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Subject: **Response to Portion of NRC RAI Letter No. 350 Related to ESBWR Design Certification Application – DCD Tier 2 Section 4.4 – Thermal and Hydraulic Design; RAI Number 4.4-23 S03**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to a portion of the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) letter number 350 sent by NRC letter dated June 15, 2009 (Reference 1). RAI Number 4.4-23 S03 is addressed in Enclosure 1. Enclosure 2 contains the DCD changes to Tier 1 and Tier 2 as a result of GEH's response to this RAI. Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 09-413 Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, GEH, *Request For Additional Information Letter No. 350 Related to ESBWR Design Certification* dated June 15, 2009

Enclosures:

1. Response to Portion of NRC RAI Letter No. 350 Related to ESBWR Design Certification Application - DCD Tier 2 Section 4.4 – Thermal and Hydraulic Design; RAI Number 4.4-23 S03
2. Response to Portion of NRC RAI Letter No. 350 Related to ESBWR Design Certification Application – DCD Tier 1 and Tier 2 DCD Markups for RAI Number 4.4-23 S03

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0106-0460 (RAI 4.4-23 S03)

ENCLOSURE 1

MFN 09-556

Response to Portion of NRC RAI Letter No. 350 Related to ESBWR Design Certification Application

DCD Tier 2 Section 4.4 – Thermal and Hydraulic Design

RAI Number 4.4-23 S03

NRC RAI 4.4-23 S03

Bundle lower tie plate, inlet orifice, and debris filter of the ESBWR GE14E fuel

In RAI4.4-23 S02 (MFN 08-613) the following request was not addressed in the response to update the DCD, Tier 2. "Considering that the bundle lower tie plate, inlet orifice, and debris filter of the ESBWR GE14E fuel are identical to those used in the operating fleet of GE14 fuel, the staff expects that GEH will address in DCD, Tier 2, Revision 5 (6), the downstream effects applicable to the ESBWR in a manner similar to that of the BWR Owners Group for operating BWRs. Debris sources and pathways for normal operation and long-term cooling which are unique to the ESBWR should be addressed, such as the Fuel and Auxiliary Pool Cooling System (FAPCS) multiple water sources (suppression pool, GDCS pool, IC/PCCS pool)."

GEH Response

Debris Blockage of Fuel Inlet Side

The BWROG efforts regarding the impact of LOCA debris downstream of the strainers on the fuel are addressing the range of potential LOCA debris sources and debris materials in the domestic BWR fleet. Initial GEH analyses performed for the BWROG, which have been reviewed with the NRC staff in a closed meeting as recently as July 23, 2009, have shown there is long term fuel cooling for GEH fuel even when it is conservatively assumed that the debris completely blocks the inlet to the fuel bundle. This analysis demonstrates that water entering from the top of the fuel bundles can supply the needed cooling to maintain acceptable peak cladding temperatures.

The BWROG is developing a simulated fuel bundle test program with LOCA downstream debris for the GEH fuel, including GE14E, as well as the fuel bundles supplied by other vendors. These tests are expected to show that there will be less than a complete blockage of the fuel bundle inlet under conservative LOCA conditions and the debris will not cause flow blockages internal to the bundle. When the tests confirm the LOCA analysis blockage criteria, the acceptable debris consequences wil be validated. The simulated fuel bundle tests are planned for 2010-2011.

The BWROG program for fuel evaluations with LOCA debris only addresses BWR types 2 through 6, and does not include any specific consideration of the ESBWR. Since the operating fleet of BWRs contain debris source materials that are considered to be more likely to form a complete flow blockage, e.g., fibrous and microporous debris, than the stainless steel reflective metal thermal insulation (RMI) used in the ESBWR, the situation is considerably less severe for the ESBWR than for the operating fleet.

The ESBWR differs from operating domestic BWRs in that the LOCA water level is always above the top of the active fuel and in the case of a mainsteam line break scenario is maintained at or above 7 m (23 ft) after around 1600 seconds (See Figure 5 and 6). This ensures cooling water to be delivered to the fuel bundle through the normal path down the downcomer and then up through the orificed fuel supports and into the fuel bundle, or through an alternate path, should this normal path become blocked, entering the fuel bundle from the top or bottom from the bypass region. Water entering from the top of the fuel bundle would provide sufficient fuel cooling as has been shown in the analyses performed for the BWROG.

For the ESBWR, much of the RMI debris would settle out in the flow from the postulated break to the water inlets (Table 1, Items 4 and 6) to the systems replenishing the water to the reactor vessel. The BWROG URG performed studies of RMI debris in the 1990s and found that the average settling velocity of typical stainless steel RMI debris produced by LOCA conditions is on the order of 0.12 m/s (0.39 ft/s) to 0.15 m/s (0.47 ft/s). For this debris to transport to the water inlet locations within the ESBWR, the flow rates would need to be considerably greater than this settling velocity. The ESBWR DBA LOCA analysis shows that the flow rate in the lower downcomer is very low and in fact the direction of flow fluctuates between 400 and 2000 seconds after the LOCA (See Figure 1). If RMI were present in the downcomer during this time period, the low and oscillating downcomer flow would allow RMI settling to the lower head region prior to being carried to the inlet of the fuel bundles.

The FAPCS suction water inlets contain strainers designed to capture the ESBWR LOCA debris that is larger than the holes in the perforated plate on the strainer surfaces. Small particulate debris from coating failures and dirt/dust in the containment would pass through these strainers and would also pass through the orificed fuel supports, the fuel inlet filters, the internal bundle structures, and would exit out the top of the fuel bundles.

The ESBWR thermal insulation is stainless steel RMI and therefore the LOCA debris will not produce a complete flow blockage at the fuel inlet. Additionally, the large volume of water above the top of the active fuel provides an alternate path for cooling water to reach the fuel should the bottom of the fuel bundle become blocked. GEH will continue to monitor the BWROG activities regarding post-LOCA fuel cooling, but with the ESBWR the fuel is not challenged as much as it is in operating plants because the operating plants contain thermal insulation types, fibrous and microporous debris, that are more likely to produce blockages at the fuel bundle inlet.

