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CHAPTER 10 - STEAM AND POWER CONVERSION SYSTEM

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DRAWINGS CITED IN THIS CHAPTER*

* The listed drawings are included as "General References" only; i.e., refer to the drawings to obtain additional detail or to obtain background information. These drawings are not part of the USAR. They are controlled by the Controlled Documents Program.

<u>DRAWING*</u>	<u>SUBJECT</u>
M05-1002	Main Steam
M05-1003	Extraction Steam
M05-1004	Reactor Feedwater System
M05-1005	Condensate System
M05-1006	Condensate Booster System
M05-1007	Condensate Polishing
M05-1008	Feedwater Heater Drains - Turbine Cycle
M05-1009	Feedwater Heater Miscellaneous Vents & Drains (DV)
M05-1010	Circulating Water System
M05-1013	Hydrogen Generator Fill
M05-1018	Condenser Vacuum

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10 STEAM AND POWER CONVERSION SYSTEM

10.1 SUMMARY DESCRIPTION

The components of the power conversion system are designed to produce electrical power utilizing the steam generated by the reactor, condense that steam into water, and return the water to the reactor as heated feedwater, with a major portion of its gaseous, dissolved, and particulate impurities removed in order to satisfy the reactor water quality requirements.

The power conversion system includes the turbine-generator, main condenser, air ejector, steam packing exhaustor, off-gas condenser, main steam system, turbine bypass system, turbine gland sealing system, condensate filters, condensate demineralizers, and the condensate and feedwater pumping and heating equipment. Heat rejected to the main condenser is removed by a closed-cycle circulating water system utilizing Lake Clinton. Figure 10.1-1 shows the power conversion system.

Steam, generated in the reactor, is supplied to the high-pressure turbine. Steam, leaving the high-pressure turbine, passes through a combined moisture separator/reheater prior to entering the two low-pressure turbines. A portion of the turbine steam is extracted for feedwater heating. The moisture separator drains, and the reheater drains are directed to the feedwater heaters. The drain from each feedwater heater is cascaded through the next low-pressure feedwater heater to the main condenser.

Steam exhausted from the low-pressure turbines is condensed and deaerated in the single-pass condenser. The condensate pumps take suction from the condenser hotwell, delivering the condensate through the steam packing exhaustor condenser, steam jet air ejector condensers, off-gas recombiner, condensate filters, and condensate demineralizers to the condensate booster pumps, which discharge through the five stages of low-pressure feedwater heaters to the reactor feed pumps. Two reactor feed pumps are steam-turbine driven. A motor-driven reactor feed pump is also provided for startup and standby use. The pumps discharge through the sixth-stage, high-pressure, feedwater heater to the reactor.

Normally, the turbine and auxiliaries will use all the steam being generated by the reactor; however, an automatic pressure-controlled turbine bypass system is provided to discharge up to 28.8% of rated steam flow directly to the condenser.

Individual components of the steam and power conversion system are based on a proven conventional design, acceptable for use in large, central station power plants.

All auxiliary equipment is sized for maximum calculated unit capability with turbine valves wide open as shown in the heat balance shown in Figure 10.1-2.

The steam and power conversion system is designed to utilize 3337 MWt available from the reactor coolant system for long-term loading conditions. The steam and power conversion system is designed with the capability of accepting 128.5% of the normal rated thermal input for transients and short-term loading conditions.

The necessary biological shielding for personnel protection is provided for the components of the power conversion system including the main turbines, reactor feed pump turbines, moisture

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separators and reheaters, feedwater heaters, condensers, and steam jet air ejectors. (See Section 12.3.)

The inlet pressure at the turbine main steam valves will not exceed rated pressure at any load as the turbine control valves are controlling the reactor pressure. The steam generated by the reactor is released through the turbine. At full rated flow (load) the control valves have approximately 3% flow margin remaining and can still control the reactor pressure. The turbine control valves wide open position is NOT a controlled operating condition and should be avoided.

Table 10.1-1 summarizes the important design and performance characteristics of the power conversion system. The principal flow quantities and fluid energy levels are shown on the turbine cycle heat balances in Figures 10.1-2 and 10.1-3 for the "valves wide open" and guaranteed reactor rating conditions respectively.

The majority of the steam and power conversion system is located in the turbine building which is a non-seismic, non-safety-related building.

Non-Safety Related Instrumentation has been provided to measure flow, pressure, differential pressure, temperature, and level throughout the steam and condensate system. The instrumentation provide input signals to the plant computer, recorders and control systems which maintain the normal operation of the plant.

Safety-Related Instrumentation has been provided to measure pressure and flow in the Main Steam lines and pressure in the turbine first stage and the main condenser. The instrumentation provide input signals to the Containment and Reactor Vessel Isolation Control System, the Reactor Protection System, and The Rod Control and Information System.

This instrumentation is further described in the following sections: Containment and Reactor Vessel Isolation Control System, 7.1.2.1.2, Reactor Protection System, 7.1.2.1.1, and Rod Control and Information System, 7.1.2.1.6.

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

1.	Turbine data	
a.	Manufacturer	GE
b.	Type/LSB length (in.)	TC4F/43
c.	Number of turbines	1-HP, 2-LP
2.	Gross generator output (kW)	1,138,345
3.	Turbine cycle heat rate (Btu/kW-hr)	10,003
4.	Design condenser pressure (in. Hg abs)	2.28
5.	Final feedwater temperature (°F)	425.4
6.	Steam conditions at throttle valve	
a.	Flow (lb/hr)	13,629,096
b.	Pressure (psia)	962
c.	Temperature (°F)	539.9
d.	Enthalpy (Btu/lb)	1190.8
e.	Moisture content (%)	0.53
7.	Turbine cycle arrangement	
a.	Steam reheat, stages	1
b.	Number of feedwater heating stages	6
c.	Heater drain system	Fully cascaded
d.	Feedwater heater stages in condenser neck	1 with external drain cooler
8.	Type of condensate demineralizer	Deep bed
9.	Main system bypass capacity (%)	28.8

* At rated turbine steam flow.

10.2 TURBINE-GENERATOR

10.2.1 Design Bases

10.2.1.1 Safety Design Bases

The turbine-generator is not required to effect or support safe shutdown of the reactor or to mitigate the consequences of an accident. The main turbine has an integral mono-block design and is not considered a potential source of high energy missiles. The turbine is designed to minimize the possibility of a failure of a turbine rotor with integral wheels. Turbine rotor integrity is discussed in Subsection 10.2.3. The effects of a postulated high energy missile are discussed in Section 3.5.

10.2.1.2 Power-Generation Design Bases

The turbine-generator is designed for the following conditions:

a.	Turbine-generator output, kW	1,138,345
b.	Throttle flow, lb/hr	13,629,096
c.	Steam Conditions at throttle pressure, psia	962
d.	Temperature, °F	539.9
e.	Moisture content, %	0.53
f.	Enthalpy, Btu/lb	1190.8
g.	Exhaust pressure, in. Hg abs	2.28
h.	Stages of reheat	1
i.	Stages of feedwater heating	6

These conditions correspond to the guaranteed Turbine-Generator rating (100% load) as shown in Figure 10.1-3.

10.2.1.3 Functional Limitations Imposed by Design or Operational Characteristics of the Reactor Coolant System

The turbine control valves are capable of full stroke openings and closure of not greater than 7 seconds for adequate pressure control performance.

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10.2.1.3.1 Turbine Stop Valve Fast Closure

During any event resulting in turbine stop valve fast closure from 100% steam flow, turbine inlet steam flow will not be reduced faster than that shown in Figure 10.2-1.

10.2.1.3.2 Turbine Control Valve Closure

10.2.1.3.2.1 Turbine Control Valve Fast Closure

During any event resulting in turbine control valve fast closure from 100% steam flow, turbine inlet steam flow will not be reduced faster than that shown in Figure 10.2-2.

10.2.1.3.2.2 Turbine Control Valve Normal Closure

The turbine control valve steam flow shutoff, upon a step reduction to zero in pressure regulation demand (no resulting bypass steam flow demand), will not be reduced slower than that shown in Figure 10.2-3. Any single control system failure or turbine-generator event will not cause a faster steam flow reduction than that shown in Figure 10.2-3 without initiating an immediate reactor trip.

10.2.1.3.3 Automatic Load Maneuvering Capability

Deleted

10.2.1.4 Applicable Codes

The turbine-generator and associated equipment is designed and manufactured in accordance with General Electric Company standards and specifications.

10.2.2 Description

10.2.2.1 Turbine-Generator

The turbine-generator consists of the turbine, moisture separator reheater, generator, exciter, controls, and associated subsystems required for the support of these components.

The steam turbine is an 1800 rpm, tandem compound, four flow reheat steam turbine with 43 inch last stage blades. Steam enters the high-pressure turbine from four stop and control valve assemblies and passes through this section, with a portion of the steam extracted within the high-pressure turbine for the final stage (sixth, 6A/6B) of feedwater heating, as shown in Drawing M05-1003. The high-pressure turbine exhaust flow is directed to the moisture separator reheaters. A portion of high-pressure turbine exhaust flow is extracted for the fifth stage (5A/5B) of feedwater heating.

There are no air-operated stop valves in the extraction steam lines to any feedwater heater. There are no valves of any kind in the extraction steam lines to the first feedwater heater (1A/1B). Refer to Drawing M05-1003. Closure time of the extraction steam check valves and their effect on stable turbine operation are discussed in 10.2.2.4. (Q&R 040.71)

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The moisture separator reheaters dry the exhaust steam and reheat it to approximately 466°F (66°F superheat). This process increases the turbine heat rate (efficiency). The turbine is also designed to be operated in the non-reheat mode if required.

A portion of the reheated steam is extracted for the auxiliary turbines which drive the reactor feed pumps and for the auxiliary steam system for radwaste evaporator heating. The remainder of the reheated steam is divided equally between the two low-pressure turbines. The steam passes through the low pressure turbines and exhausts into the main condenser, with a portion of the steam extracted within the low pressure turbines for the first four stages of feedwater heating. In addition to the external moisture separator reheaters, the turbines are designed to separate water from the steam and drain it to the next lowest extraction point.

The generator is a direct-driven, three-phase, 60-Hz, 22,000 volts, 1800 rpm, synchronous generator with a water cooled stator and a hydrogen cooled rotor. It is rated at approximately 1265 MVA at 0.9 power factor, 75 psig hydrogen pressure, and an 0.63 short circuit ratio.

The generator exciter system is a stationary silicon-diode rectifier, which is directly connected to the generator rotor. The rectifiers are rated at 3580 kW at 545 volts and are cooled by the generator stator cooling water system. The armature and field are air cooled in a closed ventilation system with the heat removed by an air to water heat exchanger.

10.2.2.2 Bulk Hydrogen System

The hydrogen system is designed to provide the necessary flow and pressure at the main turbine generator for purging carbon dioxide during startup and supplying makeup for generator leakage during normal operation.

The system consists of hydrogen supply piping with all the necessary valves, instrumentation, gas purity measuring equipment and hydrogen gas dryers.

The hydrogen system components, piping, valves and instrumentation are shown in Drawing M05-1013.

A truck pad for hydrogen supply trailers is located north of the plant and outside the security fence (see Figure 1.2-3). This facility supplies hydrogen to the Hydrogen Water Chemistry (HWC) system and the bulk hydrogen system. The HWC truck pad is located away from the nearest building containing safety-related or Class 1E components and is protected by a fence and vehicle barriers.

The hydrogen piping (see Drawing M05-1013) from the outdoor excess flow manifold to the turbine building wall is underground. Hydrogen supply piping within the turbine building is guard piped up to the hydrogen-carbon dioxide control manifold on 762'. The guard pipe is tied into a line which vents to atmosphere through a flame arrester located on the turbine building roof.

The gas filled unit is protected by temperature rate-of-rise and ionization detectors. The hydrogen seal oil unit, located at the 762' elevation, is protected with an automatic deluge system.

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Fires and explosions during filling and/or purging the generator are prevented by inerting the generator with CO₂ so that a flammable mixture cannot be produced. Unwanted hydrogen is vented outside through a flame arrestor.

10.2.2.3 Electrohydraulic Control System

The turbine-generator uses an electrohydraulic control (EHC) system which, in coordination with the NSSS steam bypass and pressure control system, controls the turbine speed, load, pressure, and flow for startup and normal operations. The EHC system operates the turbine stop valves, control valves, and combined stop and intercept valves. Turbine-generator supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

The load-control unit accepts the speed-acceleration error signal from the speed control unit and compares the signal with the preselected load demand signal, which is provided to the NSSS steam bypass and pressure control system. The load-control unit also accepts limit signals (e.g., load limit, pressure limit, power load unbalance limit, etc.) and combines them with the load demand signal to generate flow reference signals, which are provided to the flow control unit.

The flow control unit positions the turbine steam control valves at the required position to satisfy each valve flow reference signal from the load-control unit. It consists of the individual valve positioning units, which essentially are electrohydraulic, closed-loop, servo-mechanism valve position-control systems.

10.2.2.4 Turbine Overspeed Protection System

In addition to the normal speed control function provided by the turbine electrohydraulic control system, a separate turbine overspeed protection system is included. The turbine overspeed system is a highly reliable and redundant system which is classified as non-safety related.

Protection against turbine overspeed is provided by the mechanical overspeed trip and electrical backup overspeed trip. Redundancy is achieved by using two independent channels from the signal source to the output device. The sensing device, line and output device are of a different nature for each individual channel in order to increase reliability.

The overspeed sensing devices are located in the front bearing standard, and therefore are protected from the effects of missiles or pipe breaks. The hydraulic lines are fail safe, that is if one were to be broken, loss of hydraulic pressure would result in turbine trip. The electric trip signals are redundant. The 125-V circuit could be disabled by damage to the wiring, but the 24-V system is fail safe; i.e., loss of signal results in turbine trip. These features provide inherent protection against failure of the overspeed system caused by missiles.

The mechanical overspeed trip is an unbalanced ring which is held concentric with the shaft by a spring. When the speed reaches the trip speed (109.7% to 110.7% of rated), the centrifugal force of the ring overcomes the force of the spring, and the ring snaps to an eccentric position. The ring then strikes the trip finger which operates the mechanical trip valve. This releases the fluid pressure on the disk dump valves for main stop and control valves and intermediate stop and intercept valves, thereby closing the turbine steam valves.

