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U S Nuclear Regulatory Commission
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Prairie Island Nuclear Generating Plant Units 1 and 2
Dockets 50-282 and 50-306
License Nos. DPR-42 and DPR-60

Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for the Prairie Island Nuclear Generating Plant (TAC Nos. MC4707 and MC4708)

References:
1. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors", dated September 13, 2004, Accession Number ML042360586.
2. Nuclear Management Company, LLC (NMC) Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for the Prairie Island Nuclear Generating Plant, dated August 31, 2005, Accession Number ML052440054.
3. Request for Extension of Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for the Prairie Island Nuclear Generating Plant, dated December 5, 2007, Accession Number ML073400458.
4. NRC letter to NMC, "Generic Letter 2004-02 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors' Extension Request Approval for Prairie Island Units 1 and 2", dated December 21, 2007, Accession Number ML073520053.
5. Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, dated November 21, 2007, Accession Numbers ML073110269 and ML073110278.
6. NRC letter to the Nuclear Energy Institute (NEI), "Supplemental Licensee Responses to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Bases

Accidents at Pressurized-Water Reactors'", dated November 30, 2007, Accession Number ML073320176.

By letter dated September 13, 2004, the Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02 (Reference 1) which requested specific information be provided by September 1, 2005 and all actions for resolution of GL 2004-02 issues be completed by December 31, 2007. By letter dated August 31, 2005 (Reference 2), Nuclear Management Company, LLC (NMC) provided the specific information required by September 1, 2005 in response to GL 2004-02.

By letter dated December 5, 2007 (Reference 3), NMC requested an extension to March 31, 2008 for completion of the ex-vessel downstream effects analysis and in-vessel effects analysis for the Prairie Island Nuclear Generating Plant (PINGP). By letter dated December 21, 2007 (Reference 4), the NRC granted the extension.

In Reference 5, the NRC provided GL 2004-02 supplemental response guidance as follows:

> If a licensee cannot provide complete information as requested by this Content Guide by December 31, 2007 (e.g., the licensee has received an extension), that licensee should provide all relevant and available information by that date. Remaining information should be provided within 90 days of completion of all actions needed to address GL 2004-02.

In a letter to the Nuclear Energy Institute (Reference 6) the NRC authorized all pressurized water reactor licensees until February 29, 2008, to provide the supplemental responses to the NRC. In conformance with the guidance of References 5 and 6, the Enclosure to this letter provides all relevant and available information as requested by the Content Guide for resolution of GL 2004-02. As stipulated in the NMC request for extension, remaining information which addresses ex-vessel downstream effects and in-vessel effects will be provided by March 31, 2008.

If there are any questions or if additional information is needed, please contact Mr. Dale Vincent, P.E., at 651-388-1121.

Summary of Commitments

This letter contains no new commitments and no revisions to existing commitments.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on FEB 28 2008

Michael D. Wadley

Michael D. Wadley
Site Vice President, Prairie Island Nuclear Generating Plant Units 1 and 2
Nuclear Management Company, LLC

Enclosures (1)

cc: Administrator, Region III, USNRC
Project Manager, Prairie Island, USNRC
Resident Inspector, Prairie Island, USNRC

## ENCLOSURE

## GL 2004-02 Supplemental Response
## Prairie Island Nuclear Generating Plant

### INTRODUCTION

The purpose of this document is to provide the supplemental response to the Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02 (Reference 1) for the Prairie Island Nuclear Generating Plant (PINGP). PINGP is operated by the Nuclear Management Company, LLC (NMC). The initial NMC response to Reference 1 was provided in Reference 2. For PINGP, NMC has implemented an overall holistic resolution approach to resolve NRC Generic Safety Issue (GSI) 191 (Reference 1). The holistic approach includes:

- Implementation of design modifications to substantially increase the size of the containment sump screen (referred to as the containment sump strainer in this report). The new strainer is sized, with suitable margin, for the design bases debris loading and still assures that the resultant head loss is well within available margins.
- Procedural actions have been implemented to provide clear direction to the operations and technical support staff for monitoring post loss-of-coolant-accident (LOCA) long term recirculation operation. These procedures include directions for monitoring system performance and contingency actions in the event that indications warrant the need.
- The analyses that support the design modifications include several conservatisms to ensure that the overall analyses and modification design includes substantial conservatisms to account for uncertainties. NMC recognizes that uncertainties exist in various aspects of this issue and has taken more than adequate measures to accommodate these uncertainties.

Each of these aspects that make up the overall approach is described in more detail below.

The format used below for developing this supplemental response is based on that provided in NRC Letter to the Nuclear Energy Institute (NEI), “Revised Content Guide for Generic Letter 2004-02 Supplemental Responses,” (NRC Content Guide) dated November 21, 2007, Reference 3. PINGP was one of several plants that had the opportunity to be subject to an NRC audit of corrective actions for GL 2004-02. During the NRC audit, several open items were identified which are addressed in this supplemental response. Furthermore, during the NRC audit several areas or portions of areas were found to be acceptable. For areas or portions of areas found to be acceptable during the NRC audit, this supplemental response will briefly describe the approach taken in that area and the findings from the audit report. In addition, any changes that have been implemented subsequent to the audit are discussed. Attachment 1 to this Enclosure provides a table showing the ties between the NRC Content Guide section and the PINGP audit report section, noting any Open Items from the audit report and how the Open Item has been addressed.

## PLANT DESCRIPTION

PINGP Units 1 and 2 are Westinghouse two loop pressurized water reactors with similar containment arrangement for both units. The Emergency Core Cooling System (ECCS) is comprised of the Safety Injection (SI) and the Residual Heat Removal (RHR) systems. Figure 4 (provided near the back of this supplemental response) provides a simplified schematic of the ECCS. Following a LOCA, the SI and RHR pumps initially draw suction from the Refueling Water Storage Tank (RWST). The transfer to recirculation of the containment sump liquid is initiated after the liquid in the RWST reaches a set level prescribed in the Emergency Operating Procedures (EOPs). Recirculation of the liquid in the containment sump is only required following a LOCA. Containment Spray (CS) is not addressed in this evaluation because the Containment Spray System is not used during post-LOCA recirculation operation.

### Safety Injection System

The primary purpose of the SI system is to automatically deliver borated water to the Reactor Coolant System (RCS) in the event of a loss of coolant accident. This protection is afforded for all RCS pipe break sizes including a double ended pipe break.

The SI system consists of two redundant high head pumps. If, during recirculation operation, RCS pressure is above the RHR pump discharge pressure, the RHR pump(s) are aligned to provide suction to the SI pump(s) for high head recirculation.

The SI pumps discharge into both cold legs. Throttle valves are provided in the lines to balance the flow rates between the two injection lines to the RCS cold legs to ensure that adequate flow is provided to the intact cold leg should the other cold leg be ruptured. The design flow rate for the SI pumps is 700 gpm each and the runout flow rate for the SI pumps is 835 gpm each.

### Residual Heat Removal System

The RHR system serves dual functions. The normal function of the RHR system is to remove residual heat during reactor shutdown. During normal power operation the RHR system is aligned to perform the low head safety injection function. During post accident mitigation, the RHR system is used to inject borated water to the Reactor Coolant System through nozzles in the Reactor Vessel (upper plenum injection). The RHR system is also used to recirculate liquid from the containment sump to the reactor vessel or to the suction of the high head SI pumps.

The RHR system consists of two redundant low head pumps. During the injection phase of post-accident mitigation, the RHR pumps draw suction from the RWST. If post-accident RCS pressure is above the RHR Pump discharge pressure, the pumps would initially be discharging through the minimum flow bypass line during the injection phase, then to the suction of the SI pumps (“piggy-back” mode) during the recirculation phase of post-accident mitigation. The RHR system flow rates are:

- Design flow rate of each RHR pump is 2000 gpm;
- Runout flow rate of each RHR pump is 2600 gpm; and
- Maximum flow rate during recirculation of each train is approximately 2085 gpm (based on maximum pump performance and system hydraulics).

Containment Sump B is located in the basement elevation of containment to provide a water collection source for the suction of the RHR pumps. During recirculation, both RHR pumps can draw suction from Sump B. During a LOCA, Sump B will fill and a liquid level will be established on the basement floor. The height of the liquid level is a function of the size of the RCS break, that is, for the large break LOCA, a higher water level will be established due to injection of the SI Accumulators and voiding in the RCS. For a small break LOCA (depending on the RCS break size), the SI Accumulators may be isolated prior to injection and the RCS may remain full resulting in less liquid accumulation on the containment basement floor. However, for a small break LOCA, the RHR pump flow and associated net positive suction head (NPSH) requirements would be much less.

To provide bounding results, the analyses described below assume the minimum liquid water level in containment associated with a small break LOCA coupled with the runout flow rate for the RHR pumps which is more indicative of a large break LOCA. As discussed above, based on the system hydraulics, the maximum RHR pump flow rate is approximately 20% less than runout flow rate.

<u>Historical Recognition of Importance of Sump Performance at PINGP</u>

Prior to the issues associated with GSI-191 being identified by the NRC, NMC and previous plant operating organizations already recognized the importance of the containment sump in supporting long term recirculation following a postulated LOCA. For example, prior to GSI-191, containment sump performance at PINGP included the following design features, procedures and administrative controls:

(1) The plant was designed and constructed with the absence of a significant amount of fibrous material that could be a potential source of debris that could reach the sump screens. With the exception of isolated locations, insulation used inside of containment is reflective metallic (stainless steel). The primary bases for the use of reflective metallic insulation inside of containment were sensitivity to the containment sump and post-LOCA recirculation operation.

(2) Consistent with plant procedures, the CS system is secured during the injection phase provided that containment pressure has been reduced below a predetermined value.

(3) Consistent with plant procedures, the CS pumps are not operated during the recirculation phase.

(4) Only Service Level I coatings (coatings qualified for post-accident conditions) are applied inside of containment (note that some components have been provided by the equipment manufacturers with coatings that are not Service Level I); and

(5) The containment is designed and constructed with the absence of major obstructions on the containment floors that could prevent flow from reaching the containment sump screens. The flow paths from the upper levels of containment to the lower levels are relatively free, that is, open stairways and/or floor grating. The reactor coolant pump and steam generator vaults have large openings that allow liquid to spill to the containment basement elevation.

These design features and administrative controls provide reasonable assurance that long term core cooling would have been maintained prior to completing actions necessary to resolve GSI-191. The actions implemented to resolve GSI-191 provide a high level of confidence that core cooling will be maintained.

## SUMMARY OF APPROACH TO ADDRESS GSI-191 AT PINGP

As part of the holistic approach to address GSI-191, NMC implemented the following comprehensive actions.

### Design Modification

The replacement sump strainer was designed to fully satisfy the following performance objectives:

- The design should accommodate the maximum volume of debris that is predicted to arrive at the strainer, fully considering debris generation, debris transport, and any mitigating factors (e.g., curbing).
- The design should address the possibility of thin bed formation.

Subsequently, NMC concluded that, with the minimal quantities of fibrous debris inside of containment, a thin bed could not be formed; thus, the second performance objective is not applicable. The strainer is designed to ensure that all other performance objectives are satisfied. Strainer design details, the bases for the strainer design, and the analyses that support the strainer design are described in more detail throughout this supplemental response.

### Procedure Enhancements

In support of GSI-191 resolution activities, NMC has implemented several enhancements to the plant operating procedures provided to Control Room operators and guidance provided to personnel in the technical support center (TSC) (References 4 and 5). These procedure enhancements are described below.

(1) Procedure instructions are provided to plant operators and TSC personnel for monitoring post LOCA sump recirculation operations. These instructions identify appropriate system indications to monitor for the entire system; i.e., from the containment sump strainer through the ECCS and assuring adequate core cooling. The following instructions are utilized by the Control Room operators and TSC staff to monitor ECCS performance during post-LOCA recirculation:

Containment Sump Level (*) (**)
RHR Pump Suction Pressure (*)
RHR Pump Discharge Pressure (*) (**)
RHR Flow Rate (*) (**)
SI Pump Discharge Pressure (*) (**)
SI Flow Rate (*) (**)
In Core Thermocouples (*)
Subcooling Margin (*) (**)
Reactor Vessel Water Level (RVLIS) (*) (**)
RHR Pump Motor Vibrations (*)
RHR Pump Motor Current

(*) These indications are available on a single computer display and can also be plotted to enhance trending capabilities. The single system computer display provides the capability for the operations and technical support personnel to monitor the indications in aggregate and makes discerning trends much easier.

(**) Control board or other control room display is also available for these indications.

(2) Procedure directions to the plant operators were improved for expediting post-LOCA cooldown and depressurization to allow placing the systems in a more typical shutdown cooling configuration, if possible, in lieu of sump recirculation operation.

(3) Procedure directions to the plant operators were improved for reducing recirculation flow by securing one train of ECCS given system indications demonstrating that adequate cooling is provided. Reducing ECCS flow decreases the flow through the sump pool increasing the likelihood that debris will settle prior to reaching the sump strainer. Reducing the ECCS flow also decreases the head loss through the strainer.

(4) Procedure directions were implemented to provide strategies to operators and technical support staff for contingency actions in the very unlikely event that system indications indicate that blockages are occurring either at the strainer or in the system downstream of the strainer. These mitigation strategies can be described within the following groupings:

- Maintain flow using an alternate injection flow path. In this case, the charging system could be used. Within the first few hours following the event the decay heat boil-off rate is within the capacity of the charging system. The ECCS pumps could be realigned to draw suction from the RWST. However, if it is postulated that the recirculation system is adversely affected by debris ingestion then this same debris could also affect the injection flow path. The advantage of the charging system is that it would provide flow paths that would not be affected by the postulated debris ingestion.
- Securing the recirculation flow for a limited period of time may allow the postulated debris to settle out of the blockage location and free the flow path. In addition, reinitiation of the recirculation flow may dislodge the debris.
- The systems can be realigned to provide flow to the core through different flow paths. For example, normal high head recirculation returns the liquid to the RCS cold legs. As an option, the high head recirculation could be aligned to the reactor vessel injection flow paths. Or, as another example, the high head recirculation flow path could be used in lieu of the low head recirculation flow path.
- If blockage cannot be cleared, then the operator would transition to the emergency procedure for a loss of emergency coolant recirculation or the emergency procedure for addressing loss of emergency coolant recirculation specifically due to sump strainer blockage.

(5) Procedure instructions were developed to begin refilling the RWST after recirculation has been commenced. These actions ensure that sufficient water inventory in the RWST is available in the event the mitigation strategies described above needed to be utilized.

(6) Procedures for aligning the ECCS for recirculation operation were revised to maximize the water transferred from the RWST prior to initiation of recirculation. These procedure revisions maximize the available inventory in the containment sump pool.

These procedural enhancements were initially implemented as part of the NMC response to NRC Bulletin 2003-01. NMC has decided to maintain these enhancements as permanent changes as part of overall response to the issues associated with GSI-191.

**Training**

In response to the issues associated with GSI-191, NMC recognized the importance of ensuring that operations and technical personnel were aware of the issues and the plant changes implemented to address the issues. These training activities included the following (References 4 and 5):

1. Briefings of operators and appropriate TSC staff were conducted to heighten sensitivity to awareness of the issues, procedures that have been implemented, system indications that can be used to monitor recirculation system performance, and guidance on mitigation strategies from postulated debris blockage.

2. Specific training on post-LOCA cooldown and depressurization to emphasize to operations personnel the importance of expediting the cooldown of the RCS to possibly preclude the need to align for recirculation operation.

3. Training was provided to plant operators on the modification; specifically explaining the design bases, the sizing bases and assumptions for the new strainer, post-accident response, and applicable surveillance requirements.

4. Long term recirculation and issues related to GSI-191 are included in the continuing training program for operations staff.

**Administrative Controls**

1. The Technical Specification minimum level in the RWST is 200,000 gallons; corresponding to an indicated level of approximately 68%. The minimum level in the RWST was administratively increased to 90% (Reference 4). This increase provided approximately 65,000 gallons of additional water to the containment sump pool. This provides the following benefits:

   - Increases the drawdown time of the RWST which increases the time before recirculation is commenced. This increases the likelihood that debris will settle in the pool.
   - The increased pool volume provides for overall reduced flow velocities through the pool increasing the likelihood that debris will settle in the pool prior to reaching the sump strainer.
   - The increased pool volume increases the available static head to the suction of the RHR pumps.
   - Increasing the liquid volume in the pool reduces the debris concentration in the pool liquid. This, in turn, results in decreasing the wear rates of the components downstream of the sump strainers. This positive effect is not credited in the analyses.

   Subsequently, a license amendment request was submitted to revise the Technical Specifications to increase the RWST minimum water level to be consistent with the administrative controls (Reference 6). On December 14, 2007, the NRC issued amendments to the PINGP Technical Specifications which increase the required RWST level.

2. Additional measures were implemented to provide more aggressive requirements for containment closeout and foreign material controls.

3. The containment closeout procedures were enhanced to include specific verifications that containment drainage paths are not blocked.

4. The post-outage containment inspection procedure specifically looked at the sump strainer for evidence of structural distress or abnormal corrosion.

**Conservatisms**

The analyses, design modification and procedure enhancements include significant conservatisms. Where feasible, the design and analyses were based on the concept that the optimum time to include margin is during the initial design. With this in mind conservatisms and margin were included throughout the analyses and design. These are summarized below.

Debris Generation

The break selection and debris generation analyses were performed following the NRC Staff guidelines with the following conservative approaches:

- The RCS loop piping is contained within the Steam Generator and Reactor Coolant Pump Vaults. Break selection was simplified by assuming that the entire vault is within the zone of influence (ZOI) from any postulated break location in the vault, with the exception of the Transco reflective metallic insulation (RMI) used on the Unit 1 steam generators. This methodology conservatively maximized the debris generated by the break.
- All insulation materials within the ZOI are assumed to fail.
- All qualified coatings within the ZOI are assumed to fail.
- All unqualified coatings inside of containment are assumed to fail. No credit is taken for the Electric Power Research Institute (EPRI) original equipment manufacturer (OEM) coating testing. A relatively large percentage of the unqualified coatings inside of containment are on Unistrut, a structural member used to support components such as cable trays and conduit. Samples of Unitstrut from PINGP were submitted to EPRI as part of the OEM coating testing program. The coatings on these Unitstrut members demonstrated acceptable performance during the testing.
- All foreign materials (e.g., tags, tape, stickers and cable ties) inside of containment are assumed to fail. This includes foreign materials that are installed using relatively robust methods. During the containment walkdowns for identification of potential debris sources, a detailed inventory of all foreign materials was developed by each general area inside of containment, including areas that are not exposed to the break or containment spray and are not within areas of water flow in containment during the post-accident mitigation.

- The methods used to determine latent debris (e.g., dirt, dust) inside of containment were aimed at maximizing these debris sources.
- All fiber debris inside of containment (miscellaneous and latent debris) is assumed to become fine debris during the accident.

The above approach conservatively maximizes the debris available for transport to the containment pool and the containment sump strainer.

Debris Transport

The debris transport analysis was performed following the NRC Staff approved methodology. In this case, the analysis was performed following the baseline methodology approach where 100% of the debris generated was assumed to be transported to the containment sump, with the exception of the reflective metallic insulation. The one exception to the 100% transport assumption is that for strainer prototype testing, transport of significant quantities was not assumed. The bases for not assuming 100% transport of the metallic insulation is discussed in the NRC Audit Report for PINGP and determined to be appropriate. Assuming 100% debris transport of all other types of debris is an analytical conservatism rather than a best estimate of realistic debris transport behavior. This approach to debris transport represents a conservative upper bound to the amount of debris that would be expected to transport during an actual LOCA. More specifically, this approach is conservative for the following reasons:

- 100% transport is assumed for all qualified coating debris generated by the accident.
- As discussed previously, all the unqualified coatings inside of containment are assumed to fail, regardless of location inside of containment. All of these failed unqualified coatings are assumed to be transported to the containment sump strainer. This is very conservative as a relatively large percentage of the locations of the unqualified coatings are not exposed to the postulated break or containment spray and not in regions exposed to flow patterns.
- As discussed previously, all the foreign materials inside of containment are assumed to fail, regardless of location inside of containment. All of these failed foreign materials are assumed to be transported to the containment sump strainer. This is very conservative as a relatively large percentage of the locations of the foreign materials are not exposed to the postulated break or containment spray and not in regions exposed to flow patterns.
- All of the latent debris (e.g., dirt, dust, latent fibers) are assumed to be transported to the containment sump strainer, regardless of the location inside of containment, with the exception of that which could be held-up in the inactive pool volume. Credit for debris hold-up in the inactive pool volume is consistent with References 7 and 8.

Therefore, the conservatisms in the debris generation term coupled with the very conservative method of assuming that all of the debris generated is transported to the sump strainer provides a bounding debris source term available in the vicinity of the sump strainer.

