Enclosure 2

MFN 15-024

GEH Response to RAI 06.03-1

ABWR DCD DRAFT Revision 6 Markups

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 ~~NRC Bulletin 93-02~~these bulletins/letters and has ~~reviewed the design of the ABWR for potential weaknesses in coping with the bulletin's concerns. GEH has~~ determined that the ABWR design ~~is more resistant to these problems~~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~~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 sepia 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. Temporary filters may be used during post construction systems testing and refueling outages, at which times they are subject to plant housekeeping and foreign material exclusion procedures, and represent insignificant potential for introducing debris to the suppression pool.

In the event ~~that small quantities of~~ 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 ~~provides~~ 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 suction strainers at Perry did not meet the current regulatory requirements. The ABWR ECCS suction strainers will utilize a "T" arrangement with conical strainers on the 2 free legs~~

of the "T". This design separates the strainers so that it minimizes the potential for a contiguous mass to block the flow to an ECCS pump. 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 AC (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

6.C.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 will utilize right angle cones acting in both directions;shall be consistent with Methods 1, 2, or 3 from the zone of influence approach in Reference 6C-3.

(2) The amount of insulation debris generated will be assumed to be 100% of the insulation in a distance of 3 L/D of the postulated break within the right angle cones including targeted insulation;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) All of the insulation debris generated will be assumed to be transported to the suppression pool;

(43) 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 RHR suction strainers and a single HPCF or RCIC suction strainer.

6.C.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).

6.C.3.3 Downstream Effects

The effects of debris passing through the strainers shall be 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 sizing of the RHR suction strainers will assume that the insulation debris in the suppression pool is evenly distributed to the 3 pump suctions. The strainer size will be determined based on this amount of insulation debris and then increased by a factor of 3. The flow rate used for calculating the strainer size will be the runout system flow rate.~~

~~The sizing of the RCIC and HPCF suction strainers will conform to the guidance of Reg Guide 1.82 and will assume that the insulation debris in the suppression pool is proportionally distributed to the pump suctions based on the flow rates of the systems at runout conditions. The strainers assumed available for capturing insulation debris will include 2 RHR suction strainers and a single HPCF or RCIC suction strainer.~~

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) ~~The SPCU system will provide early indication of any potential problem.~~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) The SPCU System operation will maintain suppression pool cleanliness.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 unlike the strainers at the incident plants.

(7) The RHR suction strainers will apply an additional factor of 3 design margins.

6C.5 COL License Information

6.C.5.1 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).

6C.6 Strainer Sizing Analysis SummaryReferences

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.

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. The following summarizes the results, which indicate strainer sizes that are acceptable within the suppression pool design constraints.

Each loop of an ECCS system has a single suppression pool suction strainer configured in a T shape with a screen region at the two ends of the T cross member. Analysis determined the area of each screen region. Thus, RHR with three loops has six screen regions. The HPCF with two loops has four screen regions, and the RCIC has two screen regions. The characteristic dimension given for the screens in the results below indicates a surface area consisting of a circle with a diameter of the dimension plus a cylinder with a diameter and length of the dimension.

~~By the requirements above, all of the debris deposits on the strainers. The distribution of debris volume to the strainer regions was determined as a fraction of the loop flow splits based on runout flow. Debris on the screen creates a pressure drop as predicted by NUREG-0897, which is referenced by R.G. 1.82. The equation for NUKON™ insulation on page 3-59 of NUREG-0897 was used for this analysis. The NUKON™ debris created pressure drop equation is a function of the thickness of debris on the screen (which is a function of debris volume), the velocity of fluid passing through the screen (runout flow used), and the screen area. The debris created pressure drop was applied in an equation as follows; the static head at the pump inlet is equal to the hydraulic losses through the pipe and fittings, plus the pressure drop through the debris on the strainers, plus the hydraulic loss through the unplugged strainer, plus a margin equal to approximately 10% of the static head at the pump inlet, and plus the required NPSH. The static head takes into account the suppression pool water level determined by the draw down calculated as applicable for a main steam line break scenario. A summary provided in Table 6C-1, and a summary of the analysis results is provided in Table 6C-2.~~

