6.3 SAFETY INJECTION SYSTEM

6.3.1 SYSTEM DESCRIPTION

The SI system is designed to supply emergency core cooling in the unlikely event of a LOCA. The system prevents fuel and cladding damage that would interfere with core cooling, and limit the cladding-water reaction to less than 1% for all breaks in the RCS piping up to and including the equivalent of a double-ended break in the largest coolant pipe, i.e., up to a flow area of 19.2 ft^2.

The safety injection water contains boron at a concentration required by technical specifications; consequently, the SI system also provides additional shutdown capability whenever the system is required to operate. This shutdown capability assists in maintaining the reactor subcritical following the rapid cooldown of the RCS caused by a rupture of a main steam line (Section 14.14). The reactivity provided by the SI system exceeds the minimum required for cold shutdown.

The SI system consists of high-pressure and low-pressure subsystems, shown on Figures 6-1 (Unit 1) and 6-10 (Unit 2).

The high-pressure subsystem is capable of delivering emergency coolant at a discharge pressure up to 1275 psia. Three HPSI pumps take suction from two independent suction headers. After the headers are initially supplied with at least 360,000 gallons of borated water from the Refueling Water Tank (RWT), a Recirculation Actuation Signal (RAS) occurs. The RAS shifts the suction of the headers from the RWT to the containment sump to recirculate the borated water.

The LPSI system utilizes four pressurized SITs and two LPSI pumps. Each of the two pumps is connected to one of the two independent suction headers which serve the high-pressure pumps. This assures an adequate supply of borated water.

Control valve CV-306, between the low-pressure pumps and the LPSI header, is a fail-open valve manufactured in accordance with the American Society of Mechanical Engineers (ASME) Code for Pumps and Valves for Nuclear Power. The material and welds were inspected, tested and documented to the same code. The normally locked open valve is not required to function during or subsequent to a LOCA.

The LPSI subsystem is designed to the performance capability required by Atomic Energy Commission (AEC) General Design Criterion 41. Criterion 41 requires that, as a minimum, each ESF shall provide its required safety function assuming a failure of a single active component. Failure of a pipe or valve body pressure boundary constitutes a passive failure. The system piping is fabricated and constructed in accordance with the ANSI B31.7 Code - Nuclear Power Piping. Materials and welds were inspected, tested and documented in accordance with the applicable class of B31.7.

A passive failure of such high quality components, inspected throughout plant life, is not considered credible over a short-term period.

During the recirculation mode (the earliest this is reached is about 30 minutes following the break), the LPSI subsystem is automatically shut down and the HPSI pumps are used to recirculate water from the containment sump. Thus, the LPSI subsystem functions over a short-term period for the transient.

The water from the SITs re-covers the core following a RCS blowdown to minimize core damage until the SI pumps can provide adequate water for reactor cooling. In the normal mode, there are two check valves, with a locked open, motor-operated valve (MOV) in series between the pressurized SIT and the RCS. The tanks are designed to passively inject large quantities of borated water into the RCS immediately following a large pipe break. The water covers and cools the core, thereby limiting clad-melting and metal-water reaction (Section 14.17). The separate and independent tanks are each connected to one of four reactor vessel inlet pipes. The driving head for water injection is provided by nitrogen gas pressure within the tanks at a minimum pressure of 200 psig. As the RCS pressure falls below tank pressure, check valves open in the line connecting each tank to the system. The tanks operate as a passive stored-energy safety feature; no outside power or signal is required for their operation. A remotely-operated valve is provided to isolate the tanks during a normal depressurization of the RCS. The position of these motor control valves is displayed by the use of lights on the main control boards. Two lights are provided for each valve that indicate open or closed and are actuated by individual limit switches on the valve motor operator. A Control Room annunciator is actuated whenever the control switch is not in the open position. These valves are positioned and the position is checked as part of the startup check off. Once the valves are placed in the open position, a key is required to move the control switch and thus change the position of the valve. During normal operation, these valves are required to be open with power removed by maintaining the feeder breaker open. Furthermore, the system functions such that the four valves will be automatically opened whenever primary system pressure exceeds a preset value or a SI actuation signal (SIAS) is present. Two of the valves will be opened by signal from pressurizer pressure bistable PY103X and the other two by the redundant pressurizer pressure bistable PY103X-1. Safety Injection Actuation Signal Channel A opens two of the valves and Channel B opens the other two. A small drain valve controlled remotely from the Control Room is used to drain any inleakage from the RCS. The SITs are protected from overpressure by relief valves. Piping to each tank is arranged such that the operability of each tank can be demonstrated.

The tank size, gas/water fraction, gas pressure, and outlet pipe size for the SITs were selected to fulfill the following criteria:

a. The volume of water in the SITs is selected so that the contents of three of the four tanks injecting into the RCS following the worst case LOCA, will cover the top of the core;
b. The tank gas/water fractions, gas pressure, and outlet pipe size are selected to allow three of the four tanks to re-cover the core before significant clad melting or zirconium-water reaction can occur.

