December 5, 2006

MEMORANDUM TO: Michele G. Evans, Director
Division of Component Integrity

Patrick L. Hiland, Director
Division of Engineering

FROM: Thomas O. Martin, Director ***/RA/***
Division of Safety Systems

SUBJECT: AUDIT PLAN FOR VERIFYING THE ADEQUACY OF LICENSEE RESPONSES TO GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"

This memorandum transmits the staff's plan for auditing a sample of licensee responses to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," as part of the effort to resolve potential safety concerns identified in Generic Safety Issue (GSI) 191, "Assessment of Debris Accumulation on Pressurized-Water Reactor (PWR) Sump Performance."

In GL 2004-02, the staff requested licensees to perform a mechanistic evaluation of the potential for post-accident debris blockage and operation with debris-laden fluids to impede or prevent the recirculation functions of the emergency core cooling system (ECCS) and containment spray system (CSS). The GL requested that licensees submit to the Nuclear Regulatory Commission by September 1, 2005, the results of their analyses and their intended actions to resolve this issue. In addition to reviewing licensee responses to the GL, the staff is conducting detailed audits of licensee corrective actions across a sample of licensees intended to be reasonably representative of the spectrum of reactor designs, as well as of the types of replacement strainers being designed and installed to address the GL. The staff expects to conduct about 12 audits before March 30, 2008. Site visits for three of the 12 have been performed using a draft version of this audit plan.

This audit plan was developed in consultation with your staffs, and they have agreed to support the audits in the areas identified in Table 1 of the enclosure. Please contact me at (301) 415-0467 if you have any concerns regarding your divisions' capability to support the audits as described in the enclosure.

Enclosure: As stated

CONTACT: M. Scott, SSIB/DSS/NRR
415-0565

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Enclosure: As stated

DISTRIBUTION: ADAMS DCullison MScott JGrobe AHiser SLee

ADAMS Accession #ML062370100 NRR-106

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AUDIT PLAN

Adequacy of Licensee Responses to NRC Generic Letter 04-02

Applicability: This audit plan applies to all holders of operating licenses for pressurized-water reactors whose plants are selected by the staff for audit.

Objective: To review selected licensees' actions taken in response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors." Specifically, the staff will:

1. assess the adequacy of licensee responses to the generic letter,
2. assess the adequacy of licensee corrective actions (if any),
3. identify if additional evaluation of licensee resolutions through the NRC inspection program is necessary, and
4. if additional inspection effort is needed, identify areas to be inspected and guidance needed to support inspection effort (i.e., a Temporary Instruction).

Audit Site Selection**:** The staff will select plants for audit based on the following criteria:

1. a representative sampling of contractors and vendors,
2. a representative sampling of containment designs,
3. sites using passive and active strainers (if applicable),
4. sites using the standard and alternative evaluation methodologies (if applicable),
5. a representative sampling of licensees, and
6. a representative sampling of sites from different Regions.

Audit Requirements: The following analyses and programs will be included in the audit scope:

1. the licensee's 10 CFR 50.59 safety evaluations (if performed),
2. the licensee's containment walkdown surveillance,
3. the licensee's plant-specific analyses performed in response to GL 2004-02,
4. the licensee's ongoing containment cleanliness program, and
5. the licensee's planned modifications and corrective actions to address GL 2004-02

Audit Guidance

1. Guidance

    a. Licensee's 50.59 safety evaluation

        Purpose: To perform a technical review to verify that implementation of any modification or other corrective action did not create new safety concerns (e.g., hydrodynamic loads), as well as to verify that the licensee's safety evaluation is sufficiently comprehensive to ensure that no additional safety concerns were caused by the licensee's resolution of this issue.

ENCLOSURE

The auditor will review the licensee's 10 CFR 50.59 safety evaluations performed in response to its GL 04-02 resolution to assess the:

- adequacy of scope of resolution (e.g., is change only required to low pressure emergency core cooling system (ECCS) pumps)
- potential for new failures not previously evaluated being created by the resolution
- potential for an increase in the probability of a failure previously evaluated

The auditor will perform a technical review of the 10 CFR 50.59 safety evaluation to confirm that the licensee's resolution adequately addressed the potential impacts of any modifications or other corrective actions on plant safety. The auditor needs to take into account during the review that licensees may be operating their plants with new sump screens installed and a licensing basis that has not been updated to reflect analyses performed in response to GL 2004-02. In this case, the auditor verifies that the licensee has appropriately determined compliance of the new design with the existing licensing basis.

b. Plant-specific containment walkdown surveillance

Purpose: Evaluate the adequacy of any containment walkdown surveillances performed in support of the plant-specific analysis.