RHR Pump Net Positive Suction Head (NPSH) Margin

The pump NPSH margin is the difference between the available NPSH and the pump required NPSH. The available NPSH for the RHR pumps is a function of the static head at the suction of the pump and the head loss through the strainer and the system. The static head at the suction of the pump is a function of the liquid volume in the containment pool (i.e., the liquid level). The head loss is a function of the debris at the sump strainer, the flow rate and the liquid temperature. The pump required NPSH is a function of the pump flow rate. The following conservatisms are used in the determination of the pump NPSH margin:

- A minimum containment pool liquid level is determined by maximizing the liquid inventories held-up in the RCS (for both large break and small break LOCAs), maximizing the liquid volumes held-up within containment (outside of the sump pool), and using minimum initial volumes for the RWST and SI Accumulators. It is noted that an initial volume of 68% was assumed for the RWST corresponding to the requirements in Technical Specification 3.5.4. The administrative controls, discussed above, increasing the RWST level to 90% were not credited to demonstrate that sufficient margin was available to the RHR pumps. The increase from 68% to 90% provides approximately 65,000 additional gallons of liquid to the containment sump which adds margin. In accordance with an NMC license amendment request (LAR) (Reference 6), the NRC issued amendments to the Technical Specifications which require the RWST level to be maintained above 90%.
- The determination of the head loss through the ECCS piping from the containment sump to the suction of the RHR pumps is determined based on the RHR pumps operating at runout flow (2600 gpm). Based on system hydraulics the maximum achievable pump flow is calculated to be 2085 gpm. This corresponds to a margin of approximately 20% in assumed flow or an equivalent head loss margin of approximately 35% (based on head loss corresponding to flow squared).
- Containment overpressure is not credited. Furthermore, credit is also not taken for the increase in the partial pressure of the air in containment. Assuming that air behaves as an ideal gas, the partial pressure of the air would vary proportional to the temperature change.
- Head loss through the debris bed on the strainer is determined based on testing. The debris quantities used in the testing are greater than the design bases debris loadings which, as discussed above, include significant conservatisms.
- As discussed above, consistent with plant procedures, the operators would be working towards reducing ECCS recirculation flow from the sump. These actions are not credited in the determination of the head loss through the system.

- RHR pump required NPSH is based on pump runout flow (2600 gpm). From the pump curve, the required NPSH at 2600 gpm is 14 feet. Based on system hydraulics the maximum achievable pump flow is calculated to be 2085 gpm. From the same pump curve, the required NPSH at 2085 gpm is approximately 9 feet. This assumption, alone, adds 5 feet of margin.

Downstream Effects

The analyses of downstream effects includes evaluations for both blockage and wear. The analyses were performed following the NRC Staff approved guidelines. The downstream effects analyses include the following conservative assumptions:

- 100% of the debris source term inside of containment is assumed to be at the strainer and available for passing through the strainer and entering the ECCS. Assuming 100% debris transport of the debris is an analytical conservatism rather than a best estimate of realistic debris transport behavior.
- Margin is added to the significantly conservative debris source term described above.
- 100% of the debris smaller than the criteria in the approved guidance is assumed to pass through the strainer and enter the ECCS. This results in 100% of the transported qualified coatings, unqualified coatings, miscellaneous debris and latent debris (with the exception of the latent fiber in the fuels analysis) entering the ECCS. For analysis of the potential for fuel blockage the bypass fraction assumed is very conservative relative to the values measured during the strainer testing and conservative compared to the approved guidelines. These assumptions provide bounding conditions for debris bypass.
- Assumed system and component operating times are conservative relative to expected or limiting operating times to maximize the predicted component wear results.
- Flow rates are selected to maximize wear. This includes assuming flow rates corresponding to pump runout flow and pump dead head conditions, where appropriate, to maximize pump wear.
- Debris concentrations in the recirculation liquid are determined based on minimum liquid volume determinations. This maximizes the debris concentrations which maximize the wear on components in the fluid stream. As previously discussed, the determination of the minimum liquid in the pool is based on an initial RWST level of 68% versus the 90% minimum limit in plant procedures and the license amendment issued by the NRC on December 14, 2007.

Structural Analyses

The design of the new sump strainer includes the requisite structural analyses of the strainer for all of the postulated loading conditions. Several conservatisms are included in this analysis, including the following:

- Maximum sump pool liquid level is assumed for determination of the hydrodynamic loadings. This maximizes these loadings.
- The seismic analysis is based on a seismic spectra corresponding to the 711 ft - 6 inches Mean Sea Level (MSL) elevation inside of containment. The strainer is located at elevation 697 ft - 6 inches inside of containment. The spectra at elevation 711 ft - 6 inches are more limiting than the spectra at elevation 697 ft – 6 inches. Thus, using the spectra for the higher elevation increases the seismic loading and adds margin to the analyses.

## Conclusions

In summary, as described above, NMC has implemented a holistic approach that provides a high level of confidence that the issues associated with GSI-191 have been effectively addressed. This high level of confidence has been provided through implementing the following:

- Design modifications;
- Procedure enhancements;
- Training;
- Administrative controls; and
- Significant analytical conservatisms implemented in the design and analyses.

## RESPONSE TO SPECIFIC REVIEW AREAS

The U.S. Nuclear Regulatory Commission (NRC) has audited, on a sample basis (related to reactor type, containment type, strainer vendor, NRC regional office, and sump replacement analytical contractor), licensee corrective actions for Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004 (Reference 1), for approximately ten commercial pressurized water reactors (PWRs). The purpose of the audits was to verify that the implementation of Generic Safety Issue (GSI) -191, “Assessment of Debris Accumulation on PWR Sump Performance” sump strainer and related modifications bring those reactor plants into full compliance with 10 CFR 50.46, “Acceptance Criteria for Emergency Core Cooling Systems for Light-water Nuclear Power Reactors,” (Reference 9) and related requirements, and to draw conclusions as to the probable overall effectiveness of GL 2004-02 corrective actions for the 69 U.S. operating PWRs. PINGP, Unit 1, was selected for focus for an audit because a major part of the design, analyses, testing and installation of the new strainer had been completed for that unit. The new strainers were installed in Unit 1 in the Spring of 2006. Subsequent to the audit, the new strainers were installed in Unit 2 in the Fall of 2006.

The audit commenced on October 4, 2006 when NMC presented an overview of the GSI-191 Project for PINGP to the NRC Staff audit team. Following review of the presentation materials and other documents provided during the overview session, the onsite portion of the audit commenced on October 23, 2006 with the NRC Staff audit team exiting the site on October 27, 2006. Several audit areas continued to be reviewed after the onsite audit was completed, with telephone conferences held on November 2 and December 6, 2006 and a final call on January 3, 2007. The audit provided an opportunity for the NRC to:

1. Review the basis, including the detailed mechanistic analysis and design documents, for the proposed new strainer design; and
2. Identify areas that may need clarification or generic resolution.

The following technical categories related to sump performance were reviewed and discussed: debris generation; debris transport; coatings; debris characterization; system head loss; chemical head loss; modifications; upstream and downstream effects; and net positive suction head (NPSH) for emergency core cooling system (ECCS) pumps.

The NRC Staff reviewed the design documents provided by NMC and interacted with NMC staff and its vendors to develop a thorough understanding of major aspects of the design and analysis.

During the course of the audit, NRC Staff concluded that the new strainer design at PINGP provides ample NPSH margin but also identified issues related to NMC's implementation and plans that needed to be assessed as part of NMC's completion of corrective actions for GL 2004-02. The audit report was issued on May 2, 2007 (Reference 11). Open Items identified during the audit were identified throughout the audit report, and were communicated to NMC staff during audit meetings and telephone conferences.

The audit open items are addressed in this supplemental response. Furthermore, during the audit several technical categories or portions of technical categories were found to be acceptable. For categories or portions of categories found to be acceptable during the audit, this supplemental response will briefly describe the approach taken for that technical category and the findings from the audit report. In addition, any changes that have been implemented subsequent to the audit will be discussed. Attachment 1 to this supplemental response provides a table showing the ties between the NRC Content Guide section and the PINGP Audit Report section, noting any Open Items from the Audit report and how the Open Item has been addressed.

The format used below for addressing the specific review areas is based on NRC Letter to the Nuclear Energy Institute, "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," Revision 1, dated November 21, 2007 (Reference 3).

1. Overall Compliance

PINGP Unit 1 and 2 ECCS recirculation functions are in compliance with the regulatory requirements identified in GL 2004-02 under debris loading conditions. As discussed previously, PINGP does not utilize the containment spray system during recirculation operation. The modifications were installed prior to December 31, 2007. The discussion throughout this supplemental response to GL 2004-02 provides the details for how compliance is assured and maintained.

As a result from the analyses, NMC replaced the original sump screens with new strainers. Performance Contracting, Inc. (PCI) provided the strainers.

Activities to bring PINGP into full compliance with the regulatory requirements identified in GL 2004-02 included:

- Containment walkdowns to quantify potential debris sources;
- Debris generation and transport analysis;
- Calculation of required and available NPSH;
- Defining strainer requirements;
- Strainer structural analyses;
- Procedures to address sump strainer blockage;

- Chemical effects analysis;
- Downstream effects analyses;
- Upstream effects evaluation; and
- Latent debris control and monitoring program.

These are described in more detail below.

2. General Description of and Schedule for Corrective Actions

Corrective actions that have been completed include analyses, installation of new strainers, procedural enhancements, training, implementation of administrative controls, and a license amendment request. The only outstanding action is:

- NMC submitted a Request for Extension of Supplemental Response to Generic Letter 2004-02 (Reference 12) to extend the ECCS in-vessel and ex-vessel downstream effects analyses. These analyses will be completed by March 31, 2008.

3. Specific Information Regarding Methodology for Demonstrating Compliance

a. Break Selection

The analysis of break selection was reviewed in detail during the NRC Staff audit at PINGP. Regarding break selection, the NRC Audit Report (Reference 11) states:

> The NRC Staff finds the licensee's evaluation of break selection to be acceptable. The evaluation was generally performed in a manner consistent with the SE [Safety Evaluation]-approved methodology. Deviations from the staff-approved methodology were judged by the staff to be acceptable based on the technical basis provided by the licensee. [NRC Audit Report, Section 3.1, page 13]

NMC has not made any changes subsequent to the audit that affect the break selection methodology or results and these conclusions remain applicable to PINGP.

Summary of Analysis Methodology (reviewed during NRC audit)

The objective of the break selection process is to identify the break size and location that presents the greatest challenge to post-accident sump performance. Sections 3.3 and 4.2.1 of the Nuclear Energy Institute (NEI) Guidance Report (GR) (Reference 7) and NRC Safety Evaluation (SE) (Reference 8) provide the criteria to be considered in the overall break selection process in order to identify the limiting break. In general, the principal criterion used to define the most challenging break is the estimated head loss across the sump strainer. Therefore, all phases of the accident scenario are considered for each postulated break location: debris generation; debris transport; debris accumulation; and sump strainer head loss. Two attributes of break selection that are emphasized in the approved evaluation methodology and can contribute to head loss are: (1) the maximum amount of debris transported to the strainer; and (2) the worst combinations of debris mixes that are transported to the strainer. Additionally, the approved methodology states that breaks should be considered in each high-pressure system that relies on recirculation, including secondary side system piping, if applicable. Note that, at PINGP, per plant emergency operating procedures, during a secondary line break scenario, safety injection would be secured prior to reaching the criteria for switchover from the RWST. Thus, PINGP does not rely on recirculation from the containment sump following a secondary line break.

The PINGP configuration consists of two reactor coolant loops, A and B, each consisting of a reactor coolant pump, a steam generator, and reactor coolant piping. On each unit, the B Loop also contains the pressurizer and associated piping. The loops are located in the containments within concrete vaults. RMI is used exclusively on reactor coolant system components. Breaks in primary reactor coolant system piping having the potential to rely on ECCS recirculation from the containment sump were considered.

Based on a review of the type and quantity of insulation present, the mix of debris generated, and the proximity to the sump, the bounding postulated break was determined to be a break in the hot leg of RCS Loop B. Vault B, which houses RCS Loop B, was determined to have the largest potential to generate insulation debris; primarily because this vault also contains the pressurizer and the pressurizer surge line. Vault B is also located closer to the recirculation sump. Therefore, NMC concluded that the potential for debris to transport to the recirculation sump would be greater for Vault B than for Vault A. Since the coating debris volume is larger in Vault A than Vault B for one of the units, the coating debris in Vault B was assumed to be the same as Vault A. This methodology assured that the break selection methodology resulted in bounding debris quantities at the most limiting location relative to the strainer. An additional break was also included for each unit outside the vault that would allow for easy transport of debris to the sump.

As discussed above, the NRC reviewed the break selection methodology and determined that it was acceptable with no open items.

b. Debris Generation/Zone of Influence (ZOI) (excluding coatings)

The debris generation analyses, including zones of influence considerations, were reviewed in detail during the NRC Staff audit at PINGP. Regarding Debris Generation/Zone of Influence, the NRC Audit Report states:

> In conclusion, the staff finds the licensee's ZOI evaluation to be acceptable. The evaluation was performed in a manner consistent with the SE-approved methodology. The licensee applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE, which allows use of debris-specific spherical ZOIs. The licensee applied material-specific damage pressures and corresponding ZOI radius/break diameter ratios as shown in Table 3-2 of the staff SE. The staff therefore found that the licensee provided an adequate level of technical justification with respect to ZOI analyses. [NRC Audit Report, Section 3.2, page 15]

NMC has not made any changes subsequent to the audit that affect the debris generation determination methodology or results and these conclusions remain applicable to the PINGP.

Summary of Analysis Methodology (reviewed during NRC audit)

The objective of the debris generation/zone of influence (ZOI) process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; (2) the amount of debris generated by the break jet forces; and, (3) the size characteristics of the postulated debris. Sections 3.4 and 4.2.2 of the GR (Reference 7) and the NRC SE (Reference 8) provide the methodology to be considered in the ZOI and debris generation analytical process.

The ZOI refinement discussed in Section 4.2.2.1.1 of the SE was applied, which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term.

For insulation debris, ZOIs sized in accordance with the guidance in the SE were assumed. When these ZOIs were overlaid onto composite piping plans at the selected break locations, it was found that the ZOI would encompass nearly the entire vault, with the exception of the Transco RMI with its much smaller ZOI relative to the vault size.

The insulation within PINGP containment vaults that could be damaged is RMI. Most of the RMI is Mirror® with standard bands manufactured by Diamond Power Specialty Corporation. One exception is the insulation on the Unit 1 steam generators, which is Transco RMI. The debris generation report also quantifies some potential quantities of LOCA-generated fibrous debris that are very small compared to the estimated latent fiber. In addition to the fiber contribution from latent debris, the sources of fibrous material include small quantities of fiber cloth on cables, fibrous vent fan expansion bellows, and other miscellaneous fibrous material. There is also some calcium silicate insulation inside of containment that is encapsulated within steel plates and located outside of the various ZOIs and therefore not a potential source of debris.

Because the application of the spherical ZOI nearly encompasses the respective vaults, the quantities of debris are limited by the vault walls rather than the ZOI, with the exception of Transco RMI on the Unit 1 steam generators.

The Mirror® RMI size distribution was based on the Boiling Water Reactor Owners Group (BWROG) debris generation data, as presented in the SE (specifically, Figure VI-4 of the SE Appendix VI). For the Transco RMI, a generic size distribution was specified, i.e., 75% for small debris (< 4 inches and 25% for larger debris (≥ 4 inches). Other debris types were considered to be very fine debris. These size distributions are acceptable based on the application of the insulation specific information and conservatisms as referenced in the SE.

As discussed above, the NRC reviewed the debris generation and zone of influence process analyses and determined that it was acceptable with no open items.

c. Debris Characteristics

The analysis of debris characteristics was reviewed in detail during the NRC Staff audit at PINGP. In summary, regarding Debris Characteristics, the NRC Audit Report (Reference 11) states:

> The staff reviewed the licensee's assumptions concerning the characteristics of debris sources that are present in the Prairie Island [PINGP] containment buildings, including Mirror® and Transco stainless steel reflective metallic insulation (RMI), miscellaneous fibrous debris, foreign materials, and latent fibrous and particulate debris (note that the characteristics of qualified and unqualified coatings debris are discussed separately in the coatings debris characteristics section … ). The staff did not perform a detailed review of the debris characteristics associated solely with the information-only

> head loss calculation since this calculation was not relied upon to validate the replacement strainer design. On the basis of the preceding detailed discussion for Section 3.3, the staff generally found the licensee's debris characteristics assumptions to be acceptable, and no open items were identified. [NRC Audit Report, Section 3.3.7, page 18]

NMC has not made any changes subsequent to the audit that affect the determination of debris characteristics and these conclusions remain applicable to PINGP.

Summary of Methodology (reviewed during NRC audit)

Several types of debris are present in the PINGP containment buildings, including Mirror® and Transco stainless steel RMI, miscellaneous fibrous debris, various types of qualified and unqualified coatings, foreign materials, and latent fibrous and particulate debris. The characteristics assumed by NMC for each type of debris were reviewed by the NRC Staff during the audit and the summary for each type of debris is discussed below, with the exception of qualified and unqualified coatings (the characteristics of which are discussed in the Section 3.h. below).

<u>Mirror Stainless Steel RMI</u>

The analyses were performed using an assumed size distribution for Mirror® RMI debris based on the distance from the analyzed pipe break to the target insulation. The zone of influence (ZOI) was divided into three subregions for which separate debris size distributions were applied. The methodology supporting this debris size distribution was derived from Appendix VI in the NRC Staff SE (Reference 8). Figure VI-4 in this appendix provides data for Mirror® RMI debris in the range of destruction pressures from 0 to 120 psi. However, the test data in Appendix VI were based on air jet testing rather than two-phase steam/water jets. Therefore, consistent with the discussion in Section 3.4.2.2 of the NRC Staff SE, a 40% reduction to the destruction pressures (Pdest) given in Appendix VI to the SE was applied.

Regarding the Mirror RMI, the NRC Audit Report states:

> The staff considers the Mirror® RMI debris size distribution assumed by the licensee to be acceptable because the debris size distribution follows the conservative guidance in Appendix VI to the SE and incorporates the 40% reduction in destruction pressure to account for uncertainties associated with two-phase steam/water jets that is discussed in Section 3.4.2.2 of the staff's SE. [NRC Audit Report, Section 3.3.1, page 16]

Transco Stainless Steel RMI

It is assumed that 75% of the Transco RMI debris would be less than 4 inches in size, referred to as small pieces, and that the remaining 25% would be greater than 4 inches, referred to as large pieces. This size distribution is consistent with guidance provided in Section 3.4.3.3.2 of NEI 04-07.

Regarding the Transco RMI, the NRC Audit Reports states:

> The staff considers the licensee's assumed size distribution for Transco RMI to be acceptable because it follows the guidance in NEI 04-07 that was approved by the NRC staff's SE. [NRC Audit Report, Section 3.3.2, page 16]

Miscellaneous Fibrous Debris

Several sources of miscellaneous fibrous debris were noted in the debris generation and transport calculations. These sources of fibrous material include small quantities of fiber cloth on cables, fibrous vent fan expansion bellows, and other miscellaneous fibrous material. In the debris transport calculation, volumes were calculated for these sources of fibrous debris.

The miscellaneous fibers make up a small fraction of the overall volume of fibrous debris within containment (i.e., less than 5% of the total volume). Furthermore, it is conservatively assumed that 100% of the miscellaneous fiber would become fine debris during an accident, and that 100% of the miscellaneous fiber would transport to the recirculation sump strainers. The review of miscellaneous fiber debris, as documented in Reference 11, included debris characteristics such as size and density.

Regarding the miscellaneous fibrous debris, the NRC Audit Report states:

> Thus, based upon the fact that the licensee's debris characteristics assumptions appear reasonable and the fact that the licensee included significant conservatism in its analytical treatment of miscellaneous fibrous debris, the staff considers the assumed characteristics for miscellaneous fibrous debris discussed above to be acceptable. [NRC Audit Report, Section 3.3.3, page 17]

Foreign Materials

Foreign materials that may be found in containment include self-adhesive labels, stickers, and placards. The test plan for the replacement strainers accounted for foreign materials by adding surrogate debris rather than allowing sacrificial strainer area. This methodology of including representative materials in the strainer prototypical testing was utilized in lieu of using sacrificial strainer area to account for foreign materials.

Regarding foreign materials, the NRC Audit Report states:

> The staff considers the licensee's assumptions in the debris generation and transport calculations regarding the characteristics of foreign materials to be acceptable because they are generally consistent with the guidance in NEI 04-07, as approved by the staff's SE. However, the staff noted that the licensee's strainer test plan accounted for foreign materials by adding surrogate debris rather than allowing sacrificial strainer area as per the SE. Although the test plan's treatment of foreign materials was inconsistent with the discussion in the debris generation and transport calculations, testing with surrogate debris is also considered to be an appropriate general methodology by the staff's SE if the testing is performed in a manner that is prototypical of the actual plant environment. The specific details of the licensee's head loss testing are reviewed in the Prototypical Head Loss Testing Section … of this audit report. [NRC Audit Report, Section 3.3.4, page 18]

<u>Latent Debris</u>

Latent debris includes dirt, dust, lint, and fibers. The analyses assume that 15% of latent debris is composed of fibrous debris, based upon guidance in Section 3.5.2.3 of the NRC Staff SE on NEI 04-07 (Reference 8). Furthermore, it is conservatively assumed that latent debris is composed of small fines based upon Section 3.6.3 of the NRC Staff SE on NEI 04-07 (Reference 8).

