ENCLOSURE 2

Report BWROG-ECCS-WP-3-1, “Summary of Member Responses to BWROG Survey on Strainer Head Loss and Near-Field Effects” – Non-Proprietary Information

GE Hitachi Nuclear Energy

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BWROG Report

Summary of Member Responses to BWROG Survey on Strainer Head Loss and Near-Field Effects

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INFORMATION NOTICE

This is a non-proprietary version of the BWROG document 0000-0151-9755P, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]]. Appendices C, D, E and F are not included as they are proprietary.

IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

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1.0 ABSTRACT

This paper discusses the results of a BWROG survey of domestic BWR owners regarding head loss evaluations for the ECCS suction strainers at their plants, the scaling of strainer test results to determine this head loss, and whether strainer testing included near-field effects. This survey was developed to address two areas of concern (issues) related to potential differences in the treatment of strainers for BWRs and PWRs as agreed to by the BWROG and the NRC. The two issues are Head Loss Predictions (BWROG Strainer Committee issue number 3) and Test Scaling/Near-Field Effects (BWROG Strainer Committee issue number 11).

Because the strainer test methods and head loss predictions were developed by the individual strainer suppliers, the survey responses are tabulated in separate spreadsheets for each of the four domestic BWR strainer suppliers as Appendices to this report. The report includes a summary of the survey responses for each survey question and strainer supplier. A Head Loss and Scaling/Near-Field Effects Assessment Flow Chart is also provided to BWROG members for use in assessing the adequacy of their strainer head loss evaluations.

2.0 BACKGROUND

In 1996 the NRC issued a bulletin requesting BWR licensees to implement procedures, practices and plant modifications to minimize the potential for LOCA debris clogging of the ECCS suction strainers (Reference 1). In response to this NRC request the BWROG developed Utility Resolution Guidelines (URG) (Reference 2) and BWR owners installed new ECCS suction strainers.

The ECCS strainers installed in domestic BWRs were developed by four separate suppliers, Performance Contracting Inc. (PCI), General Electric – now General Electric - Hitachi (GEH), ENERCON, and Asea Atom (ABB) - now Westinghouse Atom and owned by Toshiba Corp. The NRC issued a Safety Evaluation Report (Reference 3) on the URG which approved much of the BWROG guidance contained in the URG, although the head loss prediction method included in the URG was not approved. The BWROG members worked with strainer suppliers to develop strainer head loss test programs and head loss predictions. The plant-specific strainer designs and head loss predictions were documented by the BWR licensees and approved by the NRC.

In 2004 the NRC issued a generic letter to PWR owners regarding NRC Generic Safety Issue 191, Assessment of Debris Accumulation on PWR Sump Performance (Reference 4). In November 2007, The NRC identified some technical issues raised during their review of GSI-191 that might warrant further consideration by BWR owners and the NRC made a presentation to the BWROG (Reference 5). The BWROG formed a committee – BWROG ECCS Suction Strainer Committee - to review new knowledge gained during the review of GSI-191 and this committee defined 12 issues that warranted further review, which are documented in a BWROG program plan.

3.0 BWROG PLAN AND SURVEY

Of the 12 issues defined in the BWROG ECCS strainer program plan, two of them are addressed in this report; issue # 3 which pertains to strainer Head Loss Predictions and issue # 11 which concerns Test Scaling and Near-Field Effects. The BWROG ECCS Suction Strainer Committee developed a survey to gather additional information on these two issues from the BWROG members. The survey requested answers to questions on how the strainer head loss was determined, including test methods and correlations.

A draft of the BWROG survey questions was provided to the NRC Staff for comment. The NRC Staff provided suggestions and comments on the draft survey (Reference 6) and the survey was revised in response to these NRC suggestions before being sent out to the member utilities of the BWROG (Reference 7). The survey questions and responses are contained in Appendices C through F.

The purpose of the survey is to determine if the methods used by the utilities and the strainer suppliers for BWR strainer head loss tests and head loss predictions contained any non-conservatism as identified during the more recent experience with PWR strainers in response to GSI-191. One potential non-conservatism is the impact on strainer head loss associated with the formation of chemical precipitants in ECCS cooling water. This issue is being addressed as issue #4 and is not specifically addressed by the survey.

4.0 COMPARISON TO PWR GUIDANCE

During the resolution phase of GSI-191 the NRC staff issued regulatory guidance concerning acceptable strainer head loss testing methods and strainer head loss predictions. This NRC guidance was issued in March 2008 and is titled *NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing* (Reference 8).

The NRC guidance report identifies fourteen areas that the NRC staff considers important for their review of PWR strainer submittals. These areas are:

1. Schematic of ECCS system
2. Minimum submergence of strainer
3. Results of vortex evaluations
4. Summary of methods, assumptions, and head loss results
5. Strainer's ability to handle maximum volume of debris
6. Strainer's ability to handle thin debris beds
7. Basis for the maximum head loss
8. Significant margins and conservatisms
9. The strainer head loss without debris present
10. Summary of debris head loss
11. Potential for partial submergence and need for venting
12. How was near-field settling addressed
13. How were test results scaled for changes in temperature and viscosity
14. Was credit taken for containment overpressure

Many of these review areas were addressed by BWR licenses during the plant-specific licensing when the BWR strainers were installed, typically in the late 1990s. There are some differences between how BWR utilities addressed some of these areas and the detailed PWR review guidance. The BWROG considers it acceptable for the regulatory methods to differ between BWRs and PWRs provided that each provides acceptable public and plant safety. In fact, it is understandable that the methods may differ between the two reactor types since the methods for each type of reactor were developed by independent industry groups roughly a decade apart. It would not be cost effective to revise the BWROG guidance and the associated supporting licensing documentation that already conservatively addresses a technical assumption just for the sake of being able to say that it has been changed to be consistent with the PWR guidance when there is no associated improvement in plant safety.

Of the fourteen review areas in the PWR review guidance document, areas numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13 and 14 were previously addressed by BWR licensees in their ECCS strainer evaluations and documents. Generally area 6 (thin beds) was addressed in less detail than is the current practice for PWR strainers because BWROG tests had shown that "alternate geometry strainers," e.g., stacked-disk and star geometries, did not produce a higher head loss when there was less fiber debris than with the maximum amount of fiber for the tested debris loads containing fibrous debris, coating debris, and sludge particulate (Reference 2, Section

3.2.6.2.3, Strainer Head Loss Calculation, page 118 and Reference 3, Staff Evaluation of Section 3.2.6, 3rd to last bullet, top of page 46).

Area 12 (near-field settling) was not explicitly addressed in the BWR licensing documents although the vendors typically took measures to prevent debris settling during strainer tests. The exception being ENERCON strainers which have a large surface area and low approach velocities where the testing was designed to simulate suppression pool conditions in the Mark III containments where they are installed.

All of the areas other than 6 (thin beds) and 12 (near-field settling) were addressed in a similar or an equivalent manner to the PWR regulatory guidance and therefore do not need to be revisited except for the effect of any changes to areas 6 and 12. The survey was designed to gather further information particularly for the areas 6 and 12. Obviously any changes to the methods for areas 6 and 12 may also impact area 4 (summary of methods and head loss results), 7 (basis for maximum head loss), and 10 (summary of debris head loss).

