9.2 SHUTDOWN COOLING SYSTEM

9.2.1 DESIGN BASIS

The Shutdown Cooling (SDC) System is used to remove core decay heat and reactor coolant sensible heat during plant cooldowns and cold shutdowns. The system also cools the containment spray water during Containment Spray System (CSS) operation following a Recirculation Actuation Signal (RAS) and maintains RCS temperature during refueling operations. Additionally, the heat exchangers can be used to provide additional spent fuel pool cooling (SFPC) when the complete core is removed from the reactor vessel and temporarily stored in the spent fuel pool (SFP).

Portions of the SDC System piping are ASME Class 1, and thus require a fatigue analysis of the applicable thermal shock transients, and other operational cycles. In addition to design cyclic transients a, d, and e of Section 4.1.1, the SDC System fatigue analysis considers 500 initiations of SDC. In this transient, 300°F water from the RCS is injected into the SDC piping which is at a higher temperature due to the residual effects of the RCS normal operating temperatures. See Reference 1 for further details.

Gas accumulation in this water system can result in water hammer, pump cavitation and pumping of non-condensable gas into the reactor vessel. These effects may result in the system being unable to perform its specified safety function. The NRC issued Generic Letter 2008-01, Managing Gas Accumulation, to address the issue of gas accumulation in this system. See UFSAR Section 1.8.5 for further information.

9.2.2 SYSTEM DESCRIPTION

The SDC system is shown schematically in Figure 9-5. The system uses portions of other systems, i.e., the RCS (Section 4.1) and the engineered safeguards (Sections 6.3 and 6.4).

In the SDC mode of operation, reactor coolant is circulated through the tube side of the SDC heat exchanger using the low-pressure safety injection (LPSI) pumps. The flow path from the pump discharge runs through normally locked-closed valve, SI 658, through the shutdown cooling heat exchangers, and through normally locked-closed valve, SI 657, to the LPSI header, and enters the RCS through the four safety injection nozzles. The circulating fluid flows through the core and is returned from the RCS through the SDC nozzle in the loop No. 2 reactor vessel outlet (hot leg) pipe. The coolant is returned to the suction of the LPSI pumps through normally locked-closed valves SI-651 and SI-652.

In Mode 5, 6, or defueled, a containment spray pump may be used to circulate reactor coolant through the tube side of the SDC heat exchangers. The appropriate valve lineup and plant operating conditions are specified in the Operating Procedures.

During CSS operation, prior to recirculation, RWT inventory passes through the tube side of the SDC heat exchanger via containment spray pumps for containment cooling purposes. After recirculation, the containment spray pumps switch suction from the RWT to the containment sump and sump water is circulated through the SDC heat exchangers.

In both the SDC mode of operation and during CSS operation, component cooling (CC) water flows through the shell side of the SDC heat exchangers. During shutdown cooling, CC cools reactor coolant and during containment spray operation after RAS, CC cools the containment sump fluid. Prior to RAS, CC is not needed for cooling purposes because RWT water does not need cooling. Also note that prior to RAS, CC is not cooled by Saltwater, so CC could provide no cooling.

Shutdown cooling and total low-pressure injection flow are measured by a flow element installed in the low-pressure injection header. Flow is indicated in the Control Room. The flow element also transmits a signal to a controller which will provide automatic flow control during SDC operation.

9.2.3 SYSTEM COMPONENTS

The SDC system is made up of portions of the SI system and the RCS. The principal characteristics of the major components in those systems are given in Sections 6.3 and 4.1, respectively.

Each component is inspected and cleaned prior to installation. Demineralized water is used to flush each system. Initially the system is operated and tested to verify that the flow path, flow, thermal capacity and mechanical operability meet the design requirements. Instruments are calibrated during testing. The automatic flow control is tested.

Periodic testing of the LPSI pumps, as described in Section 6.3.6, assures the availability of this equipment for shutdown cooling. Data can be taken during refueling operations to confirm heat transfer capacity.

9.2.4 SYSTEM OPERATION

During normal plant operation, there are no components of the system in operation. All components are on standby for possible emergency operation, as a part of the CSS and SI system. The SDC capability may be used during the early stages of plant startup to control the reactor coolant temperature. As the coolant temperature approaches 300°F and the pressure approaches 270 psig, this method of control must be discontinued and the system aligned for emergency operation.

Following reactor shutdown and cooldown, the system is operated in the shutdown mode for further cooling of the RCS when the coolant temperature falls below 300°F and the coolant pressure falls below 270 psig. At this time, the system must be manually realigned for shutdown cooling. Prior to placing the system in operation, the boron concentration is verified at various points in the system. During the early stages of shutdown cooling, the cooldown rate is controlled by limiting the flow through the tube side of the heat exchanger. Constant flow through the core is maintained by using valve SI 306 as a heat exchanger bypass valve.