Regarding latent debris, the NRC Audit Report states:

> The staff considers the licensee's assumptions regarding the characteristics of latent debris to be acceptable because they are consistent with the guidance in NEI 04-07, as approved by the staff's SE. [NRC Audit Report, Section 3.3.5, page 18]

In conclusion as discussed above, the NRC reviewed the debris characteristics used in the analyses and determined that these were acceptable with no open items.

d. Latent Debris

The determination of latent debris was reviewed in detail during the NRC Staff audit at PINGP. Regarding latent debris, the NRC Audit Report (Reference 11) states:

> Because the PI [PINGP] fibrous debris source term is very low, the licensee assumes that a thin bed can not form. Consequently, certain decisions were made, including conducting head loss tests with coatings in the form of chips versus 10 μ particles. The latent fiber is the primary contributor toward the formation of a thin bed. This makes monitoring and control of latent fiber more important as a small increase in fibrous material could lead to a postulated thin bed. In light of this increased importance, PI has plans for a follow-on assessment of the latent debris. These plans are to include more substantial sampling, so that some items deemed overly-conservative can be reduced, and the latent debris source term reduced accordingly. Additionally, to ensure that the analysis remains bounding, NMC will perform measurements to estimate the amount of latent dirt and dust inside containment every other refueling outage. Assuming the results indicate that the housekeeping practices provide an adequate level of cleanliness, NMC may choose to relax this frequency.
>
> In conclusion, the NRC staff found that the PI evaluation for latent debris was performed in a manner consistent with the SE-approved methodology, and is acceptable. However, because of the plant's sensitivity to latent fiber in the sump performance evaluation, the staff considered that the containment sampling should be strengthened. The staff considered that latent debris sampling, quantification, and monitoring should be covered in a routine and ongoing documented program. The program should include tracking, trending, and appropriate acceptance criteria. This is **Open Item 3.4-1**. [NRC Audit Report, Section 3.4, page 20]

Open Item 3.4-1 states:

> Latent debris sampling, quantification, and monitoring were not covered and documented in a formalized program. The program was informal and lacked tracking, trending, and appropriate acceptance criteria.

Actions taken to address Open Item 3.4-1 are discussed below.

Summary of Methodology (reviewed during NRC audit)

Note that the discussion of foreign material latent debris is discussed above in Section 3.c. The following discussion focuses on the latent dirt, dust, and fiber debris.

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump strainer head loss. NMC documented the assumptions and methodology applied to determine the amount, type, and impact of latent debris on sump strainer head loss in the associated analyses. The latent debris source term was determined through the collection of debris samples from multiple locations throughout the PINGP containments. Measurements were completed during refueling outages in each unit prior to the NRC Staff audit. The characterization of latent debris followed the guidance approved in the NRC SE (Reference 8).

The evaluation for latent debris is performed in a manner consistent with the NRC SE-approved methodology. The latent debris source term is determined through the collection of debris samples from multiple locations throughout both PINGP containments, that is, specific values are determined for each containment based on sampling inside of that containment. Areas sampled included those that could be exposed to containment spray and/or recirculation flow and areas not exposed to containment spray. Vertical and horizontal surfaces were included. Samples were taken at a time during the respective refueling outages when the level of dirt and dust would be much higher than during normal power operation. Subsequent to the sampling activities, but prior to unit startup, extensive cleaning was performed. These cleaning activities are consistent with normal housekeeping practices and associated administrative requirements.

NMC has taken the following actions to close Open Item 3.4-1:

A formalized latent debris program was developed by NMC to contain the requirements for periodic sampling, quantification, tracking, and trending. The program includes a formalized calculation with an allowable debris quantity based upon strainer surface area, debris fiber percentage, potential chemical effects, and allowable thin bed thickness. A test procedure associated with the program is performed early in each refueling outage to sample various areas of containment in a manner consistent with the methods previously evaluated in the NRC Audit Report (Reference 11). Sample data obtained from the test procedure is used to determine the total mass of debris inside containment. This total mass of debris is compared to the allowable levels in the calculation to determine required corrective actions. This inspection frequency may be relaxed in the future if the sample data continues to show a wide margin to the latent debris levels used in the sump strainer performance analysis.

The latent debris program requires maintenance of the GSI-191 Debris Monitoring spreadsheet that is used to track and trend previous debris levels. This spreadsheet is updated after each debris sampling evolution. The debris levels are compared with historical levels after each update to determine if any adverse trends are occurring. Any adverse trends are documented using the corrective action process. Prior to containment closeout for each refueling outage, the spreadsheet is also used to project the expected inventory at the beginning of the next refueling outage using previous data and debris accumulation rates as a guide. If the expected debris inventory at the beginning of the next refueling outage exceeds the maximum allowable level, the issue is documented using the corrective action process and appropriate actions are taken to minimize the debris inventory.

Subsequent to the on-site NRC Audit, the Unit 2 Fall 2006 refueling outage was entered during which the second round of latent debris sampling was performed. This time the sampling was performed at a point in the outage representative of an “as-found” condition, i.e., shortly after unit shutdown but prior to any significant activity inside of containment. The results from the sampling in Fall 2006 outage indicated that Unit 2 now had a total latent debris quantity of 30.2 lbm which is less than 30% of that determined in the initial Unit 2 sampling program. The sampling during the Unit 2 Fall 2006 outage was the initial follow-up latent debris sampling performed as part of the overall latent debris control program. During the inspection and close-out walkdowns, the surfaces inside of containment were visibly cleaner than when the sampling was performed at the beginning of the outage. Therefore, there is reasonable assurance that 30.2 lbm is a conservative latent debris quantity for PINGP Units 1 and 2.

Based on the establishment of a program to control and monitor latent debris inside of containment, Open Item 3.4-1 is considered closed.

e. Debris Transport

The debris transport analysis was reviewed in detail during the NRC Staff during the audit. Regarding debris transport, the NRC Audit Report (Reference 11) states:

> The licensee essentially assumed that 100% of the debris generated by a LOCA would be transported to the containment recirculation sump strainers. As discussed above, the staff generally considered this

> assumption to be highly conservative and acceptable for strainer design purposes. The staff also noted above that the quantity of RMI debris used for the strainer qualification head loss testing program was significantly less than the amount assumed to reach the strainers analytically. Based upon the additional justification provided by the licensee during the audit, the staff concluded that the quantity of RMI added to the flume during head loss testing was acceptable. In conclusion, the staff considered the licensee's treatment of debris transport to be acceptable and did not identify any open items. [NRC Audit Report, Section 3.5.2, page 25]

NMC has not made any changes subsequent to the audit that affect the debris transport analysis or results and these conclusions remain applicable to PINGP.

Summary of Methodology (reviewed during NRC audit)

The debris transport methodology utilized for PINGP is based on guidance from NEI 04-07 (Reference 7), as modified by the associated NRC SE (Reference 8). In lieu of performing a rigorous analysis of the phenomena governing debris transport, the analysis is based on the assumption that 100% of the generated debris transports to the sump strainers for all debris types, with one exception. The assumption of 100% debris transport for all types of debris is an analytical conservatism rather than a best estimate of realistic debris transport behavior. Thus, the debris transport results represent a conservative upper bound to the amount of debris that would be expected to transport during a LOCA.

The exception to the 100% debris transport assumption is that a significant quantity of RMI was assumed not to transport to the strainer surfaces. A portion of RMI and jacketing debris would be retained in the reactor coolant system loop vaults since fluid velocities along the containment floor would be too low to transport most of this debris to the strainers. Using the RMI debris head loss correlation recommended in NEI 04-07, even if all of the RMI debris and its jacketing were assumed to accumulate upon the strainer in a circumscribed pattern, a negligible head loss of less than one-tenth of a foot would result. Furthermore, if RMI debris and its jacketing could be postulated to form a large pile that circumscribes the strainer, the resulting debris bed would be relatively porous, allowing fluid to flow through to the strainer, but filtering out a fraction of the suspended debris prior to its arrival on the strainer surface. Such an accumulation pattern could actually provide a potential head loss benefit by collecting debris upstream of the strainers. Performing head loss testing with 100% of the RMI and jacketing debris generated by the accident (and analytically assumed to reach the recirculation sump strainers) could nonconservatively prevent other debris from reaching the strainers. Thus, it was conservative for the prototypical strainer testing, not to assume 100% transport of RMI.

The material quantities assumed to be transported to the strainer are detailed in the NRC Audit Report (Reference 11), Section 3.5, and are not repeated here.

f. Head Loss and Vortexing

The analyses of head loss and vortex potential were reviewed in detail during the NRC Staff audit at the PINGP. Regarding head loss and vortexing, the NRC Audit Report (Reference 11) states:

> Head Loss Evaluation
>
> The licensee performed plant-specific prototypical strainer head-loss testing and vortex testing. The system input evaluation, the testing matrix, the testing procedures and the results were reviewed during the audit. Because the estimated head loss based on the maximum measured head loss is significantly less than the NPSH margin for the designed sump flow rate and the temperature, the staff considers that the PI new strainer will likely not cause significant head loss to challenge the ECCS NPSH margin excluding any potential head loss change due to chemical effects. However, the following open items need to be addressed by the licensee to justify the NPSH margin, the flashing margin, and lack of vortex formation.
>
> **Open Item 3.6-1:**
>
> After performing additional latent debris assessments of PI Unit 2, the licensee needs to reevaluate the assumption that there would be insufficient latent fiber debris to form a thin bed. If the amount of fiber debris is enough to form a thin bed, the licensee needs to justify the use of coating chips during the head loss testing instead of fine particulate surrogate material.
>
> **Open Item 3.6-2:**
>
> The licensee needs to provide sufficient justification to address why the PCI clean strainer head loss correlation can be applied to PI's new strainer array, considering differences from the PCI Prototype II strainer testing module. In particular, the licensee needs to address the impact of the following geometrical differences on the conservatism of the correlation:

1. Significantly different diameter/length, core tube area/slot open area ratio;
2. Existence of an annular flow region in the PI strainer assemblies;
3. Different number of slots and differences in slot's open area.

If a new head loss correlation is indicated, the licensee needs to re-evaluate the NPSH and flashing margins.

Vortex Evaluation

Because the new strainer array uses the PCI uniform flow control device and a localized high flow rate is not feasible, it is reasonable to believe that it is unlikely to form a vortex on top of the PI strainer array because of significant submergence. However, the licensee has not provided an adequate justification to demonstrate this.

**Open Item 3.6-3**

The licensee needs to reevaluate vortex formation to ensure design margins exist to prevent vortex formation on top of the PI strainer arrays.

[NRC Audit Report, Section 3.6.6, pages 41 and 42]

Actions taken to address Open Items 3.6-1, 3.6-2 and 3.6-3 are discussed below.

Summary of Methodology (reviewed during NRC audit)

The NUREG/CR-6224 correlation and the uniform debris bed assumption were employed to calculate the head loss across the strainer as part of the initial strainer sizing and scoping analysis. Subsequently, prototypical head loss tests were performed using the Alden Research Laboratory (ARL) testing flume and a reduced-scale prototype testing module to assess the head loss due to the debris on the surface of the strainer. An empirical correlation was used to calculate the clean strainer head loss due to strainer disks and the strainer internal structure. As part of the prototypical head loss testing program, NMC evaluated the susceptibility of the strainers to vortex formation in addition to an analytical evaluation of vortex formation.

The discussion of the head loss and vortex evaluations are sub-divided into four technical areas (using these four areas is consistent with the four areas focused on during the NRC Audit of NMC GL 2004-02 corrective actions).

- System characterization and the design input to the head loss evaluation;
- Prototypical head loss test module design, scaling, surrogate material selection and preparation, testing procedures, results and data extrapolation;
- PCI clean strainer head loss calculation methodology and results; and
- Vortex testing procedures and the vortex formation evaluation results.

Each of these four technical areas is discussed below.

<u>System Characterization and Design Input</u>

At PINGP, long-term recirculation water flows are drawn from a single sump that is designated as Sump B. Only the RHR system pumps can draw water from this sump.

Flow Rate – As previously discussed, the RHR pumps are the only pumps that directly draw water from Sump B. Thus, the maximum flow rate through the new strainer assembly is determined by the maximum RHR pump capacity. As previously noted, the maximum runout flow rate is 2600 gpm for a single train of RHR and 5200 gpm for two-train operation. The strainer head loss evaluation was performed assuming two-train RHR operation. Therefore, the maximum flow rate for each of the two strainer assemblies is 2600 gpm. It is noted that the maximum flow rates possible, based on system hydraulics, are 4170 gpm with two pumps running and 2085 gpm with a single pump running. Therefore, the flow rate of 2600 gpm per pump is acceptable because it bounds the maximum possible flow rates.

Sump Water Temperature - The head loss determination is based on a sump liquid temperature in the estimated temperature ranges between 60°F and 260°F; 60°F is a lower bounding value. For the strainer head loss design input, 200°F was selected because it is the temperature used to determine the head loss in the piping between the sump and the pump suction. Since the selected temperature for the strainer head loss calculation is less than the temperature assumed for the NPSH calculation, 200°F is considered acceptable, because a higher temperature would result in lower head loss and higher containment pool water level.

Containment Pool Water Level - The minimum containment flood level is 1.4 feet above the strainer for single RHR train operation and 2.56 feet for two RHR train operation during a postulated large break LOCA. The small break LOCA results in containment flood levels which are 0.63 feet and 1.52 feet above the strainer for single train and two train operation respectively. At these pool liquid levels, the strainer is completely submerged. Determination of minimum containment water level is discussed below in Section 3.g. As discussed in Section 3.g., the methods and results for the determination of minimum water level were determined to be acceptable by the NRC Staff during the Audit.

Containment Pressure – The analyses for head loss and flashing assume, in accordance with the guidance in Regulatory Guide (RG) 1.82 (Reference 13), that the pressure at the surface of the containment water pool is equal to the vapor pressure of the sump water at its assumed temperature.

Regarding the system characterization, the NRC Audit Report states:

> As discussed above, the staff reviewed the analysis determining the estimated sump water temperature, minimum containment pool water level and the maximum flow rate through the sump for the strainer head loss calculation. Because these design inputs were developed either based on the previous licensing basis calculations or bounding values selected for the head loss evaluation, the staff considers them acceptable. [NRC Audit Report, Section 3.6.2, page 27]

<u>Prototypical Head Loss Testing</u>

Prototypical head loss testing was performed in order to demonstrate that the new strainer head loss for the most limiting LOCA case is less than the available NPSH margin using maximum flow rates and minimum strainer submergence. Pressure transmitters, a flow meter and thermocouples were installed to measure the head loss, total flow rate and the water temperature. Two debris-loaded head loss tests designed as a design basis case and a design basis with redundant strainers were performed.

Debris Types, Quantities and Surrogates

The specification of the debris quantities and characteristics is important to the specification of debris surrogates and debris preparation for the head loss testing. The potential debris accumulation on the replacement strainers was determined from the debris generation and transport analyses. The debris loads actually used in the tests were scaled down from the plant debris loads based on the ratio of the strainer areas and then conservatively increased by 5%. Alkyd coatings were used to test the unqualified coatings. Light bulb debris was treated as metallic foils.

Regarding the treatment of RMI in the strainer prototype testing, the NRC Audit Report states:

> Therefore, although the RMI debris was not treated precisely following the approved guidance in the GR during the prototypical head loss test, the staff considers that use of this information in the head loss evaluations is acceptable. [NRC Audit Report, Section 3.6.3.1.1, page 31]

A more detailed discussion of RMI treatment is included in Section 3.5.1 of the NRC Audit Report (Reference 11).

Regarding the treatment of miscellaneous foreign debris, such as tape and labels, in the strainer prototype testing, the NRC Audit Report states:

> The staff considers that the miscellaneous foreign debris at PI will not significantly increase the strainer head loss because the debris would not generally adhere to the screen surfaces and a substantial portion of this foreign debris would likely be much too heavy to transport effectively. This conclusion is based on the information presented above. Therefore, the treatment of miscellaneous foreign debris is acceptable for PI. [NRC Audit Report, Section 3.6.3.1.2, page 32]

Regarding the treatment of fibrous and particulate debris in the strainer prototype testing, the NRC Audit Report states:

> The licensee sponsored head loss testing documented in the head loss reports clearly resulted in the establishment of debris beds that caused significant head losses. However, those head loss tests were not performed in complete accordance with the SE and GR guidance. Specifically, the tests were conducted with the majority of the postulated coatings debris introduced as paint chips rather than the GR-recommended 10 micron powder. After this testing approach was questioned by the staff, the licensee pointed out that there would actually be insufficient fiber to form a thin bed, i.e., that the thin bed observed during testing was the result of the extra conservatism added to the licensee's latent debris estimate. The staff's conclusion regarding the licensee's evaluation of the ability to form a thin bed is discussed in Section 3.3.3 and Section 3.3.5.
>
> The current documentation of the potential PI fibrous debris includes 15.7 lbm and 17.1 lbm of latent fiber for Units 1 and 2, respectively; 0.04 lbm from fibrous insulation debris; and approximately 11.0 lbm of fiber from fiber cloth and 0.9 lbm from asbestos bellows (assuming complete decomposition of all debris into fibers). As discussed in Section 3.3.3 the licensee conservatively assumed a total of 27.6 lbm

and 29.0 lbm of fibrous debris for Units 1 and 2, respectively. If a typical Nukon™ bulk density of 2.4 lbm /ft$^3$ is assumed to apply to all of the fibrous debris, the predicted uniform fibrous debris bed on 827.3 ft$^2$ of strainer surface would be about 0.17 and 0.18 inches for Units 1 and 2, respectively, which is thicker than the GR recommended criterion of 0.125 inches. For the PI head loss testing, the latent fiber was conservatively increased to 30 lbm. This assumption suggests the licensee recognized uncertainties in the latent debris assessments. Potential uncertainties on latent debris assessments include the limited sampling that was performed and the potential for operational variance. The licensee stated that conservatism in the latent debris assessments exists because: (1) the sampling was performed at the end of an outage when more latent debris would be expected, and (2) sampling was from perceived dirtier areas of containment. The licensee plans to perform additional latent debris assessments designed to more precisely sample the containment. The outcome of these assessments will provide evidence to support the determination of whether PI can be considered as a plant with insufficient fiber to form a thin bed.

Staff Evaluation

The staff considers the treatment of coating debris potentially not consistent with the SE and GR. This guidance states that for head loss testing with a fiber bed thickness greater than that of a thin bed, the coatings debris should be introduced into the tests as a fine particulate. However, the majority of the calculated PI coatings debris, including the ZOI coatings, was introduced as chips. These simply settled to the test flume floor during the head loss test. The licensee was planning to perform additional latent debris assessment to justify that there was insufficient latent fiber debris to form a thin bed. After the new assessment is performed, the licensee needs to evaluate whether the calculated quantity of fiber debris is sufficient to form a thin bed. If the amount of fiber debris is enough to form a thin bed, the licensee needs to justify why the coating chips were used during the head loss testing instead of fine particulate surrogate material. This is **Open Item 3.6.1**. [NRC Audit Report, Section 3.6.3.1.3, page 33]

Scaling Methodology, Test Procedures, Test Results

Scaling Methodology

The PINGP strainer assemblies consist of twenty PCI SureFlow® strainer modules. The prototype strainer had a total strainer surface area of 12.2 ft$^2$. Assuming uniform debris distribution, PCI scaled the total debris loading based on the ratio between the total testing module surface area and the actual strainer surface area. The strainer approach velocity was scaled one to one. Similar to the actual strainers installed at PINGP, the prototype module had a core tube with open slots. One end of the core tube was covered by perforated plate and the other end was connected to the suction pipe. Since only four discs were used in the prototype module, the core tube length was much shorter than that of the actual strainer assembly. The outer diameter of the prototype core tube was 6 inches in comparison with the 12 inch diameter of the actual core tube.

Regarding the scaling methodology used in the strainer prototype testing, the NRC Audit Report states:

> The testing module was scaled assuming no near-field debris settlement. The uniform debris distribution is used to scale the debris loading. The screen approach velocity was kept the same as the plant screen approach velocity. Because the debris was introduced into the test flume within one to three feet upstream of the strainer and no near-field settlement was credited, the scaling methodology is considered acceptable. However, the licensee has not developed a proper scaling analysis to demonstrate the relevance of the prototype core tube to the actual strainer, therefore the staff questioned the validity of directly applying the measured clean strainer head loss data to the new strainer head loss evaluation. This is discussed further as **Open Item 3.6-2.**
> [NRC Audit Report, Section 3.6.3.2.1, pages 33 and 34]

Test Procedures

Prototypical head loss testing was performed by the strainer vendor following generic testing procedures, along with specific debris addition procedures, and testing implementation procedures. The generic testing procedures included the following: test setup; clean strainer head loss test; debris preparation; instrumentation; and debris head loss measurement procedure.

