SECTION 11.0

POWER CONVERSION SYSTEMS

11.1 SUMMARY DESCRIPTION

The components of the steam and power conversion system of each unit are identical and are designed to produce electrical power from the steam coming from the reactor, condense the steam into water, and return the water to the reactor as heated feedwater with a major portion of its gaseous, dissolved, and particulate impurities removed.

The power conversion system includes the turbine-generator, main condenser, air ejector and turbine gland seal condensers, turbine bypass system, condensate filter-demineralizers, and the feedwater pumping and heating system. The heat rejected to the main condenser is removed by a circulating water system.

Steam is generated in the reactor and is supplied to the high-pressure section of the turbine. Steam leaving the high-pressure turbine passes through moisture separators prior to admission to the low-pressure sections of the turbine. A portion of the turbine steam is extracted for feedwater heating, is condensed, and cascades through the feedwater heaters to the main condenser.

Steam is also used to drive the reactor feed pump turbines, preheat off-gas to the recombiner, seal the main turbine, and drive the steam jet air ejectors.

The exhaust steam from the low-pressure turbines is condensed and deaerated in the main condenser. The condensate pumps, taking suction from the condenser hotwell, deliver the condensate through the air ejector condensers, turbine gland seal condensers, condensate filter-demineralizers, and the feedwater heaters to the reactor feed pumps. The reactor feed pumps are steam turbine driven and discharge feedwater directly to the reactor.

Normally, the turbine utilizes all the steam being generated by the reactor; however, an automatic pressure-controlled steam bypass system is provided to discharge excess steam directly to the condenser.

11.2 TURBINE-GENERATOR

11.2.1 Power Generation Objective

The power generation objective of the turbine-generator is to receive steam from the nuclear boiler and convert the contained heat energy to electrical energy.

11.2.2 Power Generation Design Basis

The turbine-generator was designed using the following conditions:

Turbine Nameplate Rating	1,360,316 kW
Inlet Steam Conditions	
Flow	16,188,164 lb/hr
Pressure	961.5 psia
Quality	0.59% moisture
Exhaust Pressure	1.5 in Hg Abs

11.2.3 Description

The turbine-generator consists of the turbine, generator, exciter, controls, and required subsystems (Drawing M-303, Sheets 1 through 4).

The 1,800 rpm, tandem-compound, six flow, non-reheat steam turbine has 57-inch last stage blades. The maximum expected capacity with valves wide open is 1,402,953 kW.

The main turbine includes one double-flow, high-pressure turbine and three double-flow, low-pressure turbines. Exhaust steam from the high-pressure turbine passes through moisture separators before entering the three low-pressure turbines. The separators reduce the moisture content of the steam to less than 2 percent.

The generator is a direct-driven, three-phase, 60-Hz, 22,000 volt, 1,800 rpm, conductor cooled, 75 psig hydrogen pressure, synchronous generator. The generator is rated at 1,530 MVA with a 0.98 power factor (primary rating), 0.994 power factor (secondary rating), and a 0.50 short circuit ratio for Unit 2 and 1,530 MVA with a 0.90 power factor and a 0.540 short circuit ratio for Unit 3. The generator-exciter system is the Alterrex type, rated at 5,098 KVA at 0.96 power factor and 568 volts.

The turbine-generator utilizes an electrohydraulic control system (EHCS) which controls the speed, load, frequency, steam pressure

and flow for startup and planned operations. Additionally, it provides for valve chest and high-pressure shell pre-warming in order to reduce high thermal stresses during a cold start of the turbine. Also, the control system provides a Diverse Turbine Overspeed Protection System (DTOPS) electrical overspeed trip and backup electrical overspeed trip. The electrohydraulic system operates the turbine stop valves, bypass valves, control valves, combined intermediate valves, and other protective devices. Subsection 7.11, "Pressure Regulator and Turbine-Generator Control," describes in detail the functions of the turbine control system.

The provisions for overspeed control and protection of the turbine include three automatic independent lines of defense which are normally in operation as described below:

1. First, during normal operation turbine overspeed is precluded by the governing action of the EHCS, which modulates the control and intercept valves. Speed sensing for this control system is provided three magnetic pickups in conjunction with a toothed wheel on the main turbine shaft.

