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MFN 06-466 Supplement 1 Docket No. 52-010

August 17, 2007

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

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 79 - Passive Containment Cooling System - RAI Number 6.2-102 S01**

Enclosure 1 contains the GE-Hitachi Nuclear Energy Americas LLC (GEH) response to the subject NRC RAI originally transmitted via the Reference 1 letter and supplemented by an NRC request for clarification.

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

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

D068
NRO

Reference:

1. MFN 06-393, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 79 Related to ESBWR Design Certification Application*, October 11, 2006

Enclosure:

1. MFN 06-466 Supplement 1 - Response to Portion of NRC Request for Additional Information Letter No. 79 - Related to ESBWR Design Certification Application - Passive Containment Cooling System - RAI Number 6.2-102 S01

cc:	AE Cubbage	USNRC (with enclosures)
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Enclosure 1

MFN 06-466 Supplement 1

Response to Portion of NRC Request for

Additional Information Letter No. 79

Related to ESBWR Design Certification Application

Passive Containment Cooling System

RAI Number 6.2-102 S01

NRC RAI 6.2-102 S01:

DCD Tier 2, Revision 3, Sections 6.2.4.3.2.1 and 6.2.4.3.2.2, state that the passive containment cooling system (PCCS) has no containment isolation valves (CIVs). The heat exchanger modules and piping of the PCCS, outside containment, form closed systems. As the justification for having no CIVs, the DCD states that the PCCS does not penetrate containment, because the heat exchanger modules and piping are designed as extensions of the safety-related containment, and that the design pressure of the PCCS is greater than twice the containment design pressure and the design temperature is the same as the drywell design temperature.

In RAI 6.2-102, the staff stated that the PCCS must have CIVs, and, supported its position with extensive citations from the regulations (10 CFR Part 50, Appendix A, General Design Criterion 56) and the applicable official NRC guidance (Standard Review Plan 6.2.4, Rev. 2, "Containment Isolation System," and Regulatory Guide 1.141, "Containment Isolation Provisions for Fluid Systems," dated April 1978, which endorses national standard ANS-56.2/ANSI N271-1976, "Containment Isolation Provisions for Fluid Systems" (national standard)). Staff provided a quotation from the national standard that stated that even if the closed system outside containment is treated as an extension of containment, at least one CIV per line is still necessary.

GE's response, MFN 06-466, was a reiteration of their position that the system is considered an extension of the containment boundary, meaning that there are no containment penetrations in the PCCS, and therefore GDC 56, the SRP, the RG, and the national standard do not apply. The applicant cites several documents (other SRPs and GDC) which contain design provisions for the containment boundary, and states that the PCCS satisfies these provisions and so is an extension of containment.

Staff's Review of GE's Response:

(1) Staff's review found that the documents cited by the applicant only address design provisions for the containment in general such as for the walls and roof. The documents cited do not address any situation which is like the applicant's design (that is, a piping system outside of containment) or explain why no CIVs are needed in such a design. On the other hand, the guidance documents cited by the staff do specifically address designs like the PCCS.

(2) Staff understand that there is no explicit definition of "containment penetration" in the documents cited in staff's original RAI. Perhaps the authors felt that, when a pipe passes through the containment wall or roof (like the PCCS does), that this was obviously a containment piping penetration. However, there is the following definition in the national standard, in section 2, "Definitions and Terminology":

> *Penetration assembly. An assembly that allows fluid lines or electrical circuits to pass through a single aperture (nozzle or other opening) in the containment.*

Also, the national standard begins as follows:

> *1. Purpose and Scope*
>
> *The primary purposes of this Standard are to specify minimum design, testing and maintenance requirements for the isolation of fluid systems which penetrate the primary containment of light water reactors. These fluid systems include piping*

systems (including instrumentation and control) for all fluids entering or leaving the containment.

When applying the definitions of the national standard, it can reasonable be interpreted that the PCCS design does indeed have containment penetrations thus requiring CIVs.

(3) Even within the DCD, there is contradiction as to whether the PCCS has containment penetrations. Revision 3 of the DCD contains a new table, 6.2-47, titled "Containment Penetrations Subject to Type A, B, and C Testing." This table lists 18 containment penetrations in the PCCS, numbered T15-MPEN-0001 through T15-MPEN-0018.

Staff agrees that the portion of the PCCS outside of containment is considered to be an extension of containment. However, the applicant concludes without sufficient justification that this inherently means there are no containment penetrations and thus no requirement for any CIVs. The applicant has not provided precedents, regulations, guidance documents, or any other reference to support this conclusion.

Alternatively, staff has cited a national standard endorsed by Regulatory Guide 1.141 which specifically address the case of a closed system outside of containment which is considered to be an extension of containment. This national standard states that there must be at least one CIV in each line.

Provide additional justification for the current design of the PCCS, or revise the DCD with a redesign of the system to include CIVs, per the NRC's applicable regulatory position.

GEH Response:

GEH understands the position taken by the NRC in RAI 6.2-102 and its supplement, and agrees that the DCD is in need of clarification in areas that describe the ESBWR Passive Containment Cooling System (PCCS) design.

As stated in the RAI supplement, there is no explicit definition for several terms including "extension of containment", and GEH's use of these terms is necessarily different from that of several regulations that require isolation valves for pipelines of separate external cooling systems. Therefore, it is GEH's intention to provide a more explicit and specific description of the ESBWR containment's passive cooling in the DCD so it is better understood how the function is an integral part of the containment and structural boundary. This design approach is diametrically opposite of a traditional extension or closed system that provides the cooling function from outside of containment.

The original response to the RAI indicated the ESBWR containment cooling would be designed with consideration given to Standard Review Plan (SRP) 6.2.1.1.C instead of the documents listed by the staff (10 CFR 50, Appendix A, GDC 56; SRP 6.2.4, Revision 2; ANS-56.2/ANSI N271-1976; and Regulatory Guide 1.141). It was by no means GEH's intention that SRP 6.2.1.1.C would be the only guidance considered in the design of the PCCS.

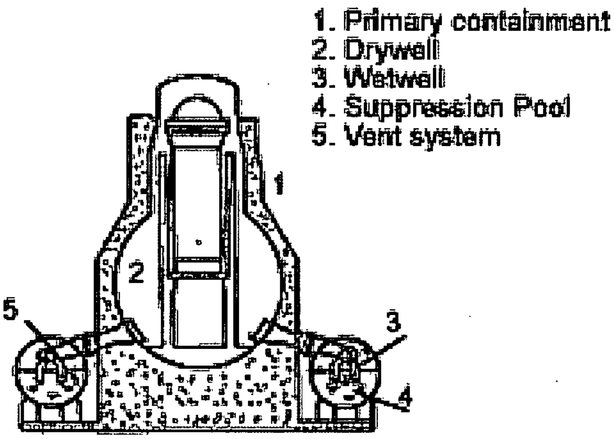
PCCS provides a functional feature of the ESBWR primary containment that assures cooling in the event of a design basis accident (DBA) or anticipated operational occurrence (AOO), the result of which is a loss of normal containment cooling. PCCS is an inherent capability designed into the containment structure, and is not intrinsically a separate fluid process system. This is a

specific departure from the past BWR plant designs including the ABWR. All past BWR containment designs have relied upon an external active safety-related fluid heat exchange system to provide containment cooling in response to DBA and AOO instrumentation and control (I&C) indications and control room operator response actions. To provide a safer and more reliable containment cooling function, PCCS negates the need for a separate active safety-related cooling system, and thus eliminates the need for fluid piping penetrations.

The ESBWR containment is designed under the scope of ASME Section III, Division 2, Article CC-1000. Within this article is Paragraph CC-1120, General Requirements, which states "The rules of Division I shall apply as required in this Subsection for parts and appurtenances not backed by structural concrete for load carrying purposes". As an integral part of the containment structural boundary not backed by concrete, PCCS is under the scope of ASME Section III, Division 1, NE-1130(a), which covers "the containment vessel."

In addition, as described in the original response to the RAI, the PCCS must be designed in accordance with GDC 2, 4, 16, 38, 39, 40, 50, 51, 52, and 53. The PCCS, therefore, does not fall under the scope of GDC 56.

Regulatory documents such as SRP 6.2.1.1.C are not limited to a simple wall and roof style containment, and the design of the ESBWR containment cooling function does have precedent. As an example, consider the Mark I style containment, shown below, which is included in the scope of SRP 6.2.1.1.C.



MARK I

In a Mark I containment, the "light-bulb" shaped drywell is connected through a reinforced-concrete barrier by a series of metal ducts to the wetwell metal torus. This wetwell design is a contiguous part of the containment (not an extension or closed system outside of containment). This design contains many features that are similar to the ESBWR, including the vent duct connections between the drywell and torus, which is a structural containment barrier that is not reinforced by concrete. The ESBWR containment can be understood as an extrapolation beginning from the Mark I containment.

Thus, the ESBWR containment design is an evolution, built on GEH's experience with previous containments, and specifically designed to incorporate the safety-related function of containment cooling directly into the containment structure. Accordingly, GEH has pursued following a design development that satisfies the applicable ASME Code requirements for Class CC and Class MC containment vessel design and construction.

The national standard definition of "penetration assembly" does not apply to the ESBWR PCCS function because the PCCS does not require fluid piping to "pass through a single aperture (nozzle or other opening) in the containment." By definition, a system that forms an integral part of the containment boundary cannot do this.

GEH understands that the DCD contains numerous inconsistencies regarding this topic. In some places, the PCCS is correctly described as function built into the containment boundary. In other places it is incorrectly described as if it were an extension of containment or a closed system outside containment.

An extensive review of the DCD has been performed to standardize the description of the PCCS as being an integral part of the containment boundary. These descriptions will be revised in both DCD Tier 1 and DCD Tier 2 to correct all inconsistencies.

DCD Impact:

The following sections of DCD, Tier 1, and DCD, Tier 2, will be revised as shown in the attached markups:

- Tier 1, Subsection 2.15.4
- Tier 1, Table 2.15.4-1
- Tier 1, Figure 2.15.4-1
- Tier 2, Figure 1.1-2
- Tier 2, Subsection 1.2.2.15.4
- Tier 2, Table 1.3-2
- Tier 2, Sections 3.1 and 3.8
- Tier 2, Table 3.2-1
- Tier 2, Subsection 3.9.3
- Tier 2, Section 6.2 and Subsection 6.6.1
- Tier 2, Tables 6.2-10 and 6.2-47
- Tier 2, Figures 6.2-1, 6.2-15, and 6.2-16
- Tier 2, Subsections 7.1.5 and 7.3.2
- Tier 2, Subsections 9.1.6 and 9.2.5
- Tier 2, Subsection 15.5.6
- Tier 2, Subsection 16.3.6.1.7, 16B.3.6.1.7, and 16B.3.7.1

2.15.4 Passive Containment Cooling System

Design Description

The Passive Containment Cooling System (PCCS), in conjunction with the suppression pool, maintains the containment within its pressure limits for DBAs such as a LOCA, by condensing steam from the Drywell atmosphere and returning the condensed liquid to the Gravity Driven Cooling System (GDCS) pools. The system is entirely passive, with no moving parts. No action is required for the PCCS to begin operation.

The PCCS consists of six low pressure, independent ~~trains~~sets of two~~, each containing a~~ steam condenser modules (passive containment cooling condensers) that condense~~s~~ steam on tube side and transfer~~s~~ heat from the drywell to water in a large cooling pool (IC/PCC pool) located outside the primary containment, which is vented to atmosphere.

Each PCCS condenser is located in a subcompartment of the IC/PCC pool. The IC/PCC 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 ~~train~~condenser.

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

The PCCS ~~loops~~ condensers are driven by the pressure difference created between the containment drywell and the suppression pool during a LOCA, and as such require no sensing, control, logic or power actuated devices for operation.

The PCCS is classified as safety-related and Seismic Category I, and designed to ASME Code Section III, Class ~~2~~MC, Quality Class B.

Together with the suppression pool, the six PCC condensers limit containment pressure to less than its design pressure. The Dryer/Separator pool and Reactor Well shall be designed to have sufficient water volume to provide makeup water to the IC/PCC pools for the initial 72 hours of a LOCA.

The PCC condensers are ~~closed loop extensions~~an integral part of the containment pressure 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 the overall containment pressure testing program. The PCC ~~loops~~ condensers can be isolated for individual pressure testing during maintenance.

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

Inspections, Tests, Analyses and Acceptance Criteria

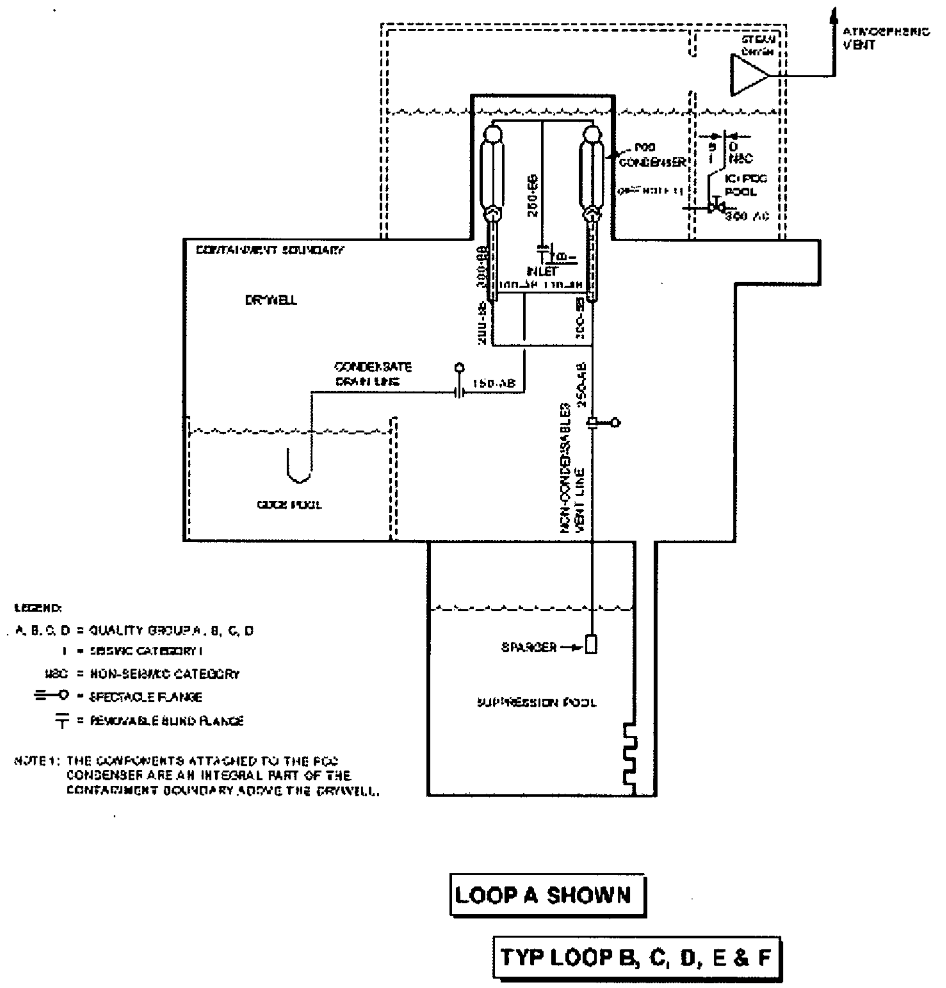
Table 2.15.4-1 provides a definition of the inspections, test and/or analyses, together with associated acceptance criteria for the Passive Containment Cooling System.

