5.6 INSTRUMENTATION APPLICATION

Process control instrumentation is provided for the purpose of acquiring data on the pressurizer and on a per-loop basis for the key process parameters of the Reactor Coolant System (RCS) (including the reactor pump motors), as well as for the Residual Heat Removal (RHR) System. The pickoff points for the RCS are shown in the flow diagram (Figure 5.1-6C and Plant Drawings 205201 and 205301); and for the RHR System, on flow diagram Plant Drawings 205232 and 205332.

In general, these input signals are used for the following purposes:

1. Provide input to the Reactor Trip System described in Section 7.

2. Provide input to the Engineered Safety Features Actuation System described in Section 7.

3. Furnish input signals to the nonsafety-related control systems and surveillance circuits.

5.6.1 Loop Temperature

One hot-leg and one cold-leg temperature reading is provided from each coolant loop to use for protection. Narrow-range thermowell resistance temperature detectors (RTDs) are provided for each coolant loop. In the hot legs, sampling scoops are used because the flow is stratified; that is, the fluid temperature is not uniform over a cross section of the hot leg. One dual-element RTD is mounted in each of the three sampling scoops associated with each hot leg. The scoops extend into the flow stream at locations 120 degrees apart in the cross-sectional plane. Each scoop has five orifices which sample the hot-leg flow along the leading edge of the scoop. Outlet ports are provided in the scoops to direct the sampled fluid past the sensing element of the RTDs. One of each RTD's dual elements is used, while the other is an installed spare. Three readings from each hot leg are averaged to provide a hot leg reading for that loop.

One dual-element RTD is mounted in a thermowell associated with each cold leg. No flow sampling is needed because coolant flow is well mixed by the reactor coolant pumps. One RTD element is used, while the other is an installed spare. The potential for the bulk reactor coolant temperature in the cold leg to be slightly lower or higher than that indicated on the cold leg RTD exists at Salem 1 and 2. This effect, known as cold leg streaming, has been accounted for in the Chapter 15 analyses.

The thermowells are pressure-boundary parts that completely enclose the RTD. They have been shop hydrotested to 1.25 times the RCS design pressure. The external design pressure and temperature are the RCS design temperature and pressure. The RTD is not part of the pressure boundary. The scoop, thermowell, and thermowell/scoop assembly have been analyzed to the ASME Boiler and Pressure Vessel Code, Section III, Class 1. The effects of seismic- and flow-induced loads were considered in the design.

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Separate RTDs, located in the thermowells in the cold- and hot-leg piping of each loop, supply signals to wide-range temperature recorders. This information is used by the operator to control coolant temperature during startup and shutdown.

5.6.2 Pressurizer Temperature

There are two temperature detectors in the pressurizer: one in the steam phase and one in the water phase. Both detectors supply signals to temperature indicators and high-temperature alarms. The steam-phase detector, located near the top of the vessel, alerts the operator if the steam becomes superheated. In addition, it is used during startup to determine water temperature when the pressurizer is completely filled with water. The water-phase detector, located at an elevation near the center of the heaters, is used during cooldown to ensure that the pressurizer temperature is consistent with the RCS.

Temperatures in the pressurizer safety and relief valve discharge lines are measured and indicated. An increase in a discharge line temperature is an indication of leakage through the associated valve. An alarm is actuated on high temperature.

The fluid temperatures in each spray line are measured and indicated. Alarms from these signals are actuated by low spray water temperature. Alarm conditions indicate insufficient flow in the spray lines through the manual throttle valves.

The temperature of the water in the pressurizer relief tank is indicated over a range of 50°F to 350°F, and an alarm, actuated by a high temperature, informs the operator that cooling of the tank contents is required.

The temperature in the leakoff line from the reactor vessel flange O-ring seal leakage monitor connections is indicated. An increase in temperature above ambient is an indication of O-ring seal leakage. High temperature actuates an alarm.

5.6.3 Pressure

Four pressurizer pressure transmitters provide signals for individual indicators in the control room, for actuation of a low pressure trip, for high pressure reactor trip, and for alarms. One of the four signals may be selected by the operator for display on a pressure recorder. Three transmitters provide independent low pressure signals for safety injection initiation and for safety injection signals to allow manual block during plant shutdown and automatic unblock during plant startup. In addition, these pressure transmitters provide inputs for pressurizer heater, spray valve, and power-operated relief valve (PORV) control.

