

## 7.4 Safe Shutdown Systems

### 7.4.1 Description

This section examines and discusses the instrumentation and control aspects of the following plant systems and functions designed to assure safe and orderly shutdown of the reactor:

- (5) Reactor Shutdown Cooling (SDC) mode of RHR
- (6) Remote Shutdown System (RSS)
- (7) Standby Liquid Control System (SLC)

See Subsection 7.1.2.4 which addresses the design basis information required by Section 3 of IEEE-279.

#### 7.4.1.1 Reactor Shutdown Cooling (SDC) Mode—Instrumentation and Controls

- (1) Function

The SDC mode of the RHR System is used during the normal or emergency reactor shutdown and cooldown. The RHR System P&ID is shown in Chapter 5.

The initial phase of the SDC mode is accomplished following insertion of the control rods and steam blowdown to the main condenser which serves as the heat sink.

Reactor shutdown cooling has three independent loops. Each loop consists of pump, valves, or heat exchanger, and instrumentation designed to provide decay heat removal capability for the core. This mode specifically accomplishes the following:

- (a) Reactor Shutdown—in conjunction with other systems removes enough residual heat (decay and sensible) from the reactor vessel water to cool it to 60°C with all three SDC loops available within 24 hours after the control rods are inserted. This RHR mode then maintains or reduces this temperature so that the reactor can be refueled and serviced. This mode is manually activated with the reactor pressure below 0.93 MPaG.
- (b) Safe Shutdown (Emergency Shutdown) brings the reactor to a cold shutdown condition (< 100°C) with two-out-of-three shutdown cooling loops available within 36 hours after control rod insertion. This mode is manually activated with the reactor pressure below 0.93 MPaG.

The RHR mode can accomplish its design objective by a preferred means of directly extracting reactor vessel water from the vessel shutdown nozzle and routing it to a heat exchanger and back to the vessel. After extracting heat via the RHR heat exchanger this cooler water is returned to the vessel via the feedwater line (Loop A) and via the core cooling injection nozzles (Loops B and C).

(2) Classification

Electrical components for the reactor SDC mode of the RHR System are safety-related and are classified as Class 1E.

(3) Power Sources

This system utilizes plant Class 1E power sources. These include 4.16 KV for the pumps, and 480 VAC for other motors (both backed by the DG), and 120 VAC instrument buses (backed by DC sources).

(4) Equipment

The reactor water is cooled by taking suction from the three SDC suction nozzles. The water is pumped through the respective RHR system heat exchanger and back to the reactor vessel via the feedwater lines (Loop A) and the LPFL injection nozzles (Loops B and C).

If it is necessary to discharge a complete core load of reactor fuel to the fuel pool, a means is provided for making a physical inter-tie between the Spent Fuel Pool Cooling and Cleanup (FPCU) System and the RHR heat exchangers. This increases the cooling capacity of FPCU to handle the heat load for this situation. The fuel pool intertie is applied only to Loops B and C (see Chapter 5 for RHR System P&ID).

(5) Initiating Circuits

The reactor Shutdown Cooling System is initiated by manual operator actions.

(6) Logic and Sequencing

The following reactor shutdown cooling operating sequence is to be utilized when pressure permissives are present:

- (a) The RHR valving should be aligned for shutdown cooling mode.
- (b) Warm up each RHR SDC loop using the RHR warm up line in accordance with plant procedure.
- (c) Aligning RHR heat exchangers and start service water for cooling.
- (d) Start the respective RHR pump.

(7) Bypasses and Interlocks

To prevent opening of the reactor shutdown cooling valves except under proper conditions, the interlocks are provided as shown in Table 7.4-1.

The three RHR pumps used for shutdown cooling are interlocked to trip if the reactor SDC valves and suction valves from the suppression pool are not properly positioned.

(8) Redundancy

The reactor SDC System consists of three independent loops. Any two of the three loops are sufficient to satisfy the cooling requirements for emergency shutdown cooling. Each loop has its own suction line with three suction valves in series. In the event one of the suction valves fails closed, normal shutdown cooling is not available for that loop. The remaining two loops will provide the shutdown cooling.

Refer to Chapter 15 for a system-level examination of the above operation.

The design basis objective for redundancy is achieved by providing three independent SDC loops.

(9) Actuated Devices

All valves in the SDC System are equipped with remote manual switches in the MCR. The only automatically activated modes of the RHR are the LPFL mode for the ECCS and the suppression pool cooling mode, as described in Subsections 7.3.1.1.1.4 and 7.3.1.1.4, respectively. Other modes of RHR are described in Subsections 7.3.1.1.3 and this subsection (7.4.1.1).

(10) Separation

Since various modes of operation of the RHR System perform safety-related functions (LPFL suppression pool cooling and wetwell and drywell spray cooling), all of the system equipment performing safety-related functions satisfies the appropriate safety separation criteria. The SDC mode of operation can utilize two diverse techniques. Separation between components utilizes three completely independent loops and thus satisfies safety separation criteria in order to accomplish its design basis.

(11) Testability

The reactor SDC pumps (RHR) may be tested to full capacity during normal plant operation. All valves except those isolated by reactor pressure interlock in the system may be tested during normal plant operation from the remote manual switches in the MCR.

