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Licensing Technical Report

ABWR ECCS SUCTION STRAINER EVALUATION OF LONG-TERM RECIRCULATION CAPABILITY

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT
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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
1	05/2017	Revised to reduce proprietary information markings and correct some paragraph spacing which reduced the page count by one page. There are no other changes. Revision bars not used.

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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. For conservatism, the worst-case load fraction for each system was applied even if it resulted from a different type of LOCA (RHR vs. MS break).
- 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
D	Outside strainer diameter	ft
L	Strainer length	ft
A_C	Circumscribed strainer area	ft^2
A_{Foil}	Foil Area on Strainer	ft^2
Q	Flow rate	gpm
T	water temperature	F
μ	Dynamic viscosity	$lbm\text{-}sec/ft^2$
ν	Kinematic viscosity	ft^2/sec
Δh	Head loss	ft H_2O
Δh_{Total}	Total strainer head loss	ft H_2O
Δh_{Clean}	Losses through a clean strainer	ft H_2O
Δh_{RMI}	Losses due to Reflective Metal Insulation (RMI) on strainer	ft H_2O
K_{clean}	Clean strainer head loss coefficient	ft H_2O
K_h	Debris head loss coefficient	-
K_{bu}	Bump up factor for non-fibrous debris	-
K_p	Proportionality Constant	-
K_t	Thickness constant for RMI material	-
K_2	Strainer flange resistance coefficient	-

Term	Description	Units
U	Circumscribed approach velocity	ft/sec
U_1	Approach velocity corrected for strainer surface area	ft/sec
U_S	Average RMI settling velocity	ft/sec
V	Flow velocity in suction line	ft/sec
M_F	Mass of fibrous debris	lbm
M_C	Mass of sludge / corrosion products	lbm
M_Z	Mass of inorganic zinc (IOZ)	lbm
M_{PC}	Mass of epoxy coated IOZ (paint chips)	lbm
M_{RF}	Mass of rust flakes	lbm
M_{CD}	Mass of cement dust / dirt	lbm
d	Interfiber distance	ft
d_f	Fiber diameter	ft
t	Debris bed thickness	ft
t_a	Theoretical RMI Bed Thickness	ft
t_p	Projected RMI Bed Thickness	ft
t_{max}	Max RMI Bed Thickness	ft

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 For the purpose of estimating viscosity for head loss through the strainer, the suppression pool temperature is assumed to be [[

]]

1.5.3 [[ ]] the best estimate head loss predictions obtained with the methodology described in Reference 5 will provide reasonable assurance of producing a bounding head loss estimate.

1.5.4 It is 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.

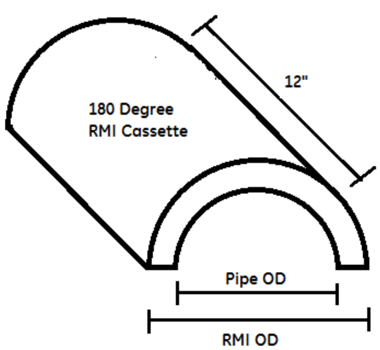
The above considerations suggest the ABWR sludge generation rate would be less than the typical operating BWR. Therefore, the assumed ABWR sludge load of 200 lbm (100 lbm per year with a two-year operating cycle) is considered reasonable. Furthermore, there is a COL Item in Section 6.2.7.3 of the ABWR 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 It is assumed that a surface-area-to-volume ratio of [[ ]] for RMI debris. [[

]], Table 1 below, [[
]]

Table 1: RMI Surface Area to Volume Ratio

Values Taken Explicitly from Table 3 of Reference 15				**Derived to support this assumption**	
Pipe OD	Radial RMI Thickness	RMI OD	RMI Surface Area [[ ]]	Volume of RMI [[ ]]	Surface Area to Volume Ratio
in	in	in	in^2	in^3	-
[[					
					]]



[[ ]]

This assumption is used in Section 2.1.3.5 for the purpose of estimating the contributions of RMI debris to the strainer head loss.

1.5.6 The suppression pool, at its minimum drawdown level, provides a static head of [[ ]] above the pump inlet nozzle. This amount of static head is consistent with the static head used in [[ ]] calculation 31113-0E11-2113 (Reference 17).

2.0 DESIGN METHODS

The methodology for sizing and qualifying a stacked disk ECCS Suction Strainer was initially developed in Reference 2. After this guidance was issued, it was determined that the methodology contained certain flaws, which are addressed in Reference 3. An updated method was documented in Reference 5, and was implemented for the Economic Simplified Boiling Water Reactor (ESBWR) Fuel and Auxiliary Pools Cooling System (FAPCS) strainer in Reference 12. 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 31113-0A51-2104 Rev. 0, 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: (1) a Main Steam Line (MSL) break, and (2) a break in the Residual Heat Removal System (RHR). These two cases were selected because:

- A MSL break has the largest ZOI and generates the most debris of any break.
- Although an RHR break generates less debris than a MSL break, there is no personnel grating separating the RHR break from the drywell to wetwell connecting vents. Therefore, a larger fraction of generated debris could make its way to the wetwell, whereas some higher-elevation MSL-generated debris would be intercepted by the grating. Until these transport factors are considered, the RHR break should not be ruled out.
- Although the ZOI for an RHR break is slightly smaller than that of a Feedwater break, the amount of debris generated is slightly greater – presumably because there is more insulated pipe in close proximity to RHR piping than is the case for Feedwater piping.
- Also, a break in RHR piping results in a different combination of ECCS systems to mitigate the event compared to a MSL break. Thus, certain systems may have a higher debris load fraction for an RHR break than they would for a MSL break.

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: [[ ]] Pipe Insulation Debris Load

Break Type	NUKON	RMI
	above / below grating	above / below grating
[[		
		]]

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.

Because the MSL break deposits a much greater amount of debris in the suppression pool than RHR break, the only remaining reason to consider an RHR break is the difference in debris load fractions (fourth bullet from above). This evaluation can be simplified by assuming a MSL break (maximum debris) along with the maximum debris load fractions reported in Reference 9 (even though some may correspond to an RHR break).

Table 3: ABWR Debris Load Fractions

	Debris Load Fraction
[[	
	]]

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: ABWR Pipe Insulation Debris Load

NUKON	RMI
[[	]]

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: ABWR Other Debris Sources

Debris Type	Strainer Load	[[ ]]
M$_C$ = Sludge / corrosion prod.	200 lbm	[[
M$_Z$ = Inorganic Zinc (IOZ)	47 lbm	
M$_{PC}$ = Epoxy Coated IOZ	85 lbm	
M$_{RF}$ = Rust Flakes	50 lbm	
M$_{CD}$ = Cement Dust / Dirt	150 lbm	]]

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: System Flow Conditions

[[	
	]]

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.

The first term from the above equation represents the losses through a clean strainer. [[

]].

The second term accounts for losses due to debris accumulation on the strainer (excluding RMI). [[

]].

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. The spreadsheet contains data in the “Stats All” tab for strainer designs that have already been qualified, and leaves a blank column (Column R) for a new design to be added. [[

]] Some of these rows are not applicable to the updated method discussed in Reference 5. Others are applicable to the updated method but require more explanation and are, therefore, discussed in more detail in the following sections.

2.1.3.2 Losses through Clean Strainer and Flange

The losses through the clean strainer are easily derived based on the value [[

]]

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

]]

Table 7: Total Clean Strainer Head Loss

Clean Strainer Losses	[[
[[	
]]	]]

2.1.3.3 Debris Load Head Loss Coefficient (K_h)

The definition of K_h, is based upon the method of Reference 2 with modifications described by Reference 3. The new K_h correlation makes a distinction between two strainer loading scenarios. [[

]] The head loss coefficient is calculated to be:

[[

]]

2.1.3.4 Strainer Debris Load Bump-up Factor (K_{bu})

The methodology described in Reference 2 includes (near the end of Section 3.3) a bump-up factor to account for the presence of non-fibrous components of the debris bed. The factor is defined in Appendix A of Reference 13. Table 8 summarizes the results of each step and provides a basis for the values used.

Appendix A of Reference 13 was originally intended to derive the head loss coefficient K_h. But because this evaluation uses an alternate method to derive K_h, many of the steps below are simply marked "not required". Only the steps needed to derive K_{bu} are used.

[[

]]

Table 8: Non-Fibrous Debris Bump-Up Factor

Step	Variable	Value	Units	Basis
1	Circumscribed Strainer Area (A_C)	[[	ft^2	Row 19 of Ref. 6
2	Strainer Approach Velocity (U)		ft/sec	Row 52 of Ref. 6
3	Mass of fibrous debris (M_F)*		lbm	Section 2.1.1.1
3	Mass of corrosion products (M_C)		lbm	Table 5
3	M_C/M_F		-	Table 5
4 - 8	Not Required			
9	Mass ratios for other debris		-	Table 5
10	"a" coefficient for all debris		-	Ref. 13 Appendix A
10	"b" coefficient for all debris		-	Ref. 13 Appendix A
10	"a" coefficient for fiber / sludge only		-	Ref. 13 Appendix A
10	"b" coefficient for fiber / sludge only		-	Ref. 13 Appendix A
11	K_{bu}	]]	-	Ref. 13 Appendix A {3}]]

* The load factor is not applied in this table, because K_{bu} is simply a ratio of non-fibrous to fibrous debris.

