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BWROG17-3-381r0 Project No. 691
November 20, 2017

Dr. Mirela Gavrilas
Director, Division of Safety Systems
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Final Resolution of Potential Issues Related to Emergency Core Cooling Systems (ECCS) Strainer Performance at Boiling Water Reactors

REFERENCES: All Applicable Administrative and Technical References are Listed on Pages 10 & 11

Dear Dr. Gavrilas:

The Boiling Water Reactor Owners' Group (BWROG) has completed a detailed assessment of the twelve (12) Boiling Water Reactor (BWR) strainer performance potential issues identified in References 1 and 2 sufficient to conclude that no safety concerns exist at U.S. BWR facilities warranting further evaluation. The BWROG concludes that none of the twelve (12) potential issues necessitate a change to the original design methodology or basis, and in aggregate they present low or very low risk as represented by increased core damage frequency, as characterized by Regulatory Guide 1.174 [11]. The BWROG is confident that any further, more detailed evaluations would result in a similar or even reduced characterization of the safety significance of these issues. The BWROG therefore concludes that further investigation into these questions is not prudent, and would undeservedly divert industry resources from more safety significant issues. This risk assessment was not part of a regulatory action, but a voluntary response by the BWROG to NRC concerns arising out of lessons learned from the PWR GSI-191 resolution. The selection of Regulatory Guide 1.174 in assessing the risk significance of the issues provides a consistent and convenient framework to measure risk. Since the BWROG is not proposing any changes to licensing bases as a result of this effort, adherence to all aspects of the regulatory guide is not an expectation.

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Background

In recognition of the potential for debris fouling of ECCS suction strainers during a postulated loss of coolant accident (LOCA) as described in U.S. Nuclear Regulatory Commission (NRC) Bulletin 96-03, "Potential Plugging of ECCS Strainers by Debris in Boiling Water Reactors", the U.S. BWR fleet upgraded and replaced ECCS suction strainers in the late 1990s, following industry and NRC guidance [5,6,7]. NRC field audits of four BWR strainer designs and containment types officially closed BWR ECCS suction concerns in October of 2001 [8]. Shortly thereafter, NRC initiated research to study similar recirculation sump blockage concerns in Pressurized Water Reactor (PWR) ECCS suction strainers, and eventually issued Generic Safety Issue-191 (GSI-191) to the PWR fleet. In 2008, following significant research, testing, and study of issues associated with PWR ECCS suction strainer performance, the NRC requested the BWROG to evaluate several questions regarding differences between the PWR resolution methodology and that used by the BWRs in response to NRCB 96-03, to ensure any new information was taken into account in confirming strainer performance.

BWR Strainer Evaluation Program

These twelve (12) differences in methodology, identified as issues for purposes of evaluation, were presented by the NRC [1] and listed below:

1. Downstream Effects – Components
2. Downstream Effects – Fuel
3. Head Loss Correlations
4. Chemical Effects
5. Assessment of Coatings
6. Latent Debris
7. ZOI Adjustment for Air Jet Testing
8. ZOI of Protective Coatings
9. Debris Transport and Erosion
10. Debris Characteristics
11. Near Field Effects and Scaling
12. Spherical Zone of Influence (ZOI)

As a voluntary initiative, the BWROG convened two (2) working committees to determine the best course of action to assess the impact of these issues on the current BWR strainer performance. The first working committee (Deterministic) was established to quantify the differences between the BWR Utility Resolution Guidance (URG) methodology and the PWR Methodology presented in NEI-04-07, as well as differences in vendor head loss methods. The deterministic resolution committee also began addressing chemical effects and in-core debris blockage (Items 4 and 2), since these items had not been explicitly evaluated during the BWR resolution to NRCB 96-03.

The second working committee (Risk-Informed) was established to investigate and characterize the risk significance of the identified issues using an approach considering both the likelihood and the consequence of the potential issues as they relate to the original conclusions. The risk-informed resolution committee compiled information and developed methods needed to address these potential issues using risk quantification methods consistent with agency directives [9,10] and with regulatory guidance [11,12,13,14].

