CHAPTER 10 - STEAM AND POWER CONVERSION SYSTEM

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

CHAPTER 10 -STEAM AND POWER CONVERSION SYSTEM

10.1 SUMMARY DESCRIPTION

The power conversion systems of each unit are designed to produce electrical energy through conversion of a portion of the thermal energy contained in the steam supplied from the reactor. Both systems condense the turbine exhaust steam into water and return it to the reactor as heated feedwater, with a major portion of its impurities removed.

The power conversion systems of the two units are identical, are not interconnected, and do not have common equipment. The major components of each unit's power conversion system are:

a. Turbine-generator with auxiliaries

b. Main condenser

c. Condensate pumps

d. Air ejector with water-cooled condenser

e. Clean steam seal system

f. Turbine bypass system

g. Condensate cleanup system

h. Reactor feed pumps

i. Feedwater heaters

j. Condensate storage systems

k. Interconnecting piping and valves

The circulating water system and, ultimately, the cooling towers remove the rejected heat to the main condenser. An overall flow diagram of the system is shown in “drawings M-01, M-02, M-03, M-04, M-05, M-06, M-07, M-09, M-16, and M-21.

Steam generated in the reactor is supplied to the high pressure turbine through the main stop and control valves and exhausted through cross-around lines to six moisture separators that remove moisture from the steam. The dried steam leaves the moisture separators and enters the low pressure turbines through combined intercept valves. After passing through the LP turbines, the steam exhausts to the main condensers, where it is condensed by the circulating water system (Section 10.4.5), deaerated, collected in the hotwell of the condenser, and returned to the cycle as condensate. The SJAEs continuously use a small part of the main steam supply to continuously remove noncondensable gases from the condenser. Steam is extracted from cross-around pipes downstream of the moisture separators to drive the reactor feed pump turbines during normal power operation.

Taking suction from the condenser hotwell, the condensate pumps deliver the condensate to the reactor feed pumps through the SJAE condenser, the steam packing exhauster condenser, the condensate cleanup demineralizers, the first heater drain coolers, and the five stages of low pressure feedwater heaters. The reactor feed pumps supply feedwater to the reactor through one stage of high pressure feedwater heaters.

Steam is extracted from stages of the HP and LP turbines and used to heat the condensate as it passes through the various feedwater heaters. The extraction steam is condensed in each heater, and the condensed steam is drained to the next lowest pressure heater. The total cascaded heater drains are collected in the drain cooler, from which they drain back to the condenser. The moisture removed from the steam by the moisture separators is drained to heater No. 4, where it mixes with the condensed extraction steam and is eventually drained back to the condenser.

If the water level in any heater or moisture separator becomes too high, the drains are automatically dumped directly to the condenser and the feedwater heater extraction isolation valves are automatically closed.

Normally, the turbine uses the steam being generated by the reactor; however, an automatic steam bypass system can discharge excess steam (as much as 24.3% of the design flow) directly to the condenser (Section 10.4.4).

Biological shielding is provided to protect operating personnel from exposure to high radiation levels. Section 12.3 provides additional discussion on radiation protection.

Except for portions of the feedwater lines from the RPV to the outermost isolation valves and the main steam lines from the RPV to the turbine stop valves, along with selected instruments listed in Chapter 7 used for the RPS, no other portions of the steam conversion and power conversion systems are safety-related.

References 10.2-9, 10.2-10, and 10.2-11 provide the heat balances for Unit 1 and Unit 2.

The design and performance characteristics for the steam and power conversion system are summarized in Table 10.1-1.

Table 10.1-1

DESIGN AND PERFORMANCE CHARACTERISTICS OF
POWER CONVERSION SYSTEM FOR GUARANTEED CONDITION

STEAM CONDITIONS AT THE TURBINE STOP VALVES

	Pre MUR-PU	Post MUR-PU
Flow	14.97×10^6 lb/hr	15.287×10^6 lb/hr***
Pressure	1005 psia	1003 psia***
Temperature	545°F	
Enthalpy	1190.1 Btu/lb*	1190.0 Btu/lb***
Moisture content	0.41%*	0.43%***
FEEDWATER CONDITIONS		
Flow	14.95×10^6 lb/hr	15.255×10^6 lb/hr
Temperature	425.1°F	427.1°F
CONDENSER		
Air inleakage	337 lb/hr (75 scfm)	
Hotwell detention capacity	2 min	
MAIN STEAM BYPASS CAPACITY	25%	24.3%****

* These values are based on 0.1% moisture in the reactor steam dome and do not necessarily reflect current operating conditions.

** Data for Post MUR-PU notes differences only.

*** Conditions at upstream of turbine stop valves.

**** Turbine bypass capacity with respect to steam flow of 15.287 Mlb/hr.

10.2 TURBINE-GENERATOR

The turbine-generator receives steam from the nuclear steam supply system, converts a portion of the thermal energy contained in the steam to electric energy, and provides extraction steam for feedwater heating and for driving the reactor feed pump turbines. The turbine-generator is not safety-related.

10.2.1 DESIGN BASES

a. The turbine-generator is designed to meet the conditions listed in Table 10.2-1, which shows conditions at both 100% rerated power for LGS Units 1 and 2. The associated heat balance is Reference 10.2-9. New heat balances for last stage blade replacement are provided in References 10.2-10, and 10.2-11.

b. DELETED

c. The turbine-generator control system is designed to maintain constant reactor pressure during normal operation and to operate the steam bypass system up to 25% of full load to maintain constant reactor pressure during plant startup, transients, and shutdown. The turbine-generator control system is designed to accomplish the following control functions:

    1. Control speed and acceleration from 0% to 110%.

    2. Operate the steam bypass system to keep reactor pressure within acceptable limits.

    3. Control reactor pressure from 150 psig to 1050 psig.

d. The turbine-generator and ancillaries are designed and manufactured in accordance with GE and Siemens design practices.

10.2.2 DESCRIPTION

The general arrangement of the turbine-generator and associated systems with respect to plant structures and other systems is shown in drawings M-110, M-111, M-112, M-113, M-125, M-126, M-127, and M-128.

10.2.2.1 Turbine

The turbine unit consists of one double-flow high pressure and three double-flow low pressure turbines on the same shaft. The unit also includes six vertical moisture separator vessels of the nonreheat-type. The turbine is an 1800 rpm, tandem compound, nonreheat steam turbine.

The capability of the Unit 1 turbine when operating at 3515 MWt core thermal power with initial steam conditions of ~ 1002 psia, 1190.1 Btu/lbm, exhausting to the multi-pressure condenser and extracting steam for six feedwater heater stages and three reactor feed pump turbines is 1226.5 MW.

The capability of the Unit 2 turbine when operating at 3515 MWt core thermal power with initial steam conditions of 1004.5 psia, 1190 Btu/lbm, exhausting to the multi-pressure condenser and extracting steam for six feedwater heater stages and three reactor feed pump turbines is 1237.3 MW.

Steam from the reactor enters the turbine unit through four main steam lines. Each of the four steam lines to the HP turbine is connected to a main steam stop valve and a main steam control valve. The four stop valves and four control valves form a combined valve chest. A pressure equalizing line connects the stop valves together just below the valve seats. A nine-valve bypass chest is connected to the main steam lines between the MSIVs and the main stop valves to divert excess flow to the condenser. Steam from the high pressure turbine exhaust passes through the moisture separators, where the moisture content is reduced, through each of six combined intermediate valves to the low pressure turbines.

There is one stage of extraction from the HP turbine, one stage from the cross-around pipes upstream of the moisture separators, and four stages of extraction from each LP turbine. The extraction steam is used to heat the feedwater in six separate feedwater heater stages.

A portion of the cross-around steam is used to drive the RFPTs during normal operation. Main steam is used to drive the RFPTs during startup and shutdown modes.

10.2.2.2 Generator and Exciter

The generator is a 1,264,970 kVa, 1,800 rpm, direct-connected, four-pole, 60 Hz, 22,000 V synchronous generator with expected operating power factor of 0.985 and 0.58 short-circuit ratio, at a maximum hydrogen pressure of 75 psig. The generator is sized to accept the gross output of the turbine.

The Alterrex excitation system consists of a 60 Hz, 1800 rpm air-cooled Alterrex generator and liquid-cooled rectifiers with static thyristor automatic regulation equipment (Unit 2 only). The excitation system consists of a 60-Hz, 1800 rpm air-cooled generator and liquid-cooled rectifiers controlled by a Digital Automatic Voltage Regulator with two redundant channels (Unit 1 only). The exciter is rated for a maximum output of 3460 kW at 540 V.

The generator stator is water-cooled and the rotor is hydrogen- cooled. The generator hydrogen system includes all necessary controls and regulators for hydrogen cooling. A seal oil system is provided to prevent hydrogen leakage through the generator shaft seals. A hydrogen makeup supply from the HWC system is provided to replace any hydrogen absorbed in and rejected from the seal oil. Carbon dioxide is used for purging the hydrogen supply line and/or the generator before and after generator use and ensures that an explosive mixture cannot be formed. The hydrogen and carbon dioxide systems are shown in drawing M-28. Protective measures to prevent fires and explosions during purging and normal operations consist of hydrogen pressure control stations, excess flow shutoff valves, alarms, and pressure safety devices. The buried piping which extends from the hydrogen pressure control stations to the turbine enclosure is of a pipe-within-a-pipe design providing environmental protection in the event of leakage or extended damage. Test connections are provided to analyze the air/CO_2 and H_2/CO_2 concentrations during purging. Hydrogen analyzing equipment is provided to continuously monitor hydrogen purity during normal operations. Removable spool pieces provide additional isolation, assuring that hydrogen does not leak into the generator during maintenance activities.

Hydrogen gas will be supplied from the HWC System to the Generator Hydrogen Cooling System. The manual isolation valves and a check valve are located between the HWC System and the Generator Hydrogen Cooling System. During system makeup the Generator Hydrogen Cooling System storage bottles will be isolated. The Generator Hydrogen Cooling System pressure

reducing station(s) and excess flow valve will be utilized during system makeup from the HWC System. In the unlikely event of a hydrogen supply line rupture in the HWC System, the check valve prevents depressurization of the Generator Cooling System, thereby minimizing the possibility of a generator trip.

10.2.2.3 Protective Valve Functions

The primary function of the main stop valves is to quickly shut off steam to the turbine under emergency conditions. The stop valve discs are totally unbalanced and cannot open against full pressure drop. An internal bypass valve is provided in one of the four stop valves to permit slow warming of the combined valve chest and to permit pressurization below the stop valve seat area to allow valve opening and to allow shell warming.

The turbine stop valves are designed by using a dynamic seismic analysis to withstand the OBE and SSE loads within the limits of the manufacturer's special criteria. A statement of adequacy has been provided by the manufacturer.

The function of the control valves is to throttle steam flow to the turbine during normal operation and promptly throttle steam flow when a overspeed is sensed. The valves, because of their size relative to their cracking pressure, are partially balanced. A small internal valve is opened first to decrease the pressure in a balance chamber. The valves are opened by individual hydraulic cylinders.

The function of the bypass valves is to pass steam directly from the reactor to the condenser without going through the turbine. The bypass valve chest is connected directly to the steam lines from the reactor and is composed of nine valves operated by individual hydraulic cylinders. When the valves are open, steam flows from the chest, through the valve seat, out the discharge casing, and through connecting piping to the pressure breakdown assemblies, where a series of orifices is used to further reduce the steam pressure before the steam enters the condenser (Section 10.4.4).

The function of the CIVs is to protect the turbine against overspeed from stored steam in the cross-around piping and moisture separators following turbine trip and to throttle and balance steam flow to the LP turbines. Each valve is composed of an intercept valve and an intermediate stop valve incorporated into a single casing. The two valves have separate operating mechanisms and controls. One valve is a positioning valve, while the other is an open/closed valve; however, both valves are capable of fast closure. The valves are located as close to the turbine as possible to limit the amount of uncontrolled steam available as an overspeed source.

During normal plant operation, the intercept valves are open. The intercept valves are capable of opening against maximum cross-around pressure and of controlling turbine speed during blowdown following a load rejection. The intermediate stop valves also remain open for normal operation, and they trip closed by actuation of the emergency governor or by operation of the master trip. They provide backup protection if the intercept valves or the normal control devices fail.

10.2.2.4 Extraction System Check Valves

The energy contained in the extraction and feedwater heater system can be of sufficient magnitude to cause overspeed of the turbine-generator following an electrical load rejection or turbine trip.

Check valves are installed where necessary to prevent high energy steam from entering the turbine under these conditions. The extraction system check valves are shown in drawing M-02.

The check valves limit the amount of energy flashing back into the turbine so that the turbine speed increase is held below the maximum value. Power-assisted closure check valves are provided for heaters 3, 4, 6, and steam seal evaporator. Heater 2 is provided with spring assisted check valves. Heater 1 has no provision for preventing flashbacks into the turbine, since the distance to the turbine is short and internal energy is low. Heater 5 has no provision for preventing flashbacks into the cross-around piping, since the cross-around/ moisture separator system provides adequate capacity to protect the turbine.

The power-assisted check valves have an air piston that acts in opposition to a spring to keep the valve wide open during normal operation. On turbine trip, the extraction relay dump valve closes, venting the air from the piston actuators and thus allowing the springs to assist in closing the check valves.

10.2.2.5 System Operation

10.2.2.5.1 Control System

The turbine-generator control system is a Westinghouse Ovation® Digital EHC system. In Figure 10.2-13, the speed control unit produces the speed/acceleration error signal that is determined by comparing the desired speed from the reference speed software, with the actual speed of the turbine for steady-state conditions. Speed reference and acceleration rate control perform speed control ramps using entered targets and rates. If the turbine is off-line and in RESET condition, the operator can either enter the desired TARGET in rpm or select a preset TARGET of 1800 rpm. No validation is required when selecting speed target using the preset valve but a target entered via keyboard must satisfy the following validation rules before it is accepted by the system:

- Target must be greater than or equal to a minimum speed of 0 rpm
- Target must be less than a maximum speed of 1850 rpm
- Target must not be within a critical speed/resonance range

For step changes in speed, acceleration reference software takes over to either accelerate or decelerate the turbine at a selected rate to the new speed. There is no limit to the deceleration. In Figure 10.2-13, the speed/acceleration error signal is combined with the load requirements on the load control unit to provide the flow signal to the control valves.

Turbine control and protection are achieved via a combination of speed control, load control, flow control and overspeed protection.

In Figure 10.2-13, the speed control algorithm develops servo positioning demand signals for control valves and intercept valves to control the turbine speed and rate of acceleration. Based on the desired speed set point and selected acceleration rate, the speed control algorithm produces the speed error signal, which drives a reference bias to the output of load control algorithm. This in turn controls the positioning of the turbine control valves and hence the amount of steam energy admitted into the turbine rotating elements.

At the time of synchronization, the speed control algorithm has brought the turbine speed to a value that is close to 1800 rpm. At this point, changes to the load reference signal are used to

control synchronization speed matching in preparation for breaker closure. Upon breaker closure, the load control algorithm is used to develop a steam flow signal representing the desired turbine load, up to and including maximum turbine load. The algorithm also includes the ability to manually set an upper limit for turbine load. Under normal operation, the turbine operator controls the load reference setting via the HMI interface.

Because of the importance of overspeed protection, the speed control signal has three independent redundant channels. Three independent pulse signals are obtained from magnetic pickups located over a gear-toothed wheel on the turbine shaft. Loss of two-out-of-three (2/3) speed signals trips the turbine. (Section 10.2.2.6).

10.2.2.5.2 Emergency Trip System Functions

The emergency trip system trips the unit closing all valves on the following signals and therefore shuts down the turbine:

a. Turbine approximately 10% above rated speed (on overspeed, the tripping is performed by an electrical trip)

b. Turbine approximately 11% above rated speed while testing the overspeed trip device

c. Vacuum decreases to less than a preselected value

d. Excessive thrust bearing wear

e. Prolonged loss of generator stator coolant at loads in excess of a predetermined value

f. Remote manual trip on the control panel

g. Loss of hydraulic fluid supply pressure (loss of emergency trip system fluid pressure automatically closes the turbine valves and then energizes the master trip relay to prevent a false restart)

h. Low lubrication oil pressure

i. Loss of 2 out of 3 speed signals

j. Loss of both primary and secondary EHC power supplies

k. Operation of the manual electrical trip is at front standard

l. High level in moisture separators

m. High reactor water level

n. Power load unbalance

o. DELETED

p. DELETED

q. Reverse power

r. Generator breaker opening

To prevent spurious tripping due to single component failure, duplicated or triplicated trip sensing devices are provided for all trip inputs except for reverse power, back up overspeed and power\load unbalance and are wired to form a single fault tolerant tripping logic. Therefore, a signal from a single sensing element does not trip the turbine-generator. However, the turbine trips if a malfunction is monitored simultaneously by at least two sensing elements.

10.2.2.6 Overspeed Protection

The turbine overspeed protection system instrumentation and turbine speed control valves protect the turbine from excessive overspeed. Protection from turbine excessive overspeed is required since excessive overspeed of the turbine could generate potentially damaging missiles which could impact and damage safety-related components, equipment, or structures.

