SECTION 5

# REACTOR COOLANT SYSTEM AND CONNECTED SYSTEMS

## 5.1 SUMMARY DESCRIPTION

The Reactor Coolant System (RCS) consists of four similar heat transfer loops connected in parallel to the reactor vessel. Each loop contains a steam generator, a pump, loop piping, and instrumentation. The pressurizer surge line is connected to one of the loops. Auxiliary system piping connections into the reactor coolant piping are provided as necessary.

Reactor Coolant System design data are listed in Table 5.1-1.

Pressure in the RCS is controlled by the pressurizer, where water and steam pressure are maintained through the use of electrical heaters and sprays. Steam can either be formed by the heaters, or condensed by a pressurizer spray to minimize pressure variations due to contraction and expansion of the coolant. Instrumentation used in the pressure control system is described in Section 7. Spring-loaded safety valves and power-operated relief valves are connected to the pressurizer and discharged to the pressurizer relief tank, where the discharged steam is condensed and cooled by mixing with water.

The RCS provides a boundary for containing the coolant under operating temperature and pressure conditions. It serves to confine radioactive material and limits to acceptable values its release to the secondary system and to other parts of the plant under conditions of either normal or abnormal reactor behavior. During transient operation the system's heat capacity attenuates thermal transients generated by the core or steam generators. The RCS accommodates coolant volume changes within the protection system criteria presented in Section 7.

Reactor Vessel

The reactor vessel (Figure 5.1-1) is cylindrical with a welded hemispherical bottom head and a removable, flanged and gasketed, hemispherical upper head. The vessel contains the core, core support structures, control rods, thermal shield, and other parts directly associated with the core. The reactor vessel closure head contains head adaptors. These head adaptors are tubular members, attached by partial penetration welds to the underside of the closure head. The upper end of these adaptors contains acme threads for the assembly of the control rod drive mechanisms. The seal arrangement at the upper end of these adaptors consists of a welded flexible canopy seal.

The vessel has inlet and outlet nozzles located in a horizontal plane just below the vessel flange but above the top of the core. Coolant enters the inlet nozzles and flows down the core barrel-vessel wall annulus, turns at the bottom and flows up through the core to the outlet nozzles.

The five (5) reactor vessel closure head Core Exit Thermocouple (CET) column penetrations on the original Salem 1 and 2 reactor vessel closure heads were cut below the threaded canopy seal weld joint and were capped using full penetration butt welded caps. The replacement reactor vessel closure heads on Unit 1 and Unit 2 do not have any CET column penetrations.

The bottom head of the vessel contains penetration nozzles for connection and entry of the in-core instrumentation. Each tube is attached to the inside of the bottom head by a partial penetration weld.

The reactor vessel is designed to provide the smallest and most economical volume required to contain the reactor core, control rods, and the necessary supporting and flow-directing internals. Inlet and outlet nozzles are spaced around the vessel. Outlet nozzles are located on opposite sides of the vessel to facilitate optimum layout of the RCS equipment. The inlet nozzles are tapered from the coolant loop-vessel interfaces to the vessel inside wall to reduce loop pressure drop.

## Pressurizer

The pressurizer (Figure 5.1-2) provides a point in the RCS where liquid and vapor can be maintained in equilibrium under saturated conditions for control purposes.

The pressurizer is a vertical, cylindrical vessel with hemispherical top and bottom heads constructed of carbon steel, with austenitic stainless steel cladding on all surfaces exposed to the reactor coolant. Electrical heaters are installed through the bottom head of the vessel while the spray nozzle, relief and safety valve connections are located in the top head of the vessel. The heaters are removable for maintenance or replacement.

The pressurizer is designed to accommodate positive and negative surges caused by load transients. The surge line, which is attached to the bottom of the pressurizer, connects the pressurizer to the hot leg of a reactor coolant loop.

## Pressurizer Relief Tank

The pressurizer relief tank condenses and cools the discharge from the pressurizer safety and relief valves as well as several smaller relief valves. The tank normally contains water in a predominantly nitrogen atmosphere; however, provisions are made to permit the gas in the tank to be periodically analyzed to monitor the concentration of hydrogen and/or oxygen.

The pressurizer relief tank, by means of its connection to the Waste Disposal System, provides a means for removing any noncondensable gases from the RCS which might collect in the pressurizer vessel.

