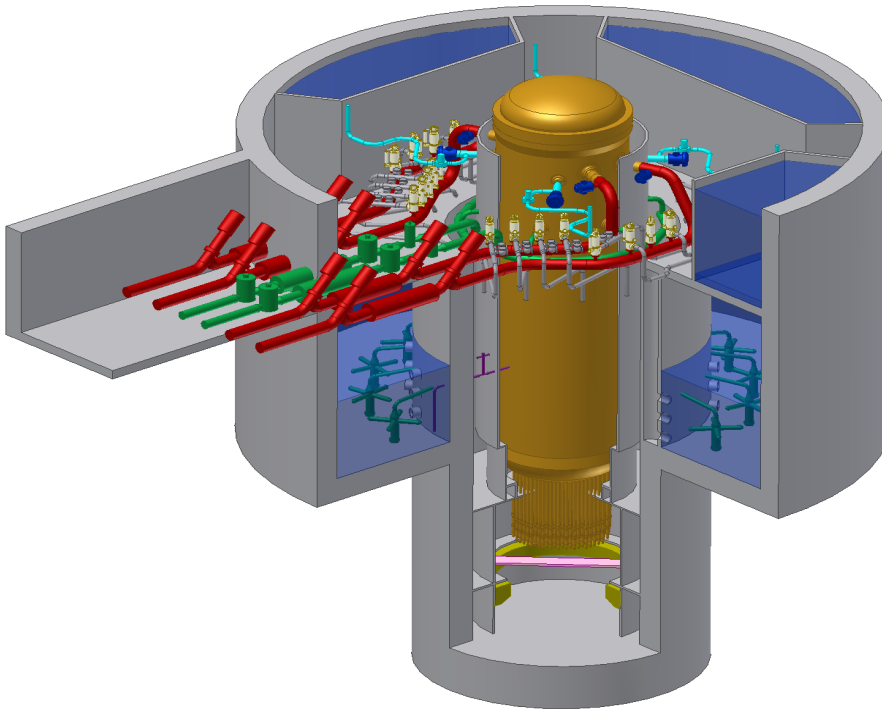




**GE Energy Nuclear**

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# **ESBWR Design Control Document**

## **Tier 2**

### **Chapter 10**

#### ***Steam and Power Conversion System***



## Contents

10. Steam and Power Conversion System .....	10.1-1
10.1 Summary Description .....	10.1-1
10.1.1 Protective Features .....	10.1-2
10.1.2 COL Unit-Specific Information .....	10.1-3
10.1.3 References .....	10.1-3
10.2 Turbine Generator .....	10.2-1
10.2.1 Design Bases .....	10.2-1
10.2.2 Description .....	10.2-2
10.2.3 Turbine Integrity .....	10.2-9
10.2.4 Evaluation .....	10.2-13
10.2.5 COL Unit Specific Information .....	10.2-14
10.2.6 References .....	10.2-14
10.3 Turbine Main Steam System .....	10.3-1
10.3.1 Design Bases .....	10.3-1
10.3.2 Description .....	10.3-2
10.3.3 Evaluation .....	10.3-3
10.3.4 Inspection and Testing Requirements .....	10.3-3
10.3.5 Water Chemistry (PWR) .....	10.3-3
10.3.6 Steam and Feedwater System Materials .....	10.3-3
10.3.7 COL Information .....	10.3-4
10.3.8 References .....	10.3-4
10.4 Other Features of Steam and Power Conversion System .....	10.4-1
10.4.1 Main Condenser .....	10.4-1
10.4.2 Main Condenser Evacuation System .....	10.4-5
10.4.3 Turbine Gland Seal System .....	10.4-8
10.4.4 Turbine Bypass System .....	10.4-10
10.4.5 Circulating Water System .....	10.4-13
10.4.6 Condensate Purification System .....	10.4-16
10.4.7 Condensate and Feedwater System .....	10.4-19
10.4.8 Steam Generator Blowdown System (PWR) .....	10.4-25
10.4.9 Auxiliary Feedwater System (PWR) .....	10.4-25
10.4.10 COL Unit Specific Information .....	10.4-26
10.4.11 References .....	10.4-26
10A. Alternative design for Steam and Power Conversion System .....	10A-1
10A.1 Abstract .....	10A-1
10A.1.1 Protective Features .....	10A-2
10A.1.2 COL Information .....	10A-2
10A.1.3 References .....	10A-2
10A.2 Turbine Generator .....	10A-9
10A.2.1 Design Bases .....	10A-9
10A.2.2 Description .....	10A-9
10A.2.3 Turbine Integrity .....	10A-13

10A.2.4 Evaluation .....	10A-20
10A.2.5 COL Information.....	10A-20
10A.2.6 References .....	10A-20
10A.3 Turbine Main Steam System.....	10A-22
10A.3.1 Design Bases .....	10A-22
10A.3.2 Description .....	10A-22
10A.3.3 Evaluation .....	10A-22
10A.3.4 Inspection and Testing Requirements .....	10A-22
10A.3.5 Water Chemistry (PWR) .....	10A-22
10A.3.6 Steam and Feedwater System Materials .....	10A-22
10A.3.7 COL Information.....	10A-23
10A.3.8 References .....	10A-23
10A.4 Other Features of Steam and Power Conversion System .....	10A-27
10A.4.1 Main Condenser .....	10A-27
10A.4.2 Main Condenser Evacuation System .....	10A-28
10A.4.3 Turbine Gland Seal System.....	10A-29
10A.4.4 Turbine Bypass System.....	10A-30
10A.4.5 Circulating Water System .....	10A-30
10A.4.6 Condensate Purification System .....	10A-31
10A.4.7 Condensate and Feedwater System.....	10A-32
10A.4.8 Steam Generator Blow Down System (PWR) .....	10A-34
10A.4.9 Auxiliary Feedwater System (PWR).....	10A-34
10A.4.10 COL Information.....	10A-34

### List of Tables

#### Abbreviations And Acronyms List

Table 10.1-1 Summary of Important Design Features and Performance Characteristics of the  
Steam and Power Conversion System

Table 10.3-1 Turbine Main Steam System Design Data

Table 10.4-1 Main Condenser Data

Table 10.4-2 Main Condenser Evacuation System

Table 10.4-3 Circulating Water System

Table 10.4-4 Condensate Purification System

Table 10.4-5 Condensate and Feedwater System Data

Table 10.4-6 Condensate and Feedwater System Component Failure Analysis

Table 10A.1-1 Summary of Important Design Features and Performance Characteristics of the  
Steam and Power Conversion System

Table 10A.3-1 Turbine Main Steam System Design Data

Table 10A.4-1 Main Condenser Data

Table 10A.4-2 Main Condenser Evacuation System

Table 10A.4-3 Circulating Water System

Table 10A.4-4 Condensate Purification System

Table 10A.4-5 Condensate and Feedwater System Data

Table 10A.4-6 Condensate and Feedwater System Component Failure Analysis

**List of Illustrations**

Figure 10.1-1. Power Cycle Schematic  
Figure 10.1-2. Rated Heat Balance  
Figure 10.1-3. Valves Wide Open-Heat Balance  
Figure 10.2-1. Turbine Stop Valve Closure Characteristic  
Figure 10.2-2. Turbine Control Valve Fast Closure Characteristic  
Figure 10.2-3. Acceptable Range for Control Valve Normal Closure Motion  
Figure 10.2-4. Hydrogen Gas Control System  
Figure 10.3-1. Turbine Main Steam System  
Figure 10.3-2. Main Turbine System  
Figure 10.4-1. Circulating Water System  
Figure 10.4-2. Main Condenser Evacuation System  
Figure 10.4-3. Turbine Gland Seal System  
Figure 10.4-4. Signal Flow Chart for Turbine Bypass Control Unit  
Figure 10.4-5. Condensate Purification System  
Figure 10.4-6a. LP Extraction Steam System  
Figure 10.4-6b. LP Drain and Vent System  
Figure 10.4-7a. HP Extraction Steam System  
Figure 10.4-7b. HP Drain and Vent System  
Figure 10A.1-1. Power Cycle Schematic  
Figure 10A.1-2. Rated Heat Balance  
Figure 10A.1-3. Valves Wide Open - Heat Balance  
Figure 10A.2-1. Turbine Stop Valve Closure Characteristic  
Figure 10A.2-2. Turbine Control Valve Fast Closure Characteristic  
Figure 10A.2-3. Acceptable Range for Control Valve Normal Closure Motion  
Figure 10A.2-4. Hydrogen Gas Control System  
Figure 10A.3-1. Turbine Main Steam System  
Figure 10A.3-2. Main Turbine System  
Figure 10A.4-1. Circulating Water System  
Figure 10A.4-2. Condensate System  
Figure 10A.4-2. Main Condenser Evacuation System  
Figure 10A.4-3. Turbine Gland Seal System  
Figure 10A.4-4. Signal Flow Chart for Turbine Bypass Control Unit  
Figure 10A.4-5. Condensate Purification System  
Figure 10A.4-6. LP Extraction Steam Drains and Vent Systems  
Figure 10A.4-7. HP Extraction Steam Drains and Vent Systems  
Figure 10A.4-8. Turbine Bypass System

## Abbreviations And Acronyms List

<b><u>Term</u></b>	<b><u>Definition</u></b>
10 CFR	Title 10, Code of Federal Regulations
ABS	Auxiliary Boiler System
AOO	Anticipated Operational Occurrence
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing Methods
BTP	NRC Branch Technical Position
BTU	British Thermal Unit
BWROG	Boiling Water Reactor Owners Group
C&FS	Condensate and Feedwater System
CFR	Code of Federal Regulations
CIRC	Circulating Water System
COL	Combined Operating License
CPS	Condensate Purification System
CS/CST	Condensate Storage Tank
$C_v$	Valve Flow Coefficient
$C_v$	Charpy V-notch
CV	Control Valve
dc / DC	Direct Current
EOS	Emergency Overpeed
EPRI	Electric Power Research Institute
ETD	Emergency Trip Device
ETS	Emergency Trip System
FATT	Fracture Appearance Transition Temperature
FFWTR	Final Feedwater Temperature Reduction
FW	Feedwater
GDC	General Design Criteria
GE	General Electric Company
HCF	High Cycle Fatigue
HEI	Heat Exchange Institute
HGCS	Hydrogen Gas Control System
HO	Hydraulic Operator
HP	High Pressure
HVAC	Heating, Ventilation and Air Conditioning
I/O	Input/Output
IP	Intermediate pressure
IS&IV	Intermediate Stop and Intercept Valve
LCF	Low Cycle Fatigue
LP	Low Pressure

## Abbreviations And Acronyms List

<b><u>Term</u></b>	<b><u>Definition</u></b>
LSB	Last Stage Blade
MCR	Main Control Room
MPI	Magnetic Particle Inspection
MSIV	Main Steam Isolation Valve
MSR	Moisture Separator Reheater
NBR	Nuclear Boiler Rated
NBS	Nuclear Boiler System
NDT	Nil Ductility Temperature
NOS	Normal Overspeed
NPHS	Normal Power Heat Sink
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OGS	Offgas System
PCV	Pressure Control Valve
PRMS	Process Radiation Monitoring System
PWR	Pressurized Water Reactor
QA	Quality Assurance
RFP	Reactor Feed Pump
RG	Regulatory Guide
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RSSV	Reheat Steam Stop Valve
RSWLTV	Reheat Steam Warming Line Valve
SB&PCS	Steam Bypass and Pressure Control System
SJAE	Steam Jet Air Ejector
SRV	Safety Relief Valve
SSC	Systems, Structures and Components
SSE	Safe Shutdown Earthquake
SSS	Shelf-Shifting and Synchronizing
SV	Stop Valve
TB	Turbine Building
TBCE	Turbine Building Compartment Exhaust
TBS	Turbine Bypass System
TBV	Turbine Bypass Valve
TG	Turbine Generator
TGCS	Turbine Generator Control System
TGSS	Turbine Gland Seal System
TMSS	Turbine Main Steam System
TSI	Turbine Supervisory Instrumentation

**Abbreviations And Acronyms List****Term**

VWO

**Definition**

Valves Wide Open



## 10. STEAM AND POWER CONVERSION SYSTEM

### 10.1 SUMMARY DESCRIPTION

The steam and power conversion system has no primary safety-related function. The components of the steam and power conversion system are designed to produce electrical power utilizing the steam generated by the reactor, condense the steam into water, and return the water to the reactor as heated feedwater. A major portion of its gaseous, dissolved, and particulate impurities are removed in order to satisfy the reactor water quality requirements.

The steam and power conversion system includes the turbine main steam system, main Turbine Generator, main condenser, main condenser evacuation system, turbine gland seal system, turbine bypass system, extraction steam system, condensate purification system, and the condensate and feedwater pumping and heating system. The heat rejected to the main condenser is removed by a circulating water system and discharged to the normal power heat sink.

At normal reactor power steam generated in the reactor is supplied to the High Pressure turbine and the second stage reheater of the steam moisture separators/reheaters. Steam leaving the High Pressure turbine passes through a combined moisture separator/reheater prior to entering the Low Pressure turbines. The moisture separator and steam reheaters drain to the high pressure feedwater heaters. The drains from the High Pressure feedwater heaters cascade to the open feedwater heater which is combined with a feedwater storage tank. The reactor feedwater pumps take suction from the open feedwater heater storage tank. The Low Pressure feedwater heater drains cascade to the condenser.

Steam exhausted from the Low Pressure turbines is condensed and deaerated in the condenser. The condensate pumps take suction from the condenser hotwell and deliver the condensate through filters and demineralizers, gland steam condenser(s), steam jet air ejector condenser(s), off-gas condenser(s), and through the Low Pressure feedwater heaters to the open feedwater heater. The reactor feedwater pumps discharge through the High Pressure feedwater heater subsystem to the reactor.

The important steam and power conversion system design features are summarized in Table 10.1-1. The main conceptual features are illustrated on Figure 10.1-1.

Normally, the turbine power heat cycle utilizes all the steam being generated by the reactor; however, an automatic pressure-controlled turbine bypass system designed for full load rejection capability is provided to discharge excess steam directly to the condenser.

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

Auxiliary equipment is designed to support the maximum calculated unit capability.

Table 10.1-1 shows the ESBWR Standard Plant steam and power conversion system heat input available from the Nuclear Steam Supply System (NSSS) when the reactor core is generating its rated output. The steam and power conversion system is designed with the capability to operate at approximately 105% of rated turbine throttle flow (assumed to correspond to turbine valves wide open).

The inlet pressure at the turbine main steam valves reflects reactor power, steam line flow and pressure regulator programming but never exceeds the pressure for which the turbine components and steam lines are designed.

The necessary biological shielding for personnel protection is provided for all required radiation producing components of the steam and power conversion system including the main turbines, moisture separator reheaters, feedwater heaters, condenser and steam jet air ejectors.

The approximate rated and valves-wide open flow quantities and fluid pressures and temperatures are shown on the turbine cycle heat balances, Figures 10.1-2 and 10.1-3, respectively. These represent the reference cycle; actual values can vary.

The majority of the steam and power conversion system is located in the turbine building, which is a Seismic Category II, nonsafety-related building.

Nonsafety-related instrumentation is provided to measure flow, pressure, differential pressure, temperature, and level throughout the main steam and Condensate and Feedwater System (C&FS). The instrumentation provides input signals to the plant computer and control systems that maintain the normal operation of the plant.

Safety-related instrumentation is provided to measure the turbine main steam header pressure, main condenser pressure, main turbine stop valve positions, hydraulic pressure of the turbine control valves, and the bypass valve positions. These signals go to each division of Reactor Protection System (RPS). (See Subsection 7.2.1 for a description of the RPS interface for these devices.)

### **10.1.1 Protective Features**

#### ***10.1.1.1 Loss of External Electrical Load and/or Turbine Trip***

Load rejection capabilities of the steam and power conversion systems are discussed in Subsection 10.4.4.

#### ***10.1.1.2 Overpressure Protection***

The following components are provided with overpressure protection in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII:

- Moisture separator/reheater vessels and drain tanks.
- Selected Low Pressure feedwater heaters.
- The High Pressure feedwater heaters.
- Open feedwater heater storage tank

#### **10.1.1.2.1 Turbine Overspeed Protection**

Turbine overspeed protection is discussed in Subsection 10.2.2.4.

#### **10.1.1.2.2 Turbine Integrity**

Turbine integrity is discussed in Subsections 3.5.1 and 10.2.3.

### 10.1.2 COL Unit-Specific Information

None

### 10.1.3 References

None

Table 10.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

Parameter	Standard Plant Value*
<b>Nuclear Steam Supply, Full Power Operation:</b>	
Rated reactor core power, (MWt)	4500
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Reactor steam dome pressure, MPa (psia)	7.17 (1,040)
Reactor rated steam flow, kg/s (lbm/hr)	2432.6 (19.3x10 <sup>6</sup> )
Reactor nominal outlet steam moisture, %	0.1 (Design)
Reactor inlet feedwater temp, °C (°F)	215.6 (420)
<b>Turbine-Generator:</b>	
Nominal gross Rating, (MWe)	1605
LP Turbine type	Tandem compound, six flow, 132-cm (52-in) last-stage blade (LSB)
Operating speed, (rpm)	1800
Turbine throttle steam pressure, MPa (psia)	6.67 (968)
Throttle steam nominal moisture, (%)	0.5
<b>Moisture Separator/Reheaters (MSRs):</b>	
Number of MSRs per unit	4
Stages of moisture separation	1
Stages of reheater	2
<b>Main Condenser (Site Dependent):</b>	
Type	Multiple pressure
Design duty, MW (Btu/hr)	3057 (10.43x10 <sup>9</sup> )
Circulating water flow rate, m <sup>3</sup> /hr (gpm)	152,000 (671,000)
Circulating water temperature rise, °C (°F)	16.5 (29.7)
<b>Condensate Pumps:</b>	
Number of pumps	4 (3 Normally Operating)
Pump type	Fixed speed, centrifugal, vertical
Driver type	Motor

Table 10.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

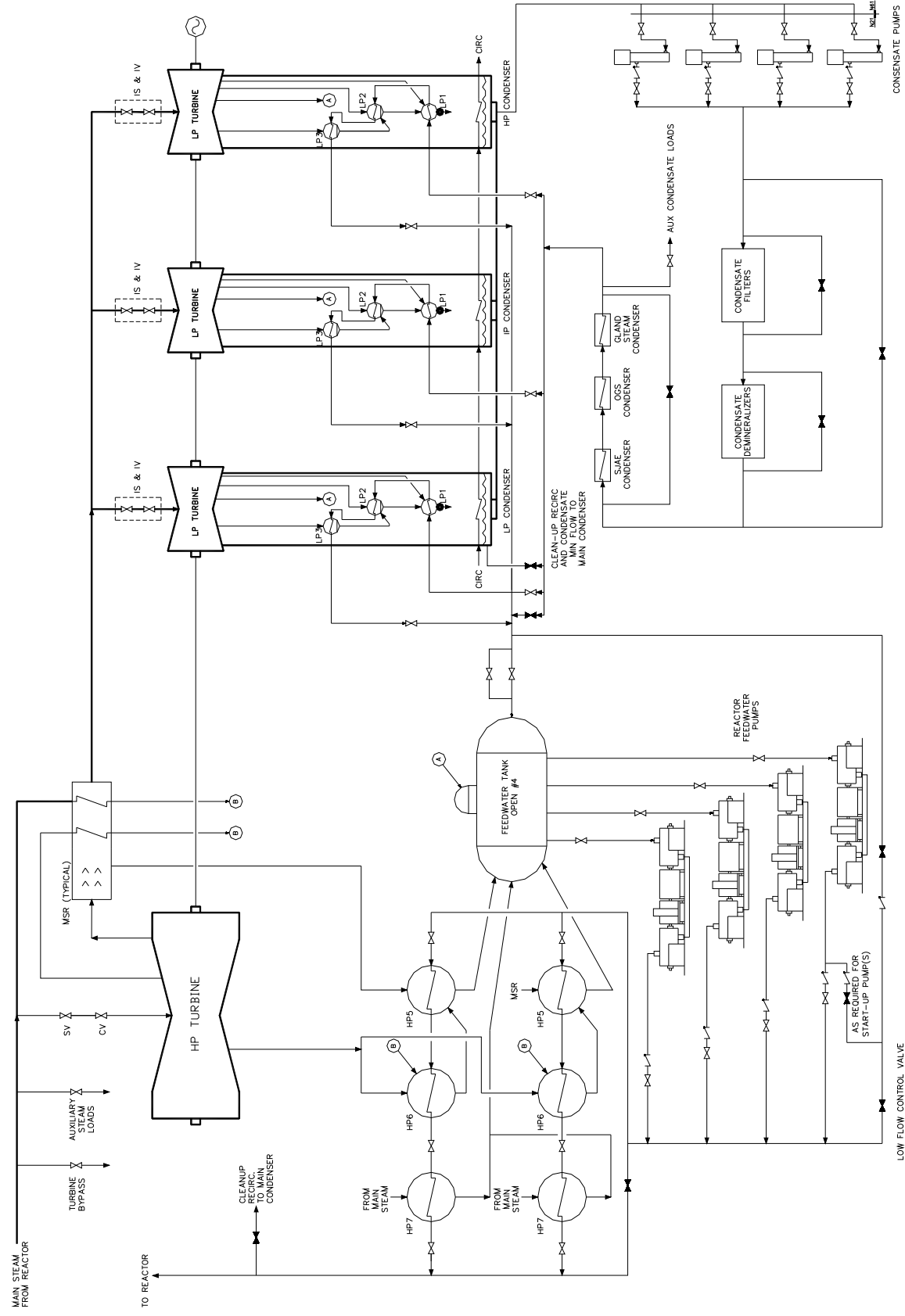
<b>Parameter</b>	<b>Standard Plant Value*</b>
Normal flow, kg/hr (lb/hr)	5.8x10 <sup>6</sup> (12.8x10 <sup>6</sup> )
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This row was deleted in its entirety.	
<b>Feedwater Heaters:</b>	
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This line was deleted in its entirety.	
This line was deleted in its entirety.	
This line was deleted in its entirety.	
No. 1:	
Number per stage	3
Stage pressure, kPa (psia)	55 (8)
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No. 2:	
Number per stage	3
Stage pressure, kPa (psia)	110 (16)
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No. 3:	
Number per stage	3
Stage pressure, kPa (psia)	221 (32)
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No. 4 (Open type. Feedwater Tank)	
Number per stage	1
Stage pressure, kPa (psia)	407 (59)
Net feedwater volume, m <sup>3</sup> (ft <sup>3</sup> )	680 (24x10 <sup>3</sup> )
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Table 10.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

<b>Parameter</b>	<b>Standard Plant Value*</b>
No. 5:	
Number per stage	2
Stage pressure, kPa (psia)	1282 (186)
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No. 6:	
Number per stage	2
Stage pressure, kPa (psia)	2255 (327)
No. 7:	
Number per stage (Used for Power Maneuvering only)	2
<b>Reactor Feedwater Pump:</b>	
Number of pumps (booster and main pump)	4 (3 Normally Operating)
Pump type	Variable speed, centrifugal, horizontal
Driver type	Motor
Normal flow, Kg/hr (lb/hr)	$8.8 \times 10^6$ ( $19.3 \times 10^6$ )
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\* Reference Value is shown for rated operation. These are representative values for the reference cycle; actual values can vary slightly.



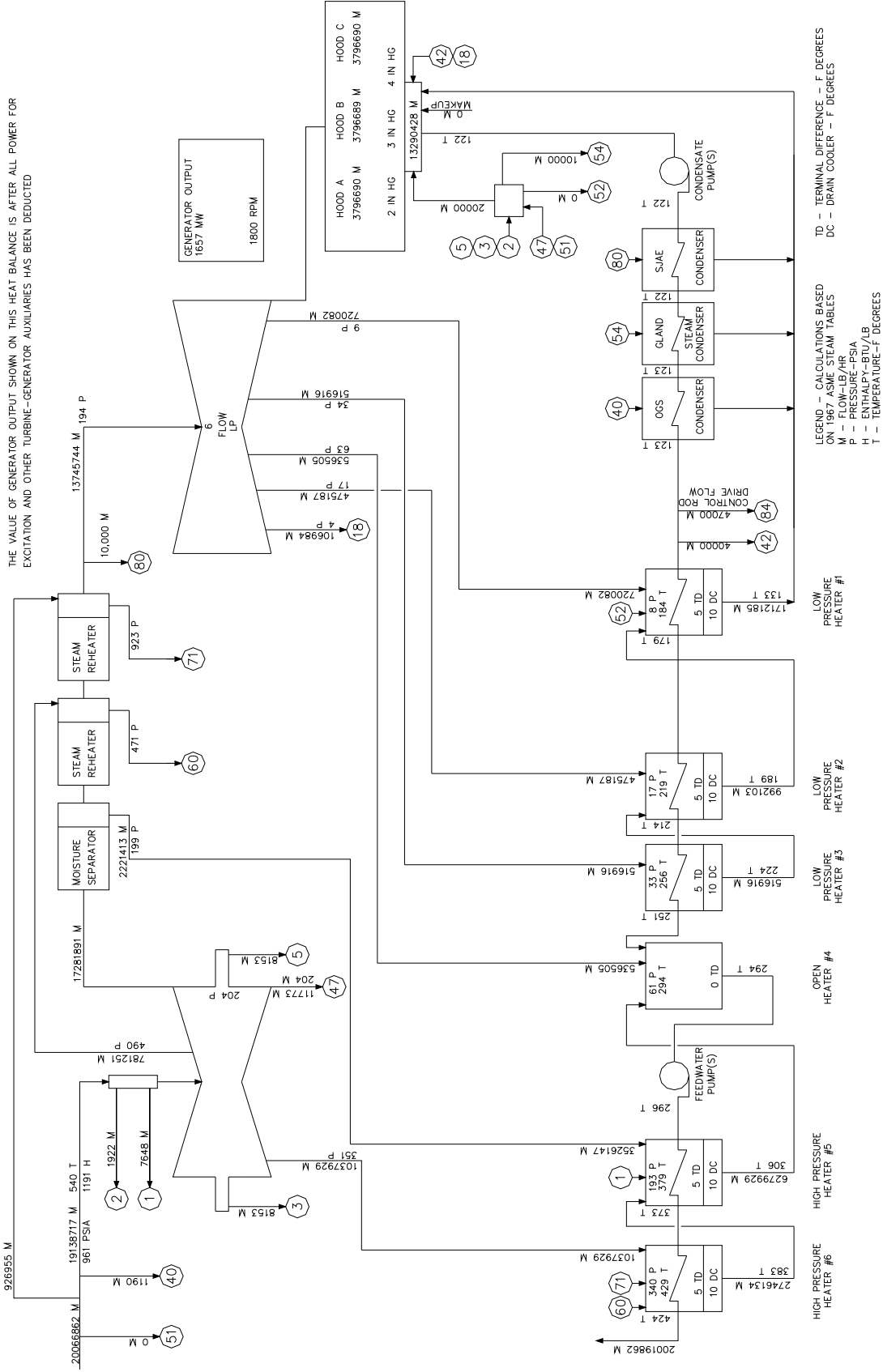
GENERATOR OUTPUT  
1605 MW

1800 RPM





20066862	M	19138717	M	540	T
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### Figure 10.1-3. Valves Wide Open-Heat Balance

## 10.2 TURBINE GENERATOR

### 10.2.1 Design Bases

The design of the Turbine Generator (TG) system meets the requirement of General Design Criterion 4 as related to the protection of safety-related structures, systems and components from the effects of turbine missiles. It provides a redundant turbine overspeed protection system to minimize the probability of generation of turbine missiles and locating and orienting them so as to avoid any potential impact on safety-related structures and equipment. The probability of Turbine Generator missiles generation, assuming the recommended inspection and test frequencies, is less than  $1 \times 10^{-5}$  per year.

#### *10.2.1.1 Safety (10 CFR 50.2) Design Bases*

The TG does not perform or support any safety-related function, and thus, has no safety design basis. The Turbine Generator is, however, a potential source of high energy missiles that could damage safety-related equipment or structures. The turbine is designed to minimize the possibility of failure of a turbine blade or rotor. Turbine integrity is discussed in Subsection 10.2.3. The effects of potential high energy missiles are discussed in Section 3.5 and Subsection 10.2.4. In addition, the main steam turbine stop valves are analyzed to demonstrate structural integrity under Safe Shutdown Earthquake (SSE) loading conditions.

#### *10.2.1.2 Non-Safety Power Generation Design Bases*

- The TG is intended for base load and load following capability. The gross generator outputs at reference reactor rated thermal power and Valves Wide Open (VWO) operation are given on the heat balances shown on Figures 10.1-2 and 10.1-3, respectively.
- The TG load change characteristics are compatible with the instrumentation and control system, which coordinates TG and reactor operation.
- The TG is designed to accept a sudden loss of full load with sufficient margin to the overspeed trip.
- The TG is designed to permit periodic testing under power operation conditions of steam valves important to overspeed protection and overspeed trip circuits.
- The failure of any single component does not cause the rotor speed to exceed the Emergency Overspeed (EOS).
- Turbine control functions, which are required for turbine protection, possess sufficient redundancy such that failure of a single component input does not compromise the integrity of the turbine protection system.
- The TG auxiliary systems (stator cooling, lube oil cooling, etc.) are designed either with enough redundancy to support full power operation with a single failure or to provide a signal to the main control room to prompt a reduction in power to within the capability of the remaining auxiliary systems.

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

Turbine main steam stop, control valves, intermediate stop valves and intercept valves protect the turbine from excessive speeds. The Steam Bypass and Pressure Control System (SB&PC) protects the reactor system from abnormal pressure surges. The valve arrangements and valve closure times are such that a failure of any single valve to operate does not result in the unit exceeding EOS or an abnormal pressure surge in the event of a TG trip signal or near full load rejection.

#### **10.2.1.3.1 Turbine Stop Valve**

During an event resulting in turbine stop valve fast closure, turbine inlet steam flow is not reduced faster than that shown in Figure 10.2-1.

#### **10.2.1.3.2 Turbine Control Valve**

During any event resulting in turbine control valve fast closure, the turbine inlet steam flow is not reduced faster than that shown in Figure 10.2-2.

The turbine control valve steam flow shutoff rate, upon a step reduction to zero in pressure regulation flow demand (no resulting bypass steam flow demand), is within the region shown in Figure 10.2-3. Any single control system failure or TG event does not cause a faster steam flow reduction than that shown in Figure 10.2-3 without generating control valve fast closure signals to the RPS.

The turbine control valves are capable of full stroke opening and closing times required for adequate pressure control performance.

#### **10.2.1.3.3 Load Maneuvering Capability**

The plant is capable of daily load following with control rod drive operation between 100% and 50% of rated power on a 14-1-8-1 hour cycle and with ramp rates up to  $\pm 1\%$ /minute.

Power maneuvers within the capabilities above do not require isolation or bypass of condensate/feedwater equipment such as feedwater heaters.

## **10.2.2 Description**

### ***10.2.2.1 General Description***

The Turbine Generator consists of an 1800 rpm turbine, moisture separator/reheaters, generator, exciter, controls, and associated subsystems.

The turbine for the ESBWR Standard Plant consists of a double-flow, High Pressure unit, and three double flow Low Pressure units in tandem. The High Pressure turbine has extraction points for reheater reheating steam and high pressure feedwater heating.

Moisture separation and reheating of the High Pressure turbine exhaust steam is performed by the Moisture Separator Reheaters (MSRs). The MSRs are located on each side of the TG centerline. The steam then passes through the Low Pressure turbines, each with extraction points for the Low Pressure stages of feedwater heating, and exhausts into the main condenser. In

addition to the moisture separators in the external MSRs, the turbine steam path has provisions for removing some additional moisture and routing it to extraction lines.

The generator is a direct driven, three-phase, 60 Hz, 1800 rpm synchronous generator with a water-cooled armature winding and hydrogen-cooled rotor.

The turbine generator uses a digital monitoring and control system, which, in coordination with the turbine SB&PC, controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine stop valves, control valves, and intermediate stop and intercept valves. TG supervisory instrumentation is provided for operational analysis and malfunction diagnosis.

TG accessories include the bearing lubrication oil system, Turbine Generator Control System (TGCS), turbine hydraulic system, turning gear, hydrogen gas control system, seal oil system, stator cooling water system, exhaust hood spray system, turbine gland seal system, MSR reheater heating steam system and turbine supervisory instrument system.

The TG unit and associated high energy piping, valves, and instruments are located completely within the Turbine Building. Any postulated failure associated with the TG unit does not affect any essential systems or components as defined in BTP SPLB 3-1. Failure of TG equipment cannot preclude safe shutdown of the reactor system.