The logic is tested by automatic self-test (see subsection 7.1.2.1.6).

(12) Environmental Considerations

The only reactor SDC control component located inside the drywell that must remain functional in the environment is the control mechanism for the inboard isolation SDC valve. The control and instrumentation equipment located outside the drywell is selected in consideration of the normal and accident environments in which it must operate.

The RHR equipment is seismically qualified and environmentally classified as discussed in Sections 3.2, 3.10, and 3.11. RHR control logic is contained and operated within Safety System Logic and Control (SSLC) and is thus qualified as part of SSLC (see Section 7.1).

(13) Operational Considerations

All controls for reactor shutdown cooling are located in the MCR. Reactor operator information is provided as described in the RHR discussion of LPFL mode (Subsection 7.3.1.1.4).

(14) Setpoints

There are no setpoints involved in the operation of the SDC mode of the RHR System except that reactor pressure and water level setpoints must be satisfied before the operator can begin this mode.

### 7.4.1.2 Remote Shutdown System (RSD)

#### 7.4.1.2.1 General

The Remote Shutdown System (RSD) provides a means to carry out the reactor shutdown functions from outside the main control room (MCR) and bring the reactor to hot shutdown and subsequent cold shutdown through suitable procedures, in a safe and orderly fashion.

#### 7.4.1.2.2 Postulated Conditions Assumed to Exist as the Main Control Room Becomes Inaccessible

- (1) The plant is operating initially at or less than design power.
- (2) The plant is not experiencing any transient situations. Even though the loss of offsite AC power is considered unlikely, the remote shutdown panel or facilities are powered from Class 1E power system buses A4 and B4 so that backup AC power would be automatically supplied by the respective bus diesel generator. Manual controls of the diesel generator are also available locally.
- (3) The plant is not experiencing any accident situations. No design basis accident (including a LOCA) shall be assumed, so that complete control of engineered safeguard feature systems from outside the MCR shall not be required.

- (4) All plant personnel have evacuated the MCR.
- (5) The MCR continues to be inaccessible for several hours.
- (6) The initial event that causes the MCR to become inaccessible is assumed to be such that the reactor operator can manually scram the reactor before leaving the MCR. If this was not possible, the capability of opening the RPS logic input power breakers from outside the MCR can be used as a backup means to achieve initial reactor reactivity shutdown.
- (7) The main turbine pressure regulators may be controlling reactor pressure via the bypass valves. However, in the interest of demonstrating that the plant can accommodate even the loss of the turbine controls, it is assumed that this turbine generator control panel function is also lost. Therefore, main steamline isolation is assumed to occur at a specified low turbine inlet pressure and reactor pressure is relieved through the relief valves to the suppression pool.
- (8) The reactor Feedwater System, which is normally available, is also assumed to be inoperable. Reactor water is made up by the HPCF System.
- (9) It shall be assumed that the event causing the evacuation will not cause any failure of the DC or AC control power supplies to the remote shutdown panels or any failure of the DC or AC power feeds to the equipment whose functions are being controlled from the remote shutdown panels.

The above initial conditions and associated assumptions are very severe and conservatively bound any similar postulated situation.

#### 7.4.1.2.3 Remote Shutdown Capability Description

RSD provides the capability for remote control of reactor systems needed to carry out the shutdown function from outside the MCR and bring the reactor to hot shutdown and subsequent cold shutdown through suitable procedures. RSD also provides a variation to the normal system used in the MCR permitting the shutdown of the reactor when feedwater is unavailable and the normal heat sinks (turbine and condenser) are lost.

Reactor pressure will be controlled and core decay and sensible heat rejected to the suppression pool by relieving steam pressure through the automatic activation of relief valves. Reactor water inventory will be maintained by the HPCF System. During this phase of shutdown, the suppression pool will be cooled by operating the RHR System in the Suppression Pool Cooling mode.

Manual operation of the relief valves will cool the reactor and reduce its pressure at a controlled rate until reactor pressure becomes so low that HPCF System operation is discontinued.

The RHR System will then be operated in the Shutdown Cooling mode using the RHR System heat exchanger in the reactor water circuit to bring the reactor to the cold low pressure condition.

#### 7.4.1.2.4 Remote Shutdown Capability Controls and Instrumentation—Equipment, Panels, and Displays

(1) **Main Control Room (MCR)**—Remote Shutdown Capability Interconnection Design Considerations

Some of the existing systems used for normal reactor shutdown operations are also utilized in the remote shutdown capability to shut down the reactor from outside the MCR. The functions needed for remote shutdown control are provided with manual transfer devices which override controls from the MCR and transfer the controls to the remote shutdown control. Control signals are interrupted by the transfer devices at the hardwired, analog loop. Process signals to the MCR are separately routed to the remote shutdown panels for continuous display. Control signals from the MCR are routed from the RMUs, through the remote shutdown transfer devices, and then to the interfacing system equipment. Actuation of the transfer devices interrupts the connection to the RMUs and transfers control to the Remote Shutdown System. Control of all necessary power supply circuits is also transferred to the remote shutdown system. Remote shutdown control is not possible without actuation of the transfer devices. Operation of the transfer devices causes an alarm in the MCR. The remote shutdown control panels are located outside the MCR. Access to this point is administratively and procedurally controlled.

