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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 124 Related to ESBWR Design Certification Application – Passive Containment Cooling System – RAI Number 3.8-117**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC Letter 124 dated January 14, 2008 (Reference 1). RAI Number 3.8-117 is addressed in Enclosure 1.

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

If you have any questions or require additional information, please contact me.

Sincerely,

James C. Kinsey
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 08-029, Letter from U.S. Nuclear Regulatory Commission to Mr. Robert E. Brown, Senior Vice President, Regulatory Affairs, GE-Hitachi Nuclear Energy Americas, LLC, *Request For Additional Information Letter No. 124 Related To ESBWR Design Certification Application,* dated January 14, 2008.

Enclosure:

1. Response to Portion of NRC Request for Additional Information Letter No. 124 Related to ESBWR Design Certification Application – Passive Containment Cooling System (PCCS) -- RAI Number 3.8-117

cc:	AE Cubbage	USNRC (with enclosure)
	GB Stramback	GEH/San Jose (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRF	0000-0082-3674

Enclosure 1

MFN 08-430

Response to Portion of NRC Request for

Additional Information Letter No. 124

Related to ESBWR Design Certification Application

Passive Containment Cooling System (PCCS)

RAI Number 3.8-117

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

NRC RAI 3.8-117

NRC Summary:

Provide a comprehensive description of Passive Containment cooling System (PCCS) in view of the rules for Class MC containment vessels in ASME Code Section III.

NRC Full Text:

DCD Revision 4, Section 3.8.2.1 has been revised to add the PCCS condensers as steel components of the concrete containment vessel. DCD Revision 4, Section 3.8.2.4.1.5 has also been added, to provide a description of the PCCS condensers. The fourth paragraph states "The PCCS condenser parts conform to the design requirements of Subarticles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC). The PCCS condenser support is evaluated in accordance with the ASME Code, Section III, Subsection NF."

In order to complete its review, the staff requests the applicant to address the following:

a. ASME Code Section III, Subsection NE (Class MC), Subarticle NE-1120 states "Only containment vessels and their appurtenances shall be classified as Class MC. Piping, pumps, and valves which are part of the containment system (NE-1130) or which penetrate or are attached to the containment vessel shall be classified as Class 1 or 2 by the Design Specification and meet the requirements of the applicable Subsection." It appears to the staff that the PCCS condensers and the piping between the condensers and the drywell would be more appropriately classified as Class 1 or Class 2. These sections of the ASME Code (NB- 3200 and 3300 or NC-3200 and 3300) provide design and analysis procedures that the staff considers more applicable to piping and components. Explain the exact meaning of the statement "The PCCS condenser parts conform to the design requirements of Subarticles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC)." Were the condensers and piping initially designed to NE, NB, or NC? If NB or NC, were any design modifications necessary to conform with NE? If NE, would any design modifications be necessary to conform with NB or NC?

b. The PCCS condensers are designated as part of the containment pressure boundary. This appears to be a unique application of condensers. In order to develop reasonable assurance that the containment has been adequately designed, the staff requests the applicant to provide a comprehensive description of the condenser and connecting piping. The description should include details and figures showing the individual parts of the condenser and how they are connected; dimensions; materials; the piping and pipe supports between the containment top slab and condenser; and the supporting elements from the condenser to the top slab and lateral supports to the pool walls.

c. Since the PCCS condensers and piping are part of the containment pressure boundary, include in the DCD a description of the analysis and design evaluation (including results) comparable to the information provided for other steel components of containment.

d. Provide a detailed description of how the preoperational pressure tests will be performed for the PCCS condenser and associated piping in accordance with the requirements of the applicable subsection of ASME Code Section III, including discussion of the provisions of the Code where it is not obvious the Code provisions can be met. As an example, how is examination for leakage accomplished after application of test pressure?

e. Provide a detailed description of how the preservice and inservice inspection requirements of ASME Code Section XI, Subsection IWE, will be effectively implemented for the PCCS condensers and associated piping. The staff notes that the IWE requirements are applicable primarily to accessible shell type structures.

GEH Response

a. The statement "The PCCS condenser parts conform to the design requirements of Subarticles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC)" means that the PCCS components above the drywell are classified as part of the containment boundary.

Previous revisions of the DCD have indicated these were Class 2 components (Subsection NC), but it has always been GEH's intention that these components function as part of the containment boundary. No design modifications are necessary to conform with Subsection NE other than to perform the appropriate analyses described in the other parts of this RAI.

b. The PCCS Condensers are described in DCD Tier 2 Subsection 6.2.2. Two figures showing the PCCS Condenser and supports will be added in DCD Tier 2 Appendix 3G for details of the overall configuration including individual components and their supports, key dimensions and associated materials. DCD Tier 2 Figure 3.8-7 shows typical detail for the PCCS passages through the RCCV Top Slab.

c. A finite-element analysis model supplemented with hand calculation is used to determine the stresses in the different components of the PCCS Condenser and supports. A description of the analysis and main results for the PCCS Condenser and supports is included in DCD Tier 2 Appendix 3G, Subsections 3G.1.5.4, 3G.1.5.4.1, 3G.1.5.4.1.5, Figures 3G.2-71a, 3G.1-71b, 3G.1-72, and Table 3G.1-60.

d. The preoperational pressure tests of the PCCS Condensers are performed in accordance with ASME Section III Article NE-6000. The specific testing procedure will be developed as part of the detailed design, and there do not appear to be any parts of the Code that cannot obviously be met. The PCCS Condensers can remain open to the containment during the ILRT, or can be flanged off and tested independently as described in DCD Tier 2 Subsection 6.2.2.4. All joints and connections in the PCCS Condensers are accessible for examination of leakage during the test.

e. The preservice and inservice inspections of the PCCS Condensers are performed in accordance with ASME Section XI Article IWE-6000. The specific inspection procedure will be developed as part of the detailed design, and there do not appear to be any parts of the Code for which the PCCS will require any special treatment.

