11.0 WATER AND AIR SYSTEMS

The water systems necessary for plant operational support are discussed in this chapter. The water systems provide water supplies required by plant processes, auxiliary cooling functions necessary to support plant equipment, and cooling functions to remove decay heat for forced cooldown of the reactor. The cooling water provided may be from a variety of sources such as lakes, rivers, oceans, cooling towers, or cooling ponds.

11.0.1 Circulating Water System (Section 11.1)

The Circulating Water System (CWS) supplies cooling water to turbine condensers to reject heat from the steam cycle. The system also provides for dilution and dispersion of radioactive wastes released from the station.

11.0.2 Reactor Building Service Water System (Section 11.2)

The Reactor Building Service Water System (RBSW) transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool.

11.0.3 Reactor Building Closed Loop Cooling Water System (Section 11.3)

The Reactor Building Closed Loop Cooling Water (RBCLCW) System cools selected auxiliary equipment over the full range of plant operations. The RBCLCW System provides a closed cooling water loop between systems which are potentially radioactive and the service water system. This provides an additional barrier between the possibly contaminated systems and the service water discharged to the environment.

11.0.4 Turbine Building Service Water System. (Section 11.4)

The Turbine Building Service Water System (TBSW) supplies cooling water to non-safety related components located in the turbine building and rejects the heat to the Long Island Sound.

11.0.5 Turbine Building Closed Loop Cooling Water System (Section 11.5)

The Turbine Building Closed Loop Cooling Water System (TBCLCW) cools selected auxiliary balance of plant equipment located in the turbine building and transfers that heat load to the Turbine Building Service Water System.

11.0.6 Service and Instrument Air System (Section 11.6)

The Service and Instrument Air System provides a continuous supply of compressed air of suitable quality and pressure for instruments, controls, and station use. The system also supplies air to the safety/relief valves and primary containment vacuum relief valves.

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11.1 CIRCULATING WATER SYSTEM

The purpose of the circulating water system is to provide cooling water for the station main condensers. Four circulating water pumps draw water from Long Island Sound and discharge the water to the main condensers where the water removes the heat from the main turbine exhaust steam. The heated circulating water then passes to the discharge tunnel where it is returned to Long Island Sound. The system is controlled from the main control room.

11.1.1 System Description

Four pumps mounted in the intake structure take suction from separate screenwell bays through individual traveling water screens. Each pump discharges into a 78 in. concrete-encased steel pipe. The inlet lines are connected to the water boxes through expansion joints. Each line is monitored just prior to the expansion joint by a temperature element which provides a computer point. In addition to the inlet temperature indication, the circulating water pressure at each condenser water box is monitored by a pressure transmitter which provides a computer point and indication of pressure in the main control room.

The condenser outlet water boxes, each monitored by a pressure transmitter, which provides a computer point, connected to the discharge tunnel through 78 in. lines. The lines then descend under the turbine building floor where they penetrate the turbine building wall and enter the discharge tunnel.

The circulating water discharge tunnel is a 10 ft-6 in. high by 12 ft wide concrete structure which runs underground along the south wall of the turbine building. The rectangular discharge tunnel transforms into a fiberglass pipe which returns the circulating water to Long Island Sound.

11.1.2 Component Description

Only the major Circulating Water System components are discussed in the paragraphs which follow.

11.1.2.1 Circulating Water Pump/Motor

The circulating water pumps are vertical, one-stage, single-suction, open-impeller units. Each pump is designed for total head of 34.2 ft at 143,400 gpm. Each pump is driven by a vertical, squirrel cage, induction motor. Each motor is rated for 1,500 hp and rotates at 295 rpm. Each motor requires 3 phase, 60 Hz, 4,160 v power.

11.1.3 Normal Operations

During plant power generation at any power level, the normal operating mode of the circulating water system is four circulating water pumps in operation supplying all four quadrants of the main condenser unit. The vacuum priming system removes any air in the condenser water boxes, piping, or discharge tunnel.

11.1.4 System Interfaces

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

11.1.4.1 4160V Normal Distribution System (Section 9.1)

The electrical distribution system provides all the electrical power requirements for the Circulating Water System.

11.1.4.2 Service Water System (Section 11.1)

The Service Water System is physically connected to the Circulating Water System, for normal return to the Long Island Sound.

11.1.4.3 Liquid Radwaste System (Section 8.2)

The Liquid Radwaste System is physically connected to the Circulating Water System, this can be a means of discharging liquid radwaste to the Sound.

11.1.4.4 Service and Instrument Air System (Section 11.8)

The Service and Instrument Air System provides air for pneumatically operated valves.

11.1.4.5 Chemical Feed and Sampling System (No section in manual)

The Circulating Water System receives chemicals from the Chemical Feed System for the purpose of removing algae and preventing tube fouling in the main condensers.

11.1.5 BWR Differences

The design of the system described in this section is specific to one plant. The function of the Circulating Water System is performed by similar systems at all facilities. However the arrangement of pumps, heat loads, and water sources varies from plant to plant.

11.1.6 Summary

Classification: Power Generation System

Purpose: The purpose of the circulating wate system is to provide cooling water for the station main condensers

Components: Pumps, Motors, Vacuum Priming Unit

System Interfaces: Electrical Distribution, Service and Instrument Air System, Service Water System, Process Sampling System, Plant Chemical Feed System, Liquid Radwaste System.

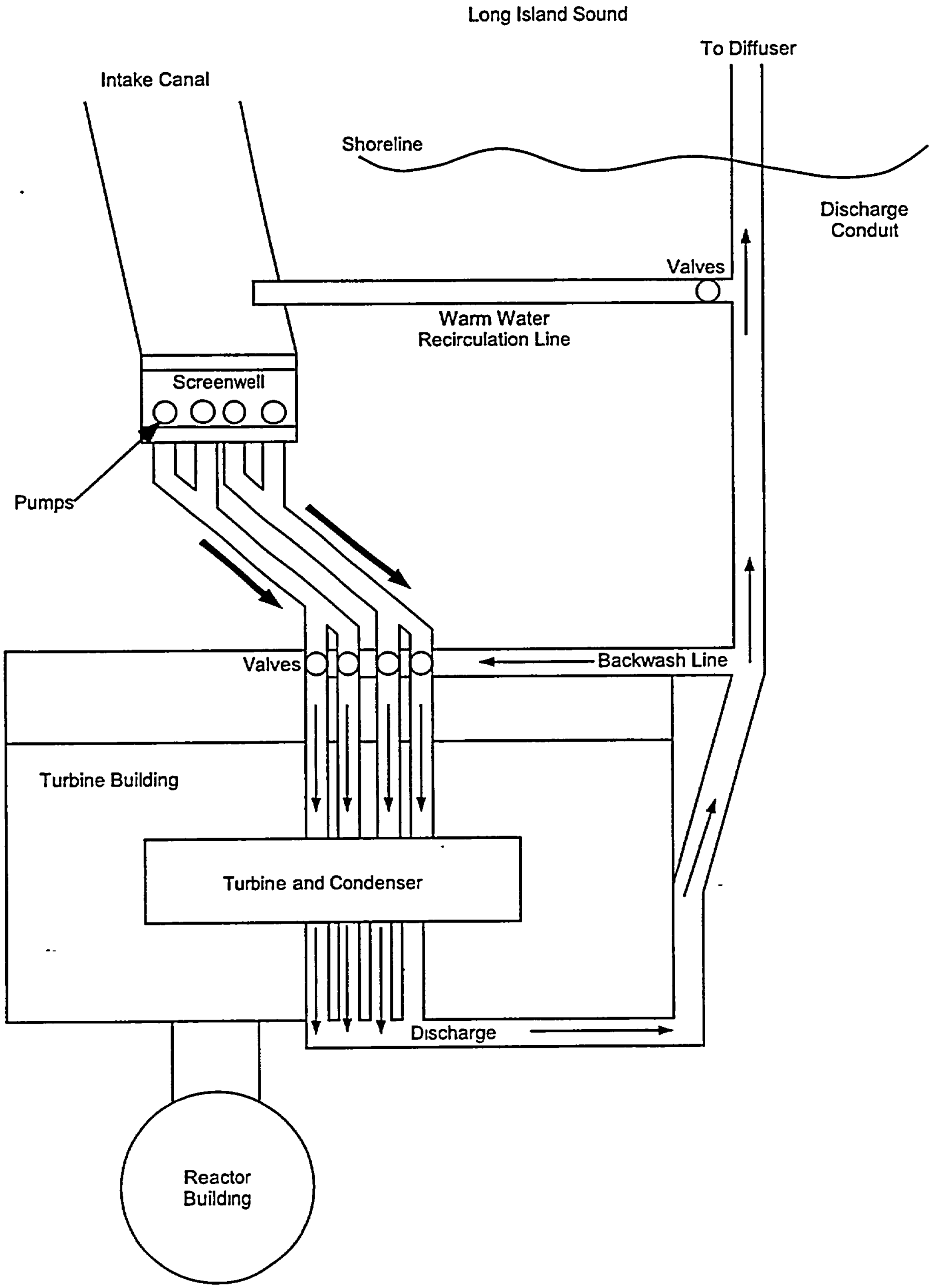

Figure 11.1-1 Circulation Water System

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11.2 Reactor Building Service Water

The purpose of the Reactor Building Service Water System (RBSW) is to transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool.

11.2.1 System Description

The Reactor Building Service Water System (RBSW) is divided into two loops which supply safety related components. Loads on the two loops are redundant to ensure that at least one set of the nuclear safety related components is supplied in the event of a single service water component failure.

Four service water pumps take suction from the screenwell. All four pump discharge lines combine in a common header. Two normally open isolation valves are located in the common discharge and automatically close during LOCA or loss of emergency bus voltage conditions to split the RBSW system into two independent loops.

A radiation monitor draws a RBSW sample off of each RHR heat exchanger outlet and returns the sample to the same piping. The radiation monitor will detect inleakage of radioactive materials from the RHR system and be indicated in the main control room. Service water to the ultimate cooling connection and the spent fuel pool, if injected, would not be returned to the discharge tunnel but be retained in the reactor building.

11.2.2 Component Description

The major components of the Reactor Building Service Water system are described in the paragraphs that follow.

11.2.2.1 RBSW Pumps

The Reactor Building Service Water pumps are vertically mounted, two stage, centrifugal, rated at 8600 gpm @ ~70 psig. The pumps are driven by a 450 Hp, 4160 VAC, 3 phase, induction electric motor.

11.2.3 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.2.3.1 Normal Operations

During non accident conditions the RBSW system normally has one pump per loop (A or C and B or D) operating and supplying RBSW to the following components:

- One of two RCBCLCW booster heat exchanger.
- One of two RBCLCW heat exchanger.
- One of four RBSVS and CRAC chilled water condensers.
- RBNVS chilled water condenser.

The warmed water from the system is directed to the circulating water discharge tunnel and out to the Sound.

11.2.3.2 System Interfaces

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

4160V Emergency Distribution System (Section 9.2)

The RBSW pumps and motor operated valves receive power from the Emergency Power System , and the RBSW supplies cooling water to the Emergency Diesel Generator Engines.

Service & Instrument Air System (Section 11.8)

The emergency diesel engine outlet valve (AOV-16A, B, and C) receive air for valve movement from the Station Air System.

Circulating Water System (Section 11.1)

The Circulating Water System shares the screenwell suction pits with the RBSW. The CWS also provides a discharge path for return water of the RBSW to the Long Island Sound.

11.2.4 Summary

Classification:	Safety related system.
Purpose:	To transfer heat from the reactor building components to the Long Island Sound, and provide an emergency source of cooling water to the reactor vessel and spent fuel pool.
Components:	Pumps, Strainers,Pipes, and Valves
System Interfaces:	Emergency Power System, Station Air System, Circulating Water System.

