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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 Revision 1

Docket No. 52-010

August 2, 2010

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

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

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) revised response (Revision 1) to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 6.2-202 S01 sent by Reference 1. It replaces our response sent as Reference 2.

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

Enclosure 4 contains markups to Revision 1 of NEDE-33572P, "ESBWR PCCS Condenser Structural Evaluation," and Enclosure 5 contains the public version of these markups. Enclosure 6 contains markups to Revision 2 of NEDO-33251, "ESBWR I&C Diversity and Defense-In-Depth Report."

Please be aware that GEH is still completing LS-Dyna analyses that are required to finalize Appendix C of Enclosure 4. Therefore, Appendix C of Enclosures 4 and 5 (public version) will be provided at a later date. Also note that Appendix B of Enclosure 4 is marked DRAFT Unverified. The verified version of Appendix B to Enclosures 4 and 5 will also be provided later.

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

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versions, respectively, which do not contain proprietary information and are suitable for public disclosure.

The affidavit contained in Enclosure 7 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.

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 Supplement 1, Letter from Richard E. Kingston to U.S. Nuclear Regulatory Commission, Response to NRC Request for Additional Information Letter No. 401 Related to ESBWR Design Certification Application – Engineered Safety Features — RAI Number 6.2-202 Supplement 1, May 22, 2010

Enclosures:

1. MFN 10-044 Supplement 1 - Revised Response (Revision 1) 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 - Revised Response (Revision 1) 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 - Revised Response (Revision 1) 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 - Revised Response (Revision 1) 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 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 - Revised Response (Revision 1) 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 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 - Revised Response (Revision 1) 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 NEDO-33251 Revision 2, "ESBWR I&C Diversity and Defense-In-Depth Report," May 2009
7. MFN 10-044 Supplement 1 - Revised Response (Revision 1) 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)
	HA Upton	GEH (with enclosures)
	TL Enfinger	GEH (with enclosures)
	eDRFSection	0000-0117-8858, Rev. 2 (Response and DCD Markups)
		0000-0121-3094, Rev 1 (DCD Tier 2 Ch 7 and NEDO-33251 Rev 2 Markups)
		0000-0115-2094, Rev. 3 (NEDE-33572 Rev 1 Markups)
		0000-0121-2968 (DCD Tier 1 Markups)

Enclosure 2

MFN 10-044 Supplement 1 Revision 1

Revised Response (Revision 1) 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 Revision 1 – Revised Response (Revision 1) 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

Items A through H below are the unaltered questions from the original RAI 6.2-202 S01. Items H through KK and i through iii have been appended to the original question set and constitute the revised supplement 1 RAI.

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.

Items H through KK below are questions that have been appended to the original RAI 6.2-202 S01. Some statements are made in reference to, and in context with the originally submitted RAI and the GEH response.

H. Section 2.2.4.2 of NEDE-33572P, Revision 1, references an Electric Power Research (EPRI) document which describes the effects of various aerosols and particulates on the recombination performance in prototypical passive autocatalytic recombiners. However, NEDE-33572P does not describe how the EPRI document is applicable to ESBWR.

1. NEDE-33572P, Revision 1, states that "The [EPRI] evaluation considered poisons and inhibitors such as steam, water, smoke, soot, iodine vapor, and *carbon monoxide." Although the design includes a cover intended to prevent any condensate from dripping onto the catalyst plates, a water droplet carried over by the noncondensible could settle on catalyst plates affecting their performance. For the ESBWR design, provide an assessment of the potential performance inhibitors and an evaluation of their effect on the catalyst performance including effect of water droplet carryover by the noncondensable gases.*

2. NEDE-33572P, Revision 1, states that "The [EPRI] evaluation concluded that although some noticeable short-term effects were detected, these diminished as the catalyst reached operating temperatures and the overall performance was not significantly affected." Explain how this conclusion is applicable to ESBWR by defining the time involved in "short-term" and the time that takes for the catalyst used in ESBWR to reach operating temperatures. Also, provide a definition of the start time after which the warm-up time is measured (e.g., starting at introduction of hydrogen and oxygen into the module).

3. Recognizing that the current recombiner is being aimed for design basis accidents, explain if deleterious impacts can be envisioned under severe accident conditions (e.g., build-up of large quantities of aerosols resulting in large pressure drops at the entrance to the vent line reducing the venting capacity and subsequently the PCCS performance).

I. Section 2.2.4.2 of NEDE-33572P, Revision 1, references a "similar" catalyst that was tested in Jülich, Germany where for an initial hydrogen concentration of 4%, the catalyst was found to recombine the hydrogen contents completely for flow velocities below 0.25 m/s, which is higher than the PCCS vent flow velocity.

1. Provide the desired range of the recombination rate to which the system will need to be designed under ESBWR design basis accident conditions. Explain how the duration of the test and rate of the recombination are applicable to PCCS.

2. Explain how the hydrogen concentration and expected flow velocities at the entrance to the vent pipe would result in similar performance for the ESBWR catalyst module.

3. Explain how the duration of the test and rate of the recombination are applicable to PCCS.

J. NEDE-33572P, Revision 1, does not provide results of any ESBWR-specific LOCA calculations that consider the impact of various design parameters of the catalyst module on the gas stream mixture composition entering the vent line. The design parameters of interest include:

- The nominal recombination efficiency for the catalyst module as a function of inlet hydrogen concentration,

- The minimum hydrogen concentration to achieve the desired recombination efficiency,

- The warm-up time for the catalyst module,

- The expected temperature of catalyst module at maximum efficiency, and

- The influence of any liquid droplet carry-over with the gas stream entering the catalyst module on the recombination efficiency.

Provide results of calculations performed using specific catalyst module design parameters to show that the proposed module can effectively reduce the hydrogen concentration in the gas stream entering the vent line over the time scale of interest at temperatures below the autoignition limit.

K. Section 2.2.4.4 of NEDE-33572P, Revision 1, states that "The length of [drain] pipe runs is small compared to the length of the vent line, and the constant liquid flow through them prevents significant concentrations of hydrogen from accumulating." However, if the drain pipe runs are not flowing full of liquid, hydrogen may accumulate in them. If hydrogen accumulates in drain pipe runs, a detonation occurring in the lower drum may likely to propagate into the drain pipe runs. Confirm that hydrogen will not accumulate to detonable levels in the drain pipe runs.

L. Table 3-2 of NEDE-33572P, Revision 1, lists detonation loads assumed for PCCS components. The vent and drain pipes appear to have no effect from hydrogen detonation occurring in the lower drum and the resultant high pressure mixture being vented through those pipes. Explain, how the pressures in vent and drain pipes are unaffected by hydrogen detonation occurring in the lower drum.

M. NEDE-33572P, Revision 1, states that the increase in PCCS tube thickness and change in material will increase conduction resistance through the tube wall, which will have a negative effect on the overall heat transfer coefficient of the PCCS. To compensate for this effect, based on TRACG evaluations, GEH increased the number of tubes per PCCS module in order to keep the containment pressure response bounded by the values described in DCD, Revision 7.

1. Confirm that TRACG validation for calculating PCCS heat transfer is applicable to the new design because the test data used to validate TRACG was for a PCCS with different tube material, thickness, and internal diameter, and different number of tubes. In particular evaluate the applicability of the PANTHERS tests given the new tube design characteristics.

2. Provide the results of TRACG analysis confirming that after increasing the number of PCCS tubes per module the containment pressure is bounded by values presented in DCD, Revision 7.

3. Confirm that data used to validate TRACG covers the expected conditions of the new design. In particular discuss the effect of potential non-uniform steam distribution, caused by the increased number of tube, on "completeness" of steam condensation within individual tubes.

4. Confirm that scaling groups used for showing applicability of tests for PCCS are still applicable to the new design.

N. GEH's response to RAI 6.2-201 S01 states that the PCCS design capacity was reduced to 7.8 MW per module from 11 MW stated in DCD, Revision 7. Confirm that the reduction in PCCS capacity did not affect the TRACG results for containment pressurization presented in DCD, Revision 7. In particular evaluate the applicability of the integral PANDA tests given the new tube design characteristics.

O. Confirm whether the number of tubes, thickness of the IC tubes, heat capacity are changed. If the IC configuration is changed, the staff needs to verify the validity of the TRACG qualification test and the IC performance test. Full scale testing of an IC module was performed in the PANTHERS/ICS test facility at SIET, Italy. Provide a table similar to the table provided in the revised RAI 6.2-202,SO1 response (MFN 10-044, Supp-1 dated May 22, 2010) for PCCS comparing the current IC configuration to the PANTHERS prototype. Confirm that the current ICS configuration is within the applicable range of the TRACG code to accurately calculate IC performance and that the system functional test of the IC is still valid.

P. RAI 6.2-201 S01 Response, Item B - For LOCA events, ICS is isolated after DPV opens. The pressure drops to almost atmospheric in 1060 seconds and the steam fraction do not drop below 0.37. GEH agrees that this is not high enough to prevent ignition. However, GEH is using 20% steam condition in using a CJ multiplier of 13.3 instead of 19 as in PCCS case. First, why 37% is mentioned at all in the response if not used in the design? Second, how one will make sure that the worst condition for ICS will contain 20% steam fraction, which may affect both the CJ pressure and DLF.

Q. RAI 6.2-201 S01 Response, Item C - Non-safety temperature sensors are used to determine if NCG have accumulated. GEH responded that no matter whether these sensors work or not during an accident, the ICS is designed to the RCS pressure, which bounds the detonation pressure. Explain why we discuss about these sensors at all. No safety evaluation can be relied on these non safety components.

R. RAI 6.2-201 S01 Response, Item E2 - Response to E.2.a states: "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."*

Response to E.2.b states: "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."

The statements above are somewhat contradictory. If Service Level C is being used as acceptance criterion for the design of the PCCS, when subjected to detonation loads, then this must be clearly stated in the relevant sections of the DCD and LTR. It should be noted that, although Service Level C does allow for stresses to be slightly higher than the yield limit, two design objectives can be achieved: (a) the response of the component remains essentially elastic, and (b) ratcheting and other undesirable plastic7 instabilities are precluded.

Given that the PCCS design must take into account unique loading conditions while maintaining its pressure boundary and heat removal functions, a safety determination cannot be made unless a substantial level of analysis and design detail is reviewed by the staff, including calculations which demonstrate that stresses for all load combinations are within acceptable limits per the ASME B&PV Code. Therefore, if further design changes are necessary to bring the stresses to within acceptable limits, then these changes must be completed and submitted for review. The relevant sections of the DCD and LTR should be modified accordingly.

S. RAI 6.2-201 S01 Response, Item E4 - As requested in the original RAI, the DCD should contain a summary of analysis and design results from the LTR, as well as sufficient information to support a safety determination. This information does not appear to be included in the DCD markups submitted for review.

T. RAI 6.2-201 S01 Response, Item E5 - Response to E.5.b states: "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."

A detailed description of this alternate calculation should be submitted for review, including numerical results to show that "the effects of detonations on the entire PCCS *assembly including its supporting structure are bounded by the seismic loading." This information should be included in the LTR.*

Note that the load combination used to evaluate the effects of detonations also includes seismic loads; i.e., D + DET + Ta + SSE (Table B-1, LTR Rev.1). Therefore, whether the effects of detonations are bounded or not by seismic loads, both load cases should be considered in the stress analysis of the entire PCCS assembly.

In response to item E.5.d, GEH stated that the FE models will capture the stress concentrations in the locations of concern. Based on the analysis what are the stress amplifications at the junction of the tubes with the lower drum for PCCS. Also, provide modeling assumptions made in the analysis for this region of the PCCS and ICS

U. LTR NEDE-33572P Rev. 1, Section 2.0 - Paragraph 1 states: "The acceptance criterion for components subject to detonation is based on the ability of those components to retain their pressure integrity without significant plastic deformation following 12 consecutive detonation cycles."

Paragraph 2 states: "Inputs are provided for the finite element analysis that describes increased thicknesses for the PCCS tubes and lower drum that are expected to satisfy the acceptance criteria for elastic-plastic analysis."

These statements should be clarified in light of the assertion that the "goal of the improved PCCS condenser design is to keep the component within the analyzed elastic range." What is the extent of plastic deformation and what is the acceptance criterion for elastic-plastic analysis?

V. LTR NEDE-33572P Rev. 1, Section 2.2.2.2 - The justification provided for using DLF=2 for the analysis of the condenser tubes does not appear to be sufficiently conclusive. The information provided is summarized in the table below.

Dilutant	*Concentration*	*V_{CJ} (m/s)*	*DLF (*)*
N.A.	*0%*	*2800*	*2*
Steam	*10%*	*2700*	*2*
Argon	*25%*	*2200*	*2*
Argon	*60%*	*1800*	*Between 2 and 4*
Argon	*80%*	*1500*	*4*

(*) Determined form visual comparison with Figures 7 and 9 in Reference 3.

If steam concentrations are between 25% and 80%, the CJ velocities could be as low as the resonant velocity (i.e., [[ ]]), so the DLF could potentially be higher than 2.

On the other hand, the CJ pressure multiplier in these cases would typically be lower than the assumed value of 19. Furthermore, CJ velocities corresponding to steam could be higher than those for argon. However, these justifications are only qualitative. Additional quantitative information should be provided to show that steam concentrations between 25% and 80% result in equivalent static pressures (DLF x CJ pressure) that are bounded by 407 kPa x 19 x 2=15.5 MPa

W. LTR NEDE-33572P Rev. 1, Section 2.2.3 - The discussion on delayed DDT does not appear to be sufficiently conclusive. On the one hand, it is stated that steam concentrations of up to 40% result in detonation cell sizes, which are still relatively small (up to 7.9 mm) relative to the tube diameter, indicating "small" run-up distances and "fast" transition to detonation. On the other hand, it is also mentioned that typical run-up distances are in the range of 15-40 times the tube diameter (750-2000 mm). Are these run-up distances "small" or "large"? In addition, although the CJ pressure multiplier in these cases would typically be lower than the assumed value of 19, there is no indication of how low this value would be.

These justifications are only qualitative. Additional quantitative information should be provided to show that steam concentrations of up to 40% result in delayed DDT pressures in the condenser tubes that are bounded by 407 kPa x 19 x 2 x 2.5 = 38.7 MPa.

X. LTR NEDE-33572P Rev. 1, Section 2.2.4.1 - This section states: "The lower drum of the PCCS condenser is also subject to the accumulation of hydrogen and oxygen (at similar concentrations as the lower portions of the tubes), however, the combustion of these gases is expected to occur by a different mechanism than that described above for the tubes. Whereas the interior of the tube is a relatively restricted volume with a small diameter and long length, the drum interior is a more spacious and open volume. The top of the lower drum is vented through the tubes, which have a cumulative flow area of approximately [[ ]]. Because of the less constrained geometry and ample pathway for pressure relief, it is expected that the progression of the reaction will be more along the lines of a constant volume combustion rather than a traditional CJ detonation."

"Constant volume combustions do not have the same characteristic pressure response as a CJ detonation. However, for conservatism, the same series of pressure multipliers will be assumed for the lower drum as was assumed for the tubes in Section 2.2.2.3."

Additional discussion should be provided in this regard. In particular, calculations to show that the pressure associated with constant volume combustions in the lower drum is bounded by 407 kPa x 19 x 2 x 2.5 = 38.7 MPa.

Y. LTR NEDE-33572P Rev. 1, Section 2.2.5 - LTR Section 2.2.5 addresses post-detonation pressure relief. The analysis for the vent pipe is very close to minimum thickness requirements. Explain why the dynamic factor is not included in the analysis. Also, the LTR states that though the margin is small, the actual pressure inside the vent pipe will be much less. Is there any experiment or analysis to indicate this phenomenon. ALSO, what about the MC part of the drain pipe?

Technical basis should be provided for choosing 7.73 MPa as the design pressure for the vent pipe (CJ pressure with no DLF or reflection amplification). The staff notes that the applied loads are still dynamic.

Z. LTR NEDE-33572P Rev. 1, Section 2.3.1 - This section states: "The PCCS condenser is designed to ASME Section III, Subsection NE as a Class MC component. As such it must be designed to accommodate the loads within the acceptance criteria stated in that part of the Code. This report postulates a detonation as a Service Level D event (See Appendix B, Table B-2b), but also evaluates how the detonation loads compare to the Service Level C allowables (See Appendix B.6). For areas in which the detonation loads exceed Service Level C allowables there is an assessment of what additional modifications would be necessary in order for the detonation to be classified as a Service Level C event instead of a Level D event."

This statement is not consistent with other sections in the LTR, DCD, and RAI response. See comment on Item E2 of the RAI response, above. The staff notes that Service Level D permits stresses beyond yield, which is not consistent with the assertion that the "goal of the improved PCCS condenser design is to keep the component within the analyzed elastic range."

AA. LTR NEDE-33572P Rev. 1, Section 3.2 - Per Figure 1c, a portion of the drain pipe below the lower drum nozzle is classified as class MC. Table 3-1 must clarify this ASME class change.

BB. LTR NEDE-33572P Rev. 1, Section 3.3 - Per Section 2.2.5, the design pressure in the upper portion of the vent pipe is 7.73 MPa. However, Table 3-2 indicates this is 0.407 MPa. This inconsistency should be clarified.

Per Figure 1c, a portion of the drain pipe below the lower drum nozzle is classified as class MC. Table 3-2 indicates the design pressure for this portion is 0.407 MPa. Technical basis should be provided for using this design pressure and not 38.7 MPa used in the lower drum design.

CC. LTR NEDE-33572P Rev. 1, Section 4.2 - For ICS, CJ multiplication factor of 13.3 is used based on the experimental data in Ref. 17. GEH stated that the experimental set up is comparable with the ICS design conditions. Provide this comparison. Also, *13.3 factor is based on some steam fraction exists in the ICS. Provide details of the assumptions made for the use of this CJ multiplication factor and DLF=2 for ICS design.*

LTR Section does not address the fatigue assessment of components subject to 12 detonation cycles, specifically for MC components (e.g., bolts). GEH stated that the alternating stress due to this is well below the fatigue endurance curve. Provide details of this assessment.

DD. LTR NEDE-33572P Rev. 1, Section B.1.1 - Additional information on the following issues should be provided:

1. Explanation of how the stresses due to detonation loads are combined with stresses due to other load cases, given the differences in the FE models used.

2. Explanation of the boundary conditions imposed on the tube submodel.

3. Additional stresses in the tubes resulting from displacements in the lower drum (from the lower drum submodel analysis) imposed as displacement boundary conditions on the tube submodel.

4. The computed stress amplifications at the tube bends and at the junction of the tubes with the lower drum.

EE. LTR NEDE-33572P Rev. 1, Section B.1.2 - Additional information on the following issues should be provided:

1. Explanation of how the stresses due to detonation loads are combined with stresses due to other load cases, given the differences in the FE models used.

2. Explanation of the boundary conditions imposed on the lower drum submodel, especially at the connection of the lower drum nozzle with the drain pipe and with the RCCV top slab liner plate. This is particularly important since "The portion having the condensate nozzle has been selected as the most critical header area."

3. The connections of the lower drum nozzle with the drain pipe, and with the RCCV top slab liner plate do not appear to be part of the FE submodel. If this is the case, it is not clear how these PCCS components are analyzed and designed for detonation loads.

4. The computed stress amplifications at the connection of the lower drum nozzle with the drain pipe.

FF. LTR NEDE-33572P Rev. 1, Section B.1.3 - Additional information on the following issues should be provided:

1. Explanation of how the stresses due to detonation loads are combined with stresses due to other load cases, given the differences in the FE models used.

2. Explanation of which loads are applied and how the analysis is performed.

3. This section states: "RCCV top slab passages are not represented in detail since they are outside the scope." However, the staff notes that the connections of the lower drum nozzle with the drain pipe, and with the RCCV top slab liner plate, as well as a portion of the drain pipe, are within the jurisdictional boundary of ASME B&PV Code Section III, Subsection NE, as part of the containment pressure boundary. As mentioned above, it is not clear how these PCCS components are analyzed and designed for detonation and other loads.

GG. LTR NEDE-33572P Rev. 1, Section B.3 - The acceptance criterion specified for the load combination including detonation loads (i.e., D + DET + Ta + SSE) shown in Table B-1 is not consistent with other sections in the LTR, DCD, and RAI response. See comment on Item E2 of the RAI response, above. The staff notes that Service Level D permits stresses beyond yield, which is not consistent with the assertion that the "goal of the improved PCCS condenser design is to keep the component within the analyzed elastic range."

The load combinations listed in Table B-1 are slightly different from those listed in Table 3.8.-4 of the DCD markup submitted for review, and from the load combinations specified in SRP 3.8.2 and RG 1.57. For example, there is no mention of load cases L, Ra, SRV or LOCA (which includes CO, CHUG and PS) as defined in the DCD. This inconsistency should be clarified.

HH. LTR NEDE-33572P Rev. 1, Section B.5 - Additional information on the following issues should be provided:

1. Explanation of which load combinations in Table B-1 correspond to the stresses listed under the heading "Service Level C/D" in Table B-2b.

2. Explanation of which load combinations in Table B-1 correspond to the stresses listed under the heading "Service Level D" in Table B-2b. Note that, for components not directly affected by the detonation loads (e.g., Upper Header), the calculated stresses under "Service Level D" are lower than under "Service Level C/D."

3. Explanation of how the connections of the lower drum nozzle with the drain pipe, and with the RCCV top slab liner plate, as well as a portion of the drain pipe are within the jurisdictional boundary of ASME B&PV Code Section III, Subsection NE, are analyzed and designed for detonation and other loads. These results should be added to Table B-2b.

4. Item E.5.b of the RAI response indicates that the effects of detonations on the entire PCCS assembly, including its supporting structure, are bounded by *seismic loading. However, as previously mentioned, the load combination used to evaluate the effects of detonations also includes seismic loads (i.e., D + DET + Ta + SSE, Table B-1). Therefore, whether the effects of detonations are bounded or not by seismic loads, both load cases should be considered in the stress analysis of the entire PCCS assembly. The stresses listed in Table B-2b do not appear to consider this. See also comment on Item E5 of the RAI response, above.*

5. Fatigue evaluation performed in accordance with ASME B&PV Code, Section III, Subsection NE-3221 to account for cyclic loading, including the detonation cycles.

II. LTR NEDE-33572P Rev. 1, Section B.6 - This section indicates that the stresses due to detonation loads in the PCCS are within Service Level C limits for all components except the lower drum and the lower drum cover. Several strategies are proposed to bring these stresses to within acceptable limits. However, it is stated that: "Since the changes described above are readily achievable, these modifications to the PCCS will be made during the detailed design phase and compliance with the ASME acceptance criteria (including the Service Level C criteria) will be demonstrated in the closure of ITAAC item 2a1 in Table 2.15.4-2 of DCD Tier 1."

It is emphasized again that a safety determination cannot be made unless a substantial level of analysis and design detail is reviewed by the staff, including calculations which demonstrate that stresses for all load combinations are within acceptable limits per the ASME B&PV Code. Therefore, if further design changes are necessary to bring the stresses to within acceptable limits, then these changes must be completed and submitted for review. The relevant sections of the DCD and LTR should be modified accordingly.

JJ. In GEH response to RAI 6.2-202 Supplement 1, the proposed revision to DCD Section 3.8.2.6 lists SA312 as a forging spec. This is a tubing spec. The staff think this is a typo.

NEDE-33572P, revision 1 Section 5.4 Weld and Weld Filler list 308L as being used to weld XM-19. The minimum tensile strength of XM-19 is 100KSI while the minimum tensile strength of 308L is 75KSI. Have GEH taken into account the use of such an under matched weld filler metal?

KK. In the Draft DCD Rev. 7 Section 5.4.6.1.1, the following is added:"-----and there after the ICS isolation valves are closed following any two opened DPV's with a time delay.-------"

Describe the technical bases for the time delay set point and revise the applicable DCD sections to include the time delay set point.

GEH Response

Items A through H below are unaltered responses to the original RAI 6.2-202 S01 that has been submitted to the NRC under MFN 10-044 Supplement 1. Items H through KK and i through iii have been appended to the original response set and constitute the revised supplement one 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 DPVs opening. A calculation to support the appropriateness of the six-hour time delay for ICS venting based on dissolved hydrogen in the RPV at the initiation of the event is being prepared by GEH and will be available for review after August 9, 2010.

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 S01.3 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. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

E.4

Revision 1 of the LTR has been updated with additional details and results. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

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 Appendix B of the LTR. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

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. The details related to this calculation are currently been prepared, and will be provided in Appendix C of the LTR when results are verified and released.

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.

Items H through KK below are responses to requests for additional information that have been appended to the RAI 6.2-202 S01 original response. Some statements are made in reference to, and in context with the originally submitted response.

H.

Catalytic recombination involving coated metallic substrates, is a dependable and widespread technology that is applied in everyday usage such as chemical refining and pollution control for internal combustion engines (i.e., passenger automobiles). These devices provide years of predictable and efficient service with little if any degradation even with exposure to harsh environments and imprecise process streams. The use of this technology for combustible gas control (passive autocatalytic recombiners or PARs) during postulated accidents in commercial nuclear power plants has been investigated and studied since the early 1990's. Multiple test results and reports indicate that PARs offer an effective, passive solution for neutralizing potentially combustible atmospheres. The chief uncertainty in the use of PARs lies with their questioned capability to appreciably influence general areas of a large and somewhat compartmentalized containment structure under dynamic and uncertain accident conditions. This is not the case with the application of catalytic recombination in the PCCS, where the combustible gases are focused and directed through the catalyst vent module. Catalytic recombination offers the added benefit of returning hydrogen and oxygen back into the form of water, which enhances heat removal, and thereby aids in reducing containment pressure which is not credited in the containment response.

The EPRI evaluation of passive autocatalytic recombiners (PARs) is applicable to the ESBWR in that its evaluation of poisons and inhibitors on PAR performance bounds both design basis accident (DBA) and severe accident conditions of ESBWR. Generation of significant quantities of poisons and inhibitors (other than steam) is not credible in the ESBWR containment for either condition.

The EPRI evaluation demonstrated that PARs continue to function when subjected to poisons generated under beyond DBA conditions (such as CO gas from core-concrete-interaction and particulates from fires) and to poisons generated under DBA conditions (such as iodine from fuel failures).

In order for poisons or inhibitors to become relevant in the evaluation of the ESBWR PCCS vent catalyst, they first must be generated and then transported to the vent catalyst in the form of gases or aerosols. In the drywell and wetwell containment compartments, potential sources exist in the form of organic compounds such as coatings and cabling insulation. For ESBWR containment, all of these materials are qualified for harsh DBA environments (elevated temperatures and high humidity). Coatings meet Regulatory Guide 1.54 and the standards of ASTM D 5144 where required (DCD Tier 2, Section 6.1.2). Cable insulation meets standards specified in

DCD Tier 2, Section 3.11 and Subsection 8.3.3.2. Therefore the generation of gases or aerosols from these sources is not credible.

The reactor pressure vessel (RPV) provides the only other potential source of poisons and inhibitors (fission products from fuel damage and steam) inside containment. During all DBA LOCA's, the ESBWR core remains covered (DCD Tier 2, Section 6.3) thereby preventing any fuel damage and generation of poisons and inhibitors in the form of fission products. Steam becomes the only credible inhibitor that is continuously supplied to the drywell making it available to the PCCS where it is mostly condensed.

H.1

The low gas velocities at the entrance of the vent catalyst hood preclude carryover of water droplets. Velocities are kept below the threshold for droplet carryover into the catalyst region given the final design configuration of the condensate hood and the analyzed volumetric flow rates. Condensate will enter the lower drum in the form of a steady stream, or as "large" droplets. Atomization of the condensate does not occur as it exits the bottom of the tubes due to the very low gas velocities through each individual tube. Condensate that falls directly onto the hood will puddle and stream or drip from the drip edge of the hood, which is below the active surface elevation of the catalyst module. The annular gap between the drip edge of the hood and the main module body will be sufficiently large and thus gas velocities low enough such that any water stream or droplet will not be carried upward and into the catalyst area, effectively acting as a moisture separator. Velocities will average around 0.01 m/s with peak values not exceeding 0.1 m/s. Conservatively high peak volumetric flow rates are assumed when sizing the critical hood dimensions.

For DBA conditions no performance inhibitors will exist in the vicinity of the catalyst module with the exception of small amounts of liquid water (steam and water vapor are not performance inhibitors due to their inability to condense onto the surface of the catalyst). At the time when hydrogen and oxygen are introduced to the lower drum, the steady state temperature of the PCCS vent components is expected to be above the saturation temperature of the steam and therefore any water that might be locally deposited on the catalyst surface will be quickly driven off as vapor by the exothermic reaction, with virtually no impact upon recombination efficiency.

H.2

During the early stages of a LOCA (first three hours), significant amounts of nitrogen and steam from the drywell pass through the vent line to the suppression pool, effectively preheating the vent module and catalyst plates, so that by the time hydrogen and oxygen begin to accumulate, the catalyst is at or near the lower end of the operating temperature band. Due to the design of the condensate hood, the only inhibitor present during a DBA will be very limited and localized areas of water. The vast majority of the catalyst surface area will be unimpeded by water and therefore recombination will commence in immediate response to the introduction of hydrogen and oxygen. (Note that the vent module contains twice as much catalyst surface area as required for complete recombination.) The relatively small surface area where the catalyst may have been wetted by water will quickly clear by evaporation from the heat of the exothermic reaction of recombination (the Julich tests indicate that significant heatup occurred within 2 minutes with a 4% hydrogen mixture). The catalyst plate temperature will quickly reach nominal operating conditions and any small amounts of continued moisture carryover will evaporate prior to settling on the catalyst. The catalyst will remain at nominal or higher temperatures for as long as hydrogen and oxygen remain at recombinable concentrations and the exothermic reaction proceeds. The large metal mass of the module and conductive heat transfer from the drywell below will assist in maintaining catalyst temperatures elevated during those periods when vent flow is minimal.

H.3

New section 2.2.4.2.4 has been added to the LTR to discuss the impact of aerosols generated during severe accident conditions, including in-vessel core melt progression. Section 2.2.4.2.4 concludes that neither the recombination efficiency nor the venting capacity is significantly affected by this severe accident scenario.

I.

I.1

The required recombination rate of hydrogen for ESBWR will be 1 g/(m^2-sec), which is an analyzed peak value, with average required rates less than one-third that value. The Julich tests demonstrate that the recombination capacity of the wash-coated catalyst plate increases linearly with increasing hydrogen and oxygen concentration, with test data showing actual recombination rates as high as 7.5 g/(m^2-sec). The test duration is not a critical parameter since the catalyst does not deplete. The inlet flow rates for the ESBWR are not a function of temperature, in contrast to PAR's that depend on temperature induced convective currents to attain operational flow rates. ESBWR flow rates are a function of drywell pressure and wetwell pressure where the higher drywell pressure provides the inlet flow rates. And as previously stated, inlet hydrogen flow rates do not exceed 1 g/(m^2-sec) which is significantly lower than the test data presented by Julich.

I.2

While the hydrogen concentrations in the tests were not as high as for ESBWR conditions, the total hydrogen removal rates were significantly higher than will be required in the PCCS and the flow velocities were more than 50 percent higher than the peak velocities that are predicted through the PCCS catalyst module.

I.3

The test duration is not a critical parameter since the catalyst does not deplete. The Julich tests demonstrated recombination rates that exceeded the hydrogen mass flow rates that are predicted in the PCCS vent stream.

J.

ESBWR Specific parameters relative to catalyst performance (note that the reviewer's second and third bullets have been combined into bullet number two in the response below):

- Nominal Efficiency - The Julich tests demonstrated complete recombination of a 4% hydrogen mixture when velocities were maintained at or below 0.25 m/s. Also, the 4% hydrogen mixture for Julich, yielded a recombination flux rate of 1.8 g/(m2-s) as compared to the PCCS catalyst module design peak rate of only1.0 g/(m2-s). The nominal or average catalyst module recombination flux rate will be less than 0.1 g/(m2-s), and therefore the nominal recombination efficiency for the PCCS catalyst module is expected to be 100% or complete recombination for the amount of catalyst area available.
- Warm-up time and minimum hydrogen concentration – Warm-up or startup time as is applied to PARs relates to their mode of operation in which convective currents induced by the exothermic recombination process are relied upon to draw in or introduce hydrogen and oxygen to the active catalyst. Therefore some minimum quantities of hydrogen (and oxygen) are required to begin the reaction and subsequently achieve the flow rates needed to affect "large" general areas inside containment. In the case of the PCCS catalyst module, hydrogen and oxygen are introduced to the catalyst by the differential pressure that exists between the drywell and wetwell such that a "warm-up" time is not required. All of the hydrogen and oxygen that is vented in a stoichiometric ratio will recombine in the presence of the catalyst.
- Maximum efficiency operating temperature – At the peak recombination flux rate for ESBWR (1.0 g/m^2-sec), the temperature of the catalyst is expected to reach a minimum of 370^{o}C. Although it is not expected that the catalyst surface temperature will reach the point of autoignition, such an event would not be detrimental to the vent module or the PCCS condenser.
- Influence of liquid droplet carry-over – Given the condensate hood design and the low volumetric flow rates of the vented gasses, very little liquid droplet carry-over is expected. For the small amounts of liquid that may be introduced, the steady state temperature of the PCCS vent components is expected to be above the saturation temperature of the steam and therefore any water that might be locally deposited on the catalyst surface will be quickly driven off as vapor by the exothermic reaction, with virtually no impact upon recombination efficiency.

K.

To address the possibility of the drain lines not fully flowing with condensate during the post-72 hour period of LOCA, the drain thickness shall be designed to withstand a detonation using design by formula with the applicable ASME Section III, Subsections NE and NC. By using design by formula, the drain line will meet acceptance criteria for Service Levels A and B, which bound both Service Levels C and D and will assure an elastic response by the drain line. A design pressure of 38.7 MPa will be used (407 kPa x 19 x 2 x 2.5).

The LTR Section 2.2.4.4 has been modified to include these design details as discussed above.

L.

As discussed in Item K above, the drain line shall be designed to withstand a detonation load of the same magnitude as the lower drum. The maximum pressure for the vent line has been re-evaluated based on the response to Item Y. Table 3-2 of the LTR has been updated accordingly.

M.

M.1

- The qualification tests (PANTHERS and PANDA - NEDC 32725P Rev 1) for TRACG validation are still applicable to the new PCCS design considering the different tube material, tube thickness, tube internal diameter and different number of tubes.
- The overall changes to the PCCS design have a relatively small impact on the overall heat transfer and PCCS performance as shown below in the comparisons of overall heat transfer coefficient, thermal resistance, fluid transport time and thermal time constant of the tube wall.

Table 6.2-202 M1 summarizes the differences between the modified PCCS design and the DCD Rev 7 PCCS design. The scaling report (NEDC-33082P Rev 2) evaluated the DCD Rev 7 design relative to the PANTHERS prototype. The PANTHERS PCCS test component or module is identical to the DCD Rev 7 PCCS design with only [[ ]] and there are no scaling distortions.

Table 6.2-202 M1 Comparisons of PCCS Designs

	DCD Rev 7 PCCS Design	Modified PCCS Design	Modified Design vs DCD Rev 7 (%Change)
Tube Material	Stainless Steel 304	XM-19	-22%[1]
Number of Tubes	560	[[	
Tube Outer Diameter (mm)	50.8		
Tube Inner Diameter (mm)	47.5		
Tube Thickness (mm)	1.65		
Individual Tube Flow Area (mm²)	1.77E+03		
Total Flow Area (mm²)	9.92E+05		
Individual Tube Inside Surface Area (mm²)	2.75E+05		
Total Inside Surface Area (mm²)	1.54E+08		]]
Tube Length (mm)	No changes were made to the tube lengths.		0%

Note 1: Percentage change in material thermal conductivity.

The thermal properties of XM-19 are similar to stainless steel 304 with a small decrease in thermal conductivity. The increase in the tube thickness causes some effect on the conduction through the tube wall, discussed below. TRACG is qualified for calculating conduction heat transfer through the tube wall used in the PCCS analysis. The local effect of reduced heat transfer per PCCS tube due to the thicker XM-19 wall is compensated by the increase in the number of tubes from 560 (in the DCD Rev 7 PCCS design) to [[ ]] in the modified PCCS design. The change to the tube inner diameter is small and therefore will have a small impact on the convective/condensation heat transfer inside the tube due to the change in tube flow area. This is particularly true since the thermodynamic conditions including the non-condensable gas fractions entering the PCCS tubes remain approximately the same and are not affected by the PCCS design change. The overall change to the heat transfer from PCCS tubes is small, and therefore, the TRACG qualification tests including the PANTHERS tests related to PCCS heat transfer are still applicable.

An evaluation of the local or "bottom-up" scaling of the PCCS tube heat transfer has been performed to validate that the PANTHERS prototype test data is still applicable. With respect to the changes in geometry from the DCD Rev 7 PCCS design to the new design, the total flow area and total inside surface area of all PCCS tubes are kept relatively the same. There is a small decrease in the total flow area and a small increase in the total inside surface area as shown in Table 6.2-202 M1. The number of tubes is increased by [[ ]] and the tube wall thickness has been increased by [[ ]] to maintain the heat transfer out of the PCCS to be about the same as in DCD Rev 7 PCCS design. From a scaling perspective, all of these changes are within the same order of magnitude (i.e., within the range of [[ ]]) of the DCD Rev 7 and PANTHERS PCCS designs.

The evaluations below consider the thermal resistances at the PCCS inside and outside tube walls, and through the tube wall material. The thermal resistances, heat transfer coefficients, fluid transport time and thermal time constants are from the Design Basis LOCA Main Steamline Break with Offsite Power analyses for the DCD Rev 7 PCCS design and for the modified design at 6, 16, 34 and 72 hours averaged over the length of the tube unless otherwise noted. These values are used for the evaluation purposes since PCCS heat transfer is most important for the long-term containment response following a LOCA.

A comparison of the PCCS overall heat transfer coefficient based on the inner tube wall, between the DCD Rev 7 and modified design, is presented in Table 6.2-202 M2. The overall heat transfer coefficient for the PCCS is calculated from the following equation/definition where U is based on the inner surface area of the tube:

$$U_i = \frac{1}{\left(\frac{1}{h_i}\right) + \left[\frac{A_i \ln\left(\frac{r_o}{r_i}\right)}{2\pi k L}\right] + \left(\frac{A_i}{A_o h_o}\right)}$$

Where

U_i = PCCS Overall Heat Transfer Coefficient Based On Inner Tube Wall

h_i = Inner Tube Wall Heat Transfer Coefficient

A_i = Inner Tube Wall Surface Area

r_i = Tube Inner Radius

r_o = Tube Outer Radius

k = Tube Material Thermal Conductivity

L = Tube Length [[ ]]

A_o = Outer Tube Wall Surface Area

h_o = Outer Tube Wall Heat Transfer Coefficient

As shown in Table 6.2-202 M2, the change in the overall heat transfer coefficient per tube between the DCD Rev 7 and modified design is approximately [[ ]] in the beginning of the long term transient, i.e, at 6 hours, very close after 16 hours and is almost zero after 34 hours. The reduction in the overall heat transfer coefficient in the early period shown in Table 6.2-202 M2 is compensated by an increase number of tubes and surface area such that the necessary decay heat removal function is met.

Table 6.2-202 M2 Comparison of PCCS Overall Heat Transfer Coefficient

Time (hours)	Tube Overall Heat Transfer Coefficient Based On Inner Area (W/m²K)	
	DCD Rev 7	Modified Design
6	[[	
16		
34		
72		]]

A comparison of the PCCS tube thermal resistances, between the DCD Rev 7 and modified design, is presented in Table 6.2-202 M3. The thermal resistances are the terms in the denominator of the equation for the of overall heat transfer coefficient, U, discussed above.

Inner Tube Wall Convective Thermal Resistance:

$$R_i = \frac{1}{h_i}$$

Where

R_i = Inner Tube Wall Convective Thermal Resistance

h_i = Calculated Inner Tube Wall Heat Transfer Coefficient

Outer Tube Wall Convective Thermal Resistance:

$$R_o = \left(\frac{A_i}{A_o h_o}\right)$$

Where

R_o = Outer Tube Wall Convective Thermal Resistance

h_o = Calculated Inner Tube Wall Heat Transfer Coefficient

A_i = Inner Tube Wall Surface Area

A_o = Outer Tube Wall Surface Area

Tube Wall Conduction Thermal Resistance:

$$R_w = \left[\frac{A_i \ln\left(\frac{r_o}{r_i}\right)}{2\pi kL} \right]$$

Where

R_w = Tube Wall Conduction Thermal Resistance

A_i = Inner Tube Wall Surface Area

r_i = Tube Inner Radius

r_o = Tube Outer Radius

k =Tube Wall Thermal Conductivity

L = Tube Length

Table 6.2-202 M3 shows that although the conduction thermal resistance for the tube wall increased by a factor of 3, the conduction thermal resistance is still one order of magnitude less than the thermal resistances at the inner surface (convection/condensation) and outer wall surface (convection/boiling). The DCD Rev 7 design tube wall conduction thermal resistance is only about [[ ]] of the total thermal resistance. The modified design has a tube wall thermal conduction resistance of only [[ ]] of the total thermal resistance. Also, the thermal-hydraulic conditions of the PCCS pool, the ultimate heat sink, are unchanged. The tube side convection/condensation heat transfer remains limiting. Thus the overall heat removal and steam condensation capacities of the two PCCS designs remain approximately the same.

Table 6.2-202 M3 Comparisons of Thermal Resistances

	Inner Tube Wall Convective Thermal Resistance (K-m²/W)		Outer Tube Wall Convective Thermal Resistance (K-m²/W)		Tube Wall Conduction Thermal Resistance (K-m²/W)	
Time (hours)	DCD Rev 7	Modified Design	DCD Rev 7	Modified Design	DCD Rev 7	Modified Design
6	[[					
16						
34						
72						]]

A comparison of the fluid transport times through the PCCS tubes, between the DCD Rev 7 and modified design, is presented in Table 6.2-202 M4. The average fluid/gas transport times are calculated from the following equation:

$$T_t = \frac{L_{tube}}{V_{fg}}$$

Where

T_t =Transport Time

L_{tube} =Tube Length

V_{fg} = Average Velocity of Fluid/Gas in PCCS Tube Inlet

As shown in Table 6.2-202 M4, the transport times are approximately the same for both the DCD Rev 7 design and the modified design.

Table 6.2-202 M4 Comparisons of PCCS Tube Transport Times

	Fluid Transport Time Based on Inlet Velocity (s)	
Time (hours)	**DCD Rev 7**	**Modified Design**
6	[[	
16		
34		
72		]]

A comparison of the PCCS tube thermal time constants, between the DCD Rev 7 and modified PCCS design, is presented in Table 6.2-202 M5. The time constants for the PCCS tube wall are calculated with the following definition:

$$t_c = \frac{\rho_s c_{ps} V_s}{h_i A_i}$$

Where

t_c = Time Constant

ρ_s = Tube Wall Material Density

c_{ps} = Tube Wall Material Specific Heat Capacity

V_s = Half Volume of Tube Wall

h_i = Tube Inner Wall Heat Transfer Coefficient

A_i = Tube Inner Wall Surface Area

As shown in Table 6.2-202 M5, the PCCS tube wall thermal time constants have increased from the DCD Rev 7 values of [[ ]] seconds to the modified design values of [[ ]] seconds. However this change in thermal time constant is insignificant for the very slow long-term containment pressure response. As discussed in Chapters 7 and 8 of ESBWR Scaling Report, Rev 2, NEDC-33082P, April 2008, the "system" or "top-down" characteristic time of the drywell and wetwell pressure change is on the order of <u>100,000 seconds or several hours</u>. Thus there is virtually no change in the total PCCS heat removal capability and containment pressure as discussed below. This also reinforces the validity of the "system" or "global" or "top-down" scaling of containment pressure and the global scaling parameters or Pi-groups for the drywell and wetwell pressure rates presented in the ESBWR scaling report. Therefore, no change is necessary in the ESBWR Scaling Report because of the modified PCCS heat exchanger design.

Table 6.2-202 M5 Comparisons of PCCS Tube Wall Time Constants

	Tube Wall Time Constant (s)	
Time (hours)	**DCD Rev 7**	**Modified Design**
6	[[	
16		
34		
72		]]

The qualification of models for the highly ranked PCCS heat transfer phenomenon is documented in Tables 3.3-2, 3.3-3, and 3.3-4 in NEDC-33083-P-A for Separate effects, component and integral tests respectively. In addition to PANTHERS Component tests, the qualification includes GIRAFFE & PANDA PCCS component qualification and GIRAFFE & PANDA integral qualification. The tests include a varying number of PCCS tubes and confirm that TRACG accurately calculates containment pressure with the varying number of tubes and is slightly conservative in its calculation of PCCS heat transfer rate. TRACG's capabilities and qualification are broader than the PANTHERS PCCS design. Table 3.3-1 "High Ranked ESBWR Containment/LOCA Phenomena and TRACG Model Capability Matrix", in NEDC-33083-P-A indicates the code contains models for all of the highly ranked PCCS heat transfer phenomenon (PCCS section of the table).

TRACG incorporates qualified models that show that TRACG can accurately calculate the containment response with the design modifications being made in response to this RAI.

M.2

The results of the TRACG analysis that includes the change in tube material, number of tubes, tube thickness and tube inner diameter is presented in Figures 6.2-202 M1 and 6.2-202 M2. Figure 6.2-202 M1 presents the containment pressure response for the updated TRACG analysis vs. the containment pressure for the TRACG analysis in the DCD Tier 2 R7 Figure 6.2-14j1. They are approximately the same and the modified analysis has a slightly lower maximum pressure than the DCD Rev 7 analysis. Figure 6.2-202 M2 presents the PCCS power for the updated TRACG analysis. The PCCS power is similar to the PCCS power presented in the DCD Tier 2 R7 Figure 6.2-14l1 (Figure 6.2-202 M3). The difference in the curves in each of these figures is due to uncondensed steam flowing to the wetwell from the drywell in the early blow down and from the PCCS in the long term. The figures show that the difference between the decay heat and PCC power in the LOCA transient is similar for the DCD Rev 7 and modified design.

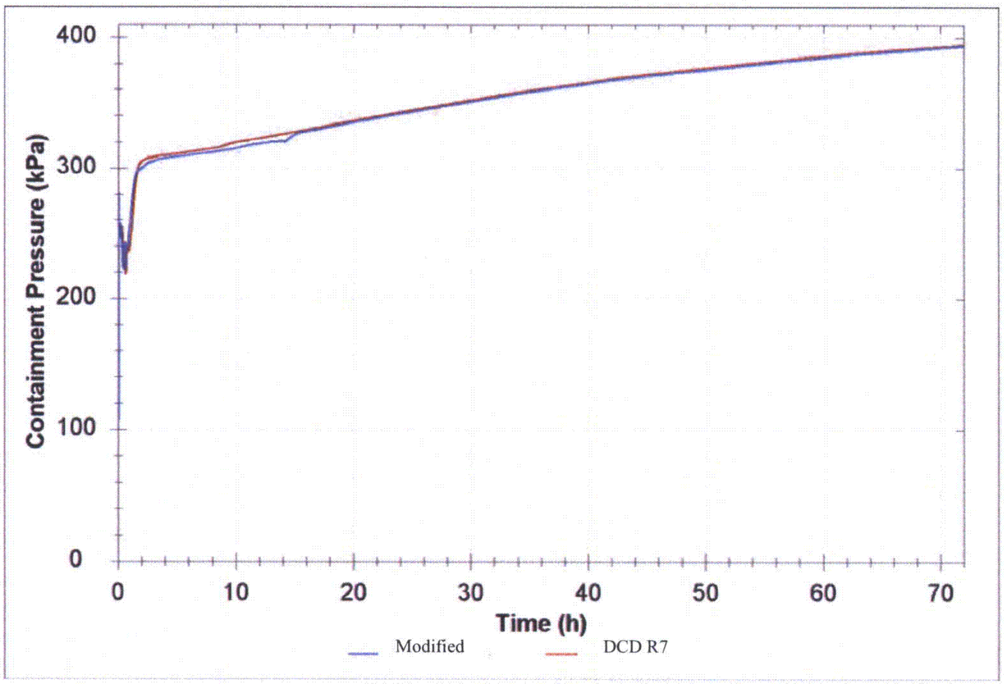

Figure 6.2-202 M1

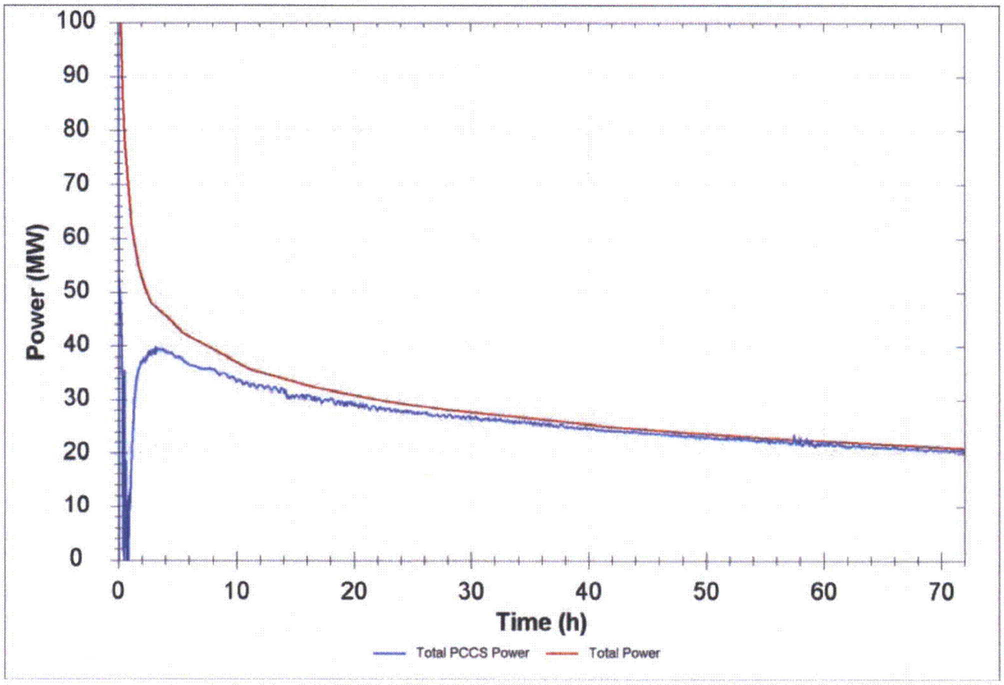

Figure 6.2-202 M2

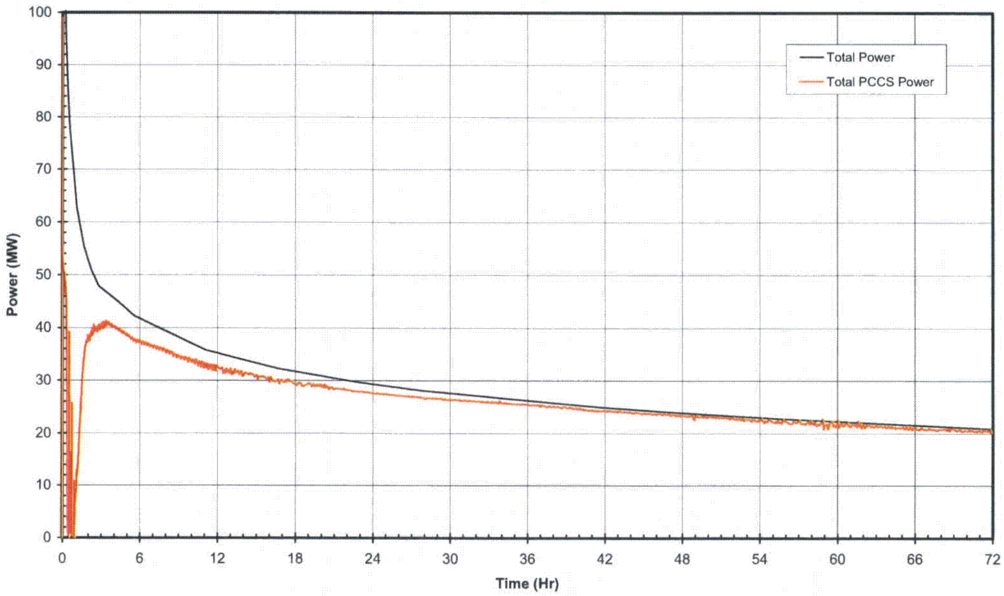

Figure 6.2-202 M3 (DCD Tier 2 R7 Figure 6.2-14I1)

M.3

The data used to validate TRACG covers the expected conditions of the new design.

A comparison of the PCCS tube exit average non-condensable gas fraction, between the DCD Rev 7 and modified PCCS design, is presented in Table 6.2-202 M6. As shown in the Table, the change in the non-condensable gas fraction between the DCD Rev 7 and modified design is small. This indicates that the amount of condensation is approximately the same.

Table 6.2-202 M6

Time (hours)	Non Condensable Gas Fraction at PCCS Tube Exit	
	DCD Rev 7	Modified Design
6	[[	
16		
34		
72		]]

M.4

The local or "bottom-up" scaling discussed in section M1 shows that PANTHERS tests for PCCS are still applicable to the new design since the PCCS overall heat transfer has not changed. Therefore the Pi-groups for the "top-down" scaling groups remain the same and no change is necessary to the scaling groups.

N.

- The PCCS heat transfer rate in the modified design of the PCCS component is nearly the same as the DCD Rev 7 design. Therefore the integral PANDA tests are still applicable to the modified PCCS design.

As seen in Figure 6.2-202 M1, the changes to the PCCS did not affect the TRACG results for containment pressure. The updated analysis shows that the long term LOCA response remains approximately the same as the previous analysis. This is because the wall thermal conductivity decrease offset the surface area increase. The PCCS continues to operate below its 100% steam capacity rating (47 MW total rated capacity for 6 PCCS condensers) in the long term (6-72 hour period) DBA LOCA as indicated by the Total PCCS Power in Figure 6.2-202 M2. It is operating below its 47 MW (7.8 MW per unit) capacity during the DBA LOCA. The integral PANDA tests included all of the features required for an integral system simulation for a long term LOCA response. Figure 6.2-202 M2 shows the PCCS power, which in comparison to the DCD R7 PCCS power (Figure 6.2-202 M3) is similar, and therefore, the integral long term LOCA response of the system will remain the same and PANDA tests are still applicable.

O.

The configuration of the IC has not changed in response to RAI 6.2-202 S01 and therefore a table has not been provided comparing the IC configuration to the PANTHERS prototype.

P.

In LTR Section 4.2, it is described how the ICS is isolated during a LOCA to prevent accumulation of high amounts of combustible gas. A TRACG evaluation of the ICS behavior during such an event determined that the minimum steam concentration inside the condenser was 37%. As described in the LTR, the presence of steam is credited with reducing the CJ pressure. In order to bound this effect, it was assumed that the steam concentration was 20%, which is conservatively lower than the minimum value determined by TRACG. The LTR cites a table in a research report (Ref. 17 of the LTR) in which the thermo-chemical properties of stoichiometric mixtures of hydrogen and oxygen are computed for various concentrations of steam dilution. This table is used as the basis for CJ velocities and CJ pressures for a mixture with 20% steam.

It is also true that the presence of steam can also impact the detonation velocity, which factors into the justification of a DLF of 2. Refer also to the response to Item CC.1 in this RAI Supplement. An additional discussion will be added to the LTR Section 4.2 to demonstrate that the ICS remains bounded by a DLF of 2 for the full range of possible steam concentrations. The justification is similar to what is presented in the response to item V.

Q.

The temperature sensors were added as a defense-in-depth measure only, and with the exception of their pressure boundary impact, they are nonsafety-related. The safety-related means for mitigating a detonation in the ICS is described in Section 4 of the LTR. The temperature sensors will be retained in the design as defense in depth.

R.

The LTR Section 2.6.6 will be revised to consistently and clearly state that the Service Level C criteria will be applied for detonation loading. A statement will also be included emphasizing that although Service Level C allows for local stresses slightly higher than the yield limit, the response of each component remains essentially elastic and ratcheting and other undesirable plastic instabilities are precluded. The linearized stresses that are compared against ASME allowables are within the elastic range.

The PCCS condenser analysis is currently being revised to implement the design changes required for all components to meet the Service Level C requirements. The LTR Appendix B has been updated with preliminary results of this reanalysis. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

S.

In response to the original RAI 6.2-202, DCD Appendix 3G.1.5.4.1.5 was modified to refer to the LTR, which contains the details and results of the analysis. The DCD contains the requirement that the PCCS be constructed in accordance with the ASME Code requirements for the load combinations described in Table 3.8-4 (which includes detonation loads). The ITAAC requirements in Tier 1 Table 2.15.4-2 also require that the PCCS be designed in accordance with the ASME Code.

T.

A detailed description of the LS-DYNA alternate calculation will be included in revision 2 of the LTR as Appendix C, which demonstrates that the global affect of a detonation on the PCCS structure is less than that of the seismic loading. Since the load combination for detonation includes seismic loading, the seismic loading will be doubled in order to bound the global effects of detonation.

The amplification at the tube bend is the limiting stress area and the membrane stress is 275 MPa (as reported in Table B-2b of the LTR). The stresses decrease significantly (below 150 MPa) throughout the tube transition as it approaches the interface with the surface of the lower drum. The tube submodel extends all the way to the inner surface of the lower drum. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

U.

The term "elastic-plastic analysis" is valid for this discussion. An "elastic-plastic analysis" is performed to show that the components stay within the elastic range as established by the ASME Code criteria. Clarifying statements will be added to the LTR so that this is made clear. Refer to Item R.

V.

Reference 17 in the LTR contains data that is more directly applicable to the discussion of detonation velocities (DCJ) as they relate to the DLF. Instead of relying on a comparison with argon data, Table 5.1.8 of Ref. 17 will be cited as the basis for detonation velocity data. This table contains the calculated thermo-chemical properties resulting from a detonation of stoichiometric hydrogen and oxygen in the presence of varying concentrations of steam. The DCJ velocity follows the predicted trend – decreasing with increasing steam concentration. The maximum steam concentration presented in this table is 72% at which the corresponding DCJ value is 1815 m/s. Although the range of steam data in this table does not reach all the way to 80%, the data on CJ Pressure (PCJ) indicates that at a steam concentration of 65%, the CJ Pressure ratio has dropped to 9.3:1 (compared to the assumed 19:1 ratio at low steam concentrations). At this level of dilution and higher, a DLF of 4 is offset by a CJ Pressure that is less than half of what was assumed at low steam concentrations.

W.

Section 2.2.3 of the LTR will be revised to focus on how the loads related to a DDT event are bounded by the dynamic factors already being applied.

X.

Because the lower drum is being evaluated in the context of a CJ detonation, the discussion related to constant volume combustion is not considered necessary and will be removed from Section 2.2.4.1 of the LTR.

Y.

LTR Section 2.2.5 will be revised to consider a dynamic factor of 2. Credit will also be taken for pressure reduction due to volumetric expansion. Table 3-2 has been updated accordingly as described in Item BB below.

Z.

The LTR will be revised to consistently and clearly state that the Service Level C criteria will be applied for detonation loading, and consistent with the DCD and revised RAI response (refer to Item R above).

AA.

Table 3-1 of the LTR will be revised to clarify that the drain pipe contains both NC and NE portions, consistent with figure 1c.

BB.

Table 3-2 of the LTR will be revised to indicate the revised design pressure of the vent pipe as detailed in item Y above. Likewise this table will be updated to indicate the revised design pressures of the vent and drain pipe as described in Items K and Y above.

CC.

CC.1 (1st Paragraph)

The discussion in Section 4.2 of the LTR will be clarified to include a justification for the DLF of 2, and to indicate that the referenced data is based on thermo-chemical calculations that are representative of the experimental mixtures of steam and radiolytic gases. As described in Item P above, these data indicate that a multiplication factor of 13.3 is an appropriate CJ pressure ratio considering the initial starting temperature and assumed dilution of 20% steam. The data presented in this table is not dependent on the experimental geometry.

CC.2 (2nd Paragraph)

The FEM described in Appendix B (and will eventually be supported by new Appendix C) addresses the dynamic response of the entire PCCS condenser structure and the reaction loads that are imposed on the anchor bolts.

Section B.7 has been added to Appendix B to address fatigue. Note that the version of Appendix B included in this submittal is preliminary and unverified.

Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

DD.

DD.1

Detonation loads determined in the Tube Submodel and Lower Drum Submodel were combined with other loads as a direct summation of maximum stresses. This is now explained in Section B.3.

DD.2

The forces at the boundary conditions were defined to equalize the internal pressure assumed for the Tube Submodel. This is now explained in Section B.1.1. The pressure is applied to the inside of the tube extending all the way to the inner surface of the lower drum.

DD.3

Detonations in the lower drum are not assumed to occur simultaneously with a detonation in the tube. Therefore the displacements associated with the Lower Drum Submodel are not factored into the boundary condition of the Tube Submodel. The displacement resulting from a detonation in the lower drum does not impose significant stress on the tubes, because the design of the PCCS support structure allows for expansion in the vertical direction.

DD.4

The amplification at the tube bend is the limiting stress area and is 275 MPa (as reported in Table B-2b of the LTR). The stresses decrease significantly throughout the tube transition as it approaches the interface with the inner surface of the lower drum.

Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

EE.

EE.1

Detonation loads determined in the Tube Submodel and Lower Drum Submodel were combined with other loads as a direct summation of maximum stresses. This is now explained in Section B.3.

EE.2

The Lower Drum Submodel has been expanded to include the interface between the drain nozzle and the pool liner plate. Tables B-3a/b and B-4a/b have been added to describe the stress imparted to the anchor bolts on the PCCS supports.

These loads will be used to design the seal and anchor bolts that secure the connection to the pool liner. The contribution of detonation loads will be accounted for by doubling the seismic loads (to be justified in Appendix C of the LTR).

EE.3

The connections were modeled and accounted for as described above in item EE.2. Figures 1b and B-1b in the LTR will be updated to clarify that there is a bolted connection between the drain line and the pool liner at the penetration of the top slab.

EE.4

Figures 1b and B-1b of the LTR has been updated to clarify that there is a bolted connection between the drain and the pool liner. Therefore, any reactions due to seismic or detonations would not impose loads directly to the pool liner.

The Lower Drum Submodel has been expanded to include the upper portion of the annular drain and its connection to the lower drum condensate nozzle. The stresses included in Table B-2a and B-2b include those stresses associated with this interface.

Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

FF.

FF.1

Detonation loads determined in the Tube Submodel and Lower Drum Submodel were combined with other loads as a direct summation of maximum stresses. This is now explained in Section B.3.

FF.2

The PCCS Analysis Model was used for all loads other than DET. These loads were then combined with the DET loads from the sub models. This is now explained in Section B.3.

FF.3

The Lower Drum Submodel has been extended to include the interface between these two components is discussed in Item EE.4 above.

The RCCV liner is outside the scope of this evaluation. In the next revision of the LTR, Figures 1b and B-1b will be clarified to show a bolted connection between the drain pipe and the top slab. Loads that are transmitted through this connection will not be imparted to the liner, but rather to the anchorage in the concrete. The structural analysis of the PCCS has determined the loads to be accommodated by these bolts (this information has been provided in Tables B-3a/b and B-4a/b), and this connection to the top slab penetration will be sized accordingly in detailed design.

Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

GG.

The LTR will be revised to consistently and clearly state that the Service Level C criteria will be applied for detonation loading, and will be consistent with the DCD and revised RAI response (refer to Item R above).

LOCA and SRV loads described in Table B-1 are consistent with DCD Table 3.8-4. These loads are not considered at the same time as DET loads, because a detonation is not possible in the earliest stages of a LOCA. Therefore, there are effectively two separate load combinations considered for Service Level C, the most bounding of which is reported in Table B-2b. Live loads (L) and pipe reactions (Ra) were considered but determined to be insignificant in the context of the PCCS condenser. A footnote will be added to LTR Table B-1 to provide this clarification. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

HH.

HH.1 and 2

LTR section B.5 will be revised. After changing the detonation load to Service Level C, there are no load combinations unique to Service Level D, therefore that row is deleted from the table. The headings in Table B-2b will be modified accordingly to delete columns for Service Level D.

HH.3

The discussion in Items EE.2, EE.3, and EE.4 addresses the concern identified here.

HH.4

The DET load will be bounded by doubling the SSE load. When the results for Appendix C are available, they will be added to the LTR to demonstrate how the Seismic load bounds the DET load.

HH.5

This subject has been addressed in response to item CC.2, (2nd paragraph) above.

Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

II.

A reanalysis has been performed using the design modifications proposed in Rev. 1 of the LTR (Section B.6). The results are provided in an updated Appendix B in this submittal. Note that the version of Appendix B included in this submittal is preliminary and unverified. Once the results are verified, the final version of NEDE-33572P Rev. 2 will be provided.

JJ.

DCD Tier 2, Section 3.8.2.6 has been revised to change the form specification to SA-182 in accordance with the attached markup. The LTR has been changed to include weld material ER209 to provide the required strength.

KK.

The time delay following DPV opening is no longer in the design. Refer to the attached DCD Tier 2, section 5.4.6.1.1 markup.

<u>Additional Related DCD or LTR Impacts</u>

In addition to the concerns described in the formal RAI, the following items have resulted in DCD or LTR changes:

i.

In a teleconference between GEH and NRC, GEH agreed to update NEDO-33306 (SAMDA report) to address the concerns pertaining to hydrogen detonation. NEDO-33306 will be updated with reference to the latest PRA. None of the conclusions or insights have changed.

ii.

In correspondence between GEH and NRC, it was pointed out that the ICS heat removal capacity is not a significant input parameter to the ECCS-LOCA analysis. As a result, DCD Tier 2, Table 6.3-1 has been revised to remove the ICS heat removal capacity in accordance with the attached markup.

iii.

GEH identified that the ITAAC in Tier 1, Table 2.4.1-3, item 19 prohibited manual opening of the ICS vent valves during normal operation. In order to allow for the necessary inservice testing, this ITAAC will be deleted. The deletion of this ITAAC does not adversely affect plant safety.

iv.

The below listed DCD Tier 2, Chapter 7 subsections, tables and figures were revised to facilitate the ICS isolation and vent valve logic changes.

DCD Impact

The DCD markups listed here are all-inclusive of both the original and revised RAI 6.2-202 Supplement 1. In some cases markups that were included with the original response have been altered or omitted as a result of the revised RAI.

DCD Tiers 1 and 2 will be revised as noted in the attached markups (Enclosure 3). The sections, tables, and figures are identified below:

Tier 1

Table 2.2.10-1

Table 2.2.13-2

Subsection 2.2.15

Table 2.2.15-1

Subsection 2.4.1

Table 2.4.1-1

Table 2.4.1-2

Table 2.4.1-3

Figure 2.4.1-1

Table 2.15.1-1a

Table 2.15.1-1d

Subsection 2.15.4

Table 2.15.4-1

Table 2.15.4-2

Figure 2.15.4-1

Subsection 3.2

Table 3.2-1

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

Figure 3.8-7

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

Subsection 5.4.16

Table 5.4-1

Figure 5.4-4b

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 6.2.4.3.1.1

Subsection 6.2.5.5.1

Subsection 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

Table 6.3-1

Subsection 7.1.2

Subsection 7.1.2.8

Subsection 7.1.2.8.1

Subsection 7.1.2.8.3

Subsection 7.1.2.8.3.1.3

Subsection 7.1.2.8.9 (new)

Subsection 7.1.6.6

Subsection 7.1.6.6.1

Subsection 7.1.6.6.1.1

Subsection 7.1.6.6.1.17

Subsection 7.1.6.6.1.18

Table 7.1-1

Table 7.1-2

Figure 7.1-1

Figure 7.1-3

Subsection 7.3.1.2.2

Subsection 7.3.1.2.3

Subsection 7.3.1.2.5

Subsection 7.3.2

Subsection 7.3.3

Subsection 7.3.7 (New)

Figure 7.3-5

Subsection 7.4.4.1

Subsection 7.4.4.3

Subsection 7.8.1

Subsection 7.8.1.2.5

Table 7.8-3

Table 7B-1

Subsection 15.5.5.3

Table 15.2-23

Table 15.5-10a

Table 15.5-10b

Chapter 16 Section 3.3.5.3

Chapter 16 Section 3.3.5.4

Chapter 16 Section 3.3.6.3

Chapter 16 Section 3.6.1.7

Chapter 16 B3.3.5.3

Chapter 16 B3.3.5.4

Chapter 16 B3.3.6.3

Chapter 16 B3.3.6.4

Chapter 16 B3.5.4

Chapter 16 B3.5.5

Chapter 16 B3.6.1.7

Subsection 19.3.2.1

Subsection 19.3.2.4

Subsection 19.3.4.2.8

Subsection 19A.5

Subsection 19A.6.1.3.1

Subsection 19A.8.4.3

Subsection 19A.8.4.10

Table 19A-2

Section 19B.6

Table 19B-11

Chapter 19 AC 3.3.4

Chapter 19 AC B3.3.4

Chapter 19 AC B3.6.3

Chapter 19 AC 3.6.4 (new)

Chapter 19 AC B3.6.4 (new)

LTR Impact

Markups are included (Enclosures 4, 5 and 6) for the following impacted LTRs:

LTR NEDE-33572P, Rev 1

LTR NEDO-33251, Rev 2

[[

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

[[

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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)

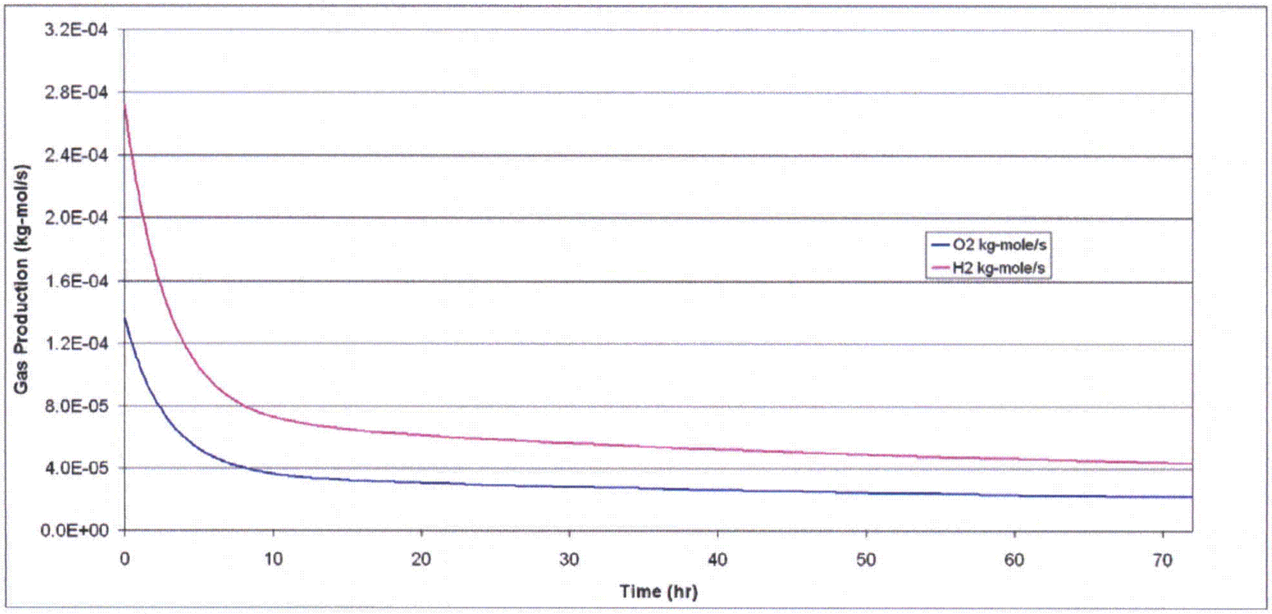


Figure 6.2-202 S01.3. ESBWR Post-LOCA Radiolytic Gas Production of Hydrogen and Oxygen in RPV

Enclosure 3

MFN 10-044 Supplement 1 Revision 1

Revised Response (Revision 1) 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

2.2.15 Instrumentation & Control Compliance With IEEE Std. 603

Design Description

IEEE Std. 603 establishes the minimum functional and design requirements for the power, instrumentation, and control portions of safety systems. ESBWR divides safety systems into two parts: the safety-related distributed control and information system (Q-DCIS) platforms, and the associated functional systems that contain the sensors and actuators used by the Q-DCIS platforms.

In accordance with the software development process described in Section 3.2 and the defense-in-depth and diversity strategy described in Subsection 2.2.14, the protection systems are executed as software projects on particular Q-DCIS platforms. The software projects are named RTIF, NMS, SSLC/ESF, Vacuum Breaker Isolation Function(VBIF), ATWS/SLC, ~~and~~ HP CRD Isolation Bypass Function, and ICS DPV Isolation Function.

Table 2.2.10-1 shows the relationship between the Q-DCIS platforms and their corresponding software projects. As shown, the RTIF-NMS platform has two software projects: RTIF and NMS. The SSLC/ESF platform has one software project: SSLC/ESF. The Independent Control Platform has ~~three~~four software projects: VBIF, ATWS/SLC, ~~and~~ HP CRD Isolation Bypass Function and ICS DPV Isolation Function.

Demonstration of compliance with IEEE Std. 603 means the Q-DCIS documentation includes design bases that make appropriate reference to IEEE Std. 603 design criteria and that the resulting as-built equipment has been inspected, tested, or analyzed to show that the Q-DCIS will be capable of performing in accordance with the design bases. The choice of whether an inspection, test, or analysis is required to close a particular ITAAC is defined in the documentation associated with the {{Design Acceptance Criteria}} ITAAC closure report for the software projects in response to ITAAC defined in Section 3.2.

IEEE Std. 603 divides the Q-DCIS into three features: sense, command, and execute features. Sense features comprise sensors. Command features comprise the Q-DCIS platforms. Execute features comprise actuators. Each of these features is treated differently within Tier 1 because of influences outside of the scope of IEEE Std. 603.

As a result of these differences, Table 2.2.15-1 was developed to group the software projects with their associated functional system(s), if any, and to define how the various IEEE Std. 603 criteria will be demonstrated by an ITAAC for each software project.

Table entries marked with an R means the IEEE Std. 603 criterion compliance report(s) for the indicated software projects (i.e., RTIF, NMS, SSLC/ESF, VBIF, ATWS/SLC, ~~and~~ HP CRD Isolation Bypass Function**, and ICS DPV Isolation Function**) include(s) the associated parts of the functional systems marked with a C or string of Cs, if any, immediately to the right of the R. Table entries marked with a C means compliance with the IEEE Std. 603 criterion is documented by one or more reports written against the first software projects marked with an R, to the left of the C(s). For example, the report(s) for the RTIF software projects will demonstrate compliance to IEEE Std. 603 criterion 5.1 for RPS, LD&IS MSIV, Containment Monitoring System (CMS)-Suppression Pool Temperature Monitoring (SPTM), NBS, and CRD. The report(s) may be referenced or attached to a software project lifecycle phase summary baseline review record (BRR) reference described in Subsection 3.2 to close the Table 2.2.15-2 ITAAC.

Table headings contain the software projects or the functional system identifier and a parenthetical reference to the section or subsection where additional information about the software projects or functional system can be found. These parenthetical references are reverse references that point back to the originating system. The IEEE Std. 603 criteria apply only to those structures, systems, or components (SSCs) directly associated with the performance of the safety-related function of the software projects. Complete lists of applicable SSCs and functions are defined in the documentation associated with the {{Design Acceptance Criteria}} ITAAC closure report for each software project in response to ITAAC defined in Section 3.2. These lists along with the information in the tables associated with a software project or functional system in each column define the scope of the IEEE Std. 603 ITAAC.

Refer to Sections 3.2, 3.3, 3.6, 3.7, and 3.8, as described, for ITAAC associated with the IEEE Std. 603 criteria that do not appear in Table 2.2.15-1.

When the IEEE Std. 603 design criteria are applied to platforms relying on the use of software to perform their safety-related functions, additional criteria from IEEE Std. 7-4.3.2, which augments the IEEE Std. 603 criteria, also apply to the software projects as described under the applicable IEEE Std. 603 criterion. The evaluation of Q-DCIS platforms for compliance with IEEE Std. 603 and IEEE Std. 7-4.3.2 criteria includes consideration of the effects that the associated sensors and actuators have on the performance of the safety-related function.

IEEE Std. 603, Criteria 4.2, 4.3, 4.10, 4.11, and 4.12, are not included as ITAAC because NUREG 0800, Section 14.3.5, and RG 1.206, Section C.II.1, do not include these criteria as ITAAC.

IEEE Std. 603, Criterion 5.3, Quality, requires that the Q-DCIS be of a quality that is consistent with minimum maintenance requirements and low failure rates and be designed, manufactured, inspected, installed, tested, operated, and maintained in accordance with a prescribed quality assurance (QA) program. The QA program for Q-DCIS is not addressed in Tier 1.

The following paragraphs provide references to the tables associated with the software projects and their associated functional systems. For example, RPS refers to Subsection 2.2.7, which associates Tables 2.2.7-1, 2.2.7-2, and 2.2.7-3 with RPS.

Process sensors and actuators that provide sense and execute functions associated with the software projects in Table 2.2.15-1 are found in Tables 2.1.2-2, 2.2.2-6, 2.2.4-5, 2.4.1-2, 2.4.2-2, 2.15.1-1c, and 2.15.7-1, and marked "Yes" in the Control Q-DCIS column.

Functional arrangement of the software projects platforms (except VBIF and ICS DPV Isolation Function) are found in Tables 2.2.5-1, 2.2.7-1, 2.2.13-1, 2.2.14-1, and 2.2.16-1.

The independent control platforms associated with the VBIF and ICS DPV Isolation Function software projects are found in Table 2.15.1-1c and Table 2.4.1-2 respectively.

Functions, initiators, and interfacing systems associated with the software projects (except for the functional system LD&IS) are found in Tables 2.2.5-2, 2.2.7-2, 2.2.13-2, 2.2.14-2, and 2.2.16-2.

The isolation functions and monitored variables associated with the functional system LD&IS are found in Table 2.2.12-2.

Table 2.2.10-1

Q-DCIS Platforms

Platform	Software projects
Reactor Trip & Isolation System Function Neutron Monitoring System (RTIF/NMS)	RTIF
	NMS
Safety System Logic & Control / Engineered Safety Features (SSLC/ESF) Platform	SSLC/ESF
Independent Control Platform (ICP)	Vacuum Breaker Isolation Function (VBIF)
	ATWS/SLC
	HP CRD Isolation Bypass Function
	ICS DPV Isolation Function

Table 2.2.13-2

SSLC/ESF Automatic Functions, Initiators, and Associated Interfacing Systems

Function	Initiator	Interfacing System
ADS	RPV reactor water level low (Level 1) Drywell pressure high	NBS CMS
GDCS Injection	RPV reactor water level low (Level 1) Drywell pressure high	NBS, GDCS CMS
GDCS Equalizing Lines	RPV reactor water level low (Level 1)	NBS, GDCS
ICS	RPV reactor water level low (Level 1)	NBS, ICS
	Steam Supply Line and Drain Line Isolation (Any 2 DPVs Open)	NBS, ICS
SLC	RPV reactor water level low (Level 1)	NBS, SLC, ATWS/SLC
CRHAVS emergency filtration mode	CRHA inlet air supply radiation high from Process Radiation Monitoring System (PRMS)	PRMS, CRHAVS
CRHAVS temperature control	CRHA high room temperature	Nonsafety-related MCR N-DCIS Load Groups A, B and C

Table 2.2.15-1
IEEE Std. 603 Criterion System Applicability Matrix [(1)(2)]

Software projects			RTIF-NMS Platform						SSLC/ESF Platform										ICP			
			RTIF					NMS											VBIF	ATWS/ SLC	HP CRD IBF	ICS DPV IF
Table 2.2.15-2, Item No.	IEEE Std. 603 Criterion	RTIF (2.2.10)	RPS (2.2.7)	LD&IS MSIV (2.2.12) [Note (4)]	CMS-SPTM (2.15.7)	NBS (2.1.2)	CRD (2.2.2)	NMS (2.2.5)	SSLC/ESF (2.2.13)	LD&IS non-MSIV (2.2.12) [Note (3)]	PRMS (2.3.1)	CMS non-SPTM (2.15.7) [Note (4)]	NBS (2.1.2)/ADS (N/A)	GDCS (2.4.2)	ICS (2.4.1)	SLC (2.2.4)	CBVS (2.16.2.2, 2.16.2.3) [Note (5)]	CRD (2.2.2)	VB Isolation Function (2.15.1)	ATWS/SLC (2.2.14)	HP CRD Isolation Bypass Function (2.2.16)	ICS DPV Isolation Function (2.4.1)
1	4.1	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
2	4.4	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
3	4.5	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
4	4.6	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
5	4.7	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
6	4.8	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
7	4.9	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
8	5.1	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
9	5.2 and 7.3	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
10	5.6 and 6.3	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
11	5.7 and 6.5	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
12	5.9	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
13	5.10	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
14	5.11	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
15	5.12	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R

Table 2.2.15-1
IEEE Std. 603 Criterion System Applicability Matrix (1)(2)

Software projects			RTIF-NMS Platform						SSLC/ESF Platform										ICP			
			RTIF					NMS											VBIF	ATWS/ SLC	HP CRD IBF	ICS DPV IF
Table 2.2.15-2, Item No.	IEEE Std. 603 Criterion	RTIF (2.2.10)	RPS (2.2.7)	LD&IS MSIV (2.2.12) [Note (4)]	CMS-SPTM (2.15.7)	NBS (2.1.2)	CRD (2.2.2)	NMS (2.2.5)	SSLC/ESF (2.2.13)	LD&IS non-MSIV (2.2.12) [Note (3)]	PRMS (2.3.1)	CMS non-SPTM (2.15.7) [Note (4)]	NBS (2.1.2)/ADS (N/A)	GDCS (2.4.2)	ICS (2.4.1)	SLC (2.2.4)	CBVS (2.16.2.2, 2.16.2.3) [Note (5)]	CRD (2.2.2)	VB Isolation Function (2.15.1)	ATWS/SLC (2.2.14)	HP CRD Isolation Bypass Function (2.2.16)	ICS DPV Isolation Function (2.4.1)
16	6.1 and 7.1	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
17	6.2 and 7.2	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
18	6.4	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
19	6.6 and 7.4	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
20	6.7, 7.5, and 8.3	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
21	6.8	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
22	8.1	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R
23	8.2	R	C	C	C	C	C	R	R	C	C	C	C	C	C	C	C	C	R	R	R	R

Notes:

(1) R means the IEEE Std. 603 criterion compliance report(s) for the indicated software projects (i.e., RTIF, NMS, SSLC/ESF, VB Isolation Function, ATWS/SLC, and HP CRD Isolation Bypass Function) include(s) the associated parts of the functional systems marked with a C or string of Cs, if any, immediately to the right of the R. C means compliance with the IEEE Std. 603 criterion is documented by one or more reports written against the first software projects marked with an R, to the left of the C(s). For example, the report(s) for the RTIF software projects will demonstrate compliance to IEEE Std. 603 criterion 5.1 for RPS, LD&IS MSIV, CMS-SPTM, NBS, and CRD.

