15.5 Increase in Primary Coolant Inventory

PCS pressure is controlled during normal operation by a feed and bleed system. (The PCS description is in Chapter 5 [Primary Coolant System].) This system maintains a coolant inventory balance between addition of coolant into the system from a constant flow of gland seal water and pressurizing pump flow and the subtraction of coolant through a back-pressure control valve to the degassing tank. Since gland seal flow typically exceeds leakage, the degassing tank level is maintained by a control valve that bleeds inventory to the gland seal feed tank. Pressure is controlled at the reactor inlet piping as indicated by the PPS instruments.

Coolant addition from the pressurizing pumps through FCV-1-8 [Chapter 5 (Primary Coolant System)] is controlled by the setpoint of FRC-1-8. The gland seal flow is manually adjusted for each seal. The pressure controller, PIC-1-1, controls pressure at the reactor inlet piping at the setpoint by adjusting flow (taken from coolant inventory) to the degassing tank through PCV-1-1. Due to transmitter location, the controller pressure indicates approximately 10 psig higher than PPS pressure. The total PCS inventory is maintained by flow from the bypass demineralizer system to the gland seal feed tank through LCV-1-3C. The position of LCV-1-3C is controlled by the setpoint of LIC-1-3 to maintain the level in the degassing tank.

The pressure control system has automatic functions that are designed to maintain coolant inventory of the PCS. If PIC-1-1 pressure decreases to 360 psig, PCV-1-1 and LCV-1-3C will trip closed to stop the reduction in coolant inventory by the pressure control system. A further reduction in PCS pressure will result in an indication of low discharge pressure at the pressurizing pump which causes an automatic start of the standby pressurizing pump thereby enabling delivery of 600 gpm (design) to the PCS through FCV-1-8. As PCS pressure decreases, the surge tank level also decreases. When the surge tank level decreases to three in. below nominal, FCV-1-8 trips open to allow maximum makeup to the PCS.

The design will also control high pressures in the PCS. If the primary pump discharge pressure as monitored by PIC-1-8 increases above an adjustable setpoint, nominally set about 10 psig above normal discharge pressure, PIC-1-8 will override the control signal from FIC-1-8 to FCV-1-8 to reduce the coolant makeup from the degas tank and maintain system pressure at the setpoint of PIC-1-8.

A surge tank with a normal capacity of 950 ft^3 of water and 50 ft^3 of pressurized air damps small system pressure variations. The air pressure in the surge tank is manually controlled by adding air from HPA system receivers or by bleeding air to the degassing tank.

Two relief valves on the reactor vessel lower drain line provide relief capacity to prevent system rupture due to severe overpressurization. The ATR specified design pressures are 390 psig from the butterfly valve to the PCPs suction, 576 psig from the pump discharge to the block valves, and 485 psig from the block valves to the butterfly valve.

A number of faults which could result in an increase in primary coolant inventory are postulated. These events will not result in a power-coolant mismatch in the fuel elements unless pressure boundary failure occurs. In this case the event will become a LOCA (Section 15.5). The acceptance criteria for these events that result in an increase in inventory is that the pressure not exceed 110% of design pressure for high-probability (Condition 2) events and to not exceed 120% of design pressure for low-probability (Condition 3 and 4) events. These events are:

A. Backpressure valve PCV-1-1 closes due to operator error or controller failure.

B. Pressurizing flow control valve FCV-1-8 opens due to operator error or controller failure, or a second pressurizing pump is started.

C. Excessive HPA is valved into the surge tank.

D. Diesel generator overspeed (≤ 15%) causes pressurizing pump overspeed and increased flow.

E. A loss of instrument air closes back-pressure control valve (PCV-1-1) and opens pressurizing flow control valve (FCV-1-8).

F. FCV-1-8 fails to close when PCV-1-1 fails closed or PCV-1-1 fails to respond to increased pressurizing flow.

G. Extreme diesel generator overspeed resulting in high pressurizing pump discharge flow.

H. A loss of power to the diesel-commercial bus and the output from the instrument battery backed power closes PCV-1-1 and opens FCV-1-8.

I. A loss of instrument air closes PCV-1-1 and opens FCV-1-8 with concurrent failure of the inlet pressure subsystem.

Based on analysis in the DBR (EG&G Idaho 1994), items A-E are considered to be Condition 2 events, items F and G Condition 3 events, and item I a Condition 4 event. Item H requires failure of three power sources, one of which is a battery-backed source; it is therefore conservatively estimated to be Condition 4.