Safety injection is initiated either when the pressurizer pressure drops below the trip setpoint or when the containment pressure rises above the trip setpoint. Diversity of the SIAS is thus provided.

Upon initiation of SI, two of the three high-pressure and two LPSI pumps start and twelve SI line isolation valves open, injecting water from the RWT into the RCS. After sufficient water has been transferred from the tank, a continuous source of borated water is provided by recirculating containment sump water directly to the pump suction. Recirculation is automatically initiated by low water level in the RWT. In the event the automatic transfer fails to occur upon RAS, the operator can manually initiate recirculation using two buttons labeled Recirculation Manual Actuation Channel "A" ("B") on the main control board. As an additional backup, transfer to the recirculation mode may also be manually initiated by the Control Room operator via individual component handswitches.

Net Positive Suction Head (NPSH) is ensured for the HPSI pumps because the containment sump water level is 14'5" plant elevation at the time of RAS, and the centerline of the pump is at -12' plant elevation.

All manual valves that constitute barriers to the environment for isolation of the RWT are locked closed. Redundant, automatic motor-operated valves are provided on the safety features pumps recirculation line back to the tank. These valves may receive a close signal upon a RAS. However, this signal is normally overridden to ensure minimum flow for SI pumps.

There are no interlocks associated with the containment sump recirculation line motor-operated valves. These valves are closed during normal operation. When the valves are stroked during periodic testing, the check valves located downstream of the sump recirculation line valves protect against dumping the RWT contents into the containment sump. The check valves are designed to seat against the head of water from the RWT. The check valves can be tested for seat leakage via a drain connection between the sump recirculation valves and the check valves.

The valves will be operated from the ESF panels in the Control Room by simulating a RAS. This signal will open a 24" motor-operated sump valve on one line and close the 18” motor-operated RWT outlet valve on the same header. The valve position lights in the Control Room will verify that the valve has functioned properly. Upon verification that the valve has functioned properly, the operator will return the valve to its original position and test the remaining channel in the same manner.

The minimum time at which switchover to the recirculation mode could be required is 30 minutes. This period is based upon operation of two high-pressure pumps, both low-pressure pumps, and the containment spray pumps, all operating at or above design capacity. The maximum charging flow from the RWT is also considered. The system is designed to keep the core covered following initial SI. One high-pressure pump has sufficient capacity with complete spillage of the maximum flow leg to maintain core water level at the start of recirculation.

The automatic recirculation signal shuts down the LPSI pumps, sends an open signal to both recirculation line isolation valves, a close signal to RWT outlet valves, and a close signal to the minimum flow line isolation valves to signal isolation of the RWT. However, the minimum flow valves are normally locked out in the open position in the Control Room to prevent possible SI pump damage. The Control Room valve handswitch is actually locked out. The lock-out switch is turned to ON when the RWT reaches a low level before RAS, allowing the valves to automatically close on RAS. Further, the RWT outlet valves’ handswitches must be in AUTO for the RAS to initiate the valve closure. The Operator places the handswitches in AUTO after verifying sump level increasing and RWT level decreasing prior to RAS. The HPSI pumps continue to operate to provide core cooling water.

A key-operated manual override of the RAS contact in the LPSI pumps is installed to allow the LPSI pumps to run regardless of RWT level during long-term cooling.

In the recirculation mode, the HPSI pumps take suction directly from the containment sump. At the discretion of the operator, a portion of the cooled water from the Containment Spray System may be diverted to the suction of the HPSI pumps. The spray diversion valves are not powered from the diesel generators and therefore are not available on loss of offsite power. This method of operation provides additional cooling and NPSH, but is not necessary to meet core cooling requirements.

The containment spray pumps are centrifugal pumps which discharge at the design flow rate against containment design pressure and system losses. When the system is switched over to the recirculation mode of operation, the pumps take suction from the Containment Building and therefore do not have to pump against the pressure in the containment. The reduced pumping requirements during recirculation cause the pump to operate at a higher capacity thus providing more spray flow. This excess spray flow can be diverted to the suction of the HPSI pumps without compromising the Containment Spray Systems effectiveness.

The design of the suction piping in the SI system conservatively assumes that the recirculated fluid is saturated at containment pressure and temperature conditions, therefore subcooled fluid at the SI pump inlet is not needed to meet NPSH requirements.

However, in the unlikely event of cavitation in the SI pump, the operator could divert a portion of the Containment Spray System water to the suction of the SI system pumps if offsite power is available. The operator can monitor the SI pumps for cavitation by observing SI system flow meters, pump ammeters, and pressure gauges for decreased and erratic readings.

The LPSI pumps are also used to supply coolant flow to remove heat from the reactor following reactor shutdown and to maintain a suitable temperature for refueling and maintenance operations. In this mode the system is designed to cool the RCS from 300°F to 130°F. The maximum coolant pressure during this cooldown is approximately 300 psig.