Table 2.15.4-1

ITAAC For The Passive Containment Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1. The basic configuration for the PCCS is as shown in Figure 2.15.4-1.	1. Inspections of the as-built system will be conducted.	1. The as-built PCCS conforms to the basic configuration shown in Figure 2.15.4-1.
a. The PCCS is classified as safety-related and Seismic Category I, and designed to ASME Code Section III, Class ~~2~~MC, Quality Class B.	a. Inspections of the as-built PCCS is classified as safety-related and Seismic Category I, and designed to ASME Code Section III, Class ~~2~~MC, Quality Class B.	a. The design reports of the as-built PCCS is classified as safety-related and Seismic Category I, and designed to ASME Code Section III, Class ~~2~~MC, Quality Class B.
2. ~~The ASME Code components of the PCCS retain their pressure boundary integrity under internal pressures that will be experienced during service.~~The pressure boundary of the PCCS retains its integrity under the design pressure of 310 kPa gauge (45 psig)	2. ~~A hydrostatic test will be conducted on those Code Components of the PCC System required to be hydrostatically tested.~~A containment Structural Integrity Test (SIT) will be conducted per ASME requirements at a test pressure of 1.15 times the design pressure. The first prototype containment structure will be instrumented to measure strains per ASME Code Section III, Div. 1, NE-6320	2. ~~The results of the hydrostatic test of the ASME Code Components of the PCC conform to the requirements in the ASME Code, Section III.~~Test results demonstrate compliance to ASME Code Section III, Div. 1, NE-3226
3. ~~The PCCSs are closed train extensions of the containment pressure boundary to which the containment leakage limits apply.~~Deleted	3. ~~A pneumatic test of the PCCS will be conducted as part of the pre-service containment integrated leak rate test.~~Deleted	3. ~~Test report(s) document that the overall leakage of the containment system, which includes the PCCSs, is within 10 CFR 50, Appendix J acceptance limits.~~Deleted
4. The PCCS together with the pressure suppression containment system will	4. An analysis will be performed using similar or more conservative	4. Analyzed containment pressure at 72 hours after a LOCA is less than

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
limit containment pressure to less than its design pressure for 72 hours after a LOCA.	performance characteristics than those of a full-scale test unit of established performance capability.	containment design pressure.


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

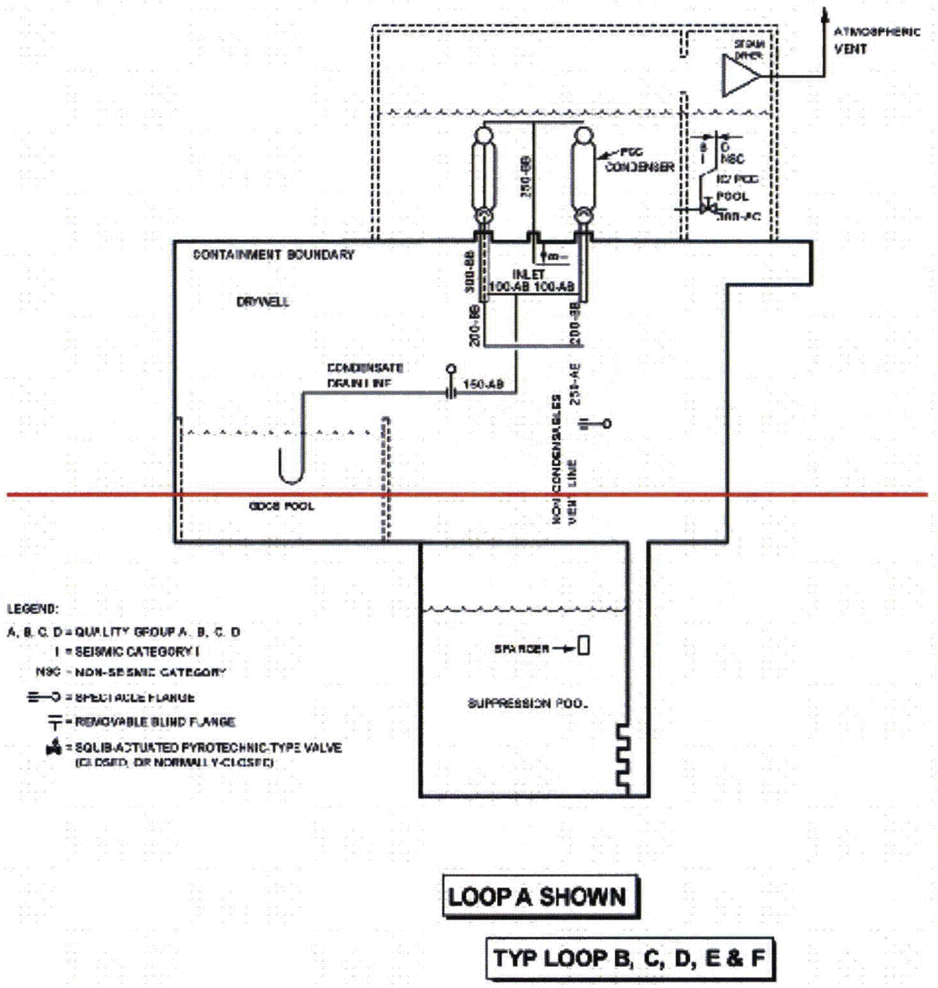
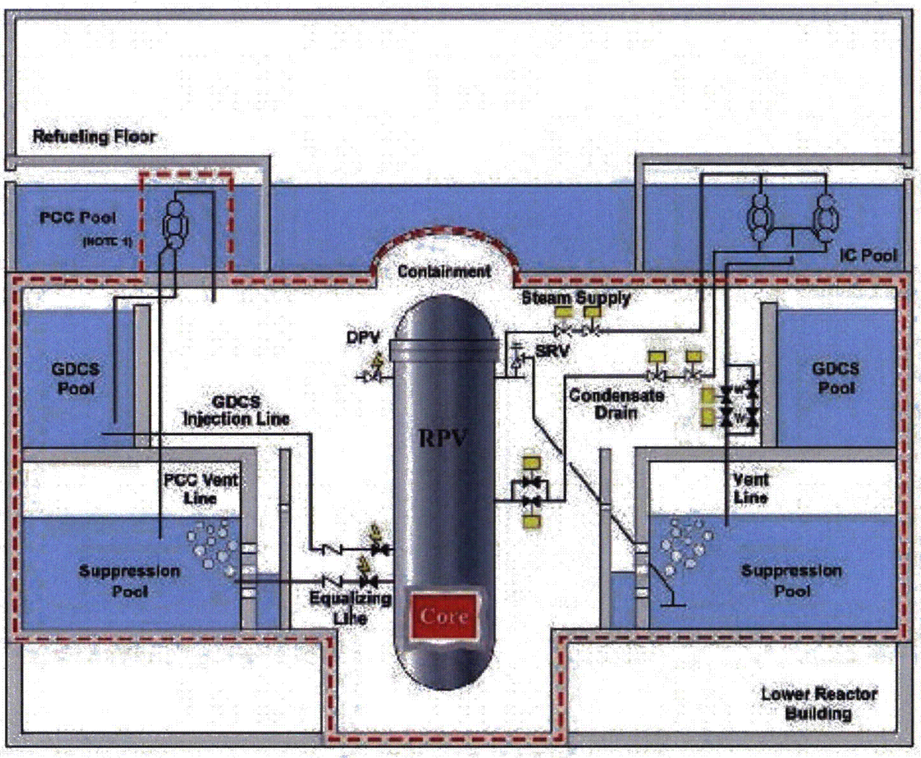


Figure 2.15.4-1. Passive Containment Cooling System Schematic



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)

gratings. Monorails are suspended from the ceiling of the drywell for hoists to work on NSSS equipment.

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 ~~after initiation,~~ requires no moving components for initiation or operation~~move~~.

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

Each PCCS condenser is located in a subcompartment of the IC/PCC pools. The IC/PCC 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~~loop~~. ~~There is no cross connection between the two IC/PCC pools.~~

Each condenser~~train~~, which is ~~open to~~ 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 ~~trains~~ 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.

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/PCC pool volume, combined with the additional water volume that is tied in automatically from the Dryer/Separator Pool and Reactor Well, provides sufficient water volume for at least 72 hours after a LOCA without external make-up to the IC/PCC pools.

The PCC condensers are an integral part ~~closed loop extensions~~ of the containment ~~pressure~~ 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 ~~trains~~ can be isolated for individual pressure testing during maintenance.

During refueling outages, in-service inspection (ISI) of PCCS condensers can be performed, if necessary.~~, because u~~Ultrasonic testing of tube-to-drum ~~header~~ welds and eddy current testing of tubes can be done with PCCS condensers in place. ~~The PCC condensers are located in the IC/PCC pools.~~

The safety-related monitored parameters for the IC/PCC pools are pool water level and pool radiation. IC/PCC 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/PCC 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 1.3-2 Comparison of Emergency Core Cooling Systems and Safety-Related Containment Cooling Systems

System	Units	ESBWR	ABWR
Capacity per division	m^3/s (gpm)	0.139 (2) (2200)	N/A
Containment Cooling System (Section 6.2)			
Residual Heat Removal (RHR)			
Number of loops		None	3
Number of pumps		N/A	3
Number of heat exchangers		N/A	3
Heat exchanger type		N/A	Horizontal U-Tube/Shell
Passive Containment Cooling System			
Number of pumps		0	N/A
Number of heat exchangers		6	N/A
Heat exchanger type		Vertical Tubes connected to Horizontal Drums	N/A
Heat transfer/unit	MW (Btu/s)	11.0 (3) ($1.0435x10^4$)	N/A
Number of cooling pools		6 (4)	N/A
Cooling pool capacity		72 hrs decay heat	N/A

Notes for Table 1.3-2:

(1) Interfacing with 3 GDCS pools.
(2) Reported GDCS flow rate is after quasi steady-state is reached with a 13.8 kPa (2 psid) back pressure.
(3) The heat transfer is based on (a) pure saturated steam condensing in the tubes at 308 kPa (45 psia), and (b) pool water at 101°C (214°F) and open to atmosphere.
(4) The PCCS pools are arranged in two sets of three subcompartments. All IC/PCC pool subcompartments communicate at their lower ends to allow full use of the collective water inventory.

3.1.4.8 Criterion 37 — Testing of Emergency Core Cooling System

Criterion 37 Statement

The Emergency Core Cooling System (ECCS) shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the active components of the system, and (3) the operability of the system as a whole and, under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system.

Evaluation Against Criterion 37

Each of the ECCS subsystems (ADS and GDCS) is designed to permit periodic testing to assure operability and performance of active components of each system.

The ADS DPVs and the GDCS valves cannot be tested during power operation; selected actuators are removed and test fired during refueling outages. The GDCS check valves can be functionally tested via dedicated test line connections every refueling outage. GDCS flow testing is conducted as part of preoperational testing. Provisions for flushing the GDCS injection lines and venturi within the GDCS injection nozzle are provided. The ECCS is subject to periodic tests to verify the logic sequence that initiates ADS and the GDCS system. A periodic self-test of the logic circuitry is performed to verify operability.

The design of the ECCS subsystems meets the requirements of Criterion 37. For further discussions, see the following subsections:

Chapter/ Section	Title
5.2.2	Overpressure Protection
6.3	Emergency Core Cooling Systems
7.3.1.1	Automatic Depressurization Subsystem
7.3.1.2	Gravity-Driven Cooling System
16	Technical Specifications

3.1.4.9 Criterion 38 — Containment Heat Removal

Criterion 38 Statement

A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any LOCA and maintain them at acceptably low levels.

Redundancy in components and features and interconnections, leak detection, isolation, and containment capabilities shall be provided to assure that for on-site electric power system operation (assuming off-site power is not available) and for off-site electric power system

operation (assuming on-site power is not available), the system safety function can be accomplished, assuming a single failure.

Evaluation Against Criterion 38

The containment heat removal function is accomplished by the Passive Containment Cooling System (PCCS). The PCCS provides sufficient decay heat removal post-LOCA, to assure that containment pressure never exceeds its design pressure and temperature.

The PCCS consists of six independent steam condensers that are an integral part of the containment. Each PCCS condenser contains two heat exchanger modules that condense steam on the tubeside and transfer heat to water in the Isolation Condenser/Passive Containment Cooling (IC/PCC) pool which is vented to atmosphere. The IC/PCC pool is positioned above, and outside, the ESBWR containment (drywell). To assure availability, no valves are employed, thus precluding inadvertent isolation of the Passive Containment Cooling (PCC) condensers.

