7.0 REACTIVITY CONTROL SYSTEMS

The systems described in this chapter are used to control the core reactivity under normal, abnormal, and emergency conditions. The systems used to control core reactivity are shown in simplified form in Figure 7.0-1.

7.0.1 Reactor Manual Control System (Section 7.1)

The Reactor Manual Control System provides rod movement control signals to the control rod drive system, to vary core power level and power distribution.

7.0.2 Recirculation Flow Control System (Section 7.2)

The Recirculation Flow Control System provides a means for control of core power level, over a limited range, by controlling recirculation system flow, which in turn determines the flow rate of water through the reactor core.

7.0.3 Reactor Protection System (Section 7.3)

The Reactor Protection System automatically initiates a rapid reactor shutdown (scram) by inserting control rods, to preserve the integrity of the fuel cladding and reactor coolant pressure boundary.

7.0.4 Standby Liquid Control System (Section 7.4)

The Standby Liquid Control system injects a neutron absorbing poison solution into the reactor vessel to shutdown the reactor, independent of any control rod movement, and maintain the reactor subcritical as the plant is cooled to maintenance temperature.

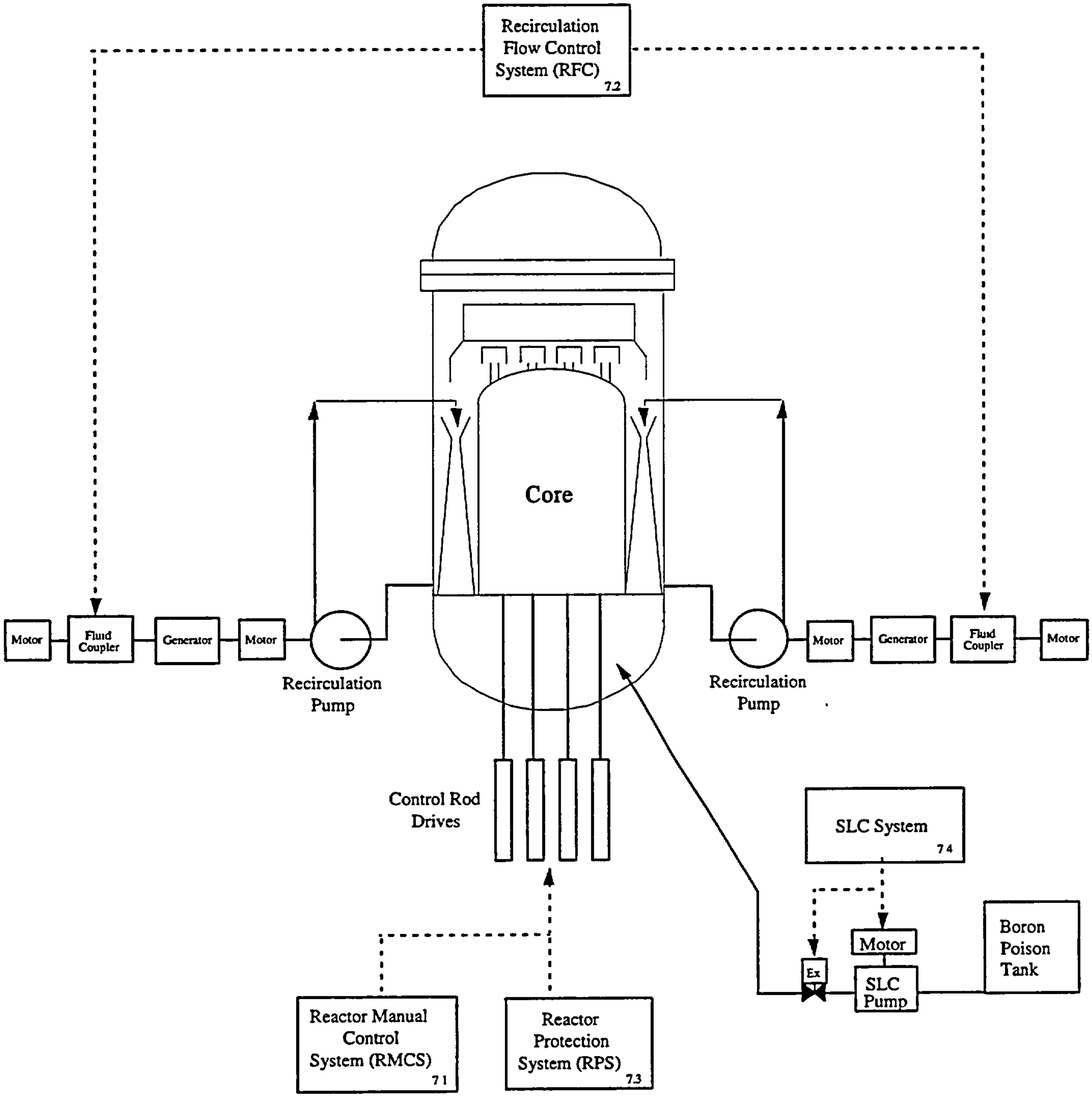


Figure 7.0-1 Simplified BWR Reactivity Control Systems

Table of Contents

List of Tables

List of Figures

7.1 REACTOR MANUAL CONTROL SYSTEM

The purposes of the Reactor Manual Control System (RMCS) are:

1. To provide control signals to the control rod drive system for normal control rod movement.

2. To prevent control rod movement during potentially unsafe conditions.

The functional classification of the RMCS is that of a power generation system.

7.1.1 System Description

The Reactor Manual Control System consists of the switches, relays, interlocks, alarms, and electrical equipment necessary to result in control rod movement. The RMCS provides the necessary sequence and timing signals to the direction control solenoid valves of the control rod selected for movement. Operation of the control rod drive in response to the directional control solenoid valves is covered in Section 2.3. Normal control rod movement is one notch at a time through the timing sequence, but continuous movement controls are provided.

The basic inputs to the RMCS are manual signals originating from the operation of rod selection pushbuttons and rod movement control switches. Also, interlocks are provided to block the selection of a control rod and/or the movement request if plant conditions are abnormal.

7.1.2 Component Description

The major components of the Reactor Manual Control System are discussed in the paragraphs which follow and are illustrated in Figure 7.1-1.

7.1.2.1 Rod Select Matrix

The manual rod selection capability is provided by 137 pushbutton type switches arranged to the approximate geometry of the core, Figure 7.1-2. The pushbuttons are wired so that when one switch is depressed, control power is removed from all other rod select pushbuttons.

7.1.2.2 Rod Selection Relays

Energization of a rod selection relay indicates that a rod select pushbutton request has been honored. For the request to be honored, rod select block interlocks must also have been satisfied. Section 7.1.3.3 contains a listing of possible select blocks. Power is applied to the rod control relays when the rod selection relay energizes.

7.1.2.3 Rod Control Relays

The rod control relays allow the request for rod movement to be transmitted from the rod movement control switches to the timer logic, if certain permissive are met. These permissive are termed "rod blocks" which can be found in Table 7.1-1.

7.1.2.4 Timer Logic

The timer logic provides the required signals to the directional control solenoids in the proper sequence and timing to cause the selected control rod drive to respond as requested by the operator.

7.1.2.5 Rod Movement Control Switches

Control rod drive movement request is accomplished through the use of two control switches, the control rod movement control switch and/or the emergency in/notch override switch.

The control rod movement control switch has three positions: rod in, off, and rod notch out (spring return to off). Through the use of this switch the operator can initiate notch in and notch out cycles. Notch movement means moving a control rod from one even position indication to the next. If the switch is held in the notch out position, the control rod will complete one notch out cycle and stop. If the switch is held in the rod in position the control rod will continuously drive in until the switch is released.

The emergency in/notch override switch has three positions: emergency in, off, and notch override (spring return to off). The notch override allows the operator to make a continuous rod withdrawals, when used simultaneously with the rod movement control switch. The emergency in position is provided to allow control rod insertion if the timer logic is not available.

7.1.3 System Features

A short discussion of system features is given in the paragraphs which follow.

7.1.3.1 Rod Withdraw Blocks

If an unsafe condition is being approached by any of the monitored parameters indicated on Table 7.1-1, a control rod withdraw will be inhibited.

7.1.3.2 Rod Insert Blocks

Rod insert blocks are applied only by the Rod Sequence Control System (RSCS) and the Rod Worth Minimizer (RWM) System. These systems limit rod movement to limit control rod worth during startup and low power operation. Refer to the following sections for details: Rod Worth Minimizer (Section 6.1) and the Rod Sequence Control System (Section 6.2).

7.1.3.3 Rod Select Blocks

Rod select blocks are imposed automatically upon receipt of a timer malfunction or a signal from the Rod Sequence Control System. The timer malfunction select block prevents an unrequested continuous rod withdraw. The Rod Sequence Control System select block limits rod worth during startup and low power operation.

7.1.4 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

7.1.4.1 Neutron Monitoring Systems (Chapter 5.0)

All of the neutron monitoring systems provide rod withdraw block signals to the RMCS.

7.1.4.2 Rod Worth Minimizer System (Section 6.1)

The RWM provides insert and withdraw block signals to the RMCS.

7.1.4.3 Rod Sequence Control System (Section 6.2)

The RSCS provides all three types of rod block signals to the RMCS.

7.1.4.4 Control Rod Drive System (Section 2.3)

The RMCS provides the control signals necessary to result in movement of control rods.

7.1.5 Summary

Classification:

Power generation system

Purpose:

To provide control signals to the Control Rod Drive System for normal control rod movement. To prevent control rod movement during potentially unsafe conditions.

Components:

Rod select matrix; rod Interfaces - Rod Worth Minimizer System; Rod Sequence Control System; Neutron Monitoring System; Control Rod Drive System.

Interfaces:

Neutron Monitoring System; Rod Worth Minimizer; Rod Sequence Control System.

Table 7.1-1 Rod Withdrawal Blocks and Setpoints

Rod Block	Setpoint
APRM Inop	1. Function Switch out of operate. 2. <11 LPRM inputs. 3. Module unplugged.
APRM High (1)	>.66W + 42% (RUN mode only)
APRM High (1)	>12% (Not in RUN)
APRM Downscale	3% (RUN mode only)
Flow Converter Unit	1. Hi 108% 2. 10%Δ between flow signals 3. Inop, a. Function switch out of operate. b. Module unplugged.
RBM Hi (1)	1. >.66 W + 25% (push to set up) 2. >.66 W + 33% (push to set up) 3. >.66 W + 41% (set high)
RBM Inop	1. Function switch out of operate. 2. Module unplugged. 3. More than one rod selected. 4. Fail to null. 5. LPRMs downscale (too few inputs <50%)
RBM Downscale (1)	<3%
RBM Null	Null sequence in progress.
RWM	Deviation from prescribed rod sequence.
RSCS	Deviation from prescribed rod sequence.
SRM Detector wrong (1) position.	Detector not full in, <100 cps, IRM range 1 or 2. (Bypassed on IRM 3 or above)
SRM High (1) (2)	>10^5 cps
SRM Inop (2)	1. Function switch not in operate. 2. Module unplugged 3. High voltage low.
SRM Downscale (1) (2)	<3 cps
IRM Downscale (1) (2)	<5/125 (bypassed on range 1)

Table 7.1-1 Rod Withdrawal Blocks and Setpoints

Rod Block	Setpoint
APRM Inop	1. Function Switch out of operate. 2. <14 LPRM inputs. 3. Module unplugged.
APRM High (1)	>.66W + 42% (RUN mode only)
APRM High (1)	>12% (Not in RUN)
APRM Downscale	3% (RUN mode only)
Flow Converter Unit	1. Hi 110% 2. 10%Δ between flow signals 3. Inop, a. Function switch out of operate. b. Module unplugged.
RBM Hi (1)	1. >.66 W + 25% (push to set up) 2. >.66 W + 33% (push to set up) 3. >.66 W + 41% (set high)
RBM Inop	1. Function switch out of operate. 2. Module unplugged. 3. More than one rod selected. 4. Fail to null. 5. LPRMs downscale (too few inputs <50%)
RBM Downscale (1)	<3%
RBM Null	Null sequence in progress.
RWM	Deviation from prescribed rod sequence.
RSCS	Deviation from prescribed rod sequence.
SRM Detector wrong (1) position.	Detector not full in, <100 cps, IRM range 1 or 2. (Bypassed on IRM 3 or above)
SRM High (1) (2)	>10^5 cps
SRM Inop (2)	1. Function switch not in operate. 2. Module unplugged 3. High voltage low.
SRM Downscale (1) (2)	<3 cps
IRM Downscale (1) (2)	<5/125 (bypassed on range 1)

Table 7.1-1 Rod Withdrawal Blocks and Setpoints (continued).

Rod Block	Setpoint
IRM Wrong Position (2)	Detector not full in.
IRM High (1) (2)	>108/125
IRM Inop (2)	1. Function switch out of operate 2. Module unplugged. 3. High voltage low.
Scram Instrument Volume High	25 gallons
Scram Instrument Volume High Bypassed	Key locked switch in bypass.
Mode Switch in Shutdown	
One rod permissive (in Refuel)	
Refueling platform over the core.	Mode switch in startup or refuel, grapple is full up and the frame hoist, trolley hoist, service platform hoist, and the grapple are not loaded.
Fuel loading on refuel platform grapple. (3)	1000 lb. Load
Refueling platform grapple not full up.(3)	Extended 1/4"
Fuel loaded on frame hoist. (3)	400 lb. Load
Fuel loaded on trolley hoist .(3)	400 lb. Load
Fuel loaded on service platform. (3)	Mode switch in startup or refuel and platform loaded to 400 lb. Load.

(1) Values included here are technical specification required values.

(2) All IRM trips bypassed in RUN mode, all SRM trips are bypassed on IRM range 8 and above.

(3) These items will give a rod block in the REFUEL mode; they will also give a rod block in the STARTUP mode if the refueling platform is over the core area.

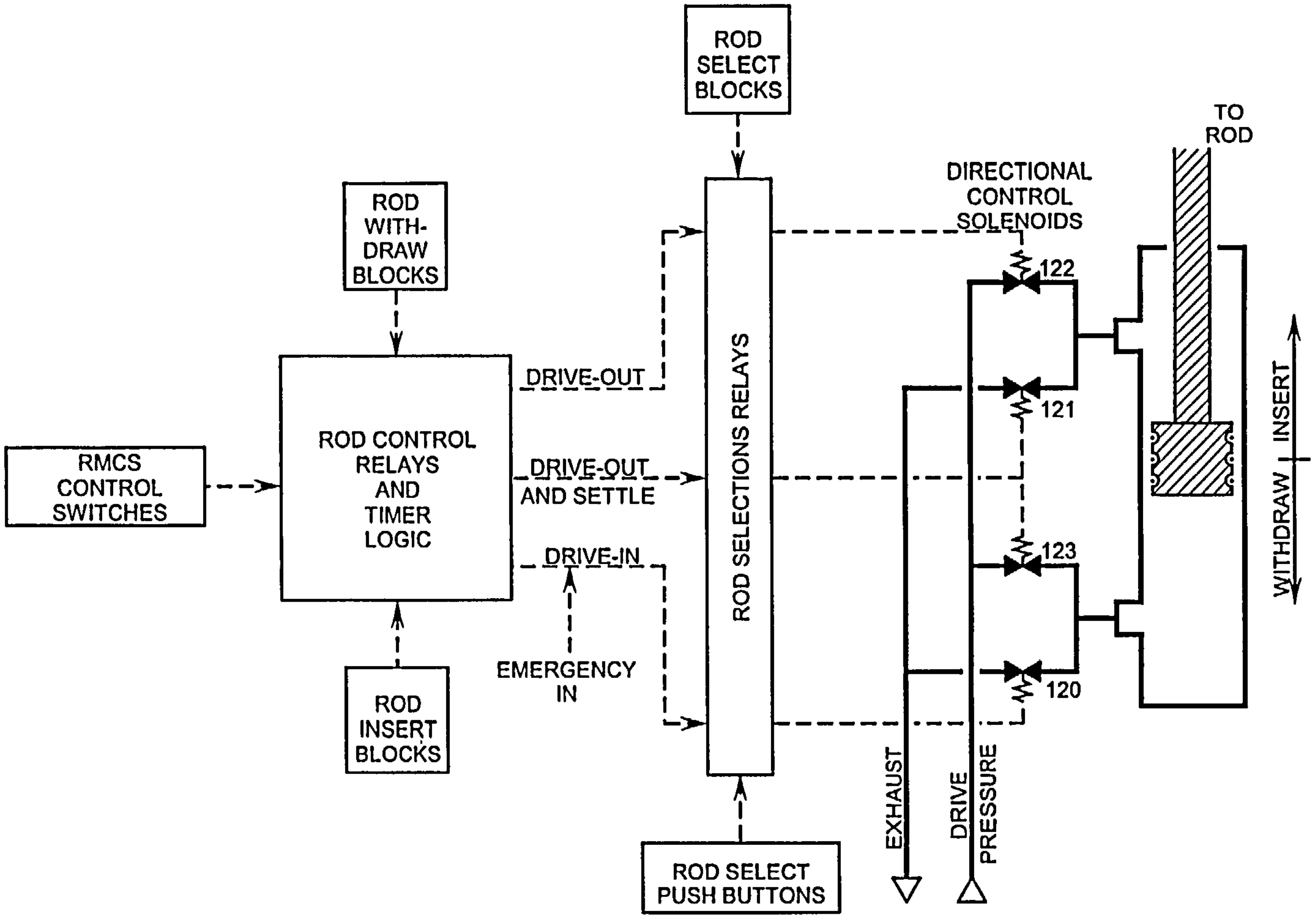
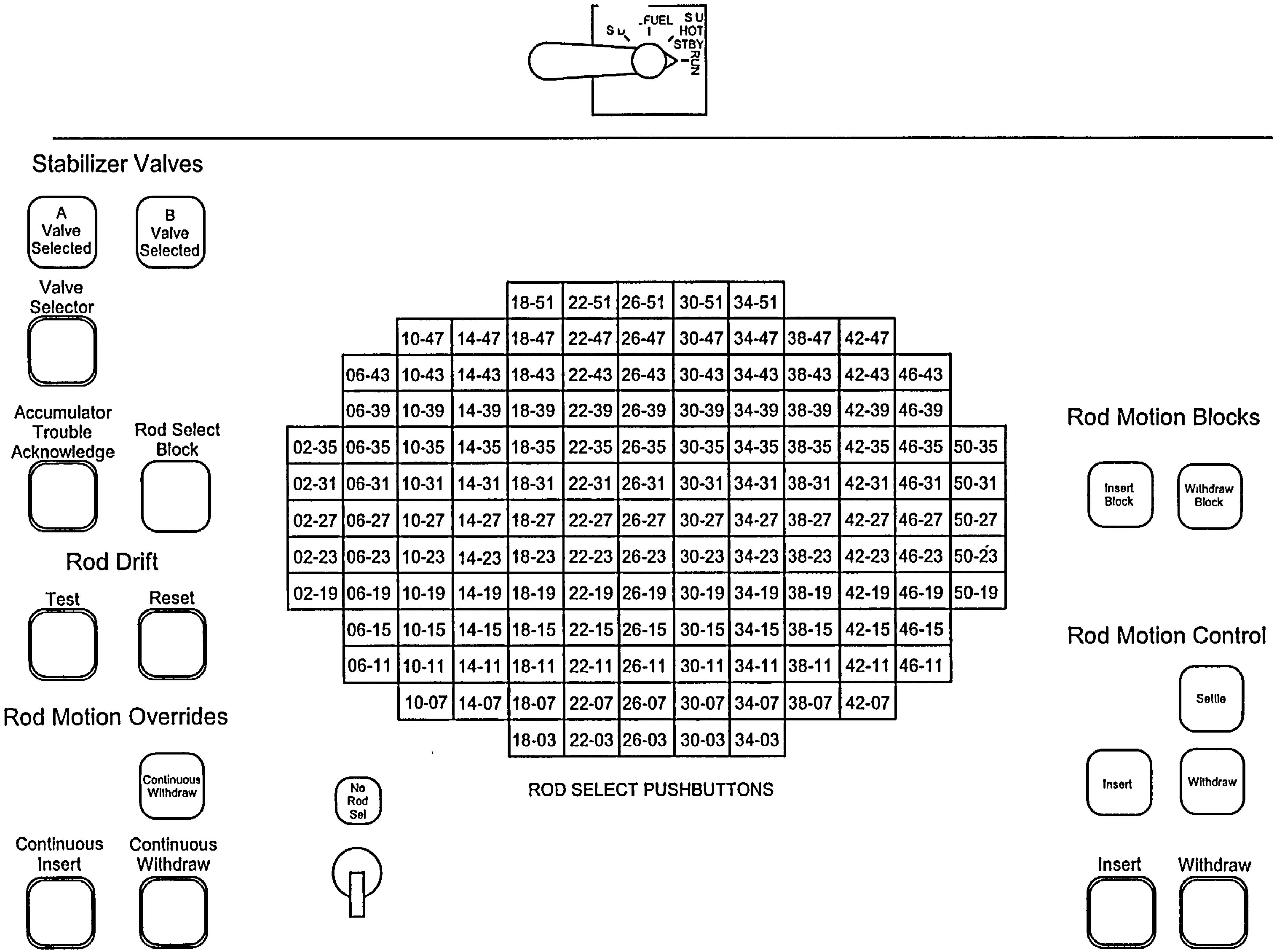


Figure 7.1-1 Reactor Manual Control



			18-51	22-51	26-51	30-51	34-51					
		10-47	14-47	18-47	22-47	26-47	30-47	34-47	38-47	42-47		
	06-43	10-43	14-43	18-43	22-43	26-43	30-43	34-43	38-43	42-43	46-43	
	06-39	10-39	14-39	18-39	22-39	26-39	30-39	34-39	38-39	42-39	46-39	
02-35	06-35	10-35	14-35	18-35	22-35	26-35	30-35	34-35	38-35	42-35	46-35	50-35
02-31	06-31	10-31	14-31	18-31	22-31	26-31	30-31	34-31	38-31	42-31	46-31	50-31
02-27	06-27	10-27	14-27	18-27	22-27	26-27	30-27	34-27	38-27	42-27	46-27	50-27
02-23	06-23	10-23	14-23	18-23	22-23	26-23	30-23	34-23	38-23	42-23	46-23	50-23
02-19	06-19	10-19	14-19	18-19	22-19	26-19	30-19	34-19	38-19	42-19	46-19	50-19
	06-15	10-15	14-15	18-15	22-15	26-15	30-15	34-15	38-15	42-15	46-15	
	06-11	10-11	14-11	18-11	22-11	26-11	30-11	34-11	38-11	42-11	46-11	
		10-07	14-07	18-07	22-07	26-07	30-07	34-07	38-07	42-07		
			18-03	22-03	26-03	30-03	34-03					

Figure 7.1-2 RMCS Controls

0102

Table of Contents

List of Figures

7.2 RECIRCULATION FLOW CONTROL SYSTEM

The purpose of the Recirculation Flow Control (RFC) System is to control the rate of recirculation system flow, allowing control of reactor power over a limited range.

The functional classification of the RFC System is that of a power generation system.

7.2.1 System Description

The Recirculation Flow Control System consists of two motor driven variable speed generator sets and the speed control logic needed to vary the generator speed. The motor driven variable speed generators provide the power to drive the recirculation pump motors, Figure 7.2-1. By varying the speed of the generator, the recirculation pump speed will then vary.

Changing recirculation flow results in a change in core flow rate and core power. Varying the core flow varies core power, from the effect core flow has on steam voids in the core. The mechanisms controlling reactor power are discussed in Chapter 1.12, Reactor Physics.

7.2.2 Component Description

The major components of the recirculation flow control system are discussed in the paragraphs which follow and illustrated on Figure 7.2-1.

7.2.2.1 Recirculation Motor Generator Set

The recirculation motor generator set consists of a drive motor, fluid coupler, generator, and the necessary auxiliary components to support motor generator set operation.

The recirculation motor generator set drive motor is a constant speed 9000 horse power motor. The drive motor supplies the fluid coupler with motive force through a constant speed input shaft.

The fluid coupler transmits a portion of the drive motor torque to the generator shaft. The amount of torque that is transmitted to the generator is determined by the coupling between the drive motor and generator, which is determined by the amount of oil in the fluid coupler. The quantity of oil in the fluid coupler is regulated by the positioning of a device called a "scoop tube". The greater the quantity of oil in the fluid coupler, the greater the coupling between the drive motor and generator. Therefore, the scoop tube position determines the torque transmitted to the generator and thus the generator and recirculation pump speed. The recirculation pump speed control logic described in Section 7.2.2.2 regulates the positioning of the scoop tube.