For speeds above 100% rated speed, the speed control system would fully close the turbine control valves by the time that 105% of rated speed is reached and the CIVs would be fully closed by the time that 107% of rated speed is reached.

To protect the turbine-generator against overspeed due to failure of the speed control system, two trip devices are provided, either of which when initiated closes the main stop valves, control valves, and combined intermediate valves, thus shutting down the turbine.

These two trip devices are as follows:

a. A primary electronic overspeed trip is provided by the Emergency Trip System (ETS) that uses Diverse Turbine Overspeed Protection System (DTOPS) and is initiated if the turbine speed reaches approximately 10% above rated speed.

b. A backup electronic overspeed trip is provided by the Turbine Control System (TCS) and is initiated at approximately 11 % above rated speed.

In Figure 10.2-11, the primary electronic overspeed trip uses a diverse and separate set of magnetic pickups which are comprised of 3 passive speed sensors for sensing speed from a toothed wheel mounted to the turbine shaft. When the turbine speed reaches the trip speed (10% above rated speed), the three independent overspeed protection trip modules located inside the DTOPS device provides three independent trip outputs that interface to the three Emergency Trip System (ETS) Testable Dump Manifold (TDM) solenoids. The ETS TDM utilizes a two-out-of-three (2/3) trip logic configuration to trip the turbine.

In Figure 10.2-11, the backup electronic overspeed trip uses a diverse and separate set of magnetic pickups which are comprised of 3 active speed sensors for sensing speed from a toothed wheel mounted to the turbine shaft. When the turbine speed reaches the trip speed (11 % above rated), the Turbine Control System (TCS) utilizes a two-out-of-three (2/3) trip logic and provides a trip output to its respective TDM unit, which utilizes a two-out-of-three (2/3) trip logic configuration to trip the turbine. This trip uses speed detector modules that are independent of the TCS software. In addition, the TCS software also generates a trip of the TDM unit.

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

Any one of these actions will trip the turbine, i.e., close the stop, control, and combined intercept valves.

When the overspeed trip system is under test, the TDMs can be tested with the plant on-line, without removing or disabling any actuation device.

An additional feature of the protective system that will minimize the likelihood of an overspeed condition is the power/load unbalance software. In Figure 10.2-12, generator load is sensed by means of three current transformers and is compared with the turbine power input which is sensed by the turbine intermediate pressure sensor. If the difference between the steam power input and the generator output rises to at least 40% in 35 msec, auxiliary relays will be actuated that will energize the control valves fast closing solenoids, and remove the load reference at the load control unit. The power load unbalance condition will trip the turbine through the generator protection circuit.

The diversity of devices shown on Table 10.2-2 ensures that stable operation following a turbine trip proceeds from the requirement that both the stop valves and the combined intermediate valves close in a turbine trip, thereby preventing steam from the main steam line from entering the turbine and preventing the expansion of steam already in the high pressure stage and in the moisture separator. An additional provision is made to automatically isolate the major steam extraction lines from the turbine by power-assisted check valves. Closure times of the check valves will be in accordance with the turbine manufacturer's recommendations.

There are four steam lines at the high pressure stage. Each line is provided with one stop valve in series with one control valve. Steam from the high pressure stage flows to the moisture separators and then to the three low pressure stages. Each of the six low pressure lines has a combined intermediate valve that consists of a stop valve in series with a control valve, in one housing. When a turbine trip is initiated, the above valve stroke time is within 0.2 seconds. Assuming a single failure within the above system of 20 valves in case of a turbine overspeed trip signal, the turbine will be successfully tripped.

Any postulated accident, including the effects of high or moderate energy pipe failures, that results in a loss of hydraulic pressure or loss of the electrical signal to the mechanical trip valve or the lockout valve will result in the closure of the main stop valves, control valves, and combined intermediate valves, thereby preventing a turbine overspeed condition. Damage to nearby safety-related equipment or systems or to the turbine overspeed equipment from a high energy or moderate energy piping failure (including failure of the connection from the low pressure turbine to the condenser, or a failure of the turbine bypass line) would not affect the capability to achieve safe shutdown, to scram the reactor, or to initiate a turbine trip.

Safety-related equipment located in the turbine enclosure includes:

a. PT-01-1N052A, B, C, D

b. PT-01-1N075A, B, C, D

c. PT-01-1N076A, B, C, D

d. PS-01-102A, B, C, D

e. ZS-01-104A, B, C, D

The functions of PS-01-102 and ZS-01-104 are described in Section 7.2.1. PT-01-1N052 monitors first-stage pressure on the turbine steam supply lines upstream of the high pressure turbine first stage. The signal is used to generate an automatic bypass of the reactor scrams, when the turbine load is below a preset value, resulting from turbine stop valve closure and turbine control valve fast closure.

PT-01-1N075 initiates MSIV closure on loss of main condenser vacuum, while PT-01-1N076 initiates MSIV closure in the event of low pressure in the main steam line.

For high energy or moderate energy pipe breaks, these instruments are not relied on to initiate a reactor trip or MSIV closure because other instruments are available to perform these functions. For example, a pipe break involving the main steam lines outside containment would cause automatic closure of the MSIVs due to any of the following signals: a) low pressure in the main steam lines b) high flow in the main steam lines, and c) high temperature in the vicinity of the main steam lines. MSIV closure would in turn generate a reactor trip signal.

Assuming an electrical load increase due to a system frequency dip with steady steam input to the turbine, the turbine speed decreases. In Figure 10.2-13, the active speed sensors pick up the change in speed. The speed control unit produces the speed/acceleration error signal that is determined by comparing the desired speed from the reference speed software, with the actual speed of the turbine for steady-state conditions. Speed reference and acceleration rate control perform speed control ramps using entered targets and rates.

In Figure 10.2-13, the speed control algorithm develops servo positioning demand signals for control valves and intercept valves to control the turbine speed and rate of acceleration. Based on the desired speed set point and selected acceleration rate, the speed control algorithm produces the speed error signal, which drives a reference bias to the output of load control algorithm. This in turn controls the positioning of the turbine control valves and hence the amount of steam energy admitted into the turbine rotating elements.

10.2.3 TURBINE DISC INTEGRITY

10.2.3.1 Material Selection

Turbine wheels and rotors for turbines operating with light water reactors are made from vacuum melted or vacuum-degassed Ni-Cr-Mo-V alloy steel by processes that 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 wheel and rotor materials have the lowest fracture appearance transition temperatures and highest Charpy V-notch energies obtainable, on a consistent basis from water quenched Ni-Cr-Mo-V material at the sizes and strength levels used. Since the actual levels of FATT and Charpy V-notch energy vary, depending on 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. Information regarding ranges of material and chemical properties for the limiting wheels (discs), including material chemical analysis of disc and rotor forgings and mechanical properties of disc material, is

contained in Reference 10.2-2. This information, while provided for turbines in operation at the time, is also applicable to the LGS turbines. The actual material characteristics are used to determine the probability of missile generation and inspection intervals (Section 10.2.3.6).

Built-up rotors (with disks shrink-fitted on a shaft) of low pressure turbines operating with light water reactors are exposed to a wet steam and risk of stress corrosion cracking in areas of high tensile stress. Stress corrosion cracks may grow to a size which could eventually result in disk disintegration and generation of missiles external through the turbine casing. The original General Electric low pressure rotors have been replaced because of early stress corrosion crack indications. The new Siemens low pressure turbine built-up rotors are made of NiCrMoV steel with 3.5% nickel and 1.5% chromium content with excellent through hardenability. The material has DIN designation 26NiCrMoV14 5 (similar to ASTM A 471 Class 14).

With this material it is possible to reach excellent fracture toughness and consistent yield strength levels throughout the entire forging. This is achieved by specifying a proper chemical composition with a low phosphor content to suppress temper embrittelment during the Quality Heat Treatment, and low sulfur content for high forging purity. In addition, a low silicon content, or Vacuum Carbon Deoxidization are specified respectively, to avoid macro segregation and to make sure that an adequate forging technique is selected.

Information regarding disk material selection, design considerations, manufacturing and heat treatment procedures, rotor life expectancy and stress corrosion conditions is contained in Reference 10.2-1.

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of the materials described above to produce a balance of adequate material strength and toughness to ensure safety while simultaneously providing high reliability, availability, efficiency, etc, during operation. Bore stress calculations include components due to centrifugal loads, interference fit, and thermal gradients where applicable. The ratio of material fracture toughness, (K) (as derived from material tests on each wheel or rotor), to the maximum tangential stress for wheels and rotors at speeds from normal to 120% of rated speed is at least 2 square root inches (the highest anticipated speed resulting from a loss of load is 110%). Adequate material fracture toughness needed to maintain this ratio is ensured by destructive tests on material taken from the wheel or rotor. Fracture toughness estimation at room temperature was done using the formulas of Belgly and Logsden modified by Siemens for the uppershelf fracture toughness. Information regarding FATT and operating temperatures for the discs is contained in Reference 10.2-3. The actual material characteristics are used to determine the probability of missile generation and inspection intervals (Section 10.2.3.6).

The Siemens low pressure turbine rotors have a very low FATT such that warm-up time is not required to assure that toughness will be adequate to prevent brittle fracture during startup.

10.2.3.3 Compressive Stress

Besides environment and material strength, the operating stress levels substantially effect the crack initiation time and crack growth rate. Laboratory research and operational experience have proven that if the tensile stress level in the critical areas of the disk bore and keyways is limited to less than 50% of the yield stress level, the crack initiation time is substantially prolonged and crack growth rate is substantially reduced.

The stress in the critical areas of the shrink fit surface is a combination of shrink fit stress, thermal gradient stress, centrifugal force stress and the residual stress resulting from the manufacturing process. Siemens has developed a special High Quality Heat Treatment of turbine disks which is aimed at inducing a high level residual compressive stress (up to 60 Ksi) in the shrink fit and key way areas. As a result the combined stress on the surface is reduced to an acceptable level. In some critical areas, shot peening and rolling are introduced to further reduce the surface stress level, and consequently the risk of stress corrosion crack initiation.

10.2.3.4 Turbine 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. The maximum tangential stress in wheels and rotors resulting from centrifugal forces, interference fit, and thermal gradients does not exceed 0.75 of the yield strength of the material at 125% of rated speed.

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

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

10.2.3.5 Preservice Inspection

The preservice inspection program is as follows:

a. Wheel and rotor forgings are rough machined with minimum stock allowance before heat treatment.

b. Each rotor and wheel forging is subjected to a 100% volumetric (ultrasonic) examination. Each finish- machined rotor and wheel is subjected to a surface magnetic particle and visual examination. Results of the above examination are evaluated by use of Siemens acceptance criteria. These criteria are more restrictive than those specified for Class 1 components in ASME Section III and V, and include the requirement that subsurface sonic indications are either removed or evaluated to ensure that they do not grow to a size that compromises the integrity of the unit during the service life of the unit.

c. All finish-machined surfaces are subjected to a magnetic particle examination. No magnetic particle flaw indications are permissible in bores, holes, keyways, and other highly stressed regions.

d. Each fully bucketed turbine rotor assembly is spin tested at or above the maximum speed anticipated following a load rejection from full load.

10.2.3.6 Inservice Inspection

The following Turbine System Maintenance Program describes the required inservice component testing and inspections which ensure that the missile generation probabilities described in UFSAR Section 3.5.1.3, Turbine Missiles, and Table 3.5-9, Turbine System Reliability Criteria, are maintained. Periodic inspection of the Turbine Stop Valves, Turbine Control Valves, Combined Intermediate Valves, and power-assisted steam extraction check valves are also included to provide additional assurance of reliable operation of the turbine overspeed protection systems.

The Turbine System Maintenance Program includes the following:

1. The low pressure turbine elements will be disassembled for inspection on a frequency that is determined by the missile probability analysis. The interval between each low pressure turbine's individual inspection will not exceed 110,000 operating hours. This inspection consists of visual, surface, and volumetric examinations. Inspections will be conducted in accordance with the supplier's instructions and will encompass the following techniques:

    a. Volumetric examination of the low pressure turbine disks,

    b. Visual and surface examination of the low pressure turbine stationary parts,

    c. Visual examination of accessible surfaces of low pressure turbine rotors and disks.

2. The overspeed protection system will be routinely tested in conformance with the assumptions of the missile probability analysis, as follows:

    a. The main turbine stop valves, main turbine control valves, and main turbine combined intermediate valves will be routinely exercised to ensure full freedom of motion. Exercising is accomplished by closing each valve and observing, by the valve position indicator, that it moves smoothly to a fully closed position. The frequency of testing (see Technical Requirements Manual, Section 3/4.3.8) will be determined by the missile generation probability analysis, but will not be greater than once per 3 months.

    b. The power-assisted extraction check valves will be routinely exercised to ensure full freedom of motion at a frequency of once per week. Testing will be performed to verify that each is capable of being actuated by its power cylinder.

    c. Verification of the proper operation of the following overspeed protection system devices/circuits will be performed in accordance with the missile generation probability analysis contained in Reference 10.2-4 at a frequency of once per month:

        i. Primary Overspeed Trip Circuit (Electrical Trip System)

        ii. Backup Overspeed Trip Circuit (Electrical Trip System

3. The turbine's Electro-hydraulic Control System fluid will be sampled and analyzed at a frequency not greater than once per 3 months.

4. The following is not required by the Missile Generation Probability Analysis, but will be performed to provide additional assurance of reliable operation of the turbine overspeed protection systems.

   At least one power-assisted steam extraction check valve will be dismantled for visual and surface examination, at approximately 3-1/3 year intervals, during refueling or maintenance shutdowns. If indications of excessive wear or other conditions that could impair the proper functioning of the valve are found, additional valve inspection(s) will be conducted to determine if the condition is common to all extraction valves.

10.2.4 EVALUATION

The turbine-generator has no safety-related function. Failure of the system does not compromise any safety-related system or component or prevent a safe shutdown of the plant.

The turbine-generator control system design provides a stable control response to normal load fluctuations.

The main turbine bypass valves are capable of responding to the maximum closure rate of the turbine control valves so that reactor steam flow is not significantly affected until the magnitude of the load rejection exceeds the capacity of the bypass valves (24.3% of 15.287 Mlb/hr steam flow for Post MUR-PU conditions). Load rejections in excess of bypass valve capacity may cause the reactor to scram due to high pressure. Any condition causing the turbine stop valves to close directly initiates a scram before reactor pressure or neutron flux rise to the trip level.

Loss of electrical or hydraulic power causes all valves to close. If the control valves are tripped closed, the reactor scrams.

Abnormal operational transient analyses have been made for a component failure in the turbine-generator system and are discussed in Chapter 15. Operation with one turbine control valve (TCV) or one turbine stop valve (TSV) closed has been evaluated and reported in UFSAR Reference 5.4-3. This evaluation establishes steamline flow restrictions.

The primary source of activity in the steam and power conversion system is radiation from nitrogen-16 (N-16). N 16 has a half-life of approximately 7 seconds. The activated nitrogen is carried with the steam to the turbine. Fission product noble gases and other activation gases, such as oxygen-19 (0-19), nitrogen-17 (N-17), and nitrogen-13 (N-13), are also carried with the steam to the turbine. Some nongaseous fission and activation products are present in the turbine as a result of moisture carryover in the steam from the NSSS. A summary discussion of the anticipated operating concentrations of radioactive contaminants in the turbine-generator and associated systems is provided in Section 12.2.1.

The activity entering the LP turbine is reduced because of moisture separation and the transit time between the HP and LP turbines that permits the N-16 to decay.

The noncondensable gases in the condenser are removed by the SJAEs to the offgas system for processing and holdup before release to the environment; the offgas system is described in Section 11.3.

The activity remaining in the condensate is reduced significantly by the 2 minute (minimum) holdup time in the condenser hotwell.

Shielding requirements and expected radiation levels are discussed in Section 12.3.2 and drawings N-110, N-111, N-112, N-113, N-115, N-125, N-126, N-127, N-128, and N-130. The turbine-generator is in an administratively controlled access area.

10.2.5 TURBINE-GENERATOR SUPERVISORY INSTRUMENTS

Although the turbine is not readily accessible during operation, the turbine supervisory instrumentation is sufficient to detect any potential maloperation. The turbine supervisory instrumentation includes monitoring of the following variables:

a. Vibration and eccentricity

b. Thrust bearing wear

c. Exhaust hood temperature and spray pressure

d. Oil system pressures, levels, and temperatures

e. Bearing metal and oil drain temperatures

f. Shell temperatures

g. Deleted

h. Shell and rotor differential expansion

i. Electrical load, and control valve inlet pressure indication

j. Hydrogen temperature, pressure, and purity

k. Stator coolant temperature and conductivity

l. Stator winding temperature

m. Exciter air temperatures

n. Steam seal pressure

o. Steam packing exhauster vacuum

p. Steam chest pressure

q. Seal oil pressure

10.2.6 TESTS AND INSPECTIONS

Preoperational tests are performed in accordance with the requirements of Chapter 14. System operation is demonstrated by use during normal system operation. Inservice inspection and testing are discussed in Section 10.2.3.6.