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.

6.3.2 SYSTEM COMPONENTS

6.3.2.1 High-Pressure Safety Injection Pumps

The HPSI pumps are sized to ensure that one high-pressure pump will keep the core covered at the start of recirculation, assuming complete spillage of the maximum flow leg.

The requirements for boron injection for the steam line break and the injection requirements for smaller break sizes are also considered in the sizing. The high-pressure pumps are designed for the thermal transient conditions of 40°F to 300°F in 5 to 10 seconds and 300°F to 40°F in 5 to 10 seconds.

The high-pressure pumps are seven-stage, horizontal, centrifugal units. Mechanical seals are used and are provided with leak-offs to the Waste Processing System which collects any leakage past the seals. The seals are cooled by water that is taken from the pump flow and is cooled by component cooling water flow in the seal cooler heat exchanger of each pump. With the heat exchangers in operation, the seals can operate continuously at a pump flow temperature of 300°F. If the heat exchanger function is lost post-RAS due to loss of component cooling water, the seals can operate at least 2 hours at a pump flow temperature of up to 250°F. This 2 hours will allow manual realignment of valves to allow the containment spray pumps to substitute for the HPSI pumps. The bearings of each HPSI pump are cooled by component cooling water flow to the bearing housings. If component cooling water flow is lost, the bearings can also operate at least 2 hours. The pump motor is capable of starting and accelerating the pump to full speed with 75% of rated voltage. The pumps are provided with drain and flushing connections to permit reduction of the radiation levels before maintenance. The pressure-containing parts of the pump are stainless steel with internals selected for compatibility with boric acid. The materials selected were analyzed to ensure that differential expansion during design transients can be accommodated with the clearances selected. The following inspections were performed on the HPSI pumps:

a. All surfaces of pressure-containing castings were liquid penetrant inspected in accordance with techniques and acceptance standards of ANSI B31.1, Paragraph 136.5.3(d);

b. Pressure containing parts were hydrostatically tested in accordance with American Petroleum Institute (API) Standard 610, Paragraph 34 except design pressure was used in lieu of maximum discharge pressure.

The pumps are provided with minimum flow protection to prevent damage resulting from operation against a closed discharge. These are nearly identical in design to those used for Palisades plant of Consumers Power Company (Docket No. 50-255) except for a slightly larger impeller. One Palisades pump was subjected to the following transient tests while operating at the design point:

a. Suction temperature increase from 70°F to 315°F in a range of 5 seconds;

b. Suction temperature decrease from 300°F to 70°F in a range of 10 seconds.

No adverse effects of the temperature transients upon pump performance were noted, nor was there any excessive vibration which would indicate any tendency of running parts to bind. When the tests were completed, the pump was disassembled and inspected. No abnormal wear was noted.

A full-scale hydraulic test was performed on each Calvert Cliffs pump assembly. All pump test setups, test procedures and instrumentation were in accordance with the Standards of the Hydraulic Institute and the ASME Power Test Code, PTC 8.2. This included verification of satisfactory operation at the stated NPSH. Figure 6-3 shows the pump performance obtained during the hydraulic testing. During the spring 1985 Unit 1 refueling outage extended HPSI pump flow testing was performed on HPSI Pump Nos. 11 and 13. This testing demonstrated that the pumps would operate satisfactorily in the pre-RAS condition with the minimum available system resistance. It is necessary in the post-RAS condition to throttle back HPSI flow to maintain adequate NPSH margin.

The high-pressure pump data are shown in Table 6-1.

The design temperature for the HPSI pumps is based upon the saturation temperature of the reactor coolant at the containment design pressure, about 300°F, plus a design tolerance of 50°F, yielding a design temperature of 350°F. The design pressure for the HPSI pumps is based upon the sum of the LPSI pump design pressure and the shutoff head of the HPSI pump.

6.3.2.2 Low-Pressure Safety Injection Pumps

The LPSI pumps are horizontal, single-stage, centrifugal units equipped with mechanical face seals backed up by a bushing, with a leak-off to collect the leakage past the seal. The seals are cooled by water that is taken from the pump flow and is cooled by component cooling water flow in the seal cooler heat exchanger of each pump. With the heat exchangers in operation, the seals can operate continuously at a pump flow temperature of 300°F. If the heat exchanger function is lost post-RAS due to loss of component cooling water, the seals can operate at least 2 hours at a pump flow temperature of up to 350°F. This 2 hours will allow manual realignment of valves to allow the containment spray pumps to substitute for the LPSI pumps. The bearings of each LPSI pump are cooled by component cooling water flow to the bearing housings. If component cooling water flow is lost, the bearings can also operate at least 2 hours. The pump motor is capable of starting and accelerating the pump to full speed with 75% of rated voltage. The pumps are provided with drain and flushing connections to permit reduction of radiation levels before maintenance. The pressure-containing parts are fabricated from stainless steel; the internals are selected for compatibility with boric acid. The pumps are provided with minimum flow protection to prevent damage when starting against a closed system.