#### ***10.2.2.2 Component Description***

The MSRs, MSR drain tanks, stator water coolers, and stator water demineralizer are designed to ASME Code Section VIII requirements. The balance of the TG is designed to turbine manufacturer's standards and applicable state required design codes and standards.

##### **10.2.2.2.1 Main Stop and Control Valves**

Four High Pressure main stop and four control valves admit steam to the High Pressure (HP) turbine. The primary function of the main stop valves is to quickly shut off the steam flow to the turbine under trip conditions. The primary function of the control valves is to control steam flow to the turbine in response to the turbine control system.

The main stop valves are hydraulically operated in an open-closed mode either by the turbine overspeed protection system in response to a turbine trip signal, or by a test solenoid valve and a fast acting solenoid valve for periodic testing. The disks are unbalanced and cannot open against full differential pressure. A bypass is provided to pressurize the below seat areas of the four valves. Springs in the valves are designed to improve the closing time response of the main stop valve under the abnormal conditions listed in Subsection 10.2.2.5.

Each stop valve contains a steam strainer to limit foreign material from entering the control valves and turbine.

The control valves are designed to ensure tight shutoff. The valves are of sufficient size, relative to their cracking pressure, to require a partial balancing. Each control valve is hydraulically operated by a servomotor opened by a high pressure fire-resistant fluid supplied through a servo valve.

**10.2.2.2.2 High Pressure Turbine**

The HP turbine receives steam through four steam leads, one from each control valve outlet. The steam is expanded axially across several stages of stationary and moving blades. Extraction steam from the turbine supplies the last stage of feedwater heating. HP turbine exhaust steam is collected in eight cold reheat pipes, four at each end of the HP casing, and is routed to the MSR inlet.

**10.2.2.2.3 Moisture Separator Reheaters**

Horizontal cylindrical shell, combined MSRs are installed in the steam path between the high and Low Pressure turbines. The MSRs serve to dry and reheat the HP turbine steam exhaust (cross around steam), before it enters the Low Pressure turbines. This improves cycle efficiency and reduces moisture-related erosion and corrosion in the Low Pressure turbines. Cold reheat steam is piped into the bottom of the MSR. Moisture is removed in chevron-type moisture separators, and is drained to the appropriate stage of feedwater heating. The steam next passes upward across the two reheater stages. Heating steam to the first reheater stage is supplied by extraction steam and heating steam to the second reheater stage is supplied with main steam. Reheated steam is routed to the intermediate stop and intercept valves, which are located just upstream of the Low Pressure turbine inlet nozzles. Safety relief valves are provided on the MSR for overpressure protection.

**10.2.2.2.4 Intermediate Stop and Intercept Valves**

Hydraulically operated intermediate stop and intercept valves are provided in each hot reheat line just upstream of the Low Pressure (LP) inlet.

Upon loss of load, the intercept valves first close then throttle steam to the LP turbine, as required to control speed. The intermediate stop valves close on a turbine trip. The intermediate stop and intercept valves are designed to rapid close to control turbine overspeed.

**10.2.2.2.5 Low Pressure Turbines**

Each LP turbine receives steam from two hot reheat lines. The steam expands axially across several stages of stationary and moving blades.

Extraction steam from the LP turbines supplies the first stages of feedwater heating.

**10.2.2.2.6 Extraction Non-return Valves**

Upon loss of load, the steam contained downstream of the turbine extractions can flow back into the turbine, across the remaining turbine stages, and into the condenser. Associated condensate can flash to steam under this condition and contribute to the backflow of steam or can be entrained with the steam flow and damage the turbines. Non-return valves are employed in selected extraction lines to minimize potential for overspeeding and also for preventing water entrainment (see Subsection 10.2.2.4).

**10.2.2.2.7 Generator**

The generator is a direct-driven, three-phase, 60 Hz, 1800 rpm, four-pole synchronous generator with water-cooled armature winding and hydrogen-cooled rotor.

The rotor is manufactured from forged components and includes layers of field windings embedded in milled slots. The windings are held radially by slot wedges, at the rotor outside diameter. The wedge material maintains its mechanical properties at elevated temperature. The magnetic field is generated by DC power, which is fed to the windings through collector rings located outboard of the main generator bearings.

The rotor body and shaft is machined from a single, solid steel forging. Detailed examinations include:

- Material property checks on test specimens taken from the forging.
- Photomicrographs for examination of microstructure.
- Magnetic particle and ultrasonic examination.
- Surface finish tests of slots for indication of a stress riser.

#### **10.2.2.2.8 Hydrogen Gas Control System**

The Hydrogen Gas Control System (HGCS) is illustrated on Figure 10.2-4. The hydrogen system is designed to provide the necessary flow and pressure at the main generator for purging carbon dioxide during startup and supply makeup hydrogen for generator leakage during normal operation.

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

Fires and explosions during filling and/or purging of the generator are prevented by inerting the generator with CO<sub>2</sub> so that a flammable mixture of hydrogen and oxygen cannot be produced. Unneeded hydrogen is vented outside through a flame arrestor.

The bulk hydrogen system utilizes the guidelines given in Reference 10.2-2. Specifically, the bulk hydrogen system piping and components are located to reduce risk from their failures. The bulk hydrogen storage is located outside the Turbine Building at a distance great enough to ensure no structural damage from a hydrogen detonation. The hydrogen lines are provided with a pressure reducing station that limits the maximum flow to less than 100 standard cubic meters per minute before entering the Turbine Building. Equipment and controls are designed to be accessible and remain functional after a bulk hydrogen storage detonation. The design features and/or administrative controls are provided to ensure that the hydrogen supply is isolated when normal building ventilation is lost.

The arrangement of buildings at the facility and location of building doors and the bulk hydrogen storage tanks are designed to ensure that damage to buildings containing safety-related equipment due to detonation or combustion of hydrogen is unlikely.

Additionally, the bulk hydrogen system piping in the Turbine Building is designed in accordance with the industry practice and applicable codes and standards.

#### **10.2.2.3 Normal Operation**

During normal operation, the main stop valves, intermediate stop valves, and intercept valves are wide open. Operation of the TG is under the control of the TGCS. The SB&PC controls the turbine control valves through the TGCS to regulate reactor pressure. The normal function of the

TGCS is to generate the position signals for the main stop valves, main control valves, intermediate stop valves, and intercept valves.

#### ***10.2.2.4 Turbine Overspeed Protection System***

The normal speed control system comprises a first line of defense against turbine overspeed. This system includes the main steam control valves, intermediate steam intercept valves, extraction system non-return valves, and fast-acting valve-closing functions within the TGCS. The normal speed control unit utilizes three speed signals. Loss of any two of these speed signals initiates a turbine trip via the Emergency Trip System (ETS). An increase in speed above setpoint tends to close the control and intercept valves in proportion to the speed increase. Rapid turbine accelerations resulting from a sudden loss of load at higher power levels normally initiate the fast-acting solenoids via the speed control system to rapidly close the control and intercept valves irrespective of the current turbine speed. The normal speed control system is designed to limit peak overspeed resulting from a loss of full load, to at least 1% below the overspeed trip set point. Typically, this peak speed is in a range of 106-109% of rated speed, and the overspeed trip set point is typically close to 110% of rated speed. All turbine steam control and intercept valves are fully testable during normal operation. The fast closing feature, provided by action of the fast-acting solenoids, is testable during normal operation.

If the normal speed control should fail, the overspeed trip devices closes the steam admission valves including the main and intermediate stop valves. This turbine overspeed protection system comprises the second line of defense against turbine overspeed. It is redundant and highly reliable. The overspeed protection system is designed to ensure that failure of the normal speed control system does not result in turbine speed exceeding 120% of rated speed. In addition, the components and circuits comprising the turbine overspeed protection system are testable when the turbine is in operation.

The overspeed trip system is electrical and redundant and consists of the Primary and Emergency overspeed trip functions. Reliability is achieved by using two sets of redundant speed sensing probes, which input to the independent Primary and Emergency Trip modules in the control system. For additional reliability, two-out-of-three logic is employed in both the Primary and Emergency overspeed trip circuitry. Either trip module can de-energize the trip solenoids of the electro-hydraulic Emergency Trip Device (ETD). The ETD is configured in a two-out-of-three tripping mode (i.e., if any two trip solenoids are de-energized the emergency trip fluid system is de-pressurized) rapidly closing all steam inlet valves. A single component failure does not compromise trip protection, and normally does not result in an undesirable turbine trip. Each trip solenoid valve in the ETD is testable while the turbine is in operation.

The overspeed sensing devices are located in the turbine front bearing standard, and are therefore protected from the effects of missiles or pipe breakage. The hydraulic lines are fail-safe; if one were to be broken, loss of hydraulic pressure would result in a turbine trip. The ETD is also fail-safe. Each trip solenoid transfers to the trip state on a loss of control power, resulting in a turbine trip. These features provide inherent protection against failure of the overspeed protection system caused by low trajectory missiles or postulated piping failures.

The Primary and Emergency electrical overspeed trip modules each consist of three independent circuits. Each circuit monitors a separate speed signal and activates trip logic at specific speed

levels based on voted inputs and outputs. This arrangement provides diversity in overspeed protection.

Each turbine extraction line is reviewed for potential energy and contribution to overspeed. The number and type of extraction non-return valves required for each extraction line are specified based on the enthalpy and mass of steam and water in the extraction line and feedwater heater. Higher energy lines are provided with power-assisted closed non-return valves, controlled by air relay dump valves, which in turn, are activated by the emergency trip fluid system. The air relay dump valves, actuated on a turbine trip, dump air from the extraction non-return valve actuators to provide rapid closing. The closing time of the extraction non-return valves is sufficient to minimize steam contribution to the turbine overspeed event.

The following component redundancies are employed to guard against excessive overspeed:

- (1) Main stop valves/Control valves
- (2) Intermediate stop valves/Intercept valves
- (3) Normal speed control/Primary overspeed control/Emergency overspeed control
- (4) Fast-acting solenoid valves/Emergency trip fluid system (Emergency trip device)
- (5) Speed control signals/Primary overspeed trip/Emergency overspeed trip

The main stop valves and control valves provide full redundancy in that these valves are in series and have independent control signals and operating mechanisms. Closure of all four stop valves or all four control valves effectively shuts off all main steam flow to the HP turbine. The intermediate stop and intercept valves are also in series and have independent control signals and operating mechanisms. Closure of either valve or both valves in each of the six sets of intermediate stop and intercept valves effectively shuts off steam flow to the three LP turbines. This arrangement is such that failure of a single valve to close does not result in a maximum speed in excess of design limits.

#### ***10.2.2.5 Turbine Protection System***

In addition to the overspeed trip signals discussed, the ETS closes the main stop and control valves and the intermediate stop and intercept valves to shut down the turbine on the following signals.

- Emergency trip in control room
- Moisture Separator high level
- High condenser pressure
- Low lube oil pressure
- LP turbine exhaust hood high temperature
- High reactor water level
- Thrust bearing wear
- Emergency trip at front standard
- Loss of stator coolant (if runback fails)



- Low hydraulic fluid pressure
- Selected generator trips
- Loss of TGCS electrical power
- Excessive turbine shaft vibration
- Loss of two speed signals – either Normal Speed Control or Emergency
- Loss of two pressure control channels

All of the above trip signals except generator trips, loss of power, vibration and manual trips use two-out-of-three coincident trip logic.

When the ETS is activated, it overrides all operating signals and trips the main stop and control valves, and intermediate stop and intercept valves.

#### ***10.2.2.6 Turbine-Generator Supervisory Instruments***

Although the turbine is not readily accessible during operation, the Turbine Supervisory Instrumentation (TSI) is sufficient to detect most malfunctions. The turbine supervisory instrumentation includes monitoring of the following:

- Vibration and eccentricity
- Thrust bearing wear
- Exhaust hood temperature
- Oil system pressures, levels and temperatures
- Bearing metal and oil drain temperatures
- Shell temperature
- Valve positions
- Shell and rotor differential expansion
- Shaft speed, electrical load, and control valve inlet pressure indication
- Hydrogen temperature, pressure and purity
- Stator coolant temperature and conductivity
- Stator-winding temperature
- Exciter temperatures
- Turbine gland sealing pressure
- Gland steam condenser vacuum
- Steam chest pressure
- Seal oil pressure

### ***10.2.2.7 Testing***

The Primary and Emergency overspeed trip circuits and devices are tested remotely at rated speed, under load, by means of controls in the Main Control Room (MCR). Operation of the overspeed protection devices under controlled speed conditions is checked at startup and after each refueling or major maintenance outage. In some cases, operation of the overspeed protection devices can be tested just prior to shutdown, thus negating the need to test overspeed protection devices during subsequent startup, if no maintenance is performed affecting the overspeed trip circuits and devices.

During refueling, or maintenance shutdowns, coinciding with the in-service inspection schedule required by Section XI of the ASME Code for reactor components, at intervals defined in Subsection 10.2.3.7, at least one main steam stop valve, one turbine control valve, one intermediate stop valve, and one intercept valve are dismantled to conduct visual and surface examinations of valve seats, disks and stems. If unacceptable flaws or excessive corrosion is found in a valve, all other valves of that type are dismantled and inspected. Valve bushings are inspected and cleaned, and bore diameters checked for proper clearance.

Main steam stop valves and turbine control valves, reheat intercept and reheat stop valves are exercised at least once within each calendar quarter (or as required by the missile probability analysis) by closing each valve and observing the remote valve position indicator for fully CLOSED position status. This test also verifies operation of the fast close function of each main steam stop, turbine control, reheat intercept and reheat stop valve during the last few percent of valve stem travel.

Access to required areas outside of the turbine shielding is provided on the turbine floor under operating conditions.

Provisions for testing each of the following devices while the unit is operating are included:

- Main steam stop valves and turbine control valves
- Low pressure turbine intermediate stop and intercept valves
- Emergency trip devices
- Turbine extraction non-return valves
- Remote trip solenoids
- Lubricating oil pumps
- Control fluid pumps
- Normal and Emergency trip device
- Power-load Unbalance circuits

## **10.2.3 Turbine Integrity**

### ***10.2.3.1 Materials Selection***

Turbine rotors are made from vacuum treated or remelted alloy steel components using processes that minimize flaw occurrence, assure uniform strength and provide adequate fracture toughness.

Undesirable elements, such as sulfur and phosphorus, are controlled to the lowest practical concentrations consistent with good scrap selection and melting practice, and consistent with obtaining adequate initial and long-life fracture toughness for the environment in which the parts operate. The turbine materials have the lowest Fracture Appearance Transition Temperatures (FATT) and highest Charpy V-notch (Cv) energies obtainable, on a consistent basis from material at the sizes and strength levels used.

Low pressure turbine wheel (disc) forgings are made from vacuum treated Ni-Cr-Mo-V alloy steel forgings. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with ASTM A-370, will be no higher than 0°F for low pressure turbine wheel (disc) forgings. The Cv energy at the minimum operating temperature will be at least 60 ft-lbs for a low pressure turbine wheel (disc) forging. A minimum of three Cv specimens will be tested in accordance with specification ASTM A-370 to determine this energy level. The determination of FATT is used in lieu of nil-ductility transition temperature methods.

Large integral rotors are also made from vacuum treated Ni-Cr-Mo-V alloy steel forgings. Their larger size limits the achievable properties. The fracture appearance transition temperature (50% FATT), as obtained from Charpy tests performed in accordance with ASTM A-370, will be no higher than +30°F for large integral forgings. The Cv energy at the minimum operating temperature will be at least 45 ft-lbs for a large integral rotor forging. A minimum of three Cv specimens will be tested in accordance with specification ASTM A-370 to determine this energy level.

Current turbine designs utilize rotors produced from large integral forgings. Future turbine designs may include fabricated rotors produced from multiple wrought components. Acceptable material properties will be consistent with component size and fabrication method.

#### ***10.2.3.2 Fracture Toughness***

Suitable material toughness is obtained through the use of selected materials as described in Subsection 10.2.3.1, to produce a balance of material strength and toughness to ensure safety while simultaneously providing high reliability, availability and efficiency during operation.

Stress calculations include consideration of centrifugal loads, interference fit and thermal gradients where applicable. The ratio of material fracture toughness,  $K_{Ic}$  (as derived from material tests on each major part or rotor), to the maximum tangential stress intensity at speeds from normal to design overspeed, is at least two at minimum operating temperature. Adequate material fracture toughness needed to maintain this ratio is assured by a large historical database of tests. When required, sufficient warm-up time or other procedures will be specified in the turbine operating instructions to ensure that the above ratio of fracture toughness to stress intensity is maintained during all phases of anticipated turbine operation.

#### ***10.2.3.3 High Temperature Properties***

The operating temperature range of both the High Pressure and Low Pressure rotors is below the stress rupture temperature range of the materials used. Therefore, creep-rupture is not considered to be a significant failure mechanism for these components.

#### ***10.2.3.4 Turbine Design***

The turbine assembly is designed to maintain structural integrity during normal operating conditions including anticipated operational occurrences and accidents resulting in a turbine trip. The design of the turbine assembly meets the following criteria.

- Turbine shaft bearings are designed to retain their structural integrity under normal operating loads, anticipated operational occurrences, and accidents resulting in turbine trips.
- The natural lateral critical frequencies of the turbine shaft assemblies existing between zero speed and 20% overspeed are controlled in the design and operation so as to cause no distress to the unit during operation. A torsional vibration analysis shall show that the Turbine Generator rotor resonance is outside of the normal operating frequency and its harmonics.
- The turbine rotor average tangential stress (excluding stresses in the blade/wheel region) at design overspeed resulting from centrifugal forces, interference fit (as applicable), and thermal gradients does not exceed 0.75 of the minimum specified yield strength of the material.
- The overspeed trip set point of the turbine is approximately 110%. This overspeed trip set point is at least 1% above the highest anticipated speed resulting from loss of load, which is normally in the range of 106-109%. The turbine assembly is designed and tested to withstand the stresses corresponding to an emergency overspeed level of 120%, which is approximately 10% above the highest anticipated speed resulting from loss of load. On a unit-specific basis, a report will provide the overspeed basis (including setpoints) applicable to the site and discuss how the turbine assembly is designed to withstand the normal conditions, anticipated operational occurrences, and accidents resulting in a turbine trip.
- An integral turbine rotor design is inherently less likely to have a failure resulting in a turbine missile than previous designs with shrunk-on discs and keyways. There are no wheel keyways that can be potential locations for stress concentrations and corrosive contaminate accumulation in the steam environment. Turbine rotors are designed to facilitate in-service inspection of critical regions. On a unit-specific basis, a report will provide a general description of the design features of the turbine, rotor, shaft, couplings and buckets/blades, including number of stages, bucket (blade) design, how the buckets are attached to the rotor, whether the turbine rotor is forged, and pertinent fabrication methods, (e.g., provide drawings).

#### ***10.2.3.5 Pre-Service Inspection***

The pre-service inspection procedures and acceptance criteria are as follows.

- Forgings are rough-machined with minimum stock allowance prior to heat treatment.
- Forgings undergo volumetric (ultrasonic) examination in all critical regions subject to established inspection methods and acceptance criteria. Subsurface sonic indications are not accepted if found to compromise the integrity of the unit during its service life. Rotor

forgings may be bored to remove defects, obtain material for testing and to conduct bore sonic inspection.

- Finished machined rotors are subject to magnetic particle test. Surface indications are evaluated and removed if found to compromise the integrity of the unit during its service life.
- Each fully bladed turbine rotor assembly is factory spin-tested at 20% overspeed.

Additional pre-service inspections include air leakage tests performed to determine that the hydrogen cooling system is leak-tight before hydrogen is introduced into the generator casing. The hydrogen purity is tested in the generator after hydrogen has been introduced. The generator windings and required motors are megger-tested. Vibration tests are performed on required motor-driven equipment. Hydrostatic tests are performed on required coolers. Required piping is pressure-tested for leaks.

#### ***10.2.3.6 In-Service Inspection of Turbine Rotors***

The in-service inspection program for the turbine assembly includes the complete inspection of all normally inaccessible parts such as couplings, coupling bolts, turbine shafts, turbine blades and turbine rotors. During plant shutdown (coinciding with the in-service inspection schedule for ASME Section III components, as required by the ASME Boiler and Pressure Vessel Code Section XI) turbine inspection is performed in sections during the refueling outages so that a total inspection has been completed at least once within the time period recommended by the manufacturer.

The recommended maintenance and inspection program plan for the turbine assembly, valves and controls ensures that the annual Turbine Generator missile probabilities are maintained at or below the acceptable level. (See Subsection 10.2.1.)

This inspection consists of visual, surface and volumetric examinations as indicated below.

- Visual, magnetic particle and ultrasonic examination of all accessible surfaces of rotors
- Visual, magnetic particle or liquid penetrant examination of all turbine blades
- Visual, magnetic particle examination of couplings and coupling bolts

#### ***10.2.3.7 In-Service Inspection of Turbine Valves***

All main stop valves, control valves, extraction non-return valves, intermediate stop, and intercept valves are tested under load. Test controls installed in the MCR permit full stroking of the stop valves, control valves, and intermediate stop and intercept valves. Valve position indication is provided in the MCR. Some load reduction may be necessary before testing main stop and control valves, intermediate stop and intercept valves. Extraction non-return valves are tested by equalizing pressure across the cylinder.

Main stop valves, control valves, extraction non-return valves, and intermediate stop and intercept valves are tested in accordance with the Boiling Water Reactor Owners Group (BWROG) turbine surveillance test program, by closing each valve and observing by the MCR valve position indication that the valve moves smoothly to a fully closed position. Closure of each main stop valve, control valve and intermediate stop and intercept valve during test are

verified by observation of the MCR valve position indication. This test also verifies the fast closure function during the last portion of valve travel.

Tightness tests of the main stop and control valves are performed at least once per maintenance cycle by checking the coast down characteristics of the turbine from no load with each set of four valves closed alternately, or using warm-up steam as an indicator with the valves closed.

All main stop valves, main control valves, and intermediate stop and intercept valves are disassembled and visually inspected once during the first three refueling shutdowns. Subsequent inspections are scheduled in accordance with the recommendations of the Boiling Water Reactor Owners Group (BWROG) turbine surveillance test program. The inspections are conducted for

- Wear of linkages and valve stem packing,
- Erosion of valve seats and stems,
- Deposits on stems and other valve parts, which could interfere with valve operation, and
- Distortions, misalignment or cracks.

Inspection of all valves of one functional type (i.e., stop, control, intercept) are conducted for any detrimental unusual condition (as defined by the turbine valve in-service inspection program) if one is discovered during the inspection of any single valve.

#### 10.2.4 Evaluation

The turbine-generator is nonsafety-related, and is not needed to effect or support a safe shutdown of the reactor.

The turbine is designed, constructed, and inspected to minimize the possibility of any major component failure.

The turbine has a redundant, testable overspeed trip system to minimize the possibility of a turbine overspeed event.

Uncontrolled release of stored energy in the extraction steam system is reduced to an acceptable minimum by the addition of non-return valves in selected extraction lines (see Subsection 10.2.2.2.6).

The TG equipment shielding requirements and the methods of access control for areas required of the Turbine Building ensure that the dose criteria specified in 10 CFR 20 for operating personnel are not exceeded.

All areas in proximity to TG equipment are zoned according to expected occupancy times and radiation levels anticipated under normal operating conditions.

Specification of the various radiation zones in accordance with expected occupancy is listed in Chapter 12.

If deemed necessary during unusual occurrences, the occupancy times for certain areas are reduced by administrative controls enacted by health physics personnel.

The design basis operating concentrations of  $N^{16}$  in the turbine cycle are indicated in Section 12.2.

The connection between the Low Pressure turbine exhaust hood and the condenser is made by means of a steel weld or rubber or stainless steel expansion joint. Because there are no essential systems or components (as defined in BTP SPLB 3-1), in the turbine area, and the condenser is at sub-atmospheric pressure during all modes of turbine operation, failure of the joint would have no adverse effects on safety-related equipment.

The TG trip logic and control schemes use coincident logic and redundant controllers and input signals to support the plant availability goals and avoid spurious trips.

All safety-related Systems, Structures and Components (SSCs) outside containment are excluded from the low-trajectory turbine missile strike zone, as defined in RG 1.115, except

- Four condenser pressure transmitters,
- Four position limit switches per turbine bypass valve,
- Four Reactor Feed Pump (RFP) breakers, and
- Cabling and connections to the RPS.

The safety-related equipment listed above is potentially within the low-trajectory turbine missile strike zone and subject to direct and indirect effects from turbine missiles. The safety-related condenser pressure transmitters and turbine bypass valve limit switches are part of the safety-related RPS and are therefore classified as safety-related. However, equipment within the RPS is designed to fail into a trip-initiating state on loss of power, loss or disconnection of any input signal, or loss of any internal or external device-to-device connection signal (see Subsection 7.2.1.2.4). Accordingly, damage to the safety-related condenser pressure transmitters and turbine bypass valve limit switches and any associated cabling and connections as the result of low-trajectory turbine missiles would not inhibit the safety-related function of the RPS. Therefore, turbine missile protection is not relevant to these affected safety-related SSCs.

Four safety-related reactor feed pump breakers are also located within the Turbine Building and potentially included in the turbine missile strike zone. These breakers are required to perform a safety-related function. Therefore, they are located outside of the low-trajectory turbine missile strike zone illustrated in Figure 3.5-2 or provided with a protective barrier as described in RG 1.115.

## **10.2.5 COL Unit Specific Information**

### ***10.2.5.1 Turbine Missile Probability Analysis***

The COL Holder will provide an evaluation of the probability of turbine missile generation using the criteria in accordance with NRC requirements such as in Reference 10.2-3 and NUREG-0933 item A37. (See Subsection 3.5.1.1.2.)

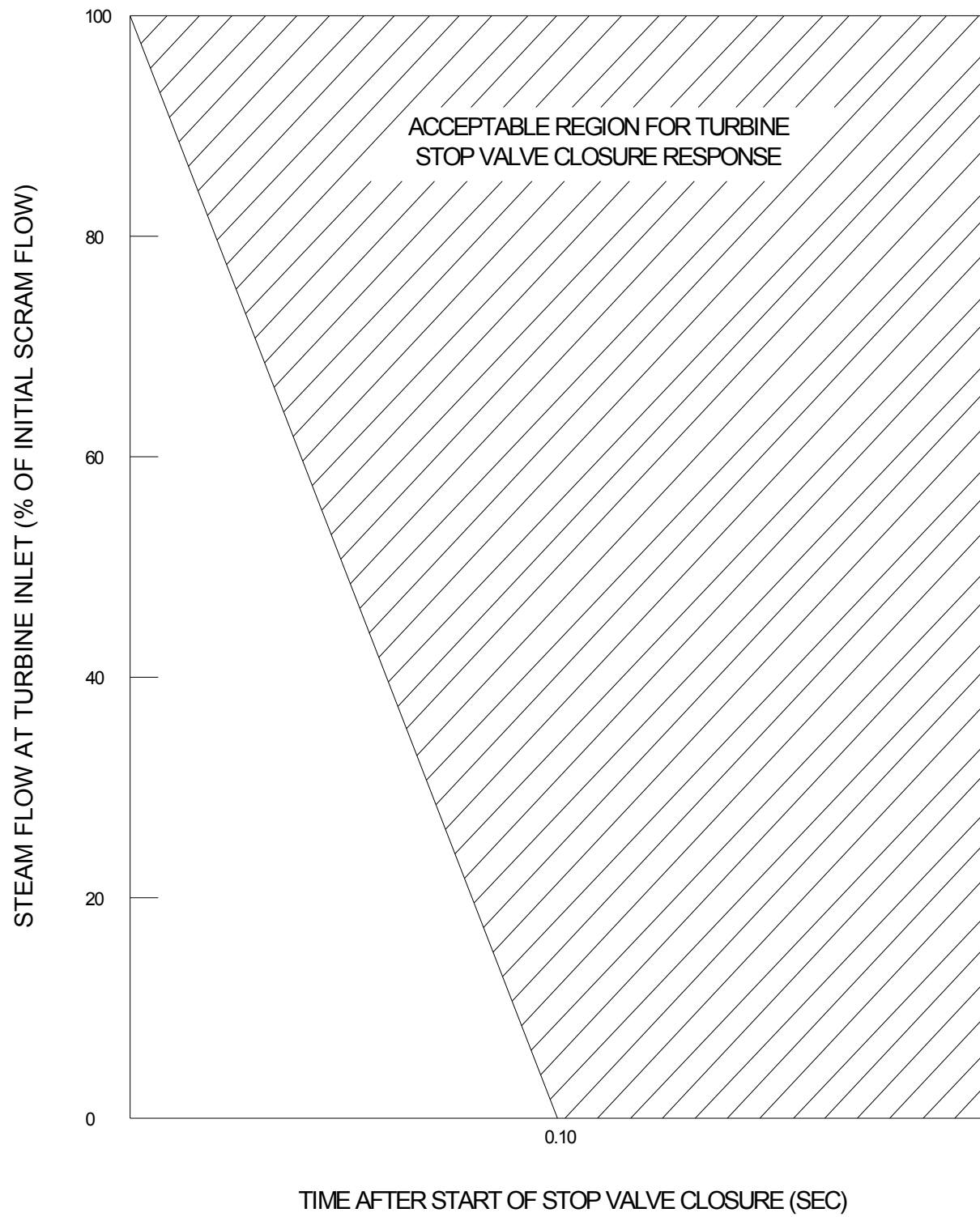
## **10.2.6 References**

10.2-1 J. A. Begley and W.A. Logsdon, Westinghouse Scientific Paper 71-1E7 MSLRF-P1.

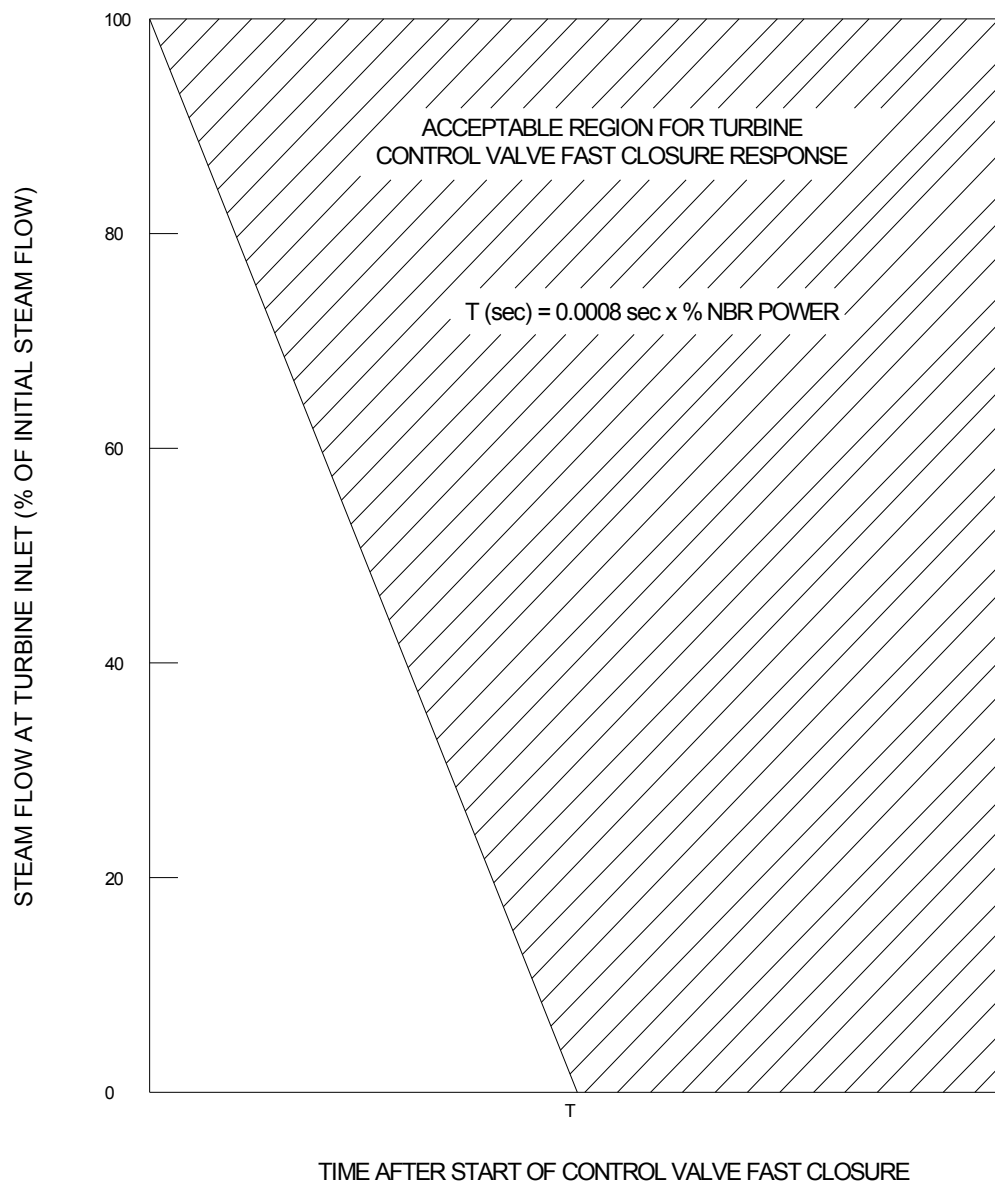
10.2-2 Electric Power Research Institute, "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations – 1987," EPRI NP-5283-SR-A, September 1987.