10.2.7 REFERENCES

10.2-1 "Reliable Disk-Type Rotors for Nuclear Power Plants" for Presentation at the American Power Conference, April 27-29, 1987.

10.2-2 "LP Turbine Disks", Siemens Technical Specifications TLV 9123-33/35 - SIEMENS PROPRIETARY.

10.2-3 "Missile Analysis Report, Limerick Units 1 and 2," Siemens Energy, Inc., CT-27554, November 29, 2016 *(including, as Appendix A: "Missile Probability Analysis Methodology for Limerick Generating Station, Units 1 and 2, with Siemens Retrofit Turbines" Siemens Power Corporation Engineering Report, ER-9605, Revision 2, June 18, 1997 - SIEMENS PROPRIETARY.

10.2-4 "Impact of Increasing Test Interval for Turbine Overspeed Protection System on Turbine Missile Probability," MPR Associates, Inc., MPR-2892 Revision 0, April 4, 2006.

10.2-5 Deleted.

10.2-6 Deleted.

10.2-7 LEAM-MUR-0038, Reactor Heat Balance, Rev. 0, dated December, 2009.

10.2-8 LEAM-MUR-0005, Condensate Cleanup System, Rev. 0, dated September, 2009.

10.2-9 "Limerick Unit 1 and 2 Rated Condition with New Diagonal Ring," Seimens Heat Flow Diagram Drawing Number WB-11614-2, July 10, 2010 (N-00E-246-00191).

10.2-10 LM-0300, "Limerick Unit Heat Balance at Rerate Power Levels of 3458 MWt and 3528 MWt (105% Rated and 102% of 105% Rerated Core Power), Revision 4.

10.2-11 LM-0722, LGS Unit 2 PEPSE Heat Balance Model, Revision 0.

Table 10.2-1

TURBINE-GENERATOR DESIGN CONDITIONS

TURBINE-GENERATOR OUTPUT		
At 100% rerated reactor power (maximum guaranteed)	1,245,475 kW	
STEAM CONDITIONS AT TURBINE STOP VALVES		
	Pre MUR-PU	Post MUR-PU
Flow		
100% flow	14.97×10^6 lb/hr	15.394×10^6 lb/hr***
Pressure	1005 psia	1002.9 psia***
Temperature	545.2°F	544.9°F
Moisture content	0.41%*	0.42%***
Exhaust pressure, in. Hga		
High pressure shell	2.75	2.15
Intermediate pressure shell	2.10	1.66
Low pressure shell	1.60	1.32
FINAL FEEDWATER TEMPERATURE		
100% flow (maximum)	425.1°F	432.2°F
STAGES OF FEEDWATER HEATING	6	
GENERATOR POWER FACTOR	0.985 (expected operating conditions)	
GENERATOR RATING	1,264,970 kVA	
VOLTAGE	22,000 V	
HYDROGEN PRESSURE	75 psia	

* This value is based on 0.1% moisture in the reactor steam dome and does not necessarily reflect current operating conditions.

** Data for Post MUR-PU notes differences only.

*** Conditions at upstream of turbine stop valves.

Table 10.2-2

TURBINE OVERSPEED PROTECTION

DEVICE	DESCRIPTION/ FUNCTION	TRIP SETTING	ACTUATING DEVICE INTERMEDIATE	ACTUATING DEVICE FINAL	ACTUATED VALVE	ACTUATED POSITION	POSTULATED EVENT INCLUDING CONSEQUENCES OF HIGH OR MODERATE ENERGY PIPE RUPTURE	RESPONSE
Speed Control Unit 2 Redundant Systems	Compares desired speed with reference speed	Above rated speed CV Start to close at approximately 101%			All CV All IV	Close	Loss of electrical signal[(1)]	
	Load control unit provides flow signal to control valves	CV closed by 105% rated speed IV closed by 107% rated speed					Loss of hydraulic pressure	Close all SV, CV and CIV
Overspeed Trip	Close TMD remove electro-hydraulic control oil pressure	110% of rated speed	DTOPS	Testable Dump Manifold	All SV All CV All CIV	Close	Loss of hydraulic pressure	Close all SV, CV and CIV
Backup Overspeed Trip	Toothed wheel magnetic pickup speed sensor electronic signal amplifier	111% of rated speed	TCS speed detector modules	Testable Dump Manifold	All SV All CV All CIV	Close	Loss of electrical signal[(2)]	Close all SV, CV, CIV

Table 10.2-2 (Cont'd)

DEVICE	DESCRIPTION/ FUNCTION	TRIP SETTING	ACTUATING DEVICE INTERMEDIATE	ACTUATING DEVICE FINAL	ACTUATED VALVE	ACTUATED POSITION	POSTULATED EVENT INCLUDING CONSEQUENCES OF HIGH OR MODERATE ENERGY PIPE RUPTURE	RESPONSE
	Close TMD remove electro-hydraulic control oil pressure					Loss of hydraulic pressure	SV, CV, and CIV	Close all
Power/ Load Unbalance	Gen current & steam pressure transducers, electronic comparators & control logics	40% Unbalanced within 35 msec			All CV	No change	Loss of electrical signal	
							a) Loss of generator output signal	Close all CV
							b) Loss of turbine pressure signal	No action
	Energize CV fast closing solenoids & remove electro-hydraulic control oil press from the CVs.						Loss of hydraulic pressure	Close all SV, CV, and CIV

SV = Stop Valve
CV = Control Valve
CIV = Combined Intermediate Valve
IV = Intercept Valve

(1) Because there are two redundant systems, its function would not be impaired unless the electrical signal from both were lost. If the electrical signal from both are lost, the turbine would be tripped.

(2) Backup electrical overspeed would normally de-energize the solenoids of the associated Testable Dump Manifold.

10.3 MAIN STEAM SUPPLY SYSTEM

The main steam supply system transports steam from the nuclear steam supply system to the power conversion system and to various kinds of auxiliary equipment.

10.3.1 DESIGN BASES

The design bases of the main steam supply system are as follows:

a. To deliver the required steam flow from the reactor to the turbine-generator, at rated temperature and pressure, over the full range of operation from turbine warmup to valves wide open

b. To provide motive steam to the SJAEs

c. To provide steam for the steam seal evaporator and driving steam for reactor feed pump turbines

d. To provide steam for the offgas recombiner preheater and condenser hotwell steam spargers

e. To bypass reactor steam to the condensers during startup and any time the quantity of steam produced by the reactor is more than the turbine-generator requires

The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the main steam supply system are discussed in Section 3.2. Environmental design is discussed in Section 3.11. Inservice inspection is discussed in Section 6.6.

10.3.2 DESCRIPTION

The main steam supply system is shown in drawings M-01 and M-41, and the design parameters are listed in Table 10.3-1. The system extends from the outermost containment isolation valve, up to but not including the turbine stop valves, and includes connected piping of 2½ inches nominal diameter or larger, up to and including the first valve that is either normally closed or is capable of automatic or remote manual closure during all modes of reactor operation.

The main steam piping consists of four 26 inch outside diameter lines from the outermost MSIVs to the main turbine stop valves. The use of four main steam lines permits testing of the turbine stop valves and MSIVs during plant operation, with only minimum load reduction.

The main steam line nuclear pressure relief system and MSIVs are described in Sections 5.2.2 and 5.4.5, respectively. The main stop valves and associated piping and components downstream of the valves are discussed in Section 10.2. The MSIVs, shutoff valves in connecting piping, turbine stop valves, and bypass valves are designed to close against maximum steam flow.

The main steam supply piping is designed and tested according to ASME Section III, Class 2 requirements and is fabricated of seam welded carbon steel.

Each main steam line is provided with a drain downstream of the outermost containment isolation valve. The drains are routed to the condenser through a common 3 inch header (drawing M-41). These drain lines form part of the boundary for the MSIV Leakage Alternate Drain Pathway

discussed in Section 6.7. Each main steam line is also provided with low point drains consisting of a drip leg which, under normal operation, collects moisture and drains it to the condenser through a normally open valve and a restricting orifice.

Pressure equalizing lines, 14 inch nominal size, branch from each main steam line and connect to the bypass valve chest through two 18 inch headers.

The main steam supply system also provides connections to supply steam to the SJAE, steam seal evaporator, gaseous radwaste recombiner preheater, reactor feed pump turbines, and condenser hotwell steam spargers.

10.3.3 EVALUATION

The main steam lines from the outer MSIV, up to but not including the turbine stop valve, and all branch lines 2½ inches in diameter and larger, up to and including their first valve, are seismic Category I and ASME Section III, Class 2. The main steam piping is supported to seismic Category I requirements up to and including the turbine stop valve. The pipe supports and restraints on this piping are designed in accordance with ANSI B31.7, Class II.

The main steam piping is seismic Category I up to the main stop valves. The main steam lines, up to and including the second isolation valves, are located in a seismic Category I structure. The remainder of the main steam piping, up to the stop valves, is located in the turbine enclosure, which is seismic Category II. However, as described in Sections 3.8.4.1.8 and 10.3.3, those portions of the turbine enclosure that support the main steam lines are designed so that the main steam lines, the turbine stop valves, and their supports maintain their integrity under the seismic loading resulting from the SSE.

In addition, all nonseismic Category I systems and components in the vicinity of the main steam lines are designed as seismic Category IIA as discussed in Section 3.2.1 for an SSE condition.

The dynamic input loads for the design of the main steam lines are derived from a time history model analysis of the supporting structures or an equivalent method, as described in Section 3.7. The main steam line supporting structures (those portions of the turbine enclosure) are such that the main steam lines and their supports can maintain their integrity within the ASME Section III, Class 2 requirements under seismic Category I loading conditions.

These seismic Category IIA items will be identified in UFSAR Table 3.2-1 to ensure that any maintenance of or modifications to these items will employ the level of quality assurance necessary to retain their seismic Category IIA classification.

Therefore no seismic Category I structures, systems, or components in the vicinity of the main steam lines will damage the main steam line during an SSE.

The main steam lines are designed with suitable accesses to permit inservice testing and inspections in accordance with ASME Section XI.

A system level qualitative-type failure modes and effects analysis is provided in Section 15.9.6 for active components associated with the main steam lines. Additional discussion of failures in these components is provided in Sections 6.7.3 and 15.2.4 and in Table 6.7-1.

10.3.4 INSPECTION AND TESTING REQUIREMENTS

The main steam lines are fabricated, examined, and tested in accordance with ASME Section III, Class 2.

The system is preoperationally tested in accordance with the requirements of Chapter 14 and periodically tested in accordance with the requirements of Chapter 16.

10.3.5 WATER CHEMISTRY (PWR)

This section is not applicable to LGS.

10.3.6 STEAM SUPPLY SYSTEM MATERIALS

10.3.6.1 Fracture Toughness

Design specifications for Class 2 piping do not require impact testing.

10.3.6.2 Material Selection and Fabrication

a. All materials used in the main steam lines are included in appendix I to ASME Section III.

b. Austenitic stainless steel is not used in the main steam supply system; therefore, Regulatory Guide 1.31, "Control of Stainless Steel Welding," Regulatory Guide 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel," and Regulatory Guide 1.44, "Control of the Use of Sensitized Stainless Steel," are not applicable.

c. The cleaning procedures for the main steam supply system are based on ANSI N45.2.1, Class B criteria. A discussion of compliance with Regulatory Guide 1.37 is included in Section 1.8.

d. Regulatory Guide 1.50, "Control of Preheat Temperature for Welding of Low Alloy Steel," is not applicable, since no low alloy steel is used in this system.

e. Regulatory Guide 1.71, "Welder Qualification for Areas of Limited Accessibility," is not applicable, since no low alloy or high alloy material is installed in the main steam supply system as described in this section.

f. Preheat temperatures for the welding of carbon steel components are in accordance with ASME Section III, Article D-1000.

g. Butt-welded pipe receives 100% radiography. Socket- welded pipe receives 100% magnetic particle or liquid penetrant examination. All nondestructive examination procedures conform to the ASME B&PV Code.

Table 10.3-1

MAIN STEAM SUPPLY SYSTEM DESIGN PARAMETERS

MAIN STEAM SUPPLY SYSTEM	
Number of lines	4
Size, O.D.	26 inches
Design pressure	1,115 psig
Design temperature	582ºF

10.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

10.4.1 MAIN CONDENSERS

The main condenser system is designed to condense and deaerate the exhaust steam from the main turbine and provide a heat sink for the turbine bypass system. The main condenser system is not safety-related.

10.4.1.1 Design Bases

The design bases of the main condenser system are as follows:

a. To condense and deaerate the exhaust steam from the main turbine and reactor feed pump turbines

b. To accept and deaerate the drains from the feedwater heaters and other components in the heat cycle

c. To serve as a heat sink for the turbine bypass steam, extraction steam line drains, and heat cycle relief valve discharge

d. To retain for a minimum of 2 minutes the condensate formed during full load operation, to allow radioactive decay before returning the condensate to the cycle

10.4.1.2 Description

The main condenser is a triple pressure deaerating-type, comprising three separate shells, one low pressure, one intermediate pressure, and one high pressure. Differential pressure between shells ensures that gases are cascaded from higher to lower pressure shells. Main condenser design parameters are listed in Table 10.4-1. The condensers are supported on the turbine foundation mat, with each of the shells connected to the exhaust of one of the three LP turbines by a rubber expansion joint, which is secured between two steel frames, one welded to the turbine exhaust and the other to the condenser. General plant arrangement of the equipment is shown in drawings M-110, M-111 and M-112.

During normal operation, steam from each LP turbine is exhausted directly downward into its condenser shell through exhaust openings in the bottom of the turbine casings. The condenser also serves as a heat sink for several other flows, such as exhaust steam from the reactor feed pump turbines, cascading heater drains, air ejector condenser drain, condensate and reactor feed pump recirculation lines, feedwater heater shell operating vents, cross-around piping relief valves, and condensate pump suction vents. The steam exhausted to the condenser is condensed by water circulated through the condenser tubes by the circulating water system (Section 10.4.5).

The condensers are provided with reheating/deaerating hotwells that remove inleakage of air, plus hydrogen and oxygen present as a result of dissociation of water in the reactor and carry over to the condenser via main steam. Hydrogen is produced at a maximum design rate of approximately 138.4 scfm at full power operation. These noncondensable gases are cascaded from the HP shell, through the IP shell, to the LP shell, terminating at the cold water inlet end of the LP shell. They concentrate in the air cooling section of the condenser, from which they are removed by the mechanical vacuum pump at startup and by the SJAEs during normal operation (Section 10.4.2).

The condenser design air inleakage rate is 75 cfm. The circulating water quality is controlled through chemical treatment and blowdown. The oxygen content of the condensate does not exceed 0.0035 cm^3/l through all load ranges, as measured at the discharge of the condensate pumps, with an air inleakage of up to 75 cfm.

The condenser hotwells have sufficient storage capacity together with internal baffling to ensure a minimum retention of 2 minutes for condensate from the time it enters the hotwell until it is removed by the condensate pumps.

The inlet water boxes of the LP condenser shell and the outlet water boxes of the HP condenser shell are each provided with butterfly valves, permitting any of the condenser's four separate circulating water flow paths to be removed from service. This arrangement is schematically shown in Drawing M-09.

A loss of condenser vacuum actuates an alarm and ultimately trips the turbine and isolates the steam source. The condenser low vacuum alarm and low vacuum trip setpoints are bounded by those used in the loss of condenser vacuum transient evaluated in Section 15.2.5. However, should the turbine fail to isolate on loss of condenser vacuum, four rupture diaphragms on each condenser shell protect the condenser and turbine exhaust hoods against overpressure.

The condenser is designed to withstand the blowdown effects of steam from the turbine bypass system with no deleterious effects. High temperature drains are discharged into the condenser via spray pipe headers, which reduce the temperatures and pressures to an acceptable level for the condenser tubes before the steam enters the condenser, thus protecting the tubes from failures. The turbine bypass system is described in Section 10.4.4.

The condenser is fitted with 18 BWG Admiralty tubes and in the Unit 2 condenser some 90-10 copper-nickel tubes are also used, except in high velocity areas, where 20 BWG stainless steel tubes are used in the Unit 1 and Unit 2 condensers. Direct high velocity impingement of steam or water on the tubes and structural members inside the condenser is avoided by the use of baffles. The design parameters for the Admiralty tubes are shown in Table 10.4-1.

The condenser is designed and built to the standards of the Heat Exchange Institute and Foster Wheeler's standard practice.

10.4.1.3 Safety Evaluation

The main condenser system is not safety-related and is not required to be operable following a LOCA. Following a LOCA, the main condenser system is the ultimate heat sink for MSIV leakage alternate drain pathway described in Section 6.7. Failure of the system will not compromise any safety-related system or component or prevent the safe shutdown of the plant.

The anticipated inventory of radioactive contaminants during both operation and shutdown is discussed in Sections 11.1 and 11.3. The shielding and controlled access arrangement for the main condensers is described in Section 12.3.

