TABLE OF CONTENTS

CHAPTER 10.0

STEAM AND POWER CONVERSION SYSTEM

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

CHAPTER 10.0

STEAM AND POWER CONVERSION SYSTEM

10.1 SUMMARY DESCRIPTION

The steam and power conversion system is designed to remove heat energy from the reactor coolant in the four steam generators and convert it to electrical energy. The system includes the main steam system, the turbine-generator, the main condenser, the condensate system, the feedwater system, and other auxiliary systems. The turbine cycle is a closed cycle with water as the working fluid. Two stages of reheat and seven stages of regeneration are included in the cycle. The heat input is provided by reactor coolant in the steam generators. Work is performed by the expansion of the steam in the high and low pressure turbines. Steam is condensed and waste heat is rejected by the main condenser. The condensate and feedwater systems preheat and pressurize the water and return it to the steam generators, thereby closing the cycle.

Figure 10.1-1 is an overall flow diagram of the steam and power conversion system. Table 10.1-1 gives the major design and performance data of the system and its major components. A heat balance at the guaranteed steam generator conditions is included as Figures 10.1-2.

10.1.1 GENERAL DISCUSSION

The main steam system supplies steam to the high pressure turbine and the second stage of steam reheating. The steam is expanded in the high pressure turbine. High pressure turbine extraction steam supplies the first stage of steam reheating and the sixth and seventh stage feedwater heaters. High pressure turbine exhaust steam is fed to the combined moisture separator reheaters (MSRs) and the fifth stage feedwater heaters. Steam is dried and superheated in the MSRs before it is supplied to the low pressure turbines and to the steam generator feedwater pump (SGFP) turbines. Extraction steam from the low pressure turbines supplies the low pressure feedwater heaters. The steam generator blowdown (SGB) flash tank steam is fed to the fifth stage feedwater heaters.

Exhaust steam from the low pressure turbines is condensed and deaerated in the main condenser. Volume change in the secondary side fluid is handled by the surge capacity of the condensate storage tank. Heating of the condensate first occurs in the reheating hotwells of the main condenser; the heating system is the SGFP turbine exhaust. Condensate is pumped from the condenser hotwells by the main condensate pumps through the condensate demineralizers and the low pressure feedwater heaters to the suction of the SGFP. A portion of the condensate is directed to the SGB regenerative heat exchanger to recover additional heat while cooling the blowdown. The heater drain pumps feed the suction of the SGFPs from the heater drain tank. Feedwater is pumped through the high pressure feedwater heaters to the steam generators by means of the SGFPs.

10.1.2 PROTECTIVE FEATURES

10.1.2.1 Loss of External Electrical Load and/or Turbine Trip

Load rejection capabilities of the steam and power conversion systems are discussed in Section 10.3.

10.1.2.2 Overpressure Protection

Overpressure protection for the steam generators is discussed in Section 10.3. The following components are provided with overpressure protection in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII:

a. MSRs

b. Low pressure feedwater heaters

c. High pressure feedwater heaters

d. Heater drain tank

e. SGB flash tank

f. SGB regenerative heat exchanger

10.1.2.3 Loss of Main Feedwater Flow

Loss of main feedwater flow is discussed in Section 10.4.9.

10.1.2.4 Turbine Overspeed Protection

Turbine overspeed protection is discussed in Section 10.2.2.

10.1.2.5 Turbine Missile Protection

Turbine missile protection is discussed in Sections 10.2.3 and 3.5.1.3.

10.1.2.6 Radioactivity

Under normal operating conditions, there are no significant radioactive contaminants present in the steam and power conversion system. It is possible for this system to become contaminated by a steam generator tube leakage. In this event, radiological monitoring of the main condenser air removal system and the steam generator blowdown system, as described in Section 11.5, will detect contamination.

Equilibrium secondary system activities, based on assumed primary-to-secondary side leakages, are developed in Chapter 11.0. The steam generator blowdown system and the condensate demineralizer system serve to limit the radioactivity level in the secondary cycle, as described in Sections 10.4.6 and 10.4.8.

TABLE 10.1-1 SUMMARY OF IMPORTANT DESIGN FEATURES AND PERFORMANCE CHARACTERISTICS OF THE STEAM AND POWER CONVERSION SYSTEM

Nuclear Steam Supply System, Full Power Operation	
Rated NSSS power, MWt	3,579
Steam generator outlet pressure, psia	867-1022
Steam generator inlet feedwater temp,°F	390 to 446
Steam generator outlet steam moisture, %	0.10
Quantity of steam generators per unit	4
Flow rate per steam generator, 10^6 lb/hr	3.67-3.99
Turbine-Generator	
Rating, MWe	1,284
Turbine type	Tandem, compound six flow, 1 high pressure turbine 3 low pressure turbines
Operating speed, rpm	1,800
Number of stages	18
Moisture Separator Reheater (MSR)	
Stages of reheat	2
Stages of moisture separation	1
Quantity of MSRs per unit	4
Main Condenser	
Type	Multiple pressure, 3-shell
Quantity, per unit	1
Condensing capacity, Btu/hr	7.87×10^9
Circulating water flow rate	See Site Addenda Section 10.4.5
Circulating water temperature rise	See Site Addenda Section 10.4.5
Condenser Vacuum Pumps	
Type	Rotary, motor driven, water sealed
Hogging capacity, each, std. cfm	72 @ 5 in. Hga
Holding capacity, each, std. cfm	35 @ 1 in. Hga
Pump speed, rpm	435
Motor hp, each	150
Motor speed, rpm	1,800
Quantity, per unit	3

TABLE 10.1-1 (Sheet 2)

Condensate Pumps	
Type	Vertical, centrifugal motor driven
Design Conditions	
Flow, gpm	7,266
Total head, ft	1,285
Motor hp	3,500
Quantity per unit	3
Feedwater Heaters	
Low Pressure	
a. No. 1	
Quantity per unit	3
Duty, Btu/hr	2.194×10^8
b. No. 2	
Quantity per unit	3
Duty, Btu/hr	1.713×10^8
c. No. 3	
Quantity per unit	3
Duty, Btu/hr	1.749×10^8
d. No. 4	
Quantity per unit	3
Duty, Btu/hr	1.916×10^8
High Pressure	
e. No. 5	
Quantity per unit	2
Duty, Btu/hr	2.415×10^8
f. No. 6	
Quantity per unit	2
Duty, Btu/hr	3.259×10^8
g. No. 7	
Quantity per unit	2
Duty, Btu/hr	3.354×10^8
Steam Generator Feedwater Pumps	
Pump type	Horizontal, centrifugal
Turbine type	multistage noncondensing
Quantity per unit	2
Design conditions, pump	
Flow, gpm	17,620

TABLE 10.1-1 (Sheet 3)

Total head, ft	2,387
Turbine hp @ 5,560 rpm	14,328
Motor-Driven Feedwater Pump	
Type	Horizontal, centrifugal Motor driven
Design conditions	
Flow, gpm	480
Total head, ft	1,820
Motor hp	300
Quantity per unit	1
Heater Drain Pumps	
Type	Vertical, centrifugal motor driven
Design conditions	
Flow, gpm	5,670
Total head, ft	910
Motor hp	1,500
Quantity per unit	2
Steam Generator Blowdown Regenerative Heat Exchanger	
Duty, Btu/hr	26.64×10^6
Quantity per unit	1
Steam Generator Blowdown Flash Tank	
Steaming rate, lb/hr (max. blowdown)	40,000-52,800
Outlet steam pressure, psia	135-185
Quantity per unit	1
Heater Drain Tank	
Quantity per unit	1
Operating pressure, psia	166.6

10.2 TURBINE GENERATOR

The turbine-generator (T-G) receives high pressure steam from the main steam system and converts a portion of its thermal energy into electrical energy. The T-G also supplies extraction steam and condensate therefrom for feedwater heating and steam for driving the steam generator feedwater pump turbines.

10.2.1 DESIGN BASES

10.2.1.1 Safety Design Bases

The T-G serves no safety function and has no safety design basis.

10.2.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The T-G is intended for base load operation. The gross generator output at rated reactor power is given on Figure 10.1-2.

POWER GENERATION DESIGN BASIS TWO - The T-G load change characteristics are compatible with the instrumentation and control system which coordinates T-G and reactor operation.

POWER GENERATION DESIGN BASIS THREE - The T-G is designed to accept a sudden loss of full load without exceeding design overspeed.

POWER GENERATION DESIGN BASIS FOUR - The T-G is designed to permit periodic testing of steam valves important to overspeed protection, emergency overspeed trip circuits, and several other trip circuits under load.

POWER GENERATION DESIGN BASIS FIVE - The failure of any single component will not cause the rotor speed to exceed the design speed.

POWER GENERATION DESIGN BASIS SIX - Unlimited access to all levels of the turbine area under all operating conditions is provided.

10.2.2 SYSTEM DESCRIPTION

10.2.2.1 General Description

The T-G system is shown in Figure 10.2-1. Performance characteristics are provided in Section 10.1.

The turbine consists of double-flow, high-pressure, and low-pressure elements in tandem. Moisture separation and reheating of the steam are provided between the high-pressure and low-pressure elements by four combined moisture separator reheater (MSR) assemblies. Two assemblies are located on each side of the T-G centerline. The generator is coupled directly to the turbine shaft. It is equipped with an excitation system.

T-G accessories include the bearing lubrication oil system, electrohydraulic control (EHC) system, turning gear, hydrogen system, seal oil system, stator cooling water system, exhaust hood spray system, steam seal system, and vibration monitoring equipment.

The T-G unit and associated piping, valves, and controls are located completely within the turbine building. As identified in Sections 7.2.1.1.2.f, 10.4.7, and 10.4.8, there are components important to safety located in the turbine building. However, based on the extremely low probability of failure involving the T-G unit as described in Section 3.5, there is an equally low or lower probability of this equipment failing in a manner that would preclude safe shutdown of the reactor.

There is unlimited access to T-G components and instrumentation associated with T-G overspeed protection, under all operating conditions.

10.2.2.2 Component Description

The MSRs, MSR drain tanks, stator water coolers, and stator water demineralizer are designed to ASME Section VIII. The balance of the T-G is designed to General Electric (GE) and Alstom Company Standards.

MAIN STOP AND CONTROL VALVES - Four high pressure, angle body, main stop and control valve chests admit steam to the high pressure (HP) turbine. The primary function of the main stop valves is to quickly shut off the steam flow to the turbine under emergency conditions. The primary function of the control valves is to control steam flow to the turbine in response to the turbine control system. The four sets of valves are located at El. 2033, south of the high pressure turbine shell. The valve chests are made of a copper-bearing, low-carbon steel.

The main stop valves are single disc type valves operated in an open-closed mode either by the emergency trip, fluid operated, fast acting valve for tripping, or by a small solenoid valve for testing. The discs are totally unbalanced and cannot open against full differential pressure. An internal bypass valve is provided in the number two main stop valve to pressurize the below seat areas of the four valves. Springs are designed to close the main stop valve in 0.19 second under the emergency conditions listed in Section 10.2.2.3.4.

Each main stop valve has one inlet and one outlet. The outlet of each valve is welded directly to the inlet of a control valve casing. The four stop valves are also welded together through below-seat equalizers. Each stop valve contains a permanent steam strainer to prevent foreign matter from entering the control valves and turbine.

The control valves are poppet-type valves with venturi seats. The valve discs have spherical seats to ensure tight shutoff. The valves are of sufficient size, relative to their cracking pressure, to require partial balancing. This is accomplished by a skirt on the valve disc sliding inside a balance chamber. When a control valve starts to open, a small internal valve is opened to decrease the pressure in the balance chamber. Further lifting of the stem opens the main disc. Each control valve is operated by a single acting, spring-closed servomotor opened by 1,600 psi fire-resistant fluid through a servo valve. The control valve is designed to close in 0.20 second.

HIGH PRESSURE TURBINE - The HP turbine receives steam through four pipes, called steam leads, one from each control valve outlet. The steam is expanded axially across seven stages of stationary and moving blades. Steam pressure immediately downstream of the first stage is used as a load reference signal for reactor control. Extraction steam from the third turbine stage supplies the seventh stage of feedwater heating and the first stage of steam reheating. Extraction steam from the fifth and seventh turbine stages supplies the sixth and fifth stages of feedwater heating, respectively. Turbine exhaust steam is collected in eight pipes called cold reheat pipes, four at each end of the turbine.

The turbine casings are made of 2.25-percent chrome-molybdenum steel. The rotor is a single forging of nickel-chromium-molybdenum-vanadium steel. Buckets and diaphragms (i.e., stationary buckets) are 12-percent chromium, ferritic steel. The blades are of high tensile strength stainless steel with integral root dovetails for attachment to the rotor.

MOISTURE SEPARATOR REHEATERS - Four horizontal cylindrical-shell, combined moisture separator reheater (MSR) assemblies are installed in the steam lines between the high and low pressure turbines. The MSRs serve to dry and reheat the steam before it enters the low pressure turbine. This improves cycle efficiency and reduces moisture-related erosion and corrosion in the low pressure turbines. Steam from the high pressure turbine is piped into the bottom of the MSR. Moisture is removed in chevron-type moisture separators, and is drained to the moisture separator drain tank and from there to the heater drain tank. The dry steam passes upward across the tube bundle of the first stage reheater. The first stage reheater steam source is extraction steam from the third HP turbine stage. The reheater is drained to the first stage reheater drain tank and from there to the sixth feedwater heater. The dried and reheated steam then passes through the tube bundle of the second stage reheater. The second stage reheater steam source is main steam. The reheater is drained to the second stage reheater drain tank and from there to the seventh feedwater heater. Safety valves are provided on the MSR for overpressure protection.

COMBINED INTERMEDIATE VALVES - Two combined intermediate valves (CIV) per LP turbine are provided, one in each steam supply line, called the hot reheat line, from the MSR. The CIV consists of two valves sharing a common casing. The two valves are the intercept valve and the intermediate stop valve. Although they utilize a common casing, these valves have entirely separate operating mechanisms and controls. The function of the CIVs is to protect the turbine against overspeed from stored steam between the main stop and control valves and the CIVs. Three CIVs are located on each side of the turbine.

Steam from the MSR enters the single inlet of each valve casing, passes through the permanent basket strainer, past the intercept valve and stop valve disc, and discharges through a single outlet connected to the LP turbine. The CIVs are located as close to the LP turbine as possible to limit the amount of uncontrolled steam available for overspeeding the turbine. Upon loss of load, the intercept valve first closes then throttles steam to the LP turbine, as required, to control speed and maintain synchronization. It is capable of opening against full system pressure. The intermediate stop valve closes only if the intercept valves fail to operate properly. It is capable of opening against a pressure differential of approximately 15 percent of the maximum expected system pressure. The intermediate stop valve and intercept valve are designed to close in 0.2 second.

LOW PRESSURE TURBINES - Each LP turbine receives steam from two CIVs. The steam is expanded axially across eleven stages of stationary and moving buckets. Turbine stages are numbered consecutively, starting with the first HP turbine stages. Extraction steam from stages 9, 12, 14, and 16 supply the fourth, third, second, and first stage of feedwater heating, respectively. The twelfth stage extraction is also the normal source of turbine gland sealing steam. The seventeenth turbine stage is a moisture removal stage where moisture is removed to protect the last stages from erosion induced by water droplets. This extraction is drained directly to the condenser.

The LP turbine casings and bearing brackets are fabricated from carbon steel. The LP rotors are produced by welding together six forged, hollow drums. The rotor forgings are made of a chromium-nickel-molyobdenum steel.

The buckets are of high tensile strength stainless steel with integral root dovetails for attachment to the rotor disc. An erosion-resistant, hardened surface is provided on the leading edge of the last stage buckets. Integral shrouds are machined on the tips of the last stage buckets to prevent large vibrations of one bucket relative to another.

EXTRACTION NONRETURN VALVES - Upon loss of load, the steam contained within turbine extraction lines could flow back into the turbine, across the remaining turbine stages, and into the condenser. Condensate contained in feedwater heaters will flash to steam under this condition and contribute to the backflow of steam. Extraction nonreturn valves are installed in the third, fifth, ninth, twelfth, and fourteenth stage turbine extraction lines to guard against this backflow of steam and the contribution it would make to a rotor overspeed condition. The nonreturn valves are free-swinging. The fourteenth stage nonreturn valves have double "D" swing plates. The plates are closed by a torsion spring as flow decreases. For the remaining nonreturn valves, under normal operation, air bears against a piston which mechanically prevents a coiled spring from assisting in valve closure. Upon turbine trip, the air is dumped to atmosphere via the turbine control system's air relay dump valve.

GENERATOR - The generator operates at 1,800 rpm and is rated at 1,373,100 kVA at 75 psig hydrogen pressure and a 0.9 power factor. The stator core and rotor conductors are cooled by hydrogen circulated by fans mounted at each end of the generator shaft. Two water-cooled hydrogen coolers are mounted in the generator frame. A seal oil system isolates the hydrogen from the atmosphere. The stator conductors are water cooled.

The rotor consists of layers of field windings embedded in milled slots. The winding material is silver-bearing copper in preformed coils, carried in molded glass liners in the slots. The windings are held radially by steel slot wedges at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperature, which could occur as a result of loss of cooling, for example. The magnetic field is generated by dc power which is fed to the windings through collector rings located outboard of the main generator bearings. The rotor body and shaft is machined from a single, solid steel forging. The material is a nickel-molybdenum-vanadium alloy steel. Detailed examinations and tests are carried out at each stage of rotor manufacture. These include:

a. Material property checks on test specimens taken from the forging

b. Ultrasonic tests for internal flaws

c. Photomicrographs for examination of microstructure

d. Magnetic particle and ultrasonic examination of the bore

e. Surface finish tests of slots for indication of a stress riser

The rotor end turns are restrained against centrifugal force by retaining rings. The rings are the highest stressed components of the generator. The retaining ring is shrunk on a machined fit at the end of the rotor body. It is locked against axial and circumferential movement by a locking ring screwed into the retaining ring and keyed to the rotor body. The ring material is a manganese-chromium, alloy steel forging. All retaining ring forgings are tested for chemical composition, tensile properties, Charpy-V notch impact properties, grain size, internal flaws by ultrasonic inspection, surface flaws by dye penetrant inspection, and performance by cyclic hydrostatic testing.

10.2.2.3 System Operation

10.2.2.3.1 Normal Operation

Under normal operation, the main stop valves and CIVs are wide open. Operation of the T-G is under the control of the electro-hydraulic control (EHC) system. The EHC system is comprised of three basic subsystems: the speed control unit, the load control unit, and the flow control unit. The normal function of the EHC system is to generate the position signals for the four main stop valves, four main control valves, and six CIVs.

The speed control unit provides a speed error signal for input to the load control unit. Two independent rotor speed circuits are provided for redundancy; failsafe circuitry protects the turbine in the event of failure of the primary circuit. A light on the EHC control panel indicates that one of the circuits is not functioning. The speed control unit generates a third speed error signal which is derived from first differentiating one of the speed signals to generate an acceleration signal and then integrating the signal. The primary function of the acceleration signal is to provide an input for control valve positioning during periods of controlled rotor acceleration (i.e. startup). A low value gate receives the three signals and transmits the signal demanding the smallest control valve opening. A circuit is incorporated into the unit to slowly vary rotor speed above and below speeds that are near turbine blade critical frequencies to prevent the unit from extended operation in a resonant condition during startup of the T-G.

The basic purpose of the load control unit is to receive signals from other units of the EHC system and use these signals in conjunction with functions designated as load control unit functions to generate flow reference signals for the flow control unit. Under steady state conditions, it calculates the turbine load based upon the actual position of the control valves and compares that load with the load set. Normally, the load set is established by the operator; however, load set can be changed automatically, depending on circumstances which cause the T-G protection circuits to come into action. For example, loss of generator stator cooling will automatically cause the maximum permissible load set to be reduced. Pushbuttons on the EHC control panel permit changing the load set at .05, .166, 1, and 1/2 percent per minute. The reactor is capable of accepting these rates without abnormal effect or bypass of steam to the atmosphere or condenser.

The flow control unit positions the main stop and control valves and the CIVs. Normally, the flow control unit receives the speed error and load set error signals and positions the control valves to make the error signals zero.

10.2.2.3.2 Operation Upon Loss of Load

Upon loss of generator load, the EHC system acts to prevent rotor speed from exceeding design overspeed. Refer to Table 10.2-1 for the description of the sequence of events following loss of turbine load. Failure of any single component will not result in rotor speed exceeding design overspeed (i.e., 120 percent of rated speed). The following component redundancies are employed to guard against overspeed:

a. Main stop valves/Control valves

b. Intermediate stop valves/Intercept valves

c. Primary speed control/Backup speed control

d. Fast acting solenoid valves/Emergency trip fluid system (ETS)

e. Speed control/Overspeed trip/Backup overspeed trip

The main stop valves and control valves are in series and have completely independent operating controls and operating mechanisms. Closure of either all four stop valves or all four control valves shuts off all main steam flow to the HP turbine. The combined stop and intercept valves are also in series and have completely independent operating controls and operating mechanisms. Closure of either all six stop valves or all six intercept valves shuts off all MSR outlet steam flow to the three LP turbines.

The speed control unit utilizes two speed signals obtained from two magnetic pick-ups on a toothed wheel on the HP turbine shaft. Increase of either speed signal tends to close control valves. Loss of one signal will transfer control to the other speed signal. Loss of both speed signals will initiate trip via the ETS.

Fast acting solenoid valves initiate fast closure of control valves under load rejection conditions that might lead to rapid rotor acceleration. The solenoid valve dumps ETS pressure at the control valve. Valve action will occur when power exceeds load by more than 40 percent and generator current is lost suddenly. The ETS initiates fast closure of the valves whether the fast-acting solenoid valves work or not. The ETS pressure is dumped by any one of several devices in the front standard, including the mechanical and electrical overspeed trips.

If speed control should fail, the overspeed trip devices must close the steam admission valves to prevent turbine overspeed. The mechanical overspeed trip uses an unbalanced rotating ring and a stationary trip finger operating a trip valve which dumps ETS pressure. It is set to operate at nominal 110 percent of rated speed. The electrical, backup overspeed trip is set to dump ETS pressure at a nominal 110.5 percent of rated speed. Component redundancy and fail safe design of the ETS hydraulic system and trip circuitry provide turbine overspeed protection. Three speed signals independent of the speed control unit are inputs to the backup, overspeed trip. These three speed pickups are located in the front standard. The two speed pickups for the speed control unit are located in the front standard with the mechanical overspeed trip. For reliability, two-out-of-three logic is employed in the electrical overspeed trip circuitry. Single component failure does not compromise trip protection. Two separate electrical busses supply power to the trip circuits. The primary power source is the shaft-mounted, permanent magnet generator. The station house power is the backup power supply. Loss of power trips the turbine through fail safe circuitry.

10.2.2.3.3 Testing

The electrical and mechanical overspeed trip devices can be tested remotely at rated speed, under load, by means of lighted pushbuttons on the EHC test panel. Operation of the overspeed protection devices under controlled, overspeed condition, should be checked immediately before each outage unless major outage maintenance is performed on the front standard of the turbine and then the overspeed protection devices are checked during turbine startup.

10.2.2.3.4 Turbine Trips

a. Emergency trip pushbutton in control room

b. Moisture separator high level

c. Low condenser vacuum. Note: The low condenser vacuum trip circuit for each turbine exhaust hood has a defeat switch. This reduces the possibility of a turbine trip while the pressure switches on that hood are being calibrated during turbine operation.

d. Low lube oil pressure

e. LP turbine exhaust hood high temperature

f. Reactor trip

g. Thrust bearing wear

h. Overspeed (electrical and mechanical)

i. Manual trip handle on front standard

j. Loss of stator coolant

k. Low hydraulic fluid pressure

l. Any generator trip

m. Loss of EHC electrical power

n. AMSAC

o. High vibration Note: The high vibration trip circuit has two defeat switches. One is to reduce the possibility of a turbine trip during maintenance on the vibration monitoring system. The second is administratively controlled to by-pass the turbine trip.

10.2.3 TURBINE DISK INTEGRITY

10.2.3.1 Materials Selection

Turbine rotors are made from vacuum melted or vacuum degassed Cr-Ni-Mo alloy steel by processes which minimize flaw occurrence and provide adequate fracture toughness. Tramp elements are controlled to the lowest practicable concentrations consistent with good scrap selection and melting practices, and consistent with obtaining adequate initial and long life fracture toughness for the environment in which the parts operate. The turbine rotor materials have the lowest fracture appearance transition temperatures (FATT) and highest Charpy V-notch energies obtainable, on a consistent basis, from water quenched Cr-Ni-Mo material at the sizes and strength levels used. Since actual levels of FATT and Charpy V-notch energy vary, depending upon the size of the part and the location within the part, etc., these variations are taken into account in accepting specific forgings for use in turbines for nuclear application. Charpy tests, essentially in accordance with Specification ASTM A 370, are included.

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of materials described in Section 10.2.3.1, to produce a balance of adequate material strength and toughness to ensure safety while simultaneously providing high reliability, availability, efficiency, etc. during operation. Stress calculations include components due to centrifugal loads and thermal gradients, where applicable. The ratio of material fracture toughness, K_{IC} (as derived from material tests on each rotor) to the maximum tangential stress for rotors at speeds from normal to 114 percent of rated speed (the highest anticipated speed resulting from a loss of load is 110 percent) is at least 2 inches. Adequate material fracture toughness needed to maintain this ratio is confirmed by destructive tests on material taken from the rotor, using correlation methods which are more conservative than that presented in Reference 1.

Turbine-operating procedures are employed to preclude brittle fracture at startup by ensuring that the metal temperature of rotors is adequately above the FATT and, as defined above, is sufficient to maintain the fracture toughness to tangential stress ratio at or above 2 inches. Details of these startup procedures are contained in Reference 2.

10.2.3.3 High Temperature Properties

The operating temperatures of the high-pressure rotors are below the stress rupture range. Therefore, creep-rupture is not considered a significant failure mechanism.

Basic stress and creep-rupture data are obtained in standard laboratory tests at appropriate temperatures with equipment and procedures commensurate with ASTM recommendations.

10.2.3.4 Turbine Disk Design

The turbine assembly is designed to withstand normal conditions and anticipated transients, including those resulting in turbine trip without loss of structural integrity. The design of the turbine assembly meets the following criteria:

a. Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.

b. The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20 percent overspeed are controlled in the design and operation so as to cause no distress to the unit during operation.

c. The maximum tangential stress in rotors resulting from centrifugal forces, and thermal gradients does not exceed 0.75 of the yield strength of the materials at 114 percent of rated speed.

10.2.3.5 Preservice Inspection

The preservice procedures and acceptance criteria are as follows:

a. Rotor disc forgings are rough machined with minimum stock allowance and are 100-percent volumetric (ultrasonic) tested.

b. Each rotor weld is subjected to 100-percent volumetric (ultrasonic), surface and visual examinations, using Alstom acceptance criteria. These criteria include the requirement that subsurface sonic indications are either removed or evaluated to ensure that they will not grow to a size which will compromise the integrity of the unit during its service life.

c. All finished machined surfaces are subjected to a magnetic particle test with no flaw indications permissible.

d. Each fully bucketed turbine rotor assembly is spin tested at 20-percent overspeed.