~~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.~~

~~Table 6C-1 Debris Analysis Input Parameters~~

~~Estimated debris created by a main steam line break~~	~~2.6 m^3~~
~~RHR runout flow (Figure 5.4-11, note 13)~~	~~1130 m^3/h~~
~~HPCF runout flow (Table 6.3-8)~~	~~890 m^3/h~~
~~RCIC controlled constant flow (Table 5.4-2)~~	~~182 m^3/h~~
~~Debris on RHR screen region, 3 RHR loops operating~~	~~0.434 m^3~~
~~Debris on HPCF screen region~~	~~0.369 m^3~~
~~Debris on RCIC screen region~~	~~0.097 m^3~~
~~RHR required NPSH (Table 6.3-9)~~	~~2.4 m~~
~~HPCF required NPSH (Table 6.3-8)~~	~~2.2 m~~
~~RCIC required NPSH (Table 5.4-2)~~	~~7.3 m~~
~~RHR pipe, fittings and unplugged strainer losses*~~	~~0.60 m~~
~~HPCF pipe, fittings and unplugged strainer losses*~~	~~0.51 m~~
~~RCIC pipe, fittings and unplugged strainer losses*~~	~~0.39 m~~
~~Suppression pool static head above pump suction~~	~~5.05 m~~

~~* Calculated hydraulic losses~~

~~Table 6C-2 Results of Analysis~~

~~RHR screen region area/characteristic dimension~~	~~5.66 m^2/1.20 m~~
~~HPCF screen region area/characteristic dimension~~	~~1.46 m^2/0.61 m~~
~~RCIC screen region area/characteristic dimension~~	~~0.27 m^2/0.26 m~~
~~Total ECCS screen region area~~	~~40.0 m^2~~

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

Table 1.8-20 NRC Regulatory Guides Applicable to ABWR (Continued)

RG No.	Regulatory Guide Title	Appl. Rev.	Issued Date	ABWR Applicable?	Comments
1.77	Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors	0	5/74	No	PWR only
1.78	Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release	0	6/74	Yes	
1.79	Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors	1	9/75	No	PWR only
1.81	Shared Emergency and Shutdown Electric Systems for Multi-Unit Power Plants	1	1/75	Yes	
1.82	Water Sources for Long-Term Recirculation Cooling Following Loss-of-Coolant Accident	~~1~~3	~~11/85~~11/2003	Yes	
1.83	Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes	1	7/75	No	PWR only
[*1.84*	*Design and Fabrication Code Case Acceptability, ASME Section III, Division 1*	*27*	*11/90*	*Yes*](1)	
1.85	Materials Code Case Acceptability, ASME Section III, Division 1	27	11/90	Yes	
1.86	Termination of Operating Licenses for Nuclear Reactors	0	6/74	----	COL Applicant
1.87	Guidance for Construction of Class 1 Components in Elevated-Temperature Reactors (Supplement to ASME Section III Code Cases 1592, 1593, 1594, 1595, and 1596)	1	6/75	No	
1.88	Collection, Storage, and Maintenance of Nuclear Power Plant Quality Assurance Records		Super-ceded		See Table 17.0-1
[*1.89*	*Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants*	*1*	*6/84*	*Yes*](2)	
1.90	Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons	1	8/77	---	COL Applicant
1.91	Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants	2	2/78	Yes	
[*1.92*	*Combining Modal Responses and Spatial Components in Seismic Response Analysis*	*1*	*2/76*	*Yes*](1)	

Table 1.8-22 Experience Information Applicable to ABWR (Continued)

