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Proprietary Notice
This letter transmits **proprietary information** in accordance with 10 CFR 2.390. Upon removal of **Enclosure 4**, the balance of the letter may be considered non-proprietary information.

M180068

Docket Number: 52-045

March 28, 2018

US Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555-0001

Subject: **GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – Additional Information for GEH Response to RAIs 06.03-4 through 06.03-9**

In Letter M170209 dated August 23, 2017 (Reference 1), GEH responded to Requests for Additional Information (RAI) 06.03-4 through 06.03-9. GEH and NRC representatives discussed the GEH responses to RAIs 06.03-4 through 06.03-9 in a public teleconference held on March 1, 2018. Additional information regarding the GEH response to these RAIs is provided in Enclosure 1. Associated DCD markups are provided in Enclosure 2.

Also, please find GEH licensing technical report NED-33878, Revision 3 (NEDO public version, Enclosure 3; NEDE proprietary version, Enclosure 4) reflecting the additional information.

If you have any questions, please contact me.

Sincerely,

Jerald Head

Jerald G. Head
Senior Vice President, Regulatory Affairs

Commitments: No additional commitments are made.

D106
NRO

Reference:

1. Letter, NRC to J. Head (GEH), Subject: "NRC Requests for Additional Information Letter Numbers 11 and 13 Related to Chapter 6 for GE Hitachi Nuclear Energy Advanced Boiling Water Reactor Design Certification Rule Renewal Application – GEH Revised Response to RAI 06.03-3 and Responses to RAIs 06.03-4 through 06.03-9," M170209, August 23, 2017.

Enclosures:

1. Additional Information Regarding GEH Responses to RAIs 06.03-4 through 06.03-9
2. ABWR DCD Markups
3. NEDO-33878, Revision 3, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, March 2018 – Class I (Public)
4. NEDE-33878P, Revision 3, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, March 2018 – GEH Proprietary Information – Class II (Internal)

cc: A. Muniz (NRC)
DBR-0031255 R1

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, Patricia L. Campbell, state as follows:

(1) I am the Vice President, Washington Regulatory Affairs, of GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in GEH proprietary report, NEDE-33878P, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Revision 3, Class II (Internal)(GEH Proprietary Information, March 2018. GEH proprietary information text in NEDE-33878P is identified by a dark red dotted underline inside double square brackets. [[This sentence is an example.{3}]] Figures and large equation objects containing GEH proprietary information are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit that provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act (FOIA), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies under the narrower definition of trade secret, within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over GEH and/or other companies.

b. Information that, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information that reveals aspects of past, present, or future GEH customer-funded development plans and programs, that may include potential products of GEH.

d. Information that discloses trade secret and/or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to the NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary and/or confidentiality agreements that provide for maintaining the information in confidence. The initial designation of this information as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GEH.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary and/or confidentiality agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it contains results and details of analysis methods and techniques developed by GEH for evaluations of the ABWR ECCS pumps suction strainers. Development of these methods, techniques, and information and their application for the design, modification, and analyses methodologies and processes for the ABWR ECCS pumps suction strainers was achieved at a significant cost to GEH. The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH. The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial. GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 20th day of March 2018.

Patricia L. Campbell

Patricia L. Campbell
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Enclosure 1

M180068

Additional Information Regarding GEH Responses to RAIs 06.03-4 through 06.03-9

IMPORTANT NOTICE REGARDING CONTENTS OF THIS DOCUMENT

Please Read Carefully

During a public teleconference held on March 1, 2018, the NRC discussed with GEH certain items regarding the GEH responses to NRC Request for Additional Information (RAI) questions 06.03-03 and 06.03-04 through 06.03-9 submitted in GEH Letter M170209 dated August 23, 2017 (ML17236A060) and its enclosures (Encl. 1 ML17236A061, Encl. 2 ML17236A062, and Encl. 3 ML17236A063). These RAIs relate to the Emergency Core Cooling System (ECCS) Suction Strainer RAI responses and Technical Report NEDE-33878P. GEH provides the information below to address the two items that were discussed in detail during the public teleconference and describes the GEH actions taken.