The auditor will review the licensee's containment walkdown surveillance methodology and results to assess the adequacy of the surveillance to:

- identify debris sources
- identify conditions in containment that would impact the flow of water to the containment sump

c. Plant-specific analyses performed in response to GL 2004-02

Purpose: Evaluate plant-specific application of an NRC-approved methodology in plant analyses to determine the potential for the adverse effects of post-accident debris blockage and operation with debris-laden fluids to impede or prevent the recirculation functions of the ECCS and containment spray system (CSS).

The auditor will review the licensee's plant-specific sump performance analyses:

- to assess the overall application of the NRC-approved methodology to the plant
- to confirm appropriately consistent application of the NRC-approved methodology, understanding that each plant's application will depend on plant-specific conditions
- to evaluate licensee analyses of areas where the NRC-approved methodology does not provide detailed guidance (e.g., evaluation of chemical effects)
- to assess the adequacy of the licensee's basis for determining its strainer head loss
- to assess the adequacy of the licensee's basis for calculation of its net positive suction head (NPSH) margin
- to assess the licensee's evaluation of upstream and downstream effects

Limited confirmatory calculations will be performed, as necessary, to confirm consistency in the application of the guidance methodologies and technical acceptability. Examples could be: headloss and computational fluid dynamic calculations.

d. Ongoing containment cleanliness program

Purpose: To confirm that the licensee's program to ensure appropriate levels of containment cleanliness is adequate to ensure operability of the ECCS.

The auditor will review the licensee's containment cleanliness program to confirm the licensee has established an adequate containment cleaning program including:

- procedures to evaluate cleanliness
- criteria for cleaning containment
- frequency of containment evaluation and cleaning
- basis for cleaning frequency and criteria
- adequate administrative controls on the program (e.g., included in the plant maintenance program)

e. Planned modifications and corrective actions

Purpose: To confirm the adequacy of any modifications and other corrective actions.

The auditor will review the licensee's analyses to confirm that:

- modifications are adequately designed (e.g., compliant with applicable regulations, codes, etc.)
- corrective actions (e.g., programmatic changes, operator training) other than modifications are sufficient to address the underlying issue.

2. Supplemental guidance

Table 1 identifies key audit review areas and identifies the division or branch responsible for the review area.

Attachment 1 to this audit plan provides additional guidance on the specific information which will be evaluated by the auditors. The auditors will review plant drawings, calculations, strainer specifications, and other design documentation, as appropriate.

Reporting Requirements: The results of this audit will be documented in a report. The report will receive the concurrence of the Director, Division of Safety Systems, NRR. A copy of the report will be forwarded to the Project Manager for the audited plant. Issues not resolved by the end of the audit period will be documented in the report. These open items will be closed out during the staff review of the licensee's supplement to the Generic Letter response/response to requests for information discussed in the letter from C. Haney to specific PWR license holders, dated March 28, 2006 (ML0608702740.)

Completion Schedule: These audits should be completed by June 30, 2008.

Contact: Questions regarding this audit plan should be directed to Dave Cullison at 301-415-1212.

Statistical Data Reporting: Hours expended for this audit, including preparation time, should be reported under the plant-specific TAC number for GL 2002-04 followup.

Organization Responsibility: This audit plan was initiated by the Safety Issue Resolution Branch (SSIB).

Resource Estimate: It is estimated that each audit will require approximately 600 hours (60 hours per auditor), with 10 NRR representatives (employees and contractor personnel) and one Regional inspector on each audit. The staff estimates approximately 40 hours at each audit site or in-house review with another 20 hours of preparation, documentation, and offsite review.

Conduct of Audit (all timeframes are approximate):

1. Six months prior to the start of the audit

    a. Chief, Safety Issue Resolution Branch selects the team leader for the audit from the SSIB staff.
    b. Team Leader informs the affected plant NRC Project Manager and Region of the tentative plans and schedule for the upcoming audit.

2. Three months prior to the start of the audit

    a. Team Leader contacts the plant to be audited through the NRC Project Manager (PM).
        i. Ascertains the status of the licensee's analyses and corrective actions
        ii. Negotiates:
            (1) the submittal of documents needed for the audit
            (2) the dates of the onsite portions of the audit
            (3) presentations by the licensee (as desired by the Team Leader and the licensee)
        iii. Based on information provided by licensee, decides what areas will be reviewed during the audit
        iv. Informs the Region of finalized intention

    b. Team Leader selects team members and submits list to Chief, Safety Issue Resolution Branch for approval.

3. Six weeks prior to the start of the audit

    a. Team members identify documents/information needed for review.