7.2.2.2 Recirculation Pump Speed Control Logic

Figure 7.2-1 is a simplified block diagram of the recirculation flow control logic. The principle of operation is to set a desired pump speed, measure the actual speed, compare these signals and produce a control signal used to position the scoop tube to obtain the desired pump speed. The components performing this function are discussed in the paragraphs which follow.

7.2.2.2.1 Master Flow Controller

The master flow controller provides the means of controlling both recirculation motor generator sets from a single controller. Normal operation of the master controller is in the manual mode of operation. By adjusting the manual potentiometer a demand signal is developed and transmitted to the manual-automatic transfer station via a dual limiter.

7.2.2.2.2 Manual-Automatic Transfer Station Controllers

The manual-automatic transfer station controllers provide the means of controlling both motor generator sets independently or as a paired unit. Similar to the master controller, the manual automatic transfer stations contain two modes of operation, i.e., manual and automatic. Normal mode of operation for both controllers is automatic.

7.2.2.2.3 Minimum Speed Limiters

There are two speed limiters used in the control logic to limit the maximum and/or minimum speed demand signal according to plant operating conditions.

The output of the manual-automatic transfer station controller is routed through two speed limiters. The first of these limiters restrains recirculation pump speed to a maximum of 28% with the pump discharge valve not full open or feedwater flow less than 20%. This limiter prevents overheating of the recirculation pumps with the discharge valve not full open (low flow conditions) and cavitation problems for the recirculation pumps and jet pumps at low feedwater flow rates (low net positive suction head - NPSH).

The second limiter (operational limiter) restricts the maximum recirculation pump speed demand to less than 45%. That restraint ensures a sufficient supply of feedwater is available to the reactor vessel to recover or maintain normal operating level following loss of a feedwater train pump at 100% power. This limiter is bypassed whenever level is normal or if all reactor feed train pumps are in service.

7.2.2.2.4 Speed Control Summer

The speed control summer, during normal operation, compares the speed demand signal to the actual generator speed and develops an error signal which is sent to the speed controller. The error signal is limited to about 8% of the control band.

7.2.2.2.5 Speed Controller

The speed controller establishes and maintains a speed demand signal in accordance with the error signal received from the speed control summer.

7.2.2.2.6 Scoop Tube Positioner

The scoop tube positioner converts the electrical input signal from the speed controller to a mechanical scoop tube position.

7.2.3 System Features

A short discussion of system features is given in the paragraphs which follow.

7.2.3.1 Power/Flow Map

The power/flow map is a plot of percent core thermal power versus percent of total core flow for various operating conditions. The power/flow map contains information on expected systems performance. A brief description of the curves on the power/flow map, Figure 7.2-2, is given in the paragraphs which follow.

7.2.3.1.1 Natural Circulation Line

As reactor power is increased by withdrawing control rods, core flow increases due to the change in moderator density and steam formation (voids) within the core region. The colder (more dense) water in the downcomer region coupled with the less dense water in the core region supports a natural core flow that supplements forced circulation.

7.2.3.1.2 28% Pump Speed Line

Startup operations of the plant are normally carried out with both recirculation pumps at minimum speed. Reactor power and core flow follow this line for the normal control rod withdraw sequence with the recirculation pumps operating at approximately 28% speed.

7.2.3.1.3 Design Flow Control Line

This line is defined by the control rod withdraw pattern which results in being at 100% core thermal power and 100% core flow, assuming equilibrium xenon conditions. Reactor power should follow this line for recirculation flow changes with a fixed control rod pattern.

7.2.3.1.4 Pump Constant Speed Line

This line illustrates the change in core flow associated with a power reduction from 100% power, 100% core flow, while maintaining a constant recirculation pump speed.

7.2.3.1.5 Minimum Expected Flow Control Line

This line represents the flow control line for plant startup in which the recirculation pump speed is increased above minimum speed as soon as the 20% feedwater interlock is cleared.

7.2.3.1.1 Region of Instability

This area of the Power/Flow Map represents the point(s) where core thermal hydraulic stability problems may exist at all BWRs. Generally,intentional operation in this area is not permitted.

7.2.3.2 Recirculation Pump Trip

An end of cycle - recirculation pump trip (EOC-RPT) circuit provides an automatic rapid trip of the recirculation pumps on a main turbine trip or load rejection, if greater than 30% power. The trip is accomplished by opening the breakers between the pump motor and the variable speed generator. The purpose of the pump trip is to reduce the peak reactor pressure and power resulting from those transients coincident with a failure of the turbine steam bypass valves.

The acronym "ATWS-RPT" refers to an anticipated transient without scram (ATWS) recirculation pump trip (RPT). If a plant transient were to occur, necessitating a reactor scram, and for some reason the scram function did not occur, then an ATWS event would exist. To lessen the effects of an ATWS event, negative reactivity must be added to the reactor core by another means. The means chosen is to trip the recirculation pumps which rapidly adds negative reactivity due to a sudden increase in steam voiding in the core area as core flow decreases. When reactor pressure reaches 1120 psig or reactor water level decreases to the low-low level setpoint, the recirculation motor generator set drive motor breaker trips.

7.2.4 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

7.2.4.1 Recirculation System (Section 2.4)

The recirculation flow control system regulates the speed of the recirculation pumps.

7.2.4.2 Main Steam System (Section 2.5)

The Main Steam System provides the trip input signals for the EOC-RPT circuit.

7.2.4.3 Feedwater Control System (Section 3.3)

The Net Positive Suction Head (NPSH) interlock (<20% total feedwater flow) is provided by the Feedwater Control System.

7.2.4.4 Condensate and Feedwater System (Section 2.6)

The Condensate and Feedwater System provides a bypass signal for the 45% speed limiter.

7.2.4.5 Reactor Vessel Instrumentation System (Section 3.1)

The Reactor Vessel Instrumentation System provides the bypass signal for the 45% speed limiter and the input signals for reactor vessel high pressure and low-low water level ATWS-RPT signals.

7.2.5 Summary

Classification :

Power generation system

Purpose:

To control the rate of reirculation system flow, allowing control of reactor power over a limited range.

Components:

Motor generator set; speed control logic; RPT breakers.

System Interfaces:

Recirculation System; Main Steam System; Feedwater Control System; Condensate and Feedwater System.

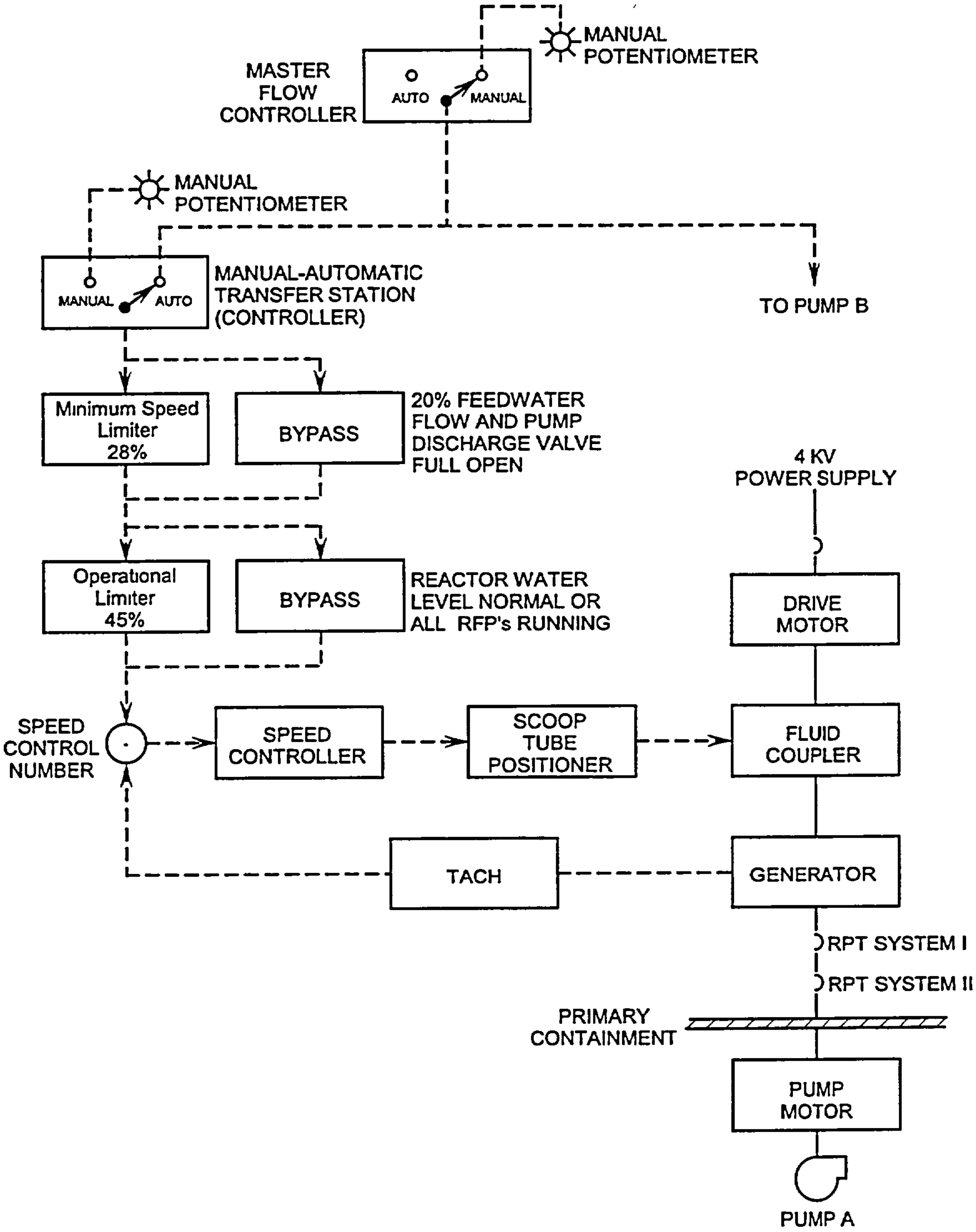


Figure 7.2-1 Recirculation Flow Control

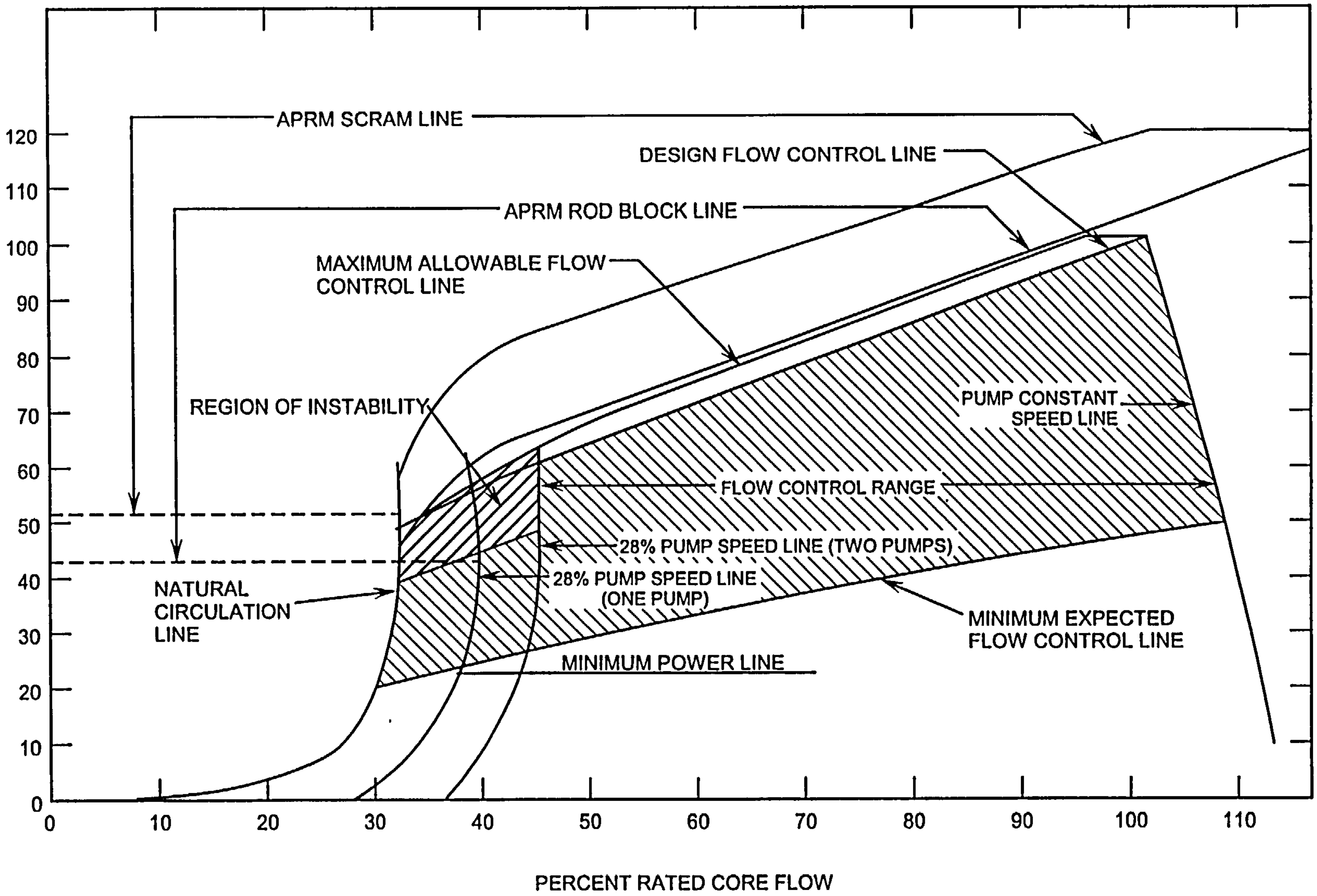


Figure 7.2-2 Power/Flow Map

0102

Table of Contents

List of Tables & Figures

7.3 REACTOR PROTECTION SYSTEM

The purpose of the Reactor Protection (RPS) System is to initiate a reactor scram to:

1. Preserve the integrity of the fuel cladding.
2. Preserve the integrity of the reactor coolant system.
3. Minimize the energy which must be absorbed following a loss of coolant accident.

The functional classification of the RPS is that of a safety related system. Its regulatory classification is reactor trip system.

7.3.1 System Description

The reactor protection system is a fail safe system, composed of two independent trip channels, A and B, each made up of two automatic scram logics and one manual scram logic (Figure 7.3-1). Trip channel A consists of reactor automatic scram logics Al and A2 along with the manual scram logic A3. Trip channel B consists of the same type of logic arrangement as trip channel A, designated Bl, B2, and B3. Each automatic scram logic receives inputs from at least one independent sensor monitoring each of the critical parameters. An unbypassed trip occurring in any trip logic(s) of trip channel A, together with an unbypassed trip occurring in any logic(s) of trip channel B, generates a reactor scram. Note that a trip of one trip channel, with the other trip channel not tripped, does not cause a reactor scram.

7.3.2 Component Description

The major components of the Reactor Protection System are discussed in the paragraphs which follow and are illustrated in Figure 7.3-1.

7.3.2.1 Power Supplies

The RPS receives power from two independent power supplies, RPS bus A and RPS bus B. Each bus is supplied normal power from a separate motor generator set. The motor generator sets are equipped with a high inertia flywheel to minimize the effects of momentary changes to the electrical supply of the motor generator set.

Alternate power is available to the RPS buses and is used when one of the motor generator sets is out of service. To prevent feeding both RPS buses A and B from the alternate power supply, an interlock is provided that will not allow both alternate supply breakers to be closed at the same time.

7.3.2.2 RPS Logic

The RPS is referred to as a dual channel protection system arranged in a one-out-of-two-twice logic scheme. Each channel is completely independent of the other. The RPS logic, Figure 7.3-1, consists of two separately powered trip channels. Each channel contains two automatic trip logics and one manual trip logic. The automatic trip logics of channel A are designated Al and A2 and both receive at least one input signal from the same monitored parameter. Thus, any monitored parameter supplying an automatic trip signal would have a minimum of four sensors.

An out of tolerance sensor in either automatic trip logic, Al or A2, would cause a trip in channel A. A trip condition in channel A would de-energize all of the A scram solenoid valves for each and every control rod. This condition is referred to as a half scram. Likewise, any sensor in channel B out of tolerance (trip condition) will cause a half scram. This type of logic arrangement is called one out of two.

To produce a reactor scram, both trip channels A and B must be in the trip condition. The over- all logic is termed one-out-of-two-twice.

The manual trip logics A3 and B3 contain the operator initiated scram signals, such as manual scram buttons and reactor mode switch.

7.3.2.3 Scram Valve Arrangement

Each of the 137 control rods is equipped with two scram solenoid valves, Figure 7.3-1. The scram solenoid valves are normally in an energized, untripped condition, and control the air supply to the control rod drive scram inlet and outlet valves. The scram inlet and outlet valves open with spring pressure and close (normal position) with air pressure. The scram inlet valve controls the scram water provided to the control rod drive by the scram accumulator. The scram outlet valve aligns the top of the control rod drive piston to the scram discharge volume. A reactor scram is initiated when both scram solenoid valves are de-energized, venting the air from the scram valves. When spring pressure overcomes the air pressure, the scram inlet and outlet valves open. Opening of the scram inlet valve allows the stored energy of the scram accumulator to be felt on the bottom of the drive piston. Opening of the scram outlet valve aligns the top of the drive piston with the scram discharge volume, which is at atmospheric pressure. With 1500 psig of water pressure below the drive piston and atmospheric pressure above the drive piston a large differential pressure is created to force the control rod rapidly into the core.

Note that on loss of air pressure or electrical power a reactor scram would be initiated. This is the fail safe feature of the Reactor Protection System.

7.3.3 System Features

A short discussion of system features is given in the paragraphs which follow.

7.3.3.1 Mode Switch

There are four principal modes of the Reactor Protection System: SHUTDOWN, REFUEL, STARTUP/HOT STANDBY, AND RUN. Each operating mode has its own individual restrictions for safe reactor operation. A keylock mode switch is provided to ensure that all applicable restrictions are imposed at the proper time and to ensure the transition from one mode to the next is also safe.

7.3.3.2 Scram Functions and Bases for Trip Settings

The following discussions cover the functional considerations for each parameter monitored by the RPS. Table 7.3-1 lists all reactor scram signals, basis and bypass conditions.

7.3.3.2.1 Neutron Monitoring System Trips

Provides fuel cladding protection against excessive power generation. This protection is accomplished by monitoring neutron flux to initiate a reactor scram.

7.3.3.2.2 High Reactor Pressure

High pressure within the nuclear system process barrier poses a direct threat of reactor coolant system rupture and a core power excursion from void collapse. The scram counteracts a pressure increase by quickly reducing core fission heat generation. The high pressure scram also serves as a backup to the Neutron Monitoring System high flux scram.

7.3.3.2.3 Reactor Vessel Water Level Low

A low water level scram prevents power operation at water levels lower than those assumed in the safety analysis. Low water level in the reactor indicates the core is in danger of having inadequate cooling.

7.3.3.2.4 Turbine Stop Valve Closure

Closure of the turbine stop valve, with the reactor at power, can result in a significant addition of positive reactivity to the core as the nuclear system pressure rise collapses steam voids. The turbine stop valve closure scram, which initiates a scram earlier than either the neutron monitoring system or nuclear system high pressure, is required to provide a satisfactory margin below core thermal hydraulic limits for this category of abnormal operation transients. Although the nuclear system high-pressure scram, in conjunction with the pressure relief system, is adequate to preclude overpressurizing the nuclear system, the turbine stop valve closure scram provides additional margin to the nuclear system pressure limit.

7.3.3.2.5 Turbine Control Valve Fast Closure

The turbine control valve fast closure scram is also called the generator load reject scram. A mismatch between generator power and the turbine power causes rapid closure of the control valves. This rapid closure results in a situation similar to a turbine stop valve closure. Therefore, this scram is provided for the same reasons as those discussed for a turbine stop valve closure scram.

7.3.3.2.6 Main Steam Line Isolation Valve Closure

Closure of main steam line isolation valves, with the reactor at power, can result in a significant addition of positive reactivity to the core as the nuclear system pressure rise collapses steam voids. A main steam line isolation valve closure scram is required to provide a satisfactory margin below core thermal hydraulic limits for this category of abnormal operational transients.

7.3.3.2.7 Scram Discharge Volume High Level

The scram discharge volume receives the water displaced by the motion of the control rod drive pistons during a scram. Should the scram discharge volume fill up with water to the point where insufficient volume remains to receive water displaced during a scram, control rod movement would be hindered in the event a scram were required. To prevent this situation, the reactor is scrammed when the water level in the discharge volume attains a value high enough to verify that the volume is filling up, yet low enough to ensure that the remaining capacity in the volume can accommodate a scram.

7.3.3.2.8 Main Condenser Low Vacuum

To protect the main condenser against overpressure, a loss of condenser vacuum initiates automatic closure of the turbine stop valves and turbine bypass valves. To anticipate the transient and automatic scram that would result from the closure of the turbine stop valves, low condenser vacuum initiates a scram. The low vacuum scram setpoint is selected to initiate a scram before closure of the turbine stop valves is initiated.

7.3.3.2.9 Drywell Pressure High

High drywell pressure may indicate a break in the reactor coolant pressure boundary. It is, therefore, prudent to scram the reactor in such a situation to minimize the possibility of fuel damage and to reduce the energy transfer from the core to the coolant, which in turn minimizes the energy that the containment/suppression pool may be required to absorb. The high drywell pressure scram setting is selected to be as low as possible without inducing spurious scrams.

7.3.3.2.10 Mode Switch in SHUTDOWN

The mode switch provides appropriate protective functions for the condition in which the reactor is to be operated. The reactor is to be shut down with all control rods inserted when the mode switch is in SHUTDOWN. To enforce the condition defined for the SHUTDOWN position, placing the mode switch in the SHUTDOWN position initiates a reactor scram. This scram is not required to protect the fuel or nuclear system process barrier, and it bears no relationship to minimizing the release of radioactive material from any barrier. The scram signal is removed after a short time delay, permitting a scram reset which restores the normal valve lineup in the control rod drive hydraulic system.

7.3.3.2.11 Manual Scram Buttons

Two manual scram pushbuttons are provided to allow the operator to scram the reactor in advance of imminent trips and follow up automatic scrams.

7.3.3.3 Reset Circuit

Once a scram has occurred and the condition causing the scram has been corrected, a manual reset is required to begin the process of returning the reactor plant to a normal condition. A single reset switch is provided for this purpose.

Three conditions are necessary to reset a scram signal:

1. The scram signal(s) must all be cleared or bypassed.

2. Ten seconds must have elapsed since the scram was initiated.

3. The reset switch must be momentarily placed in both reset positions.

A ten second time delay function is provided to allow the slowest control rods to be fully inserted into the reactor core prior to being able to reset a scram. This time delay does not apply on a single channel trip, since there is no control rod motion.

7.3.4 System Interfaces

The RPS has interfaces with all of the systems which provide parameter inputs to the RPS trip logic. These parameters are listed in Table 7.3-1. Other interfaces that this system has with other plant systems are discussed in the paragraphs which follow.

7.3.4.1 Control Rod Drive System (Section 2.3)

The Control Rod Drive System provides the motive force for control rod insertion when the scram inlet and outlet valves open.

7.3.4.2 Service and Instrument Air System (Section 11.6)

The Service and Instrument Air System supplies the air pressure used to close the scram inlet and outlet valves. Air pressure is also provided to keep the scram discharge volume vent and drain valves open during normal operation.

7.3.5 Summary

Classification:

Safety related system

Purpose:

To initiate a reactor scram to:

1. Preserve the integrity of the fuel cladding.
2. Preserve the integrity of the reactor coolant system.
3. Minimize the energy which must be absorbed following a loss of coolant accident.

Components:

Power supplies; logic; scram valves; sensors.

System Interfaces:

All systems that provide parameter inputs; CRD System; Service and Instrument Air System.

Table 7.3-1 Reactor Protection Scram Signals

Scram Signal	Signal Bypass	Probable Cause	Reason for Scram
Low Reactor Water Level	None	Abnormal Operational Transient or line break	Protect fuel cladding from inadequate cooling.
NMS-IRM Inop	Mode switch in RUN	Low voltage, card unplugged or switch misaligned.	Protect fuel cladding integrity
NMS-IRM High High	Mode switch in RUN	Failure to uprange IRM's or to short of a reactor period.	Protect fuel cladding against excessive power and short period.
NMS-APRM Down scale & Companion IRM Up scale.	Mode Switch not in Run	Not monitroing Reactor power level.	Protect fuel cladding integrity
NMS-APRM Inop	None	Too few LPRM inputs, card unplugged or switch misaligned.	Protect fuel cladding integrity
NMS-APRM High High (Fixed 15% or 120%)	None	Abnormal Operational Transient	Protect fuel cladding from excessive power.
NMS-APRM High High (Flow biased)	Mode switch not in RUN	Abnormal Operational Transient	Protect fuel cladding from excessive power.
MSIV Closure	Mode switch not in RUN	Any MSIV closure signal	Protect fuel cladding against positive $\Delta K/K$ insertion from void collapse
Turbine Stop Valve Closure	<30% Turbine First stage pressure.	Any Turbine Trip	Protect fuel cladding against positive $\Delta K/K$ insertion from void collapse
Turbine Control Valve Fast Closure	<30% Turbine First stage pressure.	Generator Load Rejection	Protect fuel cladding against positive $\Delta K/K$ insertion from void collapse
Condenser Low Vacuum	Mode switch not in RUN	Loss of Circulating Water System	Protect fuel cladding against positive $\Delta K/K$ insertion from turbine trip.