Regarding the testing procedures, the NRC Audit Report states:

> Although the debris introduction sequence may significantly alter the head loss measurement results, the staff believes that the specific debris introduction sequence for PI would not have an unacceptable impact on the head loss. The staff considers the procedure acceptable because of the expected bare screen area and high particulate diffusion in a relatively thin debris bed. The head loss was stabilized very quickly after the fiber was introduced a few feet upstream of the strainer. Therefore, the test termination criteria used for the PI strainer head loss test is considered acceptable. Other relevant testing

> procedures were previously reviewed by the staff during the Watts Bar audit and they were found to be applicable to PI head loss testing. [NRC Audit Report, Section 3.6.3.2.2, page 34]

Test Results

The PINGP prototypical strainer test program consisted of two debris loading tests runs (referred to as Test #1 and Test #2 in Table 1, below). Test #1 was conducted using the design basis debris loading. Test #2 used twice the design basis debris loading. The clean strainer head loss was measured prior to the introduction of debris into the flume. The measured head loss results are summarized in Table 1.

**Table 1**
**Strainer Test Results**

| Test # | Test Module Flow Rate (gpm) | Clean Strainer Head Loss (ft) | Debris Loaded Head Loss (ft) | Average Fluid Temperature (°F) |
|---|---|---|---|---|
| 1 | 76.86 | 0.0203 | 7.766 | 48.0 |
| 2 | 76.87 | 0.0203 | 12.115 | 50.1 |

Based on the measured head loss test data, an extrapolation methodology was used to calculate the debris bed head loss at the specified fluid temperature. During the audit, the methodology used for extrapolation of the head loss was reviewed by the NRC and determined to be acceptable.

During the on-site audit, the NRC Staff identified an inconsistency between the final total head loss tabulated in the analysis and the calculated clean strainer head loss data provided by PCI. NMC used the measured clean strainer head loss from the head loss testing report instead of the calculated clean strainer head loss of the entire strainer array. The finding resulted in the issuance of a Condition Report and relevant corrective actions. During the on-site audit period, the NRC Staff was provided a copy of NMC's Corrective Action Report which was in response to the NRC Staff identified error in the head loss calculation.

Regarding the interpretation of testing results, the NRC Audit Report states:

> Although the staff identified a discrepancy in the licensee's head loss calculation summary report, the extrapolation methodology for debris head loss evaluation is considered acceptable because of the use of standard methodology based on the assumption that the debris bed

> head loss is directly proportional to the absolute viscosity. [NRC Audit Report, Section 3.6.3.2.3, page 35]

Subsequent to the NRC audit, corrective actions were completed to close the discrepancy in the head loss calculation summary report; which included revising the head loss calculation to reflect determination of the clean strainer head loss based on the PCI standard methodology in lieu of basing the determination on data from the prototypical strainer testing.

<u>Clean Strainer Head Loss</u>

Calculation of clean strainer head loss includes determination of head losses through the strainer assemblies and head losses through the connecting piping and fittings.

Attached Piping and Fittings

Figures 1, 2 and 3 showing the general arrangement for the replacement strainers are provided in Section 3.j of this supplemental response. The new PINGP strainer assembly is attached to 14-inch outside diameter strainer discharge piping. The pipe is connected with the 12-inch outside diameter core tube through a 12 inch x14 inch reducer fabricated from 11 gauge stainless steel material. The strainer discharge flow goes through this pipe and then enters two reversed back-to-back angular transitions. After this transitional piping run, the strainer discharge flow passes through a 90 degree, short-radius elbow, followed by several feet of straight pipe, another 90 degree short-radius elbow, and then discharges into the containment sump. There is a head loss associated with each of these flow path segments. PCI performed the hydraulic analysis using industry standard methodology based on Crane Technical Paper 410 (Reference 14). The fluid velocity was calculated based on a single phase flow assumption and the continuity equation.

Regarding determination of the head loss through the attached piping and fittings, the NRC Audit Report (Reference 11) concluded:

> The licensee performed the head loss calculation for the attached piping and fittings using hydraulic analysis methods based on Crane Technical Paper 410, which is considered the industry standard approach for single phase fluid flow resistance evaluation. Since no vapor flashing is expected inside the strainer following a LOCA, the flow resistance can be evaluated assuming a single phase fluid. Therefore, the overall approach using Crane Technical Paper 410 is considered reasonable. [NRC Audit Report, Section 3.6.4.1, page 36]

Strainer Assemblies

One of the unique features of the PCI SureFlow® strainer is the use of a uniform flow control device inside the strainer. The uniform flow control device provides a controlled axial pressure distribution and to achieve uniform flow across the strainer array, regardless of the distance between a particular strainer disk and the exit of the core tube. Advantages of having a uniform flow control device are that the debris may tend to uniformly distribute on the surface of the strainer and it is more difficult for a vortex to form on top of the strainer modules, adjacent to the core tube exit. Absent a flow control device, flows near the pump suction may be higher than average flow across the strainer perforated surface. The challenge of having a uniform flow control device is the accurate prediction of the clean strainer head loss across the flow control device, which consists of a steel core tube with open slots of different size distributed along the tube. The PCI strainer design is different in size for each plant and has different core tubes and open slots. No standard hydraulic analysis methodology is considered applicable to the device considering the complex geometry involved.

An empirical correlation was used to predict the pressure drop across the PINGP strainer array core tube. The correlation is identified as the PCI analysis that was reviewed by the NRC. PCI's correlation was developed based on PCI Boiling Water Reactor Prototype II test strainer head loss testing data. In order to justify that this correlation is applicable to the PINGP strainer array, PCI compared these two strainers and summarized the major differences. The major differences considered were:

1. Internal Core Tube Diameter and Exit Velocity Relationship

   The core tube exit velocity is an important independent variable in predicting clean strainer head loss. Since the PINGP core tube exit velocity is within the range of the test data, the correlation is applicable.

2. Strainer Perforated Sheet Metal Head Loss

   Since the PINGP strainer surface approach velocity is less than that of the Prototype II strainer, the correlation is expected to bound the PINGP perforated sheet metal head loss.

3. Strainer Length Head Loss

   The two strainers have significant different lengths. The calculated friction loss through the core tube of the PINGP strainer array is only

> 0.0082 feet of water head loss, thus, the length difference does not have significant impact.

In addition to these justifications based on analysis, PCI indicated that prototypical head loss testing for the PINGP strainers was conducted with a small section of core tube and open slots. PCI concluded that the clean strainer head loss results demonstrated that the prediction based on the correlation is conservative. Based on the analysis evaluation and the testing, PCI concluded that this correlation could be conservatively applied to the PINGP new strainer array.

In addition to the above summary, the NRC Audit Report contains a significant amount of discussion regarding the clean strainer head loss predicted for the PINGP strainer assemblies (Section 3.6.4 of Reference 11). Regarding the evaluation of the clean strainer head loss, the NRC Audit Report states:

> … the staff does not believe that PCI has provided sufficient justification to demonstrate that the clean strainer head loss correlation, based on PCI Prototype II test data, can be used to conservatively predict PI strainer array clean strainer head loss. Additional justification is needed to demonstrate that the clean strainer head loss correlation is conservative. This justification should at a minimum consider the following aspects of PI strainer array compared with the PCI Prototype II testing module:
>
> 1. Significantly different diameter/length, slot open/ core tube area ratio;
> 2. Existence of an annular flow region in the PI strainer array;
> 3. Different number of slots and slot's open area.
>
> This is **Open Item 3.6-2**.
> [NRC Audit Report, Section 3.6.4.2.3, pages 39 and 40]

<u>Vortex Evaluation</u>

RG 1.82 (Reference 13) provides criteria for standard 1.5 inches or deeper floor grating or its equivalent to suppress vortex formation with at least 6 inches of submergence. The design configuration of the PINGP strainer meets and/or exceeds the 6 inches submergence due to the close spacing of various strainer components and the small hole size of the perforated plate. The configuration for the PINGP strainer in combination with the containment post-LOCA pool level results in a minimum submergence of 2.56 feet for two RHR train operation and 1.4 feet for single RHR train operation to the top of the strainer assembly following a large break LOCA and 1.52 feet for two train operation and 0.63 feet for

single train operation following a small break LOCA. Therefore, RG 1.82 guidance is satisfied with respect to submergence. In addition, the water flow would have to pass through a minimum of 3 inches of combined perforated plate, wire stiffener and cross-bracing. In conjunction with the existing structure submergence, the NMC concluded that these complex geometries further preclude the formation of a vortex in either the core tube or the sump.

In addition to performing an evaluation based on RG 1.82 Rev. 3, PCI also evaluated vortex formation during prototypical head loss testing for PINGP. The testing module was submerged less than 0.63 feet with maximum flow rate representative of both RHR pumps at runout conditions and no vortex was observed. Therefore, PCI concluded that the PINGP strainer discs would not be subject to vortex-induced air ingestion.

Regarding the potential for vortex formation, the NRC Audit Report states:

> The staff agreed with the licensee that based on RG 1.82 Rev. 3, the PI strainer core tubes and the ECCS suction lines would not be subject to direct contact with a vortex because the core tubes and the suction lines are enclosed by the sump pit cover or the strainer discs. However, RG 1.82 Rev. 3 did not address the scenario where the vortex suppressors and the structures above the suction lines are part of the flow path between the suction line and the containment pool, and function as a fluid suction source. Therefore, addressing RG 1.82 does not preclude the possibility of vortex formation on top of the strainer discs and consequent air ingestion.
>
> The PI reduced-scale prototypical head loss testing was conducted with the same average screen surface approach velocity as that for the actual strainer array. Because the testing module size was reduced, the circumscribed velocity was much less than that of the actual strainer. Therefore, it is not clear to the staff that the total fluid flow on top of the strainer was representative and provided a bounding condition. In addition, the size of the testing module may also affect the fluid field above the strainer. PCI has not performed an adequate scaling analysis to demonstrate that fluid conditions above the testing module would bound the actual fluid condition relevant to vortex formation.
>
> Overall, considering the use of PCI uniform flow device and the relative low approach velocity, the staff considers that a vortex is unlikely to form on top of the PI strainer array. However, the licensee has not provided adequate justification to demonstrate this. This is **Open Item 3.6-3.**

[NRC Audit Report, Section 3.6.5, pages 40 and 41]

As noted above, three Open Items (3.6-1, 3.6-2 and 3.6-3) were identified during the NRC audit of the head loss and vortex analyses. NMC actions to close these Open Items are discussed below.

NMC has taken the following actions to close Open Item 3.6-1:

Subsequent to the on-site NRC audit, the Unit 2 Fall 2006 refueling outage was entered during which the second round of latent debris sampling was performed. The sampling was performed at a point in the outage representative of an “as-found” condition, i.e., shortly after unit shutdown but prior to any significant activity inside of containment. The sampling results in the Fall 2006 outage indicated that Unit 2 containment had a total latent debris quantity of 30.2 lbm which is less than 30% of that determined in the initial Unit 2 sampling program. The sampling during the Unit 2 Fall 2006 outage was the initial follow-up latent debris sampling performed as part of the overall latent debris control program. The same engineers who performed the sampling program at the beginning of the Unit 2 Fall 2006 refueling outage were also involved in the containment inspection and close-out activities at the conclusion of the outage. During the inspection and close-out walkdowns, the surfaces inside of containment were visibly cleaner than when the sampling was performed at the beginning of the outage. Therefore, there is reasonable assurance that 30.2 lbm is a conservative latent debris quantity for PINGP Units 1 and 2. With 30.2 lbm of latent debris the total fiber loading inside of containment is approximately 2.0 $ft^3$. Assuming that the total volume of fiber was evenly distributed over the strainer surface area (827.3 $ft^3$), the fiber thickness would be much less than 0.125 inches which is required to form a thin bed. Thus, characterizing the coating debris as chips in the prototype testing is appropriate. The program that NMC has implemented to control latent debris quantities in containment is described above in Section 3.d.

In addition, NMC has obtained additional strainer prototype testing using debris quantities that bound the PINGP design bases debris loadings that demonstrate that the head losses measured during the PINGP prototype testing was conservative. Based on the actions taken, NMC considers Open Item 3.6-1 closed.

NMC has taken the following actions to close Open Item 3.6-2:

Clean strainer head loss correlations used for the PINGP strainer assemblies were developed by PCI. In addition to PINGP, PCI has also provided strainer assemblies to operating nuclear power plants domestically and internationally. Issues associated with the clean strainer head loss correlation are being treated as generic to the PCI strainers. To address any generic concerns, PCI performed follow-up evaluations that conclude that the clean strainer head loss methodology is applicable to the PINGP strainer. Furthermore, PCI has provided the additional evaluation to the NRC (Reference 15). Based on the actions taken, NMC considers Open Item 3.6-2 closed.

NMC has taken the following actions to close Open Item 3.6-3:

PCI performed an evaluation of the potential for vortex formation for the PINGP strainer assemblies. In addition to PINGP, PCI has also provided strainer assemblies to operating nuclear power plants domestically and internationally. Issues associated with the evaluation of the potential for vortex formation are being treated as generic to the PCI strainers. To address any generic concerns, PCI performed follow-up evaluations that conclude that the clean strainer head loss methodology is applicable to the PINGP strainer. In addition, it is noted that no vortex formation was observed during the prototype testing. The depth of water above the top of the strainers in the prototype testing was much less than that predicted for the sump pool during PINGP post-LOCA mitigation. Furthermore, PCI has provided the additional evaluation of the potential for vortex formation to the NRC (Reference 15). Thus, based on the evaluation and testing, vortex formation is not expected and NMC considers Open Item 3.6-3 closed.

g. Net Positive Suction Head (NPSH)

The analyses of minimum containment pool liquid level and RHR pump NPSH margin was reviewed in detail during the NRC Staff audit of PINGP. In conclusion, regarding determination of pump net positive suction head margin, the NRC Audit Report (Reference 11) states:

> The licensee performed the NPSH margin calculations using a standard single-phase hydraulics methodology. The assumptions and the selection of physical parameters that provide the numerical basis for the calculations generally follow conservative guidance provided by RG 1.82. The staff also considered the values of the parameters used in the calculations to be largely reasonable. As a result of the staff's review, the staff considered the NPSH margin results computed by the licensee to be very likely conservative provided that the licensee acceptably resolves **Open Item 3.7-1,** which is associated with the effect of dissolved air on pumping performance. [NRC Audit Report, Section 3.7.4, page 49]

Open Item 3.7-1 states:

> The licensee's NPSH calculations did not consider the effect of cavitation induced by dissolved air and the related issue of air ingestion on pump performance.

Actions taken to address Open Item 3.7-1 are discussed below.

Summary of Methodology (reviewed during NRC audit)

During the recirculation phase of a LOCA, two RHR pumps are available to draw suction from a common containment recirculation sump (Sump B) to provide long-term reactor core cooling. As previously discussed, the containment spray pumps are not operated during sump recirculation operations.

Calculations were performed to establish the RHR pumps' NPSH margins during the recirculation phase of a LOCA in the absence of the planned replacement strainers and collected debris. These values of NPSH margin are used as criteria for determining the adequacy of the replacement sump strainer design. NPSH margin was determined for sump liquid temperatures of 200°F and 60°F, for large-break and small-break LOCAs, and for one and two trains of the RHR system operating in recirculation mode. The calculations utilize the definition of NPSH margin from RG 1.82 (Reference 13), which is the difference between the NPSH available (NPSHA) and NPSH required (NPSHR).

<u>Pump NPSH Margin</u>

The NPSHA is computed using a single-phase fluid hydraulic model constructed based on plant isometric drawings and piping diagrams. The NPSHA is defined as the difference between the pressure (normally expressed as a pressure head in feet of water) of the water at the inlet to the RHR pump and the vapor pressure of the water at the assumed sump water temperature. The pressure at the inlet to the pump is equal to the atmospheric pressure at the surface of the pool of water on the containment floor, plus the static head of liquid above the pump inlet centerline, minus the sum of hydraulic losses along the flow path from the surface of the pool to the pump centerline. Note that this calculation of NPSHA excludes the sump strainer assembly and debris bed head losses which are evaluated separately.

The calculations compute the hydraulic head loss using a model that consists of a collection of pipe segments, elbows, valves, tees, pumps and the sump. Pump flow rates are determined, and flow resistance factors are determined for the pipe segments and components using standard single-phase hydraulics methodology. Hydraulic resistance values were obtained from Crane (Reference 14). Given the assumed flow rates, fluid density, containment water level and component elevations, the pressure drop along each segment and across each component are computed. The fluid head loss from the containment pool surface to each pump is computed (excluding the strainer assembly and debris bed).

The analysis conservatively assumes that the pressure at the surface of the containment pool is equal to the vapor pressure of the sump water at its assumed temperature, consistent with NRC guidance with respect to NPSH margin calculations (Reference 13). As a result of this assumption, the NPSHA is simply equal to the difference between the hydrostatic head of liquid above the RHR pumps' centerline and the fluid head loss along the suction path to the pumps. The hydrostatic head is computed using a model for the water inventory available on the containment floor at the initiation of recirculation along with information concerning the geometry of internal structures that influence the liquid level in containment.

The NPSHA is computed for each pump as a function of assumed sump temperature and pump flowrate conditions. The NPSH margin for the system is computed in feet of liquid head as the difference between the NPSHA, evaluated at the applicable sump temperature, and the NPSHR. The NPSHR is provided by the pump manufacturer from measurements at room temperature. A hot fluid correction factor is not used to increase the NPSH margin to account for elevated sump liquid temperatures following a LOCA (relative to the pump manufacturer's data at room temperature). This approach is consistent with NRC guidance for performing NPSH margin calculations (Reference 13).

There are several parameters that influence the determination of the NPSH margin. The approach to determine these parameters is described in more detail below:

<u>ECCS Configuration</u>

Water transferred to the containment and potentially available for recirculation following a LOCA includes: (1) water blown down from the RCS as a result of the break; (2) RWST water; and (3) SI accumulator water.

The plant response to a large-break LOCA involves SI accumulator injection, safety injection from the RWST using the SI pumps and the RHR pumps, and long-term recirculation using the RHR pumps. The NPSH calculations consider three time periods following the initiation of a LOCA: (1) the period of injection from the RWST prior to the initiation of alignment for recirculation; (2) the period of alignment for recirculation; and (3) the period of established recirculation. Potential single failures were considered when evaluating the plant response. The potential single failures could impact ECCS flow rates, containment pool liquid level and drawdown times of the liquid in the RWST, affecting the time period for the injection phase. As shown in Figure 4 (near end of this Enclosure), the ECCS is divided into two independent trains. Each train's RHR pump draws water through independent piping from the containment sump. Thus, a single failure will not affect an individual pump flow rate or head loss from the sump to the pump suction. Head loss across the strainer is maximized with both RHR pumps operating. Containment pool liquid level is potentially affected by a single failure during the injection phase, resulting in a reduced quantity of liquid pumped from the RWST. This is factored into the determination of pool minimum liquid level. (Note that discussion of CS is not included here since the RWST water volume injected by CS is included in the total calculated RWST water assumed in containment. CS is shut off prior to transfer of RHR to recirculation.)

During the injection period, the SI accumulators deliver water to the vessel. In the case of a large-break LOCA, the SI accumulators dump their entire inventory. For the small-break LOCA analyzed in the NPSH calculation, only a fraction of the inventory from the SI accumulators is credited to be delivered.

For the large-break LOCA, during the safety injection time period, RWST water is delivered via the safety injection and RHR pumps, with the computed volume delivered based upon the minimum RWST level required by Technical Specifications (68%). During the period of alignment to recirculation, procedures call for the continued operation of both SI pumps and both RHR pumps in injection mode until a specified time that one of the RHR pumps is reconfigured to recirculation mode. The cumulative volume of water delivered by this time would depend on whether one or two trains of RHR have functioned successfully during the injection period. Immediately after the alignment to recirculation is completed for one RHR pump, the RHR pump would experience the minimum water level in containment which is the limiting water level condition for the NPSHA calculation for the RHR pumps. During the period of established recirculation for both RHR pumps, the RHR pumps draw suction from Sump B and provide flow to the reactor vessel. At this point in the accident, the inventory of the RWST would have been reduced to the 8% level, and the water volume delivered to the containment would be maximized.

For a small-break LOCA, the SI pumps provide high-pressure injection flow to the vessel from the RWST. At the time of transfer to the high-pressure recirculation mode, one RHR pump is started to provide flow to one high-head SI pump in the "piggy-back" mode. At this time in a small-break LOCA, the inventory of water in containment is minimized, and this volume of water is evaluated for the calculation of NPSH for the RHR pumps.

Regarding the ECCS configurations credited in the NPSH calculation, the NRC Audit Report concluded:

> Given the data presented for flowrates, setpoints and liquid inventories, a sampling of the licensee's calculations indicates that they are reasonable and consistent with NRC guidance. [NRC Audit Report, Section 3.7.3, page 46]

Minimum Water Level

The water level of interest to the calculation of NPSHA is the static height of liquid as measured from the RHR pump centerline to the surface of the pool in containment. This height of water can be represented as the sum of the height of liquid from the RHR pump centerline to the basement floor, plus the additional height from the basement floor to the surface of the pool in containment. The RHR pump centerline is at elevation 666.85 ft, and the basement floor is at an elevation of 697.5 ft.