Table 11.2-1 RBSW Load List

Reactor Building Service Water Loop "A"

- RHR A heat exchanger
- RBCLCW A heat exchanger
- RBCLCW A booster heater exchanger
- Emergency diesel engine A, B, and C coolers
- RBSVS and CRAC chilled water system A
- RBNVS chilled water system
- Emergency water supply to the reactor vessel
- Emergency water supply to the spent fuel pool

Reactor Building Service Water Loop "B"

- RHR B heat exchanger
- RBCLCW B heat exchanger
- RBCLCW B booster heater exchanger
- Emergency diesel engine A, B, and C coolers
- RBSVS and CRAC chilled water system B
- RBNVS chilled water system
- Emergency water supply to the reactor vessel
- Emergency water supply to the spent fuel pool
- RBSW/TBSW cross connect.

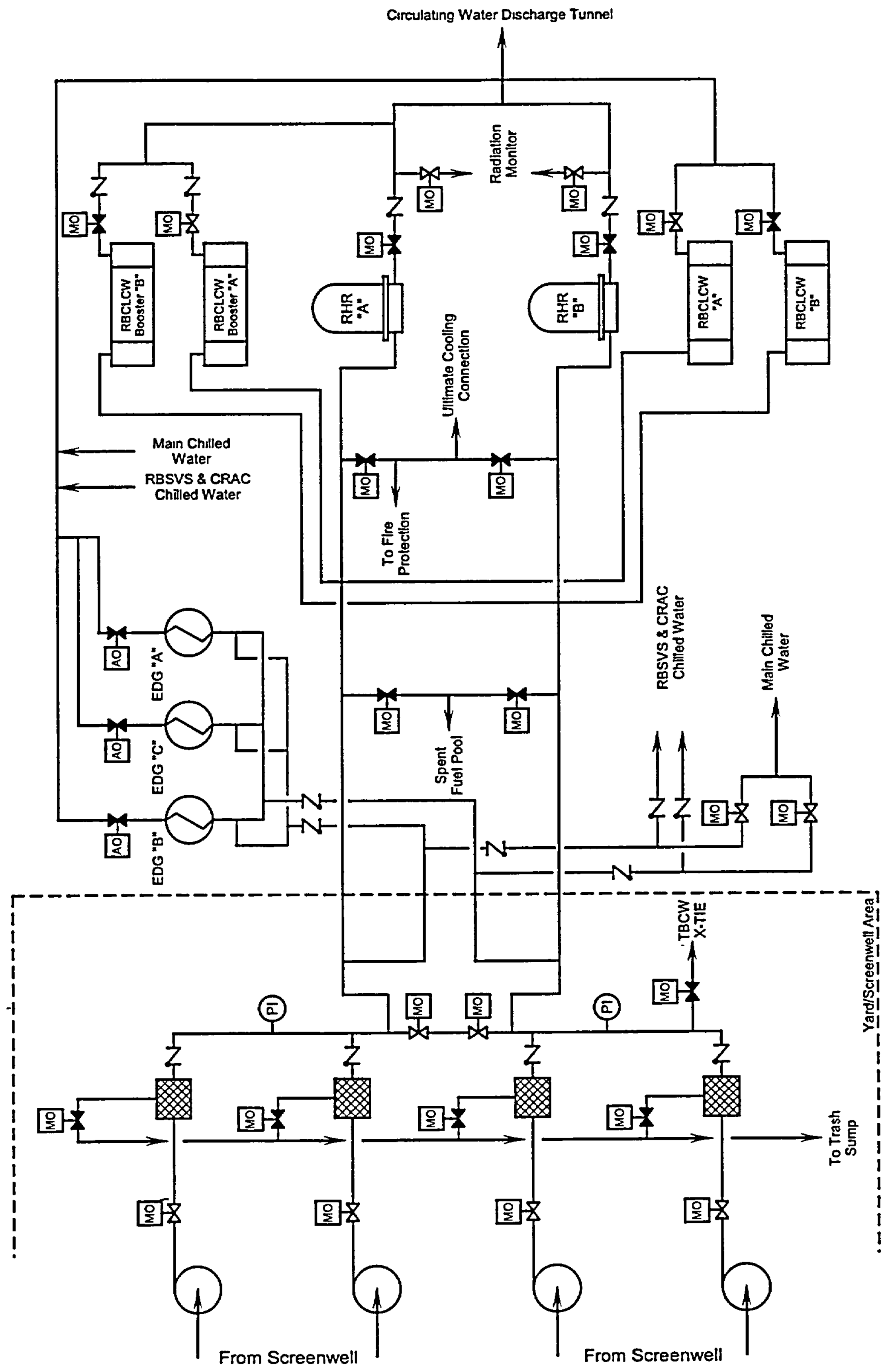

Figure 11.2-1 Reactor Building Service Water System

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11.3 Reactor Building Closed Loop Cooling Water System

The purpose of the Reactor Building Closed Loop Cooling Water System (RBCLCW) is; to transfer heat from the components cooled by RBCLCW to the Reactor Building Service Water System via heat exchangers, provide cooling water to reactor auxiliary equipment and other miscellaneous reactor building equipment during normal operation, and provide nuclear safety related systems with a redundant means of cooling during an accident condition in order to accomplish and maintain a safe shutdown.

11.3.1 System Description

The Reactor Building Closed Loop Cooling Water System is a redundant, closed loop system providing nuclear safety and non-nuclear safety related equipment with a reliable source of cooling water. Loads on the safety related loops are redundant to ensure that at least one half of the nuclear safety related components served by RBCLCW are supplied in the event of a single RBCLCW component failure. Loads on the non-safety related loops supply auxiliary components that are not required to operate during accident conditions. The two non-safety related loops automatically isolate during an accident.

Each non-safety related loop return line ties into its associated safety related loop return piping. The safety related loop returns to the inlet of an RBCLCW heat exchanger. The two heat exchangers are cross connected on both the inlet and outlet sides. The two heat exchangers discharge to a common suction header supplying the three RBCLCW pumps.

Between the RBCLCW heat exchangers and the common pump suction, two additional RBCLCW pumps take suction and supply the recirculation pump M/G set fluid coupling oil coolers.

11.3.2 Component Description

Only the major Reactor Building Closed Loop Cooling Water System components are discussed in the paragraphs which follow.

11.3.2.1 Reactor Building Closed Loop Cooling Water System Pumps/Motors

The RBCLCW circulating water pumps are; 50 % capacity each, centrifugal pumps, rated at 1600 gpm flow at 165 ft. head. The motor that drives the pumps are; 100 Hp, 480 VAC, 3 phase, 60 Hz, induction motors.

11.3.2.2 Recirculation Pump Cooling Water Circulating Pumps/Motors

The Recirculation pump M/G set fluid coupling cooler water circulating pumps are; 100% capacity each, centrifugal pumps, rated at 1600 gpm flow at 118 ft. head. The motors that drives the pumps are; 75 Hp, 480 VAC, 3 phase, 60 Hz.

11.3.2.3 Reactor Building Closed Loop Cooling Water Heat Exchangers

The RBCLCW heat exchangers are; single pass, counter flow, shell and tube type. Service water supplies the shell side at a pressure less than RBCLCW system pressure. Each heat exchanger is 100% capacity.

11.3.2.5 Radiation Monitor

The inlet to the radiation monitor is located on the common pump discharge header. the monitor is designed to detect the inleakage of radioactive contaminants due to the failure of a cooler served by the system.

11.3.3 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.3.3.1 Normal Operations

Two of the three circulating pumps take a suction from a common suction header and discharge to a common discharge header, the third is in automatic, available to start immediately to replace one of the operating pumps. During normal system operation with two pumps running, the discharge header pressure is approximately 65-68 psig.

The two non-safety related loop s return lines tie into their respective safety related loop return lines. Each of the two safety related loop return lines supplies an RBCLCW heat exchanger.

Two head tanks connect to the common pump suction line to provide a surge volume and ensure sufficient pump NPSH is available.

11.3.3.2 System Interfaces

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

4160V Emergency Distribution System (Section 9.2)

The RBCLCW pumps and motor operated valves receive power from the Emergency Power System.

Service & Instrument Air System (Section 11.8)

The heat exchangers temperature control valves and the head tank makeup valve receive motive air from the station air system.

Reactor Building Service Water System (Section 11.2)

The Reactor Building Service Water System is the heat sink for the Reactor Building Closed Loop Cooling Water System.

11.3.4 Summary

Classification:

Safety Related System

Purpose:

The purpose of the Reactor Building Closed Loop Cooling Water System (RBCLCW) is; to transfer heat from the components cooled by RBCLCW to the Reactor Building Service Water System via heat exchangers, provide cooling water to reactor auxiliary equipment and other miscellaneous reactor building equipment during normal operation, and provide nuclear safety related systems with a redundant means of cooling during an accident condition in order to accomplish and maintain a safe shutdown.

Components:

Pumps, heat exchangers, booster heat exchangers, temperature control valves, head tanks, radiation monitors, and pressure control valve.

System Interfaces:

Emergency Power System, Station Air System, and Reactor Building Service Water System.

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11.4 Turbine Building Service Water System

The purpose of the Turbine Building Service Water System (TBSW) is to transfer heat from non-safety related components in the turbine building to the Long Island Sound. The major components of the TBSW system are shown in figure 11.4-1.

11.4.1 System Description

The Turbine Building Service Water System (TBSW) supplies non-safety related components in the turbine building. The system pumps takes water from the screenwell. Normally two of the three pumps are running discharging into a common discharge/supply header via MOV-112 A, B, and C , each discharge valve is bypassed by a normally open butterfly valve which provides for system fill prior to discharge valve opening. The common discharge header supplies two motor operated, self cleaning, strainers that are arranged in parallel.

The TBSW supply to the TBCLCW heat exchangers is controlled by isolation valves on the outlet of the heat exchangers. the outlets of the two TBCLCW heat exchangers combine in a single return line containing a single normally open isolation valve.

11.4.2 Component Description

The major components of the Turbine Building Service Water system are described in the paragraphs that follow.

11.4.2.1 TBSW Pumps

The Turbine Building Service Water pumps are vertically mounted, centrifugal, rated at 800 gpm @ ~50 psig. The pumps are driven by a 350 Hp, 4160 VAC, 3 phase, induction electric motor.

11.4.2.2 TBSW Strainers

The TBSW pumps have two common discharge strainer. The strainers are self cleaning, electric motor driven, and automatically backwash to the trash sump.

11.4.3 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.4.3.1 Normal Operations

During normal operations the TBSW system has two pump operating supplying service water to the components cooled by the system. The third pump in normally aligned to the standby mode of operation.

11.4.3.2 System Interfaces

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

4160V Normal Distribution System (Section 9.1)

The TBSW pumps and motor operated valves receive power from the Normal Power System .

Circulating Water System (Section 11.1)

The Circulating Water System shares the screenwell suction pits with the TBSW. The CWS also provides a discharge path for return water of the TBSW to the Long Island Sound.

11.4.4 Summary

Classification:
Power Generation system.

Purpose:
To transfer heat from the turbine building components to the Long Island Sound.

Components:
Pumps, Strainers,Pipes, and Valves

System Interfaces:
Normal Power System, Circulating Water System.

