10.0 STEAM AND POWER CONVERSION SYSTEM

This chapter describes the steam (secondary) cycle for each of the two units. In general, descriptions in this chapter apply equally to either Unit No. 1 or Unit No. 2 except where specifically noted. The systems described in this chapter are included in each unit unless specifically designated as shared.

10.1 GENERAL DESCRIPTIONS

The steam and power conversion system is designed to convert heat produced in the reactor to useful electric energy. Heat in the reactor coolant is transferred to the main steam system in the four steam generators of the reactor coolant system. The turbine cycle can match reactor load changes at a rate of 55 MWe per minute and step load increases of 110 MWe, within the load range of 165 MWe to full load. At a reactor output of 3304 MWt (3468 MWt for Unit 2), sufficient steam is produced to drive a tandem compound reheat steam turbine with an approximate net output of 1114 MWe (1220 MWe for Unit 2) operating in a closed condensing cycle with six stages of regenerative feedwater heating. Exhaust steam is condensed in three surface type steam condensers and returned to the steam generators via the turbine driven main feed pumps. The four-casing, six-flow exhaust, 1800 rpm turbine is directly coupled to a single water-and-hydrogen-cooled generator. The system is designed to receive and dispose of the total heat produced in the reactor coolant system following a rapid shutdown of the turbine generator from any load. Heat dissipation under this condition is accomplished by the steam dump system to the condenser, the steam generator power relief valves, and the steam generator safety valves.

Radiation monitoring of secondary side discharge points is provided and described in Section 10.11.

Turbine driven and motor driven auxiliary feed pumps are provided to ensure that adequate feedwater may be supplied to the steam generators for reactor decay heat removal under all circumstances, including loss of power and loss of the normal heat sink. Auxiliary feedwater flow can be maintained until power is restored or reactor decay heat removal can be accomplished by other systems. Auxiliary feed pumps and piping are designed as Class I components.

10.2 MAIN STEAM SYSTEM

The Main Steam System for Units No. 1 and No. 2 are shown in Figures 10.2-1, 10.2-1A, 10.2-1B and 10.2-1C.

10.2.1 Design Bases

The design bases of the Main Steam System are largely derived from past design experience with fossil fuel stations and have evolved over a long period. They are modified in order to meet special requirements associated with nuclear application and include provisions for specific earthquake, tornado, missile and reactor protection as further described in other sections.

Design codes applicable to the main steam system include, but are not limited to:

a. ASME Boiler and Pressure Vessel Code, Sections III, VIII, and IX.

b. ANSI Power Piping Code B31.1

c. AEP Specifications

10.2.2 Description

The Main Steam System is designed to deliver steam from the steam generators to the turbine and to other equipment or systems requiring main steam, including:

1. Motive steam to the turbine driver of an auxiliary feedwater pump. Steam to this turbine is supplied by 4-inch branch connections upstream of the Steam Generator Stop Valves on two of the four steam lines. Either line is sufficient to supply steam for the turbine but two are provided for redundancy. These two 4-inch lines are tied together with a motor operated shut-off valve and a check valve in each line before the tie.
2. Motive steam for the main feed pump turbines during start-up and power operation.
3. Heating steam for the reheaters.
4. Turbine by-pass system (Steam Dump)
5. Auxiliary steam system.
6. Turbine steam seals (Unit 2 only).

The system is best described by following the flow path from the steam generator to the turbine. Refer to Figures 10.2-1 and 10.2-1B.

Steam from the four steam generators flows through carbon steel pipes designed for 1085 psig, 600°F, through the containment penetrations.

A steam flow measuring device located in each lead within the containment provides a signal for steam generator level control and initiation of reactor safeguards system in the event of a main steam line rupture.

Following penetration of the containment a power relief valve and bank of five safety valves are installed on each steam lead. The five identical safety valves are equipped with a 16 in.^{2} orifice and provide a combined relieving capacity of 4,288,450 lb/hr per lead (17,153,800 lb/hr for 4 leads at 1172 psi). This capacity is sufficient for the steam generation rate at maximum calculated conditions. The capacity of the power relief valve is approximately 10% of full load flow. It opens automatically if steam pressure exceeds a pre-set value.

Downstream of the safety valves a parallel slide gate valve is installed in each line as close to the containment wall as possible. This valve, known as the Steam Generator Stop Valve, is capable of closing rapidly in the event of a main steam line rupture occurring anywhere in the piping between the steam generator and turbine. Analyses of the steam break accidents are given in Chapter 14, and a safety evaluation of the steam system is given in Section 10.2.3.

The Steam Generator Stop Valves are designed to close against flow in either the normal or reverse direction to limit the effect of a steam line rupture to the blowdown of the one affected steam generator; assuming, conservatively, the failure of one of the four valves to close.

The Steam Generator Stop Valve design incorporates a piston, which is attached to the valve stem. The steam above and below the piston is normally at line pressure. The cylinder volume above the piston is piped through a three-way valve into a pair of redundant, air-operated dump valves. Upon receipt of a signal to close, the dump valves open and vent the steam from the cylinder. The steam pressure in the valve body below the piston forces the piston to move rapidly and close the valve. The dump valves, which open to vent the steam from the Steam Generator Stop Valve, are air operated and depend on a solenoid being energized to open the dump valve which in turn causes the stop valve to go closed. Steamline isolation is complete 11 seconds after the setpoint is reached. The isolation time allows 8 seconds for valve closure plus three seconds for electronic delays and signal processing. Speed of closing is controlled by the setting of a needle restrictor within the hydraulic opening and closing system.

