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Proprietary Notice
This letter forwards proprietary information in accordance with 10CFR2.390. Upon the removal of Enclosures 1 and 4, the balance of this letter may be considered non-proprietary.

MFN 10-044 Supplement 1

Docket No. 52-010

May 22, 2010

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 Supplement 1**

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 the Reference 1 NRC letter. It supplements the responses sent as References 2 and 3. The GEH response to RAI Number 6.2-202 S01 is provided in Enclosure 1 (proprietary version) and Enclosure 2 (public version).

Enclosure 3 contains markups to DCD Tier 1 and Tier 2 as noted in the Enclosure 1 response.

Enclosure 4 contains Revision 1 of NEDE-33572P, "ESBWR PCCS Condenser Structural Evaluation," and Enclosure 5 contains the public version of this report.

Enclosures 1 and 4 contain GEH proprietary information as defined by 10 CFR 2.390. GEH customarily maintains this information in confidence and withholds it from public disclosure. Enclosures 2 and 5 are the non-proprietary versions, respectively, which do not contain proprietary information and are suitable for public disclosure.

The affidavit contained in Enclosure 6 identifies that the information contained in Enclosures 1 and 4 has been handled and classified as proprietary to GEH. GEH hereby requests that the information of Enclosures 1 and 4 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 10-146, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application,* April 12, 2010
2. MFN 10-044, Letter from Richard E. Kingston to U.S. Nuclear Regulatory Commission, Response to Portion of NRC Request for Additional Information Letter No. 401 Related to ESBWR Design Certification Application – Engineered Safety Features — RAI Number 6.2-202, February 1, 2010
3. MFN 10-044 Revision 1, Letter from Richard E. Kingston to U.S. Nuclear Regulatory Commission, Response to Portion of NRC Request for Additional Information Letter No. 406 Related to ESBWR Design Certification Application – Engineered Safety Features — RAI Number 6.2-202, March 23, 2010

Enclosures:

1. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – GEH Proprietary Information
2. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – Public Version
3. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – Markups to ESBWR DCD Tier 1 and Tier 2

4. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – NEDE-33572P Revision 1, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," May 2010 - GEH Proprietary Information
5. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – NEDO-33572 Revision 1, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," May 2010 - Public Version
6. MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – Affidavit

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH (with enclosures)
	DH Hinds	GEH (with enclosures)
	SC Moen	GEH (with enclosures)
	TL Enfinger	GEH (with enclosures)
	eDRFsection	0000-0117-8858 (Response and Markups)
		0000-0115-2094, Rev. 2 (NEDE-33572 Revision 1)

Enclosure 2

MFN 10-044 Supplement 1

Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application

Engineered Safety Features

RAI Number 6.2-202 S01

Public Version

NON-PROPRIETARY INFORMATION NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 10-044 Supplement 1 - Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

NRC RAI 6.2-202 S01

Explain how ESBWR would address possible accumulation of high concentrations of hydrogen and oxygen in the PCCS and the ICS.

A. The title of the Licensing Topical Report (LTR) NEDE-33572P report "ESBWR PCCS condenser structural evaluation" does not include the evaluation of the ICS. Update the title of this report to include the evaluation of the ICS.

B. Because of the potential for accumulation of noncondensable gas in the ICS condensers, the ICS condensers will be designed using the methodology described in NEDE-33572P. In the revised response to RAI 6.2-202 and the LTR NEDE-33572P Revision 0 (both dated 3-23-10), GEH stated that LOCA analyses presented in DCD Tier 2 Sections 6.2 and 6.3 do not credit heat transfer for the ICS. However, GEH also indicated that main steam line break (MSLB) analysis does credit heat transfer, as shown in Figures B.1 and B.2. Figure B.1 shows accumulation of non-condensable gas within the first few hours of a MSLB in the tubes. Because the non-condensable gas is not vented, the tube's condensation rate is quickly reduced. The ICS vent lines do not open during LOCA conditions. The lower drum and drain line will be subject to the same accumulation. From Figure B.2, the upper drum accumulates non-condensable gas for the first hours then drops below for the remainder of the 72 hours.

In its response to Item B of this RAI, GEH is now committed to design the ICS using the methodology described in NEDE-33572P for the PCCS. Therefore, in the design of the ICS including its condensers GEH is requested to address all PCCS-related concerns included in the RAI supplement to ITEM C. In addition, GEH is also requested to address the following specific concerns that are not applicable to the PCCS:

1. *Justify the use of Service Level D of the ASME Code Section III, Subsection NC for the detonation load.*
2. *Explain how the heat transfer function of the ICS condensers is demonstrated during a main steam line break (MSLB) LOCA, since Appendix F of the ASME Code acceptance criteria for Service Level D load combinations are applicable to the pressure boundary function only.*

The staff emphasizes that, in order to arrive at a safety determination, the complete analysis and design of the ICS condensers needs to be reviewed. In the revised response to RAI 6.2-202, GEH states that this information will be submitted as part of LTR NEDE-33572P. Therefore, the staff requests the final version of this report for review, including all appendices.

C. In the response to RAI 6.2-202, Revision 1, Figures 6.2-202-1, 2 (Pages 6 and 7 of the Letter) indicate potentially flammable/detonable mixture of noncondensable gases in ICS tubes and top drums at Post LOCA conditions. Even though the IC tubes and drums are designed to withstand the potential detonation, as a defense in depth measure, it is prudent to take preventive actions to mitigate the detonation.

For high levels of non-condensable gases, what mitigating actions planned to prevent the potential detonation inside the IC tubes and drums?

1. Are you planning to provide instrumentation for hydrogen monitoring of the ICS tubes and drum?

2. If the Hydrogen level is high inside the IC Tubes and drums, what manual or automatic actions planned for IC operation?

3. Revise DCD Section 5.4.6 to describe the system design and operation changes to incorporate mitigating actions for hydrogen control

D. In NEDE-33572P, Revision 0, GEH stated that the evaluation for PCCS is described in Appendix A (modified by Appendix B to include detonation). A similar evaluation will be performed for the ICS to validate the design using the same methodology described in this report. Based on initial pressure and temperature condition, a peak pressure ratio of 19:1 is used on the PCCS for the calculation of peak pressures. During the LOCA and Post LOCA condition, the ICS has not the same initial temperature and pressure as PCCS has experienced. The staff requests GEH to provide the following:

1. Discussion of the initial pressure and temperature of ICS during the LOCA and Post LOCA condition.

2. Provide the technical justification of the use of peak pressure ratio for ICS.

3. Provide the configuration of added vent line, ICS assembly, flow paths of ICS and its function.

E. The revised response to RAI 6.2-202 and the LTR NEDE-33572P Revision 0 provide information regarding the potential accumulation of high concentrations of hydrogen and oxygen in certain components of the PCCS during a LOCA, and how the PCCS design addresses the resulting possibility of deflagrations or detonations in these components. The RAI response further states that, in the event of a combustible gas mixture (hydrogen and oxygen) accumulation, the PCCS is designed to withstand overpressures from possible deflagrations or detonations such that: (a) the structural integrity of the containment pressure boundary is maintained, and (b) the long term heat removal function is not compromised. However, the staff finds that the information provided appears to be insufficient to support the stated design intent; therefore, additional information is requested as described below.

1. The response to Item C.1 of the RAI indicates that the methodology of assessment for hydrogen and oxygen accumulation in the PCCS condenser is contained in the LTR. However, the version of the LTR provided to the staff is not finalized because it focuses on the preliminary sizing of the PCCS condenser tubes, and does not contain a complete stress analysis of the PCCS assembly. It is emphasized that to arrive at a safety determination, the complete analysis and design of the PCCS needs to be reviewed by the staff. Therefore, provide the final version of the LTR for review, including all its appendices.

2. The response to Item C.2 of the RAI indicates that a new detonation load case and new load combinations for PCCS design are added to the DCD, as detailed in the LTR. In addition, the response states that the acceptance criterion used for the load combinations that include detonation loads is Service Level D per the ASME Code, Section III, Division I, Subsection NE. Provide technical justification for the load combinations and the corresponding acceptance criteria used in the PCCS design, and include this information in the LTR. A detailed discussion of the following issues should be included:

a. Since the PCCS is required to maintain the containment pressure boundary and also meet its functional requirement of heat removal during the 72-hour period associated with a LOCA, the proposed acceptance criteria of satisfying Service Level D of the ASME Code, Section III, Division I, Subsection NE may not be appropriate. Service Level D permits stresses beyond yield and may thereby result in distortions such that the PCCS is not able perform its function of heat removal. Therefore, the analytical approach and the acceptance criteria used to demonstrate both PCCS functions of maintaining pressure boundary and removal of heat must be technically justified. Note that if the analysis and design allow strains beyond yield, then the method for developing equivalent static pressures (for detonation loads) proposed in the current version of the LTR may not be valid because it is based on an essentially elastic response of the component.

b. Regarding the acceptance criteria used to demonstrate heat removal functionality, explain what subsection of the ASME Code Section III, Division I, is being followed. Note that neither Subsection NE nor Appendix F address functionality of mechanical components.

c. If plastic deformation does occur at any location in the PCCS, discuss the ratcheting effects for five or more detonations, and the combination with elastically calculated stresses due to other non-detonation load cases (e.g., seismic, dead weight and thermal).

3. The response to Item C.3 of the RAI indicates that detonation pressures and dynamic load factors are derived from experiments described in the technical literature, as described in the LTR. Provide the following additional information on *the detonation pressure load values used in the analysis and design of PCCS, and include this information in the LTR:*

Confirm the number of multiple detonations that are expected to occur (previous statements were made that it is 5 or more) during the 72-hour period associated with a LOCA.

a. LTR Table 3-3 listed the dynamic load factors (DLF) used for various components of the PCCS. The report provides detailed analysis of DLF only for the PCCS tubes. Provide detailed justification of DLFs for all other components listed in LTR Table 3-3.

b. Provide a detailed discussion of the effect of the deflagrations or detonation waves in all components of the PCCS, not only the lower drums and the condenser tubes. In particular, discuss the estimation of loads in various components associated with flame acceleration (FA) and deflagration-to-detonation transition (DDT). The staff notes that the calculations in the LTR assume the highest possible concentrations of hydrogen and oxygen (in stoichiometric ratio without steam) which leads to detonations without delay. However, steam could be present in the mixture delaying DDT in the PCCS drain and vent pipes which are relatively long. Delayed DDT could generate higher pressures than those calculated in the LTR. Therefore, provide analyses of DLF including occurrence of delayed DDT with presence of steam in PCCS drain and vent pipes to determine conservative loading scenarios.

c. Discuss the use of Chapman-Jouguet (CJ) pressure versus the DDT pressure, which could be much higher than the CJ pressure in certain cases.

d. Discuss the bounding effect of reflected CJ detonation waves.

e. Discuss the effect of the uncertainty in the combustible gas concentrations and the presence of dilutants (e.g., steam); specifically, with regard to possible variations in peak pressure values, detonation velocities, and LFs used in the analysis.

f. Discuss the effect of initial temperature conditions on the peak pressure.

g. Discuss the effect of PCCS geometry (e.g., presence of bends, tees, tube size) if the experimental values of different configurations are used.

h. Provide the modified PCCS assembly and flow paths of PCCS.

4. The response to Item C.4 of the RAI indicates that certain sections of the DCD have been modified to include a description of detonation loads, to delete information referring to stress analysis results, and to refer to the LTR for these stress analysis results as well as for other analysis and design details. As indicated under Item E.1 above, the complete analysis and design of the PCCS *needs to be reviewed by the staff. Therefore, the final version of the LTR should be provided, including all its appendices. In addition, the DCD should also contain a summary of analysis and design results from the LTR, as well as sufficient information to support a safety determination.*

5. The response to Item C.5 of the RAI indicates that detonations inside the PCCS have negligible impact on the overall containment pressure. The response also provides the magnitude of the energy released during a detonation event. However, the response does not explain how this energy release is translated into stresses in the PCCS support frame, floor anchors, and other PCCS components not directly affected by the detonation and, therefore, not captured in the stress analysis described in the LTR. To address this and other related issues, provide a detailed discussion of the following:

a. The assumptions and methods used in the stress analyses of the various PCCS components, especially if elastic-plastic analysis is used; include this information in the LTR.

b. The effect of detonations on the entire PCCS assembly, including: the PCCS support frame, support frame floor anchors, and pressure retaining components beyond the tubes and drums (e.g., steam inlet connections to the pool floor), etc.; include this information in the LTR.

c. Technical justification for using a margin of 40 percent for all support values to account for all uncertainties.

d. The effect of stress concentrations and potential plastic deformations at applicable locations such as pipe and tube bends, and the weld junction of the tubes to the drums. Confirm that the FE mesh used in the stress analysis is sufficiently refined to capture these effects.

F. LTR NEDE-33572P, Revision 0 Section 5.0 discusses inservice inspections and fabrication inspections for the PCCS and ICS. The staff requests that the applicant address the following:

1. Section 5.1 discusses PCCS and ICS inservice inspection (ISI) but does not provide a clear description of the ISI that will be performed on the PCCS and ICS. The staff requests that the applicant provide a detailed description of the ISI that will be performed on the PCCS and ICS including references to applicable portions of ASME Code. The staff notes that ESBWR Section 5.4.6.4 states that UT is required for the ISI of IC tube-to-header welds but the applicant proposes to delete this statement and replace it with Ref . 5.4-3 which does not require UT examination for ISI.

2. Section 5.2.1 describes tube-to-header weld fabrication examinations. The applicant states that a PT will be performed and references the requirements of NE-5350. The staff requests that the applicant also address the required inspections for ICS welds. In addition, the staff requests that the applicant *provide the category of these welds and discuss how it came to the conclusion that a PT is sufficient and RT is not required. The staff notes that if a PT examination only is to be performed on tube welds and tube-to-header welds, the staff expects that the applicant will perform a VT-1 examination of ID surface of the welds.*

3. Section 5.2.2 describes the applicant's tube bending requirements for the PCCS tubes. The staff requests that the applicant also provide tube bending requirements for ICS tubes.

4. Section 5.2.3 lists weld filler materials for the tube-to-header welds. The staff assumes that the filler materials listed are for the PCCS and not the ICS. The staff requests that the applicant also list weld filler materials for the ICS tube-to-header welds.

G. Provide clarification of the use of TRACG code results in the structural evaluation of PCCS and ICS components for detonation of accumulated noncondensable gas mixtures. The staff has concerns about the capability of TRACG to predict transient behavior with noncondensable gas present. It may be acceptable to utilize the TRACG results for trending and in support of key assumptions, such as the location of gas accumulation during a LOCA, but specific quantitative results should not be utilized without additional code qualification using test measurements or other benchmarks.

GEH Response

The possible accumulation of hydrogen and oxygen in the PCCS and the ICS is addressed through individual component design and automatic control design changes. The PCCS condensers are strengthened to withstand multiple deflagrations and detonations while maintaining containment pressure boundary and heat removal capacity. The PCCS vent lines are equipped with catalyst modules that maintain their hydrogen accumulation below the lower flammability limit (greater than 80% steam concentrations). More discussion and a schematic on the addition of catalyst modules are provided in Section 2.2.4.2 of LTR. These catalyst modules are of similar design as described in AREVA's U.S. EPR Final Safety Analysis Report, Subsection 6.2.5 in which their detailed description and testing is incorporated by Reference 8 in Section 6.2.8, ANP-10268P, Revision 0.

The ICS is automated to isolate during LOCA events and to vent during non-LOCA events such as station-blackout. Venting is accomplished by opening the lower header vent line on a six hour time delay after ICS initiation and isolation is accomplished by closing the ICS containment isolation valves on any two DPV's opening.

A.

The title is changed to "ESBWR ICS AND PCCS CONDENSER COMBUSTIBLE GAS MITIGATION AND STRUCTURAL EVALUATION."

B.

To prevent the accumulation of hydrogen during non-LOCA events such as Station Blackout, the ICS is automated to vent through the lower header vent line at a six hour time delay after ICS is initiated. Analysis has shown that at around ten hours hydrogen accumulation will exceed the lower flammability limit, but by opening the vent line at six hours a four hour margin is maintained.

The vent line is equipped with a flow restricting orifice of flow area 0.167 cm^2 to reduce the loss of RPV inventory. It is located down stream of valve F010, See markups for DCD Tier 2, Figure 5.1-3. Revised water levels for Station Blackout are reported in DCD Tier 2, Subsection 15.5.5.3 and Table 15.5-10b, which show that level is still maintained above Level 1. These results are based on an orifice flow area of 0.667 cm^2, which provides conservative results for RPV inventory losses.

During LOCA events, the ICS is isolated after any of two DPV's opening. This provides sufficient time for the ICS condensate to drain into the RPV. Results reported in DCD Tier 2 Sections 6.2 and 6.3 credit the additional makeup during LOCA events but heat transfer from the ICS to the ICS/PCCS pools is not credited. A Main Steam Line Break analysis crediting ICS heat transfer with ICS isolation after the DPV's open demonstrate prior-to-isolation steam fractions that remain above the limit needed to inhibit ignition (steam fractions above 80%). After isolation, the total ICS pressure drops below 103.4 kPa (15 psia) within 2000 seconds, and steam fractions do not drop below 0.37. This is still high enough to prevent ignition. A discussion on how ICS mitigates the possibility of hydrogen combustion after isolation is given in Section 4.2 of the LTR. Figure 6.2-202 S01.1 provides ICS total pressure before and after isolation. The offsite power case for Main Steam Line Break was chosen to maximize any build up of noncondensable gases; DPV's do not open until 1060 seconds.

B.1

The design pressure of the ICS during its normal operation is 8618 kPaG (1250 psig) and will not be exceeded due to any possible combustion of hydrogen as discussed above.

B.2

Heat transfer is not credited during LOCA events as analyzed in DCD Tier 2, Chapter 6 and is therefore able to be isolated before the lower flammability limit of hydrogen is exceeded. But for the purpose of analyzing the impact of noncondensable gases on ICS, the heat transfer function is assumed to occur. The build up of gases can only result from steam condensation.

The addition of automated opening of vent lines and closing of containment isolation valves for the ICS is described in markups of DCD Tier 2, Section 5.4.6. An analysis of venting after six hours of ICS initiation during non-LOCA events demonstrates the lower flammability limit is not reached. See Figure 6.2-202 S01.2.

The analysis for the limiting LOCA scenario for hydrogen accumulation shows that closing the ICS containment isolation after any two DPV's opening prevents the lower flammability limit from being exceeded before isolation. After isolation, the total pressure drops in the ICS, thereby maintaining any pressure due to a postulated combustion below the design pressure of the ICS.

C.

As discussed in Part B of this response, the ICS has automated vent line opening that purges the ICS during RPV isolation (non-LOCA events) and automated ICS containment isolation valve closing that limits the buildup of hydrogen to below the lower flammability limit during LOCA events. In addition, nonsafety-related temperature sensors are located inside the ICS (see markups for DCD Tier 2, Subsection 5.4.6.5). Operators can use these temperature sensors to determine if noncondensable gases have accumulated and take appropriate action to vent or isolate. Automatic opening of the lower header vent line at six hours post ICS initiation is still required.

C.1

It is not intended that hydrogen level inside the IC tubes and drums will be monitored. Nonsafety-related temperature sensors are located inside the ICS, which give an indication of noncondensable gas buildup. Operators may take steps to mitigate the buildup during the time prior to the automatic action.

C.2

Automatic actions to mitigate hydrogen accumulation are described in Part B of this response. Operators can take manual action to vent during the time prior to the vent valves automatic opening or manually isolate prior to automatic isolation of the ICS. Temperature sensors will provide indication to the operator of hydrogen accumulation.

C.3

DCD Tier 2, Section 5.4.6 will be revised. Markups of the section are enclosed.

D.

D.1

ICS initial pressure and temperature are higher compared to the PCCS at the start of a LOCA due to its direct connection to the RPV. But, the pressure is quickly brought down as the LOCA break depressurizes the RPV and soon after the ADS is activated. Prior to isolation, hydrogen accumulation does not exceed the lower flammability limit. After isolation, the pressure and temperature dramatically drops well below the pressures and temperatures seen by the PCCS during post-72 hour LOCA. See Section 4.2 of the LTR for a more detailed discussion of mitigating combustible build up after isolation.

D.2

Peak pressure ratios used for PCCS are not applicable to ICS prior to their isolation during a LOCA event. The lower flammability limit is not exceeded.

After isolation, peak pressure ratios take credit for steam inside the ICS. See Section 4.2 of the LTR for a discussion on ICS peak pressure ratios after ICS has been isolated.

D.3

The automated venting function during non-LOCA events is accomplished through the existing vent line on the lower header of the ICS. Vent valves F009 and F010 are opened and restricting flow orifice is placed downstream of valve F010. See markups of DCD Tier 2, Figure 5.1-3.

E.

E.1

A complete analysis has been incorporated in Revision 1 of the LTR.

E.2.a

A finite element analysis of the condenser is performed and results are shown in Revision of the LTR. Although results shown are compared to acceptance criteria for Service Level D, most of the components meet Service Level C acceptance criteria. Those components that are not within the Service Level C acceptance criteria can be brought into compliance by reducing conservatism in the pressure load definition or other conservatisms or by making further design changes. Appendix B of the LTR provides additional discussion. The goal of the improved PCCS condenser design is to keep the component within the analyzed elastic range.

E.2.b

Because of its passive design, the PCCS condenser does not rely on the functionality of mechanical components to provide its heat removal functionality. If the condenser retains its pressure integrity while remaining in the elastic range, then by extension it retains its heat removal capability. A Service Level C allowable will be used to assure components remain in the elastic range. See Appendix B of the LTR for further discussion on the application of Service Level C.

E.2.c

The goal of the improved PCCS condenser design is to keep the component within the elastic range for the analysis.

E.3

Twelve detonation cycles are postulated in the 72 hour period associated with a LOCA. Assuming the initial postulated detonation occurs after six hours of the LOCA (it takes approximately six hours to relocate the remaining nitrogen in the drywell to the wetwell via the PCCS vents lines), it will take about 6.8 hours to accumulate the bounding load mixture within the PCCS. Then subsequent detonations are postulated at a 6.8-hour interval, which gives a total of 10 detonations. The 12 detonations assumed in the analysis provides additional margin.

The refilling time of the PCCS is based on conservatively assuming radiolytic gases are only available to fill the PCCS. Figure 6.2-202 S0.3 shows radiolytic production of hydrogen and oxygen for ESBWR post-LOCA.

E.3.a

New mitigation strategies have been described in the LTR such that the approach to Section 3.0 in Rev. 0 of the LTR is no longer necessary. Instead of tabulating an array of different DLFs in Section 3.0, a more detailed discussion has been provided in Section 2.0 that discusses the new mitigation strategies, and how they are justified.

E.3.b

The LTR has been revised to include a discussion of the topic of delayed DDT.

E.3.c

Please refer to the revised LTR for more detailed discussion of DDT.

E.3.d

Reflected waves are a factor that was considered and accounted for by the 2.5 multiplication factor in Revision 0 of the LTR. This is unchanged in Revision 1 of the LTR.

E.3.e

The presence of diluents in the gas mixture is discussed in more detail in the LTR, particularly as is relates to delayed DDT.

E.3.f

A discussion of the effects of initial temperature on peak pressure was provided in Revision 0 of the LTR (Section 2.2.1.2), and is included in Revision 1.

E.3.g

The assumption that reflections take place within the PCCS, bounds the effects of geometry on amplification of peak detonation pressures. A factor of 2.5 is used to account for reflections. The LTR notes the use of dynamic load factors on PCCS components affected by detonations when they apply.

E.3.h

The modified PCCS will be included in Appendix B of the final response.

E.4

Revision 1 of the LTR has been updated with additional details and results.

E.5.a

Finite element analysis is used for the PCCS condenser components to evaluate detonation loads statically with dynamic load factors for the PCCS tubes, PCCS tube-to-header connections, the PCCS lower header, and the PCCS lower header connection to pool floor. The PCCS condenser as a whole with its supporting structure is evaluated using finite element analysis with load combinations as given in Table A-1 in Appendix A of the LTR.

E.5.b

The effects of detonations on the entire PCCS assembly including its supporting structure are bounded by the seismic loading. An alternate calculation, which takes into account the dynamic nature of detonation, shows the reaction forces on the anchoring due to a detonation are bounded by the reaction forces due to seismic loading. The alternate calculation was conducted using LS-DYNA, which through partnership, has been adopted into the ANSYS Software suite under the trade name ANSYS LS-DYNA.

E.5.c

The 40 percent margin commitment made in the previous response to RAI 6.2-202 was made to account for uncertainties in the dynamic response of the PCCS supporting structures. The margin is not applicable, since a dynamic analysis has shown the seismic loading is bounding. The margin previously provided was based on a Service Level D allowable, which is not applicable due to the change to Service Level C.

E.5.d

The meshing used in the FE models is sufficient to capture stress concentrations in the locations of concern such as pipe and tube bends, and the weld junction of the tubes to the drums.

F.

F.1

Section 5.0 of the LTR has been revised to more clearly state the requirements for the ICS and PCCS condensers.

F.2

Section III Subsection NC-5000 of the ASME Code allows the substitution of UT and PT for RT under certain circumstances. This is described more clearly in the revised Section 5.0 of the LTR.

F.3

Section 5.0 of the LTR has been revised to more clearly state the tube bending requirements for the ICS.

F.4

Section 5.0 of the LTR has been revised to more clearly state the acceptable weld filler metal for the ICS tube to header welds.

G.

The qualification of TRACG for calculations involving noncondensable gases is documented in NEDE-32177, NEDE-33083 Supplement 0, NEDC-32725 and NEDC-33080. Important phenomenon considered in the qualification, include light noncondensables, and purging of noncondensables (Table 3.2-1 NEDE-33083 Supplement 0). The code includes documented models which cover these phenomenon as shown on Table 3.3-1 of NEDE-33083 Supplement 0. The code is qualified against specific tests which cover these phenomenon identified in Tables 3.3-3 and 3.3-4 of NEDE-33083 Supplement 0. The scaling of TRACG to the tests has been documented in NEDC-33082.

Evaluations of combustible concentrations with TRACG are consistent with the models used for containment pressure calculations. Radiological generation of hydrogen and oxygen is determined with a conservative G-factor. No credit is taken for dilution of combustible gas by nitrogen, the total noncondensable gas fraction is assumed to be consistent of hydrogen and oxygen with no nitrogen component. TRACG is not relied on to determine the exact location of non-condensables in the tube bundle; it is used only to determine which components have high concentrations.

The ICS/PCCS pool temperature is also used to bound the lowest steam partial pressure inside the PCCS through the use of steam tables. The steam/gas mixture temperature inside the condenser can not be lower than the outside pool temperature.

The PCCS configuration is compared to the PANTHERS prototype below.

	Number of Tubes	Tube Thickness, mm	Tube Inner Diameter, mm	Tube Material Thermal Conductivity[1], W/m-K
PANTHERS	[[ ]]	[[ ]]	[[ ]]	16.5
DCD Rev. 7	560	[[ ]]	[[ ]]	16.5
Current Configuration (NEDE-33572)	[[ ]]	[[ ]]	[[ ]]	12.8

1. Values at a temperature of 121 °C. TRACG analyses use temperature dependent thermal conductivities for the specific material specified.

Based on the codes ability to predict PCCS performance the PANTHER's prototype tests as well as single tube tests, PANDA and GIRAFFE integral tests, the current configuration is within the application range of the TRACG code to accurately calculate PCCS performance.

DCD Impact

LTR NEDE-33572P, Rev 0 will be revised.