Item: Potential debris plugging of ECCS pump seals based on stated size of orifice holes for pump seal cooling flow as compared to suction strainer openings.

The NRC noted that Regulatory Guide (RG) 1.82, Revision 4, Section 1.1.1.10, explains that:

> If wear or internal blockage evaluations indicate that a component may not be able to accomplish its design function throughout its mission time and that it is not practical to install a suction strainer with openings small enough to filter out debris that cause excessive damage to ECCS pump seals or bearings, the NRC expects licensees to modify the ECCS pumps or procure new ECCS pumps that can operate long term under the postulated conditions.

GEH Response:

GEH agrees that including an orifice size for the ECCS pump seal cooling water flow lines could create confusion. NEDE-33878P Revision 2 describes a specific ECCS pump seal cooling water line orifice hole size (0.0625" and larger) (Legacy BWR Perry RHR) rather than maintaining a qualitative assessment of safety and operational concerns for failure of ECCS pumps associated with particles that pass through the ECCS suction strainers. GEH has evaluated this approach and is making changes in the Technical Report and is incorporating it by reference into the ABWR Design Control Document (DCD) as shown on the attached DCD and Technical Report markups for the reasons explained below.

The Auxiliary Equipment Evaluation presented in Technical Report NEDE-33878P (and NEDO-33878, which is the public version) Tables A4 through A8 (Appendix A of the Technical Report) was updated to reflect that ECCS pump design is based on ECCS suction strainer sizing to prevent clogging of pump internal passages including mechanical seal assemblies. The ECCS pump manufacturer will specify cyclone separator performance and seal cooling line orifice hole size to prevent debris plugging.

> *The ECCS pump design is coordinated with the ECCS suction strainer sizing to prevent clogging of pump internal passages including mechanical seal assemblies. The consequence of a plugged pump seal line would be high seal temperature and poor seal life.*

The ECCS pump includes a mechanical seal assembly with cyclone particle separator and seal-cooling heat exchanger (as required). A cyclone separator type of filtration is provided to maintain a clean cooling water supply to the seal.

The size of orifices used to control the flow to ECCS pump seals is specified by the pump manufacturer to ensure the pump seal cooling lines are not susceptible to plugging by debris not filtered by the suction strainer and the cyclone separator type filter or debris larger than the seal cooling line orifice hole diameter.

To clarify the purpose of the assessments performed in NEDE-33878P and NEDO-33878, Appendix A.4.1, Auxiliary Equipment Evaluation, GEH is revising the DCD and the Technical Report to reflect that the report is incorporated by reference in the ABWR DCD Tier 2. Accordingly, the Technical Report is considered DCD Tier 2 information for purposes of the ABWR design certification renewal application. Thus, the Technical Report imposes requirements on ABWR design.

As described in NEDE-33878P, A.4 WEAR RATE AND COMPONENT EVALUATION, A.4.1 Auxiliary Equipment Evaluation, ECCS pump performance for the specific plant as-built configuration will require demonstration of acceptable performance under design conditions including design debris loading. Demonstration of acceptable performance for as-built ECCS pumps is validated under ASME QME-1-2007, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants (Reference 40), as endorsed by RG 1.100, "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants," Revision 3, September 2009 (previously added to ABWR DCD Table 1.8-20 as an applicable regulatory guide for qualification guidance of the ECCS pumps and components under post-LOCA conditions, including debris loading).

DCD Revision 6 Tier 1 Tables 2.4.1, 2.4.2 and 2.4.4 provide ITAAC requirements for as-built ECCS pump and component performance under design debris loading with the acceptance criteria per QME-1 applied.

As shown on the attached markups to NEDE-33878P, clarifications are made regarding the potential debris plugging of the ECCS pump seal cooling water lines.