Safety-related main steam radiation monitors are installed downstream of the outboard MSIVs in the main steam tunnel. These monitors provide a means of determining if high radiation is present

in the main steam entering the turbine/condenser. The main steam radiation monitoring system, including detection and control, is discussed in Sections 7.3.1.1, 7.6.1.1, and 11.5.2.1.

10.4.1.3.1 Radioactive Gases

Under normal operation, these gases are removed by the SJAEs and delivered to the gaseous radwaste system. To prevent unacceptable accidental releases of radioactivity to the environment, the ventilation system maintains a slight vacuum in the condenser area. Any radioactive gases that leak out of the condenser under abnormal conditions are removed by the ventilation system and processed through charcoal filters before being vented out of the turbine enclosure stack. Any noncondensable gases that accumulate in the condenser during operation are removed as described in Section 10.4.1.2. There is no significant buildup of hydrogen in the main condenser during shutdown, because it is isolated from potential sources of hydrogen. After processing, gases removed from the condenser are discharged to the atmosphere through the north vent stack. The north vent stack exhaust is monitored and controlled as discussed in Section 11.5.2.1. The condenser evacuation system, turbine enclosure ventilation system, and gaseous radwaste system are discussed in Sections 10.4.2, 9.4.4, and 11.3, respectively.

10.4.1.3.2 Condenser Leakage

If one or more condenser tubes develop leaks, or if a tube-to-tube sheet joint fails, the circulating water is forced into the condensate, thus raising its conductivity. To detect this condition, conductivity cells are installed in the condenser hotwell that alarm if the conductivity rises above acceptable limits. The measuring point location, together with flow path isolation capability, indicates which of the four flow paths contains the leaking tube so that the section may be dewatered. Condenser tube leaks beyond the ability of the condensate cleanup system to maintain conductivity within certain limits will cause a high conductivity alarm in the control room, followed by an orderly reactor shutdown. The reactor water chemistry limits are as follows:

a. Conductivity: $\leq$10 μmho/cm at 25°C

b. Chlorides: $\leq$0.5 ppm

c. pH: 5.3 to 8.6 at 25°C

This system is discussed in Section 10.4-6.

Potential contaminants from the circulating water include 1019 ppm total cations (as $CaCO_3$), 1019 ppm total anions (as $CaCO_3$), and 48 ppm SiO_2. If the condenser is operated with circulating water inleakage and the condensate cleanup system is fully bypassed, the critical contaminant for the reactor is chloride. With a circulating water chloride concentration of 164 ppm (as Cl) and assuming a nominal chloride concentration in the reactor vessel of 10 ppb, a 1 gpm condenser leak will allow operation for 100 minutes before the allowable concentration in the reactor of 200 ppb is exceeded. For a 2 gpm leak, the allowable operating time is 50 minutes, and so on. Maintenance of water quality when the condensate cleanup system is in operation is discussed in Section 10.4.6.

To prevent loss of vacuum, the condenser is of welded construction wherever practicable. The condenser is hydrostatically tested after installed to verify leak-tightness. Any potentially leakage

spots, such as the condensate pump gland seals, will be adjusted. Additional measures to prevent loss of vacuum include:

a. Maintaining adequate flow in the circulating water system.

b. Completely filling and maintaining level in the condenser water boxes to prevent air blanketing.

c. Maintaining the mechanical vacuum pump and a redundant SJAE to ensure adequate vacuum in the condenser.

Fouling of the condenser tubes is prevented by chlorination to prevent bacterial slime growth. Erosion of the condenser tubes and structural components is prevented by baffle plates (Section 10.4.1.2). High velocity areas of the condenser use 20 BWG stainless steel tubes (Section 10.4.1.2.).

10.4.1.3.3 Circulating Water System Rupture

The presence of any water accumulation in the condenser area due to a condenser or circulating water system leak or failure (i.e., expansion joint double guillotine rupture) is detected by sensors installed in each of the north and south basement areas, which actuate an alarm in the control room if there is flooding. These sensors are duplicated, with different alarm points so that the operator receives two warnings, separated by a time interval, to ensure that the warning is not false. On receipt of this alarm, the operator can shut down the circulating water pumps and close motorized condenser inlet and outlet valves.

In the event the expansion joint fails in the circulating water system, actions by the operator to isolate the leaking loop will limit the extent of flooding. If the isolation valves are inoperable or are not actuated by the operator, the maximum steady-state water level would be about el 223'.

In addition to the flooding sensors discussed above, the following measures are provided to protect other areas of the plant and minimize flood damage:

a. Annunciators in the control room indicate to the operator the location of the flooding, i.e., the north area or the south area.

b. The circulating water butterfly valves, motor operators, flooding sensors, and electrical power and control cables to them are operable underwater. However, no credit was taken for operation of the circulating water butterfly valves in calculating the maximum steady-state flood water level at el 223'.

c. The floor drainage system in the condenser area is designed so that water from the flooded area does not enter other areas of the plant. At the maximum steady- state water level of el 223', the water would overflow from the condenser area to the yard. The yard grade slopes away from the structure, so the water would flow across the yard, over the railroad, and into the Schuylkill River. There are no safety-related structures in the flow path.

d. The condenser chamber is watertight up to the maximum flood level of el 223', with watertight doors and seals in the pipe tunnel and HVAC ducts, and is designed to withstand the corresponding water pressure.

e. All electric conduits that exit a flood area below the maximum flood level of el 223' are sealed to prevent the flood from spreading to other areas. All cables in the cable trays below that elevation have waterproof insulation.

Neither a major rupture of the circulating water system nor a rupture of the condenser hotwell has any effect on any safety-related system.

10.4.1.4 Tests and Inspections

Each condenser shell receives a field hydrostatic test before initial operation, and the shell surfaces are inspected for visible leakage and/or excessive deflection. Each condenser water box also receives a shop hydrostatic test, a field hydrostatic test, and an inspection of all joints and external surfaces. After the completion of the tubing of the condenser, all tube joints are leak tested.

In addition prior to installation on the condenser all the tubes are subjected to either a pneumatic test or a hydrostatic test and are nondestructively tested by the eddy current method.

Inservice inspection of the main condenser will be performed as necessary. Those conditions that would lead to condenser inspection are high conductivity and/or loss of ability to maintain adequate vacuum.

10.4.2 MAIN CONDENSER EVACUATION SYSTEM

The main condenser evacuation system, shown in drawing M-07, establishes a vacuum in the condenser during startup and removes noncondensable gases during normal operation. The system is not safety-related.

10.4.2.1 Design Bases

The main condenser evacuation system is designed to perform the following functions:

a. Establish and maintain vacuum in the condenser during startup and normal operation

b. Remove the noncondensable gases from the main condenser during normal operation and discharge them to the gaseous radwaste recombination system

c. Condense any steam removed from the condenser with the noncondensable gases and return the condensate to the hotwell.

The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the main condenser evacuation system are discussed in Section 3.2.

10.4.2.2 System Description

The main condenser evacuation system consists of one 100% capacity vacuum pump with a water separator silencer and a seal water cooler, two redundant 100% capacity SJAE trains, associated valves, piping, and controls as shown in drawing M-07. System design parameters are listed in Table 10.4-2.

10.4.2.2.1 Mechanical Vacuum Pump

The mechanical vacuum pump is used during startup to establish vacuum in the condenser and to discharge the air drawn from the condenser to the atmosphere through the turbine enclosure equipment compartment exhaust air filter assemblies and turbine enclosure vent stack.

The mechanical vacuum pump and its suction valve are operated remotely from the control room. The suction valve is automatically closed on a main steam high-high radiation signal. The pump is shut down on high-high radiation or low seal water flow to the pump. A water separator removes the water droplets from the noncondensable gases before discharging the gases to the atmosphere through the turbine enclosure equipment compartment exhaust air filter assemblies and turbine enclosure vent stack.

The vacuum pump is designed to evacuate the main condenser from atmospheric pressure to 5 inches Hg absolute in approximately 4 hours.

10.4.2.2.2 Steam Jet Air Ejector

Once condenser vacuum has been established by the mechanical vacuum pump, one SJAE is placed in service to maintain vacuum, and the mechanical vacuum pump is shut down (see Section 11.3.2.1.4.7.1 for alternative SJAE operating modes). The air ejector is a full capacity two-stage unit, including four 25% capacity first-stage ejectors and one full capacity condenser and second-stage ejector. A redundant SJAE train is provided to maintain condenser vacuum if the first train is not available.

The four first-stage steam jet ejectors continuously remove noncondensable gases and some steam from the condenser and discharge them to the SJAE condenser where the carryover steam is condensed and returned to the main condenser. The gases are then removed from the SJAE condenser by the second-stage ejector and discharged to the gaseous radwaste recombination system, together with the second-stage ejector motive steam.

These gases normally include air inleakage, dissociated hydrogen and oxygen coolant activation products, and noble gases plus their daughter products. The largest contribution to the main condenser's offgas activity is the N-16 source.

For an inventory of radioactive contaminants in the effluent from the SJAE and the associated doses and a description of the gaseous radwaste recombination system (Section 11.3).

The steam and gas mixture present downstream of the second-stage SJAE eliminates the possibility of an explosion in the line, even though a mixture rich in hydrogen is present. The ejectors require motive steam at 110 psig to operate, which is obtained either from main steam or the auxiliary boilers when available, reduced in pressure through self-regulating pressure-reducing valves. The minimum required main steam pressure at the main steam stop valves for proper ejector operation is approximately 205 psig. Condensate taken from the condenser hotwell by the condensate pumps is used as the cooling medium for the SJAE condenser.

10.4.2.3 Safety Evaluation

The main condenser evacuation system has no safety-related function. Failure of the system does not jeopardize the function of any safety-related system or component or prevent a safe shutdown of the plant.

The radiological consequences of a failure of the SJAE line are evaluated in Chapter 15.

10.4.2.4 Tests and Inspections

The main condenser evacuation system is preoperationally tested in accordance with the requirements of Chapter 14.

10.4.2.5 Instrumentation Applications

Local and remote indicators, alarms, and pressure relief valves are provided to monitor the system process and protect system components.

The pressure in the motive steam line to both the primary ejector and secondary ejector and in the outlet line from the second-stage SJAE is sensed by a pressure switch that alarms on high pressure in the control room.

The mechanical vacuum pump is shut down automatically on receipt of a main steam high radiation signal.

A flow switch actuates a low flow alarm in the control room whenever low seal water flow exists concurrently with the operation of the mechanical vacuum pump.

A pressure transducer in the second-stage SJAE discharge actuates a pressure control valve to provide recycle flow to the condenser in the event of recombiner system transient conditions which approach maximum design conditions.

10.4.3 STEAM SEAL SYSTEM

10.4.3.1 Design Bases

a. The steam seal system is designed to provide a continuous supply of clean (low level radioactive) steam to the main turbine shaft seals, the stem packings of the stop valves, control valves, combined intermediate valves and bypass valves, the shaft seals of the reactor feed pump-turbines, and the stem packings of the reactor feed pump-turbine stop and control valves.

b. The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the steam seal system are discussed in Section 3.2.

10.4.3.2 Description

The steam seal system (drawing M-07) consists of a steam seal evaporator, a steam seal pressure regulator, steam seal header, two full capacity steam packing exhausters with their respective condensers, associated piping, and valves. Major steam seal system design parameters are listed in Table 10.4-3.

The sealing function is provided by supplying clean (low radioactivity) steam to the turbine shaft seals and various valve stems. Of the sealing steam entering the turbine shaft seals, some leaks inward toward the turbine and some leaks outward into a vent annulus, which is maintained at a slight vacuum by the steam packing exhauster. A small amount of air is drawn into this vent annulus from the outside, and this air, together with the sealing steam, is drawn to the steam packing exhauster where the steam is condensed and returned to the condenser. The saturated air is discharged by the exhauster to the turbine enclosure vent stack. With this arrangement, radioactive steam is completely contained within the turbine loop. The cooling medium for condensing the steam is condensate from the condensate system.

The clean (low level radioactive) steam for the seals is generated in the steam seal evaporator by heating condensate with extraction or main steam. The evaporator is a horizontal shell and U-tube heat exchanger in which the extraction or main steam is passed through the U-tube bundle, which is partially immersed in condensate. The condensate for the evaporator is taken from the condensate system from a point downstream of the condensate demineralizer, and the heating steam is taken either from a main steam line or from the extraction steam line to heater No. 3.

The level of condensate in the evaporator is maintained within the required limits by a control valve. The sealing steam generated in the evaporator enters the steam seal supply header through the pressure control valve, which is set to maintain the pressure of the sealing steam at a preset value. Redundancy for this pressure control valve is provided by a motor-operated bypass valve that can be throttled to maintain the pressure of the sealing steam if the pressure control valve fails. An alternative source of sealing steam is available from the auxiliary boilers when available.

The steam packing exhausters discharge to the atmosphere through the north vent stack. The exhauster discharge is monitored for radioactivity.

10.4.3.3 Safety Evaluation

The steam seal system has no safety-related function. Failure of the system does not compromise any safety-related system or component or prevent a safe shutdown of the plant. If there is a failure in the steam seal system, the auxiliary boilers, when available, can provide an alternative source of clean sealing steam to the system. Therefore there is no radioactive leakage path to the environment.

10.4.3.4 Tests and Inspections

The system is preoperationally tested in accordance with the requirements of Chapter 14.

10.4.3.5 Instrumentation Applications

Local and remote indicators, alarms, and pressure relief valves are provided to monitor the system process and protect system components.

Pressures in the tube side of the steam seal evaporator and in the sealing steam header are sensed by pressure switches that alarm on low pressure in the control room. The condensate level in the steam seal evaporator drain tank and in the steam seal evaporator shell side are monitored by level switches that alarm on high or low water levels, respectively, in the control room. High pressure in the exhaust inlet header to the steam packing exhauster is also alarmed in the control room.

10.4.4 TURBINE BYPASS SYSTEM

The turbine bypass system, shown in drawing M-01, dissipates the energy of the main steam generated by the reactor that cannot be used by the turbine (24.3% of 15.287 Mlb/hr steam flow for Post MUR-PU conditions). The turbine bypass system is not safety-related.

10.4.4.1 Design Bases

a. The turbine bypass system is designed to control the pressure in the reactor during the following modes of operation:

   1. Reactor vessel heatup to rated pressure and subsequent cooldown

   2. Turbine run-up and run-down

   3. Power operation when the quantity of steam generated by the reactor exceeds that required by the turbine. In this mode, the system can bypass to the main condenser (24.3% of 15.287 Mlb/hr steam flow for Post MUR-PU conditions).

b. The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the turbine bypass system are discussed in Section 3.2.

10.4.4.2 System Description

The turbine bypass system is shown in drawing M-01 and consists of:

a. Bypass valve chest assembly

b. Piping between the discharges of the bypass valves and the condensers

c. Pressure reducer assemblies

The bypass valve chest consists of nine separate bypass control valves mounted in individual compartments of a common valve chest. The valves are globe-type, with the stems arranged so that they reach the outside of the chest through the discharge chamber of the respective valve. This minimizes leakage when the valves are closed, since it is necessary only to seal the stem against condenser vacuum.

The discharge connections of the bypass valves are piped individually to the condensers. To reduce the pressure at which the bypassed steam enters the respective condenser, a pressure reducer assembly is installed in each bypass valve discharge line. The pressure reducer assembly consists of a series of pressure breakdown plates. Therefore, steam flow from any open bypass

valve is throttled through its pressure reducer assembly before discharging at reduced pressure via a spray pipe to the condenser.

To operate, the turbine bypass system receives a signal from the turbine control system (initial pressure regulator) to open the bypass valves whenever the actual steam pressure exceeds the preset steam pressure (lower than the main steam relief valve setpoint pressures) by a small margin. This occurs when the amount of steam generated by the reactor cannot be entirely absorbed by the turbine. The bypass valves are tripped closed when the vacuum in the main condenser falls below a preset value.

The bypass valves open sequentially and are used during normal startup and shutdown. If there is a full load rejection, such as would occur if the generator circuit breaker opened, all nine valves open to bypass (24.3% of 15.287 Mlb/hr steam flow for Post MUR-PU conditions), which is the maximum design flow of the bypass valves.

Failure of the bypass valves to open for any reason, such as a mechanical malfunction or insufficient vacuum in the condenser, causes the pressure in the reactor to increase, ultimately lifting the main steam relief valves, which discharge the excess steam to the suppression pool. The effect of such a situation on the reactor coolant system is described in Chapter 15.

10.4.4.3 Safety Evaluation

The turbine bypass system has no safety-related function. Failure of the turbine bypass system, including failure of the turbine bypass line, would have no effect on the capability to achieve safe shutdown of the plant.

10.4.4.4 Tests and Inspections

The system is preoperationally tested in accordance with the requirements of Chapter 14.

During the operations phase, bypass valves are inspected and tested consistent with industry practices. Test frequencies are determined in accordance with the Surveillance Frequency Control Program as described in the plant Technical Specifications.

10.4.4.5 Controls and Instrumentation

Pressure sensors are provided to close the bypass valves when the vacuum in the main condenser falls below a preset value.