Two narrow range differential pressure transmitters connected to the RCS sample line on the No. 1 hot leg and on the No. 3 hot leg are installed to monitor RCS level during Mid-Loop operation. A wide range differential pressure transmitter is connected on the No. 3 hot leg to monitor RCS level during midloop operation, reduced inventory and vacuum fill.

Two wide-range transmitters provide pressure indication over the full operating range. The indicators serve as a guide to the operator during plant startup and shutdown and also provide the open permissive signals and automatic closure signals for the RHR loop isolation valves interlock circuit.

Two local pressure indicators are provided for operator reference during shutdown. They are located in two separate loops and are provided with maximum (drag) pointers to indicate the maximum pressure attained since the last resetting of the pointers.

A pressurizer relief tank (PRT) pressure transmitter provides a signal to close valve PCV-472 on high pressure should it be open when a safety valve lifts discharging steam into the PRT.

5.6.4 Pressurizer Water Level

Three pressurizer liquid level transmitters provide signals for use in the Reactor Control and Protection System, and the Chemical and Volume Control System (CVCS). Each transmitter provides an independent high water level signal that is used to actuate an alarm and, upon two out of the three transmitter signals, will cause a reactor trip. The transmitters may also provide independent low water level signals that will activate an alarm. Each transmitter also provides a signal for a level indicator that is located on the main control board.

In addition, any of the three level transmitters may be selected for display on a level recorder located on the main control board.

Two of the three transmitters may be selected to provide an alarm when the liquid level falls to the fixed low level setpoint. The same signal will trip the pressurizer heaters "off" and close the letdown line isolation valves. The low pressurizer level signal can be bypassed, in accordance with EOPs, allowing operator control of the Letdown isolation valves when Letdown Bypass Switch is placed in bypass mode. Two transmitters are similarly selected to supply a signal to the liquid level setpoint controller.

A fourth independent pressurizer level transmitter is calibrated for low temperature conditions, provides water level indication during startup, shutdown and refueling operations.

A PRT level transmitter supplies a signal for an indicator and for high and low level alarm.

Two RHR pressure transmitters are installed and connected to the sensing lines of PI631 and PI632 to monitor RHR pumps 1RHE1, 1RHE2, 2RHE1 and 2RHE2 suction pressure during Mid-Loop operation.

5.6.5 Reactor Vessel Water Level

The Reactor Vessel Level Instrumentation System uses three sets of differential pressure (d/p) cells, with two identical cells per set for redundancy, to measure the water level in the vessel. Each of these sets uses cells with different ranges to obtain three different vessel water level measurements.

One set of two d/p cells is installed to sense the fluid pressure differential between the top of the vessel and the loop piping. One side of each cell is connected to a dedicated RVLIS sensing tap in the RVCH and the other sides of the cells are connected to the hot legs of Loops 1 and 4. Each cell's level indicator in the control room shows reactor vessel water level between the hot leg and the top of the vessel. If any reactor coolant pump (RCP) is operating, the associated level indicator will display "INVALID."

Two d/p cells are installed to sense the fluid pressure differential between the bottom and top of the reactor vessel. One side of each cell is connected to the head vent penetration; the other side is connected to an in-core instrumentation conduit at or near the seal table. When no RCP is running, these cells measure the differential pressure between the top and bottom of the reactor vessel to measure the water level above and below the reactor core. The associated level indicator displays "INVALID" if any RCP is operating.

Two d/p cells, with installation similar to that of the two cells used for narrow range measurement, measure reactor core and internal pressure drop for any combination of operating RCPs which, when compared with the normal single phase pressure drop, provides an indication of the relative void content or density of the circulating coolant. These cells may be used on a continuous basis. The RVLIS-86 stores four values of expected reactor coolant void fraction. These expected values correspond to one through four RCPs running. The expected value of void fraction corresponding to the current pump operating status is displayed on the RVLIS-86 remote display panels. When all pumps are off, the indicator displays "INVALID."

All of the d/p cells are located outside of containment to minimize post-accident environmental effects and to facilitate calibration, cell replacement, reference leg checks, and filling and venting. Hydraulic sensors (inside containment) and hydraulic isolators (outside containment), connected by a seal sensing line, are installed between each d/p cell and its connection to the vessel/RCS. These features assure containment isolation in case of a sensing line break and prevent flow of primary coolant to outside containment. To obtain the required accuracy for vessel water level measurement, the d/p cell indications are compensated using measured temperatures of both the d/p cell reference legs and the reactor coolant.