Building on the groundwork established by the BWROG Deterministic committee, the BWROG Risk-Informed committee took a phased approach to address the 12 issues, starting with a single pilot addressing two ex-vessel issues (Phase I), then addressing 8 ex-vessel issues for the single pilot (Phase II). Next, the BWROG committee evaluated the same 8 ex-vessel issues for another pilot plant (Phase III), and then the 10 ex-vessel issues for the entire fleet (Phase IV). The final phase (Phase V) addressed the remaining two in-vessel issues (Items 2 and 4, fuel blockage and chemical effects) integrated with the 10 ex-vessel issues for the entire fleet completing all issues for all plants. This letter documents the closure of these 12 issues for the entire BWR fleet.

Phase I – Pilot I

(3) Head Loss Correlations
(8) ZOI of Protective Coatings

Phase II – Pilot I

(3) Head Loss Correlations
(6) Latent Debris
(7) ZOI Adjustment for Air Jet Testing
(8) ZOI of Protective Coatings
(9) Debris Transport and Erosion
(10) Debris Characteristics
(11) Near Field Effects and Scaling
(12) Spherical Zone of Influence (ZOI)

Phase III – Pilot 2

(3) Head Loss Correlations
(6) Latent Debris
(7) ZOI Adjustment for Air Jet Testing
(8) ZOI of Protective Coatings
(9) Debris Transport and Erosion
(10) Debris Characteristics
(11) Near Field Effects and Scaling
(12) Spherical Zone of Influence (ZOI)

Phase IV– Fleet

(1) Downstream Effects Components
(3) Head Loss Correlations
(4) Chemical Effects at Strainer
(5) Coatings Assessments
(6) Latent Debris
(7) ZOI Adjustment for Air Jet Testing
(8) ZOI of Protective Coatings
(9) Debris Transport and Erosion
(10) Debris Characteristics
(11) Near Field Effects and Scaling
(12) Spherical Zone of Influence (ZOI)

Phase V– Fleet

(1) Downstream Effects Components
(2) Downstream Effects- Fuel
(3) Head Loss Correlations
(4) Chemical Effects at Strainer and In-vessel
(5) Coatings Assessments
(6) Latent Debris
(7) ZOI Adjustment for Air Jet Testing
(8) ZOI of Protective Coatings
(9) Debris Transport and Erosion
(10) Debris Characteristics
(11) Near Field Effects and Scaling
(12) Spherical Zone of Influence (ZOI)

Evaluation Approach

Expertise was enlisted from subject matter experts (SMEs) in Probabilistic Risk Assessment (PRA), BWR plant operations, thermal hydraulics, BWR strainer design and testing, GSI-191 risk-informed resolution, LOCA accident phenomenology, and ECCS-related regulatory guidance. Initial meetings with NRC confirmed that although this evaluation was voluntary and not a license application, design change, or compelled by a Regulatory requirement, RG 1.174 [11] contains applicable guidance for evaluating these potential issues using a risk-informed approach. All conclusions of this study are in consideration of the applicable criteria of RG 1.174, such as, change in Core Damage Frequency (ΔCDF) and change in Large Early Release Frequency (ΔLERF). RG 1.174 provides useful metrics for characterizing risk significance based on ΔCDF and ΔLERF. It is recognized that this evaluation is not part of or related to any Licensing Basis (LB) change; however, the spirit and intent of all five (5) principles of risk-informed decision making from RG 1.174 were used in the analysis.

A comprehensive industry survey was performed to determine the full scope of industry variability with respect to containment type, strainer characteristics, insulation inventories, LOCA-related Emergency Operating Procedures, and plant design features. Appendix A of both the Phase IV report [4] and the Phase V report [16] summarizes that input. The results and conclusions of this evaluation cover all domestic BWRs, except for Oyster Creek (planned shutdown in 2019 and no longer a BWROG member).

