Enclosure 5

M170046

Technical Report NEDO-33878

Public Information

IMPORTANT NOTICE REGARDING CONTENTS OF THIS DOCUMENT Please Read Carefully

HITACHI

GE Hitachi Nuclear Energy

NEDO-33878
Revision 0
February 2017

Non-Proprietary Information – Class I (Public)

Licensing Technical Report

ABWR ECCS SUCTION STRAINER EVALUATION OF LONG-TERM RECIRCULATION CAPABILITY

INFORMATION NOTICE

This is a non-proprietary version of the document NEDE-33878P Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT
Please Read Carefully

This document provides certain details of the Emergency Core Cooling System Suction Strainers for the ABWR standard design. The information contained in the document is furnished to the NRC for the purpose of conducting its review for the renewal of the ABWR standard design certification. The use of this information by anyone for any other purpose than that for which it is intended is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

TABLE OF CHANGES

Rev. #	Date	Revision Summary
0	02/2017	Initial Issue

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

The Advanced Boiling Water Reactor (ABWR) design was certified as 10 CFR Part 52, Appendix A, in a final rulemaking published May 12, 1997, effective June 11, 1997. In the certified design, emergency core cooling system (ECCS) suction strainers were included to address concerns with debris that could block the suction of the ECCS pumps when recirculating from the suppression pool.

On December 7, 2010, GEH applied to the U.S. Nuclear Regulatory Commission (NRC) for the renewal of the ABWR standard plant design certification (DC), which the NRC had issued on June 11, 1997. Because of lessons learned from BWR operating experience and from the review of Generic Safety Issue-191, Assessment of [Effect of] Debris Accumulation on PWR Sump Performance, the staff determined that additional information was required to evaluate compliance of the Emergency Core Cooling System (ECCS) design with 10 CFR 50.46(b)(5). Lessons learned included recognition of the inadequacy of the criterion to allow 50 percent blockage of the strainer surface area and recognition of chemical precipitates as a potential debris source. The staff incorporated these and other lessons learned into revisions of Regulatory Guide (RG) 1.82, Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident.

In a July 20, 2012 response to GEH's application for certification renewal, the NRC communicated the list of design changes that the NRC considered to be regulatory improvement or changes that could meet the 10 CFR 52.59(b) criteria. Item 9 requested that GEH confirm that the emergency core cooling system suction strainer design complies with 10 CFR 50.46(b)(5), including providing net positive suction head (NPSH) margins using RG 1.82, Revision 4, addressing chemical, in-vessel, and ex-vessel downstream effects, providing a structural analysis, and updating the ITAAC as necessary consistent with the new guidance.

<u>ECCS Suction Strainer Debris Issue</u>

Boiling Water Reactor (BWR) strainer performance issues were evaluated in the mid-1990s after some incidents at foreign and domestic BWRs led to concerns about strainer performance. Evaluation of these issues led to enlargement of strainer size, and the NRC's conclusion almost a decade ago that the questions regarding BWR strainer performance had been resolved. In 2007, the NRC did a preliminary area-by-area comparison of regulatory and technical treatment of BWRs vs. PWRs. The NRC's initial conclusion was that there were disparities in treatment, but there is not enough information to validate the issues or their significance. The NRC concluded additional evaluations were needed to determine the safety significance of these issues.

The NRC's Office of Nuclear Regulatory Research and the BWR Owners' Group (BWROG) have begun new work on BWR strainer performance. The NRC and the BWR Owners Group have met on several occasions to discuss a path forward. The NRC staff has provided perspective to the BWROG on some of the subject areas related to strainer performance based on lessons learned from evaluations of PWR Sump Performance.

Currently operating BWR strainer designs are based on guidance from sources such as the BWR Owners Group Utility Resolution Guidance, the accompanying safety evaluation (SE) and NUREG/CR-6224, Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris. In future evaluations, BWR strainer designs consider subsequent guidance developed during the resolution of GSI-191 and GL 2004-02 including chemical and downstream effects and strainer head loss and vortexing.

ABWR Solution

The ABWR ECCS strainers are sized to conform with the guidelines provided in Reg Guide 1.82 Rev. 4, for the most severe of all postulated breaks.

- The debris generation model was developed in accordance with the Utility Resolution Guidance, NEDO-32686-A (Reference 1).
- The design debris load transported to the suppression pool is based on the Utility Resolution Guidance, NEDO-32686-A (Reference 1).
- The ECCS Strainer design is based on the Debris Load Fraction that accumulates on a given strainer for the Loss of Coolant Accident (LOCA) case considered. [[ ]]
- Suction strainer sizing criteria is based on meeting NPSH requirements at runout system flow.

The ABWR design provides reasonable assurance that downstream effects as a result of debris bypassing the strainers will not have a deleterious effect on critical components such as fuel rods, valves and pumps downstream of the suction strainers.