Table 7.3-1 Reactor Protection Scram Signals (continued)

Scram Signal	Signal Bypass	Probable Cause	Reason for Scram
High Reactor Pressure	**None**	**Abnormal Operational Transient**	**Protect reactor coolant pressure boundary integrity.**
High Drywell Pressure	None	Line break in Drywell	Minimize energy SP must absorb, prevent recriticality.
Scram Discharge Instrument Volume High Level	Keylock switch in "Bypass" and mode switch in SHUTDOWN or REFUEL	Leaking scram outlet valves or any other scram just happened.	Allows RPS to scram while the ability still exists.
Manual P/B's	None	Manual scram P/B's depressed.	Allows manual scram whenever operator deems prudent.
Mode switch in SHUTDOWN	When 10 second timer times out.	Mode switch was placed in SHUTDOWN.	Enforce shutdown conditions defined for "SHUTDOWN" mode.

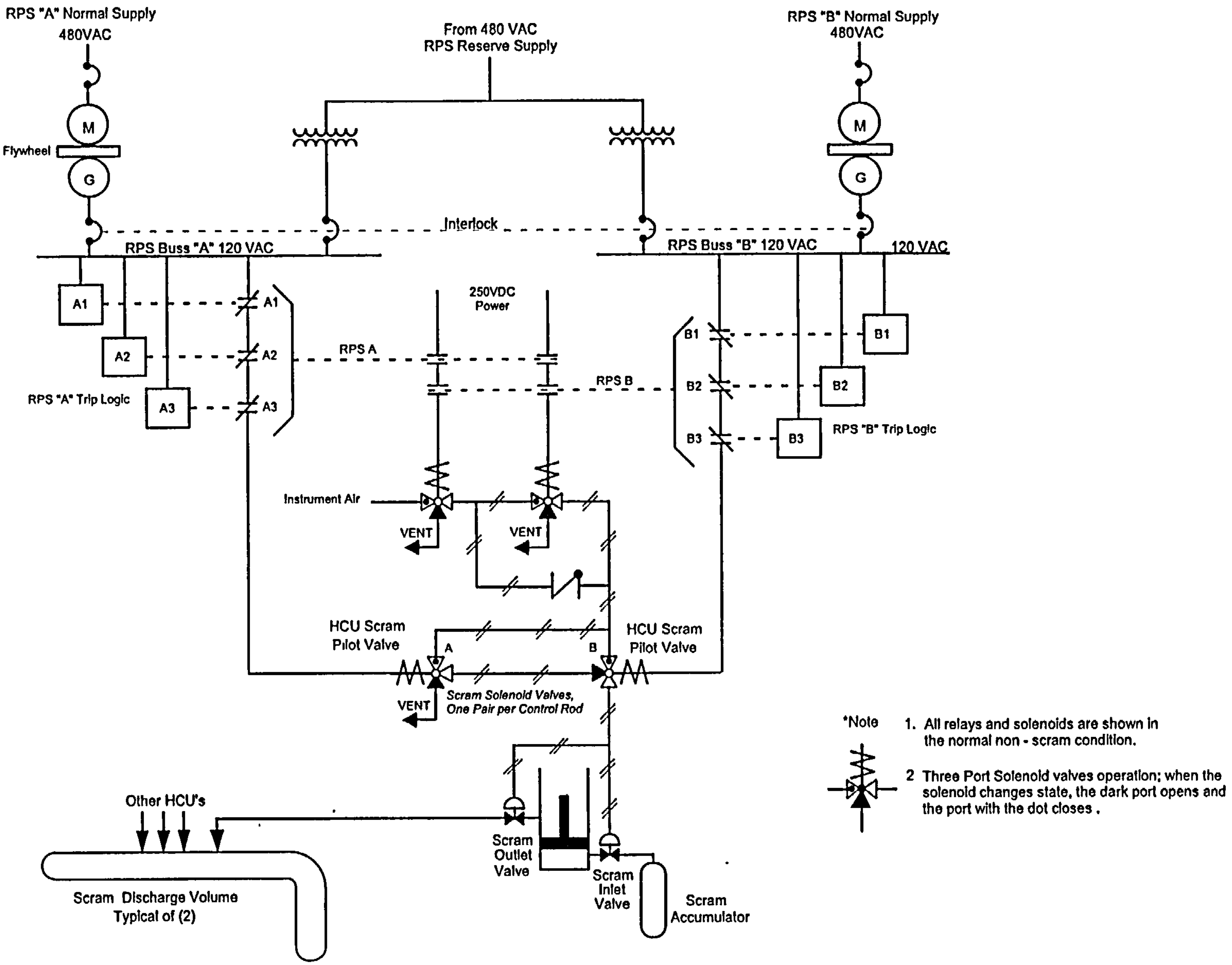
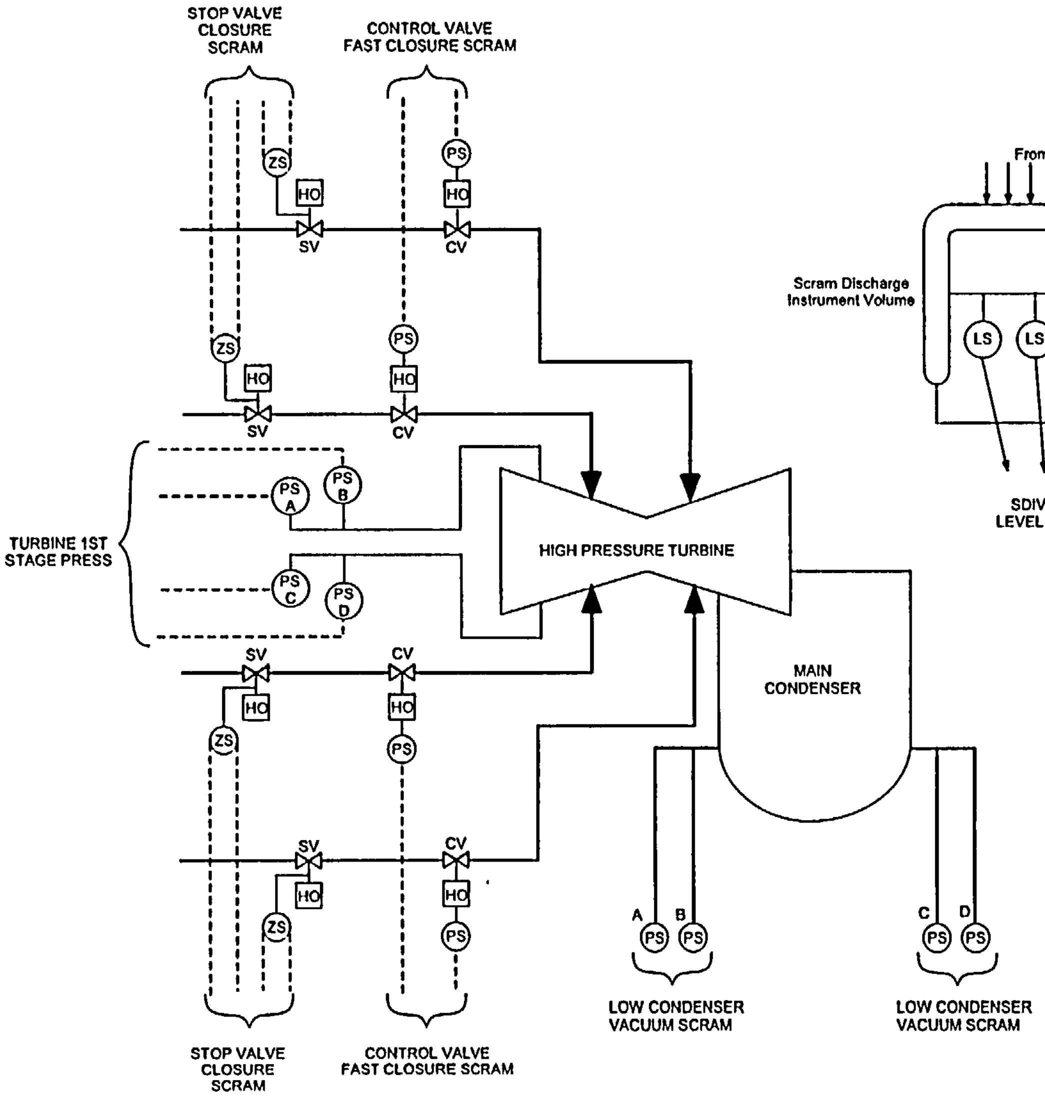
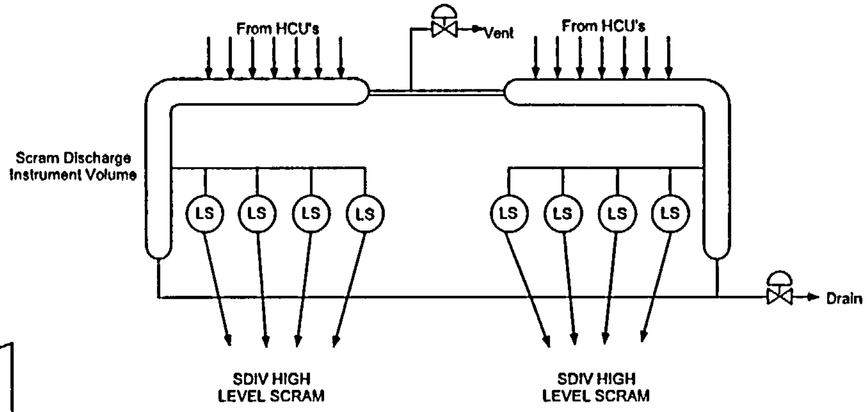


Figure 7.3-1 Simplified Reactor Protection System





RPS SUBCHANNEL ASSIGNMENTS				
	A1	A2	B1	B2
MSIV's	A & B	C & D	A & C	B & D
STOP VALVES	1 & 2	3 & 4	1 & 3	2 & 4
CONTROL VALVES	1	3	2	4
APRM's	A,E	C,E	B,F	B,D
IRM's	A,E	C,G	B,F	D,H

Figure 7.3-2 Reactor Protection System Sensors (Continued)

Table of Contents

List of Figures

7.4 STANDBY LIQUID CONTROL SYSTEM

The purpose of the Standby Liquid Control (SLC) System is to shutdown the reactor by chemical poisoning in the event of failure of the control rod drive system.

The functional classification of the SLC System is that of a safety related system.

7.4.1 System Description

The Standby Liquid Control system, Figure 7.4-1, consists of a heated storage tank, two positive displacement pumps, two explosive actuated injection valves, and piping necessary to inject the neutron absorber solution into the reactor vessel. The system contains a sufficient quantity and concentration of neutron absorbing solution to shut down the reactor any time in core life without the use of control rods.

The SLC System provides the operator with a relatively slow method of achieving reactor shutdown conditions. The SLC System was never designed to serve as a backup for the reactor scram function of the Reactor Protection System (Section 7.3)

7.4.2 Component Description

The major components of this system are discussed in the paragraphs which follow and are illustrated in Figure 7.4-1.

7.4.2.1 Storage Tank

The standby liquid control storage tank is a stainless steel tank with a capacity of 4,850 gallons. The tank provides the means for storage and mixing of the neutron absorber solution. To prevent the neutron absorber solution, sodium pentaborate, from precipitating out of solution, the storage tank is equipped with immersion heaters. The heaters are automatically controlled to regulate the solution temperature at 80±5°F.

7.4.2.2 Standby Liquid Control Pumps

The sodium pentaborate solution is pumped into the reactor vessel by either of two 100% capacity positive displacement pumps. At a minimum, each pump will have a capacity greater than 39 gpm.

7.4.2.3 Explosive Valves

The explosive actuated valves used to control the flow path of sodium pentaborate solution to the reactor vessel,are zero leakage valves. Unless the valves have been fired, no solution will enter the reactor vessel. Each explosive valve consist of two firing circuits, a ram, and shear plug. When the firing circuits are actuated, the ram drives forward and shears off the integral cap (shear plug) on the valve inlet fitting. The extended ram prevents the sheared cap from obstructing the passage of sodium pentaborate solution into the reactor vessel.

7.4.2.4 Test Tank

The test tank is provided for pump capacity and relief valve testing.

7.4.2.5 Vessel Injection Line

The vessel injection line serves a dual function within the reactor vessel. It provides an injection path for the sodium pentaborate solution and a tap for vessel instrumentation. The line penetrates the reactor vessel through a pipe in the bottom section of the vessel, (Section 2.1). This external pipe minimizes thermal shock to the vessel penetration welds. Inside the reactor vessel the injection line has circumferential holes drilled throughout its entire length. Injection beneath the core plate into the region of turbulent flow from jet pump diffuser outlets ensures proper mixing.

7.4.3 System Features

A short discussion of system features is given in the paragraphs which follow.

7.4.3.1 System Operation

System actuation is accomplished with the use of a key lock switch located in the control room. When a decision is made to inject sodium pentaborate into the reactor, a key must be inserted into the key lock switch and the switch turned to System 1 or System 2 position. Turning the switch to either position starts a single pump, fires both explosive valves, and isolates the Reactor Water Cleanup System. While reactor power is decreasing from poison addition, the control room operators conduct a normal plant shutdown and cooldown. Because of the one to two hour shutdown time required to reduce reactor power to zero percent, it should be obvious that the SLC System was not designed to serve as a backup for the reactor scram function of the Reactor Protection System.

7.4.3.2 Neutron Absorber Solution

The neutron absorber solution is made by dissolving measured amounts of boric acid and borax in demineralized water in the storage tank, forming a sodium pentaborate solution. Following chemical additions, the solution is thoroughly mixed and a sample is taken to ensure the concentration complies with that required to meet the purpose of the system.

As a result of the 10CFR50.62 requirement, BWRs must have a SLC system with the capability of injecting 86 gallons per miniute of 13 weight percent sodium pentaborate decahydrate solution at the natural boron-10 isotope.

Some utilities have opted to change the enrichment of the boron-10 in the storage tank rather than to increase the pumping rate. It is the boric acid constituent that is enriched. This approach maintains the SLC System redundancy of having two pumps capable of independent operation. It also permits the sodium pentaborate concentration within the tank to be reduced form 13.4% by weight to less than 9.2% by weight, which lowers the saturation temperature to 40^{0}F and thereby eliminates the requirement for monitoring and maintaining the solution temperature.

7.4.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

7.4.4.1 Reactor Vessel System (Section 2.1)

The SLC System injects the neutron absorbing solution into the reactor vessel through a penetration in the bottom section of the vessel.

7.4.4.2 Reactor Water Cleanup System (Section 2.8)

The initiation of the SLC system automatically isolates the Reactor Water Cleanup System to prevent poison removal.

7.4.5 Summary

Classification:

Safety related system

Purpose:

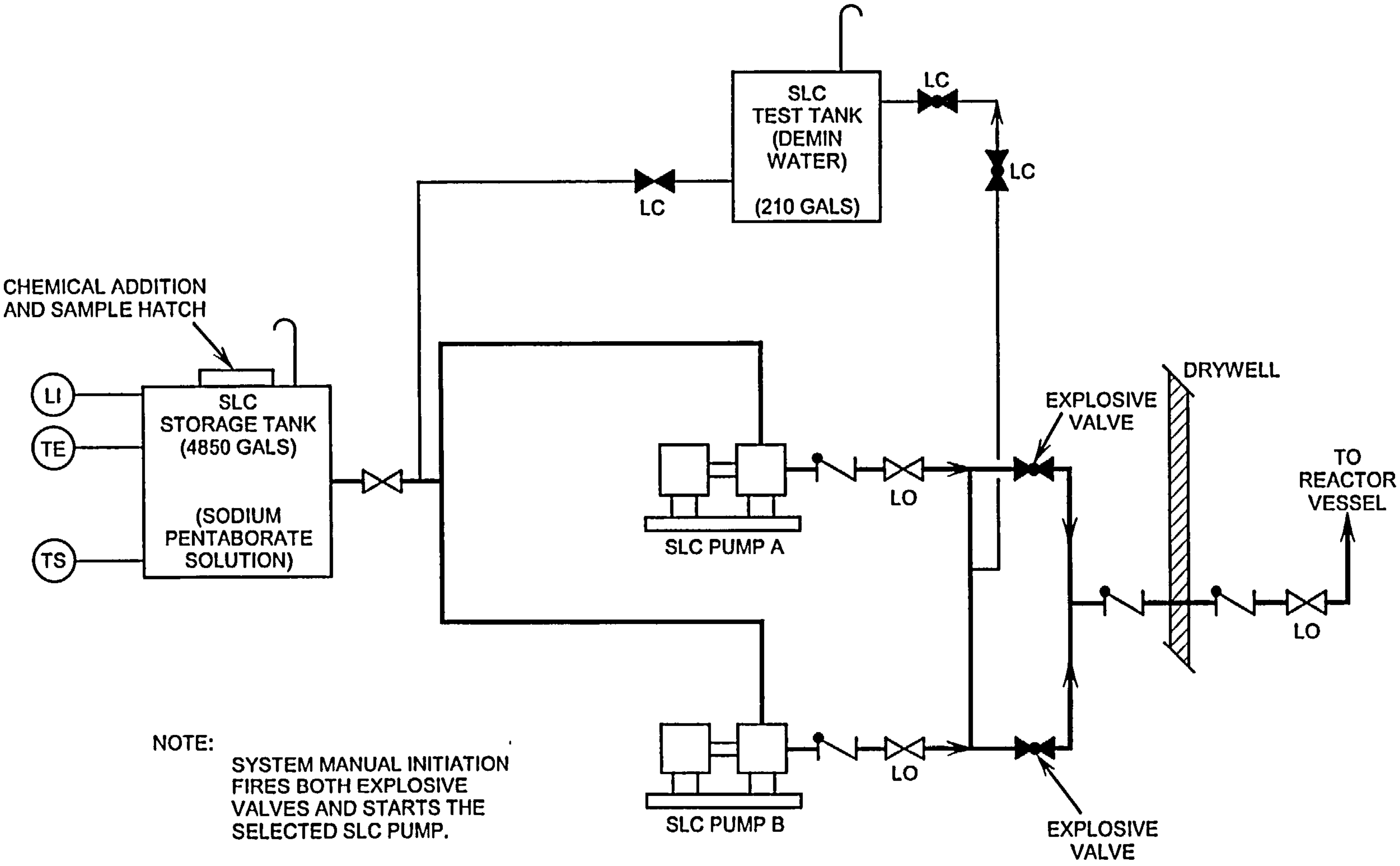
To shutdown the reactor by chemical poisoning in the event of failure of the control rod drive system.

Components:

Storage tank; 2-100% capacity pumps; 2-100% capacity explosive valves; injection pipe; test tank.

System Interfaces:

Reactor Water Cleanup System; Reactor Vessel and Internals; Service and Instrument Air; Demineralize Water System.



NOTE:

SYSTEM MANUAL INITIATION FIRES BOTH EXPLOSIVE VALVES AND STARTS THE SELECTED SLC PUMP.

Figure 7.4-1 Standby Liquid Control System

8.0 RADIOACTIVE WASTE PROCESSING AND MONITORING SYSTEMS

The Radioactive Waste and Monitoring Systems are designed to monitor, collect, process, store, and prepare for off site shipment and disposal, plant wastes which contain or could contain radioactive material.

8.0.1 Offgas System (Section 8.1)

The Offgas System reduces the off site exposures to as low as reasonably achievable. The Offgas System performs its function by reducing the offgas volume by recombining radiolytic hydrogen and oxygen into water, delaying passage of krypton and xenon by adsorption on charcoal to permit decay, and releasing system effluent at an elevated release point.

8.0.2 Liquid Radwaste System (Section 8.2)

Radioactive liquid waste disposal is a batch controlled process. Water and other process solutions are collected in tanks, processed, and again collected as batches in tanks. The tanks are analyzed for radioactive material and chemical content to determine the best method of dealing with them. The methods include processing the waste and reusing it as condensate, disposing it offsite as solid radwaste and diluting it in an effluent canal. Processing consists of filtration, demineralization, distillation, concentration, and decay.

8.0.3 Solid Radwaste System (Section 8.3)

The Solid Radwaste System is used to process wet and dry solid waste for offsite disposal. Wet wastes are dewatered and packaged in 55 gallon drums. Dry wastes are compacted to reduce free volume and packaged in approved shipping containers or 55 gallon drums as required.

8.0.4 Process Radiation Monitoring System (Section 8.4)

The Process Radiation Monitoring System monitors the radiation levels of various liquid and gaseous process streams that may serve as discharge routes for radioactive materials. Also included in this section is area radiation monitoring. The area radiation monitors sense the gamma radiation level of selected working and storage areas within the plant buildings.

Table of Contents

List of Tables and Figures

8.1 OFFGAS SYSTEM

The purpose of the Offgas System is to process noncondensible gases removed from the main condenser to limit radioactive gaseous releases to as low as reasonably achievable (ALARA).

The functional classification of the Offgas System is that of a power generation system.

8.1.1 System Description

The Offgas System removes noncondensible gases from the main condenser via steam jet air ejectors which provide the dilution and motive force for the remainder of the gaseous system. From the steam jet air ejector discharge, the gaseous mixture is first processed by a catalytic recombiner to reduce the explosive hydrogen and oxygen concentration. The remaining mixture is then retained in a holdup volume to allow the short lived radioactive isotopes and particulate daughter products to decay. The offgas stream then passes through a high efficiency filter to remove particulates and then to charcoal adsorbers to retard the passage of xenon, krypton and iodine. The processed offgas is then monitored for release and discharged to the Plant Exhaust Ventilation System. The Offgas System is illustrated on Figure 8.1-1. Major gases processed by the Offgas System are listed in Table 8.1-1.

8.1.2 Component Description

The major components of the Offgas System are discussed in the paragraphs which follow.

8.1.2.1 Steam Jet Air Ejectors

Noncondensible gases are removed from the main condenser by two stage steam jet air ejectors which are supplied steam from the Main Steam or Auxiliary Boiler System. The first stage is equipped with an intercondenser which minimizes water droplet carryover, limiting the amount of moisture that enters the Offgas System. The second stage is noncondensing; it dilutes the concentration of hydrogen gas to less than 4% by volume and provides the driving force for process flow through the Offgas System.

8.1.2.2 Catalytic Recombiner

The catalytic recombiner receives the gaseous mixture containing the radioactive fission gases, radiolytic hydrogen and oxygen produced from the disassociation of water, and the dilution steam. It removes the majority of the hydrogen and oxygen gases by recombining them into pure water vapor which is then condensed, thus reducing the process volume and limiting the hydrogen content for safety reasons. The intent of the recombiner is to combine sufficient hydrogen and oxygen so that the final hydrogen concentration is less than 1% by volume.

8.1.2.3 Hold-Up Volume

The hold-up volume is a large pipe where the short-lived radioactive isotopes (principally N-13, N-16, 0-19 and certain isotopes of xenon and krypton) decay either to stable isotopes or radioactive particulate daughter products.

8.1.2.4 High Efficiency Filters

The high efficiency filters serve to remove particulate daughter products in the offgas stream. The filters consist of two 100% capacity filter elements and are designed to remove particles of .3 micron size and larger.

8.1.2.5 Charcoal Adsorbers

The adsorber beds contain activated carbon in granular charcoal form. The charcoal acts as a medium to retard the progress of xenon and krypton gases in the offgas stream, allowing the radioactive isotopes to decay to particulate daughter products which can then be removed by filtration. The iodine remaining is essentially removed by adsorption in the charcoal.

8.1.2.6 Mechanical Vacuum Pumps

There are two motor driven mechanical vacuum pumps which are used to establish initial vacuum in the main condenser. They are not operated while the unit is at power. The pumps discharge to the turbine building exhaust ventilation system.

8.1.3 System Features

A short discussion of system features is given in the paragraphs which follow.

8.1.3.1 System Description

The Offgas System is maintained in operation during plant startups, while at power, and during plant shutdown. Main condenser vacuum is initially created by using the mechanical vacuum pumps and then maintained by using the steam jet air ejectors to remove noncondensible gases. If the offgas flow path becomes blocked for any reason, the result is a loss of main condenser vacuum which: scrams the reactor; causes a main turbine trip and closure of the bypass valves.