The pumps are of identical design to those used at the Palisades plant, Docket No. 50-255; one of these pumps was subjected to a suction temperature which was changed from 84°F to 351°F in 10 seconds while the pump was operating at the design point. No adverse effect upon pump performance was caused by this transient, nor was any excessive vibration detected that would indicate rubbing or binding. After the test was completed, the pump was disassembled and inspected. No abnormal wear was noted.

The following inspections were performed on the LPSI pumps:

a. All surfaces of pressure-containing castings were liquid penetrant inspected in accordance with techniques and acceptance standards of ANSI B31.1, Paragraph 136.5.3(d);
b. Pressure containing parts were hydrostatically tested in accordance with API Standard 610, Paragraph 34 except design pressure was used in lieu of maximum discharge pressure.

A full-scale hydraulic test of the pumps was performed. Figure 6-4 shows the pump performance obtained during the testing.

The design temperature for the LPSI pumps is based upon the temperature of the reactor coolant at the initiation of shutdown cooling, about 300°F nominal, plus a design tolerance of 50°F, yielding a total of 350°F. The design pressure for the low-pressure pumps is based upon the sum of the maximum pump suction pressure, which occurs at the initiation of shutdown cooling, and the pump shutoff head. This yields a nominal design pressure of 500 psig.

Table 6-2 contains the LPSI pump data.

6.3.2.3 Safety Injection Tanks

The four SITs are used to flood the core with borated water following a depressurization as a result of a LOCA. The tanks are sized to ensure that three of the four tanks will provide sufficient water to recover the core following a DBA. The tanks contain borated water at a sufficient boron concentration to ensure that the reactor will remain subcritical during the reflood stage of a large break LOCA. The tanks are pressurized with nitrogen at 250 psig.

Level and pressure instrumentation is provided to monitor the availability of the tanks during plant operation. Verifying availability (boron concentration) consists of monitoring in-leakage and sampling when appropriate. Provisions have been made for sampling, filling, draining, venting and correcting boron concentration. The tanks are carbon steel internal clad with stainless steel. Design, construction and overpressure protection are in accordance with the ASME Code Section III, Class C

Table 6-3 contains the SIT data.

6.3.2.4 Refueling Water Tank

The RWT is used to perform the following functions:

a. To provide borated water to the suction of the HPSI pumps, LPSI pumps and containment spray pumps for the initial operation of these pumps following a LOCA;
b. To provide a makeup water for the spent fuel pool;
c. To provide a storage for the contents of the refueling pool.

The tank is provided with connections for level control, sampling, filling, draining and venting. It is a flat bottom tank with a concave roof. The floor to shell weld is a double fillet; the shell is connected to the roof by a rolled angle. This angle is butt-welded to the shell and joined to the roof by a single lap weld. The tank is designed and fabricated to ASME Section III, Class C, and the floor welds, shell to bottom welds, and bottom course vertical welds were inspected by vacuum box. (ASME Code, Section III, Class C. "ND-3800, Design of Atmospheric and 0 to 15 psig Storage Tanks" follows very closely the API 650 Code. Due to the lack of shell weld definition in ASME Code, Section III, the definition of shell weld contained in API 650 is observed.)

In order to protect the tank contents from freezing in winter, a 60-gpm pump provides circulation through an external heat exchanger, heated by plant heating system hot water. Surveillance of the temperature of the tank contents is required by the Technical Specifications.

Periodic sampling of boron concentration and tank level surveillance are required by the Technical Specifications. A sample connection on the RWT is provided for these periodic samples which are taken to check the chemistry. The tank has an interconnecting line to the Chemical and Volume Control System (CVCS) which can be used to maintain the proper chemistry. The turbidity and radiological quality limits will be met by processing the water, while it is in the refueling pool or in the RWT, using the spent fuel pool purification system and/or portions of the CVCS.

To prevent gas intrusion into the ECCS pumps during a LOCA, the RAS setpoint is selected to ensure sufficient submergence of the RWT outlet nozzles to prevent vortex formation by closing the RWT outlet valves. In addition, the LPSI pumps are manually secured prior to RAS to reduce the RWT outlet nozzle flowrate. This action is in addition to the stop signal sent to the LPSI pumps by RAS.

The RWT is provided with both a wide range and narrow range level indicator. The narrow range instrument provides both a high and low level alarm. The wide range instrument provides only a low level alarm. The high level alarm is to alert the operators of an impending overflow of water from the RWT to the Miscellaneous Waste Processing System (MWPS). The low level alarms are used to assist the operator in monitoring for sufficient water inventory in the RWT. Redundant temperature instruments provide both high and low temperature alarms.