The opening of the bypass valves at any time is alarmed by a limit switch on each bypass valve.

Meters and indicating lamps are provided to show valve position.

10.4.5 CIRCULATING WATER SYSTEM

10.4.5.1 Circulating Water

10.4.5.1.1 Design Bases

The circulating water system is designed to remove the design plant heat load using a hyperbolic natural draft cooling tower.

10.4.5.1.2 System Description

The circulating water system is a closed-loop system consisting of a cooling tower, the main condenser, four 25% capacity circulating water pumps, and associated piping, valves, controls, and instrumentation. The system is shown schematically in drawing M-09. The circulating water pumps and the cooling tower design parameters are given in Tables 10.4-4 and 10.4-5, respectively. Plant general arrangement is shown in drawings C-2, M-110 and M-126.

Circulating water from the cold water outlet of the cooling tower basin flows by gravity through the condensers to the suction of the circulating water pumps. The LP condenser is supplied by two 96 inch lines, each of which branches into two 78 inch lines before being connected to the condenser water boxes. The circulating water discharging from the LP condenser flows into the IP condenser and subsequently to the HP condenser in series. From the discharge of the HP condenser, each pair of 78 inch lines is combined into one of two 96 inch headers, with each header feeding two circulating water pumps. The pump discharge headers are run underground back to the cooling towers.

Motor-operated butterfly valves are provided in each of the 78 inch circulating water lines, one at the inlet to the LP condenser and another at the outlet from the HP condenser. These permit any of the four flow paths on the circulating water side (tube side) of the condensers to be isolated if there is tube leakage. Rubber expansion joints are provided at the inlet connections to the LP condenser, the outlet connections from the HP condenser, and in the interconnecting piping between the LP, IP, and HP condensers.

The circulating water pumps are the vertical, mixed flow, dry-pit type and are driven by electric motors. They are located in the circulating water pump structure, which also houses the service water and fire water pumps.

Motor-operated butterfly valves are provided in the suction and discharge of each pump so that they can be isolated if necessary. Expansion joints are also provided at the inlet and outlet connections of each pump.

The circulating water is chlorinated to prevent the formation of biological growth. Sodium hypochlorite is used as the biocide. A brominated salt solution is also being injected to improve the effectiveness of the biocide. Sulfuric acid is added to the system on an intermittent basis to control pH and prevent scaling on condenser tubes. A cooling tower chemical treatment system is also being used to control mild steel and copper corrosion, heat exchanger scaling (service water and condenser), and deposition. Supplemental chemical treatment may also be used as needed for cooling tower foam control.

Makeup water is provided to the circulating water system to replace the water lost due to evaporation and drift in the cooling towers and blowdown from the system. The blowdown prevents the buildup of dissolved solids in the circulating water. The makeup water system is described in Section 10.4.5.2. See Section 2.4.11 for low water considerations.

Stationary screens, removable for cleaning, are located at the cooling tower outlet to prevent debris from entering the circulating water piping, condenser, and circulating water pumps, service water system, fire protection, RHRSW, and ESW systems.

The circulating water is transported through reinforced concrete flumes and carbon steel pipe lined with coal tar epoxy.

Each cooling tower is a hyperbolic, natural draft structure employing the cross-flow principle of heat transfer. The design circulating water flow rate through each tower is 476,600 gpm. The cooling tower basin has a storage capacity of $7.2x10^6$ gallons of water. A blowdown system is provided to maintain the dissolved solids concentration ratio. Blowdown is taken from each cooling tower basin, combined, monitored, and discharged to the Schuylkill River.

10.4.5.1.3 <u>Safety Evaluation</u>

The circulating water system has no safety-related function and is not required to be operable following a LOCA. Failure of the system does not compromise any safety-related system or component, or prevent a safe shutdown of the plant. A postulated complete rupture of one of the expansion joints in the system does not affect any safety-related system. The floor drainage system in the condenser area is designed so that water from the flooded area does not enter other areas of the plant. The condenser area is designed so that water that would flow from a ruptured condenser inlet expansion joint overflows from the condenser area into the yard and does not affect any equipment outside the condenser compartment. The yard grade slopes away from the structure, so the water would flow across the yard, over the railroad, and into the Schuylkill River. For a more detailed discussion of a circulating water system rupture, see Section 10.4.1.3.3.

The potential for damage to other plant structures if the cooling tower collapses is slight, because the structure would tend to collapse inward. In addition, the structure is located a sufficient distance, over 500 feet, from any equipment or structure important to reactor safety to prevent damage due to cooling tower collapse.

10.4.5.1.4 <u>Tests and Inspections</u>

The condenser is tested as described in Section 10.4.1.3. The pumps, butterfly valves, and expansion joints are all tested by their respective manufacturers before shipment.

A hydrostatic test is performed on the circulating water pipe in accordance with AWWA standards.

The system is preoperationally tested in accordance with the requirements of Chapter 14.

10.4.5.1.5 <u>Controls and Instrumentation</u>

Pressure relief valves, local and remote indicators, and alarms are provided to monitor the system performance and protect system components. High and low water levels in the cooling tower basin are monitored and alarmed in the control room. The Perkiomen cooling tower makeup water flow control valves are closed automatically on a high water level in the cooling tower basin. The cooling tower stilling well temperature is monitored, and a heater is provided to prevent freezing within the well. The cooling tower is also provided with an icing control system to prevent freezing in the cooling tower fill. Flooding in the condenser compartments is monitored and alarmed in the control room.

Low and high pressures in the suction and discharge sides of the circulating water pumps, respectively, and low pressure in the lube water and cooling water supply headers to the circulating water pumps are monitored and alarmed in the control room.

Local indication of the pressure drop across each condenser shell is provided by pressure differential indicators. Thermocouples are also installed in these locations to monitor the circulating water temperature.

10.4.5.2 Makeup Water System

10.4.5.2.1 Design Bases

Makeup water is provided from the Perkiomen Creek and Schuylkill River. The makeup water system is common to Units 1 and 2. System design parameters are listed in Table 10.4-6.

10.4.5.2.2 System Description

The makeup water flow to the cooling tower is controlled by motor-operated flow control valves on the supplies from the Perkiomen pumping station and the Schuylkill pumping station. Unit 1 and Unit 2 flow is controlled manually via the respective valve position controllers. Makeup for the nonconsumptive use of water (blowdown) is provided from the Schuylkill River intake/pumping station. Makeup for the consumptive use of water (evaporation and drift) is provided from either the Schuylkill River pumping station or the Perkiomen Creek intake/pumping station, in accordance with criteria established by the Delaware River Basin Commission.

The Perkiomen makeup supply consists of three 50% capacity pumps, cylindrical wedge-wire screens and associated equipment, a 7.6 mile buried pipeline, and a 1,500,000 gallon makeup water storage tank at the plant site. The system is shown schematically in drawing M-09. The Perkiomen Creek pump design parameters are given in Table 10.4-6.

The Perkiomen Creek make-up pumps maintain tank level within normal range while supplying the needed make-up water flow rate. The pump motor drives are interlocked so that no more than two makeup pumps can run simultaneously. The pumps can be operated from either the control room or locally.

The Schuylkill River makeup water supply consists of three 29.8% capacity pumps and two 10.6% capacity pumps, with traveling water screens and associated equipment. The system is shown schematically in drawing M-09. Design parameters are listed in Table 10.4-6.

10.4.5.2.3 Safety Evaluation

The makeup water system has no safety-related function. Failure of the system does not compromise any safety-related system or component or prevent a safe shutdown of the plant.

10.4.5.2.4 Tests and Inspections

The pumps and associated equipment are tested by their respective manufacturers.

The makeup water system is preoperationally tested in accordance with the requirements of Chapter 14.

10.4.5.2.5 Controls and Instrumentation

Pressure relief valves, local and remote indicators, and alarms are provided to monitor the system performance and protect system components.

10.4.6 CONDENSATE CLEANUP SYSTEM

The condensate cleanup system is used for filtration and demineralization of the full hotwell condensate flow to maintain a high degree of purity in the nuclear steam and feedwater systems. The condensate cleanup system is not safety-related.

10.4.6.1 Design Bases

The condensate cleanup system is designed to maintain the condensate at the required purity by removing the following contaminants:

a. Products resulting from corrosion in the main steam and turbine extraction piping, feedwater heater shells, and drains

b. Suspended and dissolved solids that may be introduced by small leakages of circulating water through condenser tubes

c. Fission and activation products that are entrained in reactor steam and retained in the condensate leaving the hotwell

d. Solids carried into the condenser by makeup water and miscellaneous drains

The system is designed to clean the feedwater to maintain the following criteria during normal operation:

CONDENSATE QUALITY DURING NORMAL OPERATION

Specific conductivity @ 25°C	0.07 micromho/cm
pH @ 25°C	6.0 to 7.5
Total metallic impurities	9 ppb
Total iron (as Fe)	5 ppb
Total copper (as Cu)	0.1 ppb
Total nickel (as Ni)	2 ppb
Silica (as SiO_2)	5 ppb
Chloride (as Cl)	1 ppb

The bases for these limits are the prevention of crud buildup on fuel heat transfer surfaces, the need to minimize the transport of active corrosion products outside the core, and the protection of the RCPB.

The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the condensate cleanup system are discussed in Section 3.2.

Protection against dynamic effects associated with the postulated rupture of piping is discussed in Section 3.6. This system is designed and operated in accordance with Regulatory Guide 1.56.

10.4.6.2 System Description

The condensate cleanup (CCU) system is shown in drawing M-16. It consists of eight filter/demineralizers and eight deep bed demineralizers with their corresponding pumps, valves, piping, and controls. System design parameters are shown in Table 10.4-7. The condensate filter/demineralizer (CFD) subsystem and the deep bed condensate demineralizer (DBCD) are operated in series .

The system is used for filtration and demineralization of the full hotwell condensate flow to maintain a high degree of purity in the nuclear steam and feedwater systems. The condensate is pumped from the condenser hotwell by the condensate pumps, through the SJAE condenser and the steam packing exhauster condenser before entering the CCU system. Treated condensate leaving the CCU system passes through one drain cooler and five stages of low pressure feedwater heaters. From there, the reactor feed pumps feed the water through one stage of high pressure feedwater heaters into the reactor vessel.

The CCU demineralizers remove radioactive material created by corrosion product and fission product carryover from the main steam system. While radioactivity does not affect the capacity of the resins, the concentration of such radioactive materials in the demineralizer equipment requires shielding (Section 12.3).

The CFD system consists of eight filter/demineralizers, non-precoat type elements,which remove suspended solids from the condensate and feedwater streams. All eight vessels are in service at one time during normal conditions. However, full condensate flow can be maintained through seven vessels.

The condensate filter/demineralizers have been designed for vessel differential pressure cycle length as an indication of when to backwash the vessel. Accordingly, each vessel will be backwashed if:

a. The pressure drop from inlet to outlet reaches a preselected value between, due to buildup of suspended solids, or 10 to 20 psid.

b. The cycle length reaches a preselected value of runlength days, dependant upon the filter requirements.

Due to their high ionic capacity, the condensate deep bed demineralizers are the determining factor for pH control and ionic removal in the primary coolant.

The refueling water or condensate transfer pumps supply condensate quality water for backwashing the units. The exhausted resin is backwashed to the condensate backwash receiving tank for subsequent processing by the radwaste system (Section 11.4).

The condensate filter demineralizer system automatic flow balancing controls have the capability to be operated in either automatic or manual.

In the automatic mode of operation, a master flow controller, operating in conjunction with flow controllers located on each of the eight filter/demineralizer units, maintains an equal flow (±5%) through each of the seven operating filter/demineralizers. The master controller is overridden turning all operating vessel effluent valves wide open at a preselected value for high header differential pressure.

In the manual mode of operation, an operator will monitor individual filter demineralizer flows during normal operator rounds and manually adjust the flow with the individual flow controllers to achieve the desired flow balance among all of the operating condensate filter demineralizers.

In the automatic or manual mode of operation, if the differential pressure between the influent and effluent headers exceeds a predetermined value, a differential pressure switch sounds an annunciator on the control panel and in the control room. If there is an additional increase, the main bypass valve opens.

The flow rate through each filter/demineralizer is measured by a flow element and transmitter on the suction line of the vessel. Flow indication is provided both locally and in the main control room.

Condensate filter/demineralizers are manually placed in or out of service locally by the operator due to flow demand. The condensate filter/demineralizers are removed from service when the specific vessel reaches its backwash endpoint. Filter/demineralizer backwash operation is performed using system operating procedures. The backwash equipment is common to all eight vessels.

The Deep Bed Demineralizers consist of a battery of eight demineralizers vessels. All eight vessels are in service at one time during normal operating conditions. However, full condensate flow can be maintained through seven vessels.

Each vessel is filled (or refilled) with new resin using an eductor system. An air mix system is available, if required, to ensure a homogenous resin mix after the resin loading step is complete. Next, the vessel is filled, vented, and pressurized prior to aligning to condensate. Prior to aligning a new DBCD vessel to condensate (cut-in), the bed is rinsed to the hotwell at approximately 1500 gpm to allow residual contaminants from the resin manufacturing processes to be flushed from the bed.

The DBCD subsystem operates in series with the CFD subsystem.

This is accomplished as filtered condensate enters the vessels through an inlet flow distributor, passes vertically through a resin bed, and exits through a collector system. Resin used in the DBCD vessels is the bead type with a nominal bead size range between 20 and 40 mesh. The resin rests on a stainless steel collector system designed to withstand full condensate system differential pressure. The collector system is comprised of a header/lateral system which uses screen to support the bed. Immediately downstream of the vessels are basket strainers. The collector system and basket strainers provide redundant protection against bead resin intrusion to primary coolant.

A layup system is provided for extended outage periods which preserves the resin bed by maintaining a recirculating flow of condensate from the DBCD system outlet header to the inlet header.

This is a accomplished through the use of DBCD system block valves (HV-16-191 and 192) and two 3000 gpm centrifugal pumps configured for parallel operation. A layup flow of approximate 20% (or 750 gpm) normal in-service flow can be maintained though the use of these pumps.

Power for the DBCDs is provided from the site services substation. This substation is fed from the Moser 363 Line (formerly 2300 Line). The site services substation feeds the DBCD system MCC located in the Turbine Enclosure 217 elevation.

The control system for the DBCD system consists primarily of a programmable logic controller (PLC) for system monitoring and control. Input/output (I/O) cabinets provide the interface between system instruments and equipment and the PLC via I/O bus. Personal computers (PCs) are used to either interrogate the PLC for system status or to provide commands. The control of the DBCD system is maintained in software resident in the PLC and operator control station.

The DBCDs are controlled from either of two operator control stations located in a common console in the Radwaste Control Room. Each station consists of an 80386 microprocessor-based computer, operator and programming keyboards, and monitor display. Operator commands are entered onto the system through the operator keyboards and system status including system alarms are displayed on the monitors. Two operator control stations are provided to control and monitor different processes simultaneously.

A portable engineering work station comprised of an 80386 microprocessor-based computer is used to link with the common data highway network for system troubleshooting and performance monitoring.

In the Main Control Room (MCR), the DBCD has individual vessel flow indication (eight indicators - one per vessel), a system differential pressure indicator, and a system bypass valve control switch with interlocking high system differential pressure bypass. The bypass switch function is performed by the FCS and is independent of the Radwaste Control Room and the PLC/PC control system.

All DBCD vessel flow control valves have been aligned in a fixed open position (typically 80 - 100%) by de-energizing their associated motor operators on high differential pressure a 12" bypass valve is opened providing a bypass flow equivalent to one vessel. If differential pressure continues to increase a 30" bypass valve is opened allowing full DBCD system flow to be bypassed.

When the resin in a DBCD vessel has reached its designated endpoint, it is hydropneumatically transferred to the spent resin receiving tanks (SRT) in the Turbine Enclosure 200' elevation. This transfer sequence is automatically executed by the PLC after operator remote initiation. Because of the nature of the deep bed demineralizers, a vessel that has reached the endpoint still has a considerable amount of ion exchange capacity remaining. Therefore, these resins are stored in the SRTs for reuse in the radwaste floor and equipment drain processing system demineralizers (Section 11.2.2.4). Four SRTs are located in the Turbine Enclosure, each capable of holding one DBCD vessel's resin volume (320 ft^3). These tanks are located in a shielded locked high radiation area (Room 252A) which is sealed to contain tank leakage. Designated portions of SRT resin are educted to a resin measuring tanks (RMT) for hydropneumatic transfer to the radwaste demineralizers or from Unit 2 RMT to Unit 1 SRT "A" (1AT928). The operator can select resin transfer volumes to allow for use of 100% DBCD spend resin, or a new resin underlay and/or overlay in the radwaste demineralizers if necessary to enhance demineralizer performance. These operations are also automatically executed through the PLC after remote initiation by the radwaste control room operator. Valving, pumps, eductors, and instrumentation necessary to complete

these transfers are primarily located adjacent to the SRT room in a high radiation area (Zone IV) which is shielded from the SRTs. This configuration allows for maintenance and I&C activities while maintaining exposure ALARA. Service air used for hydropneumatic transfers is vented to the SRTs, where it is exfiltrated through the TEECE system. For transfers to the radwaste demineralizers, service air is vented to the radwaste enclosure ventilation system. One of four Unit 1 SRTs (1AT928) is provided with a recirculation loop and transfer pump which enables transfer to the external processing valve station for vendor processing. The SRTs are provided with overflow protection, level indication and high level alarms. All pressure-retaining equipment has been designed, procured, inspected, and tested consistent with Regulatory Guide 1.143.