During refueling, the reactor head and associated RVLIS piping are removed. The instrument sensing line normally connected to the RVLIS pressure tap is manually realigned to sense atmospheric pressure. When the refueling mode is selected at the RVLIS-86, the sensors' outputs are re-scaled by the RVLIS-86 software. The upper range transmitters are used to provide the reduced inventory level indication from 97.3 feet to 106.0 feet. The dynamic range transmitters provide the refueling cavity level indication from 104 feet to 130 feet.

Additional information is presented in Section 7.

5.6.6 Reactor Coolant Flow

Flow in each reactor coolant loop is monitored by three d/p measurements at a piping elbow tap in each reactor coolant loop. These measurements on a two-out-of-three coincidence circuit per loop provide a low flow signal to actuate a reactor trip.

Elbow taps are used in the RCS as an instrument device that indicates the status of the reactor coolant flow. The basic function of this device is to provide information as to whether or

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not a reduction in flow rate has occurred. The correlation between flow reduction and elbow tap readout has been well established by the following equation:

$$\frac{\Delta P}{\Delta P_o} = \left(\frac{w}{w_o}\right)^2$$

where ΔP_O is the referenced pressure differential with the corresponding referenced flow rate ω_O and ΔP is the pressure differential with the corresponding referenced flow rate ω. The full flow reference point is established during initial plant startup. The low flow trip point is then established by extrapolating along the correlation curve. The technique has been well established in providing core protection against low coolant flow in Westinghouse pressurized water reactor (PWR) plants. The expected absolute accuracy of the channel is within ±10 percent and field results have shown the repeatability of the trip point to be within ± 1 percent. The analysis of the loss of flow transient presented in Section 14.1 assumed instrumentation error of ±3 percent.

The combined flow from the hot and cold leg RTD manifolds passes through an orifice before discharging back to the RCS at the suction side of the RCP. The flow is indicated locally by a d/p gage and by status lights in the control room. Low flow through either the hot or cold leg warns of possible inaccuracy in the corresponding temperature signals; therefore, an alarm is actuated.

5.6.7 Reactor Coolant Pump Motor Instrumentation

A dual purpose switch is provided on the high pressure oil lift system. Upon low oil pressure the switch actuates an alarm on the main control board. In addition, the switch is part of an interlock system that prevents starting of the pump until the oil lift system is operating and oil pressure is established. A local pressure gage is also provided.

Level switches are provided in the motor radial bearings and thrust bearing oil reservoirs. The switches actuate high and low level alarms on the main control board.

Thermocouples are located in the upper and lower thrust bearing shoes. These elements provide signals for multi-point recorder on the main control board and actuate an alarm on high temperature.

A RCP trip criterion has been adopted which assures pump trip for all losses of primary coolant for which pump trip is considered necessary, but which also permits pump operation during most non-LOCA events, including steam generator tube rupture events up to the design basis double-ended tube rupture. The controlling parameter selected for pump trip actuation is RCS pressure. The RCS wide-range pressure instrumentation will be monitored.

5.6.8 Loose Parts Monitoring

A Loose Parts Monitoring (LPM) System supplied by Westinghouse Electric Corporation has been installed for each of the two units of Salem Generating Station. (This LPM System has been designated as the Metal Impact Monitoring System by Westinghouse). The LPM System has been designed to enable early detection of the presence of metallic debris, loose parts, or restrained loose parts, inside the Nuclear Steam Supply System (NSSS) during plant startup and commercial operation. Any form of metallic debris, loose parts, or restrained loose parts, when carried or agitated by the reactor coolant flow may attain sufficient velocities to impact and damage the interior of the NSSS pressure boundary.

The LPM system is realized by on-line processing, transmission, and conditioning of the signals from a group of strategically located Piezoelectric accelerometers (a total of 12) mounted externally to the wall of NSSS with proper indication and alarms.

When the insides of the reactor and steam generator walls are struck by metallic debris, loose parts, or restrained loose parts, the structure is shock excited producing local wall acceleration that can be detected in time and frequency domain. These impact signatures can be separated in the frequency domain from the general vessel and background signature. Once the proper frequency band is selected, a threshold Amplitude Detection System and associated rate can be used to activate an Alarm System.