Additional preservice inspections include air leakage tests performed to determine that the hydrogen cooling system is tight before hydrogen is introduced into the generator casing. The hydrogen purity is tested in the generator after hydrogen has been introduced. The generator windings and all motors are megger tested. Vibration tests are performed on all motor-driven equipment. Hydrostatic tests are performed on all coolers. All piping is pressure tested for leaks. Motor-operated valves are factory leak tested and inplace tested once installed.

10.2.3.6 Inservice Inspection

The inservice inspection program for the turbine assembly includes the disassembly of the turbine and complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, turbine shafts, low-pressure turbine buckets, low-pressure rotors, and high-pressure rotors. During plant shutdown coinciding with the inservice inspection schedule for ASME Section III components, as required by the ASME Boiler and Pressure Vessel Code, Section XI, turbine inspection is done in sections during the refueling outages so that in intervals of 100,000 hours of operation, total inspection has been completed at least once.

This inspection consists of visual and surface examinations as indicated below:

a. Visual examination of all accessible surfaces of rotors

b. Visual and surface examination of all low-pressure buckets

c. 100-percent visual examination of couplings and coupling bolts

Inservice inspection of the bore of the high-pressure turbine rotor will be in accordance with the manufacturer's recommendations.

The inservice inspection of valves important to overspeed protection includes the following:

a. All main stop valves, control valves, extraction nonreturn valves, and CIVs will be tested under load. Pushbuttons on the EHC test panel permit full stroking of the stop valve, control valves, and CIVs. Valve position indication is provided on the panel. No load reduction is necessary before testing main stop valves and CIVs. Extraction nonreturn valves are tested to ensure that no binding is present at each valve shaft.

b. Main stop valve, CIVs, and control valves will be full stroke tested quarterly. Complete closure of each valve during the test will be verified by direct observation of the valve motion. Main stop valves and control valves will be partial stroke tested monthly. Extraction nonreturn valves will be tested monthly, but these valves cannot fully close under load.

   Tightness tests of the main stop and control valves are performed at least once per 18 months, or after major maintenance on the stop or control valves, by turbine shell and chest warming, using each set of four valves closed alternately.

c. All main stop, main control, and CIVs will be inspected once during the first three refueling or maintenance shutdowns. Subsequent inspections will be scheduled so that each valve is inspected at 8-year intervals. The inspections will be conducted for:

   Wear of linkages and stem packings

   Erosion of valve seats and stems

   Deposits on stems and other valve parts which could interfere with valve operation

   Distortions, misalignment

Inspection of all valves of one type will be conducted if any unusual condition is discovered

10.2.4 EVALUATION

The reactor system is a PWR type; hence, under normal operating conditions, there are no significant radioactive contaminants present in the steam and power conversion system.

No radiation shielding is required for the turbine-generator system. Continuous access to the components of the system for inservice inspection, etc., is possible during all operating conditions. Even in the event of a large primary-to-secondary steam generator leak, the T-G system will not become contaminated to the extent that access is precluded.

A full discussion of the radiological aspects of primary-to-secondary leakage, including anticipated operating concentrations of radioactive contamination, anticipated releases to the environment, and limiting conditions for operation, is included in Chapter 11.0.

10.2.5 REFERENCES

1. Begley, J. A., and Logsdon, W. A., "Correlation of Fracture Toughness Charpy Properties for Rotor Steels," Westinghouse, Scientific Paper 71-1E7-MSLRF-P1, July 26, 1971

2. Spencer, R.C., and Timo, D. P., "Starting and Loading of Turbines," General Electric Company, 36th Annual Meeting of the American Power Conference, Chicago, Illinois, April 29-May 1, 1974

TABLE 10.2-1 EVENTS FOLLOWING LOSS OF TURBINE LOAD WITH POSTULATED EQUIPMENT FAILURES

Approximate Speed-Percent	Event
100	Full load is lost. Speed begins to rise.
101	Control valves begin to close. As turbine stage pressures decrease, extraction nonreturn valves swing closed.
105	Control valves fully closed. Intercept valves begin to close.
107	Intercept valves fully closed.
109	Peak transient speed with normally operating control system.
	Assume that power/load unbalance and speed control systems had failed prior to loss of load.
110	Mechanical overspeed trip signals all valves to close. Operation of air relay dump valves releases spring closure mechanisms of extraction nonreturn valves.
111	Backup overspeed trip signals all valves to close.
113	All valves full closed, activated by mechanical overspeed trip.
114	All valves fully closed, activated by backup overspeed trip.
119	Peak transient speed with normal control system failure and operation of mechanical overspeed trip. See note.
120	Peak transient speed with failure of both normal control systems and mechanical overspeed trips, proper operation of backup overspeed trip. See Note.

Note: The Alstom rotors have a peak transient speed of 114%, therefore the GE values listed are conservative.

10.3 MAIN STEAM SUPPLY SYSTEM

The function of the main steam supply system (MSSS) is to convey steam generated in the steam generators by the reactor coolant system to the turbine-generator system and auxiliary systems for power generation.

10.3.1 DESIGN BASES

10.3.1.1 Safety Design Bases

The portion of the MSSS from the steam generator to the steam generator isolation valves is safety related and is required to function following a DBA and to achieve and maintain the plant in a safe shutdown condition.

SAFETY DESIGN BASIS ONE - The safety-related portion of the MSSS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The safety-related portion of the MSSS is designed to remain functional after a SSE or to perform its intended function following postulated hazards of fire, internal missile, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Component redundancy is provided so that safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-34).

SAFETY DESIGN BASIS FOUR - The MSSS is designed so that the active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI.

SAFETY DESIGN BASIS FIVE - The MSSS uses design and fabrication codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The MSSS provides for isolation of the secondary side of the steam generator to deal with leakage or malfunctions and to isolate nonsafety-related portions of the system.

SAFETY DESIGN BASIS SEVEN - The MSSS provides means to dissipate heat generated in the reactor coolant system during hot shutdown and cooldown (GDC-34).

SAFETY DESIGN BASIS EIGHT - The MSSS provides an assured source of steam to operate the turbine-driven auxiliary feedwater pump for reactor cooldown under emergency conditions and for shutdown operations (GDC-34).

10.3.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The MSSS is designed to deliver steam from the steam generators to the turbine-generator system for a range of flows and pressures varying from warmup to rated conditions. The system provides means to dissipate heat during plant step load reductions and during plant startup. It also provides steam to:

a. The turbine-generator system second stage reheaters

b. The main feed pump turbines and auxiliary feed pump turbine

c. The steam seal system

d. The turbine bypass system

e. The auxiliary steam reboiler

f. The process sampling system

g. Condenser spargers

10.3.2 SYSTEM DESCRIPTION

10.3.2.1 General Description

The MSSS is shown in Figure 10.3-1. The system conveys steam from the steam generators to the turbine-generator system. The system consists of main steam piping, power-operated relief valves, safety valves, and main steam isolation valves. The turbine bypass system is discussed in detail in Section 10.4.4.

The MSSS instrumentation, as described in Table 10.3-1, is designed to facilitate automatic operation and remote control of the system and to provide continuous indication of system parameters. As described in Chapter 7.0, certain devices are involved in the steam line break protection system.

10.3.2.2 Component Description

Codes and standards applicable to the MSSS are listed in Table 3.2-1. The MSSS is designed and constructed in accordance with quality group B and seismic Category I requirements from the steam generator out to the torsional restraint downstream of the main steam isolation valves (MSIV). The remaining piping out to the turbine-generator and auxiliaries meets ANSI B31.1 requirements. Design data for the MSSS components are listed in Table 10.3-2.

MAIN STEAM PIPING - Saturated steam from the four steam generators is conveyed to the turbine generator by four 28-inch-O.D. lines. The lines are sized for a pressure drop of 25 psi from the steam generators to the turbine stop valves at turbine manufacturer's guaranteed conditions. Refer to Figure 10.1-2.

Each of the lines is anchored at the containment wall and has sufficient flexibility to provide for relative movement of the steam generators due to thermal expansion. The main steam line and associated branch lines between the containment penetration and the first torsional restraint downstream of the MSIV are designed to meet the "no break zone" criteria of NRC BTP MEB 3-1, as described in Section 3.6.

Each line is equipped with:

a. One power-operated atmospheric, relief valve

b. Five spring-loaded safety valves

c. One main steam isolation valve and associated by-pass isolation valve

d. One low point drain, which is piped to the condenser through a drain valve

All main steam branch process line connections are made downstream of the isolation valves with the exception of the line to the power-operated atmospheric relief valve, connections for the safety valves, lines to the auxiliary feedwater pump turbine, and low point drains and high point vents.

Each steam generator outlet nozzle contains a flow restrictor of 1.4 square feet to limit flow in the event of a MSLB.

Immediately upstream of the turbine stop valves, each main steam pipe is cross connected, via an 18-inch line, to a 36-inch header to equalize pressure and flow to the four turbine stop valves. The 18-inch equalizing line limits the back flow from the three intact steam generators in the event of a MSLB. The cross-connecting piping is sized to permit on-line testing of each turbine stop valve without exceeding allowable limits on steam generator differential pressure. Branch piping downstream of the isolation valves provides steam to the second stage reheaters, steam seal system, main feedwater pump turbines, turbine bypass system, auxiliary steam reboiler, and condenser spargers.

POWER-OPERATED ATMOSPHERIC RELIEF VALVE - A power-operated, atmospheric, relief valve is installed on the outlet piping from each steam generator. The four valves are installed to provide for controlled removal of reactor decay heat during normal reactor cooldown when the main steam isolation valves are closed or the turbine bypass system is not available. The valves will pass sufficient flow at all pressures to achieve a 50°F per hour plant cooldown rate. The total capacity of the four valves is 15 percent of rated main steam flow at steam generator no-load pressure. The maximum actual capacity of the relief valve at design pressure is limited to reduce the magnitude of a reactor transient if one valve would inadvertently open and remain open.

The atmospheric relief valves are air operated carbon steel, 8 inch 1,500 pound globe valves, supplied by a safety-related air supply (as described in Section 9.3.1), and controlled from Class 1E sources. A nonsafety-related air supply is available during normal operating conditions. The capability for remote manual valve operation is provided in the main control room and at the auxiliary shutdown panel. Manual operation is also provided by a local pneumatic controller for AB-PV-2 and 3. The valves are opened by pneumatic pressure and closed by spring action.

SAFETY VALVES - The spring-loaded main steam safety valves provide overpressure protection in accordance with the ASME Section III code requirement for the secondary side of the steam generators and the main steam piping. There are five valves installed in each main steam line. Table 10.3-2 identifies the valves, their set pressure, and capacities. The valves discharge directly to the atmosphere via vent stacks. The maximum actual capacity of the safety valves at the design pressure is limited to reduce the magnitude of a reactor transient if one of the valves would open and remain open.

MAIN STEAM ISOLATION VALVES AND BYPASS ISOLATION VALVES - One MSIV and associated bypass isolation valve (BIV) is installed in each of the four main steam lines outside the containment and downstream of the safety valves. The MSIVs are installed to prevent uncontrolled blowdown from more than one steam generator. The valves isolate the nonsafety-related portions from the safety-related portions of the system. The valves are bidirectional, double disc, parallel slide gate valves. The MSIV actuators utilize two separate actuation trains, which are energized from separate Class 1E sources. Energy for closing an MSIV is provided by the process fluid (main steam), which is admitted to the volume above the actuator piston (upper Piston Chamber) to close the valve. The MSIV actuators utilize six solenoid valves, three solenoids per actuation train, to perform their safety design functions. Process fluid will be directed to the actuator upper piston chamber (to close the valve) by two parallel trains consisting of one two-way solenoid valve and one three-way solenoid valve series. For closure, both upper piston chamber solenoid valves within an actuation train are de-energized to admit process fluid from the valve bonnet chamber to the actuator upper piston chamber. The actuator lower piston chamber is vented through a two-way solenoid valve and a three-way solenoid valve connected in parallel to the actuator lower piston chamber, which are in a de-energized state (vented position). After a 120 second time delay both actuator lower piston chamber solenoid valves will energize, aligning the lower piston chamber to the valve bonnet chamber. Aligning the lower piston chamber to valve bonnet chamber will prevent any leakage of process fluid from either the piston rings or the steam seal from venting through the lower piston chamber to the condenser. Since the MSIV actuators use system-medium (main steam) to actuate, the stroke time of the actuators varies according to system pressure. The response time of the MSIV actuators at different steam pressures is documented in the Technical Specification Bases. Valve closure capability is tested in the manufacturer's facility by pressurizing the valve body and closing the valve twice, each time with a different set of actuator controls.

Preservice and inservice tests are also performed as discussed in Sections 10.3.4.2 and 10.3.4.3, respectively.

The main steam BIV is used when the MSIVs are closed to permit warming of the main steam lines prior to startup. The bypass valves are air-operated globe valves. For emergency closure, either of two separate solenoids, when de-energized, will result in valve closure. Electrical solenoids are energized from a separate Class 1E source.

10.3.2.3 System Operation

NORMAL OPERATION - At low plant power levels, the MSSS supplies steam to the steam generator feedwater pump turbines, the auxiliary steam reboiler, and the turbine steam seal system. At high plant power levels, these components are supplied from turbine extraction steam. Steam is supplied to the second stage steam reheaters in the T-G system when the T-G load exceeds 15 percent.

If a large, rapid reduction in T-G load occurs, steam is bypassed (40 percent of VWO) directly to the condenser via the turbine bypass system. The system is capable of accepting a 50-percent load rejection without reactor trip and a full load rejection without lifting safety valves. If the turbine bypass system is not available, steam is vented to the atmosphere via the power-operated relief valves (PORV) and the safety valves, as required.

EMERGENCY OPERATION - In the event that the plant must be shut down and offsite power is lost, the MSIV (with power available from 125 Vdc separation groups 1 or 4) and other valves (except to the auxiliary feedpump turbine) associated with the main steam lines are closed. The PORV may be employed to remove decay heat and to lower the steam generator pressure to achieve cold shutdown. If the power-operated atmospheric relief valve for an individual main steam line is unavailable due to the loss of its control gas supply or power supply, the associated safety valves will provide overpressure protection. The remaining PORV are sufficient to achieve cold shutdown.

In the event that a DBA occurs which results in a SLIS (i.e., large steam line break), the MSIV automatically closes (with power available from 125 Vdc separation groups 1 or 4). Steam is automatically provided to the auxiliary feedwater pump turbine from one of two steam lines upon low-low level in two steam generators or loss of offsite power. Redundant check valves are installed in the lines to the turbine to ensure that only one steam generator will feed a ruptured main steam line. The closure of three out of four MSIVs will ensure that no more than one steam generator can supply a postulated break. In addition, closure of the HP turbine steam stop and steam control valves prevents uncontrolled blowdown of more than one steam generator following a postulated main steam line break inside the containment. Reliability of the turbine trip system is discussed in Section 10.2. Coordinated operation of the auxiliary feedwater system (refer to Section 10.4.9) and PORV or safety valve may be employed to remove decay heat.

10.3.3 SAFETY EVALUATION

Safety evaluations are numbered to correspond to the safety design bases of Section 10.3.1.1.

SAFETY EVALUATION ONE - The safety-related portions of the MSSS are located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the MSSS are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - As indicated by Table 10.3-3, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - The MSSS is initially tested with the program given in Chapter 14.0. Periodic inservice functional testing is done in accordance with Section 10.3.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the MSSS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Table 10.3-2 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and controls necessary for safety-related functions of the MSSS are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Redundant power supplies and power trains operate the MSIVs to isolate safety and nonsafety related portions of the system. Branch lines upstream of the MSIV contain normally closed, power-operated relief valves which modulate open and closed on steam line pressure. The atmospheric relief valves fail closed on loss of air, and the safety valves provide the overpressure protection.

Accidental releases of radioactivity from the MSSS are minimized by the negligible amount of radioactivity in the system under normal operating conditions. Additionally, the main steam isolation system provides controls for reducing accidental releases, as discussed in Chapter 15.0, following a steam generator tube rupture.

Detection of radioactive leakage into and out of the system is facilitated by area radiation monitoring (discussed in Section 12.3.4), process radiation monitoring (discussed in Section 11.5), and steam generator blowdown sampling (discussed in Section 10.4.8).

SAFETY EVALUATION SEVEN - Each main steam line is provided with safety valves that limit the pressure in the line to preclude overpressurization and remove stored energy. Each line is provided with an atmospheric relief valve to permit reduction of the main steam line pressure and remove stored energy to achieve an orderly shutdown. The auxiliary feedwater system, which is described and evaluated in Section 10.4.9, provides makeup to the steam generators consistent with the steaming rate.

SAFETY EVALUATION EIGHT - The steam line to the auxiliary feedwater pump turbine is connected to a cross-connecting header upstream of the MSIV. This arrangement ensures a supply of steam to this turbine when the steam generators are isolated. Redundant check valves are provided in each supply line from the main steam lines to preclude any potential backflow during a postulated main steam line break. The auxiliary feedwater system is described in Section 10.4.9.

10.3.4 INSPECTION AND TESTING REQUIREMENTS

10.3.4.1 Preservice Valve Testing

The set pressures of the safety valves are individually checked during initial startup either by bench testing or with a pneumatic test device. A pneumatic test device is attached to the valve stem. The pneumatic pressure is applied until the valve seat just lifts, as indicated by the steam noise. Combination of the steam pressure and pneumatic pressure with calibration data furnished by the valve manufacturer verifies the set pressure.

The lift-point of each PORV is checked against pressure gauges mounted in the main steam piping.

The MSIVs are checked for closing time prior to initial startup.

10.3.4.2 Preservice System Testing

Preoperational testing is described in Chapter 14.0.

The MSSS is designed to include the capability for testing through the full operational sequence that brings the system into operation for reactor shutdown and for MSLB accidents, including operation of applicable portions of the protection system and the transfer between normal and standby power sources.

The safety-related components of the system, i.e. valves and piping, are designed and located to permit preservice and inservice inspections to the extent practicable.

10.3.4.3 Inservice Testing

The performance and structural and leaktight integrity of all system components are demonstrated by continuous operation.

The redundant actuator power trains of each MSIV are subjected to the following test:

> Closure time - The valves are checked for closure time in accordance with the Inservice Testing Program.

Additional discussion of inservice inspection of ASME Code Class 2 and 3 components is contained in Section 6.6.

10.3.5 SECONDARY WATER CHEMISTRY (PWR)

10.3.5.1 Chemistry Control Basis

Steam generator secondary side water chemistry control is accomplished by:

a. A close control of the feedwater chemistry to limit the amount of impurities that can be introduced into the steam generator

b. The capability of a continuous blowdown of the steam generators to reduce concentrating effects of the steam generator

c. Chemical addition to establish and maintain an environment that minimizes system corrosion

d. By post-construction cleaning of the feedwater system

e. Minimizing feedwater oxygen content prior to entry into the steam generator by deaeration in the hotwell

f. The capability of continuous demineralization and filtration of the condensate system through full-flow, deep bed condensate demineralizers

Secondary water chemistry is based on the all volatile treatment (AVT) method. This method employs the use of volatile additives to maintain system pH and to scavenge dissolved oxygen present in the feedwater. Ammonia or an alternate amine is added to establish and maintain alkaline conditions in the feedtrain. Although ammonia or amines are volatile they will reach an equilibrium level which will establish an alkaline condition in the steam generator.

Hydrazine is added to scavenge dissolved oxygen present in the feedwater and condensate systems. Hydrazine also tends to promote the formation of a protective oxide layer on metal surfaces by keeping these layers in a reduced chemical state.

Ammonia or an alternate amine and hydrazine can be injected continuously at the discharge headers of the condensate pumps and are added, as necessary, for chemistry control.

Operating chemistry guidelines for secondary steam generator water are based on the EPRI PWR Secondary Water Chemistry Guidelines.

The condensate demineralizer system is discussed in Section 10.4.6.

10.3.5.2 Corrosion Control Effectiveness

Alkaline conditions in the feedtrain and the steam generator reduce general corrosion at elevated temperatures and tend to decrease the release of soluble corrosion products from metal surfaces. These conditions promote formation of a protective metal oxide film and thus reduce the corrosion products released into the steam generator.

Hydrazine also promotes formation of a metal oxide film by the reduction of ferric oxide to magnetite. Ferric oxide may be loosened from the metal surfaces and be transported by the feedwater. Magnetite, however, provides an adhesive, protective layer on carbon steel surfaces. Hydrazine also promotes formation of protective metal oxide layers on copper surfaces. Removal of oxygen from the secondary waters is also essential in reducing corrosion. Oxygen dissolved in water causes general corrosion that can result in pitting of ferrous metals, particularly carbon steel. Oxygen is removed from the steam cycle condensate in the main condenser deaerating section. Additional oxygen protection is obtained by chemical injection of hydrazine into the condensate stream. Maintaining a residual level of hydrazine in the feedwater ensures that any dissolved oxygen not removed by the main condenser is scavenged before it can enter the steam generator.

The presence of free hydroxide (OH) can cause rapid corrosion (caustic stress corrosion) if it is allowed to concentrate in a local area. Free hydroxide is avoided by maintaining proper pH control and by minimizing impurity ingress into the steam generator.

AVT control is a technique whereby both soluble and insoluble solids are kept at a minimum within the steam generator. This is accomplished by maintaining strict surveillance over the possible sources of feedtrain contamination (e.g., main condenser cooling water leakage, air inleakage, and subsequent corrosion product generation in the low pressure drain system, etc.). Solids are also excluded, as discussed above, by injecting only volatile chemicals to establish conditions that reduce corrosion and, therefore, reduce transport of corrosion products into the steam generator.

In addition to minimizing the sources of contaminants entering the steam generator, condensate demineralizers are used, and a continuous blowdown from the steam generators is employed to limit the concentration of contaminants. With the low solids level that results from employing the above procedures, the accumulation of scale and deposits on steam generator heat transfer surfaces and internals is limited. Scale and deposit formations can alter the thermal hydraulic performance in local regions which creates a mechanism that allows impurities to concentrate and thus possibly cause corrosion. The effect of this type of corrosion is reduced by limiting the ingress of solids into the steam generator and limiting their buildup.

The chemical additives, because they are volatile, do not concentrate in the steam generator and do not represent chemical impurities that can themselves cause corrosion.

10.3.6 STEAM AND FEEDWATER SYSTEM MATERIALS

10.3.6.1 Fracture Toughness

Compliance with fracture toughness requirements of ASME III, Articles NC-2300 and ND-2300, is discussed in Section 6.1.

10.3.6.2 Material Selection and Fabrication

All pipe, flanges, fittings, valves, and other piping material conform to the referenced ASME, ASTM, ANSI, or MSS-SP code.

The following code requirements apply:

	Stainless Steel	Carbon Steel
Pipe	ANSI B36.19	ANSI B36.10
Fittings	ANSI B16.9, B16.11 or B16.28	ANSI B16.9, B16.11 or B16.28
Flanges	ANSI B16.5	ANSI B16.5

The following ASME Material Specifications apply specifically:

ASME SA-155 GR KCF 70 Class 1 (impact tested)

ASME SA-155 GR KCF 70 Class 1

ASME SA-106, GR C (impact tested)

ASME SA-106, GR, B

ASME SA-106, GR, B (normalized)

ASME SA-234 GR WPB

ASME SA-234 GR WPBW (Mfd from gr 70 plate)

ASME SA-234 GR WPC

ASME SA-105

ASME SA-193 GR B7

ASME SA-194 GR 2H

ASME SA-216 GR WCB

ASME SA-333 GR 6 (impact tested)

ASME SA-420 GR WPL6 (impact tested)

ASME SA-508 Class 1 (impact tested)

ASME SA-312, TP 304

ASME SA-403, WP-304

ASME SA-403, WP-304 W

ASME SA-182, F-304

ASME SA-672 GR C70

ASME SA-671 GR CC70 C1 32

ASME SA-672 GR C70 C1 22

Compliance with the following Regulatory Guides is discussed in Section 6.1:

Regulatory Guide 1.31 - Control of Stainless Steel Welding

Regulatory Guide 1.36 - Nonmetallic Thermal Insulation for Austenitic Stainless Steel

Regulatory Guide 1.37 - Quality Assurance Requirement for Cleaning of Fluid Systems and Associated Components of Water-cooled Nuclear Power Plants

Regulatory Guide 1.44 - Control of the Use of Sensitized Stainless Steel

Regulatory Guide 1.50 - Control of Preheat Temperatures for Welding of Low-Alloy Steels

Regulatory Guide 1.71 - Welder Qualification for Areas of Limited Accessibility

TABLE 10.3-1 MAIN STEAM SUPPLY SYSTEM CONTROL, INDICATING AND ALARM DEVICES

Device	Control Room	Local	Control Room Alarm
Flow rate indication[(1)]	Yes	-	Yes[(2)]
Pressure indication[(3)] [(4)]	Yes	-	-
Pressure Control	Yes[(5)]	-	-

(1) Two per steamline

(2) Steam flow - feed flow mismatch

(3) For each generator, three devices are involved in 2-out-of-3 logic to generate input to reactor trip, SLIS, and SIS

(4) Total of four per steamline

(5) One per steamline (power-operated relief valves)

TABLE 10.3-2 MAIN STEAM SUPPLY SYSTEM DESIGN DATA

Main Steam Piping (Safety-Related Portion)	
Design flowrate at 1016 psia* and 0.10 percent moisture, lb/hr	15,950,000
Number of lines	4
O.D., in.	28
Minimum wall thickness, in.	1.5
Design pressure, psia	1,200
Design temperature, F	600
Design code	ASME Section III, Class 2
Seismic design	Category I
Main Steam Isolation Valves	
Number per main steam line	1
Closing time, seconds	System pressure dependent**
Design code	ASME Section III, Class 2
Seismic design	Category I
Atmospheric Relief Valves	
Number per main steam line	1
Normal set pressure, psig	1,125
Capacity (each) at 1,107 psia, lb/hr	594,642
Capacity (each) at 100 psia, lb/hr	54,000
Design code	ASME Section III, Class 2
Seismic design	Category I
Main Steam Safety Valves	
Number per main steam line	5
Orifice area, sq in.	16
Size, in.	6 x 8 x 8

TABLE 10.3-2 (Sheet 2)

Design code	ASME Section III, Class 2
Seismic design	Category I

Number	Set Pressure (psig)	Minimum Capacity at 3-Percent Accumulation (lb/hr)
1	1185	803,844
2	1197	825,418
3	1210	847,954
4	1222	874,679
5	1234	901,762

---

* Based on licensing level of 5% equivalent SG tube plugging; 15.96 x 10^6 lb/hr at 1022 psia based on 0% tube plugging.