The water level in containment is computed for the various scenarios from the inventories of water delivered from the RCS, the RWST and the SI accumulators. The total volume of water delivered for each scenario was distributed to a number of "sinks" in containment that are delineated in the calculation. The "sinks" include sumps, cavities, other volumes, and the mass of steam in containment. The relevant containment geometry, including the occupied containment volume, is presented in the calculation. The remaining water is then assumed to fill containment from the containment floor upwards, to a liquid level determined by the free volume available as a function of height above the containment floor. The liquid sources, "sinks" and structures that could displace liquid volume in the bottom floor of containment are detailed in the analysis that was reviewed as part of the NRC Staff audit. To summarize, liquid sources, "sinks", and structures are determined as follows:

- Sources of liquid to the pool include the RCS, the RWST and the SI accumulators. The credited volumes from these sources are minimized by assuming minimum initial volumes, maximum final volumes and conservative initial temperatures. A conservative minimum volume of water in containment for the purpose of calculating the NPSHA for the RHR pumps occurs during the process of alignment from injection to recirculation. Consistent with plant procedures, the calculation assumes that the injection pumps continue to discharge water into containment during the alignment period and that this added water continues to raise the containment water level until the first RHR pump is started in recirculation mode.

- Available "sinks" include such areas as sumps, cavities, empty spray piping, and the mass of the steam in containment. All of these areas are assumed to be completely empty prior to the event which maximizes the water volume that could be held-up in these "sinks".
- Structures that could displace liquid in the pool volume were conservatively considered. In this case, conservative would be a minimum volume is used for these structures. A minimum liquid volume displacement results in a minimum pool liquid level.

Regarding determination of minimum water level, the NRC Audit Report concludes:

> Based upon the discussion above, the staff's review of the licensee's water level calculation indicates that the relevant factors have been considered and that, in general, assumptions were made that conservatively minimize the computed water level. [NRC Audit Report, Section 3.7.3, page 47]

<u>Sump Liquid and Containment Atmosphere Temperatures</u>

Two sump water temperatures were assumed in the calculations, 200°F and 60 °F. 200°F is conservative from an NPSH perspective because, for most of the period directly following the LOCA, the sump temperature is greater than 200°F and assuming a lower temperature minimizes the contribution of the static head of water to the NPSHA. In addition, the lower temperature leads to a higher suction line head loss given the same volumetric flowrate, which is also conservative. The 60°F case was calculated to determine the effect of liquid contraction on static head and on the resulting NPSH, which would account for conditions where recirculation continues to the point where the containment pool has cooled down significantly from its initial value.

The containment atmosphere temperature was taken as 254°F for any time that the sump liquid temperature is greater than 200°F. This atmospheric temperature maximizes the steam mass in the containment atmosphere which, in turn, minimizes the volume of liquid on the containment floor and the static head of liquid.

Regarding sump liquid and containment atmosphere temperatures used in the NPSH calculation, the NRC Audit Report concludes:

> The staff considers the licensee's choices of temperatures to be conservative since they bound the values expected during a LOCA. [NRC Audit Report, Section 3.7.3, page 48]

Pump Capacities

The assumed RHR pump capacities influence the piping frictional head loss aspect of the NPSHA calculation. For this purpose, the calculations use the runout flowrate of an RHR pump (2600 gpm), which is conservative because it maximizes suction line head losses, thereby minimizing the calculated NPSHA. As previously discussed, using 2600 gpm for the assumed pump flow rate is approximately 20% greater than the maximum predicted pump flow rates based on the system hydraulics. This 20% flow increase results in approximately 35% margin in the predicted head loss.

Containment Pressure

The NPSHA calculations conservatively assume, in accordance with the guidance in Regulatory Guide (RG) 1.82 (Reference 13), that the pressure at the surface of the containment water pool is equal to the vapor pressure of the sump water at its assumed temperature. No increase in NPSHA was credited based upon elevated containment accident pressures resulting from the LOCA or for the initial atmospheric pressure in containment prior to the postulated LOCA.

NPSHR and the Hot Fluid Correction Factor

The NPSHR of the RHR pumps is specified as a function of pump flow rate in the form of a graph from the pump manufacturer. The NPSHR is given as 14 feet of water at the runout flowrate of 2600 gpm and at the test temperature. The tests are usually performed by the manufacturer at room temperature, a temperature much lower than the assumed sump water temperature. RG 1.82, Section 1.3.1.5, provides guidance that a hot fluid correction factor should not be used in determining the NPSH margin. Not crediting a hot fluid correction factor is conservative and consistent with this regulatory guidance.

As stated above, the NPSHR value of 14 feet corresponds to a pump runout flow rate of 2600 gpm. The NPSHR at 2085 gpm, the maximum predicted pump flow rate, is approximately 9 feet. Thus, basing the NPSHR on pump runout flow adds 5 feet of margin.

Piping Network Head Loss

Piping head loss calculations are performed for the large-break LOCA case assuming a sump water temperature of 200°F and the RHR pump runout flowrate of 2600 gpm. The computed piping network head loss (4.7 feet of water) was applied to the small-break LOCA calculations using the argument that “...the small break LOCA uses the head losses corresponding to an RHR flow rate intended to bound the maximum flow rate expected for a large break LOCA.” This is acceptable since the small-break LOCA piping head loss depends on the pump flowrate, and the maximum RHR flowrate is also applicable to the small-break LOCA.

NMC has taken the following actions to close Open Item 3.7-1:

The head loss analyses have subsequently been revised to consider the effect of cavitation induced by dissolved air and the related issue of air ingestion on pump performance. Gas solubility is a function of pressure and temperature. For a given solution, a reduction in pressure can result in gas coming out of solution. Similarly an increase in temperature reduces the solubility and results in gas coming out of solution. The analysis addresses the potential for gas to come out of the recirculation sump solution downstream of the strainer (for example, at the RHR pump suction). This concern pertains to the liquid in the containment pool following a LOCA. There will be some amount of dissolved gas in the liquid in the containment liquid pool. The specific concern is if some of this gas could come out of solution at the suction of the RHR pump(s) and adversely affect RHR pump operation. As noted either of two changes could result in the dissolved gas coming out of solution: (1) a decrease in the pressure of the liquid; and/or (2) an increase in the temperature of the liquid. These are addressed separately, and summarized below.

Pressure Decrease

The pressure at the pump suction could be less than the pressure of the containment liquid pool if the pressure losses at the strainer and the piping to the RHR pump suction are greater than the static head between the sump liquid level and the pump suction. The analysis shows that the gain in static head from the sump pool to the RHR pump suction is much greater than the pressure losses through the system (i.e., strainer assembly and piping from sump to RHR pump suction). Thus, the pressure at the RHR pump suction would be greater than the pressure at the pool surface. Therefore, dissolved gases would not come out of solution due to a reduction in pressure.

Temperature Increase

There are no mechanisms available to add heat to the fluid between the containment liquid pool and the pump suction. In fact, although not credited, some temperature decrease would be expected due to heat losses from the piping to ambient. Thus, the temperature at the RHR pump suction would not be greater than the temperature at the pool.

Therefore, dissolved gases would not come out of solution due to an increase in temperature.

Conclusions

This analysis demonstrates that dissolved gases will not come out of solution at the suction of the RHR pump since the pressure will be greater at the pump suction than at the containment liquid pool surface and the liquid temperature (at the most) would be the same as the containment liquid pool. Therefore based on this analysis, cavitation induced by dissolved or ingested air is not expected and NMC considers Open Item 3.7-1 closed.

h. Coatings Evaluation

Regarding containment coatings zone of influence, the NRC Audit Report (Reference 11) states:

> The quantities of LOCA-generated qualified coatings debris were based on applying the spherical ZOI model. The NRC SE recommends a ZOI for qualified coatings with an equivalent radius of 10 length/diameter (L/D) for the largest pipe. The PI qualified coatings debris is based on a 12 L/D ZOI radius about a 29-inch hot-leg break. This ZOI is larger than a 10 L/D ZOI based on a 31-inch interim-pipe break, and the 12 L/D ZOI is larger than the vault in which the break is located. Therefore, the PI qualified coatings ZOI conservatively encompasses all of the qualified coatings within the vault. The staff therefore finds the licensee's treatment of the ZOI for coatings acceptable. [NRC Audit Report, Section 3.8.1, page 49]

NMC has not made any changes subsequent to the audit that affect the coating generation analysis and these conclusions remain applicable to PINGP.

Regarding containment coatings debris characteristics, the NRC Audit Report (Reference 11) states:

> As discussed in the Coatings Zone of Influence Section of this report (above), the licensee applied a ZOI of 12 L/D on a 29-inch hot-leg break. All coatings were assumed to fail as 10 μ particulate within the ZOI. For coating debris outside of the ZOI, the licensee assumes that all of the unqualified coatings will fail as 10 μ particulate. The quantities of unqualified coatings within containment were determined by containment walkdown assessments.

The NRC Staff's SE addresses two distinct scenarios for formation of a fiber bed on the sump screen surface. For a thin bed case, the SE states that all coatings debris should be treated as particulate and assumes 100% transport to the sump screen. For the case in which no thin bed is formed, the staff's SE states that the coating debris should be sized based on plant-specific analyses for debris generated from within the ZOI and from outside the ZOI, or that a default chip size equivalent to the area of the sump screen openings should be used. As discussed below and in the latent debris section of this report …, it is unclear whether the plant-specific debris loading for PI results in a fiber bed across the strainer surface.

Although the licensee's analytical approach for coatings debris characteristics is acceptable to the staff, the characteristics of the coatings surrogates used in the head loss testing are not consistent with the analysis; coating chips were used in the head loss tests rather than fine particulate. The staff has concerns about the discrepancy in the debris characteristics used in the analysis and those used in the testing. During the audit representatives of PI stated that they plan to revise the latent debris calculations based on a walkdown of the Unit 2 containment. By revising the latent debris calculations the licensee plans to reduce the amount of fiber in order to justify the use of coatings chips rather than particulate in the head loss testing. The staff's concerns with the head loss testing are discussed in greater detail in the head loss section of this report …. The staff will review any revisions to the analysis as part of the final closeout of Generic Letter 2004-02.

During interaction with PWR licensees for resolution of GSI-191, the NRC staff has questioned the current industry method of assessing qualified coatings. The staff has asked licensees to either prove that their assessment techniques can accurately identify the amount of degraded qualified coatings in containment, or assume all of the coatings fail. The licensee stated that they will rely on the results of an ongoing test program conducted by Electric Power Research Institute and the Nuclear Utilities Coatings Council to validate their assessment techniques at PI. The referenced testing will subject visually sound and visually degraded coatings to physical testing, that is adhesion tests, in an attempt to show that visual assessments are capable of identifying coatings that would not remain adhered during a design basis accident. This testing has not been performed and therefore has not been reviewed by the NRC staff. Assessment of qualified coatings is **Open Item 3.8-1**, pending industry validation testing and NRC staff review of the results. [NRC Audit Report, Section 3.8.2, page 50]

Open Item 3.8-1 states:

> The licensee has not completed an assessment of qualified coatings to remain adhered during a design basis accident, stating PI will rely on the results of an ongoing test program conducted by Electric Power Research Institute and the Nuclear Utilities Coatings Council to validate their assessment techniques.

The resolution to Open Item 3.8-1 is discussed below. It is noted that Open Item 3.6-1 pertains to the sizing of the coating debris used during the strainer prototype testing. The resolution to related Open Item 3.6-1 is discussed above in Section 3.f of this supplemental response to GL 2004-02.

Summary of Methodology (Reviewed during NRC Audit)

As discussed above in Section 3.b, the objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; (2) the amount of debris generated by the break jet forces; and, (3) the size characteristics of the postulated debris. Sections 3.4 and 4.2.2 of the GR (Reference 7) and the NRC SE (Reference 8) provide the methodology to be considered in the ZOI and debris generation analytical process. The ZOI refinement discussed in Section 4.2.2.1.1 of the SE was applied, which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term.

For coating debris, ZOIs sized in accordance with the guidance in the SE were assumed, except that a 12 L/D sphere was used for the coatings. When this ZOI was overlaid onto composite piping plans at the selected break locations, it was found that the ZOI would encompass nearly the entire vault. Thus, all of the qualified coatings within the vault with the postulated break were assumed to be generated into debris.

NMC has taken the following actions to close Open Item 3.8-1:

The containment coating inspection involves conducting a general visual examination of accessible coated surfaces within the Containment Building. Examinations of coatings are conducted by qualified condition assessment personnel as defined in the Safety Related Coatings Program. A detailed assessment report is written as a follow up action to the containment coating inspection procedure to document activities performed to verify coatings continue to meet the design and licensing basis. This report includes a summary of inspections performed, new findings, unqualified and degraded coatings remaining in containment, and remedial actions taken (e.g., removal or repair). The report also compares current coatings performance against established acceptance criteria and previous assessment results. Detailed instructions on conducting coating examinations, including deficiency reporting criteria and documentation requirements are delineated in PINGP procedures.

The acceptability of visual inspection as the first step in monitoring of Containment Building coatings is validated by EPRI Report No. 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings," August 2007. Monitoring of Containment Building coatings is conducted at a minimum, once each fuel cycle in accordance with the PINGP Safety Related Coatings Program. Qualified inspectors, that meet the guidance of ASTM D 5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant, will perform containment coating inspections during the next refueling outage in each unit. These inspections implement the findings of EPRI Report No. 1014883. Therefore, based on the EPRI evaluation and implementation of its findings, NMC considers Open Item 3.8-1 closed.

i. Debris Source Term

Regarding debris source term refinements, the NRC Audit Report (Reference 11) states:

> Section 5.1 of the GR and SE discuss five categories of design and operational refinements which could affect the debris source term.
>
> 1. Housekeeping and foreign material exclusion programs
> 2. Change-out of insulation
> 3. Modification of existing insulation
> 4. Modification of other equipment or systems
> 5. Modification or improvement of coatings program
>
> The SE states that these additional refinements should be evaluated for their potential to improve plant safety and reduce the risks associated with sump screen blockage.

Staff Evaluation

The licensee addressed these candidate refinements as follows:

1. Housekeeping and foreign material exclusion programs

   The NRC Staff reviewed the PI Containment Cleanliness, Foreign Material Exclusion, and Engineering Change Process control programs for their potential to maintain housekeeping and foreign material control. The staff found that these programs appear to adequately control their respective processes for maintenance of the debris source term as needed to maintain ECCS strainer function. One item that was noted during the audit of PI Procedure SP 1750 [2750] "Post Outage Containment Close-Out Inspection" was that this procedure does not require a final verification by the Operations or Plant Manager. Although this is not a requirement, many plants consider this to be the appropriate level of verification for this program.

2. Change-out of Insulation

   The licensee has not committed to change-out of any insulation as a corrective action to meet the requirements of GL 2004-02.

3. Modification of Existing Insulation

   The licensee has not committed to modification of any insulation as a corrective action to meet the requirements of GL 2004-02.

4. Modification of Other Equipment or Systems

   The licensee indicated that a number of modifications were to be made to other equipment or systems related to the change-out of the ECCS sump strainer. Several existing components, such as cable tray supports, were to be relocated and/or reconfigured to clear space for the new strainers. The modification also removed the trash rack over the sump that was used to remove large pieces of debris. The licensee stated that this will remove the potential for large debris to clog upstream flow paths to the ECCS strainer. Other changes associated with this modification included capping abandoned waste liquid disposal pipes located in the sump. The staff agreed with the licensee that these additional modifications will support the new ECCS strainers in their ability to reduce the risks associated with sump screen blockage, and did not identify the need for consideration of any additional modifications needed in this area. [NRC Audit Report, Section 4.1, pages 51 and 52]

It is noted that the NRC Audit Report did not address item 5, modification or improvement of containment coatings program. NMC actions with respect to item 5 are discussed below.

NMC has not made any changes subsequent to the audit that affect the conclusions in the audit report regarding refinements to the debris source term and the conclusions remain applicable to the PINGP. However, the following additional points are highlighted:

- Reducing debris source term

  Because PINGP uses RMI in lieu of fiber insulation, there are very low quantities of fiber inside of containment. The latent fiber is the primary contributor to the fiber quantities inside of containment. Consequently, monitoring and control of latent fiber is very important since a small increase in fibrous material could lead to a postulated thin bed. NMC recognizes the importance of minimizing the latent fiber inside of containment. Reducing the latent fiber is primarily accomplished through the containment cleanliness program. At the conclusion of each plant outage, aggressive cleaning is performed inside of containment to minimize latent dirt, dust, fiber, and so on. The results of this cleaning were evidenced during the Unit 2 Fall 2006 refueling outage.

  During the Unit 2 Spring 2005 refueling outage, the first round of latent debris sampling was performed. This sampling was performed at a point in the outage to maximize the latent debris, i.e., near the completion of the outage but prior to any organized clean-up activities. The results from the Spring 2005 Unit 2 sampling indicated that Unit 2 had a total latent debris quantity of approximately 114 lbm. Prior to Unit 2 startup following the Spring 2005 refueling outage, an aggressive clean-up campaign was undertaken.

  At the beginning of the Unit 2 Fall 2006 refueling outage the second round of latent debris sampling was performed. The sampling was performed at a point in the outage representative of an “as-found” condition, i.e., shortly after unit shutdown but prior to any significant activity inside of containment. The results from the sampling indicated Unit 2 had a total latent debris quantity of 30.2 lbm. During the inspection and close-out walkdowns, the surfaces inside of containment were visibly cleaner than when the sampling was performed at the beginning of the outage.

Thus, there is objective assurance that the containment cleanliness program is effective at reducing the latent debris quantities inside of containment.

- Modification or improvement of coatings program

  NMC has not made changes to the coatings program as a corrective action to meet the requirements of GL 2004-02. However, the coatings program is being brought into compliance with ASTM D 5163-05a as discussed in the actions to close Open Item 3.8-1 above (Section 3.h of this Supplemental Response).

- Programmatic controls

  As discussed previously, NMC has developed a Latent Debris Monitoring Program that determines latent debris levels and uses that information to trend and project future debris levels. This program maintains debris levels less than that which could form a 1/32 inch bed due to fiber in the presence of chemical effects precipitants.

- Foreign material exclusion programmatic controls

  During the NRC Audit of PINGP, the NRC Staff reviewed the containment housekeeping practices, foreign material exclusion and engineering change processes to evaluate their ability to maintain housekeeping and foreign material control. As noted above, the NRC found these programs to be adequate.

- Programmatic controls to plant changes

  Plant changes (either permanent or temporary) are controlled using the NMC engineering change (EC) process. The EC process for these types of changes includes checklists that require the preparer and reviewers to evaluate potential affects that the proposed plant change could have on the sump strainer and associated analyses.

- Maintenance activities

  Maintenance activities are controlled to ensure that potential sources of debris are not introduced and the analyses assumptions are maintained. During plant conditions above Mode 5, containment is treated as a foreign material exclusion (FME) area. Site procedures require that all items entering containment are logged. Use of the log provides assurance that materials entering containment are removed and do not become a potential debris source. Materials allowed inside of containment, during these plant conditions, are evaluated to ensure that they could not adversely impact the sump or equipment operability.

j. Screen Modification Package

The sump screen modification package was reviewed in detail during the NRC audit of PINGP. Regarding the sump screen modification package, the NRC Audit Report (Reference 11) states:

> Based on the review described in Section 3.0 of this audit report, the staff believes that the new sump design will be able to accommodate the maximum volume of debris. However, Open Item 3.4-1 … has been identified relating to the assumed amount of latent debris as it impacts whether or not a thin bed can be formed. [NRC Audit Report, Section 4.2, page 52]

The resolution to Open Item 3.4-1 is discussed above in Section 3.d of this supplemental response to GL 2004-02. It is also noted that the response to Open Item 3.6-1 also addresses the possibility for forming a thin bed: refer to the discussion in Section 3.f.

Summary of Modification

In response to NRC GL 2004-02 (Reference 1), NMC removed the existing trash racks and installed a new Sure-Flow® strainer designed by Performance Contracting, Inc (PCI). The diameter of the strainer holes is designed to ensure that any debris that can pass through the strainer will not cause blockage or excessive wear to components in the ECCS flow path. This includes pumps, valves, nozzles, and the nuclear fuel. The new strainer is a passive component for which the only identified failure mode is structural failure. The strainer assembly is designed specifically for PINGP and is designed to provide both debris filtering and vortex suppression.
The intent of the modification is to provide the hardware changes required for full resolution of NRC GSI-191 for PINGP. This modification replaces the existing Metcon grating/screens for the PINGP Sump B located outside the missile shield walls on the basement floor of the Unit 1 and Unit 2 Containment Buildings. To prevent debris from entering the open sump, the original screen configuration utilized a standard floor grate that extended from the floor in an A-frame shape with 3/4 x 3-11/16 inch openings to completely cover the sump inlet. The screen provided approximately 49.2 $ft^2$ of available flow area. Due to the size of the screen openings, only large pieces of debris were prevented from entering the sump. In addition, the sump is surrounded by a six-inch high curb which was used to prevent sediment from entering the pit.

The modification installed a passive, safety-related Sure-Flow® Strainer assembly engineered and manufactured by Performance Contracting, Inc (PCI). The strainer arrangement for each of the PINGP units consists of two strainer headers of Sure Flow® Strainer modules connecting to a common sump cover plate designed to form a suction chamber in the existing sump. Modification installation is complete in both Unit 1 and Unit 2.