<u>Item: RAI 06.03-4 asked about the Debris Ingestion Model that states that material will tend to settle out in low flow area in piping. The GEH response says that the system flow velocity exceeds the debris settling velocity. This appears to be inconsistent. Please explain further.</u>

<u>GEH Response:</u>

GEH agrees that there could be confusion in the assessment of debris transport described in NEDE-33878P, which states debris material will tend to settle out in low flow areas in the ECCS piping. NEDE-33878P and NEDO-33878 Appendix A.4 A.4.1, Auxiliary Equipment Evaluation is revised as shown on the attached markups to reflect the assessment for instrument line plugging and wear is based on instrumentation line configuration and orientation and not system flow and materials settling velocities as is the criteria for process piping.

IMPACT ON NED Reports and DCD:

NEDE / NEDO 33878 Section	Change
Table of Contents	Updated to reflect changes made under Revision 3 of the report.
Appendix A4, A.4.1, Auxiliary Equipment Evaluation	Updated report to reflect that the report is incorporated by reference in the ABWR DCD Tier 2. This report imposes requirements on ABWR design.
	Updated report to reflect that the assessment addresses the plugging and wear on instrumentation tubing based on instrumentation line configuration and orientation.
Table A-4 through Table A-8	Updated Auxiliary Equipment Evaluation for ECCS Pumps (Component) associated with clogging of pump internal passages including mechanical seal assemblies under design debris loading.
DCD Section	**Change**
Tier 2:	
• Table 1.6-1 Referenced Reports	Removed NEDO-33878 and NEDE-33878P, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, and added these reports to Table 1.6-2, Reports Incorporated by Reference, to reflect these reports impose requirements on ABWR design.
• Table 1.6-2, Reports Incorporated by Reference	Updated revision level for NEDO-33878 and NEDE-33878P, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, and added these reports to Table 1.6-2, Reports Incorporated by Reference, to reflect these reports impose requirements on ABWR design
• 6C Containment Debris Protection for ECCS Strainers	Updated 6C.2, ABWR Mitigating Features, to reflect that the ECCS pump design is coordinated with the ECCS suction strainer sizing to prevent clogging of pump internal passages including mechanical seal assemblies. Updated 6C.3.3, Downstream Effects, to describe the configuration of ECCS instrument line taps in process lines that prevent settling of debris in instrument lines. Updated 6C.7. References, to reflect revision of NEDE-33878P and NEDO-33878.

Enclosure 2

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ABWR DCD Markups

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-32084P-A Rev. 2	"TASC-03A - A Computer Program for Transient Analysis of a Single Channel," July 2002.	6.3
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 (using an updated head loss correlation).	6C
NEDO-33173 Supplement 4-A, Revision 1	"Implementation of PRIME Models and Data in Downstream Methods," November 2012.	6.3
~~NEDE-33878P~~	~~"ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017 (GEH Proprietary Information); NEDO-33878, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017.~~	6C

Move to Table 1.6-2 as Incorporate by Reference

Table 1.6-2 Reports Incorporated by Reference

Report No.	Title	Tier 2 Section No.
NEDO-33875	"ABWR US Certified Design Aircraft Impact Assessment, Licensing Basis Information and Design Details for Key Design Features," Rev. 3, February 2017, except for Appendices A and D.	19G
NEDE-33875P	"ABWR US Certified Design Aircraft Impact Assessment, Licensing Basis Information and Design Details for Key Design Features," Rev. 3, February 2017, except for Appendices A and D.	19G

ADD

Report No.	Title	Tier 2 Section No.
NEDE-33878P	"ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability", Rev. 3, March 2018	6C
NEDO-33878	"ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability", Rev. 3, March 2018	6C

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Details of the inservice testing program, including test schedules and frequencies, will be reported in the inservice inspection and testing plan to be provided by the applicant referencing the ABWR design. The plan will integrate the applicable test requirements for safety-related pumps and valves, including those listed in the technical specifications, Chapter 16, and the containment isolation system, Subsection 6.2.4. For example, the periodic leak testing of the reactor coolant pressure isolation valves (See Appendix 3M for design changes made to prevent intersystem LOCAs) in Table 3.9-9 will be performed in accordance with Chapter 16 Surveillance Requirement SR 3.6.1.5.10. This plan will include baseline pre-service testing to support the periodic inservice testing of the components. Depending on the test results, the plan will provide a commitment to disassemble and inspect the safety-related pumps and valves when limits of the OM Code are exceeded, as described in the following paragraphs. The primary elements of this plan, including the requirements of Generic Letter 89-10 for motor operated valves, are delineated in the subsections to follow. (See Subsection 3.9.7.3 for COL license information requirements.)

