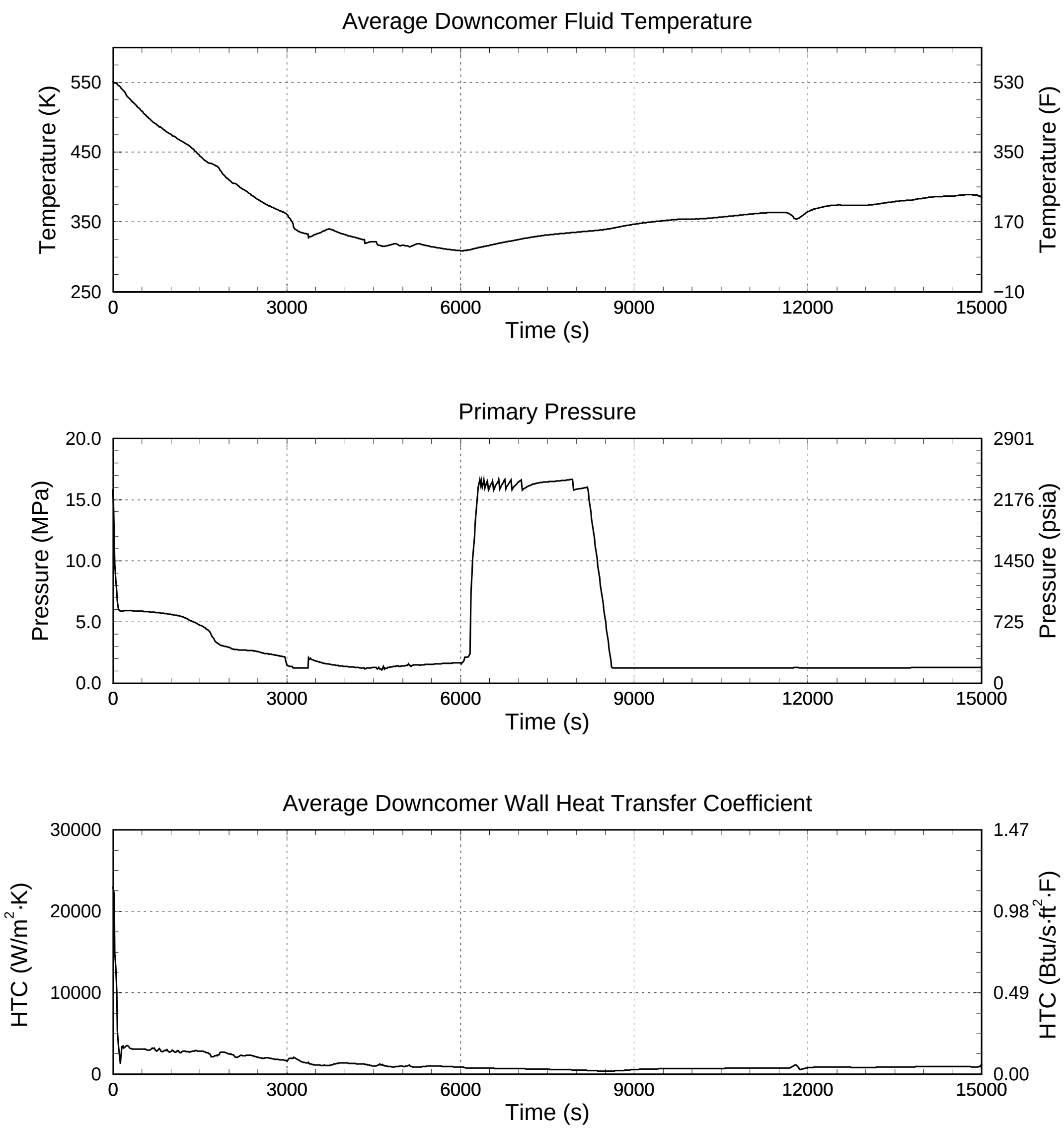


Figure A-78 Calvert Cliffs PTS Results for Case 078

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	329.7 K [133.8EF] at 5,985 s
Comments	None.

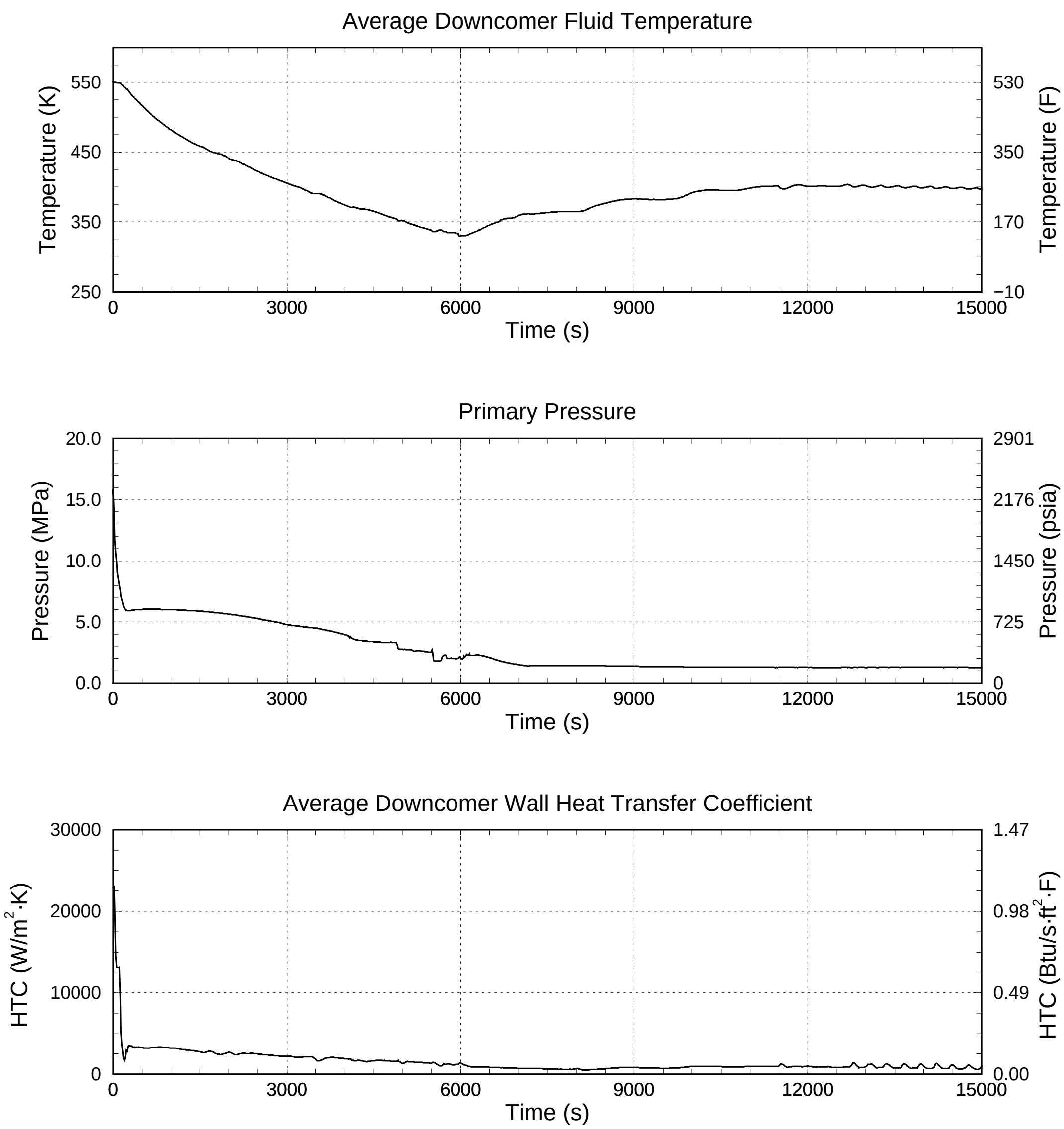


Figure A-79 Calvert Cliffs PTS Results for Case 079

Case Category	RT/TT, HZP
Primary Failures	One stuck open pressurizer SRV that recloses at 6,000 s from HZP.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	329.7 K [133.8EF] at 5,985 s
Comments	None.

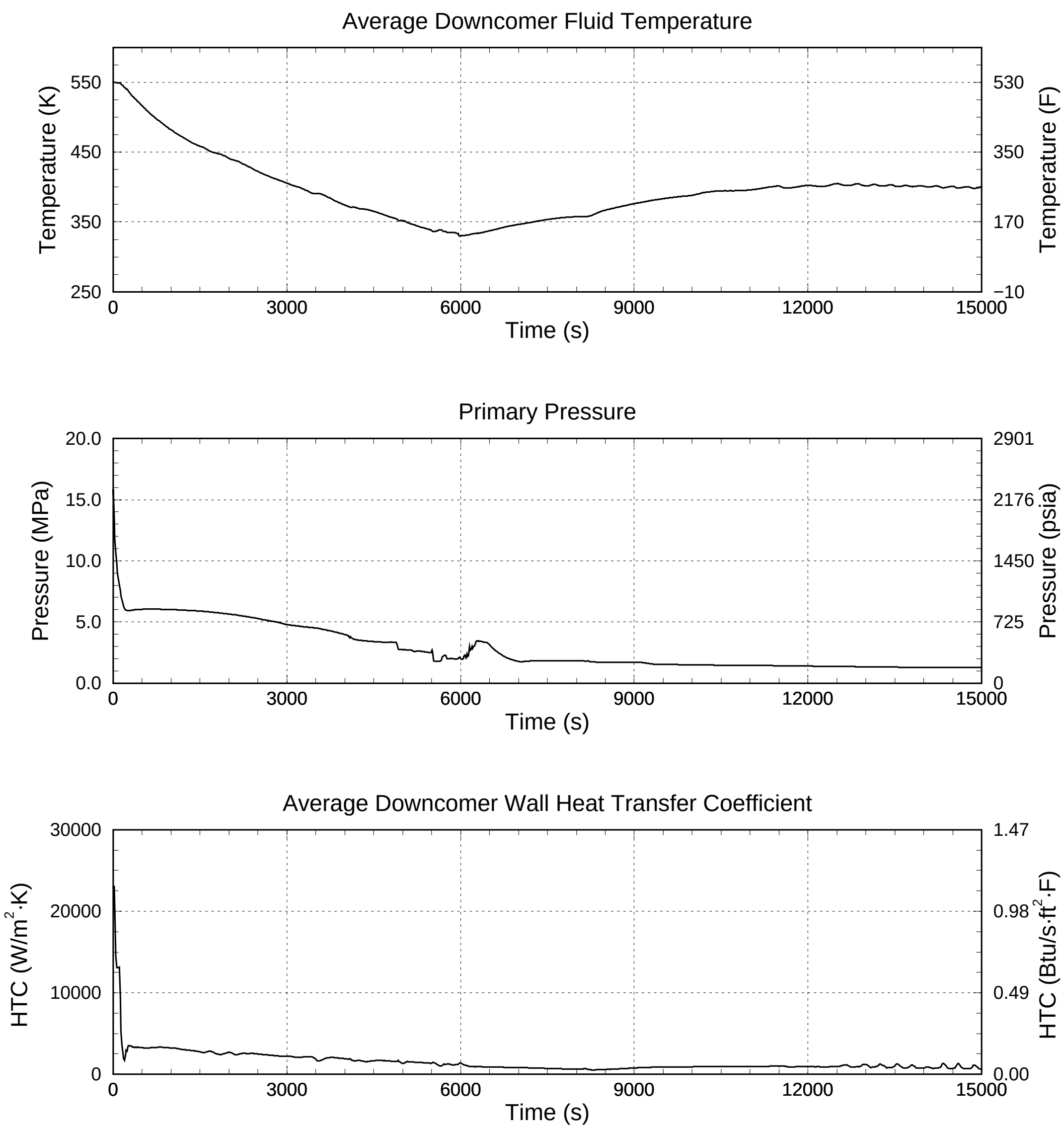


Figure A-80 Calvert Cliffs PTS Results for Case 080

Case Category	LOCA
Primary Failures	7.18 cm [2.828 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	307.6 K [93.9EF] at 8,115 s
Comments	DC fluid to wall heat transfer coefficient decreased by 30%.