(2) IEEE Std. 603 criteria apply only to the safety-related portions of the functional systems that perform sense, command, or execute functions.

(3) LD&IS non-MSIV functions control the safety-related actuators (isolation valves and isolation dampers) in the following nonsafety-related systems: RWCU/SDC, FAPCS, EFDS, CIS, CWS, HPNSS, SAS, RBVS, CBVS, FBVS, CRD.

(4) CMS (non-SPTM) provides sensor inputs for both LD&IS MSIV and LD&IS non-MSIV functions.

(5) CBVS includes the safety-related CB isolation dampers (see Note 3), EFU and CRHAVS. SSLC/ESF platform executes the CRHS function logic for the safety-related CBVS subsystems, CRHAVS and EFU.

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

• Open position on two or more DPVs

(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, openh igh RPV pressure after time delay following condensate return or condensate bypass valve opening signals~~a. The lower IC header vent valve (V-9) opens upon an ICS initiation signal generated by the SSLC/ESF platform followed by a time delay.

b. The lower IC header vent valve (V-10) opens upon an ICS initiation signal generated by the DPS platform followed by a time delay.

(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.~~(Deleted)

(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)

(29) a. Valves on lines attached to the RPV that require maintenance have maintenance valves such that freeze seals will not be required.

b. The as-built location of valves on lines attached to the RPV that require maintenance shall be reconciled to design requirements.

(30) The Lower IC Header Vent Line restricting orifices shown in Table 2.4.1-1 are sized so that the water level in the RPV during station blackout events does not reach the Level 1 setpoint within 72 hours of the blackout event.

Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.4.1-3 provides a definition of the inspections, test and analyses, together with associated acceptance criteria for the Isolation Condenser System.

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~~No	Yes	~~Closed~~Open
Lower IC (A) Header Vent Line Valve	V-10(A)	Yes	Yes	No	~~Yes~~No	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	RO(A)	Yes	Yes	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
IC (B) Condensate Return Line Bypass Valve	V-6(B)	Yes	Yes	Yes	No	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
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~~No	Yes	~~Closed~~Open
Lower IC (B) Header Vent Line Valve	V-10(B)	Yes	Yes	No	~~Yes~~No	Yes	~~Closed~~Open
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
Lower IC (B) Header Vent Line Restricting Orifice	RO(B)	Yes	Yes	No	–	–	–
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
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	–	–

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) 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~~No	Yes	~~Closed~~Open
Lower IC (C) Header Vent Line Valve	V-10(C)	Yes	Yes	No	~~Yes~~No	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
Lower IC (C) Header Vent Line Restricting Orifice	RO(C)	Yes	Yes	No	–	–	–
Train D Isolation Condenser	–	–	–	–	–	–	–
IC (D) Heat Exchanger	–	Yes	Yes	No	No	–	
Inline Vessel (D)	–	Yes	Yes	Yes	No		–

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 (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
Lower IC (D) Header Vent Line	–	Yes	Yes	No	No	–	–
Lower IC (D) Header Vent Line Valve	V-9(D)	Yes	Yes	No	~~Yes~~No	Yes	~~Closed~~Open
Lower IC (D) Header Vent Line Valve	V-10(D)	Yes	Yes	No	~~Yes~~No	Yes	~~Closed~~Open
Lower IC (D) Header Vent Line Valve	V-11(D)	Yes	Yes	No	Yes	No	–

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 Valve	V-12(D)	Yes	Yes	No	Yes	Yes	Open
Lower IC (D) Header Vent Line Restricting Orifice	RO(D)	Yes	Yes	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 2.4.1-2

ICS Electrical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	Control Q-DCIS / DPS	Seismic Category I	Safety-Related	Safety-Related Display	Remotely Operated Valve	Containment Isolation Valve Actuator
IC (A) Steam Supply Line Isolation Valve	V-1(A)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (A) Steam Supply Line Isolation Valve	V-2(A)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (A) Condensate Return Line Isolation Valve	V-3(A)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (A) Condensate Return Line Isolation Valve	V-4(A)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (A) Condensate Return Line Valve	V-5(A)	Note 1	Yes	Yes	Position	Yes	No
IC (A) Condensate Return Line Bypass Valve	V-6(A)	Note 1	Yes	Yes	Position	Yes	No
Upper IC (A) Header Vent Line Valve	V-7(A)	Yes/No	Yes	Yes	Position	Yes	Yes
Upper IC (A) Header Vent Line Valve	V-8(A)	Yes/No	Yes	Yes	Position	Yes	Yes
Lower IC (A) Header Vent Line Valve	V-9(A)	Yes/No	Yes	Yes	Position	Yes	~~Yes~~No
Lower IC (A) Header Vent Line Valve	V-10(A)	~~Yes/No~~No/ Yes	Yes	Yes	~~Position~~No	Yes	~~Yes~~No
Lower IC (A) Header Vent Line Valve	V-12(A)	Yes/No	Yes	Yes	Position	Yes	Yes
Pool Cross Connect Valve (Squib)	V-13(A)	Yes/Yes	Yes	Yes	Position	Yes	No
Pool Cross Connect Valve (Pneumatic)	V-14(A)	Yes/Yes	Yes	Yes	Position	Yes	No
IC (B) Steam Supply Line Isolation Valve	V-1(B)	Yes/No	Yes	Yes	Position	Yes	Yes

Table 2.4.1-2

ICS Electrical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	Control Q-DCIS / DPS	Seismic Category I	Safety-Related	Safety-Related Display	Remotely Operated Valve	Containment Isolation Valve Actuator
IC (B) Steam Supply Line Isolation Valve	V-2(B)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (B) Condensate Return Line Isolation Valve	V-3(B)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (B) Condensate Return Line Isolation Valve	V-4(B)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (B) Condensate Return Line Valve	V-5(B)	Note 1	Yes	Yes	Position	Yes	No
IC (B) Condensate Return Line Bypass Valve	V-6(B)	Note 1	Yes	Yes	Position	Yes	No
Upper IC (B) Header Vent Line Valve	V-7(B)	Yes/No	Yes	Yes	Position	Yes	Yes
Upper IC (B) Header Vent Line Valve	V-8(B)	Yes/No	Yes	Yes	Position	Yes	Yes
Lower IC (B) Header Vent Line Valve	V-9(B)	Yes/No	Yes	Yes	Position	Yes	~~Yes~~No
Lower IC (B) Header Vent Line Valve	V-10(B)	~~Yes/No~~No/ Yes	Yes	Yes	~~Position~~No	Yes	~~Yes~~No
Lower IC (B) Header Vent Line Valve	V-12(B)	Yes/No	Yes	Yes	Position	Yes	Yes
Pool Cross Connect Valve (Squib)	V-13(B)	Yes/Yes	Yes	Yes	Position	Yes	No
Pool Cross Connect Valve (Pneumatic)	V-14(B)	Yes/Yes	Yes	Yes	Position	Yes	No
IC (C) Steam Supply Line Isolation Valve	V-1(C)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (C) Steam Supply Line Isolation Valve	V-2(C)	Yes/No	Yes	Yes	Position	Yes	Yes

Table 2.4.1-2

ICS Electrical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	Control Q-DCIS / DPS	Seismic Category I	Safety-Related	Safety-Related Display	Remotely Operated Valve	Containment Isolation Valve Actuator
IC (C) Condensate Return Line Isolation Valve	V-3(C)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (C) Condensate Return Line Isolation Valve	V-4(C)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (C) Condensate Return Line Valve	V-5(C)	Note 1	Yes	Yes	Position	Yes	No
IC (C) Condensate Return Line Bypass Valve	V-6(C)	Note 1	Yes	Yes	Position	Yes	No
Upper IC (C) Header Vent Line Valve	V-7(C)	Yes/No	Yes	Yes	Position	Yes	Yes
Upper IC (C) Header Vent Line Valve	V-8(C)	Yes/No	Yes	Yes	Position	Yes	Yes
Lower IC (C) Header Vent Line Valve	V-9(C)	Yes/No	Yes	Yes	Position	Yes	~~Yes~~No
Lower IC (C) Header Vent Line Valve	V-10(C)	~~Yes/No~~No/Yes	Yes	Yes	~~Position~~No	Yes	~~Yes~~No
Lower IC (C) Header Vent Line Valve	V-12(C)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (D) Steam Supply Line Isolation Valve	V-1(D)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (D) Steam Supply Line Isolation Valve	V-2(D)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (D) Condensate Return Line Isolation Valve	V-3(D)	Yes/No	Yes	Yes	Position	Yes	Yes
IC (D) Condensate Return Line Isolation Valve	V-4(D)	Yes/No	Yes	Yes	Position	Yes	Yes

Table 2.4.1-2

ICS Electrical Equipment

Equipment Name (Description)	Equipment Identifier See Figure 2.4.1-1	Control Q-DCIS / DPS	Seismic Category I	Safety-Related	Safety-Related Display	Remotely Operated Valve	Containment Isolation Valve Actuator
IC (D) Condensate Return Line Valve	V-5(D)	Note 1	Yes	Yes	Position	Yes	No
IC (D) Condensate Return Line Bypass Valve	V-6(D)	Note 1	Yes	Yes	Position	Yes	No
Upper IC (D) Header Vent Line Valve	V-7(D)	Yes/No	Yes	Yes	Position	Yes	Yes
Upper IC (D) Header Vent Line Valve	V-8(D)	Yes/No	Yes	Yes	Position	Yes	~~Yes~~No
Lower IC (D) Header Vent Line Valve	V-9(D)	~~Yes/No~~No/ Yes	Yes	Yes	~~Position~~No	Yes	~~Yes~~No
Lower IC (D) Header Vent Line Valve	V-10(D)	Yes/No	Yes	Yes	Position	Yes	Yes
Lower IC (D) Header Vent Line Valve	V-12(D)	Yes/No	Yes	Yes	Position	Yes	Yes
ICS DPV Isolation Function Independent Control Platform	–	Yes/No	Yes	Yes	No	Yes	No

Note 1: Valve pair V-5 and V-6 must have a total of four control inputs to the pair. The minimum control inputs for this pair must include two different Q-DCIS divisions to one of the valves and a third different Q-DCIS division and DPS to the other valve. The design is such that any combination of two of four divisions or DPS can initiate ICS flow in all four ICS trains.

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. • Open position on two or more DPVs	Valve closing tests will be performed using simulated automatic actuation signals. ~~An isolation valve closure test will be performed using simulated signals.~~	The ICS isolation valves close upon receipt of automatic actuation 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 parallel, solenoid operated lower vent line valves, listed in Table 2.4.1-1, open on high RPV pressure after time delay following condensate return or condensate bypass valve opening~~18a. The lower IC header vent valve (V-9) opens upon an ICS initiation signal generated by the SSLC/ESF platform followed by a time delay.	~~A valve opening test will be performed using simulated high reactor pressure after a time delay following condensate reurn or condensate bypass valve opening signals~~A valve-opening test will be performed on the lower IC header vent valve (V-9) using a simulated SSLC/ESF platform ICS initiation signal.	~~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~~The lower IC header vent valve (V-9) opens upon an ICS initiation signal generated by the SSLC/ESF platform followed by a time delay.

Table 2.4.1-3

ITAAC For The Isolation Condenser System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
18b. The lower IC header vent valve (V-10) opens upon an ICS initiation signal generated by the DPS platform followed by a time delay.	A valve-opening test will be performed on the lower IC header vent valve (V-10) using a simulated DPS platform ICS initiation signal.	The lower IC header vent valve (V-10) opens upon an ICS initiation signal generated by the DPS platform followed by a time delay.
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.~~(Deleted)	~~A test(s) will be performed that manually opens the vent valves during pre-operational testing following condensate return or condensate bypass valve opening signals.~~	~~The three vent lines with two series, solenoid-operated vent line valves each, opens on a manual initiation following condensate return or condensate bypass valve opening signals only if the condensate return or condensate bypass valve is not closed.~~
20. The accumulators for the pneumatic isolation valves, listed 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.	A test and analysis or test will be performed to demonstrate the capacity of the isolation valve accumulators.	Isolation valve accumulators have the capacity to close the valves three times with the DW pressure at the design pressure.
21. Upon loss of pneumatic pressure to the condensate bypass valve (V-6), the valve strokes to the fully open position.	Tests will be performed to demonstrate that the condensate bypass valve will stroke to the full open position upon the loss of pneumatic pressure to the condensate bypass valve accumulator.	The condensate bypass valve fully opens when pneumatic pressure is removed from the condensate bypass valve.
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.	Using prototype test data and as-built IC unit information, an analysis will be performed to establish the heat removal capacity of the IC unit with IC pool at atmospheric saturated conditions.	The ICS train unit heat removal capacity is greater than or equal to 33.75 MWt (assumed in the analysis of Abnormal Events) with the reactor at or above normal operating pressure.

Table 2.4.1-3

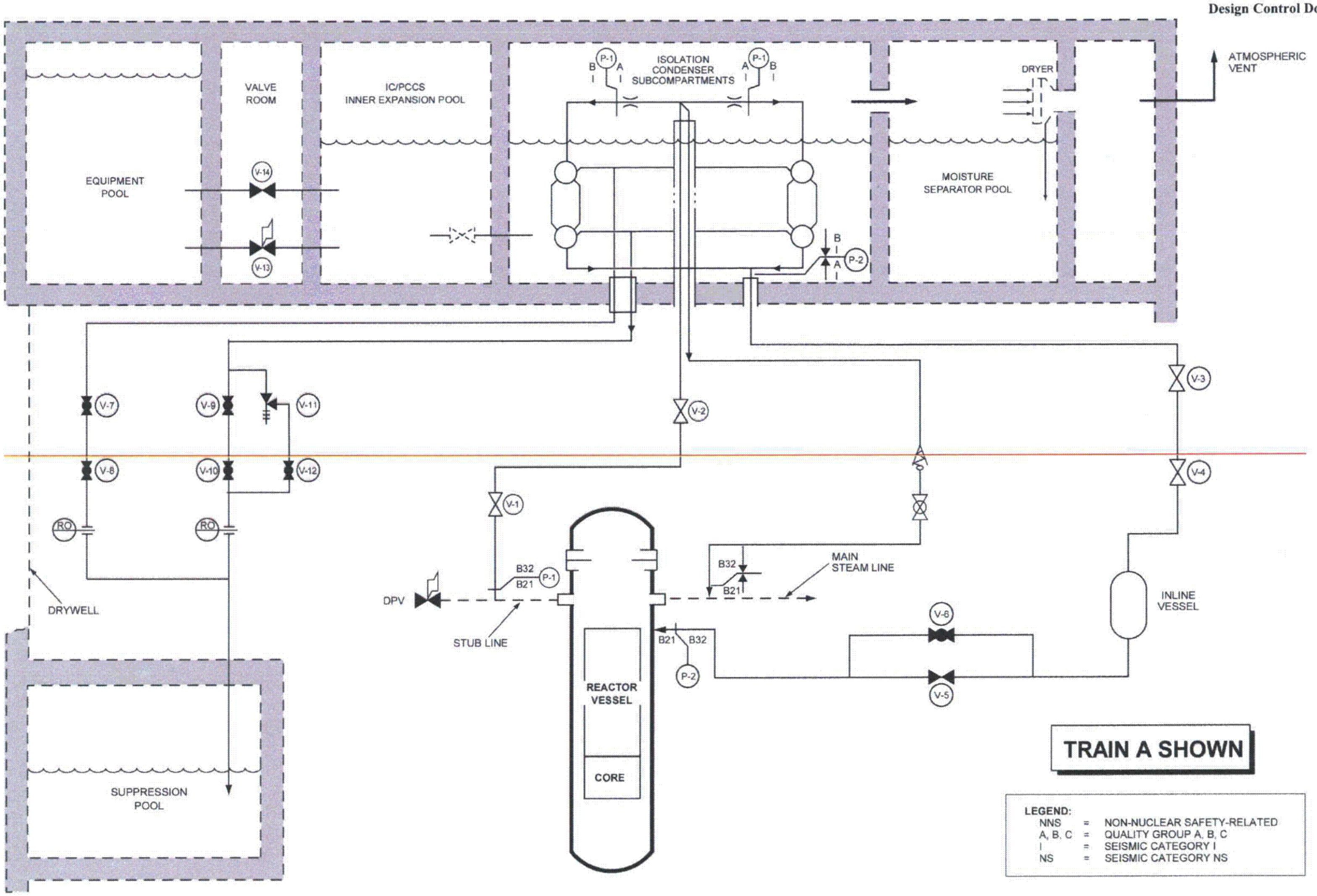
ITAAC For The Isolation Condenser System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
23. Each ICS train provides at least the minimum drainable liquid volume available for return to the RPV assumed in analysis of Abnormal Events.	An analysis will be performed for the as-built isolation condenser system.	The as-built ICS train provides at least $13.88 m^3$ ($490.1 ft^3$) (assumed in the analysis of Abnormal Events) of the liquid volume available for return to the RPV.
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.	i. A valve-opening test will be performed on the pneumatic valves using simulated low-level water signal from the IC/PCCS expansion pool.	i. The pneumatic valves open on a simulated low-level water signal from the IC/PCCS expansion pool.
	ii. A physical measurement will be performed on the dimensions and water level in the IC/PCCS pools, Equipment Pool, and Reactor Well to demonstrate that the required water volume is achieved.	ii. Measurements show that the combined water volume of the IC/PCCS pools, Equipment Pool, and Reactor Well is no less than 6,290 m^3 (222,000 ft^3).
	iii. A type test will be performed on the squib valve.	iii. The squib valves open on a simulated open signal.
25. The IC/PCCS pools are safety-related and Seismic Category I.	Inspections, tests, type tests, and analyses for the IC/PCCS pools confirm that they are safety-related and Seismic Category I.	The IC/PCCS pools are safety-related and Seismic Category I.

Table 2.4.1-3

ITAAC For The Isolation Condenser System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
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.	Inspection will be performed to confirm that the flow area at these transition locations is limited.	Each steam supply branch line contains a flow limiter which is no greater than 76.2 mm (3 in) in diameter, and that the condensate branch lines are no greater than 101.6 mm (4 in) in diameter.
27. (Deleted)		
28. (Deleted)		
29a. Valves on lines attached to the RPV that require maintenance have maintenance valves such that freeze seals will not be required.	Inspections of piping design isometric drawings will be conducted. {{Design Acceptance Criteria}}	A review of piping design isometric drawings confirms that maintenance valves are included such that freeze seals will not be required. {{Design Acceptance Criteria}}
29b. The as-built location of valves on lines attached to the RPV that require maintenance shall be reconciled to design requirements.	A reconciliation evaluation of valves on lines attached to the RPV using as-designed and as-built information will be performed.	A design reconciliation has been completed for the as-built location of valves relative to the design requirements.
30. The Lower IC Header Vent Line restricting orifices shown in Table 2.4.1-1 are sized so that the water level in the RPV during station blackout events does not reach the Level 1 setpoint within 72 hours of the blackout event.	Inspections of the as-built Lower IC Header Vent Line restricting orifice will be conducted.	The diameter of the Lower IC Header Vent Line restricting orifices shown in table 2.1.4-1 is 4.60 mm (0.181 in) ±0.025 mm (0.001 in).


VALVE ROOM
IC/PCCS INNER EXPANSION POOL
ISOLATION CONDENSER SUBCOMPARTMENTS
DRYER
ATMOSPHERIC VENT
EQUIPMENT POOL
MOISTURE SEPARATOR POOL
V-14
V-13
P-1
P-2
V-7
V-8
V-9
V-10
V-11
V-12
V-2
V-1
V-3
V-4
RO
B32
B21
DPV
STUB LINE
MAIN STEAM LINE
INLINE VESSEL
V-6
V-5
DRYWELL
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

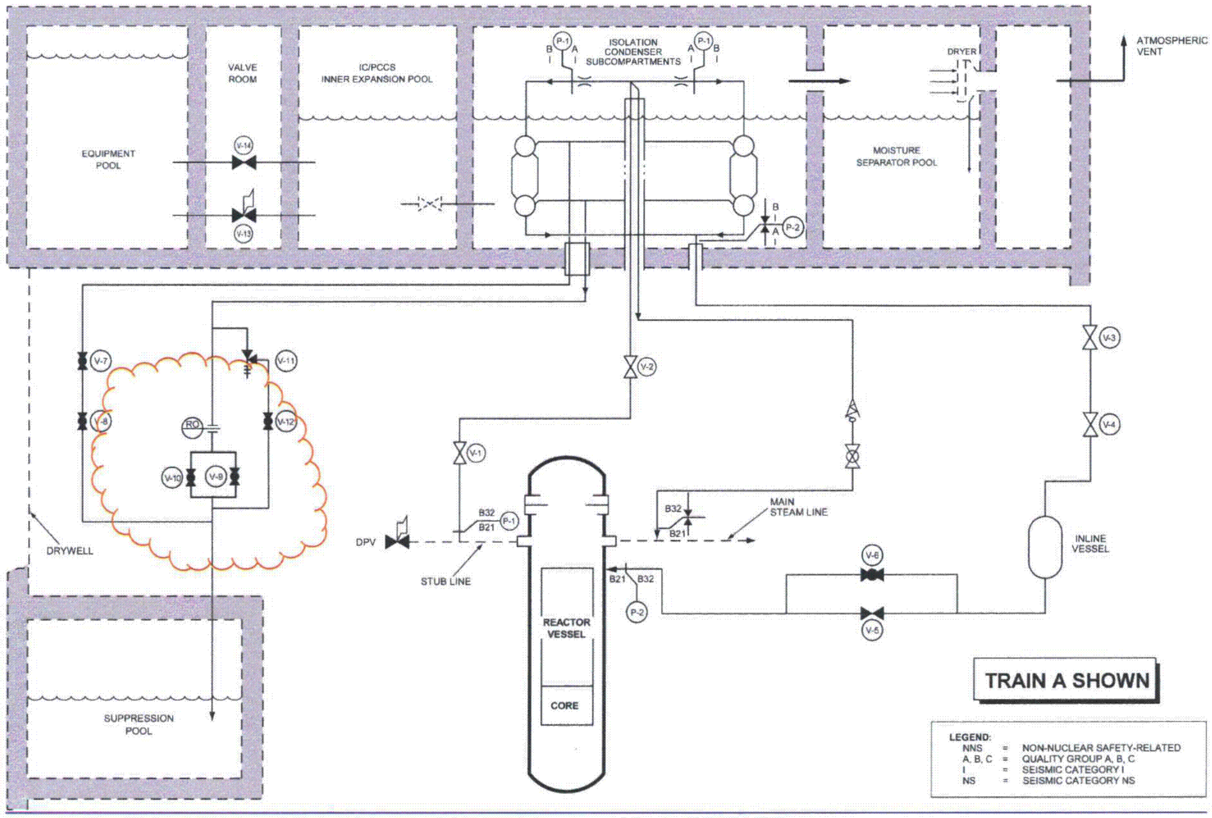


Figure 2.4.1-1. Isolation Condenser System Schematic

(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 2.15.1-1a

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
(Deleted)~~Inboard condenser lower header inboard vent valve (4 valves)~~	~~Yes~~	~~Yes~~	~~Yes~~	~~Yes~~	~~No~~	~~closed~~	~~closed~~	~~closed~~
(Deleted)~~Outboard condenser lower header outboard vent valve (4 valves)~~	~~Yes~~	~~Yes~~	~~Yes~~	~~Yes~~	~~No~~	~~closed~~	~~Open/closed~~	~~closedopen~~
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

Table 2.15.1-1d

Containment System Penetration Isolation Valve Closure Times

Equipment Name	Closure Time (sec)[1]
Nuclear Boiler	
Inboard main steam isolation valve (MSIV) (4 valves)	3 - 5 sec
Outboard MSIV (4 valves)	3 - 5 sec
Inboard MSIV upstream drain line inboard containment isolation valve (1 valve)	15 sec max
Inboard MSIV upstream drain line outboard containment isolation valve (1 valve)	15 sec max
Outboard MSIV upstream drain line outboard containment isolation valve (4 valves)	15 sec max
FW supply line second outboard containment isolation valve (2 valves)	10 - 15 sec
FW supply line outboard containment isolation valve (2 valves)	10 - 15 sec
FW supply line inboard containment isolation valve (2 valves)	–
RWCU/SDC to Feedwater outboard containment isolation valve (2 valves)	–
Isolation Condenser	
Steam supply line inboard isolation valve (4 valves)	60 sec max
Steam supply line outboard isolation valve (4 valves)	60 sec max
Condensate return line inboard isolation valve (4 valves)	35 sec max
Condensate return line outboard isolation valve (4 valves)	35 sec max
Condenser upper header inboard vent valve (4 valves)	15 sec max
Condenser upper header outboard vent valve (4 valves)	15 sec max
~~Condenser lower header inboard vent valve (4 valves)~~	~~15 sec max~~
~~Condenser lower header outboard vent valve (4 valves)~~	~~15 sec max~~
Bypass lower header inboard vent valve (4 valves)	–
Bypass lower header outboard vent valve (4 valves)	15 sec max

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	–	–	–
PCCS Vent Catalyst Module	–	Yes	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 (445~~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

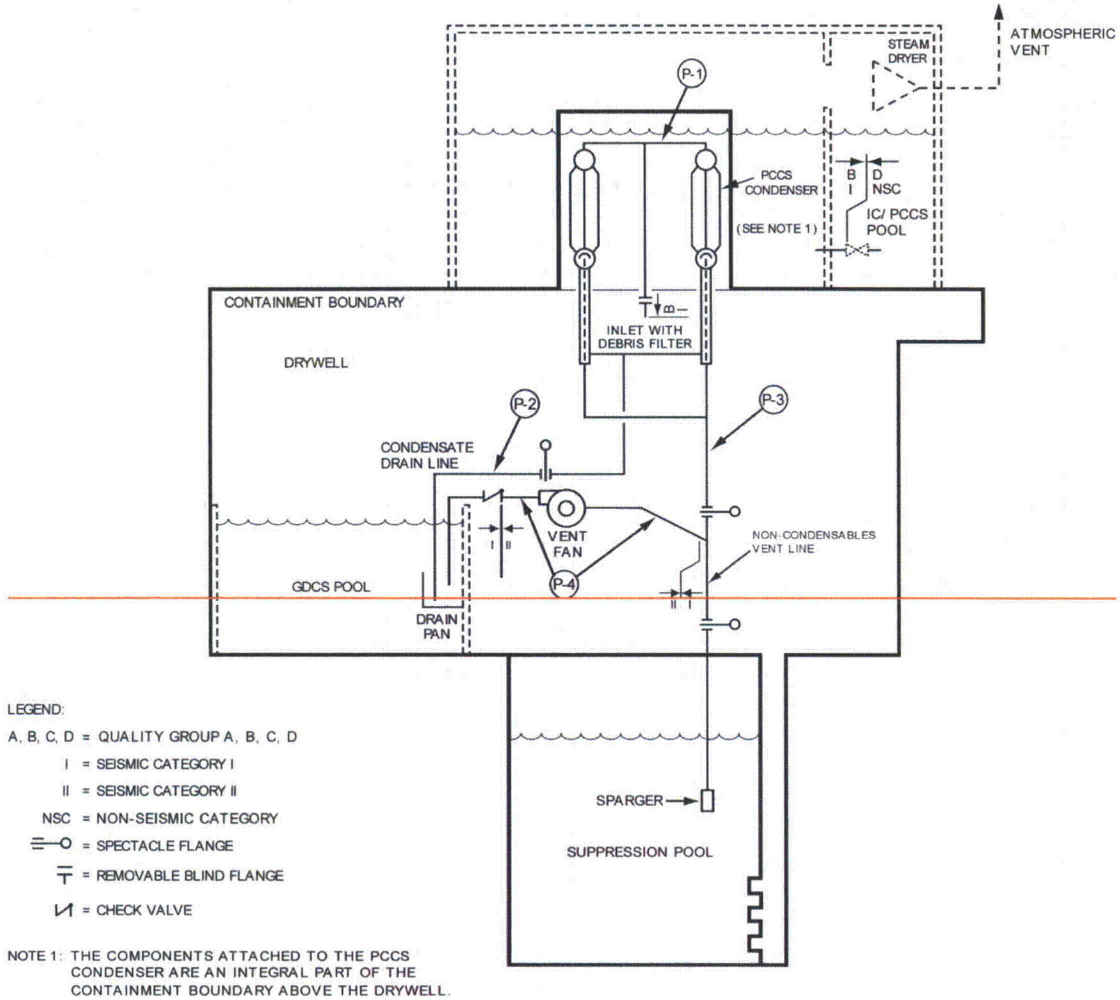
ITAAC For The Passive Containment Cooling System

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 and the block valves open when the PCCS vent fans are 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

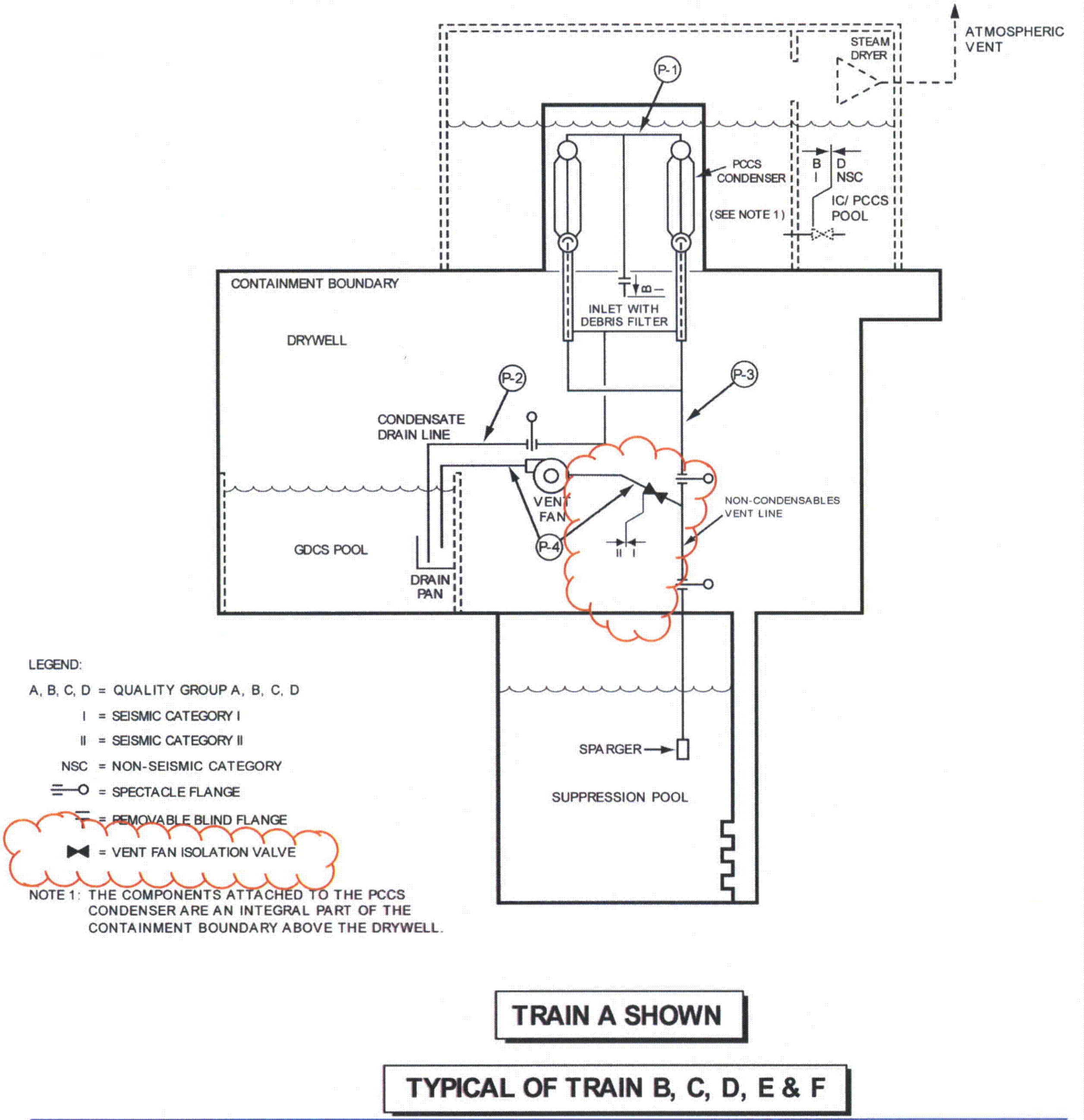


Figure 2.15.4-1. Passive Containment Cooling System Schematic

3.2 SOFTWARE DEVELOPMENT

Inspections, Tests, Analyses, and Acceptance Criteria Summary

Design Description

The safety-related Distributed Control and Information Systems (Q-DCIS) comprise the platforms that are defined in Table 2.2.10-1. A subset of the nonsafety-related Distributed Control and Information Systems (N-DCIS) comprise the network segments that are defined in Table 2.2.11-1. These platforms and network segments comprise systems of integrated software and hardware elements. Software projects are developed for the various platforms and network segments.

Each platform and network segment software projects follows a development process that comprises the following 3-stages:

(1) Develop the platform and network segment software plans and cyber security programs for each platform. {{Design Acceptance Criteria}}

- Software Management Program Manual (SMPM)
  - Software Management Plan (SMP)
  - Software Development Plan (SDP)
  - Software Integration Plan (SintP)
  - Software Installation Plan (SIP)
  - Software Operation and Maintenance Plan (SOMP)
  - Software Training Plan (STrngP)
- Software Quality Assurance Program Manual (SQAPM)
  - Software Quality Assurance Plan (SQAP)
  - Software Safety Plan (SSP)
  - Software Verification & Validation Plan (SVVP)
  - Software Configuration Management Plan (SCMP)
  - Software Test Plan (STP)
- Cyber Security Program Plan (CySPP)
  - Cyber Security Program (CySP)

(2) Implement the software projects for each platform and network segment in accordance with the approved platform and network segment software plans and cyber security programs to ensure the process produces adequate software products at the conclusion of each software life-cycle phase baseline as documented by the life-cycle phase Summary Baseline Review Records (BRR).

(3) Perform a multiple-phase test process as part of the installation phase to confirm that the as-built platform and network segment performs as designed.

In support of the above described software development process, the following 3-stage software design commitments are made:

1a1. The SMP is developed for the RTIF software projects.

1a2. The SMP is developed for the NMS software projects.

1a3. The SMP is developed for the SSLC/ESF software projects.

1a4. The SMP is developed for the ATWS/SLC software projects.

1a5. The SMP is developed for the VBIF software projects.

1a6. The SMP is developed for the GENE DPS software projects.

1a7. The SMP is developed for the PIP software projects.

1a8. The SMP is developed for the HP CRD Isolation Bypass Function software projects.

1a9. The SMP is developed for the ICS DPV Isolation Function software projects.

1b1. The SDP is developed for the RTIF software projects.

1b2. The SDP is developed for the NMS software projects.

1b3. The SDP is developed for the SSLC/ESF software projects.

1b4. The SDP is developed for the ATWS/SLC software projects.

1b5. The SDP is developed for the VBIF software projects.

1b6. The SDP is developed for the GENE DPS software projects.

1b7. The SDP is developed for the PIP software projects.

1b8. The SDP is developed for the HP CRD Isolation Bypass Function software projects.

1b9. The SDP is developed for the ICS DPV Isolation Function software projects.

1c1. The SIntP is developed for the RTIF software projects.

1c2. The SIntP is developed for the NMS software projects.

1c3. The SIntP is developed for the SSLC/ESF software projects.

1c4. The SIntP is developed for the ATWS/SLC software projects.

1c5. The SIntP is developed for the VBIF software projects.

1c6. The SIntP is developed for the GENE DPS software projects.

1c7. The SIntP is developed for the PIP software projects.

1c8. The SIntP is developed for the HP CRD Isolation Bypass Function software projects.

1c9. The SintP is developed for the ICS DPV Isolation Function software projects.

1d1. The SIP is developed for the RTIF software projects.

1d2. The SIP is developed for the NMS software projects.

1d3. The SIP is developed for the SSLC/ESF software projects.

1d4. The SIP is developed for the ATWS/SLC software projects.

1d5. The SIP is developed for the VBIF software projects.

1d6. The SIP is developed for the GENE DPS software projects.

1d7. The SIP is developed for the PIP software projects.

1d8. The SIP is developed for the HP CRD Isolation Bypass Function software projects.

1d9. The SIP is developed for the ICS DPV Isolation Function software projects.

1e1. The SOMP is developed for the RTIF software projects.

1e2. The SOMP is developed for the NMS software projects.

1e3. The SOMP is developed for the SSLC/ESF software projects.

1e4. The SOMP is developed for the ATWS/SLC software projects.

1e5. The SOMP is developed for the VBIF software projects.

1e6. The SOMP is developed for the GENE DPS software projects.

1e7. The SOMP is developed for the PIP software projects.

1e8. The SOMP is developed for the HP CRD Isolation Bypass Function software projects.

1e9. The SOMP is developed for the ICS DPV Isolation Function software projects.

1f1. The STrngP is developed for the RTIF software projects.

1f2. The STrngP is developed for the NMS software projects.

1f3. The STrngP is developed for the SSLC/ESF software projects.

1f4. The STrngP is developed for the ATWS/SLC software projects.

1f5. The STrngP is developed for the VBIF software projects.

1f6. The STrngP is developed for the GENE DPS software projects.

1f7. The STrngP is developed for the PIP software projects.

1f8. The STrngP is developed for the HP CRD Isolation Bypass Function software projects.

1f9. The STrngP is developed for the ICS DPV Isolation Function software projects.

1g1. The SQAP is developed for the RTIF software projects.

1g2. The SQAP is developed for the NMS software projects.

1g3. The SQAP is developed for the SSLC/ESF software projects.

1g4. The SQAP is developed for the ATWS/SLC software projects.

1g5. The SQAP is developed for the VBIF software projects.

1g6. The SQAP is developed for the GENE DPS software projects.

1g7. The SQAP is developed for the PIP software projects.

1g8. The SQAP is developed for the HP CRD Isolation Bypass Function software projects.

1g9. The SQAP is developed for the ICS DPV Isolation Function software projects.

1h1. The SSP is developed for the RTIF software projects.

1h2. The SSP is developed for the NMS software projects.

1h3. The SSP is developed for the SSLC/ESF software projects.

1h4. The SSP is developed for the ATWS/SLC software projects.

1h5. The SSP is developed for the VBIF software projects.

1h6. The SSP is developed for the GENE DPS software projects.

1h7. The SSP is developed for the PIP software projects.

1h8. The SSP is developed for the HP CRD Isolation Bypass Function software projects.

1h9. The SSP is developed for the ICS DPV Isolation Function software projects.

1i1. The SVVP is developed for the RTIF software projects.

1i2. The SVVP is developed for the NMS software projects.

1i3. The SVVP is developed for the SSLC/ESF software projects.

1i4. The SVVP is developed for the ATWS/SLC software projects.

1i5. The SVVP is developed for the VBIF software projects.

1i6. The SVVP is developed for the GENE DPS software projects.

1i7. The SVVP is developed for the PIP software projects.

1i8. The SVVP is developed for the HP CRD Isolation Bypass Function software projects.

1i9. The SVVP is developed for the ICS DPV Isolation Function software projects.

1j1. The SCMP is developed for the RTIF software projects.

1j2. The SCMP is developed for the NMS software projects.

1j3. The SCMP is developed for the SSLC/ESF software projects.

1j4. The SCMP is developed for the ATWS/SLC software projects.

1j5. The SCMP is developed for the VBIF software projects.

1j6. The SCMP is developed for the GENE DPS software projects.

1j7. The SCMP is developed for the PIP software projects.

1j8. The SCMP is developed for the HP CRD Isolation Bypass Function software projects.

1j9. The SCMP is developed for the ICS DPV Isolation Function software projects.

1k1. The STP is developed for the RTIF software projects.

1k2. The STP is developed for the NMS software projects.

1k3. The STP is developed for the SSLC/ESF software projects.

1k4. The STP is developed for the ATWS/SLC software projects.

1k5. The STP is developed for the VBIF software projects.

1k6. The STP is developed for the GENE DPS software projects.

1k7. The STP is developed for the PIP software projects.

1k8. The STP is developed for the HP CRD Isolation Bypass Function software projects.

1k9. The STP is developed for the ICS DPV Isolation Function software projects.

1l1. The CySP is developed for the RTIF software projects.

1l2. The CySP is developed for the NMS software projects.

1l3. The CySP is developed for the SSLC/ESF software projects.

1l4. The CySP is developed for the ATWS/SLC software projects.

1l5. The CySP is developed for the VBIF software projects.

1l6. The CySP is developed for the GENE DPS software projects.

1l7. The CySP is developed for the PIP software projects.

1l8. The CySP is developed for the HP CRD Isolation Bypass Function software projects.

1l9. The CySP is developed for the ICS DPV Isolation Function software projects.

2a1. The planning phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.

2a2. The planning phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.

2a3. The planning phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.

2a4. The planning phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.

2a5. The planning phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.

2a6. The planning phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.

2a7. The planning phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.

2a8. The planning phase activities detailed in the HP CRD Isolation Bypass Function software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.

2a9. The planning phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.

2b1. The requirements phase activities detailed in the RTIF software plans and the CySP are completed for the RTIF software projects.

2b2. The requirements phase activities detailed in the NMS software plans and the CySP are completed for the NMS software projects.

2b3. The requirements phase activities detailed in the SSLC/ESF software plans and the CySP are completed for the SSLC/ESF software projects.

2b4. The requirements phase activities detailed in the ATWS/SLC software plans and the CySP are completed for the ATWS/SLC software projects.

2b5. The requirements phase activities detailed in the VBIF software plans and the CySP are completed for the VBIF software projects.

2b6. The requirements phase activities detailed in the GENE DPS software plans and the CySP are completed for the GENE DPS software projects.

2b7. The requirements phase activities detailed in the PIP software plans and the CySP are completed for the PIP software projects.

2b8. The requirements phase activities detailed in the HP CRD Isolation Bypass Function software plans and the CySP are completed for the HP CRD Isolation Bypass Function software projects.

2b9. The requirements phase activities detailed in the ICS DPV Isolation Function software plans and the CySP are completed for the ICS DPV Isolation Function software projects.

2c1. The design phase activities detailed in the RTIF software plans and the CySP are completed for the RTIF software projects.

2c2. The design phase activities detailed in the NMS software plans and the CySP are completed for the NMS software projects.

2c3. The design phase activities detailed in the SSLC/ESF software plans and the CySP are completed for the SSLC/ESF software projects.

2c4. The design phase activities detailed in the ATWS/SLC software plans and the CySP are completed for the ATWS/SLC software projects.

2c5. The design phase activities detailed in the VBIF software plans and the CySP are completed for the VBIF software projects.

2c6. The design phase activities detailed in the GENE DPS software plans and the CySP are completed for the GENE DPS software projects.

2c7. The design phase activities detailed in the PIP software plans and the CySP are completed for the PIP software projects.

2c8. The design phase activities detailed in the HP CRD Isolation Bypass Function software plans and the CySP are completed for the HP CRD Isolation Bypass Function software projects.

2c9. The design phase activities detailed in the ICS DPV Isolation Function software plans and the CySP are completed for the ICS DPV Isolation Function software projects.

2d1. The implementation phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.

2d2. The implementation phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.

2d3. The implementation phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.

2d4. The implementation phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.

2d5. The implementation phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.

2d6. The implementation phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.

2d7. The implementation phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.

2d8. The implementation phase activities detailed in the HP CRD Isolation Bypass Function software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.

2d9. The implementation phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.

2e1. The test phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.

2e2. The test phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.

2e3. The test phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.

2e4. The test phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.

2e5. The test phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.

2e6. The test phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.

2e7. The test phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.

2e8. The test phase activities detailed in the HP CRD software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.

2e9. The test phase activities detailed in the ICS DPV Isolation Function and CySP are completed for the ICS DPV Isolation Function software projects.

3a1. The installation phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.

3a2. The RTIF software projects performs as designed.

3a3. The RTIF software projects is cyber secure.

3l1. The SSLC/ESF software projects performs as designed.

3l2. The SSLC/ESF software projects is cyber secure.

3m1. The ATWS/SLC software projects performs as designed.

3m2. The ATWS/SLC software projects is cyber secure.

3n1. The VBIF software projects performs as designed.

3n2. The VBIF software projects is cyber secure.

3o1. The GENE DPS software projects performs as designed.

3o2. The GENE DPS software projects is cyber secure.

3p1. The PIP software projects performs as designed.

3p2. The PIP software projects is cyber secure.

3q1. The HP CRD Isolation Bypass Function software projects performs as designed.

3q2. The HP CRD Isolation Bypass Function software projects is cyber secure.

3r1. The installation phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.

3r2. The ICS DPV Isolation Function software projects performs as designed.

3r3. The ICS DPV Isolation Function software projects is cyber secure.

3s1. The ICS DPV Isolation Function software projects performs as designed.

3s2. The ICS DPV Isolation Function software projects is cyber secure

Inspections, Tests, Analyses, and Acceptance Criteria

Table 3.2-1 defines the inspections, tests and analyses, together with associated acceptance criteria, which will be applied to the software and hardware platforms and network segments.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1a6. The SMP is developed for the GENE DPS software projects.	Inspection of the SMP for the GENE DPS software projects will be performed. {{Design Acceptance Criteria}}	The SMP for GENE DPS software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1a7. The SMP is developed for the PIP software projects.	Inspection of the SMP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SMP for PIP software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1a8. The SMP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SMP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SMP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1a9. The SMP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SMP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SMP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1b1. The SDP is developed for the RTIF software projects.	Inspection of the SDP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The SDP for the RTIF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1b7. The SDP is developed for the PIP software projects.	Inspection of the SDP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SDP for PIP software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1b8. The SDP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SDP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SDP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1b9. The SDP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SDP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SDP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1c1. The SIntP is developed for the RTIF software projects.	Inspection of the SIntP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The SIntP for the RTIF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1c2. The SIntP is developed for the NMS software projects.	Inspection of the SIntP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The SIntP for NMS software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1c8. The SIntP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SIntP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SIntP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1c9. The SIntP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SIntP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SIntP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d1. The SIP is developed for the RTIF software projects.	Inspection of the SIP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The SIP for the RTIF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d2. The SIP is developed for the NMS software projects.	Inspection of the SIP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The SIP for NMS software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d3. The SIP is developed for the SSLC/ESF software projects.	Inspection of the SIP for the SSLC/ESF software projects will be performed. {{Design Acceptance Criteria}}	The SIP for SSLC/ESF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1d4. The SIP is developed for the ATWS/SLC software projects.	Inspection of the SIP for the ATWS/SLC software projects will be performed. {{Design Acceptance Criteria}}	The SIP for ATWS/SLC software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d5. The SIP is developed for the VBIF software projects.	Inspection of the SIP for the VBIF software projects will be performed. {{Design Acceptance Criteria}}	The SIP for VBIF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d6. The SIP is developed for the GENE DPS software projects.	Inspection of the SIP for the GENE DPS software projects will be performed. {{Design Acceptance Criteria}}	The SIP for GENE DPS software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d7. The SIP is developed for the PIP software projects.	Inspection of the SIP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SIP for PIP software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d8. The SIP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SIP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SIP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1d9. The SIP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SIP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SIP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1e6. The SOMP is developed for the GENE DPS software projects.	Inspection of the SOMP for the GENE DPS software projects will be performed. {{Design Acceptance Criteria}}	The SOMP for GENE DPS software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1e7. The SOMP is developed for the PIP software projects.	Inspection of the SOMP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SOMP for PIP software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1e8. The SOMP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SOMP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SOMP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1e9. The SOMP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SOMP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SOMP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1f1. The STrngP is developed for the RTIF software projects.	Inspection of the STrngP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The STrngP for the RTIF software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1f7. The STrngP is developed for the PIP software projects.	Inspection of the STrngP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The STrngP for PIP software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1f8. The STrngP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the STrngP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The STrngP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1f9. The STrngP is developed for the ICS DPV Isolation Function software projects.	Inspection of the STrngP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The STrngP for ICS DPV Isolation Function software projects complies with the criteria contained in the SMPM. {{Design Acceptance Criteria}}
1g1. The SQAP is developed for the RTIF software projects.	Inspection of the SQAP for the RTIF software projects will be performed. {Design Acceptance Criteria}}	The SQAP for the RTIF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1g2. The SQAP is developed for the NMS software projects.	Inspection of the SQAP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The SQAP for NMS software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1g8. The SQAP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SQAP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SQAP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1g9. The SQAP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SQAP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SQAP for ICS DPV Isolation Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1h1. The SSP is developed for the RTIF software projects.	Inspection of the SSP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The SSP for the RTIF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1h2. The SSP is developed for the NMS software projects.	Inspection of the SSP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The SSP for NMS software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1h3. The SSP is developed for the SSLC/ESF software projects.	Inspection of the SSP for the SSLC/ESF software projects will be performed. {{Design Acceptance Criteria}}	The SSP for SSLC/ESF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1h9. The SSP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SSP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SSP for ICS DPV Isolation Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i1. The SVVP is developed for the RTIF software projects.	Inspection of the SVVP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for the RTIF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i2. The SVVP is developed for the NMS software projects.	Inspection of the SVVP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for NMS software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i3. The SVVP is developed for the SSLC/ESF software projects.	Inspection of the SVVP for the SSLC/ESF software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for SSLC/ESF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i4. The SVVP is developed for the ATWS/SLC software projects.	Inspection of the SVVP for the ATWS/SLC software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for ATWS/SLC software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1i5. The SVVP is developed for the VBIF software projects.	Inspection of the SVVP for the VBIF software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for VBIF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i6. The SVVP is developed for the GENE DPS software projects.	Inspection of the SVVP for the GENE DPS software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for GENE DPS software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i7. The SVVP is developed for the PIP software projects.	Inspection of the SVVP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for PIP software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i8. The SVVP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SVVP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1i9. The SVVP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SVVP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SVVP for ICS DPV Isolation Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1j6. The SCMP is developed for the GENE DPS software projects.	Inspection of the SCMP for the GENE DPS software projects will be performed. {{Design Acceptance Criteria}}	The SCMP for GENE DPS software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1j7. The SCMP is developed for the PIP software projects.	Inspection of the SCMP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The SCMP for PIP software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1j8. The SCMP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the SCMP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The SCMP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1j9. The SCMP is developed for the ICS DPV Isolation Function software projects.	Inspection of the SCMP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The SCMP for ICS DPV Isolation Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1k1. The STP is developed for the RTIF software projects.	Inspection of the STP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The STP for the RTIF software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1k7. The STP is developed for the PIP hardware and software projects.	Inspection of the STP for the PIP software projects will be performed. {{Design Acceptance Criteria}}	The STP for PIP software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1k8. The STP is developed for the HP CRD Isolation Bypass Function hardware and software projects.	Inspection of the STP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The STP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1k9. The STP is developed for the ICS DPV Isolation Function hardware and software projects.	Inspection of the STP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The STP for ICS DPV Isolation Function software projects complies with the criteria contained in the SQAPM. {{Design Acceptance Criteria}}
1l1. The CySP is developed for the RTIF software projects.	Inspection of the CySP for the RTIF software projects will be performed. {{Design Acceptance Criteria}}	The CySP for the RTIF software projects complies with the criteria contained in the CySPP. {{Design Acceptance Criteria}}
1l2. The CySP is developed for the NMS software projects.	Inspection of the CySP for the NMS software projects will be performed. {{Design Acceptance Criteria}}	The CySP for NMS software projects complies with the criteria contained in the CySPP. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
118. The CySP is developed for the HP CRD Isolation Bypass Function software projects.	Inspection of the CySP for the HP CRD Isolation Bypass Function software projects will be performed. {{Design Acceptance Criteria}}	The CySP for HP CRD Isolation Bypass Function software projects complies with the criteria contained in the CySPP. {{Design Acceptance Criteria}}
119. The CySP is developed for the ICS DPV Isolation Function software projects.	Inspection of the CySP for the ICS DPV Isolation Function software projects will be performed. {{Design Acceptance Criteria}}	The CySP for ICS DPV Isolation Function software projects complies with the criteria contained in the CySPP. {{Design Acceptance Criteria}}
2a1. The planning phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The planning phase outputs are inspected and analyzed for the RTIF software projects. {{Design Acceptance Criteria}}	Planning Phase Summary BRR(s) exist and conclude that the RTIF software projects planning phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2a2. The planning phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The planning phase outputs are inspected and analyzed for the NMS software projects. {{Design Acceptance Criteria}}	Planning Phase Summary BRR(s) exist and conclude that the NMS software projects planning phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2a9. The planning phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The planning phase outputs are inspected and analyzed for the ICS DPV Isolation Function software projects. {{Design Acceptance Criteria}}	Planning Phase Summary BRR(s) exist and conclude that the ICS DPV Isolation Function software projects planning phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2b1. The requirements phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The requirements phase outputs are inspected and analyzed for the RTIF software projects. {{Design Acceptance Criteria}}	Requirements Phase Summary BRR(s) exist and conclude that the RTIF software projects requirements phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2b2. The requirements phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The requirements phase outputs are inspected and analyzed for the NMS software projects. {{Design Acceptance Criteria}}	Requirements Phase Summary BRR(s) exist and conclude that the NMS software projects requirements phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2b9. The requirements phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The requirements phase outputs are inspected and analyzed for the ICS DPV Isolation Function software projects. {{Design Acceptance Criteria}}	Requirements Phase Summary BRR(s) exist and conclude that the ICS DPV Isolation Function software projects requirements phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2c1. The design phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The design phase outputs are inspected and analyzed for the RTIF software projects. {{Design Acceptance Criteria}}	Design Phase Summary BRR(s) exist and conclude that the RTIF software projects design phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2c2. The design phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The design phase outputs are inspected and analyzed for the NMS software projects. {{Design Acceptance Criteria}}	Design Phase Summary BRR(s) exist and conclude that the NMS software projects design phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2c9. The design phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The design phase outputs are inspected and analyzed for the ICS DPV Isolation Function software projects. {{Design Acceptance Criteria}}	Design Phase Summary BRR(s) exist and conclude that the ICS DPV Isolation Function software projects design phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP. {{Design Acceptance Criteria}}
2d1. The implementation phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The implementation phase outputs are inspected and analyzed for the RTIF software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ RTIF software projects implementation phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2d2. The implementation phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The implementation phase outputs are inspected and analyzed for the NMS software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ NMS software projects implementation phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2d3. The implementation phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.	The implementation phase outputs are inspected and analyzed for the SSLC/ESF software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ SSLC/ESF software projects implementation phase activities were performed in compliance with the SSLC/ESF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2d4. The implementation phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.	The implementation phase outputs are inspected and analyzed for the ATWS/SLC software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ ATWS/SLC software projects implementation phase activities were performed in compliance with the ATWS/SLC software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2d5. The implementation phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.	The implementation phase outputs are inspected and analyzed for the VBIF software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ VBIF software projects implementation phase activities were performed in compliance with the VBIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2d6. The implementation phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.	The implementation phase outputs are inspected and analyzed for the GENE DPS software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ GENE DPS software projects implementation phase activities were performed in compliance with the GENE DPS software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2d7. The implementation phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.	The implementation phase outputs are inspected and analyzed for the PIP software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ PIP software projects implementation phase activities were performed in compliance with the PIP software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2d8. The implementation phase activities detailed in the HP CRD Isolation Bypass Function software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.	The implementation phase outputs are inspected and analyzed for the HP CRD Isolation Bypass Function software projects.	~~Implementation Phase Summary BRR(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects implementation phase activities were performed in compliance with the HP CRD Isolation Bypass Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2d9. The implementation phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The implementation phase outputs are inspected and analyzed for the ICS DPV Isolation Function software projects.	ICS DPV Isolation Function software projects implementation phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e1. The test phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The test phase outputs are inspected and analyzed for the RTIF software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ RTIF software projects test phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e2. The test phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The test phase outputs are inspected and analyzed for the NMS software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ NMS software projects test phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e3. The test phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.	The test phase outputs are inspected and analyzed for the SSLC/ESF software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ SSLC/ESF software projects test phase activities were performed in compliance with the SSLC/ESF software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2e4. The test phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.	The test phase outputs are inspected and analyzed for the ATWS/SLC software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ ATWS/SLC software projects test phase activities were performed in compliance with the ATWS/SLC software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e5. The test phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.	The test phase outputs are inspected and analyzed for the VBIF software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ VBIF software projects test phase activities were performed in compliance with the VBIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e6. The test phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.	The test phase outputs are inspected and analyzed for the GENE DPS software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ GENE DPS software projects test phase activities were performed in compliance with the GENE DPS software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e7. The test phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.	The test phase outputs are inspected and analyzed for the PIP software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ PIP software projects test phase activities were performed in compliance with the PIP software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
2e8. The test phase activities detailed in the HP CRD Isolation Bypass Function software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.	The test phase outputs are inspected and analyzed for the HP CRD Isolation Bypass Function software projects.	~~Test Phase Summary BRR(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects test phase activities were performed in compliance with the HP CRD Isolation Bypass Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.
2e9. The test phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The test phase outputs are inspected and analyzed for the ICS DPV Isolation Function software projects.	ICS DPV Isolation Function software projects test phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3a1. The installation phase activities detailed in the RTIF software plans and CySP are completed for the RTIF software projects.	The installation phase outputs for the RTIF software projects, including RTIF FAT and RTIF Cyber Security FAT, are inspected and analyzed .	~~Installation Phase Summary BRR(s) exist and conclude that the~~ RTIF software projects installation phase activities were performed in compliance with the RTIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3a2. The RTIF software projects performs as designed.	FAT is performed on the RTIF software projects.	~~RTIF FAT report(s) exist and concludes that the~~ RTIF software projects is in compliance with the RTIF software plans as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3a3. The RTIF software projects is cyber secure.	A cyber security FAT will be performed for the RTIF software projects.	~~RTIF cyber security FAT report(s) exist and conclude that the~~ RTIF software projects is in compliance with the RTIF cyber security program requirements as derived from the SMPM, SQAPM, and CySPP.
3b1. The installation phase activities detailed in the NMS software plans and CySP are completed for the NMS software projects.	The installation phase outputs for the NMS software projects, including NMS FAT and NMS Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exists and concludes that the~~ NMS software projects installation phase activities were performed in compliance with the NMS software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3b2. The NMS software projects performs as designed.	FAT is performed on the NMS software projects.	~~NMS FAT report(s) exist and conclude that the~~ NMS software projects is in compliance with the NMS software plans as derived from the SMPM, SQAPM, and CySPP.
3b3. The NMS software projects is cyber secure.	A cyber security FAT will be performed for the NMS software projects.	~~NMS cyber security FAT report(s) exist and conclude that the~~ NMS software projects is in compliance with the NMS cyber security program requirements as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3c1. The installation phase activities detailed in the SSLC/ESF software plans and CySP are completed for the SSLC/ESF software projects.	The installation phase outputs for the SSLC/ESF software projects, including SSLC/ESF FAT and SSLC/ESF Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ SSLC/ESF software projects installation phase activities were performed in compliance with the SSLC/ESF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3c2. The SSLC/ESF software projects performs as designed.	FAT is performed on the SSLC/ESF software projects.	~~SSLC/ESF FAT report(s) exist and conclude that the~~ SSLC/ESF software projects is in compliance with the SSLC/ESF software plans as derived from the SMPM, SQAPM, and CySPP.
3c3. The SSLC/ESF software projects is cyber secure.	A cyber security FAT will be performed for the SSLC/ESF software projects.	~~SSLC/ESF cyber security FAT report(s) exist and conclude that the~~ SSLC/ESF software projects is in compliance with the SSLC/ESF CySP as derived from the SMPM, SQAPM, and CySPP.
3d1. The installation phase activities detailed in the ATWS/SLC software plans and CySP are completed for the ATWS/SLC software projects.	The installation phase outputs for the ATWS/SLC software projects, including ATWS/SLC FAT and ATWS/SLC Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ ATWS/SLC software projects installation phase activities were performed in compliance with the ATWS/SLC software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3d2. The ATWS/SLC software projects performs as designed.	FAT is performed on the ATWS/SLC software projects.	~~ATWS/SLC FAT report exist and conclude that the~~ ATWS/SLC software projects is in compliance with the ATWS/SLC software plans as derived from the SMPM, SQAPM, and CySPP.
3d3. The ATWS/SLC software projects is cyber secure.	A cyber security FAT will be performed for the ATWS/SLC software projects.	~~ATWS/SLC cyber security FAT report(s) exist and conclude that the~~ ATWS/SLC software projects is in compliance with the ATWS/SLC CySP as derived from the SMPM, SQAPM, and CySPP.
3e1. The installation phase activities detailed in the VBIF software plans and CySP are completed for the VBIF software projects.	The installation phase outputs for the VBIF software projects, including VBIF FAT and VBIF Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ VBIF software projects installation phase activities were performed in compliance with the VBIF software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3e2. The VBIF software projects performs as designed.	FAT is performed on the VBIF software projects.	~~VBIF FAT report(s) exist and conclude that the~~ VBIF software projects is in compliance with the VBIF software plans as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3e3. The VBIF software projects is cyber secure.	A cyber security FAT will be performed for the VBIF software projects.	~~VBIF cyber security FAT report(s) exist and conclude that the~~ VBIF software projects is in compliance with the VBIF CySP as derived from the SMPM, SQAPM, and CySPP.
3f1. The installation phase activities detailed in the GENE DPS software plans and CySP are completed for the GENE DPS software projects.	The installation phase outputs for the GENE DPS software projects, including GENE DPS FAT and GENE DPS Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ GENE DPS software projects installation phase activities were performed in compliance with the GENE DPS software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3f2. The GENE DPS software projects performs as designed.	FAT is performed on the GENE DPS software projects.	~~GENE DPS FAT report(s) exist and conclude that the~~ GENE DPS software projects is in compliance with the GENE DPS software plans as derived from the SMPM, SQAPM, and CySPP.
3f3. The GENE DPS software projects is cyber secure.	A cyber security FAT will be performed for the GENE DPS software projects.	~~GENE DPS cyber security FAT report(s) exist and conclude that the~~ GENE DPS software projects is in compliance with the GENE DPS CySP as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3g1. The installation phase activities detailed in the PIP software plans and CySP are completed for the PIP software projects.	The installation phase outputs for the PIP software projects, including PIP FAT and PIP Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ PIP software projects installation phase activities were performed in compliance with the PIP software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3g2. The PIP software projects performs as designed.	FAT is performed on the PIP software projects.	~~PIP FAT report(s) exist and conclude that the~~ PIP software projects is in compliance with the PIP software plans as derived from the SMPM, SQAPM, and CySPP.
3g3. The PIP software projects is cyber secure.	A cyber security FAT will be performed for the PIP software projects.	~~PIP cyber security FAT report(s) exist and conclude that the~~ PIP software projects is in compliance with the PIP CySP as derived from the SMPM, SQAPM, and CySPP.
3h1. The installation phase activities detailed in the HP CRD Isolation Bypass Function software plans and CySP are completed for the HP CRD Isolation Bypass Function software projects.	The installation phase outputs for the HP CRD Isolation Bypass Function software projects, including HP CRD Isolation Bypass Function FAT and HP CRD Isolation Bypass Function Cyber Security FAT, are inspected and analyzed.	~~Installation Phase Summary BRR(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects installation phase activities were performed in compliance with the HP CRD Isolation Bypass Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3h2. The HP CRD Isolation Bypass Function software projects performs as designed.	FAT is performed on the HP CRD Isolation Bypass Function software projects.	~~HP CRD Isolation Bypass Function FAT report(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects is in compliance with the HP CRD Isolation Bypass Function software plans as derived from the SMPM, SQAPM, and CySPP.
3h3. The HP CRD Isolation Bypass Function software projects is cyber secure.	A cyber security FAT will be performed for the HP CRD Isolation Bypass Function software projects.	~~HP CRD Isolation Bypass Function cyber security FAT report(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects is in compliance with the HP CRD Isolation Bypass Function CySP as derived from the SMPM, SQAPM, and CySPP.
3i. The complete ESBWR instrumentation and control systems with sensors and actuators is capable of operating as designed.	An overlapping and encompassing SAT is performed on the as-built platforms and network segments.	~~The Installation Phase Summary BRR for the complete ESBWR instrumentation and control system SAT exists and concludes that t~~The complete ESBWR instrumentation and control system with sensors and actuators is capable of operating as designed and is in compliance with the software projects plans and CySP as derived from the SMPM, SQAPM and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3j1. The RTIF software projects performs as designed.	A RTIF software projects SAT is performed.	~~RTIF cyber security SAT report(s) exist and conclude that t~~The RTIF software projects is in compliance with the RTIF CySP as derived from the SMPM, SQAPM, and CySPP.
3j2. The RTIF software projects is cyber secure.	A RTIF software projects cyber security SAT is performed.	~~RTIF cyber security SAT report(s) exist and conclude that the~~ RTIF software projects is in compliance with the RTIF CySP as derived from the SMPM, SQAPM, and CySPP.
3k1. The NMS software projects performs as designed.	A NMS software projects SAT is performed.	~~NMS SAT report(s) exist and conclude that the~~ NMS software projects is in compliance with the NMS software plans as derived from the SMPM, SQAPM, and CySPP.
3k2. The NMS software projects is cyber secure.	A NMS software projects cyber security SAT is performed.	~~NMS cyber security SAT report(s) exist and conclude that the~~ NMS software projects is in compliance with the NMS CySP as derived from the SMPM, SQAPM, and CySPP.
3l1. The SSLC/ESF software projects performs as designed.	A SSLC/ESF software projects SAT is performed.	~~SSLC/ESF SAT report(s) exist and conclude that the~~ SSLC/ESF software projects is in compliance with the SSLC/ESF software plans as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3l2. The SSLC/ESF software projects is cyber secure.	A SSLC/ESF software projects cyber security SAT is performed.	~~SSLC/ESF cyber security SAT report(s) exist and conclude that the~~ SSLC/ESF software projects is in compliance with the SSLC/ESF CySP as derived from the SMPM, SQAPM, and CySPP.
3m1. The ATWS/SLC software projects performs as designed.	An ATWS/SLC software projects SAT is performed.	~~ATWS/SLC SAT report(s) exist and conclude that the~~ ATWS/SLC software projects is in compliance with the ATWS/SLC software plans as derived from the SMPM, SQAPM, and CySPP.
3m2. The ATWS/SLC software projects is cyber secure.	An ATWS/SLC software projects cyber security SAT is performed.	~~ATWS/SLC cyber security SAT report(s) exist and conclude that the~~ ATWS/SLC software projects is in compliance with the ATWS/SLC CySP as derived from the SMPM, SQAPM, and CySPP.
3n1. The VBIF software projects performs as designed.	A VBIF software projects SAT is performed.	~~VBIF SAT report(s) exist and conclude that the~~ VBIF software projects is in compliance with the VBIF software plans as derived from the SMPM, SQAPM, and CySPP.
3n2. The VBIF software projects is cyber secure.	A VBIF software projects cyber security SAT is performed.	~~VBIF cyber security SAT report(s) exist and conclude that the~~ VBIF software projects is in compliance with the VBIF CySP as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3o1. The GENE DPS software projects performs as designed.	A GENE DPS software projects SAT is performed.	~~GENE DPS SAT report(s) exist and conclude that the~~ GENE DPS software projects is in compliance with the GENE DPS software plans as derived from the SMPM, SQAPM, and CySPP.
3o2. The GENE DPS software projects is cyber secure.	A GENE DPS software projects cyber security SAT is performed.	~~GENE DPS cyber security SAT report(s) exist and conclude that the~~ GENE DPS software projects is in compliance with the GENE DPS CySP as derived from the SMPM, SQAPM, and CySPP.
3p1. The PIP software projects performs as designed.	A PIP software projects SAT is performed.	~~PIP SAT report(s) exist and conclude that the~~ PIP software projects is in compliance with the PIP software plans as derived from the SMPM, SQAPM, and CySPP.
3p2. The PIP software projects is cyber secure.	A PIP software projects cyber security SAT is performed.	~~PIP cyber security SAT report(s) exist and conclude that the~~ PIP software projects is in compliance with the PIP CySP as derived from the SMPM, SQAPM, and CySPP.

Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3q1. The HP CRD Isolation Bypass Function software projects performs as designed.	A HP CRD Isolation Bypass Function software projects SAT is performed.	~~HP CRD Isolation Bypass Function SAT report(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects is in compliance with the HP CRD Isolation Bypass Function software plans as derived from the SMPM, SQAPM, and CySPP.
3q2. The HP CRD Isolation Bypass Function software projects is cyber secure.	A HP CRD Isolation Bypass Function software projects cyber security SAT is performed.	~~HP CRD Isolation Bypass Function cyber security SAT report(s) exist and conclude that the~~ HP CRD Isolation Bypass Function software projects is in compliance with the HP CRD Isolation Bypass Function CySP as derived from the SMPM, SQAPM, and CySPP.
3r1. The installation phase activities detailed in the ICS DPV Isolation Function software plans and CySP are completed for the ICS DPV Isolation Function software projects.	The installation phase outputs for the ICS DPV Isolation Function software projects, including ICS DPV Isolation Function FAT and ICS DPV Isolation Function Cyber Security FAT, are inspected and analyzed.	ICS DPV Isolation Function software projects installation phase activities were performed in compliance with the ICS DPV Isolation Function software plans and CySP as derived from SMPM, SQAPM, and CySPP.
3r2. The ICS DPV Isolation Function software projects performs as designed.	FAT is performed on the ICS DPV Isolation Function software projects.	ICS DPV Isolation Function software projects is in compliance with the ICS DPV Isolation Function software plans as derived from the SMPM, SQAPM, and CySPP.

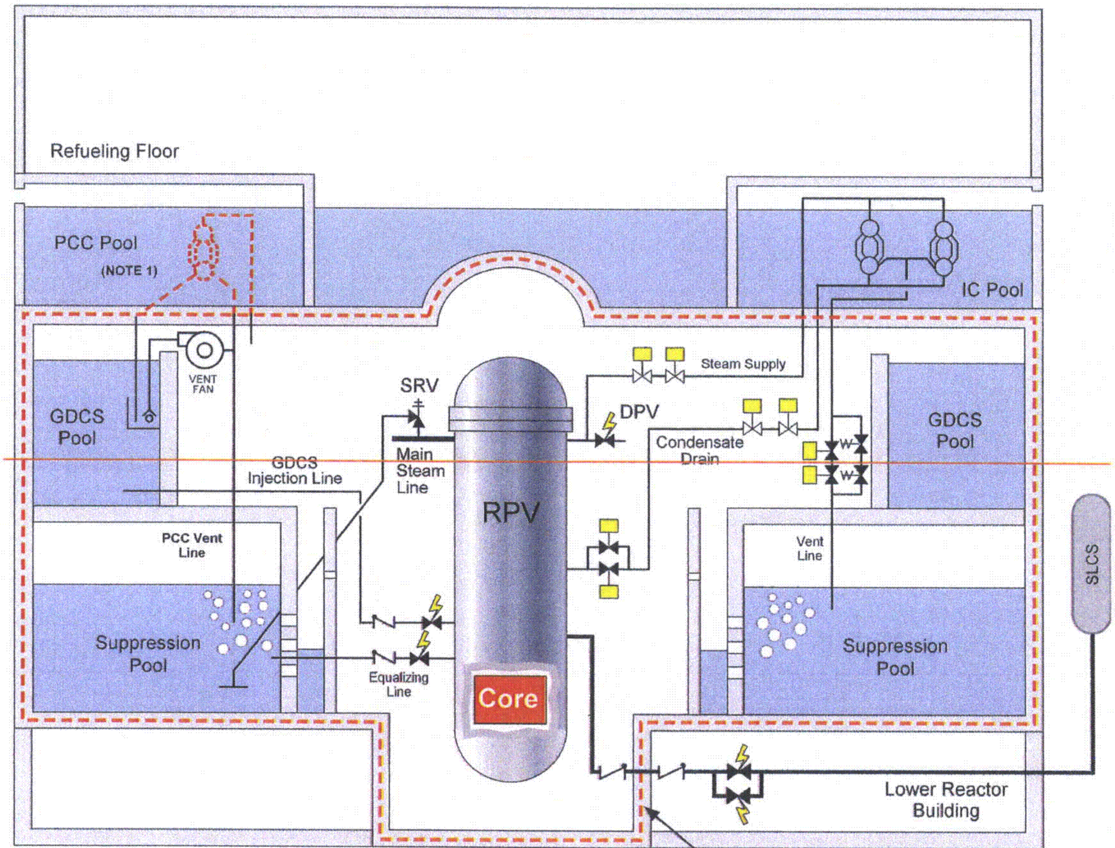
Table 3.2-1
ITAAC For Software Development

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
3r3. The ICS DPV Isolation Function software projects is cyber secure.	A cyber security FAT will be performed for the ICS DPV Isolation Function software projects.	ICS DPV Isolation Function software projects is in compliance with the ICS DPV Isolation Function CySP as derived from the SMPM, SQAPM, and CySPP.
3s1. The ICS DPV Isolation Function software projects performs as designed.	A ICS DPV Isolation Function software projects SAT is performed.	ICS DPV Isolation Function software projects is in compliance with the ICS DPV Isolation Function software plans as derived from the SMPM, SQAPM, and CySPP.
3s2. The ICS DPV Isolation Function software projects is cyber secure.	A ICS DPV Isolation Function software projects cyber security SAT is performed.	ICS DPV Isolation Function software projects is in compliance with the ICS DPV Isolation Function CySP as derived from the SMPM, SQAPM, and CySPP.

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
Vent Line Catalyst Module	12	CV	ESF	100 Days	MH



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

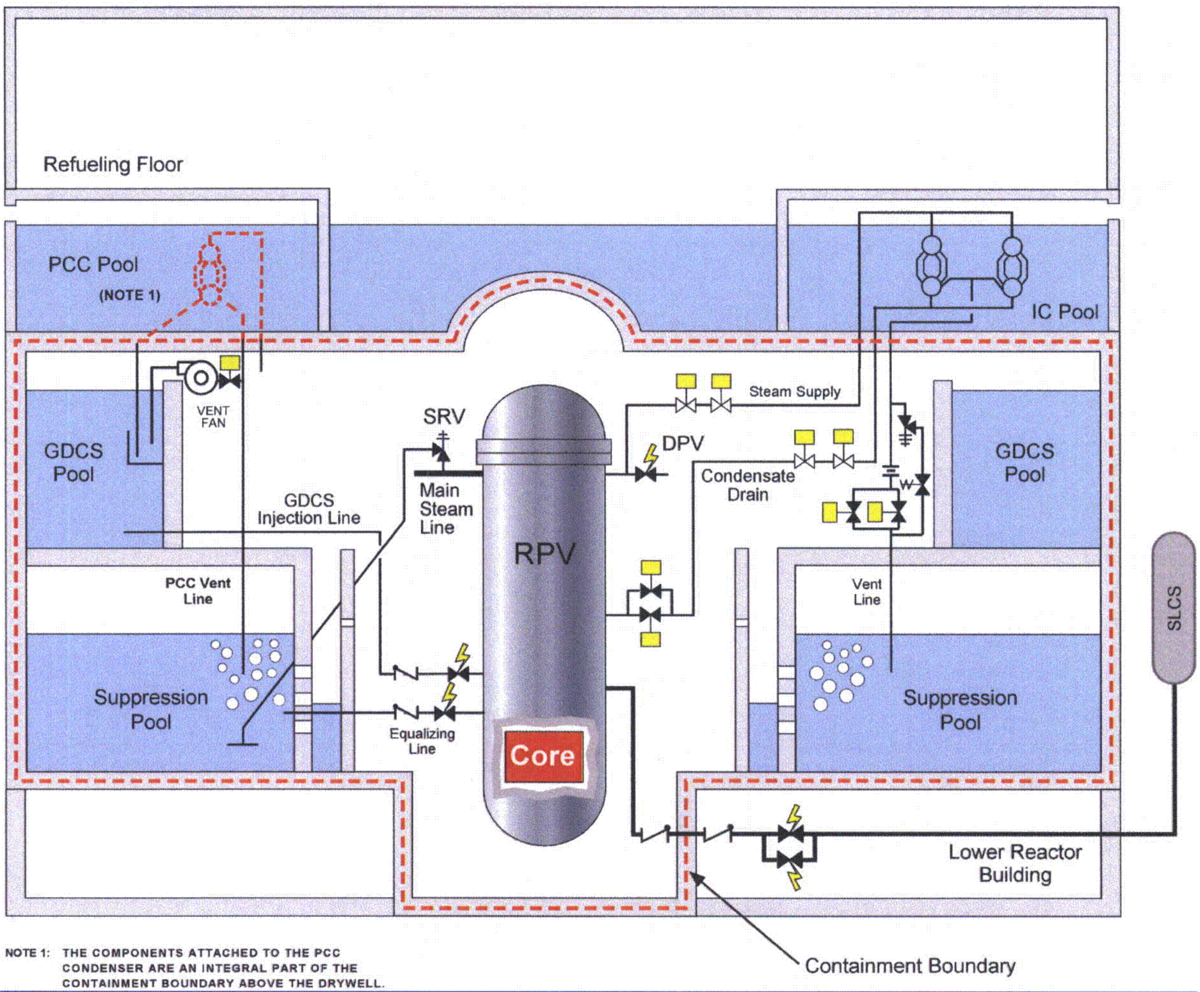


Figure 1.1-2. Safety System Configuration (not to scale)

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 automatically isolated after two or more DPV's 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.

A passive catalyst recombiner module is installed at the intake of the PCCS vent in the lower drum of the condenser. The catalyst functions to recombine radiolytically-generated hydrogen and oxygen that would otherwise accumulate in the vent line.

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.

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-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
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

* 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
18. Components (piping, valves, fittings) for the above-valve-seat main steam drain piping from downstream of the seismic restraint, and also for the main steam low-point drain piping from the second drain isolation valve, to the condenser nozzle connection.	N	TB	D	S	NS	(5) c Analyzed to demonstrate structural integrity under SSE conditions.
19. Electrical modules, cables and instrumentation supporting diverse protection functions	N	CV, RB, TB	—	S	II	(5) c, (5) i, (5) j
B32 Isolation Condenser System (ICS)						
1. Steam supply line piping and valves (including supports) from the reactor up to and including the venturis outside containment and purge line returning to main steamline	1	CV, RB	A	Q	I	
2. Isolation condenser and piping outside containment from the supply line venturis to the condensate return line tee.	2	RB	B	Q	I	
3. Condensate return line piping and valves (including supports) from the reactor to the tee connection outside containment	1	CV, RB	A	Q	I	
4. Vent piping and valves (including supports) to suppression pool	2	CV, RB	B	Q	I	

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.