The electrical backup overspeed trip is part of the auxiliary speed sensor unit which consists of three independent circuits. Each circuit monitors a separate speed signal voltage and activates

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voltage comparators at various speed levels. The output of these circuits is used in a two-out-of-three logic configuration in tripping and monitoring of the turbine. As soon as two of the three differential voltage comparators detect a speed greater than the reference overspeed setting the tripping and monitoring circuits will deenergize the coil of the electrical trip solenoid valve. When the coil is deenergized, the electrical trip valve operates to release the fluid pressure on the actuator of the steam valves.

Two air relay dump valves are provided which actuate on turbine trip. The valves control air to the extraction steam check valves which limit contributions to turbine overspeed from steam and water in the extraction lines and feedwater heaters. The air is vented from the extraction steam check valve power assist actuators within 2 seconds, initiating check valve closure.

Additional overspeed protection is provided for conditions of load rejection by the following actions:

- a. Above 10% load, fast closing of the intercept valves is initiated any time an excess error is detected between the intercept valve and the position signal due to load rejection.
- b. For an unbalance between turbine power input and generator power output in excess of 40% of rated, the power/load unbalance relay will operate. The power/load unbalance relay:
 1. actuates the control valve solenoid valves to cause fast closing of the control valves;
 2. removes any increasing signals for the load set motor and runs it towards the 2% load setting.

10.2.2.5 Turbine Protection System

In addition to the overspeed trip signals discussed above, the emergency trip system closes the main stop and control valves and the intermediate stop and intercept valves, shutting down the turbine on the following signals:

- a. loss of vacuum trip;
- b. excessive thrust bearing wear;
- c. prolonged loss of generator stator coolant at loads in excess of a preset value;
- d. remote manual trip on the control panel;
- e. 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);
- f. low bearing oil pressure;

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- g. loss of both speed signals, when not in standby control mode;
- h. high exhaust hood temperature;
- i. deleted;
- j. loss of either the 24 vdc or 125 vdc (when below 75% of rated speed) control power supply;
- k. operation of the manual mechanical trip at the front standard;
- l. high level in moisture separators;
- m. high reactor water level;
- n. start of RCIC injection to the reactor vessel;
- o. generator trip;
- p. low shaft oil pump discharge pressure, when speed is above 75% of rated speed.

When the emergency trip system (ETS) is activated, it overrides all operating signals and trips the main stop valves, reheat stop valves, control valves, and intercept valves directly by way of their disc/dump valves. The valves are totally independent of each other; each valve having their own separate hydraulic actuator. The valve arrangement provides a full redundancy in that the main stop valves are in series with the control valves and reheat stop valves are in series with the intercept valves. The valve closure time for all valves is 0.3 seconds or less, and within the limits shown on Figures 10.2-1 and 10.2-2.

10.2.2.6 Turbine-Generator Supervisory Instruments

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

- 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. valve positions;
- h. shell and rotor differential expansion;

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- i. shaft speed, 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. gland steam condenser vacuum;
- p. steam chest pressure, and
- q. seal oil pressure.

10.2.2.7 Testing Provisions

Provisions have been made for testing each of the following devices when the unit is operating:

- a. main stop and control valves,
- b. bypass valves,
- c. intermediate stop and intercept valves,
- d. overspeed governor,
- e. turbine extraction system nonreturn valves,
- f. condenser vacuum trip,
- g. thrust bearing wear detector,
- h. master trip solenoid,
- i. lubricating oil system pumps, and
- j. EHC fluid system pumps.

A turbine trip bypass switch is provided to allow bypass of the following electrical turbine trip signals during on-line turbine testing:

- a. excessive thrust bearing wear,
- b. loss of generator stator cooling,
- c. loss of hydraulic fluid supply pressure,

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- d. low bearing oil pressure,
- e. loss of both speed signals, when not in standby control mode,
- f. high exhaust hood temperature,
- g. deleted,
- h. high level in moisture separators,
- i. low shaft oil pump discharge pressure, when >75% rated speed,
- j. loss of 125Vdc power when <75% rated speed,
- k. Electrical Trip Solenoid Valve (ETSV) test trip,
- l. Electrical Backup Overspeed Trip (BOST), and
- m. 24Vdc input from Master Trip from the operator's console (125Vdc input is not bypassed).

10.2.3 Turbine Rotor Integrity

10.2.3.1 Materials Selection

Turbine rotors with integral wheels for turbines operating with light-water reactors are made from vacuum melted or vacuum degassed Ni-Cr-Mo-V alloy steel by processes which minimize flaw occurrence and provide adequate fracture toughness. Tramp elements are controlled to the lowest practical concentrations consistent with good scrap selection and melting practices, and consistent with obtaining adequate initial and long-life fracture toughness for the

environment in which the parts operate. The turbine rotor with integral wheel material has the lowest fracture appearance transition temperatures (FATT) and highest Charpy V-notch energies obtainable on a consistent basis from waterquenched Ni-Cr-Mo-V material at the sizes and strength levels used. Since actual levels of FATT and Charpy V-notch energy vary depending upon the size of the part and the location within the part, etc., these variations are taken into account in accepting specific forgings for use in turbines for nuclear application. Charpy tests are performed essentially in accordance with Specification ASTM A-370.

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of materials described in Subsection 10.2.3.1 to produce a balance of adequate material strength and toughness to ensure safety while simultaneously providing high reliability, availability, and efficiency during operation. All of the rotating components have sufficient margin to tensile strength at design component temperatures and design speed of 120% of normal operating speed.

Turbine operating procedures are employed to preclude brittle fracture at startup by ensuring that the metal temperature of the rotor with integral wheels are (a) adequately above the FATT, and (b) sufficient to maintain the fracture toughness to tangential stress ratio at or above 2 inches. Adequate material fracture toughness needed to maintain this ratio is assured by destructive tests on material taken from the rotor with integral wheels using correlation methods which are more conservative than those presented in Reference 1.

The rotors for the main turbine are of monoblock construction and do not have shrunk on wheels. Therefore, the formerly dominant brittle fracture failure mechanism of the original built-up rotors is not applicable to the monoblock rotors.

10.2.3.3 High-Temperature Properties

The operating temperatures of the high-pressure rotor are below the creep rupture range. Creep rupture is therefore not considered to be a significant factor in assuring rotor integrity over the lifetime of the turbine. Basic data was obtained from laboratory creep rupture tests.

10.2.3.4 Turbine Rotor Design

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

- a. Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.
- b. The multitude of natural critical frequencies of the turbine shaft assemblies which exist between zero speed and 20% overspeed are controlled in the design and operation so no distress is caused to the unit during operation.
- c. All of the rotating components have sufficient margin to tensile strength at design component temperatures and design speed of 120% of normal operating speed.

10.2.3.5 Preservice Inspection

The manufacturer's preservice inspection program is as follows:

- a. Rotor with integral wheel forging is rough machined with minimum stock allowance prior to heat treatment.
- b. Each finished machined rotor with integral wheels is subjected to 100% volumetric (ultrasonic), surface, and visual examinations using GE acceptance criteria. These criteria are more restrictive than those specified for Class 1 components in the ASME Boiler and Pressure Vessel Code, Sections III and V, and include the requirement that subsurface sonic indications are either removed or evaluated to assure that they do not grow to a size which compromises the integrity of the unit during its service life.
- c. All finished machined surfaces are subjected to a magnetic particle test with no flaw indications permissible.
- d. Each fully bucketed turbine rotor assembly is spin-tested at 120% of rated speed which is above the maximum speed anticipated following a turbine trip from full load.

10.2.3.6 Inservice Inspection

The major components of the turbine-generator will undergo a planned inspection and maintenance program at periodic intervals coinciding with plant shutdown for refueling. During the planned inspections, the selected components will be disassembled and all normally inaccessible parts, such as rotors with integral wheels, buckets, seals, bearings, etc., will be inspected.

To keep the probability of a significant overspeed event very low, periodic maintenance and inspection of valves and other overspeed protection components are required. Therefore, main stop and control valves and combined intermediate (stop and intercept) valves will be inspected on a rotating basis during planned intervals. Turbine stop valves, control valves, and combined intermediate valves will be inspected based on manufacturers recommendations under CPS preventive maintenance program. The main steam stop valves, the combined intermediate (stop and intercept) valves and main steam turbine control valves will be exercised by fully closing each valve and observing the valve position indicator. The frequency of exercise will be based on manufacturer's recommendation. The turbine bypass valves will be exercised every 31 days. Generator and alternator components, including shaft seals, will be inspected on a periodic basis.

The extraction steam non-return valves are a straight-through type having a swinging disc rotating on a heavy shaft in bushed bearings. The disc and disc arm are steel to guard against breakage, and the disc is so attached to the disc arm that the disc is self-aligned on the seat. The shaft extends through a stuffing box to the outside of the valve. Stuffing box and internal balanced shaft applies only to 12-inch and smaller valves. Larger valves have hardened stainless steel bushings with leakoff to reduce friction. To insure positive closings, a spring-loaded air cylinder is installed on the outside of the valve body connected by means of a piston rod and suitable linkage to the shaft. When air is vented off, the spring assists the valve to

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close and helps maintain tight valve closure. The air operated cylinder is cast steel, with a steel piston and a Uneepac seal on the piston.

The extraction steam non-return valves are periodically tested. The valves will normally be exercised weekly during operation (Q&R 040.74).

10.2.4 Evaluation

The primary source of activity in the steam and power conversion system is radiation from nitrogen-16, formed by activation of primary coolant water in the reactor. This activity is carried with the steam to the turbine. Fission-product noble gases and other activation gases, such as oxygen-19, nitrogen-17, and nitrogen-13, are also carried with the steam to the turbine. Nongaseous fission and activation products are present in the turbine due to moisture carry-over in the steam from the NSSS. The maximum anticipated operating concentration of radioactivity in the high-pressure turbine is the same as that indicated in the tables in Section 11.1, multiplied by the following appropriate carry-over factors:

- a. noble gases - 1 (100% carry-over);
- b. halogens - 0.02; and
- c. other fission products - 0.001.

The activity entering the low-pressure turbine is reduced by the presence of moisture separation between the high-pressure and low-pressure turbines.

As described in Section 11.3, most of the gaseous activity in the condenser is removed by the steam jet air ejector to the gaseous waste system. The activity that is not removed by the air ejector is reduced significantly by the approximate 1.7-minute holdup time in the condenser hotwell. Therefore, the activity entering the condensate and feedwater lines is significantly less than that originally entering the steam and power conversion system.

Biological shielding requirements are discussed in Section 12.1. The turbine is in an administratively controlled access area.

10.2.5 References

1. J. A. Begley and W. A. Logsdon, Westinghouse Scientific Paper 71-1E7 MSLRF-PI.

10.3 MAIN STEAM SUPPLY SYSTEM

This section discusses that portion of main steam piping which extends from the outboard main steamline isolation valve to the main turbine stop valve.

The main steamline pressure relief system, main steamline flow restrictors, and main steamline isolation valves are described in Subsections 5.2.2, 5.4.4, and 5.4.5, respectively. Main steam piping from the reactor nozzles through the outboard MSIV is discussed in Subsection 5.4.9.

10.3.1 Design Bases

10.3.1.1 Safety Design Bases

The main steam supply system is not required to effect or support safe shutdown of the reactor or to perform in the operation of reactor safety features, however, the main steam supply system is designed:

- a. In accordance with applicable codes and standards in order to accommodate operational stresses such as internal pressure and dynamic loads without a failure that could lead to the release of radioactivity in excess of the guideline values in published regulations;
- b. To accommodate normal and abnormal environmental conditions; and
- c. With suitable accesses to permit inservice testing and inspections.

10.3.1.2 Power-Generation Design Bases

The steam supply system is designed to perform the following functions:

- a. Deliver steam from the reactor to the turbine generator from warmup to reactor rated flow and pressure conditions;
- b. Deliver steam from the reactor to the reheaters, the steam jet air ejectors, auxiliary steam system, reactor feed pump turbines, and the steam seal evaporator;
- c. Deliver steam to the 28.8% bypass valve manifold which bypasses steam around the turbine-generator to the condenser during startup and in the event the steam required by the turbine is less than that produced by the NSSS;
- d. Deliver high-pressure turbine exhaust to reheater and reheated steam to the low-pressure turbine.

10.3.2 Description

The main steam supply is shown in Drawing M05-1002. The main steam piping consists of four 24-inch diameter lines from the outboard main steamline isolation valves to a common 36-inch diameter header, and then four 24-inch diameter lines from this common header to the main turbine stop valves. The use of multiple main steamlines reduces the load reduction required to permit testing main steamline isolation valves during station operation. The design pressure

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and temperature of this 24-inch and 36-inch main steam piping is 1250 psig and 575°F, respectively, the same values as the design parameters of the reactor. The main steamlines are classified as discussed in Section 3.2.

The main steam shutoff (block) valves are located downstream of the outboard main steam isolation valves in the auxiliary building steam tunnel. The main steam shutoff valves are leaktight, motor-operated gate valves powered by a Class 1E source separate from that which powers the main steam isolation valves. They are normally open and are manually actuated from the main control room when additional assurance of steamline isolation is required. The Main Steam Line Outboard Drain Isolation Valve may also be remote manually operated from the Auxiliary Building MCC outside the Main Control Room (MCR) with the valve transfer and control switches located at the MCC. The valve transfer and control switches are considered part of the Remote Shutdown System (RSS).

At the discharge of the shutoff valves, the four steamlines are connected to a header upstream of the turbine stop valves. This header arrangement ensures that the turbine bypass system is connected to the operating steamlines and not to idle lines. A drain line is connected to the low points of each main steamline, both inside the drywell and outside the containment. Both sets of drains are headed and connected by valving to allow drainage to the main condenser. To permit intermittent draining of the steamline low points at low loads, an orifice and line are provided around the final valve to the main condenser. The steamline drains maintain a continuous downward slope from system low point to the orifice outside the drywell. The drain line from the orifice to the condenser also slopes downward. To permit purging the lines for maintenance, an additional drain is provided from the low point of each drain to the radwaste system.

The drains from the steamlines inside containment are connected to the steamlines outside containment to permit equalizing pressure across the main steamline isolation valves during startup and following a steamline isolation. The isolation valves outside the drywell are opened first and then the drain connection is used to warm up and pressurize the outside steamlines. The main steamline isolation valves inside the drywell are then opened in preparation for plant operation.