10.2-3 USNRC, "Safety Evaluation Report Relating to the Operation of Hope Creek Generating Station", NUREG-1048, Supplement No. 6, July 1986

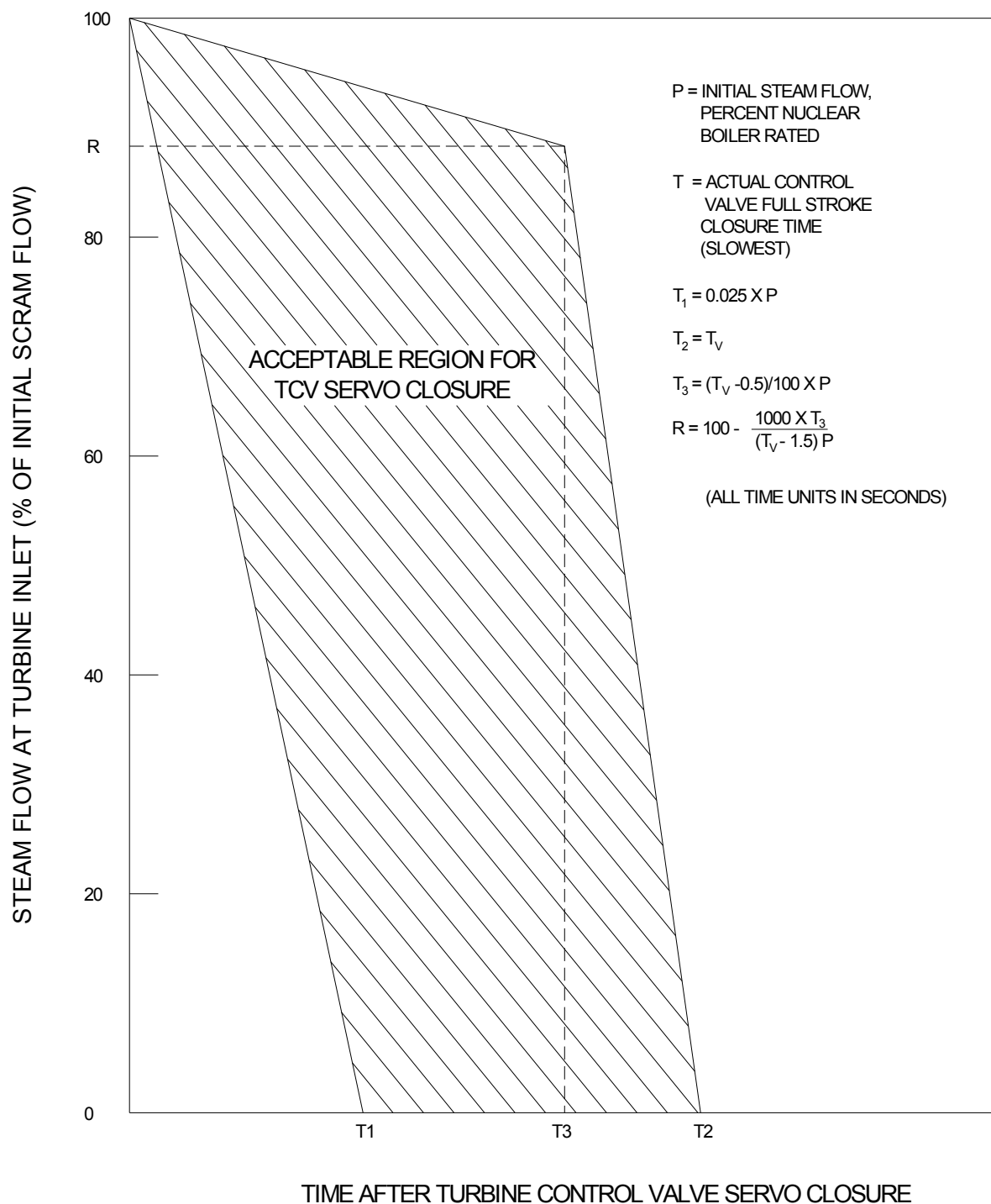




**Figure 10.2-1. Turbine Stop Valve Closure Characteristic**



**Figure 10.2-2. Turbine Control Valve Fast Closure Characteristic**



**Figure 10.2-3. Acceptable Range for Control Valve Normal Closure Motion**

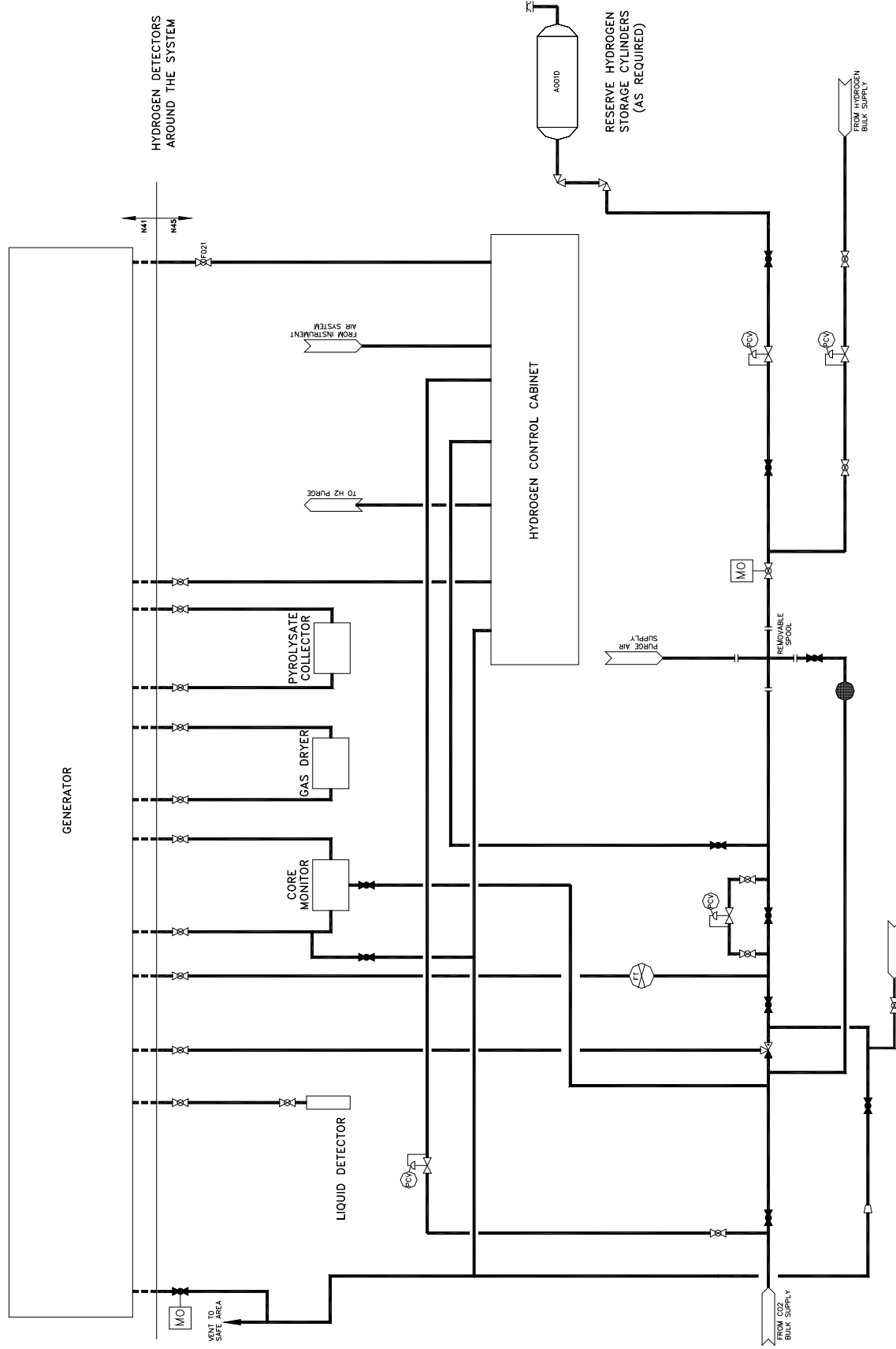


Figure 10.2-4. Hydrogen Gas Control System

### 10.3 TURBINE MAIN STEAM SYSTEM

The Turbine Main Steam System (TMSS) conveys steam generated in the reactor to the turbine plant. The TMSS is bounded by, but does not include, the seismic interface restraint, turbine stop valves and turbine bypass valves. Steam supply lines to other services, up to and including their isolation valves are, also part of the TMSS.

The main steamline Safety Relief Valves (SRVs), main steamline flow restrictors, Main Steamline Isolation Valves (MSIVs), and main steam piping from the reactor nozzles through the outboard MSIVs to the seismic interface restraint are described in Subsections 5.2.2, 5.4.4, 5.4.5 and 5.4.9, respectively.

#### 10.3.1 Design Bases

##### *10.3.1.1 Safety (10 CFR 50.2) Design Bases*

The TMSS is not required to perform or support any safety-related function. However, the supply system is designed to

- (1) Accommodate operational stresses such as internal pressure and dynamic loads without failures,
- (2) Provide a seismically analyzed fission product leakage path to the main condenser,
- (3) With suitable accesses to permit in-service testing and inspections, and
- (4) Close the steam auxiliary isolation valve(s) on branch lines between the MSIVs and Main Turbine Stop Valves (excluding the fission product leakage path to the condenser) on an MSIV isolation signal. (These valves fail closed on loss of electrical power to the valve actuating solenoid or on loss of pneumatic pressure.)

The TMSS piping consists of four lines from the seismic interface restraint to the main turbine stop valves. The header arrangement upstream of the turbine stop valves allows them to be tested online, and supplies steam to the power cycle auxiliaries, as required, and turbine bypass valves.

The TMSS is analyzed, fabricated and examined to ASME Code Class 2 requirements, classified as Nonsafety-related, Seismic Category II, and subject to pertinent QA requirements of Appendix B, 10 CFR 50. In-service inspection is performed in accordance with ASME Section XI requirements for Code Class 2 piping. ASME authorized nuclear inspector and ASME Code stamping is not required.

TMSS piping from the seismic interface restraint to the main stop valves and main turbine bypass valves (including the steam auxiliary valves) is analyzed to demonstrate structural integrity under SSE loading conditions. The MSIV fission product leakage path to the main condenser is analyzed to demonstrate structural integrity under SSE loading conditions. The drain valve(s), that are required to change position to provide the MSIV leakage path to the main condenser are equipped with reliable power sources or designed to fail to the required position on loss of power or air. The drain valve(s) are periodically tested, as required, to ensure continued reliability.

### ***10.3.1.2 Non-Safety Power Generation Design Bases***

The system is designed to deliver steam from the reactor to the Turbine Generator for a range of flows and pressures varying from warm-up to rated conditions. It also provides steam to the MSRs, the steam jet air ejectors, the turbine gland seal system, the offgas system and the turbine bypass system.

## **10.3.2 Description**

### ***10.3.2.1 General Description***

The TMSS is illustrated in Figure 10.3-1. The system design data is provided in Table 10.3-1. The TMSS piping consists of four lines from the seismic interface restraint to the main turbine stop valves. The four TMSS steam lines are connected to a header upstream of the turbine stop valves to permit testing of the MSIVs during plant operation with a minimum load reduction. This header arrangement is also provided to ensure that the turbine bypass and other main steam supplies are connected to operating steam lines and not to idle lines. The TMSS steam process, downstream of the turbine stop valves, is illustrated in Figure 10.3-2.

The design pressure and temperature of the TMSS piping are provided in Table 10.3-1. The TMSS lines are classified as discussed in Section 3.2.

A drain line is connected to the low points of each main steam line, both inside and outside the containment. The drain lines are routed to a common header and are connected with isolation valves, as required, to allow drainage to the main condenser. Orifice lines are provided around the valves to the main condenser to permit continuous draining of the steam line low points. The steam line drains maintain a downward slope from the steam system low points to the orifice located near the condenser. The drain lines are provided with low point drain valves to permit emptying to the radwaste system for maintenance.

The drains from the steam lines inside containment are connected to the steam lines outside the containment to permit equalizing pressure across the MSIVs during startup and following a steam line isolation.

The allowable MSIV leakage is required to be less than or equal to the value used in the Section 15.4 Main Steamline Break Accident Outside Containment analysis. (See Subsection 15.4.4.5.2.3.)

### ***10.3.2.2 Component Description***

The TMSS lines are made of carbon steel and are sized for a normal steady-state velocity shown in Table 10.3-1. The lines are designed to permit hydrostatic testing following construction and major repairs without addition of temporary pipe supports, but may require control (pinning of spring cans for example) of installed hangers.

### ***10.3.2.3 System Operation***

At low plant power levels, the TMSS may be used to supply steam to the turbine gland steam seal system. At high plant power levels, turbine gland sealing steam is normally supplied from HP Turbine exhaust steam, depending on pressure and heat balance.

Steam is supplied to the cross around steam re-heaters in the Main Turbine system as turbine load is increased. Steam pressure is regulated at low power levels.

If a large, rapid load reduction occurs, steam is bypassed directly to the condenser via the turbine bypass system (see Subsection 10.4.4 for a description of the turbine bypass system).

### **10.3.3 Evaluation**

All components and piping for the TMSS are designed in accordance with the codes and standards listed in Section 3.2. This ensures that the TMSS accommodates operational stresses resulting from static and dynamic loads, including steam hammer and relief valve discharge loads, normal and abnormal environmental conditions, and includes provisions to limit water entrainment. Operating and maintenance procedures include adequate precautions to avoid steam hammer.

The break of a main steam line or any branch line does not result in offsite radiation exposures in excess of the limits of 10 CFR 100 because of the safety features designed into the plant. The main steamline pipe break accident outside containment is addressed in Chapter 15, and high energy pipe failure is discussed in Section 3.6.

### **10.3.4 Inspection and Testing Requirements**

Inspection and testing are in accordance with the requirements of Section 6.6. The main steam line is hydrostatically tested to confirm leak tightness.

### **10.3.5 Water Chemistry (PWR)**

This section applies to a Pressurized Water Reactor (PWR), and is therefore not applicable.

### **10.3.6 Steam and Feedwater System Materials**

Steam and feedwater component materials that are within the Reactor Coolant Pressure Boundary are addressed in Section 5.2.

#### ***10.3.6.1 Fracture Toughness of Class 2 Components***

The materials in the ASME Code Section III, Class 2, portion of the TMSS meet the fracture toughness requirements of NC-2300, "Fracture Toughness Requirements for Material". The Class 2 portion of the TMSS is defined in Figure 3.2-1 and Table 3.2-3.

#### ***10.3.6.2 Materials Selection and Fabrication***

The materials specified for use in Class 2 components conform to Appendix I to ASME Code Section III, and to Parts A, B, and C of Section II of the Code.

Regulatory Guide 1.84, "Design and Fabrication and Material, Code Case Acceptability, ASME Section III," describes acceptable code cases that are used in conjunction with the above specifications.

The following criteria are applicable to all components.

- Regulatory Guide 1.71, “Welder Qualification for Areas of Limited Accessibility,” provides the following criteria for assuring the integrity of welds in locations of restricted direct physical and visual accessibility:
  - The performance qualification should require testing of the welds when conditions of accessibility to production welds are less than 30 to 35 cm in any direction from the joint.
  - Re-qualification is required for different accessibility conditions or when other essential variables listed in the Code, Section IX, are changed.
  - The qualification and re-qualification tests required by (a) and (b) above may be waived, provided that the joint is to be 100% radio-graphed or ultrasonically examined after completion of all weld passes. Examination procedures and acceptance standards should meet the requirements of ASME Code Section III. Records of the examination reports and radiographs should be retained and made part of the Quality Assurance documentation of the completed weld.

As alternative method, positions documented in Reference 10.3-1 could be used (see Subsection 5.2.3.4.2).

- Regulatory Guide 1.37, “Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants” describes acceptable procedures for cleaning and handling Class 2 components of the steam and feedwater systems. Vented tanks with de-ionized or de-mineralized water are an acceptable source of water for final cleaning or flushing of finished surfaces. The oxygen content of the water in these vented tanks need not be controlled.
- Acceptance criteria for nondestructive examination of tubular products are given in ASME Code Section III, Paragraphs NC 2550 through 2570.

### 10.3.7 COL Information

None

### 10.3.8 References

- 10.3-1 NEDO 11209-04a, "GE Nuclear Energy Quality Assurance Program Description," Revision 8.



**Table 10.3-1**  
**Turbine Main Steam System Design Data**

<b>Turbine Main Steam Piping</b>	<b>Standard Plant Value*</b>
Design flow rate at 6.67 MPaA and 0.50% moisture kg/s (lb/hr)	2437 (19.3x10 <sup>6</sup> )
Normal steady-state velocity, m/s (ft/s)	< 45.7 (150)
Number of lines	4
Nominal diameter, cm (in)	80 (32) as required for pressure drop
Minimum wall thickness, mm (in)	As Required per ASME III
Design pressure, MpaG (psig)	8.62 (1250)
Design temperature, °C (°F)	302 (575)
Design code	ASME III, Class 2
Seismic design	Analyzed for SSE design loads CAT II

\* Values shown for approximate rated operation. These are representative values for the standard plant; actual values can vary.

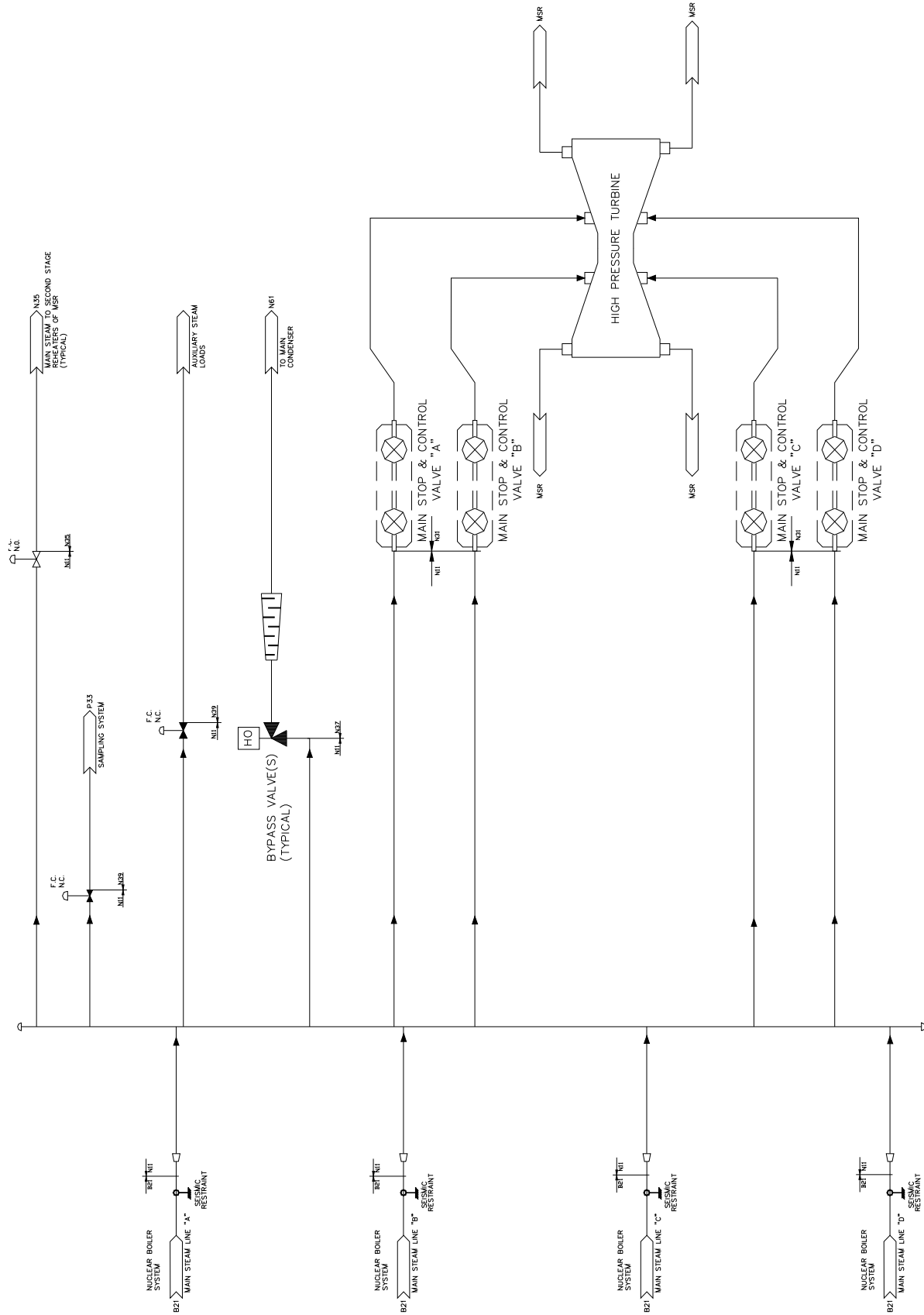


Figure 10.3-1. Turbine Main Steam System

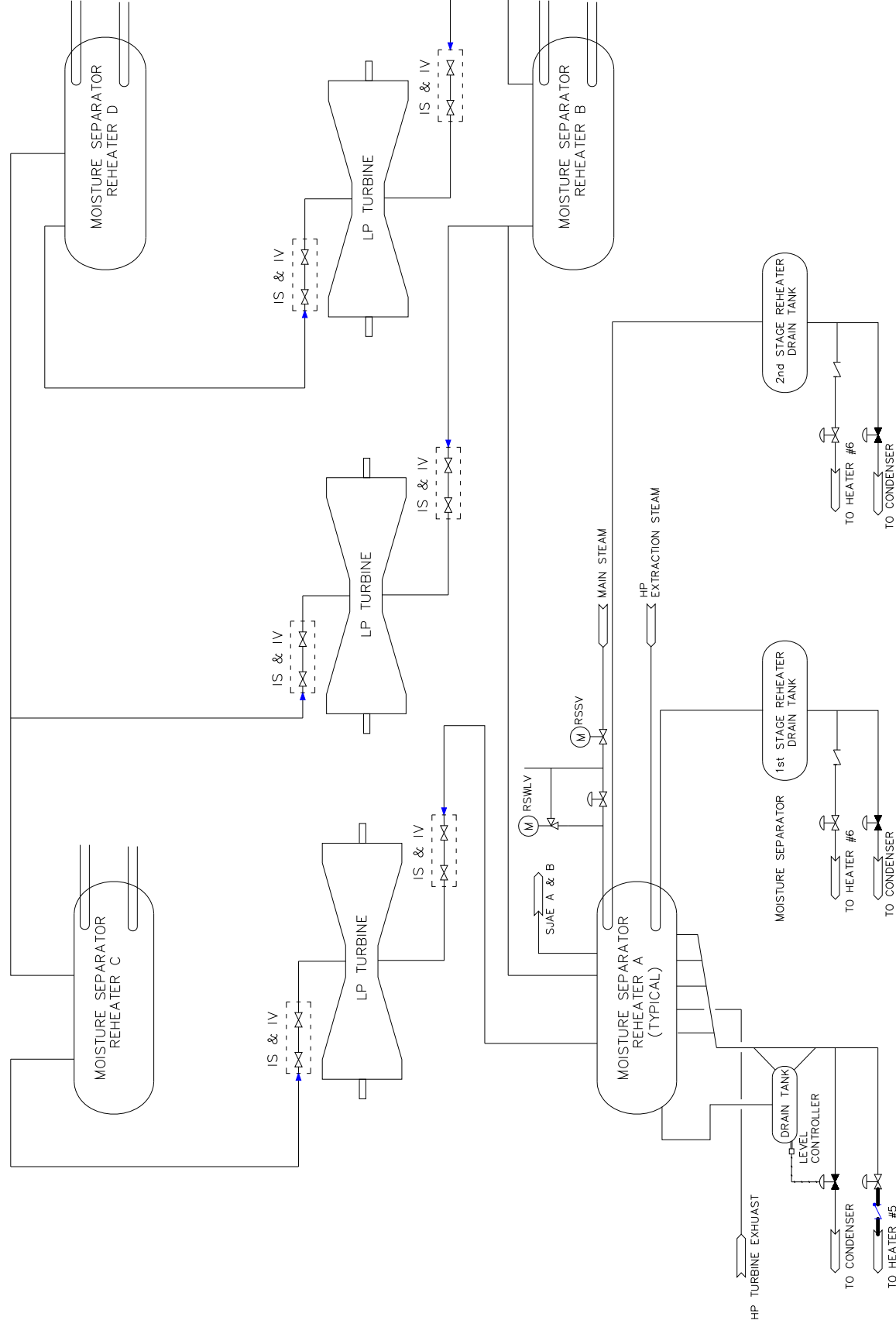


Figure 10.3-2. Main Turbine System

## 10.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

This section provides discussions of each of the principal design features of the Steam and Power Conversion System not described elsewhere in this chapter.

### 10.4.1 Main Condenser

The main condenser is the steam cycle heat sink. During normal operation, the main condenser receives, condenses, deaerates, and holds up for  $N^{16}$  decay, the main turbine exhaust steam. It performs the same functions for the turbine bypass steam whenever the turbine bypass system is operated. The main condenser is also a collection point for other steam cycle miscellaneous drains and vents.

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

#### 10.4.1.1 Design Bases

##### 10.4.1.1.1 Safety (10 CFR 50.2) Design Bases

The main condenser does not perform, support or ensure any safety-related function, and thus has no safety bases. It is, however, designed with necessary shielding and controlled access to protect plant personnel from radiation. In addition, the main condenser hotwell provides a hold-up volume for MSIV fission product leakage. The condenser supports and anchors are designed to maintain condenser integrity following a safe shutdown earthquake. [See Table 3.2-1 (N61).]

For evaluation against GDC 60, see Subsection 3.1.6.1.

##### 10.4.1.1.2 Non-Safety Power Generation Design Bases

- The main condenser is designed to function as the steam cycle heat sink and the collection point for miscellaneous drains and vents.
- The main condenser is designed to accommodate the turbine bypass steam flow following a full load rejection.
- The main condenser is designed to minimize air in-leakage and provides for the separation of noncondensable gases from the condensing steam and their removal by the main condenser air removal system (Subsection 10.4.2).
- At minimum normal operating hotwell water level, and normal full load condensate flow rate, the condenser provides a two-minute minimum condensate hold up time for  $N^{16}$  decay.
- The main condenser provides for deaeration of the condensate, such that condensate dissolved oxygen content does not exceed 15 ppb during normal operation above 50% load.
- The guidance provided in Reference 10.4-1 is considered in the condenser design.

### **10.4.1.2 Description**

#### **10.4.1.2.1 General Description**

The main condenser for the ESBWR Standard Plant design is a multi-pressure, three-shell, deaerating unit. Each shell is located beneath its respective Low Pressure turbine. Other site-specific condenser designs may be considered.

The three condenser shells are designated as the Low Pressure shell, the intermediate-pressure shell, and the High Pressure shell. Each standard design shell has two tube bundles. Circulating water flows in series through the three single-pass shells (Figure 10.4-1).

Vertical partition plate(s) divide each condenser shell hotwell longitudinally. Condensate channels interconnect the hotwells of the three shells. The condensate pumps take suction from the High Pressure condenser hotwell (see Figure 10.1-1).

The condenser shells are located below the Turbine Building operating floor and are supported on the Turbine Building base mat. Expansion joints or welds are provided between each turbine exhaust opening and the steam inlet connections of the condenser shell. In the standard plant design, the three Low Pressure feedwater heaters are located in the steam dome of each shell. Piping is installed for hotwell level control and condensate sampling. The flooding evaluation is within Section 3.4.

#### **10.4.1.2.2 Component Description**

Table 10.4-1 provides ESBWR standard plant condenser design data that is typical of condensers operating with closed loop circulating water systems. Nothing in this section precludes the use of a single pressure condenser and parallel (instead of series) or alternate circulating water system.

#### **10.4.1.2.3 System Operation**

During plant operation, steam expanding through the Low Pressure turbine is directed downward into the 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 cascading heater drains and miscellaneous turbine cycle drains and vents.

Other flows occurring periodically or continuously originate from

- The minimum recirculation flows of the condensate pumps,
- Feedwater line startup flushing,
- Steam cycle equipment vents and drains,
- Low-point drains,
- Condensate storage clean up feed and bleed, and
- Makeup, etc.

During Anticipated Operational Occurrence (AOO) conditions, the condenser is designed to receive turbine bypass steam and high level dump from the feedwater heaters and moisture separator and reheater drain tanks. The condenser is also designed to receive relief valve

discharges and any necessary venting from moisture separator/reheater vessels, feedwater heater shells, gland seal steam header, steam seal regulator, sampling system and various other steam and liquid supply lines. Spray pipes and baffles are designed to provide protection of the condenser tubes and components from high-energy inputs to the condenser. The condensate is pumped from the condenser hotwell by the condensate pumps described in Subsection 10.4.7.

Because the main condenser shells normally operate at a vacuum, air 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 at selected locations in the hotwell. Sampling methods are described in Subsection 9.3.2. During normal operation, radioactive leakage to the atmosphere via circulating water does not occur.

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

The condenser and water boxes are welded carbon steel or low alloy ferrite steel. The tubes are stainless steel or titanium with compatible stainless steel or titanium clad carbon steel tube sheets depending on circulating water chemistry. 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 a portion of the condenser to be isolated and removed from service.

Condensate is retained in the main condenser for a minimum of two minutes to permit radioactive decay before entering the condensate system. During normal power operation, the condensate is deaerated to reduce the level of dissolved oxygen to the required concentration before leaving the condenser.

Hotwell level controls provide automatic or manual makeup or rejection of condensate to maintain a normal level in the condenser hotwells. On low hotwell water level, the makeup control valve(s) opens and admits condensate to the hotwell from the condensate storage tank. When the hotwell level is brought to within normal operating range, the valve(s) closes. On high water level in the hotwell, the condensate reject control valve can open to divert condensate from the condensate pump discharge (downstream of the demineralizers and Gland Steam, Steam Jet Air Ejector and Off gas condensers) to the condensate storage tank; rejection can be stopped when the hotwell level falls to within the required operating range. This subsystem can be used to feed and bleed the Condensate Storage Tank (CS/CST) as needed. The hotwell level signals and controller are at least triple and dual redundant, respectively, to ensure availability of the condensate pumps.

During the initial cooling period after plant shutdown, the main condenser removes residual heat from the reactor via the turbine bypass system. However, if the condenser is not available to receive steam via the turbine bypass system, the reactor can still be safely cooled down using only Nuclear Island systems.

### ***10.4.1.3 Evaluation***

During normal 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 (Sections 12.1 and 12.3).

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 does not occur, because the main condenser is not receiving enough steam flow to cause significant hydrogen buildup.

The main condenser tube side circulating water is treated as required to limit algae growth and prevent long-term corrosion of the tubes and other components. Corrosion of the outside of the condenser tubing is limited by maintaining water quality using the condensate purification system described in Subsection 10.4.6. The construction materials used for the main condenser are selected such that the potential for corrosion by galvanic and other effects is minimized.

The potential flooding which would result from failure of the condenser is discussed in Section 3.4, which shows that failure of the condenser does not adversely affect any equipment required for safe shutdown of the reactor.

The loss of main condenser vacuum causes a turbine trip, reactor scram, bypass valve closure, and closure of the MSIVs. The effects of a turbine trip are discussed in Chapter 15. Should the turbine stop, control or bypass valves fail to close on loss of condenser vacuum, rupture diaphragms on each turbine exhaust hood protect the condenser and turbine exhaust hoods against overpressure.

### ***10.4.1.4 Tests and Inspections***

Each condenser shell receives a field hydrostatic test before initial operation. This test consists of filling the condenser shell to the required level with water and, at the resulting static head, inspecting all tube to tube sheet joints, accessible welds, and surfaces for visible leakage and/or excessive deflection. Each condenser water box receives a field hydrostatic test for all visually inspectable joints and external surfaces.