6.3.2.5 Shutdown Cooling Heat Exchangers

The shutdown cooling heat exchangers are used to remove decay and sensible heat during plant cooldowns, cold shutdowns and emergency containment spray operation. Additionally, the units are capable of achieving refueling temperature

(≤140°F) within 36 hours following shutdown of an infinitely irradiated core, given a maximum component cooling water temperature of 120°F. The units are further specified to accept a 40°F to 276°F transient in 10 seconds when the containment spray pump suction is switched to the containment sump. The units are designed and constructed to the standards of ASME, Section III, Class C, and Tubular Exchanger Manufacturers Association (TEMA), Class R requirements. The units are of a U-tube design with two tube-side passes and one shell-side pass. The tubes are austenitic stainless steel and the shell is carbon steel.

The design temperature and pressure for the shutdown cooling heat exchangers are compatible with the design temperature and pressure for the LPSI pumps (Section 6.3.2.2).

Table 6-5 contains the shutdown cooling heat exchanger data.

6.3.2.6 Piping

The SI system piping is fabricated of austenitic stainless steel and conforms to the standards set forth in ANSI B31.7. Flexibility and seismic loading analyses have confirmed the adequacy of the system piping.

Safety Injection Piping

All piping is fabricated and constructed in accordance with the ANSI B31.7 Code, Nuclear Power Piping. Material and welds were inspected, tested and documented in accordance with the applicable class of B31.7. All valves are manufactured in accordance with the ASME Code for Pumps and Valves for Nuclear Power. The material and welds were inspected, tested and documented to the same code.

Recirculation Piping

Engineered safety features piping connected to the containment sump is an extension of reactor containment during the recirculation mode of core and containment cooling. The following items pertain to suction piping from the sump to the first isolation valve:

a. The piping has a nominal wall thickness of 3/8" which results in a maximum allowable pressure for the pipe minimum wall thickness of at least 12.5 times the maximum expected pressure of 50 psig;

b. All piping was designed, fabricated, tested and inspected in accordance with ANSI B31.7, Class II, including weld and material testing. The valves were manufactured, inspected and tested in accordance with the ASME Code for Pumps and Valves for Nuclear Power, Class II;

c. The recirculation lines from the containment out to and including the first isolation valve is enclosed in a pressure and leak-tight encapsulation barrier. This barrier will contain any possible leakage resulting from postulated pressure failure of the pipe or valve. The barrier is tightly attached to the exterior concrete of the containment. The encapsulation barrier is designed for 50 psig and is in accordance with the criteria for Category I structures;

d. Pipe material is Type 304 stainless steel.

The containment sump suctions are enclosed by particulate screens as described in Section 6.4.

6.3.3 SYSTEM OPERATION

Any condition which causes a low pressurizer pressure or high containment pressure will result in a SIAS. This signal will start two HPSI pumps, both LPSI pumps, open twelve SI system isolation valves and close the four check valve leak-off lines at the SITs. (Safety Injection Actuation Signal also performs some functions in the CVCS; Section 9.1.)

When RCS pressure falls below approximately 1275 psig, the HPSI pumps start delivering flow through both the high-pressure header and the auxiliary high-pressure header.

If reactor coolant pressure falls below approximately 200 psig, the passive pressurized SITs will start delivering flow into each cold leg along with the LPSI pumps.

The SI pumps initially draw borated water from the RWT. This tank has sufficient water volume to supply SI flow for at least 30 minutes assuming two high-pressure and two LPSI pumps and two containment spray pumps are running. The maximum charging flow from the RWT is also considered. When the RWT level reaches the RAS setpoint, a signal occurs which opens the isolation valves in the two lines from the containment sump, closes the RWT outlet valves in the two lines from the RWT and shuts down the LPSI pumps. At the operator's discretion, the use of the key-operated manual override of the RAS to the LPSI pumps is allowed as long as the minimum flow requirements of the LPSI pumps are met. The RWT outlet valves control room handswitches are placed in AUTO after Operators verify that sump level is increasing and RWT level is decreasing in preparation for RAS. In AUTO, the RWT outlet valves will close on RAS. The RWT outlet valves can be manually controlled pre- and post-RAS using the handswitches in the Control Room. Back flow through either RWT suction line is prevented by check valves. The mini-flow isolation valves will automatically close on RAS to prevent containment sump water from entering the RWT. However, the minimum flow valves are normally locked out in the open position in the Control Room to prevent possible SI pump damage. The Control Room Valve handswitch is actually locked out. The lock-out switch is turned to ON when the RWT reaches a low level before RAS, allowing the valves to automatically close on RAS. The earliest automatic recirculation would occur is 30 minutes assuming two HPSI, two LPSI, and two Containment Spray pumps are running. The maximum charging flow from the RWT is also considered. The recirculation mode can also be accomplished manually by the operator.

In the recirculation mode the HPSI pumps take suction from the containment sump. The SI flow spilling from the break in the RCS is cooled by mixing in the containment sump with the cooler containment spray water.