DCD Impact

DCD Tier 2 Subsections 3.8.2.1.5, 3.8.2.4.1.5, 6.2.2.2.2, 3G.1.5.4, 3G.1.5.4.1, 3C.6.3, Figures 3.8-7, 3G.1-71a, 3G.1-71b, 3G.1-72, and Table 3G.1-60 will be revised in DCD Tier 2, Revision 5, as shown in the attached DCD markup. New subsection 3G.1.5.4.1.5 will be added to DCD Tier 2, Revision 5, as shown in the attached DCD markup.

distance from the RCCV wall to minimize conductive heat transfer to the RCCV wall. With regard to the local areas of concrete around high energy penetrations, thermal analyses have been carried out to demonstrate that concrete temperature limits in ASME Section III, Division 2, CC-3440 are satisfied. In all cases the concrete temperature is lower than 93°C (200°F) for normal operation, and lower than 177°C (350°F) for accident condition. The sleeve length for hot penetrations is designed to meet these temperature requirements.

Figures 3.8-6, 3.8-7, 3.8-8, 3.8-9, 3.8-10 and 3.8-11 show the typical details for the containment mechanical and electrical penetrations.

3.8.2.1.4 Drywell Head

A 10,400 mm (34 ft. 1-7/16 in.) diameter opening in the RCCV upper drywell top slab over the RPV is covered with a removable steel torispherical drywell head, which is part of the pressure boundary. This structure is shown in Appendix 3G Figure 3G.1-51. The drywell head is designed for removal during reactor refueling and for replacement prior to reactor operation using the Reactor Building crane. One pair of mating flanges is anchored in the drywell top slab and the other is welded integrally with the drywell head. Provisions are made for testing the flange seals without pressurizing the drywell.

There is water in the reactor well above the drywell head during normal operation. The height of water is 6.7 m (21 ft. 11-3/4 in.). The stainless steel clad thickness for the drywell head is 2.5 mm (98 mils) and is determined in accordance with NB-3122.3 requirements so that it results in negligible change to the stress in the base metal.

There are six (6) support brackets attached to the inner surface of the drywell head circumferentially to support the head on the operating floor during refueling. These support brackets have no stiffening effect and do not resist loads when the head is in the installed configuration.

To provide a leak resistant refueling seal, a structural seal plate with an attached compressible-bellows sealing mechanism between the Reactor Vessel and Upper Drywell opening is utilized. The Refueling Seal is a continuous gusseted radial plate that is anchored to the Drywell opening in the Top floor slab. The radial plate surrounds the RPV with a radial gap opening to allow for thermal radial expansion of the RPV. A circumferential radial bracket from the RPV connects to a circumferential bellows that is also connected to the underside of the Drywell opening plate, thus providing a refueling seal, and allowing for axial thermal expansion of the RPV.

3.8.2.1.5 PCCS Condenser

There are six (6) PCCS Condensers located in the PCC subcompartment pools. The condensers form an integral part of the containment boundary while the pool structure and pool water are outside containment. The PCCS Condensers are described in Subsection 6.2.2, and their structural evaluation is documented in Appendix 3G.

3.8.2.2 Applicable Codes, Standards, ~~and~~ Specifications and Regulatory Guides

3.8.2.2.1 Codes, ~~and~~ Standards and Regulatory Guides

In addition to the documents~~codes and standards~~ specified in Subsection 3.8.1.2.2, the following ~~codes and standards~~code, standard and regulatory guide apply:

discontinuity stresses induced by the combination of external, dead, and live loads, including the effects of earthquake loadings, are evaluated. The required analyses and limits for the resulting stress intensities are in accordance with Subarticles NE-3130, NE-3200 and NE-3300 of ASME Code Section III, Division 1.

3.8.2.4.1.2 Equipment Hatches

An equipment hatch assembly consists of the equipment hatch cover and the equipment hatch body ring, which is imbedded in the RCCV wall and connects to the RCCV liner.

A finite-element analysis model and/or manual calculation is used to determine the stresses in the body ring and hatch cover of the equipment hatch. The equipment analysis and the stress intensity limits are in accordance with Sub-articles NE-3130, NE-3200 and NE-3300 of ASME Code Section III. The hatch cover with the bolted flange is designed in accordance with Subarticle NE-3326 of ASME Code Section III.

3.8.2.4.1.3 Other Penetrations

Piping penetrations and electrical penetrations are subjected to various combinations of piping reactions, mechanical, thermal and seismic loads transmitted through the RCCV wall structure. The resulting forces due to various load combinations are combined with the effects of external and internal pressures. The required analysis and associated stress intensity limits are in accordance with Subarticle NE-3200 of ASME Code Section III, Division 1, including fatigue evaluation as required.

Main Steam and Feedwater penetrations are analyzed using the finite element method of analysis for applicable loads and load combinations. The resulting stresses meet the acceptance criteria stipulated in Subarticle NE-3200 of ASME Code Section III, Division 1, including fatigue evaluation as required.

3.8.2.4.1.4 Drywell Head

The drywell head, consisting of shell, flanged closure and drywell-head anchor system, is analyzed using a finite-element stress analysis computer program or manual calculation. The stresses, including discontinuity stresses induced by the combination of external pressure or internal pressure, dead load, live load, thermal effects and seismic loads, are evaluated. The required analyses and limits for the resulting stress intensities are in accordance with Subarticles NE-3130, NE-3200 and NE-3300 of ASME Code Section III, Division 1.

The compressive stress within the knuckle region caused by the internal pressure and the compression in other regions caused by other loads are limited to the allowable compressive stress values in accordance with Subarticle NE-3222 of ASME Code Section III, Division 1, or Code Case N-284.

3.8.2.4.1.5 PCCS Condenser

The PCCS condensers are composed of two modules consisting of drum-and-tube type heat exchangers using horizontal upper and lower drums connected with multiple vertical tubes. Two identical modules are coupled to form one PCCS heat exchanger unit. The condenser assembly forms an integral part of the containment boundary and is submerged in the water of an IC/PCC pool subcompartment. The pool water lies outside the containment boundary. Three (3) sleeves containing the feed line, return line and drain lines penetratepass through the RCCV Top Slab. The lines connected to the condenser and the sleeves are part of the containment boundary. Figure 3.8-7 shows the typical configuration for these passages through the RCCV Top Slab and Table 3.8-17 lists each of these passages and their function.