4. One month prior to the start of the audit

a. Team leader sends request for documents/information to licensee via PM (Note: The Team leader should request that the information be provided in a format that allows an auditor to easily find the information relevant to their review area.)

b. Team members make travel plans for onsite visit.

5. Start of in-house review period (2-3 weeks prior to onsite visit.)

   a. Team leader meets with team and provides instructions on conduct of audit.
   b. Team members review licensee documents and develop audit plans for onsite portion of the audit.
   c. Team members provide team leader a list of documents that need to be available onsite.
   d. Team members identify any individuals they will need to interview while onsite.

6. First onsite visit

   a. Team members will normally travel to the site on Monday and return to NRC at the completion of their onsite work. The Team Leader will make arrangements for the team to be badged at the site (as necessary) and notify team of badging requirements.
   b. Team holds entrance meeting with site personnel.
   c. Team members meet as directed by the Team Leader.
   d. Team holds exit meeting with site personnel as determined appropriate by Team Leader.

7. In-house week

   a. Team members review information gathered while onsite, determine what areas still need to be reviewed, and provide team leader audit plan and list of personnel to be interviewed.

8. Second onsite visit (if required)

   a. Team members will normally travel to the site on Monday and return to NRC at the completion of their onsite work. If badging is required, team members not previously badged should make their travel arrangements so as to be able to be badged on Monday.
   b. By the middle of the week, team members should provide the Team Leader a list of findings and potential open items.
   c. Team holds exit meeting with site personnel and discusses any findings and potential open items. This meeting may address first and second onsite visits as appropriate.

9. First week after completion of visit(s)

   a. Team members draft report input and provide to Team Leader by close of business that Friday. Draft input will be in the format requested by the Team Leader.

10. Second and third week after second onsite visit

    a. Team leader drafts audit report.
    b. Team leader briefs DSS and DCI management on audit results.

Training: No specific training requirements are associated with this audit.

References

1. Generic Letter 04-02, " Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-water Reactors," September 2004 (accession number ML042360586).

2. NRC Bulletin 03-01, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors," June 9, 2003.

3. NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated May 11, 1993.

4. NRC Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated February 18, 1994.

5. NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris" dated October 1995.

6. NRC Bulletin 95-02, "Unexpected Clogging of Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," dated October 17, 1995.

7. Regulatory Guide 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," dated November 2003.

8. NRC Generic Letter 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," dated October 7, 1997.

9. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," dated December 6, 2004.

10. Letter from A. R. Pietrangelo, NEI to J. H. Hannon, USNRC, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Nuclear Energy Institute, (proposed document number NEI 04-07) dated May 28, 2004.

11. NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," dated December 15, 2004.

Table 1. GSI-191 September 2005 Response/Audit Areas for Review	
Review Area	Responsible Branch
GL 2004-02	SSIB
SE Sections and Appendixes:	
2. REGULATORY EVALUATION	SSIB
3. BASELINE EVALUATION	
3.3 BREAK SELECTION	SSIB
3.4 DEBRIS GENERATION	
3.4.2 Zone of Influence	CSGB/SSIB
- Coatings	CSGB
- Non-Coatings	SSIB
3.4.3 Quantification of Debris Characteristics	SSIB
- Coatings	CSGB
- Non-Coatings	SSIB
Appendix I. ZOI Size: Break Jet Pressure Evaluation	SSIB
Appendix II. Debris Size Distributions	SSIB
3.5 LATENT DEBRIS	SSIB
Appendix VII. Latent Debris	SSIB
3.6 DEBRIS TRANSPORT	SSIB
Appendix III. CFD Pool Transport	SSIB
Appendix IV. Debris Transport Comparison	SSIB
Appendix VI. Blowdown/Washdown Debris Transport Analysis	SSIB
3.7 HEAD LOSS	SSIB
- Available	SSIB
- Required	CPTB
Appendix V. Confirmatory Head Loss Analysis	SSIB
Appendix VIII. Thin-Bed	SSIB
3.8 Acceptance of NEI Baseline Guidance	All
4. ANALYTICAL REFINEMENTS	
4.2 METHOD DESCRIPTION	SSIB
4.2.1 Break Selection	SSIB
CPTB support needed if licensee uses MEB 3-1	
4.2.2 Debris Generation	CSGB/SSIB
- Coatings	CSGB
- Non-Coatings	SSIB
4.2.3 Latent Debris	SSIB
4.2.4 Debris Transport	SSIB
4.2.5 Head Loss	SSIB
- Available	SSIB
- Required	CPTB
5. DESIGN AND ADMINISTRATIVE CONTROL REFINEMENTS	
5.1 DEBRIS SOURCE TERM	SSIB
5.2 DEBRIS TRANSPORT CHARACTERISTICS	SSIB
5.3 SCREEN MODIFICATION	SSIB
6. ALTERNATE EVALUATION	SSIB
SSIB is the lead with CPTB support as necessary	