The ABWR design incorporated improvements from the currently operating boiling water reactor (BWR) design:

- ABWR design eliminates recirculation piping external to the reactor pressure vessel (RPV), which removes a significant source of insulation debris and reduces the likelihood of a large high energy pipe break leading to the introduction of debris.
- ABWR main steam and feedwater piping connects to the RPV above the core, thus eliminating a large break loss of coolant accident (LOCA) below the top of active fuel.
- ABWR uses a stainless-steel liner for the submerged portion of the ABWR suppression pool as opposed to carbon steel used in earlier designs of BWR suppression pools, significantly lowering the amount of corrosion products which can accumulate in the suppression pool.
- The use of several materials in the primary containment are prohibited or minimized (e.g., aluminum, zinc), mitigating many of the chemical effects from debris.
- The ABWR has diversification of ECCS delivery points, which helps to reduce the consequences of downstream blockage. Two High Pressure Core Flooder (HPCF) loops deliver coolant to the region above the core (i.e., at the outlet of the fuel assemblies). One of three LPCF loops provide coolant through one of the feed water lines. The Reactor Core Isolation Cooling (RCIC) system delivers coolant to the other feedwater line. Two LPCF systems deliver coolant through separate spargers into the outer annulus region. Should any blockage occur in the lower core region (such as the fuel inlet) which could limit the effectiveness of systems like Residual Heat Removal (RHR)), the HPCF system will still be effective at providing cooling water because it delivers water through spargers located above the core.

1.2 Purpose

The purpose of this technical report is to provide certain supporting technical information regarding the new design of the ECCS suction strainers for the ABWR.

This technical report provides supporting information to show conformance with RG 1.82, Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident, Revision 4.

1.3 Acronyms

Acronym	Explanation
ABWR	Advanced Boiling Water Reactor
DBA	Design Basis Accident
DCD	Design Control Document
ECCS	Emergency Core Cooling System
ESBWR	Economic Simplified Boiling Water Reactor
FAPCS	Fuel and Auxiliary Pools Cooling System
GPM	Gallons per Minute
HPCF	High Pressure Core Flooder
IOZ	Inorganic Zinc
LOCA	Loss of Coolant Accident
MSL	Main Steam Line
NPSH	Net Positive Suction Head
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
RMI	Reflective Metal Insulation

1.4 Definitions

To understand certain design terms or supporting information, definitions are provided below.

Term	Description	Units
[[		
		]]

Term	Description	Units
[[		
		]]

1.5. Assumptions

1.5.1 Some design details from [[ ]]which are used as inputs to this evaluation, are considered representative of the ABWR standard plant. Examples include:

- The pipe insulation debris load calculation (Reference 7).
- The NPSH calculations given in References 17, 18, and 19.

1.5.2 [[

1.5.3

]]

1.5.4 It's assumed that a design basis sludge load of 200 lbm per cycle bounds the generation rate for a typical ABWR.

Section 3.2.4.3.2 of the URG (Reference 1), describes a survey of operating BWRs that measured the rate of sludge generation. The data, collected from 12 plants with Mark I, II, and III containment designs, indicated a median sludge generation rate of 88 lbm per year. The URG recommends a value of 150 lbm per year to bound these results unless a lower plant-specific value can be justified.

The ABWR design features many improvements over the conventional BWRs that will help to minimize the generation of sludge. Specifically, the suppression pool is equipped with a stainless steel liner, and many interfacing systems utilize stainless steel pipe, which reduces the generation of carbon steel corrosion products. The ABWR suppression pool is enclosed in a concrete compartment and protected from the drywell environment, unlike some containment designs (from the BWROG survey), which are subject to dirt and debris falling through grating into the pool.

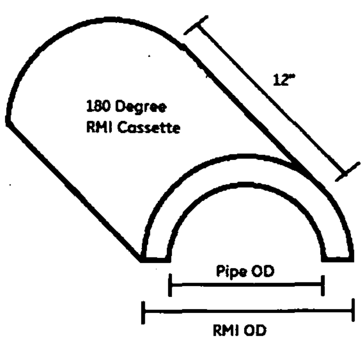
The above considerations suggest the ABWR sludge generation rate would be less than the typical operating BWR. Therefore, the assumed ABWR sludge load of 200 lbm (100 lbm per year with a two-year operating cycle) is considered reasonable. Furthermore, there is a COL Item in Section 6.2.7.3 of the ABWR Design Control Document (DCD) (Reference 21) that requires the applicant to establish a method for maintaining a level of cleanliness that supports this assumption.

1.5.5 [[

]], Table 1 below, [[
]]

Table 1: [[ ]]

[[[redacted]				[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]				[redacted]	
					]]



[[

]].

1.5.6 The suppression pool, at its minimum drawdown level, provides a static head of [[ ]] above the pump inlet nozzle. [[

]]

2.0 DESIGN METHODS

The methodology for sizing and qualifying a stacked disk ECCS Suction Strainer was initially developed in Reference 2. [[

]] These references are used as the model for this ABWR evaluation.

For simplicity, an existing strainer design will be selected from those evaluated in Reference 5. The ABWR-specific debris load, flow rate, and pool conditions will then be applied using the methods described in Reference 5 to demonstrate that a qualified strainer design exists to support ABWR certification. Note that this evaluation demonstrates a single bounding design for the ABWR standard design to ensure compliance to 10CFR50.46(b)(5).

Future COLA applicants or COL licensees that elect to develop a more optimal sizing for each of the three ECCS strainers would need to seek NRC approval of a departure to the ABWR standard design for the strainers, which would require review and approval by the NRC as part of the COLA or in a post-COL license amendment request.