### ***10.4.1.5 Instrumentation Applications***

#### ***10.4.1.5.1 Hotwell Water Level***

The condenser hotwell water level is normally measured by at least three level transmitters. These transmitters provide signals to indicator(s), annunciator(s), the plant computer, and the hotwell level control system. Level is controlled by two sets of modulating control valves. Each set consists of a normal and an emergency valve.

One set of valves allows water to flow from the condensate storage tank to the condenser hotwell as the level drops below the setpoint. If the level increases above another setpoint, the second set of valves located on the discharge of the condensate pumps opens to allow condensate to be

pumped back to the storage tank. If desired, these valves may be used to feed and bleed water to the CS/CST

#### **10.4.1.5.2 Pressure**

Condenser pressure instruments provide signals to indicator(s), annunciator(s), the TGCS, and to the SB&PCS. In addition, four independent safety-related condenser pressure instruments are included in the RPS to provide signals for reactor scram and MSIV closure on high condenser pressure. These safety-related pressure instruments are located above the flood level in the Turbine Building.

As condenser pressure increases above normal levels, an alarm is activated. A further increase in pressure results in a turbine trip and reactor scram. As pressure increases toward a complete loss of vacuum, the main steam isolation valves and the turbine bypass valves are closed to prevent overpressurization of the condenser shell. Ultimate overpressure protection for the condenser is provided by rupture discs on the LP turbine casings.

The approximate set points for these functions are provided in Table 10.4-1.

#### **10.4.1.5.3 Temperature**

Temperature is measured in each LP turbine exhaust hood by temperature sensors and controllers modulate a control valve in the water spray line protecting the exhaust hoods from overheating.

Circulating water temperatures are monitored upstream and downstream of each condenser tube bundle and are fed to the plant computer and the main control room instrumentation for use during periodic condenser performance evaluations.

#### **10.4.1.5.4 Leakage**

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

Condensate conductivity is monitored at selected locations in the condenser. Conductivity and selected impurities are monitored at the discharge of the condensate pumps. High condensate conductivity or impurity content, which indicate a condenser tube leak, can be individually alarmed in the main control room.

### **10.4.2 Main Condenser Evacuation System**

Noncondensable gases are removed from the power cycle by the condenser air removal system. The condenser air removal system removes the hydrogen and oxygen produced by radiolysis of water in the reactor, and other power cycle noncondensable gases. The condenser air removal system exhausts to the Offgas System (OGS) during normal power operation, and to the Turbine Building Compartment Exhaust (TBCE) subsystem, during startup and shutdown (see Turbine Building HVAC system description in Subsection 9.4.4).



### **10.4.2.1 Design Bases**

#### **10.4.2.1.1 Safety (10 CFR 50.2) Design Bases**

The condenser air removal system does not perform, ensure or support any safety-related function, and thus, has no safety design basis.

#### **10.4.2.1.2 Non-Safety Power Generation Design Bases**

- The condenser air removal system is designed to remove air and other power cycle noncondensable gases from the condenser during plant startup, cool down, and power operation and exhaust them to the OGS or TBCE subsystem.
- The condenser air removal system establishes and maintains a vacuum in the condenser during power operation by the use of steam jet air ejectors, and by the mechanical vacuum pumps during early startup and when the unit is shutdown.

### **10.4.2.2 Description**

For the condenser air removal system components that may contain radioactive materials, Regulatory Guides 1.33 and 1.28, as they relate to the quality assurance programs, are applied. The applicability of Regulatory Guide 1.33 during construction and operation is addressed with in Section 17.2.

The components of the condenser air removal system are designed to Quality Group D as defined in Regulatory Guide 1.26, and are not designed to safe shutdown earthquake seismic standards. The quality standards meet the requirements of 10 CFR 50.55a for water- and steam-containing components that may contain radioactive materials but are not part of the reactor coolant pressure boundary.

The condenser air removal system (Table 10.4-2 and Figure 10.4-2) consists of two 100%-capacity Steam Jet Air Ejector (SJAЕ) units for power operation, and two 50%-capacity (minimum) mechanical vacuum pumps for use during startup and shutdown. One SJAЕ unit is normally in operation and the other is in standby or they can be operated simultaneously in partial load.

During the initial phase of startup, when the desired rate of air and gas removal exceeds the capacity of the steam jet air ejectors, the mechanical vacuum pumps can be used to establish a vacuum in the main condenser and other parts of the power cycle. The discharge from the vacuum pumps is then routed to the TBCE system, because there is then little or no effluent radioactivity present. Process Radiation Monitoring System (PRMS) radiation detectors in the TBCE system and plant vent stack produce an alarm in the main control room if abnormal radioactivity is detected (Section 11.5). Radiation monitors are provided on the main steam lines, which trip and isolate the mechanical vacuum pump(s) if abnormal radioactivity is detected in the steam being supplied to the condenser.

The SJAЕs are placed in service to remove the gases from the main condenser after vacuum is established in the main condenser by the mechanical vacuum pumps and when sufficient steam pressure is available.

During normal power operations, the SJAEs are normally driven by cross-around steam, with the main steam supply on automatic standby. The main steam supply is normally used during startup and low load operation. Auxiliary steam may be available for use of the SJAEs as an alternative to the main steam or if the mechanical vacuum pumps are unavailable.

#### ***10.4.2.3 Evaluation***

The offgas 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 SJAEs is evaluated in Section 11.3.

Steam and oxygen (or air) supply to the steam jet air ejector is maintained above a minimum flow to ensure adequate dilution of hydrogen and prevent the offgas from reaching the flammability limit of hydrogen. In addition, operation of the mechanical vacuum pumps is limited above specified reactor power levels to ensure the flammability limit of hydrogen is not reached.

The condenser air removal system, which is part of the main condenser and auxiliaries system, has no safety-related function (see Table 3.2-1) and does not interface with any safety-related structure, system or component. Thus, failure of the system would not compromise any safety-related system or components required for safe reactor shutdown.

Should the condenser in-leakage increase or air removal system fail completely, a gradual reduction in condenser vacuum would result from the buildup of noncondensable gases. This reduction in vacuum would first cause a lowering of turbine cycle efficiency due to the increase in turbine exhaust pressure. If the condenser air removal system remained unavailable or has insufficient capacity for increased in-leakage, condenser pressure could reach the turbine trip set point and a turbine trip would result. The loss of condenser vacuum incident is discussed in Section 15.2.

#### ***10.4.2.4 Tests and Inspections***

Testing and inspection of the system is performed prior to plant operation in accordance with applicable codes and standards.

Components of the system are monitored during operation to ensure satisfactory performance. Periodic inspections of the condenser air removal system are performed in conjunction with the scheduled maintenance outages.

#### ***10.4.2.5 Instrumentation Applications***

Local and/or remote indicating devices for parameters such as pressure, temperature, and flow are provided as required for monitoring the system operation. Dilution steam, oxygen, or air flow, and vacuum pump and SJAE suction valve position indication are monitored in the main control room.

##### ***10.4.2.5.1 Steam Jet Air Ejectors***

Ejector steam supply pressure and flow are monitored and controlled. Pressure controllers sense pressure and modulate the steam supply control valves upstream of the air ejectors. The flow

transmitters provide inputs to logic devices for isolating the main condenser offgas flow to the air ejector unit on a two-out-of-three logic. This arrangement limits accumulation of explosive mixtures under low dilution flow conditions.

#### **10.4.2.5.2 Mechanical Vacuum Pump**

The vacuum pump exhaust streams are discharged to the TBCE subsystem. The PRMS provides for radiation monitoring of the system effluents prior to their release through the plant vent stack to the atmosphere.

Each vacuum pump is tripped and isolated upon receiving a main steam high radiation signal.

### **10.4.3 Turbine Gland Seal System**

The Turbine Gland Seal System (TGSS) reduces the escape of radioactive steam from the turbine shaft/casing penetrations and valve stems and limits air in-leakage through sub-atmospheric turbine glands.

#### ***10.4.3.1 Design Bases***

##### **10.4.3.1.1 Safety (10 CFR 50.2) Design Bases**

The TGSS does not perform, ensure or support any safety-related function, and thus, has no safety design basis.

##### **10.4.3.1.2 Non-Safety Power Generation Design Bases**

- The TGSS is designed to limit atmospheric air leakage into the turbine casings and to minimize radioactive steam leakage out of the turbine glands and valves.
- The TGSS returns the condensed steam to the condenser and exhausts the noncondensable gases, via the TBCE subsystem, to the plant vent stack.
- The TGSS has sufficient capacity to handle steam and air flows resulting from greater than normal gland clearances.

#### ***10.4.3.2 Description***

##### **10.4.3.2.1 General Description**

For the TGSS components that may contain radioactive materials, Regulatory Guides 1.33 and 1.28, as they relate to the quality assurance programs, are applied. The applicability of RG 1.33 during construction and operation is addressed within Section 17.2.

The TGSS provides for the collection and condensation of sealing steam and the venting of noncondensable gases. The components are designed to Quality Group D as defined in Regulatory Guide 1.26, and are not designed to safe shutdown earthquake seismic standards (see Section 3.2).

The turbine gland seal system is illustrated in Figure 10.4-3. The turbine gland seal system consists of sealing steam pressure controls, sealing steam header, gland steam condenser(s), with two full-capacity exhausters blowers, and the associated piping, valves and instrumentation.

#### **10.4.3.2.2 System Operation**

The annular space through which the turbine shaft penetrates the casing is sealed by steam supplied to the shaft seals. Where the gland seals operate against positive pressure, the sealing steam flows either inwards for collection at an intermediate leak-off point or outwards and into the vent annulus. Where the gland seals operate against vacuum, the sealing steam either is drawn into the casing or leaks outward to a vent annulus. At all gland seals, the vent annulus is maintained at a slight vacuum, and receives air in-leakage from the outside. From each vent annulus, the air-steam mixture is drawn to the gland steam condenser.

The seal steam header pressure is regulated automatically by redundant pressure controllers. During startup and low load operation, the seal steam can be supplied from the Auxiliary Boiler System (ABS). At all loads, gland sealing can be achieved using clean steam directly from the ABS. In low load and normal operation, main steam or extraction steam is a supply to the turbine gland seal system.

The outer portion of all glands of the turbine and main steam valves is connected to a gland steam condenser, which is maintained at a slight vacuum by an exhaustor blower. This vacuum may be adjusted to suit system requirements. During plant operation, the gland steam condenser and one of the two installed 100% capacity motor-driven blowers are in operation. The exhaustor blower to the TBCE subsystem effluent stream is monitored by the PRMS prior to being discharged (see Section 11.5). The gland steam condenser is cooled by main condensate flow.

#### **10.4.3.3 Evaluation**

The TGSS is designed to minimize leakage of radioactive steam from the main turbine shaft glands and the valve stems. The High Pressure turbine shaft seals must accommodate a range of turbine shell pressures from full vacuum to full load operating pressure in the shell at the glands. The Low Pressure turbine shaft seals normally operate against a vacuum. The gland seal outer portion steam/air mixture is exhausted to the gland steam condenser via the seal vent annulus, which is maintained at a slight vacuum. In addition, the ABS is designed to provide a backup to the normal gland seal process steam supply. At least one full capacity gland steam condenser is provided and equipped with two 100% capacity blowers.

Relief valve(s) on the seal steam header prevent excessive seal steam pressure. The valve(s) discharge to the condenser shell.

#### **10.4.3.4 Tests and Inspections**

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

### ***10.4.3.5 Instrumentation Application***

#### **10.4.3.5.1 Gland Steam Condenser Exhausters**

##### **10.4.3.5.1.1 Pressure**

Gland steam condenser exhauster suction pressure is monitored and reported to the main control room. A degraded vacuum signal actuates a main control room alarm.

##### **10.4.3.5.1.2 Level**

Water levels in the gland steam condenser drain leg are monitored and makeup is added as required to maintain loop seal integrity. Abnormal levels are alarmed in the main control room.

##### **10.4.3.5.1.3 Effluent Monitoring**

The TGSS effluents are normally monitored by a system-dedicated radiation monitor installed on the gland steam condenser exhauster blower discharge. High monitor readings are alarmed in the main control room. The system effluents are then discharged to the TBCE subsystem and the plant vent stack, where further effluent radiation monitoring is performed. (See Section 12.2 for the radiological analysis of the TGSS effluents.)

##### **10.4.3.5.2 Sealing Steam Header**

Sealing steam header pressure is monitored and reported to the main control room and plant computer. Header steam temperature is also measured and recorded.

#### **10.4.4 Turbine Bypass System**

The Turbine Bypass System (TBS) provides the capability to discharge main steam from the reactor via the TMSS directly to the condenser to minimize step load reduction transient effects on the Nuclear Boiler System (NBS). The TBS is also used to discharge main steam during reactor hot standby and cool-down operations. Operation of the TBS eliminates the need to rely solely on safety-related systems for shutting down the plant during normal operations.

The TBS satisfies General Design Criterion 4 in that failure of the TBS due to a pipe break or malfunction of the TBS would not adversely affect any safety-related system or component (i.e., those necessary for safe shutdown or accident prevention or mitigation). There is no essential system and component, as defined in BTP SPLB 3-1, in the TBS.

##### ***10.4.4.1 Design Bases***

###### **10.4.4.1.1 Safety (10 CFR 50.2) Design Bases**

The TBS does not perform, ensure or support any safety-related function. However, it does mitigate the effects of AOOs (which are defined as part of normal operation in 10 CFR 50 Appendix A and General Design Criterion 10) and Anticipated Transients Without Scram events, if some of the MSIVs remain open and the main turbine stop/control valves are closed. The TBS is analyzed to demonstrate structural integrity under SSE loading conditions.

#### 10.4.4.1.2 Non-Safety Power Generation Design Bases

- The TBS has a design capacity of 110% of the rated main steam flow.
- The TBS is designed to bypass steam to the main condenser during plant startup and to permit a normal cooldown of the reactor from a hot shutdown condition to a point consistent with initiation of shutdown cooling operation.
- The TBS is designed, in conjunction with other reactor systems, to provide for a full load rejection or turbine trip without lifting of the reactor SRVs.
- No single failure can disable more than 50% of the installed bypass capacity.

#### 10.4.4.2 Description

##### 10.4.4.2.1 General Description

The TBS in the ESBWR Standard Plant design comprises Turbine Bypass Valves (TBV) connected to the TMSS Main Steam Lines. The outlets of TBVs are connected to the Main Condenser via pressure reducers. The system and its components are shown in Figure 10.3-1.

The TBS, in combination with the reactor systems, provides the capability to shed 100% of the TG rated load without the operation of SRVs.

The TBS is provided with an uninterruptible redundant power source. The worst case of an AOO with a single failure would result in a loss of no more than 50% of bypass capacity. The TBS has a design capacity of 110% of rated main steam flow. Failure of a single TBV to open does not result in a system capacity less than 100% of rated main steam flow.

##### 10.4.4.2.2 Component Description

Each bypass valve is operated by hydraulic fluid pressure with spring action to close. The valve assembly includes hydraulic supply and drain piping, hydraulic accumulator(s), servo valve(s), fast acting solenoid valve(s), and valve position transmitters.

The turbine bypass valves are operated by the turbine hydraulic fluid power unit, making it possible to isolate (double isolation required) the High Pressure fluid to the turbine valves while supplying hydraulic fluid to the bypass valves. High Pressure hydraulic fluid is provided to the valve actuator and is drained back to the fluid reservoir.

##### 10.4.4.2.3 System Operation

The turbine bypass valves are opened by redundant signals received from the SB&PCS whenever the actual steam pressure exceeds the setpoint 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 individual valve(s). 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 condenser pressure increases to a preset value. Individual bypass valves close on loss of electrical power or hydraulic system pressure to their operator. Bypass valve hydraulic accumulators have the capacity to stroke the valves at least six times with hydraulic power unit failure.

When the plant is at zero power, hot standby or initial cool-down, the system is operated manually by the control room operator or by the plant automation system. The measured reactor pressure is then compared against, and regulated to, the pressure set by the operator or automation system.

The turbine bypass control system can malfunction in either the open or closed mode, but requires multiple failures to do so. The effects of these potential failure modes on the NSSS and turbine system are addressed in Chapter 15. If the bypass valves fail open, additional heat load is placed on the condenser. If this load is great enough, the turbine is tripped on degraded condenser vacuum. If the bypass valves fail closed, the NBS relief valves and the Isolation Condenser System permit controlled cool-down of the reactor.

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

#### ***10.4.4.3 Evaluation***

The TBS does not perform or support any safety-related function. There is no safety-related equipment in the close vicinity of the TBS, except four position sensors at each bypass valve that provide valve status to the RPS logic. These safety-related bypass valve position sensors are fail-safe such that they cannot prevent actuation of the reactor protection function. All high-energy lines of the TBS are located in the Turbine Building. The TBS has no essential system and component as defined in BTP SPLB 3-1.

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.

#### ***10.4.4.4 Inspection and Testing Requirements***

Before the TBS is placed in service, all turbine bypass valves are tested for operability. The steam lines are hydrostatically tested to confirm leak-tightness. Pipe weld joints are inspected by radiography per ASME III, Class 2 requirements upstream and ASME B31.1 downstream of the bypass valve(s). The bypass valves are tested while the unit is in operation. Periodic tests and inspections are performed within a preventive maintenance program in accordance with manufacturer's recommendations and industry practice.

#### ***10.4.4.5 Instrumentation Applications***

Main steam pressure is redundantly measured in the reactor steam area by pressure transmitters. Under normal conditions a validated pressure signal is used by the SB&PCS. If one of the signals fails, an alarm activates, but the bypass control and/or reactor pressure regulation is unaffected.

Input to the system also includes load demand and load reference signals from the turbine speed load control system. The SB&PC system uses these signals to position the turbine control valves

(via the Turbine Generator control system) and the bypass valves. A complete description of the turbine bypass valve control system is included within Chapter 7.

#### **10.4.5 Circulating Water System**

The Circulating Water System (CIRC) provides cooling water for removal of the power cycle heat from the main condensers and transfers this heat to the Normal Power Heat Sink (NPHS).

The CIRC does not interface with any safety-related structure, system or component, and no CIRC failure could adversely affect any safety-related structure, system or component. (See Subsection 10.4.5.3 for flooding analysis).

##### ***10.4.5.1 Design Bases***

###### **10.4.5.1.1 Safety (10 CFR 50.2) Design Bases**

The CIRC does not perform, ensure or support any safety-related function, and thus, has no safety design basis.

###### **10.4.5.1.2 Non-Safety Power Generation Design Bases**

- The CIRC supplies cooling water at a sufficient flow rate to condense the steam in the condenser, as required for plant operation.
- The CIRC is automatically isolated in the event of gross leakage into the Turbine Building (TB) condenser area to prevent flooding of the Turbine Building (see Subsection 10.4.5.6).
- The CIRC supplies cooling water at a sufficient flow to accommodate full load rejection without reactor scram.
- The CIRC supplies cooling water at a sufficient flow to accommodate transition to the Turbine Island mode without exceeding the condenser pressure turbine trip setpoint.

##### ***10.4.5.2 Description***

###### **10.4.5.2.1 General Description**

The portion of the Circulating Water System (Figure 10.4-1) in the scope of the ESBWR standard plant consists of the following components.

- Condenser water boxes and piping and valves
- Condenser tube cleaning equipment, if installed
- Water box drain subsystem

Table 10.4-3 includes the NPHS temperature range for water entering the CIRC, and for water delivered by the CIRC to the main condenser.

The cooling water is circulated by motor-driven pumps; the quantity and capacity of the pumps are plant specific.



For the ESBWR standard plant, the pumps are arranged in parallel and discharge lines combine into two parallel circulating water supply lines to the main condenser. Each circulating water supply line connects to a Low Pressure condenser shell inlet water box. An interconnecting line fitted with a butterfly valve is provided to connect both circulating water supply lines. The discharge of each pump is fitted with a remotely operated valve. This arrangement permits isolation and maintenance of any one pump while the others remain in operation and minimizes the backward flow through a tripped pump.

The CIRC and condenser are designed to permit isolation of each set of the three series connected tube bundles to permit repair of leaks and cleaning of water boxes while operating at reduced power.

The CIRC includes water box vents to help fill the condenser water boxes during startup and remove accumulated air and other gases from the water boxes during normal operation.

A chemical additive subsystem may also be provided to prevent the accumulation of biological growth and chemical deposits within the wetted surfaces of the system. Other non-chemical cleaning systems may be used as needed.

#### **10.4.5.2.2 Component Description**

Codes and standards applicable to the CIRC are listed in Section 3.2. The system is designed and constructed in accordance with quality Group D specifications.

Table 10.4-3 provides reference parameters for the major components of the CIRC.

#### **10.4.5.2.3 System Operation**

The CIRC operates continuously during power generation, including startup and shutdown. Pump and condenser isolation valve actuation are controlled by local controls and/or controls located in the main control room.

The circulating water pumps are tripped and the pump and condenser isolation valves as well as the circulating lines interconnecting valve are closed in the event of a system isolation signal from the TB condenser area high water level switch(es). Level switches are provided in the TB condenser area and the water level trip is initiated upon high level detection. A TB condenser area high level alarm is provided in the control room prior to reaching the trip level setpoint. The water level trip is set high enough to prevent inadvertent plant trips from unrelated failures, such as a sump overflow. A reliable logic scheme is used (e.g., two-out-of-three logic) to minimize potential for spurious isolation trips.

#### **10.4.5.3 Evaluation**

The CIRC is not a safety-related system; however, a flooding analysis of the Turbine Building is performed on the CIRC (see Section 3.4 and Subsection 10.4.5.6).

#### **10.4.5.4 Tests and Inspections**

The CIRC and related systems and facilities are tested and checked for acceptable leakage integrity prior to initial plant startup and, as appropriate, following major maintenance.

Selected portions of the CIRC are accessible for inspection and maintenance/testing during normal power operation.

#### ***10.4.5.5 Instrumentation Applications***

Temperature monitors are provided upstream and downstream of each condenser shell section.

Indication is provided in the control room to identify open and closed positions of remotely operated valves in the CIRC piping.

Major CIRC valves, which control the flow path, are operated by local controls or by remote controls located at the main control room. The pump discharge isolation valves are interlocked with the circulating water pumps so that when a pump is started, its discharge valve is opening while the pump is coming up to speed, thus assuring that there is water flow through the pump. When a pump is stopped or trips, the discharge valve closes automatically to prevent or minimize backward rotation of the pump and motor.

Monitoring of the performance of the Circulating Water System is accomplished by differential pressure transducers located on each condenser waterbox with indication provided in the main control room. Temperature signals from the supply and discharge sides of the condenser are transmitted to the plant computer for recording, display and condenser performance calculations.

Temperature elements, located in each condenser supply line and monitored in the main control room, are utilized in throttling the warm water recirculation valve to maintain the minimum inlet temperature of approximately 5°C.

#### ***10.4.5.6 Flood Protection***

Level switches are provided in the Turbine Building to trip the CIRC pumps and close the required valves in case of a CIRC system component failure. The flooding signal initiates from a high water level detection. In the hypothetical situation of a circulating water system pipe or expansion joint failure, if not detected and isolated, the water discharged would cause internal Turbine Building flooding above grade level, with excess water potentially spilling over on site. If a failure occurred within a condensate system (condenser shell side), the resulting flood level would be below grade level due to the relatively small hotwell inventory relative to the Turbine Building capacity.

Failure of other systems that have piping or components inside the Turbine Building, such as the Turbine Component Cooling Water System, Reactor Component Cooling Water System and Plant Service Water System are discussed within Section 3.4.

#### ***10.4.5.7 Portions of the CIRC Outside of Scope of ESBWR Standard Plant***

The portion outside the ESBWR Standard Plant includes the following:

- Normal Power Heat Sink,
- Pump and intake screen area,
- Pumps and pump discharge and interconnecting valves, and
- CIRC piping outside the Turbine Building.

Related support facilities such as makeup water system, water treatment, inventory blow down, and general maintenance.

#### **10.4.5.7.1 Safety (10 CFR 50.2) Design Basis (Interface Requirements)**

None

#### **10.4.5.7.2 Non-Safety Power Generation Design Bases (Interface Requirements)**

Systems and components are included with the following interface considerations:

- Compatible design as described in Subsection 10.4.5.2.
- Evaluation per Subsection 10.4.5.3
- Tests and inspections per Subsection 10.4.5.4
- Instrument applications per Subsection 10.4.5.5
- Flood protection per Subsection 10.4.5.6

#### ***10.4.5.8 Normal Power Heat Sink (Conceptual Design)***

The Normal Power Heat Sink is outside the ESBWR Standard Plant scope.

The standard design for the ESBWR Normal Power Heat Sink utilizes two natural-draft cooling towers. Water circulation, chemical control, and inventory blow down are all part of the Circulating Water System. Nothing in this section precludes the use of mechanical draft cooling towers or once-through cooling systems because these have no effect on the Nuclear Island.

### **10.4.6 Condensate Purification System**

The Condensate Purification System (CPS) purifies and treats the condensate as required to maintain reactor feedwater purity, using filtration to remove suspended solids, including corrosion products, and ion exchange to remove dissolved solids and other impurities.

#### ***10.4.6.1 Design Bases***

##### **10.4.6.1.1 Safety (10 CFR 50.2) Design Bases**

The CPS does not perform, ensure or support any safety-related function, and thus, has no safety design bases.

##### **10.4.6.1.2 Non-Safety Power Generation Design Bases**

- The CPS removes dissolved and suspended solids from the condensate to maintain reactor feedwater quality.
- The CPS removes corrosion products from the condensate and from drains returned to the condenser hotwell, to limit accumulation of corrosion products in the cycle.
- The CPS removes impurities entering the power cycle due to condenser circulating water leaks as required to permit continued power operation within specified water quality limits as long as such condenser leaks are small and readily located and repaired.

- The CPS limits the entry of dissolved solids into the feedwater system in the event of large condenser leaks, such as a tube break, to permit a reasonable amount of time for orderly plant shutdown.
- The CPS maintains the condensate storage tank water quality as required for condensate makeup and miscellaneous condensate supply services.
- The CPS flow controls and bypass are arranged such that the condensate system flow is uninterrupted even in the presence of a single failure.

#### ***10.4.6.2 System Description***

##### **10.4.6.2.1 General Description**

The CPS (shown in Figure 10.4-5) consists of high efficiency filters arranged in parallel and operated in conjunction with a normally closed filter bypass. The CPS also includes bead resin ion exchange demineralizer vessels arranged in parallel. The number of filters and demineralizers are indicated in Table 10.4-4. A resin trap is installed downstream of each demineralizer vessel to preclude gross resin leakage into the power cycle in case of vessel resin retention screen failure. The CPS achieves the water quality effluent conditions required for reactor power operation defined in the water quality specification. The CPS components are located in the Turbine Building.

Provisions are included to permit cleaning and replacement of the ion exchange resin. Each of the demineralizer vessels has inlet and outlet isolation valves which are remotely controlled from the local and MCR control panel(s).

A demineralizer system bypass valve is also provided which is controlled from the local control panel or the main control room. Pressure downstream of the demineralizer or high demineralizer differential pressure is indicated and is alarmed in the main control room to alert the operator. The bypass is used during start-up and in an emergency and for a short period of time until the CPS flow is returned to normal or the plant is brought to an orderly shutdown.

##### **10.4.6.2.2 Component Description**

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

- Condensate Filters - The CPS includes back-washable high efficiency filters.
- Condensate Demineralizers - demineralizer vessels are constructed of carbon steel and lined to minimize corrosion or leaching.

##### **10.4.6.2.3 System Operation**

The CPS is operated to maintain feedwater purity levels.

Full condensate flow is passed through the filters and demineralizers, each of which are piped in parallel. A filter or demineralizer may be in service, in standby, or out of service for maintenance. The service run of each demineralizer is terminated by either high differential pressure across the vessel, high effluent conductivity, high sodium effluent, volumetric

throughput, or age. Alarms for some of these parameters are provided on the local control panel or the main control room.

The local control panel is equipped with the appropriate instruments and controls to allow the operators to perform the following operations.

- Remove a filter from service, temporarily allowing some condensate filter bypass if needed. Clean up the isolated filter by backwashing and place it back in operation.
- Remove an exhausted demineralizer from service and replace it with a standby unit, temporarily allowing some condensate demineralizer bypass.
- Transfer the resin inventory of the isolated demineralizer vessel into the resin receiver tank for cleaning or disposal.
- Transfer the received resin bed from the receiver tank to the storage tank. Alternately, load the storage tank(s) with fresh new resin.
- Transfer the resin storage tank resins to any isolated demineralizer vessel.
- Transfer exhausted resin from the receiver tank to the radwaste system.

On termination of a demineralizer service run, the exhausted vessel is taken out of service and isolated, and the standby unit is placed in service from the local control panel. The resin from the exhausted vessel is transferred to the resin receiver tank and replaced by a clean resin bed that is transferred from the resin storage tank. A final rinse of the new bed is performed in the isolated vessel by condensate recycle before it is placed on standby or returned to service. The rinse can be monitored by conductivity analyzers; and the process is terminated when the required minimum rinse has been completed and normal clean bed conductivity is obtained and fines are reviewed from a grab sample.

To support automation, the CPS is designed to be operated with a constant number of on line demineralizers and filters from 25 to 100% power or to automatically sequence the filters and demineralizers as necessary to support any power level between 25 – 100%.

Through normal condensate makeup and reject, the condensate storage tank water inventory is processed through the CPS. Tank water quality is maintained as required for condensate makeup to the cycle and miscellaneous condensate supply services.

The condensate purification and related support system wastes are processed by the radwaste system, as described within Chapter 11.

#### ***10.4.6.3 Evaluation***

The CPS does not perform, ensure or support any safety-related function.

The CPS removes condensate system corrosion products and impurities resulting from condenser tube leakage in addition to some radioactive material, activated corrosion products and fission products that are carried-over from the reactor. The concentration of such radioactive material in the CPS requires shielding (see Chapter 12). Wastes from the condensate purification system are collected in controlled areas and sent to the radwaste system for treatment and/or disposal. Chapter 11 describes the activity level and removal of radioactive material from the condensate system.

Chemistry threshold limits and administrative actions are established to mitigate chemistry excursions in the condensate system.

The CPS complies with Regulatory Guide 1.56.

The CPS and related support facilities are located in nonsafety-related buildings. Potential equipment or piping failures does not adversely affect safety-related equipment or structures.

#### ***10.4.6.4 Tests and Inspections***

Preoperational tests are performed on the CPS to ensure operability, reliability, and integrity of the system. Each filter and demineralizer vessel can be isolated during normal plant operation to permit testing and maintenance.

#### ***10.4.6.5 Instrumentation Applications***

Conductivity elements are provided for the system influent and for each demineralizer vessel effluent and monitored at the local control panel or in the main control room. System influent conductivity elements detect condenser leakage and demineralizer effluent conductivity elements provide indication of resin exhaustion. The demineralizer effluent conductivity elements also monitor the quality of the condensate that is recycled through a standby vessel before it is returned to service. Differential pressure is monitored across each filter vessel, demineralizer vessel and discharge resin strainer to detect blockage of flow. The flow through each demineralizer is monitored and used as control input to assure even distribution of condensate flow through all operating vessels and by correlation with the vessel pressure drop, or flow, to permit evaluation of the vessel throughput capacity. Individual demineralizer vessel effluent conductivity, differential pressure, and flow measurements are monitored. Individual filter vessel pressure drop and flow data are provided at the system control panel(s). An indicator is included in the local panel and main control room to alarm abnormal conditions within the system.

The Process Sampling System monitors other water quality parameters as necessary for proper operation of the filters, demineralizers, and miscellaneous support services (see Subsection 9.3.2).

### **10.4.7 Condensate and Feedwater System**

The C&FS receives condensate from the condenser hotwell(s), supplies condensate to the condensate purification system, and delivers high purity Feedwater (FW) to the reactor, at the required flow rate, pressure and temperature.

#### ***10.4.7.1 Design Bases***

##### **10.4.7.1.1 Safety (10 CFR 50.2) Design Bases**

The C&FS does not perform, ensure or support any safety-related function, and thus, has no safety design basis.