2.1.3.5 RMI Insulation Losses

The contribution of RMI type insulation to the overall strainer head loss is small compared to that of other types of debris. The methodology for estimating the RMI head loss is given in Appendix B of Reference 13. Table 9 summarizes the results of each step and provides a basis for the values used.

Note that the debris table in Reference 8 specifies that RMI is stainless steel foil [[

]]

For additional conservatism, this entire amount is assumed to collect entirely on one strainer (i.e., the debris load factor is not applied).

Table 9: RMI Head Loss

Step	Variable	Value	Units	Basis
-	RMI Type	[[	-	Section 2.1.3.5
-	RMI Thickness		in	Reference 8
-	Strainer Length (L)		ft	Row 8 of Ref. 6
-	Strainer Outer Diameter (D)		ft	Row 9 of Ref. 6
-	Maximum Flow Rate (Q)		GPM	Table 6
-	Foil Area on Strainer (A_{Foil})		ft^2	Section 2.1.3.5
1	Circumscribed Strainer Area (A_C)		ft^2	Row 19 of Ref. 6
2	Strainer Approach Velocity (U)		ft/sec	Row 52 of Ref. 6
3	Average RMI Settling Velocity (U_S)		ft/sec	Table B-1 of Ref. 13*
3	Max RMI Bed Thickness (t_{max})		ft	Appendix B of Ref. 13
4	Empirical Thickness Constant (K_t)		ft	Table B-2 of Ref. 13*
4	Theoretical Bed Thickness (t_a)		ft	Appendix B of Ref. 13
5	Projected Bed Thickness (t_p)		ft	Appendix B of Ref. 13
6	Proportionality Constant (K_p)			Table B-3 of Ref. 13*
6	Head Loss (Δh) for RMI	]]	ft	Appendix B of Ref. 13

* [[
]]

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. The total head loss equation has been updated as shown to include various conservative factors and assumptions described in previous sections [[

]]

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

Table 10: Summary of Data

Variable	Value	Units	Basis
[[			
			]]

The total RHR strainer head is calculated as follows [[

]]

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 [[ ]].

[[ ]] the strainer losses calculated in this evaluation can be adjusted based on water viscosity. [[ ]]

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. PLM Object 0000-0080-3041 Rev. 0, *Evaluation Report* (GEH Proprietary)
4. PLM Object 002N1768 Rev. 1, *Closure Letter* (GEH Proprietary)
5. PLM Object 0000-0080-3039 Rev. 2, Plant Summary Design Notes FINAL.pdf (GEH Proprietary)
6. PLM Object 0000-0081-1211 Rev. 2, *USBWR Strainer Stats20080520.xls* (GEH Proprietary)
7. PLM Object A60-00051-00, Design Record File for Suppression Pool Suction Strainers (GEH Proprietary)
8. 31113.62.3031, Suppression Pool Strainer [[ ]] (GEH Proprietary)
9. 31113.62.3031-01600 Rev. 1, Suppression Pool Suction Strainer [[ ]] (GEH Proprietary)
10. 31113-0U71-1000 Rev. 3, [[ ]] Reactor Building Design Specification (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. PLM Object 0000-0092-3114 Rev. 1, 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. 105E2586 Rev. 4, Assembly Drawing Suction Strainer, RHR, [[ ]]

17. 31113-0E11-2113 Rev. 1, [[ ]] Residual Heat Removal System – Pump NPSH Calculation (GEH Proprietary)

18. 31113-0E22-2106 Rev. 0, [[ ]] High Pressure Core Flooder System – Pump Total Head Calculation (GEH Proprietary)

19. 31113-0E51-2121 Rev. 0, [[ ]] Reactor Core Isolation Cooling System – Pump NPSH Calculation (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. 31113-1E11-M2001 through M2010, Piping and Instrument Diagram Residual Heat Removal System (GEH Proprietary)

25. 31113-1E22-M2001 and M2002, Piping and Instrument Diagram HP Core Flooder System (GEH Proprietary)

26. 31113-1E51-M2001 through M2003, Piping and Instrument Diagram Reactor Core Isolation Cooling System (GEH Proprietary)

27. 31113-1N22-M2001, Piping and Instrument Diagram Feedwater System (GEH Proprietary)

28. 31113-1E11-M0100, Rev 9, Residual Heat Removal System Design List (GEH Proprietary)

29. 31113-1E22-M0100, HP Core Flooder System Design List (GEH Proprietary)

30. 31113-1E51-M0100, Reactor Core Isolation Cooling System Design List (GEH Proprietary)

31. 31113-1N22-M0100, Feedwater System Design List (GEH Proprietary)

32. 31113-0E11-2010, Rev.4, Residual Heat Removal (RHR) System Design Description (GEH Proprietary)

33. 31113-0E22-2010, Rev.5, High Pressure Core Flooder System Design Description (GEH Proprietary)

34. 31113-0E51-2010, Rev. 4, Reactor Core Isolation Cooling System (RCIC) Design Description (GEH Proprietary)

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

36. 105E2763 R3, 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.

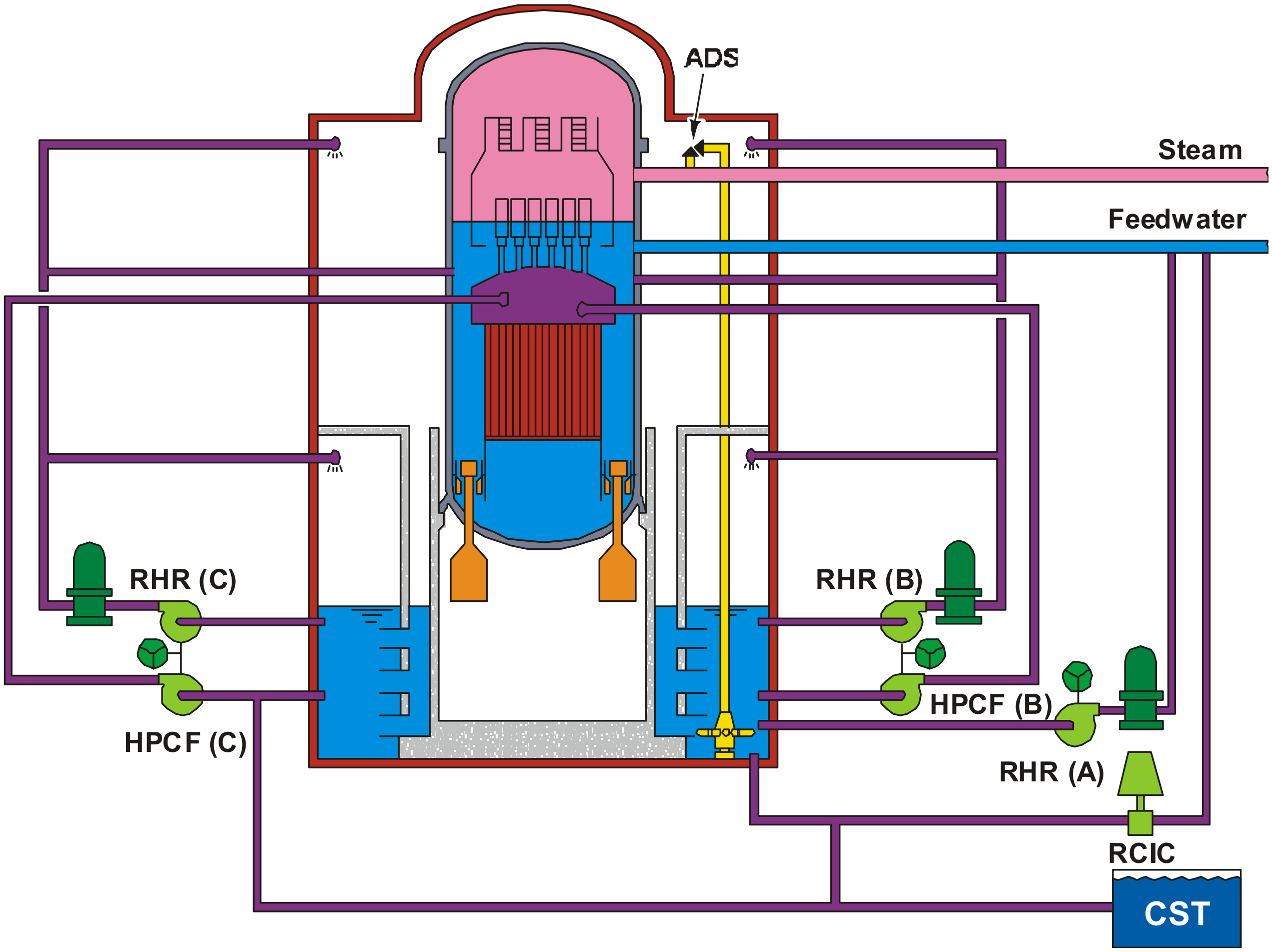


FIGURE A-1, ABWR ECCS FLOW PATHS

Table A-1: ECCS Mode, Mission Time and Description

Emergency Cool Cooling System	Mode of Operation	Mission Time	Description
RHR CORE COOLING	[[	100 days	[[
RHR SUPPRESSION POOL COOLING		100 days	
RHR WETWELL SPRAY		100 days	
HIGH PRESSURE CORE FLOODER		100 days	
REACTOR CORE ISOLATION COOLING SYSTEM		12 hrs	
RHR Alternate Flow path (not credited)	]]	Based on fire water tank / diesel fire pump fuel capacity	]]