Review Area	Responsible Branch
7. ADDITIONAL DESIGN CONSIDERATIONS	
7.1 SUMP STRUCTURAL ANALYSIS	EGCA
7.2 UPSTREAM EFFECTS	SSIB
7.3 DOWNSTREAM EFFECTS	CPTB/CSGB/SSIB
SSIB to provide systems input to CPTB SSIB responsible for downstream effects related to fuel	
7.4 CHEMICAL EFFECTS	CSGB

Note: Lead Reviewers from the Responsible Division are responsible for obtaining assistance from other Divisions/Branches as necessary to complete the review of an area.

Audit Elements

Introduction

These audit elements are provided strictly as a guide to assist auditors in their evaluation. The list of elements is not considered to be all-inclusive. Unless otherwise noted, the element numbers correspond to the applicable section in the Nuclear Energy Institute (NEI) Guidance Report (GR) (reference 11) and associated staff safety evaluation (SE) (NEI 04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, Volumes 1 and 2) (reference 9). Auditors of the sections of the GR and SE without specific guidance in the elements listed below will be using those sections of the GR and SE as guidance for performing the audit. All licensees, with the exception of Davis Besse, have stated that they used the methodology in the GR and the staff's SE. Davis Besse stated that it used Regulatory Guide 1.82, Revision 3.

All the elements listed below may or may not be used during every audit.

1. Section 2 - Regulatory Evaluation

   Use Section 2 of the GR (reference 11) and the SE (reference 9) as a reference for reviewing this area.

2. Break Selection

   a. Section 3.3

      i. Review a summary of results (preferably in a tabular format) which demonstrates that a systematic approach was applied to identify the limiting break location, and that a full range of break locations was considered. Information should identify all break locations considered, and include technical basis for any break locations where all phases of the analysis (i.e. debris generation, transport, accumulation, and head loss) were not performed. (Identify where engineering judgement was applied to conclude that a certain break location is bounded by another break location). Such a summary table ideally would include quantitative results from all phases of the accident (debris generation, transport, accumulation, and head loss).

      ii. Secondary side break locations should be evaluated as required by the methodology. Review information to confirm that the break selection methodology applied is consistent with that for loss-of-coolant accident (LOCA) piping.

   b. Section 4.2.1 - Break Selection Refinement. Use Section 4.2.1 of the GR (reference 11) and the SE (reference 9) as additional guides for reviewing break selections if the licensee uses any of the GR-proposed refinements.

3. Debris Generation

   a. General

      i. Review the application of GR Section 3.4 guidance and the SE guidance for the determination of LOCA-generated debris quantities for each type of insulation, fire barrier, and miscellaneous material in containment including:

         (1) the identification of materials in containment,
         (2) the specification of the minimum destruction pressure used to size the spherical zone of influence (ZOI), which includes the cautionary 40% reduction to account for undetermined two-phase effects unless the licensee has conducted two-phase testing or otherwise justified the destruction pressure,
         (3) the specification of the ZOI radius based on conservative recommended values,
         (4) the application of robust barriers (e.g., what credit has been taken for the shielding effect of robust barriers), and
         (5) the determination of the volumes of debris source materials within the ZOI.

      ii. Review the application of Section 3.4 guidance for the determination of LOCA-generated debris quantities for coating materials in containment, based on plant-specific data for area and thickness, including:

         (1) The quantities of all coatings within a ZOI of 10D (i.e., a factor of 10 times the pipe diameter) unless a different ZOI is determined and justified appropriately.

         (2) The quantities of all unqualified and degraded qualified coatings within containment.

      iii. Review licensee debris size distributions to ensure agreement with GR baseline guidance as specified in GR Table 3-3 and supplemental guidance provided in the SE. Coatings debris will be considered to be 10 μm particles as specified in the SE.

      iv. If the licensee substantiates that a thin bed of debris cannot form to filter the particles, the staff review will verify that the coating debris and other particulate debris that would be considered too fine for filtration without a thin bed of fibrous debris is sized based on plant-specific analyses.

      v. Review the appropriateness of the physical properties assigned to the respective debris components, which should be insulation-specific if possible (Section 8).

   b. Section 4.2.2 Debris Generation

      i. Review analytical refinements to the debris generation methodology provided in the GR baseline guidance for both coating and non-coatings debris.

         (1) Alternative methods to the baseline methodology spherical ZOI, such as a direct jet impingement model, will be reviewed to ensure the debris generation estimates remain conservative.