The DBCD system has been designed for continuous operation to use the resin to either a total throughput endpoint or an endpoint determined by radwaste operations as necessary to meet radwaste floor and equipment drain demineralizer resin needs. The total throughput endpoint will be determined to ensure a reserved removal capacity consistent with Regulatory Guide 1.56. The performance of these vessels is best analyzed by measuring conductivity. The conductivity of the condensate is measured at the common influent header, the discharge of each demineralizer vessel, and the common effluent header. A high conductivity alarm for the common effluent header is found in the control room. Conductivity is monitored and local alarms for high reading are on the Deep Bed Condensate Demineralizer control panel (PC) in the radwaste control room.

10.4.6.3 Safety Evaluation

The condensate cleanup system has no safety-related function and is not required to be operable following a LOCA. Failure of the system does not compromise any safety-related system or component or prevent a safe shutdown of the plant.

10.4.6.4 Tests and Inspections

The DBCD and CFD vessels are tested in accordance with ASME Section VIII. Piping is inspected and tested in accordance with ANSI B31.1 with the exception of spent resin subsystem piping. This piping and associated pressure boundary equipment is inspected and tested in accordance with Regulatory Guide 1.143 .

The CFD system is preoperationally tested in accordance with the requirements of Chapter 14. The DBCD system was tested in accordance with Section 13.5.1.6. The condensate cleanup system is periodically tested in accordance with the requirements of Chapter 16.

10.4.6.5 Instrumentation Applications

Local and remote indicators, alarms, and pressure relief valves are provided to monitor the system process and to protect system components.

The conductivities are monitored for the following:

a. Influent of the condensate filter/demineralizer system

b. Influent A -D Effluent of the deep bed condensate demineralizer system

c. Effluent of each deep bed condensate demineralizer

In addition, conductivity alarms are provided to alert the operator for off-normal conditions. Flow rate and pressure differential indication, as well as alarms for high and low flow and high pressure differential are provided for each filter/demineralizer and deep bed demineralizer. A flow totalizer is provided for each deep bed demineralizer, rather than a recording flowmeter as suggested in Regulatory Guide 1.56.

The following instrumentation is specific for the Deep Bed Condensate Demineralizer system:

1) All indications and alarms are provided through PCs in the Deep Bed control panel located in the Radwaste Control Room.

2) System pressure differential indication and indication of each demineralizer flow is provided in the Main Control Room.

3) High system effluent conductivity is alarmed in the Main Control Room.

4) Conductivities for effluent from each demineralizer and for system influent and effluent are stored within the PCs located in the Deep Bed control panel.

5) Flows and total volume throughput of each demineralizer are stored within the PCs located in the Deep Bed control panel.

10.4.7 CONDENSATE AND FEEDWATER SYSTEMS

The condensate and feedwater systems remove condensed main steam from the condenser hotwells, heat it, and return it to the reactor to be converted into steam.

10.4.7.1 Design Bases

a. The condensate and feedwater systems are designed to return condensate from the condenser hotwell to the reactor at the required flows, pressure, temperature, and quality.

b. The systems are designed to automatically maintain the water levels in the reactor and the condenser hotwell during steady-state and transient conditions.

c. The condensate and feedwater systems from the condenser hotwell up to, but not including, the outermost primary containment isolation valve are not safety-related. The feedwater system from the outermost primary containment isolation valve to the reactor is safety-related. For the isolation criteria between this system and the RCPB, see Section 6.2.4.

d. Inservice inspection is performed in accordance with ASME Section XI for that portion of the feedwater system furnished in accordance with ASME Section III.

e. The condensate and feedwater systems are designed to permit continued operation of the plant at reduced power without reactor trip on loss of one of the three condensate pumps, one of the three reactor feed pumps, or one of the three strings of feedwater heaters.

f. The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the condensate and feedwater systems are discussed in Section 3.2.

10.4.7.2 System Description

The condensate and feedwater systems are shown in drawings M-05 and M-06, respectively. The systems' design parameters are shown in Tables 10.4-8 and 10.4-9.

10.4.7.2.1 Condensate System

Three, 33-1/3% capacity, vertical, centrifugal condensate pumps take suction from a common header, which is connected to each condenser hotwell for flow equalization, and discharge into another common header. The condensate flow is then directed through the SJAE condenser and the steam packing exhauster condenser and into the condensate filter/demineralizer's common influent header. The condensate cleanup system is discussed in Section 10.4.6. Condensate then proceeds through the condensate demineralizer system and discharges into the common inlet header of the feedwater system.

The sealing water for the condensate pump seals is taken from the CST. The leak-off from the seals is piped to the liquid radwaste system.

A condensate recirculation system is furnished to maintain a minimum flow through each condensate pump, SJAE condenser, and steam packing exhauster condenser. A total minimum flow of 7500 gpm for all three condensate pumps is automatically maintained by a control valve in the common recirculation line. A bypass valve is provided around the control valve for maintenance accessibility during plant operation for Unit 1. Recirculated condensate is returned to the condenser.

A hotwell makeup and reject system maintains the condenser hotwell level during steady-state and transient conditions. Condensate is rejected to the CST to decrease the hotwell level or drained into the condenser from the storage tank to make up the hotwell level. A combination of small and large control valves, with a bypass valve, is used to control the makeup and reject flows. The small control valve controls the smaller normal flows, whereas the larger control valve is used during larger transient flows. The control valves are controlled by water level in the condenser hotwell. The condensate reject valves close on high level in the CST.

10.4.7.2.2 Feedwater System

Condensate from the deep bed condensate demineralizer effluent header divides and passes through three parallel strings of LP feedwater heaters. Feedwater downstream of the heaters is combined into a common header from which three, 1/3 capacity, turbine-driven reactor feed pumps take suction. The reactor feed pumps discharge the feedwater through HP feedwater heaters into a common mixing header for distribution through reactor containment isolation valves and into the reactor.

Injection water for the reactor feed pump seals is taken from the condensate pump discharge header and drained to the main condenser. An injection water booster pump is furnished to maintain a minimum differential pressure of 25 psid between the injection pressure and the reactor feed pump suction pressure.

Each reactor feed pump has a recirculation line connected to the main condenser. This recirculation line is tapped off the discharge line between the reactor feed pump and its discharge check valve and is used to maintain a minimum flow through the feed pump at startup and low load operation to avoid pump vibration and high running temperatures. A modulating reactor feed pump recirculation system is used. Reactor feed pump flow to the vessel is used to establish the flow requirement through the recirculation line. The total reactor feed pump flow is the summation of recirculation flow and flow to the reactor as measured downstream of the HP feedwater heaters.

The reactor feed pump recirculation valve is positioned, via an open loop control signal, to ensure that the minimum required flow through the pump is maintained.

The reactor feed pumps are driven by variable speed, six-stage turbines that receive steam from either the main steam header or the cross-around piping downstream of the moisture separators. During normal full power operation, the turbine drivers use low pressure cross-around steam. High pressure main steam is used during startup, low load, or transient conditions, when cross-around steam is either not available or is of insufficient pressure. The exhaust steam from each turbine driver is piped to the main condenser.

Before starting the reactor, the feedwater lines between the condensate cleanup system and the reactor are flushed to remove any crud present. The flow is pumped through these lines by the condensate pumps and recirculated to the condenser through the startup recirculation line. This ensures proper reactor water quality during startup.

The feedwater flow branches into two separate lines before entering the primary containment. Primary containment isolation in each branch is provided by a motor-operated stop-check valve, a pneumatic check valve outside the containment, and a check valve inside the containment. The motor-operated stop-check valves are supplied by a Class 1E power supply. Pneumatic check valves fail closed on loss of air pressure. However, the spring-loaded piston of the check valve will not close the valve on loss of power against normal flow from the normal direction. Section 6.2.4 contains a discussion of the containment isolation system.

Normally, the three condensate and three reactor feed pumps are in service, together with all three strings of feedwater heaters. The system is designed so that it can operate with any two condensate pumps, two reactor feed pumps, or two feedwater heater strings in service without a reactor scram. An abnormal operational transient analysis of the loss of a feedwater heater string is included in Chapter 15.

Both the condensate pumps and reactor feed pumps are designed to provide the maximum required design flows plus adequate margins to account for both transients and pump wear. Adequate margin is provided in the net positive suction head requirements to ensure noncavitating performance under operating and run-out conditions.

Each of the six feedwater heaters and drain coolers per heater string has BWG, 304 L stainless steel tubes installed.

During operation, steam and condensate are present in the feedwater heating portion of the system, which includes the extraction steam piping, feedwater heater shells, heater drain piping, and heater vent piping (drawings M-03 and M-04). If there is equipment leakage, the reactor feed pump turbines and feedwater heaters are compartmentalized to localize resultant higher radiation. Shielding and access requirements are provided as necessary (Section 12.3). The condensate and feedwater systems are designed to minimize leakage, with welded construction used where practicable. Relief valve discharges and operating vents are handled through closed systems.

To reduce radiation buildup on primary piping and components, soluble zinc oxide is injected into the suction side of the A/B reactor feed pumps from the Zinc Injection Passivation (GEZIP) skid which is installed at turbine building EL. 217'-0".

10.4.7.3 Safety Evaluation

The condensate and feedwater systems are not safety-related and are not required to be operable following a LOCA. Failure of the systems does not compromise any safety-related system or component or prevent a safe shutdown of the plant.

Feedwater system primary containment penetrations and isolation valves and piping inside containment are designed to seismic Category I and ASME Section III, Class 1 requirements as discussed in Sections 3.2, 3.7, and 6.2.

Protection against dynamic effects associated with the postulated rupture of piping is discussed in Section 3.6.

10.4.7.4 Tests and Inspections

That portion of the feedwater system designed to ASME Section III, Class 1 or 2 is inspected and tested in accordance with ASME Section XI.

The condensate and reactor feed pumps' performance is verified by shop testing. The casings of the condensate and reactor feed pumps are hydrostatically tested by their respective manufacturers before shipment. The shell and tube side of all feedwater heaters and drain coolers are hydrostatically tested to 1.5 times their design pressure in accordance with ASME Section VIII.

Before initial operation, the completed condensate and feedwater system receives a field hydrostatic test and inspection in accordance with the applicable code.

The system is preoperationally tested in accordance with the requirements of Chapter 14.

10.4.7.5 Instrumentation Applications

Local and remote indicators, alarms, and pressure relief valves are provided to monitor the system process and protect system components.

Controls are provided to maintain the condenser hotwell level so that on high level the excess condensate is transferred to the CST, while on low level makeup from the storage tank is admitted to the system. The condensate reject valves close on high level in the CST. Controls are also provided to maintain the correct levels in the feedwater heaters.

During startup the water level in the reactor is controlled by the condensate system startup valve and reactor feed pump discharge bypass valve. During normal operation the reactor feed pump-turbine speed regulates the level. The turbine speed signal is generated by the FCS. The FCS is discussed in Section 7.7 .

Monitoring equipment, including pressure indicators, flow and temperature indicators, and alarms for abnormal conditions, is provided in the control room to ensure the proper operation of system components.

10.4.8 STEAM GENERATOR BLOWDOWN SYSTEM (PWR)

This section is not applicable to LGS.

10.4.9 AUXILIARY FEEDWATER SYSTEM (PWR)

This section is not applicable to LGS.

10.4.10 AUXILIARY STEAM SYSTEM

The auxiliary steam system provides a source of LP noncontaminated steam for various startup and plant service functions. The system is not safety-related.

10.4.10.1 Design Bases

The system is designed to provide the operational flexibility necessary to accommodate the varying steam demands during all seasons and modes of operation.

The auxiliary steam system is designed to operate independently of the NSSS.

The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the auxiliary steam system are discussed in Section 3.2.

10.4.10.2 System Description

The auxiliary steam system is shown schematically on drawing M-21. Major component design parameters are listed in Table 10.4-10.

The plant auxiliary boilers are common to both Units 1 and 2. The auxiliary steam system consists of three water tube package boilers, a deaerator, three boiler feedwater pumps, three fuel oil pumps, a fuel oil storage tank for No. 2 oil, a chemical feed tank and pumps, and associated piping, valves, controls, and instrumentation. All major components of the auxiliary steam system are located in the auxiliary boiler structure, the fuel oil pump house, and the tank dike area.

The boiler control system is basically designed for unattended operation, except for cold startup operation of a boiler. Process steam and plant heating steam are distributed from the boiler steam outlet header. Condensate recovered from the plant heating system is returned to the deaerator, which provides condensate storage. Demineralized water is used for boiler makeup. An atmospheric blowdown tank is provided to control the water quality in the boilers. A pressure-reducing valve maintains plant heating steam system pressure. Final pressure reduction is accomplished, as required, by individual valves adjacent to the equipment served. Steam heating coils are provided in the auxiliary boiler mud drums to prevent freezing when the unit is not in operation. The auxiliary steam system can provide a backup for the clean steam seal system. The auxiliary steam system can provide a backup for main steam to the SJAE's for plant startup and shutdown. It also provides steam for condensate deaeration in the hotwell during plant startup. The condensate from this process is not returned to the deaerator but is drained to the main condenser.

The only connections between the auxiliary steam system and seismic Category I systems are those used for testing of the HPCI and RCIC turbines. The connections are made through pipe spools containing spectacle flanges. After testing the blind portion of the spectacle flange is installed and the auxiliary steam system is isolated from any seismic Category I system. The

connections between the auxiliary steam system and nonseismic Category I portions of the main steam system are protected by normally closed valves.

10.4.10.3 Safety Evaluation

The auxiliary steam system has no safety-related function. The system is designed so that a failure of the system or one of its components does not compromise any safety-related system or component or prevent a safe reactor shutdown.

10.4.10.4 Test and Inspections

The auxiliary steam system is proven operable by its use during startup and normal plant operation.

10.4.10.5 Instrumentation Application

Local and remote indicators, alarms, and pressure relief valves are provided to monitor the system process and protect system components. A common boiler trouble alarm is located in the control room.

10.4.11 HYDROGEN WATER CHEMISTRY SYSTEM

10.4.11.1 Design Bases

The purpose of the hydrogen water chemistry (HWC) system is to mitigate, in a timely manner, the chemical conditions in the recirculation water that allow intergranular stress corrosion cracking (IGSCC). The addition of hydrogen to the feedwater reduces the oxidizing chemistry conditions which promote IGSCC in reactor piping and components. Other regions of the reactor such as components in the vessel lower plenum, can also be protected from IGSCC by injecting hydrogen. The maximum injection rate for hydrogen gas is 1.6 ppm (71 scfm) to mitigate IGSCC in the recirculation piping and regions of the reactor vessel. The HWC system also supplies hydrogen to the Generator Hydrogen Cooling System.

Signals from the HWC control panel are sent to the Main Control Room for alarm, shutdown and process monitoring capabilities.

The HWC control system requires an interface with the Feedwater control system. Feedwater pump discharge flow and total feedwater flow are required by the HWC system.

The HWC control system also requires an interface with the Gaseous Radwaste/Recombination System. An SJAE train/recombiner trip signal is provided to trip the HWC system.

Flow control and air-operated isolation valves fail closed upon loss of instrument air or control power. Excess flow check valves in the hydrogen and oxygen supply lines mitigate the effects of a line break in the Turbine enclosure.

Manual shutdown switches are provided in the Main Control Room and on the local HWC control panel. These switches are provided as backup to the automatic trips of the system. Manual switches allow HWC system shutdown from the MCR if the controllers would fail in a locked-up mode.

10.4.11.2 Safety Evaluation

The HWC system is not safety related; however, the installation and operation of the system increases the carryover of N-16 from the reactor to the steam system. Hydrogen injection by the HWC system causes the reactor water chemistry to become less oxidizing which results in a re-distribution of the N-16 normally produced by radiolysis in the reactor core. Under HWC conditions, more of the N-16 is carried over into the steam and less remains in the reactor water. Thus, areas where there is steam piping will experience a greater level of radiation due to the increased N-16. This increase results in a measurable increase in the gamma dose rate both inside and outside the radiation controlled area. Exposure at locations outside plant structures will also increase due to direct radiation and turbine shine from the N-16, which is a high energy gamma emitter. In order to minimize these effects, additional radiation shielding has been installed around the high pressure turbine and combined intermediate values. The increased exposure is within the estimates provided within Chapters 11 and 12.