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 length (l) of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to [[

]]

The maximum width (w) of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to [[

]]

The maximum thickness (t) of deformable particulates that may pass through the penetrations (holes) in a passive suction strainers is equal to [[

]]

The maximum cross-sectional area (a) of deformable particulates that may pass through the penetrations (holes) in a passive suction strainer is equal to [[

]]

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: ABWR Debris Source Term

Debris Type	Strainer Load	Debris Downstream Strainer
Sludge / corrosion prod.	200 lbm	200 lbm
Inorganic Zinc (IOZ)	47 lbm	47 lbm
Epoxy Coated IOZ	85 lbm	85 lbm
Rust Flakes	50 lbm	50 lbm
Cement Dust / Dirt	150 lbm	150 lbm
NUKON	51.6 lbm	51.6 lbm Note1
Reflective Metal Insulation	38,500 lbm	38,500 lbm Note 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, RHR CORE COOLING MODE A1 (Ref: 31113-1E11-M2001 through M2010, Piping and Instrument Diagram Residual Heat Removal System) (Reference 24)
- TABLE A-5, RHR SUPPRESSION POOL COOLING MODE B1 (Ref: 31113-1E11-M2001 through M2010, Piping and Instrument Diagram Residual Heat Removal System) (Reference 24)
- TABLE A-6, RHR CONTAINMENT SPRAY with HEAT REMOVAL MODE E (Ref: 31113-1E11-M2001 through M2010, Piping and Instrument Diagram Residual Heat Removal System) (Reference 24)
- TABLE A-7, HIGH PRESSURE CORE FLOODER MODE B1(Ref: 31113-1E22-M2001 and M2002, Piping and Instrument Diagram HP Core Flooder System) (Reference 25)
- TABLE A-8, REACTOR CORE ISOLATION COOLING SYSTEM MODE C {Ref:31113-1E51-M2001 through M2003, Piping and Instrument Diagram Reactor Core Isolation Cooling System (Reference 26) and 31113-1N22-M2001, Piping and Instrument Diagram Feedwater System (GEH Proprietary) (Reference 27)

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.

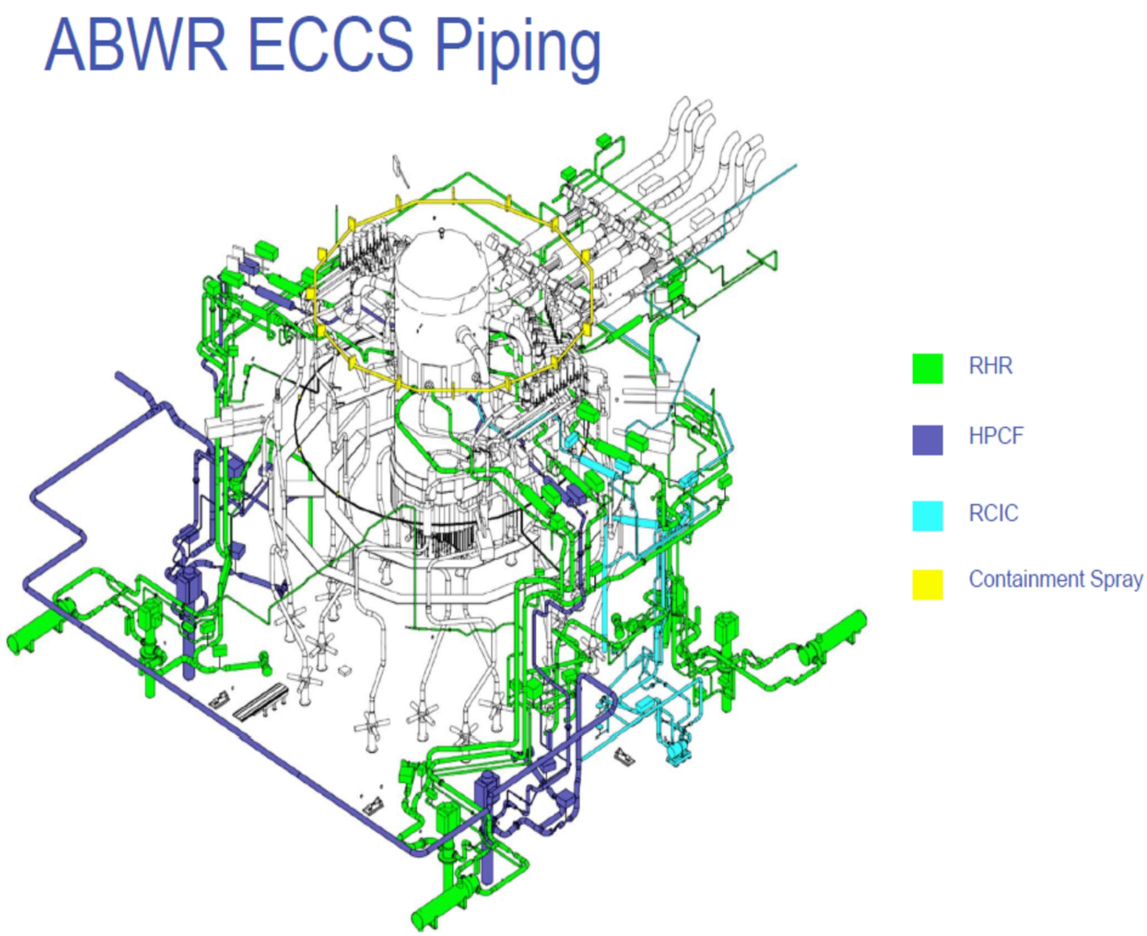


FIGURE A-2, LAYOUT OF ECCS COMPONENTS FOR DOWNSTREAM ASSESSMENT

Table A-3: ABWR Debris Downstream Concentration

Debris Type	Concentration in SP ppm by weight [% by vol]	Assessment from NEDO-32686 Vol 4
Sludge / corrosion prod.	[[	Sludge is a generic term for rust particles from the carbon steel piping connected to the suppression pool. Sludge is generated during normal operation when the suppression pool is inaccessible. The sand will not melt or form a large enough agglomeration to significantly block flow.
Dust / Dirt		Dirt / Dust is generated during normal operation when the suppression pool is inaccessible.
Inorganic Zinc (IOZ)		The failure mode for the IOZ could include some small flakes that would very rapidly break up into particles or very small pieces. The size of the very small pieces would probably be much less than 0.060 inches across. The small chips or flakes would result only where the IOZ was disbanded, if such areas existed. A tightly bonded IOZ would erode by powdering and would not flake or chip off the surface.
Rust Flakes		Rust particles are generated during normal operation when the suppression pool is inaccessible. The rust chips are of low strength and will fracture into even smaller pieces upon interaction with other components.
Epoxy Coated IOZ		Failed epoxy coating would be expected to produce chips or small sheets because epoxies have good tensile strength and are somewhat flexible during a LOCA event. The epoxy paint is also relatively brittle and will breakup into smaller pieces upon interaction with other components.
NUKON		(1) Assume all NUKON passes through strainer (2) Assume 23% NUKON (fines) pass through strainer The glass fibers are so fragile that they have virtually no mechanical strength. The rust, paint, and f berglass debris that pass through the suppression pool strainers will be subjected to the ECCS flow rates and turbulence that will cause disintegration into particles of even smaller sizes.
Reflective Metal Insulation		(1) Assume all RMI passes through strainer (2) Assume 4.3% RMI small pieces pass through strainer
Total Non-Fiber Debris Concentration	]]	(1) Assume non-fiber debris contributes to wear/erosion with all RMI passing through strainer (2) Assume non-f ber debris contributes to wear/erosion with 4.3% RMI passing through strainer Experimental data on effects of particulates on pump hydraulic performance applied to ECCS type pumps show that pump performance degradation is neglig ble for particulate concentrations less than 1% by volume. [Ref NUREG / CR 2792]

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.