5.0 CHEMICAL EFFECTS

The potential for the head loss in the strainer debris bed to increase as a result of chemical precipitates being captured or formed in the debris bed is being addressed by the BWROG ECCS Suction Strainer Committee as issue # 4, Chemical Effects. The NRC strainer head loss review guidance of March 2008 (Reference 8) includes guidance on how to treat chemical effects in determining strainer head loss. However, since the BWROG is addressing chemical effects as a separate issue, it was not specifically addressed in the survey. Once the BWR chemical effects dissolution tests are completed and the potential BWR chemical precipitates are identified and quantified, the impact of any such precipitates on debris bed head loss will be assessed.

6.0 SURVEY QUESTIONS AND SUMMARY OF RESPONSES

Most of the fleet of domestic BWRs responded to the BWROG head loss and scaling survey. There are 15 domestic BWRs with strainers supplied by PCI and responses were received for 13 of these BWRs. There are 13 domestic BWRs with strainers supplied by GE and responses were received for 12 of these BWRs, and GEH provided information for the other BWR that did not respond. All of the domestic BWRs with ENERCON and ABB supplied strainers responded to the survey with 3 and 4 plants respectively for these two strainer suppliers. The ENERCON strainers are only used in BWR 6s with Mark III containments.

Spreadsheets of the survey responses are provided in Appendices C through F. The Appendices use alphabetical characters to designate the source plant names. Some individual responses were modified to remove any reference to the plant name. Some lengthy responses that contained tables, graphs, test results, etc. were shortened so they would better fit in the spreadsheet. The responses are meant to provide an understanding of the methods used by the BWR plants and will not be specifically used for plant design purposes. Therefore, the transposition of the survey responses into the Appendices has not been verified – although since much of the cell data was cut and pasted from the responses, the data fidelity is expected to be high. Where BWR licensees responded for multiple units with a single response, only the one response is included in the survey table. For example, ABB strainers were installed at two sites with dual units and therefore there are only two survey responses for plants with ABB strainers.

There were 15 questions in the survey and in the following sections the third digit represents the question number, e.g., 6.2.8 represents question number 8 in the survey.

6.1 Survey Questions on Head Loss

6.1.1 Head Loss Prediction

Was the strainer head loss for your plant determined with:

a. A vendor-provided correlation (if so, provide name of vendor),
b. A vendor-provided correlation with confirmatory plant-specific tests,
c. Direct use of plant-specific test data,
d. By another means (if so, please describe)?

Responses:

For plants with strainers provided by PCI (15 domestic BWRs), the strainer head losses were determined by a proprietary HLOSS code (version 1.0) developed by Innovative Technology Solutions (ITS). The HLOSS code is based on the NUREG/CR-6224 correlation (Reference 9). Some plants used the BLOCKAGE code (see Section 6.1.3) to account for debris settling in the suppression pool. These head loss and settling predictions were performed by Innovative Technology Solutions, which has become a part of Alion Science and Technology.

For some plants with PCI strainers, confirmatory head loss tests were performed at the EPRI non-destructive test center in Charlotte, NC for plant-specific strainer configurations and debris loads. These PCI tests confirmed that the HLOSS correlation had conservatively predicted the strainer head loss.

For plants with strainers provided by GE (13 domestic BWRs), the strainer head losses were typically determined by a proprietary head loss correlation that was conservatively based on a series of tests of a full-scale prototype strainer with varying debris constituents. These tests with the prototype strainer were performed at the EPRI large test facility. Based on the test results, GE developed a strainer head loss correlation for the GE optimized stacked disk strainers. GE submitted a Licensing Topical Report regarding the proprietary head loss correlation and this LTR was approved by the NRC.

Three of the plants with GE strainers have primarily RMI insulation and for these plants a set of confirmatory tests were performed with plant specific debris loads. Two other plants had debris compositions that were outside the range of the GE correlation and plant-specific tests were performed for these plants, which resulted in a plant-unique correlation. One other plant performed plant-specific tests that confirmed that the correlation provided a conservative head loss prediction.

For plants with strainers provided by ENERCON (3 domestic BWR6s), the strainer head losses were determined with a correlation that scaled test results from a one-quarter scale strainer and Mark III suppression pool to plant full scale conditions.

For plants with strainers provided by ABB (4 domestic BWRs), the strainer head losses were determined with a proprietary strainer head loss correlation that was based on test results with various sludge-to-fiber ratios for tests performed at the EPRI large test facility.

6.1.2 Problematic and Coating Debris

a. Does the debris source term for your plant contain any calcium silicate or microporous (such as Min-K or Microtherm) debris?
b. If so, what is the average mass of each problematic debris material (Min-K, Microtherm, and Calcium Silicate) per square foot of strainer surface area that is transported to the strainer?
c. Were your failed qualified and unqualified coatings treated as paint chips or particulate? Describe the size characteristics for failed qualified and unqualified coatings.

Responses:

Some plants have calcium silicate, Min-K or Microtherm insulation debris. For the plants reporting the quantity of these debris types per strainer unit surface area, the two largest values for each debris type were: [[

]] As can be seen from the responses, for most BWRs the amount of these problematic debris materials is relatively small per strainer surface area.

A report in the URG developed by coatings experts from the Bechtel Corporation indicated that most coatings, other than inorganic zinc, outside the Zone of Influence would fail as paint chips. Most of the BWR plants treated failed coatings outside the ZOI, other than inorganic zinc, as paint chips and treated failed inorganic zinc coatings as zinc particulate. Some plants increased the quantity of sludge used in their strainer tests to account for failed coating debris. For most BWRs the quantity of sludge particulates is typically significantly greater than the quantity of failed coating debris.

6.1.3 Debris Settling

a. Did your plant take any credit for debris settling within the suppression pool in the debris transport analysis?
b. If so, how was it calculated, e.g., the BLOCKAGE or STRAIN codes?
c. What was the basis for the settling parameters used in the analysis?

Responses:

For the plants with PCI strainers, The BLOCKAGE code version 2.5 (Reference 10) was used by ITS to determine the quantity of debris that reached the strainers. For the strainers supplied by GE, the individual plants determined their strainer debris loadings and some plants did not credit any settling while some used the BLOCKAGE or STRAIN (Reference 11) computer codes to determine the amount of debris settling. One of these plants performed CFD analysis to determine the inputs for BLOCKAGE. For plants with strainers supplied by ABB, no credit was taken for debris settling. For plants with strainers supplied by ENERCON, the quantities of generated debris were not reduced by a settling analysis, but because of the large surface area of these strainers and the associated very low strainer approach velocities, some of the debris settled out during the strainer testing. The strainer tests for the PCI, GE, and ABB strainers were designed to prevent debris from settling, although there was some settling of RMI debris noted for the ABB strainer tests.

6.1.4 Time Dependence

a. Did the strainer head loss analysis consider time-dependent transport of debris to the strainer?
b. If so, how was this time-dependence modeled?

Responses:

For the plants with PCI strainers, most of the plants did not take credit for a time delay in the debris reaching the strainer other than what is contained in the BLOCKAGE code; although, one plant used a seventy-five second delay time for transport of the debris to the strainers. For plants with GE strainers, some of the plants took credit for a suppression pool filtration time constant to determine the quantity of debris on the strainers during the first ten minutes of the postulated LOCA, with the remainder of the debris reaching the strainers at ten minutes, when credit could be taken for operator actions to adjust ECCS flow rates. One GE strainer plant took credit for settling of cable ties and RMI after blowdown was complete. For plants with ABB and ENERCON strainers no credit was taken for a time delay in the debris reaching the strainers.