#### 10.4.7.1.2 Non-Safety Power Generation Design Bases

- The C&FS is designed to provide a dependable FW supply to the reactor at the required flow rate, pressure, and temperature under all anticipated steady-state and transient conditions.
- The C&FS is designed to supply at least 135% of the rated FW flow during anticipated operational occurrences.
- The C&FS is designed to permit long-term full power operation with one FW pump and/or one condensate pump out-of-service.
- The C&FS is designed to permit long-term operation with one LP heater string out of service at the maximum load permitted by the turbine manufacturer. This value is set by steam flow limitation on the affected LP turbine.
- The C&FS is designed to heat up the reactor FW to approximately 215.6°C (420°F) during full power operation.
- The C&FS is designed to cool the auxiliary condensers and support other auxiliary condensate loads.
- The C&FS is designed so that no single operator error or equipment failure shall cause more than a 55.6°C (100°F) decrease in final feedwater temperature.
- The C&FS, in conjunction with the Condensate Purification System, is designed to maintain water quality suitable for all plant conditions, including power operation, startup, shutdown and extended outages. The Condensate Purification System is discussed in Subsection 10.4.6.
- The C&FS is designed to allow for Final Feedwater Temperature Reduction (FFWTR) operation.
- During plant startups the C&FS is designed to pump preheated FW to the Reactor Pressure Vessel (RPV) for the purpose of RPV initial heating if sufficient core decay heat is not available.
- All C&FS functions needed to support safe power operation use at least dual redundant controllers and triply redundant signals; a single control system failure does not cause an inadvertent pump trip or valve operation.

#### 10.4.7.2 Description

##### 10.4.7.2.1 General Description

The C&FS (Table 10.4-5 and Figure 10.1-1) consists of the piping, valves, pumps, heat exchangers, controls and instrumentation, and the associated equipment and subsystems that supply the reactor with heated FW in a closed steam cycle utilizing regenerative FW heating. The system described in this subsection extends from the main condenser outlet to (but not including) the seismic interface restraint outside of containment. The remainder of the system, extending from the restraint to the reactor, is described in Chapter 5. Turbine cycle steam is utilized for FW heating. The drains from each stage of the closed Low Pressure FW heaters are cascaded through successively lower pressure FW heaters to the main condenser. The High

Pressure heater drains are routed to the open feedwater tank. The cycle extraction steam, drains and vents systems are illustrated in Figures 10.4-6a, b and 10.4-7a, b.

The C&FS consists of four 33.3-37% capacity condensate pumps (three normally operating and one in standby), four 33.3-45% capacity reactor FW pumps (three normally in operation and one on automatic standby), three stages of Low Pressure closed FW heaters, an open FW heater (feedwater tank) and three (3) stages of High Pressure FW heaters, piping, valves, and instrumentation. The condensate pumps take suction from the condenser hotwell(s) and discharge the deaerated condensate into one common header, which feeds the CPS. Downstream of the CPS, the condensate is taken by a single header, through the auxiliary condenser/coolers which are the: gland steam condenser(s), SJAЕ condenser(s) and offgas condenser(s). The condensate then branches into parallel strings of Low Pressure FW heaters. Each string contains three (3) stages of Low Pressure FW heaters. The strings join together at a common header, which is routed to the feedwater tank, that supplies heated feedwater to the suction of the reactor FW pumps.

Another input to the feedwater tank consists of the cascaded drains from the High Pressure FW heaters.

The reactor FW pumps discharge the FW into two parallel High Pressure FW heater strings, each with three (3) stages of High Pressure FW heating. The last stage (No. 7) of FW heating is used for final feedwater temperature control and is normally not in service. Downstream of the High Pressure FW heaters, the two strings are then joined into a common header, which divides into two FW lines that connect to the reactor with six penetrations.

A bypass is provided around the FW tank and reactor FW pumps to permit supplying FW to the reactor during early startup without operating the FW pumps, using only the condensate pumps. During startup, RPV level is controlled by a low flow control valve with flow supplied by either the condensate pumps or via selected FW pump(s).

One more bypass, equipped with a flow control valve, provides a flow path around the HP heater(s) to facilitate maintenance or for reducing final FW temperature to extend the end of fuel cycle.

During power operation, the condensate is deaerated in the condenser and oxygen injection is used to maintain the level of oxygen content in the final FW.

To minimize corrosion product input to the reactor during startup, recirculation lines to the condenser are provided from the High Pressure FW heater outlet header. Cleanup is also accomplished by allowing the system to recirculate through the condensate demineralizers for treatment prior to feeding water to the reactor during startup.

#### 10.4.7.2.2 Component Description

All pressure retaining components of the C&FS are designed and constructed in accordance with applicable codes as referenced in Section 3.2.



#### 10.4.7.2.2.1 Condensate Pumps

The four condensate pumps are identical, fixed speed motor-driven pumps, three are normally operated, and the fourth is on automatic standby. Isolation valves are provided to allow individual pumps to be removed from service.

A minimum flow recirculation line is provided downstream of the auxiliary condensers for condensate pump protection and for auxiliary condenser minimum flow requirements.

#### 10.4.7.2.2.2 Low Pressure Feedwater Heaters

Three parallel and independent strings of three Low Pressure FW heaters are provided. The drains cascade to the next lower stage heater of the same string except for the lowest pressure heater that drains to the main condenser. The heater shells are either carbon steel or low alloy ferrite steel, and the tubes are stainless steel. Each Low Pressure FW heater string has an upstream and downstream isolation valve which closes on detection of high level in any one of the Low Pressure heaters in the string. The LP heater bypass valve automatically opens and the extraction steam non-return valves close upon isolation of a single string of LP heaters and allows operation with a reduction in power to protect the condenser tubes from excess steam flow in the remaining two sections. Only one string of LP heaters may be isolated and bypassed.

#### 10.4.7.2.2.3 High Pressure Feedwater Heaters

Two parallel and independent strings of three (3) High Pressure FW heaters are located in the Turbine Building. The High Pressure heaters have integral drain coolers. The No. 7 and No. 5 heaters drain to the open feedwater tank. The No. 6 heater drains to the No. 5 heater of the same string. The heater shells are carbon steel, and the tubes are stainless steel.

Additional High Pressure feedwater heaters (No. 7) are supplied to assist in power maneuvers via control of Final Feedwater Temperature. These heaters are not normally in use during steady state operations. The heating steam is supplied from the main steam system.

The High Pressure FW heater string bypass valve and isolation valves are provided to allow one string of High Pressure heaters to be removed from service, thus slightly reducing final FW temperature. The heater string isolation valves and extraction steam non-return valves are closed and the by-pass valve is opened on detection of abnormally high level in either of the three (3) High Pressure heaters in their respective string.

The startup and operating vents from the steam side of the FW heaters are piped to the main condenser. Discharge from the shell relief valves on the steam side of the FW heaters is piped to the main condenser.

Each heater shell is provided with an alternate drain line to the main condenser for automatic dumping upon detection of high level. The alternate drain line is also used during startup and shutdown when it is desirable to dump the drains for FW quality purposes.

#### 10.4.7.2.2.4 MSR Drain Tanks

A drain tank is provided on each moisture separator and each reheater drain circuit. Moisture separator drain tank levels are maintained by the control valve in the respective drain tank discharge line.

The drain tanks are provided with an alternate drain line to the main condenser for automatic dumping upon detection of high level. The alternate drain line is also used during startup and shutdown when it is desirable to dump the drains for FW quality purposes.

#### **10.4.7.2.2.5 Open FW Heater**

Low pressure heater stage No. 4 is combined with a large horizontal storage tank (feedwater tank). The open FW heater receives condensate from the outlet of the Low Pressure heater strings. Heating steam flows to the open FW heater to raise the temperature of the condensate to approximately saturation level. Non-condensable gases are vented through an orifice and valve assembly to the main condenser.

The shell of the open FW heater and feedwater tank is made of carbon steel. Stainless steel piping may be used where flashing could occur.

A high-level dump line provides overflow protection to the feedwater tank. During high-level conditions, water from the feedwater tank is drained to the main condenser.

#### **10.4.7.2.2.6 Reactor Feedwater Pumps**

Four identical and independent 33.3–45% capacity adjustable speed, motor-driven reactor FW pumps are provided. Each reactor FW pump consists of main feedwater pump and its booster pump. The feedwater booster pumps take suction from the open feedwater tank and provide flow to the main feedwater pumps. The main feedwater pumps provide flow to the High Pressure FW heaters.

Three of the four reactor FW pumps normally operate in parallel while the other remains in standby. If one of the FW pumps in operation trips, the standby FW pump automatically starts up. Three reactor FW pumps can supply 135% of rated FW flow.

Isolation valves are provided which allow each reactor FW pump to be individually removed from service for maintenance, while the plant continues operation at or near full power with the three remaining pumps.

FW recirculation is provided from the discharge side of each reactor FW pump to the open FW heater. This provision ensures that the minimum safe flow through each reactor FW pump is maintained during operation.

#### **10.4.7.2.3 System Operation**

Under normal operating conditions, system operation is automatic. Automatic and redundant level control systems control the levels in all FW heaters, Moisture Separator Reheater (MSR) drain tanks, open feedwater heater and the condenser hotwells. Feedwater heater levels are controlled by modulating drain valves. Control valves at the discharge of the LP feedwater heaters control the level in the feedwater tank. Valves in the makeup line to the condenser from the condensate storage tank and in the return line to the condensate storage tank control the level in the condenser hotwells.

During power operation, FW flow is automatically controlled by the reactor FW pump speed that is set by the speed control system. The control system can utilize measurements of steam flow, FW flow, and reactor level to regulate the FW pump speed.

During startup and shutdown, FW flow is automatically regulated by the low flow control valve. The low flow control valve can also regulate flow from a condensate pump to the reactor vessel for initial fill and cleanup. Control valves at the discharge of the LP heaters regulate condensate flow to control the feedwater tank level and to isolate flow to the storage tank when the low flow control valve is used to by-pass the feedwater pumps and storage tank during direct condensate flow to the reactor vessel.

Feedwater heater No. 7 can be used to control reactor power during startup and power maneuvers by controlling final feedwater temperature. The maximum feedwater temperature is limited to less than or equal to 215.6°C (420°F) at all power levels by use of administrative controls, equipment design, or a combination of both.

The C&FS has sufficient capacity and control stability to accommodate normally anticipated step and ramp changes in reactor power. In conjunction with the Turbine Bypass System, the system is capable of accepting a full generator load rejection without reactor trip and without the operation of reactor safety relief valves.

#### ***10.4.7.3 Evaluation***

The C&FS does not serve or support any safety-related function. Systems analyses show that failure of this system cannot compromise any safety-related system/function or prevent safe shutdown. C&FS component failure analysis results are provided in Table 10.4-6.

During operation, radioactive steam and condensate are present in the FW heating portion of the system, which includes the extraction steam piping, FW heater shells, heater drain piping, and heater vent piping. Shielding and access control are provided as necessary (see Chapter 12). The C&FS is designed to minimize leakage with welded construction utilized where practicable. Relief valve discharges and operating vents are channeled through closed systems.

If it is necessary to remove a component from service such as a FW heater, pump, or control valve, continued operation of the system is possible by use of the multi-string arrangement and the provisions for isolating and bypassing selected equipment and sections of the system.

The majority of the condensate and FW piping considered in this section is located within the nonsafety-related Turbine Building. The portion that connects to the seismic interface restraint outside the containment is located in the steam tunnel between the Turbine and Reactor Buildings. This portion of the piping is analyzed for dynamic effects from postulated seismic events. The FW control system is designed to ensure that there could not be large sudden changes in FW flow that could induce water hammer.

The C&FS trip logic and control schemes respectively use coincident logic and redundant controllers and input signals to support plant availability goals and avoid spurious trips. This specifically includes all FW heater level controllers, all C&FS flow and minimum flow controllers, and pump suction pressure trips, FW heater string isolation/high level trips and C&FS bypass system(s) operation.

#### ***10.4.7.4 Tests and Inspections***

##### **10.4.7.4.1 Preservice Testing**

Each FW heater and condensate pump receives a shop hydrostatic test, which is performed in accordance with applicable codes. All tube joints of FW heaters are shop leak tested. Prior to initial operation, the completed C&FS receives a field hydrostatic test and inspection in accordance with the applicable code.

##### **10.4.7.4.2 In-Service Inspections**

The performance, leak-tightness, and structural integrity of system components are demonstrated by continuous operation.

Periodic tests and inspections of the system are performed in conjunction with scheduled maintenance outages.

#### ***10.4.7.5 Instrumentation Applications***

FW flow-control instrumentation measures the FW flow rates from each reactor FW pump and the low flow control valve. These FW system flow measurements combined with steam flow, reactor level, and setpoint level are used by the Feedwater Control System (see Section 7.7) to regulate the reactor.

Pump flow is measured on the pump discharge line and flow controls provide automatic pump recirculation flow for each reactor FW pump. Automatic controls also regulate the condensate flow through the auxiliary condensers (i.e., offgas recombiner condenser/coolers, gland steam condenser, and SJAE condensers) and maintain condensate pump minimum flow during normal power operation. Measurements of pump suction and discharge pressures are provided for all pumps in the system. Reactor FW pump suction pressure, discharge pressure and flow are indicated in the main control room.

Sampling means are provided for monitoring the quality of the condensate and final FW, as described in Subsection 9.3.2. Temperature measurements are provided for each stage of FW heating. Steam pressure measurements are provided at each FW heater. Level instrumentation and controls are provided for automatically or manually regulating the heater drain flow rate to maintain the proper level in each FW heater shell. Control valves, where required, provide automatic dump-to-condenser of heater drains on detection of high level in the heater shell.

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

#### **10.4.8 Steam Generator Blowdown System (PWR)**

Not applicable to the ESBWR.

#### **10.4.9 Auxiliary Feedwater System (PWR)**

Not applicable to the ESBWR.

**10.4.10 COL Unit Specific Information**

None

**10.4.11 References**

10.4-1 Standards for Steam Surface Condensers, Heat Exchanger Institute.

**Table 10.4-1**  
**Main Condenser Data**

Parameter	Standard Plant Value*
Condenser Type	Transversal, 3 shells, multipressure
Design duty, total 3 shells, MW (BTU/hr)	3057 (10.43x10 <sup>9</sup> )
Shell pressures 30°C (86°F) Circ. water, MPaA (psia)	0.0067 (0.98), 0.0089 (1.29), 0.012 (1.7)
Circulating water flow rate, m <sup>3</sup> /hr (gpm)	~152,000 (671,000)**
Tube side temperature rise-total 3 shells, °C (°F)	16.5 (29.7)
Shell design pressure range, MPaA (psia)	0 to 0.35(0 to 50.76)
Hotwell storage capacity-total 3 shells, m <sup>3</sup> (ft <sup>3</sup> )	316 (11.2·10 <sup>3</sup> )
Channel design pressure range, MPaA (psia)	0 to 0.38 (0 to 55.1)
Surface Area, m <sup>2</sup> (ft <sup>2</sup> )	1.5x10 <sup>5</sup> (1.61x10 <sup>6</sup> )*
Number of tube passes per shell	1
Applicable codes and standards	HEI Standards for Steam Surface Condensers
Alarms and Trips:	
High condenser pressure turbine alarm, MPaA (psia)	0.017 (2.5)
High condenser pressure turbine trip and reactor scram, MPaA (psia)	0.024-0.034 (3.4-4.9)
Main steam isolation valve closure, and Bypass valve closure, MPaA (psia)	0.068-0.078 (9.8-11.3)
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\* Condenser surface and performance parameters are site dependent. Values quoted are for reference purposes only.

\*\* This is CIRC flow required for 100% turbine bypass following a turbine trip. This flow has not been analyzed to support island mode under all conditions.

**Table 10.4-2**  
**Main Condenser Evacuation System**

Parameter	Standard Plant Value
Steam Jet Air Ejector System:	
Number of ejector stages per element	2
Number of intercondensers per set	2
Number of ejector sets and capacity	2 x 100%
Required supply steam pressure, MPaA (psia)	0.827 (120)
Normal steam supply source	Cross-around
Start-up Vacuum Pump System:	
Number of pumps and capacity	2 x 50% (minimum)

**Table 10.4-3**  
**Circulating Water System**

Parameter	Standard Plant Value*
Circulating Water Pumps:	
Number of pumps	4
Pump type	Vertical, wet pit
Unit flow capacity**, m <sup>3</sup> /hr (gpm)	Approx. 38300 (170000)
Driver Type	Electric motor
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Operating Temperatures:	
Normal Power Heat Sink temperature range for water entering the CIRC, °C (°F)	0*** to 37.8 (32 to 100)
Temperature range of water delivered to the main condenser, °C (°F)	5*** to 37.8 (41 to 100)
CIRC temperature for rated turbine performance, °C (°F)	30 (86)
Maximum CIRC temperature for 100% turbine bypass capability, °C (°F)	35.6 (96)****

\* Number of pumps and pump flow are site dependent. Values quoted above are for reference purposes only.

\*\* This capacity is for condenser cooling requirements only, see Table 9.2-2 for potential additional capacity requirements for Plant Service Water.

\*\*\* If the Normal Power Heat Sink does not have the capability to control the minimum temperature, the minimum temperature would be maintained by warm water recirculation.

\*\*\*\* Maximum temperature is based on 81°F wet bulb temperature (2% exceedence) and a typical 15°F approach temperature for natural draft cooling towers (see Table 2.0-1).



**Table 10.4-4**  
**Condensate Purification System**

<b>Parameter</b>	<b>Standard Plant Value*</b>
<b>Condensate Filters:</b>	
Filter type	High efficiency
Number of vessels	6
Total design flow rate, m <sup>3</sup> /hr (gpm)	6480 (28530)
<b>Condensate Demineralizers:</b>	
Demineralizer type	Mixed bed ion exchanger
Number of vessels	8
Total design flow rate, m <sup>3</sup> /hr (gpm)	6480 (28530)
Specific flow rate, ℓ/s/m <sup>2</sup> (gal/s/ft <sup>2</sup> )	< 27.2 (<0.67)
<b>Other System Features:</b>	
Filter backwash tank	1
Resin receiver tank	2
Resin storage tank	2

\* The number and type of condensate filters and demineralizers, design flow and specific design flow rate are site dependent, values quoted above are for reference purposes only.

**Table 10.4-5**  
**Condensate and Feedwater System Data**

Parameter	Standard Plant Value
Condensate Piping:	
Normal flow rate, kg/hr (lbm/hr)	$6.59 \times 10^6$ ( $14.5 \times 10^6$ )
This line was deleted.	
Nominal pipe size(mm/inch)	1000/40
Fluid velocity, m/s (ft/s)	2.56 (8.4)
Fluid temperature, °C (°F)	145.5 (294)
Design code	ASME B31.1
Seismic design	Non Seismic
Main Feedwater Piping:	
Design (VWO) flow rate, kg/hr (lbm/hr)	$9.1 \times 10^6$ ( $20 \times 10^6$ )
Number of lines	2
Nominal pipe size (mm/inch)	650/26
Fluid velocity, m/s (ft/s)	4.1(13.4)
Fluid temperature, °C (°F)	215.5 (420)**
Design code	ASME B31.1
Seismic design	See Section 3.2

\* Based on VWO FW flow. These are representative values for the standard plant; actual values may vary.

\*\* Can be varied during normal operations.

**Table 10.4-6**  
**Condensate and Feedwater System Component Failure Analysis**

<b>Component</b>	<b>Failure Effect on Train</b>	<b>Failure Effect on System</b>	<b>Failure Effect on NBS</b>
Condensate pump	None. Condenser hotwells and condensate pumps are interconnected.	None. Operation continues at full capacity, by automatic start up of the standby pump. The feedwater tank absorbs the flow transient.	None
No.1, 2 or 3 FW heater	One train of No. 1, 2 and 3 heaters is shut down. Remaining trains continue to operate.	Operation continues at reduced capacity, using parallel FW heaters. Load must not exceed turbine vendor's requirements to protect the LP turbines from excessive steam flow.	Reactor control system is used to reduce reactor power to a level compatible to the safe LP turbine operation.
MSR drain tanks	Drains from affected drain subsystem are dumped to condenser.	100% of the corresponding drains are dumped to condenser.	None. The drain systems are designed to permit operation with normal full reactor power, FW temperature, and flow rate.
Reactor FW pump	None. Feedwater pumps are interconnected.	None. Operations may continue at full capacity by automatic start up of the standby pump	None.
FW open heater	Open heater overflow caused by condensate control valve failure.	None. There is an evacuation line to Main Condenser.	None

**Table 10.4-6**  
**Condensate and Feedwater System Component Failure Analysis**

<b>Component</b>	<b>Failure Effect on Train</b>	<b>Failure Effect on System</b>	<b>Failure Effect on NBS</b>
Low flow control valve	None. Not train dependent.	None. The low flow control valve is used up to 15% power. The low flow control valve is provided with a capacity ( $C_v$ ) that supports up to 20% to ensure control at 15%.	Full power: None. Low Power (<15%): Bypass system accepts excess steam flow until the reactor control system reduces power to an acceptable level.
No. 5 or 6 FW heater.	One train is shut down.	C&FS operation continues at capacity, using parallel train and bypass line.	Reactor control system is used to adjust the reactor power to permit continued operation with the reduced FW temperature.

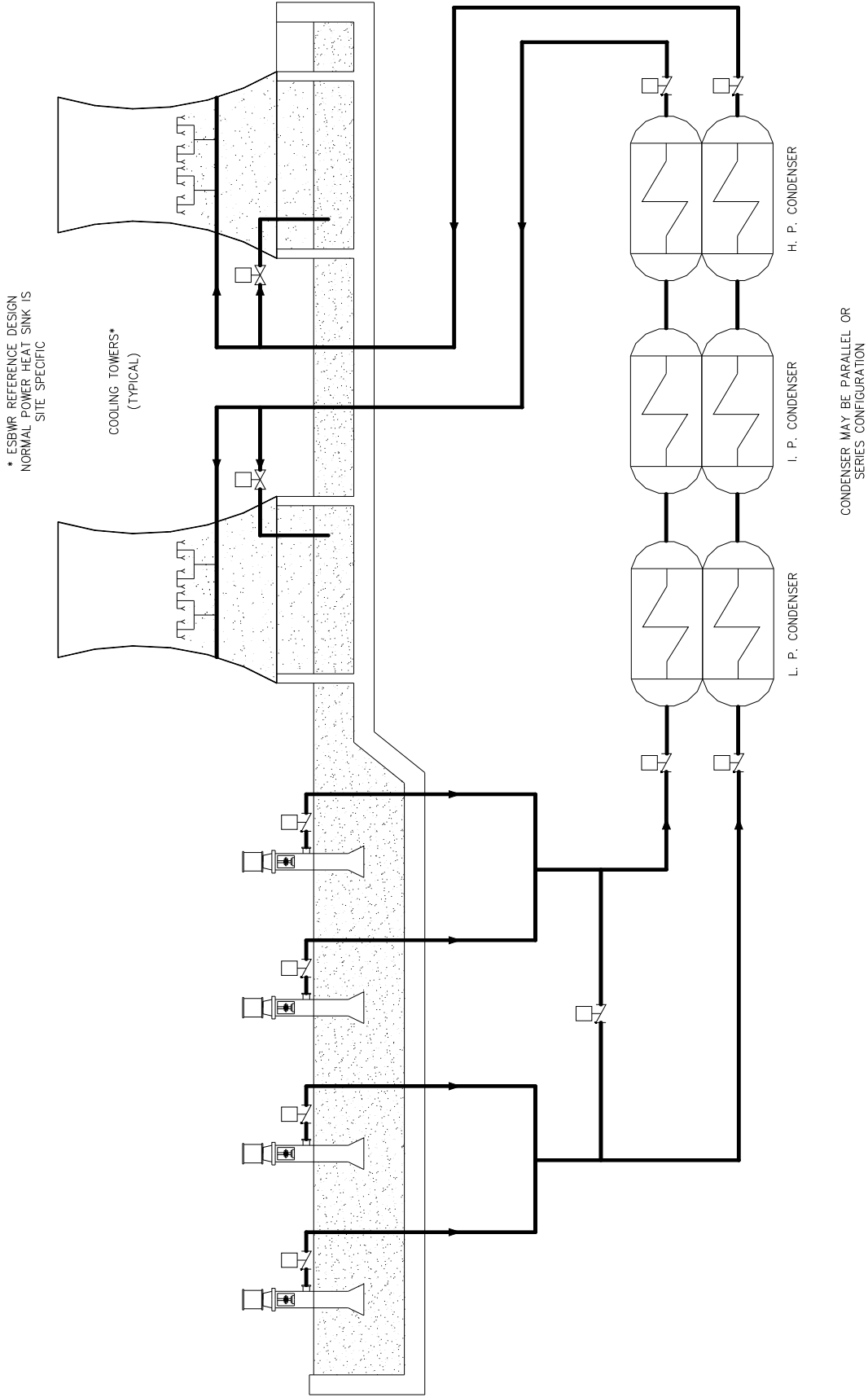


Figure 10.4-1. Circulating Water System

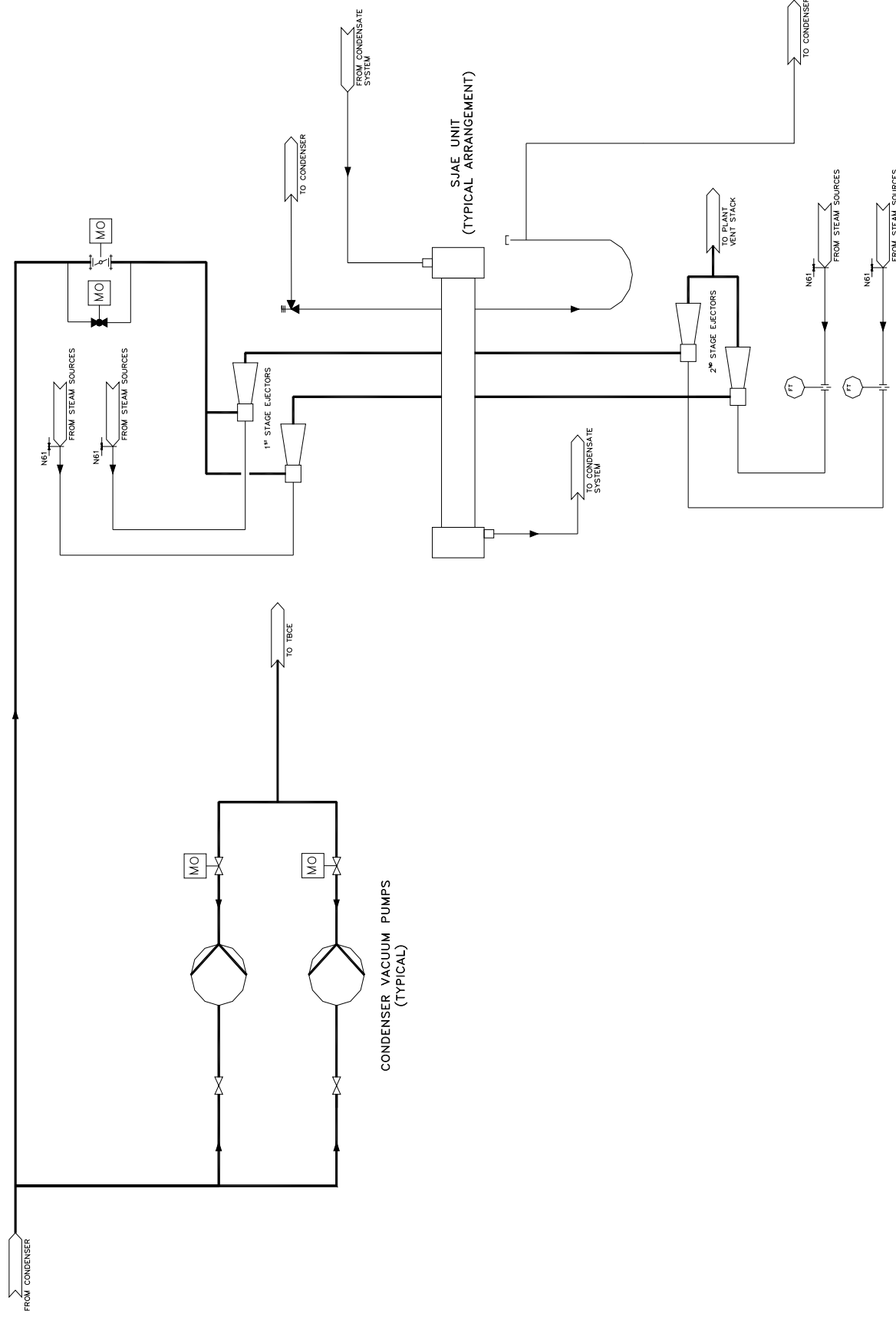


Figure 10.4-2. Main Condenser Evacuation System

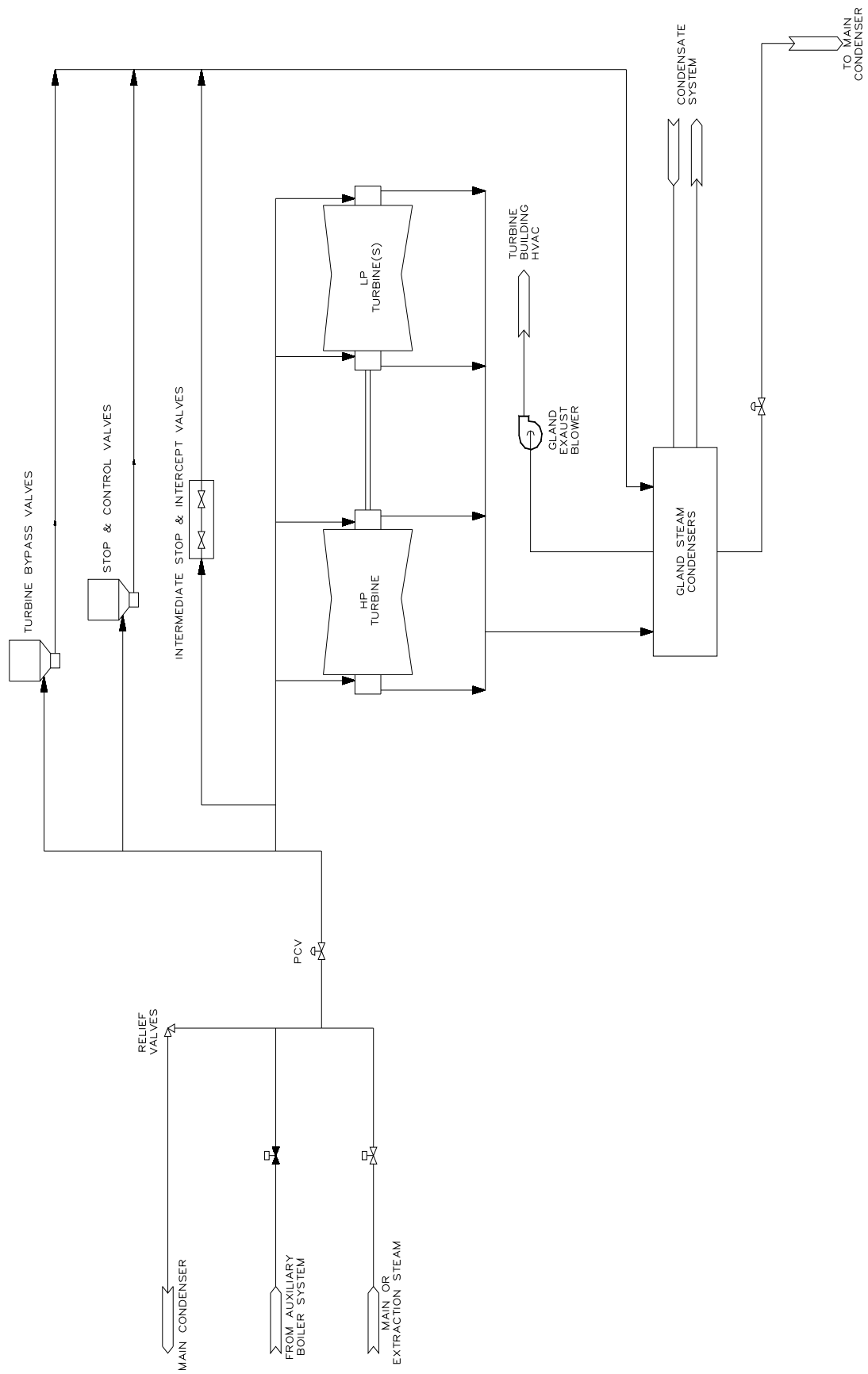
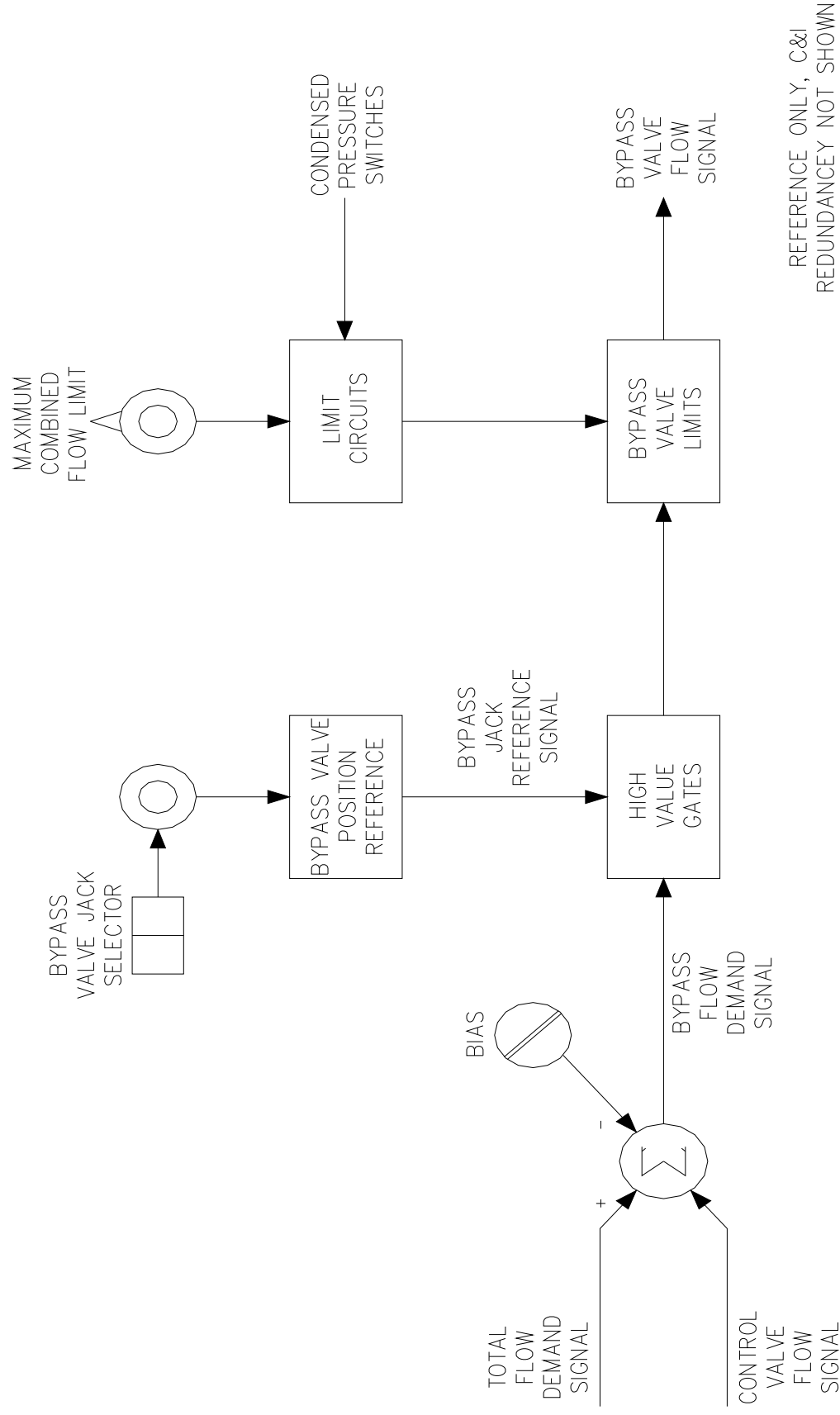