6.3.3.1 ECCS Long-Term Cooling Flush

During post-accident long-term cooling conditions for a large cold leg break, it is possible to have a boric acid reconcentration occur in the core area, due to the small core flow in effect. This condition may result in the crystallization of boric acid in the core and restriction of cooling flow. In order to prevent such an occurrence, two procedures have been developed. The operators will decide which method to use based on plant conditions.

Hot leg injection promotes flow through the core by establishing a flow path from the containment sump, through the LPSI system via the warm-up line, to the shutdown cooling suction line, and into the hot leg.

Pressurizer injection promotes flow through the core by diverting flow from one HPSI pump through the pressurizer auxiliary spray line and into the hot leg.

A minimum of 150 gpm injection flow (flow to the reactor coolant system hot side) is necessary to overcome the coolant boil-off rate and cause a net flushing flow downward through the core. The required injection flow must be provided within at least 11 hours after the accident.

The HPSI pumps are the preferred method of core flush. The LPSI pumps could be used for core flush only as a backup to the HPSI pumps when pressurizer injection is not possible.

The containment spray pumps can be aligned to provide core flush into the hot leg by realigning valves on the -10 foot level of the Auxiliary Building. This realignment can be made after the containment spray pumps have completed the performance of their required post-LOCA function for spray service to reduce containment pressure. The containment spray pumps would only be used as a backup to the LPSI pumps.

6.3.4 DESIGN EVALUATION

The design bases and system requirements during a DBA are met with the operation of the SITs and one high-pressure and one LPSI pump, delivering rated flow and assuming complete spillage of the maximum flow leg through the break. During recirculation, one HPSI pump has sufficient capacity to maintain the water level in the reactor vessel above the core.

Ability to meet the core protection criteria is assured by the following features.

a. A high-capacity passive system (SITs) which requires no power source and will supply large quantities of borated water to rapidly recover the core after a major LOCA up to a break of the largest RCS pipe.

b. Low-pressure and high-pressure pumping and water storage systems with internal redundancy which will inject borated water. This capability provides core protection for RCS break sizes equal to and smaller than the largest line connected to the RCS (the 12" pressurizer surge lines or the shutdown cooling and SI lines). The pumping systems also provide borated water to keep the core covered and to continue cooling the core after the passive water supply has been exhausted. In addition, the high-pressure system will remove reactor core decay and sensible heat during long-term operation after the RCS rupture. Instrumentation and sampling provisions allow monitoring of the recirculated coolant.

c. Separated pump rooms and redundant pumping systems which will permit minimum safety features equipment to operate should pipe failure during long-term operation cause one pump room to flood.

d. Redundant onsite power supplies in the form of four emergency diesel generators, two dedicated to each unit, each of which has sufficient capacity for minimum safety features operation.

e. All active components which must function individually for the system to meet the performance criteria stated for core protection can be tested during normal reactor operation. Instrument sensors are tested for functioning at operating conditions. In addition, extensive shop and preoperational tests are performed to verify adequate component and system operation.

f. Most of the active components are located outside the containment where they are protected from accident-generated missiles and from post-accident environmental conditions. Those active components located inside the containment need only operate for a short time period after the accident.

g. The four injection lines are arranged such that movement of a ruptured reactor coolant pipe will not cause a subsequent failure of injection lines in non-ruptured loops. The maximum movement of the reactor coolant pipe at the injection nozzle in the non-ruptured loop will not damage the injection line.

h. The SI systems have been designed to meet the single failure criterion. This includes the fluid systems and the electrical control and instrument systems. All pumps and critical power-operated valves can be actuated from their respective switchgear or control centers. Instrumentation is also provided at locations other than the Control Room to ensure adequate control of the SI system if Control Room evacuation is required. Valve CV-306 in the LPSI system has instrument air removed from the valve operator to ensure the valve remains open under all required conditions.

i. All components, piping, cabling structures, power supplies, etc., in the SI support systems are designed to Category I seismic criteria.

The effectiveness of the SI system to satisfy the criteria stated for core protection can be shown by the blowdown and refill transient curves following a LOCA. This analysis is presented in Section 14.17, LOCA.

6.3.5 SYSTEM RELIABILITY AND AVAILABILITY

The HPSI system is designed to minimize the amount of equipment which must operate when a SIAS is received. All valves not required to operate on initiation of SI are either isolated from the SI flow path or locked in the SI position during operation. Administrative controls ensure that the locked valves are in the correct position.

Three pumps are provided in the high-pressure system. Note that as described in Chapter 7, two HPSI pumps [11(21), 13(23)] are lined-up for automatic initiation, the third [12(22)] is in pull-to-lock. These pumps are located outside the containment. The pump rooms are in a controlled access area and are ventilated through charcoal filters to the plant vent. Floor drainage is collected and pumped to the MWPS.

The pump room location outside the containment is most favorable for extended operation and equipment life following a major LOCA. Temperature, humidity, and radiation levels will all be significantly lower, thus permitting the use of standard or more nearly standard equipment and components of proven performance and reliability. This location is also more rapidly accessible for service and inspection of the safety features systems components during plant operation and during the period of long-term cooling following the postulated LOCA.