(2) The review will ensure that worst-case alternate jet directions were determined if a direct jet impingement model was used.

ii. Review material destruction pressures used to size material-specific ZOIs. If jacket-seam-oriented destruction pressures are used in conjunction with a direct jet impingement model, the review will ensure that the seam-oriented destruction pressures are suitable based on experimental debris generation data.

iii. Review the debris size distributions to ensure the size distributions are conservative (based on experimental debris generation data) and in agreement with the debris transport methodology. (Baseline two-size-group debris size distributions were based on the baseline debris transport methodology.)

4. Zone of Influence

a. Section 3.4.2 Zone of Influence - Coatings

i. If the identified size of the coating ZOI is different than default value in the methodology, assess the technical justification. This justification may include testing; testing should correlate to the plant conditions experienced during postulated event including temperature, delta T, pressure, pressure shock, and erosion effects.

ii. The ZOI may be different for different coating materials, i.e., epoxy, inorganic zinc (based upon initial industry testing). The licensee should use the appropriate ZOI for a given material. The size of the material-specific ZOI should be supported by test data.

iii. The assessment for coatings inside the ZOI should identify the types, thickness and amounts of coatings.

iv. An assessment should identify if coatings exist on components under insulation. If so, the coating type should be identified and the incorporation of debris considered.

b. Zone of Influence - Non-Coatings

i. The zone of influence review is coordinated with the section 3.4 review of debris generation discussed in paragraph 2 above.

ii. The review should examine any plant-specific determinations of ZOIs to ensure the determinations are conservative and consistent with the GR approach.

iii. If alternate ZOI approaches are used, consider the overall conservatism of the approach taken.

iv. Review any plant-specific testing or analyses which support determinations of ZOIs for materials that were not provided in the GR/SE.

5. Quantification of Debris Characteristics

   a. Section 3.4.3 Quantify Debris Characteristics - Coatings

      i. Review the plant assessment of containment coatings and the coating program. Determine when the last assessment was performed and how frequently assessments are performed.

      ii. Review the condition of coating types identified and extent of maintenance performed.

      iii. Review the types of coatings identified and the amounts of unqualified and degraded qualified coatings scheduled for repair.

      iv. If degraded qualified coatings exist, the plant assessment should include methods to assess the presence of degradation, methods to assess the extent of degradation, and methods to estimate the amount of additional degradation that may occur during ensuing operating cycles (may need to have multiple condition assessments to determine).

      v. Review the location of qualified, degraded, and/or unqualified coatings. If the licensee is using specific failure modes for different coatings, the type of coating may need to be identified (i.e., epoxy, inorganic zinc, alkyd, etc.).

      vi. Review the thickness of coating types identified or assumed and bases for the thicknesses determined.

      vii. If debris is considered to exist as chips and/or flakes outside the ZOI, review the appropriate bases and size distribution (similar review is expected for debris inside the ZOI if not using particulate)

      viii. Review the physical data provided regarding coatings (i.e., density, specific gravity).

         (1) Review the bases for the transport characteristics of coating debris.

         (2) If no thin bed is substantiated or assumed, review the technical basis for coatings debris size distribution (chip size).

   b. 3.4.3 Quantify Debris Characteristics - Non-Coatings

      Use Section 3.4.3 of the GR (reference 11) and the SE (reference 9) as additional guides for reviewing this area.

6. Latent Debris

   a. Section 3.5 Latent Debris

      I. Review licensee latent debris estimates to ensure agreement with GR baseline guidance as specified in GR Section 3.5 and supplemental guidance provided in the SE.

(1) Check the sampling program used for collection and estimation of amounts of latent debris. Verify the scope and rigor are consistent (does not necessarily have to be identical) with instructions in SE.

(2) Verify latent debris characterization is consistent with, or conservative with respect to specifications in the SE.

(3) Check for sump screen performance sensitivity to amounts and types of latent debris.

(4) Back calculate the potential for the formation of a thinbed from latent debris fiber only. Compare this potential to the overall evaluation of the sump screen performance.

b. Section 4.2.3 Latent Debris

Use Section 4.2.3 of the GR (reference 11) and the SE (reference 9) as additional guides for reviewing latent debris if the licensee uses any of the GR-proposed refinements.

7. Debris Transport

a. Section 3.6 Debris Transport

i. Review licensee debris transport estimates to ensure agreement with GR baseline guidance as specified in GR Section 3.6 and supplemental guidance provided in the SE.

ii. Review predicted pool flow velocities relative to characteristic debris transport velocities to determine whether or not the transport of large-piece debris can be neglected as assumed in the GR baseline guidance.