6.1.5 Debris Mixtures

a. Was your strainer head loss based on a debris source term containing fibrous debris?
b. If so, did you consider the head loss from both debris loads with a maximum amount of fiber as well as debris loads with a lesser amount of fiber? Please explain.
c. If problematic debris and fiber are components in your debris source term, did you consider debris loads with a maximum amount of problematic debris but less than the full amount of fiber? Please explain.
d. Do you have postulated breaks that will produce both fiber debris as well as RMI debris that will transport to the strainer? If so, how was the strainer head loss determined for debris mixtures containing both fiber and RMI debris?

Responses:

For plants with PCI strainers, the HLOSS computer code analysis included some break location cases with less than the maximum amount of fiber and for at least one of these plants the analysis was performed for a debris bed of 1/8th of an inch thickness. The responses do not indicate that an HLOSS analysis of a 1/8th inch thick debris bed was typically performed for every PCI strainer. For PCI strainer plants, when there is both RMI and mixed debris the head loss from each bed type is added to determine the total strainer head loss.

For plants with GE strainers, the GE strainer head loss correlation was used to predict the strainer head loss at the maximum debris load. During the testing performed to develop the GE strainer head loss correlation, the thin bed effect was not noted. The GE strainer tests performed at the Charlotte EPRI facility showed that the addition of RMI typically did not increase the head loss of a mixed debris bed. The GE head loss correlation treats RMI head loss separately from the head loss of a mixed debris bed and the head losses from the two types of debris beds are compared and the larger head loss is used as the predicted head loss. One plant with a GE strainer added the two separate head losses when their values were comparable.

One BWR licensee with GE strainers considered other operating modes of the Residual Heat Removal (RHR) system, other than the maximum fiber case (one RHR pump functioning), involving multiple LPCI pumps. For these operating modes the quantity of debris on the strainers is reduced from the maximum amount because the debris is split between more strainers. Although the amount of debris on the strainers is less for these cases, there can be an increase in head loss associated with the increased flow velocity.

For plants with ENERCON strainers, the strainer head loss was based on one quarter-scale testing. One plant had very little fiber debris and RMI was the main type of debris. The other two plants used one-quarter scale tests of the strainer and a Mark III containment with the maximum plant debris load. One of these two plants discovered additional sources of problematic debris after performing the tests, and they increased the strainer head loss by 20% to account for this added debris.

For the plants with ABB strainers, tests were performed with various ratios of sludge debris to fiber debris. Two of the plants with ABB strainers do not have RMI debris and the other two have a low approach velocity that allows the RMI to settle out prior to reaching the strainer. One of the plants has Min-K debris inside of welded steel cassettes and the Min-K was treated as Nukon for testing purposes.

6.1.6 Thin Bed

a. Did you explicitly consider head loss for thin fibrous debris beds (i.e., fiber bed thicknesses between 1/16 and 1/2 inch)?
b. How was strainer head loss determined for thin fibrous bed conditions:
    i. With the same correlation as used for the maximum debris bed,
    ii. With a separate correlation,
    iii. With plant-specific thin bed tests,
    iv. Demonstrated with head loss tests to have a head loss less than with the maximum fibrous debris load
    v. Or by another means (if so, please describe)

Responses:

For plants with PCI strainers, the HLOSS computer code was used for some plants to analyze thin beds with as little as a 1/8th inch fiber bed. For plants with GE strainers and fiber debris, the GE head loss correlation was used to analyze the debris bed with the maximum fiber thickness for the specific plant; as GE strainer prototype tests with sludge and fiber had shown the maximum head loss would occur with the maximum bed thickness.

For plants with ABB strainers, the strainer tests were performed with fiber being added incrementally during the testing in order to address all fiber bed thicknesses including thin beds. For plants with ENERCON strainers and fiber debris, the strainer testing at one-quarter scale did not indicate the occurrence of the "thin bed effect."

6.2 Specific Information on Head Loss Correlations (including vendor correlations)

6.2.7 Problematic Debris

a. If a correlation was used to predict strainer head loss, did the correlation explicitly consider all debris materials applicable to the plant, including "problematic" debris?
b. If the correlation did not explicitly consider all debris materials, how was the head loss associated with the excluded materials modeled?

Responses:

For plants with PCI strainers, the HLOSS correlation was used to predict the head loss included modeling of the problematic debris materials in a manner similar to NUREG/CR-6224, which was the basis for the HLOSS correlation. Because of the variation in the debris mixtures for the plants with PCI strainers, the survey responses identify a range of additional measures taken to address debris mixtures with problematic debris.

GE developed a strainer head loss correlation from a series of tests (44) performed on a GE prototype strainer with varying amounts of sludge, fiber, and RMI debris and with varying flow rates. About 1/3rd of the tests included RMI debris and it was decided to use a separate RMI debris head loss correlation as the head loss with RMI debris added to fibrous debris can be less than the head loss of the fibrous debris alone. The head loss values from these full-scale prototype tests were used to develop the empirical constants contained in the GE proprietary head loss correlation (Appendix B contains a discussion of a GEH issued safety communication related to the GE head loss correlation).

For plants with GE strainers, the GE strainer head loss correlation incorporates the miscellaneous debris bump-up factor for debris materials such as paint, rust, dust, and calcium silicate, as developed by the BWROG and documented in the URG. The GE head loss correlation also includes a debris-specific bump-up factor determined from comparative gravity head loss test data to account for the head loss from other debris materials not included in the miscellaneous bump-up factor, such as Min-K. Some of the GE tests performed with the prototype strainer had thin fiber beds and a thin bed effect was not noted. The GE head loss correlation treats RMI head loss separately from the head loss of a mixed debris bed and the head losses from the two types of debris beds are compared and the larger head loss is used as the predicted head loss.

The plants with ENERCON strainers did not use a correlation and instead scaled the head loss results from quarter-scale and small scale strainer tests. The testing for two of these plants included the problematic debris, while the tests for the other licensee did not include problematic debris and that licensee increased the strainer head loss by 20% to account for the problematic debris.

For plants with ABB strainers, the head loss was determined with a proprietary head loss correlation. How the correlation treats problematic debris has not been provided to the BWROG.

6.2.8 Temperature Scaling

a. Did the correlation specifically address temperature dependence on head loss?
b. If so, how was the temperature dependence modeled (e.g., viscosity scaling)?

Responses:

For plants with PCI strainers, the head loss was scaled with temperature in accordance with the NUREG/CR-6224 correlation.

For plants with GEH strainers the head loss is scaled with water viscosity in accordance with the proprietary GEH correlation.

For plants with ABB strainers the scaling of head loss was performed in accordance with the proprietary ABB correlation, which is believed to use the kinematic viscosity of water in scaling the test results.

For plants with ENERCON strainers the head loss testing was performed at room temperatures and there was no scaling of the head loss with temperature.