(2) High Pressure Core Flooder System (HPCF)

(a) The following HPCF loop B equipment functions have transfer and control switches located on the Division II remote shutdown control panel:

- (i) Valve (pump suction from condensate storage)
- (ii) Valve (HPCF injection)
- (iii) Valve (minimum flow to suppression pool)
- (iv) Valve (test line isolation)
- (v) Valve (pump suction from suppression pool)
- (vi) HPCF Pump (B)

- (b) The following HPCF instrumentation is provided on the Division II remote shutdown control panel:
  - (i) HPCF flow indication
  - (ii) HPCF pump discharge pressure indication
  - (iii) HPCF pump suction pressure indication
  - (iv) Indicating lights for all valve (with RSD interface) positions and for the HPCF pump B stop/run
  
- (3) Residual Heat Removal System (RHR)
  - (a) The following RHR equipment functions have transfer and control switches located on one or both remote shutdown panels as indicated:
    - (i) Residual heat removal pump (A, B)
    - (ii) Valve (suppression pool suction) (A, B)
    - (iii) Valve (heat exchanger bypass) (A, B)
    - (iv) Valve (shutdown cooling injection) (A, B)
    - (v) Valve (heat exchanger outlet) (A, B)
    - (vi) Valve (suppression pool injection) (A, B)
    - (vii) Valve (shutdown cooling suction - inboard isolation) (A, B)
    - (viii) Valve (shutdown cooling suction - outboard isolation) (A, B)
    - (ix) Valve (shutdown cooling suction) (A, B)
    - (x) Valve (minimum flow) (A, B)
    - (xi) Valve (liquid waste flush isolation) (A, B)
    - (xii) Valve (drywell spray) (B)
    - (xiii) Valve (wetwell spray) (B)
    - (xiv) Valve (fuel pool cooling isolation) (A, B)
  
  - (b) The following RHR instrumentation is located on both remote shutdown control panels as indicated:
    - (i) RHR flow indication (A,B)
    - (ii) RHR heat exchanger inlet temperature indication (A,B)
    - (iii) RHR heat exchanger outlet temperature indicators (A,B)
    - (iv) RHR heat exchanger bypass valve position (A,B)
    - (v) RHR heat exchanger outlet valve position (A,B)
    - (vi) RHR pump discharge pressure indication (A,B)
    - (vii) Indicating lights for valve (with RSD interface) positions and for RHR pump stop/run (A,B)

- (4) Main Steam System (MS)
  - (a) The following functions have transfer and control switches located at the remote shutdown control panels:

Four air-operated safety relief valves (SRVs) (The valves are 125 VDC solenoid pilot operated.). Three of these valves have switches on the Division I panel, the fourth valve has switches on the Division II panel.
  - (b) The following main steam system instrumentation is provided on the remote shutdown control panels as indicated:
    - (i) Reactor water level wide range indication (A,B)
    - (ii) Reactor water level shutdown range indication (A,B)
    - (iii) Reactor pressure indication (A,B)
    - (iv) Indicate lights for four SRV valve open/close condition (three on Division I panel and one on Division II panel.)
- (5) Reactor Building Cooling Water System (RBCW)
  - (a) The following functions have transfer and control switches located on the remote shutdown panels as indicated:
    - (i) RBCW pumps (A1, A2 and B1, B2)
    - (ii) RBCW heat exchanger cooling water outlet valves (A1, A2, A3 and B1, B2, B3)
    - (iii) RBCW, RHR heat exchanger, outlet valve (A,B)
    - (iv) RBCW, diesel generator, outlet valve (A1, A2 and B1, B2)
    - (v) RBCW separator valve between essential and non-essential loads (A,B)
    - (vi) RBCW temperature control valves (A,B)
  - (b) The following RBCW instrumentation is provided on the RSD control panels as indicated:
    - (i) RBCW loop flow indication (A,B)
    - (ii) Flow indication for RBCW flow to RHR heat exchanger (A, B)
    - (iii) Temperature indication for RBCW entering RHR heat exchanger (A, B)
    - (iv) Temperature indication for RBCW leaving RHR heat exchanger (A, B)
    - (v) Indicating lights for valve positions and for pump stop/run (A,B)

- (6) Reactor Building Service Water System (RBSW)
  - (a) The following functions have transfer and control switches located on the remote shutdown panels as indicated:
    - (i) RBSW pumps (A1, A2 and B1, B2)
    - (ii) RBCW heat exchanger service water inlet valve (A1, A2, A3 and B1, B2, B3)
    - (iii) RBSW pump discharge valve (A1, A2 and B1, B2)
    - (iv) RBCW heat exchanger service water outlet valve (A1, A2, A3 and B1, B2, B3)
    - (v) Spray network isolation valve (A1, A2 and B1, B2)
    - (vi) Spray network bypass valve (A, B)
  - (b) The following RBSW instrumentation is provided on the RSD control panels as indicated:
    - (i) Indication of differential pressure between inlet and outlet of service water strainers (A1, A2 and B1, B2)
    - (ii) Indicating lights for all valve positions and RBSW pump stop/run conditions are provided on both RSD panels.
- (7) Medium Voltage Distribution System (MVD)
  - (a) The following functions have transfer and control switches located on the Division I remote shutdown panel:
    - (i) 4160V feeder breaker: Plant investment protection bus A3 to M/C bus A4
    - (ii) 4160V feeder breaker: Reserve auxiliary transformer RAT1 to M/C bus A4
    - (iii) 4160V feeder breaker: Emergency diesel generator A to M/C bus A4
    - (iv) 4160V feeder breaker: Reserve auxiliary transformer RAT2 to M/C bus A4

