Enclosure 2

MFN 16-034

GEH's Response to RAI 06.03-2

ABWR DCD Revision 6 Markups

Table 2.4.1 Residual Heat Removal System (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
4. continued c. The RHR pumps have sufficient NPSH.	4. continued c. Inspections, tests and analyses will be performed upon the as -built RHR System. NPSH tests of the pumps will be performed in a test facility. The analyses will consider the effects of: – Pressure losses for pump inlet piping and components. – Suction from the suppression pool with water level at the minimum value. – ~~5O% blockage of pump suction strainers.~~ → Analytically derived values for blockage of pump suction strainers based upon the as-built system. – Design basis fluid temperature (100°C). – Containment at atmospheric pressure.	4. continued c. The available NPSH exceeds the NPSH required by the pumps.

Table 2.4.2 High Pressure Core Flooder System (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
3. continued d. The HPCF System flow in each division is not less than a value corresponding to a straight line between a flow of 182 m^3/h at a differential pressure of 8.12 MPa and a flow of 727 m^3/h at a differential pressure of 0.69 MPa.	3. continued d. Tests will be conducted on each division of the as-built HPCF System in the HPCF high pressure flooder mode. Analyses will be performed to convert the test results to the conditions of the Design Commitment.	3. continued d. The converted HPCF flow satisfies the following: The HPCF System flow in each division is not less than a value corresponding to a straight line between a flow of 182 m^3/h at a differential pressure of 8.12 MPa and a flow of 727 m^3/h at a differential pressure of 0.69 MPa.
e. The HPCF System has the capability to deliver at least 50% of the flow rates in item 3d with 171°C water at the pump suction.	e. Analyses will be performed of the as-built HPCF System to assess the system flow capability with 171°C water at the pump suction.	e. The HPCF System has the capability to deliver at least 50% of the flow rates in item 3d with 171°C water at the pump suction.
f. System flow into the reactor vessel is achieved within 16 seconds of receipt of an initiation signal and power available at the emergency busses.	f. Tests will be conducted on each HPCF division using simulated initiation signals.	f. The HPCF System flow is achieved within 16 seconds of receipt of a simulated initiation signal.
g. The HPCF pumps have sufficient NPSH available at the pumps.	g. Inspections, tests and analyses will be performed upon the as-built system. NPSH tests of the pumps will be performed in a test facility. The analyses will consider the effects of: – Pressure losses for pump inlet piping and components. – Suction from the suppression pool with water level at the minimum value. – ~~50% minimum blockage of the pump suction strainers~~. Analytically derived values for blockage of pump suction strainers based upon the as-built system.	g. The available NPSH exceeds the NPSH required by the pumps.

Table 2.4.4 Reactor Core Isolation Cooling System (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
3. continued j. The RCIC System pump has sufficient NPSH.	3. continued j. Inspections, tests, and analyses will be performed based upon the as-built system. NPSH tests of the pump will be performed at a test facility. The analyses will consider the effects of: (1) Pressure losses for pump inlet piping and components. (2) Suction from suppression pool with water level at the minimum value. (3) ~~50% blockage of pump suction strainers.~~ Analytically derived values for blockage of pump suction strainers based upon the as-built system. (4) Design basis fluid temperature (77°C). (5) Containment at atmospheric pressure.	3. continued j. The available NPSH exceeds the NPSH required by the pump.
k. The RCIC System operates for a period of at least 2 hours under conditions of no AC power availability and no other simultaneous failures, accidents, or other design basis conditions.	k. Inspections and analyses of the as-built RCIC and supporting systems will be performed to determine RCIC capability.	k. The RCIC System can operate for a period of at least 2 hours under conditions of no AC power availability and no other simultaneous failures, accidents, or other design basis conditions.
l. The RCIC can be started by local operation of the RCIC System components outside the MCR.	l. Tests will be conducted locally on RCIC System components required for system operation.	l. RCIC System components required for system operation can be actuated locally.
4. If a system initiation signal occurs during the full flow test mode, the RCIC System automatically aligns to the RPV water makeup mode.	4. Test will be conducted using simulated initiation signals.	4. The RCIC System automatically aligns to RPV water makeup mode from test mode upon receipt of an initiation signal.