The PCCS condenser is anchored to the RCCV Top Slab and is laterally supported by the IC/PCC pool wallsa 3D steel frame structure that transmits the horizontal dynamic forces to the RCCV Top Slab. Figures 3G.1-71a and 3G.1-71b show the PCCS condenser and supports.

The PCCS condenser is subjected to various combinations of piping reactions, mechanical, thermal and seismic loads including sloshing. The resulting forces due to various load combinations are combined with the effects of differential pressures.

A finite-element analysis model supplemented with hand calculation is used to determine the stresses in the different components of the PCCS condenser and supports. The PCCS condenser parts conform to the design requirements of Subarticles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC). The PCCS condenser support is evaluated in accordance with the ASME Code, Section III, Subsection NF.

3.8.2.5 Structural Acceptance Criteria

The structural acceptance criteria for the steel components of the RCCV (i.e., the basis for establishing allowable stress values, the deformation limits, and the factors of safety) are established by and in accordance with ASME Code Section III, Subsection NE.

In addition to the structural acceptance criteria, the RCCV is designed to meet minimum leakage rate requirements discussed in Section 6.2. Those leakage requirements also apply to the steel components of the RCCV.

The combined loadings designated under "Normal", "Construction", "Severe Environmental", "Extreme Environmental", "Abnormal", "Abnormal/Severe Environmental" and "Abnormal/Extreme Environmental" in Table 3.8-2 are categorized according to Level A, B, C and D service limits as defined in NE-3113. The resulting primary and local membrane, bending, and secondary stress intensities, including compressive stresses, are calculated and their corresponding allowable limit is in accordance with Subarticle NE-3220 of ASME Code Section III.

In addition, the stress intensity limits for testing, design and Level A, B, C and D conditions are summarized in Table 3.8-4.

Stability against compression buckling is assured by an adequate factor of safety.

The allowable stress limits used in the design and analysis of non-pressure-resisting components are in accordance with Subsection 3.8.2.2.1 (2).

3.8.2.6 Materials, Quality Control, and Special Construction Techniques

The steel pressure retaining components of the RCCV meet the requirements of Article NE-2120 of ASME Section III. The principal materials for the RCCV locks, hatches, penetrations, drywell head, and PCCS condensers are fabricated from the following materialsas follows:

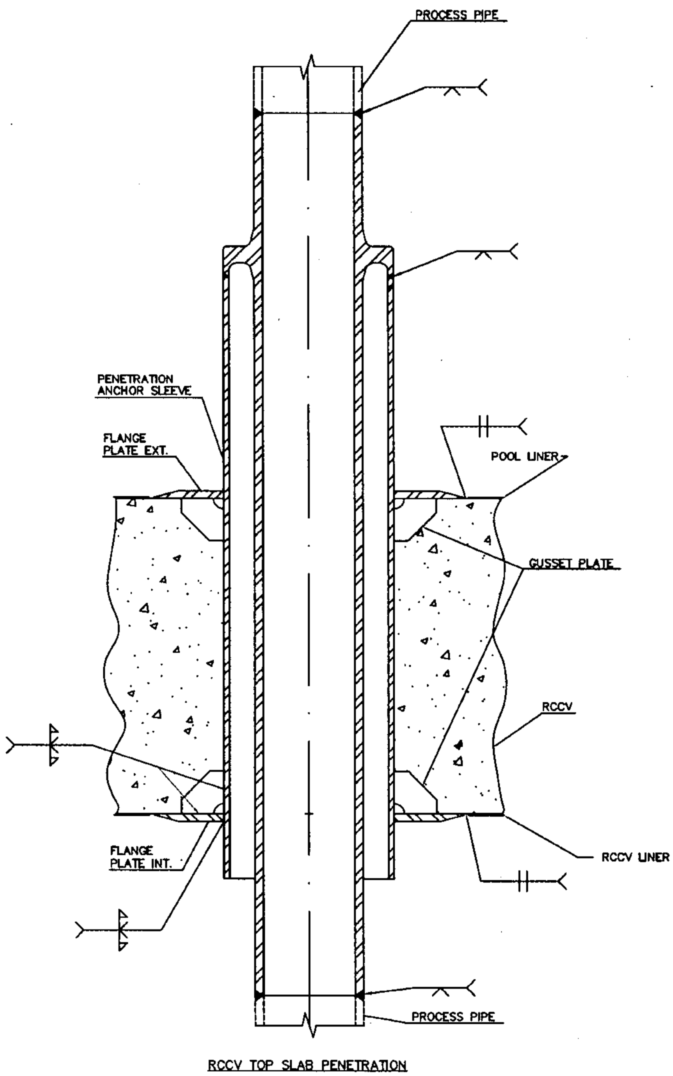


Figure 3.8-7. RCCV Top Slab Penetration and PCCS Passages

- Element: triangle and quadrilateral elements
- Surface heat transfer: convection and radiation
- Temperature condition: steady-state and transient temperature conditions

3C.5.2 Validation

TEMCOM2 is written and maintained by Shimizu Corporation of Tokyo, Japan. Program validation documentation is available at Shimizu Corporation.

3C.5.3 Extent of Application

This program is used in the transient heat transfer analysis of the concrete containment and the RB.

3C.6 STATIC AND DYNAMIC STRUCTURAL ANALYSIS SYSTEMS: ANSYS

3C.6.1 Description

ANSYS is a large, finite element program for a broad range of analyses types. The structural analysis capabilities include material and geometric non-linear analysis, static analysis and a variety of dynamic analyses.

The element used in concrete cracking analysis allows for a full non-linear analysis of reinforced concrete with cracking and crushing of concrete.

3C.6.2 Validation

ANSYS is maintained by ANSYS INC., located at 275 Technology Drive, Canonsburg, PA, 15317.

3C.6.3 Extent of Application

This program is used for the containment dynamic analysis of containment loads, and for the static and dynamic analysis of the PCCS condenser. ~~the containment ultimate capacity analyses and the containment seismic margin analysis.~~

3C.7 SOIL-STRUCTURE INTERACTION

3C.7.1 Dynamic Soil-Structure Interaction Analysis Program—DAC3N

3C.7.1.1 Description

DAC3N is a three-dimensional dynamic analysis program used for the seismic response analysis of a building structure considering soil-structure interaction. The response analysis is performed using the time history method solved by direct integration, Newmark's beta method. Eingenvalue analysis is performed using Subspace method.

