Millstone Power Station Unit 2
Safety Analysis Report

Chapter 10: Steam and Power Conversion System

CHAPTER 10—STEAM AND POWER CONVERSION SYSTEM

Table of Contents

CHAPTER 10—STEAM AND POWER CONVERSION SYSTEM
Table of Contents (Continued)

CHAPTER 10—STEAM AND POWER CONVERSION SYSTEM

Table of Contents (Continued)

CHAPTER 10—STEAM AND POWER CONVERSION SYSTEM

List of Tables

NOTE: REFER TO THE CONTROLLED PLANT DRAWING FOR THE LATEST REVISION.

CHAPTER 10—STEAM AND POWER CONVERSION SYSTEM

List of Figures

CHAPTER 10 – STEAM AND POWER CONVERSION SYSTEM

10.1 SUMMARY DESCRIPTION

The components of the steam and power conversion system are designed to electromechanically produce electrical power using steam from the steam generators. The steam is condensed, and returned to the steam generators as heated feedwater. The gaseous, dissolved and particulate impurities are maintained within the level acceptable to the steam generators.

The power conversion system includes the turbine generator, main condenser, air ejector and steam packing exhauster, turbine steam dump and bypass system, and the feedwater pumping and heating system. The heat rejected to the main turbine condenser is transferred to the circulating water system.

Steam is generated in two generators and supplied to the high pressure section of the turbine. Steam leaving the high pressure turbine passes through moisture separators and reheaters prior to entering the low pressure sections of the turbine. A portion of the turbine steam is extracted for feedwater heating. The moisture separator drains, reheater drains, and drains from the top three highest pressure feedwater heaters are pumped into the feedwater stream. The drains from the remaining lower three feedwater heaters are cascaded to the condenser.

Steam exhausted from the low pressure turbines is condensed and deaerated in the condenser. The condensate pumps take suction from the condenser hotwell, delivering the condensate through the turbine steam packing exhauster, the condensate polishing demineralizers, the air ejector condenser, and five stages of low pressure feedwater heaters to two turbine-driven steam generator feedwater pumps whose suction and discharge are headered together. Steam generator feedwater pumps discharge feedwater through high pressure heaters into each steam generator. The condensate and feedwater heating equipment is duplicate, half-capacity and arranged in parallel trains from the air ejectors to the steam generators.

The turbine cycle utilizes all the steam being generated by the steam generators. The turbine steam dump and bypass system is provided to discharge steam directly to the condenser during load transient and turbine trip. If the condenser is not available, steam is discharged to the atmosphere through atmospheric dump valves and/or main steam safety valves.

The Steam Generator blowdown liquid is normally discharged to the circulating water outlet, and approximately one-third of the steam generator blowdown liquid is flashed to steam and is discharged to the environment via the Unit 2 steam generator blowdown tank vent on the enclosure building roof. When in use, the blowdown quench tank condenses the flashed steam, and non-condensibles are vented to the gaseous waste processing system. Steam generator blowdown from the sample line prior to the blowdown tank is continuously monitored for radioactivity. Blowdown stop, blowdown tank drain, and blowdown quench tank drain valves are closed when high radioactivity is detected. Residual quantities in the blowdown system can be manually diverted to the radioactive waste processing system.

TABLE 10.1-1 DELETED

FIGURE 10.1–1 DELETED BY FSARCR 03-MP2-007]

FIGURE 10.1–2 DELETED BY FSARCR 03-MP2-007

10.2 TURBINE GENERATOR

10.2.1 DESIGN BASES

10.2.1.1 Functional Requirements

The turbine generator converts steam energy to mechanical energy and mechanical into electrical energy. The turbine generator is capable of receiving steam with up to 2715 MW thermal energy from the steam generators. The total energy available is converted to 935 MW electrical energy, and the remainder is rejected to the condenser. A closed regenerative turbine cycle heats the condensate and feedwater and returns it to the steam generators.

10.2.1.2 Design Criteria

The following criteria have been used in the design of the turbine-generator:

a. The turbine generator shall have the capacity to utilize all the steam produced by the steam generators at full power except that required for auxiliary use.

b. The system shall have suitable means of controlling the speed, load, pressure and flow for startup, normal operations and all emergencies such that plant equipment is operated safely and in accordance with the prescribed mode.

c. The system shall be designed to permit periodic testing of the important components such as main steam stop and control valves, combined intermediate valves, extraction no-return valves, and emergency overspeed trip systems. See Section 10.2.4.2 for a detailed description.

10.2.2 SYSTEM DESCRIPTION

10.2.2.1 System

The General Electric turbine generator consists of the turbine, generator, exciter, controls, moisture separator/reheaters, turbine lubricating oil, gland seal, stator system winding cooling water system, generator hydrogen sealing system and electrohydraulic control system. The moisture separation package and reheat tube bundles for the moisture separator/reheaters have been replaced with equipment manufactured by the Senior Engineering Company. The General Electric pressure vessels have been retained.

The 1,800 rpm turbine includes one double flow high pressure turbine and two double flow low pressure turbines. Exhaust steam from the high pressure turbine passes through two parallel moisture separators/reheaters before entering the two low pressure turbines. The low pressure turbines exhaust steam to the main turbine condenser.

The turbine generator utilizes an electrohydraulic control (EHC) system which governs the speed, load, and flow for startup, operation and shutdown. The EHC unit trips the turbine on any of the conditions listed in Section 7.4.6.3.3. Low hydraulic oil pressure signals are supplied from the turbine EHC system to the reactor protective system to trip the reactor. The turbine first-stage pressure is fed to the reactor regulating system as a load reference.

The turbine lubricating oil system supplies lubrication for the bearings. A bypass stream of the turbine lubricating oil flows continuously through an oil conditioner at a rate sufficient to process the oil inventory once every six hours.

The generator shaft is provided with oil seals to prevent hydrogen leakage. The generator field excited by an alternator located on the stub shaft of the generator.

The turbine generator supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

10.2.2.2 Components

The major system components and associated performance data are listed in Table 10.2-1.

10.2.3 SYSTEM OPERATION

The turbine generator is designed to normally operate as a base-loaded machine.

10.2.3.1 Startup

The turbine generator is started at 900 psia (controlled) steam generator pressure. Startup times and initial speeds are functions of the turbine metal temperature. When the machine is at rated speed, it is synchronized with the electrical 345 kV network and then manually connected to the system.

10.2.3.2 Normal Operation

The turbine generator is operated and controlled by the EHC system which combines the turbine generator speed error signals with the generator load signal to produce the steam flow demand. The steam flow demand accurately positions the turbine steam flow control valves to maintain the required speed and thereby satisfy the generator load. The turbine generator is capable of accommodating reactor maximum maneuvering limitations of a power change at a rate of five percent of full power per minute or up to a step change of 10 percent of full power.

10.2.4 AVAILABILITY AND RELIABILITY

10.2.4.1 Special Features

The turbine generator is equipped with an electrohydraulic control system. It is highly reliable and employs components and subsystems of proven high reliability and a completely redundant speed control subsystem (including speed pickups and logic). Logic is processed in electronic and hydraulic channels.

Valve opening actuation is provided by a 1500 psig hydraulic system which is totally independent of the bearing lubrication system, and utilizes a fire resistant fluid. Valve closing actuation is provided by springs and steam forces upon the reduction or relief of fluid pressure. The system is designed to respond to a loss of fluid pressure for any reason, and leads to turbine inlet valve closing and consequent turbine generator shutdown.

Because of the extreme importance of guarding against excessive overspeed, three lines of defense are provided. These consist of:

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

b. The second line of defense against turbine overspeed is the primary overspeed trip system, utilizing the same three magnetic pickups used to provide the control system governing action.

c. The third line of defense is provided by the emergency overspeed trip system. This is an independent electrical tripping function in which a set of three magnetic pickups, independent from the primary speed signal magnetic pickups, sense the speed of the toothed wheel on the main turbine shaft. The primary overspeed trip and emergency overspeed trip systems constitute two separate and independent means of protecting the turbine against an overspeed condition.

10.2.4.1.1 Overspeed Protection Inherent in Normal Operating Control System

Under normal operation, turbine overspeed is precluded by the governing action of the electrohydraulic control system. Speed sensing for this control system is provided by three magnetic pickups in conjunction with the toothed wheel on the main turbine shaft. The median value of the three speed signals is used for control and also for the primary overspeed protection logic. The circuitry and software for these control signals is isolated from, and independent of, the emergency overspeed trip circuitry and software. Failure of two of the three primary speed control signals results in a turbine trip.