Although the HWC system includes measures to prevent and detect leakage of hydrogen in the Turbine Enclosure, the potential for an undetected hydrogen leak has been considered. Pipe break leakage is limited by excess flow check valves. An analysis was performed for a hydrogen leak in the Turbine Enclosure (reference 2). Each area where the hydrogen line is located was considered with respect to ventilation. In the event of a loss of ventilation, the hydrogen monitors will provide an indication and alarm if a hydrogen leak were to develop. If a hydrogen monitor was to become inoperable, it will provide an alarm to alert Operations personnel to take corrective action.

The hydrogen and oxygen gas supply systems consist of high pressure tube vessels (trailers) located outside the plant's protected area. The tube vessels and trailers are DOT (Department of Transportation) approved and maintained in accordance with the applicable DOT regulations. Based on siting criteria in the EPRI Guidelines and National Fire Protection Association (NFPA) 50A, the hydrogen and oxygen tube trailers have been sited at sufficient distances from each other and structures, air intakes, or safety-related equipment to preclude an unacceptable impact on safety-related functions or analyses.

The transportation route for the hydrogen gas tube vessel delivery to the storage facility has been established following the guidelines of Regulatory Guide 1.91. A discussion on establishing the transportation route is provided in Section 2.2.

10.4.12 REFERENCES

1. "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations - 1987 Revision," EPRI NP-5283-SR-A, September 1987.

2. "An Analysis of a Hydrogen Leak in the Turbine Building," LM-0542.

Table 10.4-1*

MAIN CONDENSER DESIGN PARAMETERS

MAIN CONDENSER	LOW PRESSURE SHELL	INTERMEDIATE PRESSURE SHELL	HIGH PRESSURE SHELL
Quantity	1	1	1
Type	Shell & tube	Shell & tube	Shell & tube
Features: three shell triple pressure, surface condenser			
Duty (Btu/hr)	2.571×10^9	2.544×10^9	2.610×10^9
Shell design			
Fluid	Steam	Steam	Steam
Turbine valve wide open flow rate (lb/hr)	2,784,090	2,784,090	2,784,090
Turbine maximum guaranteed load operating pressure	2.81 in Hga	3.56 in Hga	4.67 in Hga
Design pressure	29.5 in Hg vac	29.5 in Hg vac	29.5 in. Hg vac
Tube design			
Fluid	Water	Water	Water
Flow rate (gpm)	450,600	450,600	450,600
Operating pressure	15.15 psig	15.15 psig	15.15 psig
Design pressure	60 psig	60 psig	60 psig
Length (feet)	36	42	48
Inlet temperature (°F), design/ maximum	88.9/95	100.31/106.41	111.60/117.70
Hotwell storage volume at minimum level (gallons)	27,050	31,700	36,350
Overall Dimensions	36' tube sheet-to tube sheet x 29'-0" x 58'-8"H	41'-11¾" tube sheet-to -tube sheet x 29'-0" x 58'-8"H	47'-11¾" tube sheet-to -tube sheet x 29'-0" x 58'-8"H

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-1 (Cont'd)

MAIN CONDENSER DESIGN PARAMETERS

MAIN CONDENSER	LOW PRESSURE SHELL	INTERMEDIATE PRESSURE SHELL	HIGH PRESSURE SHELL
No. of Tubes	24940	24940	24940
Exhaust steam temperature w/o bypass (°F)			
Maximum	114.0	123.0	135.00
Exhaust Steam Temperature w/bypass (°F)			
Maximum	105.0	110.0	116.0
Material	Admiralty[(1) (2)] B.111	Admiralty[(1) (2)] B.111	Admiralty[(1) (2)] B.111
OD (inches)	1.125	1.125	1.125
Gauge (BWG)	18	18	18
Total effective surface (ft^2)	262,638	306,666	350,696
Tube velocity (fps)	7.01	7.01	7.01

(1) 320 Type 304 stainless steel, 20 BWG tubes in the impingement area.

(2) Unit 2 condenser contains some 20 BWG ASTM B543-85 C706000 90-10 copper-nickel tubes.

Table 10.4-2

MAIN CONDENSER EVACUATION SYSTEM DESIGN PARAMETERS *

MECHANICAL VACUUM PUMP	
Quantity	1
Type	Rotary water ring
Capacity	2000 cfm
Design suction pressure	0 in Hga
Design temperature	150°F
Motor power rating	200 hp
SEAL WATER COOLER	
Quantity	1
Type	Horizontal, single-pass, straight tube
Duty	570,000 Btu/hr
Shell design	
Fluid	Distilled condensate
Flow rate	60 gpm
Design pressure	300 psig
Design temperature	300°F
Tube design	
Fluid	Drywell chilled water
Flow rate	150 gpm
Design pressure	150 psig
Design temperature	300°F
SEAL WATER PUMP	
Quantity	1
Type	Centrifugal, single-stage
Capacity	60 gpm
Head	73 ft
Motor power rating	2 hp
STEAM JET AIR EJECTORS	
Quantity	2 trains (100% capacity each) 4 first-stage elements per train (25% capacity each element) 1 second-stage element per train (100% capacity)
Design first-stage suction pressure	1.0 in Hga
Design second-stage suction pressure	7 psig

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-2 (Cont'd)

MAIN CONDENSER EVACUATION SYSTEM DESIGN PARAMETERS *

Noncondensable gas flows measured at 70°F and 1 atmosphere	
Hydrogen	138.4 cfm
Oxygen	69.1 cfm
Dry air	75 cfm
Motive steam operating pressure	
Maximum/normal	200/110 psig
AIR EJECTOR CONDENSERS	
Quantity	2 (100% capacity each)
Type	Intercondenser only, horizontal, two-pass, single shell
Duty	15.7×10^6 Btu/hr
Shell design	
Steam flow rate	12,500 lb/hr
Noncondensable flow rate	724 lb/hr
Design pressure	50 psig & vacuum
Design temperature	600°F
Tube design	
Fluid	Condensate
Flow rate	14,821,800 lb/hr
Design pressure	700 psig
Design temperature	200°F

Table 10.4-3 *

STEAM SEAL SYSTEM DESIGN PARAMETERS

STEAM SEAL EVAPORATOR	
Quantity	1
Type	Horizontal, two-pass, U-tube, with appended drain tank
Tube design	
Fluid	Steam
Flow rate	55,000 lb/hr
Design pressure	150 psig
Design temperature	450°F
Shell design	
Fluid	Water
Flow rate	127 gpm
Design pressure	150 psig
Design temperature	450°F
STEAM PACKING EXHAUSTER CONDENSERS	
Quantity	2 (100% capacity each)
Type	Horizontal, two-pass, single shell
Shell design	
Flow rate: air	2927 lb/hr
Steam	8435 lb/hr
Design pressure	15 psig
Design temperature	200°F
Tube design	
Fluid	Condensate
Flow rate	14,885,226 lb/hr
Design pressure	700 psig
Design temperature	200°F
STEAM PACKING EXHAUSTERS	
Quantity	2 (100% capacity each)
Fan type	Vertical, centrifugal
Capacity, each: air	4300 lb/hr
Steam	2614 lb/hr
Motor power rating	40 hp

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-4

CIRCULATING WATER PUMPS DESIGN PARAMETERS

CIRCULATING WATER PUMPS	
Number of pumps per unit	4 (25% capacity each)
PUMP	
Type	Dry pit, mix flow
Rated flow and head, each	113,000 gpm at 110 feet
Rated speed	505 rpm
Power rating	3450 hp
MOTOR	
Type	Induction
Voltage/phase/frequency	13.2 kV/3 phase/60 Hz
Power rating	3500 hp

Table 10.4-5 *

COOLING TOWER DESIGN PARAMETERS

COOLING TOWERS	
Number of towers per unit	1
Type	Natural draft hyperbolic with cross-flow fill
SHELL	
Height	507.5 ft
Diameter	
Base	372 ft
Throat	201 ft
Top	220 ft
Material	Reinforced concrete
FILL	
Height	69 ft
Diameter	
Top	512 ft
Base	488 ft
Material	
Support	Reinforced concrete
Spacers	Glass reinforced polyester
Splash bars	Polyvinyl Chloride
RATED PERFORMANCE (PER TOWER)	
Flow rate	476,600 gpm
Wet-bulb temperature	75°F
Relative humidity	66%
Water temperature	
Entering	122.4°F
Leaving	88.9°F
Duty	7.9×10^9 Btu/hr
BASIN	
Height	9 ft
Diameter	488 ft
Capacity	7.2×10^6 gal.

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-6

COOLING TOWER MAKEUP SYSTEMS DESIGN PARAMETERS

PERKIOMEN CREEK MAKEUP PUMPS	
Number of pumps	3 (50% capacity each)
PUMP	
Type	Wet-pit, vertical turbine
Rated flow and head, each	14,600 gpm at 440 ft
Rated speed	1180 rpm
Power rating	1915 hp
MOTOR	
Type	Induction
Voltage/phase/frequency	4.0 kV/3 phase/60 Hz
Power rating	2000 hp
SCHUYLKILL RIVER MAKEUP PUMPS (LARGE CAPACITY)	
Number of pumps	3 (29.8% capacity each)
PUMP	
Type	Wet-pit, vertical turbine
Rated flow and head, each	11,300 gpm at 224 ft
Rated speed	880 rpm
Power rating	775 hp
MOTOR	
Type	Induction
Voltage/phase/frequency	2.3 kV/3 phase/60 Hz
Power rating	800 hp
SCHUYLKILL RIVER MAKEUP PUMPS (SMALL CAPACITY)	
Number of pumps	2 (10.6% capacity each)
PUMP	
Type	Wet-pit, vertical turbine
Rated flow and head, each	4000 gpm at 224 ft
Rated speed	1180 rpm
Power rating	320 hp
MOTOR	
Type	Induction
Voltage/phase/frequency	2.3 kV/3 phase/60 Hz
Power rating	350 hp

Table 10.4-7 *

CONDENSATE CLEANUP SYSTEM DESIGN PARAMETERS

FILTER/DEMINERALIZER	
Quantity	8
Type	Non-precoat elements
Design flow rate, each	4315 gpm
Design temperature	150°F
Design pressure	700 psig
<u>PRECOAT TANK</u>	
Quantity	1
Type	Cylindrical
Capacity	595 gal (approx)
Diameter/height	54 in/60 in
Design pressure	Atmospheric
Design temperature	105°F
<u>PRECOAT PUMP</u>	
Quantity	1
Type	Centrifugal
Capacity	1410 gpm
Head	60 ft
Motor power rating	30 hp
<u>HOLDING PUMP</u> (Abandoned in place)	
<u>DEEP BED DEMINERALIZERS</u>	
Quantity	8
Type	Deep Bed, Resin Beads
Design flow rate, each	4315 gpm (45 gpm/ft^{2})
Design temperature	150°F
Design pressure	700 psig

Table 10.4-7 (Cont'd)

CONDENSATE CLEANUP SYSTEM DESIGN PARAMETERS

SPENT RESIN TANKS	
Quantity	4
Type	Cylindrical
Capacity (Operating)	450 ft^3
Diameter/height	7'11"/9'-9"
Design Temperature	110°F
Design Pressure	Atmospheric
REFILL OVERFLOW TANK	
Quantity	1
Type	Cylindrical
Capacity	16 ft^3
Diameter/height	2'/5'(str)
Design Temperature	110°F
Design Pressure	Atmospheric
RESIN MEASURING TANK	
Quantity	1
Type	Cylindrical
Capacity (Operating)	105 ft^3
Diameter/height	4'6"/6'-6" str
Design Pressure	100 psig
Design Temperature	130°F
LAYUP PUMP	
Quantity	2
Type	Centrifugal
Capacity	3000 gpm
Head	58 ft
Motor Power Rating	60 hp
EDUCTOR PUMP	
Quantity	1
Type	Centrifugal
Capacity	150 gpm
Head	231 ft
Motor Power Rating	20 hp

Table 10.4-7 (Cont'd)

CONDENSATE CLEANUP SYSTEM DESIGN PARAMETERS

RESIN TRANSFER PUMP

Quantity (Unit Only)	1
Type	Centrifugal
Capacity	200 gpm
Head	125 ft
Motor Power Rating	15 hp

DEWATERING PUMP

Quantity	1
Type	Centrifugal
Capacity	240 gpm
Head	116 ft
Motor Power Rating	15 hp

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-8 *

CONDENSATE SYSTEM DESIGN PARAMETERS

CONDENSATE PUMPS	
Quantity	3 (33½% capacity each)
Type	Seven-stage, vertical, canned centrifugal
Capacity, each	11,570 gpm
Head	1260 ft
motor power rating	4500 hp
CONDENSATE DRAIN TANK	
Quantity	1
Type	Horizontal, cylindrical
Volume	420 gal
Design pressure	Atmospheric
Design temperature	200ºF

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-9 *

FEEDWATER SYSTEM DESIGN PARAMETERS

DRAIN COOLERS 1AE107, 1BE107, and 1CE107

Quantity	3 (33-1/3% capacity each)
Type	Low pressure, horizontal, two-pass, U-tube, removable shell
Duty at VWO, each	84,091,000 Btu/hr
Shell side design	
Fluid	Drains
Flow rate each at VWO	1,966,506 lb/hr
Design pressure	50 psig and vacuum
Design temperature	300°F
Tube side design	
Flow rate each at VWO	4,941,324 lb/hr
Design pressure	700 psig
Design temperature	300°F

FEEDWATER HEATERS 11AE101, 11BE101, and 11CE101

Quantity	3 (33-1/3% capacity each)
Type	Low pressure horizontal two-pass, U-tube, mounted in condenser neck, removable tube bundle
Duty at VWO, each	$137.320x10^6$ Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Extraction steam and moisture/ 177,176 lb/hr Cascading drains in/1,789,330 lb/hr Cascading drains out/1,966,506 lb/hr
Design pressure	50 psig and vacuum
Design temperature	300°F
Tube side design	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	700 psig
Design temperature	300°F

* The values in this table represent equipment design parameters. The equipment has been evaluated for the operating conditions described per Reference 10.2-9.

Table 10.4-9 (Cont'd)

FEEDWATER SYSTEM DESIGN PARAMETERS

FEEDWATER HEATERS 12AE102, 12BE102, and 12CE102

Quantity	3, 33-1/3% capacity each
Type	Low pressure, horizontal, two-pass, U-tube, mounted in condenser neck, removable tube bundle
Duty at VWO, each	$186.392x10^6$ Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Extraction steam and moisture/ 177,678 lb/hr Cascading drains in/1,611,563 lb/hr Cascading drains out/1,789,330 lb/hr
Design pressure	50 psig and vacuum
Design temperature	300°F
Tube side design	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	700 psig
Design temperature	300°F

FEEDWATER HEATERS 13AE103, 13BE103, and 13CE103

Quantity	3, 33-1/3% capacity each
Type	Low pressure, horizontal, two-pass, U-tube, removable shell
Duty at VWO, each	$316.584x10^6$ Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Extraction steam and moisture/ 252,020 lb/hr Cascading drains in/1,359,633 lb/hr Cascading drains out/1,611,650 lb/hr
Design pressure	75 psig and vacuum
Design temperature	320°F
Tube side design	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	700 psig
Design temperature	320°F

Table 10.4-9 (Cont'd)

FEEDWATER SYSTEM DESIGN PARAMETERS

<u>FEEDWATER HEATERS 14AE104, 14BE104, and 14CE104</u>

Quantity	3, 33-1/3% capacity each
Type	Low pressure, horizontal, two-pass, U-tube, removable shell
Duty at VWO, each	211.174x10^{o} Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Extraction steam/149,714 lb/hr Miscellaneous drains/558,770 lb/hr Cascading drains in/651,149 lb/hr Cascading drains out/1,359,633 lb/hr
Design pressure	125 psig and vacuum
Design temperature	375°F
Tube side design:	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	700 psig
Design temperature	355°F

<u>FEEDWATER HEATERS 15AE105, 15BE105, and 15CE105</u>

Quantity	3, 33-1/3% capacity each
Type	Low pressure, horizontal, two-pass, U-tube, removable shell
Duty at VWO, each	235.227x10^{6} Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Cross-around steam/276,538 lb/hr Cascading drains in/374,611 lb/hr Cascading drains out/651,149 lb/hr
Design pressure	217 psig and vacuum
Design temperature	410°F
Tube side design:	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	700 psig
Design temperature	410°F

Table 10.4-9 (Cont'd)

FEEDWATER SYSTEM DESIGN PARAMETERS

REACTOR FEED PUMPS 1AP101, 1BP101, and 1CP101

Quantity	3, 33-1/3% capacity each
Type	Single-stage, double suction, centrifugal, variable-speed, horizontal
Capacity, each	12,900 gpm
Head	2314 ft
Driver	Dual admission steam turbine rated at 8000 hp

FEEDWATER HEATERS 16AE106, 16BE106, and 16CE106

Quantity	3, 33-1/3% capacity each
Type	High pressure, horizontal, two-pass, U-tube, removable shell
Duty at VWO, each	$289.155x10^6$ Btu/hr
Shell side design	
Fluid/flow rate at VWO, each	Extraction steam/374,611 lb/hr Drains out/374,611 lb/hr
Design pressure	425 psig and vacuum
Design temperature	490°F
Tube side design:	
Fluid	Feedwater
Flow rate at VWO, each	4,941,342 lb/hr
Design pressure	2100 psig
Design temperature	490°F