DCD Tier 1 and 2 will be revised as noted in the attached markups. The sections, tables, and figures are identified below.

Tier 1

Section 2.4.1

Table 2.4.1-1

Table 2.4.1-3

Figure 2.4.1-1

Table 2.15.1-1a

Section 2.15.4

Table 2.15.4-1

Table 2.15.4-2

Figure 2.15.4-1

Table 3.8-1

Tier 2

Figure 1.1-2

Subsection 1.2.2.4.1

Subsection 1.2.2.15.4

Table 1.6-1

Table 3.2-1

Subsection 3.8.2.6

Subsection 3.8.7

Table 3.8-4

Table 3.9-8

Table 3.11-1

Subsection 3G.1.6

Figure 5.1-3

Subsection 5.4.6.1.1

Subsection 5.4.6.2.2

Subsection 5.4.6.2.3

Subsection 5.4.6.5

Section 5.4.16

Table 5.4-1

Table 6.1-1

Subsection 6.2.1.1.10.2

Subsection 6.2.2.1

Subsection 6.2.2.2.2

Subsection 6.2.2.2.3

Subsection 6.2.2.4

Subsection 6.2.5.5.1

Section 6.2.9

Table 6.2-6a

Table 6.2-10

Table 6.2-24

Table 6.2-26

Table 6.2-28

Table 6.2-30

Figure 6.2-15

Figure 6.2-16

Section 7.3.2

Subsection 7.4.4.3

Subsection 15.5.5.3

Table 15.5-10a

Table 15.5-10b

Chapter 16 SR 3.6.1.7.4

Chapter 16 SR 3.6.1.7.5

Chapter 16 B3.5.4

Chapter 16 B3.6.1.7

Subsection 19A.6.1.3.1

Chapter 19 AC B3.6.3

[[

{3}]]

Figure 6.2-202 S01.1. ICS Pressure During Main Steam Line Break LOCA with ICS Isolation at 1060 Seconds.

[[

]]

Notes: 0.2 NC gas fractions correspond to 80% steam concentration.

Figure 6.2-202 S01.2. Noncondensable (NC) Gas Fractions in ICS During SBO with Venting (Orifice Flow Area of 0.167 cm^2)

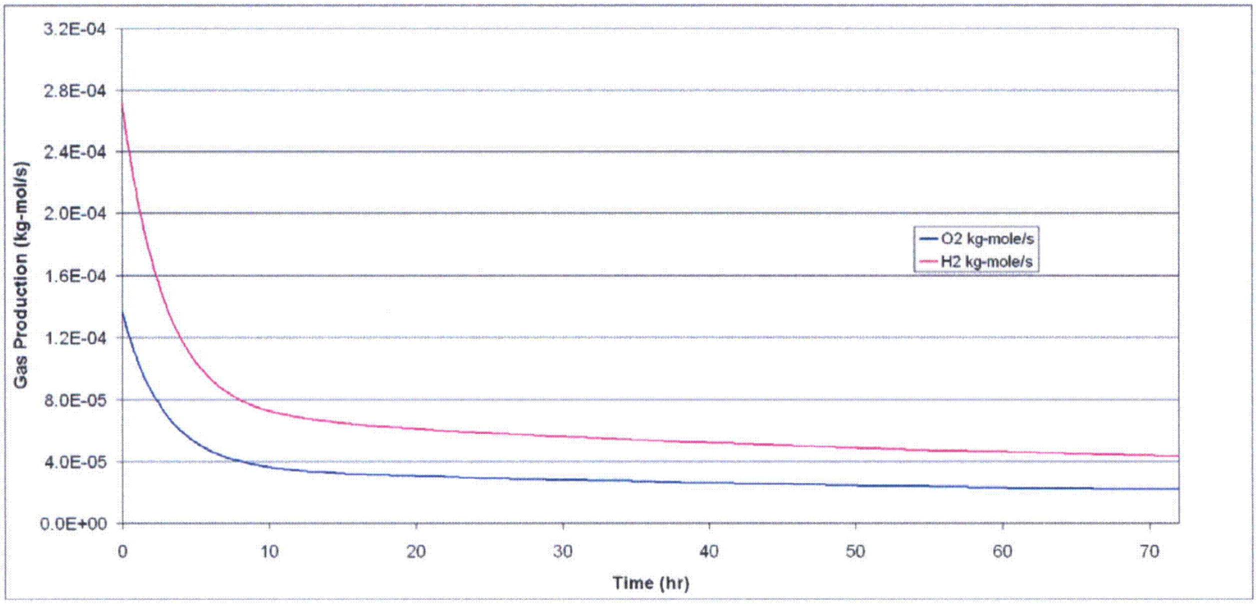


Figure 6.2-202 S0.3. ESBWR Post-LOCA Radiolytic Gas Production of Hydrogen and Oxygen in RPV

Enclosure 3

MFN 10-044 Supplement 1

Response to NRC Request for Additional Information Letter No. 411 Related to ESBWR Design Certification Application

Engineered Safety Features

RAI Number 6.2-202 S01

Markups to ESBWR DCD Tier 1 and Tier 2

2.4 CORE COOLING SYSTEMS USED FOR ABNORMAL EVENTS

The following subsections describe the core cooling systems in response to Abnormal Operating Occurrences (AOOs) and accidents.

2.4.1 Isolation Condenser System

Design Description

The Isolation Condenser System (ICS) removes decay heat from the RPV when the reactor is isolated. Decay heat removal keeps the RPV pressure below the SRV pressure setpoint. ICS consists of four independent trains, each containing a heat exchanger that condenses steam on the tube side and transfers heat by heating and boiling water in the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pools, which is then vented to the atmosphere. The ICS is as shown in Figure 2.4.1-1.

The environmental qualification of ICS components is addressed in Section 3.8; and the environmental and seismic qualification of digital instrumentation and controls equipment is addressed in Section 3.8.

The containment isolation portions of the ICS are addressed in Subsection 2.15.1.

ICS software is developed in accordance with the software development program described in Section 3.2.

Conformance with IEEE Standard 603 requirements by the safety-related control system structures, systems, or components is addressed in Subsection 2.2.15.

The ICS alarms, displays, controls, and status indications in the main control room are addressed in Section 3.3.

(1) The functional arrangement of the ICS is as described in the Design Description of this Subsection 2.4.1, Table 2.4.1-1, Table 2.4.1-2, and as shown in Figure 2.4.1-1.

(2) a1. The components identified in Table 2.4.1-1 as ASME Code Section III are designed in accordance with ASME Code Section III requirements.

a2. The components identified in Table 2.4.1-1 as ASME Code Section III shall be reconciled with the design requirements.

a3. The components identified in Table 2.4.1-1 as ASME Code Section III are fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

b1. The piping identified in Table 2.4.1-1 as ASME Code Section III is designed in accordance with ASME Code Section III requirements.

b2. The as-built piping identified in Table 2.4.1-1 as ASME Code Section III shall be reconciled with the piping design requirements.

b3. The piping identified in Table 2.4.1-1 as ASME Code Section III is fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

(3) a. Pressure boundary welds in components identified in Table 2.4.1-1 as ASME Code Section III meet ASME Code Section III non-destructive examination requirements.

b. Pressure boundary welds in piping identified in Table 2.4.1-1 as ASME Code Section III meet ASME Code Section III non-destructive examination requirements.

(4) a. The components identified in Table 2.4.1-1 as ASME Code Section III retain their pressure boundary integrity at their design pressure.

b. The piping identified in Table 2.4.1-1 as ASME Code Section III retains its pressure boundary integrity at its design pressure.

(5) The equipment identified in Table 2.4.1-1 and Table 2.4.1-2 as Seismic Category I can withstand Seismic Category I loads without loss of safety function.

(6) a. Each of the ICS divisions (or safety-related loads/components) identified in Table 2.4.1-2 is powered from its respective safety-related division.

b. In the ICS, independence is provided between safety-related divisions, and between safety-related divisions and non-safety related equipment.

(7) a. Each mechanical train of the ICS located outside the containment is physically separated from the other train(s) so as not to preclude accomplishment of the intended safety-related function.

b. Each mechanical train of the ICS located inside the containment is physically separated from the other train(s) so as not to preclude accomplishment of the intended safety-related function.

(8) (Deleted)

(9) Re-positionable (NOT squib) valves designated in Table 2.4.1-1 open, close, or both open and close, under differential pressure, fluid flow, and temperature conditions.

(10) The pneumatically operated valve(s) designated in Table 2.4.1-1 fail in the mode listed if either electric power to the valve actuating solenoid is lost, or pneumatic pressure to the valve(s) is lost.

(11) (Deleted)

(12) (Deleted)

(13) Each condensate return valve, listed in Table 2.4.1-1, opens to initiate the ICS.

(14) The normally open ICS isolation valves in the steam supply and condensate return lines, listed in Table 2.4.1-1, close automatically on receipt of high vent line radiation from the Process Radiation Monitoring System (PRMS).

(15) The normally open ICS isolation valves in the steam supply and condensate return lines, listed in Table 2.4.1-1, close ~~upon~~automatically on receipt of the following automatic actuation signals: ~~from the~~

• LD&IS

• Time delay following DPV's opening

(16) Each ICS train normally closed condensate return valve, listed in Table 2.4.1-1, opens upon receipt of the following automatic actuation signals:

•RPV high pressure following a time delay

- RPV water level below level 2 following a time delay
- RPV water level below level 1
- Loss of power to 2 of 4 reactor feed pumps with the reactor mode switch in RUN
- MSIVs in 2 of 4 steam lines less than fully open with the reactor mode switch in RUN

(17) Each ICS train normally closed condensate return bypass valve, listed in Table 2.4.1-1, opens upon receipt of the following automatic actuation signals:

- RPV high pressure following a time delay
- RPV water level below level 2 following a time delay
- RPV water level below level 1
- Loss of power to 2 of 4 reactor feed pumps with the reactor mode switch in RUN
- MSIVs in 2 of 4 steamlines less than fully open with the reactor mode switch in RUN.

(18) The two-series, solenoid-operated lower vent line valves, listed in Table 2.4.1-1, open upon receipt of the following automatic actuation signals:

- hHigh RPV pressure after time delay following condensate return or condensate bypass valve opening signals.
- Time delay following condensate return and condensate bypass valve opening

(19) The three vent lines with two-series, solenoid-operated upper and lower vent line valves, listed in Table 2.4.1-1, open on manual actuation only if condensate return or condensate bypass valve is not closed.

(20) The accumulators for the pneumatic isolation valves, shown in Table 2.4.1-1, in the ICS steam supply and condensate return valves have the capacity to close the valves three times with the DW at the DW design pressure.

(21) Upon loss of pneumatic pressure to the condensate bypass valve (V-6), the valve strokes to the fully open position.

(22) Each ICS train has at least the minimum heat removal capacity assumed in analysis of Abnormal Events with reactor at or above normal operating pressure.

(23) Each ICS train provides at least the minimum drainable liquid volume available for return to the RPV assumed in analysis of Abnormal Events.

(24) The Equipment Pool and Reactor Well provide sufficient makeup water volume to the IC/PCCS expansion pool to support operation of the ICS and PCCS for the first 72 hours.

(25) The IC/PCCS pools are safety-related and Seismic Category I.

(26) Each ICS flow path is constrained to a maximum flow area at transitions between Class 1 piping from containment to Class 2 piping outside containment in order to limit flow in the event of a break.

(27) (Deleted)

(28) (Deleted)

Table 2.4.1-1

ICS Mechanical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated	Loss of Motive Power Position
Lower IC (A) Header Vent Line Valve	V-9(A)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (A) Header Vent Line Valve	V-10(A)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (A) Header Vent Line Valve	V-11(A)	Yes	Yes	No	Yes	No	
Lower IC (A) Header Vent Line Valve	V-12(A)	Yes	Yes	No	Yes	Yes	Open
Lower IC (A) Header Vent Line Restricting Orifice of 0.167 cm^2 (0.0259 in^2) flow area.	RO(A)	Yes	Yes	No	No	No	-
Train B Isolation Condenser							
IC (B) Heat Exchanger	–	Yes	Yes	No	–	–	–
Inline Vessel (B)	–	Yes	Yes	Yes	–	–	–
IC (B) Steam Supply Line	P-1(B)	Yes	Yes	Yes	–	–	–
IC (B) Steam Supply Line Isolation Valve	V-1(B)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (B) Steam Supply Line Isolation Valve	V-2(B)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (B) Condensate Return Line	P-2(B)	Yes	Yes	Yes	No	–	–
IC (B) Condensate Return Line Isolation Valve	V-3(B)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (B) Condensate Return Line Isolation Valve	V-4(B)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (B) Condensate Return Line Valve	V-5(B)	Yes	Yes	Yes	No	Yes	As-Is

Table 2.4.1-1

ICS Mechanical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated	Loss of Motive Power Position
IC (B) Condensate Return Line Bypass Valve	V-6(B)	Yes	Yes	Yes	No	Yes	Open
Upper IC (B) Header Vent Line	–	Yes	Yes	No	–	–	–
Upper IC (B) Header Vent Line Valve	V-7(B)	Yes	Yes	No	Yes	Yes	Closed
Upper IC (B) Header Vent Line Valve	V-8(B)	Yes	Yes	No	Yes	Yes	Closed
Lower IC (B) Header Vent Line	–	Yes	Yes	No	–	–	–
Lower IC (B) Header Vent Line Valve	V-9(B)	Yes	Yes	No	Yes	Yes	~~Closed~~<u>Open</u>
Lower IC (B) Header Vent Line Valve	V-10(B)	Yes	Yes	No	Yes	Yes	~~Closed~~<u>Open</u>
Lower IC (B) Header Vent Line Valve	V-11(B)	Yes	Yes	No	Yes	No	NA
Lower IC (B) Header Vent Line Valve	V-12(B)	Yes	Yes	No	Yes	Yes	Open
<u>Lower IC (B) Header Vent Line Restricting Orifice of 0.167 cm^2 (0.0259 in^2) flow area.</u>	<u>RO(B)</u>	<u>Yes</u>	<u>Yes</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>–</u>
Train C Isolation Condenser	–	–	–	–	–	–	–
IC (C) Heat Exchanger	–	Yes	Yes	No	–	–	–
Inline Vessel (C)	–	Yes	Yes	Yes	–	–	–
IC (C) Steam Supply Line	P-1(C)	Yes	Yes	Yes	–	–	–
IC (C) Steam Supply Line Isolation Valve	V-1(C)	Yes	Yes	Yes	Yes	Yes	As-Is

Table 2.4.1-1

ICS Mechanical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated	Loss of Motive Power Position
IC (C) Steam Supply Line Isolation Valve	V-2(C)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (C) Condensate Return Line	P-2(C)	Yes	Yes	Yes	No	–	–
IC (C) Condensate Return Line Isolation Valve	V-3(C)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (C) Condensate Return Line Isolation Valve	V-4(C)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (C) Condensate Return Line Valve	V-5(C)	Yes	Yes	Yes	No	Yes	As-Is
IC (C) Condensate Return Line Bypass Valve	V-6(C)	Yes	Yes	Yes	No	Yes	Open
Upper IC (C) Header Vent Line	–	Yes	Yes	No	–	–	–
Upper IC (C) Header Vent Line Valve	V-7(C)	Yes	Yes	No	Yes	Yes	Closed
Upper IC (C) Header Vent Line Valve	V-8(C)	Yes	Yes	No	Yes	Yes	Closed
Lower IC (C) Header Vent Line	–	Yes	Yes	No	–	–	–
Lower IC (C) Header Vent Line Valve	V-9(C)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (C) Header Vent Line Valve	V-10(C)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (C) Header Vent Line Valve	V-11(C)	Yes	Yes	No	Yes	No	–
Lower IC (C) Header Vent Line Valve	V-12(C)	Yes	Yes	No	Yes	Yes	Open

Table 2.4.1-1

ICS Mechanical Equipment

Equipment Name (Description)	Equipment Identifier See Figure ~~2.4.1-1~~	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated	Loss of Motive Power Position
Lower IC (C) Header Vent Line Restricting Orifice of 0.167 cm^2 (0.0259 in^2) flow area.	RO(C)	Yes	Yes	No	No	No	-
Train D Isolation Condenser	–	–	–	–	–	–	–
IC (D) Heat Exchanger	–	Yes	Yes	No	No	–	
Inline Vessel (D)	–	Yes	Yes	Yes	No		–
IC (D) Steam Supply Line	P-1(D)	Yes	Yes	Yes	No	–	–
IC (D) Steam Supply Line Isolation Valve	V-1(D)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (D) Steam Supply Line Isolation Valve	V-2(D)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (D) Condensate Return Line	P-2(D)	Yes	Yes	Yes	No	–	–
IC (D) Condensate Return Line Isolation Valve	V-3(D)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (D) Condensate Return Line Isolation Valve	V-4(D)	Yes	Yes	Yes	Yes	Yes	As-Is
IC (D) Condensate Return Line Valve	V-5(D)	Yes	Yes	Yes	No	Yes	As-Is
IC (D) Condensate Return Line Bypass Valve	V-6(D)	Yes	Yes	Yes	No	Yes	Open
Upper IC (D) Header Vent Line	–	Yes	Yes	No	No	–	–
Upper IC (D) Header Vent Line Valve	V-7(D)	Yes	Yes	No	Yes	Yes	Closed
Upper IC (D) Header Vent Line Valve	V-8(D)	Yes	Yes	No	Yes	Yes	Closed

Table 2.4.1-1

ICS Mechanical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated	Loss of Motive Power Position
Lower IC (D) Header Vent Line	–	Yes	Yes	No	No	–	–
Lower IC (D) Header Vent Line Valve	V-9(D)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (D) Header Vent Line Valve	V-10(D)	Yes	Yes	No	Yes	Yes	~~Closed~~Open
Lower IC (D) Header Vent Line Valve	V-11(D)	Yes	Yes	No	Yes	No	–
Lower IC (D) Header Vent Line Valve	V-12(D)	Yes	Yes	No	Yes	Yes	Open
Lower IC (D) Header Vent Line Restricting Orifice of 0.167 cm^2 (0.0259 in^2) flow area	RO(D)	Yes	Yes	No	No	-	-
Pool Cross-Connect Valve (Squib)	V-13(A)	Yes	Yes	No	No	Yes	As-is
Pool Cross-Connect Valve (Pneumatic)	V-14(A)	Yes	Yes	No	No	Yes	As-is
Pool Cross-Connect Valve (Squib)	V-13(B)	Yes	Yes	No	No	Yes	As-is
Pool Cross-Connect Valve (Pneumatic)	V-14(B)	Yes	Yes	No	No	Yes	As-is

Table 2.4.1-3

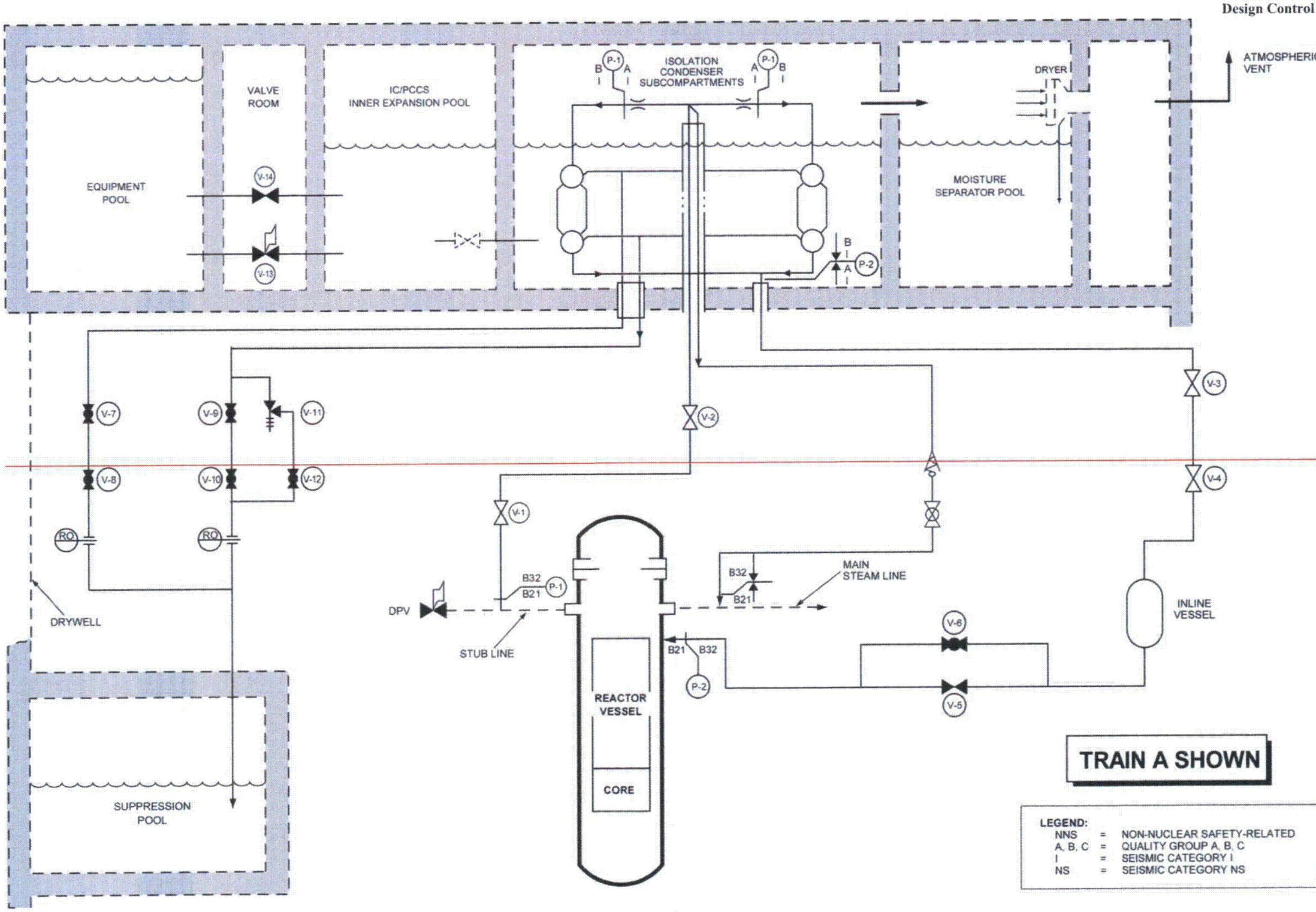
ITAAC For The Isolation Condenser System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
14. The normally open ICS isolation valves in the steam supply and condensate return lines, listed in Table 2.4.1-1, close automatically on receipt of high vent line radiation from the Process Radiation Monitoring System (PRMS).	An isolation valve closure test will be performed using simulated signals.	The ICS isolation valves close upon receipt of signals from the PRMS.
15. The normally open ICS isolation valves in the steam supply and condensate return lines, listed in Table 2.4.1-1, close upon ~~automatically on~~ receipt of the following automatic actuation signals: • ~~signals from the~~ LD&IS~~.~~ • Time Delay following DPV's opening	An isolation valve closure test will be performed using simulated signals.	The ICS isolation valves close upon receipt of signals from the LD&IS.

Table 2.4.1-3

ITAAC For The Isolation Condenser System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
17. Each ICS train normally closed condensate return bypass valve, listed in Table 2.4.1-1, opens upon receipt of the following automatic actuation signals: • RPV high pressure following a time delay • RPV water level below level 2 following a time delay • RPV water level below level 1 • Loss of power to 2 of 4 reactor feed pumps with the reactor mode switch in RUN • MSIVs in 2 of 4 steamlines less than fully open with the reactor mode switch in RUN.	Valve opening tests will be performed using simulated automatic actuation signals.	The condensate return valves open upon receipt of automatic actuation signals.
18. The two-series, solenoid-operated lower vent line valves, listed in Table 2.4.1-1, open upon receipt of the following automatic actuation signals: • ~~on h~~High RPV pressure after time delay following condensate return or condensate bypass valve opening signals~~.~~ • Time delay following condensate return or condensate bypass valve opening signals	Valve opening tests will be performed using simulated automatic actuation signals~~A valve opening test will be performed using simulated high reactor pressure after a time delay following condensate return or condensate bypass valve opening signals~~.	The two-series, solenoid-operated lower vent line valves, open upon receipt of automatic actuation~~The two-series, solenoid-operated vent line valves open on a simulated high RPV pressure signal after a time delay following condensate return or condensate bypass valve opening signals~~.


EQUIPMENT POOL
VALVE ROOM
IC/PCCS INNER EXPANSION POOL
ISOLATION CONDENSER SUBCOMPARTMENTS
MOISTURE SEPARATOR POOL
DRYER
ATMOSPHERIC VENT
DRYWELL
SUPPRESSION POOL
DPV
STUB LINE
REACTOR VESSEL
CORE
MAIN STEAM LINE
INLINE VESSEL
TRAIN A SHOWN
LEGEND:
NNS = NON-NUCLEAR SAFETY-RELATED
A, B, C = QUALITY GROUP A, B, C
I = SEISMIC CATEGORY I
NS = SEISMIC CATEGORY NS

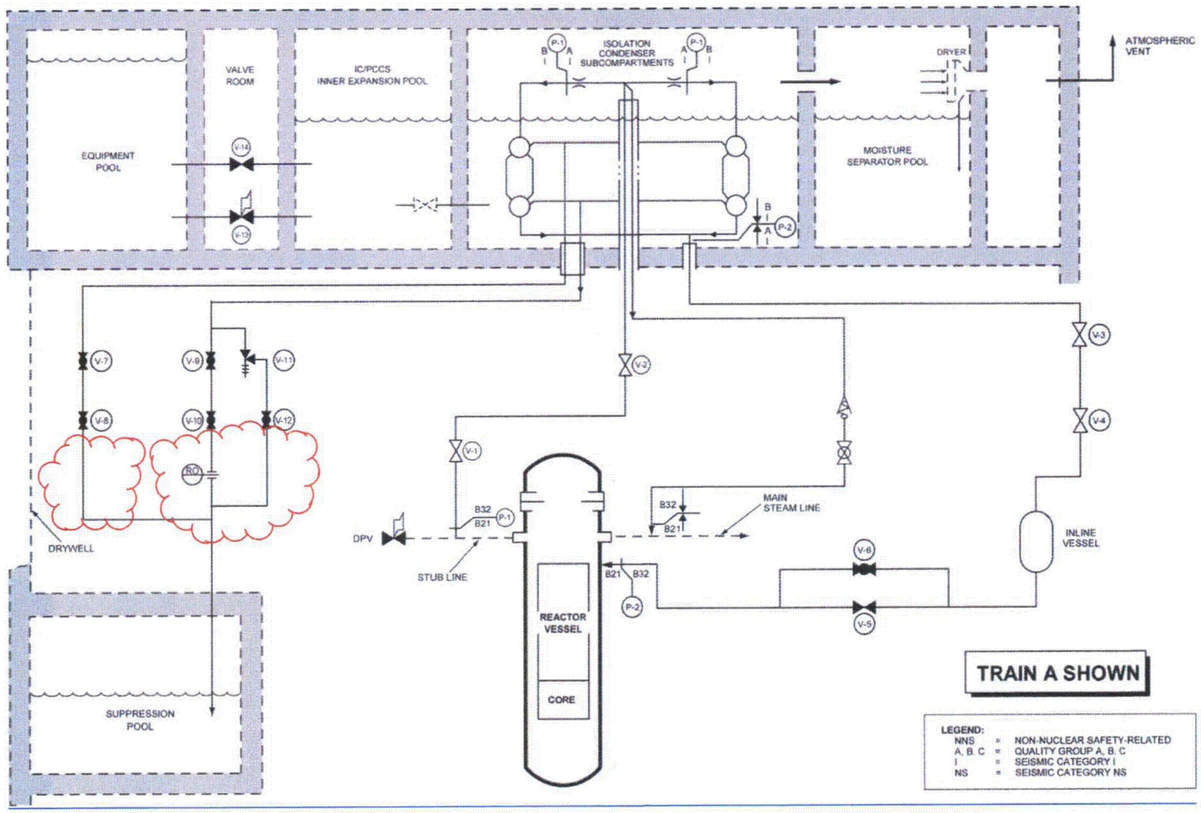


Figure 2.4.1-1. Isolation Condenser System Schematic

Table 2.15.1-1a

Containment System Penetrations[1] and Equipment

Equipment Name	ASME Code Section III	Seismic Cat. I	Remote Manual Operation	Safety-Related	Containment Isolation Signal	Normal Position	Post-Accident Position	Loss of Motive Power Position
Inboard condenser lower header inboard vent valve (4 valves)	Yes	Yes	Yes	Yes	No	closed	open/closed	~~closed~~open
Outboard condenser lower header outboard vent valve (4 valves)	Yes	Yes	Yes	Yes	No	closed	Open/closed	~~closed~~open
Inboard bypass lower header inboard vent valve (4 valves)	Yes	Yes	No	Yes	No	closed	open/closed	–
Outboard bypass lower header outboard vent valve (4 valves)	Yes	Yes	Yes	Yes	No	closed	open/closed	open
Standby Liquid Control								
Total 2 Penetrations (One penetration per SLC injection line)								
SLC injection line squib valve (4 valves)	Yes	Yes	No	Yes	No	closed	open	as-is
SLC injection line outboard check valve (2 valves)	Yes	Yes	No	Yes	No	closed	open/closed	–
SLC injection line inboard check valve (2 valves)	Yes	Yes	No	Yes	No	closed	open/closed	N/A
Process Radiation Monitoring								
Total 2 Penetrations (One penetration per DW Fission Product Monitoring Line)								
DW Fission Product Monitoring Line Inboard isolation Valve (1 valve)	Yes	Yes	Yes	Yes	Yes	open	open	as-is
DW Fission Product Monitoring Line Outboard isolation Valve (1 valve)	Yes	Yes	Yes	Yes	Yes	open	open	as-is

2.15.4 Passive Containment Cooling System

Design Description

The Passive Containment Cooling System (PCCS), in conjunction with the suppression pool, maintains the containment within its pressure limits for DBAs such as a LOCA, by condensing steam from the DW atmosphere and returning the condensed liquid to the Gravity Driven Cooling System (GDCS) pools. The system is passive, with no components that must actively function in the first 72 hours after a DBA.