** Closing time based on system pressure, documented in the Technical Specification Bases.

TABLE 10.3-3 MAIN STEAM SYSTEM SINGLE ACTIVE FAILURE ANALYSIS

	Component	Failure	Comments
1.	Main steam line isolation valve (MSIV)	Loss of power from one power supply	Valve fails closed upon loss of either train of power. Slight venting of steam will occur through the opposite train solenoid valves. This slight venting has been evaluated and found acceptable.
		Loss of one solenoid valve	Valve can still be closed by the redundant actuation train. Slight venting of steam may occur through the failed solenoid valve. This potential has been evaluated and found acceptable.
		Valve fails to close upon receipt of automatic signal (SLIS) requirements	Closure of three out of four isolation valves adequate to meet requirements.
2.	Main steam line isolation bypass valve	Loss of power from one power supply	Redundant power supply provided.
		Valve fails to close upon receipt of automatic signal (SLIS) requirements	Closure of three out of four isolation valves adequate to meet requirements.
3.	Atmospheric relief valves	Loss of power or air to valve fails to modulate upon high pressure	Safety valves provide overpressure protection for the associate line. Atmospheric relief valves on two out of four lines adequate to meet shutdown requirements.
4.	Pressure transmitters	No signal generated for protection logic	For each generator 2-out-of-3 logic reverts to 1-out-of-2 logic, and protection logic is generated by other devices. Refer to Chapter 7.0.

TABLE 10.3-3 (Sheet 2)

	Component	Failure	Comments
5.	Main steam line drain line isolation valve	Valve fails to close upon receipt of automatic signal (SLIS)	Negligible steam lost from generator. In addition, three of four intact secondary loops are required to meet safety requirements.
6.	Steam supply valve to auxiliary feedpump turbine	Valve fails to open upon receipt of automatic signal (AFAS)	Redundant valve provides 100 percent of flow requirements to the auxiliary feed pump turbine.
		Supplied from broken secondary loop and train of power for redundant supply valve lost	Redundant motor-driven auxiliary feedwater pump meets 100 percent of auxiliary feedwater requirements.

TABLE 10.3-4 DELETED

10.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

This section provides discussions of each of the principal design features of the steam and power conversion system.

10.4.1 MAIN CONDENSERS

The main condenser is the steam cycle heat sink. During normal operation, it receives and condenses main turbine exhaust steam, steam generator feedwater pump turbine exhaust steam, and turbine bypass steam. The main condenser is also a collection point for other steam cycle miscellaneous flows, drains, and vents.

The main condenser is utilized as a heat sink in the initial phase of reactor cooldown during a normal plant shutdown.

10.4.1.1 Design Bases

10.4.1.1.1 Safety Design Bases

The main condenser serves no safety function and has no safety design basis.

10.4.1.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The main condenser is designed to function as the steam cycle heat sink and miscellaneous flow collection point.

POWER GENERATION DESIGN BASIS TWO - The main condenser accommodates up to 40 percent of the VWO main steam flow which is bypassed directly to the condenser by the turbine bypass system.

POWER GENERATION DESIGN BASIS THREE - The main condenser provides for the removal of noncondensable gases from the condensing steam through the main condenser air removal system, as described in Section 10.4.2.

POWER GENERATION DESIGN BASIS FOUR - The main condenser provides the surge volume required for the condensate and feedwater system.

POWER GENERATION DESIGN BASIS FIVE - The main condenser provides for deaeration of the condensate, such that condensate oxygen content will not exceed 7 ppb under any normal operating condition.

10.4.1.2 System Description

10.4.1.2.1 General Description

The main condenser is a multipressure, three-shell, deaerating unit. Each shell is located beneath its respective low-pressure turbine. The tubes in each shell are oriented transverse to the turbine-generator longitudinal axis.

The three condenser shells are designated as the low-pressure shell, the intermediate-pressure shell, and the high-pressure shell. Each shell has four tube bundles. Circulating water flows through six circuits in series through the three single-pass shells, as shown in Figure 10.4-1.

Exhaust steam from the steam generator feedwater pump turbine is used to reheat the condensate in the condenser. Each hotwell is divided longitudinally by a vertical partition plate. The condensate pumps take suction from these hotwells, as shown in Figure 10.4-2.

The condenser shells are located in pits below the turbine building operating floor and are supported above the turbine building foundation. Failure of or leakage from a condenser shell will only result in a minimum water level in the condenser pit. Expansion joints are provided between each turbine exhaust opening and the steam inlet connections of the condenser shell. Water seals are provided around the entire outside periphery of these expansion joints. Level indication provides detection of leakage through the expansion joint. The hotwells of the three shells are interconnected by steam-equalizing lines. Four low-pressure feedwater heaters are located in the steam dome of each shell. Piping is installed for hotwell level control and condensate sampling.

10.4.1.2.2 Component Description

Table 10.4-1 provides the design data for each condenser shell for both the closed loop and open loop circulating water systems.

10.4.1.2.3 System Operation

During normal operation, exhaust steam from the low-pressure turbines is directed into the main condenser shells. The condenser also receives auxiliary system flows, such as feedwater heater vents and drains and feedwater pump turbine exhaust.

Hotwell level controls provide automatic makeup or rejection of condensate to maintain a normal level in the condenser hotwells. On low water level in a hotwell, the makeup control valves open and admit condensate to the hotwell from the condensate storage tank. When the hotwell is brought to within normal-operating range, the valves close. On high water level in the hotwell, the condensate reject control valve opens to divert condensate from the condensate pump discharge (downstream of the demineralizers) to the condensate storage tank; rejection is stopped when the hotwell level falls to within normal operating range.

Sparger piping is provided for distribution of turbine bypass discharge and other high temperature drains. Orifices are provided internal to the spargers where necessary for pressure reduction prior to distribution within the condenser. Where sparger piping cannot be utilizied due to space limitations, baffles are provided to direct the discharge away from the tubes and other condenser components. Pressure reducing orifices are provided in the drains piping outside the condenser, where required.

The main condenser, with the assistance of auxiliary steam at low loads, deaerates the condensate so that dissolved oxygen does not exceed 7 ppb over the entire load range. Both the air inleakage and the noncondensable gases contained in the turbine exhaust are collected in the condenser and removed by the condenser air removal system.

During the initial cooling period after plant shutdown, the main condenser removes residual heat from the reactor coolant system via the turbine bypass system. The main condenser receives up to 40 percent of VWO main steam flow through the turbine bypass valves. If the condenser is not available to receive steam via the turbine bypass system, the reactor coolant system can be safely cooled down by discharging steam through the atmospheric relief valves or the main steam safety valves, as described in Section 10.3.

Circulating water leakage occurring within the condenser is detected and alarmed in the control room by monitoring the condensate leaving each hotwell (six monitoring points altogether). This information permits determination of which tube bundle has sustained the leakage. Steps may then be taken to isolate and dewater that bundle and its water boxes and, subsequently, repair or plug the leaking tubes.

During normal operation and shutdown, the main condenser has a negligible inventory of radioactive contaminants. Radioactive contaminants may enter through a steam generator tube leak. A discussion of the radiological aspects of primary-to-secondary leakage, including anticipated operating concentrations of radioactive contaminants, is included in Chapter 11.0. No hydrogen buildup in the main condenser is anticipated.

The failure of the main condenser and the resulting flooding will not preclude operation of any essential system because no safety-related equipment is located in the turbine building, and the water cannot reach the equipment located in the auxiliary building. Refer to Section 10.4.5.

10.4.1.3 Safety Evaluation

The main condenser serves no safety-related function.

10.4.1.4 Tests and Inspections

The condenser shells are hydrostatically tested after erection.

The condenser waterboxes, tubesheets, and tubes are hydrostatically tested as a unit.

10.4.1.5 Instrument Applications

The main condenser hotwells are equipped with level control devices for automatic control of condensate makeup and rejection. Local and remote indicating devices are provided for monitoring the water level in the condenser shells. High, low, and low-low hotwell water level alarms are provided in the control room.

Instruments are provided to monitor condenser back-pressure. Condenser high back-pressure alarm and turbine trip are activated when operating limits, recommended by the turbine manufacturer, are exceeded.

Conductivity and sodium content of the condensate from each condenser shell is monitored to provide an indication of condenser tube leakage.

Turbine exhaust hood temperature is monitored and controlled with water sprays supplied from the condensate pump discharge.

10.4.2 MAIN CONDENSER EVACUATION SYSTEM

Main condenser evacuation is performed by the main condenser air removal system (MCARS). The MCARS removes noncondensable gases and air from the main condenser during plant startup, cooldown, and normal operation.

10.4.2.1 Design Bases

10.4.2.1.1 Safety Design Bases

The MCARS serves no safety function and has no safety design bases.

10.4.2.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The MCARS is designed to remove air and noncondensable gases from the condenser during plant startup, cooldown, and normal operation.

POWER GENERATION DESIGN BASIS TWO - The MCARS establishes and maintains a vacuum in the condenser during startup and normal operation by the use of mechanical vacuum pumps.

10.4.2.2 System Description

10.4.2.2.1 General Description

The MCARS, as shown in Figure 10.4-3, consists of three mechanical vacuum pumps which remove air and noncondensable gases from the main condenser during normal operation and provide condenser hogging during startup.

The seal water cooler uses service water so that the seal water is kept cooler than the saturation temperature of the condenser at its operating pressure. As described in Section 9.4.4, air inleakage and noncondensable gases that are removed from the condenser and discharged from the pumps are processed through the charcoal adsorption train and monitored for radioactivity prior to discharge to the unit vent.

The noncondensable gases and vapor mixture discharged to the atmosphere from the system is not normally radioactive. However, it is possible for the mixture discharged to become contaminated in the event of primary-to-secondary system leakage.

A discussion of the radiological aspects of primary-to-secondary leakage, including anticipated release from the system, is included in Chapter 11.0.

As long as the MCARS is functional, its operation does not affect the reactor coolant system. Should the air removal system fail completely, a gradual reduction in condenser vacuum would result from the buildup of noncondensable gases. This reduction in vacuum would cause a lowering of turbine cycle efficiency which requires an increase in reactor power to maintain the demanded electrical power generation level. The reactor power is limited by the reactor control system, as described in Section 7.7. The reactor protection system, described in Section 7.2, independently guarantees that the reactor is maintained within safe operation limits.

If the MCARS remains inoperable, condenser vacuum decreases to the turbine trip setpoint and a turbine trip is initiated. A loss of condenser vacuum incident is discussed in Section 15.2.5.

10.4.2.2.2 Component Description

MECHANICAL VACUUM PUMPS - The mechanical vacuum pumps are 150 hp motor-driven pumps which operate at 435 rpm.

SEAL WATER COOLERS - The seal water coolers are shell and tube heat exchangers. Mechanical vacuum pump seal water flows through the shell side of the coolers, and service water flows through the tubes.

Piping and valves are carbon steel. All piping is designed to ANSI B31.1. The design parameters of the system are provided in Table 10.4-2.

10.4.2.2.3 System Operation

During normal plant operation, noncondensable gases are removed from the condenser, and the condenser vacuum is automatically maintained by the condenser vacuum pumps.

During startup operation, air is rapidly removed from the condenser by three condenser mechanical vacuum pumps.

10.4.2.3 Safety Evaluation

The main condenser evacuation system has no safety-related function.

10.4.2.4 Tests and Inspections

Testing and inspection of the system is performed prior to plant operation.

Components of the system are continuously monitored during operation to ensure satisfactory operation. Periodic inservice tests and inspections of the evacuation system are performed in conjunction with the scheduled maintenance outages.

10.4.2.5 Instrumentation Applications

Local indicating devices such as pressure, temperature, and flow indicators are provided as required for monitoring the system operation. Pressure switches are provided for automatic operation of the standby mechanical vacuum pump during normal operation.

Volumetric flow indication is provided locally to monitor the quantity of exhausted noncondensable gases.

A radiation detector is provided in the turbine building HVAC system to monitor the discharge of the condenser mechanical vacuum pumps. The radiation detector is indicated and alarmed in the control room.

10.4.3 TURBINE GLAND SEALING SYSTEM

The turbine gland sealing system (TGSS) prevents the escape of steam from the turbine shaft/casing penetrations and valve stems and prevents air inleakage to subatmospheric turbine glands.

10.4.3.1 Design Bases

10.4.3.1.1 Safety Design Basis

The TGSS serves no safety function and has no safety design basis.

10.4.3.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The TGSS is designed to prevent atmospheric air leakage into the turbine casings and to minimize steam leakage out of the casings of the turbine-generator and steam generator feedwater pump turbines.

POWER GENERATION DESIGN BASIS TWO - The TGSS returns the condensed steam to the condenser and exhausts the noncondensable gases to the atmosphere.

POWER GENERATION DESIGN BASIS THREE - The TGSS has a capacity to handle steam and air flows resulting from twice the normal packing clearances.

10.4.3.2 System Description

10.4.3.2.1 General Description

The TGSS is shown in Figure 10.4-4. It consists of steam seal inlet and exhaust headers, feed and unloading valves, steam packing exhauster, blowers, and associated piping and valves.

10.4.3.2.2 System Operation

The annular space through which the turbine shaft penetrates the casing is sealed by steam supplied to shaft packings. Where the packing seals against positive pressure, the sealing steam connection acts as a leakoff. Where the packing seals against vacuum, the sealing steam either is drawn into the casing or leaks outward to a vent annulus that is maintained at a slight vacuum. The vent annulus also receives air leakage from the outside. The air-steam mixture is drawn to the steam packing exhauster.

Sealing steam is distributed to the turbine shaft seals through the steam-seal header. Steam flow to the header is controlled by the steam-seal feed valve which responds to maintain steam-seal header pressure. In case of low steam-seal header pressure, a pressure regulator signal opens the feed valves to admit steam from the main steam piping upstream of the turbine stop valves, from the auxiliary steam headers, or from twelfth stage turbine extraction. In case of high pressure, the steam packing unloading valve automatically opens to bypass excess steam directly to the main condenser.

During the startup phase of turbine-generator operation or at low turbine loads, steam is supplied to the turbine gland sealing system from the main steam piping or auxiliary steam header. During low-load operation, turbine-generator sealing steam is supplied from the main steam system through the steam-seal feed valve to maintain the necessary steam flow to the steam-seal header. As the turbine-generator load is increased, steam leakage from the control valve packings and turbine high-pressure packings increases, and enters the steam-seal header. When this leakage is sufficient to maintain steam-seal header pressure, sealing steam to all turbine seals, including the low-pressure turbine casings and the main feedwater pump turbine, is supplied entirely from these high-pressure packings. At full load, more steam leaks from the high-pressure packings than is required by vacuum packings, and excess steam is discharged directly to the main condenser. Steam leak-off from the turbine stop valves feeds into the high-pressure turbine exhaust.

The outer ends of all glands are provided with collection piping which routes the mixture of air and excess seal steam to the steam packing exhauster. The steam packing exhauster is a shell and tube heat exchanger; the steam-air mixture passes into the shell side, and service water flows through the tube side. The steam packing exhauster is maintained at a slight vacuum by a motor-operated blower, which discharges to the turbine building roof. There are two blowers mounted in parallel which provide 100-percent redundancy. Condensate from the steam-air mixture drains to the main condensers, while noncondensables are exhausted to the atmosphere.

The mixture of noncondensable gases discharged to the atmosphere by the steam packing exhauster blower is not normally radioactive; however, in the event of significant primary-to-secondary system leakage due to a steam generator tube leak, it is possible for the mixture discharged to be radioactively contaminated. Primary-to-secondary system leakage is detected by the radiation monitors in either the main steam sample system or the condenser air removal system. A full discussion of the radiological aspects of primary-to-secondary system leakage is included in Chapter 11.0.

In the absence of primary-to-secondary leakage, failure of the turbine gland seal system will result in no leakage of radioactivity to the atmosphere. A failure of this system would, however, result in a loss of condenser vacuum.

10.4.3.3 Safety Evaluation

The TGSS has no safety-related function.

10.4.3.4 Tests and Inspections

The system is tested, in accordance with written procedures, during the initial testing and operation program. Since the TGSS is in constant use during normal plant operation, the satisfactory operation of the system components will be evident.

10.4.3.5 Instrumentation Applications

A pressure controller is provided to maintain steam-seal header pressure by providing signals to the steam-seal feed valve.

Local and remote indicators, as well as alarm devices, are provided for monitoring the operation of the system.

10.4.4 TURBINE BYPASS SYSTEM

The turbine bypass system (TBS) has the capability to bypass main steam from the steam generators to the main condenser in a controlled manner to minimize transient effects on the reactor coolant system of startup, hot shutdown and cooldown, and step load reductions in generator load. The TBS is also called the steam dump system.

10.4.4.1 Design Bases

10.4.4.1.1 Safety Design Bases

The TBS serves no safety function and has no safety design basis.

10.4.4.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The TBS has the capacity to bypass 40 percent of the VWO main steam flow to the main condenser.

POWER GENERATION DESIGN BASIS TWO - The TBS is designed to bypass steam to the main condenser during plant startup and to permit a normal manual cooldown of the reactor coolant system from a hot shutdown condition to a point consistent with the initiation of residual heat removal system operation.

POWER GENERATION DESIGN BASIS THREE - The TBS will permit a 50-percent electrical step load reduction without reactor trip. The system will also allow a turbine and reactor trip from full power without lifting the main steam safety valves.

10.4.4.2 System Description

10.4.4.2.1 General Description

The TBS is shown on Figure 10.3-1, Main Steam System. The system consists of a manifold connected to the main steam lines upstream of the turbine stop valves and lines from the manifold with regulating valves to each condenser shell. The system is designed to bypass 40 percent of the VWO main steam flow directly to the condenser.

The capacity of the system, combined with the capacity of the RCS to accept a 10-percent step-load change, provides the capability to shed 50 percent of the turbine-generator rated load without reactor trip and without the operation of relieve and safety valves. A load rejection in excess of 50 percent is expected to result in a reactor trip and operation of the main steam, power-operated, relief valves.

There are 12 turbine bypass valves. Seven valves discharge into the low pressure condenser, four valves discharge into the intermediate condenser, and a single valve discharges into the high pressure condenser. The system is arranged in this manner to allow for the differences in the heat sink capacities of the three condenser shells.

Turbine generator power production is administratively limited to operating at a vacuum recommended by the turbine generator manufacturer.

The steam bypassed to the main condenser is not normally radioactive. In the event of primary-to-secondary leakage, it is possible for the bypassed steam to become radioactively contaminated. A full discussion of the radiological aspects of primary-to-secondary leakage is contained in Chapter 11.0.

10.4.4.2.2 Component Description

The TBS contains 12 air-actuated carbon steel, 8 inch, 1,500 pound globe valves. The valves are pilot-operated, spring-opposed, and fail closed upon loss of air or loss of power to the control system. Sparger piping distributes the steam within the condenser. Isolation valves permit maintenance of the bypass valve while the plant is in operation.

10.4.4.2.3 System Operation

The TBS, during normal operating transients for which the plant is designed, is automatically regulated by the reactor coolant temperature control system to maintain the programmed coolant temperature. The programmed coolant temperature is derived from the high pressure turbine first stage pressure, which is a load reference signal. The difference between programmed reactor coolant average temperature and measured reactor coolant average temperature is used to activate the steam dump system under automatic control. The system operates in two fundamental modes. In one mode, two groups of six valves each trip open sequentially in approximately 3 seconds. This operational mode is activated during a large reactor-to-turbine power mismatch. In the second mode, four groups of three valves each modulate open sequentially in approximately 10 seconds. A logic diagram is shown in Figure 7.2-1 (Sheet 10).

When the plant is at no load and there is no turbine load reference, the system is operated in a pressure control mode. The measured main steam system pressure is compared against the pressure set by the operator in the control room. The pressure control mode is also used for plant cooldown. The valves to any one condenser shell are prevented from opening on increasing shell pressure.

The turbine bypass control system can malfunction in either the open or closed mode. The effects of both these potential failure modes on the NSSS and turbine system are addressed in Chapter 15.0. If the bypass valves fail open, additional heat load is placed on the condenser. If this load is great enough, the turbine is tripped on low condenser vacuum. Ultimate overpressure protection for the condenser is provided by rupture discs. If the bypass valves fail closed, the atmospheric relief valves permit controlled cooldown of the reactor.

10.4.4.3 Safety Evaluation

The TBS serves no safety function and has no safety design basis. There is no safety-related equipment in the vicinity of the TBS. All high energy lines of the TBS are located in the turbine building.

10.4.4.4 Inspection and Testing Requirements

All turbine bypass valves are tested for operability. The steam lines were hydrostatically tested to confirm leaktightness. The bypass valves may be tested while the unit is in operation. All system piping and valves are accessible for inspection.

10.4.4.5 Instrumentation Applications

The turbine bypass control system is described in Section 7.7. Hand switches in the main control room are provided for selection of the system operating mode. Pressure controllers and valve position lights are also located in the main control room.

10.4.5 CIRCULATING WATER SYSTEM

The circulating water system (CWS) within the standard power block consists of the circulating water piping and water box venting subsystems. In addition to the following description for the CWS, refer to Section 10.4.5 of the Site Addendum.

10.4.5.1 Design Bases

10.4.5.1.1 Safety Design Bases

The CWS serves no safety-related function.

10.4.5.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The CWS supplies cooling water at a sufficient flow rate to condense the steam in the condenser, as required by the turbine cycle heat balance for each site.

POWER GENERATION DESIGN BASIS TWO - The CWS will be automatically isolated in the event of gross leakage into the condenser pit to prevent flooding of the turbine building.

POWER GENERATION DESIGN BASIS THREE - The CWS within the standard power block is designed to limit the temperature rise through the main condensers to a maximum of 30°F under design conditions.

10.4.5.2 System Description

10.4.5.2.1 General Description

The CWS within the standard power block consists of piping, valves, seal tanks, and instrumentation, as shown in Figure 10.4-1.

The CWS provides cooling water for the removal of heat from the main condensers and rejects heat to a heat sink. The water box venting subsystem helps to fill the condenser water boxes during startup and removes accumulated air and other gases from the water boxes during normal operation.

A description of the site-related portion of the CWS, including pumps and corrosion control, is provided in Section 10.4.5 of the Site Addendum. System parameters are listed in Table 10.4-3.

10.4.5.2.2 Component Description

Codes and standards applicable to the CWS are listed in Table 3.2-1. The system is designed and constructed in accordance with quality group D specifications. Table 10.4-3 provides the design parameters for major components in the circulating water system located within the standard power block.

10.4.5.2.3 System Operation

The CWS operates continuously during power generation, including startup and shutdown. The isolation valves in the standard power block are controlled by locally mounted hand switches. The butterfly valves on the discharge of the circulating water pumps will be closed in the event of an isolation signal from the condenser pit high level switches, which are actuated when the water level reaches 5 feet above the bottom of the condenser pit. An alarm is provided in the control room. The water level trip is set high to prevent inadvertent trips from unrelated failures, such as a sump overflow.

Filling of the CWS is initiated by closing the circulating water pump discharge valves and starting the service water system. The service water will fill the entire CWS to El. 2027 (the top of the water boxes). During normal operation, noncondensable gases will be removed automatically through the water box vent valves.

Approximately one-sixth of the tubes of each of the three condensers can be isolated by closing associated inlet and outlet water box isolation valves.

Draining of any condenser water box that is selected is initiated by closing the condenser isolation valves and opening the drain connection and a vent valve on the water box. When the suction standpipe of the condenser drain pump is filled, the pump is manually started. A low level switch is provided in the standpipe, on the suction side of the drain pump. This switch will automatically stop the pump in the event of low water level in the standpipe to protect the pump from cavitation.

10.4.5.3 Safety Evaluation

The CWS is not a safety-related system; however, a flooding analysis of the turbine building was performed on the CWS which postulated a complete rupture of a single expansion joint. A complete description of the CWS flooding analysis is provided in Section 3B.4.3.

10.4.5.4 Tests and Inspections

Preoperational testing is described in Chapter 14.0. The performance and structural and leak tight integrity of all system components are demonstrated by continuous operation.

10.4.5.5 Instrumentation Applications

Temperature monitors are provided at the inlet and outlet water boxes of each condenser shell section.

Indication is provided in the control room to identify open and closed positions of motor-operated butterfly valves in the CWS piping.

10.4.6 CONDENSATE CLEANUP SYSTEM

The condensate cleanup function is performed by the condensate demineralizer system (CDS). The CDS is designed to maintain the required purity of feedwater for the steam generators by filtration to remove corrosion products and by ion exchange to remove condenser leakage impurities. The secondary side water chemistry requirements are given in Section 10.3.5.

10.4.6.1 Design Bases

10.4.6.1.1 Safety Design Bases

The CDS serves no safety function and has no safety design bases.

10.4.6.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The CDS removes dissolved and suspended solids from the condensate prior to startup.

POWER GENERATION DESIGN BASIS TWO - The CDS removes impurities entering the secondary cycle from condenser leaks that would otherwise deposit or increase corrosion rates in the secondary cycle.

POWER GENERATION DESIGN BASIS THREE - The CDS removes corrosion products from the condensate and any drains returned to the condenser hotwell so as to limit any accumulation in the secondary cycle.

POWER GENERATION DESIGN BASIS FOUR - The CDS limits the entry of dissolved solids into the feedwater system in the event of large condenser leaks, such as a tube break, to permit a reasonable amount of time for plant shutdown.

10.4.6.2 System Description

10.4.6.2.1 General Description

The CDS consists of demineralizer vessels, regeneration tanks, pumps, piping, instrumentation, and controls, as shown in Figure 10.4-5. The CDS components are located in the turbine building at El. 2000, E1. 1983.

10.4.6.2.2 Component Description

Codes and standards applicable to the CDS are listed in Table 3.2-2. The system is designed and constructed in accordance with quality group D requirements. Design data for major components of the CDS are listed in Table 10.4-4.

CONDENSATE DEMINERALIZER VESSELS - There are six 20-percent-capacity spherical vessels with deep-bed regenerable mixed strong acid cation/strong base anion resins, each constructed of carbon steel and lined with natural rubber. The design flowrate is 50 gpm per square foot of bed, and the bed depth is 36 inches.

REGENERATION TANKS - The three resin regeneration tanks are the resin separation and cation regeneration tank, anion regeneration tank, and the resin mixing and storage tank. All tanks are constructed of carbon steel and lined with natural rubber.

MISCELLANEOUS EQUIPMENT - Miscellaneous equipment includes two sulfuric acid feed pumps (one standby); two caustic soda feed pumps (one standby); four sluice water pumps, two pumps (one standby) furnishing demineralized water as the preferred water source from the DWST, the other two pumps (one standby) furnishing condensate as an alternate water source from the CST; one sulfuric acid day tank; one caustic soda day tank; one resin addition hopper with eductor; one caustic dilution hot water tank; one waste collection tank, piping; instrumentation, and controls. In addition, one sulfuric acid and one caustic feed pump, which take suction from their respective day tanks, are included to feed chemicals into the high TDS tanks for neutralization of pH adjustment.

10.4.6.2.3 System Operation

The CDS will be operated as necessary to maintain feedwater purity levels. The condensate demineralizers are capable of hydrogen, amine or ammonia cycle operation.

The ammonia or amine cycle operation with negligible condenser leakage will allow an extended demineralizer run of several weeks. Operation with large condenser leakage requires that the demineralizer beds be run in the hydrogen cycle to meet secondary side chemistry requirements. The waste processing of the regenerative waste is limited to one bed every 2 days, on a continuous basis. Allowable condenser inleakage is limited to levels that will not require continuous regeneration of a demineralizer bed more than once every 2 days.

The service run for a demineralizer vessel is terminated by either high differential pressure across the vessel or high cation conductivity or sodium content in the demineralizer effluent water. Alarms for each of these monitoring points are provided via operator stations.