8.1.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

8.1.4.1 Main Condenser

The main condenser is the source of process gases which enter the Offgas System via the steam jet air ejectors.

8.1.4.2 Main Steam System (Section 2.5)

The Main Steam System supplies the Offgas System with reduced pressure steam to the steam jet air ejectors.

8.1.4.3 Condensate and Feedwater System (Section 2.6)

The Condensate and Feedwater System supplies cooling water to the SJAE intercondenser.

8.1.4.4 Process Radiation Monitoring System (Section 8.4)

The Process Radiation Monitoring (PRM) System isolates the mechanical vacuum pumps upon receipt of a main steam line high radiation signal. The PRM System monitors the Offgas System pretreatment and carbon bed vault levels. The PRM System also isolates the Offgas System from the plant vent upon receipt of a post treatment radiation monitor high level trip.

8.1.4.5 Plant Stack

The Offgas System discharges to the Plant Exhaust Ventilation System.

8.1.5 Summary

Classification:

Power generation system

Purpose:

To process noncondensible gases removed from the main condenser to limit radioactive gaseous release to as low as reasonably achievable.

Components:

Steam jet air ejectors; catalytic recombiner; holdup volume; high efficiency filters; charcoal adsorbers; mechanical vacuum pumps.

System Interfaces:

Main condenser; Main Steam System; Process Radiation Monitoring System; Plant Exhaust Ventilation System.

Table 8.1-1 Principal Isotopes In The Offgas Flow

Activation Products Of Water

Nuclide	Half-life	Formation Mechanism
N-16	7.1 seconds	O-16(n,p)N-16
O-19	29 seconds	O-18(n)O-19
N-13	10 minutes	O-16(p,a)N-13
F-18	110 minutes	O-18(p,n)F-18
H-3 (tritium)	12.33 years	H-2(n)H-3 &Tertiary fission

Iodine Nuclides

Nuclide	Half-life	% fission yield
I-134	52.3 minutes	7.176
I-132	2.28 hours	4.127
I-135	6.7 hours	6.386
I-133	20.8 hours	6.762
I-131	8.06 days	2.774

Fission Gases

Nuclide	Half-life	% fission yield
Xe-138	14.2 minutes	6.235
Kr-87	76 minutes	2.367
Kr-88	2.79 hours	3.642
Kr-85m	4.4 hours	1.332
Xe-135	9.16 hours	6.732
Xe-133	5.26 days	6.776

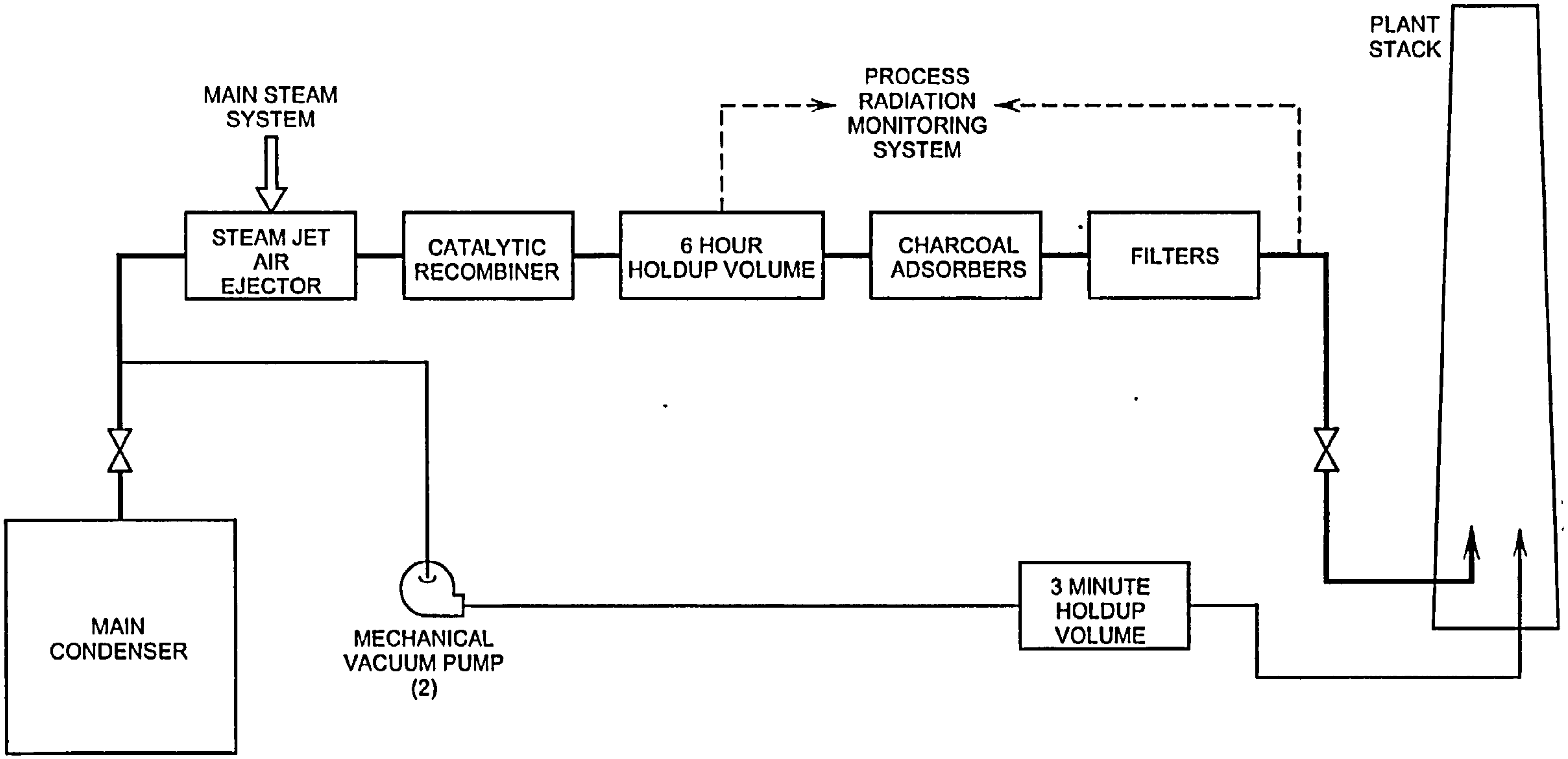


Figure 8.1-1 Offgas System Block Diagram

0102

Table of Contents

List of Figures

8.2 LIQUID RADWASTE SYSTEM

The purpose of the Liquid Radwaste System is to collect, treat, and return radioactive liquid wastes to the plant for reuse or off site disposal.

The functional classification of the Liquid Radwaste System is that of a power generation system.

8.2.1 System Description

The basic processes used in the Liquid Radwaste Systems are collection, treatment, storage, and analysis for disposition or further treatment. The treatment methods are batch processes so that adequate control of radioactive discharge and records of operations may be kept. A basic radioactive waste system process flow diagram is shown in Figure 8.2-1.

8.2.2 Component Description

The major subsystems of the Liquid Radwaste System are discussed in the paragraphs which follow.

8.2.2.1 Equipment Drains Subsystem

The equipment drains subsystem processes low conductivity (high chemical purity) effluent from equipment drains and from backwashing of filter/demineralizers. During normal operation only the waste collector tank is in use. The waste surge tank accumulates wastes during refueling or reactor startup when greater flows of effluent may pass to the radwaste system from the primary system.

Normally the high purity effluent (sometimes referred to as clean radwaste) is filtered, demineralized, and returned to the condensate storage tank for future use.

8.2.2.2 Floor Drains Subsystem

The floor drains are low purity wastes (sometimes referred to as dirty radwaste). This subsystem receives effluent from the floor drain systems of the containment, reactor, turbine, and radwaste buildings. The effluent is first filtered and then pumped to the waste collector/evaporator. The evaporator removes high purity water (as steam) for reuse and concentrates impurities for disposal as solid waste. An alternate flow path allows discharge of low purity waste to the Circulating Water System discharge canal for dilution and offsite release.

8.2.2.3 Chemical Drains Subsystem

The chemical drains subsystem receives various chemical drains from throughout the plant. These drains are treated as low purity effluent after a chemical neutralization process. Both low purity and chemical drains can be processed at low flow rates through the waste evaporator.

8.2.2.4 Detergent Drains Subsystem

The detergent drains subsystem receives waste from laundry facilities and decontamination operations where detergents are likely to be used. These wastes are processed by filtration for particle removal and then discharged in a controlled manner to the Circulating Water System discharge canal for dilution and offsite release.

8.2.3 System Features

A short discussion of system features given in the paragraphs which follow.

8.2.3.1 System Operation

The equipment and floor drain treatment subsystems are arranged so that any batch can be recycled as necessary until it meets discharge requirement. They can also be interconnected so that if any batch is considered to require treatment appropriate to one of the other subsystems, this can be done. For example, low purity effluent can be passed through a demineralizer before discharge, or high purity effluent can be evaporated or discharged from the site. Water returned to the condensate storage tank must be of reactor water quality. Treated effluent is discharged from the site only after sampling and analysis.

Sampling lines are provided from each collection, sampling, and surge tank to a sampling station cabinet. Samples are taken from the sampling station to the laboratory for analysis. Also, samples of plant cooling water are taken at the intake to the facility and at a point downstream of where the waste is discharged into the Circulating Water System waste effluent canal, to audit the background and discharge levels of radioactivity.

8.2.3.2 Sources of Liquid Waste

Radioactivity in the water and steam comes from reactor coolant activation, corrosion product activation, and fission products resulting from fuel leaks. Radioactive liquids accumulated in the waste collection facilities arise from various controlled drains in the process system, removal of excess reactor water (blowdown), backwashing of filters and filter/demineralizers, and the infrequent chemical decontamination of various pieces of primary system equipment.

8.2.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

8.2.4.1 Process Radiation Monitoring System (Section 8.4)

The Process Radiation Monitoring (PRM) System monitors Liquid Radwaste System discharges to the environment.

8.2.4.2 Circulating Water System (Section 11.3)

The Circulating Water System supplies dilution flow for liquid waste discharges.

8.2.5 Summary

Classification:

Power generation system

Purpose:

Collect, treat, and return radioactive liquid wastes to the plant for reuse or offsite disposal.

Components:

Equipment drain subsystem; floor drain subsystem; chemical drains subsystem; detergent drains subsystem.

System Interfaces:
Process Radiation Monitoring System; Circulating Water System.

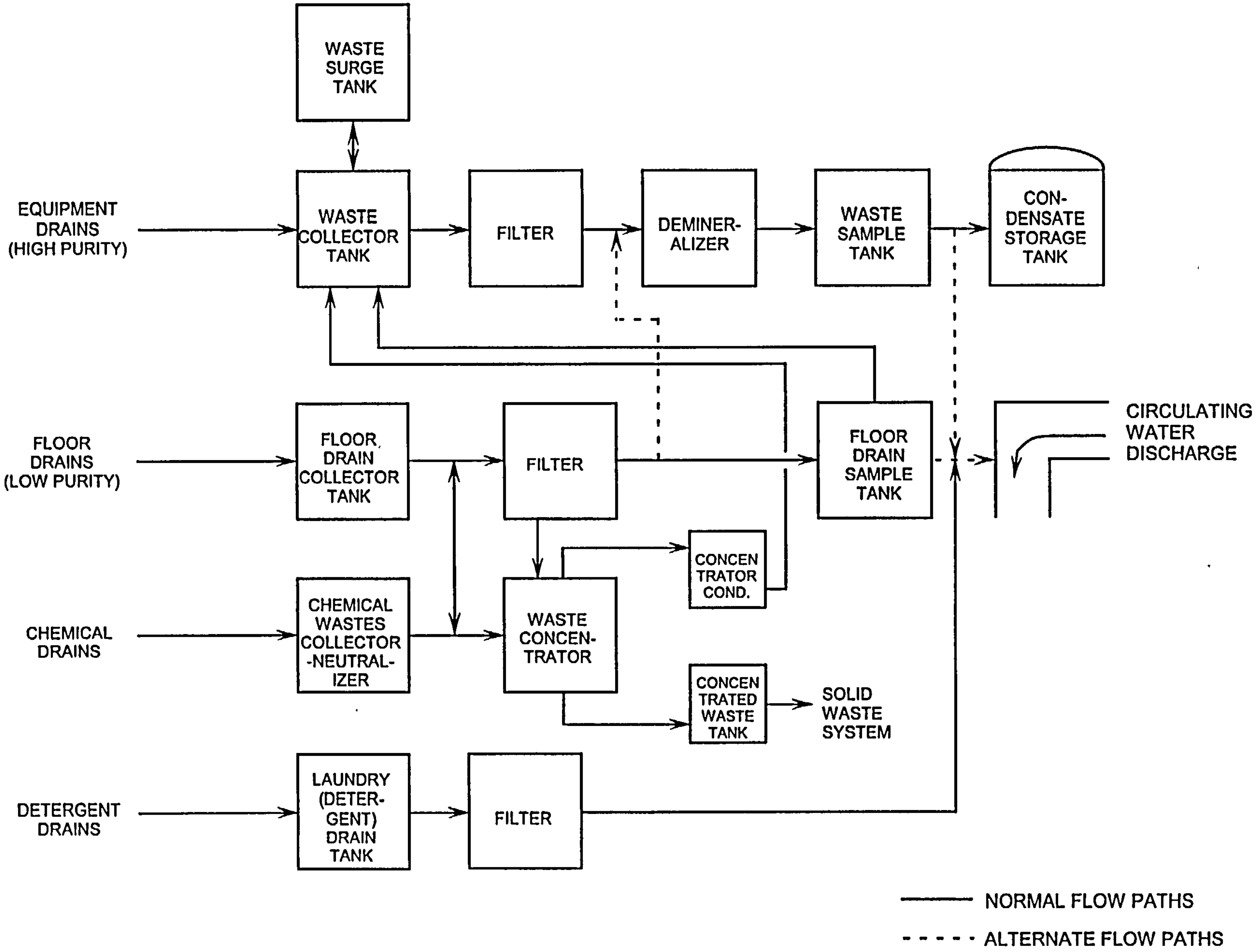


Figure 8.2-1 Typical Liquid Radwaste System

1297-8

Table of Contents

List of Figures

8.3 SOLID RADWASTE SYSTEM

The purpose of the Solid Radwaste System is to process wet and dry solid waste for off site disposal.

The functional classification of the Solid Radwaste System is that of a power generation system.

8.3.1 System Description

The Solid Radwaste System is used to process wet and dry solid waste for off site disposal. Wet wastes are dewatered and packaged in 55 gallon drums. Dry wastes are compacted to reduce their volume and then packaged in approved shipping containers or 55 gallon drums as required. See Figure 8.3-1 for a basic system diagram.

8.3.2 Component Description

The major components of the Solid Radwaste System are discussed in the paragraphs which follow.

8.3.2.1 Receiving/Phase Separator Tanks

Slurry waste products from various plant systems, fuel pool filter/demineralizers, condensate filter/demineralizers, reactor water cleanup filter/demineralizers, and various liquid radwaste filter/demineralizers are backwashed to receiving/phase separator tanks. Excess liquid is decanted off and routed to the Liquid Radwaste System. The sludges resulting from this operation are generally kept separated because of differences in radiation levels of the resulting solid wastes. The tanks provide a secondary function of holding the sludge for short lived radioactive decay prior to further processing.

8.3.2.2 Centrifuges

The sludge is periodically routed to a centrifuge where dewatering is performed to produce a moist solid with little free water present. The solids are discharged to a hopper beneath the centrifuge. The liquid is routed to the Liquid Radwaste System.

8.3.2.3 Drums

The processed solids are remotely loaded into 55 gallon drums which are positioned under the hopper by a conveyor system. After loading, the drums are moved to a capping machine where the lids are placed and secured. The conveyor then moves them to a temporary storage facility within the plant.

8.3.3 System Features

A short discussion of system features is given in the paragraphs which follow.

8.3.3.1 System Operation

The Solid Radwaste System is a batch process system. This allows segregating the more radioactive solids from the less radioactive ones. This minimizes the shielding required for on site storage and off site shipment.

Handling of high level solid radwaste storage drums is minimized by use of remote handling equipment controlled from a shielded structure.

8.3.3.2 Other Solid Waste

The activity of most other categories of solid wastes is low enough to permit handling of packages by contact. These wastes are collected in containers located in appropriate zones around the plant. The containers (fiber, drums, cartons, or boxes) are monitored periodically during filling so that the contents do not exceed a practical maximum external dose rate before disposal.

The containers are then sealed and moved to a controlled access, enclosed storage area for temporary storage. Compressible wastes are compacted into drums by a hydraulic press baling machine to reduce their volume and then stored temporarily. Compacted and noncompressible wastes are eventually shipped to an approved off site facility for storage. Equipment too large to be handled in this way is handled as a special case.

8.3.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

8.3.4.1 Liquid Radwaste System (Section 8.2)

The Liquid Radwaste System provides most of the sources of solid radioactive wastes in the form of sludges and resins.

8.3.5 Summary

Classification:

Power generation system

Purpose:

To process wet and dry solid radioactive waste for shipment from the facility.

Components:

Phase separator tanks, centrifuges, drums.

System Interfaces:

Liquid Radwaste System.

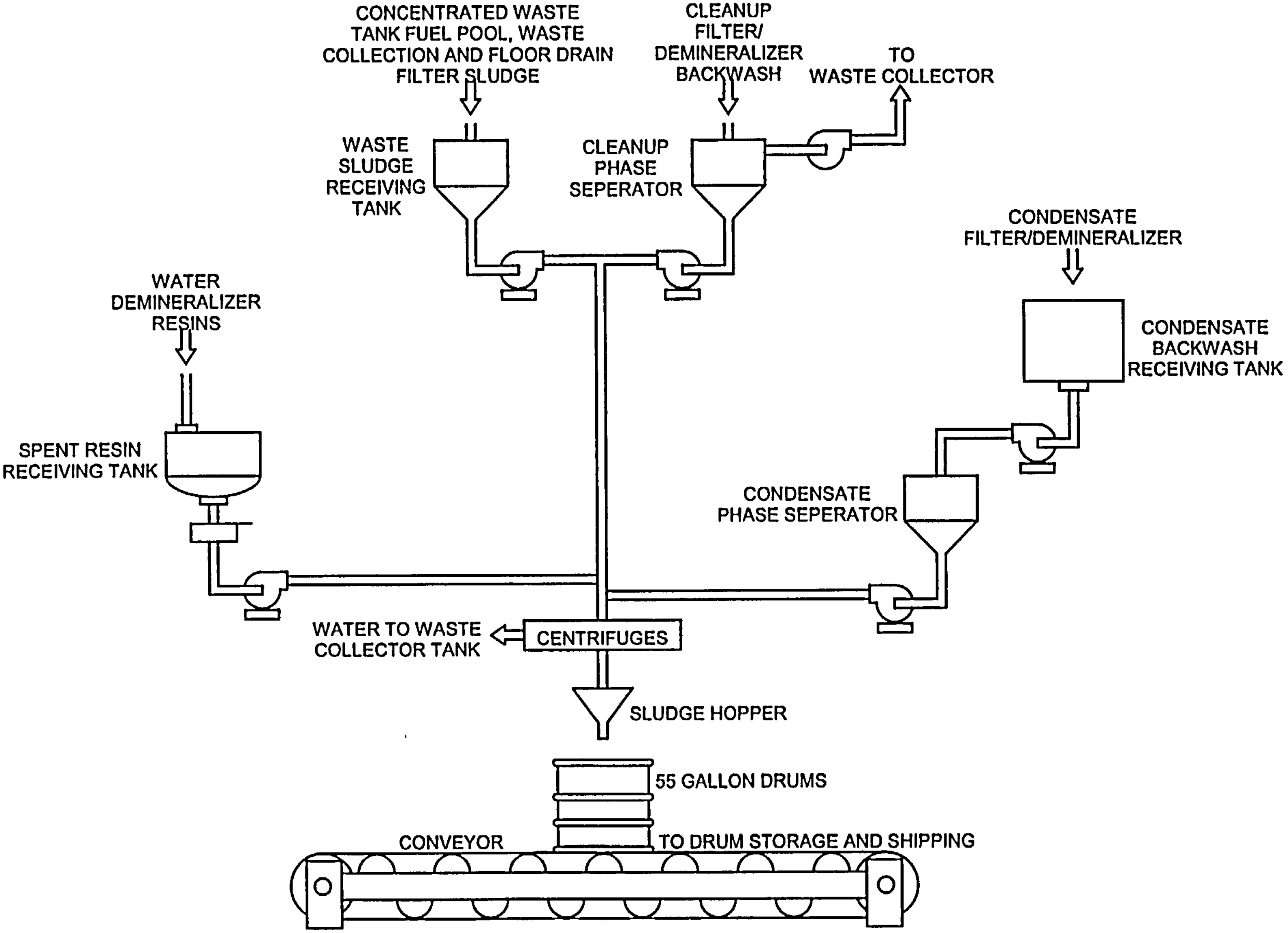


Figure 8.3-1 Basic Solid Radwaste System

Table of Contents

8.4 PROCESS RADIATION MONITORING SYSTEM

The purpose of the Process Radiation Monitoring (PRM) System is to monitor the radiation level of various process systems and areas throughout the plant to alert plant personnel of abnormal conditions.

The functional classification of the PRM System is that of a power generation system.

8.4.1 System Description

The Process Radiation Monitoring (PRM) System monitors radiation levels of specified liquid systems, gaseous systems, and general areas throughout the plant; assists in controlling the release of radioactive material; and provides personnel safety by warning of abnormal radiation levels. The sensed radiation levels are also recorded by chart recorders to provide a permanent record of radiation levels.

8.4.2 Component Description

The major subsystems of the Process Radiation Monitoring System are discussed in the paragraphs which follow.

8.4.2.1 Main Steam Line Radiation Monitoring Subsystem

The main steam line radiation monitoring subsystem is provided to detect and initiate control action upon significant increases in the gross radiation level caused by large releases of fission products into the main steam lines. This condition is indicative of major fuel failure.

Because of the magnitude of radiation involved in a major fuel failure a reactor scram and closure of the main steam line isolation valves is initiated by the main steam line radiation monitoring subsystem. This is done to minimize the release of fission products to the environs.

8.4.2.2 Offgas Radiation Monitoring Subsystem

The offgas radiation monitoring subsystem consists of two separate systems used to continuously monitor the radiation level of the main condenser offgas prior to and after treatment. The after treatment radiation monitors prevent instantaneous discharges of radioactivity to the atmosphere from exceeding the maximum permissible offgas release rate. When the radiation level of the offgas exceeds the offgas release rate limit, control action is initiated to isolate the offgas discharge.

8.4.2.3 Process Liquid Radiation Monitoring Subsystem

Process radiation monitoring is provided for the following systems:

1. Reactor Building Closed Cooling Water System
2. Emergency Equipment Cooling Water System
3. Resedual Heat Removal Service Water System
4. Turbine Building Cooling Water System.
5. Liquid Radwaste System (effluent).

Continuous gross radiation records of radioactive waste effluent are maintained in compliance with licensing requirements.

Trip circuits are included to annunciate abnormal concentrations of radioactive products so that action can be taken to prevent the accidental release or transfer of highly radioactive materials. Trip circuits in the Liquid Radwaste System effluent monitors isolate the discharge paths automatically. These systems can be monitored to detect failures or leaks in other plant process systems.

8.4.2.4 Ventilation Radiation Monitoring Subsystem

The ventilation radiation monitors provide indication, alarms, and/or control actions when the reactor building, radwaste building, or the turbine building exhaust radiation levels exceed a predetermined radiation limit. Unlike the other ventilation systems monitored, the control room ventilation intake is monitored to preclude the introduction of radioactive materials into the control room.

8.4.2.5 Area Radiation Monitoring Subsystem

The area radiation monitors (ARM's) consists of a series of radiation detectors located throughout the plant.

The purpose of the area radiation monitors is to warn of abnormal radiation levels in areas where radioactive material may be present, stored, handled, or inadvertently introduced. They also provide operating personnel with records and indications in the control room of radiation levels at selected locations within the various plant buildings. The ARM's provide local alarms where it is necessary to warn personnel of substantial immediate changes in radiation levels.

8.4.3 System Features

A short discussion of system features is given in the paragraphs which follow.

8.4.3.1 Normal Operation

The Process Radiation Monitoring System is in operation continuously.

8.4.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

8.4.4.1 Primary Containment Isolation System (Section 4.4)

The PRM System sends isolation demand signals to the PCIS upon main steam line radiation monitor trips.