2. The second line of defense against turbine overspeed is the overspeed trip system comprising a DTOPS diverse electrical trip system. The initiating device de-energization of at least two of the three solenoids in the ETS Testable Dump Manifold (TDM).

3. The third line of defense is provided by the backup overspeed trip. This is an independent electrical tripping function in which three separate magnetic pickups sense the speed of the toothed wheel on the main turbine shaft. The DTOPS and backup electrical overspeed trip systems constitute diverse and independent means of protection for the turbine against overspeed condition.

Overspeed Protection Inherent in the Normal Operating Control System

Under normal operation, turbine overspeed is precluded by the governing action of the EHCS. Speed sensing for this control system is provided by three magnetic pickups in conjunction with the toothed wheel on the main turbine shaft. Failure of 2-of-the-3 speed signals results in a turbine trip. The circuitry for these control signals is isolated from, and independent of, the backup electrical overspeed trip circuitry.

Primary Electrical Overspeed Trip

The diverse electrical overspeed trip is provided by a Diverse Turbine Overspeed Protection System (DTOPS). DTOPS uses a diverse and separate set of magnetic pickups which are comprised of 3 passive speed sensors for sensing speed from a toothed wheel mounted to the turbine abaft. When the turbine speed reaches the trip speed (approximately 109%), the three independent overspeed protection trip modules located inside the DTOPS device provides three independent trip outputs that interface to the three ETS Testable Dump Manifold (TDM) solenoids. The ETS TDM utilizes a two-out-of-three (2/3) trip logic configuration to depressurization ETS fluid resulting in fast closure of the main stop valves, the control valves, the intercept valves, and the intercept stop valves.

Backup Electrical Overspeed Trip

The backup electrical overspeed trip uses a diverse and separate set of magnetic pickups which are comprised of 3 active speed sensors for sensing speed from a toothed wheel mounted to the turbine shaft. When the turbine speed reaches the trip speed (approximately 110.5%), the Turbine Control System (TCS) provides a trip output to the TCS TDM unit, which utilizes a two-out-of-three (2/3) trip logic configuration to trip the turbine.

Cross trip functions are provided for interlocking the DTOPS trip with the TCS trip.

11.2.4 Power Generation Evaluation

The original turbine inspection program, used a probabilistic approach for the scheduling of the inspection and replacement of the low pressure turbine rotors with shrunk-on discs. This turbine inspection program was based upon the General Electric Company proprietary report titled Probability of Missile Generation in General Electric Nuclear Turbines. This methodology was reviewed by the NRC staff and found acceptable for use in establishing maintenance and inspection schedules for specific turbine systems (NUREG-1048, Safety Evaluation Report related to the operation of Hope Creek Generating Station Supplement No.6, July 1986).

The intent of the program evaluated in NUREG-1048 is to assure that the probability of a turbine generating a missile is consistent with sections 3.5.1.3 and 2.2.3 of the Standard Review Plan. The program takes into account specific turbine wheel operating conditions, material properties, results of periodic in-service inspections, and other factors. The program's determination of missile probability is based upon the probabilities of individual parameters which may lead to the

generation of a turbine missile. As a result, the program can facilitate evaluations of the effects of changes in any parameter. Table 11.2.1, Turbine System Reliability Criteria has been extracted from NUREG-1048, Table U.1, for use with an unfavorably oriented turbine.

The low pressure turbines have since been replaced with Alstom rotors of the welded design. The General Electric Company proprietary report titled Probability of Missile Generation in General Electric Nuclear Turbines is no longer applicable. Inspections for the Alstom rotors should follow Alstom Report ST00012829, "Peach Bottom Unit 2 & 3 LP Retrofit - Missile Analysis" (SOOC #E-091-VC-44). Table 11.2.1 is still applicable for the LP Turbine rotors as the Alstom approach follows NUREG-0800, Standard Review Plan.