- (b) The following functions have transfer and control switches located on the Division II remote shutdown panel:
    - (i) 4160V feeder breaker: Plant investment protection bus B3 to M/C bus B4
    - (ii) 4160V feeder breaker: Reserve auxiliary transformer RAT1 to M/C bus B4
    - (iii) 4160V feeder breaker: Emergency diesel generator B to M/C bus B4
    - (iv) 4160V feeder breaker: Reserve auxiliary transformer RAT 2 to M/C bus B4
  - (c) A 4160V M/C (A4, B4) voltmeter is provided on RSD Division I and Division II panels, respectively.
- (8) Flammability Control System (FCS)
- (a) The following FCS equipment function has transfer and control switches located on the Division II remote shutdown panel:
    - (i) Valve (cooling water inlet) (B)  
Indicating lights to show this valve's position are also provided on the Division II remote shutdown panel.
- (9) Containment Monitoring System (CMS)
- (a) Suppression pool water level indication is provided on both RSD panels.
  - (b) Suppression pool water temperature indication is provided on both RSD panels.
- (10) Condensate Storage and Transfer System (CSTF)
- (a) Condensate storage pool level indication is provided on both RSD panels.
- (11) Emergency Diesel Generator System (DG)
- (a) Status lights provide DG status indication (run/stop) on each RSD panel (I, II).
- (12) Reactor Core Isolation Cooling System (RCIC)
- (a) The following devices are provided on RSD Division I control panel:
    - (i) RCIC flow controller
    - (ii) RCIC turbine speed indicator
    - (iii) RCIC transfer switch

- (13) Nitrogen Supply System (N<sub>2</sub>)
  - (a) Main steam safety relief valve (SRV) nitrogen supply header pressure indication is provided on the RSD Division I control panel.

#### 7.4.1.3 Standby Liquid Control System (SLC)— Instrumentation and Controls

##### (1) Function

The instrumentation and control for SLC is designed to initiate and continue injection of a liquid neutron absorber (boron solution) into the reactor when either manually or automatically called upon to do so. This equipment also provides the necessary controls to maintain this liquid chemical solution well above saturation temperature in readiness for injection. The system P&ID is shown in Chapter 9.

##### (2) Classification

SLC provides a backup method to shut down the reactor to cold subcritical conditions by independent means other than the normal method by the CRD System. Thus, the system is considered a safe shutdown system. The SLC process equipment, instrumentation, and control essential for injection of the neutron absorber solution into the reactor is classified as nuclear safety related, and is designed to withstand Seismic Category I earthquake loads. Any nondirect process equipment, instrumentation, and control of the system is not required to meet Seismic Category I requirements; however, the local and MCR mounted equipment is located in seismically qualified panels.

##### (3) Power Sources

The power supply to one motor-operated injection valve, storage tank discharge valve, and injection pump is powered from Class 1E Division I, 480 VAC. The power supply to the other motor-operated injection valve, storage tank outlet valve, and injection pump is powered from Class 1E Division II, 480 VAC. The power supply to the tank heaters and heater controls is connectable to a standby AC power source. The standby power source is Class 1E from an onsite source and is independent of the offsite power. The power supply to the main MCR benchboard indicator lights and the level and pressure sensors is powered from a Class 1E instrument bus.

##### (4) Equipment

SLC is a special plant-capability event system. No single active component failure of any plant system or component would necessitate the need for the operational function of SLC. It is included for a number of special consideration events:

- (a) Plant capability to shut down the reactor without control rods from normal operation (Chapter 15).

- (b) Plant capability to shut down the reactor without control rods from a transient incident (Chapter 15).

(5) Initiating Circuits

The Safety System Logic and Control (SSLC) provides the ATWS signals which automatically initiate SLC. An ATWS signal is sent from each of the four divisions of SSLC to each of the two divisions of SLC, where a two-out-of-four vote is performed to confirm the initiation signals. The SLC is initiated manually in the MCR by turning keylocking switches for system A or for system B to the START position.

(6) Logic and Sequencing

When one division of SLC is initiated, one injection valve and one tank discharge valve start to open immediately. The pump that has been selected for injection will not start until its associated tank discharge valve is at the fully open position. In order to provide maximum Motor Operated Valve (MOV) availability when the SLC is in normal standby readiness, the thermal overloads for the storage tank outlet valves are bypassed by a contact from a test switch in its NORMAL position. When the TEST position is selected, the overload short is removed, thus allowing motor protection during test operation of the valves.