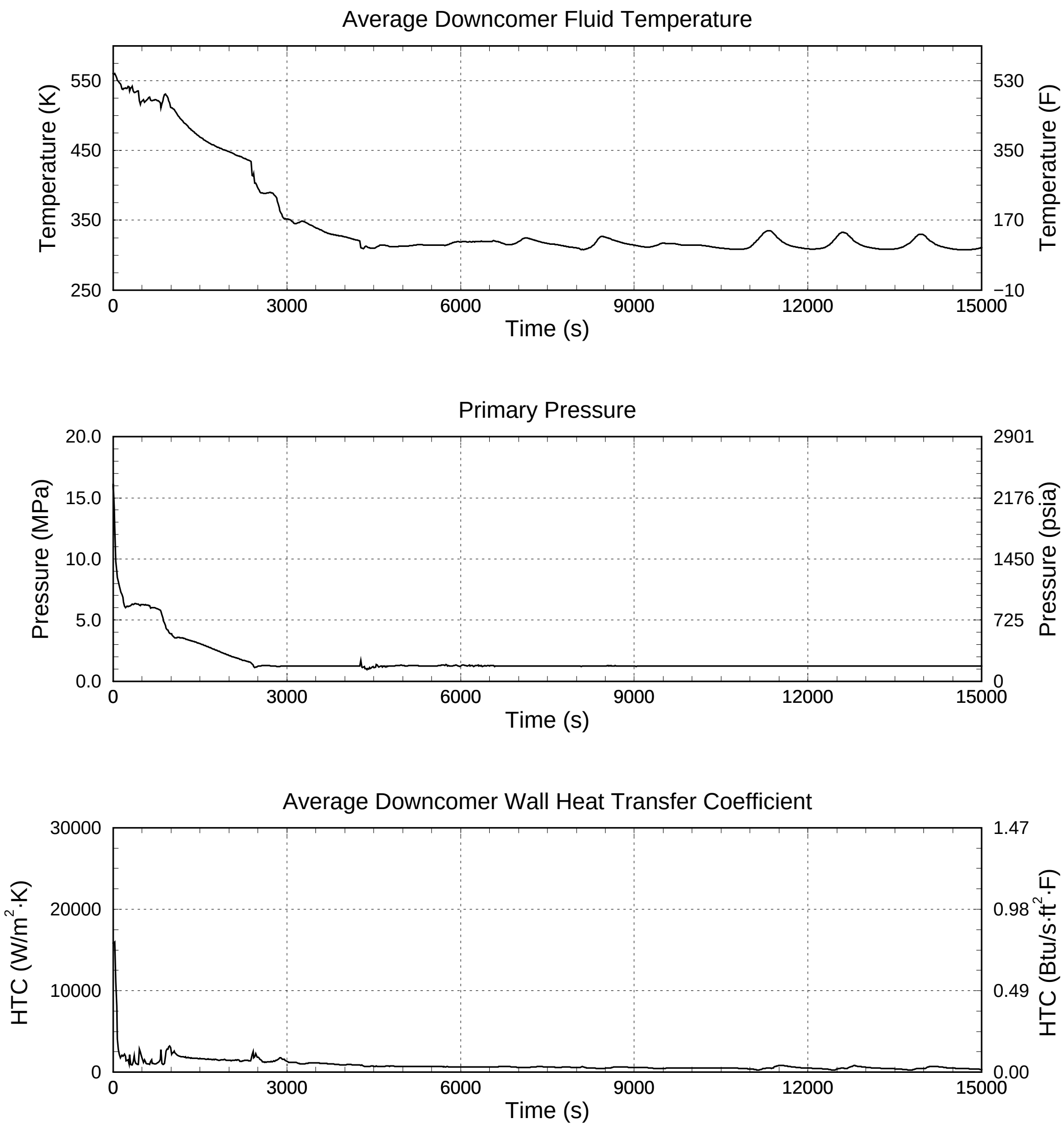


Figure A-81   Calvert Cliffs PTS Results for Case 081

Case Category	LOCA
Primary Failures	7.18 cm [2.828 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	303.5 K [86.7EF] at 15,000 s
Comments	DC fluid to wall heat transfer coefficient increased by 30%.

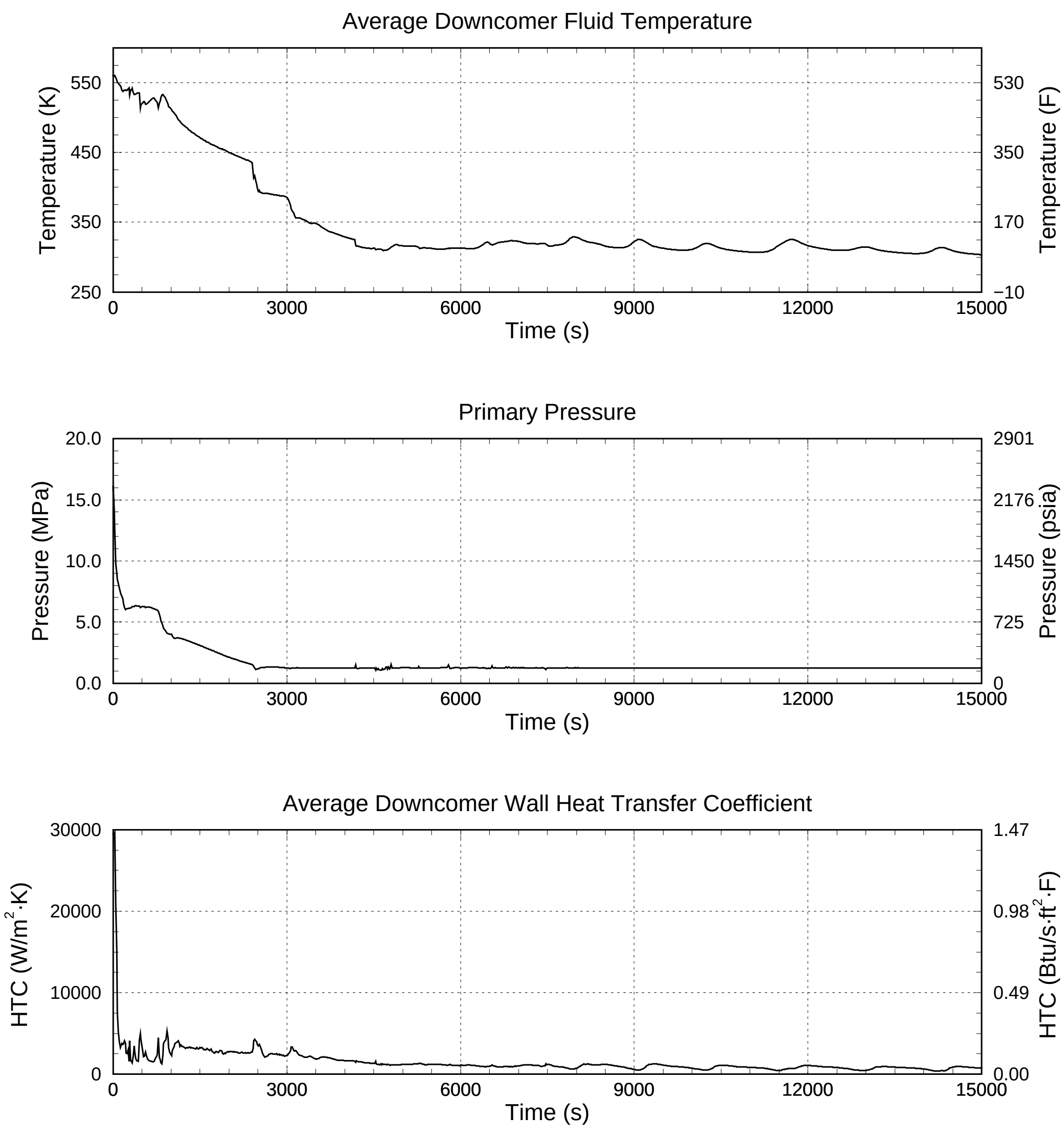
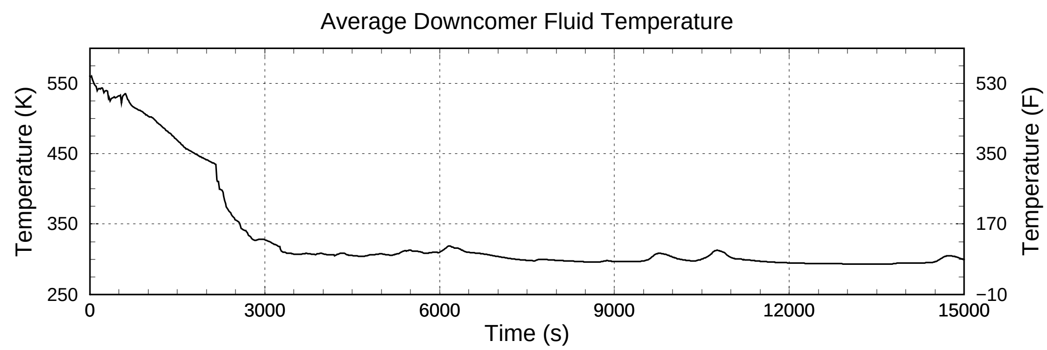
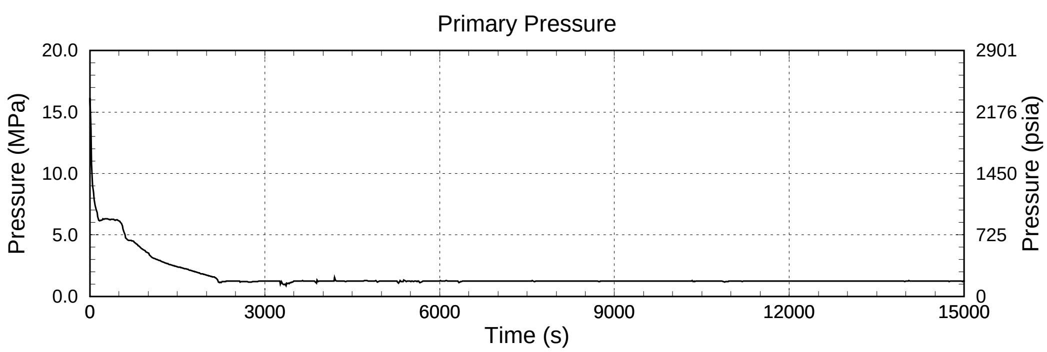


Figure A-82 Calvert Cliffs PTS Results for Case 082

Case Category	LOCA
Primary Failures	8.5 cm [3.347 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	293.0 K [67.8EF] at 13,725 s
Comments	DC fluid to wall heat transfer coefficient increased by 30%.