During Mode 6 operation, the SDC system serves to remove decay heat and other residual heat from the RCS, provide mixing of borated coolant, to provide sufficient coolant circulation to minimize the effects of a boron dilution accident, and to prevent boron stratification. Heat is removed from the RCS by circulating reactor coolant through the SDC heat exchangers where its heat is transferred to the component cooling water system which is, in turn, cooled by the Saltwater System. Therefore, in Mode 6, an OPERABLE SDC loop requires the support of a functional component cooling and saltwater subsystem. In Mode 6 conditions where both SDC loops are required to be operable (water level < 23 feet above the tops of the irradiated fuel assemblies seated in the reactor vessel), only one functional component cooling and one saltwater subsystem is necessary, provided their heat removal capacity is sufficient.

9.2.5 SYSTEM PERFORMANCE

The SDC system is designed to reduce the temperature of the reactor coolant at the controlled cooldown rate from 300°F to refueling temperature (≤ 140°F) within 36 hours after shutdown. This assumes both CC pumps, both CC heat exchangers, and both SDC heat exchangers are on line and CC reaches a maximum of 120°F. This further assumes that each LPSI is circulating 3000 gpm and each CC pump is circulating 2500 gpm through the SDC heat exchanger (Section 6.3.2.5). Cooldown will occur more or less rapidly depending on pump and heat exchanger availability and component cooling loads on line.

The SDC system is designed to cool containment spray flow in order to bring containment temperature down to 120°F within 30 days following an accident. This assumes minimum safeguards: one train of containment spray, one train of safety injection, and one train of containment air coolers. This also assumes a CC flow of 1800 gpm and a containment spray flow of 1250 gpm.

9.2.6 DESIGN EVALUATION, AVAILABILITY, AND RELIABILITY

During normal cooldown the system utilizes the LPSI pumps to circulate the reactor coolant through the two SDC heat exchangers, returning it to the RCS through the LPSI header. Cooldown rate is controlled by adjusting the flow through the heat exchangers. Both heat exchangers are required to achieve cooldown at the maximum design rate. One exchanger provides cooldown capability at a reduced rate.

Control valves which were originally equipped with two sets of packing and intermediate leakoff connections that discharged to the WPS were repacked with Chesterton packing. Valves that are repacked with Chesterton packing have one set of packing. These valves may have their leakoff lines removed and the valve leakoff connection plugged or tubing capped. Some manual valves have backseats to facilitate repacking.

All piping in the SDC system is austenitic stainless steel. The piping is welded except for flanged connections at the pumps and components, which can be removed for maintenance.

During plant operation, double valves with a relief valve between the two valves, isolate the suction of both LPSI pumps from the RCS. These two valves, SI-651 and 652, are key-locked closed at the control board during plant operation. Additionally, the valve between the SDC heat exchangers and the LPSI header, SI-657, is locked shut during plant operation, both locally and at the control board. The keys are kept under administrative control to ensure that these valves cannot be opened inadvertently during plant operation.

Pressurizer pressure instrument channels P-103 and P-103-1 each provide an open permissive interlock to the two LPSI pump suction isolation valves SI-651 and 652, respectively. These independent and redundant interlocks prevent opening of these valves whenever the RCS is already pressurized at or above the SDC System design pressure. The suction piping to the LPSI pumps is the SDC System component with the limiting design pressure rating.

During SDC System operation, a visual and audible alarm on the main control board is activated whenever either SI-651 or 652 are not fully closed and RCS pressure is above the SDC System design pressure. These two separate alarms are tested at each refueling outage to ensure reliability and are designed to alert the operator in the event of an alarm or control circuit power supply failure. These alarms, associated procedural controls and operator training ensures a high probability of achieving double isolation of the SDC System from the RCS when the RCS pressure is raised above the SDC System design pressure.

The suction isolation valves, SI-651 and SI-652, and associated control system design, therefore, provide two independent and redundant means for achieving and maintaining isolation of the SDC System from the RCS.

Overpressure protection of the SDC System is provided by relief valve RV-468, which is located on the SDC Return Header downstream of 1(2)-MOV-651. This valve is sized to protect the SDC flowpath from overpressure due to the simultaneous operation of three charging pumps while on SDC with the pressurizer in a solid condition.