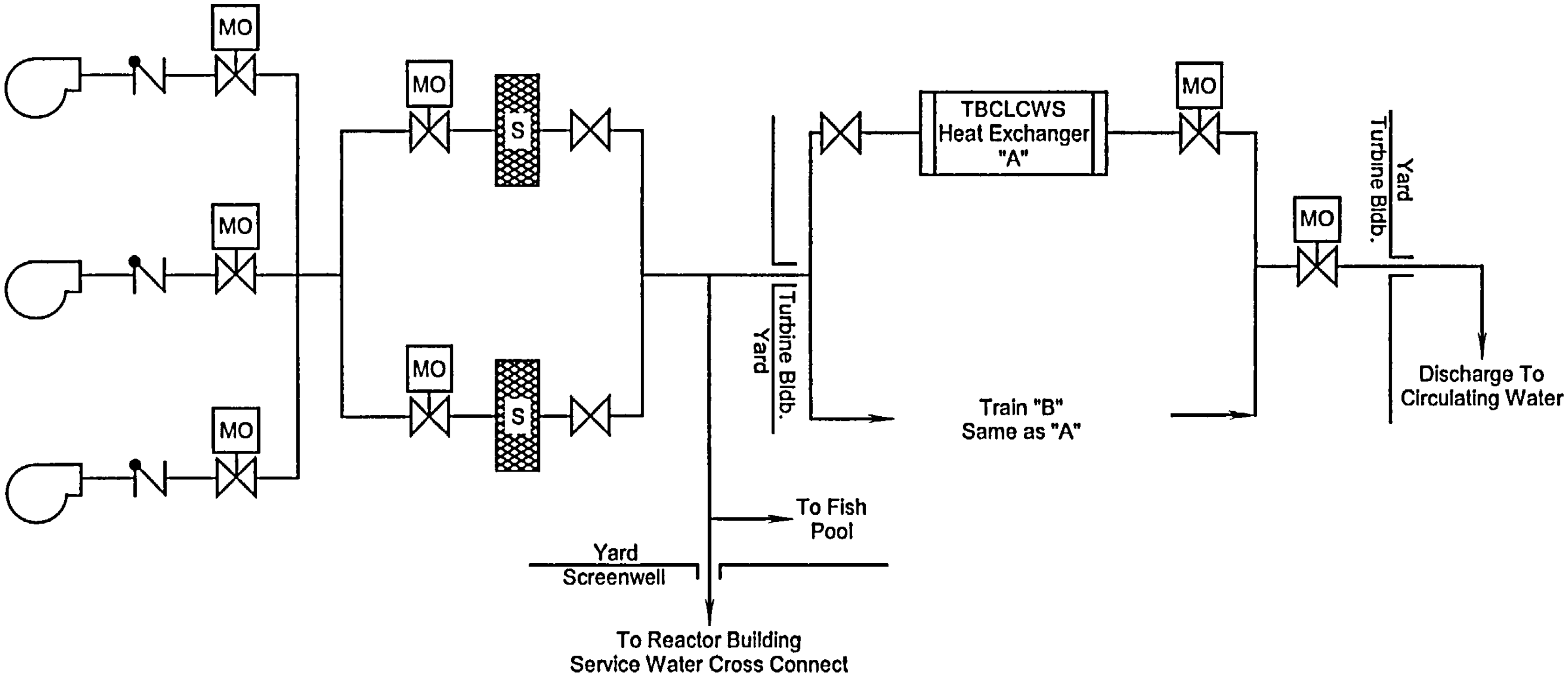

FIGURE 11.4-1 Turbine Building Service Water System

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11.5 Turbine Building Closed Loop Cooling Water System

The purpose of the Turbine Building Closed Loop Cooling Water System (TBCLCWS) is to transfer heat from non-safety related components in the turbine building, radwaste building, and service building to the Turbine Building Service Water System. The major components of the TBCLCWS system are shown in figure 11.5-1.

11.5.1 System Description

The Turbine Building Closed Loop Cooling Water System (TBCLCWS) is a closed loop piping system consisting of two full-capacity centrifugal pumps, two full-capacity heat exchangers, a surge tank, two motor-operated pump discharge isolation valves and automatic system temperature and pressure control valves. The system is shown in Figure 11.5-1.

11.5.2 Component Description

The major components of the Turbine Building Closed Loop Cooling Water system are described in the paragraphs that follow.

11.5.2.1 TBCLCW Pumps

The TBCLCW pumps are single stage pumps, rated at 17.8 Kgpm @ 85 psig. The pumps are driven by a 1000 hp, 4.16kv, 3 phase, 60Hz, squirrel cage induction motor.

11.5.2.2 TBCLCW Surge Tank

A surge tank is located above the pump suction manifold. Connected to the pump suction manifold, the tank will reduce pressure surges, permit thermal expansion of loop water, provide a low pressure inlet for makeup water, ensure the minimum NPSH for the system pumps, and provide a method for detecting and measuring leakage. Makeup water is automatically supplied from the demineralized water system

11.5.2.3 TBCLCW Pressure Control Valve

Pressure transients caused by placing coolers in the system in or out-of-service, are compensated for automatically by pressure control valve.

11.5.2.3 TBCLCW Temperature Control Valve

A heat exchanger bypass line containing a automatic temperature control valve. Closed loop cooling water discharge temperature is maintained at a constant 95°F by modulation of bypass flow around the heat exchanger.

11.5.3 System Features and Interrelations

System operation and interrelations between this system and other plant systems are discussed in the paragraphs that follow.

11.5.4.1 Normal Operations

During normal operation one of the TBCLCW pumps is operating with the other pump in standby. If the operating pump should trip, the standby pump will start, the discharge valve of the starting pump will automatically open 10 seconds after the standby start.

11.5.4.3 System Interfaces

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

4160V Normal Distribution System (Section 9.1)

The TBCLCW pumps and motor operated valves receive power from the Normal Power System .

Turbine Building Service Water (Section 11.4)

The Turbine Building Service Water System cools the TBCLCW system.

11.5.5 Summary

Classification:
Power Generation system.

Purpose
To transfer heat from the turbine building components to the Turbine Building Service Water system.

Components:
Pumps, Pipes, and Valves

System Interfaces:
Normal Power System, Turbine Building Service Water system.

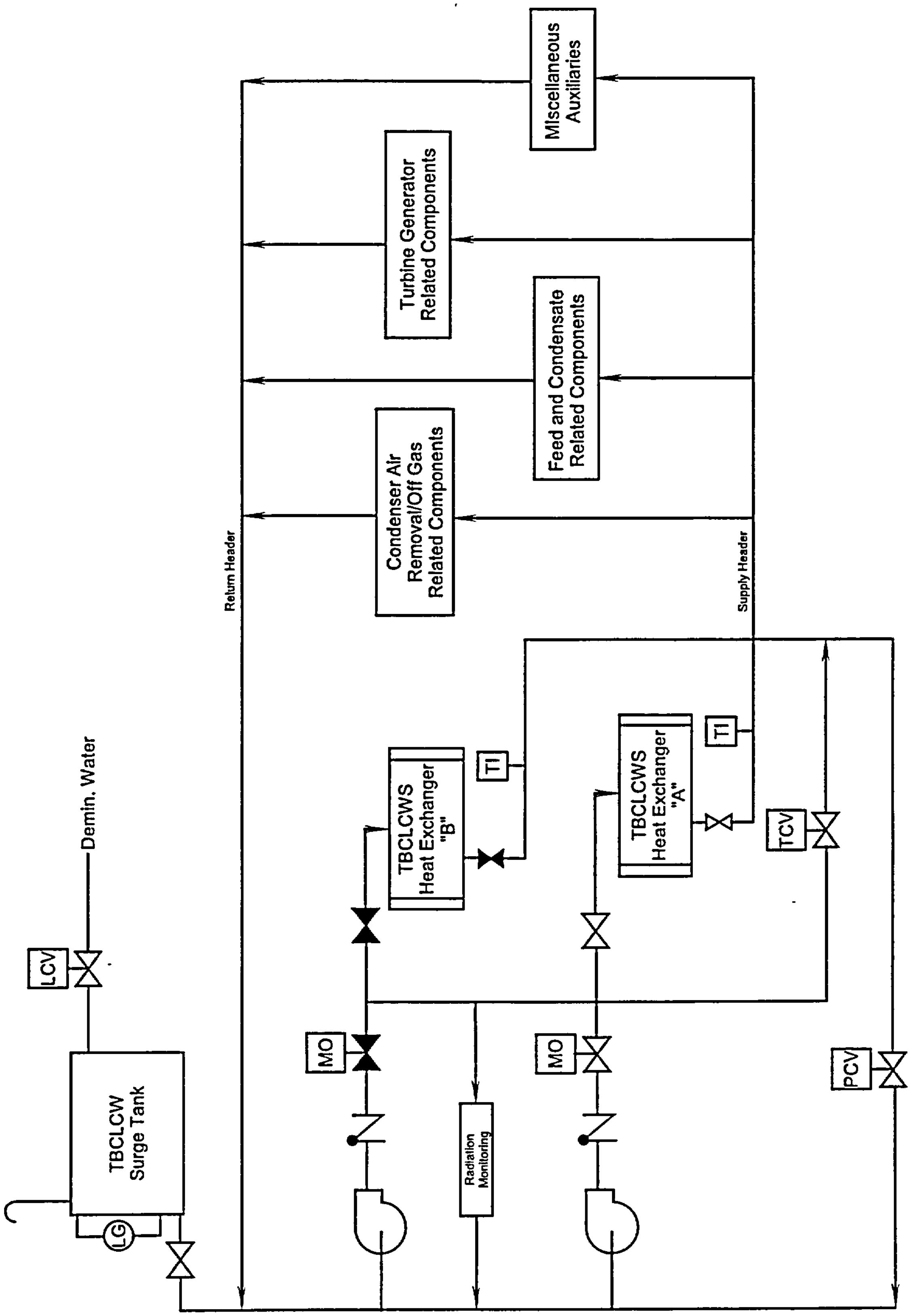

FIGURE 11.5-1 Turbine Building Closed Loop Cooling Water System

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11.6 SERVICE & INSTRUMENT AIR SYSTEM

The purposes of the Service and Instrument Air System are:

1. To supply compressed air throughout the plant for general purposes such as pneumatic tools operations, cleaning, and non-essential support services.
2. To supply clean compressed air to plant instruments, control devices, and air operated valves.

The functional classification of the Service and Instrument Air System is that of a power generation system. Some components are safety related.

11.6.1 System Description

Three centrifugal air compressors are used to supply the service and instrument air requirement. Two compressors are operated simultaneously to meet normal air requirements for both units, the third compressor is maintained in the standby mode.

Aftercoolers are located in the air piping downstream of each compressor. The aftercoolers reduce the temperature of the compressed air. Each compressor is also served by an air receiver which provides a reserve surge capacity to the air supply system. The receivers supply air to service and instrument air headers.

Service air is not required to be cleaned and dried, therefore, it is supplied directly off the air receiver discharge piping. Distribution headers direct the air to various plant buildings where it is available for general plant services.

Instrument air services require clean, dry, and oil free air. Prior to distribution throughout the plant, it passes through filtration and drying equipment to remove particulate matter, moisture and oil.

11.6.2 Component Description

The major components of the Service and Instrument Air System are discussed in the paragraphs that follow.

11.6.2.1 Service and Instrument Air Compressors

The station air compressors are designed to supply all of the service and instrument air requirement for a single unit. The compressors are of a multistage, oil-free, centrifugal, electric motor driven design and are capable of supplying a minimum of 1000 scfm of air at 125 psig.

Air is drawn into the compressor through an air filter silencer which removes particles from process air.

11.6.2.2 After Cooler

Associated with each compressor is an after cooler to cool the flow of air to 110°F. The after coolers are air to water heat exchangers cooled by raw water.

11.6.2.3 Air Receivers

Compressed air from the outlet of each after cooler flows into its associated air receiver. The air receivers dampen pressure pulsations caused by the compressors, and serve as a storage volume. The storage capacity provides sufficient time for the standby compressor to start and load should system air pressure decrease due to excessive usage or leakage. The air receivers are designed for 150 psig.

11.6.2.4 Dryer/Filter Trains

The Instrument Air System contains a dryer/filter train arrangement to provide drying and cleaning of the air prior to use in order to minimize malfunctions of pneumatic instruments and valves. The train consists of a series arrangement of two parallel prefilters, dual tower dryer units, and after filters. Only one of the parallel components is used at a time, which allows cleaning or changing of filters during system operation. Each air dryer consists of an interconnected set of two desiccant chambers. Air flow is automatically alternated through each chamber to permit the simultaneous drying of air in one chamber and the drying of air desiccant in the other chamber. Drying of the desiccant is accomplished by purging dry air through the chamber. At the outlet of the dryers are air filters which function to remove dirt and other contaminants from the process air.

11.6.3 System Features

A discussion of system features is given in the following paragraphs.

11.6.3.1 Normal System Operation

Two of the three air compressors are normally running with the third compressor in a standby mode. The operating compressors draw air from the room in which they are located, raise the pressure to approximately 125 psig, and discharge the air to storage receivers. Pressure switches located on the receivers control normal operation of the running compressors. The compressors load (compress air) when receiver pressure drops to 120 psig and unload at 130 psig.