10.2.4.1.2 Primary Overspeed Trip

The turbine protective system consists of a highly reliable trip manifold assembly along with the EHC system software and hardware. The trip manifold assembly consists of two independent hydraulic circuits arranged in parallel. Each circuit includes three Emergency Trip Devices (ETDs) arranged hydraulically for two-out-of-three voting logic. The ETD solenoids, which are de-energized to trip, can be de-energized by either the primary or emergency overspeed protection systems using independent circuits. If two ETDs in the same hydraulic circuit are de-energized, the EHC fluid trip supply header is isolated and the emergency trip system header is depressurized.

The primary overspeed trip system utilizes the primary speed pickup signals. The median value of the three signals is compared to the overspeed trip setpoint of 109 percent of rated speed. When the setpoint is reached, the primary trip relays de-energize all six ETDs in the trip manifold assembly, removing emergency trip system hydraulic pressure. This causes the fast closure of the main stop valves and the slower control valves which are in series in the high pressure stage turbine inlet. Also, the trip system pressure removal causes the rapid closure of the intercept and reheat stop valves which are in series in the inlet to the low- pressure stage of the turbine.

10.2.4.1.3 Emergency Overspeed Trip

The emergency overspeed trip system utilizes the emergency speed pickup signals. The median value of the three signals is compared to the emergency overspeed trip setpoint of 109.5 percent of rated speed. When the setpoint is reached, the emergency trip relays de-energize all six ETDs in the trip manifold assembly, thereby removing the emergency trip system hydraulic pressure and activating the fast closure of all the turbine steam valves previously mentioned.

The emergency overspeed trip system magnetic pickups, I/O modules, software and processors are independent from the components used for control and primary overspeed protection.

10.2.4.1.4 Testing

Testability during operation is provided for both the control system and the two overspeed protection systems. The test features provide coverage of the initiating, tripping, and controlling devices.

10.2.4.1.5 Valves

Two valves in series are used in the high pressure stage inlet to the turbine.

a. Control valves are normally controlled by the redundant speed control system and (tripped) closed rapidly when pressure in the emergency trip fluid system is removed by the redundant trip valves.

   The operation of each control valve, including the operating and fast closing devices, can be tested during normal operation.

b. Main stop valves are held open by the hydraulic pressure of the emergency trip fluid system and tripped closed rapidly upon removal of the pressure.

   The operation of each stop valve including its fast closing device can be tested during normal operation.

Stop valves of the steam-sealed design have been used on over 650 General Electric steam turbines since 1948. There have been no reports of a main stop valve failing to close, when required, to protect the turbine. Impending sticking has been disclosed by means of testing so that a planned shutdown could be made to make necessary corrections. This almost always involves removal of the oxide layer which builds up in the stem and bushing. This oxide buildup does not occur on a low-temperature nuclear application.

Combined stop and intercept valves are furnished to prevent the energy stored in reheaters or moisture separators from accelerating the turbine generator to excessive overspeed. These two independently operated valves are arranged in series in one valve body.

a. The intercept valves are normally wide open but are closed by the speed control system upon a moderate speed increase and are tripped closed rapidly upon removal of the pressure in the emergency trip fluid system.

   The intercept valves are also provided with a stem seal. Each intercept valve, including its fast closing devices, can be tested during normal operation.

b. Reheat stop valves are normally open but are closed rapidly upon removal of the pressure in the emergency trip fluid system. They are also provided with a steam seal. Each reheat stop valve, including its fast closing devices, can be tested during normal operation.

Thus, there are two independent valves for defense against overspeed in each steam admission line to the turbine. The normal speed control system modulates one of them to prevent overspeed and the overspeed trip systems close both of them on a higher overspeed. All valves are testable during operation and the fast closing feature of any valve is fully operative while the valves are being tested.

Where necessary to provide adequate overspeed protection resulting from the energy stored in extraction lines, positive closing nonreturn valves are fitted and actuated indirectly by the emergency trip fluid system. Station piping, heater, and check valve systems are reviewed during the design stages to make sure the entrained steam cannot overspeed the unit beyond safe limits.

The described design, inspection and testing features adequately preclude the possibility of a destructive overspeed condition from occurring.

10.2.4.2 Tests and Inspection

Equipment, instruments and controls are regularly inspected to ensure proper functioning of the system.

a. Test the main stop valves and combined intermediate valves fully closed by sequence testing at the EHC control panel.

b. Close extraction check valves, equipped with air-operated closing mechanism, part way by operating the test levers.

c. Test the fully closed control valves by sequence testing at the EHC control panel.

d. Test the alarm on the oil tank level gage.

e. Check the hydraulic thrust wear detectors.

f. Test the overspeed trip systems operation by using the controls on the EHC panel.

g. Deleted by MP-PACKAGE-FSC-MP2-UCR-2013-013.

h. Test power load unbalance circuits.

i. Deleted by MP-PACKAGE-FSC-MP2-UCR-2013-013.

j. Deleted by MP-PACKAGE-FSC-MP2-UCR-2013-013.

k. Lift pump test.

l. Check automatic starting of turbine motor-driven oil pumps.

m. Deleted by MP-PACKAGE-FSC-MP2-UCR-2013-013.

n. Check main stop and control valve tightness.

o. Test automatic pump starting.

p. Deleted by MP-PACKAGE-FSC-MP2-UCR-2013-013.

The moisture separator reheaters are tested periodically for tube leaks.

The detectable flaw size in the rotating members of the turbine generator is several orders of magnitude smaller than any critical crack which might develop from normal operation and could possibly result in a rotor failure.

10.2.5 BULK HYDROGEN STORAGE FACILITY

The bulk hydrogen storage facility is located outside, on the west side of Unit 2 Turbine building. A firewall is provided between the Turbine building and the Hydrogen Storage Facility. The cylinders are isolated from personnel by a chain link fence. “No Smoking” signs and “Hydrogen Flammable Gas - No Open Flames” signs are posted per NFPA requirements. The H_2 bulk supply header is run above ground from H_2 bulk storage area to the Unit 2 Turbine Building west wall. An excess flow check valve is installed on the hydrogen supply piping outside the Turbine building. The H_2 distribution headers inside Unit 2 are run as follows:

1. Headers are located to prevent physical damage to pipe.

2. Headers are located as safe distances from equipment that present a fire hazard to H_2.

3. Headers are run through well-ventilated areas.

4. H_2 piping is provided with guard pipes.

The equipment supplied with H_2 is the volume control tank and the main turbine generator. The following protective measures are provided to prevent fires and explosions during operation:

1. Volume Control Tank

   During normal operation N_2 and H_2 are supplied to the volume control tank pressure-reducing valves at a maximum pressure of 75 psig. If a tank leak occurs there is adequate ventilation to exhaust the H_2 to the atmosphere. During purging, N_2 is used to purge that tank to the gaseous waste processing system.

2. Main Turbine Generator

   During normal operation, H_2 at 60 psig is used to cool the turbine generator rotor. To prevent H_2 from leaking through the generator shaft seal glands into the turbine building, a shaft oil sealing system is provided. During purging of the H_2 from the generator, CO_2 is used to prevent fires and the mixture of H_2 and CO_2 is exhausted through a vent line to the outside atmosphere.

TABLE 10.2-1 TURBINE GENERATOR COMPONENT DESCRIPTION

Turbine

Steam generator power, rated design/(MWth)	2715
Throttle steam pressure, rated design (psia)	870
Main steam moisture content, max (%)	2.0
kW output, rated-design	935, 338
Makeup (%)	0
Turbine backpressure, (inches Hg abs)	2.0
Points of extraction	6

Note: The MP2 original licensed power was 2607 MWth Steam Generator Power. License up-rating took place during 1979 to stretch power of 2715 MWth Steam Generator Power.

Generator

Rating (kVA)	1,011,000
Power factor	0.9
Voltage (volts)	24,000
Hydrogen pressure (psig)	60

10.3 MAIN STEAM SUPPLY SYSTEM

10.3.1 DESIGN BASES

10.3.1.1 Functional Requirements

The main steam system (MSS) will perform the following functions:

a. Deliver steam from the steam generators to the turbine generator from warmup to valve wide open flow and pressure.

b. Provide steam for turbine gland seals, steam jet air ejectors (SJAE), moisture separators reheaters, and steam generator main and auxiliary feedwater pump (AFP) turbines.

c. Transfer heat generated by the nuclear steam supply system (NSSS) to the condenser or atmosphere in the event the turbine generator is out of service.