2.1 Discussion

This section describes the strainer qualification process, and the reasoning for each step.

2.1.1 Debris Types / Quantities

This subsection discusses the types and quantities of debris in the ABWR standard design.

2.1.1.1 Piping Insulation

The debris generated from pipe insulation for [[ ]] was calculated in [[ ]] which can be found in [[ ]]. This calculation is based on Method 3 of Reference 1, which uses spherical zones of influence with a volume based on destruction pressure specific to the type of insulation. This calculation evaluates Nukon fiber debris and reflective metal insulation (RMI) debris under two scenarios: [[ ]] and (2) [[ ]] These two cases were selected because:

- [[

]].

Additional discussion is provided in [[ ]]. The basis described above was used to generate the debris values found in Section 4.3.1.6.1 of the [[ ]]. The values were updated for Rev. 1 of that specification to those shown below:

Table 2: [[ ]]

[[		
		]]

The basis for the values in Table 2 is discussed in [[ ]]. This discussion explains that the original insulation quantities were updated based on the restrictions for Nukon to small bore piping and, also, to include transport factors have been included in the derivation of these numbers. Because transport has already been considered, there is no longer a reason to distinguish the debris above the grating from debris below the grating. The numbers represent the quantity of debris that has already made its way to the suppression pool. Therefore, the details related to the grating have been removed as they are no longer pertinent.

[[

]].

Table 3: [[ ]]

[[	
	]]

As shown in Table 3, the E11 and E22 load fractions of [[ ]], respectively, are based on the combined flow of one HPCF and one RHR loop at rated flow following a break in one of the three RHR loops (with no operation of RCIC). In a more realistic scenario, the two remaining RHR loops would be running in parallel and HPCF would be drawing from the CST. But because this results in no debris load on the HPCF strainer, and a load fraction of only 0.5 split between the two RHR strainers, the alignment described above is more conservative.

The E51 load fraction of [[ ]] is based on the combined flow of one RHR, one HPCF, and one RCIC loop at rated flow following a break in one of the three RHR loops. In a more realistic scenario, given the large size of an RHR break, the RCIC system would not be credited in the overall ECCS performance. RCIC performance is credited in medium and small break LOCAs, which would have correspondingly less debris generated. Therefore, the load fraction assumed above is conservative.

With this justification, the RHR debris generation values will be ignored in favor of the MSL values.

Lastly, it was recommended in Volume 1, page 59, of Reference 7, that an additional 1 ft^3 of fibrous debris be added to account for miscellaneous foreign material left in containment. This will be factored into the calculation as if it were Nukon insulation. Therefore, the [[ ]] of Nukon resulting from a MSL break is increased by 1 ft^3 (0.028 m^3) to give the following finalized piping insulation values:

Table 4: [[ ]]

[[	
	]]

The total Nukon volume of [[ ]] can be converted to a Total Fibrous Debris Mass (**M_F**) on a density of 2.4 lbm/ft^3 (per Section 6.3.3 of Reference 11).

M_F = [[ ]]

2.1.1.2 Debris from Other Sources

The debris generated from other sources was determined in accordance with Reference 11, making conservative assumptions where appropriate. The values below are taken from Section 4.3.1.6.2 in Revision 1 of Reference 8 and related discussion can be found in Volume 1, pages 58-59 of Reference 7. The "M_X" designations for debris type are used later in this evaluation, as are the ratios in the third column.

Table 5: [[ ]]

[[		
		]]

2.1.2 Selection of Bounding Strainer Design

The flow rate through the strainer is assumed to be equivalent to the runout flow for the corresponding ECCS pump. These flows are taken from Reference 9:

Table 6: [[ ]]

[[	
	]]

The pool water temperature is assumed to be at [[ ]] per Assumption 1.5.2.

A range of qualified stacked disk strainers from the operating fleet is given in Reference 6. To simplify this evaluation, the [[ ]] strainer (Reference 16) is used to evaluate applicability to the ABWR RHR System. It is understood that the [[ ]] RHR system flow [[ ]] is substantially higher than the ABWR RHR flow rate reported above, and therefore may be oversized for the application. This is conservative for the safety function the strainer performs, but may not be the most practical or economical choice. If future COLA applicants or COL licensees elect to seek NRC approval of a departure from the standard design, future design work can be performed to qualify a more optimized strainer size, as discussed in Section 2.0 above, following the process described herein.

Because the E22 and E51 strainers have lower flow rates and lower debris load factors than the E11 strainer, it is assumed that their performance is bounded by the evaluation of the E11 system. Therefore, the head loss evaluation will be performed for only the E11. In Section 3.0, a check is performed against the NPSH requirements for each of the three ECCS systems. As with E11, future work can determine a more optimal size for the E22 and E51 strainers.

2.1.3 Head Loss Evaluation

The head loss correlation given by Reference 2 is defined as:

[[

]]

See Section 1.4 for a definition of these variables. Some additional factors will be added to this correlation to address considerations such as RMI insulation. The content of this section will explain the derivation of each of these parameters, and the final correlation is summarized in Section 3.

[[

]].

[[

]].