For the evaluation, two pilot plants with RG-1.200 peer reviewed PRA's were selected. The Facts and Observations (F&O's) resulting from the PRA model peer review were verified to not adversely affect the quality of the PRA for this evaluation. The pilot plants encompassed the majority of the salient risk significant attributes, as well as the majority of the technologies used in the US BWR fleet. A BWR/4 with a Mark I containment was selected to represent plants having compact containment geometry and a toroidal suppression pool, and a BWR/5 with a Mark II containment was selected to represent plants having a higher thermal power output, higher inventories of microporous insulation, and larger containment / transport regions. Computer aided design (CAD) models that describe spatial relationships between pipe break locations and target materials, including thermal insulation and coatings were developed for both plants. The two CAD models allowed mapping of plant-specific insulation types and quantities to GE containment designs. Plant specific PRA models for both pilot plants were used to evaluate the mitigation capabilities that exist within the two BWR vintages and containment designs. The plant specific PRA models were enhanced to incorporate additional debris-induced effects on the ECCS suction strainers and in-vessel coolant flow paths to the fuel bundles.

ECCS strainer failure probabilities were calculated using CASA Grande, a code developed for GSI-191 resolution that calculates debris generation and transport for all possible break sizes and break directions at every weld location. Both CASA Grande and the PRA models apply identical LOCA initiating event frequencies obtained from NUREG 1829 [14]. All break scenarios were partitioned into Large, Medium and Small breaks occurring either above or below top of active fuel. These categories directly match existing initiating events in the two (2) pilot plant PRA models and are consistent with typical industry PRA models. CASA Grande calculates the accumulation of debris on plant-specific strainer areas using plant-specific flow rates for each system drawing suction from the suppression pool. For the Phase IV evaluation of potential issues directly affecting strainer performance (i.e., upstream of the ECCS pumps), debris was modeled with no fiber penetration through the strainer. For the Phase V evaluation which includes the debris impacts on fuel, fibrous debris was modeled as penetrating the strainers as prescribed by an appropriately conservative function (dependent on strainer bed thickness) supported by BWROG testing. Debris modeled to penetrate the strainer was assumed to accumulate and block flow at the fuel bundle lower tie plate inlet debris filter in the reactor vessel. 5 g of fiber per bundle was assumed to be trapped at this location. Fiber amounts greater than 5 g/bundle were assumed to return to the suppression pool for accumulation on any operating ECCS strainer(s).

Several strainer failure criteria were developed and exercised during the Pilot Plant studies (Phase II and III), including predictive head-loss correlations that combine debris types and plant-specific strainer qualification tests. In the end, a simplifying and conservative generic failure criterion of 1/8" debris bed thickness was established that would address the potential of a thin-bed and the uncertainty associated with debris head loss correlations. Declaring strainer failure once reaching 1/8" theoretical thickness of fiber at the strainer is consistent with industry evaluating experience and can be applied across the entire BWR fleet. In the Phase IV analysis, CASA Grande tracks accumulation of fiber as a function of time for all strainers (in proportion to associated flow rates) and reports the break scenario as a failure if any single strainer accumulates greater than 1/8" of fiber. In the Phase V analysis, CASA Grande tracks debris in the pool, accumulated on strainers, and accumulated downstream (e.g., at the fuel bundle lower tie plate). In Phase V, debris accumulates on strainers in proportion to break-specific flow rates, with a strainer's flow assuming to cease completely once 1/8" of debris accumulation occurs. Successive loss of strainers is tracked to determine the expected operation time for each safety system. The Phase V analysis distinguishes between Residual Heat Removal (RHR) and Core Spray (CS) strainers to acknowledge the different effects of downstream flow path (i.e., RHR Low Pressure Coolant Injection via the fuel bundle lower tie plate vs. Core Spray from above the core) on fuel cooling.

