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Chapter 10 Steam and Power Conversion System

10.1 Summary Description

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

Replace the third sentence of the third paragraph with the following.

VCS CDI

The MSRs drain to the open feedwater heater (see Figure 10.1-1R).

Replace the fifth paragraph with the following.

The important steam and power conversion system design parameters are summarized in Table 10.1-1R. The principal features are illustrated in Figure 10.1-R.

Replace the first sentence of the ninth paragraph with the following.

Table 10.1-1R 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.

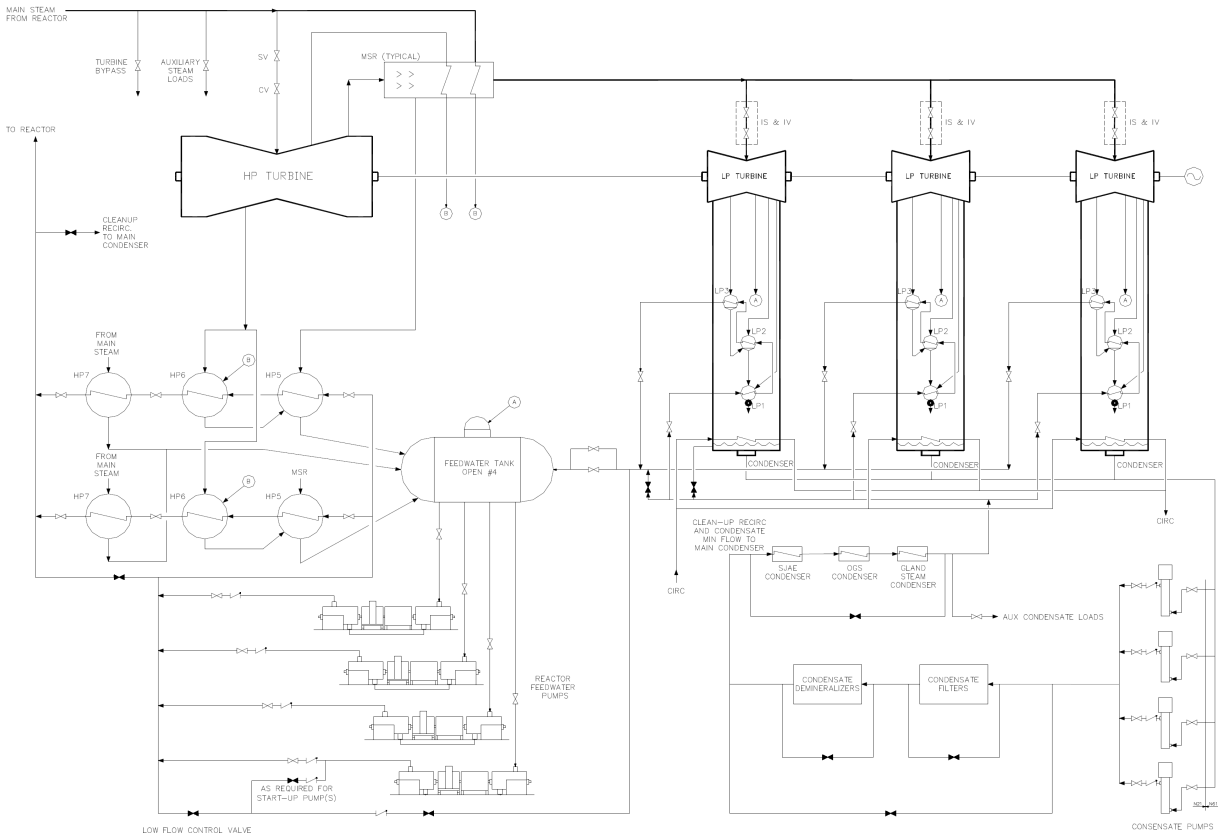
Table 10.1-1R
Summary of Important Design Features and Performance Characteristics of the Steam and Power Conversion System

Parameter	Standard Plant Value[a]
Nuclear Steam Supply, Full Power Operation:	
Rated reactor core power, (MWt)	4500
Reactor steam dome pressure, MPA (psia)	7.17 (1,040)
Reactor rated steam flow, kg/s (lbm/hr)	2432.6 (19.3×10^6)
Reactor nominal outlet steam moisture, (%)	0.1 (Design)
Reactor inlet feedwater temp, °C (°F)	215.6 (420)
Turbine-Generator:	
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
Moisture Separator/Reheaters (MSRs):	
Number of MSRs per unit	4
Stages of moisture separation	1
Stages of reheater	2
Main Condenser:	
Type	Single pressure
Design duty, MW (BTU/hr)	3057 (10.43×10^9)
Circulating water flow rate, m^3/hr (gpm)	250,000 (1,100,000)
Circulating water temperature rise, °C (°F)	18 (32.4)
Condensate Pumps:	
Number of pumps	4 (3 Normally Operating)
Pump type	Fixed speed, centrifugal, vertical
Driver type	Motor
Normal flow, kg/hr (lbm/hr)	5.8×10^6 (12.8×10^6)
Feedwater Heaters:	
No. 1:	
Number per stage	3
Stage pressure, kPa (psia)	55 (8)
No. 2:	
Number per stage	3
Stage pressure, kPa (psia)	110 (16)