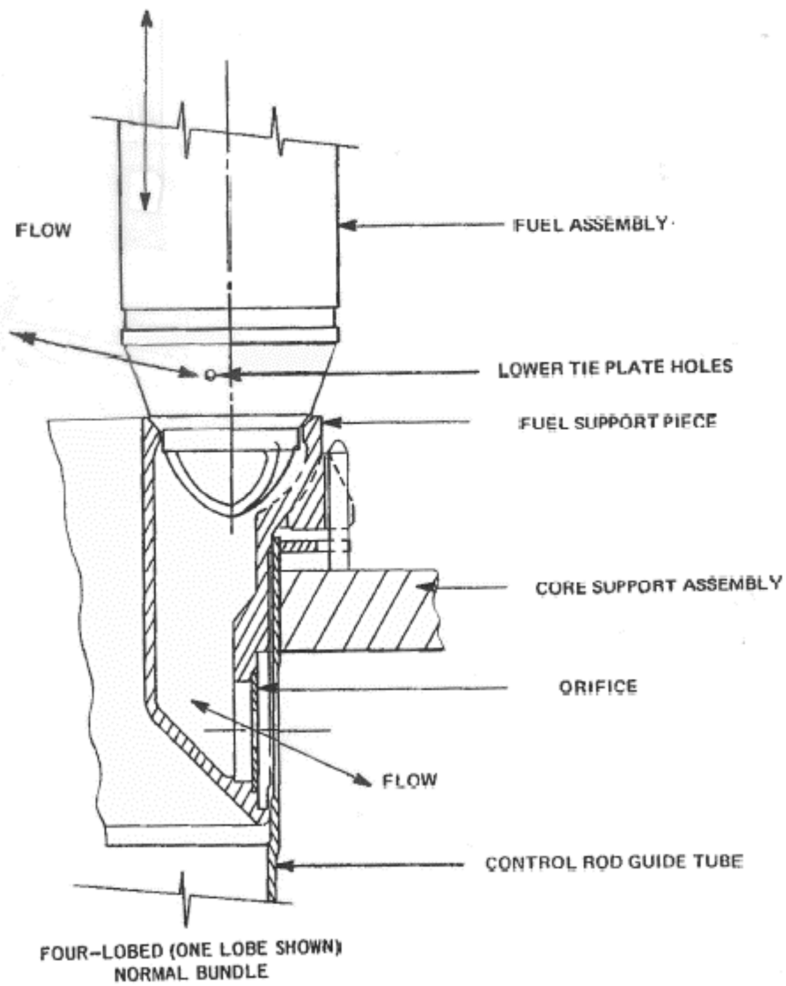


FIGURE A-3, NORMAL FUEL CHANNEL COOLING FLOW PATHS

Table A-4: ECCS Suction Strainer Downstream Effects-RHR Core Cooling Mode A1

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
ECCS PID ID	ECCS components in flow path to be assessed	[[ ]]	[[ ]]	It is assumed that settling (instrument sensing lines/ components) will occur when the flow velocity is less than the settling velocity for the debris type. If settling is not present, debris will remain in solution and not clog lines and components. The settling velocity for 2.5 mil SS RMI is assumed to be 0.4 ft/sec [ref NEDO 32686 (URG)]. A settling velocity of 0.2 ft/ s was assigned for paint chips. Finally, a settling velocity of 0.4 ft/s was assigned to concrete dust and other drywell particulates. [ref NUREG CR 6224]. A settling velocity for NUCON fibers used for preliminary assessment is 0.25 ft/sec based on having geometry of particles that would bypass the suction strainer. [ref bounding NUREG CR 6224 Table B-3 and NEI 04-07 Table 4-2].	[[ ]]	[[ ]] In general, the assumptions account for particles larger than the screen opening size and assume all transportable material with the above dimensions or smaller passes through the suction strainer unimpeded thus maximizing the calculated particulate and fibrous debris concentrations in the post-LOCA process fluid. The maximum length of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to two times (2X) the maximum linear dimension of the penetration (hole) in the suction strainer. The maximum width of deformable particulates that may pass through the penetrations {holes) in passive suction strainer is equal to the maximum linear dimension of the penetration (hole) in the suction strainer, plus 10 percent (10%). The maximum thickness of deformable particulates that may pass through the penetrations {holes) in a passive suction strainer is equal to one-half (1/2) the maximum linear dimension of the penetration {hole) in the suction strainer. [[	[[ ]] Consider how wear of internal surfaces of pump components will affect pump hydraulic performance (total dynamic head and flow), the mechanical performance (vibration), and pressure boundary integrity (shaft seals). [[ ]] Sludge / corrosion prod. 200 lbm [density 324 lb/ft^3 per NEI 04-07 Table 4-2] Inorganic Zinc (IOZ) 47 lbm [0.2516 ft^3 per URG] Epoxy Coated IOZ 85 lbm 0.65 ft^3 per URG] [[	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]] It is assumed no settling of material once in solution. The material will tend to settle out in low flow areas in piping, the reactor vessel, the containment floor, or hold-up volumes. It is assumed the debris forms a homogeneous solution at the start of the event.	]] Experimental data on the effects of particulates on pump hydraulic performance applied to ECCS type pumps show that pump performance degradation is negligible for particulate concentrations less than 1% by volume. [Ref: NUREG/CR 2792] NUREG/CR 2792 notes conservative estimates of the nature and quantities of debris show that fine abrasives may be present in concentrations of about 0.1% by volume (about 400 ppm by weight). and that very conservative estimates of fibrous material yield concentrations of less than 1% by volume. Published data on the effects of particulates on pumps generally deal with particulate concentrations at many times these values.	
U71	Containment Drywell Connecting Vents					[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]]		
E11-01	RHR System	[[ ]]	[[ ]]		[[ ]]	[[ ]]	Materials of construction for ECCS system components are listed in DCD Table 6.1-1 Engineered Safety Features Component Materials. Considering an ECCS mission time of 100 days (2400 hrs.), the wear of components subjected to the debris particles in solution (0.083 % SP volume) is considered insignificant. (ref: An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, NUREG/ CR-2792)	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]
D001 B	Suction Strainer	[[ ]]	[[ ]]		[[	[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					]]	]]		
X-202	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F001B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
C001B	RHR Pump B	[[ ]]	[[ ]]	[[	[[	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.	As described in NUREG /CR 2792, An Assessment of Residual Heat Removal and Containment Spray Performance Under Air and Debris Ingesting Conditions, concludes that under LOCA conditions with generated debris at the pump, pump performance degradation is expected to be negligible. In the event of shaft seal failure due to wear or loss of cooling fluid, seal safety bushings limit leakage rates. This is based on a debris concentration less than 0.5% by volume.	NEDO-32686 (URG) Vol 4 Evaluation of the Effects of Debris on ECCS Performance (GE-NE-T23-00700-15-21), addresses safety and operational concerns for failure of ECCS pumps associated with particles that pass through the ECCS suction strainers. Orifices that control the flow to the ECCS pump seals are susceptible to plugging by particulates larger than the inlet seal cooling line hole diameter. Orifice holes in this application are

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]	]]		[[ ]]	0.0625" and larger. Hard and round particulates smaller than 0.0625" would pass through the orifice. Loose strands of fiber less than 0.0625" in diameter may pass through the orifice, however large concentrations (blitz) of the fiber could plug the orifice. The consequence of a plugged orifice is high seal temperature and poor seal life. Wear rings and bushings are specifically designed (hard materials) to resist wear due to hard particulates in the process fluid. If the concentration of hard particulates is unusually excessive, the effect could be a long-term deterioration in the pump performance, in the form of low pump head. The requirement of 100 days of post LOCA operation is not considered long-term. Seal Faces New seal faces are lapped to very flat and smooth surfaces. The working gap between the faces is a fraction of a micron. This means that large particulates would pass over the seal faces, and would not enter the interface to destroy the smoothness of the face and cause leakage. For the passive strainer with the holes sized at 0.125 in., little fiber is expected to pass through after the initial filter bed is formed. Little of the other debris (except for minimum sized iron oxide sludge) is expected to pass after the initial filter bed precoat is formed. Therefore, all materials would most likely pass through the orifice if 1% by volume of fiber does not cause a highly unlikely "blitz" which plugs the orifice. Because all particles are larger than a fraction of a micron, they would not enter the pump seal face. For shafts and bushings, debris in quantities of one percent or less of the pump fluid is likely to not constitute a major threat to the bushing integrity. [[

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
							It is expected that ECCS pumps operated for 100 days (2400 hrs.) under modes of operation assessed and pumping liquid at maximum suspended solids will not wear to a point where vibration will affect operability.	]]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
F002B	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F003B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
B001B	Heat Exchanger	[[ ]]	[[ ]]	[[ ]]		The RHR heat exchanger tube ID is 17.22 mm. The ECCS strainer will restrict debris to less than 3.18 mm. Therefore, the RHR heat exchanger will not become clogged from debris passing downstream of the ECCS suction strainer.		NEDO-32686 (URG) Vol 4 includes evaluation of ECCS heat exchangers: Heat Exchangers Significant effect on RHR heat exchanger performance can occur if a large quantity of debris is retained inside the heat exchangers causing blockage of the flow and/or fouling of the outer surfaces of the tubes. Flow from the suppression pool is channeled through the shell side of the RHR heat exchangers. The shell side flow velocity of a RHR heat exchanger varies from 2.5 to 5 ft/ sec. At these velocities, the flow will entrain the small particles without allowing them to settle in the heat exchanger. The most restrictive opening along the flow path is the spacing between adjacent tubes, which ranges from 0.25" to 0.5" in RHR heat exchangers. The tubes sizes are 0.75" or 1.0" diameter. The results of the size distribution analyses are evaluated as follows: 1. The rust chips are the largest, but are very likely to break into smaller pieces. Considering the possibility that the largest chips get through the strainer holes and through the pumps without

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								being broken up, (not considered credible), they may get stuck somewhere in the closely packed tubes of the tube bundle. They could then serve as nuclei to collect other debris. If this were to occur in a substantial quantity, fouling of the tube outer surface could take place and this would adversely affect heat exchanger performance. In addition, Cu-Ni tubes are used in some RHR heat exchangers. Iron oxide (Fe,O, or Fe,04) promotes oxidation and corrosion on the outside diameter of the Cu-Ni tubes and may contribute to fouling and/ or thinning of the tubes. 2. Epoxy paint chips are small and light enough that they will be swept through the heat exchangers, and are of no concern. 3. The size of the sand grains are small enough that it is unlikely that they will be captured along the flow path, but may be heavy enough to settle in pockets of low velocity near the bottom of the heat exchanger. Because they will not settle on the outer surface of the tubes, they will not affect the heat exchanger performance. 4. Of the samples evaluated in Reference 1, only 0.1% of the fiber population had a length of 0.39" or greater. With this length, it is unlikely they could attach to the outside diameter of even the smaller (0.75") diameter tubes. Moreover, the fibers were so fragile that any attempt to disperse the clumps caused extensive breakage of the longer fibers. These fibers also will be easily swept away and carried out of the heat exchanger without affecting heat exchanger performance. In summary, a review of heat exchanger performance concludes that nonsoluble insulation material will not deteriorate the performance of the as-built heat exchanger. The rust chips could present some potential effect to RHR heat exchanger performance. However, this concern is minimized by the fact that a large fraction of the bigger chips are so thin that they will flow through the heat exchangers while others will be broken into still smaller pieces by the rapid flow and therefore easily pass through the heat exchanger.