10.3.3 Evaluation

All components and piping for the main steam supply system are designed in accordance with the codes and standards listed in Section 3.2. This ensures that the main steam supply system accommodates operational stresses resulting from static and dynamic loads, including steam hammer and normal and abnormal environmental conditions. The break of a main steamline or any branch line will not result in radiation exposures in excess of the limits of 10 CFR 50.67 to persons located offsite because of the safety features designed into the system. The main steamline break accident is addressed in Chapter 15, and high-energy pipe failure is discussed in Subsection 3.6.2.

10.3.4 Inspection and Testing Requirements

Inspection and testing will be carried out in accordance with the requirements of Section 3.2. The main steamline will be hydrostatically tested to confirm leaktightness.

10.3.5 Water Chemistry

This section applies to a pressurized water reactor (PWR), and is therefore not applicable to the Clinton Power Station.

10.3.6 Steam and Feedwater System Materials

10.3.6.1 Fracture Toughness

The main steam and feedwater systems are classified as either Quality Group A, B, or D as described in Section 3.2. Material used for Quality Group A portions of the main steam and feedwater systems are impact tested in accordance with Paragraph NB-2300 of the ASME B&PV Code, Section III. Impact testing is not specified for the materials used for Quality Group B or D portions of the main steam and feedwater systems.

The material used in the main piping in the Quality Group D main steam and Quality Group D feedwater systems is ASTM A106, Grade B. The material used in the main piping in the Quality Group B main steam and feedwater is ASME SA-106, Grade B. The material used in the main piping in the Quality Group A main steam is ASME SA-106 Grade B normalized or SA-333 Grade 6.

10.3.6.2 Materials Selection and Fabrication

All materials used in the main steam and feedwater systems are listed in the Summer 1974 Addenda to the 1974 Edition of Section III of the ASME Code.

Austenitic stainless steel is not used in the Quality Group A or B portions of the main steam or feedwater systems and therefore Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," 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 to the Clinton Power Station main steam and feedwater systems.

Cleaning and cleanliness control activities for each phase of the erection of the Clinton Power Station (manufacturing, construction, testing, etc.) was planned prior to initiation of work. Execution of the plan is accomplished by the appropriate contractors through procurement and erection specifications. Verification of compliance to specified criteria is in accordance with the station program and appropriate procedures. The overall cleanliness specification was developed by Sargent & Lundy, with input from the NSSS and equipment vendors.

The cleanliness program is intended to comply with the requirements of ANSI N45.2.1 and Regulatory Guide 1.37.

Low-alloy steel is not used in the main steam or feedwater systems, and therefore Regulatory Guide 1.50, "Control of Preheat Temperature for Welding of Low-Alloy Steel" is not applicable.

Compliance with Regulatory Guide 1.71, "Weld Qualification for Areas of Limited Accessibility" is described in Section 1.8.

Tubing products are not used in the Quality Group A or B portion of the main steam or feedwater systems.

10.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

10.4.1 Main Condensers

10.4.1.1 Design Bases

10.4.1.1.1 Safety Design Basis

The main condenser is not required to affect or support safe shutdown of the reactor or to perform in the operation of reactor safety features. It is, however, designed with necessary shielding and controlled access to protect plant personnel from radiation.

10.4.1.1.2 Power Generation Design Bases

10.4.1.1.2.1 Performance Requirements

The design objective of the main condenser is to condense and deaerate the turbine exhaust steam and provide the necessary heat sink for the turbine bypass steam, and other turbine cycle flows. The main condenser also receives and collects these flows for return to the reactor.

Physical data and performance characteristics for the main condensers are shown in Table 10.4-2.

10.4.1.1.2.2 Turbine Bypass Steam

The main condenser is designed to accept up to 28.8% of the main steam flow at design conditions from the turbine bypass system described in Subsection 10.4.4. This condition is accommodated without increasing the condenser back pressure to the turbine trip setpoint or exceeding the allowable turbine exhaust temperature. Internal spray pipes have been installed to help dissipate the energy of the turbine bypass steam and thus protect the condenser tubes.

10.4.1.1.2.3 Condensate Deaeration

The main condenser is designed to deaerate the condensate to the required water quality. The dissolved oxygen in the condenser hotwell effluent is expected to be approximately 14 ppb but is guaranteed not to exceed 50 ppb under normal full load operation. Condensate and feedwater oxygen levels may be adjusted with oxygen injection to minimize the iron input into the reactor.

10.4.1.1.2.4 Air Inleakage

The main condenser is designed to minimize air inleakage. Welded construction is used for the condenser shell and, wherever practicable, for the condenser shell connections and penetrations. Equipment and piping connected to the condenser shell are also designed to minimize air inleakage to the main condenser.

The design capacity of the evacuation system described in Subsection 10.4.2 has been calculated to be in accordance with the recommendations of the Heat Exchange Institute "Standards for Steam Surface Condensers." Also included in the design are the expected amounts of hydrogen and oxygen from radiolysis of water in the reactor.

10.4.1.1.2.5 Condensate Retention

The condenser hotwell is designed to provide under normal conditions, a 98 second effective retention of condensate for radioactive decay which is provided by its 98 second active storage volume.

10.4.1.1.2.6 Design Codes

The condenser is designed in accordance with the requirements of the Heat Exchange Institute "Standards for Steam Surface Condensers."

10.4.1.1.2.7 Operation With Leaking Condenser Tubes

The condensate polishing system described in Section 10.4.6 is designed to operate for short periods of time with a condenser leak which would permit circulating water to mix with the condensate. Plant reaction to condenser tube leakage is controlled with site procedures.

10.4.1.2 System Description

During plant operation, steam expanding through the low-pressure turbine is directed downward into the single-shell condenser through the exhaust openings in the bottom of the turbine casings and is condensed. The condenser also serves as a heat sink for several other flows, such as exhaust steam from the feedwater pump turbines, cascading heater drains, and miscellaneous turbine cycle drains.

Other flows occurring periodically or continuously originate from the minimum recirculation flows of the reactor feed pumps, condensate booster pumps, and condensate pumps: feedwater line startup flushing; turbine equipment clean drains; low-point drains; deaerating steam; makeup, etc.

During transient conditions, the condenser is designed to receive turbine bypass steam and feedwater heater and drain tank high-level dumps. These drain tanks include the moisture separator and reheater drain tanks. The condenser is also designed to receive relief valve discharges from moisture separator reheater, feedwater heater shells, steam seal regulator, and various other steam supply lines. Spray pipes and baffles have been installed where they are required to protect the condenser tubes and components from high energy inputs to the

condenser. At startup, steam may be admitted to the condenser shell to assist in condensate deaeration. The condensate is pumped from the condenser hotwell by the condensate pumps described in Subsection 10.4.7.

Since the main condenser operates at a vacuum, any leakage is into the shell side of the main condenser. Provision is made for detection of circulating water leakage into the shell side of the main condenser. Water leakage is detected by measuring the conductivity of sample water extracted from a tray located beneath the tube bundles. A leak will allow the circulating water to drain over the tube bundles and collect in the tray. Sampling methods are described in Subsection 9.3.2. Radioactive leakage to the atmosphere cannot occur.

The shell side of the condenser contains condensed reactor steam and is normally radioactive. The tube side of the condenser contains circulating water from Lake Clinton, which is nonradioactive. Radioactive particulates are removed from the condenser by the condensate cleanup system discussed in Subsection 10.4.6. Radioactive gases which are removed from the condenser by the steam jet air ejectors are processed by the off-gas system described in Section 11.3. During normal operation, the condenser shell side pressure is 3.8" Hg, which is considerably below the circulating water pressure in the condenser tubes and this pressure difference precludes leakage of radiation out of the condenser. When the condenser is not in operation, condensate is stored exclusively in the hot well. No potentially radioactive fluids are in contact with the condenser tubes so no path for leakage of radioactivity outside the condenser exists. (Q&R 040.80)

Air leakage and noncondensable gases, including hydrogen and oxygen gases, contained in the turbine exhaust system due to disassociation of water in the reactor, are collected in the condenser from which they are removed by the main condenser evacuation system described in Subsection 10.4.2.

The main condenser is a single-shell, single-pass, deaerating-type condenser with a divided water box. The condenser and water boxes are all welded ASTM A-285 Grade C carbon steel. The tubes and sheets are 304 stainless steel. The condenser is cooled by the circulating water system, as described in Subsection 10.4.5. Valves are provided in the circulating water system to permit either half of the condenser to be removed from service.

The condenser shell is supported on the turbine foundation mat, with expansion joints provided between each turbine exhaust opening and the steam inlet connections of the condenser shell.

The condenser hotwell has horizontal and vertical baffles to ensure a normal detention of 98 seconds duration for all condensate from the time it enters the hotwell until it is removed by the condensate pumps. Condensate is detained in the main condenser for the minimum 98 seconds to permit radioactive decay before the condensate enters the condensate system.

10.4.1.3 Safety Evaluation

During operation, radioactive steam, gases, and condensate are present in the shells of the main condenser. The anticipated inventory of radioactive contaminants during operation and shutdown is discussed in Sections 11.1 and 11.3.

Necessary shielding and controlled access for the main condenser are provided (see Sections 12.1 and 12.3).

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Hydrogen buildup during operation is not expected to occur due to provisions for continuous evacuation of the main condenser. During shutdown, significant hydrogen buildup in the main condenser will not occur as the main condenser will then be isolated from potential sources of hydrogen.

Main condenser tubeside water is treated with chlorine to limit algae growth and prevent long-term corrosion of the tubes and components. Corrosion of the outside of the condenser tubing is prevented by maintaining strict water quality using the condensate polishing system described in 10.4.6. The construction materials used for the main condenser were selected such that the electromotive force of the materials are approximately equal, thereby providing protection from galvanic corrosion.

The potential flooding which would result from failure of the condenser is discussed in attachment D3.6.4. Failure of the condenser will not adversely affect any equipment required for safe shutdown of the reactor.

The loss of the main condenser vacuum will cause a turbine trip and closure of the MSIV's. The consequences of a turbine trip are discussed in Subsection 15.2.3. Should the turbine stop, control or bypass valves fail to close on loss of condenser vacuum, two rupture diaphragms on each turbine exhaust hood protect the condenser and turbine exhaust hoods against overpressure.

A discussion of the effect of loss of main condenser vacuum on the operation of the main steam isolation valves is given in Subsections 10.4.1.3 and 10.4.1.5.2. Further information is given in Subsections 7.7.1.5.3.4.4.1 and 7.3.1.1.2.4.1.14. (Q&R 040.85)

10.4.1.4 Tests and Inspections

Each condenser shell received a field hydrostatic test before initial operation. This test consisted of filling the condenser shell with water and, at the resulting static head, inspecting all tube joints, accessible welds, and surfaces for visible leakage and/or excessive deflection. Each condenser water box received a field hydrostatic test with all joints and external surfaces inspected for leakage.

CPS will monitor condenser performance and tube leakage by monitoring the conductivity level in the condensate trays and condensate pump discharge. CPS has established a limit of 0.2 $\mu\text{mho/cm}$ at 25° C. If this limit is reached, a sample will be taken of the feedwater and reactor water and an analysis performed to determine what corrective action is required. Therefore, CPS does not feel it is necessary to perform periodic hydrostatic tests of the main condenser to determine potential leakage. The steam side of the main condenser will normally be inspected each refueling outage.

10.4.1.5 Instrumentation Application

10.4.1.5.1 Hotwell Water Level

The condenser hotwell water level is measured by two electronic differential pressure type level transmitters. These transmitters provide signals to an indicator, annunciator trip units, the plant computer, and the hotwell level control system. Level is controlled by modulating two sets of air-operated control valves. Each set consists of a normal and an emergency valve. One set of valves allows water to flow from the cycled condensate storage tank to the condenser hotwell as

the level drops below setpoint. If the level increases above setpoint, the second set of valves located on the discharge of the condensate booster pumps open to allow condensate to be pumped back to the storage tank.

10.4.1.5.2 Pressure

Condenser pressure is measured by gauges, pressure switches, and electronic pressure transducers. The pressure switches provide input signals to the turbine control system and the annunciator. Two electronic pressure transducers provide input signals to the plant computer, a recorder, and a trip unit. The trip unit provides input signals to the reactor recirculation system and steam bypass and pressure regulation system. In addition, four independent and redundant safety-related pressure transmitters provide input signals to the nuclear steam supply shutoff system.

As condenser pressure increases above normal levels, an annunciator is activated. A further increase in pressure results in a turbine trip. As pressure increases toward a complete loss of vacuum, the main steam isolation valves and the main steam bypass valves are closed to prevent overpressurization of the condenser shell.

10.4.1.5.3 Temperature

Temperature is measured in each of the two exhaust hoods by pneumatic temperature controllers. The controllers modulate a control valve in the water spray line protecting the exhaust hoods from overheating.

10.4.1.5.4 Leakage

Leakage of circulating water into the condenser shell is monitored by the process sampling system as described in Subsection 9.3.2.

Conductivity of the condensate is monitored at four locations in the condenser tube trays and at the discharge of the condensate pumps. High conductivity indicates a condenser tube leak and is individually alarmed on a local panel and on a common trouble alarm in the main control room.

10.4.2 Main Condenser Evacuation System

10.4.2.1 Design Bases

10.4.2.1.1 Power Generation Design Bases

The condenser air removal system is designed to achieve and maintain a vacuum in the main condenser to permit plant startup and power generation.

The steamjet air ejectors are designed to remove the expected quantities of hydrogen and oxygen produced by radiolysis of water.

The system is also designed to remove the noncondensable gases from the main condenser, including air leakage and dissociation products originating in the reactor and exhaust them to the gaseous radwaste system.

10.4.2.2 System Description

The main condenser evacuation system for each unit consists of two 100%-capacity, multiple element, multistage, steam jet air ejector (SJAE) units (complete with intercondensers) for normal plant operation, and mechanical vacuum pumps for use during startup. The last stage of the SJAE is a noncondensing stage. The system is shown schematically in Drawing M05-1018.

During startup, when the desired rate of air and gas removal exceeds the capacity of the steam jet air ejectors and when the steam pressure is not adequate to operate the air ejector units, the mechanical vacuum pump removes the air leakage and off-gases from the main condenser. The discharge from the vacuum pump is then routed to the plant vent since this pump is in service during startups when there is little or no radioactive gas present. Radiation detectors in the plant vent alarm in the main control room if abnormal radioactivity is detected (see Subsection 7.7.1.10). The operator would then manually trip the vacuum pumps. Radiation monitors are provided on the main steamlines which trip the vacuum pump if abnormal radioactivity is detected in the stream being supplied to the condenser.