2.1.3.1 Spreadsheet Instructions

Reference 5 contains instructions on how to use a spreadsheet template (verified in Reference 6) to simplify many of the calculations related to strainer dimensions and debris bed thickness. [[

]]

2.1.3.2 [[ ]]

[[

]]

A similar method is used to determine the losses through the connecting flange. [[

]]

Table 7: [[ ]]

[[	
	]]

2.1.3.3 [[ ]]

[[

]]:

[[

]]

2.1.3.4 [[ ]]

[[

]]

Table 8: [[				]]
[[				
				]]

[[

]]

2.1.3.5 [[ ]]

[[

]].

Table 9: [[ ]]

[[				
				]]

[[

]]

3.0 DESIGN RESULTS & ACCEPTANCE CRITERIA

3.1 Design Results

The head loss is calculated by compiling all the factors discussed in Section 2.1.3. [[

]]

[[

]]

Table 10 below summarizes each value and where in this report it was derived.

Table 10: [[ ]]

[[			
			]]

[[

]]

3.1.1 RHR Acceptance Criteria

The required NPSH for the RHR pumps is given in DCD Table 6.3-9 (Reference 21) as 2.4 m (7.9 ft). According to a [[ ]] calculation [[ ]], there is an available NPSH of [[ ]], assuming the strainer losses do not exceed [[ ]].

[[

]]

This adjustment shows that the strainer design from this evaluation can satisfy the NPSH requirements of the RHR system of a typical ABWR.

3.1.2 HPCF Acceptance Criteria

The required NPSH for the HPCF pumps is given in DCD Table 6.3-8 (Reference 21) as 2.2 m (7.2 ft). According to a [[ ]] calculation [[ ]], the HPCF system provides an available NPSH of [[ ]], assuming that the maximum strainer losses are limited to [[ ]] of head given a temperature of 100°C and a runout flow of 890 m^3/hr.

The results shown in Section 3.1 meet the [[ ]] of head required by [[ ]]. There is significant conservatism in this method, because the NPSH margin for the [[ ]] HPCF system was determined at a lower flow rate and viscosity.

3.1.3 RCIC Acceptance Criteria

The required NPSH for the RCIC pumps is given in DCD Table 5.4-2 (Reference 20) as 7.3 m (24.0 ft). According to a [[ ]] calculation [[ ]], the RCIC system provides an available NPSH of [[ ]], assuming that the maximum strainer losses are limited to [[ ]]of head given a temperature of 77°C and a runout flow of 199 m^3/hr.

The results shown in Section 3.1 meet the [[ ]]of head required by [[ ]]. There is significant conservatism in this method, because the NPSH margin for the [[ ]] RCIC system was determined at a lower flow rate and viscosity.

4.0 CONCLUSIONS

It has been shown that a strainer design exists that can be applied to the RHR System for the ABWR such that under the most limiting debris load and environmental conditions, the head losses across the debris bed, strainer, and pipe flange shall be limited to [[ ]] of water under the conservative assumptions of pump runout flow and higher viscosities resulting from an assumed low temperature of [[ ]]. This low temperature assumption was not credited when calculating NPSH margin.

This bounding strainer design was shown to also satisfy the NPSH requirements for the HPCF and RCIC pumps.

5.0 REFERENCES

1. NEDO-32686-A Rev. 0, Utility Resolution Guidance for ECCS Suction Strainer Blockage, November 1996

2. NEDC-32721P-A Rev. 2, Licensing Topical Report: Application Methodology for the GE Stacked Disk ECCS Suction Strainer, March 2003 (GEH Proprietary)

3. [[ ]] *Evaluation Report* (GEH Proprietary)

4. [[ ]] *Closure Letter* (GEH Proprietary)

5. [[ ]] Plant Summary Design Notes FINAL.pdf (GEH Proprietary)

6. [[ ]] *USBWR Strainer Stats20080520.xls* (GEH Proprietary)

7. [[ ]], Design Record File for Suppression Pool Suction Strainers (GEH Proprietary)

8. [[ ]] (GEH Proprietary)

9. [[ ]] (GEH Proprietary)

10. [[ ]] (GEH Proprietary)

11. NUREG/CR-6224 (SEA No. 93-554-06-A:1), Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris, October 1995

12. [[ ]] Preliminary Sizing of FAPCS Strainer (GEH Proprietary)

13. Continuum Dynamics Report 95-09, Testing of Alternate Strainers with Insulation Fiber and Other Debris, November 1996

14. NEDM-20363-13-01, Hydraulics of Boiling Water Reactors, August 2006

15. Continuum Dynamics Report 95-17, Structural Properties of Reflective Metal Insulation Installed in U.S. BWR's, 1996

16. [[ ]], Assembly Drawing Suction Strainer, RHR, [[ ]]

17. [[ ]] (GEH Proprietary)

18. [[ ]]. (GEH Proprietary)

19. [[ ]] (GEH Proprietary)

20. 25A5675AG Rev. 6, ABWR Design Control Document, Tier 2, Chapter 5

21. 25A5675AH Rev. 6, ABWR Design Control Document, Tier 2, Chapter 6

22. 25A5675BB Rev. 6, ABWR Design Control Document, Tier 2, Chapter 21

23. NEDO-32686-A, Utility Resolution Guide for ECCS Suction Strainer Blockage Volume 4 Technical Support Documentation [GE-NE-T23-00700-15-21 March 1996 (Rev. 1) Evaluation of the Effects of Debris on ECCS Performance]