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
T15 Passive Containment Cooling System (PCCS)						
1. All components other than vent fans and vent fan piping	2	CV	B	Q	I	
2. Vent fans and vent fan piping	N	CV	B	S	II	(5) b, (5) c, (5) h
3. Vent Line Catalyst Module	2	CV	B	Q	I	
T31 Containment Inerting System						
1. Piping and valves (including supports) forming part of the containment boundary	2	RB	B	Q	I	
2. Electrical modules and cables with safety-related function	3	RB, CB	—	Q	I	
3. Other mechanical modules (including nitrogen storage tanks, and vaporizers), piping, valves, and electrical modules and cables with no safety function	N	RB, OO	—	N	NS	
4. Hardened containment vent line to RB/FB stack	N	RB	—	S	NS	(5) k
T41 Drywell Cooling System (DCS)	N	CV	—	S	II	(5) c

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
T49 Passive Autocatalytic Recombiner System (PARS)	~~N~~	~~CV~~	—	~~S~~	~~I~~	~~(5) c, (5) h~~
1. PARS units	N	CV	-	S	I	(5) c, (5) h
2. Igniters in lower drum of PCCS condensers	N	CV	-	S	II	(5)c
3. Electrical penetration for igniters	3	CV, RB	-	Q	I	
T62 Containment Monitoring System						
1. Mechanical components involved in containment isolation function	2	CV, RB	B	Q	I	
2. Other safety-related mechanical components	3	CV, RB, CB	C	Q	I	
3. Safety-related electrical modules, cables and instrumentation	3	CV, RB, CB	—	Q	I	
4. Electrical modules, cables and instrumentation supporting diverse protection functions	N	CV, RB, CB	—	S	II	(5) c, (5) j
5. Other nonsafety-related portions of system	N	CV, RB, CB	—	N	NS	
T64 Environmental Monitoring System	N	OL	—	N	NS	
U STRUCTURES AND SERVICING SYSTEMS						
U31 Cranes, Hoists, and Elevators						
1. Reactor building cranes, fuel building crane	N	RB, FB	—	S	I	(5) a **Cranes** — The reactor building and fuel building cranes are designed to maintain their position and hold up their loads under conditions of an SSE.

boundary. Figure 3.8-7 shows the typical configuration for these passages through the RCCV Top Slab and Table 3.8-17 lists each of these passages and their function.

The PCCS condenser is anchored to the RCCV Top Slab and is laterally supported by a 3D steel frame structure that transmits the horizontal dynamic forces to the RCCV Top Slab.

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

A finite-element analysis model supplemented with hand calculation is used to determine the stresses in the different components of the PCCS condenser and supports. Details of this analysis, including relevant drawings and results, can be found in Reference 3.8-1. The PCCS condenser parts conform to the design requirements of Subarticles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC). The PCCS condenser support is evaluated in accordance with the ASME Code, Section III, Subsection NF.

3.8.2.5 Structural Acceptance Criteria

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

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

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

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

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

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

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.

3.8.2.6 Materials, Quality Control, and Special Construction Techniques

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

- *Plate (SA-240 type 304L, SA-516 grade 60 or 70)*

- *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-182F 304L~~ SA-182 grade FXM-19)*
- *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 ~~0~~1, Ma~~rch~~y 2010; NEDO-33572, Revision ~~0~~1, Class I (Non-proprietary), Ma~~rch~~y 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~~	(Deleted)~~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.*

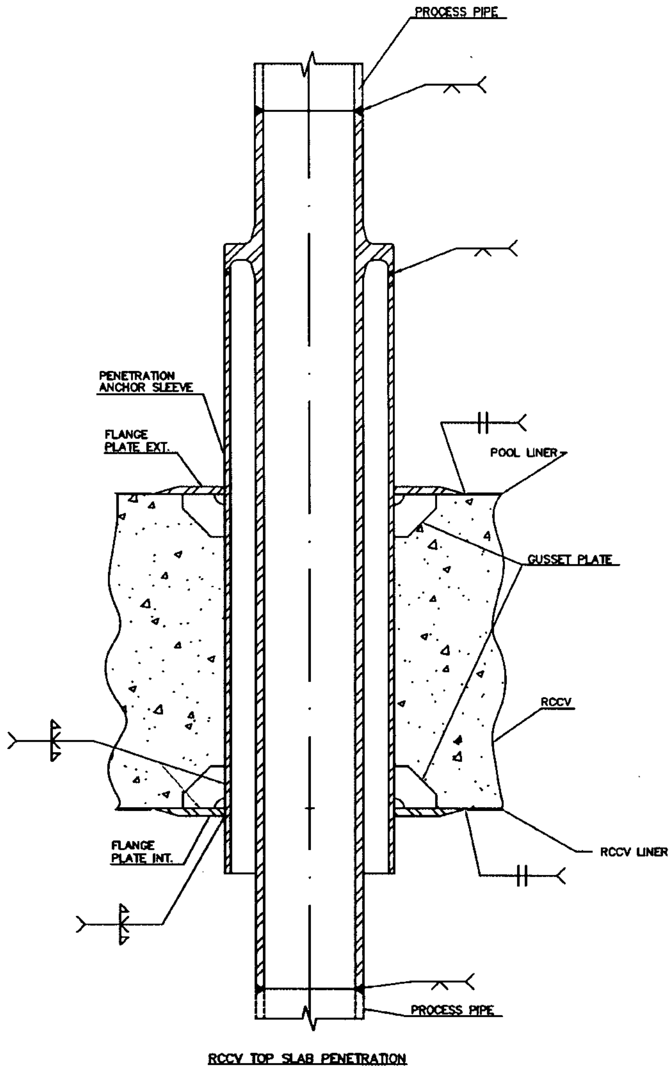


Figure 3.8-7. Typical RCCV Top Slab Penetration and PCCS Passages

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~~N	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~~N	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
Vent Line Catalyst Module	12	CV	ESF	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

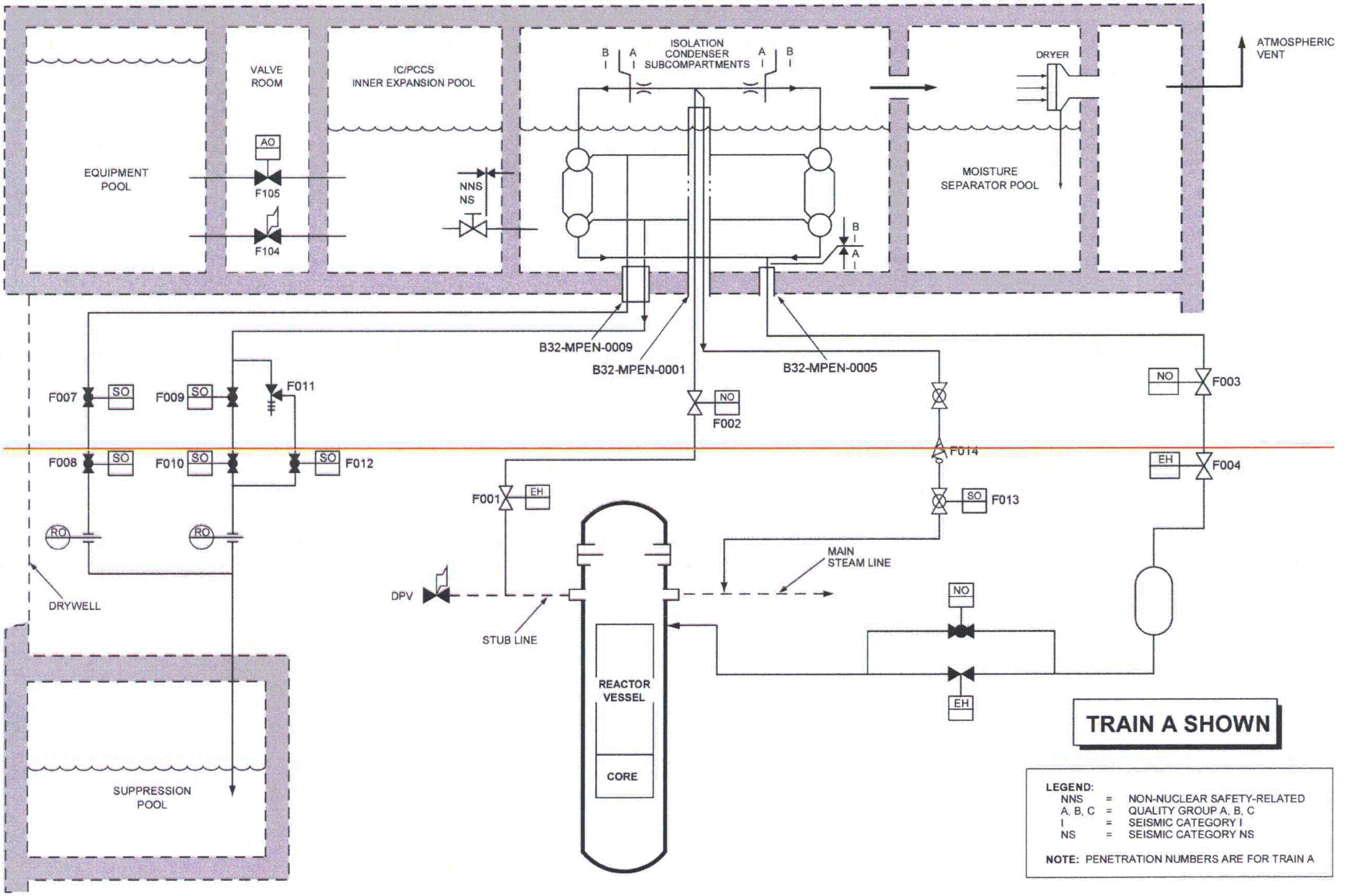
The minimum thickness required to prevent penetration, concrete spalling and scabbing is evaluated. The methods and procedures are shown in Subsection 3.5.3.1.1. The minimum thickness required is less than the minimum 1000 mm (39.4 in) and 700 mm (27.6 in) thickness provided for the RB external walls 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
A
B
I
DRYER
ATMOSPHERIC VENT
MOISTURE SEPARATOR POOL
B32-MPEN-0009
B32-MPEN-0001
B32-MPEN-0005
F007
F008
F009
F010
F011
F012
SO
RO
NO
F002
F001
EH
F003
F004
F013
F014
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

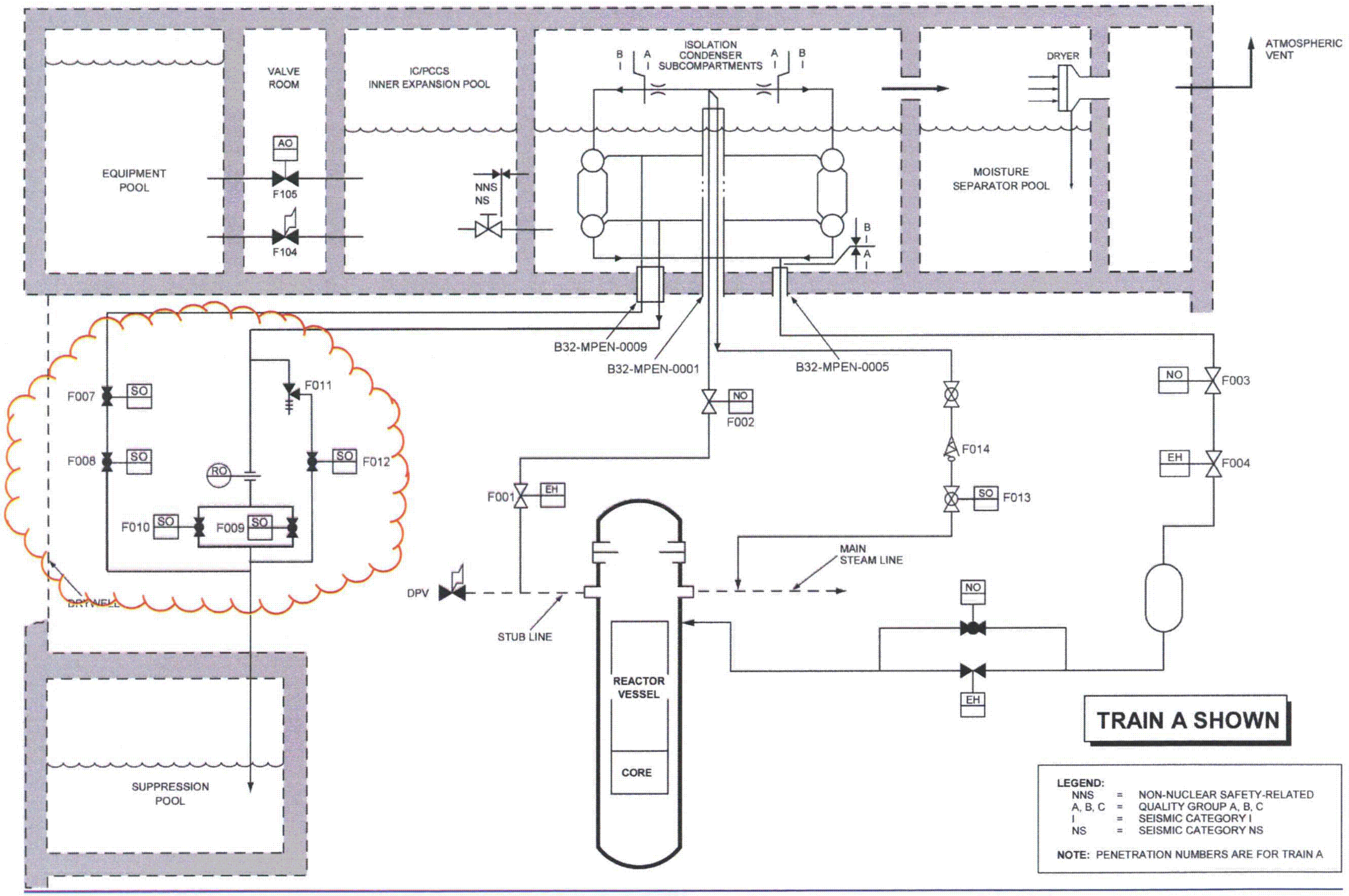


Figure 5.1-3. Isolation Condenser System Schematic

- Hydrostatic testing and nondestructive examinations per ASME B&PV Code requirements.

After installation, preoperational testing (described in Section 14.2) assures that the MSIVs and FWIVs will operate as designed, including opening and closing strokes, leaktightness, generation of position indication signals, and response to automatic actuation logic signals.

The MSIVs are tested for operability during plant operation by periodic test cycling. The MSIVs and FWIVs are tested for operability during planned outages. During outages, the MSIVs, FWIVs, FWCVs, and branch isolation testable check valves are functionally tested, leak-tested, and visually inspected as required by their corresponding programs. Leak-testing provisions are further discussed in Subsection 6.2.6. Required periodic tests and inspections of the MSIVs and FWIVs are identified in the plant-specific Technical Specifications.

5.4.5.6 Instrumentation Requirements

MSIV and FWIV positions are indicated in the main control room. The safety-related position sensors provide multiple independent channels to support safety-related instrument and control signal requirements.

Additional position indication sensing (e.g., limit switches, or other means) is provided on each valve, as required to support nonsafety-related instrumentation and control requirements. Additional position indication is used on the MSIVs for initiating a turbine control system trip and for signal input to the DPS logic. The FWIVs are also provided additional position indication for signal input to the DPS logic.

MSIV and FWIV instrumentation requirements are described further in Section 7.3.3.

5.4.6 Isolation Condenser System

The ESBWR ICS is the most comparable system to the BWR Reactor Core Isolation Cooling (RCIC) System. The ESBWR is a passive plant relying almost exclusively on natural phenomena to drive plant functions, which differs significantly from the BWR RCIC which relies heavily on active systems to accomplish its functions. However, the ESBWR ICS does meet acceptance criteria that are based on meeting the relevant requirements of GDC 4, 5, 33, 34, 54, 55, and 10 CFR 50.63. The specific criteria met by the ESBWR to meet the requirements of the above GDCs and 10 CFR 50.63 are as follows:

- GDC 4, as related to dynamic effects associated with flow instabilities and loads (e.g. water hammer);
- GDC 5 as it relates to safety-related structures, systems and components not being shared among nuclear power units unless it can be demonstrated that sharing does not impair its ability to perform its safety function;
- GDC 33 as it relates to the system capability to provide reactor coolant makeup for protection against small breaks in the RCPB so the fuel design limits are not exceeded;
- GDC 34 as it relates to the system design being capable of removing fission product decay heat and other residual heat from the reactor core to preclude fuel damage or RCPB overpressurization;

- 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 i~~In the event of a LOCA, ~~. T~~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. Upon the opening of any two DPVs, the ICS isolation valves are automatically signaled to close. Closing the ICS isolation valves when the RPV is depressurized 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~~ automatic and continuous venting of radiolytically generated noncondensable gases 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, and 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.

- 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 parallel, normally closed, fail-~~closed~~open, solenoid-operated lower header vent valves are located in the vent line from the lower headers. They ~~can be~~are 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). They can also be opened**~~ and~~ manually by the control room operator. **The lower header vent valves are energized-to-close, and therefore will fail open on loss of power.** There is a bypass line around the lower header vent valves, which contains one relief valve ~~and~~**in series with** 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 bypass flow path for the lower header vent does not contain a flow restricting orifice.

- 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)~~After a six-hour time delay following initiation, the lower header~~bottom~~ vent valves (F009 and F0101) 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~~ to prevent the accumulation of radiolytically generated hydrogen and oxygen (see Reference 5.4-3). If the pressure increases above 7.929 MPa gauge (1150 psig), the lower header vent bypass valves (F011 and F012) 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 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 automatically signaled to closed upon receipt of an open signal from any two DPV's. Closing the ICS isolation valves mitigates the accumulation of radiolytic hydrogen and oxygen (see Reference 5.4-3), and there is sufficient time allotted for the water stored in the ICS condensate line to drain to the RPV prior to the isolation.

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
- GDC 34, which specifies requirements for systems for RHR (see Subsection 5.4.6).

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)

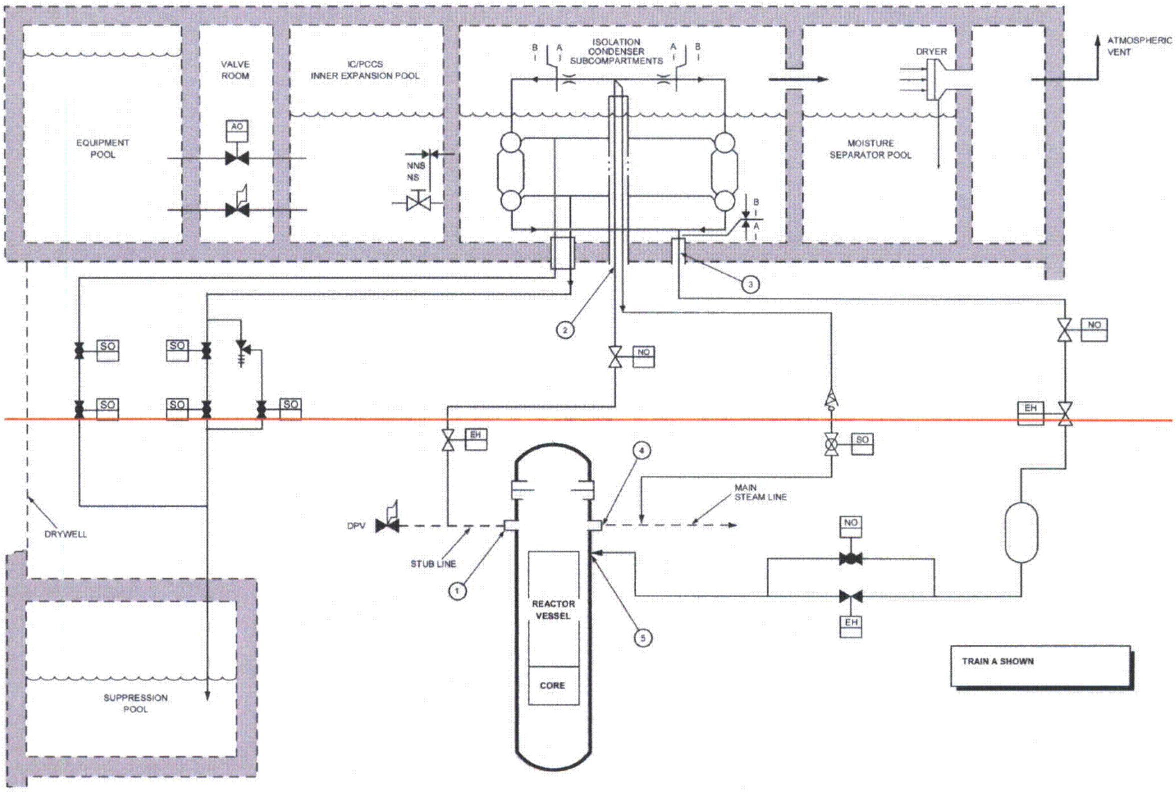
5.4-2 GE Nuclear Energy, "Depressurization Valve Development Test Program Final Report," GEFR-00879, October 1990

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.

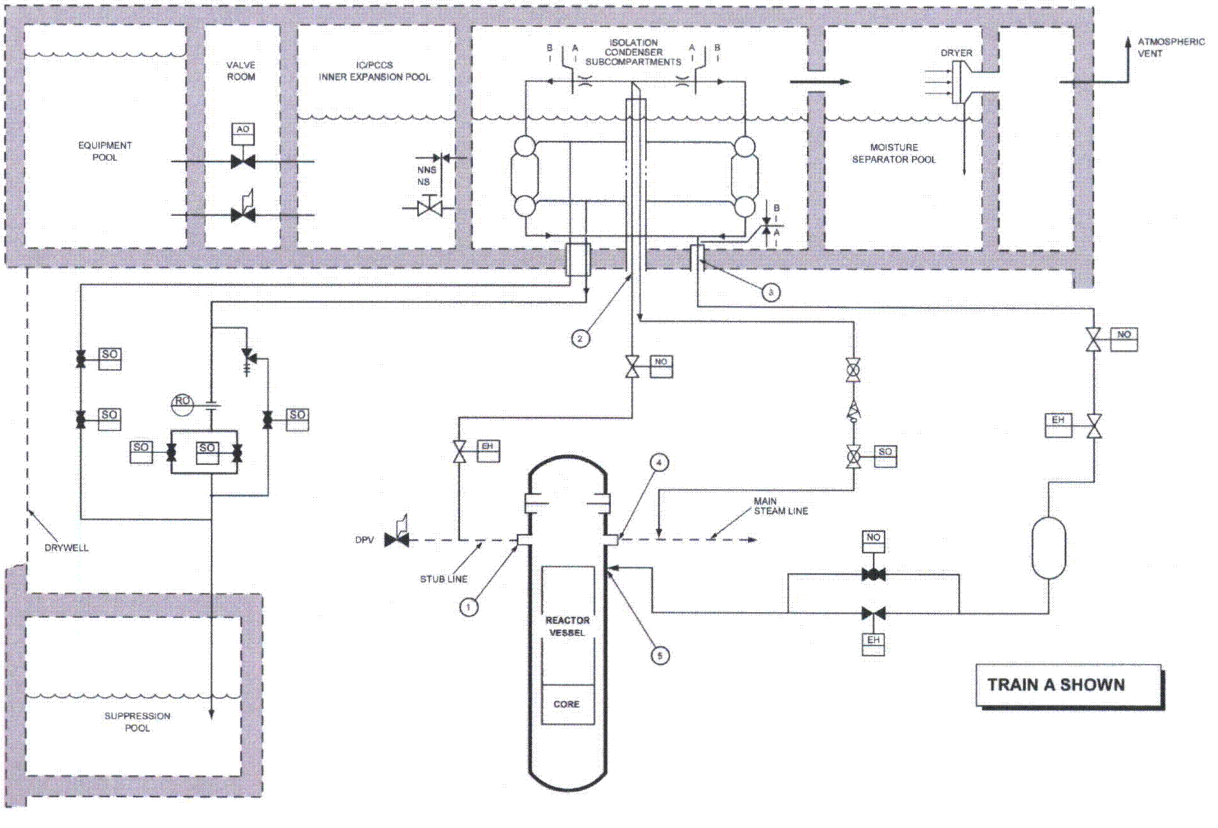
Table 5.4-1

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.



Note: The data for this process diagram is shown on Figure 5.4-4c.



Note: The data for this process diagram is shown on Figure 5.4-4c.

LEGEND: A, B = Quality Group A or B
I = Seismic Category I

Figure 5.4-4b. Isolation Condenser System Simplified Process Diagram

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~~FXM-19
		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. Reference 6.2-14 provides details regarding hydrogen accumulation in the PCCS and their design to withstand deflagrations and detonations~~the stress analysis of the condenser and supports~~.

To prevent the accumulation of combustible gas in the PCCS vent lines, catalyst modules containing metal parallel plates coated with platinum/palladium catalyst are placed at the entrance to the vent line, within each lower drum. These safety-related vent line catalyst modules are seismic category I and are environmentally qualified for the harsh post-accident environment in combination with the operating conditions of catalytic recombination, given their 60 year design life. The vent line catalyst modules are designed and built to withstand detonation loading in combination with other applicable dynamic loads, without losing their catalytic recombination functionality or negatively impacting the venting capability of the condenser. Reference 6.2-14 provides details regarding the detonation loading and structural response of the modules. The catalyst recombination performance requirements are given in Table 6.2-10. The vent line catalyst modules and catalyst plates are designed with provisions for surveillance testing and wholesale changeout of the module assembly or catalyst plates if so desired.

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 its 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.

6.2.3 Reactor Building Functional Design

Relevant to the function of a secondary containment design, this subsection addresses (or references to other DCD locations that address) the applicable requirements of GDC 4, 16, and 43 and Appendix J to 10 CFR 50 discussed in SRP 6.2.3 R2. The plant meets the relevant and applicable requirements of:

- GDC 4 as it relates to safety-related structures, systems and components being designed to accommodate the effects of normal operation, maintenance, testing and postulated accidents, and being protected against dynamic effects (for example, the effects of missiles, pipe whipping, and discharging fluids) that may result from equipment failures;
- GDC 16 as it relates to reactor containment and associated systems being provided to establish an essentially leak-tight barriers against the uncontrolled release of radioactive material to the environment;
- GDC 43 as it relates to atmosphere cleanup systems having the design capability to permit periodic functional testing to ensure system integrity, the operability of active components, and the operability of the system as a whole and the performance of the operational sequence that brings the system into operation; and
- 10 CFR 50, Appendix J as it relates to the secondary containment being designed to permit preoperational and periodic leakage rate testing so that bypass leakage paths are identified.

This subsection applies to the ESBWR RB design. The RB structure encloses penetrations through the containment (except for those of the main steam tunnel and IC/PCCS pools). The RB:

- Provides an added barrier to fission product released from the containment in case of an accident;
- Contains, dilutes, and holds up any leakage from the containment; and
- Houses safety-related systems.

CIVs be locked closed. Powered or non-powered CIVs in the ESBWR design that are defined as passive valves (Table 3.9-8) are designed to have their position administratively controlled or are prudently inhibited from being repositioned (for example, by inadvertent operator control action). For these valves, the Combined License (COL) Holder may use any of the administrative methods that apply, including but not limited to, wire locks, tab locks, chain or bar and padlocks, secured or covered switches, deenergized and locked-out electrical breakers, removed fuses, or closed-and-locked fluidic power supply valves, in conjunction with alignment control procedures. These administrative controls meet the requirements of RG 1.141 and satisfy the standards of ANS-56.2/ANSI N271-1976. Where applicable, and using technically reliable design(s), check valves are equipped with a means for position indication. Excess flow check valves, typically used in instrument line isolation, are also equipped with position indication devices. If a safety or relief type valve is used as a Containment Isolation Valve (CIV), a position indication device is included in the design to indicate that the valve is open, either by direct sensing of disk position (e.g., follower rod with inductive sensor) or indirect means (e.g., tailpipe thermal sensor).

6.2.4.3 Design Evaluation

A discussion of the main objectives of the containment, the arrangements, the redundancies and the position control of all non-powered isolation valves and all power operated isolation valves is included in Subsection 6.2.4.2.5.

6.2.4.3.1 Evaluation Against General Design Criterion 55

The RCPB, as defined in 10 CFR 50, Section 50.2, consists of the RPV, pressure-retaining appurtenances attached to the vessel, valves and pipes which extend from the RPV up to and including the outermost isolation valves. The lines of the RCPB, which penetrate the containment, include functions for isolation of the containment, thereby precluding any significant release of radioactivity. Similarly, for lines which do not penetrate the containment but which form a portion of the RCPB, the design ensures that isolation of the RCPB can be achieved.

The following paragraphs summarize the basis for ESBWR compliance with the requirements imposed by General Design Criterion 55.

6.2.4.3.1.1 Influent Lines

GDC 55 states that each influent line, which penetrate the containment directly to the RCPB, be equipped with at least two isolation valves, one inside the containment and the other as close to the external side of the containment as practical. Table 6.2-13 lists the influent pipes that comprise the RCPB and penetrate the containment. The table summarizes the design of each line as it satisfies the requirements imposed by General Design Criterion 55.

Feedwater Line

The feedwater line is part of the reactor coolant pressure boundary as it penetrates the containment to connect with the RPV (Figure 5.1-2). It has three containment isolation valves, the inboard isolation is a simple check valve with process-actuated closure, and the two outboard valves are gate valves with automatic closure. There is a branch connection to each feedwater line on the outboard side of the penetration and between the penetration and the inner outboard feedwater isolation valve. The branch connection is isolated by a testable check valve. An additional simple check valve is located outboard of the feedwater containment isolation valves for function redundancy. Two check valves redundantly isolate the feedwater line or branch connection line in the event of an outboard feedwater pipe or branch connection pipe rupture (feedwater HELB). Two gate valves, isolate the line in the event of an inboard feedwater pipe rupture or other LOCA, or vessel overfill event. The inboard and outboard isolation valves are located as close as practicable to the containment wall. More detail about the feedwater lines isolation configuration is provided in Subsection 5.4.5.

Isolation Condenser Condensate and Venting Lines

The containment isolation provisions for the ICS condensate, vent, and purge lines constitute an alternative design basis beyond what is described by GDC 55. ~~Instead of one isolation valve outside the containment and one isolation valve inside the containment, the ICS influent lines rely upon two valves inside containment as well as a closed system outside the containment.~~ The following rationale support this alternative design:

The isolation condenser condensate lines contain two valves in series inside containment which, combined with a closed loop outside containment provide sufficient containment isolation. ~~penetrate the containment and connect directly to the RPV.~~ The isolation condenser venting lines extend from the isolation condenser through the containment~~ and connect together~~. The containment isolation provisions for the vent lines are all inboard of containment and are all associated with a closed loop outside containment in addition to a submerged discharge point inside containment (in the suppression pool). In addition, the vent lines are configured as follows:

- Upper header vent line is equipped with two normally closed, fail closed, safety-related solenoid valves in series (F007 and F008).
- Lower header vent line is equipped with a flow restricting orifice. The flow restricting orifice has a hole size of 0.167 cm^2 (0.0259 in^2), which is equivalent to a hole diameter of 4.60 mm (0.181 in).
- Lower header vent bypass line is equipped with a safety-related high-pressure relief valve (F011) in series with a safety-related normally closed, fail open solenoid valve (F012) for the lower header vent bypass line.

~~downstream of two tandem installed normally-closed stop valves.~~ The venting lines described above connect together downstream of these containment isolation provisions and terminates below the minimum drawdown level in the suppression pool. An isolation condenser purge line also penetrates the containment and it contains an excess flow check valve and a normally open shutoff valve. Each IC condensate line has two open condensate return line isolating shutoff valves (F003 and F004) located in the containment where they are protected from outside environmental conditions, which may be caused by a failure outside the containment. The condensate lines are automatically isolated when leakage is detected.

The IC condensate line isolation valves and the pipes penetrating the containment are designed in accordance to ASME Code Section III, Class 1 Quality Group A, Seismic Category I. Penetration sleeves used at the locations where the condensate return pipes exit the pool at the containment pressure boundary are designed and constructed in accordance with the requirements specified within Subsection 3.6.2.1. In addition, the IC System outside the containment consists of a closed loop designed to ASME Code Section III, Class 2, Quality Group B, Seismic Category I, which is a "passive" substitute for an open "active" valve outside the containment. ~~The containment isolation for the vent lines is very similar in design to the condensate lines. Instead of automatic isolation valves inside containment the vent lines utilize two normally closed fail closed valves in series.~~ The vent lines are 20 mm (0.75 inch) in diameter, and their inboard isolation valves (and restricting orifice) are designed to ASME Code Section III, Class 2 Quality Group B, Seismic Category I. The IC purge line isolation valves and the pipes penetrating the containment are designed in accordance to ASME Code Section III, Class I Quality Group A, Seismic Category I. The purge line is a 20 mm (0.75 inch) line that utilizes a closed system outside containment, and a fail closed isolation valve in series with an excess flow check valve inside containment. The combination of an already closed loop outside the containment plus the two series automatic isolation valves inside the containment comply with the requirements of isolation functions of US NRC Code of Federal Regulations 10 CFR 50, Appendix A, Criteria 55. It is more practical to locate both valves inside containment because a valve outside containment would be submerged in the IC/PCCS pool. The isolation valves shall be located as close to the containment boundary as possible, and the pipe between the outermost isolation valve and the containment shall be designed to the requirements of SRP 3.6.2 to minimize the chances of a break in this area. A break on any of these influent lines could be contained by either of the redundant isolation valves. Furthermore, a break between the isolation valves and the containment would still be contained by the closed system outside containment, and would require an additional break before a radioactive release could occur. Therefore, this design can accommodate a single failure.

Standby Liquid Control System Line

The SLC system line penetrates the containment to inject directly into the RPV. In addition to a simple check valve inside the containment, a check valve, together with two parallel squib-activated valves are located outside the DW. Because the SLC line is normally closed, rupture of this non-flowing line is extremely improbable. However, should a break occur subsequent to the opening of the squib-activated valves, the check valves ensure isolation. All mechanical components required for boron injection are at least Quality Group B. Those portions which are part of the reactor coolant pressure boundary are classified Quality Group A.

6.2.4.3.1.2 Effluent Lines

GDC 55 states that each effluent line, which form part of the reactor coolant pressure boundary and penetrate the containment, be equipped with two isolation valves; one inside the containment and one outside, located as close to the containment wall as practicable.

Table 6.2-14 lists those effluent lines that comprise the reactor coolant pressure boundary and which penetrate the containment.

Main Steam and Drain Lines

The main steam lines, which extend from the RPV to the main turbine and condenser system, penetrate the containment. The main steam drain lines connect the low points of the steam lines, penetrate the containment and are routed to the condenser hotwell. For these lines, isolation is

6.2.5.5 Post-Accident Radiolytic Oxygen Generation

For a design basis LOCA in the ESBWR, the ADS would depressurize the reactor vessel and the GDCS would provide gravity driven flow into the vessel for emergency core cooling. The safety analyses show that the core does not uncover during this event and as a result, there is no fuel damage or fuel clad-coolant interaction that would result in the release of fission products or hydrogen. Thus, for design basis LOCA, the generation of post-accident oxygen would not result in a combustible gas condition and a design basis LOCA does not have to be considered in this regard.

For the purposes of post-accident radiolytic oxygen generation for the ESBWR, a severe accident with a significant release of iodine and hydrogen is more appropriate to consider.

Because the ESBWR containment is inerted, the prevention of a combustible gas deflagration is assured in the short term following a severe accident. In the longer term there would be an increase in the oxygen concentration resulting from the continued radiolytic decomposition of the water in the containment. Because the possibility of a combustible gas condition is oxygen limited for an inerted containment, it is important to evaluate the containment oxygen concentration versus time following a severe accident to assure that there is sufficient time to implement Severe Accident Management actions. It is desirable to have at least a 24 hour period following an accident to allow for Severe Accident Management implementation. This section discusses the rate at which post-accident oxygen is generated by radiolysis in the ESBWR containment following a severe accident, and establishes the period of time that would be required for the oxygen concentration in containment to increase to a value that would constitute a combustible gas condition (5% oxygen by volume) in the presence of a large hydrogen release, thus de-inerting the containment in the absence of mitigating Severe Accident Management actions.

6.2.5.5.1 Background

The rate of gas production from radiolysis depends upon the power decay profile and the amount of fission products released to the coolant. Appendix A of SRP Subsection 6.2.5 provides a methodology for calculation of radiolytic hydrogen and oxygen generation. The analysis results 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 DPVs 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
- Iodine release up 100%.

6.2.5.5.3 Analysis Results

The analysis results show that the time required for the oxygen concentration to increase to the de-inerting value of 5% is significantly greater than 24 hours for a wide range of fuel clad-coolant interaction and iodine release assumptions up to and including 100%. The results support the conclusion that there is sufficient time available to activate the emergency response organization and implement the Severe Accident Management actions necessary to preclude a combustible gas deflagration.

Also, the potential combustion of radiolytically generated gas inside the PCCS and ICS condensers has been considered as described in Reference 6.2-14.

6.2.6.5 (Deleted)

6.2.7 Fracture Prevention of Containment Pressure Boundary

The reactor containment system includes the functional capability of enclosing the reactor system and of providing a final barrier against the release of radioactive fission products attendant postulated accidents.

Fracture prevention of the containment pressure boundary is assured. The ESBWR meets the relevant requirements of the following regulations:

- General Design Criterion 1 (as it relates to the quality standards for design and fabrication) - See Subsection 3.1.1.1.
- General Design Criterion 16 (as it relates to the prevention of the release of radioactivity to the environment) - See Subsection 3.1.2.7.
- General Design Criterion 51 (as it relates to the reactor containment pressure boundary design) - See Subsection 3.1.5.2.

To meet the requirements of GDC 1, 16 and 51, the ferritic containment pressure boundary materials meet the fracture toughness criteria for ASME Section III Class 2 components. These criteria provide for a uniform review, consistent with the safety function of the containment pressure boundary within the context of RG 1.26, which assigns correspondence of Group B Quality Standards to ASME Code Section III Class 2.

6.2.8 COL Information

6.2-1-H (Deleted)

6.2.9 References

6.2-1 GE Nuclear Energy, "TRACG Application for ESBWR," NEDC-33083P-A, Class III, (Proprietary), March 2005, and NEDO-33083-A, Class I (Non-proprietary), October 2005.

6.2-2 Galletly, G.D., "A Simple Design Equation for Preventing Buckling in Fabricated Torispherical Shells under Internal Pressure," ASME Journal of Pressure Vessel Technology, Vol.108, November 1986.

6.2-3 GE letter from David H. Hinds to U.S. Regulatory Commission, TRACG LOCA SER Confirmatory Items (TAC # MC 8168), Enclosure 2, Reactor Pressure Vessel (RPV) Level Response for the Long Term PCCS Period, Phenomena Identification and Ranking Table, and Major Design Changes from Pre-Application Review Design to DCD Design, MFN 05-105, October 6, 2005.

6.2-4 GE letter from David H. Hinds to U.S. Regulatory Commission, Revised Response – GE Response to Results of NRC Acceptance Review for ESBWR Design Certification Application – Item 2, MFN 06-094, March 28, 2006.

6.2-5 Moody, F.J., "Maximum Flow Rate of a Single Component, Two-Phase Mixture," Journal of Heat Transfer, Trans. ASME, Series C, Vol. 87, P 134, February 1965.

6.2-6 (Deleted)

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 ~~0~~1, Ma~~rch~~y 2010; NEDO-33572, Revision ~~0~~1, Class I (Non-proprietary), Ma~~rch~~y 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 ratio 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~~(Deleted	~~F010A~~(Deleted)	F011A	F012A	F013A	F014A
Valve Location	Upper Header Vent	Upper Header Vent	~~Lower Header Vent~~	~~Lower Header Vent~~	Lower Header Bypass Vent	Lower Header Bypass Vent	Purge line	Excess Flow Purge
Applicable Basis	GDC 55[1]	GDC 55[1]	~~GDC 55[1]~~	~~GDC 55[1]~~	GDC 55[1]	GDC 55[1]	GDC 55[1]	GDC 55[1]
Tier 2 Figure	5.1-3	5.1-3	~~5.1-3~~	~~5.1-3~~	5.1-3	5.1-3	5.1-3	5.1-3
ESF	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
Fluid	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases	~~Cond/Steam /Non Cond Gases~~	~~Cond/Steam /Non Cond Gases~~	Cond/Steam /Non Cond Gases	Cond/steam /Non Cond Gases	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases
Line Size*	20mm (0.75 in)	20mm (0.75 in)	~~20mm (0.75 in)~~	~~20mm (0.75 in)~~	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)
Type C Leakage Test	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
(Deleted)								
Leakage Through Packing[a]	N/A	N/A	~~N/A~~	~~N/A~~	N/A	N/A	N/A	N/A
Leakage Past Seat[b]	b_6[4]	b_6[4]	~~b_6[4]~~	~~b_6[4]~~	b_6[4]	b_6[4]	b_6[4]	b_6[4]
Location	Inboard	Inboard	~~Inboard~~	~~Inboard~~	Inboard	Inboard	Inboard	Inboard
(Deleted)								

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~~(Deleted)**	**~~F010A~~(Deleted)**	**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	~~Closed~~	~~Closed~~	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~	~~Closed~~	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 t~~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~~(deleted)	~~F010B~~(Deleted)	F011B	F012B	F013B	F014B
Valve Location	Upper Header Vent	Upper Header Vent	~~Lower Header Vent~~	~~Lower Header Vent~~	Lower Header Bypass Vent	Lower Header Bypass Vent	Purge line	Excess Flow Purge
Applicable Basis	GDC 55[1]	GDC 55[1]	~~GDC 55[1]~~	~~GDC 55[1]~~	GDC 55[1]	GDC 55[1]	GDC 55[1]	GDC 55[1]
Tier 2 Figure	5.1-3	5.1-3	~~5.1-3~~	~~5.1-3~~	5.1-3	5.1-3	5.1-3	5.1-3
ESF	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
Fluid	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases	~~Cond/Steam /Non Cond Gases~~	~~Cond/Steam /Non Cond Gases~~	Cond/Steam /Non Cond Gases	Cond/steam /Non Cond Gases	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases
Line Size*	20mm (0.75 in)	20mm (0.75 in)	~~20mm (0.75 in)~~	~~20mm (0.75 in)~~	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)
Type C Leakage Test	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
(Deleted)								
Leakage Through Packing[a]	N/A	N/A	~~N/A~~	~~N/A~~	N/A	N/A	N/A	N/A
Leakage Past Seat[b]	b_6[4]	b_6[4]	~~b_6[4]~~	~~b_6[4]~~	b_6[4]	b_6[4]	b_6[4]	b_6[4]
Location	Inboard	Inboard	~~Inboard~~	~~Inboard~~	Inboard	Inboard	Inboard	Inboard
(Deleted)								

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~~(deleted)**	**~~F010B~~(Deleted)**	**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	~~Closed~~	~~Closed~~	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~	~~Closed~~	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 t~~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**	**(Deleted)~~F0~~**	**(Deleted)~~F0~~**	**F011C**	**F012C**	**F013C**	**F014C**
Valve Location	Upper Header Vent	Upper Header Vent	~~Lower Header Vent~~	~~Lower Header Vent~~	Lower Header Bypass Vent	Lower Header Bypass Vent	Purge line	Excess Flow Purge
Applicable Basis	GDC 55[1]	GDC 55[1]	~~GDC 55[1]~~	~~GDC 55[1]~~	GDC 55[1]	GDC 55[1]	GDC 55[1]	GDC 55[1]
Tier 2 Figure	5.1-3	5.1-3	~~5.1-3~~	~~5.1-3~~	5.1-3	5.1-3	5.1-3	5.1-3
ESF	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
Fluid	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases	~~Cond/Steam /Non Cond Gases~~	~~Cond/Steam /Non Cond Gases~~	Cond/Steam /Non Cond Gases	Cond/steam /Non Cond Gases	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases
Line Size*	20mm (0.75 in)	20mm (0.75 in)	~~20mm (0.75 in)~~	~~20mm (0.75 in)~~	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)
Type C Leakage Test	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
(Deleted)								
Leakage Through Packing[a]	N/A	N/A	~~N/A~~	~~N/A~~	N/A	N/A	N/A	N/A
Leakage Past Seat[b]	b_6[4]	b_6[4]	~~b_6[4]~~	~~b_6[4]~~	b_6[4]	b_6[4]	b_6[4]	b_6[4]
Location	Inboard	Inboard	~~Inboard~~	~~Inboard~~	Inboard	Inboard	Inboard	Inboard
(Deleted)								

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	(Deleted)~~F0~~	(Deleted)~~F0~~	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	~~Closed~~	~~Closed~~	Open/Closed	Open/Closed	Open/Close	Open
Power Fail Position	Closed	Closed	~~Closed~~	~~Closed~~	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 t~~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**	**(Deleted)~~F009D~~**	**(Deleted)~~F010D~~**	**F011D**	**F012D**	**F013D**	**F014D**
Valve Location	Upper Header Vent	Upper Header Vent	~~Lower Header Vent~~	~~Lower Header Vent~~	Lower Header Bypass Vent	Lower Header Bypass Vent	Purge line	Excess Flow Purge
Applicable Basis	GDC 55[1]	GDC 55[1]	~~GDC 55[1]~~	~~GDC 55[1]~~	GDC 55[1]	GDC 55[1]	GDC 55[1]	GDC 55[1]*
Tier 2 Figure	5.1-3	5.1-3	~~5.1-3~~	~~5.1-3~~	5.1-3	5.1-3	5.1-3	5.1-3
ESF	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
Fluid	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases	~~Cond/Steam /Non Cond Gases~~	~~Cond/Steam /Non Cond Gases~~	Cond/Steam /Non Cond Gases	Cond/steam /Non Cond Gases	Cond/Steam /Non Cond Gases	Cond/Steam /Non Cond Gases
Line Size*	20mm (0.75 in)	20mm (0.75 in)	~~20mm (0.75 in)~~	~~20mm (0.75 in)~~	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)	20mm (0.75 in)
Type C Leakage Test	Yes	Yes	~~Yes~~	~~Yes~~	Yes	Yes	Yes	Yes
(Deleted)								
Leakage Through Packing[a]	N/A	N/A	~~N/A~~	~~N/A~~	N/A	N/A	N/A	N/A
Leakage Past Seat[b]	b_6[4]	b_6[4]	~~b_6[4]~~	~~b_6[4]~~	b_6[4]	b_6[4]	b_6[4]	b_6[4]
Location	Inboard	Inboard	~~Inboard~~	~~Inboard~~	Inboard	Inboard	Inboard	Inboard
(Deleted)								

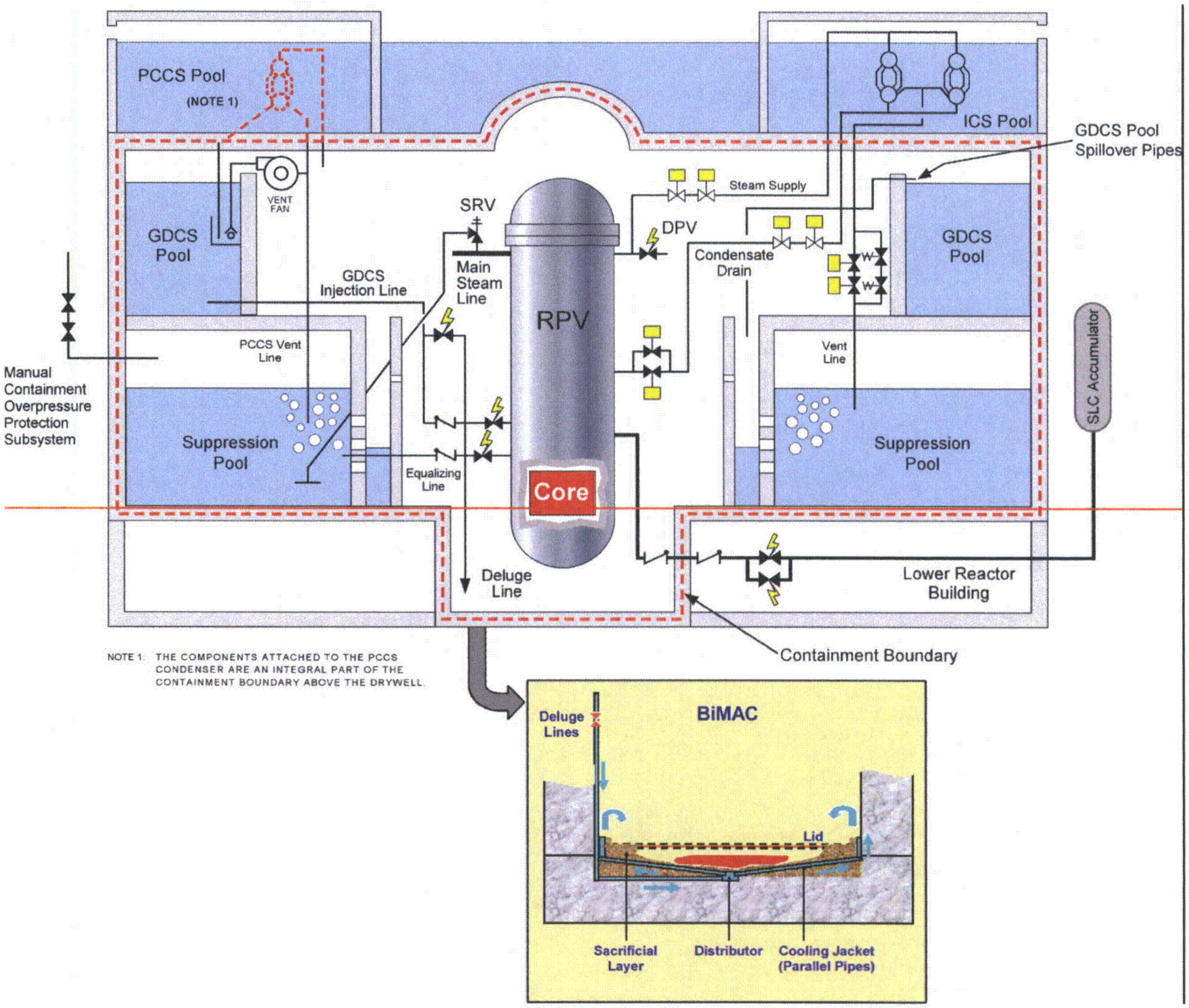
Table 6.2-30

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**	**(Deleted)~~F009D~~**	**(Deleted)~~F010D~~**	**F011D**	**F012D**	**F013D**	**F014D**
(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	~~Closed~~	~~Closed~~	Open/Closed	Open/Closed	Open	Open
Power Fail Position	Closed	Closed	~~Closed~~	~~Closed~~	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 t~~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
Steam Supply
SRV
GDCS Pool
DPV
Condensate Drain
GDCS Pool
GDCS Injection Line
Main Steam Line
RPV
Manual Containment Overpressure Protection Subsystem
PCCS Vent Line
Vent Line
SLC Accumulator
Suppression Pool
Suppression Pool
Equalizing Line
Core
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.
BiMAC
Deluge Lines
Lid
Sacrificial Layer
Distributor
Cooling Jacket (Parallel Pipes)

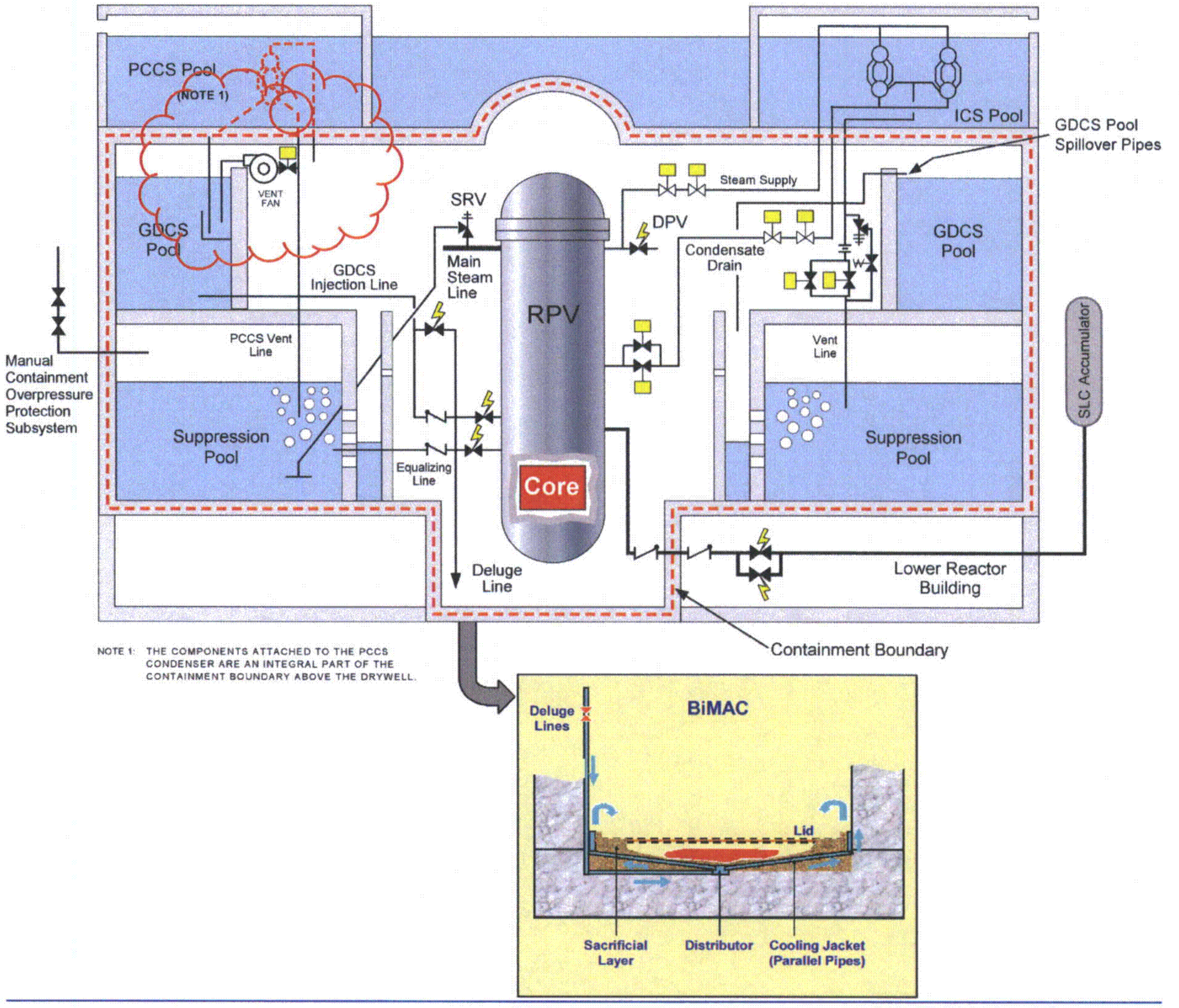
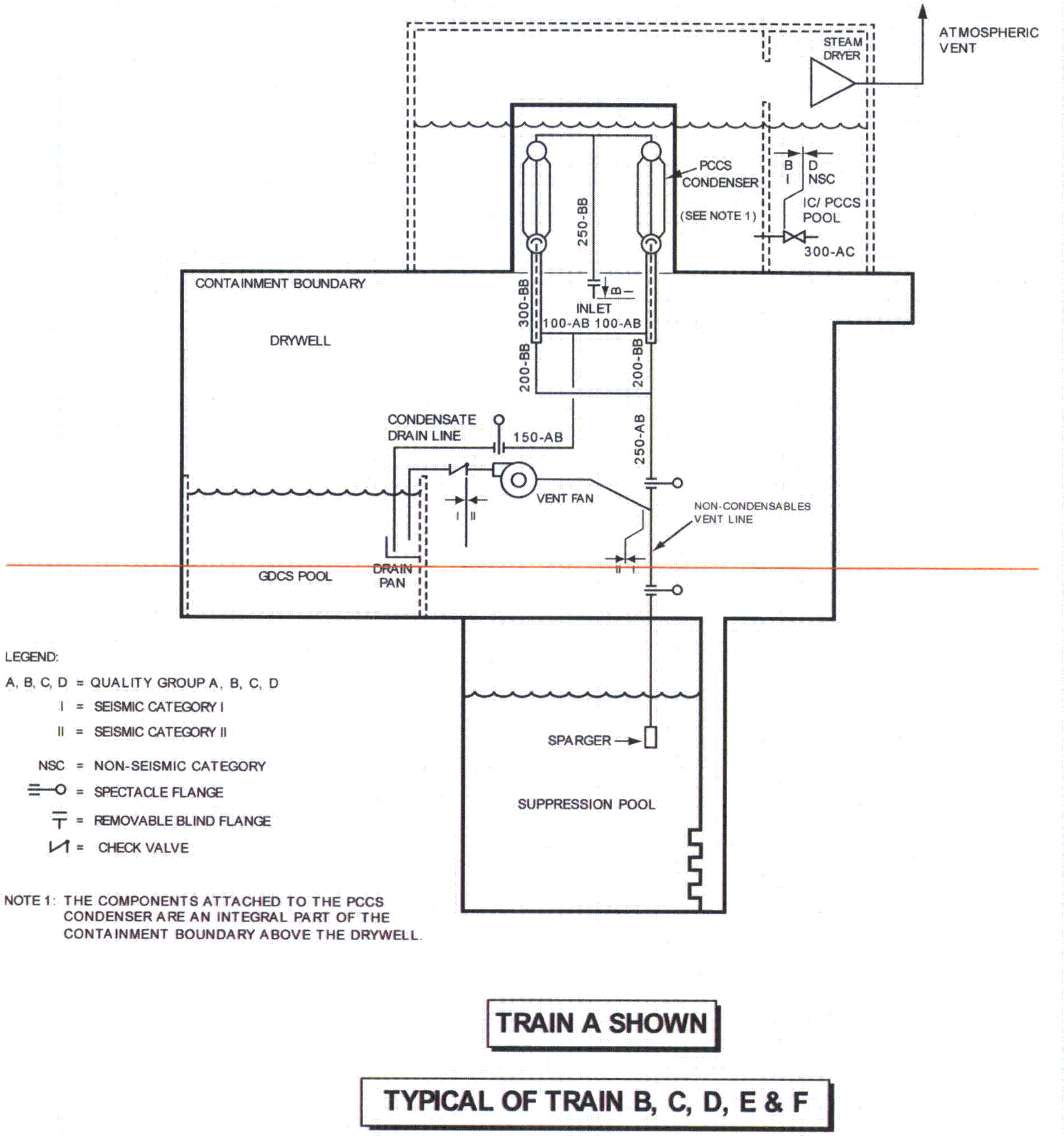


Figure 6.2-15. Summary of Severe Accident Design Features


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

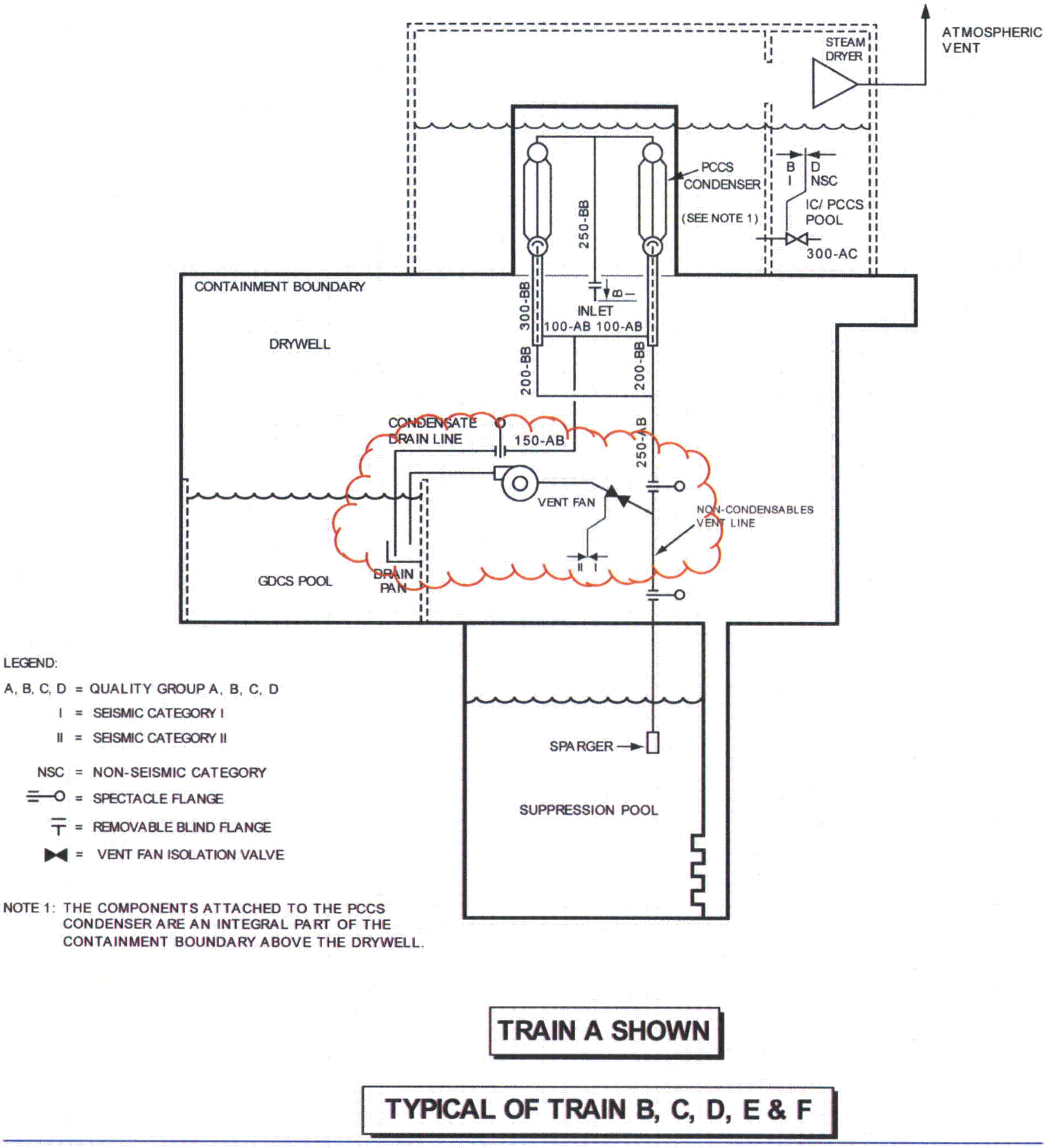


Figure 6.2-16. PCCS Schematic Diagram

PCC – Passive Containment Cooling System

Table 6.3-1

Significant Input Variables to the ECCS-LOCA Performance Analysis

B.2b Gravity-Driven Cooling System (Long-Term)		
Variable	**Units**	**Value**
Permissive Signal Delay Time after Level 1	min	30
Initiation Signal Level 0.5 after Permissive Signal	meters (above TAF) [ft] (above TAF)	1.00 [3.28]
B.3 Isolation Condenser System		
Variable	**Units**	**Value**
Initiating Signal	—	Loss of feedwater
Maximum Sensor Response Time	sec	2
(Deleted)~~Heat Removal Capacity per Unit~~	~~MW~~	~~33.75~~
Minimum Drainable Liquid Volume per System	m^3 [ft^3]	13.88 [490.1]
Isolation Condenser Water Inventory	—	Credited
B.4 Standby Liquid Control System		
Variable	**Units**	**Value**
Initiating Signal	—	DPV actuation from B.1a
Liquid Volume per Tank	m^3 [ft^3]	7.8 [275.4]
B.5 Automatic Depressurization Subsystem		
Variable	**Units**	**Value**
Initiating Signal	—	Confirmed initiating signal (See B.1a, B.1b)
Valve Actuation Sequence:		
5 ADS	sec	0
5 ADS	sec	10
3 DPVs	sec	50
2 DPVs	sec	100
2 DPVs	sec	150
1 DPVs	sec	200
Total Number of Safety Relief Valves With ADS Function	—	10
Total Min. ADS Flow Capacity at Vessel Pressure(1)	kg/s MPa (gauge) [lbm/hr] [psig]	1,380 8.618 [1.093×10^7] [1250]
Total Number of Depressurization Valves	—	8

7. INSTRUMENTATION AND CONTROL SYSTEMS

7.1 INTRODUCTION

This chapter presents specific detailed design and performance information for the Instrumentation and Control (I&C) systems that are significant for plant operation and that are used throughout the plant. I&C Distributed Control and Information Systems (DCIS) are designated as either Safety-related DCIS (Q-DCIS) or Nonsafety-related DCIS (N-DCIS). A description of the system of classification is found in Section 3.2.

The following subsections, tables, and figures provide a synopsis of the DCIS.

- Subsection 7.1.1 contains a brief description of the DCIS.
- Subsection 7.1.2 summarizes the Q-DCIS.
- Subsection 7.1.3 contains a detailed description of the Q-DCIS.
- Subsection 7.1.4 summarizes the N-DCIS.
- Subsection 7.1.5 contains a detailed description of the N-DCIS.
- Subsection 7.1.6 discusses DCIS conformance to regulatory requirements, guidelines, and industry codes and standards.
- Table 7.1-1 is a regulatory requirements applicability matrix.
- Table 7.1-2 is a section roadmap of an evaluation of IEEE Std. 603 specific criteria compliance.
- Figure 7.1-1 is a simplified network functional diagram of the DCIS.
- Figure 7.1-3 is a distributed power-sensor diversity diagram.
- Figure 7.1-4 is a hardware/software (architecture) diversity diagram.

7.1.1 Distributed Control and Information System

The DCIS is an arrangement of I&C networked components and individual systems that together provide:

- Digital processing and logic capability;
- Remote and local data acquisition;
- Datalinks and gateways between systems and components;
- Operator monitoring and control interfaces;
- Secure communications to external computer systems and networks;
- Alarm management functions; and
- Communications between the systems.

Figure 7.1-1 shows a simplified network functional diagram of the DCIS. The data communication systems embedded in the DCIS perform the data communication functions that are part of or support the systems described in Sections 7.2 through 7.8.

The Q-DCIS and N-DCIS architectures, their relationships, and their acceptance criteria are further described throughout Section 7.1.

The Q-DCIS and N-DCIS functions are implemented with diverse power and sensors as indicated in Figure 7.1-3, and diverse hardware and software architectures as shown in Figure 7.1-4. These are discussed in Reference 7.1-4, the Licensing Topical Report (LTR), "ESBWR I&C Diversity and Defense-In-Depth Report," NEDO-33251.

The Q-DCIS comprise the platforms that are defined in Table 7.1-1. The N-DCIS comprise the network segments that are defined in Table 7.1-1. These platforms or network segments comprise systems of integrated software and hardware elements. Software projects are developed for the various platforms or networks segments. The software development process is described in Appendix 7B.

7.1.2 Q-DCIS General Description Summary

The Q-DCIS, which performs the safety-related control and monitoring functions of the DCIS, is organized into four physically and electrically isolated divisions. The Q-DCIS uses three diverse platforms that operate independently of each other: Reactor Trip and Isolation Function-Neutron Monitoring System (RTIF-NMS), Safety System Logic and Control/Engineered Safety Features (SSLC/ESF), and the Independent Control Platform (ICP). The ICP provides independent logic control of the Anticipated Transient Without Scram mitigation and Standby Liquid Control (ATWS/SLC) functions, vacuum breaker (VB) isolation function, ~~and the~~ High Pressure Control Rod Drive (HP CRD) isolation bypass function, and the Isolation Condenser System (ICS) DPV Isolation Function (IDIF). The ICP platform ~~that~~ is diverse from the other two safety-related platforms; RTIF-NMS ~~platform~~ and ~~the~~ SSLC/ESF. The ICP platform is implemented in a system composed of custom programmable logic devices (CPLDs) and does not execute or run any active software (either operating system or application code) to perform its safety-related control function. The ICP control functions implemented in the CPLDs are 100% testable. Since the ICP does not run software to perform its control function and it is 100% testable therefore it is ~~and~~ not susceptible to a common-cause failure (CCF) with respect to other control platforms and systems.

The Q-DCIS major cabinets are Reactor Trip and Isolation Function (RTIF) cabinet, Neutron Monitoring System (NMS) Function cabinet and the SSLC/ESF cabinet. These cabinets include the following systems and functions:

- RTIF Platform Systems and Functions
  - Reactor Protection System (RPS) (Refer to Subsection 7.2.1);
  - Main Steam Isolation Valve (MSIV) functions of the Leak Detection and Isolation System (LD&IS) (Refer to Subsection 7.3.3); and
  - Suppression Pool Temperature Monitoring (SPTM) function of the Containment Monitoring System (CMS) (Refer to Subsection 7.2.3).

~~ICP Systems and Functions~~

~~VB isolation function of the containment system (Refer to Subsection 7.3.6); and~~

~~ATWS/SLC functions (Refer to Subsection 7.4.1 and 7.8.1).~~

~~HP CRD Isolation Bypass function (Refer to Section 4.6 as well as Subsections 7.1.2.8.8, 7.3.3, and 7.4.5).~~

- NMS Functions:

  NMS is implemented using the same hardware/software platform as RTIF systems; NMS includes the following systems and functions:

  - Startup Range Neutron Monitor (SRNM) functions and
  - Power Range Neutron Monitor (PRNM) functions that include:
    - Local Power Range Monitor (LPRM) functions,
    - Average Power Range Monitor (APRM) functions, and
    - Oscillation Power Range Monitor (OPRM) functions.

- Safety System Logic and Control/Engineered Safety Features (SSLC/ESF) Platform, ~~s~~Systems, and Functions
  - Emergency Core Cooling System (ECCS) functions that include:
    - Automatic Depressurization System (ADS) functions,
    - Gravity-Driven Cooling System (GDCS) functions,
    - Isolation Condenser System (ICS) functions, and
    - SLC system functions.
  - LD&IS Functions (except the MSIV functions);
  - Control Room Habitability System (CRHS) functions; and
  - Safety-related information systems.

- ICP Platform, Systems, and Functions
  - VB isolation function of the containment system (Refer to Subsection 7.3.6 for additional information); and
  - ATWS/SLC functions (Refer to Subsection 7.4.1 and 7.8.1 for additional information).
  - HP CRD Isolation Bypass function (Refer to Section 4.6 as well as Subsections 7.1.2.8.8, 7.3.3, and 7.4.5 for additional information).
  - ICS DPV Isolation Function (Refer to Subsection 7.3.7 for additional information).

  Space consideration may dictate locating the ICP hardware in separate cabinets.

The Q-DCIS major components include:

- Fiber-optic cable and hardwired networks,
- System control processors,
- Non-microprocessor based logic,
- Remote multiplexer units (RMUs),

- Load drivers (discrete outputs),
- Communication interface modules (CIMs),
- Video display units (VDUs),
- Hard controls/indicators (for monitoring), and
- Cabinets for housing devices such as power supplies.

The Q-DCIS provides the interface functions for the RTIF, NMS, SSLC/ESF, and ICP protection systems. These functions include data acquisition, monitoring, communication, and control functions. As a safety-related system, Q-DCIS is qualified for the environments and conditions that exist before, during, and following the abnormal events identified in Table 15.0-2. Each division of the Q-DCIS is electrically isolated from other Q-DCIS divisions and from the N-DCIS. Data communication is controlled between the Q-DCIS divisions and between the Q-DCIS and the N-DCIS. Communication between Q-DCIS divisions and between the Q-DCIS and the N-DCIS is via fiber-optic cable. Data communication between the Q-DCIS and the N-DCIS is managed by isolation devices, which are safety-related components within the Q-DCIS, via datalinks and N-DCIS gateways. The RTIF, NMS, ~~and~~ SSLC/ESF, and ICP protection systems are designed so that no safety-related function depends on the existence or function of any nonsafety-related component, data, or communication channel. The ICP has no data communications interface to nonsafety-related components.

The Q-DCIS uses RMUs for data acquisition for the RTIF, NMS, and SSLC/ESF protection systems and for safety-related displays in the Main Control Room (MCR) and Remote Shutdown System (RSS). These data acquisition and network communication units are either distributed within the division or reside in specific chassis and are not dedicated to specific RTIF, NMS, or SSLC/ESF protection systems.

For added reliability and diversity, the architecture of the RTIF and NMS protection systems is different from the architecture of the SSLC/ESF protection system (refer to Figure 7.1-3 and Figure 7.1-4). These systems operate automatically under normal conditions, without operator input.

The RTIF and NMS status is monitored on the divisional Q-DCIS safety-related MCR and RSS VDUs that are connected to the SSLC/ESF (the N-DCIS VDUs also have the capability to independently monitor the RTIF and NMS statuses but only after isolation and with no capability to control the Q-DCIS). The RTIF and NMS process and status data are sent per division through the required safety-related isolation and via a one-way dedicated communication path for display on the corresponding divisional safety-related VDU. The RTIF, NMS, and SSLC/ESF operate independently of the VDUs. They continue to perform their safety-related functions if there is a failure of the VDU network. The VDUs have no capability to control the RTIF or the NMS. Safety-related VDUs are provided in the MCR and at the RSS panels and operate independently of one another. The safety-related VDUs provide data display capability for the RTIF, NMS, and SSLC/ESF safety-related systems but manual control capability only for the SSLC/ESF safety-related systems in the same division as the safety-related VDU, all in a Human Factors Engineering (HFE) approved format.

power supplies or communications paths within a division fails, the division and VDU operation continue automatically, without operator intervention. Failures in three divisions are required before there is a loss of a safety-related function.

The Q-DCIS indications and alarms provided in the MCR, as a minimum, are :

- Q-DCIS MCR alarms for Division 1, 2, 3, and 4 trouble; and
- Q-DCIS MCR indications for Division 1, 2, 3, and 4 diagnostic displays.

7.1.2.7 Q-DCIS Boundary Summary

There are no Q-DCIS components in the N-DCIS. The Q-DCIS does not include the sensors or the sensor wiring to the RMUs or the RMU output wiring to the actuators.

7.1.2.8 Q-DCIS Major Systems Description Summary

The Q-DCIS systems and components include equipment for the Reactor Trip System (RTS), and Engineered Safety Features Actuation System (ESFAS). The RTS includes the RPS function, the SRNM and PRNM functions of the NMS, and the SPTM function of the CMS. The SSLC/ESF is the designated ESFAS. The automatic decision-making and trip logic functions associated with the safety-related RTS and ESFAS are accomplished by independent, separate, and diverse protection logic platforms, each using four logic-processing divisions. Input signals from redundant channels of safety-related instrumentation are used to perform logic operations that result in decisions for safety-related action through the associated actuation devices (for example, pilot solenoid valves, squib valves, and air operated valves). The Q-DCIS also includes the ICP platform and systems which include the ATWS/SLC functions, ~~the~~ VB isolation function, ~~and~~ HP CRD isolation bypass function, and ICS DPV isolation function.

7.1.2.8.1 Reactor Protection System Description Summary

The RPS implements the reactor trip functions. The RPS is the overall complex of instrument channels, trip logics, trip actuators, manual controls and scram logic circuitry that initiates rapid insertion of control rods to shut down the reactor in situations that could result in unsafe reactor operations. This action prevents or limits fuel damage and system pressure excursions, minimizing the release of radioactive material.

The RPS also establishes appropriate logic for different reactor operating modes, provides monitoring and control signals to other systems, and actuates alarms.

The RPS overrides selected operator actions and process controls and is based on a fail-safe design philosophy. The RPS design provides reliable, single failure-proof capability to automatically or manually initiate a reactor scram while maintaining protection against unnecessary scrams resulting from single failures. This is accomplished through the combination of fail-safe and fault-tolerant equipment design, and a two-out-of-four voting logic algorithm.

~~Although t~~The RTIF cabinets house the ~~RPS~~**ICP platform systems, which include**~~,~~ the ATWS/SLC functions, the VB isolation function, and the HP CRD isolation bypass function, the logics for the ATWS/SLC **functions**, VB isolation **function**, ~~and the~~ HP CRD isolation bypass **function, and ICS DPV isolation function.**~~functions~~ **Space consideration may dictate locating the ICP hardware in separate cabinets. The ICP** use**s** diverse hardware **from the other two Q-DCIS** platforms; RTIF-NMS and SSLC/ESF. The ICP logic function~~and their~~ designs are not fail-safe. The RPS hardware/software platform is diverse from the SSLC/ESF hardware/software, from the ICP hardware platform, ~~the VB isolation function, the ATWS/SLC , the HP CRD isolation bypass function,~~ and from the Diverse Protection System (DPS) hardware/software platforms~~;~~. T~~t~~he RPS and DPS sensors are diverse and RPS sensors are not shared with other Q-DCIS or N-DCIS systems.

7.1.2.8.2 Neutron Monitoring System Description Summary

The NMS monitors neutron flux in the reactor core from the startup source range to beyond rated power. The NMS provides logic signals to the RPS to automatically shut down the reactor when a condition necessitating a reactor scram is detected. The system provides indication of neutron flux that can be correlated with thermal power level for the entire range of flux conditions that can exist in the core. The NMS comprises the following systems.

- The SRNM system monitors thermal neutron flux levels from very low average power levels to a power level above 15% of rated power. Between 1% and 15% of rated power the monitoring function overlaps the LPRM/APRM systems functions to assure continuous monitoring of thermal neutron flux levels. The SRNM channel is able to provide local power information up to 100% of rated power. The SRNM system generates trip signals to prevent fuel damage resulting from abnormal positive reactivity insertions under conditions that are not covered by the APRMs. The SRNMs generate trips on high neutron flux and high rate of increase in neutron flux (i.e., high startup rate or short reactor period).
- The PRNM system includes the LPRM, the APRM, and the OPRM functions. The outputs of the individual LPRMs are averaged to provide the average power level of the reactor core, and the OPRM System provides monitoring of neutron flux and core thermal hydraulic instabilities.
- The Automatic Fixed In-core Probe (AFIP) is a nonsafety-related component of the NMS system and does not provide information to the Q-DCIS. It calibrates the LPRM system by providing neutron flux information to 3D MONICORE.
- The Multi-Channel Rod Block Monitor (MRBM) is a nonsafety-related component of the NMS system and is completely isolated from the Q-DCIS by one-way communication through qualified safety-related isolation devices and via fiber-optic cable communication. It provides control rod blocks to the Rod Control and Information System (RC&IS) to prevent core thermal limit violations.

7.1.2.8.3 SSLC/ESF System Description Summary

The SSLC/ESF is the overall ~~complex~~collection of instrument channels, trip logics, trip actuators, manual controls, and actuation logic circuitry that initiates protective action to mitigate the consequences of design basis events (DBEs). Input signals from redundant channels of safety-related instrumentation are used to make trip decisions and perform logic operations that result in accident mitigating actions. The SSLC/ESF provides the automatic decision-making and trip logic to actuate:

- The various ECCS;

- Leak detection, containment isolation, and radioactivity release barrier defense; and
- Control room habitability

7.1.2.8.3.1 Emergency Core Cooling System Description Summary

The ECCS provides emergency core cooling for events that threaten reactor coolant inventory, such as a Loss-of-Coolant-Accident (LOCA). The ECCS comprises the ADS, the GDCS, the ICS, and the SLC system. The ECCS function is discussed further in Subsection 7.3.1.

7.1.2.8.3.1.1 Automatic Depressurization System Description Summary

The ADS resides within the Nuclear Boiler System (NBS) and comprises Safety Relief Valves (SRVs), Depressurization Valves (DPVs), and associated I&C. The ADS depressurizes the reactor to allow the low head GDCS to provide makeup coolant to the reactor. The ADS logic resides in the SSLC/ESF portion of the Q-DCIS.

7.1.2.8.3.1.2 Gravity-Driven Cooling System Description Summary

Following the receipt of an actuation signal, the GDCS provides emergency core cooling when the reactor has been depressurized. The GDCS is capable of injecting large volumes of water into the Reactor Pressure Vessel (RPV) to keep the core covered for at least 72 hours following a LOCA. The GDCS also performs a deluge function that drains the GDCS pools to the lower drywell if a severe accident core melt sequence occurs. The GDCS deluge logic, which is nonsafety-related except for permissives to avoid inadvertent actuation, is separate and diverse from the Q-DCIS. The basic components of the GDCS are within the containment. The GDCS pools, piping, and valves are in the drywell. The suppression pool is on the outer periphery of the drywell within the containment envelope. The GDCS I&C is designed to:

- Automatically initiate the GDCS to prevent fuel cladding temperatures from reaching their limits;
- Respond to a need for emergency core cooling following reactor depressurization;
- Be completely automatic in operation. Manual initiation of the GDCS is possible at any time providing protective permissive conditions have been satisfied; and
- Prevent the inadvertent actuation of the deluge valves, thus preventing inadvertent draining of the GDCS pools.

7.1.2.8.3.1.3 Isolation Condenser System Description Summary

The ICS removes reactor decay heat following reactor shutdown and isolation. It also prevents unnecessary reactor depressurization and operation of the ECCS. The primary function of the ICS is to limit reactor pressure and prevent SRV operation following an isolation of the main steam lines. The ICS, together with the water stored in the RPV, provides sufficient reactor coolant volumes to avoid automatic depressurization caused by low reactor water level. The ICS passively removes excess sensible and core decay heat from the reactor, with minimal loss of coolant inventory from the reactor, when the normal heat removal systems are unavailable. The primary ICS logic resides in the SSLC/ESF platform~~portion~~ of the Q-DCIS. Refer to Subsection 7.4.4 for additional information.

The ICS DPV isolation function control logic is implemented in the ICP. Refer to Subsection 7.3.7 for additional information.

The nonsafety-related ICS vent function control logic is implemented in the DPS. Refer to Subsection 7.8.1.1 for additional information.

7.1.2.8.3.1.4 Standby Liquid Control System Description Summary

The SLC system performs dual functions. In its ECCS mode, it provides additional coolant inventory to respond to a LOCA. It is also a backup method for bringing the nuclear reactor to subcriticality, by adding soluble poison, and then maintaining subcriticality as the reactor cools.

The SLC system bases are discussed in Subsection 7.4.1. The SLC logic resides in the SSLC/ESF and the ATWS/SLC portions of the Q-DCIS.

7.1.2.8.3.2 Leak Detection and Isolation System Description Summary

The LD&IS monitors leakage sources from the Reactor Coolant Pressure Boundary (RCPB). It automatically initiates closure of the appropriate valves to isolate the source of the leak if monitored system variables exceed preset limits. This limits coolant release from the RCPB and, therefore, the release of radioactive materials into the environment. Refer to Subsection 7.3.3 for additional information.