The receivers supply air to instrument and service air headers. Instrument air passes through air dryers and filters prior to supplying various plant components. Dryers remove moisture from the air supply and filters remove foreign particles. The dryers and filters are necessary components because of the materials and small clearances of the internal moving parts of pneumatic equipment. Clean, dry, and oil free air is required for reliable trouble free operation. The air from the conditioning equipment is distributed throughout the instrument air system.

The instrument air system is subdivided by building location, i.e., turbine building, auxiliary building, fuel building, and containment building. The turbine building instrument air supplies components such as the hotwell level control valves, turbine extraction steam and heater drain system, various valve actuators that control cooling water flow to generator hydrogen and oil systems, condensate system demineralizer valves, building heating and air conditioning, and the steam sealing system for the turbines, The auxiliary building instrument air loads include the outboard main steam isolation valves and various other components. The containment air supply is used in the control rod drive hydraulic system, inboard main steam isolation valves, and equipment and floor drain isolation valves. The instrument air supply to the containment is equipped with an automatic isolation valve that closes on a containment isolation signal. Of course, when an isolation occurs, the air supply header inside the containment will depressurize.

The service air system is used to supply air to components such as the demineralizer backwash and precoat system and hose stations for pneumatic tools. Many boiling water reactor plants utilize separate service air systems to meet this need.

11.6.3.2 Abnormal System Operation

In the event that air consumption exceeds the capacity of the operating compressors, the following sequence of events will occur as pressure continues to decrease:

1. The standby compressor will start.
2. The service air header will isolate.
3. The reactor scrams due to loss of air to the scram pilot valve air header.

11.6.4 System Interfaces

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

11.6.4.1 Turbine Building Cooling Water System (Section 11.5)

The Turbine Building Cooling Water System supplies normal cooling for the compressors and after coolers.

11.6.4.2 Normal Auxiliary Power System (Section 9.1)

Power for the Control and Instrument Air System is from the Normal Auxiliary Power System.

11.6.5 Summary

Classification:

Power generation system with some supplied components classified as safety related.
Purpose:

To provide a continuous supply of compressed air of suitable quality and pressure for instruments, controls, and station use.To supply air to the safety/relief valves, main steam isolation valves, and other safety related components.

Components:

Compressors, receivers, air dryers, and filters.

System Interfaces:

Raw Cooling Water System, Normal Auxiliary Power System.

12.0 REACTOR OPERATIONS

Detailed written operating procedures for all modes of plant operation are prepared prior to the initial startup and critical testing period. Appropriate changes in these procedures are made during the startup test program. The following is a discussion of the general operating procedures that are used for plant startup, power operation, and shutdown. This information is presented to indicate the general method of operation.

The order to startup the reactor for power operation, or to shutdown for maintenance or refuelng, is issued by the plant superintendent or assistant superintendent. The load schedule during power operation is issued by the load dispatcher's office with concurrence from the plant. To support these operations, the shift supervisor schedules the startup or shutdown of various systems and components as required and issuing the necessary orders to the control room personnel.

The following sections describe the sequence of general plant operations during startup, power operation, and shutdown.

12.1 COLD STARTUP PROCEDURES

Prior to cold startup, prestartup check lists are completed on all systems required to support startup and power operation. Included in these checks are the following: operational checks of safety related systems to ensure their availability; nuclear steam supply and balance of plant system valve and switch lineups from control room panels; and functional checks of systems such as the Neutron Monitoring Systems and Reactor Manual Control System.

The shutdown cooling mode of the Residual Heat Removal (RHR) System is secured, and the recirculation pumps are started and run at minimum speed. The Condensate and Feedwater System is prepared to supply water to the reactor vessel. This includes bringing chemistry into specification by recirculating water from the condenser hotwell through the condensate demineralizers and feedwater heaters. A vacuum is drawn in the main condenser to aid in the removal of noncondensible gases in the reactor vessel and main steam lines.

12.1.1 Approach to Critical and Pressurization of the Reactor

After the completion of the prestartup checks, authorization for startup must be received from the station management. The reactor mode switch is placed in the startup position, and control rods are withdrawn, using the Reactor Manual Control System, according to the specified sequence. When a control rod has been withdrawn to the full out position, a coupling check is made by attempting to further withdraw the rod. If the control rod blade is uncoupled from the control rod drive, a rod overtravel alarm is received and corrective measures must be taken. Control rod withdrawal continues until criticality is achieved. The time, rod position, reactor period, and reactor water temperature are then recorded.

After neutron flux measurement overlap with the intermediate range monitors (IRM) has been demonstrated, the source range monitor (SRM) detectors are withdrawn as required to maintain the count rate between 10^2 and 10^5 counts/sec.

After the reactor is critical, a reactor period on the order of about 100 seconds is established to raise power to the heating range. The IRM's are ranged upward as required to maintain the proper on-scale readings. The power increase continues until heating power is reached. At this point control rod withdrawal is governed by the heatup rate limit (usually about 90°F/hr). The 90°F/hr heatup rate is a procedural limit. The Technical Specification limit is 100°F/hr. Control rod withdrawal is constrained to an approved sequence such that control rod positions remain symmetrical and the reactivity worth of a given rod is minimized.

As reactor water temperature increases, the coolant expands, causing the reactor vessel level to increase. In order to maintain a constant level during heatup, water must be removed from the reactor vessel. The Reactor Water Cleanup System (RWCU) is aligned to reject water to the main condenser or to the Liquid Radwaste System. It is usually more desirable to reject the excess water to the condenser in order to minimize the water processing load on the Liquid Radwaste System. This evolution continues until rated temperature and pressure are reached.

As temperature increases from 212°F, the moderator in the reactor vessel begins to pressurize. At about 100 psig, the Reactor Core Isolation Cooling (RCIC) System and the High Pressure Coolant Injection (HPCI) System, low steam pressure isolation is reset, and the steam lines to auxiliary steam loads such as Reactor Feedwater Pump (RFP) turbines and Steam Jet Air Ejectors (SJAE's) are warmed.

As pressure approaches 150 psig, the Electro Hydraulic Control (EHC) System pressure regulator would start to open bypass valve number 1. To avoid bypassing steam and to allow plant pressurization, the pressure setpoint is increased to 920 psig.

At about 350 psig a reactor feed pump is started and placed in service. At about 450 psig, steam to the SJAEs is shifted from auxiliary steam supply to reactor steam. Also at this time, the main turbine is reset and prepared for starting.

As pressure reaches 920 psig, the bypass valves begin to open to control reactor pressure at the EHC System pressure setpoint. Control rods are withdrawn to increase power, which results in further opening of the bypass valves. When power reaches 5% to 12%, the reactor mode switch is shifted to the "RUN" mode, and the IRMs are fully withdrawn. Control rods are withdrawn until 3 to 5 bypass valves are open, representing sufficient steam flow to roll the main turbine and provide minimum loading following synchronization to the grid. At about this time, the Feedwater Control System is placed in automatic, and RWCU System reject flow is discontinued.

12.1.2 Startup and Synchronization of the Generator

A turbine acceleration rate is chosen, depending upon various turbine temperatures, and the turbine is rolled to synchronous speed. The generator is then synchronized to the transmission system, and the generator load break switch is closed.

As the operator now increases load on the generator by using the load selector to open the control valves, the bypass valves automatically close to maintain a constant reactor pressure. This is all accomplished using the EHC System.

Once all bypass valves are closed, a further increase on the load selector performs a setpoint adjustment only, and the load selector is set to the expected power level. Further increase in generator load is now performed by increasing reactor power by control rod withdrawal, either in the individual or gang modes.

As control rods are withdrawn, reactor power and pressure increase. As reactor pressure increases, steam throttle pressure also increases which causes the EHC System to open the control valves more, increasing turbine and hence generator power.

12.1.3 Increase of Power to Rated

Because of fuel warranty requirements, control rod withdrawal is used to increase power to approximately 60%. When approximately 60% power is reached, the control rods have been withdrawn to what is called a 100% rod pattern. This rod pattern, in turn, yields 100% reactor power when recirculation flow is increased to 100%.

The power increase from 60% to 100% is accomplished by increasing recirculation flow. The Recirculation Flow Control System is aligned with the individual loop contrtolers in master manual control. Recirculation flow is then increased to near 100% with the master flow controller.

During the increase to rated power, additional support equipment is started as necessary; i.e., condensate, condensate booster and reactor feed pumps; condensate demineralizers, etc.

12.2 POWER OPERATION

After the generator is synchronized to the transmission grid and producing a substantial output, reactor power output is changed to meet the grid system requirements by adjustment of control rod position, manual adjustment of reactor recirculation flow, or a combination of these two methods.

12.2.1 Control Rod Adjustment

Withdrawing a control rod reduces neutron absorption and adds core reactivity. Reactor power then increases until the increased steam formation just balances the change in reactivity caused by the rod withdrawal. The increase in boiling rate tends to raise reactor pressure, causing the EHC System pressure regulator to open the turbine control valves sufficiently to maintain a programmed throttle pressure. When a control rod is inserted, the reverse effect occurs.

12.2.2 Recirculation Flow Control

Reactor power output can be varied over a power range of approximately 35% of rated power, by adjustment of reactor recirculation flow, which maintains a near uniform power distribution. Reactor power change is accomplished by using the negative void coefficient. An increase in recirculation flow temporarily reduces the volume of steam in the core by raising the boiling boundary. This addition of reactivity to the core causes reactor power level to increase. The increased steam generation rate then returns the steam volume in the core to approximately its original value, and a new constant power level is established. When recirculation flow is reduced, reactor power is reduced in a similar manner.

During initial power operation, the operating curve or power/ flow map is established relating reactor power to recirculation flow. The first point of the curve is full flow and rated power. When a rod pattern is established for this point, recirculation flow is reduced in steps, at that rod pattern, and the relationship of flow to power is plotted for steady state conditions. Other curves are established at lower power ratings and other rod patterns as desired. During operation, reactor power may be changed by flow control adjustment, rod positioning, or a combination of the two, while adhering to established operating curves.

Although control rod movement is not required when the load is changed by recirculation flow adjustment, the long term reactivity effects of fuel burnup can be compensated for by control rod adjustment.

Operating personnel are engaged in many activities during normal power operation. The following list includes some of the most typical activities:

1. Routine data taking and writing of operational logs.
2. Routine system instrument and valve tests.
3. Special periodic operational tests.
4. Manipulation of control rods and recirculation flow to maintain a balanced flux distribution, accommodate major changes in load demand, and secure optimum plant performance.
5. Evaluation of abnormal conditions as annunciated and indicated, and taking required action to minimize potentially dangerous effects on equipment and systems.

6. Sampling of process steam and water.
7. Surveillance of plant equipment for proper operation, including making of necessary adjustments and minor repairs.
8. Confining radioactive contamination to the smallest possible area, and preventing contamination of personnel areas.

12.3 NORMAL SHUTDOWN FROM POWER

A plant shutdown is accomplished by essentially reversing the steps described in Sections 12.1 and 12.2, cold startup and power operation.

Preparation for plant shutdown involves testing of turbine oil systems, flushing of the Residual Heat Removal System (shutdown cooling piping), and other equipment checks.

Reactor power is reduced from 100% to approximately 60% by using the Recirculation Flow Control System. This requires adjusting the master flow controller to reduce recirculation pump speed to minimum.

Control rods are now inserted in reverse of the withdrawal sequence to obtain a reactor power of approximately 10%. At this time, the IRM detectors are inserted, and the reactor mode switch is transferred to the startup position.

Generator load is reduced to a minimum, and the turbine generator is separated from the transmission system. Turbine steam flow is picked up automatically by the bypass valves. Control rod insertion continues until all rods reach the full in position. Reactor cooldown is commenced by withdrawing steam from the reactor via the bypass valves and maintaining vessel inventory using a reactor feed pump. A cooldown rate of 90°F/hr. is established.

When reactor pressure has been reduced to approximately 50 psig, the shutdown cooling mode of the RHR System is initiated and is used to cool the nuclear system down to a temperature of 150°F.