(7) Bypasses and Interlocks

Pumps are interlocked so that either the storage tank discharge valve or the test tank discharge valve must be fully open for the pump to run. When SLC is initiated to inject the neutron absorber into the reactor, the outboard isolation valves of the reactor water cleanup system automatically close.

(8) Redundancy and Diversity

Under special shutdown conditions, SLC is functionally redundant to the Control Rod Drive System in achieving and maintaining the reactor subcritical. SLC active components and control channels are redundant for serviceability.

SLC provides a diverse means for shutting down the reactor using a liquid neutron absorber in the event of a control rod drive system failure.

The method of identifying redundant power cables, signal cables, and cable trays and the method of identifying non-safety-related cables as associated circuits are discussed in Chapter 8.

(9) Actuated Devices

When SLC is automatically initiated to inject a liquid neutron absorber into the reactor, the following devices are actuated:

- (a) The two injection valves are opened.
- (b) The two storage tank discharge valves are opened.
- (c) The two injection pumps are started.
- (d) The reactor water cleanup isolation valves are closed.

When the SLC is manually initiated to inject a liquid neutron absorber into the reactor, the following devices are actuated:

- (a) One of the two injection valves is opened.
- (b) One of the two storage tank discharge valves is opened.
- (c) One of the two injection pumps is started.
- (d) The reactor water cleanup isolation valves are closed.

Additionally, the pressure and tank level sensing equipment indicates that the SLC is pumping liquid into the reactor.

(10) Separation

SLC is separated both physically and electrically from the CRD System. The SLC two electrical control divisions are electrically and physically separated in accordance with the requirements of Chapter 8.

(11) Testability

SLC is capable of being tested by manual initiation of actuated devices during normal operation. In the test mode, demineralized water is circulated in the SLC loops rather than sodium pentaborate. During reactor shutdown, demineralized water may be injected into the reactor vessel for the injection test mode.

(12) Environmental Considerations

The environmental considerations for the instrument and control portions of SLC are the same as for the active mechanical components of the system (Section 3.11). The instrument and control portions of SLC are seismically qualified not to fail during, and to remain functional following, a safe shutdown earthquake (SSE) (see Section 3.10 for seismic qualification aspects).

(13) Operational Considerations

SLC is automatically initiated upon receiving an ATWS signal or can be manually initiated in the MCR by inserting the key in either the A or B keylocking switch and turning it to the START position. It will take between 60 and 150 minutes to complete the injection and for the storage tank level sensors to indicate that the storage tank is dry (e.g., injection will occur in 61 minutes at minimum tank level with both pumps operating). When the injection is completed, the system automatically shuts down on low tank level or may be manually turned off by turning the keylocking switch counterclockwise to the STOP position.

(14) Reactor Operator Information

(a) The following items are located in the MCR for operation information:

(i) Analog Indication

- Storage tank solution level
- Storage tank solution temperature
- System (pump discharge) pressures

(ii) Status Lights

- Pump or storage tank outlet valve overload trip or power loss
- Position of injection line manual service valve
- Position of storage tank outlet valve and in-test status
- Position of test tank discharge manual service valve
- SLC manually out of service
- Pump auto trip

(iii) Annunciators

SLC annunciators indicate:

- Manual or automatic out-of-service condition of SLC loops A and/or B due to:
  - Operation of manual out-of-service switch
  - Storage tank outlet valve in test status
  - Overload trip or power loss in pump or storage tank outlet valve controls

- Standby liquid storage tank high or low temperature
  - Standby liquid tank high or low level
  - Standby liquid pump A (B) auto trip
- (b) The following items are located locally at the equipment for operator utilization:
- (i) Analog Indication
    - Storage tank level
    - System pressures
    - Storage tank temperature
  - (ii) Indicating lamps
    - Pump status
    - Storage tank operating heater status
    - Storage tank mixing heater status

(15) Setpoints

SLC has setpoints for the various instruments as follows:

- (a) The high and low standby liquid temperature switch is set to activate the annunciator at temperatures outside the range allowed for correct chemical balance of the boron concentration.
- (b) The high and low standby liquid storage tank level switch is set to activate the annunciator when the level is outside its allowable limits.
- (c) The low standby liquid storage tank level switches are set to trip the operating pumps when the level is low.
- (d) The thermostatic controller and operating heater assure that the temperature of the liquid is maintained within the range allowed for correct chemical balance of the boron concentration.

The Technical Specifications for SLC are in Chapter 16.

## 7.4.2 Analysis

### 7.4.2.1 Reactor Shutdown Cooling (SDC) Mode — Instrumentation and Controls

#### 7.4.2.1.1 General Functional Requirements Conformance

The design of the reactor shutdown cooling mode of the RHR System meets the general functional requirements as follows:

(1) Valves

Manual control and position indication is provided in the MCR. Three independent loops assure that no single failure in the valve electrical circuitry can result in loss of capability to perform a safety function.

Interlocks are provided to close the valves if a low reactor water level signal is present or if high reactor pressure exists.

(2) Instrumentation

Indicators are provided for RHR pump inlet and discharge pressures, heat exchanger flow (pressure differential across the heat exchanger), RHR flow rate, and heat exchanger inlet and discharge temperatures.