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

Parameter	Standard Plant Value[a]
No. 3:	
Number per stage	3
Stage pressure, kPa (psia)	221 (32)
No. 4 (Open type, Feedwater Tank):	
Number per stage	1
Stage pressure, kPa (psia	407 (59)
Net feedwater volume, m^3 (ft^3)	680 ($24x10^3$)
No. 5:	
Number per stage	2
Stage pressure, kPa (psia)	1282 (186)
No. 6:	
Number per stage	2
Stage pressure, kPa (psia)	2255 (327)
No. 7:	
Number per stage (Normally only used for power maneuvering)	2
Reactor Feedwater Pump:	
Number of pumps (booster and main pump)	4 (3 Normally Operating)
Pump type	Variable speed, centrifugal, horizontal
Driver type	Motor
Design flow, kg/hr (lbm/hr)	$8.8x10^6$ ($19.3x10^6$)

a. Value is shown for rated operation. These are representative values for the ESBWR standard plant cycle; actual values can vary slightly.



VCS CDI

Figure 10.1-1R Power Cycle Schematic

10.2 Turbine Generator

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

10.2.3.4 **Turbine Design**

Insert the following as the first paragraph:

STD SUP 10.2-1

The General Electric Company manufactures the turbine and generator. The model N3R turbine is from General Electric's N series nuclear steam turbines.

10.2.3.8 **Turbine Missile Probability Analysis**

Replace the last paragraph with the following.

STD COL 10.2-1-H

The probability of turbine missile generation will be calculated for the specific turbine selected. Final information on TGS material properties, fabrication, and design features will also be provided in the turbine missile analysis. This analysis will be completed no later than one year prior to fuel load. The FSAR will be revised, as necessary, to reflect this analysis as part of a subsequent FSAR update.

10.2.5 **COL Information**

10.2-1-H **Turbine Missile Probability Analysis**

STD COL 10.2-1-H

This COL Item is addressed in Section 10.2.3.8.

10.3 Turbine Main Steam System

This section of the referenced DCD is incorporated by reference with no departures or supplements.

10.4 Other Features of Steam and Power Conversion System

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

10.4.1.2.1 General Description

Replace the first three paragraphs with the following.

VCS CDI

The main condenser is a two-pass, three-shell, single-pressure, de-aerating unit. One condenser shell is located beneath each low-pressure turbine casing.

The 50% redundant, parallel, two-pass arrangement results in each shell having four tube bundles. The three condenser shells are cross-connected on the steam side to equalize pressure. Circulating water flows in parallel through the condenser three shells (see Figure 10.4-201).

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 condenser hotwell. The site-specific changes to the power cycle schematic as a result of using a single-pressure two-pass, three-shell condenser are depicted in Figure 10.1-1R. Other design changes due to use of a single-pressure two-pass, three-shell condenser are to be evaluated during the detailed design phase.

Replace the third sentence in the fourth paragraph with the following:

VCS CDI

Low-pressure feedwater heaters are located in the neck of the condenser shells.

10.4.1.2.2 Component Description

Replace the first paragraph with the following:

VCS CDI

Table 10.4-1R provides general condenser design data for a unit operating with a three-shell, single-pressure condenser and a once-through cooling system.

10.4.5.2.1 General Description

Replace the text with the following:

VCS CDI

The circulating water system (CIRC) is depicted in Figure 10.4-201. The CIRC consists of the following components:

- Cooling basin, with dikes for water flow control, surrounded by an embankment (see Subsection 10.4.5.8)
- Cooling basin intake and outfall structures
- Condenser water boxes, piping, and valves
- Condenser tube cleaning equipment
- Water box and piping priming equipment
- Vacuum breakers

Table 10.4-3R includes site-specific data about normal power heat removal duty, the circulating water pumps (type and flow rate) and operating temperatures of the cooling basin water and water delivered to the main condenser.