8.4.4.2 Offgas System (Section 8.1)

The PRM System trips the mechanical vacuum pumps and closes the discharge valves upon main steam line radiation monitor trips. The PRM System monitors the Offgas System pretreatment and carbon bed vault levels. The PRM System also isolates the Offgas System from the plant vent upon post treatment radiation monitor trips.

8.4.4.3 Control Room Ventilation System

The PRM System causes the Control Room Ventilation System to isolate and energizes the emergency air cleanup units upon high radiation levels at the air intakes.

8.4.4.4 Standby Gas Treatment System (Section 4.3)

The PRM System monitors the SGTS exhaust. The PRM System also automatically starts the SGTS upon radiation monitor trips in the reactor building ventilation exhaust, or refueling floor area.

8.4.4.5 Plant Exhaust Ventilation System

The PRM System monitors plant stack exhaust vent radiation levels.

8.4.4.6 Turbine Building Ventilation System

The PRM System monitors airborne activity in ventilation exhausts within the turbine building.

8.4.4.7 Secondary Containment System (Section 4.2)

The PRM System monitors radiation levels in the Reactor Building HVAC System exhaust, and refueling floor area.

8.4.4.8 Service Water System (Section 11.3)

The PRM System monitors the SW System for radioactivity to detect inleakage.

8.4.4.9 Residual Heat Removal Service Water (Section 11.4)

The PRM System monitors the RHRSW System for radioactivity to detect inleakage.

8.4.4.10 Reactor Building Closed Loop Cooling Water System (Section 11.1)

The PRM System monitors the RBCLCW System for radioactivity to detect inleakage.

8.4.4.11 Liquid Radwaste System (Section 8.2)

The PRM System monitors radiation levels in the liquid effluent discharge line. Upon high radiation in the liquid effluent line, the discharge line is isolated and the flow returns to the Liquid Radwaste System

8.4.4.12 Radwaste Building Ventilation System

The PRM System monitors the radwaste building ventilation exhaust. Upon high radiation, the normal system is isolated, and the exhaust air cleanup unit is started.

8.4.5 Summary

Classification:

Power generation system.

Purpose:

To monitor radiation levels and proces liquids, gases and remote plant locations.

Components:

Main steam radiation monitoring; offgas monitoring; process liquid monitoring; ventilation monitoring; and area monitoring.

System Interfaces:

Primary Containment Isolstion System; Offgas System; Standby Gas Treatment System; Plant Exhaust Vent System; Turbine Building Ventilation System.

9.0 ELECTRICAL SYSTEMS

The purpose of the plant electrical systems is to provide redundant, diverse, and dependable power sources for all plant operating conditions. In the event of a total loss of off site power, on-site diesel generators and batteries are provided to supply electrical power equipment necessary for the safe shutdown of the plant.

9.0.1 Normal Auxiliary Power System (Section 9.1)

The Normal Auxiliary Power System supplies power to equipment required for normal power operation of the plant. The power for this system is supplied from the unit main generator or from two independent off site supplies.

9.0.2 Emergency AC Power System (Section 9.2)

The Emergency AC Power System provides power distribution to vital safety related loads required for safe plant shutdown and mitigation of accidents. Self contained diesel generators provide this power in the event that all off site power is lost.

9.0.3 120V AC Distribution System (Section 9.3)

The 120V AC Distribution System provides a reliable power source to control, instrumentation, and monitoring systems vital for safe plant operation.

9.0.4 D.C. Electrical Distribution (Section 9.4)

The DC electrical system provides a reliable power supply to vital plant systems during normal and emergency conditions.

Table of Contents

List of Figures

9.1 NORMAL AUXILIARY POWER SYSTEM

The purposes of the Normal Auxiliary Power System are to provide power to unit auxiliary loads needed for plant operations, and to deliver two physically independent off-site power supplies from the utility transmission network to the standby auxiliary power system.

The functional classification of the Normal Auxiliary Power System is that of a safety related system because of its functional requirement to connect offsite power to the Emergency AC Power System.

9.1.1 System Description

The Normal Auxiliary Power System consists of the components, distribution network, and boards necessary to supply electrical power for startup, normal operation and shutdown of the unit. During normal operation, power is supplied by the main generator via the generator breaker and transformer. During plant conditions when the main generator is not available, power is supplied from the 138 kV switchyard. When power is not available from either source, power is supplied via the reserve transformer from the 69 kV switchyard.

9.1.2 Component Description

The major components of the Normal Auxiliary Power System are discussed in the following paragraphs and illustrated on Figure 9.1-1.

9.1.2.1 Unit Generator

The rotating shaft of the main turbine is coupled to the generator rotor. The rotor supplies the rotating magnetic field necessary to produce electricity from the generator. To produce large amounts of electricity and maintain the generator at a reasonable size, hydrogen gas is used to cool the rotor windings, and demineralized water is used to cool the stator.

The unit generator supplies 880 megawatts (880 MWe) at full power. Power from the generator is connected via generator breakers through forced cooled isolated phase bus duct to a bank of three, single phase, step up transformers.

9.1.2.2 Generator Breaker

The generator breaker consists of three (one per phase) output circuit breakers installed between the generator and the main transformer. The generator breaker provides electrical isolation and protection for the main generator.

All turbine trips and generator trips will trip the generator breakers, separating the generator from the electrical system without interrupting the incoming power to the unit station service transformers.

9.1.2.3 138 kV Distribution

The 138 kV distribution system receives the output of the station's main generators and delivers this output to transmission lines for off-site use. Also provided by the 138kV distribution system is a means to supply power to the unit when the generator breakers are open. The 138 kV distribution is designed to ensure that no single probable event would prevent the output of the plant from being transmitted to the 138 kV grid network.

9.1.2.4 Normal Auxiliary Electrical Distribution

The normal auxiliary electrical distribution system provides power for plant auxiliaries during startup, shutdown, and power operation, plus a highly reliable power source for plant loads which are important to its safety. Auxiliary loads include such loads as condensate pumps, condensate booster pumps, oil pumps, and air compressors.

9.1.3 System Features

A short discussion of the system features is given in the paragraphs which follow.

9.1.3.1 Normal Auxiliary Power System Lineup

During normal conditions, all AC loads associated with the reactor and turbine generators are supplied from the unit station service transformer via the unit generator or main transformers.

9.1.3.2 System Interfaces

The Normal Auxiliary Power System interfaces directly with the control, operation, and instrumentation of virtually every plant system.

9.1.4 Summary

Classification - Safety related system

Purpose - Provide power to unit auxiliary loads needed for plant operations and deliver physically independent off-site power supplies from the utility transmission network to the standby auxiliary power system.

Components:

Unit generator; generator breaker; 138 kV distribution; normal auxiliary electrical distribution.

System Interfaces:

All loads

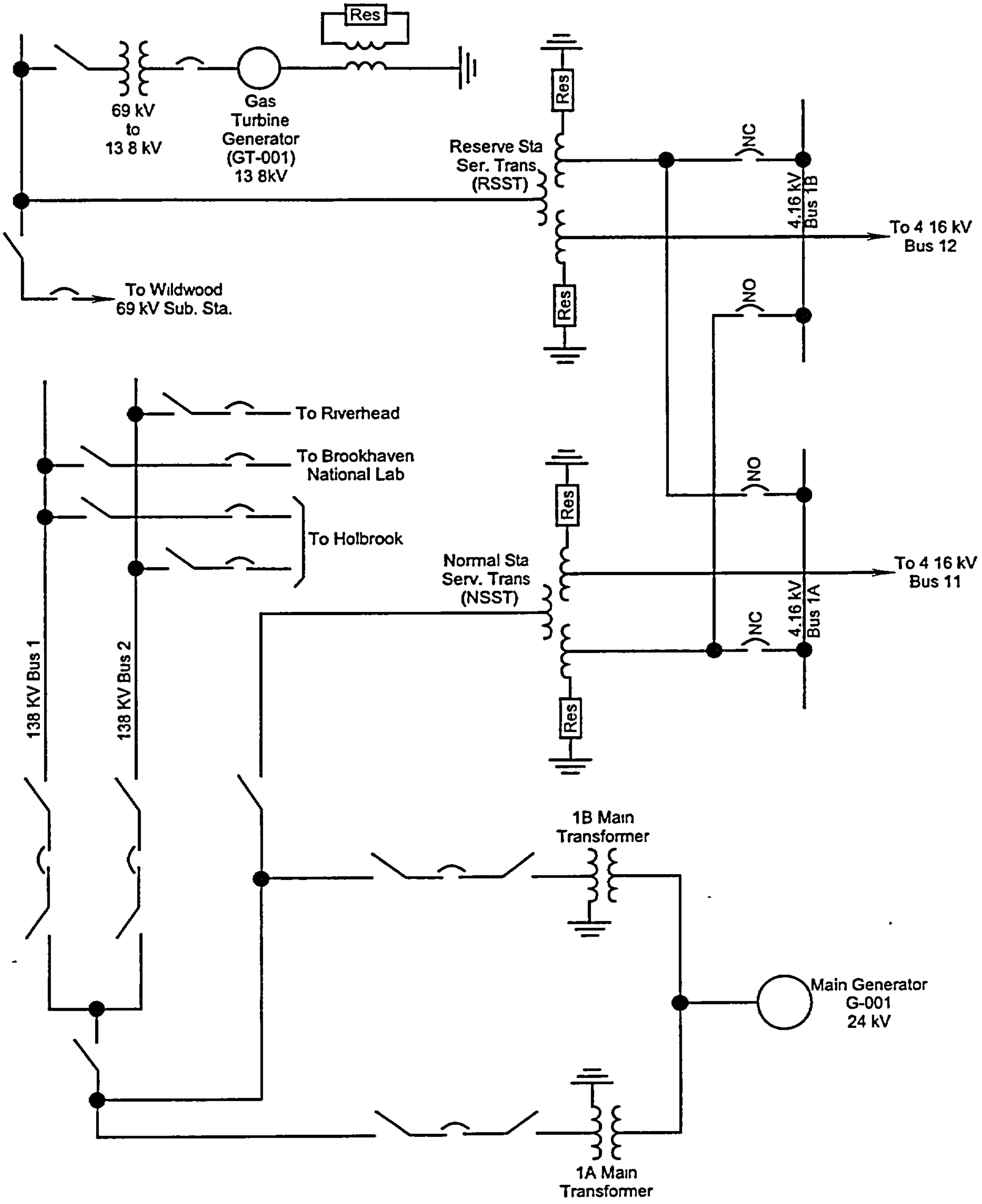


FIGURE 9.1-1 Main One Line Diagram

Table of Contents

List of Tables and Figures

9.2 EMERGENCY AC POWER SYSTEM

The purpose of the Emergency AC Power System is to provide a reliable source of electrical power to all loads which are required for safe shutdown of the plant.

The regulatory classification of the emergency AC power system is that of an engineered safety feature system.

9.2.1 System Description

The emergency AC power system consists of 4160V switchgear, three diesel generators, 480V secondary unit substations (SUSs), motor control centers (MCC), and power panels (PP). Figure 9.2-1 shows the electrical feeds available to the emergency busses and the major loads supplied from the busses. The three diesel generators are provided as a emergency power source to be used on loss of the normal power supply. Each diesel generator is assigned to one 4160V shutdown board.

9.2.2 Component Description

The major components of the Emergency AC Power System are discussed in the paragraphs which follow and are illustrated in Figure 9.2-1.

9.2.2.1 4160V AC EP System Switchgear

The EP system consists of three separate and independent 4.16KV AC buses (red - 101, blue-102, and orange - 103). Each of these busses is connected to an associated diesel generator, and each has connections to two 4.16KV AC buses in the NP System. The three 4160V AC EP buses are the most reliable medium voltage AC buses in the plant. There are no bus ties between the three divisions at any voltage level within the EP System. They are physically and electrically independent from each other, so a failure of one bus has no effect on the operation of the remaining two buses.

Every EP system division can receive power from one of three power sources: the normal preferred source supplied through the NSST; the reserve preferred source supplied through the RSST; or the emergency source supplied from a diesel generator. Each of the three EP divisions has the capability to automatically switch from its normal preferred source of power to the reserve preferred source of power or to the emergency source of power. Every one of the three 4.16KV AC EP system switchgears has switching and interrupting devices, instruments, protective relays, a bus bar, main bus conductors, interconnecting wiring, accessories, supporting structures, and enclosures.

9.2.2.2 Diesel Generators

The emergency diesel generators supply emergency power to the 4160V AC EP system busses. The generator portion of the EDG is directly coupled to a large commercial diesel engine. Each diesel engine is a four stroke, eight cylinder, turbocharged, water cooled, fuel injected. Each engine is directly coupled to an air cooled, 4.16KV AC, 3 phase, 60 Hz, salient pole, synchronous generator. The continuous rating of each diesel generator is 3500 KW. The time required to achieve rated voltage and frequency is less than 10 seconds. All necessary auxiliaries directly associated with each diesel generator unit, such as cooling water, lubricating oil, circulating pumps, ventilating fans, and battery chargers are powered from their associated emergency bus.

9.2.3 System Features

A short discussion of the system features is given in the paragraphs which follow.

9.2.3.1 Normal Operations

During normal operation, the three 4.16KV AC EP system buses are fed from unit generator power or offsite sources through the NP System. The NSST transformer steps down the 138KV power supply to 4.16KV AC. Off site power is fed from the 138KV AC and 69KV AC substations through the NSST and RSST respectively, to the NP system. Power is delivered to the three 4160V AC EP system divisions from the 4160V AC NP system busses normally power by the NSST.

9.2.3.2 Diesel Generator Automatic Start

The diesel generators receive an auto start signal from any one of the following:

1. High drywell pressure.
2. Reactor water level, Level 1
3. Loss of voltage on 4160V buses
4. Loss of voltage on 4160V board. Only the diesel associated with that board will start.

After receipt of the automatic start signal, the diesel will be up to speed and ready to accept load within 10 seconds.

9.2.3.3 Loss of Preferred Power (LOPP)

Upon a loss of the normal source of power to the emergency busses, searching logic on the buses first checks the availability of the RSST source. If the RSST is available, a fast transfer to that source is made approximately 5 cycles after bus undervoltage is detected. The function is only available from the normal to the backup source of preferred power and not in reverse.

9.2.3.4 System Interfaces

The emergency AC power system interfaces with many plant systems. Table 9.2-1 list the loads supplied from the shutdown boards, other important interfaces are discussed in the paragraphs which follow.

9.2.3.4.1 Normal Auxiliary Power System (Section 9.1)

The emergency AC power system receives normal power from the normal auxiliary power system.

9.2.3.4.2 D.C. Power System (Section 9.4)

Control power for the circuit breakers is provided by the respective D.C. Power System division while the battery chargers are powered from the emergency AC power system.

9.2.4 Summary

Classification :

Safety Related System

Purpose:

To provide a reliable source of electrical power to all loads which are required for safe shutdown of the plant.

Components:

4160V boards; diesel generators; 480V boards.

System Interfaces:

All loads served; Normal Auxiliary Power System; D.C. Power System.

Table 9.2-1

Bus 101 - Red Division RHR pump "A" Core spray pump "A" Service water pump "A" CRD water pump "A" 480 SUS and loads
Bus 102 - Blue Division RHR pump "B" Core spray pump "B" Service water pump "B" CRD water pump "B" 480 SUS and loads
Bus 103 - Orange Division RHR pumps "C" and "D" Service water pumps "C" and "D" 480 SUS and loads

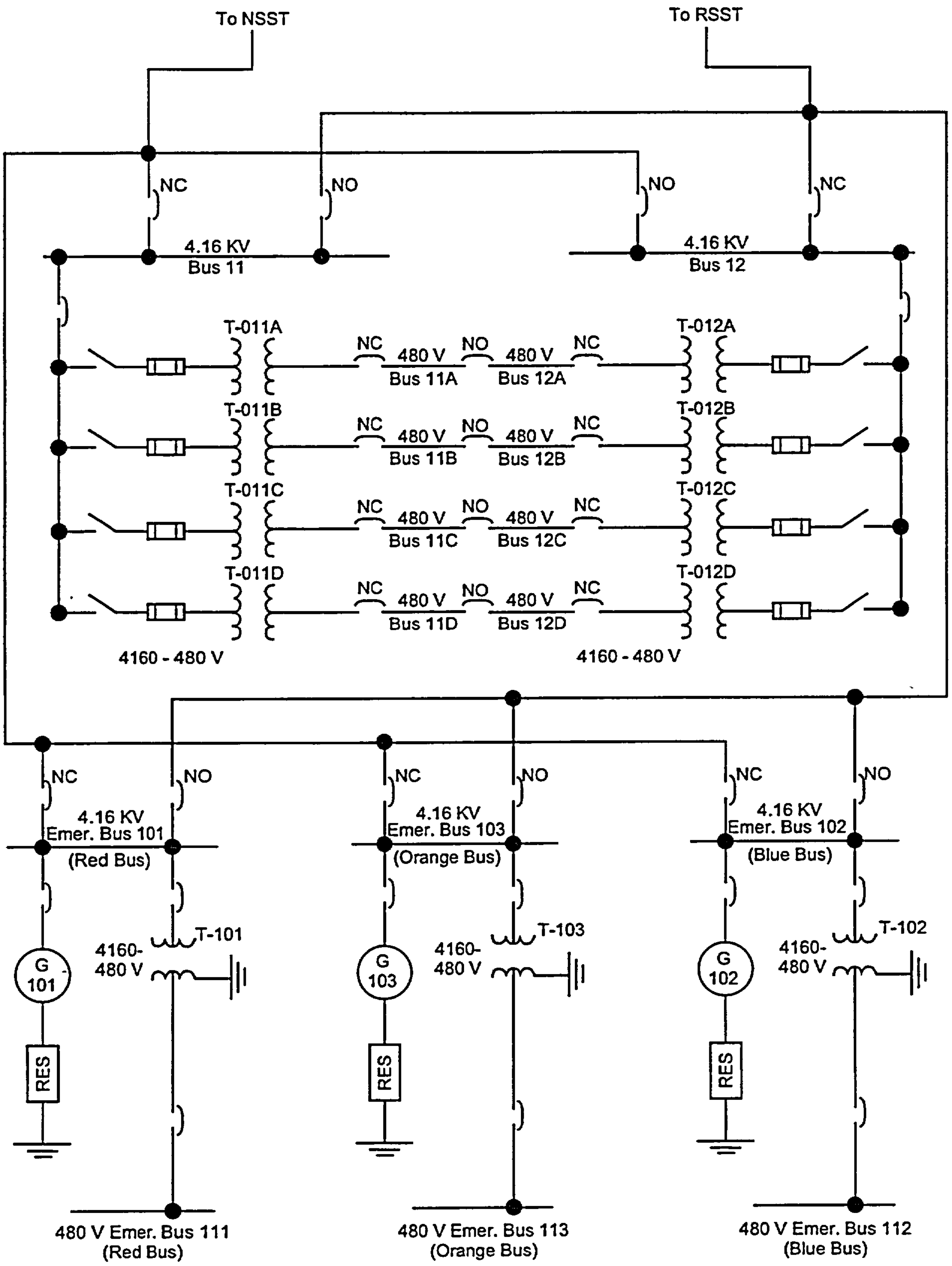


FIGURE 9.2-1 Emergency AC Power System

Table Of Contents

List of Figures

9.3 120 VAC POWER SYSTEMS

9.3.1 System Introductions

The 120 VAC Power Systems are divided into four systems; safety related control and instrument power system, normal control and instrument power system, reactor protection power system, and the uninterruptible power system.

9.3.1.1 Safety Related Control and Instrument Power System

The safety related control and instrumentation system consists of three independent subsystems. Each subsystem has a minimum of two power sources and associated distributed panels. Each power source is a single phase transformer with its primary connected to an emergency 480 VAC bus and its secondary connected to a distribution panel. The panels contain manually operated circuit breakers for protection of safety related circuits and devices.

9.3.1.2 Normal Control and Instrument Power System

The normal control and instrument power system consists of independent power sources and distribution panels to supply power to conventional instruments and noncritical monitors and controls. Each power source is a single phase transformer with its primary connected to a normal 480 VAC bus and its secondary connected to a distribution panel. The panels contain manually operated circuit breakers for protection of the circuits that supply instruments and monitors. Certain buses have automatic transfer from one power source to another where high reliability is desired during normal operations.

9.3.1.3 Reactor Protection System

The reactor protection power system consists of two independent and redundant power sources and an associated power supply panel. Each power source is a motor generator set with a high inertia flywheel that receives power from an emergency 480 VAC bus and delivers single phase 120 VAC to the distribution bus. There is an alternate source of power from a transformer with its primary connected to an emergency 480 VAC bus to allow for maintenance of a motor generator with no loss of reactor protection system function. For more information about the reactor protection system, see chapter 7.3.

9.3.1.4 Uninterruptible Power System

The purpose of the Uninterruptible Power Systems (UPS) is to supply 120 VAC power to non-safety related controls and instrumentation used for orderly operation of the plant. Since the UPS has the 125 VDC system (with batteries) as its alternate supply, its output should not be lost during the interval between a loss of offsite power and restoration of emergency AC by the diesel generators. The UPS output will continue for a minimum of two hours in the event of a total loss of AC power (blackout).

Each of the two systems consists of a rectifier, an inverter, static transfer switch, manual transfer switch, and a distribution panel (Figure 9.3-1). One system supplies power to the plant computer and the other supplies vital instruments and controls and part of the control room lighting. (There is a third unrelated system that supplies power to the station security system which will not be discussed).

Each inverter produces a 120 VAC output which is then supplied to a distribution panel. The normal supply is an internal rectifier which receives power from an emergency 480 VAC bus.

The backup supplies are from 125 VDC buses. An auctioneering circuit will allow the DC bus to supply the inverter without interruption if the AC source fails. A static transfer switch will allow the same 480 VAC bus to supply the 120 VAC distribution panel through a transformer in the event of an inverter failure. There is another 480 to 120 VAC path provided by the manual bypass switch for use during maintenance of either the inverter of the static transfer switch.

9.3.2 Component Descriptions

9.3.2.1 Internal Rectifier

The input of the internal rectifier is connected to the secondary of a step down transformer. Three phase AC is converted to DC by a full wave array that uses diodes and silicone controlled rectifiers (SCRs). The output voltage is maintained constant during varying input conditions by adjusting the amount of time in each half cycle that the SCRs conduct. This is called phase angle control. The output of the rectifier is connected to the inverter through a filter which is designed to reduce the ripple of the rectifier output.

9.3.2.2 Inverter

An inverter is a solid state device to transform DC power to AC power. The fundamental principle of operation of an inverter is the periodic switching of silicon control rectifiers to change the direction of current in a load. The frequency of the resultant wave is a function of the switching rate. The UPS synchronizes the frequency and phase of its output with the reference signal (the AC supply) as long as the frequency is within 1% of 60 Hz. The UPS will maintain its phase within 5 degrees of the reference signal during steady state conditions. This feature allows "make before break" load transfers. If the reference signal deviates from 60 Hz by more than 1%, the UPS will not follow, but will synchronize again when the reference returns to nominal. The UPS can supply 125% of full rated load for an unlimited time while maintaining output voltage within 10% of its nominal value.

9.3.2.3 Static Transfer Switch

The static transfer switch associated with the inverter makes transfers between the preferred source (inverter) to the alternate source (transformer) without interruption on a "make before break" basis, ensuring that there will be no transient or power interruption. The purpose of the transfer from the inverter to the alternate source is to continue to supply 120 VAC in the event of an inverter failure. This transfer is made automatically when inverter output drops below 106 volts. The transfer back to the inverter is by manual action only. The transfer from inverter to alternate supply can be accomplished manually as long as there is no more than a 5 degree phase difference between the two sources.

9.3.2.4 Manual Bypass Switch

The manual bypass switch allows for maintenance on the inverter or the static transfer switch by providing for "make before break" transfers between the inverter and the alternate source. The switch is interlocked with the static transfer switch so that a transfer can not occur unless the static switch is supplying power from the alternate source or the output voltage of the static switch is zero.

9.3.3 System Features and Interfaces

9.3.3.1 Normal Operation

Each UPS normally operates on power from an emergency 480 VAC bus. This 480 VAC power is stepped down in voltage, rectified, filtered, and sent to the input of an inverter. The inverter produces 120 VAC which is sent to a distribution bus. During this normal mode of operation, the 125 VDC power, which is used as a backup supply, is in standby. The static transfer switch and the manual bypass switch are both selected to the inverter output, so there is no input from the alternate AC supply.

9.3.3.2 Abnormal and Emergency Operation

The abnormal modes of operation for UPS occur when the 480 VAC is unable to supply power, or when either the inverter or the static transfer switch is unable to function properly. In the first case, a loss of 480 VAC, the 125 VDC input will supply the inverter with no interruption in output. In the case of malfunction or maintenance of the inverter, the static transfer switch automatically selects the alternate AC supply when the inverter output falls below 106 VAC. There is no interruption in power output because the static transfer switch does a "make before break" transfer. If the malfunction or maintenance includes the static transfer switch, it would be necessary to transfer to the alternate AC supply with the manual bypass switch. It is also a "make before break" transfer.