Certain transients in the RCS, such as an inadvertent RCP or HPSI pump start, can cause a pressure transient that exceeds the capacity of RV-468. However, these transients are prevented or mitigated by the LTOP controls outlined in Section 4.2.2 and in the Technical Specifications. The LTOP controls are in place at all times when both SDC is in operation and a pressurization event is possible (e.g., until the RCS is vented to at least 8 square inches).

9.2.7 OPERATION AT REDUCED INVENTORY

Generic Letter 88-17, Loss of Decay Heat Removal, described concerns and recommended actions for operation of the RCS and the SDC System during reduced inventory conditions. Reduced inventory is defined by the generic letter as an RCS inventory which results in a reactor vessel level lower than 3’ below the vessel head flange. Three key areas were addressed in the resolution of this issue: (1) Prevention of a loss of decay heat removal; (2) In-depth mitigation of a loss of decay heat removal; and (3) Providing a closed containment before the core uncovers if a loss of decay heat removal occurs. These three areas were addressed in responses to the recommendations made in the generic letter. The recommendations and their responses are provided below:

a. Provide reliable indication of parameters that describe the state of the RCS and the performance of systems normally used to cool the RCS for both normal and accident conditions. At a minimum, provide the following in the Control Room:

    1. Two independent RCS level indications.

       We have at least two independent, continuous level indications and audible alarms. (Section 7.5.9.4)

    2. At least two independent temperature measurements representative of the core exit whenever the reactor vessel head is located on top of the reactor vessel.

       We have two independent, continuous coolant temperature indications that are representative of the core exit conditions. (Section 7.5.9.4)

    3. The capability of continuously monitoring decay heat removal system performance whenever the system is used for cooling the RCS.

       We have instrumentation to monitor SDC pump suction pressure, discharge pressure, motor current, system flow and RCS level. (Section 7.5.9.4)

    4. Visible and audible indications of abnormal conditions in temperature, level and decay heat removal system performance.

       We have visible and audible indications in the Control Room for temperature, level and SDC performance. (Section 7.5.9.4)

b. Develop and implement procedures that cover reduced inventory operation and that provide an adequate basis for entry into a reduced inventory condition. Procedures should cover normal and off-normal operation of the Nuclear Steam

Supply System during times when cooling is normally provided by the SDC System.

There are procedures and administrative controls which cover normal and off-normal operation of the RCS, SDC, supporting systems and containment. Additionally, we have implemented controls that ensure the status of each containment penetration required for containment closure is known, and the time and method of closure has been addressed for those penetrations which are open. The definition of containment closure is consistent with Technical Specifications.

c. Ensure adequate equipment is operating, operable and/or available to provide cooling for the RCS. Adequate equipment must remain operable or available to mitigate a loss of SDC. In addition, adequate equipment must be provided for personnel communications for activities necessary to maintain the RCS in a stable and controlled condition.

Normally, the SDC System provides cooling for the RCS. Technical Specifications require that the SDC System remain operable. The HPSI pump and one other means remain available to mitigate the consequences of a loss of SDC. The normal plant paging system provides communication capability onsite. Any page can be overridden by a Control Room page which is simultaneously broadcast to all zones.

d. Conduct analyses to supplement existing information and develop a basis for procedures, instrument and installation and response, and equipment/Nuclear Steam Supply System interactions and response. The analysis should encompass thermodynamic and physical conditions, and should emphasize complete understanding of Nuclear Steam Supply System behavior.

Analyses have been performed and include: time to reach saturated conditions; peak pressurization of the RCS based on reactor vessel head vent paths; times to reach core uncovery for a variety of conditions, assuming no operator action; effects of steam generator nozzle dam installation; instrument uncertainties; and analyses of flow paths as a function of RCS back pressure. Containment response and airborne activity analyses were also performed. All calculations are dependent upon initial conditions, such as: RCS heat sinks; level; temperature; vent paths; and time after shutdown.

e. The Technical Specifications should not restrict the safety benefit of actions identified under Generic Letter 88-17.

We reviewed our Technical Specifications and made the necessary changes.

Subsequent to the original Generic Letter 88-17 responses, a containment outage door was installed at the exterior of the equipment hatch opening as an additional programmed enhancement to provide for closure during Mode 5 and 6 conditions. The containment outage door is designed to mitigate the offsite radiological consequences of a fuel handling incident and a loss of shutdown cooling incident. Because it can be opened and shut more quickly than the equipment hatch, the containment outage door increases the availability of the equipment hatch opening for access to the Containment during unit outages.

9.2.8 REFERENCES

1. Bechtel Specification 6750-M-0310A, "Design Specification for Piping, Valves, and Associated Equipment of the Shutdown Cooling System"