24. [[ ]] (GEH Proprietary)

25. [[ ]] (GEH Proprietary)

26. [[ ]] (GEH Proprietary)

27. [[ ]] (GEH Proprietary)

28. [[ ]] (GEH Proprietary)

29. [[ ]] (GEH Proprietary)

30. [[ ]] (GEH Proprietary)

31. [[ ]] (GEH Proprietary)

32. [[ ]] (GEH Proprietary)

33. [[ ]] (GEH Proprietary)

34. [[ ]] (GEH Proprietary)

35. NEDC-32976P, SAFER/GESTR-LOCA Loss of Coolant Accident Analysis [[ ]] (GEH Proprietary)

36. [[ ]], HPCF Sparger (GEH Proprietary)

37. NEI 04-07 Rev 0, Pressurized Water Reactor Sump Performance Methodology

38. NUREG/CR-6808 (LA-UR-03-0880), Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance, February 2003

39. NEDC-33302P, Fiber Insulation Effects with Defender Lower Tie Plate, March 2007 (GNF Proprietary)

APPENDIX A DOWNSTREAM EFFECTS EVALUATION

A.1 OVERVIEW

Evaluation of the ABWR containment includes a review of the flow paths downstream of the emergency core cooling systems (ECCS). The concerns addressed for downstream effects are:

- Blockage of flow paths in equipment; for example, spray nozzles or tight-clearance valves
- Wear and abrasion of surfaces; for example, pump running surfaces, heat exchanger tubes and orifices
- Blockage of flow clearances through fuel assemblies

In general, the downstream review broadly considers flow blockage in the ECCS flow paths, as well as examining wear and abrasion in systems, structures, and components in the ECCS flow paths that are credited for long-term cooling functions.

The downstream review considers the flow clearance through the ECCS suction strainer. This determines the maximum size of particulate debris that will pass through the suction strainer and enter the ECCS flow paths. If passages and channels in the ECCS downstream of the suction strainer are larger than the flow clearance through the suction strainer, blockage of those passages and channels by ingested debris is not a concern. If there are passages and channels equal to or smaller than the flow clearance through the suction strainer, then the potential for blockage exists and an evaluation is made to determine if the consequences of blockage are acceptable or if additional evaluation or enhancements are warranted.

Similarly, wear and abrasion of surfaces in the ECCS is evaluated, based on the flow rates to which the surfaces will be subjected and the grittiness or abrasiveness of the ingested debris. The abrasiveness of the debris is plant-specific and depends on the insulation materials that become debris. For example, fiberglass is a known to be an abrasive material.

The detailed ABWR ECCS downstream effects evaluation is documented in Appendix A, Tables A-4 through A-8.

A.2 ECCS SYSTEM DESCRIPTIONS AND MISSION TIMES

The downstream review defines both long-term and short-term system operating lineups, conditions of operation, and mission times (see Table A-1). Where more than one ECCS configuration is used during long-term and short-term operation, each lineup is evaluated with respect to downstream effects. The definition of the mission times form the premise from which the short- and long-term consequences are determined and evaluated.

Once conditions of operation and mission times are established, downstream process fluid conditions are defined, including assumed fiber content, hard materials, soft materials, and various sizes of material particulates. It can be shown that particles larger than the sump-screen mesh size will not pass through to downstream components. Debris may pass through because of its aspect ratio or because it is "soft" and differential pressure across the screen pulls it through the mesh. No credit is taken for thin-bed filtering effects.

See Figure A-1 below illustrating ECCS flow paths.