6.3 Specific Information on Generic and Plant-Specific Head Loss Tests

6.3.9 Debris Characteristics and Tests

a. What debris materials and debris surrogates were used in plant-specific or generic tests that are the basis for the predicted strainer head loss?
b. Describe how the debris materials and surrogates were prepared prior to the tests (e.g., Nukon fiber and coating debris preparation)?
c. What were the size characteristics of the debris materials and surrogates used in testing?
d. Are the size characteristics for the coating materials used in testing consistent with the coating debris expected to reach the strainer following a LOCA?
e. Do you have photos of the debris materials and/or surrogates prior to testing?
f. Describe the process used to introduce debris materials into water (including the mass or volume of debris materials per volume of water if the debris was pre-mixed with water) and the test facility tank/plume in plant-specific or generic tests?
g. In what sequence were the debris materials/surrogates introduced into the test water?

Responses:

For plants with PCI strainers the tests were performed at the EPRI test facility. The Nukon fiber materials were supplied by PCI and were prepared in a manner similar to that used for the BWROG tests. The size distribution of the shredded fibers was compared to the distribution used in the BWROG tests and the size distributions were similar. Black iron oxides were obtained from Hansen Engineering Inc. with a distribution of 95% by weight of Grade 2008 and 5% by weight of Grade 9101-N-40. The RMI debris was similar in size to the 0.0025 inch thick stainless steel RMI used in the BWROG tests.

The full scale GE strainer prototype tests were conducted at EPRI. The Nukon insulation was supplied by PCI and prepared by cutting it into 3 inch squares that were then shredded in a leaf shredder, similar to the procedure used in the BWROG tests. Samples of the Nukon fiber were collected and analyzed. The analysis showed the shredded fibers had a similar size distribution similar to that of the BWROG tests. Black Iron Oxides were obtained from Hansen Engineering, Inc. and were used to simulate sludge. The composition of these corrosion products were 95% Grade 2008 and 5% Grade 9101-N-40 by weight.

The RMI debris used in the GE tests was 0.0025" thick stainless steel foil. It was divided into 3/8", 3/4" 1.5" and 6" pieces that were crumbled to simulate RMI debris. Approximately 50% of the total RMI was made up of 6" pieces and the other four sizes made up the other 50%. This RMI debris was similar to the RMI debris used in the BWROG tests. The Tempmat insulation was provided by a utility and prepared by EPRI. The Tempmat blanket was cut into 3" squares and shredded in a leaf shredder. After shredding the Tempmat fiber, the material size distribution was compared to the size distribution used in the BWROG tests and was found to be similar.

For plants with ENERCON strainers (only installed in BWR 6s), a quarter-scale Mark III containment facility was used for the testing. The debris materials were prepared in a manner to simulate the LOCA debris properties. The ENERCON tests used all of the identified debris materials as defined by the utility. The debris quantities were scaled for the quarter scale test facility.

There was insufficient information in the survey responses to provide a description of the methods used for testing ABB strainers. It is believed that their debris materials were prepared in a manner similar to that used in the BWROG testing and the tests were performed at the large scale EPRI facility in Charlotte.

6.3.10 Debris Settling

a. Were the strainer tests designed to transport the debris materials to the strainer during testing?
b. If no credit was taken for settling in plant-specific or generic tests, what measures were used to ensure that settling did not occur?
c. If debris materials were allowed to settle during testing, what measures were used to ensure that the settling was prototypical or conservative?
d. If available, please provide photographic or other recorded evidence of the amount of debris that settled in strainer tests?

Responses:

For plants with PCI, GEH and ABB strainers the tests were performed at EPRI and the test facility was designed to minimize settling of the debris.

For plants with ENERCON strainers, water jets were used to agitate the water in the test tank and prevent settling of debris on the floor. However, some of the larger and heavier debris materials did settle on the test facility floor, as would be expected with the low strainer approach velocities.

6.3.11 Test Termination

a. What criteria were used in deciding when to terminate head loss tests?
b. If test results were extrapolated to a higher final head loss value, how was this extrapolation performed?

Responses:

For PCI strainers, the test termination criteria were a steady state head loss and clear water in the tank. For high particulate debris mixtures, the termination criterion was a less than 5% increase in measured pressure drop during 30 minutes.

For GE strainers, the test termination criterion was when the debris head loss had reached steady state as determined by the differential pressure measurement.

For ENERCON strainers, the test termination criterion was no change in the measured debris head loss.

The test termination criteria for tests with ABB strainers has not been provided to the BWROG.

6.3.12 Temperature Scaling

a. Were strainer head loss test results scaled to account for differences in test vs. plant water temperature?
b. If so, what scaling method was used?
c. Was there any evidence of "bore holes" (holes that form in thin beds when subjected to high head losses) such as fluctuations in pressure drop across the bed with time during the testing?
d. If available, please provide a copy of the time history of the pressure drop for tests performed with thin fibrous beds?
e. Were test flows varied, i.e., were there various flow rates for the same debris bed, to determine whether the flow through the debris bed was laminar?

Responses:

For plants with PCI strainers, the head losses were scaled with water viscosity and water density according to the NUREG/CR-6224 equations.

For plants with GE strainers, the head losses were scaled with water viscosity as GE had performed tests that showed the head losses associated with the turbulent flow term (dependent on fluid density and flow velocity squared) were insignificant at the conditions for which GE strainers are designed.

For plants with ABB strainers, the head losses were scaled in accordance with the proprietary ABB head loss correlation. It is believed that the ABB correlation contains terms that are scaled with both water viscosity and water density.

For plants with ENERCON strainers, the head losses obtained during testing were not scaled for temperature.

6.3.13 Test Geometry Scaling.

One concern with strainer head loss tests concerns how prototypic the debris deposition on the test article was vs. the expected deposition on the plant strainer following a LOCA.

a. Please provide a brief description of the similarities and differences between the strainer test article and the plant strainer.

b. Does the plant strainer design contain features that encourage a uniform deposition of debris on the strainer surfaces?
c. Were similar features used in the strainer test article?
d. Was there evidence of a non-uniform debris deposition on the test article?
e. Is there photographic evidence, or other documentation, that shows the debris bed on the test strainer and whether it had a uniform thickness?
f. Were strainer tests based on having an equivalent debris load per unit strainer area and an equivalent flow velocity through the bed as would be expected for the plant strainer following a LOCA?
g. If the test did not use an equivalent debris load per unit area and/or flow velocity, what scaling method was used to obtain strainer head losses for the plant?

Responses:

PCI strainers contain a "sure flow" control feature that encourages uniform flow among the disks along the length of the strainer. For plants with PCI strainers, tests were performed with a scaled strainer. Some plants with PCI strainers tested with a full size PCI strainer. Tests were performed with an equivalent debris load and flow velocity per unit surface area. Bore holes were not noted in the tests of the PCI strainers.

GE strainers contain flow control features that promote uniform flow among the disks and GE named their design an optimized stacked disk strainer. GE performed a series of tests with a full scale prototype strainer which contained these features. Some plants with GE strainers performed tests with their plant-specific strainers. Bore holes were not noted in the GE BWR strainer tests and the pressure-drop time plots do not indicate differential pressure fluctuations typically associated with borehole formation. Debris deposition in the gap between disks was typically U-shaped with the larger quantity of debris at the inner diameter of the disk. The test results were used to develop a head loss correlation that considered debris materials, debris bed thickness, debris particulate-to-fiber ratios, water temperature and flow velocities.