REACTOR FEED PUMP SEAL INJECTION BOOSTER PUMP 10P176

Quantity	1, 100% capacity
Type	Single-stage, centrifugal horizontal
Capacity	450 gpm
Head	235 ft
Driver	Electric motor at 50 hp

VWO - Valves wide open

Table 10.4-10

AUXILIARY STEAM SYSTEM DESIGN PARAMETERS

AUXILIARY BOILERS	
Quantity	3
Steam output, each	45,000 lb/hr
Design pressure	300 psig
Steam quality	99.5%
Fuel	No. 2 fuel oil
Atomizer	Steam or air
Fan type	Centrifugal, air foil design
Fan rating	12,900 cfm @ 11.5 in . water gauge
Fan motor power rating	40 hp
DEAERATOR	
Quantity	1
Type	Horizontal spray tray, uncontrolled inlet
Capacity	148,500 lb/hr
Storage	1650 gallons
Design pressure	50 psig
Water temperature	221°F
Oxygen guarantee	0.005 cm^3/l
AUXILIARY BOILER FEED PUMPS	
Quantity	3
Type	Vertical, canned suction, centrifugal, multistage
Capacity, each	150 gpm
Head	840 feet
Motor power rating	60 hp
BLOW-OFF TANK	
Quantity	1
Type	Atmospheric, vertical
Capacity	6000 lb/hr
Design pressure	75 psig

Figure 10.1-1
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Figure 10.1-2
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Figures 10.2-1 thru 10.2-3

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Figure 10.2-4
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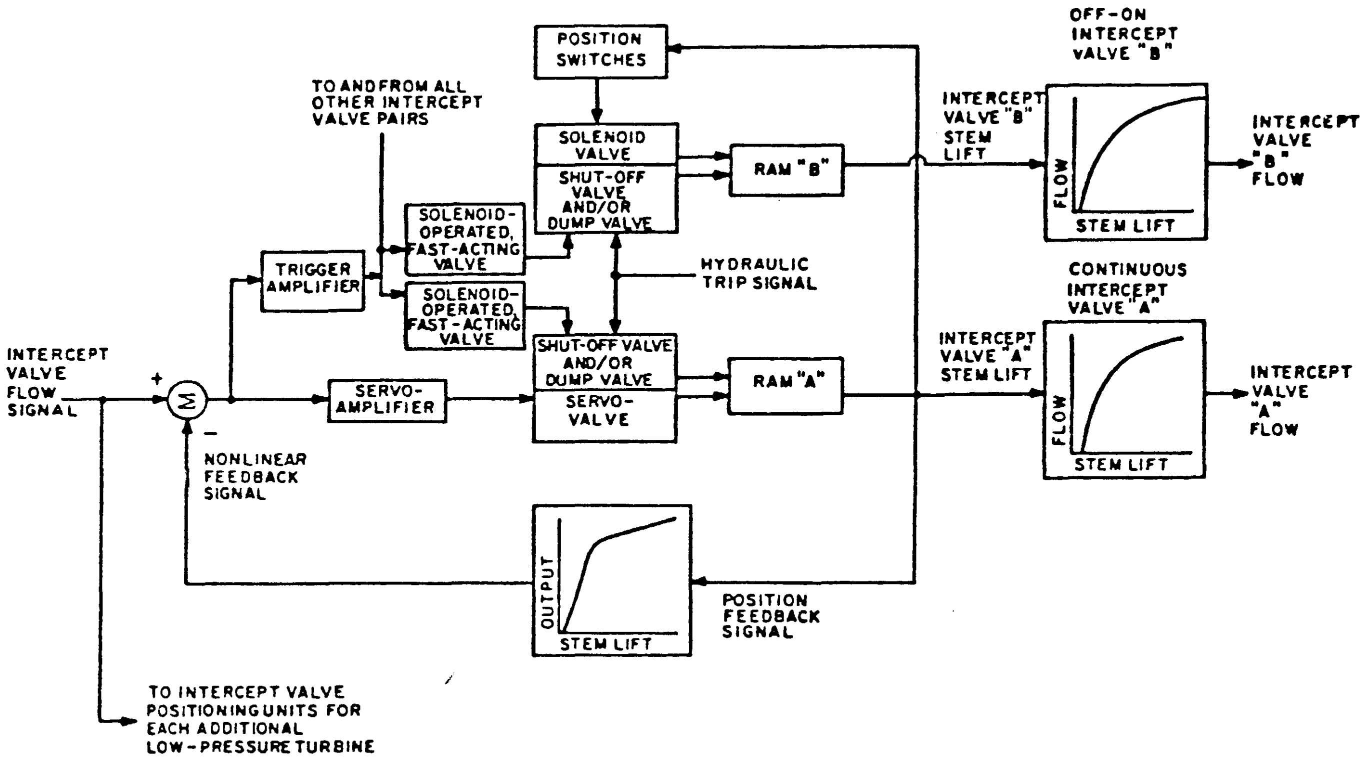

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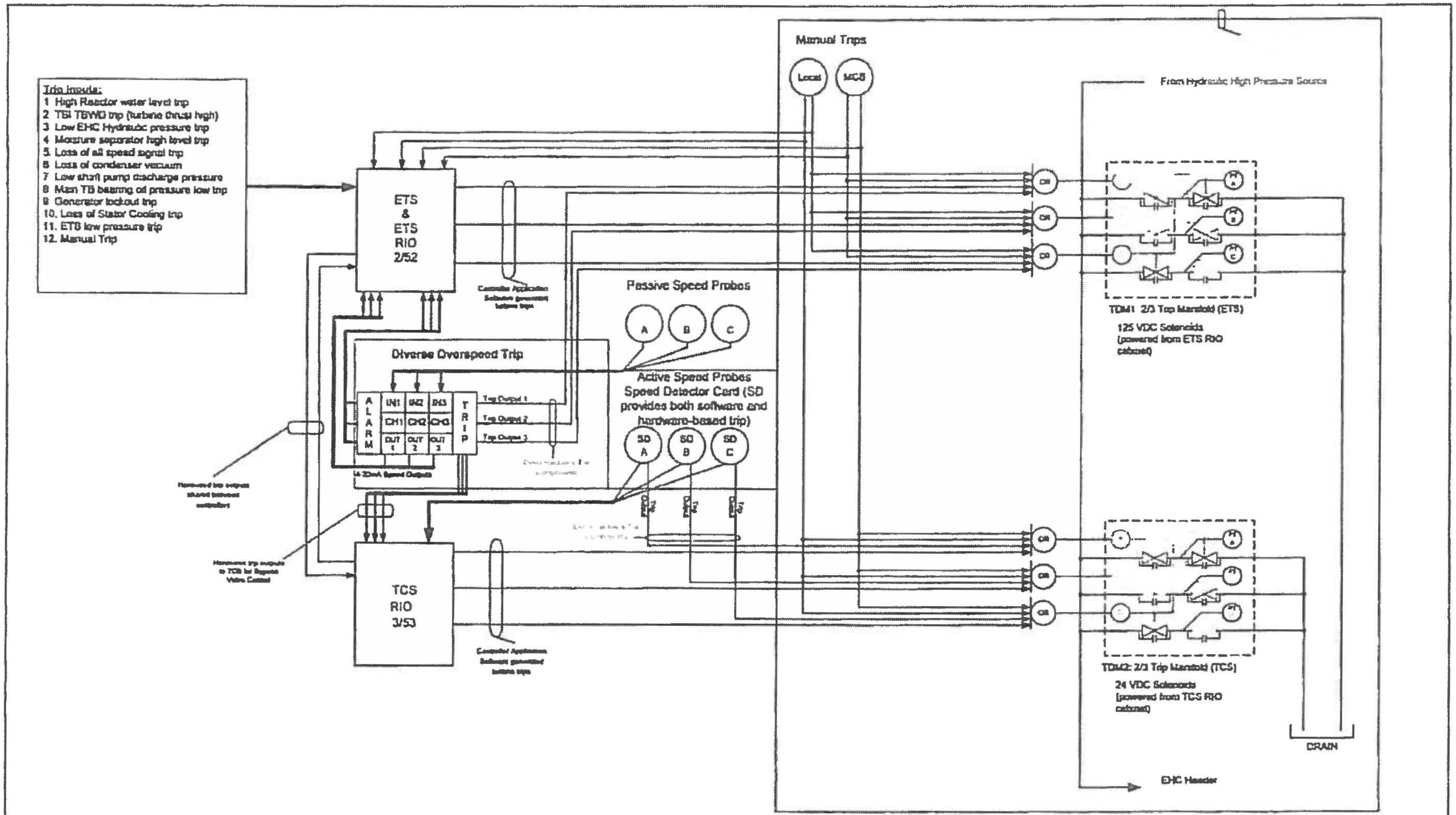
INTERCEPT VALVE POSITIONING

FIGURE 10.2-10



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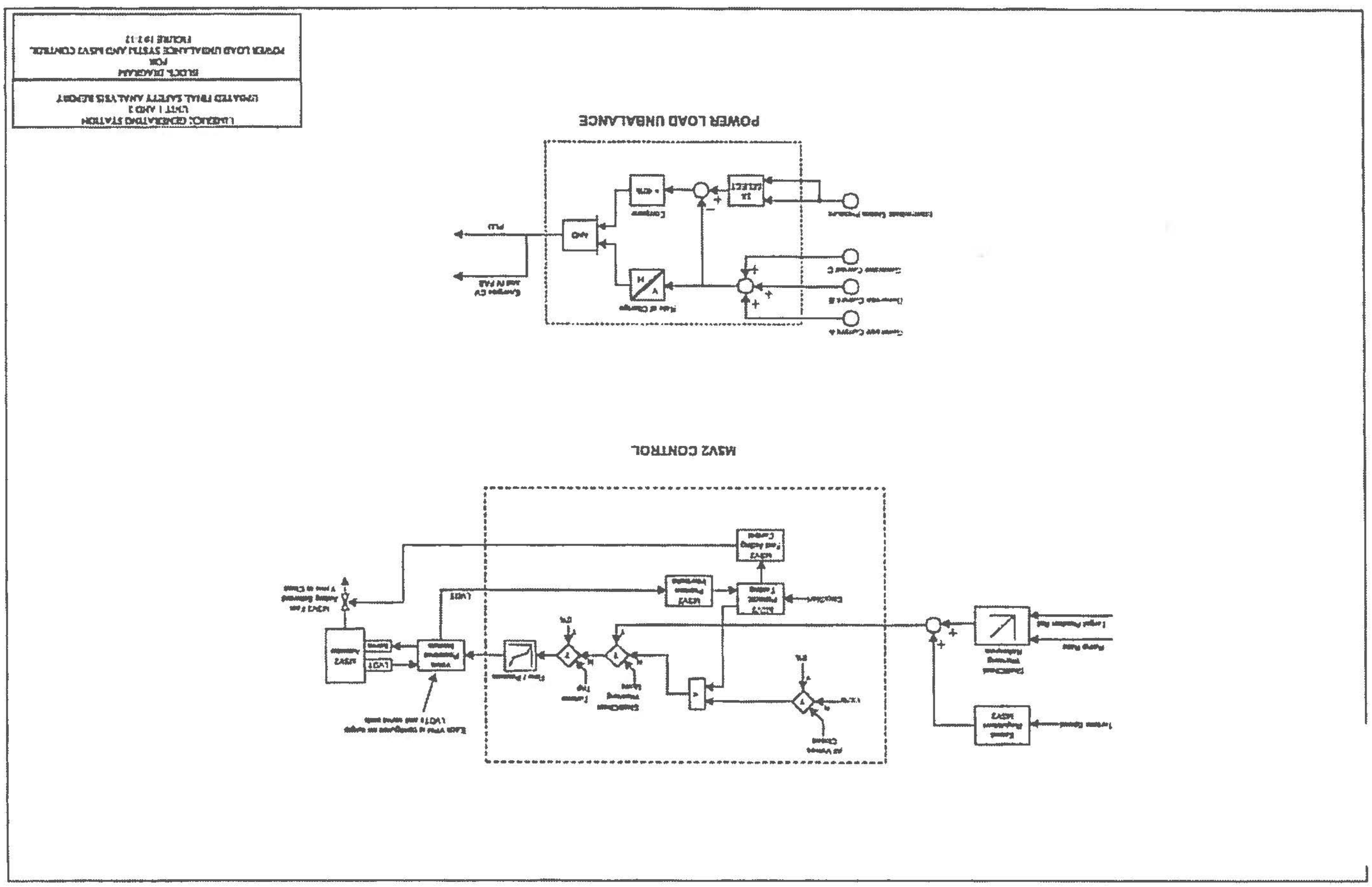
EMERGENCY TRIP SYSTEM BLOCK DIAGRAM
FIGURE 10.2-11 REV. 18 09/06



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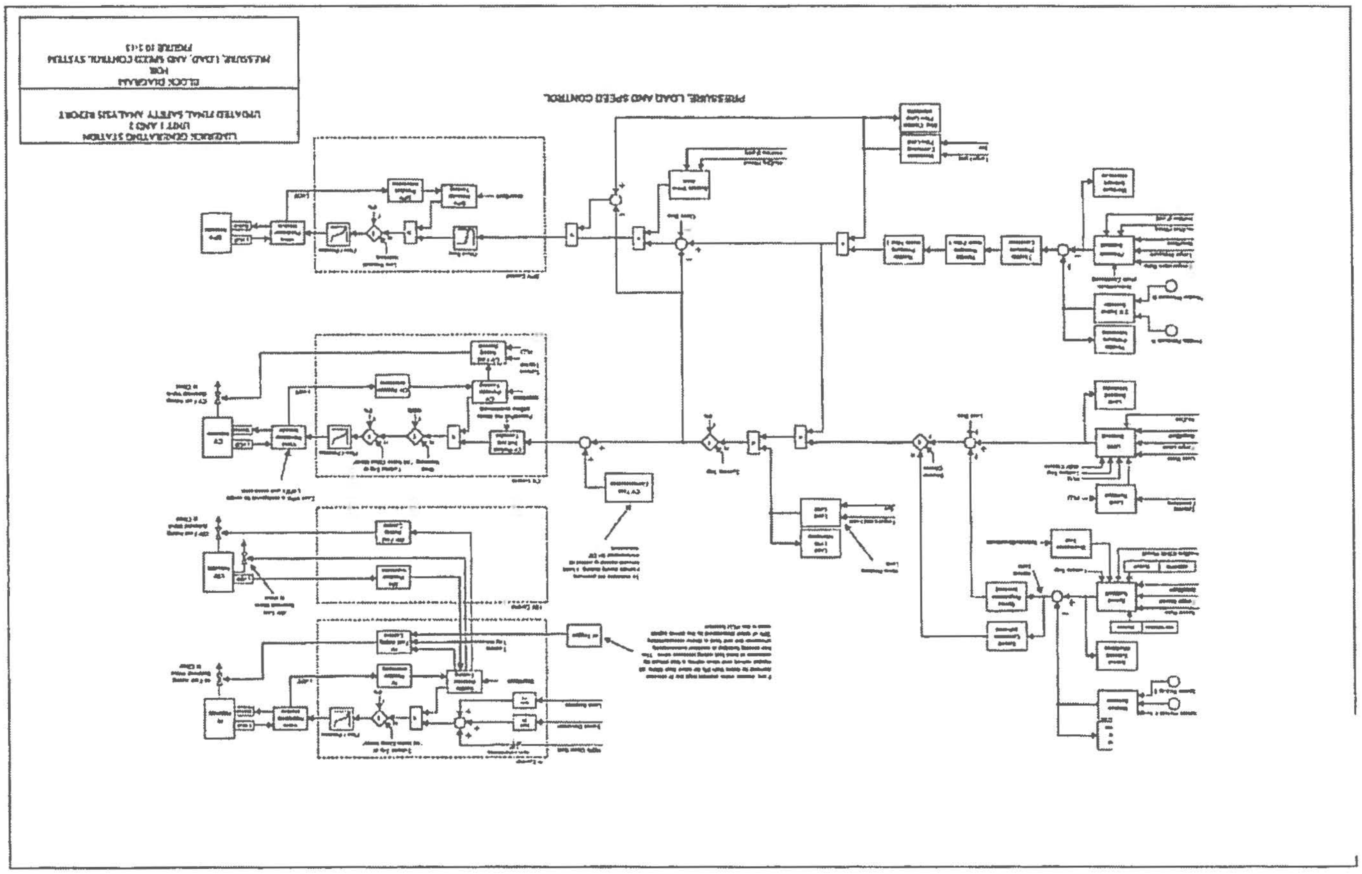
BLOCK DIAGRAM FOR
POWER LOAD UNBALANCE SYSTEM AND MSV2 CONTROL
FIGURE 10.2-12 REV. 18 09/16



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BLOCK DIAGRAM FOR
PRESSURE LOAD AND SPEED CONTROL SYSTEM
FIGURE 10.2-13 REV. 18 09/16

Figure 10.3-1

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Figures 10.4-1 thru 10.4-8

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