Table 1.6-1 Referenced Reports (Continued)

Report No.	Title	Tier 2 Section No.
NEDC-30851P-A	W. P. Sullivan, "Technical Specification Improvement Analyses for BWR Reactor Protection System", March 1988.	19D.6
NEDE-31096-A	"GE Licensing Topical Report ATWS Response to NRC ATWS Rule 10CFR 50.62", February 1987.	19B.2
NEDE-31152-P	"GE Bundle Designs", December 1988.	4.2
NEDO-31331	Gerry Burnette, "BWR Owner's Group Emergency Procedure Guidelines", March 1987.	18A
NEDC-31336	Julie Leong, "General Electric Instrument Setpoint Methodology", October 1986.	7.3
NEDC-31393	"ABWR Containment Horizontal Vent Confirmatory Test, Part I", March 1987.	3B
NEDO-31439	C. VonDamm, "The Nuclear Measurement Analysis & Control Wide Range Neutron Monitoring System (NUMAC-WRNMS)", May 1987	20.3
NEDC-31858P	Louis Lee, "BWROG Report for Increasing MSIV Leakage Rate Limits and Elimination of Leakage Control System", 1991	15.6
NEDE-31906-P	A. Chung, "Laguna Verde Unit I Reactor Internals Vibration Measurement", January 1991.	7.4
NEDO-31960	Glen Watford, "BWR Owners' Group Long-Term Stability Solutions Licensing Methodology", June 1991.	4.4
NEDC-32267P	"ABWR Project Application Engineering Organization and Procedures Manual", December 1993.	17.1
NEDO-32686-A	"Utility Resolution Guide for ECCS Suction Strainer Blockage", October 1998.	6C

NEDC-32721P-A	"Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer", Rev. 2, March 2003	6C

Table 5.4-2 Design Parameters for RCIC System Components (Continued)

(a)	~~Pump NPSH requirements are satisfied when strainer is 50% plugged; and particles over 2.4 mm diameter are restrained from passage into the pump and feedwater sparger.~~

Pump NPSH requirements are satisfied given the strainer design methods described in Appendix 6C.

6.C Containment Debris Protection for ECCS Strainers

6C.1 Background

NRC Bulletin No. 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," references NRC guidance and highlights the need to adequately accommodate suppression pool debris in design by focusing on an incident at the Perry Nuclear Plant. Similar concerns were later identified throughout the industry and documented by subsequent bulletins and generic letters including NRC Bulletin 95-02, NRC Bulletin 96-03, Generic Letter 97-04, and Generic Letter 98-04. GEH reviewed the concerns addressed by these bulletins/letters and has determined that the ABWR design satisfactorily accommodates suppression pool debris for a number of reasons as discussed in the following:

The ultimate concern raised by the Perry incident was the deleterious effect of debris in the suppression pool and how it could impact the ability to draw water from the suppression pool during an accident. To address this concern, the ABWR design has committed to following the guidance provided in Regulatory Guide 1.82 as well as NEDO-32686-A (Utility Resolution Guide for ECCS Suction Strainer Blockage), and additional guidance as described below.

The ABWR is designed to inhibit debris generated during a LOCA from preventing operation of the Residual Heat Removal (RHR), Reactor Core Isolation Cooling (RCIC) and High Pressure Core Flooder (HPCF) systems.

6C.2 ABWR Mitigating Features

The ABWR has substantially reduced the amount of piping in the drywell relative to earlier designs and consequently the quantity of insulation required. Furthermore, there is no equipment in the wetwell spaces that requires insulation or other fibrous materials. The ABWR design conforms with the guidance provided by the NRC for maintaining the ability for long-term recirculation cooling of the reactor and containment following a LOCA.