The PCCS condensers receive a steam-gas mixture supply directly from the drywell. PCCS flow is driven by the pressure difference created between the containment drywell and the suppression pool during a LOCA. The PCCS does not require power supplies, sensors, control logic, power-actuated devices or operator actions to function. During normal plant operation, the PCCS condensers are in "ready standby".

The PCCS is designed to Quality Group B Requirements per RG 1.26. The system is designed as Seismic Category I per RG 1.29. The common pool that the PCC condensers share with the ICs of the Isolation Condenser System is an Engineered Safety Feature (ESF). This pool is designed such that no locally generated force (such as an IC tube rupture) can destroy its function. Protection requirements against mechanical damage, fire and flood apply to the common IC/PCC pool.

The safety-related IC/PCC pool subcompartments provide protection for the PCCS condensers to comply with 10 CFR 50, Appendix A, Criteria 2 and 4.

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

The PCCS provides the containment heat removal function required in Criterion 38. For further discussion, see the following subsections:

Chapter/ Section	Title
6.2.2	Passive Containment Cooling System

3.1.4.10 Criterion 39 — Inspection of Containment Heat Removal System

Criterion 39 Statement

The Containment Heat Removal System shall be designed to permit appropriate periodic inspection of important components, such as torus, sumps, spray nozzles, and piping, to assure the integrity and capability of the system.

Evaluation Against Criterion 39

The PCCS condenser is an integral part of the containment (drywell) pressure boundary and it is used to mitigate the consequences of an accident. Because of this function it is classified as a safety-related Engineered Safety Feature (ESF). The PCCS is designed to ASME Code Section III, Class MC and Section XI, IWE requirements for design and accessibility of welds for in-service inspection to meet 10 CFR 50 Appendix A, Criterion 16. Ultrasonic testing of tube-to-header welds and eddy current testing of tubes can be done with the PCC condenser in place.

The containment heat removal system is designed to permit periodic inspection of major components to meet the requirements of Criterion 39. For further discussion, see the following subsections:

Chapter/ Section	Title
6.2.2	Passive Containment Cooling System

3.1.4.11 Criterion 40 — Testing of Containment Heat Removal System

Criterion 40 Statement

The Containment Heat Removal System shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the active components of the system, and (3) the operability of the system as a whole, and, under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system.

Evaluation Against Criterion 40

The Passive Containment Cooling System accomplishes the containment heat removal function. The PCCS is an integral part of the containment boundary. It is designed to be periodically pressure tested as part of overall Containment Leakage Rate Testing Program (Subsections 6.2.6.1, 6.2.6.2 and 6.2.6.3) to demonstrate structural and leaktight integrity. Also, the PCCS loops can be isolated for individual pressure testing during maintenance or in-service inspection using various non-destructive examination methods.

Functional and operability testing is not needed because there are no active components of the system. Performance testing during power operation is not feasible; however, the performance capability of the PCCS is proven by full-scale PCC 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.

The design of the testing of containment heat removal system meets the requirements of Criterion 40. For further discussion, see the following subsections:

The design of the CIS meets the requirements of Criterion 43. For further discussion, see the following sections:

Chapter/ Section	Title
1.2	General Plant Description
6.2.5	Combustible Gas Control in Containment
7	Instrumentation and Control Systems
9.4.9	Containment Inerting System

3.1.4.15 Criterion 44 — Cooling Water

Criterion 44 Statement

A system to transfer heat from structures, systems, and components important to safety, to an ultimate heat sink shall be provided. The system safety function shall be to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions.

Redundancy in components and features, and interconnections, leak detection, and isolation capabilities shall be provided to assure that for on-site electric power system operation (assuming off-site power is not available) and for off-site electric power system operation (assuming on-site power is not available), the system safety function can be accomplished, assuming a single failure.

Evaluation Against Criterion 44

The ESBWR ultimate heat sink is the IC/PCC pool. In the event of a design basis accident, heat is transferred to the IC/PCC pool(s) through the Isolation Condenser System (ICS) and the Passive Containment Cooling System (PCCS). The water in the IC/PCC pool(s) is allowed to boil and the resulting steam is vented to the environment. The PCCS has no active components and requires no electrical motive power or control and instrumentation functions to perform its safety-related function of transferring heat to the ultimate heat sink. The initial IC/PCC pool volume, combined with the additional water volume that is tied in automatically from the Dryer/Separator Pool and Reactor Well, provides sufficient water volume for at least 72 hours after a LOCA without external make-up to the IC/PCC pools. Therefore, no credible single failure can prevent the IC/PCC pools from performing its safety-related function.

The requirements of Criterion 44 for heat transfer to the ultimate heat sink are met. For further discussion, see the following sections:

Chapter/ Section	Title
1.2	General Plant Description
5.4.6	Isolation Condenser System
6.2.2	Passive Containment Cooling System

9.2.5 Ultimate Heat Sink

3.1.4.16 Criterion 45 — Inspection of Cooling Water System

Criterion 45 Statement

The Cooling Water System shall be designed to permit appropriate periodic inspection of important components, such as heat exchangers and piping, to assure the integrity and capability of the system.

Evaluation Against Criterion 45

The IC/PCC pool is located outside containment and is accessible for periodic inspections. During outages, the IC/PCC pool compartments can be drained to permit inspection of the IC/PCC pool components.

The features of the IC/PCC pools meet the requirements of Criterion 45. For further discussion, see the following sections:

Chapter/ Section	Title
1.2	General Plant Description
5.4.6	Isolation Condenser System
6.2.2	Passive Containment Cooling System
9.2.5	Ultimate Heat Sink
14	Initial Test Program

3.1.4.17 Criterion 46 — Testing of Cooling Water System

Criterion 46 Statement

The Cooling Water System shall be designed to permit appropriate periodic pressure and functional testing to assure (1) the structural leaktight integrity of its components, (2) the operability and the performance of the active components of the system, and (3) the operability of the system as a whole and, under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation for reactor shutdown and for loss-of-coolant accidents, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources.

Evaluation Against Criterion 46

Redundancy and isolation are provided to allow periodic inspection of the IC/PCCS pool compartments. As discussed in the evaluation of Criterion 44, the IC/PCCS pools contain no active components aside from connections to the Dryer/Separator Pool that open passively to ensure adequate coolant is provided for at least the initial 72 hours following an accident. These connections are accessible during an outage to permit inspection. The periodic inspections described in the response to Criterion 45 verify system integrity (see the evaluation of Criterion 40).

The design of the IC/PCC pools meets the requirements of Criterion 46. For further discussion, see the following sections:

Chapter/ Section	Title
1.2	General Plant Description
5.4.6	Isolation Condenser System
6.2.2	Passive Containment Cooling System
9.2.5	Ultimate Heat Sink
14	Initial Test Program
16	Technical Specifications

3.1.5 Group V — Reactor Containment

3.1.5.1 Criterion 50 — Containment Design Basis

Criterion 50 Statement

The reactor containment structure, including access openings, penetrations, and the Containment Heat Removal System, shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of peak conditions, such as energy in steam generators and, as required by Section 50.44, energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters.

Evaluation Against Criterion 50

Design of the containment is based on consideration of a full spectrum of postulated accidents, which would result in the release of reactor coolant to the containment. These accidents include liquid breaks, steam breaks, and partial breaks (both steam and liquid). The evaluation of the containment design is based on enveloping the results of this range of analyses, plus provision for appropriate margins. The most limiting short-term and long-term pressure and temperature responses are assessed to verify adequacy of the containment structure.

The design of the containment system meets the requirements of Criterion 50. For further discussion, see the following sections:

Chapter/ Section	Title
3.7	Seismic Design
3.8	Design of Seismic Category I Structures

Evaluation Against Criterion 55

The Reactor Coolant Pressure Boundary (RCPB), as defined in 10 CFR 50, Section 50.2, consists of the reactor pressure vessel, pressure-retaining appurtenances attached to the vessel, valves and pipes which extend from the reactor pressure vessel up to and including the outermost isolation valves. The lines of the RCPB, which penetrate the containment, have isolation valves capable of isolating the containment, thereby precluding any significant release of radioactivity. Justification for the design of each RCPB line penetrating containment is provided in Subsection 6.2.4.

The manner in which RCPB lines that penetrate primary containment meet the requirements of Criterion 55 is discussed further in the following sections:

Chapter/ Section	Title
5.2	Integrity of Reactor Coolant Pressure Boundary
5.4.5	Main Steamline Isolation System
5.4.6	Isolation Condenser System
5.4.8	Reactor Water CleanUp/Shutdown Cooling System
5.4.9	Main Steamlines and Feedwater Piping
6.2.4	Containment Isolation System
6.2.5	Combustible Gas Control in Containment
7	Instrumentation and Control Systems
15	Safety Analyses
16	Technical Specifications

3.1.5.7 Criterion 56 — Primary Containment Isolation

Criterion 56 Statement

Each line that connects directly to the containment atmosphere and penetrates primary reactor containment shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instruments lines, are acceptable on some other defined basis:

(1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or

(2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or

(3) One locked closed isolation valve inside and one automatic isolation valve outside containment (a simple check valve may not be used as the automatic isolation valve outside containment); or

(4) One automatic isolation valve inside and one automatic isolation valve outside containment (a simple check valve may not be used as the automatic isolation valve outside containment).

Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.

Evaluation Against Criterion 56

Lines penetrating containment and connecting directly to the containment atmosphere are isolatable by one of the methods specified in Criterion 56 or are exempted. A justification is provided for each containment penetration in Subsection 6.2.4.

The manner in which the containment isolation system meets the requirements of Criterion 56 is discussed further in the following sections:

Chapter/ Section	Title
6.2.4	Containment Isolation System
7	Instrumentation and Control Systems
15	Safety Analyses
16	Technical Specifications

3.1.5.8 Criterion 57 — Closed System Isolation Valves

Criterion 57 Statement

Each line that penetrates primary reactor containment and is neither part of the reactor coolant pressure boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve which shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside the containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve.

Evaluation Against Criterion 57

Each line that penetrates the containment and is not connected to the containment atmosphere and is not part of the reactor coolant pressure boundary has at least one isolation valve outside containment.

The manner in which lines that penetrate the containment boundary but are not part of the RCPB nor connect to the containment atmosphere meet the requirements of Criterion 57 is discussed further in the following subsection:

Chapter/ Section	Title
6.2.4	Containment Isolation Systems

Table 3.2-1

Classification Summary

Principal Components[1]	Safety Class.[2]	Location[3]	Quality Group[4]	QA Req.[5]	Seismic Category[6]	Notes
T15 Passive Containment Cooling System (PCCS)	2	CV	B	B	I	
T31 Containment Inerting System						
1. Piping and valves (including supports) forming part of the containment boundary	2	RB	B	B	I	
2. Electrical modules and cables with safety-related function	3	RB, CB	—	B	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	—	E	NS	
T41 Drywell Cooling System (DCS)	N	CV	—	E	II	
T49 Passive Auto-Catalytic Recombiner System (PARS)	3	CV	—	B	I	
T62 Containment Monitoring System						
1. Mechanical components involved in containment isolation function	2	CV, RB	—	B	I	
2. Other safety-related portions of System	3	CV, RB, CB	—	B	I	
3. Nonsafety-Related portions of system	N	CV, RB, CB	—	E	NS	
T64 Environmental Monitoring System	N	OL	—	E	NS	

3.8.1.7.3.11 Acceptance Criteria

The acceptance standards of the material specification or IWB-3517.1 shall be used for the evaluation of bolting. For other preservice and inservice examinations, the requirements of IWE-3000 for Class MC components and metallic liners or IWL-3000 for Class CC components shall be used for evaluation. The ultrasonic acceptance standard of IWE-3511.3 for Class MC components shall also be applied to metallic liners of Class CC components.

3.8.1.7.3.12 Evaluation of Inaccessible Areas

During operation, areas inaccessible for examination for acceptability shall be evaluated if conditions exist in accessible areas that indicate the presence of or result in the degradation of the inaccessible areas. For each such area identified, the following information shall be included in the In-service Inspection (ISI) Summary report required by ASME Section XI, IWA-6000:

(1) A description of the type and estimated extent of degradation, and the conditions that led to the degradation.

(2) An evaluation of each area and the result of the evaluation.

(3) A description of necessary corrective actions.

3.8.2 Steel Components of the Reinforced Concrete Containment

3.8.2.1 Description of the Steel Containment Components

The ESBWR has a reinforced concrete containment vessel (RCCV) as described in Subsection 3.8.1. This section describes the following steel components of the concrete containment vessel:

(1) Personnel Air Locks

(2) Equipment Hatches

(3) Penetrations

(4) Drywell Head

(5) PCCS Condenser

3.8.2.1.1 Personnel Air Locks

Two personnel air locks with an inside diameter sufficient to provide 1850 mm (6 ft. 13/16 in.) high by 750 mm (2 ft. 5-1/2 in.) wide minimum clearance above the floor at the door way are provided. One of these air locks provides access to the upper drywell and the other provides access to the lower drywell.

Lock and swing of the doors is by manual and automatic means. The locks extend radially outward from the RCCV into the Reactor Building and are supported by the RCCV only. The minimum clear horizontal distance not impaired by the door swing is 1850 mm (6 ft. 13/16 in.).

Each personnel air lock has two pressure-seated doors interlocked to prevent simultaneous opening of both doors and to ensure that one door is completely closed before the opposite door can be opened. The design is such that the interlocking is not defeated by postulated malfunctions of the electrical system. Signals and controls that indicate the operational status of

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

3.8.2.1.4 Drywell Head

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

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

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

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

3.8.2.1.5 PCCS Condenser

There are six (6) PCCS Condensers located in the PCC subcompartment pools. The condensers form an integral part of the containment boundary while the pool structure and pool water are outside containment. The PCCS Condensers are described in Subsection 6.2.2.

3.8.2.2 Applicable Codes, Standards, and Specifications

3.8.2.2.1 Codes and Standards

In addition to the codes and standards specified in Subsection 3.8.1.2.2, the following codes and standards apply:

(1) American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, Nuclear Power Plant Components, Subsection NE, Class MC and Code Case N-284.