Downstream Effects on Equipment

LOCA debris downstream of strainers can potentially affect the performance of pump, pump ancillary features such as seal cooling, valves, flow-control orifices and other equipment used to supply water to the reactor vessel and the fuel bundles.

Operating domestic BWRs addressed downstream LOCA debris in a 1996 report within the Utility Resolution Guidance (URG) for ECCS Suction Strainer Guidance, Evaluation of the Effects of Debris on ECCS Performance, GE-NE-T23-00700-15-21 Revision 1, dated March, 1996, by PF Kachel of Engineering & Licensing Consulting Services. (URG Volume III, Tab 5). The report discussed debris parameters and passage sizes, concluding that bypass debris did not result in any safety concern.

The domestic PWRs are currently addressing downstream debris effects. The PWROG authorized Westinghouse to assess this issue in WCAP-16406-P Revision 1 issued in

August 2007, Evaluation of Downstream Sump Debris Effects in Support of GSI-191. The GSI-191 methodology entailed a more rigorous program of evaluation and testing than previously provided by the URG. The program addresses pumps, valves, orifices, instrument lines, and evaluates the effects of abrasive wear vs. equipment mission time.

During recently completed and ongoing PWR Sump Strainer efforts to address GSI-191, a detailed evaluation and analysis was performed that pertained to the effects of debris that passes through strainer screens, and migrates through system piping and components. This debris has the potential to have a deleterious effect on components that have small clearances or passageways, and can cause abrasive and/or erosive wear on pump wear rings and seals, to provide a few examples.

The BWROG is currently gathering detailed plant information on potential LOCA debris. From these plant specific evaluations, the BWROG will develop a conservative downstream debris mixture and quantity for use in evaluation of domestic BWRs using methods similar to those developed in WCAP-16406-P. The GEH ESBWR design team is monitoring these BWROG activities for any lessons-learned and equipment modifications and will ensure that any resulting equipment modifications are applied to the ESBWR design.

For the PWRs that have been evaluated with the WCAP methodology, equipment modifications were sometimes required for pump cyclone separators, pump seals and bushings, and trim on small manual throttle valves. GEH is aware of these needed modifications and is considering them in the design of ESBWR systems and plant equipment. It should be noted that the ESBWR does not require injection flow balancing and therefore throttle valves are not installed in the flow path from GDCS or FAPCS.

The ESBWR uses stainless steel liners for the suppression pool and other plant features, but small amounts of iron oxide sludge might still reach the FAPCS system. GEH has been designing ECCS equipment that will operate with suspended iron oxide sludge for many years, and will apply the same design rules to the FAPCS system so any sludge would not degrade equipment performance.

Although the FAPCS does not have a safety-related function to deliver long-term core cooling, the ESBWR is being designed with an understanding of the potential impact of LOCA downstream debris. The selected ESBWR equipment is being evaluated against on-going industry-wide evaluations of downstream LOCA debris. Because the ESBWR uses stainless steel RMI as thermal insulation, its' systems and equipment have much less exposure to downstream LOCA debris.

Debris Sources

As given in response to RAI 6.2-173 S01, the bounding debris is RMI of 5.55 m^3 (196 ft^3) generated by a main steam line break (MSLB) of which only half, 2.8 m^3 (98 ft^3) is credited for transport to the suppression pool and will settle out (Table 1, Item 4). While the MSLB does not produce the lowest level in the reactor pressure vessel (RPV), all other RPV level bounding line break scenarios (DCD Tier 2, Table 6.3-5) do not produce debris that is transported to the RPV. See response to RAI 6.2-173 S01 for a discussion of debris generation by various line breaks.

Other types of debris are "paint" chips produced during a break and existing debris such as dirt/dust and rust. "Paint" chips are minimized by the use of approved coatings (DCD Tier 2, Section 6.1), and rust is minimized by the use of stainless steel liners for the suppression pool and GDCS pools and by the use of approved coatings where stainless steel is not used.

Pathways

For normal operations at 100% power the feedwater lines are the potential pathways for debris to be injected into the RPV. Response to RAI 4.4-23 S01 demonstrated adequate cooling for ESBWR channels at 100% power conditions.

There are two potential pathways for injecting debris into the RPV during a LOCA: GDCS Pool injection lines and one feedwater line. The FAPCS in LPCI mode draws water from the suppression pool and injects into the RPV via the single feedwater line. The IC/PCCS pools are outside containment and are not used to provide makeup to the RPV. Table 1 discusses the potential transport of debris for both pathways by following the sequence of events for the MSLB.

From Table 1, RMI will settle out onto the GDCS and suppression pool floors and debris less than 2.508 mm (0.0988 inches) in size will pass through the FAPCS suppression pool suction strainer and potentially reach the RPV where it will pass through the bundle internals.

Conclusion

The MSLB will produce the largest amount of debris in RMI most of which if transported will settle to the bottom of the GDCS and suppression pool floors due to the long time delay between the start of the break and injection by the FAPCS in LPCI mode and by the GDCS pool injection lines. Debris smaller in size than 2.508 mm (0.0988 inches) will potentially pass through the FAPCS suppression pool suction strainer, and thereby limit the size of debris entering the inlet side of a bundle and allowing it to pass through the bundle. In the event that a bundle should become blocked, water may enter through the top and provide sufficient cooling. Water above the bundles will be present, since water is always above top of active fuel. See DCD Tier 2 Table 6.3-5.

The FAPCS suppression pool suction strainer is a Seismic Category I component (DCD Tier 2, Table 3.2-1). DCD Tier 2 Subsection 9.1.3.2 will be revised to add the perforated plate hole size and DCD Tier 1 Table 2.6.2-1, Table 2.6.2-2, and Figure 2.6.2-1 will be revised to add the suction strainer.