The operator stations are equipped with the appropriate instruments and controls to allow the operators to perform the following operations:

a. Remove an exhausted demineralizer from service and replace it with a standby unit

b. Initiate resin transfer from the demineralizer vessel into the cation regeneration tank

c. Initiate resin transfer from the resin mixing and holding tank to the empty demineralizer vessel

d. Initiate a complete resin regeneration process

e. Initiate a resin wash-air scrub process without chemical regeneration

On termination of a service run, the exhausted demineralizer vessel is taken out of service, and the standby unit is put in service from the operator stations. The resin from the exhausted vessel is transferred to the cation regeneration tank. The anion and cation resins are hydraulically separated. The anion resin is transferred to the anion regeneration tank. Each resin is then backwashed, chemically regenerated, rinsed, and transferred to the resin mixing and storage holding tank for final rinsing and mixing.

The regeneration process used is a cation/anion separation process which facilitates ammonia or amine cycle operation. The hydraulic process effectively separates and isolates the respective resin components; hence, the technique ensures complete conversion of both resins to the desired regenerated form. This reduces the potential of either sodium or sulfate leaching into the condensate stream. During the wash-air scrub process, a similar procedure is followed, except that there is no chemical regeneration involved.

This process is used for crud removal when the resin bed has been exhausted by high differential pressure.

Final rinse recycle procedure is performed on the demineralizer before it is placed in service. The rinse is monitored by conductivity analyzers, and the process is terminated when the required conductivity is obtained.

Regenerant chemicals are 66-degrees Baume sulfuric acid and 50-percent liquid caustic soda. Dilution of the sulfuric acid and caustic soda to the required application concentrations and temperatures is accomplished at the time of use in closed low-pressure systems employing in-line mixing tees.

Regenerant wastes are segregated by total dissolved solid content (TDS). Regenerant wastes of less than approximately 100 ppm TDS are sent to the low TDS tank in the secondary liquid waste system. Low TDS waste is generated in the initial backwash and during the final stages of resin rinsing following chemical regeneration. The backwash is usually high in particulate content. The high TDS (greater than 300 μmho conductivity) is generated from the chemical regeneration and the initial stages of the rinsing after chemical regeneration. Approximately 29,000 gallons of high TDS and 66,000 gallons of low TDS wastes are generated as a result of a regeneration cycle. These values may vary considerably depending on the condition of the secondary system.

Processing of high and low TDS waste in the secondary liquid waste system is described in Section 10.4.10.

The demineralizer system includes all isolation valves, piping for vessels, post strainers, and equipment necessary for resin transfer. There is also a recirculation line to the condenser for purging aerated water from any vessel being placed in service.

10.4.6.2.4 Radioactivity

Under normal operating conditions, there is insignificant radioactivity present in the steam and power conversion system. It is possible for the cycle to become contaminated through a steam generator tube leak. Based on a postulated primary-to-secondary leak rate, the equilibrium secondary system activities are developed in Chapter 11.0. The condensate demineralizers will reduce the radioactivity level in the secondary cycle, as described in Chapter 11.0.

Based on the condensate activity and the bed run times, the radioactivity that concentrates on the demineralizer beds will not reach a significant level. The small quantity of radioactive material introduced to the secondary liquid waste system is discussed in Section 10.4.10.

Radiation levels near the demineralizers can be limited by increasing the frequency of regeneration of the beds to remove the radioactive material from the resin beds. Administrative controls can be implemented to limit personnel access, if required.

10.4.6.3 Safety Evaluation

The CDS serves no safety function.

10.4.6.4 Tests and Inspections

Preoperational testing of the CDS, as described in Chapter 14.0, ensures the proper functioning of the equipment and instrumentation. The system operating parameters are monitored during power operation.

10.4.6.5 Instrumentation Applications

Continuous, on-line instrumentation is provided to monitor equipment performance in service or during the regeneration cycle. Operator stations display all alarms to indicate trouble in the system. Trouble alarms also annunciate in the main control room. Systematic analysis of local samples is performed to monitor the accuracy of the automatic equipment. Flow and differential pressure are continually monitored, in addition to ionic concentration for both influent and effluent streams.

10.4.7 CONDENSATE AND FEEDWATER SYSTEM

The function of the condensate and feedwater system is to supply a sufficient quantity of feedwater to the steam generator secondary side inlet during normal operating conditions and to ensure feedwater isolation when required. The condensate pumps take suction from the condenser hotwell, and the two turbine-driven main feedwater (MFW) pumps deliver water to the steam generators at elevated temperatures and pressures.

10.4.7.1 Design Bases

10.4.7.1.1 Safety Design Bases

The portion of the CFS from the steam generator to the steam generator isolation valves is safety related and is required to function following a DBA and to achieve and maintain the plant in a safe shutdown condition.

SAFETY DESIGN BASIS ONE - The safety-related portion of the CFS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The safety-related portion of the CFS is designed to remain functional after an SSE or to perform its intended function following postulated hazards of fire, internal missiles, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-34).

SAFETY DESIGN BASIS FOUR - The CFS is designed such that the active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI.

SAFETY DESIGN BASIS FIVE - The CFS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - For a main feedwater line break inside the containment or an MSLB, the CFS is designed to limit high energy fluid to the broken loop and to provide a path for addition of auxiliary feedwater to the three intact loops.

SAFETY DESIGN BASIS SEVEN - For a main feedwater line break upstream of the main feedwater isolation valve (outside of the containment), the CFS is designed to prevent the blowdown of any steam generator and to provide a path for the addition of auxiliary feedwater.

SAFETY DESIGN BASIS EIGHT - The CFS is designed to provide a path to permit the addition of auxiliary feedwater for reactor cooldown under emergency shutdown conditions (GDC-34).

10.4.7.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The CFS is designed to provide a continuous feedwater supply to the four steam generators at required pressure and evaluated temperature under anticipated steady-state and transient conditions.

POWER GENERATION DESIGN BASIS TWO - The CFS is designed to control the dissolved oxygen content and pH in the turbine cycle and the steam generators.

POWER GENERATION DESIGN BASIS THREE - The CFS is designed to maintain feedwater flow following a 50-percent step reduction in electrical load.

POWER GENERATION DESIGN BASIS FOUR - The CFS is designed to provide heated feedwater to the steam generators during startup and shutdown to minimize thermal stresses and preclude steam generator feedwater nozzle cracking.

10.4.7.2 <u>System Description</u>

10.4.7.2.1 General Description

The CFS, as shown in Figures 10.4-2 and 10.4-6, consists of three condensate pumps, two 67-percent capacity turbine-driven steam generator feedwater pumps, one 480 gpm capacity motor-driven feedwater pump, four stages of low-pressure feedwater heaters, and three stages of high-pressure feedwater heaters, piping, valves, and instrumentation. The condensate pumps take suction from the condenser hotwell and discharge the condensate into one common header which feeds the condensate demineralizers. The condensate demineralizers may be bypassed. Downstream of the condensate demineralizers, the header branches into three parallel trains. Each train contains four stages of low-pressure feedwater heaters. The trains join together at a common header which branches into two lines which go to the suction of the steam generator feedwater pumps. The turbine-driven feedwater pumps discharge the feedwater into two cross-connected parallel trains. Each of the two trains contains three stages of high-pressure feedwater heaters. Another feedwater path is provided to allow the low pressure feedwater heaters and the turbine-driven feed pumps to be bypassed during start-up and shutdown. The motor-driven feedwater pump in this path discharges into the common header downstream of the turbine-driven feed pumps and upstream of the high-pressure feedwater heaters. Downstream of the high-pressure feedwater heaters, the two trains are then joined into a common header, which divides into four lines which connect to the four steam generators. Each of the four lines contains a main feedwater control valve and main feedwater bypass control valve, a feedwater flow element, a system-medium regulated main feedwater isolation valve (MFIV), an auxiliary feedwater connection, a chemical injection connection, and a nozzle check valve.

The condensate and feedwater chemical injection system, as shown in Figure 10.4-7, is provided to inject hydrazine and ammonia or an alternate amine into the condensate pump discharge downstream of the condensate demineralizers and additional hydrazine and ammonia into the four main feedwater lines connecting with the four steam generators. Injection points are shown in Figure 10.4-6.

During normal power operation, hydrazine and ammonia or an alternate amine are added continuously to the condensate system. As discussed in Section 10.3.5, the addition of ammonia or an alternate amine and hydrazine establishes the design pH according to the condensate and feedwater system chemistry requirements and establishes a constant initial hydrazine residual in the feedwater system so that oxygen inleakage can be scavenged.

The following measures have been taken to protect personnel from any toxic effects of chemicals:

a. Ammonium hydroxide or an alternate amine and hydrazine solution and measuring tanks are provided with a vent line routed outside the turbine building to minimize ammonia, amine and hydrazine vapors in the general atmosphere of the turbine building.

b. Concentrated chemicals are diluted in the solution tanks.

c. Corrosion-resistant construction materials (stainless steels) are used throughout the storage and injection equipment.

d. Chemical mixing is accomplished by closed-loop recirculation with centrifugal recirculation pumps. No external tank mixers are used to agitate tank contents.

e. Chemical tote or drum unloading is accomplished with UL-listed explosion proof motor and pumps, which are nonsparking and pose no electrical hazard to personnel.

The manually controlled feedwater ammonia or alternate amine and hydrazine system is provided for special plant conditions, such as hydrostatic test, hot standby, layup, etc. These conditions require high levels of pH and hydrazine residual to minimize corrosion in the steam generators.

Component failures within the CFS which affect the final feedwater temperature or flow have a direct effect on the reactor coolant system and are listed in Table 10.4-5. Occurrences which produce an increase in feedwater flow or a decrease in feedwater temperature result in increased heat removal from the reactor coolant system, which is compensated for by control system action, as described in Section 7.7. Events which produce the opposite effect, i.e., decreased feedwater flow or increased feedwater temperature, result in reduced heat transfer in the steam generators. Normally, automatic control system action is available to adjust feedwater flow and reactor power to prevent excess energy accumulation in the reactor coolant system, and the increasing reactor coolant temperature provides a negative reactivity feedback which tends to reduce reactor power. In the absence of normal control action, either the high outlet temperature or high pressure trips of the reactor by the reactor protection system are available to assure reactor safety. Loss of all feedwater, the most severe transient of this type, is examined in Chapter 15.0.

Refer to Section 5.4 for a discussion of steam generator design features to preclude fluid flow instabilities, such as water hammer. The feedwater connection on each of the steam generators is the highest point of each feedwater line downstream of the MFIV. The feedwater lines contain no high point pockets which, if present, could trap steam and lead to water hammer. The horizontal run length from the feedwater nozzle of each steam generator is minimized. The routing of the main feedwater lines is shown in Figures 1.2-12, 1.2-15, and 1.2-17.

The non-safety auxiliary feedwater pump (NSAFP) recirculation line discharges to the condensate reject line and then to the condensate storage tank as shown in Figure 10.4-2 (sheet 2).

10.4.7.2.2 Component Description

Codes and standards applicable to the CFS are listed in Table 3.2-1. The CFS is designed and constructed in accordance with quality group B and seismic Category I requirements from the steam generator out to the torsional restraint upstream of the main feedwater isolation valves. The remaining piping of the CFS meets ANSI B31.1

requirements. Branch lines out to and including isolation valves for the auxiliary feedwater and chemical injection are designed and constructed in accordance with quality group B and seismic Category I requirements. Refer to Tables 10.1-1 and 10.4-6 for design data. Safety-related feedwater piping materials are discussed in Section 10.3.6.

MAIN FEEDWATER PIPING - Feedwater is supplied to the four steam generators by four 14-inch carbon steel lines. Each of the lines is anchored at the containment wall and has sufficient flexibility to provide for relative movement of the steam generators due to thermal expansion. The main feedwater line and associated branch lines between the containment penetration and the torsional restraint upstream of the MFIV are designed to meet the "no break zone" criteria, as described in NRC BTP MEB-3-1 (refer to Section 3.6).

MAIN FEEDWATER ISOLATION VALVES - One main feedwater isolation valve (MFIV) is installed in each of the four main feedwater lines outside the containment and downstream of the feedwater control valve. The MFIVs are installed to prevent uncontrolled blowdown from any steam generator in the event of a feedwater pipe rupture in the turbine building. The main feedwater check valve provides backup isolation. The MFIVs isolate the nonsafety-related portions from the safety-related portions of the system. In the event of a secondary cycle pipe rupture inside the containment, the MFIV limits the quantity of high energy fluid that enters the containment through the broken loop and provides a pressure boundary for the controlled addition of auxiliary feedwater to the three intact loops. The valves are bi-directional, double disc, parallel slide gate valves. The MFIV actuators utilize two separate actuation trains, which are energized from separate Class 1 E sources. Energy for closing an MFIV is provided by the process fluid (feedwater), which is admitted to the volume above the actuator piston (upper piston chamber) to close the valve. The MFIV actuators utilize six solenoid valves, three solenoids per actuation train, to perform their safety design functions. Process fluid will be directed to the actuator upper piston chamber (to close the valve) by two parallel trains consisting of one two-way solenoid valve and one three-way solenoid valve in series. For emergency closure, both upper piston chamber solenoid valves within an actuation train must be de-energized. Once the two upper piston chamber solenoids within an actuation train de-energize, they open to admit process fluid from the valve bonnet chamber to the actuator upper piston chamber. The actuator lower piston chamber is vented through a two-way solenoid valve and a three-way solenoid valve connected in parallel to the actuator lower piston chamber, which are in a de-energized state (vented position). After a one hundred twenty-second time delay both actuator lower piston chamber solenoid valves will energize, isolating the lower piston chamber. Isolating the lower piston chamber will prevent any leakage of process fluid from either the piston rings or the stem seal from venting through the lower piston chamber to the condenser.

MAIN FEEDWATER CONTROL VALVES AND BYPASS CONTROL VALVES - The main feedwater control valves (also known as main feedwater regulating valves) are air-operated angle valves which automatically control feedwater between 20 percent and full power. The bypass control valves are air-operated globe valves, which are normally used up to 25 percent power (although a bypass control valve(s) may occasionally be opened during power operation above 25 percent power to support maintenance, post-maintenance testing, or other plant activities). The main feedwater control valves and bypass control valves are located in the turbine building.

In the event of a secondary cycle pipe rupture inside the containment, the main feedwater control valve (and associated bypass valve) provide a diverse backup to the MFIV to limit the quantity of high energy fluid that enters the containment through the broken loop. For emergency closure, both solenoids, when de-energized, will result in valve closure. Electrical solenoids are energized from separate Class 1E sources. A backup nitrogen system is available to simultaneously close the main feedwater control valves in the event of a loss of offsite power.

MAIN FEEDWATER CHECK VALVES - The main feedwater check valves are located inside the containment, downstream of the auxiliary feedwater connection. In the event of a secondary cycle pipe rupture, inside the containment, the main feedwater check valves provide a diverse backup to the MFIV to ensure the pressure boundary of any intact loop not receiving auxiliary feedwater.

In the event of a feed line rupture between the containment and the main feedwater check valve, the feedwater check valve will close and terminate blowdown from the steam generator.

CHEMICAL ADDITION LINE CHECK VALVES AND ISOLATION VALVES -The check valves are located downstream of the isolation valves in the chemical addition lines. The check valves provide a diverse backup to the isolation valves to ensure the pressure boundary. The normally closed isolation valves are air-operated valves which fail closed.

CONDENSATE PUMPS - The three condensate pumps are motor driven and operate in parallel. Valving is provided to allow individual pumps to be removed from service. Pump capacity is sufficient to meet full power requirements with two of the three pumps in operation.

LOW-PRESSURE FEEDWATER HEATERS - Parallel strings of closed feedwater heaters are located in the condenser necks. The No. 1, 2, 3, and 4 heaters have integral drain coolers, and their drains are cascaded to the next lower stage feedwater heater in each case. The drains from No. 1 heaters are dumped to the main condenser. Feedwater leaving the No. 4 heaters is headered and goes to the steam generator feed pumps. The heater shells are carbon steel, and the tubes are stainless steel.

HIGH-PRESSURE FEEDWATER HEATERS - Parallel strings of three high-pressure feedwater heaters with integral drain coolers in heaters 6 and 7 are used. The No. 7 heaters are drained to the No. 6 heaters which, in turn, drain to the heater drain tank. The No. 5 heaters drain directly to the heater drain tank. The heater shells are carbon steel, and the tubes are stainless steel.

Isolation valves and bypasses are provided which allow each string of high-pressure and low-pressure heaters to be removed from service. System operability is maintained at reduced power in the case of the low-pressure heaters with the parallel heaters and bypass line.

Full power operation at reduced RCS Tavg and feedwater temperature has been evaluated. The method to accomplish this operation is to throttle the high pressure feedwater heater bypass valve AEHV0038 as discussed in Section 10.4.7.2.3.

Provisions are made in all heater drain lines, except No. 5, which drains via the heater drain tank, to allow direct discharge to the condenser in the event the normal drain path is blocked.

HEATER DRAIN TANK - A single heater drain tank drains the shells of No. 5 and No. 6 feedwater heaters and provides reservoir capacity for drain pumping. The heater drain tank is installed in such a way that the No. 5 heaters drain freely by gravity flow. The drain level is maintained within the tank by a level controller in conjunction with a heater drain pump.

The heater drain tank is provided with an alternate drain line to the main condenser for automatic dumping upon high level. The alternate drain line is also used during startup and shutdown when it is desirable to bypass the drain piping for feedwater quality purposes.

HEATER DRAIN PUMPS - Two motor-driven heater drain pumps operate in parallel, taking suction from the heater drain tank and discharging it into the suction of the steam generator feed pumps.

The piping arrangement allows each heater drain pump to be individually removed from service while operating the remaining pump.

STEAM GENERATOR FEEDWATER PUMPS - The steam generator feedwater pumps (SGFP) operate in parallel and discharge to the high-pressure feedwater heaters. The pumps take suction following the No. 4, low-pressure feedwater heaters and discharge through the high-pressure feedwater heaters. Each pump is turbine driven with independent speed-control units. Steam for the turbines is supplied from the main steam header at low loads and from the moisture separator reheater outlet during normal operation.

Isolation valves are provided which allow each steam generator feed pump to be individually removed from service, while continuing operations at reduced capacity.

PUMP RECIRCULATION SYSTEMS - Minimum-flow control systems are provided to allow all pumps in the main condensate and feedwater trains to pump at the manufacturer's recommended minimum flow rate to prevent damage.

MOTOR-DRIVEN FEEDWATER PUMP - One motor-driven feedwater pump (MDFP) is provided to feed heated feedwater to the steam generators during start-up and shutdown conditions. The pump takes suction from the steam generator blowdown regenerative heat exchanger and discharges through the high-pressure feedwater heaters.

10.4.7.2.3 System Operation

START-UP AND SHUTDOWN OPERATION - During start-up and shutdown, the low-pressure feedwater heaters and turbine-driven pumps are not utilized. Instead, the condensate is directed to the steam generator blowdown regenerative heat exchanger where it is heated by the liquid discharge from the steam generator blowdown flash tanks. The heated fluid is then pumped by the motor-driven feed pump through feedwater heaters 5, 6 and 7 to the steam generators. As the feedwater passes through feedwater heater 5, it is further heated by the steam discharge diverted from the steam generator blowdown flash tank. The feedwater is heated to within 250°F of the steam generator temperature to minimize thermal stresses on the feedwater piping and steam generator feedwater nozzles.

NORMAL OPERATION - Under normal operating conditions, system operation is automatic. Automatic level control systems control the levels in all feedwater heaters, the heater drain tank, and the condenser hotwells. Feedwater heater levels are controlled by modulating drain valves. Control valves in the discharges of the heater drain pumps control heater drain pump flows in reaction to the level in the heater drain tank. Three valves, two in the makeup line to the condenser from the condensate storage tank and another valve in the return line to the condensate storage tank, control the level in the condenser.

At very low power levels, feedwater is supplied by the motor-driven feedwater pump. Once sufficient steam pressure has been established, a SGFP turbine is started, and from this low power level to approximately 25 percent power feedwater flow is under the control of the feedwater bypass control valves and their control system. Switchover from the bypass feedwater control system to the main feedwater control system is initiated by the operator and can be completed either automatically by the digital feedwater control system or manually by the control room operators. The SGFP turbine speed can be controlled in automatic by the feedwater-steam header differential pressure. The differential pressure setpoint can be varied by the operator at the control station.

At approximately 20 percent power, the SGFP turbine speed control can be selected to Hi Power Programmed differential pressure from the Low Power Adjustable differential pressure control by the operator or be allowed to occur automatically. The feedwater flow is controlled by the main feedwater control valves and the SGFP speed is automatically controlled by the programmed differential pressure.

The steam generator feedwater pump turbines are controlled by a speed signal from the feedpump speed control system. The control system utilizes measurements of steam generator steam flow, feedwater pressure, and steam pressure to produce this signal.

The pump speed is increased or decreased in accordance with the speed signal by modulating the flow of steam admitted to the pump turbine drivers.

The feedwater flow to each steam generator is controlled by a three-element feedwater flow control system to maintain a programmed water level in the steam generator. The feedwater controllers regulate the feedwater control valves by continuously comparing steam generator water level with the programmed level and feedwater flow with the pressure-compensated steam flow signal.

Throttling the high pressure feedwater heater bypass valve AEHV0038 has been evaluated to increase unit output or to operate at reduced RCS T_{avg}. Throttling AEHV0038 lowers feedwater temperature.

Operation with AEHV0038 throttled at nominal RCS T_{avg} has been evaluated. Other than reduced unit efficiency, no adverse effects will result from this mode of operation.

During operation with reduced RCS T_{avg}, rated RCS thermal power may not be possible with the turbine control valves full open. In order to increase plant output, operation with high pressure heater bypass valve AEHV0038 throttled open has been evaluated. Tests have shown that with RCS T_{avg} decreased to 584.4°F, full rate RCS power can generally be obtained with AEHV0038 at or near full open. The effects with the resultant lowering of feedwater temperature have been evaluated. While operating with reduced RCS T_{avg}, the T_{ref} signal for both the Rod Cotnrol and Steam Dump systems are re-scaled to the full power turbine first stage pressure which occurs with reduced RCS T_{avg} and the full power throttled position of AEHV0038. After re-scaling in this fashion, changes in the position of AEHV0038 are minimized, except to maintain full power at the reduced RCS T_{avg}. With control systems re-scaled in this fashion and changes in the full power position of AEHV0038 minimized, the T_{ref} signal will continue to change linearly with turbine load changes during reduced T_{avg} conditions.

If reduced feedwater/RCS T_{avg} operations are desired or restored to previous nominal values, changes including the P-13 permissive and control system interlocks C-5, C-7, and C-20 (See Tables 7.2-2 and 7.7-1) will be implemented.

Ten-percent step load and 5-percent per minute ramp changes are accommodated without major effect in the CFS. The system is capable of accepting a 50-percent step load rejection. Under this transient, heater drain pump flow is lost, and the high pressure feedwater heater drain flows are dumped to the condenser via the heater drain tank. The condensate pumps pass full feedwater flow until heater drain pump flow is restored.

EMERGENCY OPERATION - In the event that the plant must be shut down and offsite power is lost, or a DBA occurs which results in a feedwater isolation signal, the MFIV and other valves associated with the main feedwater lines are closed. Coordinated operation of the auxiliary feedwater system (refer to Section 10.4.9) and the main steam supply system (refer to Section 10.3) is employed to remove decay heat.

A turbine-driven main feedwater (MFW) pump is in service when the pump's stop valves are open, the governor control valves are either in manual or automatic control, and feedwater is being supplied to the steam generators.

A trip of both turbine-driven MFW pumps is an indication of a loss of MFW such that there would be a subsequent need for some method of removing reactor decay heat and the stored thermal energy of the RCS to bring the reactor back to no-load temperature and pressure. Each turbine-driven MFW pump is equipped with two pressure switches that provide one actuation signal in separation group 1 and one in separation group 4 on the oil line for the speed control system. These oil pressure switches (FCPSL0025, FCPSL0026, and FCPSL0126) measure hydraulic oil trip header pressure for the turbine-driven MFW pump turbine stop valve control fluid. These switches effect a channel trip when the oil pressure decreases below its actuation setpoint. When a main feedwater pump turbine trip signal is received by the turbine, the hydraulic trip fluid pressure is vented back to the oil reservoir and the pressure switches detect the low pressure condition. A low pressure signal from either of these pressure switches indicates a trip of that pump's turbine. The actuation logic for ESFAS instrumentation function 6.g in Technical Specification Table 3.3.2-1 is shown in FASR Figure 7.3-1 (sheet 2).

A single turbine-driven MFW pump may be in service in MODE 1 at reduced power levels if the other turbine-driven MFW pump has not yet been placed into service during power ascension or has been removed from service for maintenance. Prior to placing a turbine-driven MFW pump into service, the status of its turbine control circuitry is changed from "tripped" to "reset" via its Trip/Reset handswitch (FCHIS0018 or FCHIS0118) such that the two oil pressure switch channels on that turbine-drive MFW pump experience the high oil pressures indicative of an operating pump prior to that turbine-driven MFW pump providing feedwater flow to the steam generators. In this status, the turbine-driven MFW pump that is not yet in service would not satisfy the AFW start function actuation logic if the operating turbine-driven MFW pump were to trip at this time since it takes one tripped channel on each turbine-driven MFW pump in the same separation group to initiate an auxiliary feedwater actuation signal. Therefore, with one turbine-driven MFW pump turbine in reset, both oil pressure channels on that turbine-driven MFW pump are inoperable.

10.4.7.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases of Section 10.4.7.1.1.

SAFETY EVALUATION ONE - The safety-related portions of the CFS are located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the CFS are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to ensure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - The CFS safety functions are accomplished by redundant means, as indicated by Table 10.4-7. No single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - Preoperational testing of the CFS is performed as described in Chapter 14.0. Periodic inservice functional testing is done in accordance with Section 10.4.7.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code Section XI requirements that are appropriate for the CFS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Table 10.4-6 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and controls necessary for the safety-related functions of the CFS are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - For a main feedwater line break inside the containment or an MSLB, the MFIVs located in the auxiliary building and the main feedwater control valves located in the turbine building are automatically closed upon receipt of a feedwater isolation signal or low-low steam generator level signal. For each intact loop, the MFIV and main feedwater control valve and associated redundant isolation of the chemical addition line will close, forming a pressure boundary to permit auxiliary feedwater addition. The auxiliary feedwater system is described in Section 10.4.9. A backup nitrogen system is available to simultaneously close the main feedwater control valves in the event of a loss of offsite power. The nitrogen system is described in Section 9.3.1.

SAFETY EVALUATION SEVEN - For a main feedwater line break upstream of the MFIV, the MFIVs are supplied with redundant power supplies and power trains to ensure their closure to isolate safety and nonsafety-related portions of the system. Branch lines downstream of the MFIVs contain normally closed, power-operated valves which close on a feedwater isolation signal. These valves fail closed on loss of power.

Releases of radioactivity from the CFS due to the main feedwater line break are minimal because of the negligible amount of radioactivity in the system under normal operating conditions. Additionally, following a steam generator tube rupture, the main steam isolation system provides controls for reducing accidental releases, as discussed in Section 10.3 and Chapter 15.0. Detection of radioactive leakage into and out of the system is facilitated by area radiation monitoring (discussed in Section 12.3.4), process radiation monitoring (discussed in Section 11.5), and steam generator blowdown sampling (discussed in Section 10.4.8).