(2) ANSI/AISC N690-1994s2 (2004) Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities

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

3.8.2.4.1.3 Other Penetrations

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

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

3.8.2.4.1.4 Drywell Head

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

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

3.8.2.4.1.5 PCCS Condenser

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

The PCCS condenser is anchored to the RCCV Top Slab and is guided by the IC/PCC pool walls.

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

The PCCS condenser parts conform to the design requirements of Sub-Articles NE-3200 and NE-3300 of ASME Code, Section III, Subsection NE (Class MC). The PCCS condenser support is evaluated in accordance with the ASME Code, Section III, Subsection NF.

3.8.2.5 Structural Acceptance Criteria

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

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

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

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

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

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

3.8.2.6 Materials, Quality Control, and Special Construction Techniques

The steel components of the RCCV locks, hatches, penetrations, drywell head, and PCCS condensers are fabricated from the following materials:

- Plate (SA-516 grade 70, SA-240 type 304L, SA-516 grade 60 or 70 purchased to SA-264)
- Pipe (seamless SA-333 grade 1 or 6 or SA-106 grade B or SA-312 type 304L or SA-671 Gr CC70)
- Forgings (SA-350 grade LFl or LF2 or SA-182F 304L/316L)
- Tubes (SA-213 grade TP304L)
- Bolting (SA-320-L43 or SA-193-B7 or SA-193-B8 bolts with SA-194-7 or A325 or A490 nuts)
- Castings (SA-216, grade WCB or SA-352, grade LCB, A27, or 7036)

Table 3.8-17

PCCS Passages Through RCCV Top Slab

Passage Number	Description	RCCV Sector
0001	Condenser Steam Inlet Line A	I
0007	Condenser Condensate + Vent Line A1	I
0008	Condenser Condensate + Vent Line A2	I
0002	Condenser Steam Inlet Line B	I/III
0009	Condenser Condensate + Vent Line B1	I/III
0010	Condenser Condensate + Vent Line B2	I/III
0003	Condenser Steam Inlet Line C	III
0011	Condenser Condensate + Vent Line C1	III
0012	Condenser Condensate + Vent Line C2	III
0004	Condenser Steam Inlet Line D	II
0013	Condenser Condensate + Vent Line D1	II
0014	Condenser Condensate + Vent Line D2	II
0005	Condenser Steam Inlet Line E	II/IV
0015	Condenser Condensate + Vent Line E1	II/IV
0016	Condenser Condensate + Vent Line E2	II/IV
0006	Condenser Steam Inlet Line F	IV
0017	Condenser Condensate + Vent Line F1	IV
0018	Condenser Condensate + Vent Line F2	IV

Notes:
(1) All PCCS Passages are located in the RCCV Top Slab.

methods of stress analysis for the core support structures and other reactor internals are discussed in Subsection 3.9.5.

3.9.3.3 Main Steam (MS) System Piping

The piping systems extending from the reactor pressure vessel to and including the outboard main steam isolation valve are designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code Section III, Class 1 criteria. Stresses are calculated on an elastic basis for each service level and evaluated in accordance with NB-3600 of the Code. Table 3.9-9 shows the specific load combinations and acceptance criteria for Class 1 piping that apply to this piping. For the main steam Class 1 piping, the thermal loads per Equation 12 of NB-3600 are less than 2.4 S_m, and are more limiting than the dynamic loads that are required to be analyzed per Equation 13 of NB-3600.

The MS system piping extending from the outboard main steam isolation valve to the turbine stop valve is constructed in accordance with the Code, Class 2 Criteria.

3.9.3.4 Other Components

Standby Liquid Control (SLC) Accumulator

The standby liquid control accumulator is designed and constructed in accordance with the requirements of the Code, Class 2 component.

SLC Injection Valve

The SLC injection valve is designed and constructed in accordance with the requirements for the Code, Class 1 component.

Gravity Driven Cooling System (GDCS) Piping and Valves

The GDCS valves connected with the RPV, including squib valves, and up to and including the biased-open check valve are designed and constructed in accordance with the requirements of the Code, Class 1 components. Other valves in the system are class 2 components.

Main Steamline Isolation, Safety Relief, and Depressurization Valves

The main steamline isolation valves, SRVs, and Depressurization Valves (DPVs) are designed and constructed in accordance with the Code, Subsection NB-3500 requirements for Class 1 components.

Safety Relief Valve Piping

The relief valve discharge piping extending from the relief valve discharge flange to the vent wall penetration is designed and constructed in accordance with the Code requirements for Class 3 components. The relief valve discharge piping extending from the diaphragm floor penetration to the quenchers is designed and constructed in accordance with the Code requirements for Class 3 components.

Isolation Condenser System (ICS) Condenser and Piping

The ICS piping inside the primary containment between the reactor pressure vessel and the condenser isolation valve is designed and constructed in accordance with the Code requirements

3.9.3.7.4 Floor-Mounted Major Equipment

Because the major active valves are supported by piping and not tied to building structures, valve "supports" do not exist (Subsection 3.9.3.7).

The Isolation Condenser (IC) heat exchangers are analyzed to verify the adequacy of their support structure under various plant operating conditions. In all cases, the load stresses in the critical support areas are within ASME Code allowables.

3.9.3.8 Other ASME III Component Supports

The ASME III component supports and their attachments (other than those discussed in the preceding subsection) are designed in accordance with Subsection NF of the Code up to the interface with the building structure. The intermediate building structural steel component supports are designed in accordance with the codes as specified in Section 3.8. The loading combinations for the various operating conditions correspond to those used to design the supported component. The component loading combinations are discussed in Subsection 3.9.3.1. Active component supports are discussed in Subsection 3.9.3.5. The stress limits are per ASME III, Subsection NF and Appendix F. The supports are evaluated for buckling in accordance with ASME III.

3.9.4 Control Rod Drive (CRD) System

This subsection addresses the Control Rod Drive system as discussed in SRP 3.9.4. The Control Rod Drive (CRD) system consists of the control rods and the related mechanical components that provide the means for mechanical movement. As discussed in General Design Criteria 26 and 27, the CRD system provides one of the independent reactivity control systems. The rods and the drive mechanism are capable of reliably controlling reactivity changes either under conditions of anticipated operational occurrences, or under postulated accident conditions. A positive means for inserting the rods is always maintained to ensure appropriate margin for malfunction, such as stuck rods. Because the CRD system is a safety-related system and portions of the CRD system are a part of the reactor coolant pressure boundary (RCPB), the system is designed, fabricated, and tested to quality standards commensurate with the safety-related functions to be performed. This provides an extremely high probability of accomplishing the safety-related functions either in the event of anticipated operational occurrences or in withstanding the effects of postulated accidents and natural phenomena such as earthquakes, as discussed in General Design Criteria (GDC) 1, 2, 14, and 29 and 10 CFR 50.55a.

The plant design meets the requirements of the following regulations:

(1) GDC 1 and 10 CFR 50.55a, as it relates to the CRD system being designed to quality standards commensurate with the importance of the safety-related functions to be performed.

(2) GDC 2, as it relates to the CRD system being designed to withstand the effects of an earthquake without loss of capability to perform its safety-related functions.

(3) GDC 14, as it relates to the RCPB portion of the CRD system being designed, constructed, and tested for the extremely low probability of leakage or gross rupture.

6.2 CONTAINMENT SYSTEMS

6.2.1 Containment Functional Design

6.2.1.1 Pressure Suppression Containment

Relevant to ESBWR pressure suppression containment system, this subsection addresses or references to other DCD locations that address the applicable requirements of General Design Criteria (GDC) 4, 16, 50, and 53 discussed in Standard Review Plan (SRP) 6.2.1.1.C Rev. 6. The plant meets the requirements of

(1) GDC 4, as it relates to the environmental and missile protection design, requires that safety-related structures, systems, and components be designed to accommodate the dynamic effects (e.g., effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures) that may occur during normal plant operation or following a loss-of-coolant accident;

(2) GDC 16 and 50, as they relate to the containment being designed with sufficient margin, require that the containment and its associated systems can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident; and

(3) GDC 53 as it relates to the containment design capabilities provided to ensure that the containment design permits periodic inspection, an appropriate surveillance program, and periodic testing at containment design pressure.

6.2.1.1.1 Design Bases

The pressure suppression containment system, which comprises the Drywell (DW) and Wetwell (WW) and supporting systems, is designed to meet the following Safety Design Bases:

- The containment structure shall maintain its functional integrity during and following the peak transient pressures and temperatures, which would occur following any postulated loss-of-coolant accident (LOCA). A design basis accident (DBA) is defined as the worst pipe break, which leads to maximum DW and WW pressure and/or temperature, and is postulated to occur simultaneously with loss of preferred power. For structural integrity evaluation, safe shutdown earthquake (SSE) loads are combined with LOCA loads.
- The containment structure design shall accommodate the full range of loading conditions consistent with normal plant operation, safety relief valve (SRV) discharge and accident conditions including the LOCA related design loads.
- The containment structure is designed to accommodate the maximum internal negative pressure difference between DW and WW, and the maximum external negative pressure difference relative to the reactor building surrounding the containment.
- The containment structure and reactor building, with concurrent operation of containment isolation function (isolates all pipes or ducts which penetrate the containment boundary) and other accident mitigation systems, shall limit fission product leakage during and following the postulated DBA to values less than leakage rates which would result in off-site doses greater than those set forth in 10 CFR 50.67.

- The containment structure shall withstand coincident fluid jet forces associated with the flow from the postulated rupture of any pipe within the containment.
- The containment structure shall accommodate flooding to a sufficient depth above the active fuel to maintain core cooling and to permit safe removal of the fuel assemblies from the reactor core after the postulated DBA.
- The containment structure shall be protected from or designed to withstand hypothetical missiles from internal sources and uncontrolled motion of broken pipes, which could endanger the integrity of the containment.
- The containment structure shall direct the high energy blowdown fluids from postulated LOCA pipe ruptures in the DW to the pressure suppression pool and ~~to~~ through the Passive Containment Cooling System (PCCS) condensers.
- The containment system shall allow for periodic tests at the calculated peak or reduced test pressure to measure the leakage from individual penetrations, isolation valves and the integrated leakage rate from the containment structure to confirm the leak-tight integrity of the containment.
- The Containment Inerting System establishes and maintains the containment atmosphere to ≤ 3% by volume oxygen during normal operating conditions to ensure inert atmosphere operation.
- PCCS shall remove post-LOCA decay heat from the containment for a minimum of 72 hours, without operator action, to maintain containment pressure and temperature within design limits.

6.2.1.1.2 Design Features

The containment structure is a reinforced concrete cylindrical structure, which encloses the reactor pressure vessel (RPV) and its related systems and components. Key containment components and design features are exhibited in Figures 6.2-1 through 6.2-5. The containment structure has an internal steel liner providing the leak-tight containment boundary. The containment is divided into a DW region and a WW region with interconnecting vent system. The functions of these regions are as follows:

- The DW region is a leak-tight gas space, surrounding the reactor pressure vessel and reactor coolant pressure boundary, which provides containment of radioactive fission products, steam, and water released by a LOCA, prior to directing them to the suppression pool via the DW/WW Vent System. A relatively small quantity of DW steam is also directed to the PCCS during the LOCA blowdown.
- The WW region consists of the suppression pool and the gas space above it. The suppression pool is a large body of water to absorb energy by condensing steam from SRV discharges and pipe break accidents. The pool is an additional source of reactor water makeup and serves as a reactor heat sink. The flow path to the WW is designed to entrain radioactive materials by routing fluids through the suppression pool during and following a LOCA. The gas space above the suppression pool is leak-tight and sized to collect and retain the DW gases following a pipe break in the DW, without exceeding the containment design pressure.

The DW/WW Vent System directs LOCA blowdown flow from the DW into the suppression pool.

The containment structure consists of the following major structural components: RPV support structure (pedestal), diaphragm floor separating DW and WW, suppression pool floor slab, containment cylindrical outer wall, cylindrical vent wall, containment top slab, and DW head. The containment cylindrical outer wall extends below the suppression pool floor slab to the common basemat. This extension is not part of containment boundary, however, it supports the upper containment cylinder. The reinforced concrete basemat foundation supports the entire containment system and extends to support the reactor building surrounding the containment.

The design parameters of the containment and the major components of the containment system are given in Tables 6.2-1 through 6.2-4. A detailed discussion of their structural design bases is given in Section 3.8.

Drywell

The DW (Figure 6.2-1) comprises two volumes: (1) an upper DW volume surrounding the upper portion of the RPV and housing the main steam and feedwater piping, Gravity Driven Cooling System (GDCS) pools and piping, PCCS piping, Isolation Condenser System (ICS) piping, SRVs and piping, depressurization valves (DPVs) and piping, DW coolers and piping, and other miscellaneous systems; and (2) a lower DW volume below the RPV support structure housing the lower portion of the RPV, fine motion control rod drives, other miscellaneous systems and equipment below the RPV, and vessel bottom drain piping.

The upper DW is a cylindrical, reinforced concrete structure with a removable steel head and a diaphragm floor constructed of steel girders with concrete fill. The RPV support structure separates the lower DW from the upper DW. There is an open communication path between the two DW volumes via upper DW to lower DW connecting vents, built into the RPV support structure. Penetrations through the liner for the DW head, equipment hatches, personnel locks, piping, electrical and instrumentation lines are provided with seals and leak-tight connections.

The DW is designed to withstand the pressure and temperature transients associated with the rupture of any primary system pipe inside the DW, and also the negative differential pressures associated with containment depressurization events, when the steam in the DW is condensed by the PCCS, the GDCS, the Fuel and Auxiliary Pools Cooling System (FAPCS), and cold water cascading from the break following post-LOCA flooding of the RPV.

For a postulated DBA, the calculated maximum DW temperature and absolute pressure remain below their design values, shown in Table 6.2-1.