For emergency operation, protective logic is supplied to isolate all steam generators by rapid closure of the four stop valves for any of the following conditions:

a. Containment spray actuation signal initiation Hi-Hi pressure.

b. High steam flow coincident with Lo/Lo T_{avg}.

c. Steam line pressure low.

d. In addition, emergency closure can be initiated by operator actuation of the dump valves in the steam generator stop valve control system.

In the event of a steam generator tube rupture occurring, the recovery procedure involves closure of the steam generator stop valve associated with the affected steam generator. However, for this accident, rapid closure of the valve is not essential and the operator may close the valve using the hydraulic actuator.

Normal opening and closing of the valve is achieved by use of the hydraulic actuator, which is bypassed in case of an emergency closing requirement. The operating switch, in the control room, actuates the reversing solenoid and starts the electrically driven hydraulic fluid pump supplying hydraulic fluid to the valve actuator. Limit switches are fitted to the valve and wired up to display position indication in the control room.

All four main steam lines are connected to a common header, which equalizes the pressure before the steam flows through the turbine admission valves. This header is also connected to the turbine by-pass system (steam dump system).

The capacity of the turbine by-pass system is approximately 26 percent to 39 percent of full load steam flow, depending upon the full load steam pressure. All or several of the steam dump valves open under the following conditions provided a condenser vacuum permissive interlock is satisfied:

1. On a large step load decrease the turbine bypass system creates an artificial load on the steam generators by bypassing the turbine and "dumping" steam directly to the condenser. An error signal exceeding a set value of reactor coolant T_{avg} minus T_{ref} will fully open all the steam dump valves in 3 seconds. T_{ref} is a function of load and is set automatically. The steam dump valves close automatically as the automatic reactor control repositions control rods for the new load. For very large step decreases in load, the probability of a reactor trip is high due to the upset initiating protective devices even with proper operation of the bypass system.

2. After a shutdown of the turbine generator the turbine bypass system is transferred to the pressure mode of control. In this mode main steam pressure is maintained

constant by opening and closing of nine steam dump valves. The pressure to be maintained can be selected by an adjustable setpoint. If cooldown of the reactor is required, the steam dumps are operated in manual to control cooldown rate until the reactor coolant system temperature is reduced to the point where the Residual Heat Removal System can be placed in service.

3. During cool-down, startup, hot standby service, or physics testing, the steam dump valves are capable of being manually operated from the main control room.

The steam dump valves are prevented from opening on loss of condenser vacuum in which case excess steam pressure is relieved to the atmosphere through the power relief valve and/or the main steam safety valves. Interlocks are provided to safeguard against spurious opening of the dump valves.

10.2.3 Performance Analysis

The main steam system up to and including the Steam Generator Stop Valves is designed to Seismic Class I criteria. If a main steam pipe rupture occurs, the steam generator stop valves in all four main steam lines trip closed as described in Section 10.2.2. This limits rapid cooling of the Reactor Coolant System and the ensuing reactivity insertion. Stop valve closure also ensures a supply of steam to the turbine drives for an auxiliary feedwater pump.

If a steam line ruptures between a steam generator stop valve and a steam generator, the affected steam generator continues to blow down. The stop valve closure in the ruptured line prevents blowdown of the other steam generators.

In the event that the stop valve in the ruptured line fails to close, the stop valves in the other lines prevent blowdown of the other steam generators.

10.2.4 Testing and Inspection

Steam generator safety valve set points are checked periodically prior to or during scheduled outages. The Steam Generator Stop Valves are also tested periodically. Testing of the turbines and other active equipment in the main steam system is described in the sections dealing with the equipment.

10.3 TURBINE GENERATOR

10.3.1 Design Bases

The turbine generator converts the thermal energy of steam into mechanical shaft power and thence into electrical energy with a high degree of operational reliability at optimum thermal performance.

10.3.2 Equipment Description

Each Unit's turbine generator consists of a tandem compound (single shaft) arrangement of a double-flow, high-pressure turbine and three functionally identical low-pressure turbines driving a direct-coupled generator at 1800 rpm.

The Unit No. 1 low-pressure turbines are manufactured by Alstom Power, Inc. of Rugby, England; and the Unit No. 1 high-pressure turbine and generator are manufactured by the General Electric Company of Schenectady, New York. The HP & LP turbine-generator for Unit No. 2 are manufactured by "Alstom Power, Inc. of Rugby England". The equipment description in this section applies to either Unit No. 1 or No. 2 turbine generator except where specifically noted.

The flow of steam is as follows: Main steam is admitted to the high-pressure turbine through four emergency stop and four (load) control valves. (On Unit 2 steam is admitted to the high-pressure turbine through four control and four stop valves.) After expanding through the high-pressure turbine, exhaust steam passes through external moisture separators and steam-to-steam shell and tube type reheaters. Reheated steam is admitted to the three low-pressure turbines through reheat stop and intercept valves. The steam then expands through the low-pressure turbines to the main condensers, one serving each 1-p casing.

Bleed steam for feedwater heating (Figure 10.3-1 and 10.3-1A) is provided from the following sources:

Heater	Extraction Source	
	Unit 1	Unit 2
6	HP turbine 2nd stage	HP turbine 5th stage
5	HP turbine exhaust	HP turbine 8th stage
4	LP turbine 7th stage	HP turbine exhaust
3	LP turbine 8th stage	LP turbine 13th stage
2	LP turbine 11th stage	LP turbine 15th stage
1	LP turbine 13th stage	LP turbine 16th stage

Motive steam for the main feed pump turbines is supplied from the main steam system. This steam can be supplemented with reheat steam at higher power levels to improve turbine cycle efficiency. The hot-reheat steam is supplied from a point upstream of the reheat stop valves. The main steam is supplied from the steam generator through a connection on the turbine bypass system.