The MSIV isolation logic of the LD&IS is fail-safe and therefore performed as part of the RTIF logic platform. The non-MSIV isolation logic of the LD&IS is performed as part of the SSLC/ESF logic platform.

7.1.2.8.3.3 Control Room Habitability System Description Summary

The primary function of the CRHS is to provide a safe environment for the operators to control the nuclear reactor and its auxiliary systems. The CRHS monitors the Control Room Habitability Area (CRHA) inlet ventilation air and actuates logic to isolate and filter the CRHA on detection of hazardous environmental conditions. The CRHS logic resides in the SSLC/ESF portion of the Q-DCIS.

7.1.2.8.4 ATWS/SLC System Description Summary

The ATWS mitigation logic provides a diverse means of reducing power excursions from certain transients and a diverse means of emergency shutdown. The ATWS mitigation logic, which uses the soluble boron injection capability of the SLC system as a diverse means of negative reactivity insertion, is implemented using the ICP as safety-related logic (designated as ATWS/SLC), and is diverse from the RTIF-NMS platform and the SSLC/ESF platform and therefore not susceptible to a common-cause failure. The ATWS/SLC logic also provides a feedwater run-back signal to attenuate power excursions.

In the event that the control rods cannot provide sufficient negative reactivity insertion, the SLC system provides the capability of an orderly and safe shutdown by a diverse means. In addition to providing hot shutdown capability, the SLC is sized to counteract the positive reactivity that results from shutting down from rated power to a cold shutdown condition. The SLC system can be initiated manually, or automatically via the ATWS mitigation logic or the SSLC/ESF logic as an ECCS function. (Refer to Subsection 7.1.2.8.3.1.4.) The SLC logic resides on the SSLC/ESF and ATWS/SLC portions of the Q-DCIS.

RTIF-NMS platform and the SSLC/ESF platform and not susceptible to a common-cause failure. Refer to Section 4.6 as well as Subsections 7.3.3 and 7.4.5 for additional information.

7.1.2.8.9 ICS DPV Isolation Function

The ICS DPV isolation function ensures that, upon detection of DPV open position, there is no loss of long-term containment integrity. It is implemented in the ICP platform. Refer to Section 7.3.7 for additional information.

7.1.3 Q-DCIS Specifics

The Q-DCIS architecture, its relationships, and its acceptance criteria are described below. The Q-DCIS data communication systems are embedded in the DCIS, which performs the data communication functions that are part of or support the systems described in Sections 7.2 through 7.8. A simplified network functional diagram of the DCIS appears as Figure 7.1-1, which shows the elements of the Q-DCIS and the N-DCIS, and is a functional representation of the design.

7.1.3.1 Q-DCIS Design Bases

7.1.3.1.1 Q-DCIS Safety-Related Design Bases

The safety-related design bases applicable to the Q-DCIS are found in IEEE Std. 603, Sections 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, and 4.12. These sections specify that the Q-DCIS:

- Reads signals from the safety-related instrumentation locally and through RMUs;
- Performs required signal conditioning, if this function is required, and then digitizes and formats the input signals into messages for transmission on the Q-DCIS network or data path;
- Transmits the data signals and commands onto the Q-DCIS network or data path for interface with other safety-related systems;
- Supports safety-related system monitoring and operator input to and from the MCR and RSS VDUs;
- Performs safety-related logic functions;
- Performs closed loop control and logic independently of the VDUs;
- Transmits the actuation signals to safety-related equipment via load drivers or contactors;
- Provides self-diagnostic and process alarm information to the operator; and
- Isolates data communication to and from the N-DCIS.

7.1.3.1.2 Q-DCIS Power Generation (Nonsafety-Related) Design Bases

The power generation design basis for the Q-DCIS is to transmit plant parameters and other safety-related system data through qualified safety-related isolation devices to the N-DCIS for use by nonsafety-related system logic and displays for power generation.

included in Section 7.8, and specifically addresses the issues of defense-in-depth and diversity and defense against common mode failures.

BTP HICB-16, Guidance on the Level of Detail Required for Design Certification Applications Under 10 CFR Part 52. BTP HICB-16 is applicable to all sections of Chapter 7 of the Design Control Document and all sections conform to it.

BTP HICB-16 states that the application should:

- Describe the resolution of unresolved and generic safety issues applicable to the I&C systems;
- Describe the interface requirements to be met by portions of the plant for which the application does not seek certification and which are necessary to ensure proper functioning of the I&C system; and
- Identify and describe the validation of innovative means of accomplishing I&C system safety-related functions.

Applications that propose the use of computers for systems with safety-related uses should describe the computer system development process. Applications that propose the use of computers for RTS and ESFAS functions should also describe the design of the overall I&C systems with respect to defense-in-depth and diversity requirements.

The I&C design has no unresolved or generic safety-related issues. The I&C related issues are either not applicable to safety-related I&C systems or are addressed by the safety-related I&C design. Within the scope of the DCD submitted for certification application, there are no interface requirements described here that fall into this category.

The design uses the voluminous data available from operating plants and from the testing and licensing efforts performed to license the predecessor designs and individual plants. The I&C design does not use innovative means for accomplishing safety functions.

BTP HICB-17, Guidance on Self-Test and Surveillance Test Provisions. Refer to Subsection 7.2.1.3.5 and 7.3.4.3 discussions. The Q-DCIS design conforms to BTP HICB-17.

BTP HICB-18, Guidance on the Use of Programmable Logic Controllers in Digital Computer-Based Instrumentation and Control Systems. The Q-DCIS design conforms to BTP HICB-18.

BTP HICB-19, Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems (Item II.Q of SECY-93-087). The Q-DCIS, DPS and associated N-DCIS interfacing systems design conform to BTP HICB-19. The implementation of an additional diverse instrumentation and control system is described in Section 7.8.

BTP HICB-21, Guidance on Digital Computer Real-Time Performance. The Q-DCIS design conforms to BTP HICB-21.

7.1.6.6 Industry Standards

The safety evaluation subsections throughout Chapter 7 address the RGs identified by the SRP. The IEEE standards that are endorsed by RGs are not addressed separately.

requirements may also be adopted as design bases for some nonsafety-related I&C components and systems such as for accident monitoring instrumentation, in accordance with RG 1.97. Compliance with the requirements of IEEE Std. 603 is also identified as compliance with the requirements and guidance contained within the federal regulations, GDC, SRM, and RGs, as described throughout Section 7.1. The safety-related I&C design comprises the Q-DCIS which includes the equipment in the RTIF~~,~~ (which may include ICP unless space consideration dictates locating the ICP hardware in separate cabinets), NMS, and SSLC/ESF cabinets. The design conforms to IEEE Std. 603. ITAACs are provided for the major attributes for compliance with IEEE Std. 603 and are not intended to limit the scope of compliance.

When the IEEE Std. 603 design criteria are applied to platforms relying on the use of software to perform their safety-related functions, additional criteria from IEEE Std. 7-4.3.2, which augments the IEEE Std. 603 criteria, also apply to the platform as described under the applicable IEEE Std. 603 criterion. The evaluation of Q-DCIS platforms for compliance with IEEE Std. 603 and IEEE Std. 7-4.3.2 criteria includes the examination of the effects that the associated sensors and actuators have on the performance of the safety-related function.

In accordance with the software development process described in Appendix 7B and the defense-in-depth and diversity strategy described in Section 7.8, the protection systems are executed as software projects on particular Q-DCIS platforms. The software projects are named RTIF, NMS, SSLC/ESF, VBIF, ATWS/SLC, ~~and~~ HP CRD, and ICS DPV isolation function.

Table 7B-1 shows the relationship between the Q-DCIS platforms and their corresponding software projects. As shown, the RTIF-NMS platform has two software projects: RTIF and NMS. The SSLC/ESF platform has one software project: SSLC/ESF. The Independent Control Platform has ~~three~~four software projects: VBIF, ATWS/SLC, ~~and~~ HP CRD, and ICS DPV isolation function.

7.1.6.6.1.1 Safety System Designation (IEEE Std. 603, Section 4, et al)

IEEE Std. 603, Section 4, requires that a specific basis be established for the design of each safety-related system. The designs of the Q-DCIS platforms are based on the abnormal events in Table 15.0-2.

Criterion 4.1 requires identification of the DBEs applicable to each mode of operation of the plant along with the initial conditions and allowable limits of plant conditions for each such event. Table 1.3-1 defines the reactor system design characteristics. Tables 15.0-3, 15.0-4, 15.0-5, and 15.0-6 define the safety-related analysis acceptance criteria for the anticipated operational occurrence (AOOs), infrequent events, special events, and accidents. Table 15.1-2 defines the ESBWR operating modes for the entire operating envelope. Table 15.1-3 defines the ESBWR abnormal events with applicable operating modes. Table 15.2-1 defines the input parameters, initial conditions, and assumptions for AOO events and infrequent events. Table 15.5-2 defines the initial conditions and bounding limits for ATWS events. Credited systems, interlocks, and functions for each DBE are described in Sections 15.2, 15.3, 15.4, and 15.5. Additional details about the specific safety-related or nonsafety-related interfacing system design bases, interlocks, and functions are found in Sections 4.6, 5.2, 5.4, 6.2, 6.3, 8.3, 9.1, 9.3, 9.4, 10.2, 10.3, and 10.4. Information provided for each design basis item enables the detailed design of the system to be carried out. Safety-related system design basis descriptions are included in the various sections of this chapter as indicated below.

Some codes or standards that are not mentioned in the SRP are used in specific system applications. These are identified in the system description and the corresponding reference section. In accordance with the SRP format, the following IEEE standards applicable to the I&C equipment are addressed in other chapters.

IEEE Std. 323, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations." Safety-related systems are designed to meet the requirements of IEEE Std. 323. Environmental qualification is addressed in Section 3.11.

IEEE Std. 344, "Recommended Practices for Seismic Qualification of Safety-related Equipment for Nuclear Power Generating Stations." Safety-related I&C equipment is classified as Seismic Category I and designed to withstand the effects of the safe shutdown earthquake (SSE). It remains functional during normal and accident conditions. Qualification and documentation procedures used for Seismic Category I equipment and systems satisfy the provisions of IEEE Std. 344 as indicated in Section 3.10.

IEEE Std. 379, "IEEE Standard for the Application of the Single Failure Criterion to Nuclear Power Generating Station Safety Systems." The three Q-DCIS platforms, RTIF-NMS, SSLC/ESF, ~~ATWS/SLC logic controllers, HP CRD isolation bypass logic controllers, and Vacuum Breaker Isolation Function (VBIF) logic controllers,~~and ICP are organized into four physically and electrically isolated divisions that use principles of redundancy and independence to conform to the single failure criterion.

IEEE Std. 383, "IEEE Standard for Type Test of Safety-related Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations." Electric cable conforms to this standard. Fiber-optic cable insulation/covering/jacketing also conforms to the requirements for flame tests in IEEE Std. 383.

IEEE Std. 384, "IEEE Standard Criteria for Independence of Safety-related Equipment and Circuits." See the discussion of RG 1.75 in Subsection 7.1.6.4.

IEEE Std. 497, "IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations." Accident monitoring instrumentation is discussed in Section 7.5.

IEEE Std. 518, "IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources." The design conforms to IEEE Std. 518.

IEEE Std. 603, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations." Conformance to IEEE Std. 603 is discussed in Subsection 7.1.6.6.1.

IEEE Std. 1050, "IEEE Guide for Instrumentation Control Equipment Grounding in Generating Stations." The design conforms to IEEE Std. 1050.

7.1.6.6.1 IEEE Std. 603 – IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations

The scope of IEEE Std. 603 includes safety-related I&C systems that are described in Sections 7.1 through 7.8. IEEE Std. 603 does not directly apply to nonsafety-related systems, other than to require independence between nonsafety-related systems and safety-related systems. IEEE Std. 603 provides design criteria for safety systems. ESBWR divides safety systems into two parts: the Q-DCIS platforms, and the subsystems that contain the sensors and actuators used by the Q-DCIS platforms. This section describes how the IEEE Std. 603 criteria are allocated to the different Q-DCIS platforms and subsystems. For convenience, some of these

- Reactor Trip System;
  - RPS (Subsection 7.2.1),
  - NMS (Subsection 7.2.2), and
  - Suppression Pool Temperature Monitoring (Subsection 7.2.3).
- SSLC/ESF (Subsection 7.3.5);
  - ECCS (Subsection 7.3.1):
    - ADS (Subsection 7.3.1.1),
    - GDCS (Subsection 7.3.1.2),
    - ICS (Subsection 7.4.4), and
    - SLC system (Subsection 7.4.1).
- PCCS (Subsection 7.3.2);
- LD&IS non-MSIV functions (Subsection 7.3.3) (MSIV functions of the LD&IS are located in the RTIF cabinets);
- CRHS (Subsection 7.3.4);
- RSS (Subsection 7.4.2);
- RWCU/SDC (Subsection 7.4.3);
- PAM system (Subsection 7.5.1);
- CMS (Subsection 7.5.2);
- PRMS (Subsection 7.5.3);
- ATWS/SLC (Subsection 7.8.1);
- CRHS (Subsection 7.5.2);
- VB isolation function (Subsection 7.3.6); ~~and~~
- HP CRD (Subsection 7.4.5); and
- ICS DPV isolation function (Subsection 7.3.7).

Criterion 4.2 requires identification of the safety-related functions and corresponding protective actions of the execute features for each event evaluated in the Nuclear Safety Operational Analysis (NSOA). Table 15.1-5 defines the execute systems required to respond to each event. Table 15.1-6 defines the automatic safety-related instrument trips in response to each event. Additionally, safety-related design bases for each system are discussed in the Safety Evaluation section for each applicable system as part of conformance to 10 CFR 50.55 a(h).

Criterion 4.3 requires identification of the permissive conditions for each operating bypass capability that is to be provided. Additionally, the permissive conditions for each operating bypass for each system are discussed in the Safety Evaluation section for each applicable system as part of conformance to 10 CFR 50.55 a(h).

The safety-related I&C that remains operable is qualified for the resulting temperature rise with passive heat removal. This scheme protects the equipment and maximizes operator comfort. Additional description of the HVAC design, including the use of room coolers powered by the ancillary diesel generators is included in Subsection 9.4.1 and Appendix 19A.

7.1.6.6.1.14 Multi-Unit Stations (IEEE Std. 603, Section 5.13)

The multi-unit station criteria do not apply to the standard single unit plant design submitted for NRC certification.

7.1.6.6.1.15 Human Factors Considerations (IEEE Std. 603, Section 5.14)

The I&C system design includes a HFE design process that is consistent with the requirements outlined in NUREG-0711, "Human Factors Engineering Program Review Model." The HFE process defines a comprehensive, iterative design approach for the development of a human-centered control and information infrastructure and is described in Chapter 18.

7.1.6.6.1.16 Reliability (IEEE Std. 603, Section 5.15)

The degree of redundancy, diversity, testability, and quality of the safety-related I&C design achieves the necessary functional reliability. Safety-related equipment is provided under GEH's 10 CFR 50 Appendix B Quality Assurance Program. The BTP HICB-14 and IEEE 7-4.3.2 (as endorsed by RG 1.152) guidance followed for software development processes achieves reliable software design and implementation. The Design Reliability Assurance Program (D-RAP) described in Section 17.4 confirms that any quantitative or qualitative reliability goals established for the protection systems have been met. To achieve defense against common mode failure, the design includes defense-in-depth and diversity measures including the incorporation of the DPS described in Section 7.8. Reference 7.1-4 provides specific information on the redundancy and diversity used in safety-related I&C systems. The Q-DCIS is included in the consideration of the probabilistic risk assessment (PRA). (Refer to Chapter 19.)

7.1.6.6.1.17 Automatic Control (IEEE Std. 603, Sections 6.1 and 7.1)

~~The RTIF-NMS, and ATWS/SLC logic automatically initiates reactor trip and the RTIF for LD&IS (non-MSIV), SSLC/ESF and VBIF logic automatically actuates the ESF that mitigate the consequences of DBEs.~~ The~~se~~ ESBWR automatic protection actions are implemented through two-out-of-four voting logic whenever one or more process variables reach their actuation setpoint. Variables are monitored and measured by each of the RTIF - NMS, ~~ATWS/SLC,~~ SSLC/ESF, and ~~VBIF~~ICP divisions.

Plant-specific setpoint analyses determine the protection systems' instrument setpoints using the methodology described in Reference 7.1-9. The GEH setpoint methodology uses plant-specific setpoint analyses to ensure that the combination of characteristics of the instruments such as range, accuracy and resolution provide the required high probability that the analytical limits in Chapter 15 analyses are not exceeded for the safety-related control system components and systems of the safety-related I&C. The response times of the I&C systems are assumed in the safety-related analyses and verified by plant specific surveillance testing or system analyses. The Q-DCIS application software, hardware processing rates, and internal and external communication system design ensures that the real-time performance of the safety-related control systems is deterministic.

7.1.6.6.1.18 Manual Control (IEEE Std. 603, Sections 6.2 and 7.2)

Each protective action can be manually initiated at the system level, in conformance to RG 1.62, and at the division level in conformance to IEEE Std. 603, Sections 6.2 and 7.2. The manual initiation satisfies divisional rules for independence and separation. Two manual actions, each in a separate division, are required in order to satisfy the two-out-of-two system logic or the two-out-of-four division logic that initiates a reactor trip in the RPS and ESF functions in the SSLC/ESF systems.

The operator can manually initiate the ESF and ICP functions by performing the appropriate action in two-out-of-four divisions; thus, satisfying the two-out-of-two system initiation logic. The ESF functions that use squib valves use a redundant two-step arm and fire sequence. This prevents single failures from firing or from inhibiting the firing of the squib valves. The squib valves are the GDCS pool injection valves, the suppression pool injection valves, the GDCS deluge valves, the ADS DPV, and the SLC injection valves. To manually initiate the GDCS short-term and long-term injection systems, a low-pressure signal must be present in the RPV. This prevents inadvertent manual initiation of the system during normal reactor operation.

The operator can manually initiate reactor emergency shutdown, reactor trip, with control rods by using any of three different methods using redundant or diverse controls. The manual reactor trip occurs independently of the automatic trip logic and sensor status.

The two manual scram switches, the Reactor Mode Switch, and the four divisional manual trip switches (per protective system) are located in the MCR and are easily accessible to the operator.

The two MCR manual scram switches, the RSS manual scram switches share no equipment with the automatic controls and require no software for their operation, and the DPS manual scram switches share a minimum of equipment with the automatic controls. The MCR and RSS manual scram switches are directly connected to the power feed for the load drivers that are, in turn, connected directly to the scram pilot valve solenoids. The DPS can manually scram by controlling both the HCU scram solenoid valves (by interrupting the current in the 120 VAC return from the solenoid) and the ARI scram air header dump valves.

After manual initiation, the protective actions go to completion in conformance to IEEE Std. 603, Section 5.2 as described in Subsection 7.1.6.6.1.3. The manual initiation of a protective action performs actions carried out by automatic initiation.

In the Q-DCIS design, protective actions are automatic. There are also no manual actions necessary to maintain safe conditions after the completion of protective actions for 72 hours after a DBE.

The manual controls are designed so that the information provided, display content and location are taken into consideration for operator access and action in the MCR. Further information about the design of manual controls and HFE considerations, as well as plant manual operation procedure requirements, are included in Chapter 18. Additionally, manual controls for each system are discussed in the Safety Evaluation section for each applicable system as part of conformance to 10 CFR 50.55 a(h).

Table 7.1-1
I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
10 CFR																									
~~50.55a(a)(1)~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~
~~50.55a(h)~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~	~~X~~				
50.34(f)(1)(v) [II.K.3.13]								X				X	X	X											
50.34(f)(1)(x) [II.K.3.28]												X													
50.34(f)(2)(iii) [I.D.1]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
50.34(f)(2)(iv) [I.D.2]																						X			
50.34(f)(2)(v) [I.D.3]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X
50.34(f)(2)(viii) [II.B.3]								X			X														
50.34(f)(2)(x) [II.D.1]								X			X														
50.34(f)(2)(xi) [II.D.3]								X				X													
50.34(f)(2)(xiv) [II.E.4.2]	X		X					X	X																

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)[6]	CMS (includes SPTM)[6]	NBS[6]	CRD[6]	NMS	SSLC/ESF[3]	LD&IS (non-MSIV)[1][6]	PRMS	CMS[6]	NBS (includes ADS)[6]	GDCS	ICS	SLC[6]	CBVS[2]	CRD[5][6]	VBIF	ATWS/SLC[4][6]	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
50.34(f)(2)(xv) [II.E.4.4]								X	X															X	
50.34(f)(2)(xvii) [II.F.1]								X		X	X														X
50.34(f)(2)(xviii) [II.F.2]								X				X													X
50.34(f)(2)(xix) [II.F.3]								X		X	X	X													X
50.34(f)(2)(xxi) [II.K.1.22]	X	X						X						X							X		X		
50.34(f)(2)(xxiii) [II.K.2.10]		X						X						X											
50.34(f)(2)(xxiv) [II.K.3.23]																									X
50.34(f)(2)(xxvii) [III.D.3.3]								X		X	X														X
50.34(f)(2)(xxviii) [III.D.3.4]								X		X						X									
50.43(e)[11]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
50.44(c)(4)								X			X														
50.49	Refer to Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification)																								

Table 7.1-1
I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
50.55a(a)(1)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
50.55a(h)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
50.62							X	X						X					X			X	X	X	
50.63	X	X	X			X		X	X				X	X		X									
52.47(a)(21)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
52.47(b)(1)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
52.47(a)(25)	N/A																								
52.47	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
52.47(c)(2)(11)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
GENERAL DESIGN CRITERIA																									
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																				N-DCIS			
	RTIF - NMS Platform						SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF					NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10	X	X					X																		
12	X	X					X															X			
13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
15	X		X					X	X			X													
16	X		X					X	X									X			X				
19	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
23	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)[6]	CMS (includes SPTM)[6]	NBS[6]	CRD[6]	NMS	SSLC/ESF[3]	LD&IS (non-MSIV)[1][6]	PRMS	CMS[6]	NBS (includes ADS)[6]	GDCS	ICS	SLC[6]	CBVS[2]	CRD[5][6]	VBIF	ATWS/SLC[4][6]	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
24	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
25	X	X					X															X			
26	X	X				X	X												X			X			
27	X	X				X	X												X			X			
28																	X					X			
29	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
30								X	X			X													
33								X				X	X	X							X		X		
34								X						X							X				
35								X				X	X	X	X				X		X				
37								X				X	X	X	X				X		X				

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
38																							X		
41								X			X													X	
42																								X	
43								X			X													X	
44														X											
63								X																	X
64								X		X	X														X
Staff Requirements Memoranda on SECY 93-087																									
II.Q	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
II.T								X														X			X
Regulatory Guides (RG)																									
1.22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				

Table 7.1-1
I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)[6]	CMS (includes SPTM)[6]	NBS[6]	CRD[6]	NMS	SSLC/ESF[3]	LD&IS (non-MSIV)[1][6]	PRMS	CMS[6]	NBS (includes ADS)[6]	GDCS	ICS	SLC[6]	CBVS[2]	CRD[5][6]	VBIF	ATWS/SLC[4][6]	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
1.45								X	X	X	X														
1.47	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.53	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.62	X	X	X					X	X			X	X	X		X		X	X	X	X				
1.75	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.89	Refer to Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification)																								
1.97[10]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.100	Refer to Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification)																								
1.105	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1.118	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.151 [8]		X		X	X	X			X		X	X	X	X	X				X	X			X	X	
1.152[7]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
1.153	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.168(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.169(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.170(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.171(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.172(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.173(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1.180(9)	Refer to Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification)																								
1.204	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
1.209	Refer to Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification)																								
Branch Technical Positions (BTP)																									
BTP HICB-3	N/A																								

Table 7.1-1
I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)(6)	CMS (includes SPTM)(6)	NBS(6)	CRD(6)	NMS	SSLC/ESF(3)	LD&IS (non-MSIV)(1)(6)	PRMS	CMS(6)	NBS (includes ADS)(6)	GDCS	ICS	SLC(6)	CBVS(2)	CRD(5)(6)	VBIF	ATWS/SLC(4)(6)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
BTP HICB-6	N/A																								
BTP HICB-8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
BTP HICB-9	X	X				X																			
BTP HICB-10(10)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BTP HICB-11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
BTP HICB-12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
BTP HICB-13	N/A																								
BTP HICB-14(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
BTP HICB-16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BTP HICB-17(7)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
BTP HICB-18(7)	X	X					X	X										X	X	X	X				

Table 7.1-1

I&C Regulatory Requirements Applicability Matrix

	Q-DCIS																					N-DCIS			
	RTIF - NMS Platform							SSLC/ESF Platform										Independent Control Platform				Network Segments			
	RTIF						NMS																		
Applicable Criteria Guidelines: SRP NUREG-0800, Section 7.1	RTIF	RPS	LD&IS (MSIV Only)[6]	CMS (includes SPTM)[6]	NBS[6]	CRD[6]	NMS	SSLC/ESF[3]	LD&IS (non-MSIV)[1][6]	PRMS	CMS[6]	NBS (includes ADS)[6]	GDCS	ICS	SLC[6]	CBVS[2]	CRD[5][6]	VBIF	ATWS/SLC[4][6]	HP CRD Isolation Bypass Function	ICS DPV Isolation Function	GENE	PIP A/B	BOP	PCF
BTP HICB-19[7]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
BTP HICB-21[7]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				

Notes:

(1) LD&IS (non-MSIV) controls the safety-related actuators (for the isolation valves and dampers) associated with the following nonsafety-related systems: RWCU/SDC, FAPCS, EFDS, CIS, CWS, CMS, HPNSS, RBVS, and FBVS. RWCU/SDC provides safety-related sensor inputs to LD&IS (non-MSIV). The regulatory requirements associated with these actuators and sensors are addressed as part of LD&IS.

(2) CBVS includes the CRHS and Control Room Habitability Area HVAC Subsystem (CRHAVS) and EFUs.

(3) SSLC/ESF includes RSS, MCRP and safety-related VDUs.

(4) Includes the NBS sensors associated with ATWS/SLC.

(5) SSLC/ESF platform column for CRD includes safety-related sensors associated with control rod separation detection.

(6) The following safety-related systems have logic implemented on multiple platforms in support of their protective functions: CMS, CRD, LD&IS, NBS and SLC. Refer to DCD Sections 7.2, 7.3, 7.4, and 7.5 for detailed descriptions of the system functions.

(7) These criteria are addressed with digital computer-related functions of the Q-DCIS and N-DCIS.

(8) Sections of the ISA standard that are not specific to safety-related systems, but provide guidance on design practices for tubing, vents and drains apply to the systems associated with the N-DCIS network segments.

(9) Hardware associated with the N-DCIS network segments uses industrial methods for EMI/EMF/RFI/EMC compliance.

(10) The ESBWR I&C conforms to RG 1.97 and applies the guidance in IEEE std. 497. RG 1.97 endorses IEEE Std. 497 (with clarifications and exceptions stated in RG 1.97) and the use of the HFE development process to determine the human actions during and following accident scenarios. Specific instruments credited for RG 1.97 compliance are determined as part of the HFE development process as discussed in Section 7.5.

(11) The use of other innovative means as described in 10 CFR 52.47(c)(2) in the design of the three Q-DCIS platforms (RTIF-NMS, SSLC/ESF and ICP) may occur as part of the development process. If it does, then the software projects executed per the software development process described in Appendix 7B will conform to the requirements of 10 CFR 50.43(e).

Table 7.1-2

I&C Systems - IEEE Std. 603 Criteria Compliance Cross-Reference

		Q-DCIS																				
		RTIF - NMS PLATFORM							SSLC/ESF PLATFORM										INDEPENDENT CONTROL PLATFORM			
		RTIF						NMS														
IEEE Std. 603 Section	Functions (1)	RTIF	RPS	LD&IS (MSIV Only) (6)	CMS (includes SPTM) (6)	NBS (6)	CRD (6)	NMS (3)	SSLC/ESF (4)	LD&IS (Non-MSIV) (2)&(6)	PRMS	CMS (6)	NBS (includes ADS) (6)	GDCS	ICS	SLC (6)	CBVS (7)	CRD (6)	VBIF	ATWS / SLC (5),(6)&(7)	HP CRD Isolation Bypass Function	<u>ICS DPV Isolation Function</u>
4.1	Design basis events	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.2	Safety-related functions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1 7.5.5.3.1	7.1.6.6.1.1 7.5.5.3.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.3	Permissive conditions for operating bypasses	7.1.6.6.1.1	7.1.6.6.1.1 7.2.1.3.1	7.1.6.6.1.1 7.3.3.3.1	7.1.6.6.1.1 7.2.3.3.1	7.1.6.6.1.1 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.1	7.1.6.6.1.1 7.2.2.3.1	7.1.6.6.1.1 7.3.5.3.1	7.1.6.6.1.1 7.3.3.3.1	7.1.6.6.1.1 7.5.3.3.1	7.1.6.6.1.1 7.5.2.3.1	7.1.6.6.1.1	7.1.6.6.1.1 7.3.1.2.3.1	7.1.6.6.1.1 7.4.4.3.1	7.1.6.6.1.1 7.4.1.3.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1 7.3.6.3.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.4	Monitored variables, and associated analytical limits	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.5	Minimum criteria for manual actions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.6	Spatially dependent variables	7.1.6.6.1.1	7.1.6.6.1.1 7.2.1.3.1	7.1.6.6.1.1 7.3.3.3.1	7.1.6.6.1.1 7.2.3.3.1	7.1.6.6.1.1 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.1	7.1.6.6.1.1 7.2.2.3.1	7.1.6.6.1.1 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.1 7.3.3.3.1	7.1.6.6.1.1 7.5.3.3.1	7.1.6.6.1.1 7.5.2.3.1	7.1.6.6.1.1	7.1.6.6.1.1 7.3.1.2.3.1	7.1.6.6.1.1 7.4.4.3.1	7.1.6.6.1.1 7.4.1.3.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1 7.3.6.3.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.7	Range of transient and steady-state conditions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.8	Adverse environmental conditions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.9	Reliability methods	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.10	Abnormal Event critical times / conditions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>
4.11	Equipment protective provisions	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	<u>7.1.6.6.1.1</u>

Table 7.1-2

I&C Systems - IEEE Std. 603 Criteria Compliance Cross-Reference

		Q-DCIS																				
		RTIF - NMS PLATFORM							SSLC/ESF PLATFORM										INDEPENDENT CONTROL PLATFORM			
		RTIF						NMS														
IEEE Std. 603 Section	Functions (1)	RTIF	RPS	LD&IS (MSIV Only) (6)	CMS (includes SPTM) (6)	NBS (6)	CRD (6)	NMS (3)	SSLC/ESF (4)	LD&IS (Non-MSIV) (2)&(6)	PRMS	CMS (6)	NBS (includes ADS) (6)	GDCS	ICS	SLC (6)	CBVS (7)	CRD (6)	VBIF	ATWS / SLC (5),(6)&(7)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function
4.12	Special design basis	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1	7.1.6.6.1.1
5.1	Single failure criterion	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2	7.1.6.6.1.2
5.2	Completion of protective action	7.1.6.6.1.3	7.1.6.6.1.3 7.2.1.3.1	7.1.6.6.1.3 7.3.3.3.1	7.1.6.6.1.3 7.2.3.3.1	7.1.6.6.1.3 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.3	7.1.6.6.1.3 7.2.2.3.1	7.1.6.6.1.3 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.3 7.3.3.3.1	7.1.6.6.1.3 7.5.3.3.1	7.1.6.6.1.3 7.5.2.3.1	7.1.6.6.1.3	7.1.6.6.1.3 7.3.1.2.3.1	7.1.6.6.1.3 7.4.4.3.1	7.1.6.6.1.3 7.4.1.3.1	7.1.6.6.1.3	7.1.6.6.1.3	7.1.6.6.1.3 7.3.6.3.1	7.1.6.6.1.3	7.1.6.6.1.3	7.1.6.6.1.3
5.3	Quality	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4	7.1.6.6.1.4
5.4	Equipment qualification	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5	7.1.6.6.1.5
5.5	System Integrity	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6	7.1.6.6.1.6
5.6	Independence	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7	7.1.6.6.1.7
5.7	Capability for test and calibration	7.1.6.6.1.8	7.1.6.6.1.8 7.2.1.3.1	7.1.6.6.1.8 7.3.3.3.1	7.1.6.6.1.8 7.2.3.3.1	7.1.6.6.1.8 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.8	7.1.6.6.1.8 7.2.2.3.1	7.1.6.6.1.8 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.8 7.3.3.3.1	7.1.6.6.1.8 7.5.3.3.1	7.1.6.6.1.8 7.5.2.3.1	7.1.6.6.1.8	7.1.6.6.1.8 7.3.1.2.3.1	7.1.6.6.1.8 7.4.4.3.1	7.1.6.6.1.8 7.4.1.3.1	7.1.6.6.1.8	7.1.6.6.1.8	7.1.6.6.1.8 7.3.6.3.1	7.1.6.6.1.8	7.1.6.6.1.8	7.1.6.6.1.8 7.3.7.4
5.8	Information displays	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9	7.1.6.6.1.9
5.9	Control of Access	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10	7.1.6.6.1.10
5.10.	Repair	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11	7.1.6.6.1.11
5.11	Identification	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12	7.1.6.6.1.12
5.12	Auxiliary features	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13	7.1.6.6.1.13
5.13	Multi-unit stations	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14	7.1.6.6.1.14
5.14	Human factors considerations	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15	7.1.6.6.1.15
5.15	Reliability	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16	7.1.6.6.1.16
6.1	Automatic Control	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17

Table 7.1-2

I&C Systems - IEEE Std. 603 Criteria Compliance Cross-Reference

		Q-DCIS																				
		RTIF - NMS PLATFORM							SSLC/ESF PLATFORM											INDEPENDENT CONTROL PLATFORM			
		RTIF						NMS														
IEEE Std. 603 Section	Functions (1)	RTIF	RPS	LD&IS (MSIV Only) (6)	CMS (includes SPTM) (6)	NBS (6)	CRD (6)	NMS (3)	SSLC/ESF (4)	LD&IS (Non-MSIV) (2)&(6)	PRMS	CMS (6)	NBS (includes ADS) (6)	GDCS	ICS	SLC (6)	CBVS (7)	CRD (6)	VBIF	ATWS / SLC (5),(6)&(7)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function
6.2	Manual control	7.1.6.6.1.18	7.1.6.6.1.18 7.2.1.3.1	7.1.6.6.1.18 7.3.3.3.1	7.1.6.6.1.18 7.2.3.3.1	7.1.6.6.1.18 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.18	7.1.6.6.1.18 7.2.2.3.1	7.1.6.6.1.18 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.18 7.3.3.3.1	7.1.6.6.1.18 7.5.3.3.1	7.1.6.6.1.18 7.5.2.3.1	7.1.6.6.1.18	7.1.6.6.1.18 7.3.1.2.3.1	7.1.6.6.1.18 7.4.4.3.1	7.1.6.6.1.18 7.4.1.3.1	7.1.6.6.1.18	7.1.6.6.1.18	7.1.6.6.1.18 7.3.6.3.1	7.1.6.6.1.18	7.1.6.6.1.18	7.1.6.6.1.18 7.3.7.3.1
6.3	Interaction between the sense and command features and other systems	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19	7.1.6.6.1.19
6.4	Derivation of system inputs	7.1.6.6.1.20	7.1.6.6.1.20 7.2.1.3.1	7.1.6.6.1.20 7.3.3.3.1	7.1.6.6.1.20 7.2.3.3.1	7.1.6.6.1.20 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.20	7.1.6.6.1.20 7.2.2.3.1	7.1.6.6.1.20 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.20 7.3.3.3.1	7.1.6.6.1.20 7.5.3.3.1	7.1.6.6.1.20 7.5.2.3.1	7.1.6.6.1.20	7.1.6.6.1.20 7.3.1.2.3.1	7.1.6.6.1.20 7.4.4.3.1	7.1.6.6.1.20 7.4.1.3.1	7.1.6.6.1.20	7.1.6.6.1.20	7.1.6.6.1.20 7.3.6.3.1	7.1.6.6.1.20	7.1.6.6.1.20	7.1.6.6.1.20 7.3.7.3.1
6.5	Capability for testing and calibration	7.1.6.6.1.21	7.1.6.6.1.21 7.2.1.3.1	7.1.6.6.1.21 7.3.3.3.1	7.1.6.6.1.21 7.2.3.3.1	7.1.6.6.1.21 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.21	7.1.6.6.1.21 7.2.2.3.1	7.1.6.6.1.21 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.21 7.3.3.3.1	7.1.6.6.1.21 7.5.3.3.1	7.1.6.6.1.21 7.5.2.3.1	7.1.6.6.1.21	7.1.6.6.1.21 7.3.1.2.3.1	7.1.6.6.1.21 7.4.4.3.1	7.1.6.6.1.21 7.4.1.3.1	7.1.6.6.1.21	7.1.6.6.1.21	7.1.6.6.1.21 7.3.6.3.1	7.1.6.6.1.21	7.1.6.6.1.21	7.1.6.6.1.21 7.3.7.3.1
6.6	Operating bypasses	7.1.6.6.1.22	7.1.6.6.1.22 7.2.1.3.1	7.1.6.6.1.22 7.3.3.3.1	7.1.6.6.1.22 7.2.3.3.1	7.1.6.6.1.22 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.22	7.1.6.6.1.22 7.2.2.3.1	7.1.6.6.1.22 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.22 7.3.3.3.1	7.1.6.6.1.22 7.5.3.3.1	7.1.6.6.1.22 7.5.2.3.1	7.1.6.6.1.22	7.1.6.6.1.22 7.3.1.2.3.1	7.1.6.6.1.22 7.4.4.3.1	7.1.6.6.1.22 7.4.1.3.1	7.1.6.6.1.22	7.1.6.6.1.22	7.1.6.6.1.22 7.3.6.3.1	7.1.6.6.1.22	7.1.6.6.1.22	7.1.6.6.1.22 7.3.7.3.1
6.7	Maintenance bypass	7.1.6.6.1.23	7.1.6.6.1.23 7.2.1.3.1	7.1.6.6.1.23 7.3.3.3.1	7.1.6.6.1.23 7.2.3.3.1	7.1.6.6.1.23 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.23	7.1.6.6.1.23 7.2.2.3.1	7.1.6.6.1.23 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.23 7.3.3.3.1	7.1.6.6.1.23 7.5.3.3.1	7.1.6.6.1.23 7.5.2.3.1	7.1.6.6.1.23	7.1.6.6.1.23 7.3.1.2.3.1	7.1.6.6.1.23 7.4.4.3.1	7.1.6.6.1.23 7.4.1.3.1	7.1.6.6.1.23	7.1.6.6.1.23	7.1.6.6.1.23 7.3.6.3.1	7.1.6.6.1.23	7.1.6.6.1.23	7.1.6.6.1.23 7.3.7.3.1
6.8	Setpoints	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24	7.1.6.6.1.24
7.1	Automatic Control	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17	7.1.6.6.1.17

Table 7.1-2

I&C Systems - IEEE Std. 603 Criteria Compliance Cross-Reference

		Q-DCIS																				
		RTIF - NMS PLATFORM							SSLC/ESF PLATFORM										INDEPENDENT CONTROL PLATFORM			
		RTIF						NMS														
IEEE Std. 603 Section	Functions (1)	RTIF	RPS	LD&IS (MSIV Only) (6)	CMS (includes SPTM) (6)	NBS (6)	CRD (6)	NMS (3)	SSLC/ESF (4)	LD&IS (Non-MSIV) (2)&(6)	PRMS	CMS (6)	NBS (includes ADS) (6)	GDCS	ICS	SLC (6)	CBVS (7)	CRD (6)	VBIF	ATWS / SLC (5),(6)&(7)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function
7.2	Manual control	7.1.6.6.1.18	7.1.6.6.1.18 7.2.1.3.1	7.1.6.6.1.18 7.3.3.3.1	7.1.6.6.1.18 7.2.3.3.1	7.1.6.6.1.18 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.18	7.1.6.6.1.18 7.2.2.3.1	7.1.6.6.1.18 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.18 7.3.3.3.1	7.1.6.6.1.18 7.5.3.3.1	7.1.6.6.1.18 7.5.2.3.1	7.1.6.6.1.18	7.1.6.6.1.18 7.3.1.2.3.1	7.1.6.6.1.18 7.4.4.3.1	7.1.6.6.1.18 7.4.1.3.1	7.1.6.6.1.18	7.1.6.6.1.18	7.1.6.6.1.18 7.3.6.3.1	7.1.6.6.1.18	7.1.6.6.1.18	7.1.6.6.1.18 7.3.7.3.1
7.3	Completion of protective action	7.1.6.6.1.3	7.1.6.6.1.3 7.2.1.3.1	7.1.6.6.1.3 7.3.3.3.1	7.1.6.6.1.3 7.2.3.3.1	7.1.6.6.1.3 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.3	7.1.6.6.1.3 7.2.2.3.1	7.1.6.6.1.3 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.3 7.3.3.3.1	7.1.6.6.1.3 7.5.3.3.1	7.1.6.6.1.3 7.5.2.3.1	7.1.6.6.1.3	7.1.6.6.1.3 7.3.1.2.3.1	7.1.6.6.1.3 7.4.4.3.1	7.1.6.6.1.3 7.4.1.3.1	7.1.6.6.1.3	7.1.6.6.1.3	7.1.6.6.1.3 7.3.6.3.1	7.1.6.6.1.3	7.1.6.6.1.3	7.1.6.6.1.3 7.3.7.3.1
7.4	Operating bypass	7.1.6.6.1.22	7.1.6.6.1.22 7.2.1.3.1	7.1.6.6.1.22 7.3.3.3.1	7.1.6.6.1.22 7.2.3.3.1	7.1.6.6.1.22 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.22	7.1.6.6.1.22 7.2.2.3.1	7.1.6.6.1.22 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.22 7.3.3.3.1	7.1.6.6.1.22 7.5.3.3.1	7.1.6.6.1.22 7.5.2.3.1	7.1.6.6.1.22	7.1.6.6.1.22 7.3.1.2.3.1	7.1.6.6.1.22 7.4.4.3.1	7.1.6.6.1.22 7.4.1.3.1	7.1.6.6.1.22	7.1.6.6.1.22	7.1.6.6.1.22 7.3.6.3.1	7.1.6.6.1.22	7.1.6.6.1.22	7.1.6.6.1.22 7.3.7.3.1
7.5	Maintenance bypass	7.1.6.6.1.23	7.1.6.6.1.23 7.2.1.3.1	7.1.6.6.1.23 7.3.3.3.1	7.1.6.6.1.23 7.2.3.3.1	7.1.6.6.1.23 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.23	7.1.6.6.1.23 7.2.2.3.1	7.1.6.6.1.23 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.23 7.3.3.3.1	7.1.6.6.1.23 7.5.3.3.1	7.1.6.6.1.23 7.5.2.3.1	7.1.6.6.1.23	7.1.6.6.1.23 7.3.1.2.3.1	7.1.6.6.1.23 7.4.4.3.1	7.1.6.6.1.23 7.4.1.3.1	7.1.6.6.1.23	7.1.6.6.1.23	7.1.6.6.1.23 7.3.6.3.1	7.1.6.6.1.23	7.1.6.6.1.23	7.1.6.6.1.23 7.3.7.3.1
8.1	Electrical power sources	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25	7.1.6.6.1.25
8.2	Non-electrical power sources	7.1.6.6.1.26	7.1.6.6.1.26 7.2.1.3.1	7.1.6.6.1.26 7.3.3.3.1	7.1.6.6.1.26 7.2.3.3.1	7.1.6.6.1.26 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.26	7.1.6.6.1.26 7.2.2.3.1	7.1.6.6.1.26 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.26 7.3.3.3.1	7.1.6.6.1.26 7.5.3.3.1	7.1.6.6.1.26 7.5.2.3.1	7.1.6.6.1.26	7.1.6.6.1.26 7.3.1.2.3.1	7.1.6.6.1.26 7.4.4.3.1	7.1.6.6.1.26 7.4.1.3.1	7.1.6.6.1.26	7.1.6.6.1.26	7.1.6.6.1.26 7.3.6.3.1	7.1.6.6.1.26	7.1.6.6.1.26	7.1.6.6.1.26 7.3.7.3.1

Table 7.1-2

I&C Systems - IEEE Std. 603 Criteria Compliance Cross-Reference

		Q-DCIS																				
		RTIF - NMS PLATFORM							SSLC/ESF PLATFORM										INDEPENDENT CONTROL PLATFORM			
		RTIF						NMS														
IEEE Std. 603 Section	Functions (1)	RTIF	RPS	LD&IS (MSIV Only) (6)	CMS (includes SPTM) (6)	NBS (6)	CRD (6)	NMS (3)	SSLC/ESF (4)	LD&IS (Non-MSIV) (2)&(6)	PRMS	CMS (6)	NBS (includes ADS) (6)	GDCS	ICS	SLC (6)	CBVS (7)	CRD (6)	VBIF	ATWS / SLC (5),(6)&(7)	HP CRD Isolation Bypass Function	ICS DPV Isolation Function
8.3	Maintenance Bypass	7.1.6.6.1.27	7.1.6.6.1.27 7.2.1.3.1	7.1.6.6.1.27 7.3.3.3.1	7.1.6.6.1.27 7.2.3.3.1	7.1.6.6.1.27 7.2.1.3.1 7.3.1.2.3.1 7.3.3.3.1 7.3.5.3.1	7.1.6.6.1.27	7.1.6.6.1.27 7.2.2.3.1	7.1.6.6.1.27 7.3.5.3.1 7.4.2.3.1	7.1.6.6.1.27 7.3.3.3.1	7.1.6.6.1.27 7.5.3.3.1	7.1.6.6.1.27 7.5.2.3.1	7.1.6.6.1.27	7.1.6.6.1.27 7.3.1.2.3.1	7.1.6.6.1.27 7.4.4.3.1	7.1.6.6.1.27 7.4.1.3.1	7.1.6.6.1.27	7.1.6.6.1.27	7.1.6.6.1.27 7.3.6.3.1	7.1.6.6.1.27	7.1.6.6.1.27	7.1.6.6.1.27 7.3.7.3.1

Notes:

(1) The IEEE Std. 603 criteria apply to the safety-related portions of the systems identified in this table.

(2) LD&IS (non-MSIV) controls the safety-related actuators (for the isolation valves and dampers) associated with the following nonsafety-related systems: RWCU/SDC, FAPCS, EFDS, CIS, CWS, CMS, HPNSS, RBVS, and FBVS. RWCU/SDC provides safety-related sensor inputs to LD&IS (non-MSIV). The regulatory requirements associated with these actuators and sensors are addressed as part of LD&IS.

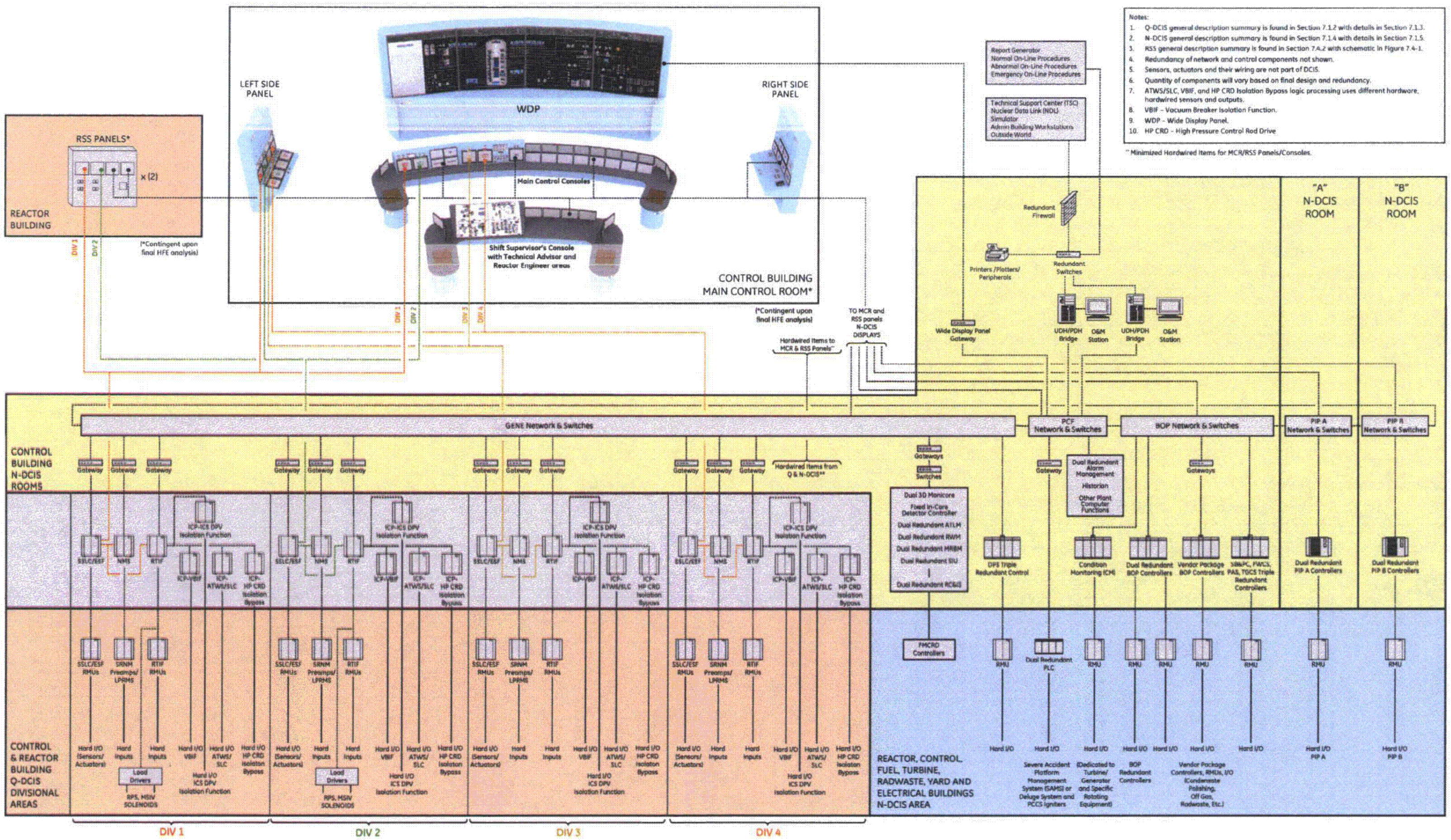
(3) NMS has Q and N parts. The Q parts are SRNM, LPRM, APRM, and OPRM. The N parts are AFIP and MRBM.

(4) SSLC/ESF includes the RSS, MCRP, and safety-related VDUs.

(5) Includes the NBS sensors associate with ATWS/SLC.

(6) The following safety-related systems have logic implemented on multiple platforms in support of their protective functions: CMS, CRD, LD&IS, NBS and SLC. Refer to DCD Sections 7.2, 7.3, 7.4, and 7.5 for detailed descriptions of the system functions.

(7) CBVS includes the CRHS and CRHAVS subsystems and EFUs.


Notes:
1. Q-DCIS general description summary is found in Section 7.1.2 with details in Section 7.1.3.
2. N-DCIS general description summary is found in Section 7.1.4 with details in Section 7.1.5.
3. RSS general description summary is found in Section 7.4.2 with schematic in Figure 7.4-1.
4. Redundancy of network and control components not shown.
5. Sensors, actuators and their wiring are not part of DCIS.
6. Quantity of components will vary based on final design and redundancy.
7. ATWS/SLC, VBIF, and HP CRD Isolation Bypass logic processing uses different hardware, hardwired sensors and outputs.
8. VBIF – Vacuum Breaker Isolation Function.
9. WDP – Wide Display Panel.
10. HP CRD – High Pressure Control Rod Drive
** Minimized Hardwired Items for MCR/RSS Panels/Consoles.
RSS PANELS*
x (2)
REACTOR BUILDING
(*Contingent upon final HFE analysis)
LEFT SIDE PANEL
WDP
RIGHT SIDE PANEL
Main Control Consoles
Shift Supervisor's Console with Technical Advisor and Reactor Engineer areas
CONTROL BUILDING MAIN CONTROL ROOM*
(*Contingent upon final HFE analysis)
Hardwired Items to MCR & RSS Panels**
TO MCR and RSS panels N-DCIS DISPLAYS
"A" N-DCIS ROOM
"B" N-DCIS ROOM
GENE Network & Switches
PCF Network & Switches
BOP Network & Switches
PIP A Network & Switches
PIP B Network & Switches
CONTROL BUILDING N-DCIS ROOMS
CONTROL & REACTOR BUILDING Q-DCIS DIVISIONAL AREAS
REACTOR, CONTROL, FUEL, TURBINE, RADWASTE, YARD AND ELECTRICAL BUILDINGS N-DCIS AREA
DIV 1
DIV 2
DIV 3
DIV 4

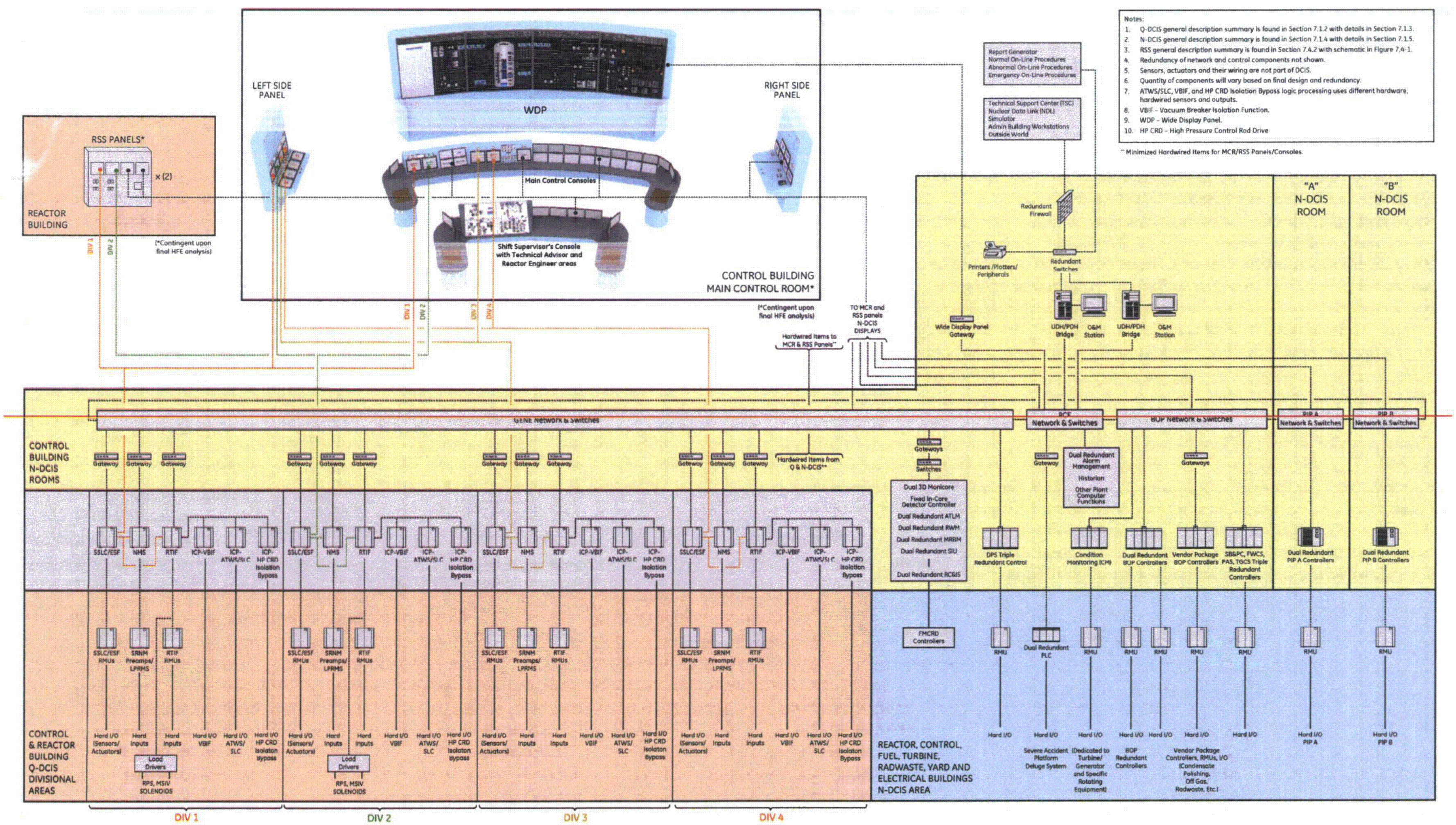
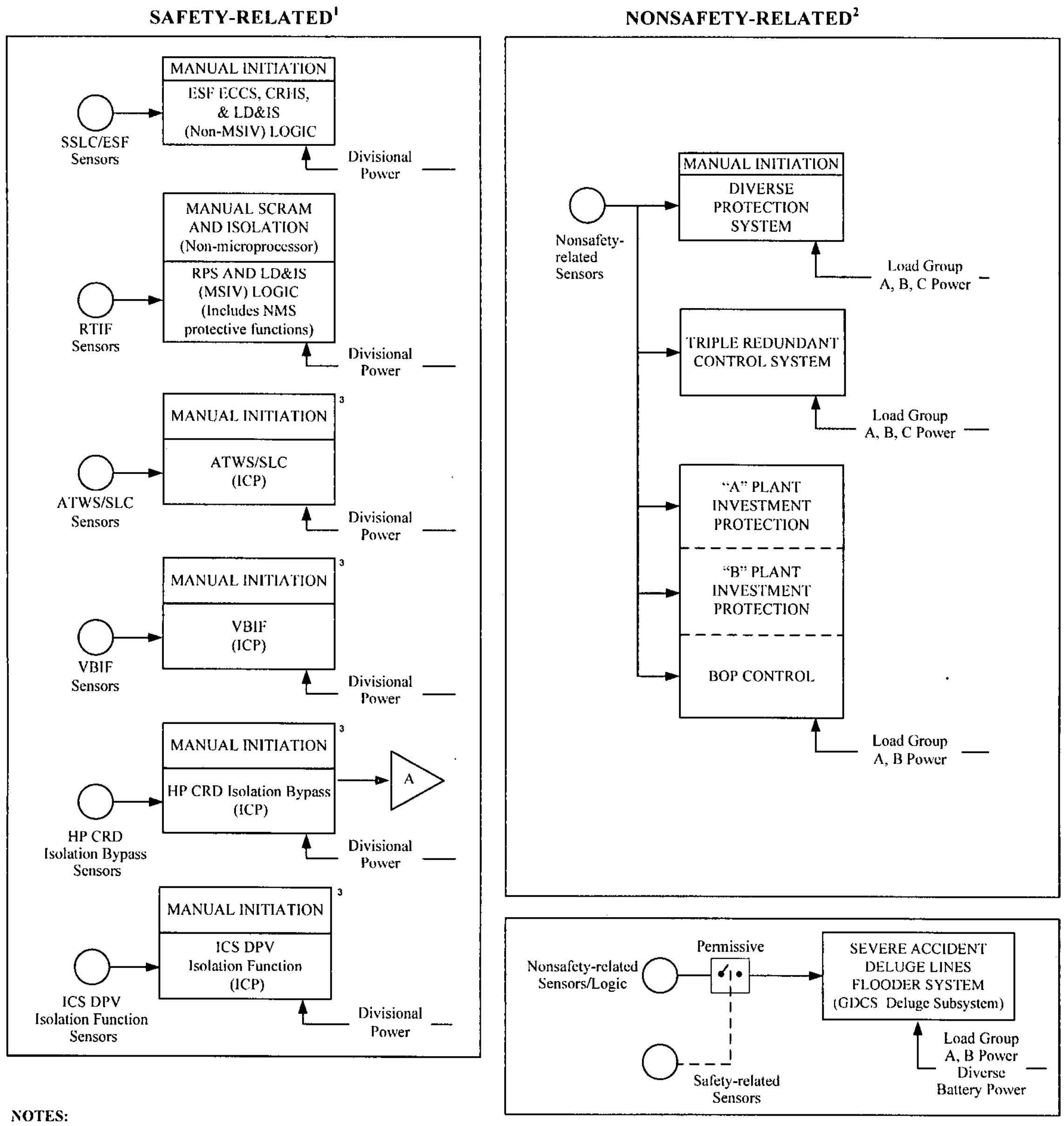
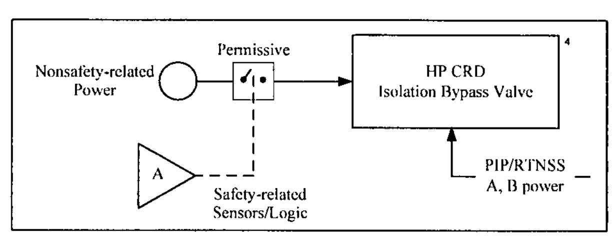


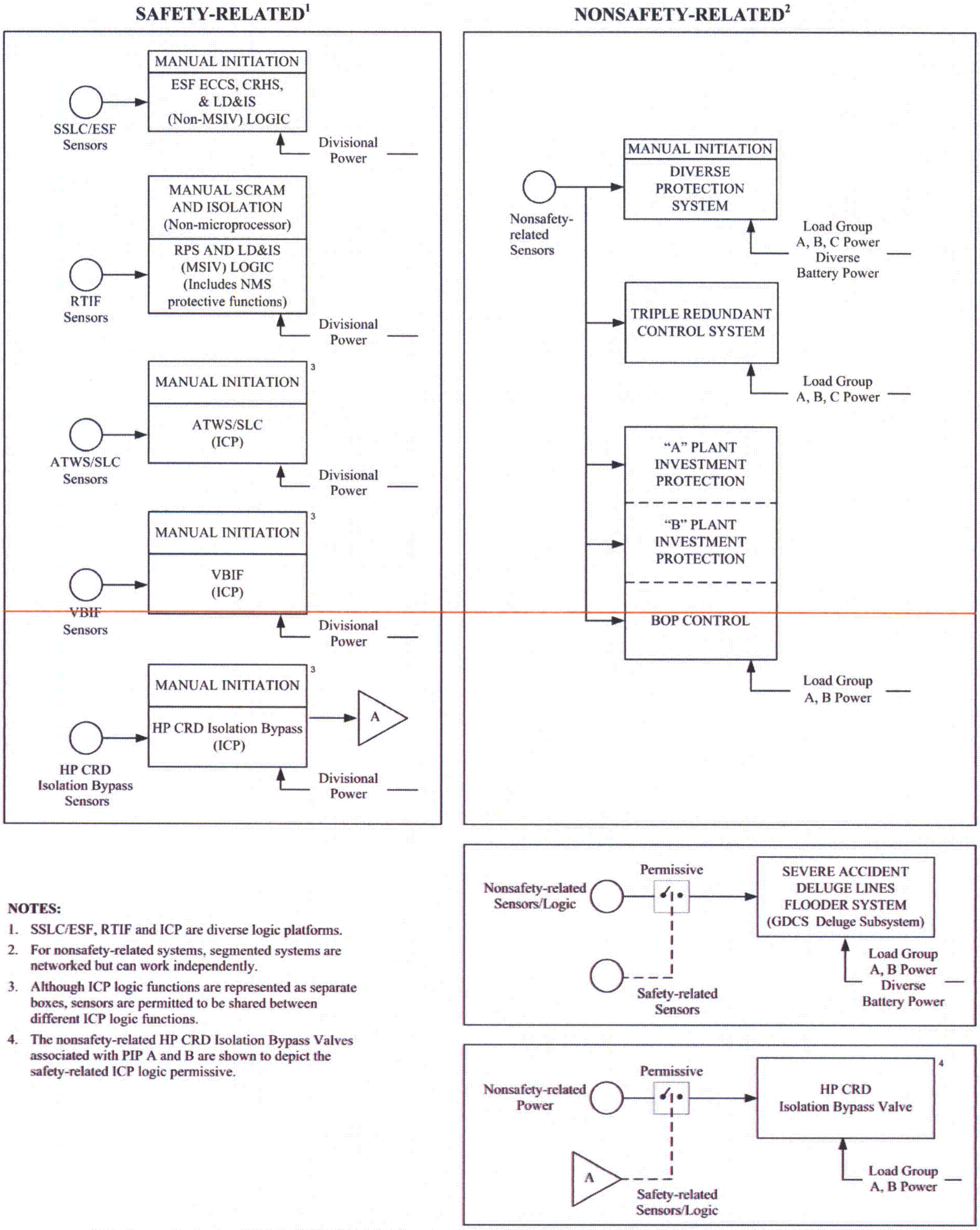
Figure 7.1-1. ESBWR DCIS Simplified Network and Functional Diagram





NOTES:

1. SSLC/ESF, RTIF and ICP are diverse logic platforms.
2. For nonsafety-related systems, segmented systems are networked but can work independently.
3. Although ICP logic functions are represented as separate boxes, sensors are permitted to be shared between different ICP logic functions.
4. The nonsafety-related HP CRD Isolation Bypass Valves associated with PIP A and B are shown to depict the safety-related ICP logic permissive.



NOTES:

1. SSLC/ESF, RTIF and ICP are diverse logic platforms.
2. For nonsafety-related systems, segmented systems are networked but can work independently.
3. Although ICP logic functions are represented as separate boxes, sensors are permitted to be shared between different ICP logic functions.
4. The nonsafety-related HP CRD Isolation Bypass Valves associated with PIP A and B are shown to depict the safety-related ICP logic permissive.

Figure 7.1-3. ESBWR Distributed Power-Sensor/Logic Diversity Diagram

- Prevent the inadvertent actuation of the deluge valves thus preventing inadvertent draining of the GDCS pools.
- Prevent any single control logic and instrumentation failure from inadvertently opening a GDCS injection valve or equalizing valve.
- Display GDCS valve positions and GDCS pool levels on the mimic on the WDP in the MCR.

7.3.1.2.2 System Description

The GDCS system comprises the GDCS injection and equalization functions as well as the deluge subsystem. The injection and equalization functions are used to cool the core in the event of a LOCA. The deluge system is used to flood the containment floor in the event of a core breach.

The GDCS injection and equalization functions are implemented by four injection lines from the three GDCS pools to the RPV and four equalization lines from the suppression pool to the RPV. There are two valves on each injection line, with four squib initiators per valve (three divisional initiators and one from the DPS [see Section 7.8]), for a total of eight GDCS injection valves and 32 squib initiators. There is one squib valve on each of the four equalizing lines and four squib initiators per valve (three divisional initiators and one from the DPS [see Section 7.8]), for a total of four equalizing valves and 16 squib initiators. The equalizing valves are used after reactor core decay heat has boiled away sufficient vessel inventory added by the GDCS to again begin lowering the RPV water level. With three divisional initiators per valve, the system can be without two divisions of power and still perform its intended function.

The GDCS pools are located within the drywell at an elevation above the top of active fuel (TAF) and provide core cooling water by the force of gravity. The suppression pool is located within the drywell, with its equalization lines located above the TAF.

Safety-related and nonsafety-related sensors continuously monitor the GDCS pool water level. These values are continuously shown on the safety-related and nonsafety-related displays. Both high and low pool levels result in alarms from the PCF (part of N-DCIS).

The overall design of the system assures that, when needed, all eight injection valves and all four equalizing valves are fired - even with a complete failure of any two divisions. However, no squib is fired inadvertently as a result of any single failure.

Automatic Operation

Actuation of the GDCS injection function is performed automatically, without need for operator action. The signal to open the GDCS injection valves is given after a time delay (Table 7.3-4) When the RPV water level drops below Level 1 sustained for 10 seconds, the GDCS time delay is initiated. For certain LOCA events where RPV water level does not drop below Level 1, GDCS injection valve time delay is also initiated on drywell pressure high signal, sustained for 60-minutes. With three divisional initiators per valve, the system can tolerate the complete loss of two divisions of power (one in bypass and one failure) and still perform its intended function.

Actuation of the GDCS equalizing function is performed automatically, without need for operator action. The GDCS equalizing valves initiation occurs automatically following a sustained RPV Level 1 signal, for 10 seconds, plus Table 7.3-4 time delay, and only after the

RPV water level decreases below RPV Level 0.5 (1m above TAF). This action results in the actuation of the four equalizing squib valves mounted on the suppression pool equalizing lines. With three divisional initiators per valve, the system can tolerate the complete loss of two divisions (one bypass and one failure) of power and still perform its intended function.

GDCS injection and equalize subsystem initiation is inhibited automatically under ATWS conditions as described in Subsection 7.8.1.1.1.2.

Manual Operation

Each safety-related VDU provides a display with an "arm/fire" switch (one per division, for a total of four) to manually initiate the GDCS sequence as a system. If the operator uses any two of the four switches, the GDCS sequence seals in and starts the GDCS valve sequencing. This manual actuation also is interlocked with RPV pressure. This requires four deliberate (two-arm and two-fire) operator actions. For all of the manual initiations, operator use of the "arm" portion of the display triggers a plant alarm.

The safety-related VDUs in the MCR provide a display format allowing the operator to manually open each GDCS injection valve independently, using the primary SSLC/ESF logic function. Likewise, each nonsafety-related VDU in the MCR provides a display format allowing the operator to individually open each GDCS injection valve independently, using the DPS logic function. Each display uses an "arm/fire" configuration (interlocked with a low reactor pressure signal) requiring at least two deliberate operator actions. Operator use of the "arm" portion of the display triggers a plant alarm. The two manual opening schemes from the SSLC/ESF (primary) and the DPS (backup) are diverse.

In addition the safety-related VDUs in the MCR provide a display format allowing the operator manually to open each GDCS equalizing valve independently, using the primary SSLC/ESF logic function. Likewise, each nonsafety-related VDU in the MCR provides a display format allowing the operator to individually open each GDCS equalizing valve independently, using the DPS logic function. Each display uses an "arm/fire" configuration requiring at least two deliberate operator actions (interlocked with a low reactor pressure signal). Operator use of the "arm" portion of the display triggers a plant alarm. The two manual opening schemes from the SSLC/ESF (primary) and the DPS (backup) are diverse.

Actuation Logic

The logic elements providing controls for the actuation of the GDCS injection and equalizing squib valves are contained in the SSLC/ESF platform within Q-DCIS, outside the drywell containment. The RPV water level sensors and the drywell pressure sensors used to initiate GDCS, are located on racks outside the drywell.

The GDCS injection and equalizing valve logic includes the SSLC/ESF "division of sensors" bypass switch, two-out-of-four trip decisions, and single failure proof actuation logic - with any three of the four divisions of safety-related power available. The valve logic also is single failure proof against inadvertent actuation, meaning each division of logic has three load drivers each of which must operate for the associated squib valves to fire.

The wide range level and drywell pressure sensors that are used for the ADS logic and fuel zone range RPV water level sensors are also used for the GDCS equalizing valve logic; these are separate and independent from the sensors used for RPS functions and diverse from those used by the DPS. Both sets of RPV water level sensors belong to the NBS.

The generation of the RPV-Level 1 or Drywell Pressure High signal for the GDCS is described above (Automatic Operation). The logic for all squib initiators is similar. The signals are acquired per division by RMUs of the same division. The data are sent via fiber-optic cables to the SSLC/ESF cabinets located in the corresponding divisional I&C equipment rooms in the Control Building (CB). Each division's logic compares the measured parameters to setpoints. If the measured parameter is at or past the setpoint, a divisional sensor trip is generated and sent both to its own division and to each of the other divisions by appropriately isolated fiber-optic cables.

Each division has access to all four divisional sensor trip signals, and performs a redundant two-out-of-four vote on the four sensor trip signals. (The vote is two-out-of-three if one division is bypassed, because no more than one division can be bypassed at any one time.)

Each division uses triply redundant logic to perform the two-out-of-four vote on the four divisional sensor trip signals. The effect is that any two divisions sensing the appropriate trip conditions results in all divisions providing a trip signal.

The existence of the multiple logic trips per division is necessitated by the requirement that no injection or equalizing squib valve inadvertently be fired as the result of a single failure.

For the eight GDCS injection squib valves logic, when a sustained RPV Level 1 is detected for 10 seconds or a sustained Drywell Pressure High is detected for 60 minutes, adjustable timers will be activated at a preset time delay (as specified in Table 7.3-4). After the time delay, a trip signal is output to the GDCS squib load drivers/discrete outputs. There are eight injection squib valves, each with three divisional squib initiators, and one DPS squib initiator.

Within the RMU, for each equalizing valve squib initiator, there is a series circuit of divisional power, three load drivers/discrete outputs in series, a current monitor, and a normally closed disable/test switch. The triply redundant logic in the main SSLC/ESF processors must transmit separate close signals to each of the three load driver/discrete outputs. The effect is that two of the three triply redundant processors must separately command all of the load drivers/discrete outputs to fire the divisional squib initiator, making the design single failure proof against inadvertent actuation. Because each GDCS injection squib valve has three squib initiators, powered by three different divisions, the design is also single failure proof if required to operate all eight valves, and even will initiate with the loss of two divisions of power.

The current monitor continuously verifies squib electrical continuity, and the disable/test switch is used when performing maintenance or surveillance testing, or testing the current monitor. If the disable/test switch opens the circuit, an alarm signal is sent to the MCR, indicating that the squib initiator (not the valve) is inoperable.

For diversity, the DPS also is able to fire its squib electrical initiator on each of the eight GDCS injection squib valves, using single failure proof logic (both to operate and to avoid inadvertent operation). This is accomplished using a completely separate squib initiator connected to the DPS system (see Figures 7.3-1b 1and 7.3-1c). The DPS system uses diverse (from the SSLC/ESF) sensors, hardware, and software to operate the GDCS injection valves. Figure 7.3-2 shows the initiation logic of a typical equalizing squib valve.

Within the RMU, for each squib initiator, there is a series circuit of divisional power, three load drivers/discrete outputs in series, a current monitor, and a normally closed disable/test switch. To fire the equalizing valve squib initiator, the triply redundant logic in the SSLC/ESF must time out the post GDCS initiation signal permissive, acquire at least two of four fuel zone range signals, determine that the measured value is at or below Level .5 and two-out-of-four vote the resulting divisional sensor trips and transmit separate close signals to each of the three load driver/discrete outputs. The effect is that two of the three triply redundant processors must separately command all of the load drivers/discrete outputs to fire the divisional squib initiator, making the design single failure proof against inadvertent actuation.

Because each equalizing valve has three divisional squib initiators powered by three different divisions, the design is also single failure proof whenever required to operate all four valves, with any three of the four divisions of safety-related power available. The equalizing valves are needed for the long term, so they are not automatically operated by the DPS system. The equalizing valves are included in the manually initiated GDCS valve logic, and also have capability to be fired individually from safety-related VDU displays or nonsafety-related VDU displays.

Deluge System

The severe accident deluge system (GDCS subsystem) is designed to flood the containment floor in the event of a core breach that results in molten fuel on the containment floor. This system is made up of two individual and identical trains both of which contain an automatic actuation and manual actuation ability. There are 12 deluge valves each with four squib initiators (each valve train has a manual and automatic initiator). Each of these valves feeds the Basemat-Internal Melt Arrest Coolability (BiMAC) deluge system, which floods the containment floor following a severe accident. The BiMAC system is described in more detail in Subsection 6.2.1. The logic for the deluge valves is executed in a pair of dedicated nonsafety-related PLCs and a pair of dedicated safety-related temperature switches.

Automatic actuation of the deluge valves is accomplished in concert with lower drywell high temperature. The containment floor area is divided into 30 cells, with two thermocouples installed in each cell. One thermocouple from each cell is monitored in one PLC, while the other thermocouple from each cell is monitored in a second PLC. When measured temperatures exceed the setpoint (see Table 7.3-4) at one set of thermocouples coincident with setpoints being exceeded at a second set of thermocouples in an adjacent cell, a trip signal is generated in each PLC.

The trip signal in each PLC starts an adjustable deluge squib valve non-bypassable timer. At the end of the deluge squib valve set time delay, each of the two timers outputs a trip signal to the respective deluge valve squib load driver/discrete output. The timer outputs are wired in series so each of the two timers must transmit a temperature trip signal to the corresponding series load driver/discrete output. Additionally, a pair of dedicated safety-related temperature switches monitor the drywell temperature below the RPV. Each temperature switch uses a capillary and bulb action to close a contact wired in series with the PLC timer outputs. The effect is that both PLC timer outputs and both temperature switch outputs must operate to fire the squib initiator. The temperature switches serve as permissives for the deluge logic. These temperature switches are safety-related to prevent inadvertent actuation of the deluge system, which could needlessly drain the GDCS pools.

An additional function of the PLC logic is to initiate operation of battery powered ignitors in the PCCS heat exchangers to prevent the accumulation of explosive mixtures of hydrogen (generated from the interaction with zircalloy) and oxygen (concrete containment floor) associated with the severe accident/core breach while the containment is at a high pressure. The ignitors will be pulsed at an appropriate rate after deluge system initiation and are powered from the same batteres that power the squib ignitors on the GDCS deluge valves. The severe accident deluge system is appropriate for this function since the PCCS heat exchangers are designed to withstand hydrogen/oxygen explosions at containment pressures associated with design basis accidents.

The deluge logic implemented in PLC is completely separate from and independent of the Q-DCIS and the N-DCIS, and is powered by dedicated pair of batteries supported by battery chargers operating on nonsafety-related power. In the event that this nonsafety-related primary electrical power is lost, deluge logic power is supplied from dedicated batteries for 72 hours. The deluge valves and PCCS ignitors are also ~~are~~ powered by a pair of dedicated batteries supported by battery chargers operating on nonsafety-related power. In the event that this nonsafety-related power is lost, deluge valve and ignitor power is supplied from each pair of dedicated batteries for 72 hours.

The batteries for the deluge valves and ignitor are separate from and independent of the batteries for the deluge logic. Each of these batteries can fire all 12 deluge valve squibs and operate the PCCS ignitors. All of the deluge valve/ignitor batteries are separate from and independent of the other plant batteries.

The logic elements providing the controls for the actuation of the deluge valves and ignitors are contained within a separate pair of dedicated nonsafety-related PLCs and a pair of dedicated safety-related temperature switches. The only safety-related function of the deluge and ignitor logic is prevention of inadvertent actuation. The deluge logic is independent from all the other plant controls, and also is located outside containment.

Temperature indications and alarms, as well as continuity alarms and valve open/close indications for each squib valve are available in the MCR. Each valve has a normally closed disable/test switch available for maintenance purposes.

Two control switches are furnished in the MCR, to allow the operator manually to open the 12 deluge valves. These switches are of the "arm/fire" type, and are wired in series such that four deliberate operator actions (two for "arm" and two for "fire") and the safety-related temperature switches located under the RPV are required to operate the valves. These switches actuate the squib initiator on each deluge valve. A similar pair of MCR switches is used for manual initiation of the PCCS ignitors. Operator use of the "arm" portion of the switch triggers a plant alarm in the PCF.

7.3.1.2.3 Safety Evaluation

Section 6.3 evaluates the individual and combined capabilities of ADS and GDCS. For the entire range of nuclear process system break sizes, the ADS and GDCS ensure that the reactor core is always submerged.

Instrumentation initiating the ADS and GDCS injection and equalizing functions must respond to the potential inadequacy of core cooling regardless of the location of the breach in the RCPB. Such a breach inside or outside the containment is sensed by RPV low water level. This signal is completely independent of breach location, and is therefore used to initiate the GDCS injection and equalizing functions.

Operator action is normally not required to initiate the correct response of the GDCS. However, if the system fails to initiate, the MCR operator manually accomplishes GDCS initiation through controls and displays in the MCR. Sufficient alarms and indications in the MCR allow the operator to assess the performance of the GDCS. Specific instrumentation is addressed in Subsection 7.3.1.2.5.

The redundancy of the control and monitoring equipment for the GDCS injection and equalizing functions is consistent with the redundancy of the four divisions of the GDCS. Control and monitoring equipment is located in the MCR and is under the supervision of the MCR operator.

The initiation scheme for the GDCS injection and equalizing functions is designed such that no single failure in the initiation circuitry, with any three of the four divisions of safety-related power available, can prevent the GDCS from providing the core with adequate cooling. This is assured by the redundancy of the components in the four divisions of the GDCS.

The GDCS has no equipment protective interlocks that could interrupt automatic system operation. To initiate the GDCS injection and equalization systems manually, a RPV low-pressure signal must be present. This prevents system initiation while the reactor is at operating pressure. The GDCS injection and equalizing functions are designed to operate from safety-related power. The system instrumentation is powered by divisionally separated safety-related power. The injection squib valve, and the equalizing squib valve logic and initiation circuitry is powered by divisionally separated, safety-related power (refer to Section 8.3.1.4.1). The mechanical aspects of the GDCS are discussed in Subsection 6.3.2.

The two deluge system temperature switches and related contacts are safety-related only to prevent the inadvertent actuation of the deluge valves. No single failure within the deluge system control and monitoring equipment causes an inadvertent actuation of the deluge system. This is to protect against inadvertently draining the GDCS pools, thereby preventing the injection and equalizing systems from performing their safety functions. <u>Similarly no single failure will cause the inadvertent actuation of the PCCS ignitors although inadvertent actuation is not a safety or operational concern.</u>

Table 7.1-1 identifies the GDCS and the associated codes and standards applied in accordance with the SRP. This subsection addresses I&C systems conformance to regulatory requirements, guidelines, and industry standards. Any exceptions or clarifications are so noted.