The steam jet air ejector is put into service to remove the gases from the main condenser after a partial vacuum is established in the main condenser by the mechanical vacuum pump, and when sufficient steam pressure is available.

10.4.2.3 Safety Evaluation

The off-gas from the main condenser is one source of radioactive gas in the station. Normally it includes the activation gases nitrogen-16, oxygen-19, and nitrogen-13, plus the radioactive noble-gas parents of strontium-89, strontium-90, and cesium-137. An inventory of radioactive contaminants in the effluent from the steam jet air ejectors is evaluated in Section 11.3.

Main steam to the second stage ejector is maintained at a minimum specified flow to ensure adequate dilution of hydrogen to prevent the off-gas from reaching the flammable limit of hydrogen.

Instrumentation is provided which isolates the condenser from the off-gas system whenever steam flow falls below the specified level. The instrumentation and its operation is described in Subsection 10.4.2.5. The system has no safety-related function as discussed in Section 3.2. Failure of the system will not compromise any safety-related system or component and will not prevent safe reactor shutdown.

The explosion resistance of the steam air ejectors and associated air ejector lines is discussed in Subsection 11.3.2.1.14, items a and b, and Subsection 11.3.2.2.1.9.

Isolation valves are available to close off sources of leakage following detection by one of the systems in Subsection 11.3.2.1.14, items c and d.

The equipment and components in the Condenser Vacuum System are quality Group D as shown on Drawing M05-1018 and revised Table 3.2-1. (Q&R 460.6)

10.4.2.4 Tests and Inspections

Tests and inspections of the equipment that is part of the main condenser evacuation system are performed in accordance with applicable codes and standards.

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10.4.2.5 Instrumentation Applications

10.4.2.5.1 Steam Jet Air Ejectors

Steam pressure and flow is measured and controlled in the steam supply lines by a pneumatic pressure controller, a differential pressure type flow switch, and an electronic differential pressure type flow transmitter.

The pneumatic controller senses steam pressure at the second stage inlet and modulates an air-operated control valve upstream of the air ejectors.

The flow transmitter provides signals to a recorder and an alarm trip unit which activates on low flow. Should the steam flow drop below acceptable limits for dilution of the off-gas, the flow switch will isolate the off-gas flow to the air ejector.

10.4.2.5.2 Condenser Vacuum Pumps

Pressure is measured on the suction line of each condenser vacuum pump by a pressure switch. Upon reaching a vacuum, the pressure switch de-energizes a solenoid valve which allows additional seal water to be pumped to the vacuum pumps. Seal pump discharge pressure is locally monitored. Seal water cooler discharge temperature is measured by a temperature indicating switch. On high temperature, the switch activates an annunciator in the main control room. A main steam high-high radiation signal trips the vacuum pump. The vacuum pump discharge valve then closes, if not overridden by its local control switch.

10.4.3 Turbine Gland Sealing System

10.4.3.1 Design Bases

10.4.3.1.1 Power Generation Design Bases

- a. The objectives of the turbine gland sealing system is to prevent air leakage into and radioactive steam leakage out of the main turbine.
- b. The turbine gland sealing system utilizing steam from the gland steam seal evaporator provides the means of sealing the turbine shaft glands and valve stems (main stop, control, combined stop and intercept). The gland steam seal evaporator is a shell-and-tube heat exchanger. The gland steam seal evaporator evaporates the condensate to produce the sealing steam. Extraction steam is used as the heating medium. The condensed steam from the sealing system is returned to the main condenser, and the noncondensable gases removed from the seal steam are exhausted to the plant vent.

10.4.3.2 System Description

The turbine gland sealing system consists of a gland steam seal evaporator, steam seal pressure regulator, steam seal header, two full-capacity steam packing exhausters/condensers,

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each with two full-capacity exhauster blowers, and the associated piping, valves and instrumentation (see Drawing M05-1018).

Sealing steam for turbine shaft packing glands and valve steam packing glands (stop and control valves) is supplied from the steam seal header. The source of the sealing steam is from a separate gland steam seal evaporator during normal plant operation. Main steam reduced in pressure, or auxiliary steam, provides sealing steam when the steam evaporator is out of service.

The gland steam seal evaporator is a shell-and-tube heat exchanger designed to provide a continuous supply of clean sealing steam to the steam seal header. The steam supply to the evaporator is supplied at low loads by the main steamline and at high loads from a turbine extraction.

The outer ends of all glands of the low-pressure turbines are routed to the steam packing exhauster/condenser which is maintained at a slight vacuum by the exhauster blower. During plant operation, one steam packing exhauster/condenser and motor-driven blower are in operation. The exhauster blower discharges gland air leakage to the plant vent. The steam packing exhauster/condenser is cooled by the main condensate flow.

Each steam packing exhauster/condenser, consisting of a single U-tube heat exchanger that recovers condensate from the mixture of air and steam which is drawn from the shaft packings, exhausts the air leakage to the atmosphere by means of the motor-driven blower mounted on top of the exhauster. Main condensate is used as the cooling medium.

The motor-driven exhauster blower is designed to discharge the air leakage to the atmosphere through the plant vent stack. The blower is designed to adequately operate between 10 inches to 12 inches of water gage at the steam packing exhauster suction with normal packing clearance. With worn packing, the gage pressure may go up to 20 inches of water.

10.4.3.3 Safety Evaluation

The turbine gland sealing system is designed to provide a continuous supply of clean, nonradioactive steam at approximately 19 psia to the main turbine shaft glands and the valve stems. The high-pressure turbine shaft seal must accommodate a range of turbine shell pressure from full vacuum to approximately 220 psia. The low-pressure turbine shaft seals operate against a vacuum at all times. The sealing steam enters the high- and low-pressure turbine shaft seals and the valve stem seals through an annulus. The steam is exhausted to the seal steam condenser via the vent annulus, which is maintained at a slight vacuum.

Since a supply of clean, nonradioactive steam is available from the gland steam seal evaporator, the turbine gland sealing system should always have available a supply of clean, nonradioactive sealing steam. Two 100% capacity steam packing exhauster condensers are provided, each equipped with a 100% capacity blower.

Relief valves on the seal steam header prevent excessive seal steam pressure. The valves are vented to the condenser shell.

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10.4.3.4 Tests and Inspections

Testing and inspection of the system will be performed prior to plant operation. Components of the system are continuously monitored during operation to ensure that they are functioning satisfactorily. Periodic tests and inspections may be performed in conjunction with maintenance outages.

10.4.3.5 Instrumentation Application

10.4.3.5.1 Steam Seal Evaporators

10.4.3.5.1.1 Pressure

There are two sources of steam to the steam seal evaporators: main steam and extraction steam. To avoid reverse steam flow into the extraction steamline, two air assisted check valves are provided in the extraction steamline. A differential pressure switch compares the evaporator tube side pressure to the extraction pressure. If the extraction pressure is not greater than the tube side pressure, the pressure switch deenergizes a solenoid pilot valve which vents the air operators to assist the valves in closing.

Pressure is measured on both the shell and tube sides of the evaporator by gauges, pneumatic controllers, and electronic transmitters. Both pressure controllers modulate the air-operated team feed control valve. A high signal selector passes the greater of the two signals which calls for the least opening of the valve. The pressure transmitters provide signals to the plant computer and main control room indicators.

10.4.3.5.1.2 Level

Level is measured in the evaporator shell by an electronic level transmitter and pneumatic level transmitter. The pneumatic transmitter provides a signal to a pneumatic controller which modulates the water supply control valve, the electronic level transmitter provides signals to a main control room indicator, annunciator trip units, and a trip unit which closes the motor-operated water supply valve.

Level is measured in the evaporator tube drain chamber by two electronic differential pressure type level transmitters. One transmitter provides signals to a high/low level annunciator trip unit and the normal level controller. The normal level controller modulates the control valve which drains to the low-pressure feedwater heater 3B. If that heater has a high level, the control valve will be vented closed and the emergency level transmitter/controller will then modulate a control valve which drains to the main condenser.

10.4.3.5.2 Steam Packing Exhausters

10.4.3.5.2.1 Pressure

Steam packing exhauster suction pressure is measured by gauges, an electronic pressure transmitter, and a pressure switch.

The pressure transmitter provides a signal to a main control room indicator and the plant computer. The pressure switch initiates a main control room annunciator.

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10.4.3.5.2.2 Level

Level is measured in the drain leg of each exhauster by a differential pressure type electronic transmitter. Each transmitter provides signals to a high level annunciator trip unit and electronic controllers which modulate the air-operated control valves to maintain the level at the desired level.

10.4.3.5.3 Steam Seal Header

10.4.3.5.3.1 Pressure

Steam seal header pressure is measured by an electronic pressure transmitter, a gauge, and a pneumatic pressure controller. The transmitter provides signals to a main control room indicator, a high/low annunciator trip unit, and the plant computer.

The pneumatic pressure controller modulates an air-operated control valve in the main steam/auxiliary steam supply line to the steam seal header. When this line is not in use, pressure is controlled in the steam seal evaporator discharge line by a self-contained pressure control valve which measures downstream pressure.

10.4.3.5.3.2 Temperature

Temperature is measured in the steam seal header which provides a signal to the plant computer.

10.4.4 Turbine Bypass System

10.4.4.1 Design Bases

10.4.4.1.1 Power Generation Design Bases

- a. The steam bypass system is designed to control pressure; (a) during reactor vessel heatup to rated pressure, (b) while the turbine is brought up to speed and synchronized, (c) during power operation when reactor steam generation exceeds the turbine requirements, and (d) during cooldown of the nuclear boiler.
- b. The turbine bypass system capacity is designed for 35% with pre-EPU operation of the guaranteed reactor steam flow, and 28.8% bypass system capacity guaranteed reactor steam flow with EPU. The bypass system works in conjunction with the turbine controls (pressure control) (see Subsection 7.7.1.5).
- c. The turbine bypass valves are capable of being exercised to verify that the valves are operable.

10.4.4.2 System Description

The turbine bypass system piping is shown on the main steam system P&ID in Drawing M05-1002. The turbine bypass system consists of six hydraulically operated regulating bypass valves. These valves are operated automatically and in sequence.

The turbine bypass system is considered a part of the Main Steam System and no separate P&ID is provided. The turbine bypass valves and discharge lines to the condenser are shown

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on the Main Steam P&ID (Drawing M05-1002, sheets 3 and 4). A simplified diagram of the functional controls is shown on Figure 7.7-10. (Q&R 040.88)

Two valve chests are provided; each one houses three individual bypass valves. The inlet manifolds for the valve chests are connected to the main steamlines upstream of the turbine main stop valves. Each bypass valve outlet is piped directly to the main condenser through a pressure breakdown assembly. There are no atmospheric dump valves on the system. Each bypass valve is an angle body type operated by hydraulic fluid pressure with spring action to close. Each valve chest assembly includes hydraulic supply and drain piping, three hydraulic accumulators, (one for each bypass valve), servo valves, fast acting solenoid valves, and valve position transmitters.

The turbine bypass valves are provided with a separate hydraulic fluid power unit. The unit includes high-pressure fluid pumps, filters, and heat exchangers. Hydraulic fluid at 1600 psig is provided at the bypass valve actuator and drained back to the fluid reservoir.

The turbine bypass valves are opened by a signal received from the steam bypass and pressure regulation system whenever the actual steam pressure exceeds the preset steam pressure by a small margin. This occurs when the amount of steam generated by the reactor cannot be entirely used by the turbine. This bypass demand signal causes fluid pressure to be applied to the operating cylinder which opens the first of the six individual valves. As the bypass demand increases, additional bypass valves are opened dumping the steam to the condenser. The bypass valves are equipped with fast acting solenoid valves to allow rapid opening of bypass valves upon turbine trip or generator load rejection.

The bypass valves automatically trip closed whenever the vacuum in the main condenser falls below a preset value. The bypass valves are also closed on loss of electrical power or hydraulic system pressure. The hydraulic accumulators at the bypass valves have the capability to stroke the valves at least 3 times should the hydraulic power unit fail.

A 28.8% load rejection can be accommodated by opening all bypass valves. This requires no changes in recirculation flow nor control rod motion.

The turbine bypass system valves and piping conform to the applicable codes as referenced in Section 3.2.

10.4.4.3 Safety Evaluation

The effects of a malfunction of the turbine bypass system valves and the effects of such a failure on other systems and components are evaluated in Chapter 15. The steam bypass system is not a safety-related system.

The turbine bypass system is a portion of the Steam Bypass and Pressure Regulation System which controls reactor pressure. The instrumentation for this system is discussed in Subsection 7.7.1.5.3. Failure of the pressure regulation system is discussed in Subsections 15.1.3 and 15.2.1. Failure of the bypass valves to open when needed under worst case conditions is discussed in subsections 15.2.2 and 15.2.3. (Q&R 040.91).

10.4.4.4 Tests and Inspections

The opening and closing of the turbine bypass system valves will be checked during initial startup and shutdown for performance and timing. The bypass steamline will be hydrostatically tested to confirm leaktightness. Visual inspection of pipe weld Joints will confirm the exterior condition of the weld. Pipe weld joints will also be inspected by Volumetric examination, either UT or RT per ANSI B31.1 or ASME Section XI.

Turbine Bypass Valve inspection will be performed on a rotating basis within the CPS preventive maintenance program; testing will be in accordance with manufacturer's recommendation. The operability of the bypass valves will be verified in accordance with Clinton Power Station Technical Specifications.

10.4.4.5 Instrumentation Application

Main steam pressure is measured in the equalizing header by electronic pressure transmitters. Each transmitter supplies a signal to a corresponding pressure regulator. Under normal conditions the regulator output signal that has been selected by the operator will be transmitted to the steam bypass and pressure regulatory system. If, however, the error detection circuitry detects a divergent failure in one of the signals, the valid signal will be used and an annunciator will be activated to warn the operator of the failed regulatory output.

Input to the system also includes load demand and load reference signals from the turbine speed load control system. The steam bypass and pressure regulation system uses these three signals to position the turbine control valves and the bypass valves. A complete description of the control system is included in Subsection 7.7.1.5.

10.4.5 Circulating Water System

10.4.5.1 Design Basis

10.4.5.1.1 Safety Design Basis

The circulating water system is not required to perform or to assist in performing nuclear safety functions, such as safe shutdown of the station or to mitigate the consequences of a nuclear accident.