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								The key factors in heat exchanger performance are the routine maintenance, inspection, and cleaning of the heat exchanger. Debris that pass through the ECCS suction strainers do not affect heat exchanger performance Therefore, there is no abnormal operational or safety concern with the identified debris on RHR heat exchanger performance, assuming they are properly maintained.
F004B	Motor Operated Control Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
FE-006B	Flow Element	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
D003B	Flow Restricting Orifice	[[ ]]	[[ ]]	[[	[[ ]]			

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F005B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
X-32A	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F006	Check Valve (N2 Testable)	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F007	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
Reactor Internals [Reactor Pressure Vessel B11]	RHR Spargers	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		As described in NEDO-32686 (URG) Vol 4, containment spray nozzles were found to have orifices or openings sized from 0.125" to 1.5". It is highly unlikely that any of the identified debris which would be expected to be much smaller

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				by the time it reached the orifices, would be able to block the orifice. A very few longer particles would be expected to pass through the passive suction strainers. There is no safety significance due to the small number of particles versus the large number of containment spray nozzles and orifices. Therefore, the expected debris will be of no safety concern for the containment spray operation.
Reactor Internals [Reactor Pressure Vessel B11]	Reactor Assembly	[[ ]]	[[ ]]		RHR injection is through the spargers above the core outside the core shroud in the annulus. Flow is directed through the inlet orifice / lower tie plate to the fuel assembly from lower plenum flooding. Flow from spray is also available through the bypass hole / lower tie plate. Flow is also available to the fuel assemblies through the upper tie plates.	The reactor vessel flow area orifices exceed the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
J11 Fuel Assembly		[[ ]]	[[ ]]		The ABWR evaluation examines the effects of bundle inlet clogging that reduces the available inlet flow from natural circulation phenomena following initial core refill when the core region is covered by a two-phase mixture. [[ ]] Once the bundle decay heat has decreased and insufficient voids exist to maintain the level in the bundle above the top of the fuel channel, adequate cooling from the upper plenum spillover will exist. Thus, the evaluation concludes that for significant bundle inlet clogging following initial core refill, BWR fuel bundle cooling is assured.	.		As described in NEDO-32686 (URG) Vol 4, a safety evaluation by the GEF has addressed the fiberglass debris as it might affect the new GE11 and GE13. This document states that even though the fibrous insulation would not be expected to plug the debris filter, the consequences of plugging were considered from an ECCS cooling standpoint. As a result of these considerations, it was concluded that adequate core cooling would be provided 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

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								the fuel channels. 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 debris identified.

Table A-5: ECCS Suction Strainer Downstream Effects-RHR Suppression Pool Cooling Mode B1

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
ECCS PID ID	ECCS components in flow path to be assessed	[[ ]]	[[ ]] Determine flowrate at points in system and use the flow / velocity to evaluate settling and wear	It is assumed that settling (instrument sensing lines/ components) will occur when the flow velocity is less than the settling velocity for the debris type. If settling is not present, debris will remain in solution and not clog lines and components. The settling velocity for 2.5 mil SS RMI is assumed to be 0.4 ft/sec [ref NEDO 32686 (URG)] A settling velocity of 0.2 ft/ s was assigned for paint chips. Finally, a settling velocity of 0.4 ft/s was assigned to concrete dust and other drywell particulates. [ref NUREG CR 6224] A settling velocity for NUCON fibers used for preliminary assessment is 0.25 ft/sec based on having geometry of particles that would bypass the suction strainer. [ref bounding NUREG CR 6224 Table B-3 and NEI 04-07 Table 4-2]	[[ ]]	[The quantity of debris and makeup downstream of the strainer needs to be determined to assess wear rate of piping and components] 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 (1/8-inch diameter) In general, the assumptions account for particles larger than the screen opening size and assume all transportable material with the above dimensions or smaller passes through the suction strainer unimpeded thus maximizing the calculated particulate and fibrous debris concentrations in the post-LOCA process fluid. The maximum length of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to two times (2X) the maximum linear dimension of the penetration (hole) in the suction strainer. The maximum width of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to the maximum linear dimension of the penetration (hole) in the suction strainer, plus 10 percent (10%). The maximum thickness of deformable particulates that may pass through the penetrations (holes) in a passive suction strainer is equal to one-half (1/2) the maximum linear dimension of the penetration (hole) in the suction strainer. The maximum cross-sectional area of deformable particulates that may pass through the penetrations (holes) in a passive suction strainer is equal to the	There are two types of wear of close running clearances within the pump; 1) free-flowing abrasive wear and 2) packing-type abrasive wear. Wear within close-tolerance, high-speed components is a complex analysis. The actual abrasive wear phenomena will likely not be either a classic free-flowing or packing wear case, but a combination of the two. Both should be considered in the evaluation of their components. Consider how wear of internal surfaces of pump components will affect pump hydraulic performance (total dynamic head and flow), the mechanical performance (vibration), and pressure boundary integrity (shaft seals). Valve and heat exchanger wetted materials should be evaluated for susceptibility to wear, surface abrasion, and plugging. Wear may alter the system flow distribution by increasing flow down a path (decreasing resistance caused by wear), thus starving another critical path. Or conversely, increased resistance from plugging of a valve opening, orifice, or heat exchanger tube may cause wear to occur in another path that experiences increased flow. Sludge / corrosion prod. 200 lbm [density 324 lb/ft^3 per NEI 04-07 Table 4-2] Inorganic Zinc (IOZ) 47 lbm [0.2516 ft^3 per URG] Epoxy Coated IOZ 85 lbm [0.65 ft^3 per URG] Rust Flakes 50 lbm [324 lb/ft^3 per NEI 04-07 Table 4-2] Dust / Dirt 150 lbm [156 lb/ft^3 per NEI 04-07 Table 4-2] Supp. Pool (SP) Initial Vol. (min.) = 3455 m3 (Ref DCD T6.2-2) = 3.455 x 10^6 liters.	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						maximum cross-sectional flow area of the penetration (hole) in the suction strainer, plus 10 percent (10%). 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. [WCAP-016406-P] The materials involved are relatively stiff and incompressible and account for long, thin strands, of insulation being able to pass through tight openings. It is assumed no settling of material once in solution. The material will tend to settle out in low flow areas in piping, the reactor vessel, the containment floor, or hold-up volumes. It is assumed the debris forms a homogeneous solution at the start of the event.	[[ ]] Experimental data on the effects of particulates on pump hydraulic performance applied to ECCS type pumps show that pump performance degradation is negligible for particulate concentrations less than 1% by volume. [Ref: NUREG/CR 2792] NUREG/CR 2792 notes conservative estimates of the nature and quantities of debris show that fine abrasives may be present in concentrations of about 0.1% by volume (about 400 ppm by weight). and that very conservative estimates of fibrous material yield concentrations of less than 1% by volume. Published data on the effects of particulates on pumps generally deal with particulate concentrations at many times these values.	
U71	Containment Drywell Connecting Vents					[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]]		
E11-01	RHR System	[[ ]]	[[ ]]		The Emergency Core Cooling (ECC) Systems are designed to withstand a hostile environment and still perform their function for 100 days following an accident. [ref DCD S1A.2.31] [[ ]]	DCD S3I.3.2.3 Water Quality and Submergence, provides reactor water quality characteristics for the design basis LOCAs inside primary containment. [[ ]]	Materials of construction for ECCS system components are listed in DCD Table 6.1-1 Engineered Safety Features Component Materials. Considering an ECCS mission time of 100 days (2400 hrs.), the wear of components subjected to the debris particles in solution (0.083 % SP volume) is considered insignificant. (ref: An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, NUREG/ CR-2792)	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]
D001 B	Suction Strainer	[[ ]]	[[ ]]		[[ ]] The sizing of the RHR suction strainers conforms to the guidance of Reg Guide 1.82. The sizing is based on satisfying the NPSH requirements at runout flow, plus margin, with	[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					postulated piping insulation debris in the SP accumulated on the pump suction strainers. The sizing of the strainers is based on 100 days of post- LOCA operation. RHR design has a provision for installation of a temporary strainer in each loop during pre-operational and startup testing. Strainers are located to avoid air entrainment during a LOCA blowdown or from vortexing action and away from the safety relief valve quencher discharge zones. Strainers shall be sized to prevent clogging of pump internal passages. [Ref: 31113-0E11-2010 (Ref. 32)]	]]		
X-202	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F001B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
C001B	RHR Pump B	[[ ]]	[[ ]]	[[	[[	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.	As described in NUREG /CR 2792, An Assessment of Residual Heat Removal and Containment Spray Performance Under Air and Debris Ingesting Conditions, concludes that under LOCA conditions with generated	NEDO-32686 (URG) Vol 4 Evaluation of the Effects of Debris on ECCS Performance (GE-NE-T23-00700-15-21), addresses safety and operational concerns for failure of ECCS pumps