The environmental qualification of PCCS components is addressed in Section 3.8.

(1) The functional arrangement for the PCCS is as described in the Design Description in this Subsection 2.15.4, Table 2.15.4-1 and Figure 2.15.4-1.

(2) a1. The components identified in Table 2.15.4-1 as ASME Code Section III are designed in accordance with ASME Code Section III requirements.

a2. The components identified in Table 2.15.4-1 as ASME Code Section III shall be reconciled with the design requirements.

a3. The components identified in Table 2.15.4-1 as ASME Code Section III are fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

b1. The piping identified in Table 2.15.4-1 as ASME Code Section III is designed in accordance with ASME Code Section III requirements.

b2. The as-built piping identified in Table 2.15.4-1 as ASME Code Section III shall be reconciled with the piping design requirements.

b3. The piping identified in Table 2.15.4-1 as ASME Code Section III is fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

(3) a. Pressure boundary welds in components identified in Table 2.15.4-1 as ASME Code Section III meet ASME Code Section III non-destructive examination requirements.

b. Pressure boundary welds in piping identified in Table 2.15.4-1 as ASME Code Section III meet ASME Code Section III non-destructive examination requirements.

(4) a. The components identified in Table 2.15.4-1 as ASME Code Section III retain their pressure boundary integrity at their design pressure.

b. The piping identified in Table 2.15.4-1 as ASME Code Section III retains its pressure boundary integrity at its design pressure.

(5) The equipment identified in Table 2.15.4-1 as Seismic Category I can withstand Seismic Category I loads without loss of safety function.

(6) Each mechanical train of the PCCS located inside the containment is physically separated from the other train(s) so as not to preclude accomplishment of the intended safety-related function.

(7) The PCCS together with the pressure suppression containment system will limit containment pressure to less than its design pressure for 72 hours after a LOCA.

(8) (Deleted)

(9) The elevation of the PCCS vent line discharge point is submerged in the suppression pool at an elevation below low water level and above the uppermost horizontal vent.

(10) The PCCS will be designed to limit the fraction of containment leakage through the condensers to an acceptable value.

(11) The PCCS vent fans flow rate is sufficient to meet the beyond 72 hours containment cooling requirements following a design basis LOCA.

(12) The PCCS vent fans can be remotely operated from the MCR.

(13) The PCCS drain piping is installed to allow venting of non-condensable gases from the PCCS drain lines to the PCCS condenser vent lines to prevent collection in the PCCS drain lines.

(14) The elevation of the PCCS vent fan discharge point is submerged within the drain pan located in the GDCS pool at an elevation below the lip of the drain pan.

(15) PCCS vent catalyst modules are mounted within each PCCS vent line.

(16) To reduce hydrogen accumulation in the PCCS vent lines, vent line catalyst modules recombine hydrogen at a required minimum rate at a minimum allowed velocity.

Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.15.4-2 provides a definition of the inspections, tests and analyses, together with associated acceptance criteria for the Passive Containment Cooling System.

Table 2.15.4-1

Passive Containment Cooling System Mechanical Equipment

Equipment Name (Description)	Equipment Identifier see Figure 2.15.4-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated Valve	Loss of Motive Power Position
PCCS Heat Condenser	PCCS Condenser	Yes	Yes	No	–	–	–
PCCS Inlet Line	P-1(A[1])	Yes	Yes	No	–	–	–
Condensate Drain Line	P-2(A[1])	Yes	Yes	No	–	–	–
Vent Fan ~~Check~~Isolation Valve	~~Check~~ Vent Fan Isolation Valve	Yes	Yes	No	–No	–Yes	–As-Is
Non-Condensables Vent Line	P-3(A[1])	Yes	Yes	No	–	–	–
Vent Fan	Vent Fan	No	No	No	–	–	–
Non-Condensables Vent Line Sparger	Sparger	No	Yes	No	–	–	–
PCCS Inlet Pipe Debris Filter	–	No	Yes	No	–	–	–
PCCS Vent Fan Line	P-4 (A[1])	Yes	No	No	–	–	–

Equipment Name (Description)	Equipment Identifier see Figure 2.15.4-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve	Remotely Operated Valve	Loss of Motive Power Position
PCCS Vent Fan Catalyst Module	-	No	Yes	No	-	-	-

[1] Train A; Typical for Trains B, C, D, E & F.

Table 2.15.4-2

ITAAC For The Passive Containment Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
7. The PCCS together with the pressure suppression containment system will limit containment pressure to less than its design pressure for 72 hours after a LOCA.	Using prototype test data and as-built PCC unit information, an analysis will be performed to establish the heat removal capability of the PCC unit.	Analyzed containment pressure for 72 hours after a LOCA is less than ~~containment design pressure, and the PCC~~ unit heat removal capacity is no less than ~~11~~7.8 MWt given the following conditions: • Pure saturated steam in the tubes at 308 kPa (44~~4.7~~ psia) absolute and 134°C (273°F) • IC/PCCS pool water temperature is at atmospheric pressure and 102°C (216°F)
8. (Deleted)		
9. The elevation of the PCCS vent discharge point is submerged in the suppression pool at an elevation below low water level and above the uppermost horizontal vent.	A visual inspection will be performed of the PCCS vent discharge point relative to the horizontal vents.	The elevation of the discharge on the PCCS vent line is > 0.85 m (33.5 in) and < 0.90 m (35.4 in) above the top of the uppermost horizontal vent.
10. The PCCS will be designed to limit the fraction of containment leakage through the condensers to an acceptable value.	A pneumatic leakage test of the PCCS will be conducted.	The combined leakage from each of the PCCS heat exchangers is ≤0.01% of containment air weight per day.

Table 2.15.4-2

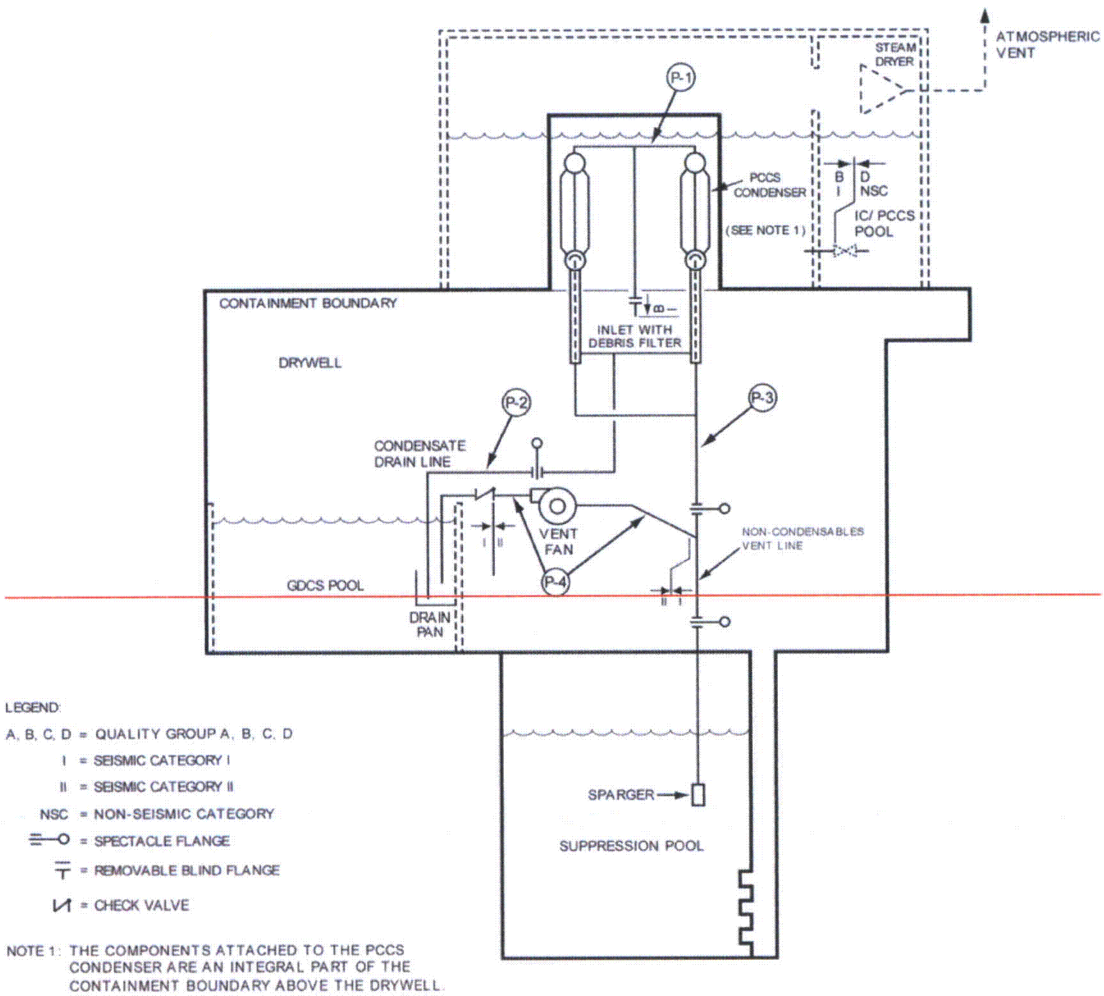
ITAAC For The Passive Containment Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
11. The PCCS vent fans flow rate is sufficient to meet the beyond 72 hours containment cooling requirements following a design bases LOCA.	For each PCCS vent fan line, a flow rate test will be performed with the containment at pre-operational ambient conditions. Flow measurements will be taken on flow to the GDCS pools. An analysis of the test configuration will be performed.	• The tested and analyzed flow rates are greater than or equal to the flow rates of the design basis LOCA containment analysis model for the PCCS vent fan lines at containment pre-operational ambient conditions.
12. The PCCS vent fans can be remotely operated from the MCR.	PCCS vent fans will be started using manually initiated signals from the MCR.	The PCCS vent fans start when manually initiated signals are sent from the MCR.
13. The PCCS drain piping is installed to allow venting of non-condensable gases from the PCCS drain lines to the PCCS condenser vent lines to prevent collection in the PCCS drain lines.	Inspection(s) will be conducted of as-built PCCS drain piping to ensure there are no elevated piping loops or high-point traps in piping runs to the GDCS pools.	Based on inspection(s) of as-built PCCS drain piping, the as-built piping conforms to a design that allows venting of non-condensable gases from the PCCS drain lines to the PCCS condenser vent lines.
14. The elevation of the PCCS vent fan discharge point is submerged within the drain pan located in the GDCS pool at an elevation below the lip of the drain pan.	A visual inspection will be performed of the PCCS vent fan discharge point relative to the lip of the drain pan.	The elevation of the discharge on the PCCS vent fan line is 24 cm (9.4 in) below the top of the drain pan lip with a tolerance of 1.4 cm (0.6 in).
15. PCCS vent catalyst modules are mounted within each PCCS vent line.	Inspection will be performed of the as-built installation of PCCS vent catalyst modules in each PCCS vent line.	A total of 12 PCCS vent catalyst modules are installed with one module per PCCS vent line.

Table 2.15.4-2

ITAAC For The Passive Containment Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
16. To reduce hydrogen accumulation in the PCCS vent lines, vent line catalyst modules recombine hydrogen at a required minimum rate at a minimum allowed velocity.	Type tests will be performed to verify a minimum required hydrogen recombination rate at a minimum allowed velocity.	Type tests show that the as-built catalyst module will recombine hydrogen at a minimum rate of 1.66 kg/h (3.66 lbm/h) when exposed to a test stream consisting of 4% hydrogen in its stoichiometric ratio with oxygen, the balance being inert gas, and whose minimum velocity through the module is 0.166 m/s (0.545 ft/s).



TRAIN A SHOWN

TYPICAL OF TRAIN B, C, D, E & F

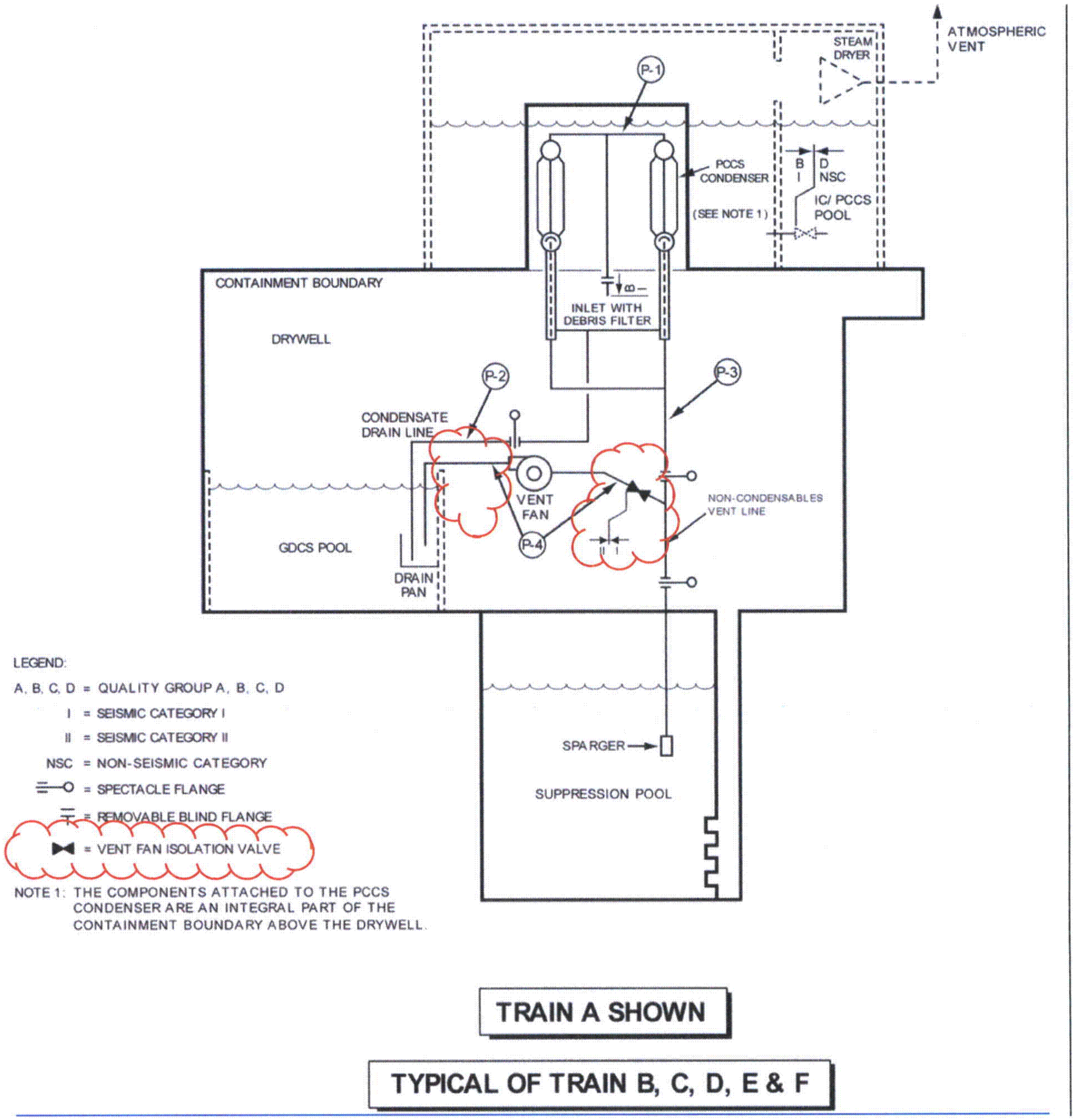
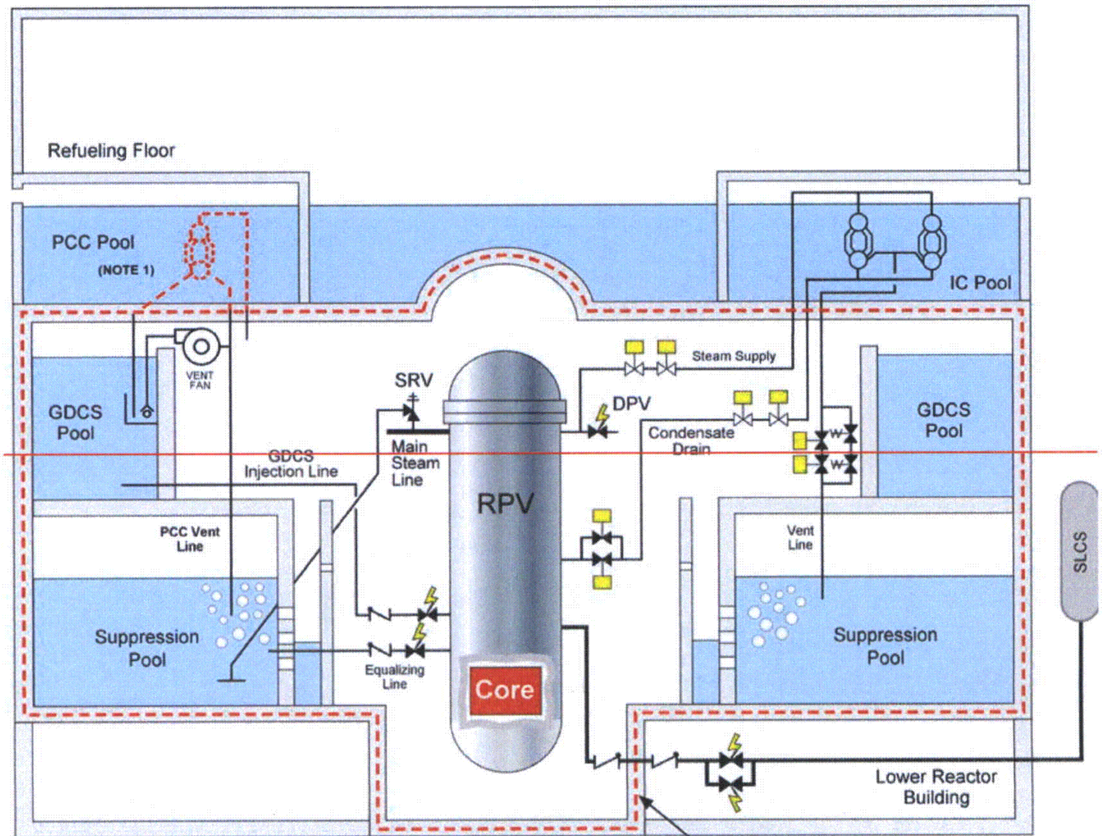


Figure 2.15.4-1. Passive Containment Cooling System Schematic

Table 3.8-1

Electrical and Mechanical Equipment for Environmental Qualification

Components (note 5)	Quantity	Location (note 1)	Function (note 2)	Required Operation Time (note 3)	Qualification Program (note 4)
Isolation Power Center Supply Breaker to Division 250 VDC Normal Battery Charger	12	RB	ISOL	100 Days	E
Electrical Modules and Cable	All	CV, CB, RB, TB	ESF	100 Days	E
Raceway System					
Electrical Penetrations	All	CV	PB	100 Days	EH
Conduit, Cable Trays and Supports	All	CV, CB, RB, TB, FB	ESF	100 Days	EH
Containment System					
Vacuum Breakers	3	CV	ESF	100 Days	MH
Vacuum Breaker Isolation Valves	3	CV	ESF	72 hr	MH
Instrumentation and Cables	All	CV	ESF	100 Days	EH
Basemat Internal Melt Arrest Coolability (BiMAC) Temperature Element	ALL	CV	ESF	100 Days	EH
BiMAC Temperature Switch	ALL	CV	ESF	100 Days	EH
Passive Containment Cooling System					
Vent Fan ~~Check~~ Isolation Valves	6	CV	ESF	100 Days	MH
Passive Containment Cooling System (PCCS) Vent Fan	6	CV	ESF	100 Days	EH
Containment Inerting System					
Isolation Valve	10	CV, RB	ISOL	100 Days	MH



NOTE 1: THE COMPONENTS ATTACHED TO THE PCC CONDENSER ARE AN INTEGRAL PART OF THE CONTAINMENT BOUNDARY ABOVE THE DRYWELL.

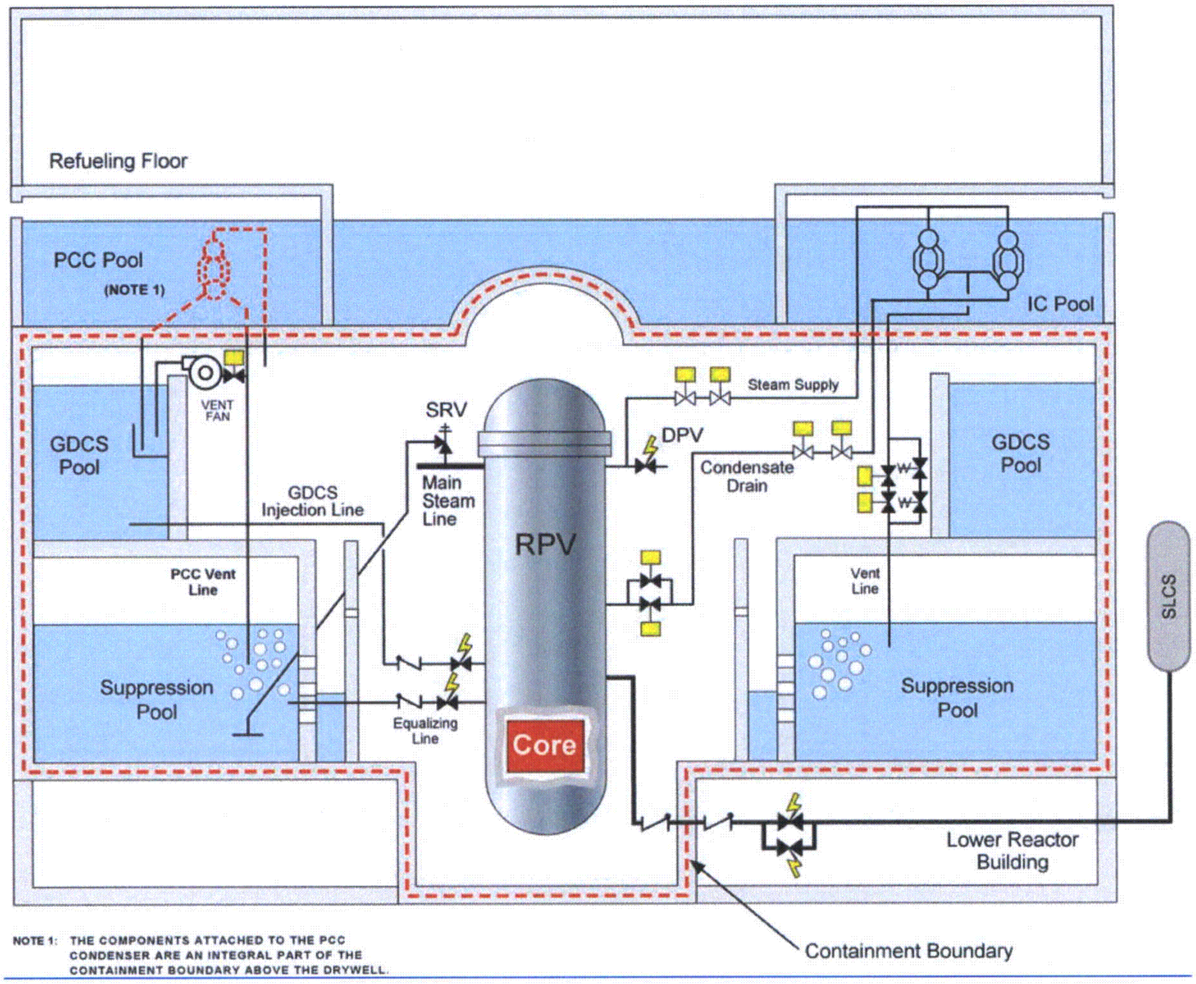


Figure 1.1-2. Safety System Configuration (not to scale)

Legend for figure:

DPV	Depressurization Valve	GDCS	Gravity-Driven Cooling System
IC	Isolation Condenser	PCC	Passive Containment Cooling
RPV	Reactor Pressure Vessel	SLCS	Standby Liquid Control System
SRV	Safety Relief Valve		

- A single channel radiation monitor continuously monitors the Technical Support Center Ventilation intake duct. Upon detection of radioactivity at the outside air intake, the Air Handling Unit outdoor air damper is closed and a filter train fan is started.
- The Fuel Building Ventilation Exhaust Air Handling Unit Radiation Monitoring Subsystem consists of four channels that monitor the radiation level of the air entering the Fuel Building Ventilation unit area exhaust Air Handling Units.
- The Fuel Building Combined Ventilation Exhaust Radiation Monitoring Subsystem continuously monitors halogens, particulates and noble gases releases from the Fuel Building Vent to the Fuel/Reactor Building stack for both normal and accident conditions.
- Separate radiation monitoring subsystems are provided for the Reactor Building/Fuel Building, Turbine Building and Radwaste Building stacks to monitor particulate, iodine and gaseous concentrations in the stack effluent for both normal and accident plant conditions. These stack monitoring subsystems are composed of three sampling channels that are designed to meet the requirements of both 10 CFR 20 for low level effluent releases and Regulatory Guide 1.97 for accident effluent releases. Provisions for monitoring tritium are also provided.