3.9.6.1 Testing of Safety-Related Pumps

For each pump, the design basis and required operating conditions (including tests) under which the pump will be required to function will be established. These designs (design basis and required operating) conditions include flow rate and corresponding head for each system mode of pump operation and the required operating time for each mode, acceptable bearing vibration levels, seismic/dynamic loads, fluid temperature, ambient temperature, and pump motor minimum voltage.

The COL applicant will establish the following design and qualification requirements and will provide acceptance criteria for these requirements. For each size, type, and model the COL applicant will perform testing encompassing design conditions that demonstrate acceptable flow rate and corresponding head, bearing vibration levels, and pump internals wear rates for the operating time specified for each system mode of pump operation. From these tests the COL applicant will also develop baseline (reference) hydraulic and vibration data for evaluating the acceptability of the pump after installation. The COL applicant will ensure that the pump specified for each application is not susceptible to inadequate minimum flow rate and inadequate thrust bearing capacity. With respect to minimum flow pump operation, the sizing of each minimum recirculation flow path is evaluated to assure that its use under all analyzed conditions will not result in degradation of the pump. The flow rate through minimum recirculation flow paths can also be periodically measured to verify that flow is in accordance with the design specification.

The ABWR safety-related pumps and piping configurations accommodate in-service testing at a flow rate at least as large as the maximum design flow for the pump application. The safety-related pumps are provided with instrumentation to verify that the net positive suction head (NPSH) is greater than or equal to the NPSH required during all modes of pump operation. These pumps can be disassembled for evaluation when Part 6 testing results in a deviation which falls within the "required action range." The Code provides criteria limits for the test

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parameters identified in Table 3.9-8. A program will be developed by the COL applicant to establish the frequency and the extent of disassembly and inspection based on suspected degradation of all safety-related pumps, including the basis for the frequency and the extent of each disassembly. The program may be revised throughout the plant life to minimize disassembly based on past disassembly experience. (See Subsection 3.9.7.3(1) for COL license information requirements.)

It is demonstrated that the ECCS pumps (including mechanical seal) can perform specified functions under all design basis conditions including post-LOCA debris loading conditions. Demonstration of acceptable performance for as-built ECCS pumps is validated under QME-1 2007, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants as endorsed by RG 1.100 Revision 3.

3.9.6.2 Testing of Safety-Related Valves

3.9.6.2.1 Check Valves

(1) Design and Qualification

For each check valve with an active safety-related function, the design basis and required operating conditions (including testing) under which the check valve will be required to perform will be established.

The COL applicant will establish the following design and qualification requirements and will provide acceptance criteria for these requirements. By testing each size, type, and model the COL applicant will ensure the design adequacy of the check valve under design (design basis and required operating) conditions. These design conditions include all the required system operating cycles to be experienced by the valve (numbers of each type of cycle and duration of each type cycle), environmental conditions under which the valve will be required to function, severe transient loadings expected during the life of the valve such as waterhammer or pipe break, life-time expectation between major refurbishments, sealing and leakage requirements, corrosion requirements, operating medium with flow and velocity definition, operating medium temperature and gradients, maintenance requirements, vibratory loading, planned testing and methods, test frequency and periods of idle operation. The design conditions may include other requirements as identified during detailed design of the plant systems. This testing of each size, type and model shall include test data from the manufacturer, field test data for dedication by the COL applicant, empirical data supported by test, or test (such as prototype) of similar valves that support qualification of the required valve where similarity must be justified by technical data. The COL applicant will ensure proper check valve application including selection of the valve size and type based on the system flow conditions, installed location of the valve with respect to sources of turbulence, and correct orientation of the valve in the piping (i.e., vertical vs horizontal) as