SAFETY EVALUATION EIGHT - In the event of loss of offsite power, loss of the steam generator feedwater pumps, or other situations which may result in a loss of main feedwater, the feedwater isolation signal will automatically isolate the feedwater system and permit the addition of auxiliary feedwater to allow a controlled reactor cooldown under emergency shutdown conditions. The auxiliary feedwater system is described in Section 10.4.9.

10.4.7.4 Tests and Inspections

10.4.7.4.1 Preservice Valve Testing

The MFIVs and feedwater control valves are checked for closing time prior to initial startup.

10.4.7.4.2 Preoperational System Testing

Preoperational testing of the CFS is performed as described in Chapter 14.0.

10.4.7.4.3 Inservice Inspections

The performance and structural and leaktight integrity of all system components are demonstrated by continuous operation.

The redundant actuator power trains of each MFIV are subjected to the following tests:

a. Closure time - The valves are checked for closure time in accordance with the Inservice Testing Program.

Additional discussion of inservice inspection of ASME Code Class 2 and 3 components is presented in Section 6.6.

10.4.7.5 Instrumentation Applications

The main feedwater instrumentation, as described in Table 10.4-8, is designed to facilitate automatic operation, remote control, and continuous indication of system parameters. As described in Chapter 7.0, certain devices are involved in the secondary cycle pipe rupture protection system.

The feedwater flow to each steam generator is controlled by a three-element feedwater flow control system to maintain a programmed water level in the steam generator. The three-element feedwater controllers regulate the feedwater control valves by continuously comparing the feedwater flow and steam generator water level with the programmed level and the pressure-compensated steam flow signal (refer to Section 7.7.1.7).

The steam generator feedwater pump turbine speed is varied to maintain a programmed pressure differential between the steam header and the feed pump discharge header. The pump speed is increased or decreased in accordance with the speed signal by modulating the steam pressure at the inlet of the pump turbine drivers.

Both SGFP turbines are tripped upon any one of the following:

a. High-high level in any one steam generator

b. Feedwater isolation signal from the engineered safety features actuation system

c. Any condition which actuates safety injection (refer to Section 7.3)

d. Trip of all condensate pump motors

e. High feedwater system pressure

In the event both main SGFP turbines are tripped during MODES 1 and 2, a start signal is generated to the motor-driven auxiliary feedwater pumps as discussed in Section 7.3.6 (except when blocked for limited durations as permitted by the Technical Specification).

One turbine trips when any one of the following directly affects it:

a. Low lube oil pressure

b. Turbine overspeed

c. Low vacuum

d. Thrust bearing wear

A flow element with a transmitter is installed on the discharge of each of the condensate and heater drain pumps. The transmitters provide the automatic signals to open the minimum flow valves for the pumps.

A flow element is installed on the suction of each of the steam generator feedwater pumps to provide the control signal to open the minimum recirculation valves for the steam generator feedwater pumps.

The median of three feedwater header pressure inputs is used to develop a feedwater header pressure input to the digital feedwater control system (DFWCS). Similarly, the median of three steam header pressure inputs is used to develop a steam header pressure input to the digital feedwater control system, and the median of three main feedwater pump speed inputs is used to develop a pump speed input to the digital feedwater control system. This allows the loss of a single input without adversely impacting the control system. Failure or excessive drifting of an input results in the control system switching to the average of the remaining two signals. A flow element with two flow transmitters is located on the inlet to each of the four steam generators to provide signals for the three-element feedwater control system.

The total water volume in the condensate and feedwater system is maintained through automatic makeup and rejection of condensate to the condensate storage tank. The system makeup and rejection are controlled by the condenser hotwell level controllers.

The system water quality is maintained through the injection of hydrazine and ammonia or an alternate amine into the condensate system. The ammonia or alternate amine and hydrazine injection are controlled by conductivity and by hydrazine residual in the system, which are continuously monitored by the process sampling system.

Instrumentation, including pressure indicators, flow indicators, and temperature indicators, required for monitoring the system is provided in the control room.

10.4.8 STEAM GENERATOR BLOWDOWN SYSTEM

The steam generator blowdown system (SGBS) helps to maintain the steam generator secondary side water within the chemical specifications prescribed by the NSSS supplier. Heat is recovered from the blowdown and returned to the feedwater system. The blowdown is then treated to remove impurities before being returned to the condenser.

10.4.8.1 Design Bases

10.4.8.1.1 Safety Design Basis

Portions of the SGBS are safety related and are required to function following a DBA and to achieve and maintain the plant in a safe shutdown condition. The following safety design bases have been met:

SAFETY DESIGN BASIS ONE - The safety-related portion of the SGBS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The safety-related portion of the SGBS remains functional after an SSE or performs its intended function following a postulated hazard, such as a fire, internal missile, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-34).

SAFETY DESIGN BASIS FOUR - The active components of the SGBS are capable of being tested during plant operation. Provisions are made to permit inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI.

SAFETY DESIGN BASIS FIVE - The SGBS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The capability of isolating components or piping of the SGBS is provided. This includes isolation of components to deal with leakage or malfunctions and isolation of nonsafety-related portions of the system. An isolation valve is provided in each main line which automatically closes to isolate the secondary side of the steam generator in the event of a DBA.

SAFETY DESIGN BASIS SEVEN - The containment isolation valves for the steam generator drain line are selected, tested, and located in accordance with the requirements of 10 CFR 50, Appendix A, General Design Criteria 54 and 56, and 10 CFR 50, Appendix J, Type C testing.

10.4.8.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The SGBS is designed to ensure that blowdown treatment is compatible with the condensate and feedwater to ensure an effective secondary system water chemistry control program.

POWER GENERATION DESIGN BASIS TWO - The SGBS is designed to accommodate flows up to 44,000 pounds per hour (nominally 90 gpm) per steam generator, while returning to the feedwater system a sizable portion of the heat removed from the steam generators.

POWER GENERATION DESIGN BASIS THREE - During normal operation without primary-to-secondary leakage, the SGBS is designed to process blowdown to meet the chemical composition limits for release to the environment or for return to the condenser hotwell/condensate storage tank.

POWER GENERATION DESIGN BASIS FOUR - During periods of abnormal operation with a primary-to-secondary steam generator leak, the SGBS will maintain the plant effluent within the radiological specification for plant discharge.

POWER GENERATION DESIGN BASIS FIVE - Portions of the SGBS use design and fabrication codes consistent with quality group D (augmented) as assigned by Regulatory Guide 1.143 for radioactive waste management systems.

10.4.8.2 System Description

10.4.8.2.1 General Description

The SGBS is shown in Figure 10.4-8. The system consists of a flash tank, a regenerative heat exchanger, a nonregenerative heat exchanger, filters, demineralizers, a surge tank, and discharge and drain pumps.

The SGBS is designed to control the secondary side water chemistry, in conjunction with the condensate and feedwater chemical addition system and the condensate demineralizer system, to meet the water chemistry specifications controlled by the secondary chemistry program. The SGBS serves to remove impurities in the blowdown that originate from sources such as primary-to-secondary leakage, main condenser leakage, sodium carry-over from deep-bed condensate demineralizers, and the corrosion and wear of other secondary cycle components and piping.

Each of the four steam generators has its own blowdown and sample lines. The total continuous blowdown range of 60-360 gpm is provided to administratively permit blowdown to match the variable and cyclic nature of the sources of contamination.

The steam generator blowdown fluid (blowdown) is extracted from the steam generators through two blowdown taps connected to a peripheral groove machined on the top of the tube sheet.

The blowdown flow rate from each steam generator is controlled manually using throttling valves just upstream of the blowdown flash tank. The flashed vapor from the flash tank is sent to the number five feedwater heater (or to the condenser or atmosphere during startup).

The liquid effluent from the flash tank is first cooled in the regenerative heat exchanger (heat recovery medium is a portion of the condensate flow) and then further cooled by the nonregenerative heat exchanger (cooling medium is service water). The fluid may then be filtered and/or demineralized before being returned to the condenser or before being discharged.

It is intended that the blowdown will normally be returned to the condenser. However, the operator has the option of discharging or returning the blowdown to the condenser. Any limitations on discharges from the plant will be within the limits defined by the Technical Specifications.

Leak detection from the SGBS is provided by visual examination and by the floor drain system described in Section 9.3.3.

Section 3.6 provides an evaluation that demonstrates that the pipe routing is physically separated from essential systems to the maximum extent practical. Protection mechanisms that may be required to mitigate the dynamic effects of piping ruptures are also discussed in Section 3.6.

10.4.8.2.2 Component Description

Codes and standards applicable to the SGBS are listed in Tables 3.2-1 and 10.4-9. The SGBS is designed and constructed in accordance with the following quality group requirements: Steam generator blowdown lines from the steam generators to the outer SGBS isolation valve are quality group B and are seismic Category I. The flash tank, regenerative heat exchanger, and nonregenerative heat exchangers, which contain minimal radioactivity, are located in the turbine building; all other components are located in seismically designed buildings. Components downstream of the outer SGB isolation valve are quality group D (augmented). Design data for the SGBS components are listed in Table 10.4-9.

STEAM GENERATOR BLOWDOWN FLASH TANK - The flash tank pressure is maintained between 185 and 135 psia. This causes the high-temperature high-pressure blowdown liquid to be flashed (i.e., reduced in temperature and pressure). The four steam generator blowdown lines enter the flash tank tangentially at equally spaced distances around the tank.

STEAM GENERATOR REGENERATIVE BLOWDOWN HEAT EXCHANGERS -The heat exchanger cools the blowdown from the flash tank. The heat exchanger is of shell and welded tube design. The cooling medium is condensate water.

STEAM GENERATOR NONREGENERATIVE HEAT EXCHANGER - The heat exchanger cools the blowdown from the flash tank or the regenerative heat exchanger to less than 135°F before it flows to the demineralizers. The heat exchanger is of shell and welded tube design. The cooling medium is service water.

STEAM GENERATOR BLOWDOWN FILTER - This filter removes particulate matter from the steam generator blowdown fluid before it flows to the demineralizers. This serves to extend the operating life of the demineralizer resins.

STEAM GENERATOR BLOWDOWN MIXED-BED DEMINERALIZERS - Two sets of two parallel, 50-percent capacity, mixed-bed demineralizers operated in series are provided in the blowdown treatment train. Resin bed exhaustion is determined by high ionic impurities as measured by sampling the bed effluent. Ion exchange material other than mixed resin may be used as necessary to improve water quality and minimize waste.

STEAM GENERATOR BLOWDOWN SURGE TANK - The surge tank collects the blowdown water prior to discharge from the system, and provides the necessary suction head for the discharge pumps.

STEAM GENERATOR BLOWDOWN DISCHARGE PUMP - The inline centrifugal pumps are provided to pump the treated blowdown water from the surge tank to the plant discharge, or recycle the blowdown water through the demineralizer train. One pump is normally operated with the second serving as an installed spare.

STEAM GENERATOR DRAIN PUMP - Two inline centrifugal pumps are provided to pump steam generator water to the process train or the secondary cycle to drain a steam generator.

BLOWDOWN LINES - Blowdown from each of the four steam generators is conveyed to the SGB flash tank by four 4-inch lines. Each of the lines is anchored at the containment wall and has sufficient flexibility to provide for relative movement of the steam generators due to thermal expansion. The blowdown line and associated branch lines between the reactor building penetration and associated branch lines between the reactor building penetration and the first torsional restraint, past the blowdown isolation valve (BIV) are designed to meet the "no break zone" criteria, as described in NRC BTP MEB 3-1.

BLOWDOWN ISOLATION VALVES - One BIV is installed in each of the four blowdown lines outside the containment. The BIVs are installed to prevent uncontrolled blowdown from more than one steam generator. Failure of the blowdown isolation valve for an unaffected steam generator after an MSLB will result in blowdown from that steam generator to blowdown flash tank. This steam loss has less effect on primary system than does the steam lost as a result of other failures discussed in Section 15.1.5. The valves isolate the nonsafety-related portions from the safety-related portions of the system. The valves are air-operated globe valves which fail closed. For emergency closure, either of two safety-related solenoids is deenergized to dump air supplied to the valve actuator. The electrical solenoids are energized from separate Class 1E sources and are tripped upon receipt of a SGBSIS (AFAS) signal.

One needle valve and one check valve, in parallel, have been added downstream of the solenoid valves for each BIV. This configuration gives throttled air supply to slowly open the BIVs and allows full exhaust flow to quickly close the BIVs.

An additional nonsafety-related solenoid is provided which is de-energized to close the BIV upon receipt of a high radiation level signal or other system-related trip signals.

SAMPLE ISOLATION VALVES - Three safety-related sample isolation valves (SIV) are installed in each of the four sample lines. Two are inside the containment (one from each sample point), and one is outside. The SIVs are installed to prevent uncontrolled blowdown from more than one steam generator. The valves isolate the nonsafety-related portions from the safety-related portions of the system. The valves are solenoid operated, are energized from separate Class 1E sources, and are tripped upon receipt of a SGBSIS (AFAS) signal.

An additional nonsafety-related solenoid valve is provided outside the containment which is de-energized to close upon receipt of a high radiation level signal or other system-related trip signal.

10.4.8.2.3 System Operation

During full power operation, the SGBS can be operated in one of several different modes, depending upon the type and level of contaimination in the blowdown. The operator determines, based on prior knowledge of secondary cycle water chemistry conditions and radioactivity levels in conjunction with technical specification limitations and state and local discharge permit restrictions, the extent of processing required by the blowdown system.

NORMAL OPERATION WITH FULL SYSTEM PROCESSING - Normally, the SGBS is operated, utilizing the full processing capability of the system with heat recovery.

Figure 10.4-8 shows valve positions aligned to process the blowdown fluid through the demineralizer processing portion of the system and then to the secondary cycle.

The blowdown flash tank pressure is normally maintained from 185 psia to a minimum of 135 psia (corresponding to No. 5 feedwater heater pressure at approximately 80-percent power) by a backpressure control valve in the flash tank vent line. Depending upon station load, approximately 23 to 30 percent of the blowdown flow will be flashed into vapor. This flow, containing about half of the total blowdown heat energy, is returned to the feedwater system via the No. 5 feedwater heater shell.

The remaining saturated fluid from the flash tank is first cooled by the regenerative heat exchanger to an intermediate temperature (approximately 140-190°F) and then further cooled by the nonregenerative heat exchanger to less than 135°F. Level control valves in each of the processing flow paths (to the condenser, condensate storage tank, and blowdown surge tank) maintain a level in the flash tank that provides an elevation head on the fluid entering the heat exchangers for suppression of further fluid flashing.

Additional heat recovery is attained with the regenerative heat exchanger which uses a portion of the condensate flow (less than 2 percent of VWO flow) for cooling water. This condensate flow is diverted from the condensate system downstream of the condensate demineralizers and is returned to the heater drain tank. The outlet temperature from the regenerative heat exchanger is normally maintained at 140-190°F with the temperature control valve provided in the line to the heater drain tank to control the condensate flow through the regenerative heat exchanger. During periods of low blowdown flow rates, a lower regenerative outlet temperature can be obtained.

Cooling water for the nonregenerative heat exchanger is service water. A three-way temperature control valve is provided in the bypass line around the nonregenerative heat exchanger to maintain a high service water flow rate through the shell side of the heat exchanger, during periods of low service water temperatures and low blowdown flow rates.

The high service water flow rates are required to minimize particle deposition within the heat exchanger and thereby reduce the fouling tendency of the heat exchanger.

Following the flash tank and heat exchangers, the liquid portion of the blowdown is directed through a radiation monitor prior to processing through two filters in parallel and two sets of two parallel demineralizers operated in series. In addition, strainers are provided upstream of each filter and downstream of each demineralizer. The radiation monitor will alarm on a high reading indicative of a steam generator tube failure. The processing system is designed to operate continuously provided the resin beds are periodically replaced. The effluent water will normally meet the specifications for water purity and radioactivity for return to the condenser hotwell. Resin bed exhaustion is determined by high ionic impurities as measured by sampling the blowdown demineralizer effluent. The ion exchange material in the exhausted beds will either become the upstream beds as prefilters or removed and replaced with new or regenerated ion exchange material.

The processed blowdown can be sent either to the condenser, discharge monitor tanks, or discharged to the environment. If the blowdown is to be discharged directly to the environment, the fluid is directed into the steam generator blowdown surge tank. From the surge tank, the fluid is pumped by the discharge pumps to the radwaste building discharge line through a radiation monitor. The discharge rate is matched to the liquid effluent rate from the flash tank and controlled by a flow control valve in the discharge line from the pumps. Level instrumentation is provided on the surge tank to prevent damage to the discharge pumps on loss of level. Upon indication of high activity by the radiation monitors, the blowdown discharge valve is closed and the discharge pumps are stopped, automatically terminating discharge, and the blowdown isolation valve in each blowdown line is closed, thereby automatically terminating blowdown. High level in the surge tank terminates blowdown by automatically closing the blowdown isolation valves and the flash tank level control to the blowdown surge tank. In addition, discharge of blowdown to the environment is auto-matically terminated on a low dilution water flow signal. A flow path can be established to allow the fluid in the surge tank to be reprocessed through the processing portion of the blowdown system.

During periods of primary-to-secondary leakage, the blowdown fluid is purified by the processing portion of the blowdown system to limit any radioactive contamination of the secondary system.

OPERATION WITHOUT BLOWDOWN PROCESSING - As permitted by the type and level of the contaminants in the blowdown fluid, the operator can determine the extent of system processing required to meet the chemistry requirements for either discharge or return to the condenser. The radiation monitor will alarm on a high reading indicative of a steam generator tube failure, and alarms only when the operator should be made aware that processing may be required. A bypass flow path can be established from a point downstream of the heat exchangers to either the condenser or the surge tank for periods of operation where processing within the blowdown system is not required.

During normal operating conditions with no significant radioactive contaminants in the system and where the chemistry of the blowdown fluid meets the technical specification limitations for release restrictions, the processing portion of the system can be bypassed and the fluid can be discharged. When discharging, the fluid is directed to the surge tank and through the radiation monitor to the environment.

Also, during periods of normal plant operation with the condensate demineralizers in service and with insignificant radioactive contaminants in the system, the processing portion of the blowdown system (i.e. filters and demineralizers) can be bypassed and the fluid can be returned directly to the condenser, provided that the feedwater remains within the chemistry specifications.

During normal plant operating conditions, the steam generator blowdown demineralizers may be operated in a single - series configuration, provided a maximum flow of 75,000 lbm/hr is maintained through the demineralizers.

OPERATION WITH REGENERATIVE HEAT EXCHANGER OUT OF SERVICE - During periods of operation when the regenerative heat exchanger is out of service, a bypass line is provided to permit continued operation. The maximum blowdown rate is then limited by the nonregenerative heat exchanger's capacity for reducing the fluid temperature to less than 135°F. System operation downstream of the heat exchangers continues to be based on the processing requirements to maintain the chemistry specifications.

OPERATION WITH THE NONREGENERATIVE HEAT EXCHANGER OUT OF SERVICE - In this mode, three-way temperature control valve in the bypass line around the nonregenerative heat exchangers is manually maintained open. The temperature control valve which maintains blowdown fluid outlet temperature from the regenerative heat exchanger is set for approximately 150°F. This temperature setting may require that the demineralizers be bypassed in order to prolong resin life and preclude the possibility of eluting the radioactivity that has been adsorbed by the resin. With the flash tank venting to the condenser, the total steam generator blowdown then is limited to about 50,000 lbs/hr.

USE OF THE STEAM GENERATOR BLOWDOWN DEMINERALIZERS BY THE SECONDARY LIQUID WASTE (SLWS) - As a backup to the SLWS demineralizer, interties have been provided between the SLWS and the steam generator blowdown system to allow the processing of SLWS low TDS waste by either of the two sets of two parallel steam generator blowdown demineralizers. The system is designed so that blowdown can be processed by the set of demineralizers not being used for processing the low TDS waste.

SAMPLING - The blowdown system sample points are arranged to provide selectively extracted samples from each of the steam generator drums, each individual blowdown line, and the surge tank. The nuclear sample connection from the blowdown lines is located as close to the steam generator as possible to minimize transit time from the steam generator water mass to the point of use and to ensure maximum sample quality.

The process sampling system is normally used to continuously determine the chemical composition of the liquid in each of the steam generators. The process sample extraction points are located in the turbine building.

A continuous inline radioactivity monitor is provided to detect the presence of activity which would indicate a primary-to-secondary leak. Anytime the unprocessed blowdown activity level exceeds 1.0×10^{-5} μCi/gm (excluding tritium), periodic samples are taken at the nuclear sampling station and analyzed in the hot lab to ascertain the affected steam generator and to monitor any increase in primary-to-secondary leakage. The nuclear sampling system is capable of receiving intermittent or continuous samples from either each of the steam generator drums or each of the individual blowdown lines. The chemical composition is continuously monitored by the process sampling system.

STARTUP AND SHUTDOWN OPERATION - The startup and shutdown operations of the blowdown system are the same as for normal operation, except that the secondary cycle is not able to receive the flash tank vent fluid. When feedwater is not flowing through the No. 5 feedwater heater, the flash tank vent is directed to the condenser. If condenser vacuum is not being maintained, the vent is directed to the atmosphere. In the event that the condensate pumps (which would provide condensate cooling flow for the regenerative heat exchanger) or the heater drain tank are unavailable, it is possible for the liquid blowdown to be returned to the environment or the condensate storage tank rather than the condenser. Under these conditions, the total steam generator blowdown flow is limited by the capability of the nonregenerative heat exchanger to maintain cooled blowdown below the required limits. When demineralization or discharge to the environment is required, a 135°F limit is maintained. If the blowdown is being directed to the condensate storage tank, the blowdown is cooled to a maximum of 150°F.

During shutdown with the steam generator depressurized, the steam generator drain pumps may be employed to drain and dispose of or process steam generator water. A connection is available to the suction side of the condensate pumps for processing of the liquid through the condensate demineralizers and bypassing the condenser.

Wet layup capabilities are provided to protect the steam generators from corrosive attack during inactive periods. This is achieved by ensuring the exclusion of oxygen and controlling the pH of the water mass inside the steam generators.

EMERGENCY OPERATION - The isolation valves of the blowdown and sample systems are closed automatically by the SGBSIS (AFAS) signal. All of these valves are capable of being remotely closed from the control room.

Following a radiation monitor alarm, or start of the auxiliary feedwater system, the sample system isolation valves may be reopened from the control room. This capability permits identification, and subsequent isolation, of the steam generator responsible for fission product transfer from the primary to the secondary system. After reset of the AFAS, the blowdown system isolation valves may be reopened from the control room.

10.4.8.3 Radioactive Releases

In the event radioactivity is transmitted to the secondary side of the steam generator, it will show up in the blowdown fluid. For conditions of primary-to-secondary leakage, it is expected that all blowdown fluid will be processed and returned to the main condenser. Any discharge of radioactive fluid from this system is considered unlikely.

If the blowdown fluid is being discharged to the environment and the activity level in the discharged fluid approaches the limit defined by the Technical Specification, the radiation monitor in the discharge line alarms and automatically terminates discharge and blowdown. In addition, blowdown discharge to the environment is automatically terminated on a low dilution water flow signal.

When discharging to the environment, the discharge temperature is between 60-135°F, exit pressure is 35-100 psig, and the flow rate is a maximum of 270 gpm.

The operating criteria for the secondary side blowdown system are dictated by the need for limiting the secondary side build-up of dissolved solids. The equilibrium radioactive concentrations based on a assumed primary-to-secondary leakrate are given in Chapter 11.0 for the steam generators.

10.4.8.4 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases in Section 10.4.8.1.

SAFETY EVALUATION ONE - The safety-related portions of the SGBS are located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the SGBS are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) and (N) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - The component and system description for the SGBS shows that complete redundancy is provided and, as indicated by Table 10.4-10, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - Periodic inservice functional testing is done in accordance with Section 10.4.8.5. Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the SGBS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Table 10.4-9 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and control function necessary for the safety functions of the system are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Section 10.4.8.2 describes provisions made to identify and isolate leakage or malfunction and to isolate the steam generator water inventory from the nonsafety-related portions of the system.

SAFETY EVALUATION SEVEN - Sections 6.2.4 and 6.2.6 provide the safety evaluation for the system containment isolation arrangement and testability for the steam generator drain line penetration.

10.4.8.5 Tests and Inspections

The performance and structural and leaktight integrity of all system components is demonstrated by continuous operation.

The SGBS is testable through the full operational sequence that brings the system into operation for reactor shutdown and for DBAs, including operation of applicable portions of the protection system and transfer between normal and standby power.

The safety-related components are located to permit preservice and inservice inspections.

10.4.8.6 Instrumentation Applications

The SGBS instrumentation, as described in Table 10.4-11, is designed to facilitate automatic operation, remote control, and continuous indication of system parameters. As described in Chapter 7.0, certain devices are involved in the protection system.

The process radiation monitors provided downstream of the steam generator blowdown flash tank and in the plant discharge line are discussed in Section 11.5.

10.4.9 AUXILIARY FEEDWATER SYSTEM

The auxiliary feedwater system (AFS) is a reliable source of water for the steam generators. The AFS, in conjunction with safety valves in the main steam lines, is a safety-related system, the function of which is to remove thermal energy from the reactor coolant system by releasing secondary steam to the atmosphere. The AFS also provides emergency water following a secondary side line rupture. Removal of heat in this manner prevents the reactor coolant pressure from increasing and causing release of reactor coolant through the pressurizer relief and/or safety valves.

The auxiliary feedwater (AFW) system automatically supplies feedwater to the steam generators to remove decay heat from the reactor coolant system upon the loss of the normal feedwater supply. The motor-driven AFW pumps start automatically upon steam generator water level low-low in any steam generator, upon trip of both turbine-driven MFW pumps (an anticipatory start signal for which no credit is taken in any accident analysis), upon actuation of AMSAC (anticipated transient without scram mitigation system actuation circuitry), and upon actuation by the LOCA sequencer or shutdown sequencer. The turbine-driven AFW pump is automatically started by steam generator water level low-low in any two steam generators, 4.16-kV safety-related bus NB01 or NB02 undervoltage, and upon actuation of AMSAC. All three AFW trains can also be manually actuated. Initiating circuitry is described further in Section 7.3.6.1.1.a.

The auxiliary feedwater system may also be used following a reactor shutdown in conjunction with the condenser dump valves or atmospheric relief valves, to cool the reactor coolant system below approximately 350°F and 400 psig, at which temperature the residual heat removal system is brought into operation.

10.4.9.1 Design Bases

10.4.9.1.1 Safety Design Bases

SAFETY DESIGN BASIS ONE - The AFS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The AFS is designed to remain functional after an SSE or to perform its intended function following a postulated hazard, such as a fire, internal missile, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - The safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power. The system requirements may be met with a complete loss of ac power (GDC-34).

SAFETY DESIGN BASIS FOUR - The AFS is designed so that the active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI.