Vacuum breakers are provided between the DW and WW. The vacuum breaker is a process-actuated valve, similar to a check valve. The purpose of the DW-to-WW vacuum breaker system is to protect the integrity of the diaphragm floor slab and vent wall between the DW and the WW, and the DW structure and liner, and to prevent back-flooding of the suppression pool water into the DW. The vacuum breaker is provided with redundant proximity sensors to detect its closed position. On the upstream side of the vacuum breaker, a DC-powered solenoid-controlled and spring-operated backup valve designed to fail-close is provided. The vacuum breaker is illustrated in Figure 6.2-28. During a LOCA, when the vacuum breaker opens and allows the flow of gas from WW to DW to equalize the DW and WW pressure and subsequently does not

completely close as detected by the proximity sensors, a control signal will close the upstream backup valve to prevent extra bypass leakage due to the opening created by the vacuum breaker and therefore maintain the pressure suppression capability of the containment. Redundant vacuum breaker systems are provided to protect against a single failure of vacuum breaker, i.e., failure to open or failure to close when required. The design DW-to-WW pressure difference and the vacuum breaker full open differential pressure are given in Table 6.2-1.

The vacuum breaker valves are protected from pool swell loads by structural shielding designed for pool swell loads determined based on the Mark II/III containment design.

A safety-related PCCS is incorporated into the design of the containment to remove decay heat from DW following a LOCA. The PCCS uses six elevated heat exchangers (condensers) that are an integral part of the containment boundary located ~~outside the containment~~ in large pools of water outside the containment at atmospheric pressure to condense steam that has been released to the DW following a LOCA. This steam is channeled to each of the condenser tube-side heat transfer surfaces where it condenses and the condensate returns by gravity flow to the GDCS pools. Noncondensable gases are purged to the suppression pool via vent lines. The PCCS condensers are an ~~extension~~integral part of the containment boundary, do not have isolation valves, and start operating immediately following a LOCA. These low pressure PCCS condensers provide a thermally efficient heat removal mechanism. No forced circulation equipment is required for operation of the PCCS. Steam produced, due to boil-off in the pools surrounding the PCCS condensers, is vented to the atmosphere. There is sufficient inventory in these pools to handle at least 72 hours of decay heat removal. The PCCS is described and discussed in detail in Subsection 6.2.2.

The containment design includes a Drywell Cooling System (DCS) to maintain DW temperatures during normal operation within acceptable limits for equipment operation as described in Subsection 9.4.8.

Protection against the dynamic effects from the piping systems is provided by the DW structure. The DW structure provides protection against the dynamic effects of plant-generated missiles (Section 3.5).

An equipment hatch for removal of equipment during maintenance and an air lock for entry of personnel are provided in both the lower and upper DW. These access openings are sealed under normal plant operation and are opened when the plant is shut down for refueling and/or maintenance.

During normal operation, the Containment Inerting System has a nitrogen makeup subsystem, which automatically supplies nitrogen to the WW and the DW to maintain a slightly positive pressure to preclude air in-leakage from the surrounding reactor building region. Before personnel can enter the DW, it is necessary to de-inert the DW atmosphere. The Containment Inerting System provides the purge supply and exhaust subsystems for de-inerting, and is discussed in Subsection 9.4.8.

Wetwell

The WW is comprised of a gas volume and suppression pool water volume. The WW is connected to the DW by a vent system comprising twelve (12) vertical/horizontal vent modules. Each module consists of a vertical flow steel pipe, with three horizontal vent pipes extending into

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 with the Isolation Condenser/Passive Containment Cooling (IC/PCC) pool inventory not being replenished.

The PCCS is an engineered safety feature (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 design basis accidents (DBAs). The PCCS is designed as a passive system without power actuated valves or other components that must actively function. 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 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 101°C (214°F)).

Design Pressure and Temperature

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

The PCCS condenser is ~~in a closed loop extension~~an integral part of the containment pressure boundary. Therefore, ASME Code Section III Class 2MC, Seismic Category I, and TEMA 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 Drywell and the Wetwell, which are parts of the ESBWR pressure suppression type containment system. The Drywell and Wetwell vacuum breaker must fully close after each demand to support the PCCS operation. If the vacuum breaker does not close, a backup isolation valve will close.

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

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

6.2.2.2.2 Detailed System Description

The PCCS maintains the containment within its pressure limits for DBAs. The system is designed as a passive system with no components that must actively function, 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 loopssets of two, each containing a steam condenser modules (Passive Containment Cooling Condensers), as shown Figure 6.2-16. Each PCCS condenser loop is designed for 11 MWt capacity and is made of two identical modules. Together with the pressure suppression containment (Subsection 6.2.1.1), the PCCS condensers limit containment pressure to less than its design pressure. The Dryer/Separator pool and Reactor Well are designed to have sufficient water volume to provide makeup water to the IC/PCC pools for at least the initial 72 hours after a LOCA without makeup to the IC/PCC pool, and beyond 72 hours with pool makeup.

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

Each PCCS condenser is configured (see Figure 6.2-16) as follows.

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

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

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 PCCS loops condensers receive a steam-gas mixture supply directly from the DW. The PCCS loops condensers are initially driven by the pressure difference created between the containment DW and the suppression pool during a LOCA and then by gravity drainage of steam condensed in the tubes, so they require no sensing, control, logic or power-actuated devices to function. The PCCS loops condensers are an extension integral part of the safety-related containment and do not have isolation valves.

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

Located on the drain line and submerged in the GDCS pool, just upstream of the discharge point, is a loop seal: it prevents 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.

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

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

Pool water can heat up to about 101°C (214°F); steam formed, being non-radioactive and having a slight positive pressure relative to station ambient, vents from the steam space above each PCCS condenser where it is released to the atmosphere through large-diameter discharge vents.

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

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

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

Cooling and cleanup of IC/PCC pool water is performed by the Fuel and Auxiliary Pools Cooling System (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 reactor building, whereby a post-LOCA water supply can be connected.

6.2.2.2.3 System Operation

Normal Plant Operation

During normal plant operation, the PCCS ~~loops~~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/PCC 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 Wetwell through the vent line.

6.2.2.3 Design Evaluation

The PCCS condenser is an ~~extension~~ 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 ~~2~~ 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 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/PCC pool.

~~As protection from missile, tornado and wind, t~~The PCCS ~~parts outside the containment are~~components located in a subcompartment of the safety-related IC/PCC pool are protected by the IC/PCC pool subcompartment from the effects of missiles tornados to comply with 10 CFR 50, Appendix A, Criteria 2 ~~&~~ and 4.

The PCCS condenser can not fail in a manner that damages the safety-related ICS/PCC 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, which is reported in Subsection 6.2.1.1 and Chapter 15.

6.2.2.4 Testing and Inspection Requirements

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

If additional inservice inspection becomes necessary, it is unnecessary to remove the PCCS condenser because ultrasonic testing of tube-to-~~header~~ drum welds and eddy current testing of tubes can be done with the PCCS condensers in place during refueling outages.

6.2.2.5 Instrumentation Requirements

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

- meet Seismic Category I design requirements; and
- are protected against a high energy line break outside of containment when needed for containment isolation.

High Pressure Nitrogen Supply System

The High Pressure Nitrogen Supply System penetrates the containment at two places. Each line has one air-operated shutoff valve outside and one check valve inside the containment.

~~**Passive Containment Cooling System**~~

~~The passive containment cooling system (PCCS) does not have isolation valves as the heat exchanger modules and piping are designed as extensions of the safety-related containment. The design pressure of the PCCS is greater than twice the containment design pressure and the design temperature is same as the drywell design temperature.~~

6.2.4.3.2.2 Effluent Lines from Containment

Tables 6.2-33 through 6.2-42 identify the isolation functions in the effluent lines from the containment.

Fuel and Auxiliary Pools Cooling System Suction Lines

The FAPCS suction line from the GDCS pool is provided with two power-assisted shutoff valves, one pneumatic-operated or equivalent inside and one pneumatic-operated or equivalent outside the containment.

Before it exits containment, the FAPCS suction line from the suppression pool branches into two parallel lines, each of which penetrate the containment boundary. Once outside, each parallel flow path contains two pneumatic isolation valves in series after which the lines converge back into a single flow path. Because the penetration can be under water under certain accident conditions, there can be no isolation valve located inside the containment. The valves are located as close as possible to the containment.

Subsection 9.1.3.3 contains additional information about the containment isolation design for FAPCS

Chilled Water System

The CWS effluent lines penetrating the containment each has a pneumatic-operated or equivalent shutoff valve outside containment and a pneumatic-operated or equivalent shutoff valve inside the containment.

Containment Inerting System

The penetration of the Containment Inerting System consists of two tandem quarter-turn shutoff valves (normally closed) in parallel with tandem stop or shutoff valves. All isolation valves on these lines are outside of the containment to provide accessibility to the valves. Both containment isolation valves are located as close as practical to the containment. The valve nearest to the containment is provided with a capability of detection and termination of a leak. The piping between the containment and the first isolation valve and the piping between the two isolation valves are designed as per requirements of SRP 3.6.2. These piping are also designed to:

- meet Safety Class 2 design requirements;
- withstand the containment design temperature;
- withstand internal pressure from containment structural integrity test;
- withstand loss-of-coolant accident transient and environment;
- meet Seismic Category I design requirements; and
- are protected against a high energy line break outside of containment when needed for containment isolation.

Process Radiation Monitoring System

The penetrations for the fission products monitor sampling lines consist of one sampling line and one return line. Each line uses three tandem stop or shutoff valves . One valve is a manual-operated valve used for maintenance and is located close to the containment. The other two valves are pneumatic, solenoid or equivalent power operated valves and are used for isolation. All three valves are located outside the containment for easy access. The piping to these valves is considered an extension of the containment boundary.

~~**Passive Containment Cooling System**~~

~~The passive containment cooling system (PCCS) does not have isolation valves as the heat exchanger modules and piping are designed as extensions of the safety related containment. The design pressure of the PCCS is greater than twice the containment design pressure and the design temperature is same as the drywell design temperature.~~

6.2.4.3.2.3 Conclusion on Criterion 56

In order to ensure protection against the consequences of an accident involving release of significant amounts of radioactive materials, pipes that penetrate the containment have been demonstrated to provide isolation capabilities on a case-by-case basis in accordance with Criterion 56.

In addition to meeting isolation requirements, the pressure-retaining components of these systems are designed to the quality standards commensurate with their importance to safety.

6.2.4.3.2.4 Evaluation Against General Design Criterion 57

The ESBWR has no closed system lines penetrating the containment that require automatic isolation.

6.2.4.3.2.5 Evaluation Against Regulatory Guide 1.11

Instrument lines that connect to the RCPB and penetrate the containment have 1/4-inch orifices and manual isolation valves, in compliance with Regulatory Guide 1.11 requirements.

6.2.4.3.3 Evaluation of Single Failure

A single failure can be defined as a failure of a component (e.g., a pump, valve, or a utility such as offsite power) to perform its intended safety-related functions as a part of a safety-related system. The purpose of the evaluation is to demonstrate that the safety-related function of the

Table 6.2-10

Passive Containment Cooling Design Parameters

Number of PCCS ~~Loops~~Condensers-	Six (6)
Heat Removal Capacity for Each ~~Loop~~Condenser-	11 MWt Nominal 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.
System Design Pressure-	758.5 kPa(g) (110 psig)
System Design Temperature-	171°C (340°F)

Table 6.2-47

Containment Penetrations Subject To Type A, B, and C Testing

Penetration Number (1)	Description	Location (3)/Room #	RCCV Sector	Penetration Type (4)	Leak Test Type (5)
P54-MPEN-0001	Supply to MSIV Accumulators	UD	TBD	B	A
P54-MPEN-0002	Supply to ADS and ICIV Accumulators	UD	TBD	B	A
T11: Containment Vessel: Equipment & Personnel Access Hatches					
T11-SPEN-TBD	LD Equipment Hatch	LD/1206	II/III	Hatch	B
T11-SPEN-TBD	LD Personnel Airlock	LD /1205	I/IV	Air Lock	B
T11-SPEN-TBD	Wetwell Access Hatch	WA/1600	III	Hatch	B
T11-SPEN-TBD	UD Equipment Hatch	UD /1740	IV	Hatch	B
T11-SPEN-TBD	UD Personnel Airlock	UD/1710	I	Air Lock	B
6.2.9.1.1 T11: Containment Vessel: Temporary Services During Outages & Spare Penetrations					
T11-MPEN-TBD	Temporary Services During Outages	LD	TBD	TBD	B
T11-MPEN-TBD	Temporary Services During Outages	LD	TBD	TBD	B
T11-MPEN-TBD	Temporary Services During Outages	UD	TBD	TBD	B
T11-MPEN-TBD	Temporary Services During Outages	UD	TBD	TBD	B
T11-MPEN-TBD	Temporary Services During Outages	WA	III	TBD	B
T11-MPEN-TBD	Spare Mechanical Penetration	TBD	TBD	S	A
T11-MPEN-TBD	Spare Mechanical Penetration	TBD	TBD	S	A
T11-MPEN-TBD	Spare Mechanical Penetration	TBD	TBD	S	A
T11-EPEN-TBD	Spare Electrical Penetration	TBD	I	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	II	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	III	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	IV	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	I	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	II	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	III	E	B
T11-EPEN-TBD	Spare Electrical Penetration	TBD	IV	E	B
~~T15: Passive Containment Cooling System (PCCS)~~					
~~T15-MPEN-0001~~	~~Condenser Steam Inlet Line A (6)~~	~~TS~~	~~I~~	~~B~~	~~A~~
~~T15-MPEN-0007~~	~~Condenser Condensate + Vent Line A1 (6)~~	~~TS~~	~~I~~	~~B~~	~~A~~
~~T15-MPEN-0008~~	~~Condenser Condensate + Vent Line A2 (6)~~	~~TS~~	~~I~~	~~B~~	~~A~~
~~T15-MPEN-0002~~	~~Condenser Steam Inlet Line B~~	~~TS~~	~~I/III~~	~~B~~	~~A~~
~~T15-MPEN-0009~~	~~Condenser Condensate + Vent Line B1~~	~~TS~~	~~I/III~~	~~B~~	~~A~~