The Perry incident was not the result of a LOCA but rather debris entering the Suppression Pool during normal operation. The arrangement of the drywell and wetwell/wetwell airspace on a Mark III containment (Perry) is significantly different from that utilized in the ABWR design. In the Mark III containment, the areas above the suppression pool water surface (wetwell airspace) are substantially covered by grating with significant quantities of equipment installed in these areas. Access to the wetwell airspace (containment) of a Mark III is allowed during power operations. In contrast, on the ABWR the only connections to the suppression pool are the 10 drywell connecting vents (DCVs), and access to the wetwell or drywell during power operations is prohibited. The DCVs will have horizontal steel plates located above the openings that will prevent any material falling in the drywell from directly entering the vertical leg of the DCVs. This arrangement is similar to that used with the Mark II connecting vent pipes. Vertically oriented trash rack construction will be installed around

the periphery of the horizontal steel plate to intercept debris. The trash rack design shall allow for adequate flow from the drywell to wetwell. In order for debris to enter the DCV it would have to travel horizontally through the trash rack prior to falling into the vertical leg of the connecting vents. Thus the ABWR is resistant to the transport of debris from the drywell to the wetwell.

In the Perry incident, the insulation material acted as a septa to filter suspended solids from the suppression pool water. The Mark I, II, and III containments have all used carbon steel in their suppression pool liners. This results in the buildup of corrosion products in the suppression pool which settle out at the bottom of the pool until they are stirred up and re-suspended in the water following some event (SRV lifting). In contrast, the ABWR liner of the suppression pool is fabricated from stainless steel which significantly lowers the amount of corrosion products which can accumulate at the bottom of the pool.

A further mitigating feature for the ABWR is that the insulation installed on the ASME Section III, Class 1 piping greater than 80 mm in the drywell, i.e., the large bore piping, is reflective metal type (RMI). Use of RMI minimizes the fibrous insulation source term from the upper drywell used in the suction strainer design. This use of RMI is a significant factor in design that reduces the potential suction strainer debris load and further reduces the potential for suction strainer clogging.

Since the debris in the Perry incident was created by roughing filters on the containment cooling units a comparison of the key design features of the ABWR is necessary. In the Mark III design more than 1/2 of the containment cooling units are effectively located in the wetwell airspace. For the ABWR there are no cooling fan units in the wetwell air space. Furthermore the design of the ABWR Drywell Cooling Systems does not utilize roughing filters on the intake of the containment cooling units during plant operation.

In the event debris enters the suppression pool and does not settle on the pool bottom, the Suppression Pool Cleanup System (SPCU) will remove the suspended debris during normal plant and SPCU operation. The SPCU is described in Section 9.5.9 and shown in Figure 9.5-1. The SPCU is designed to provide a continuous cleanup flow of 250 m^3/h. This flow rate is sufficiently large to effectively maintain the suppression pool water at the required purity. The SPCU system is intended for continuous operation and the suction pressure of the pump is monitored and an alarm is provided on low pressure. Early indication of any deterioration of the suppression pool water quality will be provided if significant quantities of debris were to enter the suppression pool and cause the strainer to become plugged resulting in a low suction pressure alarm.

The ABWR design also has additional features not utilized in earlier designs that could be used in the highly improbable event that all suppression pool suction strainers were to become plugged. The alternate Alternating Current independent water addition (ACIWA) mode of RHR allows water from the Fire Protection System to be pumped to the vessel and sprayed in the wetwell and drywell from diverse water sources to maintain cooling of the fuel and containment. The wetwell can also be vented at low pressures to assist in cooling the containment.

6C.3 Design Considerations

6C.3.1 RG 1.82 Improvement

All ECCS strainers will at a minimum be sized to conform with the guidance provided in Reg Guide 1.82 for the most severe of all postulated breaks.

The following clarifying assumptions will also be applied and will take precedence:

(1) The debris generation model ~~shall be consistent with Methods 1, 2, or 3 from the zone of influence approach in~~utilizes spherical zones of influence (ZOI) in accordance with the Utility Resolution Guidance, Reference 6C-3.

(2) Of the debris generated, the amount that is transported to the suppression pool shall be determined in accordance with Reference 6C-3 based on similarity of the Mark III upper drywell design. This approach is conservative due to the ABWR containment improvements over the Mark III as discussed in Section 6C.2.

(3) The debris in the suppression pool will be assumed to remain suspended until it is captured on the surface of a strainer.