In the DAC3N, soil-structure interaction system is modeled by the combination of soil spring and damping coefficient. Spring and damping coefficient are determined as frequency independent values, which fit the frequency dependent real and imaginary parts of soil spring

Reinforcing steel also has tendency to decrease in strength at elevated temperatures. The reduction of reinforcing steel strength is based upon the following equation excerpted from Reference 3G.1-1.

⊟Reduction Factor

- $\phi = 1.0 - 0.000873\ (T-21.1)$ 21.1°C (70°F) $\leq T \leq$ 204.4°C (400°F)

3G.1.5.2.3.3 Structural Steel

Properties of structural steel used for the design analyses are included in Table 3G.1-12. ASTM A-36 is used for the steel plates of the composite floor slabs.

3G.1.5.3 Stability Requirements

The RB foundation has the following safety factors against overturning and sliding. Because the impact on the stability by seismic load is larger than wind and tornado, the load combinations for W and W_t, which are shown in Table 3.8-14, are excluded.

Load Combination	Overturning	Sliding	Floatation
D + H + E'	1.1	1.1	
D + F'			1.1

Where

D = Dead Load, F' = Buoyant forces of design basis flood

H = Lateral soil pressure, E' = Safe Shutdown Earthquake

3G.1.5.4 Structural Design Evaluation

The evaluation of the containment structure, the containment internal structures, and the RB structures is based on the results from the load combinations indicated in Subsection 3G.1.5.2.2.

Figure 3G.1-28 shows the location of the sections that are selected for evaluation of reinforced concrete structures. They are selected, in principle, from the center and both ends of walls and slabs, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. The computer program SSDP-2D is used for the evaluation of stresses in rebar and concrete. The input to SSDP-2D consists of rebar ratios, material properties, and element geometry at the section under consideration together with the forces and moments from the NASTRAN analysis, which are shown in Tables 3G.1-13 through 3G.1-21. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.1-29. Figures 3G.1-30 through 3G.1-38 indicate deformations of structures obtained by NASTRAN analyses for the loads corresponding to Table 3G.1-13 through 3G.1-21.

Figure 3G.1-39 shows a flow chart for the structural analysis and design. Figures 3G.1-40 through 3G.1-47 present the design drawings used for the evaluation of the containment and the Reactor Building structural design. Figures 3G.1-48 through 3G.1-50 show the design details of containment liner plate. Figures 3G.1-51 through 3G.1-54 show the design details of containment major penetrations. Figures 3G.1-55 through 3G.1-59 show the details of containment internal structures. Figures 3G.1-71a and 3G.1-71b show the details of the PCCS condenser and supports.

3G.1.5.4.1 Containment Structure

Tables 3G.1-22 through 3G.1-26 show the resultant combined forces and moments in accordance with the selected load combinations listed in Table 3G.1-10. Table 3G.1-27 lists the sectional thicknesses and rebar ratios used in the evaluation. At each section, in general, three elements are analyzed at azimuth 0°, 90° and 135°.

Tables 3G.1-28 through 3G.1-32 show the rebar and concrete stresses at these sections for the representative elements. Tables 3G.1-33 and 3G.1-34 summarize evaluation results for transverse shear and tangential shear in accordance with ASME Section III, Division 2, Article CC-3520.

Table 3G.1-35 shows the maximum strains of containment liner plate. Table 3G.1-36 shows the stress summary of drywell head.

Table 3G.1-60 shows the stress summary of PCCS condenser and support.

3G.1.5.4.1.1 Containment Wall Including RPV Pedestal

Sections 1 through 9 shown in Figure 3G.1-28 are considered critical sections for the containment wall including the RPV pedestal. Maximum stress in the meridional rebar is found to be 287.5 MPa (41.70 ksi) at Section 4 near the bottom of the RCCV Wetwell due to load combination CV-11a, as shown in Table 3G.1-31. The maximum stress in the circumferential rebar is found to be 343.6 MPa (49.83 ksi), which occurs also at Section 4, the bottom of the RCCV Wetwell due to load combination CV-11a, as shown in Table 3G.1-31. The maximum concrete stress is found to be 17.7 MPa (2.57 ksi), which occurs at Section 1 due to load combination CV-11a.

The maximum transverse shear stress is found to be 4.56 MPa (0.66 ksi) at Section 1 for the load combination CV-11b. The amounts of shear ties provided satisfy the required values at all sections, as indicated in Table 3G.1-33.

As for tangential shear, the maximum stress of 4.26 MPa (0.62 ksi) is found at Section 4, the bottom of the Wetwell, due to the combination CV-11b. The value is less than the allowable tangential shear stress provided by orthogonal reinforcement, which is described in Table 3.8-3. The amounts of reinforcement provided satisfy the required values at all sections, as indicated in Table 3G.1-34.

Table 3G.1-35 shows liner plate strains. The liner maximum strain is found to be 0.0045 at Section 6, which is within allowable limits given in Table CC-3720-1, ASME Code Section III, Division 2. The liner stresses during construction are kept within the allowable values found in Table CC-3720-1 of ASME Code Section III, Division 2 by limiting concrete placement pressure to a maximum of 167 kPa (24.22 psi) for the top slab, 48 kPa (6.96 psi) for the upper drywell/lower drywell wall and 32 kPa (4.64 psi) for the wetwell wall.

3G.1.5.4.1.2 Containment Top Slab and Suppression Pool Slab

Sections 12 through 17 are examined for the Containment Top Slab and Suppression Pool Slab. The locations of these sections are shown in Figure 3G.1-28. The maximum rebar stresses are found to be 260.3 MPa (37.75 ksi) at Section 17 due to the load combination CV-11b in the Top Slab, and 252.9 MPa (36.68 ksi) at Section 14 due to the combination CV-11a in the Suppression

Fatigue evaluation is conducted as follows:

$S_a = K_e \cdot S_n$ = 1993 MPa (289 ksi)

E_1 = 207 GPa (30000 ksi)

E_2 = 194 GPa (28100 ksi)

Where

E_1: Modulus of elasticity given on the design fatigue curve from Figure I-9.1 of Appendix I of Sec. III.