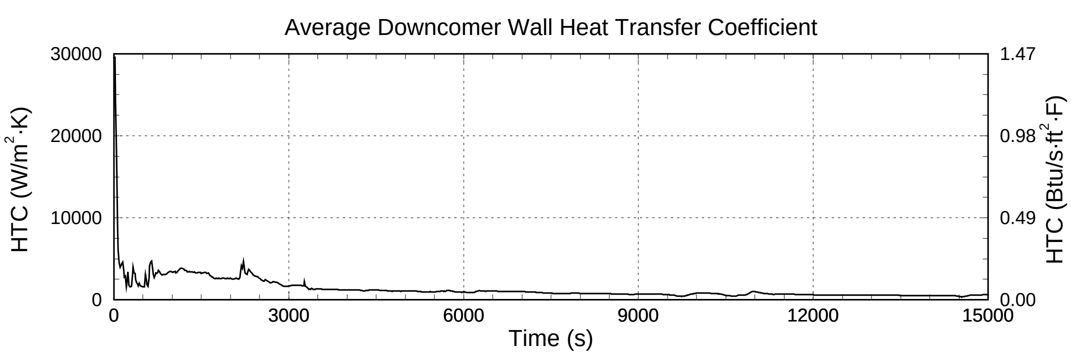


Figure A-83 Calvert Cliffs PTS Results for Case 083

Case Category	LOCA
Primary Failures	6.01 cm [2.366 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	301.4 K [82.8EF] at 5,490 s
Comments	Winter conditions assumed.

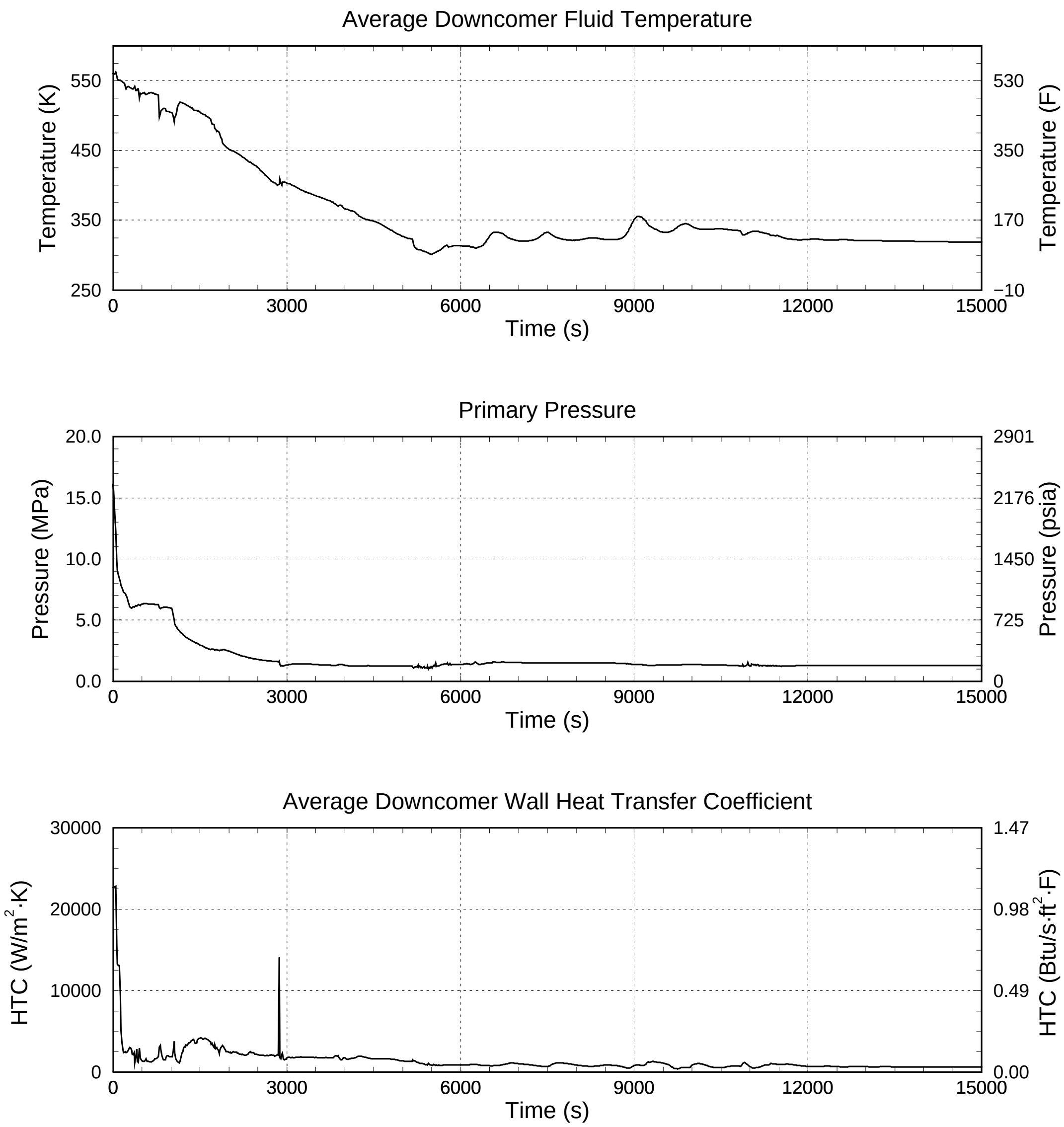


Figure A-84   Calvert Cliffs PTS Results for Case 084

Case Category	LOCA
Primary Failures	6.01 cm [2.366 in] cold leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	339.5 K [151.4EF] at 14,280 s
Comments	None.

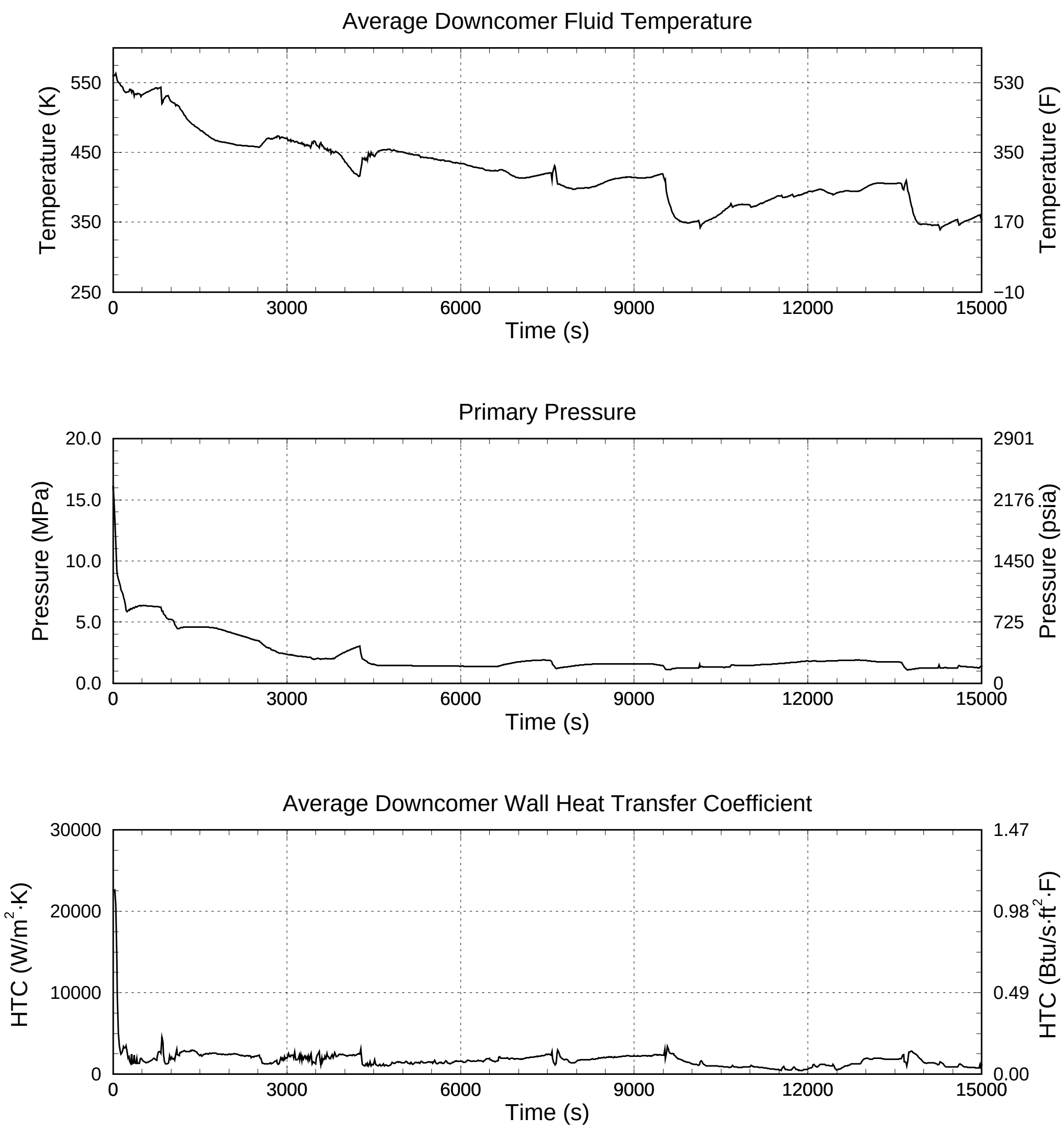


Figure A-85 Calvert Cliffs PTS Results for Case 085

Case Category	LOCA, HZP
Primary Failures	8.5 cm [3.347 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	300.4 K [81.1EF] at 15,000 s
Comments	Summer conditions assumed.