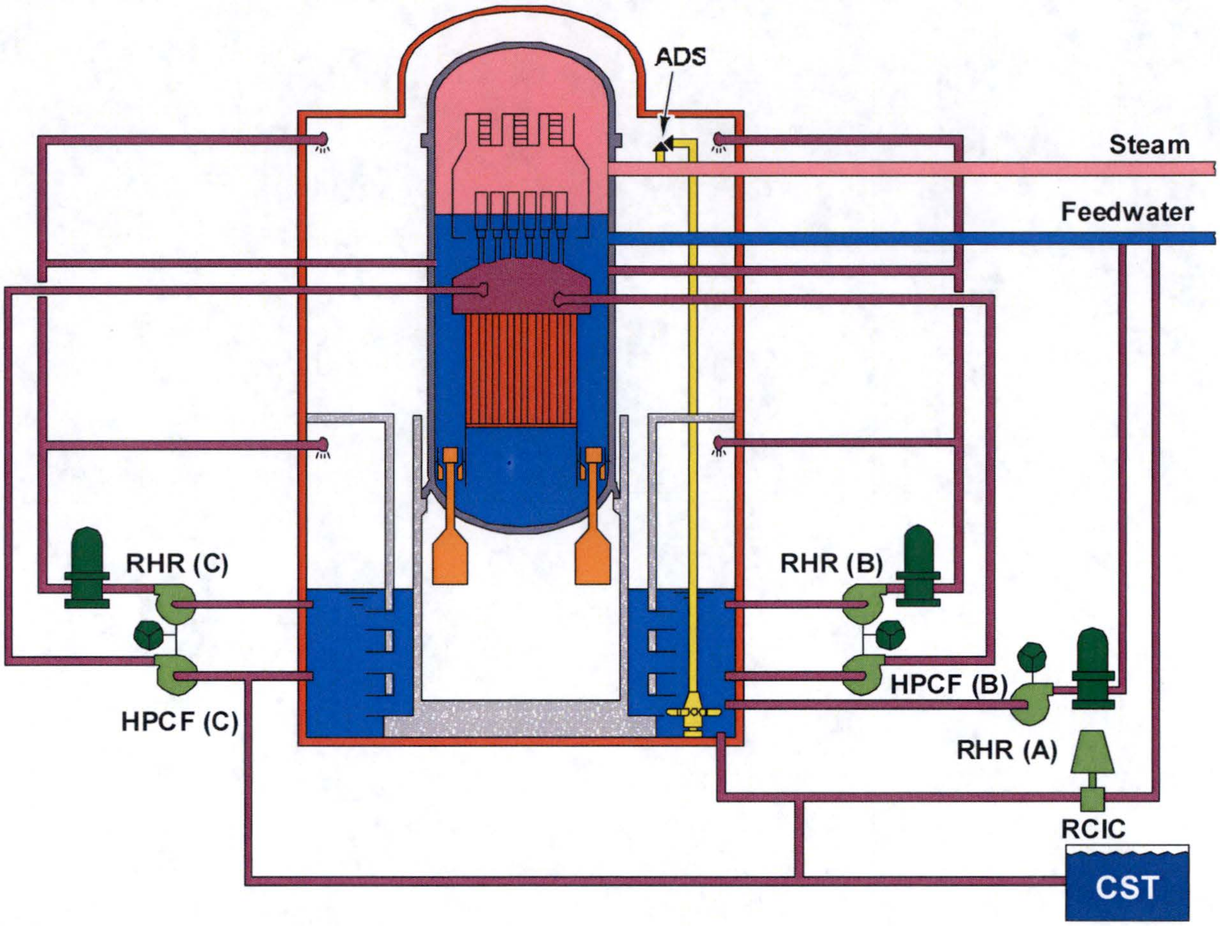


FIGURE A-1, ABWR ECCS FLOW PATHS

Table A-1: [[ ]]

[[			
			]]

A.3 DEBRIS INGESTION

A summary of the debris ingestion model used to assess the equipment in the ECCS systems is provided below in Table A-2, ABWR Debris Source Term. The debris considered includes fibrous insulation debris and particulate debris consisting of paint chips, concrete dust, and reflective metallic insulation shards small enough to pass through the holes of the ECCS suction strainer perforated plates.

For passive screens the amount of debris, both fibrous and particulate, that passes through the screen is dependent upon the size of the flow passages in the suction strainer and the ratio of the open area of the screen to the closed area of the screen. There are other factors affecting debris bypass through the suction strainer, such as the fluid approach velocity to the screen, and the screen geometry.

The ABWR suction strainer perforated discs are fabricated from 11 gauge (0.12 in.) thick stainless steel plate with 0.125 in. diameter holes with 0.188 in. staggered spacing (Reference 16).

A series of assumptions has been applied in determining the make-up of the post-LOCA fluid:

1. No credit is provided for filtering of material due to a thin bed of material on the suction strainer
2. The dimensions of particulates passing through a suction strainer are assumed as follows:

[[

]]

The maximum dimension (length, width, and/or thickness) of non-deformable particulates that may pass through a suction strainer is limited to the cross-sectional flow area of the penetration (hole) in the suction strainer.

Table A-2: [[ ]]

[[		
		]]

[[

]]

A.4 WEAR RATE AND COMPONENT EVALUATION

A.4.1 Auxiliary Equipment Evaluation

The methodology presented in NEI 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology (Reference 37), was applied to assess auxiliary components subject to debris-laden post LOCA fluid. The following ECCS modes of operation were assessed for downstream effects. ECCS component sizing was developed from [[ ]] ABWR P&IDs:

- TABLE A-4, [[ ]]
- TABLE A-5, [[ ]]
- TABLE A-6, [[ ]]
- TABLE A-7, [[ ]]
- TABLE A-8, [[ ]]

NEDO-32686-A, Utility Resolution Guide for ECCS Suction Strainer Blockage, Volume 4, Technical Support Documentation [Evaluation of the Effects of Debris on ECCS Performance GE-NE-T23-00700-15-21 March 1996 (Rev. 1)] (Reference 23), provides a generic safety evaluation for ECCS auxiliary components that bounds the ECCS components for ABWR.

This assessment addresses auxiliary components including ECCS pumps required to operate during recovery from LOCA and containment steam line break accidents. The ECCS pumps are assumed to operate for the required mission time of 100 days following a LOCA. The evaluations consider ECCS and CSS pump hydraulic performance, mechanical shaft seal assembly performance, and pump mechanical performance (vibration).

NEDO-32686-A, Utility Resolution Guide for ECCS Suction Strainer Blockage, Volume 4, Technical Support Documentation [Evaluation of the Effects of Debris on ECCS Performance GE-NE-T23-00700-15-21 March 1996 (Rev. 1)] (Reference 23), provides a generic safety evaluation for ECCS auxiliary components including pumps that bounds the ECCS systems for ABWR.