(3) Alarms

The following system functional alarms apply to all modes of the RHR System and to each of the three RHR loops except as noted:

- (a) Motor overload of any pump.
- (b) Heat exchanger service water outlet temperature high.
- (c) High wetwell air space temperature.
- (d) Low reactor pressure.
- (e) Discharge line pressure too high or too low.
- (f) RHR logic power failure (SSLC out-of-service).
- (g) Suppression pool water temperature high (common alarm).
- (h) Shutdown line pressure high.
- (i) Reactor water Level 1.5 (common alarm).
- (j) High drywell pressure (common alarm).
- (k) Overload of any RHR valve.

- (l) LPCF or SPC manual initiation armed.
  - (m) RHR autostart.
  - (n) RHR loop out of service.
  - (o) RHR MOVs in test status.
  - (p) RHR pump motor auto trip.
  - (q) RHR fill pump trip.
  - (r) RHR pump operation switch in pull-lock.
  - (s) All RHR pump suction valves closed.
- (4) Pumps

Manual controls and stop and start indicators are provided in the control room. Interlocks are provided to trip the pumps if the shutdown suction valves are not open and no other suction path exists.

Chapter 15 considers the operation and the system-level qualitative aspects of this system.

Loss of plant instrument air or cooling water will not, by itself, prevent reactor shutdown capability.

#### 7.4.2.1.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the RHR SDC mode with associated codes and standards applied in accordance with the Standard Review Plan. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

- (1) 10CFR50.55a (IEEE-279):

The SDC mode of the RHR System is a three-loop, three-division system which is redundantly designed so the failure of any single element will not interfere with the required safety action of the system. As an operating mode of RHR, the system is designed to meet the same requirement as the ECCS.

All components used for the safety isolation functions are qualified for the environments in which they are located (Sections 3.10 and 3.11). However, this mode of RHR (unlike the LPFL mode which is automatically actuated by LOCA) is manually actuated providing reactor pressure and water level are at permissible levels.

The containment is divided into four quadrants, each housing the electrical equipment which, in general, corresponds to the mechanically separated divisions assigned to each section (i.e., mechanical Divisions A, B, C, and D correspond with electrical Divisions I, II, III, and IV, respectively). The RHR SDC mode utilizes mechanical Divisions A, B, and C with electrical Divisions I, II, and III, respectively. Electrical separation is maintained between the redundant divisions. RHR SDC logic resides in the SSLC cabinets in Division I, II, and III.

With regards to IEEE-279, Section 4.19, RHR annunciates activity at the loop level (i.e., “RHR LOOP A,B, or C ACTIVATED”). However, the individual RHR mode is not separately annunciated.

Those portions of IEEE-279 which relate to automatically initiated systems are not applicable to the manually actuated shutdown cooling mode of the RHR System. However, the system is designed in accordance with all other requirements of IEEE-279.

(2) General Design Criteria (GDC)

In accordance with Table 7.1-2, with the Standard Review Plan for Section 7.4, the following GDCs are addressed for the SDC:

- (a) **Criteria:** GDCs 1, 2, 4, 13, 19, 24, 34, 35, and 38.
- (b) **Conformance:** SDC is in compliance (in part, or as a whole, as applicable) with all GDCs identified in (a). All GDCs are generically discussed in Subsection 3.1.2.

(3) Regulatory Guides (RGs)

In accordance with the Standard Review Plan for Section 7.4, and with Table 7.1-2, the following RGs are addressed for the SDC:

- (a) RG 1.22 –*Periodic Testing of Protection System Actuation Functions*
- (b) RG 1.47–*Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems*
- (c) RG 1.53–*Application of the Single-Failure Criterion to Nuclear Power Protection Systems*
- (d) RG 1.62–*Manual Initiation of Protective Actions*
- (e) RG 1.75–*Physical Independence of Electric Systems*
- (f) RG 1.105–*Instrument Setpoints for Safety-Related Systems*
- (g) RG 1.118–*Periodic Testing of Electric Power and Protection Systems*

- (h) RG 1.153—*Criteria for Power, Instrumentation, and Control Portions of Safety System*

SDC conforms with all the above-listed RGs, assuming the same interpretations and clarifications identified in Subsections 7.3.2.1.2 and 7.1.2.11.

With regard to RG 1.105, there are no actuation setpoints, since the RHR SDC mode is manually initiated. However, reactor pressure and level interlocks are provided to assure the mode cannot be actuated under the wrong conditions. These interlocks are derived from shared signals in the Main Steam System (MS) and the Containment Monitoring System (CMS).

- (4) Branch Technical Positions (BTPs)

In accordance with Table 7.1-2, and with the Standard Review Plan for Section 7.4, the following BTPs are addressed for the RHR SDC:

- (a) BTP HICB-11—*Guidance on Application and Qualification of Isolation Devices*
- (b) BTP HICB-12—*Guidance for Establishing and Maintaining Instrument Setpoints*

- (5) 10CFR50.34(f)(2) TMI-Related Requirements

In accordance with Table 7.1-2, and with the Standard Review Plan for Section 7.4, there are no TMI related requirements applicable to the RHR SDC.