During emergency operations, the UPS should continue to supply 120 VAC to its loads as previously explained for normal and abnormal operations as long as either 480 VAC or 125 VDC is available. If offsite power is lost, UPS will use 125 VDC until the diesel generators supply the 480 VAC. For a sustained loss of all AC (blackout), the batteries will supply 125 VDC for at least two hours.

9.3.3.3 Interfaces

The 120 VAC power system interfaces with many plant systems. Loads include normal and emergency instrumentation and control systems and the plant computer. Other important interfaces are discussed in the paragraphs that follow.

Normal AC Power System (Section 9.1)

The normal AC power system supplies power to the normal control and instrument power system.

Emergency AC Power System (Section 9.2)

The emergency AC power system supplies power to the safety related control and instrument power system and the reactor protection system motor generator sets.

125 VDC Power System (Section 9.4)

The 125 VDC power system supplies backup power to the uninterruptible power system through inverters.

9.3.4 BWR Differences

The discussion in this section is typical for BWR/4 facilities. Specific buses and loads will vary from plant to plant. All BWR facilities have a 120 VAC power system by one name or another, but those of other BWR plants are somewhat different from the one in this discussion.

9.3.5 Summary

The purpose of the 120 VAC power system is to provide 120 VAC to safety and non safety related control and instrument buses, the plant computer, and to the reactor protection system. 120 VAC buses are supplied by 480 VAC buses through transformers, motor generator sets, or uninterruptible power supplies.

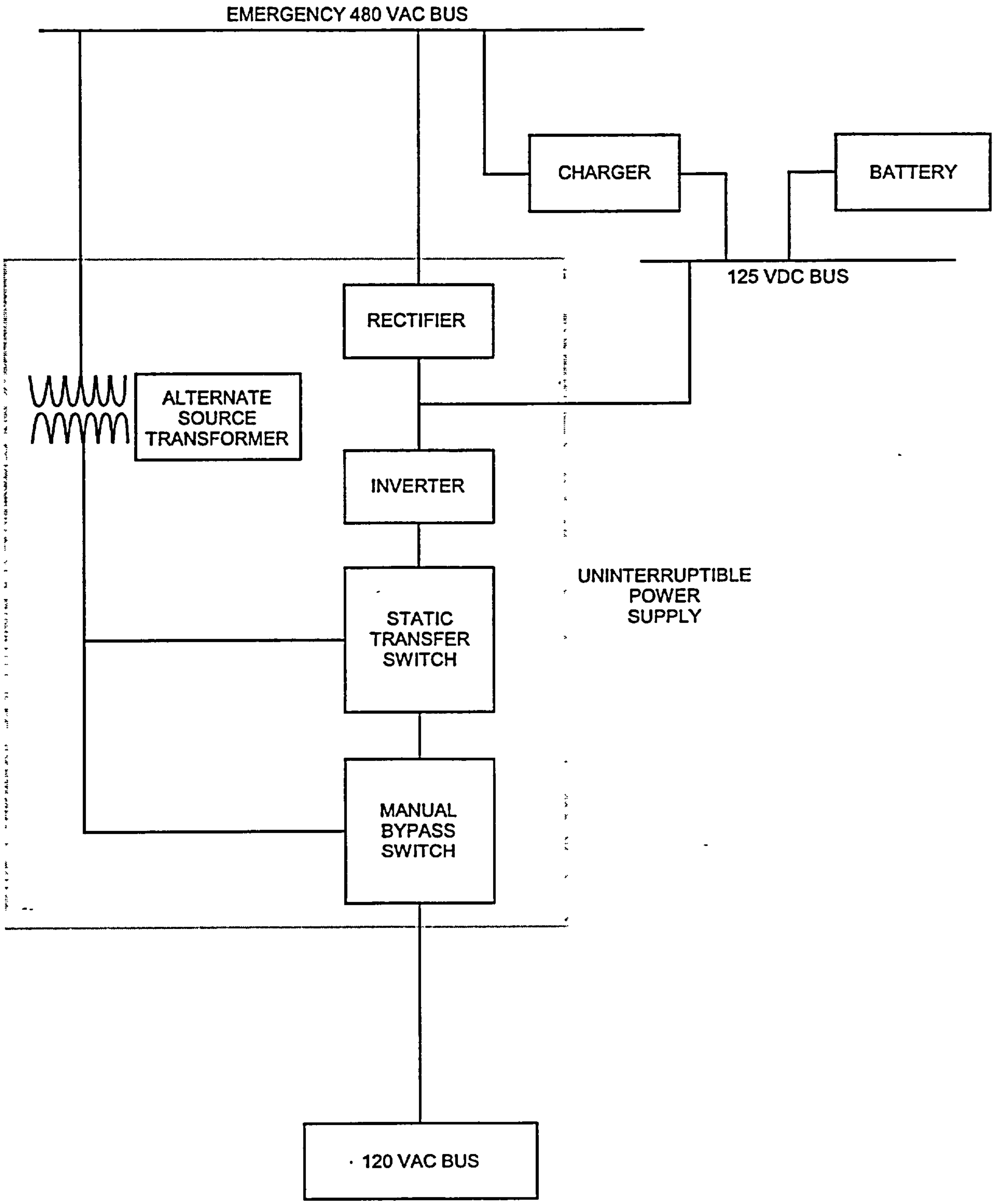


FIGURE 9.3-1 Uninterruptible Power Supply

9.4 DC POWER SYSTEM

9.4.1 System Introduction

The purpose of the DC Power System is to provide highly reliable 125 VDC and 24 VDC to selected equipment required for safe shutdown of the plant and to loads that are essential for normal plant operation.

The 125 VDC system is divided into four separate divisions. Three divisions are for engineered safety features (ESF) equipment. This equipment includes ESF control systems (to prevent spurious operation on loss of AC power), equipment required to restore emergency AC supplies, and equipment that must operate at all times (including the interval between loss of offsite power and restoration of emergency AC power by diesel generators). The fourth division consists of four independent systems to provide power for non safety related systems. Two of the systems supply control and protective equipment, and auxiliaries required to achieve safe shutdown when offsite power is lost. The third system provides power for the emergency response facility, and the fourth for the security systems.

Each distribution bus has two sources as shown in Figure 9.4-1. One is a solid state battery charger that receives power from a 480 VAC bus, and the other is a 125 VDC battery.

The 24 VDC power system provides electrical power to the neutron monitoring system (source and intermediate ranges). This system is not safety related since the instruments supplied by the system do not trip the reactor or place the plant in a safe shutdown condition. There is a separate, unrelated 24 VDC system that supplies radwaste and process radiation monitoring systems that will not be discussed in this section. There are two separate 24 VDC distribution buses. Each bus consists of three wires (positive,negative, and ground) which are supplied by two batteries and two battery chargers. Both battery chargers associated with a distribution bus are supplied by an emergency 480 VAC bus through a step down transformer. Figure 9.4-2 shows a 24 VDC distribution bus.

9.4.2 Component Descriptions

9.4.2.1 Batteries

The 125 VDC batteries are pasted-plate lead acid type, made up of 60 cells, and sealed in clear plastic containers. Each cell has high and low electrolyte level marks, a built-in hydrometer reading tube, a vent hole thermometer, and a specific gravity correction scale on the pilot cell of each battery. The float voltage of each cell is 2.17V to 2.25V. The recommended equalizing and charging voltage is 2.33 volts per cell. There are ground alarm relays provided for each safety related bus.

The 24 VDC batteries are pasted-plate lead acid type that are made up of 12 cells in clear plastic containers. Each cell has electrolyte level marks and specific gravity and temperature monitoring.

9.4.2.2 Battery Chargers

The 125 VDC battery chargers are the normal source of power to the 125 VDC buses. The chargers are transformer rectifier units cooled by natural convection. They are rated at 300 amp continuous output. The rectifiers are silicon diodes and silicon controlled rectifiers (SCRs). The output is controlled by varying the phase angle of the SCRs. The output of the rectifier is smoothed by a smoothing circuit to reduce AC ripple. A current limiter will bias the output voltage if the current exceeds 360 amps. Alarms are provided for voltage greater than 145 and less than 105.

The 24 VDC battery chargers are convection cooled, single phase, rectifier units. The rectifiers use SCRs connected in a full wave bridge configuration. The output voltage is controlled by adjusting the firing angle of the SCRs. The output "float" voltage is set for 26 to 27, and the equalizing setpoint is 28 to 29 volts. A current limiter circuit will limit the output to 30 amps. The rectifier output is filtered by a choke circuit to reduce AC ripple. There are alarms for low voltage, low current, and loss of AC power input.

9.4.3 System Features and Interfaces

9.4.3.1 Normal Operation

During normal operations, the battery chargers will supply the normal steady state DC loads, and also "float" charge the batteries. The chargers have enough capacity to carry the steady state loads while recharging the batteries from minimum voltage to charged state within 24 hours. While the batteries are "floating", they are acting as filters against voltage transients.

9.4.3.2 Infrequent Operation

At specific time intervals as specified by the battery manufacturer, an equalizing charge is placed on the battery banks to bring weak cells back to within specific cell voltage limits and to extend battery life.

9.4.3.3 Abnormal and Emergency Operation

Loss of a battery charger causes annunciation of the appropriate alarms locally and in the control room. The associated battery will carry the loads of that bus until the battery charger is again available. If there is a loss of 480 VAC supply, the batteries will carry the loads until AC power is restored. A loss of offsite power will cause a loss of AC until the diesel generators restore emergency AC power in 10-12 seconds.

The worst case scenario for DC power systems occurs when there is a loss of coolant accident (LOCA) coincident with a loss of offsite power. If the diesel generators do not restore emergency AC power (blackout), the batteries will carry the load until emergency AC is restored. The 125 VDC batteries will be loaded heavily during the first minute due to initiation of engineered safeguard equipment. After this initial period, loads will be reduced to steady state conditions. The 125 VDC batteries can meet worst case loads for two hours in the event of a blackout. The 24 VDC batteries can supply its loads for four hours with no output from the battery chargers.

9.4.3.4 Interfaces

The DC power system interfaces with many plant systems. Table 9.4-1 lists the loads supplied by the safety related buses A1, B1, and C1. Other important interfaces are discussed in the paragraphs that follow.

Normal AC Power System (Section 9.1)

The normal AC power system supplies power to the non safety related battery chargers.

Emergency AC Power System (Section 9.2)

The emergency AC power system supplies power to the safety related battery chargers.

120 VAC Power System (Section 9.3)

The 125 VDC power system supplies backup power to the uninterruptible power system through inverters.

9.4.4 BWR Differences

The discussion in this section is typical for BWR/4 facilities. Specific buses and loads will vary from plant to plant. All BWR facilities have a DC power system by one name or another, but those of other BWR plants are somewhat different from the one in this discussion.

9.4.5 Summary

The purpose of the DC power system is to provide highly reliable 125 VDC to safety and non safety related loads and 24 VDC power to the neutron monitoring system. All DC buses are supplied by a battery charger that will carry the normal loads and maintain a charge on the battery. Each bus has a battery that will supply the bus in the event of a loss of power to the charger or a failure of the charger.

Table Of Contents

List Of Figures

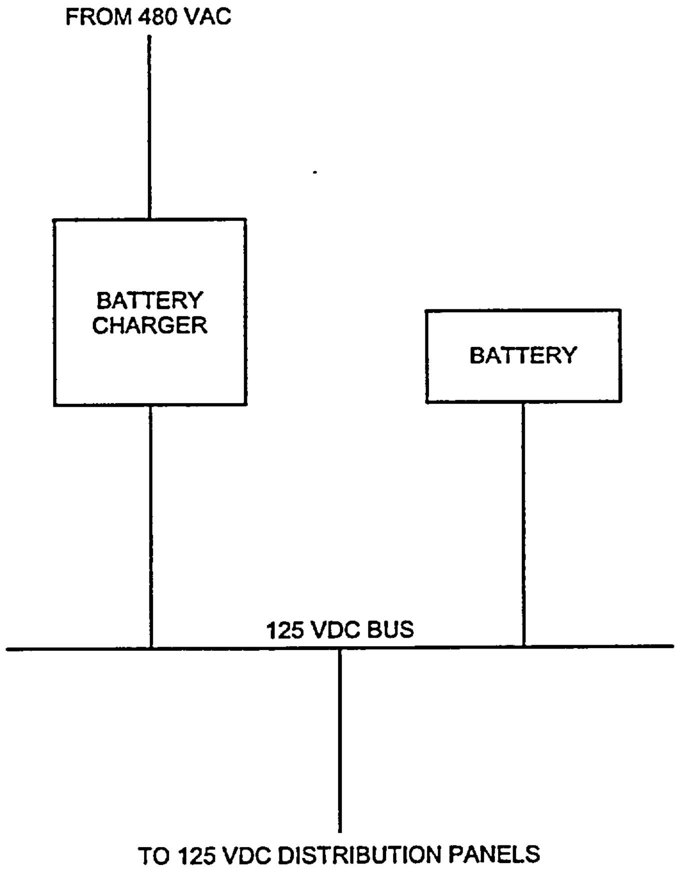


FIGURE 9.4-1 Typical 125 VDC Distribution

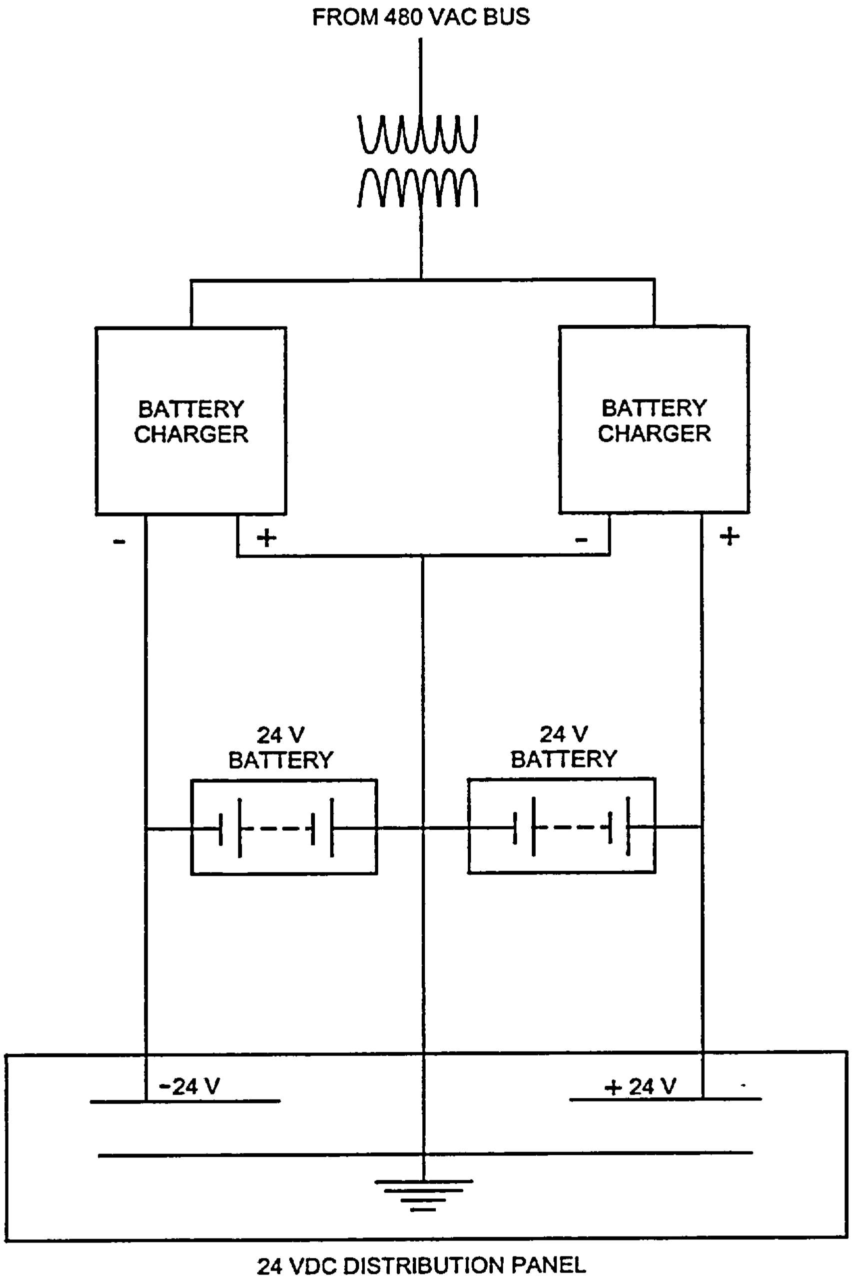


FIGURE 9.4-2 Typical 24 VDC Distribution

10.0 EMERGENCY CORE COOLING SYSTEMS

The purpose of the Emergency Core Cooling Systems (ECCS) is to provide core cooling under loss of coolant accident (LOCA) conditions to limit fuel cladding damage.

The ECCS, shown in Figure 10.0-1, consists of two high pressure systems and two low pressure systems. The high pressure systems are the High Pressure Coolant Injection (HPCI) System and the Automatic Depressurization System (ADS). The low pressure systems are the Low Pressure Coolant Injection (LPCI) mode of the Residual Heat Removal (RHR) System and the Core Spray (CS) System

10.0.1 High Pressure Coolant Injection System (Section 10.1)

The High Pressure Coolant Injection System maintains adequate reactor vessel water inventory for core cooling on small break LOCA's, depressurizes the reactor vessel to allow the low pressure emergency core cooling systems to inject on intermediate break LOCA's, and backs up the function of the Reactor Core Isolation Cooling System (RCIC) (Section 2.7) under reactor vessel isolation conditions.

10.0.2 Automatic Depressurization System (Section 10.2)

The Automatic Depressurization System serves as a backup to the HPCI system to depressurize the reactor vessel so that the low pressure emergency core cooling systems can inject water into the reactor vessel following small or intermediate break LOCA's.

10.0.3 Core Spray System (Section 10.3)

The Core Spray System provides spray cooling to the reactor core to help mitigate the consequences of large break LOCA's when reactor pressure is low enough for the system to inject water into the reactor vessel.

10.0.4 Low Pressure Coolant Injection (Section 10.4)

The low pressure coolant injection (LPCI) mode of the Residual Heat Removal System restores and maintains water level in the reactor vessel following large break LOCA's when reactor pressure is low enough for the system to inject water into the reactor vessel. The RHR System has several other operational modes, some of which are safety related and some of which are not. Each mode is described in Section 10.4.

10.0.5 Commission Requirements

The Code of Federal Regulations requires the ECCS to be designed so that following any LOCA the reactor core remains in a geometrical configuration amenable to immediate and long-term cooling. The basic criteria are to limit fuel cladding temperature and oxidation, in order to minimize clad fragmentation, and to minimize the hydrogen generation from clad oxidation, in order to protect the containment.

10.0.6 ECCS Initiation Signals

Both low reactor water level and high drywell pressure are conditions which indicate that a loss of coolant accident is in progress.

The Level 2 initiation setpoint is set low enough to allow the HPCI System to recover level in the case of small line breaks or loss of reactor feedwater without causing unnecessary initiation of the low pressure emergency core cooling systems. The Level 1 water level initiation setpoint is high enough to allow start up of the low pressure ECCS, Core Spray and Low Pressure Coolant Injection, in sufficient time to reflood the reactor vessel before fuel cladding temperatures reach 2,200°F following a design basis loss of coolant accident.

The high drywell pressure initiation setpoint is high enough to prevent inadvertant initiation due to normal fluctuations in pressure but low enough to ensure earliest practical cooling to the core. High drywell pressure sends initiation signals to all emergency core cooling systems.

10.0.7 Performance Analysis

The manner in which the ECCS operate to protect the core is a function of the rate at which coolant is lost from the break in the nuclear system process barrier. The HPCI is designed to operate while the nuclear system is at high pressure. The Core Spray System and LPCI System are designed for operation at low pressures. If the break in the nuclear system boundary is of such a size that the loss of coolant exceeds the capacity of the HPCI, nuclear system pressure drops at a rate fast enough for the Core Spray and LPCI Systems to commence coolant addition to the reactor vessel in time to cool the core.

Automatic depressurization is provided to automatically reduce nuclear system pressure if a break has occurred and the HPCI System is inoperable. Rapid depressurization of the nuclear system is desirable to permit flow from the Core Spray and LPCI Systems to enter the vessel so that core temperature rise is limited.

If, for a given size break, the HPCI has the capacity to make up for all the coolant loss from the nuclear system, flow from the low pressure portion of the ECCS is not required for core protection until nuclear system pressure has decreased below approximately 150 psig. This pressure is above the value at which the HPCI turbine steam stop valve shuts due to low steam supply pressure (~100 psig).

10.0.8 Integrated ECCS Performance

The performance of the ECCS as an integrated package is evaluated by determining which remain functional following a postulated LOCA (concurrent with loss of offsite power) and a single failure of an active ECCS related component. The remaining ECCS and components must meet the 10 CFR requirements over the entire spectrum of LOCA's. The integrated performance for small, intermediate, and large sized breaks is shown in Figure 10.0-2. Table 10.0-1 gives the sequence of ECCS actions during a design basis LOCA i. e., a double ended circumferential recirculation line break, concurrent with a loss of offsite power.

Time	Events
0 sec	Recirculation System line is assumed to break. Preferred power is assumed to be lost.
0+ sec	Drywell high pressure (~2#) is reached. All diesel generators are signalled to start. The reactor scrams. HPCI,CS,and LPCI are signal-led to start on high drywell pressure.
3 sec	Reactor vessel Level 2 is reached reactor recirc pumps trip.
6-8 sec	Reactor vessel Level 1 is reached. MSIV'S close. ADS timers start.
13 sec	Diesel Generators ready for load. 480 volt emergency boards energized. Start all four LPCI pumps.
14 sec	Fuel completely steam blanketed.
20 sec	Signal both CS pumps to start.
22 sec	RPV reaches 465# and 338#, signal CS and LPCI injection valves to open.
26 sec	Reactor at 310 psig signal recirc discharge valves to close.
30 sec	The core is assumed to be completely uncovered with the reactor vessel depressurized low enough for low pressure ECCS to inject water.
46 sec	One RHR (LPCI) pump injection valve is open. (Worst single failure is failure of the injection valve on the good recirc loop.)
62 sec	Recirc line valves closed.
108 sec	The core is effectively flooded.