10.3.1.2 Design Criteria

The following design criteria have been used in the design of the main steam supply system:

a. The steam line leaving each steam generator is equipped with isolation valves located outside the containment. The isolation valves are designed to function so as to isolate a steam generator in the event of a rupture of the steam piping at any point, and to maintain at least one steam generator as a heat sink to remove reactor decay and sensible heat.

b. Each main steam line is provided with spring-loaded safety valves upstream of the isolation valves. The total relieving capacity is in excess of 100 percent steam flow at 2700 MWt rated thermal power. The safety valves discharge to the atmosphere.

c. A steam generator AFP turbine is supplied with steam from either main steam line upstream of the isolation valves.

d. The main steam supply system is provided with an automatically actuated steam dump system and turbine bypass to control steam pressure (hence, reactor coolant temperature) at hot standby zero load operation and to remove reactor coolant system (RCS) stored energy following a turbine trip. Atmospheric dump valves (ADV) from each steam generator are provided to limit or control secondary pressure whenever the condenser is out of service. Either steam dump system to the condenser or the atmospheric dump is capable of cooling the plant to the point of shutdown cooling manual initiation.

e. The main steam piping, from the steam generators up to and including the main steam isolation safety valves and steam dump to atmosphere valves, is designed to withstand a Class I seismic disturbance.

f. The main steam piping from the main steam isolation valves (MSIV) to the turbine stop valves is designed to with stand dynamic loading resulting from rapid closure of the turbine stop valves.

An analysis was performed on the 34 inch Atwood and Morrill main steam isolation swing check valve under the dynamic loads associated with postulated steam line breaks.

The valve disc kinetic energy was calculated by determining its velocity at the time of impact with the seat. The forces acting on the disc due to steam pressure were integrated with time to determine the terminal velocity. The pressures were calculated assuming a full area break on the main steam line under maximum flow conditions. The flow conditions were evaluated at different degrees of disc closure and the effects of choked flow were considered.

The inner portion of the disc and the point of impact on the body casting go plastic during impact. However, the zones of plastic deformation at any instant of time are surrounded by a sufficient amount of material in the elastic stress range to prevent failure.

The stresses were calculated using the SAAS computer program. The SAAS was a state-of-the-art program at the time the analysis was performed. The SAAS program is a finite element code that calculates the time history of stresses due to impact on an elastic basis.

Although this analysis proved that a failure of the MSIV disc would not occur, several modifications were made by Atwood and Morrill to preclude the possibility of local surface failures at the farthest point from the disc arm. The modifications consisted of increasing the seating area and a redesign of the disc from a flat configuration to a shallow spherical shell configuration.

10.3.2 SYSTEM DESCRIPTION

10.3.2.1 System

The main steam supply system is shown in Figure 10.3–1. The main steam piping consists of two parallel 34 inch OD lines and terminates at the 34 inch cross tie header which manifolds to the four turbine stop valves.

Each steam line has eight spring-loaded safety valves, set to sequentially discharge to the atmosphere. The spring-loaded safety valves have setpoints ranging from 985 psig to 1035 psig, and the total relieving capacity for all valves on all of the steam lines is 12.7 x 10^6 lb/hr, which is 108 percent of the total secondary steam flow of 11.8 x 10^6 lb/hr at 100 percent rated thermal power. See Section 4.3.2 for more details.

The atmospheric steam dump system consists of one automatically actuated dump valve for each steam generator which exhausts to the atmosphere. The total atmospheric dump system capacity is 15 percent of 2700 MWt rated thermal power. The turbine bypass and dump-to-condenser system consists of four automatically actuated valves which exhaust to the condenser. It has a total capacity of approximately 40 percent of the 2700 MWt rated thermal power. The system control valves are arranged for automatic operation but can be manually operated. More details may be found in Section 7.4.5.

The MSIV assemblies are located outside of and adjacent to the containment building. Each consists of an air-operated trip valve adjacent to a free swinging, reverse flow check valve and a motor-operated bypass valve.

Each air-operated trip valve is equipped with a separate auxiliary air accumulator to assure an air supply for its operation if the normal air supply fails.

A pressure switch alarms in the control room in the event of loss of air supply to the accumulator. The mechanism has a spring-assist feature which closes if there is a loss of air in the accumulators or if it is vented by a solenoid pilot. The trip valve component of the assembly protects the steam generator and reactor from damage in the event a rupture occurs in the main steam line downstream of the isolation valve.

Closing of the isolation valve within a maximum of six seconds after a command signal is initiated prevents rapid flashing and blowdown of water stored in the shell side of the steam generator, thus avoiding a rapid uncontrolled cooldown of the RCS. As an auxiliary function, the isolation valves also prevent the release of the contents of the secondary sides of both steam generators in the event of a rupture in one main steam line upstream of the valves. During normal operation these valves remain open. Low steam generator pressure or high containment pressure causes a steam generator isolation signal to energize the closing mechanism of the valves to stop the steam flow through the main and bypass valves.

Four pressure transmitters on each steam generator are monitored by four independent bistables. Upon low pressure in either steam generator and 2-out-of-4 coincidence bistable trip signals, both air-operated MSIVs are closed.

Automatic closure of the air-operated MSIVs via the low steam generator pressure signal can be manually blocked to permit orderly startup and shutdown of the unit (see Section 7.3). The high containment pressure signal cannot be blocked.

One 4-inch line is provided from each main steam line upstream of the MSIV to feed the AFP turbine.

Each steam supply line from the respective main steam line to the AFP turbine is equipped with a check valve and a remote (main control room) manual motor-operated gate valve for isolation to prevent the blowdown of the isolated steam generator in the event of a steam line break at the other steam generator. Each of the remote, manual, motor-operated gate valves has an upstream drain line with a manual isolation valve. This valve can be opened for draining the upstream side of a gate valve while an operator is in attendance. These valves will otherwise be maintained in the “locked closed” position while containment integrity is required.

Seismic Class I design requirements are placed on the main steam line, bypass piping, branch lines to auxiliary feedwater pumps and to the atmospheric dump valves, up to and including the isolation trip valve outside the containment. This includes the piping up to and including the main steam safety valves, the atmospheric dump valves and the steam generators. All downstream components are designed to seismic Class II requirements.

10.3.2.2 Components

Table 10.3-1 describes the major components of the main steam system.

10.3.3 SYSTEM OPERATION

10.3.3.1 Startup

Steam produced by the steam generator is bypassed from the turbine generator to the condenser to maintain steam generator pressure and temperature at 900 psia and 532°F. Steam flow is increased according to the turbine metal temperature-steam temperature differentials. Steam flow to the steam generator feed pump (SGFP) turbines is changed from high to low pressure and the condenser air removal mode changed to SJAE operation from mechanical pump operation, according to moisture separator pressure and main steam availability, respectively.

10.3.3.2 Normal Operation

Main steam is led to the turbine stop valve inlet headers from each steam generator through separate 34-inch OD main steam lines to the turbine with no steam bypassed and the generator producing steam as required by the turbine generator. Feedwater flow is controlled by the feedwater control valve constant differential characteristic which adjusts feedwater flow; therefore, steam flow is according to steam demand.

10.3.3.3 Emergency Condition

During a reactor-turbine trip from full power, the four (4) steam dump to condenser valves (CDVs) and the two (2) main steam dump to atmosphere valves (ADVs) are fully open within four (4) and five (5) seconds, respectively, to avoid lifting of the safety valves. These limiting stroke times include any control circuit processing time. In the event of a loss of condenser vacuum, the steam dump to condenser valves close automatically. The ADVs open at a preset steam pressure of 920 psig to exhaust the steam generated by decay heat. The atmospheric dump capacity, equivalent of 15 percent of 2700 MWt (rated thermal power), is sufficient to cool the RCS to 300°F when shutdown cooling is initiated. A flow equivalent to 55 percent of 2700 MWt is sufficient to prevent lifting of the main steam safety valves. As the RCS approaches the shutdown cooling temperature, the steam pressure also decreases and if the bypass valve capacity is not sufficient to continue the desired rate of cooldown, the operator can partially open the steam dump to condenser or the ADVs to obtain the desired rate of cooldown.

Under normal operation, the ADV will not open. A steam dump valve is assumed to open inadvertently for the accident analysis Sections 14.1.3 and 14.1.4 address increase in steam flow events that bound the inadvertent opening of an ADV. The inadvertent operation of these valves is unlikely.