An evaluation has been performed for the turbine-driven feedpumps, HPCI, and RCIC. Wheel average tangential stresses in the feedpump, HPCI, and RCIC turbines are sufficiently low that wheel failure is not predicted even at the theoretical runaway condition of twice-rated speed. An assumed failure of a feedpump turbine, located in the turbine building, is evaluated as a lesser case of the main turbine already discussed. Additionally, the HPCI and RCIC turbines are located in separate concrete rooms within the reactor building. Therefore, failure of these turbines is considered so improbable as to be of no consequence with respect to becoming a potential missile or affecting safe shutdown of the plant.

The following abnormal operational transient analyses have been assessed for a component failure in the turbine-generator system, and Section 14.0, "Plant Safety Analysis", discusses the results:

1. Load rejection (45 percent for turbine control valve fast closure).

2. Turbine or generator trip (turbine stop valves closure).

    a. Turbine trip high power with bypass.

    b. Turbine trip from high power without bypass.

    c. Turbine trip from low power without bypass.

3. Loss of main condenser vacuum.

4. Closure of all MSIV's.

5. Closure of one MSIV.

6. Pressure regulator failure.

7. In addition, operation with one turbine stop valve or one turbine control valve closed has been evaluated. Limits for operation in this configuration are discussed in Section 14.5.2.2.

TABLE 11.2.1

TURBINE SYSTEM RELIABILITY CRITERIA

Probability, yr^{-1}	Unfavorably oriented turbine	Required action
(A)	$P_1 < 10^{-5}$	This is the general, minimum reliability requirement for loading the turbine and bringing the system on line.
(B)	$10^{-5} < P_1 < 10^{-4}$	If this condition is reached during operation, the turbine may be kept in service until the next scheduled outage, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion (above) before returning the turbine to service.
(C)	$10^{-4} < P_1 < 10^{-3}$	If this condition is reached during operation, the turbine is to be isolated from the steam supply within 60 days, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion (above) before returning the turbine to service.
(D)	$10^{-3} < P_1$	If this condition is reached at any time during operation, the turbine is to be isolated from the steam supply within 6 days, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion (above) before returning the turbine to service.

11.3 MAIN CONDENSER

11.3.1 Power Generation Objective

The power generation objective of the main condenser is to provide a heat sink for the turbine exhaust steam, turbine bypass steam, and other flows. It also deaerates and stores the condensate for reuse after a period of radioactive decay.

11.3.2 Power Generation Design Basis

1. The condenser is capable of accepting the heat load at design conditions.

2. The condenser is capable of accepting up to 21.96 percent of the main steam flow, at design conditions, through the turbine bypass system without decreasing condenser vacuum or increasing the turbine exhaust temperature beyond the turbine trip setpoints.

3. The condenser is designed to deaerate the condensate to provide feedwater of required quality, and to remove non-condensible gases from the condensing steam and air in-leakage.

4. The condenser is designed to store a sufficient volume of condensate and provide at least a 2-min retention time of the condensate for radioactive decay.

11.3.3 Description

The main condenser produces a maximum back pressure of 5.0 inches Hg Abs when operating at Design Core Thermal Power with 90°F design value for circulating water inlet temperature and 65 percent clean tubes. Refer to Table 11.3.1 for the condenser design parameters. With a circulating inlet temperature of 56°F and a flow rate of 756,000 gpm, the approximate expected nominal condenser back pressure, at rated Core Thermal Power, is 2.1 inches Hg Abs. With a circulating water inlet temperature of 82°F and a flow rate of 756,000 gpm, the approximate expected nominal condenser back pressure, at rated Core Thermal Power, is 3.7 inches Hg Abs.

The main condenser is a single pass, single pressure, deaerating type with a reheating deaerating hotwell and divided waterboxes. The condenser consists of three sections, each section located below the low-pressure elements of the turbine, with the tubes oriented transverse to the turbine-generator axis. The steam exhausts directly down into the condenser shells through exhaust

openings in the bottom of each low-pressure turbine casing. A large access hatch (24 in x 36 in) is located approximately 18 in above the top of the condenser tubes permitting safe and convenient access for personnel and materials. The condensers are supported on a foundation. Rubber expansion joints are provided between each turbine exhaust opening and the s\team inlet connections in the condenser shells. The condensers also receive steam from the feed pump turbines.