The effective surface area of the new strainer for each header is 413.65 $ft^2$, for a total of 827.3 $ft^2$. This will reduce flow velocity through the strainers to 0.014 fps at a total RHR flow rate of 5200 gpm. 5200 gpm corresponds to both RHR pumps at pump runout flow conditions which, as discussed above, bounds the maximum flow rates possible based on pump capability and system performance. The strainer configuration is designed to limit the head loss to less than 10 feet during post-LOCA design conditions.

There are 10 modules in each strainer train (Figure 1), a core tube, and mounting tracks. The modules are essentially identical with the only difference being the hole sizes in the core tube. Each module is independently supported. The modules are connected with thin gauge stainless steel bands that are used to prevent debris from entering the system between the two modules. This connection permits relative motion in the axial direction as the core tube can slide relative to the stainless steel bands.

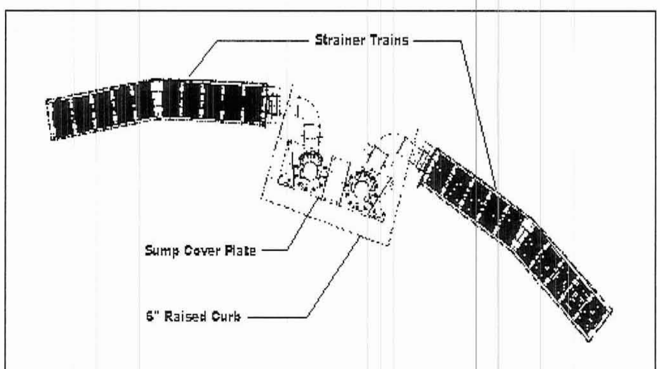



**Figure 1**
**PINGP Strainer Assembly Top View**

Each module (Figure 2) is made of stainless steel perforated plate with hole-diameter of 0.085 inch. The perforated sheets are riveted together along the outside edge and shop welded to a core tube along the inner edges. The modules are located approximately 3 inches above the containment floor. As such, the six-inch high curb surrounding the sump no longer provides a barrier to prevent sediment from entering the strainers. The sump is now totally enclosed by the sump cover plate preventing material from falling directly into the sump without passing through the strainer assemblies (Figure 3).

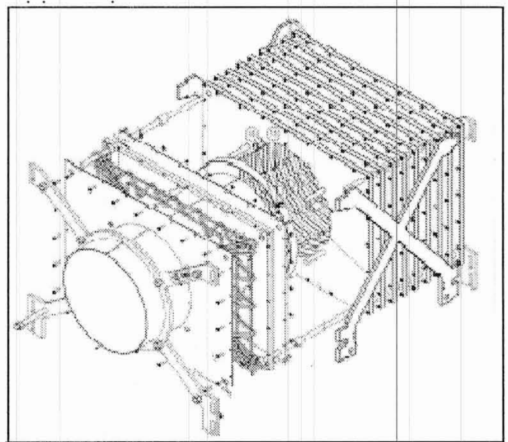


Figure 2
Single PCI Strainer Module

The core tube is a 12-inch diameter, 16-gauge, stainless steel pipe. The core tubes of each module are connected together by means of a coupling sleeve fitted over the core tubes and secured by a latch. The core tube has "windows" cut in the wall to admit flow of strained water from the inside of the perforated sheets. The modules are pin connected to a mounting track, which in turn is bolted to the containment floor. The mounting track is made of structural shapes: angles and plates. The strainer design allows for disassembly, replacement of modules, or addition of future modules as needed. A 14-inch schedule 10 stainless steel pipe, double elbows (one vertical, one horizontal with an intermediate straight piece) and 14 inch x12 inch eccentric reducer sloped upwards from the first module delivers the strained water into the sump by penetrating through the sump cover plate. The vertical elbow attached to the sump cover plate is removable to allow access into the sump during outages for inspection and testing.

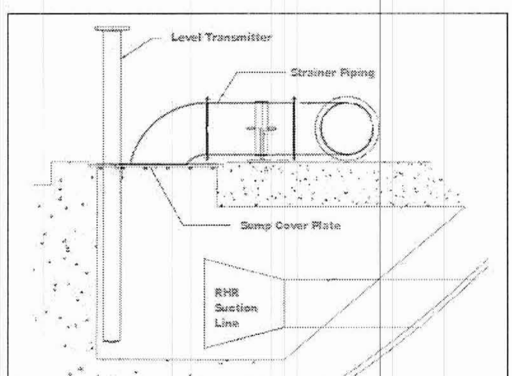



Figure 3
Containment Sump B Side View

Two 6-inch pipe-stands for the B-Sump level transmitters in each unit were relocated to the corners of the sump cover plate and supported on the 6-inch wide curb 1 ft - 3 inches above the sump bottom and restrained using new seismic restraints. The standpipe has seven 1-inch diameter holes above the bottom of the strainer core tube that were sealed to prevent ingestion of air into the sump. The remaining open holes are covered with screens containing 0.063 inch square openings, which are less than the new strainer perforations. These level instruments are considered backups and would be used only as indication to inform the operator that there was sufficient level in the sump to switch from the injection to recirculation phase.

Other changes associated with this modification included capping abandoned Waste Liquid Disposal pipes located in the sump, and relocating and/or reconfiguring several existing components to remove interferences associated with the new strainer installation.

k. Sump Structural Analysis

The structural analyses include two separate analyses, one for the strainer assemblies and one for the sump cover plate and connecting piping between the strainers and the cover plate.

Regarding the sump strainer structural analysis, the NRC Audit Report states:

> Based on the review of the information provided, the staff concludes that; (1) The standard used in the analysis meets the guidance of NUREG-0800, Section 3.8.4 in which the ANSI/AISC Standard N690-1984 is to be followed for strainer analysis, and (2) The load combinations used in the analysis, which considered normal operating, operation basis earthquake and design basis earthquake loading conditions, are in accordance with the guide lines described in the NUREG-0800, Section 3.8.4. The seismic spectrum and damping ratios used in the dynamic analysis are reasonable and within the specification identified in RG 1.60. The analysis and calculation results showed that the proposed suction strainer modules and their supporting structures meet Class I Seismic Criteria for their intended safety function. Because an acceptable result was obtained using methods consistent with NRC-approved guidance, the staff finds the strainer structural loading to be acceptable. [NRC Audit Report, Section 5.1, page 54]

Regarding the evaluation of the sump cover and piping for the strainers, the NRC Audit Report states:

> Based on the review of the information provided, the staff concludes that the standards used in the analysis are compatible with the guidance provided in Regulation Guide (RG) 1.70, in which the ANSI/AISC Standard N690-1984 is the listed standard. The load combinations used in the analysis, which considered normal operating, operation basis earthquake and design basis earthquake loading conditions, are in accordance with the guidelines described in the NUREG-0800, Section 3.8.4. The seismic spectrum and damping ratios used in the dynamic analysis meet the provisions of RG1.60. The analysis/calculation results show that the proposed strainer piping

and their supporting elements meet Class I seismic criteria for their intended safety function. [NRC Audit Report, Section 5.1, page 56]

NMC has not made any changes subsequent to the audit that affect the structural analysis of the sump strainers, covers or associated piping and these conclusions remain applicable to PINGP.

Summary of Methodology (reviewed during NRC audit)

General guidance for considerations to be used when performing a structural analysis of the containment sump strainer is contained in the NEI GR (Reference 7) and the NRC Staff SE (Reference 8). General items identified for consideration include: (1) verifying maximum differential pressure caused by combined clean strainer and maximum debris load at rated flow rates; (2) geometry concerns; (3) sump strainer material selection for the post-accident environment; and (4) the addition of hydrodynamic loads from a seismic event. The analyses for the replacement sump strainer include structural analyses and related calculations.

<u>Sump Strainer Structural Analysis</u>

The structural analysis of the strainer assemblies were performed using a combination of manual calculations and finite element analyses using the GTSTRUDL and the ANSYS finite element model computer program. In the evaluation, seismic loads response analysis on the strainers and their supporting elements was performed to determine whether they meet Class I seismic criteria for their intended safety function after an accident. The strainer performance was analyzed to verify it can withstand the hydrodynamic loads and inertial effects of water in the containment basement, at full debris loading, without loss of structural integrity.

In the analysis, the following considerations/assumptions were used:

1. Thermal loads

   Thermal loads are not included since the strainers are free standing and free to expand without restraint.

2. Pressure loads

   (a) The normal operating pressure load (pressure drop across a clean strainer) were considered; and
   (b) The differential pressure load during accident conditions when the strainers are covered with debris was considered.

3. Dynamic loads

   (a) The inertial effects of the added hydrodynamic mass due to the submergence of the piping were considered; and
   (b) Hydrodynamic drag loads due to sloshing were not considered. The analysis of the seismic sloshing loads for the PINGP strainers concluded that the maximum sloshing load is less than 5 lbs per module; therefore, this load can be ignored in the analysis.

4. Seismic loads

   A response spectrum of the design basis earthquake was used in the analysis. The strainer assembly was qualified using the response spectra method; therefore, a response spectra analysis was performed to analyze the seismic inertia loads. Horizontal and vertical spectra for the design basis earthquake load case provided at elevation 711 ft - 6 inches were used in the analysis. The sump strainers are actually located at elevation 697 ft - 6 inches; thus, using the spectra for elevation 711 ft - 6 inches is conservative.

5. Flood loads

   These loads were considered; however, no additional load was used in the analysis because of the submerged condition (hydrostatic load was determined to not be an issue).

6. Missiles, pipe whipping and pipe rupture loads

   Loads from missiles, pipe whip or jet impingement were not considered since the analyses show that there are no direct paths from potential break locations to the strainers. This was confirmed by the NRC during the on-site audit (discussed in Section 5.1 of Reference 11).

Detailed strainer structural analysis calculations were performed which included manual calculations that produced the inputs necessary for the structural analysis utilizing computer software (GTSTRUDL and ANSYS). The analysis results are presented in terms of maximum stress interaction ratios (i.e., calculated stress divided by allowable stress). The results showed that all ratios were smaller than 1.0 by using standards of USAS (ANSI) B31.1 Power Piping 1967 and 1998 Editions, AISC-1963 Edition, American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, Subsections NB, NC, and Appendices, 1998 Edition, through 1999 Addenda, and ANSI/AISC N690-1994. This demonstrates that there is margin in the design.

<u>Sump Cover and Piping for the Sump Strainers</u>

The analysis of the sump cover and connecting piping between the strainer assemblies and the sump cover were performed by combining manual calculations and computerized analysis using the AutoPIPE Program. A seismic loads response analysis on the strainer piping and their supporting elements was conducted to confirm that the components meet Class I seismic criteria.

In the analysis, the following considerations/assumptions were used:

1. The loads considered in the analysis were weight, pressure, and thermal loads

   The weight includes the weight of the pipe and flange. The enclosed water inside the piping was not accounted for because of buoyancy in the "wet" condition.

   The maximum differential pressure load acting on the piping was considered as the hydrostatic pressure associated with the maximum allowed head loss through the debris-covered strainers because the piping is open-ended.

   Thermal expansion loads were determined by thermal expansion analysis based on the maximum water temperature of 253°F.

2. Seismic Inertia Loads

   The seismic sloshing loads were not included because they were insignificant by comparison with other seismic loads. The inertial effects of the added hydrodynamic mass due to the submergence of the piping were considered. Based on the natural frequency of the system (15.9 Hz), the analyzed configuration was considered to be the bounding configuration for any potential shortening of spool pieces to align the strainer modules and avoid interferences. The calculated hydrodynamic mass in the lateral direction is 5.26 times the mass of the water enclosed in the pipe and the vertical mass is about 2.80 times that mass. The AutoPIPE input conservatively adjusted the specific gravity of the contents to 5.26. The piping was qualified using the response spectra method; therefore, a response spectra analysis was performed to analyze the seismic inertia loads. Horizontal and vertical spectra with 0.5% damping for the design basis earthquake load case provided at elevation 711 ft – 6 inches were used in the analysis. The sump strainers are actually located at elevation 697 ft - 6 inches; thus, using the spectra for elevation 711 ft - 6 inches is conservative.

The analysis results are given in terms of Interaction Ratio, which is the ratio of calculated maximum pipe stresses for each loading condition to their allowable stress. The allowable stresses are based on ANSI B31.1 Power Piping 1967 Edition, ASME Section III, Appendix L, and AISC - 1963 Edition. The calculation results showed that under all loading conditions considered, the interaction ratios are smaller than 1.0, therefore the calculated stresses are well below the allowable stresses. This demonstrates that there is margin in the design.

I. Upstream Effects

During the on-site NRC audit, NMC staff discussed upstream debris accumulation and water hold-up with the NRC auditors. During these discussions with the NRC Staff, no credible mechanisms were identified that could prevent significant quantities of drainage from the containment sprays and the ruptured pipe from reaching the containment pool. Regarding upstream effects, the NRC Audit Report (Reference 11) states:

> During the onsite portion of the audit, the licensee provided a verbal basis to support its position that debris accumulation in the containment upstream of the recirculation sump strainer will not impede the drainage of fluid from the containment sprays and the pipe rupture. The staff designated it **Open Item 5.2-1** for the licensee to document this explanation in a written, verified evaluation which specifically addresses the staff's concerns regarding the potential for blockage at the refueling cavity drain line. With the exception of this open item, the staff considered the licensee's evaluation of upstream debris accumulation to be acceptable. [NRC Audit Report, Section 5.2.1, page 58]

Open Item 5.2-1 states:

> The upstream debris accumulation evaluation was not comprehensive and had not been formalized under the normal calculation/verification process. In particular, the potential for debris accumulation to result in blockage or partial obstruction of the refueling cavity drain line was not fully addressed.

NMC has taken the following actions to close Open Item 5.2-1:

Following the audit, NMC completed a documented evaluation of upstream effects to formally assess the potential for debris accumulation and water hold-up. The general methodology utilized for the evaluation was to evaluate flow paths from the various postulated break locations to the liquid pool at the bottom floor of containment. This included evaluation of the flow path for containment spray liquid. The methodology used and summary of results is described below.

- The first step is to determine flow paths for liquid expelled from the postulated breaks. Potential flow paths for each postulated break location were addressed. In general, potential break locations are:

  1. <u>Break inside of the RCS Vaults (RCS Loop or Pressurizer Surge Line)</u>:

     For break locations in the vault the liquid expelled from the break will flow through the large openings and directly to the liquid pool at the 697 ft - 6 inches elevation. Some liquid would be expelled into the containment atmosphere as steam and liquid droplets entrained in the steam flow. This would be a small volume compared to the overall liquid expelled from the break. Injection flow from the RWST would exit the break mostly as liquid and spill directly to the pool.

  2. <u>Break at 711 ft - 6 inches Elevation (6-inch RHR Low Head Injection Line)</u>:

     For the postulated break location at the 6-inch RHR low head injection line at the 711 ft - 6 inches elevation, the liquid expelled from the break will flow through the open stairwells and directly to the liquid pool at the 697 ft - 6 inches elevation. Some liquid would be expelled into the containment atmosphere as steam and liquid droplets entrained in the steam flow. This would be a small volume compared to the overall liquid expelled from the break. Injection flow from the RWST would exit the break mostly as liquid and spill directly to the pool through the open stairwells.

  3. <u>Break at 697 ft - 6 inches Elevation (8- inch RHR Hot leg Suction Line, Unit 1 12-inch SI Accumulator Injection Line, Pressurizer Spray Line)</u>:

     This is applicable to a postulated break in the 8-inch RHR Hot Leg Suction line, the 12-inch Accumulator Injection line in Unit 1 and the Pressurizer Spray line. Note that one of the 12-inch SI Accumulator Injection Lines (between RCS piping and first check valve) is routed outside of the vault, resulting in the additional postulated break location in Unit 1. For the postulated break locations at the 697 ft - 6 inches elevation, the liquid expelled from the break will collect directly in the liquid pool at the same elevation. Some liquid would be expelled into the containment atmosphere as steam and liquid droplets entrained in the steam flow. This would be a small volume compared to the overall liquid expelled from the break. Injection flow from the RWST would exit the break mostly as liquid and spill directly to the pool.

For each break location, Containment Spray (CS) would be injected through the spray rings near the top of the containment dome. Note that CS is only used during the injection phase of post-LOCA mitigation, that is, CS is not used during post-LOCA recirculation operation.

- Next, based on where the break flow is expelled to, the drainage paths to the containment liquid pool at elevation 697 ft - 6 inches are evaluated. As discussed above, most of the liquid expelled from the postulated break would collect directly in the pool at the 697 ft - 6 inches elevation. The liquid volumes that would not directly collect in the pool would be the steam and entrained liquid droplets expelled from the break and containment spray. Since containment spray is only operated during the injection mode, this time period is relatively short. Liquid in the form of steam and containment spray would collect on horizontal and vertical surfaces and drain towards the pool at the 697 ft - 6 inches elevation (also referred to as the 'liquid pool' in this evaluation). This part of the evaluation reviewed the paths for this liquid to flow to the pool starting at the upper elevation and working downward. As the flow paths from each elevation in containment are evaluated, the potential for hold-up of liquid volume that could preclude that liquid from collecting in the pool at the 697 ft - 6 inches elevation are considered. The results from this evaluation are summarized below.

<u>Polar Crane Rail</u>

Liquid could collect on the Polar Crane rail from containment spray and condensation of steam expelled from the break. The upper and lower webs of the rail have several drainage holes that prevent collected liquid from being held-up.

<u>Elevation 755 ft</u>

Containment spray exits the spray nozzles in the upper regions of containment (Rings are at elevations ranging from approximately 867 ft to 883 ft). It is assumed that the spray is evenly distributed throughout containment as the spray falls and reaches the 755 ft elevation. This is a reasonable assumption given the distance of more than 100 feet between the spray nozzles and the 755 ft elevation. At the 755 ft elevation, the liquid can take a variety of flow paths:

(1) Some of the liquid will fall into the two RCS vaults. From the RCS vaults, the liquid will flow out the bottom of the vault directly to the liquid pool.
(2) Some of the liquid will fall directly to the 711 ft - 6 inches elevation in the vicinity of the Reactor Head Stand through open air or through floor grating. The flow path from the 711 ft - 6 inches elevation to the liquid pool is discussed below.
(3) Some of the liquid will fall into the Refueling Cavity (including the location near the Reactor Vessel Head). The flow path from the Refueling Cavity to the liquid pool is discussed in more detail below.
(4) Some of the liquid will collect on the containment shell wall and will flow down the wall surfaces directly to the 711 ft - 6 inches elevation. The flow path from the 711 ft - 6 inches elevation to the liquid pool is discussed below.
(5) The remaining portion of the liquid will collect on the 755 ft MSL elevation. From the 755 ft elevation the liquid will flow down open stairwells to the 733 ft - 9 inches elevation. Some liquid could also flow down through the floor drains directly to Sump A at the 697 ft - 6 inches elevation which would overflow to the liquid pool. However, the flow path through the floor drains is not credited in this evaluation.

Thus, liquid will not be held-up on the 755 ft elevation.

<u>733 ft - 9 inches Elevation</u>

Liquid could collect on the 733 ft - 9 inches elevation from flow through the stairwells from the 755 ft elevation and from condensation from the steam in the environment. From the 733 ft - 9 inches elevation the liquid will flow down open stairwells to the 711 ft - 6 inches elevation. Some liquid could also flow down through the floor drains directly to Sump A at the 697 ft - 6 inches elevation which would overflow to the liquid pool. However, the flow path through the floor drains is not credited. Thus, liquid will not be held-up on the 733 ft - 9 inches elevation.

<u>711 ft - 6 inches Elevation</u>

Liquid could collect on the 711 ft - 6 inches elevation from flow through the stairwells from the 733 ft - 9 inches elevation, from liquid directly falling into the Reactor Head Stand area, from liquid flowing down the containment shell wall and from condensation from the steam in the environment. From the 711 ft - 6 inches elevation the liquid will flow down open stairwells to the 697 ft - 6 inches elevation. Some liquid could also flow down through the floor drains directly to Sump A at the

697 ft - 6 inches elevation which would overflow to the liquid pool. However, the flow path through the floor drains is not credited. Thus, liquid will not be held-up on the 711 ft - 6 inches elevation.

Refueling Cavity

Liquid that collects in the Refueling Cavity will either flow down the sides of the Reactor Vessel and collect in the cavity area below the Reactor Vessel, or flow towards the cavity drain. The cavity drain is at the physically lowest region of the Refueling Cavity and most of the liquid in the cavity will flow towards the drain. As previously noted, the cavity area below the Reactor Vessel is already included as a potential hold-up volume. The Refueling Cavity drain is a 4-inch pipe that flows directly to Sump A. The single isolation valve in this line is maintained locked open during operation. The cavity drain is covered with a coarse screen (more like a trash rack). The fuel handling rail is physically located above the drain opening. Without a fine mesh screen, complete plugging of the opening is considered to be very unlikely. The debris source term following a postulated LOCA is composed of RMI pieces, coatings (small chips or fines), miscellaneous debris (such as tags, labels, and tie wraps) and latent dirt and dust. The potential for each of these debris sources to block the cavity drain is considered.