7.3.1.2.3.1 Code of Federal Regulations

10 CFR 50.34(f)(1)(v)[II.K.3.13], HPCI and RCIC initiation levels,

- Conformance: The GDCS design conforms to these requirements.

10 CFR 50.34(f)(2)(iii)[I.D.1], Human factors engineering principles applied to control room design:

- Conformance: The GDCS design conforms to these requirements.

10 CFR 50.34(f)(2)(v)[I.D.3], Bypass and operable automatic status indication of safety systems:

- Conformance: The GDCS design conforms to these requirements.

optic cables for interconnections between safety-related divisions for data exchange and for interconnections between safety-related and nonsafety-related devices.

BTP HICB-12, Guidance on Establishing and Maintaining Instrument Setpoints:

- Conformance: GDCS logic resides within the SSLC/ESF conforming to BTP HICB-12.

BTP HICB-14, Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The GDCS design conforms to BTP HICB-14.

BTP HICB-16, Guidance on the Level of Detail Required for Design Certification Applications Under 10 CFR Part 52:

- Conformance: The GDCS design conforms to BTP HICB-16

BTP HICB-17, Guidance on Self-Test and Surveillance Test Provisions:

- Conformance: The GDCS design conforms to BTP HICB-17.

BTP HICB-19, Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The GDCS design conforms to BTP HICB-19. The implementation of an additional diverse instrumentation and control system is described in Section 7.8.

BTP HICB-21, Guidance on Digital Computer Real-Time Performance:

- Conformance: The GDCS design conforms to BTP HICB-21.

7.3.1.2.3.6 Three Mile Island Action Plan Requirements

In accordance with the SRP for Section 7.3 and Table 7.1-1, 10 CFR 50.34(f)(2)(v)[I.D.3] (addressed above) apply to the GDCS. The GDCS design complies with these requirements. TMI action plan requirements are generically addressed in Appendix 1A.

7.3.1.2.4 Testing and Inspection Requirements

The GDCS TLUs are self-tested continually at preset intervals. The TLUs of each logic division, and the timers for the automatic logic, can be tested during plant operation. GDCS equipment inside containment is tested during refueling outages. Refer to Subsection 6.3.2.7.4 for a discussion of mechanical tests performed on the GDCS.

7.3.1.2.5 Instrumentation and Control Requirements

The performance and effectiveness of the GDCS in a postulated accident is verified by observing the following MCR indications (additional discussion on the GDCS instrumentation is contained in Subsection 7.3.1.2.2 and in Subsection 6.3.2.7.5):

- Status indication of locked-open maintenance valves;
- Status indication and alarm of the squib-actuated valves;
- Position indication of the GDCS check valves;
- Drywell and RPV pressure indication;

- Suppression pool high/low level alarm;
- GDCS pool high/low level alarm;
- Water level indication for the GDCS pools, suppression pool and RPV; and
- Squib valve open alarm.

The safety-related GDCS instrumentation is designed to operate in a drywell environment resulting from a LOCA. The thermocouples that initiate the deluge valves are qualified to operate in a severe accident environment. The PCCS ignitors are qualified to operate in a severe accident environment. Safety-related instruments, located outside the drywell, are qualified for the environment in which they must perform their safety-related functions.

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. For severe accident events, ignitors have been added to the lower drum of each PCCS heat exchanger to prevent the accumulation of explosive mixtures of hydrogen and oxygen with simultaneous containment high pressure conditions. 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 and the ICP platform (reference 7.3.4 and 7.3.6). 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.

BTP HICB-14, Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The VB isolation function design conforms to BTP HICB-14.

BTP HICB-16, Guidance on the Level of Detail Required for Design Certification Applications Under 10 CFR Part 52:

- Conformance: The level of detail in the VB isolation function description conforms to BTP HICB-16.

BTP HICB-17, Guidance on Self-Test and Surveillance Test Provisions:

- Conformance: The VB isolation function design conforms to BTP HICB-17.

BTP HICB-18, Guidance on the Use of Programmable Logic Controllers in Digital Computer-Based Instrumentation and Control Systems:

- Conformance: Q-DCIS hardware, embedded and operating system software, and peripheral components conform to the guidance of Branch Technical Position HICB-18. Q-DCIS is built and qualified specifically for ESBWR applications as safety-related and not as commercial grade PLCs. The embedded and operating system software meet the acceptance criteria contained in BTP HICB-14, for safety-related applications.

BTP HICB-19, Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The VB isolation function design conforms to BTP HICB-19. The discrete logic and solid state controls used in this design are not subject to the vulnerabilities described by BTP HICB-19.

BTP HICB-21, Guidance on Digital Computer Real-Time Performance:

- Conformance: The VB isolation function design conforms to BTP HICB-21.

7.3.6.3.6 Three Mile Island Action Plan Requirements

In accordance with the SRP for 7.3 and with Table 7.1-1, 10 CFR 50.34(f)(2)(v)[I.D.3] applies to the VB isolation function. The VB isolation function complies with the requirements as indicated above. TMI action plan requirements are addressed in Appendix 1A.

7.3.6.4 Testing and Inspection Requirements

The VB isolation function TLUs are self-tested continually at preset intervals and can be tested during plant operation. VB isolation function equipment is tested during reactor operation to support VB Isolation Valve stroke testing as specified in Table 3.9-8 and Subsection 6.2.1.1.5. Refer to Subsection 6.2.1.1.5 for a discussion of mechanical tests performed on the VB isolation functions.

7.3.6.5 Instrumentation and Control Requirements

The performance and effectiveness of the VB isolation function in a postulated accident is verified by observing the following MCR indications (additional discussion on the VB isolation function instrumentation is contained in Subsection 7.3.6.1 and in Subsection 6.2.1.1.5):

- Status indication of VB position;
- Status indication of VB isolation valve position;
- Drywell and wetwell pressure indication;
- Drywell and wetwell temperature indications;
- VB isolation valve bypass status; and
- Status indication of bypass leakage.

The VB isolation function instrumentation located in the drywell is designed to operate in the harsh drywell environment that results from a LOCA. Safety-related instruments, located outside the drywell, are qualified for the environment in which they must perform their safety-related function.

7.3.7 ICS DPV Isolation Function

The ICS DPV isolation function which is implemented in the ICP prevents the loss of long-term containment integrity upon detection of DPV open position,. Figures 7.1-1 and 7.3-5 indicate ICS DPV isolation function interfaces.

7.3.7.1 System Design Bases

The ICS DPV isolation function has the following safety-related requirements:

- Automatically isolates all Isolation Condensers by closing the two steam admission isolation valves to each of the ICs.
- The two steam admission isolation valves per IC are qualified for a harsh environment inside the drywell.
- Manual opening and closing of the IC steam admission isolation valves is provided for in the design.
- No single control logic and instrumentation failure opens/closes more than one IC steam admission isolation valve.
- IC steam admission isolation valve positions are displayed in the MCR.
- The safety-related function is met with one IC steam admission valve path isolated together with any active identifiable single failure.
- Divisional instruments performing IC steam admission valve isolation valve logic are powered by the associated safety-related divisional power supplies.
- ICS DPV isolation function logic controllers are independent.

7.3.7.2 System Description

The ICS DPV isolation function comprises ICPs and four pair of steam admission isolation valves (two per IC). A more detailed description is given in Subsection 5.4.6.

- Automatic Operation

- Closure of the IC steam admission isolation valves are performed automatically, without need for operator action, once DPV position signals representing two or more open DPVs are detected.
- Automatic actuation logic is performed by a control system with components similar to those used in the ATWS/SLC control system. These components are an independent Q-DCIS subsystem.
- Each IC steam admission isolation valve has dedicated logic. Each IC steam admission isolation valve actuator operates independently of the other IC steam admission isolation valves according to input received from the DPV position sensors. Logic is processed for each individual isolation valve; failure of the logic for one isolation valve does not affect the logic for any other isolation valve.

- Manual Operation
  - Manual controls are available to the operator to:
    - Open each IC steam admission isolation valve (this logic is contained in SSLC/ESF), and
    - Close each IC steam admission isolation valve.
  - Manual controls are independent for each IC steam admission isolation valve and are hardwired to the same hardware as the IC steam admission isolation valve automatic control logic.
- Actuation Logic
  - The primary ICP closure demand for the IC steam admission isolation valve is based upon detection of two or more DPV valves open position signals and upon the bypass status of the associated division of logic.
  - Other IC steam admission isolation valve closure demand signals are originated with SSLC/ESF logic using different isolation valve actuators.
  - Manual control over each IC steam admission isolation valve is available to the operator.
  - Logic for each IC steam admission isolation valve is controlled by separate position switches on each DPV (one switch per division per DPV). Each DPV position is available to each of the four divisional ICPs whose logic will initiate the isolation when any two DPVs are open.
  - Additional and separate position switches per DPV are used for the four divisions of SSLC/ESF isolation logic.
  - Each ICS DPV isolation function ICP division can be placed into manual sensor bypass status that is automatically indicated in the MCR.

7.3.7.3 Safety Evaluation

Section 5.4.6.1 and reference 5.4-3 evaluate the IC steam admission isolation valve isolation function and indicates that closing the ICS isolation valves when the RPV is depressurized mitigates the accumulation of radiolytic hydrogen and oxygen.

Table 7.1-1 identifies the ICS DPV isolation function and the associated codes and standards applied, in accordance with the SRP. This subsection addresses I&C systems conformance to regulatory requirements, guidelines, and industry standards.

7.3.7.3.1 Code of Federal Regulations

10 CFR 50.34(f)(2)(iii)[I.D.1], Human factors engineering principles applied to control room design:

- Conformance: The ICS DPV isolation function design conforms to these requirements.

10 CFR 50.34(f)(2)(v)[I.D.3], Bypass and operable automatic status indication of safety systems:

- Conformance: The ICS DPV isolation function conforms to these requirements.

10 CFR 50.34(f)(2)(xxi)[II.K.1.22], Auxiliary heat removal systems functional requirements under conditions when main feedwater system is not operable:

- Conformance: The ICS DPV isolation function conforms to these requirements.

10 CFR 50.43(e), Innovative means of accomplishing safety functions:

- Conformance: When innovative means are used in the I&C design it complies with 10 CFR 50.43(e).

10 CFR 50.49, Environmental qualification of electric equipment important to safety for nuclear power plants:

- Conformance: The ICS DPV isolation function conforms to these requirements. See Table 3.11-1 (Electrical and Mechanical Equipment for Environmental Qualification).

10 CFR 50.55a(a)(1), Quality standards for systems important to safety:

- Conformance: The ICS DPV isolation function conforms to this requirement for the use of the applicable these standards.

10 CFR 50.55a(h), Protection and safety systems compliance with IEEE Std. 603:

- Conformance: The ICS DPV isolation function conforms to IEEE Std. 603. Conformance information is found in Subsection 7.1.6.6.1.1 through 7.1.6.6.1.27. Additional information concerning how the ICS DPV isolation function conforms to IEEE Std. 603 is discussed below.
  - IEEE Std. 603, Section 4.2 (Safety-Related Function): See Subsection 7.3.7.1.
  - IEEE Std. 603, Section 4.3 (Permissive Conditions for Operating Bypasses): Permissive conditions for operating bypasses are not applicable for the ICS DPV isolation function.
  - IEEE Std. 603, Section 4.6 (Spatially Dependent Variables): See the Actuation Logic section of Subsections 7.3.7.2 and 6.2.1.1.5.5.1.

- IEEE Std. 603, Section 5.7 (Capability for Test and Calibration): See Subsection 7.3.7.4.
- IEEE Std. 603, Sections 6.2 and 7.2 (Manual Control): See Subsections 7.3.7.1 and 7.3.6.2.
- IEEE Std. 603, Section 6.4 (Derivation of System Inputs): Derivation of system inputs for the ICS DPV isolation function are not applicable beyond that discussed in Subsection 7.1.6.6.1.20.
- IEEE Std. 603, Section 6.5 (Capability of Test and Calibration): See Subsection 7.3.7.4.
- IEEE Std. 603, Sections 6.6 and 7.4 (Operating Bypasses): Operating bypasses for the ICS DPV isolation function are not applicable beyond that discussed in Subsection 7.1.6.6.1.22.
- IEEE Std. 603, Sections 6.7 and 7.5 (Maintenance Bypasses): Maintenance Bypasses for the ICS DPV isolation function are not applicable beyond that discussed in Subsection 7.1.6.6.1.23.
- IEEE Std. 603, Section 8.2 (Non-Electrical Power Sources): Non-Electrical power sources for the ICS DPV isolation function are not applicable beyond that discussed in Subsection 7.1.6.6.1.26.
- IEEE Std. 603, Section 8.3 (Maintenance Bypasses): Maintenance bypasses for the ICS DPV isolation function are not applicable beyond that discussed in Subsection 7.1.6.6.1.27.

10 CFR 52.47, Contents of applications; technical information, level of design information:

- Conformance: The level of detail provided for the design for the IC isolation valves and the ICS DPV isolation function within the DCD conforms to this requirement.

10 CFR 52.47(a)(21), Resolution of unresolved and generic (medium- and high-priority) safety issues identified in NUREG–0933:

- Conformance: Resolution of unresolved and generic safety issues is discussed in Section 1.11.

10 CFR 52.47(a)(25), Interface requirements for portions of the plant not within scope of certified design application:

- Conformance: There are no interface requirements for this section.

10 CFR 52.47(b)(1), ITAAC in design certification application:

- Conformance: ITAAC are provided for the I&C systems and equipment in Tier 1.

10 CFR 52.47(c)(2), Innovative means to accomplish safety function design completeness requirements per 10 CFR 50.43(e):

- Conformance: The I&C design may use innovative means for accomplishing safety-related functions.

- Conformance: The I&C design may use innovative means for accomplishing safety-related functions.

7.3.7.3.2 General Design Criteria

GDC 1, 2, 4, 13, 16, 19, 20, 21, 22, 23, 24 and 29, 33, 24, 35, 37 and 44:

- Conformance: The ICS DPV isolation function design complies with these GDCs.

7.3.7.3.3 Staff Requirements Memoranda

SRM on Item II.Q of SECY 93-087:

- Conformance: The IC steam admission valve isolation function design conforms to these criteria through demonstration that no postulated common-mode failure of the control system could disable the IC steam admission valve isolation function. The discrete logic and solid state controls used in this design are not subject to these vulnerabilities.

7.3.7.3.4 Regulatory Guides

RG 1.22, Periodic Testing of Protection System Actuation Functions:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.22. System logic and components are tested periodically during refueling outages.

RG 1.47, Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.47. Automatic indication is provided in the MCR to inform the operator that the system is inoperable or a division is bypassed.

RG 1.53, Application of the Single Failure Criterion to Safety Systems:

- Conformance: The IC steam admission valve isolation function is organized into four physically and electrically-isolated divisions that use the principles of independence and redundancy to conform to the single failure criterion as defined by IEEE Std. 379, Section 4, and IEEE Std. 603, Section 5.1; additionally, the design meets N-2 conditions. Analyses complying with IEEE Std. 379 will be used to confirm the safety-related system designs' conformance to the single failure criterion.

RG 1.62, Manual Initiation of Protective Actions:

- Conformance: The IC steam admission valve isolation function design complies with RG 1.62. Each division has a manual actuation switch. Initiation of the system requires actuation of two switches to ensure that manual initiation is a deliberate act.

RG 1.75, Criteria for Independence of Electrical Safety Systems:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.75 as described in Subsections 8.3.1.3 and 8.3.1.4.

RG 1.89, Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants:

- Conformance: The ESBWR I&C conforms to RG 1.97. Specific instruments credited for RG 1.97 compliance are determined as part of the HFE development process as discussed in Section 7.5.

RG 1.100, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.100. See Sections 3.9 (Mechanical Systems and Components) and 3.10 (Seismic and Dynamic Qualification of Mechanical and Electrical Equipment).

RG 1.105, Setpoints for Safety-Related Instrumentation:

- Conformance: The setpoints established to control the IC steam admission valve conform to RG 1.105. Reference 7.3-2 provides a detailed description of the GEH methodology.

RG 1.118, Periodic Testing of Electric Power and Protection Systems:

- Conformance: Periodic testing of the protection systems is performed in accordance with IEEE Std. 338, as modified by RG 1.118.

RG 1.152, Criteria for Use of Computers in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.152.

RG 1.153, Criteria for Safety Systems:

- Conformance: The IC steam admission valve isolation function is designed to satisfy the requirements of IEEE Std. 603, as endorsed by RG 1.153.

RG 1.168, Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.168 as implemented on the independent control platform.

RG 1.169, Configuration Management Plans for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.169 as implemented on the independent control platform.

RG 1.170, Software Test Documentation for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.170 as implemented on the independent control platform.

RG 1.171, Software Unit Testing for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The ICS DPV isolation function design conforms to RG 1.171 as implemented on the independent control platform.

RG 1.172, Software Requirements Specifications for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.172 as implemented on the independent control platform.

RG 1.173, Developing Software Life Cycle Processes for Digital Computer Software Used in Safety Systems of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.173 as implemented on the independent control platform.

RG 1.180, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.180. See Table 3.11 1 (Electrical and Mechanical Equipment for Environmental Qualification).

RG 1.204, Guidelines for Lightning Protection of Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.204.

RG 1.209, Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants:

- Conformance: The IC steam admission valve isolation function design conforms to RG 1.209. See Table 3.11 1 (Electrical and Mechanical Equipment for Environmental Qualification).

7.3.7.3.5 Branch Technical Positions

In accordance with the SRP for Section 7.3 and Table 7.1-1, the following BTPs are addressed for the ICS DPV isolation function:

BTP HICB-8, Guidance for Application of Regulatory Guide 1.22:

- Conformance: The IC steam admission valve isolation function design conforms to BTP HICB 8.

BTP HICB-10, Guidance on Application of Regulatory Guide 1.97:

- Conformance: The ESBWR I&C conforms to RG 1.97. Specific instruments credited for RG 1.97 compliance are determined as part of the HFE development process as discussed in Section 7.5.

BTP HICB-11, Guidance on Application and Qualification of Isolation Devices:

- Conformance: Logic controllers for the IC steam admission valve isolation function use safety-related fiber-optic CIMs and fiber-optic cables for interconnections between safety-related divisions for data exchange and for interconnections between safety-related and nonsafety-related devices.

BTP HICB-12, Guidance on Establishing and Maintaining Instrument Setpoints:

- Conformance: The setpoints established to control the IC steam admission isolation valve conform to this guide. Reference 7.3-2 provides a detailed description of the GEH methodology.

BTP HICB-14, Guidance on Software Reviews for Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The IC steam admission valve isolation function design conforms to BTP HICB-14.

BTP HICB-16, Guidance on the Level of Detail Required for Design Certification Applications Under 10 CFR Part 52:

- Conformance: The level of detail in the IC steam admission valve isolation function description conforms to BTP HICB-16.

BTP HICB-17, Guidance on Self-Test and Surveillance Test Provisions:

- Conformance: The ICS DPV isolation function design conforms to BTP HICB-17.

BTP HICB-18, Guidance on the Use of Programmable Logic Controllers in Digital Computer-Based Instrumentation and Control Systems:

- Conformance: Q DCIS hardware, embedded and operating system software, and peripheral components conform to the guidance of Branch Technical Position HICB 18. Q DCIS is built and qualified specifically for ESBWR applications as safety-related and not as commercial grade PLCs. The embedded and operating system software meet the acceptance criteria contained in BTP HICB 14, for safety-related applications.

BTP HICB-19, Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems:

- Conformance: The ICS DPV isolation function design conforms to BTP HICB-19. The discrete logic and solid state controls used in this design are not subject to the vulnerabilities described by BTP HICB-19.

BTP HICB-21, Guidance on Digital Computer Real-Time Performance:

- Conformance: The ICS DPV isolation function design conforms to BTP HICB-21.

7.3.7.3.6 Three Mile Island Action Plan Requirements

In accordance with the SRP for 7.3 and with Table 7.1-1, 10 CFR 50.34(f)(2)(v)[I.D.3] applies to the ICS DPV isolation function. The ICS DPV isolation function complies with the requirements as indicated above. TMI action plan requirements are addressed in Appendix 1A.

7.3.7.4 Testing and Inspection Requirements

The ICS DPV isolation function TLUs are self-tested continually at preset intervals and can be tested during plant operation. ICS DPV isolation function equipment is tested during reactor operation to support IC steam admission isolation valve stroke testing as specified in Table 3.9-8 and Subsection 5.4.6.4.

7.3.7.5 Instrumentation and Control Requirements

The performance and effectiveness of the ICS DPV isolation function in a postulated accident is verified by observing the following MCR indications (additional discussion on the ICS DPV isolation function instrumentation is contained in Subsection 7.3.7.1 and in Subsection 5.4.6):

- Status indication of the IC steam admission isolation valve position;
- DPV position indication; and
- ICS DPV isolation function bypass status.

The ICS DPV isolation function instrumentation located in the drywell is designed to operate in the harsh drywell environment that results from a LOCA. Safety-related instruments, located outside the drywell, are qualified for the environment in which they must perform their safety-related function.

~~7.3.7~~ 7.3.8 COL Information

None.

~~7.3.8~~ 7.3.9 References

7.3-1 (Deleted)

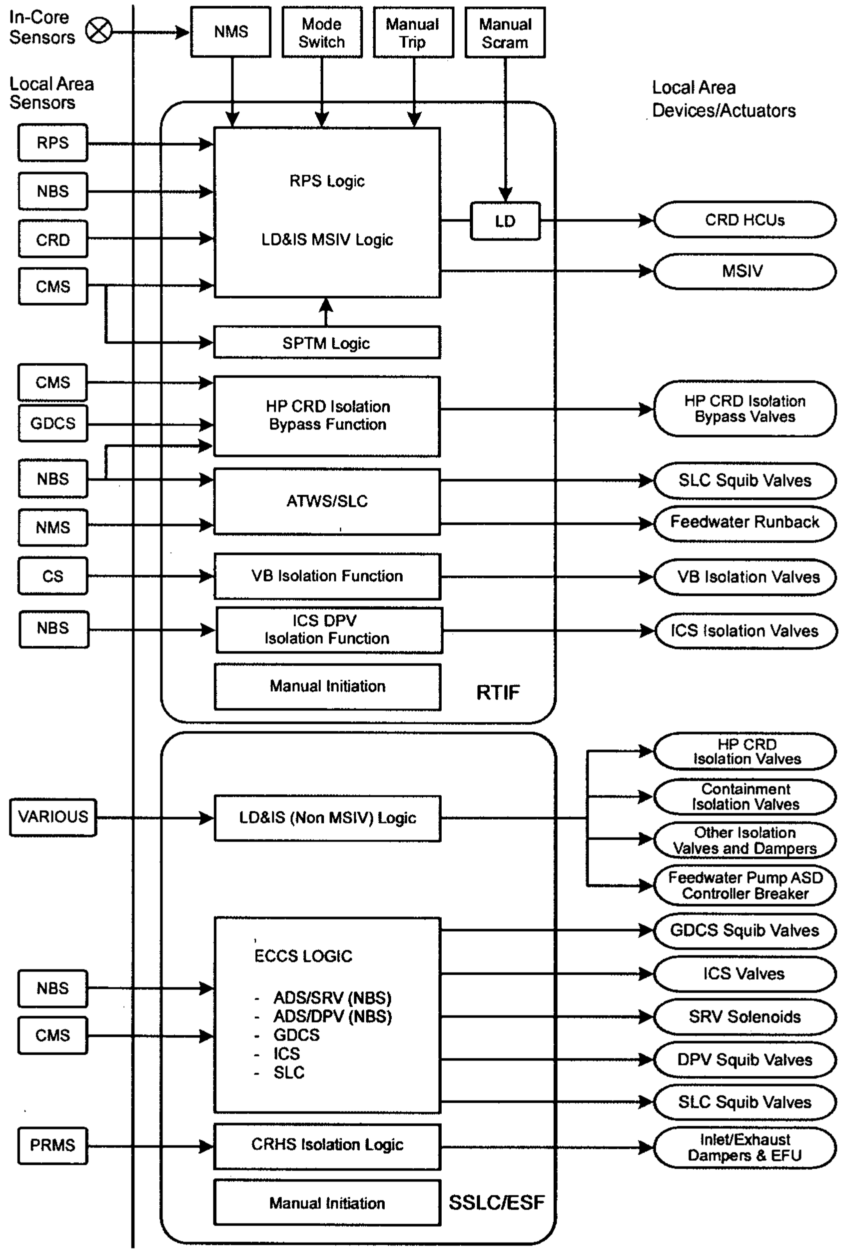
7.3-2 [*GE Hitachi Nuclear Energy, "GEH ESBWR Setpoint Methodology," NEDE-33304P, Class III (Proprietary), Revision ~~3~~4, ~~February~~ May 2010, and NEDO-33304, Class II (Non-proprietary), Revision ~~3~~4, ~~February~~ May 2010.*]*

7.3-3 [*GE Hitachi Nuclear Energy, "ESBWR - Software Management Program Manual," NEDE-33226P, Class III (Proprietary), Revision5, February 2010, and NEDO-33226, Class I (Non-proprietary), Revision 5, February 2010.*]*

7.3-4 [*GE Hitachi Nuclear Energy, "ESBWR - Software Quality Assurance Program Manual," NEDE-33245P, Class III (Proprietary), Revision 5, February 2010, and NEDO-33245, Class I (Non-proprietary), Revision 5, February 2010.*]*

7.3-5 (Deleted)

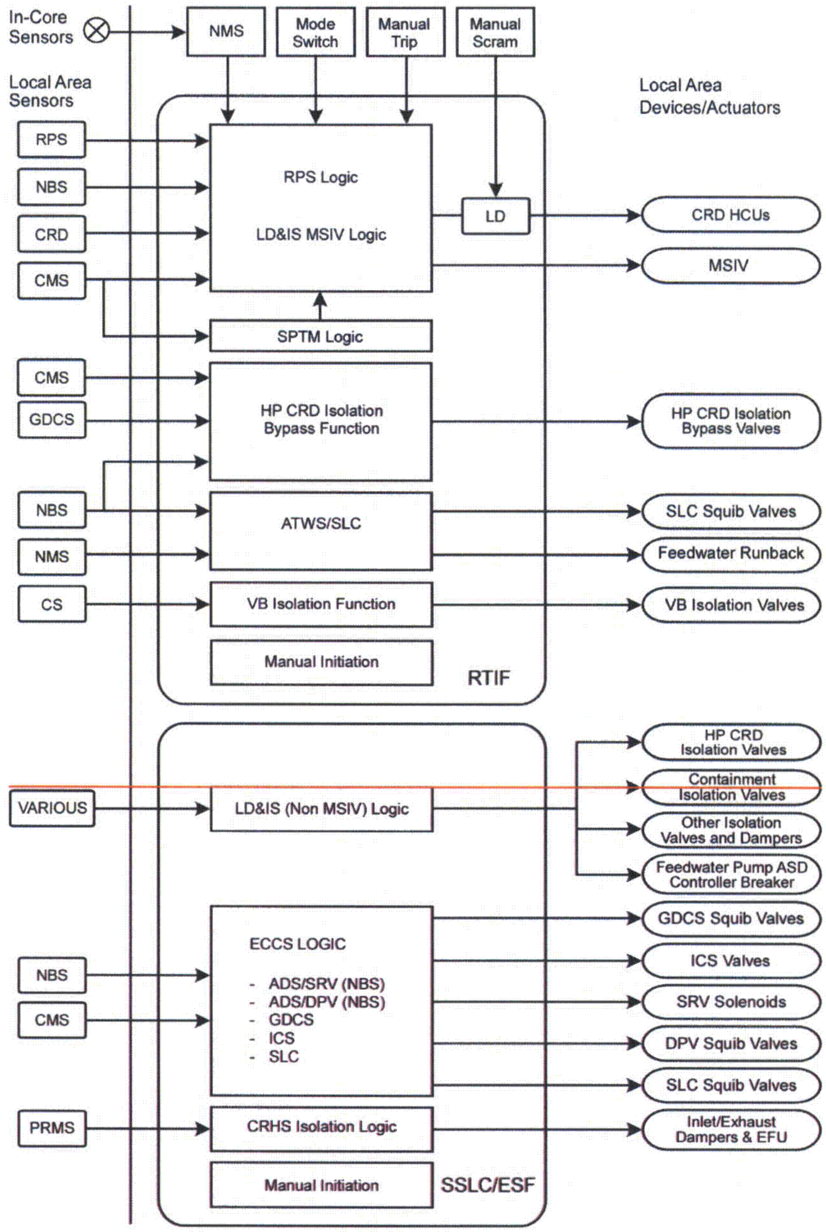
References that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2. Prior NRC approval is required to change.



Notes: 1) Local area sensors include:

RPS:	Turbine stop valve position, turbine CV oil pressure, turbine bypass valve position, main condenser pressure and loss of power generation bus
PRMS:	Process radiation - control room inlet ventilation
NBS:	MSIV position (for RTIF only), RPV pressure, water level
CRD:	Scram accumulator charging water header pressure
CMS:	Drywell pressure, drywell level, suppression pool temperature
HP CRD	High Pressure Control Rod Drive System
CS:	(Containment System) wetwell and drywell temperature, Vacuum Breaker (VB) and VB isolation valve position

2) Manual scram interrupts power to the LD circuit
3) LD&IS MSIV isolation logic shares RTIF sensors. LD&IS non-MSIV isolation logic shares SSLC/ESF sensors.
4) The various LD&IS sensors and functions are depicted on Figure 7.3-3
5) Space consideration may dictate locating the ICP hardware in separate cabinets.



Notes: 1) Local area sensors include:

RPS:	Turbine stop valve position, turbine CV oil pressure, turbine bypass valve position, main condenser pressure and loss of power generation bus
PRMS:	Process radiation - control room inlet ventilation
NBS:	MSIV position (for RTIF only), RPV pressure, water level
CRD:	Scram accumulator charging water header pressure
CMS:	Drywell pressure, drywell level, suppression pool temperature
HP CRD	High Pressure Control Rod Drive System
CS:	(Containment System) wetwell and drywell temperature, Vacuum Breaker (VB) and VB isolation valve position

2) Manual scram interrupts power to the LD circuit
3) LD&IS MSIV isolation logic shares RTIF sensors. LD&IS non-MSIV isolation logic shares SSLC/ESF sensors.
4) The various LD&IS sensors and functions are depicted on Figure 7.3-3.

Figure 7.3-5. SSLC/ESF System Interface Diagram

- Position indications for containment isolation valves, flow control valves, and motor-operated valves;
- Temperature indication for demineralizer influent water;
- Conductivity recorders for demineralizer influent and effluent;
- Temperature of the system supply water (from the RPV bottom head);
- Temperature of the system return water (to feedwater line);
- Temperatures of the non-regenerative and regenerative heat exchanger water (coolant side);
- Process alarms (for example, high water temperatures, high overboarding line pressure, low system flow, high system flow, high conductivity); and
- Pressure indication for the overboarding line.

7.4.4 Isolation Condenser System

7.4.4.1 System Design Bases

Refer to Subsection 5.4.6.1 for the design bases of the ICS. Figure 5.1-3 shows the basic configuration of the ICS.

The ICS is one of the ESF systems whose I&C implemented in SSLC/ESF and whose isolation functions are implemented in both SSLC/ESF and ICP, belong to a group of systems collectively called the Q-DCIS. A simplified network functional diagram of the DCIS is included as Figure 7.1-1. This diagram indicates the relationships of the SSLC/ESF with its safety-related peers, and with nonsafety-related plant data systems collectively called the N-DCIS. Section 7.1 contains a description of these relationships.

7.4.4.2 System Description

Refer to Subsection 5.4.6.2 for the ICS system description.

7.4.4.3 Safety Evaluation

Conformance of ICS equipment to the requirements of IEEE Std. 603 (other than I&C) is addressed in Subsections 5.4.6.2 and 5.4.6.3. The paragraph on "Isolation Condenser Operation" in Subsection 5.4.6.2 addresses the requirements of IEEE Std. 603, Section 4.10. Subsection 5.4.6.3 addresses the requirements of IEEE Std. 603, Section 4.8. Conformance of ICS I&C equipment to the requirements of IEEE Std. 603, Sections 5.1 and 8.1, is addressed in this subsection. The ICS is designed to operate from safety-related power sources. The system instrumentation is powered by four divisionally separated sources of safety-related power. The ICS uses two-out-of-four logic from SSLC/ESF (refer to Subsection 7.3.5) for automatic operation and two-out-of-four logic in SSLC/ESF and ICP or isolation of each of the four separate isolation condenser trains as shown in Figure 7.4-3. The actuating logic and actuator power for the inner isolation valves for the four ICS trains are on two safety-related 120 VAC divisional UPS (Refer to Subsection 8.3.1.1.3) different from the two divisional power sources for the outer isolation valves.

- IEEE Std. 603, Section 4.6 (Spatially Dependent Variables): Spatial dependency of monitored variables is not applicable to ICS.
- IEEE Std. 603, Section 5.2 (Completion of Protective Actions): Completion of Protective Actions are not applicable beyond that discussed in Subsection 7.1.6.6.1.3.
- IEEE Std. 603, Section 5.7 (Capability for Test and Calibration): Test and Calibrate features are discussed in Subsection 5.4.6.4.
- IEEE Std. 603, Sections 6.2 and 7.2 (Manual Control): See Subsections 5.4.6.2.2 and 5.4.6.2.3.
- IEEE Std. 603, Section 6.4 (Derivation of System Inputs): The ICS derives its sense and command features from direct measurements as described in Subsections 5.4.6.5, 7.4.4.3 and 7.8.
- IEEE Std. 603, Section 6.5 (Capability of Test and Calibration): Capability for Test and Calibrate features beyond that discussed in are discussed in Subsection 5.4.6.4.
- IEEE Std. 603, Sections 6.6 and 7.4 (Operating Bypasses): Operating bypasses for the ICS beyond that discussed in Subsections 7.1.6.6.1.22 are not applicable.
- IEEE Std. 603, Sections 6.7 and 7.5 (Maintenance Bypasses): Maintenance bypasses for the ICS beyond that discussed in Subsection 7.1.6.6.1.23 are not applicable.
- IEEE Std. 603, Section 8.2 (Non-Electrical Power Sources): Non-Electrical power sources for the ICS beyond that discussed in Subsection 7.1.6.6.1.26 are not applicable.
- IEEE Std. 603, Section 8.3 (Maintenance Bypasses): Maintenance bypasses for the ICS beyond that discussed in Subsection 7.1.6.6.1.27 are not applicable.

~~10 CFR 50.62, Requirements for reduction of risk from ATWS events for light-water-cooled nuclear power plants:~~

~~Conformance: The ICS conforms to these requirements.~~

10 CFR 50.63, Loss of all alternating current power:

- Conformance: The ICS conforms to these requirements.

10 CFR 52.47, Contents of applications; technical information, level of design information:

- Conformance: The level of detail provided for the ICS within the DCD conforms to this requirement.

10 CFR 52.47(a)(21), Resolution of unresolved and generic (medium- and high-priority) safety issues identified in NUREG–0933:

- Conformance: Resolution of unresolved and generic safety issues is discussed in Section 1.11.

10 CFR 52.47(a)(25), Interface requirements for portions of the plant not within scope of certified design application:

- Conformance: There are no interface requirements for ICS.

7.8 DIVERSE INSTRUMENTATION AND CONTROL SYSTEMS

7.8.1 System Description

The Anticipated Transient Without Scram and Standby Liquid Control (ATWS/SLC) system and the Diverse Protection System (DPS) comprise the diverse I&C systems that are part of the diversity and defense-in-depth strategy. They provide diverse backup to the Reactor Protection System (RPS) and the Safety System Logic and Control/Engineered Safety Features (SSLC/ESF). The ATWS mitigating logic is designed to meet the diverse shutdown requirements of 10 CFR 50.62, "Requirements For Reduction of Risk from Anticipated Transients Without Scram (ATWS) Events for Light-Water-Cooled Nuclear Power Plants." The ATWS mitigating logic system is implemented with the Safety-Related Distributed Control and Information System (Q-DCIS) and the Nonsafety-Related Distributed Control and Information System (N-DCIS).

The nonsafety-related DPS (which is part of the N-DCIS) processes the nonsafety-related portions of the ATWS mitigation logic. It is designed to mitigate the possibility of digital protection system common mode failures discussed in Item II.Q of SECY 93-087 and SRM on Item II.Q of SECY 93-087. Figure 7.8-1 provides a simplified block diagram of the DPS.

The relationships between the ATWS mitigation logic, the DPS, the Q-DCIS and the N-DCIS are discussed in Section 7.1. Figure 7.1-1 provides a simplified network functional diagram of the relationship between the ATWS/SLC System and the Q-DCIS, the DPS, and the N-DCIS.

The ATWS/SLC logic provides a diverse means of emergency shutdown using the SLC System for soluble boron injection. Alternate rod insertion, which hydraulically scrams the plant using the three sets of ARI valves of the Control Rod Drive (CRD) System, is also used for ATWS mitigation. This logic is implemented in the DPS. Detailed ATWS mitigation features are described later in this subsection.

The DPS is a nonsafety-related, triple redundant system powered by redundant nonsafety-related load group power sources. The highly reliable, isolated, and independent DPS provides diverse reactor scram using a subset of the RPS scram signals. The DPS provides diverse emergency core cooling by independently actuating the Emergency Core Cooling System (ECCS). The DPS performs selected containment isolation functions as part of the diverse ESF function. Any DPS manual initiation requires operation of two switches, with each switch requiring two distinct operator actions. Additional DPS features are described in Subsection 7.8.1.2. The design scope of the DPS functions is based on the diversity and defense-in-depth strategy developed via analyses that show the design meets criteria of BTP HICB-19, as outlined in Licensing Topical Report (LTR) NEDO-33251, "ESBWR I&C Diversity and Defense-In-Depth Report." (Reference 7.8-1). A confirmatory analysis supports and validates the DPS design scope requirements of BTP HICB-19. Conformance to BTP HICB-19 is described further in Subsection 7.8.3.5.

Table 7.8-1 provides a summary of the functions, initiators, and interfacing systems used by the diverse I&C systems for ATWS mitigation or for mitigation of design basis events described in Chapter 15. Table 7.8-2 provides a list of the controls, interlocks, and bypasses used by the diverse I&C systems for ATWS mitigation or for mitigation of design basis events described in Chapter 15. Tables 7.8-3 and 7.8-4, both which address BTP HICB-19, describe additional diverse instrumentation and control features used to ensure that releases during a common mode protection system failure coincident with the design basis events discussed in the Safety Analysis of Chapter 15 do not exceed the radiation guidelines from 10 CFR 52.47(a)(2)(iv).

Mitigation of common mode failures is provided by:

- Manual scram and Main Steam Isolation Valve (MSIV) isolation by the operator in the Main Control Room (MCR) in response to diverse parameter indications;
- Availability of diverse manual initiation of the passive ECCS functions including Gravity-Driven Cooling System (GDCS) squib valve initiation, Safety Relief Valve (SRV) initiation, Depressurization Valve (DPV) initiation, Isolation Condenser System (ICS) initiation, ICS vent function, and SLC System squib valve initiation. Manual initiation functions are available in the safety-related systems and in the DPS;
- Core makeup water capability from the Condensate and Feedwater System (C&FS), CRD System, and Fuel and Auxiliary Pools Cooling System (FAPCS) in the Low Pressure Coolant Injection (LPCI) mode;
- Long-term shutdown capability in the two redundant Remote Shutdown System (RSS) panels which are equipped with Division 1 and 2 controls for manual scram and MSIV closure, Division 1 and 2 safety-related Video Display Units (VDUs), and nonsafety-related displays and controls to allow monitoring and control of all plant systems. Local displays of process variables in the RSS system are continuously powered and are available for monitoring at any time;
- Diverse scram, which is different from the safety-related RPS, using diverse hardware and software;
- Diverse ESF initiation logic, which is different from the SSLC/ESF, using diverse hardware and software;
- ATWS mitigation using liquid boron injection for emergency plant shutdown through the SLC system;
- ATWS mitigation using ARI to hydraulically scram the plant using the three sets of ARI valves of the CRD system;
- Selected Control Rod Run-in (SCRRI) command to the Rod Control and Information System (RC&IS);
- Select Rod Insert (SRI) to hydraulically insert selected control rods with every SCRRI action; and
- Manual initiation capability of the ATWS mitigation functions (ARI/SLC/Feedwater Runback).

7.8.1.1 Anticipated Transients Without Scram Mitigation Functions

The ATWS mitigation control functions are:

- Automatic SLC System initiation, as shown in Figure 7.8-3. The SLC System is described in Subsection 7.4.1.

The ICS logic is configured to allow the availability of each ICS loop flow path from the four safety-related divisions and the DPS.

7.8.1.2.3 ATWS Mitigation Logic to Inhibit ADS Initiation by DPS

To prevent ATWS events from escalating to more serious events (as described in Subsection 7.8.1.1.1.2), the DPS sustained RPV Level 1 logic is inhibited by the following signals:

- Coincident low RPV water level (Level 2) and SRNM ATWS permissive signals (i.e., an SRNM signal from the NMS that is above a specified setpoint).
- Coincident high RPV pressure and SRNM ATWS permissive signals that persist for 60 seconds.

The ADS inhibit logic also inhibits the ADS and GDCS Injection sequenced initiation from occurring via DPS logic.

The DPS – ADS Inhibit logic is also used to inhibit the DPS feedwater isolation on high-high drywell pressure (described in Subsection 7.8.1.2.4).

MCR controls are provided to inhibit the sustained RPV Level 1 logic, ADS and GDCS Injection sequenced initiation, and feedwater isolation on high-high drywell pressure logic within DPS under ATWS conditions.

7.8.1.2.4 Diverse Isolation Logic by DPS

The DPS also provides the following major isolations using two-out-of-four sensor logic and two-out-of-three processing logic. The isolation functions performed as part of the diverse ESF are "energize to actuate."

- Closure of the MSIVs on detection of high steam flow rate, low RPV pressure, or low RPV water level (Level 2). The isolation function is performed by contacts in the 120 VAC MSIV solenoid return circuit. The logic is enabled when the Reactor Mode Switch is in the Run position.
- Closure of the Reactor Water Cleanup and Shutdown Cooling (RWCU/SDC) isolation valves on high differential flow rate.
- Isolation of the feedwater lines on a feedwater line break inside containment or LOCA conditions that pose a challenge to containment design pressure. The line break is sensed by differential pressure between feedwater lines coincident with high drywell pressure. A feedwater isolation also occurs on high-high drywell pressure or high drywell pressure coincident with high drywell water level. The DPS trips the main feedwater pump adjustable speed drive (ASD) motor circuit breakers and closes the feedwater containment isolation valves.
- Isolation of CRD high pressure makeup water injection (HP CRD) on high drywell pressure coincident with high drywell level, or low level in two out of three GDCS pools.

7.8.1.2.5 Additional Functions of DPS

The following additional functions are performed by the DPS.

- With logic similar to the SSLC/ESF, the DPS initiates the ICS on high RPV dome pressure, low RPV water level (Level 2), or MSIV closure to provide core cooling.
- With logic similar to the SSLC/ESF, the DPS opens the ICS lower header vent valves after six hours of ICS initiation.
- The DPS trips the feedwater pumps on high RPV water level (Level 9).
- The DPS opens pool cross-connect valves between the equipment storage pool and the IC/PCCS expansion pools when a low level condition is detected in the IC/PCCS inner expansion pool to which the valves are connected. DPS uses the four nonsafety-related level sensors in each IC/PCCS inner expansion pool which are part of FAPCS (Subsection 9.1.3.5).

The diverse protection logics for ESF function initiation, in combination with the ATWS mitigation feature, other diverse backup scram protection, and selected diverse RPS logics provide the diverse protection necessary to satisfy the design position specified in BTP HICB-19.

7.8.1.3 Diverse Manual Controls and Displays

All safety-related systems have displays and controls located in the MCR that provide manual system-level actuation of their safety-related functions and monitoring of parameters that support those safety-related functions.

In addition to the manual controls and displays for the safety-related reactor protection and SSLC/ESF functions, the DPS also has displays and manual control functions that are independent and diverse from those of the safety-related protection and SSLC/ESF functions. They are not subject to the same common mode failure as the safety-related protection system components. The manual controls permit manual initiation of the SRV, DPV, GDCS, and SLC System valves, and the ICS.

The operator is provided with a set of diverse displays separate from those supplied through the safety-related software platform. The displays that provide independent confirmation of the status of major process parameters include:

- Reactor pressure;
- Reactor pressure high alarm;
- RPV water level;
- RPV water level high alarm;
- RPV water level low alarm;
- Drywell pressure;
- Drywell pressure high alarm;
- Drywell water level;
- Drywell water level high alarm;
- Suppression pool temperature;
- Suppression pool temperature high alarm;

Table 7.8-3
Diverse Instrumentation and Control Systems
Functions, Initiators, and Interfacing Systems to Address BTP HICB-19[1]

Function	Initiator	Interfacing Systems
Diverse Scram (DPS)	RPV dome pressure high	NBS, RPS
	RPV water level high (Level 8)	NBS, RPS
	RPV water level low (Level 3)	NBS, RPS
	Drywell pressure high	CMS, RPS
	Suppression pool temperature high	CMS, RPS
	MSIV closure	NBS, RPS
	RPS Scram	RPS
	SCRRI/SRI command with power levels remaining elevated	NMS, RC&IS, RPS
ADS initiation (DPS)	RPV water level low (Level 1)	NBS
GDCS initiation (DPS)	RPV water level low (Level 1)	NBS, GDCS
ICS initiation (DPS)	RPV water level low (Level 1)	NBS, ICS
	RPV water level low (Level 2)	NBS, ICS
	MSIV closure	NBS, ICS
	RPV dome pressure high	NBS, ICS
ICS vent function (DPS)	Six hours after ICS initiation	ICS
SLC system initiation (DPS)	RPV water level low (Level 1)	NBS, SLC

Table 7B-1

Q-DCIS Platforms

Platform	Software Project
Reactor Trip & Isolation System Function Neutron Monitoring System (RTIF-NMS)	RTIF
	NMS
Safety System Logic & Control / Engineered Safety Features (SSLC/ESF) Platform	SSLC/ESF
Independent Control Platform (ICP)	VBIF
	ATWS/SLC
	HP CRD Isolation Bypass Function
	ICS DPV Isolation Function

Table 7B-2

N-DCIS Network Segments†

GENE (DPS)
PIP A and PIP B
BOP
PCF

†Network segments are described in Subsection 7.1.4.8. RTNSS components of the network segments are identified in parentheses.

Table 7B-3

(Deleted)

Table 7B-4

(Deleted)

Table 15.2-23

Instrument Response Time Limits for RPS, ECCS, MSIV, ICS, CRHAVS, Isolation, and SCRRI/SRI Functions

Process Variable	Initiating System(14)	Response Function	Sensor Time Constant / Delay	Total Initiation Delay(1)	Control Logic Delay	Actuation Time Delay	Actuation Time Response
ICS Steam Line Flow - High	Isolation	ICS Isolation	---	1.0 sec	---	0.5 sec	Section 6.2 Tables
ICS Return Line Flow – High	Isolation	ICS Isolation	---	1.0 sec	---	0.5 sec	Section 6.2 Tables
ICS DPV - Opened	Isolation	ICS Isolation	---	1.0 sec	---	0.5 sec	Section 6.2 Tables
ICS Pool Vent Discharge Radiation – High(9)	Isolation	ICS Isolation	---	---	---	---	Section 6.2 Tables
GDCS Pool Level – Low	Isolation	HP CRD Isolation	---	1.0 sec	---	1.0 sec	15 sec
Drywell level - High	Isolation	HP CRD Isolation FW Isolation	--- ---	1.0 sec 1.0 sec	--- ---	1.0 sec 1.0 sec	15 sec 15 sec
CRHAVS Air Intake Radiation – High-High(10)	CRHAVS	CRHAVS Isolation	---	---	---	---	---
FW Temperature Reduction	DPS	SCRRI/SRI	---	1.05 sec	---	---	Table 15.2-2 and 15.2-3 (2)

- 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 density~~ICS venting after 6 hours and an assumed vent flow area that exceeds the flow area of the restricting orifice stated in Section 6.2.4.3.1.1, the wide range measured level is above 1~~3~~2.~~6~~7 m (44~~1~~1.~~6~~7 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~~5.25 (~~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)

3.3 INSTRUMENTATION

3.3.5.3 Isolation Condenser System (ICS) Instrumentation

LCO 3.3.5.3 Three ICS instrumentation channels associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," and LCO 3.8.7, "Distribution Systems - Shutdown," for the Functions in Table 3.3.5.3-1 shall be OPERABLE.

APPLICABILITY: According to Table 3.3.5.3-1.

ACTIONS

- NOTE -

Separate Condition entry is allowed for each ICS instrumentation channel.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more Functions with one required instrumentation channel inoperable.	A.1 Restore required channel to OPERABLE status.	12 hours
B. Required Action and associated Completion Time of Condition A not met. <u>OR</u> One or more Functions with ICS actuation capability not maintained.	B.1 Declare ICS trains inoperable.	Immediately

SURVEILLANCE REQUIREMENTS

- NOTES -

Refer to Table 3.3.5.3-1 to determine which SRs apply for each ICS Function.

SURVEILLANCE		FREQUENCY
SR 3.3.5.3.1	Perform CHANNEL CHECK on each required channel.	12 hours
SR 3.3.5.3.2	Perform CHANNEL FUNCTIONAL TEST on each required channel.	31 days
SR 3.3.5.3.3	Perform CHANNEL CALIBRATION on each required channel consistent with Specification 5.5.11, "Setpoint Control Program (SCP)."	24 months
SR 3.3.5.3.4	Verify ICS RESPONSE TIME of each required channel is within limits.	24 months on a STAGGERED TEST BASIS

Table 3.3.5.3-1 (page 1 of 1)
Isolation Condenser System (ICS) Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	SURVEILLANCE REQUIREMENTS
1. Reactor Vessel Steam Dome Pressure - High	1,2,3,4,5	SR 3.3.5.3.1 SR 3.3.5.3.2 SR 3.3.5.3.3 SR 3.3.5.3.4
2. Reactor Vessel Water Level - Low, Level 2	1,2,3,4,5	SR 3.3.5.3.1 SR 3.3.5.3.2 SR 3.3.5.3.3 SR 3.3.5.3.4
3. Reactor Vessel Water Level - Low, Level 1	1,2,3,4,5	SR 3.3.5.3.1 SR 3.3.5.3.2 SR 3.3.5.3.3 SR 3.3.5.3.4
4. Main Steam Isolation Valve - Closure	1	~~SR 3.3.5.3.1~~ SR 3.3.5.3.2 SR 3.3.5.3.3 SR 3.3.5.3.4
5. Power Generation Bus Loss	1	SR 3.3.5.3.1 SR 3.3.5.3.2 SR 3.3.5.3.3 SR 3.3.5.3.4
6. Condensate Return Valve - Open (per Isolation Condenser)	1,2,3,4,5	SR 3.3.5.3.2 SR 3.3.5.3.3

B 3.3 INSTRUMENTATION

B 3.3.5.3 Isolation Condenser System (ICS) Instrumentation

BASES

BACKGROUND

The purpose of the ICS instrumentation is to initiate appropriate actions to ensure ICS operates following a reactor pressure vessel (RPV) isolation after a scram to provide adequate RPV pressure reduction to preclude safety relief valve operation, conserve RPV water level to avoid automatic depressurization caused by low water level. In addition, in the event of a loss of coolant accident (LOCA), the ICS instrumentation ensures the system operates to provide liquid inventory to the RPV. The ICS instrumentation also ensures the ICS is vented to mitigate the accumulation of radiolytic hydrogen and oxygen in order to prevent a detonation. The equipment involved with ICS is described in the Bases for LCO 3.5.4, "Isolation Condenser System (ICS) - Operating."

Technical Specifications are required by 10 CFR 50.36 to contain limiting safety system settings (LSSS) defined by the regulation as "...settings for automatic protective devices related to those variables having significant safety functions." Where LSSS is specified for a variable on which a Safety Limit (SL) has been placed, the setting must be chosen such that automatic protective action will correct the abnormal situation before a SL is exceeded. The Analytical Limit is the limit of the process variable at which a safety action is initiated, as established by the safety analysis, to ensure that a SL is not exceeded. Any automatic protection action that occurs on reaching the Analytical Limit therefore ensures that the SL is not exceeded. Where LSSS is specified for a variable having a significant safety function but which does not protect SLs, the setting must be chosen such that automatic protective actions will initiate consistent with the design basis. The Design Limit is the limit of the process variable at which a safety action is initiated to ensure that these automatic protective devices will perform their specified safety function.

The actual settings for automatic protective devices must be chosen to be more conservative than the Analytical / Design Limit to account for instrument loop uncertainties related to the setting at which the automatic protective action would actually occur. The methodology for determining the actual settings, and the required tolerances to maintain these settings conservative to the Analytical / Design Limits, including the requirements for determining that the channel is OPERABLE, are defined in the Setpoint Control Program (SCP), in accordance with Specification 5.5.11, "Setpoint Control Program (SCP)."

BACKGROUND (continued)

The Limiting Trip Setpoint (LTSP) is a predetermined setting for a protective device chosen to ensure automatic actuation prior to the process variable reaching the Analytical / Design Limit and thus ensuring that the SL would not be exceeded (i.e., for Analytical Limits), or that automatic protective actions occur consistent with the design basis (i.e., for Design Limits). As such, the LTSP accounts for process and primary element measurement errors, and uncertainties in setting the device (e.g., calibration), uncertainties in how the device might actually perform (e.g., accuracy), changes in the point of action of the device over time (e.g., drift during surveillance intervals), and any other factors that may influence its actual performance (e.g., harsh accident environments). In this manner, the LTSP ensures that SLs are not exceeded and that automatic protective devices will perform their specified safety function. As such, the LTSP meets the definition of an LSSS. The nominal trip setpoint to which the setpoint is reset after calibration is the $NTSP_F$, which is more conservative than the LTSP and has margin to assure that the Allowable Value is not exceeded during calibration.

Technical Specifications contain values related to the OPERABILITY of equipment required for safe operation of the facility. OPERABLE is defined in Technical Specifications as "...being capable of performing its safety function(s)." For automatic protective devices, the required safety function is to ensure that a SL is not exceeded and that automatic protective actions will initiate consistent with the design basis. Therefore, the LTSP is the LSSS as defined by 10 CFR 50.36. However, use of the LTSP to define OPERABILITY in Technical Specifications would be an overly restrictive requirement if it were applied as an OPERABILITY limit for the "as-found" value of a protective device setting during a Surveillance.

However, there is also some point beyond which the device would have not been able to perform its function due, for example, to greater than expected drift. This value is specified in the SCP, as required by Specification 5.5.11, in order to define OPERABILITY of the devices and is designated as the Allowable Value which is the least conservative value of the as-found setpoint that a channel can have during CHANNEL CALIBRATION. The LTSP, $NTSP_F$, Allowable Value, "as-found" tolerance, and "as-left" tolerance and the methodology for calculating the "as-left" and "as-found" tolerances will be maintained in the SCP, as required by Specification 5.5.11.

BASES

BACKGROUND (continued)

The Allowable Value is the least conservative value that the setpoint of the channel can have when tested such that a channel is OPERABLE if the setpoint is found conservative with respect to the Allowable Value during the CHANNEL CALIBRATION. Note that, although a channel is OPERABLE under these circumstances, the setpoint must be left adjusted to a value within the established "as-left" tolerance of the $NTSP_F$ and confirmed to be operating within the statistical allowances of the uncertainty terms assigned in the setpoint calculation. As such, the Allowable Value differs from the $NTSP_F$ by an amount equal to or greater than the "as-found" tolerance value. In this manner, the actual setting of the device will ensure that a SL is not exceeded or that automatic protective actions will initiate consistent with the design basis at any given point of time as long as the device has not drifted beyond that expected during the surveillance interval. If the actual setting of the device is found to be non-conservative with respect to the Allowable Value the device would be considered inoperable from a Technical Specification perspective. This requires corrective action including those actions required by 10 CFR 50.36 when automatic protective devices do not function as required.

The ICS can be automatically or manually initiated. The ICS actuates automatically in response to signals from any of the following:

1. Reactor Steam Dome Pressure - High for 10 seconds,
2. RPV Water Level - Low (Level 2), with time delay,
3. RPV Water Level - Low (Level 1),
4. Indication that two Main Steam Isolation Valves (MSIVs) in separate Main Steamlines (MSLs) are not fully open with the reactor mode switch in the run position, or
5. Loss of power generation buses.

ICS venting can be automatically or manually initiated. ICS venting actuates automatically, following a 6-hour time delay, in response to a signal that at least one Condensate Return Valve (i.e. the condensate return valve or the condensate return bypass valve) for a given ICS train has opened.

The Safety System Logic and Control Engineered Safety Features (SSLC/ESF) System controls the initiation signals and logic for ICS. SSLC/ESF is a four division, separated protection logic system designed to provide a very high degree of assurance to both ensure ICS initiation when required and prevent inadvertent initiation. The input and output trip determinations for all ICS functions are based upon a two-out-of-four logic arrangement. Each division of SSLC/ESF is configured such that all functions (e.g., the digital trip module (DTM) function and voter logic unit (VLU) function) are implemented in triply redundant processors to support the requirement that single divisional failures cannot result in inadvertent actuation.

BACKGROUND (continued)

Four separate instrument channels are used to monitor ICS initiation parameters. Signals from sensors are multiplexed at the divisional level and the triply redundant sensor data is then transmitted to the SSLC/ESF triply redundant digital trip module (DTM) function for setpoint comparison. The output of each divisional DTM function (a trip/no-trip condition) is routed to all four divisional triply redundant VLU functions such that each divisional VLU function receives input from each of the four divisional DTM functions.

For maintenance purposes and added reliability, each DTM function has a division of sensors bypass such that all instruments in that division will be bypassed in the trip logic at the VLU functions. Thus, each VLU function will be making its trip decision on a two-out-of-three logic basis for each variable. It is possible for only one division of sensors bypass condition to be in effect at any time.

The processed trip signal from its own division and trip signals from the other three divisions are processed in the triply redundant VLU function for two-out-of-four voting.

The load driver arrangement for actuation of the ICS Condensate Return Valves are such that an actuation signal from two divisions of ICS actuation logic are required to actuate a condensate return flow path.

Equipment within a single division is powered from the safety-related power source of the same division.

This Specification provides Operability requirements for the ICS instrumentation from the input variable sensors through the DTM function. Operability requirements for the ICS actuation circuitry consisting of timers, VLU functions, and load drivers are provided by LCO 3.3.5.4, "Isolation Condenser System (ICS) Actuation." Operability requirements for the actuated components are addressed in LCO 3.5.4.

APPLICABLE SAFETY

The actions of the ICS are explicitly assumed in the safety analyses of Reference 1. The ICS is initiated to preserve the integrity of the

BASES

ANALYSES, LCO and APPLICABILITY	fuel cladding by limiting the post-LOCA peak cladding temperature to less than the 10 CFR 50.46 limits. Actuation of the ICS precludes actuation of safety relief valves and limits the peak RPV pressure to less than the ASME Section III Code limits.

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

The ICS Instrumentation satisfies Criterion 3 of 10 CFR 50.36(c)(2)(ii).

The OPERABILITY of the ICS is dependent on the OPERABILITY of the individual instrumentation channel Functions specified in Table 3.3.5.3-1. Each Function must have the required number of OPERABLE channels, with their setpoints in accordance with the SCP, where appropriate. The actual setpoint is calibrated consistent with the SCP. Each channel must also respond within its assumed response time.

$NTSP_F$s are specified in the SCP, as required by Specification 5.5.11. The $NTSP_F$s are selected to ensure the actual setpoints are conservative with respect to the Allowable Value between successive CHANNEL CALIBRATIONS. Operation with a trip setpoint less conservative than the $NTSP_F$, but conservative with respect to its Allowable Value, is acceptable. A channel is inoperable if its actual trip setpoint is non-conservative with respect to its required Allowable Value.

The individual Functions are required to be OPERABLE in the MODES specified in the Table which may require an ICS actuation to mitigate the consequences of a design basis accident or transient.

Although there are four channels of ICS instrumentation for each function, only three ICS instrumentation channels for each function are required to be OPERABLE. The three required channels are those channels associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," and LCO 3.8.7, "Distribution Systems - Shutdown." This is acceptable because the single-failure criterion is met with three OPERABLE ICS instrumentation channels, and because each ICS instrumentation division is associated with and receives power from only one of the four electrical divisions.

The specific Applicable Safety Analyses, LCO and Applicability discussions are listed below on a Function-by-Function basis.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

1. Reactor Vessel Steam Dome Pressure - High

ICS is designed to operate following reactor pressure vessel (RPV) isolation to provide adequate RPV pressure reduction to preclude safety relief valve operation and provide core cooling while conserving reactor water inventory. Therefore, Reactor Vessel Steam Dome Pressure - High Function existing for 10 seconds initiates an ICS actuation for transients that result in a pressure increase. Actuation of the ICS provides RPV pressure reduction to preclude safety relief valve operation and provide core cooling.

High reactor pressure signals are initiated from four pressure sensors that sense reactor pressure. The Reactor Vessel Steam Dome Pressure - High Allowable Value provides a sufficient margin to the ASME Section III Code limits during the event.

Three channels of Reactor Vessel Steam Dome Pressure - High Function are required to be OPERABLE to ensure no single instrument failure will preclude ICS actuation.

The Function is required to be OPERABLE in MODES 1, 2, 3, 4, and 5 .

2. Reactor Vessel Water Level - Low, Level 2

Low reactor vessel water level indicates the capability to cool the fuel may be threatened. Should reactor vessel water level decrease too far, fuel damage could result. Therefore, an ICS actuation is initiated at Level 2, with a 30-second time delay to provide a source of core cooling. The time delay provides an allowance for temporary transients that may reduce RPV level below the Level 2 setpoint. This Function is assumed to be available to support the transient and design basis analyses (Ref. 1).

Reactor Vessel Water Level - Low, Level 2, signals are initiated from four wide range level sensors.

Three channels of Reactor Vessel Water Level Low, Level 2, Function are required to be OPERABLE to ensure no single instrument failure will prevent ICS actuation from this Function on a valid signal.

The Function is required to be OPERABLE in MODES 1, 2, 3, 4, and 5.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

3. Reactor Vessel Water Level - Low, Level 1

Low Reactor Vessel Water Level indicates the capability to cool the fuel may be threatened. Should RPV water level decrease too far, fuel damage could result. Therefore, ICS receives the signals necessary for initiation from this Function. The Reactor Vessel Water Level - Low, Level 1 is one of the Functions assumed to be OPERABLE and capable of actuating the ICS during the accidents analyzed in Reference 1. The core cooling function of the ICS along with the ECCS and the scram action of the RPS, assures that the fuel peak cladding temperature remains below the limits of 10 CFR 50.46.

Reactor Vessel Water Level - Low, Level 1 signals are initiated from four wide range level sensors.

Three channels of Reactor Vessel Water Level - Low, Level 1 Function are required to be OPERABLE when ICS is required to be OPERABLE to ensure that no single instrument failure can preclude ICS actuation, when required.

The Function is required to be OPERABLE in MODES 1, 2, 3, 4, and 5.

4. Main Steam Isolation Valve - Closure

Main Steam Isolation Valve (MSIV) closure results in loss of the main turbine and the condenser as a heat sink for the nuclear steam supply system and indicates a need to isolate the reactor to reduce excessive steam line flow or leakage outside the containment. Therefore, an ICS actuation is initiated on an MSIV closure signal before the MSIVs are completely closed in anticipation of the complete loss of the normal heat sink and subsequent overpressurization transient. MSIV closure is assumed in the transients and accidents analyzed in Reference 1. The ICS actuation, along with the reactor scram, assures that the fuel peak cladding temperature remains below the limits of 10 CFR 50.46.

The logic for the Main Steam Isolation Valve - Closure Function is arranged such that ICS initiation occurs if two MSIVs in separate MSLs are not fully open with the Reactor Mode Switch in run.

The MSIV - Closure Allowable Value is specified to ensure that an ICS initiation occurs prior to a significant reduction in steam flow, thereby reducing the severity of the subsequent pressure transient.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

Three channels of MSIV - Closure Function are required to be OPERABLE to ensure no single instrument failure will prevent the ICS actuation from this Function on a valid signal. This Function is only required in MODE 1 because with the MSIVs open and the heat generation rate high, a pressurization transient can occur if the MSIVs close.

5. Power Generation Bus Loss

The plant electrical system has four redundant power generation buses that operate at 13.8 kV. These buses supply power for the feedwater pumps and other pumps. In MODE 1, at least three of the four buses must be powered. The purpose of ICS initiation on losing feedwater flow is to provide a source of core cooling following the loss of feedwater pump function.

The Allowable Value was selected high enough to detect a loss of voltage in order to mitigate the reactor water level drop to Level 1 following the loss of feedwater pump function.

Three channels of Power Generation Bus Loss Function are required to be OPERABLE to ensure that no single instrument failure will prevent the ICS actuation from this Function on a valid signal. The Function is required in MODE 1 where considerable energy exists in the reactor coolant system resulting in the limiting transients and accidents. During MODES 2, 3, 4, 5, and 6, the core energy is significantly lower.

6. Condensate Return Valve – Open (per Isolation Condenser)

When an ICS initiation signals occurs, the condensate return valve and condensate return bypass valve for each ICS train open, which starts isolation condenser operation. After a six-hour time delay following either condensate return valve opening, the lower header vent valves automatically open to prevent the accumulation of radiolytically generated hydrogen and oxygen.

The logic for the Condensate Return Valve – Open Function is arranged such that the SSLC/ESF-actuated ICS vent valve will open upon opening of either of the condensate return valves on the associated ICS train.

Condensate Return Valve – Open signals are initiated from four position switches located on each condensate return and condensate return bypass valve.

BASES

Three channels of the Condensate Return Valve - Open Function for each Condensate Return Valve on each ICS train are required to be OPERABLE when ICS is required to be OPERABLE to ensure that no single instrument failure can preclude ICS vent actuation, when required.

The Function is required to be OPERABLE in MODES 1, 2, 3, 4, and 5.

ACTIONS

The ACTIONS have been modified by a Note to permit separate Condition entry for each ICS instrumentation channel. Section 1.3, Completion Times, specifies once a Condition has been entered, subsequent divisions, subsystems, components or variables expressed in the Condition discovered to be inoperable or not within limits, will not result in separate entry into the Condition. Section 1.3 also specifies Required Actions of the Condition continue to apply for each additional failure, with Completion Times based on initial entry into the Condition. However, the Required Actions for inoperable ICS instrumentation channels provide appropriate compensatory measures for separate inoperable Condition entry for each inoperable ICS instrumentation channel.

ACTIONS (continued)

A.1

With one or more Functions with one required channel inoperable, the affected required channel must be restored to OPERABLE status within 12 hours. The 12-hour Completion Time is acceptable based on engineering judgment considering the diversity of sensors available to provide actuation signals, the redundancy of the ICS instrumentation design, and the low probability of an event requiring ICS actuation during this period.

However, this out of service time is only acceptable provided the associated Function still maintains ICS actuation capability (refer to Required Actions B.1 Bases).

Alternatively, if the instrumentation channel can not be restored to OPERABLE status, Condition B must be entered and its Required Action taken when the Completion Time of Required Action A.1 expires.

BASES

B.1

With the Required Action and associated Completion Time of Condition A not met or if multiple, untripped required channels (i.e., two or more required channels for most Functions) for the same Function result in the Function not maintaining ICS actuation capability, the associated feature(s) may be incapable of performing the intended function and the ICS trains must be declared inoperable immediately. A Function is considered to be maintaining ICS actuation capability when sufficient channels are OPERABLE or in trip such that the ICS logic will generate an initiation signal from the given Function on a valid signal.

SURVEILLANCE REQUIREMENTS

The Surveillance Requirements are modified by a Note. The Note directs the reader to Table 3.3.5.3-1 to determine the correct SRs to perform for each ICS Instrumentation Function.

SR 3.3.5.3.1

Performance of the CHANNEL CHECK once every 12 hours ensures that a gross failure of instrumentation has not occurred.

SURVEILLANCE REQUIREMENTS (continued)

The SSLC/ESF is cyclically tested from the sensor input point to the logic contact output by online self-diagnostics. The self-diagnostic capabilities include microprocessor checks, system initialization, watchdog timers, memory integrity checks, input/output (I/O) data integrity checks, communication bus interface checks, and checks on the application program (checksum).

A CHANNEL CHECK will detect gross channel failure; thus, it is key to verifying the instrumentation continues to operate properly between each CHANNEL CALIBRATION.

Agreement criteria are determined by the plant staff, based on a combination of the channel instrument uncertainties, including indication and readability. If a channel is outside the criteria, it may be an indication that the instrument has drifted outside its limit.

The Frequency is based upon operating experience that demonstrates channel failure is rare. The CHANNEL CHECK every 12 hours supplements less formal, but more frequent, checks of channels during normal operational use of the displays associated with the channels required by the LCO.

BASES

SR 3.3.5.3.2

A CHANNEL FUNCTIONAL TEST is performed on each required channel to ensure that the entire channel will perform the intended function. This test ensures a complete CHANNEL FUNCTIONAL TEST of required instrument channels from the sensor input through the DTM function.

The SSLC/ESF is cyclically tested from the sensor input point to the logic contact output by online self-diagnostics. The self-diagnostic capabilities include microprocessor checks, system initialization, watchdog timers, memory integrity checks, input/output (I/O) data integrity checks, communication bus interface checks, and checks on the application program (checksum).

The Frequency of 31 days is based on the reliability of the channels.

SURVEILLANCE REQUIREMENTS (continued)

SR 3.3.5.3.3

A CHANNEL CALIBRATION is a complete check of the instrument loop and the sensor. This test verifies the required channel responds to the measured parameter within the necessary range and accuracy. CHANNEL CALIBRATION leaves the required channel adjusted to the $NTSP_F$ within the "as-left" tolerance to account for instrument drifts between successive calibrations consistent with the methods and assumptions required by the SCP.

The Frequency is based upon the assumption of a 24 month calibration interval in the determination of the magnitude of equipment drift in the setpoint analysis.

SR 3.3.5.3.4

This SR ensures that the individual required channel response times are less than or equal to the maximum values assumed in the accident analysis. The ICS RESPONSE TIME acceptance criteria are included in Reference 2.

ICS RESPONSE TIME may be verified by actual response time measurements or any series of sequential, overlapping, or total channel measurements. This test encompasses the ICS instrumentation from the input variable sensors through the DTM function. This test overlaps the

BASES

testing required by SR 3.3.5.4.2 to ensure complete testing of instrumentation channels and actuation circuitry.

COL 16.0-1-A 3.3.5.3-2

[However, some sensors for Functions are allowed to be excluded from specific ICS RESPONSE TIME measurement if the conditions of Reference XX are satisfied. If these conditions are satisfied, sensor response time may be allocated based on either assumed design sensor response time or the manufacturer's stated design response time. When the requirements of Reference XX are not satisfied, sensor response time must be measured. Furthermore, measurement of the instrument loops response times is not required if the conditions of Reference XX are satisfied.]

SURVEILLANCE REQUIREMENTS (continued)

ICS SYSTEM RESPONSE TIME tests are conducted on a 24-month STAGGERED TEST BASIS for three channels. The Frequency of 24 months on a STAGGERED TEST BASIS ensures that each required channel is alternately tested. The 24-month test Frequency is consistent with the typical refueling cycle and with operating experience that shows that random failures of instrumentation components causing serious response time degradation, but not channel failure, are infrequent.

REFERENCES

1. Chapter 15.
2. Section 15.2.

3.3 INSTRUMENTATION

3.3.5.4 Isolation Condenser System (ICS) Actuation

LCO 3.3.5.4 Three ICS actuation logic divisions associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," and LCO 3.8.7, "Distribution Systems - Shutdown," for each Function in Table 3.3.5.4-1 shall be OPERABLE.

APPLICABILITY: MODES 1, 2, 3, 4, and 5.

ACTIONS

- NOTE -
Separate Condition entry is allowed for each ICS actuation division.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more Functions with one required actuation division inoperable.	A.1 Restore required division to OPERABLE status.	12 hours
B. Required Action and associated Completion Time of Condition A not met. OR One or more Functions with ICS actuation capability not maintained.	B.1 Declare affected actuation device(s) inoperable.	Immediately

SURVEILLANCE REQUIREMENTS

- NOTE -
Refer to Table 3.3.5.4-1 to determine which SRs apply for each ICS Actuation Function.

SURVEILLANCE		FREQUENCY
SR 3.3.5.4.1	Perform LOGIC SYSTEM FUNCTIONAL TEST on each required division.	24 months
SR 3.3.5.4.2	Verify ICS RESPONSE TIME of each required division is within limits.	24 months on a STAGGERED TEST BASIS

Table 3.3.5.4-1 (page 1 of 1)
Isolation Condenser System Actuation

FUNCTION	SURVEILLANCE REQUIREMENTS
1. ICS Initiation Actuation	SR 3.3.5.4.1 SR 3.3.5.4.2
2. ICS Vent Actuation	SR 3.3.5.4.1

B 3.3 INSTRUMENTATION

B 3.3.5.4 Isolation Condenser System (ICS) Actuation

BASES

BACKGROUND

The purpose of the ICS actuation logic is to initiate appropriate actions to ensure ICS operates following a reactor pressure vessel (RPV) isolation after a scram to provide adequate RPV pressure reduction to preclude safety relief valve operation and to conserve RPV water level to avoid automatic depressurization caused by low water level. In addition, in the event of a loss of coolant accident (LOCA), the ICS instrumentation ensures the system operates to provide additional liquid inventory to the RPV upon opening of the condensate return valves. The ICS actuation logic also ensures the ICS is vented to mitigate the accumulation of radiolytic hydrogen and oxygen in order to prevent a detonation.

A detailed description of the ICS actuation instrumentation is provided in the Bases for LCO 3.3.5.3, "Isolation Condenser System (ICS) Instrumentation."

This specification addresses OPERABILITY of the ICS actuation circuitry from the outputs of the Digital Trip Module (DTM) functions through the voter logic unit (VLU) functions, the timers and the load drivers (LDs) associated with the ICS. Operability requirements associated with ICS instrumentation channels are provided in LCO 3.3.5.3. Operability requirements for actuated components are addressed in LCO 3.5.4, "Isolation Condenser System (ICS) - Operating."

APPLICABLE SAFETY ANALYSES, LCO and APPLICABILITY

The actions of the ICS are explicitly assumed in the safety analyses of Reference 1. The ICS is initiated to preserve the integrity of the fuel cladding by limiting the post-LOCA peak cladding temperature to less than the 10 CFR 50.46 limits. Actuation of the ICS also, precludes actuation of safety relief valves and limits the peak RPV pressure to less than the ASME Section III Code limits.

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

Although there are four divisions of ICS actuation, only three ICS actuation divisions for each function are required to be OPERABLE. The three required divisions are those divisions associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," and LCO 3.8.7, "Distribution Systems - Shutdown." This is acceptable because the

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

single-failure criterion is met with three OPERABLE ICS instrumentation divisions, and because each ICS instrumentation division is associated with and receives power from only one of the four electrical divisions.

1. ICS Initiation Actuation

The ICS Initiation Actuation logic is the logic associated with automatically placing the ICS into service.

The ICS Initiation Actuation divisions receive input from the following:

- Reactor Steam Dome Pressure - High for 10 seconds,
- RPV Water Level - Low (Level 2), with time delay,
- RPV Water Level - Low (Level 1),
- Indication that two Main Steam Isolation Valves (MSIVs) in separate Main Steamlines (MSLs) are not fully open with the reactor mode switch in the run position, or
- Loss of power generation buses.

The ICS Initiation Actuation is required to be OPERABLE in MODES 1, 2, 3, 4, and 5, to preclude actuation of safety relief valves and limit the peak RPV pressure to less than the ASME Section III Code limits. Additionally, ICS Initiation Actuation assists in preserving the integrity of the fuel cladding by limiting the post-LOCA peak cladding temperature to less than the 10 CFR 50.46 limits, and removing reactor decay heat following reactor shutdown and isolation.

2. ICS Vent Actuation

The ICS Vent Actuation divisions receive input from the Condensate Return Valve Position – Open signals for each Condensate Return Valve. The logic is arranged such that if either Condensate Return Valve is open for an ICS train, then its vent will open after a 6-hour time delay.

The ICS Vent Actuation is required to be OPERABLE in MODES 1,2,3,4, and 5 to support proper operation of the ICS and to mitigate the accumulation of radiolytic hydrogen and oxygen that could cause a detonation.

ACTIONS

A.1

BASES

Condition A exists when one required ICS actuation division is inoperable. In this Condition, ICS actuation still maintains actuation trip capability but can not accommodate a single failure. The 12-hour Completion Time is acceptable based on engineering judgment considering the diversity of sensors available to provide trip signals, the redundancy of the ICS actuation design, and the low probability of an event requiring ICS actuation during this period. However, this out of service time is only acceptable provided the associated Function still maintains ICS actuation capability (refer to Required Actions B.1 Bases).

B.1

With the Required Action and associated Completion Time of Condition A not met or if two or more required actuation divisions are inoperable, the affected ICS actuation device(s) must be declared inoperable immediately. ICS automatic actuation capability is considered to be maintained when sufficient actuation divisions are OPERABLE or in trip such that the ICS logic will generate an actuation signal on a valid signal.

SURVEILLANCE REQUIREMENTS

~~SR 3.3.5.4.1~~As noted at the beginning of the Surveillance Requirements, the SRs for each ICS Actuation Function are located in the SRs column of Table 3.3.5.4-1.

SR 3.3.5.4.1

The LOGIC SYSTEM FUNCTIONAL TEST demonstrates the OPERABILITY of the required ICS logic for a specific division.

The 24 month Frequency is based on the need to perform this Surveillance under the conditions that apply during a plant outage and the potential for an unplanned transient if the Surveillance were performed with the reactor at power. Operating experience has shown these components usually pass the Surveillance when performed at the 24 month Frequency.

SR 3.3.5.4.2

This SR ensures that the individual required division response times are less than or equal to the maximum values assumed in the accident analysis. The ICS RESPONSE TIME acceptance criteria are included in Reference 2.

BASES

ICS RESPONSE TIME may be verified by actual response time measurements in any series of sequential, overlapping, or total division measurements. This test encompasses the ICS actuation circuitry from the outputs of the DTM function through the VLU function, the timers and the LDs associated with the ICS. This test overlaps the testing required by SR 3.3.5.3.4 to ensure complete testing of instrument channels and actuation circuitry.

COL 16.0-1-A
3.3.5.4-1

[However, some portions of the ICS actuation circuitry are allowed to be excluded from specific ICS RESPONSE TIME measurement if the conditions of Reference XX are satisfied. Furthermore, measurement of the instrument loops response times is not required if the conditions of Reference XX are satisfied.]

ICS RESPONSE TIME tests are conducted on a 24 month STAGGERED TEST BASIS for three divisions. The Frequency of 24 months on a STAGGERED TEST BASIS ensures that each required division is alternately tested.

The 24-month test Frequency is consistent with the typical industry refueling cycle and with operating experience that shows that random failures of instrumentation components causing serious response time degradation, but not channel failure, are infrequent.

REFERENCES

1. Chapter 15.

2. Section 15.2.

3.3 INSTRUMENTATION

3.3.6.3 Isolation Instrumentation

LCO 3.3.6.3 Three isolation instrumentation channels associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," for the Functions in Table 3.3.6.3-1 shall be OPERABLE.

APPLICABILITY: According to Table 3.3.6.3-1.

ACTIONS

- NOTES -

1. Penetration flow paths may be unisolated intermittently under administrative controls.
2. Separate Condition entry is allowed for each channel.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more Functions with one required instrumentation channel inoperable.	A.1 Restore required channel to OPERABLE status.	12 hours
B. Required Action and associated Completion Time of Condition A not met. <u>OR</u> One or more Functions with isolation capability not maintained.	B.1 Enter the Condition referenced in Table 3.3.6.3-1 for the associated Function.	Immediately

CONDITION	REQUIRED ACTION		COMPLETION TIME
C. As required by Required Action B.1 and referenced in Table 3.3.6.3-1.	C.1	Declare associated containment isolation valves inoperable.	Immediately
D. As required by Required Action B.1 and referenced in Table 3.3.6.3-1.	D.1	Be in MODE 3.	12 hours
	AND		
	D.2	Be in MODE 5.	36 hours
E. As required by Required Action B.1 and referenced in Table 3.3.6.3-1.	E.1	Initiate action to restore required channel to OPERABLE status.	Immediately
	OR		
	E.2	Initiate action to isolate Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) isolation valves.	Immediately

SURVEILLANCE REQUIREMENTS

- NOTE -

Refer to Table 3.3.6.3-1 to determine which SRs shall be performed for each isolation Function.