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6C 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

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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 suction strainers design at Perry preceded and did not meet the current regulatory requirements. The ABWR ECCS suction strainers are patented GE optimized stacked disk design in accordance with NEDC-32721P-A Rev.2. This strainer design was developed in response to NRC Bulletin 96-03 as a replacement of existing ECCS strainers with a large capacity passive strainer design. This strainer design utilizes disks whose internal radius and thickness vary over the height of the strainer. The selected variation in these parameters achieves an increased surface area compared to existing strainers of the same size to provide a

To avoid debris clogging the flow restrictions downstream of the strainers, the size of the holes in the perforated sheets is chosen by considering specific flow paths of ECCS equipment and piping (for example, the containment spray nozzle and the ECCS pump seal cooling flow cyclone separator type filters and orifices). The strainers will have holes no larger than 3.175 mm (0.125 inch).

higher capacity for debris capture. The ABWR strainer will perform with a minimum head loss for the range of possible amounts of debris while fitting in the required volume. ~~To avoid debris clogging the flow restrictions downstream of the strainers, the size of the holes in the perforated sheets is chosen by considering specific flow paths of ECCS equipment and piping (for example, the containment spray nozzle and the ECCS pump seal cooling flow orifices). The strainers will have holes no larger than 3.175 mm (0.125 inch).~~

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 maximum debris load fraction assuming 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 ~~suction strainers and a single~~loop, one HPCF loop, and the~~or~~ RCIC system~~suction strainer~~.

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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 chemical precipitate debris that may contribute to blockage and head loss.

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.

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. NEDE-33878P, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, Rev. 2, (Reference 6C-5) evaluated the impact of debris downstream of the ECCS strainers causing blockage or wear and abrasion. The three areas of concern evaluated are (1) blockage of system flow paths at narrow flow passages (e.g., ECCS sparger spray nozzles), (2) wear and abrasion of surfaces (e.g., pump running surfaces and heat exchanger tubes and orifices), and (3) blockage of flow paths through 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).~~

This assessment concludes that ECCS flow paths and components downstream of the strainers, including fuel assemblies, are not susceptible to failure from debris blockage, particulate

The assessment credited the configuration of ECCS instrument line taps in the process piping. ECCS instrument lines in service during post-LOCA operation are installed with taps above the horizontal plane of the process piping. No settling of debris in an instrument line with this orientation is expected. *Also, pressure instruments measure through impulse piping. There is no flow with this configuration to pull debris into the measuring devices.*

ingestion, abrasive effects and long term degradation and can perform required safety functions during the required mission time.

The assessment includes the effects of debris settling in instrument lines and components, blockage and binding of tight clearance valves (such as throttle and check valves) and wear of ECCS components (pumps and heat exchangers).

~~The assessment credited the configuration of ECCS instrument line taps in the process piping. ECCS instrument lines in service during post-LOCA operation are installed above the horizontal plane of the process piping. No settling of debris in an instrument line with this orientation is expected.~~

The assessment used the listed ECCS valve positions for post-LOCA system alignment:

- Table 1, Valve Position Chart, DCD Figure 5.4-11, Reactor Heat Removal System PFD (sheet 2 of 2)
- Table 1, Valve Position Chart, DCD Figure 6.3-1, High Pressure Core Flooder System PFD (sheet 2 of 2)
- Table 1, Valve Position Chart, DCD Figure 5.4-9, Reactor Core Isolation Cooling System PFD (sheet 2 of 2)

ECCS pump and component performance qualification will be validated using the guidance of QME-1, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants.

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.

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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.

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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 m3/h) to rated flow (954 m3/h), which reduces the pressure drop across the debris.

Based on these considerations, the ABWR ECCS suction strainers are the GE stacked disk strainer design analyzed for the sizing methodology in NEDC-32721 P-A (Ref. 6C-4). The ABWR selected strainer design utilizes sizing for the RHR service for each of the strainers. The ABWR ECCS suction strainer configuration is as follows:

- Type: GE stacked disk passive suction strainer.
- Flow Area: Each strainer has perforated area 36 m^2 with 20 disks, which provides a combined surface area of 216 m^2 for three (3) RHR, two (2) HPCF and one (1) RCIC strainer(s).
- Hole Size: 3.2 mm diameter.
- Flow Rate Sizing: 2180 m^3/hr.