DCD Impact

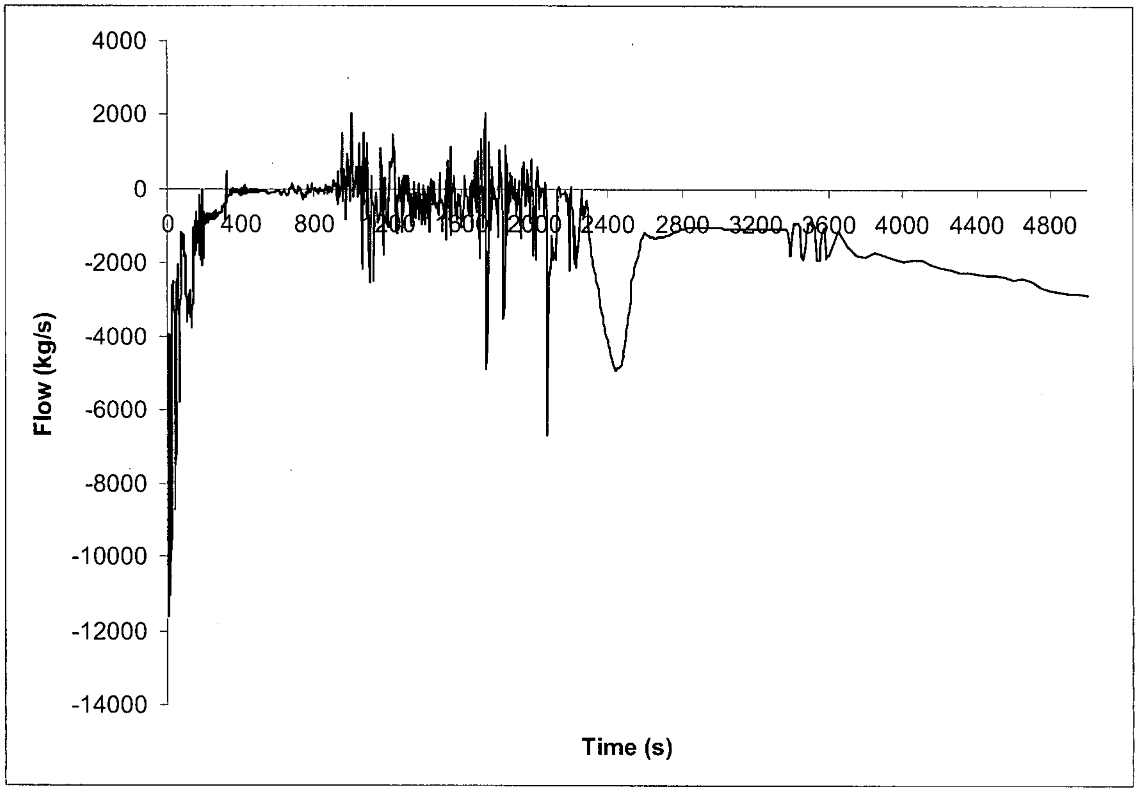
DCD Tier 1 Table 2.6.2-1, Table 2.6.2-2, and Figure 2.6.2-1 and Tier 2 Subsection 9.1.3.2 will be revised as noted in the attached markups.

Table 1. MSLB Debris Transport Sequence of Events

#	Event Description	Discussion
1	MSLB occurs and steam jet impinges on pipes, equipment, and GDCS pool wall.	RMI debris is generated by the steam jet on surrounding pipes and equipment. Debris can potentially enter the GDCS pool through the gap between the top of the wall and the drywell ceiling. The gap is 0.245 m (0.804 ft), and is protected by shield(s) and covered with a perforated plate with holes of maximum diameter of less than 38 mm (1.5 inches). This prevents debris sizes of greater than 38 mm (1.5 inches from entering a pool. The amount of debris entering the pool is minimized by the shield(s) covering the gap where jet impingement is expected and by placing the holes away from these locations. The latitude to place holes is provided by about 95% gap area that can be covered without holes and still drain a GDCS Pool during a LOCA. In addition to the protection provided by shield(s) and plate, any debris impacting the wall would fall to the diaphragm floor, since the most credible location for a break is at the main steam line nozzles, which are about 1.4 m (4.6 ft) below the top of GDCS pool wall. The predicted jet impingement will not impact above the top of the wall. Figure 3 illustrates the jet impingement on the GDCS pool wall from main steam line nozzle breaks.
2	Debris generated in upper drywell transported to suppression pool.	Half of the debris generated is transported to the suppression pool via the vertical/horizontal vents.
3	Operator inadvertently actuates FAPCS in LPCI mode.	LPCI will not start to inject into vessel until RPV depressurizes to below 2.0 MPa (290 psi). 2.0 MPa (290 psi) is the potential maximum pressure the system can provide (Table 9.1-8, tube side maximum pressure for FAPCS heat exchanger).
4	RPV depressurizes below 2.0 MPa (290 psi).	From DCD Tier 2 Figures 6.2-14a2 and 6.2-14j2, it takes about 200 seconds for the RPV to reach 2.0 MPa (290 psi). Given this time, any RMI would settle to the bottom of the suppression pool. The low end settling velocity for RMI is 0.12 m/s (0.39 ft/s) as previously discussed and the high water level for the pool is 5.5 m (18 ft). This gives a settling time of about 46 seconds, which is about a quarter of the time to reach 2.0 MPa (290 psi) leaving ample time for RMI to settle to the bottom.