A shaft sealing system using steam to seal the annular openings where the shaft emerges from the casings, prevents steam outleakage and air inleakage along the shaft. The gland sealing system includes all necessary piping, valves, controls and a gland steam condenser, and automatically maintains the steam seals.

The hydrogen and water cooled generators, rated at 1280 MVA at 90% power factor (Unit No. 1), and 1361 MVA at 90% power factor (Unit No. 2) produce power at 26 kv and 60 Hz. Generator rating, temperature rise and class of insulation are in accordance with applicable standards. Excitation is provided by a shaft-driven alternator with its output rectified. A conventional automatic, oil-sealed hydrogen cooling system provides rotor cooling. The hollow stator conductors are water cooled by a self-contained, automatic stator water system. Differential relays protect the generator against electrical faults.

Turbine-generator bearings are lubricated by a conventional oiling system of proven components. A turbine shaft driven lube oil pump takes suction from the lube oil tank through an oil-turbine driven booster pump (Unit No. 1) or by direct suction (Unit No. 2). For start-up and until full

speed is reached, a motor-driven oil pump provides lubrication. Heat from the bearings is removed by oil coolers using water from the Non-Essential Service Water System.

Supervisory instruments continuously monitor and record such turbine- generator parameters as:

a. Generator load
b. Shaft vibration at the main bearings
c. Shaft eccentricity in the front standard (only on turning gear)
d. Shell expansion
e. Differential expansion between shell and rotor
f. Turbine speed
g. Control valve position
h. Metal temperatures
i. Lube-oil and bearing metal temperatures
j. Hydrogen gas and stator cooling water temperatures
k. Field temperature
l. Generator frequency
m. Exhaust hood temperature
n. Condenser vacuum

Other parameters which are continuously indicated are:

a. Phase currents and voltage
b. Stator winding temperatures
c. Field current and voltages
d. Oil pressures

Many of the supervisory instruments also provide alarms when high (or low) limits are exceeded.

10.3.3 Turbine Controls

The prime function of the turbine control system is to control the speed of the turbine when the generator is not synchronized with the system and to control the output of the unit when the generator is "on line". This is accomplished by positioning the main steam control valves to regulate the flow of steam to the turbine. In both units, the control valves are operated by piston type servo-motors, using a pressurized non-flammable hydraulic fluid for opening the valves. The hydraulic system receives control signals from a Digital Control System (DCS). The turbine

control system is further described in Chapter 14. In addition to speed and load control, the control system automatically trips the turbine generator under any of the conditions stated in Section 7.2.3 under Turbine Generator Trip discussion.

10.3.4 Loss of External Electrical Load

The steam dump system, more fully described in Section 10.2.2, is designed to dump approximately 26 percent to 39 percent of full load steam flow, depending upon the full load steam pressure. Dump capacity increases with any transient increase in steam pressure. The steam dump valves are capable of opening fully in three seconds. The steam is dumped to the main condensers.

The steam dump is controlled by the mismatch between reactor coolant average temperature and the value of the temperature program for the corresponding turbine load. Dump flow is reduced as the reactor coolant average temperature is reduced toward the programmed value. A turbine trip with a reactor trip will also initiate dump action. The dump valves may be manually controlled during cooldown, start-up, hot stand-by service, or physics testing.

10.3.5 Test and Inspection

The rotor has undergone the normal quality assurance and quality control tests associated with the design and manufacture of large turbine- generators. Provisions for ultrasonically testing for cracks are also included in the rotor design. These tests can be run if deemed necessary when the rotors are removed for turbine inspection.

Operational tests include full closure tests of the turbine stop and control valves (both main and reheat), and the feed-pump turbine HP stop valve (Unit 1) and partial closure tests of the feed-pump turbine LP stop valve (Unit 1) and the feed-pump turbine stop valve (Unit 2). Overspeed trip and other turbine protective devices associated with the turbines are tested as plant operating conditions permit and in accordance with accepted practice and/or manufacturers' recommendations.

10.4 MAIN CONDENSERS

10.4.1 Design Basis

The surface condensers are designed to condense the low-pressure turbine exhaust steam to condensate so it may be efficiently pumped through the steam cycle. The condensers also serve as a collecting point for the regenerative steam cycle drains and vents to conserve condensate. The condenser hotwell serves as a storage reservoir for the condensate. The condenser serves as a heat sink for the turbine bypass system, which is capable of handling approximately 26 percent to 39 percent of full load steam flow, depending upon the full load steam pressure. Heat is removed from the condenser by the circulating water system.

10.4.2 Description

Each unit employs one three-shell condenser, each shell condensing steam from one of the three low-pressure turbines. Each are of conventional shell and tube design with steam on the shell side and circulating water in the tubes. The condenser shells are joined to the turbine and exhaust neck by rubber belt type expansion joints. The internal condenser design provides for the effective condensing of steam, scavenging and removal of non-condensable gases and deaeration of the condensate. The combined hotwells of the three condenser shells have a condensate storage capacity (at normal level) equivalent to approximately four minutes of full load operation.

The steam dump (turbine bypass) system consists of a total of nine control (dump) valves and spray pipes to dissipate the steam energy in the condenser and create a load for the NSSS under conditions of transient electrical loads. In addition, the steam dump system is instrumental in controlling the reactor coolant system average temperature during startup, cooldown or when maintaining the unit in a hot standby condition. Three control valves are located adjacent to each condenser shell with the three associated spray pipes arranged within so as to provide for even steam distribution and efficient condensing.