1.2.2.3.2 Area Radiation Monitoring System

The Area Radiation Monitoring System (ARMS) continuously monitors the gamma radiation levels within various key areas throughout the plant and provides an early warning to operating personnel when high radiation levels are detected so the appropriate action can be taken to minimize occupational exposure.

The ARMS consists of a number of channels, each consisting of a Radiation Detection Assembly and a Signal Conditioning Unit. When required, a local Auxiliary Unit with a display and audible alarm is also provided. Each ARMS radiation channel has two independently adjustable trip alarm circuits. One circuit is set to trip on high radiation and the other is set to trip on downscale indication (loss of sensor input). ARMS alarms in both the MCR and at plant local areas. Each ARMS Signal Conditioning Unit is equipped with a test feature that monitors for gross failures and activates an alarm on loss of power or when a failure is detected.

This system is nonsafety-related. The radiation monitors are powered from the nonsafety-related 120 VAC sources.

The trip alarm setpoints are established in the field following equipment installation at the site. The exact settings are based on sensor location, background radiation levels, expected radiation levels, and low occupational radiation exposures.

1.2.2.4 Core Cooling Systems Used For Abnormal Events

1.2.2.4.1 Isolation Condenser System

The Isolation Condenser System (ICS) removes decay heat after any reactor isolation during power operations. Decay heat removal limits further pressure rise and keeps the RPV pressure below the SRV pressure setpoint. It consists of four independent trains, each containing a heat exchanger that condenses steam on the tube side and transfers heat by heating/evaporating water in the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pools, which are vented to the atmosphere.

The ICS is initiated automatically on a high reactor pressure, MSIV closure or a low water level signal. To start an IC into operation, a condensate return valve and condensate return bypass valve are opened, whereupon the standing condensate drains into the reactor and the steam-water interface in the IC tube bundle moves downward below the lower headers to a point in the main condensate return line. The ICS can also be initiated manually from the MCR. A fail-open nitrogen piston-operated condensate return bypass valve is provided for each IC, which opens if power is lost, or on a low reactor water level signal.

An in-line vessel is located on the condensate return line, downstream of the nitrogen motor operated valve. The in-line vessel is located on each ICS train to provide additional condensate volume for the RPV.

The ICS is isolated automatically when either a high radiation level or excess flow is detected in the steam supply line or condensate return line. The ICS is also isolated after the DPVs have been opened.

The Equipment Storage Pool and Reactor Well are designed to have sufficient water volume to provide makeup water to the IC/PCCS expansion pools for the initial 72 hours of a LOCA. This water is supplied via ICS pool cross-connect valves that open on a low level condition in either IC/PCCS inner expansion pool.

The IC/PCCS pool is divided into subcompartments that are interconnected at their lower ends to provide full use of the water inventory for heat removal by any IC. The Fuel and Auxiliary Pools Cooling System (FAPCS) performs cooling and cleanup of IC/PCCS pool water. During IC operation, IC/PCCS pool water can boil, and the steam produced is vented to the atmosphere. This boil-off action of non-radioactive water is a safe means for removing and rejecting all reactor decay heat.

The IC/PCCS pool has an installed capacity that provides at least 72 hours of reactor decay heat removal capability. The heat rejection process can be continued indefinitely by replenishing the IC/PCCS pool inventory. A safety-related FAPCS makeup line is provided to convey emergency makeup water into the IC/PCCS expansion pool from the Fire Protection System or from a valve connection point in the yard area just outside of the reactor building. The flow path for this makeup can be established independent of FAPCS operation, simply by manually opening the isolation valve on the FAPCS makeup line located at grade level in the yard area external to the reactor building.

The ICS passively removes heat from the reactor (i.e., heat transfer from the IC tubes to the surrounding IC/PCCS pool water is accomplished by natural convection, and no forced circulation equipment is required) when the normal heat removal system is unavailable following any of the following events:

- Sudden reactor isolation at power operating conditions;
- During station blackout (i.e., unavailability of all AC power);
- Anticipated Transient Without Scram (ATWS); and
- Loss-of-Coolant Accident (LOCA).

The ICs are sized to remove post-reactor isolation decay heat with 3 of 4 ICs operating and to reduce reactor pressure and temperature to safe shutdown conditions, with ~~occasional~~ venting of radiolytically generated noncondensable gases to the suppression pool. The heat exchangers (ICs) are independent of station AC power and function whenever normal heat removal systems are unavailable to maintain reactor pressure and temperature below limits.

The portions of the ICS (including isolation valves), which are located inside the containment and on the steam lines out to the IC flow restrictors, are designed to ASME Code Section III, Class 1, Quality Group A. Other portions of the ICS are ASME Code Section III, Class 2, Quality Group B. The IC/PCCS pools are safety-related and Seismic Category I.

The control room operators can perform periodic surveillance testing of the ICS valves via manual switches that actuate the isolation valves and the condensate return valves. Status indicators on the valves verify the opening and closure of the valves.

The safety-related monitored parameters for the IC/PCCS pools are pool water level and pool radiation. IC/PCCS pool water level monitoring is a function of the FAPCS, which is addressed in Subsections 1.2.2.6.2 and 9.1.3. IC/PCCS pool radiation monitoring is a function of the PRMS, which is addressed in Subsection 1.2.2.3.1 and Section 11.5.

1.2.2.4.2 Emergency Core Cooling System — Gravity-Driven Cooling System

Emergency core cooling is provided by the Gravity-Driven Cooling System (GDCS) in conjunction with the ADS in case of a LOCA. When an initiation signal is received, the ADS depressurizes the reactor vessel and the GDCS injects sufficient cooling water to maintain the fuel cladding temperatures below temperature limits defined in 10 CFR 50.46.

In the event of a severe accident that results in a core melt with the molten core in the lower drywell region, GDCS floods the lower drywell cavity region with the water inventory of the three GDCS pools and the suppression pool.

The GDCS is an engineered safety feature (ESF) system. It is classified as safety-related and Seismic Category I. GDCS instrumentation and DC power supply are safety-related.

Basic system parameters are:

- Three independent subsystems
  - Short-term cooling (injection)
  - Long-term cooling (equalization)
  - Deluge (drywell flooding)
- Initiation signal: see Subsection 7.3.1
- A time delay between initiation and actuation for short-term water injection
- A time delay between initiation and actuation for long-term water injection
  - Permissive: Interlocked to RPV water level
- Deluge system initiated on high lower drywell floor temperature

1.2.2.15.4 Passive Containment Cooling System

The Passive Containment Cooling System (PCCS) maintains the containment within its pressure limits for design basis accidents such as a LOCA. The system is passive, and requires no moving components for initiation or operation.

The PCCS consists of six low pressure, independent steam condenser modules (passive containment cooling condensers) that condense steam on the tube side and transfer heat from the drywell to water in a large cooling pool (IC/PCCS pool), which is vented to the atmosphere.

Each PCCS condenser is located in a subcompartment of the IC/PCCS pools. The IC/PCCS pool subcompartments on each side of the Reactor Building communicate at their lower ends to enable full use of the collective water inventory, independent of the operational status of any given PCCS condenser.

Each condenser, which is an integral part of the containment, contains a drain line to the GDCS pool and a vent discharge line, the end of which is submerged in the pressure suppression pool.

The PCCS condensers are driven by the pressure difference created between the containment drywell and the wetwell during a LOCA. Consequently, they require no sensing, control, logic or power actuated devices for operation.

PCCS vent fans are teed off of each PCCS vent line and exhaust to the GDCS pools. The fans aid in the long-term removal of non-condensable gas from the PCCS for continued condenser efficiency.

The PCCS is classified as safety-related and Seismic Category I.

Together with the pressure suppression containment system, the six PCCS condensers limit containment pressure to less than its design pressure. The initial IC/PCCS pool volume, combined with the additional water volume that is tied in automatically from the Equipment Storage Pool and Reactor Well, provides sufficient water volume for at least 72 hours after a LOCA without external make-up to the IC/PCCS pools.

The PCCS condensers are an integral part of the containment boundary. Therefore, there are no containment isolation valves and they are always in "ready standby".

The PCCS can be periodically pressure-tested as part of overall containment pressure testing. The PCCS condensers can be isolated for individual pressure testing during maintenance.

During refueling outages, in-service inspection (ISI) of PCCS condensers can be performed, if necessary. ~~Ultrasonic testing of tube-to-drum welds and eddy current testing of tubes can be done with PCCS condensers in place.~~

The safety-related monitored parameters for the IC/PCCS pools are pool water level and pool radiation. IC/PCCS expansion pool water level monitoring is a function of the FAPCS, which is addressed in Subsections 1.2.2.6.2 and 9.1.3. IC/PCCS expansion pool radiation monitoring is a function of the PRMS, which is addressed in Subsection 1.2.2.3.1 and Section 11.5.

1.2.2.15.5 Containment Inerting System

The Containment Inerting System is designed to establish and maintain an inert atmosphere within the containment during all plant operating modes, except during plant shutdown for refueling or equipment maintenance and during limited periods of time to permit access for

Table 1.6-1

Referenced GE / GEH Reports

Report No.	Title	Section No.
NEDE-33516P	[*GE Hitachi Nuclear Energy, "ESBWR Qualification Plan Requirements for a 72-Hour Duty Cycle Battery," NEDE-33516P, Class III (Proprietary), Revision 2, December 2009.*]*	3.11
NEDE-33536P NEDO-33536	[*GE-Hitachi Nuclear Energy, "Control Building and Reactor Building Environmental Temperature Analysis for ESBWR," NEDE-33536P, Class III (Proprietary), Revision 0, December 2009, NEDO-33536, Class I (Non-proprietary), Revision 0, December 2009.*]*	3H
NEDE-33572P NEDO-33572	GE Hitachi Nuclear Energy, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," NEDE-33572P, Class II (Proprietary), Revision ~~0~~1, Ma~~rch~~y 2010; NEDO-33572, Revision ~~0~~1, Class I (Non-proprietary), Ma~~rch~~y 2010.	3G.1, 3.8, 5.4, 6.2
NEDE-33564P NEDO-33564	GE Hitachi Nuclear Energy, "Leakage Detection Instrumentation Confirmatory Test for the ESBWR Wetwell-Drywell Vacuum Breakers," NEDE-33564P, Class II (Proprietary), Revision 0, March 2010; NEDO-33564, Revision 0, Class I (Non-proprietary), March 2010.	6.2

* References that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior NRC approval is required to change Tier 2* information.

Table 3.2-1

Classification Summary

Principal Components[1]	Safety Class.[2]	Location[3]	Quality Group[4]	Safety-Related Classification[5]	Seismic Category[6]	Notes
5. Electrical modules and cable with safety-related function	3	CV, RB	—	Q	I	
6. Pneumatic accumulators	3	CV, RB	C	Q	I	
7. Electrical modules and cables supporting diverse protection functions	N	CV, RB	—	S	II	(5) c, (5) i, (5) j
8. Pool cross-connect valves	3	RB	C	Q	I	
9. Electrical modules and cables supporting ICS lower header temperature monitoring	N	RB	—	S	II	(5)c
C CONTROL AND INSTRUMENT SYSTEMS						
C11 Rod Control and Information System (RC&IS)	N	RB, CB	—	S / N	NS	(5) j
C12 Control Rod Drive (CRD) System						
1. CRD primary pressure boundary	1	CV	A	Q	I	
2. CRD internals	3	CV	—	Q	I	
3. Hydraulic control unit (HCU)	2	RB	—	Q	I	(8)
4. Piping including supports – insert line	2	CV, RB	B	Q	I	
5. High pressure makeup piping including supports, from and including the check valve and test valve in the common line, isolation valves and isolation bypass valves up to the connection to RWCU/SDC	2	RB	B	Q	I	CRD piping classification is consistent with piping to which it connects.

- *Pipe (seamless SA-333 grade 1 or 6; or SA-106 grade B or SA-312 type 304L or Welded SA-671 Gr CC70)*
- *Forgings (SA-~~182~~312 grade XM-19~~F 304L~~)*
- *General Tubing (SA-213 grade TP304L)*
- *PCCS Condenser Tubing (SA-312 grade XM-19)*
- *Bolting (SA-193-B8 or SA-437 Gr B4B bolts. Nuts shall conform to SA-194 or to the requirements for nuts in the specification for the bolting material to be used.)*
- *Clad (SA-240 type 304L)*]*

Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2. Prior NRC approval is required to change.

3.8.2.7 Testing and In-service Inspection Requirements

Testing and In-service Inspection Requirements of the containment vessel, including the steel components, is described in Subsection 3.8.1.7.

3.8.2.7.1 Welding Methods and Acceptance Criteria

Welding activities conform to requirements of Section III of the ASME Code. The required NDE and acceptance criteria are provided in Table 3.8-5.

3.8.2.7.2 Shop Testing Requirements

The shop tests of the personnel air locks include operational testing and an overpressure test. After completion of the personnel air locks tests (including all latching mechanisms and interlocks), each lock is given an operational test consisting of repeated operating of each door and mechanism to determine whether all parts are operating smoothly without binding or other defects. All defects encountered are corrected and retested. The process of testing, correcting defects, and retesting is continued until no defects are detectable.

For the operational test, the personnel air locks are pressurized with air to the maximum permissible code test pressure. All welds and seals are observed for visual signs of distress or noticeable leakage. The lock pressure is then reduced to design pressure and a thick bubble solution is applied to all welds and seals and observed for bubbles or dry flaking as indications of leaks. All leaks and questionable areas are clearly marked for identification and subsequent repair.

During the overpressure testing, the inner door is blocked with holddown devices to prevent unseating of the seals. The internal pressure of the lock is reduced to atmospheric pressure and all leaks are repaired. Afterward, the lock is again pressurized to the design pressure with air and all areas suspected or known to have leaked during the previous test are retested by the bubble technique. This procedure is repeated until no leaks are discernible.

3.8.7 References

3.8-1 GE Hitachi Nuclear Energy, "ESBWR ICS and PCCS Condenser Combustible gas Mitigation and Structural Evaluation," NEDE-33572P, Class II (Proprietary), Revision 01, Marchy 2010; NEDO-33572, Revision 01, Class I (Non-proprietary), Marchy 2010.

[*Table 3.8-4*

Load Combination, Load Factors and Acceptance Criteria for Steel Containment Components of the RCCV [(1), (2), (3)]

Service Level	No	Load Combination [1]																	Acceptance Criteria			
		D	L	P_t	P_o	P_a	T_t	T_o	T_a	E'	W	W'	R_o	R_a	Y [4]	SRV [12]	DET [12]	$LOCA$ [5][12]	P_m	P_L	P_L+P_b [8]	P_L+P_b+Q
Test Condition	1	1.0	1.0	1.0			1.0												0.75 S_y	1.15Sy	1.15Sy [11]	N/A [10]
Design Condition	2	1.0	1.0			1.0			1.0					1.0					1.0 S_{mc}	1.5 S_{mc}	1.5 S_{mc}	N/A
Level A, B [9]	3	1.0	1.0		1.0			1.0					1.0						1.0 S_{mc}	1.5 S_{mc}	1.5 S_{mc}	3.0 S_{ml}
	4	1.0	1.0		1.0			1.0								1.0						
	5	1.0	1.0			1.0			1.0					1.0				1.0				
	6	1.0	1.0			1.0			1.0					1.0		1.0		1.0				
Level C [6]	7	1.0	1.0		1.0			1.0		1.0			1.0						1.2 S_{mc} or* 1.0 S_y	1.8 S_{mc} or* 1.5S_y	1.8 S_{mc} or* 1.5S_y	N/A
	8	1.0	1.0			1.0			1.0	1.0				1.0		1.0		1.0				
	9	1.0	1.0			1.0			1.0	1.0				1.0				1.0				
	12[13]	1.0	1.0						1.0	1.0							1.0					
Level D [7]	10	1.0	1.0			1.0			1.0	1.0				1.0	1.0	1.0		1.0	S_f	1.5S_f	1.5S_f	N/A
	11	1.0	1.0			1.0			1.0	1.0				1.0	1.0			1.0				
	~~12[13]~~	~~1.0~~	~~1.0~~						~~1.0~~	~~1.0~~							~~1.0~~					

Notes:

(1) The loads are described in Subsection 3.8.1.3.

(2) For any load combination, if the effects of any load component (other than D) reduces the combined load, then the load component is deleted from the load combination.

(3) P_a, T_a, SRV and LOCA are time-dependent loads. The sequence of occurrence is given in Appendix 3B.

(4) Y includes Y_j, Y_m and Y_r.

(5) LOCA loads include CO, CHUG and PS. They are time-dependent loads. The sequence of occurrence is given in Appendix 3B. LOCA loads include hydrostatic pressure (with a load factor of 1.0) due to containment flooding.

(6) Limits identified by (*) indicate a choice of the larger of the two.

(7) S_f is 85% of the general primary membrane allowable permitted in Appendix F, ASME B&PV Code, Section III. In the application of Appendix F, S_{ml}, if applicable, is as specified in Section II, Part D, Subpart 1, Tables 2A and 2B of ASME B&PV Code, which is the same as S_m.

(8) Values shown are for a rectangular section. See NE-3221.3(d) for other than a solid rectangular section.

(9) The allowable stress intensity S_{ml} is the S_m listed in Section II, Part D, Subpart 1, Tables 2A and 2B of the ASME B&PV Code. The allowable stress intensity S_{mc} is 1.1 times the S_m listed in Section II, Part D, Subpart 1, Tables 1A and 1B of the ASME B&PV Code, except that S_{mc} does not exceed 90% of the material's yield strength at temperature shown in Section II, Part D, Subpart 1, Tables Y-1 of the ASME B&PV Code.

(10) N/A = No evaluation required.

(11) Bending and General Membrane P_m+P_b.

(12) The peak responses of dynamic loads do not occur at the same instant. SRSS method to combine peak dynamic responses is acceptable for steel structures.]*

(13) These loads are applicable only to the PCCS condenser.

Table 3.9-8

Inservice Testing

Number	Quantity	Description(g)	Valve Type(i)	Actuator(b)	Code Class(a)	Code Category(c)	Valve Function(d)	Normal Position	Safety Position	Fail Safe Position	Containment Isolation Valve	Test Parameter(e)	Test Frequency(f)
F008	4	Condenser upper header vent valve	GB	SO	2	A	A	C	C	C	Y	L P SC FC	App J 2 yrs 3 mo 3 mo
F009	4	Condenser lower header vent valve	GB	SO	2	A	A	C	O/C	~~C~~O	Y	L P SC FC	App J 2 yrs 3 mo 3 mo
F010	4	Condenser lower header vent valve	GB	SO	2	A	A	C	O/C	~~C~~O	Y	L P SC FC	App J 2 yrs 3 mo 3 mo
F011	4	Bypass lower header vent valve	RV	SA	2	A	A	C	O/C	N/A	Y	R L	10 yrs App J

Table 3.9-8

Inservice Testing

Number	Quantity	Description(g)	Valve Type(i)	Actuator(b)	Code Class (a)	Code Category(c)	Valve Function(d)	Normal Position	Safety Position	Fail Safe Position	Containment Isolation Valve	Test Parameter(e)	Test Frequency(f)
F002	3	Drywell wetwell vacuum breaker valve (g3)	VB	SA	2	A, C	A	C	O/C	N/A	--	SO SC L P R	RO RO 2 yrs 2 yrs RO
~~T15 Passive Containment Cooling System Valves~~													
F001	6	Vent fan ~~check~~isolation valves	~~CK~~QBL	~~SA~~NO	2	A~~, C~~	~~A~~P	C	O/C	~~N/A~~As-Is	--	L ~~SO~~ ~~SC~~	2 yrs ~~RO~~ ~~RO~~
T31 Containment Inerting System Valves													
F012	1	Suppression pool exhaust line outboard isolation valve (g19)	QBF	AO	2	A	A	C	C	C	Y	L P SC FC	App J 2 yrs RO RO
F007	1	Air/Nitrogen supply line to suppression pool outboard isolation valve (g19)	QBF	AO	2	A	A	C	C	C	Y	L P SC FC	App J 2 yrs RO RO

Table 3.11-1

Electrical and Mechanical Equipment for Environmental Qualification

Components	Quantity	Location (note 1)	Function (note 2)	Required Operation Time (note 3)	Qualification Program (note 4)
Isolation Power Center Supply Breaker to Division 250 VDC Normal Battery Charger	12	RB	ISOL	100 Days	E
Electrical Modules and Cable	All	CV, CB, RB, TB	ESF	100 Days	E
R31 Raceway System					
Electrical Penetrations	All	CV	PB	100 Days	EH
Conduit, Cable Trays and Supports	All	CV, CB, RB, TB, FB	ESF	100 Days	EH
T10 Containment System					
Vacuum Breakers	3	CV	ESF	100 Days	MH
Vacuum Breaker Isolation Valves	3	CV	ESF	72 hr	MH
Instrumentation and Cables	All	CV	ESF	100 Days	EH
Basemat Internal Melt Arrest Coolability (BiMAC) Temperature Element	ALL	CV	ESF	100 Days	EH
BiMAC Temperature Switch	ALL	CV	ESF	100 Days	EH
T15 Passive Containment Cooling System					
Vent Fan ~~Check~~Isolation Valves	6	CV	ESF	100 Days	MH
Passive Containment Cooling System (PCCS) Vent Fan	6	CV	ESF	100 Days	EH
T31 Containment Inerting System					
Isolation Valve	10	CV, RB	ISOL	100 Days	MH

3G.1.5.5.4 *Foundation Settlement*

The basemat design is checked against the normal and differential settlement of the RB/FB. It is found that the basemat can resist the maximum mat foundation corner settlement of 103 mm (4.0 in) and the settlement averaged at four corners of 65 mm (2.6 in). The relative displacement between two corners along the longest dimension of the building basemat calculated under linearly varying soil stiffness is 77 mm (3.0 in). The estimated differential settlement between buildings (RB/FB and CB) is 85 mm (3.3 in). These values are specified as maximum settlements in Table 2.0-1.

3G.1.5.6 Tornado Missile Evaluation

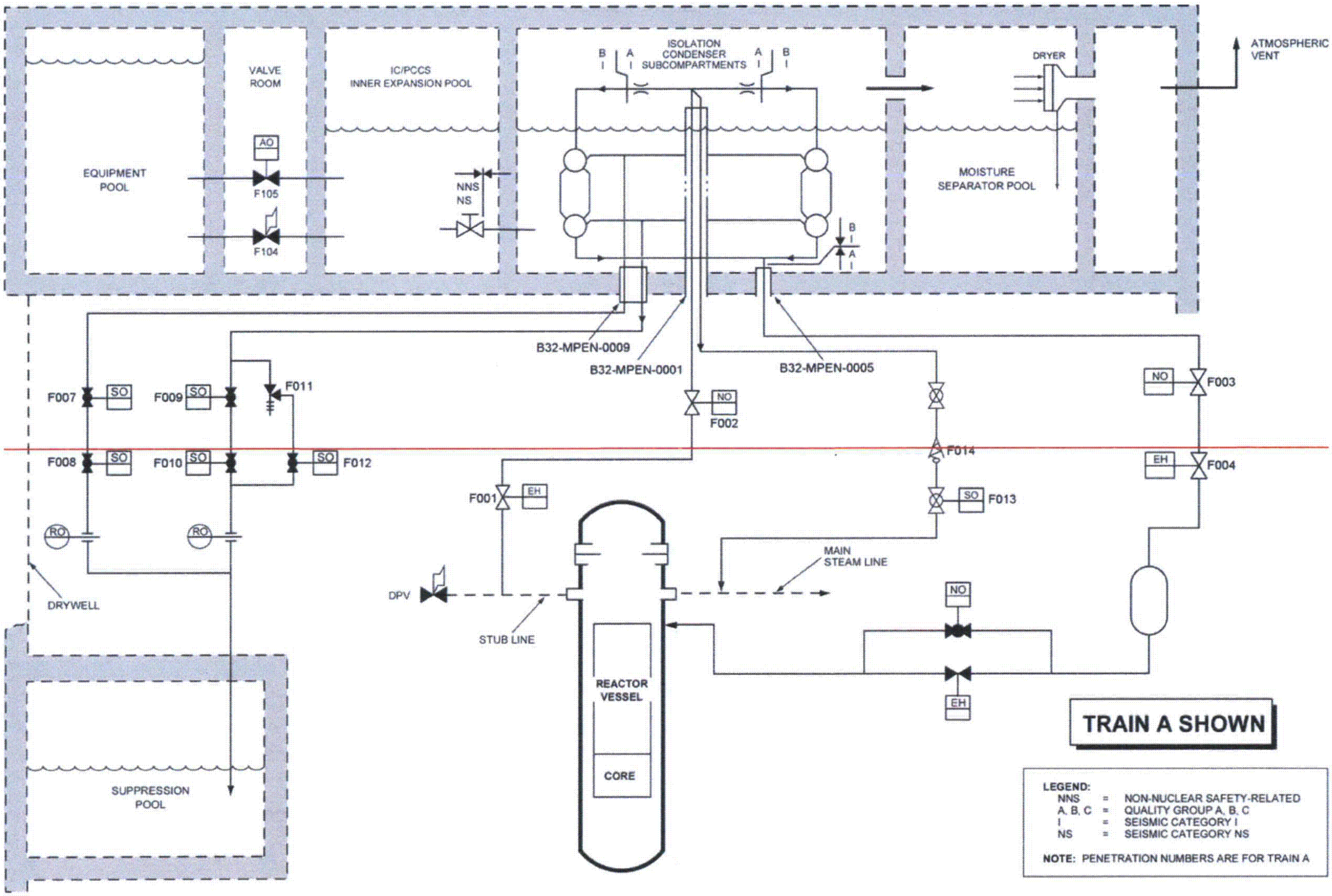
The minimum thickness required to prevent penetration, concrete spalling and scabbing is evaluated. The methods and procedures are shown in Subsection 3.5.3.1.1. The minimum thickness required is less than the minimum 1000 mm (39.4 in) and 700 mm (27.6 in) thickness provided for the RB external walls and roof, respectively.