The ENERCON and ABB strainers do not contain any flow control features. The ENERCON tests were performed in a quarter-scale test facility that replicated the geometry of the strainer and a BWR Mark III containment suppression pool (ENERCON strainers were only installed in BWRs with Mark III containments). ENERCON tests were performed with debris quantities from 59 to 440% of the theoretical maximum debris concentration. These tests showed that for smaller concentrations the debris would start to accumulate near the portion of the strainer near the pump suction and the portions of the strainer located more remotely from the pump suction would not accumulate debris. For higher debris concentrations the debris would start to accumulate near the pump suction and the debris accumulation would progressively move further away from the pump suction. The tests used an equivalent average debris loading per unit surface area and an equivalent flow velocity per unit area. There was no evidence of bore holes.

6.3.14 Thin Bed Tests

a. Were tests performed for a range of fiber bed thicknesses, including thin beds (1/8 inch thickness or less)?
b. If thin bed tests were performed, was there any evidence of "bore holes" in the debris bed?
c. Please provide a time history of the pressure drop in the bed for tests performed with thin beds?

Responses:

For plants with PCI strainers there were some tests with high particulate-to-fiber ratios. The "thin bed effect" phenomenon was not noted.

The GEH head loss correlation is limited to the range of tested debris variables, primarily iron oxide sludge and Nukon fiber, and does not include very high particulate-to-fiber ratios.

For plants with ENERCON strainers, all of the debris was assumed to make it to the suppression pool.

Extensive testing with calcium silicate and microporous debris and fiber beds of approximately 1/8 inch was not performed by any of the strainer suppliers. The PCI, GE and ABB strainer suppliers believed their "alternate geometry" designs were not susceptible to the "thin bed effect" based on observations during both BWROG and vendor-specific strainer testing, typically with debris mixtures containing iron oxide sludge and Nukon fibers.

6.4 Other pertinent information

6.4.15 Other

a. Is there other information that pertains to your strainer head loss prediction that was not addressed by this survey? If so, please describe.

Responses:

One BWR licensee with an ENERCON strainer commented that there was very little difference between the measured clean strainer head loss and the measured strainer head loss with debris. This was attributed to the ENERCON's strainer having a large amount of perforated area and the low approach velocity.

One BWR licensee with a PCI strainer provided some additional discussion on the BLOCKAGE code and assumed filtration efficiencies.

7.0 CONCLUSIONS REGARDING HEAD LOSS SURVEYS

The survey responses indicate that most of the head loss issues that are being addressed in response to GSI-191 were considered when the BWROG URG was prepared. The BWROG and the BWR owners addressed some of the technical areas in a similar manner to that which is being used by PWRs to respond to GSI-191 and addressed some of the areas in a different, but not necessarily non-conservative, way than the PWR responses to GSI-191. The survey responses do indicate some technical areas where further efforts are needed to ensure that they are treated realistically or conservatively.

7.1 Near-field effects

The BWR strainer vendors did not take credit for near field effects in their strainer tests except for the ENERCON strainers, which because of their large size have a very low approach velocity. The other three BWR strainer vendors performed their tests at the large scale EPRI test facility and all of these tests included specific measures to prevent debris from settling during the tests. The settling of debris for the ENERCON strainer tests occurred because of the very low approach velocity associated with these large strainers, which is representative of the expected LOCA conditions at a BWR with an installed ENERCON strainer. BWR owners with ENERCON strainers will need to review the approach velocities used during the ¼ scale testing to ensure that these approach velocities were realistic or conservative.

7.2 Debris settling

Some of the BWR owners considered debris settling in determining their debris load on their strainers. The computer codes BLOCKAGE and STRAIN were used to determine how much debris would settle before reaching the strainer. These debris settling analyses should be reviewed to determine if the assumed debris settling parameters are consistent with latest BWROG guidance (BWROG Issue # 9 addresses debris transport and erosion).

Some BWR owners determined the time dependent deposition of debris on the strainers using standard filtration equations and were able to take credit for operator actions to adjust the ECCS pump speeds ten minutes after the LOCA initiation. The assumptions used in these analyses should be reviewed against the latest BWROG guidance on debris transport and erosion (Issue # 9).

7.3 Use of NUREG/CR-6224 head loss correlation

The head loss correlation HLOSS for the PCI strainers was based on the NUREG/CR-6224 correlation. PWR testing has shown that when using the NUREG/CR-6224 correlation with problematic and microporous debris materials, improved accuracy is obtained by using specified debris characteristics as inputs for these debris materials. Those plants with PCI strainers that have microporous/problematic debris will need to review their head loss evaluations to determine if their assumed debris material characteristics are consistent with the latest industry practices for the use of NUREG/CR-6224 and, if not, revise their head loss evaluations.

7.4 Characteristics of failed coatings

Some of the BWR strainer suppliers, e.g., GE, treated failed unqualified epoxy coatings as paint chips, while PWR strainer vendors typically treated such failed coatings as particulate unless they did not have a fiber bed (Reference 12). The plant-specific debris material characteristics should be compared to the latest BWROG debris characteristics guidance [Issue # 10] and if necessary revised. Note that since BWRs typically have a much larger quantity of iron oxide sludge particulate than PWRs, a change in the quantity of failed coating particulates might only produce a small percentage change in the particulate debris load, and therefore there would be only a small change in the strainer head loss.

7.5 Thin bed effect

In the 1990's the BWR strainer suppliers performed tests with their strainer test articles and prototype strainers and the test data indicated the maximum head loss occurred with the maximum fiber load for strainers with an "alternate strainer geometry" (alternate refers to differing from a flat plate strainer and was represented by the stacked-disk design of PCI and GE and the star design by ABB) for the debris mixtures tested. During the more recent GSI-191 tests for PWRs, the "thin bed effect" phenomenon was noted for some debris mixtures containing calcium silicate and/or microporous debris. Most BWR plants typically do not have large quantities of these problematic debris materials (see individual survey responses and summary in Section 6.1.2).

The BWROG is planning a series of tests with potential BWR debris mixtures containing calcium silicate/microporous debris and BWR strainers to determine if there are conditions under which the "thin bed effect" phenomenon could occur. These tests would be used to define a set of conditions, including debris mixtures, for which a thin bed might occur such that BWR owners would know to avoid these conditions (by removing problematic debris) or that their strainer should be tested for the potential to have a "thin bed effect" phenomenon.

7.6 Debris and surrogate materials and introduction into the test facility

During the testing of PWR strainers, there was a focus on how debris materials and surrogate materials were prepared and introduced into the test facility. The tests of BWR strainers were performed with large-scale strainer prototypes in large-scale test facilities (mostly in the EPRI test facility in Charlotte) using the debris material preparation methods developed by the URG. The sludge was obtained from rusted steel and sized according to measured sludge characteristics, the Nukon fiber was passed through a leaf shredder and the size characteristics were compared to the URG standard fiber length distribution, coating debris was either obtained by painting and stripping paint off of surfaces or a surrogate particulate was used for zinc oxide coatings.

Other debris materials were either obtained from the insulation manufacturer or supplied by a BWR licensee from their on-site insulation supplies. These debris materials were reduced to a small size by mechanical damage prior to testing. Although the size distributions of some of these debris materials and surrogates may differ from the distributions used in some PWR tests, they are considered acceptable for the performed BWR strainer tests, which are maximum bed thickness tests. Should further tests of BWR strainers be performed, the recent NEI guidance (Reference 13) will be considered in preparing and introducing fibrous debris.