Table 1. MSLB Debris Transport Sequence of Events

#	Event Description	Discussion
5	LPCI begins into RPV.	Debris suspended in the vicinity of the suction strainer is drawn to it and blocked if greater than 2.508m (0.0988 inches) in size. Debris is limited by the location of the suction strainer since most vertical/horizontal vents are located away from the strainer (See Figure 4). Debris of less than 2.508 mm (0.0988 inches) in size is transported to the RPV. The debris transported will be composed of "paint" chips, which are minimized by the use of qualified coatings, and dirt/dust. RMI on the pool floor will not be pulled to the strainer because of the low velocities. Any debris entering inlet side of a bundle would pass through.
6	150 seconds after Level 1 confirmed GDCS pool injection line valves open.	The GDCS pool injection line valves open approximately 500 seconds after the break. Any RMI that entered the pool at the onset of the MSLB has settled to the bottom of the pool. The high water level for the pool is 6.7 m (22 ft). With the same settling velocity as discussed above, RMI would settle to the pool floor at about 56 seconds. Velocities at the GDCS injection line intake are not high enough to lift the RMI off the floor.
7	Water level remains above top of active fuel.	Water inside the shroud remains above top of active fuel and rises above the top of chimney approximately 1600 seconds and remains at or above that level indefinitely (See Figure 5 and 6). The top of the chimney is located about 7 m (23 ft) above top of active fuel. In the event the inlet side of any bundle blocked, it will receive water from the top of the bundle and at the bottom through the gap that exists between the channel sleeve and lower tieplate. BWROG has demonstrated by analysis that water entering from the top of the fuel bundles can supply the needed cooling to maintain acceptable peak cladding temperatures.



Note: Negative values indicate flow in the downward direction.