(1) If the licensee determined that large debris transport could be substantial, then the transport analysis for large debris must also be reviewed per the GR supplemental guidance in Section 4.2.4.

iii. Review the estimate for debris trapped in inactive pools to ensure the limit of 15% imposed in SE Section 8 is not exceeded.

b. Section 4.2.4 Debris Transport

i. Review the debris transport analyses to ensure conservative estimates for debris transport to the sump screen, which includes the following primary analytical aspects:

(1) Review the blowdown/washdown debris transport to determine the quantities of debris estimated to remain trapped in the upper levels of containment. This analysis should also indicate the quantities and locations of debris deposited onto the sump floor prior to the establishment of the sump pool; the potential for erosion of debris by the containment sprays and spray drainage; and the location distribution of debris entering the sump pool along with the containment spray drainage flows.

(2) Review the transport of debris within the sump as water fills the sump to establish the sump pool. Debris initially deposited onto the floor during the blowdown phase can become redistributed by the sheeting flow as water spreads across the floor. During this phase quantities of debris can transport into inactive regions of the sump pool (e.g., the reactor cavity) where the debris likely remains.

(3) Review the transport of debris within an established sump pool where water is drawn from the sump pool by the recirculation pumps. Debris enters the established pool with the drainage of the containment sprays into the pool. This analysis involves the estimation of detailed localized pool flow velocities to determine localized debris transport that must be integrated into a pool debris transport model. This analysis may include debris entrapment within the pool due to obstructions.

ii. Review the potential for debris to erode into finer debris within the sump pool due to pulsations from water turbulence (refer to GR SE Appendix III.3.3.3).

iii. Review the accumulation of debris on the sump screens.

c. Section 5.2 Debris Transport Characteristics

i. General guidance for considerations to be used when performing an analysis of engineered debris transport obstructions is contained in Section 5.2 of the staff SE and NEI GR.

ii. General items identified for consideration include (1) verifying transport obstruction can trap and hold the qualified debris load at rated flow rates, (2) reviewing for geometry concerns, (3) determining whether construction material is capable of withstanding the post-accident environment, and (4) determining whether obstruction can perform its function following hydrodynamic loads from a seismic event.

iii. Verify that the overall screen design/debris transport analysis does not assume the debris transport obstruction will withhold a larger amount, or different debris characterization, than the obstruction design will provide.

iv. Debris transport obstructions may be required to withstand loads from break-jet impingement as required by plant specific licensing basis. If so, verify analysis demonstrates the obstructions' adequacy.

8. Head Loss

a. Section 3.7 Head Loss

i. Review the specification of the maximum emergency core cooling system (ECCS) flow rate used to calculate the head loss across the sump screens.

ii. Review the determination of minimum water level with regard to sump screen submergence, which affects both the water approach velocity and the minimum available net positive suction head (NPSH) margin.

iii. Review the determination of water temperature used to determine the viscosity used in the head loss calculations.

iv. Review debris-specific parameters (i.e., densities and surface areas) for each type of debris used in the head loss calculations.

v. Review the methods used to estimate properties for mixtures of debris from the properties of the individual components.

vi. Review the applicability of head loss data used to validate the application of head loss correlations and head loss estimates.

vii. Review the validity of the application of the NUREG/CR-6224 correlation or any alternate correlations for specific types of insulation and particulate debris with regard to the correlation validation for application debris compositions over application temperature and velocity ranges.

viii. Review any determination that a thin bed of fibrous debris cannot form to ensure that the parameters used to perform that determination are sufficiently conservative to compensate for uncertainties associated with that determination. If calcium silicate or other particulate insulations are present in the debris bed, review the determination of whether or not a debris bed can form without sufficient fibrous debris present to form a debris thin bed.

ix. Review the treatment of buoyant debris accumulation on the sump screen with regard to whether or not this debris can contribute to head loss.

x. This area of the review can be divided into two categories. If the licensee uses the NUREG/CR-6224 correlation to design their sump, staff can focus on the application range and limits of the NUREG/CR-6224 correlation and examine the detailed application process. If the licensee uses plant-specific test or data to design its sump, the staff needs to review the licensee's testing plan, test facility and the test data processing. The check list is provided below:

(1) Category One: Sump Design Performed Using NUREG/CR-6224 Correlation

(a) Verify the following items according to SE Section 3.7, Appendix V and VIII.