Table 10.0-1 Design Basis Accident Eccs Performance

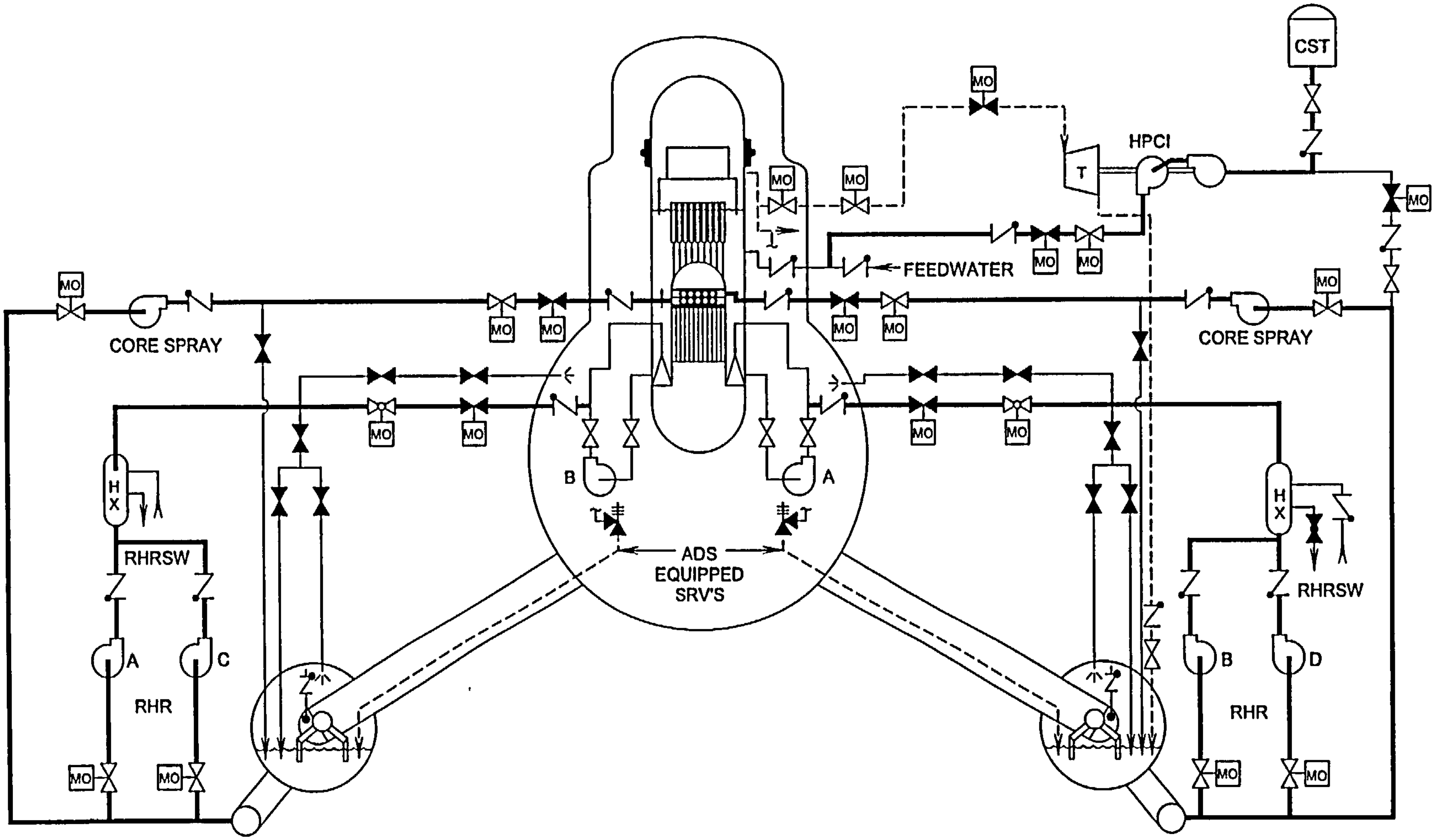


Figure 10.0-1 Emergency Core Cooling System

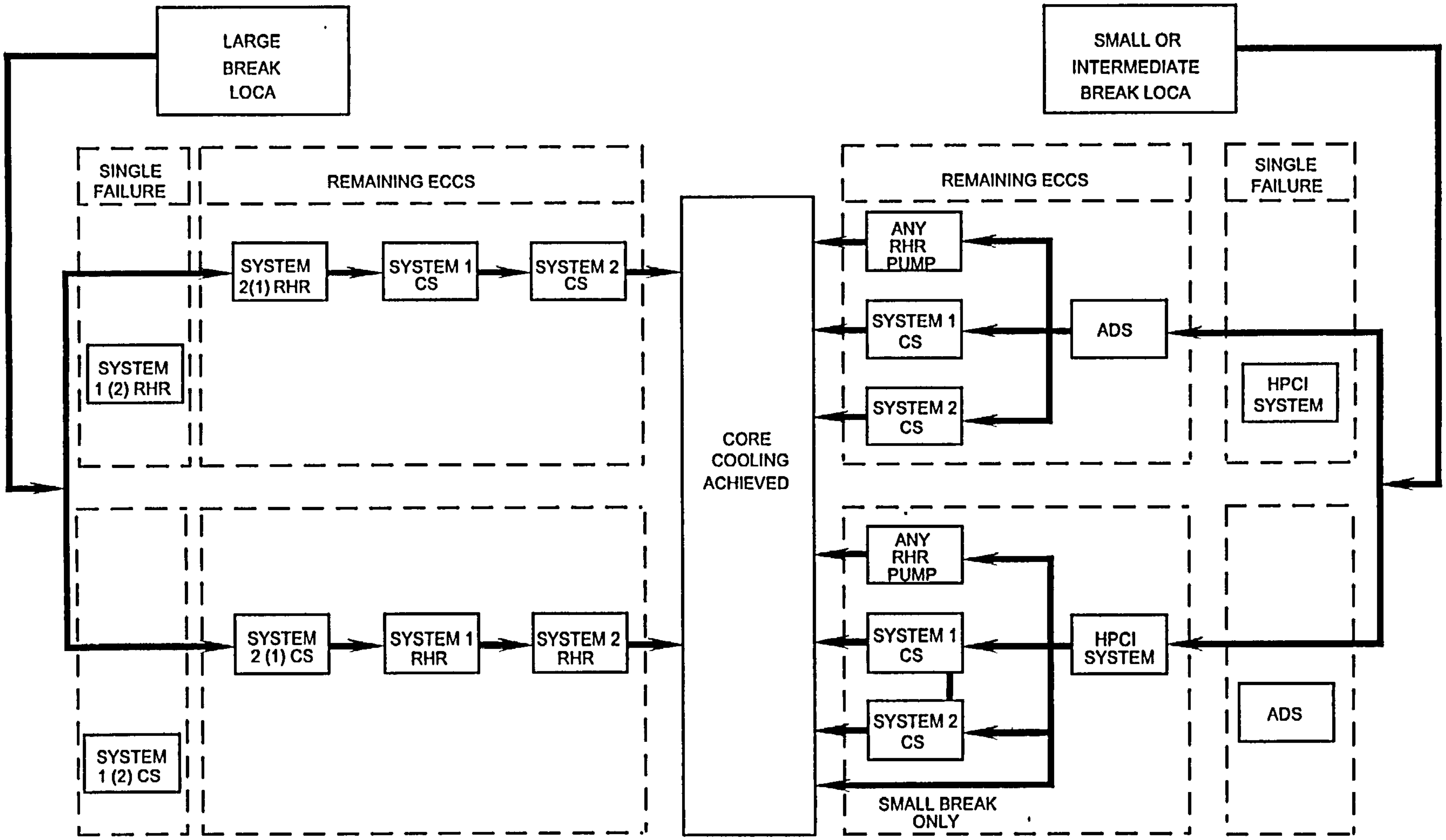


Figure 10.0-2 EECS Integrated Performance

Table of Contents

List of Figures

10.1 HIGH PRESSURE COOLANT INJECTION SYSTEM

The purposes of the High Pressure Coolant Injection (HPCI) System are:

1. To provide makeup water to the reactor vessel for core cooling under small and intermediate sized loss of coolant accidents (LOCAs).
2. To backup the Reactor Core Isolation Cooling System (RCIC, Section 2.7).

The functional classification of the HPCI System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

10.1.1 System Description

The HPCI System, shown in Figure 10.1-1, is an independent emergency core cooling system requiring no auxiliary AC power, plant service and instrument air, or external cooling water systems to perform its purpose. The HPCI System consists of a turbine, turbine driven pumps, and the normal auxiliary systems required for turbine operation.

The HPCI System provides high pressure emergency core cooling for small and intermediate line breaks. It is possible on such breaks that the reactor water level could drop to a level where the core is not adequately cooled, while reactor pressure could remain at or near rated pressure. With reactor pressure high, the low pressure ECCS would not be capable of supplying water to the reactor vessel. The HPCI System can supply makeup water to the reactor from above rated reactor pressure to a reactor pressure below that at which the low pressure ECCS can inject. System initiation can be accomplished by automatic signals or manually by the control room operator. Receipt of either a Level 2 reactor water level or high drywell pressure will automatically start the HPCI System.

10.1.2 Component Description

The components of this system are discussed in the paragraphs which follow, and illustrated on Figure 10.1-1.

10.1.2.1 Steam Supply Isolation Valves

The steam supply line to the HPCI turbine taps off one of the four main steam lines on the reactor side of the inboard main steam isolation valve. The two normally open motor operated valves provide inboard and outboard primary containment isolation upon receipt of an isolation signal, (Section 10.1.3.3).

10.1.2.2 Steam Supply Shutoff Valve

The steam supply shutoff valve is used for normal steam isolation for the HPCI turbine in the standby condition.

The steam supply shutoff valve is normally closed and receives an auto open signal on HPCI automatic initiation.

10.1.2.3 Turbine Stop Valve

Located in the HPCI steam line ahead of the control valves is the HPCI stop valve. The stop valve provides turbine protection by rapidly shutting off steam flow to the turbine, during turbine trip conditions (Section 10.1.3.4).

10.1.2.4 Turbine Control Valves

The HPCI turbine control valves provide the means to vary steam flow to the turbine. By throttling the steam supply to the turbine, turbine speed and therefore pump flow can be controlled.

Positioning of the control valves is accomplished by adjusting the hydraulic operating oil via the flow controller.

10.1.2.5 HPCI Flow Controller

The HPCI System utilizes a flow controller to automatically or manually control system flow upon initiation. Selection of either automatic or manual mode is performed by the control room operator. In the automatic mode (normal position), the controller compares actual HPCI System flow (sensed by a flow element on the discharge of the pump) with the desired flow setpoint (adjusted by the operator at the controller). Any deviation between actual and desired flow is then converted into a hydraulic signal which positions the control valves as required to balance the flow signals. In manual mode the operator has direct control of HPCI System flow. The operator simply adjusts a manual potentiometer, at the flow controller, to create a signal used for positioning the control valves to obtain the desired flow.

10.1.2.6 HPCI Turbine

The HPCI turbine is designed to accelerate rapidly from a cold standby condition to full load conditions within 25 seconds. The HPCI turbine is a two stage, horizontally mounted, radial reentry, noncondensing model. It is designed to operate with a steam supply pressure ranging from 150 psig to 1150 psig. Turbine exhaust is routed to the suppression pool to condense the residual steam.

10.1.2.7 Suction Path

The HPCI pump takes suction from either the condensate storage tank or the suppression pool via motor operated suction valves. Normal suction lineup is from the condensate storage tank, with the suppression pool serving as a backup. Both automatic and manual transfer of the suction path is provided.

10.1.2.8 HPCI Pump Assembly

The HPCI pump assembly is turbine driven and consists of a single stage centrifugal booster pump, a reduction gear, and a multistage centrifugal main pump with a capacity of 4000 gpm. The booster pump takes water from one of the two water sources and discharges the water, at higher pressure, to the suction of the main pump. The main pump further increases the water pressure for injection into the reactor vessel via a feedwater line.

10.1.3. System Features

A short discussion of the system features is given in the paragraphs which follow.

10.1.3.1 HPCI Automatic Initiation

The HPCI System will automatically initiate from either of two initiation signals, high drywell pressure or Level 2 reactor vessel water level.

When the initiation signal is received, several actions occur. The normal discharge path to the reactor is aligned and the test return line isolates. The HPCI auxiliary oil pump starts and supplies oil to the turbine stop valves, control valves and bearings. The steam supply line to the turbine aligns, the steam supply isolation and shutoff valves open.

As the oil pressure increases, the turbine stop valve and control valves begin to open. The stop valve opens fully, while the control valves throttle the steam flow to the turbine to regulate the turbine speed hence pump flow. As the turbine speed continues to increase, pump flow and discharge pressure increase until a flow of 4000 gpm is achieved (flow controller setting).

Once initiated, the HPCI System continues to operate until it is manually secured, a turbine trip signal is actuated, an isolation signal is received. When reactor vessel inventory increases to Level 8 the steam supply shutoff vlave will close to secure the HPCI System. If vessel level subsequently decreases to Level 2 setpoint, the HPCI will automatically reinitiate.

10.1.3.2 Suction Path Transfer

Automatic transfer of suction from the condensate storage tank to the suppression pool occurs when the condensate storage tank level is low or the suppression pool level is high. The automatic transfer of the suction path on low condensate storage tank level ensures a sufficient water source is available to the HPCI pump. Requiring the suction path to transfer on suppression pool high level ensures that a sufficient free air space exists above the water level to allow the accumulation of noncondensible gases, following a LOCA.

10.1.3.3 Automatic Isolation

Because the steam supply line to the HPCI turbine is part of the nuclear system process barrier, automatic isolation signals are employed to isolate the HPCI System upon detection of a leak. Isolating the HPCI System minimizes the release of radioactive material. The HPCI System will automatically isolate from any one of the following: HPCI high steam line flow, HPCI steam line area temperature high, steam supply pressure low, or high pressure between turbine exhaust rupture diaphragms.

Once an isolation signal is generated, the following automatic actions occur:

1. Isolation signal seals in.
2. Inboard and outboard steam supply isolation valves close.
3. HPCI turbine trips.
4. HPCI pump suction from the suppression pool closes, if open.

10.1.3.4 Automatic Turbine Trips

The HPCI turbine is automatically shut down, by closing (tripping) the turbine stop and control valves, to protect the physical integrity of the HPCI System. If any of the following conditions are detected the HPCI System will automatically trip:

1. Turbine exhaust pressure high.
2. Turbine overspeed.
3. Pump suction pressure low.
4. Any isolation signal.
5. High reactor water level.

10.1.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

10.1.4.1 Main Steam System (Section 2.5)

The Main Steam System provides the HPCI System with steam from one of the main steam lines

10.1.4.2 Standby Gas Treatment System (Section 4.3)

The Standby Gas Treatment System removes and processes the noncondensible gases from the HPCI turbine gland seal leakoff condenser.

10.1.4.3 Condensate and Feedwater System (Section 2.6)

The HPCI system uses the feedwater line to inject water into the reactor vessel. The condensate storage tank provides the normal suction path for the HPCI System.

10.1.4.4 Primary Containment

The suppression pool is the alternate source of water for the HPCI pump. It also condenses the HPCI turbine exhaust steam. The HPCI pump minimum flow water is routed to the suppression pool.

10.1.5 Summary

Classification:

Safety related system. Engineered Safety FeatureSystem.

Purpose:

To provide makeup water to the reactor vessel for core cooling under small and intermediate sized loss of coolant accidents. To backup the RCIC system.

Components:

Steam supply isolation valves; steam supply shutoff valve; turbine stop valve; turbine control valves; turbine; suction path; pump assembly; flow controller.

System Interfaces:

Main Steam System; Standby Gas Treatment System; Condensate and Feedwater System; Primary Containment.

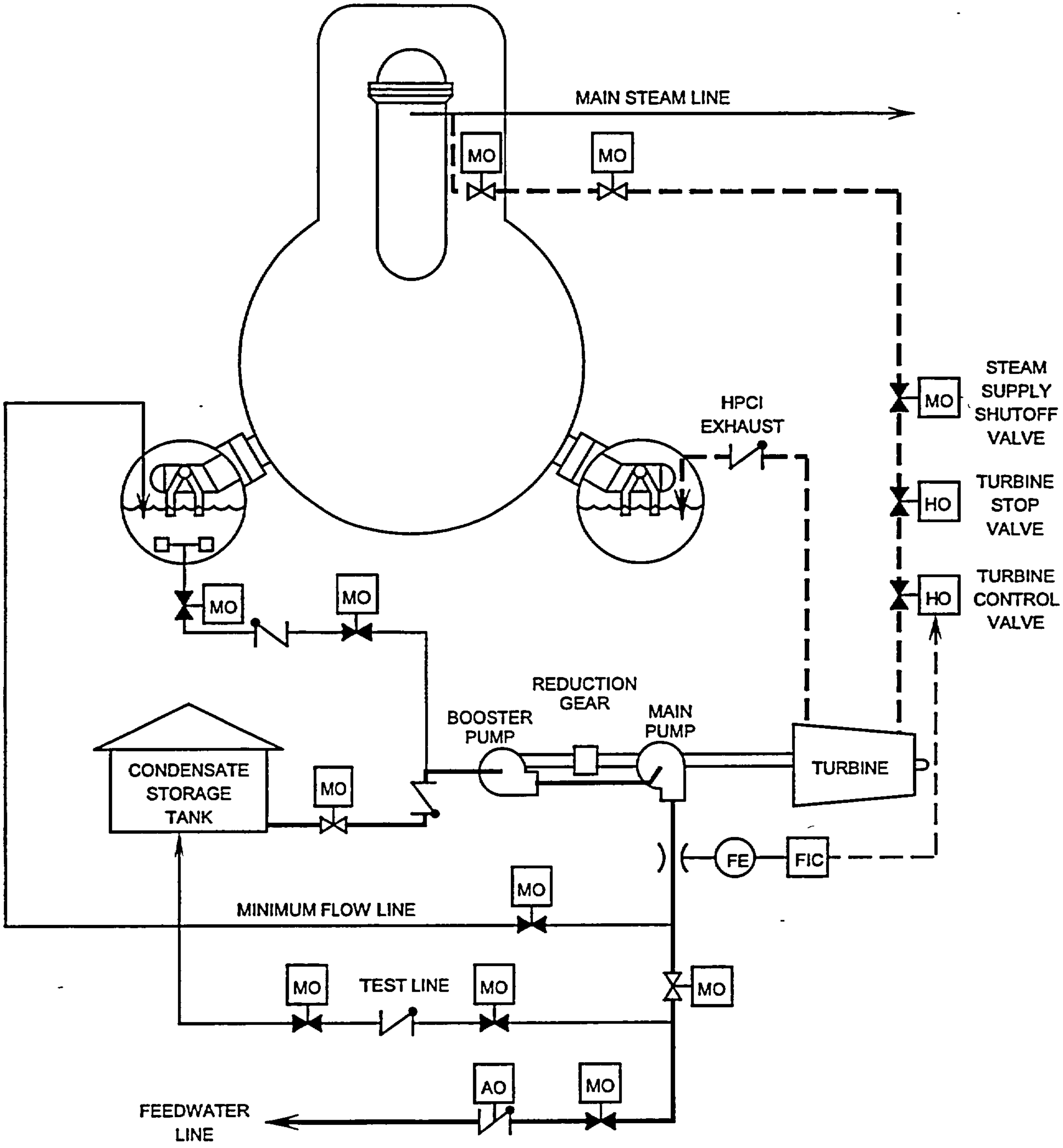


Figure 10.1-1 High Pressure Coolant Injection System

Table of Contents

List of Figures

10.2 AUTOMATIC DEPRESSURIZATION SYSTEM

The purpose of the Automatic Depressurization System (ADS) is to depressurize the reactor vessel so that the low pressure emergency core cooling systems can provide cooling for small and intermediate sized loss of coolant accidents.

The functional classification of the ADS System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

10.2.1 System Description

The Automatic Depressurization System (ADS) consists of redundant signal logics arranged in two separate channels that control power to solenoid operated air pilot valves on each safety/relief assigned the ADS function. For simplicity sake, only the signals necessary for ADS actuation are indicated on Figure 10.2-1. The ability of the ADS to actuate when required is based on signals from reactor vessel water level and the confirmation of a low pressure ECCS pump running.

Seven of the eleven safety/relief valves receive actuation signals from the ADS logic circuits. The safety/relief valves associated with ADS open automatically, if required, to provide reactor vessel depressurization for events involving small or intermediate breaks in the nuclear system process barrier if the High Pressure Coolant Injection System is not available or cannot recover vessel level.

10.2.2 Component Description

The major components of the Automatic Depressurization System are discussed in the paragraphs that follow.

10.2.2.1 Safety/Relief Valves

The ADS uses seven of the existing eleven safety/relief valves mounted on the main steam lines to carry out its function. Operation of the seven safety/relief valves by the ADS logic is discussed in Main Steam System (Section 2.5.2.1).

10.2.2.2 Pneumatic Supply

Each of the safety/relief valves provided for automatic depressurization is equipped with an accumulator and check valve. The check valve is used to isolate the accumulator from the pneumatic supply upon loss of that supply. The accumulators assure that the ADS valves can be opened and held open following failure of the pneumatic supply to the ADS valves.

10.2.3 System Features

A short discussion of the system features is given in the paragraphs which follow.

10.2.3.1 Automatic Initiation (Figure 10.2-1)

Automatic actuation of the ADS is initiated upon completion of a 105 second time delay concurrent with low reactor vessel water level, and any low pressure ECCS pump running.

The reactor vessel water level signals, Level 3 and Level 1, indicate that the fuel is in danger of becoming overheated. The Level 3 level signal is only a confirmatory signal to prevent any spurious system actuation. The Level 1 level signal would not normally occur unless the HPCI System (HPCI, Section10.1) has failed.

The low pressure ECCS pump running signal is provided to ensure that there is reactor vessel inventory makeup available prior to initiating the 105 second time delay.

The 105 second time delay allows the HPCI system and RCIC system time to restore reactor vessel water level. If during the 105 second period, reactor water level signals clear or the low pressure ECCS pumps are not running the 105 second timer will reset. The control room operator may also reset the 105 second timer, anytime after initiation, when in his judgement, the ADS is not needed.

10.2.3.2 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

10.2.3.2.1 Main Steam System (Section 2.5)

The ADS uses seven of the safety/relief valves, which are part of the main steam system, to carry out its function.

10.2.3.2.2 Emergency Core Cooling System (Section 10.0)

The low pressure emergency core cooling pumps provide permissive signals to the ADS logic.

10.2.3.2.3 Primary Containment (Section 4.1)

The safety/relief valves use the suppression pool as a heat sink.

10.2.4 Summary

Classification:

Safety related system; Engineered safety feature system.

Purpose:

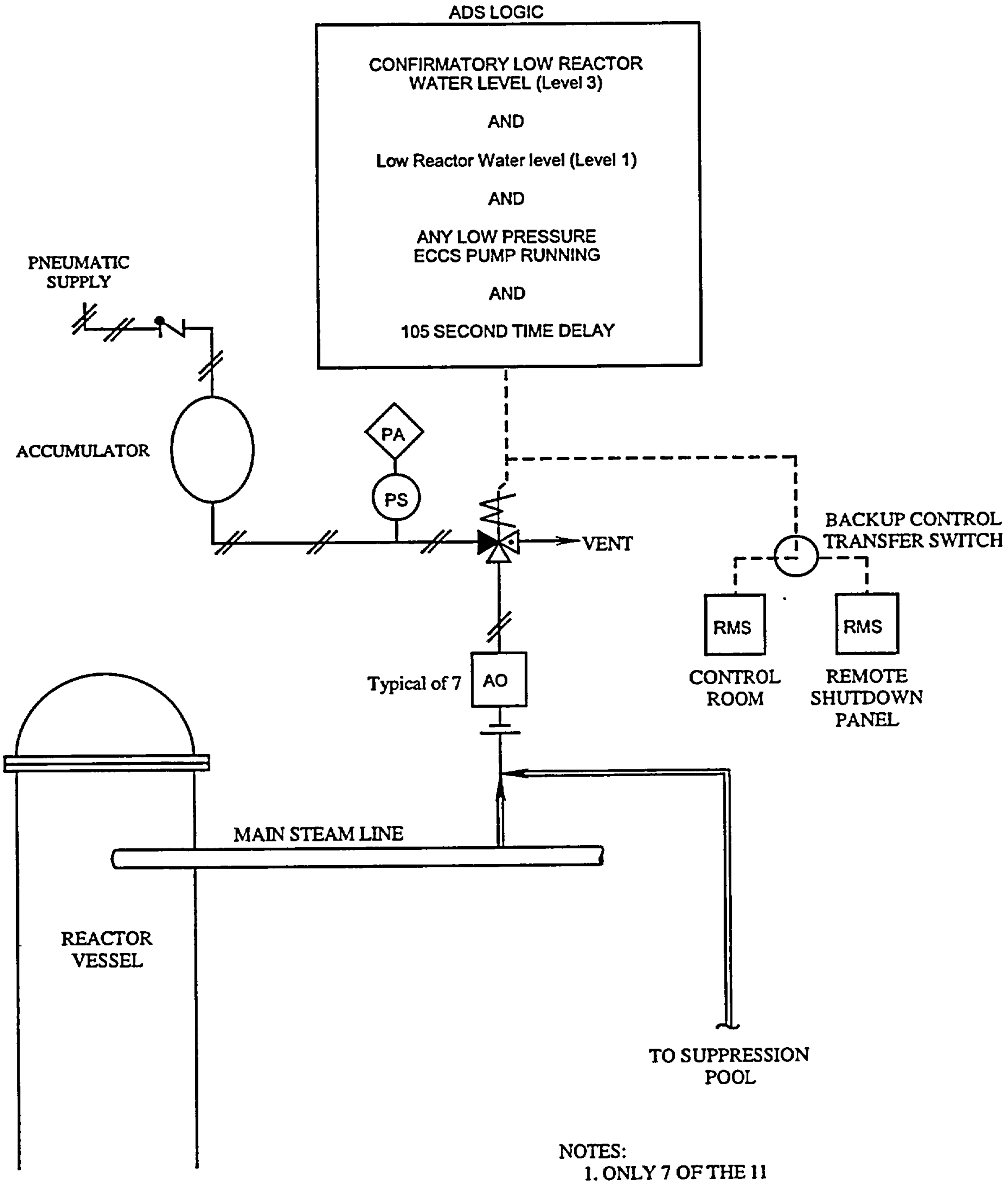
To allow the low pressure emergency core cooling system to provide core cooling for small and intermediate sized loss of coolant accidents.

Components:

Safety/relief valves, logic

System Interfaces:

Main Steam System; ECCS; Vessel instrumentation.



NOTES:
1. ONLY 7 OF THE 11 SRV'S ARE EQUIPPED WITH THE ADS LOGIC.
2. THESE ARE THE SAME SRV'S DISCUSSED WITH THE MAIN STEAM SYSTEM (2.5).