The reactor shutdown is essentially complete. Some plant shutdowns may require flooding of the reactor vessel. This is normally done using a condensate pump and would be necessary if the plant was going into refueling operations.

13.0 BWR DIFFERENCES

This chapter is provided to give the student some insight into major differences between the various BWR product lines.

13.0.1 Reactor Vessels

The reactor vessel consists of the reactor pressure vessel, the components that support and contain the core, and the components that provide flow paths and separation for steam and water. The major differences between reactor vessels of all product lines are based upon design considerations pertaining to required coolant flow paths, ability to flood the core following a loss of coolant accident, and emergency core cooling system penetrations.

13.0.2 Recirculation and Recirculation Flow Control

All BWRs use forced circulation of coolant and each BWR Recirculation System supports this concept. The way that forced circulation is achieved involves differences in the basic design. The BWR/2 design has no jet pumps inside the reactor vessel but has five external recirculation loops to provide the required flow. The BWR/3 through BWR/6 designs do have jet pumps internal to the reactor vessel and have only two external recirculation loops. The jet pumps used in the BWR/5 and BWR/6 product lines use a five nozzle design which is more efficient than the single nozzel design used in the BWR/3 and BWR/4 product lines.

In the BWR/2, BWR/3 and BWR/4 product lines core flow is controlled by changing speed of the variable speed recirculation pumps located in each recirculation loop.

The BWR/5 and BWR/6 product lines control core flow by changing the dual speed recirculation pumps from one discreet speed to another and by throttling a variable position flow control valve located on the discharge side of each pump. The Recirculation Flow Control System for all product lines allows individual or ganged control of each flow control device. The BWR/5 and BWR/6 product lines have an additional controller, flux controller, that uses the Average Power Range Monitoring System as an input to maintain a desired power level using core flow.

13.0.3 Reactor Isolation Pressure and Inventory Control

In the event the reactor becomes isolated from its normal heat sink, some component or system must control reactor vessel pressure and inventory. All BWR plants have safety relief valves (SRVs) to provide overpressure protection, and hence control reactor pressure. Some BWR facilities have a system which can control pressure without requiring the use of SRVs. All BWR facilities have a means of providing high pressure makeup water to the reactor vessel to compensate for inventory loss via the pressure control method.

In the case of the BWR/2 product line and certain plants of the BWR/3 product line, both isolation functions are carried out by a single system called the Isolation Condenser System. The Isolation Condenser System draws off reactor steam, condenses the steam in a condenser, and returns the resultant condensate to a Recirculation System suction line. By conserving inventory, this system eliminates the need for additional sources of high pressure makeup.

All BWRs of other product lines use SRVs for pressure control and the Reactor Core Isolation Cooling (RCIC) System to provide high pressure makeup water to the reactor vessel. Additionally, some later model BWR/4 product line plants, all BWR/5 and BWR/6 product line plants have another option available. The steam condensing mode of the Residual Heat Removal (RHR) System can be used for reactor pressure control. In this mode, reactor steam pressure is reduced and then condensed in the RHR heat exchangers. Since the resultant condensate can be directed to the RCIC pump suction, both systems can be used together to provide an inventory conserving closed loop operation.

13.0.4 Residual Heat Removal

All BWR facilities have either one large system capable of several operational modes or a collection of separate systems to carry out basic heat removal functions. The earlier product line plants have individual systems, while the later product line plants use an integrated RHR System. For example, BWR/2 and early BWR/3 facilities have a separate Shutdown Cooling System and use the Control Rod Drive System for the head spray function while later product line plants use various modes of the RHR System to accomplish the same functions.

13.0.5 Emergency Core Cooling Systems

The ECCS package provided for a particular product line is dependent primarily on the vintage of the plant. All BWR product lines have high pressure and low pressure ECCSs. The BWR/2 product line high pressure ECCS consists of the Isolation Condenser System and the Automatic Depressurization System (ADS). Low pressure ECCS consists of a Core Spray System.

The BWR/3 product line high pressure ECCS consists of either a Feedwater Coolant Injection (FWCI) System or a High Pressure Coolant Injection System (HPCI), and ADS. The BWR/3 low pressure ECCS consists of two Low Pressure Coolant Injection (LPCI) System loops (either as a separate system or as part of the RHR System), and two Core Spray System loops.

BWR/4 Technology Manual

Appendix A

Glossary Of Terms

This Glossary of Terms is taken in part from NUREG-0770, "Glossary of Terms: Nuclear Power and Radiation."

GLOSSARY OF TERMS*
(FOR BOILING WATER REACTORS)

TERM	DEFINITION
absorber tubes	The tubes that form the control rods contain natural boron in the form of B_4C. The n α a reaction produces Li^7 and He^4.
access lock	A lock that preserves the containment's pressure integrity while transferring equipment or personnel through the containment.
accident analysis	A standard approach to ensure the license applicant has analyzed both expected and unexpected transients and accidents, that conservative values are applied in the analysis,and that the plant design has incorporated an adequate margin of safety. The accident analysis section of the FSAR shall include the analysis of several transients and accidents. These analyzed incidents are placed in four categories or conditions of operation; normal operations, faults of moderate frequency, infrequent faults, and limiting faults.
active failure	A malfunction, excluding passive failures, of a component which relies on mechanical movement to complete its intended function on demand.
active fuel length	End-to-end dimension of fuel material within a fuel element.
adsorption	Retention of materials by adhesion to the surface of another.
airborne radioactive	Any radioactive material dispersed in the air in the material form of dusts, fumes, mists, vapors, or gases.
alpha radiation (α)	A positively charged particle emitted by certain radioactive materials. It is composed of two neutrons and two protons, hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material. It is stopped by a sheet of paper. It is not dangerous to plants, animals, or man, unless the emitting substance has entered the body.

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*These are the more commonly used terms. This list is not intended to be all inclusive.

average planar linear heat generation rate (APLHGR)	The average value of the linear heat generation rate of all the fuel rods at any given horizontal plane along a fuel bundle.
axial peaking factor (APF)	The ratio of the heat flux at the axial location of interest to the heat flux average over the active length of the fuel (assembly or rod) of interest.
axial power shape	The relative heat flux along an axial line. In each core region, the axial shape can be determined by a TIP traverse or by fitting a curve through a set of LPRM values. Knowledge and control of axial shape throughout the core is aided by maintaining symmetry in the rod pattern and a similar axial shape in all radial regions.
base loaded	A term describing a power plant which is maintained at constant load. A base-loaded plant is the opposite of a load-following plant.
beta radiation (ß)	An elementary particle emitted from a nucleus during active decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation may cause skin burns, and beta-emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal.
biological shield	A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level that is safe for human beings.
black and white rod pattern	One in which each rod is either fully inserted (black) or fully withdrawn (white) and no rods are partially withdrawn (gray).
boiling	The process in which vapor forms within a continuous liquid phase. Typically, tiny bubbles of vapor which grow and detach are formed at the heat-transfer surface. This is <u>nucleate boiling</u> which may be subcooled or saturated. <u>Subcooled boiling</u> occurs when the bulk liquid temperature is below saturation, and only the liquid film at the heat transfer surface is at saturation. <u>Film boiling</u> occurs when a continuous film of vapor blankets the heat transfer surface. The transition from subcooled to saturated nucleate boiling is continuous; the transition to film boiling is relatively sharp.
boiling length (LB)	The linear distance from the onset of bulk boiling to the transition boiling point.

boiling water reactor	A power reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be separated from the water and fed either directly or through a heat exchanger to a turbine-generator.
burnable poison	A neutron absorber or poison (such as gadolinium) that, when purposely incorporated in the fuel or fuel clad- ding of a nuclear reactor, gradually "burns up" (is changed into nonabsorbing material) under neutron irradiation. This process compensates for the loss of reactivity that occurs when fuel is consumed and fission- product poisons accumulate, and keeps the overall characteristics of the reactor nearly constant.
capacity factor	The ratio of the average power load of an electric power plant to its rated capacity. Sometimes called "plant factor."
carryover	The weight-fraction of liquid water carried as droplets with the steam as it leaves the reactor. Water droplets cause erosion in the turbine and carry activated corrosion products and fission products into the turbine, potentially causing maintenance problems. Carryover to the turbine is typically kept below 0.1 wt%.
carryunder	The weight-fraction of steam bubbles entrained in the recirculating reactor water, i.e., not separated out and sent to the turbine. The entrained steam reduces the subcooling at the reactor inlet and thus increases the local and exit steam qualities of the fuel assemblies and core average voids. It may also aggravate or cause recirculation or jet pump cavitation. Carryunder is principally a drag on plant efficiency, whereas carryover is a hazard to the turbine.
cavitation	Bubble formation and collapse at a low-pressure point in a flowing stream. Bubbles will form where the local pressure falls below the vapor pressure of the liquid and will then be transported with the liquid, and collapse where the pressure is above the vapor pressure. This is a common potential problem with large pumps when operated at "off-standard" conditions.
cerenkov radiation	Light emitted when charged particles pass through a transparent material at a velocity greater than that of light in that material. It can be seen, for example, as a blue glow in the water around the fuel elements of pool reactors. P. A. Cerenkov is the Russian scientist who first explained the origin of this light.

coast down	The stretch out of a cycle by holding a constant control rod pattern and permitting the reactor power level to decrease gradually as the core reactivity decreases.
contamination, radioactive	Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful.
control rod withdrawal sequence	The order in which control rods are scheduled to be withdrawn. The sequence begins with all rods inserted and is, or can be, extended to withdrawal of all rods.
control rod worth	The reactivity worth of a single control rod in a finite reactor core under a defined set of conditions.
cooldown	The cooling of a reactor after it has been shut down.
core flow	That coolant going through the core. See "jet pump flow."
critical	Capable of sustaining a chain reaction at a constant level. Prompt critical is being capable of sustaining chain reaction without the aid of delayed neutrons.
critical power (CP)	The fuel bundle power, above which, the nucleate boiling process breaks down at some point within the bundle and transition boiling commences. It is characterized by abrupt, unstable variations in heat transfer surface temperature, and is a function of inlet enthalpy, bundle steam quality, boiling length, etc.
critical power ratio (CPR)	The ratio of critical power to bundle operating power; used as a figure of merit to evaluate BWR core thermal performance.
criticality	The state of a nuclear reactor when it is sustaining a chain reaction.
daughter	A nuclide formed by the radioactive decay of another nuclide, called in this context the parent.
decay heat	The heat produced by the decay of radioactive nuclides. Decay heat is released in a reactor following shutdown, first from fissions caused by delayed neutrons and heat capacity of core components and, over a longer period, by the radioactive decay of fission products in the reactor. This requires provision for cooling a reactor for long periods of time following shutdown.

decontamination	The removal of radioactive contaminants from surfaces or equipment, as by cleaning and washing with chemicals.
derate	Any administrative action which limits the reactor power to a value less than the nameplate rating. Derating can be used for cycle stretch-out. It may or may not involve a physical limitation in plant capability.
detergent waste filter	The detergent waste filter removes lint and other particulate matter from the radioactive decontamination drains. The filter is equipped with inlet and outlet connections in addition to vent and drain connections.
doppler effect	An increase in neutron absorption by a material as a result of an increase in its temperature. The Doppler effect of the fertile material in a reactor is an important factor for achieving safety in large thermal and fast reactors because of the decrease in reactivity with temperature.
doppler (fuel temperature coefficient)	The change in the core reactivity level for a unit change in the fuel temperature. The change results from the broadening effects of temperature on the neutron absorption resonance.
doubling time	The time for the neutron flux level to double.
driving flow	Driving flow (sometimes called recirculation flow) measurements are commonly made of the DP across the pump(s) or venturi. This is the flow through the recirculation pumps.
dryer/separator canal	The dryer and separator canal provide underwater access between the dryer-separator storage pool and the reactor well.
dryer/separator storage pool	The pool is located on the refueling floor and provides storage and servicing facilities for the dryer and separator when they have been removed from the reactor vessel.
drywell	The containment vessel enclosing the reactor and recirculation system and forming part of the primary pressure suppression system.