10.4.5.1.2 Power Generation Design Basis

The circulating water system is designed to deliver water from the cooling lake to the main condenser and return it in sufficient quantities to condense the steam exhausted from the main and auxiliary turbines. The cooling lake is designed to dissipate the rejected heat before the water returns to the system intake in the screen house.

10.4.5.2 System Description

The circulating water system consists of the following components: screen house, intake screens, pumps, pump building, tube side of the main condenser, condenser water box air evacuation subsystem, fill water subsystem, water box drain subsystem and all required piping and valving. The schematic arrangement of the system is shown in Drawing M05-1010.

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The cooling lake is designed to maintain the temperature of the water entering the circulating water system within the range of 32°F to 95°F. The circulating water system includes a warm water circulation subsystem to maintain a 40°F minimum temperature for the water delivered to the condenser .

The cooling water is circulated by three one-third capacity motor driven pumps. The capacity of each pump, for full-rated load operation of the power station, is 189,567 gpm at 96.2 ft head, when the cooling lake water level is at low level elevation of 677 feet 0 inch and all three pumps are operating.

The circulating water pumps are housed in a building, which provides the pumps and motors with shelter from snow, ice, and freeze protection for the motor bearing cooling lines.

The three pumps are arranged in parallel and discharge into a common header. The discharge of each pump is fitted with a butterfly valve. This arrangement permits isolation of any one pump while the other two remain in operation.

The condenser water box consists of two separate and equal halves. The piping entering and leaving the water boxes is equipped with a valving arrangement designed to permit the isolation of one half while the other half remains in operation. The design also incorporates piping and valving to permit each half of the water boxes to be drained or filled independently.

The total capacity of the condenser water boxes is 162,000 gallons. The main circulating water pipes carrying water to and from the condenser include piping 13 feet in diameter.

A designed chemical treatment capability is provided to prevent an accumulation of biological growth and scale buildup within the wetted surfaces of the circulating water system. During periodic, intermittent treatments, sodium hypochlorite is injected in an automatic and controlled manner to minimize biological growth. The injections occur via the circulating water system pump suctions located in the circulating water screen house. In addition, the design capability of the chemical treatment system provides for an automatic, controlled injection of a scale inhibitor into the discharge of the circulating water system pumps. The scale inhibitor is used to prevent formation of insulating scale deposits on the main condenser heat transfer surfaces. The chemical treatment capability and the total residual chemical concentrations in the discharge to the cooling lake (Ultimate Heat Sink) are subject to the environmental discharge limitations of the National Pollution Discharge Elimination System (NPDES) Permit.

No unusual corrosion problems are anticipated to occur, therefore no other chemicals are added to the circulated water to control corrosion. However, deposits of suspended solids or biological growth could increase the Main Turbine back pressure or the pressure differential across the Main Condenser. Therefore, dispersants may also be added to suspend solid and/or biological growth. The dispersants work to suspend the silt or biological growth in the Main Condenser allowing circulating water to flush these materials out. A secondary benefit of using these dispersants is a potential increase in efficacy of the biocide (sodium hypochloride). The addition of these dispersants is performed under controlled conditions and only as required, as controlled by the NPDES Permit.

The characteristics of circulating water system components are shown in Table 10.4-1.

10.4.5.3 Safety Evaluation

There are no essential systems located in the turbine building basement. However, in the event of a circulating water pipe expansion joint rupture at the inlet or the outlet of the condenser water boxes, the spilled water is designed to be confined to the condenser pit, which is enclosed by walls extending to the 715 feet 0 inch elevation. For detailed discussion on how this confinement is accomplished, see Subsection 10.4.5.5.

In addition to these flood protection measures, the turbine building basement is separated from the auxiliary building (where essential equipment is located) by 3 foot high door curbs. All penetrations between the turbine building and the auxiliary building below the 737 feet 0 inch elevation are provided with watertight seals.

The design of the circulating water system piping and components include the following two distinct maximum pressure segments:

- a. 70 psig, for the portion between the circulating water pumps and the condenser (including condenser water boxes and tubes);
- b. 30 psig, for the remaining portion downstream of the condenser.

10.4.5.4 Tests and Inspections

All active components of the circulating water system (except for main condensers) are accessible for inspection and maintenance/testing during normal power station operation.

10.4.5.5 Instrumentation Application

All major circulating water system valves which control the flow path are operated by remote manual switches, located on the main control board. The pump discharge isolation valves are interlocked with the circulating water pumps so that when a pump is started, its discharge valve will be opening while the pump is coming up to speed, thus assuring there is water flow through the pump. When the pump is stopped, the discharge valve closes automatically to minimize the length of time that the pump and motor are rotating backwards during the back flow of water.

To satisfy the bearing lubricating water and shaft sealing water interlocks during startup, the circulating water pump bearing lubricating and shaft seal flow switches, located in the lubricating seal water supply lines, must sense a minimum flow of 5 gal/min to provide pump start permissive.

During normal operation, should an expansion joint rupture in the condenser supply or discharge lines, water will accumulate in the condenser pit, and turbine building basement. Three level switches, located to detect a high water level in the condenser pit will energize and close the motor-operated valve which connects the condenser pit to the turbine building floor drain sump when any two of the three switches are tripped. Isolating the condenser pit from the turbine building floor drain sump slows early flooding of the turbine basement.

Three different level switches, located to detect a high-high water level in the condenser pit, will deenergize the circulating water pumps when any two of the three switches are tripped. The level switches that stop the circulating water pumps are powered by CW Pump A control power. Therefore, if the CW Pump A control fuses are pulled, these level switches would not stop CW Pumps B & C, if required.

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Monitoring the performance of the circulating water system is accomplished by differential pressure transducers across each half of the condenser with remote differential pressure indicators located in the main control room. Thermal element signals from the supply and discharge side of the condenser are transmitted to the plant computer for recording, display and condenser performance calculations.

To prevent icing and freeze up when the ambient temperature of the lake decreases from seasonal change, warm water from the discharge side of the condenser is recirculated back to the screen house intake. Thermal elements, located in each condenser supply line and monitored in the main control room, are utilized in throttling the warm water recirculation valve, which maintains the minimum inlet temperature of approximately 40° F.

10.4.6 Condensate Cleanup System

10.4.6.1 Design Bases

The objective of the condensate cleanup system is to remove both suspended and dissolved solids from the condensate continuously to maintain the required purity of feedwater flowing to the reactor. The system polishes and deionizes the high quality water rejected to the condensate storage and transfer system and protects the feedwater loop from contamination by circulating water in case of leakage in the main condenser. The condensate cleanup system is designed to treat a condensate flow of 30,500 gpm at temperatures up to 140° F.

Design bases influent concentrations are shown below. Startup concentrations are defined to occur for periods of a few days to approximately 1 week. Extended normal operation concentrations are defined as those occurring during full power operation.

Impurity	Concentration	
	Startup	Extended Normal Operation
Iron: Soluble	40 ppb	5 ppb
Insoluble	1000 ppb*	25 ppb
Copper (Total)	50 ppb	7 ppb
Other Metals: Soluble and Insoluble (depending on the metal)	40 ppb	3 ppb
Influent pH at 25° C***	6 to 8	6.5 to 7.5
Influent Conductivity at 25° C	0.5 µmho/cm	0.2 µmho/cm
Chloride: Normal + Maximum	10 ppb ---	10 ppb **
Sodium (as Na)	60 ppb	10 ppb
Silica (as SiO ₂)	500 ppb	20 ppb

* This might be as much as 4000 ppb for several hours at initial plant startup.

+ This value is used for equipment specification purposes and is not to be inferred as being normal; without condenser tube leaks, chloride is much lower.

** Maximum chloride input is that which occurs during a condenser tube leak. It is equal to the rate at which units can be kept in service without breakthrough.

*** When influent conductivity is less than 1.0-micromhos/cm, pH need not be measured.

During normal operation, based on the previous influent concentrations, the effluent from the condensate cleanup system is maintained at the following quality limits:

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Specific conductivity at 25° C	0.1 mmho/cm
pH at 25° C ++	6.5 to 7.5
Total iron (as Fe)	Total of 10 ppb
Copper (as Cu)	of which copper shall
Nickel (as Ni)	not exceed 2 ppb
Silica (as SiO ₂)+++	5 ppb
Chloride (as Cl)+++	2 ppb
Sodium (as Na)+++	5 ppb

++ When effluent conductivity is less than 1.0 micromhos/cm, pH need not be measured.

+++The values listed for concentrations of silica, chloride, and sodium represent design bases values for the condensate cleanup system and are not typically measured.

During initial plant testing and startup, the normal limit of metallic impurities may be exceeded for the first 500 hours of effective full-power operation. During such a period, the average concentration of metallic impurities does not exceed 50 ppb and the maximum concentration does not exceed 100 ppb. These higher limits are permitted so as not to hinder startup. The system is designed to allow operators to keep the water quality within the specified limits during normal operation.

During restart or transient periods, the metallic impurities may exceed 10 ppb. A limit of 50 ppb is permitted, but this condition must not exceed 14 days in any 12-month period.

During periods of condenser leakage, the level of dissolved solids may rise to not more than 50 ppb or 1% of influent concentration, whichever is higher. Under the same conditions, the level of suspended solids may rise to not more than 25 ppb or 10% of inlet concentration, whichever is higher.

The filter, demineralizer and regeneration vessels in the condensate cleanup system are designed and constructed in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. All piping, pumps and valves are in accordance with the ANSI B31.1-1973 Code of Pressure Piping.

10.4.6.2 System Description

The condensate cleanup system is shown in Drawing M05-1007. The cleanup system at the Clinton Power Station consists of nine trains, each with a filter vessel and mixed-bed demineralizer vessels. The trains are arranged for parallel operation. Normal flow rate through each of eight active trains is 3820 gpm and 3400 gpm each for nine trains. There is a prefilter installed prior to the polisher for "A", "B", "C", "D", "E", and "F". Polishers "G", "H" and "J" do not have prefilters installed. Clinton Power Station will be using throwaway resin; the polishing beds will be replaced with new resin upon exhaustion.

Each lot of condensate demineralize resin will be sampled for total initial capacity of both anion and cation resins. The supplier confirms the capacities as determined by a procedure recommended by the resin manufacturer. (Q&R 281.8)

Included in the system are the associated piping, valves, resin strainer, tanks, ultrasonic cleaner, and instrumentation and controls required to provide proper operation and protection against malfunction. Provisions are included to permit mechanical cleaning (air and water backwash or ultrasonic technique) and/or bed replacement of the exhausted resin beds.

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Each of the demineralizer vessels has fail open inlet and outlet isolation valves which are remotely controlled from the local demineralizer control panel. A cleanup system flow bypass valve is also provided which is manually controlled from the main control room. Pressure measured downstream of the cleanup system is indicated and low pressure is alarmed in the main control room.

With the use of the throwaway resin, the resin is no longer regenerated. Resin transfer for mechanical cleaning may be performed either manually or semi-automatically at the local control panel. Normally, condensate is recycled through a demineralizer vessel to the hot well before its placement into service. Recirculation is terminated when the specific conductance of the recycled condensate meets the specified limit. One spare bed of resin may be maintained in the system.

One demineralizer vessel is interconnected with the suppression pool cleanup system to provide additional capacity to remove impurities from the pool water. However, the demineralizer is only available for suppression pool cleanup when it is acting as a standby vessel for condensate cleanup. For further details, refer to Subsection 9.3.6.

The filter portion of the condensate cleanup system is a modification to the original design which aids the system in maintaining water purity. The filters are designed to remove insoluble impurities from the condensate water prior to entering the demineralizers. The primary impurity targeted for removal from the reactor coolant water is insoluble iron.

A condensate filter is placed upstream of each of the first six demineralizers along with the associated valves, piping, and instrumentation. A common backwash header services all the filters, and routes filter backwash water to the Low Conductivity sump.

Each of the filters is located in the same shielded cubicle as the associated demineralizer, all located on the 712' level in the Turbine Building. Normal access to the shielded cubicles is provided via a doorway which may be shielded.

Filter equipment operation is controlled by a Programmable Logic Controller (PLC) that positions the filter subsystem valves to accomplish all control and operational modes.

The filter control panel located near the local demineralizer control panel uses the digital PLC and touch screens to provide control. The touch screens can be interchangeably used for system display or single filter display and control. An additional work station, located remotely, is also used for full filter system display or for selecting a single filter for display and control.

Flow is distributed to the filter/demineralizer trains by the original system valves upstream from the filter vessels. Each filter fails to bypass and alarms in the Main Control Room.

Conductivity alarms for the condensate polishing system have local annunciation and actuate a common trouble alarm in the control at the following conditions:

- a. Marginal performance of demineralizer system
- b. Noticeable breakthrough of one or more demineralizers (Q&R 281.6)

10.4.6.3 Safety Evaluation

The condensate cleanup system removes some impurities created by corrosion, fission products, and carry-over from the reactor. While radioactive effects from these sources do not affect the capacity of the resin, the concentration of such radioactive material requires shielding (see Subsection 12.1.2). Some vent gases and waste water from the condensate cleanup system are sent to the radwaste system for treatment and/or disposal. The addition of new resin will be done manually. Chapter 11 describes the activity level and removal of radioactive material from the condensate system. Clinton Power Station's compliance with Regulatory Guide 1.56, "Maintenance of Water Purity in Boiling Water Reactors," is explained in USAR Section 1.8.

All condensate cleanup system piping and vessels are located in the non-safety-related turbine and radwaste buildings. Therefore, the effects of postulated piping failures are not analyzed.

10.4.6.4 Tests and Inspections

Preoperational tests are performed on the condensate cleanup system to ensure operability, reliability, and integrity of the system. Each filter vessel, demineralizer vessel and the external regeneration equipment can be isolated during normal plant operation to permit testing and maintenance. Refer to CPS Technical Specifications and the Operational Requirements Manual (ORM) for frequency of sampling to monitor chemistry requirements.

The condition of the demineralizer units will be determined by monitoring the conductivity of the individual effluent of each bed. In addition, the remaining capacity of the most depleted bed will be calculated periodically when in service. When feeding the reactor, the beds will be discarded when the calculated remaining capacity falls below 50% of original capacity.