## 7.4.2.2 Remote Shutdown System—Instrumentation and Controls

### 7.4.2.2.1 General Functional Requirements Conformance

The Remote Shutdown System (RSD) is classified as a safety-related system because it interfaces with nuclear safety-related equipment in other systems. No LOCA, seismic event or other abnormal plant condition (except loss of offsite power) is assumed to occur coincident with the event necessitating MCR evacuation. It is assumed that the emergency AC power buses are energized by normal AC power (offsite power) or by the backup diesel generators.

The RSD provides instrumentation and controls outside the MCR to allow prompt hot shutdown of the reactor after a scram and to maintain safe conditions during hot shutdown. It also provides capability for subsequent cold shutdown of the reactor through the use of suitable procedures.

### 7.4.2.2.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the RSD and the associated codes and standards applied in accordance with the Standard Review Plan. The following analysis lists the applicable criteria in order of

the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

(1) 10CFR50.55a (IEEE-279)

The RSD consists of two panels (Division I and Division II) which are located in separate rooms in the Reactor Building.

The RSD provides remote control capability as defined by the following interfaces:

System	Total Channels	RSD Interface
Residual Heat Removal	A, B, C	A, B
High Pressure Core Flooder	B, C	B
Main Steam System	A, B, C, D	A, B
Reactor Bldg. Cooling Water	A, B, C	A, B
Reactor Bldg. Service Water	A, B, C	A, B
Electrical Power Distribution	I, II, III, IV	I, II
Flammability Control System	B, C	B

The RSD is designed such that it does not degrade the capability of the interfacing systems. All equipment is qualified as Class 1E, consistent with the safety-related interfaces.

Separation and isolation is preserved both mechanically and electrically in accordance with IEEE-279 and Regulatory Guide 1.75.

With regard to Paragraph 4.2 of IEEE-279, a single-failure event is assumed to have occurred to cause the evacuation of the MCR. The RSD is not designed to accommodate additional failures for all scenarios. The effects of such failures are analyzed as follows:

The loss of one complete RHR loop could extend the time needed for the reactor to reach the emergency shutdown conditions. However, the ability of the RSD to ultimately facilitate such conditions is not impaired. An analysis was performed for this scenario using the nominal decay heat curve. The results showed that the time to reach 100°C with only one RHR loop available varied from 38 to 51.4 hours as the temperature of the ultimate heat sink varied from 29 to 35°C.

In the event of a complete loss of Division II, safe shutdown can be achieved by depressurizing the reactor with the three SRVs in Division I to the point at which RHR shutdown cooling can

be initiated. This assumes that the operator reaches the RSD panels in a timely manner (i.e., within 10 minutes after scram). No core uncovering is expected even though no high pressure coolant makeup capability is available.

In the event of a complete loss of Division I, the reactor can be depressurized with one SRV in Division II. Therefore, the time required to reach low pressure conditions will be extended. However, the probability of an event requiring MCR evacuation in addition to a failure resulting in loss of Division I (external to the MCR) is so low that it is not considered credible.

Other sections of IEEE-279 which relate to testability of sensors, etc., are not applicable to the RSD of itself, but are applicable to the primary systems which interface with the RSD. All other applicable criteria of IEEE-279 are met by the RSD.

(2) General Design Criteria (GDC)

In accordance with the Standard Review Plan for Section 7.4, and with Table 7.1-2, the following GDCs are addressed for the RSD:

- (a) **Criteria:** GDCs 1, 2, 4, 13, 19, 24, 34, and 35.
- (b) **Conformance:** Assuming the clarification for a single failure explained in Subsection (1) above, the RSD is in compliance (in part, or as a whole, as applicable) with the GDCs identified in (a). All GDCs are generically discussed in Subsection 3.1.2.

(3) Regulatory Guides (RGs)

In accordance with the Standard Review Plan for Section 7.4, and with Table 7.1-2, the following Reg. Guides are addressed for the RSD:

- (a) RG 1.53—*Application of the Single-Failure Criterion to Nuclear Power Protection Systems*
- (b) RG 1.62—*Manual Initiation of Protection Actions*
- (c) RG 1.75—*Physical Independence of Electric Systems*

With regard to Regulatory Guide 1.53, a single failure is assumed to have occurred which caused the need to evacuate the MCR. The RSD is not designed to accommodate an additional failure for all scenarios. The result of postulated worst case additional failures is discussed in (1) above. Otherwise, the RSD conforms with the above listed Reg. Guides assuming the same interpretations and clarifications identified in Subsections 7.3.2.1.1 and 7.1.2.11.

(4) Branch Technical Positions (BTPs)

In accordance with the Standard Review Plan for Section 7.4, and with Table 7.1-2, there are no BTPs applicable for the RSD.

(5) 10CFR50.34 (f)(2) TMI-Related Requirements

In accordance with the Standard Review Plan for Section 7.4 and with Table 7.1-2, there are no TMI related requirements applicable for the RSD. However, all TMI action plan requirements are generically addressed in Appendix 1A.

### 7.4.2.3 Standby Liquid Control System — Instrumentation and Controls

#### 7.4.2.3.1 General Functional Requirements Conformance

Redundant positive displacement pumps, injection valves, storage tank outlet valves, and control circuits (Subsection 7.4.1.3) constitute all of the active equipment required for injection of the sodium pentaborate solution. Indicator lights provide indication on the reactor control bench board of system status. Testability and redundant power sources are described in this subsection and Subsection 7.4.1.3.