electrical capacity factor	The ratio of electrical energy produced in a given time interval to the electrical energy that would have been produced in that same interval if the turbine-generator were to operate continuously as its maximum rating. Note that the thermal capacity factor and the electrical capacity factor would, in general, be different and that the thermal capacity factor is the term that is more generally useful in any problem involving fuel exposure.
elevation head	Pressure exerted by a column of fluid which is proportional to the density and height of the column. (The difference in elevation head of the boiling fuel channels and a subcooled annular region provides the pressure driving head of natural circulation reactors.)
enrichment	A process by which the relative abundances of the isotopes of a given element are altered, thus producing a form of the element that has been enriched in one particular isotope.
enthalpy	Internal energy plus mechanical equivalent of heat energy contained by a unit mass of fluid.
excess reactivity	More reactivity than that needed to achieve criticality. Excess reactivity is built into a reactor (by using extra fuel) in order to compensate for fuel burnup and the accumulation of fission-product poisons during operations.
exclusion area	An area immediately surrounding a nuclear reactor where human habitation is prohibited to ensure safety in the event of an accident.
exit quality	Quality existing at the effluent end of a fuel channel or of the entire core.
fast fission	Fission resulting from the collision of a nucleus and a high-energy neutron. Some nuclei, such as those of U-238, fission only by fast neutrons.
fertile	Capable of being transformed into a fissionable substance by capture of a neutron. Fertile material, not itself fissionable by thermal neutrons, can be converted into a fissile material by irradiation in the reactor. Common examples are U-238, Th-232 and Pu-240. When these fertile materials capture neutrons, they are partially converted into fissile Pu-239, U-233 and Pu-241, respectively.
film boiling	See "boiling"

filter/demineralizer	Removes chlorides, sulfides, oxides, etc. from radwaste effluent using Powdex resins or other suitable filtration material.
fission fragments	The two nuclei that are formed by the fission of a nucleus. Also referred to as primary fission products. They have medium atomic weights and are radioactive.
fission gas	Those fission products which exist in the gaseous state at normal temperatures and pressures.
fission, nuclear	The division of a heavy nucleus into two approximately equal parts. For the heaviest nuclei the reaction is highly exothermic, the release of energy being about 210 MeV per fission. A well-known example is the spontaneous fission of U-238. Other examples are the fissions of U-233 and Pu-239 after neutron capture.
fission poisons	Fission fragments that readily absorb neutrons; for example, Xe-135, which has an absorption cross section of 3.5 million barns for slow neutrons.
fission-product poisoning	The absorption or capture of neutrons by fission products in a reactor, thereby decreasing its reactivity.
fission products	The nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay. Some of the fission products are, or become, strong neutron absorbers.
fissionable	Capable of being fissioned by the capture of a particle, such as a neutron or photon. The most common fissionable materials are U-235, Pu-239, and U-233.
flux; neutron flux (see also "heat flux")	A measure of the intensity of neutron radiation. It is the number of neutrons passing through 1 square centimeter of a given target in 1 second. Expressed as nv, where n = the number of neutrons per cubic centimeter and v = their velocity in centimeters per second.
forced circulation	Forced circulation is induced partially by rotating and partially by jet pumps. The gross core flow and the individual fuel assembly flows are weak functions of power.
fuel assembly	A fuel assembly is a "bundle" of fuel rods held in a rigid rectangular array by tie-plates at the top and bottom, supported at intermediate levels with spacers, and enclosed by a fuel channel.

fuel bundle sampler	The device for obtaining water or gas samples from a fuel bundle in the shutdown reactor or in the storage pool. (Also called the "sipper.")
fuel storage pool	A pool that provides storage and servicing facilities for activated fuel elements.
fuel time-constant	The specific heat of the UO-2, combined with its thermal conductivity, yields a fuel temperature time-constant of a few seconds. The time-constant is the time required for the temperature to change by a fraction 1/e of the steady-state temperature differences associated with two flux levels if the flux level change is made as a step. This few-second fuel time constant is a very important characteristic of all UO_2 fueled reactors.
gamma radiation (γ)	High-energy, short-wavelength, electromagnetic radiation.Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead or depleted uranium. The rays are similar to X rays, but usually are more energetic, and are nuclear in origin.
half-life	The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Each radionuclide has a unique half-life. Measured half-lives vary from millionths of a second to billions of years.
heat flux	Rate of heat flow across a boundary (usually cladding surface), expressed in Btu/hr-ft or watts/cm^2.
hertz (Hz)	Unit of frequency, equal to one cycle per second.
hot	A slang term meaning highly radioactive.
hot spot	A surface area of higher-than-average radioactivity. Also a part of a fuel element surface that has one of the highest heat fluxes in the core.
important to safety	Those structures, systems, and components that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public. Encompasses the broad class of plant features that contribute in an important way to the safe operation and protection of the public in all phases and aspects of facility operations. Includes Safety Grade or Safety-Related as a subset.

instrument channel	An arrangement of sensor and associated components used to evaluate plant variables and produce discrete outputs used in logics. A channel terminates and loses its identity where individual channel outputs are combined in logics.
integrated neutron flux	Flux multiplied by time; usually expressed as nvt, where n = the number of neutrons per cubic centimeter, v = their velocity in centimeters per second, and t = time in seconds.
interlock	A device usually electrical and/or mechanical, to prevent activation of a control until a preliminary condition has been met, or prevent hazardous operations. Its purpose usually is safety.
ion exchange	A chemical process involving the reversible interchange of various ions between a solution and solid material, usually a plastic or resin. The process is used to separate and purify chemicals, such as fission products and rare earths, in solutions.
ionization	The process of creating ions by adding or subtracting one or more electrons to or from atoms or molecules. High temperatures, electrical discharges, or nuclear radiation can cause ionization.
irradiation	Exposure to radiation, as in a nuclear reactor.
isolated condition	Normal isolation of the reactor from the main condenser, including the closure of the main steam line isolation valves.
jet pump flow	The same (except for the relatively insignificant control rod drive flow) as total core flow. The driving flow, or recirculation flow, mixes with suction flow in the throat and diffuser of the jet pump before entering the core.
leakage, neutron	The loss of neutrons from a reactor core by outward diffusion. When there is a reflector, leakage refers to net loss of neutrons that leave the core and are not reflected back into it. Leakage lowers the neutron level in a reactor.
leakage flow	Coolant flow that is diverted to other regions of the reactor outside the fuel channels to remove heat from control rods, sources and fission chambers. About 10% of the total core flow is leakage flow, removing about 3% of the heat generated in the core.

limiting conditions for operation (LCO)	Specify the minimum acceptable levels of system performance necessary to ensure safe startup and operation of the facility. When the conditions are met the plant can be operated safely and abnormal situations can be safely controlled.
limiting safety system setting (LSSS)	Instrumentation settings which initiate automatic protective action at a level such that the safety limits will not be exceeded. The region between the safety limit and these settings represents margin with normal operation lying below these settings.
linear heat generation rate (LHGR)	The heat generation system rate per unit length of a fuel rod. Common units are kW/ft.
load following	A term describing a power plant whose power is raised and lowered to meet the day-to-day demands of its electrical grid. A load-following plants the opposite of a base-loaded plant.
local peaking factor	Ratio of the maximum-to-average fuel rod power within a fuel assembly.
local power	The power generation in an arbitrary unit of volume, usually a small length of a fuel assembly called a node. It is the integral of the heat flux over the heat transfer area in the unit of volume or length, plus an increment for the heat deposited in the water by thermalization of neutrons and absorption of gamma energy where applicable.
logic	That array of components which combines individual bistable output signals to produce decision outputs.
maximum average planar linear heat generation rate (MAPLHGR)	The maximum in-core value of average planar linear heat gemeration rate.
megawatt-day per ton	A unit for expressing the burnup of fuel in a reactor; specifically, the number of megawatt-days of heat per metric ton.
minimum critical power ratio (MCPR)	The smallest critical power ratio existing anywhere in the core. This expression is used in place of such terms as "minimum burnout ratio" and "minimum burnout margin." The control room problem is to determine the magnitude, and the location in the core, of the MCPR. Nomograms, worksheets, and procedures are provided so that the MCPR value can be determined for the operating condition that exists. An on-line computer may be used to determine this important

	value. Ordinarily, it is sufficient to determine the MCPR value following any change in operating conditions, or at intervals of once per shift of base load operation.
moderator	A material used in a reactor to slow down high-velocity neutrons and increase the likelihood of further fission. Moderators commonly include ordinary water, heavy water and graphite. Liquid moderators can also serve as the coolant. Neutrons lose energy by scattering collisions with nuclei of the moderator. A good moderator has high scattering cross section and low atomic weight.
moderator temperature coefficient	The change in the core reactivity level per a unit change in the moderator temperature. The moderator temperature coefficient of reactivity is the composite of three principal effects. These are: (1) the temperature effect in k_∞, (2) the temperature effect on core neutron leakage, and (3) the temperature effect on the control rod system worth. The latter is a large negative effect. The composite coefficient becomes less negative with fuel depletion, reaching the least negative value at the end of each fuel cycle.
moderator void coefficient	The change in the core reactivity level per a unit change in the moderator void content. The moderator void coefficient of reactivity is a composite of the same three effects as in the temperature coefficient, but refers only to in-channel changes in moderator density, i.e., voids. As in the temperature coefficient, the void coefficient becomes less negative with fuel depletion.
multiplication factor	The effective multiplication constant (K_{eff}) is the ratio of the number of neutrons present in a reactor at a given time to the number present one finite neutron lifetime earlier. The "excess reactivity" is $K_{eff}-1$ which can be likened to the "interest rate per neutron lifetime," and excess of 1% means that the neutron population (capital) will increase by a factor of 1.01 in a one neutron lifetime. A reactor is said to be subcritical if $K_{eff}<1$, critical if $K_{eff}=1$, and supercritical if $K_{eff}>1$.
natural circulation	The coolant (usually water) in a reactor is circulated without pumping; that is, by natural convection resulting from the different densities of relative cold and heated portions.
natural uranium	Uranium as found in nature, containing 0.7% U-235, 99.3% U-238, and a trace of U-234.
net positive suction	The pressure head, in feet of fluid, acting to suppress cavitation

head (NPSH)	at the elevation of interest. It is the excess of the static head over the saturation pressure corresponding to the fluid temperature. The NPSH can be increased by greater submergence of the pump below the fluid surface and/or by greater subcooling of the suction fluid.
neutron flux	See "flux."
neutron leakage	See "leakage."
noble gases	Radioactive (nonreactive) elements, such as argon, xenon, and krypton released in the fission process.
nuclear fission	See "fission, Nuclear."
nucleate boiling	See "boiling."
nv	Neutron flux, units of neutrons per second per square centimeter.
offgas	The accumulation of air through in-leakage around the BWR turbine, the fission gases present in the steam and the hydrogen and oxygen from disassociation of water; and exhausted through the steam jet air ejectors or mechanical vacuum pumps.
passive failure	A breech of a fluid pressure boundary or blockage of a process flow path.
peaking factor, total	The ratio of the maximum fuel rod surface heat flux in any assembly to the core average fuel rod surface heat flux.
plant factor	See "capacity factor."
period	The time required for one cycle of a regularly repeated series of events. In a nuclear reactor, it is the time required for the power level to change by the factor of 2.718, which is known as e (the base of natural logarithms).
poison	Any material of high absorption cross section that absorbs neutrons unproductively and hence removes them from the fission chain reaction in a reactor and decreases its reactivity. It may be in the form of poison curtains or an accumulation of material resulting from operation, especially fission products of high-neutron-absorption cross section.
power	<u>Power</u> is the rate of heat production, transfer or flow.