Figure 10.4-3. Turbine Gland Seal System



**Figure 10.4-4. Signal Flow Chart for Turbine Bypass Control Unit**



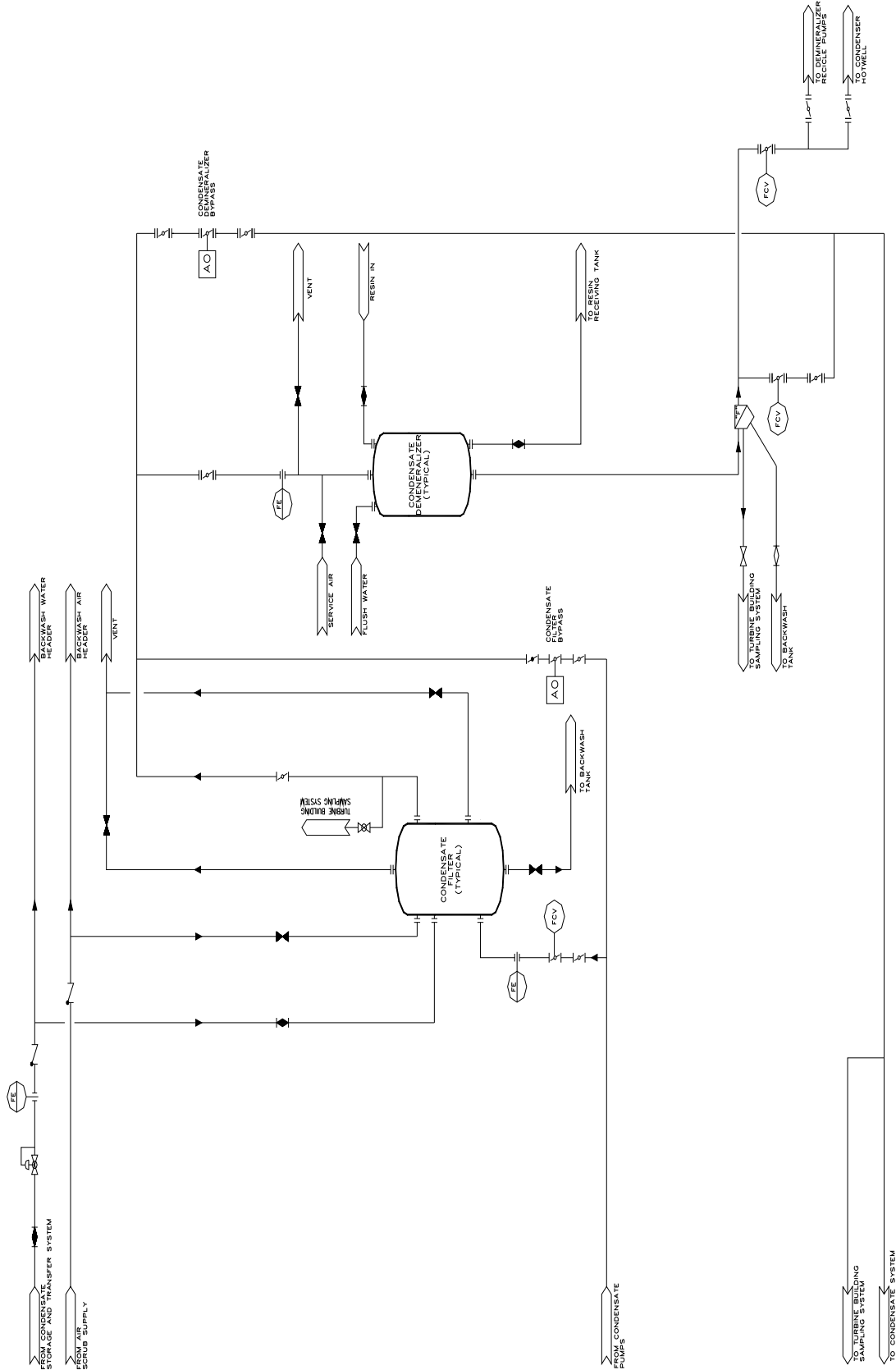


Figure 10.4-5. Condensate Purification System

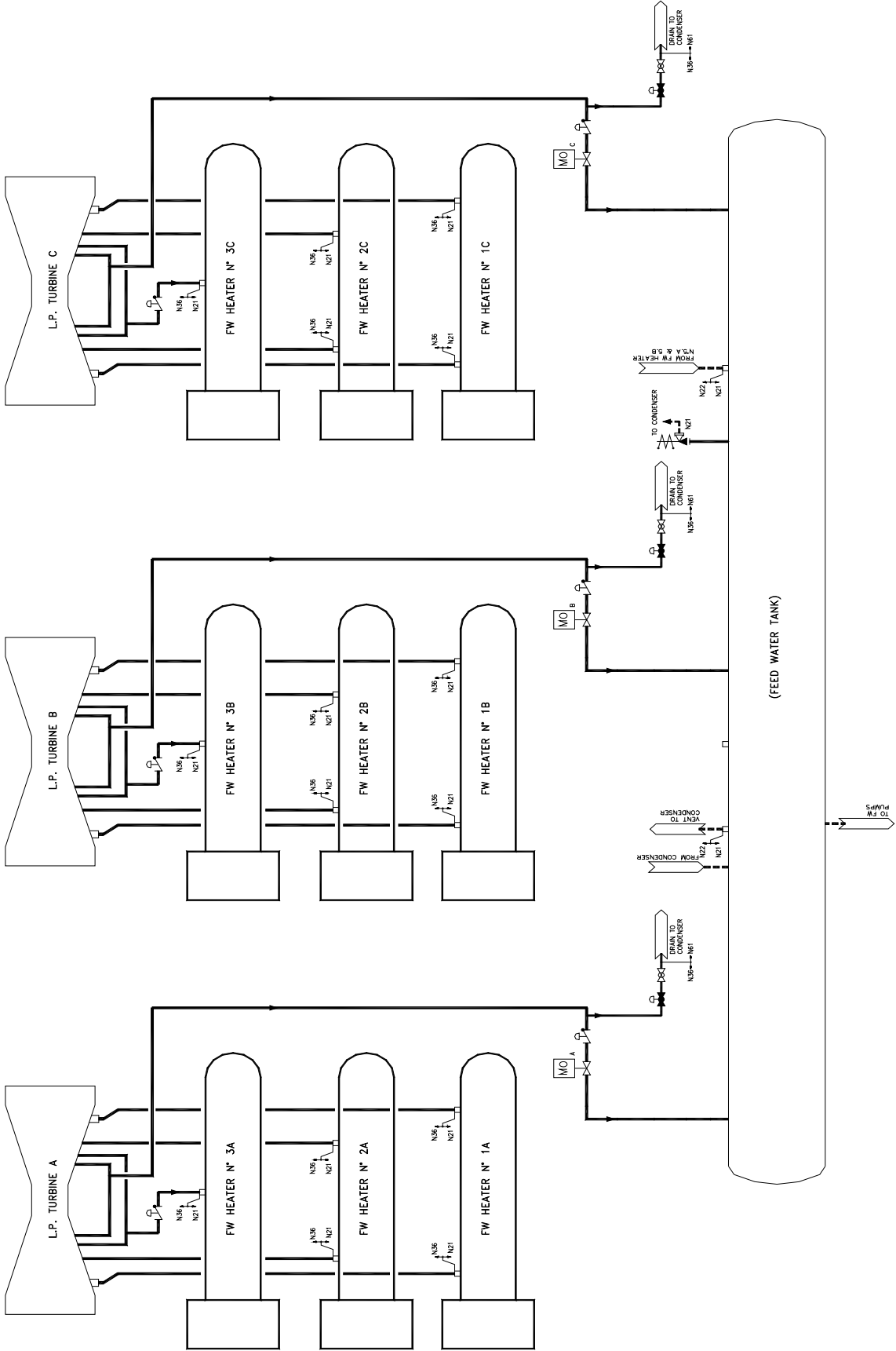


Figure 10.4-6a. LP Extraction Steam System

TYPICAL FOR EACH LOW PRESSURE FEEDWATER HEATER TRAIN

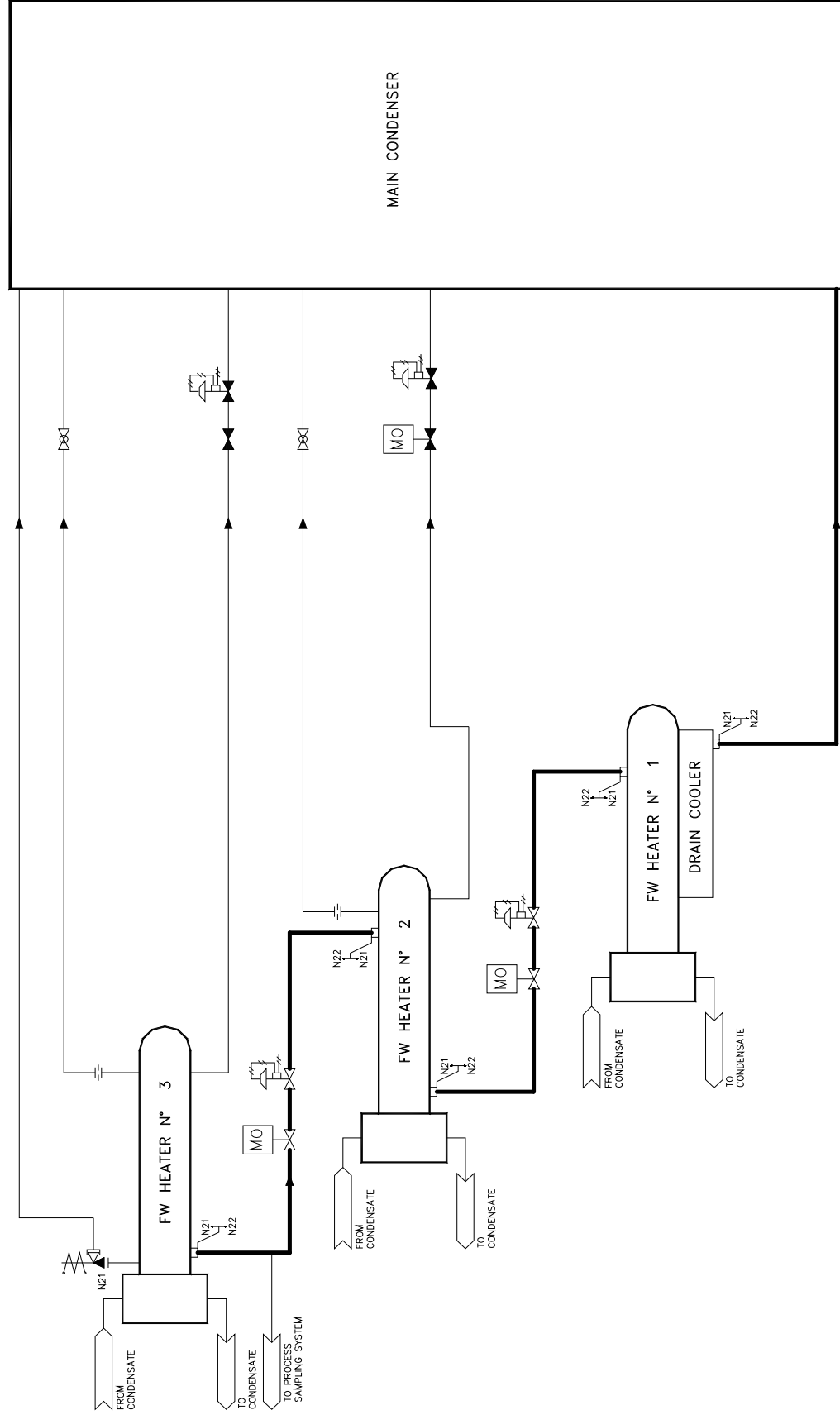


Figure 10.4-6b. LP Drain and Vent System

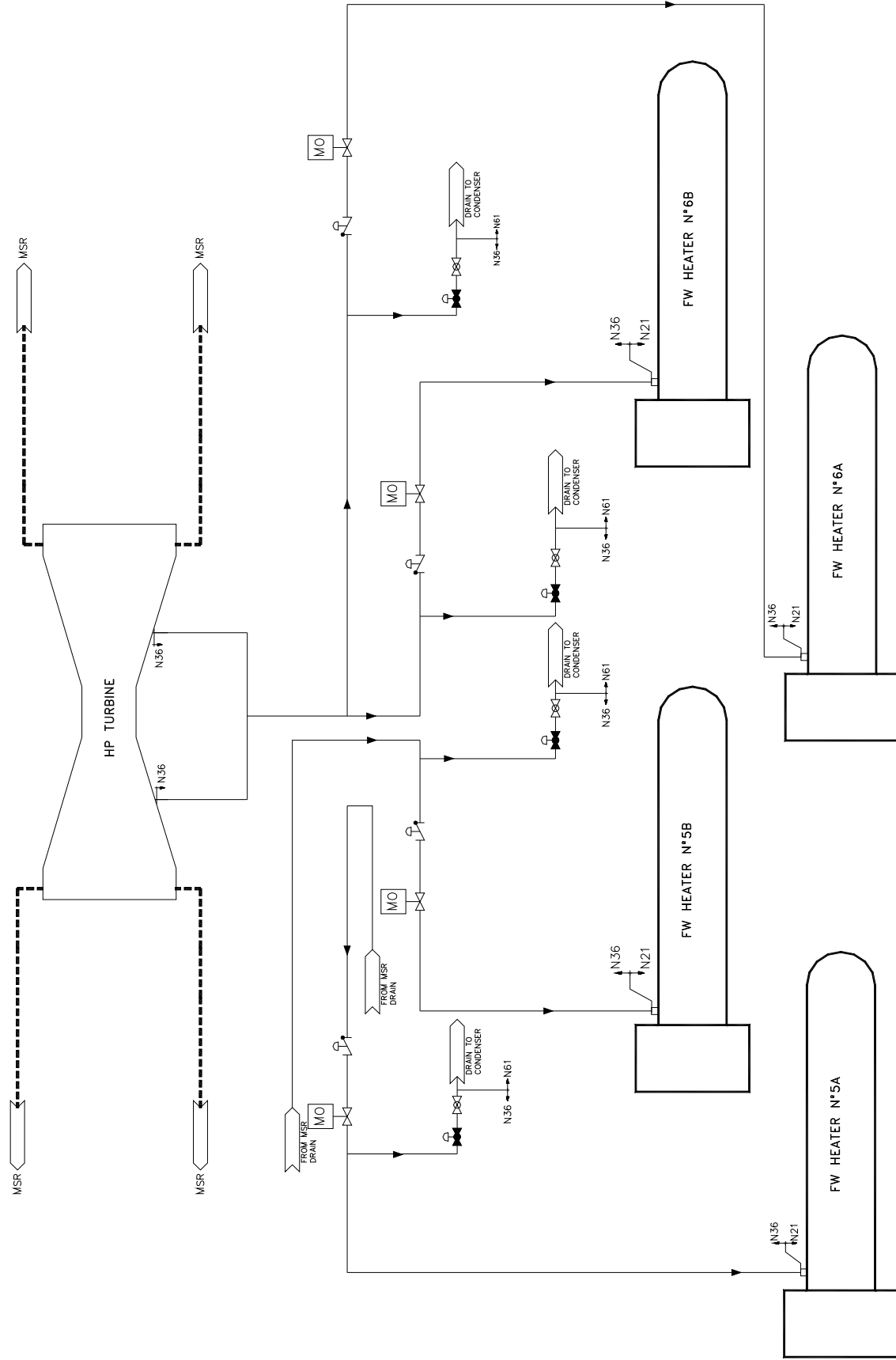


Figure 10.4-7a. HP Extraction Steam System

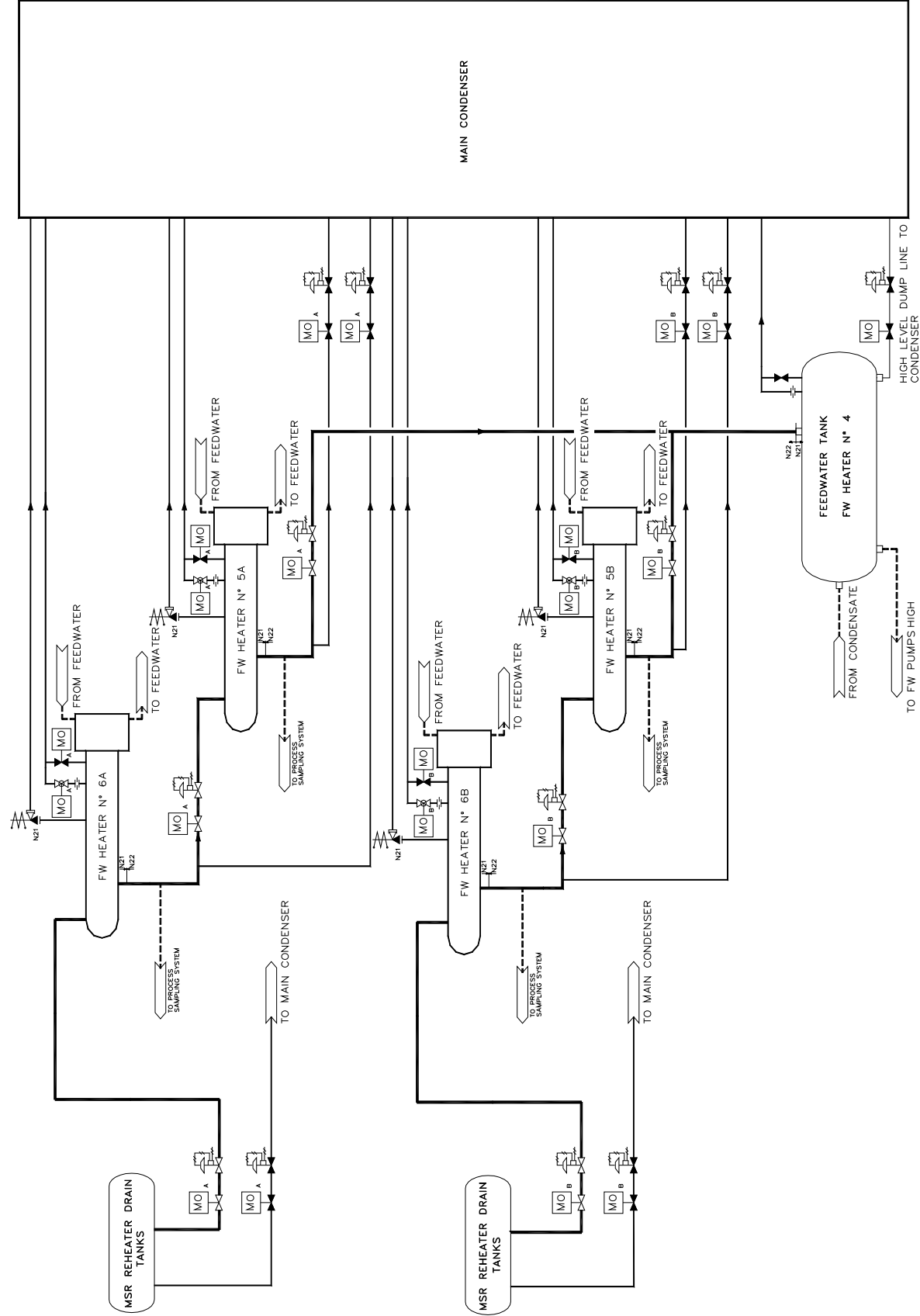


Figure 10.4-7b. HP Drain and Vent System

## 10A. ALTERNATIVE DESIGN FOR STEAM AND POWER CONVERSION SYSTEM

### 10A.1 ABSTRACT

Chapter 10 describes the ESBWR Steam and Power Conversion System standard plant design. However, alternative designs may have to be considered depending on site specific data and eventual Utility requirements.

The site environmental temperatures and the normal power heat sink used (e.g., the sea, a lake, cooling towers, etc.) have a significant impact on the plant's performance and general arrangement. Other power cycle characteristics such as final feedwater temperature, Low Pressure turbine last stage size, and other power cycle equipment impact the plant electrical power and Turbine Building arrangement.

A Steam and Power Conversion System alternative design is described in this Appendix, as an example of possible significant changes in systems configuration. In it, the most important aspects of the Steam and Power Conversion System design have been modified as follows:

- The power cycle heat sink is a lake instead of the natural draft cooling towers foreseen in the ESBWR standard plant design. This signifies the following changes with respect to the standard design:
  - The Circulating Water System is open circuit instead of closed circuit.
  - The Main Condenser is single pressure instead of multi-pressure, and therefore all of the Low Pressure turbines have the same exhaust pressure.
  - The Main Condenser pressure is lower than in the standard design.
- The final feedwater temperature is 220°C (428°F), instead of the 215.6°C (420°F) contemplated in the standard design.
- The LP turbine last stage blade is 57" instead of the 52" of the standard design.
- The designs of the turbine, condenser and some feedwater heaters are different than what is considered in the standard design.

There is no difference between the power cycle standard and alternative designs from a nuclear safety point of view and both comply with the reactor interface requirements; therefore, they have no effect on the Nuclear Island.

To facilitate understanding of the Steam and Power Conversion System alternative designs, only the paragraphs with relevant differences, with respect to the ESBWR standard plant design, are included in this Appendix. Section 10 text references to Tables and Figures have a corresponding Table and Figure in Section 10A. Similar Section 10A text differences also may reference Tables and Figures in Section 10A.

**SUMMARY DESCRIPTION**

*Same as the ESBWR standard plant design except in the following paragraphs:*

*5<sup>th</sup> paragraph*

The Steam and Power Conversion System important design features are summarized in Table 10A.1-1. The main conceptual features are illustrated in Figure 10A.1-1, assuming a single pressure condenser, using a once through, cooling water system. This type of condenser and other site dependent ESBWR plant features and parameters are given here to more completely define the ESBWR Turbine Island once through standard design.

*9<sup>th</sup> paragraph*

The Steam and Power Conversion System is designed to operate at approximately 103% of rated turbine throttle flow (assumed to correspond to turbine valves wide open).

*11<sup>th</sup> paragraph*

The necessary biological shielding for personnel protection is as needed provided for radiation producing components of the Steam and Power Conversion System including the main turbines, high velocity separators, feedwater deaerator storage tank and feed heaters, condenser and steam jet air ejector.

*13<sup>th</sup> paragraph*

The majority of the Steam and Power Conversion System is located in the turbine building, which is a non-seismic, nonsafety-related building as originally designed, however the TB design will be upgraded to Seismic Category II with BWR shielding for ESBWR application.

**10A.1.1 Protective Features**

*Same as ESBWR standard plant design.*

**10A.1.2 COL Information**

*Same as ESBWR standard plant design.*

**10A.1.3 References**

*Same as ESBWR standard plant design.*

Table 10A.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

*Same as the ESBWR standard plant design except in the following values*

Parameter	Standard Plant Value
<b>Nuclear Steam Supply, Full Power Operation:</b>	
Rated reactor core power, (MWt)	
Design NSSS power, (MWt)	
Reactor steam outlet pressure, MPa (psia)	
Reactor rated steam flow, kg/s (lbm/hr)	
Reactor nominal outlet steam moisture, %	
Reactor inlet feedwater temp, C° (°F)	220 (428)
<b>Turbine-Generator:</b>	
Nominal Rating (MWe)	1,636
Turbine type	Tandem compound, six flow, 144.6 cm (57") last stage blade
Operating speed (rpm)	
Turbine throttle steam pressure, MPa (psia)	6.67 (967.4)
Throttle steam nominal moisture, (%)	0.4
<b>Moisture Separator/Reheaters (MSRs) :</b>	
Number of MSRs per unit	2
Stages of moisture separation	
Stages of reheat	
<b>Main condenser:</b>	
Type	Single pressure
Design duty, MW (Btu/h)	~ 2,895 (9.88x10 <sup>9</sup> )
Circulating water flow rate, m <sup>3</sup> /s (gpm)	~ 72 (1,140,000)
Circulating water temperature rise, °C (°F)	~ 9.7 (17.5)
<b>Condensate pumps:</b>	
Number of pumps	
Pump type	



Table 10A.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

*Same as the ESBWR standard plant design except in the following values*

Parameter	Standard Plant Value
Driver type	
Normal flow, m <sup>3</sup> /s (gpm)	0.56 (8877)
Total head m (ft.)	260 (853)
Rated motor power, MW (hp)	1.9 (2.55x10 <sup>3</sup> )
<b>Feedwater heaters:</b>	
Low Pressure Heaters	
a. No. 1:	
Number per stage	3 (duplex LP1/LP2)
Stage pressure, kPa (psia)	25.3 (3.7)
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b. No. 2:	
Number per stage	3 (duplex LP1/LP2)
Stage pressure, kPa (psia)	120.2 (17.43)
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c. No. 3:	
Number per stage	2
Stage pressure, kPa (psia)	326.0 (47.33)
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d. No. 4:	
Number per stage	2
Stage pressure, kPa (psia)	523.0 (75.85)
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High Pressure Heaters	
e. No. 5:	
Number per stage	1 (Feedwater deaerator storage tank)
Stage pressure, kPa (psia)	988 (143)
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Table 10A.1-1

**Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System**

*Same as the ESBWR standard plant design except in the following values*

Parameter	Standard Plant Value
f. No. 6:	
Number per stage	2
Stage pressure, kPa (psia)	1595 (231.3)
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g. No. 7:	
Number per stage	2
Stage pressure, kPa (psia)	2456 (356)
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<b>Reactor Feedwater Pump:</b>	
Number of pumps	
Pump type	
Driver type	
Normal flow, m <sup>3</sup> /s (gpm)	0.92 (14.6*10 <sup>3</sup> )
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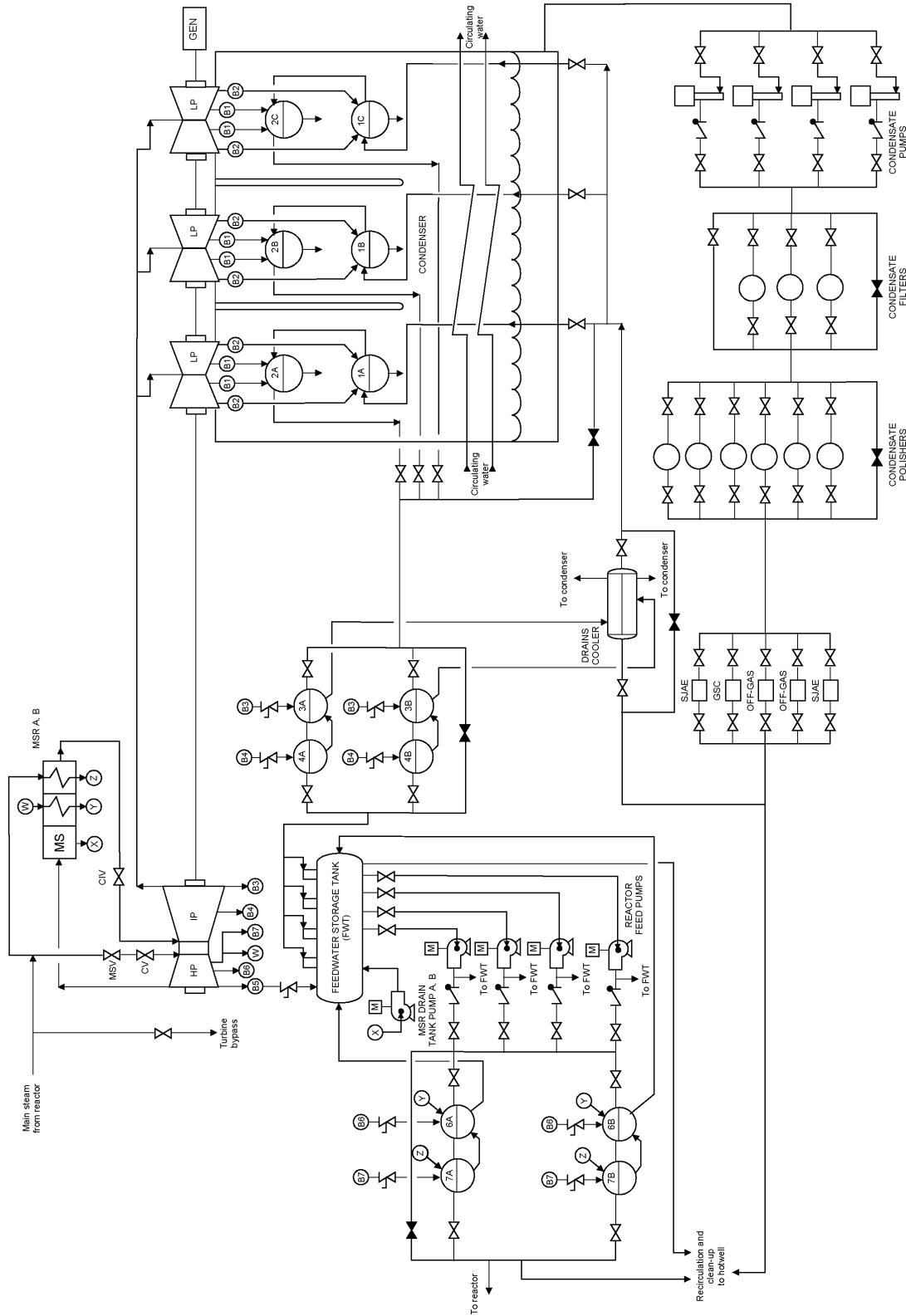