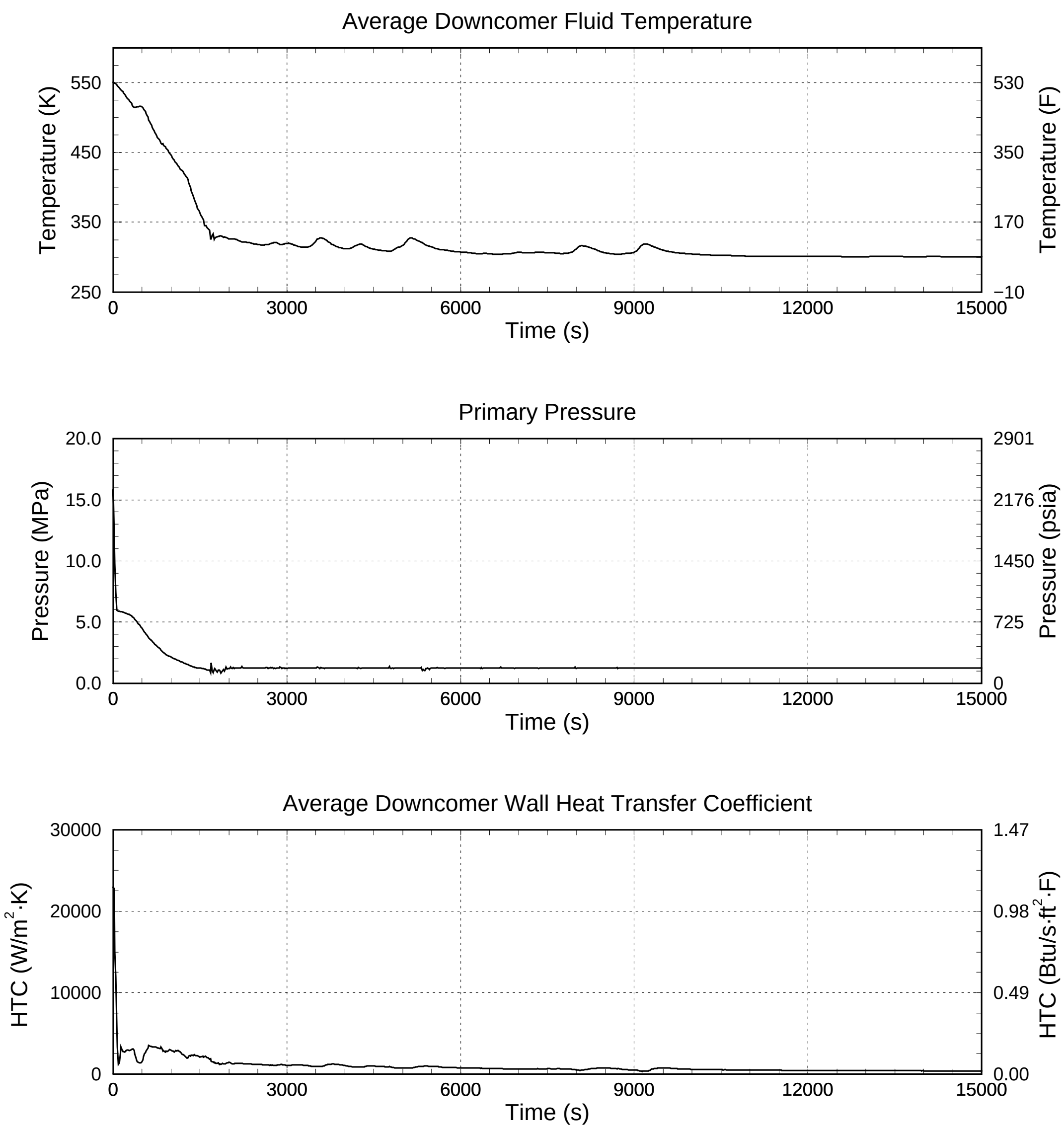
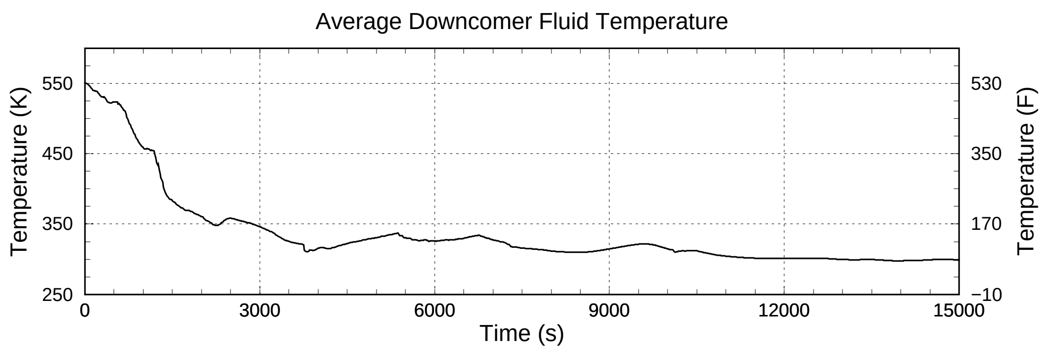
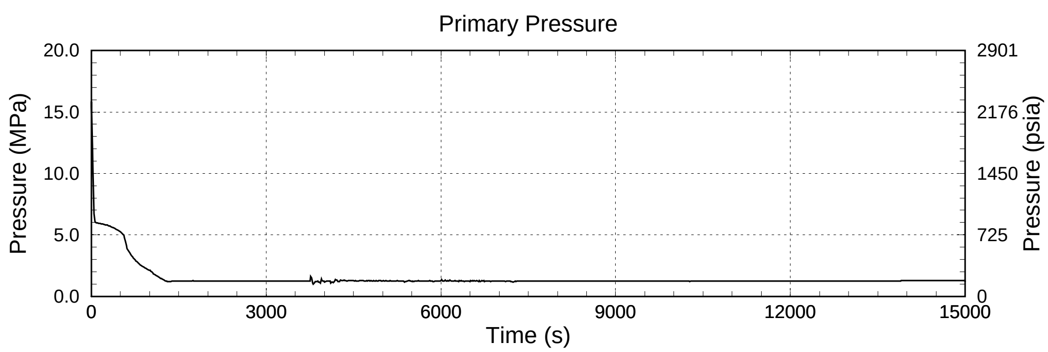


Figure A-86 Calvert Cliffs PTS Results for Case 087

Case Category	LOCA, HZP
Primary Failures	6.01 cm [2.366 in] cold leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	297.7 K [76.2EF] at 13,935 s
Comments	HPI flow increased by 10%.





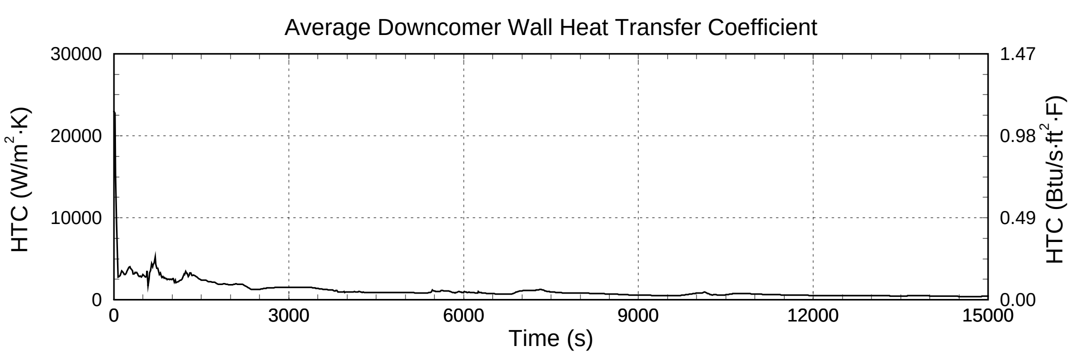


Figure A-87   Calvert Cliffs PTS Results for Case 088

Case Category	LOCA, HZP
Primary Failures	6.01 cm [2.366 in] cold leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	303.4 K [86.4EF] at 13,890 s
Comments	Winter conditions assumed.

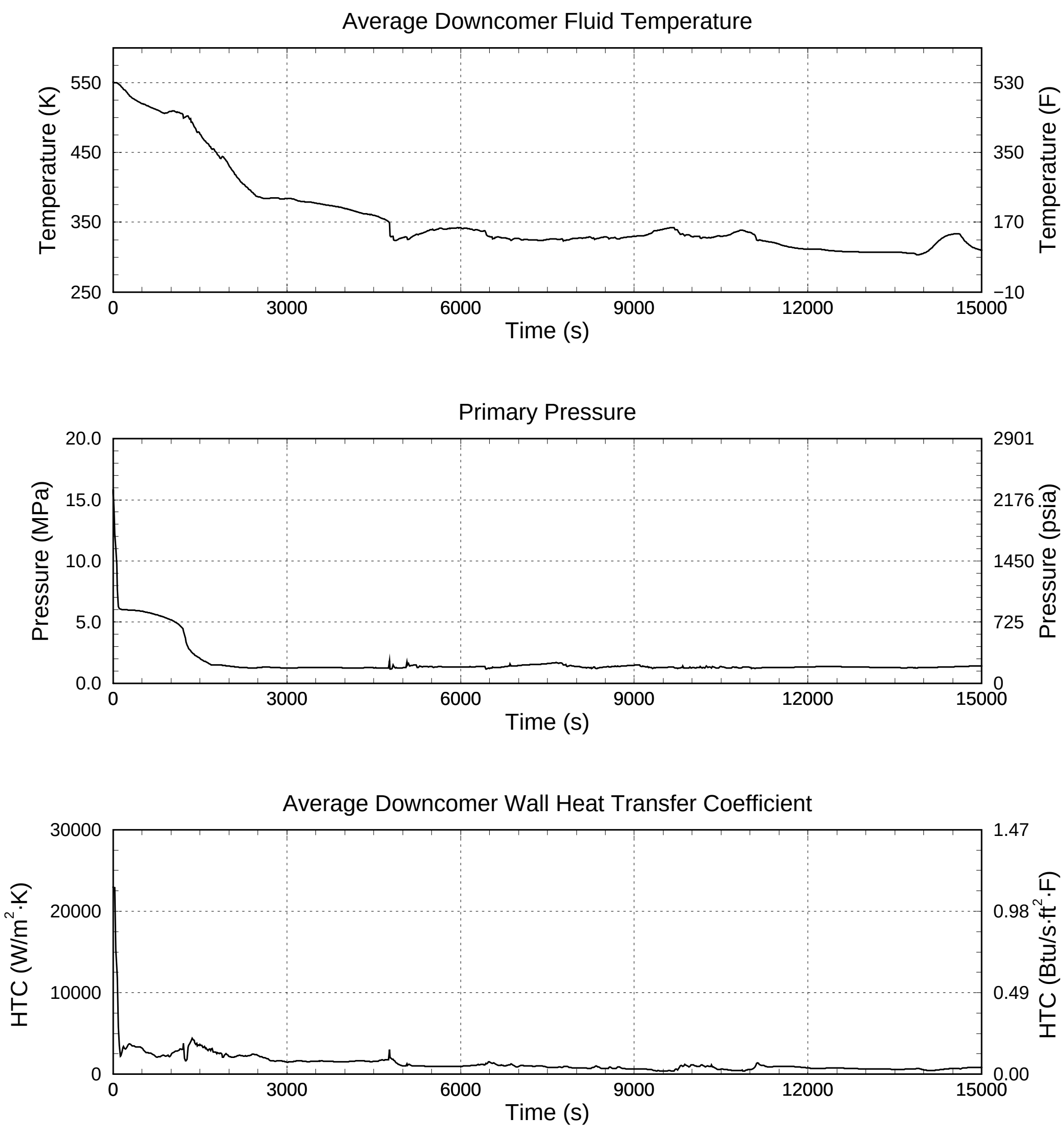


Figure A-88 Calvert Cliffs PTS Results for Case 089

Case Category	LOCA
Primary Failures	20.32 cm [8.0 in] cold leg break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.0 K [60.5EF] at 11,715 s
Comments	Winter conditions assumed.