Given the diversity of available external RPV makeup systems and the associated procedures and training for the U.S. BWR fleet, the BWROG commissioned a survey of the BWR fleet to identify:

- The list of alternate external RPV injection systems that are proceduralized and credited in the utility's plant specific Probabilistic Risk Assessment (PRA) model, and
- The Human Reliability Analysis (HRA) to support the calculation of Human Error Probabilities (HEP) for the alignment of external RPV makeup systems credited in the utility's plant specific PRA model

Additionally, in support of this evaluation, the BWROG Emergency Procedures Committee (EPC) concluded that the training and procedures at U.S. BWRs provide operators guidance to diagnose and mitigate potential loss of ECCS suction strainer issues (e.g., pump cavitation).

The plant responses to the BWROG survey identified that all sites rely and train on the use of multiple and diverse alternate external RPV makeup systems in the plant which are therefore credited in the PRA models.

For the Phase IV risk evaluation, an operator action for aligning only one (1) alternate external RPV injection path (e.g., Service Water crosstie) is conservatively credited for each plant.

In addition to limiting credit for operator action, the Phase IV analysis also conservatively assumes:

- No credit for Feedwater or Reactor Core Isolation Cooling
- Limited credit for High Pressure Coolant Injection (or High Pressure Core Spray) for selected plants and selected scenarios (e.g., Small LOCA)

Other conservatisms are detailed in the Phase IV risk evaluation report that was made available for Staff review via electronic portal.

The CASA Grande / CAFTA PRA software used for the Pilot Plant PRA models was capable of performing numerous parameter studies to vary each of the risk-informed topics and to study them in aggregation to identify possible interactions.

In the Phase V evaluation, the in-vessel impact of debris and chemical effects (issues 2 and 4) was incorporated. The Phase IV evaluation conservatively assumed that all the debris would accumulate on the ECCS suction strainers. The Phase V evaluation assumes some debris will pass through the strainer and arrive at the core inlet. To simplify the effect of this debris on the fuel bundles, the Phase V evaluation assumes immediate clogging of all the fuel inlet debris filters at the bundle lower tie plate once the vessel re-floods after the LOCA. For selected plants where low risk margin is calculated based on the initial conservative risk calculations, operator action to align alternate external injection is credited to reduce the calculated risk so that the risk can be characterized as being in Region II or III of R.G. 1.174. MAAP thermal hydraulic calculations are used to verify the success criteria for the credited plant specific alternate injection system (e.g., allowable operator action timing and necessary flow rate to the RPV to prevent core damage) when conservatively assuming complete clogging of the fuel inlet debris filters and the need to overfill from the top of the fuel channels. Consistent with the methodology applied for the Phase IV evaluation, the calculated Human Error Probabilities (HEPs) for operator alignment of alternate injection have been updated for the Phase V evaluation to account for any changes in the allowable timings and flow rates associated with the adverse impacts of in-vessel debris clogging issues.

Over the course of the phased evaluation, the BWROG actively communicated progress to the NRC through public meetings, electronic portal reviews of BWROG reports, and three (3) contractor review workshops [15]. A summary of the individual issues and resolution is provided in Table 1 "Description of ECCS Suction Strainer Potential Issues".

<u>Results</u>

The Phase IV and V analyses enabled the characterization of plant risk associated with the 12 identified potential debris-induced ECCS issues. Risk (ΔCDF) is driven by the strainer failure associated with the 1/8" debris accumulation and the plant's ability to align an alternate injection source with sufficient head, flow rate, and volume to provide coolant to the upper tie plate and into the top of the fuel assembly. The use of the 1/8" debris bed for strainer failure criterion (all flow is stopped) is conservative in that during strainer experiments that have exhibited high head losses with high particulate to fiber ratios, that flow continues, although may be degraded. The 1/8" strainer failure criteria proved to be a valuable threshold for evaluating the issues since nearly every issue suggested a potential increase in debris load. By introducing more debris into the pool and failing the strainer as early as possible, a conservative risk metric is produced.