Suction Strainer sizing is based on satisfying NPSH requirements at runout flow~~, plus margin,~~ with the design basis debris in the suppression pool accumulated on the suction strainers.

The sizing of the suction strainers assumes that the insulation debris in the suppression pool is proportionally distributed to the pump suctions based on the flow rates of the operating systems at limiting runout conditions. The strainers assumed available for capturing insulation debris for the limiting design condition are~~ two~~ one RHR loop~~suction strainers,~~ ~~and a single~~one HPCF loop and ~~or~~ the RCIC system~~ suction strainer~~.

6C.3.2 Chemical Effects

~~The chemical effects of the post-LOCA environment on debris shall be evaluated to assess the extent to which chemical reaction products contribute to blockage of the ECCS strainers. The evaluation shall be submitted by the COL Applicant and shall demonstrate that the effects of chemical reaction products from post-LOCA debris shall not prevent long-term cooling of the core (COL 6.12).~~

The ABWR design has been reviewed for the potential generation of chemical precipitates which may contribute to strainer head loss following a LOCA. In general, the ABWR design features preclude the materials and environmental conditions which are most problematic for generation of corrosion products.

The primary containment will not contain reactive materials such as aluminum, phosphates, or calcium silicate, and minimizes zinc by prohibiting it except for a small amount in galvanized steel and inorganic primers. Inorganic zinc primers are top coated with an epoxy layer that prevents exposure to the LOCA environment. Coatings are qualified as

described in Subsection 6.1.2. The debris load described in Table 6C-1 accounts for coatings that are destroyed during a LOCA.

An important consideration in the generation of corrosion products is the post-LOCA environment which, for some plant designs, can be of an acidic nature due to the use of boric acid in the primary coolant. The ABWR does not utilize boric acid. The Standby Liquid Control System is capable of injecting a sodium pentaborate solution, however this system is not used during a LOCA. Standby Liquid Control is only used to mitigate ATWS events as described in Appendix 15E. Consequently, the post-LOCA environment inside containment is relatively pH neutral with a flat time history throughout the event as described in Section 6.1.1.2.

Prior to the initial fuel load, chemical effects testing shall be performed to assess the potential for corrosion products generation and transport in the post-LOCA BWR environment. An evaluation report submitted by the COL Applicant shall account for any differences between the ABWR design and the conditions of the test program to demonstrate that chemical effects shall not prevent long-term cooling of the core (COL 6.12).

6C.3.3 Downstream Effects

The effects of debris ~~passing through the strainers shall be~~being transported from the suppression pool are evaluated for interactions with downstream components such as pumps, valves, and heat exchangers and also for the potential blockage of coolant flow at the entrance to the fuel assemblies. ~~The evaluation shall be submitted by the COL Applicant and shall demonstrate that the effects of debris bypass of the strainer shall not prevent long-term cooling of the core (COL 6.12).~~ The ABWR design includes several mitigating features that reduce the likelihood of such adverse debris interactions. These include:

- Minimal opportunity for debris generation in the wetwell. High energy breaks are restricted to the drywell, and debris generated there must pass through trash racks and vertical / horizontal vents before reaching the suppression pool.
- Diverse ECCS delivery locations, which include injection both inside and outside the core shroud,
- Bypass flow paths which exist around the debris filters of the fuel assemblies,
- The Suppression Pool Cleanup System will minimize the quantity of latent debris in the suppression pool. A suppression pool cleanliness program will be developed (Subsection 6.2.7.3) to minimize the quantity of latent debris.
- The suction strainers themselves, which capture any particles greater than the hole size of the perforated strainer plates.

Prior to the initial fuel load, a downstream effects evaluation based on test results shall be performed to assess the effect of small debris passing through the suction strainers and creating an obstruction to core flow into the fuel assemblies. An evaluation report submitted by the COL Applicant shall demonstrate that the ABWR design (including ECCS system characteristics, debris loading, and fuel design) is bounded by the scope of the downstream effects test and that the effects of debris bypass of the strainer shall not prevent long-term cooling of the core (COL 6.12).