The condenser hotwells have vertical dividing plates along the axis of the tubes. Each half of the hotwell is provided with horizontal and vertical baffles which, together with the storage capacity of the hotwells, ensure a minimum retention time of 2 minutes for condensate from the time it enters the hotwell until it is removed by the condensate pumps.

The divided water boxes, each provided with an inlet circulating water valve, permit individual operation or removal from service of either half of each of the condensers. Condenser tubes are titanium and are expanded and welded into titanium tube sheets.

Air in-leakage plus the hydrogen and oxygen gases contained in the turbine steam due to dissociation of water in the reactor is removed from the condenser by the steam jet air ejectors.

The condenser is capable of maintaining dissolved oxygen levels for the condensate at the condensate pump discharge to 0.0035 cc/liter (5 ppb) at all loads and any expected circulating water temperature over the operating range. Reheating steam coils are provided in the hotwells to assist deaeration at partial loads up to 70 percent of rated load.

For overpressure protection of the condenser, in the event the turbine steam bypass valves fail to close on a loss of condenser vacuum, two rupture diaphragms are provided on each condenser shell.

TABLE 11.3.1

MAIN CONDENSER

Type	Single Pass, Single Pressure Three Shells
Effective Surface	718,590 sq ft
Condenser Unit	9.21×10^9 Btu/hr
Rated Back Pressure	5.0 inches Hg Abs
Circulating Water Temp. (inlet)	90°F
Tube Water Velocity	6.5 fps
Material, Shell:	Carbon Steel
Tube Material/Thickness	Titanium/22 BWG
Tube Size	1 in O.D.
Overall Tube Length	50.0 ft
Cleanliness Factor	65%
Rated Maximum Free Oxygen in Condensate	0.0035 cc/liter
Hotwell Storage Capacity at Minimum Level	90,000 gal

11.4 MAIN CONDENSER GAS REMOVAL AND SEALING STEAM SYSTEMS

11.4.1 Power Generation Objective

The power generation objective of the main condenser gas removal system is to remove non-condensible gases from the condenser.

The power generation objective of the sealing steam system is to prevent air leakage into, or steam leakage out of, the main turbine; reactor feed pump turbines and the main turbine steam valves.

11.4.2 Power Generation Design Basis

1. The main condenser gas removal system removes non-condensibles from the condenser, including air in-leakage and dissociation products originating in the reactor, and exhausts the non-condensible gases to the gaseous radwaste system during operation, and to the off-gas system during startup or shutdown.

2. The sealing steam system seals the main turbine; the reactor feed pump turbines and main turbine steam valves. The steam from the sealing system is returned to the main condenser, via the condensate drain tank. Non-condensibles are exhausted to the main stack via the steam packing exhausters.

11.4.3 Description

11.4.3.1 Main Condenser Gas Removal System

Steam jet air ejectors, complete with inter- and after-condensers, are provided to remove air and non-condensibles from the main condensers during power operation. A mechanical vacuum pump is provided for startup and shutdown Drawing M-310, Sheets 1 through 4).

11.4.3.1.1 Steam Jet Air Ejectors

Two sets of two-stage air ejectors with inter- and after-condensers are provided. One set is on standby, and is manually placed in service when required. The air ejectors remove gases and vapors from the main condenser using main steam, reduced in pressure, as the driving medium, and deliver non-condensible gases to the gaseous radwaste system. The inter- and after-condensers use condensate as their cooling medium.

The air ejector discharge is monitored for radioactivity prior to entering the gaseous radwaste system. An alarm is provided to annunciate high radiation levels.

The air ejectors are manually isolated on high radiation levels, since the delay provided by the gaseous radwaste system allows time to close the isolation valves. (See paragraph 9.4.5, "Air Ejector Off-Gas Subsystem", and paragraph 7.12.2A, "Air Ejector Off-Gas Radiation Monitoring System.")

11.4.3.1.2 Mechanical Vacuum Pump

A mechanical vacuum pump removes air and non-condensible gases from the main condenser during startup and shutdown, when adequate steam pressure is not available to establish vacuum conditions using the steam jet air ejectors. The discharge from the pump is routed to the off-gas stack.