Figure 10A.1-1. Power Cycle Schematic

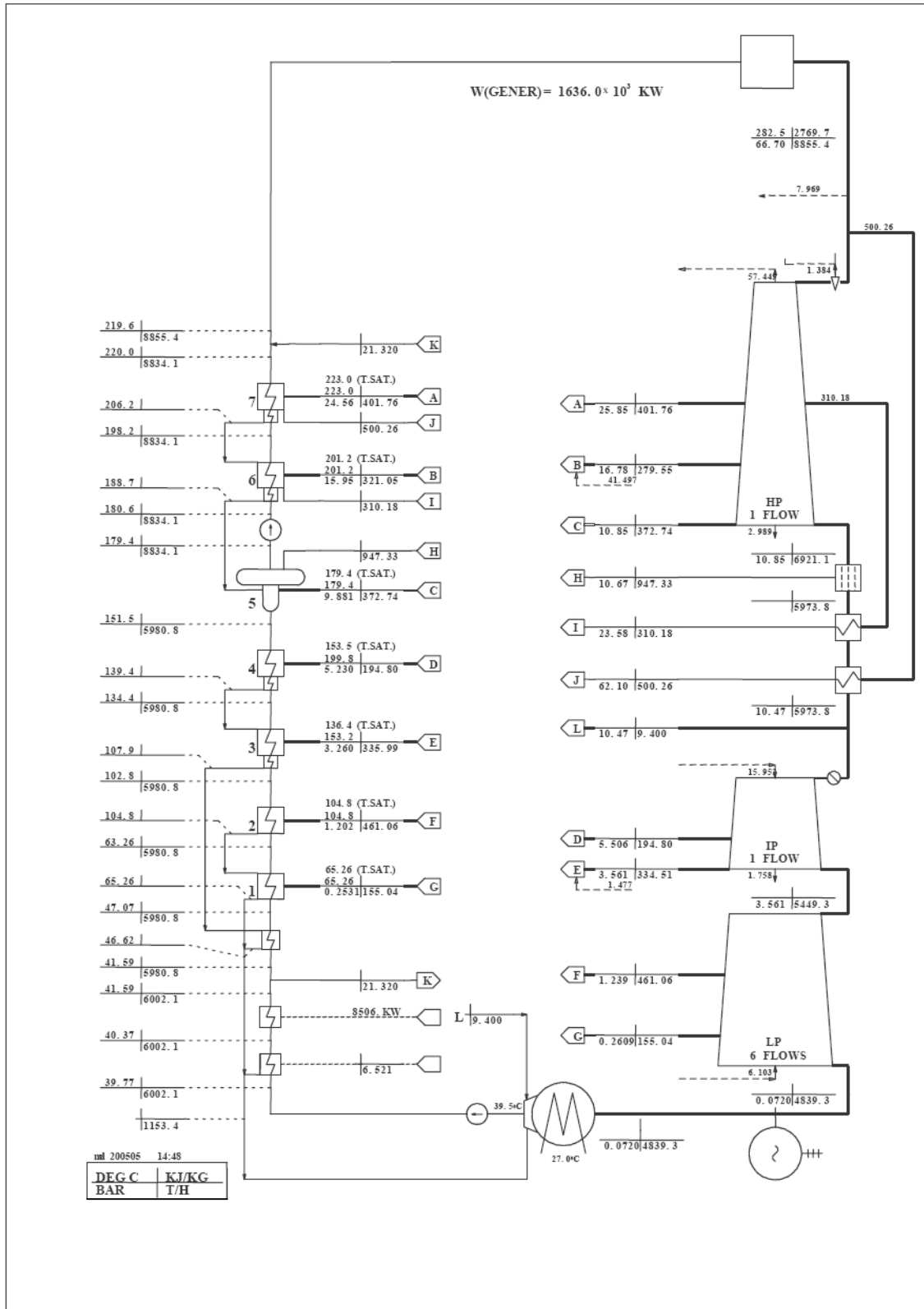


Figure 10A.1-2. Rated Heat Balance

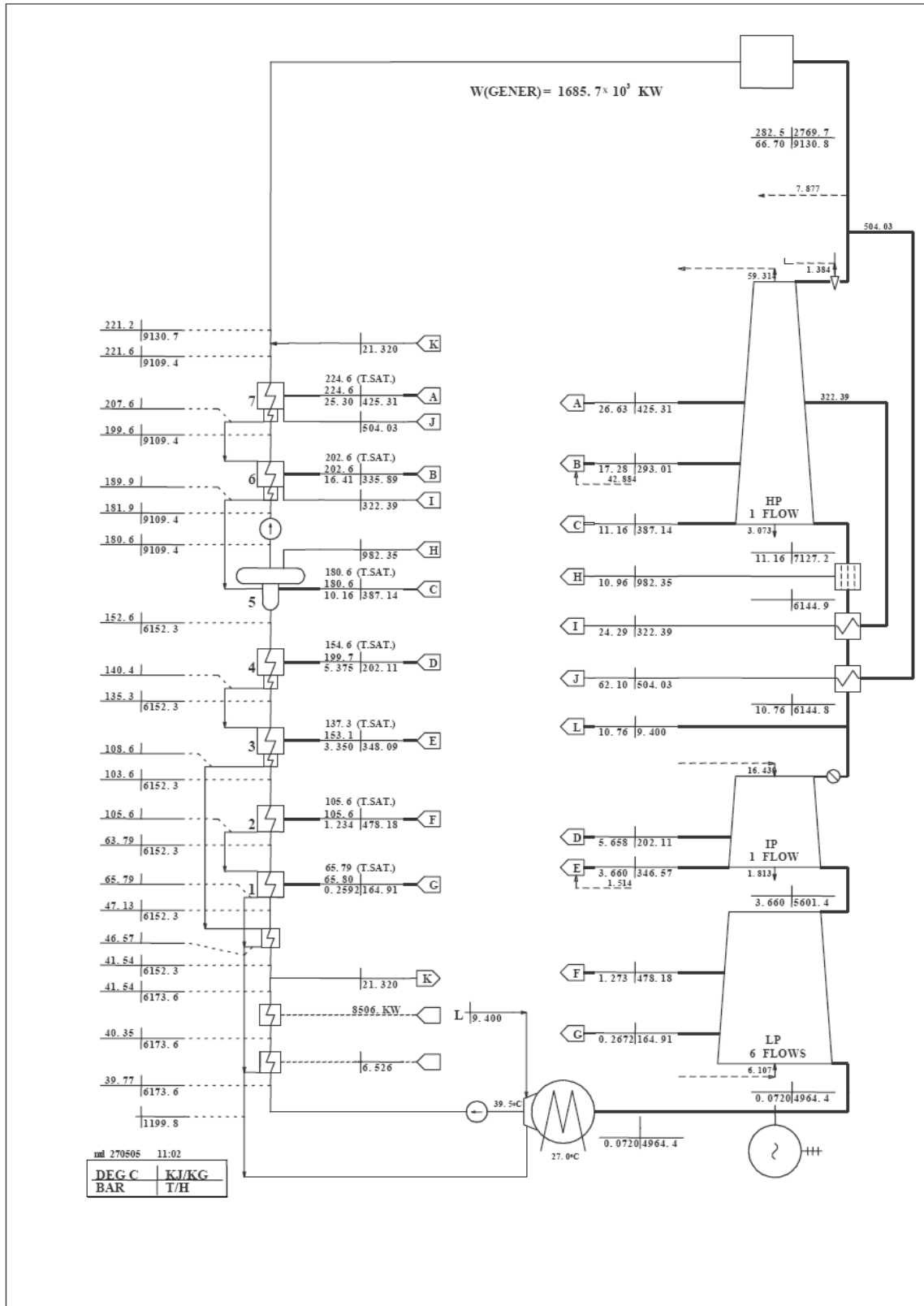


Figure 10A.1-3. Valves Wide Open - Heat Balance

## 10A.2 TURBINE GENERATOR

### 10A.2.1 Design Bases

*Same as the ESBWR standard plant design.*

#### 10A.2.1.1 Safety (10 CFR 50.2) Design Bases

*Same as ESBWR standard plant design.*

#### 10A.2.1.2 Non-Safety Power Generation Design Bases

*Same as the ESBWR standard plant design except in the following paragraphs:*

(6) The TG is designed to support the plant availability goals by utilizing two-out-of-three or two-out-of-four coincident trip logic. Similarly, Turbine Generator control system functions, which are required for equipment and personal safety, use at least dual redundant controllers and triply redundant control inputs.

#### 10A.2.1.3 Functional Limitations Imposed by the Design or Operational Characteristics of the Reactor Coolant System

*Same as in ESBWR standard plant design.*

### 10A.2.2 Description

#### 10A.2.2.1 General Description

*Same as the ESBWR standard plant design except in the following paragraphs:*

The Turbine-Generator consists of an 1800 rpm turbine, moisture separator/reheaters, generator, exciter, controls, and associated subsystems. The turbine is a four cylinder machine, composed of one combined HP/IP module and three identical double flow LP modules, with moisture separation and intermediate reheating. It drives a four pole synchronous generator. This generator is a direct driven, three-phase, 60 Hz, 1800 rpm synchronous generator.

The TG unit and associated piping, valves, and mechanical controls are located completely within the Turbine Building. There are no safety-related systems or components located within the Turbine Building with the exception of the Reactor Protection System (RPS) sensors on the TG unit, condenser, steam lines and turbine bypass valves. The safety-related switches or transducers used to detect closure of the turbine main stop valves, fast closure of the turbine control valves and high-high condenser back pressure are fail safe. Any local failure associated with the TG unit does not adversely affect any safety-related equipment. Failure of TG equipment cannot preclude safe shutdown of the reactor.

#### 10A.2.2.2 Component Description

*Same as the ESBWR standard plant design except in the following paragraphs:*

**10A.2.2.2.1 Steam admission valves**

The admission valves are arranged after the HP admission, and between the MSRs and the Intermediate Pressure (IP) admission. As the MSRs provide a significant steam capacity and energy storage, it is necessary to be able to control the IP steam flow to prevent in particular any risk of overspeed.

The steam admission is controlled by sets of two series-mounted individual valves, each of which has an essential and independent function. One valve fulfills a protection function (stop valve) and the other a control and protection function (control valve). This independence improves the system's reliability.

The two types of valves are fitted into two separate chests, which are welded together. The shape of the components has been designed and experimentally tested to obtain good flow stability and reduce pressure drops.

Each HP stop valve contains a permanent steam strainer to prevent foreign matter from entering the control valves and turbine.

**10A.2.2.2.2 HP Steam Admission** - The HP steam admission is provided with four assemblies, each composed of one main steam stop valve and one control valve.

The two valves are of the "pull-to-open" type, i.e. their plug is built on a rod, which is pulled by a servomotor against the continuous force of a spring for opening.

**10A.2.2.2.3 IP Steam Admission** - The IP steam admission is provided with four sets of valves, each of which is composed of one reheat steam stop valve and one intercept control valve.

The large steam flow admitted to the IP casing has led to the adoption of butterfly-type valves. The disc of each valve can rotate by 90° (from closed to open position) by a pull of the servomotor.

**10A.2.2.2.4 HP/IP module**

The design features a combined HP/IP cylinder module, which contains the HP and IP steam paths in opposite flows, in a single-shell casing. The HP and IP steam admissions, which constitute hot areas, are located at the center of the module and the exhausts at its two extremities. This layout, which is favorable to the overall thermal equilibrium of the section, also facilitates the arrangement of connection piping.

**10A.2.2.2.5 HP Section**

The HP turbine receives steam through four steam leads, one from each main steam control valve outlet. The steam is expanded axially across 8 stages of stationary and rotating blades. Extraction steam from the turbine at 2 locations supplies the 6th and 7th stages of feedwater heating and the heating steam to the first stage reheaters. HP turbine exhaust steam is collected in four cold reheat pipes. Most of the exhaust steam is routed to the MSR inlet, but part of it is diverted and supplies the 5th stage of feedwater heating.

#### 10A.2.2.2.6 IP Section

After removal of the water content and reheating in the MSRs, the steam is directed through four steam inlet pipes in the IP part of the HP/IP module, where it expands further in three stages of stationary and rotating blades. This feature enables a longer single flow expansion compared to traditional designs, which is an advantage in terms of efficiency. Extraction steam from the IP section of the HP/IP module supplies the 3<sup>rd</sup> and 4<sup>th</sup> stages of feedwater heating.

#### 10A.2.2.2.7 Moisture Separator Reheaters

Two horizontal cylindrical-shell, combined Moisture Separator Reheaters (MSRs) are installed in the steam path between the high and intermediate pressure turbine. The MSRs serve to dry and reheat the HP turbine steam exhaust (cross around steam), before it enters the intermediate-pressure turbines. This improves cycle efficiency and reduces moisture related erosion and corrosion in the intermediate-pressure turbines. Crossaround steam is piped into the bottom of the MSR. Moisture is removed in chevron-type moisture separators, and is drained to the moisture separator drain tanks and, from there, is pumped back to the feedwater deaerator storage tank. The dry cross around steam next passes upward across two stages of reheaters, which are supplied with turbine extraction steam (1<sup>st</sup> reheating stage) and main steam (2<sup>nd</sup> reheating stage). Finally, the cross around steam is routed to the intermediate stop and intercept valves, which are located just upstream of the intermediate-pressure turbine inlet nozzles.

The reheaters drain, via drain tanks, to the High Pressure heaters. Safety valves are provided on the MSR for overpressure protection.

#### 10A.2.2.2.8 LP modules

Each of the 3 LP turbines receives steam from the IP outlet, through cross-under pipes fitted with expansion bellows.

The LP modules are each composed of an inner structure and an exhaust hood. The inner structure supports the LP blade carriers and the LP bearings. It rests directly on the foundation by means of supports in the same manner as the HP/IP casing. The outer casing collects the steam exhausted from the last LP stages. Installed independently of the inner casing, the exhaust hood is welded onto the condenser which is itself directly anchored to the foundation slab. The exhaust hood can freely move in all required directions. A flexible sealing ring provided at each extremity ensures vacuum tightness between this exhaust hood and the inner LP structure. This arrangement characterizes the “independent structure.”

The inner LP casing is provided with internal headers allowing water to be injected in the exhaust structures and preventing any excessive temperature rise in no-load operation or at low loads.

Extraction steam from the LP turbines supplies the 1st and 2nd stages of feedwater heating.

#### 10A.2.2.2.9 Extraction Non-return Valves

Upon loss of load, the steam contained downstream of the turbine extractions could flow back into the turbine, across the remaining turbine stages, and into the condenser. Associated condensate could flash to steam under this condition and contribute to the backflow of steam or could be entrained with the steam flow and damage the turbines. Extraction non-return valves



are installed in the extraction lines to the third, fourth, fifth, sixth and seventh stage of turbine extractions to guard against this backflow and the resulting potential damage due to water entrainment or overspeed condition.

#### **10A.2.2.2.10 Generator**

The generator is directly driven by the turbine and supplies the step-up transformer with medium voltage. It is a 4-pole machine and is cooled by internal hydrogen circulation. The field winding is directly cooled by hydrogen gas. The stator winding is directly cooled by an internal circulation of de-ionized water. The generator is designed according to IEC recommendations. The auxiliaries include cooling system, gas supply and shaft sealing circuits. The static generator excitation system is controlled by an automatic voltage regulator.

The frame, which constitutes the outer envelope, is made of an assembly of heavy welded steel plates, forming a cylindrical shell. As the machine is gas tight, the hydrogen coolers are located in twin domes welded to the generator frame. The coolers are mounted horizontally.

The generator rotor is constituted of solid, alloyed steel forging with high tensile strength, elaborated in an electric furnace and cast under vacuum. The slots for the field coils are milled in the central body of the rotor. The coils are made of silver alloyed copper strips, which improve their mechanical behavior.

The field winding is directly cooled by hydrogen derived from axial ducts arranged under the slots. The system of cooling with radial vents provides a uniform distribution and thus avoids any risk of thermal unbalance. A radial type fan is mounted on each end of the rotor, outboard of the rotor body. The rotor terminates with collector rings at one end of the rotor and drive coupling at the other end.

The auxiliary systems ensure:

- Filling, make-up and control of hydrogen cooling circuit;
- Seal oil circulation, control and purification; and
- Circulation, treatment and cooling of deionized water for stator cooling.

#### **10A.2.2.3 Normal Operation**

*Same as the ESBWR standard plant design except in the following paragraphs:*

Operation of the TG is under the control of the Turbine controller. During normal operation, HP stop valves, IP stop and control valves are fully opened. HP control valves are throttling to control the reactor pressure.

#### **10A.2.2.4 Turbine Overspeed Protection System**

*Same as the ESBWR standard plant design.*

#### **10A.2.2.5 Turbine Protection System**

*Same as the ESBWR standard plant design.*

**10A.2.2.6 Turbine Generator Supervisory Instruments**

*Same as the ESBWR standard plant design.*

**10A.2.2.7 Testing**

*Same as the ESBWR standard plant design except in the following paragraph:*

Provisions for testing each of the following devices while the unit is operating are included:

- Condenser vacuum trip
- MSR shell over pressure trip

**10A.2.3 Turbine Integrity****10A.2.3.1 Materials Selection**

*Same as the ESBWR standard plant design except in the following paragraphs:*

Turbine rotors and parts 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 practice, and consistent with obtaining adequate initial and long-life fracture toughness for the environment in which the parts operate. The turbine materials have the lowest Fracture Appearance Transition Temperatures (FATT) and highest Charpy V-notch energies obtainable, on a consistent basis, from water quenched Ni-Cr-Mo-V material at the sizes and strength levels used. Because 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.

**10A.2.3.2 Fracture Toughness**

*Same as the ESBWR standard plant design except in the following paragraphs:*

Stress calculations include components due to centrifugal loads and thermal gradients. Fracture mechanics calculations are performed on the rotors taking into account the maximum size defect acceptable after US controls. Two types of cycles are applied to the defect: High Cycle Fatigue (HCF) for alternate bending stresses, and Low Cycle Fatigue (LCF) for start-up. Calculations verify that the initial defect, after increasing due to LCF during the equipment lifetime does not propagate under HCF and remains non-critical as regards brittle fracture with a large margin. Adequate material fracture toughness is assured by destructive tests on material samples using correlation methods which are as conservative, or more so, than those presented in Reference 10.2-1.

**10A.2.3.3 High Temperature Properties**

*Same as the ESBWR standard plant design.*

**10A.2.3.4 Turbine Design**

*Same as the ESBWR standard plant design except in the following paragraphs:*

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:

- Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.
- The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20% overspeed are controlled in the design and operation so as to cause no distress to the unit during operation. A torsional vibration analysis shall show that the Turbine Generator rotor resonance is outside of the normal operating frequency and its harmonics.
- The maximum tangential stress resulting from centrifugal forces, interference fit, and thermal gradients does not exceed 0.75 of the yield strength of the materials at 115% of rated speed.
- The design overspeed of the turbine is more than 10% above the highest anticipated speed resulting from a loss of load. On a unit-specific basis, a report will provide the overspeed basis (including setpoints) applicable to the site and discuss how the turbine assembly is designed to withstand the normal conditions, anticipated operational occurrences, and accidents resulting in a turbine trip.
- The turbine disk design facilitates in service inspection of high stress regions. The turbine rotor design is based on using welded rotor technology rather than shrunk-on disks. On a unit-specific basis, a report will provide a general description of the design features of the turbine, rotor, shaft, couplings and buckets/blades, including the number of stages, bucket (blade) design, how the buckets are attached to the rotor, whether the turbine rotor is forged, and pertinent fabrication methods (e.g., provide drawings).

#### **10A.2.3.5 Pre-service Inspection**

*Same as the ESBWR standard plant design except in the following paragraphs:*

The Quality Assurance (QA) document includes the following tests performed in the supplier's factories, of which the Customer at least receives a report.

- Rotors
  - Chemical analysis (cast)
  - Preliminary ultrasonic examination before gashing
  - Mechanical tests
  - FATT curves
  - Final ultrasonic examination
  - Balancing test of the bladed rotor
  - Overspeed test of bladed rotor
- Blades

- Chemical analysis
- Hardness test
- Mechanical tests
- Ultrasonic examination

#### **10A.2.3.6 In Service Inspection**

*Same as the ESBWR standard plant design except in the following paragraphs:*

In general the design of each main turbine cylinder is such that each HP/IP or LP cylinder only needs to be inspected by opening it's casing approximately every 10 years.

The list below describes the most important inspection tasks performed during maintenance outages.

#### **General**

##### **Prior to Shutdown**

- Recording of vibration levels at steady load.
- General recording of main operation parameters at full load
- (live steam, bearing metal & lube oil).
- Tests at no load (tripping, steam valves closure, and etc.).
- Governing system tests.
- Cold Turbine
  - Check of expansion values (return to position 0).
  - Opening of Pedestals
  - Recording of rotor/bearing position.
  - Check of thrust bearing clearances.
  - Opening of Cylinders
  - Measurement of clearances and displacements.
  - Concentricity check.
  - Measurement of radial clearances with coupled rotors.
  - Measurement of the rotor displacements.
- Re-assembly
  - Measurement of clearances.
  - Recording of bearing/rotor positions.

##### **HP/IP Cylinder (closed casing)**

- Check of rotor radial centering.

- Check of HP/IP/LP coupling co-axiality.
- Check of shaft/coupling guard relative positions.
- Check of clearance at fixed-point key (rear).
- Check of thrust bearing clearance.
- Check of casing load distribution.
- Check of instrumentation fastening.

**HP/IP Cylinder (open casing)**

- Casing
  - Visual inspections (joint plane, welds, and etc.).
  - Check of casing load distribution.
  - Check of casing bolts (magnetic particle and dimensional inspections).
- Diaphragms
  - Inspection of spring-loaded sealing segments.
  - Inspection of suspension and vertical centering keys.
- Fixed blades
  - Liquid penetrant inspection/Magnetic Particle Inspection (MPI)
- Gland Seal Boxes
  - Inspection of spring-loaded sealing segments.
  - Inspection of suspension and vertical centering keys.
- Rotors
  - Visual inspections (Surface condition, coupling flange, thrust bearing collar and etc.).
  - Check of balancing weights.
  - Demagnetizing.
- Moving blades
  - Visual inspection + MPI.
  - Ultrasonic inspection of blade roots.
- Pipes
  - Visual inspection of flange mating surfaces.
  - Inspection of inlet and exhaust flange bolts  
(MPI + bolt elongation measurement).
  - Inspection of joints.

**LP Cylinders (closed casing)**

- Check of radial centering of gland seal boxes at location of first segment.
- Check of coupling flange co-axiality.
- Check of relative shaft/cylinder axial positioning.
- Check of relative shaft/coupling guard axial positioning.
- Visual inspection of inner casing support stop blocks.
- Visual inspection of inner casing support anchor bolts.
- Inspection inner cylinder support points.
- Inspection of inner cylinder axial fixed points.
- Check of rupture disc sealing.
- Check of balancing door correct operation.

**LP Cylinders (open casing)**

- Exhaust hood
  - Visual inspections (flexible seal ring, joint plane, spray water header, and etc.)
  - Check of rupture disc sealing.
  - Check of balancing door correct operation.
- Inner Casing
  - Visual inspections (joint plane, heat screens).
  - Inspection of drain points.
  - Check of casing load distribution.
- Fixed blades
  - Visual inspection + Liquid penetrant inspection / MPI
  - Inspection of spring-loaded sealing segments
- Gland Seal Boxes
  - Centering check.
  - Inspection of spring-loaded sealing segments.
  - Inspection of stop pins and screws.
- Pipes
  - Inspection of steam pipe elbow vanes.
  - Inspection of steam extraction pipes.
- Rotors

- Visual inspections (journals, gland seals, coupling flanges).
- Inspection of balancing weights.
- Moving blades
  - Visual inspection + MPI.
  - Check for erosion of last stage blades.
  - Ultrasonic inspection of blade roots.

**Shaftline**

- Alignment check in cold state.
- Demagnetization check.
- Protection of coupling flanges.

**Pedestals**

- Pedestals
  - Visual inspections (pedestals & bearings, lube oil inlets & outlets, etc.).
  - Bearing tightening check.
- Bearings
  - Visual inspections.
  - Dimensional check.
- Jacking oil system
  - Inspection of pipes.
  - Jacking oil system check.
- Thrust bearing
  - Full visit.

**Steam admission Valves**

- HP Control Valves
  - Visual inspections.
  - Inspection of bolts (MPI and bolt elongation measurement).
  - Tightness check.
  - Check of full stroke.
  - Liquid penetrant inspection of stem leak-off flow pipes.
- HP Stop Valves
  - Visual inspections.

- Inspection of bolts (MPI and bolt elongation measurement).
- Tightness check.
- Check of full stroke and pilot valve stroke.
- Inspection of strainer.
- IP Stop and Control Valves
  - Check of correct operation before disassembly.
  - Inspection of dampers.
  - Disassembly of bearings.
  - Tightness check.
  - Visual inspection of gland boxes.
  - Inspection of bolts (MPI and bolt elongation measurement).

**Auxiliaries**

- Governing / Safety System
  - Overhaul of HP servomotors.
  - Overhaul of IP servomotors.
- Turning Gears
  - Inspection of main turning gear & Shelf-Shifting and Synchronizing (SSS) Clutch.
  - Inspection of auxiliary turning gear.
- Lube oil system
  - Oil tank draining.
  - Visual inspection of return strainer.
  - Overhaul of shaft-driven main oil pump.
  - Tightness check of tank top.
- Control Fluid System
  - Control fluid analysis.
  - Fluid tank draining.
  - Overhaul of pumps.
  - Inspection of filters.

**Prior to re-assembly**

- Fill in the equipment data sheets.
- Check points raised in Inspection Reports.



- Perform relevant control system tests.
- Perform re-balancing if required.
- Re-condition turbine heat insulation.

### **Functional Tests of Auxiliary Systems to be Performed During Overhaul Maintenance**

- TG Controller
  - Check of connections.
  - Check of power supplies.
  - I/O checks.
- Check of position loop cards.
- Check of Turbine Supervisory Instrumentation.
- Lube oil - Jacking oil systems tests.
- Safety system tests.
- Control system tests.
- Check of control circuit
  - Static tests.
  - Dynamic tests.
  - Check of the correct operation of the auxiliary systems

#### **10A.2.4 Evaluation**

*Same as the ESBWR standard plant design except in the following paragraph:*

*8<sup>th</sup> paragraph*

The exhaust hoods of the LP turbines and the condenser form a unique box that collects the steam exhausting from the LP turbines. The connection with the LP turbines inner casings is made by circular expansion joints.

#### **10A.2.5 COL Information**

##### ***10A.2.5.1 Turbine Missile Probability Analysis***

Same as Reference Design.

#### **10A.2.6 References**

None

**Figure 10A.2-1. Turbine Stop Valve Closure Characteristic**

*Same as ESBWR standard plant design.*

**Figure 10A.2-2. Turbine Control Valve Fast Closure Characteristic**

*Same as ESBWR standard plant design.*

**Figure 10A.2-3. Acceptable Range for Control Valve Normal Closure Motion**

*Same as ESBWR standard plant design.*

**Figure 10A.2-4. Hydrogen Gas Control System**

*To be provided in COL phase*

**10A.3 TURBINE MAIN STEAM SYSTEM**

*Same as ESBWR standard plant design.*

**10A.3.1 Design Bases****10A.3.1.1 Safety (10 CFR 50.2) Design Bases**

*Same as ESBWR standard plant design.*

**10A.3.1.2 Non-Safety Power Generation Design Bases**

*Same as ESBWR standard plant design.*

**10A.3.2 Description****10A.3.2.1 General Description**

*Same as ESBWR standard plant design.*

**10A.3.2.2 Component Description**

*Same as ESBWR standard plant design.*

**10A.3.2.3 System Operation**

*Same as the ESBWR standard plant design.*

**10A.3.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.3.4 Inspection and Testing Requirements**

*Same as ESBWR standard plant design.*

**10A.3.5 Water Chemistry (PWR)**

*Same as ESBWR standard plant design.*

**10A.3.6 Steam and Feedwater System Materials**

*Same as ESBWR standard plant design.*

**10A.3.6.1 Fracture Toughness of Class 2 Components**

*Same as ESBWR standard plant design.*

**10A.3.6.2 Materials Selection and Fabrication**

*Same as ESBWR standard plant design.*

**10A.3.7 COL Information*****10A.3.7.1***

*Same as ESBWR standard plant design.*

**10A.3.8 References**

*Same as ESBWR standard plant design.*

**Table 10A.3-1****Turbine Main Steam System Design Data***Same as the ESBWR standard plant design except in the following values*

<b>Turbine Main Steam Piping</b>	<b>Standard Plant Value</b>
Design flow rate at 6.67 MPaA and 0.40% moisture, kg/s (Mlbm/hr)	2459.8 (19.52)
Normal steady-state velocity, m/s (ft/s)	42.1 (138)
Number of lines	
Nominal diameter, cm (in)	
Minimum wall thickness, mm (in)	
Design pressure, MPaG (psig)	
Design temperature, °C (°F)	
Design code	
Seismic design	

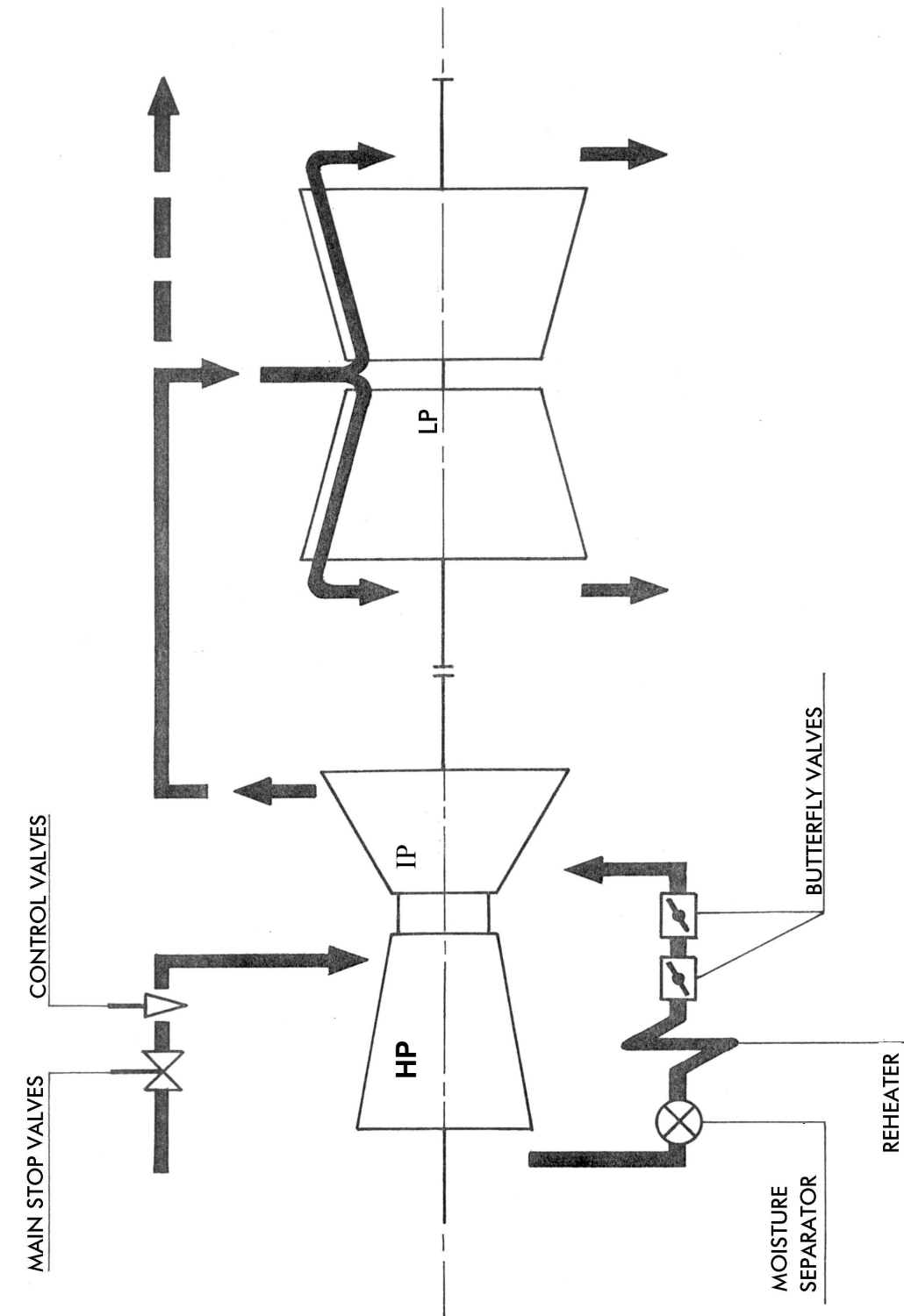


Figure 10A.3-1. Turbine Main Steam System

PRELIMINARY

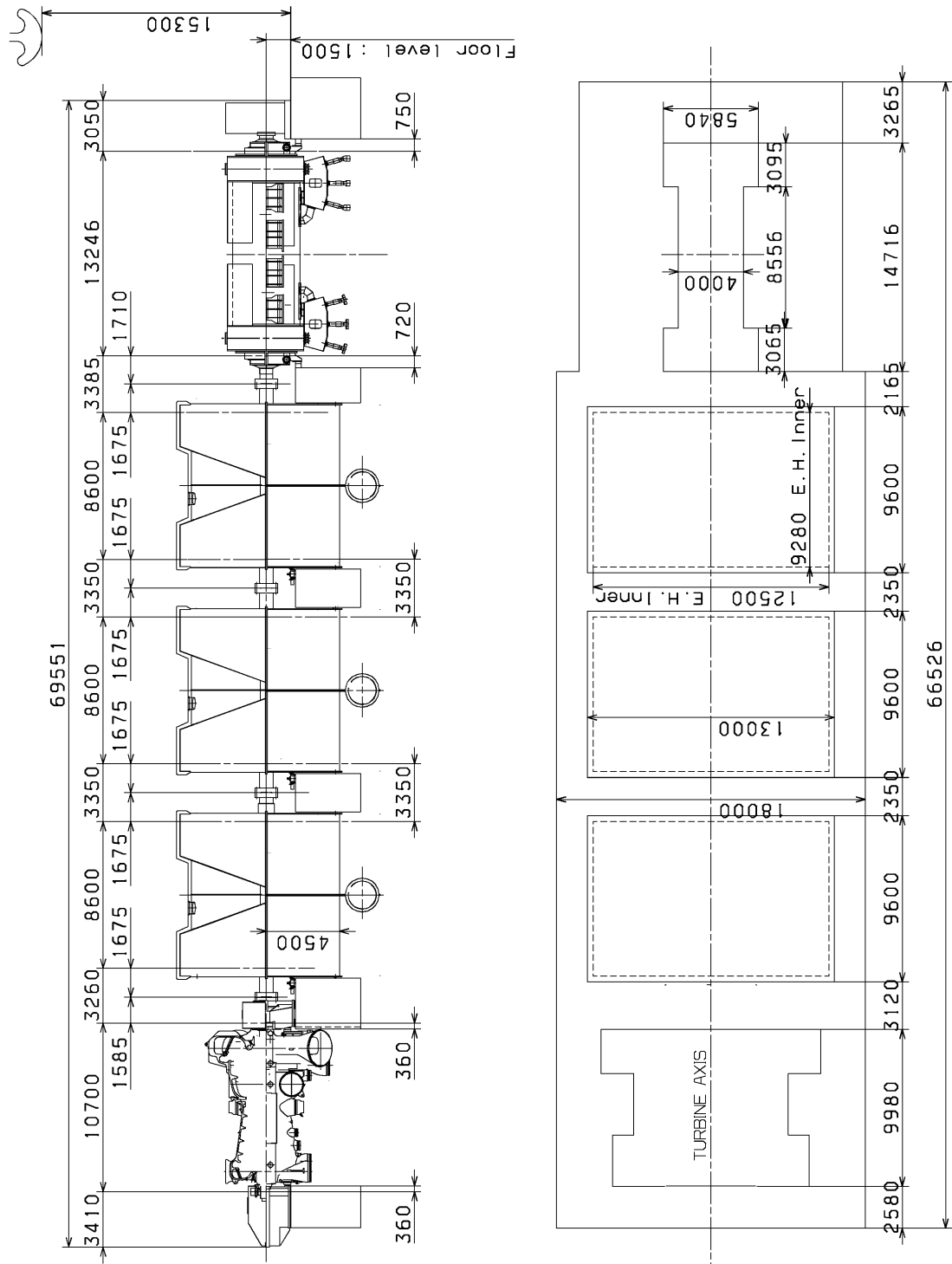


Figure 10A.3-2. Main Turbine System

## 10A.4 OTHER FEATURES OF STEAM AND POWER CONVERSION SYSTEM

*Same as ESBWR standard plant design.*

### 10A.4.1 Main Condenser

*Same as ESBWR standard plant design.*

#### 10A.4.1.1 Design Bases

*Same as ESBWR standard plant design.*

#### 10A.4.1.2 Description

##### 10A.4.1.2.1 General Description

The main condenser is a single-pressure, single shell, de-aerating unit. The monobloc condenser is located beneath the Low Pressure turbine.