E_2: Modulus of elasticity at 340°F (171°C) from Table TM-1 of Sec. II, Part D

$S_a' = S_a \cdot (E_1/E_2)$ = 2131 MPa (309 ksi)

S_a for 10 cycles is 3999 MPa (580 ksi) from Table I-9.1 (UTS ≤ 80 ksi) and N for S_a' = 2131 MPa (309 ksi) is obtained as 38 from Table I-9.1, General Note (b). So the requirement of NE-3228.3 (c) is satisfied.

(4) NE-3228.3 (d)

Because an accident temperature T_a is not a cyclic load, the thermal ratcheting can be neglected.

(5) NE-3228.3 (e)

From Table NE-3228.3(b)-1, the maximum temperature T_{max} is 370°C (700°F) for carbon steel. T_a is 171°C (340°F), so it satisfies this requirement.

(6) NE-3228.3 (f)

Specified minimum yield strength S_y and specified minimum tensile strength S_u of SA-516 Gr. 70 are 262 MPa (38 ksi) and 483 MPa (70 ksi) respectively. The ratio of S_y to S_u is calculated as 0.543. This value is below 0.80. So it satisfies this requirement.

Fatigue Evaluation

Fatigue evaluation is performed in accordance with ASME B&PV Code Section III, Subsection NE-3221.5(d) in which the limits on peak stress intensities as governed by fatigue are considered and satisfied when the Service Loadings meet the stipulated condtion.

3G.1.5.4.1.5 PCCS Condenser

Figures 3G.1-71a and 3G.1-71b show the design details. A finite-element analysis model supplemented with hand calculation is used to determine the stresses in the different components of the PCCS condenser and supports. The finite-element analysis is performed using ANSYS computer code. The 3D finite-element model presented in Figure 3G.1-72 is used. The 3D steel frame structure and the vertical tubes are modeled by beam-type elements. The rest of PCCS condenser components are modeled by shell-type elements. Static and dynamic analyses are performed to evaluate the different loads. The dynamic load cases are analyzed by the response spectrum method. The stress evaluation is performed for loads and load combinations in accordance with Table 3.8-4 and associated acceptance criteria for pressure retaining components of the condenser. The condenser supports are designed to the same loads and load combinations in accordance with the acceptance criteria of ASME Code, Section III, Subsection NF.

The calculated stresses in various elements of the PCCS condenser and supports are shown in Table 3G.1-60 and are within allowable stress limits.

3G.1.5.4.2 Containment Internal Structures

Tables 3G.1-37 through 3G.1-44 show the summary of stress analysis results for containment internal structures.

The type of analyses for various loads considered for the containment internal structures, such as diaphragm floor, vent wall (VW), RPV support bracket (RPVSB), reactor shield wall and GDCS pool are:

(1) Dead load

Static analysis is performed for the dead load to all containment internal structures. Hydrostatic loads of pool water are also applied statically to vent wall and GDCS pool.

(2) Pressure load

Static analysis is performed for the pressure load (P_o and P_a) applied to diaphragm floor and vent wall.

(3) Thermal load

Static analysis is performed for the thermal load (T_o and T_a) to all internal structures. All steel temperature is the same as atmospheric temperature. The temperature of the intermediate node of VW rib plate is the average value of outer and inner plate ones.

(4) Seismic load

Static analyses are performed for the seismic load on diaphragm floor, vent wall, RPV support bracket and reactor shield wall in the integral NASTRAN model, and on GDCS pool in the GDCS pool local model.

In this response spectra analysis, it is assumed that all pool water mass is distributed uniformly on the GDCS pool wall and RCCV wall. This is considered as a conservative assumption, therefore sloshing is not considered in GDCS pool local model. For integral NASTRAN model, however, sloshing load is considered as the static pressure load on DF upper surface and static reaction load from GDCS pool wall. The results from integral NASTRAN model due to these loads are used for the structural integrity evaluation of the structures other than GDCS pool, while the results from GDCS pool local model are used for evaluation of GDCS pool itself.

(5) Hydrodynamic load

Static analysis is performed for the hydrodynamic load (CO, CH and SRV) on vent wall taking DLF = 2 into account.

(6) Pipe Break loads consist of Annulus Pressurization (AP) load, jet impingement and pipe-whip restraint loads