The mechanical vacuum pump is provided with isolation instrumentation to trip the air inlet valve to the vacuum pump and trip the pump motor upon sensing low seal water flow or a main steam high radiation signal (subsection 7.12, "Process Radiation Monitoring").

11.4.3.2 Sealing Steam System

The sealing steam system consists of a steam seal pressure regulator for supplying steam to the seals on the main turbine, the reactor feed pump turbines and main turbine steam valves at a pressure slightly above atmosphere, and a steam packing exhauster and condenser which collects and condenses sealing steam and discharges non-condensibles to the main stack. Main steam is the source of sealing steam, except during startup periods when auxiliary steam is used. The gland seal condenser uses the condensate pump discharge as its cooling medium after it passes through the air ejector condensers. Two full-capacity steam packing exhauster and condenser units are provided. The standby unit is put into service manually.

11.5 TURBINE BYPASS SYSTEM

11.5.1 Power Generation Objective

The power generation objective of the turbine bypass system is to dissipate directly to the condenser that amount of main steam generated by the reactor which cannot be utilized by the turbine (up to 22.39 percent of the design flow.

11.5.2 Power Generation Design Basis

1. The turbine bypass system controls reactor pressure during reactor heatup to rated pressure, while the turbine is brought up to speed and synchronized, during power operation when the reactor steam generation exceeds the transient turbine steam requirements, and when cooling down the reactor.

2. The turbine bypass system capacity is based on 22.39 percent of design main steam flow for. The system works in conjunction with the turbine control system and the pressure regulator.

3. The turbine bypass system valves are capable of being tested.

11.5.3 Description

The turbine bypass system consists of nine modulating-type hydraulically actuated control valves mounted on a valve manifold. The manifold is connected with two steam lines to the four main steam lines upstream of the turbine stop valves. Each control valve outlet is piped to the main condenser, and a pressure reducing orifice is located at the condenser connection.

The system works in conjunction with the turbine control valves to accommodate a 22.39 percent load rejection without causing a total reactor steam flow change.

The turbine bypass system receives from the turbine control system a signal corresponding to the mismatch between the turbine control valve opening required by the pressure regulator and the actual turbine control valve position. The opening of a turbine bypass valve is indicated on the main turbine annunciator panel. For control of momentary differences during normal operational transients, an adjustable bias signal is provided to maintain the bypass valves closed.

Provisions are made for remote manual opening of the bypass valves for plant startup and shutdown. During planned operations, each bypass valve can be tested independently and remotely. During the test, the stroke time of valves is increased to limit the rate of change of bypass flow. The bypass valve positions are indicated in the main control room.

11.5.4 Power Generation Evaluation

The effects of malfunctions of the turbine bypass system valves, and the effects of such failures on other components are evaluated in Section 14.0, "Plant Safety Analysis."

11.6 CIRCULATING WATER SYSTEM AND COOLING TOWERS

11.6.1 Power Generation Objective

The power generation objective of the circulating water system is to provide the main condenser with a continuous supply of cooling water for removing the heat rejected by the turbine or turbine bypass system. Cooling towers are installed to remove a portion of the heat from the circulating water system prior to discharge to the river.

11.6.2 Power Generation Design Basis

1. The circulating water system provides the required water flow to the condenser.

2. The cooling towers are available to limit the temperature of cooling water discharged to the Conowingo Pond.

11.6.3 Description

The circulating water system is designed for open cycle (once through) operation with three mechanical draft, cross-flow type cooling towers available to limit the discharge temperature. Water passes through the intake screen structure, enters the intake pond, and goes into the pump structure, which houses the circulating water pumps and service water pumps. The circulating water pumps deliver water to the main condensers. The condenser discharge flows into the discharge pond. A portion of the warm water may be pumped through the cooling towers before entering the discharge canal (Drawings M-312, Sheets 1 and 2, M-322, Sheets 1 and 2). Cooling towers are operated in accordance with the station NPDES permit. The circulating water system cooling towers and associated mechanical and electrical equipment are seismic Class II.