Utilization of the 1/8" metric precludes the need for alternative sensitivity cases to study certain potential issues. Namely, potential issues associated with the usage of head loss correlations, chemical effects at the strainer, uncertainties in coatings assessments, ZOI-generated coatings debris, uncertainties in debris characteristics, and near field effect and scaling of empirical analyses (Issues 3, 4, 5, 8, 10, and 11) do not require separate sensitivities because the 1/8" metric is insensitive to the effects of these issues, as discussed in the Phase IV report [4].

The upstream issues are well represented in the results of the Phase IV "baseline" CASA Grande evaluation of suction strainer failure probability. The results of this analysis support the conclusion of low generic risk, as all plants are within Regions II or III of Reg. Guide 1.174 ΔCDF guidelines. Additionally, the total CDF of any plant that was characterized to be in Region II using the simplified assumptions of this evaluation were verified to have a total CDF less than 1E-4 per year.

Based on the calculated ΔCDF and on qualitative evaluations for containment performance in Phases II and III, the changes in Large Early Release Frequency (ΔLERF) would not be the limiting figure of merit. This means that ΔLERF would also represent small changes in risk (i.e., Region II) or very small changes in risk (i.e., Region III).

The ex-vessel downstream effect of debris on components (Issue 1) was evaluated separately in Phase IV using the dominant risk contributing case from the Phase II and Phase III pilot plant evaluations. The risk-informed evaluation of downstream effect of debris focused on evaluating the functionality of those components that contribute to an outcome of low risk significance. Component exposure to debris was evaluated in conjunction with possible failure mechanisms. The impact of debris was determined to be of low risk significance to these components based on design margin, system configuration or limited mission time. When BWR fleet design variations were considered, there was no discernible change to calculated pilot plant risk caused by similarities of BWR safety significant components.

Additionally, it was considered that non-qualified coating inventories in BWRs may be greater than established at the time the BWR strainer debris source terms were originally defined due to 1) existing programs that may not adequately monitor degradation of qualified coatings, and 2) existing programs that may not adequately address changes to the unqualified coatings inventory. The BWROG tracked this issue as Issue #5, Coatings Assessments, and developed a survey for BWRs based on queries from the NRC Staff Review Guidance of March 2008 [18] to 1) establish whether there are programs in place to track qualified and unqualified coatings sources, and 2) validate unqualified coating source terms used in the strainer head loss analyses. The results of the survey were tabulated and circulated to BWROG members for peer comparison. The results of the survey indicate all respondents have a program that routinely monitors the coatings in the drywell and suppression pool.

The Phase V analysis shows that sufficient core cooling can be provided by either Core Spray flow directly from above the fuel, or by flow through the bypass region around the fuel bundle channels and into the bundle from the top via RHR Low Pressure Coolant Injection or alternate injection. Given that GEH TRACG calculations support the conclusion that one (1) Core Spray subsystem alone can prevent core damage with assumed immediate clogging of all fuel inlet debris filters, the incremental risk caused by in-vessel debris impacts is lower than the risk impact from blockage of the ECCS suction strainers alone.

Finally, Phase V evaluated the risk significance of potential in-vessel chemical effects produced from dissolved insulating materials and corrosion products (issue 4). The approach taken was similar to that done in the PWR evaluations. The mass, volume and likely chemical species compositions were determined as a function of time following a LOCA. A conservative approach was used in assuming the source term was based on exposure of materials in containment to 30 days of post-LOCA conditions. The effect of predicted chemical deposition on fuel rod cladding, on rod-to-rod clearances, and cladding temperatures was then evaluated. The evaluation determined that there is no increased risk to the fuel.

Summary

In conclusion and as previously stated, a systematic and robust assessment of the twelve (12) issues in References 1 finds them to be of low or very low potential risk for all member BWRs, and without the need of further action or consideration. The BWROG therefore concludes that further investigation into these questions is not prudent, and would undeservedly divert industry resources from more safety significant issues. As a result, the BWROG plans no further analyses regarding the twelve (12) issues.