	Fission power or (neutron power) refers to the rate of the basic fission process, and this responds essentially instantaneously to a neutron flux change. Fission power can be determined only by calibrated nuclear instrumentation during a fast transient.
	Heat flux power refers to the rate of transfer of the heat from the fuel to the coolant. In any neutron flux transient, the rate of heat transfer lags behind the fission power generation rate because of the few second time constant of the UO2 fuel. Since heat flux cannot be measured directly, transient values must be calculated from other measurements.
	Reactor power is determined by a coolant heat-balance under steady-state conditions by measuring pressure, or temperatures, and coolant flows to determine enthalpys and heat removal and addition rates. The calibration of primary nuclear instrumentation and the basic plant heat production records depend directly on the heat-balance data.
power density	The rate of heat generated per unit volume of a reactor core.
quality, steam	The percentage of weight of water that is in the vapor phase. In fluid flow, steam quality refers to the weight-fraction of steam in the two-phase flowing mixture of steam and liquid in the channel passing the point of interest. Thus, in a fuel assembly the quality increases from zero (below the elevation where boiling begins) to the maximum or exit value at the top of the assembly. Steam quality is the important property when considering the thermal properties of the fluid.
radial peaking factor (RPF)	The ratio of the fuel assembly power or heat flux in a particular assembly to the power or heat flux of the core average fuel assembly.
radiation	The emission and propagation of energy through matter or space by means of electromagnetic disturbances that display both wave like and particle like behavior. The term radiation; such radiation is commonly classified according to frequency, as Hertzian, infrared, visible (light), ultraviolet, X-ray, and gamma-ray. By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, are classified as cosmic radiation. Nuclear radiation is that emitted from atomic nuclei in various nuclear reactions, including alpha, beta, and gamma radiation and neutrons.
reactivity	A measure of the departure of a nuclear reactor from criticality. It is about equal to the effective multiplication factor minus one and is thus precisely zero at criticality. If there is excess reactivity (positive reactivi-

	ty), the reactor is supercritical and its power will rise. Negative reactivity (subcriticality) will result in a decreasing power level.
recirculation flow	See "driving flow."
refueling	The removal and addition of fuel assemblies to the core; however, the term is often extended to include any and all additions, rearrangements, or removals of core components which affect reactivity.
refueling platform	The platform that moves over the reactor pool and the fuel storage pool to carry operators, refueling tools, and fuel.
refueling outage	Includes all of the planned operations associated with a normal refueling except those tests in which the reactor is taken out of and returned to the shutdown (more than one rod subcritical) condition. The following operations are included in refueling: planned physical movement of core components (fuel, control rods, etc.), refueling test operations (except criticality and shutdown margin tests), and planned maintenance.
roentgen equivalent man (rem)	A measure of the dose of any ionizing radiation to body tissues in terms of its estimated biological effect. A dose of 1 rad of X, gamma or ß radiation is equivalent to 1 rem.
safety-grade	This term is not explicitly used in regulations. It is equivalent to "Safety-Related", and is a subset of "Important to Safety".
safety limits	Limits below which the reasonable maintenance of the integrity of the cladding and primary systems are assured. Operation beyond such a limit may not in itself result in serious consequences, but indicate an operational deficiency subject to regulatory review.
safety related	Those structures, systems, or components designed to remain functional for the Safe Shutdown Earthquake necessary to assure required safety functions. i.e: (1) The integrity of the reactor coolant system pressure boundary (2) The capability to shutdown the reactor and maintain it in a safe shutdown condition, or (3) The capability to prevent or mitigate the consequences of accidents which could result in potential off-site exposures comparable to the guidelines in 10 CFR 100 Appendix A.
saturation	Refers to the enthalpy or temperature of a liquid at which the vapor pressure equals the local pressure. At saturation, further additions of heat cause some of the liquid to change to vapor; that is, boiling occurs.

scram	The sudden shutdown of a nuclear reactor by rapid insertion of the control rods. Emergencies or deviations from normal reactor operation cause the reactor operator or automatic control equipment to scram the reactor.
secondary containment integrity	This is attained when the reactor building is closed and the following conditions are met: At least one door at each access opening is closed. The Standby Gas Treatment System is operable. All reactor building ventilation system automatic isolation valves are operable or are secured in the closed position.
separator/dryer storage pool	The pool is located in the refueling floor and provides storage and servicing facilities for the separator and dryer when they are removed from the reactor vessel.
service platform	The platform placed over the reactor at the level of the vessel flange to permit operators to work on the core. Normally, this platform rests on a seal surface protector.
shutdown margin	The amount of reactivity by which the reactor is subcritical. Mathematically, $1\text{-}K_{eff}$ (for $K_{eff} <1$). The value specified normally assumes that the strongest control rod is stuck in the fully withdrawn condition.
single failure	An occurrence which results in the loss of capability of a component to perform its intended safety function when called upon. Multiple failures resulting from a single occurrence are to be considered a single failure. Fluid process systems are considered to be designed against an assumed single failure if neither a single active nor a single passive failure results in a loss of the safety function to the nuclear unit.
sipper	See "fuel bundle sampler."
spent (depleted) fuel	Nuclear reactor fuel that has been irradiated to the extent that it can no longer effectively sustain a chain reaction.Fuel becomes spent when its fissionable isotopes have been partially consumed and fission - product poisons have accumulated in it.
stack	The chimney used to disperse the offgas from reactor operation.

storage and handling facilities, fuel	Fuel storage and handling facilities and procedures are designed to ensure that an unintentional criticality cannot occur. Any proposed change in equipment, geometry, or procedure involving either new or exposed fuel must be rigorously examined for a change in criticality risk.
subcooled boiling	See "boiling."
subcooling	The difference between the saturation enthalpy and the actual enthalpy of water in the liquid phase. Common units are Btu/lb, cal/gm, and ^{0}F.
suction flow	Suction flow is a mixture of subcooled feedwater and saturated water discarded by the steam separators and dryers above the jet pump suction inlet. This suction flow is drawn into the jet pump by the venturi effect of the driving flow.
superheating	A heating of a vapor, particularly saturated (wet) steam, to a temperature higher than the boiling point at the existing pressure. This is done in power plants to improve efficiency and to reduce condensation in the turbines.
temperature coefficient of reactivity	The change in reactor reactivity (per degree of temperature) occurring when the operating temperature changes. The coefficient is positive when an increase in temperature increases the reactivity and negative when an increase in temperature decreases reactivity. Negative temperature coefficients help to prevent power excursions. See"Doppler (Fuel Temperature) Coefficient" and "Moderator Temperature Coefficient."
thermal efficiency	The ratio of the electric power produced by a power plant to the amount of heat produced by the fuel; a measure of the efficiency with which the plant converts thermal energy to electrical energy.
thermal (slow) neutron	A neutron in thermal equilibrium with its surrounding medium. Thermal neutrons are those that have been slowed down by a moderator to an average speed of about 2200 meters per second (at room temperature) from the much higher initial speeds they had when expelled by fission. This velocity is similar to that of gas molecules at ordinary temperatures.
trip system	An arrangement of instrument channel trip signals and auxiliary equipment required to initiate action to accomplish a protective trip function.

tripped (technical specifications)	The change of state of a bistable device which represents the change from a normal condition. A trip signal, which results from a trip, is generated in the channels of a trip system and produces subsequent trips and trip signals through the system as directed by the logic.
two-phase pressure drop	The DP produced by the flow of a mixture of liquid and vapor through a resistive path. The DP for a given mass flow rate is dependent on the weight fraction of the mass flow that is steam.
velocity limiter	An integral part of the control rod designed to limit the free-fall velocity of the control rod in water.
void coefficient	The change in reactivity resulting from a percentage change in void fraction.
void fraction	Fraction of the volume of the coolant stream (moderator) that is in the vapor phase. Void fraction is an important property when considering nuclear properties such as reactivity, moderation, etc.

BWR/4 Technology Manual

Appendix C

List Of Common Abbreviations

This Collection of Abbreviations is taken in part from NUREG-0544/Rev 3
"NRC Collection of Abbreviations."

LIST OF COMMON ABBREVIATIONS
(FOR BOILING WATER REACTORS)

A	TERM
ac	Alternating current
A/C	Air conditioning
ACU	Analog comparator unit
ACC	Accumulator
A/D	Analog to digital
ADS	Automatic depressurization system
AHU	Air handling unit
AID	Alarm initiated display
ALF	Automatic load following
AO	Air operator
APF	Axial peaking factor
APLHGR	Average planar linear heat generation rate
APRM	Average power range monitor
ARM	Area radiation monitor
ASM	Auxiliary select module
ATWS	Anticipated transient without scram
ATWS-RPT	Anticipated transient without scram recirculation pump trip
B	
BAF	Bottom of active fuel
BOC	Beginning of cycle
BOL	Beginning of life
BOP	Balance of plant
BPV	Bypass valve
BUOT	Backup overspeed trip
BWR	Boiling water reactor
C	
CAEQ	Core average exit quality
CB	Circuit breaker
CCGC	Containment combustible gas control
CCW	Closed cooling water or Condenser circulating water
C/D	Cooldown
CIV	Combined intermediate valve
CMFLPD	Core maximum fraction of limiting power density
CMPF	Core maximum peaking factor
cpm	Counts per minute

EOC-RPT	End of cycle recirculation pump trip
EOF	Emergency operations facility
E/P	Electrical/pneumatic
EPR	Electric pressure regulator
ERF	Emergency response facility
ERFIS	Emergency response facility information system
ESF	Engineered safety feature
ETS	Emergency trip system
ETV	Electric trip valve
<u>F</u>	
FB	Fuel building
FCPM	Feedwater corrosion product monitor
FCU	Fan coil unit
FCV	Flow control valve
F/D	Filter/demineralizer
FLC	Fuel loading chamber
FPCC	Fuel pool cooling and cleanup
FS	Flow switch
FSCRD	Fast scram control rod drive
FT	Flow transmitter
FWCI	Feedwater coolant injection (BWR/2, BWR/3)
FWCS	Feedwater control system
FWCV	Feedwater control valve
FWOL	Fuel warranty operating limits
<u>G</u>	
GAF	Gain adjustment factor
GEXL	General Electric critical quality (X_c)-boiling length (LB) correlation
GM	Geiger-Mueller
gpm	Gallons per minute
GSLO	Gland seal leak off
<u>H</u>	
HAD	Heat actuated device
HCU	Hydraulic control unit
HEPA	High efficiency particulate air
HIS	Hydrogen ignition system
HO	Hydraulic operator
HP	High pressure
HPCI	High pressure coolant injection
HPCS	High pressure core spray (BWR/5, BWR/6)
HPSP	High power setpoint

HPSU	Hydraulic power supply unit
HPU	Hydraulic power unit
H/U	Heat-up
HVAC	Heating, ventilation, and air conditioning
HX	Heat exchanger
<u>I</u>	
IC	Isolation condenser (BWR/2, BWR/3)
I/O	Input/output
I/P	Current/pneumatic
IRM	Intermediate range monitor
IV	Intercept valve
<u>K</u>	
kV	Kilovolts
kW	Kilowatts
<u>L</u>	
LBS	Load break switch
LCR	Log count rate
LD	Leak detection
LED	Light emitting diode
LFMG	Low frequency motor generator (BWR/5, BWR/6)
LHGR	Linear heat generation rate
LI	Level indicator
LIC	Level indicating controller
LIS	Level indicating switch
LITS	Level indicating transmitting switch
LOCA	Loss of coolant accident
LOPP	Loss of preferred power
LP	Low pressure
LPAP	Low power alarm point
LPCI	Low pressure coolant injection
LPCS	Low pressure core spray (BWR/5, BWR/6)
LPF	Local peaking factor
LPRM	Local power range monitor
LPSP	Low power setpoint
LR	Liquid radwaste or Load reject
LS	Level switch
LT	Level transmitter
LTNGP	Low temperature noble gas process
LU	Logic unit
LVDT	Linear variable differential transformer