The intake screen structure has 24 traveling water screens. A screen wash and trash handling system is provided. The intake pond is divided into two sections. A cross tie gate between the Unit 2 intake canal and the discharge pond can be opened to provide recirculation heating to intake water during winter months to minimize the formation of frazil ice and also to provide a backup water supply to the intake pond if the outer screen structure should become clogged. The pump structure houses three circulating water pump bays and one service water bay (housing both service water and high-pressure service water pumps) for each unit, and an emergency service water pump bay subdivided into two sections. Each circulating water pump bay is provided with its own traveling screen. Two additional traveling water screens

serve each unit's service water bay and emergency service water pump.

Three circulating water pumps of the vertical, mixed-flow type, each rated at 250,000 gpm, are provided for each unit (Table 11.6.1).

Three cooling tower pumps of the vertical, mixed-flow type are provided for the two units (Table 11.6.2). Pumps A, B, and C are each rated at 292,000 gpm.

Cooling tower pumps A, B, and C are each located in a pump structure adjacent to the respective cooling tower.

In the event of LOCA on either unit, all cooling tower pumps and fans are automatically shed.

11.6.4 Power Generation Evaluation

The circulating water flow is 750,000 gpm per unit. The design conditions for the three cooling towers are listed in Table 11.6.3. The cooling towers are operated in accordance with the station’s NPDES permit.

TABLE 11.6.1

CIRCULATING WATER PUMPS

Number of Pumps/Unit	3
Pump	
Type	Wet Pit, Mixed Flow
Rated Flow and Head	250,000 gpm at 25 ft
Rated Speed	200 rpm
Bhp at Rating	1,820 hp
Motor	
Type	Synchronous
Voltage/Phase/Frequency	2,300 V/3 Phase/60 Hz
Rated hp	2,000 hp

TABLE 11.6.2

COOLING TOWER PUMPS

Number of Pumps	3
Pumps A, B, C	
Type	Wet Pit, Mixed Flow
Rated Flow and Head	292,000 gpm at 52 ft
Rated Speed	257 rpm
‘A’ & ‘C’ Bhp at Rating	4,300 Bhp
‘B’ Bhp at Rating	4,400 Bhp
Motors A, B, C	
Type	Synchronous
Voltage/Phase/Frequency	2,300 V/3 Phase/60 Hz
Rated hp	5,000 hp

TABLE 11.6.3

COOLING TOWER

Number of Towers	3
Towers	A,B,C
Type	Crossflow
Cells Per Tower	11
Tower Size, l x w x h overall	515 x 74 x 53 ft
Height, curb to stack/stack	35.3 ft/18 ft
Static Pumping Head Above Curb	30.9 ft
Materials, framework/fill	Treated wood/PVC/fiberglass
Rated Performance	
Water Flow, total for towers	876,000 gpm
Water Temperature, entering/ leaving	105.8°F/92°F
Heat Transfer, total for towers	6.045×10^9 Btu/hr
Wet Bulb Temperature	78°F
Fans	
Number Per Cell	1
Capacity Per Fan	1 at 1,399,320 scfm
Fan hp	200 hp
Fan Blade Material	Glass reinforced polyester

11.7 CONDENSATE FILTER-DEMINERALIZER SYSTEM

11.7.1 Power Generation Objective

The power generation objective of the condensate filter-demineralizer system is to maintain the required purity of feedwater flowing to the reactor.

11.7.2 Power Generation Design Basis

1. The system removes dissolved and suspended solids, fission, corrosion, and activation products from the feedwater to maintain a high purity reactor feedwater.

2. The system provides final polishing of makeup water entering the reactor feedwater loop.

3. The system maintains high purity water rejected to condensate storage and transfer system.

4. Provides polishing of refuel storage tank and condensate storage tank, as required, during power generation.

11.7.3 Description

The condensate filter-demineralizer system consists of 12 filter-demineralizers operating in parallel (Drawing M-311, Sheets 1 through 12, and 15 through 18). In addition to the filter-demineralizers, the condensate filter-demineralizer system includes the associated piping, valves, instrumentation, and controls for proper operation and protection against malfunction.

Equal flow through each on-stream condensate filter-demineralizer is manually controlled by Operations.