The north and south condenser shells each have a drip leg to receive the drains of the steam cycle. The drip leg separates the flashed vapors from the drains. The vapor rises in the vertical pipe and enters the condenser through a connection near the top of the steam space over the condenser tubes. The condensate falls to the bottom of the drip leg and flows to the condenser hotwell through a bottom loop seal connection.

The water side of the condenser is single pass with each shell having two vertically divided circulating water circuits. Each water circuit can be isolated for in-service inspection, cleaning

and repair/plugging of leaking tubes by closing the motor-operated butterfly valves on the inlet and outlet waterbox connections.

Four sets of two-stage twin element steam jet air ejectors (also referred to as holding ejectors) with associated inter-and-after condensers are provided for removing non-condensable gases from the main condenser shells and feed pump turbine condenser shells. During normal operation at least one two-stage element of the twin element steam-jet air ejector is connected to each main condenser shell and feed pump turbine condenser shell, for a total of four two-stage jets in operation. The steam-jet air ejectors may be normally operated with both two-stage twin elements in service to account for the potential for unusually heavy air leakage into the main condenser and feed pump turbine condenser shells. For added flexibility, the individual air off-takes are joined to a common header with crosstie valves. The inter-and-after condensers are cooled by condensate.

Since the introduction of radioactivity into the secondary system via a steam generator tube leak would probably first become apparent in the non-condensable gases removed from the condenser, the air ejector exhaust gases being vented to atmosphere are continuously monitored for radiation.

For start-up condenser shell side air removal, a non-condensing start-up ejector (or hogger) is provided for each shell. During periods of unit cooldown when the condenser is used as a sink for decay heat removal, either the holding or the start-up ejectors are used as required to maintain condenser vacuum. Driving steam for both the holding and start-up ejectors is supplied from the main steam system or from the heating boiler steam system.

10.4.3 Design Evaluation

The condensers are designed to provide a reliable heat sink and vacuum for steam cycle requirements. The condensers are designed to take turbine main steam dump flow during transient conditions equivalent to 85% of full power steam flow; however, the bypass system has been modified such that its flow capacity is now approximately 26 percent to 39 percent of full load steam flow, depending upon the full load steam pressure. They can operate with one-half of one condenser shell (one of six circulating water-circuits) out of service.

10.4.4 Tests and Inspections

The active components of the system are in continuous use during normal plant operation and no special periodic tests are required. Periodic visual inspections and preventive maintenance are conducted following normal industry practice.

10.5 CONDENSATE AND FEEDWATER SYSTEM

The Feedwater System for both units is shown on Figure 10.5-1. The Condensate System is shown on Figure, 10.5-2 and 10.5-2A for Unit 1, and on Figures 10.5-3 and 10.5-3A for Unit 2. The Heater Drain and Vent System is shown on Figures 10.5-4 and 10.5-4A for Unit No. 1 and Figures 10.5-5 and 10.5-5A for Unit 2.

10.5.1 Main Condensate and Feedwater System

10.5.1.1 Design Basis

The condensate and drain systems are designed to provide sufficient condensate to the main feedwater pumps at adequate NPSH under normal operating and transient conditions. The variable speed turbine driven main feedwater pumps are designed to provide the required feedwater flow to the steam generators. During hot start-up and hot standby, heated feedwater can be provided to the steam generator to reduce the magnitude of the cyclic stresses on the steam generator inlet elbows.

10.5.1.2 System Description

Condensate is withdrawn from the condenser hotwells by three half-capacity motor driven vertical hotwell pumps. The pumps discharge into a common header which carries the condensate through four parallel steam jet air ejector condensers to the suction of three half capacity motor driven horizontal condensate booster pumps. A portion of the condensate flow from the hotwell pump discharge is directed by one of two full capacity turbine auxiliary cooling water pumps through a parallel circuit for turbine auxiliary cooling and returned to the condensate header upstream of the condensate booster pumps. The total condensate flow is then pumped by the booster pumps through three parallel strings of No. 1 heaters, each string consisting of a separate external heater drain cooler and a low-pressure extraction feedwater heater. Any one string can be isolated for maintenance with full flow capability available through the remaining two strings. Downstream of the No. 1 heaters are two parallel strings of three stages of low-pressure feedwater heaters with integral drain coolers. Maintenance on any heater in the three stage low-pressure parallel strings can be accomplished by opening the heater bypass line and isolating the string of heaters in which the defective heater is located. The low-pressure heater bypass also facilitates restoration of suction pressure to the main feed pumps in case of accidental reduction or loss of feedpump suction pressure. The condensate from the No. 4 heaters is then routed to two half capacity main feed pumps via a common header.

There are two turbine driven variable speed main feed pumps installed in parallel; each has its own suction strainer. Minimum flow through each pump is maintained by two recirculation valves and lines which terminate as spray pipes in the condensers. The recirculation valves open sequentially as the flow decreases below 4000 and 2000 gpm. The feedwater from the main feed pumps is discharged through two parallel strings of high-pressure feedwater heaters, each string consisting of a No. 5 and a No. 6 heater. Maintenance on any high-pressure feedwater heater can be accomplished by opening the bypass line and isolating the string in which the defective heater is located.

After discharge from the No. 6 heaters, the feedwater is distributed to the four steam generators through individual feedwater control valves.

Upon receipt of a feedwater isolation signal main feedwater control valves and isolation valves close. The initiator of the feedwater isolation signal (safety injection, Hi-Hi Steam Generator, or Reactor Trip) trips the main feedwater pumps. The trip of the feed pumps closes the feed pump discharge valves.