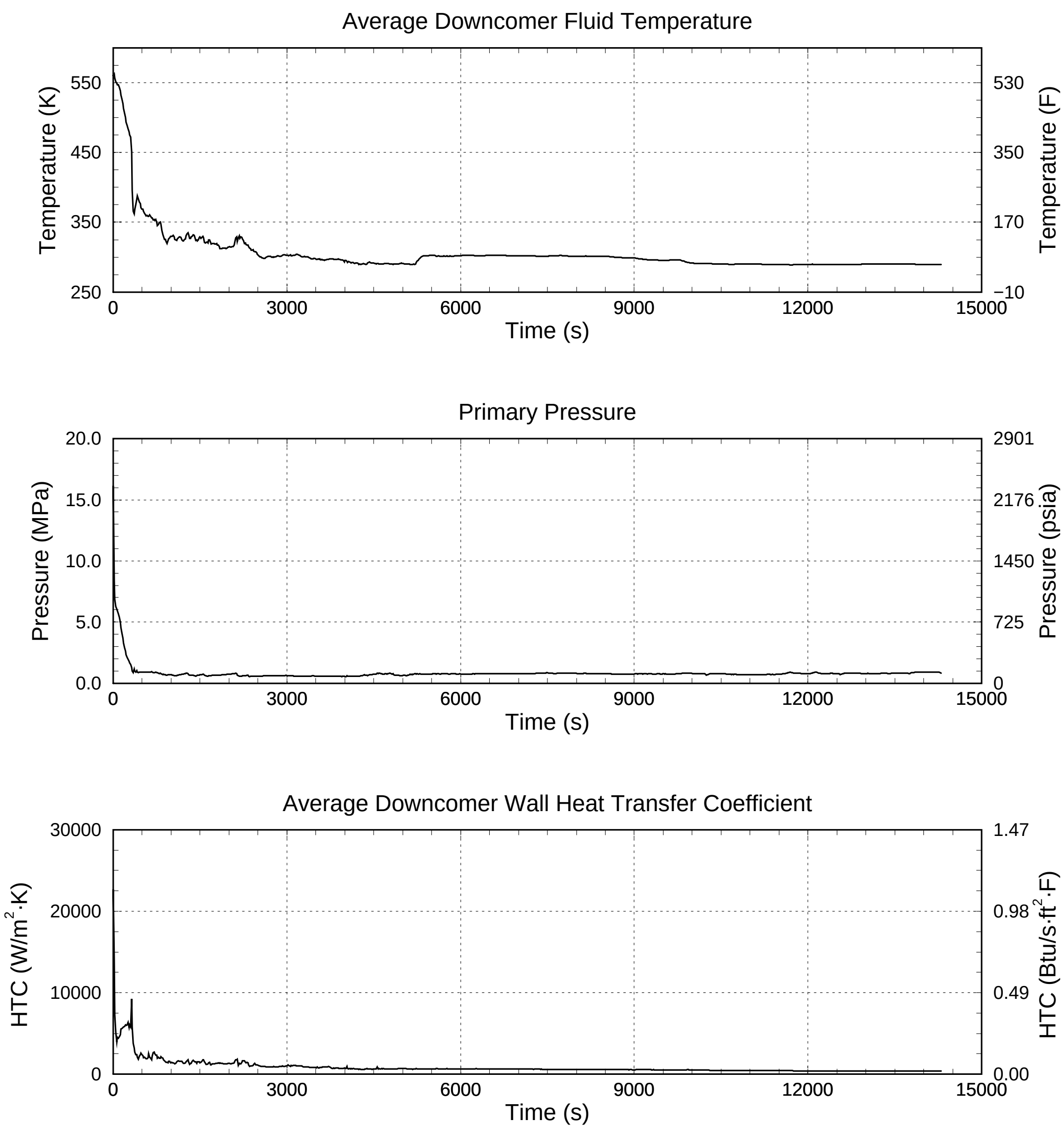
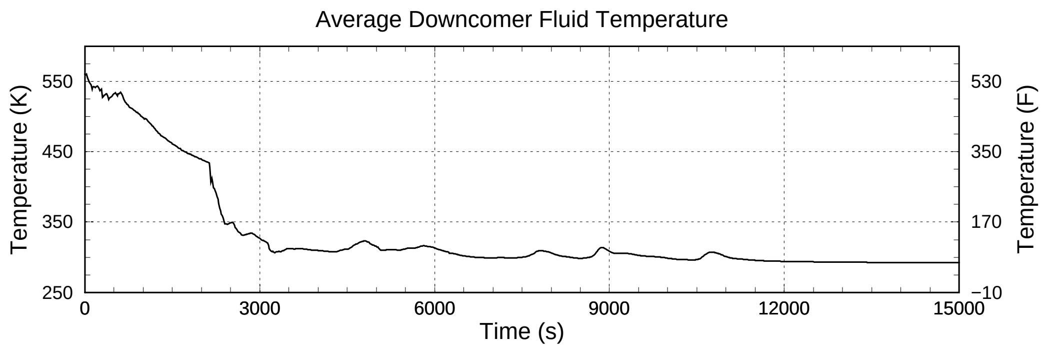
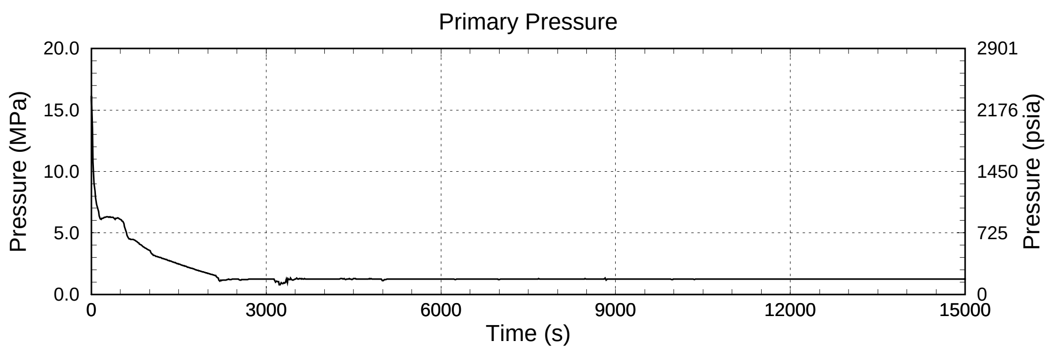


Figure A-89 Calvert Cliffs PTS Results for Case 091

Case Category	LOCA
Primary Failures	8.5 cm [3.347 in] surge line break.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	292.2 K [66.4EF] at 14,520 s
Comments	None.





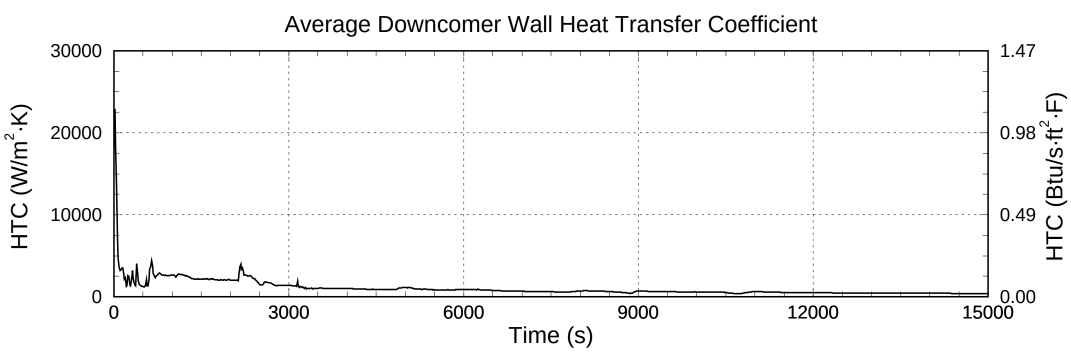


Figure A-90   Calvert Cliffs PTS Results for Case 093

Case Category	LOCA, HZP
Primary Failures	20.32 cm [8.0 in] cold leg break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	279.3 K [43.0EF] at 14,265 s
Comments	Winter conditions assumed.

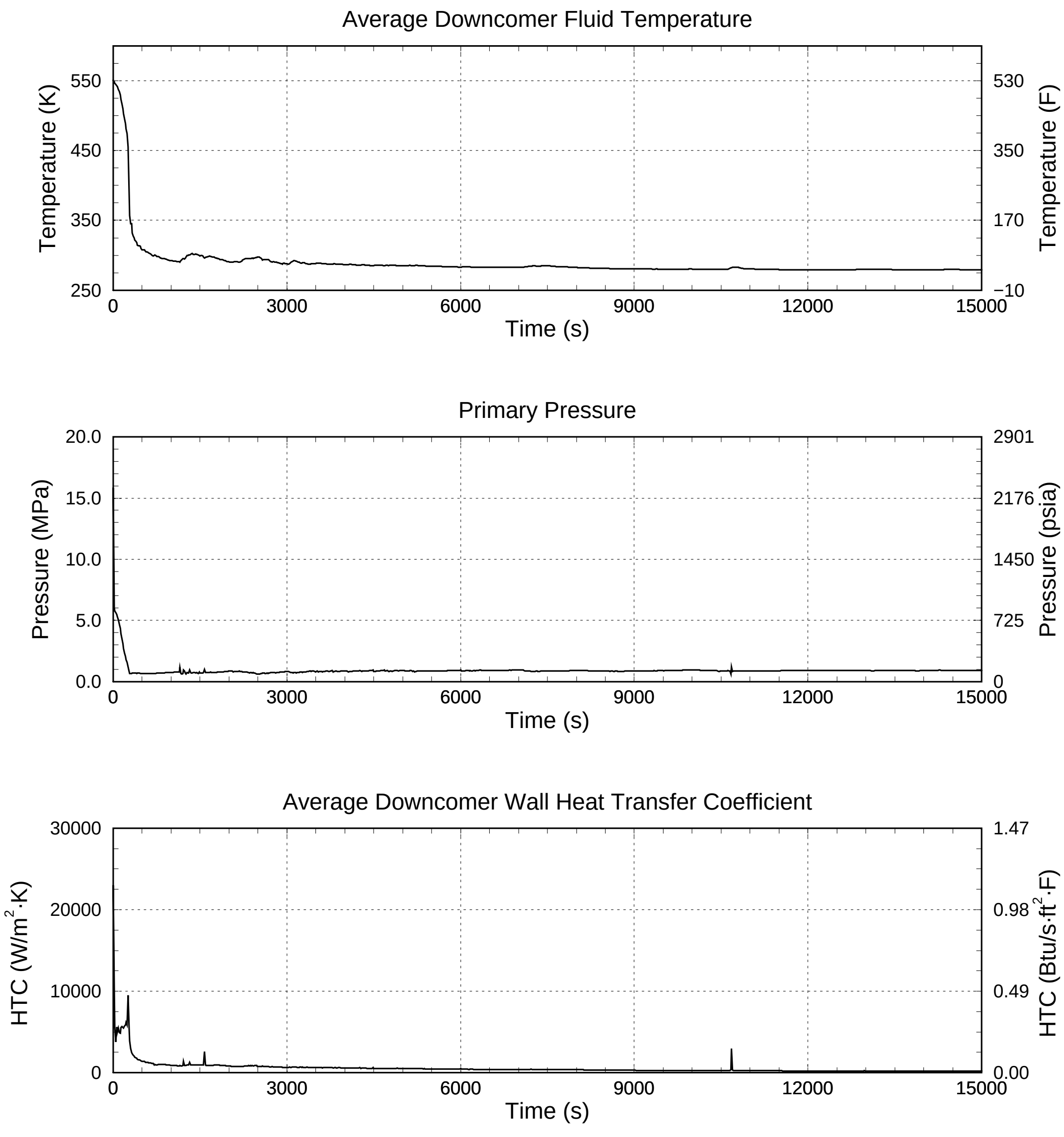


Figure A-91   Calvert Cliffs PTS Results for Case 094

Case Category	LOCA, HZP
Primary Failures	8.5 cm [3.347 in] surge line break from HZP.
Secondary Failures	None.
Operator Actions	None.
Min DC Temperature	289.4 K [61.2EF] at 15,000 s
Comments	None.