The condensate filter-demineralizer system is controlled from local panels. Valves and pumps are remotely operated. Filter differential pressure and conductivity monitors are provided for each filter-demineralizer to indicate when each unit needs regeneration. Suitable alarms and pressure-drop indicators are provided, and system influent and effluent conductivity is monitored. An automatic bypass is provided to maintain the required NPSH to the reactor feed pumps. The bypass opens on high-pressure differential across the filter-demineralizer system. The high-pressure differential and opening of the bypass valve is annunciated.

The condensate filter-demineralizer system is sized to limit the condensate impurity concentration during planned operations and in periods of peak contamination.

The filter-demineralizer does remove radioactive corrosion products and fission products. While radioactivity effects from these sources do not measurably affect the capacity of the resins, concentration of such radioactive material necessitates the shielding provided for the condensate filter-demineralizer equipment (subsection 12.3, "Radiation Shielding"). Waste sludge from the filter-demineralizers is sent to the radwaste system for disposal (Section 9.0, "Radioactive Waste Systems").

* NOTE: For 2 out of 12 condensate filter demineralizers may be operated without precoat

11.8 CONDENSATE AND FEEDWATER SYSTEMS

11.8.1 Power Generation Objective

The power generation objectives of the condensate and feedwater systems are to provide a dependable supply of feedwater to the reactor and to provide feedwater heating.

11.8.2 Power Generation Design Basis

1. The feedwater equipment provides the required flow to the reactor nozzle at 1,060 psig pressure allowing sufficient margin to provide continued flow under anticipated transient conditions.

2. The feedwater heaters provide the required feedwater temperature to the reactor with five stages of closed feedwater heating.

3. A startup recirculation line is provided from the reactor feedwater lines to the condenser hotwell to minimize corrosion product input to the reactor.

11.8.3 Description

The condensate and feedwater systems take condensate from the main condenser and deliver it to the reactor at an elevated temperature and pressure. Condensate is pumped through the steam jet air ejector inter- and after-condensers and the steam packing exhauster by three motor driven vertical condensate pumps, each rated at one-third the total required capacity. After leaving the steam packing exhauster, condensate passes through the full-flow condensate filter-demineralizer system. Demineralizer effluent is then split into three parallel streams, each with five stages of feedwater heating. Feedwater, at the required suction head, then flows to the suction of the feed pumps. The feed pumps are also each rated at one-third the total required capacity. The flow from the three centrifugal turbine driven feedwater pumps goes directly to the reactor (Drawing M-307, Sheets 1 through 6 and Drawing M-308, Sheets 1 through 4). Soluble zinc oxide is injected continuously into the feedwater system to control radiation buildup from cobalt-60 deposition on primary system piping and components. (Drawing M-308, Sheets 7 and 9.)

A portion of the condensate flow is taken from the supply to the steam jet air ejectors and used to cool the off-gas recombiner condenser. The condensate is then returned to the main condenser for re-use in the system.

The hydrogen addition portion of the hydrogen water chemistry system injects hydrogen gas into the suction side of the reactor feed pumps to eliminate the oxidizing chemistry conditions which promote intergranular stress corrosion cracking (IGSCC) of reactor piping and components.

A vent/purge connection is provided which permits the hydrogen piping to be vented to atmosphere during purging. There is a small possibility of a release of slightly contaminated gas and/or water vapor from the vent line. These potential releases have been determined to be insignificant and the vent points will not be added to the ODCM. The vent points will be routinely monitored.

The oxygen addition portion of the hydrogen water chemistry system injects oxygen gas into the suction header of the condensate pump B to maintain the recommended dissolved oxygen level to protect the feedwater piping from general corrosion and prevent the release and subsequent transport of soluble iron to the reactor.

11.8.3.1 Condensate Pumps

Three one-third capacity centrifugal, motor driven, vertical condensate pumps are provided. The condensate pumps provide the required head to overcome the flow and static resistance of the condensate system, and provide excess over the suction pressure requirements of the feedwater pumps. Table 11.8.1 lists the design parameters for the condensate pumps.

11.8.3.2 Feedwater Heaters

Three parallel trains of heaters, each consisting of five feedwater heaters, are provided. The heaters are located before the feedwater pumps. The lowest pressure heater has a separate drain cooler while all others have integral drain coolers. All heaters have welded tube-to-tube sheet construction. Design parameters are listed in Table 11.8.2.