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]	]]		debris at the pump, pump performance degradation is expected to be negligible. In the event of shaft seal failure due to wear or loss of cooling fluid, seal safety bushings limit leakage rates. This is based on a debris concentration less than 0.5% by volume. When considering long-term pump operation and performance, it is necessary to consider how wear of internal pump components will affect the pump hydraulic performance (total dynamic head and flow), the mechanical performance (vibration), and pressure boundary integrity (shaft seals). The wear of the close running clearances may affect the hydraulic performance because of increased internal or bypass leakage. Multistage pumps, designed for high head service, usually operate at speeds above the first natural frequency of the rotating assembly. The running clearances of the suction side and discharge side of each impeller stage are designed and manufactured to provide hydrostatic support and damping for the rotating assembly, thus allowing operation at super-critical speeds without dynamic instability. Increasing the close running clearances due to wear may reduce the overall shaft support stiffness at each impeller location, thus affecting the dynamic stability of the pump. Debris in the pumped fluid may affect the sealing capability of mechanical shaft seals. These seals are dependent on seal injection flow to cool the primary seal components. Debris in the pumped flow has the potential of blocking the seal injection flow path or of limiting the performance of the seal components due to debris buildup in bellows and springs. These effects may lead to primary seal failure. Graphite safety bushings (disaster bushings) may fail if exposed	associated with particles that pass through the ECCS suction strainers. Orifices that control the flow to the ECCS pump seals are susceptible to plugging by particulates larger than the inlet seal cooling line hole diameter. Orifice holes in this application are 0.0625" and larger. Hard and round particulates smaller than 0.0625" would pass through the orifice. Loose strands of fiber less than 0.0625" in diameter may pass through the orifice, however large concentrations (blitz) of the fiber could plug the orifice. The consequence of a plugged orifice is high seal temperature and poor seal life. Wear rings and bushings are specifically designed (hard materials) to resist wear due to hard particulates in the process fluid. If the concentration of hard particulates is unusually excessive, the effect could be a long-term deterioration in the pump performance, in the form of low pump head. The requirement of 100 days of post LOCA operation is not considered long-term. Seal Faces New seal faces are lapped to very flat and smooth surfaces. The working gap between the faces is a fraction of a micron. This means that large particulates would pass over the seal faces, and would not enter the interface to destroy the smoothness of the face and cause leakage. For the passive strainer with the holes sized at 0.125 in., little fiber is expected to pass through after the initial filter bed is formed, and also little of the other debris (except for minimum sized iron oxide sludge) is expected to pass after the initial filter bed precoat is formed. Therefore, all materials would most likely pass through the orifice if 1% by volume of fiber does not cause a highly unlikely "blitz" which plugs the orifice. Because all particles are larger than a fraction of a micron, they would not enter the pump seal face. For shafts and bushings, debris in quantities of one percent or less of the

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
							to high pressure fluid with debris following a primary seal failure thus, providing an outside containment path for post-LOCA fluid. [[ ]]	pump fluid is likely to not constitute a major threat to the bushing integrity. [[

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								]]
F002B	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F003B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
B001B	Heat Exchanger	[[ ]]	[[ ]]	[[ ]]		The RHR heat exchanger tube ID is 17.22 mm. The ECCS strainer will restrict debris to less than 3.18 mm. Therefore, the RHR heat exchanger will not become clogged from debris passing downstream of the ECCS suction strainer.		NEDO-32686 (URG) Vol 4 includes evaluation of ECCS heat exchangers: Heat Exchangers Significant effect on RHR heat exchanger performance can occur if a large quantity of debris is retained inside the heat exchangers causing blockage of the flow and/or fouling of the outer surfaces of the tubes. Flow from the suppression pool is channeled through the shell side of the RHR heat exchangers. The shell side flow velocity of a RHR heat exchanger varies from 2.5 to 5 ft/ sec. At these velocities, the flow will entrain the small particles without allowing them to settle in the heat exchanger. The most restrictive opening along the flow path is the spacing between adjacent tubes, which ranges from 0.25" to 0.5" in RHR heat exchangers. The tubes sizes are 0.75" or 1.0" diameter. The results of the size distribution analyses are evaluated as follows: 1. The rust chips are the largest, but are very likely to break into smaller pieces. Considering the possibility that the

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								largest chips get through the strainer holes and through the pumps without being broken up, (not considered credible), they may get stuck somewhere in the closely packed tubes of the tube bundle. They could then serve as nuclei to collect other debris. If this were to occur in a substantial quantity, fouling of the tube outer surface could take place and this would adversely affect heat exchanger performance. In addition, Cu-Ni tubes are used in some RHR heat exchangers. Iron oxide (Fe,O, or Fe,04) promotes oxidation and corrosion on the outside diameter of the Cu-Ni tubes and may contribute to fouling and/ or thinning of the tubes. 2. Epoxy paint chips are small and light enough that they will be swept through the heat exchangers, and are of no concern. 3. The size of the sand grains are small enough that it is unlikely that they will be captured along the flow path, but may be heavy enough to settle in pockets of low velocity near the bottom of the heat exchanger. Because they will not settle on the outer surface of the tubes, they will not affect the heat exchanger performance. 4. Of the samples evaluated in Reference 1, only 0.1% of the fiber population had a length of 0.39" or greater. With this length, it is unlikely they could attach to the outside diameter of even the smaller (0.75") diameter tubes. Moreover, the fibers were so fragile that any attempt to disperse the clumps caused extensive breakage of the longer fibers. These fibers also will be easily swept away and carried out of the heat exchanger without affecting heat exchanger performance. In summary, a review of heat exchanger performance concludes that nonsoluble insulation material will not deteriorate the performance of the as-built heat exchanger. The rust chips could present some potential effect to RHR heat exchanger performance. However, this concern is minimized by the fact that a large fraction of the bigger chips are so thin that they will flow through the heat exchangers while others will be broken into still smaller pieces by the rapid flow and therefore easily pass through the heat exchanger. The key factors in heat

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								exchanger performance are the routine maintenance, inspection, and cleaning of the heat exchanger. Debris that pass through the ECCS suction strainers do not affect heat exchanger performance Therefore, there is no abnormal operational or safety concern with the identified debris on RHR heat exchanger performance, assuming they are properly maintained.
F004B	Motor Operated Control Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
FE-006B	Flow Element	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
D004B	Flow Restricting Orifice	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F008B	Motor Operated Control Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F0055B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
X-205	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Table A-6: ECCS Suction Strainer Downstream Effects-Containment Spray with Heat Removal Mode E