In addition, the BWROG assessment has concluded that none of the twelve (12) issues would necessitate a change to the original design methodology or design basis, and that, all are nonsignificant-risk contributors to increased core damage frequency, as characterized by Regulatory Guide 1.174. Based on our evaluations, the safety of BWRs is not significantly affected by these 12 issues, and no further investigation of these issues is needed.

The BWROG has used this opportunity to communicate to our industry members the insights gained from this evaluation. Specifically, that the BWR's design and operational practices enable it to be tolerant of debris that may accumulate on the strainers or downstream of the ECCS pumps on components (i.e., ex-vessel) or fuel assemblies (i.e., in-vessel). Additional insights gained from this systematic and robust evaluation include, 1) It is important to continue to maintain cleanliness and minimize latent debris in containment, 2) Maintaining capability of external RPV injecting sources provides added margin for responding to debris effects, 3) The internal bypass holes in the BWR fuel bundle design provide benefit should fuel filters accumulate debris, and 4) Core Spray systems provide diversity for core cooling in the event of debris accumulation at the fuel inlet debris filter.

It should be noted that this evaluation includes several conservative simplifications and assumptions. The quantifications herein are intended to characterize the related risk consistent with a bounding or screening approach and are not to represent the actual LOCA-induced debris CDF or LERF contribution for any specific unit. Therefore, none of the specific numerical results from the Phase IV or Phase V reports should be used in any future applications for any individual plant.

While the viewpoint described above represents the intent of all BWROG industry members, this letter should not be considered a commitment on the part of any specific licensee. All BWR plants have reviewed this letter and the reports and validated that the inputs, assumptions, and results are valid for their plant.

Respectfully,

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Enclosure: Table 1, Description of ECCS Suction Strainer Potential Issues

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BWROG ECCS SS Committee
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REFERENCES

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2. BWROG Letter, BWROG-09024, Boiling Water Reactor Owners' Group - Potential Issues Related to Emergency Core Cooling Systems (ECCS) Strainer Performance at Boiling Water Reactors, April 13, 2009
3. Regulatory Guide 1.174, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to Licensing Basis, Revision 2 (May 2011)
4. BWROG Report 1U004.000.600-RPT-13098, Phase IV ECCS Suction Strainer Risk Informed Analysis, Revision 0
5. NUREG / CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris", October 1995
6. NEDO-32686-A (ML092530482), "Utility Resolution Guide for ECCS Suction Strainer Blockage", Volume 1, October 1998
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8. ML012970229, NRC Memorandum from Robert B. Elliott to Gary M. Holohan, October 18, 2001
9. 60 FR 42622, "Use of Probabilistic Risk Assessment Methods in Nuclear Activities: Final Policy Statement," Federal Register, Volume 60, Number 158, p. 42622, Washington, DC, August 16, 1995
10. NRC Staff Requirements – SECY-10-0113 – Closure Options for Generic Safety Issue – 191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance, December 23, 2010
11. Regulatory Guide 1.174, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, U.S. Nuclear Regulatory Commission, May 2011, Revision 2
12. Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," U.S. Nuclear Regulatory Commission, Washington, DC
13. NUREG-1855, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making," Volume 1, March 2009

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14. NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process, Volume 1-2, April 2008

15. ML16252A522, "Boiling Water Reactor Owners' Group Emergency Core Cooling System Suction Strainer Project – US Nuclear Regulatory Commission Staff Audit Summary of a Risk-Informed Approach to Potential Issue(s) Resolution," Project No. 691, February 2017

16. BWROG Report 1U007.000.500-RPT-13384, Phase V ECCS Suction Strainer Risk Informed Analysis, Revision 0

17. Structural Integrity Associates Calculation Package 1601367.301P, Evaluation of LOCA Deposit Thickness and Impact on Cladding Temperature, Revision 0