3G.1.6 *References*

3G.1-1 *Burns & Roe, "State-of-the-Art Report on High Temperature Concrete Design," prepared for US. Department of Energy, Document No. DOE/CH/94000-1, November 1985.*

3G.1-2 *Tseng, W.S. and Liou, D.D., "Simplified Methods for Predicting Seismic Basemat Uplift of Nuclear Power Plant Structures, Transactions of the 6th International Conference on SmiRT", Paris, France, August 1981.*

3G.1-3 *GE Hitachi Nuclear Energy, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation Structural Evaluation," NEDE-33572P, Class II (Proprietary), Revision 1~~0~~, Ma~~rch~~y 2010; NEDO-33572, Revision ~~0~~1, Class I (Non-proprietary), Ma~~rch~~y 2010.*


EQUIPMENT POOL
VALVE ROOM
AO
F105
F104
IC/PCCS INNER EXPANSION POOL
NNS
NS
ISOLATION CONDENSER SUBCOMPARTMENTS
B A A B
DRYER
ATMOSPHERIC VENT
MOISTURE SEPARATOR POOL
B32-MPEN-0009
B32-MPEN-0001
B32-MPEN-0005
F007
F008
F009
F010
F011
F012
SO
F002
NO
F001
EH
F014
F013
F003
F004
RO
DRYWELL
DPV
STUB LINE
MAIN STEAM LINE
REACTOR VESSEL
CORE
SUPPRESSION POOL
TRAIN A SHOWN
LEGEND:
NNS = NON-NUCLEAR SAFETY-RELATED
A, B, C = QUALITY GROUP A, B, C
I = SEISMIC CATEGORY I
NS = SEISMIC CATEGORY NS
NOTE: PENETRATION NUMBERS ARE FOR TRAIN A

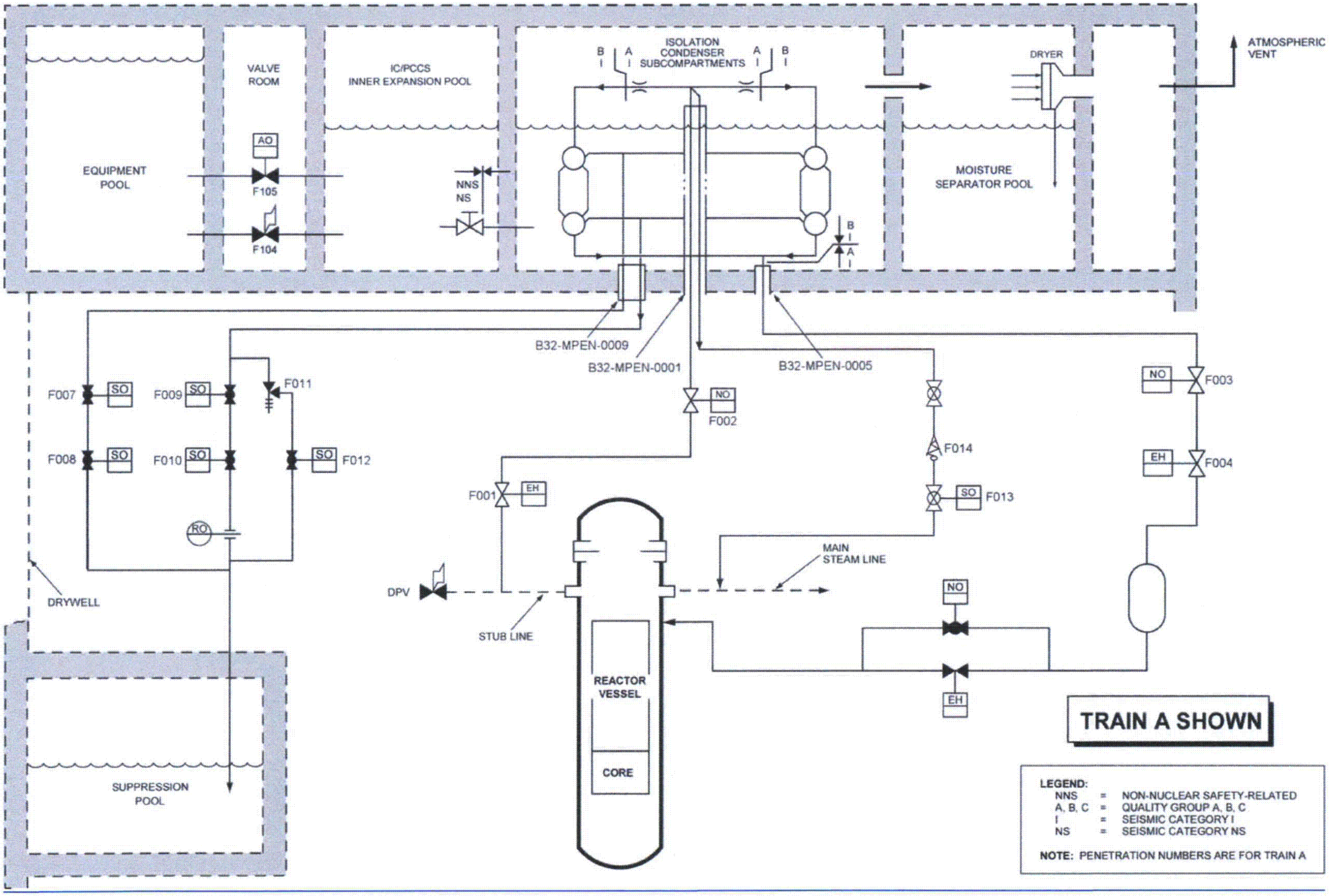


Figure 5.1-3. Isolation Condenser System Schematic

- GDC 54 as it relates to piping systems penetrating primary containment being provided with leak detection and isolation capabilities.
- GDC 55 as it relates to isolation for piping systems that are part of RCPB and penetrate containment; and
- 10 CFR 50, §50.63, "Loss of All Alternating Current (AC) Power," as related to design provisions to support the plant's ability to withstand and recover from a Station Black-Out of a specified duration.

The ESBWR passive decay heat removal systems (Isolation Condensers) are capable of achieving and maintaining safe stable conditions for at least 72 hours without operator action following non-LOCA events. Operator action is credited after 72 hours to refill Isolation Condenser pools or initiate non-safety shutdown cooling.

5.4.6.1 Design Bases

5.4.6.1.1 Safety Design Bases

Functions

The ICS removes residual sensible and core decay heat from the reactor, in a passive way and with minimal loss of coolant inventory from the reactor, when the normal heat removal system is unavailable, following any of the following events:

- Station blackout (i.e., unavailability of all AC power);
- Anticipated transient without scram (See Subsection 15.5.4.3); and
- Loss-of-coolant-accident.

The ICS functions to avoid unnecessary use of other engineered safety features (ESFs) for residual heat removal (RHR) and in the event of a LOCA. The ICS also provides additional liquid inventory upon opening of the condensate return valves to initiate the system. In the event of ICS initiation by reactor level below Level 2, the ICS also removes core heat causing initial depressurization of the reactor before the ADS initiates. Because of this vessel pressure reduction with return of condensed steam plus the additional initial ICS stored condensate inventory, the ADS can initiate from a lower reactor water level to complete the vessel depressurization.

The ICS is designed as a safety-related system to remove reactor decay heat following reactor shutdown and isolation. It also prevents unnecessary reactor depressurization, and operation of other ESFs, that can also perform this function.

In the event of a LOCA, the ICS provides additional liquid inventory upon opening of the condensate return valves to initiate the system and there after the ICS isolation valves are closed following any two opened DPV's with a time delay. Closing the ICS isolation valves mitigates the accumulation of radiolytic hydrogen and oxygen (see Reference 5.4-3). The ICS also provides initial depressurization of the reactor before ADS in event of loss of feed water, such that the ADS can take place from a lower water level.

In order to ensure an adequate inventory of cooling water is available for at least 72 hours following an accident, each IC/PCCS pool is connected to the equipment storage pool by two valves in parallel where one valve is a pneumatic-operated valve with an accumulator and the other is a squib valve. These valves, which are shown in the valve rooms depicted on Figure 6.2-2, open on a low level condition in either of the IC/PCCS inner expansion pools and allow the water volume in the equipment storage pool and reactor well to communicate with the IC/PCCS pools.

General System Requirements

The ICS is designed to remove post-reactor isolation decay heat with 3 out of 4 isolation condenser heat exchangers operating and to reduce Nuclear Steam Supply System (NSSS) temperature to safe shutdown conditions in 36 hours (and NSSS pressure below containment design conditions in 72 hours) with ~~occasional~~ venting from the lower header to the suppression pool of radiolytically generated noncondensable gases beginning ~~four~~six hours after isolation (see Table 5.4-1). The isolation condenser heat exchangers are independent of plant AC power, they function whenever normal heat removal systems are unavailable, to maintain reactor pressure and temperature below limits.

The ICS is designed and qualified as a safety-related system.

The ICS provides isolation valves for containment isolation (Subsection 6.2.4).

Performance Requirements

The heat removal capacity of the ICS (with three of four isolation condenser trains in service) at reactor pressure with saturated steam is presented in Table 5.4-1. The condensate return valve stroke-open time and logic delay time is presented in Table 5.4-1.

5.4.6.1.2 Power Generation Design Bases

The ICS automatically limits the reactor pressure and prevents SRV operation following an AOO.

The ICS removes excess sensible and core decay heat from the reactor, in a passive way and with minimal loss of coolant inventory from the reactor, when the normal heat removal system is unavailable, following AOOs and any event that results in reactor isolation.

5.4.6.2 System Description

5.4.6.2.1 Summary Description

The ICS consists of four independent trains, each containing an isolation condenser that condenses steam on the tube side and transfers heat to the IC/PCCS pool, which is vented to the atmosphere as shown on Figure 5.1-3.

The isolation condenser, connected by piping to the RPV, is placed at an elevation above the source of steam (vessel) and, when the steam is condensed, the condensate is returned to the vessel via a condensate return pipe.

The steam side connection between the vessel and the isolation condenser is normally open and the condensate line is normally closed. This allows the isolation condenser and drain piping to fill with condensate, which is maintained at a subcooled temperature by the pool water during normal reactor operation.

The isolation condenser is started into operation by opening condensate return valves and draining the condensate to the reactor, thus causing steam from the reactor to fill the tubes which transfer heat to the cooler pool water.

5.4.6.2.2 Detailed System Description

The ICS consists of four high-pressure, independent trains, each containing a steam isolation condenser as shown on the ICS schematic (Figure 5.1-3 and 5.4-4a & b).

Each isolation condenser unit is made of two identical modules (see Table 5.4-1). The units are located in subcompartments adjacent to a large water pool (IC/PCCS expansion pool) positioned above, and outside, the ESBWR containment (drywell).

The isolation condenser is configured as follows:

- The steam supply line (properly insulated and enclosed in a guard pipe which penetrates the containment roof slab) is vertical and feeds two horizontal headers through four branch pipes. Each pipe is provided with a built-in flow limiter, sized to allow natural circulation operation of the isolation condenser at its maximum heat transfer capacity while addressing the concern of isolation condenser breaks downstream of the steam supply pipe. Steam is condensed inside Inconel 600 vertical tubes and condensate is collected in two lower headers. To achieve an adequate heat transfer coefficient, each module contains approximately 135 tubes. Two pipes, one from each lower header, take the condensate to the common drain line, which vertically penetrates the containment roof slab.
- A vent line is provided for both upper and lower headers to remove the noncondensable gases away from the unit, during isolation condenser operation. The vent lines are routed to the containment through a single penetration. The lower header vent line in the drywell is composed of the main vent line and bypass line. The main vent line has a 0.167 cm^2 (0.0259 in^2) restricting orifice located downstream of valve F010 (see Figure 5.1-3) which limits RPV inventory loss during its operation.
- A purge line is provided to assure that, during normal plant operation (ICS standby conditions), an excess of noncondensable gases does not accumulate in the isolation condenser steam supply line, thus assuring that the isolation condenser tubes are not blanketed with noncondensables when the system is first started. The purge line penetrates the containment roof slab.
- Containment isolation valves are provided on the steam supply piping and the condensate return piping. The valve designs are the same for all four valves, either gate valves or quarter-turn ball valves. For two of the valves (one per line), the actuators are nitrogen-powered piston operators, which are similar to piston air operators. Nitrogen is supplied from accumulators. For the other two valves, the actuators are electro-hydraulic operators, which use an electric motor-driven pump to drive the piston.
- Located on the condensate return piping just upstream of the reactor entry point is a loop seal and a parallel-connected pair of valves: (1) a condensate return valve (electro-hydraulic operated, fail as is) and (2) a condensate return bypass valve (nitrogen piston operated, fail open). Two different valve actuator types are used to assure an open flow path by eliminating common mode failure. Therefore, the condensate return valves are

single failure proof for each unit. Because the steam supply line valves are normally open, condensate forms in the isolation condenser and develops a level up to the steam distributor, above the upper headers. To place an isolation condenser into operation, the electro-hydraulic operated condensate return valve and condensate return bypass valves are opened, whereupon the standing condensate drains into the reactor and the steam-water interface in the isolation condenser tube bundle moves downward below the lower headers to a point in the main condensate return line. The fail-open nitrogen piston-operated condensate return bypass valve opens if the DC power is lost.

- System controls allow the reactor operator to manually open both of the condensate return valves at any time.
- Located on the condensate return line, downstream from the second inboard containment isolation valve is an in-line vessel. The inline vessel is located on each ICS train to provide the additional condensate volume for the RPV. The volume of each vessel is no less than 9 m^3 (318 ft^3). This in-line vessel contributes a large portion of the total drainable water volume in the condensate return piping of each ICS train (see Table 6.3-1). The added inventory of the inline vessel supports:
  - Use of a single level logic for emergency core cooling system (ECCS) initiation, and
  - Reactor vessel level that does not fall below the Level 1 setpoint during a loss of feedwater or loss of preferred power.
- The equipment storage pool and reactor well are designed to have sufficient water volume to provide makeup water to the IC/PCCS expansion pools for the initial 72 hours of a LOCA response. This water is provided through ICS pool cross-connect valves between the equipment storage pool and IC/PCCS inner expansion pools. The pool cross-connect valves open when the level in the IC/PCCS inner expansion pool to which they are connected reaches a low set point. The IC/PCCS pools, equipment storage pool, and reactor well have a minimum combined water inventory of no less than 6,290 cubic meters (222,130 cu ft) to be used for 72 hours of post-accident decay heat removal.
- A loop seal at the RPV condensate return nozzle assures that condensate valves do not have superheated water on one side of the disk and subcooled water on the other side during normal plant operation, thus affecting leakage during system standby conditions. Furthermore, the loop seal assures that steam continues to enter the isolation condenser preferentially through the steam riser, irrespective of water level inside the reactor, and does not move counter-current back up the condensate return line.

During ICS normal operation, noncondensable gases collected in the isolation condenser are vented from the isolation condenser top and bottom headers to the suppression pool. Venting is controlled as follows:

- Two normally closed, fail-~~closed~~open, solenoid-operated lower header vent valves are located in the vent line from the lower headers. They can be actuated both automatically (when RPV pressure is high and either of condensate return valves is open or six hours after either of the condensate return valves is opened) and manually by the control room operator. The lower header vent valves open on loss of DC power. There is a bypass line around the lower header vent valves, which contains one relief valve and one normally closed, fail-open solenoid valve. The valves are designed to open automatically (with or without power) at a pressure set point higher than that of the primary lower header vent valves and at a lower pressure that what is needed to lift the SRVs.

- The vent line from the upper headers is provided with two normally closed, fail-closed, solenoid-operated upper header vent valves to permit opening of this noncondensable gas flow path by the operator, if necessary.
- All the vent valves are located in vertical pipe run near the top of the containment. The vent piping is sloped to the suppression pool to prevent accumulation of condensate in the piping.

The cross-tie between isolation condenser steam line and depressurization valves (DPVs) in the ESBWR produces no significant negative impact on the loads and safety margins. The key details are as follow:

- During a LOCA event, the peak operation of ICS occurs during the early part of the depressurization and before the DPV openings.
- At the time of first DPV opening, there is no subcooled water inside the isolation condenser drain line and in the downcomer region. The total dynamic head (DPV flow + isolation condenser steam flow) inside the stub tube is small and does not induce back flow into the isolation condenser tubes.
- Failure of one isolation condenser drain valve or one DPV valve does not prevent the operation of the other system connecting to the common stub line.
- Based on first and third bullets above, the common-tie between the ICS and DPVs on the stub line has no significant impact on the safety margins [refer to fifth bullet below]. Therefore, the physical separation of these two systems is not necessary.
- Parametric studies were performed with and without the function of the isolation condenser heat transfer (i.e., no isolation condenser condensation). The results indicate that the long-term containment pressure is slightly higher for the case without the function of isolation condenser heat transfer.

During ICS standby operation, discharge of excess hydrogen or air is accomplished by a purge line that takes a small stream of gas from the top of the isolation condenser and vents it downstream of the RPV on the main steamline upstream of the MSIVs.

Each isolation condenser is located in a subcompartment of the IC/PCCS pool, and all pool subcompartments communicate at their lower ends to enable full utilization of the collective water inventory, independent of the operational status of any given isolation condenser train. A valve is provided at the bottom of each IC/PCCS pool subcompartment that can be closed so the subcompartment can be emptied of water to allow isolation condenser maintenance.

When the heat exchanger goes into operation, the pool water can heat up to about 101°C (214°F) and start to boil; steam formed, being nonradioactive and having a slight positive pressure relative to station ambient, vents from the steam space above each isolation condenser segment 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.

IC/PCCS pool makeup clean water supply for replenishing level during normal plant operation and level monitoring is provided from the Fuel and Auxiliary Pools Cooling System (FAPCS) (Subsection 9.1.3).

A safety-related independent FAPCS makeup line is provided to convey emergency makeup water into the IC/PCCS expansion pool, from piping connections located at grade level in the reactor yard external to the reactor buildings.

Four radiation monitors are provided in the IC/PCCS pool steam atmospheric exhaust passages for each isolation condenser train. They are shielded from all radiation sources other than the steam flow in the exhaust passages for a specific isolation condenser train. The radiation monitors are used to detect isolation condenser train leakage outside the containment. Detection of a low-level leak (radiation level above background - logic 2/4) results in alarms to the operator. At high radiation levels (exceeding site boundary limits - logic 2/4), isolation of the leaking isolation condenser occurs automatically by closure of steam supply and condensate return line isolation valves.

Four sets of differential pressure instrumentation are located on the isolation condenser steam line and another four sets on the condensate return line inside the drywell. Detection of excessive flow beyond operational flow rates in the steam supply line or in the condensate return line (2/4 signals) results in alarms to the operator, plus automatic isolation of both steam supply and condensate return lines of the affected isolation condenser train.

5.4.6.2.3 System Operation

Normal Plant Operation

During normal plant operation, each isolation condenser train is in "ready standby," with both steam supply isolation valves and both isolation valves on the condensate return line in a normally open position, condensate level in the isolation condenser extending above upper headers, condensate return valve-pair both closed, and with the small vent lines from the isolation condenser top and bottom headers to the suppression pool closed. Steam flow is induced from the steam distributor through the purge line by the pressure differential caused by flow in the main steamline.

The valve status, failure mode, actuation mode, pipe size, valve type, and line are shown in Tables 3.9-8 and 6.2-23 through 6.2-30.

Plant Shutdown Operation

During refueling, the isolation condenser is isolated from the reactor, with all steam supply and condensate return isolation valves closed. The isolation condenser lower and upper header vent valves are also closed.

Isolation Condenser Operation

Any of the following sets of signals generates an actuation signal for ICS to come into operation:

- Two or more MSIV positions indicating ≤ 92% open, in separate main steamlines (MSLs), with Reactor Mode Switch in "run" only (% open values are those used in the safety analyses);
- RPV dome gauge pressure ≥ 7.447 MPa (1080 psig) for 10 seconds;

- Reactor water level below Level 2, with time delay;
- Reactor water below Level 1;
- Loss of Feed Water (loss of power to 2-out-of-4 feed water pumps) in Reactor Run Mode; and
- Operator manual initiation.

When one of these ICS initiation signals occurs, condensate return valves open within required stroke time (Table 5.4-1), which starts isolation condenser operation. If, during isolation condenser operation and after the initial transient, the RPV pressure increases above 7.516 MPa gauge (1090 psig), the bottom vent valves automatically open; and when the RPV pressure decreases below 7.447 MPa gauge (1080 psig) (reset value) and after a time delay to avoid too many cycles, these valves close. If the pressure increases above 7.929 MPa gauge (1150 psig), the lower header vent bypass valves automatically open.

In the early stages of RCS depressurization (0 ~ 500 seconds, before the opening of DPVs), the ICS is in operation and condenses significant steam flow (~ 36 kg/s (79.4 lbm/s) per isolation condenser, MSL break case) from the RPV. The steam flow to the ICS reduces as the RPV pressure decreases and the downcomer water level drops. The first group of ADS valves open after the downcomer level drops below the Level 1 setpoint (Table 6.3-1, Item B.5; NOTE: Level 1 is representatively shown on Figure 7.7-1). Consequently, both the RPV pressure and the steam flow to the ICS reduce further after the first ADS valve opening. The first group of DPV valves opens at 50 seconds after the first ADS valve opening. At this time, the RPV pressure decreases to about 700 kPa (100 psia), the DPV flow is about 7.5 kg/s (16.5 lbm/s) per DPV and the isolation condenser steam flow reduces to about 4 kg/s (8.8 lbm/s) per isolation condenser. The total velocity inside the stub tube is in the range of 35 m/s (114.8 ft/s). The dynamic head is in the range of 2.2 kPa (0.3 psia), which is small compared to the static head of two-phase mixture in the vertical portion of the isolation condenser drain line.

At the time of DPV opening, the RPV downcomer as well as the isolation condenser drain lines are filled with saturated two-phase mixture due to the fast depressurization resulting from the opening of ADS valves. As the result of additional depressurization from the DPV opening, the downcomer two-phase level could swell up a few meters from the Level 1 position, and get closer to or below the stub line elevation. However, there is no subcooled water inside the isolation condenser drain line, or inside the downcomer near by the nozzle elevations of the isolation condenser drain line or the stub line.

In addition, there are loop seals at the lowest elevation of the isolation condenser drain lines, near by the injection nozzles. The loop seal provides extra static head; in addition to the 15 meters (49.2 feet) of static head of the two-phase mixture inside the vertical portion of the isolation condenser drain line, to prevent any flow reversal in the isolation condenser drain line and steam inlet line due to the DPV opening.

After reactor isolation and automatic ICS operation, the control room operator can control the venting of noncondensable gases from the isolation condenser, to enable it to hold reactor pressure below safe shutdown limits. The lower header vent valves are opened automatically after a six hour time delay from start of ICS operation. This mitigates the accumulation of radiolytically generated hydrogen and oxygen in the ICS during non-LOCA scenarios (see Reference 5.4-3).

The ICS is also designed to provide makeup water to the RPV during LOCA event by draining the isolation condenser and condensate return line standby inventory into the RPV. The ECCS, see Section 6.3, and the ICS are designed to flood the core during a LOCA event to provide required core cooling. By providing core cooling following a LOCA, the ECCS and ICS, in conjunction with the containment, limits the release of radioactive materials to the environment following a LOCA. The ICS isolation valves are closed following any two opened DPV's with a time delay. Closing the ICS isolation valves mitigates the accumulation of radiolytic hydrogen and oxygen (see Reference 5.4-3) and allows time for ICS to provide its makeup water to the RPV.

5.4.6.3 Safety Evaluation

The ICS is used to transfer decay and residual heat from the reactor after it is shutdown and isolated. This function can also be performed by the RWCU/SDC system or other ESF of the ADS, Passive Containment Cooling System (PCCS), and GDCS which back up the ICS. The ICS is designed and qualified as a safety-related system to comply with 10 CFR 50 Appendix A, Criterion 34 and to avoid unnecessary use of other ESFs for residual heat removal.

The ICS parts (including isolation valves) which are located inside the containment and out to the isolation condenser flow restrictors are designed to ASME B&PV Code Section III, Class 1, RG 1.26, Quality Group A. The ICS parts, which are located outside the containment downstream of the flow restrictor, are designed to ASME B&PV Code Section III, Class 2, RG 1.26, Quality Group B. The electrical design systems are designed to comply with safety-related requirements per RG 1.153, and the entire system is designed to Seismic Category I per RG 1.29.

Three out of four ICS trains remove post-reactor isolation decay heat and depressurize the reactor to safe shutdown conditions when the reactor is isolated after operation at 100% power.

As protection from missile, tornado, and wind, the ICS parts outside the containment (the Isolation Condenser itself) are located in a subcompartment of the safety-related IC/PCCS pool to comply with 10 CFR 50 Appendix A, Criteria 2, 4, and 5.

For its function to provide makeup water to the RPV during a LOCA, the ICS is designed to meet the requirements of GDC 2, 17, 35, 36, and 37 and 10 CFR 50.46 in conjunction with the other ECCS. Conformance to these criteria is discussed in Section 6.3, Emergency Core Cooling Systems.

The isolation condenser steam supply pipes include flow restrictors with an inner diameter no greater than 76 mm (3 in). The isolation condenser condensate drain pipes are limited to an inner diameter no greater than 100 mm (4 in) so that, in the event of an isolation condenser piping or tube rupture in the IC/PCCS pool, the resulting flow-induced dynamic loads and pressure buildup in the IC/PCCS pool are limited. Penetration sleeves are used at the locations where the isolation condenser steam supply and condensate return pipes enter the pool at the containment pressure boundary. These penetration sleeves are designed and constructed in accordance with the requirements specified in Section 3.6. The ICS valve actuators inside the drywell are qualified for continuous service during normal conditions and to be for service in a DBA environment. Thereafter, the valves are required to remain in their last position.

The ICS steam supply lines, condensate return lines, instrument lines, and vent lines that penetrate containment are provided with isolation valves to satisfy containment isolation requirements as discussed in Subsections 6.2.4.

Compliance of instrumentation and control equipment is addressed in Subsection 7.4.4.

5.4.6.4 Testing and Inspection Requirements

Inspection

During plant outages, routine in-service inspection is required for the isolation condenser, piping, containment, penetration sleeves, and supports according to ASME B&PV Code Section III and Section XI (requirements for design and accessibility of welds).

Isolation condenser removal for routine inspection is not required.

Refer to Reference 5.4-3 for inspection requirement for the ICS condenser.

Testing

Preoperational testing is accomplished as described in Section 14.2. Such testing includes hydrostatic testing for pressure integrity and system functional controls testing. Testing that requires the reactor to be in operation, such as vibration testing under operating conditions, and flow capability testing is performed as part of initial startup testing.

Periodic heat removal capability testing of the ICS is performed every 24 months on a staggered test basis to ensure at least one ICS train is tested every 24 months and that each isolation condenser train is tested at least every eight years. This test is accomplished using data derived from the temperature sensor located downstream of the condensate return isolation valve, together with the Leak Detection and Isolation System (LD&IS) differential pressure signal from one of the differential pressure transmitters, on the condensate return line.

A valve operability test is also performed during normal plant operation. A periodic surveillance test cycles the normally-closed condensate return and condensate return bypass valves (sequentially opening and closing each valve) on the condensate line to the RPV.

The test procedure for the condensate return valves starts after the condensate return line isolation valves are closed; this avoids subjecting the isolation condenser to unnecessary thermal heatup/cooldown cycles.

Isolation valves on the steam supply line remain open to avoid isolation condenser depressurization.

The test is performed by the control room operator via manual switches that actuate the isolation valves and the condensate return valves; the opening and closure of the valves is verified in the main control room.

The procedure for condensate return valve operability testing is as follows:

- Close condensate return line containment isolation valves;

- Fully open and subsequently close condensate return and then condensate return bypass valve; and
- Reopen isolation valves to put the isolation condenser in standby condition.

The isolation valves are tested periodically, one at a time.

If a system actuation signal occurs during the test, all the valves automatically align to permit the isolation condenser to start operation.

Each vent valve is periodically tested.

The valves which are located in series are opened one at a time during normal plant operation. A permissive is provided for that (the operator can open one vent valve if the other one in series is closed).

The purge line root valve is periodically tested.

5.4.6.5 Instrumentation Requirements

Control logic for ICS system is addressed in Subsection 7.4.4 and instrumentation in Subsection 7.5.5. The following paragraphs give a brief description of the instrumentation for each of the isolation condenser subsystems shown on Figure 5.1-3.

Four radiation sensors are installed in each isolation condenser pool exhaust passage to the outside vent lines that vent the air and evaporated coolant (vapor) to the environment. These sensors are part of the LD&IS described in Subsection 5.2.5.2. On high radiation signal coming from any two of the four radiation monitors installed near each isolation condenser compartment, all the lines from/to the isolation condenser are isolated. This means closure of all steam supply and condensate return isolation valves. The high radiation can be due to a leak from any isolation condenser tube and a subsequent release of noble gas to the air above the IC/PCCS pool surface.