SAFETY DESIGN BASIS FIVE - The AFS is designed and fabricated consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The AFS, in conjunction with the condensate storage tank (nonsafety-related and not credited for accident mitigation) or essential service water system, which is credited for accident mitigation, provides feedwater to maintain sufficient steam generator level to ensure heat removal from the reactor coolant system in order to achieve a safe shutdown following a main feedwater line break, a main steamline break, or an abnormal plant situation requiring shutdown. The auxiliary feedwater system is capable of delivering full flow when required, after detection of any accident requiring auxiliary feedwater (refer to Chapter 15.0).

SAFETY DESIGN BASIS SEVEN - The capability to isolate components or piping is provided, if required, so that the AFS safety function will not be compromised. This includes isolation of components to deal with leakage or malfunctions and to isolate portions of the system that may be directing flow to a broken secondary side loop.

SAFETY DESIGN BASIS EIGHT - The AFS has the capacity to be operated locally as an alternate, redundant means of feedwater control, in the unlikely event that the control room must be evacuated.

10.4.9.1.2 Power Generation Design Bases

The condensate and feedwater system is designed to provide a continuous feedwater supply to the steam generators during startup normal plant operation, and shutdown. If the normal motor-driven startup feedwater pump is not available the AFS may be operated with the auxiliary feedwater pump discharge valves throttled when the reactor is below 10% power to maintain steam generator water levels during plant heatups or cooldowns. Refer to Section 10.4.7.

10.4.9.2 <u>System Description</u>

10.4.9.2.1 General Description

The system consists of two motor-driven pumps, one steam turbine-driven pump, and associate piping, valves, instruments, and controls, as shown on Figure 10.4-9 and described in Table 10.4-12. Figure 10.4-10 shows the piping and instrumentation for the steam turbine.

Each motor-driven auxiliary feedwater pump will supply 100 percent of the feedwater flow required for removal of decay heat from the reactor. The turbine-driven pump is sized to supply up to twice the capacity of a motor-driven pump. This capacity is sufficient to remove decay heat and to provide adequate feedwater for cooldown of the reactor coolant system at 50°F/hr within 1 hour of a reactor trip from full power.

The nonsafety-related condensate storage tank (CST) and the nonsafety-related hardened condensate storage tank (HCST) provide a source of water to the auxiliary feedwater pumps. However, since these tanks are not seismic Category I and not credited for accident mitigation, two redundant safety-related back-up sources of water from the essential service water system (ESWS) are provided for the pumps. For a more detailed description of the automatic sequence of events, refer to Section 10.4.9.2.3.

The condensate storage tank capacity allows the plant to remove decay heat from the primary system during a 4 hour Station Blackout event, as discussed in Table 8.3A-1, item III.A. Refer to Section 9.2.6 for a description of the condensate storage system.

The HCST serves as an alternate supply of condensate to the AFS to remove heat from the reactor following a beyond design basis external event (BDBEE) resulting in an extended loss of AC power event (ELAP). The HCST is seismically designed but is not credited for accident mitigation; therefore, it is not considered a safety-related component. The CST is used for normal operation and is the primary source of water for the AFS. Upon low AFW pump suction pressure due to reduced level in the CST, an automatically aligned suction path to the HCST is effected (via non-safety related instrumentation) before transfer to the ESW system occurs. The HCST will align to the AFS prior to the ESW swap-over during accident conditions and an extended loss of AC power (ELAP).

The non-safety auxiliary feedwater pump (NSAFP) can be manually aligned to provide an alternate source of cooling water to the steam generators through the Auxiliary Feedwater System as shown in Figure 10.4-9. The NSAFP will be aligned upon the following events occurring simultaneously: loss of offsite power, loss of onsite power, and failure of the turbine-driven auxiliary feedwater pump.

In order to remove decay heat by the steam generators, auxiliary feedwater must be supplied to the steam generators in the event that the normal source of feedwater is lost. The minimum auxiliary feedwater flow rate required to fulfill the acceptance criteria for the heatup events can be found in Section 15.2.

Provisions are incorporated in the AFS design to allow for periodic operation to demonstrate performance and structural and leaktight integrity. Leak detection is provided by visual examination and in the floor drain system described in Section 9.3.3.

10.4.9.2.2 Component Description

Codes and standards applicable to the AFS are listed in Tables 3.2-1 and 10.4-12. The AFS is designed and constructed in accordance with quality groups B and C and seismic Category I requirements.

MOTOR-DRIVEN PUMPS - Two auxiliary feedwater pumps are driven by ac-powered electric motors supplied with power from independent Class 1E switchgear busses. Each horizontal centrifugal pump takes suction from the nonsafety-related condensate storage tank, or alternatively, from the ESWS. Pump design capacity includes minimum flow recirculation, which is controlled by automatic recirculation control check valves.

TURBINE-DRIVEN PUMP - A turbine-driven pump provides system redundancy of auxiliary feedwater supply and diversity of motive pumping power. The pump is a horizontal centrifugal unit. Pump bearings are cooled by the pumped fluid. Pump design capacity includes continuous minimum flow recirculation. AC powered valves required for operability of the turbine driven pump are aligned in accordance with Technical Specifications such that their positions are not required to change upon a loss of all ac power. Air operated valves, controls and instrumentation required for operation of the turbine driven pump are powered by the Class 1E dc system or dc backed vital ac system. Swapover to ESW supply is not postulated during a loss of all ac power as discussed in Section 8.3A. The turbine driven pump is diverse from the two ac motor driven pumps with ac motor operated valves powered from the diesel backed on-site power system.

Steam supply piping to the turbine driver is taken from two of the four main steam lines between the containment penetrations and the main steam isolation valves. Each of the steam supply lines to the turbine is equipped with a locked-open gate valve, normally closed air-operated globe valve with air-operated globe bypass to keep the line warm, and two nonreturn valves. Air-operated globe valves are equipped with dc-powered solenoid valves. These steam supply lines join to form a header which leads to the turbine through a normally closed, dc motor-operated mechanical trip and throttle valve. The main steam system is described in Section 10.3.

The steam lines contain provisions to prevent the accumulation of condensate. The turbine driver is designed to operate with steam inlet pressures ranging from 92 to 1,290 psia. Exhaust steam from the turbine driver is vented to the atmosphere above the auxiliary building roof. Refer to Safety Evaluation Two for a discussion of the design provisions for the exhaust line.

PIPING AND VALVES - All piping in the AFS is seamless carbon steel. Welded joints are used throughout the system, except for flanged connections at the pumps and the automatic recirculation control check valves.

The piping from the ESWS to the suction of each of the auxiliary feedwater pumps is equipped with a motor-operated butterfly valve, an isolation valve, and a nonreturn valve. Each line from the condensate storage tank is equipped with a motor-operated gate valve and a nonreturn valve. Each motor-driven pump discharges through a automatic recirculation control check valve and a locked-open isolation valve to feed two steam generators through individual sets of a locked open isolation valve, a normally open, motor-operated control valve, a check valve followed by a flow restriction orifice, and a locked-open globe valve. The turbine-driven pump discharges through a nonreturn valve, a locked-open gate valve to each of the four steam generators through individual sets of a locked-open isolation valve, a normally open air-operated control valve, followed by a nonreturn valve, a flow restriction orifice, and a locked-open globe valve.

The turbine-driven pump discharge control valves are air operated with dc-powered solenoid valves. At each connection to the four main feedwater lines, the auxiliary feedwater lines are equipped with check valves.

The system design precludes the occurrence of water hammer in the main feedwater inlet to the steam generators. For a description of prevention of water hammer, refer to Section 10.4.7.2.1.

10.4.9.2.3 System Operation

NORMAL PLANT OPERATION - The AFS is not required during normal power generation. The pumps are placed in the automatic mode, lined up with the nonsafety-related condensate storage tank, and are available if needed.

EMERGENCY OPERATION - In addition to remote manual-actuation capabilities, the AFS is aligned to be placed into service automatically in the event of an emergency. Anyone of the following conditions will cause automatic startup of both motor-driven pumps:

a. Two out of four low-low level signals in any one steam generator

b. Trip of both main feedwater pumps

c. Safeguards sequence signal (initiated by safety injection signal or loss-of-offsite power)

d. Class 1E bus loss of voltage sequence signal (i.e. loss-of-offsite power)

e. AMSAC

The turbine-driven pump is actuated automatically on either of the following signals.

a. Two out of four low-low level signals in any two steam generators

b. Class 1E bus loss of voltage sequence signal (i.e. loss-of-offsite power)

c. AMSAC

The common water supply header from the nonsafety-related condensate storage tank contains a locked-open, 12-inch butterfly isolation valve and a locked-open, 12-inch gate valve. Correct valve position is verified by periodic surveillance. In the case of a failure of the water supply from the nonsafety-related condensate storage tank, the normally closed, motor-operated butterfly valves from the ESWS are automatically opened on low suction header pressure. Valve opening time and pump start time are coordinated to ensure adequate suction pressure with either onsite or offsite power available.

If a motor-driven pump supplying two of the three intact steam generators fails to function, the turbine-driven pump will automatically start when a low-low level is reached in two of the four steam generators. During all of the above emergency conditions, the normally open control valves are remote manually operated.

During all of the above emergency conditions, the motor-driven pump normally open control valves are automatically operated to limit runout flow under all secondary side pressure conditions. This is required to prevent pump suction cavitation at high flow rates. The turbine-driven pump design includes a lower NPSH requirement. Therefore, the turbine-driven pump control valves are remote manually operated.

Low pump discharge pressure alarms will alert the operator to a secondary side break. The operator will then determine which loop is broken by observing high auxiliary feedwater flow, using control room flow indication, and close the appropriate discharge control valve. This can be accomplished within 10 minutes after pump start. Refer to Chapter 15.0.

10.4.9.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases in Section 10.4.9.1.1.

SAFETY EVALUATION ONE - The AFS is located in the auxiliary building. This building is designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of the auxiliary building.

SAFETY EVALUATION TWO - The AFS is designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to ensure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained. For a more complete description of motor qualification, refer to Sections 3.10(B) and 3.11(B).

As shown on Figures 10.4-10 and 3.6-1, Sheet 49, the exhaust steam from the turbine driver is routed from the auxiliary building wall through the auxiliary boiler building, which is designed to UBC seismic requirements and is not expected to fail during a seismic event. If the auxiliary boiler building were to catastrophically fail and the exhaust line were sheared off completely, the AFP turbine would operate properly.

Even if the exhaust line were to crimp significantly, the AFP turbine driven pump would still deliver design flow rates. The back pressure on the turbine may be increased significantly before the required flow rates will not be available. The AFP turbine driven pump is capable of delivering the design flow even with a local constriction of 44 percent of the free area of the exhaust line. This type of failure is not considered to be credible, however the exhaust line and its support are re-classified as Special Scope II/I to assure they will not be degraded and thus affect the operation of the AFP turbine.

Breaks in seismic Category I piping are not postulated during a seismic event. Thus an MSLB or MFLB inside containment or in the steam tunnel are not postulated following a seismic event and the design of the exhaust line does not enter into the evaluation of these breaks.

For a seismically induced MSLB in the turbine building, various single failures can be postulated, none of which result in adverse conditions even if the AFP turbine is inoperable. If an MSLIV fails to close, one steam generator will blow down; however, two motor driven AFW pumps are available to feed three intact steam generators. If one motor driven pump train fails for any reason, the other motor driven pump will feed two steam generators as required. In this case, the break has been isolated by the MSLIV, and all four steam generators are intact.

SAFETY EVALUATION THREE - Complete redundancy is provided and, as indicated by Table 10.4-13, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

The turbine-driven pump is energized by steam drawn from two main steam lines between the containment penetrations and the main steam isolation valves. Turbine bearing lube oil is circulated by an integral shaft-driven pump. Turbine and pump bearing oil is cooled by pumped auxiliary feedwater. AC powered valves required for operability of the turbine driven pump are aligned in accordance with Technical Specifications such that their positions are not required to change upon a loss of all ac power. Air operated valves, controls and instrumentation required for operation of the turbine driven pump are powered by the Class 1E dc system or dc backed vital ac system. Swapover to ESW supply is not postulated during a loss of all ac power as discussed in Section 8.3A. The turbine driven pump is diverse from the two ac motor driven pumps with ac motor operated valves powered from the diesel backed on-site power system.

SAFETY EVALUATION FOUR - The AFS is initially tested with the program given in Chapter 14.0. Periodic operational testing is done in accordance with Section 10.4.9.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the AFS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to this system and supporting systems. Table 10.4-12 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and control function necessary for safe function of the AFS are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - The AFS provides a means of pumping sufficient feedwater to prevent damage to the reactor following a main feedwater line break inside the containment, or a main steamline break incident, as well as to cool down the reactor coolant system at a rate of 50°F per hour to a temperature of 350°F, at which point the residual heat removal system can operate. Pump capacities, as shown in Table 10.4-12, and start times are such that these objectives are met. Automatic flow control valves for the motor-driven pumps limit the flow to the broken loop so that adequate cooldown flow can be provided to the other steam generators for removal of reactor decay heat and so that containment design pressure is not exceeded. The overall minimum auxiliary feedwater flow rate needed to fulfill the acceptance criteria for the feedline break analysis can be found in Section 15.2.8. The maximum time period required to start the electric motors and the steam turbine which drive the auxiliary feedwater pumps is chosen so that sufficient flowrates are established within the required time for primary system protection. Refer to Chapter 15.0.

SAFETY EVALUATION SEVEN - As discussed in Sections 10.4.9.2 and 10.4.9.5 and Chapter 15.0, adequate instrumentation and control capability is provided to permit the plant operator to quickly identify and isolate the auxiliary feedwater flow to a broken secondary side loop. Isolation from nonsafety-related portions of the system, including the condensate storage tank, is provided as described in Section 10.4.9.2.

SAFETY EVALUATION EIGHT - The AFS can be controlled from either the main control room or the auxiliary shutdown panel. Refer to Section 7.4 for the control description.

10.4.9.4 Tests and Inspections

The performance and structural and leaktight integrity of system components is demonstrated by periodic operation.

The AFS is testable through the full operational sequence that brings the system into operation for reactor shutdown and for DBA, including operation of applicable portions of the protection system and the transfer between normal and standby power sources.

The safety-related components, i.e., pumps, valves, piping, and turbine, are designed and located to permit preservice and inservice inspection.

10.4.9.5 Instrumentation Applications

The AFS instrumentation is designed to facilitate automatic operation and remote control of the system and to provide continuous indication of system parameters.

Redundant tank level indication and alarms are provided in the control room for the nonsafety-related condensate storage tank. The backup indication and alarms use auxiliary feedwater pump suction pressure by converting it to available tank level. Both alarms provide at least 20 minutes for operator action (e.g., refill the tank), assuming that the largest capacity auxiliary feedwater pump is operating.

Pressure transmitters are provided in the discharge and suction lines of the auxiliary feedwater pumps. Auxiliary feedwater flow to each steam generator is indicated by flow indicators provided in the control room. If the condensate supply from the nonsafety-related storage tank fails, the resulting reduction of pressure at the pump suction is indicated in the control room.

Flow transmitters and control valves with remote control stations are provided on the auxiliary feedwater lines to each steam generator to indicate and allow control of flow at the auxiliary shutdown panel and in the control room. Flow controllers for the motor-driven pump control valves position the valves to limit the flow to a preset value throughout the full range of downstream operating pressures.

Table 10.4-14 summarizes AFS controls, alarms, indication of status, etc.

10.4.10 SECONDARY LIQUID WASTE SYSTEM

The function of the secondary liquid waste system (SLWS) is to process condensate demineralizer regeneration wastes and potentially radioactive liquid waste collected in the turbine building. Processed liquid waste may be reused in the plant or discharged to the environment.

10.4.10.1 Design Bases

10.4.10.1.1 Safety Design Bases

The SLWS is not a safety-related system, and its failure will not compromise any safety-related system or prevent a safe shutdown of the reactor.

10.4.10.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - During normal plant operation, the SLWS will be utilized to the extent required to meet chemical composition limits for release to the environment or for recyle of processed fluids back to the condenser.

POWER GENERATION DESIGN BASIS TWO - The SLWS will process recyclable turbine building waste during normal operation with the radioactivity levels identified in Appendix 11.1A.

POWER GENERATION DESIGN BASIS THREE - During abnormal operation, the SLWS will have provisions to receive from nonradioactive turbine building sumps liquids that may be radioactively contaminated. This condition could occur if, for example, condensation from the turbine building air coolers contained radioactive contamination or if during maintenance a major component's normal drainage path was not available.

POWER GENERATION DESIGN BASIS FOUR - The SLWS will process condensate demineralizer regeneration waste products for recycle back to the condenser or discharge to the environment. The SLWS is designed to accept and process condensate demineralizer regeneration wastes resulting from the regeneration of one demineralizer vessel every 2 days.

POWER GENERATION DESIGN BASIS FIVE - The SLWS includes cross-connections with the liquid radwaste system to provide improved reliability by providing alternate treatment.

The SLWS includes cross-connections with the steam generator blowdown system to provide improved reliability by providing back-up demineralization capability.

10.4.10.2 System Description

10.4.10.2.1 General Description

The SLWS consists of several tanks and pumps, an oil interceptor, and filters, as shown in Figure 10.4-12. Also included is the SLW Discharge Filter System which consists of 4 parallel bag filters.

Turbine building wastes consist of wastes collected in turbine building floor and equipment drains and condensate demineralizer regeneration wastes. The turbine building drains are segregated into two categories. The first category consists of drains which could include potentially radioactive turbine cycle leakage. The other category consists of nonradioactive sources.

The potentially radioactive turbine building drains are collected, as described in Section 9.3.3, in specific sumps throughout the turbine building and sent to the SLW drain collector tanks for processing. Drain processing is based on operator knowledge of secondary system chemistry and radioactive contamination, in conjunction with technical specification limitations and state and local discharge permit restrictions. In all cases, the waste is processed through an oil interceptor to remove oil which might be present in the sumps. In addition, the waste may be processed by filtration, and/or demineralization. Provisions exist to monitor the radioactivity of the nonradioactive waste and to divert it to be processed if necessary. All discharges from the standard power block are monitored for radioactivity levels.

The condensate demineralizer regeneration waste is divided into two types -- high and low total dissolved solids (TDS).

High TDS waste results from the acid and caustic rinses used when chemically regenerating spent resins. Low TDS waste results from the initial backflushing of unregenerated resin and the final rinsing of the regenerated resin to remove the acid and caustic. These high and low TDS wastes are collected separately in two high and two low TDS collector tanks.

These input streams are retained within the appropriate collection tanks and then processed by various combinations of filtration, crud sedimentation, charcoal adsorption, and demineralization. The processed SLW liquids can then be collected and sampled or routed to the LRW Discharge Monitor Tanks.

The SLW drain collector tanks are sized based on 10,000 gpd of leakage in all areas of the turbine building. The 15,000 gallon SLW drain collector tanks can each receive drainage for at least 1.5 days. This delay provides the surge capacity to facilitate repair, maintenance, or inspection that may be required on the process equipment or abnormal usage demands which may be made of the SLWS. The SLW drain collector tank pumps are cross-connected to take suction from either tank. A recirculation line from the pumps' discharge to either tank is provided to allow the tank contents to be mixed so that accurate sampling can be accomplished. The SLW drain collector tank contents are then processed via the SLW discharge filter system and sent to the LRW discharge monitor tanks.

In addition, the floor drain system described in Section 9.3.3 provides leakage detection capabilities to assure that any abnormal leakage is detected and repaired.

10.4.10.2.2 Component Description

Codes and standards applicable to the SLWS are listed in Table 3.2-1. Major components are described in Table 10.4-15.

10.4.10.2.3 System Operation

Turbine Building Recyclable Drains

The turbine building recyclable drains are collected in drain sumps throughout the turbine building. These sumps are normally aligned to discharge, via the sump pumps, to the secondary liquid waste (SLW) oil interceptor. After passing through the oil interceptor, the de-oiled water is pumped, via the SLW oil interceptor transfer pumps, to the SLW drain collector tanks.

Prior to processing the SLW drain collector tank contents, a sample may be taken to determine the optimum means of processing. The options available are:

a. pH alteration

b. Filtration

c. Deleted

d. Charcoal adsorption

e. Demineralization

or any combination of these options. Two SLW drain collector tank pumps are available to pump the drain fluids to the radwaste building for processing. The operator selects the appropriate tank/pump combination, starts the pump, and, when ready to initiate processing, opens an air-operated valve located at the discharge of the drain collector tank pumps. The processing liquid can either be routed to the HI TDS collection tanks for pH changes then to the LRW discharge monitor tanks or directly to the LRW discharge monitor tanks. If the fluid is sent directly to radwaste for processing, the drain fluid is passed through a filter to remove particulates. Normal processing is done using 4 parallel bag filters. After filtering, the processed liquid is then routed to the LRW discharge monitor tanks where it is sampled and discharged.

Condensate Demineralizer Regenerant Wastes

The condensate demineralizer system and the regeneration process are described in Section 10.4.6.

High Total Dissolved Solids (TDS) Wastes

High TDS wastes are wastes that result from the acid and caustic rinses used to regenerate condensate demineralizer resins. These wastes (though high in dissolved solids) are generally low in crud content. These wastes flow by gravity from the demineralizer regeneration system to the high TDS transfer tank located in the condenser pit of the turbine building. These waste fluids are then pumped by either or both of the high TDS transfer tank pumps to the high TDS collector tanks.

Two high TDS collector tanks are provided to accept the wastes and the contents of the SLW collection tanks for pH alteration. Air manifolds are provided on the high TDS collector tanks to effectively mix the tank contents to obtain an accurate sample.

After sampling the tank contents, the operator adds any necessary chemicals to adjust the pH. The chemical storage tanks and metering pumps are provided as part of the condensate demineralizer regeneration system. This step is normally not required as the condensate demineralizer regeneration system should control the outlet fluids to an acceptable pH range for processing in the SLW equipment. After pH adjustment, the bubbler system continues to operate to again insure even distribution of tank contents. The operator next chooses the proper tank and pump combination (using the high TDS collector tank pumps) and starts the pump to prepare for processing. The operator, when ready to accept high TDS for processing, opens the air-operated valve located at the high TDS collector tank pump discharge in the turbine building. Subsequent processing is as described previously.

Low Total Dissolved Solids (TDS) Wastes

Low TDS wastes are wastes that result from the resin washing, flushing, and sluicing operations that are a part of the condensate demineralizer regeneration process. These wastes (though low in dissolved solids) are relatively high in crud content. These wastes flow by gravity from the demineralizer regeneration system to the low TDS transfer tank in the condenser pit of the turbine building. These waste fluids are then pumped by either or both low TDS transfer tank pumps to the two low TDS collector tanks. These tanks are designed to promote settling of crud and are provided with a nozzle to drain off the settled crud.

Two low TDS collector tank pumps are provided for pumping the waste to processing equipment. If insufficient time has been allowed for clarification of the waste, the low TDS collector tanks can be processed through a local bag filter and returned to the collector tanks. When the operator is ready to process the low TDS collector tanks, he selects the proper tank/pump combination, starts the pump, and, when ready to initiate processing, opens an air-operated valve located at the discharge of the low TDS collector tank pumps.

The waste then flows to the radwaste building where it passes through one of two low TDS filters or through the SLW discharge filter system. The waste next flows to the SLW demineralizer, the SLW monitor tanks, or to the discharge monitor tanks and processing is completed as described previously.

If demineralization is required, the SLW demineralizer is not available and the plant can be operated at one-half the maximum steam generator blowdown rate, the option exists to process the low TDS wastes via two of the steam generator blowdown demineralizers.

Abnormal Operation

If abnormally large amounts of nonradioactively contaminated drainage collect in the turbine building recyclable sumps, such as a fire deluge, then the SLW system can be bypassed completely and the water discharged via the oily waste discharge pipe.

System Releases

Prior to discharge to the environment, the effluent is isolated within the appropriate monitor tank. The tank contents are recirculated to assure that they are well mixed and then sampled to assure that the release would not exceed release limits. The discharge to the environment passes through a process radiation monitor, which automatically closes the discharge valve on high radioactivity. The method of processing secondary liquid wastes and whether to recycle or discharge the processed wastes will depend on the radioactivity concentrations. The radioactivity content of the SLWS releases will be limited, along with radioactivity in other liquid releases, so as not to exceed Technical Specification limits.

The radioactivity releases provided in Section 11.1 and Appendix 11.1A are based on the analytical models of the GALE code and do not reflect the normal variations in the concentrations of radioactive isotopes in the secondary system which depend on the status of the fuel, primary-to-secondary leakage, operation of the steam generator blowdown system, and extent of removal of radioisotopes from secondary steam to the

MSR and high pressure heater drains (which are recycled directly to the steam generators).

It is estimated that the annual liquid volume released from the SLWS will be approximately 37,600,000 gallons (103,000 gallons per day with an 80-percent plant capacity factor). As described above, the releases would be on a batch basis from the SLW monitor tanks and/or the discharge monitor tanks. The maximum discharge rate will be 450 gpm with a discharge duration based on variations in plant operation. The temperature of water discharged will be less than 135°F.

10.4.10.3 Safety Evaluation

The secondary liquid waste system is not a safety-related system.

10.4.10.4 Tests and Inspections

Preoperational testing is performed as described in Chapter 14.0.

Continuous operation demonstrates the operability, performance, and structural and leaktight integrity of all system components.

10.4.10.5 Instrumentation Applications

The SLWS instrumentation is designed to facilitate automatic operation, remote control, and continuous indication of system parameters, as described in 10.4.10.2.3.

TABLE 10.4-1 CONDENSER DESIGN DATA

Item	
Type	Multipressure, 3-shell
Design duty, Btu/hr-total 3 shells	7.8696×10^9
Shell pressure w/80°F circ. water, inches Hga	2.06/2.56/3.22
Waterbox circulating flow, gpm	530,000
Tubeside temperature rise, F	30.0
Design pressure-shell	Full vacuum to 15 psig
Hotwell storage capacity - total 3 shells, gallon	159,000
Design pressure-channel, psig	70 and full vacuum
Number of tubes	73,020
Tube material	Sea Cure S.S.
Surface area, sq. ft.	988,836
Overall dimensions	
Length	100'
Width	90'
Height	72'
Number of tube pases	1
Steam flow, lb/hr	
Normal	7,940,886
Maximum	8,270,751
Circulating Water Temp, F	
Design	80
Maximum	95
Steam temperature, F	
Normal (avg.)	110

TABLE 10.4-1 (Sheet 2)

Item	
Maximum (without turbine bypass)	134
Maximum (with turbine bypass	141
Applicable codes and standards:	ANSI Standards, HEI Standards for Steam Surface Condensers
Effluent oxygen content, ppb	7

TABLE 10.4-2 MAIN CONDENSER AIR REMOVAL SYSTEM DESIGN DATA

Component Description		
Condenser Mechanical Vacuum Pumps		
Quantity	3	
Type	Rotary water ring	
Holding capacity	35 SCFM @ 1" Hga	
Hogging capacity	72 SCFM @ 5" Hga	
Speed	435 rpm	
Cooling water flow	700 gpm	
Motor Data		
Horsepower	150	
Speed	1,800 rpm	
Electrical requirements	460 Volt, 60 Hz, 3	
Seal Water Coolers		
Quantity	3	
Type	Straight tube	
Heat exchanged	14,600 Btu/hr	
	Shell Side	Tube Side
Fluid	Seal water	Service water
Total fluid entering	90 gpm	700 gpm
Design pressure, psig	150	250
Design temperature, F	300	300
Test pressure, psig	225	375
Piping and Valves		
Material	Carbon steel	
Design temperature, F	175	
Design pressure, psig	225	

Charcoal bed adsorber and filters are described in Section 9.4.4.