Table 6.2-47

Containment Penetrations Subject To Type A, B, and C Testing

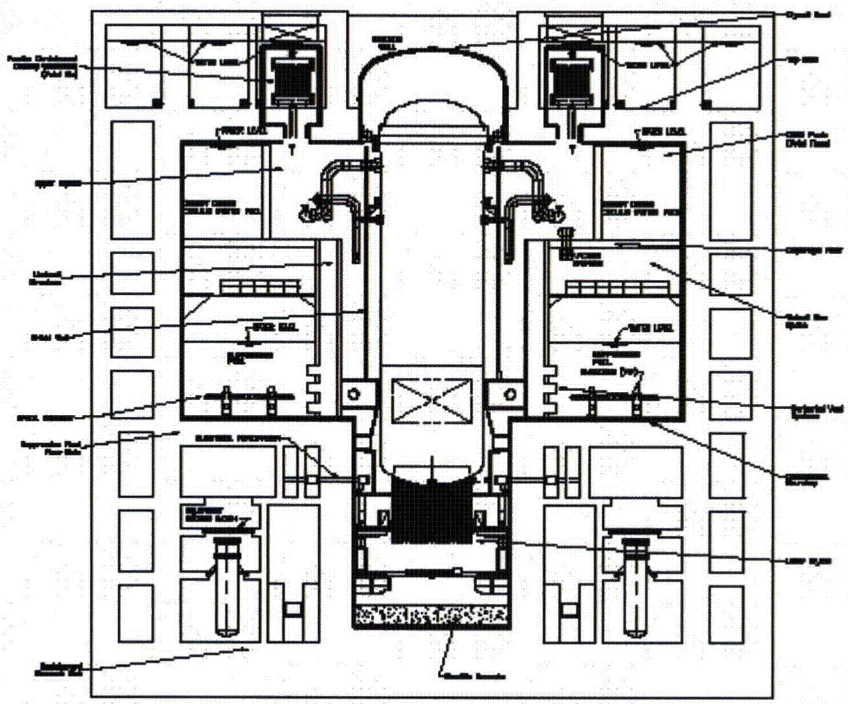
Penetration Number (1)	Description	Location (3)/Room #	RCCV Sector	Penetration Type (4)	Leak Test Type (5)
~~T15-MPEN-0010~~	~~Condenser Condensate + Vent Line B2~~	~~TS~~	~~I/III~~	~~B~~	~~A~~
~~T15-MPEN-0003~~	~~Condenser Steam Inlet Line C (6)~~	~~TS~~	~~III~~	~~B~~	~~A~~
~~T15-MPEN-0011~~	~~Condenser Condensate + Vent Line C1 (6)~~	~~TS~~	~~III~~	~~B~~	~~A~~
~~T15-MPEN-0012~~	~~Condenser Condensate + Vent Line C2 (6)~~	~~TS~~	~~III~~	~~B~~	~~A~~
~~T15-MPEN-0004~~	~~Condenser Steam Inlet Line D~~	~~TS~~	~~II~~	~~B~~	~~A~~
~~T15-MPEN-0013~~	~~Condenser Condensate + Vent Line D1~~	~~TS~~	~~II~~	~~B~~	~~A~~
~~T15-MPEN-0014~~	~~Condenser Condensate + Vent Line D2~~	~~TS~~	~~II~~	~~B~~	~~A~~
~~T15-MPEN-0005~~	~~Condenser Steam Inlet Line E~~	~~TS~~	~~II / IV~~	~~B~~	~~A~~
~~T15-MPEN-0015~~	~~Condenser Condensate + Vent Line E1~~	~~TS~~	~~II / IV~~	~~B~~	~~A~~
~~T15-MPEN-0016~~	~~Condenser Condensate + Vent Line E2~~	~~TS~~	~~II / IV~~	~~B~~	~~A~~
~~T15-MPEN-0006~~	~~Condenser Steam Inlet Line F~~	~~TS~~	~~IV~~	~~B~~	~~A~~
~~T15-MPEN-0017~~	~~Condenser Condensate + Vent Line F1~~	~~TS~~	~~IV~~	~~B~~	~~A~~
~~T15-MPEN-0018~~	~~Condenser Condensate + Vent Line F2~~	~~TS~~	~~IV~~	~~B~~	~~A~~
T31: Containment Inerting System (CIS)					
T31-MPEN-0001	Upper Drywell Injection Line	UD	TBD	C	A
T31-MPEN-0002	Suppression Pool Airspace Injection Line	WA	TBD	C	A
T31-MPEN-0003	Main Exhaust Line (Lower Drywell)	LD	TBD	C	A
T31-MPEN-0004	Second Exhaust Line (Suppression Pool Airspace)	UD	TBD	C	A
T31-MPEN-TBD	Containment Pressure Test (GDCS Pool)	UW	TBD	C	A
T31-MPEN-TBD	Containment Pressure Test (Lower Drywell)	WA	TBD	C	A
T62: Containment Monitoring System (CMS)					
T62-MPEN-TBD	H2-O2 & Drywell Gas Sample Line From Upper Drywell (Loop A)	UD	TBD	C	A
T62-MPEN-TBD	H2-O2 & Drywell Gas Sample Return Line to Upper Drywell (Loop A)	UD	TBD	C	A

HCW - HIGH CONDUCTIVITY WASTE
LCW - LOW CONDUCTIVITY WASTE

(4) Penetration type:
Type A = Penetration with thermal sleeve for High Energy Pipelines; (Main Steam & Feed Water Lines) (Fig. 3.8-6)
Type B = Penetration with thermal sleeve for Low / High Energy Flow (DCD, Rev.3 Fig. 3.8-6 and 3.8-7)
Type C = Embedded penetration without thermal sleeve (Cold Type for flow Tmax<93°C(200°F)) (Fig. 3.8-8)
Type E = Penetration with flanges (Electrical, Maintenance, etc) (Fig. 3.8-10)
Type I = Instrumentation and Radiation Monitoring. (TBD)
Type M = Multiple penetration with sleeve (Fig. 3.8-9)
Type S = Spare Mechanical Penetration (TBD)

(5) All penetration will be subject to the Type A, Integrated Leak Rate Test (ILRT)
All penetrations excluded from Type B testing are welded penetrations and do not include any resilient seals in their design.

~~(6)PCCS Pool designations are subject to change~~



Note: The components attached to the PCC condenser are an integral part of the containment boundary above the drywell. The IC/PCC pool structure and cooling water are located outside the containment boundary.

Figure 6.2-1. Containment System

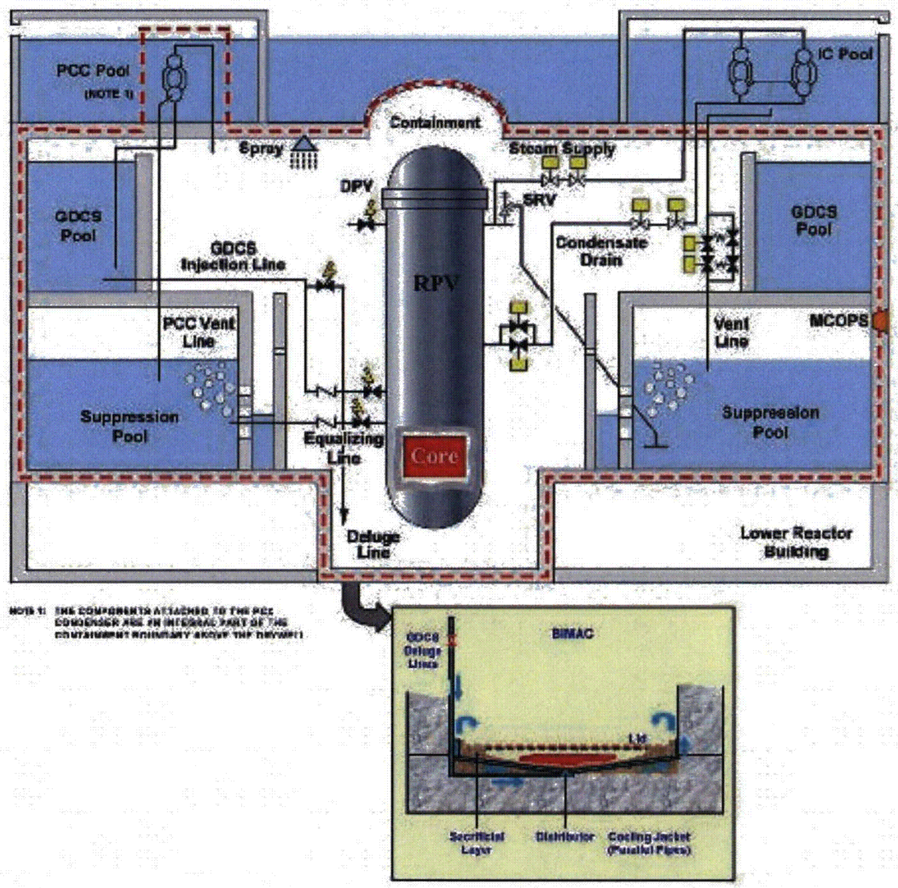


Figure 6.2-15. Summary of Severe Accident Design Features

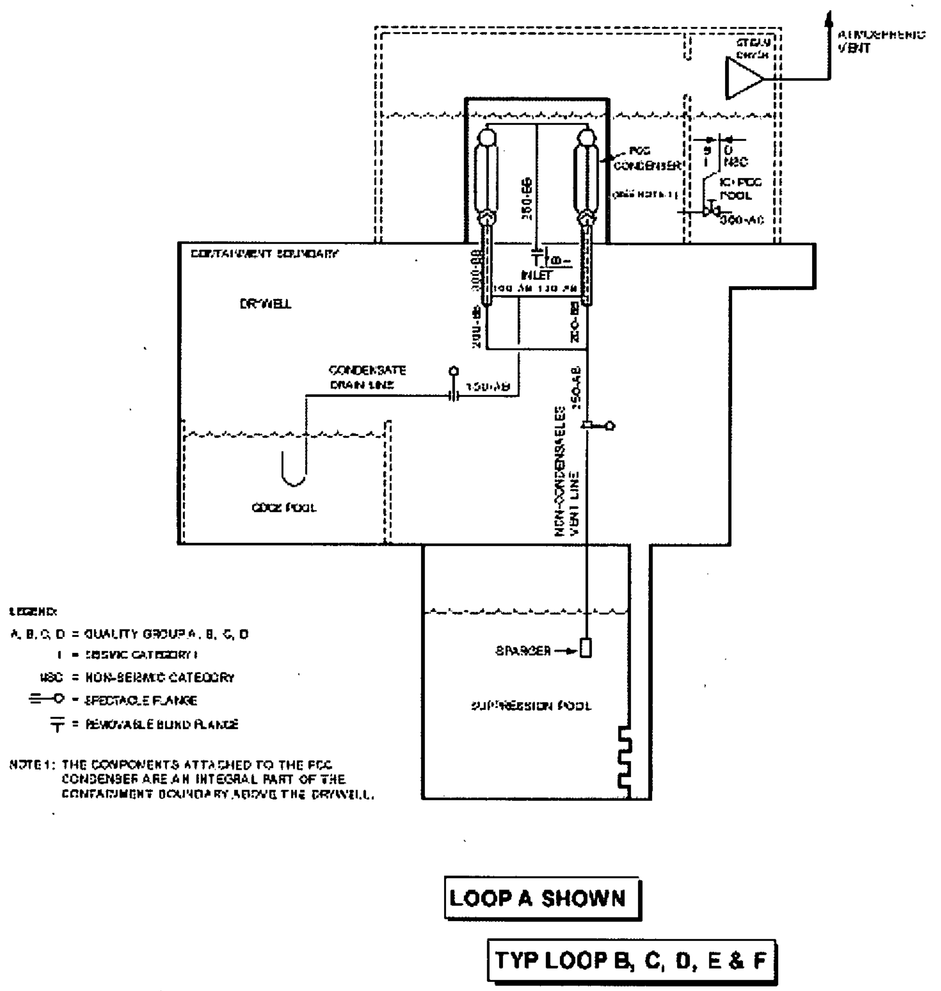


Figure 6.2-16. PCCS Schematic Diagram

6.6 PRESERVICE AND INSERVICE INSPECTION AND TESTING OF CLASS 2 AND 3 COMPONENTS AND PIPING

The ESBWR meets requirements for periodic inspection and testing of Class 2 and 3 systems in General Design Criteria (GDC) 36, 37, 39, 40, 42, 43, 45 and 46, as specified in part in 10 CFR Section 50.55a, and as detailed in Section XI of the ASME Code. Compliance with the preservice and inservice examinations of 10 CFR 50.55a, as detailed in Section XI of the Code, satisfies in part the requirements of GDC 36, 37, 39, 40, 42, 43, 45 and 46. ESBWR meets SRP 6.6, Revision 1 acceptance criteria by meeting the ISI requirements of these GDC and 10 CFR 50.55a for the areas of review described in Subsection I of the SRP.

This subsection describes the preservice and inservice inspection and system pressure test programs for Quality Groups B and C, i.e., ASME Code Class 2 and 3 items, respectively, as defined in Table 3.2-3. This section describes those programs implementing the requirements of ASME B&PV Code, Section XI, Subsections IWC and IWD.

The development of the preservice and inservice inspection program plans will be the responsibility of the COL Holder, and is based on the ASME Code, Section XI, Edition and Addenda specified in accordance with 10 CFR 50.55a. The COL Holder specifies the Edition of ASME Code to be used, based on the date of issuance of the construction permit or license, per 10 CFR 50.55a.

6.6.1 Class 2 and 3 System Boundaries

The Class 2 and 3 system boundaries for both preservice and inservice inspection programs and the system pressure test program include item boundaries include all or part of the following:

- (Deleted)
- Nuclear Boiler System (NBS)
- Isolation Condenser System (ICS)
- Control Rod Drive (CRD) system
- Standby Liquid Control (SLC) system
- Gravity Driven Cooling System (GDCS)
- Fuel and Auxiliary Pools Cooling System (FAPCS)
- Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) system
- Chilled Water System (CWS)

~~□Passive Containment Cooling System (PCCS).~~

6.6.1.1 Class 2 System Boundary Description

Those portions of the systems listed in Subsection 6.6.1 within the Class 2 boundary, based on Regulatory Guide 1.26, for Quality Group B (QGB) are as follows:

- Portions of the Reactor Coolant Pressure Boundary as defined within Subsection 3.2.2.1, but which are excluded from the Class 1 boundary pursuant to Subsection 3.2.2.2.