Chapter 15 examines the system-level aspects of SLC under applicable plant events. Loss of plant instrument air or cooling water will not, by itself, prevent this reactor shutdown capability.

#### 7.4.2.3.2 Specific Regulatory Requirements Conformance

Table 7.1-2 identifies the Standby Liquid Control System (SLC) and the associated codes and standards applied in accordance with the Standard Review Plan. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

(1) 10CFR50.55a (IEEE-279)

SLC is manually actuated (or automatically actuated for ATWS events) and serves as a backup method for shutting down the reactor when no control rods can be inserted from the full power setting. It is not necessary for SLC to meet the single-failure criterion because it is considered redundant to (and therefore kept independent of) the control rod scram system.

There are two redundant channels of control circuits, discharge pumps and motors, storage tank discharge valves and injection valves. These two channels are independent of each other so that failure in one channel will not prevent the other from operating and performing the SLC reactivity control function. No components of SLC are required to operate in the drywell environment. An isolation check valve is the only component located inside the drywell. Other SLC equipment are designed to remain functional following an SSE.

SLC utilizes motor-operated injection valves. It is designed to meet all applicable portions of IEEE-279 as clarified above.

## (2) General Design Criteria (GDCs)

In accordance with the Standard Review Plan for Section 7.3 and with Table 7.1-2, the following GDCs are addressed for SLC:

- (a) **Criteria:** GDCs 1, 2, 4, 13, 19, 24, 26, 27, and 28.
- (b) **Conformance:** The SLC is in compliance (in part, or as a whole, as applicable) with these GDCs. All GDCs are generically discussed in Subsection 3.1.2.

## (3) Regulatory Guides (RGs)

In accordance with the Standard Review Plan for Section 7.3 and with Table 7.1-2, the following RGs are addressed for the SLC:

- (a) RG 1.22—Periodic Testing of Protection System Actuation Functions
- (b) RG 1.47—Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Issues
- (c) RG 1.53—Application of the Single-Failure Criterion to Nuclear Power Protection Systems
- (d) RG 1.62—Manual Initiation of Protective Actions
- (e) RG 1.75—Physical Independence of Electric Systems
- (f) RG 1.105—Instrument Setpoints for Safety-Related Systems
- (g) RG 1.118—Periodic Testing of Electric Power and Protection Systems
- (h) RG 1.152, Criteria for Digital Computers Used in Safety Systems for Nuclear Power Plants
- (i) RG 1.153, Criteria for Power, Instrumentation, and Control Portions of Safety Systems

SLC is designed to be redundant (and diverse) from the control rod scram system. The two channels of active components assure that no single failure of these components will prevent the SLC from accomplishing its safety function. Passive components which are not redundant include the boron tank, injection pipeline, etc.

With that clarification, SLC (in combination with the rod scram system) fully meets the intent of the Regulatory Guides listed above.

## (4) Branch Technical Positions (BTPs)

In accordance with the Standard Review Plan for Section 7.3 and with Table 7.1-2, BTPs 8, 11 and 12 are considered applicable for SLC. BTP 8 is addressed as follows:

- (a) BTP HICB 8—Guidance for Application of Regulatory Guide 1.22

All actuated equipment within the SLC can be tested during reactor operation. Actual injection can be simulated during shutdown using demineralized water.

- (b) BTP HICB 11—Guidance for Application of Qualification of Isolation Devices
- (c) BTP HICB 12—Guidance for Establishing and Maintaining Instrument Setpoints

The SLC fully conforms with BTP HICB 11 and 12.

- (5) 10CFR50.34 (f)(2) TMI-Related Requirements

In accordance with the Standard Review Plan for Section 7.3, and with Table 7.1-2, there are no TMI-related requirements applicable to the SLC.

Table 7.4-1 Reactor Shutdown Cooling Bypasses and Interlocks

Valve Function	Reactor Pressure Exceeds Shutdown Cooling Permissive	Isolation Valve Closure Signal
Inboard suction isolation <sup>*</sup>	Cannot open	Closes (A) <sup>†</sup>
Outboard suction isolation <sup>*</sup>	Cannot open	Closes (A)
Reactor injection <sup>‡</sup>	Cannot open <sup>f</sup>	Closes (A)
Radwaste discharge inboard <sup>*</sup>	Can open (M) <sup>**</sup>	Closes (M)
Radwaste discharge outboard <sup>*</sup>	Can open (M)	Closes (M)
Valve function <sup>††</sup>		
Inboard suction isolation	Closes (A) <sup>f</sup>	Closes (A)
Outboard suction isolation	Closes (A)	Closes (A)
Reactor injection	Closes (A) <sup>f</sup>	Closes (A)

\* Valves have manual control for opening.

† (A) denotes automatic.

‡ Valves have manual and auto control for opening.

<sup>f</sup> Injection valve cannot be opened at reactor pressure above the injection pressure (approx. 3.04 MPa G).

\*\* (M) denotes manual.

†† Valves have manual and auto control for closing; manual close is not constrained.