No.	Issue Date	Title	Comment
91-04	04/02/91	Changes in Technical Specification Surveillance Intervals to Accommodate a 24-Month Fuel Cycle	
91-05	04/04/91	Licensee Commercial Grade Procurement and Dedication Programs	
91-06	04/29/91	Resolution of Generic Issue A-30, “Adequacy of Safety-Related DC Power Supplies”, Pursuant to 10CFR50.54(f)	Subsection 19B.2.52
91-10	07/08/91	Explosive Searches at Protected Area Portals	COL Applicant
91-11	07/19/91	Resolution of Generic Issue 48, “LCOs for Class 1E Tie Breakers”, Pursuant to 10CFR50.54(f)	Subsection 19B.2.52
91-14	09/23/91	Emergency Telecommunications	
91-16	10/03/91	Licensed Operators' and Other Nuclear Facility Personnel Fitness for Duty	COL Applicant
91-17	10/17/91	Generic Safety Issue 29, “Bolting Degradation or Failure in Nuclear Power Plants”	Subsection 19B.2.62
92-04	8/19/92	Resolution of the Issues Related to Reactor Vessel Level Instrumentation in BWRs Pursuant to 10CFR50.54(f)	
97-04	10/7/97	Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps	COL Applicant
98-04	7/14/98	Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment	COL Applicant
Type: IE Bulletins			
79-02	3/8/79	Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts	
79-08	4/14/79	Events Relevant to BWR Identified During TMI Incident	
80-01	1/11/80	ADS Valve Pneumatic Supply	
80-03	2/6/80	Loss of Charcoal from Absorber Cells	
80-05	3/10/80	Vacuum Condition Resulting in Damage to Chemical and Volume Control System (CVCS) Holdup Tanks	COL Applicant
80-06	3/13/80	ESF Reset Controls	
80-08	4/7/80	Containment Lines Penetration Welds	COL Applicant
80-10	5/6/80	Non-Radioactive System – Potential for Unmonitored Release	COL Applicant
80-12	5/9/80	Decay Heat Removal System Operability	COL Applicant

Table 1.9-1 Summary of ABWR Standard Plant COL License Information (Continued)

Item No.	Subject	Subsection
5.10	RIP Installation and Verification During Maintenance	5.4.15.4
6.1	Protection Coatings and Organic Materials	6.1.3.1
6.2	Alternate Hydrogen Control	6.2.7.1
6.3	Administrative Control Maintaining Containment Isolation	6.2.7.2
6.4	Suppression Pool Cleanliness	6.2.7.3
6.5	Wetwell-to-Drywell Vacuum Breaker Protection	6.2.7.4
6.5a	Containment Penetration Leakage Test (Type B)	6.2.7.5
6.6	ECCS Performance Results	6.3.6.1
6.7	ECCS Testing Requirements	6.3.6.2
6.7a	Limiting Break Results	6.3.6.3
6.8	Toxic Gases	6.4.7.1
6.9	SGTS Performance	6.5.5.1
6.9a	SGTS Exceeding 90 Hours of Operation per Year	6.5.5.2
6.10	PSI and ISI Program Plans	6.6.9.1
6.11	Access Requirement	6.6.9.2
6.12	ECCS Suction Strainer	6C.5.1
7.1	Cooling Temperature Profiles for Class 1E Digital Equipment	7.3.3.1
7.2	APRM Oscillation Monitoring Logic	7.6.3.1
7.3	Effects of Station Blackout on HVAC	7.8.1
7.4	Electrostatic Discharge on Exposed Equipment Components	7.8.2
7.5	Localized High Heat Spots in Semiconductor Material for Computing Devices	7.8.3
8.1	Diesel Generator Reliability	8.1.4.1
8.2	Periodic Testing of Offsite Equipment	8.2.4.1
8.3	Procedures When a Reserve or Unit Auxiliary Transformer is Out of Service	8.2.4.2
8.4	Offsite Power Systems Design Bases	8.2.4.3
8.5	Offsite Power Systems Scope Split	8.2.4.4
8.6	Capacity of Auxiliary Transformers	8.2.4.5
8.7	Not Used	8.3.4.1
8.8	Diesel Generator Design Details	8.3.4.2
8.9	Not Used	8.3.4.3