8.0 HEAD LOSS ASSESSMENT FLOW CHART

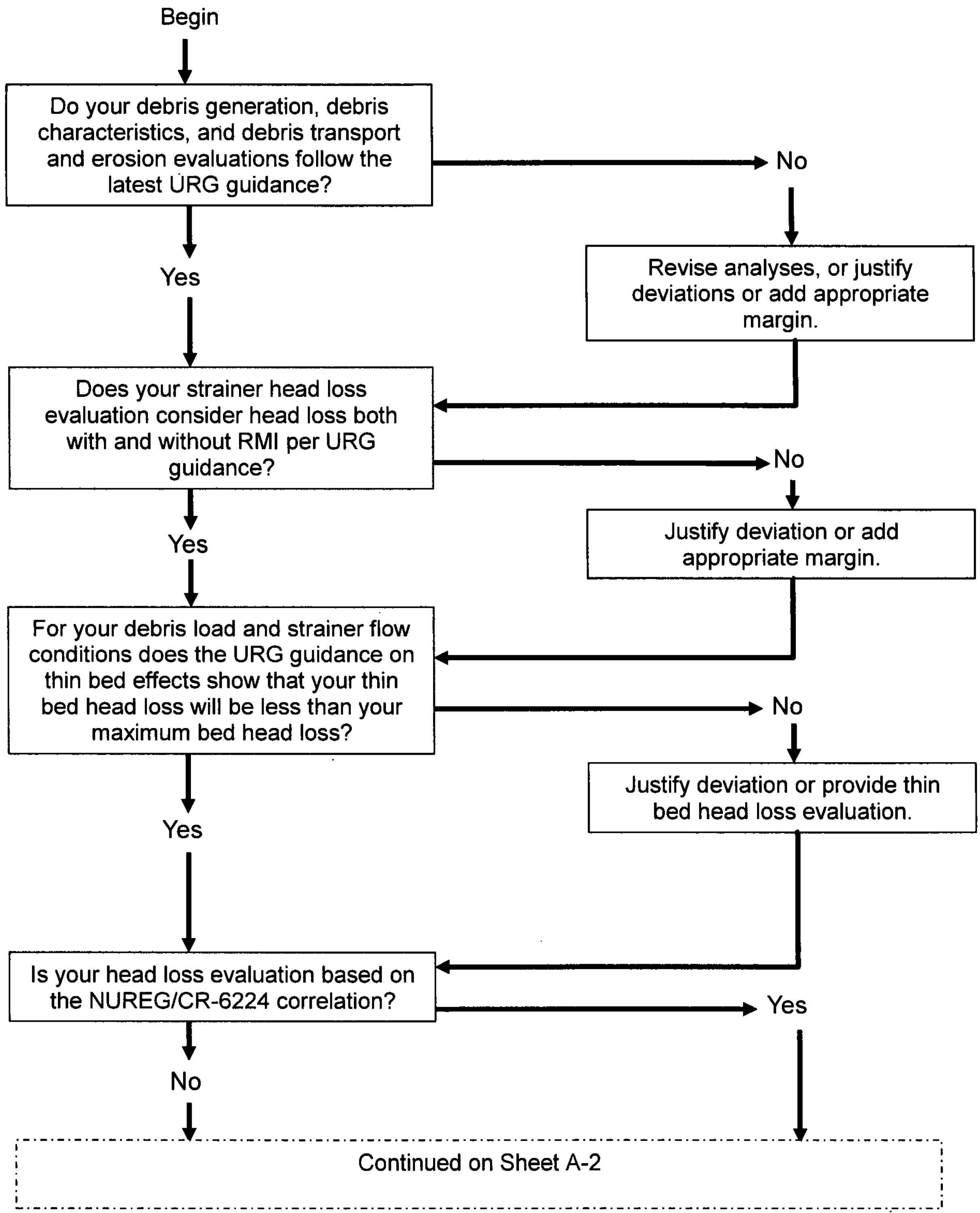
A head loss and near-field effects assessment flow chart has been developed for use by BWR owners. This flow chart provides a series of yes or no questions that allows BWR owners to assess whether their strainer head loss evaluations meet the latest BWROG guidelines (some of which are still in progress of being developed). The flow chart is provided in Appendix A. BWR licensees should start at the beginning of the flow chart and answer each question as directed by the flow chart, make any necessary revisions to their head loss evaluations as indicated by the flow chart, and then document their strainer head loss evaluation and that it is compliant with the flow chart.