(i) Sump temperature assumption
(ii) Sump geometry assumption
(iii) Water level history
(iv) Approaching velocity and pool dynamics
(v) Debris type and characterization
(vi) De-aeration calculation
(vii) Sv, two coefficients selection
(viii) Bounding case selection considering the thin-bed effect
(ix) The assumption of the blocked area and non-uniform debris distribution (open sump screen only)

(b) Category Two: Sump Design Performed Using Plant/Vendor-Specific Test Data

(i) The test facility needs to be audited following 10 CFR 50 Appendix B QA requirements:

1) Test plan and matrix
2) QA procedure
3) Test data processing
4) Scaling Analysis
5) Correlation development
6) Test apparatus and measurement equipment

(ii) Perform confirmatory analysis to verify the licensee's head loss prediction.

(c) Computational Fluid Dynamics (CFD) Model Review. CFD may have been extensively used in the licensee's submittal to calculate the transport and pool dynamics. Although CFD codes may be mature enough for single-phase flow, the detailed modeling techniques need to be reviewed to ensure the proper nodalization and calculation procedures were used.

b. Section 4.2.5 Head Loss

i. Review any additional refinements to the estimation of debris bed head loss not covered in Section 3.7.

9. Section 3.8 Acceptance of NEI Baseline Guidance

a. Determine the acceptance of the licensee submittal based on GR Section 3 baseline guidance in conjunction with corresponding supplemental SE guidance and SE-specified conditions and limitations outlined in Section 8.

10. Alternate Evaluation - Section 6

a. Review the application of the alternate break size and determination of single- vs. double-sided breaks to ensure correct application of the methodology.

b. Review the application of credit for existing piping restraints and supports, or other plant structural members that can be shown through analysis to limit pipe movement.

c. Review application of the ZOI for partial breaks in the reactor coolant system (RCS) main loop piping for Region I breaks (these would not be double-ended guillotine breaks).

d. Assess the adequacy of computer codes and analytical methods used for Region II analyses. These were not specifically identified in the NEI GR.

e. Review NPSH calculations with respect to use of realistic parameter values, timing of events, allowed credit for containment accident pressure, and other realistic assumptions.

f. Review analyses (both Region I and II) to confirm that acceptance criteria are satisfied (adequate core and containment cooling).

g. Review risk-informed analyses used to justify operator actions or screen modifications to ensure that the licensee's estimate of sump capability reliability considers the appropriate factors and to ensure that the licensee properly addresses performance monitoring.

h. Review any 10 CFR 50.59 evaluations which conclude that licensing actions (license amendment requests or exemptions) are not needed to support application of the Section 6 methodology.

11. Sump Design

a. Section 5.3 - Screen Modifications

i. Review design features of any new screen designs to ensure that the design can accommodate the maximum volume of debris that is predicted to arrive at the screen, given the full consideration of debris generation, transport and any mitigating factors that may be in place (e.g., curbing).

ii. Review design features of any new screen designs to ensure that the design addresses the possibility of thin-bed formation.

b. Section 7.1, Sump Structural Analysis

i. General guidance for considerations to be used when performing a structural analysis of the containment sump screen is contained in Section 7.1 of the NEI GR (Reference 66) and the approved staff SE.

ii. General items identified for consideration include verifying (1) maximum differential pressure caused by combined clean screen and maximum debris load at rated flow rates, (2) geometry concerns, (3) sump screen material selection for the post accident environment, and (4) the addition of hydrodynamic loads from a seismic event.

iii. Dynamic loads imposed on the related sump screen related structures due to break-jet impingement should be evaluated on a case-by-case basis as requirements are determined by the plant-specific licensing basis.

12. Upstream Effects

a. Section 7.2, Upstream Effects

i. Verify that the licensee has performed a review of the flow paths leading to the sump screen and has evaluated potential choke points.

ii. Verify the licensee has considered its plant-specific insulation and any unique geometric features of its containment.

iii. Verify that administrative controls are or will be in place to ensure the licensee evaluates the effect the future placement of curbs and debris racks intended to trap debris may have on the holdup of water.

13. Downstream Effects

a. Section 7.3, Downstream Effects: Industry guidance, WCAP 16406-P, is still undergoing staff evaluation. Interim staff review guidance follows:

i. Review the list of all components and flowpaths considered to determine the scope of the licensee's downstream evaluation (pumps, valves, instruments, and heat exchangers, etc).

ii. Review design and license mission times and system lineups to support mission-critical systems.

iii. Evaluate the vulnerability of the high-pressure safety injection (HPSI) throttle valves to clogging by determining the HPSI system's use (e.g., Is HPSI piggybacked to low-pressure safety injection (LPSI)? Or is it used for long-term boration control?) The time that the valves are exposed to debris is a significant factor in determining their vulnerability. Depending on plant design, some plants need to use the HPSI lineup to perform hot leg injection for boron precipitation control, and this may be needed for the remaining duration (i.e. 30 days) of the event. Some of these plants have the capability of using only the HPSI system, while others need to use the HPSI system piggy-backed with LPSI system. Some plants have the capability of performing hot-leg/vessel injection with the LPSI system alone, so problems with the HPSI system vulnerability to downstream effects is not applicable. Valve vulnerability to downstream effects is a function of valve design, system operation, and mission time.