18. NRC Staff Review Guidance Regarding GL 2004-02 Coating Evaluations, March 2008, ML080230462

Table 1
DESCRIPTION OF ECCS SUCTION STRAINER POTENTIAL ISSUES

Issue No.	NRC / BWROG Concern	Risk Evaluation
1. Downstream Effects (Components & Systems)	BWROG should consider a more rigorous evaluation of erosion, abrasion and blockage of downstream components due to debris penetrating suction strainer	Explicitly addressed as part of a supplemental Phase IV evaluations BWROG-ECCS-TP-1-1 and BWROG-ECCS-TP-1-2. This issue is addressed in a risk-based approach in conjunction with deterministic methodology.
2. Downstream Effects (Fuel / In-vessel)	NRC has not seen a written evaluation of the potential for downstream effects of debris on BWR fuel	Downstream Effects (Fuel / In-vessel) were addressed in a risk-informed framework as part of a Phase V of this evaluation

Table 1
DESCRIPTION OF ECCS SUCTION STRAINER POTENTIAL ISSUES

Issue No.	NRC / BWROG Concern	Risk Evaluation
3. Debris Head-Loss Correlations	NRC has concerns on the reliability of the head loss predictions using correlations in the: Treatment of microporous debris and calcium silicate insulations that may result in high head losses The treatment of thin fibrous / particulate debris beds (thin-bed effect)	All CASA Grande evaluations model any accumulation of at least 1/8" of debris bed as an ECCS suction strainer failure in lieu of NPSH or structural limits calculated using debris head-loss correlations. This evaluation precludes any reliance on correlations for predicting head loss. The basis for the 1/8" of fibrous debris is taken from test report, Zigler, G, "Test Evaluation Report for Test TPP-VL0400-005: LaSalle Strainer Fiber and RMI Debris Tests, ITS Corporation, June 1998. This report was reviewed by the NRC (see Section 3.1.7 of LA-UR-01-1595, BWR ECCS Strainer Blockage Issue: Summary of Research and Resolution Actions, March 21, 2001). Test 1 in this report is Minimum Fiber Bed Threshold Test involved investigating the fiber loading needed to completely coat the strainer with a uniform nominal 1/8" to 1/4" fiber bed. Results of the test concluded that the assumption of a fiber volume equivalent to a 1/8" uniform bed thickness is sufficient to cover all the strainer surface areas homogenously and is very conservative with the actual value closer to 1/4". It is acknowledged that problematic debris (microporous or calcium silicate) may exhibit higher head losses at beds less than the selected 1/8" threshold. Appendix H of the Phase IV report as well as Appendix B of the Phase V report present and discuss the application of an additional weighting factor on strainer failure probability to account for thinner problematic debris beds.

Table 1

DESCRIPTION OF ECCS SUCTION STRAINER POTENTIAL ISSUES

Issue No.	NRC / BWROG Concern	Risk Evaluation
4. Chemical Effects	BWROG should consider the chemical environment, including corrosion products, may impact the debris head loss at the strainer or downstream component (e.g., fuel)	Chemical effects impact on debris head loss is greatly simplified based on the Debris Head Loss Correlation criteria developed above (Issue #3). Since the chemical impact on head loss is negligible or zero prior to the accumulation of at least 1/8" debris bed and debris beds at or greater than 1/8" is assumed a failure in terms of loss of NPSH, chemical effects are essentially included or bounded by the risk evaluation. Downstream Effects (Chemical / In-vessel) were addressed in a risk-informed framework as part of a Phase V of this evaluation
5. Coatings Assessments	NRC is concerned that non-qualified coating inventories in BWRs may be greater than established at the time the BWR strainer debris source terms were defined: Existing programs may not adequately monitor degradation or qualified coatings Existing programs may not adequately address changes to the unqualified coatings inventory	The evaluation of a 1/8" fiber debris bed as the only criterion for ECCS strainer failure is designed to capture strainer failures caused by large loadings of particulate debris types, which may include debris captured in coatings assessments. This issue is more directly assessed in the BWROG survey response regarding programmatic controls.
6. Latent Debris	NRC noted that the BWROG methodology assumed that latent debris is made up solely of particulate with a generic quantity of 150 lbm. PWRs validated the quantity and size characteristics of latent debris through source term walkdowns and determined the source term may contain a fibrous component. Neglecting this fibrous component can be potentially non-conservative for plants with little or no fiber.	CASA Grande evaluations analyze the effects of latent fibrous debris. The sensitivity case models 15% of latent debris as fibrous (similar to PWRs) and fully transports this amount to the ECCS suction strainers along with the ZOI-generated debris for evaluation of debris bed formation on the ECCS strainers. The value of latent debris is taken as either the plant-specific value or 150 lbm.
7. Zone of Influence (ZOI) Adjustment for Air Jet Testing (AJT)	The BWROG Zone of Influence (ZOI) is based on debris generation tests conducted with air as the test fluid. The NRC is concerned that steam may be more destructive than air, requiring an increase in the size of the ZOIs.	The issue of steam may be more destructive than air has been resolved with the Staff and no reduction factor on the damage pressure need be applied (ML15062A365). However, CASA Grande sensitivity case increases the ZOI by 10% to address Issue #7 and Issue #12. This 10% increase in ZOI diameter increases the ZOI volume by 33% and is designed to capture problematic insulation sources outside the spherical ZOI.