Figure 1. Lower Downcomer Flow

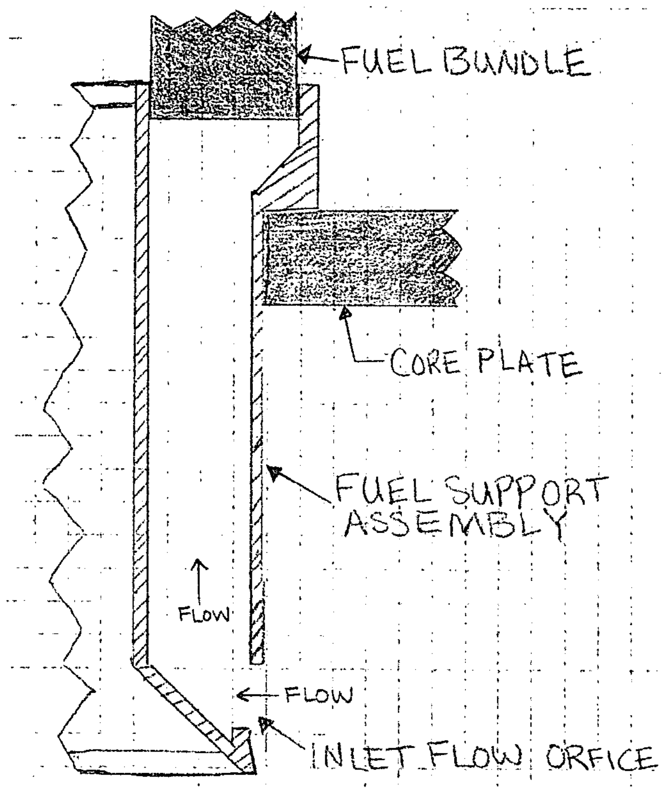


Figure 2. Sketch of Fuel Support Assembly Cross-section

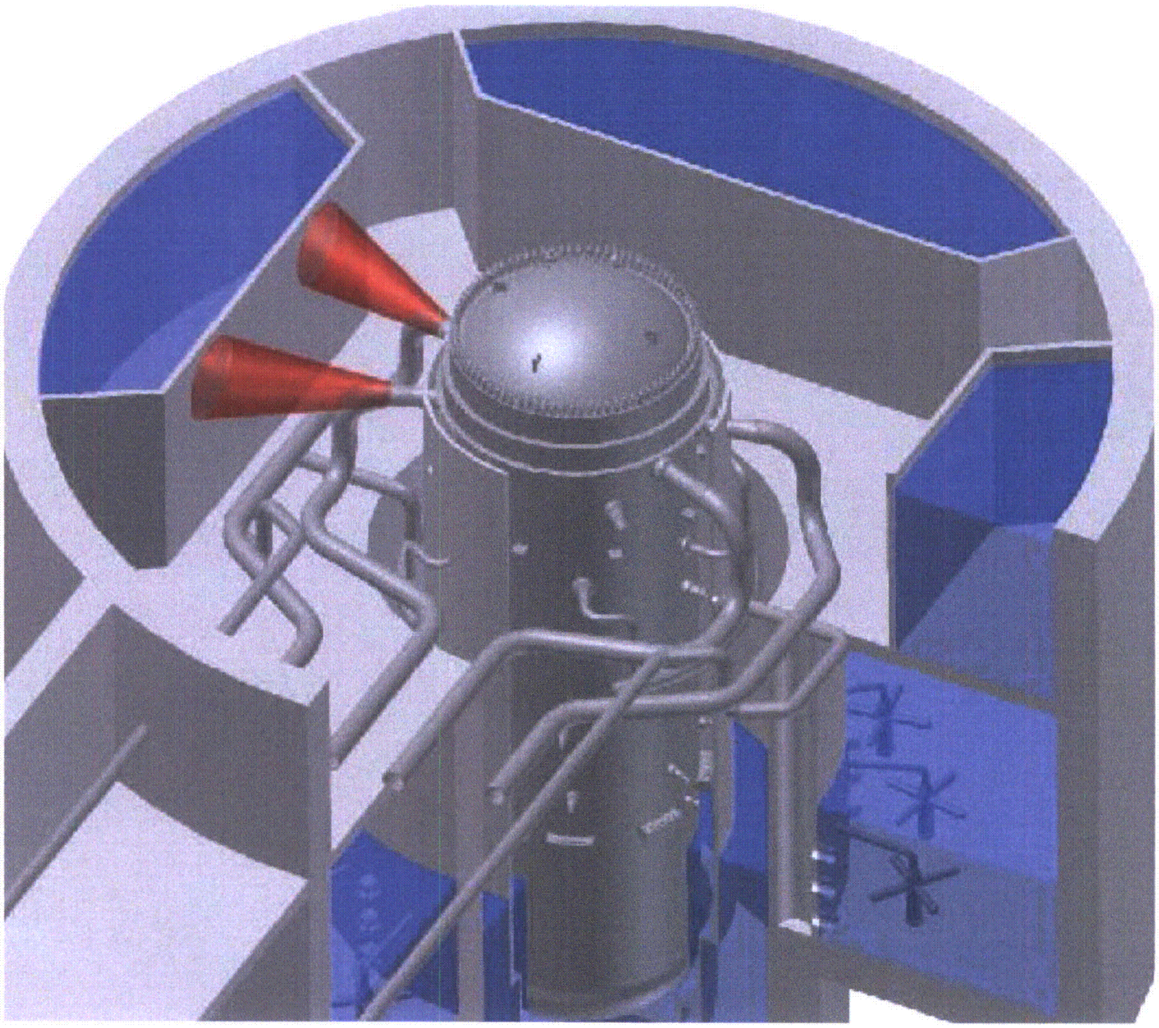


Figure 3. Jet Impingement on GDCS Wall By MSLB at Nozzles

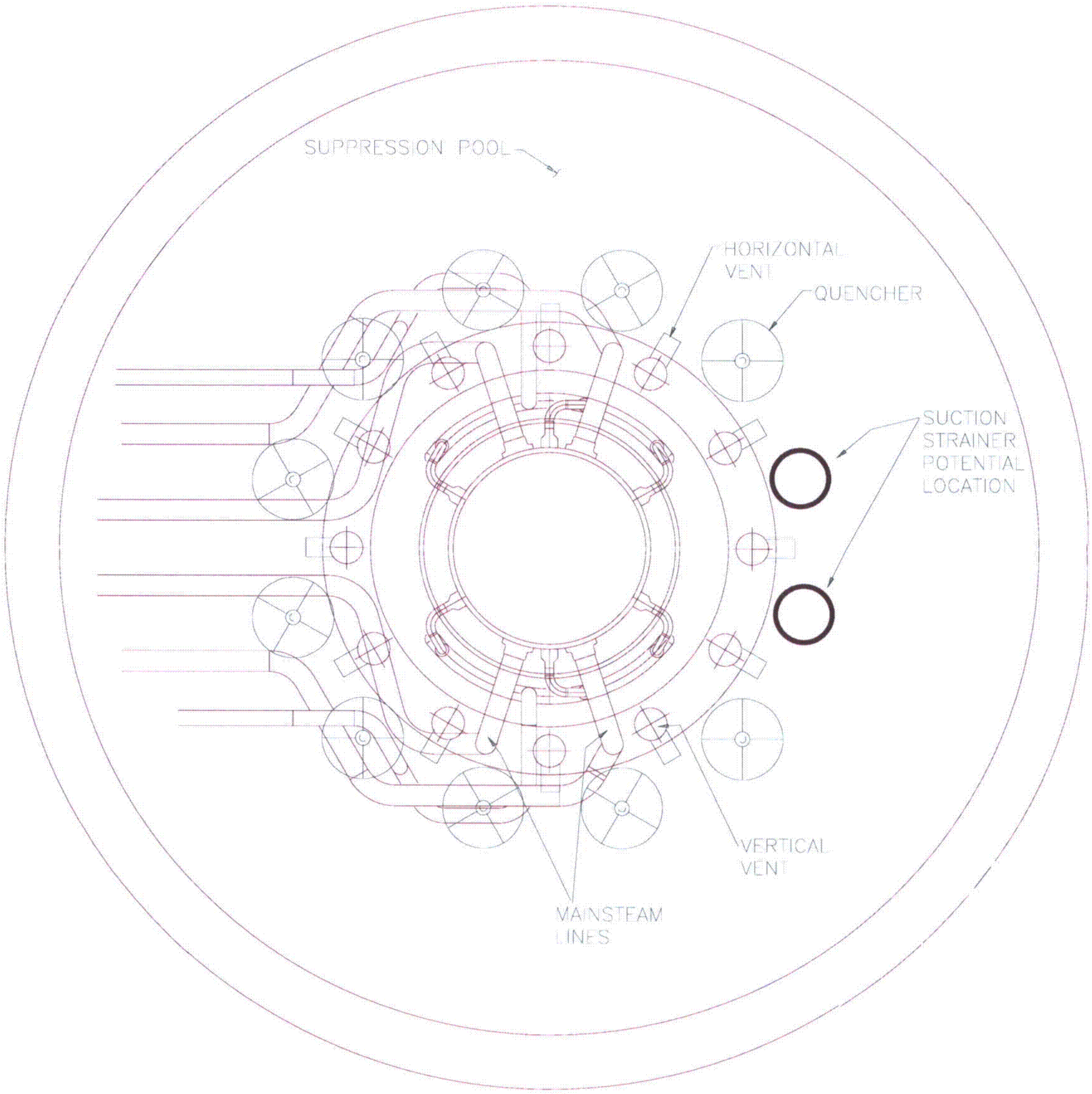


Figure 4. Top View - Suppression Pool with Diaphragm Floor Removed

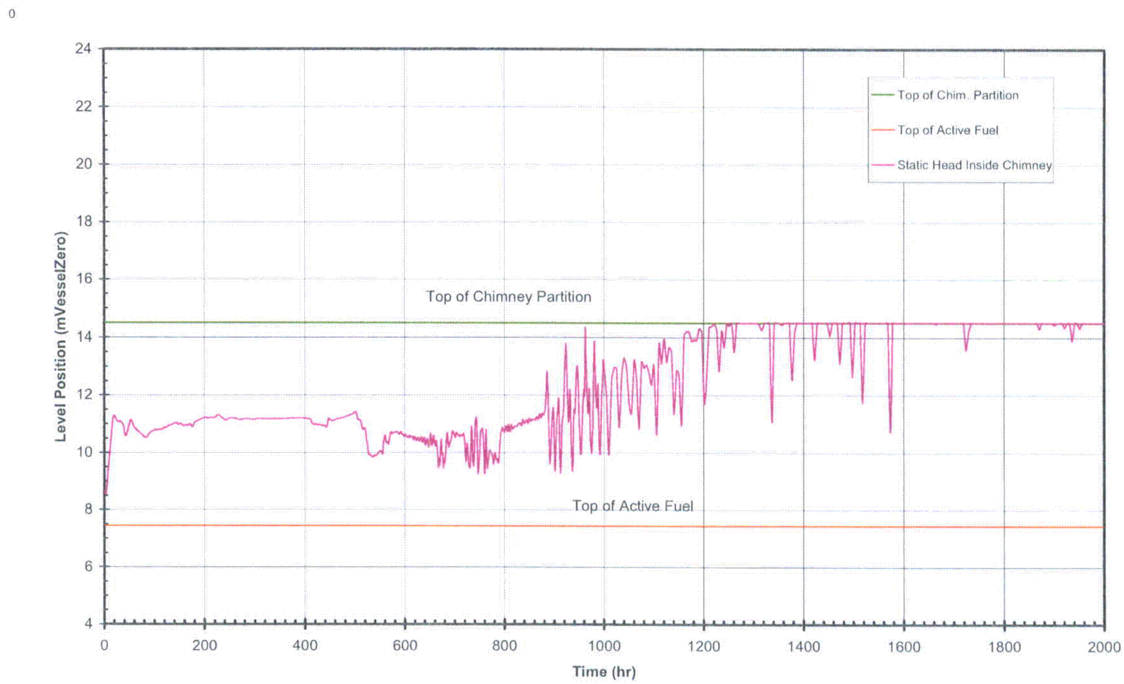
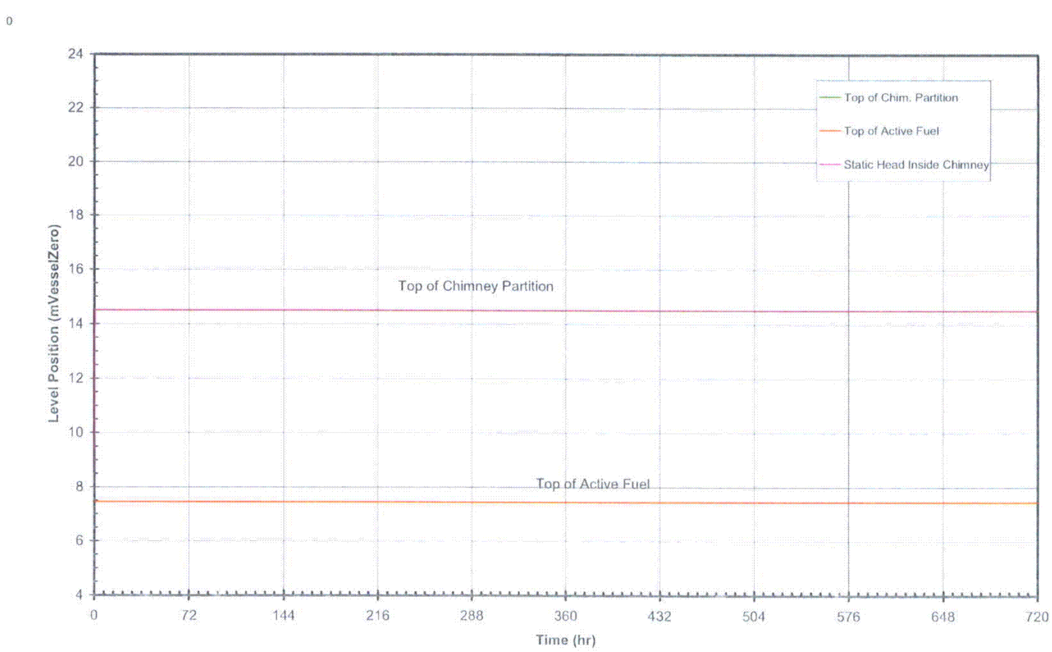


Figure 5. RPV Water Level: 30 Days Post-LOCA Response – First 2000 Seconds



Note: Chimney partition remains full and level is at or above the top of the chimney partition. Data up to the top of the chimney partition is only shown.

Figure 6. RPV Water Level: 30 Days Post-LOCA Response

ENCLOSURE 2

MFN 09-556

Response to Portion of NRC RAI Letter No. 350
Related to ESBWR Design Certification Application