SURVEILLANCE		FREQUENCY
SR 3.3.6.3.1	Perform CHANNEL CHECK on each required channel.	12 hours
SR 3.3.6.3.2	Perform CHANNEL FUNCTIONAL TEST on each required channel.	31 days

SURVEILLANCE		FREQUENCY
SR 3.3.6.3.3	Perform CHANNEL CALIBRATION on each required channel consistent with Specification 5.5.11, "Setpoint Control Program (SCP)."	24 months
SR 3.3.6.3.4	-- **- NOTE -** Radiation detectors may be excluded. -- Verify ISOLATION SYSTEM RESPONSE TIME of each required channel is within limits.	 24 months on a STAGGERED TEST BASIS

Table 3.3.6.3-1 (page 1 of 2)
Isolation Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	CONDITIONS REFERENCED FROM REQUIRED ACTION B.1	SURVEILLANCE REQUIREMENTS
1. Reactor Vessel Water Level - Low, Level 2	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
	5,6	E	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
2. Reactor Vessel Water Level - Low, Level 1	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
3. Drywell Pressure - High	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
4. Main Steam Tunnel Ambient Temperature - High	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
5. RWCU/SDC Differential Mass Flow - High (per subsystem)	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
	5,6	E	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
6. Isolation Condenser Steam Line Flow - High (per Isolation Condenser)	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4

Table 3.3.6.3-1 (page 2 of 2)
Isolation Instrumentation

FUNCTION	APPLICABLE MODES OR OTHER SPECIFIED CONDITIONS	CONDITIONS REFERENCED FROM REQUIRED ACTION B.1	SURVEILLANCE REQUIREMENTS
7. Isolation Condenser Condensate Return Line Flow - High (per Isolation Condenser)	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
8. Isolation Condenser Pool Vent Discharge Radiation - High (per Isolation Condenser)	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
9. Depressurization Valve – Open	1,2,3,4	C	SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
~~9~~10. Feedwater Lines Differential Pressure - High	1,2,3,4	D	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
~~10~~11. Reactor Building Exhaust Radiation - High	1,2,3,4	C	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
~~11~~12. Drywell Water Level - High	1,2,3,4	D	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
~~12~~13. Reactor Vessel Water Level Low - Level 0.5	1,2,3,4	D	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4
~~13~~14. Drywell Pressure - High-High	1,2,3,4	D	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4

~~14~~15. Gravity-Driven Cooling System Pool Water Level - Low	1,2,3,4	D	SR 3.3.6.3.1 SR 3.3.6.3.2 SR 3.3.6.3.3 SR 3.3.6.3.4

B 3.3 INSTRUMENTATION

B 3.3.6.3 Isolation Instrumentation

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BACKGROUND

The isolation instrumentation contained in this specification provides the capability to generate isolation signals to the containment isolation valves, the reactor building heating, ventilation and air conditioning system isolation dampers, and feedwater isolation valves. The function of the isolation valves and dampers, in combination with other accident mitigation systems, is to limit fission product release during and following postulated Design Basis Accidents (DBAs). The function of the feedwater isolation valves is to also limit the mass addition of water into containment during and following a design basis feedwater line rupture inside containment. The function of the reactor water cleanup/shutdown cooling (RWCU/SDC) isolation valves in MODES 5 and 6 is to protect the core by isolating the RWCU/SDC system from the reactor pressure vessel and minimizing a potential loss of coolant resulting from a line break in the RWCU/SDC system. The function of high pressure control rod drive (HP CRD) makeup water injection isolation is to prevent the long-term addition of inventory into containment following a loss of coolant accident (LOCA). The function of the ICS isolation that occurs when 2 or more Depressurization Valves (DPVs) are open is to mitigate the accumulation of radiolytic hydrogen and oxygen that could result in a detonation.

Technical Specifications are required by 10 CFR 50.36 to contain limiting safety system settings (LSSS) defined by the regulation as "...settings for automatic protective devices related to those variables having significant safety functions." Where LSSS is specified for a variable on which a Safety Limit (SL) has been placed, the setting must be chosen such that automatic protective action will correct the abnormal situation before a SL is exceeded. The Analytical Limit is the limit of the process variable at which a safety action is initiated, as established by the safety analysis, to ensure that a SL is not exceeded. Any automatic protection action that occurs on reaching the Analytical Limit therefore ensures that the SL is not exceeded. Where LSSS is specified for a variable having a significant safety function but which does not protect SLs, the setting must be chosen such that automatic protective actions will initiate consistent with the design basis. The Design Limit is the limit of the process variable at which a safety action is initiated to ensure that these automatic protective devices will perform their specified safety function.

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BACKGROUND (continued)

The actual settings for automatic protective devices must be chosen to be more conservative than the Analytical / Design Limit to account for instrument loop uncertainties related to the setting at which the automatic protective action would actually occur. The methodology for determining the actual settings, and the required tolerances to maintain these settings conservative to the Analytical / Design Limits, including the requirements for determining that the channel is OPERABLE, are defined in the Setpoint Control Program (SCP), in accordance with Specification 5.5.11, "Setpoint Control Program (SCP)."

The Limiting Trip Setpoint (LTSP) is a predetermined setting for a protective device chosen to ensure automatic actuation prior to the process variable reaching the Analytical / Design Limit and thus ensuring that the SL would not be exceeded (i.e., for Analytical Limits), or that automatic protective actions occur consistent with the design basis (i.e., for Design Limits). As such, the LTSP accounts for process and primary element measurement errors, and uncertainties in setting the device (e.g., calibration), uncertainties in how the device might actually perform (e.g., accuracy), changes in the point of action of the device over time (e.g., drift during surveillance intervals), and any other factors that may influence its actual performance (e.g., harsh accident environments). In this manner, the LTSP ensures that SLs are not exceeded and that automatic protective devices will perform their specified safety function. As such, the LTSP meets the definition of an LSSS. The nominal trip setpoint to which the setpoint is reset after calibration is the $NTSP_F$, which is more conservative than the LTSP and has margin to assure that the Allowable Value is not exceeded during calibration.

Technical Specifications contain values related to the OPERABILITY of equipment required for safe operation of the facility. OPERABLE is defined in Technical Specifications as "...being capable of performing its safety function(s)." For automatic protective devices, the required safety function is to ensure that a SL is not exceeded and that automatic protective actions will initiate consistent with the design basis. Therefore, the LTSP is the LSSS as defined by 10 CFR 50.36. However, use of the LTSP to define OPERABILITY in Technical Specifications would be an overly restrictive requirement if it were applied as an OPERABILITY limit for the "as-found" value of a protective device setting during a Surveillance.

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BACKGROUND (continued)

However, there is also some point beyond which the device would have not been able to perform its function due, for example, to greater than expected drift. This value is specified in the SCP, as required by Specification 5.5.11, in order to define OPERABILITY of the devices and is designated as the Allowable Value which is the least conservative value of the as-found setpoint that a channel can have during CHANNEL CALIBRATION. The LTSP, $NTSP_F$, Allowable Value, "as-found" tolerance, and "as-left" tolerance, and the methodology for calculating the "as-left" and "as-found" tolerances will be maintained in the SCP, as required by Specification 5.5.11.

The Allowable Value is the least conservative value that the setpoint of the channel can have when tested such that a channel is OPERABLE if the setpoint is found conservative with respect to the Allowable Value during the CHANNEL CALIBRATION. Note that, although a channel is OPERABLE under these circumstances, the setpoint must be left adjusted to a value within the established "as-left" tolerance of the $NTSP_F$ and confirmed to be operating within the statistical allowances of the uncertainty terms assigned in the setpoint calculation. As such, the Allowable Value differs from the $NTSP_F$ by an amount equal to or greater than the "as-found" tolerance value. In this manner, the actual setting of the device will ensure that a SL is not exceeded or that automatic protective actions will initiate consistent with the design basis at any given point of time as long as the device has not drifted beyond that expected during the surveillance interval. If the actual setting of the device is found to be non-conservative with respect to the Allowable Value the device would be considered inoperable from a Technical Specification perspective. This requires corrective action including those actions required by 10 CFR 50.36 when automatic protective devices do not function as required.

The containment isolation function is performed by the Leak Detection and Isolation (LD&IS) portion of the Safety System Logic and Control/ Engineered Safety Features (SSLC/ESF) System. Functional diversity is provided by monitoring a wide range of independent parameters. Containment isolation occurs in response to signals from any of the following:

- Reactor Vessel Water Level - Low, Level 2,
- Reactor Vessel Water Level - Low, Level 1,
- Drywell Pressure - High,
- Main Steam Tunnel Ambient Temperature - High,
- RWCU/SDC Differential Mass Flow - High (per subsystem),

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BACKGROUND (continued)

- Isolation Condenser Steam Line Flow - High (per Isolation Condenser),
- Isolation Condenser Condensate Return Line Flow - High (per Isolation Condenser),
- Isolation Condenser Pool Vent Discharge Radiation - High (per Isolation Condenser), or
- Reactor Building Exhaust Radiation – High.

The RWCU/SDC isolation function in MODES 5 and 6 is performed by the LD&IS portion of the SSLC/ESF System. RWCU/SDC isolation in MODES 5 and 6 isolation occurs in response to signals from either of the following:

- Reactor Vessel Water Level - Low, Level 2, or
- RWCU/SDC Differential Mass Flow - High (per subsystem),

The feedwater isolation function is performed by the LD&IS portion of the SSLC/ESF. Feedwater isolation occurs in response to any of the following:

- Feedwater Lines Differential Pressure - High concurrent with Drywell Pressure - High,
- Drywell Pressure - High concurrent with Drywell Water Level - High,
- Reactor Vessel Water Level - Low, Level 0.5, or
- Drywell Pressure - High-High.

<u>The ICS isolation function that mitigates the accumulation of combustible gas is performed by the LD&IS portion of the SSLC/ESF. ICS isolation occurs in response to the following signal:</u>

- <u>Depressurization Valve – Open</u>

<u>At least 2 DPVs must be open for this ICS isolation to be initiated.</u>

The HP CRD isolation function is performed by the LD&IS portion of the SSLC/ESF. HP CRD isolation occurs in response to any of the following:

- Drywell Pressure - High concurrent with Drywell Water Level - High, or
- Gravity-Driven Cooling System (GDCS) Pool Water Level - Low.

The SSLC/ESF controls the initiation signals and logic for isolation. SSLC/ESF is a four division, separated protection logic system designed

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to provide a very high degree of assurance to both ensure isolation when required and prevent inadvertent initiation. The input and output trip determinations for all isolation functions are based upon a two-out-of-four logic arrangement. Each division of SSLC/ESF is configured such that all functions (e.g., the digital trip module (DTM) function and voter logic unit

BACKGROUND (continued)

(VLU) function) are implemented in triply redundant processors to support the requirement that single divisional failures cannot result in inadvertent actuation.

Four separate instrument channels are used to monitor isolation initiation parameters. Signals from sensors are multiplexed at the divisional level and triply redundant sensor data is then transmitted to the SSLC/ESF triply redundant DTM function for setpoint comparison. The output of each divisional DTM function (a trip/no-trip condition) is routed to all four divisional triply redundant VLU functions such that each divisional VLU function receives input from each of the four divisional DTM functions.

For maintenance purposes and added reliability, each DTM function has a division of sensors bypass such that all instruments in that division will be bypassed in the trip logic at the VLU functions. Thus, each VLU function will be making its trip decision on a two-out-of-three logic basis for each variable. It is possible for only one division of sensors bypass condition to be in effect at any time.

The processed trip signal from its own division and trip signals from the other three divisions are processed in the triply redundant VLU function for two-out-of-four voting.

The LD&IS logic is designed to seal-in the isolation signal once the trip has been initiated. The isolation signal overrides any control action to cause the closure of isolation valves. Reset of the isolation logic is required before any isolation valve can be manually opened.

Equipment within a single division is powered from the safety-related power source of the same division.

This Specification provides Operability requirements for the isolation instrumentation from the input variable sensors through the DTM function. Operability requirements for the isolation actuation circuitry consisting of timers, VLU functions, and load drivers are provided by LCO 3.3.6.4, "Isolation Actuation." Operability requirements for the actuated components are addressed in LCO 3.6.1.3, "Containment Isolation Valves

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(CIVs)," and LCO 3.6.3.1, "Reactor Building (Contaminated Area Ventilation Subsystem (CONAVS) Area)."

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY

The containment isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate closure of containment isolation valves and reactor building boundary isolation dampers to limit off-site doses. Refer to LCO 3.6.1.3, "Containment Isolation Valves (CIVs)," Applicable Safety Analyses Bases, for more detail on containment isolation valves and LCO 3.6.3.1, "Reactor Building (Contaminated Area Ventilation Subsystem (CONAVS) Area)," Applicable Safety Analyses Bases for more detail on reactor building boundary isolation dampers.

The RWCU/SDC isolation signals generated by the isolation instrumentation are assumed in the analyses of Reference 3 to initiate closure of the RWCU/SDC isolation valves to protect the core by minimizing a potential loss of reactor pressure vessel coolant inventory in MODES 5 and 6.

The feedwater isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate closure of feedwater isolation valves to limit mass water additions to the containment during and following a design basis feedwater line rupture inside containment.

<u>The ICS isolation signals generated by the isolation instrumentation in response to the opening of 2 or more DPVs are assumed in the safety analyses of References 1 and 2 to mitigate the accumulation of radiolytic hydrogen and oxygen that could result in a detonation that would fail the ICS condensers and cause a breach of containment.</u>

The HP CRD isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate closure of HP CRD makeup water injection isolation valves to limit mass water additions to the containment following a LOCA.

Isolation instrumentation satisfies Criterion 3 of 10 CFR 50.36(c)(2)(ii). However, certain monitored instrumentation parameters are retained for other reasons and are described below in the individual process parameter discussion.

The OPERABILITY of the isolation instrumentation is dependent on the OPERABILITY of the individual instrumentation channel Functions specified in Table 3.3.6.3-1. Each Function must have the required

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number of OPERABLE channels, with their setpoints in accordance with the SCP, where appropriate. Each channel must also respond within its assumed response time, where appropriate. $NTSP_F$s are specified in the SCP, as required by Specification 5.5.11. The $NTSP_F$s are selected to ensure the setpoints are conservative with respect to the Allowable Value between successive CHANNEL CALIBRATIONS. Operation with a trip setpoint less conservative than

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

the $NTSP_F$, but conservative with respect to its Allowable Value, is acceptable. A channel is inoperable if its actual trip setpoint is non-conservative with respect to its required Allowable Value.

In general, the individual monitored process parameters are required to be OPERABLE in MODES 1, 2, 3, and 4 consistent with the Applicability of LCO 3.6.1.3 and LCO 3.6.3.1. Functions that have different Applicabilities are discussed below in the individual Functions discussion.

Although there are four channels of isolation instrumentation for each function, only three channels of isolation instrumentation for each function are required to be OPERABLE. The three required channels are those channels associated with the DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating." This is acceptable because the single-failure criterion is met with three OPERABLE isolation instrumentation channels, and because each isolation instrumentation division is associated with and receives power from only one of the four electrical divisions.

The specific Applicable Safety Analyses, LCO and specific Applicability discussions are provided below on a Function basis.

1. Reactor Vessel Water Level - Low, Level 2

Low reactor pressure vessel (RPV) water level indicates the capability to cool the fuel may be threatened. Should RPV water level decrease too far, fuel damage could result. The isolations of valves whose penetration communicate with the containment or the reactor vessel and the isolation of the reactor building boundary isolation dampers limit the release of fission products to help ensure that offsite does limits are not exceeded. The Reactor Vessel Water Level - Low, Level 2 is credited in the LOCA inside containment radiological analysis (Ref. 4).

In MODES 5 and 6, low RPV water level may indicate a loss of coolant. Should RPV water level decrease too far, the ability to cool the core may be threatened. Closure of the RWCU/SDC isolation valves isolates the system from the RPV, minimizing the potential loss of coolant inventory. The Reactor Vessel Water Level - Low, Level 2 is implicitly credited in the shutdown probabilistic risk assessment (Ref. 3), and therefore satisfies Criterion 4 of 10 CFR 50.36(c)(2)(ii).

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

Reactor Vessel Water Level - Low, Level 2 signals are initiated from four level sensors that sense the difference between the pressure due to a constant column (reference leg) of water and the pressure due to the actual water level (variable leg) in the vessel. Three channels of Reactor Vessel Water Level - Low, Level 2 Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The Reactor Vessel Water Level - Low, Level 2 Allowable Value was chosen to be the same as the Isolation Condenser System Reactor Vessel Water Level - Low, Level 2 Allowable Value.

This Function isolates the RWCU/SDC lines, Equipment and Floor Drain System lines, Containment Inerting System lines, and the Fuel and Auxiliary Pools Cooling System process lines.

2. Reactor Vessel Water Level - Low, Level 1

Low RPV water level indicates the capability to cool the fuel may be threatened. Should RPV water level decrease too far, fuel damage could result. The isolations of valves whose penetration communicate with the containment or the reactor vessel and the isolation of the reactor building boundary isolation dampers limit the release of fission products to help ensure that offsite does limits are not exceeded. The Reactor Vessel Water Level - Low, Level 1 channels are provided as a backup to the Reactor Vessel Water Level - Low, Level 2 channels and is not credited in the safety analysis.

Reactor Vessel Water Level - Low, Level 1 signals are initiated from four level sensors that sense the difference between the pressure due to a constant column (reference leg) of water and the pressure due to the actual water level (variable leg) in the vessel. Three channels of Reactor Vessel Water Level - Low, Level 1 Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The Reactor Vessel Water Level - Low, Level 1 Allowable Value was chosen to be the same as the Automatic Depressurization System Reactor Vessel Water Level - Low, Level 1 Allowable Value.

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

This Function isolates the RWCU/SDC lines, Process Radiation Monitoring System lines, Equipment and Floor Drain System lines, Containment Inerting System lines, Chilled Water System lines, and the Fuel and Auxiliary Pools Cooling System process lines.

3. Drywell Pressure - High

High drywell pressure can indicate a break in the reactor coolant pressure boundary. The isolations of valves whose penetration communicate with the containment and the isolation of the reactor building boundary isolation dampers limit the release of fission products to help ensure that offsite dose limits are not exceeded. The Drywell Pressure - High channels are not explicitly credited in the safety analyses but retained for the overall redundancy and diversity of the isolation instrumentation.

High drywell pressure signals are initiated from four pressure sensors that sense the pressure in the drywell. Three channels of Drywell Pressure - High are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The Drywell Pressure - High Allowable Value was chosen to be the same as the Reactor Protection System Drywell Pressure - High Allowable Value.

This Function isolates the Process Radiation Monitoring System lines, Equipment and Floor Drain System lines, Containment Inerting System lines, Chilled Water System lines, Fuel and Auxiliary Pools Cooling System process lines, and High Pressure Nitrogen Gas Supply System lines. In addition, this Function, in conjunction with either Feedwater Lines Differential Pressure - High or Drywell Water Level - High, isolates the feedwater lines. This Function, in conjunction with Drywell Water Level - High, also isolates the HP CRD makeup water injection line.

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

4. Main Steam Tunnel Ambient Temperature - High

Main Steam Tunnel Ambient Temperature - High Function is provided to detect a leak in the reactor coolant pressure boundary. The isolation occurs when a very small leak has occurred. If the small leak is allowed to continue without isolation, off-site dose limits may be reached. However, credit for these instruments is not taken in any transient or accident analysis because bounding analyses are performed for large breaks such as a MSL break.

Temperature signals are initiated from thermocouples located away from the main steam lines so they are only sensitive to ambient air temperature. Three channels of Main Steam Tunnel Temperature - High Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The ambient temperature monitoring Allowable Value is based on the room or compartment size and the cooling provisions of the ventilation system.

The Main Steam Tunnel Ambient Temperature - High Function isolates the RWCU/SDC System lines.

5. RWCU/SDC Differential Mass Flow - High (per subsystem)

The Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) System Differential Mass Flow - High signal is provided to detect a break in the RWCU System outside containment. Should the reactor coolant continue to flow out the break off-site dose limits may be exceeded. Therefore, isolation of the RWCU System is initiated when RWCU/SDC System Differential Mass Flow - High is sensed to prevent exceeding off-site doses. This Function is directly assumed in the RWCU/SDC System line failure event outside containment (Ref. 5).

In MODES 5 and 6, high RWCU/SDC differential flow may indicate a loss of coolant. Should RPV water level decrease too far, the ability to cool the core may be threatened. Closure of the RWCU/SDC isolation valves isolates the system from the RPV, minimizing the potential loss of coolant inventory. The Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) System Differential Mass Flow - High is implicitly credited in the shutdown probabilistic risk assessment (Ref. 3), and therefore satisfies Criterion 4 of 10 CFR 50.36(c)(2)(ii).

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

Each RWCU/SDC subsystem includes a suction line near the mid level of the reactor pressure level (RPV) and another suction line at the RPV bottom. Each suction line includes a venturi-type flow element inside containment. Each flow element is instrumented with four flow sensors. The temperature of each suction line is also monitored by four temperature elements close to the venturi-type flow element. Each RWCU/SDC subsystem also includes a return line to the feedwater lines and another return line to the overboarding lines. These lines are instrumented consistent with the suction lines. Each flow rate signal is converted to a mass flow rate signal using its associated temperature element. A differential flow rate is calculated from the difference between the suction flows and return flows. This differential flow rate is compared to the setpoint. Therefore, each differential flow channel consists of all the components necessary to calculate the differential flow signal and provide a trip signal.

Three channels of the RWCU/SDC System Differential Mass Flow - High Function per RWCU/SDC subsystem are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The RWCU/SDC System Differential Mass Flow - High Allowable Value ensures that a leak or a line break of the RWCU/SDC piping is detected.

This Function isolates the RWCU/SDC lines.

<u>6, 7, and 8. Isolation Condenser Steam and Condensate Return Line Flow - High and Pool Vent Discharge Radiation - High</u>

The Isolation Condenser Steam Line Flow - High, Condensate Return Line Flow - High, and Pool Vent Discharge Radiation - High Functions are provided to monitor the pressure boundary status of each individual Isolation Condenser System (ICS) subsystem. The Isolation Condenser Steam Line Flow - High and Condensate Return Line Flow - High Functions will isolate the associated subsystem when a leak or a break has occurred while the Pool Vent Discharge Radiation - High Function will isolate the associated subsystem when leakage is detected outside the drywell. These Functions are not assumed in any transient or accident analysis since bounding analyses are performed for large breaks such as MSL breaks.

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APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

The isolation signals can be initiated from a total of 12 instruments per ICS subsystem, with each ICS subsystem having four differential pressure sensors per ICS subsystem steam line, four differential pressure sensors per ICS subsystem condensate line, and four radiation detectors located in its associated ICS subsystem vent discharge into the pool area. The flow instrumentation is designed to detect leakage both inside and outside of the drywell. The radiation detectors are designed to detect leakage outside of containment. Three channels of each monitored parameter for each ICS subsystem are required to be OPERABLE to ensure no single instrument failure can preclude the isolation functions.

The Allowable Value is chosen to be low enough to ensure that the isolation occurs to prevent fuel damage and maintains the MSL break event as the bounding event.

These Functions isolate the associated ICS lines.

9. Depressurization Valve – Open

The DPV – Open Function is provided to indicate that RPV depressurization has occurred and that the ICS is no longer required to perform its heat removal function. In this situation, the ICS is required to be isolated to mitigate the accumulation of radiolytic hydrogen and oxygen that could result in a detonation that would cause a containment breach. This Function is assumed in the safety analyses of References 1 and 2.

The position of each DPV is measured by 4 divisional position switches. The logic is arranged such that ICS Isolation will occur whenever 2 or more DPVs are open. Three channels of the DPV – Open Function are required to be OPERABLE for each DPV required by LCO 3.5.1, "Automatic Depressurization System (ADS) – Operating," to ensure no single instrument failure can preclude the isolation function.

This Function isolates the ICS lines.

~~9~~10. Feedwater Lines Differential Pressure - High

The Feedwater Line Differential Pressure - High signal is provided to detect a break in the feedwater lines inside containment. Should the feedwater continue to flow into containment, containment integrity could be challenged as a result of the mass and energy addition to the containment drywell from the external feedwater system. Therefore, isolation of the feedwater system flow is initiated when Feedwater Lines Differential Pressure - High is sensed to protect containment integrity. This Function is implicitly assumed in the safety analyses of References 1 and 2.

The differential pressure between the two feedwater lines is monitored by four divisions of LD&IS. A high differential pressure is indicative of a feedwater line break inside and outside the containment.

Three channels of the Feedwater Line Differential Pressure - High Function are required to be OPERABLE to ensure that no single instrument failure can preclude the isolation function.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

The Feedwater Line Differential Pressure - High Allowable Value ensures that a leak or a line break of the feedwater piping is detected, in accordance with the containment analyses (Ref. 1).

This Function in conjunction with the Drywell Pressure - High Function isolates the feedwater lines.

~~10~~11. Reactor Building Exhaust Radiation - High

High radiation in the reactor building exhaust or the refueling area exhaust is an indication of fission gases from a leak or an accident. The release may have originated from the containment due to a break in the reactor coolant pressure boundary or the refueling floor due to a fuel handling accident. When a Reactor Building Exhaust Radiation - High signal is detected, the Reactor Building Heating, Ventilation and Air Conditioning System is isolated. This Function is assumed to be available during high energy line break conditions and during a LOCA because the reactor building is credited for hold up and as a plate out barrier.

The Reactor Building Exhaust Radiation - High signal is initiated from radiation detectors that are located on the ventilation exhaust piping coming from the reactor building. Three channels of the Reactor Building Exhaust Radiation - High Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation functions.

The Reactor Building Exhaust Radiation - High Allowable Value is chosen to ensure the RB is isolated prior to radioactivity release exceeding the assumptions of the offsite does analyses.

~~11~~12. Drywell Water Level - High

High drywell water level is an indication of a possible line break inside containment. This Function is provided to ensure that feedwater and HP CRD are isolated in the event of a LOCA, but remains capable of coolant injection for other accident scenarios.

Drywell water level is monitored by four channels of water level instrumentation. Three channels of the Drywell Water Level - High Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

The Drywell Water Level - High Allowable Value is chosen to be low enough to ensure feedwater isolation occurs, limiting the flow of condensate into containment in accordance with the containment analyses (Ref. 1).

This Function in conjunction with the Drywell Pressure - High Function isolates the feedwater lines and the HP CRD makeup water injection line.

~~12~~13. Reactor Vessel Water Level - Low, Level 0.5

Low RPV water level indicates the capability to cool the fuel may be threatened. Should RPV water level decrease too far, fuel damage could result. The isolations of valves whose penetration communicate with the containment or the reactor vessel limit the release of fission products to help ensure that offsite does limits are not exceeded. Reactor Vessel Water Level - Low, Level 0.5 signals are initiated from four fuel zone level sensors.

The Reactor Vessel Water Level - Low, Level 0.5 Allowable Value is chosen to ensure that feedwater line isolations occurs in accordance with the assumptions of Reference 4.

Three channels of Reactor Vessel Water Level - Low, Level 0.5 Function are required to be OPERABLE to ensure that no single instrument failure can preclude feedwater line isolation.

~~13~~14. Drywell Pressure - High-High

High drywell pressure is an indication of a possible line break inside containment. This Function is provided to ensure that feedwater is isolated in the event of a LOCA, but remains capable of coolant injection for other accident scenarios.

Drywell pressure is monitored by four channels of pressure instrumentation. Three channels of the Drywell Pressure - High-High Function are required to be OPERABLE to ensure no single instrument failure can preclude the isolation function.

The Drywell Pressure - High-High Allowable Value is chosen to be higher than the scram setpoint to prevent undesired initiation, and low enough to retain effectiveness throughout the entire spectrum of LOCA events.

This Function isolates the feedwater lines.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

~~14~~15. Gravity-Driven Cooling System Pool Water Level - Low

Low GDCS pool water level indicates the injection of water from the GDCS pools in the event of a LOCA. This Function is provided to ensure that the HP CRD makeup water injection is isolated to prevent the long-term addition of inventory to the containment following GDCS injection in response to a LOCA.

GDCS pool water level is monitored by four channels of water level indication in each GDCS pool. Three channels of the GDCS Pool Water Level - Low Function are required to be OPERABLE in each GDCS pool. This Function initiates upon a low level in two out of the three GDCS pools.

The GDCS Pool Water Level - Low Allowable Value is determined by analysis to ensure effectiveness under the full spectrum of LOCA events.

This Function isolates the HP CRD makeup water injection line.

ACTIONS

The ACTIONS are modified by two NOTES. Note 1 allows penetration flow path(s) to be unisolated intermittently under administrative controls. These controls consist of stationing a dedicated operator at the controls of the valve, who is in continuous communication with the control room. In this way, the penetration flow path can be rapidly isolated when a need for isolation is indicated. Note 2 has been provided to modify the ACTIONS related to Isolation Instrumentation channels. Section 1.3, Completion Times, specifies once a Condition has been entered, subsequent divisions, subsystems, components or variables expressed in the Condition discovered to be inoperable or not within limits, will not result in separate entry into the Condition. Section 1.3 also specifies Required Actions of the Condition continue to apply for each additional failure, with Completion Times based on initial entry into the Condition. However, the Required Actions for inoperable Isolation Instrumentation channels provide appropriate compensatory measures for separate inoperable channels. As such, a Note has been provided which allows separate Condition entry for each inoperable Isolation Instrumentation channel.

BASES

ACTIONS (continued)

A.1

With one or more Functions with one required channel inoperable, the affected required channel must be restored to OPERABLE status within 12 hours. The 12-hour Completion Time is acceptable based on engineering judgment considering the diversity of sensors available to provide isolation signals, the redundancy of the isolation design, and the low probability of an event requiring isolation during this interval. However, this out of service time is only acceptable provided the associated Function still maintains isolation capability (refer to Required Actions B.1 Bases). If the inoperable required channel cannot be restored to OPERABLE status within the 12-hour Completion Time, the affected instrumentation division must be verified to be in trip. This is acceptable because verifying the affected isolation instrumentation division in trip conservatively compensates for the inoperability by placing the isolation instrumentation in a one-out-of-two configuration, restoring the capability to accommodate a single failure.

Alternatively, if it is not desirable to verify the required instrument channel in trip (as in the case where it is desirable to place the affected channel of sensors in bypass), Condition C must be entered and its Required Action taken when the Completion Time of Required Action A.1 expires.

B.1

This Required Action directs entry into the appropriate Condition referenced in Table 3.3.6.3-1 if the Required Action and Completion Time of Condition A is not met or if multiple, inoperable, untripped required channels for the same Function result in the Function not maintaining isolation capability. A Function is considered to be maintaining isolation capability when sufficient channels are OPERABLE or in trip such that the isolation logic will generate a trip signal from the given Function on a valid signal so that at least one valve in the associated penetration flow path is isolated. The applicable Condition specified in the Table is Function and MODE or other specified condition dependent and may change as the Required Action of a previous Condition is completed.

BASES

ACTIONS (continued)

C.1

If the affected instrumentation channel cannot be verified to be in trip within the specified Completion Time or if isolation capability is not maintained, plant operations may continue if the associated Containment Isolation Valve(s) (CIVs) is declared inoperable immediately. Because this Function is required to ensure that the CIVs perform their intended function, sufficient remedial measures are provided by declaring the associated CIV(s) inoperable.

D.1 and D.2

If the affected instrumentation channel cannot be verified to be in trip within the specified Completion Time or if isolation capability is not maintained, 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.

E.1 and E.2

If the affected instrumentation channel cannot be verified to be in trip within the specified Completion Time or if isolation capability is not maintained, the associated flow path should be isolated. However, if the RWCU/SDC function is needed to provide core cooling, these Required Actions allow the flow path to remain unisolated provided action is immediately initiated to restore the channel to OPERABLE status or to isolate the RWCU/SDC system (i.e., provide alternate decay heat removal capabilities so the flow path can be isolated). ACTIONS must continue until the channel is restored to OPERABLE status or the RWCU/SDC system is isolated.

SURVEILLANCE REQUIREMENTS

As noted at the beginning of the Surveillance Requirements, the SRs for each isolation instrumentation Function are located in the SRs column of Table 3.3.6.3-1.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.3.6.3.1

Performance of the CHANNEL CHECK once every 12 hours ensures that a gross failure of instrumentation has not occurred.

The SSLC/ESF is cyclically tested from the sensor input point to the logic contact output by online self-diagnostics. The self-diagnostic capabilities include microprocessor checks, system initialization, watchdog timers, memory integrity checks, input/output (I/O) data integrity checks, communication bus interface checks, and checks on the application program (checksum).

A CHANNEL CHECK will detect gross channel failure; thus, it is key to verifying the instrumentation continues to operate properly between each CHANNEL CALIBRATION.

Agreement criteria are determined by the unit staff, based on a combination of the channel instrument uncertainties, including indication, and readability. If a channel is outside the match criteria, it may be an indication that the instrument has drifted outside its limit.

The Surveillance Frequency is based on operating experience that demonstrates channel failure is rare.

The CHANNEL CHECK supplements less formal, but more frequent checks of channels during normal operational use of the displays associated with the LCO required channels.

SR 3.3.6.3.2

A CHANNEL FUNCTIONAL TEST is performed on each required channel to ensure that the channel will perform the intended function. This test ensures a complete CHANNEL FUNCTIONAL TEST of required instrument channels from the sensor input through the DTM function.

The SSLC/ESF is cyclically tested from the sensor input point to the logic contact output by online self-diagnostics. The self-diagnostic capabilities include microprocessor checks, system initialization, watchdog timers, memory integrity checks, input/output (I/O) data integrity checks, communication bus interface checks, and checks on the application program (checksum).

BASES

SURVEILLANCE REQUIREMENTS (continued)

The Frequency of 31 days is based on the reliability of the Isolation Instrumentation channels and the self-diagnostic features that monitor the channels for proper operation.

SR 3.3.6.3.3

CHANNEL CALIBRATION is a complete check of the instrument loop and the sensor. This test verifies that the required channel responds to the measured parameter within the necessary range and accuracy. CHANNEL CALIBRATION leaves the required channel adjusted to the $NTSP_F$ within the "as-left" tolerance to account for instrument drifts between successive calibrations consistent with the methods and assumptions required by the SCP.

The Surveillance Frequency is based on the assumption of a 24 month calibration interval in the determination of the magnitude of equipment drift in the setpoint analysis.

SR 3.3.6.3.4

This SR ensures that the individual required channel response times are less than or equal to the maximum values assumed in the accident analysis. The instrument response times must be added to the associated closure times to obtain the ISOLATION SYSTEM RESPONSE TIME. ISOLATION SYSTEM RESPONSE TIME acceptance criteria are included in Reference 6.

ISOLATION SYSTEM RESPONSE TIME may be verified by actual response time measurements in any series of sequential, overlapping, or total channel measurements. This test encompasses the isolation instrumentation from the input variable sensors through the DTM function. This test overlaps the testing required by SR 3.3.6.4.2 to ensure complete testing of instrumentation channels and actuation circuitry.

A Note to the Surveillance states that the radiation detectors may be excluded from ISOLATION SYSTEM RESPONSE TIME testing. This Note is necessary because of the difficulty of generating an appropriate detector input signal and because the principles of detector operation virtually ensure an instantaneous response time. Response Time for radiation detection channels shall be measured from detector output or the input of the first electronic component in the channel.

BASES

SURVEILLANCE REQUIREMENTS (continued)

COL 16.0-1-A
3.3.6.3-2

[However, some sensors are allowed to be excluded from specific ISOLATION SYSTEM RESPONSE TIME measurement if the conditions of Reference XX are satisfied. If these conditions are satisfied, sensor response time may be allocated based on either assumed design sensor response time or the manufacturer's stated design response time. When the requirements of Reference XX are not satisfied, sensor response time must be measured. Furthermore, measurement of the instrument loops response time for some Functions is not required if the conditions of Reference XX are satisfied.]

ISOLATION SYSTEM RESPONSE TIME tests are conducted on a 24-month STAGGERED TEST BASIS for three channels. The Frequency of 24 months on a STAGGERED TEST BASIS ensures that the required channels associated with each division are alternately tested. The 24-month test Frequency is consistent with the refueling cycle and has with operating experience that shows that random failures of instrumentation components causing serious response time degradation, but not channel failure, are infrequent.

REFERENCES

1. Section 6.2.
2. Chapter 15.
3. NEDO-33201, ESBWR Certification Probabilistic Risk Assessment, Revision 5, February 2010.
4. Subsection 15.4.4.
5. Subsection 15.4.9.
6. Section 15.2.

B 3.3 INSTRUMENTATION

B 3.3.6.4 Isolation Actuation

BASES

BACKGROUND

The isolation actuation logic is designed to isolate the affect penetration flow paths when one or more monitored parameters exceed the specified limit. The isolation actuation logic actuates the following containment isolation flow paths: (a) Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) System lines, (b) Isolation Condenser System (ICS) lines, (c) Process Radiation Monitoring System lines, (d) Equipment and Floor Drain System lines, (e) Containment Inerting System lines, (f) Chilled Water System lines, (g) Fuel and Auxiliary Pools Cooling System (FAPCS) process lines, and (h) High Pressure Nitrogen Gas Supply System lines. The isolation actuation logic also isolates the reactor building boundary isolation dampers. The function of the containment isolation valves and reactor building boundary isolation dampers, in combination with other accident mitigation systems, is to limit fission product release during postulated Design Basis Accidents (DBAs). Containment and reactor building isolation within the times specified ensure that the release of radioactive materials to the environment will be consistent with the assumptions used in the analysis of DBAs.

The isolation actuation logic is also designed to isolate the RWCU/SDC System from the reactor pressure vessel (RPV) in MODES 5 and 6, isolate feedwater flow into containment and trip main feedwater pump breakers, isolate the ICS when 2 or more Depressurization Valves (DPVs) are open, and isolate high pressure control rod drive (HP CRD) makeup water injection when one or more monitored parameters exceed the specified limit. The function of the feedwater isolation valves is to limit the mass addition of water into containment during and following a design basis feedwater line rupture inside containment. The function of the reactor water cleanup/shutdown cooling (RWCU/SDC) isolation valves in MODES 5 and 6 is to protect the core by isolating the RWCU/SDC system from the reactor pressure vessel and minimizing a potential loss of coolant resulting from a line break in the RWCU/SDC system. The function of the ICS isolation that occurs when 2 or more DPVs are open is to mitigate the accumulation of radiolytic hydrogen and oxygen that could result in a detonation. The function of the HP CRD makeup water isolation is to prevent the long-term addition of inventory to the containment following a loss of coolant accident (LOCA).

A detailed description of the isolation instrumentation and isolation actuation logic is provided in the Bases for LCO 3.3.6.3, "Isolation Instrumentation."

BASES

BACKGROUND (continued)

This Specification provides Operability requirements for the isolation actuation circuitry consisting of timers, voter logic unit (VLU) functions, and load drivers. Operability requirements for the isolation instrumentation from the input variable sensors through the DTM function are provided by LCO 3.3.6.3, "Isolation Instrumentation." Operability requirements for the actuated components are addressed in LCO 3.6.1.3, "Containment Isolation Valves (CIVs)," and LCO 3.6.3.1, "Reactor Building (Contaminated Area Ventilation Subsystem (CONAVS) Area)."

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY

The containment isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate closure of valves and reactor building boundary isolation dampers to limit off site doses. Refer to LCO 3.6.1.3, Applicable Safety Analyses, for more details of containment isolation valves. Refer to LCO 3.6.3.1, Applicable Safety Analyses, for more details of the reactor building isolation dampers.

The RWCU/SDC isolation signals generated by the isolation instrumentation are assumed in the analyses of Reference 3 to initiate closure of the RWCU/SDC isolation valves to protect the core by minimizing a potential loss of reactor pressure vessel coolant inventory in MODES 5 and 6.

The feedwater isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate closure of feedwater isolation valves to limit mass water additions to the containment during and following a design basis feedwater line rupture inside containment.

The ICS isolation signals generated by the isolation instrumentation in response to the opening of 2 or more DPVs are assumed in the safety analyses of References 1 and 2 to mitigate the accumulation of radiolytic hydrogen and oxygen that could result in a detonation that would fail the ICS condensers and cause a breach of containment. A time delay is provided to ensure the ICS liquid inventory is drained to the RPV prior to isolation.

The HP CRD isolation signals generated by the isolation instrumentation are assumed in the safety analyses of References 1 and 2 to initiate isolation of the HP CRD makeup water injection line to prevent the long-term addition of inventory to the containment following a LOCA.

BASES

Isolation Actuation satisfies Criteria 3 and 4 of 10 CFR 50.36(c)(2)(ii).

Although there are four isolation actuation divisions, only three are required to be OPERABLE to ensure no single automatic actuation division failure will preclude an isolation to occur on a valid signal. The three required divisions are those divisions associated with the DC and

Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating." This is acceptable because the single-failure criterion is still met with three OPERABLE isolation actuation divisions, and because each isolation division is associated with and receives power from only one of the four electrical divisions.

The individual containment isolation actuation divisions are required to be OPERABLE in the MODES 1, 2, 3, and 4 consistent with the Applicability of LCO 3.6.1.3 and LCO 3.6.3.1. The feedwater isolation valve actuation divisions are required to be OPERABLE in MODES 1, 2, 3, and 4 consistent with the assumptions of References 1 and 2. The RWCU/SDC isolation actuation division is also required to be OPERABLE in MODES 5 and 6 consistent with the assumptions of Reference 3.

1. Reactor Water Cleanup/Shutdown Cooling System Isolation

The RWCU/SDC System Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 2; Reactor Vessel Water Level - Low, Level 1; Main Steam Tunnel Ambient Temperature - High; and Reactor Water Cleanup/Shutdown Cooling System Differential Mass Flow - High (per RWCU/SDC subsystem) Functions. In MODES 5 and 6, the RWCU/SDC System Isolation actuation divisions receive input from the Reactor Vessel Water Level - Low, Level 2 and from the Reactor Water Cleanup/Shutdown Cooling System Differential Mass Flow - High (Per RWCU/SDC subsystem) Functions. Three Reactor Water Cleanup/Shutdown Cooling System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

2. Isolation Condenser System Isolation

The Isolation Condenser System Isolation actuation divisions receive input from the following isolation instrumentation: Isolation Condenser Steam Line Flow - High (per ICS subsystem); Isolation Condenser

BASES

Condensate Line Flow - High (per ICS subsystem); ~~and~~ Isolation Condenser Pool Vent Discharge Radiation - High (per ICS subsystem); and Depressurization Valve - Open Functions. Three Isolation Condenser System Isolation actuation divisions ~~per ICS subsystem~~ are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

3. Process Radiation Monitoring System Isolation

The Process Radiation Monitoring System Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 1; and Drywell Pressure - High Functions. Three Process Radiation Monitoring System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

4. Equipment and Floor Drain System Isolation

The Equipment and Floor Drain System Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 2; Reactor Vessel Water Level - Low, Level 1; and Drywell Pressure High Functions. Three Equipment and Floor Drain System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

5. Containment Inerting System Isolation

The Containment Inerting System Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 2; Reactor Vessel Water Level - Low, Level 1 and Drywell Pressure - High Functions. Three Containment Inerting System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

6. Chilled Water System Isolation

The Chilled Water System Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 1; and Drywell Pressure - High Functions. Three Chilled Water System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

7. Fuel and Auxiliary Pools Cooling System Process Lines

The FAPCS Process Lines isolation actuation divisions receive input from the following isolation instrumentation: the Reactor Vessel Water Level - Low, Level 2; Reactor Vessel Water Level - Low, Level 1; and Drywell Pressure - High Functions. Three FAPCS Process Lines isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

8. Reactor Building Heating, Ventilation and Air Conditioning System Isolation

Reactor Building Heating, Ventilation and Air Conditioning System Isolation actuation divisions receive input from the Reactor Building Exhaust Radiation - High. Three Reactor Building Heating, Ventilation and Air Conditioning System Isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

9. High Pressure Nitrogen Gas Supply Isolation

The High Pressure Nitrogen Gas Supply Isolation actuation divisions receive input from the following isolation instrumentation: Reactor Vessel Water Level - Low, Level 1; and Drywell Pressure - High Functions. Three High Pressure Nitrogen Gas Supply isolation actuation divisions are required to be OPERABLE to ensure no single isolation actuation failure can preclude the isolation function.

10. Feedwater Isolation Valves Isolation

The Feedwater Isolation Valve Isolation actuation divisions receive input from the Feedwater Lines Differential Pressure - High, Drywell Water Level - High, Reactor Vessel Level - Low, Level 0.5, Drywell Pressure - High, and Drywell Pressure - High-High isolation instrumentation channels. Each feedwater line includes one feedwater control valve installed as the inboard containment isolation valve and the first of two in-series feedwater isolation valves is installed as the outboard containment isolation valve. The second feedwater isolation valve and feedwater control valve provide functional redundancy. This Function actuates the two feedwater isolation valves in each feedwater line to

BASES

APPLICABLE SAFETY ANALYSES, LCO, and APPLICABILITY (continued)

provide isolation in the event of a feedwater line break inside containment. Three Feedwater Isolation Valve - Isolation actuation divisions are required to be OPERABLE to ensure that no single isolation actuation failure can preclude the Function.

11. High Pressure Control Rod Drive Isolation

The HP CRD Isolation actuation divisions receive input from the Gravity Driven-Driven Cooling System (GDCS) Pool Water Level - Low, Drywell Pressure - High, and Drywell Water Level - High isolation instrumentation channels. The HP CRD makeup water injection line contains two in-series isolation valves. This Function actuates the two isolation valves in the HP CRD makeup water injection line to prevent addition of inventory to the containment by this pathway following a LOCA. Three HP CRD Isolation actuation divisions are required to be OPERABLE to ensure that no single isolation actuation failure can preclude the isolation function.

ACTIONS

The ACTIONS are modified by two NOTES. Note 1 allows penetration flow path(s) to be unisolated intermittently under administrative controls. These controls consist of stationing a dedicated operator at the controls of the valve, who is in continuous communication with the control room. In this way, the penetration flowpath can be rapidly isolated when a need for isolation is indicated. Note 2 has been provided to modify the ACTIONS related to isolation actuation. Section 1.3, Completion Times, specifies once a Condition has been entered, subsequent divisions, subsystems, components or variables expressed in the Condition discovered to be inoperable or not within limits, will not result in separate entry into the Condition. Section 1.3 also specifies Required Actions of the Condition continue to apply for each additional failure, with Completion Times based on initial entry into the Condition. However, the Required Actions for inoperable isolation actuation provides appropriate compensatory measures for separate inoperable isolation actuation divisions. As such, a Note has been provided which allows separate Condition entry for each inoperable isolation actuation division.

BASES

ACTIONS (continued)

A.1

The 4-hour Completion Time is consistent with the Completion Times of LCO 3.6.1.3 for penetration flow paths with two CIVs and is acceptable based on engineering judgment considering the diversity of sensors available to provide isolation signals, the redundancy of the isolation design, and the low probability of an accident requiring isolation during this time. However, this out of service time is only acceptable provided the associated Function still maintains isolation actuation capability (refer to Required Actions B.1 Bases). If the inoperable division cannot be restored to OPERABLE status within the 4-hour Completion Time, the affected required actuation division must be verified to be in trip. This is acceptable because verifying the affected isolation actuation division in trip conservatively compensates for the inoperability by placing the isolation actuation in a one-out-of-two configuration, restoring the capability to accommodate a single failure.

Alternatively, if it is not desirable to verify the affected required actuation division in trip (as in the case where it is desired to place the affected division in bypass), Condition C must be entered and its Required Action taken when the Completion Time of Required Action A.1 expires.

B.1

This Required Action directs entry into the appropriate Condition referenced in Table 3.3.6.4-1 if the Required Action and Completion Time of Condition A is not met or if multiple, inoperable, untripped required divisions of isolation actuation (i.e., one or two divisions associated with each isolation valve or damper in a penetration flow path) result in the isolation actuation capability not maintained. Isolation automatic actuation capability is considered to be maintained when sufficient actuation divisions are OPERABLE or in trip such that the isolation logic will generate a trip signal on a valid signal to close one valve on the associated penetration. The applicable Condition specified in the Table is Function and MODE or other specified condition dependent and may change as the Required Action of a previous Condition is completed.

BASES

ACTIONS (continued)

C.1

With the Required Action and associated Completion Time of Condition A not met, or if isolation actuation capability is not maintained, the affected isolation actuation device(s) must be declared inoperable immediately. Isolation actuation capability is considered to be maintained when sufficient actuation divisions are OPERABLE such that isolation logic will generate an actuation signal on a valid signal.

D.1 and D.2

With the Required Action and associated Completion Time of Condition A not met, or if two or more required actuation divisions inoperable, 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.

E.1 and E.2

If the affected actuation division cannot be verified to be in trip within the specified Completion Time or if isolation capability is not maintained, the associated flow path should be isolated. However, if the RWCU/SDC function is needed to provide core cooling, these Required Actions allow the flow path to remain unisolated provided action is immediately initiated to restore the division to OPERABLE status or to isolate the RWCU/SDC system (i.e., provide alternate decay heat removal capabilities so the flow path can be isolated). ACTIONS must continue until the division is restored to OPERABLE status or the RWCU/SDC system is isolated.

SURVEILLANCE REQUIREMENTS

As noted at the beginning of the SRs, the SRs for each isolation actuation Function are located in the SRs column of Table 3.3.6.4-1.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.3.6.4.1

The LOGIC SYSTEM FUNCTIONAL TEST demonstrates the OPERABILITY of the isolation actuation divisions. The testing in LCO 3.3.6.3, LCO 3.6.1.3, and LCO 3.6.3.1 overlaps this Surveillance to provide complete testing of the assumed safety function.

The 24-month Frequency is based on the need to perform this Surveillance under the conditions that apply during a plant outage and the potential for an unplanned transient if the Surveillance were performed with the reactor at power. Operating experience has shown that these components usually pass the Surveillance when performed at the 24-month Frequency.

SR 3.3.6.4.2

This SR ensures that the individual required division response times are less than or equal to the maximum values assumed in the accident analysis. The instrument response times must be added to the associated closure times to obtain the ISOLATION SYSTEM RESPONSE TIME. ISOLATION SYSTEM RESPONSE TIME acceptance criteria are included in Reference 4.

ISOLATION SYSTEM RESPONSE TIME may be verified by actual response time measurements in any series of sequential, overlapping, or total channel measurements. This test encompasses the isolation actuation circuitry consisting of timers, VLU functions, and load drivers. This test overlaps the testing required by SR 3.3.6.3.4 to ensure complete testing of instrumentation channels and actuation divisions.

COL 16.0-1-A
3.3.6.4-1

[However, some portions of the isolation actuation circuitry are allowed to be excluded from specific ISOLATION SYSTEM RESPONSE TIME measurement if the conditions of Reference XX are satisfied. Furthermore, measurement of the instrument loops response time for some Functions is not required if the conditions of Reference XX are satisfied.]

BASES

SURVEILLANCE REQUIREMENTS (continued)

ISOLATION SYSTEM RESPONSE TIME tests are conducted on a 24-month STAGGERED TEST BASIS for three divisions. The Frequency of 24 months on a STAGGERED TEST BASIS ensures that the channels associated with each required division are alternately tested. The 24-month test Frequency is consistent with the refueling cycle and with operating experience that shows that random failures of instrumentation components causing serious response time degradation, but not channel failure, are infrequent.

SR 3.3.6.4.3

A system functional test is performed to verify that the mechanical portions of the actuation function operate as designed when demanded. This includes verifying that RWCU/SDC isolation valves, feedwater isolation valves, and HP CRD makeup water injection isolation valves automatically close. The LOGIC SYSTEM FUNCTIONAL TEST in SR 3.3.6.4.1 and LCO 3.3.8.1 (for RWCU/SDC isolation valves) overlaps this SR to provide complete testing of the safety function.

The 24-month Frequency is based on the need to perform this Surveillance under the conditions that apply during a plant outage and the potential for an unplanned transient if the Surveillance were performed with the reactor at power.

REFERENCES

1. Section 6.2.
2. Chapter 15.
3. NEDO-33201, ESBWR Certification Probabilistic Risk Assessment, Revision 5, February 2010.
4. Section 15.2.

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, ~~R~~radiolytically 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~~parallel 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 valves are normally closed, fail-open solenoid-operated valves. One of the valves is controlled by the Safety System Logic and Control /Engineered Safety Features (SSLC/ESF) System described in the Bases for LCO 3.3.5.3, "Isolation Condenser System (ICS) Instrumentation," and LCO 3.3.5.4, "Isolation Condenser System (ICS) Actuation." The other lower header vent valve is controlled by the Diverse Protection System (DPS), which is designed to mitigate digital protection system common mode failures. 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

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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).

BACKGROUND (continued)

Each of the condensate return valves is equipped with four solenoids (i.e., initiators). A signal to any of the four initiators will actuate the valve. Three of the four initiators on each valve are actuated by the Safety System Logic and Control /Engineered Safety Features (SSLC/ESF) System described in the Bases for LCO 3.3.5.3, "Isolation Condenser System (ICS) Instrumentation," and LCO 3.3.5.4, "Isolation Condenser System (ICS) Actuation." The fourth initiator is actuated by the Diverse Protection System (DPS), which is designed to mitigate digital protection system common mode failures. The operator is able to stop any individual ICS train whenever the RPV pressure is below a reset value, overriding ICS automatic actuation signals.

Power to each of the three safety-related initiators on each ICS valve is supplied from a different division of the DC and Uninterruptible AC Electrical Power Distribution. As such, at least two of the three initiators in each ICS condensate return valve will be associated with divisions required by LCO 3.8.6, "Distribution Systems - Operating."

Each ICS condenser forms a closed safety-related loop outside the containment that acts as a "passive" substitute for an open "active" valve outside the containment. In addition, the ICS steam supply line and condensate return line each include two, normally open containment isolation valves in series. These valves close automatically to isolate the RPV on indication of a leak or break in the ICS that could bypass the containment. Specifically, high flow indicated on two of the four differential pressure transmitters on each steam supply line or high flow indicated on two of the four differential pressure transmitters on each condensate return line will close all four isolation valves on the associated ICS train. Additionally, elevated radiation levels on two of the four radiation monitors associated with the steam space above each ICS pool subcompartment cause an alarm on radiation levels indicative of a minor leak and will isolate the steam supply and condensate return line of the associated ICS train on radiation levels indicative of a significant leak. Similarly, each ICS purge line also penetrates the containment to the closed system and is equipped with an excess flow check valve and a

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normally open shutoff valve. Each ICS venting line also penetrates the containment to the closed system. ~~and is equipped with two normally closed control valves in series.~~ The upper header vent line is equipped with two normally closed, fail-closed solenoid valves in series; the lower header vent line is equipped with a restricting orifice in series with two valves that fail-open and are in parallel with respective to each other; and the lower header vent bypass line is equipped with a high-pressure relief valve in series with a normally closed, fail-open solenoid valve.

In order to mitigate the buildup of hydrogen and oxygen following a LOCA, the ICS trains are also automatically isolated upon indication of 2 or more open Depressurization Valves (DPVs). A time delay is provided before isolation occurs in order to allow sufficient time for the ICS to deliver its water inventory to the RPV.

BACKGROUND (continued)

The ICS is designed to ensure that no single active component failure will prevent automatic initiation and successful operation of the minimum required ICS subsystems when any three of the four divisions of DC and Uninterruptible AC Electrical Power Distribution and the associated instrumentation divisions are OPERABLE.

APPLICABLE SAFETY ANALYSES

The ICS is assumed to function following an RPV isolation or low water level (Level 2) event (Ref. 1). Operation of three of the four ICS trains after RPV isolation will limit RCS pressure enough to prevent safety relief valve (SRV) actuation. By conserving reactor water inventory following the RPV isolation, ICS minimizes the need for automatic reactor depressurization that would be required to add additional water inventory from low pressure sources.

The ICS also has an ECCS function to provide liquid inventory to the RPV during the initial stages of a LOCA. The ICS also provides the initial depressurization of the reactor during a loss of feed water so that ADS initiation can be delayed.

ICS - Operating satisfies Criterion 3 of 10 CFR 50.36(c)(2)(ii).

LCO

This LCO requires four ICS trains to be OPERABLE. OPERABILITY of each condensate return valve and ~~each of~~ the ~~two~~ SSCL/ESF-actuated lower header vent valve~~s~~ requires OPERABILITY of two safety-related initiators associated with electrical divisions required by LCO 3.8.6. The

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condensate return bypass valve, the DPS-actuated lower header vent valve, and the lower head vent bypass valves are not required for ICS OPERABILITY.

The isolation valve for each ICS 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 ICS train for at least 72 hours after an RPV isolation or LOCA without the need for operator action. With the ICS 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

Four ICS trains are required to be OPERABLE in MODES 1 and 2 and in MODES 3 and 4 when < 2 hours since reactor was critical, to remove reactor decay heat, or provide additional RCS inventory following a LOCA, a loss of feedwater, or a reactor shutdown with isolation. In addition, in MODES 1 and 2, the ICS is required to be OPERABLE to prevent unnecessary automatic reactor depressurization or SRV actuation following RPV isolation or low water level events. ICS requirements in MODES 3 and 4 when ≥ 2 hours since reactor was critical, and in MODE 5 are specified in LCO 3.5.5, "Isolation Condenser System (ICS) - Shutdown."

ACTIONS

A.1

This Condition applies when one of the four ICS trains is inoperable. In this Condition, the remaining three trains have adequate capacity to respond to events described in References 1 and 2. However, the overall reliability is reduced because a failure in one of the OPERABLE trains could result in an insufficient ICS capacity. In this Condition, the inoperable ICS train must be restored to OPERABLE status within 14 days. This Completion Time is acceptable based on engineering judgment considering the low probability of a failure of an additional ICS train concurrent with a design basis event during this period.

B.1

This Condition applies when two or more ICS trains are inoperable. In this condition, the ICS may not have sufficient capacity to respond to events described in References 1 and 2. This Condition also applies when the Required Actions and associated Completion Time of Condition

BASES

A or B are not met. In this Condition, the plant must be brought to a MODE in which the LCO does not apply. To achieve this status, the plant must be brought to MODE 3 within 12 hours. The allowable Completion Time is reasonable, based on plant design, to reach the required unit conditions from full power conditions in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.4.1

This SR requires periodic verification that each ICS manual, power-operated, and automatic valve in the flow path, that is not locked, sealed, or otherwise secured in position, is in the correct position. This SR is intended to ensure proper valve alignment in any flow path required for proper operation of the ICS. This SR does not apply to valves that are locked, sealed, or otherwise secured in position, since these were verified to be in the correct position upon locking, sealing, or securing.

This SR does not require any testing or valve manipulation. Rather, it involves verification, through a system walkdown, that those valves outside containment and capable of being mispositioned are in the correct position. The 31-day Frequency for performing this SR is acceptable based on engineering judgment and was chosen to provide added assurance that ICS valves are correctly positioned.

SR 3.5.4.2

This SR requires verification every 31 days that the High Pressure Nitrogen Supply System (HPNSS) pressure to each nitrogen-operated ICS steam supply and condensate return valve is within the specified limit. The 31-day Frequency is acceptable because HPNSS low pressure alarms will provide prompt notification of an abnormal pressure in the HPNSS.

SR 3.5.4.3

This SR requires verification every 31 days of the continuity of two safety-related initiators associated with DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6 for each condensate return valve and each SSLC/ESF-actuated lower header vent valve. The 31-day Frequency is acceptable because either of the two safety-related initiators in each valve is capable of actuating the associated ICS valve. Additionally, an alarm will provide prompt notification of loss of circuit continuity for the required initiators in each ICS valve.

BASES

This SR is modified by a Note that continuity is not required to be met for one required initiator intermittently disabled under administrative controls. This allows the continuity monitor to be tested and allows surveillance and maintenance with the assurance that the valve will not be opened inadvertently. The operation of the disable/test switch in either division does not disable the ICS valve because the valve will still be opened by the initiator in the other division.

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.4.4

This SR requires periodic verification that each ICS 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 ICS train may not be capable of performing its design functions. The 24-month Frequency for this SR is based on engineering judgment and is acceptable because the manual isolation valves between the IC/PCCS pool and the ICS subcompartments are locked open and maintained in their correct position under administrative controls.

SR 3.5.4.5

This SR requires periodic verification that the ICS actuates on an actual or simulated automatic initiation signal. The ICS is required to actuate automatically to perform its design function. This Surveillance test verifies that the automatic initiation logic will cause the ICS to operate as designed when a system initiation signal (actual or simulated) is received. The LOGIC SYSTEM FUNCTIONAL TEST in LCO 3.3.5.4 overlaps this Surveillance to provide complete testing of the assumed ICS function.

The 24-month Frequency for performing this SR is acceptable based on the need to perform this Surveillance under the conditions that apply during a plant outage and the potential for an unplanned transient if the SR were performed with the reactor at power.

SR 3.5.4.6

This SR requires periodic verification that the heat removal capability of each ICS train satisfies requirements specified in Reference 1. The temperature sensor located downstream of the condensate return isolation valve and the differential pressure transmitter on the condensate return line may be used to provide test data. The Frequency, prior to

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exceeding 25% RTP if not performed in the previous 24 months on a STAGGERED TEST BASIS, is based on engineering judgment and allows deferring performance until plant conditions needed to perform the test are established.

REFERENCES

1. Section 5.4.6.
2. Section 6.3.3.

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B 3.5 Emergency Core Cooling Systems (ECCS)

B 3.5.5 Isolation Condenser System (ICS) - Shutdown

BASES

BACKGROUND

The ICS is designed to operate either automatically or manually following reactor pressure vessel (RPV) isolation to provide adequate RPV pressure reduction to preclude safety relief valve operation and provide core cooling while conserving reactor water inventory (Ref. 1). A description of the ICS is provided in the Bases for LCO 3.5.4, "Isolation Condenser System (ICS) - Operating." When the reactor is shutdown, a reduced ICS capability is maintained to provide cooldown capability and to ensure a highly reliable and passive alternative to the Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) system for decay heat removal.

RWCU/SDC consists of two independent and redundant trains powered from separate electrical divisions that can be powered from either offsite power or the standby diesel generators. However, RWCU/SDC is a nonsafety-related system that cannot be assumed to remain available following an equipment failure or a loss of offsite power. Depending on plant and equipment status, various alternatives to the RWCU/SDC for decay heat removal can be configured in MODES 3, 4 and 5. When the Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pool and the individual ICS pool subcompartments are flooded, use of one or more ICS loops is the preferred backup method for decay heat removal in MODES 3 and 4.

Although not effective for decay heat removal in MODE 5, the ICS does provide a highly reliable and passive backup to the RWCU/SDC for decay heat removal in this MODE. If normal decay heat removal capability is lost, the reactor coolant temperature will increase until the ICS provides the required decay heat removal capacity.

APPLICABLE SAFETY ANALYSES

A highly reliable, safety-related, and passive alternative to RWCU/SDC for decay heat removal when shutdown not required for mitigation of any event or accident evaluated in the safety analyses. However, decay heat removal must be accomplished to prevent core damage.

ICS - Shutdown satisfies Criterion 4 of 10 CFR 50.36(c)(2)(ii).

BASES

LCO

This LCO requires that two trains of ICS be OPERABLE when shutdown to provide a backup method for decay heat removal. OPERABILITY of each condensate return valve and ~~each of~~ the ~~two~~ Safety System Logic and Control/Engineered Safety Feature (SSLC/ESF)-actuated lower header vent valve~~s~~ requires OPERABILITY of two safety-related initiators associated with electrical divisions required by LCO 3.8.6. The condensate return bypass valve, the Diverse Protection System (DPS)-actuated lower header vent valve, and the lower head vent bypass valves are not required for ICS OPERABILITY.

With the RPV water level above the ICS steam supply line, OPERABILITY of the ICS function is not impacted (Ref. 2).

When in MODE 5, required ICS loops require functionality of associated IC/PCCS expansion pools as heat sink for the ICS condensers.

APPLICABILITY

This LCO requires that two trains of ICS be OPERABLE in MODES 3 and 4 when it has been ≥ 2 hours since the reactor was critical, and in MODE 5.

ACTIONS

A.1, A.2, A.3, and A.4

If one or more of the required ICS trains are not available, the plant may not have a reliable and passive alternative to RWCU/SDC for decay heat removal. Therefore, action must be taken immediately to restore the required ICS train(s) to operable status.

With one of the two required ICS trains inoperable, the remaining train is capable of providing the required decay heat removal. However, the overall reliability is reduced. Therefore, an alternate method of decay heat removal must be provided. With both ICS trains inoperable, an alternate method of decay heat removal must be provided in addition to that provided for the initial ICS train inoperability. The 1-hour Completion Time is based on the decay heat removal function and the probability of a loss of the available decay heat removal capabilities. Furthermore, verification of the functional availability of these alternate method(s) must be reconfirmed every 24 hours thereafter. This will provide assurance of continued decay heat removal capability.

The required cooling capacity of the alternate method should be ensured by verifying (by calculation or demonstration) its capability to maintain or

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reduce temperature. Decay heat removal by ambient losses can be considered as, or contributing to, the alternate method capability.

ACTIONS (continued)

Alternate methods that can be used include (but are not limited to) the RWCU/SDC System and the Fuel and Auxiliary Pools Cooling System. With one or more required ICS train(s) inoperable, at least one method of decay heat removal is verified to be in operation. The 1-hour Completion Time is based on engineering judgment recognizing the need to provide decay heat removal. Furthermore, verification must be reconfirmed every 12 hours thereafter. This will provide assurance of continued decay heat removal capability.

During the period when the required ICS train(s) is inoperable, the reactor coolant temperature and pressure must be periodically monitored to ensure proper function of the alternate method. The once per hour Completion Time is deemed appropriate.

B.1 and B.2

This Condition applies when the Required Actions and associated Completion Times are not met. In this Condition, action must be initiated immediately to establish reactor building refueling and pool area HVAC subsystem (REPAVS) and contaminated area HVAC subsystem (CONAVS) area isolation boundary. This can be accomplished by isolating the REPAVS and CONAVS dampers or verifying the automatic capability of the respective exhaust high radiation function. This action is needed to establish appropriate compensatory measures for a loss of decay heat removal.

SURVEILLANCE REQUIREMENTS

SR 3.5.5.1

This SR requires verification every 31 days that each ICS manual, power-operated, and automatic valve in the flow path, that is not locked, sealed, or otherwise secured in position, is in the correct position. This SR is intended to ensure proper valve alignment in any flow path required for proper operation of the ICS. This SR does not apply to valves that are locked, sealed, or otherwise secured in position, since these were verified to be in the correct position upon locking, sealing, or securing.

This SR does not require any testing or valve manipulation. Rather, it involves verification, through a system walkdown, that those valves outside containment and capable of being mispositioned are in the correct position.

SURVEILLANCE REQUIREMENTS (continued)

The 31-day Frequency for performing this SR is acceptable based on engineering judgment and was chosen to provide added assurance that ICS valves are correctly positioned.

SR 3.5.5.2

This SR requires verification every 31 days that the High Pressure Nitrogen Supply System (HPNSS) pressure to each nitrogen-operated ICS valve is within the specified limit. The 31-day Frequency is acceptable because highly reliable HPNSS low pressure alarms will provide prompt notification of an abnormal pressure in the HPNSS.

SR 3.5.5.3

This SR requires verification every 31 days of the continuity of two safety-related initiators associated with DC and Uninterruptible AC Electrical Power Distribution Divisions required by LCO 3.8.6, "Distribution Systems - Operating," and LCO 3.8.7, "Distribution Systems - Shutdown," for each condensate return valve and each SSLC/ESF-actuated lower header vent valve.

The 31-day Frequency is acceptable because either of the two safety-related initiators in each valve is capable of actuating the associated ICS valve. Additionally, an alarm will provide prompt notification of loss of circuit continuity for the required initiators in each ICS valve.

This SR is modified by a Note that continuity is not required to be met for one required initiator intermittently disabled under administrative controls. This allows the continuity monitor to be tested and allows surveillance and maintenance with the assurance that the valve will not be opened inadvertently. The operation of the disable/test switch in either division does not disable the ICS valve because the valve will still be opened by the initiator in the other division.

SR 3.5.5.4

This SR requires verification every 24 months that each ICS subcompartment manual isolation valve is locked open. This SR is necessary to ensure that the full volume of water in the IC/PCCS pools is available to each condenser. If this SR is not met, the associated ICS loop may not be capable of performing its design functions. The 24-month Frequency for this SR is based on engineering judgment and is

BASES

SURVEILLANCE REQUIREMENTS (continued)

acceptable because the manual isolation valves between the IC/PCCS pool and the ICS subcompartments are locked open and maintained in their correct position under administrative controls.

SR 3.5.5.5

This SR requires verification every 24 months that the ICS actuates on an actual or simulated automatic initiation signal. The ICS is required to actuate automatically to perform its design function. This Surveillance test verifies that the automatic initiation logic will cause the ICS to operate as designed when a system initiation signal (actual or simulated) is received. The LOGIC SYSTEM FUNCTIONAL TEST performed in LCO 3.3.5.4 overlaps this Surveillance to provide complete testing of the assumed ICS function.

The 24-month Frequency for performing this SR is acceptable based on the need to perform this Surveillance under the conditions that apply during a plant outage and the potential for an unplanned transient if the SR were performed with the reactor at power.

REFERENCES

1. Section 5.4.6.
2. NEDO-33201, ESBWR Certification Probabilistic Risk Assessment, Section 16.4.1, Revision 5, February 2010.

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. <u>AND</u> B.2 Be in MODE 5.	12 hours 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
<u>SR 3.6.1.7.4</u>	<u>Visually examine each PCCS vent catalyst module and verify there is no evidence of abnormal conditions.</u>	<u>24 months on a STAGGERED TEST BASIS for each PCCS condenser</u>
<u>SR 3.6.1.7.5</u>	<u>Verify performance of a representative sample of PCCS vent catalyst module plates.</u>	<u>24 months on a STAGGERED TEST BASIS for each PCCS condenser</u>

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. <u>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.</u> 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.

BASES

BACKGROUND (continued)

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. 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. 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	A.1 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. B.1 and B.2 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.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.6.1.7.4

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.

sufficient reactor coolant volume to avoid automatic depressurization caused by low reactor water level. 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, after any of the following events:

- Sudden reactor isolation from power operating conditions;
- Station blackout (unavailability of all AC power);
- Anticipated Transient Without Scram (ATWS); and
- Loss-of-Coolant-Accident (LOCA).

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 Engineered Safety Features that can also perform this function. In the event of a LOCA, the ICS provides additional liquid inventory from an in-line condensate reservoir upon opening of the condensate return valves to initiate the system.

19.3.2 Severe Accident Mitigative Features

19.3.2.1 Hydrogen Generation and Control

The potential for containment failure due to hydrogen generation is addressed by considering physical characteristics of the containment, notably the inerted condition and containment structural capability, as well as the reliability of passive systems engineered to perform the containment functions of isolation, vapor suppression, and heat removal. Containment failure due to combustible gas deflagration in the drywell and wetwell airspace is shown to be negligible considering the inerted containment and time period required to generate enough oxygen to create a combustible gas mixture. In addition, ICS and PCCS components are designed to maintain their integrity for combustible gas deflagration that may occur in design basis accidents and severe accidents.

Because the ESBWR containment is inerted, the prevention of a combustible gas deflagration in the drywell and wetwell airspace is assured in the short term following a severe accident. In the longer term, there is an increase in the oxygen concentration resulting from the continued radiolytic decomposition of the water in the containment. Because the possibility of a combustible gas condition is oxygen-limited for an inerted containment, it is important to evaluate the containment oxygen concentration versus time following a severe accident to assure that there will be sufficient time to implement recovery actions. It is desirable to have at least a 24-hour period following an accident to allow for actions with a high likelihood of success. This subsection discusses the rate at which post-accident oxygen will be generated by radiolysis in the ESBWR containment following a severe accident, and establishes the period of time that would be required for the oxygen concentration in containment to increase to a value that would constitute a combustible gas condition (5% oxygen by volume) in the presence of a large hydrogen release.

The rate of gas production from radiolysis depends upon the power decay profile and the amount of fission products released to the coolant. Analysis results have been developed in a manner consistent with the guidance provided in SRP 6.2.5 and Regulatory Guide 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. For a design-basis LOCA, ADS depressurizes the reactor vessel and GDCS provides gravity-driven flow into the vessel for emergency core cooling. The core coolant is subcooled initially and then it is saturated, resulting in steam flow out of the vessel and into the containment. The PCCS heat exchangers remove the energy by condensing the steam.

A similar situation exists for a severe accident that results in core melt followed by reactor vessel failure. In this case, the GDCS coolant covers the melted core material in the lower drywell, with an initial period of subcooling followed by steaming. The PCCS heat exchangers remove the energy in the same manner as described above for a design basis LOCA.

Each PCCS heat exchanger has a vent line that transfers non-condensable gases to the suppression pool vapor space, driven by the drywell to suppression pool pressure differential. In this way, the majority of the non-condensable gases will be in the suppression pool. The accumulation of combustible noncondensable gases in the PCCS and ICS heat exchangers is discussed below. A vent fan is installed in each vent line to redistribute the non-condensable gases from the wetwell to the drywell when deemed appropriate during long-term (post 72-hour) recovery actions.

The calculation of post-accident radiolytic oxygen generation accounts for this movement of non-condensable gases to the suppression pool after they are formed in the drywell. In addition, the effect of the core coolant boiling, which strips dissolved gases out of the liquid phase resulting in a higher level of radiolytic decomposition, is accounted for in the analysis.

Analysis Assumptions

The analysis of the radiolytic oxygen concentration in containment is performed consistent with the methodology of Appendix A to SRP 6.2.5 and Regulatory Guide 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 drywell non-condensable gases to wet-well vapor space;
- Fuel clad-coolant reaction up to 100%;
- Iodine release up 100%;
- Adequate gas mixing throughout containment;
- Passive Auto-catalytic Recombiners are not credited.

Analysis Results

The analysis results show that the time required for the oxygen concentration to increase to the de-inerting value of 5% is significantly greater than 24 hours for a wide range of fuel clad-coolant interaction and iodine release assumptions up to and including 100%. Thus, the containment failure due to combustible gas deflagration in the drywell and wetwell airspace is shown to be unrealistic considering the inerted containment and time period required to generate enough oxygen to create a combustible gas mixture.

Combustible Gas Accumulation in PCCS and ICS

Radiolytic generation of combustible gases occurs in all light water reactors. The generation of hydrogen and oxygen gases occurs in a stoichiometric ratio at a rate proportional to the core decay heat. During a LOCA, these gases escape into the containment, resulting in very dilute concentrations of combustible gases in the drywell (below concentrations that could result in ignition).

PCCS condensers are designed to receive the drywell atmosphere during an accident, (which is a mixture of steam and noncondensable gases); to condense the steam; and to return the condensate back to the drywell. Each PCCS condenser consists of two modules submerged in a pool of cooling water. Each module contains an upper and lower drum connected by an array of tubes. Gases from the drywell pass up a central supply line that feeds both upper drums. The steam component of the gases condenses as it moves downward through the tube array (transferring its heat to the pool water) and condensate collects in the lower drum and drains back to the drywell by gravity. The pool water level drops slowly over the course of the accident as water boils off. The leftover noncondensable gases exit the PCCS condenser through a vent line that connects the lower drum to the wetwell. As steam and noncondensable gases enter the condenser, the vent operates passively to bleed the gases from the lower drum using the pressure differential between the drywell and wetwell as the driving force. In this way, something close to an equilibrium state is reached in which noncondensable gases remain in the condenser while small amounts continue to come in with the steam and go out through the vent.

In the initial stage of a LOCA, the majority of the noncondensable gas in the drywell is nitrogen. This gas is eventually forced into the wetwell by the depressurization of the RPV. Over time, the primary noncondensable gases in the drywell are radiolytically generated hydrogen and oxygen. Analytical modeling shows that noncondensable gases accumulate in the lower portions of the tubes and lower drum. When this gas transitions from mostly nitrogen to a stoichiometric mixture of hydrogen and oxygen, a combustible concentration may exist.

PCCS components have been evaluated to determine the effects of radiolytically generated hydrogen and oxygen based on a range of mixture concentrations. A bounding detonation pressure for a pure stoichiometric mixture of hydrogen and oxygen is calculated using the highest peak pressures during a LOCA. It is then applied statically using dynamic load factors in a finite element model for the PCCS condenser. The calculated stresses for the detonation load are combined with those from seismic and LOCA thermal loads. The acceptance criterion for components subject to detonation is based on the ability of those components to retain their pressure integrity without plastic deformation.

Two postulated detonation scenarios have been analyzed in the finite element model: a detonation in one tube and a detonation in the lower drum. The finite element analyses determine the necessary thicknesses for the PCCS tubes and lower drum that satisfy the acceptance criteria for elastic-plastic analysis. Therefore, the thickness of downstream piping and components is sized to accommodate the resulting detonation loads. The magnitude of the detonation loads on the downstream components is minimized by igniters in each lower drum, and safety-related catalyst modules at the entrance of each vent pipe in the condenser lower drum. The igniters prevent excessive oxygen from accumulating to a combustible mixture during severe accident conditions. The catalyst modules keep hydrogen concentrations in the PCCS vent below levels at which detonation events can occur.

During plant transients in which the RPV is isolated, ICS removes heat, while the condenser vent lines keep the units continuously purged of noncondensable gases. The ICS vent valves automatically open on a time delay after ICS is initiated, regardless of system pressure. Once open, the vent lines bleed steam and noncondensable gases from the condensers to the suppression pool, keeping the steam fraction in the lower drums at high levels throughout the event. The vent valves are designed to fail open on a loss of power to provide additional reliability for this function. A flow orifice in the vent line limits the maximum flow rate to minimize the amount of water inventory lost from the reactor as a result of the constant flow through the vent lines.

During a LOCA, ICS initiates in order to supply the additional condensate stored in its drain piping to the RPV. This additional water keeps the core covered during a design basis accident. The actual heat removal through the ICS condenser is relatively small during a LOCA. However, if the condensers are not isolated, there is potential for condensation to occur, and given enough time, a combustible gas concentration accumulates in the ICS condenser following a LOCA. In order to prevent this buildup from occurring, the ICS containment isolation valves automatically close after receiving an indication that the depressurization valves on the RPV have opened.

ICS and PCCS components are designed to maintain their integrity for postulated design basis accidents as well as severe accidents. This includes the consideration of combustible gas accumulation in the condensers under transient or LOCA conditions.

19.3.2.2 Core Debris Coolability

In the event of a severe accident in which the core melts through the reactor vessel, it is possible that the containment could be breached if the molten core is not sufficiently cooled. In addition, interactions between the core debris and concrete can generate large quantities of non-condensable gases, which could contribute to eventual containment failure.

The ESBWR design incorporates mitigating features to enhance core debris coolability. The lower drywell floor is designed with sufficient floor space to enhance debris spreading, and also contains the BiMAC device to protect the containment liner and basemat. The core debris coolability analysis shows that the BiMAC device is effective in containing the potential core melt releases from the RPV in a manner that assures long-term coolability and stabilization of the resulting debris. Therefore, the possibility of corium-concrete interaction is negligible.

Subsections 19.3.2.5 and 19.3.2.6 describe the function of the deluge system and the BiMAC.

19.3.2.3 High-Pressure Core Melt Ejection

The set of potential High-Pressure Core Melt Ejection (HPME) accidents that lead to Direct Containment Heating (DCH) consists of those involving core degradation and vessel failure at high primary system pressure. A necessary condition for this is that a minimum of 2 out the 4 isolation condensers (IC) have failed due to either water depletion on the secondary side, or due to failure to open the condensate return valves that keep the isolation condensers isolated during normal operation. In addition, all 8 of the squib activated, reactor depressurization valves, and all 10 of the ADS Safety Relief Valves must fail to operate.

The probability of a high-pressure core melt is significantly reduced due to the highly reliable depressurization system. In addition, the following ESBWR containment design features mitigate the possible effects of high-pressure core melt:

- The containment is segregated into an upper drywell and a lower drywell, which communicate directly, but the ability of high-pressure core melt, ejected within the lower drywell, to reach the upper drywell is mitigated by this design;
- The upper drywell atmosphere can vent into the wetwell through a large vent area and an effective heat sink; and
- The containment steel liner is structurally backed by reinforced concrete, which cannot be structurally challenged by DCH.

19.3.2.4 Containment Performance

A spectrum of potential containment failure modes has been evaluated for the ESBWR, including the potential for a break outside of containment, potential ex-vessel steam explosion, direct containment heating and basemat penetration challenges. In this subsection, the focus is on the containment challenges associated with potential combustible gas deflagration, over-pressurization and bypass. The potential for containment failure due to these challenges is addressed by considering physical characteristics of the containment, notably the inerted condition and containment structural capability, as well as the reliability of passive systems engineered to perform the containment functions of isolation, vapor suppression and heat removal. The containment response has been evaluated for a 24-hour period following the onset of core damage. To provide additional insight, containment effectiveness will be quantified to demonstrate that the containment provides a reliable barrier to radionuclide release after a severe accident.

Analysis of the ultimate strength of the containment indicates that the drywell head is the most likely failure location if the containment were to over-pressurize. The pressure capability of the containment's limiting component is higher than the pressure that would be experienced if assuming a 100 per cent fuel clad-coolant reaction.

The deterministic analysis for containment pressure capability is presented in Appendix 19B and the probabilistic analysis for containment pressure fragility in Appendix 19C.

Because of the ESBWR design and reliability of containment systems, the most likely containment response to a severe accident is associated with successful containment isolation, vapor suppression and containment heat removal. As a result, the containment provides a highly reliable barrier to the release of fission products after a severe accident, with the dominant release category being that defined by the nominal allowed leakage variable, TSL. This conclusion is based on the following insights:

(1) The combustible gas generation analysis indicates that a combustible gas mixture within **the drywell and wetwell airspace of** containment would not occur within 24 hours after the occurrence of a severe accident. Thus, containment failure by this mechanism is not

considered further. Combustible gas generation within the ICS and PCCS heat exchangers is controlled by the means discussed in subsection 19.3.2.1.