A 500,000 gallon storage tank "floats" on the condensate system to maintain proper inventory by accommodating changes arising from thermal effects on cycle inventory and cycle losses. Make-up to the system is added to the condenser and excess is removed either to the condensate storage tank via the hotwell pump discharge header or to the Turbine Room Sump via the condensate overboarding flowpath.

On Unit No. 1, reheater steam coil drains flow to the No. 6 feedwater heaters and the No. 6 feedwater heaters drain to the No. 5 feedwater heaters where the moisture separator drains also flow. One heater drain pump takes suction from each No. 5 feedwater heater and returns the drainage to the condensate system upstream of the feed pump strainers. An installed spare heater drain pump can be aligned to take suction from either No. 5 feedwater heater. Each No. 5 feedwater heater can be drained through an alternate flow path directly to the main condenser.

The drains from low-pressure heaters Nos. 4, 3, 2, and 1 cascade to the main condenser. Low-pressure heaters Nos. 3 and 2 can also be directly drained to the main condenser through alternate flow paths.

On Unit No. 2 reheater steam coil drains flow to the No. 6 feedwater heaters and the No. 6 feedwater heaters drain to the No. 5 feedwater heaters. The No. 5 feedwater heaters normally drain to the No. 4 low-pressure heater or can be drained directly to the main condenser through an alternate flow path. The moisture separator drains also flow to the No. 4 low-pressure heater. One heater drain pump takes suction from each No. 4 low-pressure heater and returns the drainage to

the condensate cycle upstream of the feedpump strainers. An installed spare heater drain pump can be aligned to take suction from either No. 4 low-pressure heater. Each No. 4 low-pressure heater can be drained through an alternate flow path directly to the main condenser.

The drains from low-pressure heaters Nos. 3, 2 and 1 cascade to the main condenser. Low-pressure heaters Nos. 3 and 2 can also be directly drained to the main condenser through alternate flow paths.

10.5.1.3 Design Evaluation

The condensate and feedwater systems are designed to provide continuous and reliable feedwater flow to all steam generators under all operating conditions. System stand-by equipment and in service isolation features help insure system reliability.

10.5.1.4 Tests and Inspections

The active components of the system are in continuous use during normal plant operation and are monitored. No additional periodic tests are required. Periodic visual inspections and preventative maintenance are conducted following normal industry practice.

10.5.2 Auxiliary Feedwater System

10.5.2.1 Design Basis

The motor-driven auxiliary feedwater pumps are sized to deliver enough water to maintain a minimum area of heat transfer in the steam generators in order to prevent loss of primary water through the pressurizer safety or relief valves. The higher capacity turbine driven pumps will maintain a tube sheet coverage of 10 feet (20-25 percent recorder range).

10.5.2.2 System Description

Installed in each unit is one turbine driven auxiliary feedwater pump (TDAFP) which feeds all four steam generators and two motor driven auxiliary feedwater pumps (MDAFP) each of which feeds two steam generators. Train orientation is maintained throughout the auxiliary feedwater system including the AFW pumps, all associated valves, instrumentation and controls. The Auxiliary Feedwater System is shown in Figure 10.5-1.

The normal water source for auxiliary feedwater pumps is from the condensate storage tank. An emergency water source is provided from the Essential Service Water System. Transfer is accomplished by a remotely-operated, motor-operated valve and a manual valve. The supply line from the Condensate Storage Tank in each unit is crosstied through a normally closed valve to

provide an additional source of high purity water. Instrumentation installed on the individual pump suction lines alerts the operator in the event of a low suction pressure condition, i.e., loss of suction supply. Each pump is equipped with a duplex strainer.

A crosstie on the discharge of the MDAFPs, from one unit to the other, provides additional emergency flexibility. These lines have a manual valve which is locked or sealed closed during normal operation.

Steam for the turbine driver is supplied from two steam generators. Each line contains a motor operated valve and a check valve. The motor operated valves, powered from independent ac power trains, provide isolation capability and the check valves preclude reverse flow.

The MDAFPs start automatically on the following signals:

1. low-low steam generator water level in 1 of 4 steam generators
2. safety injection signal (refer to Chapter 6)
3. trip of both main feedwater pumps
4. blackout signal initiated by loss of normal voltage to 4kV safety bus
5. AMSAC: less than 25% feedwater flow to 3 out of 4 loops and above 40% power.

The automatic start on low-low steam generator level, safety injection and trip of both main feedpumps is controlled by timers to ensure sequential loading on the diesel generator and Reserve Stations Transformers. The automatic start sequence is described in Section 8.1.2c) and 8.4.

The TDAFP starts automatically on the following signals:

1. low-low steam generator level in 2 of 4 steam generators
2. reactor coolant pump bus undervoltage on 2 of 4 buses
3. AMSAC: less than 25% feedwater flow to 3 out of 4 loops and above 40% power.

The TDAFP is normally operated with control air isolated from the TDAFP governor. This results in the turbine operating at its high-speed stop setpoint. Isolation of control air to the TDAFP governor ensures that a failure of the governor hand loader does not result in a low auxiliary feedwater flow rate.

Control of auxiliary feedwater flow to the steam generators is achieved by remote operation of motor operated valves in the lines to the steam generators. Flow instrumentation on the discharge of each pump closes the associated valves after a preset time delay to an intermediate position upon receipt of a high flow signal. The preset time delay was added to prevent spurious activation of the flow retention system. In the unlikely event of a feedwater or main steam line rupture, the closing of these valves to an intermediate position protects against pump runout and assures

adequate flow to the intact steam generators without operator action. For the MDAFPs, these motor operated valves as well as the motor operated valve which transfers suction to the essential service water system are powered from the same a-c engineered safeguards power source as the associated pump motor. The MDAFP motors are powered from independent power sources.