The ABWR ECCS suction strainer classification information is provided in Table 3.2-1, Classification Summary.

6C.6 COL License Information

6C.6.1 ~~Debris Evaluation for ECCS Suction Strainer~~Deleted

~~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.~~

6C.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~~4.

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

6.C-4 Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer, NEDC-32721P-A, March 2003 (using an updated head loss correlation).

6.C-5 ~~NEDE-33878P, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017 (GEH Proprietary Information); NEDO-33878, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017.~~

NEDE-33878P, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 3, March 2018 (GEH Proprietary Information); NEDO-33878, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 3, March 2018

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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)
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)

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-32084P-A Rev. 2	“TASC-03A - A Computer Program for Transient Analysis of a Single Channel,” July 2002.	6.3
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 (using an updated head loss correlation).	6C
NEDO-33173 Supplement 4-A, Revision 1	“Implementation of PRIME Models and Data in Downstream Methods,” November 2012.	6.3
~~NEDE-33878P~~	~~“ABWR ECCS Suction Strainer Evaluation of Long Term Recirculation Capability,” Rev. 2, August 2017 (GEH Proprietary Information); NEDO-33878, “ABWR ECCS Suction Strainer Evaluation of Long Term Recirculation Capability,” Rev. 2, August 2017.~~	6C

Move to Table 1.6-2 as Incorporate by Reference

Table 1.6-2 Reports Incorporated by Reference

Report No.	Title	Tier 2 Section No.
NEDO-33875	"ABWR US Certified Design Aircraft Impact Assessment, Licensing Basis Information and Design Details for Key Design Features," Rev. 3, February 2017, except for Appendices A and D.	19G
NEDE-33875P	"ABWR US Certified Design Aircraft Impact Assessment, Licensing Basis Information and Design Details for Key Design Features," Rev. 3, February 2017, except for Appendices A and D.	19G

ADD

Report No.	Title	Tier 2 Section No.
NEDE-33878P	"ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability", Rev. 3, March 2018	6C
NEDO-33878	"ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability", Rev. 3, March 2018	6C

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Details of the inservice testing program, including test schedules and frequencies, will be reported in the inservice inspection and testing plan to be provided by the applicant referencing the ABWR design. The plan will integrate the applicable test requirements for safety-related pumps and valves, including those listed in the technical specifications, Chapter 16, and the containment isolation system, Subsection 6.2.4. For example, the periodic leak testing of the reactor coolant pressure isolation valves (See Appendix 3M for design changes made to prevent intersystem LOCAs) in Table 3.9-9 will be performed in accordance with Chapter 16 Surveillance Requirement SR 3.6.1.5.10. This plan will include baseline pre-service testing to support the periodic inservice testing of the components. Depending on the test results, the plan will provide a commitment to disassemble and inspect the safety-related pumps and valves when limits of the OM Code are exceeded, as described in the following paragraphs. The primary elements of this plan, including the requirements of Generic Letter 89-10 for motor operated valves, are delineated in the subsections to follow. (See Subsection 3.9.7.3 for COL license information requirements.)

3.9.6.1 Testing of Safety-Related Pumps

For each pump, the design basis and required operating conditions (including tests) under which the pump will be required to function will be established. These designs (design basis and required operating) conditions include flow rate and corresponding head for each system mode of pump operation and the required operating time for each mode, acceptable bearing vibration levels, seismic/dynamic loads, fluid temperature, ambient temperature, and pump motor minimum voltage.