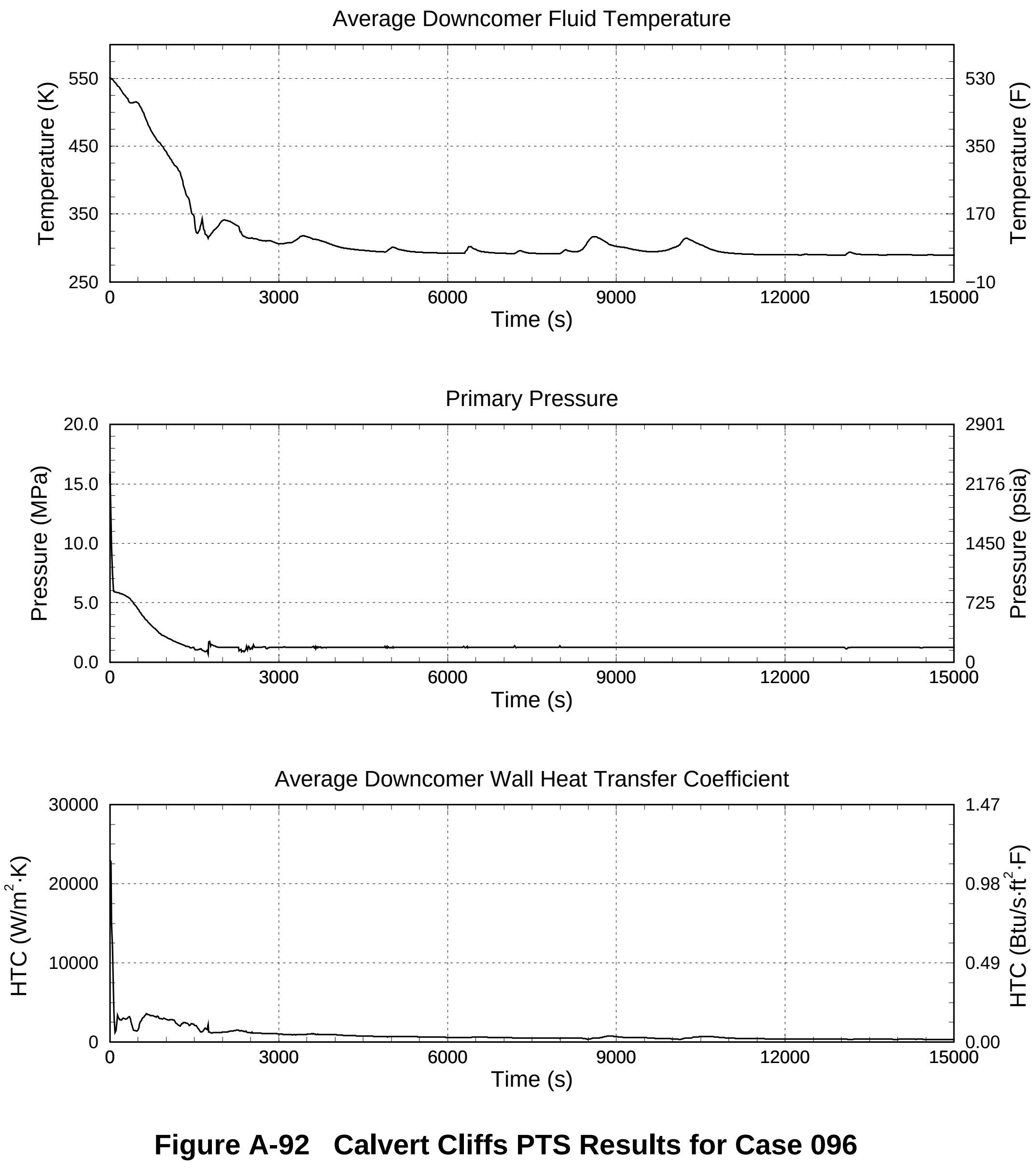


Figure A-92   Calvert Cliffs PTS Results for Case 096

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 3,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	426.2 K [307.5EF] at 14,190 s
Comments	None.

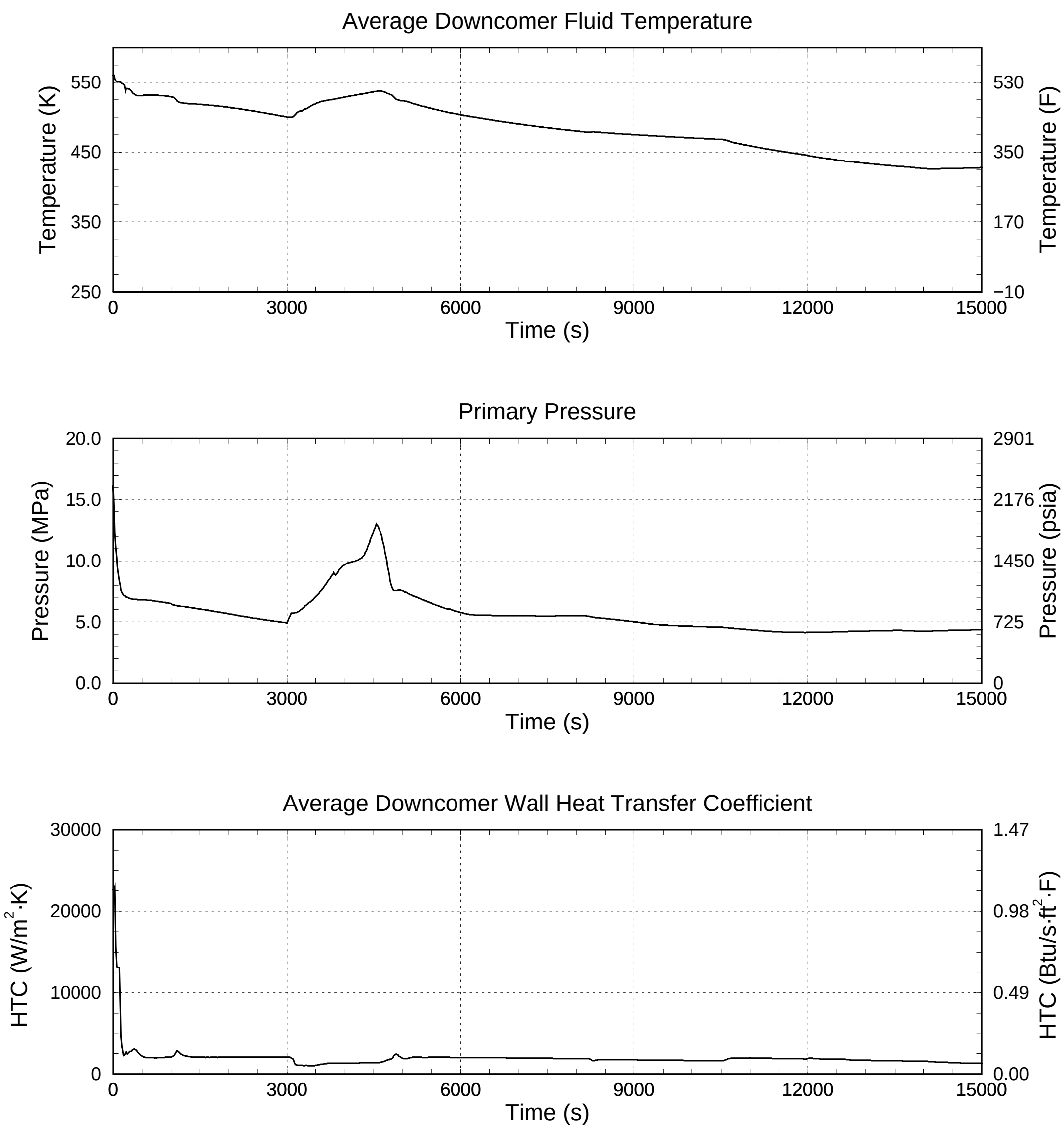


Figure A-93 Calvert Cliffs PTS Results for Case 097

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 3,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	425.2 K [305.7EF] at 13,860 s
Comments	None.

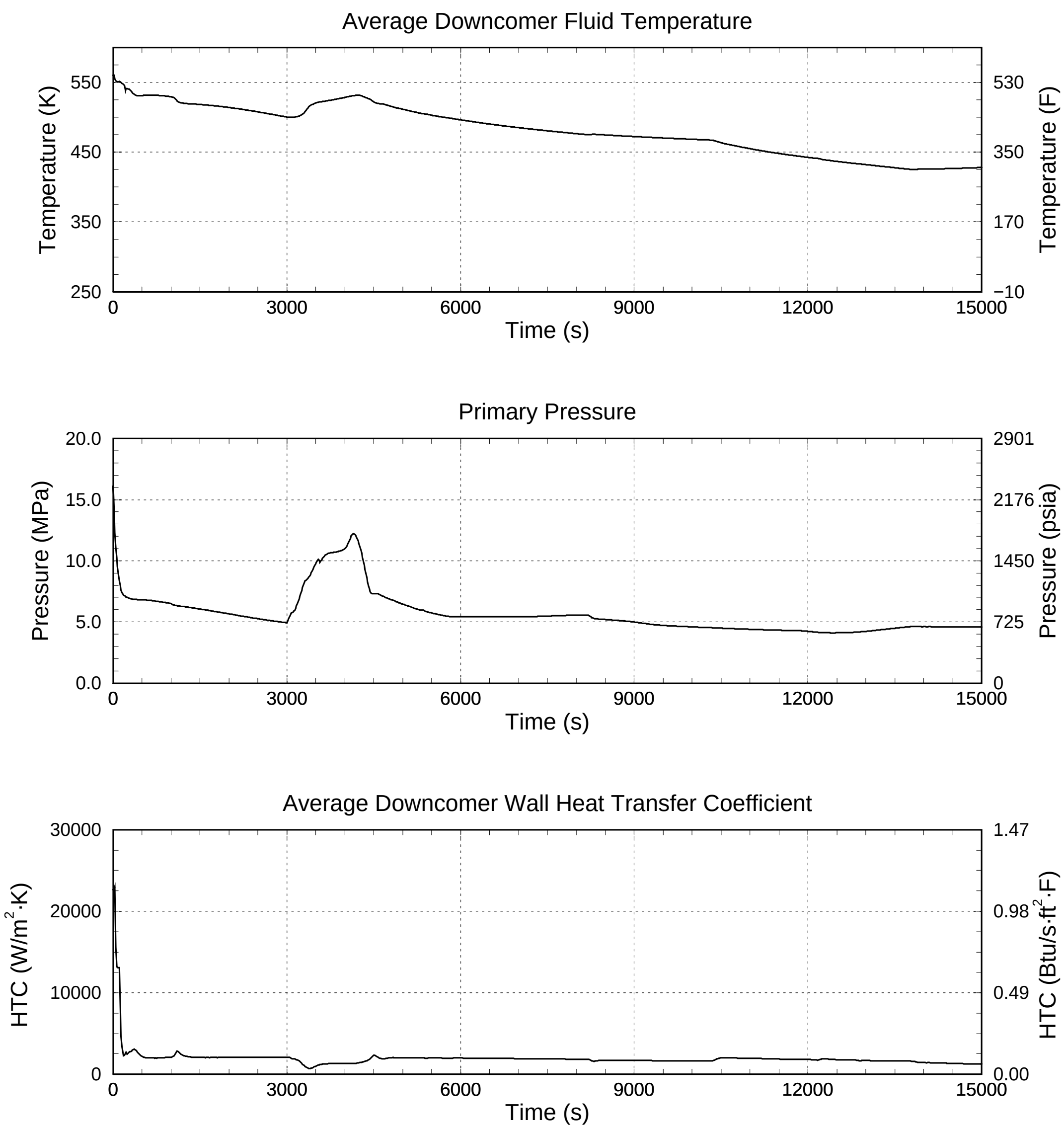


Figure A-94 Calvert Cliffs PTS Results for Case 098

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 3,000 s.
Secondary Failures	None.
Operator Actions	None. Operator does not throttle HPI.
Min DC Temperature	499.7 K [439.7EF] at 3,045 s
Comments	None.