11.8.3.3 Feedwater Pumps

Three horizontal, turbine driven feedwater pumps are provided in the feedwater system. Recirculation control valves are provided in the pump discharge lines to permit direct recirculation of feedwater to the main condenser to assure minimum flow through the feedwater pumps. Design parameters are listed in Table 11.8.3.

11.8.3.4 Reactor Feed Pump Turbine Drives

Individual steam turbines drive the feedwater pumps. The turbine drives are of the dual admission type, and each is equipped with

two sets of main stop and control valves. One set regulates high pressure steam from the reactor, and the other set regulates low pressure steam extracted from the main turbine crossaround piping. Under normal operating conditions the turbine drives run on the low pressure crossaround steam. Reactor steam is used during plant startup, low load, or transient conditions, when crossaround steam is either not available or insufficient. Design parameters are listed in Table 11.8.4.

11.8.3.5 Feedwater Controls

The feedwater control system is described in subsection 7.10, "Feedwater System Control and Instrumentation."

11.8.4 Power Generation Evaluation

An abnormal operational transient analysis for loss of feedwater heating is included in Section 14.0, "Plant Safety Analysis."

The normal feedwater system alignment at full power consists of three reactor feedwater pumps and all of the feedwater heater strings in service. There are occasions when various components, including feedwater heaters and reactor feedwater pumps, are not available. These alternative configurations can have an adverse effect on some safety analyses and require restrictions to be observed. These alternative configurations include: asymmetric feedwater temperature operation (AFTO) and operating with only two reactor feedwater pumps and two feedwater strings in service. These configurations are discussed in Sections 3.7.5.4 and 14.5.2.3.

TABLE 11.8.1

CONDENSATE PUMPS

Number of Pumps/Unit	3
Pump	
Type	Vertical, Multi-Stage, Canned Suction
Rated Flow Total Head	11,600 gpm at 1,380 ft TDH
Rated Speed	1,192 rpm
Bhp at Rating	4,570 Bhp
Motor	
Type	Vertical Induction
Voltage/Phase/Frequency	4,000 V/3 Phase/60 Hz
Rated Continuous Load	5,000 hp

TABLE 11.8.2

FEEDWATER HEATERS

	Stage No. 1	Stage No. 2	Stage No. 3	Stage No. 4	Stage No. 5	Drain Cooler No. 1
Number of Heaters	3	3	3	3	3	3
Type	U-Tube	U-Tube	U-Tube	U-Tube	U-Tube	U-Tube
Position	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Shell Design Pressure						
- psig	50	50	75	125	295	50
- in Hg vac	30	30	30	30	30	30
Temperature, °F	300	300	330	360	420	300
Material	Note 1	Note 2	Note 3	CS	CS	CS
Tube Design:						
Pressure, psig	700	700	700	700	700	700
Material	SS	SS	SS	SS	SS	SS

Note 1: Unit 2 CS
Unit 3 AS

Note 2: 2BE002 AS
Remaining CS

Note 3: 2B/CE003 AS
Remaining CS

KEY: CS = Carbon steel
SS = Stainless steel
AS = Alloy Steel * Unit 2 - 2BE002 FW HTR 3A(B)E002
Unit 3 - 3A/B/CE001 FW HTR
AS = Alloy Steel ** Unit 2 - 2BE003 FW HTR
Unit 2 - 2CE003 FW HTR
Unit 3 - 3A/CE003 FW HTR

TABLE 11.8.3

FEEDWATER PUMPS

Number of Pumps	3
Type	Horizontal, Single Stage, Centrifugal
Rated Capacity	12,270 gpm
Rated Speed	5,400 rpm
Total Head	2,310 ft
Bhp @ Rating	8,000 hp
Inlet Temperature @ Rating	378°F

TABLE 11.8.4

FEEDWATER PUMP TURBINES

Number of Turbines	3
Type	Horizontal, Dual Admission, Multi-Stage
Rated hp	8,500
Rated Speed	5,400 rpm
Low-Pressure Steam Condition	209.7 psia
High-Pressure Steam Condition	965 psia
Rated Back Pressure	1.5 in Hg
Steam Consumption at Rating	96,728 lbm/hr