Assuming a double-end break of an individual auxiliary steam supply line upstream of the common header and check valve with the reactor at rated thermal power (2700 MWt), (see Figure 10.3–1), the check valves will prevent one steam generator from blowing down and the other steam generator will blowdown at the rate of 133 pounds per second causing the reactor power to reach 105 percent of full power. This condition will continue until the operator stops the feedwater to the steam generator associated with the break and shuts down the plant. No additional protective action is required.

Assuming the line breaks in either one of the 4 inch auxiliary steam supply lines downstream of the check valves or on the common header and with the reactor at 100 percent power, the steam flow through each of the 4 inch lines is 133 pounds per second. The reactor power will increase to 109 percent of full power and will stay at this new steady state condition. Each steam generator will continue to blowdown through the break until the operator closed the remote-manual, motor operated isolation valves in the 4 inch lines, at which time the reactor will return to its initial power level. No other protective action is required.

The feeding of the steam generators using AFW combined with the dumping of steam to the environment through the atmospheric steam dump valves may be employed to provide long-term cooling during a LOCA. This would be required post-LOCA when the shutdown cooling system cannot be placed into operation or during simultaneous hot and cold leg injection. During a LOCA event, an aggressive cooldown rate is to be initiated and maintained, using the atmospheric steam dump valves, within 1 hour after the start of the accident and at a minimum rate of 40°F/hr, until steam removal from the steam generators becomes limited by the fully open atmospheric steam dump valves.

10.3.4 AVAILABILITY AND RELIABILITY

10.3.4.1 Special Features

The main steam piping, the isolation valves, the atmospheric dump, the main steam safety valves and the steam generators are designed in accordance with seismic Class I requirements.

Three self-operating valve systems, using separate components, protect the steam generator from overpressure; however, safety valves alone can do the job. Each system operates as given in Table 10.3-3.

10.3.4.2 Tests and Inspection

See Section 5.2.7.4.2 and Technical Specifications Section 4.7.1.5.

TABLE 10.3-1 MAJOR COMPONENTS OF MAIN STEAM SYSTEM

Main Steam Isolation Valves		
Description	Main steam swing check valves, 600 pound ANSI, carbon steel, butt-welded ends	Main steam swing disc trip valves, air cylinder operated 600 pound ANSI, butt-welded ends, carbon steel.
Manufacturer	Atwood & Morrill	Atwood & Morrill
Size	34 inch	34 inch
Codes and Standards	ANSI B31.1.0[a], B16.10, B16.25 MSS-SP-25, -55, -61	Draft ASME Code for pumps and valves for nuclear power, November 1968; including 1970 Addenda, Code Case 1427
Material		
Body	Cast steel ASTM A216 Gr WCB	Cast steel ASTM A-216-Gr WCB
Disc	Cast steel ASTM A216 Gr WCB	Cast Steel ASTM A216 Gr WCB
Shaft	Stainless steel ASTM A276 Type 410	Steel bar ASTM A-276 Type 410
Design pressure / temperature	1000 psig/600°F	1000 psig/600°F

a. Except weld reinforcement requirements of Code Case 83 shall apply.

Three inch motor-operated bypass valve assemblies provided for each 34 inch valve assembly. The applicable codes and material are similar to those for the main steam swing disc trip valves.

Main Steam Dump to Atmosphere				
Description		600 pound ANSI, cast steel, butt-welded ends, diaphragm operated.		
Manufacturer		Copes-Vulcan		
Size		8 inch		
Codes and Standards		ASME Code for Pumps and Valves for Nuclear Power Class II; ASME Code Case 1427; ANSI B16.5, -B16.10, -B16.25; MSS-SP-6, -25, -45, -53, -55, -61, -66.		
Material				
Body		Cast steel ASTM A-216 Gr WCB		
Plug		Stainless steel ASTM A276 Type 420		
Stem		Stainless steel ASMT A-276 Type 316-B		
Conditions and Characteristics				
Quick opening time (seconds)				5 or less

Inlet pressure (no-load steam generator			
pressure less piping losses) (psig)			896
Temperature (°F)			533
Differential pressures (psi)			829
Maximum differential pressure (psi)			985
Total combined flow rate (2 valves)(lb/hr)			1,597,590
Modulating service stroke time, max (seconds)			10
Turbine Bypass to Condenser			
Description	600 pound ANSI, cast steel, butt-welded ends, pneumatically operated piston actuator		
Size	12 inch inlet x 14 inch outlet		
Codes and Standards	ANSI B16.10, B16.25, B31.1; MSS-SP-25, -45, -53, -55, -61, -66; ASME B16.34; ISA S75.01		
Material			
Body	Cast steel ASTM A-216 Gr WCB		
Plug	Stainless steel Commercial ASTM - A479 - 410		
Stem	Stainless steel ASTM A-276 - 410		
Conditions and Characteristics		Dump mode	Bypass mode
Quick opening time (sec)		4 or less	N/A
Inlet pressure (psig)		822	879
Outlet pressure (psig)		155	155
Steam state		Dry, saturated	Dry, saturated
Total combined flow rate (lb/hr)		4,850,000	590,150
Modulating service, max (lb/hr)		4,850,000	590,150
Modulating service, stroke time (sec)		10 max	10 max

Piping - See Table 10.4-1.

Main Steam Safety Valves - See Section 4.3.2 for details.

TABLE 10.3-2 OMITTED

TABLE 10.3-3 OPERATING DETAILS FOR VALVE SYSTEMS PROTECTING STEAM GENERATIONS OF OVERPRESSURE

Valve Description	Number Of Valves	Actuating Inlet Pressure (psia)	Mode
Steam dump bypass to condenser	4; one bypass	900	Quick open; modulated on reactor T_{ave}
Atmospheric dump	2; one for each steam generator	920	Pressure controller
Main steam safety valves	16; 8 on each line	1000,1005 1015,1025 1035,1045 and 1050	Pressure controlled spring-loaded

FIGURE 10.3–1 P&ID MAIN STEAM FROM GENERATORS (25203-26002 SHEET 1)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.3–1 P&ID MAIN STEAM GENERATOR BLOWDOWN SYSTEM (25203-26002 SHEET 2)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.3–1 P&ID MAIN STEAM TURBINE AND REHEATER 1A (25203-26002 SHEET 3)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.3–1 P&ID MAIN STEAM TURBINE (25203-26002 SHEET 4)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

10.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

10.4.1 MAIN CONDENSERS

10.4.1.1 Design Bases

The purpose of the condenser is to provide a heat sink for the turbine exhaust steam, main steam dump and bypass and other flows. It also deaerates and provides storage for the condensate.

The main condenser is designed for the following conditions:

Condenser duty (Btu/hr)	6059×10^6
Condenser pressure (inch Hg absolute)	2.07
Circulating water temperature	
Inlet (°F)	60.8
Outlet (°F)	84.8
Flow (gpm)	522,500 total
Heat transfer area (square feet)	485,260 total
Design pressure	
Shell (inches Hg vacuum)	29.5
Waterbox (psig)	25

The condenser is designed to accept up to 40 percent of the design main steam flow (vwo) through the steam dump and bypass valves while maintaining turbine back pressure below 5 inches. Hg absolute without exceeding the allowable turbine exhaust temperature.

The condenser hotwell has four minutes of vwo flow storage capacity.

The condenser is designed to deaerate the condensate properly, to provide condensate of the required quality and to remove noncondensable gases and air inleakage from the condensing steam.

10.4.1.2 System Description

During planned operation, steam from the low pressure turbine is exhausted directly downward into the condenser shells through exhaust openings in the bottom of the turbine casings. The condenser consists of two sections, each section serving one double-flow, low pressure turbine section. The condenser also serves as a heat sink for several other sources, such as exhaust steam from feed pump turbines, cascading heater drains, air ejector condenser drain, steam packing exhauster condenser drain, feedwater heater shell operating vents and condensate pump suction vents.

During abnormal conditions, the condenser is designed to receive steam dump and bypass steam and feedwater heater and moisture separator/reheaters drain tank high level dump(s).

The condenser is a single-pass, single-pressure deaerating type with divided water boxes. The condenser is supported on the turbine foundation mat with expansion joints provided between each turbine exhaust opening and the steam extraction connections in the condenser shells. Condenser shells are connected by a pressure equalizing duct.

Dearation in the condenser removes normal inleakage of air plus noncondensable gases contained in the turbine steam. The noncondensable gases are then collected in the air cooling section of the condenser, from which they are removed by the mechanical vacuum pump at startup and by the steam jet air ejectors (SJAE) during normal operation.

10.4.1.3 Safety Evaluation

The condenser is designed to store a sufficient volume of condensate to provide a three minute effective retention time of the condensate for radioactive decay in the event of tube leakage of the steam generator.