The pumps are appropriately grouped, together with the pumps of the other ESF systems, in separate rooms. This arrangement permits access to, and operability of, those pumps required for minimum safety features operation.

With outside power available, the SIAS starts two high-pressure pumps and two low-pressure pumps. If outside power is not available, two high and two low-pressure pumps will be operated from the emergency diesel generators. Analyses of the LOCAs are performed assuming minimum ESF which includes only one high-pressure pump, one low-pressure pump and the four SITs (one spilling through the break).

Redundant flow paths are provided from the discharge of the HPSI pumps by independent HPSI headers. These headers, in turn, supply the four individual SI lines, one leading to each cold leg of the RCS.

Normal plant operating procedures include routine testing to ensure the operability of the pumps. The attention given to the selection of these pumps, the redundancy of power supplied, the design margins, and the fact that three pumps are installed assures a high degree of pump availability.

The HPSI valves are designed for 2485 psig. The power-operated SI isolation valves are located outside of the containment and are thus not subjected to the environmental conditions existing in the containment following any LOCA. The attention given to the selection of these valves, design margins, and the fact that eight HPSI valves are in parallel assure a high degree of valve availability. The main and auxiliary HPSI header supply valves are normally locked open.

Four SI valves are automatically opened from one emergency power bus on the initiation of SI; the remaining four HPSI valves are opened from the remaining emergency power bus on receipt of a SIAS. There is a linear flow indicator for each safety injection line and a linear total flow indicator that provides the sum of all four high pressure safety injection flows. These indicators are located on Control Room panels 1/2C08 and 1/2C09. The valves are equipped with remote position indicators in the Control Room.

During recirculation, the HPSI pumps continue to operate, taking suction from the containment sump. The operator has the option of positioning valves so that the high-pressure pumps take partial suction from the shutdown cooling heat exchangers. These are supplied with sump water by the containment spray pumps or the LPSI pumps. The pump recirculation lines, the heat exchangers, the containment spray pumps and the recirculation suction headers are arranged to provide two independent flow paths. The LPSI pumps can also be used for recirculation, if necessary.

Fouling of heat transfer surfaces during the long-term post accident cooling mode is not expected to be a problem. The concentration of boric acid in the reactor vessel following blowdown is well below the solubility limit of 25 wt% at 200°F. Furthermore, boric acid solubility increases with increasing temperature and, consequently, precipitation onto hot surfaces is not expected. Means for core flushing are provided, should fouling of core heat transfer surfaces occur.

The LPSI system is also designed to minimize the amount of equipment which must operate when a SI signal is received. All valves not required to operate on initiation of SI are either isolated from the SI flow path or locked in the SI position during operation. Administrative controls ensure that the locked valves are in the correct position.

The two parallel pumps in the low-pressure system are appropriately grouped, together with the pumps of the other ESF systems, in separate rooms. This arrangement permits access to and operability of those pumps required for minimum safety features operation.

Normal plant operations, augmented by routine testing, ensure the operability of the pumps. The attention given to the selection of these pumps, the redundancy of power supplied, the design margins, and the fact that two pumps are supplied assures a high degree of pump availability.

The four SITs comprise a completely independent and redundant source of low-pressure injection water which requires no outside signal or source of power operation. The analysis in Chapter 14 shows that the core will be recovered quickly after a major break, before any clad melting occurs.

The power-operated LPSI valves are located outside of the containment and are thus not subjected to the environmental conditions existing in the containment following any LOCA.

The attention given to the selection of these valves, design margins, and the fact that four LPSI valves are in parallel assure a high degree of valve availability. The SI valves are opened automatically on initiation of safety injection.

During recirculation, the low-pressure pumps are normally secured, but they may be arranged to take suction from the containment sump and discharge to the shutdown cooling heat exchangers or directly into the reactor vessel as backup either for the containment spray pumps or the HPSI pumps.

6.3.5.1 Tank Reliability

The tanks associated with the safety systems were ordered with quality control (QC) requirements consistent with the importance of these tanks to nuclear safety and plant reliability. Some of them were furnished under contract with Combustion Engineering, Inc. (CE) and others were ordered according to Bechtel Associates' specifications.

For tanks ordered under the Bechtel specifications, the QC requirements are specified according to criteria set forth in Bechtel's Instruction BQC-201, which invokes certain parts of Bechtel's generic specification BQC-200 according to three levels or categories. The refueling water tanks, Condensate Storage Tank No. 12, radioactive waste tanks and spent fuel pool, were classified as Category 3, and as such, the following was required of tank manufacturers:

a. The contractor was required to have written procedures and instructions for control of all special fabrication and construction processes, such as welding, heat treating, cleaning, etc.
b. The contractor was required to have a system for assuring the control, identification and location of materials used in the finished item.
c. The vendor was required to provide copies of certain QC records and procedures such as welding procedures, non-destructive examination (NDE) results, etc.
d. The contractor was required to make available his QC program description document and the procedures, records and qualification governing the control of special processes noted in Items a, b, and c.
e. All manufacturers in this category were informed that they were subject to quality surveillance by Bechtel Associates, the customer or its agent as appropriate.