The COL applicant will establish the following design and qualification requirements and will provide acceptance criteria for these requirements. For each size, type, and model the COL applicant will perform testing encompassing design conditions that demonstrate acceptable flow rate and corresponding head, bearing vibration levels, and pump internals wear rates for the operating time specified for each system mode of pump operation. From these tests the COL applicant will also develop baseline (reference) hydraulic and vibration data for evaluating the acceptability of the pump after installation. The COL applicant will ensure that the pump specified for each application is not susceptible to inadequate minimum flow rate and inadequate thrust bearing capacity. With respect to minimum flow pump operation, the sizing of each minimum recirculation flow path is evaluated to assure that its use under all analyzed conditions will not result in degradation of the pump. The flow rate through minimum recirculation flow paths can also be periodically measured to verify that flow is in accordance with the design specification.

The ABWR safety-related pumps and piping configurations accommodate in-service testing at a flow rate at least as large as the maximum design flow for the pump application. The safety-related pumps are provided with instrumentation to verify that the net positive suction head (NPSH) is greater than or equal to the NPSH required during all modes of pump operation. These pumps can be disassembled for evaluation when Part 6 testing results in a deviation which falls within the “required action range.” The Code provides criteria limits for the test

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parameters identified in Table 3.9-8. A program will be developed by the COL applicant to establish the frequency and the extent of disassembly and inspection based on suspected degradation of all safety-related pumps, including the basis for the frequency and the extent of each disassembly. The program may be revised throughout the plant life to minimize disassembly based on past disassembly experience. (See Subsection 3.9.7.3(1) for COL license information requirements.)

It is demonstrated that the ECCS pumps (including mechanical seal) can perform specified functions under all design basis conditions including post-LOCA debris loading conditions. Demonstration of acceptable performance for as-built ECCS pumps is validated under QME-1 2007, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants as endorsed by RG 1.100 Revision 3.

3.9.6.2 Testing of Safety-Related Valves

3.9.6.2.1 Check Valves

(1) Design and Qualification

For each check valve with an active safety-related function, the design basis and required operating conditions (including testing) under which the check valve will be required to perform will be established.

The COL applicant will establish the following design and qualification requirements and will provide acceptance criteria for these requirements. By testing each size, type, and model the COL applicant will ensure the design adequacy of the check valve under design (design basis and required operating) conditions. These design conditions include all the required system operating cycles to be experienced by the valve (numbers of each type of cycle and duration of each type cycle), environmental conditions under which the valve will be required to function, severe transient loadings expected during the life of the valve such as waterhammer or pipe break, life-time expectation between major refurbishments, sealing and leakage requirements, corrosion requirements, operating medium with flow and velocity definition, operating medium temperature and gradients, maintenance requirements, vibratory loading, planned testing and methods, test frequency and periods of idle operation. The design conditions may include other requirements as identified during detailed design of the plant systems. This testing of each size, type and model shall include test data from the manufacturer, field test data for dedication by the COL applicant, empirical data supported by test, or test (such as prototype) of similar valves that support qualification of the required valve where similarity must be justified by technical data. The COL applicant will ensure proper check valve application including selection of the valve size and type based on the system flow conditions, installed location of the valve with respect to sources of turbulence, and correct orientation of the valve in the piping (i.e., vertical vs horizontal) as

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6C 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

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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 suction strainers design at Perry preceded and did not meet the current regulatory requirements. The ABWR ECCS suction strainers are patented GE optimized stacked disk design in accordance with NEDC-32721P-A Rev.2. This strainer design was developed in response to NRC Bulletin 96-03 as a replacement of existing ECCS strainers with a large capacity passive strainer design. This strainer design utilizes disks whose internal radius and thickness vary over the height of the strainer. The selected variation in these parameters achieves an increased surface area compared to existing strainers of the same size to provide a

To avoid debris clogging the flow restrictions downstream of the strainers, the size of the holes in the perforated sheets is chosen by considering specific flow paths of ECCS equipment and piping (for example, the containment spray nozzle and the ECCS pump seal cooling flow cyclone separator type filters and orifices). The strainers will have holes no larger than 3.175 mm (0.125 inch).

higher capacity for debris capture. The ABWR strainer will perform with a minimum head loss for the range of possible amounts of debris while fitting in the required volume. ~~To avoid debris clogging the flow restrictions downstream of the strainers, the size of the holes in the perforated sheets is chosen by considering specific flow paths of ECCS equipment and piping (for example, the containment spray nozzle and the ECCS pump seal cooling flow orifices). The strainers will have holes no larger than 3.175 mm (0.125 inch).~~

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 maximum debris load fraction assuming 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 ~~suction strainers and a single~~loop, one HPCF loop, and the~~or~~ RCIC system~~suction strainer~~.