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
ECCS PID ID	ECCS components in flow path to be assessed	[[ ]]	[[ ]]	It is assumed that settling (instrument sensing lines/ components) will occur when the flow velocity is less than the settling velocity for the debris type. If settling is not present, debris will remain in solution and not clog lines and components. The settling velocity for 2.5 mil SS RMI is assumed to be 0.4 ft/sec [ref NEDO 32686 (URG)] A settling velocity of 0.2 ft/ s was assigned for paint chips. Finally, a settling velocity of 0.4 ft/s was assigned to concrete dust and other drywell particulates. [ref NUREG CR 6224] A settling velocity for NUCON fibers used for preliminary assessment is 0.25 ft/sec based on having geometry of particles that would bypass the suction strainer. [ref bounding NUREG CR 6224 Table B-3 and NEI 04-07 Table 4-2]	[[ ]]	[The quantity of debris and makeup downstream of the strainer needs to be determined to assess wear rate of piping and components] [[ ]] In general, the assumptions account for particles larger than the screen opening size and assume all transportable material with the above dimensions or smaller passes through the suction strainer unimpeded thus maximizing the calculated particulate and fibrous debris concentrations in the post-LOCA process fluid. The maximum length of deformable particulates that may pass through the penetrations (holes) in passive suction strainers is equal to two times (2X) the maximum linear dimension of the penetration (hole) in the suction strainer. The maximum width of deformable particulates that may pass through the penetrations {holes) in passive suction strainers is equal to the maximum linear dimension of the penetration (hole) in the suction strainer, plus 10 percent (10%). [[	[[	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]] It is assumed no settling of material once in solution. The material will tend to settle out in low flow areas in piping, the reactor vessel, the containment floor, or hold-up volumes. It is assumed the debris forms a homogeneous solution at the start of the event.	]] Experimental data on the effects of particulates on pump hydraulic performance applied to ECCS type pumps show that pump performance degradation is negligible for particulate concentrations less than 1% by volume. [Ref: NUREG/CR 2792] NUREG/CR 2792 notes conservative estimates of the nature and quantities of debris show that fine abrasives may be present in concentrations of about 0.1% by volume (about 400 ppm by weight). and that very conservative estimates of fibrous material yield concentrations of less than 1% by volume. Published data on the effects of particulates on pumps generally deal with particulate concentrations at many times these values.	
U71	Containment Drywell Connecting Vents					[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]]		
E11-01	RHR System	[[ ]]	[[ ]]		[[ ]]	DCD S3I.3.2.3 Water Quality and Submergence, provides reactor water quality characteristics for the design basis LOCAs inside primary containment. [[ ]]	Materials of construction for ECCS system components are listed in DCD Table 6.1-1 Engineered Safety Features Component Materials. Considering an ECCS mission time of 100 days (2400 hrs.), the wear of components subjected to the debris particles in solution (0.083 % SP volume) is considered insignificant. (ref: An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, NUREG/ CR-2792)	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various types of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]
D001 B	Suction Strainer	[[	[[ ]]		[[	Debris size downstream ECCS Suction Strainer.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
		]]			]]	[[ ]]		
X-202	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F001B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
C001B	RHR Pump B	[[ ]]	[[ ]]	[[ ]]	[[ ]]	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.	As described in NUREG /CR 2792, An Assessment of Residual Heat Removal and Containment Spray Performance Under Air and Debris Ingesting Conditions, concludes that under LOCA conditions with generated debris at the pump, pump performance degradation is expected to be negligible. In the event of shaft seal failure due to wear or loss of cooling fluid, seal safety bushings limit leakage rates. This is based on a debris concentration less than 0.5% by volume. [[	NEDO-32686 (URG) Vol 4 Evaluation of the Effects of Debris on ECCS Performance (GE-NE-T23-00700-15-21), addresses safety and operational concerns for failure of ECCS pumps associated with particles that pass through the ECCS suction strainers. Orifices that control the flow to the ECCS pump seals are susceptible to plugging by particulates larger than the inlet seal cooling line hole diameter. Orifice holes in this application are 0.0625" and larger. Hard and round particulates smaller than 0.0625" would pass through the orifice. Loose strands of fiber less than 0.0625" in diameter may pass through the orifice, however large concentrations (blitz) of the fiber could plug the orifice. The consequence of a plugged orifice is high seal temperature and poor seal life. Wear rings and bushings are specifically designed (hard materials) to resist wear due to hard particulates in the process fluid. If the concentration of hard particulates is unusually excessive, the effect could be a long-term deterioration in the pump performance, in the form of low pump head. The requirement of 100 days of post LOCA operation is not considered long-term. Seal Faces New seal faces are lapped to very flat and smooth surfaces. The working gap between the faces is a fraction of a micron. This means that large particulates would pass over the seal faces, and would not enter the interface to destroy the smoothness of the face and cause leakage. For the passive strainer with the holes sized at 0.125 in., little fiber is expected to pass through after the initial filter bed is formed. Little of the other debris (except for minimum sized iron oxide sludge) is expected to pass after the initial filter bed precoat is formed. Therefore, all materials would most likely pass through the orifice if 1% by volume of fiber does not cause a highly unlikely "blitz" which plugs the orifice. Because all particles are larger than a fraction of a micron, they would not enter the pump seal face. For shafts and bushings, debris in quantities of one percent or

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
							]]	less of the pump fluid is likely to not constitute a major threat to the bushing integrity. [[ ]]
F002B	Check Valve	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F003B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
B001B	Heat Exchanger	[[ ]]	[[ ]]	[[ ]]		The RHR heat exchanger tube ID is 17.22 mm. The ECCS strainer will restrict debris to less than 3.18 mm. Therefore, the RHR heat exchanger will not become clogged from debris passing downstream of the ECCS suction strainer.		NEDO-32686 (URG) Vol 4 includes evaluation of ECCS heat exchangers: Heat Exchangers Significant effect on RHR heat exchanger performance can occur if a large quantity of debris is retained inside the heat exchangers causing blockage of the flow and/or fouling of the outer surfaces of the tubes. Flow from the suppression pool is channeled through the shell side of the RHR heat exchangers. The shell side flow velocity of a RHR heat exchanger varies from 2.5 to 5 ft/sec. At these velocities, the flow will entrain the small particles without allowing them to settle in the heat exchanger. The most restrictive opening along the flow path is the spacing between adjacent tubes, which ranges from 0.25" to 0.5" in RHR heat exchangers. The tubes sizes are 0.75" or 1.0" diameter. The results of the size distribution analyses are evaluated as follows: 1. The rust chips are the largest, but are very likely to break into smaller pieces. Considering the possibility that the largest chips get through the strainer holes and through the pumps without being broken up, (not considered credible), they may get stuck somewhere in the closely packed tubes of the tube bundle. They could then serve as nuclei to collect other debris. If this were to occur in a substantial quantity, fouling of the tube outer surface could take place and this would adversely affect heat exchanger performance. In addition, Cu-Ni tubes are used in some RHR heat exchangers. Iron oxide (Fe,O, or Fe,04) promotes oxidation and corrosion on the outside diameter

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								of the Cu-Ni tubes and may contribute to fouling and/ or thinning of the tubes. 2. Epoxy paint chips are small and light enough that they will be swept through the heat exchangers, and are of no concern. 3. The size of the sand grains are small enough that it is unlikely that they will be captured along the flow path, but may be heavy enough to settle in pockets of low velocity near the bottom of the heat exchanger. Because they will not settle on the outer surface of the tubes, they will not affect the heat exchanger performance. 4. Of the samples evaluated in Reference 1, only 0.1% of the fiber population had a length of 0.39" or greater. With this length, it is unlikely they could attach to the outside diameter of even the smaller (0.75") diameter tubes. Moreover, the fibers were so fragile that any attempt to disperse the clumps caused extensive breakage of the longer fibers. These fibers also will be easily swept away and carried out of the heat exchanger without affecting heat exchanger performance. In summary, a review of heat exchanger performance concludes that nonsoluble insulation material will not deteriorate the performance of the as-built heat exchanger. The rust chips could present some potential effect to RHR heat exchanger performance. However, this concern is minimized by the fact that a large fraction of the bigger chips are so thin that they will flow through the heat exchangers while others will be broken into still smaller pieces by the rapid flow and therefore easily pass through the heat exchanger. The key factors in heat exchanger performance are the routine maintenance, inspection, and cleaning of the heat exchanger. Debris that pass through the ECCS suction strainers do not affect heat exchanger performance Therefore, there is no abnormal operational or safety concern with the identified debris on RHR heat exchanger performance, assuming they are properly maintained.
F004B	Motor Operated Control Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
FE-006B	Flow Element	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
FE-015B	Flow Restricting Orifice	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F019B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F056B	Manual Block Valve	[[	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
		]]		]]				
X-200A	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
D010	Wetwell Spray Spargers	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
FO17B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[				

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
FO18B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]				
X30A	Penetration	[[ ]]	[[ ]]	[[ ]]				
D009	Drywell Spray Spargers	[[ ]]	[[ ]]	[[ ]]				

Table A-7: ECCS Suction Strainer Downstream Effects-High Pressure Core Flooder Mode B1

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
ECCS PID ID	ECCS components in flow path to be assessed	[[ ]]	[[ ]]	It is assumed that settling (instrument sensing lines/ components) will occur when the flow velocity is less than the settling velocity for the debris type. If settling is not present, debris will remain in solution and not clog lines and components. The settling velocity for 2.5 mil SS RMI is assumed to be 0.4 ft/sec [ref NEDO 32686 (URG)] A settling velocity of 0.2 ft/ s was assigned for paint chips. Finally, a settling velocity of 0.4 ft/s was assigned to concrete dust and other drywell particulates. [ref NUREG CR 6224] A settling velocity for NUCON fibers used for preliminary assessment is 0.25 ft/sec based on having geometry of particles that would bypass the suction strainer. [ref bounding NUREG CR 6224 Table B-3 and NEI 04-07 Table 4-2]	[[ ]]	[[ ]] The maximum length of deformable particulates that may pass through the penetrations (holes) in passive suction strainer is equal to two times (2X) the maximum linear dimension of the penetration (hole) in the suction strainer. The maximum width of deformable particulates that may pass through the penetrations {holes) in passive suction strainer is equal to the maximum linear dimension of the penetration (hole) in the suction strainer, plus 10 percent (10%). The maximum thickness of deformable particulates that may pass through the penetrations {holes) in a passive suction strainer is equal to one-half (1/2) the maximum linear dimension of the penetration {hole) in the suction strainer. The maximum cross-sectional area of deformable particulates that may pass through the penetrations (holes) in a passive suction strainer is equal to the maximum cross-sectional flow area of the penetration (hole) in the suction strainer, plus 10 percent (10%). The maximum dimension {length, width and/or thickness) of non-deformable particulates that may pass through a suction strainer is limited to the cross-	[[	[[ ]]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						sectional flow area of the penetration (hole) in the suction strainer. [WCAP-016406] The materials involved are relatively stiff and incompressible and account for long, thin strands, of insulation being able to pass through tight openings. It is assumed no settling of material once in solution. The material will tend to settle out in low flow areas in piping, the reactor vessel, the containment floor, or hold-up volumes. It is assumed the debris forms a homogeneous solution at the start of the event.	]]	
U71	Containment Drywell Connecting Vents					[[ ]]		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
E22-01	HPCF System	[[ ]]	[[ ]]		[[ ]]	DCD S3I.3.2.3 Water Quality and Submergence, provides reactor water quality characteristics for the design basis LOCAs inside primary containment. [[ ]]	Materials of construction for ECCS system components are listed in DCD Table 6.1-1 Engineered Safety Features Component Materials. Considering an ECCS mission time of 100 days (2400 hrs.), the wear of components subjected to the debris particles in solution (0.083 % SP volume) is considered insignificant. (ref: An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, NUREG/ CR-2792)	]] The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various tvpes of debris: e.g. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]
D003 B	Suction Strainer	[[ ]]	[[ ]]		[[	[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					]]	]]		
X-210	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F006B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F007B	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
C001B	HPCF Pump B	[[ ]]	[[ ]]	[[	[[	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.	[[	NEDO-32686 (URG) Vol 4 Evaluation of the Effects of Debris on ECCS Performance (GE-NE-T23-00700-15-21), addresses safety and operational concerns for failure of ECCS pumps associated with particles that pass through the ECCS suction strainers.