- LD&IS, Lighting and Servicing Power Supply, Liquid Waste Management System (LWMS), Low Voltage Distribution System,
- Main Condenser and Auxiliaries, Main Turbine, Makeup Water System, Medium Voltage Distribution System, Meterological Observation Station, Moisture Separator Reheater System (MSR),
- NBS, NMS,
- Offgas System (OGS), Oil Storage and Transfer System, Oxygen Injection system (OIS),
- PAS, ~~Passive Containment Cooling System (PCCS),~~ Plant Service Water System (PSWS), Process Sampling System (PSS),
- Q-DCIS,
- Radwaste Building HVAC, RC&IS, Reactor Building HVAC, Reactor Component Cooling Water System, Reactor Water Cleanup and Shutdown Cooling System (RWCU/SCS), RPMS, RPS, RSS,
- SB&PCS, Service Air System (SAS), Service Building HVAC, Service Water Building HVAC, SLC, Solid Waste Management System, SSLC/ESF, Standby On-Site AC Power Supply, Stator Cooling Water System (SCWS),
- Turbine Auxiliary Steam System (TASS), Turbine Building Cooling Water System, Turbine Building HVAC, Turbine Bypass System (TBS), Turbine Generator Control System (TGCS), Turbine Gland Seal System, Turbine Lube Oil System (TLOS), Turbine Main Steam System (TMSS),
- Uninterruptible AC Power Supply,
- Yard Miscellaneous Drain System
- Zinc Injection System (ZNI), an optional system

7.1.6 Conformance with Regulatory Requirements and Industry Codes and Standards

NUREG 0800, Table 7.1 lists the Code of Federal Regulations, General Design Criteria (GDC), Staff Requirements Memoranda, Regulatory Guides, and Instrumentation and Controls Branch Memoranda (HICB), that provide acceptance criteria or guidelines for each subsection of Chapter 7.

The specific regulatory acceptance criteria and guidelines requirements applicable to each of these systems (safety-related or nonsafety-related but significant for plant operation) identified in the SRP are identified and tabulated in Table 7.1-1. The regulatory requirements applicability matrix for Table 7.1-1 is followed in Sections 7.2 through Section 7.8 by a regulatory conformance discussion for each specific system. The degree of applicability and conformance, along with any clarifications or justification for exceptions, are presented in the evaluation

GDCS pools and does not have the capability to manually or automatically switch over to an alternate source. This TMI item does not apply to the GDCS.

7.3.1.2.4 Testing and Inspection Requirements

The GDCS trip logic units are self-tested continually at preset intervals. The trip logic units of each logic division, and the timers for the automatic logic, may be tested during plant operation (IEEE Std. 603, Sections 5.7 and 6.5). 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 Requirements

The performance and effectiveness of the GDCS in a postulated accident may be verified by observing the following control room indications (IEEE Std. 603, Section 5.8):

- 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 pools and RPV; and
- Squib valve open alarm.

The environmental capabilities of the GDCS instrumentation, located in the drywell that is essential for system operation, are designed to operate in a drywell environment resulting from a LOCA. The thermocouples that initiate the deluge valves are qualified to operate in the severe accident environment. safety-related instruments, located outside the drywell, are qualified for the environment in which they must perform their safety-related function.

7.3.2 Passive Containment Cooling System

The Passive Containment Cooling System (PCCS) consists of ~~heat exchanger loops~~condensers that are an ~~extension~~ integral part of the containment pressure boundary. The PCCS heat exchanger tubes are located in a pool of water (IC/PCC pool) outside the containment. A rise in containment (drywell) pressure above the pressure suppression pool (wetwell) pressure, as would occur during a loss of reactor coolant into the drywell, forces flow through the PCCS ~~heat exchanger loops~~condensers. Condensate from the PCCS drains to the GDCS pools. As the flow passes through the PCCS ~~heat exchangers~~condensers, heat is rejected to the IC/PCC pool, thus cooling the containment. This action occurs automatically without the need for actuation of components. The PCCS does not have

of route are documented based on the predicted number of times usage either per year and/or per refueling or service outage.

9.1.5.4 System Description

9.1.5.5 Fuel Building and Reactor Building Cranes

Fuel Building Crane

The Fuel Building (FB) is a reinforced concrete structure enclosing the Spent Fuel Pool, cask handling and cleaning facility, and other equipment. The FB crane provides heavy load lifting capability for the Fuel Building floor. The main hook (160-ton capacity) is used to lift new fuel shipping containers and the spent fuel shipping cask (refer to Table 9.1-6). The orderly placement and movement paths of these components by the FB crane preclude transport of these heavy loads over the Spent Fuel Pool.

The FB crane is used during refueling/servicing as well as when the plant is on-line. Minimum crane coverage includes the FB floor laydown areas, cask wash down area, and the FB equipment hatch. During normal plant operation, the crane is used to handle new fuel shipping containers and the spent fuel shipping cask. The FB crane is interlocked to prevent movement of heavy loads over the Spent Fuel Pool.

Reactor Building Crane

The Reactor Building (RB) is a reinforced concrete structure enclosing the Reinforced Concrete Containment Vessel (RCCV), the refueling floor, the new fuel storage buffer pool, buffer pool deep pit pool for spent fuel storage, the dryer and chimney head/separator, and other equipment. The Reactor Building crane provides heavy load lifting capability for the refueling floor. The main hook (150-ton capacity) is used to lift the drywell head, RPV head insulation, RPV head, dryer, chimney head / separator strongback, and RPV head stud tensioning equipment (refer to Table 9.1-7). The orderly placement and movement paths of these components by the RB crane preclude transport of these heavy loads over the spent fuel racks in the deep pit buffer pool or over the new fuel rack.

The RB crane is used during refueling/servicing as well as when the plant is on-line. Minimum crane coverage includes the RPV for shield block removal and vessel servicing RB refueling floor lay down areas, RB equipment storage, refueling floor and the equipment hatches. The RB crane is interlocked to prevent movement of heavy loads over the fuel pools.

9.1.5.6 Other Overhead Load Handling System

Upper Drywell Servicing Equipment

The upper drywell arrangement provides servicing access for the main steam isolation valves (MSIVs), feedwater isolation valves, safety/relief valves (SRVs), depressurization valves (DPVs), ~~Passive Containment Cooling~~Isolation Condenser System (~~PCCS~~ICS) valves, Gravity-Driven Cooling System (GDCS) valves, and drywell cooling coils, fans and motors. Access to the space is from the RB through either the upper drywell personnel lock or equipment hatch. Equipment is removed through the upper drywell equipment hatch. Platforms are provided for servicing the feedwater and main steam isolation valves, safety/relief valves, and drywell cooling

9.2.3-2 ASME Boiler and Pressure Vessel Code (B&PVC), Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components (see Table 1.9-22)

9.2.4 Potable and Sanitary Water Systems

The Potable and Sanitary Water Systems meets GDC 60 for provisions provided to control the release of liquid effluents containing radioactive material. The Potable and Sanitary Water Systems have no interconnections to systems with the potential for containing radioactive material.

The COL applicant will provide the design of the potable and sanitary water system that provides sufficient supply and is designed to provide a minimum of 12.6 l/s (200 gpm) of potable water during peak demand periods.

The COL applicant will provide design of wastewater effluent systems that properly disposes of sanitation wastes.

9.2.5 Ultimate Heat Sink

In the event of an accident, the Ultimate Heat Sink (UHS) is provided by the Isolation Condenser / Passive Containment Cooling ~~System~~ (IC/PCC~~S~~) pools, which provide the heat transfer mechanism for the reactor and containment to the atmosphere. Subsection 5.4.6 provides a discussion of the Isolation Condenser System (ICS). Subsection 6.2.2 provides a discussion of the Passive Containment Cooling System. To ensure sufficient water inventory for the initial 72 hours of an accident, connections between the Dryer/Separator pool and IC/PCC pools open passively on a low level set point in the IC/PCC pool.

The ~~IC/PCCS~~ IC/PCC pools meet~~s~~ GDC 2, by compliance with Regulatory Guide (RG) 1.29. The applicable sections of RG 1.29 include Position C.1 and C.2. The seismic and quality group classifications are identified in Table 3.2-1. The IC/~~PCCS~~ PCC pools with makeup from the Dryer/Separator Pool and Reactor Well meet~~s~~ GDC 2, by compliance with Regulatory Guide (RG) 1.27 Positions C.2 and C.3 by providing a highly reliable source of decay heat. A separate reservoir is not required for the ESBWR Standard Plant.

The IC/PCC~~S~~ pools meet~~s~~ GDC 5 for shared systems and components important to safety. The IC/PCC~~S~~ pools Standard Plant design does not share any SSC with any other unit.

The requirements of Criterion 44 for heat transfer to the ultimate heat sink are met. The ESBWR ultimate heat sink is the IC/PCC pools. In the event of a design basis accident, heat is transferred to the IC/PCC pool(s) through either the Isolation Condenser System (ICS) or the Passive Containment Cooling System (PCCS). The water in the IC/PCC pool(s) is allowed to boil and the resulting steam is vented to the environment. The IC/PCC~~S~~ pools ha~~s~~ve no active components and require~~s~~ ~~no~~neither electrical motive power nor control and instrumentation functions to perform ~~its~~ their safety-related function of transferring heat to the ultimate heat sink. The connections to the Dryer/Separator Pool are required to ensure sufficient coolant for the initial 72 hours of an accident, however these connections open passively, are redundant, and require no motive power to operate. Therefore, no credible single failure can prevent these ~~PCCS~~pools from performing their~~its~~ safety-related function.

The IC/PCC pool is located outside containment and is accessible for periodic inspections. During outages, the IC/PCC pool subcompartments and expansion pools can be drained to permit inspection of the ~~condensers~~pool liner and components of the ICS and PCCS, including Dryer/Separator pool connections. ~~PCCS piping inside containment can be inspected during outages.~~ The features of the IC/PCCS pools meet the requirements of Criterion 45.

The design of the IC/PCCS pools meets the requirements of Criterion 46. ~~Redundancy and isolation are provided to allow periodic pressure testing of the PCCS.~~ Functional testing to assure structural leaktight integrity is accomplished by maintaining pool level and monitoring for leaks during periodic walkdowns. As discussed in the evaluation of Criterion 44, the IC/PCCS pools ~~contains~~ require no active components aside from the connections to the Dryer/Separator pool which can be periodically inspected or tested during a refueling outage~~; therefore, functional testing is not necessary.~~. These inspections and testing combined with periodic inspections described in the response to Criterion 45 verify system integrity.

The Fire Protection System (FPS) provides post accident makeup to the IC/PCCS pools through safety-related Fuel and Auxiliary Pool Cooling System (FAPCS) piping. The FPS also provides post-accident makeup to the Spent Fuel Pool (SFP). Subsection 9.5.1.1 discusses the FPS as a backup emergency makeup water source through the FAPCS. Table 9.5-2 provides IC/PCCS pools and SFP minimum total makeup flow rate at 72 hours into an event. Subsection 9.5.1 states that the FPS provides on-site makeup water capability from 72 hours to 7 days, after which time offsite makeup sources can be provided via safety-related external FAPCS connections outside the Reactor and Fuel Buildings or on-site makeup sources, if available, can be used. Table 9.5-2 provides flow rate requirements for the makeup water sources. Normally, the makeup water quality is required to meet demineralized water chemistry requirements. However, during accident conditions, makeup water quality can meet fire protection water chemistry requirements.

The principle heat source is decay heat from the fuel. The decay heat input rate decreases with time as shown in the Figure 6.2-10c series of decay heat curves. The evaporation and, therefore, makeup water demand would not exceed the Table 9.5-2 rate beyond 72 hours. Subsection 9.1.3.2 discusses the use of the FAPCS to provide water after 72 hours post-accident. The requirement for 30-day water makeup capability during an accident is identified in Table 1.9-9, SRP Section 9.2.5.

9.2.5.1 COL Unit-Specific Information

The COL applicant will develop procedures to use an external makeup water supply through the FAPCS to the IC/PCCS pools and SFP beyond 7 days following an accident. The external makeup water supply will, as a minimum, meet the flow requirements of the Table 9.5-2 section entitled, "Required minimum total makeup flow rate to IC/PCC and spent fuel pools at 72 hours into an event," and, as a minimum, the fire protection water chemistry requirements.

9.2.5.2 References

None.

- A single failure is not assumed because fire protection does not require considering a single failure. The systems available for vessel inventory and pressure control, containment pressure/temperature control and suppression pool temperature control are:
  - Isolation Condensers (ICs)
  - Control Rod Drive (CRD) pumps
  - Fuel and Auxiliary Pools Cooling System (FAPCS) in any mode
  - Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) in any mode
  - Safety Relief Valves (SRVs)
  - Depressurization Valves (DPVs)
  - Gravity-Driven Cooling System (GDCS) squib valves
  - GDCS loops
  - Passive Containment Cooling System (PCCS) ~~loops.~~
- No Spurious operation of SRV or DPV is assumed.
- It is conservatively assumed that it would take 10 minutes for operators to evacuate from MCR to remote shutdown panel (RSP).
- Four ICs are automatically initiated when the reactor water level reaches Level 2, to stabilize the plant (Three ICs are credited in the SBO analysis). Operators can monitor from RSP and manually control ICs to assure the maximum cooldown rate not exceeding 100°F/hr, if necessary.
- When the reactor water level reaches Level 2, CRD pumps are automatically initiated to provide vessel inventory makeup. (Not credited in SBO analysis). The maximum delayed time is 145 seconds upon restoring alternating current (AC) power because off-site power is not available. CRD pumps shall keep the water level above Level 1 to avoid any Automatic Depressurization System (ADS) initiation to blow down the reactor pressure vessel.
- After the operator regains the control in RSP, monitoring and manual control are necessary. RWCU/SDC shall be initiated following the normal shutdown procedure to ensure the reactor pressure vessel temperature is below 212°F within 72 hours to meet the cold shutdown requirement.
- ICs and CRD pump flow stabilize the plant. SRVs, DPVs, PCCS and GDCS can be utilized if IC does not stabilize the plant, which is very unlikely.