Four sets of differential pressure instrumentation on each steam supply line and another four sets on each condensate return line are used to detect a possible LOCA.

High differential pressure transmitter signal, coming from two of four differential pressure transmitter sensors on the same line (steam or condensate), closes all isolation valves and therefore renders the isolation condenser inoperable.

The operator cannot override either the high radiation signals from the isolation condenser atmosphere vents or the high differential pressure isolation condenser isolation signals.

A temperature element is provided in each vent line, downstream of the valves, to confirm vent valve function. These temperature elements send a signal to the control room.

A temperature element is provided in the condensate return line, downstream of the second inboard containment isolation valve and at the bottom and top of the condensate line at the RPV connection. Each temperature element is connected to the main control room. These temperature measurements provide information on temperature stratification in the piping.

A temperature element is also provided in the upper part of the isolation condenser steam supply line in the drywell that can be used to confirm the steam line is near the steam saturation temperature in the RPV and is therefore largely free of noncondensable gases.

A test connection with an end cap is provided at the upstream side of the outer steam supply isolation valve on the steam supply line, to mount a test pressure indicator and perform leak tests on steam supply isolation valves.

Nonsafety-related temperature sensors are provided in the lower header of the ICS condenser. Operators can use temperature and pressure inside the lower header to determine if noncondensable gases have accumulated. Automatic opening of the lower header vent line six hours post ICS initiation is still required; see Subsection 5.4.6.2.3.

A test connection with an end cap is provided at the downstream side of the outer condensate return isolation valve, on the condensate return line to mount a test pressure indicator and perform leak tests on condensate return isolation valves.

A test connection with an end cap is provided upstream of the solenoid-operated isolation valve and manual operated valve to mount a test pressure indicator and perform leak tests on purge line excess flow valve.

5.4.7 Residual Heat Removal System

The ESBWR is a passive plant and does not have the traditional RHR system. For normal shutdown and cooldown, residual and decay heat is removed via the main condenser and the RWCU/SDC system as discussed in Subsection 5.4.8. The ICS provides cooling of the reactor when the RCPB becomes isolated following a scram during power operations. The ICS (Subsection 5.4.6) automatically removes residual and decay heat to limit reactor pressure within safety limits when the reactor isolation occurs.

Additional reactor heat removal capability and cooling is provided by ESFs. The ADS function of the NBS depressurizes the reactor should the ICS be unable to maintain coolant level (Subsection 6.3.3). Depressurization allows the GDCS to add cool water to the RPV (Subsection 6.3.2). The GDCS is operational at low reactor vessel pressure following pressure reduction by the LOCA or the ADS.

The systems that deal with accomplishing the RHR function meet the requirements of the following regulations as presented in the referenced subsections as follows:

- GDC 1, as it relates to the quality standards and records for structures, systems and components important to safety;
- GDC 2 with respect to the seismic design of Systems, Structures and Components (SSCs) whose failure could cause an unacceptable reduction in the capability of the RHR function based on meeting position C-2 of RG 1.29 or its equivalent;
- GDC 3, as it relates to fire protection for structures, systems and components important to safety;
- GDC 4, as related to dynamic effects associated with flow instabilities and loads (e.g., water hammer);
- GDC 5, which requires that any sharing among nuclear power units of safety-related SSCs does not significantly impair their safety function;
- GDC 19 with respect to control room requirements for normal operations and shutdown; and

5.4.14.2 Description

The use and location of rigid-type supports, variable or constant spring-type supports, snubbers, and anchors or guides are determined by flexibility and seismic/dynamic stress analyses. Direct weldment to thin wall pipe is avoided where possible.

5.4.14.3 Safety Evaluation

The flexibility and seismic/dynamic analyses are performed for the design of adequate component support systems under all loading conditions, including temporary and transient conditions, expected by each component. Provisions are made to provide spring-type supports for the initial dead weight loading due to flooding of steam system piping to prevent damage to this support type.

5.4.14.4 Testing and Inspection Requirements

After completion of the installation of a support system, all hangers and snubbers are visually examined to assure that they are in correct adjustment to their cold setting position. Upon hot startup operations, thermal growth is observed to confirm that spring-type hangers and snubbers can function properly between their hot and cold setting positions. Final adjustment capability is provided on all hanger and snubber types.

Weld inspections and standards are in accordance with ASME B&PV Code Section III. Welder qualifications and welding procedures are in accordance with ASME B&PV Code Section IX and Subsection NF-4300 of ASME B&PV Code Section III.

5.4.14.5 Instrumentation Requirements

None

5.4.15 COL Information

None.

5.4.16 References

5.4-1 (Deleted)

5.4-2 GE Nuclear Energy, "Depressurization Valve Development Test Program Final Report," GEFR-00879, October 1990

5.4-3 GE Hitachi Nuclear Energy, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," NEDE-33572P, Class II (Proprietary), Revision ~~0~~1, Ma~~rch~~y 2010; NEDO-33572, Revision ~~0~~1, Class I (Non-proprietary), Ma~~rch~~y 2010.

Table 5.4-1

Component and Subsystem Design Controls

Component/Subsystem	Control(s)
Feedwater Branch Isolation Valve size:	Nominally 300 mm (12 in) diameter
Feedwater Branch Isolation Testable-Check Valve Cracking Pressure:	Greater than 34.5 kPaD (5 psid) and less than or equal to 69 kPaD (10 psid)
Feedwater Branch Isolation Testable-Check Valve Full-Open Pressure:	No greater than 138 kPa (20 psi)
Feedwater Branch Isolation Testable-Check Valve Leakage:	Allowable leak rate shall be defined under the containment isolation leak rate testing program per Section 6.2.6.
FWIV/FWCV/Branch Isolation design envelope:	Designed to accommodate demineralized, deaerated condensate at feedwater system operating conditions.
MSIV/FWIC/FWCV/Branch Isolation Valve design life:	60 years service at operating conditions.
MSIV/FWIC/FWCV/Branch Isolation Valve corrosion allowance:	60 years service.
MSIVs, FWIVs, FWCVs, and Branch Isolation Valves are designed to remain closed under long-term post-accident environmental conditions:	≥ 100 days.
Number of Isolation Condenser Trains:	Four
ICS station blackout (i.e., unavailability of all AC power) capability:	≥ 72 hours
Isolation condenser sizing:	Sized to remove post-reactor isolation decay ~~heat with three out of four isolation condensers~~ operating and to reduce reactor pressure and temperature to safe shutdown conditions, in 36 hours, with ~~occasional~~ venting of noncondensable gases to the suppression pool.

Table 6.1-1
Containment System Including PCCS, and ECCS Component Materials

Component	Applicable ASME Code Section III,	Form	Material	Specification (ASTM/ASME)
Containment				
Containment Vessel Liner	Div 2, Subsection CC	Plate	Carbon Steel	See Subsection 3.8.1.6.4
	Div 2, Subsection CC	Plate	Stainless Steel	See Subsection 3.8.1.6.4
Penetrations	Div 1, Subsection NE	Plate	Carbon Steel	See Subsection 3.8.2.6
	Div 1, Subsection NE	Pipe	Carbon Steel	See Subsection 3.8.2.6
GDCS and Suppression Pool Liner	Div 2, Subsection CC	Plate	Stainless Steel	See Subsection 3.8.1.6.4 and Subsection 3.8.3.6.5
(Deleted)				
Drywell Head, Personnel Lock, Equipment Hatch	Div 1, Subsection NE	See Subsection 3.8.2.6	See Subsection 3.8.2.6	See Subsection 3.8.2.6
Structural Steel	Div 1, Subsection NE	Shapes	Carbon Steel	A 36, A 572 Gr 50
Vent Pipe	Div 1, Subsection NE	Plate	Stainless Steel	SA-240 Gr 304L
PCCS				
Condenser and associated piping that are part of the containment pressure boundary	Div 1, Subsection NE	Forging	Stainless Steel	SA-182 Gr ~~F304L~~<u>XM-19</u>
		~~Tube~~	~~Stainless Steel~~	~~SA-312 Gr XM-19~~
		Pipe	Stainless Steel	SA-312 Gr TP304L
Piping (in drywell)	Div 1, Subsection NC	Pipe	Stainless Steel	SA-312 Gr TP304L
Flanges	Div 1, Subsection NC	Forging	Stainless Steel	SA-182 Gr F304L
Nuts and Bolts	Div 1, Subsection NC	Bar	Stainless Steel	SA-194 Gr 8, SA-193 Gr B8

6.2.1.1.10 Severe Accident Conditions

Severe Accident considerations are in the design of the ESBWR. The ESBWR design philosophy is to continue to maintain design flexibility in order to allow for potential modifications.

This section reviews the design approach and ESBWR design features for the prevention and mitigation of severe accidents.

6.2.1.1.10.1 Layered Defense-in-Depth Approach

The ESBWR utilizes the concept of defense-in-depth as a basic design philosophy. This is an approach that relies on providing numerous barriers. These barriers include both physical barriers (for example, fuel pellet, fuel cladding, reactor vessel and ultimately the containment), as well as layers that emphasize accident prevention and accident mitigation. The ESBWR considers beyond design basis events in its design approach. It provides for additional defense-in-depth by considering a broad range of events, including those with very low estimated frequency of occurrence (< 1.0E-5 per reactor year) and by incorporating design features to mitigate significant containment challenges.

Using this layered defense-in-depth approach, the following are the main elements in the design against severe accidents:

- Accident prevention;
- Accident mitigation; and
- Containment performance including design features to address containment challenges during a severe accident.

6.2.1.1.10.2 ESBWR Design Features for Severe Accident Control

Several features are designed into the ESBWR that serve either to prevent or mitigate the consequences of a severe accident. Key ESBWR features, their design intent, and the corresponding issues are summarized in Table 6.2-9. For each feature listed in Table 6.2-9, brief discussion is made below.

(1) ICS

The isolation condensers support both reactor water level and pressure control and are the first defense against a severe accident. The ESBWR is equipped with four isolation condensers, which conserve RPV inventory in the event of RPV isolation. Basically, the isolation condensers take steam from the RPV and return condensate back to the RPV. The isolation condensers begin operation when the condensate lines open automatically on diverse signals including RPV level dropping to Level 2. After operation begins, the isolation condensers are capable of keeping the RPV level above the setpoint for ADS actuation. The design mitigates noncondensable buildup in the isolation condensers (that can impair heat removal capacity) by temporarily opening a small vent line connecting the isolation condensers to the suppression pool. The vent line is operated automatically when high RPV pressure is maintained for more ~~than a set time. The vent line valves re-close automatically when RPV pressure is decreased~~ below the setpoint pressure. The lower header vent line is also automatically opened post six hours ICS initiation. This mitigates accumulation of noncondensables during long term use of ICS (e.g, station blackout for 72 hours).

The RPV depressurizes in the event of a break in the primary system or after ADS actuation. Furthermore, the ESBWR design does not require the operation of the isolation condensers to prevent containment pressurization and containment pressure control function is served by the PCCS.

(2) ADS

The ESBWR reactor vessel is designed with a highly reliable depressurization system. This system plays a major role in preventing core damage. Furthermore, even in the event of core damage, the depressurization system can minimize the potential for high pressure melt ejection and lessen the resulting challenges to containment integrity. If the reactor vessel fails at elevated pressure, fragmented core debris could be transported into the upper DW. The resulting heatup of the upper DW atmosphere could overpressurize the containment or cause over temperature failure of the DW head seals. The RPV depressurization system decreases the uncertainties associated with this failure mechanism by minimizing the occurrences of high pressure melt ejection.

(3) Compact Containment Design

The RB volume is reduced by relocating selected equipment and systems to areas outside of the RB. The major portion of this relocation is to remove non-safety items from the Seismic Class 1 structure and to place them in other structures that are classified as Non-Seismic. Along with other system design simplifications and the above described relocation of non-safety items, a compact containment design is achieved with the characteristic of having a minimum number of penetrations. This reduces the leakage potential from the containment.

(4) PCCS Heat Exchangers

The basic design of the ESBWR ensures that any fission products from fuel damage following a severe accident are not released outside the plant. One such removal mechanism is the PCCS heat exchanger tubes. These tubes act like a filter for the aerosols. They essentially "filter out" any aerosols that are transported into the PCCS units along with the steam and noncondensable gas flow. Aerosols that are not retained, in the DW or the PCCS heat exchangers, get transported via the PCCS vent line to the suppression pool where they are efficiently scrubbed.

The PCCS heat exchanger not only cools the containment by removing decay heat during accident, but also provides fission product retention within the containment.

(5) Lower Drywell Configuration

The floor area of the lower DW has been maximized to improve the potential for ex-vessel debris cooling. There is a drain sump incorporated into the lower DW floor intended to prevent water buildup on the floor. The location of the sump has been maximized to place it as far away from the RPV as possible. The sump has channels at floor level to allow water to flow into the sump. The channels are long enough that any molten debris from a severe accident will solidify before it exits the channels and reaches the sump.

- 10 CFR 52.47(a)(2)(iv), and GDC 19 of 10 CFR 50 Appendix A, as the PCCS is designed to maintain containment pressure boundary following deflagrations or detonations within PCCS from hydrogen accumulation.

6.2.2.1 Design Basis

Functions

PCCS removes the core decay heat rejected to the containment after a LOCA. It provides containment cooling for a minimum of 72 hours post-LOCA, with containment pressure never exceeding its design pressure limit, and without makeup to the IC/PCCS pools, equipment pool, and reactor well.

The PCCS is an ESF, and therefore a safety-related system.

General System Level Requirements

The PCCS condenser is sized to maintain the containment within its pressure limits for DBAs. The PCCS is designed as a passive system without power actuated valves or other components that must actively function in the first 72 hours. Also, it is constructed of stainless steel to design pressure, temperature and environmental conditions that equal or exceed the upper limits of containment system reference severe accident capability.

Performance Requirements

The PCCS consists of six PCCS condensers. Each PCCS condenser is made of two identical modules and each entire PCCS condenser two-module assembly is designed for a minimum 7.8~~11~~ MWt capacity~~, nominal,~~ at the following conditions:

- Pure saturated steam in the tubes at 308 kPa absolute (45 psia) and 134°C (273°F); and
- Pool water temperature at atmospheric pressure and 102°C (216°F).

Design Pressure and Temperature

The PCCS design pressure and temperature are provided in Table 6.2-10.

The PCCS condenser is an integral part of the containment pressure boundary. Therefore, ASME Code Section III Class MC, Seismic Category I, and Tubular Exchanger Manufacturers Association Class R apply. Material is nuclear grade stainless steel or other material, which is not susceptible to Intergranular Stress Corrosion Cracking (IGSCC).

6.2.2.2 System Description

6.2.2.2.1 Summary Description

The PCCS consists of six independent closed loop extensions of the containment. Each loop contains a heat exchanger (PCCS condenser) that condenses steam on the tube side and transfers heat to water in a large pool, which is vented to atmosphere.

The PCCS operates by natural circulation. Its operation is initiated by the difference in pressure between the DW and the WW, which are parts of the ESBWR pressure suppression type containment system. The DW and WW vacuum breaker must fully close after each demand to support the PCCS operation. If the vacuum breaker does not close, a backup isolation valve closes.

The PCCS condenser, receives a steam-gas mixture supply directly from the DW. 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 condensers do 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 sets of two steam condenser modules (Passive Containment Cooling Condensers), as shown Figure 6.2-16. Each PCCS condenser is designed for a minimum 7.8 ~~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. The Equipment Storage pool and Reactor Well are designed to have sufficient water volume to provide makeup water to the IC/PCCS pools for at least the initial 72 hours after a LOCA without makeup. The Equipment Storage pool and Reactor Well are connected to Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pools via pool cross-connect valves (see Figure 6.2-2), which open upon low level in IC/PCCS inner expansion pool. The PCCS relies on the water in the Equipment Storage pool and Reactor Well to perform its safety-related function for the first 72 hours of a DBA. The pool cross-connect valves reside within the ICS described in Subsections 5.4.6, 7.4.4, and 7.5.5. 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 DW gas through the PCCS condensers.

The PCCS condensers are located in a large pool (IC/PCCS pool) positioned above the ESBWR DW.

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

A central steam supply pipe is provided which is open to the DW airspace at its lower end. The open end of this pipe is provided with a debris filter with holes no greater than 25 mm (1 inch). The maximum inlet velocity during a LOCA is estimated to be no greater than 106 m/s (348 ft/s). The steam supply 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 through the DW through a single passage per condenser module as shown on the 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.

When the drywell pressure is higher than the combined wetwell pressure and vent line submergence, noncondensable gases vent to the suppression pool. When the drywell pressure is equal to or lower than the combined wetwell pressure and vent line submergence, noncondensable gases including hydrogen and oxygen (created by radiolytic decomposition in the core) accumulate in the lower drum of the PCCS condenser thereby producing a potentially flammable/detonable mixture. As such, the PCCS condensers are designed to withstand the overpressure and dynamic effects produced by deflagrations or detonations of these mixtures. To reduce accumulation in the PCCS vent lines, vent line catalyst modules composed of metal parallel plates coated with catalyst are placed at the entrance of each vent line. See Table 6.2-10 for PCCS vent catalyst performance requirements. Reference 6.2-14 provides details regarding hydrogen accumulation in the PCCS and their design to withstand deflagrations or detonations~~the stress analysis of the condenser and supports~~.

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 noncondensable gas from the PCCS for continued condenser efficiency. The minimum fan performance requirements are shown in Table 6.2-49. 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 PCCS 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. The vent fan discharge line is 24 cm (9.4 in) below the top of the drain pan lip with a tolerance of 1.4 cm (0.6) in. To further prevent reverse flow through an idle fan, a normally closed isolation valve is installed upstream of the fan. The valve is opened by operator action and relies on the same power source as the fan~~a check valve is installed downstream of the fan~~. Since the PCCS condensers and vent piping have the potential for containing hydrogen and oxygen, the vent fans are designed and constructed so as to not be ignition sources for combustion in accordance with NFPA 69 and AMCA 99-03.

The PCCS condensers receive a steam-gas mixture supply directly from the DW. The PCCS condensers are initially driven by the pressure difference created between the 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 DW to WW 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) and no greater than 0.900 m (35.4 in) above the top of the uppermost horizontal vent. The PCCS condensers are an integral part of the safety-related containment and do not have isolation valves.

The drain line is submerged in the GDCS pool to prevent 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/PCCS 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 PCCS 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/PCCS pool water.

IC/PCCS 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 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/PCCS expansion pool.

Cooling and cleanup of IC/PCCS 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 condensers are in "ready standby."

Plant Shutdown Operation

During refueling, the PCCS condenser maintenance can be performed, after closing the locked open valve, which connects the PCCS pool subcompartment to the common parts of the IC/PCCS pool, and drying the individual partitioned PCCS pool subcompartment.

Passive Containment Cooling Operation

The PCCS receive a steam-gas mixture supply directly from the DW; it does not have any valves, so it immediately starts into operation, following a LOCA event. Noncondensables, together with steam vapor, enter the PCCS condenser; steam is condensed inside PCCS condenser vertical tubes, and the condensate, which is collected in the lower headers, is ~~discharged to the GDCS pool. The noncondensables are purged to the WW through the vent~~ line. The PCCS vent catalyst recombines radiolytic hydrogen and oxygen entering the vent line.

The PCCS vent fan can be started to assist the natural venting action to remove noncondensable gases that could accumulate in the PCCS condensers. TRACG studies have shown that the PCCS meets its design function without the use of the PCC vent fan for at least 72 hours.

6.2.2.3 Design Evaluation

The PCCS condenser is an integral part of the containment DW pressure boundary and it is used to mitigate the consequences of an accident. This function classifies it as a safety-related ESF. ASME Code Section III, Class MC and Section XI requirements for design and accessibility of welds for inservice inspection apply to meet 10 CFR 50, Appendix A, Criterion 16. Quality Group B requirements apply per RG 1.26. The system is designed to Seismic Category I per RG 1.29. The common cooling pool that PCCS condensers share with the ICs of the Isolation Condenser System (ICS) is a safety-related ESF, and it is designed such that no locally generated force (such as an IC system rupture) can destroy its function. Protection requirements against mechanical damage, fire and flood apply to the common IC/PCCS pool.

The PCCS components located in a subcompartment of the safety-related IC/PCCS pool are protected by the IC/PCCS pool subcompartment from the effects of missiles tornados to comply with 10 CFR 50, Appendix A, Criteria 2 and 4.

The PCCS condenser cannot fail in a manner that damages the safety-related IC/PCCS pool because it is designed to withstand induced dynamic loads, which are caused by combined seismic, DPV/ SRV or LOCA conditions in addition to PCCS operating loads.

In conjunction with the pressure suppression containment (Subsection 6.2.1.1), the PCCS is designed to remove heat from the containment to comply with 10 CFR 50, Appendix A, Criterion 38. Provisions for inspection and testing of the PCCS are in accordance with Criteria 39, 52 & 53. Criterion 51 is satisfied by using nonferritic stainless steel in the design of the PCCS.

The intent of Criterion 40, testing of containment heat removal system is satisfied as follows:

- The structural and leak-tight integrity can be tested by periodic pressure testing;
- Functional and operability testing is not needed because there are no active components of the system; and
- Performance testing during in-plant service is not feasible; however, the performance capability of the PCCS was proven by full-scale PCCS condenser prototype tests at a test facility before their application to the plant containment system design. Performance is established for the range of in-containment environmental conditions following a LOCA. Integrated containment cooling tests have been completed on a full-height reduced-section test facility, and the results have been correlated with TRACG computer program analytical predictions; this computer program is used to show acceptable containment performance (Reference 6.2-10 Section 5.3, and Reference 6.2-11, Section 13), which is reported in Subsection 6.2.1.1 and Section 15.4.

6.2.2.4 Testing and Inspection Requirements

The PCCS is an integral part of the containment, and it is periodically pressure tested as part of overall containment pressure testing (Subsection 6.2.6). Also, the PCCS condensers can be isolated using spectacle flanges for individual pressure testing during maintenance.

The performance of a representative sample of PCCS vent catalyst is tested on a staggered basis at a frequency of 24 months.

PCCS condenser removal for routine inspection is not required.

Refer to Reference 6.2-14 for inspection requirement for the PCCS condenser.

6.2.2.5 Instrumentation Requirements

The PCCS does not have instrumentation. Control logic is not needed for it's functioning. There are no sensing and power actuated devices except for the vent fans. Containment System instrumentation is described in Subsection 6.2.1.7.

discussed herein were developed in a manner that is consistent with the guidance provided in SRP 6.2.5 and RG 1.7.

There are unique design features of the ESBWR that are important with respect to the determination of post-accident radiolytic gas concentrations. In the post-accident period, the ESBWR does not utilize active systems for core cooling and decay heat removal. As indicated earlier, for a design basis LOCA, the ADS would depressurize the reactor vessel and the GDCS would provide gravity driven flow into the vessel for emergency core cooling. The core would be subcooled initially and then it would saturate resulting in steam flow out of the vessel and into the containment. The PCCS heat exchangers would remove the energy by condensing the steam. This would be the post-accident mode and the core coolant would be boiling throughout this period. Although the process of steam condensation has the effect of concentrating the radiolytically generated hydrogen and oxygen within the ~~ICS and~~ PCCS condensers these components have been designed to accommodate the loads resulting from combustion. The accumulation of hydrogen and oxygen in the ICS is mitigated by continuously venting the lower header during non-LOCA scenarios and closing the isolation valves once the ICS inventory has drained into the RPV during LOCA scenarios with the DPV's opening.

A similar situation would exist for a severe accident that results in a core melt followed by reactor vessel failure. In this case, the GDCS liquid would be covering the melted core material in the lower DW, with an initial period of subcooling followed by steaming. The PCCS heat exchangers would be removing the energy in the same manner as described above for a design basis LOCA.

In order to prevent noncondensable related termination of steam condensation, the PCCS heat exchangers are provided with a vent which transfers any noncondensable gases which accumulate in the heat exchanger tubes to the suppression pool vapor space, driven by the DW to suppression pool pressure differential. In this way, the majority of the noncondensable gases are in the suppression pool. The calculation of post-accident radiolytic oxygen generation accounts for this movement of noncondensable gases to the suppression pool after they are formed in the DW.

The effect of the core coolant boiling is to strip dissolved gases out of the liquid phase resulting in a higher level of radiolytic decomposition. This effect was accounted for in the analysis.

6.2.5.5.2 Analysis Assumptions

The analysis of the radiolytic oxygen concentration in containment was performed consistent with the methodology of Appendix A to SRP 6.2.5 and RG 1.7. Some of the key assumptions are as follows:

- Reactor power is 102% of rated;
- G (O_2) = 0.25 molecules/100eV;
- Initial containment O_2 concentration = 4%;
- Allowed containment O_2 concentration = 5%;
- Stripping of DW noncondensable gases to WW vapor space;
- Fuel clad-coolant reaction up to 100%; and

6.2-7 GE Hitachi Nuclear Energy, "ESBWR Feedwater Temperature Operating Domain Transient and Accident Analysis," NEDO-33338, Revision 1, Class I (Non-proprietary), May 2009.

6.2-8 Moody, F.J. "Maximum Discharge Rate of Liquid-Vapor Mixtures from Vessels," General Electric Company, Report No. NEDO-21052-A, May 1979.

6.2-9 GE Hitachi Nuclear Energy, "ESBWR Scaling Report," NEDC-33082P, Revision 2, Class III (Proprietary), April 2008; NEDO-33082, Revision 2, Class I (Non-proprietary), April 2008.

6.2-10 TRACG Qualification for Simplified Boiling Water Reactor (SBWR), NEDC-32725P, Rev. 1, Vol. 1 and 2, August 2002.

6.2-11 GE Hitachi Nuclear Energy "ESBWR Safety Analysis - Additional Information," NEDE-33440P, Revision 2, Class III (Proprietary), March 2010; NEDO-33440, Revision 1, Class I (Non-proprietary), March 2010.

6.2-12 Idel'chik, I.E., Barouch, A. "Handbook of hydraulic resistance: coefficients of local resistance and of friction," National Technical Information Service, 1960.

6.2-13 SMSAB-02-04, "CONTAIN Code Qualification Report/User Guide for Auditing Subcompartment Analysis Calculations," Office of Nuclear Regulatory Research, September 2002 (ADAMS Accession Number ML023220288).

6.2-14 GE Hitachi Nuclear Energy, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," NEDE-33572P, Class II (Proprietary), Revision 01, Marchy 2010; NEDO-33572, Revision 01, Class I (Non-proprietary), Marchy 2010.

6.2-15 GE Hitachi Nuclear Energy, "Leakage Detection Instrumentation Confirmatory Test for the ESBWR Wetwell-Drywell Vacuum Breakers," NEDE-33564P, Class II (Proprietary), Revision 0, March 2010; NEDO-33564, Revision 0, Class I (Non-proprietary), March 2010.