TABLE 10.4-3 CIRCULATING WATER SYSTEM COMPONENT DESCRIPTION

	Above Floor	Below Floor
Circulating Water Piping		
Material	Carbon steel	Cast-in-place concrete
Inside diameter, in.	119	120 inches square
Type of interface connection	Flanged	Flanged
Code (pipe)	AWWA-C201	ACI
Code (flange)	AWWA-C207, Class D	AWWA-C207, Class D
Design pressure, psig	70 at water boxes	85 at El. 1,970
Site interface	None	Welded joint
Circulating Water Expansion Joints		
Type		Rubber
Design pressure, psig		70
Design temperature, F		125
Circulating Water Valves		
Type		Butterfly
Operator		Electric motor
Design pressure, psig		70
Design temperature, F		125
Code		AWWA
Seal Tank		
Quantity		1
Capacity, gal		53
Design pressure, psig		15
Design temperature, F		150
Design code		ASME Section VIII
Condenser Drain Pump		
Quantity		1
Type		Centrifugal
Capacity, gpm		900
Total head, feet		88
Motor horsepower		30
Design code		MS

TABLE 10.4-4 CONDENSATE DEMINERALIZER SYSTEM DESIGN DATA

Demineralizer Vessels	
Quantity	6 (including one on standby)
Design pressure, psig	700
Design temperature, F	140
Design flow per vessel, gpm	4,320
Diameter (I.D.)	10'-6"
Type	Spherical-rubber lined
Regeneration Equipment	
Cation regeneration tank	
Quantity	1
Design pressure, psig	75
Design temperature, F	140
Diameter	7'-6"
Height	13'-6"
Type	Vertical cylindrical-rubber lined
Anion regeneration tank	
Quantity	1
Design pressure, psig	75
Design temperature, F	140
Diameter	6'-6"
Height	11'-0"
Type	Vertical cylindrical-rubber lined
Resin mixing and storage tank	
Quantity	1
Design pressure, psig	75
Design temperature, F	140
Diameter	7'-6"
Height	10'-6"

TABLE 10.4-4 (Sheet 2)

Type	Vertical cylindrical-rubber lined
Acid day tank	
Quantity	1
Design pressure	Atm.
Design temperature	100
Diameter	3'-6"
Height	6'-0"
Type	Vertical cylindrical-lined
Caustic day tank	
Quantity	1
Design pressure	Atm.
Design temperature, F	100
Diameter	4'-0"
Height	4'-6"
Type	Vertical cylindrical-unlined
Sluice water pump (Preferred)	
Quantity	2 (one standby)
Type	Centrifugal-inline
Capacity, gpm	352
Head, ft	170
Sluice water pump (Alternate)	
Quantity	2 (one standby)
Type	Centrifugal-inline
Capacity, gpm	320
Head, ft	127
Acid metering pump	
Quantity	2 (one standby)
Type	Positive displacement

TABLE 10.4-4 (Sheet 3)

Capacity, gph	210
Differential pressure, psi	65
Caustic metering pump	
Quantity	2 (one standby)
Type	Positive displacment
Capacity, gph	280
Differential pressure, psi	65
Waste collection tank	
Quantity	1
Design pressure	Atm.
Design temperature	140
Diameter	3'-6"
Height	5'-0"
Special feature	Mounted in strainer
Resin addition hopper	
Quantity	1
Diameter	2'-0"
Height	2'-0"
Capacity, ft^3	7
Design pressure	Atm.
Design temperature	Amb.
Special feature	Filling by eductor

TABLE 10.4-5 CONDENSATE AND FEEDWATER SYSTEM COMPONENT FAILURE ANALYSIS

Component	Failure Effect On Train	Failure Effect On System	Failure Effect on RCS
Condensate pump	None. Condenser hotwells are interconnected.	Operation continues at full capacity, using parallel pumps (condensate pump runout capacity is 50 percent).	None
No. 1, 2, 3, or 4 feedwater heater	One train of No. 1, 2, 3, and 4 feedwater heaters is shut down. Remaining trains continue to operate.	Operation continues at reduced capacity, using parallel feedwater heaters. Load must not exceed 85 percent to protect the turbines from excessive exhaust flow.	None. No. 5 feedwater heater is designed to maintain normal outlet feedwater temperature under this condition.
Heater drain tank	Extraction steam to both No. 5 feedwater heaters must be isolated. Drains from Nos. 6 and 7 feedwater heaters are dumped to condenser.	Operation continues at reduced capacity.	Reactor control system reduces reactor power to compensate for reduced feedwater temperature.
Heater drain pump	None. Parallel pump with condensate pumps have sufficient capacity to handle full load.	50 percent of HP feedwater heater drains are dumped to condenser.	Reactor control system reduces reactor power to compensate for reduced feedwater temperature.
Steam generator feedwater pump	None. Two parallel trains are interconnected.	Operations may continue at reduced capacity, using parallel pump if the reactor does not trip. Steam generator feedwater pump runout capacity is 67 percent.	Reactor control system reduces reactor power to compensate for reduced feedwater flow.
No. 5, 6, or 7 feedwater heater	One train is shut down	CFS operation continues at full capacity, using parallel train and bypass line.	Reactor control system reduces reactor and generator output power to compensate for reduced feedwater temperature.
Low pressure feedwater heater bypass valve (ADHV0042)	Partial bypass of low pressure heaters.	See Section 15.1.1 for transient analysis.	Reactor control system reduces reactor power to compensate for reduced feedwater temperature. As analyzed in Section 15.1.1, reactor trips on OPDT.
High pressure feedwater heater bypass valve (AEHV0038)	Partial bypass of high pressure feedwater heaters	Failure of this valve is bounded by the failure evaluated for ADHV0042 reduced feedwater temperature	See ADHV0042 failure

TABLE 10.4-5 (Sheet 2)

Component	Failure Effect On Train	Failure Effect On System	Failure Effect on RCS
Digital Feedwater control system (DFWCS) software*			
Software lockup resluting in high putput to both MFRV positioners or single MFRVBV positioner	MFRVs (above approximately 25% power) or MFRVBVs (low power below approximately 25% power) will open.	See Section 15.1.2 for main feedwater flow increase transient analysis and Section 3B.4.2.3 for the Area 5 (main steam tunnel) Case 2 flooding analysis.	SG water level high-high setpoint actuates feedwater isolation, after which SG levels decrease until the reactor trips on SG water level low-low.
Software lockup such that SPC causes MFP steam control valve to open	Above approximately 65% power, MFP speed increases until reaching high speed trip setpoint and the pump trips.	See Sections 15.1.2 and 3B.4.2.3.	After MFP trip, SG water level low-low setpoint trips reactor, isolates feedwater, and starts AFW.
Software lockup or termination resulting in low output to both MFRV positioners or single MFRVBV positioner; software termination resulting in low PLC bundle outputs	MFRVs (above approximately 25% power) or MFRVBVs (low power below approximately 25% power) will close.	See Section 15.2.7 for loss of normal feedwater analysis.	SG water level low-low setpoint trips reactor, isolates feedwater, and starts AFW.
Software lockup or termination such that SPC causes MFP steam control valve to close; software termination resulting in low PLC bundle outputs	Above approximately 65% power, MFP speed decreases.	See Section 15.2.7.	SG water level low-low setpoint trips reactor, isolates feedwater, and starts AFW.

* See also the failure effects documented in Table 420.4-1 for the loss of any single DFWCS instrument in the response to NRC Question 420.4. Acronyms used above include:
MFRV - main feedwater regulating valve
MFRVBV - main feedwater regulating valve bypass valve
SPC - servo position controller
PLC - prgrammable logic controller
MFP - main feedwater pump

TABLE 10.4-6 CONDENSATE AND FEEDWATER SYSTEM DESIGN DATA

Main Feedwater Piping (Safety-Related Portion)	
Design (VWO) flowrate, lb/hr	15,960,000
Number of lines	4
Nominal size, in.	14
Schedule	80
Design pressure, psig	1,185
Design temperature, F	450
Design code	ASME Section III, Class 2
Seismic design	Category I
Feedwater Isolation Valves	
Number per main feedwater line	1
Closing time, sec	*TS Figure 3.7.3-1
Body design pressure, psig	1,950
Design temperature, F	450
Design code	ASME Section III, Class 2
Seismic design	Category I
Feedwater Control Valves	
Number per main feedwater line	1
Closing time, sec	15
Design code	ASME Section III, Class 3
Seismic design	None

* Actual stroke time is system pressure dependent.

TABLE 10.4-7 FEEDWATER ISOLATION SINGLE FAILURE ANALYSIS

Component	Failure	Comments
Main feedwater control valve (MFCV) (1)	1. Valve fails to close upon receipt of automatic signal (FWIS)	1. MFIV will close, providing adequate isolation to limit high energy fluid addition.
	2. Loss of power from one power supply	2. No impact upon loss of either train of power supply since supply is redundant; furthermore, MFIV can be closed providing adequate isolation to limit high energy fluid addition.
	3. Loss of power to one positioner	3. Valve fails as is with degraded control upon loss of power to one positioner. However, the valve can be operated in the close direction via the backup positioner. The valve cannot be operated in the open direction since slight venting will occur. Valving out and using a selector switch can disable input from the down-powered positioner and enable the other positioner to have full control. Furthermore, the MFIV can be closed to provide adequate isolation to limit high energy fluid addition.
	4. Loss of communication to one positioner	4. Valve fails as is; however, valving out and using a selector switch can disable input from the positioner with a loss of communication and enable the other positioner to have full control. Furthermore, the MFIV can be closed to provide adequae isolation to limit high energy fluid addition.
Main feedwater bypass control valve. MFBVC (1)	1. Loss of power to the positioner	1. Valve fails closed.
	2. Loss of communication to the positioner	2. Valve fails as is; however, the MFIV can be closed to provide adequate isolation to limit high energy fluid addition.
	3. Valve fails to close upon receipt of automatic signal (FWIS)	3. MFIV will close and provide adequate isolation to limit high energy fluid addition.
Main feedwater isolation valve (MFIV)	1. Valve fails to close upon receipt of automatic signal (FWIS)	1. MF control valve (1) and MF check valve close as required to isolate. The MF control valve (1) (and bypass control valve) serve to limit the addition of high energy fluid into the containment following a main feedwater line rupture inside the containment or a main steam line break.
	2. Loss of Power from one power supply	2. Valve fails closed upon loss of either train of power. Slight venting of feedwater will occur through the opposite train solenoid valves. This slight venting has been evaluated and found acceptable.
	3. Loss of one solenoid valve	3. Valve can still be closed by the redundant actuation train. Slight venting of feedwater may occur through the failed solenoid valve. This potential venting has been evaluated and found acceptable.

TABLE 10.4-7 (Sheet 2)

Component	Failure	Comments
Main feedwater check valve	Valve fails to close	MFIV will close, providing adequate isolation
Chemical addition isolation valve	1. Valve fails to close upon receipt of automatic signal (FIS)	1. Associated check valve will close, providing adequate isolation
	2. Loss of power for valve operation	2. Valve fails closed
Chemical addition check valve	Valve fails to close	Chemical addition isolation valve will close, providing adequate isolation
Auxiliary feedwater check valve	Valve fails to open properly	Remaining two intact steam generators will provide adequate auxiliary feedwater
Steam generator narrow range level (Four per steam generator)	1. No signal generated for protection logic from one transmitter	1. 2-out-of-4 logic reverts to 2-out-of-3 logic, and protection logic is generated by other channel devices
	2. Loss of one of four logic channels	2. 2-out-of-4 logic reverts to 2-out-of-3 logic, and protection logic is generated by other channel devices
Digital feedwater control system	See Table 10.4.5.	

(1) Valve provides backup isolation capability following pipe rupture of feedwater line inside containment or following a MSLB.

TABLE 10.4-8 MAIN FEEDWATER SYSTEM CONTROL, INDICATING, AND ALARM DEVICES

Device	Control Room Indication/Control	Local	Control Room Alarm
Flow rate[(1)]	Yes	No	Yes
Steam generator level(narrow range)[(2)]	Yes	No	Yes
Steam generator level (wide range)	Yes	No	No
Feedpump Speed	Yes	No	Yes

(1) Steam flow - Feedwater flow mismatch

(2) Four per steam generator - Involved in 2-out-of-4 logic to generate input to reactor trip, auxiliary feed pump start, turbine trip, and feedwater isolation signals.

TABLE 10.4-9 STEAM GENERATOR BLOWDOWN SYSTEM MAJOR COMPONENT PARAMETERS

Steam Generator Blowdown Discharge Pump	
Type	Inline centrifugal
Number	2
Design temperature, F	200
Design pressure, psig	150
Process fluid	Blowdown
Design flow, gpm	270
Discharge head, ft	290
Code	Manufacturer's standard
Material	Stainless steel
Steam Generator Blowdown Regenerative Heat Exchanger	
Type	Two stacked, BFU, two pass shell/two pass U-tube
Installation	Horizontal
Number	1
Eff. heat transfer area, ft^2	1,056
Fluid	
Tube	Blowdown fluid
Shell	Condensate fluid
Design flow	
Tube, lb/hr	140,000
Shell, lb/hr	300,000
Design temperature, F	
Shell side	400
Tube side	600
Design pressure, psig	
Shell side	700
Tube side	300
Design codes	TEMA R and ASME Section VIII, Div I
Materials	
Tube	Stainless steel
Tubesheet	Stainless steel
Shell	Carbon steel
Channel	Carbon steel
Steam Generator Blowdown Surge Tank	
Type	Vertical cylindrical
Number	1

TABLE 10.4-9 (Sheet 2)

Capacity, gallons	2,065
Tank diameter, in.	78
Design pressure, psig	0.5
Design temperature, F	175
Material	Carbon steel
Code	ASME Section VIII, Div. I
Steam Generator Blowdown Mixed-Bed Demineralizer	
Type	Flushable
Number	4
Design temperature, F	200
Design pressure, psig	300
Design pressure drop fouled condition), psi	20 @ 200 gpm
Shell diameter, in.	60
Design flow, gpm	150
Decontamination factors	
Cation (a)	10^2 (10)
Anion	10^2 (10)
Cs, Rb	2 (10)
Resin volume, ft^3	75
Material	Stainless steel
Code	ASME Section VIII, Div. I

(a) Does not include Cs, Mo, Y, Rb, Te

Steam Generator Blowdown Filter	
Type	Disposable cartridge
Number	2
Design pressure, psig	300
Design temperature, F	250
Design flow, gpm	250
Pressure drop (250 gpm, clean), psi	5
Pressure drop (fouled condition), psi	20
Particle retention	98% of 30 micron size*
Material (vessel)	Stainless steel
Code	ASME Section VIII, Div. I
Steam Generator Blowdown Drain Pump	
Type	Inline centrifugal
Number	2
Rated flow, gpm	100

TABLE 10.4-9 (Sheet 3)

Rated total dynamic head, ft	372
Design pressure, psig	150
Design temperature, F	150
Design code	Manufacturer's standard
Material	Stainless steel
Steam Generator Blowdown Nonregenerative Heat Exchanger	
Type	BFU two pass shell 4 pass-tube
Installation	Horizontal
Number	1
Eff. heat transfer area, ft^2	703
Flow, continuous max., gpm	270
Fluid	
Shell side	Service water
Tube side	Blowdown fluid
Design temperature, F	
Shell side	150
Tube side	600
Design pressure, psig	
Shell side	200
Tube side	300
Design code	ASME Section VIII Div. I, TEMA-R
Materials	
Tube	Stainless steel
Shell	Carbon steel
Tubesheet	Stainless Steel
Channel	Carbon steel
Steam Generator Blowdown Flash Tank	
Type	Vertical
Number	1
Volume, gallons	2,350
Vessel diameter, in.	72
Design temperature, F	425
Design pressure, psig	300
Material	Stainless steel
Code	ASME Section VIII, Div. I

* Standard filter cartridges are available with variable particle retention characteristics, and the selection of the filter cartridge will be based on operating data.

TABLE 10.4-10 STEAM GENERATOR BLOWDOWN SYSTEM SINGLE ACTIVE FAILURE ANALYSIS

Component	Failure	Comments
Blowdown isolation valves	Loss of power from one power supply	Redundant power supply provided
	Valve fails to close upon receipt of automatic signal (SLIS)	Closure of three out of four isolation valves adequate to meet safety requirements(Refer to Section 10.4.8.2.2)
Sample isolation valves	Loss of power from one power supply	Valves fail closed upon loss of power
	Valve fails to close upon receipt of automatic signal	Closure of three out of four isolation valves adequate to meet safety requirements

TABLE 10.4-11 STEAM GENERATOR BLOWDOWN SYSTEM CONTROL, INDICATING AND ALARM DEVICES

Device	Radwaste Building Control Room Control/Indication	Main Control Room Indication	Main Control Room Alarm
Blowdown flash tank level	X		X (1)
Blowdown flash tank pressure	X		
Surge tank level	X		X (1)
Blowdown flow	X	X	
Blowdown liquid high temperature	X		X (1)
Blowdown liquid radiation monitor	X (alarm)	X	X
Surge tank discharge radiation monitor	X (alarm)	X	X
Blowdown conductivity monitor	X		X (1)
Surge tank discharge flow	X		

(1) Common alarm window on main control board.

X denotes that indicating device is provided.

TABLE 10.4-12 AUXILIARY FEEDWATER SYSTEM COMPONENT DATA

Motor-Driven Auxiliary Feedwater Pump (per pump)	
Quantity	2
Type	Horizontal centrifugal, multistage, split case
Nominal capacity,gpm (each)	575
TDH, ft	3,200
NPSH required, ft	17
NPSH available, ft	45*
Material	
Case	Alloy steel
Impellers	Stainless steel
Shaft	Stainless steel
Design code	ASME Section III, Class 3
Seismic design	Category I
Driver	
Type	Electric motor
Horsepower, hp	800
Rpm	3,600
Power supply	4, 160 V, 60 Hz, 3-phase Class 1E
Design code	NEMA
Seismic design	Category I
Turbine-Driven Auxiliary Feedwater Pump	
Quantity	1
Type	Horizontal centrifugal, multistage, split case
Nominal capacity, gpm	1,145
TDH, ft	3,450
NPSH required, ft	17
NPSH available ft	44*
Material	
Case	Alloy steel
Impellers	Stainless steel
Shaft	Stainless steel
Design code	ASME Section III, Class 3
Driver	
Type	Noncondensing, single stage, mechanical-drive steam turbine
Rpm	3,850
Horsepower, hp	1,590

TABLE 10.4-12 (Sheet 2)

Design code	NEMA
Seismic design	Category I
Motor-Driven Pump Control Valves	
Quantity	4 (2 per pump)
Type	Motor-operated globe valve
Size, in.	4
C_v	50
Design pressure, psig	1,800
Design temperature, F	150
Material	Carbon steel
Design Code	ASME Section III
Seismic Design	Category I
Turbine-Driven Pump Control Valves	
Quantity	4
Type	Air-operated globe valve
Size, in.	4
C_v	50
Design pressure, psig	2,000
Design temperature, F	150
Material	Carbon steel
Design Code	ASME Section III
Seismic Design	Category I

* Maximum NPSH available at a water level corresponding to 281,000 gallons in the condensate storage tank.

TABLE 10.4-13 AUXILIARY FEEDWATER SYSTEM SINGLE ACTIVE FAILURE ANALYSIS

Component	Failure	Comments
Suction isolation valves from CST	In the event that the CST is unavailable, valve fails to close upon receipt of automatic isolation signal or loss of power	Redundant nonreturn check valve is provided, and sufficient ESW flow is provided to the auxiliary feedwater pumps
Suction isolation valves from ESW	In the event that the CST is unavailable, valve fails to open upon receipt of automatic signal or loss of power	Two 100-percent redundant backup ESW trains are provided. Operation of one train of the suction valves meet the requirements.
Suction header pressure transmitters	Loss of one transmitter. No protection logic generated	2-out-of-3 logic reverts to 1-out-of-2 logic, and protection logic is generated by other devices
Motor-driven auxiliary feedwater pump	Fails to start on automatic signal	Two motor-driven pumps are provided. One pump is sufficient to meet decay heat removal requirements. If due to a main steam or feedwater line break, the operating motor-driven pump cannot supply two intact steam generators, the turbine-driven pump will supply feedwater to meet decay heat removal requirements.
Turbine-driven pump steam supply valve from main steam header	Fails to open on automatic signal	Parallel connections are provided on two main steam lines. One of the two valves will supply 100 percent of the turbine steam requirements.
Turbine-driven pump	Failure resulting in loss of function	Two motor-driven pumps are provided. Either will provide 100 percent of the feedwater requirements.

TABLE 10.4-13 (Sheet 2)

Component	Failure	Comments
Motor-driven pump control valve	Failure resulting in loss of flow or loss of flow control	The second motor-driven pump will provide 100 percent of the required flow through separate control valves. If due to a main steam or feedwater line break, the operational motor-driven pump train cannot supply two intact steam generators, the turbine-driven pump will supply feedwater to meet decay heat removal requirements.
	Failure to close valve in-line feeding broken loop	Second motor-driven pump will provide 100 percent required flow through separate control valves.
Turbine-driven pump control valve	Failure resulting in loss of flow or loss of flow control	Either of the two motor-driven pumps will supply 100 percent of the required feedwater flow through separate control valves.
	Failure to close valve in-line feeding broken loop	Either of the two motor-driven pumps will supply 100 percent required flow through separate control valves.

TABLE 10.4-13A DESIGN COMPARISONS TO RECOMMENDATIONS OF STANDARD REVIEW PLAN 10.4.9 REVISION 1, "AUXILIARY FEEDWATER SYSTEM (PWR)" AND BRANCH TECHNICAL POSITION ASB 10-1 REVISION 1, "DESIGN GUIDELINES FOR AUXILIARY FEEDWATER SYSTEM PUMP DRIVE AND POWER SUPPLY DIVERSITY FOR PRESSURIZED WATER REACTOR PLANTS"

I. SRP 10.4.9 RECOMMENDATION	UNION ELECTRIC POSITION
ACCEPTANCE CRITERIA:	
General Design Criterion 2, as related to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods.	Complies. The system is located in a seismic Category I structure that is tornado, missile, and flood protected. Refer to Section 3.1.3.
General Design Criterion 4, with respect to structures housing the system and the system itself being capable of withstanding the effects of external missiles and internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks.	Complies. The system components are located in individual rooms that will withstand the effects of flooding, missiles, pipe whip, and jet impingement forces associated with pipe breaks. Refer to Section 3.1.3 and Figure 1.2-11.
General Design Criterion 5, as related to the capability of shared systems and components important to safety to perform required safety functions.	Complies. There is no sharing between units of auxiliary feedwater systems or components. Refer to Section 3.1.3.
General Design Criterion 19, as related to the design capability of system instrumentation and controls for prompt hot shutdown of the reactor and potential capability for subsequent cold shutdown.	Complies. The system can be controlled from either the main control room or the auxiliary shutdown panel as a redundant means of feedwater control. Refer to Section 3.1.3.

TABLE 10.4-13A (Sheet 2)

I. SRP 10.4.9 RECOMMENDATION	UNION ELECTRIC POSITION
General Design Criterion 44, to assure: a. The capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions. b. Redundancy of components so that under accident conditions the safety function can be performed assuming a single active component failure. (This may be coincident with the loss of offsite power for certain events.) c. The capability to isolate components, subsystems, or piping if required so that the system safety function will be maintained.	Complies. Redundancy, leak detection, systems interconnection, and isolation capability are incorporated in the system design to assure the required safety function, assuming a single failure with either onsite or offsite power. Refer to Section 3.1.3.
General Design Criterion 45, as related to design provisions made to permit periodic in-service inspection of system components and equipment.	Complies. Provisions are made to allow in-service inspection. Refer to Section 3.1.3.
General Design Criterion 46, as related to design provisions made to permit appropriate functional testing of the system and components to assure structural integrity and leaktightness, operability and performance of active components, and capability of the integrated system to function as intended during normal, shutdown, and accident conditions.	Complies. The system is designed so that active components are capable of being tested during plant operation. Refer to Chapter 14 and Sections 10.4.9.4 and 3.1.3.
Regulatory Guide 1.26, as related to the quality group classification of system components.	Complies. Refer to Table 3.2-4.

TABLE 10.4-13A (Sheet 3)

I. SRP 10.4.9 RECOMMENDATION	UNION ELECTRIC POSITION
Regulatory Guide 1.29, as related to the seismic design classification of system components.	Complies. Refer to Table 3.2-3.
Regulatory Guide 1.62, as related to design provisions made for manual initiation of each protective action.	Complies. Refer to Table 7.1-5.
Regulatory Guide 1.102, as related to the protection of structures, systems, and components important to safety from the effects of flooding.	Complies. Refer to Section 3.4.
Regulatory Guide 1.117, as related to the protection of structures, systems, and components important to safety from the effects of tornado missiles.	Complies. Refer to Section 3.3.
Branch Technical Positions ASB 3-1 and MEB 3-1, as related to breaks in high and moderate energy piping systems outside containment.	Complies. Refer to Table 3.6-2.

TABLE 10.4-13A (Sheet 4)

I. BTP ASB 10-1 RECOMMENDATION	UNION ELECTRIC POSITION
ACCEPTANCE CRITERIA:	
1. The auxiliary feedwater system should consist of at least two full-capacity, independent systems that include diverse power sources.	Complies. Refer to Section 10.4.9.2.2.
2. Other powered components of the auxiliary feedwater system should also use the concept of separate and multiple sources of motive energy. An example of the required diversity would be two separate auxiliary feedwater trains, each capable of removing the afterheat load of the reactor system, having one separate train powered from either of two ac sources and the other train wholly powered by steam and dc electric power.	Complies. Refer to Section 10.4.9.2.2.
3. The piping arrangement, both intake and discharge, for each train should be designed to permit the pumps to supply feedwater to any combination of steam generators. This arrangement should take into account pipe failure, active component failure, power supply failure, or control system failure that could prevent system function. One arrangement that would be acceptable is crossover piping containing valves that can be operated by remote manual control from the control room, using the power diversity principle for the valve operators and actuation systems.	Complies. Refer to Figure 10.4-9.

TABLE 10.4-13A (Sheet 5)

I. BTP ASB 10-1 RECOMMENDATION	UNION ELECTRIC POSITION
4. The auxiliary feedwater system should be designed with suitable redundancy to offset the consequences of any single active component failure; however, each train need not contain redundant active components.	Complies. Refer to Section 10.4.9.3 and Table 10.4-13.
5. When considering a high energy line break, the system should be so arranged as to assure the capability to supply necessary emergency feedwater to the steam generators, despite the postulated rupture of any high energy section of the system, assuming a concurrent single active failure.	Complies. Refer to Section 10.4.9.3.