All identified accidents in this section have been evaluated in the DBR. None of the events were reevaluated for this presentation for the following reasons:

- RELAP4 and RELAP5 modeling of pressure increases due to addition of mass is equivalent.
- No PPS subsystems are being added.
- No PPS subsystem setpoints are respecified.
- Reactor fuel protective margins do not require evaluation because pressure remains acceptable and therefore the fuel temperature remains within acceptable limits.

The limiting Condition 2 event is item E, while the limiting event for Condition 4 is item I; item E also envelops Condition 3 events. These events are discussed in Sections 15.5.1 and 15.5.2, respectively. Section 15.5.3 briefly discusses the other events; additional information is available in the DBR (EG&G Idaho 1994) and its references.

15.5.1 A Loss of Instrument Air Closes Back-Pressure Control Valve PCV-1-1 and Opens Pressurizing Flow Control Valve FCV-1-8

15.5.1.1 Identification of Causes and Accident Description. Loss of instrument air can occur as a result of supply failure, regulator failure, operator error, or mechanical failure of the system components. Failure of instrument air results in closure of PCV-1-1, which terminates flow to the degassing tank. The failure also opens FCV-1-8 which enables delivery of approximately 300 gpm into the PCS by the pressurizing pump. The original design resulted in start of the standby pressurizing pump on loss of instrument air as well as the valve actions. The design has been changed to eliminate pump dependence on air pressure (Durney 1993).

15.5.1.2 Analysis of Effects and Consequences

15.5.1.2.1 Method of Analysis—Analysis was completed using RELAP4 with a one node core model (Atkinson 1976a; Atkinson 1976b). The pressurizing flow was conservatively assumed to be 600 gpm at the beginning of the transient. An additional 75 gpm inflow from the gland seal system was assumed. The valve FCV-1-8 fully opened in 2.5 sec, and the valve PCV-1-1 was assumed fully closed in 1.75 sec. The analysis conservatively assumes that the standby pump starts. The rate at which the event progresses is faster with this assumption.

15.5.1.2.2 Results—The unmitigated pressure response for the reactor vessel inlet is shown in Figure 15.5-1. The design pressure of 390 psig for the inlet piping downstream of the PCS butterfly valve was reached in 3.5 sec. Design pressure plus 10% (the upper limit for Condition 2) was reached at 8.5 sec. (Pressures in Figure 15.5-1 are in absolute pressure units; the design limits are provided in gauge units.) The event is terminated by the PPS which shuts off the pressurizing and gland seal pumps (a scram also occurs). The setting to limit pressure to the design value is shown below (although the acceptance criteria is 110% of design pressure for the inlet piping (390 psig) is used).

15.5.1.2.3 Conclusions—The Condition-2 limit for the inlet piping is 10% over the design or 429 psig. The limiting event causes pressure to change at 7.8 psi/sec. Since the response time of the PPS high inlet pressure pump shutoff subsystem is 0.5 sec and the pumps respond in 0.2 sec (Atkinson, 1976b), the worst-case setpoint should be ≤ 423.5 psig. With an accuracy of 18 psi, the limiting control setting is ≤ 405.5 psig. The high pressure PPS setpoint (limiting control setting) has historically been ≤ 390.6 psig with an accuracy of 18 psi (worst case setting of 408.6 psig) and is conservative. The setting for this subsystem (≤ 390.6 psig) will prevent pressures from exceeding the design plus 10% for the Condition 2 events by shutting off the pressurizing pumps and the gland seal pumps. Retaining the setting of ≤ 390.6 psig also provides assurance that the action should occur prior to reaching the relief valve setting. However, the worse case setpoint for the lifting of the relief valves is less than the worse case setpoint for the pump shutoff system. Therefore, the possibility does exist that the relief valves could lift before the pumps were turned off. While this is not expected to happen, it is a possibility.

The outlet subsystem for high pressure provides diverse action for the inlet scram (the relief valve provides diverse action to reduce high pressure). Data from the RELAP5 calculations (Pafford 1994) are used to establish the scram settings for the outlet pressure subsystem. The calculated pressure difference between the inlet and outlet location is 122.4 psi for three pump operation and 94.7 psi for two pump operation. At the time the inlet pressure is 423.5 psig (worst case setting), the outlet pressure is 301.1 psig (122.4 psi less) for three pumps and 328.8 (94.7 psi less) for two pumps. The accuracy for the outlet

subsystem is 11.9 psi; therefore, the limiting control settings are ≤ 289.2 psig (three pumps) and ≤ 316.9 psig (two pumps). These settings historically have been ≤ 278 psig (three pumps) and ≤ 309.7 psig (two pumps). These conservative settings (≤ 278 psig and ≤ 309.7 psig) and worst-case setpoints (289.9 and 321.6 psig) are maintained as noted for the inlet subsystem above.