iv. Assess whether the leakage through seals, etc., would increase local dose rates so that credited operator actions, if any, cannot be met.

v. Review all LOCA scenarios (i.e., small-break LOCA, medium-break LOCA, and large-break LOCA) to assess system operation. For a large-break LOCA or medium-break LOCA, some plants may not need and/or use the HPSI system.

vi. Review the licensee's evaluation of the extent of air entrainment. Licensee evaluation should include review of plant operating experience. Apart from vortexing, this involves ongoing questions about ECCS and incident report evaluation on the significance of ECCS gas intrusion.

vii. Review the characterization and properties of ECCS post-LOCA fluid (abrasiveness, solids content, and debris characterization).

viii. Review the materials of all wetted downstream surfaces (wear rings, pump internals, bearings, throttle valve plug, and seat materials).

ix. Review the opening sizes and running clearances in pumps and valves.

x. Review the list of system low points and low-flow areas.

xi. Review the range of fluid velocities within piping systems. What is the minimum velocity used to assess settling? What is the maximum velocity used to assess wear?

xii. Review the presence and evaluation of equipment strainers, cyclone separators, and other components.

xiii. Review the assessment of changes in system or equipment operation caused by wear (i.e., pump vibration and rotor dynamics). Assess whether the internal bypass flow increases, thereby decreasing performance or accelerating internal wear.

xiv. Assess whether the system, piping, or component flow resistance changed, altering flow balances.

xv. Assess whether the system piping vibration response changed for any of the above reasons.

xvi. Review the listing and evaluation of instrument tubing connections.

xvii. Review ECCS heat exchanger design to identify those with small (i.e., 3/8" or less) tubes and for which the ECCS is on the tube side. What are the clearances and the potential for fouling?

xviii. Review the evaluation of downstream effects on reactor fuel and in-vessel components. Technical evaluation instructions in this area are not complete. Issues that the staff expects to be addressed in the final analysis include:

(1) Volume of debris injected into the reactor vessel and core region
(2) Debris types and properties
(3) Contribution of in-vessel velocity profile to the formation of a debris bed or clog
(4) Fluid and metal component temperature impact
(5) Gravitational and temperature gradients
(6) Debris and boron precipitation effects
(7) ECCS Injection paths
(8) Core bypass design features
(9) Radiation and chemical considerations
(10) Debris adhesion to solid surfaces
(11) Thermodynamic properties of coolant

14. Chemical Effects

a. Section 7.4 - Chemical Effects: Several NUREGs currently under development will be used as references for the chemical effects reviews when finalized. Interim criteria follow:

i. Review the licensee’s overall chemical effects evaluation strategy including any countermeasures developed to mitigate potential chemical effects.

ii. Review the types and amounts of licensee's plant-specific materials (e.g., metals, insulation materials, etc). Verify that the licensee's estimated amount of materials has accounted for, when appropriate, contributions from sources such as scaffolding, metallic-based paints, insulation jacketing, etc.

iii. Review the licensee's projected sump pool conditions, including items such as the pH buffering agent, possible range of pool pH, and pool velocity.

iv. Review the licensee's assessment of plant specific-conditions (e.g., debris materials, sump pool) compared to the joint Electric Power Research Institute (EPRI)-NRC integrated chemical effects test (ICET) parameters.

v. Verify that the licensee has identified those plant-specific conditions not represented in ICET parameters. Review the licensee's technical justification (e.g., testing, analysis) for using the results from ICET in their plant-specific evaluation. Review any additional testing used as part of the licensee's plant-specific chemical effects evaluation.

vi. If future testing and analysis are needed to develop a plant-specific chemical effects evaluation technical basis, review the detailed test plan including schedule and milestones.

vii. Review the licensee's evaluation of potential integrated sump screen head loss consequences related to chemical effects. Review any head loss test conditions relative to the expected plant specific conditions.

viii. Verify the licensee has demonstrated sufficient NPSH margin to account for chemical effects during the entire recirculation mission time.

ix. Verify the licensee has considered potential downstream effects related to chemical by-product formation.

x. Verify licensee evaluations of early chemical effects account for higher sump pool temperatures (e.g., considers higher corrosion rates) during day 1 of a LOCA relative to the constant temperature ICET tests.