(2) Containment bypass, which results in a direct path between the containment atmosphere and environment, has been evaluated. A containment penetration screening evaluation indicates that there are two systems, main steam and feedwater that require isolation to prevent significant offsite consequences. The probability of the bypass failure mode is dominated by a common cause failure of the RPS MSIV isolation signal resulting in a calculated frequency of containment bypass two orders of magnitude lower than the TSL release category.

(3) Containment over-pressurization has been evaluated in terms of early and late loss of containment heat removal, as well as the loss of the vapor suppression function. Overpressure failure is found to be about three orders of magnitude less likely than the TSL release category after a severe accident, specifically:

A. The frequency of loss of containment heat removal in the first 24 hours after accident initiation is approximately four orders of magnitude lower than the TSL release category.

B. The frequency of loss of containment heat removal in the period between 24 and 72 hours after accident initiation is about three orders of magnitude lower than the TSL release category.

C. The frequency of vacuum breaker failure, which would result in the shortest time to containment over-pressurization because of the loss of the vapor suppression function, is approximately four orders of magnitude lower than the TSL release category.

(4) The need for controlled filtered venting in the 24-hour period after onset of core damage has been evaluated. The evaluation considers loss of containment heat removal for the spectrum of applicable accident classes. In each representative sequence, operator controlled venting could be implemented to control the containment pressure boundary and potential leak path. However, venting is found not to be necessary to prevent containment failure within 24 hours after onset of core damage for scenarios in which containment heat removal is lost.

19.3.2.5 GDCS Deluge Subsystem

The lower drywell (LDW) deluge subsystem of GDCS provides automatic flow to the lower drywell if core debris discharge from the reactor vessel is detected. This subsystem is actuated on a high lower drywell floor temperature profile that is unique to a core debris discharge. Supply lines connect each of the GDCS water pools to the deluge headers, which are isolated by squib valves. The deluge headers provide water to the Basemat Internal Melt Arrest and Coolability (BiMAC) device embedded into the lower drywell floor to cool the ex-vessel core-melt debris. Temperature sensors in the BiMAC device provide the actuation signal to open the squib valves. This permits flooding the lower drywell after there has been a discharge of core material, which is significant because it minimizes the consequences of steam explosions that would occur if the lower drywell floor had been flooded prior to core discharge. Subsequent coverage of the core melt provides for debris cooling and scrubbing of fission products released from the debris. The deluge lines are sized to accommodate a single line failure, so that flow

19.3.4.2.7 Containment Pressure Control

Containment pressure control can be accomplished by removing the heat energy accumulating within containment during a severe accident or venting to reduce pressure.

Containment Heat Removal

Containment heat removal can be accomplished by the Passive Containment Cooling System (PCCS). The system is part of the containment boundary as indicated in Appendix 1A, Table 1A-1 (Item III.D.1.1). Key aspects of the PCCS are described in Subsection 6.2.2.

Containment Venting

If the severe accident generates pressure that threatens containment integrity, the ESBWR design includes a controlled vent path to terminate the pressure rise. The vent path takes suction from the suppression pool airspace, which forces escaping fission products through the suppression pool to provide significant fission product scrubbing prior to release as summarized in Subsection 6.2.5.4.

19.3.4.2.8 Combustible Gas Control

Combustible gas control is achieved in the ESBWR by maintaining an inert containment atmosphere and by controlling combustible gas concentrations in the ICS and PCCS heat exchangers. The containment is inerted during normal operation; thus, there are no active system requirements necessary to achieve combustible gas control during a severe accident. Further, analysis summarized in Subsection 6.2.5.5 indicates that the time to generate a combustible gas environment is so long that there would be a high likelihood of successful recovery actions, if required. Finally, a passive autocatalytic recombiner will limit the concentration of combustible gases after a severe accident. Combustible gas generation within the ICS and PCCS heat exchangers is controlled by the means discussed in subsection 19.3.2.1.

19.3.4.2.9 Post Accident Monitoring

Monitoring of plant conditions is necessary to place the plant in a stable configuration. Consideration of regulatory requirements and the ESBWR severe accident functional response evaluation (including emergency procedure and severe accident guideline requirements), leads to the identification of variables that require monitoring in a severe accident. Such variables include indication of containment pressure, temperature, radiation and combustible gas conditions as well as indicators of mitigative system functioning.

19.3.4.3 Severe Accident Environment

References 19.3-1 through 19.3-3 provide the requirements that an applicant must address for postulated in-vessel and ex-vessel severe accidents. References 19.3-1 and 19.3-2 require that "credible" severe accidents be considered in a survivability evaluation. Reference 19.3-3 requires that survivability should consider an accident with the release of hydrogen generated by the equivalent of a 100 percent fuel-clad metal-water reaction. These considerations establish the ESBWR severe accident environment to be considered in the equipment survivability evaluation.

19A.4.4 Summary of RTNSS Candidates from Criterion C

The focused PRA sensitivity study requires certain portions of DPS being designated as RTNSS. The portions that provide capability for a manual backup of safety-related automatic actuation of safety functions provides the level of protection necessary to meet both the CDF and LRF goals. These RTNSS DPS functions are: GDCS actuation, ADS actuation, isolation of RWCU/SDC isolation valves, and opening of the IC/PCCS pool cross-connect valves. They are risk significant and receive high regulatory oversight, as described in Subsection 19A.8.1.

The assessment of uncertainties concludes that the defense-in-depth role of FAPCS in providing a backup source of low pressure injection and suppression pool cooling is within the scope for RTNSS. Supporting systems for FAPCS include: RCCWS, standby diesel generators, PIP buses, Electrical Building HVAC, Fuel Building HVAC, Nuclear Island Chilled Water, and PSWS. In addition, the assessment of shutdown initiating events identifies that the lower drywell hatches should have regulatory oversight.

19A.5 CRITERION D: CONTAINMENT PERFORMANCE ASSESSMENT

The containment performance goal in SECY-93-087, Issue I.J is addressed in Subsection 19.3.3 and Appendices 19B and 19C.

The containment bypass issue from SECY-93-087, Issue II.G, during severe accidents is concerned with potential sources of steam bypassing the suppression pool and failure of heat exchanger tubes in passive containment cooling systems. These concerns are addressed in the Design Control Document. Subsection 19.3.2.4 addresses the steam bypass of the suppression pool. Subsection 6.2.2.3 addresses the design of the Passive Containment Cooling Heat Exchanger tubes. These Criterion D safety concerns are addressed in the ESBWR design, and no RTNSS candidates are identified.

The BiMAC device provides an engineered method to assure heat transfer between a core debris bed and cooling water in the lower drywell during severe accident scenarios. Waiting to flood the lower drywell until after the introduction of core material minimizes the potential for energetic fuel-coolant interaction. Covering core debris with water provides scrubbing of fission products released from the debris and cools the corium, thus limiting off-site dose and potential core-concrete interaction. The BiMAC device provides additional assurance of debris bed cooling by providing engineered pathways for water flow through the debris bed. BiMAC failure could occur if no water is supplied. The BiMAC device is not safety-related. It is added to the ESBWR to reduce the uncertainties involved with severe accident phenomenology. As such, the BiMAC device, the nonsafety-related GDCS deluge squib valves, and the associated actuation logic are in the scope for RTNSS.

During the initial stages of a severe accident, there is essentially no water in the vicinity of the core, so radiolysis is greatly reduced. However, large quantities of hydrogen are released into the drywell due to metal-water reactions. The high abundance of hydrogen relative to oxygen effectively reduces the potential for detonation in the PCCS. Later in the postulated event, after the core melts through the vessel and interacts with the concrete, the deluge valves open and the core once again has the potential to resume radiolysis. Thereafter, relative concentrations of hydrogen and oxygen trend closer to a stoichiometric ratio at pressures much higher than during a DBA.

The PCCS condenser may experience some plastic deformation during a detonation under these conditions. Igniters (glow plugs) in the lower drums of the PCCS condensers recombine the hydrogen and oxygen while they are still at lower concentrations, thereby keeping the resultant pressure within the analyzed values.

Because an actuation of the deluge system is a prerequisite for a detonation during a severe accident, the igniters are activated by the existing GDCS deluges (BiMAC) control system implemented in a nonsafety-related technology programmable logic controller.

19A.6 CRITERION E: ASSESSMENT OF SIGNIFICANT ADVERSE INTERACTIONS

Systems interactions are usually well recognized and, therefore, are accounted for by design engineers and within the PRA model. However, there is the potential for unrecognized subtle dependencies among the various SSCs that could be significant. The term used to describe such dependencies is adverse systems interaction (ASI). It is broadly applied in terms of functional interactions, spatial interactions and human acts of commission. Such interactions are RTNSS candidates under Criterion E.

A preliminary ASI assessment was performed, and as the design has progressed, additional assessments have been completed. The preliminary assessment and results are presented in Subsection 19A.6.1. Results of the additional assessments are provided in Subsection 19A6.2.

19A.6.1 Systematic Approach

As part of the PRA input to design programs and processes, potential ASI discovered during the construction of the PRA are assessed for applicability to the RTNSS process under Criterion E. For the purpose of this assessment, an ASI exists if the action or condition of an active, interfacing system causes a loss of safety function of a passive safety-related system. A systematic process is used to analyze specific features and actions that are designed to prevent postulated adverse interactions, while taking into consideration the extensive operating experience that has been used in the current design criteria to prevent adverse systems interactions.

Many protection provisions are already included in the design of the Emergency Core Cooling System (ECCS) passive safety-related systems. Protection is afforded against missiles, pipe whip and flooding. Also accounted for in the design are thermal stresses, loadings from a LOCA, and seismic effects. The ECCS passive systems are protected against the effects of piping failures up to and including the design basis event LOCA.

The passive safety-related systems of the ESBWR are presented below. Active systems that interact with the passive systems are identified, followed by an evaluation of potential adverse interactions. Only those nonsafety-related systems with a potential adverse effect are analyzed further as RTNSS candidates.

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.

The hurricane missile spectrum is consistent with the tornado missile spectrum identified in Table 2.0-1. The design criteria associated with hurricane missile protection follows Section 3.5 for missiles generated by natural phenomenon. The tornado wind speed is substituted with hurricane wind speed to design the concrete or steel barriers for missile impact.

19A.8.4 Regulatory Treatment

The proposed regulatory treatment of RTNSS systems is presented below, and is summarized in Tables 19A-2, 19A-3 and 19A-4.

19A.8.4.1 Nonsafety-Related ATWS Actuation Logic

ATWS actuation logic provides backup reactor shutdown methods that are diverse from the safety-related reactor protection system. Alternate Rod Insertion, Feedwater Runback, and ADS Inhibit use DPS to perform their actuation functions. These functions are RTNSS Criterion A relative to the ATWS Rule, 10 CFR 50.62. They do not have a high risk significance due to the redundancy and diversity of the reactor protection system. The proposed level of regulatory oversight for these functions is in the Availability Controls Manual.

19A.8.4.2 FPS Pool Cooling Makeup

The diesel-driven and motor-driven FPS pumps, and associated tanks, piping and valves, are RTNSS Criterion B. The pumps and the FPS piping and valves are classified as nonsafety-related but are designed so that the necessary portions of the system remain available following a seismic event to keep equipment required for safe shutdown free from fire damage during a safe shutdown earthquake. In conjunction with the pumps, FPS makeup includes the water supply, the suction pipe from the water supply to the pump, one of the supply pipes from the FPE to the Reactor Building and Fuel Building, and the connections to the FAPCS. Loss of this function does not challenge the CDF or LRF goals. Therefore, the proposed level of regulatory oversight for this function is in the Availability Controls Manual.

19A.8.4.3 Diverse Protection System

DPS provides diverse actuation functions that enhance the plant's ability to mitigate dominant accident sequences involving the common cause failure of actuation logic or controls. The following functions of DPS are significant with respect to the focused PRA sensitivity study to meet the NRC safety goal guidelines: ADS actuation, GDCS actuation, RWCU/SDC valve isolation, and IC/PCCS Pool Connection valves actuation. The risk significance is high for the special case of the focused PRA, such that the proposed level of regulatory oversight for the portions of DPS that provide these functions are contained in Technical Specifications.

DPS provides backup shutdown methods for ATWS mitigation, as described in Subsection 19A.8.4.1.

In addition, DPS provides the following backup functions that are modeled in the PRA:

- Scram
- MSIV Closure
- SRV Actuation

- FMCRD Actuation
- ICS Actuation (Condensate Return Valve and Vent Valve Opening Signals)
- SLC Actuation for LOCA
- ADS Inhibit Function

These functions do not have a high risk significance, so their proposed level of regulatory oversight is in the Availability Controls Manual.

19A.8.4.4 Post-Accident Monitoring

Post-accident monitoring is performed by Q-DCIS. Operability of the post-accident monitoring instrumentation is addressed in Technical Specification LCO 3.3.3.2, "Post-Accident Monitoring (PAM) Instrumentation." Support for the safety-related post-accident monitoring instrumentation is necessary for component cooling and lighting. The CRHAVS air handling units and auxiliary heating and cooling units ensure that, after 72 hours, room temperatures for equipment used in post-accident monitoring are within the range for qualified operation. Emergency lighting assists the operators in post-accident monitoring activities. These functions provide long-term support and are RTNSS Criterion B. Because they are not required for the first 72 hours, they do not affect core cooling or containment heat removal in the PRA, and thus have low risk significance. The proposed level of regulatory oversight for emergency lighting is in the Maintenance Rule and the proposed level of oversight for heating/cooling is in the Availability Controls Manual.

19A.8.4.5 Basemat Internal Melt Arrest and Coolability System and GDCS Deluge Lines

The BiMAC device and GDCS deluge valves play an important role in mitigating core melt scenarios. Therefore, they are candidates for RTNSS consideration. The BiMAC device and GDCS valves function during severe accidents, and thus have no effect on the Level 1 PRA. The inclusion of the BiMAC device in the ESBWR design provides an engineered method to assure heat transfer between the debris bed and cooling water. By flooding the lower drywell after the introduction of core material, the potential for energetic fuel-coolant interaction is minimized. Covering core debris with water provides scrubbing of fission products released from the debris and cools the corium, limiting potential core-concrete interaction (CCI). The BiMAC device provides additional assurance of debris bed cooling by providing engineered pathways for water flow through the debris bed. BiMAC failure can occur if no water is supplied. Other failure mechanisms include manufacturing defects, unforeseen phenomenology problems or a broken GDCS line that would divert flow. In these instances, the situation becomes similar to flooding the debris bed without the engineered flow through the corium. Thus, BiMAC failure to function can be conservatively modeled as failure to supply water from the GDCS deluge lines.

Loss of the BiMAC function does not pose a challenge to the LRF goals when other safety-related and RTNSS systems are taken into account. The proposed level of regulatory oversight for the BiMAC function is in the Availability Controls Manual.

19A.8.4.6 Nonsafety-Related Distributed Control and Information System

The Nonsafety-Related Distributed Control and Information System (N-DCIS) performs control functions for several RTNSS functions. N-DCIS provides uninterruptible AC power with battery

To support FAPCS (RTNSS C), component cooling is needed for FAPCS and the following support equipment: Standby Diesel Generators, PIP Buses, N-DCIS local cabinets, RCCWS, and Nuclear Island Chilled Water System. FAPCS cooling is performed by RCCWS and the room cooler portion of the Fuel Building HVAC System. The Standby Diesel Generators are cooled by RCCWS and the Electrical Building HVAC System. The PIP Buses, and associated N-DCIS support are also cooled by the Electrical Building HVAC System. RCCWS, Nuclear Island Chilled Water System, and associated N-DCIS support cooling is performed by the room cooler portions of the Turbine Building HVAC System.

The risk significance for these supporting functions is commensurate with the functions that they support. The proposed level of regulatory oversight for these functions is covered under the evaluations of the supported systems. The Availability Controls Manual addresses degraded or lost support systems in the context of the supported functions. No explicit availability controls are supplied for these support systems, because they are frequently or continuously operating during normal plant operations, so additional availability control surveillance requirements are not beneficial. In addition, performance monitoring of RTNSS components is required by the Maintenance Rule.

19A.8.4.10 Long-Term Containment Integrity

Long-term containment pressure control is accomplished by a combination of passive auto-catalytic recombiners (PARs) in the containment airspaces and PCCS Vent Fans, which are operated to remove the non-condensable gases from the PCCS tubes to increase heat transfer efficiency.

PARs are independently mounted components which are capable of recombining a stochiometric mix of hydrogen and oxygen into water vapor. This recombination is facilitated through the use of a selective metal catalyst, and requires no external power or controls. A Passive Containment Cooling vent fan takes suction off of each PCCS vent line and exhausts to the GDCS pool. The fan aids in the long-term removal of non-condensable gas from the PCCS for continued condenser efficiency. The fans are operated by operator action and are powered by a reliable power source which has a diesel generator backed up by an ancillary diesel if necessary without the need to enter the primary containment.

<u>During a severe accident, the PCCS condenser accumulates excessive oxygen and hydrogen, and may experience some plastic deformation during a detonation under these conditions. Igniters in the lower drums of the PCCS condensers recombine the hydrogen and oxygen while they are still at lower concentrations, thereby keeping the resultant pressure within the analyzed values.</u>

~~These functions~~ <u>The PARs and PCCS vent fans</u> maintain containment pressure below the design pressure by counteracting a slight increase in noncondensable gases over time. <u>The PCCS igniters prevent combustible gas deflagration from adversely challenging the integrity of the PCCS heat exchangers.</u> ~~They~~<u>These components</u> are not risk-significant and the proposed regulatory oversight is in the Availability Controls Manual.

19A.8.4.11 Reactor Building HVAC Accident Exhaust Filters

The reactor building contaminated area ventilation system filters (Reactor Building HVAC Accident Exhaust Filters only) must maintain the required filtering efficiency to ensure that theoretical control room doses are not exceeded for certain beyond design basis LOCAs. Failure

Table 19A-2
RTNSS Functions

RTNSS Function	Description	Availability Controls
DPS – ARI Actuation	A - ATWS Rule	ACLCO 3.3.1
DPS – FWRB Actuation	A - ATWS Rule	ACLCO 3.3.3
DPS – ADS Inhibit	A - ATWS Rule	ACLCO 3.3.4
FPS Diesel Driven Pump	B - Long Term Core Cooling: RPV At-Power and Spent Fuel Pool; Long Term Containment Integrity	ACLCO 3.7.1
FPS Motor Driven Pump	B - Long Term Core Cooling: RPV At-Power and Spent Fuel Pool; Long Term Containment Integrity	ACLCO 3.7.1
FPS to FAPCS Connection Piping	B - Long Term Core Cooling: RPV At-Power and Spent Fuel Pool; Long Term Containment Integrity	ACLCO 3.7.1
PARs	B - Long Term Containment Integrity	ACLCO 3.6.2
PCCS Vent Fans	B - Long Term Containment Integrity	ACLCO 3.6.3
Emergency Lighting	B - Post-Accident Monitoring	Maintenance Rule
DPS – GDCS Injection	C - Focused PRA (CDF, LRF) High Regulatory Oversight	TS LCO 3.3.8.1
DPS – ADS Actuation	C - Focused PRA (CDF, LRF) High Regulatory Oversight	TS LCO 3.3.8.1
DPS – Open IC/PCCS Pool Cross-Connect Valves	C - Focused PRA (CDF, LRF) High Regulatory Oversight	TS LCO 3.3.8.1
DPS – Isolation RWCU/SDC Valves	C - Focused PRA (CDF, LRF) High Regulatory Oversight	TS LCO 3.3.8.1
DPS – Scram	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
DPS – MSIV Closure	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
DPS – SRV Actuation	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
DPS- FMCRD Actuation	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
DPS – ICS Actuation <u>(Condensate Return Valve and Vent Valve)</u>	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
DPS – SLC Actuation LOCA	C - Focused PRA (CDF, LRF)	ACLCO 3.3.4
FAPCS (LPCI, SPC Modes)	C - Focused PRA (Uncertainty)	ACLCO 3.7.2 ACLCO 3.7.3

Table 19A-2
RTNSS Functions

RTNSS Function	Description	Availability Controls
BiMAC Device	D - Containment Performance	AC 4.1
GDCS Deluge Valves	D – Containment Performance	ACLCO 3.5.1
PCCS Igniters	D- Containment Performance	ACLCO 3.6.4
Reactor Building HVAC Accident Exhaust Filters	E – Adverse System Interactions	ACLCO 3.7.~~5~~4
Lower Drywell Hatches	E – Adverse System Interactions	ACLCO 3.6.1
FPS Water Tank	B - Supports core cooling for refill of pools	ACLCO 3.7.1
FPS Diesel Fuel Oil Tank	B - Supports Diesel Driven FPS pump	ACLCO 3.7.1
Ancillary Diesel Generators	B - Supports FPS Motor Driven Pump, PCCS Vent Fans, CRHAVS AHUs, Emergency Lighting, Q-DCIS	ACLCO 3.8.3
Ancillary AC Power Buses	B - AC power distribution from Ancillary Diesel Generators to plant loads.	Maintenance Rule
Ancillary DG Fuel Oil Tank	B - Supports Ancillary Diesel Generators	Maintenance Rule
Ancillary DG Fuel Oil Transfer Pump	B - Supports Ancillary Diesel Generators	Maintenance Rule
Ancillary Diesel Building HVAC	B – Supports Ancillary Diesel Generators	Maintenance Rule
N-DCIS	C - The portions that support DPS, FAPCS and supporting equipment	Maintenance Rule
Standby Diesel Generators	C - Supports FAPCS operation	ACLCO 3.8.1, ACLCO 3.8.2
6.9 kV PIP Buses	C - AC power distribution from Standby Diesel Generators to plant loads associated with FAPCS	Maintenance Rule
Standby DG Auxiliaries	C - Supports Standby DG	Maintenance Rule
RCCWS	C - Supports Standby Diesel Generators and Nuclear Island Chilled Water Subsystem (NICWS)	Maintenance Rule
Nuclear Island Chilled Water	C – Building HVAC	Maintenance Rule
PSWS	C - Supports RCCWS	Maintenance Rule
Electrical Building HVAC Area Cooling	C - Supports PIP Buses, N-DCIS for FAPCS	Maintenance Rule
Fuel Building HVAC Local Cooling	C - Supports FAPCS, N-DCIS for FAPCS	Maintenance Rule

Table 19A-2
RTNSS Functions

RTNSS Function	Description	Availability Controls
Reactor Building HVAC Local Cooling	C - Supports N-DCIS for FAPCS	Maintenance Rule
Turbine Building HVAC Local Cooling	C – Supports FAPCS	Maintenance Rule
CRHAVS Air Handling Units	B - Long-term control room habitability	ACLCO 3.7.~~6~~5
CRHAVS Air Handling Unit auxiliary heaters and coolers	B - Cooling for post-accident monitoring heat loads	ACLCO 3.7.~~6~~5

Note: All RTNSS functions have Maintenance Rule availability controls.

19B.6 PCCS HEAT EXCHANGERS

The PCCS heat exchangers are part of containment boundary. The Level C pressure capacity ~~at temperature of 260°C (500°F)~~ of the most critical component in the PCCS heat exchangers is ~~1.33~~ 38.7 Mpa~~G~~ absolute (~~193~~5613 psig).

Table 19B-11
Summary of Level C/Factored Load Category Pressure Capacity at 260°C (500°F)

Component	Pressure, MPaG (psig)
RCCV and Liners	1.011 (146.6)
Drywell Head	1.033 (149.8)
Hatches and Airlocks	1.047 (151.9)
Penetrations	3.38 (490)
PCCS Heat Exchangers (MPa absolute (psia))	~~1.33~~38.7 (~~193~~5613)

ACM 3.3 INSTRUMENTATION

AC 3.3.4 Diverse Protection System (DPS)

ACLCO 3.3.4 The DPS Functions in Table 3.3.4-1 shall be AVAILABLE.

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

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. One or more DPS Functions unavailable.	A.1	Restore DPS Function(s) to AVAILABLE Status.	30 days
B. Required Action and associated Completion Time not met.	B.1	Enter ACLCO 3.0.3.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
ACSR 3.3.4.1	Perform CHANNEL CHECK.	12 hours
ACSR 3.3.4.2	Perform CHANNEL FUNCTIONAL TEST.	31 days
ACSR 3.3.4.3	Perform CHANNEL CALIBRATION.	24 months
ACSR 3.3.4.4	Perform LOGIC SYSTEM FUNCTIONAL TEST.	24 months

DPS
AC 3.3.4

Table 3.3.4-1 (page 1 of 1)
Diverse Protection System

FUNCTION
1. Reactor Scram
2. Main Steam Isolation Valve Closure
3. Safety Relief Valve Actuation
4. Fine Motor Control Rod Drive Run-in Actuation
5. Isolation Condenser System Actuation
6. Isolation Condenser System Vent Actuation
~~6~~7. Standby Liquid Control System Actuation (for Loss-of-Coolant Accident)
~~7~~8. Automatic Depressurization System (ADS) Inhibit

ACM B 3.3 INSTRUMENTATION

AC B 3.3.4 Diverse Protection System (DPS)

BASES

DPS provides diverse actuation functions that enhance the plant's ability to mitigate dominant accident sequences involving the common cause failure of actuation logic or controls. The DPS Functions are implemented in a highly reliable triple redundant control system whose sensors, hardware, and software are diverse from their counterparts on any of the safety-related platforms.

The following diverse actuation Functions are provided by DPS:

- A set of protection logics that provide a diverse means to scram the reactor via control rod insertion (reference Subsection 7.8.1.2.1),
- A set of initiation logics that provide a diverse means to initiate certain engineered safety features (ESF) functions (safety relief valves, Isolation Condenser System, and Standby Liquid Control System (reference Subsection 7.8.1.2.2)),
- A set of initiation logics that provide a diverse means to initiate closure of the main steam isolation valves (reference Subsection 7.8.1.2.4),~~ and~~
- A set of initiation logics that provide a diverse means of control rod insertion by means of Fine Motor Control Rod Drive Run-in (reference Subsection 7.8.1.1.2), and~~.~~
- A set of initiation logics that provide a diverse means of initiating venting of the Isolation Condenser System in order to mitigate the accumulation of radiolytic hydrogen and oxygen (reference Subsection 7.8.1.2.5).

For Anticipated Transient Without Scram (ATWS) mitigation, the DPS initiation of ADS is inhibited automatically. The ADS Inhibit Function required by this availability control is automatically actuated by nonsafety-related logic that is processed by the DPS (reference Subsection 7.8.1.2.3). The ADS Inhibit Function prevents an undesirable DPS initiation of the ADS during ATWS conditions.

The DPS Functions are nonsafety-related functions that satisfy the significance criteria for Regulatory Treatment of Non-Safety Systems, and therefore require regulatory oversight. The short-term availability controls for these Functions, which are specified as Completion Times, are acceptable to ensure that the availability of these Functions 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.

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.

ACM 3.6 CONTAINMENT SYSTEMS

AC 3.6.4 Hydrogen Mitigation - Ignitors

ACLCO 3.6.4 One ignitor per Passive Containment Cooling System (PCCS) lower drum shall be AVAILABLE.

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

ACTIONS

- NOTE -

Separate Condition entry is allowed for each PCCS lower drum.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more required ignitors unavailable.	A.1 Restore ignitor to AVAILABLE Status.	7 days
B. Required Action and associated Completion Time not met.	B.1 Enter ACLCO 3.0.3.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
ACSR 3.6.4.1 Perform CHANNEL CHECK on associated drywell atmosphere thermocouples and lower drywell basemat thermocouples.	12 hours
ACSR 3.6.4.2 Energize each ignitor and perform current versus voltage measurements to verify required ignitors in service.	92 days

SURVEILLANCE		FREQUENCY
ACSR 3.6.4.3	Perform CHANNEL CALIBRATION on associated drywell atmosphere thermocouples and lower drywell basemat thermocouples.	24 months
ACSR 3.6.4.4	Perform LOGIC SYSTEM FUNCTIONAL TEST.	24 months
ACSR 3.6.4.5	Verify each required ignitor starts on an actual or simulated automatic initiation signal and operates at the required temperature.	24 months on a STAGGERED TEST BASIS for each PCCS Condenser

ACM B 3.6 CONTAINMENT

AC B 3.6.4 Hydrogen Mitigation - Ignitors

BASES

During the initial stages of a severe accident, there is essentially no water in the vicinity of the core, so radiolysis is greatly reduced. However, large quantities of hydrogen are released into the drywell due to metal-water reactions. The high abundance of hydrogen relative to oxygen effectively reduces the potential for detonation in the Passive Containment Cooling System (PCCS). Later in the postulated event, after the core melts through the vessel and interacts with the concrete, the GDCS deluge valves open and the core once again has the potential to resume radiolysis. Thereafter, relative concentrations of hydrogen and oxygen trend closer to a stoichiometric ratio at pressures much higher than during a Design Basis Accident. The PCCS condensers may experience some plastic deformation during a detonation under these conditions.

Ignitors in the lower drums of the PCCS condensers recombine the hydrogen and oxygen while they are still at lower concentrations, thus preventing a detonation that could result from the accumulation of high concentrations of these gases. Each PCCS condenser module has two lower drums, and each lower drum contains 2 ignitors. One ignitor per lower drum is required to be available to effectively recombine the hydrogen and oxygen to safe levels. The ignitors are actuated by the same drywell temperature signals and control system that actuate the GDCS Deluge Function (ACLCO 3.5.1).

The ignitor function is a nonsafety-related function that satisfies the significance criteria for Regulatory Treatment of Non-Safety Systems, and therefore requires regulatory oversight. 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.

Enclosure 5

MFN 10-044 Supplement 1 Revision 1

Revised Response (Revision 1) 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 NEDO-33572 Revision 1, "ESBWR ICS and PCCS Condenser Combustible Gas Mitigation and Structural Evaluation," May 2010

Public Version

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NEDO-33572
DRAFT Revision 2
Class III
eDRF Section 0000-0115-2094 R3
July 2010

GEH Proprietary Information

Licensing Topical Report

ESBWR ICS AND PCCS CONDENSER COMBUSTIBLE GAS MITIGATION AND STRUCTURAL EVALUATION

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT*

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ILLUSTRATIONS

1.0 SCOPE

The design of the Isolation Condenser System (ICS) and Passive Containment Cooling System (PCCS) as described in Revision 6 of the ESBWR Design Control Document (DCD) are being modified to improve their ability to mitigate the loads resulting from the buildup and possible detonation of radiolytically generated combustible gases. This report describes these changes and the conservative methodology by which the detonation loads are calculated as well as the design philosophy used to ensure the ICS and PCCS have been designed robustly to withstand the most bounding loads while not affecting their heat transfer capability.

2.0 PCCS METHODOLOGY

The PCCS components are first evaluated for accumulation of radiolytically generated hydrogen and oxygen and then the possible range of mixture concentrations is determined. A bounding detonation pressure for a pure stoichiometric mixture of hydrogen and oxygen is calculated using the highest peak pressures during a loss of coolant accident (LOCA). It is then applied statically using dynamic load factors (DLF) in a finite element model for the PCCS condenser using the approved ANSYS computer code. The calculated stresses for the detonation load are combined with those from seismic and LOCA thermal loads. The acceptance criterion for components subject to detonation is based on the ability of those components to retain their pressure integrity without significant plastic deformation following [[ ]] detonation cycles. Two postulated detonation scenarios are analyzed in the finite element model: a detonation in one tube and a detonation in the lower drum.

Inputs are provided for the finite element analysis that describes increased thicknesses for the PCCS tubes and lower drum that are expected to satisfy the acceptance criteria for elastic-plastic analysis. The impact of increased tube thickness on heat removal capacity is estimated and compensated for by adding additional tubes. This configuration is evaluated in Appendix B.

The specific routing and configuration of components downstream of the lower drum is not yet specified. Therefore, the thickness of downstream piping and components will be sized to accommodate the resulting detonation loads. The magnitude of the detonation load on the downstream components will also be minimized by the addition of a safety-related catalyst module at the entrance of the vent pipe in the condenser lower drum. The catalyst module will function to keep hydrogen concentrations in the PCCS vent below levels at which deflagration-to-detonation (DDT) events can occur.

2.1 COMBUSTIBLE GAS GENERATION / CONCENTRATION

The radiolytic generation of combustible gas is a common occurrence in typical power reactors, including ESBWR. The generation of hydrogen and oxygen gas occurs in a stoichiometric ratio at a rate proportional to the core decay heat. During a LOCA, these gases escape into the containment resulting in very dilute concentrations of combustible gas in the drywell (below concentrations that could result in ignition). The PCCS contains six condensers that are designed to receive this mixture of steam and noncondensable gas, condense the steam, and return the condensate back to the drywell. See simplified sketch, Figures 1a, 1b, and 1c, of the PCCS Condenser.

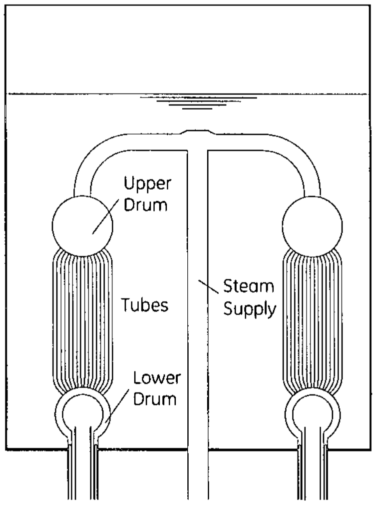

Figure 1a: PCCS Condenser Simplified Sketch

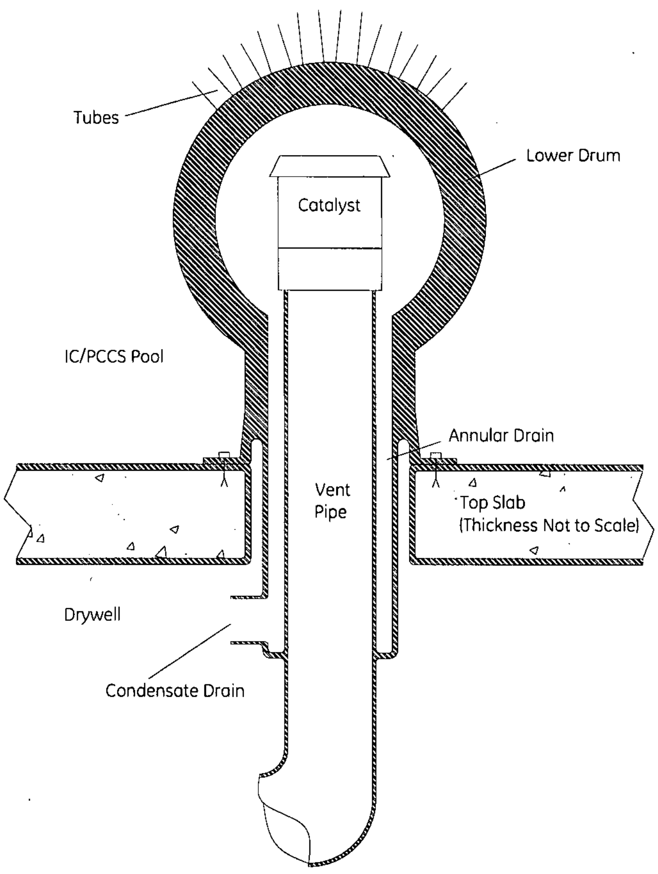

Figure 1b: PCCS Condenser Lower Drum Section View (Not to Scale)

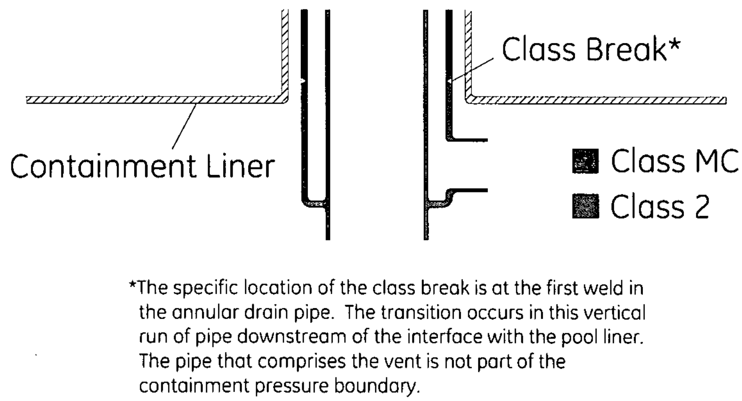

Figure 1c: PCCS Condenser ASME Jurisdictional Boundaries

Each PCCS condenser consists of two modules submerged in a pool of cooling water. Each module contains an upper and lower drum connected by an array of 2-inch diameter tubes. Gas from the drywell passes up a central supply line that feeds both upper drums. The steam component of the gas condenses as it moves downward through the tube array (transferring its heat to the pool water) and condensate collects in the lower drum and drains back to the drywell by gravity. The pool water level drops slowly over the course of the accident as water boils off.

The leftover noncondensable gas can exit the PCCS condenser through a vent line that connects the lower drum to the wetwell. As steam and noncondensables enter, the vent operates passively to bleed gas from the lower drum of the condenser when there is a sufficient pressure differential between the drywell and wetwell. In this way, something close to an equilibrium state is reached in which noncondensables persistently linger in the condenser while small amounts continue to come in with the steam and go out through the vent.

In the initial stage of a LOCA, the majority of the noncondensable gas in the drywell is nitrogen. This gas is eventually forced into the wetwell by the depressurization of the Reactor Pressure Vessel (RPV). Over time, the primary source of noncondensable gas in the drywell is the radiolytically generated hydrogen and oxygen. It has been shown in TRACG that noncondensable gas accumulates in the lower portions of the tubes and lower drum. When this gas transitions from mostly nitrogen to a stoichiometric mixture of hydrogen and oxygen, a combustible concentration may exist.

The relative concentration of steam to hydrogen and oxygen in the PCCS condenser is highly dependent on the conditions in the Isolation Condenser /Passive Containment Cooling System (IC/PCCS) pool subcompartment. Lower pool temperatures will bring down the temperature inside the condenser thereby lowering the steam fraction. The pool level can influence the variation in steam fraction over the height of the condenser tubes. TRACG analyses show that the steam fraction in the upper drum, and upper portion of the PCCS condenser tubes remains above 75%. The steam fraction in the lower portion of the tubes and the lower drum will remain above 30%.

In order to bound the amount of fuel and oxidizer inside the condenser, the atmosphere inside the PCCS is assumed to be 67% hydrogen and 33% oxygen (no steam).

Also, the initial PCCS pressure is assumed equivalent to the peak drywell pressure (407 kPa absolute) for the bounding containment LOCA even though the actual pressure inside the condenser will be significantly lower due to condensation. This approach is conservative because it results in a pure mixture (free from steam diluent) and assumes it is at an initial density greater than it could realistically achieve.

2.2 DETONATION LOADS

The process by which a detonation wave propagates through a medium and imparts stress on its surroundings is a complex subject that has been studied for a variety of applications. References 1 through 9, and 17 are reports that attempt to characterize this phenomenon. Data from these reports have been used to determine a bounding detonation load.

The entire PCCS is considered, but the focus of this report is on the condenser tubes and lower drum because of the complex geometry at the interface between the two and also because of the relatively thin walls of the tubes that make them more vulnerable to internal overpressure. The other portions of the PCCS (vent and drain piping) are considered separately in this report.

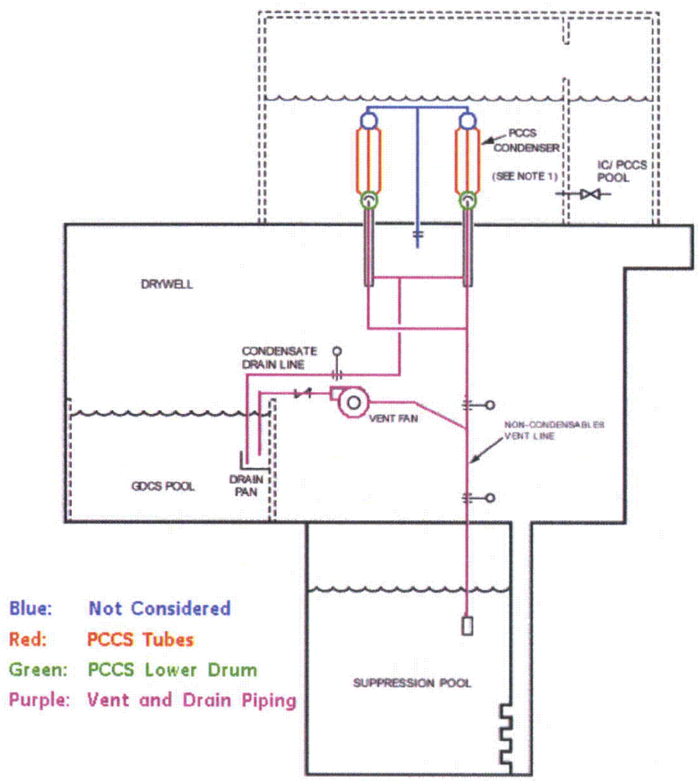

Figure 2: Portions of PCCS Considered for Detonation

The steam supply line and upper drums are not considered in this evaluation because they are constantly being flushed by steam coming from the drywell. The hydrogen and oxygen in this mixture is too dilute to support combustion.

The process used to evaluate the PCCS loads will first estimate the peak pressure resulting from detonation, and then apply this pressure in a finite element model as a static load multiplied by a dynamic load factor.

2.2.1 Peak Pressure Ratio

Many of the studies referenced in Section 6.0 describe the resultant pressure following the passage of a detonation wave, often called the Chapman-Jouguet pressure (or CJ pressure). It has been shown that a correlation can be made between the CJ pressure and the initial pressure prior to detonation. The correlation is dependent on the composition of the fuel-oxidizer mixture, the initial conditions (pressure and temperature), and the geometry of the system.

2.2.1.1 Gas Composition

Reference 3 describes a ratio between CJ pressure and initial pressure for a variety of fuel-oxidizer mixtures. For a stoichiometric mixture of hydrogen and oxygen at an initial temperature of 25°C, this ratio is given as 19:1 (See Table 1 of that report). This ratio is applicable for the PCCS, which also assumes a pure stoichiometric mixture. The assumption of a pure mixture is conservative for the purposes of maximizing the CJ pressure ratio. However, in certain circumstances the presence of steam will be considered as it has the potential to increase pressure loading (explained in Section 2.2.3).

2.2.1.2 Initial Conditions

References 2 and 7 show that lower initial temperatures result in higher peak pressure ratios. Realistic temperatures inside the PCCS at the time of detonation would be approximately 100°C. The assumption of 25°C is considerably lower than the expected temperatures inside the PCCS prior to a detonation and therefore more conservative. Likewise, the initial pressure is assumed to be 407 kPa absolute, which is equivalent to the peak drywell pressure during the most limiting LOCA. Even when the drywell is at this peak pressure, the actual pressure in the PCCS will be considerably lower due to its inherent design (submerged in a pool of cooling water). In this way, the initial conditions for the PCCS are conservatively bounded in the context of the 19:1 peak pressure ratio.

2.2.1.3 PCCS Geometry

Much of the literature cited in Section 6.0 discusses testing using simple straight-tube experiments. These simplified geometries are not necessarily representative of the PCCS condenser, which has a more complex shape with upper and lower drums connected by tubes bending at angles ranging from [[ ]]. The presence of bends, constrictions, and closed ends creates opportunities for reflections that can create localized peak pressures in excess of the

CJ pressure. Reference 9 characterizes this peak pressure for a closed volume as a maximum of 2.5 times the CJ pressure.

The design of the PCCS condenser (in particular the tubes) is more benign in terms of this loading than the tested configuration in Reference 9. Although the condenser tubes do contain bends that are subject to reflection loads, these bends are not as severe as a closed vessel that reflects the full force of the detonation wave. The tube bends range from [[ ]] to a maximum of [[ ]], and all have a bend radius of [[ ]]. Although the presence of bends will introduce some loading due to reflection, the loading will not be to the degree of a closed terminal end. Therefore, the multiplier of 2.5 is a conservative selection for the PCCS to account for effects that could amplify the internal pressure beyond the CJ pressure.

Using the methodology described above, the peak pressure for the PCCS is determined as:

407 kPa (initial pressure) • 19.0 • 2.5 = 19.3 MPa absolute

2.2.2 Dynamic Load Factor (DLF)

The dynamic load factor (DLF) is a multiplier that is factored into the peak static pressure to determine a maximum bounding load that accounts for dynamic effects resulting from a detonation.

2.2.2.1 DLF Dependence on Detonation Velocity

Reference 3 provides guidance on selecting an appropriate DLF. That study correlates the DLF (also called an amplification factor) to the velocity at which the detonation wave propagates. Low wave speeds are shown to have correspondingly low DLFs (approximately 1). As the wave reaches a "resonance" velocity, the DLF is observed to be as high as 4. At velocities above this resonance threshold, the DLF is shown to decrease and plateau around 2.

The resonance velocity is a characteristic of the tube in which the detonation occurs. A formula for calculating the characteristic resonance velocity or critical velocity (V_{c0}) for the PCCS tubes is given in Reference 3 as:

$$V_{c0} = \left[\frac{E^2 h^2}{3\rho^2 R^2 \left(1 - \nu^2\right)} \right]^{1/4}$$

where

E = Young's modulus

h = tube thickness

ρ = density

R = mean radius

ν = Poisson's ratio

When these parameters are applied in accordance with the revised PCCS condenser tube design (see Section 2.3), the equation becomes:

[[

]]

2.2.2.2 *Determination of a Conservative Detonation Velocity*

Reference 1 describes detonation velocities for a pure stoichiometric mixture of hydrogen and oxygen. The velocities reported there (Figure 1 of that report) are in excess of 2800 m/s, which is considerably higher than the V_{c0} value of [[ ]]. However, a pure mixture is not necessarily representative of the mixture in the PCCS (although it has conservatively been assumed so in Section 2.2.1.1), and there is also data to suggest that the presence of steam or other diluents could slow the propagation of the detonation wave. To justify using a DLF of 2, it is important to consider the effects of various diluents to ensure that the most limiting case does not reduce the detonation velocity to a value near V_{c0}.

Reference 17 is a thorough report dealing with the topic of combustion of radiolytic gases typical in BWRs. Chapter 5 of that report specifically examines flame accelerations and detonation properties for a range of gas mixtures. Table 5.1.8 of that report contains calculated detonation velocities based on the thermo-chemical properties of the mixture, and shows good agreement with experimental data. The data reported in this table indicates that the CJ velocities are much higher than V_{c0}, justifying the choice of a DLF of 2. It is noted that if extrapolated to 80% steam, CJ velocities could approach the value of V_{c0}, however, the corresponding CJ pressures under these conditions are much lower than the conservative value of 19, which is described in Section 2.2.1.1. At steam concentrations of 65%, the CJ velocity is 1,962 m/s (much higher than V_{c0}). The reported CJ ratio at this steam concentration is 9.3, which is already low enough to accommodate a DLF of 4 while still remaining bounded by a factor of 2 combined with a CJ ratio of 19.

The bounding detonation load (considering dynamic effects) for the condenser tubes is therefore:

407 kPa (initial pressure) • 19.0 • 2.5 • 2 = 38.7 MPa absolute

Mitigation strategies for other PCCS condenser components are described in 2.2.4.

2.2.3 Deflagration to Detonation Transition (DDT)

In some cases, an additional factor known as delayed deflagration to detonation transition (or delayed DDT) can increase localized pressures to high values. The delayed DDT phenomenon can occur when the deflagration front undergoes a substantial acceleration period before transitioning to a detonation, or when the un-burnt mixture is compressed due to obstructions or closed ends in the structure. This compression at the onset of detonation has the potential to cause much higher localized pressures loads.

Delayed DDT is a relatively complicated research area and the phenomenon is dependent on many different variables. The detonation cell size is a parameter that is typically used to characterize the sensitivity of the mixture to detonation. Reference 21 is a very comprehensive report on the nature of DDT, and Chapter 3 of that report describes certain conditions that are necessary for DDT to occur, one of which is a minimum cell size. The cell sizes for hydrogen-oxygen mixtures can be small (on the order of 1 mm). Smaller cell sizes are indicative of relatively quick transitions, which are desirable because of the smaller amount of pre-compression.

Reference 4 is an evaluation of the structural response of a tube in conditions favorable to a DDT event. The results of this study characterize the peak loads as those that occur near the closed end of the detonation tube, which maximizes the compression of the un-burnt mixture. The PCCS condenser tubes do not have closed ends, but instead are vented to larger volumes (upper and lower drums). The report concludes that these loads can be accounted for by using a dynamic factor of 4, which is bounded by the assumption used in this report ($2 \cdot 2.5 \cdot P_{CJ}$). As described in the summary of Reference 4, the DDT loads are impulsive and very short in duration and therefore need not be considered as an additional dynamic load on top of the dynamic factors already being applied.

2.2.4 Other PCCS Components

2.2.4.1 Lower Drum

The lower drum of the PCCS condenser is also subject to the accumulation of hydrogen and oxygen (at similar concentrations as the lower portions of the tubes), however, the combustion of these gases is expected to occur by a different mechanism than that described above for the tubes. Whereas the interior of the tube is a relatively restricted volume with a small diameter and long length, the drum interior is a more spacious and open volume. The top of the lower drum is vented through the tubes, which have a cumulative flow area of [[
]].

It is conservative to take the same approach for the lower drum as was used for the condenser tubes and to apply the same series of CJ detonation pressure multipliers that was assumed for the tubes in Section 2.2.2.3. The concept of delayed DDT becomes somewhat complicated in the lower drum, because its geometry is less similar to the experimental geometries (which were mostly simple tubes). Reference 21 is a comprehensive report on the subject of flame acceleration and DDT. Appendix D of that report contains experimental data that characterize the detonation cell size for hydrogen-air mixtures over a range of initial temperatures, pressures, and steam dilutions. Figure D.1-3 of that report indicates that the cell size does not go above 1 cm for a hydrogen-air mixture with 30% steam dilution at initial pressures ranging from 0.1 MPa to 0.4 MPa. The report goes on to describe methods of interpolating for different mixture types, however, this table is sufficient to conclude that the cell sizes in the lower drum also will not exceed 1 cm. Mixtures of hydrogen and oxygen are more sensitive than hydrogen and air, and will therefore have smaller cell sizes than those reported in Ref. 21. Furthermore, the cell size decreases with increasing pressure – a trend that would also result in yet smaller cell sizes for the lower drum. Therefore, because of the small cell size, the dynamic effects of a detonation in the lower drum are considered to be bounded by the combination of factors used in the tubes due to the unlikelihood of a delayed DDT event occurring at a location where it could impart significant loads on the structure of the lower drum.

2.2.4.2 Vent Pipe and Catalyst Recombiner Module

2.2.4.2.1 Description

The PCCS vent line begins with a standpipe in the lower drum, and extends downward to the drywell (routed inside the condensate drain pipe through the top slab) where it separates into an independent line that penetrates the diaphragm floor and terminates at a submerged location in the wetwell. The vent line is designed to conduct noncondensable gases from the PCCS condenser to the wetwell, therefore high concentrations of hydrogen and oxygen would be expected under normal circumstances.

Because of the uncertainties associated with the routing of the PCCS vent line, it is difficult to justify a specific DLF, and even more difficult to make a conclusive statement about the potential for DDT. Therefore, a safety-related catalyst module has been added to the design and will be relied upon to minimize the concentration of noncondensable gas in the vent line.

The catalyst module is bolted to the entrance of the vent pipe in the lower drum so that any gas entering the vent must first pass through the catalyst. The catalyst is composed of an array of platinum or palladium coated plates, arranged in a parallel pattern. The catalyst plates are installed within a housing that is a single piece, thick walled cylinder, which is robust enough to withstand the effects of a detonation inside the lower drum. A cover is provided on the catalyst that prevents condensate from dripping on the plates and also protects the plates against the direct effects of a detonation. A conceptual sketch is shown in Figure 3.

An optimization study was performed on the size of the vent line portion leading to the suppression pool downstream of the branch to the vent fan. This line, which had been sized at 10 inches, has been shown to perform sufficiently with flow areas as low as 2 inches. Therefore, in order to provide optimal structural integrity, the vent pipe is reduced to a 3-inch line.

2.2.4.2.2 Catalytic Performance

This catalyst configuration as depicted in Figure 3, was based on the design attributes (plate dimensions, spacing, etc.) of a similar catalyst that underwent extensive performance testing. The results of these tests (documented in Reference 18) show that for initial hydrogen concentrations of 4%, the catalyst will recombine virtually all of the hydrogen, provided the flow velocity remains below the tested value of 0.25 m/s. The flow velocity through the vent of the PCCS condenser has been shown to peak at [[ ]] (nominally much lower). The surface area of the catalyst is based upon the capability for it to recombine twice the mass of hydrogen that is introduced to each PCCS condenser vent, which is conservatively computed to peak at [[1.66 kg/hr [3]]] (nominally much lower). Therefore, it is assumed that the fraction of hydrogen and oxygen downstream of the catalyst is insignificant. Once downstream of the catalyst, it is unlikely that hydrogen concentrations will increase to flammable levels due to the lack of condensation in the downstream portions of the vent line. Additionally, the gas that does enter the line will eventually be pushed into the wetwell due to the slow but steady venting process. Therefore, it is assumed that the safety-related catalyst prevents hydrogen and oxygen in the vent line from reaching flammability limits.

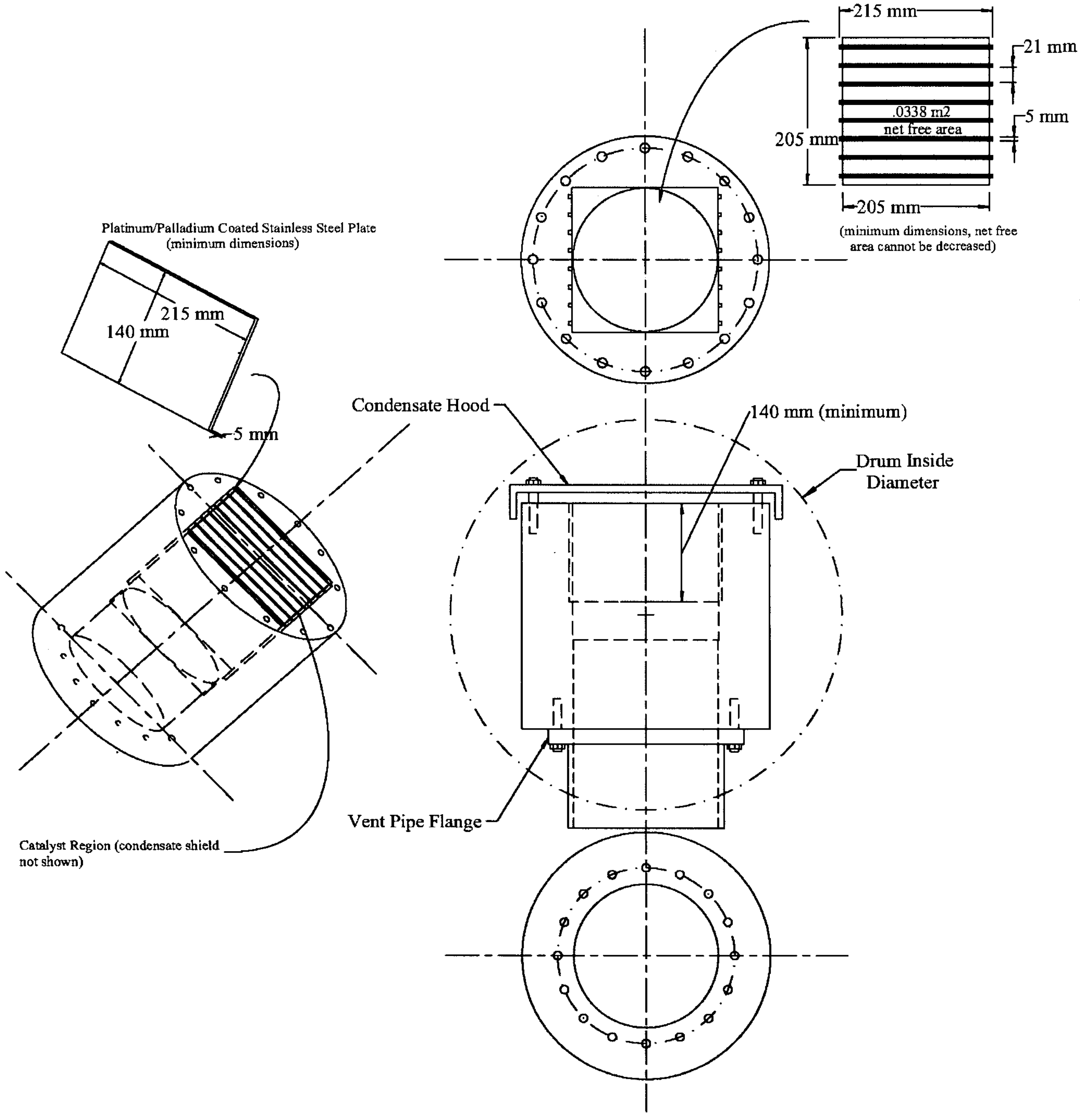

Figure 3: Conceptual Design for In-Line Catalyst

2.2.4.2.3 Effects of Poisons and Inhibitors - Design Basis Accident Conditions

During all design basis accidents postulated for ESBWR, the potential for the generation of significant levels of catalyst poisons or inhibitors is limited by prohibiting materials in containment that could be the source of such poisons or inhibitors during a DBA. Also, poisons or inhibitors that are generated by core melt do not occur during a DBA since the fuel is always covered by water. The discussion of these types of poisons and inhibitors is only applicable during severe accidents.

Liquid water has generally been thought to be an inhibitor; although testing has been performed which would indicate that it is not (See Reference 19, which is introduced in the next section). Even so, a condensate hood is provided which will have design features to mitigate liquid carryover into the vicinity of the catalyst plates.

2.2.4.2.4 Effects of Poisons and Inhibitors - Severe Accident Conditions

The Electric Power Research Institute (EPRI) conducted an extensive study on the subject of passive autocatalytic recombiners (PARs) and documented the results in a report (Reference 19). This EPRI report was submitted to the U.S. Nuclear Regulatory Commission by correspondence dated April 8, 1993. The PARs that EPRI studied utilized platinum/palladium metallic substrates that were configured very similarly to that of the PCCS vent catalyst module and the conclusions of the report are therefore considered relevant to the ESBWR application. The similarity lies in the vertically arranged catalyst racks or plates separated so as to provide flow channels for the bulk of the gasses.

The testing and analysis conducted by EPRI considered poisons and inhibitors such as steam, water, smoke, soot, iodine vapor and carbon monoxide. EPRI noted that there were some noticeable short-term effects of certain poisons and inhibitors, however, these quickly diminished as the catalyst reached operating temperature and the overall performance was not significantly affected. From their testing and analysis, EPRI made the following statements in support of the catalysts:

- "Performance of the catalyst is virtually unaffected by all of the known poisons that were selected for experimental investigation. A presoaked catalyst device functioned normally while being sprayed with water during a test."
- "Catalyst is self-cleansing (from heat of recombination) with respect to wetness or other types of potential operational contaminants and poisons during accidents."
- "Catalyst material is not consumed as it functions and is not subject to long-term aging degradation."

In addition to the extensive testing and analysis that was performed, EPRI conducted a computational analysis that is also documented in the report (Appendix E). This computational analysis demonstrated the negligible impact that aerosols would have on plate-type catalyst during severe accidents involving an in-vessel core melt progressing to lower head penetration and entry to the flooded below-vessel areas of containment (lower drywell and BIMAC). The computational analysis made very conservative assumptions pertaining to aerosol amounts, particle size, and particle density, to name a few. The analysis based many of its assumptions and input on the ALWR source term work that was documented in Reference 23. The vent catalyst module is designed to accommodate flow channels of equal or larger dimensions as compared to the EPRI prototypical design. These flow channels ensure that the majority of all postulated aerosols are continually swept into the wetwell, with no significant accumulation in the vicinity of the catalyst module.

The EPRI computational analysis results (Reference 19, Appendix E) are adjusted based on the ESBWR specific parameters, namely containment free air volume, accident leak rate, larger core size (as compared to AP600), and maximum PCCS venting velocity. The EPRI result, scaled for ESBWR, indicates that less than 1% of the catalyst plate surface area will be blocked by aerosol deposition during a severe accident. Since the installed catalyst plate surface area is 2 times that which is required, this degree of blockage will have no detrimental affect on recombination and by extension, the venting capacity of the PCCS condenser is also not compromised. It should be noted that no credit is taken for the aerosol stripping that occurs inside the PCCS tubes upstream of the catalyst as steam is condensed (DCD, Tier 2, section 15.4.4.5.2.2)

The significant production of aerosols due to core-concrete-interaction is not possible due to the operation of the GDCS deluge subsystem and the BiMAC (see response to RAI 19.1-8 Supplement 1, Part B, MFN 06-313, September 12, 2006 and RAI 19.1-8 Supplement 2, MFN 06-313 Supplement 6, August 13, 2007).

2.2.4.2.5 Environmental Qualification

The catalyst, which has a 60-year design life, will be qualified to operate during the harsh post-accident environment and under the most extreme operating conditions of recombination. The normal operating environment of the catalyst consists of an inerted nitrogen atmosphere with temperatures moderated by the PCCS pools. The catalyst is contained within a cylindrical module located in the lower drum of the PCCS condenser drum above the drywell top slab and is therefore well shielded from the effects of radiation.

2.2.4.2.6 Equipment Qualification

The catalyst module will be qualified to meet both its recombination and structural performance requirements described in Section 2.2.4.2.2 through type-testing by the manufacturer.

2.2.4.2.7 Surveillance Testing and Periodic Inspection

The catalyst module is accessible through either of the bolted covers of the lower drum and the catalyst plates can be readily removed from the module itself. These design features provide for surveillance testing and periodic inspections.

Surveillance testing will be performed on a representative number of catalyst plates of an individual PCCS condenser each refueling outage on a rotating basis and will consist of a laboratory type bench test using an appropriate acceptance criteria which is based upon the performance requirements specified in section 2.2.4.2.2. Visual inspections of the balance of the plates and the entire module assembly may be conducted in parallel with the surveillance test.

2.2.4.2.8 Structural Loading

Detonation loading of the heavy-walled catalyst module consists of both transverse and axial forces imposed by the detonation shock wave, and will be computed during detailed design using LS-DYNA, similar to the analysis performed in Appendix C assuming a pure stoichiometric mixture of hydrogen and oxygen. Detonations do not originate in or propagate into the area of the catalyst plates due to the lack of a combustible mixture. The condensate hood protects the catalyst plates from the direct effects of the shock wave such that the vertically mounted plates experience only the axial on-rush of the venting combustion gases. The plates are designed in such a way that they may not be dislodged during a detonation event.

2.2.4.3 Vent Fan Ball Valve

A ball valve is added to the vent fan branch line upstream of the fan as close as possible to the branch from the main vent line to the suppression pool. The ball valve is designed to protect the vent fan from detonations described in 2.2.4.2, and as such shall be designed robustly to remain operational after withstanding a detonation.

The classification of the valve is consistent with the RTNSS function of the vent fans. The valve is nitrogen-operated, normally closed, fail as-is, and provided with an accumulator. It is provided with nonsafety-related power (same power source as the vent fan). While the operation of the ball valve is not safety-related, it is classified as a safety-related component for the purpose of pressure integrity. Because the normally closed ball valve is a safety-related barrier that prevents water redistribution from the GDCS pool to the suppression pool, the safety-related check valve that had been included downstream of the vent fans is no longer required and has been removed from the design. The concern of water transfer from the GDCS pool to the suppression pool only exists in the early stages of an accident when there are large pressure transients in the drywell. After this initial period, the differential pressure between the drywell and wetwell is not large enough to push GDCS pool water back through the vent fan piping, therefore, there are no adverse consequences to the ball valve failing in the open position after the fans have been activated.

2.2.4.4 Drain Pipe

The drain from the PCCS condenser consists of an annular region surrounding the vent pipe. Once the combined vent/drain pipe reaches the drywell, they separate and a series of drain pipes conduct the condensate directly to the submerged discharge location in the GDCS pool. It is not clear to what extent combustible gases can accumulate in the drain lines considering the there is a continuous flow of condensate and higher temperatures (resulting in higher steam fractions). Therefore, the drains lines shall be conservatively reinforced as described below to accommodate the same detonation load as the tubes and lower drum.

The ASME Code provides guidance for determining an appropriate thickness for cylindrical components. Because the annular drain contains a transition between Subsections NE and NC of the ASME Code, there are two correlations that must be considered, and the more limiting of the two will be applied to the drain line. Subsection NE-3324.3 provides the following correlation for thickness:

$$t = \frac{PR}{S - 0.6P},$$

where

t = thickness (mm)

R = inside radius = 149 mm

P = internal pressure = 38,700 kPa

S = allowable stress = 152,000 kPa = $1.1S$ per NE-3311(a) for TP316 Stainless

The minimum required thickness for the Class MC annular drain line, given an internal radius of 149 mm is:

[[{3}]]

which is rounded up to a thickness of [[45 m{3}]].

For comparison, the following correlation is from NC-3641.1

$$t = \frac{P \cdot D_o}{2(S + P \cdot y)},$$

where

t = thickness (mm)

D_o = outer diameter (mm)

P = internal pressure = 38,700 kPa

S = allowable stress = 138,000 kPa

In order to maintain a consistent inner diameter ([[298 m{3}]]) while still meeting the allowable stress limit, this correlation was iterated with increasing outer diameters until an appropriate thickness was found. For this Class 2 evaluation, the inner radius and stress limits are satisfied with an outer diameter of [[400 mm{3}]] and a thickness of [[50 m{3}]].

The thickness of [[50 mm{3}]] shall be used for the annular drain line to conservatively bound both Class MC and Class 2 requirements.

The piping downstream of the annular drain is initially 3" Sch XXS. These 3" lines from each lower drum combine into a single 4" Sch XXS pipe that serves the full condenser. The correlation used above for the annular drain is used as shown below to demonstrate these thicknesses are adequate:

[[3" NPS: (For 3" Sch XXS, t = 0.0152m)

4" NPS: (For 4" Sch XXS, t = 0.0171m)[3]]]

2.2.5 Post-Detonation Pressure Relief

Following a postulated detonation in the lower drum, the resulting pressurized gas mixture will relieve downward through the vent line, and also upward through the tubes (reverse flow). These relief pathways may briefly be subject to higher pressures as the lower drum equalizes pressure with its surroundings. The pressures seen by the relief pathway will not include the dynamic factors associated with reflected shock waves (factor of 2.5), however a DLF of 2 will still be applied to bound other dynamic effects. The resulting lower drum pressure is 0.407 MPa • 19.0 • 2 = 15.5 MPa. As this gas expands through the relief volume, its pressure is assumed to drop according to the pressure-volume relationship of ideal gases:

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)$$

The portion of the vent that lies within the annular drain is credited as an expansion volume rather than evaluated for internal pressure because the relief pressure in this part of the vent is balanced by the same relief pressure in the drain (and the drain is reinforced to withstand a full CJ detonation as described in 2.2.4.4). The vent becomes a pressure-retaining boundary when it emerges from the drain line in the upper drywell, and it is downstream of this point that the pressure relief can impose significant stresses on the vent. Likewise, the condenser tubes are considered an expansion volume because they have been designed to withstand a full CJ detonation.

The volumes applicable for calculating pressure reduction have been calculated as follows:

[[Lower Drum (V_{LD})........................ = 0.87 m^3

Tubes (V_{tubes})........................ = 0.85 m^3

Annular Drain (V_{drain})........................ = 0.08 m^3

Vent (V_{vent})........................ = 0.08 m^3

$V_1 = V_{LD}$........................ = 0.87 m^3

$V_2 = V_{LD} + V_{tubes} + V_{vent} + V_{drain}$ = 1.88 m^3

[3]]]

The PCCS vent is [[ ]] pipe made of 304L stainless steel [[ ]]. ASME Section III, Paragraph NC-3324.3 provides a correlation to the minimum wall thickness for a given pressure. The S_m value for 304L pipe at

400°F is 15.8 ksi (drywell design temperature is 340°F). Using this information, a conservative allowable pressure for this pipe can be determined as follows:

[[ ]]

The vent pipe, therefore, is capable of relieving the CJ pressure of the lower drum. Though the initial pressure in the lower drum is higher than the allowable for the vent, the expansion reduces the pressure such that it is within the allowable by the time it reaches the pressure-retaining portion of the vent line.

2.2.6 Thermal Effects

In addition to the pressure loads described above, there are thermal stresses that can arise as a result of combustion. Reference 3 contains a discussion of the nature of these thermal stresses, and indicates that while the thermal stresses do exist in the PCCS following a detonation, they are much lower than the mechanical loads due to detonation pressure, and also are slow to evolve when compared to the brief pressure pulse. As a result, the thermal effects of a detonation are considered to be bounded by the ability of the condenser to withstand the detonation pressures.

2.3 INITIAL SIZING AND STRESS CALCULAITON

The design of the PCCS condenser as described in DCD Revision 6 is not considered robust enough to withstand the very conservative detonation loads postulated in the sections above. This section describes the methodology by which the design has been modified to withstand a detonation.

A seismic and hydrodynamic analysis was performed for the original configuration of the PCCS condenser (See Appendix A) and was described in Revision 6 of the DCD. This analysis has been redone to include detonation loads and the configuration changes described below (analysis is described in Appendix B):

- PCCS condenser tube material changed to SA312 TP XM-19.
- PCCS condenser tube thickness changed to [[ ]].
- Number of tubes for each module increased from 280 to [[ ]] (there are two modules in each PCCS condenser).
- PCCS drum material changed to SA182 FXM-19 (both upper and lower drums).
- Thickness of lower drum increased to [[ ]] (upper drum thickness remains[[ ]]).
- Catalyst module added to the entrance of the vent in the lower drum of the condenser.

- Ball valve is added to the vent fan branch line upstream of the fan. Check valve has been removed from the design.
- Vent line between the branch for the vent fans and the suppression pool is reduced to a nominal size of 3".
- Lower drum covers increased to a thickness of [[150 mm{3}]].

2.3.1 Design Criteria

The PCCS condenser is designed to ASME Section III, Subsection NE as a Class MC component. As such it must be designed to accommodate the loads within the acceptance criteria stated in that part of the Code. In the structural evaluation of the PCCS, the detonation will be applied as a Service Level C load., Appendix B contains the details of this evaluation and the results.

2.3.2 Deleted

2.4 EFFECT ON HEAT TRANSFER

The increase in tube thickness and change in material will increase conduction resistance through the tube wall, which will have a negative effect on the overall heat transfer coefficient of the condenser. To compensate for this effect, TRACG evaluations have determined that it is necessary to increase the number of tubes from 280 to [[ ]] per module in order to keep the containment pressure response bounded by the values described in Revision 7 of the DCD.

2.5 POSTULATED DETONATION SCENARIOS

The two detonation scenarios analyzed in Appendix B are for a detonation in one PCCS tube and in the PCCS lower drum. The evaluation considers the cumulative effect of [[ ]] detonation cycles. Detonations are not assumed to propagate into a component where a detonation has already occurred.

2.5.1 Detonation in Tubes

The detonation wave in a tube travels into the upper and the lower drums with it quenching in upper drum due to high steam fractions and with a possibility of reflecting back into the tube once it reaches the lower drum wall. This reflection is accounted for in the peak pressure ratio of 2.5 times 19.0 used in determining the detonation pressure for the PCCS condenser.

2.5.2 Detonation in Lower Drum

A postulated detonation in the lower drum will vent through the tubes. The potential for the reflected waves at the flanges to amplify the detonation pressure are accounted for by the 2.5 factor.

2.6 DISCUSSION OF UNCERTAINTY AND CONSERVATIVE ASSUMPTIONS

The methodology described in this report relies heavily upon theory from literature and experimental data from scientific reports. Because of the complexity and uncertainty associated with predicting detonation properties, this report has made conservative assumptions as appropriate. These assumptions are summarized below.

2.6.1 Overestimation of Radiolytic Gas Concentration

In Section 2.1, it is stated that the initial gas mixture inside the PCCS is a pure stoichiometric mixture of hydrogen and oxygen with no steam presence. This is not a realistic scenario, especially for the upper drum and upper portion of the tubes in which less condensation will have taken place. By assuming a pure stoichiometric mixture, this methodology maximizes the amount of combustible gas in the condenser.

2.6.2 Overestimation of Initial Pressure

As described in Section 2.2, the initial PCCS pressure prior to a detonation is assumed to be the drywell peak pressure following the most limiting LOCA. Because of the inherent design of the PCCS the pressure in the system will always be lower than the drywell pressure, and will not reach a value as high as 407 kPa. For the majority of the accident, the drywell pressure is actually much lower than this, and slowly increases to a peak value over the course of the first 3 days. This trend is illustrated in Table 6.2-14e11 of the ESBWR DCD. The overestimation of initial pressure is a conservative assumption to address uncertainties associated with the experimentally determined peak pressure ratio of 19.0.

2.6.3 Underestimation of Initial Temperature

As described in Section 2.2, the ratio of peak pressure to initial pressure is also dependent on the initial temperature. The references cited in the section have concluded that a lower initial temperature, which allows for a denser mixture of combustible gas, results in a higher peak pressure ratio.

The ratio of 19.0 used in this report was taken from experimental data in which a stoichiometric mixture of hydrogen and oxygen was detonated at an initial temperature of 25°C. The realistic temperature inside the PCCS remains steady in the range between 90°C - 100°C. The underestimation of initial temperature is a conservative assumption to address uncertainties associated with the experimentally determined peak pressure ratio of 19.0.

2.6.4 Bounding the Effects of Tube Bend Reflections

Section 2.2 discusses the bends associated with the PCCS tubes. The literature referenced in Section 6.0 provides experimental data to account for amplification due to the presence of bends or tees. Reference 9 states that the peak pressures resulting from reflected waves in closed vessels are "approximately 2.5 times higher than the CJ pressure". Because the tubes in the

PCCS condenser are bent to angles no greater than [[ ]] with bend radii of [[ ]], they are considered less susceptible to reflections than the case in Reference 9, yet the full 2.5 factor is applied for conservatism prior to the application of a dynamic load factor (which is determined in 2.2.2).

2.6.5 Critical Velocity for Bounding DLF Estimate

Following the guidance of Reference 3, the V_{c0} calculated for the PCCS condenser tubes was [[ ]]., which is considerably less than the detonation velocity 2800 m/s for the assumed stoichiometric mixture of hydrogen and oxygen in the PCCS. Although the assumption of no steam is conservative for estimating peak pressure, is not necessarily conservative for the determination of DLF. Therefore, an assumption of a diluted mixture was used to determine DLF. The lack of velocity data for mixtures rich in steam required the substitution of argon data. Argon, since it is heavier than steam, is considered a more effective diluent in terms of reducing detonation velocity. The theoretical detonation velocities for reasonably diluted mixtures (as much as 60%) show considerable margin still exists above the V_{c0} value. It is also worth noting that such a lean mixture would likely result in much lower peak pressures.

2.6.6 Elastic Range of Material

The design requirements use acceptance criteria that are within the elastic range of the materials used. Although there may be local stresses that exceed the yield limit, the linearized stresses will be shown to remain essentially elastic when subjected to a detonation load (consistent with Service Level C acceptance criteria).

The reported Reference 15 response of a tube with 15 mm ID and 3 mm wall thickness subjected to hydrogen/oxygen detonations with initial pressures up to 20 bar remained within the elastic range. The tube material had comparable yield and ultimate strength to that of SA-312 TP XM-19. The PCCS condenser is analyzed at much lower initial pressure of about 4 bar.

2.6.7 Deleted

3.0 CONSIDERATION FOR OTHER PCCS COMPONENTS

Section 2.0 of this report discussed the methodology for calculating detonation loads for the various portions of the PCCS. This section classifies those components and describes what pressures they are designed to withstand.

3.1 DELETED

3.2 APPLICABLE SUBSECTIONS OF ASME CODE SECTION III

The applicable subsection of ASME Code Section III for each PCCS component is given in Table 3-1.

Table 3-1: PCCS Components Applicable ASME Code III Subsection

Component	ASME Code Section III, Subsection
Steam Supply Piping (drywell)	NE
Steam Supply Piping (pool)	NE
Upper Drum	NE
Tubes	NE
Lower Drum	NE
Vent Pipe (pool)	NC
Vent Pipe (drywell)	NC
Vent Fan Ball Valve (drywell)	NC
Vent Fan Pipe[1] (drywell)	NC
Drain Pipe (pool)	NC/NE[2]
Drain Pipe (drywell)	NC

[1]Vent fans and vent fan piping are nonsafety-related components but are conservatively designed to the criteria in Subsection NC.

[2]The portion of the drain that interfaces with the lower drum is NE. There is a transition to NC as depicted in Figure 1c.

3.3 PCCS COMPONENT DETONATION LOADS

The following table is a breakdown of the diameters and thicknesses of components of the PCCS components, and a description of the detonation loads assumed, or a summary of the mitigation strategy.

Table 3-2: Evaluation of Other Components of the PCCS

[[

Basis

			7.17	Section 2.2.5
3"	0889	01524	38.7	Section 2.2.4.4
Drain Pipe (4")	0.114	0.01712	38.7	Section 2.2.4.4
(annular) Drain	400	050	38.7	Section 2.2.4.4

1) Vent line is 8" Sch 40
2) Deleted
3) Deleted
4) Deleted
5) Deleted

]]

4.0 ICS METHODOLOGY

The Isolation Condenser System (ICS) contains four condensers that are of a tube-and-drum design similar to the PCCS condensers. During a LOCA, these condensers are also vulnerable to the buildup and detonation of combustible gases.

Several design changes have been implemented for the ICS to prevent the accumulation of detonable concentrations of hydrogen.

4.1 ICS OPERATION (HIGH PRESSURE)

During scenarios in which the ICS is credited with heat removal (plant transients, station blackout, etc), the condenser vent function will be modified to keep the unit continuously purged of noncondensable gas.

The ICS vent had previously been designed to open automatically only on high pressure (indicative of a buildup of noncondensable gas). By the time this high pressure is reached, the concentration of hydrogen is expected to have already reached combustible levels (this is shown to occur after approximately 10 hours of ICS operation). In order to prevent this buildup, a logic change is implemented in which the vent valves automatically open 6 hours after the ICS is initiated regardless of the system pressure. Once open, the vent will bleed steam and noncondensables from the condenser to the suppression pool, keeping the steam fraction at high levels throughout the event. The vent valves are designed to fail open on a loss of power to provide additional reliability for this function.

A flow restriction shall be included in the vent line such that the maximum flow area is 0.167 cm^2. This flow restriction is provided to minimize the amount of water inventory lost from the reactor as a result of the constant flow through the vent lines. The flow restriction had been evaluated and shown to provide sufficient flow to keep the condensers purged, and the RPV water level is shown to remain above Level 1 for 72 hours.

4.2 ICS DURING LOCA (LOW PRESSURE)

During a loss of coolant accident (LOCA), the ICS is needed to initiate in order to supply the condensate stored in its drain piping. This additional water is credited with keeping the core covered with margin during a design basis accident. The actual heat removal through the ICS condenser is relatively small and is not credited in this type of event. However, there is potential for condensation to occur, and given enough time it is possible for combustible gases to accumulate in the ICS condenser following a LOCA.

In order to prevent this buildup from occurring, a logic change has been implemented for the ICS containment isolation valves in which the valves now automatically close after receiving an indication that the depressurization valves on the reactor have opened. The sequence of events during a design basis accident show that there is adequate time between ICS initiation and DPV opening for the condensate in the ICS drain lines to transfer to the RPV.

A TRACG evaluation shows that once it is isolated from the vessel, the ICS condenser pressure drops below 15 psia within 2,000 seconds, and noncondensable gas partial pressure does not exceed 0.63 following isolation. A detonation under these conditions is highly unlikely, however, if one were to occur the resulting loads would be within the stated design pressure of the ICS (1250 psig) as shown below.

The methodology by which the PCCS CJ pressures were calculated can be applied to the ICS, however, credit will be taken for the detonation properties of the mixture, which contains no less than 37% steam (based on the TRACG evaluation described above). The conservative CJ multiplication factor of 19.0, which was applicable to pure mixtures of hydrogen and oxygen at 25°C, can be reduced based on the thermo-chemical data contained in Reference 17. Table 5.1.8 of that report (reproduced blow) contains data for a range of steam fractions.

Table 4-1: Thermodynamic Properties of Hydrogen-Oxygen-Steam Mixtures*

%H2O	Initial pressure Po, bar	Initial temperature T, K	Sonic velocity in reactants c_{sp}, m/s	Sonic velocity in products c_{sp}, m/s	Adiabatic combustion temperature T_a, K	Adiabatic combustion pressure Picc,bar	Expansion ratio σ	Chapman-Jouguet temperature T_{CJ}, K	Chapman-Jouguet velocity D_{CJ}, m/s	Chapman-Jouguet pressure P_{CJ}, bar	Reflection pressure P_{ref}, bar
0	1	383	607	1390	3087	7.5	6.56	3642	2815	14.5	35
20	1	383	576	1280	2867	6.9	6.12	3348	2568	13.3	32
40	1	383	548	1174	2561	6.2	5.57	2989	2329	12.0	29
60	1	383	524	1052	2048	5.3	4.65	2461	2050	10.0	24
65	1	383	518	1011	1870	4.9	4.32	2280	1962	9.3	22
68	1	383	515	984	1755	4.7	4.10	2159	1902	8.9	21
70	1	383	513	964	1677	4.5	3.94	2074	1860	8.5	20
72	1	383	511	943	1597	4.3	3.78	1984	1815	8.2	19

*Excerpt from Reference 17

Because the CJ pressure is inversely proportional to the steam fraction, the CJ pressure ratio of 13.3 (corresponding to 20% steam) will be used to bound conditions in the ICS.