Steam enters the tank through a sparger pipe under the water level. This condenses and cools the steam by mixing it with water that is near ambient temperature. The tank is equipped with an internal spray and a drain which are used to cool the tank following a discharge. The tank is protected against overpressurization by two rupture discs that discharge into the reactor containment. The tank is carbon steel with a corrosion-resistant coating on the wetted surfaces. A flanged nozzle is provided on the tank for the pressurizer discharge line connection. This nozzle and the discharge piping and sparger within the vessel are austenitic stainless steel.

## Steam Generators

The steam generators are vertical shell and U-tube evaporators with integral moisture separating equipment. The reactor coolant flows through the inverted U-tubes, entering and leaving through the nozzles located in the hemispherical bottom head of the steam generator. The head is divided into inlet and outlet chambers by a vertical partition plate extending from the head to the tube sheet. Manways are provided for access to both sides of the divided head. Steam is generated on the shell side and flows upward through the moisture separators to the outlet nozzle at the top of the vessel. The units are primarily carbon steel. For Unit 1 the heat transfer tubes are Inconel, the primary side of the tube sheets is clad with Inconel, and the interior surfaces of the reactor coolant channel heads and nozzles are clad with austenitic stainless steel. The Unit 2 steam generator heat transfer tubes are Inconel 690 thermally treated and all primary side ferritic steel surfaces (primary side of the tubesheet and inside surfaces of the primary head) are clad with austenitic stainless steel (Type 308L/Type 309L) or Inconel 600 to prevent corrosion. A Unit 2 replacement steam generator (Areva NP Model 61/19T) is shown on Figure 5.1-3, and a Unit 1 replacement steam generator (Model F) is shown in Figure 5.1-3A.

## Reactor Coolant Pumps

Each reactor coolant loop contains a vertical single stage mixed flow pump that employs a controlled leakage seal assembly. The pump is shown on Figure 5.1-4 and net positive suction head characteristics are shown on Figure 5.1-5.

Reactor coolant is drawn up through the primary pump impeller, discharged through passages in the diffuser and out through a discharge nozzle in the side of the casing. The rotor-impeller can be removed from the casing for maintenance or inspection without removing the casing from the piping. All parts of the pump in contact with the reactor coolant are austenitic stainless steel or equivalent corrosion resistant materials.

Reactor Coolant Piping

The reactor coolant piping and fittings which make up the loops are austenitic stainless steel. All smaller piping which comprise part of the RCS boundary, such as the pressurizer surge line, spray and relief lines, loop drains and connecting lines to other systems are also austenitic stainless steel. The nitrogen supply line for the pressurizer relief tank is carbon steel. All joints and connections are welded, except for the pressurizer relief and the pressurizer code safety valves, where flanged joints are used. Thermal sleeves are installed at points in the system where high thermal stresses could develop due to rapid changes in fluid temperature during normal operational transients.

Valves

All valves in the RCS which are in contact with the coolant are constructed primarily of stainless steel. Other materials in contact with the coolant are special materials, such as hard surfacing and packing.

All RCS valves, (except as listed below), which contain radioactive fluid and which normally operate above 212°F, are provided with double-packed stuffing boxes and stem intermediate lantern gland leakoff connections. All throttling control valves, regardless of size, (except as listed below), are provided with double-packed stuffing boxes and with stem leakoff connections. All leakoff connections are piped to the reactor coolant drain tank or pressurizer relief tank.

The valves listed below have a single set packing configuration and inactive leakoff lines.

| Salem #1 | | | Salem #2 | | |
|---|---|---|---|---|---|
| 1PS1 | 1PS25 | 1PR6 | 2PS1 | 2PS25 | 2PR6 |
| 1PS3 | 1PS28 | 1PR7 | 2PS3 | 2PS28 | 2PR7 |
| 1PS24 | 1PS29 | 1PS59 | 2PS24 | 2PS29 | 2PS59 |

Reactor Coolant System High Point Venting

Venting of the RCS during abnormal conditions permits removal of noncondensable gases, thereby aiding natural circulation flow.

There are three principal high points in the RCS: the pressurizer, the reactor vessel head, and the steam generator tube bundle invert.