The motor operated valves associated with the TDAFP, excluding the ESW suction transfer valve and the two motor-operated valves on the steam supply line, are powered from a dedicated dc power source. This dc power source is independent of all other dc power sources and, during a station blackout, is independent of ac power. The TDAFP instrumentation and control system required for operation, with the exception of the flow retention circuit, is also powered from this dc power source.

10.5.2.3 Design Evaluation

As stated in Section 10.5.2.2 each pump driver is provided with independent power sources. Also, the water supply to the pumps is redundant. Feedwater can be supplied to all steam generators by both a turbine-driven and a motor-driven pump.

The pumps are housed in adjacent, missile protected enclosures.

The Auxiliary Feedwater System is designed to provide sufficient make-up to the steam generators when the main feedwater supply is not available, particularly under the following scenarios: Loss of main feedwater, station blackout, cooldown, rupture of main feedline and rupture of main steamline. Major rupture of a main feedwater pipe is not part of the Unit 1 license basis (see section 14.2.8, Unit 1).

A steady-state hydraulic analysis was performed for each case assuming the most limiting single failure, steam generators pressurized to the safety valve setting (plus 3% accumulation) and non-safety related control systems failing to operate. The results of these hydraulic analyses are used as inputs in the appropriate Chapter 14 safety analysis.

The TDAFP flow and head with control air isolated to the TDAFP governor is consistent with the hydraulic analyses and the Chapter 14 safety analysis inputs.

10.5.2.4 Tests and Inspections

The auxiliary feedwater pumps and certain valves are tested in accordance with applicable edition of the ASME Operation and Maintenance (OM) Code. During the tests, the pumps can be tested with flow to the steam generators or back to the condensate storage tank through a recirculation line. Performance is verified by monitoring flow meters in the test lines and pressure gauges on the suction and discharge of the pumps.

The availability of the Essential Service Water supply to the Auxiliary Feedwater System must also be determined, but without contaminating the condensate tank with lake water. Two normally closed valves, one motor operated, connect the Essential Service Water supply to each of the auxiliary feed pumps. To test, a low point valve between the two aforementioned valves is verified open to drain that portion of the line, and the two valves are independently stroked. A visual check at the low point valve will verify normal direction of flow through the manual valve and backflow through the motor operated valve, after which all valving is restored to its normal setting.

10.5.2.5 References for Section 10.5.2

1. Technical Report TR-2000-02, "Working Pressure Analysis for 3HMTA-8 & 4HMTA-6 Auxiliary Feedwater Pumps", dated February 3, 2000 (Reference AEP Correspondence Control No.: NED-2000-528-REP, Rev.0).
2. Flowserve Letter dated April 25, 2001 Rev. 1, "Pump Models 3HMTA-8 / 4HMTA-6 Pressure Rerate for Steel Casings" (Reference AEP Correspondence Control No.: 2001-2823).

10.6 CIRCULATING WATER SYSTEM

10.6.1 Design Basis

The once-through circulating water system supplies cooling water to the condensers and turbine auxiliary coolers. It also supplies the water for the screen wash system, the service water systems and miscellaneous minor water requirements for Units No. 1 and No. 2.

10.6.2 Description

Water is drawn from three submerged intake structures in the lake, located approximately **2,250** feet from the shoreline, and is piped through three parallel lines to the screen house located at the lake side of the plant proper. The screen house, common to both units, contains the circulating water pumps and valves, traveling water screens, essential service water pumps, and associated equipment. It is located in an area immediately adjacent to the west side of the turbine building. De-icing features permit a portion of the warm circulating water discharge from either unit to be redirected to the intake structures during winter months. The intake structures, the screen house and connecting piping are all designed to insure a reliable flow of cooling water to the plant at all times.

There are seven circulating water pumps - three for Unit No. 1, and four for Unit No. 2. Each pump takes suction from its respective pump well in the screen house. The water is pumped via the intake tunnels to the main condensers from where it returns to the lake via the discharge tunnels and submerged discharge pipes approximately 1150 feet from the shoreline. Cooling water for the feed pump turbine condensers and the turbine auxiliary coolers is provided by parallel circuits off the main circulating water system.

Isolation valves are provided for each condenser circuit. They are also provided for the Turbine Auxiliary Coolers. Vacuum priming is provided to remove air that might accumulate in the condenser water boxes. The normal circulating water flow rate is approximately 1,600,000 gpm total for the two units.

Figure 10.6-1 shows the arrangement of the circulating water intake and discharge structures.

The circulating water system and related structures are designed to satisfy normal operating requirements and to assure that water is available to the essential service water pumps under all foreseeable conditions.

Since the essential service water pumps are located in the screen house, the entire foundation and masonry portions of the circulating water pump house structure are designed to Seismic Class I.

Concrete barriers are provided to protect the essential service water pumps against turbine missiles and from fires or other accidents in the adjacent essential service water pump compartments. In addition, the essential service water pump compartments are designed to withstand tornado-wind effects and tornado-borne missiles. The essential service water pump motors are above Elev. 594.6' and therefore are adequately protected from the maximum flood condition anticipated due to a seiche or surge phenomenon.