10.4.1.4 Tests and Inspection

The condenser is built in accordance with Heat Exchanger Institute (HEI) standards for the steam surface condensers. The water boxes shall be tested in accordance with these standards. After erection, the condenser will be filled with water to check tube and other leaks.

10.4.1.5 Instrumentation

Condenser vacuum and temperature are monitored continuously. Necessary alarm and trip signals are provided for high pressure and exhaust hood temperatures. The condenser hotwell level is controlled by level controllers. Conductivity elements in each effluent line detect any inleakage of the circulating water into the condenser steam space.

Redundant conductivity elements are provided, one in each condenser outlet line to detect in leakage of circulating water into the feedwater system. Each conductivity cell output is continuously recorded. High conductivity will be alarmed in the Control Room.

10.4.2 MAIN CONDENSERS EVACUATION SYSTEM

10.4.2.1 Design Bases

The main condenser evacuation system is designed to remove a total of 80 scfm of noncondensable gases in accordance with HEI standards.

10.4.2.2 System Description

The main condensers evacuation system, as shown in Figure 10.4–1, includes two SJAE units complete with inter- and after-condensers which remove air and noncondensable gases from the main condenser. A mechanical vacuum pump is provided for use during startup.

Main steam, reduced in pressure by an automatic steam-pressure reducing station, is supplied as the driving medium to the twin element two-stage air ejectors. Air ejector condenser cooling is provided by the main condensate flow. Air inleakage and noncondensable gases are removed from the condenser and discharged to the Millstone stack which is continuously monitored for radioactivity.

Two full capacity mechanical vacuum pumps remove air and noncondensable gases from the condenser during startup and when the desired rate of air and gas removal exceeds the capacity of the air ejectors. The discharge from the vacuum pump is routed to the Millstone stack.

10.4.2.3 Safety Evaluation

A radiation monitor is provided in the air ejector vent line to the Millstone stack to detect primary to secondary leakage in the steam generators. Upon a high radiation signal an alarm is actuated and checks of the monitor alarm and possible leakage sources and rates are instigated.

10.4.2.4 Tests and Inspection

The air ejector inter- and after-condensers are hydrostatically tested at the manufacturer's plant in accordance with HEI standards. Mechanical vacuum pumps and air ejectors first and second stages are performance tested at the factory for the design capacity.

10.4.2.5 Instrumentation

All necessary instrumentation is provided for normal and abnormal operations.

10.4.3 TURBINE GLAND SEALING SYSTEM

10.4.3.1 Design Bases

The turbine gland seal system provides a means of sealing the turbine shaft and valve stem packing against air leakage into the cycle and to prevent steam leakage into the Turbine Room.

10.4.3.2 System Description

The turbine gland sealing system, consists of a main steam source, steam seal pressure regulator, steam seal header, one full capacity steam packing exhauster with two full capacity blowers and the associated piping and valves.

During planned operation, one blower is operating while the other is on standby. The exhaust blower discharges gland air leakage to the Millstone stack. The steam packing exhauster is cooled by main condensate flow and is drained to the main condenser.

10.4.3.3 Safety Evaluation

The radiation monitor for the Millstone stack would alarm any high radioactive releases from this system.

10.4.3.4 Tests and Inspection

The gland seal condenser is designed in accordance with American Society of Mechanical Engineers (ASME) Section VIII and is hydrostatically tested.

10.4.4 CIRCULATING WATER SYSTEM

This system is described in Section 9.7.1.

10.4.5 CONDENSATE AND FEEDWATER SYSTEM

10.4.5.1 Design Bases

10.4.5.1.1 Functional Requirement

The function of the condensate and feedwater system is to process the condensate and provide the required amount of feedwater to the steam generators. The condensate and feedwater system provides feedwater heating and maintains the required quality of feedwater.

The auxiliary feedwater system (AFWS) is comprised of two full-capacity subsystems to satisfy two safety functional requirements. One subsystem consists of two motor driven, automatically initiated AFW pumps. The second subsystem consists of one turbine-driven pump.

The first safety functional requirement is to provide cooling to either steam generator, on low-steam generator level, with or without the loss of normal AC power along with the most limiting single failure. The arrangement of these two independent subsystems ensures that the auxiliary feedwater system can accomplish this functional requirement.

The second functional requirement is that AFW must be delivered to the steam generators independently of AC power in the event of a station blackout scenario. The turbine-driven AFW pump performs this second function.

10.4.5.1.2 Design Criteria

The following criteria have been used in the design of the condensate and feedwater system:

a. The system shall provide 110 percent of the valve wide open flow at 935 psig at the steam generator feedwater nozzles.

b. The system shall maintain the required volume and quality of water in the cycle.

c. The system shall process and provide a controlled path for the fluids in the cycle.

d. The system shall provide sufficient feedwater for the cold shutdown of the RCS.

The design of the feedwater piping system had been modified to ensure that the loop seals were provided in the piping as close to the steam generator feedwater inlet nozzles as possible. These modifications had been provided in lieu of performing analyses using dynamic forcing functions associated with the draining of feedwater lines to qualify the piping system design.

The design of the feedwater piping has also been modified to the interface requirement for the design associated with steam generators installed in 1991. The modified feedwater design retains the water hammer mitigation designs described in the previous paragraph but accommodates the 1991 steam generator’s lower primary deck (below the normal water level), lower feedwater sparger ring, top discharge J-tubes, all welded thermal sleeve and a goose neck inlet design.

The following criteria have been used in the design of the AFWS:

a. The system shall have two redundant, independent subsystems, each capable of performing the functional requirements. The turbine-driven pump and associated piping is one subsystem. The two motor driven pumps and associated piping is the second subsystem.

b. The system shall have suitable subsystem and component alignments to assure operation of a complete subsystem with associated components.

c. Capabilities shall be provided to assure the system operation with onsite power (assuming offsite power is not available) or with offsite electrical power.

d. A single failure of an active component in either subsystem shall not affect the functional capability of the other subsystem.

e. The system shall be designed to permit periodic inspection of important components such as pumps, valves, piping and tanks to assure the integrity and capability of the system.

f. The system shall be designed to the general criteria as described in Section 6.1.

g. The AFWS is automatically initiated upon detection of low steam generator level.

10.4.5.2 System Description

The condensate and feedwater system is shown in Figure 10.4–2.

The condensate pumps take condensate from the condenser hotwells and pump it through the condensate polishing demineralizers and the steam packing exhauster. The flow is then split into two streams. Each stream passes through an ejector condenser, an external drain cooler and sixth- and fifth-stage feedwater heaters located in the condenser neck and three low pressure feedwater heaters and one high pressure heater.

The SGFPs are located in the cycle between the low pressure heaters and the high pressure heater.

To maintain the proper feedwater chemistry a secondary chemical feed system is provided for injecting hydrazine as an oxygen scavenger and ethanolamine (ETA) to control pH. The rate of chemical injection is controlled to maintain chemistry within the desired limits. The point of chemical injection during normal operation is in the condensate return header from the Condensate Polishing Facility (CPF), upstream of the bypass valve. An alternate point of injection, when the CPF is bypassed, is in the CPF discharge header downstream of the CPF bypass valve and upstream of the steam jet air ejectors.

Feedwater regulating and control is described in Section 7.4.

10.4.5.3 Auxiliary Feedwater System

The AFWS, shown in Figure 10.4–2, is designed to provide feedwater for the removal of sensible and decay heat, and to cool the primary system to 300°F in case the main condensate and SGFP are inoperative due to loss of normal electric power sources or the main steam. A single motor-driven pump is capable of adequately removing decay heat. This has been demonstrated by a best estimate analysis of the loss of feedwater event (Reference 10.4-1). The best estimate analysis is performed to demonstrate the automatic start of both motor driven auxiliary feedwater pumps on low steam generator level satisfies the automatic auxiliary feedwater initiation requirements of NUREG-0737 item II.E.1.2. Automatic start of the turbine driven auxiliary feedwater pump is not required. The suction condition yields a net positive suction head (NPSH) in excess of that required. The AFWS may also be used for normal system cooldown to 300°F. The AFWS supplies feedwater from the condensate storage tank (CST) to the steam generators for evaporation and heat absorption. Reactor decay heat and sensible heat are transferred to the steam generators by natural circulation of the reactor coolant if power is not available for the reactor coolant pumps (RCP).