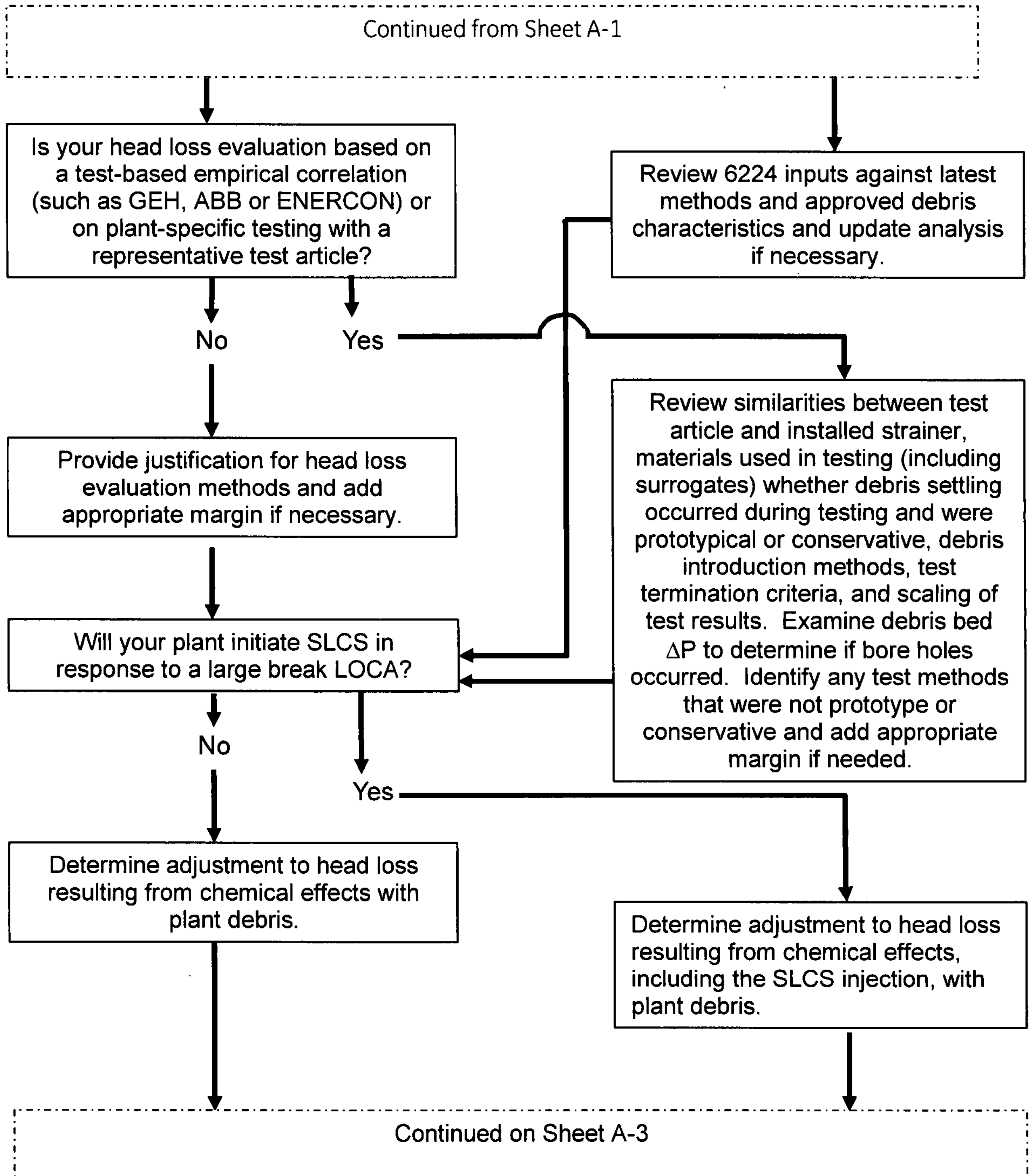
9.0 REFERENCES

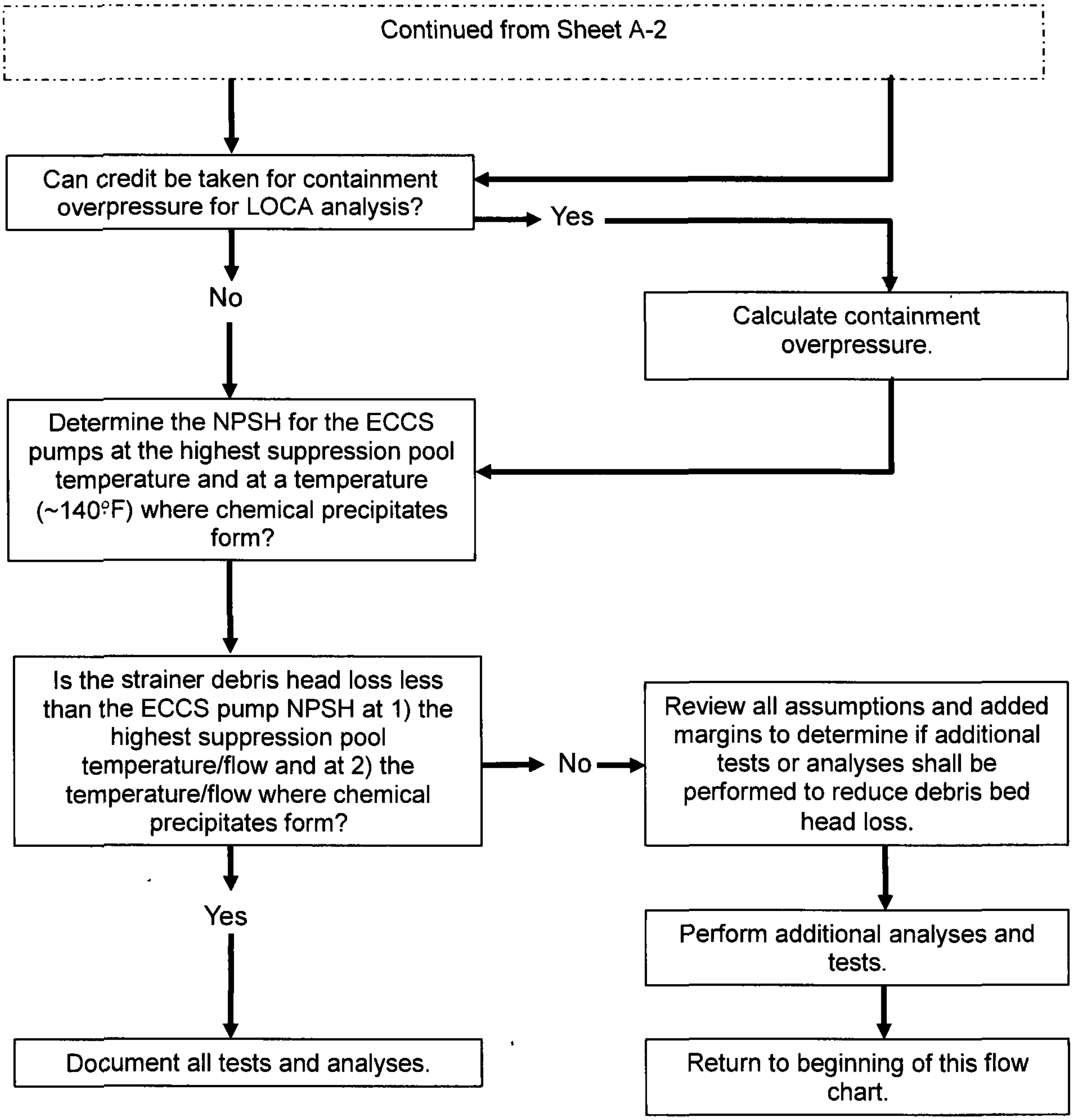
1. NRC Bulletin, *Potential Plugging of ECCS Suction Strainers by Debris in BWRs,* May 6, 1996. [ADAMS No. ML082401219].
2. BWROG Document, *Utility Resolution Guide for ECCS Suction Strainer Blockage,* NEDO-32686-A, October 1998. [ADAMS No. ML092530482]
3. NRC Letter, T.H. Essig to R. Sgarro, *Safety Evaluation for NEDO-32686, Rev. 0, "Utility Resolution Guidance Document for ECCS Suction Strainer Blockage."* August 20, 1998. [Contained in ADAMS No. ML092530482]
4. NRC GL 2004-02, *Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,* September 13, 2004. [ADAMS No. ML042360586]
5. NRC Presentation to BWROG, *Differences in Treatment of Containment Strainer/Sump Clogging Technical Issues for Boiling Water and Pressurized Water Reactors,* R. Architzel, November 27, 2007. [ADAMS No. ML073320404]
6. NRC Letter, J.R. Jolicoeur to F.P. Schiffley, *Feedback on BWROG-11018, "BWROG ECCS Suction Strainer Draft Surveys on Headloss and Unqualified Coatings"* June 9, 2011. [ADAMS No. ML11140A126]
7. GEH e-mail, R. Whelan to BWROG Distribution, *BWROG Surveys: Coatings Program and Headloss*, June, 2011.
8. NRC Report, *NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing,* March 2008. [ADAMS No. ML080230234]
9. NRC Report, *Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris,* NUREG/CR-6224, October 1995.
10. NRC Report, *BLOCKAGE 2.5 User's Manual*, NUREG/CR-6370, December 1996.
11. Continuum Dynamics Incorporated Report, *User and Technical Documentation for the STRAIN Computer Program*, Rev. 0, Technical Note No. 94-08, May 1997.
12. NRC Staff SER on Pressurized Water Reactor Sump Performance Evaluation Methodology, NEI-04-07, Rev. 1, December 2004. [ADAMS No. ML043280641]
13. NEI Letter, J. Butler (NEI) to S. Bailey (NRC), *Fibrous Debris Preparation Procedure for ECCS Recirculation Sump Strainer Testing,* Revision 1, dated January 30, 2012 [ADAMS No. ML120481052], including Attachment entitled, *ZOI Fibrous Debris Preparation: Processing, Storage and Handling*, Revision 1, January 2012. [ADAMS No. ML120481057]