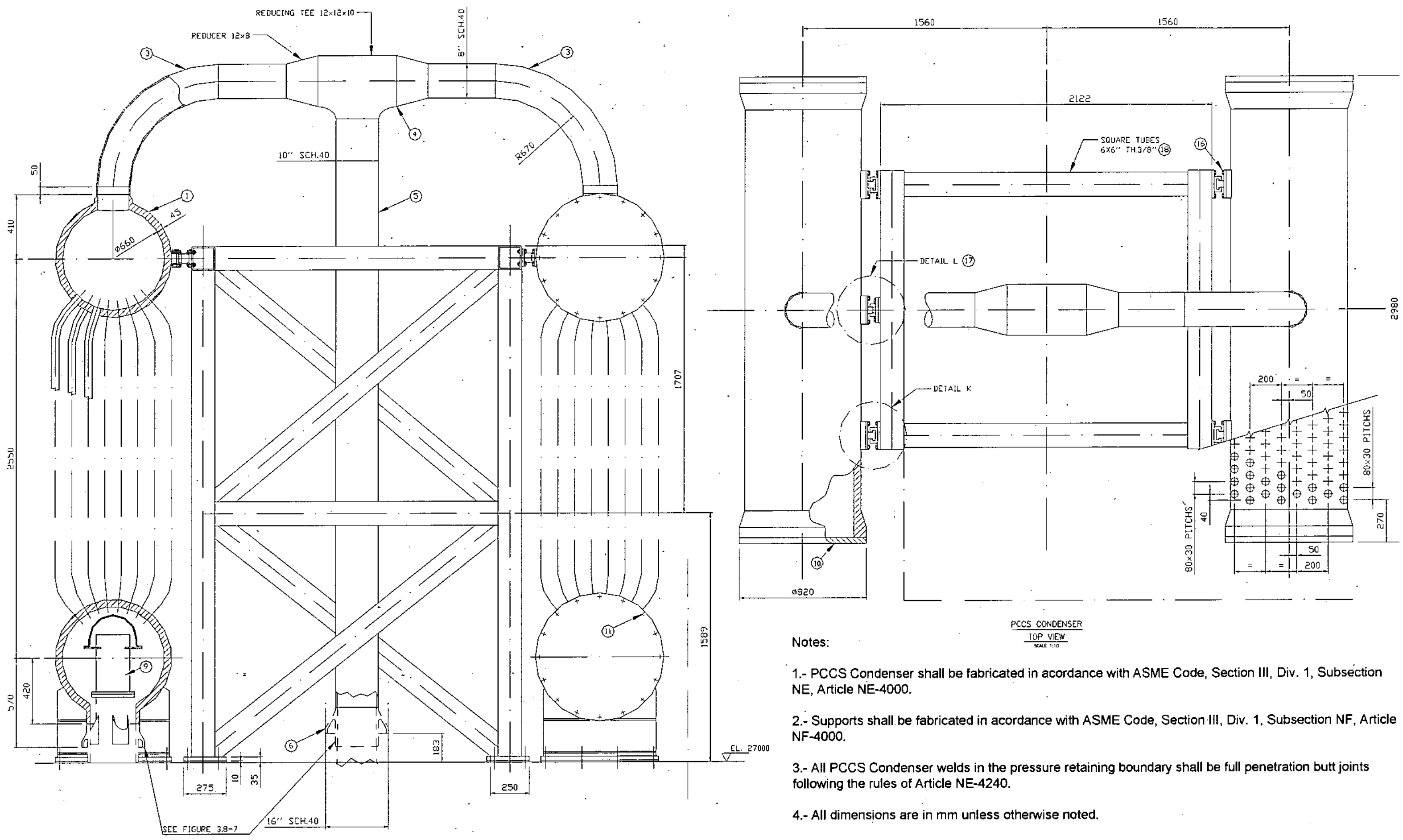
Table 3G.1-60

PCCS Condenser and Supports Stress Summary

Component	Stress Category	Test			Design			Service Level A/B			Service Level C/D		
		Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress[(1)] (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress[(2)] (MPa)	Stress Margin (%)
Upper Header	P_m	11.8	119.8	90	11.8	114.9	90	16.8	114.9	85	37.8	137.9	73
	$P_L + P_b$	11.8	183.7	94	11.8	150.6	92	16.8	150.6	89	39.8	180.7	78
Lower Header	P_m	11.8	119.8	90	11.8	114.9	90	24.8	114.9	78	47.8	137.9	65
	$P_L + P_b$	11.8	183.7	94	11.8	150.6	92	26.8	150.6	82	55.8	180.7	69
Tubes	P_m	11.4	119.8	91	11.4	114.9	90	15.4	114.9	87	19.4	137.9	86
	$P_L + P_b$	11.4	183.7	94	11.4	150.6	92	33.4	150.6	78	66.4	180.7	63
Feed Line	P_m	9.9	119.8	92	9.9	114.9	91	23.9	114.9	79	79.9	137.9	42
	$P_L + P_b$	9.9	183.7	95	9.9	150.6	93	29.9	150.6	80	110.9	180.7	39
Steam line	P_m	10.9	119.8	91	10.9	114.9	91	25.9	114.9	77	80.9	137.9	41
	$P_L + P_b$	10.9	183.7	94	10.9	150.6	93	31.9	150.6	79	112.9	180.7	38
Steam Distributor	P_m	12.6	119.8	89	12.6	114.9	89	24.6	114.9	79	67.6	137.9	51
	$P_L + P_b$	12.6	183.7	93	12.6	150.6	92	26.6	150.6	82	73.6	180.7	59
Condensate Lines	P_m	12.6	119.8	89	12.6	114.9	89	31.6	114.9	73	66.6	137.9	52
	$P_L + P_b$	12.6	183.7	93	12.6	150.6	92	37.6	150.6	75	80.6	180.7	55
Header Cover	P_m	87.0	119.8	27	87.0	114.9	24	89.0	114.9	23	92.0	114.9	20
	$P_L + P_b$	87.0	183.7	53	87.0	150.6	42	89.0	150.6	41	92.0	180.7	49
Header Bolt	Average Stress	70.3	144.7	51	70.3	110.1	36	70.3	220.2	68	70.3	220.2	68
Support Saddle	P_m	Negligible						29.0	112.6	74	87.0	168.9	48
	$P_L + P_b$							30.0	168.9	82	88.0	253.4	65
	Shear							9.0	67.6	87	26.0	101.3	74
Truss Support Structure	Tension							14.0	76.6	82	69.0	114.9	40
	Shear							3.0	51.1	94	12.0	76.6	84
	Compression							14.0	47.9	71	69.0	71.9	4
	Bending							14.0	84.3	83	70.0	126.4	45

(1) Allowable stress values correspond to Level A.

(2) Allowable stress values correspond to Level C.



Notes:

1.- PCCS Condenser shall be fabricated in acordance with ASME Code, Section III, Div. 1, Subsection NE, Article NE-4000.