Lake water enters the circulating water pump structure via three intake cribs located approximately 2,250 feet offshore in 20 feet of water. Three 16 foot diameter buried corrugated steel pipes connect these cribs to the screen house structure. The circulating water pipes are not seismically designed, because of their number and large size complete failure is not anticipated. However, in the unlikely event of complete loss of flow to the screen house through the intake pipes adequate flow for essential service water requirements can be provided from the discharge pipes. This is accomplished by opening motor operated sluice gates separating the discharge pipes from the screen house forebay. Maximum demand under such conditions would be less than 20,000 gpm. Sluice gate valves 1-WMO-17 or 2-WMO-27 may also be opened when chlorination of ESW System or NESW System is required and the unit's corresponding circulating water pumps are not in service.

Each intake crib consists of a smoothly rounded intake elbow set in the lake bottom surrounded by sacked concrete and rip-rap to prevent erosion. The intake elbow is capped by an octagonal-shaped heavy structural steel frame to protect it from ice damage. Bar racks and guides on all sides of the steel frame prevent the entry of large debris into the system from the sides while a plate steel roof prevents debris from entering from above. Water will enter the intake elbow through the interstices between the steel members with velocities sufficiently low to inhibit formation of needle ice at the intake crib.

De-icing capability to the intake cribs is provided by shutting off flow in the middle intake pipe to the screen house, by closing its motor operated sluice gate and sending a portion of "warm" discharge water from either the Unit No. 1 or Unit No. 2 discharge tunnel back through the middle pipe to the lake. The three intake cribs are arranged in a triangular pattern with the middle pipe at the apex (farthest from shore) so that the heated water will recirculate to the two other intake pipes thus keeping the intakes free of ice.

Traveling water screens of adequate capacity for normal plant operation are provided in the intake structure. The huge oversize of the screen installation, in terms of the essential flow requirements, provides assurance that adequate water is available to the essential service water pumps even under heavy conditions of plugging by debris and/or fish.

A chlorination system is available for algae and slime control in the various heat exchangers cooled by the lake water.

Additionally, provisions exist for the injection of sodium hypochlorite into the circulating water system forebay for main condenser slime control and into the service water system for slime control and zebra mussel control.

Provisions also exist for the injection and distribution of biocidal chemicals into the circulating water system for zebra mussel control.

10.6.3 Design Evaluation

All three circulating water pumps for Unit No. 1 and all four pumps for Unit No. 2 are in service during normal unit operation. If a circulating water pump is out of service, unit operation can be continued at higher condenser back pressure.

10.6.4 Tests and Inspections

The active components of the system are in continuous use during normal plant operation and no special periodic tests are required. Periodic visual inspections and preventative maintenance are conducted following normal industry practice.

10.6.5 Design Parameters

See Table 10.6-1.

10.7 TURBINE AUXILIARY COOLING SYSTEM

10.7.1 Design Basis

The Turbine Auxiliary Cooling System utilizes water from the main condensate system as a coolant for:

a. The gland steam condenser

b. The generator hydrogen coolers

c. The generator stator coolers

d. The exciter cooler

e. The bus duct enclosure

10.7.2 Description

The system is shown in Figure 10.5-2A and 10.5-3A. The system can operate in either of two modes as described below. The mode of operation is determined by chemical considerations as well as the temperature of the condensate leaving the hotwell. Normally, the system is to be operated in the closed cycle mode. Operation in open cycle is allowed provided that chemistry conditions are favorable and the temperature of the condensate is sufficiently low to provide adequate cooling of the services listed in Section 10.7.1. Operation in open cycle optimizes the thermal efficiency of the plant. The systems for Units No. 1 and No. 2 are similar except for the changeover point from closed to open cycle. For Unit No. 1, when the temperature of the condensate leaving the hotwell is above 95°F, changeover from an open to a closed cycle shall be made, for Unit No. 2, this point is 104°F. The changeover is made by manual operation of valves. Limiting open cycle operation helps minimize corrosion and corrosion products in the steam generator.

During open cycle operation, condensate is taken from the hotwell pump discharge header and is pumped by one of two full-capacity turbine auxiliary cooling pumps through the various heat exchangers. The condensate from the heat exchangers then returns to the condensate booster pump suction header. This mode reclaims heat and improves thermal efficiency of the unit. Additionally, flow may be diverted through the turbine auxiliary cooler during open cycle operation to aid in cooling condensate temperature.

In closed cycle operation, the condensate is pumped by one of the two turbine auxiliary cooling pumps through the turbine auxiliary cooler, where it is cooled by circulating water in the tube circuit of the cooler. Flow through the tube circuit is in parallel with the circulating water flow

through the main condenser. The pressure differential across the main condenser maintains the flow in the turbine auxiliary cooler. Cooled condensate from the shell side then flows through the heat exchangers and returns to the turbine auxiliary cooling pump suction. Makeup for the system is supplied by a small by-pass around the condensate isolation valve.

Operation of the system is monitored in the control room by pressure indicators and temperature recorders.

10.7.3 Design Evaluation

When the chemical conditions are favorable and the temperature of the main condensate is below 95°F, Unit No. 1, or below 104°F, Unit No. 2, the heat from the turbine auxiliary coolers may be reclaimed by utilizing the open cycle. When the chemical conditions are not favorable or the condensate temperature is above 95°F, Unit No. 1, or above 104°F, Unit No. 2, the turbine auxiliary cooler is placed in service and the heat is lost to the circulating water system.

10.7.4 Tests and Inspection

The active components of the system are in continuous use during normal plant operation. Periodic visual inspections and preventive maintenance are conducted following normal industry practice.

10.8 SERVICE WATER SYSTEMS

Lake water is used as the source of service water at Cook Plant. Two independent systems (Essential Service Water and Non-Essential Service Water) are used to supply service water in each Unit. Both systems are described in Chapter 9.