The cooling basin intake structure houses four 25% concrete volute circulating water pumps dedicated to each unit, two 50% cooling basin blowdown pumps, two plant service water makeup pumps dedicated to each unit, and screen wash pumps (one dedicated to each circulating water pump bay). Three dual flow traveling screens and multiple trash racks serve each pump.

The CIRC water is normally circulated by the four motor-driven pumps through the condenser and back to the cooling basin. Depending on ambient conditions and heat load, one CIRC pump may be taken out of operation with the flow of the remaining three CIRC pumps providing sufficient water for condenser heat removal.

Two sets of two pumps are arranged in parallel. The discharge of each pump is fitted with a remote/local-operated isolation valve and an automatic air release valve. This arrangement permits isolation and maintenance of any one pump while the others remain in operation and minimizes the backflow through an out-of-service CIRC pump. Each two adjacent CIRC pumps discharge lines are connected into a supply line that feeds half of each of the three condenser shells of the respective unit.

One interconnecting line is provided between the two CIRC supply lines to the condenser shells. The interconnecting line is provided with a motor-operated isolation valve which is used for flow balancing.

The circulating water supply piping between the cooling basin intake structure to the turbine building and from the turbine building back to the cooling basin outfall structure is installed underground except in the area of cooling basin embankment where the lines are above ground. Each of these supply pipes is sized to provide 50% of the total, per unit, main condenser flow. Each of the supply/return lines divide at the turbine building and are connected to each of the three water boxes associated with each of the three condenser shells.

Warm water from the discharge side of the condenser may be circulated back to the cooling basin intake structure to maintain the condenser minimum inlet temperature of approximately 5°C (41°F). The need and sizing of this recirculation line will be determined during the detail design phase.

The CIRC and condenser are designed to permit, under certain ambient conditions and unit load, isolation of each half of one shell and/or half of all three shells for repair of leaks and cleaning of water boxes while the unit is operating at reduced power or when one of the two circulating water supply lines is out of service.

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

The CIRC system also includes a priming system and vacuum breakers on top of the intake pipes over the embankment and discharge pipes over the embankment to the discharge outfall. The priming system is provided to remove air from high points of the piping and the vacuum breaker is provided to prevent flow siphoning backwards.

Circulating water chemistry is maintained by the chemical feed system and with blowdown. Circulating water chemical equipment injects the required chemicals into the circulating water pump bay before entering the circulating water pumps. Additionally, cleanliness of the condenser tubes is maintained by a condenser tube cleaning system.

10.4.5.2.2 **Component Description**

Replace the text with the following:

VCS CDI

Codes and standards applicable to the CIRC are listed in DCD Section 3.2 with the exception of large bore piping (piping with a nominal diameter of 27.6 inches (700 mm) and larger). Large bore CIRC piping is constructed using American Water Works Association standards. The system is designed and constructed in accordance with Quality Group D specifications.

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

10.4.5.2.2.1 CIRC Chemical Injection

Circulating water chemistry is maintained by the chemical feed system. Chemical feed equipment injects the required chemicals into the circulating water at the pump bay before water enters the circulating water pumps. The chemicals are stored in the chemical storage and transfer building located near the cooling basin intake structure.

Chemical injection can be used, as required, to maintain a noncorrosive, nonscale-forming condition and limits the biological film formation that reduces the heat transfer rate in the condenser.

Plant specific chemistry determines the required chemicals used within the system. The chemicals can be divided into five categories based on function: biocide, algaecide, pH adjuster, corrosion inhibitor, and scale inhibitor. The pH adjuster, corrosion inhibitor, and scale inhibitor are metered into the system continuously or as required to maintain proper concentrations. Biocide application frequency may vary with seasons. Chemicals that are injected in the CIRC include sodium hypochlorite, bromide based biocide, and scale inhibitors.

Circulating water chemistry is also controlled as required with blowdown.

Chemicals selected are compatible with selected materials or components used in the CIRC.

10.4.5.5 **Instrumentation Applications**

Insert the following between the fourth and the fifth paragraphs:

VCS CDI

The cooling basin level is monitored and displayed in the main control room. Level instrumentation provided in the circulating water pump forebay alarms in the main control room on low or high water levels.

Pressure indication is provided on the circulating water pump discharge. Differential pressure instrumentation is provided across the inlet and outlet to the condenser and is used to determine the frequency of operating the condenser tube cleaning system.

Local grab samples are used to periodically test the circulating water quality.

10.4.5.8 **Normal Power Heat Sink**

Replace the text in this section with the following:

VCS CDI

The normal power heat sink is a man-made cooling basin with a capacity of 106,200 acre-feet. at the normal maximum operating water level of 91.5 feet (NAVD 88). The design low-water level in the cooling basin for CIRC pump operation is 71.5 feet. The capacity of the cooling basin at the design low water level is approximately 9400 acre-feet.