15.5.2 A Loss of Instrument Air Closes PCV-1-1 and Opens FCV-1-8 with Concurrent Failure of the Inlet Pressure Subsystem

15.5.2.1 Identification of Causes and Accident Description. This fault is initiated as discussed in Section 15.5.1.1 but with concurrent failure of the inlet pressure PPS subsystem. Pressure will rise until the PCS relief valves are actuated.

15.5.2.2 Analysis of Effects and Consequences

15.5.2.2.1 Method of Analysis—Analysis for the relief valve setting pressure was performed to satisfy the ASME Code, Section III, Class 1, NB-7000, 1986 requirements (Pace 1990).

15.5.2.2.2 Results—The analysis results indicate that a safety relief valve setting at ≤ 390 psig will prevent PCS pressures from exceeding 120% of design pressure at all locations.

15.5.2.2.3 Conclusions—The PCS relief valves will act as a diverse overpressure protection system to the inlet pressure PPS subsystem and will prevent PCS pressures from exceeding 120% of design. Since this is a low probability event, a substantial overpressure (20%) is acceptable.

15.5.3 Bounded Events - Increase in Primary Coolant Inventory

15.5.3.1 Back Pressure Valve PCV-1-1 Closes Due to Operator Error or Controller Failure. Pressure control system failures were simulated as part of the ATR SO-102 tests. Failure of PCV-1-1 caused the reactor inlet pressure to reach 390 psig, but closure of FCV-1-8 by PRC-1-8 terminated the pressure rise (Magleby 1968). The rate of pressure increase for this event is slower than the limiting high-pressure event since FCV-1-8 does not open and the standby pressurizing pump does not start.

The pressure increase for this event is terminated by the PPS setting obtained in Section 15.5.1, and the consequences of this fault are bounded by the loss of instrument air which is discussed in Section 15.5.1.

15.5.3.2 Pressurizing Flow Control Valve FCV-1-8 Opens due to Operator Error or Controller Failure, or a Second Pressurizing Pump is Started. A failure of FCV-1-8 to the full-open position has little effect on PCS pressure. This transient resulted in a 6 psi increase in PCS pressure during SO-102 tests. The pressure control valve PCV-1-1 can compensate and control the transient. Either of these events is less severe than a limiting high-pressure event since PCV-1-1 does not close and remains operational.

The consequences of this fault are bounded by the loss of instrument air which is discussed in Section 15.5.1.

15.5.3.3 Excessive High Pressure Air is Valved into the Surge Tank. The air supply valves are controlled by the operator. The pressure in the HPA supply is normally controlled to < 285 psig, and the pressure in the surge tank for three-pump operation is about 240 psig [Chapter 5 (Primary Coolant System)]. (The three-pump case is considered since it envelops the two-pump operation). An error in adding high-pressure air could result in a pressure increase of 45 psi. The PPS setting described in Section 15.5.1 would clearly terminate the pressure increase. However, an increase of 45 psi for the surge tank would result in a comparable increase in inlet pressure (45 psi added to 373 psig taken from the footnote in Table 15.0-2). The maximum pressure (about 420 psig) would be less than the design value.

The consequences for this fault are bounded by the loss of instrument air which is discussed in Section 15.5.1 since the maximum pressure reached (< 420 psig) is less than the maximum pressure of 429 psig that could be reached with the least-conservative setting for the inlet pressure (high) PPS subsystem.

15.5.3.4 Diesel Generator Overspeed (≤ 15%) Causes Pressurizing Pump Overspeed and Increased Flow. An assumed maximum diesel generator overspeed of 15% would result in a maximum pressurizing flow increase of 15%. This increase in flow is less than the flow increase from starting the standby pump as discussed in Section 15.5.3.2 (conservatively modeled as a 100% increase in pressurizing flow due to starting the second pump).

The consequences of this fault are bounded by the loss of instrument air discussed in Section 15.5.1.

15.5.3.5 A Loss of Power to the Diesel-Commercial Bus and the Output From the Instrument Battery Backed Power Closes PCV-1-1 and Opens FCV-1-8. This fault is the same as discussed in Section 15.5.1. The original design resulted in the high pressure event on loss of the diesel-commercial bus. A design change provided standby power for these valves (Durney 1993).

15.5.3.6 FCV-1-8 Fails to Close when PCV-1-1 Fails Closed, or PCV-1-1 Fails to Respond to Increased Pressurizing Flow. This fault results in an increase in pressure that is less rapid than the loss of instrument air (the standby pressurizing pump does not start).

The consequences of this fault are bounded by the loss of instrument air which is discussed in Section 15.5.1.