Appendix A

HEAD LOSS ASSESSMENT FLOWCHART




Continued from Sheet A-1
Is your head loss evaluation based on a test-based empirical correlation (such as GEH, ABB or ENERCON) or on plant-specific testing with a representative test article?
Review 6224 inputs against latest methods and approved debris characteristics and update analysis if necessary.
No
Yes
Review similarities between test article and installed strainer, materials used in testing (including surrogates) whether debris settling occurred during testing and were prototypical or conservative, debris introduction methods, test termination criteria, and scaling of test results. Examine debris bed ΔP to determine if bore holes occurred. Identify any test methods that were not prototype or conservative and add appropriate margin if needed.
Provide justification for head loss evaluation methods and add appropriate margin if necessary.
Will your plant initiate SLCS in response to a large break LOCA?
No
Yes
Determine adjustment to head loss resulting from chemical effects with plant debris.
Determine adjustment to head loss resulting from chemical effects, including the SLCS injection, with plant debris.
Continued on Sheet A-3


Continued from Sheet A-2
Can credit be taken for containment overpressure for LOCA analysis?
Yes
No
Calculate containment overpressure.
Determine the NPSH for the ECCS pumps at the highest suppression pool temperature and at a temperature (~140°F) where chemical precipitates form?
Is the strainer debris head loss less than the ECCS pump NPSH at 1) the highest suppression pool temperature/flow and at 2) the temperature/flow where chemical precipitates form?
No
Review all assumptions and added margins to determine if additional tests or analyses shall be performed to reduce debris bed head loss.
Yes
Perform additional analyses and tests.
Document all tests and analyses.
Return to beginning of this flow chart.

Appendix B

Safety Communication on GE Strainer Head Loss Correlation

The GE strainer head loss correlation documented in Licensing Topical Report, "Application Methodology for the General Electric Stacked Disk ECCS Suction Strainer", NEDC-32721P-A is based on a series of strainer tests with a full-scale GE stacked-disk prototype strainer. The tests were performed at the former EPRI test facility in Charlotte, NC and used different debris bed compositions and flow rates. There were a total of 44 tests.

About one-third of the tests contained RMI debris and the results of these tests with RMI debris were not used in developing the empirical GE strainer head loss correlation as RMI debris can reduce the head loss of a mixed debris bed. A separate head loss correlation for RMI debris is used by GE when there is RMI debris present in the debris bed, and this RMI debris head loss is compared to the correlation head loss for the mixed debris without RMI, and the higher of the two head loss estimates is used.

The GE strainer head loss correlation developed from the test results represents the head loss on the GE optimized stacked-disk strainer for the given flow rate, water temperature and sludge and fiber debris quantities, and uses four multiplied factors of physical significance. The additional head loss from other debris types such as paint, rust, and dirt are represented in the form of a bump-up factor applied to the calculated head loss in accordance with the URG.

While working on developing strainers for non-US BWRs, some GEH engineers discovered that because the GE BWR strainer head loss correlation uses factors that are multiplied together to determine the head loss, there could be other correlations that would fit the test data but with differing factor values. During their review, it was also noted that the head loss for some tests had not completely stabilized.

To further understand these concerns, GEH removed the test data where head loss may not have stabilized and used a multivariate regression analyses of the test data to develop a revised strainer head loss correlation for US BWRs. Two new head loss correlations were developed – one for GE strainers where all of the debris is between the disks and another for those GE strainers where the debris fills the disk interstitial volume and accumulates on the outside of the strainer. The two correlations provide equivalent predictions for the case where the disk interstitial volume is just filled.

GEH communicated the results of these revised strainer head loss evaluations in a Safety Communication [SC 08-02, BWR Suction Strainer Head Loss, February 15, 2008] to domestic BWR licensees with GE strainers. The strainer head loss evaluations performed for the Safety Communication indicated that for ten of the thirteen BWR licensees with GE strainers, the strainer head losses were essentially the same or slightly less for both the Residual Heat Removal (RHR) and Core Spray (CS) strainers. For two licensees, higher strainer head losses were predicted for either the CS or RHR strainers and these increased head losses were within the original safety margins, while the strainers for the other system had increased safety margin.

For one licensee the head loss for both the RHR and CS strainers increased and that licensee modified plant operating conditions to increase available NPSH for the ECCS pumps.

For one BWR licensee who had a recent change from their original design basis debris load, GEH used the test data from the LTR tests where the strainer head loss had stabilized and developed modified coefficients for the factors used in the LTR correlation. GEH determined that this revised correlation was more conservative than both the original LTR correlation and the SC08-02 regression analysis correlation for the plant conditions being evaluated.

ENCLOSURE 3

Affidavit Requesting Withholding of Enclosure 1, dated October 31, 2013

BWR Owners' Group (BWROG)
AFFIDAVIT

I, **Frederick P. Schiffley, II**, state as follows:

(1) I am the elected Chairman of the BWR Owners' Group (BWROG), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding. This action is taken on behalf of the US Utility Members that financially participated (reference table below) in the development of information described in paragraph (2) (hereinafter referred to as "BWROG"):

Constellation Energy Nuclear Group – Nine Mile Point Units 1 & 2
Detroit Edison Company – Fermi Unit 2
Duke Energy Progress– Brunswick Units 1 & 2
Energy Northwest – Columbia
Entergy Nuclear – FitzPatrick, Pilgrim Unit 1, Vermont Yankee, River Bend Unit 1 and Grand Gulf Unit 1
Exelon – Clinton, Dresden Units 2 & 3, Quad Cities Units 1 & 2, LaSalle Units 1 and 2, Limerick Units 1 & 2, Peach Bottom Units 2 & 3 and Oyster Creek Units 1 & 2
FirstEnergy Corporation – Perry Unit 1
Nebraska Public Power District – Cooper
NextEra Energy – Duane Arnold
PPL Susquehanna LLC – Susquehanna Units 1 & 2
PSEG Nuclear – Hope Creek Unit 1
Southern Nuclear Operating Company, Inc. – Hatch Units 1 & 2
Tennessee Valley Authority – Browns Ferry Units 1, 2 & 3
Xcel Energy – Monticello

(2) The information sought to be withheld is contained in BWR Owners' Group (BWROG) Report, BWROG-ECCS-WP-3-1, Summary of Member Responses to BWROG Survey on Strainer Head Loss and Near-Field Effects, October 31, 2013. The proprietary information in said document is identified by [[dotted underline inside double square brackets {3}]]. Figures and other large objects are identified with double square brackets before and after the object. In all cases, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, BWROG relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively,

Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

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

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

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

c. Information that reveals aspects of past, present, or future BWROG customer-funded development plans and programs, resulting in potential products to BWROG;

d. Information that discloses potentially patentable subject matter for which it may be desirable to obtain patent protection.

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

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to BWROG. Access to such documents within BWROG is limited to a "need to know" basis.

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

(8) The information identified in paragraph (2) is classified as proprietary because it contains detailed results of analytical models, methods and processes, including

computer codes, which BWROG has developed, and applied to perform licensing and design evaluations for BWR plants.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major BWROG asset.

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

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

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

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 31st day of October 2013.

Frederick P. Schiffley, II
Chairman
BWR Owners' Group (BWROG)