Table 6.2-6a

Summary of ESBWR TRACG Nodalization Changes

(From the Design in Ref. 6.2-1 to the DCD Design)

Item #	Description	Change	Due to Design Change	Addressing Ref. 6.2-1 SER Conditions
1	Core Power	4000 MW to 4500 MW	✓	
2	Number of bundles	1020 to 1132	✓	
3	Core shroud OD	+ 0.328 m (1.076 ft)	✓	
4	Number of CRDs	121 to 269	✓	
5	GDCS pool and air space location	Connection changed from WW to DW; Eliminated the GDCS air space vent pipes to WW.	✓	✓
6	GDCS pool air space and DW connection	For bounding calculation, two pipes are used to simulate the connection between the GDCS pool air space and the DW, to purge residual noncondensable gases in this air space.	✓	
7	Total PCCS capacity	4x13.5 MW to 6x~~11~~7.8 MW	✓	
8	Total IC capacity	4x30 MW to 4x33.75 MW	✓	
9	Pressure relief system	12 ADS valves to 10 ADS valves + 8 SV	✓	
10	Containment vents	10 to 12	✓	
11	Spill-over connection (DW annulus to vertical vent module)	Changed from ten horizontal holes to twelve horizontal holes; hole inlet elevation raised to approximately 2.5 m (8.2 ft) above the suppression pool normal water level.	✓	
12	SLC System activated on ADS	Yes for the DCD design.	✓	
13	Credit for water added by HCUs during scram	Yes for the DCD design.	✓	
14	Credit for IC inventory for RPV analysis	Yes for the DCD design.	✓	
15	Integrated TRACG input deck	Combined the RPV and containment input decks into one consistent, detailed deck.		✓

Table 6.2-10

Passive Containment Cooling Design Parameters

Number of PCCS Condensers	Six (6)
Heat Removal Capacity for Each Condenser	~~11~~7.8 MWt ~~Nominal~~minimum for pure saturated steam at a pressure of 308 kPa (absolute) (45 psia) and temperature of 134°C (273.2 °F) condensing inside tubes with an outside pool water temperature of 102°C (216°F).
System Design Pressure	758.5 kPa(G) (110 psig)
System Design Temperature	171°C (340°F)
PCCS Vent Line Catalyst Modules	
Number (one per vent line)	12
Catalyst Type	Platinum/Paladium Coating on metal plate substrate
Minimum Hydrogen Recombination Capability Rate (per module) With a test stream consisting of 4% hydrogen in its stoichiometric ration with oxygen, the balance being inert gas, and whose minimum velocity through the module is 0.166 m/s (0.545 ft/s)	1.66 kg/h (3.66 lbm/h)

Table 6.2-24

Containment Isolation Valve Information for the Isolation Condenser System Loop A

Penetration Identification	B32-MPEN-0009(2)		B32-MPEN-0009(3)				B32-MPEN-0001(2)	
Valve Number	**F007A**	**F008A**	**F009A**	**F010A**	**F011A**	**F012A**	**F013A**	**F014A**
(Deleted)								
Normal Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
Shutdown Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
Post-Accident Position	Closed	Closed	Open/Closed	Open/Closed	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~Open	~~Closed~~Open	N/A	Open	Closed	N/A
Containment Isolation Signal(d)	P	P	P	P	Q	P	I, K	Q
Primary Actuation	Remote manual	Remote manual	Remote manual	Remote manual	Pressure	Remote manual	Automatic	Diff Pressure
Secondary Actuation	N/A	N/A	N/A	N/A	N/A	N/A	Remote Manual	N/A
Closure Time (sec)	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
Power Source	Div. 1	Div. 1	Div. 2, 4	Div. 2, 4	N/A	Div. 1	Div. 1, 2, 3	N/A

(1) The piping and valve arrangement for these lines meet the requirement of 10 CFR 50, App. A, GDC 55 because there are two normally closed valves in series in the line that leads from the suppression chamber back to the closed IC loop outside the containment.

(2) Two in-series valves

(3) Two in-series valves (F009/F010) in parallel with two in series valves (F011/F012)

(4) Closed barrier outside containment

* Nominal pipe size diameter

Note: For explanation of codes, see legend on Table 6.2-15. See Table 3.9-8 for valve and actuator types.

Table 6.2-26

Containment Isolation Valve Information for the Isolation Condenser System Loop B

Penetration Identification	B32-MPEN-0010[2]		B32-MPEN-0010[3]				B32-MPEN-0002[2]	
Valve Number	**F007B**	**F008B**	**F009B**	**F010B**	**F011B**	**F012B**	**F013B**	**F014B**
(Deleted)								
Normal Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
Shutdown Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
Post-Accident Position	Closed	Closed	Open/Closed	Open/Closed	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~Open	~~Closed~~Open	N/A	Open	Closed	N/A
Containment Isolation Signal[d]	P	P	P	P	Q	P	I, K	Q
Primary Actuation	Remote manual	Remote manual	Remote manual	Remote manual	Pressure	Remote manual	Automatic	Diff Pressure
Secondary Actuation	N/A	N/A	N/A	N/A	N/A	N/A	Remote Manual	N/A
Closure Time (sec)	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
Power Source	Div. 2	Div. 2	Div. 1, 3	Div. 1, 3	N/A	Div. 2	Div. 2, 3, 4	N/A

(1) The piping and valve arrangement for these lines meet the requirements of 10 CFR 50, App. A, GDC 55 because there are two normally closed valves in series in the line that leads from the suppression chamber back to the closed IC loop outside the containment.

(2) Two in series valves

(3) Two in series valves (F009/F010) in parallel with two in series valves (F011/F012)

(4) Closed barrier outside containment (IC piping outside containment is Quality Group B Design)

* Nominal pipe size diameter

Note: For explanation of codes, see legend on Table 6.2-15. See Table 3.9-8 for valve and actuator types.

Table 6.2-28

Containment Isolation Valve Information for the Isolation Condenser System Loop C

Penetration Identification	B32-MPEN-0011[(2)]		B32-MPEN-0011[(3)]				B32-MPEN-0003[(2)]	
Valve Number	F007C	F008C	F009C	F010C	F011C	F012C	F013C	F014C
(Deleted)								
Normal Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
~~Shutdown Position~~	~~Closed~~	~~Closed~~	~~Closed~~	~~Closed~~	~~Closed~~	~~Closed~~	~~Open~~	~~Open~~
Post-Accident Position	Closed	Closed	Open/Closed	Open/Closed	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~Open	~~Closed~~Open	N/A	Open	Closed	N/A
Containment Isolation Signal[(d)]	P	P	P	P	Q	P	I, K	Q
Primary Actuation	Remote manual	Remote manual	Remote manual	Remote manual	Pressure	Remote manual	Automatic	Diff Pressure
Secondary Actuation	N/A	N/A	N/A	N/A	N/A	N/A	Remote Manual	N/A
Closure Time (sec)	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
Power Source	Div. 3	Div. 3	Div. 2, 4	Div. 2, 4	N/A	Div. 3	Div. 3, 4, 1	N/A

(1) The piping and valve arrangement for these lines meet the requirements of 10 CFR 50, App. A, GDC 55 because there are two normally closed valves in series in the line that leads from the suppression chamber back to the closed IC loop outside the containment.

(2) Two in series valves

(3) Two in series valves (F009/F010) in parallel with two in series valves (F011/F012)

(4) Closed barrier outside containment (IC piping outside containment is Quality Group B)

* Nominal pipe size diameter

Note: For explanation of codes, see legend on Table 6.2-15. See Table 3.9-8 for valve and actuator types.

Table 6.2-30

Containment Isolation Valve Information for the Isolation Condenser System Loop D

Penetration Identification	B32-MPEN-0012(2)		B32-MPEN-0012(3)				B32-MPEN-0004(2)	
Valve Number	**F007D**	**F008D**	**F009D**	**F010D**	**F011D**	**F012D**	**F013D**	**F014D**
Shutdown Position	Closed	Closed	Closed	Closed	Closed	Closed	Open	Open
Post-Accident Position	Closed	Closed	Open/Closed	Open/Closed	Open/Closed	Open/Closed	Open	Open
Power Fail Position	Closed	Closed	~~Closed~~Open	~~Closed~~Open	N/A	Open	Closed	N/A
Containment Isolation Signal(d)	P	P	P	P	Q	P	I, K	Q
Primary Actuation	Remote manual	Remote manual	Remote manual	Remote manual	Pressure	Remote manual	Automatic	Diff Pressure
Secondary Actuation	N/A	N/A	N/A	N/A	N/A	N/A	Remote Manual	N/A
Closure Time (sec)	< 15	< 15	< 15	< 15	< 15	< 15	< 15	< 15
Power Source	Div. 4	Div. 4	Div. 1, 3	Div. 1, 3	N/A	Div. 4	Div. 4, 1, 2	N/A

(1) The piping and valve arrangement for these lines meet the requirements of 10 CFR 50, App. A, GDC 55 because there are two normally closed valves in series in the line that leads from the suppression chamber back to the closed IC loop outside the containment.

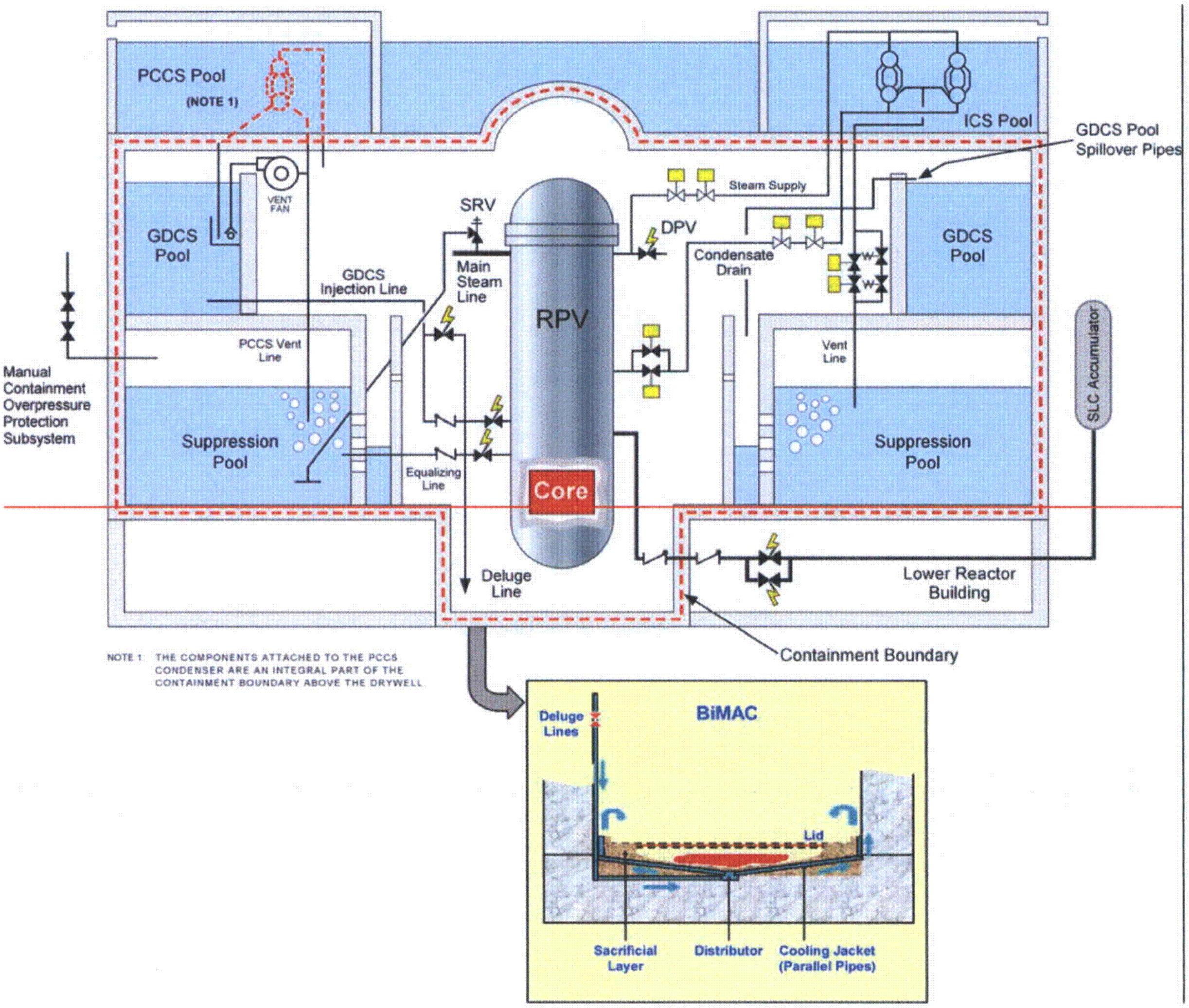
(2) Two in series valves

(3) Two in series valves (F009/F010) in parallel with two in series valves (F011/F012)

(4) Closed barrier outside containment (IC piping outside containment is Quality Group B)

* Nominal pipe size diameter

Note: For explanation of codes, see legend on Table 6.2-15. See Table 3.9-8 for valve and actuator types.


PCCS Pool
(NOTE 1)
ICS Pool
GDCS Pool Spillover Pipes
VENT FAN
GDCS Pool
SRV
Steam Supply
DPV
Condensate Drain
GDCS Pool
GDCS Injection Line
Main Steam Line
RPV
PCCS Vent Line
Vent Line
SLC Accumulator
Manual Containment Overpressure Protection Subsystem
Suppression Pool
Equalizing Line
Core
Suppression Pool
Deluge Line
Lower Reactor Building
Containment Boundary
NOTE 1 THE COMPONENTS ATTACHED TO THE PCCS CONDENSER ARE AN INTEGRAL PART OF THE CONTAINMENT BOUNDARY ABOVE THE DRYWELL
Deluge Lines
BiMAC
Lid
Sacrificial Layer
Distributor
Cooling Jacket (Parallel Pipes)

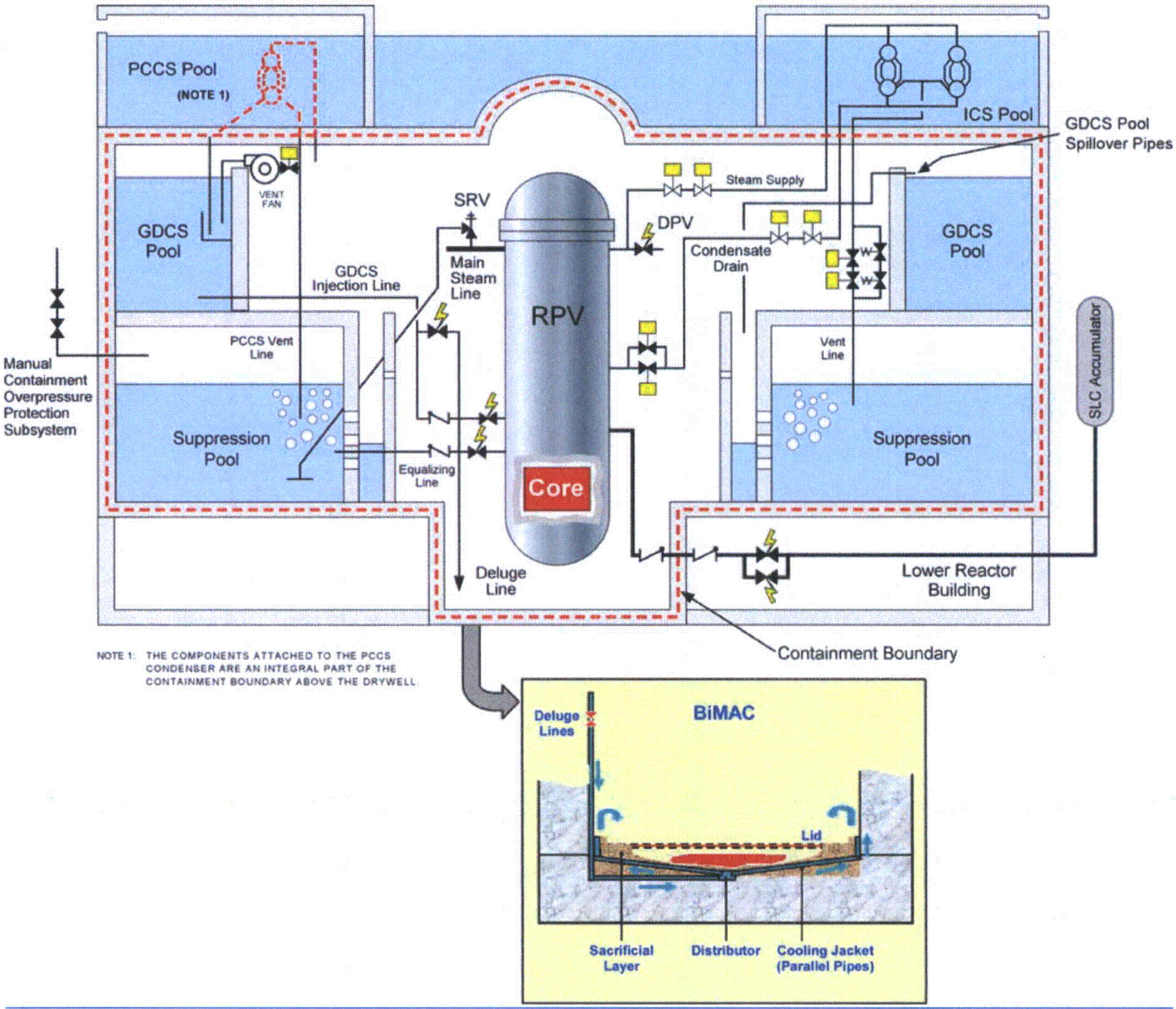
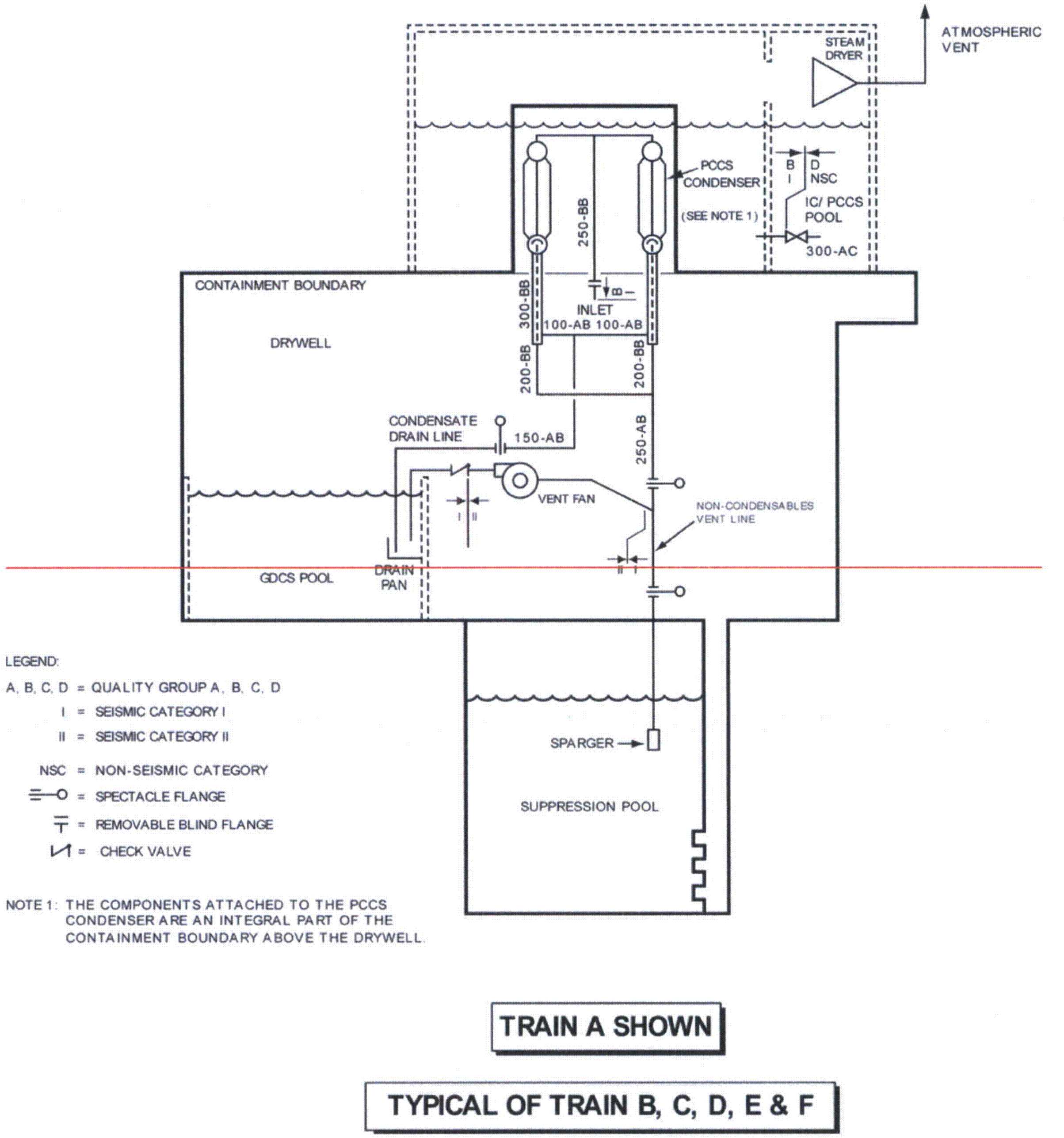


Figure 6.2-15. Summary of Severe Accident Design Features


ATMOSPHERIC VENT
STEAM DRYER
PCCS CONDENSER
(SEE NOTE 1)
B
I
D
NSC
IC/ PCCS POOL
300-AC
250-BB
300-BB
INLET
100-AB 100-AB
200-BB
200-BB
CONTAINMENT BOUNDARY
DRYWELL
CONDENSATE DRAIN LINE
150-AB
250-AB
VENT FAN
I II
NON-CONDENSABLES VENT LINE
II I
GDCS POOL
DRAIN PAN
SPARGER
SUPPRESSION POOL
LEGEND:
A, B, C, D = QUALITY GROUP A, B, C, D
I = SEISMIC CATEGORY I
II = SEISMIC CATEGORY II
NSC = NON-SEISMIC CATEGORY
= SPECTACLE FLANGE
= REMOVABLE BLIND FLANGE
= CHECK VALVE
NOTE 1: THE COMPONENTS ATTACHED TO THE PCCS CONDENSER ARE AN INTEGRAL PART OF THE CONTAINMENT BOUNDARY ABOVE THE DRYWELL.
TRAIN A SHOWN
TYPICAL OF TRAIN B, C, D, E & F

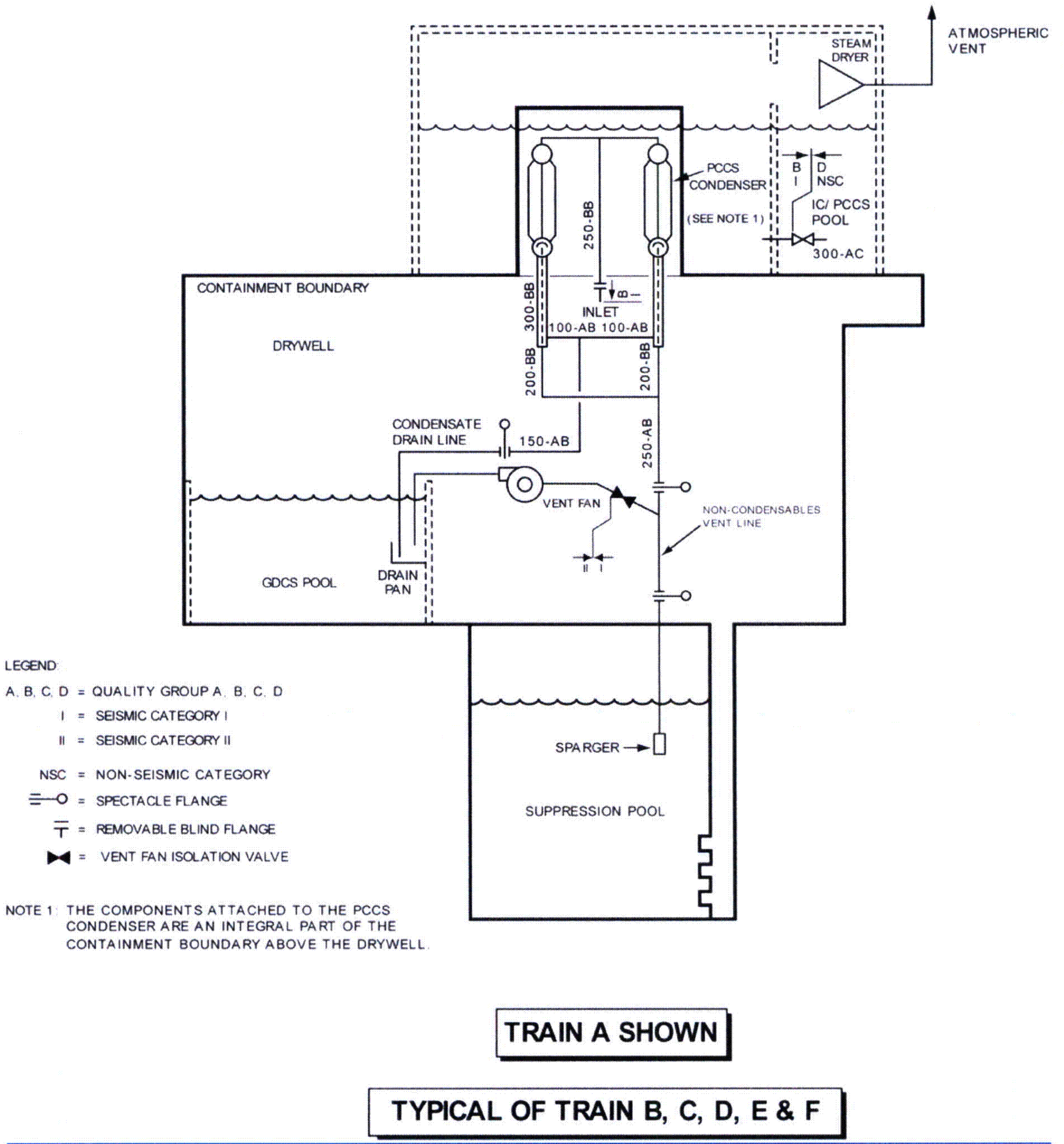


Figure 6.2-16. PCCS Schematic Diagram

PCC – Passive Containment Cooling System

7.3.2 Passive Containment Cooling System

The Passive Containment Cooling System (PCCS) consists of condensers that are an integral part of the containment pressure boundary. The PCCS heat exchanger tubes are located in the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pool outside the containment. Containment (drywell) pressure above the suppression pool (wetwell) pressure, similar to the situation during a loss of reactor coolant into the drywell, forces flow through the PCCS condensers. Condensate from the PCCS drains to the GDCS pools. As the flow passes through the PCCS condensers, heat is rejected to the IC/PCCS pool, thereby cooling the containment atmosphere. This action occurs automatically, without the need for actuation of components. The PCCS does not have instrumentation, control logic, or power-actuated valves, and does not need or use electrical power for its operation in the first 72 hours after a LOCA. For long-term effectiveness of the PCCS, the vent fans and their isolation valves are manually initiated by operator action. Other information on the PCCS is given in Subsection 6.2.2.

7.3.3 Leak Detection and Isolation System

The primary function of the Leak Detection and Isolation System (LD&IS) is to detect and monitor leakage from the RCPB and to initiate the appropriate safety action to isolate the source of the leak. The system is designed to automatically initiate the isolation of certain designated process lines penetrating the containment, to prevent release of radioactive material from the RCPB. The initiation of the isolation functions closes the appropriate containment isolation valves. The LD&IS functions are performed in two separate and diverse safety-related platforms. The Main Steam Isolation Valve (MSIV) isolation logic functions are performed in the Reactor Trip and Isolation Function (RTIF) platform, while all other containment isolation logic functions are performed in the SSLC/ESF platform. The non-safety monitoring functions of LD&IS are performed in the N-DCIS.

7.3.3.1 System Design Bases

The following safety-related system design criteria are applicable to the design of the LD&IS.