This assessment addresses the effect of wear on ECCS heat exchangers and evaluate the consequences of wall thinning on heat exchanger performance. A tube plugging evaluation would be required if the heat exchanger tube inner diameter is smaller than the largest expected particle.

This assessment addresses the effect of wear on orifice and spray nozzles in the credited ECCS. An orifice / nozzle plugging evaluation would be required if the inner diameter is smaller than the largest expected particle.

This assessment addresses the plugging and wear on instrumentation tubing based on system flow and material settling velocities.

This assessment addresses the effect of wear and plugging on system piping based on system flow and material settling velocities. The evaluation reviews areas of localized high velocity and high turbulence.

This assessment addresses the effect of wear and plugging in reactor vessel internals or reactor fuel.

See Figure A-2 for the layout of ECCS components.

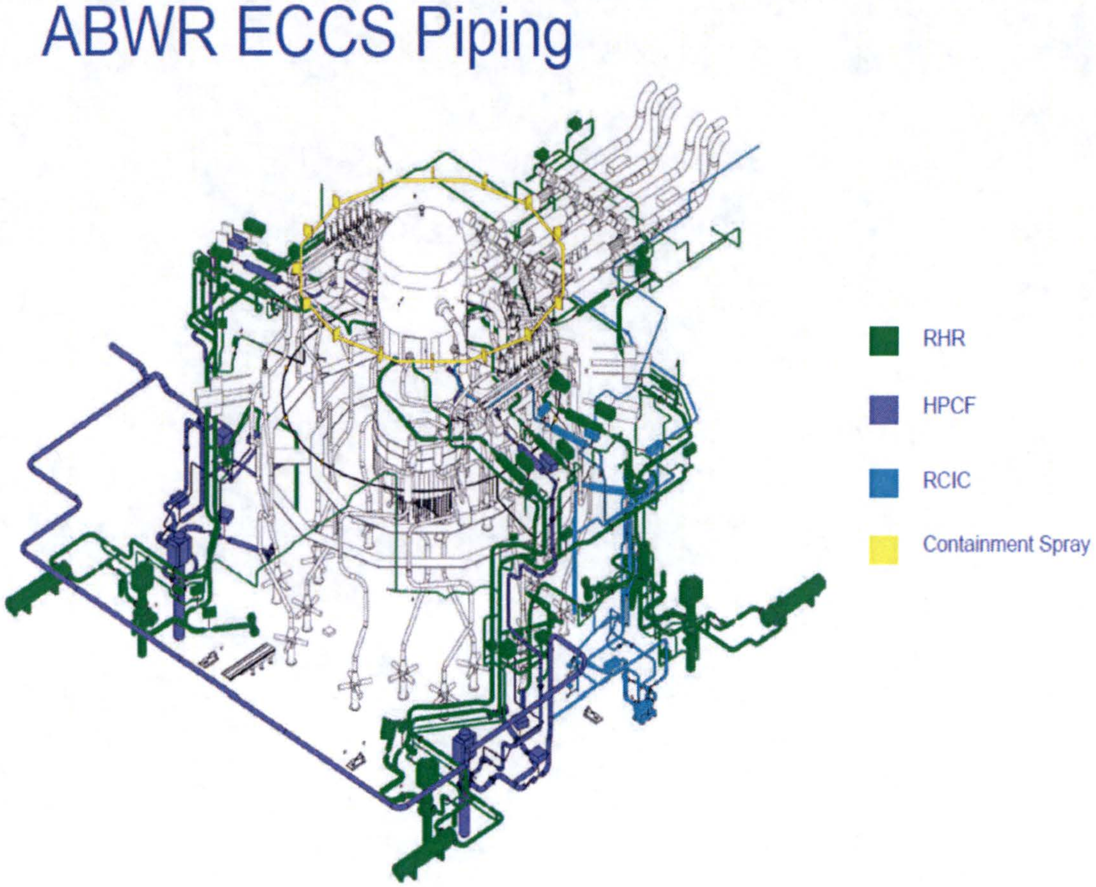


FIGURE A-2, LAYOUT OF ECCS COMPONENTS FOR DOWNSTREAM ASSESSMENT

Table A-3: [[ ]]

[[		
		]]

A.5 REACTOR INTERNALS AND FUEL BLOCKAGE EVALUATION

Flow blockage, such as that associated with core grid supports, mixing vanes, and debris filters are considered. Flow paths between upper downcomer and upper plenum/upper head are evaluated for long term cooling degradation resulting from flow interruption from plugging. All internal flow paths that influence long-term cooling are addressed for the potential for plugging these paths. The flow blockage associated with core grid supports, mixing vanes, and debris filter, and its effect on fuel rod temperature are considered.

The flow paths through the ABWR are illustrated in Figure A-1. ECCS flow with debris is injected inside the shroud (HPCF) and travels to the fuel inlet through the holes in the Lower Tie Plate, getting collected in the Lower Tie Plate grid/filter. Once the in-shroud level reaches the normal water level in the steam separators and spills into the RPV annulus, the debris will be mixed in the lower plenum and enter through the inlet orifice. Should the debris block most of the bundle inlet flow (over 95%) the coolant inside the bundle would form a level and flow would reverse at the channel top and enter the bundle from the upper plenum flow path for RHR and RCIC). The debris would then collect inside the bundle on the upper tie plate and spacers, to a much lower degree, but adequate long term cooling would still be achieved.