15.5.3.7 Extreme Diesel Generator Overspeed Resulting in High Pressurizing Pump Discharge Flow Rate. The diesel generator governor failure could allow greater than 15% overspeed. A maximum overspeed cannot be determined; however, a 100% overspeed is assumed excessive and results in a 100% increase in pressurization flow. As noted in Section 15.5.3.4, the increase in pump speed is enveloped by starting the second pressurizing pump. The consequences are less severe than those discussed in Section 15.5.1.

The consequences of this fault are bounded by the loss of instrument air which is discussed in Section 15.5.1.

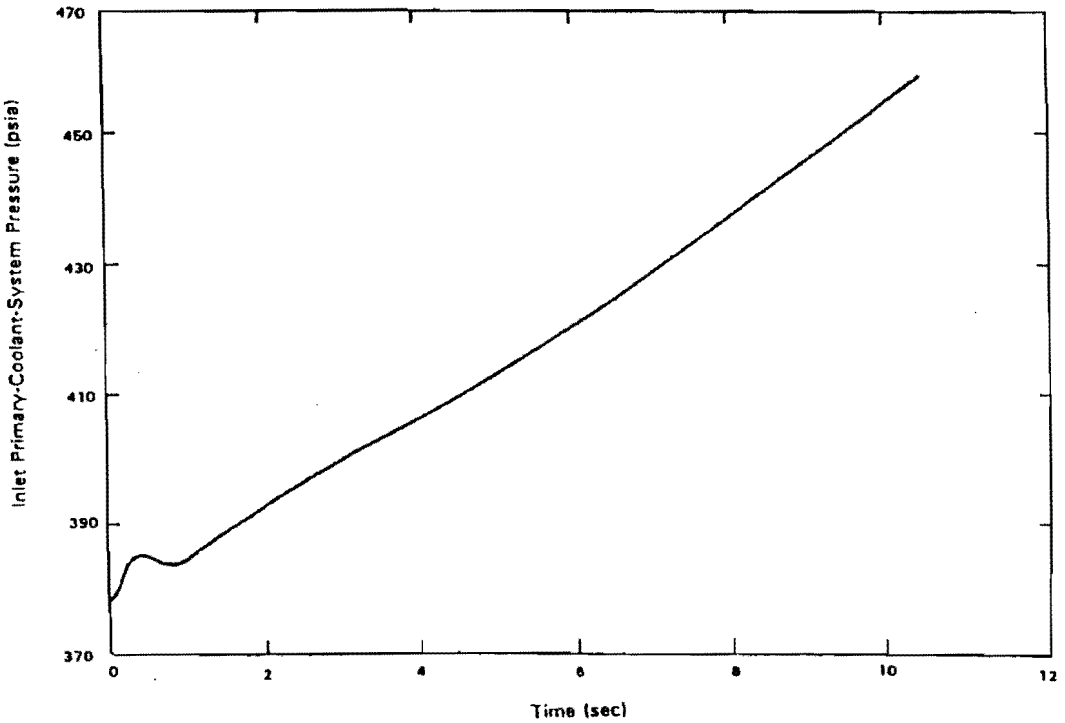

Figure 15.5-1. Unmitigated pressure response for the reactor vessel inlet during a loss of instrument air.**(For Information Only)**

15.5.4 References

Atkinson, S. A., 1976a, *ATR Technical Specifications Accidents Sensitivity to Surge Tank Level*, TR-797, Aerojet Nuclear Company, March 12, 1976.

Atkinson, S. A., 1976b, *ATR PPS Limiting Safety System Settings From ATR Technical Specifications Development Work*, TR-829, Aerojet Nuclear Company, May 1976.

Durney, J. L., 1993, *Safety Analysis Review For Process Control System Upgrade*, EDF TRA-ATR-779, Rev. 2, August 20, 1993.

EG&G Idaho, 1994, *ATR PPS and Technical Specifications Design Basis Report*, (SAR-39), Issue 030, EG&G Idaho, Inc., August 2, 1994.

Magleby, H. L., 1968, Memorandum to D. P. Halls, *ATR Pressurizing System SO-102 Tests*, MAG-4-68M, Idaho Nuclear Corporation, February 21, 1968.

Pace, N. E., 1990, *ATR Primary Coolant System Overpressure Protection Report*, PG-T-88-005, Rev. 1, EG&G Idaho, Inc., September 1990.

Pafford, D. J., 1994, Vessel Inlet and Outlet Pressure PPS Modeling in the RELAP5 Input Models for the ATR Upgraded SAR, EDF TRA-ATR-1025, October 31, 1994.

INTENTIONALLY BLANK