6C.4 Discussion Summary

In summary, the ABWR design includes the necessary provisions to prevent debris from impairing the ability of the RCIC, HPCF, and RHR systems to perform their required post-accident functions. Specifically, the ABWR design does the following:

(1) The design is resistant to the transport of debris to the suppression pool.

(2) The suppression pool liner is stainless steel, which significantly reduces corrosion products.

(3) Plant Housekeeping and Foreign Material Exclusion (FME) procedures assure pool cleanliness prior to plant operation and over plant life such that no significant debris are present in the suppression pool.

(4) Periodic SPCU operation maintains suppression pool cleanliness. Low SPCU pump suction pressure can provide early indication of debris present in the suppression pool and permit the plant operator to take appropriate corrective action.

(5) The equipment installed in the drywell and wetwell minimize the potential for generation of debris.

(6) The ECCS suction strainers meet the current regulatory requirements.

6C.5 Strainer Sizing Analysis Summary

A preliminary analysis was performed to assure that the above requirements could be satisfied using strainers compatible with the suppression pool design as shown by Figure 1.2-13i.

Each loop of an ECCS system utilizes a single stacked disk suction strainer. The strainer design conforms to the methodology defined in Reference 6C-4. The strainer has a central core of varying radius such that the flow through the entire central region is maintained at constant velocity. The constant velocity core minimizes head loss where velocities are the greatest. A number of perforated disks of varying internal diameter and whose thickness may vary with radius surround the central core.

All of the debris is assumed to deposit on the strainers. The debris load is characterized by the methods in Reference 6C-3, and quantities are summarized in Table 6C-1. The

distribution of debris volume to the strainer regions was determined as a fraction of the proportional loop flow splits. The strainer sizing is calculated based on the strainer flow rate and debris load. The head loss is calculated by a method based upon Reference 6C-4 which uses empirical correlations to test data. The methodology considers losses through a clean strainer and factors in the effects of the debris bed taking into account the thickness of the bed, and the type of debris (fiber, RMI, sludge, etc.). Consideration is given to whether the quantity of debris is sufficient to fully engulf the gaps between the strainer disks, as this has an influence on the head loss correlation.

By making realistic assumptions, the following additional conservatisms are likely to occur, but they were not applied in the analysis. No credit in water inventory was taken for water additions from feedwater flow or flow from the condensate storage tank as injected by RCIC or HPCF. Also, for the long term cooling condition, when suppression pool cooling is used instead of the low pressure flooder mode (LPFL), the RHR flow rate decreases from runout (1130 m^3/h) to rated flow (954 m^3/h), which reduces the pressure drop across the debris.

6C.5 6 COL License Information

6C.56.1 Debris Evaluation for ECCS Suction Strainer

~~An evaluation shall be submitted by the COL Applicant that demonstrates that chemical effects and the effect of debris bypass of the strainers does not prevent long-term cooling of the core (COL 6.12). The evaluation shall be based on the research and recommendations of the BWR Owner's Group GSI-191 committee.~~

An evaluation shall be submitted by the COL Applicant that demonstrates that chemical effects and the effect of debris bypass of the strainers does not prevent long-term cooling of the core (COL 6.12).

6C.6 7 References

6.C-1 Debris Plugging of Emergency Core Cooling Suction Strainers, USNRC Bulletin No. 93-02, May 11, 1993.

6.C-2 Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident, USNRC Reg. Guide 1.82 Rev. 3.

6.C-3 Utility Resolution Guidance for ECCS Suction Strainer Blockage, NEDO-32686-A, October, 1998.

6C-4 Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer, NEDC-32721P-A, March 2003

Table 6C-1 ECCS Strainer Debris Load

Debris Type	Strainer Load
Sludge / corrosion prod.	90.7 kg (200 lbm)
Inorganic Zinc (IOZ)	21.3 kg (47 lbm)
Epoxy Coated IOZ	38.6 kg (85 lbm)
Rust Flakes	22.7 kg (50 lbm)
Cement Dust / Dirt	68.0 kg (150 lbm)
Reflective Metal Insulation	35.8 m^2 (385 ft^2)
Nukon Fiber Insulation	23.4 kg (51.6 lbm)