- (a) The conductivity monitors will be calibrated in accordance with CPS procedures.
- (b) The flow rate for each demineralizer vessel is monitored by a differential pressure cell at the inlet to each vessel. The differential pressure produces a pneumatic signal which is related to flow. This signal is transmitted to the control panel where the flow rate through each unit is continuously recorded. The total integrated flow through each unit will also be shown.
- (c) The remaining capacity of each resin bed will be calculated by determining the concentration of the principal anions in the cooling water and calculating a conversion factor to estimate the amount of capacity expended for a given volume of water processed. The total amount expended since the bed was placed in service originally will be compared to the initial capacity of the bed. The result will be a best estimate of the remaining capacity of that bed.
- (d) The accuracy of this can be checked by analysis of grab samples from the individual beds. However, due to ALARA reasons, this should be performed only when the estimated value is under suspicion. If the results from the resin analysis indicate that it is appropriate, the estimated value may be corrected. (Q&R281.5)

10.4.6.5 Instrumentation Application

Conductivity elements are provided for the system influent. System influent conductivity detects condenser leakage. Differential pressure is monitored across each demineralizer vessel and each vessel's discharge resin trap to detect blockage of flow. The flow through each demineralizer is monitored to assure the even distribution of condensate flow through all operating vessels. Flow measurements are recorded in their appropriate recorders which are all mounted in the local control panel. A multipoint annunciator is included in the local panel to alarm abnormal conditions within the cleanup system. Electrical contacts for the local annunciator permit remote annunciation in the main control room. Other instrumentation includes flow indicators, pressure gauges for miscellaneous services, and timers for automatic supervision of the regeneration cycle. The control system prevents the initiation of any automatic operation which would conflict with any sequence already in progress if such an operation is in automatic control.

The operating status of each filter and its associated backwash equipment is indicated by any of two touch screens on the condensate filter control panel. Instrumentation is provided to show the individual filter flow rate, the individual filter pressure drop, integrated flow for each filter run, and during backwash the individual filter water level. Alarm contacts are furnished for each filter from the PLC to an annunciator window of the local condensate demineralizer control panel. Instrumentation setpoints provide trips for filter pressure drop, filter head water level, filter body water level, filter flow, and Low Conductivity sump level. Interlocks incorporated into the PLC filter system logic prevents the initiation of any filter system operation which would conflict with any polisher control or operational mode condition.

10.4.7 Condensate and Feedwater System

10.4.7.1 Design Bases

10.4.7.1.1 Power Generation Design Bases

The objective of the condensate and feedwater system is to provide a dependable supply of feedwater to the reactor, to provide feedwater heating, and to maintain high water quality in the feedwater. The system is designed to provide the required flow at the required pressure to the reactor, allowing a sufficient margin to provide continued flow under anticipated transient conditions.

10.4.7.1.2 Performance Requirements

The system is designed to provide the following for a reactor thermal power of 2894 MWt:

- a. Feedwater at a minimum pressure to the reactor pressure vessel. It is sized with sufficient capacity to provide 115.5% of the feedwater flow at unit rating.
- b. Final feedwater temperature of 420° F at unit rating. The feedwater heaters provide the required temperature of feedwater to the reactor with six stages of closed feedwater heating.
- c. 80% of the rated feedwater flow in the event of the trip of one reactor feed pump.

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- d. 80% of the rated feedwater flow in the event of the trip of one condensate pump or one condensate booster pump.
- e. 105% of the rated feedwater flow in the event of the use of one turbine-driven reactor feed pump with the motor-driven reactor feed pump.

10.4.7.1.3 Feedwater Quality

Condensate is sufficiently deaerated in the condenser to maintain a level of 200 ppb (or less) oxygen content in the final feedwater supplied to the reactor during normal full-load operation.

The condensate system also has the capability to inject oxygen to control the dissolved oxygen level, to minimize the release of corrosion products.

To minimize the corrosion product input to the reactor, a startup recirculation line is provided from the reactor feedwater supply lines, downstream of the high-pressure feedwater heaters, to the main condenser.

To minimize radiation dose rates, a passive GE zinc injection passivation (GEZIP) system injects small amounts of depleted zinc oxide (DZO) into the feedwater during normal operation. Depleted zinc oxide injection will reduce shutdown dose rates in the drywell because the zinc forms a thin protective oxide layer on the primary system piping and reduces Co-60 buildup. Co-60 buildup is the major source of shutdown radiation fields and occupational radiation exposure.

10.4.7.1.4 Design Codes

The condensate and feedwater system piping that contains system pressure is designed and constructed in accordance with the applicable codes as referenced in Section 3.2.

10.4.7.2 System Description

The condensate and feedwater system consists of the piping, valves, pumps, heat exchangers, controls and instrumentation, and the associated equipment and subsystems which supply the reactor with heated feedwater in a closed steam cycle utilizing regenerative feedwater heating. The system described in this subsection extends from the main condenser to the second valve outside of containment. The remainder of the system, extending to the reactor, is described in Subsection 5.4.9.

The condensate pumps take the deaerated condensate from the main condenser shell hotwell and deliver it, in turn, through the steam packing exhauster condenser, steam jet air ejector condenser, the off-gas recombiner, condensate filters, and the condensate demineralizers (see Drawing M05-1005). Demineralizer effluent then passes to the condensate booster pumps, which discharge through the low-pressure feedwater heaters to the reactor feedwater pumps (see Drawing M05-1006). The reactor feedwater pumps discharge through the sixth-stage, high-pressure feedwater heaters to the reactor, as shown in Drawing M05-1004.

Turbine extraction steam is utilized for a total of six stages of closed feedwater heating. The drains from the third and above stages of feedwater heaters are cascaded through successively lower pressure feedwater heaters to the main condenser (Drawing M05-1008). Greater control

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of feedwater quality is provided by the use of a fully cascaded feedwater heating system, since 100% of the reactor feedwater is treated by the condensate filters and demineralizers.

A startup recirculation line is provided from the reactor feedwater supply lines, at a point downstream of the high-pressure feedwater heaters, to the main condenser. This line is used to minimize the corrosion product input to the reactor during startup. Cleanup is accomplished by allowing the system feedwater to recirculate through the condensate filters and demineralizers for treatment prior to circulating it to the reactor during startup.

A small amount of depleted zinc oxide is injected into the feedwater during normal operation via the GE zinc injection passivation (GEZIP) system. The system consists of a simple passive recirculation loop off the feedwater piping. A stream of feedwater from the feedwater pump discharge is passed through the GEZIP skid zinc dissolution column which contains pelletized DZO. The feedwater dissolves the pellets as it passes through the zinc vessel carrying the dissolved DZO back into the feedwater pump suction. This process maintains trace quantities of ionic zinc in the reactor water for the purpose of reducing radiation buildup on the primary system surfaces.

10.4.7.2.1 Condensate Pumps

Three one-third capacity condensate pumps operate in parallel during normal operation. A fourth one-third capacity condensate pump is provided for manual starting if required, as shown in Drawing M05-1005. Each is a motor-driven, vertical, canned suction, multistage, centrifugal unit installed at an elevation that allows operation at low condensate level in the main condenser hotwell. The condensate pumps provide the necessary suction head at the condensate booster pumps.

Isolation valves allow each condensate pump to be removed individually from service while maintaining system operability with the remaining condensate pumps. Each pump is provided with a minimum flow recirculation control system for pump protection.

10.4.7.2.2 Condensate Booster Pumps

Three one-third capacity condensate booster pumps operate in parallel during normal operation. A fourth one-third capacity booster pump is provided for manual starting if required, as shown in Drawing M05-1006. Each takes suction from the polishing demineralizer outlet piping and discharges through the low-pressure feedwater heaters. Each is a motor-driven, horizontal single stage, centrifugal type pump. The condensate booster pumps provide the necessary suction head to the reactor feed pumps.

Isolation valves are provided which allow each condensate booster pump to be individually removed from service while maintaining system operability with the remaining condensate booster pumps.

Controlled condensate recirculation is provided downstream of the condensate booster pumps to the main condenser. This provision ensures that the minimum safe flow through the condensate booster pumps is maintained during normal operation.

10.4.7.2.3 Feedwater Heaters

The feedwater heaters are identically arranged in two parallel strings. The first stage feedwater heaters and their external drain coolers are located in the necks of the two exhaust hoods of the main condenser. Drain cooling is provided at all stages of feedwater heating. Drain cooling sections are integral with the feedwater heaters except at the first stage.

Each feedwater heater is a horizontal, closed type, installed at an elevation that allows proper shell drainage at all loads. Each feedwater heater utilizes U-tube construction. All feedwater heater and drain-cooler tubes are made of stainless steel.

Isolation and bypass valves, which are interlocked to prevent incorrect operation, allow the feedwater heaters and the drain coolers to be removed from service in groups. Heaters may be removed from service for maintenance or to facilitate cycle extension by techniques such as Final Feedwater Temperature Reduction (FFWTR). System operability is maintained with the remaining feedwater heaters and drain coolers.

The startup and operating vents from the steam side of the feedwater heaters are piped directly to the main condenser. Discharges from shell relief valves on the steam side of the feedwater heaters are piped directly to the main condenser. (See Drawing M05-1009.)

10.4.7.2.4 Reactor Feed Pumps

Two nominal one-half capacity, turbine-driven reactor feed pumps and a single one-third capacity, motor-driven reactor feed pump operate in parallel, as shown in Drawing M05-1004. These act in series with the condensate pumps and condensate booster pumps. The reactor feed pumps take suction from the fifth-stage, low-pressure feedwater heaters and discharge through the sixth-stage high-pressure heaters to provide the pressure head required by the reactor. Isolation valves are provided which allow each reactor feed pump to be individually removed from service while maintaining system operability with the remaining reactor feed pumps.

Controlled feedwater recirculation is provided from the discharge side of each reactor feed pump to the main condenser hotwell. This provision ensures that the minimum safe flow through each reactor feed pump is maintained during operation.

10.4.7.2.5 Reactor Feed Pump Turbine Drives

Each of the two one-half capacity reactor feed pumps is driven by an individual steam turbine. The turbine drives are the dual-admission type, and each is equipped with two sets of main stop and control valves. One set of valves regulates low-pressure steam flow extracted from the main turbine crossover piping. The other set regulates high-pressure steam flow from the main steam supply. During normal operation, the turbine drives run on the low-pressure crossover steam. Main steam is used during plant startup, low load, or transient conditions when crossover steam is either not available or is of insufficient pressure. The turbine drives exhaust to the main condenser.

Isolation valves are provided which allow each turbine drive to be individually removed from service while maintaining system operability with the remaining turbine-driven reactor feed pump.

10.4.7.3 Safety Evaluation

During operation, radioactive 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. Shielding and controlled access are provided as necessary (Section 12.3). The condensate and feedwater system is designed to minimize leakage with welded construction utilized where practicable. Relief discharges and operating vents are handled through closed systems.

The condensate and feedwater system is not required to effect or support the safe shutdown of the reactor or perform in the operation of reactor safety features. If it is necessary to remove a component such as a feedwater heater, pump, or control valve from service, continued operation of the system is possible by use of the multistring arrangement and the provisions for isolating and bypassing equipment and sections of the system.

An abnormal operational transient analysis of a loss of a feedwater heater is included in Chapter 15. The majority of the condensate and feedwater piping considered in this section is located within the non-safety-related turbine building. The portion which connects to the second valve outside the containment is located in the auxiliary building. This portion of the piping is analyzed for dynamic effect from postulated seismic events and safety-relief valve discharges. The entire feedwater system piping is analyzed for water hammer loads resulting from a complete feedwater pump trip.

10.4.7.4 Tests and Inspections

Each feedwater heater, condensate pump, and condensate booster pump has received a shop hydrostatic test which has been performed in accordance with applicable codes. All tube joints of feedwater heaters have been shop leak tested. Prior to initial operation, the completed condensate booster and feedwater system received a field hydrostatic and performance test and inspection in accordance with the applicable code. Periodic tests and inspections of the system are performed in conjunction with scheduled maintenance outages.

10.4.7.5 Instrumentation Application

Feedwater flow-control instrumentation measures the feedwater discharge flow rate from each reactor feed pump. These feedwater system flow measurements are used by the feedwater control system to regulate the feedwater flow to the reactor to meet system demands. The feedwater control system is described in Section 7.7.

Pump discharge flow is measured and flow controls are provided to regulate pump recirculation flow for each of the condensate pumps, condensate booster pumps, and reactor feedwater pumps. Automatic controls also regulate the condensate flow through the two off-gas recombiner condensers and the two steam jet air ejector condensers. Individual discharge pressure instrumentation is provided for all pumps in the system. Common suction header pressure instrumentation is provided for the condensate and condensate booster pumps. Upon detection of low RFP suction header pressure, an alarm is actuated in the Main Control Room. Operator actions may include starting a standby condensate pump and condensate booster pump combination or placing another condensate demineralizer vessel in service to increase the suction header pressure thus avoiding cavitation. Upon detection of low-low suction header pressure, the feedwater pumps are tripped to avoid cavitation damage.

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The feedwater isolation valves are interlocked such that as they start to close, the extraction steam admission valves for all associated heaters automatically close, and the feedwater bypass valve for the associated low pressure heaters automatically opens.

Sampling means are provided for monitoring the quality of the condensate and final feedwater, as described in Subsection 9.3.2. Temperature measurements are provided for each stage of feedwater heating. Steam-pressure measurements are provided at each feedwater heater. Level instrumentation and controls are provided for automatically regulating the heater drain flow rate to maintain the proper condensate level in each heater drain tank and the last five feedwater heater shells. High-level automatic dump-to-condenser action, with alarms on low level, is provided. High level alarms are provided for the moisture separator drain tanks.

10.4.8 Steam Generator Blowdown System (PWR)

Not applicable to BWR.

10.4.9 Auxiliary Feedwater System (PWR)

Not applicable to BWR.

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**TABLE 10.4-1
CIRCULATING WATER SYSTEM COMPONENTS**

Circulating Water Pumps

Number	3
Type	Vertical, wet pit
Capacity of each*	189,567 gpm
Head	96.2 ft

Circulating Water Pump Discharge Valves

Number per pump	1
Type	Butterfly with hydraulic actuator

Cooling Lake

Type	Man-made
------	----------

Water Levels:

High	697 ft
Normal	690 ft
Low**	677 ft

Effective surface Area (circulating water intake to discharge) Approximately 3650 acres

* When three pumps are in operation and cooling lake water level is at 677 feet.