The condenser includes six tube bundles (two transversely arranged beneath each turbine LP casing), each fitted with a separate water box on the cooling water inlet and outlet sides. (See Figure 10A.4-1).

The condenser well is fitted with a water channel extending to the bottom of the condenser well and conveying the condensate to the condensate pumps. (See Figure 10A.4-2).

The condenser is located in a pit below the Turbine Building operating floor and is supported on the Turbine Building base mat. Failure of or leakage from a condenser hotwell during plant shutdown only results in a minimum water level in the condenser pit. The exhaust hoods of the LP turbines and the condenser form a unique box that collects the steam exhausting from the LP turbines. The connection with the LP turbines inner casings is made by circular expansion joints. Two Low Pressure feedwater heaters are located in the condenser neck below each turbine LP casing. Piping is installed for hotwell level control and condensate sampling.

##### 10A.4.1.2.2 Component Description

Table 10A4-1 provides general condenser design data and reference data that is typical of condensers operating with once-through circulating water systems. Nothing in this section precludes the use of a multiple pressure condenser and series (instead of parallel) circulating water system because these have no effect on the Nuclear Island.

##### 10A.4.1.2.3 System Operation

*Same as the ESBWR standard plant design except in the following paragraph:*

*2<sup>nd</sup> paragraph*

Other flows occurring periodically or continuously originate from:

- The minimum recirculation flows of the condensate pumps
- Feedwater line startup flushing
- Turbine equipment clean drains



- Low-point drains
- Makeup, etc.

**10A.4.1.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.1.4 Tests and Inspections**

*Same as ESBWR standard plant design.*

**10A.4.1.5 Instrumentation Applications****10A.4.1.5.1 Hotwell Water Level**

*Same as ESBWR standard plant design.*

**10A.4.1.5.2 Pressure**

*Same as ESBWR standard plant design.*

**10A.4.1.5.3 Temperature**

*Same as ESBWR standard plant design.*

**10A.4.1.5.4 Leakage**

*Same as ESBWR standard plant design.*

**10A.4.2 Main Condenser Evacuation System**

*Same as ESBWR standard plant design.*

**10A.4.2.1 Design Bases**

*Same as ESBWR standard plant design.*

**10A.4.2.2 Description**

*Same as ESBWR standard plant design.*

**10A.4.2.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.2.4 Tests and Inspections**

*Same as ESBWR standard plant design.*

**10A.4.2.5 Instrumentation Applications**

*Same as ESBWR standard plant design.*

**10A.4.2.5.1 Steam Jet Air Ejectors**

*Same as ESBWR standard plant design.*

**10A.4.2.5.2 Mechanical Vacuum Pump**

*Same as ESBWR standard plant design.*

**10A.4.3 Turbine Gland Seal System**

*Same as ESBWR standard plant design.*

**10A.4.3.1 Design Bases**

*Same as ESBWR standard plant design.*

**10A.4.3.2 Description****10A.4.3.2.1 General Description**

*Same as the ESBWR standard plant design.*

**10A.4.3.2.2 System Operation**

*Same as the ESBWR standard plant design.*

**10A.4.3.3 Evaluation**

*Same as the ESBWR standard plant design except in the following paragraph:*

*1<sup>st</sup> paragraph*

The TGSS is designed to prevent leakage of radioactive steam from the main turbine shaft glands and the valve stems. The High Pressure turbine shaft seals must accommodate a range of turbine shell pressure from full vacuum to approximately 1.2 MPaA (174 psia). The intermediate pressure turbine shaft seals must accommodate a range of turbine shell pressure from full vacuum to approximately 0.5 MPaA (72.52 psia).

**10A.4.3.4 Tests and Inspections**

*Same as ESBWR standard plant design.*

**10A.4.3.5 Instrumentation Application****10A.4.3.5.1 Gland Steam Condenser Exhausters**

*Same as ESBWR standard plant design.*

**10A.4.3.5.2 Sealing Steam Header**

*Same as ESBWR standard plant design.*

**10A.4.4 Turbine Bypass System**

*Same as ESBWR standard plant design.*

**10A.4.4.1 Design Bases**

*Same as ESBWR standard plant design.*

**10A.4.4.2 Description****10A.4.4.2.1 General Description**

*To be clarified in COL phase.*

**10A.4.4.2.2 Component Description**

*To be clarified in COL phase.*

**10A.4.4.2.3 System Operation**

*To be clarified in COL phase.*

**10A.4.4.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.4.4 Inspection and Testing Requirements**

*Same as ESBWR standard plant design.*

**10A.4.4.5 Instrumentation Applications**

*Same as Reference design.*

**10A.4.5 Circulating Water System**

*Same as the ESBWR standard plant design.*

**10A.4.5.1 Design Bases**

*Same as ESBWR standard plant design.*

**10A.4.5.2 Description****10A.4.5.2.1 General Description**

*Same as the ESBWR standard plant design except in the following paragraph:*

*5<sup>th</sup> paragraph*

The CIRC and condenser are designed to permit isolation of each tube bundle to permit repair of leaks and cleaning of water boxes while operating at reduced power.

**10A.4.5.2.2 Component Description**

*Same as ESBWR standard plant design.*

**10A.4.5.2.3 System Operation**

*Same as the ESBWR standard plant design.*

**10A.4.5.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.5.4 Tests and Inspections**

*Same as ESBWR standard plant design.*

**10A.4.5.5 Instrumentation Applications**

*Same as the ESBWR standard plant design.*

**10A.4.5.6 Flood Protection**

*Same as the ESBWR standard plant design.*

**10A.4.5.7 Portions of the CIRC Outside of Scope of ESBWR Standard Plant**

*Same as ESBWR standard plant design.*

**10A.4.5.7.1 Safety (10 CFR 50.2) Design Bases (Interface Requirements)**

*Same as ESBWR standard plant design.*

**10A.4.5.7.2 Non-Safety Power Generation Design Bases (Interface Requirements)**

*Same as ESBWR standard plant design.*

**10A.4.5.8 Normal Power Heat Sink (Conceptual Design)**

*Same as ESBWR standard plant design.*

**10A.4.6 Condensate Purification System**

*Same as ESBWR standard plant design.*

**10A.4.6.1 Design Bases**

*Same as ESBWR standard plant design.*

**10A.4.6.2 System Description****10A.4.6.2.1 General Description**

*Same as ESBWR standard plant design.*

**10A.4.6.2.2 Component Description**

*Same as ESBWR standard plant design.*

**10A.4.6.2.3 System Operation**

*Same as ESBWR standard plant design.*

**10A.4.6.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.6.4 Tests and Inspections**

*Same as ESBWR standard plant design.*

**10A.4.6.5 Instrumentation Applications**

*Same as ESBWR standard plant design.*

**10A.4.7 Condensate and Feedwater System**

*Same as ESBWR standard plant design.*

**10A.4.7.1 Design Bases**

*Same as the ESBWR standard plant design except in following paragraphs:*

- (6) The CFS is designed to heat up the reactor FW to 220°C during rated power operation and to lower temperatures during part load operation.

**10A.4.7.2 Description****10A.4.7.2.1 General Description**

*Same as the ESBWR standard plant design except in following paragraph:*

*2<sup>nd</sup> paragraph*

The CFS consists of four 33-50% capacity condensate pumps (three normally operating and one on automatic standby), four 45% capacity reactor FW pumps (three normally operating and one on automatic standby), four stages of Low Pressure FW heaters, one FW deaerator storage tank and two stages of High Pressure FW heaters, piping, valves, and instrumentation. The condensate pumps take suction from the condenser hotwell and discharge the deaerated condensate into one common header, which feeds the condensate filter/demineralizers. Downstream of the condensate demineralizers, the condensate is taken by a single header and flows in parallel through five auxiliary condenser/coolers, (one gland steam exhauster condenser and two sets of SJAE condensers and offgas recombiner condenser (coolers). The condensate then flows through the condensate flow regulating station and branches into three parallel strings of Low Pressure No. 1 & 2 FW heaters followed by two strings of low pressure No. 3 & 4 FW heaters with separate drain coolers. The strings join together at a common header, which is routed to the FW deaerator storage tank.

*The following paragraph of the ESBWR standard plant design is not included in the alternative design (5th paragraph):*

A bypass is provided around the FW tank and reactor FW pumps to permit supplying FW to the reactor during early startup without operating the FW pumps, using only the condensate pumps.

During startup, RPV level is controlled by a low flow control valve with flow supplied by either the condensate pumps or via selected (two out of four) feedwater pumps.

#### **10A.4.7.2.2 Component Description**

##### **10A.4.7.2.2.1 Condensate Pumps**

*Same as the ESBWR standard plant design.*

##### **10A.4.7.2.2.2 Low Pressure Feedwater Heaters**

Three duplex heaters are provided in each condenser neck. The heaters have condensing zones only and have short extraction steam lines without any extraction steam non-return valve. The heaters drain to the main condenser. Two parallel and independent strings of the two highest-pressure FW heaters are provided on the condensate circuit. These heaters have integral drain coolers, and the drains are cascaded to the lower stage heaters of the same string and then drain heat is recovered in a drain cooler in the same string. The heater shells are either carbon steel or low alloy ferrite steel, and the tubes are stainless steel. Each Low Pressure FW heater string has an upstream and downstream isolation valve which closes on detection of high level in any one of the Low Pressure heaters in the string.

##### **10A.4.7.2.2.3 High Pressure Feedwater Heaters**

The startup and operating vents from the steam side of the FW heaters are piped to the main condenser except for the highest pressure heater operating vents which discharge to the FW deaerator storage tank which, in turn, vents to the condenser.

##### **10A.4.7.2.2.4 MSR Drain Tanks**

*Same as the ESBWR standard plant design.*

##### **10A.4.7.2.2.5 Open Feedwater Heater**

*Same as the ESBWR standard plant design except in the following paragraph:*

*1<sup>st</sup> paragraph*

Low Pressure heater stage No. 5 is combined with a large horizontal storage tank (feedwater tank). The open FW heater receives condensate from the outlet of the Low Pressure heater strings. Heating steam flows to the open FW heater to raise the temperature of the condensate to approximately saturation level. Non-condensable gases are vented to the main condenser.

##### **10A.4.7.2.2.6 Reactor Feedwater Pumps**

*Same as the ESBWR standard plant design.*

#### **10A.4.7.2.3 System Operation**

*Same as ESBWR standard plant design.*

#### **10A.4.7.3 Evaluation**

*Same as ESBWR standard plant design.*

**10A.4.7.4 Tests and Inspections****10A.4.7.4.1 Preservice Testing**

*Same as ESBWR standard plant design.*

**10A.4.7.4.2 In Service Inspections**

*Same as ESBWR standard plant design.*

**10A.4.7.5 Instrumentation Applications**

*Same as the ESBWR standard plant design.*

**10A.4.8 Steam Generator Blow Down System (PWR)**

*Same as ESBWR standard plant design.*

**10A.4.9 Auxiliary Feedwater System (PWR)**

*Same as ESBWR standard plant design.*

**10A.4.10 COL Information****10A.4.10.1 Turbine Bypass System**

The COL Holder will provide the general description, component description and system operation description for the turbine bypass system. (See subsections 10A.4.4.2.1, 10A.4.4.2.2, 10A.4.4.2.3, Figure 10A.4-4 and Figure 10A.4-8.)

**10A.4.10.2 Circulating Water System**

The COL Holder will provide circulating water system design data. (See Table 10A.4-3 and Figure 10A.4-1.)

**10A.4.10.3 Condensate and Feedwater System**

The COL Holder will provide condensate and feedwater system design data. (See Table 10A.4-5.)

**Table 10A.4-1**  
**Main Condenser Data**

(Same as the ESBWR Standard Plant design except in the following values.)

<b>Parameter</b>	<b>Standard Plant Value</b>
Condenser Type	Transversal, single shell, De-aerating
Design duty, kW-total	2,895,000
Shell pressures w / 27 °C Circ. Water, MPaA (psia)	$7.2 \times 10^{-3}$ (1.044272)
Circulating water flow rate, m <sup>3</sup> /h (gpm)	258,480 (1,138,000)
Tube side temperature rise-total, °C (°F)	9.7 (17.46)
Shell design pressure range, MPaA (psia)	
Hotwell storage capacity-total, L (gal)	
Channel design pressure range, MPaA (psia)	
Surface Area, cm <sup>2</sup> (in <sup>2</sup> )	$116.62 \times 10^7$ ( $180.761 \times 10^6$ )
Number of tube passes per shell	
Applicable codes and standards	
Alarms and Trips:	
High condenser pressure turbine alarm, MPaA (psia)	
High condenser pressure turbine trip and reactor scram, MPaA (psia)	
Main steam isolation valve closure and Bypass valve closure, MPaA (psia)	
This line was deleted in its entirety.	



**Table 10A.4-2****Main Condenser Evacuation System***Same as ESBWR Standard Plant design.*

**Table 10A.4-3**  
**Circulating Water System**

To be provided in COL phase.

**Table 10A.4-4**  
**Condensate Purification System**

*Same as ESBWR Standard Plant design.*

|

**Table 10A.4-5**  
**Condensate and Feedwater System Data**

To be provided in COL phase.

**Table 10A.4-6**  
**Condensate and Feedwater System Component Failure Analysis**

(Same as the *ESBWR Standard Plant* design except in the following values.)

<b>Component</b>	<b>Failure Effect on Train</b>	<b>Failure Effect on System</b>	<b>Failure Effect on NBS</b>
Condensate pump	None. Condensate pumps are interconnected	Operation continues at full capacity, using parallel pumps (condensate pump capacity is 33-50%).	None

**Figure 10A.4-1. Circulating Water System**

To be provided in COL phase.

This drawing was deleted in its entirety.  
**Figure 10A.4-2. Condensate System**

**Figure 10A.4-2. Main Condenser Evacuation System**

*Same as ESBWR Standard Plant design.*



**Figure 10A.4-3. Turbine Gland Seal System**

*Same as ESBWR Standard Plant design.*

**Figure 10A.4-4. Signal Flow Chart for Turbine Bypass Control Unit** |

To be provided in COL phase.

**Figure 10A.4-5. Condensate Purification System**

*Same as ESBWR standard plant design.*

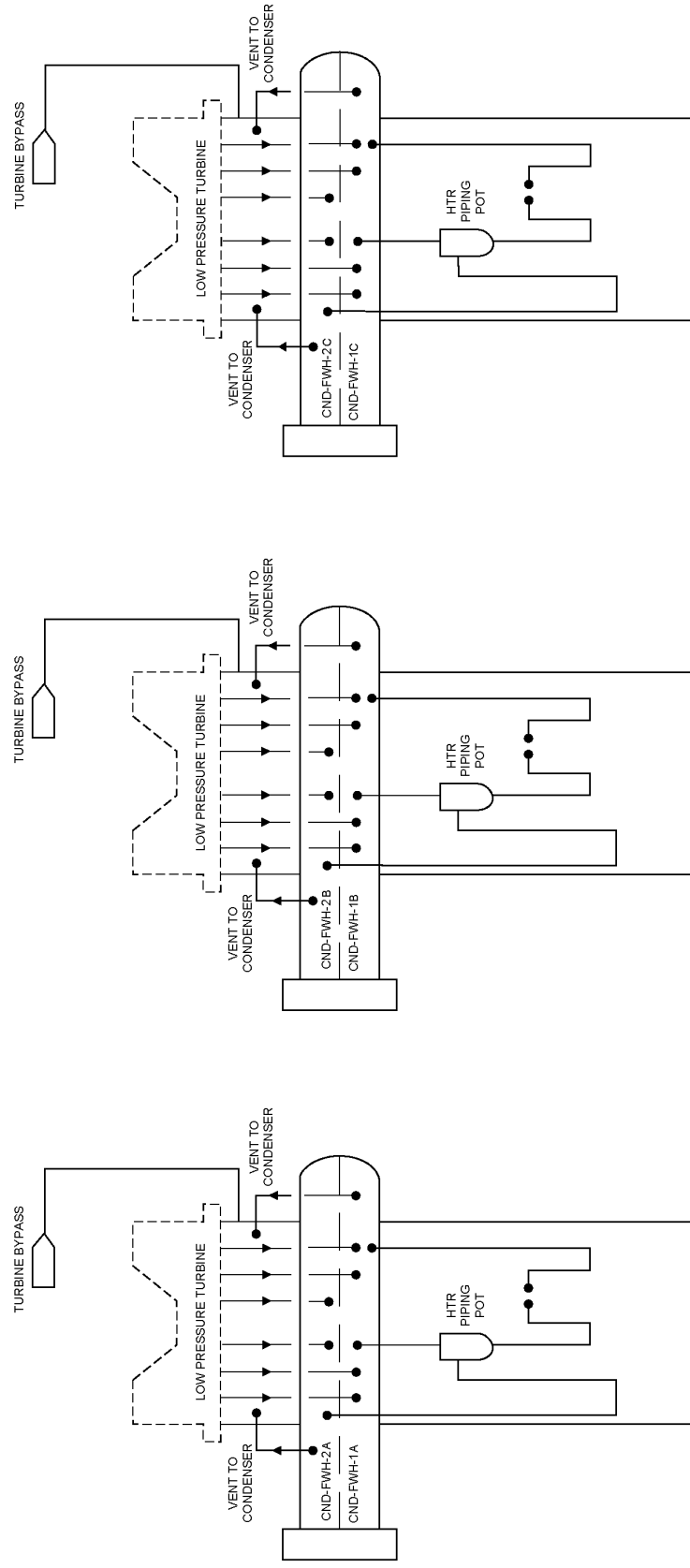


Figure 10A.4-6. LP Extraction Steam Drains and Vent Systems

Page 1 of 2

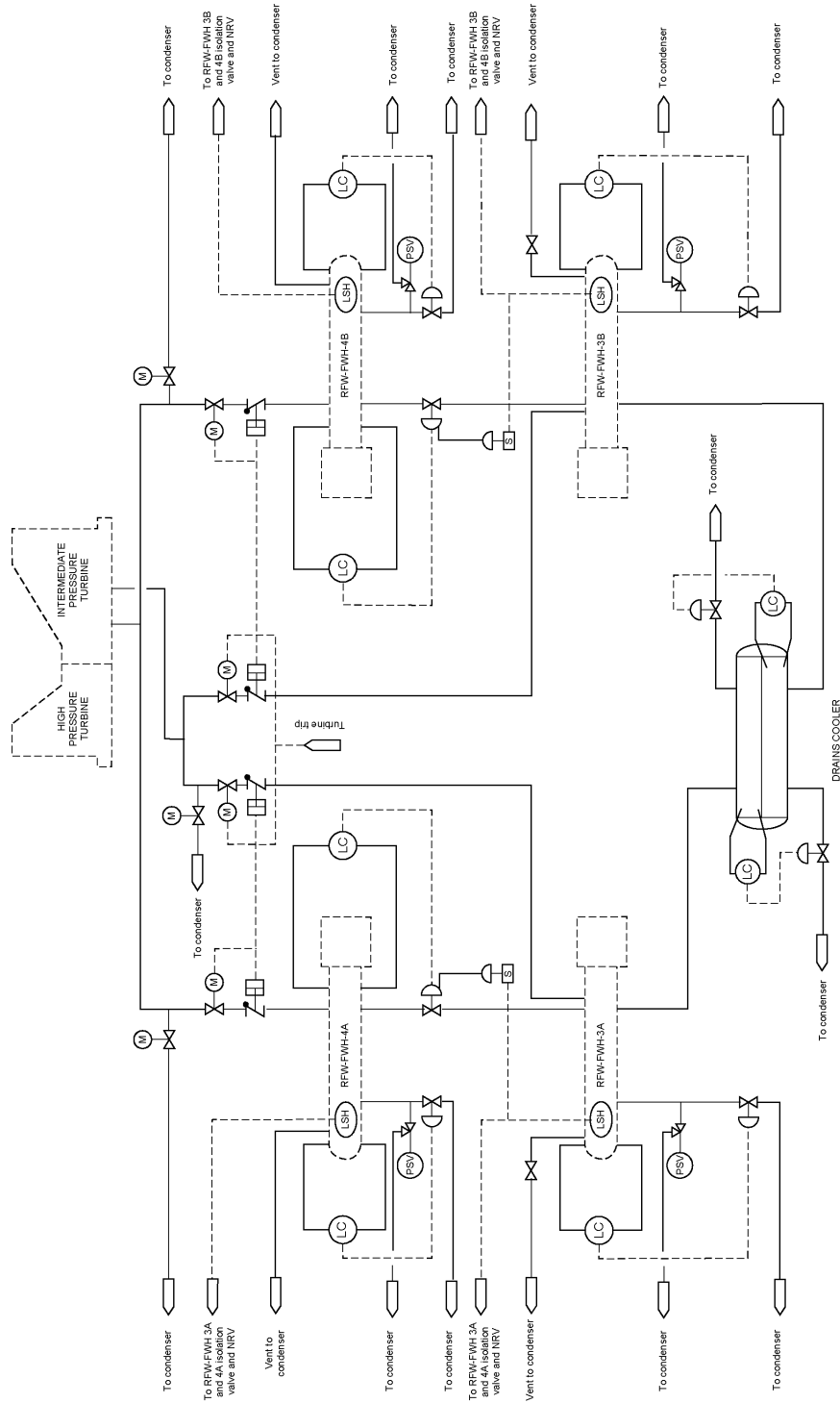
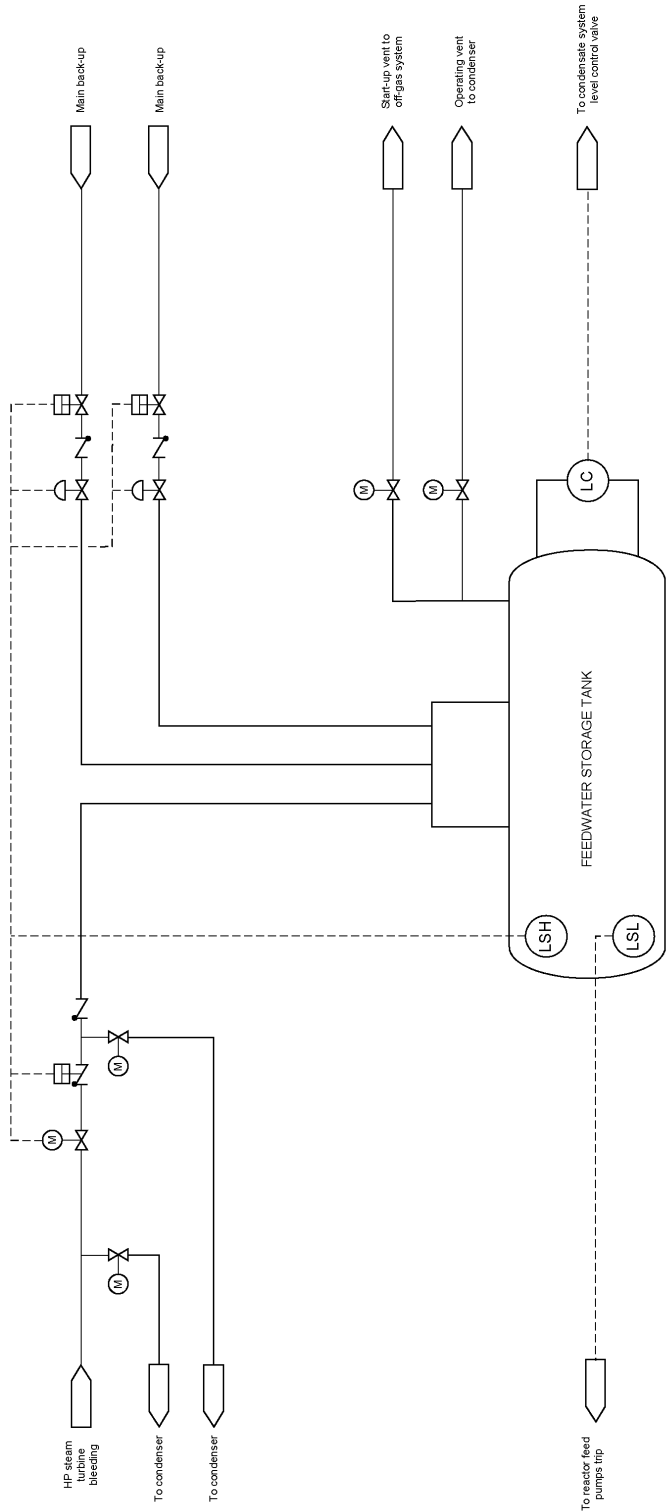
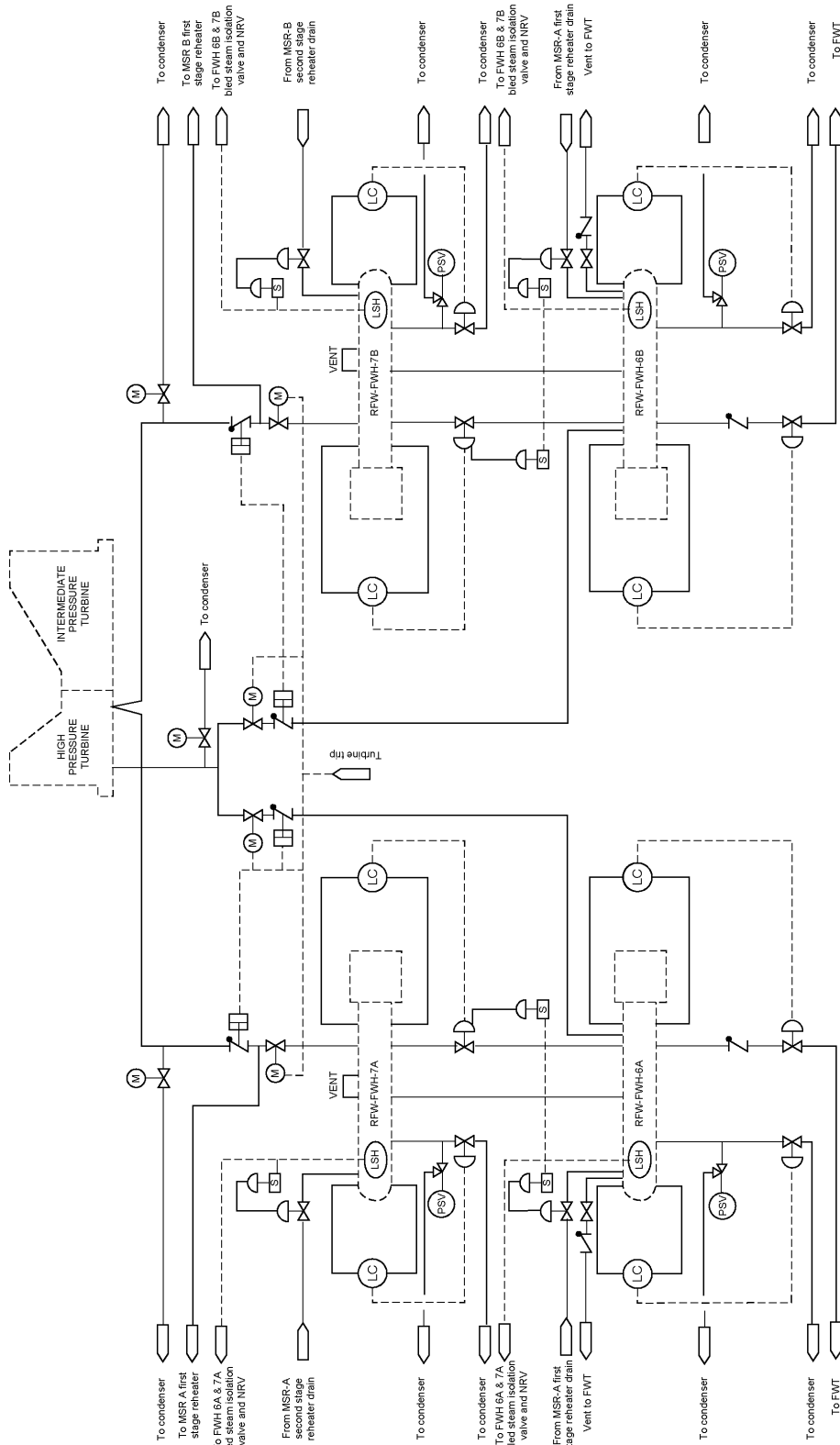


Figure 10A.4-6. LP Extraction Steam Drains and Vent Systems (continued)



REFERENCE ONLY. C & I REDUNDANCY NOT SHOWN.

Figure 10A.4-7. HP Extraction Steam Drains and Vent Systems



REFERENCE ONLY, C & I REDUNDANCY NOT SHOWN

Figure 10A.4-7. HP Extraction Steam Drains and Vent Systems (continued)

**Figure 10A.4-8. Turbine Bypass System**

To be provided in COL phase.