Figure 10.2-1 Automatic Depressurization System

Table of Contents

List of Figures

10.3 CORE SPRAY SYSTEM

The purpose of the Core Spray System is to provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident (LOCA) conditions.

The functional classification of the Core Spray System is that of a safety related system. Its regulatory classification is an engineered safety feature system.

10.3.1 System Description

The Core Spray System (Figure 10.3-1) consists of two separate and independent pumping loops. Each loop contains the following components one 100% capacity low pressure pump, minimum flow line, test line, a spray sparger, and the associated motor operated valves and instrumentation necessary to perform its purpose.

The Core Spray System pumps water from the suppression pool into the reactor vessel and through spray nozzles mounted on spargers located directly above the fuel assemblies. Core cooling is accomplished by spraying water on top of the fuel assemblies. The water runs down the sides of fuel channels thus providing a heat sink for heat radiated from the fuel rods. The heat removed by water evaporation within the fuel assemblies also provides some convection cooling.

The Core Spray System will automatically initiate upon receipt of either a Reactor Level 1 reactor vessel water level, or a high drywell pressure concurrent with a reactor low pressure signal.

10.3.2 Component Description

The major components of the Core Spray System are discussed in the paragraphs which follow.

10.3.2.1 Suction Path

Water supply for the Core Spray System is provided by the suppression pool via a normally open motor operated suction valve.

When the reactor is shutdown, the core spray pump suction path can be manually transferred from the suppression pool to the condensate storage tank. With clean water from the condensate storage tank, a test can be conducted in which water can be sprayed on top of the core. This testing verifies the integrity of the spray pattern and removes any high level radioactive corrosion products from the spray spargers.

10.3.2.2 Core Spray Pumps

There are a total of two core spray pumps in the Core Spray System, one for each core spray loop. Each pump has a 100% flow capacity and is powered by an independent power source. Each core spray pump is a single stage centrifugal pump designed to deliver 4725 gpm with a discharge pressure of 274 psig.

10.3.2.3 Motor Operated Valves

Each motor operated valve in the Core Spray System is powered from the same electrical divisional power that supplies power to the pumps system (i.e.: System I from division I, System II from division II). All motor operated valves in Systems I and II can be operated from the control room. The valves function to permit the various operations of the Core Spray System.

10.3.2.4 Testable Check Valve

Pneumatically operated check valves are provided in each core spray injection line. The check valves prevent back-flow from the reactor vessel to the core spray low pressure piping when the injection valves are open. The check valves are located inside the drywell and are not accessible during plant operation. The pneumatic operators are provided to allow testing of the check valve which ensures freedom of movement for the valve disc. The pneumatic operators are not capable of closing the check valves and do not interfere with their operation.

10.3.2.5 Core Spray Sparger

For information on the core spray sparger refer to the Reactor Vessel System, Section 2.1.

10.3.2.6 Line Fill

The purpose of the line fill line is to maintain the core spray system full of water from the pump discharge check valves to the last normally closed valve in the injection path. With the system being maintained full of water, the probability of water hammer on system initiation is greatly reduced. The condensate transfer system provides the Core Spray System with keep full water at approximately 50 psig.

10.3.3 System Features

A short discussion of system features is given in the paragraphs which follow.

10.3.3.1 Normal Operation

During normal plant operation, the Core Spray System is in a standby status as indicated on Figure 10.3-1, ready for automatic initiation when required.

10.3.3.2 System Testing

During plant operation, periodic testing of the core spray pumps and valves is required to ensure the system will perform as designed. Surveillance testing of the core spray pumps is accomplished by recirculating the suppression pool water, via the test return line, to ensure required flow rates are obtainable. Surveillance testing of the motor operated valves is accomplished by cycling the valves and timing the stroke time, when required.

10.3.3.3 Automatic Initiation

The Core Spray System will automatically align valves and start pumps upon receiving either of the two initiation signals, Reactor Level 1 reactor vessel water level or high drywell pressure coincident with low reactor pressure.

The Core Spray System responds to an initiation signal as follows:

1. The test line motor operated valves are closed and interlocked closed.

2. If normal auxiliary power is available (Section 9.1), the core spray pumps will start at a specified sequence to prevent overloading the normal auxiliary power system.

3. If normal auxiliary power is not available, the core spray pumps will start seven seconds after standby auxiliary power becomes available (Section 9.2).

4. When reactor vessel pressure decreases to a value of 465 psig, the injection valves receive a permissive to open signal.

5. When adequate pump discharge flow is acquired, the minimum flow valve will shut directing full loop flow into the reactor vessel.

10.3.3.4 Manual Override Features

With the system in operation following an automatic initiation, the operator, using his own judgement, can override some of the automatic functions by turning the pump control switch to the off position or by closing the injection valve. Either of these actions produces the appropriate indication and alarms to inform the operator of his actions. Once the system is shut down, closing the injection valve or stopping the pump(s), the system will not automatically restart unless the initiation logic is manually reset.

10.3.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

10.3.4.1 Primary Containment System (Section 4.1)

The suppression pool, which is part of the Primary Containment System, is the normal suction for the Core Spray System. Additionally the core spray minimum flow line and a full flow test line are connected to the suppression pool.

10.3.4.2 Reactor Vessel System (Section 2.1)

The Core Spray System injection piping penetrates the reactor vessel and core shroud. The core spray spargers are mounted inside the core shroud.

10.3.4.3 Standby Auxiliary Power System (Section 9.2)

The Core Spray System receives reliable electrical power for system operation from the Standby Auxiliary Power System.

10.3.5 Summary

Classification:

Safety related system; Engineered safety feature system.

Purpose:

To provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident (LOCA) conditions.

Components:

Suction path; core spray pumps; motor operated valves; testable check valves; keep full line.

System Interfaces:

Primary Containment System; Reactor Vessel System; Standby Auxiliary Power System.

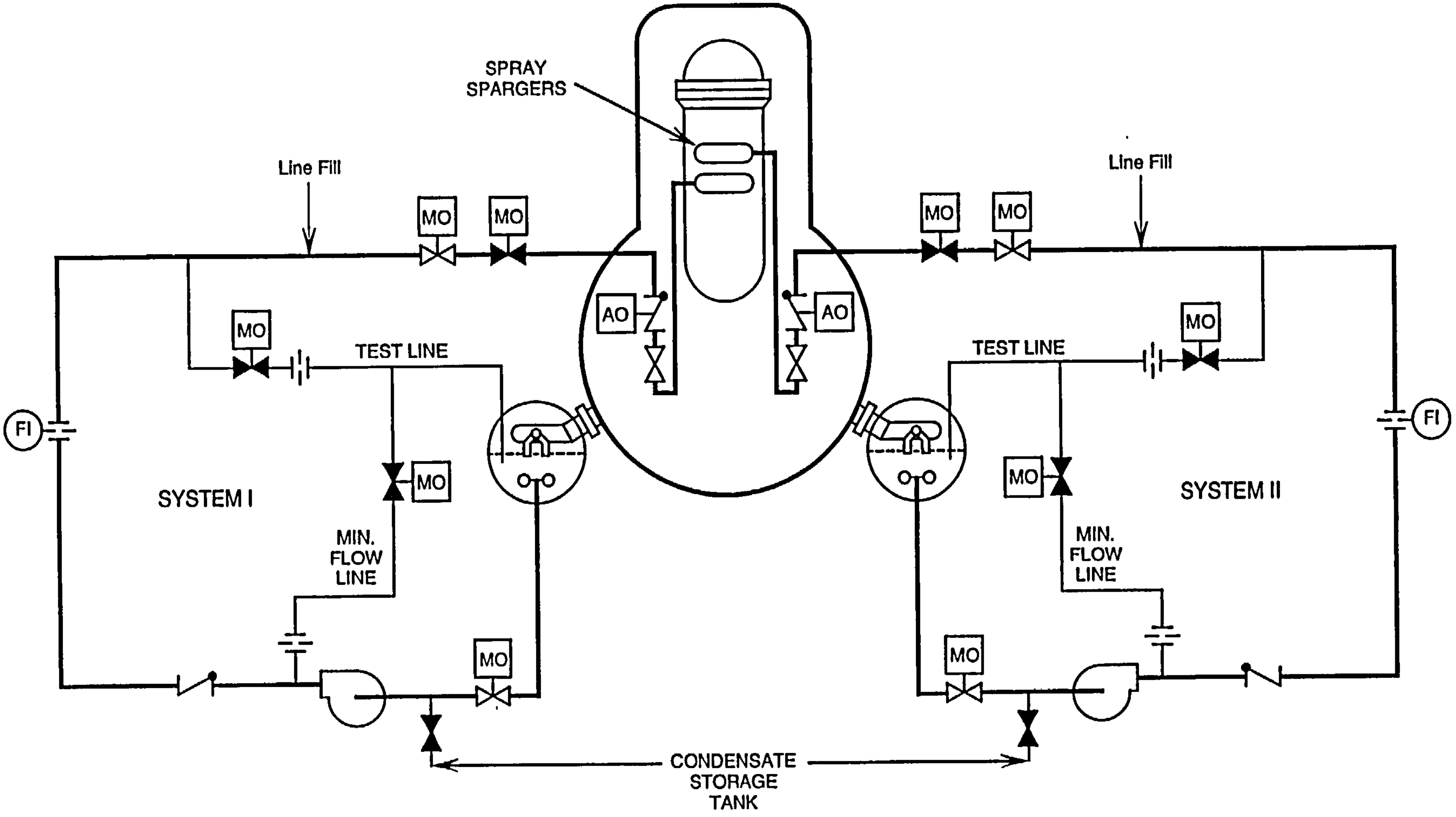


Figure 10.3-1 Core Spray System

Table of Contents

List of Figures

shutdown and cooldown. When reactor temperature/pressure has decreased to a sufficiently low value, the RHR System is placed in the shutdown cooling and head spray mode of operation. This mode is capable of completing the cooldown and maintaining reactor water temperature below 125°F to accommodate refueling operation. Water is removed from "A" recirculation loop suction piping, cooled by the RHR heat exchanger, and then discharged back to one of the recirculation loop discharge lines.

The standby coolant supply mode provides an unlimited supply of water for flooding the primary containment if required for post loss of coolant accident recovery operations. Containment flooding is accomplished by connecting the Reactor Building Service Water System (Section 11.1) to the RHR system. Water is pumped into the reactor vessel which eventually spills out the break and fills the entire containment to a level above the reactor core.

10.4.2 Component Description

The major components of the RHR System are discussed in the paragraphs that follow.

10.4.2.1 Suction Path

The suction path alignment for the RHR pumps is dictated by the operational mode. For all operational modes of the system, except shutdown cooling and head spray mode, the RHR pumps are aligned to take suction from the suppression pool. The shutdown cooling and head spray mode suction path is from the "A" recirculation loop suction line. To preclude the possibility of draining the reactor vessel to the suppression pool, the motor operated shutdown cooling and suppression pool suction valves are interlocked to prevent both valves from being open at the same time.

10.4.2.2 RHR Pumps

The RHR pumps are vertically mounted, motor driven, single stage centrifugal pumps with a design flow rate of 10,000 gpm against an indicated system pressure of 136 psig. The pumps are sized on the basis of the flow required during the LPCI mode of operation. Each pump is designed to pump water varying in temperature from 40°F to approximately 360°F.

Power to the pump motors is supplied from the 4160v Standby Auxiliary Power System (Section 9.2). The A and C pumps are supplied from the division 1 switchgear and the B and D pumps from division 2 switchgear.

10.4.2.3 RHR Heat Exchangers

Two heat exchangers, one for each loop, are provided to remove heat from the suppression pool water or the reactor water depending on the system operating mode. Reactor Building Service Water System(Section 11.1) passes through the tubes removing heat from the shell side (RHR) water. Regardless of the system operating mode, each RHR pump flow must pass through its associated heat exchanger.

10.4.2.4 Motor Operated Valves

Each motor operated valve in the RHR System is powered from the same electrical divisional that supplies power to pumps in that loop (i.e.: System 1 from division 1, System 2 from division 2). All motor operated valves in Systems 1 and 2 can be operated from the control room. The valves function to permit the various operations of the RHR System, automatically as in the LPCI mode and remote manually for all other modes.

10.4.2.5 Testable Check Valves

Pneumatic operated check valves are provided in each LPCI mode injection line. The check valves prevent back flow from the reactor vessel to the RHR low pressure piping when the injection valves are open. The check valves are located inside the drywell and are not accessible during plant operation. The pneumatic operators are provided to allow testing of the check valve which ensures freedom of movement for the valve disc. The pneumatic operators are not capable of closing the check valves and do not interfere with their operation.

10.4.2.6 Containment Spray Spargers

The containment spray spargers consists of 4 separate and independent pieces of pipe, with nozzles, routed around the inside of the containment. Each RHR loop supplies one sparger in the upper portion of the drywell and one in the suppression chamber. Placement of the spray nozzles ensures a good spray pattern to cool the associated atmosphere.

10.4.2.7 Line Fill

The purpose of the line fill line is to maintain the RHR System full of water, from the pump discharge check valves to the last normally closed valve in the injection path. With the system being maintained full of water, the probability of water hammer on system initiation is greatly reduced. The condensate transfer system provides the RHR System with keep full water at approximately 50 psig.

10.4.3 System Features

A short discussion of system features is given in the paragraphs which follow.

10.4.3.1 Normal Operation

During normal plant operation, the RHR System is in a standby status as indicated on Figure 10.4-1, ready for automatic initiation of the LPCI mode when required.

10.4.3.2 Infrequent Operation

Infrequent operation of the RHR System consists of the following:

1. Suppression pool cooling.
2. System testing.
3. Shutdown cooling and head spray mode.
4. Fuel pool cooling mode.

10.4.3.2.1 Suppression Pool Cooling

Suppression pool cooling is required to maintain the suppression pool water temperature within established limits. Cooling is usually required after RCIC or HPCI turbine operation, steam line safety/relief valve testing, or high surrounding environment temperatures during the summer. To accomplish suppression pool cooling, Reactor Building Service Water System flow is established through the designated heat exchanger to be used. Then, the suppression pool cooling/spray shutoff valve is opened. The RHR pumps are started and flow is maintained by throttling the suppression pool cooling/ test line isolation valve.

The flow path is from the suppression pool through the RHR pump(s), RHR heat exchanger(s), the full flow test line, and back to the suppression pool.

10.4.3.2.2 System Testing

During plant operation, periodic testing of the RHR pumps and valves is required to ensure the system will perform as designed. Surveillance testing of the RHR pumps is accomplished by recirculating the suppression pool water, via the test return line, to insure required flow rates are obtainable.

Surveillance testing of the RHR motor operated valves is accomplished by cycling the valve and timing the stroke time, when required.

10.4.3.2.3 Shutdown Cooling and Head Spray Mode

The shutdown cooling and head spray mode of the RHR System is used to complete the cooldown process of the nuclear system after reactor pressure has decreased to within the capability of the RHR System. One of the RHR Systems, System I or System II, may be taken out of their LPCI standby lineup when reactor pressure has been reduced to less than 125 psig. System II is preferred for use in the shutdown lineup because of its connection to the head spray line.

Prior to operating in the shutdown cooling and head spray mode, the system piping is flushed with reactor quality water to replace the high conductivity suppression pool water. To commence shutdown cooling, Reactor Building Service Water System flow is established through the RHR heat exchangers as required to control the cooldown rate. The flow path for shutdown cooling is from the suction of "A" Recirculation Loop, through the RHR pump(s), RHR heat exchangers, the LPCI mode injection valves, and into the discharge of "A" Recirculation Loop.

The head spray line is used to divert approximately 500 gpm flow into the reactor vessel head region. The spray helps to promote a more uniform cooling of the reactor vessel head and vessel mounting flange.

10.4.3.2.4 Fuel Pool Cooling Mode

One of the most infrequent operations of the RHR System is fuel pool cooling. If large quantities of irradiated fuel are to be removed from the core, the decay heat load on the Fuel Pool Cooling and Cleanup System (FPCC, Section 11.5) could be above its capacity. RHR System II may be aligned to supplement the FPCC System by closing the normal suppression pool suction valves and opening the FPCC suction valves.

The flow path for this mode is from the spent fuel pool through the RHR pumps, RHR heat exchangers, and RHR piping into the FPCC System return lines to the spent fuel pool. This flow path must be manually aligned from outside the control room.

10.4.3.3 Emergency Operation

Emergency operation of the RHR System consists of operation in the low pressure coolant injection (LPCI) mode, containment spray lineup, or the standby coolant supply mode.

10.4.3.3.1 Low Pressure Coolant Injection Mode (Figure 10.4-1)

The low pressure coolant injection (LPCI) mode of the RHR System comprises one of the ECCS. LPCI automatically initiates from the standby condition upon receipt of either a reactor vessel Level 1 water level or a high drywell pressure coincident with low reactor pressure. The Level 1 reactor water level indicates that the fuel is in danger of being overheated due to an insufficient coolant inventory. High drywell pressure coincident with low reactor pressure is indicative of a break in the nuclear system process barrier inside the drywell. Once an initiation signal is received by the LPCI control logic, the signal is sealed in until manually reset.

LPCI initiation causes several actions to occur simultaneously. All motor operated valves on the discharge side of the pumps will align to the LPCI mode. The motor operated suction valves used for shutdown cooling close, if open. If the suction valves from the suppression pool to their respective pumps are open, the RHR pumps will start. The LPCI injection valves open when reactor pressure is less than 338 psig.

10.4.3.3.2 Containment Spray

The containment spray lineup must be manually aligned by the control room operator. To divert a portion of the LPCI mode flow into the containment spray line, drywell pressure must be high and reactor vessel water level greater than (2/3) core height. Requiring the two permissive signals ensures the need for containment spray and an adequate water level in the reactor vessel.

10.4.3.3.3 Standby Coolant Supply Mode

Following a LOCA it may be necessary to flood the entire containment to a level above the top of the active fuel to facilitate removal of fuel from the reactor. Should this become necessary the Reactor Building Service Water System can be connected to the RHR System by opening normally locked closed, hand operated valves.

The flow path for containment flooding is from the Reactor Building Service Water System into the outlet piping of the RHR heat exchangers. RHR System flow can then be diverted to the suppression pool, reactor vessel, or the drywell spray header.

10.4.3. Manual Override Features

With the system in operation following an automatic initiation, the operator, using his own judgment, can override some of the automatic functions by turning the pump control switch to the off position or by closing the injection valve. Either of these actions produces the appropriate indication and alarms to inform the operator of his actions. Once the system is shutdown, closing the injection valve or stopping the pump(s), the system will not automatically restart unless the initiation logic is manually reset.

10.4.4 System Interfaces

A short discussion of interfaces this system has with other plant systems is given in the paragraphs which follow.

10.4.4.1 Recirculation System (Section 2.4)

The shutdown cooling and head spray mode suction is from the suction of "A" recirculation loop. LPCI injection is into the discharge of both recirculation loops. Upon a LPCI initiation signal the recirculation pump discharge valves receive a permissive to close signal.

10.4.4.2 Reactor Vessel System (Section 2.1)

The head spray portion of the RHR System discharges into the reactor vessel head.

10.4.4.3 Primary Containment System (Section 4.1)

The RHR System may take its suction from the suppression pool. Flow may also be returned to the suppression pool from the pump minimum flow lines, suppression chamber spray line or the test return lines. Redundant drywell spray spargers are supplied from the RHR System.

10.4.4.4 Reactor Building Service Water System (Section 11.4)

The Reactor Building Service Water System provides cooling water to the RHR heat exchangers and water for thestandby coolant supply mode.

10.4.4.5 Fuel Pool Cooling and Cleanup System (Section 11.5)

System II of the RHR System may be used to assist in fuel pool cooling.

10.4.4.6 Standby Auxiliary Power System (Section 9.2)

The Standby Auxiliary Power System provides a reliable power source for RHR System operation.

10.4.5 Summary

Classification:

Safety related system; Engineered Safety feature system.

Purpose:

Low Pressure Coolant Injection Mode:
To provide low pressure makeup water to the reactor vessel for core cooling under loss of coolant accident conditions.

Containment Spray and Cooling Mode:

1. To reduce primary containment pressure following a loss of coolant accident.

2. To remove heat from the suppression pool.

Shutdown Cooling and Head Spray Mode:

1. To remove decay heat from the reactor core following a reactor shutdown.

2. To remove residual heat from upper reactor vessel internals during a cooldown.

Standby Coolant Supply Mode:
To provide a means of flooding the primary containment.

Fuel Pool Cooling Mode:
To provide additional heat removal capability for spent fuel in the event the FPCC System is inadequate or unavailable.

Components:

Suction path; pumps; heat exchangers; motor operated valves; testable check valves; containment spray spargers.

System Interfaces:

Recirculation System; Reactor Vessel System; Primary Containment System; Reactor Building Service Water System; Fuel Pool Cooling and Cleanup System; Standby Auxiliary Power System.

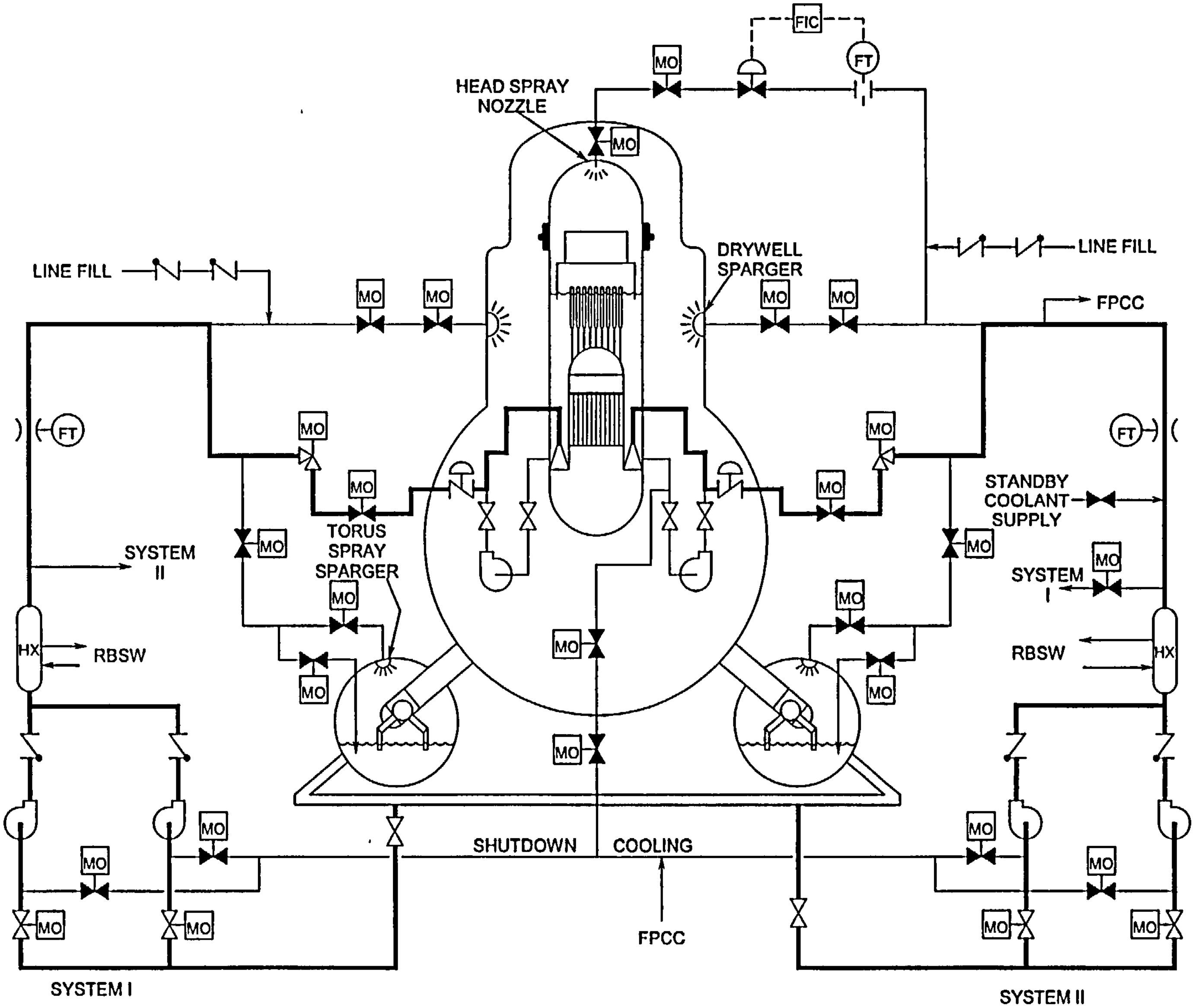


Figure 10.4-1 Residual Heat Removal System