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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 chemical precipitate debris that may contribute to blockage and head loss.

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.

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. NEDE-33878P, ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability, Rev. 2, (Reference 6C-5) evaluated the impact of debris downstream of the ECCS strainers causing blockage or wear and abrasion. The three areas of concern evaluated are (1) blockage of system flow paths at narrow flow passages (e.g., ECCS sparger spray nozzles), (2) wear and abrasion of surfaces (e.g., pump running surfaces and heat exchanger tubes and orifices), and (3) blockage of flow paths through 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).~~

This assessment concludes that ECCS flow paths and components downstream of the strainers, including fuel assemblies, are not susceptible to failure from debris blockage, particulate

The assessment credited the configuration of ECCS instrument line taps in the process piping. ECCS instrument lines in service during post-LOCA operation are installed with taps above the horizontal plane of the process piping. No settling of debris in an instrument line with this orientation is expected. *Also, pressure instruments measure through impulse piping. There is no flow with this configuration to pull debris into the measuring devices.*

ingestion, abrasive effects and long term degradation and can perform required safety functions during the required mission time.

The assessment includes the effects of debris settling in instrument lines and components, blockage and binding of tight clearance valves (such as throttle and check valves) and wear of ECCS components (pumps and heat exchangers).

~~The assessment credited the configuration of ECCS instrument line taps in the process piping. ECCS instrument lines in service during post-LOCA operation are installed above the horizontal plane of the process piping. No settling of debris in an instrument line with this orientation is expected.~~

The assessment used the listed ECCS valve positions for post-LOCA system alignment:

- Table 1, Valve Position Chart, DCD Figure 5.4-11, Reactor Heat Removal System PFD (sheet 2 of 2)
- Table 1, Valve Position Chart, DCD Figure 6.3-1, High Pressure Core Flooder System PFD (sheet 2 of 2)
- Table 1, Valve Position Chart, DCD Figure 5.4-9, Reactor Core Isolation Cooling System PFD (sheet 2 of 2)

ECCS pump and component performance qualification will be validated using the guidance of QME-1, Qualification of Active Mechanical Equipment Used in Nuclear Power Plants.

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.

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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.

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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 m3/h) to rated flow (954 m3/h), which reduces the pressure drop across the debris.

Based on these considerations, the ABWR ECCS suction strainers are the GE stacked disk strainer design analyzed for the sizing methodology in NEDC-32721 P-A (Ref. 6C-4). The ABWR selected strainer design utilizes sizing for the RHR service for each of the strainers. The ABWR ECCS suction strainer configuration is as follows:

- Type: GE stacked disk passive suction strainer.
- Flow Area: Each strainer has perforated area 36 m^2 with 20 disks, which provides a combined surface area of 216 m^2 for three (3) RHR, two (2) HPCF and one (1) RCIC strainer(s).
- Hole Size: 3.2 mm diameter.
- Flow Rate Sizing: 2180 m^3/hr.

The ABWR ECCS suction strainer classification information is provided in Table 3.2-1, Classification Summary.

6C.6 COL License Information

6C.6.1 ~~Debris Evaluation for ECCS Suction Strainer~~Deleted

~~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.~~

6C.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~~4.

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

6.C-4 Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer, NEDC-32721P-A, March 2003 (using an updated head loss correlation).

6.C-5 ~~NEDE-33878P, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017 (GEH Proprietary Information); NEDO-33878, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 2, August 2017.~~

NEDE-33878P, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 3, March 2018 (GEH Proprietary Information); NEDO-33878, "ABWR ECCS Suction Strainer Evaluation of Long-Term Recirculation Capability," Rev. 3, March 2018

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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)
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)