The four 25% rated capacity circulating water pumps take suction from the pump forebay and circulate the water through the main condenser. The circulating water is then discharged back to the cooling basin through the cooling basin outfall structure. The cooling basin uses earthen dikes to control the direction of flow from the cooling basin outfall structure to the cooling basin intake structure. The water flows around these dikes channeling the water in a circuitous path while it cools and returns to the cooling basin intake structure.

The cooling basin water inventory, and to some extent its chemistry, is controlled by makeup and blowdown.

The makeup water to the cooling basin to replace water losses due to evaporation, drift, seepage, and blowdown is provided by the Guadalupe-Blanco River Authority. The makeup water from the Calhoun Canal is pumped from the raw water makeup pumphouse.

The blowdown of the cooling basin is discharged, in accordance with Texas Pollutant Discharge Elimination System permit, to the Guadalupe River through the cooling basin blowdown diffuser. The cooling basin blowdown flow rate is coordinated with the available makeup water provided by raw water makeup pumphouse and/or precipitation.

10.4.6.3 **Evaluation**

Replace the second sentence in the third paragraph with the following:

STD COL 10.4-1-A

A table summarizing the manufacturer's recommended threshold values of key chemistry parameters and associated operator actions is provided as Table 10.4-201.

10.4.10 **COL Information**

10.4-1-A **Leakage (of Circulating Water Into the Condenser)**

STD COL 10.4-1-A

This COL Item is addressed in Subsection 10.4.6.3.

VCS CDI

Table 10.4-1R
Main Condenser Data

Parameter	Plant Value
Condenser Type	Transversal, 3 shells, single pressure
Design duty, total 3 shells, MW (Btu/hr)	3057 (10.43 x 10^9)
Shell pressure 30°C (86°F) MPaA (psia)	0.0087 (1.27)[b] at rated duty
Circulating water flow rate m^3/hr (gpm)	249,837(1,100,000)[a]
Tube side temperature rise per shells °C (°F)	10 (18)
Shell design pressure range, MPaA (psia)	≥0 to 0.35 (0 to 50.76)[b]
Hotwell storage capacity total 3 shells, m^3 (ft^3)	≥316 (11.2 x 10^3)[b]
Channel design pressure range, MPaA (psia)	≥0 to 0.38 (0 to 55.1)[b]
Surface area, m^2 (ft^2)	1.18 x 10^5 (1.27 x 10^6)[b]
Number of tube passes per shell	2
Applicable codes and standards	HEI standards for Steam Surface Condenser
Alarms and Trips	
High condenser pressure turbine alarm, MPaA (psia)	≤0.017 (2.5)[b]
High condenser pressure turbine trip and reactor scram, MPaA (psia)	≤0.024- 0.034 (3.4-4.9)[b]
Main steam isolation valve closure, and bypass valve closure MPaA (psia)	≤0.068- 0.0789 (9.8-11.3)[b]

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

b. These values are to be confirmed/validated for three shell, two pass, and a single pressure condenser during the detailed design phase.

VCS CDI

Table 10.4-3R
Circulating Water System

Parameter	Design Value
Circulating Water Pumps	
Number of pumps	4
Pump type	Concrete Volute
Unit flow capacity m^3/hr(gpm)	Approx. 62,460 (275,000)
Pump total discharge head m (ft)	23.8 (78)
Driver type	Electric Motor
Operating Temperatures	
Normal power heat sink (NPHS) cold water temperature range, °C(°F)	0[a] to 37.8 (32 to 100)
Temperature range for water delivered to main condenser, °C(°F)	5[a] 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)[b]

a. If the NPHS does not have the capability to control the minimum temperature, the minimum temperature would be maintained by warm water recirculation.

b. This value is to be provided for single pressure condenser during the detailed design phase.

STD COL 10.4-1-A

Table 10.4-201
Recommended Water Quality and Action Levels

Reactor Water Quality-Power Operation

	Action levels			
Control Parameter	0	1	2	3
Conductivity, S/cm at 25°C[a]	≤0.100	>0.300	>1	≥2
Chloride, ppb	≤0.300	>5	>50	≥200
Sillca, ppb	≤200	>500	N/A	N/A
Sulfate, ppb	≤2	>5	>50	≥200

Feedwater Quality-Power Operation[b]

	Action levels		
Control Parameter	0	1	2
Conductivity, S/cm at 25°C[c]	<0.057	>0.065	>0.100
Dissolved Oxygen, ppb as O_2[c]	30-50	< 20 or >200	N/A

a. Value depends on Hydrogen Water Chemistry System operation
b. Also Condensate Purification System Effluent
c. Applicable when Reactor Power >10%

Action Level 0: Target Value. The parameter may be outside the Action Level 0 value and not in Action Level 1, 2, or 3. In this case, efforts should be made to return the parameter to the Action Level 0 value.