- The LD&IS is engineered as a safety-related system, Seismic Category 1, and conforms to the regulatory requirements, guidelines, and industry standards listed in Table 7.1-1 for this system.
- The MSIV function of LD&IS logic design is fail-safe, such that loss of electrical power to the logic of one LD&IS division initiates a channel trip. The containment isolation function of LD&IS logic design is fail as-is such that loss of power to the logic of one division does not result in a trip.
- Isolation is initiated with precision and reliability once leakage has been detected from the RCPB.
- Once isolation is initiated, the action continues to completion. Deliberate operator action is required to reopen the isolation valves.
- The LD&IS design meets the single failure criterion because no single failure within the system, with any three of the four divisions of safety-related power available, initiates inadvertent isolation or prevents isolation when required.

equipment trains can be initiated by either DPS or any one of three SSLC/ESF divisions and their associated safety-related power source. Consequently, the loss of two of the four safety-related power supplies does not result in the loss of any one ICS equipment train. However, second and third sources of safety-related power are provided to operate the ICS automatic venting system during long-term ICS operation; otherwise the manually controlled backup venting system, which uses one of the divisional power sources starting the ICS, can be used for long-term operation.

If the three safety-related power supplies used to start an individual ICS equipment train fail, then the ICS would automatically start, because of the "fail open" actuation of the condensate return bypass valves and vent valves upon loss of electrical power to the solenoids controlling its nitrogen-actuated valves.

The ICS is initiated automatically as part of the ECCS to provide additional liquid inventory to mitigate LOCA events. The signals that initiate ICS operation are:

- High reactor pressure;
- Low reactor water level (Level 2) with time delay;
- Low reactor water level (Level 1);
- Loss of power generation buses (loss of feedwater flow) in reactor run mode;
- MSIV position indication (indicating closure) whenever the Reactor Mode Switch is in the Run position; and
- Operator manual initiation.

The ICS is automatically isolated to mitigate buildup of noncondensable gases during LOCA events. The signal that isolates ICS is a confirmed opening of any two DPV's with a time delay.

The operator is able to stop any individual ICS equipment train whenever the RPV pressure is below a reset value overriding the ICS automatic actuation signal following MSIV closure.

The IC/PCCS pool has four safety-related level sensors in each IC/PCCS inner expansion pool. These level sensors are part of the Fuel and Auxiliary Pool Cooling System (FAPCS). Each IC/PCCS inner expansion pool is connected to the equipment storage pool by two cross-connect valves in parallel where one valve is a pneumatic operated valve with an accumulator and two load drivers per initiator (actuation similar to Figure 7.4-3) and the other is a squib valve with three load drivers per initiator (actuation similar to Figure 7.3-2). Each valve has four initiators (three divisional initiators and one DPS initiator [see Section 7.8]). These valves open when a low water level condition is detected in the IC/PCCS inner expansion pool to which they are connected to provide makeup water for the first 72 hours of design basis events. The residual heat removal function of the safety-related ICS is further backed up by the safety-related ESF combination of ADS, PCCS, and GDCS; by the nonsafety-related RWCU/SDC loops; or by the makeup function of the CRD system operating in conjunction with safety relief valves and the suppression pool cooling systems.

The DPS discussed in Section 7.8 provides diverse nonsafety-related signals for ICS initiation and opening of pool cross-connect valves between the equipment storage pool and the IC/PCCS expansion pools.

- Other assumptions in Tables 15.2-1, 15.2-2 and 15.2-3 are applied to the TRACG calculation.

15.5.5.3 Analysis Results

The system response analysis results for the initial core loading documented in Reference 15.5-3 are provided in Reference 15.5-4. System response analyses bounding operation in the feedwater temperature operating domain are documented in Reference 15.5-5. A summary is provided in Appendix 15D. As shown in Figures 15.5-10a through 15.5-10f and Table 15.5-10a, during the first 2,000 seconds of depressurization, level is maintained above Level 1. Vessel inventory analysis demonstrates that level remains above Level 1 during the first 72 hours of the transient. Therefore, the requirement for reactor vessel coolant integrity is satisfied. As shown in Table 15.5-10b, considering a constant mass balance, and increased liquid densityICS venting after 6 hours and an assumed vent flow area that exceeds 0.167 cm^2 (0.0259 in^2) per IC to maximize RPV inventory loss, the wide range measured level is above 132.6-7 m (441.67 ft) above vessel zero, which provides margin to Level 1 ADS analytical limit [11.5 m (37.7 ft) above vessel zero]. The collapsed water level remains well above TAF.

Subsequent to a SBO event, hot or stable shutdown condition can be achieved and maintained by operation of ICS. Therefore, the requirement for achieving and maintaining hot or stable shutdown condition is met.

With operation of the ICS, the containment and suppression pool pressures and temperatures are maintained within their design limits since there is no release into the wetwell or the drywell. Therefore, the integrity for containment is maintained.

RPV leakage is expected to be minimal for three reasons: 1) there are no recirculation pumps in the design; 2) isolation occurs on Level 2; 3) the pressure is reduced significantly by the ICS. However, if leakage is significant and power has not been restored, the level could drop below the Level 1 setpoint. In this case ADS, GDCS and PCCS are available to provide core cooling, inventory control and containment heat removal. Because significant depressurization is provided by ICS, the impact of depressurization due to ADS initiation would not be as significant as initiation from rated pressure.

As demonstrated above, each acceptance criterion in Subsection 15.5.5.1 is met. Therefore ESBWR can successfully mitigate a SBO event to meet the requirements of 10 CFR 50.63.

This event bounds AOOs with respect to maintaining water level above the top of active fuel. Reanalysis of this event is performed for each fuel cycle.

15.5.6 Safe Shutdown Fire

The fire hazard analysis is provided in Appendix 9A. The performance evaluation is based on TRACG SBO analysis presented in Subsection 15.5.5.

15.5.6.1 Acceptance Criteria

The design meets the following acceptance criteria:

- **Core Subcriticality** - Core subcriticality is achieved and maintained with adequate core shutdown margin, as specified in the plant Technical Specifications.

Table 15.5-10a

Sequence of Events for Station Blackout

Time (s)	Event
0.0	Loss of AC power to station auxiliaries, which initiates a generator trip.
0.0	Additional Failure assumed in transfer to "Island mode" (see Subsection 8.1.1), Feedwater, condensate and circulating water pumps are tripped.
0.0	Turbine control valve fast closure is initiated.
0.0	Turbine control valve fast closure initiates main turbine bypass system operation.
0.0	Feedwater and condenser pumps are tripped.
0.04	Turbine bypass valves start to open.
0.08	Turbine control valves closed.
2.0	Loss of power on the four power generation busses is detected and initiates a reactor scram and activation of isolation condensers with one second delay.
5.0	Feedwater flow decay to 0.
6.2	Vessel water level reaches Level 3.
10	Vessel water level reaches Level 2.
18	Isolation condenser begins to drop cold water inside the vessel.
33	Isolation condenser drainage valve is fully open.
40	MSIV valve begins to close.
45	MSIV is totally closed.
6 hours	ICS lower header vent valves open.
~~72 hours~~	~~The system reached the conditions described in Table 15.5-10b.~~

Table 15.5-10b

~~Theoretical~~ Vessel Conditions at 72 hours after SBO

Parameter	Value
Dome pressure, kPaG (psig)	489.8~~0~~ (71.04~~0~~)
Vessel Bottom Pressure, kPaG (psig)	~~113000~~ 589.5 (~~16.4~~85.50)
Decay heat, MW	~~19~~20.~~5~~9
Wide range measured level over TAF, m (ft)	~~6~~5.2~~5~~5 (~~20~~17.2)
Collapsed Level over TAF, m (ft)	4.~~6~~3 (14.91)
Isolation condenser flow, kg/s (lb/hr)	~~8~~9.~~6~~7 (~~68~~7~~,.600~~8E+04)

3.6 CONTAINMENT SYSTEMS

3.6.1.7 Passive Containment Cooling System (PCCS)

LCO 3.6.1.7 Six PCCS condensers shall be OPERABLE.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. One or more PCCS condensers inoperable.	A.1	Restore PCCS condensers to OPERABLE status.	8 hours
B. Required Action and associated Completion Time not met.	B.1	Be in MODE 3.	12 hours
	<u>AND</u>		
	B.2	Be in MODE 5.	36 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.6.1.7.1	Verify that the spectacle flanges for the vent and drain line for each PCCS condenser are in the free flow position.	Prior to entering MODE 2 or 4 from MODE 5 if containment was de-inerted while in MODE 5, if not performed within the previous 92 days
SR 3.6.1.7.2	Verify each PCCS subcompartment manual isolation valve is locked open.	24 months
SR 3.6.1.7.3	Verify that both modules in each PCCS condenser have an unobstructed path from the drywell inlet through the condenser tubes to the following: a. the GDCS pool through the drain line; and b. the suppression pool through the vent line.	24 months on a STAGGERED TEST BASIS for each PCCS condenser
SR 3.6.1.7.4	Visually examine each PCCS vent catalyst module and verify there is no evidence of abnormal conditions.	24 months on a STAGGERED TEST BASIS for each PCCS condenser
SR 3.6.1.7.5	Verify performance of a representative sample of PCCS vent catalyst module plates.	24 months on a STAGGERED TEST BASIS for each PCCS condenser

B 3.5 Emergency Core Cooling Systems (ECCS)

B 3.5.4 Isolation Condenser System (ICS) - Operating

BASES

BACKGROUND

The Isolation Condenser System (ICS) actuates automatically following a reactor pressure vessel (RPV) isolation and transfers sufficient heat from the RPV to the Isolation Condenser/Passive Containment Cooling System IC/PCCS pool to prevent safety relief valve (SRV) actuation (Ref. 1). LCO 3.7.1, "Isolation Condenser/Passive Containment Cooling System (IC/PCCS) Pools," supports the ICS in removing sufficient decay heat following an RPV isolation to cool the reactor to safe shutdown conditions (MODE 4) within 36 hours and maintain the reactor in a safe condition for an additional 36 hours with minimal loss of RCS inventory (Ref. 1). The ICS also provides water inventory to the RPV at the start of a LOCA and provides the initial RPV depressurization following a loss of feedwater allowing ADS initiation to be delayed. The ICS is also assumed available to respond to a Station Blackout and an Anticipated Transient without Scram (Ref. 1).

The ICS consists of four independent trains. Each ICS train includes a heat exchanger (isolation condenser), a steam supply line that connects the top of the isolation condenser to the RPV, a condensate return line that connects the bottom of the isolation condenser to the RPV, a high point purge line, and vent lines from both the upper and lower headers of the isolation condenser. The isolation condensers are located above the containment and are submerged in a large pool of water (IC/PCCS pool) that is at atmospheric pressure. Steam produced in IC/PCCS pools by boiling around the isolation condenser is vented to the atmosphere (Ref. 1).

Each of the four isolation condensers consists of two identical modules. Each module includes an upper and lower header connected by a bank of vertical tubes. A single vertical steam supply line directs steam from the RPV to the horizontal upper header in each module through four branch lines. The branch lines include flow restrictors that limit the consequences of a line break. Steam is condensed inside banks of vertical tubes that connect the upper and lower headers in each module and the condensate collects in the lower header. Each ICS condensate return line includes an in-line vessel that provides additional water inventory to the RPV when the ICS is initiated.

Operation of each ICS train is initiated by opening either the condensate return valve or the condensate return bypass valve. These valves are in parallel and are both normally closed.

BASES

BACKGROUND (continued)

The condensate return valves open on an ICS initiation signal. The condensate return bypass valves open on loss of power.

With both the condensate return valve and condensate return bypass valves closed and the steam supply line to the reactor open, the isolation condenser and the condensate return line fill with condensate to a level above the upper headers. The steam supply line, which is insulated to prevent the accumulation of condensate, remains filled with steam. A purge line with an orifice connects the top of the isolation condenser to a main steam line. Flow through the purge line when the ICS is in standby prevents the accumulation of non-condensable gases in the top of the isolation condenser.

Upon receipt of an ICS initiation signal, the condensate return valves open causing the condensate in the isolation condenser and condensate return line to return to the RPV. Steam from the RPV continues to condense in the isolation condenser and drains back to the RPV.

Beginning six hours after ICS initiation, Rradiolytically generated non-condensable gases are automatically, continuously periodically vented to the suppression pool through vent lines connected to the lower header of the isolation condenser. The lower header vent valves also open automatically on high reactor pressure, which could be indicative of a loss of flow through the ICS. Operation of the lower header vent in each train is initiated by opening two, series connected, lower header vent valves or, opening two, series connected, lower header vent bypass valves. The lower header vent valves open automatically on high reactor pressure,which could be indicative of a loss of flow through the ICS[RHB22]. The lower header vent bypass valves are a relief valve and normally closed, fail-open solenoid valve. The lower header vent bypass valves open automatically (with or without power) at a pressure higher than the lower header vent valves and at a pressure lower than what is needed to lift the SRVs.

Each ICS condenser is located in a sub-compartment of the IC/PCCS pool. Following RPV isolation, pool water temperature could rise to about 101°C (214°F). The steam formed will be non-radioactive and have a slight positive pressure relative to station ambient. The steam generated in the IC/PCCS pool is released to the atmosphere through large-diameter discharge vents. Each ICS train is designed to remove 33.75 MWt of decay heat when the reactor is above normal operating pressure so that any three of the four ICS trains have sufficient capacity to perform the ICS design function (Ref. 1).

B 3.6 CONTAINMENT SYSTEMS

B 3.6.1.7 Passive Containment Cooling System (PCCS)

BASES

BACKGROUND

The Passive Containment Cooling System (PCCS) is designed to transfer heat from the containment drywell to the Isolation Condenser/PCCS (IC/PCCS) pools following a loss of coolant accident (LOCA). The PCCS consists of six independent condensers. Each condenser is a heat exchanger that is an integral part of the containment pressure boundary. The condensers are located above the containment and are submerged in a large pool of water (IC/PCCS pool) that is at atmospheric pressure. Steam produced in IC/PCCS pools by boiling around the PCCS condensers is vented to the atmosphere. LCO 3.7.1, "Isolation Condenser/Passive Containment Cooling System (IC/PCCS) Pools," supports the PCCS in removing sufficient post-LOCA decay heat from the containment to maintain containment pressure and temperature within design limits for a minimum of 72 hours, without operator action (Ref. 1)

Each of the six PCCS condensers consists of two identical modules. A single central steam supply pipe, open to the drywell at its lower end, directs steam from the drywell to the horizontal upper header in each module. Steam is condensed inside banks of vertical tubes that connect the upper and lower header in each module. The condensate collects in each module's lower header and drain volume and then returns by gravity flow to the Gravity-Driven Cooling System (GDCS) pools. By returning the condensate to the GDCS pools, it is available to return to the reactor pressure vessel (RPV) via the GDCS injection lines. Noncondensable gases that collect in the condensers during operation are purged to the suppression pool via vent lines. To reduce accumulation of radiolytic gas in the PCCS vent lines, vent line catalyst modules composed of metal parallel plates coated with catalyst are placed near the entrance of each vent line. Back-flow from the GDCS pool to the suppression pool is prevented by a loop seal in the GDCS drain line.

The RPV is contained within the drywell so that drywell pressure rises above the pressure in the wetwell (suppression pool) during a LOCA. This differential pressure initially directs the high energy blowdown fluids from the RPV break in the drywell through both the pressure suppression pool and through the PCCS condensers. As the flow passes through the PCCS condensers, heat is rejected to the IC/PCCS pool, thus cooling the containment.

There are no isolation valves on the PCCS inlets from the drywell, or the drain lines to the GDCS pools, or the vent lines to the suppression pool.

BASES

The PCCS does not have instrumentation, control logic, or power-actuated valves, and does not need or use electrical power for its

BACKGROUND (continued)

operation in the first 72 hours after a LOCA. This configuration makes the PCCS fully passive because no active components are required for the system to perform its design function (Ref. 2). Long-term effectiveness of the PCCS (beyond 72 hours) is supported by a vent fan that is connected to each PCCS vent line and exhausts to the GDCS pool. The PCCS vent fans aid in the long-term removal of non-condensable gas from the PCCS for continued condenser efficiency.

Spectacle flanges in the suppression pool vent line and the GDCS drain line are used to isolate the condensers to allow post maintenance leakage tests separately from Type A containment leakage tests.

Each PCCS condenser is located in a sub-compartment of the IC/PCCS pool. During a LOCA, pool water temperature could rise to about 102°C (216°F) (Ref. 1). The steam formed will be non-radioactive and have a slight positive pressure relative to station ambient. The steam generated in the IC/PCCS pool 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/PCCS pool water.

Each PCCS condenser is designed to remove a ~~nominal 11~~minimum 7.8 MWt of decay heat assuming the containment side of the condenser contains pure, saturated steam at 308 kPa absolute (45 psia) and 134°C (273°F); and, the IC/PCCS pool is at atmospheric pressure with a water temperature of 102°C (216°F).

APPLICABLE SAFETY ANALYSES

Reference 1 contains the results of analyses used to predict containment pressure and temperature following large and small break LOCAs. The intent of the analyses is to demonstrate that the heat-removal capacity of the Passive Containment Cooling System is adequate to maintain the containment conditions within design limits. The time history for containment pressure and temperature are calculated to demonstrate that the maximum values remains below the design limit.

PCCS satisfies Criterion 3 of 10 CFR 50.36(c)(2)(ii).

BASES

LCO	This LCO requires six PCCS condensers to be OPERABLE. OPERABILITY of a PCCS condenser requires that all the performance and physical arrangement SRs for the PCCS condensers be met. Additionally, the isolation valve for the PCCS condenser subcompartment pool must be locked open. This ensures that the full capacity of the IC/PCCS pools is available to provide required cooling water to the PCCS condenser for at least 72 hours after a LOCA without the need for operator action. With the PCCS subcompartment isolation valve locked open, subcompartment level is maintained in accordance with the requirements in LCO 3.7.1, "Isolation Condenser/Passive Containment Cooling System (IC/PCCS) Pools."
APPLICABILITY	The PCCS condensers are required to be OPERABLE in MODES 1, 2, 3, and 4 because a LOCA could cause a pressurization and heat up of containment. In MODES 5 and 6, the probability and consequences of a LOCA are reduced because of the pressure and temperature limitations of these MODES. Therefore, passive containment cooling is not required to be OPERABLE in MODES 5 and 6.
ACTIONS	<u>A.1</u> If one or more PCCS condensers are inoperable, the functional capability of the passive containment cooling is degraded. All six PCCS condensers must be made OPERABLE within 8 hours to ensure that containment cooling capacity is maintained. The Completion Time is based on engineering judgment considering the low probability of an event requiring PCCS operation. <u>B.1 and B.2</u> If the Required Action and Completion Time of Condition A are not met, functional capability of the passive containment cooling is assumed lost. Therefore, the plant must be placed in a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to at least MODE 3 within 12 hours and to MODE 5 within 36 hours. The Completion Time is reasonable, based on plant design, to reach required plant conditions from full power conditions in an orderly manner and without challenging plant systems.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.6.1.7.1

This SR requires periodic verification that the spectacle flanges for the vent, and drain line for each PCCS condenser are in the free flow position. This SR is required to ensure that each PCCS condenser is aligned to function properly when required.

Performance of the SR requires entry into containment. Therefore, this SR is performed prior to entering MODE 2 or 4 from MODE 5 if containment was de-inerted while in MODE 5 unless the SR was performed in the previous 92 days. This Frequency is acceptable because changing the status of the PCCS spectacle flanges requires entry into containment, is performed under administrative controls during planned maintenance activities, and is unlikely to occur inadvertently.

SR 3.6.1.7.2

This SR requires verification every 24 months that each PCCS subcompartment manual isolation valve is locked open. This SR ensures that the level in the subcompartment is the same as the level in the associated expansion pool and that the full volume of water in the IC/PCCS pools is available to each condenser. If this SR is not met, the associated PCCS condenser may not be capable of performing its design function. The 24-month Frequency is based on engineering judgment and is acceptable because the manual isolation valves between the IC/PCCS pool and the PCCS subcompartments are locked open and maintained in their correct position under administrative controls.

SR 3.6.1.7.3

This SR requires periodic verification that both modules in each PCCS condenser have an unobstructed path from the drywell inlet through the condenser tubes to both the GDCS pool through the drain line and to the suppression pool through the vent line.

The Frequency for this SR is 24 months on a STAGGERED TEST BASIS for each PCCS condenser. This Frequency requires testing one of the six PCCS condensers every 24 months, which is consistent with the normal refueling interval. The Frequency is based on engineering judgment, the simplicity of the design, and the requirement for containment access to perform the SR.

SR 3.6.1.7.4

BASES

This SR requires visual examination of each PCCS vent catalyst module and verification that there is no evidence of abnormal conditions.

The Frequency for this SR is 24 months on a STAGGERED TEST BASIS for each PCCS condenser. This frequency requires testing two of twelve vent catalyst modules every 24 months, which is consistent with the typical refueling cycle. The Frequency is based on engineering judgment, the simplicity of the design, the inerted conditions which the catalyst modules will be exposed to in their standby mode, and the requirement to access containment to perform the SR.

SR 3.6.1.7.5

This SR requires verifying performance of a representative sample of PCCS vent catalyst module plates.

The Frequency for this SR is 24 months on a STAGGERED TEST BASIS for each PCCS condenser. This Frequency requires testing two of twelve vent catalyst modules every 24 months, which is consistent with the typical refueling cycle. The Frequency is based on engineering judgment, the simplicity of the design, the inerted conditions which the catalyst modules will be exposed to in their standby mode, and the requirement to access containment to perform the SR. The representative sample consists of one plate from each PCCS vent catalyst module.

REFERENCES

1. Chapter 6.
2. Chapter 19.

19A.6.1.2 Automatic Depressurization System (ADS)

19A.6.1.2.1 Design Features

The depressurization function is accomplished through the use of safety relief valves (SRVs) and depressurization valves (DPVs). Supporting systems for ADS include the instrumentation, logic, control and motive power sources. The instrumentation and logic power is obtained from corresponding safety-related divisional uninterruptible and 120 VAC power sources. Either source can support ADS operation. The actual SRV solenoid and DPV squib initiator power is supplied by the corresponding safety-related divisional batteries. The motive power for the electrically-operated pneumatic pilot solenoid valves on the SRVs is provided by the SRV accumulators that are charged during normal operations by the nonsafety-related High Pressure Nitrogen Supply System (HPNSS). Failure of the HPNSS does not result in a loss of SRV function.

19A.6.1.2.2 System Interfaces

ADS interfaces with the following systems: Main Steam, Containment, Suppression Pool, and DC Power.

19A.6.1.2.3 Analysis of Potential Adverse System Interactions

DC Power supplies the SRV solenoids and the DPV squibs, which actuate a shearing plunger in the valve. The squibs are initiated by any of four battery-powered independent firing circuits. The firing of one initiator-booster is adequate to activate the plunger. The valve design and initiator-booster design is such that there is substantial thermal margin between operating temperature and the self-ignition point of the initiator-booster.

The design features of ADS and its supporting systems are adequate to ensure that potential adverse systems interactions are not significant.

19A.6.1.3 Isolation Condenser System (ICS)

19A.6.1.3.1 Design Features

The ICS provides additional liquid inventory to the RPV upon opening of the condensate return valves to initiate the system. ICS also provides the reactor with initial depressurization before ADS is required, in event of loss of feed water, such that the ADS can take place from a lower water level.

Each IC is located in a subcompartment of the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pool, and all pool subcompartments communicate at their lower ends to enable full utilization of the collective water inventory, independent of the operational status of any given IC train. A valve is provided at the bottom of each IC/PCCS pool subcompartment that can be closed so the subcompartment can be emptied of water to allow IC maintenance. Pool water can heat up to about 101°C (214°F); steam that is formed, being non-radioactive and having a slight positive pressure relative to station ambient, vents from the steam space above each IC segment 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. IC/PCCS pool makeup clean water supply for replenishing level during normal plant operation is provided from FAPCS. A nonsafety-related independent FAPCS makeup line is provided to provide emergency makeup water into the IC/PCCS pool from the fire protection system and from piping connections located in the reactor yard.

A purge line is provided to assure that, during normal plant operation (ICS standby conditions), excess hydrogen from radiolytic decomposition or air entering into the reactor coolant from the feedwater does not accumulate in the isolation condenser steam supply line, thus assuring that the isolation condenser tubes are not blanketed with non-condensables when the system is first started.

Upper header and lower header vent lines with valves are provided to mitigate the buildup of hydrogen during LOCA and non-LOCA events. Both valves can be operated manually. The lower header vent valve is fail-open and is automatically opened six hours after ICS is initiated.

On the condensate return piping just upstream of the reactor entry point is a loop seal and two valves in parallel: (1) a condensate return valve (fail as-is), and, (2) a condensate return bypass valve (fail open). These two valves are closed during normal station power operations. Because the steam supply line valves are normally open, condensate forms in the in-line isolation condenser reservoir and develops a level up to the steam distributor, above the upper headers. To start an isolation condenser into operation, the condensate return valve or condensate return bypass valve is opened, whereupon the standing condensate drains into the reactor and the steam-water interface in the isolation condenser tube bundle moves downward below the lower headers to a point in the main condensate return line. The fail-open condensate return bypass valve along with the fail-open vent valves opens if the DC power is lost.

The ICS is automatically isolated to mitigate buildup of noncondensable gases during LOCA events. The signal that isolates ICS is a confirmed opening of any two DPV's with a time delay.

19A.6.1.3.2 System Interfaces

System interfaces include: Main Steam, Containment, Suppression Pool, FAPCS, DC Power, and Process Radiation Monitoring

19A.6.1.3.3 Analysis of Potential Adverse System Interactions

The ICS and PCCS pools have two local panel-mounted, safety-related level transmitters. Both transmitter signals are indicated on the safety-related displays and sent through the gateways for nonsafety-related display and alarms. Both signals are validated and used to control the valve in the makeup water supply line to the IC/PCCS pool. The FAPCS IC/PCCS pools cooling and cleanup subsystem pump is automatically tripped on low water level in IC/PCCS pools. Water level in the skimmer surge tanks is maintained by automatic open/closure of the makeup water supply isolation valve. Water level in the IC/PCCS pools is maintained by automatic open/closure of the makeup water supply isolation valve.

Four radiation monitors are provided in the IC/PCCS pool steam atmospheric exhaust passages for each isolation condenser train. They are shielded from all radiation sources other than the steam flow in the exhaust passages for a specific isolation condenser train. The radiation monitors are used to detect isolation condenser train leakage outside the containment. Detection of a low-level leak results in alarms to the operator. At high radiation levels, isolation of the

ACM B 3.6 CONTAINMENT SYSTEMS

AC B 3.6.3 Passive Containment Cooling System (PCCS) Vent Fans

BASES

A branch line from each of the 6 PCCS system vents in the drywell contains a fan isolation valve, a fan and discharge line that terminates in a submerged location in the GDCS pool. When in operation, the fan will actively circulate the drywell atmosphere (steam and non-condensables) through the PCCS condensers to enhance the rate of heat removal.

The PCCS vent fan function is a nonsafety-related function that provides the ability to reduce drywell pressure and temperature after 72 hours following a DBA by forced containment cooling through the PCCS system condensers. Satisfactory results are obtained by successful operation of four out of the six fans; therefore, the ACLCO requires the AVAILABILITY of five fans. PCCS vent fans provide post 72-hour reduction in containment pressure by redistributing noncondensable gases from the wetwell to the drywell; therefore, regulatory oversight is provided. The short-term availability controls for this function, which are specified as Completion Times, are acceptable to ensure that the availability of this function is consistent with the functional unavailability in the ESBWR PRA. The surveillance requirements also provide an adequate level of support to ensure that component performance is consistent with the functional reliability in the ESBWR PRA.