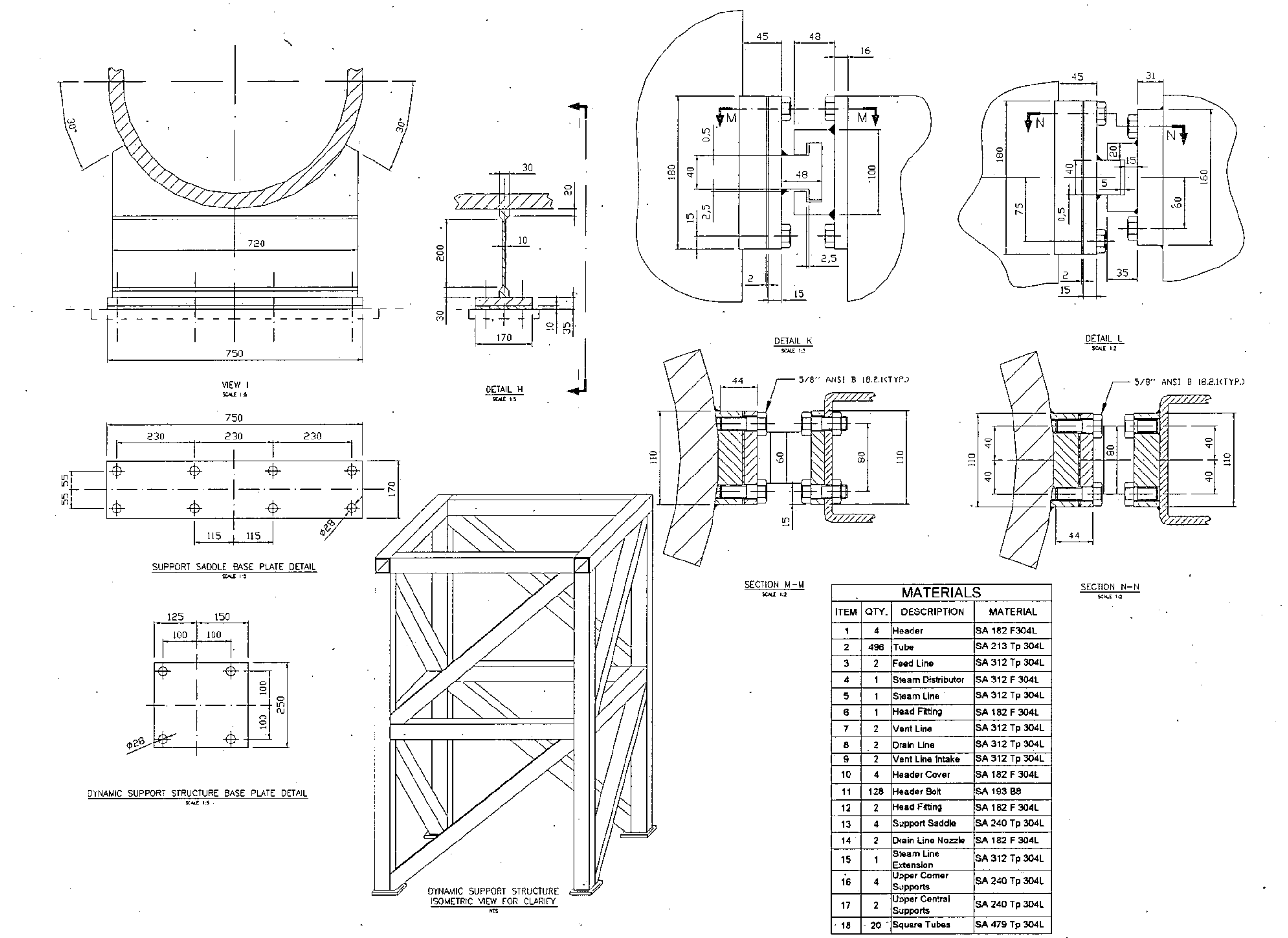
2.- Supports shall be fabricated in acordance with ASME Code, Section III, Div. 1, Subsection NF, Article NF-4000.

3.- All PCCS Condenser welds in the pressure retaining boundary shall be full penetration butt joints following the rules of Article NE-4240.

4.- All dimensions are in mm unless otherwise noted.

5.- Six (6) units as the presented one in this drawing shall be fabricated.

Figure 3G.1-71a. PCCS Condenser and Supports



MATERIALS			
ITEM	QTY.	DESCRIPTION	MATERIAL
1	4	Header	SA 182 F304L
2	496	Tube	SA 213 Tp 304L
3	2	Feed Line	SA 312 Tp 304L
4	1	Steam Distributor	SA 312 F 304L
5	1	Steam Line	SA 312 Tp 304L
6	1	Head Fitting	SA 182 F 304L
7	2	Vent Line	SA 312 Tp 304L
8	2	Drain Line	SA 312 Tp 304L
9	2	Vent Line Intake	SA 312 Tp 304L
10	4	Header Cover	SA 182 F 304L
11	128	Header Bolt	SA 193 B8
12	2	Head Fitting	SA 182 F 304L
13	4	Support Saddle	SA 240 Tp 304L
14	2	Drain Line Nozzle	SA 182 F 304L
15	1	Steam Line Extension	SA 312 Tp 304L
16	4	Upper Corner Supports	SA 240 Tp 304L
17	2	Upper Central Supports	SA 240 Tp 304L
18	20	Square Tubes	SA 479 Tp 304L