The pressurizer power-operated relief valve serves as a vent and provides remote venting capability from the control room. This vent is safety grade and meets the single failure criterion.

The high points created by the tube bundle in the steam generator cannot be vented at that location. A Westinghouse study (1) has concluded, however, that only a small amount of noncondensables would be present during any transient which would depend significantly on the steam generators for decay heat removal. It further concluded that the presence of a small amount of noncondensables would not significantly impact natural circulation in the system.

The replacement reactor vessel heads on both units contain a dedicated vent tap adjacent to the center head penetration near the top of the dome. As shown in the RCS flow diagram (Plant Drawings 205201 and 205301), the vessel head can be vented either to the pressurizer relief tank or to the containment.

The Units 1 and 2 replacement reactor vessel head vent piping is a ¾″ diameter Schedule 160 pipe and includes a 3/8″ diameter restricting orifice close to the reactor vessel, in the first horizontal piping run from the center to the periphery of the RVCH. The vent for each unit then runs to the pressurizer relief tank through a redundant grouping of solenoid valves. Break flanges are provided to allow the reactor vessel head removal and to provide room for the manipulator crane movement. The piping is supported to Seismic Category I requirements to ensure that allowable loadings on the part-length CRDM housing are not exceeded. The piping and valves are stainless steel.

The reactor vessel head vent is designed to meet the requirements of NUREG-0737 (2). The vent can be remote-manually actuated from the control room utilizing a key lock switch. The solenoid operated vent valves are powered from two redundant vital dc buses. Open/close indications for the solenoid valves are provided in the control room with both visual and audible alarms. Valve operating logic is shown on Figure 5.1-6C.

Piping, valves, and components for the reactor vessel vent are classified as Seismic Category I and Nuclear Safety Class 2. Design pressure and temperature of the piping valves and components are 2485 psi and 650°F, respectively.

Maximum conditions (pressure and temperature) for the vent piping are as specified in Public Service Electric & Gas' specifications which meet the intent of Standard Review Plan Section 5.2.3 requirements.

The reactor vessel vent system size is kept within the loss-of-coolant-accident (LOCA) definition size (3/8 inch) with a 3/8 inch diameter orifice, which permits venting 1/2 gas volume of the RCS in 1 hour. This minimizes the challenges to the Emergency Core Cooling System (ECCS) since inadvertent vent opening would not require ECCS actuation.

A pipe break in either the pressurizer or reactor vessel head vent lines is an infrequent fault and is covered in Section 15 as a loss of reactor coolant accident resulting from a small bore ruptured pipe. The analysis presented in Section 15 shows that the high head portion of the ECCS together with the accumulators provide sufficient core flooding to keep the calculated peak clad temperature below the required limits of 10CFR50.46. The 3/4-inch reactor head vent line was analyzed not as a source but as a target of High Energy Line Break. The normally pressurized portion of the Pressurizer Vent System is located within the pressurizer missile shield. The effects of internal missiles on these lines have been analyzed and found acceptable. The head vent and pressurizer vent have been analyzed for the following failures and found not to prevent essential operation of safety-related systems required for safe reactor shutdown or mitigation of the consequences of a design basis accident.

1. Seismic failure of any pressurizer vent components that are not designed to withstand the safe shutdown earthquake.

2. Postulated missiles generated by failure of pressurizer vent components.

3. Dynamic effects associated with the postulated rupture of pressurizer vent piping greater than 1-inch nominal size.

Operability testing of the reactor vessel head vent valves will be performed in accordance with Subsection IWV of Section XI of the ASME Code.

### 5.1.1 Piping and Instrumentation Diagram

The RCS is shown on Plant Drawings 205201 and 205301, and the system design and operating parameters are given in Table 5.1-1.

### 5.1.2 Arrangement Drawing

Figure 5.1-12 and Plant Drawings 204803, 204804, 204805, 204806, 204807 and 204808 are plan and elevation drawings providing principal dimensions of the RCS.

### 5.1.3 References for Section 5.1

1. "Report on Small Break Accidents for Westinghouse Nuclear Steam Supply System," WCAP-9600 (Proprietary) and WCAP-9601 (Nonproprietary), June 1979.

2. NUREG-0737, "Clarification of TMI Action Plan Requirements," U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, November 1980.