15.5.6.3 Analysis Results

At event initiation, reactor scram occurs. Therefore core subcriticality is achieved and maintained.

The analysis results (station blackout event) in Subsection 15.5.5 can be conservatively applied for this fire protection analysis, because more ICs are available for fire protection. As shown in Figure 15.5-10, with operation of three ICs, the reactor water level is well above the top of active

3.6 CONTAINMENT SYSTEMS

3.6.1.7 Passive Containment Cooling System (PCCS)

LCO 3.6.1.7 Six PCCS condensersloops shall be OPERABLE.

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

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more PCCS condensersloops inoperable.	A.1 Restore PCCS condensersloops to OPERABLE status.	8 hours
B. Required Action and associated Completion Time not met.	B.1 Be in MODE 3. AND 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 condenserloop 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 condenserloop 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 condenserloop

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 IC/PCC pools following a LOCA. The PCCS consists of six independent ~~loops~~condensers. Each ~~loop~~condenser is a heat exchanger (condenser) that is ~~a closed loop extension~~an integral part of the containment pressure boundary. The condensers are located above the ~~containment~~ drywell and are submerged in a large pool of water (IC/PCC pool) that is at atmospheric pressure. Steam produced in IC/PCC pools by boiling around the PCCS condensers is vented to the atmosphere. LCO 3.7.1, "Isolation Condenser (IC)/Passive Containment Cooling (PCC) 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 ~~containment~~ 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 GDCS pools. By returning the condensate to the GDCS pools, it is available to return to the RPV via the GDCS injection lines. Noncondensable gases that collect in the condensers during operation are purged to the suppression pool via vent lines. 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 ~~heat exchanger loops~~condensers. As the flow passes through the PCCS ~~heat exchangers~~condensers, heat is rejected to the IC/PCC pool, thus cooling the containment.

There are no isolation valves on the PCCS inlets from the drywell, or the drain lines to the GDCS pools, or the vent lines to the suppression pool. The PCCS does not have instrumentation, control logic, or power-actuated valves, and does not need or use electrical power for its

BASES

BACKGROUND (continued)

operation. This configuration makes the PCCS fully passive because no active components are required for the system to perform its design function (Ref. 2).

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/PCC pool. During a LOCA, pool water temperature could rise to about 101°C (214°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/PCC 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/PCC pool water.

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

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).

LCO

This LCO requires six PCCS ~~loops~~condensers to be OPERABLE. OPERABILITY of a PCCS ~~loop~~condenser requires that all the performance and physical arrangement SRs for the PCCS ~~loops~~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/PCC pools is available to provide required

BASES

LCO (continued)

cooling water to the PCCS ~~loop~~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 System (ICS)/Passive Containment Cooling System (PCCS) Pools." {There are no requirements for temperature in individual PCCS condenser subcompartments.}

APPLICABILITY

The PCCS ~~loops~~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 ~~loops~~condensers are inoperable, the functional capability of the passive containment cooling is degraded. All six PCCS ~~loops~~condensers must be made OPERABLE within 8 hours to ensure that containment cooling capacity is maintained. The Completion Time of 8 hours has been shown to be acceptable by Reference 3.

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 ~~loop~~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/PCC pools is available to each condenser. If this SR is not met, the associated PCCS ~~loop~~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/PCC 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 the condenser in each PCCS ~~loop~~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 ~~loop~~condenser. This Frequency requires testing one of the six PCCS ~~loops~~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

REFERENCES

1. Chapter 6.
2. Chapter 19.
3. {NEDO-33201, "ESBWR Design Certification Probabilistic Risk Assessment."}

B 3.7 PLANT SYSTEMS

B 3.7.1 Isolation Condenser (IC)/Passive Containment Cooling (PCC) Pools

BASES

BACKGROUND

The Ultimate Heat Sink (UHS) is the Isolation Condenser (IC)/Passive Containment Cooling (PCC) Pools that transfer heat from the Isolation Condenser System (ICS) and the Passive Containment Cooling System (PCCS) to the atmosphere (Ref. 1). The ICS removes heat from the Reactor Coolant System (RCS) following RCS isolation, a loss of feedwater or a Loss of Coolant Accident (LOCA). The PCCS removes heat from the containment following a LOCA or any transient that releases heat to the containment.

The IC/PCC pools are located above and outside the containment boundary, directly above the drywell top slab. The condenser module associated with each ICS train and PCCS ~~loop~~condenser is submerged in a separate subcompartment of the IC/PCC pools. Subcompartments (i.e., pools) P3A, P3B, P3C, and P3D contain the condenser modules for the ICS trains. Subcompartments P4A, P4B, P4C, P3D, P4E, and P4F contain the condenser modules for the PCCS ~~loop~~condensers.

Heat from the ICS and PCCS condensers is transferred to water in the associated subcompartment causing the water in the subcompartment to boil. Following reactor pressure vessel (RPV) isolation or a LOCA, subcompartment water temperature could rise to about 101°C (214°F). The steam formed will be non-radioactive and have a slight positive pressure. The steam from each subcompartment collects in the common air/steam space above the subcompartments and IC/PCC pools. The steam is then released to the atmosphere through two large-diameter discharge vents located on opposite sides of the expansion pools. A moisture separator is installed at the entrance to the discharge vent lines to preclude excessive moisture carryover and loss of IC/PCC pool water. No forced circulation equipment is required for operation (Refs. 2 and 3).

To support decay heat removal for 72 hours without operator action, water must be supplied to the IC and PCC subcompartments to replace the water lost by boiling. This water is supplied from the two IC/PCC expansion pools, the dryer/separator pool, and the reactor well pool.

Each IC and PCC subcompartment is connected to its associated expansion pool by a manually operated valve located below the water level, which allows makeup water from the expansion pool to flow into the

BASES

BACKGROUND (continued)

bottom of the subcompartment. The subcompartment isolation valves are normally locked open so that the full inventory of the associated expansion pool is available to any subcompartment. The subcompartment isolation valves can be closed to isolate a subcompartment allowing it to be emptied for maintenance of the condenser.

In addition to the IC and PCC subcompartments, each expansion pool is partitioned into three parts. Manually operated valves, which are normally locked open, separate each partition.

The dryer/separator pool and reactor well pool are normally isolated from the expansion pools because the dryer/separator pool and reactor well are maintained at a higher water level than the expansion pools. The dryer/separator pool is connected to each expansion pool by redundant {squib} valves that open automatically when there is a low level in the expansion pools. The dryer/separator pool is connected to the reactor well pool through the reactor well gate, which is not installed during normal plant operation. By connecting the dryer/separator pool and reactor well pool to the expansion pools, the volume of water available to the ICS and PCCS subcompartments is sufficient to support decay heat removal for 72 hours without operator action or the need to replenish the water in the expansion pools.

Cooling and clean up of IC/PCC pool water is performed by Fuel and Auxiliary Pools Cooling System (FAPCS). The FAPCS includes a separate subsystem with its own pump, heat exchanger, and water treatment unit that is dedicated for cooling and cleaning of the IC/PCC pools to prevent radioactive contamination of the IC/PCC pools. The FAPCS includes flow paths for post-accident make-up water transfer, from the fire protection system and off-site water supply sources to the IC/PCCS pools (Ref. 1).

APPLICABLE SAFETY ANALYSES

In the event of a LOCA, the passive PCCS is required to maintain the containment peak pressure and temperature below design limits for at least 72 hours after the LOCA without operator action (Ref. 3).

In the event of reactor isolation or a station blackout, the ICS must maintain the reactor coolant system pressure and temperature below design limits and remove core decay heat for at least 72 hours after reactor isolation without operator action (Ref. 2).

BASES

APPLICABLE SAFETY ANALYSES (continued)

The IC/PCC pools are also needed as a heat sink for the ICS condensers when ICS is used as a backup to the Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDC) system for decay heat removal when shutdown.

The IC/PCC pools satisfy Criterion 3 of 10 CFR 50.36(c)(2)(ii).

LCO

This LCO requires that the IC/PCC pools are OPERABLE. Operability requires the IC/PCC pools be maintained within specified limits for minimum level and maximum average temperature.

To ensure that the total volume of water in the IC/PCC pools is available to the IC and PCC condensers, isolation valves between the partitions within each expansion pool must be locked open and the isolation valves between the dryer/separator pool and the expansion pools must open automatically on a low water level signal from the expansion pools. Additionally, the reactor well gate, which connects the reactor well to the dryer/separator pool, must be removed.

APPLICABILITY

The IC/PCC pools are required to be OPERABLE in MODES 1, 2, 3, and 4 because the PCCS and ICS could be required to respond to an event that caused pressurization and heat up of containment or the ICS could be required to respond to an RPV isolation.

Requirements for the IC/PCC expansion pools in MODE 5 are determined by the requirements of LCO 3.5.5, Isolation Condenser System (ICS) - Shutdown.

ACTIONS

A.1

If the IC/PCC pool is not OPERABLE, the ICS and PCCS may not be capable of performing their required safety function for 72 hours and the initial conditions used in the analyses in References 2 and 3 may not be met. Required Action A.1 requires that the IC/PCC pools be restored within 8 hours. The Completion Time of 8 hours is acceptable because the IC/PCC pools still provide substantial heat sink capacity and there are alternate methods for providing makeup to the IC/PCC pools.

BASES

ACTIONS (continued)

B.1 and B.2

If the Required Action and associated Completion Time of Condition A are not met, Required Action B.1 requires that the plant 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.

SURVEILLANCE REQUIREMENTS

SR 3.7.1.1 and SR 3.7.1.2

This SR requires verification every 24 hours that the water levels in each expansion pool and the water level in the dryer/separator pool or reactor well are within specified limits. These levels are necessary to ensure that the volume of water in the IC/PCC pools is sufficient to support decay heat removal via the ICS and/or the PCCS for 72 hours without the need to replenish the water in the expansion pools. The 24 hour frequency is acceptable because abnormal water levels are identified by alarms and indication in the control room.

SR 3.7.1.2 is modified by a Note that specifies that this SR is not required to be met in MODES 3 and 4. Considering the reduced decay heat loads following events initiated after the reactor is shutdown, isolation of these pools from the IC/PCC expansion pools when in Modes 3 and 4 will not result in a significant reduction in the 72 hours assumed available to provide makeup to the IC/PCC pools.

SR 3.7.1.3

This SR requires verification every 24 hours that the bulk average temperature of the IC/PCC pools is ≤ 43.3°C (110°F). The bulk average temperature is calculated based on the volume and temperature of the water in the expansion pools, the IC and PCC subcompartments, the dryer/separator pool, and the reactor well. This value for the average temperature of the IC/PCC pools is an assumption in the analyses described in References 2 and 3 that determined that the heat sink capacity of the IC/PCC pools is sufficient to support decay heat removal for 72 hours without the need to replenish the water in the expansion pools. The 24 hour frequency is acceptable because operators will be promptly alerted to abnormal water temperatures by alarms and indication in the control room.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.7.1.4

This SR requires verification every 24 months that each manual isolation valve between the IC/PCC expansion pool partitions is locked open. This SR is needed to ensure that the full volume of water in each expansion pool is available to the IC and PCC subcompartments. If this SR is not met, the ICS and PCCS may not be capable of performing their 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/PCC pool partitions are locked open and maintained in their correct position under administrative controls.

SR 3.7.1.5

This SR requires verification every 24 months that the reactor well-to-dryer/separator pool gate is not installed. This SR is necessary to ensure that the volume of water in the reactor well is available to the ICS and/or the PCCS condensers. The volume of water in the reactor well is needed to support decay heat removal for 72 hours without the need to replenish the water in the expansion pools. The 24 month frequency is acceptable because installation of the reactor well-to-dryer/separator pool gate is a significant change in plant status that would not occur without the cognizance of the operators.

This SR is modified by a Note that specifies that this SR not required to be met in MODES 3 and 4. Considering the reduced decay heat loads following events initiated after the reactor is shutdown, isolation of this pool from the IC/PCC expansion pools when in Modes 3 and 4 will not result in a significant reduction in the 72 hours assumed available to provide makeup to the IC/PCC pools.

SR 3.7.1.6

This SR requires verification every 24 months that each isolation valve between the IC/PCC expansion pools and the dryer/separator actuates on an actual or simulated automatic initiation signal. At least one of the two valves that isolate each expansion pool from the dryer/separator pool must be open to ensure that the volume of water in the dryer/separator pool and the reactor well is available to the ICS and/or the PCCS ~~heat exchanger~~condensers. The volume of water in the reactor well and the dryer/separator pool is needed to support decay heat removal for 72 hours without the need to replenish the water in the expansion pools.

BASES

SURVEILLANCE REQUIREMENTS (continued)

This 24 month Frequency is consistent with the normal refueling interval. This interval will allow the SR to be performed during a plant outage. This SR is modified by a Note that excludes valve actuation as a requirement for this SR to be met. This is acceptable because the design of the {squib-actuated} valve was selected for this application because of its very high reliability.

This SR is modified by a Note that specifies that this SR not required to be met in MODES 3 and 4. Considering the reduced decay heat loads following events initiated after the reactor is shutdown, isolation of this pool from the IC/PCC expansion pools when in Modes 3 and 4 will not result in a significant reduction in the 72 hours assumed available to provide makeup to the IC/PCC pools.

SR 3.7.1.7

This SR requires verification every 10 years that each ICS and PCCS pool subcompartment has an unobstructed path for steam release through moisture separator to the atmosphere. This SR is needed to ensure that steam formed in the ICS and PCCS subcompartments will be properly vented to the atmosphere. The Frequency is based on engineering judgment and the simplicity of the design. This Frequency is acceptable because the flow path from the ICS subcompartments to the expansions pool area and through the moisture separators will be verified whenever the ICS is used.

REFERENCES

1. Chapter 9.
2. Chapter 5.
3. Chapter 6.