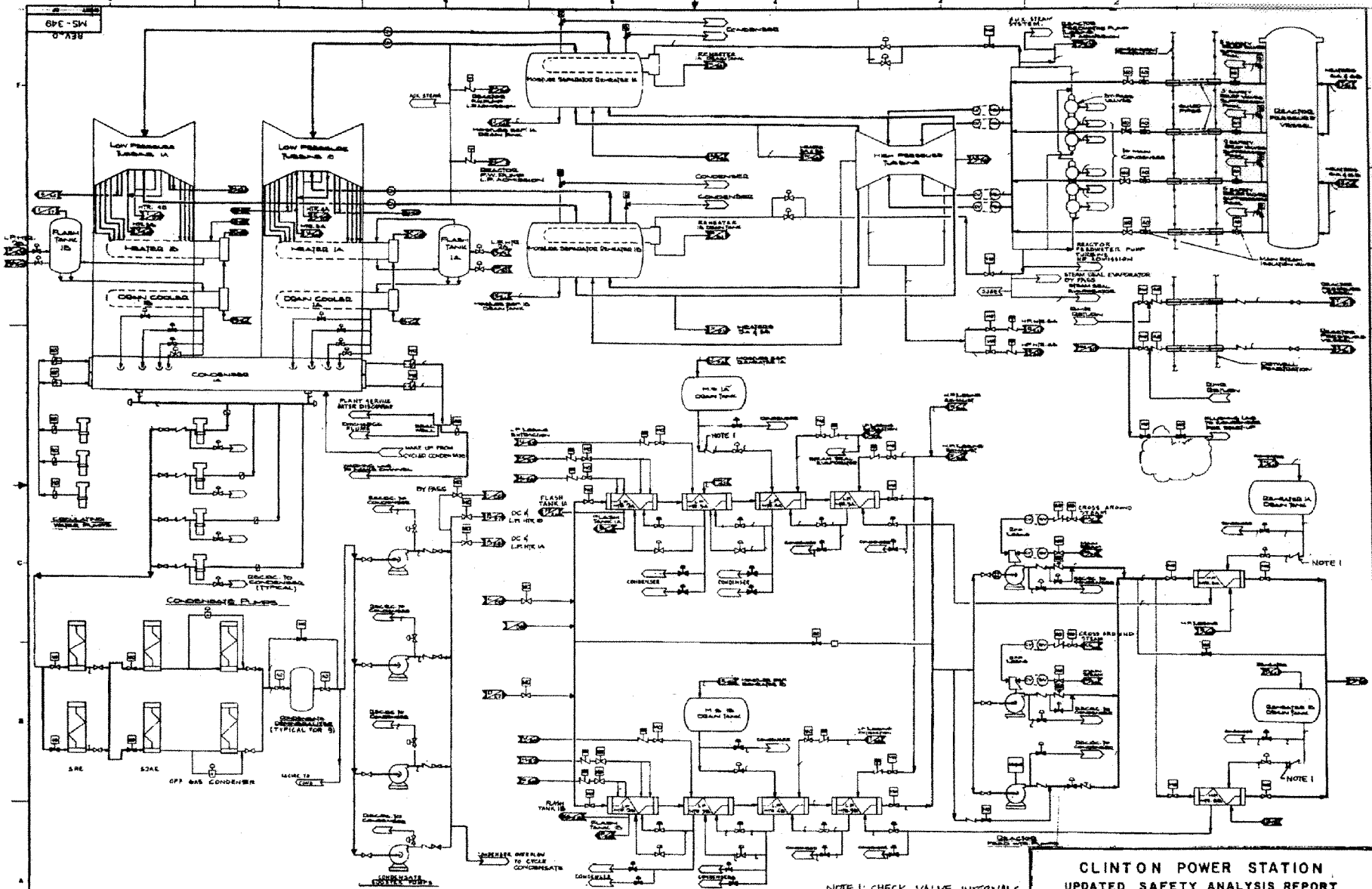
**Applicable only for operation of circulating water system.

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TABLE 10.4-2
PHYSICAL CHARACTERISTICS PERFORMANCE REQUIREMENTS AND CIRCULATING
WATER PARAMETERS OF MAIN CONDENSER

1. Physical Data
 - a) Overall Dimensions - condenser plus water box base 94 ft. 3.25 in. by 32 ft. 0.75 in. Maximum height of condenser 79 ft. 2.88 in. from basemat elevation on 714 ft. 3.12 in.
 - b) Number of condenser shells - 1
 - c) Number of condenser tubes - 53,160
 - d) Condenser surface area - 850,000 sq. ft.
 - e) Hotwell capacity - 52,500 gal.
 - f) Condenser tubes material - ASTM A249 TP 304
2. Performance Characteristics
 - a) Condenser duty (normal) - 7772.61×10^6 Btu/hr
 - *b) Condenser duty (minimum) - 64.09×10^6 Btu/hr
 - c) Condenser pressure - 3.8 in. Hg absolute
 - d) Total condensate outflow - 15.153×10^6 lb/hr
 - e) Exhaust steam flow (normal) - 8.450×10^6 lbs/hr
 - f) Exhaust steam flow (maximum) - 8.450×10^6 lbs/hr
 - g) Normal exhaust steam temperature (no turbine bypass plus normal turbine flow) - 123.7° F
 - h) Exhaust steam temperature (full turbine bypass) approximately 250° F as a weighted average
 - i) Dissolved oxygen in hotwell effluent (normal) - 14 ppb
3. Circulating Water Parameters
 - a) Flow (normal) - 585,000 gpm
 - b) Number of passes - 1
 - c) Temperature rise - 26.5° F
 - d) Average circulating water temperature (anticipated) 62.5° F
 - e) Maximum circulating water temperature 95° F

*During Startup Condenser Deaeration with Auxiliary Steam.



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FIGURE 10.1-1
POWER CONVERSION SYSTEM

NOTE 1: CHECK VALVE INTERNALS
HAVE BEEN REMOVED.

NOTE 1

NOTE 1

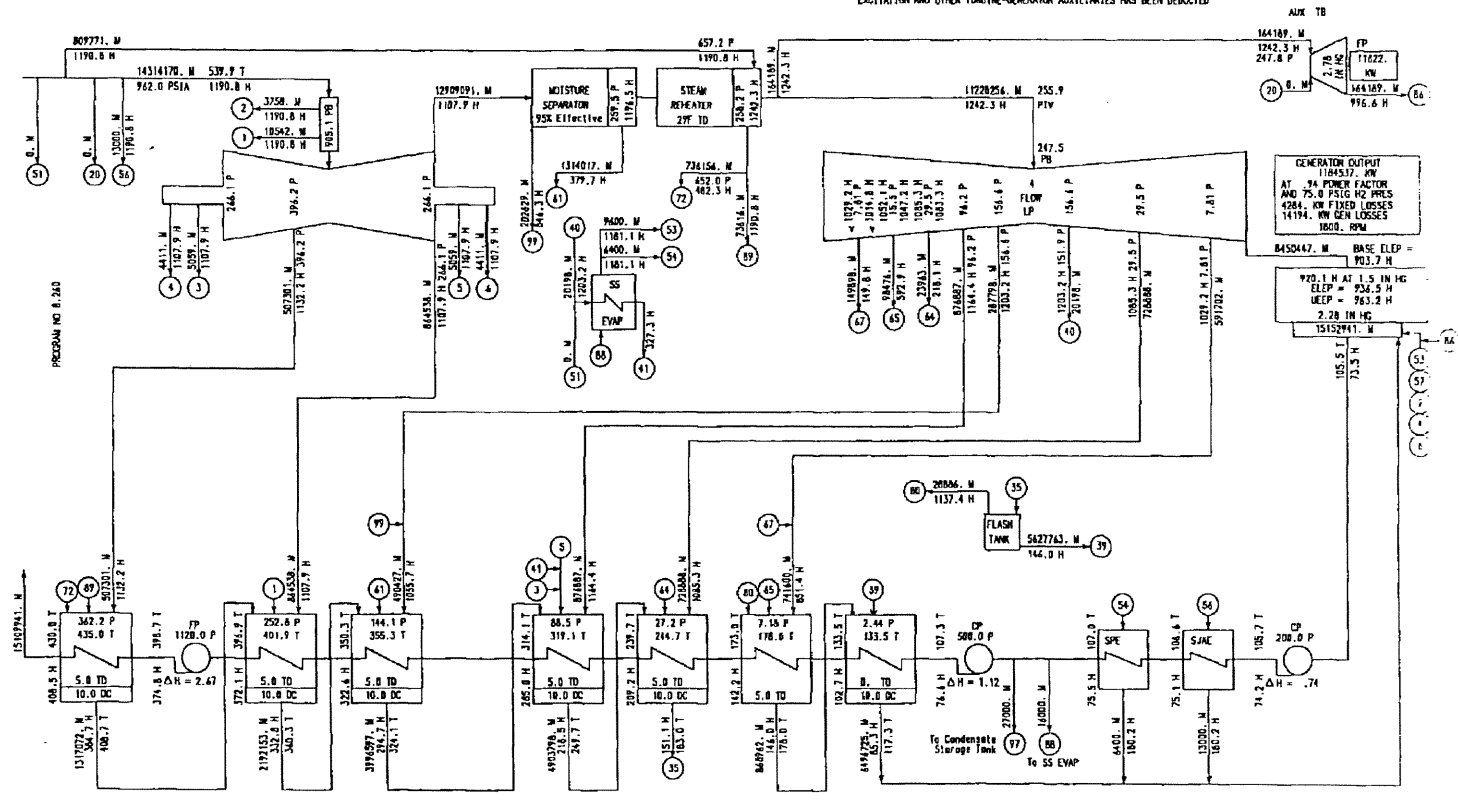
REV. 0
GPC - SW

553#2039 Rev. 1
Turbine Assumed to be in New and Clean Condition

TURBINE AND EXTRACTION ARRANGEMENT IS SCHEMATIC ONLY
CALCULATED DATA - NOT GUARANTEED

RATING FLOW IS 1342996. M AT INLET STEAM CONDITIONS OF 962.0 PSIA AND 1190.8 H TO ASSURE THAT THE TURBINE WILL PASS THIS FLOW, CONSIDERING VARIATIONS IN FLOW COEFFICIENTS FROM EXPECTED VALUES, SHOP TOLERANCES ON DRIVING AXLES, ETC. WHICH MAY AFFECT THE FLOW, THE TURBINE IS BEING DESIGNED FOR A DESIGN FLOW (RATING FLOW PLUS 5.0 PERCENT) OF 1431470. M THE VALUE OF GENERATOR OUTPUT SHOWN ON THIS HEAT BALANCE IS AFTER ALL POWER FOR EXCITATION AND OTHER TURBINE-GENERATOR AUXILIARIES HAS BEEN DEDUCTED

Figure 10: Heat Balance 553HB2039 Rev 1 New VWO Condition



14300170. M	1190.8 H	408.5 I
+ 809771. M	(1190.8 - 408.5 I	
+ 27298. M	1190.8 - 48.0 I	
NET HEAT RATE	1184537	18000 BTU KW-HR

Clinton
(170X688)

LEGEND - CALCULATIONS BASED ON 1957 ASME STEAM TABLES
M - FLOW-LB/MIN
P - PRESSURE-PSIA
H - ENTHALPY-BTU/LB
T - TEMPERATURE-DEGREES

1130345. KW 2.28 IN HG ABS
TC4F 43.0 IN L5B 1800 RPM
962.0 PSIA 1190.8 BTU / LB
GEN- 1245000. KW .90 PF L10 75.0 PSIG H2 PRES

Turbine Assumed to be in New and Clean Condition
553#2039 Rev. 1 05/17/01

GENERAL ELECTRIC COMPANY, ATLANTA, GA

VWO Heat Balance
Based on 552H82947, Rev. 3

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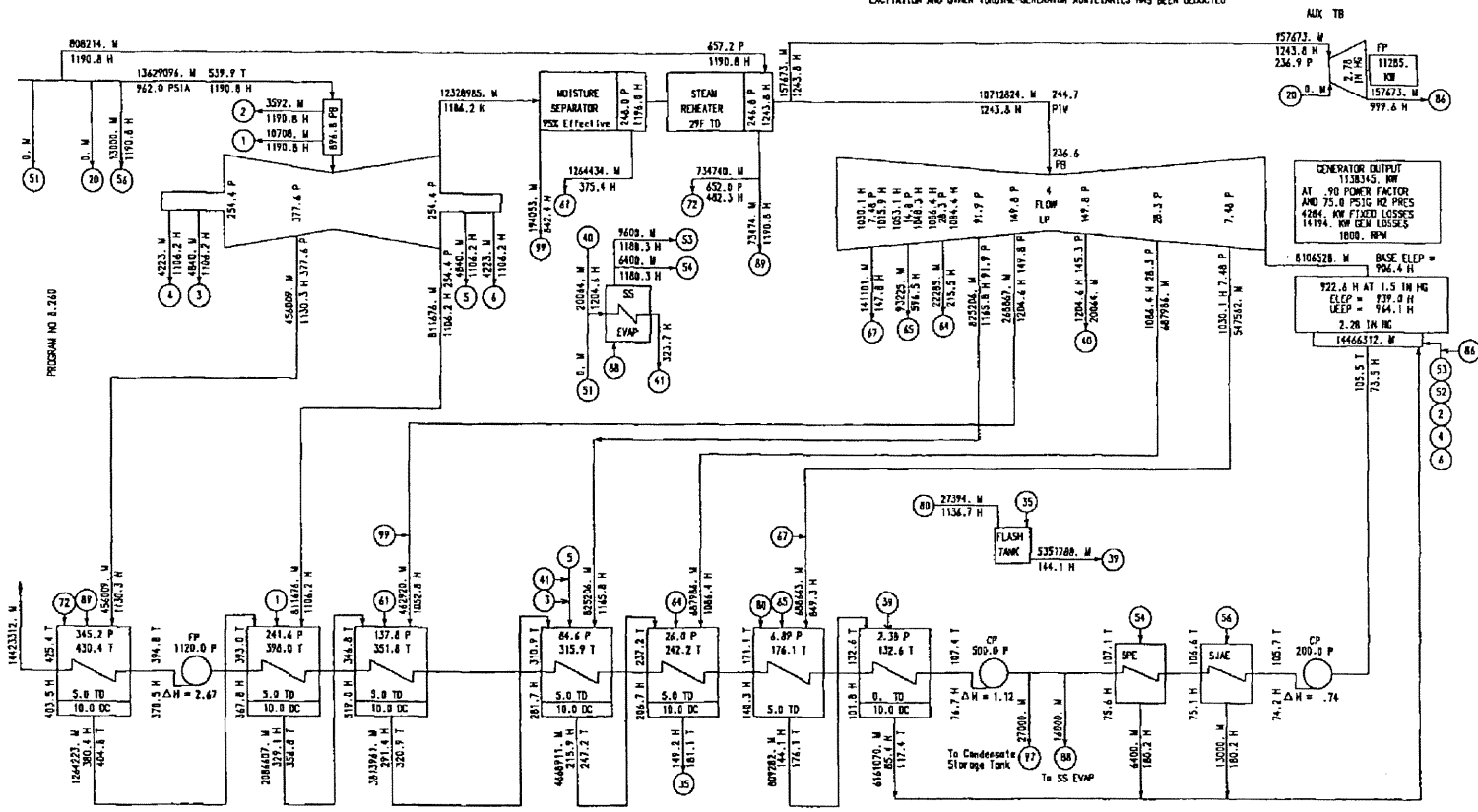
FIGURE 10.1-2
HEAT BALANCE - VALVES WIDE OPEN,
105% TURBINE RATED STEAM FLOW