DCD Tier 1 and Tier 2 Markups

for RAI Number 4.4-23 S03

Table 2.6.2-1

FAPCS Mechanical Equipment

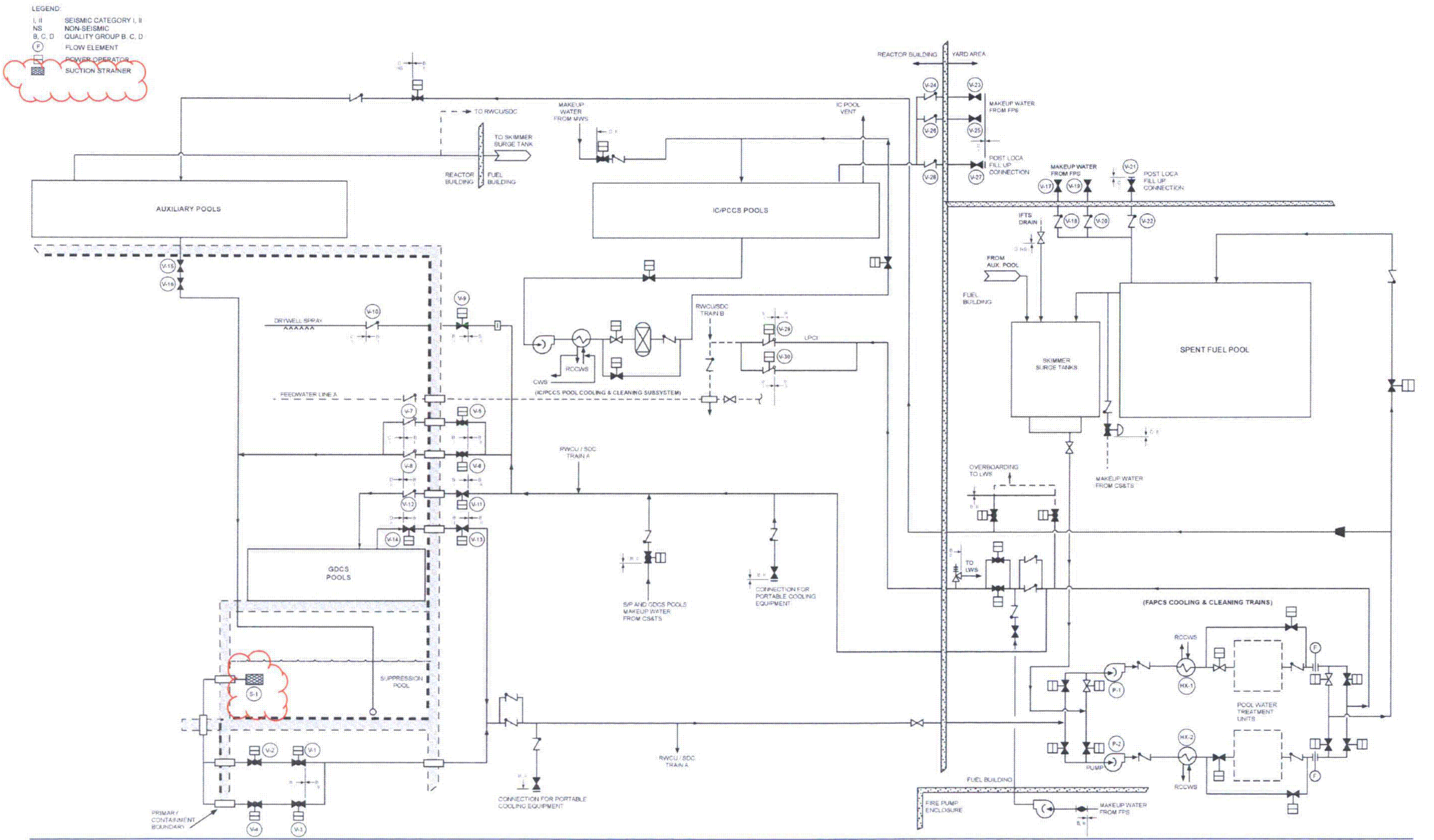
Equipment Name (Description)	Equipment Identifier See Figure 2.6.2-1	ASME Code Section III	Seismic Cat. I	RCPB Component	Containment Isolation Valve.	Remotely Operated	Loss of Motive Power Position
FACPS Heat Exchanger	HX-1	Yes	No	No	N/A	N/A	N/A
FAPCS Heat Exchanger	HX-2	Yes	No	No	N/A	N/A	N/A
FAPCS Suppression Pool Suction Strainer	S-1	Yes*	Yes	No	N/A	N/A	N/A

* ASME Section III materials only.

Table 2.6.2-2

ITAAC For The Fuel and Auxiliary Pools Cooling ~~Cleanup~~ System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
	ii. Perform a type test to confirm the heat transfer capacity of the FAPCS heat exchanger.	ii. The design heat removal capacity of a single FAPCS train is ≥ 8.3 MW under the following conditions: • Primary and secondary side flow rate of 567.8 m^3/hr (2500 gpm) • Process inlet temperature of 48.9°C (120°F) • Cooling water inlet temperature of 35°C (95°F)
	iii. Inspection of as-built FAPCS suppression pool suction intake will be performed to confirm the presence of a suction strainer with perforated plate hole sizes of < 2.508 mm (0.0988 inches).	iii. A suction strainer with perforated plate hole sizes of < 2.508 mm (0.0988 inches) is present on FAPCS suppression pool suction intake.
7b. The FAPCS performs the nonsafety-related ~~L~~low-pressure coolant injection ~~mode~~functions.	Perform a test to confirm the flow path and minimum flowrate [AH1120]from the FAPCS to the RWCU/SDC system.	~~Test report(s) document that t~~The injection flow path is demonstrated and confirmed by operation of the function. The flowrate is ≥340 m3/hr (1500 gal/~~pm~~min)[AH1121] at a differential pressure ~~of~~ ≥ 1.03 MPa (150 psi) and < 1.05 MPa (152 psi).


LEGEND:
I, II SEISMIC CATEGORY I, II
NS NON-SEISMIC
B, C, D QUALITY GROUP B, C, D
FLOW ELEMENT
POWER OPERATOR
SUCTION STRAINER
AUXILIARY POOLS
IC/PCCS POOLS
GDCS POOLS
SUPPRESSION POOL
SKIMMER SURGE TANKS
SPENT FUEL POOL
REACTOR BUILDING
YARD AREA
FUEL BUILDING
FIRE PUMP ENCLOSURE
PRIMARY CONTAINMENT BOUNDARY
DRYWELL SPRAY
FEEDWATER LINE A
(IC/PCCS POOL COOLING & CLEANING SUBSYSTEM)
(FAPCS COOLING & CLEANING TRAINS)
POOL WATER TREATMENT UNITS
RWCU / SDC TRAIN A
RWCU/SDC TRAIN B
LPCI
TO RWCU/SDC
TO SKIMMER SURGE TANK
MAKEUP WATER FROM MWS
IC POOL VENT
MAKEUP WATER FROM FPS
POST LOCA FILL UP CONNECTION
IFTS DRAIN
FROM AUX. POOL
OVERBOARDING TO LWS
MAKEUP WATER FROM CS&TS
S/P AND GDCS POOLS MAKEUP WATER FROM CS&TS
CONNECTION FOR PORTABLE COOLING EQUIPMENT
TO LWS
RCCWS
CWS
PUMP