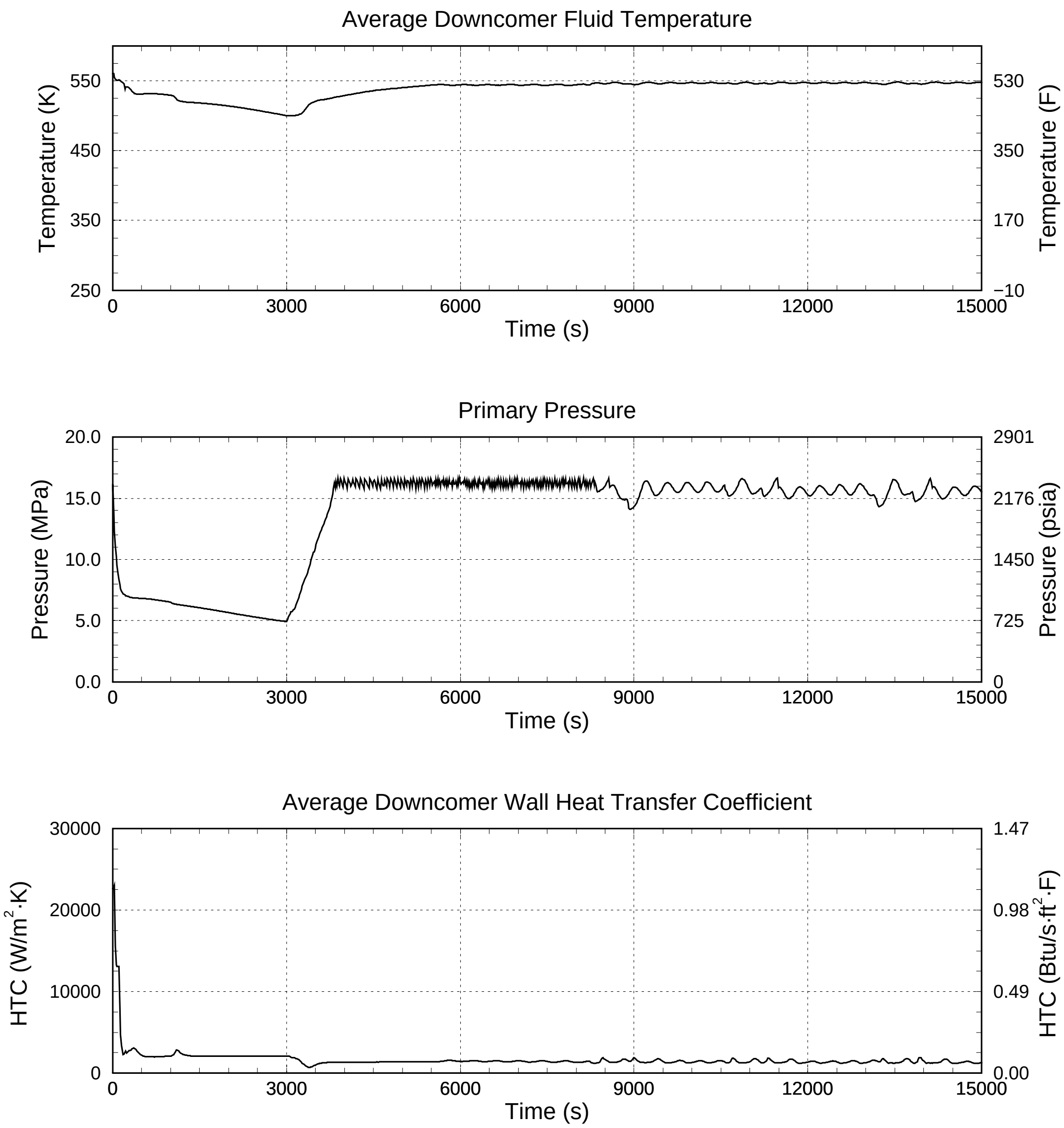


Figure A-95 Calvert Cliffs PTS Results for Case 099

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 6,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	451.7 K [353.4EF] at 15,000 s
Comments	None.

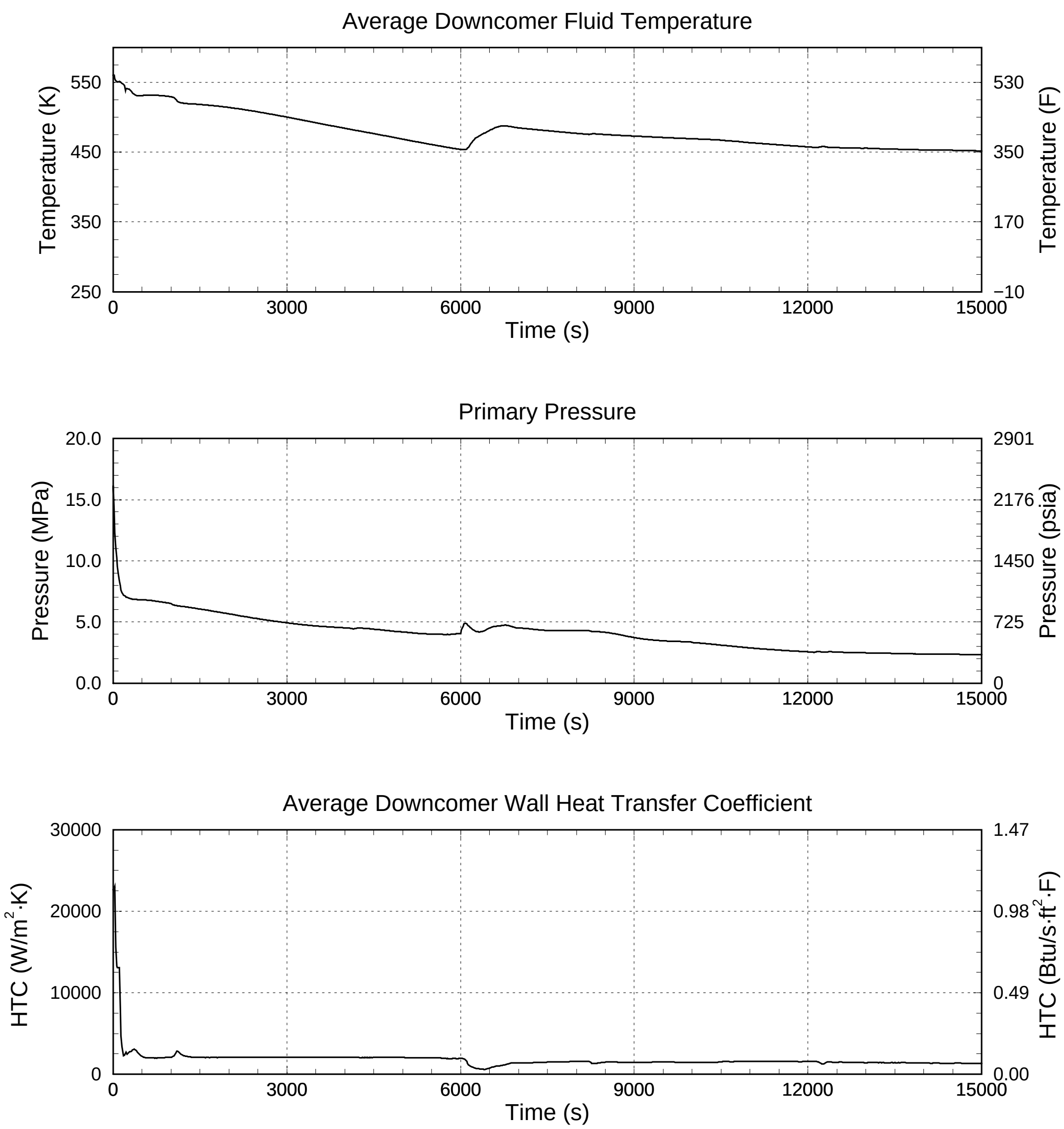


Figure A-96 Calvert Cliffs PTS Results for Case 100

Case Category	RT/TT
Primary Failures	One stuck open pressurizer SRV that recloses at 6,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	450.7 K [351.5EF] at 15,000 s
Comments	None.

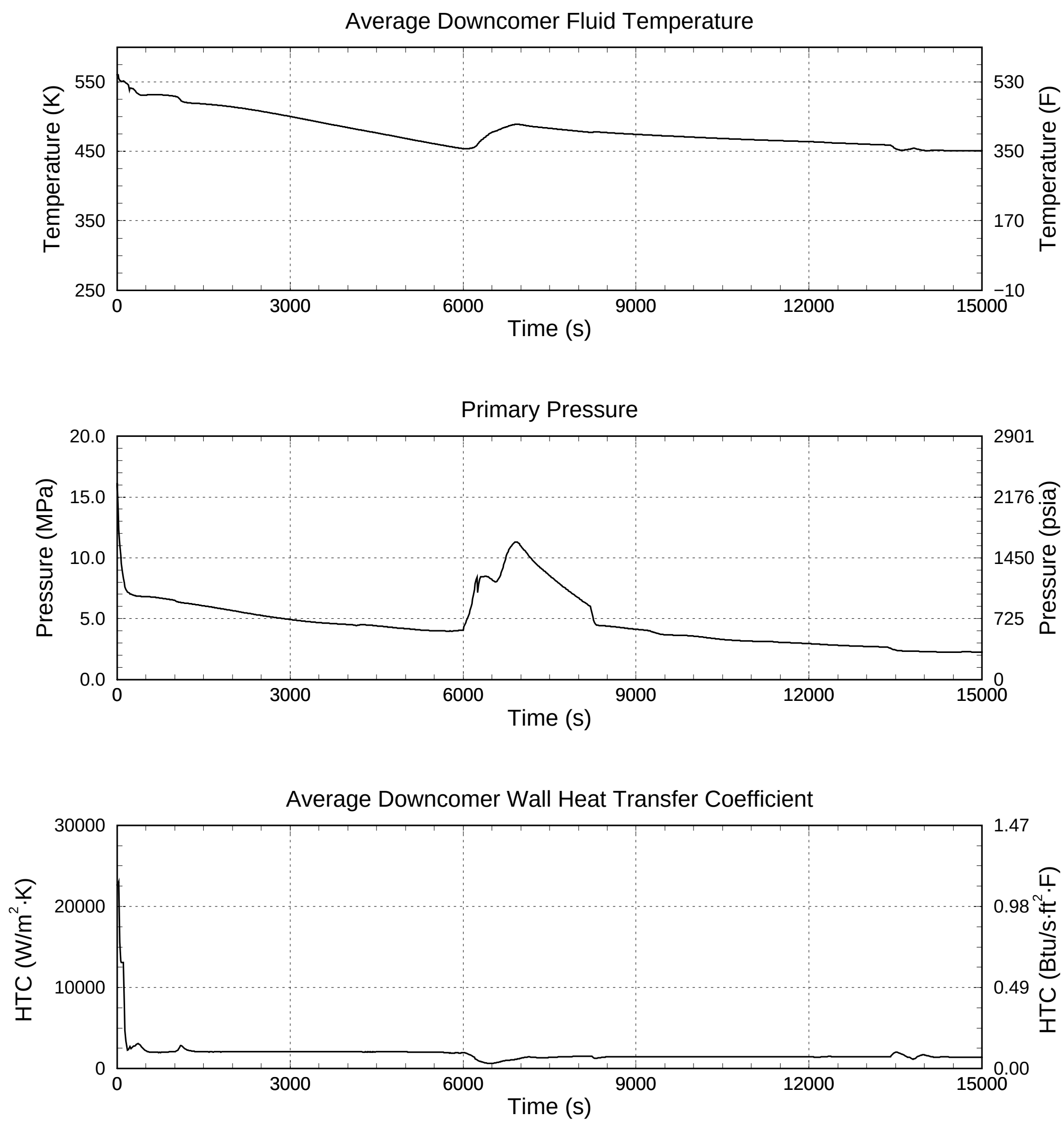


Figure A-97 Calvert Cliffs PTS Results for Case 101

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose at 3,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 1 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	415.1 K [287.5EF] at 4,365 s
Comments	None.