This bypass debris was assessed for the potential blockage of coolant flow at the entrance to the fuel assemblies as described in NEDC-33302P, Fiber Insulation Effects with Defender Lower Tie Plate (Reference 39). Tests have been performed to simulate clogging of the Defender Lower Tie Plate (DLTP) with a small concentration of fiber insulation material.

This evaluation concludes that significant BWR fuel bundle inlet clogging does not result in GNF2 fuel heat-up after the LOCA re-fill from ECCS injection. These conclusions apply to other BWR fuel bundles (e.g., ABWR GE P8x8R) with equivalent degree of inlet resistance as used in this evaluation.

NEDO-32686-A, Utility Resolution Guide for ECCS Suction Strainer Blockage, Volume 4, Technical Support Documentation [Evaluation of the Effects of Debris on ECCS Performance GE-NE-T23-00700-15-21 March 1996 (Rev. 1)], provides a generic safety evaluation for GE11 and GE 13 fuel that bounds the ECCS components for ABWR.

Even if the fibrous insulation would plug the debris filter on the fuel, the consequences of plugging, considered from an ECCS cooling standpoint, would not impede adequate core cooling during a LOCA. With normal core spray distribution, complete flow blockage of the fuel lower tie plate debris filter would allow adequate core cooling to be maintained. Consequently, it is very unlikely that excessive flow blockage of the lower tie plate debris filter would jeopardize adequate post-LOCA core cooling. It is considered inconceivable for debris to plug all channels so that flooding could not occur from below. However, if the inlet to one or more fuel channels is totally blocked from below by debris, these bundles would receive radiation cooling to the channel walls as the bypass refills, then direct cooling from water spill-over from above once the water level is restored above the top of the fuel channels. Due to the expected core reflooding rate, it is a best-estimate basis, the fuel in any blocked channels would remain well below the peak cladding temperature (PCT) limit of 2200°F.

The maximum particle sizes of the expected rust, iron oxide, epoxy paint, and sand are smaller than the fuel debris filter hole sizes and are likely to pass through without plugging. Therefore, there is no safety concern for fuel bundle flow blockage and consequent fuel damage due to all the non-fibrous debris.

See Figure A-3 for a depiction of normal fuel channel cooling flow paths.

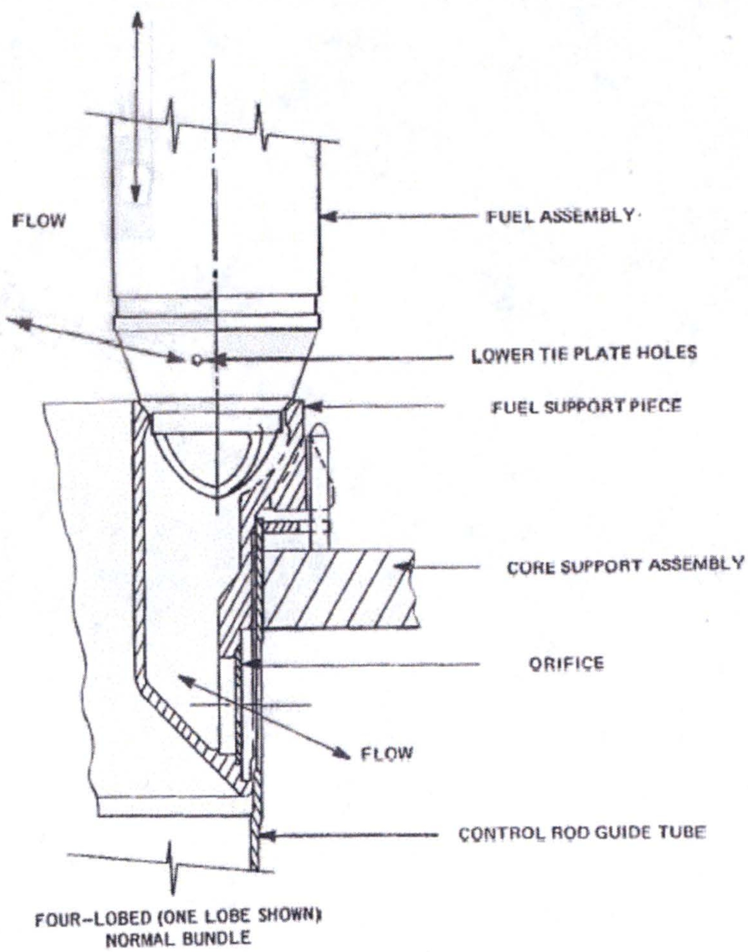


FIGURE A-3, NORMAL FUEL CHANNEL COOLING FLOW PATHS

Table A-4, [[ ]]

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								
								]]

Table A-5, [[ ]]

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								
								]]

Table A-6, [[ ]]

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

Table A-7, [[ ]]

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								
								]]

Table A-8, [[ ]]

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								

[[								
								]]