552H2947, Rev. 3

Turbine Assumed to be in New and Clean Condition

TURBINE AND EXTRACTION ARRANGEMENT IS SCHEMATIC ONLY

THE VALUE OF GENERATOR OUTPUT SHOWN IN THIS HEAT BALANCE IS AFTER ALL POWER FOR EXCITATION AND OTHER TURBINE-GENERATOR AUXILIARIES HAS BEEN DEDUCTED



VALVE BEST POINT NET HEAT RATE = $\frac{13615094 \cdot (1199.8 - 403.5) + 808214 \cdot (1199.8 - 403.5)}{27000} = 1138345$ BTU KW-HR

Clinton
(170x688)

1138.3 MWe Output and
3337 MWt NSSS Reactor Power

LEGEND - CALCULATIONS BASED ON 1967 ASME STEAM TABLES
M - FLOW-LB/HR
P - PRESSURE-PSIA
T - EXTRACTION-TEMPERATURE
T - TEMPERATURE-DEGREES

1138345 KW 2.26 IN HG ABS
TOP OF 43.0 IN L50 1800 RPM
942.0 PSIA 1199.8 BTU / LB
GEN- 1285000. RWA .90 PF L10
D - PCT MW
SINGLE STAGE REHEAT
75.0 PSIG H2 PRESS

552H2947, Rev. 3

05/17/01

Turbine Assumed to be in New and Clean Condition

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FIGURE 10.1-3
HEAT BALANCE - GUARANTEE TURBINE
RATED STEAM FLOW

Figure 9: Heat Balance 552H2947 Rev. 3 - New Rated Condition

Final

Final - 115% OLR Extended Uprate

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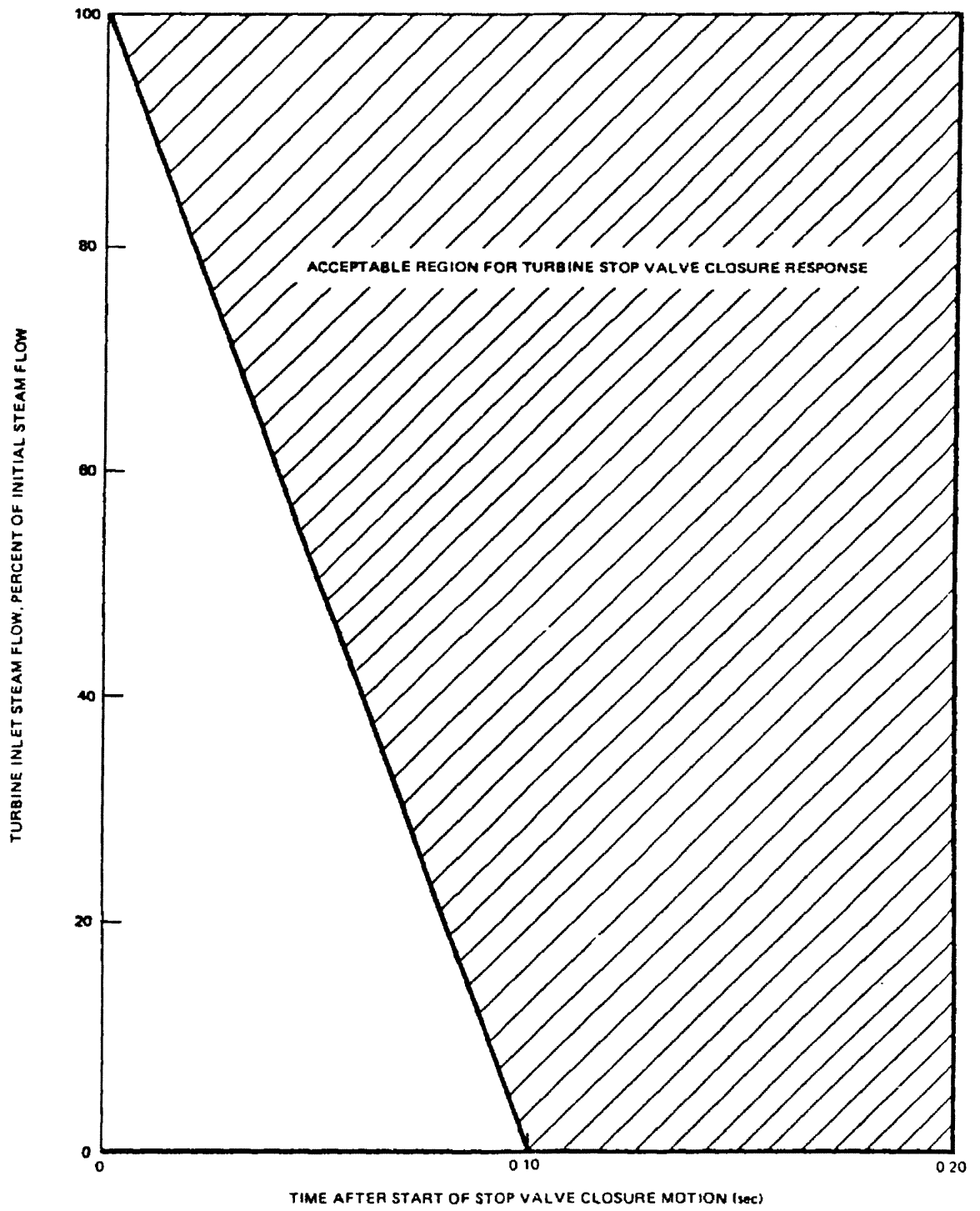


FIGURE 10.2-1. TYPICAL TURBINE STOP VALVE CLOSURE CHARACTERISTIC

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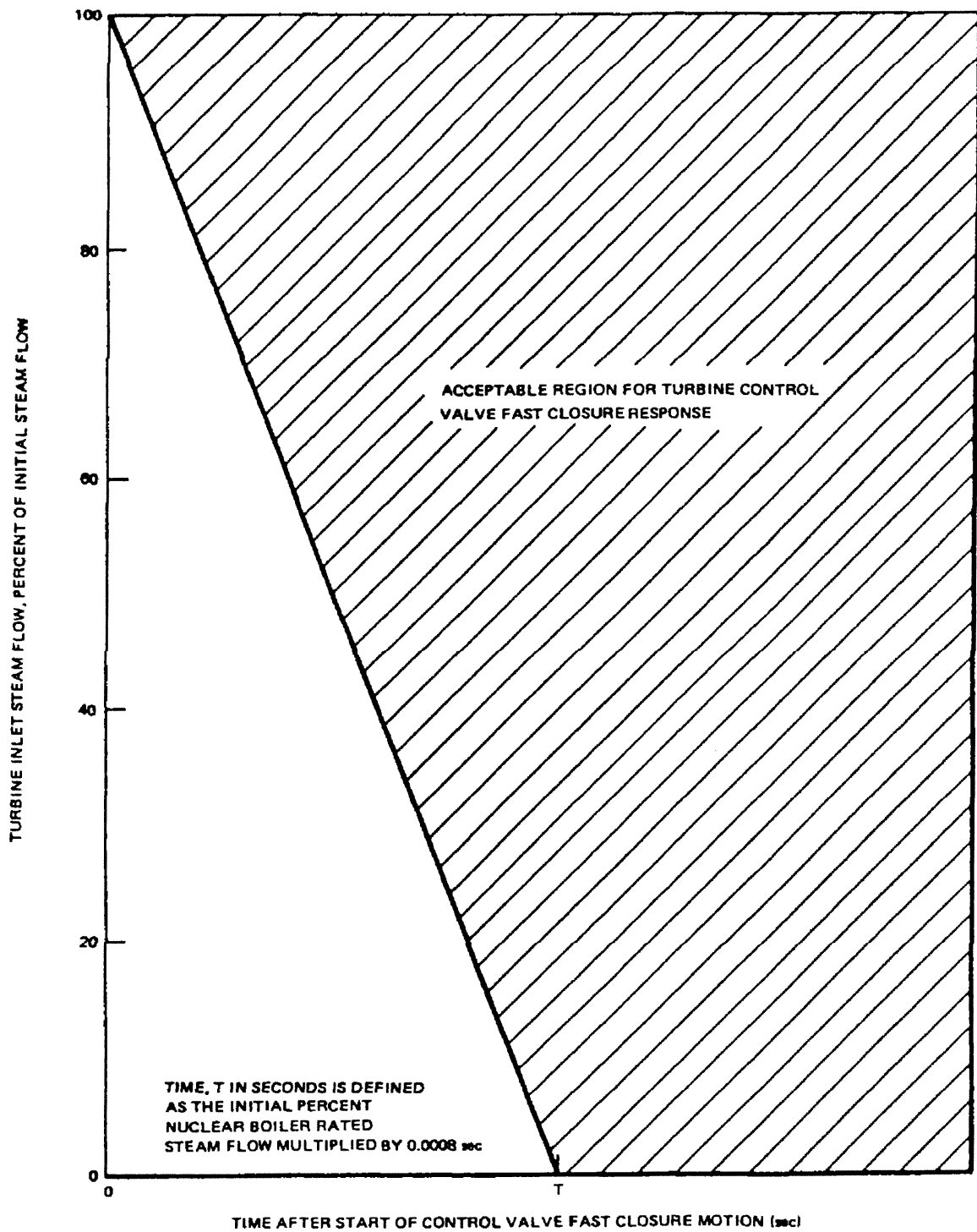
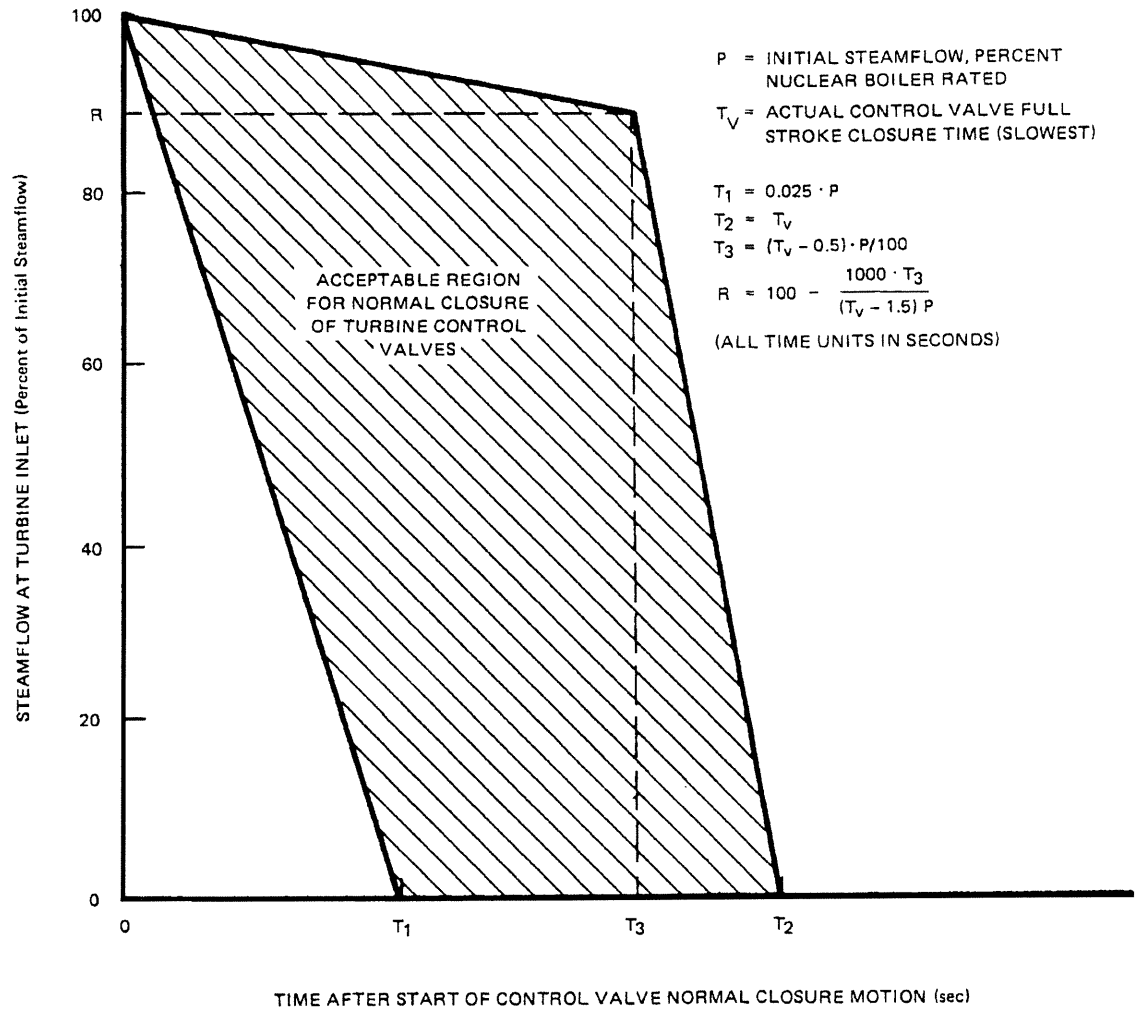


FIGURE 10.2-2. TYPICAL TURBINE CONTROL VALVE FAST CLOSURE CHARACTERISTIC



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FIGURE 10.2-3
ACCEPTABLE RANGE FOR TYPICAL
CONTROL VALVE NORMAL
CLOSURE MOTION