10.9 MAKE-UP WATER AND PRIMARY WATER SYSTEMS

The Demineralized Water Make-Up System produces the high purity, degassified water required for make-up to the reactor coolant and condensate-feedwater systems for both units. Lake water is pumped from the non-essential service water system into the make-up system retention tank. There is an alternate source of supply from the Lake Township public water system.

The water is pumped from the retention tank and processed through an ultra-filtration system, reverse osmosis system, carbon filter vessels, electro-deionization system, a vacuum degassifier and two stages of mixed-bed "polishing" demineralizers.

Following treatment, the demineralized, degassified water is distributed to the various points of usage.

The Primary Water System supplies water for miscellaneous purposes in the auxiliary building, primarily for reactor coolant make-up. The primary water is a mixture of demineralized, degassified make-up water and condensate recovered from processing reactor-coolant letdown fluid.

Primary Water is the source of Emergency Makeup to the Component Cooling Water System through a removable jumper hose.

10.10 CHEMICAL FEED SUB-SYSTEM

Chemical feed systems are provided for adding chemical solutions to the condensate and feedwater to scavenge dissolved oxygen, control pH and minimize corrosion. Chemicals are mixed using appropriate dilutions from bulk storage and stored in covered stainless steel feed tanks. When needed, the solutions are pumped from these tanks by motor driven, positive displacement pumps to the points of injection. The pumps have adjustable strokes and only have manual control.

10.11 SECONDARY VENT AND DRAIN SYSTEM

The Steam and Power Conversion System vents and drains are arranged in a similar manner to those in a fossil-fueled power station, since the system is normally non-radioactive. However, because the steam generator blowdown (SGBD) and the air ejectors discharge can become contaminated, these subsystems are monitored and discharged under controlled conditions as explained below.

10.11.1 Design Basis

The Steam Generator Blowdown System is designed to maintain the proper water chemistry within the steam generators. The secondary side water is blown down to maintain the total dissolved solids within established limits.

The Steam Jet Air Ejector unit removes non-condensable gases from the condenser shells. These exhaust gases are monitored for radiation as they are vented to the atmosphere. A small representative sample passes through a radiation monitor. Each of the condenser steam jet air ejector elements is designed to remove 15.0 cfm of non-condensable gases. Separate non-condensing start-up jets are used to reduce condenser back pressure to 15 in Hg abs during start-up.

10.11.2 Description

The steam generator blowdown and blowdown treatment systems are shown on Figures 10.2-1, 10.2-1B, and 11.5-1. The steam jet air ejector vent systems are shown on Figures 10.5-4A and 10.5-5A.

When the SGBD is routed to the start-up blowdown flash tank the steam produced in the start-up blowdown flash tank is vented to the atmosphere through a moisture separator. The water is routed to the screenhouse forebay. The start-up flash tank is equipped with a NESW supply line for quenching.

When the SGBD is routed to the normal blowdown flash tank the blowdown flashes into a mixture of approximately 40 percent steam and 60 percent water. The steam is returned to the Condensate System through the condensers and the water is routed to the screenhouse forebay either directly or through mixed-bed demineralizers. The normal blowdown flash tank is equipped with a NESW supply line for quenching.

Either the normal blowdown flash tank or the start-up blowdown flash tank may be aligned to receive SGBD flow based on secondary chemistry contaminant levels, available plant demineralized water supply, or system availability.

The blowdown rate from each steam generator is controlled by two parallel, fail closed, control valves, which are located downstream of a blowdown isolation valve. A continuous sample is taken from each Steam Generator Blowdown (SGBD) line inside containment and runs through its own isolation valve to a sample conditioning rack, where its temperature and pressure are reduced. The four sample lines are then combined and routed to a radiation monitor. The SGBD treatment system also has a radiation monitor between the second and third treatment demineralizers (see Sections 9.6 and 11.5, respectively). These radiation monitors close the main SGBD isolation and the SGBD sample valves upon detection of high radiation.

During normal operation, one of the four two-stage twin element steam jet air ejectors (SJAE) removes non-condensable gases from each of the three main condenser shells and both feedpump turbine condensers. For added flexibility, the individual air off-takes are joined to a common header with cross tie-valves. The motive steam is condensed in the SJAE inter- and after-condensers. Normally, condenser drains are returned to the condensate system. Flexibility to use other flow paths has been provided based on operating conditions. Gases removed from the condensers by the steam jet air ejectors during normal operation are discharged into a common header. These non- condensable gases are then exhausted at a slightly positive pressure to the atmosphere through a vent stack. The SJAE vent stack has an air flow meter to measure the quantity of non-condensables removed from the condensers. Since the introduction of radioactivity in the main steam system by a steam generator tube leak would probably first become apparent in the non-condensable gases removed from the condensers, the SJAE exhaust gases vented to the atmosphere are continuously surveyed for radiation by the radiation monitor.

Secondary plant piping drains are generally routed to the main condenser. Secondary plant vents from the turbine generator which handle carbon dioxide, hydrogen, oil vapor and other non-radioactive gases are discharged to the atmosphere outside the building.

Blowdown radiation monitoring and alarm initiation are maintained during the loss of offsite power. A signal from the containment isolation system (Sub-Chapter 5.4) causes the blowdown and blowdown sample isolation valves to close.

10.11.3 Testing and Inspection

The Vent and Drain Systems are in continuous use and require no special testing and inspection. The isolation valves installed in these systems are part of the containment isolation system and are tested in accordance with Sub-Chapter 5.4.

These radiation monitors are periodically calibrated and tested in accordance with applicable technical specifications.