Table 1
DESCRIPTION OF ECCS SUCTION STRAINER POTENTIAL ISSUES

Issue No.	NRC / BWROG Concern	Risk Evaluation
8. Coatings Zone of Influence (ZOI)	The destruction of qualified coatings due to HELB is ZOI-based for PWRs and the BWRs use a generic value of 85 lbm. NRC is concerned that the BWR method is not sufficiently conservative.	BWROG calculated new damage pressures and ZOIs for BWR coatings in BWROG-ECCS-TA08-001. The NRC reviewed and determined that the ZOI used by the BWROG is appropriate (ML13280A347). CASA sensitivity cases calculates the quantity of destroyed qualified coatings based on material specific damage pressures and zones of influence for comparison to the baseline generic value of 85 lbm. However, the evaluation of a 1/8" fiber debris bed as the only criterion for ECCS strainer failure is designed to capture strainer failures caused by large loadings of particulate debris types, including coatings debris produced by a ZOI.
9. Debris Transport and Erosion	The NRC is concerned that: Differences in debris size distributions used between PWRs and BWRs may not have a substantial technical basis Differences in erosion of debris should be reconciled	CASA sensitivity case considers an increase of fibrous debris erosion. The full 25% of the low-density fiberglass (LDFG) not initially transported is eroded over a 3-hour period. CASA sensitivity case considers debris to transport to suppression pool in first 60 seconds vs 10 minutes. CASA Grande sensitivity case utilizes larger transport fractions to assess the effects of increased debris erosion. This sensitivity case also models transport to the suppression pool in first 60 seconds of the accident, as opposed to 10 minutes.
10. Debris Characteristics	NRC is concerned that: Blockage potential of calcium silicate insulation and other problematic materials such as microporous insulation may not have been treated conservatively. Recent testing for PWRs has identified potential for significant head loss increases.	The evaluation of a 1/8" fiber debris bed as the only criterion for ECCS strainer failure is simplified from previous methods of head-loss estimation, which rely more heavily on debris characteristics.
11. Near Field Effect / Scaling	Assurance is needed that any debris settling during BWR strainer testing was similar or less than would occur following a LOCA in the plant, or consistent with the analyses.	The risk evaluation did not consider any settling.

Table 1

DESCRIPTION OF ECCS SUCTION STRAINER POTENTIAL ISSUES

Issue No.	NRC / BWROG Concern	Risk Evaluation
12. Spherical Zone of Influence (ZOI)	NRC noted that while a spherical Zone of Influence (ZOI) may have maximized the quantity of debris, it may have precluded selection of a lesser amount of more problematic debris targets such as microporous or calcium silicate insulation. Such a target could be outside the nominal spherical ZOI but be within a more realistic direct jet flow.	CASA Grande sensitivity case increases the ZOI by 10% to address Issue #7 and Issue #12. This 10% increase in ZOI diameter increases the ZOI volume by 33%.