In order to perform its safety-related function (per Section 14.2.7) assuming single failure, the auxiliary feedwater system (AFWS) is comprised of two full capacity subsystems. One subsystem consists of two motor driven AFW pumps, that are automatically connected to the diesel generators in the event of a loss of offsite power. The second subsystem consists of one turbine-driven pump that is independent of AC power and may be started by operator action. The turbine-driven pump has a maximum capacity of 600 gpm at 2437 feet design head (TDH) and the two motor driven pumps have a constant 300 gpm capacity each at 2437 feet TDH.

The two motor driven auxiliary feedwater pumps (AFP) received their power from redundant Facility 1E 4160VAC breakers. The 4160 VAC breakers receive control power from redundant 125VDC feeds, Facility Z1 125 VDC panel DV10 and Facility Z2 125 VDC panel DV20. The speed adjuster motor and the steam inlet valve for the turbine-driven AFP normally receive their power from Facility Z2 125 VDC panel DV20. During design basis accidents coincident with a single failure that could disable one motor driven AFP and the turbine-driven AFP simultaneously, the steam inlet valve and the speed adjuster motor are capable of being transferred to Facility Z1 125 VDC panel DV10. In the event of a loss of Facility Z2 125 or a loss of DC panel DV20, the transfer is accomplished by switching the position of two key-locked isolation switches on panel C-05. The associated wiring from panel C-05 is routed in dedicated Z5 conduit to panel C-21, panel C-10 and ultimately to the steam inlet valve and the speed adjuster motor.

The auxiliary feedwater pumps (AFP) are located in two separate pump rooms at elevation 1 foot 6 inches in the Turbine Building. The Turbine Building is protected from potential flooding by the flood wall system as shown in Figure 2.5–18 of the FSAR. Access to the first room which houses the two motor driven AFPs is by stairs leading down from the ground floor at elevation 14 feet 6 inches. The enclosure over the pump room stairwell serves as a protective barrier against direct water streams into the Pump Room due to a possible overhead pipe failure. The second room which houses the turbine-driven AFP is a vault physically separated from the motor driven AFP room by a reinforced concrete wall. The only access means to this room is through a water-tight fire door.

Separate floor drain and sump systems are provided for each pump room. A high-level alarm system which is monitored in the Control Room for each sump will indicate excessive flooding in the room. The power supply to the sump pump in the motor driven AFP room and to the ‘B’ sump pump in the steam-driven AFP room is fed from vital power supply, MCC B61.

Directly above each pump and on the ground floor of the Turbine Building is a removable hatch serviced by a monorail and hoist system for equipment removal and emergency access. The AFP and piping in both rooms are Seismic Class I.

The AFPs can each be connected to a separate diesel generator by means of a separate control switch located on the main control board with the capability to manually start each pump from the control room.

The CST capacity is 250,000 gallons. A nitrogen blanketing system is utilized to limit oxygen intrusion into the stored condensate inventory. A nitrogen sparger system is available to lower the oxygen concentration in the tank. A redundant relief protection scheme, including both breather valves and rupture disks, is provided to prevent an over-pressure or vacuum situation. At operational low level, the volume of water available for decay heat removal and cooldown of the nuclear steam supply system (NSSS) is 165,000 gallons. This is sufficient to cool down the RCS to less than 300°F following a total loss of offsite power. The 165,000 gallons are also adequate to remove decay heat alone for more than 10 hours, leaving a normal no-load water level in the steam generators at the end of 10 hours after initiation of the cooldown cycle. The 165,000 gallons includes unusable tank volume due to discharge nozzle pipe elevation above tank bottom, plus an allowance for vortex formation. CST is equipped with a recirculation heating system to prevent freezing within the tank during cold weather. The heating system includes a recirculation line that takes suction inside and near the bottom of the tank, penetrates the tank above the concrete protected region, is pumped through a heat exchanger and returns to the top of the tank. The suction line inside the tank is provided with a siphon breaker to prevent siphoning of the tank following a postulated pipe break. The siphon breaker is located at a height that will protect the minimum required tank water level to assure suction for the CST heating system, and to minimize drainage following a postulated pipe rupture.

The CST is missile protected by a concrete wall extending to a height which will provide adequate water for a safe shutdown. The exposed portion of the steel tank is designed to withstand the tornado wind pressure as described in Section 5.7.3.1.4 of the FSAR. Failure in the upper portion of the tank due to missile impact will be local and since the tank is fabricated of ductile steel, any fragmentation is unlikely. However, to ensure proper water flow from the tank in the event of a postulated free falling fragment of steel, the tank discharges are protected by screens which will prevent blockage.

The portion of the steel liner which is protected by the concrete wall could be damaged locally by a missile entering through the upper portion of the tank. In the event of local damage to the steel tank wall below the top of the exterior concrete wall, significant water loss is not possible as the steel shell is anchored to the concrete with vertical angles having a spacing of 24 inches. Any minor water leakage will be confined to the interface between the steel and concrete.

The concrete wall, which extends to a height of 25 feet, ensures that a minimum of 205,800 gallons of water is available for a safe shutdown of the plant. The concrete wall extends above the operational low-water level corresponding to 165,000 gallons.

The steam generated during decay heat removal and cooldown during an electric power failure will be discharged by the atmospheric dump valves (ADV), except for that used by the turbine-driven AFP. The turbine-driven pump operates reliably as long as there is steam pressure in excess of 50 PSIG in one of the steam generators.

The three AFPs are individually controlled from Control Room Panel CO-5 or from the Hot Shutdown Panel C-21 in the Turbine Building. In addition, the steam-driven AFP can also be controlled from the fire shutdown panel C-10 in the Turbine Building. The electric-driven pumps may be either automatically actuated or manually actuated. The steam-driven AFP can only be manually actuated. In the event of a loss of Facility Z2 125 VDC power or a loss of panel DV20, the steam-driven AFP speed adjuster motor and steam inlet valve can be swapped to Facility Z1 125 VDC power by switching two key-locked isolation switches on panel C-05.

For automatic actuation, each pump and its associated flow control valve have two switches on each panel. The first switch, the automatic permissive, either allows or blocks the automatic start of the respective pump. This auto permissive switch has three positions:

- Pull to lock, which blocks the automatic signal.
- Reset, which resets the automatic function.
- Start, which will start the electric AFPs and open the flow control valves.

The second switch selects the mode of operation of the flow control valve associated with the pump.

The three modes of selection are:

- Normal, which allows the valve to open fully for an automatic actuation.
- Override, which allows manual control of the valve position following an automatic actuation.
- Reset, which resets the electrical logic for returning the mode of operations back to normal.

Auto actuation of the electric-driven pumps and the auxiliary feedwater regulating valves occurs when 3 minutes, 25 seconds have elapsed since the steam generator levels dropped to ≤ 26.8 percent.

A manual bypass valve is provided around each air-operated AFW regulating valve, 2-FW-43A and 2-FW-43B, in the auxiliary feedwater (AF) line to each steam generator to ensure the availability of feedwater for decay heat removal should either one of the regulator valves fail in the closed position. To meet the functional requirement of providing AFW to either or both steam generators with a limiting single failure, a normally open motor-operated cross-tie valve is provided between the AF regulating valves.

In addition, the AFW regulating valves, 2-FW-43A and 2-FW-43B, are equipped with a backup air supply to provide valve closure and valve control in the event of loss of the Instrument Air System. The backup air supply is provided by high pressure air cylinders. The system is designed to operate in a harsh environment caused by the beyond design basis event of a feedwater line break inside the turbine building coincident with a failure of the main feedwater check valve (2-FW-5A or 2-FW-5B). The Instrument Air system is non-safety related. The backup air supply is safety related.

The AFW regulating valves receive an AFAIS signal to open upon low level in either steam generator to ensure feedwater flow following a loss of normal feedwater. These valves are also designed to fail open upon a loss of air or electric power. Following a MSLB or HELB, AFW to the affected steam generator is isolated. The AFW regulating valves can be closed by the backup air supply for a MSLB inside Containment or outside Containment upstream of the Main Steam Isolation Valve (MSIV). For HELBs inside the Turbine Building, the AFW regulating valves are open and the cross-tie motor-operated valve (MOV) is environmentally qualified to close to isolate the affected steam generator. Depending on which steam generator is affected, the motor driven pumps may need to be shut down and the turbine-driven pump started to feed the unaffected steam generator. In the event of a single failure in the power system that causes the AFW regulating valve 2-FW-43B to fail open and the MOV cross-tie valve to fail as-is, the affected steam generator will be isolated by local operator action following a MSLB.