Action Level 1: Lowest Severity. The parameter should be brought below this value within 96 hours. A technical review should be performed to determine the appropriate response.

Action Level 2: Moderate Severity. If the parameter is not reduced below this level within 24 hours, an orderly shutdown should be initiated.

Action Level 3: Highest Severity. If the parameter is not reduced below this level within 6 hours, an orderly shutdown should be initiated.

VCS CDI

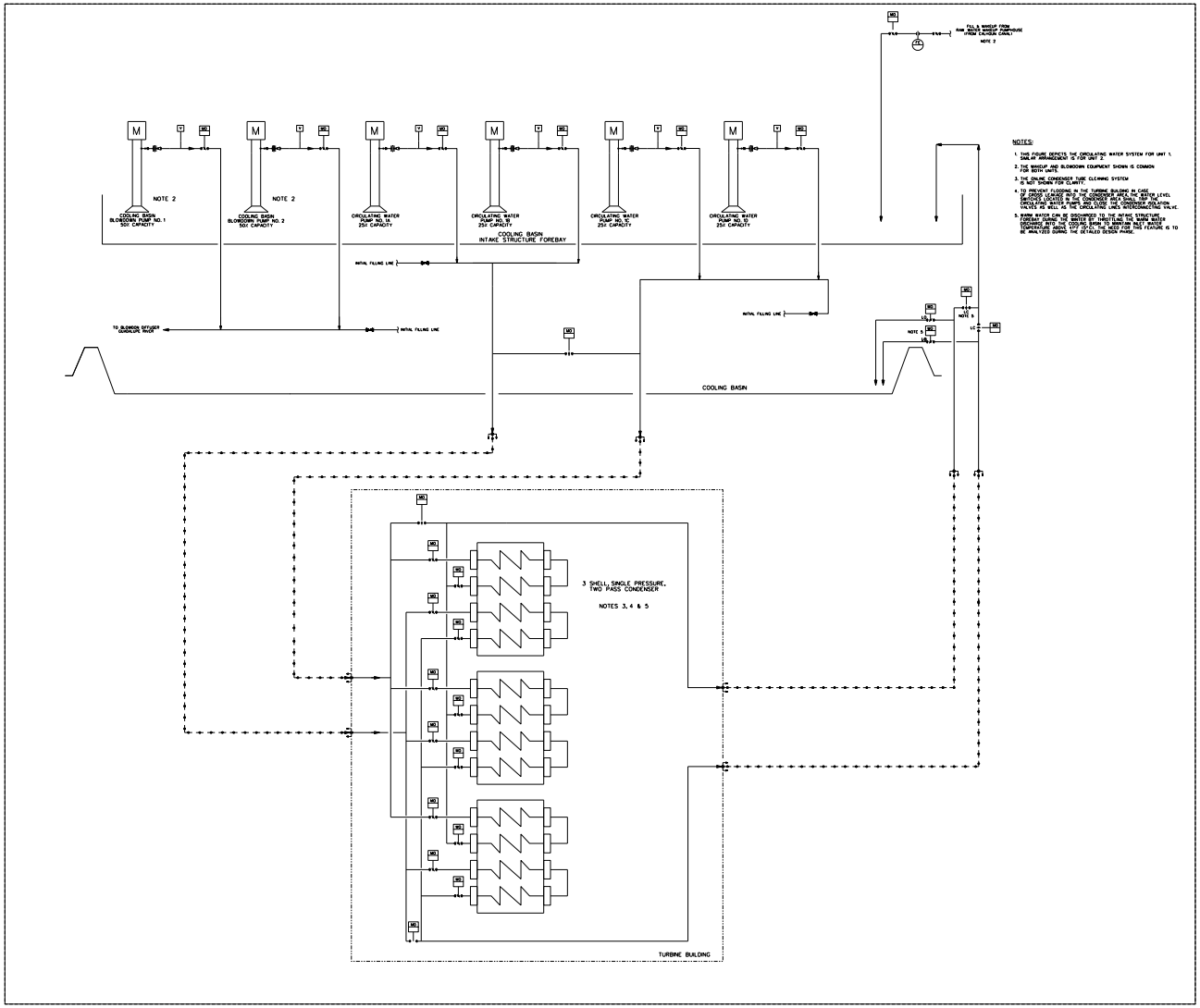


Figure 10.4-201 Circulating Water System