Figure 3G.1-71b. PCCS Condenser and Supports Details

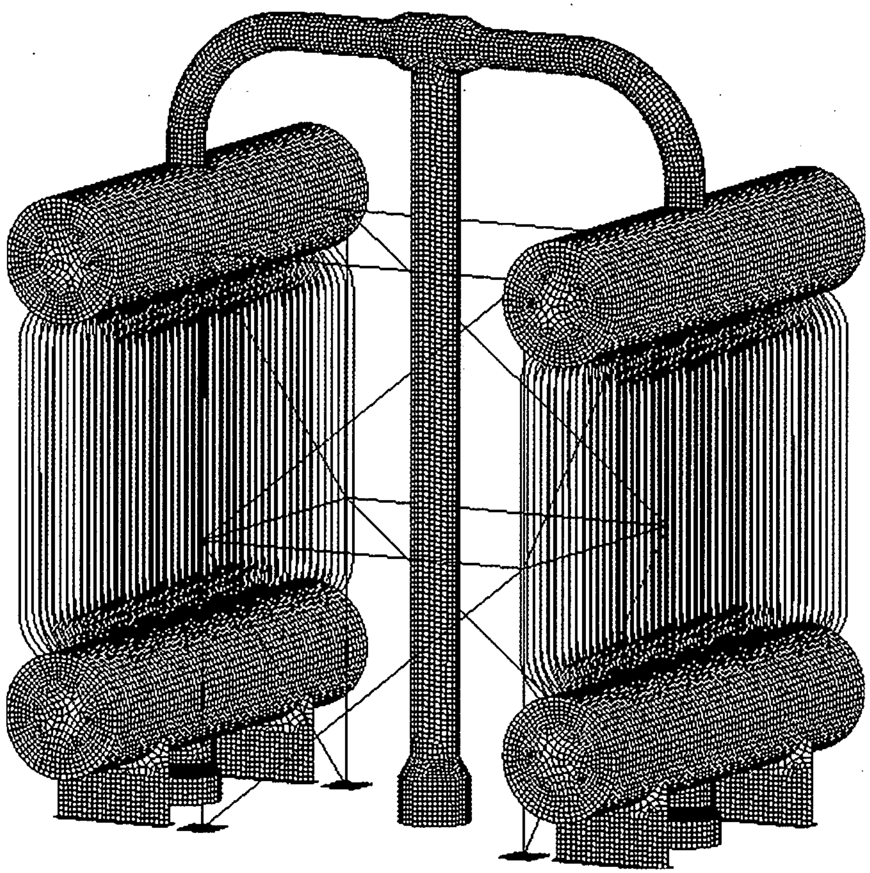


Figure 3G.1-72. FE Model of PCCS Condenser and Supports

The PCCS condenser, which is open to the containment, receives a steam-gas mixture supply directly from the drywell. The condensed steam is drained to a GDCS pool and the gas is vented through the vent line, which is submerged in the pressure suppression pool.

The PCCS loop does not have valves, so the system is always available.

6.2.2.2.2 Detailed System Description

The PCCS maintains the containment within its pressure limits for DBAs. The system is designed as a passive system with no components that must actively function in the first 72 hours after a DBA, and it is also designed for conditions that equal or exceed the upper limits of containment reference severe accident capability.

The PCCS consists of six, low-pressure, independent loops, each containing a steam condenser (Passive Containment Cooling Condenser), as shown Figure 6.2-16. Each PCCS condenser loop is designed for 11 MWt capacity and is made of two identical modules. Together with the pressure suppression containment (Subsection 6.2.1.1), the PCCS condensers limit containment pressure to less than its design pressure for at least 72 hours after a LOCA without makeup to the IC/PCC pool~~, and beyond 72 hours with pool makeup~~. Long-term effectiveness of the PCCS (beyond 72 hours) credits pool makeup and an active gas recirculation system, which uses in-line fans to pull drywell gas through the PCC condensers.

The PCCS condensers are located in a large pool (IC/PCC pool) positioned above, and outside, the ESBWR containment (DW).

Each PCCS condenser is configured as follows (see Figures ~~6.2-16~~3G.1-71a and 3G.1-71b)~~-as follows~~.

A central steam supply pipe is provided which is open to the containment at its lower end, and it feeds two horizontal headers through two branch pipes at its upper end. Steam is condensed inside vertical tubes and the condensate is collected in two lower headers.

The vent and drain lines from each lower header are routed to the DW through a single ~~containment penetration~~ passage per condenser module as shown on the ~~diagram~~figures.

The condensate drains into an annular duct around the vent pipe and then flows in a line that connects to a large common drain line, which also receives flow from the other header. The vent line goes to the Suppression pool and is submerged below the water level.

A Passive Containment Cooling vent fan is teed off of each PCCS vent line and exhausts to the GDCS pool. The fan aids in the long-term removal of non-condensable gas from the PCCS for continued condenser efficiency. The fans are operated by operator action and are powered by a reliable power source which has a diesel generator backed up by an ancillary diesel if necessary without the need to enter the primary containment. The discharge of each PCC vent fan is submerged below the GDCS pool water level to prevent backflow that could otherwise interfere with the normal venting of the PCCS. The vent fan discharge line terminates in a drain pan within the GDCS pool so that the gas seal is maintained after the GDCS pool drains. To further prevent reverse flow through an idle fan, a ball check is installed at the end of the fan discharge line.

The PCCS loops receive a steam-gas mixture supply directly from the DW. The PCCS loops are initially driven by the pressure difference created between the containment DW and the suppression pool during a LOCA and then by gravity drainage of steam condensed in the tubes, so they require no sensing, control, logic or power-actuated devices to function. In order to ensure the PCCS can maintain the drywell to wetwell differential pressure to a limit less than the value that causes pressure relief through the horizontal vents, the vent line discharge point is set at an elevation submerged below low water level and at least 0.85 m (33.5 in) above the top of the uppermost horizontal vent. The PCCS loops are an extension of the safety-related containment and do not have isolation valves.

~~Spectacle flanges are included in the drain line and in the vent line to conduct post-maintenance leakage tests separately from Type A containment leakage tests.~~

~~Located on the~~ The drain line ~~and~~ is submerged in the GDCS pool~~, just upstream of the discharge point, is a loop seal: it~~to prevent~~s~~ back-flow of steam and gas mixture from the DW to the vent line, which would otherwise short circuit the flow through the PCCS condenser to the vent line. It also provides long-term operational assurance that the PCCS condenser is fed via the steam supply line. The drain line terminates in the same drain pan as the vent fan discharge to replace any evaporation loss in the drain pan after the GDCS pool drains.

Each PCCS condenser is located in a subcompartment of the IC/PCC pool, and all pool subcompartments communicate at their lower ends to enable full use of the collective water inventory independent of the operational status of any given IC/PCCS sub-loop.

A valve is provided at the bottom of each PCC subcompartment that can be closed so the subcompartment can be emptied of water to allow PCCS condenser maintenance.

Pool water can heat up to about 102°C (216°F); steam formed, being non-radioactive and having a slight positive pressure relative to station ambient, vents from the steam space above each PCCS condenser where it is released to the atmosphere through large-diameter discharge vents.

A moisture separator is installed at the entrance to the discharge vent lines to preclude excessive moisture carryover and loss of IC/PCC pool water.

IC/PCC expansion pool makeup clean water supply for replenishing level is normally provided from the Makeup Water System (Subsection 9.2.3).

Level control is accomplished by using a pneumatic powered or equivalent Power Operated Valve (POV) in the make-up water supply line. The valve opening and closing is controlled by water level signal sent by a level transmitter sensing water level in the IC/PCC expansion pool.

Cooling and cleanup of IC/PCC pool water is performed by the FAPCS (Subsection 9.1.3).

The FAPCS provides safety-related dedicated makeup piping, independent of any other piping, which provides an attachment connection at grade elevation in the station yard outside the RB, whereby a post-LOCA water supply can be connected.

6.2.2.2.3 System Operation

Normal Plant Operation

During normal plant operation, the PCCS loops are in "ready standby."