TABLE 10.4-13B DESIGN COMPARISONS TO NRC RECOMMENDATIONS ON AUXILIARY FEEDWATER SYSTEMS CONTAINED IN THE MARCH 10, 1980 NRC LETTER

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
1. Recommendation GS-1 - The licensee should propose modifications to the Technical Specifications to limit the time that one auxiliary feedwater system pump and its associated flow train and essential instrumentation can be inoperable. The outage time limit and subsequent action time should be as required in current Technical Specifications; i.e., 72 hours and 12 hours, respectively.	The limiting conditions for operation related to the auxiliary feedwater system will be addressed in the proposed Technical Specifications. The proposed Technical Specifications will be submitted approximately one year before the scheduled fuel load for the first SNUPPS unit and will be based on NUREG-0452, Rev. 3, "Standard Technical Specifications for Westinghouse Pressurized Water Reactors."
2. Recommendation GS-2 - The licensee should lock open single valves or multiple valves in series in the auxiliary feedwater system pump suction piping and lock open other single valves or multiple valves in series that could interrupt all auxiliary valves in series that could interrupt all auxiliary feedwater system flow. Monthly inspections should be performed to verify that these valves are locked and in the open position. These inspections should be proposed for incorporation into the surveillance requirements of the plant Technical Specifications. See Recommendation GL-2 for the longer-term resolution of this concern.	This item is not applicable because the design does not include single valves or multiple valves in series that could interrupt auxiliary feedwater pump suction or all auxiliary feedwater flow.

TABLE 10.4-13B (Sheet 2)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
3. Recommendation GS-3 - The licensee has stated that it throttles auxiliary feedwater flow to avoid water hammer. The licensee should reexamine the practice of throttling auxiliary feedwater system flow to avoid water hammer. The licensee should verify that the auxiliary feedwater system will supply on demand sufficient initial flow to the necessary steam generators to assure adequate decay heat removal following loss of main feedwater flow and a reactor trip form 100 percent power. In cases where this reevaluation results in an increase in initial auxiliary feedwater system flow, the licensee should provide sufficient information to demonstrate that the required initial auxiliary feedwater system flow will not result in plant damage due to water hammer.	Throttling auxiliary feedwater flow to avoid water hammer will not be utilized. The system design precludes the occurrence of water hammer in the steam generator inlet, as described in Section 10.4.7.2.1.
4. Recommendation GS-4 - Emergency procedures for transferring to alternate sources of auxiliary feedwater system supply should be available to the plant operators. These procedures should include criteria to inform the operator when, and in what order, the transfer to alternate water sources should take place. The following cases should be covered by the procedures:	The design includes an automatic transfer to the alternate sources of supply. Procedures will provide guidance to the operator concerning alternate water sources. The normal supply from the condensate storage tank (CST) is through a locked-open butterfly valve and a locked-open gate valve. Periodic surveillance will verify valve position.

TABLE 10.4-13B (Sheet 3)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
(1) The case in which the primary water supply is not initially available. The procedures for this case should include any operator actions required to protect the auxiliary feedwater system pumps against self-damage before water flow is initiated.	Opening of valves from the backup ESWS and starting of auxiliary feedwater pumps are timed such that an AFWS start with no suction from the CST is not a mode for common failure of all auxiliary feedwater pumps.
(2) The case in which the primary water supply is being depleted. The procedure for this case should provide for transfer to the alternate water sources prior to draining of the primary water supply.	
5. Recommendation GS-5 - The as-built plant should be capable of providing the required auxiliary feedwater system flow for at least 2 hours from any one auxiliary feedwater pump train, independent of any alternating current power source. If manual auxiliary feedwater system initiation or flow control is required following a complete loss of alternating current power, emergency procedures should be established for manually initiating and controlling the system under these conditions. Since the water for cooling of the lube oil for the turbine-driven pump bearings may be dependent on alternating current power, design or procedural changes shall be made to eliminate this dependency as soon as practicable.	The turbine-driven pump in the design is capable of being automatically initiated and operated independent of an alternating current power source for at least 2 hours. Turbine lube oil cooling for the turbine-driven pump is independent of alternating current power. AC powered valves required for operability of the turbine driven pump are aligned in accordance with Technical Specifications such that their positions are not required to change upon a loss of all ac power. Air operated valves, controls, and instrumenta-tion required for operation of the turbine driven pump are powered by Class 1E dc system or dc backed vital ac system.Swapover to ESW supply is not postulated during a loss of all AC as discussed in Section 8.3A.

TABLE 10.4-13B (Sheet 4)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
Until this is done, the emergency procedures should provide for an individual to be stationed at the turbine-driven pump in the event of the loss of all alternating current power to monitor pump bearing and/or lube oil temperatures. If necessary, this operator would operate the turbine-driven pump in a manual on-off mode until alternating current power is restored. Adequate lighting powered by direct current power sources and communications at local stations should also be provided if manual initiation and control of the auxiliary feedwater system is needed. See Recommendation GL-3 for the longer-term resolution of this concern.	
6. Recommendation GS-6 - The licensee should confirm flow path availability of an auxiliary feedwater system flow train that has been out of service to perform periodic testing or maintenance as follows:	Valve lineups and independent second operator verification of valve lineups will be required on the auxiliary feedwater system after maintenance. Verification of operability will be included as part of functional testing on return from extended cold shutdown.
- Procedures should be implemented to require an operator to determine that the auxiliary feedwater system valves are properly aligned and a second operator to independently verify that the valves are properly aligned.	

TABLE 10.4-13B (Sheet 5)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
The licensee should propose Technical Specifications to assure that prior to plant startup following an extended cold shutdown, a flow test would be performed to verify the normal flow path from the primary auxiliary feedwater system water source to the steam generators. The flow test should be conducted with auxiliary feedwater system valves in their normal alignment.	
7. Recommendation GS-7 - The licensee should verify that the automatic start auxiliary feedwater system signals and associated circuitry are safety grade. If this cannot be verified, the auxiliary system automatic initiation system should be modified in the short-term to meet the functional requirements listed below. For the longer term, the automatic initiation signals and circuits should be upgraded to meet safety-grade requirements as indicated in Recommendation GL-5.	The auxiliary feedwater system is designed so that automatic initiation signals and circuits are redundant and meet safety-grade requirements. Refer to Section 7.3.6.
(1) The design should provide for the automatic initiation of the auxiliary feedwater system flow.	
(2) The automatic initiation signals and circuits should be designed so that a single failure will not result in the loss of auxiliary feedwater system function.	

TABLE 10.4-13B (Sheet 6)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
(3) Testability of the initiation signal and circuits shall be a feature of the design.	
(4) The initiation signals and circuits should be powered from the emergency buses.	
(5) Manual capability initiate the auxiliary feedwater system from the control room should be implemented so that a single failure in the manual circuits will not result in the loss of system function.	
(6) The alternating current motor-driven pumps and valves in the auxiliary feedwater system should be included in the automatic actuation (simultaneous and/or sequential) of the loads to the emergency buses.	
(7) The automatic initiation signals and circuits shall be designed so that their failure will not result in the loss of manual capability to initiate the auxiliary feedwater system from the control room.	

TABLE 10.4-13B (Sheet 7)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
8. Recommendation GS-8 - The licensee should install a system to automatically initiate auxiliary feedwater system flow. This system need not be safety grade; however, in the short term, it should meet the criteria listed below, which are similar to Item 2.1.7.a of NUREG-0578. For the longer term, the automatic initiation signals and circuits should be upgraded to meet safety-grade requirements, as indicated in Recommendation GL-2. (1) The design should provide for the automatic initiation of the auxiliary feedwater system flow. (2) The automatic initiation signal and circuits should be designed so that a single failure will not result in the loss of auxiliary feedwater system function. (3) Testability of the initiating signals and circuits should be a feature of the design. (4) The initiating signals and circuits should be powered from the emergency buses. (5) Manual capability to initiate the auxiliary feedwater system from the control room should be retained and should be implemented so that a single failure in the manual circuits will not result in the loss of system function.	See response to GS-7 above.

TABLE 10.4-13B (Sheet 8)

A. SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
(6) The alternating current powered motor-driven pumps and valves in the auxiliary feedwater system should be included in the automatic actuation (simultaneous and/or sequential) of the loads to the emergency buses.	
(7) The automatic initiation signals and circuits should be designed so that their failure will not result in the loss of manual capability to initiate the auxiliary feedwater system from the control room.	

B. ADDITIONAL SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
1. Recommendation - The licensee should provide redundant level indication and low-level alarms in the control room for the auxiliary feedwater system primary water supply, to allow the operator to anticipate the need to make up water or transfer to an alternate water supply and prevent a low pump suction pressure condition from occurring. The low-level alarm setpoint should allow at least 20 minutes for operator action, assuming that the largest capacity auxiliary feedwater system pump is operating.	The existing design provides the following redundant control room indication for condensate storage tank level. a. LI-4A shown on Figure 9.2-12. b. P1-24A, P1-25A, or P1-26A - Class 1E auxiliary feedwater pump suction pressure indication shown on Figure 10.4-9. Direct correlation between pump suction pressure and tank level is achieved by simple conversion. Exclusion of dynamic piping losses from the conversion results in a conservative determination of tank level.

TABLE 10.4-13B (Sheet 9)

B. ADDITIONAL SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
	Redundant control room tank level alarms are as follows: a. LALL-9 shown on Figure 9.2-12. b. LAL-24 - Class 1E auxiliary feedwater pump low suction pressure alarm shown on Figure 10.4-9. Setpoints for both alarm will allow at least 20 minutes for operator action, assuming that the largest capacity auxiliary feedwater pump is operating.
2. Recommendation (This recommendation has been revised from the original recommendation in NUREG-0611) - The licensee should perform a 48-hour endurance test on all auxiliary feedwater system pumps, if such a test or continuous period of operation has not been accomplished to date. Following the 48-hour pump run, the pumps should be shut down and cooled down and then restarted and run for 1 hour. Test acceptance criteria should include demonstrating that the pumps remain within design limits with respect to bearing/bearing oil temperatures and vibration and that pump room ambient conditions (temperature, humidity) do not exceed environmental qualification limits for safety-related equipment in the room.	A 48-hour, in situ endurance test on all auxiliary feedwater pumps will be performed as part of the preoperational test program.

TABLE 10.4-13B (Sheet 10)

B. ADDITIONAL SHORT-TERM RECOMMENDATIONS	UNION ELECTRIC POSITION
3. Recommendation - The licensee should implement the following requirements as specified by Item 2.1.7.b on page A-32 of NUREG-0578:	The auxiliary feedwater design provides safety-grade (Class 1E) indication in the control room of auxiliary feedwater flow to each steam generator. The design utilizes four independent Class 1E power supplies. The safety-grade steam generator level indication provides a backup method for determining the auxiliary feedwater flow to each steam generator.
Safety-grade indication of auxiliary feedwater flow to each steam generator shall be provided in the control room. The auxiliary feedwater flow instrument channels shall be powered from the emergency buses consistent with satisfying the emergency power diversity requirements for the auxiliary feedwater system set forth in Auxiliary Systems Branch Technical Position 10-1 of the Standard Review Plan, Section 10.4.9.	
4. Recommendation - Licensees with plants which require local manual realignment of valves to conduct periodic tests on auxiliary feedwater system train, and there is only one remaining auxiliary feedwater system train available for operation, should propose Technical Specifications to provide that a dedicated individual who is in communication with the control room be stationed at the manual valves. Upon instruction from the control room, this operator would realign the valves in the auxiliary feedwater system train from the test mode to their operational alignment.	This recommendation is not applicable to the design.

TABLE 10.4-13B (Sheet 11)

C. LONG-TERM RECOMMENDATIONS (Cont.)	UNION ELECTRIC POSITION (Cont.)
1. Recommendation GL-1 - For plants with a manual starting system, the licensee should install a system to automatically initiate the auxiliary feedwater system flow. This system and associated automatic initiation signals should be designed and installed to meet safety-grade requirements. Manual auxiliary feedwater system start and control capability should be retained with manual start serving as backup to automatic auxiliary system initiation.	The design includes automatic initiation of the auxiliary feedwater system. Refer to the response to GS-7.
2. Recommendation GL-2 - Licensees with plant design in which all (primary and alternate) water supplies to the auxiliary feedwater systems pass through valves in a single flow path should install redundant parallel flow paths (piping and valves).	The alternate water supply (essential service water) connects to the auxiliary feedwater pump suction piping downstream of the normally locked-open isolation valves in a single flow path from the primary water source (condensate storage tank). Valves from the alternate supply automatically open on low pump suction pressure. Refer to the response to GS-2 and GS-4.
Licensees with plants in which the primary auxiliary feedwater system water supply passes through valves in a single flow path, but the alternate auxiliary feedwater system water supplies connect to the auxiliary feedwater system pump suction piping downstream of the above valve(s) from the alternate water supply upon low pump suction pressure.	

TABLE 10.4-13B (Sheet 12)

C. LONG-TERM RECOMMENDATIONS (Cont.)	UNION ELECTRIC POSITION (Cont.)
The licensee should propose Technical Specifications to incorporate appropriate periodic inspections to verify the valve positions	
3. Recommendation GL-3 - At least one auxiliary feedwater system pump and its associated flow path and essential instrumentation should automatically initiate auxiliary feedwater system flow and be capable of being operated independently of any alternating current power source for at least 2 hours. Conversion of direct current power to alternating current power is acceptable.	The design meets this recommendation. Refer to the response to GS-5.

TABLE 10.4-13B (Sheet 13)

C. LONG-TERM RECOMMENDATIONS (Cont.)	UNION ELECTRIC POSITION (Cont.)
4. Recommendation GL-4 - Licensees having plants with unprotected normal auxiliary feedwater system supplies should evaluate the design of their auxiliary feedwater systems to determine if automatic protection of the pumps is necessary following a seismic event or a tornado. The time available to the control room operator, and the time necessary for assessing the problem and taking action should be considered in determining whether operator action can be relied on to prevent pump damage. Consideration should be given to providing pump protection by means such as automatic switchover of the pump suctions to the alternate safety-grade source of water, automatic pump trips on low suction pressure, or upgrading the normal source of water to meet seismic Category I and tornado protection requirements.	As discussed in the response to GS-4 and GL-2 above, the design includes automatic transfer to the alternate water source. The alternate source (essential service water) is protected from tornadoes and is seismic Category I.
5. Recommendation GL-5 - The licensee should upgrade the auxiliary feedwater system automatic initiation signals and circuits to meet safety-grade requirements.	As stated in the response to GS-7, the auxiliary feedwater system automatic initiation signals and circuits are safety grade.

TABLE 10.4-14 AUXILIARY FEEDWATER SYSTEM
INDICATING, ALARM, AND CONTROL DEVICES

Indication/Control	Control Room	Local[(1)]	Control Room Alarm
Condensate storage tank suction valve position[(2)]	X	X	
ESW suction valve position	X	X	
Condensate storage tank level	X	X	X
Condensate storage tank suction header pressure	X		
Low pump suction pressure	X	X	X
Low pump discharge pressure	X	X	X
Pump flow control valve operation	X	X	
Pump flow control valve position	X	X	
Auxiliary feedwater flow	X	X	
Auxiliary feedwater pump turbine trip & throttle valve position	X	X	
Auxiliary feedwater pump turbine speed	X	X	
Auxiliary feedwater pump turbine low lube oil pressure			X
Auxiliary feedwater pump turbine high lube oil temperature			X

---

(1) Local control here means the auxiliary shutdown panel.

(2) Locked-open valve APV0015 has position indication on the ESF status panel. Locked-open valve ALV0201 has no position indication.

TABLE 10.4-15 SECONDARY LIQUID WASTE SYSTEM COMPONENT DATA

SLW Charcoal Adsorber	
Quantity	1
Type	Activated carbon or other processing media
Fluid	floor drain waste
Design pressure, psig	150
Design temperture, °F	200
Design flow, gpm	35
Design pressure drop (fouled condition), psi	10 to 12 at 35 gpm
Volume, ft^3	88
Design code	ASME Section VIII
Material	304 SS
SLW Demineralizer	
Quantity	1
Type	Mixed bed or other processing media
Fluid	floor drain waste, low TDS waste
Design pressure, psig	150
Design temperature, °F	200
Design pressure drop (fouled condition), psi	12 to 15 at 100 gpm
Flow rate, gpm	100
Processing media volume, cu ft	55
Design code	ASME Section VIII
Material	304 SS
SLW Oil Interceptor	
Quantity	1
Type	Gravity separation
Design flow, gpm	150
Fluid	Turbine building drains
Design pressure	Atmospheric
Design temperature, °F	225
Design code	Manufacturer's standard
Material	304 SS
High TDS Collector Tanks	
Quantity	2
Type	Vertical, cylindrical, dished-bottom
Fluid	Regenerant waste (high TDS)

TABLE 10.4-15 (Sheet 2)

Capacity, gal	17,000
Design temperature, °F	140
Design pressure, psig	15
Internals	Air Manifold
Design code	ASME Section VIII
Material	316L SS
SLW Drain Collector Tanks	
Quantity	2
Type	Vertical, cylindrical, dished bottom
Fluid	Turbine building floor drains
Capacity, gals	15,000
Design temperature, °F	200
Design pressure	Atmospheric
Design code	ASME Section VIII
Material	304 SS
Low TDS Collector Tanks	
Quantity	2
Type	Vertical, cylindrical, conical bottom
Fluid	Regenerant waste (low TDS)
Capacity, gals	45,000
Diameter, ft-in.	24-0
Height, ft-in.	20-3
Design temperature, °F	150
Design pressure	Atmospheric
Internals	Baffles to promote settling of solids
Material	304 SS
Design code	ASME Section VIII
SLW Monitor Tanks	
Quantity	2
Type	Vertical, cylindrical, dished bottom
Fluid	Processed turbine building floor drains and condensate demineralizer regenerant wastes
Capacity, gals	15,000
Design temperature, °F	200
Design pressure	Atmospheric
Design code	ASME Section VIII
Material	304 SS
Low TDS Collector Tanks Pumps	

TABLE 10.4-15 (Sheet 3)

Quantity	2
Type	In-line centrifugal
Fluid	Regenerant waste (low TDS)
Design pressure, psig	300
Design temperature, °F	100
Capacity, gpm	100
Rated head, ft	306
NPSH required, ft	8
Design code	Manufacturer's standard
Material (wetted surface)	316 SS
Motor	30 Hp/460 V/3 phase/60 Hz
Secondary Liquid Waste Oil Interceptor Transfer Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Turbine building floor drains
Design pressure, psig	300
Design temperature, °F	150
Capacity, gpm	150
Rated head, ft	51
Design code	Manufacturer's standard
Material	316 SS
Motor	5 hp/460 V/3 phase/60 Hz
High TDS Collector Tanks Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Regenerant waste (high TDS)
Design pressure, psig	300
Design temperature, °F	130
Capacity, gpm	35
Rated head, ft	255
NPSH required, ft	8
Design code	Manufacturer's standard
Material (wetted surface)	Alloy 20
Motor	10 Hp/460 V/3 phase/60 Hz
SLW Drain Collector Tank Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Turbine building floor drains
Design pressure, psig	300

TABLE 10.4-15 (Sheet 4)

Design temperature, °F	200
Capacity, gpm	35
Rated head, ft	207
NPSH required, ft	8
Design code	Manufacturer's standard
Material (wetted surface)	316 SS
Motor	7.5 Hp/460 V/3 phase/60 Hz
SLW Discharge Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Processed secondary liquid wastes
Design pressure, psig	300
Design temperature, °F	200
Capacity, gpm	100
Rated head, ft	250
NPSH required, ft	7
Design code	Manufacturer's standard
Material (wetted surface)	316 SS
Motor	15 Hp/460 V/3 phase/60 Hz
Low TDS Filters	
Quantity	2
Type	Cartridge
Design pressure, psig	150
Design temperature, °F	250
Particle retention (Filter may be removed for operational ease)	98% of 30 micron
Pressure drop, psi @ 100 gpm	
Clean	1
Dirty	25
Design code (vessel)	ASME Section VIII
Material (vessel)	304 SS
High TDS Transfer Tank	
Quantity	1
Type	Horizontal
Fluid	Regenerant waste (high TDS)
Capacity, gals	3,120
Design temperature, °F	130
Design pressure	Atmospheric
Design code	ASME Section VIII

TABLE 10.4-15 (Sheet 5)

Material	316L SS
High TDS Transfer Tank Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Regenerant waste (high TDS)
Design pressure, psig	300
Design temperature, °F	130
Capacity, gpm	450
Rated head, ft	78
NPSH required, ft	8
Design code	Manufacturer's standard
Material (wetted surface)	Alloy 20
Motor	20 Hp/460 V/3 phase/60 Hz
Low TDS Transfer Tank	
Quantity	1
Type	Horizontal
Fluid	Regenerant waste (low TDS)
Capacity, gals	3,120
Design temperature, °F	130
Design pressure	Atmospheric
Design code	ASME Section VIII
Material	304 SS
Low TDS Transfer Tank Pumps	
Quantity	2
Type	In-line centrifugal
Fluid	Regenerant waste (low TDS)
Design pressure, psig	300
Design temperature, °F	130
Capacity, gpm	450
Rated head, ft	78
NPSH required, ft	8
Design code	Manufacturer's standard
Material (wetted surfaces)	316 SS
Motor	20 Hp/460 V/3 phase/60 Hz
SLW Evaporator Feed Filter	
Quantity	1
Type	Cartridge
Design pressure, psig	150
Design temperature, °F	250

TABLE 10.4-15 (Sheet 6)

Design flow, gpm	35
Particle retention (Filter may be removed for operational ease)	
30 micron	98%
49 micron	100%
Pressure drop at 35 gpm	
Clean, psi	1
Dirty, psi	25
Material, vessel	316L SS
Design code	ASME Section VIII
Piping and Valves	
High TDS and Evaporator Feed	
Material	316L SS
Design code	ANSI B31.1
Pressure rating, psig	150
All Others	
Material	304 SS
Design code	ANSI B31.1
Pressure rating, psig	150
SLW Discharge Filter System	
Quantity	1
Type	Bag Filter - 4 in Parallel
Design Code	ANSI B31.1 ASME Section VIII
Design Pressure	150 psig
Design Flow	150 gpm
Material	304 SS/316L SS
Particle Retention	200 micron

TABLE OF CONTENTS

CHAPTER 10.0

STEAM AND POWER CONVERSION SYSTEM

LIST OF TABLES

TABLE 10.3-4 has been deleted

10.4.5 CIRCULATING WATER SYSTEM

The Circulating Water System (CWS) includes equipment, exterior to the Standard Power Block, which supplies approximately 530,000 gpm of cooling water to the condenser. The CWS is shown schematically on Figure 9.2-1.

10.4.5.1 Design Bases

10.4.5.1.1 Safety Design Basis

The CWS serves no safety function and has no safety design basis.

10.4.5.1.2 Power Generation Design Basis

The CWS provides pumped circulation of approximately 530,000 gpm of cooling water to the unit. This flow is sufficient to remove heat at a rate of 7,860 million BTU/hr during maximum power operation with water entering the condenser at 95°F and leaving at 125°F. The cooling tower dissipates this heat by evaporation, cooling the water from 125°F to 95°F when the ambient air temperatures are 79°F wet bulb and 95°F dry bulb.

10.4.5.2 System Description

The CWS consists of three circulating water pumps, a pump suction pit, a 13 ft ID supply line to the power block, a 13 ft ID return line, a cooling tower, and ancillary valves, instruments and control. Three pumps are operated for full flow.

The circulating water pumps are single-stage, vertical, constant-speed, mixed-flow type. Each pump is equipped with a hydraulically operated butterfly valve on the discharge for isolation of the pump from the system. The valve is also programmed for quick closure in order to prevent reverse flow of water and pressure surge in the event of a pump trip. The pumps are symmetrically connected to the power block supply line. Water velocity in the 13 ft diameter supply line is approximately 8.9 fps. It is approximately 9.5 fps in the 13 ft return line because of the addition of 38,000 gpm of service water (See Section 9.2.1).

The pump suction pit under the pumphouse is connected to the cooling tower basin by an open flume which contains two sets of fixed screens. These screens, arranged in series, are provided at the inlet to the pump suction pit to remove airborne debris carried into the cooling tower basin. These screens are cleaned manually as required.

A natural draft cooling tower is used to dissipate heat rejected to the circulating and service water systems. The top of the hyperbolic-shaped concrete tower is 555 ft above grade (Elev. 845'-0" MSL) and is 250 ft in diameter at the outlet. The diameter of the tower at the inlet is 390 ft. The minimum diameter, which occurs at the throat 392 ft above grade, is 230 ft. Warm water enters the tower distribution system 45 ft above the basin normal water level.

The cooling tower basin is 428 ft in diameter and when filled to Normal Water Level (NWL), it contains a total of approximately 12 million gallons of water. Between NWL and Low Water Level (LWL), the lowest point at which circulating and service water pumps are operated, the basin contains approximately 7.8 million gallons of water. The 7'-3" variation in basin level from NWL down to LWL permits continued operation of the unit in the event of interruption of make-up water flow from the Water Treating Plant. One foot of basin wall free board above NWL is provided to contain the volume of water in residence in the cooling tower fill in the event of a trip of all three circulating water pumps.

In the pumphouse adjacent to the cooling tower basin, the floor of the circulating and service water pump suction basin is at El. 825'-6" MSL, and the service water pump suction basin is at El. 822'-0" MSL.

Blowdown from the cooling tower basin is used to limit the concentration of dissolved solids in the cooling water. Cooling tower blowdown is returned to the Missouri River. The rate of make-up flow to the cooling tower basin is controlled by water level in the cooling tower basin. Make-up flow is directed to the service water pump suction basin so that water of minimum dissolved solids concentration is passed through the plant heat exchangers to preclude deposition of carbonates. Service water, after passing through the plant heat exchangers is returned to the cooling tower via the CWS return line. Refer to Section 9.2.1 for details on the Service Water System.

The circulating/service water chemical control program may consist of the addition of chemicals for: copper corrosion control, pH control, scale control and biocides to control organic growth. Plant operating concentrations and feed rates of products are controlled per the plant National Pollutant Discharge Elimination System (NPDES) permit.

10.4.5.3 Safety Evaluation

The CWS is not a safety-related system. The cooling tower is located more than 600 ft. away from all ESF structures. The cooling tower structure has been designed to withstand the OBE.

10.4.5.4 Tests and Operation

All active components of the CWS are accessible for inspection during operation. Normal operational tests will be made, including tests of individual pump operation, system flow rate for design conditions, one pump failure, and the basin level control system.

10.4.5.5 Instrumentation Requirements

Instrumentation is provided on the main control board for monitoring the circulating water pumps. Status lights are included to indicate the pump motor starter condition. A variable cooling tower basin level indication is provided in the control room.

The circulating water pumps are individually equipped with hydraulically operated discharge isolation valves which are interlocked to open and close on pump start/stop signals. These valves are also programmed to close in approximately 5 seconds in the event of a trip of one or two pumps. This rapid closure prevents backflow through the pump(s) and consequent loss of flow through the main condenser and possible trip of the unit. If three pumps trip, the valves are to delay closure for 12 seconds before starting a two-phase Normal Closure mode closure. This three stage closure rate minimizes transient pressure surges in the piping system.