The auxiliary feedwater system can be used to provide long term cooling in the event of a LOCA in conjunction with the dumping of steam. The AFW pumps would initially take a suction on the condensate storage tank. If in the long term the CST becomes depleted and cannot be replenished by normal makeup, the operators can connect the fire water system and its two, 250,000 gallon storage tanks to the AFW pump suctions. The fire water storage tanks can be replenished from the city water supply if necessary. See Section 14.6.5.3 for a description of long term cooling in the event of a LOCA.

The AFW system contains suction and discharge connections that facilitate portable diesel engine driven AFW pump deployment and CST replenishment. These conditions are defense-in-depth design features that are available for coping with an extended loss of AC power (ELAP) event. The location of these BDB AFW Flex suction and discharge connections are shown on Figure 10.4–2, Sheet 3.

10.4.5.4 Equipment

10.4.5.4.1 Condensate Pumps

Each condensate pump is a motor driven, multistage, vertical, canned suction type, centrifugal unit. Three 55 percent capacity pumps are installed at an elevation that allows operation at low level in the condenser hotwell. Table 10.4-1 describes the detail design conditions. The third (standby) pump starts automatically on the low pressure signal from the condensate discharge header.

10.4.5.4.2 Feedwater Heaters

Two parallel trains with five low pressure heaters and one high pressure heater are provided. Drain coolers are provided for all stages of feedwater except Number 3 heater from which the drains are pumped forward, and all except Number 6 heater drain cooler sections are integral with the heaters. All heaters have 439 stainless steel tubes except Numbers 2, 3, and 4 which have 304 series SS. Table 10.4-1 provides more details.

10.4.5.4.3 Heater Drain Pumps

Heater drain pumps are motor driven centrifugal types, vertical, canned suction units. Two 55 percent capacity pumps are provided at an elevation that allows adequate NPSH at all loads. Table 10.4-1 lists the details.

10.4.5.4.4 Steam Generator Feed Pumps

Each SGFP is a horizontal turbine-driven centrifugal unit. Two 55 percent capacity pumps operate in series with the condensate pumps. Recirculation control valves are provided in the pump discharge lines to provide automatic recirculation of a portion of the feedwater flow to the main condenser. This assures that a minimum safe flow is maintained through the pumps. Table 10.4-1 lists the characteristics.

10.4.5.4.5 Steam Generator Feed Pump Turbine Drives

Each feedwater pump is driven by an individual steam turbine. The turbine drives are of the dual admission type and are equipped with stop and control valves. Under normal operating conditions, the turbine drives run on the low pressure crossover steam. Main steam is used during plant startup, low load or transient conditions when crossover steam is not available or is of insufficient pressure. The turbines operate at 2.5 inches Hg absolute back pressure and exhaust to the main condenser.

10.4.5.4.6 Condensate Polishing Facility

When in use, the Condensate Polishing Facility (CPF) receives condensate from the condenser hotwell after it passes through the Steam Packing Exhauster. After processing, condensate is returned at the air ejectors. The CPF consists of seven parallel flow demineralizers. Full condensate flow can be accommodated by six demineralizers allowing for regeneration of the seventh without reducing power. The CPF can be completely bypassed. The CPF is used to maintain the secondary system water chemistry within the limits of plant procedures.

10.4.5.5 Safety Evaluation

The components of the condensate and feedwater system are conventional and of a type that has been extensively used in fossil-fueled and other nuclear plants.

The plant can carry 55 percent load with one-half of the feedwater heaters out of service and isolated from the system, with only one condensate pump in operation and with only one SGFP in service.

The components of AFWS are designed to the general requirements including seismic response as described in Section 6.1. The components are protected from missile damage and pipe whip by physical separation of duplicate equipment as described in Section 6.1. The pumps are completely redundant. Each subsystem is capable of providing the required amount of feedwater for performing the cold shutdown of the RCS.

The total inventory of the condensate and feedwater system is approximately 209,000 gallons divided between the components as follows:

1. Condenser (shell) = 80,100 gallons

2. Condensate and Feedwater piping = 55,500 gallons

3. Moisture Separator/Reheater and Drain Tanks = 3,200 gallons

4. Feedwater Heaters = 37,000 gallons

5. Steam Generator = 33,200 gallons

The maximum flowrate to each steam generator is approximately 14,100 gpm during normal plant operation.

The potential for failures in the condensate and feedwater system are minimized by designing the piping for pressures well above any pressures possible in the system, with the low pressure heaters designed for the maximum shut-off head of the condensate pumps and the high pressure heaters designed for the SGFP shut-off head, see FSAR Section 10.4.5 and Table 10.4-1.

Failures in the condensate system can be readily detected by equipment performance alarms in the Control Room indicating the malfunction to the operator. The type of alarm depends on the severity and location of the failure and allows the operator the option of either isolating the failed component and reducing load or complete shutdown of the plant. However, as with any gross failure in this system, the alarms on the steam generator would ultimately indicate decreased flow, loss of pressure and low liquid level resulting in a possible reactor trip by the reactor protection system (RPS). The type of alarms are dependent on the location of the pipe rupture or equipment failure and are summarized below:

1. Failures in the system between the condenser and the condensate pumps would result in gradual flooding of the condenser pit setting off the condenser pit sump high-level alarm, set at 6 inches below the top of the sump. If the condenser hotwell level continues to decrease, a low level alarm is registered in the Control Room.

2. Failures in the equipment or piping between the condensate pumps and the SGFPs would result in low condensate pump discharge pressure and low SGFP suction pressure alarms in the Control Room. In addition, the steam generator would register the alarms indicated previously (i.e., low flow, pressure and liquid level).

3. Failures in the equipment or piping between the SGFP discharge and the feedwater containment isolation valves would result in a low pressure alarm indicated in the feedwater header and low-level alarms for the steam generator.

4. Failures in the piping between the containment isolation valves and the steam generator would be indicated by the low flow, pressure and water level alarms in the steam generator.

The entire system can be brought to rest, with the termination of all flow, within several seconds from the time the condensate and SGFPs are tripped. Static head would be the only driving force for water escaping through leaks at lower elevations. In the event that the entire system inventory were drained to the Turbine Building ground floor, equipment and floor drains located at low spots in the floor would drain the water to the condenser pit sumps and prevent any accumulation on the ground floor. Feedwater piping in the Enclosure Building is either routed through areas void of essential equipment or provided with restraints in other areas as required so that any ruptures occurring do not affect safe operation of the plant. Therefore, any postulated failures in the condensate and feedwater system can be detected and controlled quickly, and in no way affect the operation of essential equipment.

To increase the original design basis safety margin for a main stream line break (MSLB) inside containment, the MSI signal was modified to actuate on either high containment pressure or low steam generator pressure. The modified MSI signal provides a more rapid isolation signal for feedwater and main steam isolation during a steam line break within containment. Also, the feedwater block valves, feedpump discharge valves, feedwater regulating and bypass valves as well as the feed pumps are provided with redundant MSI trip and closure signals for ensuring feedwater isolation.

10.4.5.6 Tests and Inspection

Equipment, instruments, and controls are regularly inspected to ensure proper functioning of systems. The motor driven pumps and controls are given preoperational tests after erection and before plant warmup.

The AFWS can be tested during normal operation by recirculating an AFP flow of 50 gpm to the CST.

10.4.6 STEAM GENERATOR BLOWDOWN SYSTEM

10.4.6.1 Design Bases

The function of the steam generator blowdown system (SGBS) is to withdraw and reject the system fluid at a rate which will maintain contaminate concentrations in the steam generator water below equipment operating limits. The system has three modes of operation: sampling blowdown: condenser leakage: and startup blowdown.

10.4.6.2 System Description

The SGBS is shown in Figure 10.3–1. Blowdown and quench tanks are provided. The blowdown tank has a capacity of two percent of the vwo main steam flow and is used during startup and when condenser tube leakage occurs. The quench tank has a blowdown capacity of 10 gpm and will normally be in service at all times when the blowdown tank is not in service.

Tube sheet blowdown nozzles are provided on each steam generator. The blowdown tank vents to the atmosphere and the quench tank vents to the gas processing system. Normally, both drain to the condenser cooling water discharge. The quench tank is provided with a closed recirculating pump and cooler cycle for quench water supply.

The steam generator blowdown is automatically isolated in response to the CIAS and the low-low steam generator water level trip (AFAIS) that activates the auxiliary feedwater system.

A radioactivity monitor is located in the combined sampling line from both steam generator blowdown lines. When a high radioactivity level is detected, an alarm is annunciated in the Control Room and the blowdown stop and drain valves are closed automatically. The blowdown system residual inventory is manually diverted to the Aerated Liquid radioactive waste system. The 10 gpm quench tank blowdown may be resumed; if so, the blowdown liquid is diverted to the Clean Liquid radioactive waste system.