(i) RMI pieces destroyed by the break forces would be crumpled and, thus, very porous and would not block the cavity drain. Floor grating in the vaults preclude the potential for large pieces of RMI to be expelled upwards out of the vault from the break locations. In addition, the fuel handling rail located above the cavity drain would prevent large pieces from reaching the cavity drain. Furthermore, the flow rates in the cavity would not be sufficient to transport pieces of RMI.
(ii) Coating chips or fines would be very small compared to the screen opening and would not block the cavity drain.
(iii) Large pieces of miscellaneous debris, if failed due to the accident, would fall from their location and, most likely, not be ejected to the Refueling Cavity. Miscellaneous debris sources destroyed by the break forces could be postulated to be transported to the Refueling Cavity. These would be small and would not block the cavity drain. Floor grating in the vaults preclude the potential for large pieces of miscellaneous debris from being expelled from the break locations. Furthermore, if large pieces of miscellaneous debris were to make it to the Refueling Cavity, the pieces would not be transported based on observations from the flume testing for the prototype strainer and the low flow rates in the cavity.

(iv) Latent dirt and dust would be very small compared to the screen opening and would not block the cavity drain.

Thus, liquid will not be held-up in the Refueling Cavity.

- Conclusions

Potential break locations and flow paths from each break were considered as discussed above. From all of the postulated break locations, the majority of the liquid will flow directly to the liquid pool at the 697 ft - 6 inches elevation. The liquid that would not flow directly to the liquid pool is that expelled from the postulated break as steam or containment spray. The flow paths for the steam and containment spray were examined starting at the upper elevation in containment and working downwards towards the pool. The evaluation of these flow paths shows that liquid will not be held-up other than that already accounted for in determination of the minimum liquid volume in the containment pool. Thus, based on this evaluation, NMC considers Open Item 5.2-1 closed.

m. Downstream Effects - Components and Systems

The downstream effects analyses for the components and systems, outside of the Reactor Vessel, were reviewed in detail during the NRC Staff audit of PINGP. Regarding downstream effects on ECCS components outside of the Reactor Vessel, the NRC Audit Report (Reference 11) states:

> The PI review of downstream effects related to GSI-191 is conservative and robust. The licensee evaluation was complete and well organized. All system components and flowpaths were considered and evaluated. Line-ups, mission times, flows and pressures used to bound downstream evaluations were in all cases conservative with respect to review and evaluation of downstream components.
>
> The PI HPSI valves are normally fully open, thus minimizing the potential for clogging. Procedures and instrumentation are in place such that if an operator chooses to throttle, there is adequate indication and alarm. The HPSI system was designed such that operation with fully open throttle valves is acceptable.
>
> The licensee assumed 100% pass-through of all material less than 110% of strainer hole size. Also, 100% of all hard particles were assumed to be carried with the process fluid. The characterization and

assumed properties of bypassed process fluids was appropriate, complete and conservative.

HPSI pumps are hard-faced and are resistant to erosive and abrasive wear from hard particles entrained in the post-LOCA process fluid.

PI thoroughly assessed system low points and low flow areas.

The NRC Staff believes that there is a negligible change to PI system flow operating characteristics due to structures, systems or component wear, accumulation of debris or clogging of system components. This conclusion is based on the staff review of Calculation ENG-ME-654 … and related documentation as noted above. However, PI's analysis needed to verify this conclusion is incomplete. Specifically, the staff noted the following open items related to the methods used by the licensee.

Seal leakage into auxiliary building was not quantified. An evaluation of the affects on equipment qualification, sumps and drains operation or room habitability was not performed (**Open Item 5.3-7**).

System depletion calculations were reviewed. There was not a thorough discussion or basis for the assumption of 95% efficiency. However, it is expected that this will only have a minor impact on overall component conclusions (**Open Item 5.3-3**).

An evaluation of pump hydraulic degradation due to RHR pump internal wear was not performed (**Open Item 5.3-4**).

PI used the criterion contained in American Petroleum Institute Standard (API) 610 as acceptance criteria for pump vibration. API 610 applies to 'new' pumps. PI did not provide an evaluation supporting the conclusion that the existing pumps are as good as 'new' (**Open Item 5.3-5**).

PI utilized a three-body, erosive wear model. The internal wear mechanism for internal, non-impeller wear is two-body. The licensee did not justify their use of the two-body model (**Open Item 5.3-6**).

In general, the evaluations were thorough and conservative. [NRC Audit Report, Section 5.3.2, pages 66 and 67]

Actions taken to address Open Items 5.3-3, 5.3-4, 5.3-5, 5.3-6 and 5.3-7 are discussed below.

Summary of Methodology (reviewed during NRC audit)

NMC performed analyses to evaluate the affects of debris ingestion into the ECCS downstream of the containment sump strainers. The analyses were performed following WCAP-16406-P, Revision 1. The analyses included evaluations of blockage due to debris ingestion, long term wear of components in the flow stream and potential for debris settlement affecting components such as check valves and instrument lines. All system components and flowpaths were considered and evaluated.

Phase I - Evaluation of Potential for Blockage

The first step in evaluating the potential effects from debris ingestion through the sump strainer was to determine the flow clearances for components in the sump recirculation flow paths of the ECCS. This evaluation addresses flow clearances to identify potential blockage locations. After determining the minimum flow clearances, the sump strainer opening size was compared to the various flow clearances. The sump strainer opening size is an assumed 1/8 inch x 1/8 inch opening (0.177 inch diagonal opening). This is much larger than the perforation size of the new sump strainers (0.085 inch diameter), and thus, conservative.

Phase II – Evaluation of Other Potential Downstream Effects

Phase II of the evaluation provided the subsequent analyses of the potential downstream effects. The Phase II analyses evaluate components in the recirculation flow paths using the guidance in WCAP-16406-P. These analyses include evaluations of RHR pumps, SI pumps, RHR heat exchangers, flow restriction orifices, wear of throttle valves (specifically those used for flow balancing in the SI system), potential improper functioning of lift check valves and debris settlement in instrument lines required during post-LOCA recirculation.

The results from the Phase II analyses showed the following:

- Wear of the SI pump surfaces is 7% of the allowable value.
- Wear of the RHR pump surfaces could exceed the allowable value based on design clearance, but would not result in significant pump performance degradation. That is, the RHR pump would be able to perform the required design function for an assumed mission time of 30 days. In addition, wear on the RHR pump is also evaluated for a one year time period and determined that the pump would be able to also perform the required functions for one year.
- Wear of RHR heat exchangers is acceptable for the assumed time duration of one year.

- Wear on the flow restriction orifices in the RHR and SI systems is acceptable for the assumed mission times.
- Wear on the throttle valves in the SI system is acceptable for the assumed mission time.
- Clogging may occur of lift check valves SI-16-4 and SI-16-5 in Unit 1 and 2SI-16-4 and 2SI-16-6 in Unit 2. These are 2-inch lift check valves in the high head SI lines to the RCS cold legs. These lines would be used for a high head recirculation line-up. If the 2-inch lift check valve were to stick open, backleakage is precluded by the 6-inch check valves (e.g., SI-9-1 and SI-9-2 in Unit 1) downstream of the 2-inch lift check valves, by the pump discharge check valves and by the motor valves in the SI pump suction lines (closed for the high head recirculation line-up) and the motor valves in the SI pump minimum flow line (closed for the recirculation line-up). Therefore, even if these lift check valves were to stick open or leak due to debris, there are multiple barriers to preclude backleakage. Note that the motor valves at the SI pump suction and in the pump minimum flow lines would not be affected by debris.
- Debris settlement was not specifically evaluated in the instrument taps used for RVLIS hot leg volume sensor and RCS pressure input to sub-cooling indication. The taps into the RCS loop piping for these instruments occur at three locations equal distance apart. One tap is at the top of the pipe and the other two are on the lower sides of the pipe. The three taps are provided to support the flow. Only one of these taps needs to be available to support the RVLIS or RCS pressure indication to the subcooling margin monitor. The location of the taps (especially at the top of the pipe) precludes debris settlement from affecting all three taps.

Therefore, the downstream effects analyses concluded that debris ingestion would not prevent the ECCS from performing the required design functions.

NMC submitted a Request for Extension of Supplemental Response to Generic Letter 2004-02 (Reference 12) to extend the ECCS downstream effects analysis. This analysis, which will be completed by March 31, 2008, will address Open items 5.3-3, 5.3-4, 5.3-5 and 5.3-6.

NMC has taken the following actions to address Open Item 5.3-7.

NMC performed an evaluation of the potential for RHR pump seal leakage and the resultant effects. The mechanical seals function to provide a barrier to preclude leakage from the process fluid to the atmosphere. Consistent with WCAP-16406-P, most papers indicate the seal surfaces are not affected due to the very tight gap between the seal ring (runner) and the seal insert (stationary), keeping the debris from entering the gap when the seal functions normally. It is more likely that the seal compliance or ability to follow thermal or dynamic motion of the shaft is impaired due to debris build-up in bellows, clogging of springs, or a similar effect.

From the evaluation the following conclusions are made:

- Based on the pump design, the quantity of debris that could be transferred to the upper chamber where the mechanical seal is located would be very small. Transfer of fluid from the process fluid to the upper chamber only occurs if the mechanical seal leaks. During periodic surveillance testing only small amounts of leakage from the mechanical seal are allowed. This testing is performed at system pressures significantly higher than would be experienced during post-LOCA recirculation operation. The fluid that comes in contact with the mechanical seal is that contained in the upper chamber of the pump. The fluid in the upper chamber is circulated by the auxiliary impeller through the seal heat exchanger. (Blockage and wear on the seal heat exchanger is considered in the downstream effects analysis and shown not to be an issue. Thus, seal cooling would not be affected.) Provided that the mechanical seal does not leak, the upper chamber, seal heat exchanger and connecting piping is a closed system and no debris would be transferred from the pump process fluid to the upper chamber.

- When the seal is functioning normally, the tight gap between the seal ring and the seal insert precludes debris from entering the gap. If the seal does leak, the makeup fluid is provided from the process fluid between the shaft and the bushing. The clearance between the shaft and the bushing is 0.005 to 0.009 inches. Thus, debris particles would need to be no larger than 0.005 to 0.009 inches to be transferred to the upper chamber. Thus, large debris particles would not be transferred to the upper chamber of the pump.

- The concern for mechanical seal operation in debris laden fluid would be a potential loss of seal compliance due to debris build-up in the bellows or clogging of the springs. The RHR pumps at PINGP currently use John Crane Type 1/1B mechanical seals; however, NMC plans to replace the seals with Chesterton 180 mechanical seals.

  The John Crane Type 1/1B Seal is suitable for a wide range of service conditions: from water and steam to chemicals and corrosive materials. These service conditions include applications in pulp and paper, food processing, wastewater treatment, chemical processing, power generation and other demanding applications. Several of these applications would be more demanding than debris in the post-LOCA sump recirculation fluid could present. As discussed above, seal surfaces are not affected by debris when the seal is functioning normally due to the very tight gap between the seal ring (runner) and the seal insert (stationary), keeping the debris from entering the gap. It is more likely that the seal compliance or ability to follow thermal or dynamic motion of the shaft is impaired due to debris build-up in bellows or clogging of springs, or a similar effect. Based on the seal design, seal compliance would not be impaired due to debris build-up in bellows or clogging of springs.

Evaluations of the Chesterton 180 mechanical seal will be performed as part of the NMC modification process and the results will be provided in the supplemental response to GL 2004-02 to be submitted by March 31, 2008 which addresses ex-vessels effects.

- Although not expected, any increase in seal leakage would be small. This leakage would be well within the capabilities of the systems that service the RHR pump pit (cooling, filtered ventilation and sump pumps).

NMC submitted a Request for Extension of Supplemental Response to Generic Letter 2004-02 (Reference 12) to extend the ECCS downstream effects analysis. This analysis, which will be completed by March 31, 2008, will address Open Item 5.3-7.

n. Downstream Effects – Fuel and Vessel

The downstream effects analyses for the in-vessel components (fuel assemblies and other components inside the reactor vessel) were reviewed in detail during the NRC Staff audit of PINGP. Regarding downstream effects inside of the Reactor Vessel, the NRC Audit Report (Reference 11) states:

> Although the licensee addressed core blockage which might prevent ECCS water from entering the core during long-term cooling, other issues need to be resolved. These issues involve the potential for core internal heat transfer degradation between the fuel rods and the coolant in the presence of debris and chemicals in the recirculated sump water. Following a large hot-leg break at Prairie Island, continued boiling in the core will act to concentrate the debris and chemicals in the water between the coolant channels. As noted in the proceeding discussions, the licensee has not evaluated the duration of boiling in the core following a large hot-leg break. The licensee needs to determine the concentration of the debris mixture and chemicals in the core during the long-term cooling period and evaluate the potential for precipitation within the core channels. Chemical reaction of the

debris with the containment spray buffering agents and boric acid from the ECCS water in the presence of the core radiation field might change the chemical and physical nature of the mixture within the reactor core. Heat transfer might be affected by direct plate out of debris on the fuel rods and by accumulation of material within the fuel element spacer grids. The licensee has stated that they will rely on an ongoing program by the PWR Owners Group to investigate the effects of local blockages within fuel elements including the effect of plate out of substances on fuel rod surfaces during the long-term cooling period. The staff will reach conclusions on the effect of debris blockage of the fuel assembly support grids at Prairie Island after the results of the generic program are submitted for review.

Conclusions:

The licensee continues to evaluate the post-LOCA consequences of debris ingestion into the reactor system and its affect on long-term core cooling. The following items remain open in the staff's review.

The licensee's evaluations are based in part on the generic methodology of WCAP-16406-P. This topical report is currently under review by the NRC staff. When the staff's review of this topical report is completed, the licensee needs to reevaluate post-LOCA downstream effects for Prairie Island (**Open Item 5.3-1**).

The PWR Owners Group is evaluating the effect on core heat transfer of materials concentrated within the reactor core in the long-term cooling period following a loss of coolant accident. At the completion of this study, the licensee needs to provide plant-specific analyses for the concentration of the various particulate and chemical compounds within the reactor core during the post-LOCA period, including chemical reactions under the effect of ionizing radiation, and to demonstrate that the condition of the core remains within acceptable limits. Such evaluations should include the effect on core heat transfer of plate out of material on to the surface of fuel rods during long-term boiling and the effect of any debris trapped between the fuel element spacer grids and the adjacent fuel rod in the production of local hot spots (**Open Item 5.3-2**).

The licensee is working with the PWR Owners Group to complete evaluations for the effects of ingested debris on long-term reactor core cooling. The licensee believes that when the evaluations are completed that the effect of debris ingestion will be shown to be small. The NRC staff will review this area when the additional material is submitted in the GL 2004-02 supplemental response. [NRC Audit Report, Section 5.3.1, pages 61 and 62]

Open Item 5.3-1 states:

> The licensee evaluations of downstream component effects are preliminary; based in part on the generic methodology of WCAP-16406-P, currently under review by the NRC staff. Conclusions and findings need to be applied to the evaluation of post-LOCA downstream effects for PI.

Open Item 5.3-2 states:

> The licensee had not completed in-vessel downstream evaluations, including the effect on core heat transfer of plate-out of material on the surface of fuel rods during long-term boiling and the effect of any debris trapped between fuel element spacer grids and the adjacent fuel rod in the production of local hot spots.

Actions take to address Open Items 5.3-1 and 5.3-2 are discussed below.

Summary of Methodology (reviewed during NRC audit)

Analyses were performed to address potential blockage areas within the reactor vessel and core. Some examples of these flow restrictions are the fuel assembly inlet debris screens and the spacer grids within the fuel assemblies. Debris blockage at such flow restrictions could impede or prevent the recirculation of coolant to the reactor core leading to inadequate long-term core cooling. Evaluations were performed for the purpose of demonstrating that debris blockage of the reactor core during the long-term cooling period is not of concern for PINGP, including the potential for blockage of reactor vessel flow paths other than the core.

Concerns for debris blockage of the reactor core are primarily related to the recovery following the largest postulated reactor system piping breaks. For smaller break sizes, the goal of plant operators would be to fill the reactor system and establish closed-loop cooling using the decay heat removal system. Recirculation of sump water might not be required for small break sizes and if recirculation were needed, the flow requirements would be less than for large breaks. The amount of sump debris following a small break is expected to be less than that which would be generated following a postulated large break.

The analyses use an acceptance criterion of a fibrous debris bed of no more than 0.125 inches uniformly distributed across the core. The methodology of WCAP-16406-P is used to calculate a maximum fiber bed thickness across the top of the core of 0.076 inches following a postulated cold-leg break. For a hot-leg break, much of the ECCS water recirculated to the upper plenum would spill out of the break and would have to pass through the sump strainers on another pass before reaching the core. Much of the fiber in the spilled ECCS water would be collected at the sump strainers on the subsequent passes and therefore not reach the core.

The majority of the fibrous debris comes from the fiber constituent in the latent debris. As discussed previously, the most recent latent debris sampling, performed in the Unit 2 containment shows that the latent fiber used in the core blockage analyses is very conservative.

In addition to locations at the top of the core, NMC also addressed other possible locations of blockage within the reactor vessel internals which might affect core cooling. The smallest clearance was found to be 1.38 inches. This dimension is approximately a factor of 16 greater than the dimension of the strainer holes in the containment sump strainer. Thus, debris blockage of non-core reactor vessel internals is unlikely at PINGP.

NMC has taken the following actions to close Open Items 5.3-1 and 5.3-2.

Subsequent to the NRC audit of PINGP, the PWR Owner's Group issued WCAP-16793 to provide analyses that bound most, if not all, operating PWRs. WCAP-16793 considers the following three topical areas.

1. Evaluation of fuel clad temperature response to blockage at the inlet to the core.
2. Evaluation of fuel clad temperature response to local blockages or chemical precipitation on fuel clad surface.
3. Evaluation of chemical effects in the core region, including potential for plate-out on fuel cladding.

WCAP-16793 was reviewed for applicability to PINGP to confirm that the PINGP design is bounded by its analyses. Plant specific considerations such as the quantity of fiber that reaches the reactor vessel (i.e., fiber that bypasses the strainer), the size of the fibers that bypass the strainer, strainer perforation size, time to initiation of recirculation, debris quantities, and plate-out on fuel cladding were reviewed as part of the site specific evaluation. For fiber quantities that reach the vessel, fiber size, strainer perforation size, time to initiation of recirculation and debris quantities, the site specific conditions for the PINGP are bounded by the considerations used in WCAP-16793. For the analysis of the potential for plate-out on the fuel assemblies, without more details of the examples analyses in WCAP-16793, it is not definitively clear that PINGP is bounded by WCAP-16793. Thus, NMC will be using the LOCA-DM model to perform a site specific plate-out analysis.

NMC submitted a Request for Extension of Supplemental Response to Generic Letter 2004-02 (Reference 12) to extend the ECCS downstream effects analysis. This analysis, which will be completed by March 31, 2008, will include the plate out analysis and address Open items 5.3-1 and 5.3-2.

o. Chemical Effects

Regarding the chemical effects evaluations, the NRC Audit Report (Reference 11) states:

> PI personnel also indicated they will be conducting another latent debris survey at the start of the Unit 2 refueling outage, in an attempt to reduce the conservatism in the existing assumption concerning the amount of latent fiber. Their goal is to demonstrate that the amount of latent fiber is less than the amount needed to form a “thin bed” on the new strainers. If PI is successful in demonstrating that the amount of fiber in their containment is not sufficient to form a “thin bed” on the strainer, it will be important to understand the minimum bed that can filter chemical products and affect head loss across the strainer bed. NRC staff has observed some chemical effect tests where the debris bed did not filter particulate in the water (i.e., not enough fiber for the classic “thin bed”), but significant head loss occurred upon subsequent introduction of chemical precipitate to the test fluid (ADAMS Accession Number ML063110561).
>
> In summary, the PI chemical effects evaluation is still in progress. Therefore, resolution of chemical effects is **Open Item 5.4-1**. Within the resolution of chemical effects, the NRC staff indicated there is a general question related to the potential for coatings to contribute to chemical effects by: (1) leaching constituents that could form precipitates or affect other debris; and (2) changes to the paint itself due to the pool environment (the possibility that some of the PI paints turn into a product (e.g., a gel) that causes high head loss). The staff expects the PI evaluation of chemical effects will address this question. [NRC Audit Report, Section 5.3.1, page 69]
>
> Open Item 5.4-1 states:
>
>> The chemical effects evaluation was still in progress. The licensee has not resolved the chemical effects issue at PI.

Actions taken to address Open Item 5.4-1 are discussed below.

Summary of Methodology (reviewed during NRC audit)

The PINGP containment insulation materials include mostly RMI with very small amounts of fiber. Prior to the NRC audit, the chemical effects assessment for PINGP was performed relative to the test conditions for Integrated Chemical Effects Test (ICET) #1, since the ICET #1 test conditions, which used sodium hydroxide to adjust pH and contained fiberglass insulation, were most similar to PINGP plant-specific conditions. Strainer tests were performed at ARL using manufactured aluminum hydroxide and calcium carbonate powder as surrogates for chemical precipitates that were added to a test flume. Since the initial PINGP screen tests, the knowledge base for chemical effects continued to evolve with additional tests at Los Alamos National Laboratory, Argonne National Laboratory, testing to support WCAP-16530-NP, and additional strainer vendor tests. These additions to the chemical effects knowledge base have necessitated further evaluations of the potential for chemical precipitates to affect strainer performance at PINGP.