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]	]]			Orifices that control the flow to the ECCS pump seals are susceptible to plugging by particulates larger than the inlet seal cooling line hole diameter. Orifice holes in this application are 0.0625" and larger. Hard and round particulates smaller than 0.0625" would pass through the orifice. Loose strands of fiber less than 0.0625" in diameter may pass through the orifice, however large concentrations (blitz) of the fiber could plug the orifice. The consequence of a plugged orifice is high seal temperature and poor seal life. Wear rings and bushings are specifically designed (hard materials) to resist wear due to hard particulates in the process fluid. If the concentration of hard particulates is unusually excessive, the effect could be a long-term deterioration in the pump performance, in the form of low pump head. The requirement of 100 days of post LOCA operation is not considered long-term. Seal Faces New seal faces are lapped to very flat and smooth surfaces. The working gap between the faces is a fraction of a micron. This means that large particulates would pass over the seal faces, and would not enter the interface to destroy the smoothness of the face and cause leakage. For the passive strainer with the holes sized at 0.125 in., little fiber is expected to pass through after the initial filter bed is formed, and also little of the other debris (except for minimum sized iron oxide sludge) is expected to pass after the initial filter bed precoat is formed. Therefore, all materials would most likely pass through the orifice if 1% by volume of fiber does not cause a highly unlikely "blitz" which plugs the orifice. Because all particles are larger than a fraction of a micron, they would not enter the pump seal face. For shafts and bushings, debris in quantities of one percent or less of the pump fluid is likely to not constitute a major threat to the bushing integrity. [[

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
							]]	]]
F021B	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
FE-008B	Flow Element	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
D002B	Flow Restricting Orifice	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F003B	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
X-31A	Penetration	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F004B	Check Valve (N2 Testable)	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F005B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
Reactor Internals [Reactor Pressure Vessel B11]	HPCF Spargers	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
Reactor Internals [Reactor Pressure Vessel B11]	Reactor Assembly	[[ ]]	[[ ]]		[[	[[ ]]		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					]]			
J11 Fuel Assembly		[[ ]]	[[ ]]		[[ ]]			

Table A-8: ECCS Suction Strainer Downstream Effects-Reactor Core Isolation Cooling System Mode C

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
ECCS PID ID	ECCS components in flow path to be assessed	[[ ]]	[[ ]]	It is assumed that settling (instrument sensing lines/ components) will occur when the flow velocity is less than the settling velocity for the debris type. If settling is not present, debris will remain in solution and not clog lines and components. The settling velocity for 2.5 mil SS RMI is assumed to be 0.4 ft/sec [ref NEDO 32686 (URG)] A settling velocity of 0.2 ft/ s was assigned for paint chips. Finally, a settling velocity of 0.4 ft/s was assigned to concrete dust and other drywell particulates. [ref NUREG CR 6224] A settling velocity for NUCON fibers used for preliminary assessment is 0.25 ft/sec based on having geometry of particles that would bypass the suction strainer. [ref bounding NUREG CR 6224 Table B-3 and NEI 04-07 Table 4-2]	[[ ]]	[[	[[ ]] Sludge / corrosion prod. 200 lbm [density 324 lb/ft^3 per NEI 04-07 Table 4-2] Inorganic Zinc (IOZ) 47 lbm [0.2516 ft^3 per URG] Epoxy Coated IOZ 85 lbm 0.65 ft^3 per URG] Rust Flakes 50 lbm [324 lb/ft^3 per NEI 04-07 Table 4-2] [[	Evaluation of Downstream Effects on Major Components The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various tvpes of debris: e.g.. paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]] It is assumed no settling of material once in solution. The material will tend to settle out in low flow areas in piping, the reactor vessel, the containment floor, or hold-up volumes. It is assumed the debris forms a homogeneous solution at the start of the event.	]]	
U71	Containment Drywell Connecting Vents					[[		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
						]]		
E51-01	RCIC System	[[ ]]	[[ ]]		[[	DCD S3I.3.2.3 Water Quality and Submergence, provides reactor water quality characteristics for the design basis LOCAs inside primary containment. [[ ]]	Materials of construction for ECCS system components are listed in DCD Table 6.1-1 Engineered Safety Features Component Materials. Considering an ECCS mission time of 100 days (2400 hrs.), (12 hrs credied for RCIC) the wear of components subjected to the debris particles in solution (0.083 % SP volume) is considered insignificant. (ref: An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions, NUREG/ CR-2792)	Evaluation of Downstream Effects on Major Components Both the HPCF and RCIC systems take primary suction from the CST and secondary suction from the suppression pool (SP). The CST is clean demineralized water free of debris. This assessment assumes most conservative alignment from the SP source. The effects of debris passing through the strainers on downstream components such as pumps. valves. and heat exchangers has been evaluated as required under Reg Guide 1.82 Rev 4. This evaluation includes assessing wear on surfaces exposed to the fluid stream due to various tvpes of debris: e.g., paint chips or RMI shards. Evaluating the potential for blockage of small clearances due to downstream debris are also included. The materials and clearances for the valves. pumps. and heat exchangers downstream of the ABWR ECCS suction strainers are essentially the same as the materials and clearances for the valves. pumps. and heat exchangers downstream of the PWR containment sump suction strainers. Therefore. Utilizing aspects applied to PWR methodology for the ABWR is appropriate. [ref STP DCD 6C.3.2]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					]]			
D002	Suction Strainer	[[ ]]	[[ ]]		[[ ]]	[[ ]]		
X-214	Penetration	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F006	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]	[[ ]]	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F007	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
C001	RCIC Pump	[[ ]]	[[ ]]	[[ ]]	[[ ]]	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.	[[	NEDO-32686 (URG) Vol 4 Evaluation of the Effects of Debris on ECCS Performance (GE-NE-T23-00700-15-21), addresses safety and operational concerns for failure of ECCS pumps associated with particles that pass through the ECCS suction strainers. Orifices that control the flow to the ECCS pump seals are susceptible to plugging by particulates larger than the inlet seal cooling line hole diameter. Orifice holes in this application are 0.0625" and larger. Hard and round particulates smaller than 0.0625" would pass through the orifice. Loose strands of fiber less than 0.0625" in diameter may pass through the orifice, however large concentrations (blitz) of the fiber could plug the orifice. The consequence of a plugged orifice is high seal temperature and poor seal life. Wear rings and bushings are specifically designed (hard materials) to resist wear due to hard particulates in the process fluid. If the concentration of hard particulates is unusually excessive, the

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
							]]	effect could be a long-term deterioration in the pump performance, in the form of low pump head. The requirement of 100 days of post LOCA operation is not considered long-term. Seal Faces New seal faces are lapped to very flat and smooth surfaces. The working gap between the faces is a fraction of a micron. This means that large particulates would pass over the seal faces, and would not enter the interface to destroy the smoothness of the face and cause leakage. For the passive strainer with the holes sized at 0.125 in., little fiber is expected to pass through after the initial filter bed is formed, and also little of the other debris (except for minimum sized iron oxide sludge) is expected to pass after the initial filter bed precoat is formed. Therefore, all materials would most likely pass through the orifice if 1% by volume of fiber does not cause a highly unlikely "blitz" which plugs the orifice. Because all particles are larger than a fraction of a micron, they would not enter the pump seal face. For shafts and bushings, debris in quantities of one percent or less of the pump fluid is likely to not constitute a major threat to the bushing integrity. [[

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
								]]
FE-007	Flow Element	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
F003	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
F004	Motor Operated Block Valve	[[ ]]	[[ ]]	[[ ]]	[[ ]]	The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
N22 Feedwater System F005	Check Valve (Air Testable)	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
N22 Feedwater System F003	Check Valve (Air Testable)	[[ ]]	[[ ]]	[[		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
				]]				
N22 Feedwater System X-12B	Penetration	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
N22 Feedwater System F004B	Check Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
N22 Feedwater System F005B	Manual Block Valve	[[ ]]	[[ ]]	[[ ]]		The ECCS piping / component flow area exceeds the maximum dimension of the debris particles. Therefore, clogging is not considered credible.		
Reactor Internals [Reactor Pressure Vessel B11]	Feedwater Spargers	[[ ]]	[[ ]]	[[ ]]	[[	[[ ]]		[[ ]]

Component ID	Component	Mode of Operation	System / Component Flowrate	Fluid Velocity thru Component	System Descriptions and Mission Time	Debris Ingestion Model	Wear Rate and Component Evaluation	Auxiliary Equipment Evaluation
					]]			
Reactor Internals [Reactor Pressure Vessel B11]	Reactor Assembly	[[ ]]	[[ ]]		[[ ]]	[[ ]]		
J11 Fuel Assembly		[[ ]]	[[ ]]		[[ ]]			