6.3.6 ROUTINE TESTS AND INSPECTIONS

Routine operational testing of major portions of the logic circuits, pumps and power-actuated valves in the SI system is described in Section 7.3.

The pumps are located outside the containment for access and to permit maintenance during normal plant operations. A recirculation line is provided on the discharge of each pump. Periodic testing will be performed by recirculating water back to the RWT.

Each SIT has two check valves in series between the tank nozzle and the RCS. These valves are tested periodically with other components of the system to assure their operability, in accordance with the Inservice Testing Program. Any one of the four SITs may be isolated for testing while shutdown.

Preoperational and periodic post-operational testing and inspections will be conducted to assure that the performance capability of the emergency core cooling system (ECCS), as installed, will conform to its design requirements during the life of the facility.

Preoperational tests of the SI system were performed after system installation prior to initial hydrostatic tests of the RCS. These preoperational tests were conducted in accordance with detailed test procedures which include testing of:

a. Safety Injection System automatic and remote operated control valves;
b. Low-pressure safety injection pumps;
c. High-pressure safety injection pumps;
d. Safety injection tanks;
e. Safety injection paths to the RCS; and,
f. Alarms and interlock circuitry.

The post-operational tests and inspections to be conducted on the SI system throughout plant life are described in the Technical Specifications.

Detailed test procedures for testing the SI system ensure proper operation of:

a. All SI pumps and their control circuits;
b. All actuator operated valves required to operate on receipt of SIAS and their control circuits;
c. The 12" SI check valves (SI-217, 227, 237, and 247);
d. The 12" SIT check valves (SI-215, 225, 235 and 245);
e. The 18" RWT discharge check valves (238M-1);
f. The 24" containment sump suction check valves (238M3-1);
g. 6" SI line check valves (207M3-1).

TABLE 6-1

HIGH-PRESSURE SAFETY INJECTION PUMP DATA SUMMARY

Quantity	3
Type	Seven-stage, Horizontal, Centrifugal
Motor Voltage	4000
Design Pressure, psig	1750
Design Temperature, °F	350
Design Flow (per pump), gpm	345
Design Head, ft	2500
Pumped Fluid	Reactor Coolant
Temperature of Pumped Fluid, °F	40-300
Shutoff Head, ft	2900
Maximum Flow, gpm	740
Head at Maximum Flow (one pump), ft	755
Material	Stainless Steel
Horsepower (motor)	400
Shaft Seal	Mechanical
Acceleration Time, seconds	4
Minimum Flow, gpm	30
NPSH Available pre-RAS (750 gpm)/post-RAS (620 gpm), ft	73.7/21.4
NPSH Required pre-RAS (750 gpm)/post-RAS (620 gpm), ft	40.0/19
Design Maximum Suction Pressure, psig	250

TABLE 6-2

LOW-PRESSURE SAFETY INJECTION PUMP DATA

Quantity	2
Type	Single Stage, Horizontal, Centrifugal
Motor Voltage	4000
Design Pressure, psig	500
Design Temperature, °F	350
Design Flow (per pump), gpm	3000
Design Head, ft	350
Pumped Fluid	Reactor Coolant
Temperature of Pumped Fluid, °F	40-300
Shutoff Head, ft	420
Maximum Flow, gpm	4500
Head at Maximum Flow (one pump), ft	235
Basic Material	Stainless Steel
Horsepower	400
Seals	Mechanical
Acceleration Time, seconds	4
NPSH Available (minimum), ft	30.0
NPSH Required at 3000 gpm, ft	12
Design Maximum Suction Pressure, psig	300
Minimum Flow, gpm	40

TABLE 6-3

SAFETY INJECTION TANK DATA

Quantity	4
Total Volume, ft^3	2000
Water Volume, ft^3	1113 (min.)
Design Pressure, psig	250
Operating Pressure, psig	200 (min.)
Design Temperature, °F	200
Operating Temperature, °F	120
Relief Valve Setpoint, psig	250

TABLE 6-5

SHUTDOWN COOLING HEAT EXCHANGER DATA

Quantity		2
Type		Shell and Tube
Codes		
	Tube Side	ASME Section III, Class C
	Shell Side	ASME Section III, Class C
Tube Side		
	Fluid	Reactor Coolant
	Design Pressure, psig	500
	Design Temperature, °F	450
	Pressure Loss, (1.5×10^6 lb/hr), psi	5
	Materials	Austenitic Stainless Steel
Shell Side		
	Fluid	Component Cooling Water
	Design Pressure, psig	150
	Design Temperature, °F	250
	Pressure Loss, (2.41×10^6 lb/hr), psi	10
	Materials	Carbon Steel