Subsequent to the NRC audit of PINGP, NMC has taken the following actions to close Open Item 5.4-1.

An analysis of the potential for chemical precipitants to affect sump strainer head loss was performed. As previously discussed, PINGP has a minimal amount of fiber inside of containment. The NRC has developed draft evaluation guidance that the NRC staff can use for review of GSI-191 plant specific chemical effect evaluations (Reference 16). The NRC has made this evaluation guidance available in draft format "since it may be useful to licensees that are currently performing chemical effects evaluations …" This guidance document includes a flow diagram that provides a logical sequence outlining possible paths for different plant-specific approaches to chemical effect evaluations. The initial step in the flow diagram allows a plant with minimal amount of fibrous debris to justify that there would be sufficient bare strainer area such that the chemical precipitates are expected to pass through. The draft evaluation guidance states (Section 3, pages 9 and 10):

(1) Sufficient 'Clean' Strainer Area

Plants that are able to demonstrate sufficient bare strainer area may use a more simplified chemical effects evaluation since chemical precipitates are expected to pass through a bare strainer. The methodology used to assess that there is sufficient clean strainer area should demonstrate that sufficient bare strainer area will remain available to support the design basis flow rate to the reactor core, considering all break locations within the uncertainties of debris generation and transport.

….

b. Technical Issues

i. Strainer vendor head loss testing has shown that calculated debris beds substantially less than 1/8 inch thickness (e.g., 1/32 inch) can filter chemical products and cause significant pressure drops across the strainer. If sufficient microporous insulation, such as calcium silicate, is present, filtration of precipitates has been demonstrated to occur with almost no fibrous debris other than that from the microporous insulation's fibrous binder.

….

c. Staff Expectations

i Plants that plan to credit bare strainer area and perform a simplified chemical effect evaluation should demonstrate, for the maximum debris generation/transport break, that the screen design allows for chemical precipitates to pass unimpeded due to excess available <u>bare</u> strainer area. For the purpose of this simplified analysis, strainer area with a very thin layer of debris that covers the strainer flow area is considered to be different from bare strainer area.

….

d. GL Supplement Content

i. Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

The methodology for this evaluation was to first determine the required bare strainer surface area to support design basis flow to the reactor core. Based on ECCS configuration the required bare surface area is determined by ensuring that there is sufficient NPSH available to the RHR pumps. That is, the RHR pumps will provide the flow rate based on pump capability and system hydraulics which is much greater than the minimum flow required for long term core cooling. The strainer must be able to pass the flow rate the RHR pump(s) are capable of providing while also ensuring that adequate NPSH is provided to the pump(s). Thus, for this determination, a minimum bare strainer surface area will be determined that will still provide sufficient flow while providing sufficient head to the suction of the pump(s). The over-riding concern in making this determination is the clean strainer head loss. The analysis demonstrates that with a strainer surface area of, as little as, 15% of the total strainer surface area available, the resultant head loss at maximum flow rate would not be excessive and sufficient NPSH would be provided to the RHR pumps. In addition, it was also assured that, with the predicted head loss across the strainer with only 15% of the total strainer surface area available, flashing would not occur and the calculated strainer head loss was less than that used for structural design of the strainer.

The next step in the analysis was to determine if the available fiber quantity could cover more than 85% of the strainer surfaces. For the purposes of this part of the evaluation, it was conservatively assumed that all of the fiber inside of containment is transported to the sump pool with 15% held up in the inactive pool volumes (15% is used for this assumption consistent with Reference 8). Assuming that 100% of the fiber in containment, except for that retained in the inactive pool volumes, is considered to be a bounding assumption and not a best estimate. Some of the reasons that this is considered to be a bounding assumption are as follows:

- Containment spray is only operated for a brief time following a LOCA. That is, per plant emergency operating procedure, spray is only operated during the injection phase. Once recirculation of the containment sump liquid commences, spray is secured. For a large break LOCA, this will only be a period of minutes.

- The majority of the fiber material inside of containment is due to the latent debris source term. A significant percentage of the latent debris source term is in areas in containment that are not subject to containment spray or containment washdown. Thus, there is no reasonable method to transport these fibers to the sump liquid pool.

- Outside of the Reactor Coolant System vaults, the flow paths from the upper floors of containment to the bottom floor containment liquid pool occur through open stairwells. However, for the most part the stairwells are not located directly above each other. That is, for the flow to reach the bottom floor the liquid drops through one stairwell, and then flows across a floor surface to another stairwell. This series of flow paths will most likely result in fibers being deposited along the flow paths instead of transporting to the sump pool.

Based on the allowable quantities of latent debris in containment per the latent debris control program, the maximum total fiber volume inside of containment is 2.534 $ft^3$. Subtracting the 15% retained in the inactive pool and assuming 100% transport of the remaining fiber, the total fiber at the strainer is 2.154 $ft^3$. If the fibrous material volume of 2.154 $ft^3$ were evenly distributed over the entire strainer surface area the thickness would be 0.03125 inches. This is equivalent to the 1/32 inch thickness discussed in the NRC draft review guidance quoted above. As discussed above, the determination of this value is based on bounding assumptions. Thus, even if the fibrous material were evenly spread out over the entire strainer surface, one would not expect that there would be a sufficient fiber bed to filter the chemical precipitates.

However, based on the following discussion, for this very limited amount of fibrous material, even distribution is not expected. The PCI strainer is designed to provide a constant approach velocity to the strainer under all debris loading conditions. This is due to the suction flow control device (SFCD) design. The design employs a SFCD that is the core tube which uniformly distributes the flow energy of the strainer uniformly over the length of the assembly. Thus, with large quantities of debris, the material would tend to accumulate evenly over the strainer surfaces.

Due to the strainer location and complex geometric configuration, for the case with such small amounts of fiber material, the fiber will tend to collect as a function of where it is in the flow stream and where the flow stream comes in the vicinity of the strainer. As the debris approaches the strainer, the debris will initially accumulate on the regions of the strainer closest to the path of approach. This is discussed in more detail below.

- The strainer assembly at PINGP is located near the perimeter of the lower level of containment. The flow of water to the strainer will approach the strainer assembly from the areas away from the containment wall and from the strainer ends (depending on which Unit). For example, with the strainer assembly located near the perimeter of containment, as shown in Figure 1 (Section 3.j of this supplemental response) by the curvature of the strainer which follows the curvature of the containment wall, regions of the strainer directly oriented towards the center of containment would tend to see the fiber material first. The regions of the strainer oriented towards the containment wall would tend to see the fiber material later, if at all.

- The strainer assembly is a complex geometry made up of a series of parallel discs in lieu of a single flat perforated plate (refer to Figure 2 in Section 3.j of this supplemental response). With the parallel discs, the water flow (and thus, the fibers) will approach the outside flat surface first. Fibers will tend to adhere to the surfaces with which they come in contact first, precluding much of the fibers from reaching the inner flat vertical surfaces.

This phenomenon was observed during prototype testing of the PCI strainers at the Alden Laboratories test facilities. During testing to attempt to form a thin bed, fiber quantities greater than that theoretically required had to be added to form the thin bed as the fibrous debris did not want to equally distribute without a head loss.

In conclusion, as discussed above, with a bare strainer surface area of only 15% of the total strainer surface area, the strainer will pass more than sufficient flow for adequate core cooling to meet pump capability requirements with an acceptable head loss through the strainer. Only a fraction of the strainer surface area is in the general paths of approach for the recirculation fluid; approximately 25% of the strainer surface area is on the opposite side from the general paths of approach. Thus, there is reasonable assurance that the available bare strainer surface area will be much greater than the 15% determined necessary. This is based on the very conservative assumption that 100% of the fiber in containment (excluding that retained in the inactive pool volumes) is transported to the containment liquid pool.

Therefore, chemical precipitants are not a concern for causing excessive head loss at the suction strainers for PINGP. Based on this evaluation, NMC considers Open Item 5.4-1 closed.

p. Licensing Basis

NMC submitted a license amendment request dated December 14, 2006 (Reference 6) to revise plant Technical Specifications to clarify the inspection requirements for the replacement strainers and increase the minimum RWST level requirement from 68% to 90%. License Amendments 182 and 172 for Units 1 and 2 respectively were issued by the NRC on December 14, 2007 approving the requested changes. The change to the Technical Specifications for the strainer inspection requirements was necessitated by the replacement strainer. The change to the Technical Specifications for the change to the RWST minimum level requirements is conservative relative to the current Technical Specifications. These license amendments will be implemented by March 13, 2008. In the interim, NMC has implemented administrative controls through plant procedures that effectively implement these changes.

As part of the corrective actions for GL 2004-02, NMC revised the PINGP licensing bases as reflected in the facility USAR. In essence, these revisions are as follows:

- Revision to the description of the sump strainer to describe the replacement strainer, summarizing the basis for the strainer sizing.
- Revision to the pump parameter information to reflect changes in the RHR pump available NPSH, and discussing that the head loss across the strainer with the design bases debris bed is less than the NPSH margin where the NPSH margin is the difference between NPSH available (without the strainer) and NPSH required.
- Revision to the description of the containment vessel water level instruments to describe the changes made to the level instrumentation as a part of the replacement strainer modification.

All of these changes were evaluated by the NMC using the site 10 CFR 50.59 process and determined not to require a license amendment.

By letter dated December 5, 2007, NMC requested an extension to March 31, 2008 for completion of the ex-vessel downstream effects analysis and in-vessel effects analysis for the Prairie Island Nuclear Generating Plant (PINGP). A supplemental response to GL 2004-02 will be submitted by March 31, 2008 which provides the information requested in the Content Guide for these two issues.

## References

1. NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004, Accession Number ML042360586.

2. Nuclear Management Company Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for the Prairie Island Nuclear Generating Plant, dated August 31, 2005, Accession Number ML052440054.

3. Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, dated November 21, 2007, Accession Numbers ML073110269 and ML073110278.

4. Prairie Island Response to Nuclear Regulatory Commission Bulletin 2003-01, “Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors - 60-Day Response,” dated August 6, 2003, Accession Number ML032260664.

5. Prairie Island Supplement to 60-Day Response to Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," May 14, 2004, Accession Number ML041410029.

6. "License Amendment Request to Revise Technical Specifications (TS) in Support of Containment Sump Resolution," NMC letter dated December 14, 2006, Accession Number ML063480462.

7. NEI-04-07, NEI PWR Sump Performance Task Force Report NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Rev. 0, December 2004.

8. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report, NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, December 6, 2004, Accession Numbers ML043280008 and ML043280007.

9. Title 10 Code of Federal Regulations 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors".

10. Not used.

11. "Prairie Island Nuclear Generating Plant Corrective Actions for Generic Letter 2004-02," Audit Report, dated May 2, 2007, Accession Number ML070750065.

12. Request for Extension of Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for the Prairie Island Nuclear Generating Plant, dated December 5, 2007, Accession Number ML073400458.

13. Regulatory Guide (RG) 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," dated November 2003, Accession Number ML033140347.

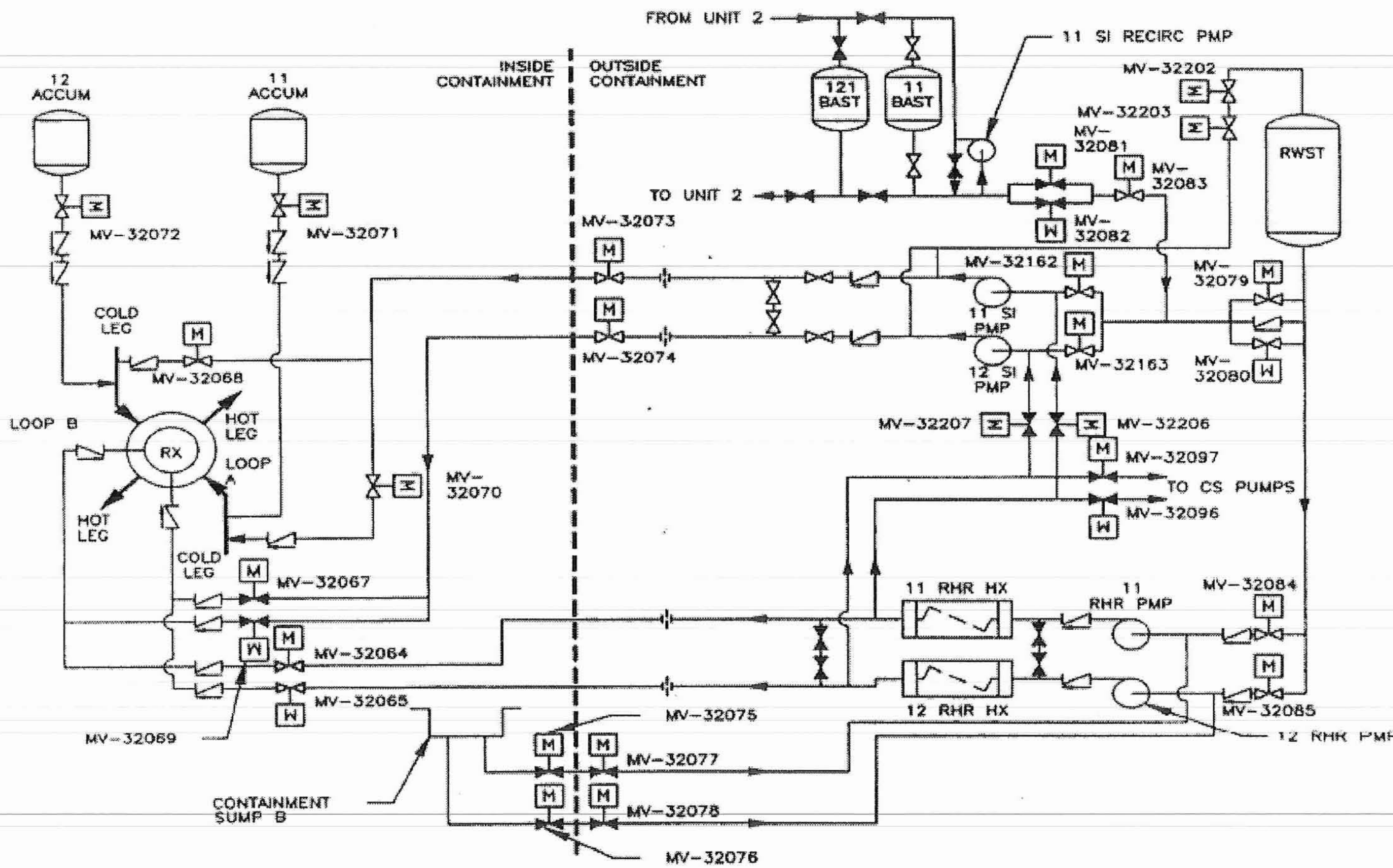
14. Crane 410, Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe," 1970.

15. Performance Contracting Inc. letter to the US NRC, "Suction Flow Control Device (SFCD) Technology Documents and Reports," dated June 8, 2007, Accession Number ML071650462.

16. Enclosure 3 to NRC letter to NEI dated September 27, 2007, "Evaluation Guidance for the Review of GSI-191 Plant-Specific Chemical Effect Evaluations," marked DRAFT, Accession Number ML072600372.

17. NRC letter to NMC, "Generic Letter 2004-02 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors' Extension Request Approval for Prairie Island Units 1 and 2", dated December 21, 2007, Accession Number ML073520053.

# Figure 4
## PINGP Unit 1
## Emergency Core Cooling Systems



## Attachment 1
## GL 2004-02 Supplemental Response Content Guide

The NRC has provided a content guide (CG) (Reference 3) for Generic Letter (GL) 2004-02 Supplemental Responses to describe content in the supplemental response that the NRC believes would be sufficient to close GL 2004-02. In accordance with the guidance of the NRC CG, for plants that been subject to an NRC audit of corrective actions for GL 2004-02 (e.g., PINGP) the supplemental response should specifically address the open items and describe how the open item has been addressed. Furthermore, for any subject area found to be acceptable during an audit, the licensee may briefly describe the approach taken in that area and refer to the audit report. The following table provides the ties between the CG section and the PINGP Audit Report section, noting any Open Items and how the Open Items have been addressed. PINGP also received a set of RAIs related to GL 2004-02 response (NRC letter dated February 9, 2006). Per the CG, specific responses to RAIs are not required provided the information in the supplemental response addresses the issues identified in the RAIs.

| Content Guide Section | Content Guide Section Title | Audit Report Section | Audit Report Open Items | How is Open Item Addressed | Comments |
|---|---|---|---|---|---|
| 1 | Overall Compliance | N/A | | | |
| 2 | General Description of and Schedule for Corrective Actions | N/A | | | |
| 3.a | Break Selection | 3.1 | None | N/A | |
| 3.b | Debris Generation/Zone of Influence | 3.2 | None | N/A | |
| 3.c | Debris Characteristics | 3.3 | None | N/A | |
| 3.d | Latent Debris | 3.4 | 3.4-1 | Latent debris program established | Include information for Unit 2 sampling performed subsequent to audit |
| 3.e | Debris Transport | 3.5 | None | N/A | |
| 3.f | Head Loss and Vortexing | 3.6 | 3.6-1 | Subsequent sampling in Unit 2 showed that there is insufficient latent debris to result in a thin bed. Additional testing demonstrates | |

| Content Guide Section | Content Guide Section Title | Audit Report Section | Audit Report Open Items | How is Open Item Addressed | Comments |
|---|---|---|---|---|---|
| | | | | that PINGP testing results were very conservative. | |
| | | | 3.6-2 | Clean strainer head loss addressed by PCI | |
| | | | 3.6-3 | Vortex potential addressed by PCI | |
| | | | Action Request (AR) 01058100 | Calculation revised and AR closed. | |
| 3.g | Net Positive Suction Head (NPSH) | 3.7 | 3.7-1 | Calculation revised to address open item. | |
| 3.h | Coatings Evaluation | 3.8 | 3.8-1 | Coatings program provides reasonable assurance of coating qualification | |
| 3.i | Debris Source Term | 4.1 | None | N/A | Include information for Unit 2 sampling performed subsequent to audit; specifically how this demonstrates the effectiveness |

| Content Guide Section | Content Guide Section Title | Audit Report Section | Audit Report Open Items | How is Open Item Addressed | Comments |
|---|---|---|---|---|---|
| | | | | | of containment cleanliness program. |
| 3.j | Screen Modification Package | 4.2 | None | N/A | |
| 3.k | Sump Structural Analysis | 5.1 | None | N/A | |
| 3.l | Upstream Effects | 5.2 | 5.2-1 | Evaluation of potential hold-up regions in containment (i.e., upstream effects) documented. | |
| 3.m | Downstream Effects – Components and Systems | 5.3.2 | 5.3-3 | Included as part of revision to downstream effects analysis to implement NRC approved version of WCAP-16406-P. | Extension was granted (Reference 17) to allow completion of this activity no later than 3/31/2008. |
| | | | 5.3-4 | Evaluation to be performed following revision to downstream effects analysis to | Extension was granted (Reference 17) to allow completion of this activity no later than 3/31/2008. |

| Content Guide Section | Content Guide Section Title | Audit Report Section | Audit Report Open Items | How is Open Item Addressed | Comments |
|---|---|---|---|---|---|
| | | | | implement NRC approved version of WCAP-16406-P. | |
| | | | 5.3-5 | Included as part of revision to downstream effects analysis to implement NRC approved version of WCAP-16406-P. | Extension was granted (Reference 17) to allow completion of this activity no later than 3/31/2008. |
| | | | 5.3-6 | Included as part of revision to downstream effects analysis to implement NRC approved version of WCAP-16406-P. | Extension was granted (Reference 17) to allow completion of this activity no later than 3/31/2008. |
| | | | 5.3-7 | Evaluation of RHR pump seal leakage documented | Extension was granted (Reference 17) to allow completion of this activity no later than 3/31/2008. |
| 3.n | Downstream Effects – Fuel and Vessel | 5.3.1 | 5.3-1 | Addressed in evaluation that reviews applicability of WCAP-16793. | For all analyses, except for the plate-out analysis, it is clear that PINGP is bounded by the analysis in WCAP-16793. For |

| Content Guide Section | Content Guide Section Title | Audit Report Section | Audit Report Open Items | How is Open Item Addressed | Comments |
|---|---|---|---|---|---|
| | | | 5.3-2 | Addressed in evaluation that reviews applicability of WCAP-16793. | the plate-out analysis, a site specific analysis will be performed using LOCA-DM. Extension request (Reference 12) has been submitted to allow completion of this activity no later than 3/31/2008. |
| 3.o | Chemical Effects | 5.4 | 5.4-1 | Addressed in a new analysis. | Consistent with the NRC Draft Evaluation Guidance for Chemical Effects, it is shown that there is sufficient clean strainer area available; thus, further chemical effects evaluation is not required. |
| 3.p | Licensing Basis | 2.2 | N/A | N/A | . |