10.4.6.3 Safety Evaluation

Failure analysis of system components is given on Table 10.4-2.

10.4.6.4 Tests and Inspection

The steam generator blowdown tank and quench tank are designed in accordance with ASME Section VIII and seismic Class II requirements. The performance of the blowdown system is ascertained by an inplace test.

10.4.7 REFERENCES

10.4-1 "Millstone Unit Number 2 FSAR Chapter 10 Loss of Normal Feedwater Flow Transient with Reduced Auxiliary Feedwater Flow," EMF-98-049, Rev. 0, Siemens Power Corporation, August 1998.

TABLE 10.4-1 MAJOR COMPONENTS OF THE CONDENSATE AND FEEDWATER SYSTEM

Steam Generator Feed Pumps		
Type	Double suction, diffuser type, single stage, vertical split, horizontal centrifugal	
Quantity	2	
Capacity each (gpm)	15,000	
Head differential tdh (feet)	2,100	
Material		
Case	ASTM A217, Gr C5	
Impeller	ASTM A296, Gr CA 15	
Shaft	AISI 410 Ht & SR	
Driver	Condensing, nonextracting, dual admission, horizontal steam turbine	
Codes	ASME Section VIII and IX, Standards of the Hydraulic Institutes, NEMA, ANSI	
Manufacturer	Ingersoll Rand	
Steam Generator Auxiliary Feed Pumps		
Type	Horizontal, split case, multistage, centrifugal	
Quantity	1 turbine driven,	2 motor driven
Capacity each (gpm)	600	300
Head (feet)	2437	2437
Material		
Case	ASTM A 216, Gr WCB	
Impeller	ASTM A 48, Class 30 for P9B; ASTM A 217, Grade CA15 for P9A, P4	
Shaft	ASTM A 582, Type 416 or ASTM A 276 Type 410	
Driver	Single-state, noncondensing steam turbine (for turbine-driven) GE motor, 350 Hp, 4160 volt, 60 Hz, 3 phase, 3600 rpm (for motor-driven pumps)	

TABLE 10.4-1 MAJOR COMPONENTS OF THE CONDENSATE AND FEEDWATER SYSTEM (CONTINUED)

Seismic requirements Codes	Class I
	ASME Code for Pumps and Valves for Nuclear Power, Class II NEMA Standard SM 20-1958 Hydraulic Institute
Manufacturer	Ingersoll Rand
Condensate Pumps	
Type	Vertical centrifugal
Quantity	3
Capacity each (gpm)	9200
Head (ft)	1050
Material	
Case	ASTM A-48, CL 30
Impeller	ASTM A-296, Gr CA-15
Shaft	ASTM A-276, Type 416
Driver	E1 motor, 3000 Hp 6600 volts, 60 Hz, 3 phase, 900 rpm
Codes	ASME Sections VIII and IX, Standards of the Hydraulic Institute, NEMA ANSI
Manufacturer	B&W Canada
Heater Drain Pumps	
Type	Vertical Centrifugal
Quantity	2 (per unit)
Capacity each (gpm)	4300
Heat (feet)	1000
Material	
Case	ASTM A-217, Gr C-5

TABLE 10.4-1 MAJOR COMPONENTS OF THE CONDENSATE AND FEEDWATER SYSTEM (CONTINUED)

Impeller	ASTM A-296, Gr. CA-15			
Shaft	ASTM A-276, Type 410 HT			
Driver	E1 motor 1250 Hp, service factor 1.15 4160 volts, 60 Hz, 3 phase, 1800 rpm			
Codes	ASME Sections VIII and IX, Standards of the Hydraulic Institute, NEMA, ANSI			
Manufacturer	Byron-Jackson			
Condenser				
Type	Two shell, single-pass with divided water boxes, surface condenser			
Design duty (Btu/hr)	6.059×10^9			
Heat transfer area (ft^2)	485,260 total			
Design pressure	Shell 29.5 in. Hg. vacuum Water box 25 psig			
Material				
Shell	ASTM A-285, Grade C			
Tubes	ASTM B 338, Gr. 2 Titanium			
Tube sheets	ASTM B-265, Gr. 2 Titanium			
Codes	Standards of the Heat Exchange Institute			
Feedwater Heaters				
Type	Closed, U-tube except drain cooler is straight			
Material	Heater 1 (A,B)	Heater 2 (A,B)	Heaters 3 & 4 (A, B)	Others
Shell	Carbon steel	Carbon steel	Carbon steel	Carbon steel
Tubes	439 SS	304 LSS	Stainless Steel	439 SS
Tube Sheets	Carbon Steel w/Inconel overlay	Carbon Steel	Carbon Steel	Carbon Steel
Codes	ASME Section VIII, Heat Exchange Institute			

Details on joints, tube-to-tube sheets	Welded & Rolled	Hydraulically Expanded & Rolled	Rolled	Rolled

Heater No.	Design Duty Each (Btu/hr)	Design Pressure (psig)		Design Temperature (°F)		Heat Transfer Area Each (ft^2)
		Shell	Tube	Shell	Tube	
1, A, B	355.215×10^6	450	1700	460	460	20,445
2, A, B	287.518×10^6	225	650	400	400	23,675
3, A, B	154.152×10^6	30 in Hg. & 150	650	370	370	12,163
4, A, B	296.046×10^6	30 in. Hg & 75	650	330	330	17,019
5, A, B	263.347×10^6	30 in. Hg & 50	650	300	300	16,144
6, A, B	198.156×10^6	30 in. Hg & 50	650	300	300	15,839
Drain cooler (6, A, B)	47.550×10^6	30 in. Hg	650	300	300	5,156
Piping						

TABLE 10.4-1 MAJOR COMPONENTS OF THE CONDENSATE AND FEEDWATER SYSTEM (CONTINUED)

Piping System	Applicable Code	Material	Design Pressure (psig)	Design Temperature °F
Main steam	ANSI B31.1.0	ASTM A-144 Gr. KC 70	1000	580
Main steam penetration piping (including atmospheric dump)	ANSI B31.7 C12	ASTM A-155 Gr. KC 70	1000	580
Feedwater	ANSI B31.1.0	ASTM A-106 Gr. C	1600	400-450
	ANSI B31.1.0	ASTM A-106 Gr. B	1100	600
	ANSI B31.1.0	ASTM A-335 Gr. P5	1100-1600	400-600
	ANSI B31.1.0	ASTM A-335 Gr. P22	1100-1600	400-600
Feedwater penetration	ANSI B31.7CL 2	ASTM A-106 Gr. B	1100	600
	ANSI B31.7CL 2	ASTM A-335 Gr. P5	1100	600
	ANSI B31.7CL 2	ASTM A-335 Gr. P22	1100	600
Condensate	ANSI B31.1.0	ASTM A-106 Gr. B or ASTM A-335 Gr. P22	650	400

TABLE 10.4-2 FAILURE ANALYSIS OF STEAM GENERATOR BLOWDOWN SYSTEM COMPONENTS

1. Steam Generator Blowdown line	Break at 2 inch diameter line inside containment	1) Containment pressure and Radiation monitoring. 2) Containment sample loss alarm	Plant shutdown	Radioactivity release only to the containment which can be held and processed through filters.
2. Steam Generator Blowdown piping	a) Outside the containment b) Break of Blowdown piping downstream valve HV4246 or 4248 in the Enclosure Building	1) Area radiation monitoring 2) Aerated waste sump level alarms.	Close control valve HV4246 & HV4248 or Plant shutdown	Radioactivity release to the Auxiliary Building is monitored as discharged to the environment through the EBFS and liquid collected in the Drain System.
3. Radiation Monitors	Radiation monitoring failure with no mechanical piping failure	Radiation monitoring failure alarm at control room.	Close control valves HV4246, HV4248, HV4245, and HV4578 and manual sampling	

FIGURE 10.4–1 P&ID CONDENSER AIR REMOVAL WATER BOX PRIMING AND TURBINE BUILDING SUMP (25203-26012)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.4–2 P&ID CONDENSATE SYSTEM (25203-26005 SHEET 1)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.4–2 P&ID CONDENSATE SYSTEM (25203-26005 SHEET 2)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.4–2 P&ID CONDENSATE STORAGE AND AUXILIARY FEED (25203-26005 SHEET 3)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 10.4–2 P&ID CONDENSATE STORAGE AND AUXILIARY FEED (25203-26005 SHEET 4)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.