A DLF of 2 is applied to the ICS condenser, as was done for the PCCS condenser in Section 2.2.2.1. The equation from that section is reproduced below, with parameters that are consistent with the design of the ICS condenser tubes:

[[

]]

The corresponding detonation velocity (from Table 5.1.8 of Reference 17) is nearly double the critical velocity, thus the DLF of 2 remains justified.

Beginning with an ICS initial pressure of 15 psia, the final load is:

15.0 • 13.3 • 2 • 2.5 = 1000 psia,

which is significantly below the ICS design pressure of 1250 psia.

4.3 APPLICABLE SUBSECTIONS OF ASME CODE SECTION III

The applicable subsection of ASME Code Section III for each ICS component is given in Table 4-1.

Table 4-1: ICS Components Applicable ASME Code III Subsection

Component	ASME Code Section III, Subsection
Steam Supply Pipe (drywell)	NB
Steam Supply Pipe up to Venturi (pool)	NB
Steam Supply Pipe from Venturi to Upper Drum (pool)	NC
Upper Drum	NC
Tubes	NC
Lower Drum	NC
Vent Pipe (pool)	NC
Vent Pipe (drywell + wetwell)	NC
Drain Pipe from Lower Drum to Tee Connection (pool)	NC
Drain Pipe from Tee Connection in Pool to Reactor Pressure Vessel	NB

5.0 PCCS AND ICS INSPECTIONS AND QUALIFICATION

This section defines the nondestructive examination (NDE) and preservice and in-service inspection requirements as they pertain specifically to the welds between the tubes and drums of the ICS and PCCS condensers. Inspection of these welds is described in detail because they are of a unique design and geometry. The other pressure retaining welds are of a more standard design and are assigned standard ASME inspection requirements.

5.1 FABRICATION INSPECTIONS

5.1.1 PCCS

Non-destructive examination for the PCCS is governed by ASME Section III, Subsection NE-5000. Paragraph NE-5200 calls for radiographic examination (RT) for all types of welded joints with the exception of socket welds (which do not apply to the PCCS). However, the requirements of NE-5280 allow for the substitution of ultrasonic (UT) and liquid penetrant (PT) testing in lieu of RT if the joint detail does not permit RT. Because of the close spacing and confined geometry of the tube-to-drum welds, this substitution of UT and PT for RT is considered appropriate.

5.1.2 ICS

Non-destructive examination for the ICS is governed by ASME Section III, Subsection NC-5000. Per NC-5220, radiographic examination is called out for circumferential welded joints; however, these requirements only apply to members that are at least 4.8 mm thick. The ICS will adhere to these rules for conservatism although the tube thickness is only [[ ]].

Like the PCCS, there is a paragraph for special substitutions for RT in which a combination of UT and PT may be used instead (Paragraph NC-5279). This substitution will be credited for the ICS condenser, as its geometry is nearly identical to the PCCS.

5.2 PRE-SERVICE / IN-SERVICE INSPECTIONS

5.2.1 PCCS

The PCCS condenser is a Class MC component that is subject to the requirements of ASME Section XI, Subsection IWE. Because the PCCS resides in a low-pressure low temperature environment, it is not subject to accelerated wear or degradation and therefore does not qualify for augmented visual inspections per the requirements of IWE-1240.

Table IWE-2500-1 defines examination requirements. Item E1.12 calls for "General Visual" inspection of the PCCS condensers. A VT-3 exam is appropriate based on the guidance of Reference 16.

5.2.2 ICS

The ICS condenser is a Class 2 component that is subject to the requirements of ASME Section XI, Subsection IWC. The guidance of paragraph IWC-1221 indicates that the ICS condenser meets the criteria for exemption from surface and volumetric exams due to the [[ ]] diameter of the ICS tubes, per IWC-1221(a)(1). Also, the requirements of IWC-1221(c) indicate that the passive nature of the condenser (statically pressurized, passive with no pumps, safety injection) also meets the exemption criteria. A General Visual inspection requirement with a VT-2 test shall be assigned to the ICS condenser tube welds.

5.3 TUBE BENDS

5.3.1 PCCS

PCCS tubes bent by cold forming shall be annealed after bending. Annealing shall be required. Annealing shall be conducted between 1065°C and 1120°C, followed by a quench to 205°C within 5 minutes. Process includes tube bends + 150 mm on each side. Interior of tubes is purged with a protective atmosphere during the process.

Tube thickness shall be verified post-bending. A qualification sample with smallest bend radius shall be sectioned to confirm wall thickness requirement is met. Tests shall also be performed to qualify the tubes for tensile, yield, and elongation requirements post-bending.

The hardness of XM-19 for PCCS tubes is limited to Rockwell C 30 for the final product.

5.3.2 ICS

Induction bending of ICS tubes shall be qualified based on the bend radius and the diameter.

Tubes shall be UT examined before bending according to the requirements of NB-2551. After bending, tubes shall be PT examined according to NB-2556. Section NB requirements are applied here for conservatism.

Tube thickness shall be verified post-bending. A qualification sample with smallest bend radius shall be sectioned to confirm wall thickness requirement is met. Tests shall also be performed to qualify the tubes for tensile, yield, and elongation requirements post-bending.

5.4 WELD AND WELD FILLER MATERIAL

Appropriate weld filler metal for XM-19 shall be 308L, or ER209. Appropriate weld filler metal for Nb-modified Alloy 600 shall be Nb-modified Alloy 82.

6.0 REFERENCES

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APPENDIX A - SUPERSEDED PCCS STRUCTURAL ANALYSIS

A.1 Description of Model

This Appendix archives the previous configuration of the PCCS that has since been superseded by Appendix B.

A finite element analysis model (FEM) using the approved ANSYS computer code was performed on the PCCS condenser with a supplemental hand calculation. Approved versions of ANSYS are given in ESBWR DCD Tier 2, Table 3D.1-1.

- The FEM models the current geometry of the PCCS condenser and supports described in Figures A-1a, A-1b, and A-2, including all components between the steam inlet passages through the RCCV Top Slab and the condensate drain/vent passages through the RCCV Top Slab.
- The following components of the PCCS condenser were modeled with [[ ]] ANSYS elements:

  [[

  o]]

- The tubes of the PCCS condenser were modeled with [[ ]] ANSYS elements with the following properties:

  [[

-]]

- The [[ ]] of the dynamic steel frame were modeled with [[ ]] ANSYS elements with the following properties:

  [[

  -]]

A.2 Load Definitions

Consideration of the following loads has been taken into account for the PCCS condenser:

- D (+B) Dead Weight (+ Buoyancy)
- P_t Test Pressure
- P_a Design accident pressure generated by a LOCA
- T_t Thermal effects during tests
- T_a Thermal effects generated by a LOCA
- SSE Safe Shutdown Earthquake
- SRVD Safety Relief Valve Discharge
- LOCA Loss of Coolant Accident

A.3 Load Combinations

Enveloping Load Combinations are described in Table A-1.

Table A-1: PCCS Load Combinations

Service Level (elastic analysis)	Load Combination
Test Condition	$D + P_t + T_t$
Design Condition	$D + P_a + T_a$
Levels A, B	$D + P_a + T_a + SRV + LOCA$
Levels C, D	$D + P_a + T_a + SSE + SRV + LOCA$

A.4 Finite Element Model Inputs

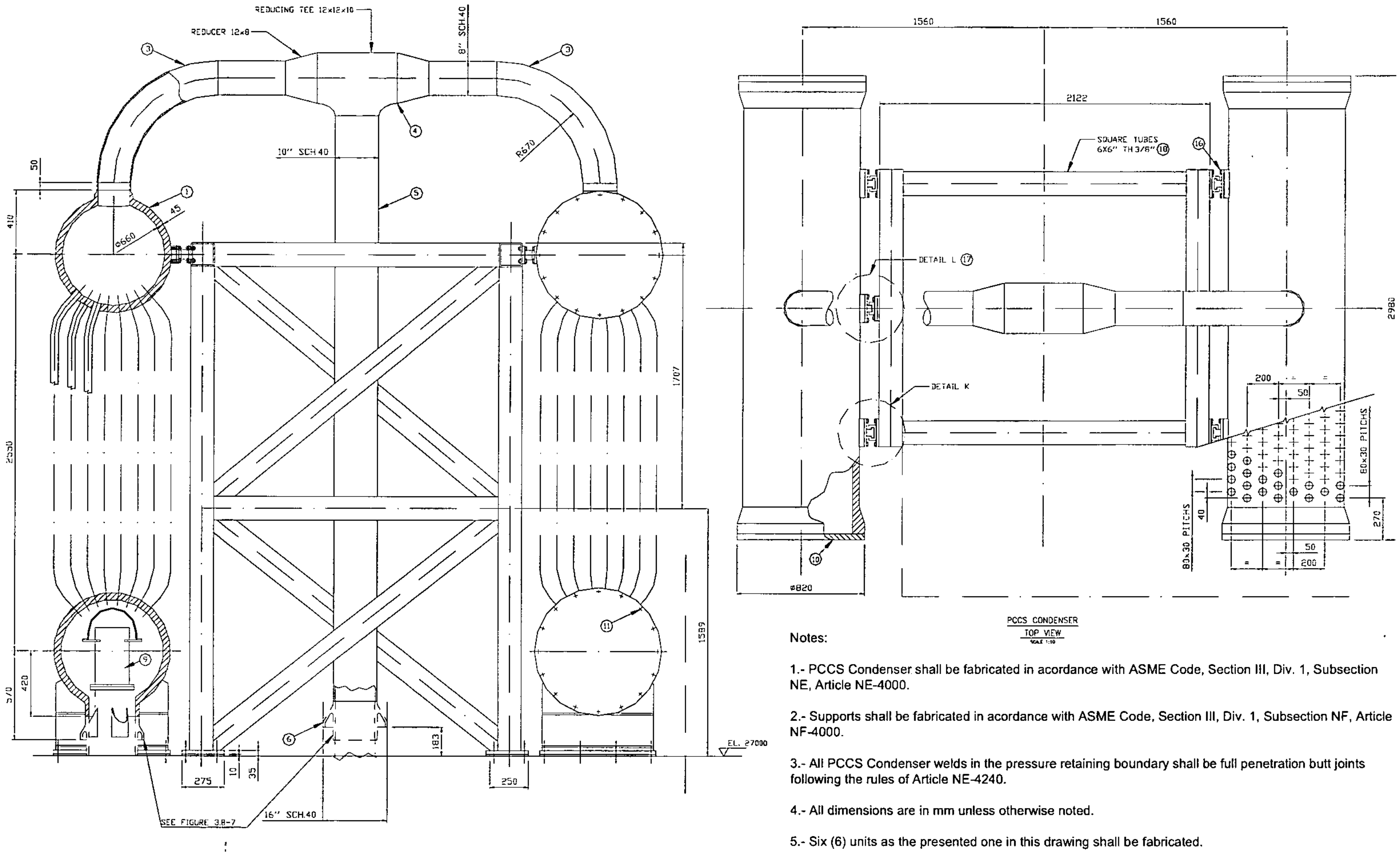
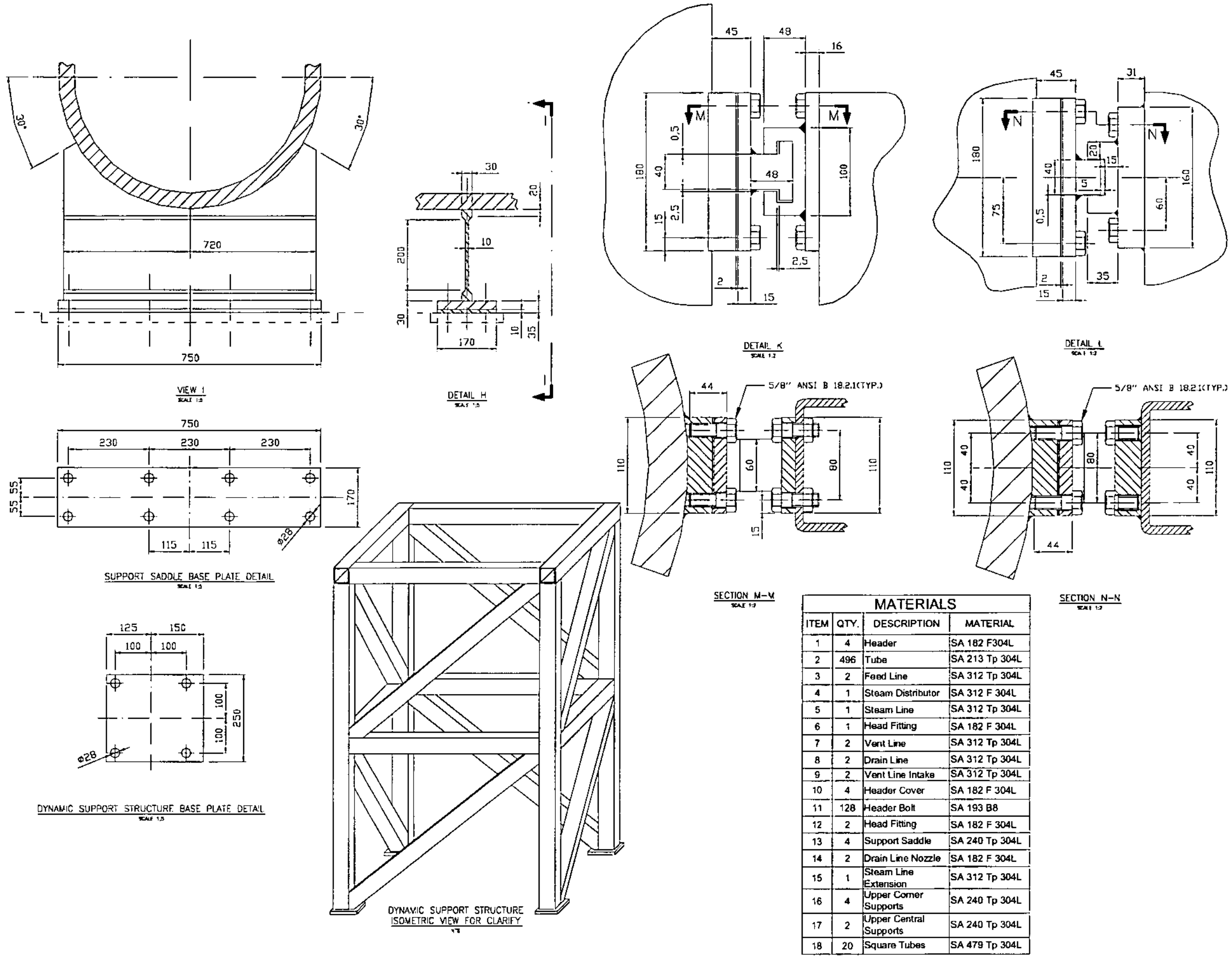


Figure A-1a: PCCS Condenser and Supports



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

Figure A-1b: PCCS Condenser and Supports Details

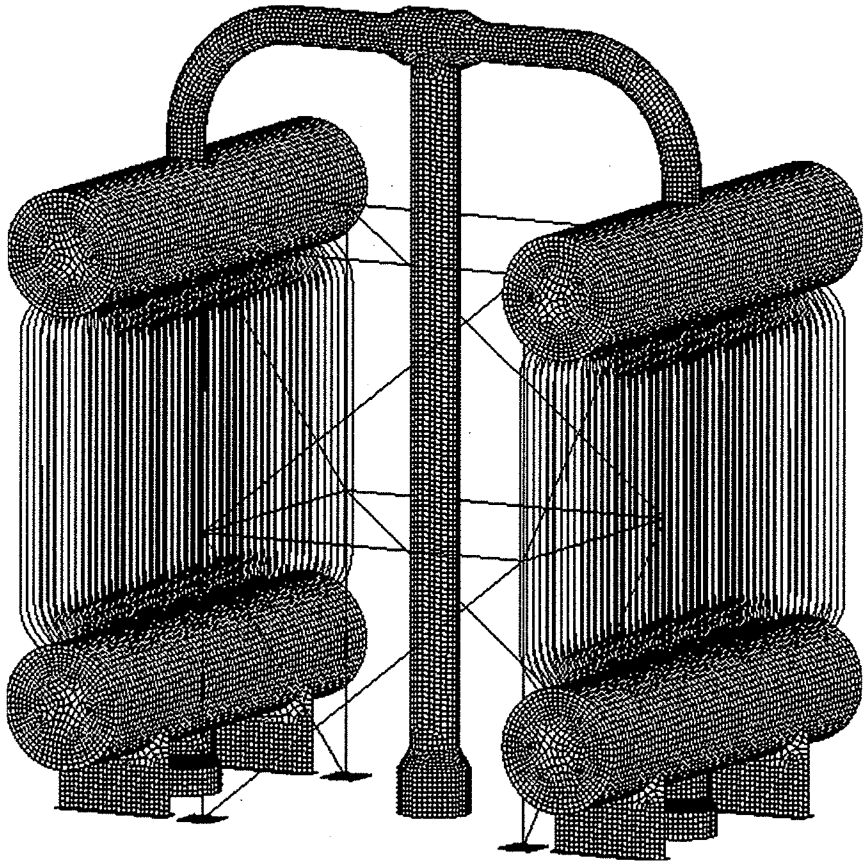


Figure A-2: FEM of PCCS Condenser and Supports

A.5 Stress Results and Margin to Allowable

Table A-2: Stress Summary of the PCCS Condenser and Supports

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

1) Allowable stress values correspond to Level A   2) Allowable stress values correspond to Level C

APPENDIX B - PCCS STRUCTURAL ANALYSIS WITH DETONATION LOADING

B.1 Description of Model

This Appendix summarizes the evaluation of the PCCS for detonation loads based on the revised configuration described in this report. The inputs to the modified analysis are as follows:

B.1.1 Tube Analysis Model

A 3-D finite element model (FEM) for the analysis of one tube under hydrogen detonation load is built with ANSYS 10.0. The forces at the boundary conditions have been defined to equalize the internal pressure. A description of the FEM follows:

- The FEM physically represents the current geometry of [[ ]] tubes and the portion of the headers that join to the tubes.
- The entire model is built with [[ ]] ANSYS elements. The mesh of the tube where the detonation pressure is applied is very refined to get accurate results.
- The detonation load of 19.333 MPa multiplied by the DLF of 2, i.e. 38.7 MPa is applied as internal pressure in one tube and along the tube length, including the hole in the headers.
- Displacement restrictions are applied at the different cut section of the headers as boundary conditions. Boundary conditions far of the analyzed tube, no impact in the results obtained
- Several analysis cases have been executed changing the tube where the detonation occurs, and the maximum resultant stress is not significantly affected.

B.1.2 Lower Header Analysis Model

A 3-D finite element model (FEM) for the analysis of the lower header under hydrogen detonation load is built with ANSYS 10.0. The portion having the condensate nozzle has been selected as the most critical header area. A description of the FEM follows:

- The FEM physically represents the current geometry of a cylindrical section of the lower header, corresponding to a [[12x8{3}]] array of the tube bank, containing the reinforced condensate nozzle and the vertical run up to the anchored flange.
- The entire model is built with [[ ]] ANSYS elements.

- The detonation load of 19.333 MPa multiplied by the DLF of 2, i.e. 38.7 MPa is applied as an internal pressure on the inner face of the header, including the nozzle opening, the drain line and the holes for the tubes. Equivalent edge pressures are applied at the two cut sections of the header to account for the edge effects. Displacement restrictions in the nodes at the sixteen bolt locations are applied.

B.1.3 Global PCCS Condenser Analysis Model

A 3-D finite element model (FEM) for the analysis of the PCCS Condenser and support is built with ANSYS 10.0. A description of the FEM follows:

- The FEM physically represents the revised geometry of the PCCS Condenser and support, including all components between the steam inlet passage through the RCCV Top Slab and the condensate drain/vent passages through the RCCV Top Slab.

- The following components of the PCCS Condenser are modeled with SHELL 63 ANSYS elements: upper headers [[ ]], lower headers [[ ]], upper header covers [[ ]], lower header covers [[150]], steam line [[ ]], feed lines [[ ]], steam distributor [[ ]], steam line sleeve [[ ]], steam line head fitting [[ ]], condensate nozzle [[80]], condensate line sleeve [[34]], support saddle [[ ]], support saddle base plates [[ ]], and steel frame support structure base plates [[ ]].

- The reinforced area of the lower header at the condensate nozzle is conservatively not considered in this global model.

[[

- The 8"x8"x0.5625" square tubes of the steel frame support structure are modeled with BEAM 44 ANSYS elements with the following geometric properties:
    - Area moment of inertia $I_t = 0.59521E\text{-}4\ m^4$.
    - Cross-sectional area $A_t = 0.10258E\text{-}1\ m^2$.
    - Torsional moment of inertia $J = 0.9923E\text{-}4\ m^4$.
    - Extreme fiber distance from the centroid = 101.6 mm.
    - Torsional stress factor $TSF = 1/(8 \cdot 8 \cdot 0.5625 \cdot 0.0254^3) = 1695\ m^{-3}$.
    - Shear area $A_s = 1/2 \cdot A_t = 0.5129E\text{-}2\ m^2$. {3}]]
- The steam line, condensate lines (from the head fittings downwards), and the vent lines, which run inside condensate lines, are not included in the model, since they do not have any structural influence in the PCCS Condenser behavior.
- The internal and external water masses are introduced in the model by increasing the material density. All components of the PCCS Condenser are cylindrical form. All members of the steel frame support structure are square tubes.
- Displacement restrictions are applied as boundary conditions at the bolt point locations of the base plates and at sixteen nodes in each lower section of the line sleeves through the RCCV Top Slab.
- In the node corresponding to the upper support location, the appropriate directional coupling is applied between the upper headers and the steel frame support structure.
- The coordinate system adopted in the FEM is the right hand Cartesian coordinate system. Direction X of the FEM follows the Y-direction (E-W) of the plant, direction Y of the FEM follows the X-direction (N-S) of the plant, and direction Z of the FEM coincides with Z-direction (vertical).

B.2 Load Definitions

Consideration of the following loads has been taken into account for the PCCS condenser:

- D (+B) Deadweight (+ Buoyancy)
- P_t Test pressure
- P_a Design accident pressure generated by a LOCA
- T_t Thermal effects during tests
- T_a Thermal effects generated by a LOCA
- SSE Safe Shutdown Earthquake
- SRVD Safety Relief Valve Discharge
- LOCA Loss of Coolant Accident
- DET Detonation pressure load

B.3 Load Combinations

Enveloping Load Combinations are described in Table B-1.

Detonation loads determined in the Tube Submodel and Lower Drum Submodel are combined with other loads (calculated from the Global PCCS Condenser Model) as a direct summation of maximum stresses.

Table B-1: Modified PCCS Load Combinations

Service Level (elastic analysis)	Load Combination*
Test Condition	$D + P_t + T_t$
Design Condition	$D + P_a + T_a$ **
Levels A, B	$D + P_a + T_a + SRV + LOCA$ **
Level C-1	$D + P_a + T_a + SSE + SRV + LOCA$ **
Level C-2	$D + DET + T_a + SSE$

* Live loads (L) are not significant loads for the equipment considered in this analysis.

** Pipe reactions (R_a) will be minimized during detailed design, by considering mitigating factors such as pipe flexibility and reduced pipe size in the pipe routing. Also, there are large margins to the allowable for cases where pipe reactions contribute to the calculated stress.

B.4 Finite Element Model Inputs

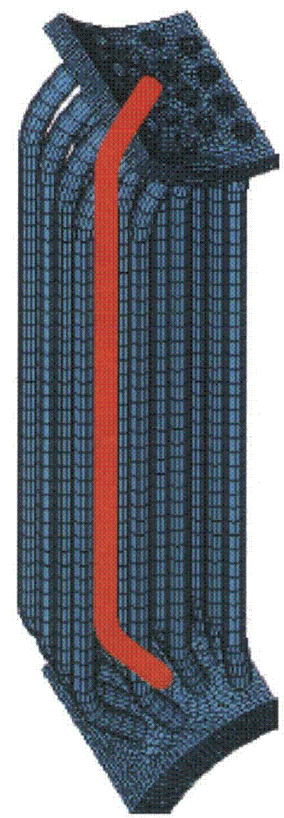


Figure B-1a: Tube FEM of and Pressure Load

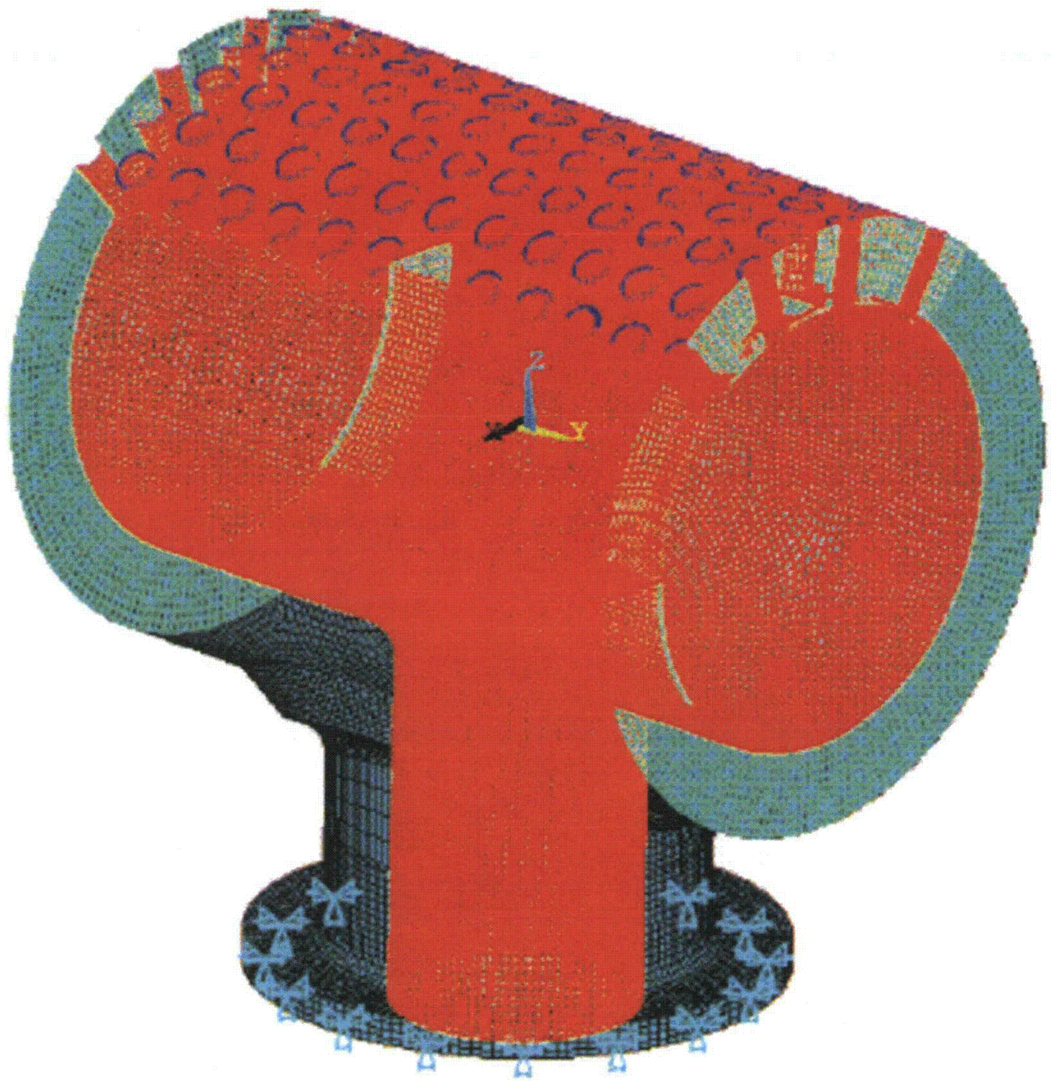


Figure B-1b: Lower Header FEM and Pressure Load

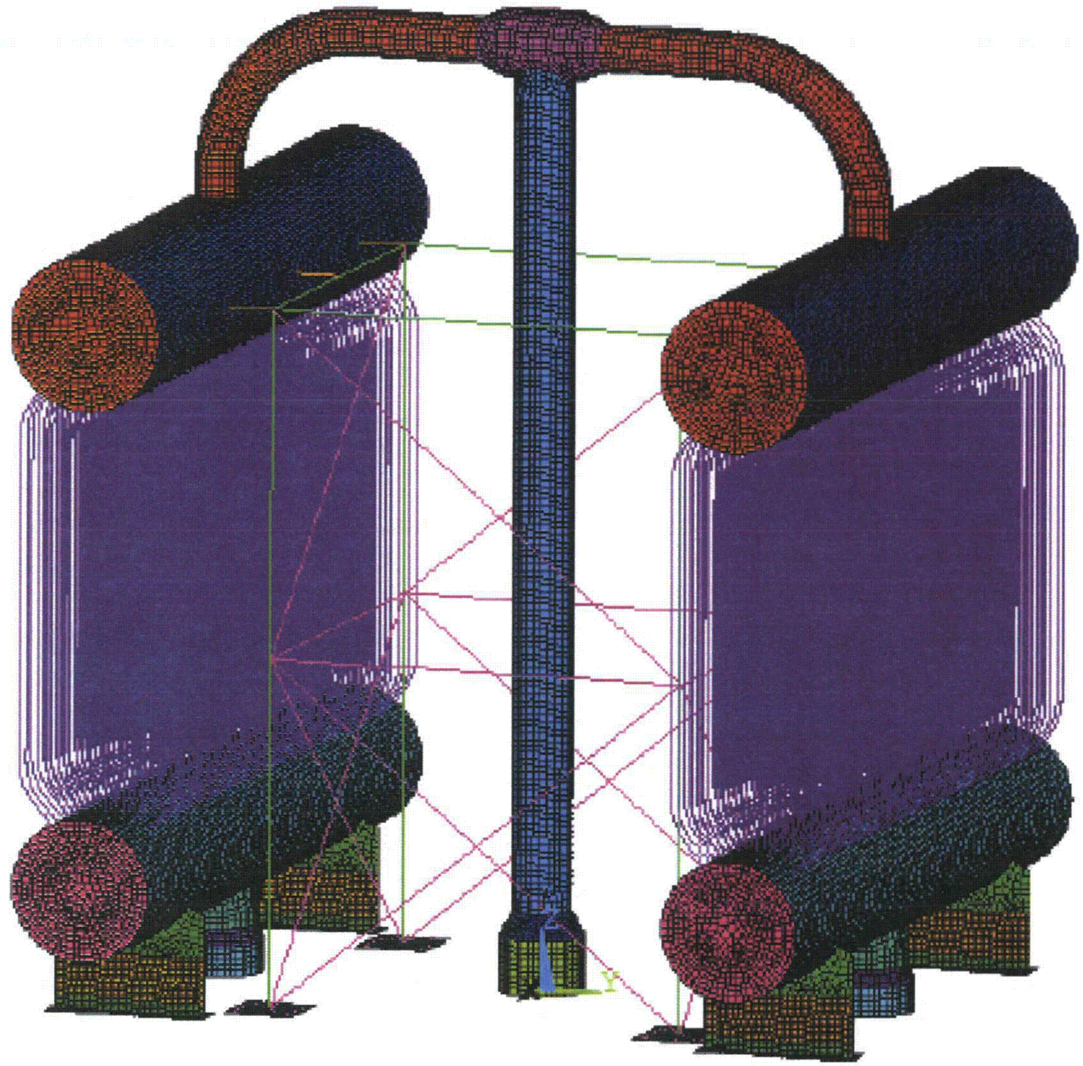
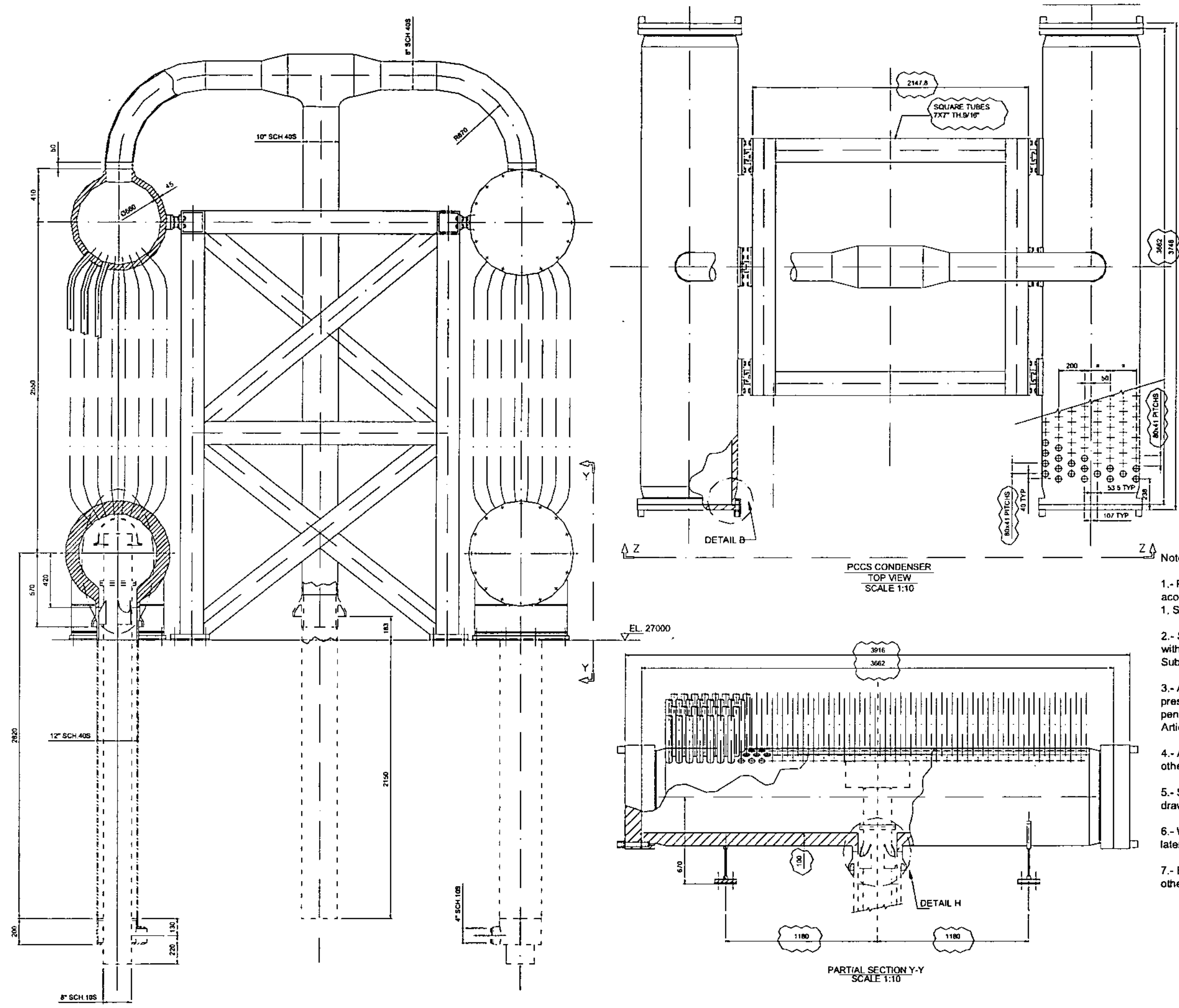


Figure B-1c: PCCS Condenser FEM



Notes:

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

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

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

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

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

6.- Welds for upper supports to be defined later.

7.- Embedded anchor bolts to be defined by others.

Figure B-2a: PCCS Condenser and Supports Details

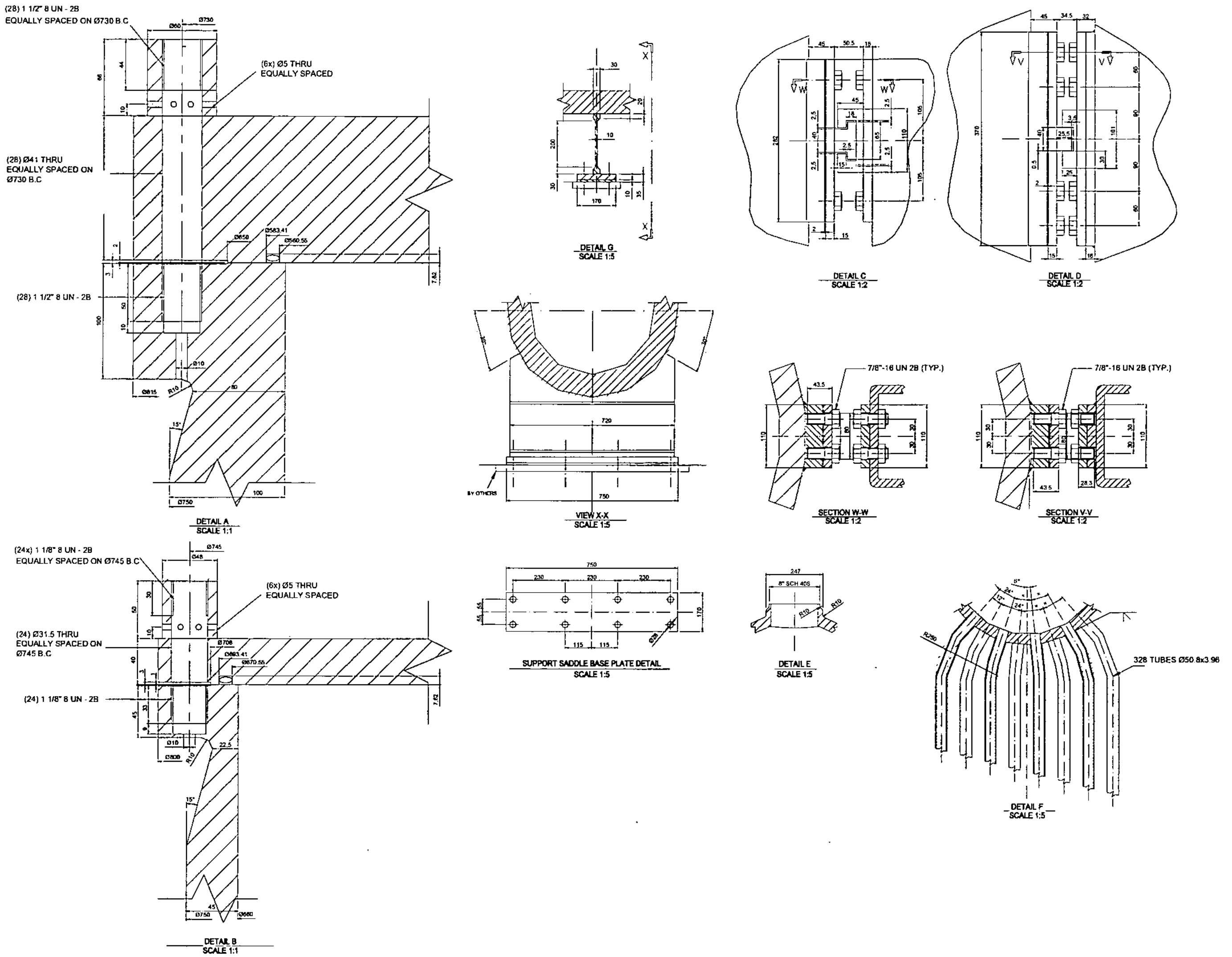


Figure B-2b: FEM of PCCS Condenser and Supports

B.5 Stress Results and Margin to Allowable

Table B-2a: Stress Summary of the PCCS Condenser and Supports

Component	Stress Category	Test			Design			Service Level A/B		
		Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)
Upper Header	P_m	11.1	119.8	90.7	11.1	114.9	90.3	13.7	114.9	88.1
	$P_L + P_b$	11.1	183.7	94.0	11.1	150.6	92.6	14.6	150.6	90.3
Lower Header (ligaments)	P_m	4.4	262.9	98.3	4.4	201.3	97.8	5.5	201.3	97.3
	$P_L + P_b$	4.4	403.1	98.9	4.4	263.7	98.3	5.7	263.7	97.8
Lower Header (drain nozzle)	P_m	4.4	262.9	98.3	4.4	201.3	97.8	5.5	201.3	97.3
	$P_L + P_b$	4.4	403.1	98.9	4.4	263.7	98.3	5.7	263.7	97.8
Tubes	P_m	4.6	262.9	98.3	4.6	201.3	97.7	4.9	201.3	97.6
	$P_L + P_b$	4.6	403.1	98.9	4.6	263.7	98.3	7.2	263.7	97.3
Feed Line	P_m	9.9	119.8	91.7	9.9	114.9	91.4	15.7	114.9	86.3
	$P_L + P_b$	9.9	183.7	94.6	9.9	150.6	93.4	18.2	150.6	87.9
Steam line	P_m	10.9	119.8	90.9	10.9	114.9	90.5	13.2	114.9	88.5
	$P_L + P_b$	10.9	183.7	94.1	10.9	150.6	92.8	14.9	150.6	91.0
Steam Distributor	P_m	12.6	119.8	89.5	12.6	114.9	89.0	15.1	114.9	86.9
	$P_L + P_b$	12.6	183.7	93.1	12.6	150.6	91.6	16.1	150.6	89.3
Condensate Lines	P_m	12.6	119.8	89.5	12.6	114.9	89.0	16.9	114.9	85.3
	$P_L + P_b$	12.6	183.7	93.1	12.6	150.6	91.6	16.9	150.6	88.8
Upper Header Cover	P_m	55.3	119.8	53.8	55.3	114.9	51.9	55.5	114.9	51.7
	$P_L + P_b$	55.3	183.7	69.9	55.3	150.6	63.3	55.5	150.6	63.1
Lower Header Cover	P_m	3.9	262.9	98.5	3.9	201.3	98.1	4.0	201.3	98.0
	$P_L + P_b$	3.9	403.1	99.0	3.9	263.7	98.5	4.0	263.7	98.5
Upper Header Bolt	Average Stress	25.7	144.7	82.2	25.7	110.1	76.7	25.7	220.2	88.3
Lower Header Bolt	Average Stress	8.3	570.7	98.5	8.3	212.3	96.1	8.3	424.6	98.0
Support Saddle	P_m	Negligible						5.4	112.6	95.2
	$P_L + P_b$							5.4	168.9	96.8
	Shear							1.1	67.6	98.4
Steel Frame Support Structure	Tension							2.7	76.6	96.5
	Shear							0.6	51.1	98.8
	Compression							2.7	47.9	94.4
	Bending							2.8	84.3	96.7

Table B-2b: Stress Summary of the PCCS Condenser and Supports

Component	Stress Category	Service Level C-1			Service Level C-2		
		Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)	Calculated Stress (MPa)	Allowable Stress (MPa)	Stress Margin (%)
Upper Header	P_m	52.8	137.9	61.7	41.6	137.9	69.8
	$P_L + P_b$	64.8	180.7	64.1	53.5	180.7	70.4
Lower Header (ligaments)	P_m	16.4	291.4	94.4	271.9	291.4	6.7
	$P_L + P_b$	18.5	437.1	95.8	326.0	437.1	25.4
Lower Header (drain nozzle)	P_m	16.4	291.4	94.4	202.9	291.4	30.4
	$P_L + P_b$	18.5	421.3	95.6	383.0	421.3	9.1
Tubes	P_m	7.4	291.4	97.5	274.8	291.4	5.7
	$P_L + P_b$	42.1	381.7	89.0	309.3	381.7	19.0
Feed Line	P_m	100.9	137.9	26.8	90.8	137.9	34.2
	$P_L + P_b$	139.9	180.7	22.6	130.0	180.7	28.1
Steam line	P_m	43.1	137.9	68.7	32.1	137.9	76.7
	$P_L + P_b$	45.7	180.7	74.7	34.7	180.7	80.8
Steam Distributor	P_m	47.1	137.9	65.8	34.5	137.9	75.0
	$P_L + P_b$	66.5	180.7	63.2	53.8	180.7	70.2
Condensate Lines	P_m	65.5	137.9	52.5	136.7	137.9	0.9
	$P_L + P_b$	65.9	180.7	63.5	53.2	180.7	70.6
Upper Header Cover	P_m	58.1	114.9	49.4	2.8	114.9	97.6
	$P_L + P_b$	58.4	180.7	67.7	3.1	180.7	98.3
Lower Header Cover	P_m	4.4	201.3	97.8	200.1	201.3	0.6
	$P_L + P_b$	4.5	381.7	98.8	200.2	381.7	47.6
Upper Header Bolt	Average Stress	25.7	220.2	88.3	0.1	220.2	100.0
Lower Header Bolt	Average Stress	8.3	424.6	98.0	423.0	424.6	0.4
Support Saddle	P_m	53.3	168.9	68.4	53.1	168.9	68.6
	$P_L + P_b$	53.4	253.4	78.9	53.2	253.4	79.0
	Shear	11.1	101.3	89.0	11.0	101.3	89.1
Steel Frame Support Structure	Tension	41.5	131.0	68.3	82.8	131.0	36.8
	Shear	9.5	87.3	89.1	18.8	87.3	78.5
	Compression	41.5	83.6	50.4	82.8	83.6	1.0
	Bending	44.5	144.1	69.1	88.8	144.1	38.4

Table B-3a: PCCS Condenser Top Slab Penetration Anchor Bolt Dynamic Reactions

	Steam Line Reaction (per bolt)		**Condensate Line Reaction (per bolt)**	
Service Level	Tension (kN)	Shear (kN)	Tension (kN)	Shear (kN)
A/B	0.7	0.1	3.2	1.0
C-1	11	0.9	40	16
C-2	22	1.8	80	32

Table B-3b: PCCS Condenser Top Slab Penetration Anchor Bolt Thermal Reactions

	Steam Line Reaction (per bolt)		**Condensate Line Reaction (per bolt)**	
Service Level	Tension (kN)	Shear (kN)	Tension (kN)	Shear (kN)
Design A/B/C/D	1.6	31	73	114

Table B-4a: PCCS Condenser Support Base Plate Anchor Bolt Dynamic Reactions

	Steel Frame Support Structure Reaction (per bolt)		**Support Saddle Reaction (per bolt)**	
Service Level	Tension (kN)	Shear (kN)	Tension (kN)	Shear (kN)
A/B	13	6	3.0	0.5
C-1	194	81	26	5
C-2	388	162	52	10

Table B-4b: PCCS Condenser Support Base Plate Anchor Bolt Thermal Reactions

	Steel Frame Support Structure Reaction (per bolt)		**Support Saddle Reaction (per bolt)**	
Service Level	Tension (kN)	Shear (kN)	Tension (kN)	Shear (kN)
Design A/B/C/D	-	-	55	-

B.6 Conclusions on Service Level C Allowable

The results tabulated in Tables B-2a and B-2b indicate that the PCCS condenser seismic and hydrodynamic loads fall within the allowables, and the detonation load meets the allowables for a Service Level C.

B.7 Fatigue

The alternating stress was calculated for the most limiting components of the PCCS condenser. The resulting number of allowable cycles is tabulated in Table B-5 below:

Table B-5: PCCS Condenser Fatigue Assessment

Component	DET Stress (MPa)	SSE Stress (MPa)	Ta Stress (MPa)	Total Stress (MPa)	Alternate Stress (MPa)	Allowed cycles
Tubes	272.0	37.3	46.3	355.6	177.8	$>10^6$
Lower Header	513.0	14.0	50.7	577.7	288.9	$8 \cdot 10^4$
Lower Header Cover	199.6	0.6	0.8	201.0	100.5	$4 \cdot 10^7$
Lower Header Cover Bolt	423	~0	~0	423x4[(3)]= 1692	846	500

The most limiting components in this table, with only 500 allowable cycles, are the bolts on the lower header.

APPENDIX C - ANCHOR BOLT REACTIONS DUE TO DETONATION

Later

Enclosure 6

MFN 10-044 Supplement 1 Revision 1

Revised Response (Revision 1) 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 NEDO-33251 Revision 2, "ESBWR I&C Diversity and Defense-In-Depth Report," May 2009

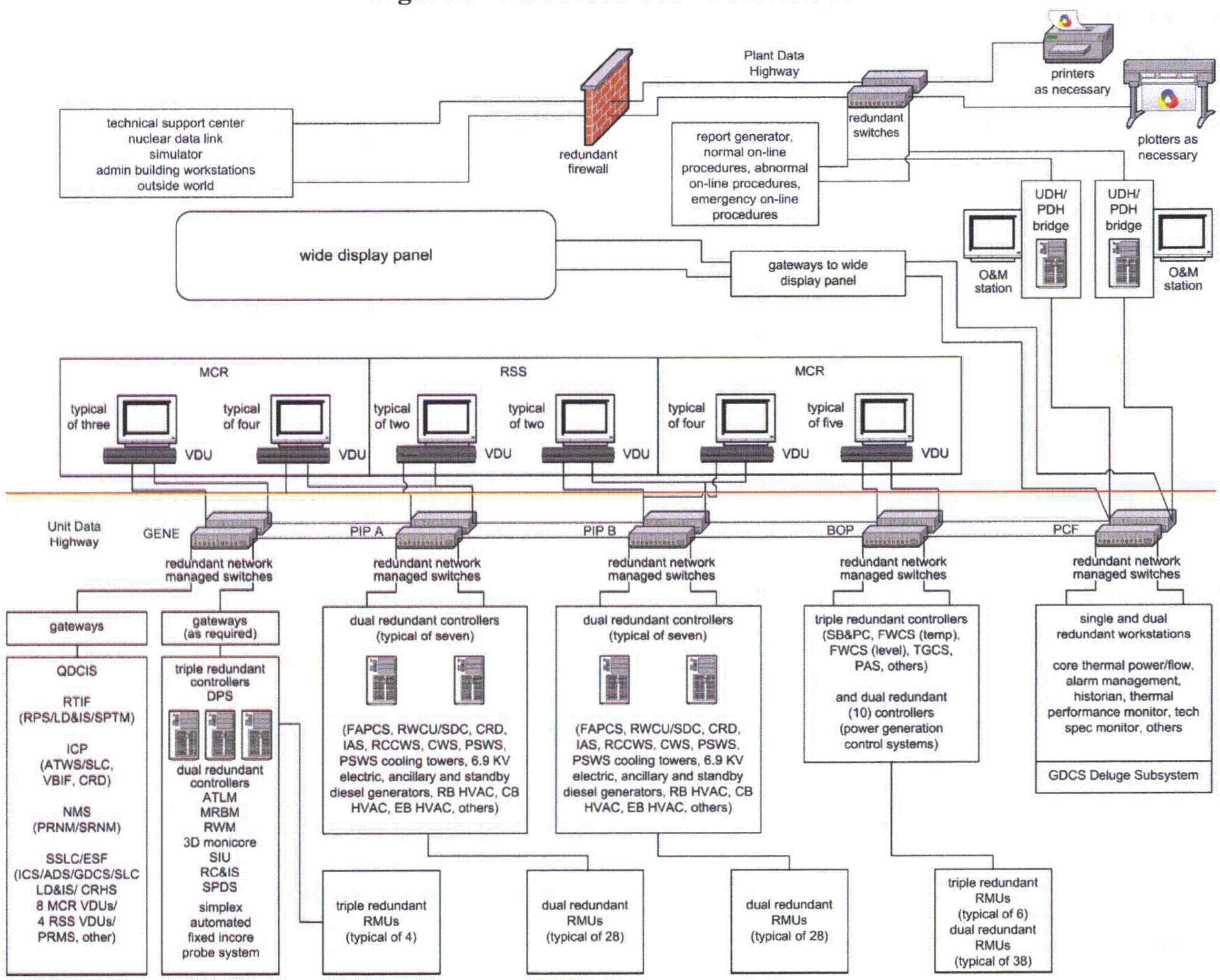
ACRONYMS AND ABBREVIATIONS

GDCS	Gravity-Driven Cooling System
GDS	Gated Diode Switch
HCU	Hydraulic Control Unit
HFE	Human Factors Engineering
HMI	Human-Machine Interface
HP CRD	High Pressure Control Rod Drive (or Control Rod Drive high pressure makeup water injection)
HSI	Human-System Interface
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation & Control
IAS	Instrument Air System
IC	Isolation Condenser
ICP	Independent Control Platform
ICS	Isolation Condenser System
IDIF	ICS DPV Isolation Function
IEEE	Institute of Electrical and Electronics Engineers
INOP	Inoperable
kV	Kilovolt (1000 volts)
LD&IS	Leak Detection and Isolation System
LFCV	Low Flow Control Valve
LOCA	Loss-of-Coolant-Accident
LPRM	Local Power Range Monitor
LTR	Licensing Topical Report
Deleted	Deleted
MCR	Main Control Room
MRBM	Multi-Channel Rod Block Monitor
MSIV	Main Steam Isolation Valve

- Safety-related Reactor Trip and Isolation Function (RTIF) cabinets. These cabinets include the fail-safe logic for the following systems and functions (in four redundant divisions):
  - Reactor Protection System (RPS),
  - (Nuclear Boiler System (NBS)) Main steam isolation valve (MSIV) and drain valve logic and MSIV and drain valve isolation functions of the Leak Detection and Isolation System (LD&IS)
  - Suppression Pool Temperature Monitoring (SPTM) function of the Containment Monitoring System (CMS) – a process sensing function supporting RPS.
- Safety-related Neutron Monitoring System (NMS), including APRM, LPRM and Startup Range Neutron Monitor (SRNM) functions (four redundant divisions)
- Safety-related Independent Control Platform (ICP) - this functional group of fail-as-is logic consists of chassis that are physically located in the RTIF cabinets (four redundant divisions):
  - Anticipated Transient Without Scram/Standby Liquid Control System (ATWS/SLC) functions (includes ATWS mitigation logic processors and SLC system control logic processors),
  - Vacuum Breaker Isolation Function (VBIF) of the Containment System, ~~and~~
  - HP CRD Isolation Bypass function~~.~~, and
  - ICS DPV isolation function

  Space consideration may dictate locating the ICP hardware in separate cabinets.
- Safety System Logic and Control (SSLC)/ESF which provides safety-related fail-as-is ESF logic. Emergency Core Cooling System (ECCS) functions (four redundant divisions) which includes:
  - Isolation Condenser System (ICS) functions,
  - Automatic Depressurization System (ADS) functions of the NBS,
  - Gravity-Driven Cooling System (GDCS) functions, and
  - Standby Liquid Control (SLC) System functions, and
  - LD&IS functions (non-MSIV),
  - Control Room Habitability System (CRHS) functions,
  - Containment Monitoring System (CMS) functions, and
  - Safety-related information systems.
  - The Process Radiation Monitoring System provides process-sensing inputs to the LD&IS and CRHS to support the isolation functions.
- Nonsafety-related nuclear systems of the N-DCIS that are divided into the following network segments
  - GENE systems (including DPS)

Figure 1 ESBWR DCIS Architecture



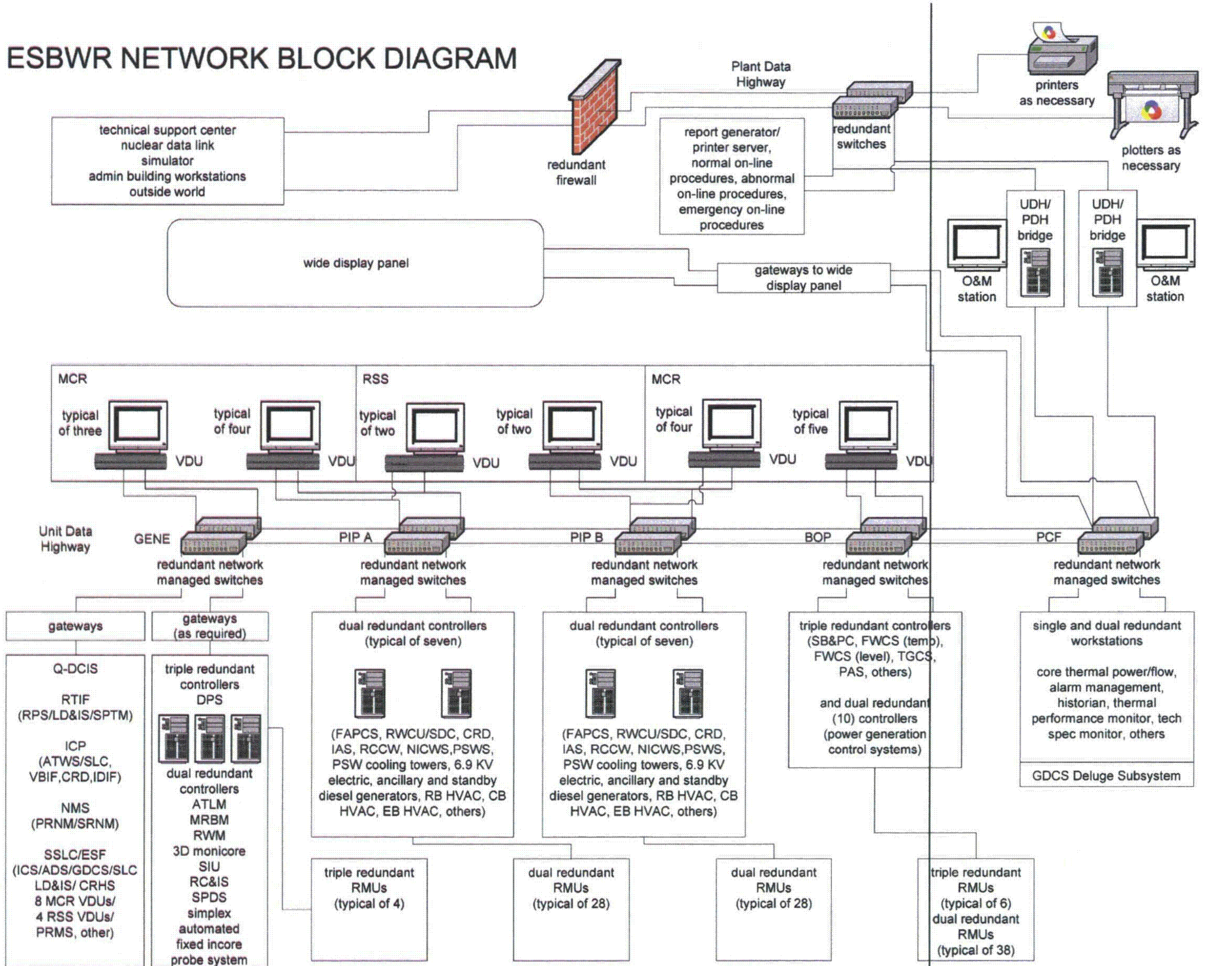
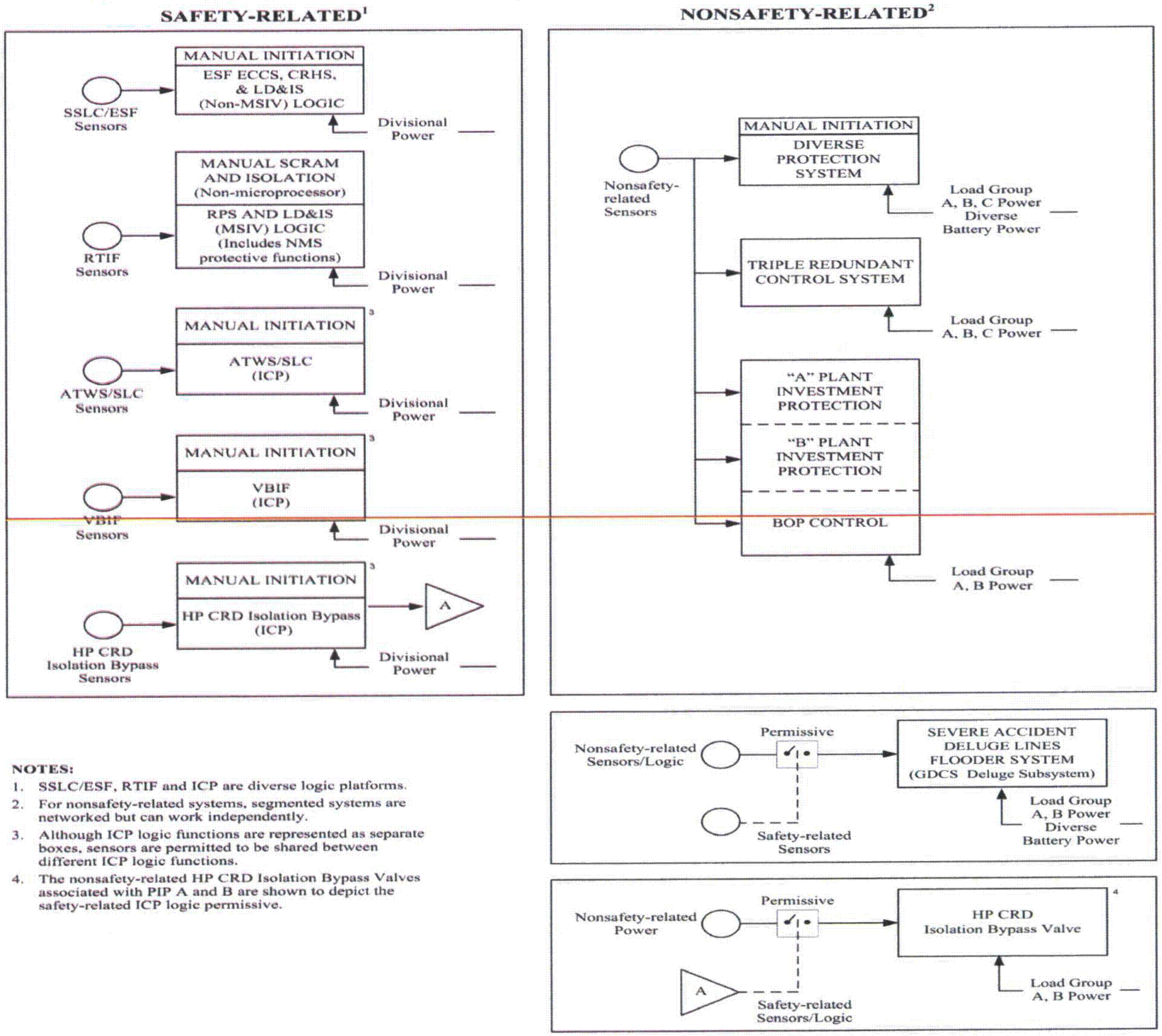
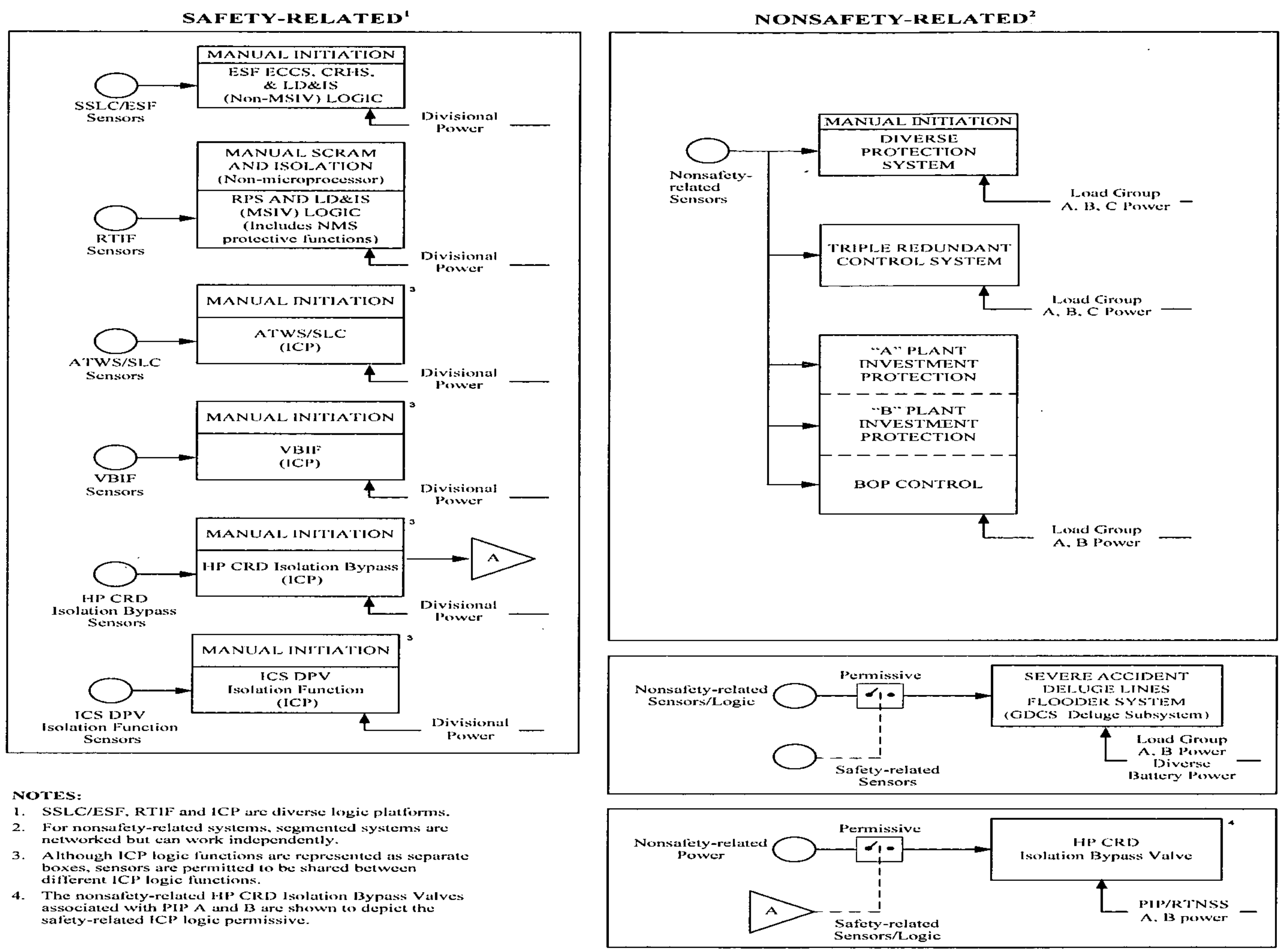

ESBWR NETWORK BLOCK DIAGRAM
technical support center
nuclear data link
simulator
admin building workstations
outside world
redundant firewall
Plant Data Highway
report generator/ printer server, normal on-line procedures, abnormal on-line procedures, emergency on-line procedures
redundant switches
printers as necessary
plotters as necessary
UDH/ PDH bridge
UDH/ PDH bridge
O&M station
O&M station
wide display panel
gateways to wide display panel
MCR
RSS
MCR
typical of three
typical of four
typical of two
typical of two
typical of four
typical of five
VDU
Unit Data Highway
GENE
PIP A
PIP B
BOP
PCF
redundant network managed switches
gateways
gateways (as required)
Q-DCIS
RTIF (RPS/LD&IS/SPTM)
ICP (ATWS/SLC, VBIF,CRD,IDIF)
NMS (PRNM/SRNM)
SSLC/ESF (ICS/ADS/GDCS/SLC LD&IS/ CRHS 8 MCR VDUs/ 4 RSS VDUs/ PRMS, other)
triple redundant controllers DPS
dual redundant controllers ATLM MRBM RWM 3D monicore SIU RC&IS SPDS simplex automated fixed incore probe system
dual redundant controllers (typical of seven)
(FAPCS, RWCU/SDC, CRD, IAS, RCCW, NICWS,PSWS, PSW cooling towers, 6.9 KV electric, ancillary and standby diesel generators, RB HVAC, CB HVAC, EB HVAC, others)
dual redundant controllers (typical of seven)
(FAPCS, RWCU/SDC, CRD, IAS, RCCW, NICWS,PSWS, PSW cooling towers, 6.9 KV electric, ancillary and standby diesel generators, RB HVAC, CB HVAC, EB HVAC, others)
triple redundant controllers (SB&PC, FWCS (temp), FWCS (level), TGCS, PAS, others)
and dual redundant (10) controllers (power generation control systems)
single and dual redundant workstations
core thermal power/flow, alarm management, historian, thermal performance monitor, tech spec monitor, others
GDCS Deluge Subsystem
triple redundant RMUs (typical of 4)
dual redundant RMUs (typical of 28)
dual redundant RMUs (typical of 28)
triple redundant RMUs (typical of 6) dual redundant RMUs (typical of 38)

Figure 3 ESBWR Logic Platform and Power Diversity



NOTES:

1. SSLC/ESF, RTIF and ICP are diverse logic platforms.
2. For nonsafety-related systems, segmented systems are networked but can work independently.
3. Although ICP logic functions are represented as separate boxes, sensors are permitted to be shared between different ICP logic functions.
4. The nonsafety-related HP CRD Isolation Bypass Valves associated with PIP A and B are shown to depict the safety-related ICP logic permissive.



NOTES:
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3. Although ICP logic functions are represented as separate boxes, sensors are permitted to be shared between different ICP logic functions.
4. The nonsafety-related HP CRD Isolation Bypass Valves associated with PIP A and B are shown to depict the safety-related ICP logic permissive.

Figure 4 Main Control Room Layout - Typical

2.2 SAFETY-RELATED DISTRIBUTED CONTROL AND INFORMATION SYSTEM OVERVIEW

The Q-DCIS consists of the RTIF–NMS logic platform, the ICP and the SSLC/ESF logic platform. These systems and their associated sensors are organized into four divisions; the VDUs associated with each division provide for the control of the safety-related ESF equipment and additionally provide the necessary monitoring of the plant safety-related functions during and following an accident as required by Regulatory Guide (RG) 1.97 (Reference 6-13). The two-out-of-four logic associated with the RTIF-NMS logic platform, ICP and SSLC/ESF logic platform and the unique nature of the ESBWR solenoid and squib actuators allow the plant to be designed as "N-2"; specifically, any two divisions can accomplish the safety-related trip and ESF functions. N-2 is a significant element of the defense-in-depth design of the ESBWR DCIS.

The general relationship of the Q-DCIS is shown in Figure 6. (There are also nonsafety-related functions of NMS that are part of the N-DCIS.) The RTIF logic processors are located in the RTIF cabinet (one per division in separate Q-DCIS rooms) that combines the RPS, LD&IS (for MSIVs and drains only), SPTM, VBIF, HP CRD Isolation Bypass Function ~~and~~, ATWS/SLC functions, and ICS DPV isolation function. Although all equipment located in the RTIF cabinet is appropriate to the division and everything in the cabinet is powered by the appropriate divisional uninterruptible and battery power, the VBIF, HP CRD Isolation Bypass ~~and~~, ATWS/SLC functions, and ICS DPV isolation function (which are part of the ICP) are segregated to separate chassis from the remaining RTIF logic processors and from one another. The ICP (i.e., VBIF, HP CRD Isolation Bypass ~~and~~, ATWS/SLC, and ICS DPV isolation) is diverse from the RTIF-NMS and SSLC/ESF logic platforms. All of the safety-related functions are implemented in hardware/software platforms diverse from the DPS.

The ESBWR RPS design has several important differences from other Boiling Water Reactor (BWR) scram logic and hardware (although many of these features were included in the ABWR design); these include:

- Per parameter trip (specifically there must be (for example) two un-bypassed level trips to scram, a pressure trip and a level trip will not cause a scram).
- No operator manipulation of the division of sensors and/or division of logic bypass, nor any operation of the RPS back panel inoperable switches can reduce scram logic redundancy to less than "any two un-bypassed same parameters in trip will cause a scram". Only one division at a time can be physically bypassed. The RPS (and MSIV LD&IS) is N-2 to scram/isolate.
- Communication with the nonsafety-related DCIS is one-way (Q-DCIS to N-DCIS) through fiber; the loss of this communication does not affect RPS functionality.
- Communication with other RPS divisions is one-way, fiber isolated, and does not mix divisional data.
- All signals are actively transported such that "fail safe" is not a "1" or a "0" but rather "trip on loss of communication". As a result, loss of communication from another division is interpreted as a trip signal (unless that division is bypassed) and loss of communication with a bypass joystick switch is interpreted as "no bypass".

- RPS (and Q-DCIS) logic is powered by divisional redundant (uninterruptible 120V AC) power supplies that are backed by redundant batteries; additionally, the systems are backed up by offsite power and either of the two diesel generators.
- The CRD Hydraulic Control Unit (HCU) scram solenoid power is local to the Reactor Building (RB) and switched by fiber driven two-out-of-four logic from the RPS logic processors (located in the RTIF cabinet in the Control Building (CB)). This avoids the long distance voltage drops to the solenoids in the older BWR designs and eliminates (along with using monitored, safety-related inverters for solenoid power) the need for Electric Protection Assemblies. Loss of communication from the CB RTIF cabinets is interpreted as a trip.
- The hardware, software and solenoid switching for the RPS are diverse from the DPS.

The ICP provides a safety-related platform that is diverse from the RTIF-NMS and SSLC/ESF platforms. The ICP implements the following ESF, diverse reactor shutdown, ATWS mitigation, and beyond design basis event mitigation functions (Reference 6-3 provides additional details on the ICP).

- <u>ATWS/SLC</u> – Certain ATWS mitigation functions are implemented as safety-related logic. The ATWS mitigation logic processors provide SLC initiation and feedwater runback signals, as well as ADS Inhibit logic that inhibits the sustained RPV Level 1, sustained drywell pressure high, and drywell pressure high-high initiation logic within the SSLC/ESF platform. SLC logic processors provide SLC system actuation and accumulator isolation functions in support of ATWS mitigation, diverse reactor shutdown, and ECCS operation. Isolation of the respective SLC accumulators on low accumulator level prevents nitrogen intrusion into containment to preclude a containment integrity or safety-related cooling system challenge.
- <u>VBIF</u> –To isolate a leak from (or failure of) any of the three Wetwell to Drywell vacuum breakers, the vacuum breaker isolation valve logic provides the backup means of isolating the Wetwell from the Drywell. The Vacuum Breaker Isolation valves provide a diverse means of system isolation to the mechanical vacuum breakers and are not required to mitigate a CCF of the RTIF-NMS or SSLC/ESF platforms.
- <u>Control Rod Drive high pressure makeup water injection (HP CRD) Isolation Bypass function</u> – HP CRD flow to the RPV is isolated by SSLC/ESF logic during accidents that could challenge peak containment pressure. As part of beyond design basis scenarios where injection of the GDCS pool inventory is not successful, HP CRD isolation is bypassed automatically by ICP logic to provide additional coolant inventory.
- <u>ICS DPV isolation function – To automatically close the ICS steam admission valves upon opening of any two DPVs. Closing the ICS steam admission valves when the RPV is depressurized mitigates the accumulation of radiolytic hydrogen and oxygen.</u>

The SSLC/ESF DCIS is implemented on a hardware/software platform that is a sub system of the Q-DCIS. The SSLC/ESF hardware/software platform is diverse from RTIF-NMS, ICP and the DPS. SSLC/ESF has a separate set of sensors from RTIF-NMS and ICP, and a diverse set of sensors from DPS. Since it is highly desirable to avoid the consequences of inadvertent actuation of ECCS (specifically automatic depressurization) and also important to reliably actuate ECCS

- PCCS Ventilation Fans
- Drywell Cooling, and
- RB, Fuel Building (FB), Control Building (CB), Switchgear Building Heating Ventilation and Air Conditioning (HVAC).

The PIP systems are organized mechanically into two trains (i.e., pump "A" and pump "B") with each train powered by a different diesel generator and 6.9 KV bus. The two trains are controlled by a deliberately segmented N-DCIS, so that the RMUs, control processors and displays that operate PIP A systems are separate from those operating PIP B systems. The segmentation is implemented using managed network switches; approximately one third of the nonsafety-related control room displays are assigned to the PIP A and the PIP B switches. Normally any control room nonsafety-related display can control/monitor any PIP or BOP system but the loss of either PIP system DCIS or the BOP DCIS will not affect the operation of the remaining PIP system or its displays.

The BOP control systems are those used principally for power generation and are not normally used for shutting down the plant, nor monitoring the more important plant parameters. They specifically include the triple redundant systems used to control the turbine, reactor pressure, RPV water level and plant automation and dual redundant systems, such as, the RC&IS, hotwell level control and condensate polishing systems.

The above systems provide margins to plant safety-related limits and improve the plant's transient performance. The systems also maintain the plant conditions within operating limits. The BOP functions can also be used to shut down the plant and are also part of the ESBWR defense-in-depth automatic and manual functions.

The PCF of N-DCIS redundantly provides for the plant AMS, some of the rod blocks for the Rod Control and Information System (RC&IS), the monitoring of thermal limits including core thermal power and flow calculation and calculation of calibration information for NMS and the isolated safety-related parameter display functions. The PCF of N-DCIS provides information to and receives demands from the nonsafety-related VDUs. The N-DCIS also provides for the acquisition and display of sensor outputs for nonsafety-related plant monitoring functions.

The N-DCIS supports the Severe Accident Deluge Lines Flooder System using diverse hardware and software and separate sensors from both the safety-related and nonsafety-related DCIS systems. The Deluge Lines Flooder System uses squib valves to drain GDCS pool water underneath the RPV should all other core cooling and shutdown systems fail. The valves are actuated by sensed containment floor high temperatures attributable to the postulated core and vessel melt.

2.4 DIVERSE PROTECTION SYSTEM OVERVIEW

The DPS is a triple redundant, nonsafety-related system that provides an alternate means of initiating a reactor trip, actuating selected Engineered Safety Features and providing plant information to the operator. The relationship is shown in Figure 6. For functions credited with mitigating a digital protection system CCF, the DPS receives signals directly from a diverse set of sensors that are electrically independent from the sensors used by the Q-DCIS platforms.

Specifically, the DPS uses hardware, software and power that are diverse from those used by the safety-related systems. The DPS is described further in Tier 2 Chapter 7 of Reference 6-3.

The DPS system performs several major/minor functions:

- It scrams the plant using a subset of the safety-related RPS parameters.
- It scrams the plant on a SCRRI/SRI command with power remaining elevated, or on receipt of an RPS scram demand from two of four RPS divisions.
- It closes the MSIVs on receipt of a high steam flow signal, low RPV water level, or low reactor pressure (i.e., low turbine inlet pressure).
- It initiates Selected Control Rod Run-in (SCRRI) and Select Rod Insert (SRI) to rapidly reduce power.
- It initiates selected ECCS.
- It transmits ATWS/SLC logic signals to cause the Feedwater Control System (FWCS) to run back feedwater flow.
- It initiates a delayed feedwater runback if elevated power levels persist following either a SCRRI/SRI command or an RPS scram command from two of four RPS divisions.
- It trips the feedwater pumps on RPV water level 9 (after they have been run back to zero flow on RPV water level 8 by the FWCS).
- It opens the ICS lower header vent valves after six hours of ICS initiation.

The DPS initiates a plant scram on a per parameter two-out-of-four coincidence of:

- Detected high or low RPV water level,
- Detected high RPV pressure,
- Detected high drywell pressure,
- Detection of high suppression pool temperature, and
- Inboard or outboard MSIV closure on two or more main steam lines.

The DPS causes a scram by interrupting the current in the 120 VAC return power from the HCU scram solenoids using the same switches used to perform individual control rod scram timing. The two-out-of-three scram decision of the triple redundant processors is sent to the scram timing test panel where they are two-out-of-three voted to open all the solenoid return power switches. The operator also has the ability to initiate a manual DPS scram from either hard switches or the N-DCIS VDUs.

The DPS processes a SCRRI/SRI signal to hydraulically scram selected control rods and to command the RC&IS to perform the SCRRI function based on any of the following initiators:

- Generator load rejection signal from the Turbine Generator Control System (TGCS),
- Turbine trip signal from the TGCS,
- Loss of feedwater heating, and

Enclosure 7

MFN 10-044 Supplement 1 Revision 1

Revised Response (Revision 1) 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

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, **Richard E. Kingston**, state as follows:

(1) I am the Vice President ESBWR Licensing, GE Hitachi Nuclear Energy ("GEH"), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in enclosures 1 and 4 of GEH's letter, MFN 10-044 Supplement 1 Revision 1, Mr. Richard E. Kingston to U.S. Nuclear Energy Commission, entitled "*Revised Response (Revision 1) to NRC Request for Additional Information Letter No. 411 – Related to ESBWR Design Certification Application – Engineered Safety Features – RAI 6.2-202 Supplement 1,*" dated August 2, 2010. The proprietary information in enclosure 1, which is entitled "*MFN 10-044 Supplement 1 Revision 1 – Revised Response (Revision 1) 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,*" and enclosure 4, which is entitled "*Markups to MFN 10-044 Supplement 1 Revision 1 – Revised Response (Revision 1) to Portion of NRC Request for Additional Information Letter No. 411 – Related to ESBWR Design Certification Application – Engineered Safety Features – RAI Number 6.2-202 S01 – NEDE-33572 Revision 1, 'ESBWR ICS and PCCS Condenser Structural Evaluation,' May 2010, GEH Proprietary Information,*" is indicated as the content contained between opening double brackets ([[) and closing double brackets (]]), and underlined. [[This sentence is an example {3}]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2) is classified as proprietary because it contains details of GEH's design and licensing methodology. The development of

the methods used in these analyses, along with the testing, development and approval of the supporting methodology was achieved at a significant cost to GEH.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 2nd day of August 2010.

Richard E. Kingston

Richard E. Kingston
GE-Hitachi Nuclear Energy Americas LLC