LVT	Linear velocity transformer
LWR	Light water reactor
<u>M</u>	
M/A	Manual/automatic
MAPLHGR	Maximum average planar linear heat generation rate
MAT	Main auxiliary transformer
MCC	Motor control center
MCPR	Minimum critical power ratio
MFLCPR	Maximum fraction of limiting critical power ratio
MG	Motor generator
MLV	Mechanical lockout valve
MO	Motor operator
MOV	Motor operated valve
MPR	Mechanical pressure regulator (BWR/2, BWR/3)
MS	Main steam
MSIV	Main steam isolation valve
MSIV-LCS	Main steam line isolation valve leakage control system
MSL	Main steam line
MSOP	Main shaft oil pump
MSR	Moisture separator reheater
MSSV	Main steam shutoff valve
MSV	Mean square voltage
MTH	Manual trip handle
MTP	Mechanical trip piston
MTPV	Mechanical trip pilot valve
MTSV	Mechanical trip solenoid valve
MTU	Master test unit
MTV	Mechanical trip valve
MWe	Megawatt electric
MWt	Megawatt thermal
<u>N</u>	
NAACP	Normal auxiliary ac power
NCC	Nuclenet control console (BWR/6)
NDL	Nuclear data link
NDTT	Nil ductility transition temperature
NMS	Neutron monitoring system
NPSH	Net positive suction head
NRHX	Nonregenerative heat exchanger
NSPS	Nuclear safety protection system (BWR/5, BWR/6)
NSS	Nuclear steam system
NSSS	Nuclear steam supply system

NSSSS	Nuclear steam supply shutoff system (BWR/5, BWR/6)
nv	Neutron flux

O

OCM	Operator control module
OD	On demand
ODYN	One dimensional core transient model
OG	Offgas
OI	Optical isolator
OSC	Operational support center
OST	Overspeed trip
OSTV	Oil trip solenoid valve
OTB	Onset of transition boiling

P

P/B	Pushbutton
PC	Process computer or Primary containment
PCI	Pellet cladding interaction
PCIOMR	Pre-conditioning interim operating management recommendation
PCIS	Primary containment isolation system
PCT	Peak cladding temperature
PCV	Pressure control valve
PGCC	Power generation control complex (BWR/6)
PI	Pressure indicator
PIS	Pressure indicating switch
PLU	Power load unbalance
PMS	Performance monitoring system (BWR/6)
PP	Power panel
ppb	Parts per billion
ppm	Parts per million
PRM	Process radiation monitor
PS	Pressure switch
PT	Pressure transmitter

R

RACS	Rod action control system
RAT	Reserve auxiliary transformer
RAU	Remote analog unit
RBCCW	Reactor building closed cooling water
RBEDT	Reactor building equipment drain tank
RBM	Rod block monitor
RCIC	Reactor core isolation cooling
RCIS	Rod control and information system

RDA	Rod drop accident
RDM	Rod display module
RDU	Remote digital unit
RECHAR	Recomber charcoal adsorber
RFC	Recirculation flow control
RFP	Reactor feed pump
RFPT	Reactor feed pump turbine
RGDS	Rod gang drive system (BWR/6)
RHR	Residual heat removal
RHRSW	Residual heat removal service water
RHX	Regenerative heat exchanger
RIS	Rod interface system
RM	Radiation monitoring
RMCS	Reactor manual control system
RMS	Remote manual switch
RPC	Rod pattern controller
RPF	Radial peaking factor
RPIS	Rod position information system
rpm	Revolutions per minute
RPS	Reactor protection system
RPT	Recirculation pump trip
RPV	Reactor pressure vessel
RSCS	Rod sequence control system (BWR/4, BWR/5)
RSS	Remote shutdown system
RTD	Resistance temperature detector
RVDT	Rotary variable differential transformer
RWB	Rod withdraw block
RWCU	Reactor water cleanup
RWM	Rod worth minimizer
RX	Reactor

S

SACPS	Standby ac power system
SBS	Static bypass switch
SCM	Steam condensing mode
SCR	Silicon control rectifier
S/D	Shutdown
SDC	Shutdown cooling
SDM	Shutdown margin
SDIV	Scram discharge instrument volume
SDV	Scram discharge volume
SGTS	Standby gas treatment system
SIA	Service and instrument air

SIP	Standby information panel
SJAE	Steam jet air ejector
SLC	Standby liquid control
SLF	Steam line flow
SLP	Steam line pressure
SP	Suppression pool
SPC	Suppression pool cooling
SPDS	Safety parameter display system
SPE	Steam packing exhauster
SPMS	Suppression pool makeup system
SRM	Source range monitor
SRV	Safety /relief valve
SSE	Steam seal evaporator or Safe shutdown earthquake
SSR	Steam seal regulator
SSW	Station service water
SSWS	Standby service water system
S/U	Startup
SUS	Secondary unit substation
SV	Stop valve
<u>T</u>	
TAF	Top of active fuel
TBCCW	Turbine building closed cooling water
TCV	Temperature control valve
TD	Time delay
TG	Turbine generator
TGOP	Turning gear oil pump
TGSS	Turbine gland sealing system
TIP	Traversing incore probe
TLO	Turbine lube oil
TPF	Total peaking factor
TSC	Technical support center
<u>U</u>	
UHS	Ultimate heat sink
UPS	Uninteruptible power supply
<u>V</u>	
Vac	Volts alternating current
Vdc	Volts direct current

BWR TECHNOLOGY COURSE (R104B) FOR BWR/4 DESIGN

PURPOSE AND OBJECTIVE SHEETS

"PURPOSE" SECTION:

This section of each sheet gives the system purposes as appropriate.

"OBJECTIVES" SECTION:

This section of each sheet gives the specific lesson objectives for each subject listed in the course outline schedule. These objectives define the material to be covered in the lesson and the level of knowledge the student should be able to exhibit upon completion of the instructor's presentation and self-study by the student.

BWR Introduction

Purpose:

To economically generate electrical power through the use of the direct cycle boiling water reactor (BWR) system design.

This design includes the nuclear fuel and internal structures within the reactor pressure vessel, systems associated with a basic steam cycle, normal auxiliary systems to accommodate the operational requirements of the plant, engineered safety systems to accommodate the safeguard requirements of the plant, and the necessary instrumentation and controls to accommodate operator control of the plant.

Lesson objectives:

1. State the three BWR reactivity coefficients and their relative magnitudes.

2. Explain the basic steam cycle as applied to BWR systems.

3. State which BWR control systems are used for the following important functions:
    a. Control of reactor power
    b. Control of reactor pressure (normal situations)
    c. Control of reactor water level

4. State the type of containment package which is provided and explain the following terms:
    a. Drywell
    b. Suppression pool
    c. Containment

5. List the four emergency core cooling systems and state which are high pressure systems and which are low pressure systems.

Reactor Vessel System (2.1)

Purposes:

1. To house and support the reactor core.
2. To provide water circulation to the reactor core to remove generated heat.
3. To separate the water and steam produced in the reactor core and deliver dry steam to the main steam system.
4. To provide an internal, refloodable volume to assure core cooling capability following a loss of coolant accident (LOCA).

Lesson objectives:

1. State the system purposes.
2. Describe how the system accomplishes its purpose.
3. Describe the internal components and their arrangement that provide the 2/3 core coverage capability following a loss of coolant accident (LOCA).

Fuel (2.2)

Purpose:

To generate energy from a nuclear fission reaction to provide heat for steam generation.

Lesson objectives:

1. State the system's purpose.

2. Describe the physical arrangement of:

   a. The fuel assemblies in the reactor vessel.
   b. A fuel rod and its internal components.

3. Explain why burnable poison is added to BWR fuel.

Control Rods (2.2)

Purposes:

1. To control reactor power level.
2. To control reactor power distribution.
3. To provide emergency shutdown capability.

Lesson objectives:

1. State the system's purposes.
2. Describe the physical arrangement of the control rods in the reactor vessel.
3. State the purpose of the following major system components:

   a. Absorber rods
   b. Coupling assembly
   c. Control rod velocity limiter

Control Rod Drive (CRD) System (2.3)

Purposes:

To position control rods to:

- a. Change reactor power.
- b. Rapidly shutdown the reactor.

Lesson objectives:

1. State the system's purposes.

2. Describe how the system accomplishes its purpose.

Recirculation System (2.4)

Purpose:

1. To provide forced circulation of water through the reactor core, permitting higher reactor power than with natural circulation.
2. To change reactor power.

Lesson objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Main Steam System (2.5)

Purposes:

1. To direct steam from the reactor vessel to the main turbine and other steam loads.
2. To provide overpressure protection for the reactor coolant system.

Lesson objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Condensate and Feedwater System (2.6)

Purposes:

1. To condense steam and collect drains in the main condenser
2. To purify, preheat, and pump water from the main condenser to the reactor vessel.

Lesson objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Reactor Core Isolation Cooling (RCIC) System (2.7)

Purposes:

To provide makeup water to the reactor vessel for core cooling when:

1. The main steam lines are isolated.
2. The condensate and feedwater system is not available.

Lesson Objectives:

1. State the system's purpose.
2. Describe how the system accomplishes its purpose.

REACTOR WATER CLEANUP (RWCU) SYSTEM (2.8)

Purposes:

1. To maintain reactor water quality by filtration and ion exchange.
2. To provide a path for removal of reactor coolant when required.

Lesson Objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Reactor Vessel Instrumentation System (3.1)

Purpose:

To provide sufficient information concerning reactor vessel water level,reactor vessel pressure, reactor vessel temperature, and core flow rate, to allow safe plant operation.

Objectives:

1. Know the parameters monitored.
2. Describe how the system accomplishes its purpose.

Electro Hydraulic Control (EHC) System (3.2)

Purposes:

1. To provide normal reactor pressure control by controlling steam flow consistent with reactor power.

2. To provide the ability to roll and synchronize the turbine generator and conduct a plant cooldown.

Lesson Objectives:

1. State the system's purposes.

2. Describe how the system accomplishes its purpose.

Feedwater Control System (FWCS) (3.3)

Purpose:

To control the rate of feedwater flow to the reactor vessel to maintain the proper vessel water level.

Lesson Objectives:

1. State the system's purpose.
2. List the parameters used by the system.
3. Describe how the system accomplishes its purpose.

Containment Systems (4.0-4.4)

Purposes:

1. To contain fission products such that radiation dose limits are not exceeded.
2. To provide a source of water for emergency core cooling systems and the Reactor Core Isolation Cooling System.
3. To provide a heat sink for certain safety related equipment.

Lesson Objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.
3. Explain what constitutes the primary containment boundary and the secondary containment boundary.

Neutron Monitoring System (NMS) (5.0)

Purposes:

1. To monitor reactor core neutron flux and provide indication during shutdown, startup, heatup, and power operation.
2. To provide trip signals to the reactor protection system to prevent fuel damage due to excessive power.

Lesson Objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Reactor Manual Control System (RMC) (7.1)

Purposes:

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.

Lesson Objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Recirculation Flow Control (RFC) System (7.2)

Purpose:

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

Lesson Objectives:

1. State the system's purpose.
2. Describe how the system accomplishes its purpose.

Reactor Protection System (RPS) (7.3)

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.

Lesson Objectives:

1. State the system's purposes.
2. Describe how the system accomplishes its purpose.

Standby Liquid Control (SLC) System (7.4)

Purpose:

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

Lesson Objectives:

1. State the system's purpose.
2. Describe how the system accomplishes its purpose.

Emergency Core Cooling Systems (ECCS) (10.0-10.4)

Purpose:

1. To provide core cooling under loss of coolant accident conditions to limit fuel cladding damage.
2. The High Pressure Coolant Injection System back up the Reactor Core Isolation Cooling System.

Lesson Objectives:

1. State the system's purpose.
2. List the systems which comprise the ECCS.
3. Describe how the system accomplishes its purpose.
4. List the automatic initiation signals for ECCS system.

Residual Heat Removal (RHR) System — Other Modes (10.4)

Purposes:

1. Containment spray mode:

   To reduce primary containment pressure and temperature following a loss of coolant accident (LOCA).

2. Suppression pool cooling mode:

   To remove heat from the suppression pool.

3. Shutdown cooling and head spray mode:

   a. To remove decay heat from the reactor core following a reactor shutdown.
   b. To remove residual heat from upper reactor vessel internals during a cooldown.

4. Steam condensing mode:

   To provide a means of reactor pressure control when the main condenser is not available.

5. Standby coolant supply:

   To provide a means of flooding the primary containment.

Lesson Objectives:

1. State the purpose of each system mode of operation.
2. Describe how the system accomplishes its purpose.