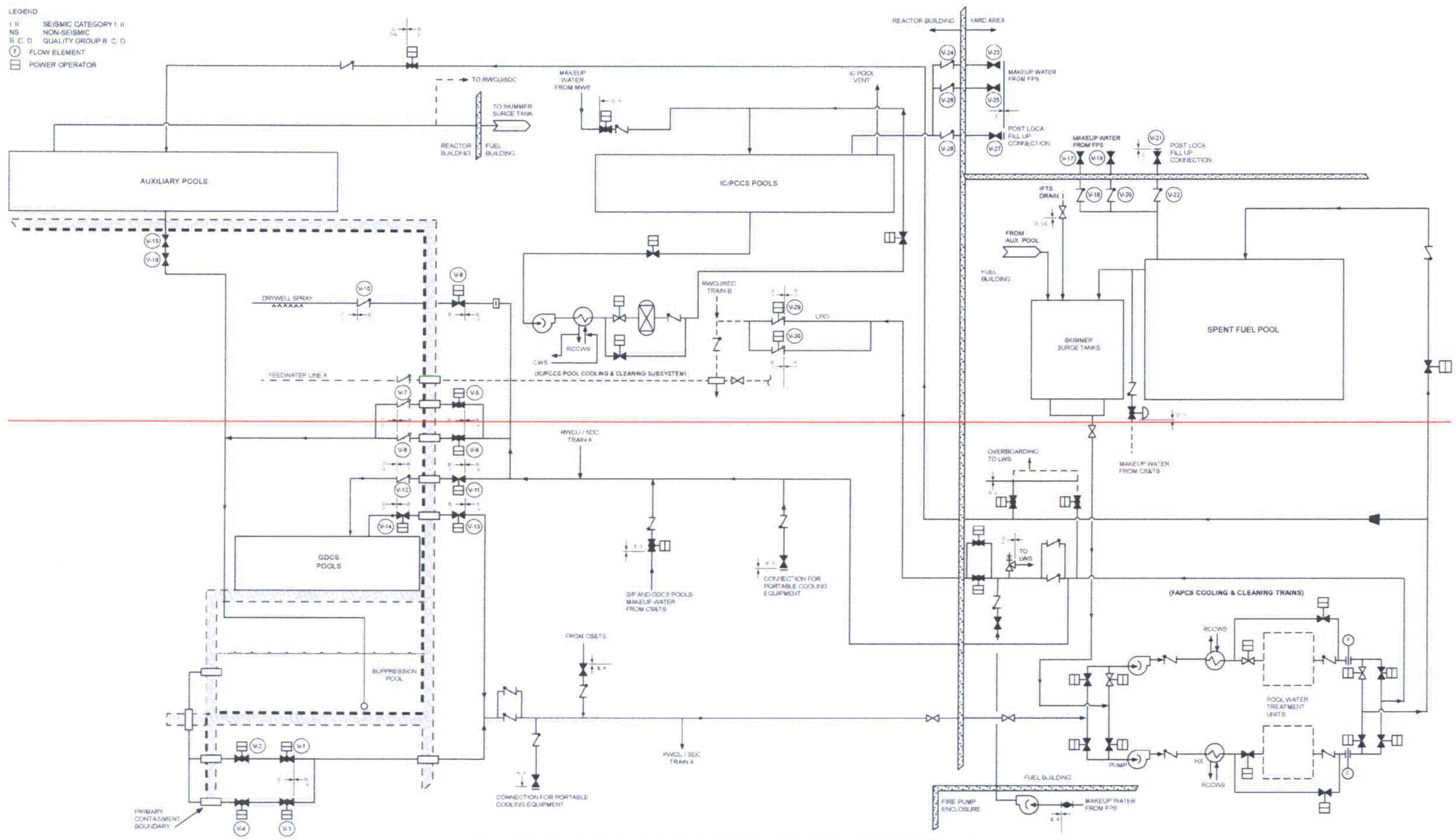


Figure 2.6.2-1. Fuel and Auxiliary Pools Cooling ~~Cleanup~~ System

- Low pressure coolant injection

This includes the suction line from the suppression pool, all of the piping and components in the cooling and cleaning trains except the water treatment units, and the discharge lines to the suppression pool and the LPCI interface up to the safety-related isolation valves.

The FAPCS piping and components that are required to support safety-related and/or accident recovery function have Quality Group B or C and Seismic I or II classification (Table 9.1-3). A Seismic I classification is required for all safety-related functions. The remaining nonsafety-related piping and components that support accident recovery functions are Seismic Category II. This classification satisfies the requirements of SRP 9.1.3 Section I.1.

Detailed System Description

The FAPCS is provided with two cooling and cleanup (C/C) trains with 100% capacity during normal operation. Each FAPCS train is physically separated and has one pump, one heat exchanger and one water treatment unit consisting of a prefilter and a demineralizer.

A manifold of four motor-–operated valves is attached to each end of the FAPCS C/Ccooling and cleanup trains (refer to Figure 9.1-1). These manifolds are used to connect the FAPCS C/Ccooling and cleanup train with one of the two pairs of suction and discharge piping loops to establish the desired flow path during FAPCS operation. One loop is used for the fuel pools and auxiliary pools, and the other loop for the GDCS pools and suppression pool and for injecting water to drywell spray sparger and reactor vessel via the RWCU/SDC System and feedwater pipes.

The use of manifolds with proper valve alignment and separate suction-discharge piping loops:

- 1) Aallows operating of one train independent of the other train to permit on-line maintenance or dual mode operation using separate trains if necessary;, and
- 2) pPrevents inadvertent draining of the pool and minimizes mixing of contaminated water in the Spent Fuel Pool with cleaner water in other pools.

Each water treatment unit is equipped with a prefilter, a demineralizer and a post-–strainer. A bypass line is provided to permit bypass of the water treatment unit, when necessary. To protect demineralizer resin, the water treatment units are bypassed automatically on a high temperature signal. The prefilter and demineralizers of the water treatment units are located in shielding cells so that radiation exposure of plant personnel is within acceptable limits.

Proper physical separation is provided between the active components of the two redundant trains to assure operation of one train in the event of failure of the other train.

A reactor makeup water discharge line is provided for injecting suppression pool water or water from the Fire Protection System to the reactor vessel via Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDC) Loop B and Feedwater Loop A discharge pipes. The suction location in the suppression pool shall beis designed with consideration given to the strainer plugging issues encountered in previous operating experience. The strainer is designed with perforated plate hole sizes of < 2.508 mm (0.0988 inches). This operating mode can utilize two sources of water. The primary flow path draws water from the suppression pool and uses one of the FAPCS trains to discharge it into the RWCU/SDC System. This injection line includes redundant shutoff valves such that the flow path branches to include two parallel flow paths,