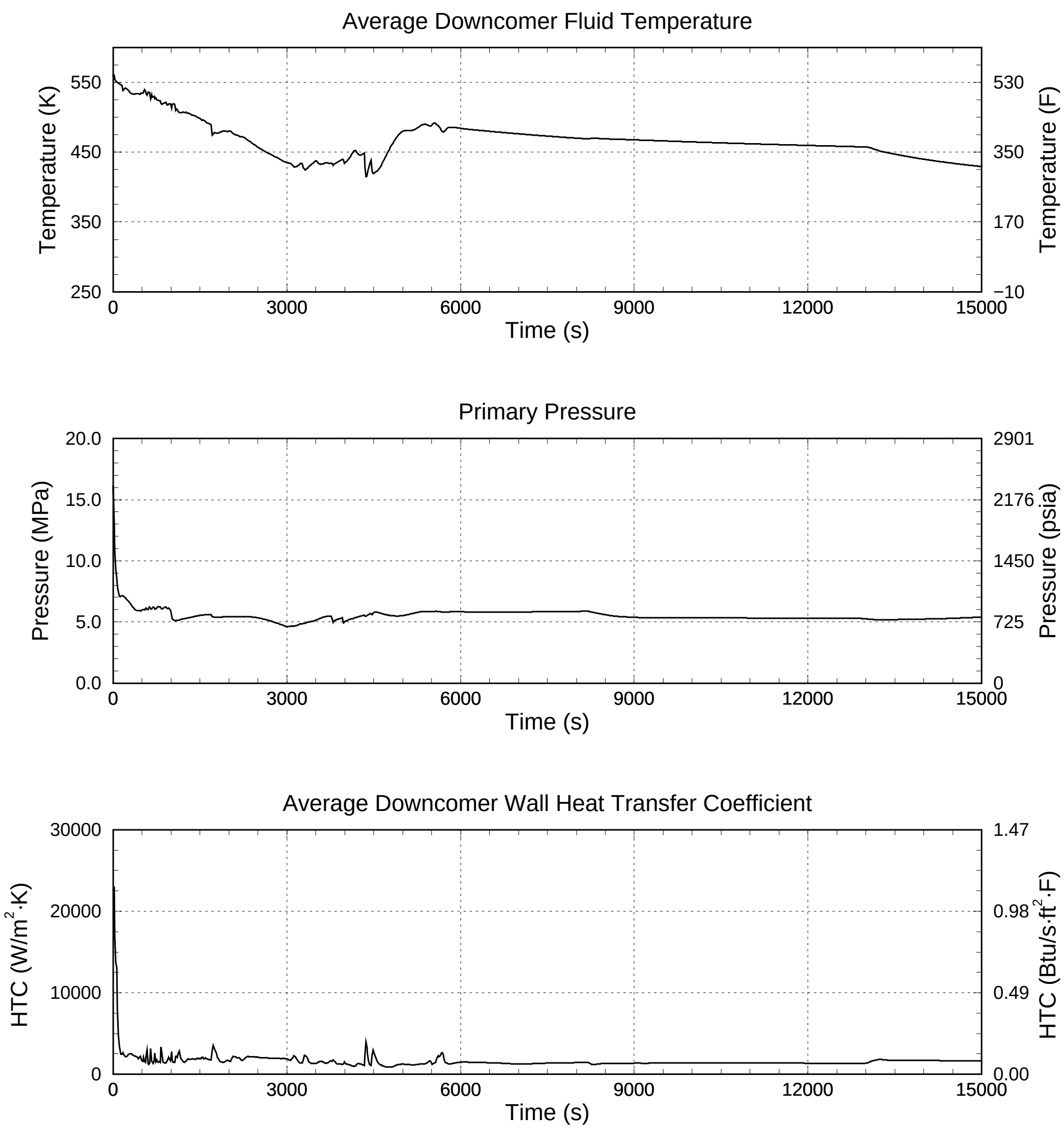


Figure A-98 Calvert Cliffs PTS Results for Case 102

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose at 3,000 s.
Secondary Failures	None.
Operator Actions	Operator throttles HPI after a 5 minute delay. After HPI is throttled, operator turns off pressurizer heaters and resumes normal letdown. When subcooling is > 55 K (100 F) and while HPI is being throttled, the operator opens the ADVs.
Min DC Temperature	415.1 K [287.5EF] at 4,365 s
Comments	None.

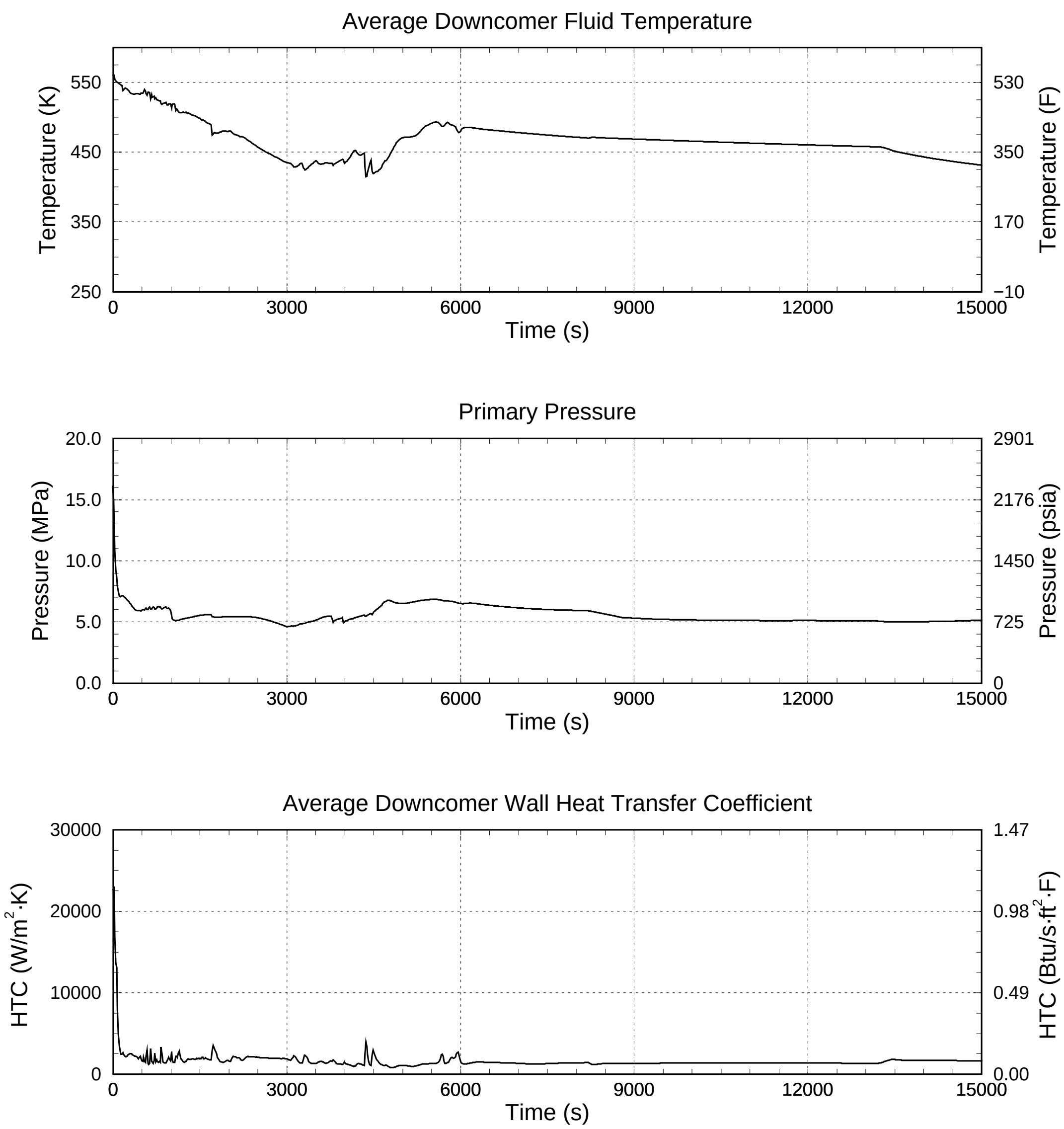


Figure A-99 Calvert Cliffs PTS Results for Case 103

Case Category	RT/TT
Primary Failures	Two stuck open pressurizer SRVs that reclose at 3,000 s.
Secondary Failures	None.
Operator Actions	None. Operator does not throttle HPI.
Min DC Temperature	412.3 K [282.5EF] at 4,395 s
Comments	None.

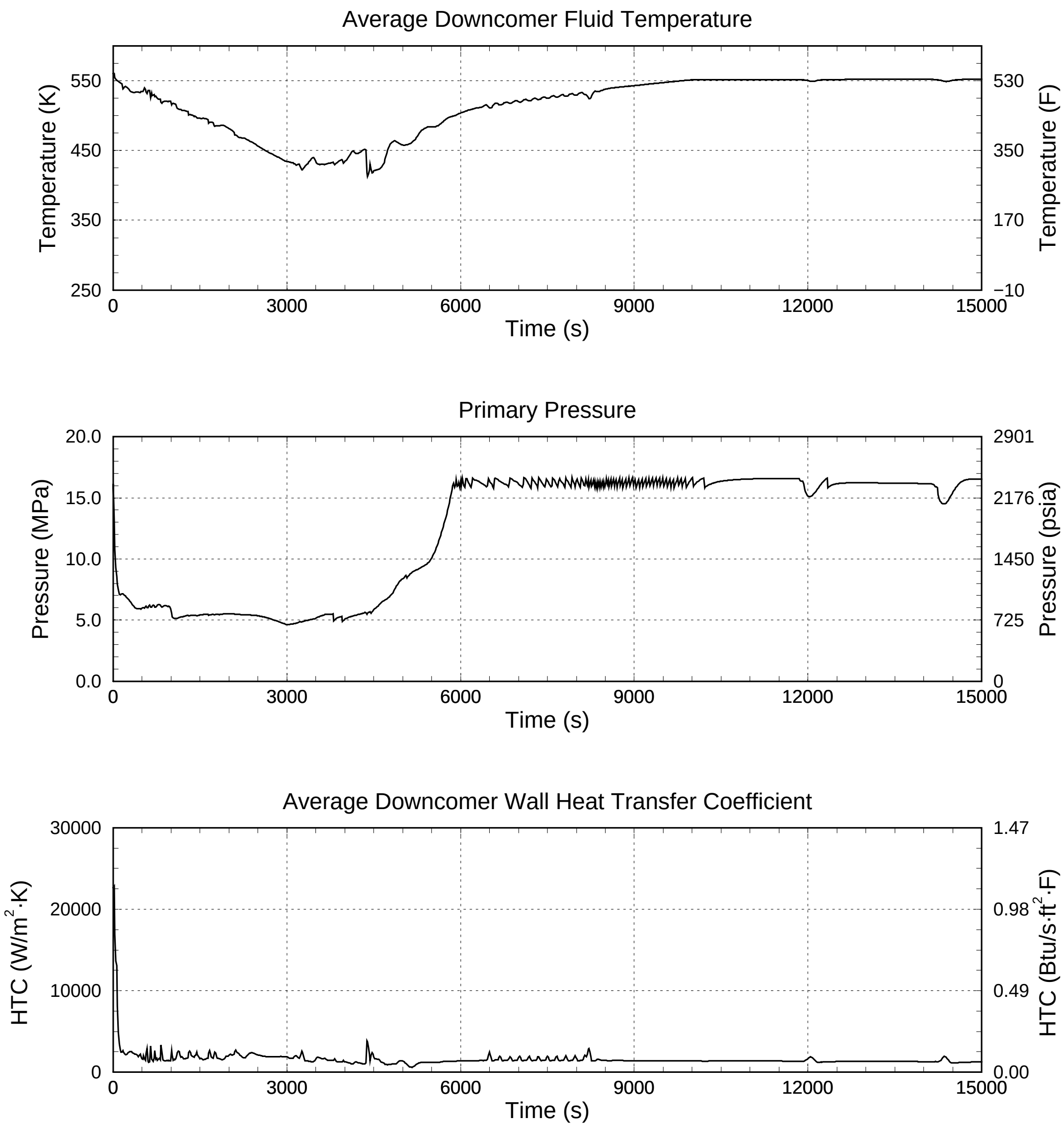


Figure A-100 Calvert Cliffs PTS Results for Case 104